Northeast Fisheries Science Center Reference Document 17-03

62nd Northeast Regional Stock Assessment Workshop (62nd SAW)

Assessment Report

by the Northeast Fisheries Science Center

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by the Northeast Fisheries Science Center

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

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole, Massachusetts
January 2017

Northeast Fisheries Science Center Reference Documents

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Information Quality Act Compliance: In accordance with section 515 of Public Law 106-554, the Northeast Fisheries Science Center completed both technical and policy reviews for this report. These predissemination reviews are on file at the NEFSC Editorial Office.

This document may be cited as:

Northeast Fisheries Science Center. 2017. 62nd Northeast Regional Stock Assessment Workshop (62nd SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-03; 822 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://www.nefsc.noaa.gov/publications/

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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 62nd SARC was convened in Woods Hole at the Northeast Fisheries Science Center, November 29 – December 2, 2016 to review benchmark stock assessments of black sea bass and witch flounder. CIE reviews for SARC62 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 Stock Assessment Review Meeting:

Text in this section is based on SARC-62 Review Panel reports (available at http://www.nefsc.noaa.gov/nefsc/saw/ under the heading "SARC-62 Panelist Reports").

The **black sea bass** assessment was accepted by the SARC-62 panel. It was effective in determining stock status, biological reference points (BRPs) and proxies, and in projecting probable short-term trends. The black sea bass stock north of Cape Hatteras, NC is not overfished and overfishing is not occurring. An assessment

model (ASAP) by north and south spatial sub-units is accepted as the best scientific information available for determining stock status. $F_{40\%}$ is still recommended as the proxy for F_{MSY} (the overfishing threshold). Although the two-area model had a major retrospective pattern in each area sub-unit, it provided reasonable estimates considering sensitivity runs and other models. Even though projections are conducted for each sub-unit, the combined projections should only be used, because of the major retrospective issues seen within each sub-unit.

The **witch flounder** age-structured assessment model, while scientifically well thought out, had major retrospective patterns in the estimates. Those model results are not recommended for management purposes. The status of the witch flounder stock is currently unknown relative to biological reference points. The panel believes that the previously accepted VPA model is not an acceptable alternative to the rejected ASAP application because it exhibits a similar major retrospective pattern. An empirical swept area approach may be useful for setting catch advice, although the Panel did not have time to fully review it in the context of the ToR of the meeting. As an F_{MSY} proxy, the Panel supports using a relative exploitation rate derived from the average exploitation (recent catch divided by recent swept area exploitable biomass estimates) in the near term, where other alternatives are unavailable. The spring and autumn NEFSC surveys are regarded as providing the best available fishery independent indices for this species and they show broadly similar patterns of a decline from the early 1960s to record low levels in the late 1980s and early 1990s, an increase to early 2000s followed by a declining trend. The empirical area swept method does not provide a biomass threshold, but does indicate that the stock is at low historical levels.

Table 1. 62nd Stock Assessment Review Committee Panel

SARC Chairman (MAFMC SSC):

Dr. Patrick Sullivan
Cornell University
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SARC Panelists (CIE):

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Nanoose Bay, BC
Canada V9P 9C1
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Table 2. Agenda, 62nd Stock Assessment Review Committee Meeting

Nov. 29 – Dec. 2, 2016

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

DRAFT AGENDA* (version: Nov. 22, 2016)

TOPIC	PRESENTER(S)	SARC LEADER	RAPPORTEUR
Tuesday, Nov. 29			
10 – 10:45 AM			
Welcome/Description of Review Process	**James Weinberg**, SAW Chair		
Introductions/Agenda		**Pat Sullivan,** SARC Chair	
Conduct of Meeting			
10:45 – 12:45 PM	Assessment Presentation (A. Black sea bass)		
	Gary Shepherd		**K. Curti**
12:45 – 1:45 PM	Lunch		
1:45 – 3:45 PM	Assesssment Presentation (A. Black sea bass)		
	Gary Shepherd	**K. Curti**	
3:45 – 4 PM	Break		
4 – 5:45 PM	SARC Discussion w/ Presenters (A. Black sea bass)		
		Pat Sullivan, SARC Chair	**K. Curti**
5:45 – 6 PM	Public Comments		
Wednesday, Nov. 30			
8:30 – 10:30 AM	Assessment Presentation (B. Witch flounder)		
	Susan Wigley		**T. Wood**
10:30 – 10:45 AM	Break		
10:45 – 12:30 PM	Assessment Presentation (B. Witch flounder)		
	Susan Wigley		**T. Wood**
12:30 – 1:30 PM	Lunch		
1:30 – 3:30 PM	SARC Discussion w/presenters (B. Witch flounder)		
		Pat Sullivan, SARC Chair	**T. Wood**

3:30 – 3:45 PM Public Comments

3:45 -4 PM Break

4 – 6 PM Revisit with Presenters (A. Black sea bass)
Pat Sullivan, SARC Chair **K. Curti**

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

Thursday, Dec. 1

8:30 – 10:30 Revisit with Presenters (B. Witch flounder)
Pat Sullivan, SARC Chair **T. Wood**

10:30 – 10:45 Break

10:45 – 12:15 Review/Edit Assessment Summary Report (A. Black sea bass)
Pat Sullivan, SARC Chair **TBD**

12:15 – 1:15 PM Lunch

1:15 – 2:45 PM (cont.) Edit Assessment Summary Report (A. Black sea bass)
Pat Sullivan, SARC Chair **TBD**

2:45 – 3 PM Break

3 – 6 PM Review/edit Assessment Summary Report (B. Witch flounder)
Pat Sullivan, SARC Chair **TBD**

Friday, Dec. 2

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, the public should not engage in discussion with the SARC.

Table 3. 62nd SAW/SARC, List of Attendees, NOVEMBER 29 – DECEMBER 2, 2016

James Weinberg	NEFSC
Russ Brown	NEFSC
Gary Shepherd	NEFSC
Mark Terceiro	NEFSC
Susan Wigley	NEFSC
Tony Wood	NEFSC
Kiersten Curti	NEFSC
Sheena Steiner	NEFSC
Chris Legault	NEFSC
Sarah Gaichas	NEFSC
Alicia Miller	NEFSC
Paul Nitzschke	NEFSC
Chuck Adams	NEFSC
Loretta O'Brien	NEFSC
John Maniscalco	NYDEC
Jamie Cournane	NEFMC
Kiley Dancy	MAFMC
Patricia Perez	NEFOP
Steve Cadrin	SMAST
Vivian Haist	Centre for Independent Experts (Reviewer)
Anders Nielsen	Centre for Independent Experts (Reviewer)
Neil Klaer	Centre for Independent Experts (Reviewer)
Pat Sullivan	NEFMC (SARC Chair)
Kirby Rootes-Murdy	ASMFC
Rich McBride	NEFSC
Nichola Meserve	MA DMF
Ashley Weston	SMAST
Greg Power	GARFO
Liz Daskey	Cornell Univ
Bob Glenn	MA DMF
Larry Alade	NEFSC
Mike Radziszewski	NEFOP
Brandon Muffley	MAFMC
Katherine Sosebee	NEFSC
Heath Cook	NEFSC
Tim Miller	NEFSC
Gavin Fay	UMASS Dartmouth
Greg DeCelles	MA DMF
Jackie Odell	NSC
Vito Giacalone	NSC
Liz Brooks	NEFSC
Brooke Wright	SMAST
Aja Szumylo	GARFO
Dave Richardson	NEFSC
Harvey Walsh	NEFSC
Amanda Hart	UMASS Dartmouth
Hannah Goodale	GARFO
Jessica Blaylock	NEFSC
Melanie Griffin	

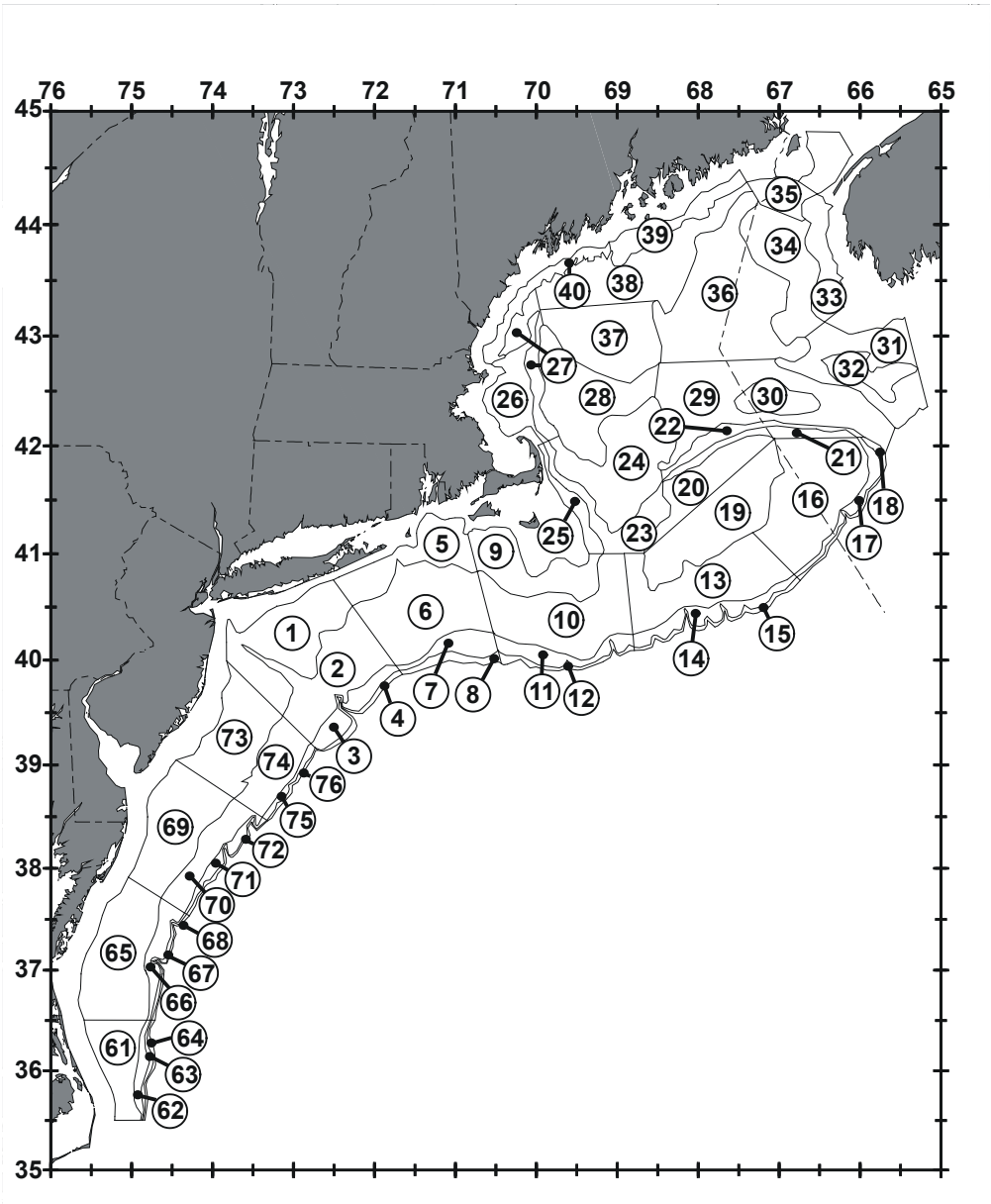


Figure 1. Offshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

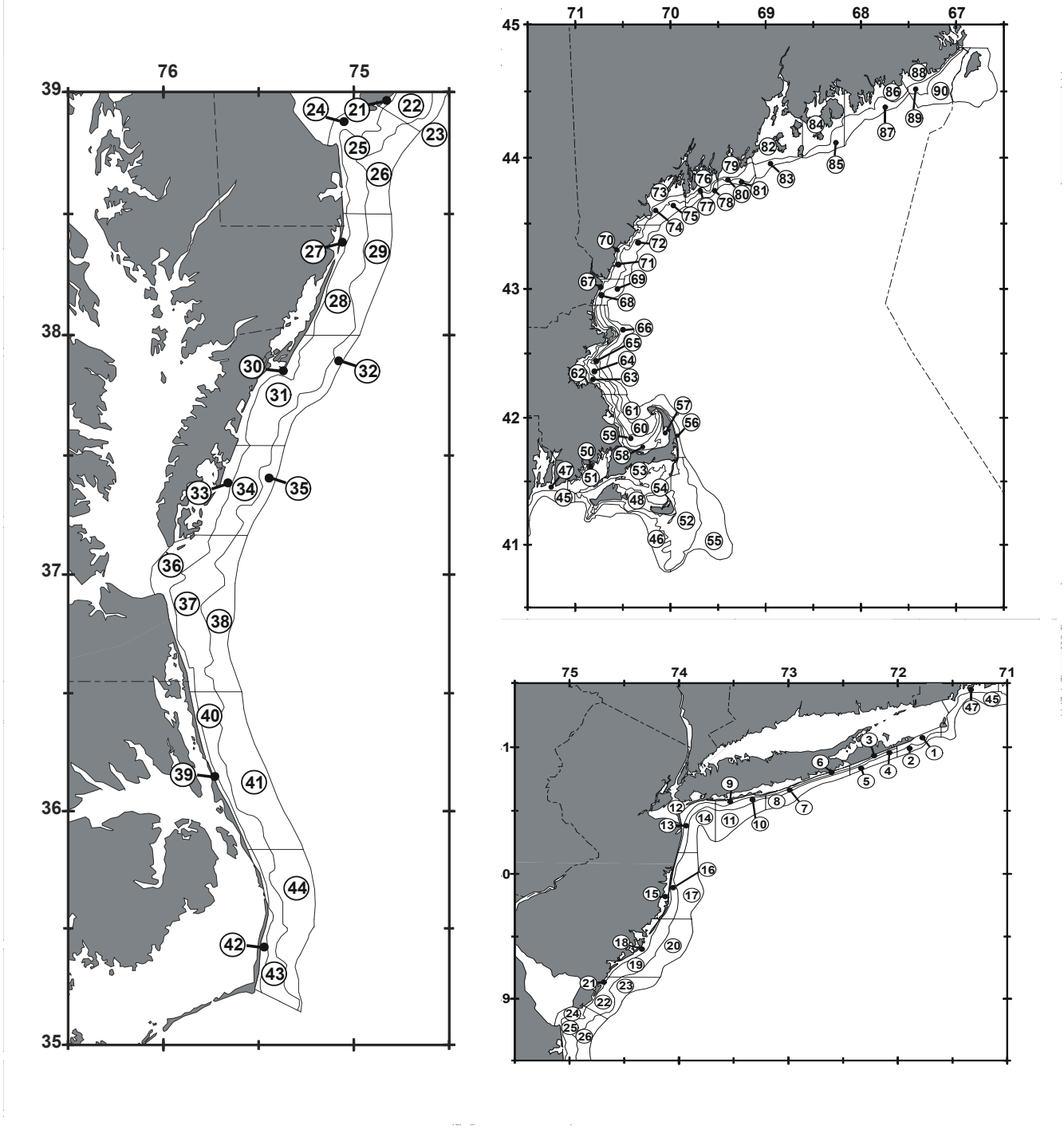


Figure 2. Inshore depth strata that have been sampled during Northeast Fisheries Science Center bottom trawl research surveys. Some of these may not be sampled presently.

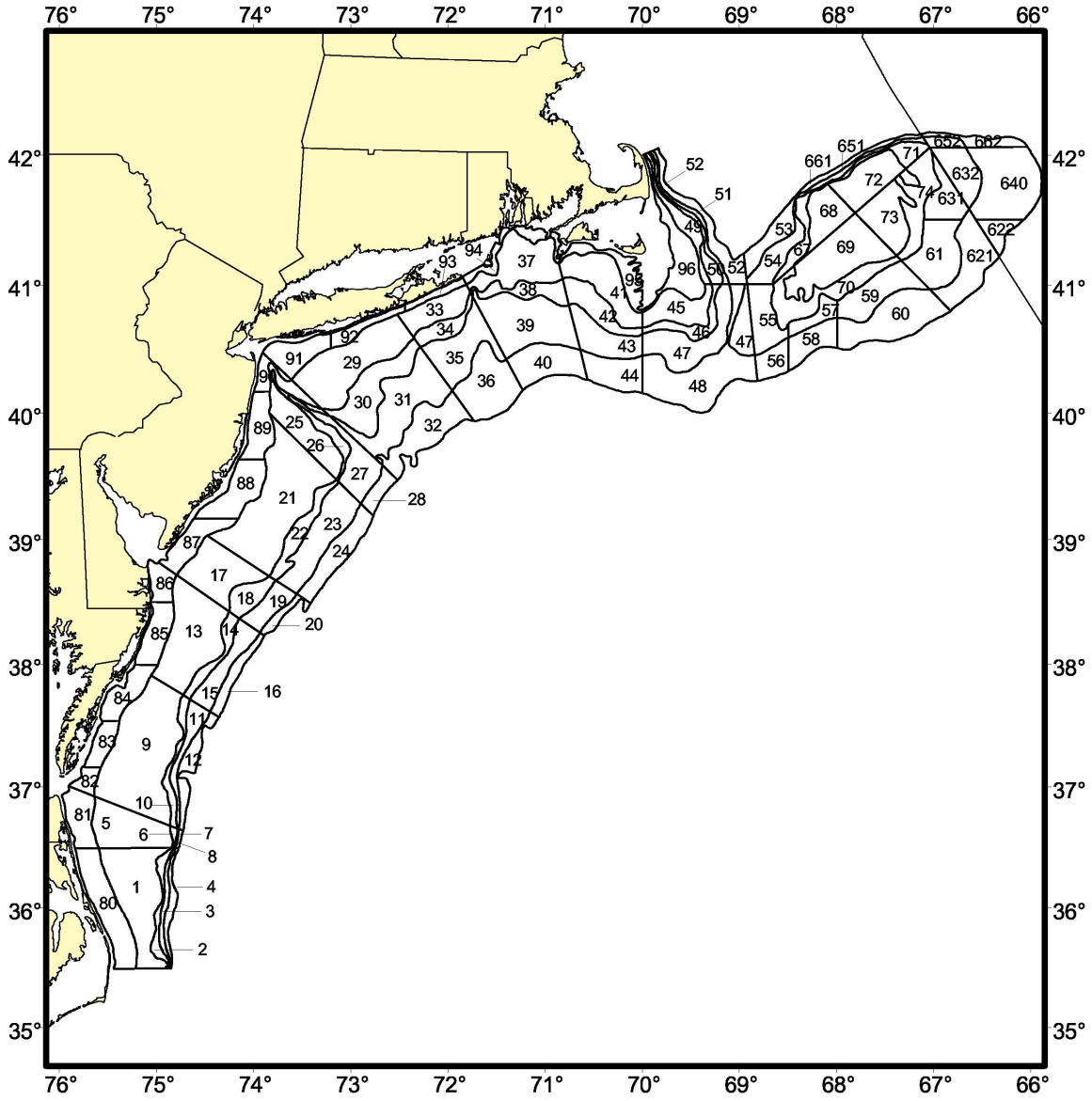
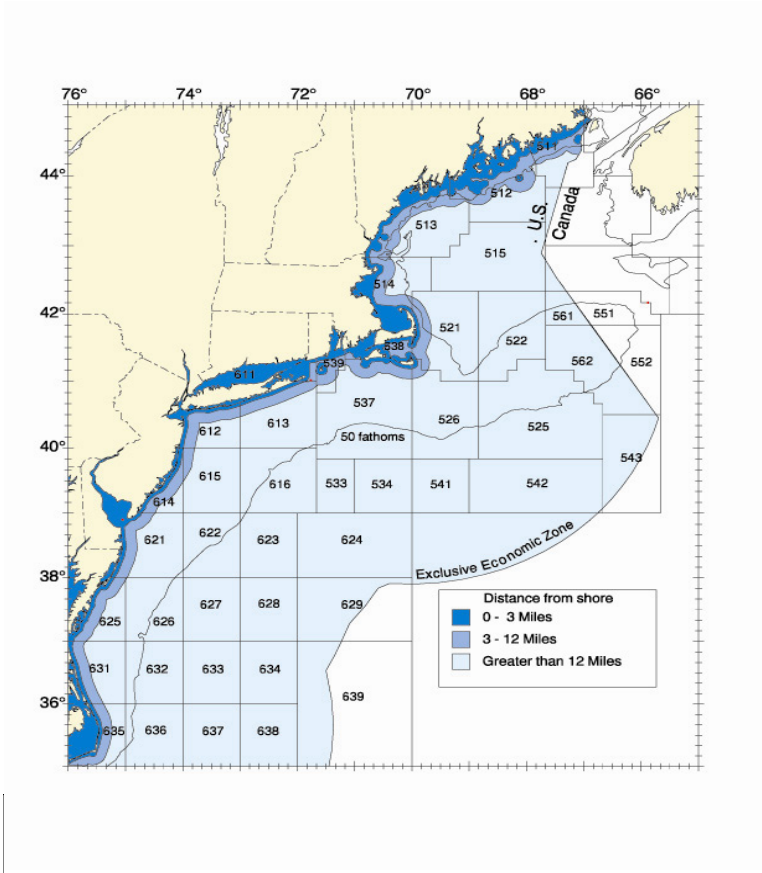


Figure 3. Depth strata sampled during Northeast Fisheries Science Center clam dredge research surveys.



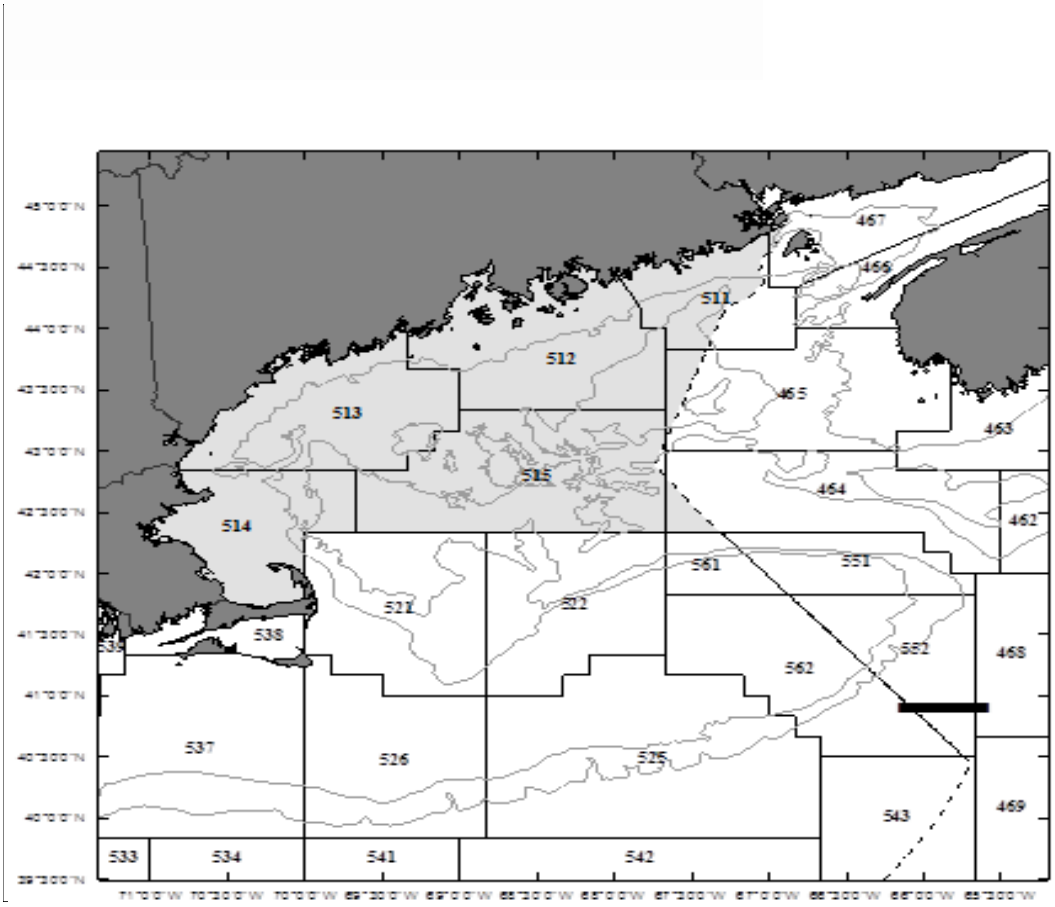


Figure 4. Statistical areas used for reporting commercial catches.

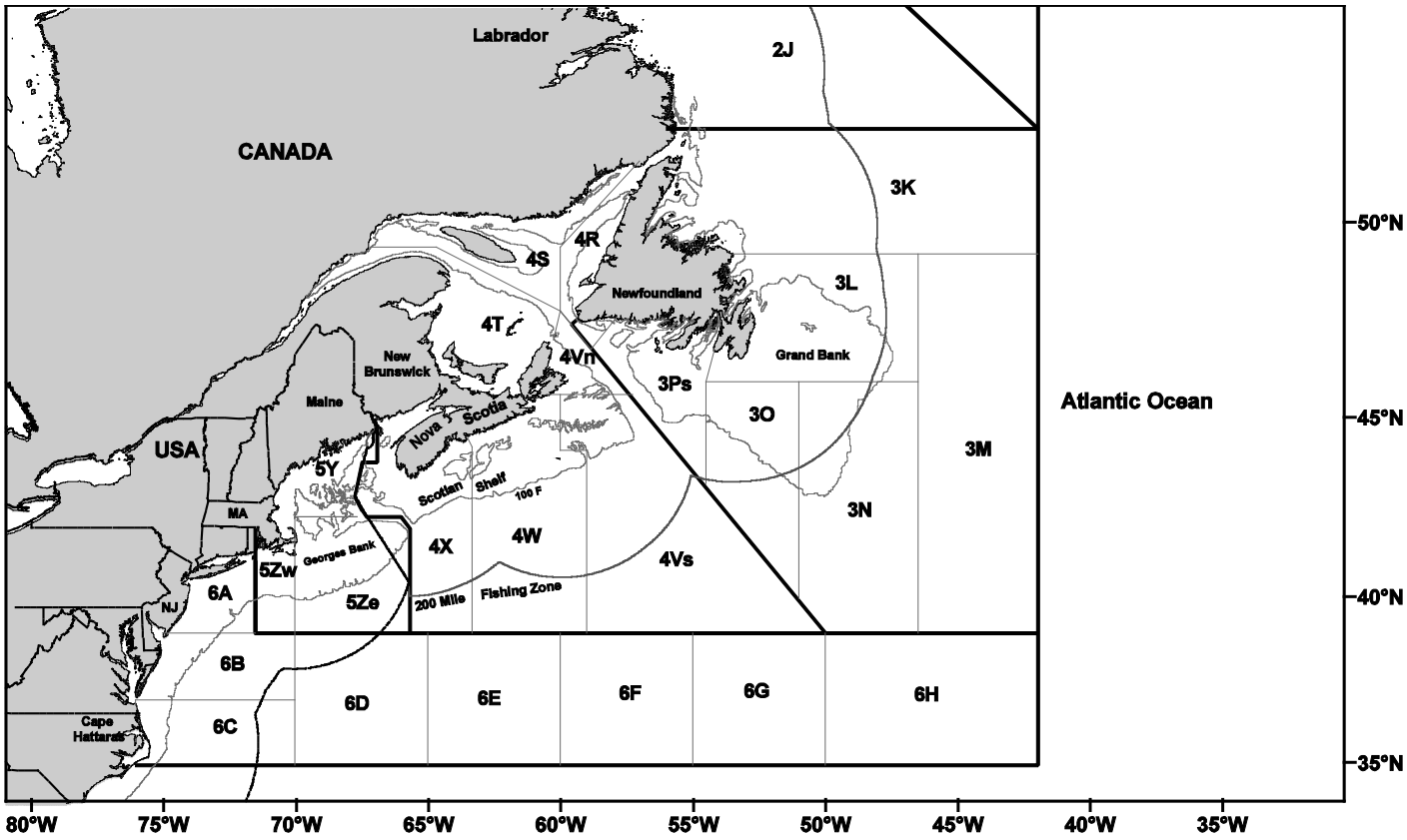


Figure 5. Catch reporting areas of the Northwest Atlantic Fisheries Organization (NAFO) for Subareas 3-6.

A. STOCK ASSESSMENT FOR BLACK SEA BASS FOR 2016

TERMS OF REFERENCE

TOR 1. Summarize the conclusions of the February 2016 SSC peer review regarding the potential for spatial partitioning of the black sea bass stock. (The consequences for the stock assessment will be addressed in TOR-6.)

TOR 2. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data. Evaluate available information on discard mortality and, if appropriate, update mortality rates applied to discard components of the catch. Describe the spatial and temporal distribution of fishing effort.

TOR 3. Present the survey data being used in the assessment (e.g., indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of fishery dependent indices as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

TOR 4. Consider the consequences of environmental factors on the estimates of abundance or relative indices derived from surveys.

TOR 5. Investigate implications of hermaphroditic life history on stock assessment model. If possible, incorporate parameters to account for hermaphroditism.

TOR 6. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock), using measures that are appropriate to the assessment model, for the time series (integrating results from TORs-1,-4, & -5 as appropriate), and estimate their uncertainty. Include a historical retrospective analysis and past projection performance evaluation to allow a comparison with most recent assessment results.

TOR 7. Estimate biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, FMSY, and MSY), including defining BRPs for spatially explicit areas if appropriate, and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

TOR 8. Evaluate overall stock status with respect to a new model or new models that considered spatial units developed for this peer review.

TOR 9. Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (3-5 years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level) that fully incorporates observation, process and model uncertainty (see Appendix to the SAW TORs). 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, and definition of BRPs for black sea bass).

b. Comment on which projections seem most realistic. Consider major uncertainties in the assessment as well as the 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.

TOR 10. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Appendix to the SAW Assessment TORs: **Clarification of Terms used in the SAW/SARC Terms of Reference**

Guidance to SAW WG about "Number of Models to include in the Assessment Report": In general, for any TOR in which one or more models are explored by the WG, give a detailed presentation of the "best" model, including inputs, outputs, diagnostics of model adequacy, and sensitivity analyses that evaluate robustness of model results to the assumptions. In less detail, describe other models that were evaluated by the WG and explain their strengths, weaknesses and results in relation to the "best" model. If selection of a "best" model is not possible, present alternative models in detail, and summarize the relative utility each model, including a comparison of results. It should be highlighted whether any models represent a minority opinion.

On "Acceptable Biological Catch" (DOC Nat. Stand. Guidel. Fed. Reg., v. 74, no. 11, 1-16-2009):

Acceptable biological catch (ABC) is a level of a stock or stock complex's annual catch that accounts for the scientific uncertainty in the estimate of Overfishing Limit (OFL) and any other scientific uncertainty…" *(p. 3208) [In other words, OFL ≥ ABC.]*

ABC for overfished stocks. For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect the annual catch that is consistent with the schedule of fishing mortality rates in the rebuilding plan. *(p. 3209)*

NMFS expects that in most cases ABC will be reduced from OFL to reduce the probability that overfishing might occur in a year. (p. 3180)

ABC refers to a level of ''catch'' that is ''acceptable'' given the ''biological'' characteristics of the stock or stock complex. As such, Optimal Yield (OY) does not equate with ABC. The specification of OY is required to consider a variety of factors, including social and economic factors, and the protection of marine ecosystems, which are not part of the ABC concept. (p. 3189)

On "Vulnerability" (DOC Natl. Stand. Guidelines. Fed. Reg., v. 74, no. 11, 1-16-2009):

"Vulnerability. A stock's vulnerability is a combination of its productivity, which depends upon its life history characteristics, and its susceptibility to the fishery. Productivity refers to the capacity of the stock to produce Maximum Sustainable Yield (MSY) and to recover if the population is depleted, and susceptibility is the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery (e.g., loss of habitat quality)." (p. 3205)

Participation among members of a Stock Assessment Working Group:

Anyone participating in SAW meetings that will be running or presenting results from an assessment model is expected to supply the source code, a compiled executable, an input file with the proposed configuration, and a detailed model description in advance of the model meeting. Source code for NOAA Toolbox programs is available on request. These measures allow transparency and a fair evaluation of differences that emerge between models.

Executive Summary

Term of reference 1. Summarize the conclusions of the February 2016 SSC peer review regarding the potential for spatial partitioning of the black sea bass stock. (The consequences for the stock assessment will be addressed in TOR-6.)

The Black Sea Bass Working Group (WG) presented information to a review panel of the Mid-Atlantic Fishery Management Council Science and Statistical Committee (MAFMC SSC) regarding spatial patterns in the black sea bass northern stock. The WG concluded that recognizing two distinct areas separated by Hudson Canyon would provide the best spatial partitioning for the stock assessment. The WG emphasized that the two areas do not constitute discrete stock areas. The review panel agreed with this spatial boundary as a starting point for evaluation in the assessment.

Term of reference 2. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data. Evaluate available information on discard mortality and, if appropriate, update mortality rates applied to discard components of the catch. Describe the spatial and temporal distribution of fishing effort.

The principal gears used in commercial fishing for black sea bass are fish pots, otter trawls and hand-lines. Commercial landings peaked in 1952 at 9,900 mt then declined substantially during the 1960s until commercial landings during the late 1980s and 1990s averaged 1,300 mt. Commercial fishery quotas were implemented in 1998 but commercial landings remained stable between 1,300 mt and 1,600 mt until 2007. After quota restrictions, commercial landings declined to 523 and 751 mt in 2009 and 2010, respectively. Commercial landings increased to 1,088 mt in 2013 and have since remained above 1,000 mt (1,113 mt in 2015). The recreational rod-and-reel fishery for black sea bass harvests a significant proportion of the total catch. After peaking in 1986, recreational landings averaged 1,700 mt annually until 1997. Recreational fishery harvest limits were implemented in 1998 and recreational landings have since ranged between 500 mt and 2,000 mt. Recreational landings in 2015 were 1,864 mt. Commercial fishery discards, although poorly estimated, appear to be a minor part of the total fishery removals from the stock. Commercial discards were generally less than 200 mt per year, but increased to 416 mt and 335 mt in 2014 and 2015, respectively. Recreational discard losses

assuming 15% hook and release mortality are similar, generally less than 500 mt per year. Estimated mortality from recreational discards was 371 mt in 2015. The distributions of the commercial and recreational fisheries were described and maps were produced based on observed trips and vessel trip reports.

Term of reference 3. Present the survey data being used in the assessment (e.g., indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of fishery dependent indices as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

The 2016 assessment model for black sea bass applied spatially explicit age-based statistical catch at age models using catch and age information since 1989. The fishery catch in two areas (north and south of Hudson Canyon) is modeled as two fleets (trawl and non-trawl) with area specific indices of stock abundance from NEFSC winter and spring surveys, the NEAMAP spring survey, recreational catch per angler, as well as state survey indices from VA, MD, DE, NJ in the south and NY, CT, RI and MA in the northern area. Several state survey index series were modeled to standardize factors that influence the indices. The standardized values were used as relative indices of abundance. Indices in the north have increased over the past decade and show a very strong 2011 year class. Indices in the southern area indicated a strong 1999 cohort, however the 2011 cohort is only average in size for the southern area. Recreational catch per angler trip (CPA) was developed using effort targeting a suite of species commonly caught with sea bass and was used as a relative index of abundance.

Term of reference 4. Consider the consequences of environmental factors on the estimates of abundance or relative indices derived from surveys.

The significant factors in the state surveys were depth, salinity and temperature. In response to issues raised in previous black sea bass assessments, a study was also conducted to evaluate the influence of winter oceanographic conditions on distribution and survival. The study concluded that warm saline conditions improved juvenile survival and the location of the shelf-slope front dictates the distribution of adults in the winter offshore habitat.

Term of reference 5. Investigate implications of hermaphroditic life history on stock assessment model. If possible, incorporate parameters to account for hermaphroditism.
In response to previous research recommendations the implication of black sea bass life history on exploitation, was evaluated in a simulation study. The study concluded that black sea bass in the northern unit stock was more robust to exploitation than typical hermaphroditic species depending on spawning contributions from secondary males. Given these findings and the findings of previously published studies, black sea bass spawning stock biomass (SSB) was defined as male and female mature biomass. Since growth between males and female black sea bass is similar, the WG concluded that use of male and female SSB accounted for the unique life history of black sea bass. Additionally, an operating model conditioned on the available black sea bass data including sex structure and hermaphroditism was used to simulate data for performance testing of alternative estimation models. The pooled-sex modeling approach developed by the WG performed relatively well for determining stock status.

Term of reference 6. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock), using measures that are appropriate to the assessment model, for the time series (integrating results from TORs 1,4, & 5 as appropriate), and estimate their uncertainty. Include a historical retrospective analysis and past projection performance evaluation to allow a comparison with most recent assessment results.
Fishing mortality (F) from the combined north and south areas varied between F = 1.34 (1993) and F = 0.24 (2015). The mortality averaged greater than 1.0 prior to implementation of management regulations in 1997. Fishing mortality remained above 0.50 between 1998 and 2008 then declined steadily to 0.24 in 2015 (value not adjusted for retrospective bias). Both the north and south area models had a pattern of retrospective bias. However the direction of patterns was different between areas, with apparently over-estimated fishing mortality (F) in the north and apparently under-estimated F in the south. A combination of retrospective adjusted Fs from each area produced a 2015 F = 0.27. Spawning stock biomass (SSB) increased from about 2,485 mt in 1991 to about 8,500 mt in 2002, then decreased to about 4,072 mt by 2007. With improved recruitment and declining fishing mortality rates, SSB has steadily increased since 2007. Total spawning biomass peaked in 2014 at 17,158 mt then declined in 2015 to 16,552 mt (value not adjusted for retrospective bias) as the 2011 cohort abundance declined. Total biomass

increased from 6,558 mt in 1989 to 16,205 mt in 2002, but decreased to 9,777 mt by 2006. However, beginning in 2007 biomass began increasing, peaking at 27,125 mt in 2014. Total biomass was slightly lower in 2015 at 24,143 mt (retrospective bias adjusted 2015 biomass equaled 32,010 mt) while the SSB retrospective adjusted value equaled 22,176 mt. Recruitment at age 1 averaged 24.318 million fish from 1989 to 2015, with peaks in 1991 (29.149 million, 1990 cohort), 1994 (27.188 million, 1994 cohort), 2000 (37.256 million, 1999 cohort) and most importantly in 2012 (68.932 million) from the 2011 cohort. The distribution of the 2011 cohort was more prevalent in the northern area of the stock. The 2014 cohort in 2015 was estimated as 24.917 million fish with a retrospective adjusted recruitment equal to 18.002 million fish. Model results in both areas show a generally decreasing trend in fishing mortality but different historical trends in recruitment and spawning stock biomass. Recent increased biomass occurred in both areas and relatively high biomass in the last year. Several alternative modeling approaches produced similar results, suggesting that the results are robust to a range of data and model decisions.

Term of reference 7. Estimate biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, FMSY, and MSY), including defining BRPs for spatially explicit areas if appropriate, and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The 2008 Northeast Data Poor Stocks Working Group (NEDPSWG) Review Panel (NEFSC 2009a) recommended $F_{40\%}$ be used as a proxy for F_{MSY} and total spawning stock biomass at $F_{40\%}$ ($SSB_{40\%}$) be used as the proxy for the stock biomass target reference point. Considering the weak stock-recruitment relationship in the range of estimated stock sizes and biological reference points for comparable species, F40% was maintained as the proxy for black sea bass MSY related reference points in the 2016 assessment. The average of the two area specific F40% values produced a F_{MSY} proxy of 0.36. Based on a long-term projection at F_{MSY} proxy, the associated SSB_{MSY} proxy equaled 9,667 mt and B_{MSY} proxy equaled 17,256 mt.

Term of reference 8. Evaluate overall stock status with respect to a new model or new models that considered spatial units developed for this peer review.

Stock status was evaluated using the combined results of the two area models (2015 retrospective adjusted average fishing mortality F=0.27) compared to the area-averaged $F_{MSY\ proxy}$ (0.36). Results indicate that overfishing is not occurring on the stock. The 2015 combined retrospective adjusted total biomass was (32,010 mt) was much greater than the $B_{MSYproxy}$ (17,256 mt) and biomass threshold of 8,628 mt. In addition, the combined retrospective adjusted SSB of 22,176 mt was well above the SSB_{MSY} proxy of 9,667 mt and SSB proxy threshold of 4,834 mt. Therefore the stock is not considered over-fished.

Term of reference 9. Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (3-5 years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level) that fully incorporates observation, process and model uncertainty (see Appendix to the SAW TORs). 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, and definition of BRPs for black sea bass).

b. Comment on which projections seem most realistic. Consider major uncertainties in the assessment as well as the 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.

Projections were made for two fishing mortality scenarios. One assumes that fishing mortality from 2017 to 2019 equaled the F_{MSY} proxy, and a second scenario assumes that F equals to the 2015 terminal year status quo value (North F_{SQ}=0.14 and South F_{SQ}=0.39). Future annual recruitments were drawn from empirical values from 2000 to 2015 and catch in 2016 was assumed equal to the allowable biological catch (3,024 mt). Starting stock size was based on area-specific estimates of 2016 abundance at age with retrospective adjustments and recent selectivity estimates. F_{MSY} projections suggest that spawning biomass would decline to 11,849 mt by 2019 and total biomass would equal 20,788 mt by 2019. Total catch under that scenario

would increase to 5,467 mt in 2017 then decline to 3,901 mt by 2019. F_{SQ} projections suggest that combined area spawning biomass would decline to 15,349 mt by 2019 and total biomass would equal 24,704 mt by 2019. Total catch under that scenario would decrease to 3,024 mt in 2017 then decline to 2,764 mt by 2019.

The projections were developed for a single stock using the combined results of the north and south areas. It was clear from the results that the area specific conditions vary and therefore the vulnerability of each area to exploitation at a common F may vary.

Term of reference 10. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

The WG reviewed previous research recommendations and concluded they had been considered and when possible completed. New recommendations for future consideration include:

expand on previous genetic studies with smaller spatial increments in sampling; consider the impact of climate change on black sea bass, particularly in the Gulf of Maine; evaluate population sex change and sex ratio, particularly comparing dynamics among communities; study black sea bass catchabilty in a variety of survey gear types; investigate and document social and spawning dynamics of black sea bass; increase work to understand habitat use in sea bass and seasonal changes; evaluate use of samples collected by industry study fleets.

Black Sea Bass Working Group :

The SARC62 Black Sea Bass Working Group conducted two data meetings (June 29-July 2 2015, Warwick RI; June 27-29, 2016, Providence RI), a spatial structure workshop (December 16 2015, Warwick RI), one model meeting (September 6-9 2016, Woods Hole MA), and several video conference calls in the development of this assessment. The formal working group consisted of:

John Maniscalco – New York Dept. of Environmental Conservation - chair
Gary Shepherd – Northeast Fisheries Science Center –assessment lead
Mike Bednarski – Massachusetts Division of Marine Fisheries (currently Virginia Dept. Game and Inland Fisheries)

Jeffrey Brust – New Jersey Department of Environmental Protection

Steve Cadrin – UMass Dartmouth

Steve Doctor – Maryland Dept. of Natural Resources - Fisheries Service

Gavin Fay – UMass Dartmouth

Robert Leaf – University of Southern Mississippi

Chris Legault – Northeast Fisheries Science Center

Jason McNamee – Rhode Island DEM- Division of Fish and Wildlife, Marine Fisheries

Other participants included Kirby Rootes-Murdy (ASMFC), Kiley Dancy (MAFMC), Kiersten Curti (NEFSC), Olaf Jensen (Rutgers Univ.), Joe Myers (ACCSP), Greg Wojcik (CT), Peter Clarke (NJDEP), Tom Wadsworth (NCDMF), Greg DeCelles (UMass Dartmouth), Mark Hoffman (AP), Mark Terceiro (NEFSC), Rich Seagraves (MAFMC), Moira Kelly (GARFO), Rich Wong (DEDFW), Alicia Miller (NEFSC), Marissa McMahan (Northeastern Univ.), Eric Powell (SCEMFIS), Alexei Sharov (MDDNR), Mike Palmer (NEFSC), Paul Nitschke (NEFSC), Chuck Adams (NEFSC), Tim Miller (NEFSC), Jeff Kipp (ASMFC), Jessica Blaylock (NEFSC).

INTRODUCTION

Life History

Black sea bass (*Centropristis striata*) are distributed from the Gulf of Maine to the Gulf of Mexico, but fish north of Cape Hatteras, NC are considered part of a single unit stock (Figure A1). Over the past decade, the distribution of sea bass has expanded into the Gulf of Maine (Bell et al. 2014) as far as eastern coastal Maine (M. McMahan, Northeastern Univ, pers. comm.). Within the stock area, distribution changes on a seasonal basis and the extent of the seasonal change varies by location. In the northern end of the range (New York to Massachusetts), black sea bass move offshore crossing the continental shelf, then south along the edge of the shelf (Moser and Shepherd 2009). By late winter, northern fish may travel as far south as Virginia, but most return to the northern inshore areas by May. Black sea bass originating inshore along the Mid-Atlantic coast (New Jersey to Maryland) head offshore to the shelf edge during late autumn, travelling in a southeasterly direction. They return inshore in spring to the general area from which they originated. Black sea bass in the southern extent of the stock (Virginia and

North Carolina) move offshore in late autumn/early winter. Given the proximity of the shelf edge, they transit a relatively short distance, due east, to reach over-wintering areas.

Black sea bass are protogynous hermaphrodites and can be categorized as temperate reef fishes (Steimle et al. 1999, Drohan et al. 2007). Transition from female to male generally occurs between the ages of two and five years (Lavenda 1949, Mercer 1978). Based on sex ratio at length from NMFS surveys, males constitute approximately 25% of the population by 15 cm, with increasing proportions of males with size (Figure A2). Following transition from female to male, sea bass can follow one of two behavioral pathways; either becoming a dominant male, characterized by a larger size and a bright blue nuccal hump during spawning season, or subordinate males (secondary males) which have few distinguishing features from females. The initiation of sexual transition appears to be based on visual rather than chemical cues (Dr. David Berlinsky, UNH, Personal communication). In studies of protogyny, among several coral reef fish species, transition of the largest female to male may occur quickly if the dominate male is removed from the reef, however, similar studies have not been published for black sea bass.

Spawning in the Middle Atlantic peaks during spring (May and June) when the fish reside in coastal waters (Drohan et al. 2007). The social structure of the spawning aggregations is poorly known although some observations suggest that large dominant males gather a harem of females and aggressively defend territory during spawning season (Nelson et al. 2003). The bright coloration of males during spawning season suggests that visual cues may be important in structuring of the social hierarchy. Black sea bass populations may also have secondary males present which are capable of spawning but do not present the same morphological features as dominant males (NEFSC 2012). Recent analysis of morphological features in mature female, primary and secondary male black sea bass showed that mature secondary males may be indistinguishable from mature females (Keigwin et al. 2016).

Age estimation for black sea bass has been routinely conducted at the NEFSC and other institutions (e.g. Virginia Institute of Marine Science (VIMS)) using both scales and otoliths. Validation of the ages and comparison between age readers is presented in Appendix A1. The study concluded that age determinations were valid using either structure, but older ages were easier to determine from otoliths. Some discrepancy remains between readers determining age 0 vs age 1 in fall samples. Consequently and for other reasons described below, fall indices were

not used in the stock assessment analysis. Any fall catch data age 0 or 1 were based on NEFSC age data.

Black sea bass attain a maximum size around 60 cm and 4 kg. Published growth curves from Lavenda (1949) suggested a maximum age for females of 8 and age 12 for males. However he noted the presence of large males (>45 cm) in deeper water that may have been older. Von Bertalanffy growth curves from NEFSC age and growth data produce estimates of Linf equal to 58.9 cm with K and t_0 of 0.22 and 0.207, respectively (Figure A3). Length at 50% maturity for both sexes combined occurs at 21.0 cm (age2), based on NEFSC maturity data from spring and winter surveys since 1984 (Figure A4). Black sea bass reach full maturity by 35 cm (age 5) (Figure A5).

Habitat

Black sea bass are commonly associated with live-bottom and reef habitats although use a variety of habitats throughout the year. Habitat use by life stage and season was summarized by Steimle et al. (1999) and provided in Table A1. Fabrizio et al. (2013,2014) examined habitat use and home range with acoustic tags within a defined area of complex habitat. The results showed that black sea bass were relatively mobile, moving among habitats from structure (e.g. rocks, wrecks, reefs) to coarse bottom until leaving the area during the annual migration. A NEFSC outreach project prior to this assessment requested information from stakeholders on habitats where black sea bass were found (Appendix A2). Among the 75 respondents, 50 fishermen (including those using net, hook and line and other gear) noted that black sea bass were common on open bottom (not structured).

Past assessment reviewers expressed concern that indices based on trawl gear used inshore cannot be representative of abundance since such gear cannot tow in structured habitat commonly used by black sea bass. However, the NEFSC spring and winter surveys in offshore strata are conducted in the same area as the commercial winter otter trawl fishery, which is towable bottom. An analysis was done in SARC 53 to examine potential biases in the offshore spring survey indices due to avoidance of structure. The frequency of gear damage during tows

was evaluated relative to black sea bass indices to identify tows in structured habitat (Nieland and Shepherd 2011). The analysis concluded that there is no evidence of a bias in black sea bass catches in the offshore strata resulting from structured habitat.

To further address these concerns over the use of inshore trawl surveys to track relative abundance and size/age composition of black sea bass, an in-depth analysis of available data was conducted to compare catch characteristics of black sea bass by different gear types and in different habitats (Appendix A3). Results indicate that both catch rates and size distribution of black sea bass are similar in structured and non-structured habitat. These results are supported by scientific literature, as well as anecdotal information from the NEFSC outreach program, that indicate that black sea bass are not dependent on areas of high relief habitat and commonly occur in areas of open (trawlable) bottom. Additionally, the analysis indicated similarities between the segment of the population sampled by trawl gear and more specialized gear types like fish pots. In fact, trawl gear seemed to sample both small and large fish better than fish pots, again implying that trawl gear is an appropriate sampling gear for black sea bass. Based on the available information and analyzes, it was determined that trawl surveys operating in open bottom areas are sampling the same population of black sea bass as would be found in structured habitat, and as a result, inshore trawl surveys are appropriate for characterizing size structure and relative abundance of black sea bass.

Food habits

Black sea bass are visual predators and have a generalized carnivorous diet of predominantly motile, benthic species including amphipods, decapods, and fishes (Sedberry 1988). Items consumed by black sea bass depend on life stage and size. Smaller black sea bass consume mostly small crustaceans; including amphipods, isopods, small crabs and shrimp; but also feed on polychaetes. Larger black sea bass feed more on fish and decapod crustaceans; including rock crabs and juvenile American lobster. Other diet items include molluscs (cephalopods) and ascidians (Steimle et al. 1999).

Stomach content data was collected from fish caught during both the spring and fall NEFSC bottom trawl surveys from 1973-1990. Fish remains found in the stomachs of 802 trawl caught black sea bass included Alepocephalids, Atlantic herring, anchovy, sea horses, northern pipefish, lanternfish, sand lance, short-horned sculpin, cusk eel, scup, windowpane flounder, and rock gunnel. The invertebrate content of black sea bass stomachs was very diverse and included

hydrozoans, anthozoans, cerianthids, bryozoans, ctenophores, annelids (including polychaetes), amphipods, isopods, copepods, ostracods, chaetognatha, lancelets, sea spiders, crabs (including cancer, swimming, box, mud, mole, spider, hermit), shrimp, hooded shrimp, krill, mysids, squat lobster, barnacles, molluscs (including bivalves, snails, sea slugs, limpets, pteropods, cephalopods - squid), echinoderms (including brittle star and sea cucumbers) and tunicates (Rountree 1999).

Sampling in the NEFSC Bottom Trawl Survey from 1973-2008 also found black sea bass as prey items in the stomachs of various predators. In order of frequency of occurrence, these included demersal sharks, summer flounder, fourspot flounder, black sea bass, monkfish, spiny dogfish, skate, windowpane, little skate, bluefish, smooth dogfish, red hake, striped bass, silver hake, Atlantic cod and winter skate. Other food web research conducted in Chesapeake Bay found young of the year black sea bass in the stomachs of Age 1 weakfish (Hartman and Brandt 1995).

Sampling of stomach contents from fish caught in the Hudson Raritan Estuary by otter trawl also provides data on black sea bass as both predator and prey. Most of the black sea bass sampled were young of year or juveniles. Prey species were dominated by crustaceans, particularly shrimp, mysids and juvenile rock crab but also included copepods, amphipods, isopods and other juvenile decapods. Several stomachs contained fish species including cunner, goby, menhaden and anchovy. Juvenile black sea bass were found as prey items in the stomachs of summer flounder, striped searobins, northern searobin, clearnose skate, bluefish, and grubby sculpin (Steimle et al. 2000).

The Northeast Area Monitoring and Assessment Program Near Shore Trawl Survey (NEAMAP) samples from Cape Cod, MA south to Cape Hatteras, NC and targets both juvenile and adult fishes. The survey sampled diet composition of 1,245 black sea bass caught by the survey from 2007 through 2013. Gut contents analysis of these black sea bass found 55% crustaceans, 26.7% fishes, 10.8% mollusks, 4.2% miscellaneous, and 2.7% worms by weight. Crustaceans were the largest portion of the diet by weight and rock crabs led the crustaceans in abundance and weight. Bay anchovy was the most frequent of the fishes and the other important food items were squid, mollusks, gastropods, and worms. Sea bass examined were predominately age zero to age four fish.

The Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP) began in 2002 and uses a large-mesh bottom trawl to sample juvenile-to-adult fishes from the head of Chesapeake Bay at Poole's Island, MD to the mouth of the Bay just outside the Chesapeake Bay Bridge Tunnel. The ChesMMAP survey sampled the diet composition of 233 black sea bass from 2002 to 2013. Black sea bass stomach contents were composed of 70.5% crustaceans, 10.5% fishes, 10.2% miscellaneous, 4.7% worms, and 4.3% molluscs by weight. Crustaceans were dominated by mysids and amphipods. Sea bass examined were predominantly age one and two fish.

The ChesMMAP survey is conducted in the Chesapeake Bay verses the NEAMAP survey which is conducted in near shore waters. Comparison of the two surveys demonstrates the reliance of the smaller fish found in the Chesapeake Bay on mysids, mud crabs, amphipods, and sand shrimp while the larger fish caught in the NEAMAP survey rely more on rock crabs and fishes. Sand shrimp, amphipods, and bay anchovies were popular food items in both surveys.

Stomach contents analyses presented above are all from trawl caught fish but the results agree with those reported by Lindquist et al. (1994) and Steimle and Figley (1996) which collected fish using hook and line, spear and traps from Onslow Bay, NC and the Atlantic Ocean, NJ, respectively.

As part of an NEFSC outreach project of stakeholders as part of the SAW 62 assessment process, fishermen were asked if they had witnessed adult black sea bass preying on young of the year sea bass. They were also asked for their observations regarding predation on adult sea bass. Among 94 respondents only 6 had ever seen evidence of cannibalism. Predation on adults was observed primarily from adult bluefish, striped bass, sharks and dogfish and cormorants.

All of the stomach content analysis done on black sea bass indicates a generalist carnivore that feeds primarily on benthic crustaceans but will opportunistically feed on any prey encountered including small fish. This includes a limited amount of cannibalism. Also common in the datasets noted above is the ontogenetic shift from small crustaceans to larger decapods including juvenile crab and lobster.

Natural Mortality

Instantaneous natural mortality (M) has been explored in several previous assessments and a value of 0.4 has been used in most the recent assessment. A maximum age of 12 (oldest age in

NEFSC data) was assumed in re-examining M using available published methods. A constant M was chosen for use in the assessment and the average value among 20 estimates equaled 0.4, with a range from 0.1 to 0.9 (Figure A6, Table A2).

Fisheries

In the Northwest Atlantic, black sea bass support commercial and recreational fisheries. In 1939 and 1940, 46-48% of the commercial landings were in New England, primarily in Massachusetts. After 1940, the center of the fishery shifted south to New York, New Jersey and Virginia. Landings peaked in 1952 at 9,883 mt (Figure A7) with the bulk of the commercial landings from otter trawls, then declined steadily to a low point of 566 mt in 1971. Historically, trawl fisheries for sea bass focused on the over-wintering areas near the shelf edge. Inshore pot fisheries, which were primarily off New Jersey, showed a similar downward trend in landings between the peak in 1952 and the late 1960s. The large increase in landings during the 1950's appears to be the result of increased landings from otter trawlers, particularly from New York, New Jersey and Virginia. During the same period, a large increase in fish pot effort, and subsequent landings, occurred in New Jersey. In recent years, fish pots and otter trawls account for the majority of commercial landings with increasing contributions from hand-line fisheries (Figure A8). Inshore commercial fisheries are prosecuted primarily with fish pots (baited and unbaited) and hand-lines. Recreational fisheries, mostly boat based, generally occur during the period that sea bass are inshore. Once fish move offshore in the winter, they are caught in a trawl fishery targeting summer flounder, scup and *Doryteuthis* squid (Shepherd and Terceiro 1994). Hand-line and pot fisheries in the southern areas may still operate during this offshore period. A small sector of the NJ charter fleet targets sea bass offshore during the winter.

Stock assessment history

Black sea bass stock assessments have been reviewed in the SARC/SAW process (SAWs 1, 9, 11, 20, 25, 27, 39, 43, Data Poor Workshop and 53) beginning with an index based assessment in 1991 (summary in Table A3). In 1995 a VPA model was approved and the results generally showed fishing mortalities exceeding 1.0 (estimated using an M=0.2). The VPA was reviewed again in 1997 when it was considered indicative of general trends but too uncertain to determine stock status. In 1998, another review was conducted and both VPA and production models were rejected as either too uncertain or inappropriate for use with a hermaphroditic species. A

suggestion was made to use an alternative method such as a tag/recapture approach. The NEFSC survey remained the main source of information regarding relative abundance and stock status. A tagging program (Moser and Shepherd 2009) was initiated in 2002 and the first year results were presented for peer review in 2004. The review panel concluded that a simple tag recovery model using the proportion recovered in the first year at large, as well as an analysis of survey indices, produced acceptable results to determine exploitation rate and stock status. The release of tags continued through 2004 and results of tag models as well as survey indices were presented for SARC review in 2006. Their findings were that the tag model did not meet the necessary assumptions and the variability in the survey indices created uncertainty which prevented determination of stock status. The panel did not recommend any alternative reference points, but they recommended continued work on length based analytical models. The black sea bass assessment was reviewed by the Northeast Data-Poor Stocks Working Group (NDPSWG) in December 2008. The review panel considered a statistical catch-at-length model (SCALE) and a variety of natural mortality options. They concluded that the length-based model was suitable for evaluating stock status and recommended a constant natural mortality option of 0.4. Although the stock was considered not overfished or experiencing overfishing, the uncertainty in the results prompted the reviewers to recommend caution in applying the results for management.

A stock assessment using a statistical catch at age model (ASAP, Legault and Restrepo 1998) was most recently reviewed by SAW53 (December 2011) but was not accepted for use in management. The review panel concluded that spatial structure within the stock and the species strong association with complex habitats when inshore compromised the ability of a single age-structured model to adequately capture the dynamics. They also concluded that new data would be required to produce an assessment useful for management.

Management Overview

The Atlantic States Marine Fisheries Commission (ASMFC or Commission) and Mid-Atlantic Fishery Management Council (MAFMC or Council) cooperate to develop fishery regulations for black sea bass from Maine through Cape Hatteras, North Carolina (for details see Appendix A4). The Council and Commission work in conjunction with the National Marine Fisheries Service (NMFS), which serves as the federal implementation and enforcement entity. The Fishery

Management Plan (FMP) defines the management unit as black sea bass (*Centropristis striata*) in US waters in the western Atlantic Ocean from Cape Hatteras, North Carolina to the US-Canadian border (MAFMC 1996).

Commercial and recreational black sea bass fisheries are managed using annual catch limits, commercial quotas, recreational harvest limits, minimum fish sizes, gear regulations, permit requirements, and other provisions as prescribed by the FMP. Based on the allocation percentages in the FMP, 49% of the total allowable landings of black sea bass is allocated to the commercial fishery as a commercial quota and 51% is allocated to the recreational fishery as a recreational harvest limit. These measures are described in more detail in subsequent sections of this document.

The Council and the Commission's Summer Flounder, Scup, and Black Sea Bass Management Board (the Board) developed a cooperative management process for black sea bass including complementary FMPs, regular joint meetings, and joint decision-making on most aspects of management. This cooperative management endeavor was developed because a significant portion of the catch is taken from both state waters (0-3 miles offshore) and federal waters (3-200 miles offshore, also known as the Exclusive Economic Zone or EEZ). Primary responsibility for management in federal waters falls to the Council, while the Commission has primary jurisdiction over the fisheries in state waters. However, many measures, including annual catch limits, are jointly established on a coastwide basis and apply in both federal and state waters.

The Commission operates under the authority of the Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) of 1993. Commission member states include all Atlantic coast states, and for black sea bass, states that have declared an interest in the fishery include Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina. All states that are included in a Commission fishery management plan must implement required conservation provisions of the FMP, or the Secretary of Commerce may impose a moratorium for fishing in the noncompliant state's waters.

The Council operates under the authority of the Magnuson-Stevens Fishery Conservation and Management Act (MSA), passed in 1976 and amended in 1996 and 2007. The MSA extended U.S. jurisdiction to 200 nautical miles and established eight regional fishery management councils with representation from the coastal states and fishery stakeholders. The Mid-Atlantic

Council's representation includes 21 voting members and four non-voting members. Seven of the voting members represent the constituent states' fish and wildlife agencies from the states of New York through North Carolina. Thirteen members are private citizens who are knowledgeable about recreational fishing, commercial fishing, or marine conservation. The four non-voting members represent the Atlantic States Marine Fisheries Commission, the U.S. Fish and Wildlife Service, the U.S. Department of State, and the U.S. Coast Guard.

As mandated under the MSA, the Council's Scientific and Statistical Committee (SSC) gives ongoing scientific advice for annual catch limits and other issues as needed. Other technical issues and analyses are addressed through the joint Summer Flounder, Scup, and Black Sea Bass Monitoring Committee and the Commission's Black Sea Bass Technical Committee. The Monitoring Committee is a joint committee of the Council and the Commission made up of staff representatives of the Mid-Atlantic and South Atlantic Fishery Management Councils, the Atlantic States Marine Fisheries Commission, the Greater Atlantic Regional Office, and the Northeast Fisheries Science Center. The Monitoring and Technical Committees annually review the performance of management measures and recommend any adjustments necessary to account for the current stock status, catch limits, and issues facing the commercial and recreational fisheries.

The Council and Commission each have Summer Flounder, Scup, and Black Sea Bass Advisory Panels, comprised of commercial, recreational, and environmental stakeholders with an interest in these fisheries. The Advisory Panels provide ongoing advice to the Council and Commission regarding on-the-water trends and issues in the fisheries.

In an annual process the Council and Commission review catch and landings limits and a specific set of commercial and recreational measures that can be modified annually. The Council and Board meet jointly each year to consider the annual catch limits for the upcoming fishing year or years, along with the commercial and recreational size limits, seasons, gear requirements, and possession limits. Multi-year specifications may be set for black sea bass for up to three years at a time. The Council and Board consider the recommendations of the SSC, the Monitoring Committee, Advisory Panel members, and public comments before recommending commercial quotas, recreational harvest limits, and other annual management measures for all three species.

More substantial modifications to the FMP or regulations are undertaken through FMP amendments, addenda, and framework actions. FMP "amendments" include major changes to the management regime that require extensive analysis, and are typically developed jointly by both the Council and the Commission. For less complicated actions, the Commission may also make changes through an "addendum" process, while the Council can make minor changes to the FMP through a "framework adjustment" process, both of which typically take less time and resources than an amendment requires.

The Council submits any recommended changes in regulations or FMP elements to the NMFS Greater Atlantic Regional Administrator to consider for implementation. The Regional Administrator reviews the recommendations in this document and may revise them, if necessary, to achieve FMP objectives and to meet statutory requirements. The Commission's actions do not require review by NMFS, and member states are responsible for implementing the Board's decisions.

TOR 1. **S**ummarize the conclusions of the February 2016 SSC peer review regarding the potential for spatial partitioning of the black sea bass stock. (The consequences for the stock assessment will be addressed in TOR-6.)

The review panel for the SAW/SARC 53 black sea bass assessment noted "*concerns over the potential for spatial structure and incomplete mixing within the stock area that compromised the ability of the forward projecting catch at age model to index abundance and fishing mortality reliably based on the data available.*" In response to this need to introduce a spatial element into the sea bass assessment, the WG developed a recommendation to partition the stock north of Cape Hatteras, NC into two sub-units divided by the Hudson Canyon for development of the assessment model. The basis for this recommendation was presented to a four member ad-hoc review panel of the Mid-Atlantic Fishery Management Council Science and Statistical Committee (MAFMC SSC) on February 16, 2016. The panel presented its report on March 3, 2016 to the full SSC committee and concluded that the recommended separation was reasonable and appropriate to use as a starting point for developing a black sea bass stock assessment model. The full report to the ad-hoc review panel and their response to the SSC are provided in Appendix A5

The implication of a split area assessment was evaluated using a simulated black sea bass population. Empirical sea bass data was used as the basis to develop a migratory sea bass population within a Stock Synthesis (SS) model framework. The pseudo-datasets were used within an SS model framework to compare results with area partitioning, without area partitioning and with both movement and area partitioning. The details of the simulations are provided in Appendix A6. The conclusion of the simulated assessment was that the two area model was more effective in capturing the dynamics of the overall population than a one-area assessment, and more complex models that account for movement among sub-units did not perform significantly better than the two-area estimation model approach.

TOR 3. Present the survey data being used in the assessment (e.g., indices of abundance, recruitment, state surveys, age-length data, etc.). Investigate the utility of commercial or recreational LPUE as a measure of relative abundance. Characterize the uncertainty and any bias in these sources of data.

Survey data considered for the assessment included NMFS winter and spring surveys and state survey data from MA, RI, CT, NY, NJ, DE, MD, VA and NEAMAP (Northeast Area Monitoring and Assessment Program) (Table A4) (see also Maps in Appendix A7). A recently published study (see TOR 4) examined the influence of winter oceanographic conditions on black sea bass abundance. The study concluded that overwintering conditions are a critical determinant of juvenile survival and abundance at age 1. Autumn survey indices are generally dominated by age 0 fish but may not be indicative of subsequent cohort strength. Consequently, the WG made a decision to limit survey abundance indices to winter or spring surveys when possible.

State Surveys

The Virginia Institute of Marine Science (VIMS) conducts a monthly trawl survey targeting juvenile fish within Virginia tributaries of the Chesapeake Bay and provided a random stratified index of black sea bass abundance (Figure A9). The index is for black sea bass sampled in May, June, and July since 1989 and contains fish that are less than 110, 150, and 175 mm total length, respectively. All are age-1 fish, assuming a Jan 1 birthdate. Thus, the mean number per tow index for 2015 represents the 2014 year class (spawned in 2014). The results shows variable recruitment trends with above average year classes in 1989 (the largest in the time series at 2.36

fish per tow), 2001, 2007 and 2010. The 2010 index (1.11 fish/tow) was above the series average of 0.67 fish/tow. Recruitment since 2013 has been below the series average (0.674 fish per tow) with a 2015 index of 0.290 fish per tow. The VA index was applied to the southern area.

The Maryland Dept. of Natural Resources conducts surveys from April through October in coastal bays using a 16ft trawl. Twenty sites have been sampled monthly since 1989. Black sea bass collected in the survey are all less than 21 cm and age 1 or less. The index (log mean) has shown a downward trend since a 2008 index of (1.42 fish per tow) (Figure A10). The most recent index in 2015 equaled 0.27 fish per tow, below the series average of 0.64 fish per tow. The MD index was applied to the southern area.

The Delaware Division of Fish and Wildlife operates a monthly (April to June) fixed station trawl survey in the Delaware portion of the Delaware Bay using a 16' trawl. The index serves as a spring index of age one abundance for the southern area (Figure A11) with a time series average of 0.26 fish per tow. The peak index occurred in 2001 (2000 cohort) at 1.82 fish per tow. There was evidence of the 2011 cohort in 2012 which had an above average index of 0.565 fish per tow. The 2015 index of 0.22 was below the time series average index.

The New Jersey Department of Environmental Protection conducts a depth and area stratified random trawl survey in state waters during January, April, June, August, and October. Data from June cruises in 1989 to 2016 were used as an index of abundance (Figure A12). The index was developed using a negative binomial GLM. Available covariates included tow depth, bottom temperature (BTmp), bottom salinity (BotS), and bottom DO, but only covariates that explained at least 5% of total deviance were retained. The final model was specified as Catch ~ Year + Depth + BotS. The resulting index was decomposed by annual length frequencies, and indices at age were developed using the southern region ALK. The composite index peaked in 2009 at 13.73 fish per tow. The 2015 total index (4.52 fish/tow) was above the series average (3.29 fish/tow). A 2016 spring index was 1.71 fish per tow, well below the series average. The NJ index was applied to the southern area.

New York Department of Environmental Conservation operates a small mesh trawl survey which targets age 0 and juvenile finfish species in the Peconic Estuary since 1987. Tows are conducted weekly from May through October at 16 randomly chosen stations out of a possible 77. Tows from eastern survey stations that occurred in May, June and July from 1990 to 2015 were used to

generate an age 1 spring index. Black sea bass ≤15cm TL in the spring were considered Age 1 (Figure A13). The index was developed using a 0-inflated negative binomial GLM with depth and salinity as significant environmental covariates that explained a combined 7% of total deviance. Bottom temperature was not a useful covariate. While the time series average is 0.11 fish/tow, significant peaks occurred in 2002 (0.34 fish/tow), 2012 (1.11 fish/tow) and 2016 (0.58 fish/tow).

The Connecticut Department of Energy and Environmental Protection Long Island Sound Trawl Survey (LISTS) is conducted from longitude 72° 03' (New London, Connecticut) to longitude 73° 39' (Greenwich, Connecticut). The sampling area includes Connecticut and New York waters from 5 to 46 m in depth and is conducted over mud, sand and transitional (mud/sand) sediment types. Prior to each tow, temperature (°C) and salinity (ppt) are measured at 1 m below the surface and 0.5 m above the bottom using a YSI model 30 S-C-T meter. Water is collected at depth with a five-liter Niskin bottle, and temperature and salinity are measured within the bottle immediately upon retrieval.

Sampling is divided into spring (April-June) and fall (Sept-Oct) periods, with 40 stratified-random sites sampled monthly for a total of 200 sites annually. For this assessment, only the spring leg of the survey was used which is believed to represent age 1 and older black sea bass. The sampling gear employed is a 14 m otter trawl with a 51 mm cod-end. The sampling area is divided into 1.85 x 3.7 km (1 x 2 nautical miles) sites, with each site assigned to one of 12 strata defined by 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). The number of sites sampled in each stratum was determined by dividing the total stratum area by 68 km2 (20 square nautical miles), with a minimum of two sites sampled per stratum. Discrete stratum areas smaller than a sample site are not sampled. The survey's otter trawl is towed from the 15.2 m aluminum R/V John Dempsey for 30 minutes at approximately 3.5 knots, depending on the tide. Black sea bass at each station are counted and total lengths measured to the nearest centimeter.

This survey was not designed to target black sea bass. In order to generate a black sea bass index of abundance, a statistical model-based standardization of the survey data was conducted to account for factors that affect black sea bass catchability. Following the approach described in the ASMFC's standardization guidelines (SEDAR 2015), an index of age 1 and older black sea

bass was created using a negative binomial generalized linear model (GLM) with a log link and bootstrapped estimates of uncertainty. Zero inflated negative binomial models were also tested and compared using a Vuong non-nested hypothesis test (Vuong 1996).

A full model that predicted catch as a linear function of year (categorical data), month (categorical data), depth (continuous data), and stratum (categorical data) was compared with nested sub-models using AIC. Temperature and salinity were not able to be used for this analysis because the recording of those covariates began late in the time series. The model that included year and month was selected because it produced the lowest AIC coupled with the lowest variance inflation. The index exhibited a marked increase from low catches early in the time-series with the increase beginning in the early 2000s to present with inter-annual variability. Diagnostics identified slight over-prediction of average annual catch per tow at the end of the time series.

The indices show low abundance until an increasing trend beginning in 2012 (Figure A14). Large age 1 indices occurred in 2002, 2012 and 2014 with the recent cohorts contributing to the sharp increase in abundance. Prior to 2012 the average index was 0.5 fish per tow compared to the 2014 and 2015 indices of 14.3 (CV=0.21) and 14.2 (CV=0.21) fish per tow, respectively.

The Rhode Island Department of Environmental Management research trawl survey is conducted with a ¾ high-rise heavy-duty bottom trawl towed for 20 minutes at 2.5 knots. Sampled areas include Narragansett Bay and Rhode and Block Island Sounds. Data include a mixture of fixed and random sampling stations, depending on the component of the survey being examined (seasonal = random stratified, monthly = fixed station). Data collection has been generally consistent from 1979 to the present, with the exception of tow numbers early in the time series, and a change to the survey doors in 2012. Investigations between survey doors during a calibration experiment indicated that there are not major differences in catchability of black sea bass between the two door designs. Data elements collected include numbers, weights, and lengths caught by species as well as a suite of environmental information including bottom and sea surface water temperature, depth, and sea conditions.

The survey has two seasonal components, a spring (April/May) and a fall (September/October) survey that has been conducted annually since 1979. Sampling is conducted during daylight hours only. For assessment purposes, only the spring survey is used, which involves

approximately 42 tows per year. The spring seasonal survey employs a stratified-random sampling design. The sampling area is divided into strata defined by depth. For each seasonal sampling cruise, sites are selected randomly from within each stratum.

All black sea bass collected are weighed (kg) and measured for total length (cm). The number of individuals measured from each tow varies by species, and also depends on the size of the catch and range of lengths. If a species is subsampled, the length frequency of the catch is determined by multiplying the proportion of measured individuals in each centimeter interval by the total number of individuals caught.

In order to generate a black sea bass index of abundance for the stock assessment, statistical, model-based standardization of the survey data was conducted to account for factors that affect black sea bass catchability. Only ages 1 and above are represented in the spring component of the RI seasonal trawl survey. Following the approach described in the ASMFC's standardization guidelines, an index of age 1 and above black sea bass was created using a negative binomial generalized linear model with a log link and bootstrapped estimates of uncertainty. Proportion of positive tows for black sea bass averaged approximately 11% across the time series, with that average increasing to 19% since 2000.

A full model that predicted catch as a linear function of year (categorical data), bottom temperature (continuous data), month (categorical data), station (categorical data), and depth (continuous data) was compared with nested sub-models using AIC. The model that included year, bottom temperature, and depth was selected because it produced the lowest AIC coupled with the lowest variance inflation. The index exhibited a marked increase from low catches early in the time series with the increase beginning in the mid-1990s to present. There is some degree of small decline at the end of the time series. Diagnostics identified slight under-prediction of average annual catch per tow

The indices have been highly variable over time, although the spring index includes several above-average years since 1999 (Figure A15). The 2015 overall index (1.025 fish/tow) was well above the series average (0.180 fish/tow, std error = 0.073). The Department also conducts a coastal pond seine survey and although the mean catches per tow are small, it does show an increasing trend, peaking in 2014 at 2.04 fish per tow.

The Massachusetts Division of Marine Fisheries has conducted trawl surveys each spring and fall since 1978. The spring survey occurs in May and the fall survey occurs in September. The survey employs a stratified random design, with stratification based on five bio-geographic regions and six depth zones. The six depth zones include 0-9.1 m, 9.1-18.2 m, 18.2-27.4 m, 27.4-36.6 m, 36.6-54.9 m, and >54.9m. Surveys from 1978-1981 were conducted aboard the F/V Frances Elizabeth. Surveys since 1982 have employed the R/V Gloria Michelle. Trawl design and trawl doors have been consistent for the duration of the survey. The net is a ¾ size North Atlantic type two-seam otter trawl (11.9 m headrope/15.5 m footrope) rigged with an 8.9 cm rubber disc sweep and a 0.6 cm knotless codend liner (1.3 cm stretched mesh). The trawl is spread behind 1.8 m x 1.0 m 147 kg wooden trawl doors, 19 m 1.0 cm chain bottom legs and 18.3 m 1.0 cm wire top legs.

Black sea bass are encountered in both the spring and the fall survey, and are captured in all regions. All sizes of BSB are captured by the survey. Black sea bass are most common in Regions 1-3, which include waters from the Massachusetts-Rhode Island border, the waters of Nantucket and Vineyard Sound, and the eastern shore of Cape Cod.

Only the spring survey was standardized for the assessment. The survey was standardized using negative binomial regression. No offset was included because tow time was standardized throughout the entire time series. Potential predictors included temperature and stratum. Models were evaluated based on AIC. Results indicated that the model with the lowest AIC was one that included an effect of temperature and stratum. Diagnostic criteria, such as qq and residual plots, indicated acceptable model fit.

The MADMF spring index declined during the 1990s, rose briefly in 2000, then again in 2008 (Figure A16). The spring 2012 mean number per tow (3.882 fish/tow and CV=0.309) was the beginning of a period of indices above the series average (1.88 fish/tow). The index spiked in 2014 (10.458 fish/tow with CV=0.29) due to the incoming 2011 year class. The index has remained above average through 2016 (4.301 fish/tow with CV=0.30).

The Northeast Area Monitoring and Assessment Program (NEAMAP) is a stratified random trawl survey conducted in coastal waters between Rhode Island and Virginia. The spring series began in 2008 when the NEFSC dropped sampling of those strata. The overall ln re-transformed mean number per tow increased slowly since 2010 (0.19 fish per tow) to a 2015 mean of 0.30

fish per tow. The spring time series was further divided into two separate north and south series. The south series included strata off the coast of NJ and south, while the north was NY and RI coastal waters. The average catch per tow in the north (1.67 fish per tow with a CV =0.64) (Figure A17) was significantly larger than the south (0.14 fish per tow with CV=0.22) (Figure A18). The northern series increased since 2008, peaking in 2014 at 3.47 fish per tow. The 2015 mean number per tow decreased to 1.93 fish per tow. The southern index had an initial downward trend but has remained generally stable with the 2015 index approximately equal to the time series average. Catches in the southern strata were small and the final assessment model used only the age 1 indices for the southern area.

NMFS surveys

The NEFSC winter bottom trawl survey was conducted between Virginia and Georges Bank with stratified random tows from 1992 until 2007. Survey strata used for an index of abundance were offshore strata in areas comparable to the location of the winter trawl fishery. The trawl gear was a flatfish net with a cookie sweep. The overall series peaked in 2003 at 17.70 fish per tow, which followed from the 2002 index of 10.84 fish per tow. In 2007 when the survey was terminated, the survey index equaled 4.36 fish per tow.

For the assessment area models, the survey area was split into north and southern strata groups relative to Hudson Canyon. The northern stratified mean number per tow reached a peak in 2003 of 4.64 fish/tow before declining to average values by 2007 of 1.18 fish per tow (Figures A19). The comparable survey indices for the southern area were considerably larger, peaking at 31.32 fish per tow in 2003 (Figure A20). The index in the final year of the survey was 7.67 fish per tow.

Indices were converted to swept area abundance estimates for use in the assessment model. The area swept per tow between the wings during the winter survey equaled 0.0131 NM^2. The winter survey indices were not included in the final northern model.

The NEFSC spring bottom trawl survey has been conducted between Nova Scotia and North Carolina since 1968. The indices (stratified mean number per tow) for black sea bass were developed using offshore strata containing at least one positive tow in the time series. Previous assessments using the NMFS data considered a log transformation of catch per tow to reduce the influence of high catches. The survey is designed to account for variation and the

transformation can violate the underlying assumption of the designed survey (T. Miller, NEFSC, pers. comm.), therefore indices were calculated as the arithmetic mean number or mean weight per tow. Sampling was conducted aboard the *FRV Albatross IV* using a Yankee 35 haddock net with a roller sweep. In 2009 the FSV *Henry B. Bigelow* replaced the *FRV Albatross IV* in conducting the survey. The *Bigelow* gear consists of 4-seam, 3 bridle net with a rock-hopper sweep and is towed for 20 minutes rather than 30 minutes with *Albatross*. Although calibration factors for the two vessels are available (calibration factor=3.41), the *Bigelow* time series was considered as a separate index series of black sea bass abundance.

The NEFSC spring mean number per tow in the *Albatross* series followed a pattern of an increasing index during the late 1970s, followed by a decline during the 1980s and 1990s (Figure A21). A second increase in the index occurred beginning in 1998, peaking in 2003 at 9.51 fish per tow, followed by a decline to 0.61 by 2008. The uncalibrated *Bigelow* series began in 2009 with an index of 2.44 fish per tow and peaked in 2013 with 11.42 fish per tow. The 2015 and 2016 indices were 3.12 and 4.97 fish per tow, respectively.

The area split for the NEFSC spring series highlights a general northward spatial distribution shift. The *Albatross* series north of Hudson Canyon peaked in 1986 with 2.30 fish per tow, however the time series average was only 0.21 fish per tow (Figure A22). The numbers per tow increased significantly during the years of the *Bigelow* series, peaking at 11.02 fish per tow in 2014. The 2015 and 2016 indices were 1.88 and 8.20 fish per tow, respectively.

The indices in the southern area reflected the multiple peaks seen in the overall index (Figure A23). The *Albatross* index series peaked in 1977 at 18.25 fish per tow and again in 2003 at 20.60 fish per tow. The *Bigelow* series since 2009 had an index of 22.56 in 2013 but declined to 4.64 and 1.01 fish per tow in 2015 and 2016, respectively.

For the purposes of the area exchange model, the north and south indices were converted to swept area abundance estimates. The area swept per tow between the wings during the spring *Albatross* series equaled 0.0112 NM^2 while the *Bigelow* area swept per tow was 0.007 NM^2

Recreational CPUE

In addition to fishery independent survey indices of abundance, the Working Group also developed a fishery dependent index of abundance from the Marine Recreational Fisheries

Statistics Survey (MRFSS[1]). For this exercise, catch was estimated using the raw (unexpanded) Type 2 and Type 3 MRFSS data files. Estimates of potential effort for a given species can be difficult using the MRFSS data due to the self-reported nature of the data. In an attempt to account for potential effort (rather than just positive trips or self-reported directed trips), effort estimates were based on effort for a species guild. Species to include in a guild were identified using the Jaccard index of similarity (Jaccard 1912). Estimation of the similarity coefficient can be summarized as follows.

1) Determine the number of trips (MRFSS intercepts) that caught the target species
2) Determine which non-target species were caught on trips when the target species was caught.
3) Determine the number of trips (MRFSS intercepts) that caught a given non-target species.
4) Divide the number of trips that caught both the target and non-target species by the number of trips that caught either the target species or the non-target species.

Mathematically, this can be expressed as

$$J = \frac{N_{11}}{N_{10} + N_{01} + N_{11}}$$

where N is the number of trips and the subscripts of 0 and 1 are binary for observation of the target and non-target species. High values of *J* suggest high correlation between the target and non-target species (*e.g.* habitat utilization), so observation of the non-target species implies presence of the target species even if it is not observed.

For the current analysis, species associations were evaluated at the regional level using all years combined. Guilds were composed of the target species and any species with a similarity coefficient greater than 5% ($J \geq 0.05$). Any trip that caught any one of the guild species was considered a potential black sea bass trip. Regional species guilds and time series of effort (# of intercepted trips with guild species) are shown in Tables A5-A6, respectively.

For each potential black sea bass trip identified through the guild analysis, trip level CPUE was estimated as the black sea bass catch divided by the number of anglers contributing to the catch (catch per angler or CPA). Because observed (Type A) and unobserved (Type B1 and B2) catch

[1] Although the MRFSS was officially replaced by the MRIP in 2012, MRFSS-based raw data files are available through 2015, allowing a continuous time series of MRFSS data for this analysis.

are handled separately by MRFSS and do not necessarily have the same number of anglers associated with the two types of catch on a given trip, it was necessary to develop separate CPA estimates for observed and unobserved fish and sum them (CPA = CPA_A + CPA_B). Admittedly, this is not ideal, but should not have an overall large effect on the results.

Trip specific CPA was then modeled using R software with a delta-lognormal GLM. Full models included covariates of year, area, wave, state, mode, and hours fished. Final models included only covariates that explained at least 5% of total deviance (Table A7).

Effort in the northern region generally increased during the 1980s, rising from less than 1000 intercepted trips in 1981 to over 4000 intercepts by 1990 (Table A6). Effort subsequently leveled off, and varied without trend between 2000 and 4000 intercepts annually for the years 1990 to 2010 before showing a general increase in recent years. CPA in the northern region remained generally stable below 0.25 fish per trip between 1989 and 1998 (Figure A24). Catch rates increased to around 0.5 for a brief period, before dropping back to previous levels in 2004 and 2005. Over the last decade, recreational catch rates of black sea bass in the northern region have shown a dramatic increase, rising from 0.23 fish per trip in 2005 to 1.7 fish per trip in 2015.

From the early 1980s to early 2000s recreational black sea bass effort in the southern region increased more than two-fold, rising from around 3000 intercepted trips per year to a peak of over 9000 intercepts in 2001 (Table A6). Since that time, effort has gradually declined, dropping to approximately 6400 intercepts in 2015. CPA in the southern region follows a similar pattern as the associated effort. Catch rates increased from around 1.0 fish per trip in early to years to over 3.0 fish per trip by the early 2000s (Figure A25). CPA subsequently dropped by approximately 35% by 2004, and has varied without trend around 2.0 fish per trip since that time. Recreational black sea bass CPA in the southern region was estimated at 1.74 fish per trip in 2015.

The overall stock-wide CPA peaked in the late 1990s-early 2000s, which followed the southern CPA pattern (Figure A26). Since 2005 there has been a steady increase in catch rate with a sharp spike in 2012.

TOR 2. Estimate catch from all sources including landings and discards. Characterize the uncertainty in these sources of data. Evaluate available information on discard mortality and, if

appropriate, update mortality rates applied to discard components of the catch. Describe the spatial and temporal distribution of fishing effort.

Spatial and Temporal Distribution

Spatial patterns in the commercial fisheries were examined and distribution maps presented in Appendix A7. The trawl fishery north of Hudson Canyon generally catches black sea bass across the shelf throughout the year. There is a trawl fishery within the New York Bight that targets scup and summer flounder as well as sea bass. As sea bass migrate out to the shelf edge with declining water temperatures, the trawl fleet follows and operates south of Hudson Canyon along the shelf edge. Pot fisheries generally operate further inshore than the trawl fleet as does the hand-line fleet. However, there is a hand-line fishery in the southern end of the stock that operates throughout the winter closer to the shelf edge.

The recreational fishery occurs from late April into October/November while black sea bass are distributed in coastal waters. There are party and charter boats that occasionally target black sea bass in January and February near the Hudson Canyon. The distribution of trips is presented across years due to confidentiality with the limited number of vessels involved. The wave 1 (January- February) fishery has been closed in recent years.

A tagging study in the mid-2000s demonstrated the migratory pathways of black sea bass originating in different areas (Moser and Shepherd 2009). Fish originating north of Hudson Canyon follow the shelf break south and are captured in the winter trawl fishery. Fish originating to the south of Hudson Canyon remain in the south. The pot and hand-line fisheries operate inshore (with the exception of the southern hand-line fishery which operates offshore adjacent to the point of origin). Consequently, mixing among the two defined spatial units is most likely to occur south of Hudson Canyon with fish from both areas present in the southern trawl catch. In order to account for the mixing, the fisheries were divided into trawl and non-trawl components with the winter trawl fishery acting as a proxy for the mixed component of the stock.

Commercial fishery

The commercial fishery on the northern black sea bass stock (Maine to Cape Hatteras, NC) is prosecuted primarily with fish pots, otter trawls and hand-lines (Figure A8). Fish pots and hand-

lines are generally fished in inshore waters when targeting black sea bass (with the exception of some lobster and sea bass pots in NY). Trawls are generally offshore in the winter months in conjunction with summer flounder and scup fisheries (Shepherd and Terceiro 1994). Fish pots have accounted for 44% of landings since 1989, followed by otter trawls at 41% and hand-lines at 9%. Other gears account for 7%. The majority of the landings occur in January through June, peaking in May.

Trends in landings were relatively stable at around 1,300 mt until 2007 (Table A8, Figures A7, Figure A27). State and Federal management plans were implemented in 1998 which included minimum size restrictions and commercial quotas. In 2008, additional quota regulations were enacted which decreased landings to an average of 739 mt between 2008 and 2012. Since 2013 commercial landings have increased to 1,113 mt in 2015. The commercial sea bass fishery is prosecuted in all states between Massachusetts and North Carolina however Massachusetts, New Jersey, Maryland and Virginia account for over 70% of total commercial landings (Table A8). The majority of landings since 1989 (54.6%) are from areas 611-622 with most trawl landings coming from areas 616 (17%), 622 (26%) and 626 (17%). Total landings by NMFS statistical areas are presented in Table A9. Black sea bass landings have been dominated by medium, large and jumbo sizes since 2000 (Figure A28, Tables A10-A17). Beginning in 2011, large and jumbos have accounted for 60% or greater of the landed fish. In 2015 sea bass from medium, large and jumbos market categories represented 23%, 37% and 29% of overall landings, respectively.

The time series of fishery data in the assessment was limited to 1989 to 2015. The NEFSC fishery observer program began in 1989. Therefore estimates of discards prior to 1989 would have to be determined via ratio estimates to other fisheries. The consensus of the WG was to limit the data series to years with empirical estimates of commercial discards. Commercial data was divided into half year time blocks for gear categories of trawl and non-trawl. The north-south criteria adopted in TOR1 was applied in the expansion of the catch at length and catch-at-age. Spatial coverage of length sampling was insufficient to allow region specific samples to be applied to the landings by market category. The WG concluded that regional variation in landing by market category would adequately capture any size differences between north and south and length distribution within market category was narrow enough to minimize any regional effect.

Average size by market category was also compared across years (Figure A29) and areas (Figure A30) to evaluate the inter-annual stability of size composition within market grades. Length distributions within market categories were relatively stable. Therefore size composition within a market category was applied between adjacent years when needed, i.e. a medium was considered a medium regardless of time or space. In summary, length distributions within market categories (small, medium, large, jumbo and unclassified) by half year period (Jan-Jun, Jul-Dec) were applied to landings by half year, region (north and south), market category and gear category (trawl vs non-trawl) for 1989-2015, using half-year region specific length-weight equations.

Length measurements (cm) of sea bass in the commercial landings are sampled by NMFS in ports from Maine to North Carolina. Samples are collected from boxes of fish available from dealers and sorted by market category. Market categories are extra small, small, medium, large, jumbo and unclassified. Length frequencies by market category and half year were expanded to total catch beginning with 1989. NMFS samples were supplemented with similar information collected by the state of North Carolina between 1989 and 1998. The NC lengths measurements were combined with NMFS data by market category and half year. Landings from the extra small category since 1989 were minimal and the size distributions were comparable to smalls. Therefore extra smalls were combined with smalls. Sample sizes and total number of fish measured from NMFS and NC data are provided in Tables A18. Sampling intensity is expressed as metric tons (mt) of landings per 100 fish measured (Tables A19-A20). Since 1989 the overall commercial sampling has averaged 21 mt per 100 lengths, with the best sampling years between 2008 and 2012 when sampling was on the order of 7 mt per 100 lengths (Figure A31).

Length weight information to convert landed weight to number was available from NMFS spring and autumn survey data since 1992. The equations applied to all length samples by season and region were:

North Spring: 1.0157e-5 * length(cm)^3.0769
North Autumn: 1.2649e-5 * length(cm)^3.0173
South Spring: 1.1448e-5 * length(cm)^3.0435
South Autumn: 1.9053e-5 * length(cm)^2.8937

In the expansion process, missing cells (Figure A32) were replaced with lengths from the same market category and the closest year or years containing measurements. The most frequent substitutions occur in the second half of the year within the unclassified category between 1993

and 2002 (Figure A33). In addition, jumbos in the second half year prior to 2002 were also poorly sampled. However, the lack of samples also reflects limited availability due to minimal landings. Since 2003 the only missing cells were unclassified in the second half of 2010 and 2011, which represented 2% and 3%, respectively, of total annual catch. Cells with substitutions are presented as shaded cells within the sampling intensity table.

The total number of black sea bass landed across both areas combined has declined since 1996 (5.0 million) to a low of 935,000 in 2009 (Figure A34). Total landings since 2010 (1.27 million) have increased steadily to 1.49 million in 2015. Overall mean length in the landings in both areas have increased steadily from around 28 cm in 1989 to 34 cm in 2004 and have remained relatively stable since 2003 around 35 cm (95% CI $\pm$12 cm). The same size trends exist within area, season and gear types (trawl vs non-trawl) (Figures A35-A37). The mean size of landings does not vary much by season, however by gear type there is some area differences with the non-trawl landings smaller in the south.

Commercial discards

Estimated discards were calculated from four gear types. Otter trawl and sink gillnet discards were calculated using the Standardized Bycatch Reporting Methodology (SBRM) (Wigley et al 2008). SBRM relies on information collected by NMFS observers on a sub-sample of commercial trips as part of a program begun in 1989. Annual discards per half-year were estimated in each region (north/south) as the ratio of recorded discards for the species in question to recorded kept of all species landed, multiplied by the total reported landings of all species in that time strata. The associated CV for the estimate was also calculated (Table A21). The observed trips for hand-line or fish pot gear was limited, therefore the SBRM approach was not used for discard estimates. Pot and hand-line discards from 1994-2015 were estimated from self-reported vessel trip logs (VTR), adjusted to total landings by gear. VTR logs were not required prior to 1994. For the period 1989-1993, the ratio of the trawl discards to pot discards and hand-line discard per half year from 1994-1996 was multiplied by the associated trawl discard estimates. Management began in 1997 so 1994-1996 was used to avoid regulatory discards influencing the results. Pot and hand-line discards were combined into the non-trawl category. Discards from trawls and sink gillnets were assumed to suffer 100% mortality because of depths fished and length of tow or soak time. Discard mortalities of 15% were applied to pot

and hand-line discards. The rationale was that depths fished generally resulted in minimal barotrauma and the volume of fish in a pot catch would result in minimal damage to released fish. Hand-line discard mortality was assumed equivalent to recreational discard mortalities. Discards from sink gillnets was minimal, with an annual average in the time series of less than 0.2 mt. The highest year for discards occurred in 1991 with 1.9 mt, however the CV for the estimate was 0.94.

The largest amount of discard mortality was attributed to the trawl fishery (Table A21). Annual discard losses ranged from 2.0 mt (CV=0.64) in the north during 1991 to 607.2mt (CV=0.62) in the south during 1996. Precision of the trawl discard estimates in the time series varied but CVs averaged 0.53 in the north and 0.42 in the south. Discards in the non-trawl gears was primarily from pots. Discard mortalities from the non-trawl gear averaged 5% of the total discards, however annual proportions ranged from 0.4% to 59.3%. The years with higher proportion of non-trawl discards occur when trawl estimates are low. Total weight of discards in non-trawl gear ranged from 0.7 mt to 23.9 mt (Table A22). In 2015 total trawl discards were 128.9 mt in the north and 186.1 mt in the south. Non-trawl discard losses totaled 17.1 mt in the north and 2.9 mt in the south.

Commercial discard length samples were divided by region (north/south), half year and gear type (trawl/non-trawl) (Table A 22a). Length samples from observed trawl trips prior to 1997 were sporadic, so length samples were pooled (pooled distribution did not include a cluster of fish in 1989 less than 9 cm that were not considered representative) (Table A22b). Length samples from non-trawl gear were limited (although observer data was not used for non-trawl discards estimation, there were limited length samples available). Substitutions for missing lengths were made from other areas, time blocks or gear depending on available alternatives. Most substitutions were made prior to 2000.

Annual commercial discard length distributions show a shift in the size composition over time (Figure A38). Prior to the FMP, discards were composed primarily of sizes below 31 cm. As minimum sizes and quotas went into effect the size distribution increased (likely due to gear changes) and included larger individuals of legal size. The primary reason for discards was quota restrictions or below minimum size (Figure A39).

Recreational Landings and Discards

The NMFS Marine Recreational Fishery Statistical Survey (MRFSS) provided catch estimates between North Carolina and Maine beginning in 1981. In 2006 following a review by the National Research Council, the design of the survey was changed and the program became the Marine Recreational Information Program (MRIP) which has continued to evolve. Calibrations have been made to adjust the MRFSS estimates to MRIP estimates from 2004 to present. However, pre-2004 estimate adjustments were left to the discretion of individual analysts. The relationship between the calibrated and uncalibrated black sea bass estimates was linear with a slope of 0.975 (R^2 = 0.90) (Figure A40). The WG concluded that re-calibration of the MRFSS estimates was unnecessary.

Estimates were downloaded from the website (http://www.st.nmfs.noaa.gov/recreational-fisheries/data-and-documentation/queries/index.html) for AB1 fish (fish kept or fish filleted, released dead, disposed in some other way) and B2 fish (released alive). Annual estimates are provided for waves (two-month periods) 2 to 6 and by state. Landings and discards were partitioned into half year blocks and regions, with NY north into the northern region and NJ south into the southern region. Wave 1 (Jan/Feb) is not sampled in the Northeast however wave 1 estimates have been produced for North Carolina since 2004. Recreational catch in wave 1 is primarily party and charter vessels which are required to submit VTR logs while fishing in federal waters. The location is designated by NEFSC statistical area, so totals from VTR records were added to the perspective region based on statistical area. North Carolina catch may occur from either stock (partitioned at Cape Hatteras, NC) therefore annual MRFSS catch estimates were split north and south of Hatteras based on intercept sites. MRFSS estimates are provided as number of fish for AB1, B2 and weight (kg) of AB1 catches. Total weight of discards was derived by applying a length-weight equation to the expanded discard length frequencies.

Stock-wide recreational landings averaged 1,438 mt between 1989 and 2003 then declined to an average of 1,138 mt thereafter (Figure A41). Some of the decline could be attributed to changes in the regulations, particularly minimum size and bag limits. Starting around 1995 there has been a steady shift in the distribution of black sea bass recreational landing from predominantly southern states to the states in the northern region (NY and north) (Table A23). The majority of sea bass landings prior to 2007 were taken in the southern region, primarily New Jersey (Figure A42). Since then, the percentage has shifted north such that 86.2 percent of the landings in 2015

were from the northern region. Total landings in weight in 2015 were 1,588 mt in the north and 276 mt in the south, which is the largest disparity in the time series (Table A24).

Length frequencies of the recreational landings were sampled by MRIP personnel during dockside interviews. Lengths were expanded to total landings by region and half year. Average length of fish in the landings has increased over time likely as a function of changing regulations. Mean length (cm) from 1989 to 1997 ranged from 27 to 31 cm. Size increased between 1997 (29 cm) and 2002 (37 cm) then remained stable (Figure A43). Overall mean length of 2015 landings was 38 cm. North and south differences were not apparent until a divergence in 2000 when northern landings were generally larger fish than in the southern region (Figure A44). On average the northern fish were 4 cm larger and the difference was as much as 7 cm in 2014. It should be noted that until 2010 recreational size limits were relatively consistent. After 2010, states from NJ south remained at 12.5" while northern states were required to adopt larger minimum sizes (up to 15") in an attempt to constrain landings. Although the harvest was not necessarily limited it did produce larger average sizes from New York north.

Regulations of the recreational fishery based on size and bag limits inevitably results in discarding. The survival rate of discarded fish is impacted by multiple factors. Fish captured at depth and brought to the surface undergo pressure changes that can cause barotrauma. In a physoclistous fish like the black sea bass, the most obvious sign of barotrauma is the expanded abdomen and displaced organs by an over-inflated swim bladder. Combinations of angler experience and terminal tackle choice can lead to hook traumas, extended handling and exposure on deck. Conditions at the surface may be significantly warmer or colder than those found at the bottom. Assessments now routinely try to account for discard mortality and there is a growing body of work that addresses it, including several articles that specifically address black sea bass. SAW-43 (NEFSC 2006) assumed a 15% discard mortality rate for black sea bass caught recreationally with a hook and line. Previous assessments (SAW 27) which included recreational discards applied a 25% mortality rate. The assessment cited the Bugley and Shepherd (1991) estimate of 4.7%, generated from black sea bass caught in waters 6-12 meters deep, but noted that fisheries in New Jersey and south accounted for a significant proportion of discards and are often prosecuted in deeper waters. Bugley and Shepherd (1991) noted mildly extended abdomens in some fish but attributed release mortality primarily to anglers with limited experience and the forcible removal of hooks from fish hooked in the esophagus.

The Northeast Data Poor Stocks Working Group (2008) applied a 25% mortality rate to recreational discards but did not offer any justification for the increase from the previous assessment.

SAW-53 (NEFSC 2011) assumed a 15% recreational discard mortality rate, after evaluating the results of black sea bass specific studies (Bugley and Shepherd, 1991 and Rudershausen et al.,2007) and peer reviewed studies for other species. Ruderhausen et al. (2007) found that 3.6 % of 199 black sea bass caught in depths from 19-71 meters (28.5 meter average) were unable to orient themselves and swim down. It was assumed that fish in this release condition would not survive. Black sea bass that were bleeding or non-jaw hooked were also more likely to be unable to swim down, but these findings were not statistically significant, perhaps due to low sample sizes. Gastric distention (barotrauma) was visibly evident in 61% of black sea bass but this condition was not associated with immediate discard mortality (poor release condition). The authors assumed that gastric distension resulted in 100% delayed mortality and estimated that 66% of black sea bass would suffer delayed mortality. Later work by these same authors would test and refute this assumption.

SEDAR 25 (2011) applied a 7% mortality rate to discards from commercial and recreational hook and line black sea bass fisheries whereas prior assessments had used 15%. This decision was based heavily upon work detailed in Rudershausen et al.(2010). Fish were caught in waters from 29-37 meters depth, tagged, release condition noted, and then after 72 hours, recaptured. Recapture rates of fish with visible barotrauma, hook trauma, those unable to swim, and those presumed dead were compared with the recapture rates of fish that were able to swim down without any visible signs of trauma (best release condition). It was assumed that fish in the best release condition survived as well as fish never caught. Six additional fishing trips, independent of tag/recapture trips, were then undertaken and a discard mortality rate for hook and line fisheries was estimated based upon prior return rates and the release condition of fish caught. Discard mortality averaged 4.3% and ranged from 0 to 6.9% over these 6 trips. In addition, Rudershausen et al. explored a number of other questions related to: a)predation on released fish swimming down from surface (not significant), b)non-jaw hook trauma (significantly lower survival rates than fish that were jaw hooked), c) post release floating as a proxy for immediate mortality (an over-estimate), d) tagging acting as inadvertent “venting” (tagging resulted in fewer floaters but did impact survival), e) the trend between discard mortality and depth was

positive, but not significant. Over the depths of this study, fish with visible barotrauma that were able to orient and swim down did not have different recapture rates (and estimated survival rates) than fish in the best release condition.

Collins et al. (1999) experimentally tested whether fish able to descend after capture with the assistance of venting had a greater chance of survival. Fish unable to orient and swim down were assumed to not survive and all other fish were held at capture depth in traps. Mortality over 24 hours in the control group (unvented) averaged 13% for black sea bass caught in waters from 20-35 meters deep (n=83). Mortality increased significantly in fish caught between 43-55 meters (39%, n=25). In addition, venting was shown to be an effective way to reduce immediate discard mortality in black sea bass caught across these depths.

Stephen and Harris (2010) collected fishery dependent data on fish release condition during commercial hook and line trips fishing from 20-80 meters depth. They estimated that 66% of released black sea bass (61/92) suffered immediate mortality due to impaired ability to swim down. Their field work occurred at greater depths (majority >40m) than previous studies (e.g. Bugley and Shepherd, 1991; Collins et al., 1999; and Rudershausen et al., 2010) and these depths are likely greater than where the majority of recreational angler activities take place. It is likely that barotraumas are contributing to the greater immediate release mortality, as was also found in Collins et al. (1999). Immediate release mortality in black sea bass did not differ with respect to size.

The data collected and reported on in Rudershausen et al. (2010) was added to, reanalyzed, and later published by Rudershausen et al. (2014), which differs from the 2010 grant report in the addition of a tagging and holding at depth component that acts as a control (no hook, pressure, deck or predation related traumas) to test the assumption that best release condition fish had 100% survival. A total of 5,131 black sea bass were tagged, with an overall tag recapture rate of 23.5%. The model estimated fish in best (surface) release condition to have a survival rate of 87%. Therefore, the fishery related median discard mortality rate (based upon the release condition of fish caught on fishing trips independent of the tag/recapture efforts) over depths from 20-35 meters was estimated to be 19%. The authors noted that in fisheries prosecuted at shallower depths (such as 6-12 meters in Bugley and Shepherd (1991)) the survival rate of surface released fish should be greater.

The five black sea bass specific studies reviewed here include a wide range (5 – 66%) of mortality estimates that could be applied to discards from the recreational hook and line fishery. Important conclusions include: a)visible barotrauma ≠ 100% mortality, b) best release condition ≠ 100% survival, c) non-jaw hook trauma (and angler experience) reduces survival to a greater extent than visible barotrauma, and d) barotrauma related mortality likely increases at depths greater than 40m.

A large proportion of the recreational fishery for black sea bass in the Mid-Atlantic occurs in depths shallower than those covered in many of these studies. Most of the studies, with the exception of Bugley and Shepherd (1991), were conducted in the South Atlantic where productive fishing grounds are generally further offshore and in deeper water. In addition, water temperatures in the South Atlantic are not reflective of most areas fished in the northern (Mid-Atlantic) stock. In the Mid-Atlantic, 75% of the recreational harvest (in pounds) and 82% of its discards (in numbers of fish) over the last 5 years (2011-2015) have been taken from within state waters (inland waters and ≤ 3 miles from the coast).

The hook and line discard mortality rate of 19% estimated by Rudershausen et al. (2014) is well supported by a large sample size, high proportion of recaptures, and an experimental control but the study was conducted in relatively deep water and surface released fish likely exposed to warmer water temperatures. The design of Bugley and Shepherd (1991) also had an experimental control, was conducted in shallower depths in New England, and estimated discard mortality in black sea bass around 5%. The working group concluded that the 15% discard mortality rate used in SAW-43 and SAW-53 is appropriate, slightly decreasing the discard mortality rate estimated in Rudershausen et al. (2014) due to the shallower depths at which most of the Mid-Atlantic recreational black sea bass fishery occurs. A discard mortality rate of 15% is well within the range (2.5 – 20%, avg 11%) of estimates used in recent (2009-2015) assessments for other physoclistous species from the Atlantic and Gulf of Mexico. A review of discard mortality studies related to black sea bass are provided in Table A25.

Overall recreational black sea bass discard losses (B2 *0.15) peaked between 2000 and 2003 with the maximum occurring in 2002 at 771 mt, well above the time series average of 263 mt (Table A24). The 771 mt represented a total number of 1.7 million fish, however the maximum number discarded in the series occurred in 2000 with 1.98 million fish. Discard losses in 2015 were 1.08 million fish equaling 317 mt (Figure A45). Discard trends in the north and south

differed over time (Table A24, A26 and Figure A46). Until 2012 the majority of discards occurred in the south but that trend reversed in 2012 (58% north) likely the result of a large incoming year class and diverging minimum sizes and season lengths between areas. The trends continued to diverge through 2015 with 79% of the discards occurring in the northern region. Discard lengths were compiled from several sources. The majority of the recreational fishery occurs from July to October, so the discard data was applied on an annual rather than seasonal basis. The American Littoral Society is a conservation group that promotes fish tagging of recreationally caught fish to follow their movement. Tagged fish are by definition B2s (caught and released alive). The lengths of the fish tagged between 1989 and 2010 were available, but measured in inches which were converted to length in cm. Additional information came from a Volunteer Angler Survey conducted by NJDEP from 2008 to 2015 involving hook and line gear. Released fish below the minimum size were classified as discards. New York DEP provided discard length information collected from party/charter boats between 1995 and 1999 as well as 2011 through 2015. Finally, the MRFSS program began at-sea sampling of party/charter boats in 2004. Mean length of discards follows a comparable pattern as landings with increasing size over time (Figure A47). Prior to 2002 southern releases tended to be larger and increasing in size over time however the trend could be a function of limited length samples. Post 2004 the regional mean lengths were comparable around 25 cm but diverge in 2011 with larger fish discarded in the north. By 2015 mean discard length in the north was 31.7 cm whereas the southern mean was 24.5 cm.

Total Catch

The pattern of total catch (commercial landings and discard losses, recreational landings and discard losses) has remained relatively stable with the exception of spikes in the early 2000s and more recently in 2014-2015 (3,631 mt and 3,683 mt, respectively) (Figure A48). The pattern by region is increasing catch in the north while the south remains stable following a decline in the mid-2000s (Figures A49-A50). The commercial catch has been less variable due in part to the quota restrictions monitored in real-time. Mean length in the catch has slowly increased in the north since the mid-1990s while mean length in the south has declined since the early 2000s (Figure A51).

Catch at age development

The primary source of age data for expansion of commercial landings and discards, recreational landings and discards and survey data was the NEFSC spring and autumn bottom trawl surveys since 1989. Commercial age samples were available since 2012 and age data collected in the NEAMAP survey provided the necessary ages for estimation of indices at age. However the available age information was incomplete for all years and in many instances was not available for all length categories. Alternative approaches were evaluated to make best use of the available ages. Sample sizes of ages by year, season, and source from 1989-2015 are given in Table A27. Ages from all years prior to 2015 are based on scales. Ages from 2015 onwards are based on otoliths.

Age Length Keys

All age length keys (ALKs) were constructed using multinomial logistic regression (Gerritsen et al. 2006; Stari et al. 2010, Weakfish Stock Assessment Subcommittee 2015) using the *multinom* function in the nnet package for R (Ripley 2016). A set of ALKs was constructed by year for spring (January-June) and fall (July-December) seasons, region (north or south) as well as by gear type (fisheries independent or commercial). Additional ALKs were constructed by year, using additional data from the previous two and subsequent two years, by season, region and gear type. Cumulative ALKs were also made for each season, region and gear type from data pooled among all years. For all ALKs, the plus group was age eight.

Age data from the northern region NEFSC fisheries-independent trawl survey in spring 2015 was insufficient to construct a suitable ALK so the 2015 age data was augmented by including data from the MADMF spring trawl survey and from NYDEC commercial market sampling.

Catch at Age

Annual catch at age (CAA) was created from recreational catch, recreational discard, commercial trawl catch, commercial trawl discard, commercial non trawl catch, and commercial non trawl discard catch at length for each region and season combination. Catch at age was calculated in two portions for each season, region and gear type combination. The first portion consisted of selecting all BSB <14 cm TL from the catch data for a specific combination. For the spring season, all BSB <14 cm TL were assumed to be age-1. For the fall season, all BSB <14cm TL were assumed to be age-0. The second portion of the CAA was constructed by selecting all BSB

for a given combination ≥14 cm TL. The ALKs were applied to this portion of the catch at length data based on criteria agreed upon by the SASC (see below).

Criteria for Key Application

Recreational CAA was created using ALKs constructed from the NEFSC trawl survey. Commercial CAA was created using ALKs constructed from commercial sampling efforts when available, otherwise the survey ALKs were applied. Criteria for key selection were based on sample size (>89) and a maximum age of at least 6. The minimum sample size was based on the median sample size for the fall season, southern region, fisheries independent age data 1984-2015. Median sample size for all other season, region and gear type combinations, with the exception of spring season, northern region, fisheries independent 1984-2015, was greater than 89. In cases where a year, gear, region and season combination ALK met the prescribed criteria, the ALK was applied directly to that catch data. If this criterion was not met, ALKs that included the previous two and subsequent two years of data were applied. If keys were not available that included the previous and subsequent two years, the cumulative key was applied.

Two exploratory exercises were conducted to explore the influence of data pooling and sample size on CAA (Appendix A8). Differences in predicted CAA based on ALKs for individual year vs those pooled among multiple years were examined. This exercise demonstrated that pooling resulted in differences <12% in predicated CAA for a given catch data set. Further, a simulation was done to create a population with a known catch and a known age structure, then ages randomly sampled from the population, ALKs constructed and then CAAs calculated from the random samples. The mean age of the catch for each year in the simulation was compared to the known catch. Using 20 truly randomly sampled ages with 1,000 truly randomly sampled lengths produced a distribution of mean age of the catch that had a median close to the true mean age of the catch for all years and the distributions were relatively small e.g. they distinguished among years as true mean age of the catch changed. This work demonstrated that the ALKs allowed the calculation of accurate CAAs at sample sizes>20, suggesting that the SASC committee's criteria of 89 was appropriate.

A summary of how the age keys were applied is presented in Table A28. The final product of the length data expansion was a catch at age matrix for 1989 to 2015 for trawl and non-trawl fleets (includes recreational catch) for the north, the south and a combined north/south matrix (Tables

A29-A32). Age 0 fish represented 2% (1989 and 1990) or less and were not included in the assessment model. The overall catch at age profile indicated full recruitment around ages 3 or 4, which constituted 63% of the catch. Black sea bass age 6 and greater represented only 4% of the overall catch in the series. More detail on the age composition of the catch and indices are provided in the assessment model diagnostic plots.

Mean weights at age were determined using the total catch at age and total weight at age by area (Table A33 and A34). Comparison of annual weights at age by area show a difference by area with the southern area consistently smaller at age across all years (Figure A52)

TOR 4. Consider the consequences of environmental factors on the estimates of abundance or relative indices derived from surveys.

Miller et al (2015) examined the influence of winter oceanographic conditions on distribution and juvenile survival. Beginning around October, black sea bass along the coast begin to migrate offshore towards the Continental Shelf break. Fish in the northern end of the range move south to the shelf edge then follow the shelf further south depending on conditions. Fish in the Mid-Atlantic move southeast or east to the shelf edge. Age 0 sea bass, which are generally less than 14 cm when they leave coastal regions, tend to be more generally distributed across the shelf, perhaps due to slower swimming speeds. Consequently their survival is related to conditions across the shelf. If warm saline Gulf Stream water moves onto the shelf in winter, survival is high. When cold conditions are the norm, survival decreases. As a result of this variable overwinter survival as a function of oceanographic conditions, indices of young of year sea bass collected in the fall do not reflect subsequent year class strength and were not used as indices of abundance.

State survey indices were evaluated with General Linear models to determine if environmental factors influence the signal from empirical data. Model configurations varied among surveys but depth, bottom salinity and bottom temperature were common factors. New Jersey and New York found depth and salinity were significant, Rhode Island was depth and temperature, Massachusetts was temperature and Connecticut was depth (temperature and salinity not considered due to lack of data). Adjustments to the indices using these covariates altered point estimates but the same overall trends remained.

TOR 5. Investigate implications of hermaphroditic life history on stock assessment model. If possible, incorporate parameters to account for hermaphroditism.

Black sea bass, like other hermaphroditic fishes, are challenging to assess (Blaylock and Shepherd 2016) because of the dynamics of length and age-specific sex ratio that vary in space, time, and as a result of differential fishing and mortality. The result is that each sex will have unequal mortality patterns (Blaylock and Shepherd 2016). Standard assessment methods that model the population resilience by understanding patterns of female growth, fecundity, and mortality and temporal changes in female biomass may not be appropriate and unique modeling approaches may be warranted (Blaylock and Shepherd 2016) because the reproductive rates at levels of fishing mortality that would not be problematic for a gonochoristic species may be so for a hermaphroditic one (Alonzo et al. 2008).

Variations in reproductive strategies in fishes are diverse and include the ability to change sex from male to female (protandry) or from female to male (protogyny), simultaneous hermaphroditism and gonochoristic sex determination (McBride et al. 2013). Aside from interest in understanding the ecology and evolutionary dynamics of species, sex change as a response to sex ratio has implications for assessment and management. Black sea bass is a protogynous hermaphrodite and its stock dynamics and life-history characteristics can be impacted by size-selective fishing mortality (Provost and Jensen 2015). Such dynamics are challenging to fishery managers because the effects of size- and age-selective fishing on hermaphroditic stocks is not well understood (Provost 2013) though recent work has shown that skewed sex ratios can make a stock more vulnerable to overexploitation (Brooks et al. 2008, Blaylock and Shepherd 2016).

In a review of such challenges and the implications for management, Provost (2013) and Provost and Jensen (2015) documented the impacts to population dynamics that sex change may have and the variety of strategies that are used to model such alterations in age-specific sex ratio in quantitative stock assessments.

There are two potential primary impacts that fishing mortality has on the dynamics of a hermaphroditic stock. The first is that fishing may cause a greater skew in sex ratios and the second is that size-selective fishing mortality may decrease the size or age at sex change (Provost and Jensen 2015). A suite of behavioral strategies including sex-specific aggression and

aggregating mating strategies may reinforce the vulnerability to fishing of one sex at a greater frequency than another and serve to increase stock vulnerability. For protogynous hermaphrodite fishes, sex-specific behavioral responses may serve to change sex ratios. For example, aggressive behavior by male Scamp may have a greater fishing mortality than females because they are more likely to bite hooks (Gilmore and Jones 1992). Another behavioral aspect of size-selective mortality on hermaphroditic fishes is the impact that removing large males from harem groups may have. The interruption of social hierarchies may reduce spawning success. The effects of differential mortality on the stock are not limited to ecological impacts. The removal of males and the resulting increasingly skewed sex ratio may have evolutionary implications as well, resulting in stocks that have fundamentally different population dynamics. Simulation modeling work has indicated that populations that are subject to sex-specific mortality may be at a greater risk of overexploitation (Brooks et al. 2008).

Work to understand, in an assessment context, the impacts of differential sex-, age- and length-specific mortality dynamics (Shepherd and Idoine 1993) has indicated that alterations to the sex ratio should be explicitly included in assessment. Departures from model assumptions from hermaphroditism result in breaking one or more model assumptions in age-structured modeling approaches (Heppell and Heppell 2012). The primary issue is that in sex changing species the catch at age time series and selectivity curve may vary by sex because the fishery differentially targets older males. The implications to management for protogynous species is that fertilization rates may be lowered (sperm limitation) resulting in reduced production which has been explored in simulation (Brooks et al. 2008) and shown to be critical in determination of biological reference points.

A simulation study specific to black sea bass populations (Blaylock and Shepherd 2016) demonstrated the vulnerability to exploitation in this hermaphroditic species. Previous work (SAW 53 WP) has shown that the sex ratio in the northern stock of black sea bass was approximately 30% males at small sizes and 30-40% female at larger sizes. This contrasts with the expectation of a typical hermaphroditic species first maturing as females then a nearly complete transformation to male at older ages. In addition, it was shown (as well as in previous work by Alonzo et al. 2008, Brooks et al.2008) that the presence of mature secondary males (males without bright coloration or nuccal humps, sometimes called sneaker males during

spawning) increases the resilience of a population to exploitation. If the large dominant male is removed and smaller mature males are available to spawn, the population is more robust than a population totally dependent on the large males or requiring mature females to change sex to replace the male. The black sea bass simulation study concluded that the northern stock of black sea bass was not a typical protogynous hermaphrodite and was more resilient to exploitation. The resilience is a result of a sex ratio which is not completely male at larger sizes and contributions by the secondary males which in combination bring black sea bass life history more in line with gonochoristic species.

Incorporating parameters into the assessment model to account for hermaphroditism would require empirical data that is not available, particularly the type of males present. A study by Brooks et al. (2008) showed that when adequate information about sex composition is unavailable, it is prudent to characterize spawning stock biomass (SSB) as the combined male and female mature biomass. To that end, this assessment incorporated that definition of SSB for modeling and development of biological reference points.

As part of the simulation work conducted using a Stock Synthesis model (Appendix A9) the implication of hermaphroditism was examined. The operating model used to simulate pseudo-data included sex structure and hermaphroditism, but sex-aggregated models performed well for recovering simulated population parameters. Simulation indicates that model results are largely unaffected by the presence or absence of the hermaphroditism criteria. Growth models between sexes are comparable so once sex change occurs, there is little change in productivity. Additionally, with SSB defined as male and female mature biomass, a change of sex does not remove fish from the SSB calculation. Nevertheless, the spawning success in black sea bass is dependent on a balanced sex ratio ensuring the presence of both sexes during spawning.

TOR 6. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock), using measures that are appropriate to the assessment model, for the time series (integrating results from TORs-1,-4, & -5 as appropriate), and estimate their uncertainty. Include a historical retrospective analysis and past projection performance evaluation to allow a comparison with most recent assessment results.

Model Development

A statistical catch at age model (ASAP) was developed for the black sea bass assessment reviewed during SAW53. The SARC 53 review panel concluded that the results were not adequate for management purposes. Spatial patterning within the stock was suggested as a reason the model did not perform to their standards. Consequently, there are no historical retrospective or past projections to evaluate, however previous biological reference points are noted under TOR7.

Fishing mortality rates and stock sizes were estimated using the Age Structured Assessment Program (ASAP) statistical catch at age model (Legault and Restrepo 1998) available in the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/). 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 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. The user can choose to estimate or hold fixed the various parameters and input uncertainty estimates associated with data 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 compositions are generally modeled assuming a multinomial distribution, while most other model components are assumed to have lognormal error including penalties when used. 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-recruitment relationship). For more technical details refer to the ASAP technical manual.

The current assessment developed an ASAP model with several scenarios. The first scenario was modeling the stock under the assumption of a single unit stock, similar to previous approaches (note: this approach served as a bridge to previous assessments). Second, two unique area-specific models were developed for north and south of Hudson Canyon. Finally, a model was developed to account for exchange between the areas within the trawl fleets as well as within the NEFSC offshore surveys. Based on the performance of the two-area approach relative to more

complicated models, as evaluated by simulation testing (Appendix A6), parsimony and practical familiarity with ASAP, the WG concluded that the use of the two area models combined for status determination provided the best results for use in management. The WG also determined that the conclusions were robust to the modeling approach. The various approaches are presented in the following text, however the Overall and Area exchange approaches are provided for comparison to the final models, which are the North and South area models.

The catch at age data described in TOR 2 (north trawl and non-trawl; south trawl and non-trawl; overall trawl and non-trawl), total catch weight by fleet and survey indices at age described in TOR 3 were input to the model. Maturity at age, weight at age and natural mortality (0.4) described in the Introduction were input for each area. The single stock model (Overall model) represented the sum of catch at age and catch weight by fleet across area.

Model exploration began with a series of trial runs (Table A35) using only NEFSC surveys to establish baseline settings which produced a model solution. The Overall model began with two selectivity blocks with a change occurring in 1997-1998 when management was introduced. Incrementally the full suite of survey indices at age were added, with adjustments to index CVs to produce root mean square error values approaching 1.0. Initial NEFSC indices were an *Albatross* and *Bigelow* combined series. Input effective sample sizes (ESS) were chosen to conform with estimated values which were based on the approach of McAllister and Ianelli (1997). The model evolved (Table A36) as catch selectivities and index selectivity patterns were explored, beginning with selectivities that were freely estimated. The final model selectivities were fixed as flat topped beyond a chosen age and freely estimated in younger ages. The age of full selection was 4 in indices at age, age 4 in the non-trawl fleet as well as the trawl fleet from 1989 to 1997 then increasing to age 5.

The final Overall model incorporated a split series in the NEFSC spring index resulting in an *Albatross* series (1989-2008) and a *Bigelow* series (2009-2015). Additional indices at age included MADMF, NEAMAP, RI, CT, NEFSC winter, Recreational CPA and NJ. Indices from NY, DE, MD and VIMS were limited to age 1 indices only.

Variation in the catch at age, by fleet, is specified by the coefficient of variation values input for each fleet and year. Commercial trawl catch was given a CV equal to 0.05 since it is based on a census of dealer reports (discards are a function of the same reported landings). However, fleet 2

includes recreational catch which is based on a survey design that has undergone multiple changes. The input CV on fleet 2 was increased with an input value of 0.2 from 1989 to 2008 then a value of 0.15 from 2009 to 2015 to reflect better commercial reporting and improved estimates in the MRIP survey.

Recruitment in black sea bass throughout the stock is regionally influenced and not well determined by traditional stock recruitment models. Consequently, recruitment in ASAP was modeled as deviations from the geometric mean (steepness fixed at 1.0). The model allows deviations to be constrained by applying a penalty on the deviations from the stock-recruitment curve, however this constraint was weak due to an input CV of 1.0.

Development of area specific models followed a similar sequence (Tables A37-A40). Selectivity was freely estimated for catch and indices, then fleets and indices with estimates at bounds were fixed. Additional variance was added to indices to produce model estimates consistent with input values and effective sample sizes were adjusted to reflect model output. The final model for the north was model 26 and for the south model 24.

The split into northern and southern areas was an attempt to address the spatial components of the stock as it was understood that the southern offshore area during winter would likely contain fish originating in the north. In an attempt to address this issue, an area exchange model was developed to permit the exchange of individuals between northern and southern areas. For black sea bass, the intent of this exchange was to account for fish caught in the southern area during the winter/spring offshore trawl fishery and NEFSC bottom trawl surveys that originated in the north. The modeling framework did not explicitly incorporate movement into the dynamics of the stock, but instead moved both fishery dependent and independent catch from the southern to the northern component before running two separate, area-specific ASAP models. The exchange of individuals impacted only total catch and aggregate indices, and did not alter age compositions.

Two components impacted the amount of catch exchanged between the areas. The first component was the overall proportion of southern catch that was assumed to originate from the northern area. The second component was related to annual variability in this assumed exchange proportion. The extent of black sea bass seasonal movement is thought to be related to water temperature. Therefore, to account for the impact of temperature on seasonal movement,

average bottom temperature from the NEFSC spring bottom trawl survey was used as an annual covariate that modified the assumed exchange proportion. The magnitude of the covariate influence on the exchange proportion was the second component that impacted the amount of catch exchanged. This magnitude was dictated by an assumed range in possible annual fluctuations of the exchange proportion and effectively acted as a covariate scalar. As the range of possible fluctuations in the exchange proportion increased, the more the annual proportions could vary from the assumed average exchange proportion and therefore, the greater the overall impact of the covariate.

For a given average exchange proportion ($\bar{p}$) and range in annual fluctuations (r), the annual exchange proportions (p) were calculated as:

$$p = lb + \frac{ub - lb}{1 + e^{cov}}$$

where cov represented the covariate as standardized (z-scored) average bottom temperature and lb and ub represented the lower and upper bounds, respectively, of the annual exchange proportion calculated as:

$$lb \text{ or } ub = \bar{p} \pm 0.5r.$$

In warmer years, it is believed that black sea bass do not migrate as far south (Miller et al. 2016); therefore, increased covariate values resulted in decreased annual exchange proportions. These annual exchange proportions were then used to develop adjusted time series of catches for the area-specific models that just represented individuals originating from that specific area.

For a given set of fishery dependent and independent catches, a series of exchange proportions and ranges were evaluated. Exchange proportion and range value combinations were only investigated if all possible annual proportions fell between zero and one. Candidate models based on adjusted time series were evaluated using the resulting combined (unweighted sum) total likelihood values of the area-specific models. The best exchange proportion and range combination was selected as the model set that produced the lowest combined likelihood. The robustness of assessment outputs, including recruitment, fishing mortality and spawning stock biomass, was evaluated across changes in exchange proportion and range values.

The final North and South models were incorporated into the area exchange model. The model was run for exchange rates between 0% (base models) and 50% by 5% increments and with

annual ranges from 0 to 50% in 10% increments. The model likelihoods for each area and the sum were evaluated to determine the optimal north-south combination.

Model Results

The predicted total index proportions at age in the OVERALL model generally matched the observed values among all the indices. The predicted indices tended to match the trend among all the observed indices but generally were unable to match the large deviations associated with strong cohorts such as the 2011 year class among northern state indices. The root mean square error (RMSE) values ranged from 0.47 for REC CPA to 1.97 for MADMF indices (Figure A53). The model resulted in annual catch estimates that matched fleet 1 (standardized residuals ranged from 0.31 to -0.11) but varied more for fleet 2 (standardized residuals from1.95 to -2.85). Both fleets tended to have positive residuals prior to 2002 and negative after 2002 (Figure A54-A55). Effective sample size for fleet 1 was constant at 60 while fleet 2 equaled 100. Catchability estimates of all the indices were less than 1, however the *Albatross* q was larger than the *Bigelow* q which was opposite of expectations. Detailed diagnostics from the model are presented in Appendix A10.

The model provided total stock number estimates showing a slowly increasing population from a low in 2005 until 2011, at which point the total abundance increased dramatically due to an incoming 2011 cohort (Figure A56). Abundance declined thereafter but remained larger in 2015 than pre-2011 abundance. Average fishing mortality (ages 4-7) was very high in the early 1990s (as high as 1.44) but declined following management implementation in 1997. Estimated F in 2007 was 0.74 but declined steadily to 0.24 by 2011 (Figure A56). The 2015 average fishing mortality was estimated as 0.20.

Spawning stock biomass (male and female combined) steadily increased from1994 to 2002 when it reached 9,796 mt (Figure A56). There was a decline until 2007 (4,081 mt) followed by a steady increase to the 2015 estimate of 19,585 mt. Total biomass and exploitable biomass followed a similar pattern with 2015 total biomass equal to 24,155 mt and exploitable biomass of 23,658 mt (Figure A56). Average recruitment over the time series equaled 25.9 million age 1 fish, with strong cohorts in 1999, 2001 and an exceptional year class in 2011 (Figure A56).

A retrospective analysis of the model, using a 7 year peel, indicated very little impact on the results from additional years in the time series (Figures A57-A62). However, using a 7 year peel resulted in the loss of the Bigelow index and the reduction of the NEAMAP indices to one year. Consequently, the analysis uses a different model once the 7 year peel is completed so the retrospective results should be viewed with caution. The F estimates, with a Mohn's rho equal to -0.11, showed no obvious pattern. Biomass, total stock number and recruitment were similar and had Mohn's rho values ranging from 0.055 (recruitment) to 0.091 (SSB).

A Monte Carlo Markov Chain (MCMC) was implemented using 1000 iterations and a thinning rate of 200. The 2016 recruitment was estimated as the geometric mean recruitment from 2000 to 2015. The 90% confidence interval of the median terminal year Fmult (0.20) ranged from 0.151 to 0.264 (Figure A63-A64). The median 2015 SSB (20,092 mt) was estimated with 90% CI between 16,501 mt to 24,675 mt (Figure A65-A66). The confidence interval for January 1 median biomass in 2015 (24,693 mt) ranged from 20,788 mt to 29,674 mt (Figure A67-A68). The terminal year values of F, SSB and total biomass adjusted for retrospective were all within the 90% CI of the base values.

The NORTH model was developed using trawl and non-trawl catches taken north of Hudson Canyon and indices from the northern strata for NEFSC spring (*Albatross* and *Bigelow* series) and NEAMAP. The NEFSC winter northern index was not included in the final model due to poor diagnostics. Also included were indices from MA, RI, CT, NY and Rec CPA of states NY and north. Model results and diagnostics are provided in Figures A69-A97. The predicted total index proportions at age and the observed values in the model matched reasonably well among indices but annual matches varied among indices. The annual proportions at age from the NEFSC *Albatross* time series fit poorly as did several other indices in the early part of the series. In comparison, indices collected since the mid to late 2000s captured the age composition reasonably well. The predicted indices tended to match the trend among all the observed indices and were generally able to match the strong 2011 year class although not always of the magnitude within an index. The root mean square error (RMSE) values ranged from 0.74 for the Rec CPA to 1.88 for NY age 1 indices. The final model configuration resulted in annual catch estimates that matched fleet 1 (standardized residuals ranged from 0.06 to -0.18) and less so for fleet 2 (standardized residuals from 0.90 to -0.67). Both fleets tended to have positive residuals

after 2009 and negative prior to 1997. Effective sample size for fleet 1 was constant at 50 while fleet 2 equaled 100. Catchability estimates of all the indices were less than 1. In addition estimated *Albatross* catchability was two times smaller than the Bigelow catchability which was comparable to the between vessel calibration coefficient (3.4), especially when considering the uncertainty in the q estimates from the model and changes in selectivity. Additional diagnostics from the model are presented in Appendix A11.

The model provided total stock abundance estimates showing a steadily increasing population beginning around 1993 until 2011, at which point the total abundance increased dramatically due to an incoming 2011 cohort (Figure A98). Abundance declined thereafter and 2015 total abundance was equivalent to abundance in 2011. Average fishing mortality (ages 4-7) was very high in the early 1990s (as high as 1.32 in 1992) but steadily declined to 0.17 by 2011 (Figure A98). Estimated fishing mortality since 2012 has remained steady at around 0.23.

Spawning stock biomass (male and female combined) steadily increased from 1994 (259 mt) to 13,119 mt in 2014 (Figure A98). There was slight decline to 11,719 mt in 2015. Total biomass and exploitable biomass followed a similar pattern with a peak total biomass equal in 2014 of 21,376 mt and exploitable biomass of 14,737 mt (Figure A98). Total biomass in 2015 decreased to 17,306 mt while exploitable biomass increased slightly to 15,079 mt. Average recruitment over the time series equaled 8.353 million age 1 fish, with an exceptional year class in 2011 of 49.88 million age 1 fish (Figure A98). Recruitment in 2013 was also above average followed by a low recruitment year in 2014.

A retrospective analysis of the model, using a 7 year peel, indicated a general mis-specification of fishing mortality, abundance and biomass. However, using a 7 year peel resulted in the loss of the Bigelow index and the reduction of the NEAMAP indices to one year. Consequently, the analysis uses a different model once the 7 year peel is completed so the retrospective results should be viewed with caution. The F estimates, with a Mohn's rho equal to 0.703, showed a pattern of over-estimation (Figure A99). Biomass, total stock number and recruitment were under-estimated and had Mohn's rho values ranging from -0.484 (recruitment) to -0.325 (exploitable biomass) (Figures A100-A104). The direction of the rho values are opposite to the pattern typically seen and results in decreased F and increased SSB following retrospective adjustments.

A Monte Carlo Markov Chain (MCMC) was implemented using 1000 iterations and a thinning rate of 200. The 2016 recruitment was estimated as the geometric mean recruitment from 2000 to 2015. The 90% confidence interval of the median terminal year Fmult (0.247) ranged from 0.181 to 0.337 (Figures A105-A106). The median 2015 SSB (11,959 mt) was estimated with 90% CI between 9,606 mt to 15,003 mt (Figures A107-A108). The confidence interval for January 1 median biomass in 2015 (17,656 mt) ranged from 14,569 mt to 21,449 mt (Figures A109-A110).

The terminal year (2015) values of F, SSB and total biomass were adjusted for retrospective patterns. The retro adjusted value of F (0.14), SSB (19,211 mt), total Jan 1 biomass (27,733 mt) fell outside the 90% confidence bounds of the terminal year estimate (Figure A110a)

The final SOUTH model was developed using trawl and non-trawl catches taken south of Hudson Canyon and indices from the NEFSC spring (*Albatross* and *Bigelow* series), NEAMAP (age 1 only because of poor diagnostics in older fish), and NEFSC winter southern strata. Also included were indices from NJ, DE, MD, VIMS and Rec CPA from states NJ and south. The only indices beyond age 1 were from the NEFSC *Albatross* and *Bigelow*, NEFSC winter, NJ and Rec CPA. The remainder provided indices of age 1 abundance. Model results and diagnostics are provided in Figures A111-A138.The predicted total index proportions at age and the observed values matched reasonably well among indices but annual matches varied among indices. The annual proportions at age from the NEFSC *Albatross* time series fit poorly. The predicted indices tended to match the trend among all the observed indices and were generally able to match the strong 1999 and 2001 year classes although not always of the magnitude within an index. The 2011 cohort was apparent as above average in several indices but not of the magnitude seen in the northern model. The root mean square error (RMSE) values ranged from 0.68 for the Rec CPA to 1.45 for NEFSC *Bigelow* indices. The final model configuration resulted in annual catch estimates that matched fleet 1 (standardized residuals ranged from 0.27 (1996) to -0.13) and less so for fleet 2 (standardized residuals from 1.73 to -1.74). Both fleets had positive residuals prior to 2002 and negative from 2003 to 2015. Effective sample size for fleet 1 was constant at 30 while fleet 2 equaled 40. Catchability estimates of all the indices were less than 1. In addition estimated *Albatross* catchability was two times smaller than the *Bigelow* catchability which was comparable to the between vessel calibration coefficient of 3.4, especially when considering the

uncertainty in the q estimates from the model and changes in selectivity. Additional diagnostics from the model are presented in Appendix A12.

The model provided total stock number estimates showing a relatively stable population beginning between 1989 and 2002, at which point the total abundance declined reaching a low point in 2006 (Figure A139). Abundance steadily increased thereafter and 2015 total abundance approached the abundance seen in 2002. Average fishing mortality (ages 4-7) was very high in the early 1990s (as high as 1.43 in 1993) but declined to 0.55 by 1999 (Figure A139). Estimated fishing mortality increased again to 0.94 in 2007 but steadily declined to 0.23 by 2015.

Spawning stock biomass (male and female combined) steadily increased from1989 (2,088 mt) to 5,801 mt in 2002 (Figure A139). There was a decline to 1,732 mt by 2007 followed by another steady increase reaching 4,834 mt by 2015. Total biomass and exploitable biomass followed a similar pattern with a peak total biomass in 2002 equal to 9,728 mt and exploitable biomass of 6,718 mt (Figure A139). Total biomass decreased to 3,614 mt in 2007 with an exploitable biomass of 2,171 mt in 2008 but both have since increased to 6,838 mt and 5,168 mt, respectively, in 2015. Average recruitment over the time series equaled 15.92 million age 1 fish, with higher recruitment between 1989 and 2002 (Figure A139). Recruitment in 2015 was above average with 21.57 million age 1 recruits.

A retrospective analysis of the model, using a 7 year peel, indicated a general mis-specification of fishing mortality, abundance and biomass (Figures A140-A145). However, using a 7 year peel resulted in the loss of the *Bigelow* index and the reduction of the NEAMAP indices to one year. Consequently, the analysis uses a different model once the 7 year peel is completed so the retrospective results should be viewed with caution. The F estimates, with a Mohn's rho equal to -0.419, showed a pattern of under-estimation. Biomass, total stock number and recruitment were over-estimated and had Mohn's rho values ranging from 0.550 (exploitable biomass) to 0.873 (recruitment).

A Monte Carlo Markov Chain (MCMC) was implemented using 1000 iterations and a thinning rate of 200. The 2016 recruitment was estimated as the geometric mean recruitment from 2000 to 2015. The 90% confidence interval of the median terminal year Fmult (0.233) ranged from 0.162 to 0.343 (Figures A146-A147). The median 2015 SSB (4,901 mt) was not as well estimated with 90% CI between 3,628 mt to 6,529 mt (Figures A148-A149). The 90% confidence interval for

January 1 median biomass in 2015 (6,920 mt) ranged from 5,432 mt to 8,845 mt (Figures A150-A151).

The terminal year values of F, SSB and total biomass were adjusted for retrospective patterns. The retro adjusted value of F (0.39), SSB (2,966 mt), total Jan 1 biomass (4,276 mt) fell outside the 90% confidence bounds of the terminal year estimate (Figure A110a)

Area Exchange Model

A model using 40% exchange in trawl catch and indices with a 10% range in annual exchange proportions produced the lowest value for the combined likelihoods (Table A41). The best model for the southern area occurred with a 50% exchange and 50% range which were at the upper bound for both exchange rate and range. The northern model minimum likelihood occurred by moving 35% of southern catch and indices to the north and no annual fluctuations in this exchange rate (0% range).

Results from the optimal area exchange model showed minimal impact on the final overall estimates but did produce some regional differences (Figures A152). The catch in the north increased substantially in the early part of the time series (1993 total catch increased 127%) but by 2015 the exchange increased the northern total catch by only 3.7%. The effect of the catch increased abundance estimates an average of 22% but only resulted in reducing F by 3%. The average trawl catch reduction in the south of 40% reduced total catch by 9% which resulted in an 8-10% decrease in total abundance, SSB, recruitment and exploitable biomass. Fishing mortality decreased by only 1%. Overall, temporal trends in area-specific assessment outputs were robust to both the selected exchange proportion and range, though they were more robust to changes in the assumed range than the exchange proportion. Additional diagnostic plots are available in Appendices A13-A14.

The area exchange approach had minimal impact on the area-specific retrospective values with the exception of the fishing mortality in the north. The Mohn's rho in the north decreased 25% from 0.70 to 0.53 but adjusted F only decreased from 0.14 to 0.13. Rho only decreased 15% in exploitable biomass, 9% in total stock number and 6% in age one recruitment. Rho values for the south model increased but only by 3% or less.

Model Comparisons

Although models were developed for a northern area and a southern area, the final product for determining stock status was a single combined estimate for the unit stock. These combined area results as well as the combined area exchange estimates were compared with results from the single overall model (Table A42). The F values from North and South were averaged to compare to the Overall model results.

In general, the overall model produced larger estimates of abundance and biomass and lower estimates of F than the area-specific models and the combined areas estimates from the exchange model were nearly identical to the overall model (Figure A153). Despite the difference in point estimates among models, the trends were nearly identical. The WG concluded that the area exchange model as configured did not produce any benefits beyond the simple area combined or the overall model. However, it did prove informative as a sensitivity run to evaluate the impact of catch misspecifications to each area and showed that the model was robust to migration effects.

There existed a trade-off between the use of the overall model and the combined area-specific models. The area-specific models resulted in retrospective patterns which were in opposite directions. However because of the reduced areas in each, the local indices of abundance were more informative (i.e. fit better) than in the overall model. In the overall model the residuals in the catch and indices were greater, however the retrospective patterns of each area essentially cancelled each other resulting in low rho values. The WG concluded that the combined area specific models provided the most information for management purposes. There were clearly local variations in recruitment strength of the 2011 cohort which was most apparent in the area models. Fortunately the overall, combined area and area exchange models all produced similar results.

Sensitivity analysis

A sensitivity analysis was conducted to evaluate the influence of individual indices on the model results for each area. The models were run with each index removed from the model (only one index missing per run). The results show that the model was robust and not dependent on any single index. Model results with any particular index dropped remained within the 90% confidence interval of the base model. Results are presented in Figures A154-A163.

The models were profiled over a range of possible values of natural mortality. Each model was run using a new M value ranging from 0.01 to 1.0. The analysis was conducted on the two area models, the areas combined and the overall model and calculated the difference between each model negative log-likelihood and the model with the minimum negative log-likelihood (Figure A164). In the southern model, the minimum negative log-likelihood occurred for M at 0.8 whereas the northern model minimum occurred at 0.15. The combination of the north and south produced a minimum at an M=0.4 while the overall model minimum was at M=0.55.

An additional sensitivity test was made to examine the implications of the higher CV values used for the non-trawl catches. The CVs in the base model were 0.2 from 1989-2008 and 0.15 in 2009-2015). These values were varied from (0.05, 0.025) to (0.35, 0.3). The results (Figure A165) suggest that the North models F and SSB were robust to the range of values explored. The South model was impacted in the early 2000s when the SSB was highest, but remained robust to the range of CV over the past decade.

In addition to developing a model using the ASAP approach, the fishery and survey data was also explored using the Stock Synthesis framework (Methot and Wetzel, 2013). The model (Appendix A9) incorporated tagging data from a project in 2003-2005 (Moser and Shepherd, 2009) and modeled the population seasonally by length and sex, accounting for hermphroditism. Although the model was not fully vetted by the BSB WG, and therefore not presented as a working model, the results were similar to ASAP. The exploratory model suggested that the stock has increased in the last decade in both areas from strong recruitment and that fishing mortality decreased to relatively low values in the last decade. Sensitivity analyses indicate that these results are robust to alternative model configurations.

TOR 7. Estimate biological reference points (BRPs; point estimates or proxies for BMSY, BTHRESHOLD, FMSY, and MSY), including defining BRPs for spatially explicit areas if appropriate, and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the appropriateness of existing BRPs and the “new” (i.e., updated, redefined, or alternative) BRPs.

Black sea bass north of Cape Hatteras, NC have been managed as a single stock since the inception of the management plan in 1997. Although the evidence presented for TOR 1 suggests regional differences within the stock, there is no evidence that more than one stock exists north of Cape Hatteras. Although the preferred model approach of the WG has been the two area model with no exchange, development of reference points and subsequent evaluation of stock status was made on the unit stock (Cape Hatteras to the Gulf of Maine).

The WG examined the two-area models for a relationship between SSB and subsequent recruitment and concluded there was no evidence of any stock/recruitment relationship in the range of estimated stock size in the assessment time series (Appendices A11 & A12). Consequently there was no direct calculation of MSY and associated F or biomass. Instead, an average value of F40% between the two areas was chosen as a proxy for F_{MSY}. In similar situations, and for species with similar life histories, the South Atlantic snapper-grouper fishery management plan uses $F_{30\%}$ or $F_{40\%}$ as F_{MSY} proxies when F_{MSY} cannot be directly estimated. Thorson et al. (2012) suggest that $F_{35\%}$ is an appropriate proxy for F_{MSY} based on a meta-analysis of stock-recruitment information from Perciformes. Zhou et al. (2012) suggested that F_{MSY} is approximately 0.922xM for Perciformes, which would correspond to F_{MSY}~0.37 for the assumed M=0.4. The estimate of F40% in the north equaled 0.355 and was 0.365 in the south. An average of 0.36 was adopted as the proxy F_{MSY}.

An approach was adopted for developing biomass reference points using empirical recruitment in a long term projection. Inputs for projections included averages from 2013 to 2015 total (Jan 1) and SSB weights at age, selectivity at age weighted by contributing catch, and natural mortality =0.4. Recruitment was chosen from a random draw for the combined area recruits between 2000 and 2015. The WG felt that recruitment over this time period was more reflective of current population dynamics. Catch input for 2016 was the Allowable Biological Catch (ABC) established by the MAFMC for 2016. Distributions of abundance at age from each model MCMC run were combined for a single stock projection. A 100 year projection with 1000 bootstrap iterations was run and the average of the final 20 years calculated as the biological reference points (SSB_{MSY} proxy, B_{MSY} proxy and MSYproxy) associated with the F_{MSY} proxy. In previous assessments using a length based model (SCALE (Northeast Data Poor Stocks Working Group 2009)) B_{MSY} proxy was chosen as a biomass reference point. Traditionally spawning stock biomass is preferred because of the potential relationship with subsequent recruitment, however

hermaphroditism presents unique challenges in defining female SSB due to sex changes. Analyses by Brooks et al. (2009) showed that SSB defined by both sexes provided a reasonable alternative. Consequently combined male and female SSB is recommended for use as a biomass reference point for black sea bass although both SSB and total biomass estimates are provided. The final estimate of SSB_{MSY} proxy equaled 9,667 mt with $\pm$ 2 SD of 4,149 mt, B_{MSY} proxy of 17,256 mt with $\pm$ 2 SD of 7,453 mt, and an MSYproxy estimate of 3,097 mt with $\pm$2 SD of 1,299 mt (Table A43). The previous basis for determining if a stock is overfished is ½ of $B_{MSY\ proxy}$ which in this stock equals 8,628 mt ($\pm$ 2 SD of 3,722 mt). An alternative approach for biomass reference point estimation using the single overall model produced results similar to the combined area model, although generally higher. Those estimates are SSB_{MSY} proxy = 10,296 mt, B_{MSY} proxy = 18,379 mt, and MSY = 3,298 mt.

Biological reference point estimates from the 2008 assessment black sea bass assessments were an F_{MSY} proxy = 0.42, SSB_{MSY} proxy of 12,537 mt and an MSY of 3,903 mt and the 2012 assessment (which was not accepted in SAW53) produced reference points of an F_{MSY} proxy = 0.32, SSB_{MSY} proxy of 8,128 mt and an MSY of 3,197 mt.

TOR 8. Evaluate overall stock status with respect to a new model or new models that considered spatial units developed for this peer review.

Retrospectively adjusted values of SSB and F from the ASAP model are being used for stock status determination. The stock of black sea bass north of Cape Hatteras, NC is not overfished, nor is it experiencing over fishing (Figures A169-A170). The retrospective adjusted estimates of F, SSB and B from each area were combined for comparison to biological reference points. The retro-adjusted 2015 biomass (32,010 mt) is currently 86% above B_{MSY} proxy and retro-adjusted 2015 SSB (22,176 mt) is 129% above the SSB_{MSY} proxy (9,667 mt). Retro-adjusted fishing mortality in 2015 ($F_{MULT} = F_{Ages\ 4\text{-}7} = 0.27$) is 25% below the F_{MSY} proxy = 0.36.

The 2015 stock biomass prior to adjustment (24,143 mt) is 40% above B_{MSY} proxy (17,256 mt) and 2015 SSB (16,552 mt) is 71% over SSB_{MSY} proxy (9,667 mt). Fishing mortality in 2015 before adjusting for the retrospective bias (F_{MULT}= 0.24) is 35% below F_{MSY} proxy = 0.36.

It should be noted that the area specific conditions are different. Relative to F40% (0.355 in the north, 0.365 in the south), the retro adjusted F in the north (0.14) is well below the threshold whereas retro adjusted F in the south (0.39) is slightly above (although well within the 80% CI of 0.30 to 0.52). Biomass reference points were not independently estimated for each area.

TOR 9. Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (3-5 years) and the statistical distribution (e.g., probability density function) of the OFL (overfishing level) that fully incorporates observation, process and model uncertainty (see Appendix to the SAW TORs). 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, and definition of BRPs for black sea bass).

b. Comment on which projections seem most realistic. Consider major uncertainties in the assessment as well as the 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.

Catch projections are presented for the unit stock, however they represent the sum of each area specific projection. Projections for the north and south area were made for years 2017 through 2020 under the assumption of either $F_{MSY\ proxy}$ or status quo F. Since 2016 catch estimates were not available, 2016 catch was interpreted as the ABC (3,024 mt) split into area based on the 3 year average ratio of catch by area. The 2013 to 2015 average catch ratio was 71% in the north and 29% in the south, therefore 2016 catch in the north was 2,150 mt and the south as 874 mt. Additional runs were included which allowed a 10% and a 20% overage in the north 2016 catch since recent years have exceeded the ABC. The 2013-2015 average weights at age, selectivity (fleets combined, weighted by catch at age), and empirical recruitment from 2000 to 2015 were input to the stochastic projection software AGEPRO. A distribution of starting numbers at ages 2 to 8+ were produced by the MCMC run of each final model. Projections were also made in each area using rho adjusted estimates. The results of each area were summed for the final catch

projections. The final products were projections for area combined, area combined rho adjusted and a comparison to projections using the overall model under F_{MSY} and F status quo (F_{SQ}).

Results without rho adjustments from the area combined model under $F_{MSY\ proxy}$ (0.36) shows a substantial increase in total catch beginning in 2017 at 4,446 mt (± 2 SD 1,687 mt) (Table A44, Figure A171). However as the 2011 cohort abundance declines, catch declines such that 2018 projected catch would drop to 3,822 mt (± 2 SD 1,299 mt) and 3,493 mt (± 2 SD 1,481 mt) in 2019. Total biomass would also decline beginning in 2016 (23,374 mt ± 2 SD 7,351 mt) and declining to 18,764 mt (± 2 SD 8,977 mt) by 2019 which is above $B_{MSY\ proxy}$ (17,256 mt, Table A44, Figure A172). Spawning biomass follows a similar trajectory, declining from 15,055 mt (± 2 SD 5,621 mt) in 2016 to 10,782 mt (± 2 SD 5,083 mt) by 2019 (Table A44, Figure A173).

Results without rho adjustments from the area combined model under F_{SQ} (0.24) shows a substantial increase in total catch beginning in 2017 at 3,127 mt (± 2 SD 1,189 mt) (Table A45, Figure A174). However as the 2011 cohort abundance declines, catch declines such that 2018 projected catch would drop to 2,904 mt (± 2 SD 996 mt) and 2,809 mt (± 2 SD 1,147 mt) in 2019. Total biomass would also decline beginning in 2016 (23,374 mt ± 2 SD 7,351 mt) and declining to 20,848 mt (± 2 SD 9,423 mt) by 2019 which is above $B_{MSY\ proxy}$ (17,256 mt, Table A45, Figure A175). Spawning biomass follows a similar trajectory, declining from 15,055 mt (± 2 SD 5,168 mt) in 2016 to 12,805 mt (± 2 SD 5,663 mt) by 2019 (Table A45, Figure A176).

Results with the rho adjustments from the area combined model under $F_{MSY\ proxy}$ (0.36) have the same trend with higher abundance (Table A43). A substantial increase in total catch would occur beginning in 2017 at 5,467 mt (± 2 SD 1,984 mt) (Table A46, Figure A171). However as the 2011 cohort abundance declines, catch declines such that 2018 projected catch would drop to 4,494 mt (± 2 SD 1,457 mt) and 3,901 MT (± 2 SD 1,502 mt) in 2019. Total biomass would decrease from 29,350 mt (± 2 SD 9,028 mt) in 2016 to 20,788 mt (± 2 SD 9,063 mt) by 2019 which is above $B_{MSY\ proxy}$ (Table A46, Figure A172). Spawning biomass follows a similar trajectory, declining from 18,670 mt (± 2 SD 6,721 mt) in 2016 to 11,849 mt (± 2 SD 5,143 mt) by 2019 (Table A46, Figure A173).

Results with the rho adjustments from the area combined model under F_{SQ} (0.27) have the same trend with higher abundance (Table A47). A decrease in total catch would occur beginning in 2017 at 3,006 mt (± 2 SD 1,126 mt) (Table A47, Figure A174). Catch continues to decline

through 2018 as projected catch would drop to 2,859 mt (± 2 SD 953 mt) and 2,764 mt (± 2 SD 986 mt) in 2019. Total biomass would decrease from 29,246 mt (± 2 SD 8,993 mt) in 2016 to 24,704 mt (± 2 SD 9,839 mt) by 2019 which is above $B_{MSY\ proxy}$ (Table A47, Figure A175). Spawning biomass follows a similar trajectory, declining from 18,587 mt (± 2 SD 6,690 mt) in 2016 to 15,349 mt (± 2 SD 6,099 mt) by 2019 (Table A47, Figure A176).

The Overall model, with no rho adjustments, was similar to the area combined estimates with the rho adjustment. Projected catch in 2017 at F_{MSY} would be 6,615 mt compared to the rho adjusted combined area model with 5,467 mt (Figure A171). SSB in 2017 in the overall model equaled 19,125 mt compared to the rho adjusted combined estimate of 15,918 mt (Figure A172).

Given the convergence of estimates from the overall model and the rho adjusted area combined model, the rho adjusted values appear to provide reasonable projection estimates. The projections assume the 2016 ABC was not exceeded. If the 2016 ABC was exceeded by 20%, the projected rho-adjusted 2017 catch at F_{SQ} would only decrease 2% to 2,993 mt. The projections also assume the selectivity estimated for 2013-2015 would apply to the future catches. Due to overages in 2015, states from NJ north adjusted regulations to reduce harvest in 2016, which may have influenced selectivity to some degree.

The assessment model and consequently the projections do not explicitly account for hermaphroditism in sea bass beyond using male and female SSB. However, hermaphroditism is unlikely to have a large impact on the assessment results but should be considered in developing management options. Finally, there is evidence in 2016 survey indices that in some areas the 2015 cohort is above average. This incoming year class would not have much influence on projections until 2018, at which time it will be included in the assessment estimates.

TOR 10. Review, evaluate and report on the status of the SARC and Working Group research recommendations listed in recent SARC reviewed assessments and review panel reports. Identify new research recommendations.

Research recommendations from SAW 53:

1. *The panel recommends multiple age-structured models be evaluated for use in a future model. Specifically, we recommend:*

a. A simple model such as a separable model with smoothing on F among years.

Not attempted for this assessment, however evaluation of catch curves is a routine diagnostic.

b. *A more complex, spatially structured model with 6 month time step within independent stock areas in spring and mixing in winter with natal homing, if data area adequate to support such a model.*

Completed in the form of the area exchange model and explored within the SS3 model.

c. *Consideration should be given to including tag return data in an age-structured (and possibly spatially-structured) assessment model.*

Tag results were considered in developing the area exchange bounds but not explicitly within the model. Explored within the SS3 model.

2. *The Panel recommends evaluation of a species specific survey, such as a pot survey to provide increased information on abundances and biological characteristics.*

Previously existed but was terminated by the MAFMC following a review of the program design.

3. *Continue and expand the tagging program to provide:*
   a. *increased age information.*
   b. *increased resolution on mixing rates among putative populations.*

No additional designed tagging projects were conducted.

4. *Continue and expand genetic studies to evaluate the potential of population structure north of Cape Hatteras.*

Some genetic work being evaluated for the Gulf of Maine by Marissa McMahon, Northeastern University.

5. *Continued research on rate, timing and occurrence of sex-change in this species. Recent research findings discussed at the SARC lead to the hypothesis that protogyny is not obligate in this species – some individuals may never have been female before maturing as a male.*

Some further work conducted by NEFSC as well as Rutgers University.

6. *The validity of the age data used in the assessment requires further evaluation, in particular the reliability of scale-based ageing needs to be determined. A scale-otolith intercalibration exercise might be of utility.*

Working paper included which explores this issue.

SAW 62 Black Sea Bass Working Group research recommendations:

1. Expand on previous genetic studies with smaller spatial increments in sampling.
2. Consider the impact of climate change on black sea bass, particularly in the Gulf of Maine.
3. Evaluate population sex change and sex ratio, particularly comparing dynamics among communities.
4. Study black sea bass catchabilty in a variety of survey gear types.
5. Investigate and document social and spawning dynamics of black sea bass.
6. Increased work to understand habitat use in sea bass and seasonal changes.
7. Evaluate use of samples collected by industry study fleets.

Acknowledgments

Special thanks to Joshua Dayton of the NEFSC Population Biology Branch for supplying age results, Alicia Miller for developing distribution maps and Kiersten Curti for development of the area exchange model and index uncertainty evaluations.

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TABLES

Table A1. Summary of life history and habitat characteristics for black sea bass, *Centropristis striata*. (YOY = young-of- the-year; SNE = southern New England; MAB = Middle Atlantic Bight; GOM = Gulf of Maine. *In:* Steimle et al. 1999.

Life Stage	Time of Year	Size and Growth	Geographic Location	Habitat	Substrate
Eggs	May-Oct; appear earlier in south and later in north	0.9-1.0 mm; incubation 2-5 days	Coastal MAB; rarely in estuaries	Upper water column, shore to > 200 m depth off Virginia	Buoyant in upper water column
Larvae	May-Nov; peak June-July; appear earlier in south and later in north	Hatch at ~2.1 mm; stage lasts to ~15 mm transition	MAB, near shore, mouths of some estuaries, but rarely in them	As for eggs, < 100 m until transition to juveniles	Upper water column until transition to juveniles
Juveniles YOY	April-Dec; most settle June-Nov	~10-16 mm to 100 mm TL by Nov	MAB into GOM, inshore and into estuaries mid-late summer	Estuarine - coastal; ~1-38 m; salt marsh edges & channels; high habitat fidelity	Rough bottom, shellfish, sponge, and eelgrass beds, nearshore shell patches, man-made objects
Juveniles Winter	Dec-April	~2-12 cm; growth rate reduced	MAB: Most move offshore and south of New Jersey to warmer, deeper waters	Mostly deeper than 38 m; may prefer 90-100 m; mid and outer continental shelf and Chesapeake Bay	Nearshore shell patches and other shelter on sandy bottoms
Adults Summer	April-Dec	> 19 cm FL; growth sexually dimorphic	Coastal: MAB into GOM	~2-38 m; larger fish stay in deeper waters	Mussel beds, rock, artificial reefs, wrecks and other structures
Adults Winter	Nov-March	> 19 cm FL	Most move offshore and south of New Jersey to warmer (> 6°C) waters.	30-240 m depths; mostly 60-150 m mid/outer continental shelf; otherwise poorly known	Poorly known, possibly available shelter on offshore silty sand (e.g., pits)
Spawning Adults	May-Oct, peak in June; begins in the south and progresses north	> 19 cm FL; mature at age 1+	Inshore MAB, south to north, during migration	~20-50 m	Over sand, sand with rock, and reefs

Table A2. Summary of results from a variety of methods used to estimate black sea bass natural mortality.

Method	Equation	L_inf	K	t_max	P 1	P 2	a_50	GI	temp	instantaneous	annual
Alverson and Carney 1975	M = 3K/(exp[0.38*K*t_max) − 1]		**X**	**X**						0.42	0.35
Rikhter and Efanov 1977	M = [1.521/(a_50^0.720)] − 0.155						**X**			0.94	0.61
Gunderson 1980	M = −0.370 + 4.64GI							X		0.56	0.43
Pauly 1980[1]	M = exp[−0.0152 + 0.6543*ln(K) − 0.279*ln(L_inf/10) + 0.4634*ln(Temp)]	**X**	**X**						X	0.32	0.28
Hoenig 1983 (rule-of-thumb)	M = −ln(P)／t_max			**X**	**X**					0.35	0.30
Hoenig 1983 (rule-of-thumb)				**X**		**X**				0.25	0.22
Roff's 1st 1984	M = 3*K/[exp(tmax*K) - 1]		**X**	**X**						0.07	0.07
Ralston 1987[4] (linear regression)	M = 0.0189 + 2.06*K		**X**							0.39	0.32
Gunderson and Dygert 1988	M = 0.03 + 1.68*GI							X		0.37	0.31
Charnov & Berrigan 1990	M = 2.2/tmax			**X**						0.18	0.17
Jensen's 1st 1996	M = 1.65*tmax			X						0.14	0.13
Jensen 1996 (theoretical)	M = 1.50*K		**X**							0.27	0.24
Jensen 1996 (derived from Pauly 1980)	M = 1.60*K		**X**							0.29	0.25
Gunderson 1997	M = 1.79*GI							X		0.36	0.30
Hewitt and Hoenig 2005	M = 4.22／t_max			**X**						0.35	0.30
Updated Tmax estimator (Then et al. 2015)	M = 5.109/tmax			X						0.43	0.35
Updated Hoenig 1983 (Then et al. 2015)	M = exp[1.717-1.01*ln(tmax)]			X						0.45	0.36
Updated Hoenig Non-linear least squares (Then et al. 2015)	M = 4.899 * tmax -0.916			X						0.50	0.40
Updated Pauly Non-linear least squares-T (Then et al. 2015)	M = 4.118 * K0.73 * Linf-0.33	X	X							0.14	0.13
Beverton[5]	M = 3*K/[exp(a_50*K) − 1]		**X**				**X**			1.65	0.81

Notes
1 Pauly's (1980) equation converted from base 10 to natural logarithms by Quinn and Deriso (1999); L_inf divided by 10 to adjust for mm
2 Values 1.44 (intercept) and -0.982 (slope) were those recommended by Hoenig (1983)
3 Equation ≈ 3／t_max when P = 0.05
4 Ralston's (1987) relationship was developed for snappers and groupers
5 Was not able to verify this equation or identify reference

Table A3. Brief summary of the history of black sea bass stock assessments at NEFSC.

- 1985 SARC 1 – Simple data review. Indices and catch.
- 1987 SARC 5 – Simple data review. Indices and catch.
- 1988 SARC 6 – Simple data review. Indices and catch.
- 1989 SARC 9 – Simple data review. Indices and catch.
- 1990 SARC 11 – length based mortality. Over-exploited.
- 1991 SARC 13 – length based mortality. Over-exploited.
- 1995 SARC 20 – ADAPT VPA accepted. High F (>1.0)
- 1997 SARC 25 – exploratory VPA, general trends accepted. Inadequate data.
- 1998 SARC 27 – not approved. Inadequate data for age based or production model
- 2004 SARC 39 – Tag based R/M, F replacement model. Exploitation from tagging ok.
- 2006 SARC 43 – Tag analysis. Not accepted as valid.
- 2008 Northeast Data Poor Stocks Working Group – Length based model (SCALE) approved for status and BRPs. Use with caution.
- 2009 SSC – Length based model considered too uncertain to use.
- 2010 SSC (a) – Model results reconsidered. Still too uncertain.
- 2010 SSC (b) – Model improved. Still considered unreliable.
- 2011 SARC 53- Not accepted for management. Date deficiencies and spatial issues.
- 2013 SSC – Data update
- 2014 SSC – Data update
- 2015 SSC – Data update

Table A4 . Summary of black sea bass survey indices used in overall and regional models.

Index Name	Assessed Area	Season	Location	Years	Fishery Independent	Type	Age Range	Filter Method	Derivation Method	Data	Spatial Range	Rank
NEFSC Winter Bottom Trawl Survey	S	Feb-Mar	Offshore	1992-2007	Yes	Absolute	1-8+	Strata subset	Stratified mean	Len,Wt & Age	Wide	3
NEFSC Spring Bottom Trawl Survey ALBATROSS	N + S	Mar-May	Offshore	1989-2008	Yes	Absolute	1-8+	Strata subset	Stratified mean	Len,Wt & Age	Wide	2
NEFSC Spring Bottom Trawl Survey BIGELOW	N + S	Mar-May	Offshore	2009-2015	Yes	Absolute	1-8+	Strata subset	Stratified mean	Len,Wt & Age	Wide	3
MA Resourse Assessment Trawl Survey	N	May	Inshore	1989-2015	Yes	Relative	1-8+	Strata subset	GLM	Length	Narrow	4
RI Seasonal Bottom Trawl Survey	N	Apr-May	Inshore	1989-2015	Yes	Relative	1-8+	All Strata	GLM	Length	Narrow	4
CT Long Island Sound Trawl Survey	N	May-Jun	Inshore	1989-2015	Yes	Relative	1-8+	All Strata	GLM	Length	Narrow	4
NY Small Mesh Trawl Survey	N	May-Jul	Inshore	1990-2015	Yes	Relative	1	Max length	GLM	Length	Narrow	5
NJ Ocean Trawl Survey	S	Jun	Inshore	1989-2015	Yes	Relative	1-8+	All Strata	GLM	Length	Medium	4
DE 16ft Trawl Survey	S	Apr-Jun	Inshore	1989-2015	Yes	Relative	1	Max length	Stratified mean	Length	Narrow	5
MD Coastal Bays 16ft Trawl Survey	S	May-Jun	Inshore	1989-2015	Yes	Relative	1	Max length	Stratified mean	Length	Narrow	5
VIMS Juvenile Fish and Blue Crab Trawl Survey	S	May-Jul	Inshore	1989-2015	Yes	Relative	1	Max length	Stratified mean	Length	Narrow	5
NEAMAP Ocean Trawl Survey	N + S	Apr-May	Coastal	2008-2015	Yes	Relative	1-8+ (N), 1 (S)	All Strata	Stratified mean	Len,Wt & Age	Medium	3
Recreational CPUE	N + S	Mar-Dec	Coastal	1989-2015	No	Relative	1-8+	Multi-Species effort	GLM	Length	Wide	1

Ranked by
Area coverage
Time series length
Ages represented

Table A5. Regional guild species used for calculation of black sea bass effort, based on Jaccard similarity.

Region	Species	*J* value
North	Black sea bass	1
	Scup	0.216
	Summer flounder	0.0826
	Sea robins	0.0749
	Tautog	0.0615
South	Black sea bass	1
	Summer flounder	0.1164
	Sea robins	0.0931
	Atlantic croaker	0.0864
	Weakfish	0.0636
	Tautog	0.0634
	Oyster toadfish	0.0597
	Bluefish	0.0572
	Spot	0.0538
	Scup	0.05
Coast	Black sea bass	1
	Scup	0.1294
	Summer flounder	0.1047
	Sea robins	0.0852
	Atlantic croaker	0.0702
	Tautog	0.064

Table A6. Time series of recreational effort by region. Effort is calculated as the number of intercepted trips with that caught one or more guild species.

Year	North	South	Coast
1989	3491	5668	6585
1990	4168	5200	7272
1991	4626	6294	9069
1992	4563	5551	8621
1993	3989	4212	7313
1994	3323	6122	8016
1995	1788	5000	5599
1996	2446	5002	6135
1997	2550	6227	6998
1998	2711	6551	7649
1999	2879	6025	7453
2000	3297	6433	8055
2001	3935	9233	11070
2002	3800	7912	9738
2003	5089	8822	11740
2004	3580	8123	9799
2005	3308	7952	9463
2006	3471	5890	7688
2007	3557	7846	9428
2008	3169	7922	9338
2009	2551	7031	8132
2010	3060	7093	8470
2011	2667	5642	6942
2012	3316	4799	6834
2013	4226	7238	9712
2014	4261	7188	9345
2015	5442	6417	10046

Table A7. Final models used to fit regional recreational black sea bass fishery indices of abundance.

	Positive	**Binary**
North (MA-NY)	lnCPUE ~ YEAR+AREA+ WAVE+STATE+HRSF	success ~ YEAR+AREA+ WAVE+STATE+MODE
South (NJ-VA)	lnCPUE ~ YEAR+AREA+ WAVE+HRSF	success ~ YEAR+AREA+ WAVE+MODE
Coast (MA-VA)	lnCPUE ~ YEAR+AREA+ WAVE+STATE+HRSF	success ~ YEAR+AREA+ WAVE+STATE+MODE

Table A8. Commercial black sea bass landings (mt) by state.

Year	State ME	NH	MA	RI	CT	NY	NJ	PA	DE	MD	VA	NC	Total
1989	1.8	0.0	157.4	94.4	0.0	40.6	381.3	0.0	0.0	134.2	294.7	0.0	1104.5
1990	0.9	0.0	193.6	98.7	0.0	34.3	449.1	0.0	0.0	223.3	401.7	0.0	1401.6
1991	0.0	0.0	109.2	35.3	0.0	45.7	469.1	0.0	85.9	218.2	226.3	0.0	1189.6
1992	0.0	0.0	19.6	64.0	0.0	52.8	564.7	0.0	0.0	300.2	263.1	0.0	1264.3
1993	0.0	0.0	16.5	102.5	0.0	58.5	626.2	0.0	0.0	202.9	346.0	0.0	1352.6
1994	0.0	0.0	7.8	42.4	0.0	55.4	433.4	0.0	0.0	132.4	176.9	0.0	848.4
1995	0.0	0.0	14.6	54.4	5.2	76.3	365.1	0.0	0.0	213.8	159.8	0.0	889.1
1996	0.0	0.0	17.2	71.9	7.6	117.6	551.7	0.0	75.4	248.7	358.2	0.0	1448.4
1997	0.0	0.0	39.5	83.5	6.5	116.7	320.0	0.0	69.2	222.8	239.1	99.6	1197.0
1998	0.0	0.0	125.7	61.6	4.0	62.3	263.9	0.0	40.3	144.6	368.9	80.3	1151.9
1999	0.0	0.0	250.6	83.0	11.6	95.0	227.3	0.0	51.6	199.4	335.6	36.3	1290.3
2000	0.0	0.0	241.0	59.1	32.7	66.6	301.8	0.0	42.6	136.8	259.7	45.8	1186.2
2001	0.2	0.0	232.5	170.0	31.4	117.1	317.6	0.0	11.5	70.0	274.0	54.5	1278.8
2002	0.0	0.0	395.6	155.3	33.3	151.1	310.1	0.0	10.9	90.2	352.6	64.6	1563.7
2003	0.0	0.0	188.1	166.1	10.1	104.4	323.6	3.3	43.6	143.8	208.2	156.1	1347.3
2004	0.0	0.2	130.3	199.4	14.0	143.3	331.7	5.1	24.4	151.1	223.3	182.7	1405.4
2005	0.0	0.0	231.3	128.9	11.4	111.9	201.9	0.0	33.8	185.0	223.9	168.6	1296.7
2006	0.0	0.0	228.2	154.1	10.8	147.9	224.6	0.0	40.1	159.2	147.6	172.9	1285.4
2007	0.0	0.0	144.1	146.7	9.3	189.4	220.2	0.0	29.5	100.7	94.6	102.2	1036.9
2008	0.0	0.0	98.6	83.7	18.2	144.9	192.9	0.0	23.2	96.0	119.3	98.2	875.1
2009	0.0	0.0	46.6	57.0	10.9	75.1	91.7	0.0	20.3	61.7	79.1	80.9	523.2
2010	0.0	0.0	62.0	109.0	44.0	113.1	136.5	0.0	34.8	70.3	134.2	47.4	751.4
2011	0.0	0.0	76.9	84.0	46.1	111.7	131.6	0.0	37.2	85.2	141.6	50.6	765.0
2012	0.0	0.0	41.5	80.2	75.5	105.7	138.1	0.0	37.9	66.9	196.5	39.9	782.1
2013	0.0	0.0	73.9	106.8	46.9	134.9	194.9	0.0	48.7	96.0	253.5	71.5	1027.0
2014	0.0	0.0	62.0	101.1	50.4	161.1	226.9	0.0	46.8	113.7	187.8	138.0	1087.8
2015	0.0	0.0	157.1	72.2	22.2	68.4	249.2	0.0	55.9	131.7	203.1	153.8	1113.4

Table A9. Commercial black sea bass landings (mt) by statistical area.

year	Stat area 511-534	537	538	539	541-600	611	612	613	614	615	616	621	622	623-624	625	626	627-629	631	632	633-634	635	636-639	Grand Tota
1989	5.8	42.3	162.4	25.3	0.0	15.5	9.2	14.1	8.6	2.1	40.4	239.5	183.8	0.0	11.8	210.5	0.0	25.4	107.2	0.0	0.7	0.0	1104.5
1990	6.0	53.2	201.7	17.9	0.0	9.0	12.6	8.5	16.8	3.6	39.2	367.7	193.6	3.2	54.1	289.6	0.0	33.4	91.0	0.0	0.4	0.0	1401.6
1991	1.2	24.8	109.7	10.4	0.0	12.0	24.4	13.0	44.3	5.5	39.4	576.0	69.9	0.8	53.7	114.0	0.0	51.0	38.8	0.0	0.4	0.0	1189.6
1992	2.5	25.5	19.7	17.4	0.0	18.4	25.6	13.8	40.3	4.4	111.5	532.0	100.8	0.0	73.3	192.7	0.0	67.7	17.7	0.0	1.1	0.0	1264.3
1993	2.3	17.7	15.9	29.0	0.0	8.9	31.3	21.8	33.2	2.4	65.2	400.1	287.6	2.9	45.7	338.1	0.3	30.2	19.1	0.0	0.7	0.0	1352.6
1994	5.4	14.0	7.0	15.4	0.3	11.6	20.1	20.7	34.4	5.0	48.3	274.4	103.5	9.0	32.9	195.6	2.6	37.5	8.6	0.1	1.0	0.9	848.4
1995	9.3	18.6	14.2	22.4	0.0	9.6	30.1	29.3	47.0	12.8	47.4	327.6	63.5	9.7	30.0	109.0	15.1	60.1	22.5	0.0	0.0	10.9	889.1
1996	6.6	30.3	17.6	28.2	73.8	19.2	37.6	43.9	45.0	19.8	96.9	298.3	250.8	6.0	89.8	218.5	0.4	83.6	80.4	0.3	1.4	0.0	1448.4
1997	3.5	34.9	40.5	25.2	65.6	24.0	19.3	54.3	34.9	11.7	85.8	289.8	49.3	2.6	69.1	149.6	0.0	81.5	55.0	0.0	100.2	0.0	1197.0
1998	14.5	29.4	114.0	30.2	0.0	13.4	6.3	26.5	31.0	5.8	35.4	225.2	80.4	0.7	111.0	129.8	0.3	63.3	149.6	0.2	82.4	2.4	1151.9
1999	11.3	53.0	243.7	37.0	0.1	23.6	10.7	43.3	33.6	9.3	38.0	283.2	71.5	1.3	81.8	163.9	0.3	88.6	55.6	1.2	35.9	3.3	1290.3
2000	4.3	31.5	228.0	39.6	0.4	43.9	9.4	39.0	29.0	15.9	33.1	186.8	77.7	2.5	63.1	196.8	3.0	84.6	56.3	0.0	41.2	0.2	1186.2
2001	8.7	49.2	226.6	61.8	0.1	50.6	11.2	57.4	30.9	15.1	131.2	79.3	178.1	22.0	60.1	115.3	5.7	58.6	56.5	0.9	59.4	0.1	1278.8
2002	15.9	88.7	355.6	63.7	2.9	58.9	32.9	68.6	50.8	30.8	94.2	104.2	229.1	7.7	74.6	92.5	0.4	89.0	47.3	2.5	53.2	0.0	1563.7
2003	6.1	27.9	178.2	119.0	0.8	63.8	20.2	41.6	44.7	38.2	49.7	219.0	157.6	14.4	68.0	121.5	0.4	35.6	49.0	0.0	91.8	0.0	1347.3
2004	11.1	57.1	140.5	73.8	1.5	47.8	61.5	55.2	13.0	40.1	110.0	239.9	238.2	17.7	48.8	80.5	11.4	50.3	34.7	0.0	65.7	6.6	1405.4
2005	13.7	69.9	194.6	55.1	0.2	49.7	22.5	41.7	13.4	13.1	88.8	246.4	235.0	20.1	28.5	117.5	17.9	31.5	12.8	0.0	20.1	4.2	1296.7
2006	17.8	81.0	178.0	50.5	0.4	55.2	27.5	71.6	45.8	39.4	113.1	298.5	126.2	3.7	14.5	54.4	0.5	48.8	28.7	0.0	8.7	21.2	1285.4
2007	11.9	68.9	123.6	61.6	0.6	42.3	34.6	112.2	24.0	42.8	106.5	208.0	65.5	10.7	9.8	56.0	1.8	32.9	15.8	0.0	3.0	4.4	1036.9
2008	32.9	52.5	68.7	31.6	0.8	37.7	21.8	96.4	23.0	39.0	42.2	141.7	89.9	4.1	17.0	133.0	0.0	24.7	17.6	0.0	0.1	0.5	875.1
2009	2.5	30.1	36.4	21.2	0.2	23.9	24.4	49.1	14.3	9.1	40.6	82.4	90.7	1.3	15.0	26.7	0.6	20.4	16.4	0.0	15.9	1.9	523.2
2010	20.0	31.4	74.8	39.6	0.3	65.8	29.9	72.2	23.3	29.1	63.4	83.9	91.4	7.0	6.7	36.5	0.1	13.9	14.6	0.1	47.1	0.0	751.4
2011	7.9	43.6	53.9	39.8	0.4	83.0	18.8	68.9	10.3	38.3	83.0	102.8	110.5	7.1	16.7	34.3	0.3	17.4	21.1	0.0	6.6	0.2	765.0
2012	8.3	41.0	25.8	56.5	0.3	108.4	17.5	84.8	9.4	62.5	114.2	98.5	50.0	4.2	14.3	28.9	0.3	25.0	26.3	0.0	3.5	2.2	782.1
2013	36.4	80.4	49.8	57.4	1.3	78.4	34.6	107.2	11.6	125.9	124.5	101.4	62.1	10.2	21.6	35.5	0.3	42.8	21.1	0.0	19.3	5.0	1027.0
2014	10.2	59.8	42.4	52.4	0.4	83.9	25.5	131.0	13.7	109.5	273.9	87.3	42.5	9.3	19.0	28.1	0.5	62.3	15.2	0.0	15.3	5.5	1087.8
2015	17.9	84.7	91.3	32.6	0.2	48.9	40.3	122.1	13.4	43.8	313.9	120.6	13.4	6.3	28.1	34.9	0.7	57.7	15.2	0.0	25.7	1.8	1113.4

Table A10. Commercial black sea bass landings (kg) by market category from trawl gear in the northern area for January-June.

Period = QTR 1,2
Region = NORTH
Gear = TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	28675	16843	2615	13158	15228	76519
1990	31993	11187	1889	22243	28837	96149
1991	23455	21387	3614	12184	10748	71388
1992	39865	10060	1424	10649	80440	142437
1993	25095	6888	958	19166	35916	88023
1994	22443	16355	2267	14639	19200	74904
1995	14183	14153	3952	13659	25996	71943
1996	25338	24867	7235	24469	60336	142245
1997	15727	20409	5668	32282	52504	126590
1998	10718	13086	4511	14572	14265	57153
1999	18046	21245	5300	32387	27354	104332
2000	17513	19225	8988	13506	23091	82324
2001	23235	55059	11002	79028	56013	224335
2002	32828	76508	29962	52371	39271	230940
2003	19208	35693	37138	18635	6777	117451
2004	16864	50347	47304	43962	16861	175338
2005	15995	42028	38344	24850	3835	125052
2006	13295	36547	64482	26085	4612	145021
2007	13277	42350	44642	36079	6878	143226
2008	9826	25013	13302	44387	13545	106073
2009	4806	24543	12600	16787	5478	64215
2010	9197	34863	28068	28185	9397	109710
2011	3561	41725	38975	26781	7601	118642
2012	4137	65760	58232	28318	5672	162117
2013	2515	69512	70375	34314	9026	185742
2014	3512	89112	127820	62501	14548	297493
2015	2875	144201	128594	71413	7204	354285

Table A11. Commercial black sea bass landings (kg) by market category from non-trawl gear in the northern area for January-June.

Period = QTR 1,2
Region = NORTH
Gear = NON-TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	40977	39006	3742	16757	254	100735
1990	14561	60892	8987	100025	330	184796
1991	73546	23085	4905	2820	43	104398
1992	14034	5324	2719	556	209	22841
1993	8109	2955	1199	3316	193	15772
1994	16795	7296	876	1948	1587	28502
1995	13921	8101	2573	6420	3480	34494
1996	14967	8468	1577	3145	1295	29451
1997	3968	17115	7556	9140	4967	42746
1998	22309	17577	6511	11962	2475	60833
1999	13569	82579	25576	72089	4337	198151
2000	21497	59956	68466	10768	2168	162855
2001	16869	37322	21291	39018	2033	116533
2002	24886	77985	77735	47373	1876	229855
2003	7650	51805	73897	20039	1019	154411
2004	14894	31986	61037	18601	6437	132955
2005	35408	35588	52978	9085	2125	135183
2006	19939	29875	110783	11842	1791	174230
2007	18320	47816	62619	24695	2768	156217
2008	16736	37765	29146	28159	3117	114922
2009	14935	33949	28058	11364	1064	89369
2010	21377	49585	59496	32408	1427	164292
2011	8490	32951	35370	12686	1569	91067
2012	18164	50168	84517	18438	2301	173588
2013	6405	17636	24244	10059	1838	60182
2014	4339	12832	23063	12877	3689	56800
2015	2044	18415	17473	9310	357	47599

Table A12. Commercial black sea bass landings (kg) by market category from trawl gear in the southern area for January-June.

Period = QTR 1,2
Region = SOUTH
Gear = TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	5387	95133	16086	110267	188775	415647
1990	427	93940	11582	166844	216572	489364
1991	568	43733	7602	54017	69721	175641
1992	618	49306	8186	68824	116077	243011
1993	24770	86183	15274	139992	337853	604071
1994	3984	44096	4194	89568	178520	320362
1995	3409	38983	6077	70474	62572	181515
1996	3036	86229	16495	116683	255777	478219
1997	12108	27728	6742	59246	83684	189507
1998	1050	73864	10067	138553	108068	331601
1999	1330	69687	10919	94119	62228	238284
2000	1059	123069	28741	69245	39544	261658
2001	398	111704	25777	152740	57878	348497
2002	1016	165608	76966	122384	9970	375944
2003	2237	136516	80817	92408	13511	325490
2004	59360	130764	105078	78557	4226	377985
2005	10163	134853	134339	61979	2664	343998
2006	6707	51994	76854	53469	3886	192910
2007	121	47755	30916	33097	386	112275
2008	502	72202	27140	95381	2319	197543
2009	79	55257	34594	23288	973	114191
2010	9	58825	44542	38768	948	143092
2011	4364	67844	45344	27324	327	145202
2012	220	43649	31571	17448	103	92990
2013	122	58143	68872	20806	290	148232
2014		34672	51044	17566	112	103395
2015	26	22820	16655	9647	7	49155

Table A13. Commercial black sea bass landings (kg) by market category from non-trawl gear in the southern area for January-June.

Period = QTR 1,2
Region = SOUTH
Gear = NON-TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	4758	17378	12682	28920	90512	154250
1990	1982	24348	11027	39003	108214	184574
1991	12466	33706	7270	52190	156297	261929
1992	23591	29240	10277	54646	170133	287886
1993	45299	18667	6938	28454	98301	197659
1994	2211	18959	5678	42641	83444	152933
1995	8525	37192	9628	58593	66004	179943
1996	33732	42989	13921	61578	134524	286743
1997	37878	50001	31986	73296	120852	314013
1998	9539	49888	43692	66997	74984	245100
1999	16739	46857	40197	57898	62409	224100
2000	15895	76314	81692	63963	67868	305730
2001	6474	51110	76697	43812	34885	212976
2002	5562	46488	85331	67241	28124	232746
2003	750	58535	60322	102838	21961	244406
2004	2697	50605	43819	57750	19734	174604
2005	17590	41949	27485	76879	13896	177800
2006	956	44836	21196	107307	15824	190119
2007	4101	39411	21235	53864	14629	133240
2008	11655	23333	13851	48486	13456	110780
2009	9398	12551	8431	47742	14637	92759
2010	7334	13572	12431	40766	8482	82585
2011	3728	15035	9187	39667	7908	75527
2012	2942	19911	17795	61425	9554	111627
2013	449	23799	17077	46510	13222	101056
2014	8668	31564	17409	52852	13267	123759
2015	5824	31483	18785	57178	11157	124427

Table A14. Commercial black sea bass landings (kg) by market category from trawl gear in the northern area for July-December.

Period = QTR 3,4
Region = NORTH
Gear = TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	31837	8327	1542	12015	9925	63645
1990	19995	7902	2897	3120	1543	35457
1991	18704	2311	1030	515	3109	25669
1992	21365	2075	706	4334	5521	34001
1993	13656	8472	2295	6678	1266	32366
1994	4422	2103	1154	1776	1034	10489
1995	8349	6680	1520	4958	8247	29753
1996	13012	9710	3561	14536	9204	50024
1997	8473	21576	6739	14545	7147	58481
1998	4868	10106	2474	13656	8307	39410
1999	3539	15938	9174	5975	1978	36604
2000	1601	2351	1098	1720	1622	8391
2001	4489	6233	5493	3622	1560	21397
2002	12754	14922	11502	4702	1081	44961
2003	13130	16089	25211	10401	2328	67158
2004	13569	26363	30154	16522	3522	90130
2005	7409	14998	51921	3731	1048	79108
2006	5143	13357	34230	10016	3620	66366
2007	10753	11809	21229	11249	4869	59908
2008	2395	11525	10233	3786	1579	29519
2009	2330	5553	9729	3081	1808	22501
2010	3009	7081	13126	3856	1203	28274
2011	3476	15867	20985	8569	1379	50276
2012	1621	14095	25331	6843	1644	49534
2013	2393	28593	46541	12932	2779	93237
2014	3300	33283	39559	16765	2797	95704
2015	2502	64011	55270	9507	354	131643

Table A15. Commercial black sea bass landings (kg) by market category from non-trawl gear in the northern area for July-December.

Period = QTR 3,4
Region = NORTH
Gear = NON-TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	58976	5652	821	7945	613	74006
1990	10818	9817	1702	8906	587	31829
1991	25875	3995	661	2619	507	33658
1992	30156	1396	1365	888	1281	35086
1993	32204	15275	294	6959	1338	56069
1994	15720	3330	950	1975	6961	28935
1995	7408	12701	3235	12702	8639	44685
1996	31637	7237	2522	9601	7595	58593
1997	13118	18632	5715	15115	7158	59736
1998	33702	31199	6659	32237	8574	112372
1999	8238	52410	22704	31590	6729	121669
2000	24563	50739	15532	69572	15199	175604
2001	27675	91976	26427	72119	16273	234470
2002	32137	111361	54513	72834	4871	275716
2003	9957	58356	50252	32872	16729	168167
2004	15673	47006	39583	47049	10757	160067
2005	23996	71914	86556	13466	1038	196969
2006	23556	56651	75076	46493	7703	209479
2007	24991	67499	33561	54191	22616	202858
2008	18641	47841	24993	32481	10023	133980
2009	4438	17388	11212	14530	4835	52403
2010	5709	31212	26940	28195	3103	95157
2011	8977	53890	34426	38396	3521	139210
2012	5344	20581	29629	14675	1450	71679
2013	16770	81610	75249	52097	5147	230873
2014	22797	72582	69026	55785	9382	229572
2015	27193	90035	69433	31365	313	218339

Table A16. Commercial black sea bass landings (kg) by market category from trawl gear in the southern area for July-December.

Period = QTR 3,4
Region = SOUTH
Gear = TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	534	3779	552	2780	6588	14233
1990	156	1718	165	1404	2060	5503
1991	265	4701	723	3655	7315	16658
1992	143	7596	1126	8929	21357	39150
1993	219	1921	164	2695	4988	9987
1994	444	4993	888	6609	2060	14995
1995	145	3896	1423	1964	2910	10338
1996	632	4590	1329	8265	18374	33191
1997	222	1198	230	1206	1836	4692
1998	521	1879	793	1533	889	5616
1999	67	1899	1092	916	587	4561
2000	13	362	164	419	285	1243
2001	40	162	109	39	134	485
2002		734	322	442	241	1739
2003	26	20419	24037	4653	58	49194
2004	2001	15612	52285	4674	43	74615
2005	158	5153	12734	456	31	18532
2006	1012	2365	18116	706	74	22273
2007	15	3350	2275	1516	16	7171
2008		7261	10548	948	3	18760
2009		1067	5578	371	16	7031
2010	6	7020	9897	553	8	17483
2011	4	7100	13426	453	8	20990
2012	79	6442	9009	1251	7	16788
2013		30462	30763	7274	60	68559
2014		24402	30158	6029	11	60600
2015		11256	8189	1493		20938

Table A17. Commercial black sea bass landings (kg) by market category from non-trawl gear in the southern area for July-December.

Period = QTR 3,4
Region = SOUTH
Gear = NON-TRAWL

	LANDINGS (KG)					
Year	Unclassified	Large	Jumbo	Medium	Small	Total
1989	13576	23608	2812	42813	122679	205487
1990	104753	33603	4866	65804	164894	373919
1991	110251	33797	6570	73331	276277	500227
1992	137809	28704	3238	58883	231287	459921
1993	80972	20256	4846	43274	199324	348672
1994	6803	20480	3967	47073	138910	217232
1995	16932	48725	7509	78413	184834	336413
1996	54550	35356	11108	61183	207687	369884
1997	46242	47974	18387	89718	198881	401201
1998	35020	46450	16276	74573	127482	299802
1999	58411	68761	22878	88342	124214	362606
2000	10660	35625	14778	50231	77067	188361
2001	4126	20791	15608	29273	50312	120110
2002	10874	32276	26581	77074	24946	171752
2003	660	55353	24150	124153	16735	221051
2004	3349	49117	20394	110222	36621	219703
2005	13079	29373	14925	138438	24273	220087
2006	20133	58542	17655	140089	48617	285035
2007	18755	54919	17096	106892	24327	221989
2008	14851	24879	14276	81075	28434	163514
2009	5433	9187	6110	47124	12860	80713
2010	7975	12265	6115	72816	11610	110781
2011	13724	16382	6769	78088	9103	124067
2012	4002	22357	11518	54271	11598	103745
2013	2257	30325	12043	80077	14392	139093
2014	4799	22901	7683	71498	13619	120499
2015	49409	28039	10152	66253	13207	167061

Table A18. Summary of black sea bass commercial length measurements by half year and market category, 1989-2015.

Qtr 1,2 year	# lengths Unclassified	Small	Medium	Large	Jumbo
1989	202	1767	1341	864	132
1990	181	3269	2537	1934	260
1991	226	568	452	172	
1992	33	993	827	614	90
1993	76	1927	1816	920	74
1994	188	1471	1150	387	2
1995	482	562	906	551	98
1996	24	1077	984	624	107
1997	384	1485	1432	830	
1998		1217	1559	661	152
1999	221	1157	1268	288	103
2000	2	954	1127	802	295
2001	188	1040	1580	932	50
2002	128	474	1359	1423	739
2003	250	1086	2900	2890	2288
2004	63	219	3387	2661	2010
2005	133	318	2991	3208	2348
2006	445	132	2704	2731	2163
2007	174	334	3186	2707	1107
2008	271	767	4196	3626	1752
2009	156	583	2727	2635	1444
2010	57	440	3623	2501	1861
2011	76	260	2880	2603	1305
2012	193	743	1993	1173	715
2013	320	471	1520	1276	904
2014	282	458	2664	2107	1081
2015		400	1124	900	236

Qtr 3,4 year	# lengths Unclassified	Small	Medium	Large	Jumbo
1989	38	84	39	48	26
1990	168	328	150	10	
1991	117	130	12	105	67
1992	37	280	142	31	
1993		56		37	
1994		67	39	42	3
1995		476	215	151	
1996	495	1099	408	491	10
1997		355	325	150	17
1998	69	671	362	18	16
1999		752	612	275	37
2000	4	621	185		
2001		500	309	127	
2002		303	417	367	269
2003	50	99	520	564	368
2004	219	109	409	212	228
2005	67	9	853	444	422
2006	181	250	1639	657	346
2007	332	299	1548	750	435
2008	317	807	992	403	497
2009	183	442	657	307	313
2010		302	302	274	469
2011	9	227	1225	879	440
2012	338	578	1375	964	414
2013	204	227	1030	1018	908
2014	201	328	848	1108	350
2015		256	402	537	83

Table A19. Summary of black sea bass commercial length sample intensity (mt per 100 lengths measured) by market category from January to June, 1989-2015.

	MT/100 lengths Qtr 1,2				
year	Unclassified	Small	Medium	Large	Jumbo
1989	40	17	13	19	27
1990	27	11	13	10	13
1991	49	42	27	71	0
1992	237	37	16	15	25
1993	136	25	11	12	33
1994	24	19	13	22	0
1995	8	28	16	18	23
1996	321	42	21	26	37
1997	18	18	12	14	0
1998	0	16	15	23	43
1999	22	14	20	77	80
2000	0	14	14	35	64
2001	25	15	20	27	270
2002	50	17	21	26	37
2003	12	4	8	10	11
2004	149	22	6	10	13
2005	60	7	6	8	11
2006	9	20	7	6	13
2007	21	7	5	7	14
2008	14	4	5	4	5
2009	19	4	4	5	6
2010	67	5	4	6	8
2011	27	7	4	6	10
2012	13	2	6	15	27
2013	3	5	7	13	20
2014	6	7	5	8	20
2015	0	5	13	24	77

Table A20. Summary of black sea bass commercial length sample intensity (mt per 100 lengths measured) by market category from July to December, 1989-2015.

	MT/100 lengths Qtr 3,4				
year	Unclassified	Small	Medium	Large	Jumbo
1989	276	166	168	86	22
1990	81	52	53	530	0
1991	133	221	668	43	13
1992	512	93	51	128	0
1993	0	369	0	124	0
1994	0	222	147	74	0
1995	0	43	46	48	0
1996	20	22	23	12	185
1997	0	61	37	60	183
1998	107	22	34	498	164
1999	0	18	21	51	151
2000	0	15	66	0	0
2001	0	14	34	94	0
2002	0	10	37	43	35
2003	48	36	33	27	34
2004	16	47	44	65	62
2005	67	293	18	27	39
2006	28	24	12	20	42
2007	16	17	11	18	17
2008	11	5	12	23	12
2009	7	4	10	11	10
2010	0	5	35	21	12
2011	0	6	10	11	17
2012	3	3	6	7	18
2013	10	10	15	17	18
2014	15	8	18	14	42
2015	0	5	27	36	172

Table A21. Annual black sea bass commercial discard estimates (mt) by region from otter trawl gear, 1989-2015

	Otter Trawl Discards			
	NORTH		SOUTH	
Year	MT	CV	MT	CV
1989	21.5	0.64	61.4	0.40
1990	7.5	0.40	51.3	0.40
1991	2.0	0.64	20.6	0.27
1992	12.7	0.71	84.4	0.42
1993	13.9	0.69	219.7	1.00
1994	5.7	0.68	36.7	0.55
1995	16.3	0.38	21.6	0.65
1996	39.5	0.44	607.2	0.62
1997	75.1	0.51	11.8	1.67
1998	13.1	0.86	150.8	0.43
1999	11.8	0.32	23.9	0.32
2000	13.3	0.65	33.1	0.28
2001	56.4	0.65	144.1	0.32
2002	25.0	1.39	12.0	0.31
2003	67.7	0.59	50.1	0.45
2004	40.2	0.44	375.7	0.25
2005	8.3	0.38	27.3	0.26
2006	12.6	0.44	11.2	0.50
2007	127.8	0.44	29.2	0.51
2008	26.6	0.49	32.8	0.31
2009	70.9	0.48	133.7	0.40
2010	40.6	0.28	96.5	0.17
2011	58.0	0.40	92.3	0.17
2012	43.5	0.43	54.0	0.17
2013	80.7	0.34	119.3	0.19
2014	260.2	0.20	146.0	0.14
2015	128.9	0.31	186.1	0.12

Table A22. Estimated black sea bass commercial discards (mt) by region, gear and season.

	North Total (mt)				South Total (mt)			
	Trawl		Non-trawl		Trawl		Non-trawl	
	1st half	2nd half	1st half	2nd half	1st half	2nd half	1st half	2nd half
1989	18.9	2.6	0.2	0.1	31.2	30.2	0.4	0.4
1990	5.6	1.9	0.1	0.0	23.0	28.2	0.3	0.4
1991	1.4	0.6	0.0	0.0	10.3	10.3	1.1	1.1
1992	9.4	3.4	0.1	0.1	41.4	43.0	0.5	0.6
1993	10.7	3.2	0.1	0.1	92.4	127.3	1.1	1.6
1994	4.5	1.3	0.4	0.1	15.9	20.8	1.2	0.5
1995	11.4	4.9	0.2	0.2	9.6	12.0	0.4	1.5
1996	32.9	6.6	0.1	0.3	278.2	329.0	1.1	1.3
1997	55.7	19.4	0.1	0.3	4.9	7.0	0.7	2.0
1998	7.9	5.2	0.6	1.9	72.2	78.6	2.5	6.8
1999	7.0	4.8	4.3	2.7	11.0	12.9	2.5	5.3
2000	7.4	6.0	5.8	5.1	15.8	17.3	3.1	4.7
2001	33.5	22.9	4.8	12.0	71.5	72.7	3.0	4.1
2002	11.1	13.9	5.2	10.8	5.7	6.4	2.5	3.5
2003	52.0	15.7	1.6	5.8	25.5	24.6	5.0	3.3
2004	24.6	15.6	1.5	2.3	175.4	200.3	2.1	3.9
2005	5.8	2.5	0.5	1.2	12.6	14.7	1.7	2.9
2006	8.9	3.7	1.1	1.4	5.7	5.5	1.8	2.2
2007	106.4	21.4	1.2	1.6	12.7	16.5	0.9	2.9
2008	12.5	14.0	0.7	2.2	14.0	18.8	1.3	2.3
2009	47.1	23.8	1.0	1.0	62.0	71.7	1.1	1.7
2010	21.7	18.9	0.8	2.2	52.4	44.1	0.8	1.4
2011	42.5	15.5	2.6	2.5	44.9	47.4	0.7	1.3
2012	28.7	14.8	2.8	1.5	29.6	24.5	0.9	0.7
2013	32.7	48.1	0.2	8.6	57.1	62.2	1.0	1.5
2014	192.4	67.7	0.3	6.4	70.9	75.1	1.1	1.6
2015	120.5	8.4	0.4	16.7	73.7	112.4	1.4	1.5

Table A22a. Number of black sea bass commercial discard lengths by gear, area and season, 1989-2015.

	Trawl North 1st half	Non-Trawl North 1st half	Trawl North 2nd half	Non-Trawl North 2nd half	Trawl South 1st half	Non-Trawl South 1st half	Trawl South 2nd half	Non-Trawl South 2nd half
1989	96				345			
1990					8			
1991					6			
1992								
1993								
1994			4	4			20	20
1995	8	8	9	9	7	5	70	70
1996	51	51	35	35	379	6	38	4
1997	198	199	62	62	40	42	62	62
1998	61	61	61	61	393	394	3	61
1999	12	12	33	33	12	12	12	33
2000	23	26	92	92	54	54	5	92
2001	102	102	38	38	27	27	53	53
2002	3	3	87	87	49	54	8	8
2003	129	129	124	44	635	53	37	37
2004	609	614	236	236	1107	190	54	54
2005	149	149	58	11	596	603	11	11
2006	148	148	94	9	277	277	32	32
2007	488	109	52	143	198	12	4	4
2008	102	47	620	190	794	22	18	18
2009	581	584	166	18	605	40	17	17
2010	1079	8	473	473	627	75	8	8
2011	635	31	144	144	716	136	8	8
2012	717	9	653	653	196	54	65	65
2013	1264	30	463	18	600	223	136	1
2014	2153	229	621	207	355	119	215	215
2015	1738	64	1581	960	137	98	540	540

Table A22b. Data source for black sea bass commercial length substitutions by gear, area and season, 1989-2015.

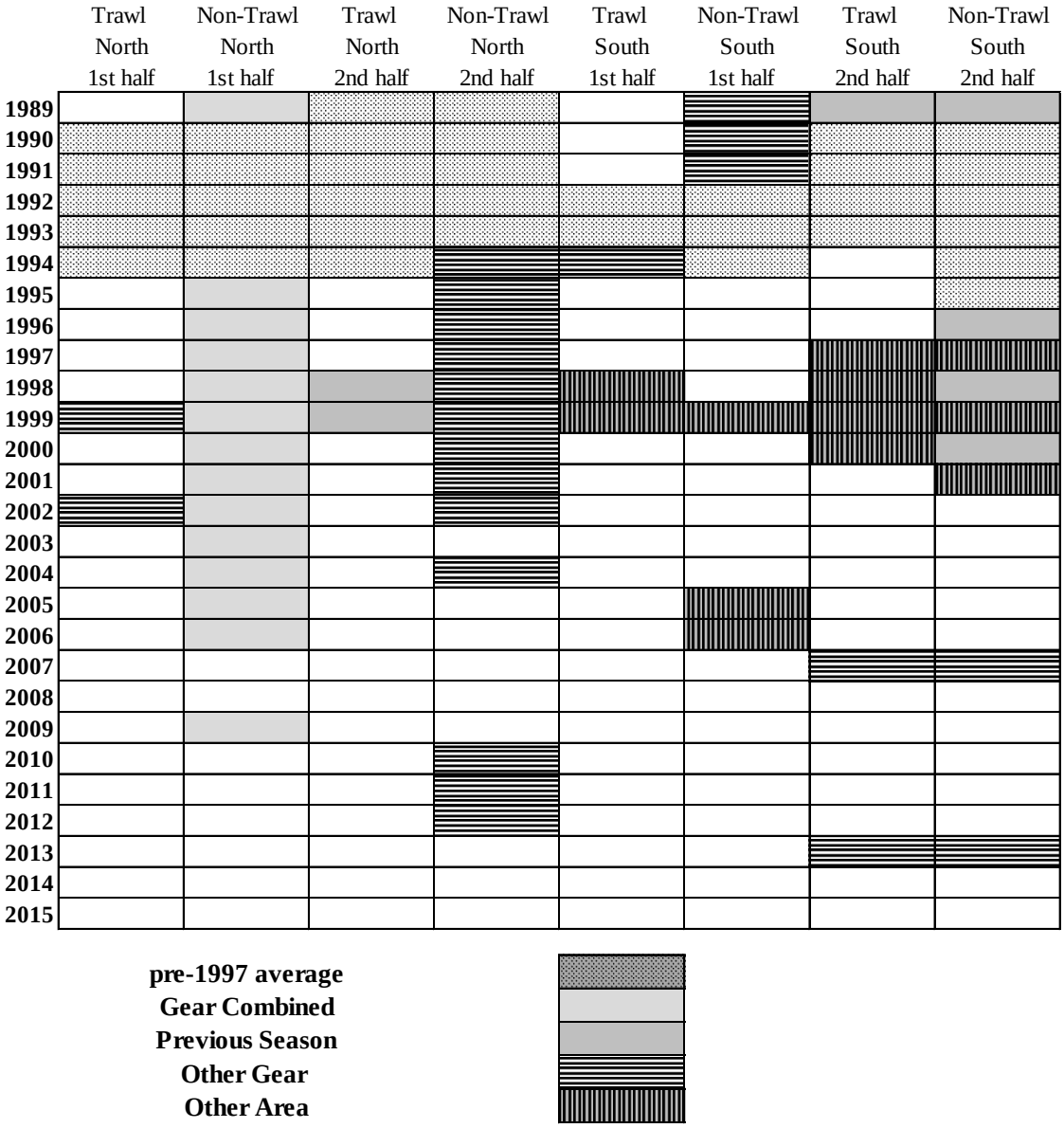

Table A23. Recreational black sea bass landings (AB1) number (000s) (note: does not include offshore wave 1 landings).

AB1 #	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC
1989	0.0	0.0	3.6	2.0	2.8	65.8	220.8	20.6	40.9	65.5	0.0
1990	0.0	0.0	3.1	0.8	0.1	35.7	150.5	11.3	49.4	134.4	2.8
1991	0.0	0.0	2.5	1.0	0.2	19.8	248.6	39.2	64.1	144.6	2.4
1992	0.0	0.0	0.6	1.2	0.8	16.4	157.9	19.6	75.8	78.3	2.2
1993	0.0	0.0	1.1	2.6	1.0	21.9	421.1	23.7	59.3	67.2	1.2
1994	0.0	0.0	0.7	1.7	0.0	21.8	191.3	6.7	27.3	91.3	1.3
1995	0.0	0.0	0.8	4.2	0.5	9.0	395.2	20.9	149.8	91.9	1.3
1996	0.0	0.0	1.7	4.3	0.5	7.9	232.0	5.9	28.7	79.9	0.9
1997	0.0	0.0	1.6	3.5	0.2	21.7	335.2	9.1	37.2	63.5	1.6
1998	0.0	0.0	0.7	2.6	0.3	1.2	27.3	5.2	35.4	39.8	2.0
1999	0.0	0.0	2.1	2.5	0.2	8.9	44.9	4.1	15.9	53.6	3.2
2000	0.0	0.0	6.6	19.7	1.5	33.5	196.1	15.1	43.3	44.8	3.6
2001	0.0	0.3	5.9	12.3	0.9	16.4	191.8	20.3	11.9	23.1	1.3
2002	0.0	0.0	18.4	7.8	1.8	22.1	175.9	60.7	33.7	13.2	3.4
2003	0.0	0.0	11.7	7.0	0.5	31.7	190.3	30.7	24.1	26.5	3.4
2004	0.0	0.0	15.8	2.7	2.6	13.3	107.8	4.4	1.6	4.6	0.7
2005	0.0	0.0	17.5	8.5	0.0	14.3	66.0	6.8	9.1	3.4	1.4
2006	0.0	0.0	10.5	4.1	0.3	26.8	53.1	11.4	12.1	8.3	1.8
2007	0.0	0.0	14.9	4.4	2.4	41.0	72.4	9.3	3.9	3.6	0.7
2008	0.0	0.0	24.6	5.2	6.0	25.9	57.9	2.3	2.6	3.8	1.7
2009	0.0	0.0	43.1	3.6	0.0	56.6	58.3	3.7	3.3	11.5	1.1
2010	0.0	0.0	70.2	16.0	1.6	54.3	68.7	2.1	3.6	3.0	1.1
2011	0.0	0.0	19.5	5.0	0.8	27.4	14.8	4.3	4.7	1.9	3.1
2012	0.0	0.3	52.0	10.3	11.1	32.1	73.5	4.0	3.3	0.4	0.4
2013	0.0	1.2	29.2	7.5	10.8	35.3	34.5	3.7	3.0	2.1	0.8
2014	0.0	0.0	45.7	21.4	40.7	42.3	46.8	2.4	6.8	1.4	0.1
2015	0.0	0.0	34.2	23.4	33.1	87.6	31.0	2.3	5.8	3.9	0.2

Table A24. Recreational black sea bass landings (AB1) and discard losses (B2*0.15) number and total weight, by region.

	AB1 # (000s) North	AB1 # (000s) South	AB1 # (000s) Total	Total AB1 wt (MT)	B2 # (000s) North	B2 # (000s) South	B2 # (000s) Total	Total B2 loss wt (MT)
1989	742.0	3479.0	4221.1	1193.0	36.1	283.2	319.3	45.9
1990	396.8	3484.2	3881.1	1159.5	11.2	777.2	788.3	124.5
1991	233.9	4990.2	5224.1	1621.7	42.2	799.4	841.5	108.9
1992	189.7	3339.5	3529.2	1133.3	19.1	626.5	645.7	96.3
1993	265.8	5727.8	5993.6	1735.5	7.4	476.0	483.4	69.5
1994	241.6	3179.9	3421.5	1128.4	50.3	545.2	595.5	116.8
1995	145.4	6594.3	6739.7	2119.4	61.4	1072.0	1133.4	233.9
1996	144.4	3478.7	3623.1	1541.2	65.0	617.8	682.9	155.1
1997	270.5	4476.8	4747.4	1730.5	90.9	811.4	902.3	161.5
1998	52.7	1100.7	1153.4	473.4	24.4	560.9	585.3	178.7
1999	142.3	1223.7	1366.0	729.3	158.0	705.1	863.1	261.0
2000	615.7	3041.4	3657.0	1702.0	297.8	1684.9	1982.7	540.9
2001	360.2	2508.7	2868.9	1522.1	142.8	1493.6	1636.5	595.4
2002	506.1	2890.4	3396.4	1952.6	333.1	1366.2	1699.2	771.1
2003	515.2	2766.2	3281.4	1890.9	179.8	1152.9	1332.8	401.2
2004	346.8	1205.0	1551.8	871.2	113.7	743.7	857.4	201.1
2005	404.9	883.5	1288.4	845.7	200.3	667.7	868.0	193.1
2006	428.6	892.5	1321.0	801.6	262.6	686.3	949.0	202.6
2007	638.2	924.0	1562.2	947.2	326.5	757.0	1083.4	200.5
2008	626.0	713.0	1339.0	908.6	357.8	1049.2	1407.0	257.0
2009	1049.9	802.2	1852.1	1158.7	340.6	777.7	1118.3	240.6
2010	1421.6	785.1	2206.6	1420.5	361.6	804.3	1165.9	272.6
2011	527.8	288.8	816.6	507.4	231.3	804.0	1035.3	232.2
2012	1059.1	816.0	1875.1	1479.5	805.1	801.7	1606.8	364.4
2013	885.3	467.6	1352.9	1198.5	729.5	576.8	1306.3	296.0
2014	1537.7	580.2	2118.0	1745.1	775.2	538.2	1313.3	382.4
2015	1783.4	431.5	2215.0	1863.6	655.9	426.7	1082.6	371.5

Table A25. Review of discard mortality estimates for hook and line fisheries among species comparable to black sea bass.

Species	Recreational Discard Mortality Estimate	Assessment	Basis
Scup	0.15	60th SAW Assesment Report (2015)	Howell and Simpson 1985
Tautog	0.025	ASMFC 2015 Benchmark Peer Review	Simpson and Gates 1999, CT DEP white paper
Spotted Sea Trout	0.08	State assessments (FL FWC)	Gearhart 2002, Murphy et al 1995, Matlock et al 1993
Weakfish	0.1	ASMFC 2016 Benchmark	Murphy et al 1995, Malchoff and Heins 1997, Swihart et al 2000, Duffy 2002, Gearhart 2002
Black Drum	0.08	ASMFC 2015 Assessment	SEDAR 18 (2009) for Red Drum
Atlantic Croaker	0.1	ASMFC 2010 Benchmark	unsupported
Red Drum	0.08	SEDAR 18 (2009)	Vecchio and Wenner 2008, Gearhart 2002, Aguilar 2003
Bluefish	0.15	60th SAW Assesment Report (2015)	Lit. review (working paper B1)
Vermillion Snapper	0.15	not considered in SEDAR 45 (2016)	Guccione 2005 - shallow depths
Gray Triggerfish	0.05	SEDAR 43 (2015)	
Gray Triggerfish	0.125	SEDAR 41 (2014)	Thorough species specific literature review
Red Grouper (GofMex)	0.116	SEDAR 42 (2015)	FL FWC work: Sauls et al. 2014
Atlantic Striped Bass	0.09	57th SAW (2013)	Diodati and Richards (1996) in addition to broader literature review
Black Grouper	0.2	SEDAR 19 (2010)	lacking empirical data, infered from similar species
Red Grouper (SA)	0.2	SEDAR 19 (2010)	Literature review indicated 0-15%, potentially related to depth of capture
Black Sea Bass	0.07	SEDAR 25 (2011)	Literature review, Rudershausen et al 2010 (4.3% from 29-37m depth)
	0.047		Bugley and Shepherd, 1991 (6-12m depths)
	0.13		Collins et al., 1999 (for depths 20-35m)
	0.036		Rudershausen et al., 2007 (immediate mortality from capture depths averageing 28.5m, ranging from 19.1-71.2m)
	0.043		Rudershausen et al., 2010 (ranged from 0 - 6.9% across 6 trips from 29-37m depth)
	0.19		Rudershausen et al., 2014 (29-34m depth)

Table A26. Recreational black sea bass discard (B2) mortalities (000s) assuming 15% discard mortality (note: does not include offshore wave 1 landings).

	ME	NH	MA	RI	CT	NY	NJ	DE	MD	VA	NC
1989	0	0	3	3	3	28	88	22	66	107	0
1990	0	0	2	1	0	8	92	19	219	433	14
1991	0	0	1	1	6	34	303	41	192	243	20
1992	0	0	0	1	0	17	160	33	164	231	39
1993	0	0	1	1	0	4	143	27	82	188	36
1994	0	0	1	0	0	49	198	31	57	207	53
1995	0	0	2	6	1	51	386	47	275	302	63
1996	0	0	3	12	3	47	211	18	87	290	11
1997	0	0	4	5	3	78	422	41	88	230	31
1998	0	0	6	4	2	12	185	43	113	200	20
1999	0	0	4	18	26	110	259	32	223	186	4
2000	0	0	40	60	13	184	832	123	484	236	10
2001	0	0	21	23	3	96	657	151	349	328	8
2002	0	0	40	36	44	212	649	185	139	367	27
2003	0	0	30	31	8	111	645	125	116	261	6
2004	0	0	12	4	5	94	469	42	39	187	7
2005	0	0	22	10	8	161	359	41	84	168	15
2006	0	0	26	24	13	199	313	49	97	204	23
2007	0	0	60	18	15	233	365	88	87	191	27
2008	0	0	61	19	29	249	666	70	101	188	24
2009	0	0	104	20	31	186	473	44	68	174	18
2010	0	0	140	32	14	175	582	35	101	79	10
2011	0	0	101	58	12	236	344	56	93	117	18
2012	0	1	162	115	152	372	575	31	44	133	21
2013	0	1	213	104	197	210	391	38	54	91	8
2014	0	0	224	131	214	198	343	35	76	86	5
2015	0	0	129	111	73	341	337	23	22	40	7

Table A27. Black sea bass age samples, by region, season and source, available for development of age length keys.

	Commercial				NEFSC Survey			
	NORTH 1	SOUTH 1	NORTH 2	SOUTH 2	NORTH 1	SOUTH 1	NORTH 2	SOUTH 2
1989	25					106	72	72
1990		76			34	97	119	110
1991					18	81	97	97
1992					4	148	56	52
1993					8	59	47	46
1994		70			12	53	45	45
1995	15	113	75	133	18	50	90	89
1996	51	417	179	520	8	59	37	37
1997					22		14	
1998					10	55	100	95
1999					35	61	101	71
2000					68	31	54	
2001					75	89	106	76
2002					69	113	192	117
2003					51	147	63	
2004					45	130	70	39
2005					48	86	99	78
2006					24	53	102	70
2007					82	33	97	69
2008	362	237	237	184	111	47	141	83
2009	229	271	321	22	141	113	208	155
2010	84	270	133	78	192	259	247	251
2011	501	661	355	510	66	133	192	194
2012	538	680	616	646	347	157	297	320
2013	764	446	505	119	214	400	283	306
2014	905	252	575	251	352	125	358	307
2015	659	179	180		49	116	321	236

Table A28. Key to application of black sea bass age length data for expansion of commercial and recreational length frequencies.

					1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
North	Commercial	Landings	Trawl	Spring	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Commercial	Landings	Trawl	Fall	A	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Commercial	Landings	Non-Trawl	Spring	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Commercial	Landings	Non-Trawl	Fall	A	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Commercial	Discards	Trawl	Spring	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Commercial	Discards	Trawl	Fall	A	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Commercial	Discards	Non-Trawl	Spring	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Commercial	Discards	Non-Trawl	Fall	A	A	A	A	A	A	A	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
North	Recreational	Landings		Spring	A	A	A	B	B	B	B	A	A	B	B	B	B	B	B	B	B	B	B	C	C	C	B	C	C	C	C
North	Recreational	Landings		Fall	B	A	A	A	A	A	A	A	A	A	B	B	C	B	B	B	C	C	C	C	B	C	C	C	C	C	C
North	Recreational	Discards		Spring	A	A	A	B	B	B	B	A	A	B	B	B	B	B	B	B	B	B	B	C	C	C	B	C	C	C	C
North	Recreational	Discards		Fall	B	A	A	A	A	A	A	A	A	A	B	B	C	B	B	B	C	C	C	C	B	C	C	C	C	C	C
South	Commercial	Landings	Trawl	Spring	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
South	Commercial	Landings	Trawl	Fall	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	A	E	D	D	D	D	C
South	Commercial	Landings	Non-Trawl	Spring	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
South	Commercial	Landings	Non-Trawl	Fall	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	A	E	D	D	D	D	C
South	Commercial	Discards	Trawl	Spring	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
South	Commercial	Discards	Trawl	Fall	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	A	E	D	D	D	D	C
South	Commercial	Discards	Non-Trawl	Spring	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
South	Commercial	Discards	Non-Trawl	Fall	A	A	A	A	A	A	D	D	A	A	A	A	A	A	A	A	A	A	A	D	A	E	D	D	D	D	C
South	Recreational	Landings		Spring	C	B	B	C	B	B	A	A	A	A	A	B	B	C	C	C	B	B	B	B	B	C	C	C	C	C	C
South	Recreational	Landings		Fall	B	C	B	B	B	B	D	B	B	B	B	B	B	C	B	B	A	B	B	C	C	C	C	B	B	A	C
South	Recreational	Discards		Spring	C	B	B	C	B	B	A	A	A	A	A	B	B	C	C	C	B	B	B	B	B	C	C	C	C	C	C
South	Recreational	Discards		Fall	B	C	B	B	B	B	D	B	B	B	B	B	B	C	B	B	A	B	B	C	C	C	C	B	B	A	C

	Key
A	**Master**
B	**NEFSC ± 2 years**
C	**NEFSC Survey**
D	**Commercial Key**
E	**Commercial ± 2 years**

Table A29. Black sea bass catch number (000s) at age from trawl gear in the northern region, 1989-2015.

000s Year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8+	total
1989	56.1	296.8	159.8	57.3	17.1	5.3	1.4	0.4	594.8
1990	44.7	171.9	178.9	45.8	10.7	5.2	1.9	0.7	460.2
1991	44.0	86.4	112.2	43.3	9.6	2.8	0.8	0.3	299.5
1992	54.9	417.0	335.2	42.0	7.9	2.0	0.4	0.1	860.2
1993	32.3	223.6	200.1	42.5	8.0	2.7	1.0	0.4	511.2
1994	19.9	120.8	140.3	32.9	6.4	2.2	0.6	0.2	323.8
1995	86.9	118.4	185.1	39.9	6.7	1.6	0.3	0.0	443.5
1996	71.1	392.0	304.6	58.6	12.6	5.1	1.3	0.3	845.7
1997	84.7	438.1	371.0	82.0	15.1	3.7	0.8	0.2	995.6
1998	24.6	71.2	125.6	41.6	10.5	3.8	1.2	0.6	279.2
1999	7.8	38.8	180.3	72.0	17.4	5.6	1.5	0.5	323.9
2000	3.6	21.0	103.0	48.0	12.8	5.1	1.4	0.4	195.3
2001	24.1	108.0	353.0	156.9	31.2	9.4	2.8	1.5	687.5
2002	7.3	82.2	284.8	153.2	41.4	14.5	3.7	0.9	606.7
2003	11.1	235.5	159.2	88.9	37.4	20.3	7.9	2.9	563.4
2004	9.5	39.9	215.9	143.3	48.2	21.9	7.8	3.1	489.7
2005	0.5	12.8	98.3	87.3	38.4	20.1	8.9	4.7	271.2
2006	2.6	26.5	115.2	82.4	36.7	22.4	10.0	5.6	301.5
2007	28.4	331.9	342.6	113.0	34.0	17.3	7.9	5.6	880.8
2008	1.1	21.6	261.5	41.1	5.5	2.0	3.9	2.6	339.3
2009	3.4	37.2	195.3	71.4	15.7	2.8	1.6	3.2	331.0
2010	0.0	48.1	124.8	75.5	30.5	10.5	3.3	1.4	294.2
2011	7.7	33.5	132.3	142.1	41.3	20.4	4.5	1.1	382.9
2012	0.2	88.4	159.4	85.0	55.0	26.6	9.6	2.0	427.8
2013	0.3	185.5	127.0	125.6	72.8	48.2	11.9	7.3	579.0
2014	0.0	35.9	806.7	141.1	98.6	52.4	29.9	9.5	1174.8
2015	0.9	32.1	167.6	476.8	86.2	44.8	14.8	19.6	843.1

Table A30. Black sea bass catch number (000s) at age from non-trawl gear in the northern region, 1989-2015.

000s Year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8+	total
1989	27.4	405.6	474.8	146.0	40.3	36.5	2.6	0.6	1133.8
1990	44.1	212.8	456.3	160.0	28.2	8.7	2.7	1.3	914.3
1991	100.1	211.5	211.4	86.6	20.2	5.8	1.5	0.5	639.9
1992	46.5	148.0	83.6	42.0	24.0	15.1	5.7	5.4	371.1
1993	43.1	202.5	123.0	42.2	10.4	3.3	1.3	0.5	431.8
1994	161.9	177.3	103.2	25.6	5.1	1.5	0.4	0.1	477.5
1995	106.0	138.0	135.6	38.9	8.1	2.0	0.4	0.0	429.4
1996	67.7	184.4	105.1	40.4	11.7	4.6	1.2	0.3	415.5
1997	121.8	222.1	147.4	69.4	17.3	5.0	1.2	0.3	584.8
1998	44.5	117.3	170.1	81.2	24.3	7.7	1.9	0.5	447.7
1999	116.6	180.3	334.2	181.9	49.9	21.8	4.6	1.5	890.7
2000	145.2	477.9	529.2	255.4	57.7	27.6	8.0	2.7	1504.2
2001	66.6	345.4	521.0	194.0	43.8	31.8	4.1	1.3	1207.9
2002	94.7	363.7	609.0	460.6	164.0	54.4	8.7	2.6	1757.6
2003	71.6	299.3	425.3	269.1	79.1	37.5	11.0	4.0	1196.9
2004	22.1	204.5	388.4	211.9	64.9	27.6	9.6	3.3	932.9
2005	50.7	195.9	307.2	274.4	98.4	64.9	22.2	7.0	1023.6
2006	129.5	276.0	288.5	235.8	162.0	54.6	32.9	22.5	1207.1
2007	65.6	531.4	454.3	330.2	54.1	46.9	11.4	21.8	1517.1
2008	112.4	327.0	687.7	244.5	12.0	5.1	17.0	13.1	1420.4
2009	62.7	407.4	618.8	411.4	79.4	15.6	4.4	21.4	1623.2
2010	44.6	409.4	946.1	435.4	238.1	64.1	22.9	13.0	2185.7
2011	39.4	276.5	359.6	330.6	88.3	33.7	5.6	2.2	1136.2
2012	237.2	473.9	558.2	496.7	253.9	128.2	24.5	13.6	2196.4
2013	78.8	654.4	383.8	359.5	267.1	143.1	92.6	59.7	2040.2
2014	40.9	281.1	1460.7	449.9	180.2	148.7	92.8	72.7	2729.9
2015	12.4	180.7	492.2	1363.9	404.1	177.4	122.5	38.6	2792.1

Table A31. Black sea bass catch number (000s) at age from trawl gear in the southern region, 1989-2015.

000s Year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8+	total
1989	448.1	852.4	569.6	259.9	90.0	26.2	7.1	3.5	2437.8
1990	160.6	845.1	801.9	337.4	93.6	20.3	4.4	2.1	2270.0
1991	76.8	358.7	229.9	118.5	44.0	11.5	2.6	1.3	845.1
1992	282.5	626.2	489.6	197.2	58.3	13.7	2.8	1.0	1678.3
1993	736.3	1790.0	1123.9	412.2	111.4	24.0	5.3	2.3	4226.2
1994	161.2	635.7	557.8	204.8	54.7	12.6	2.8	1.3	1630.9
1995	129.3	256.0	284.3	108.2	21.3	4.8	0.0	0.0	815.7
1996	2175.1	3213.7	1012.9	228.8	49.4	47.7	7.1	7.1	6741.8
1997	10.9	185.9	298.0	143.4	41.3	8.8	1.7	0.7	690.8
1998	216.9	453.0	593.7	319.3	98.9	22.2	4.2	1.4	1709.6
1999	13.9	78.6	266.3	201.9	73.6	19.7	4.6	1.9	660.5
2000	60.1	50.9	170.5	190.4	96.6	33.1	9.2	4.3	615.1
2001	182.7	312.4	386.6	364.8	145.6	36.8	8.1	3.4	1476.8
2002	21.3	35.4	137.8	250.0	143.2	52.5	14.8	6.5	683.9
2003	27.7	44.0	141.9	242.2	144.9	59.0	19.1	10.3	689.9
2004	483.7	287.4	368.9	362.0	219.7	110.6	41.1	25.0	1909.3
2005	15.2	27.0	96.2	178.4	121.1	58.0	24.2	17.7	538.0
2006	2.7	5.7	61.0	103.7	65.2	32.8	14.5	11.4	297.1
2007	39.1	57.9	74.0	83.9	42.0	15.1	5.5	4.6	322.2
2008	0.1	194.4	155.6	120.0	42.3	26.2	15.1	6.1	559.8
2009	234.9	199.2	141.7	139.5	28.3	17.5	5.7	11.3	780.3
2010	0.3	103.9	223.8	130.3	77.4	19.3	3.4	4.4	565.3
2011	0.2	275.7	100.7	187.1	82.2	24.8	4.2	3.6	678.6
2012	109.5	13.2	173.9	75.2	70.7	21.4	7.2	5.2	476.3
2013	0.0	55.2	155.8	168.0	107.4	63.8	44.0	5.8	600.0
2014	0.0	34.7	499.8	78.7	49.3	43.1	27.0	2.3	735.0
2015	584.3	271.9	109.0	78.5	38.1	18.6	7.4	4.9	1139.1

Table A32. Black sea bass catch number (000s) at age from non-trawl gear in the southern region, 1989-2015.

000s Year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8+	total
1989	328.8	2845.8	1216.4	457.8	79.1	38.7	4.9	5.8	5004.5
1990	714.1	2499.6	1912.3	666.2	211.2	49.7	8.8	12.4	6274.2
1991	1271.1	4230.7	2213.8	864.9	206.0	83.5	5.5	81.5	9020.5
1992	730.8	3175.5	1889.9	678.8	187.0	42.6	8.9	6.3	6724.7
1993	643.4	3809.3	2637.1	771.9	192.2	38.5	5.8	21.5	8170.9
1994	758.9	1495.5	2288.2	457.0	109.4	28.9	3.2	1.6	5171.0
1995	2244.3	3963.7	2040.2	620.3	72.6	16.2	1.4	384.2	9437.5
1996	805.5	2950.4	2030.8	476.0	98.9	55.4	8.3	10.6	6452.7
1997	966.9	2789.8	1950.7	1131.2	367.9	77.0	14.8	179.1	7516.2
1998	193.7	865.8	1049.0	709.4	241.7	60.5	13.8	8.3	3143.3
1999	195.9	694.9	1133.8	781.6	368.5	98.0	17.7	11.4	3313.5
2000	612.1	1604.8	2017.0	1163.8	243.1	91.8	34.2	11.7	5782.3
2001	104.7	1598.7	1740.1	741.4	209.2	229.3	31.2	13.1	4668.1
2002	91.2	578.5	2677.4	1321.1	208.7	75.5	64.6	25.6	5043.8
2003	271.1	701.1	1883.2	1372.1	479.6	108.3	30.9	7.3	4854.3
2004	179.8	433.8	1477.6	357.4	245.7	43.9	11.0	9.0	2763.3
2005	120.4	607.7	624.8	608.6	342.4	53.0	11.4	6.2	2383.1
2006	216.4	380.5	719.4	679.4	478.7	78.1	13.8	7.2	2584.6
2007	315.7	425.2	596.9	561.8	239.0	162.4	55.1	5.7	2375.4
2008	484.5	821.5	650.4	206.2	99.8	47.3	22.8	15.0	2378.1
2009	205.4	344.5	720.7	490.7	129.7	47.8	13.1	16.0	1981.0
2010	215.8	308.7	753.4	577.0	105.4	30.0	2.0	17.4	2018.8
2011	252.6	265.4	381.5	426.8	180.3	24.9	3.3	1.0	1547.1
2012	315.1	212.7	488.9	446.3	511.3	35.4	12.8	6.8	2071.8
2013	232.3	186.7	294.1	403.6	259.7	47.2	86.2	1.4	1526.7
2014	122.8	229.3	677.4	169.6	332.5	42.6	11.9	1.1	1595.1
2015	126.1	182.3	279.0	579.7	133.2	60.1	11.2	3.9	1384.7

Table A33. Black sea bass mean weight at age (kg) for the Northern region.

Year	Age 1	Age2	Age3	Age4	Age5	Age6	Age7	Age8+
1989	0.101	0.178	0.399	0.688	0.999	1.254	1.471	1.763
1990	0.157	0.225	0.369	0.560	0.844	1.293	1.593	2.236
1991	0.138	0.200	0.361	0.617	0.845	1.145	1.473	2.031
1992	0.144	0.175	0.276	0.716	1.208	1.569	1.775	2.095
1993	0.140	0.199	0.341	0.580	0.940	1.329	1.695	1.969
1994	0.124	0.185	0.321	0.542	0.858	1.193	1.514	1.944
1995	0.119	0.215	0.329	0.556	0.813	1.043	1.235	1.495
1996	0.140	0.231	0.357	0.617	0.964	1.223	1.397	1.837
1997	0.158	0.180	0.333	0.597	0.849	1.116	1.388	1.980
1998	0.188	0.269	0.390	0.641	0.929	1.203	1.545	2.199
1999	0.125	0.276	0.435	0.648	0.896	1.250	1.513	1.967
2000	0.132	0.329	0.521	0.786	0.976	1.321	1.553	1.947
2001	0.134	0.297	0.464	0.644	0.869	1.372	1.595	2.133
2002	0.118	0.319	0.476	0.819	1.099	1.525	1.475	1.950
2003	0.124	0.253	0.486	0.782	1.106	1.426	1.655	1.953
2004	0.171	0.349	0.473	0.719	1.023	1.397	1.676	2.011
2005	0.104	0.316	0.489	0.766	1.128	1.514	1.829	2.212
2006	0.125	0.312	0.455	0.680	0.999	1.442	1.814	2.691
2007	0.131	0.273	0.403	0.651	1.009	1.318	1.869	2.410
2008	0.140	0.279	0.509	0.920	1.048	1.595	1.737	2.227
2009	0.117	0.283	0.455	0.763	1.042	1.195	1.314	2.432
2010	0.083	0.358	0.536	0.772	0.956	1.272	1.334	1.767
2011	0.112	0.296	0.467	0.670	0.976	1.353	1.523	2.111
2012	0.102	0.319	0.514	0.753	1.156	1.293	1.715	2.304
2013	0.108	0.243	0.539	0.698	1.034	1.373	1.537	2.135
2014	0.112	0.256	0.451	0.819	1.086	1.559	1.753	2.299
2015	0.106	0.233	0.455	0.697	1.025	1.276	1.691	1.967

Table A34. Black sea bass mean weight at age (kg) from the southern region.

Year	Age 1	Age2	Age3	Age4	Age5	Age6	Age7	Age8+
1989	0.066	0.173	0.307	0.483	0.582	0.843	1.189	1.516
1990	0.097	0.180	0.306	0.428	0.540	0.874	1.108	1.516
1991	0.123	0.168	0.314	0.501	0.621	1.018	1.080	1.954
1992	0.126	0.208	0.290	0.432	0.637	0.840	1.077	1.317
1993	0.114	0.193	0.300	0.398	0.544	0.872	1.173	1.123
1994	0.113	0.204	0.347	0.397	0.554	0.872	1.127	1.456
1995	0.123	0.229	0.371	0.574	0.702	1.029	1.060	1.031
1996	0.116	0.181	0.450	0.462	0.669	0.860	0.925	1.637
1997	0.143	0.222	0.354	0.469	0.593	0.852	1.079	1.043
1998	0.150	0.219	0.319	0.458	0.612	0.851	1.118	1.304
1999	0.143	0.250	0.377	0.573	0.626	0.921	1.137	1.322
2000	0.122	0.242	0.385	0.604	0.690	1.063	1.306	1.496
2001	0.114	0.278	0.412	0.562	0.676	1.104	1.389	1.523
2002	0.106	0.266	0.404	0.649	0.748	1.020	1.399	1.421
2003	0.107	0.279	0.438	0.583	0.734	1.015	1.347	1.561
2004	0.109	0.217	0.434	0.521	0.723	1.078	1.381	1.576
2005	0.111	0.295	0.376	0.532	0.776	1.027	1.406	1.742
2006	0.097	0.269	0.387	0.510	0.616	0.954	1.356	1.710
2007	0.099	0.224	0.399	0.537	0.653	1.019	1.083	1.904
2008	0.105	0.275	0.462	0.566	0.742	0.865	1.311	1.493
2009	0.114	0.206	0.366	0.545	0.797	0.997	1.090	1.193
2010	0.098	0.277	0.363	0.463	0.672	1.067	1.309	1.484
2011	0.110	0.190	0.322	0.455	0.590	0.990	1.395	1.947
2012	0.081	0.216	0.318	0.455	0.743	0.871	1.239	1.553
2013	0.087	0.184	0.313	0.463	0.593	0.962	1.294	1.793
2014	0.092	0.226	0.333	0.505	0.712	1.006	1.483	1.565
2015	0.080	0.181	0.372	0.586	0.770	1.085	1.426	1.800

Table A35. Sequence of black sea bass ASAP model configurations considered for the Overall single area model.

Run	Fleets	Selectivity Blocks	Indices -Age	Indices-one age	Lambda 1	phases
A series of runs initially made to produce functional model.			Previous runs used NEFSC series split with Bigelow. Did not work, some combined with length calibration.			
Overall-1	1	2 (1989-1997, 1998-2015)	2	0	0.01	no F-Mult in first year
Overall-2	1	2 (1989-1997, 1998-2015)	2	0	0.01	no F-Mult in first year
Overall-3	1	2 (1989-1997, 1998-2015)	3	0	0.01	no F-Mult in first year
Overall-4	1	2 (1989-1997, 1998-2015)	3	7	0.01	no F-Mult in first year
Overall-4A	1	2 (1989-1997, 1998-2015)	3	7	0.01	no F-Mult in first year
Overall-4B	1	2 (1989-1997, 1998-2015)	3	7	0.01	no F-Mult in first year
Overall-4C	1	2 (1989-1997, 1998-2015)	3	7	0.01	no F-Mult in first year
Overall-4D	1	2 (1989-1997, 1998-2015)	3	7	0.05	no F-Mult in first year
Overall-5	1	2 (1989-1997, 1998-2015)	3	7	0.05	no F-Mult in first year
Overall-5(2)	1	2 (1989-1997, 1998-2015)	5	6	0.05	no F-Mult in first year
Overall-6	1	2 (1989-1997, 1998-2015)	6	5	0.05	no F-Mult in first year
Overall-7	1	2 (1989-1997, 1998-2015)	7	4	0.05	F-Mult in first year
Overall-8	1	2 (1989-1997, 1998-2015)	7	4	0.05	F-Mult in first year
Overall-5_2FLEET	2	4 (1989-1997, 1998-2015)	5	6	0.05	F-Mult in first year
Overall-6_2FLEET	2	4 (1989-1997, 1998-2015)	7	4	0.05	F-Mult in first year
Overall-10	2	3(1989-1997, 1998-2015, 1989-2015)	8	4	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
Overall-11	2	3(1989-1997, 1998-2015, 1989-2015)	8	5	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
Overall-12	2	3(1989-1997, 1998-2015, 1989-2015)	8	5	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
Overall-13_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	9	5	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
Overall-18_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	9	5	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
Overall-19_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	9	5	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
Overall-20_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	9	5	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year

Table A36. Changes within black sea bass ASAP overall single area model considered prior to selection of final model.

Run	changes	
A series of runs initially made to produce functional model.		
Overall-1	Selectivity fixed at 1 >age 5	
Overall-2	estimate catch selectivity for older ages	
Overall-3	add NEAMAP and estimate index selectivity for older ages	
Overall-4		
Overall-4A	decreased 2000-2002 NEFSC spring CV to 0.2	
Overall-4B	Alter NY CV 0.4 to 0.6	
Overall-4C	Return to emprical NEFSC spring CVs	
Overall-4D	Return to fixed NEFSC spring CVs 0.6	
Overall-5	added Rivard weight at age matrix	
Overall-5(2)	added MADMF age indices and REC CPA age index	linked REC CPA to fleet selectivity
Overall-6	added NJ indices at age	
Overall-7	added RI indices at age	
Overall-8	made NEFSC flat topped selectivity	
Overall-5_2FLEET	split fleets into trawl, non-trawl	
Overall-6_2FLEET	added MADMF,RI age indices and REC CPA age index	linked REC CPA to fleet selectivity
Overall-10	added CT indices at age	
Overall-11	aded VIMS age 1, fixed catch selectivity as flat top	
Overall-12		
Overall-13_SPLIT	added Bigelow indices at age	
Overall-18_SPLIT	all index phases 3	
Overall-19_SPLIT	Fix age 5 and over flat topped in catch selectivity	
Overall-20_SPLIT	Fix age 5 and over flat topped in catch selectivity	

Table A37. Sequence of black sea bass ASAP model configurations considered for the North area model.

North

Run	Fleets	Selectivity Blocks	Indices -Age	Indices-one age	Lambda 1	phases
ASAP-North1	1	1 (1989-2015)	3	4	0.1	no F-Mult in first year
ASAP-North2	1	1 (1989-2015)	4	3	0.1	no F-Mult in first year
ASAP-North3	1	1 (1989-2015)	4	3	0.1	no F-Mult in first year
ASAP-North4	1	1 (1989-2015)	4	3	0.1	no F-Mult in first year
ASAP-North5	1	1 (1989-2015)	4	3	0.1	no F-Mult in first year
ASAP-North6	1	1 (1989-2015)	4	3	0.05	no F-Mult in first year
NORTH-2Fleet	2	1 (1989-2015)	4	3	0.05	no F-Mult in first year
NORTH-3Fleet	2	1 (1989-2015)	3	4	0.05	no F-Mult in first year
NORTH-4Fleet	2	1 (1989-2015)	4	3	0.05	no F-Mult in first year
NORTH-4aFleet	2	1 (1989-2015)	4	3	0.05	no F-Mult in first year
NORTH-5Fleet	2	1 (1989-2015)	6	2	0.05	no F-Mult in first year
NORTH-ALB_Double_lc	2	2 (1989-2015)	5	3	0.05	no F-Mult in first year
NORTH-6Fleet	2	1 (1989-2015)	6	2	0.05	no F-Mult in first year
NORTH-7Fleet	2	1 (1989-2015)	6	2	0.05	F-Mult in first year
NORTH-8Fleet	2	2 (1989-2015)	6	2	0.05	F-Mult in first year
NORTH-9Fleet	2	2 (1989-2015)	6	2	0.05	F-Mult in first year
NORTH-10Fleet	2	2 (1989-2015)	6	2	0.05	F-Mult in first year
NORTH-11Fleet	2	2 (1989-2015)	7	1	0.05	F-Mult in first year
NORTH-12Fleet	2	2 (1989-2015)	7	1	0.05	F-Mult in first year
NORTH-13Fleet	2	2 (1989-2015)	7	1	0.05	F-Mult in first year
NORTH-14Fleet	2	2 (1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-15Fleet	2	2 (1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-16Fleet	2	2 (1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-17Fleet	2	2 (1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-18Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-19Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-20Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	6	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-21Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-23Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	7	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-24Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	8	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-24Fleet_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	8	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-26Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	8	1	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
NORTH-26	Final					

Table A38. Changes within black sea bass ASAP North area model considered prior to selection of final model.

North

Run	changes
ASAP-North1	NEFSC spring, NEAMAP,MADMF,RI,CT,NY,NEFSC winter
ASAP-North2	added MADMF aged indices
ASAP-North3	allow catch some dome in age 7,8
ASAP-North4	decrease index selectivity CV
ASAP-North5	index phase 5 to 3, increase NEFSC selectivity CV
ASAP-North6	lambda 1 reduced
NORTH-2Fleet	trawl and non-trawl split
NORTH-3Fleet	removed age comp from NEFSC spring
NORTH-4Fleet	reduced NEFSC indices to reduce catchability estimate
NORTH-4aFleet	reduced NEFSC indices to reduce catchability estimate
NORTH-5Fleet	add RI trawl indices and REC CPA
NORTH-ALB_Double_lc	tried NEFSC selectivity as double logistic
NORTH-6Fleet	reduced NEFSC q to match south
NORTH-7Fleet	new NY indices
NORTH-8Fleet	added 2nd selectivity block
NORTH-9Fleet	created flat top NEFSC indices
NORTH-10Fleet	linked REC CPA selectivity to fleet
NORTH-11Fleet	added CT ages
NORTH-12Fleet	removed REC CPA
NORTH-13Fleet	restored REC CPA
NORTH-14Fleet	change lamdda 1 CVs for fleet 2
NORTH-15Fleet	moved fixed age at catch selectivity up from 4 to 6
NORTH-16Fleet	changed catch selectivity lambdas to 0
NORTH-17Fleet	made catch selectivities equal between fleets to start
NORTH-18Fleet	added third selectivity block
NORTH-19Fleet	Fix age 5 and over flat topped in catch selectivity
NORTH-20Fleet	Fixed index selectivities as flat top, turned off ALB spring ages, unlinked REC CPUE to fleet selectivity
NORTH-21Fleet	restored ALB spring ages, made index selectivty lambda 0
NORTH-23Fleet	dropped NEFSC winter
NORTH-24Fleet	split NEFSC spring to include Bigelow; increase ESS of fleet
NORTH-24Fleet_SPLIT	index data corrections
NORTH-26Fleet	index phase adjustments to 3
NORTH-26	

Table A39. Changes within black sea bass ASAP South area model considered prior to selection of final model.

Run	Fleets	Selectivity Blocks	Indices -Age	Indices-one age	Lambda 1	phases
ASAP-South1	1	1 (1989-2015)	3	4	0.01	no F-Mult in first year
ASAP-South2Fleet	2	1 (1989-2015)	3	4	0.01	no F-Mult in first year
SOUTH-2Fleet	2	1 (1989-2015)	3	5	0.01	no F-Mult in first year
SOUTH-2AFleet	2	1 (1989-2015)	4	4	0.05	no F-Mult in first year
SOUTH-3Fleet	2	1 (1989-2015)	5	3	0.05	no F-Mult in first year
SOUTH-4Fleet	2	1 (1989-2015)	5	3	0.05	F-Mult in first year
SOUTH-5Fleet	2	2 (1989-2015)	4	4	0.05	F-Mult in first year
SOUTH-6Fleet	2	2 (1989-2015)	4	4	0.05	F-Mult in first year
SOUTH-7Fleet	2	2 (1989-2015)	5	3	0.05	F-Mult in first year
SOUTH-8Fleet	2	2 (1989-2015)	5	3	0.1	F-Mult in first year
SOUTH-10Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-11Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-12Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-13Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-14Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-15Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-16Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-17Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-18Fleet	2	3(1989-1997, 1998-2015, 1989-2015)	4	4	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 2	F-Mult in first year
SOUTH-18Fleet_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 3	F-Mult in first year
SOUTH-20Fleet_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 3	F-Mult in first year
SOUTH-21Fleet_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 3	F-Mult in first year
SOUTH-22Fleet_SPLIT	2	3(1989-1997, 1998-2015, 1989-2015)	5	3	0.05 (fleet 1), 0.2-2008, 0.15 2009-2015 fleet 3	F-Mult in first year
SOUTH24.dat	final					

Table A40. Changes within black sea bass ASAP South area model considered prior to selection of final model.

Run	**changes**
ASAP-South1	altered index selectivity CVs
ASAP-South2Fleet	altered index selectivity CVs
SOUTH-2Fleet	includes REC CPA w/o ages
SOUTH-2AFleet	added REC CPA ages
SOUTH-3Fleet	added NJ indices at age
SOUTH-4Fleet	reduced NEFSC qs
SOUTH-5Fleet	removed NEFSC winter age comps
SOUTH-6Fleet	REC CPA selectivity linked to fleet
SOUTH-7Fleet	winter age comps back in
SOUTH-8Fleet	increase catch CV
SOUTH-10Fleet	add catch selectivity block, decrease index selectivity cv, lambda 1 changes
SOUTH-11Fleet	fix flat top catch selectivity
SOUTH-12Fleet	reduce at at full selectivity for NJ index
SOUTH-13Fleet	increase rec cpa ESS
SOUTH-14Fleet	reduce NEAMAP full selection to 4
SOUTH-15Fleet	remove index select lambdas
SOUTH-16Fleet	reviseed NJ indices
SOUTH-17Fleet	revise maturity data
SOUTH-18Fleet	limit NEAMAP to age 1 only
SOUTH-18Fleet_SPLIT	split NEFSC to Alb and Bigelow
SOUTH-20Fleet_SPLIT	reduce REC CPA CV, increase fleet ESS from 20 to 30
SOUTH-21Fleet_SPLIT	correct NEFSC indices
SOUTH-22Fleet_SPLIT	revise NEAMAP cv, phase change index 2
SOUTH24.dat	final

Table A41. Likelihood values from black sea bass area exchange model. Bold cell indicates minimum value.

		Percent Movement										
Range	Area	p_0	p_0.05	p_0.1	p_0.15	p_0.2	p_0.25	p_0.3	p_0.35	p_0.4	p_0.45	p_0.5
r_0	combined	16058.7	16047.9	16044.9	16043.4	16042.6	16042.1	16041.8	16041.6	16041.6	16041.7	16041.9
r_0.1	combined		16049.5	16045.6	16043.8	16042.7	16042.1	16041.8	16041.6	**16041.5**	16041.5	16041.6
r_0.2	combined			16046.9	16044.5	16043.2	16042.4	16042.0	16041.7	16041.6	16041.6	16041.6
r_0.3	combined				16045.6	16043.9	16043.0	16042.4	16042.0	16041.8	16041.8	16041.8
r_0.4	combined					16045.0	16043.8	16043.0	16042.5	16042.3	16042.2	16042.1
r_0.5	combined						16044.8	16043.8	16043.3	16042.9	16042.7	16042.7

		Percent Movement										
Range	Area	p_0	p_0.05	p_0.1	p_0.15	p_0.2	p_0.25	p_0.3	p_0.35	p_0.4	p_0.45	p_0.5
r_0	north	9734.8	9724.0	9721.0	9719.5	9718.7	9718.2	9717.9	**9717.8**	9717.8	9717.9	9718.1
r_0.1	north		9726.0	9722.1	9720.3	9719.3	9718.8	9718.5	9718.4	9718.4	9718.5	9718.6
r_0.2	north			9723.8	9721.4	9720.2	9719.5	9719.2	9719.0	9719.0	9719.0	9719.2
r_0.3	north				9722.9	9721.3	9720.5	9720.0	9719.7	9719.7	9719.7	9719.9
r_0.4	north					9722.7	9721.6	9720.9	9720.6	9720.5	9720.5	9720.6
r_0.5	north						9722.9	9722.0	9721.6	9721.3	9721.3	9721.3

		Percent Movement										
Range	Area	p_0	p_0.05	p_0.1	p_0.15	p_0.2	p_0.25	p_0.3	p_0.35	p_0.4	p_0.45	p_0.5
r_0	south	6324.0	6324.0	6323.9	6323.9	6323.9	6323.9	6323.8	6323.8	6323.8	6323.8	6323.7
r_0.1	south		6323.5	6323.5	6323.5	6323.4	6323.3	6323.3	6323.2	6323.2	6323.1	6323.0
r_0.2	south			6323.1	6323.0	6323.0	6322.9	6322.8	6322.7	6322.6	6322.5	6322.4
r_0.3	south				6322.7	6322.6	6322.5	6322.4	6322.3	6322.2	6322.1	6321.9
r_0.4	south					6322.3	6322.2	6322.1	6322.0	6321.8	6321.7	6321.6
r_0.5	south						6321.9	6321.8	6321.7	6321.6	6321.5	**6321.4**

Table A42. Results of the black sea bass ASAP models for 2015. The North and South model combine to form the Combined Area model, the Overall model is the single area model and the Area exchange model moves fish from the south back to the north during the offshore migratory period.

2015	North model	North adjusted	South model	South adjusted	Two Area models Combined	Two Area models Combined-adjusted	Overall Single Area model	Area Exchange Model
Catch (MT)	2767.5	2767.5	915.9	915.9	3683.4	3683.4	3683.4	3683.4
F	0.24	0.14	0.23	0.39	0.24	0.27	0.20	0.21
SSB (MT)	11,719	19,211	4,834	2,966	16,552	22,176	19,585	19,828
Exploitable Biomass (MT)	15,079	22,340	5,168	3,336	20,247	25,676	23,658	24,206
Total Biomass (MT)	17,306	27,733	6,838	4,276	24,143	32,010	24,155	29,339
Recruitment (000s)	3,342	6,484	21,574	11,519	24,917	18,002	27,863	24,066

Table A43. Proxy values of black sea bass biological reference points developed assuming $F_{MSY} = F_{40\%}$.

	SSBmsy	Bmsy	Fmsy	MSY	1/2 SSBmsy	1/2 Bmsy
Combined north and south	9,667 mt	17,256 mt	0.36	3,097 mt	4,834	8,628 mt
-2 SD	5,517	9,801		1,797	2,759	4,901
+2 SD	13,816	24,709		4,396	6,908	12,355
Overall model	10,296 mt	18,379 mt	0.36	3,298 mt	5,148	9,189 mt
-2 SD	5,615	10,026		1,831	2,808	7,101
+2 SD	14,977	26,733		4,765	7,489	11,278

Table A44. Short term black sea bass projections at F_{MSY} for the **Combined** area models. Values based on estimates not adjusted for retrospective bias.

Total **no Rho adjust**

Area Combined at F_{MSY}

		- 2 STD DEV	Average	+ 2 STD DEV
SSB (mt)	2015		16,552	
	2016	9,434	15,055	20,676
	2017	8,380	13,299	18,217
	2018	7,483	11,618	15,753
	2019	5,699	10,782	15,864
Recruits (000s)	2015		24,917	
	2016	2,025	25,081	57,593
	2017	1,987	25,126	57,664
	2018	1,998	25,096	57,597
	2019	2,012	25,133	57,846
Jan 1 biomass (mt)	2015		24,143	
	2016	16,023	23,374	30,725
	2017	14,438	22,246	30,054
	2018	12,202	19,848	27,495
	2019	9,787	18,764	27,741
Catch (mt)	2015		3,683	
	2016		3,024	
	2017	2,759	4,446	6,132
	2018	2,523	3,822	5,121
	2019	2,012	3,493	4,974

Table A45. Short term black sea bass projections at F_{SQ} for the **Combined** area models. Values based on estimates not adjusted for retrospective bias.

Total **no Rho adjust**

Area Combined Fstatus quo = 0.24

		- 2 STD DEV	Average	+ 2 STD DEV
SSB (mt)	2015		16,552	
	2016	9,434	15,055	20,676
	2017	8,778	13,946	19,114
	2018	8,509	13,129	17,748
	2019	7,141	12,805	18,468
Recruits (000s)	2015		24,917	
	2016	2,025	25,081	57,593
	2017	1,987	25,126	57,664
	2018	1,998	25,096	57,597
	2019	2,012	25,133	57,846
Jan 1 biomass (mt)	2015		24,143	
	2016	16,023	23,374	30,725
	2017	14,438	22,246	30,054
	2018	13,181	21,154	29,127
	2019	11,425	20,848	30,271
Catch (mt)	2015		3,683	
	2016		3,024	
	2017	1,938	3,127	4,316
	2018	1,909	2,904	3,900
	2019	1,662	2,809	3,957

Table A46. Short term black sea bass projections at F_{MSY} for the **Combined** area models. Values based on estimates adjusted for retrospective bias.

Total Area Combined	**Rho adjusted** at F_{MSY}	- 2 STD DEV	Average	+ 2 STD DEV
SSB (mt)	2015		22,176	
	2016	11,950	18,670	25,391
	2017	10,270	15,918	21,565
	2018	8,914	13,407	17,900
	2019	6,706	11,849	16,991
Recruits (000s)	2015		18,002	
	2016	2,025	25,081	57,593
	2017	1,987	25,126	57,664
	2018	1,998	25,096	57,597
	2019	2,012	25,133	57,846
Jan 1 biomass (mt)	2015		32,010	
	2016	20,322	29,350	38,379
	2017	18,461	27,540	36,619
	2018	15,255	23,315	31,375
	2019	11,725	20,788	29,851
Catch (mt)	2015		3,683	
	2016		3,024	
	2017	3,484	5,467	7,451
	2018	3,037	4,494	5,950
	2019	2,398	3,901	5,403

Table A47. Short term black sea bass projections at F_{SQ} for the **Combined** area models. Values based on estimates adjusted for retrospective bias.

Total Area Combined		**Rho adjusted** at Fstatus quo = 0.27		
		- 2 STD DEV	Average	+ 2 STD DEV
SSB (mt)	2015		22,176	
	2016	11,897	18,587	25,278
	2017	11,052	17,131	23,210
	2018	10,792	16,121	21,451
	2019	9,250	15,349	21,448
Recruits (000s)	2015		18,002	
	2016	2,025	25,082	57,599
	2017	1,987	25,127	57,671
	2018	1,998	25,098	57,604
	2019	2,012	25,135	57,853
Jan 1 biomass (mt)	2015		32,010	
	2016	20,253	29,246	38,238
	2017	18,461	27,540	36,619
	2018	17,176	25,874	34,572
	2019	14,865	24,704	34,543
Catch (mt)	2015		3,683	
	2016		3,024	
	2017	1,880	3,006	4,132
	2018	1,906	2,859	3,812
	2019	1,778	2,764	3,750

FIGURES

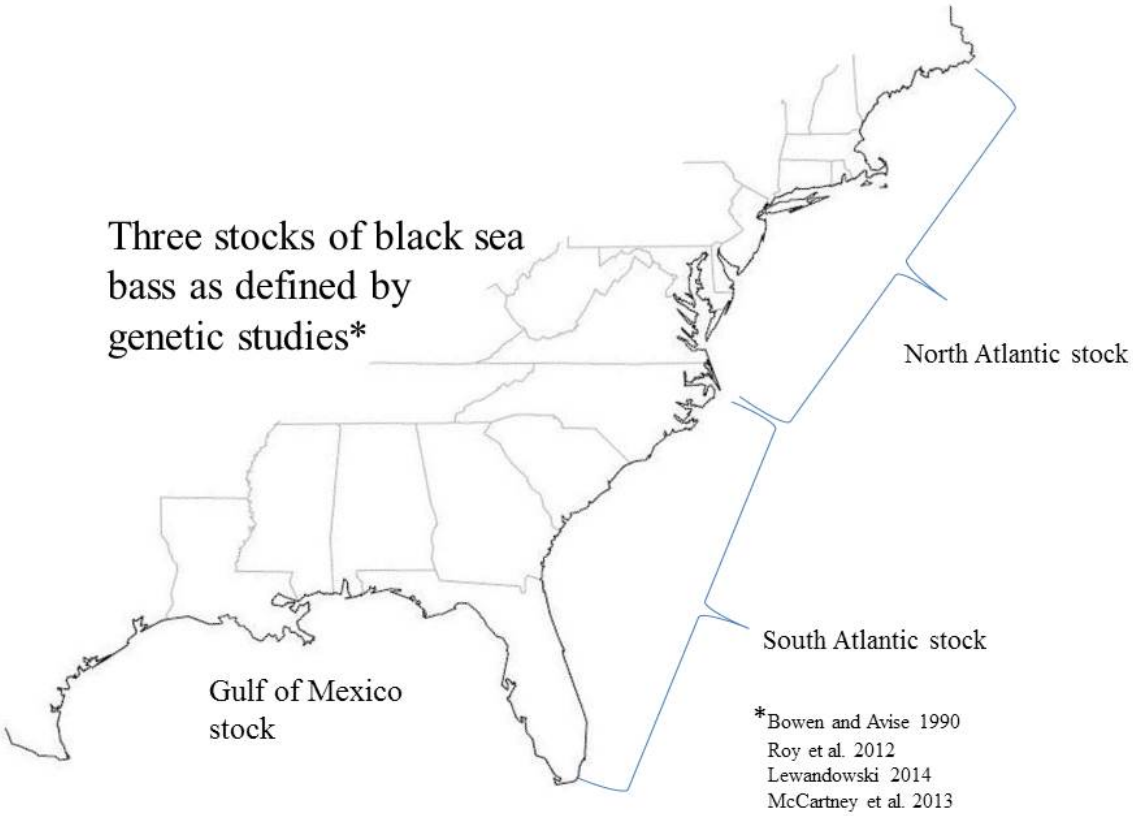

Figure A1. Map of geographic boundaries for three black sea bass stocks in United States.

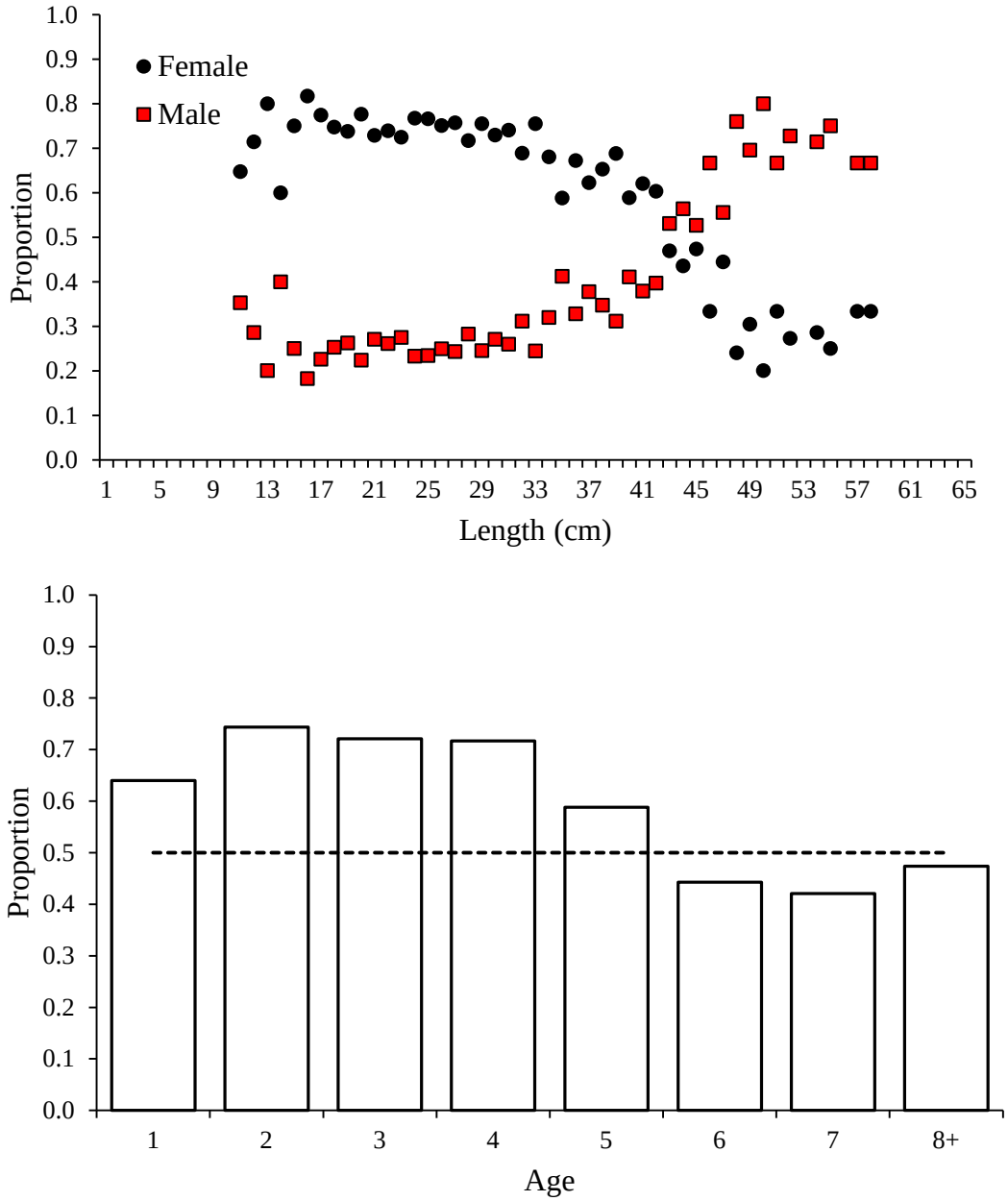

Figure A2. Black sea bass sex ratio at length and proportion female at age from NEFSC spring and winter surveys, 1984-2015.

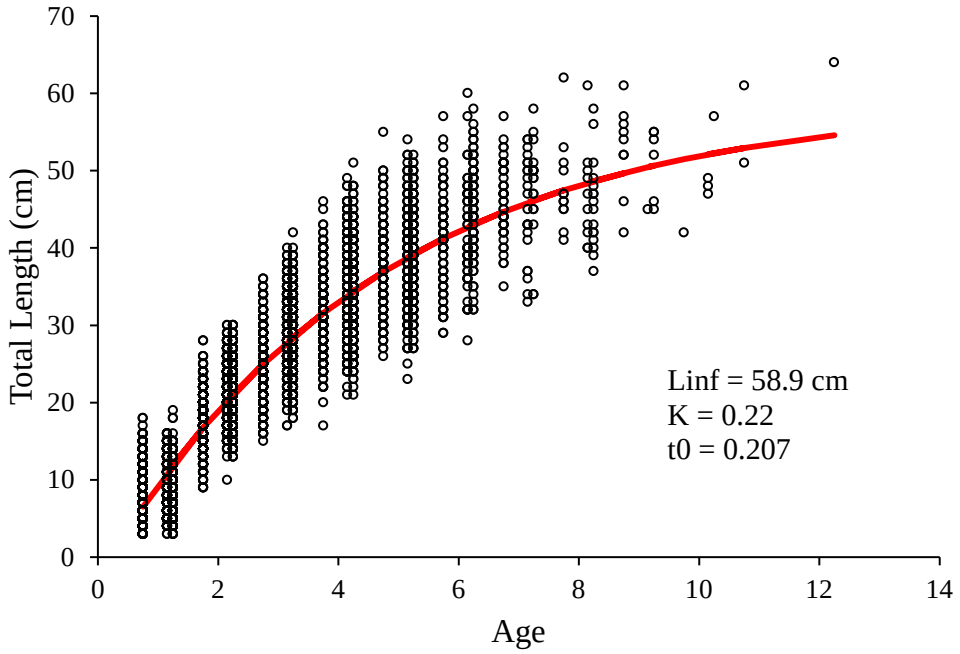

Figure A3. Black sea bass von Bertalanffy growth curve, all regions and sexes combined.

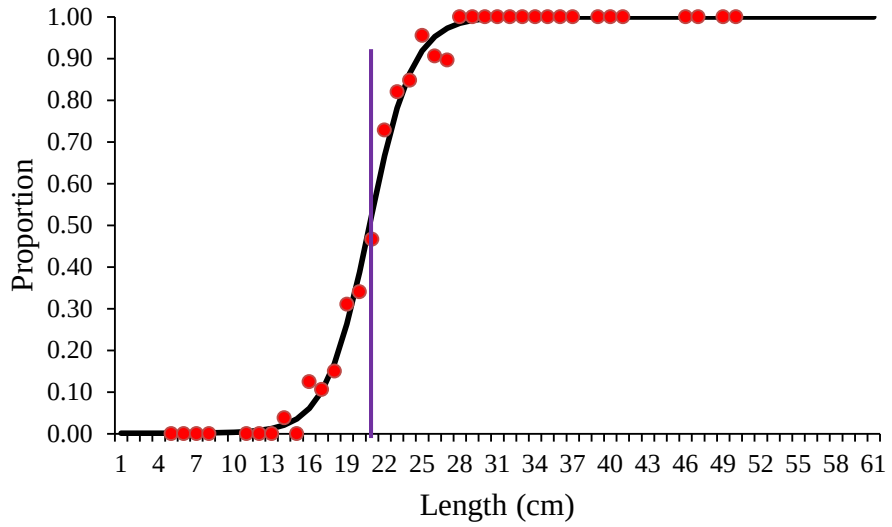

Figure A4. Black sea bass maturity at length from NEFSC spring and winter bottom trawl survey data, 1989-2015.

Figure A5. Black sea bass age at maturity from NEFSC spring and winter bottom trawl survey data, 1989-2015.

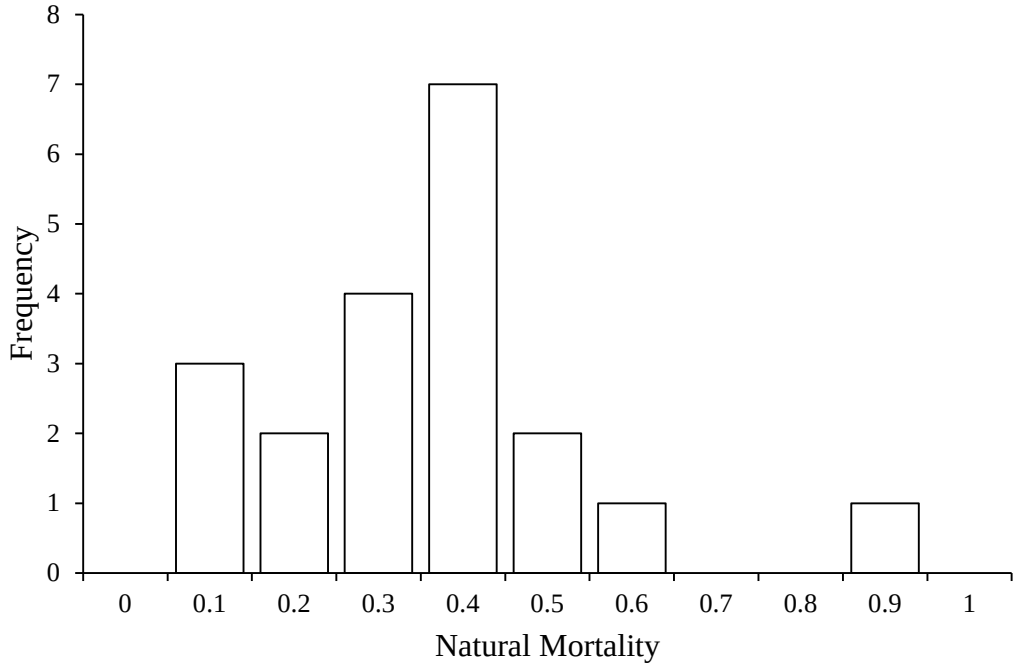

Figure A6. Frequency of natural mortality estimates from a variety of methods (see also Table A2).

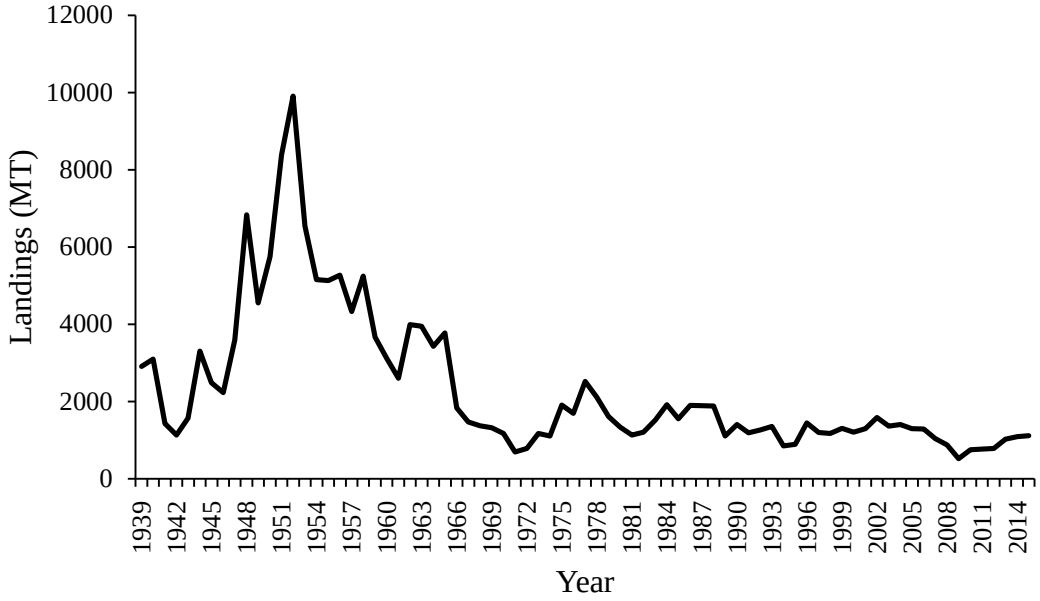

Figure A7 . Commercial landing time series for the North Atlantic stock of black sea bass.

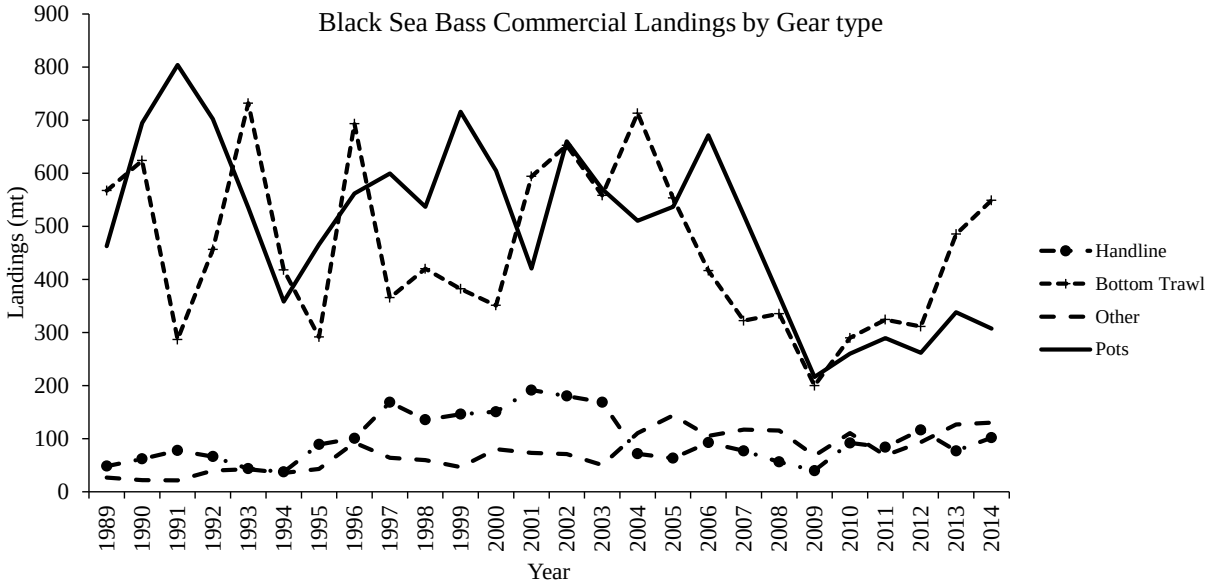

Figure A8. Black sea bass commercial landings by gear type, 1989-2015.

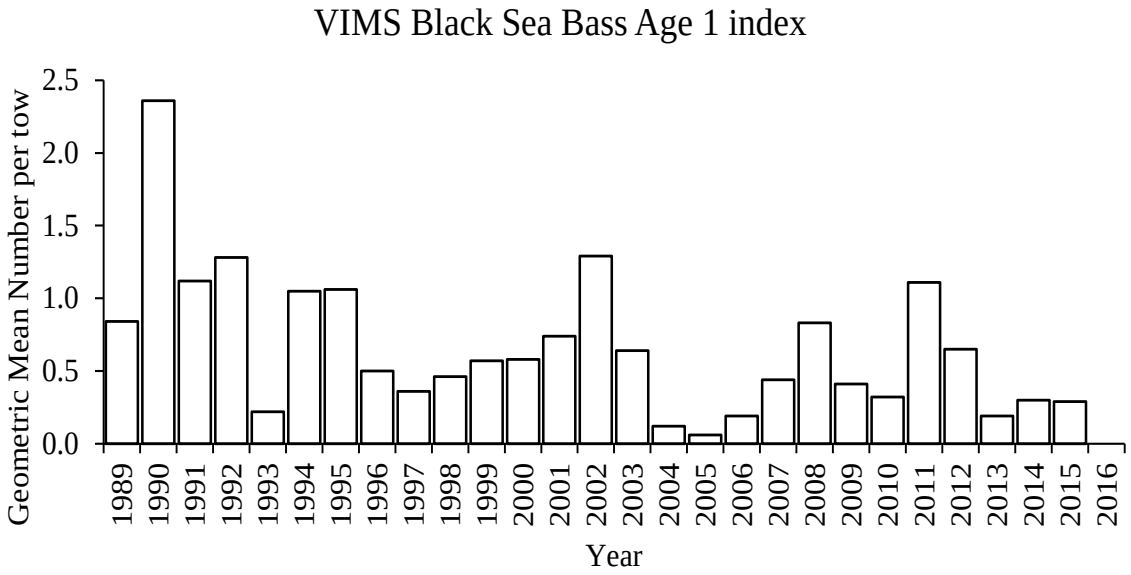

Figure A9 Black sea bass age one indices of abundance from VIMS spring trawl survey in Chesapeake Bay, 1989-2013.

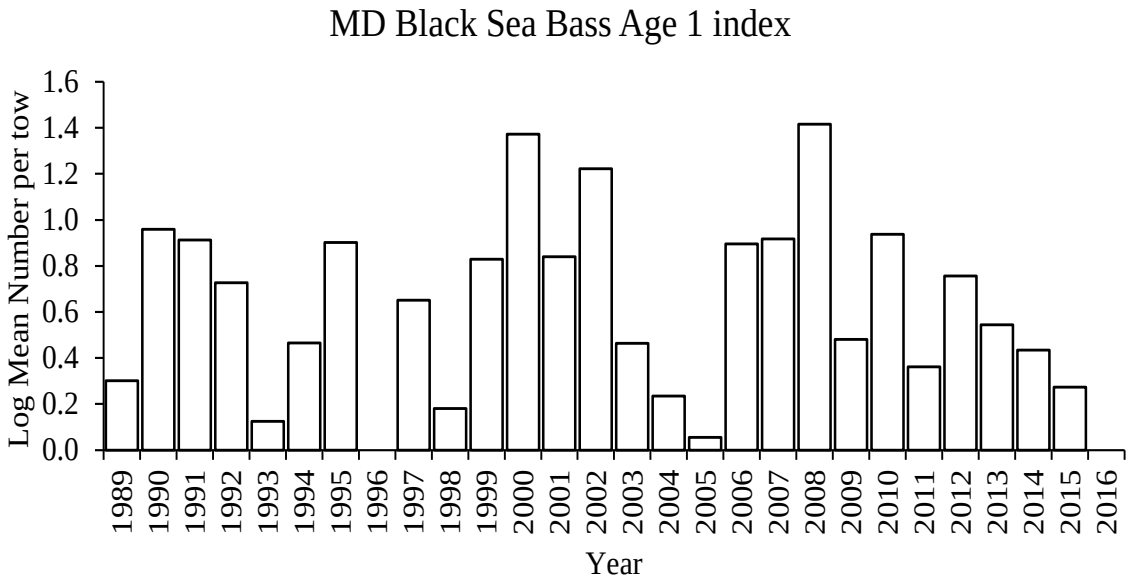

Figure A10. MD DNR trawl survey index of black sea bass age one indices of abundance in Maryland coastal bays, 1989-2015.

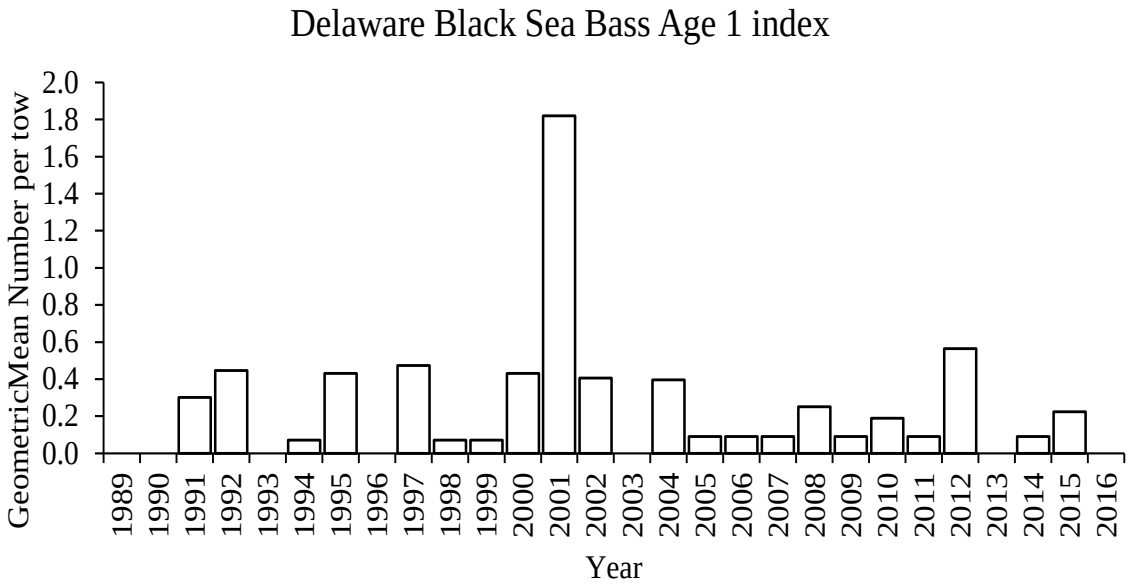

Figure A11. DE DFW trawl survey indices of black sea bass age one abundance in Delaware Bay, 1989-2015.

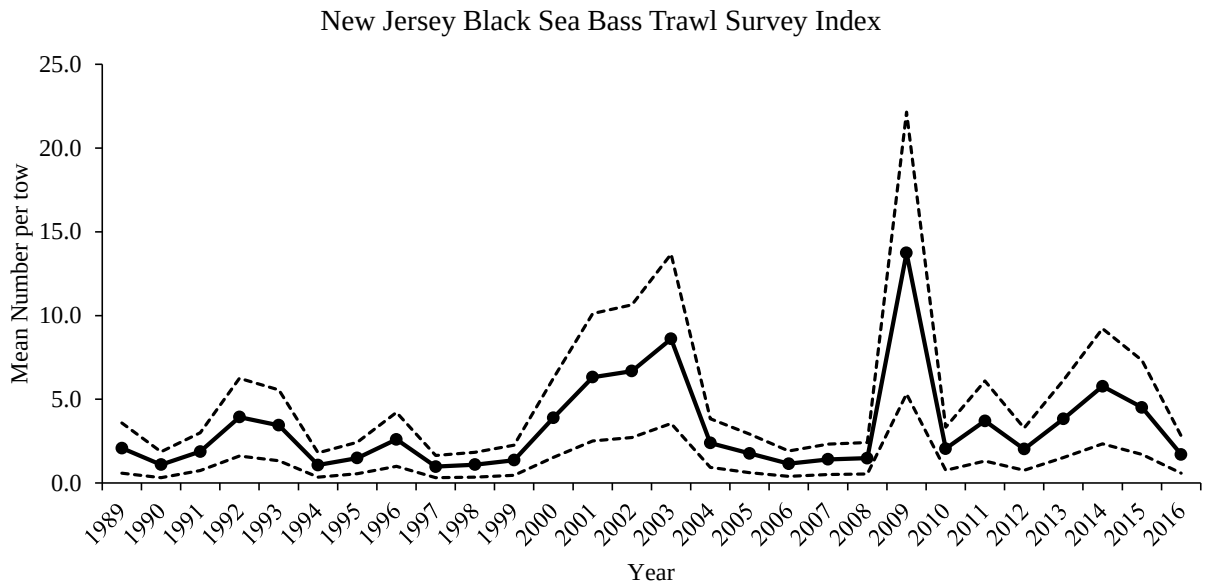

Figure A12. NJ DEM trawl survey indices (± 95% CI) of black sea bass abundance, age 1-8+ collected in coastal New Jersey, 1989-2016.

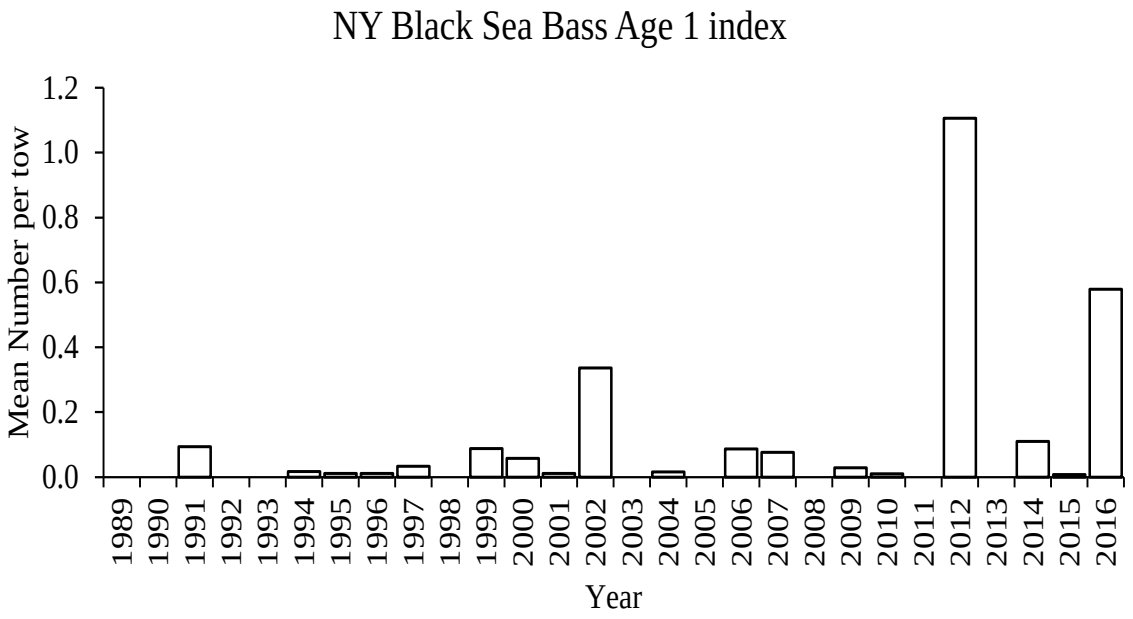

Figure A13. NY DEC spring trawl survey indices of black sea bass age one abundance collected in Peconic Bay, Long Island, 1989-2016.

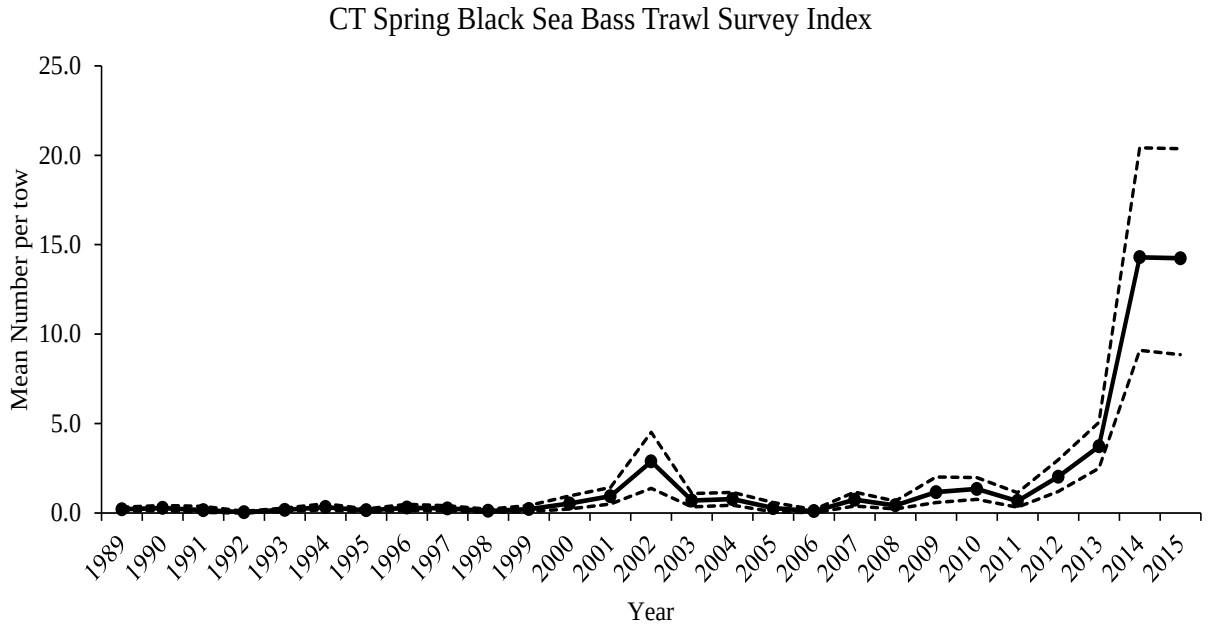

Figure A14. CT DEEP spring trawl survey indices (± 95% CI) of black sea bass, ages1-8+, collected in Long Island Sound, 1989-2015.

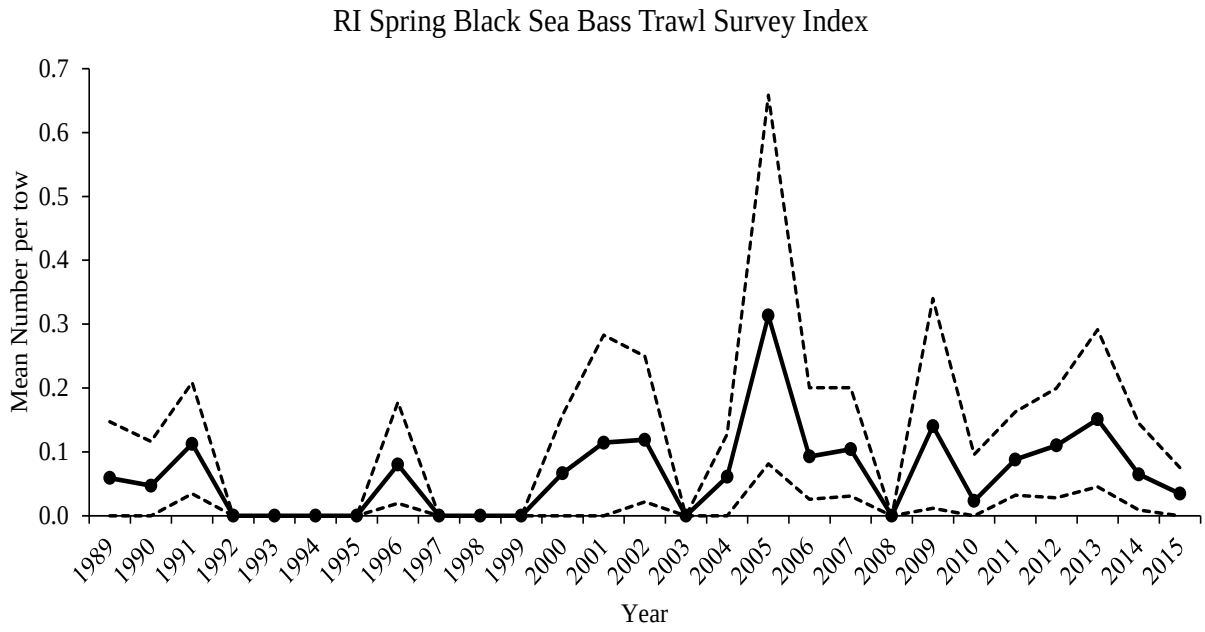

Figure A15. RI DEM spring trawl survey indices (± 95% CI) of black sea bass, ages1-8+, collected in Narragansett Bay, 1989-2015.

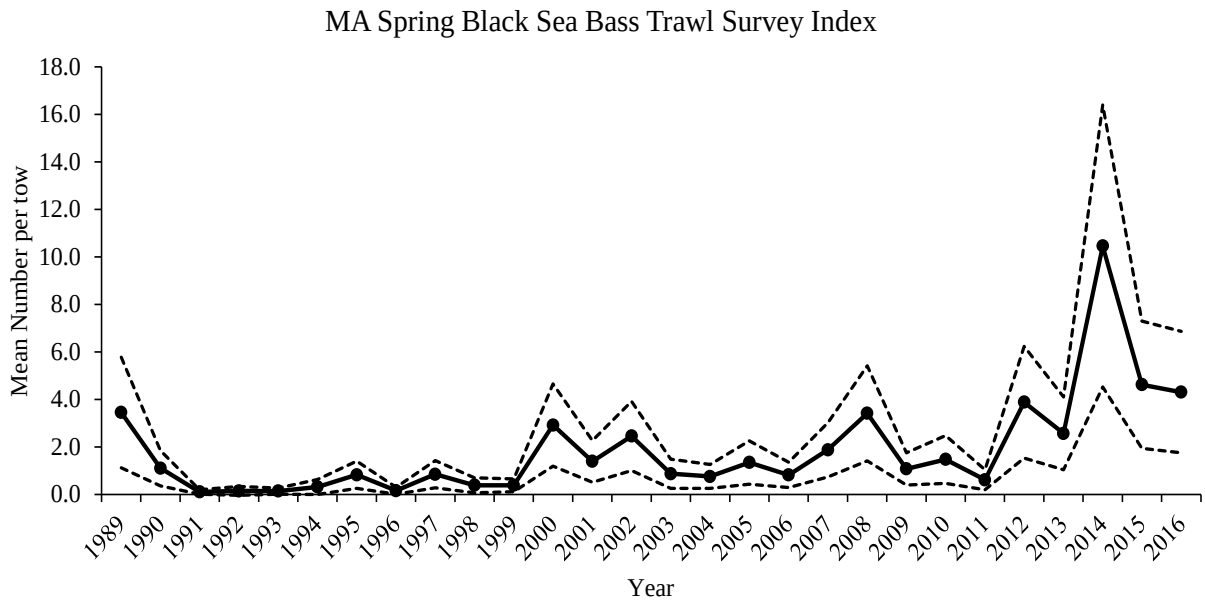

Figure A16. MA DMF spring trawl survey indices (± 95% CI) of black sea bass, ages1-8+, collected in south coastal Massachusetts, 1989-2015.

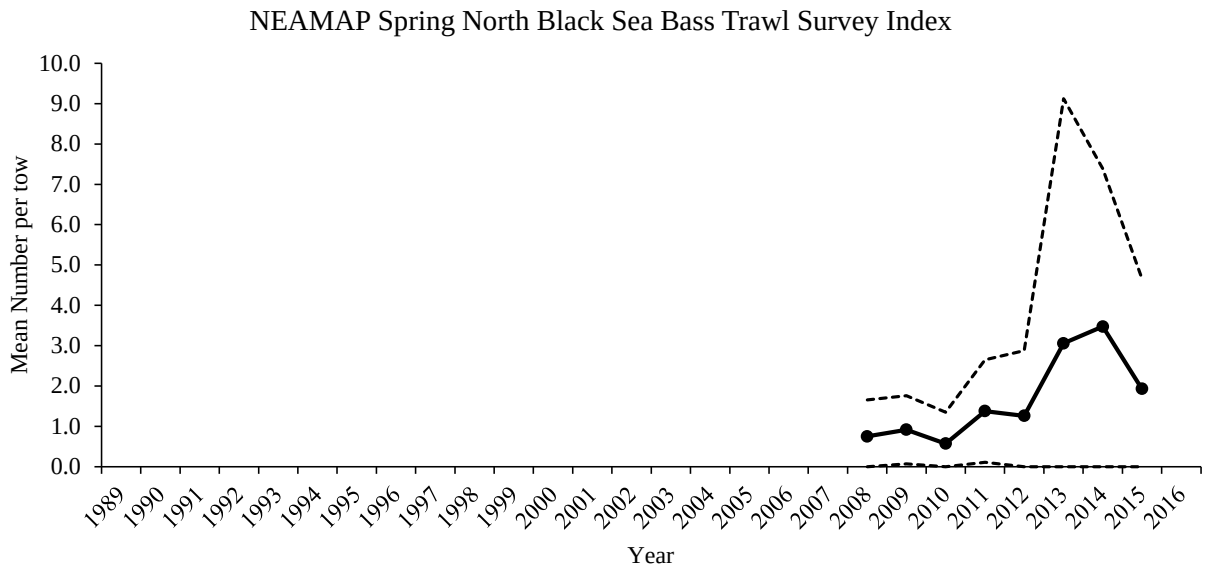

Figure A17. NEAMAP spring trawl survey indices (± 95% CI bounded by 0) of black sea bass abundance, ages 1-8+ collected in coastal strata north of Hudson Canyon, 2008-2015.

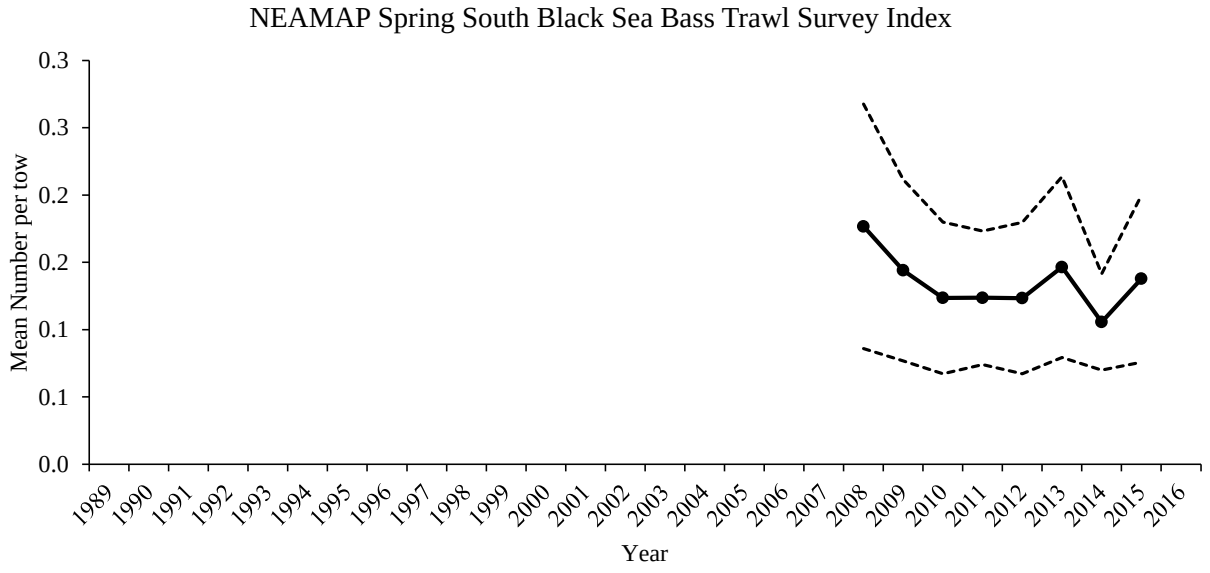

Figure A18. NEAMAP spring trawl survey indices (± 95% CI) of black sea bass abundance, ages 1-8+ collected in coastal strata south of Hudson Canyon, 2008-2015.

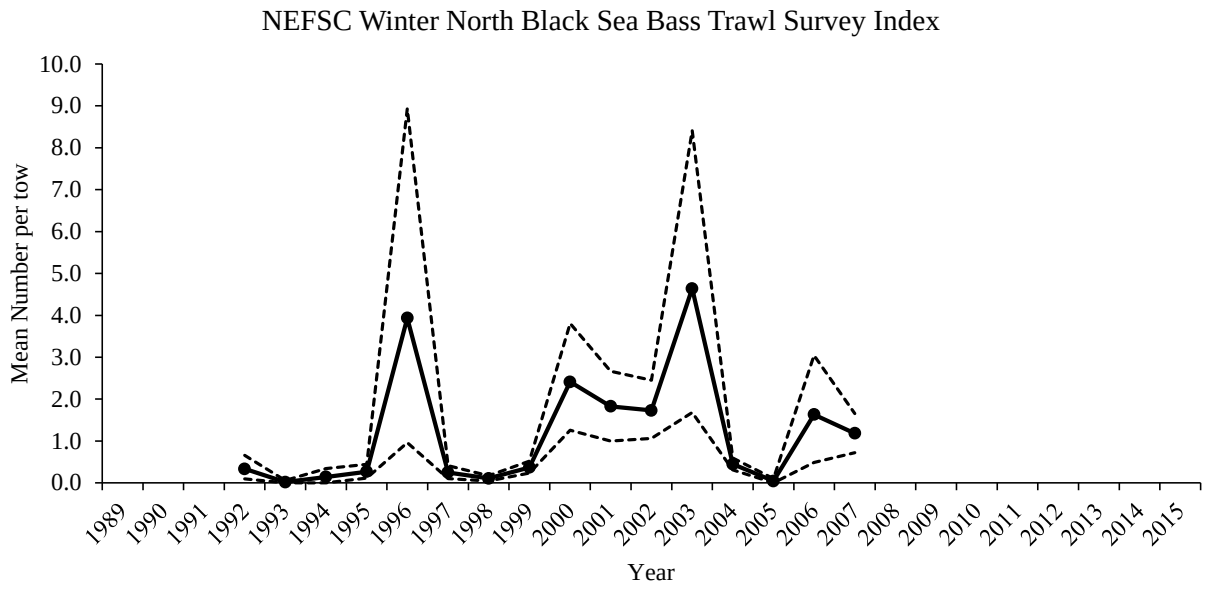

Figure A19. NEFSC winter trawl survey indices (± 95% CI) of black sea bass abundance, ages 1-8+ collected in offshore strata north of Hudson Canyon 1992-2007.

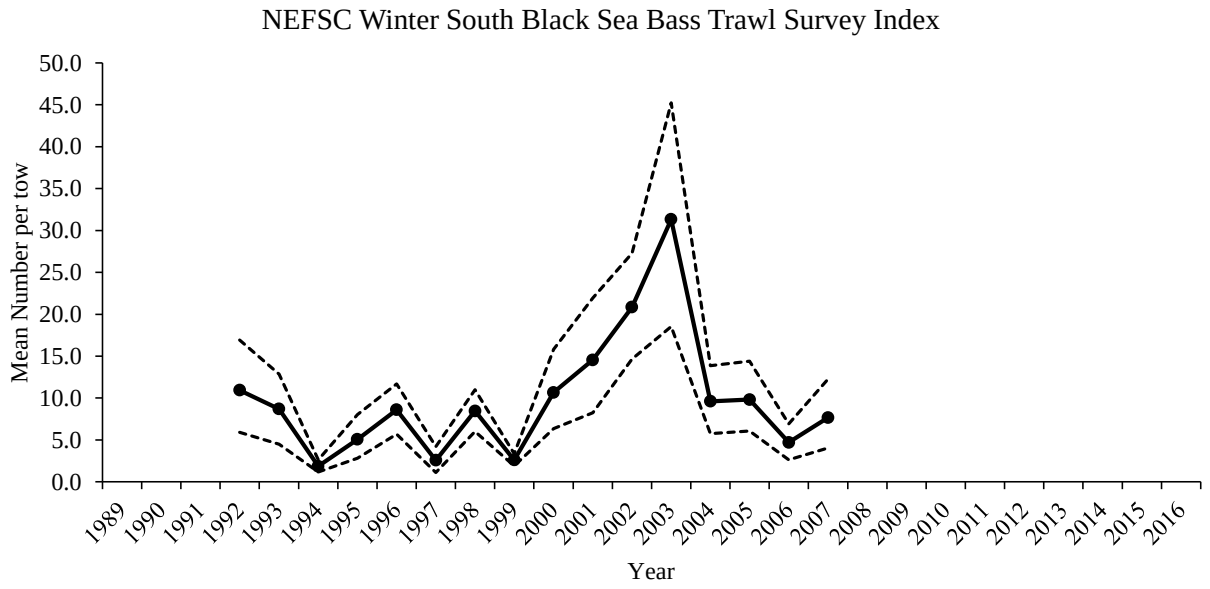

Figure A20. NEFSC winter trawl survey indices (± 95% CI) of black sea bass abundance, ages 1-8+ collected in offshore strata south of Hudson Canyon 1992-2007.

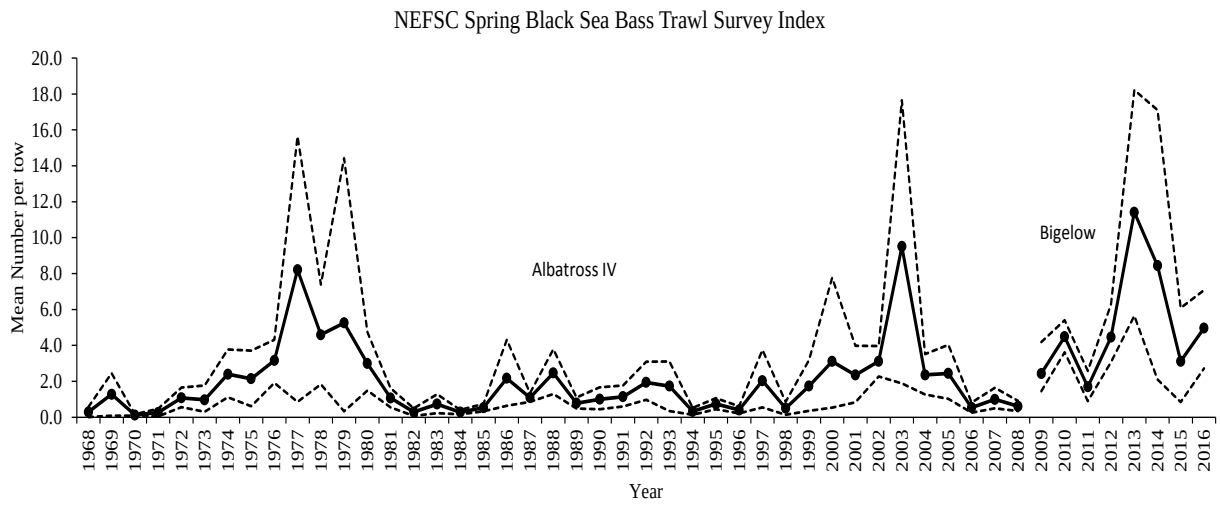

Figure A21. NEFSC spring trawl survey mean number per tow (± 95% CI), 1969-2016, from offshore strata. Bigelow indices are not calibrated to the Albatross series.

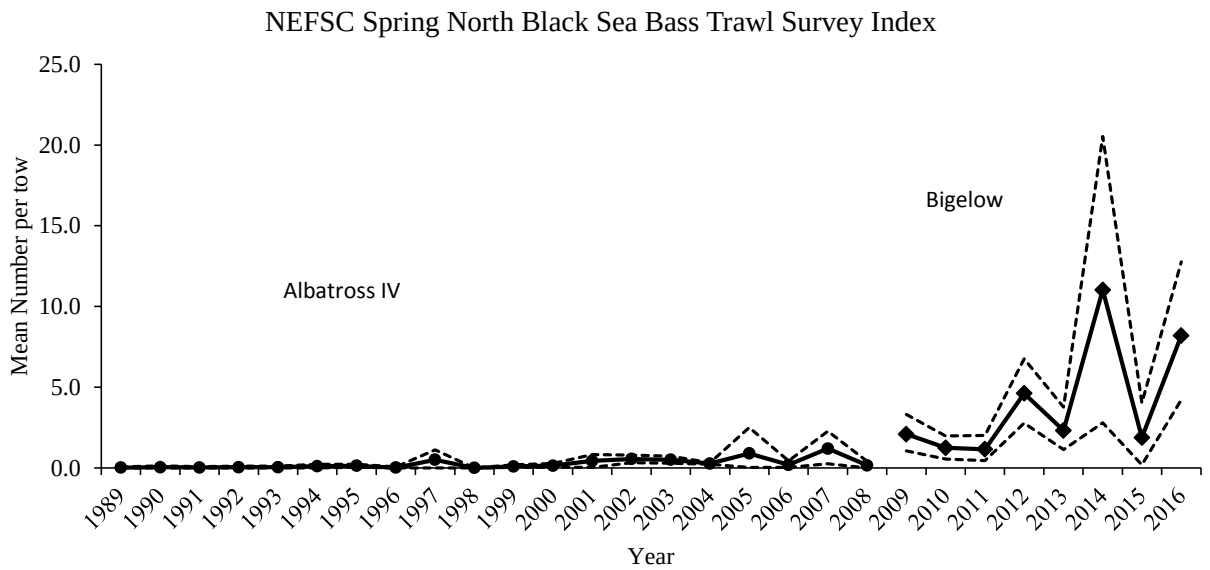

Figure A22. NEFSC spring trawl survey indices (± 95% CI) of black sea bass abundance, ages 1-8+ collected in offshore strata north of Hudson Canyon, 1989-2008 (*Albatross*) and 2009-2016 (*Bigelow*).

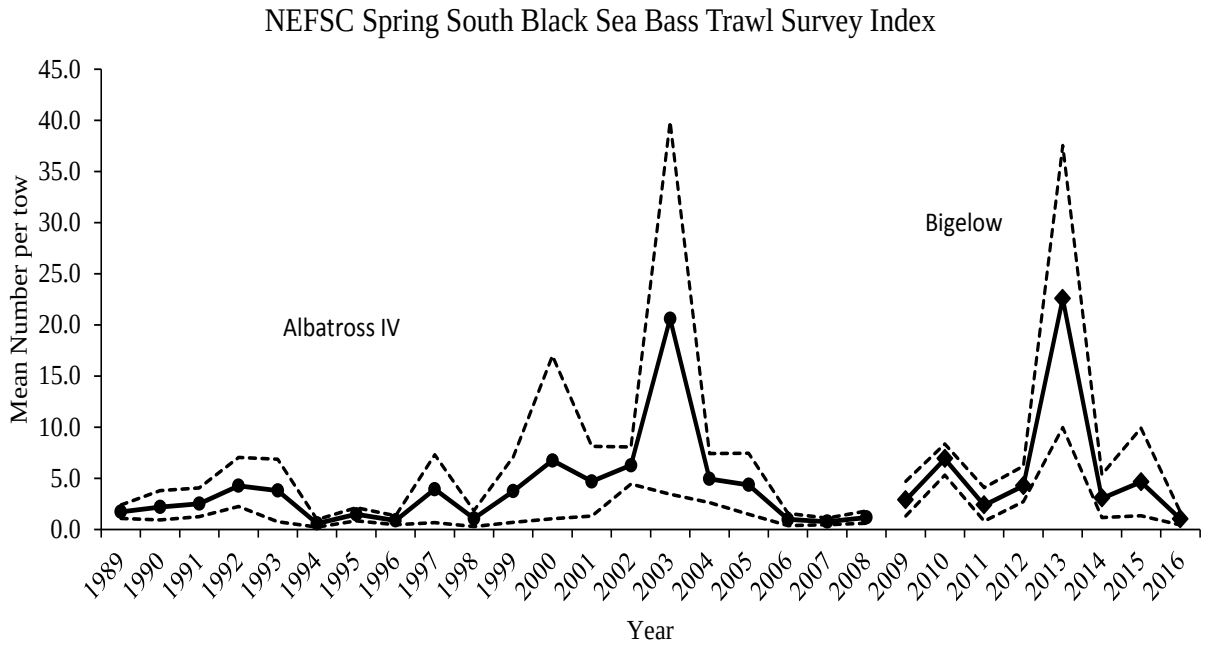

Figure A23. NEFSC spring trawl survey indices (± 95% CI) of black sea bass abundance, ages 1-8+ collected in offshore strata south of Hudson Canyon, 1989-2008 (*Albatross*) and 2009-2016 (*Bigelow*).

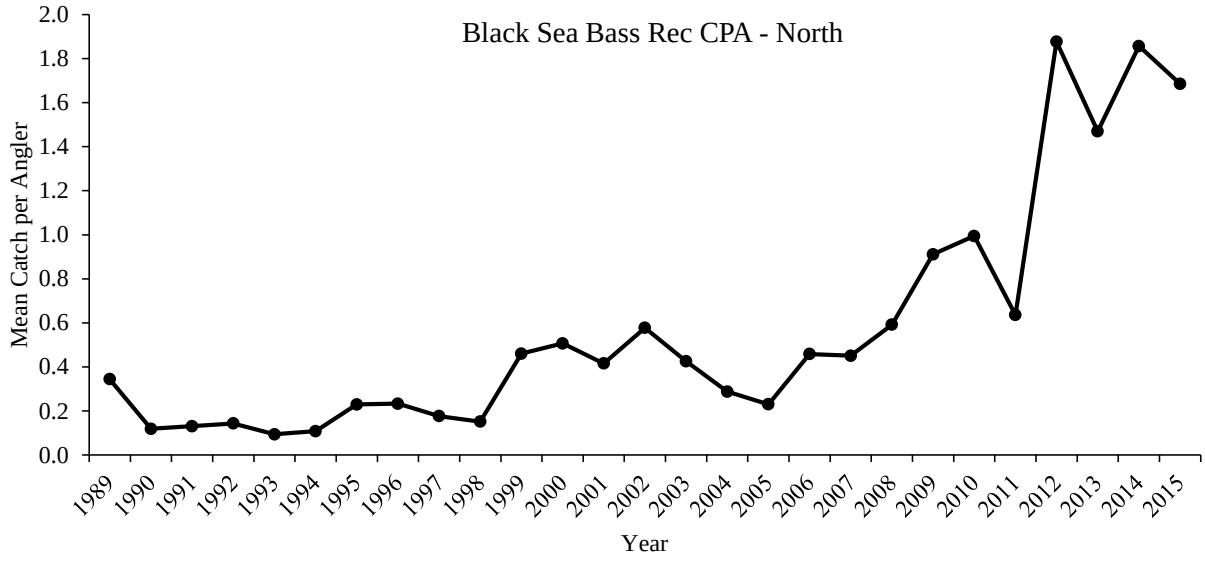

Figure A24. Recreational catch per angler for black sea bass caught from NY north, 1989-2015.

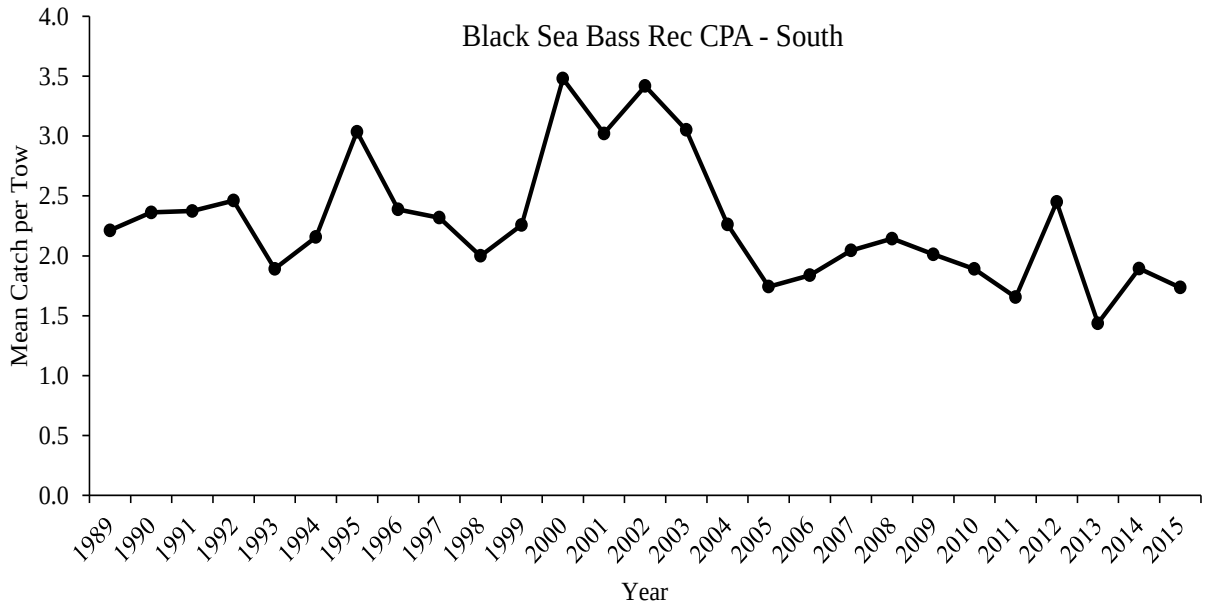

Figure A25. Recreational catch per angler for black sea bass caught from NJ south, 1989-2015.

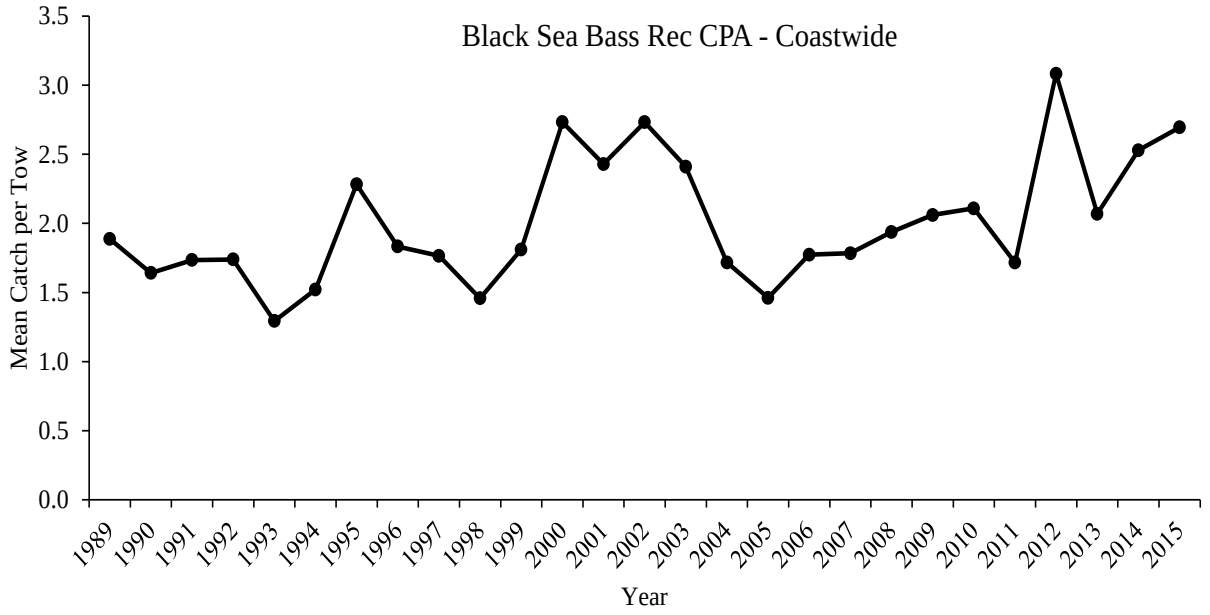

Figure A26. Recreational catch per angler for black sea bass caught from NC to ME, 1989-2015.

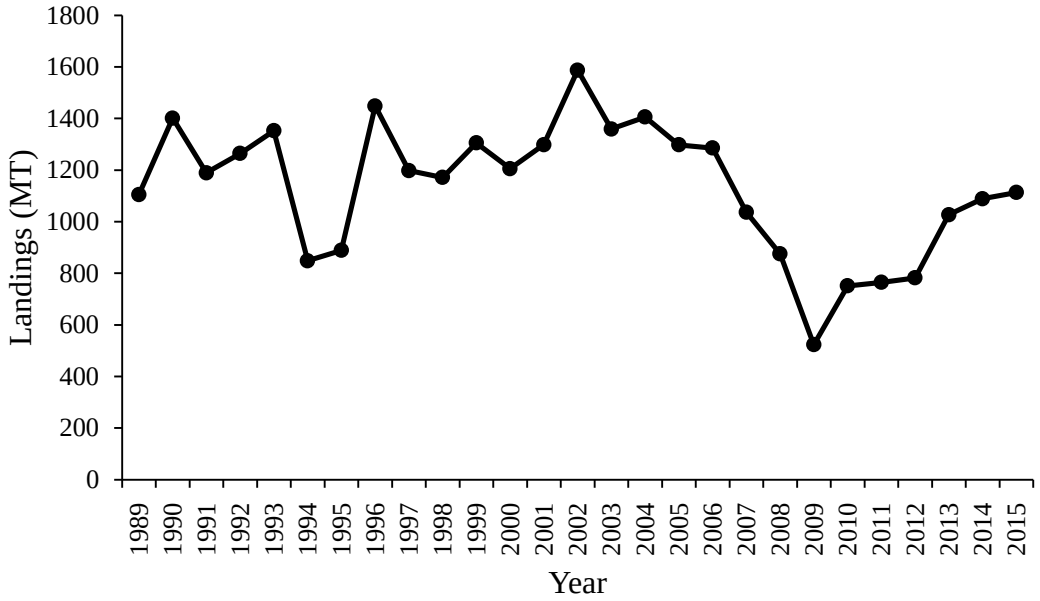

Figure A27. Commercial black sea bass Landings (mt), Maine-Cape Hatteras,NC, 1989-2015.

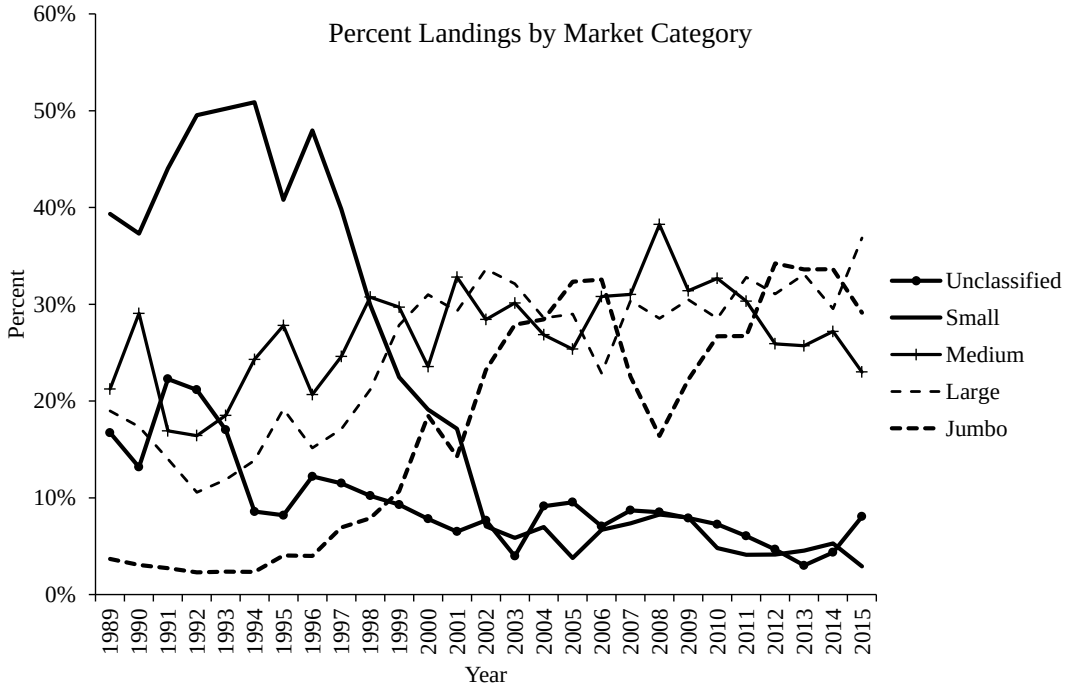

Figure A28. Percent of black sea bass commercial landings by market category, 1989-2015.

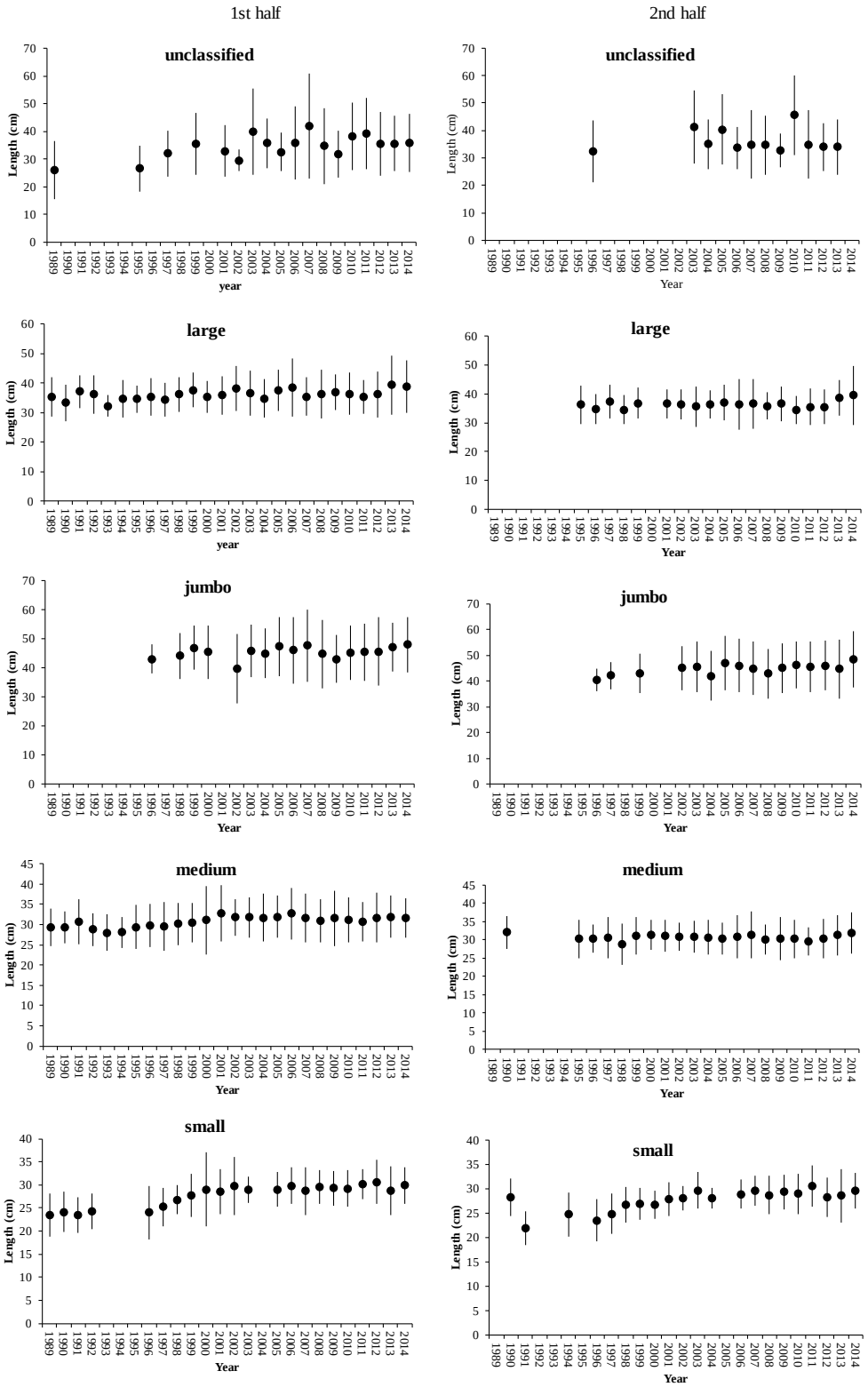

Figure A29. Mean length (cm ± 95% CI) of commercial landings black sea bass samples by market category, season and year.

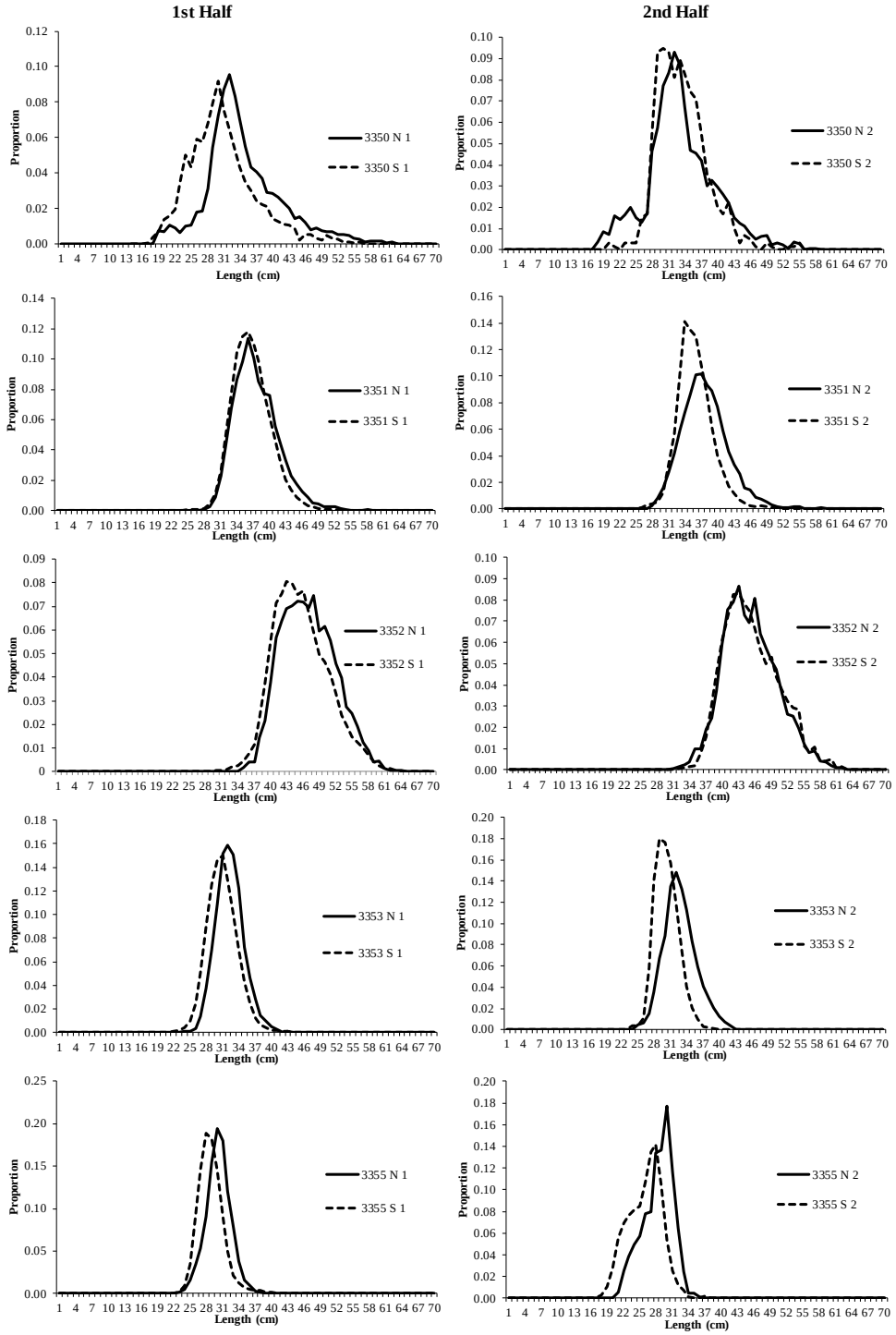

Figure A30. Comparison of black sea bass commercial landings length (cm) samples, by half year, collected north and south of Hudson Canyon. Length distributions in each panel represent the sum of samples in years common between areas.

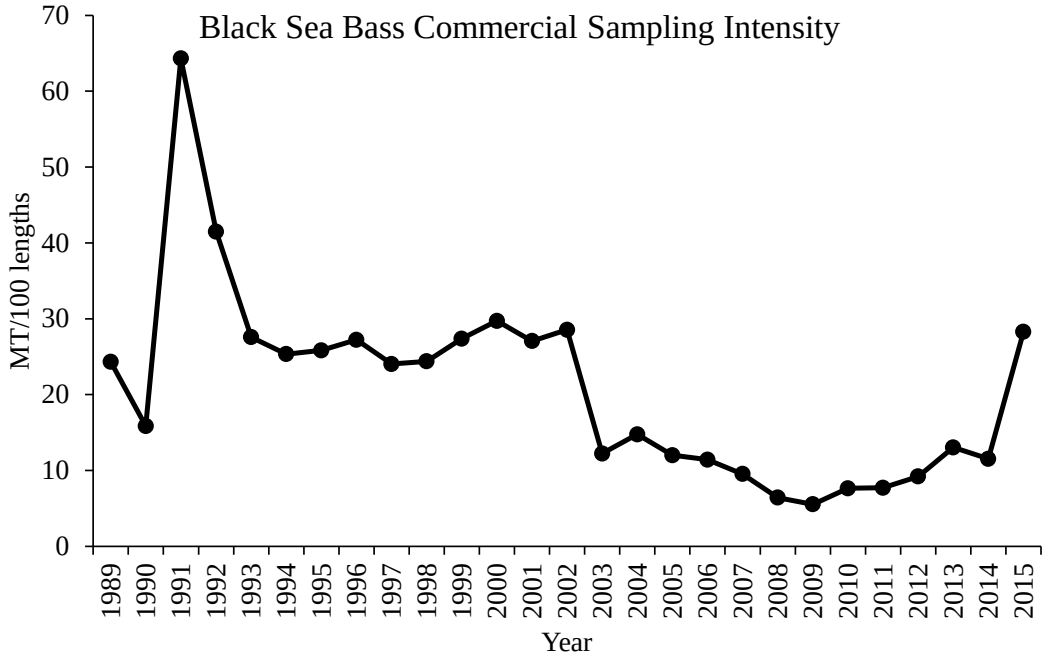

Figure A31. Annual sampling intensity for black sea bass sampled from the commercial fishery, 1989-2015. Intensity measured as the number of metric tons per length sampled. Larger values imply poorer sampling intensity.

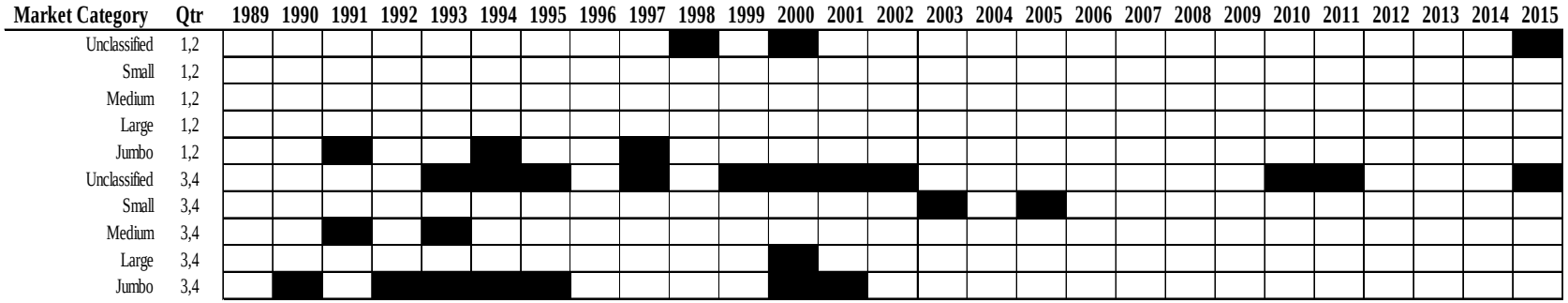

Figure A32. Black sea bass commercial length samples by market category and season (qtr 1,2 is Jan-Jun, qtr 3,4 is Jul-Dec) and year. Black squares in the matrix represent cells with no samples available and substitution required.

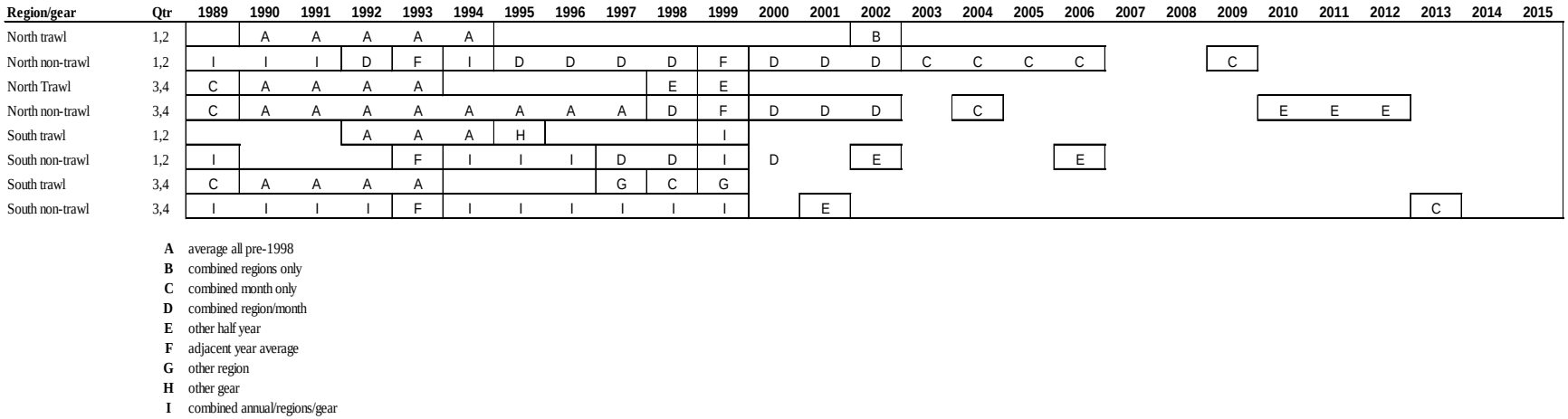

Figure A33. Sources of black sea bass commercial length sample by year, area and region. Cells without a letter indicate data available for that cell.

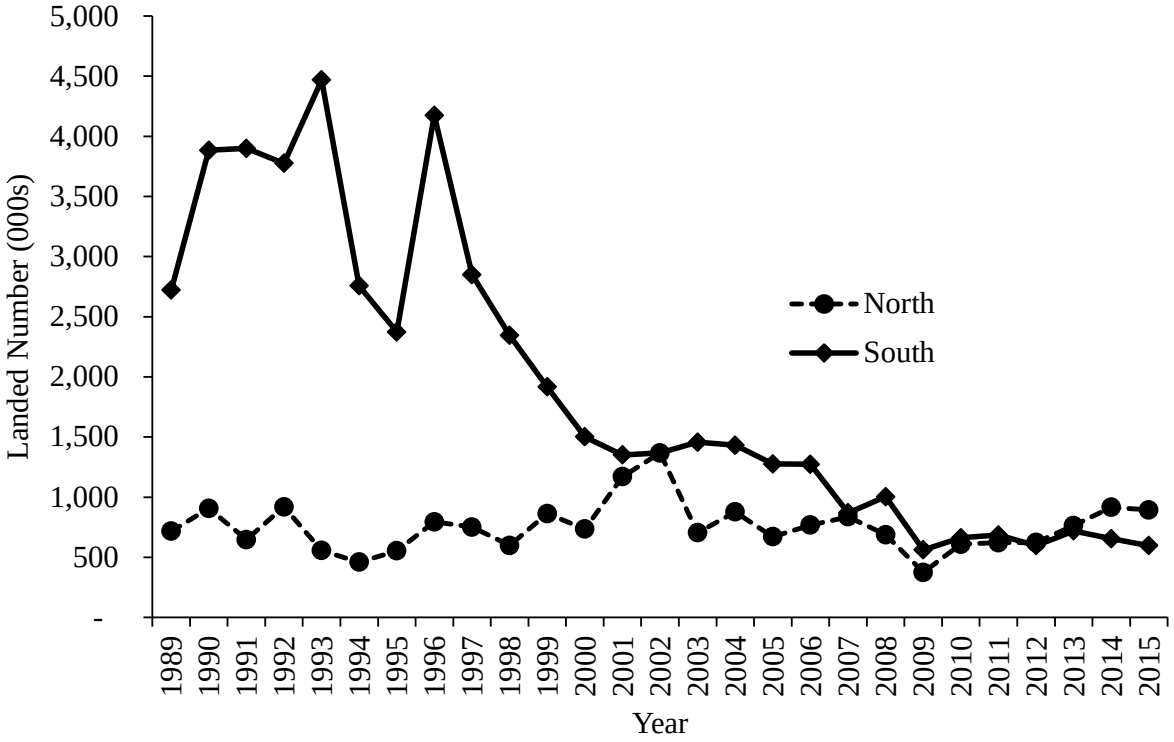

Figure A34. Black sea bass landings (number of fish in 000s) by area, 1989-2015.

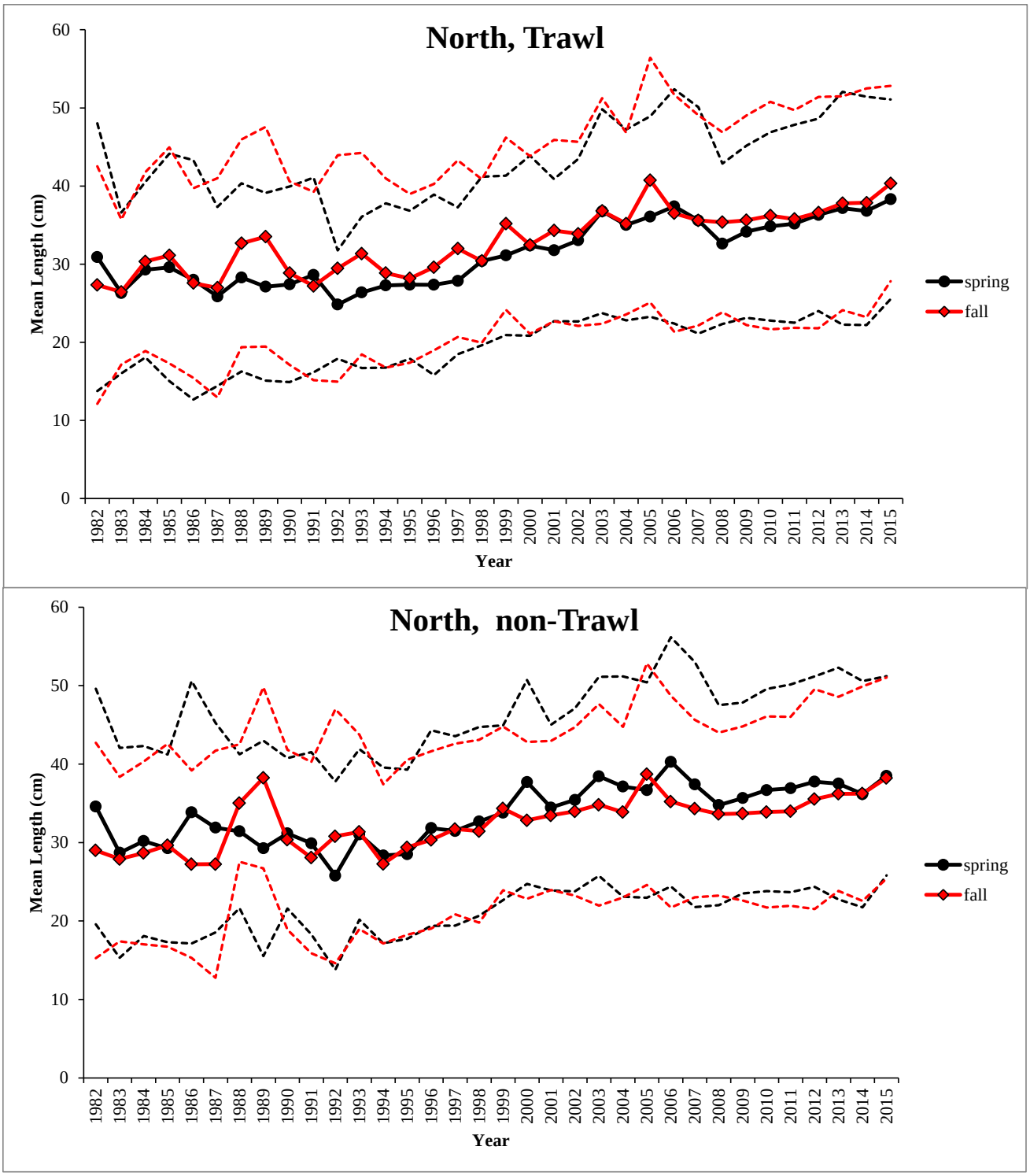

Figure A35. Annual mean length (cm ± 2 SD) from expanded black sea bass commercial landings length frequencies for northern region, by season and gear category, 1989-2015.

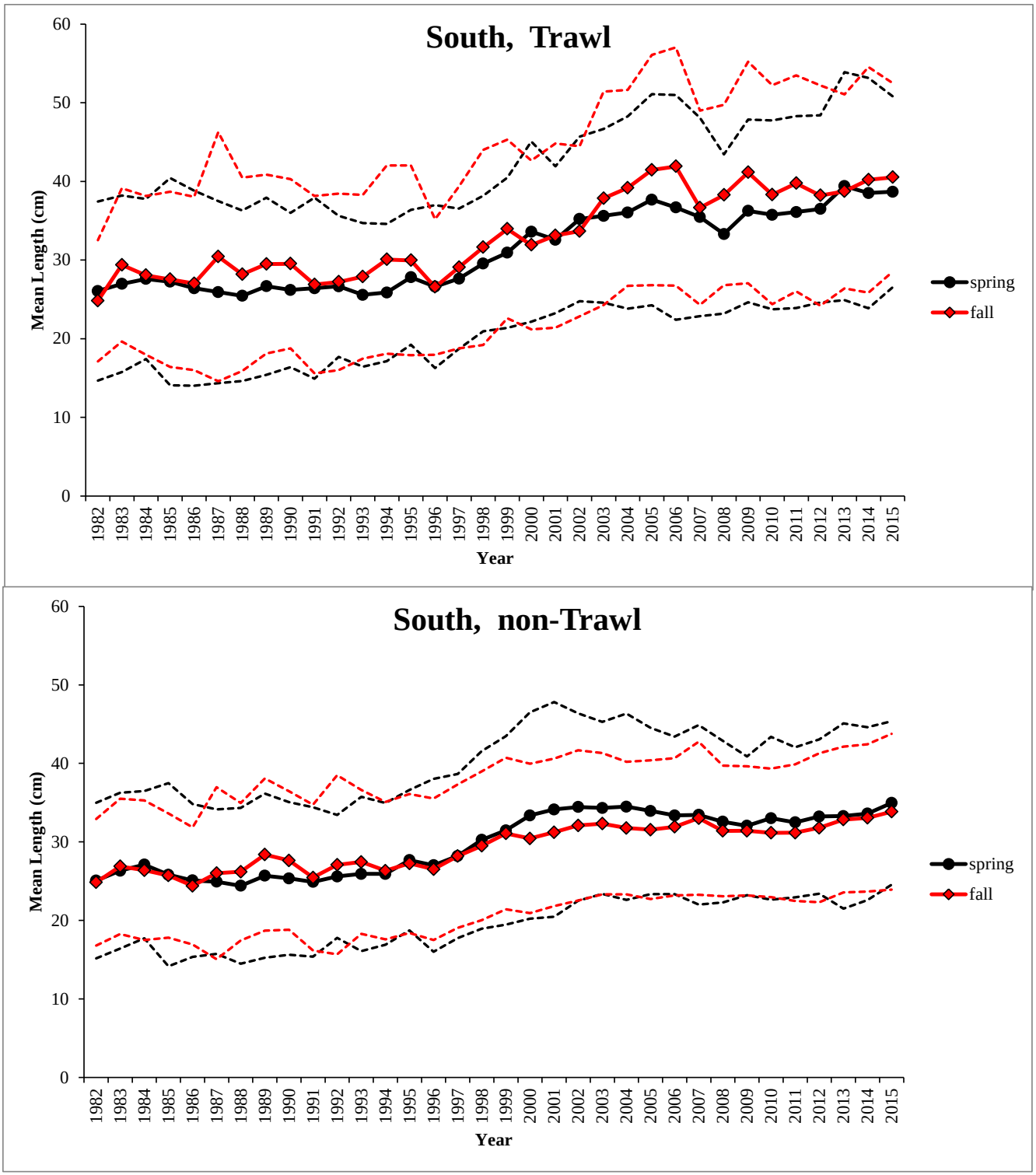

Figure A36. Annual mean length (cm ± 2 SD) from expanded commercial black sea bass landings length frequencies for South region, by season and gear category, 1989-2015.

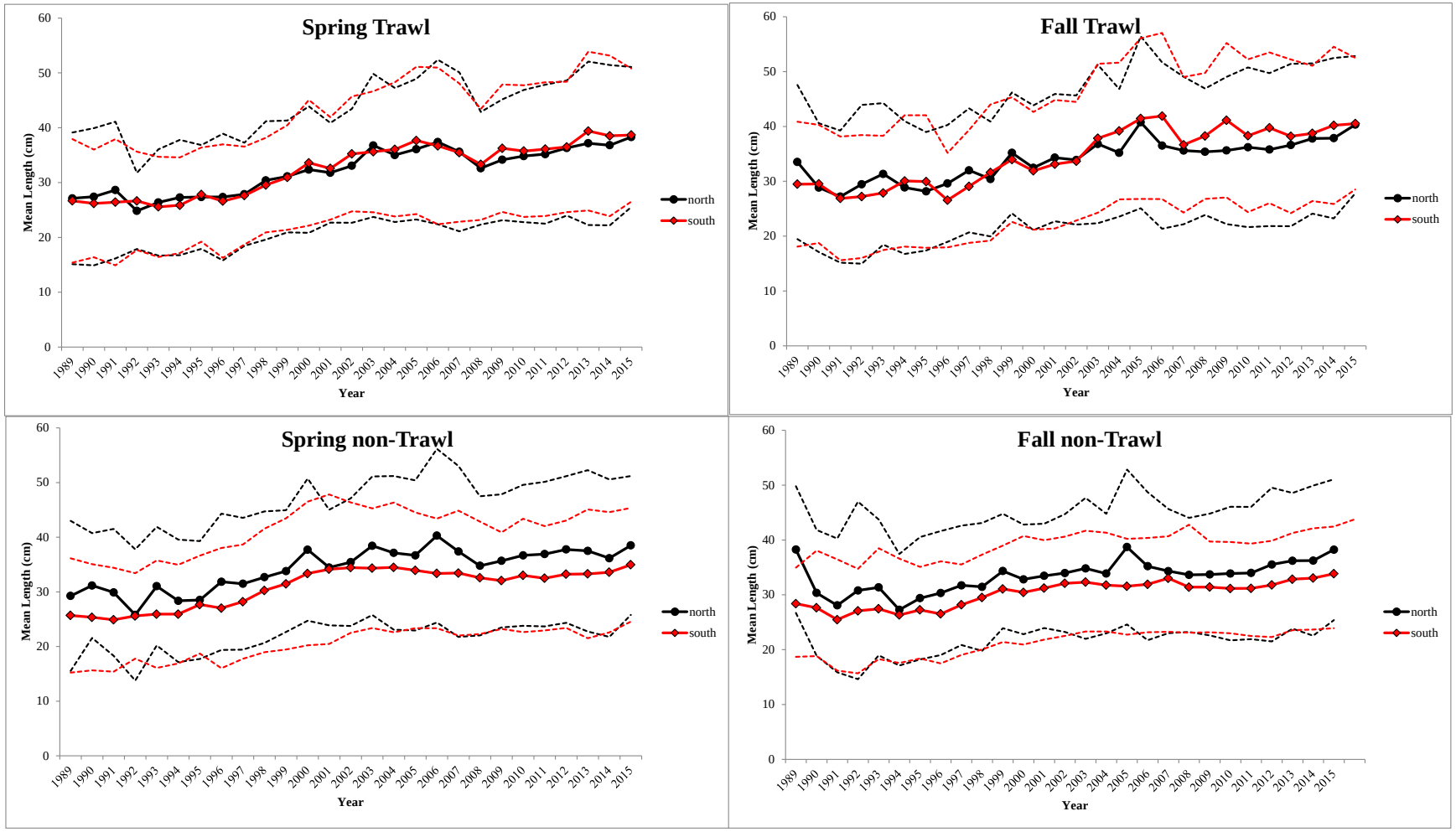

Figure A37. Annual mean black sea bass length (cm ± 2 SD) from expanded commercial landings length frequencies for region, by season and gear category, 1989-2015.

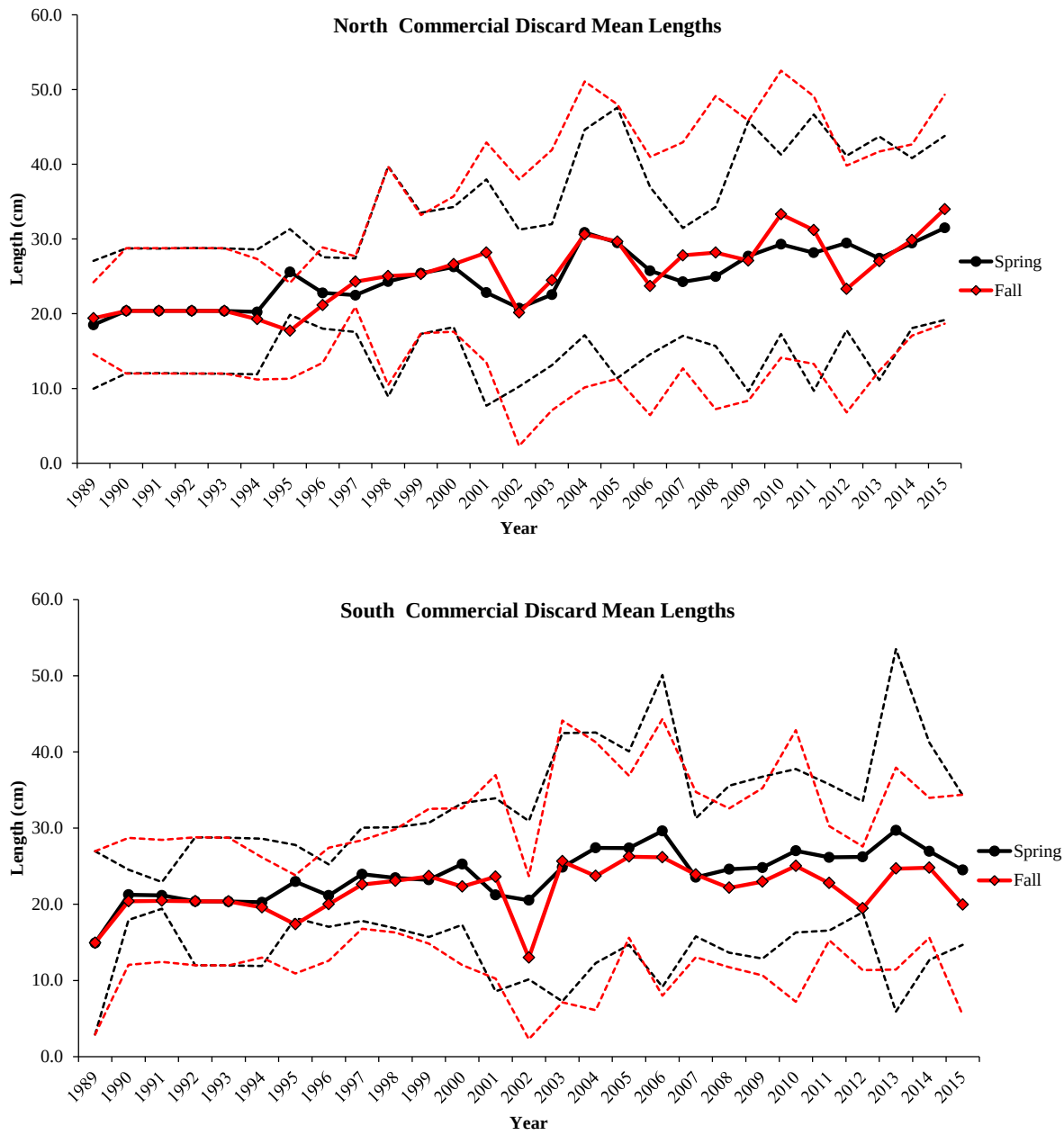

Figure A38. Annual mean black sea bass length (cm ± 2 SD) from expanded commercial discard length frequencies for region, by season 1989-2015.

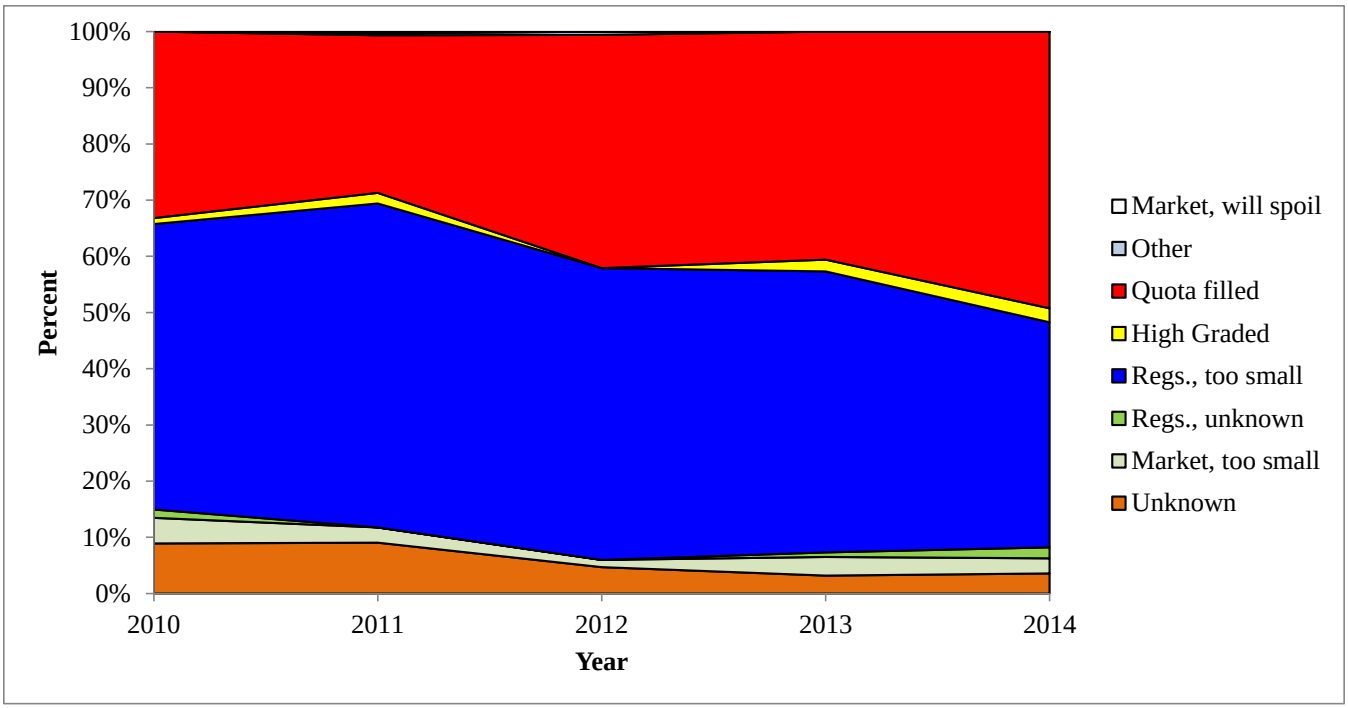

Figure A39. Reason for discarding black sea bass in commercial fisheries, 2010-2014.

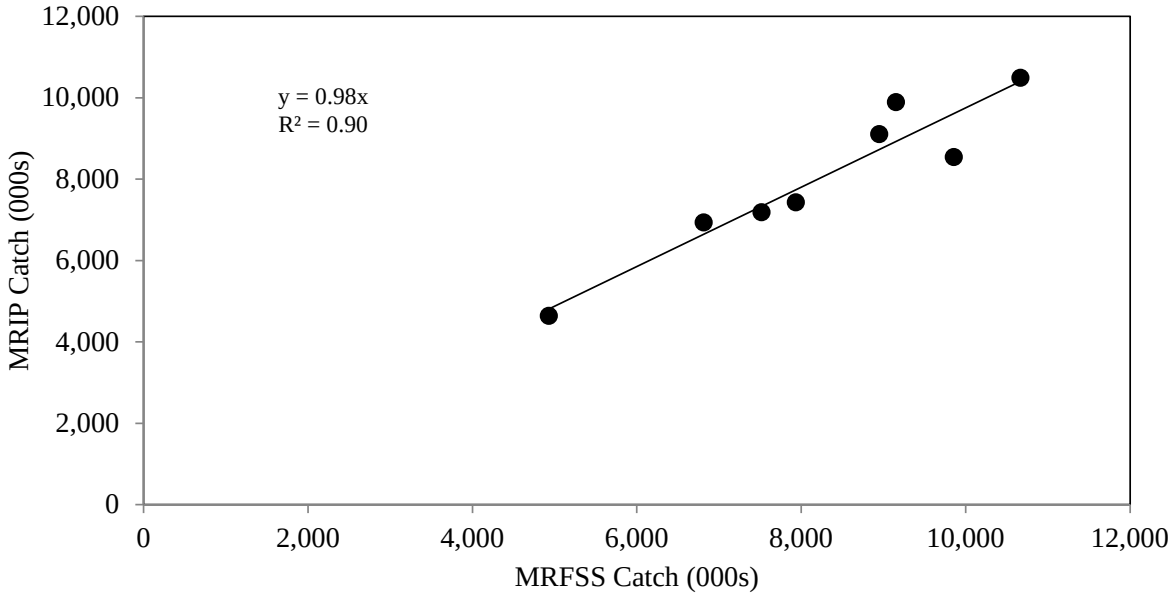

Figure A40. Relationship between black sea bass catch estimated by MRFSS survey vs MRIP survey, 2004-2011.

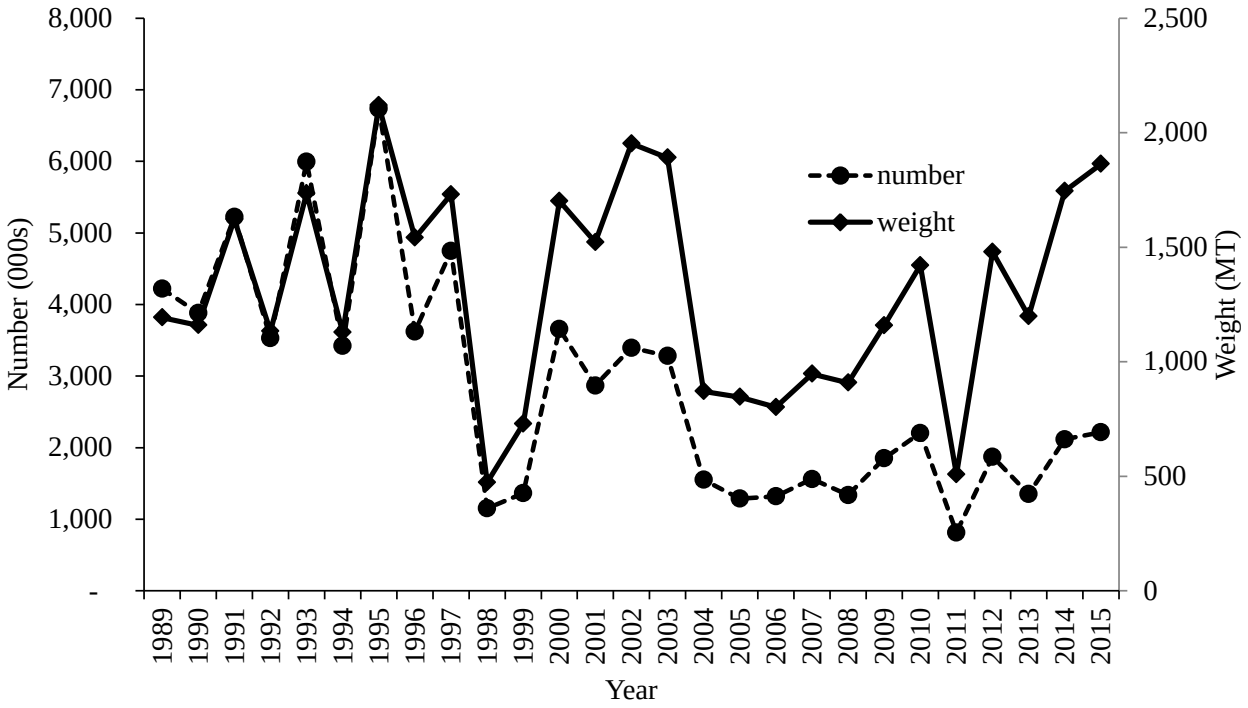

Figure A41. Black sea bass recreational landings (number) and weight (mt) coastwide, 1989-2015.

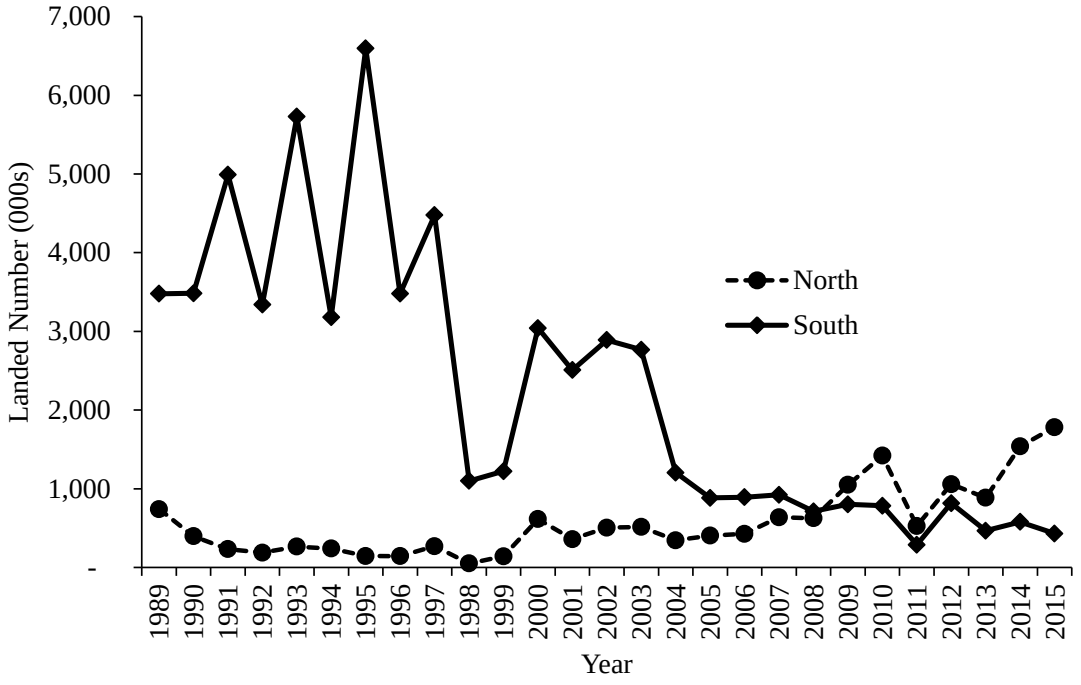

Figure A42. Black sea bass recreational landings (number) by year and region.

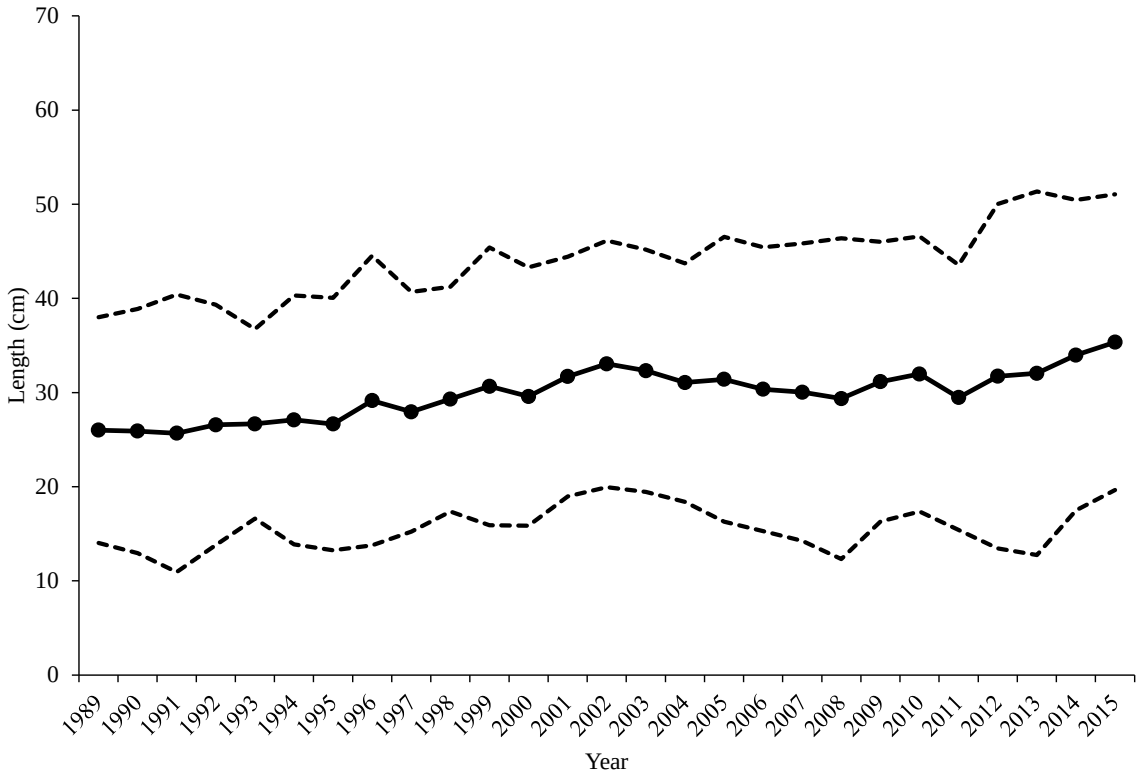

Figure A43. Mean length (± 2 SD) of black sea bass recreational landings, Maine to Cape Hatteras, NC, 1989-2015.

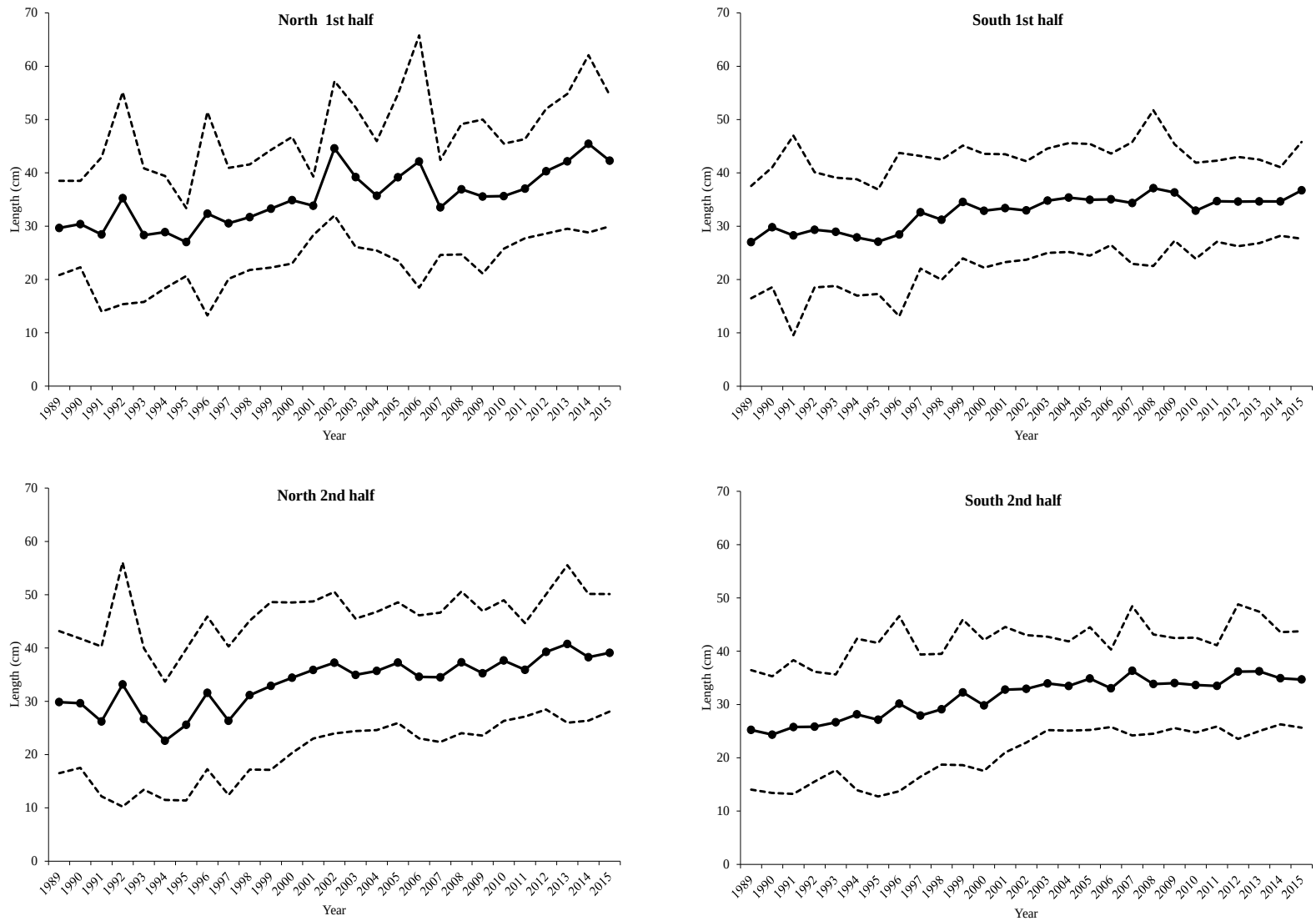

Figure A44. Mean length (cm ± 2 SD) of black sea bass recreational landings by region and season, 1989-2015.

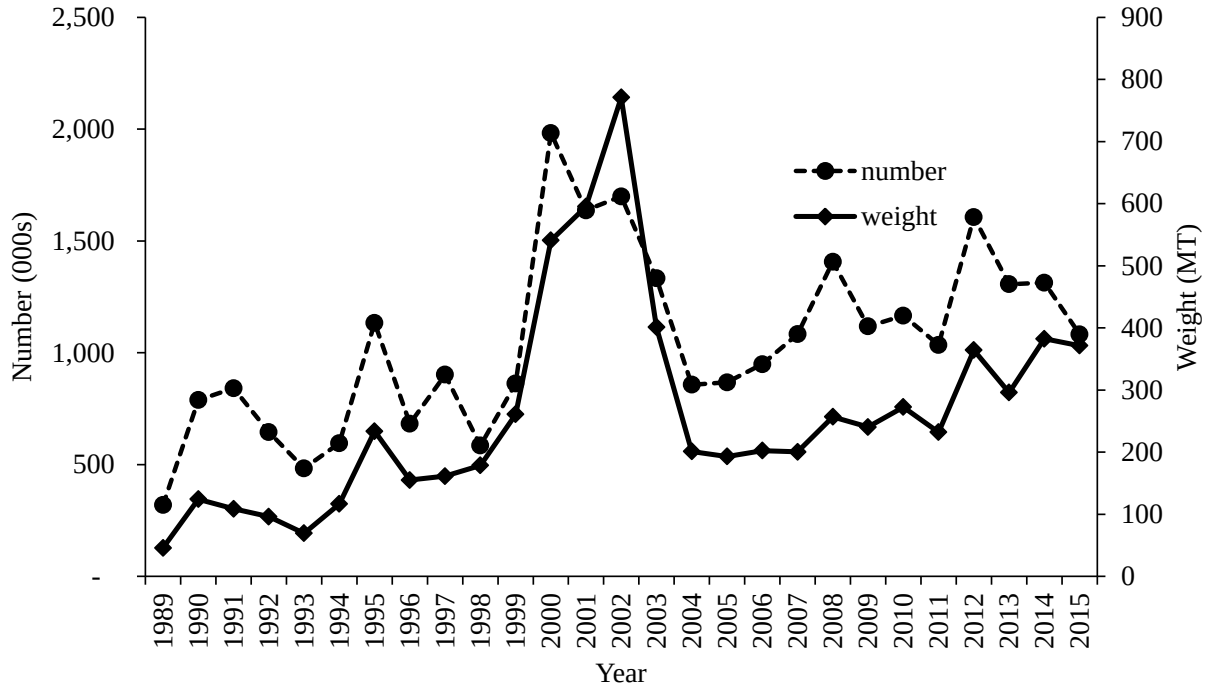

Figure A45. Black sea bass recreational discard mortalities (15% release mortality) by number and weight (mt) stock-wide, 1989-2015.

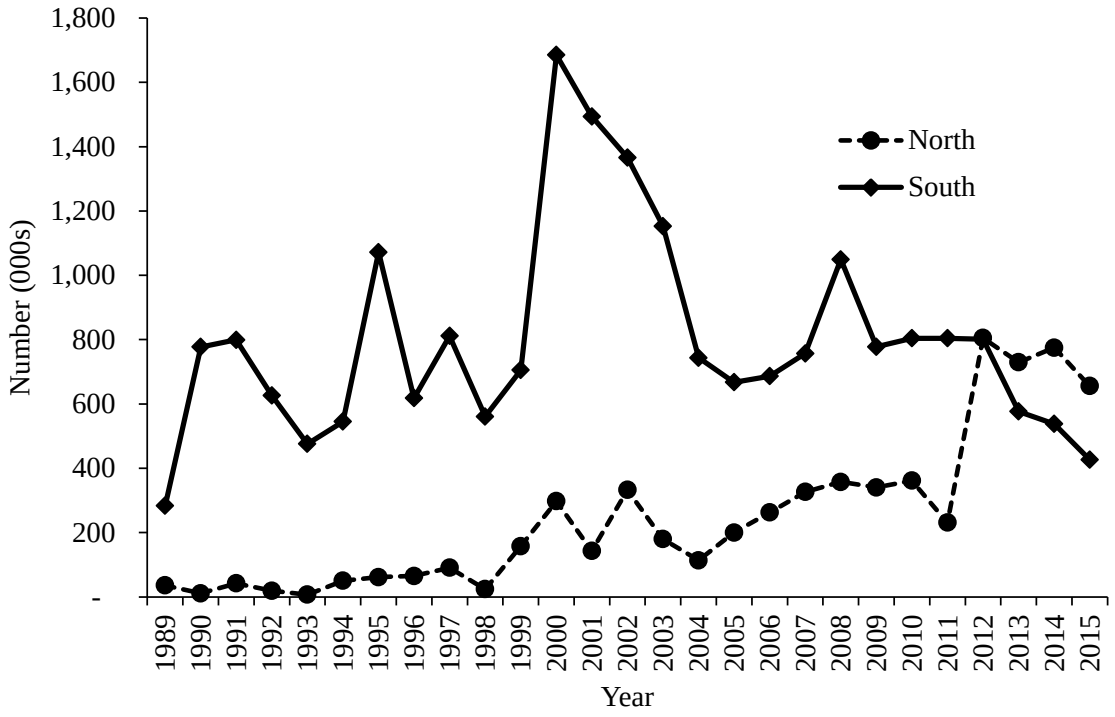

Figure A46. Black sea bass recreational discard mortalities (15% release mortality) by area, 1989-2015.

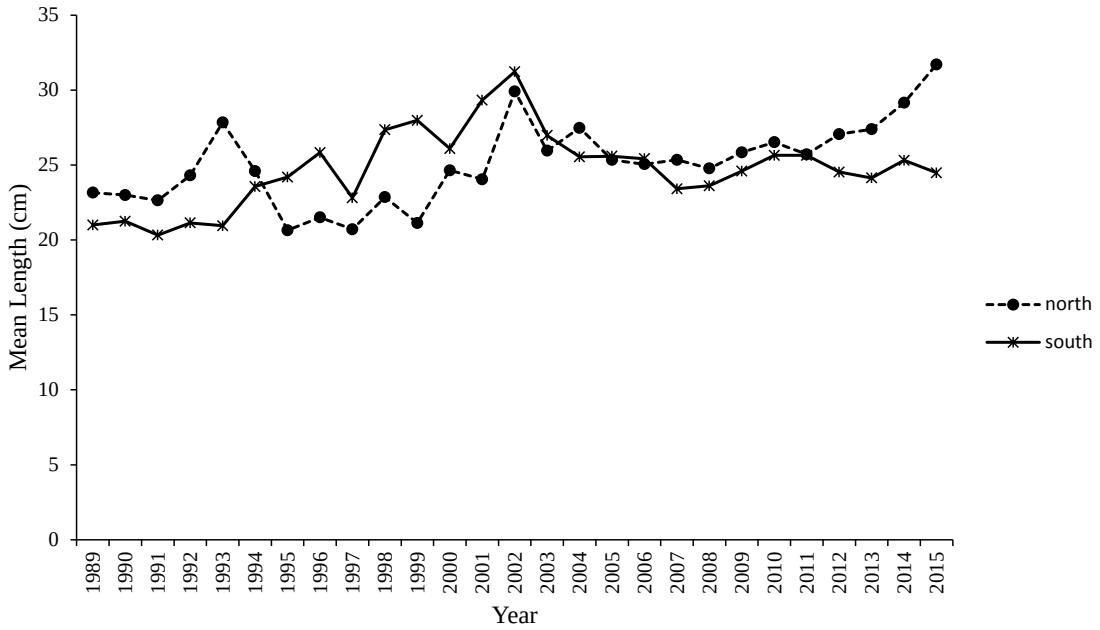

Figure A47. Mean length (cm) of black sea bass recreational discards by region.

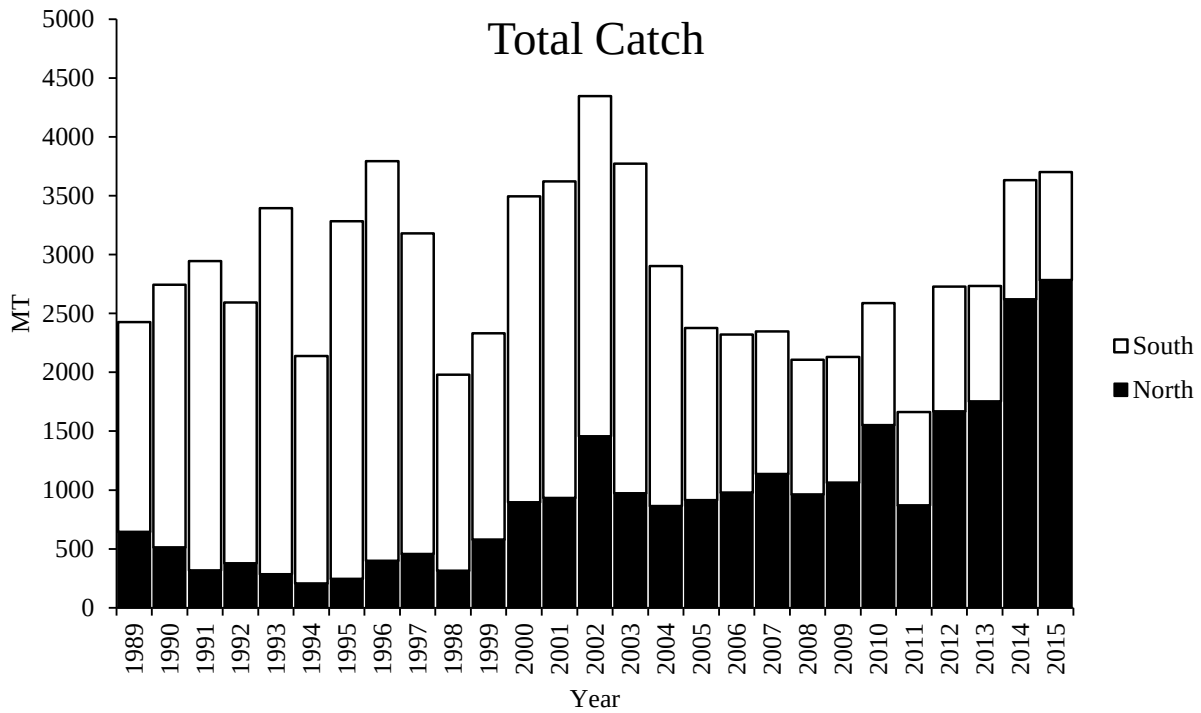

Figure A48. Total black sea bass catch (mt) by region, 1989-2015.

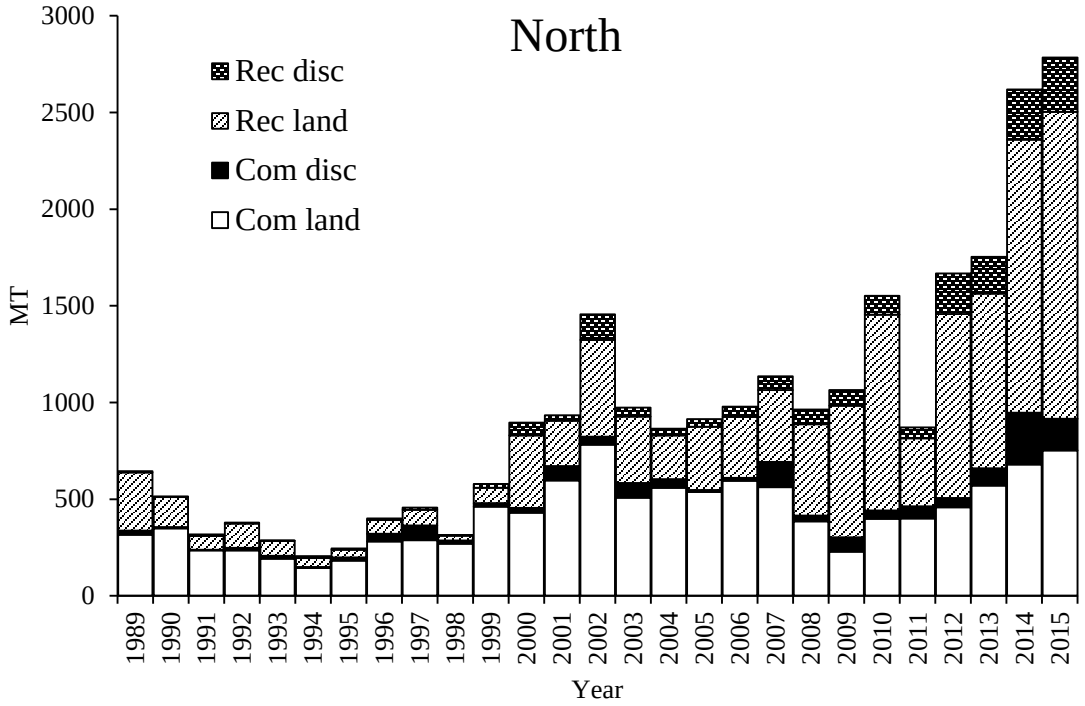

Figure A49. Total black sea bass catch (mt) by fishery and disposition for the northern region, 1989-2015.

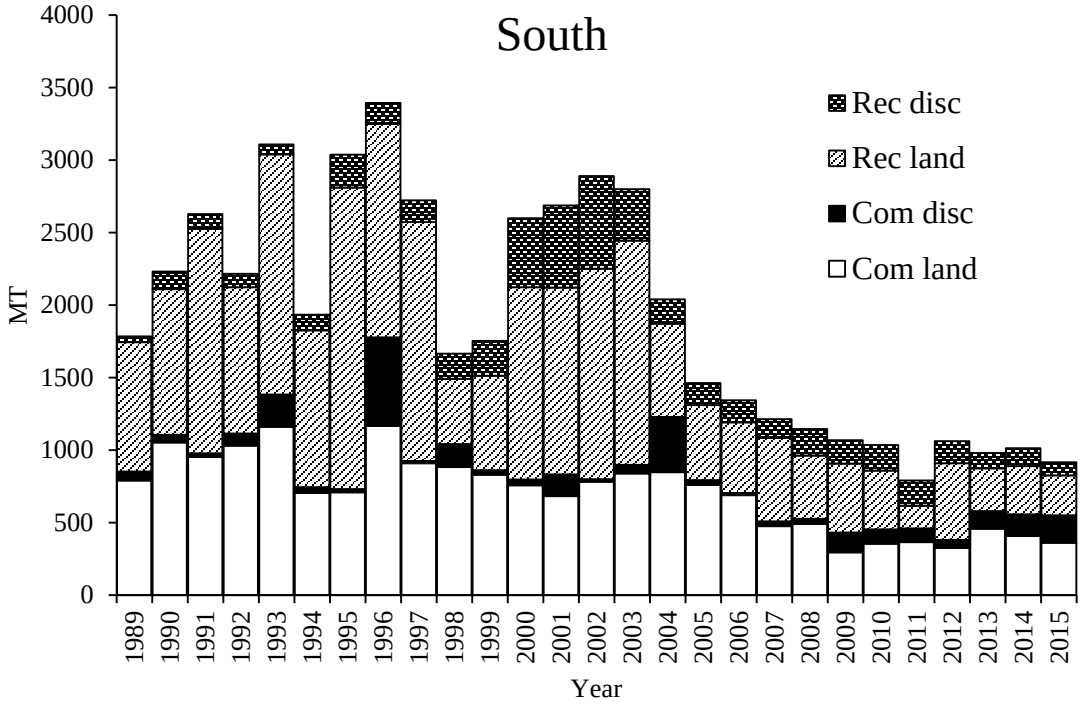

Figure A50. Total black sea bass catch (mt) by fishery and disposition for South region, 1989-2015.

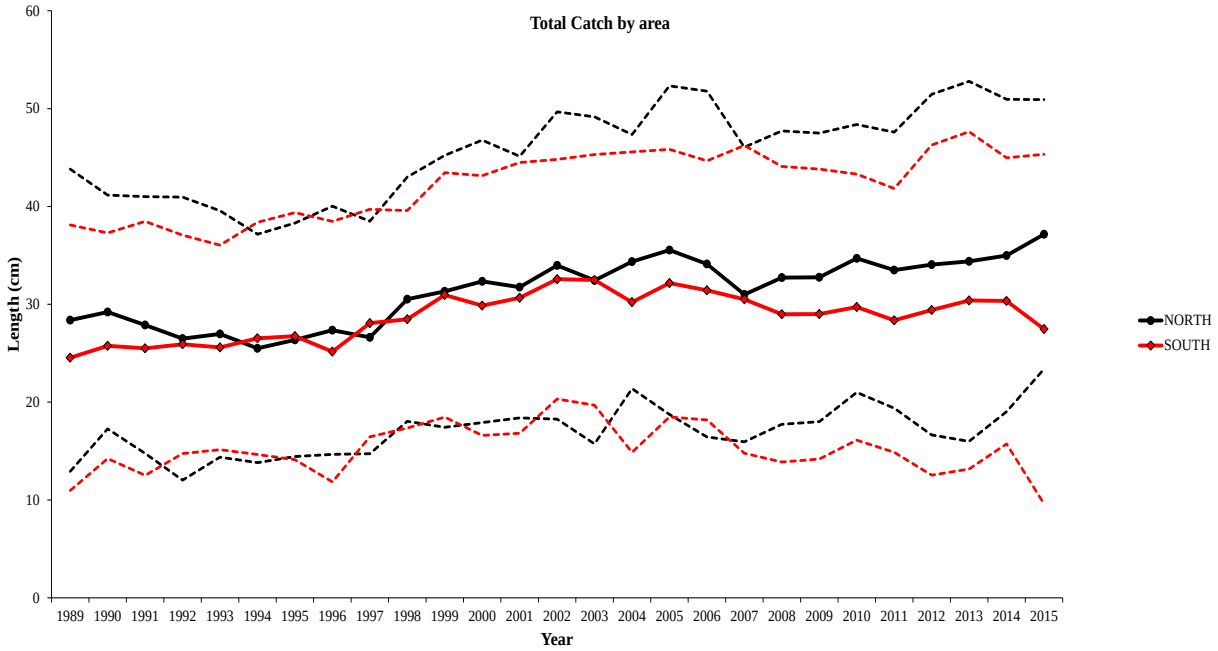

Figure A51. Mean length (± 2 SD) from black sea bass total expanded catch, by area, 1989-2015.

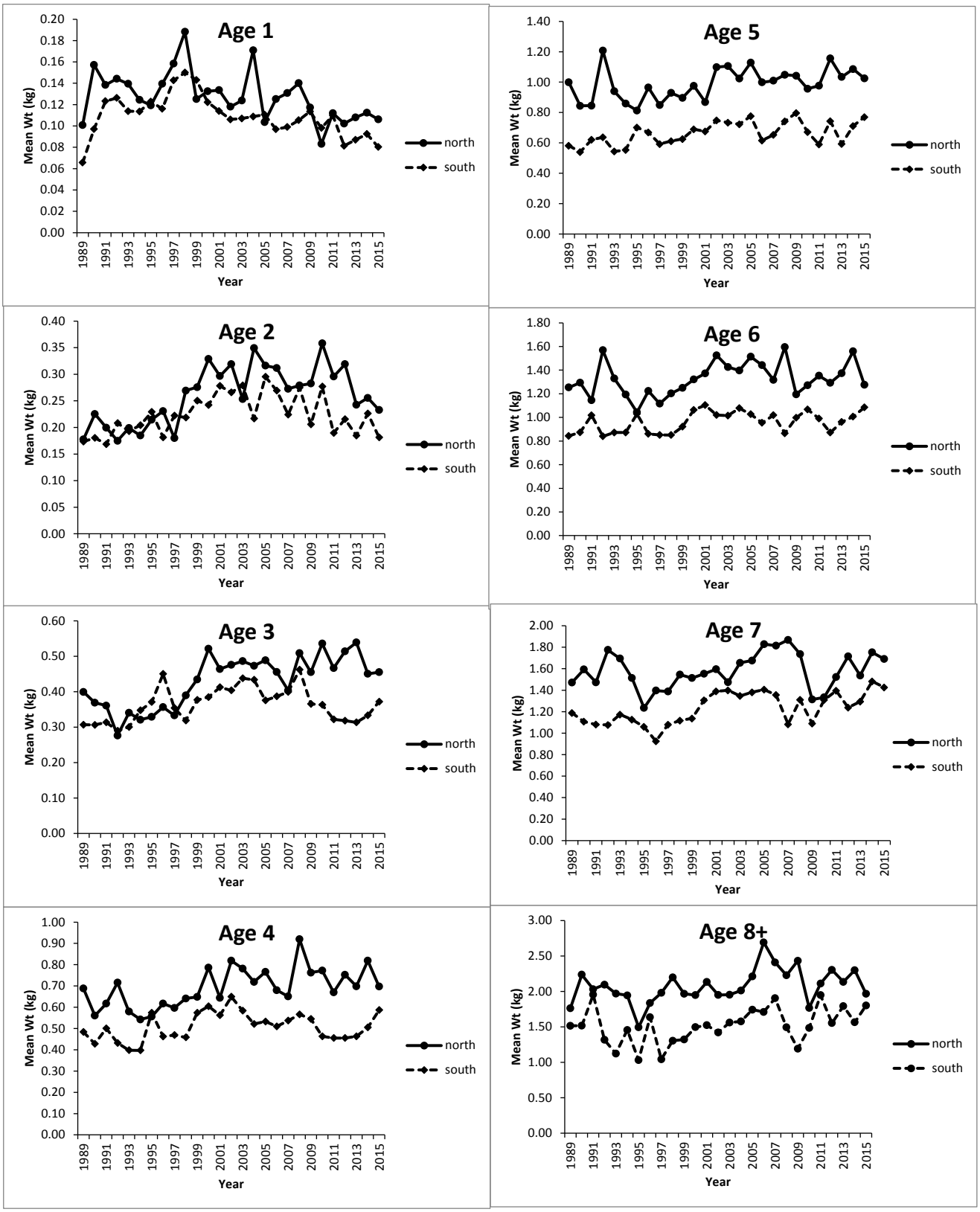

Figure A52. Mean weight at age (kg) for black sea bass by region, 1989-2015.

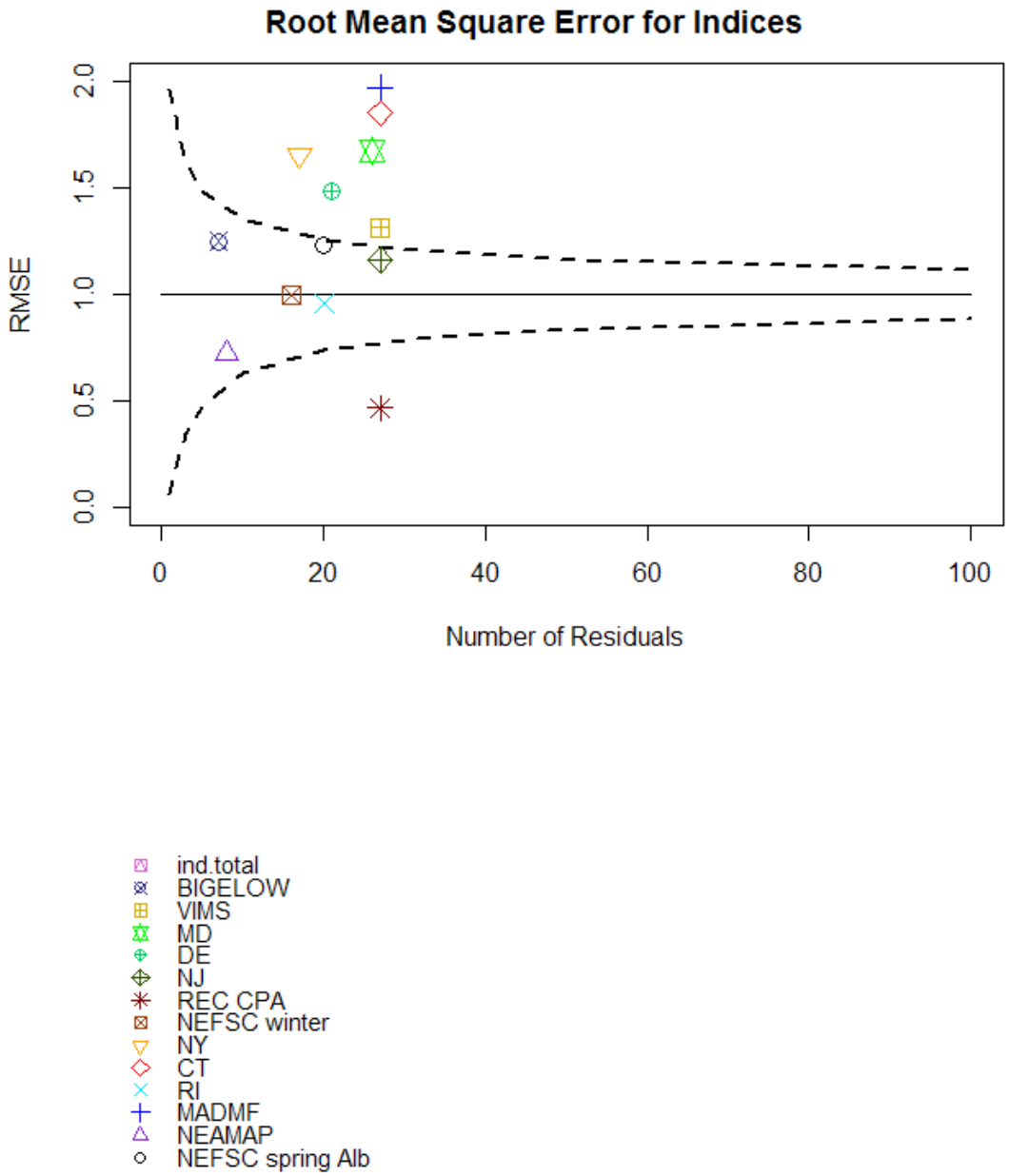

Figure A53. Final Root Mean Square Error (RMSE) values for black sea bass survey indices in final **Overall** single area model.

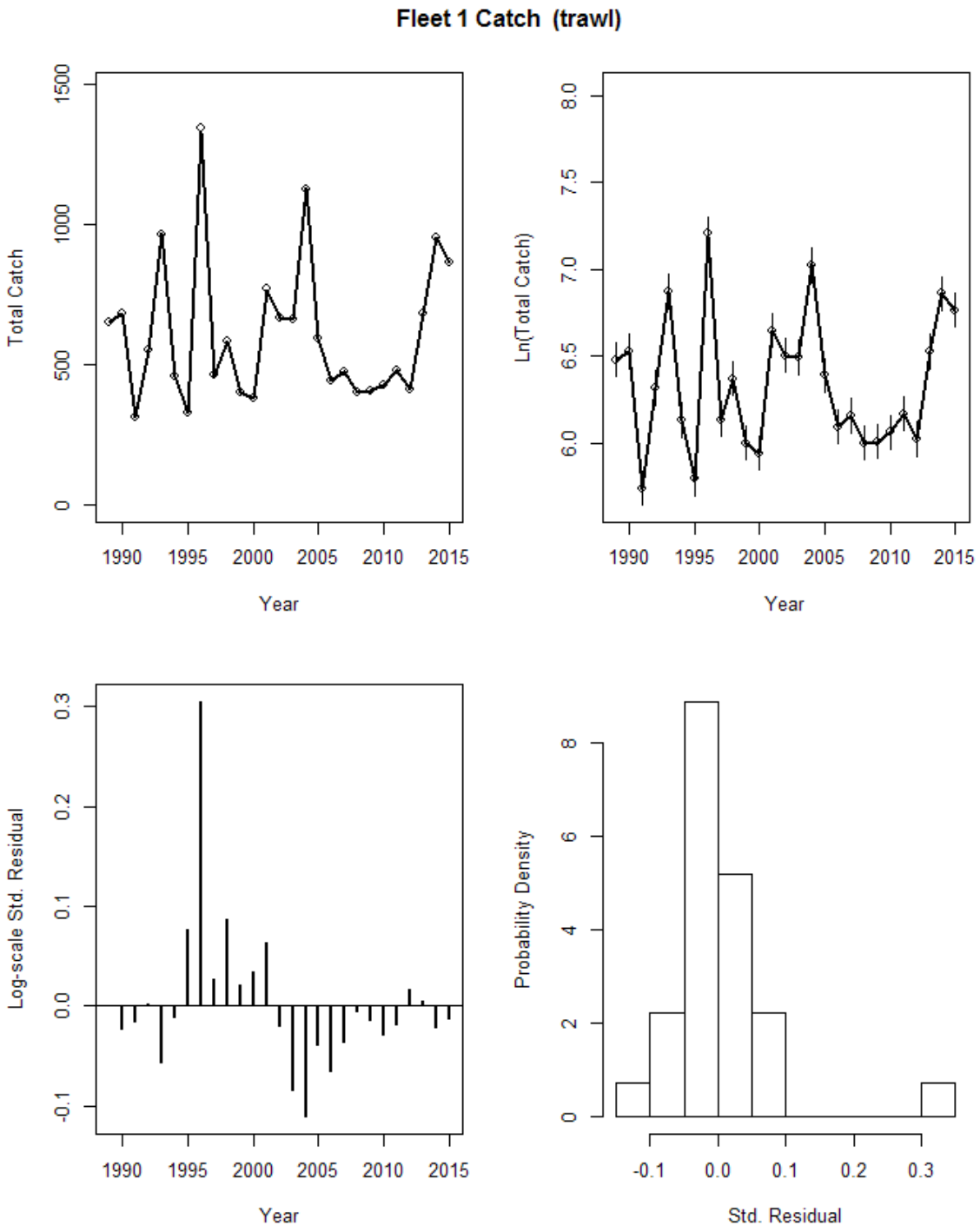

Figure A54. Fit diagnostics for the trawl catch in final black sea bass **Overall** single area model.

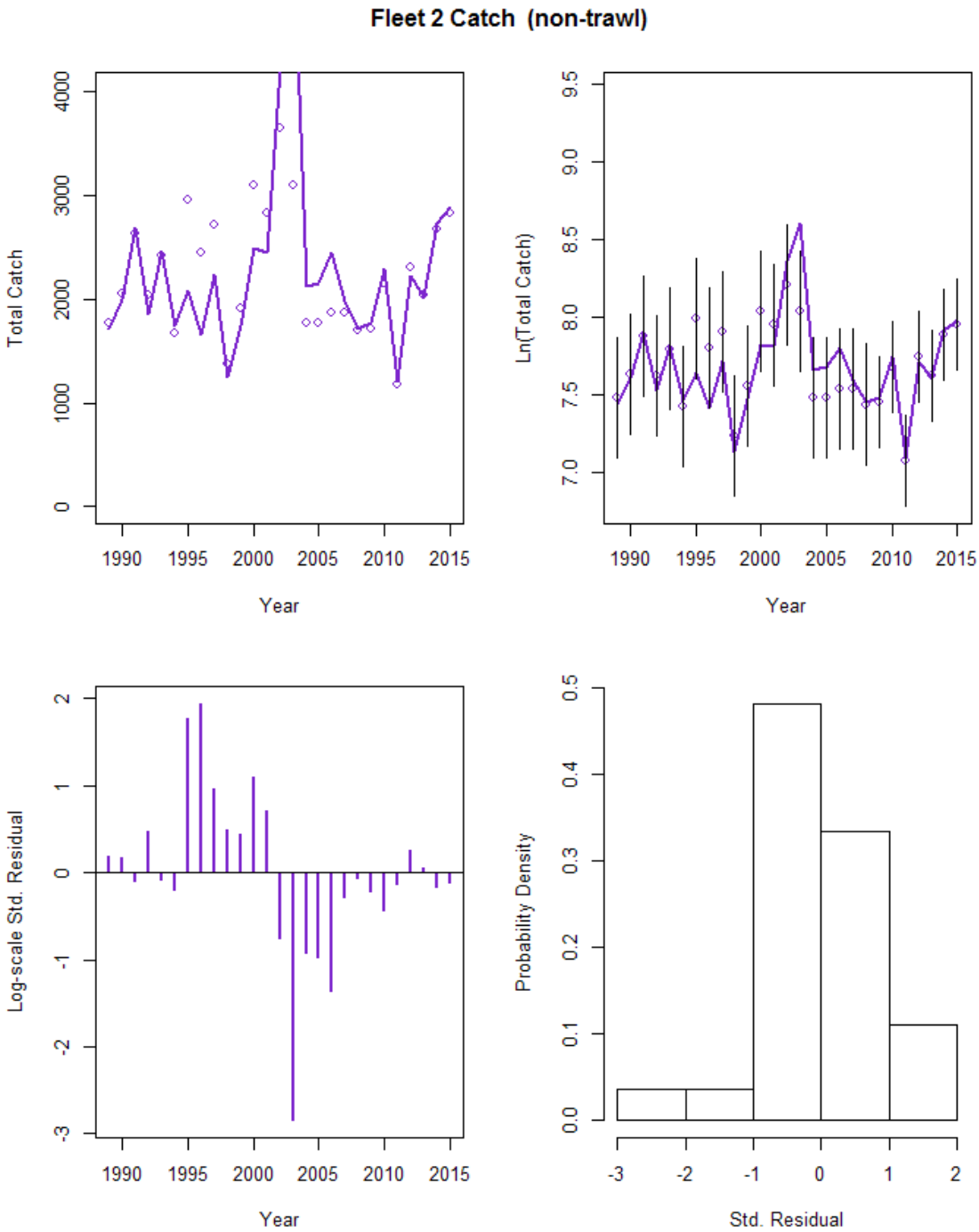

Figure A55. Fit diagnostics for the non- trawl catch in final black sea bass **Overall** single area model.

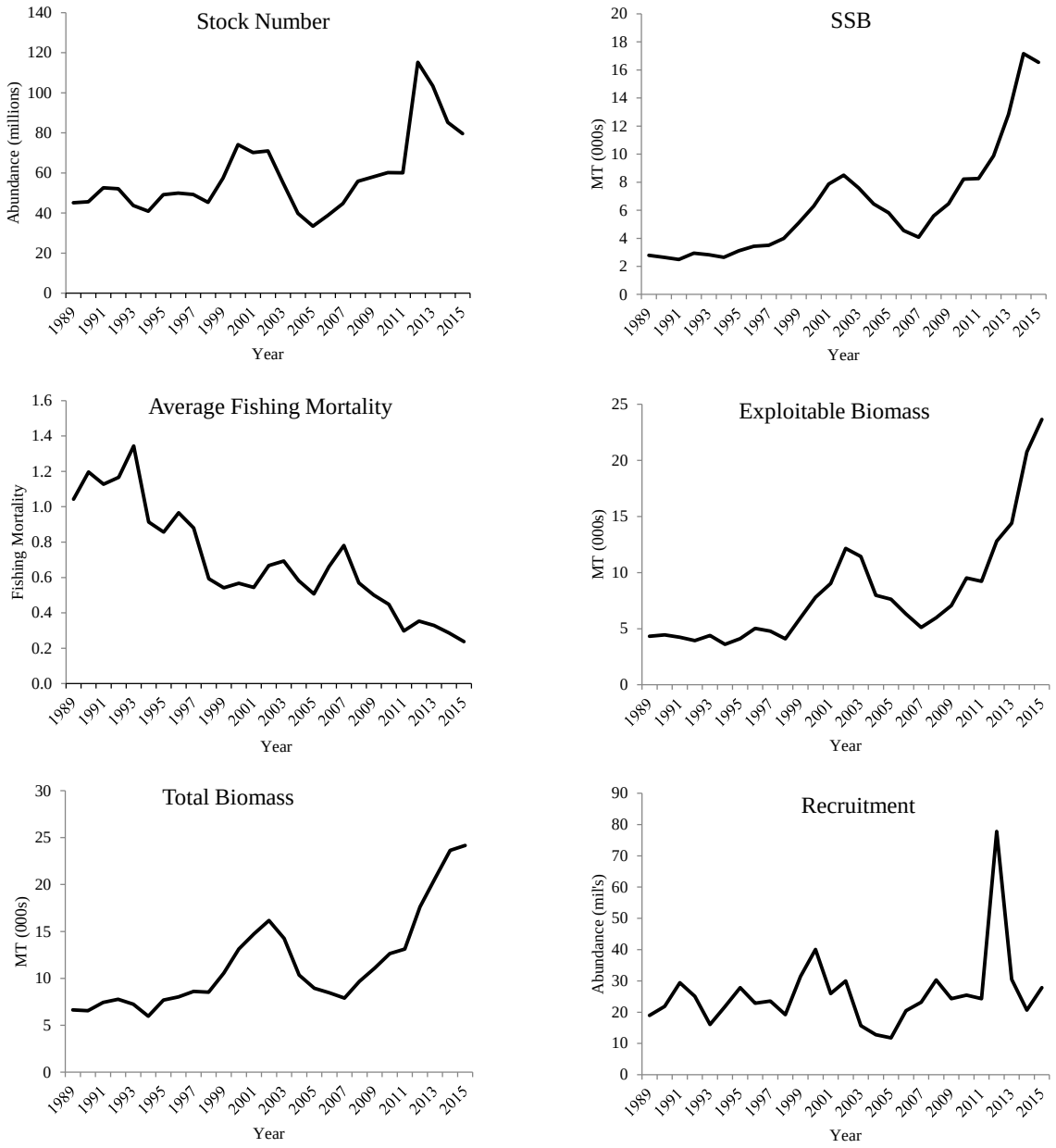

Figure A56. Results of stock number, fishing mortality, total biomass, spawning biomass, exploitable biomass and recruitment from the black sea bass **Overall** single area model.

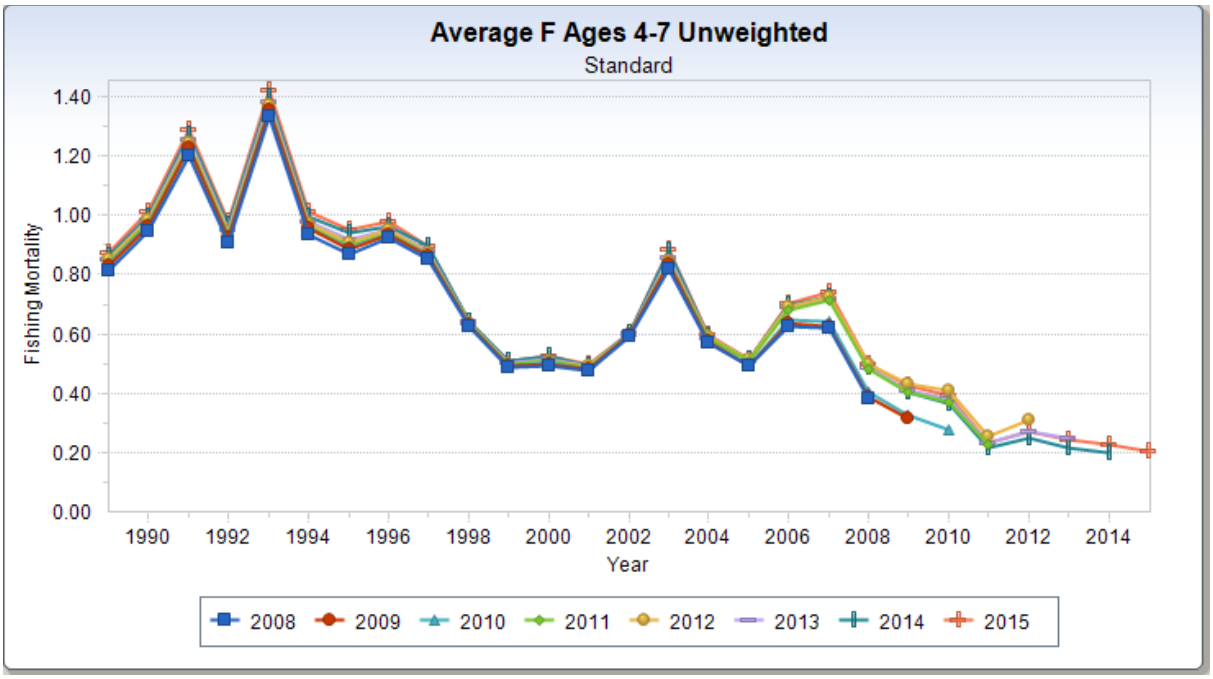

Figure A57. Retrospective pattern in average F estimates from black sea bass ASAP model for **Overall** single area model. Mohn's rho = -0.11

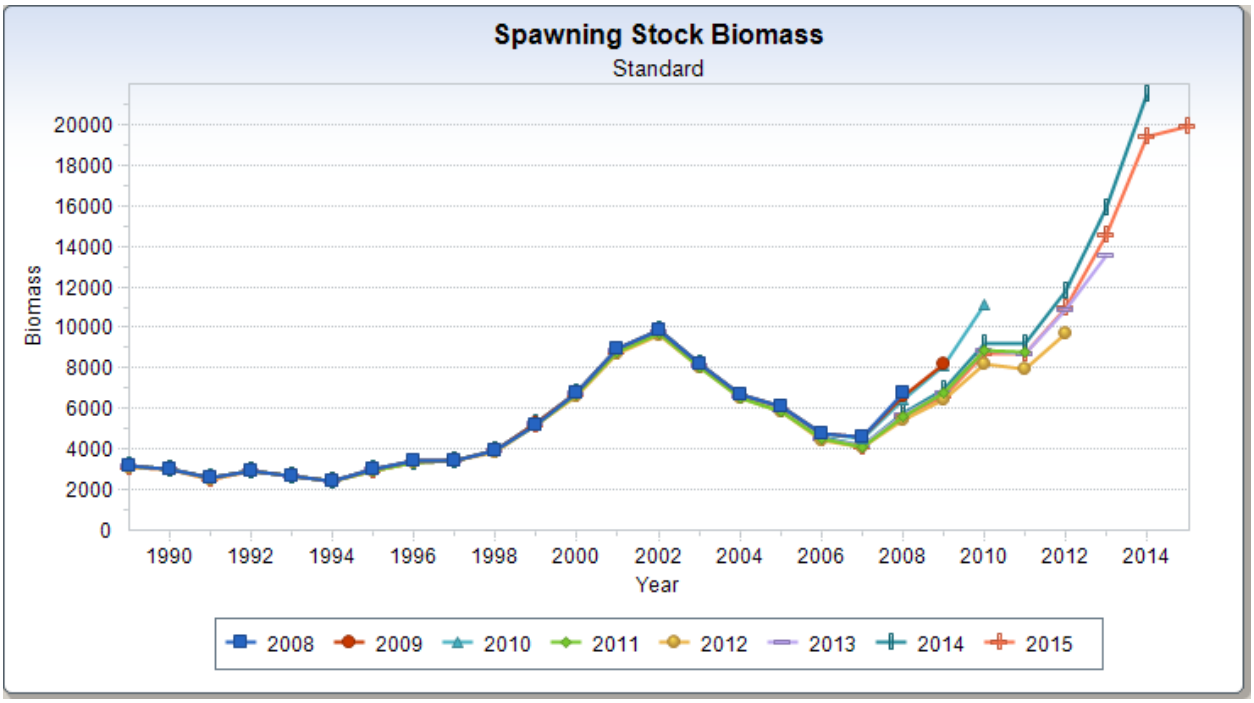

Figure A58. Retrospective pattern in spawning stock biomass (mt) estimates from black sea bass ASAP model for **Overall** single area model. Mohn's rho = 0.09

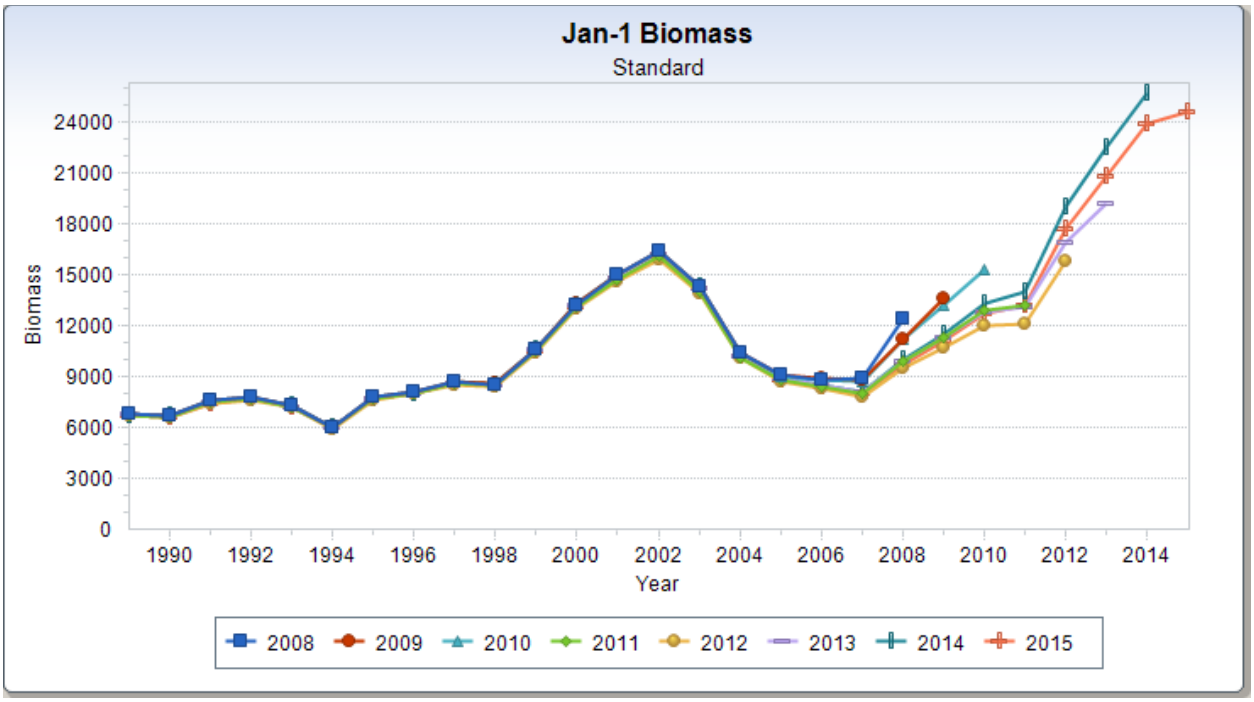

Figure A59. Retrospective pattern in total biomass (mt) estimates from black sea bass ASAP model for **Overall** single area model. Mohn's rho = 0.08

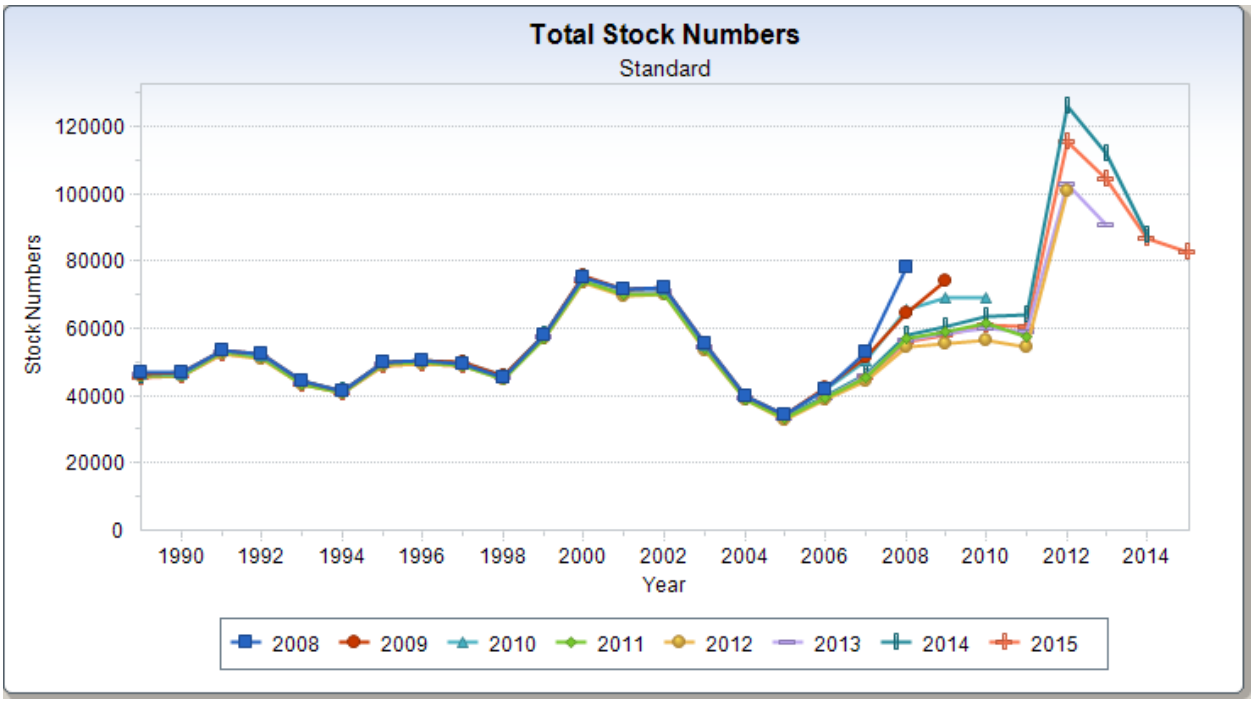

Figure A60. Retrospective pattern in total stock number estimates from black sea bass ASAP model for **Overall** single area model. Mohn's rho = 0.08

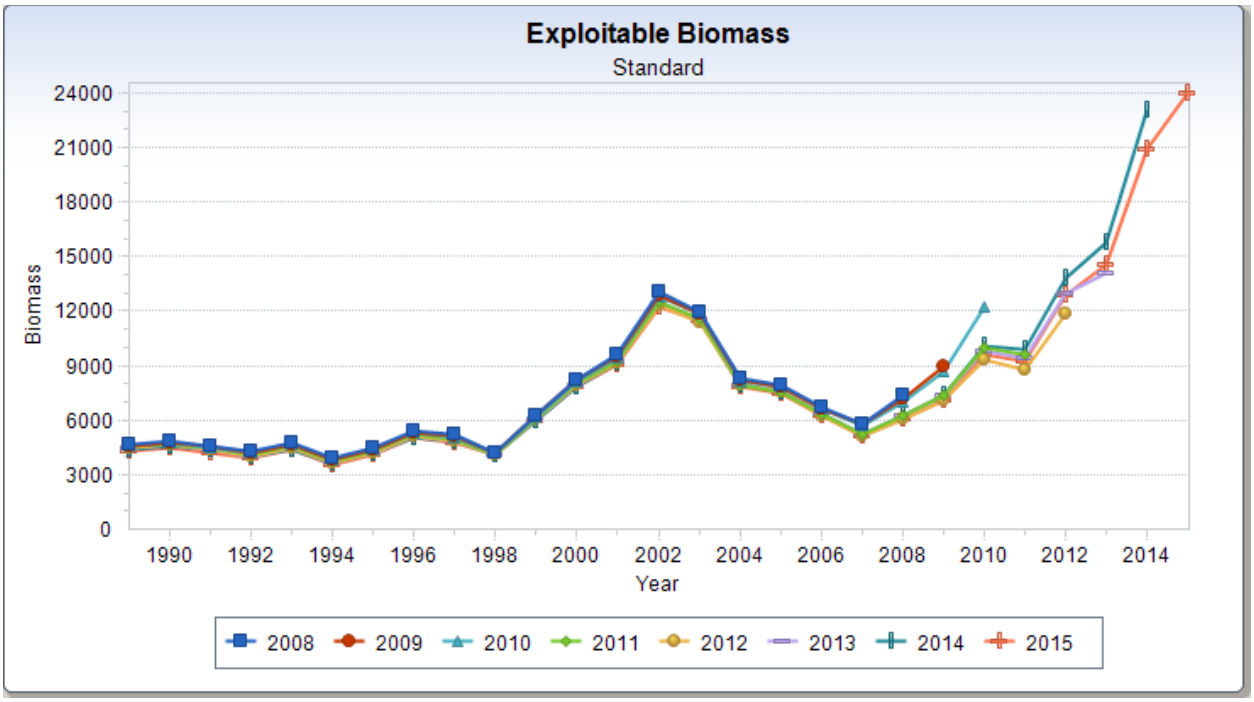

Figure A61. Retrospective pattern in exploitable biomass (mt) estimates from black sea bass ASAP model for **Overall** single area model. Mohn's rho = 0.11

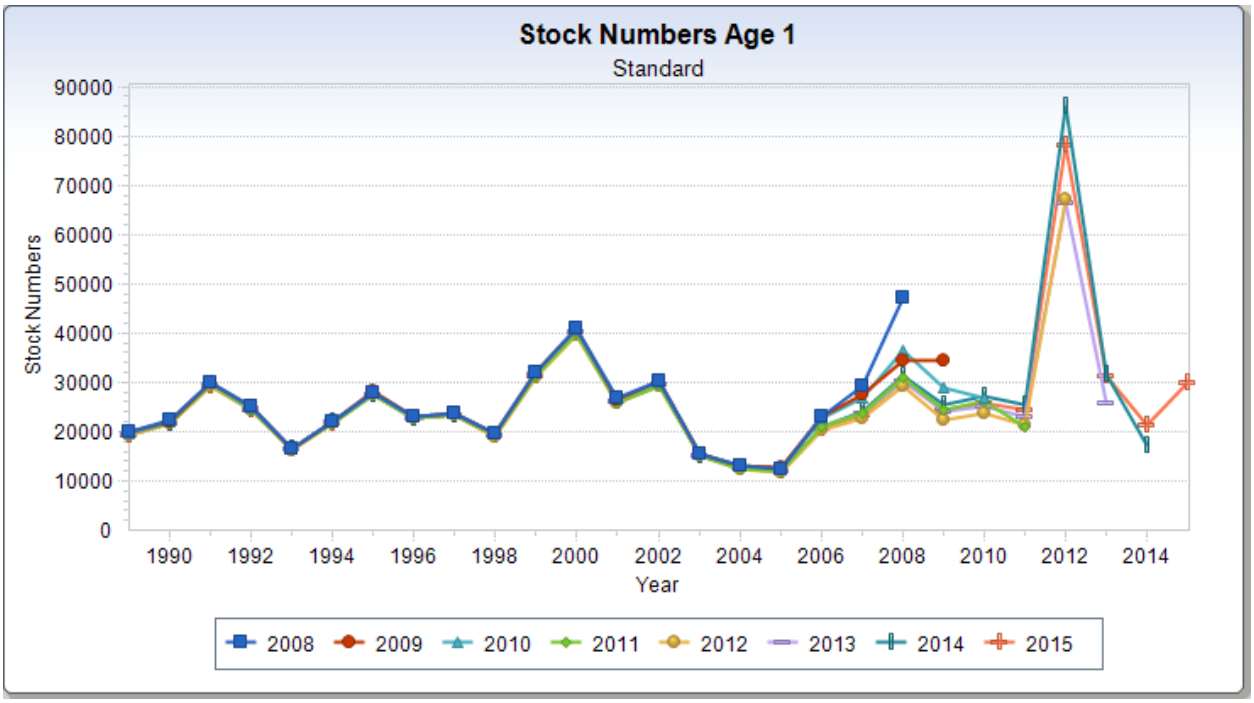

Figure A62. Retrospective pattern in age 1 stock number estimates from black sea bass ASAP model for **Overall** single area model. Mohn's rho = 0.06

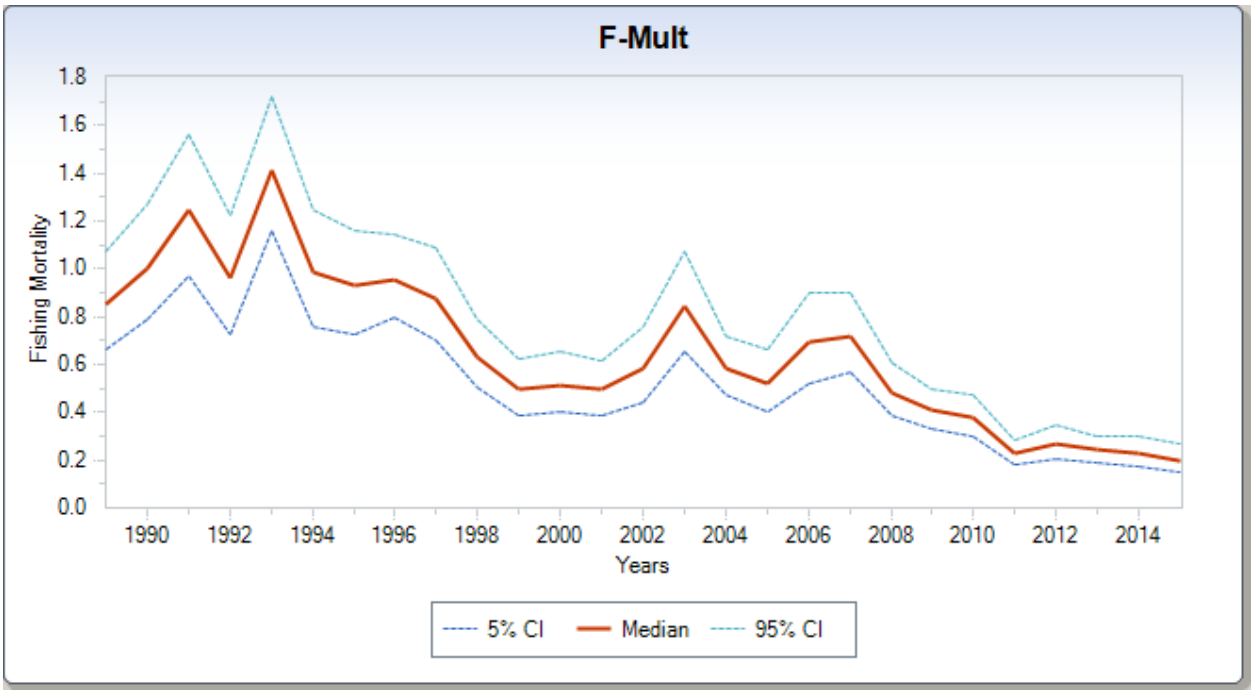

Figure A63. ASAP MCMC estimates of black sea bass F mult (± 90% CI) from **Overall** single area model.

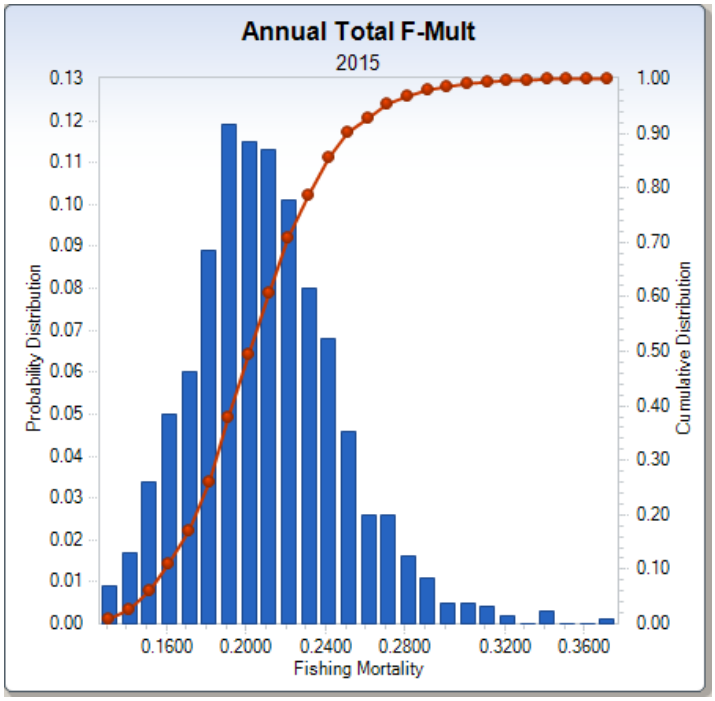

Figure A64. MCMC distribution of 2015 black sea bass Fmult estimates from **Overall** single area model.

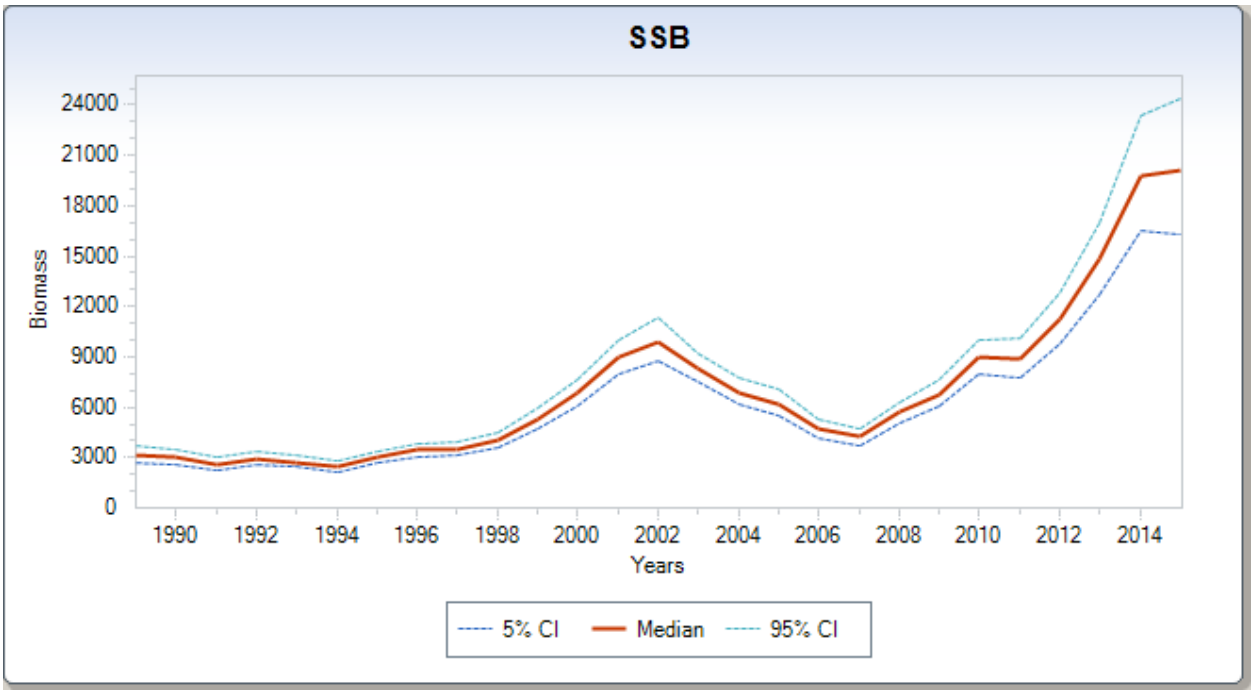

Figure A65. ASAP MCMC estimates of black sea bass spawning stock biomass (MT ± 90% CI) from **Overall** single area model.

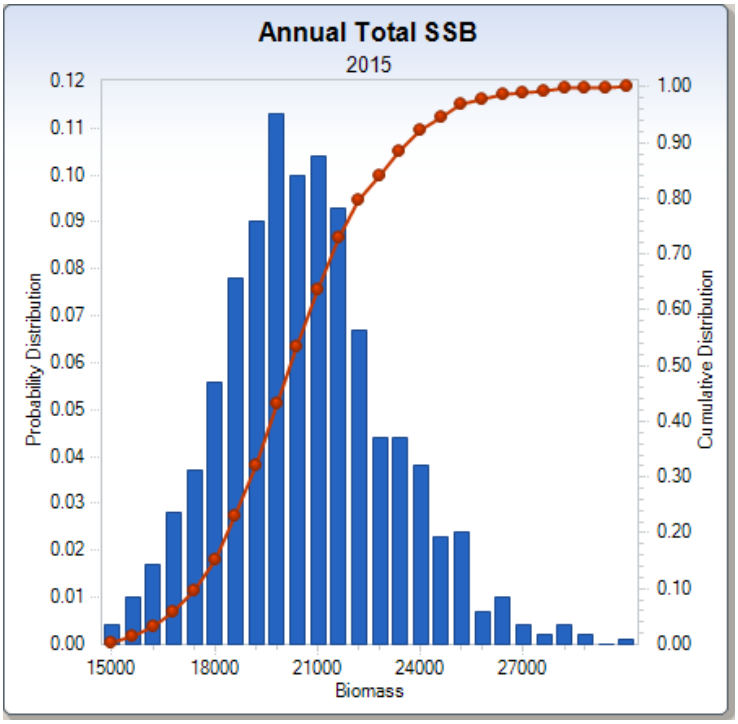

Figure A66. MCMC distribution of 2015 black sea bass spawning stock biomass (mt) estimates from **Overall** single area model.

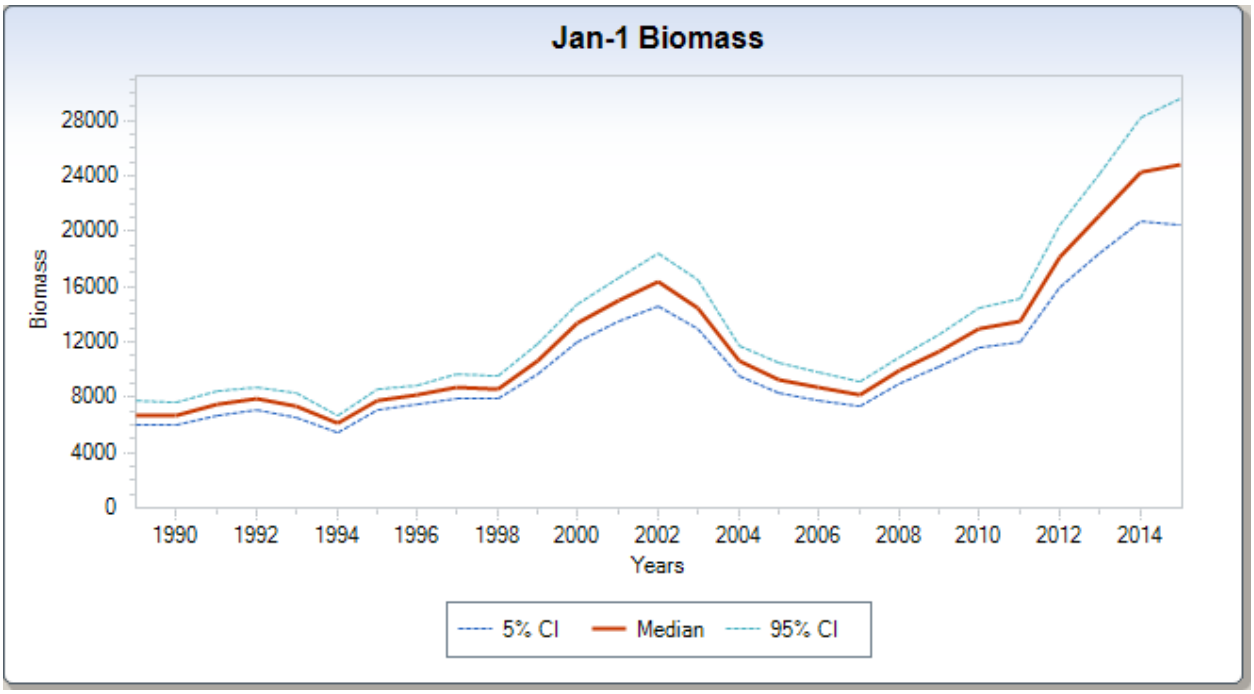

Figure A67. ASAP MCMC estimates of black sea bass total biomass (mt ± 90% CI) from **Overall** single area model.

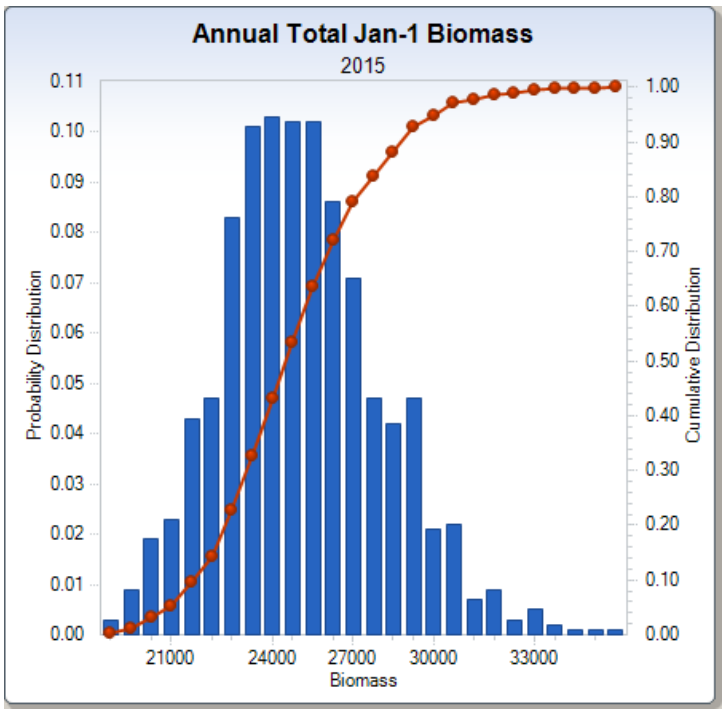

Figure A68. MCMC distribution of 2015 black sea bass total biomass (mt) estimates from **Overall** single area model.

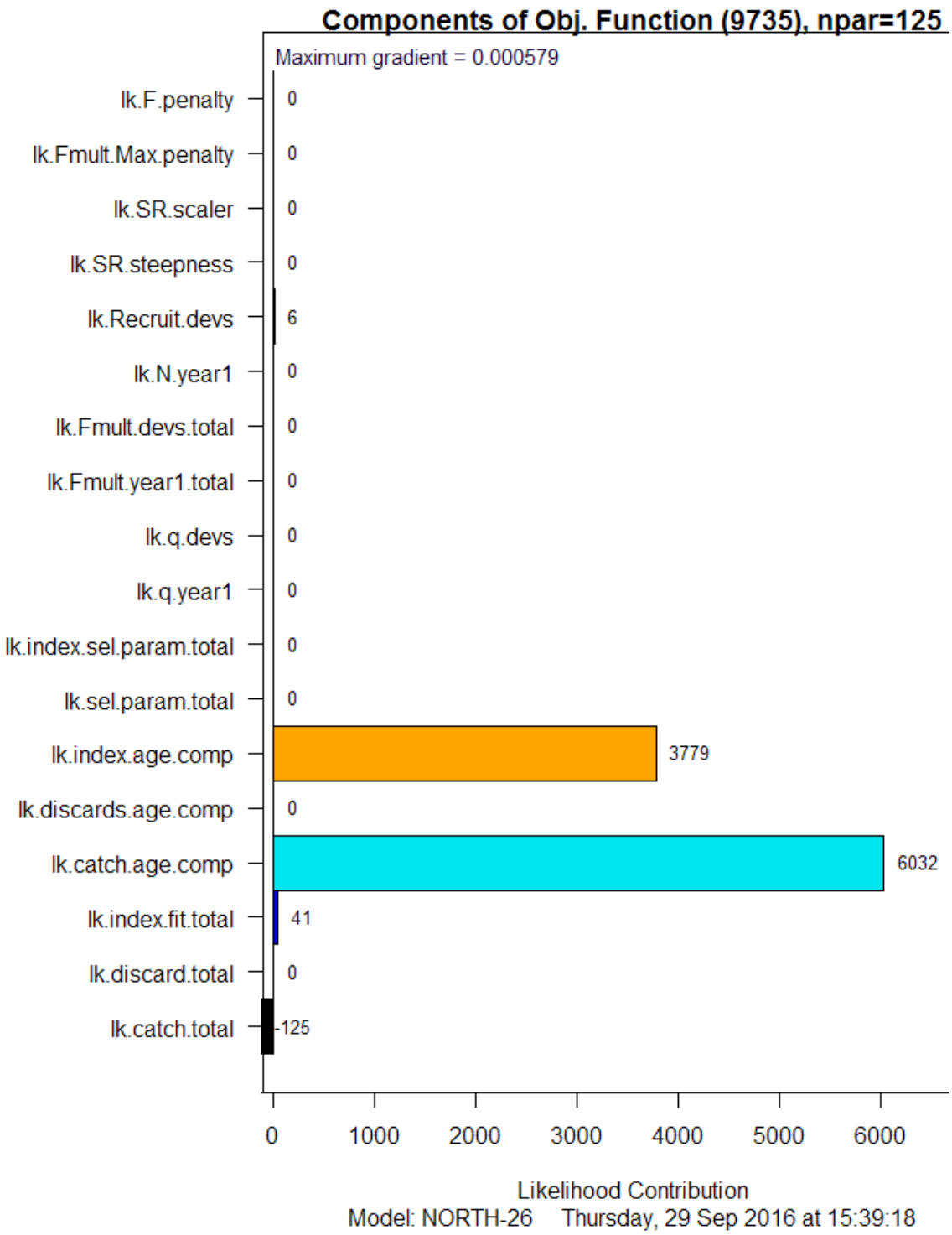

Figure A69. Distribution of objective function components contribution to total likelihood for black sea bass **North** area model.

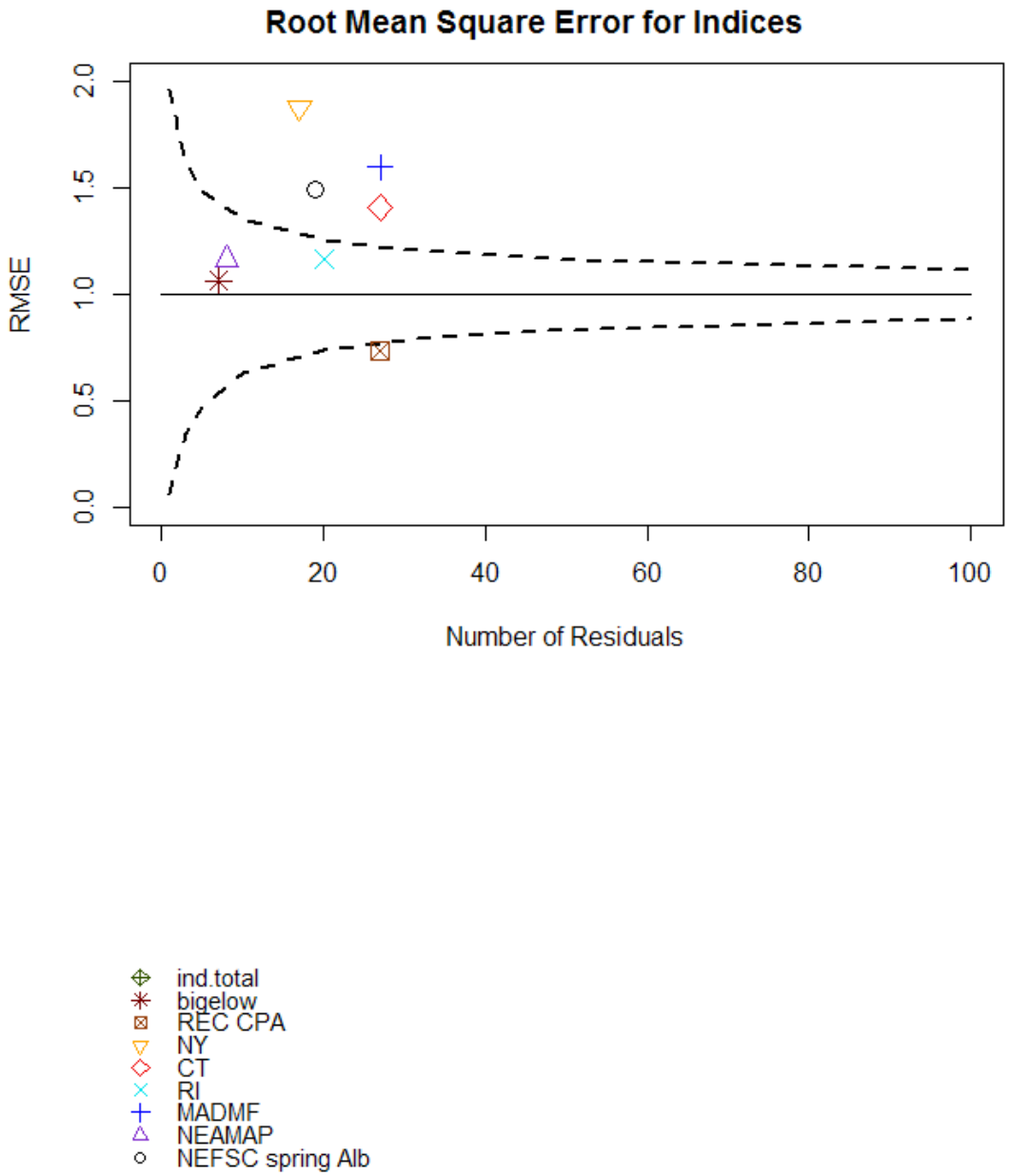

Figure A70. Final Root Mean Square Error (RMSE) values for survey indices in final black sea bass **North** area model.

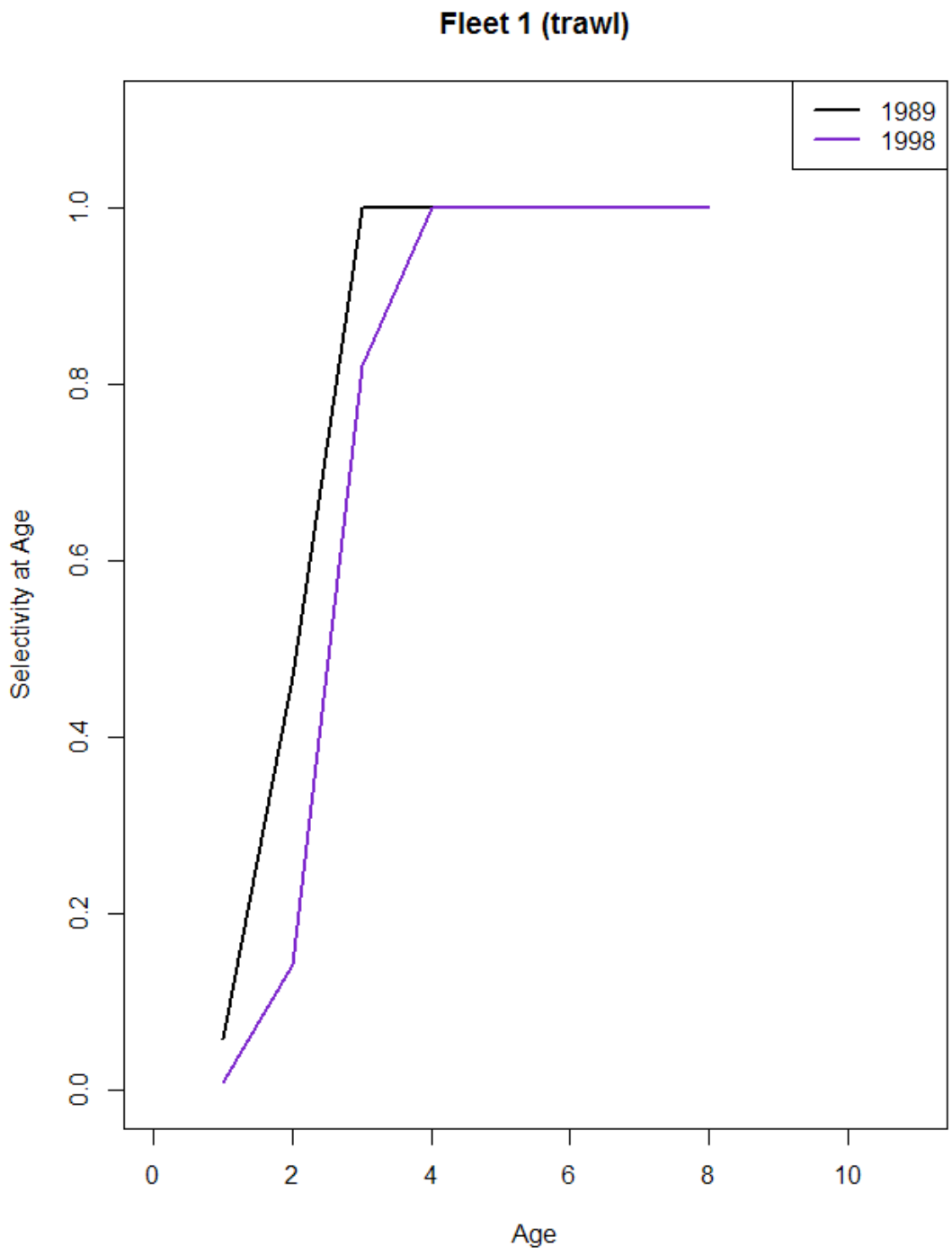

Figure A71. Selectivity at age from trawl fleet in final black sea bass **North** area model.

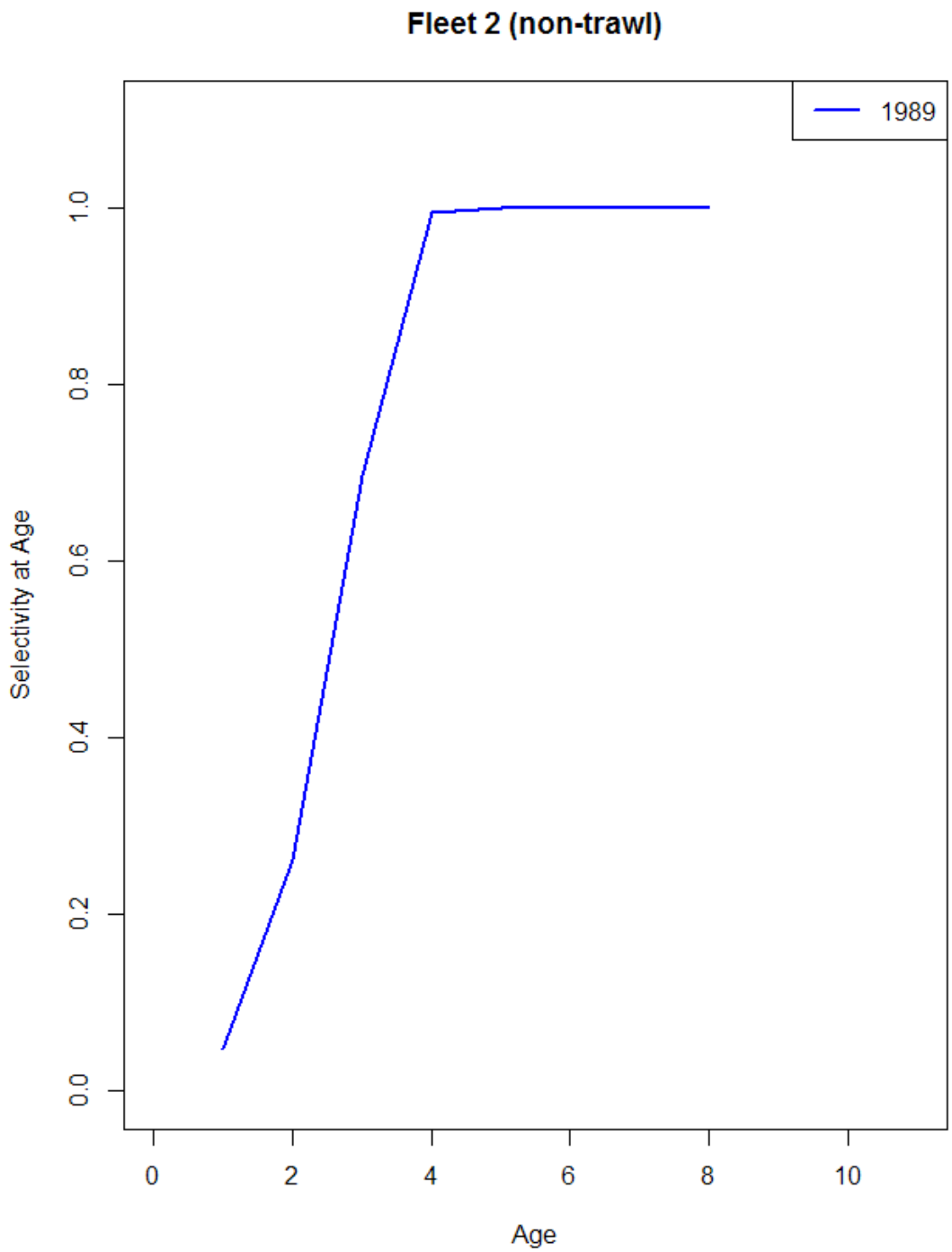

Figure A72. Selectivity at age from non-trawl fleet in final black sea bass **North** area model.

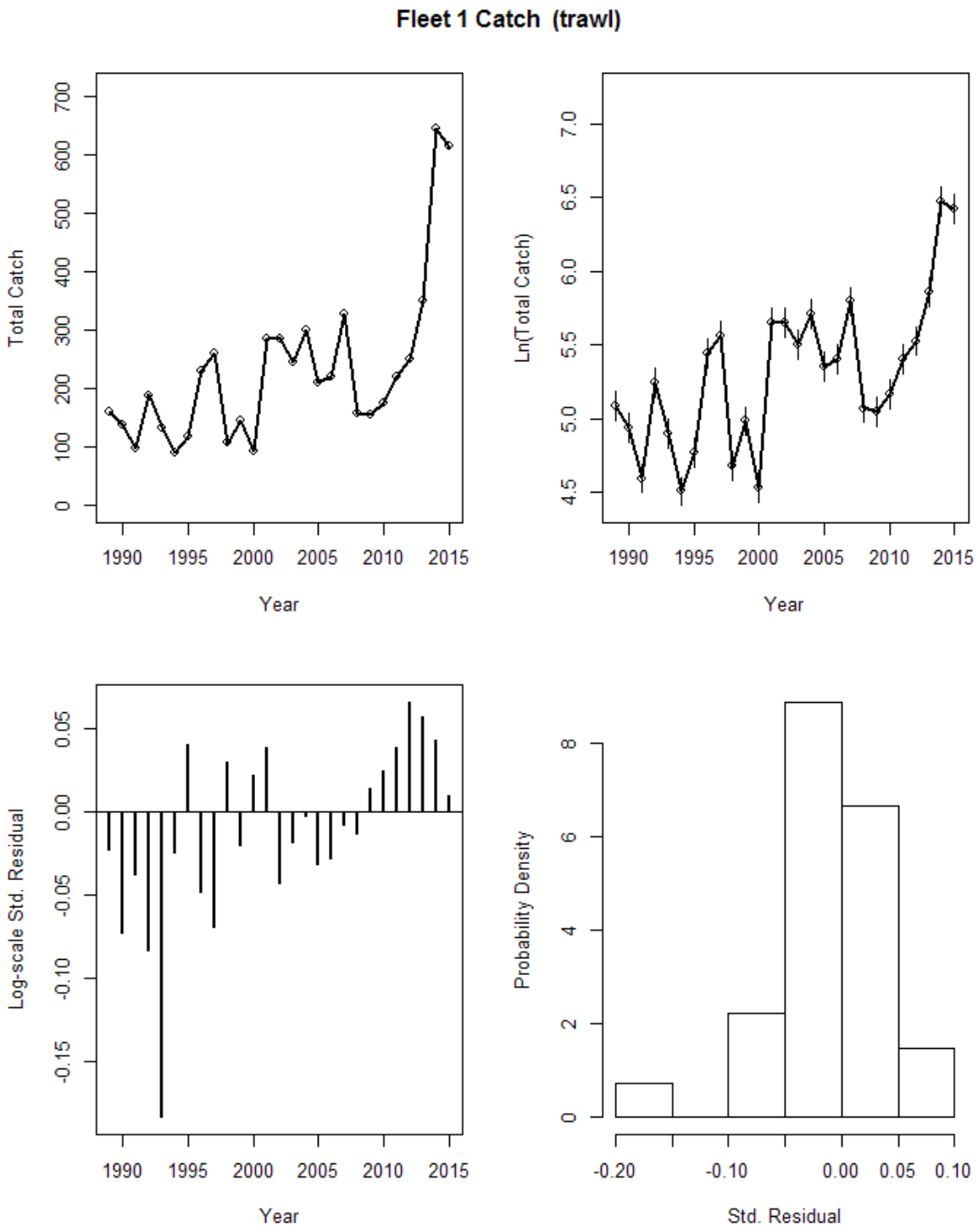

Figure A73. Fit diagnostics for the trawl catch in final black sea bass **North** area model.

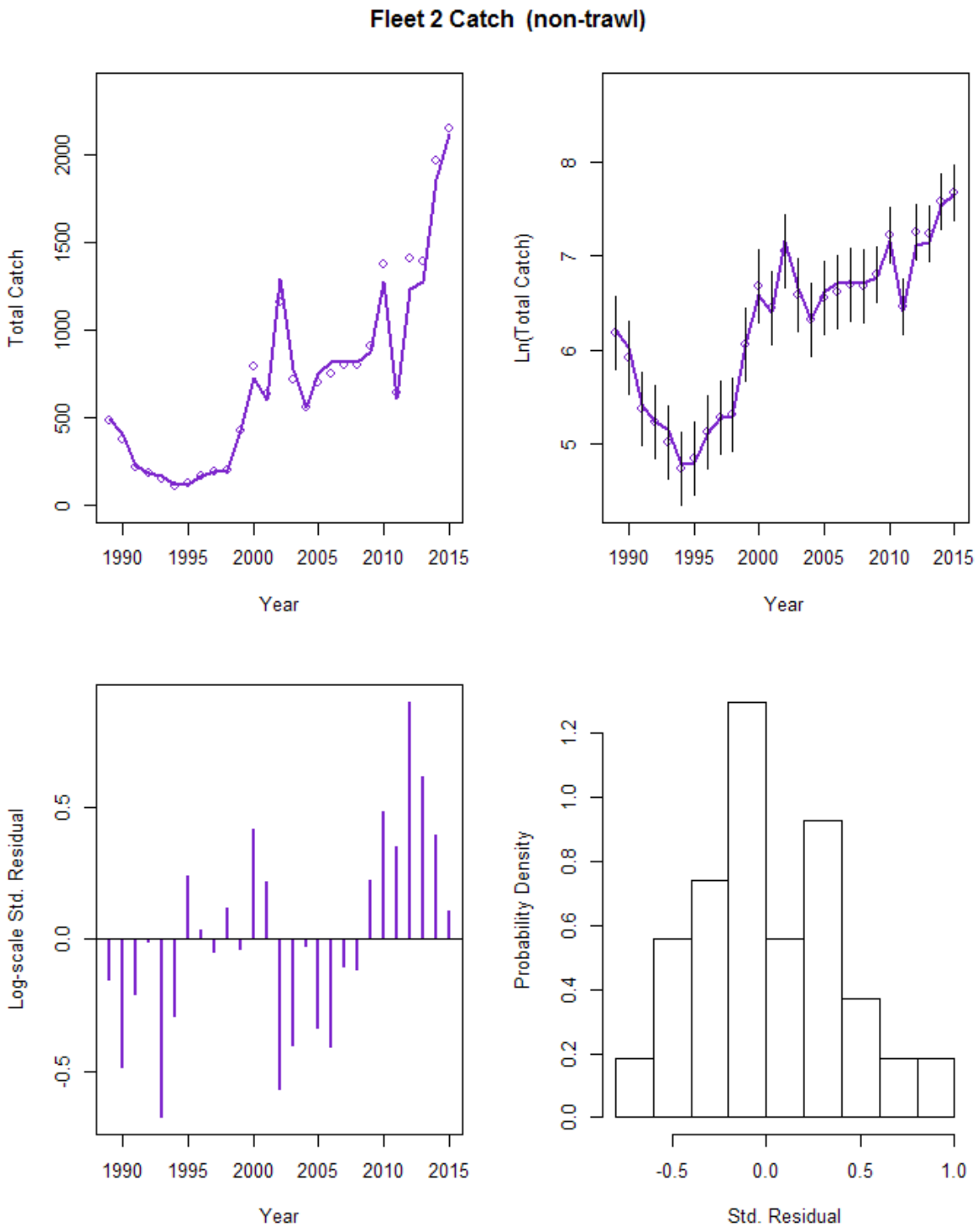

Figure A74. Fit diagnostics for the non-trawl catch in final black sea bass **North** area model.

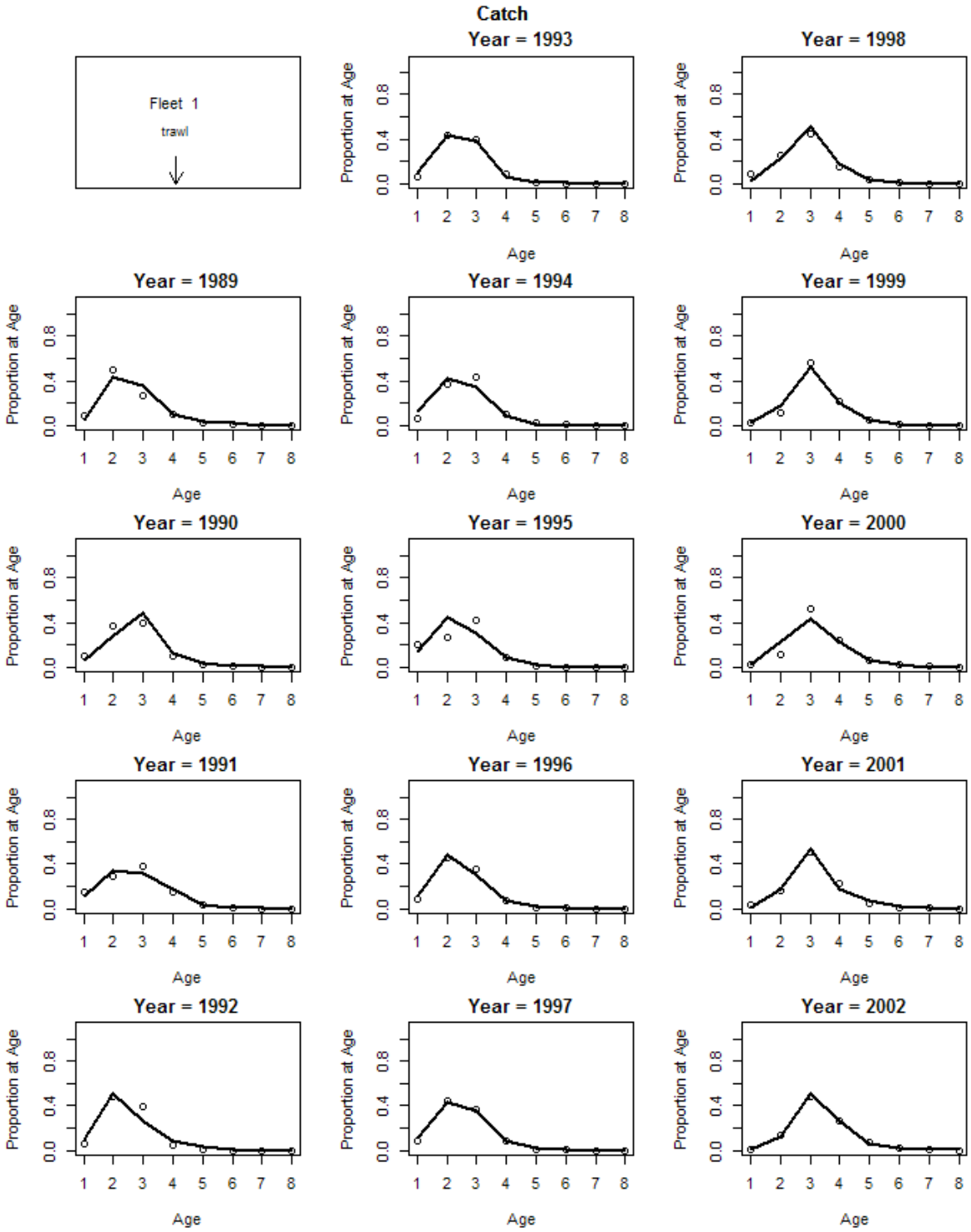

Figure A75. Fits to 1989-2002 trawl catch proportions at age in final black sea bass **North** area model.

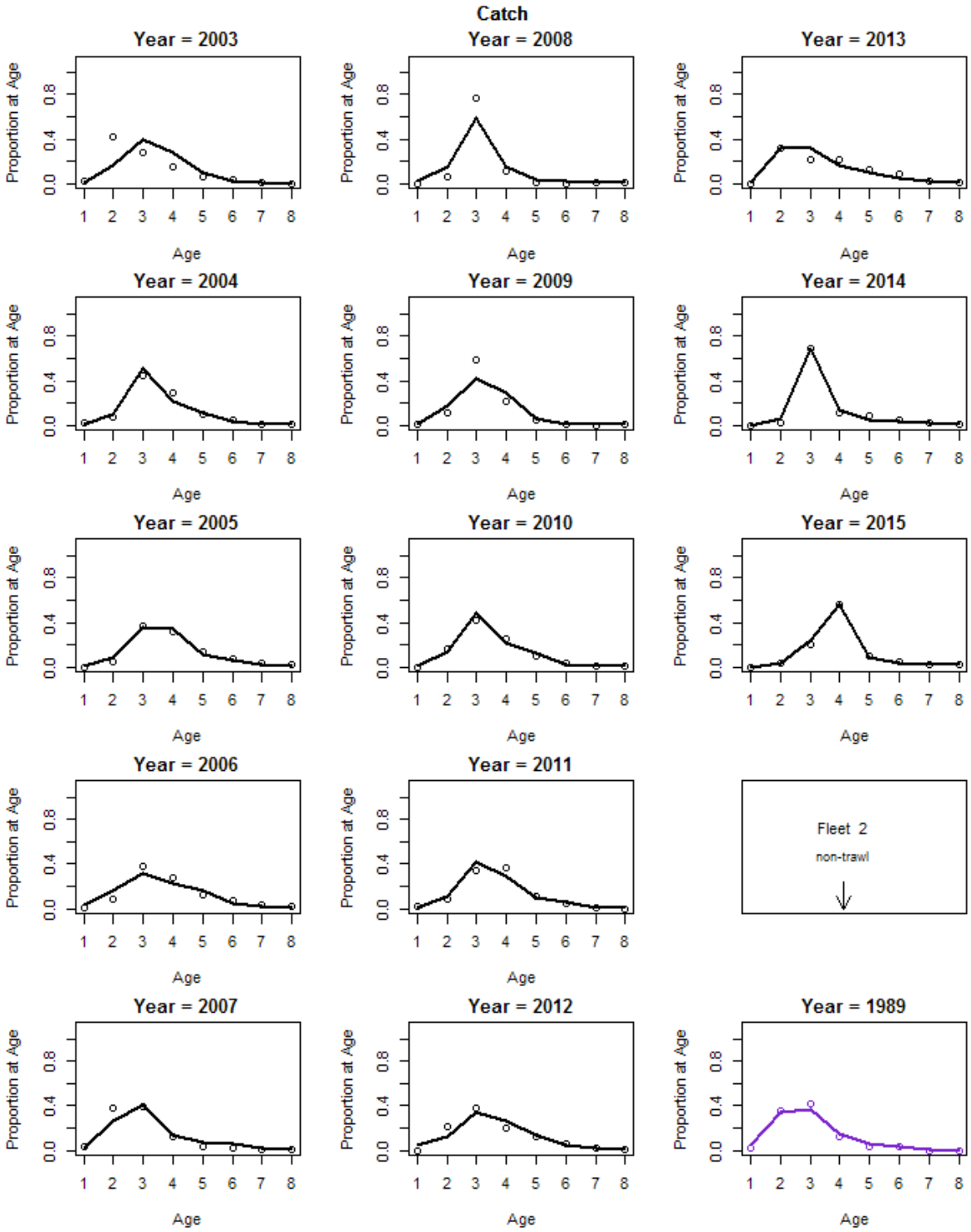

Figure A76. Fits to 2003-2015 trawl catch proportions at age and 1989 non-trawl catch proportion at age in final black sea bass **North** area model.

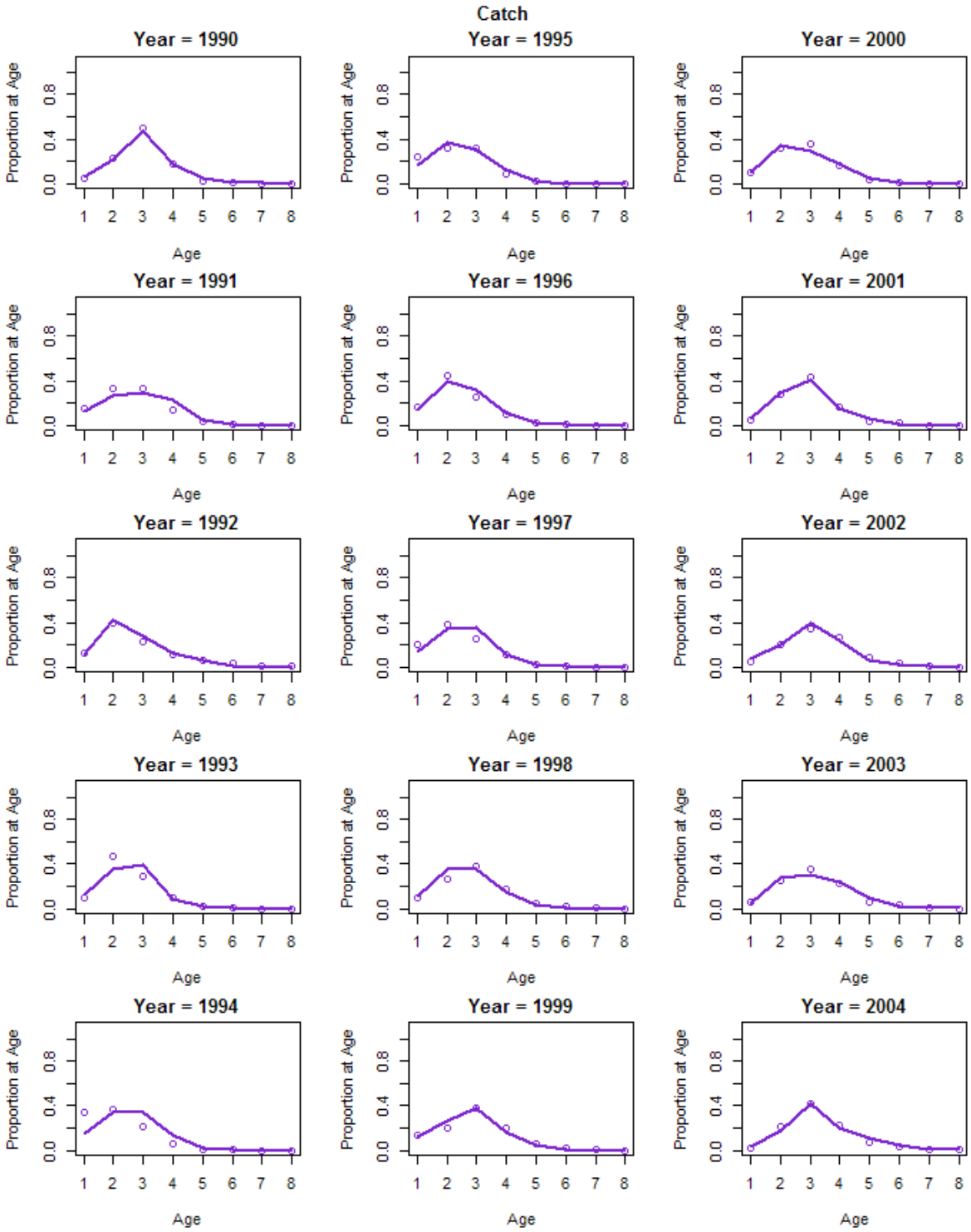

Figure A77. Fits to 1990-2004 non-trawl catch proportions at age in final black sea bass **North** area model.

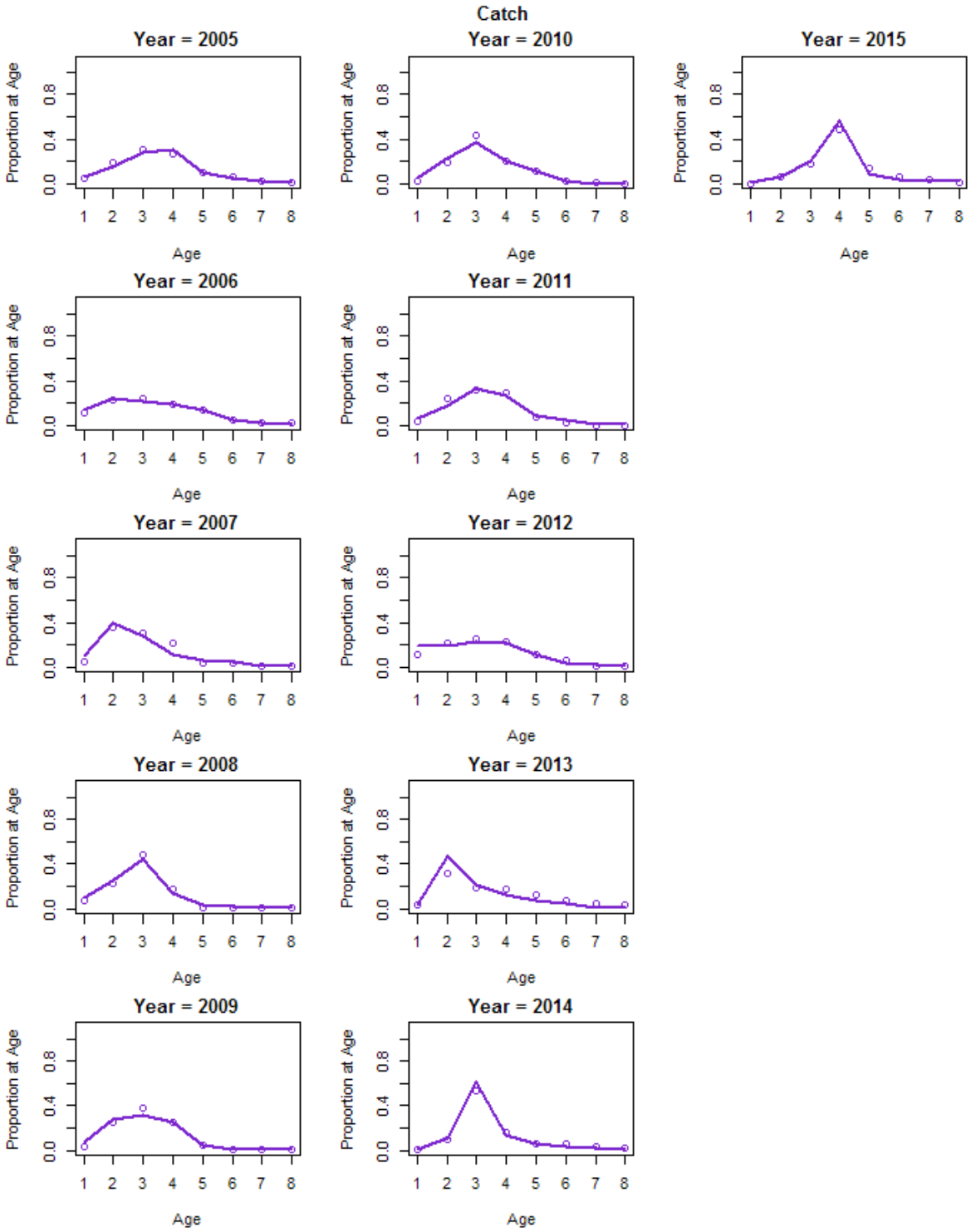

Figure A78. Fits to 2005-2015 non-trawl catch proportions at age in final black sea bass **North** area model.

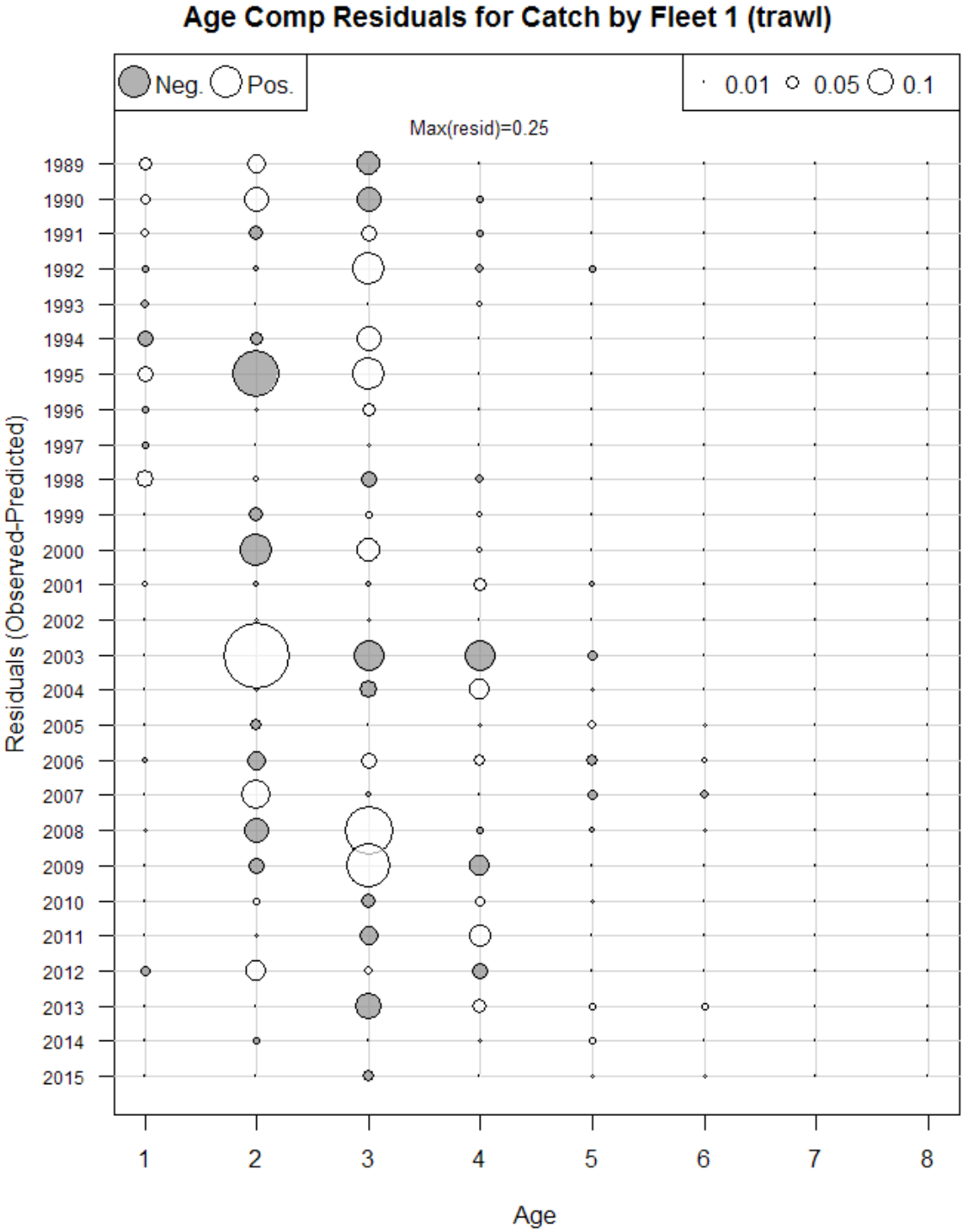

Figure A79. Trawl catch age composition residuals in final black sea bass **North** area model.

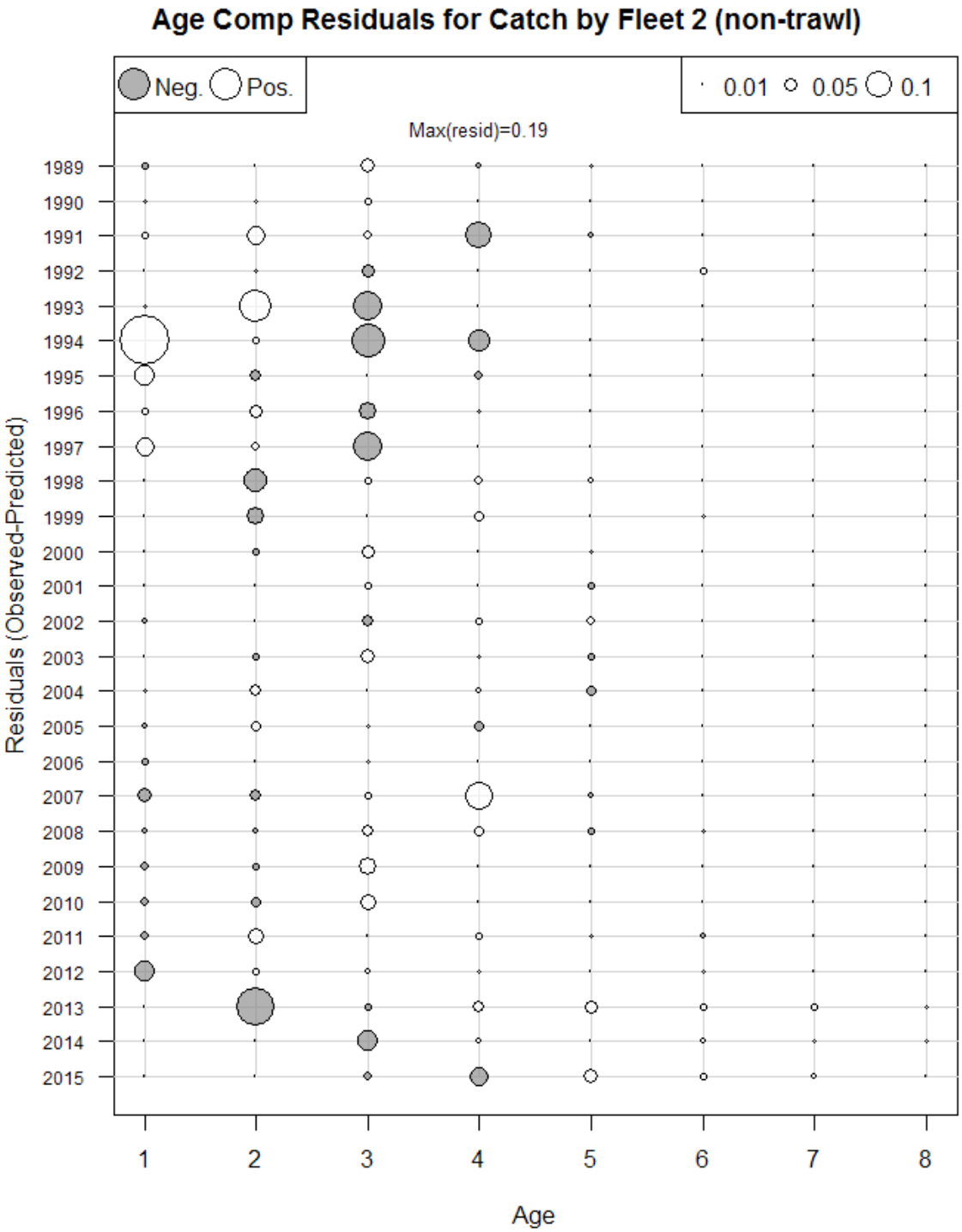

Figure A80. Non-trawl catch age composition residuals in final black sea bass **North** area model.

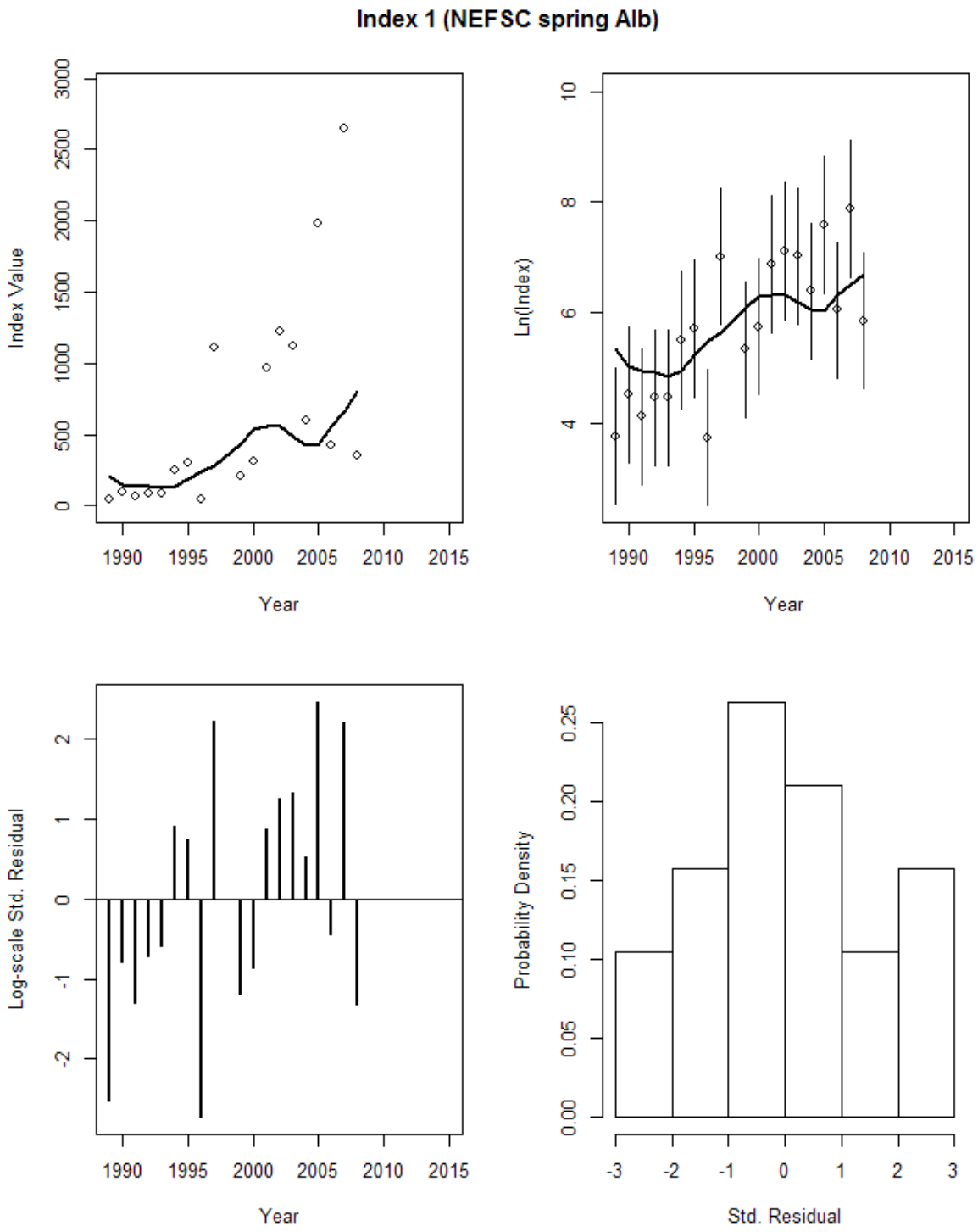

Figure A81. Fit diagnostics for the NEFSC spring trawl survey 1989-2008 (*Albatross*) in final black sea bass **North** area model.

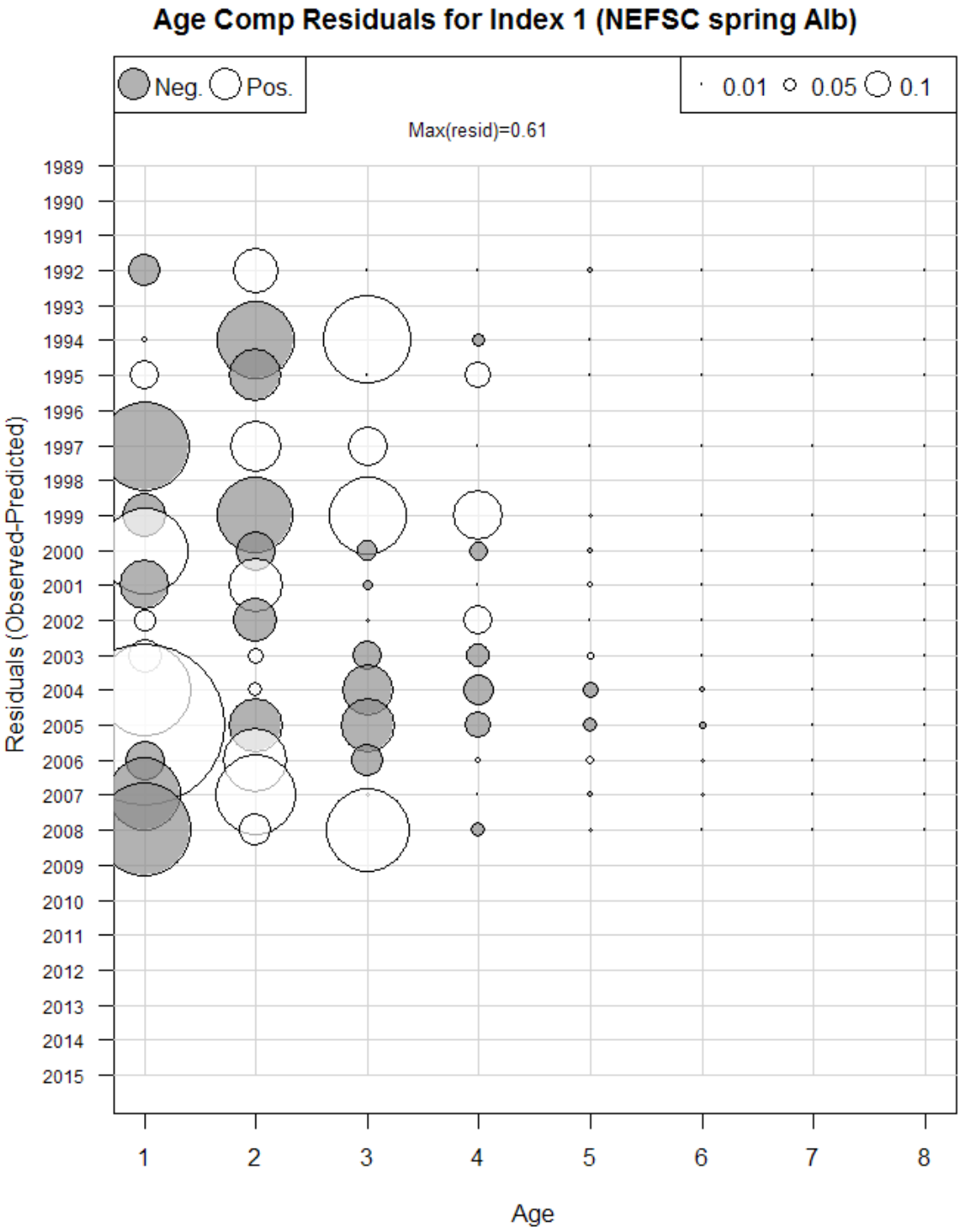

Figure A82. Age composition residuals for the NEFSC spring trawl survey 1989-2008 (*Albatross*) in final black sea bass **North** area model.

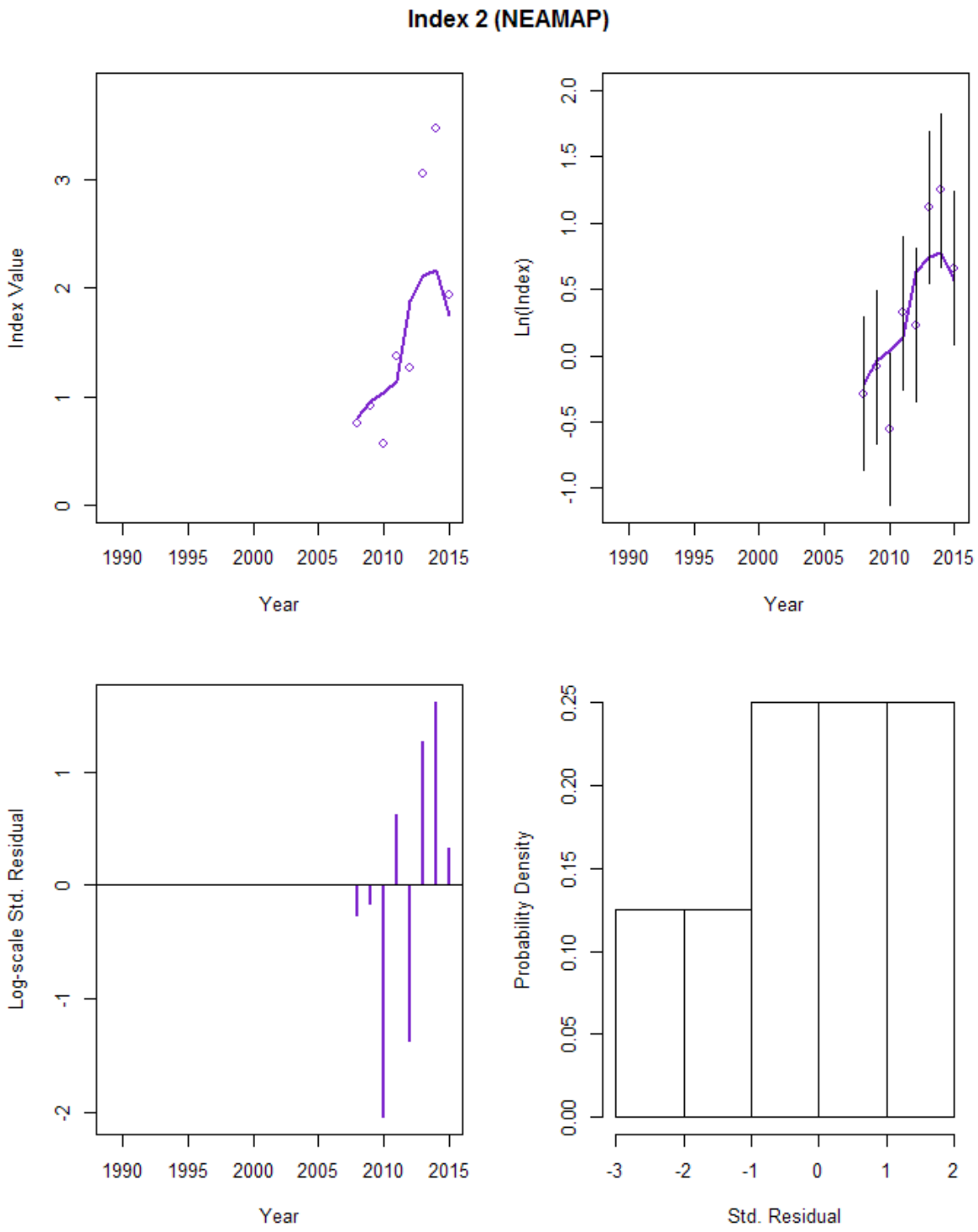

Figure A83. Fit diagnostics for the NEAMAP trawl survey in final black sea bass **North** area model.

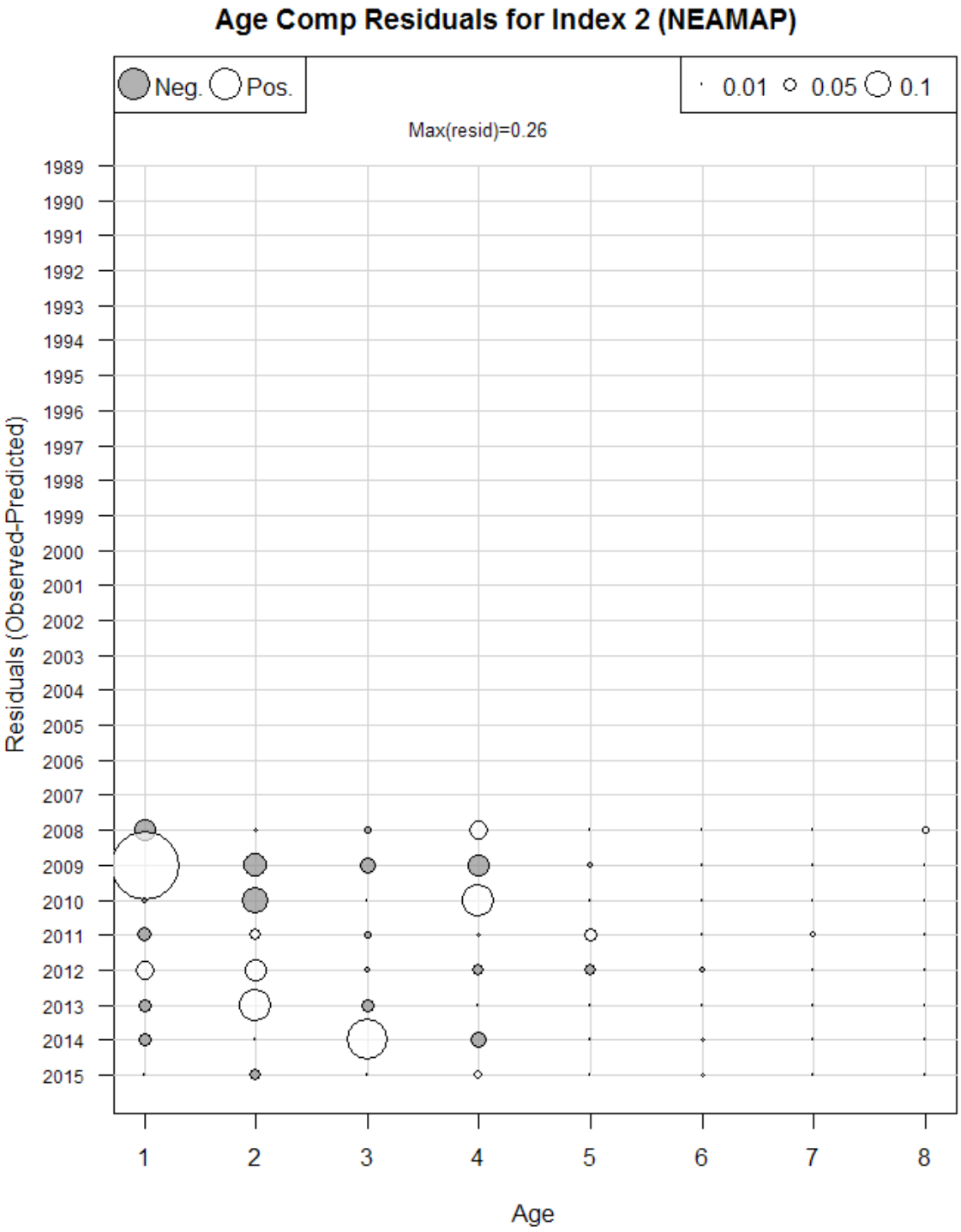

Figure A84. Age composition residuals for the NEAMAP trawl survey in final black sea bass **North** area model.

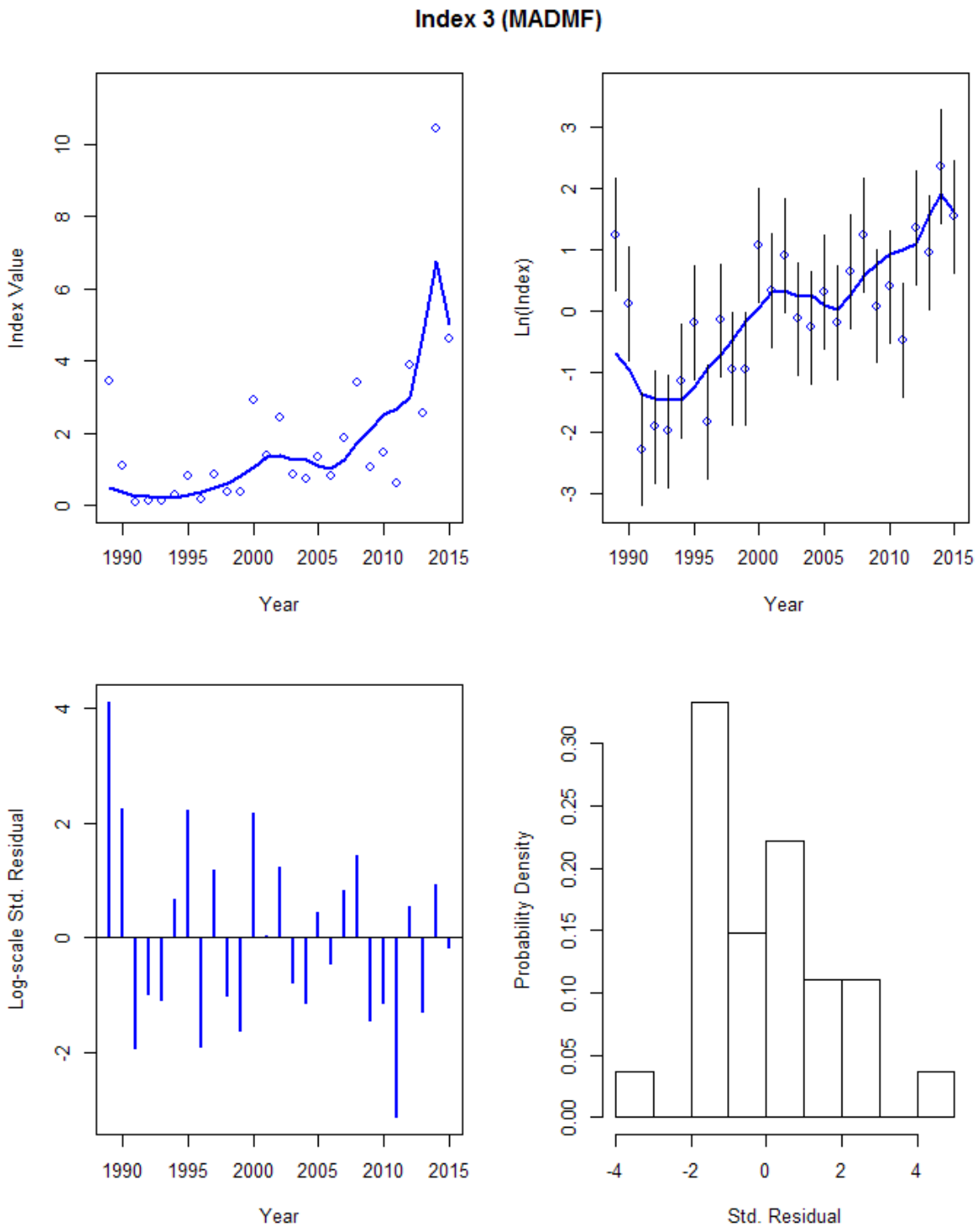

Figure A85. Fit diagnostics for the MADMF trawl survey in final black sea bass **North** area model.

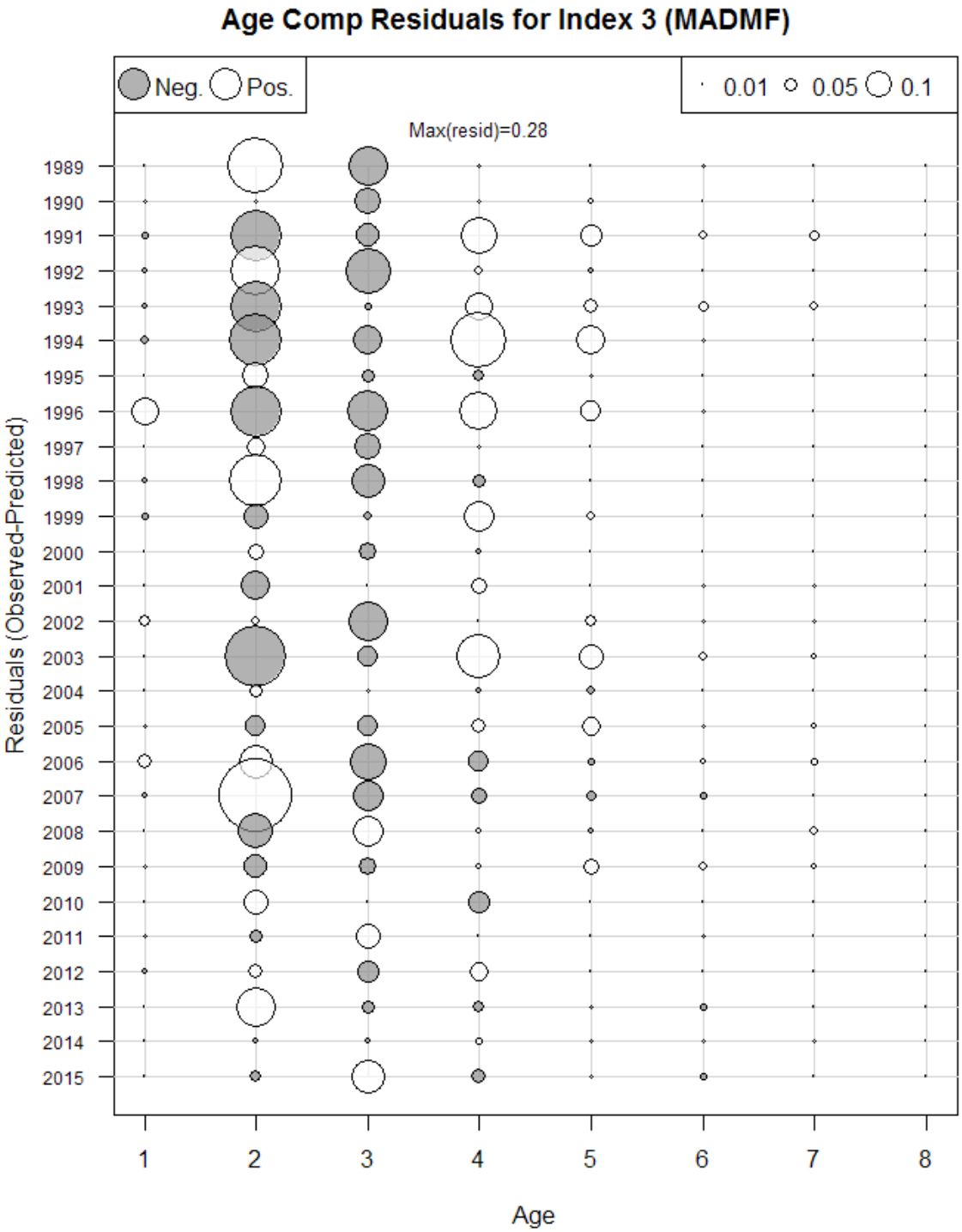

Figure A86. Age composition residuals for the MADMF trawl survey in final black sea bass **North** area model.

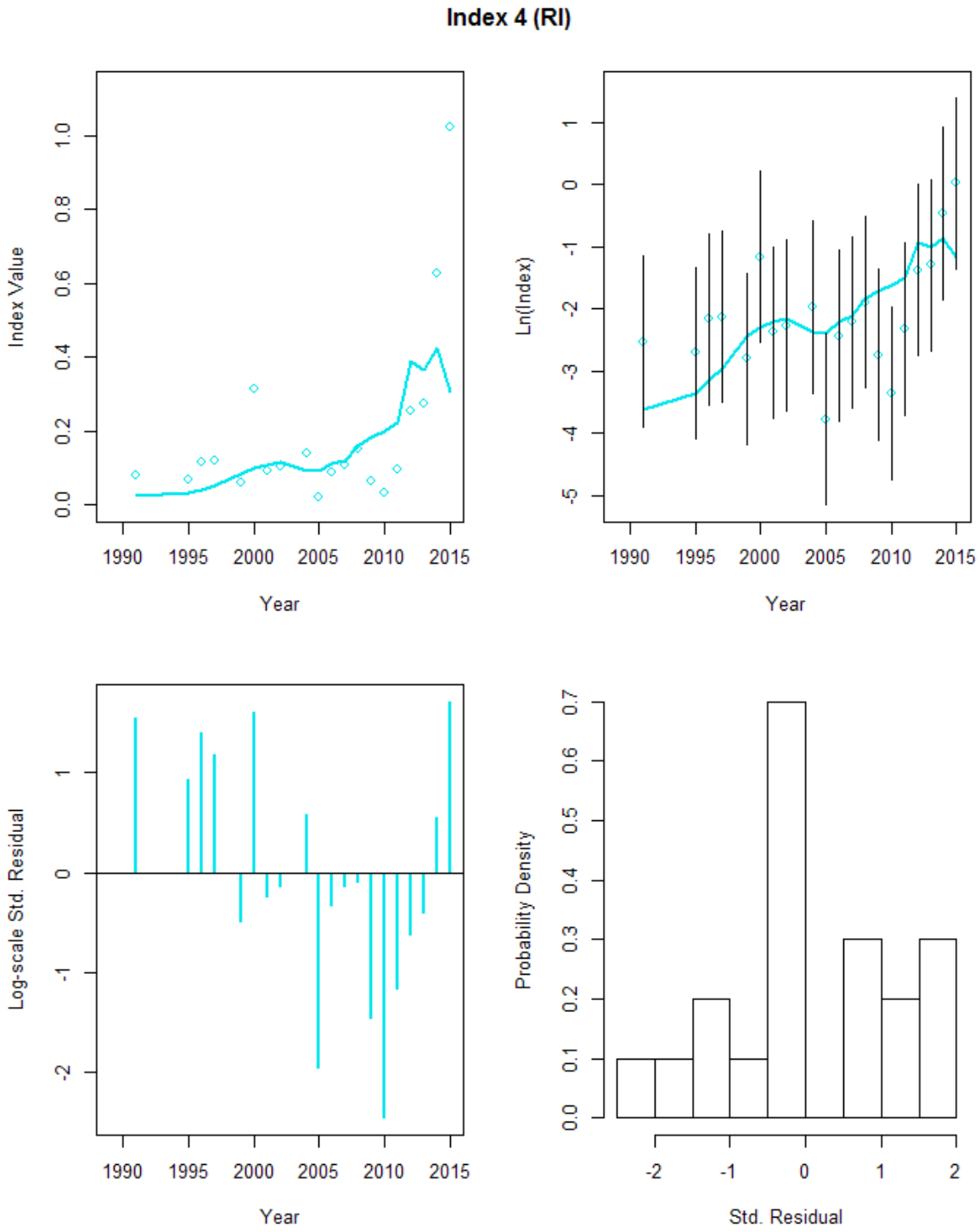

Figure A87. Fit diagnostics for the RI trawl survey in final black sea bass **North** area model.

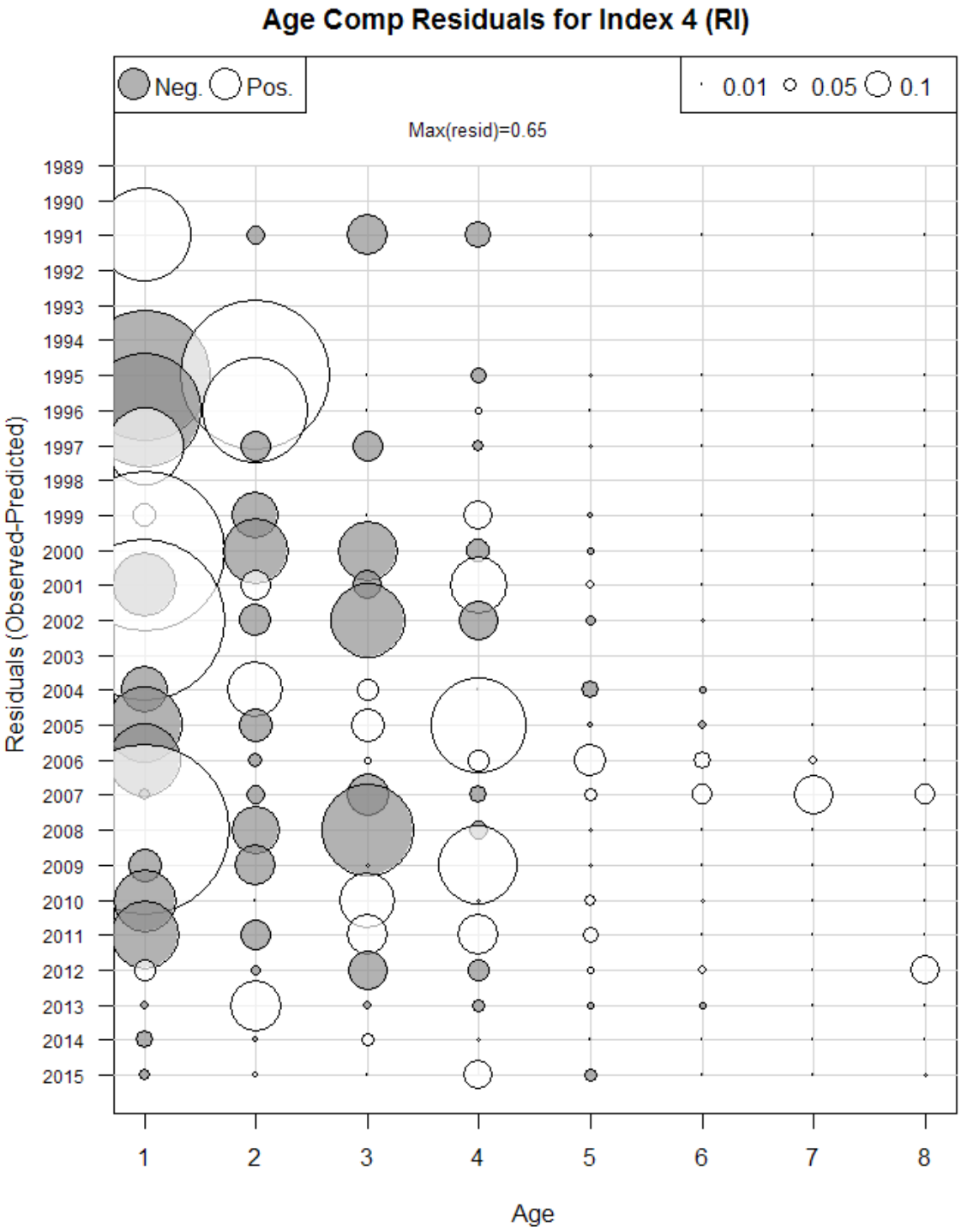

Figure A88. Age composition residuals for the RI trawl survey in final black sea bass **North** area model.

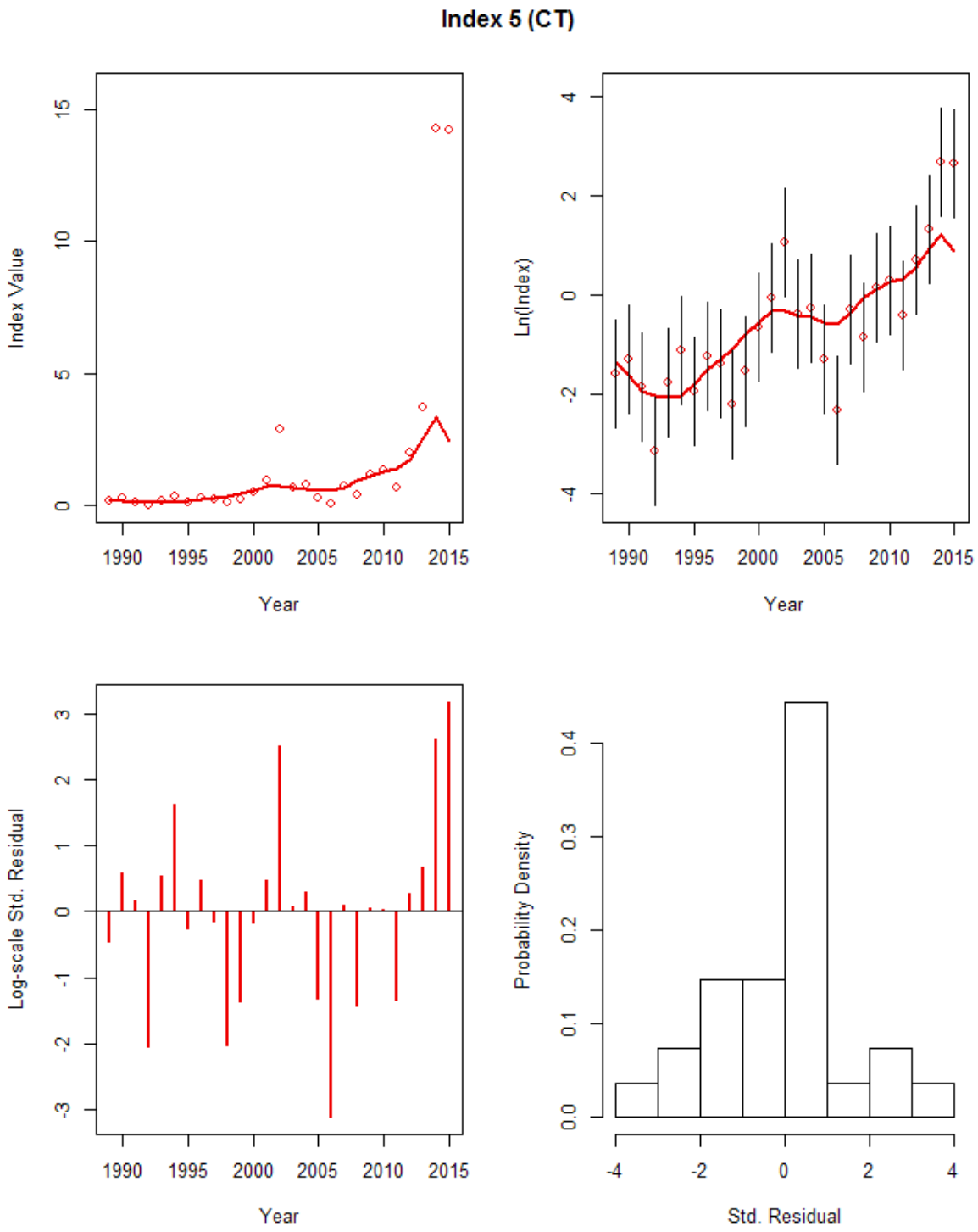

Figure A89. Fit diagnostics for the CT trawl survey in final black sea bass **North** area model.

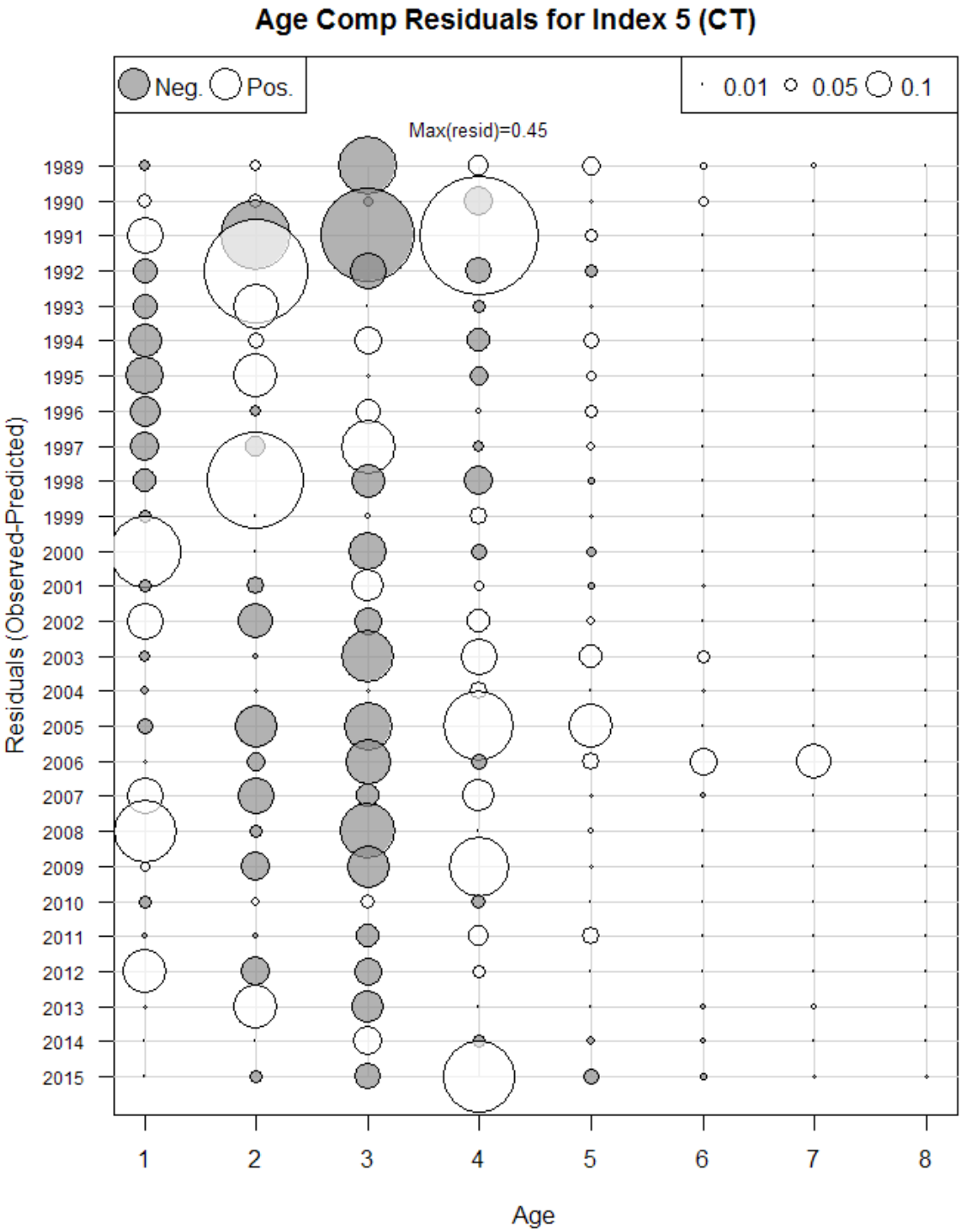

Figure A90. Age composition residuals for the CT trawl survey in final black sea bass **North** area model.

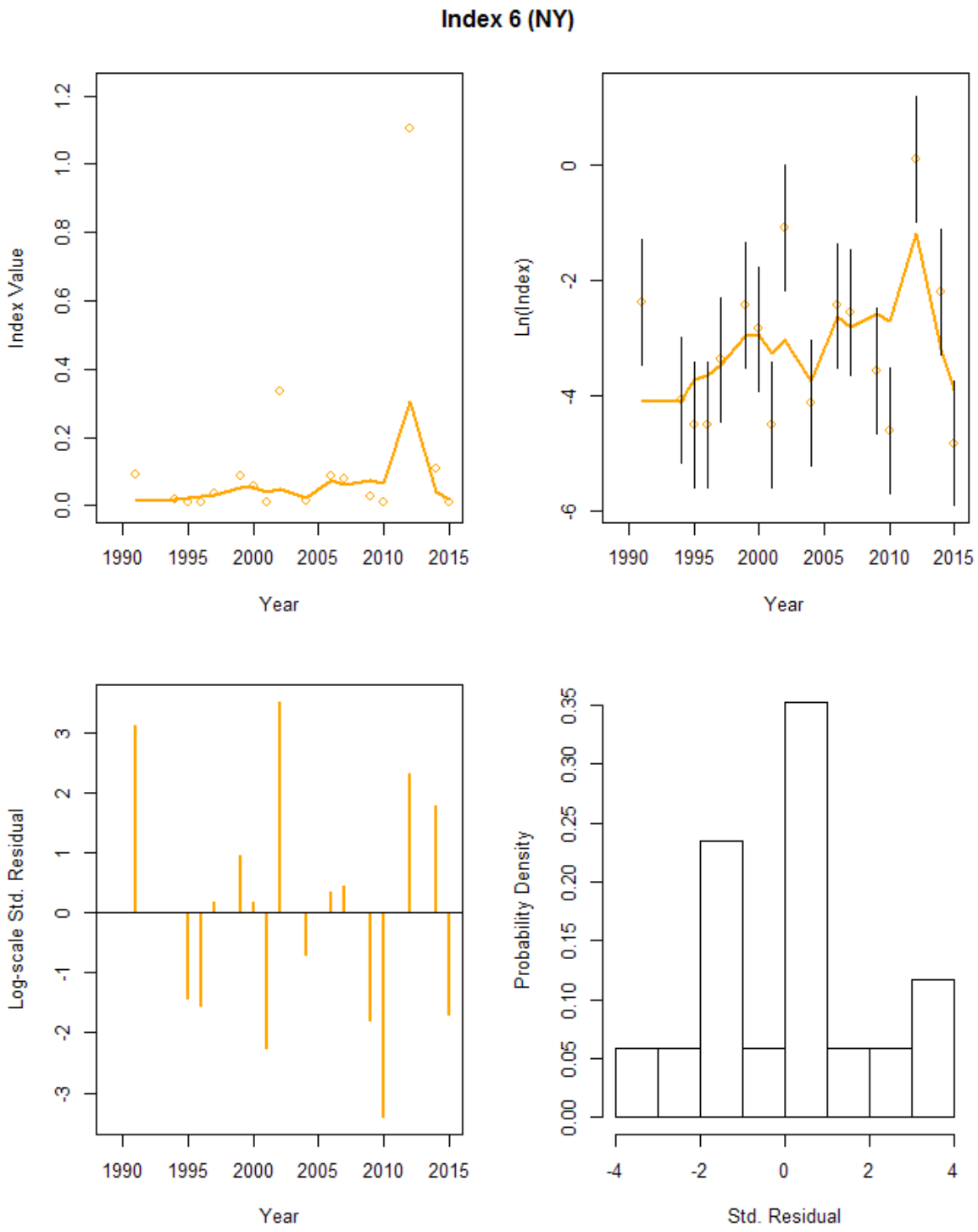

Figure A91. Fit diagnostics for the NY trawl survey in final black sea bass **North** area model.

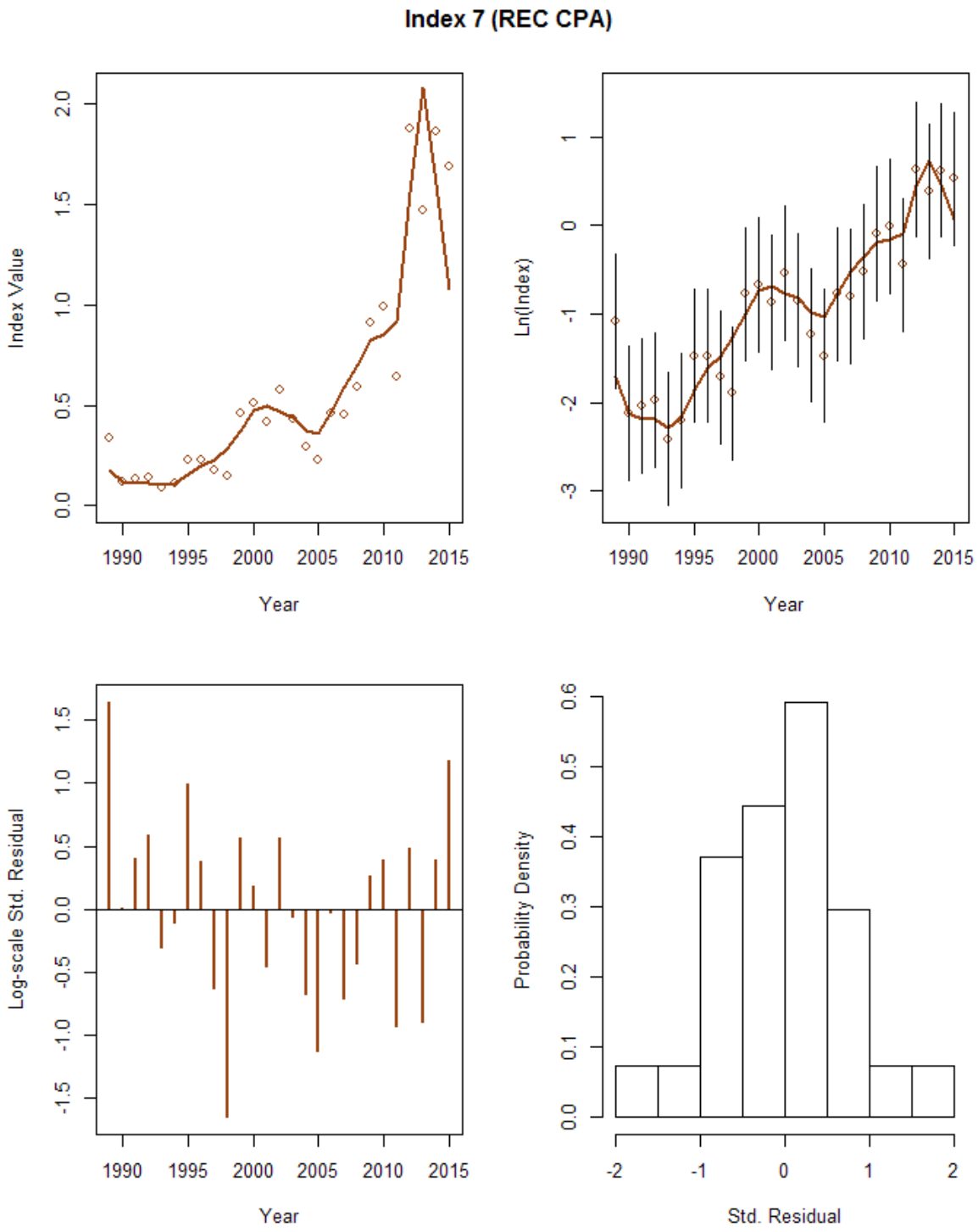

Figure A92. Fit diagnostics for the Rec CPA in final black sea bass **North** area model.

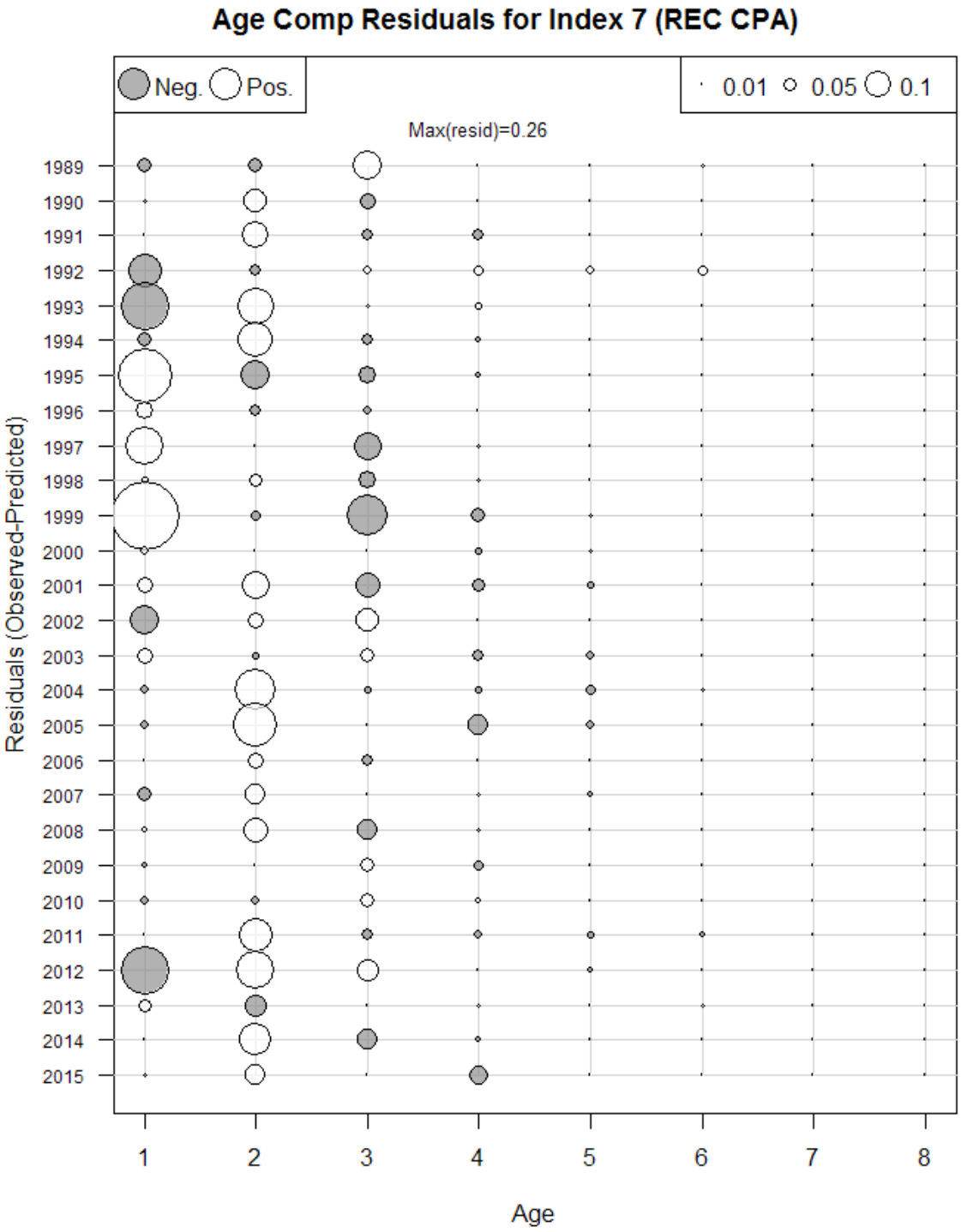

Figure A93. Age composition residuals for the Rec CPA in final black sea bass **North** area model.

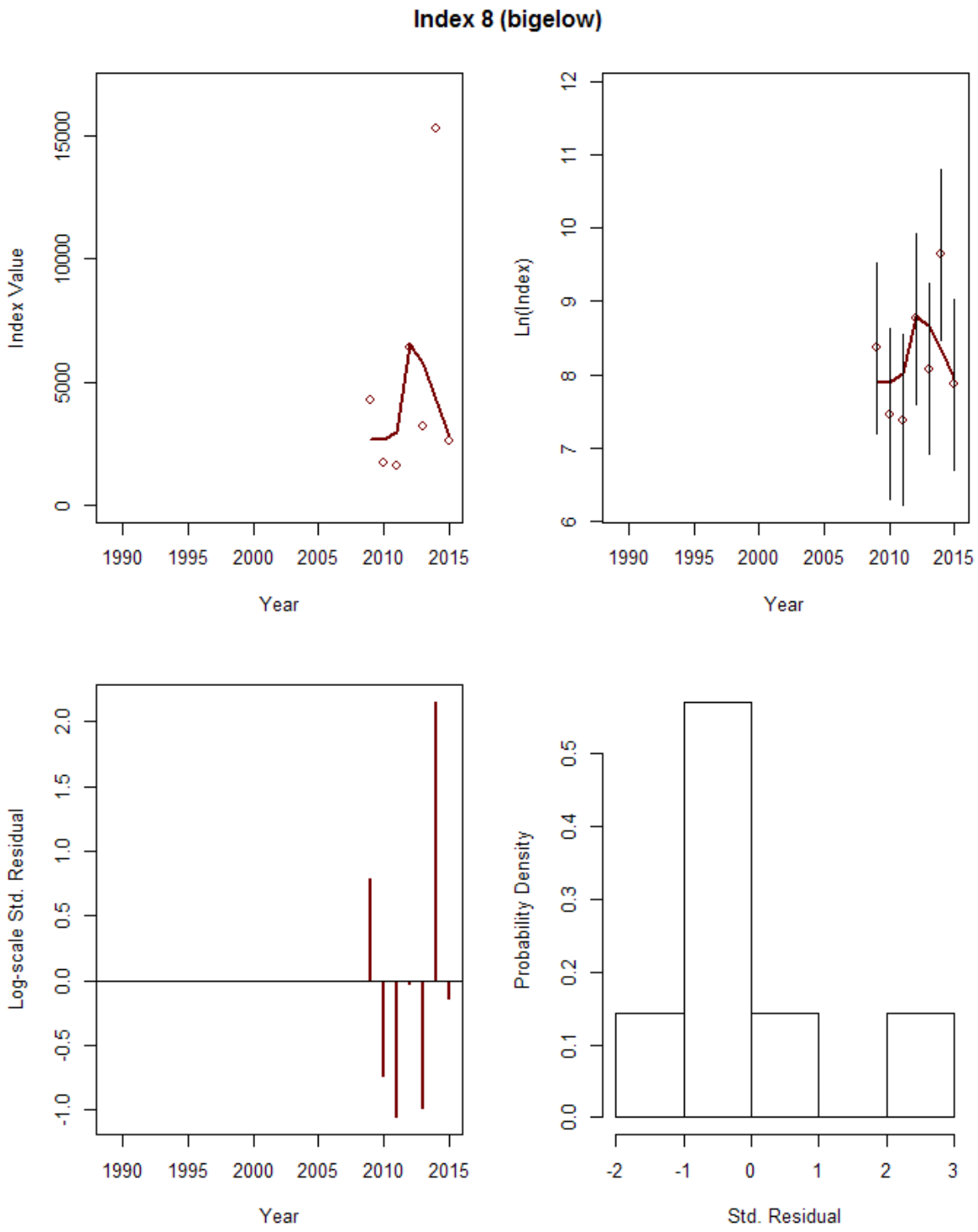

Figure A94. Fit diagnostics the NEFSC spring trawl survey, 2009-2015 (*Bigelow)* in final black sea bass **North** area model.

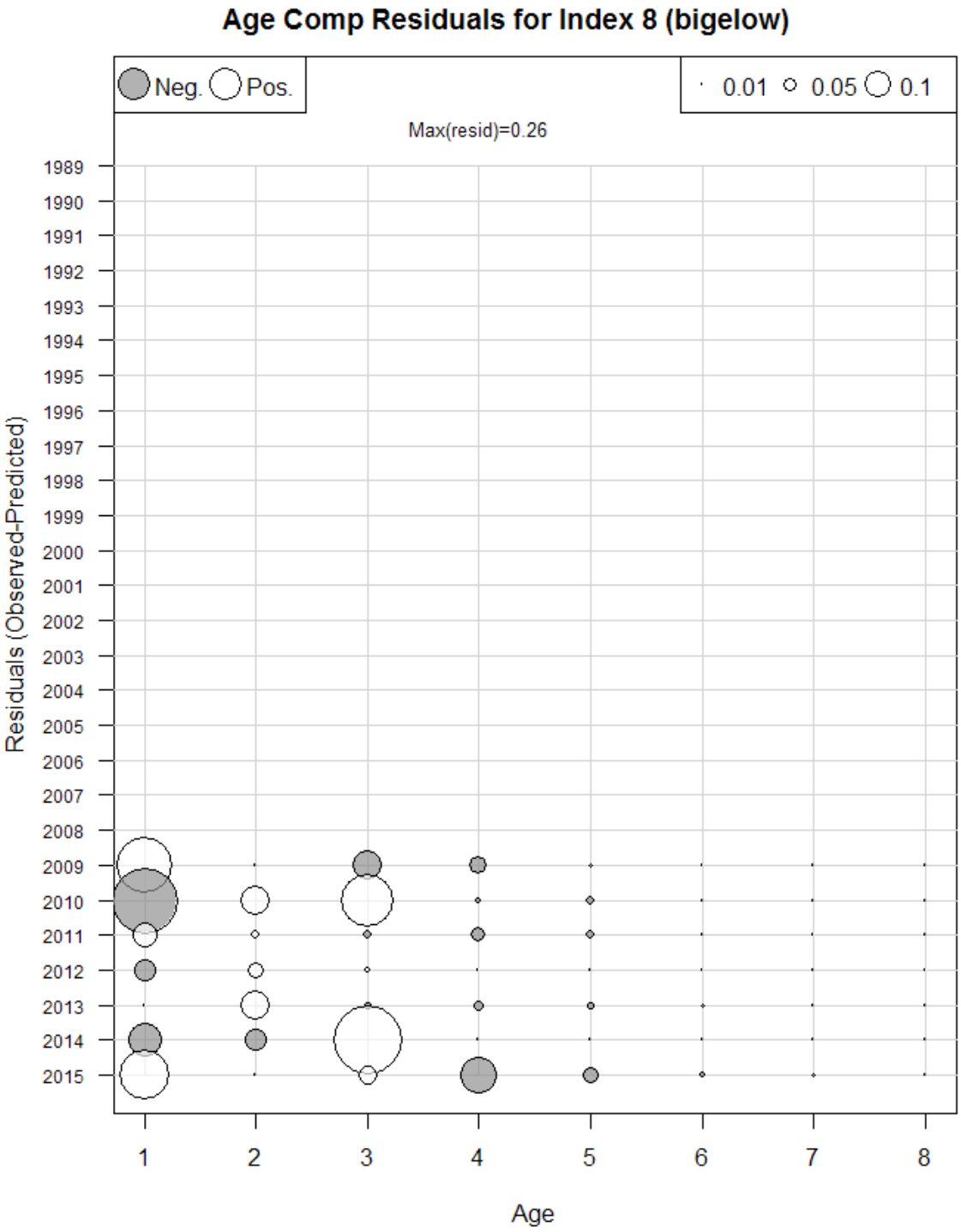

Figure A95. Age composition residuals for the NEFSC spring trawl survey, 2009-2015 (*Bigelow)* in final black sea bass **North** area model.

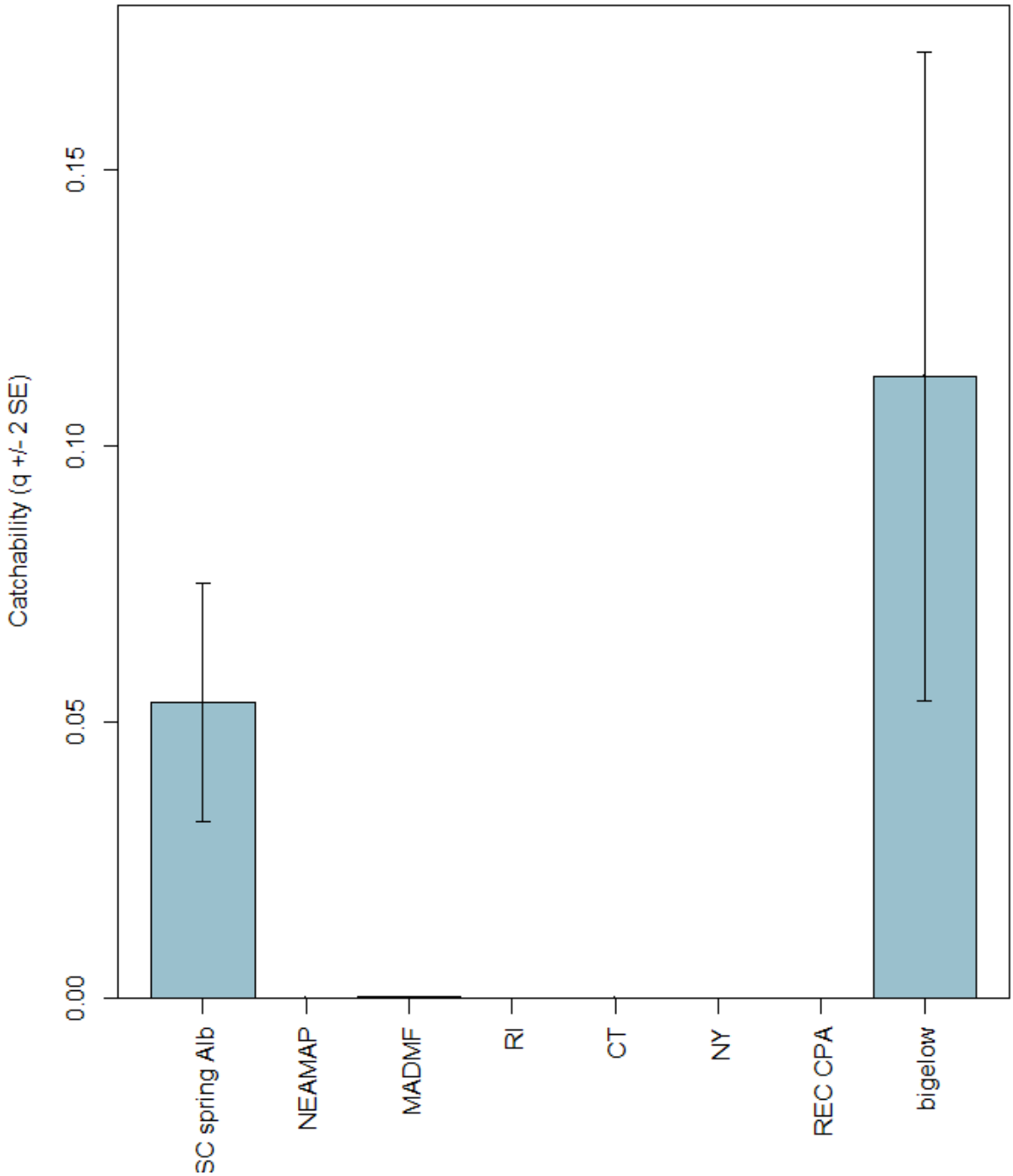

Figure A96. Index catchability estimates from final black sea bass **North** area model.

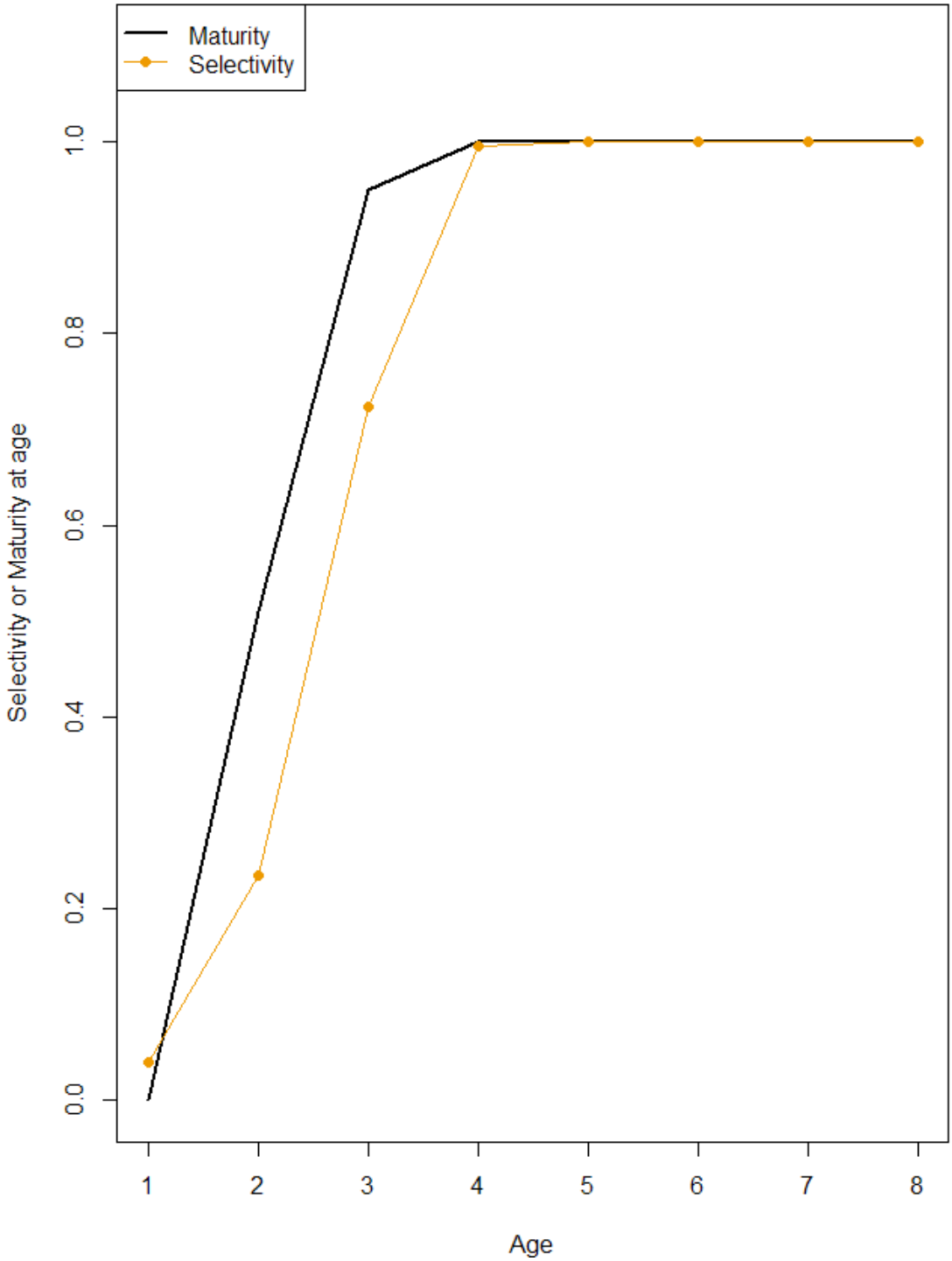

Figure A97. Comparison of age at maturity and average selectivity from final black sea bass **North** area model.

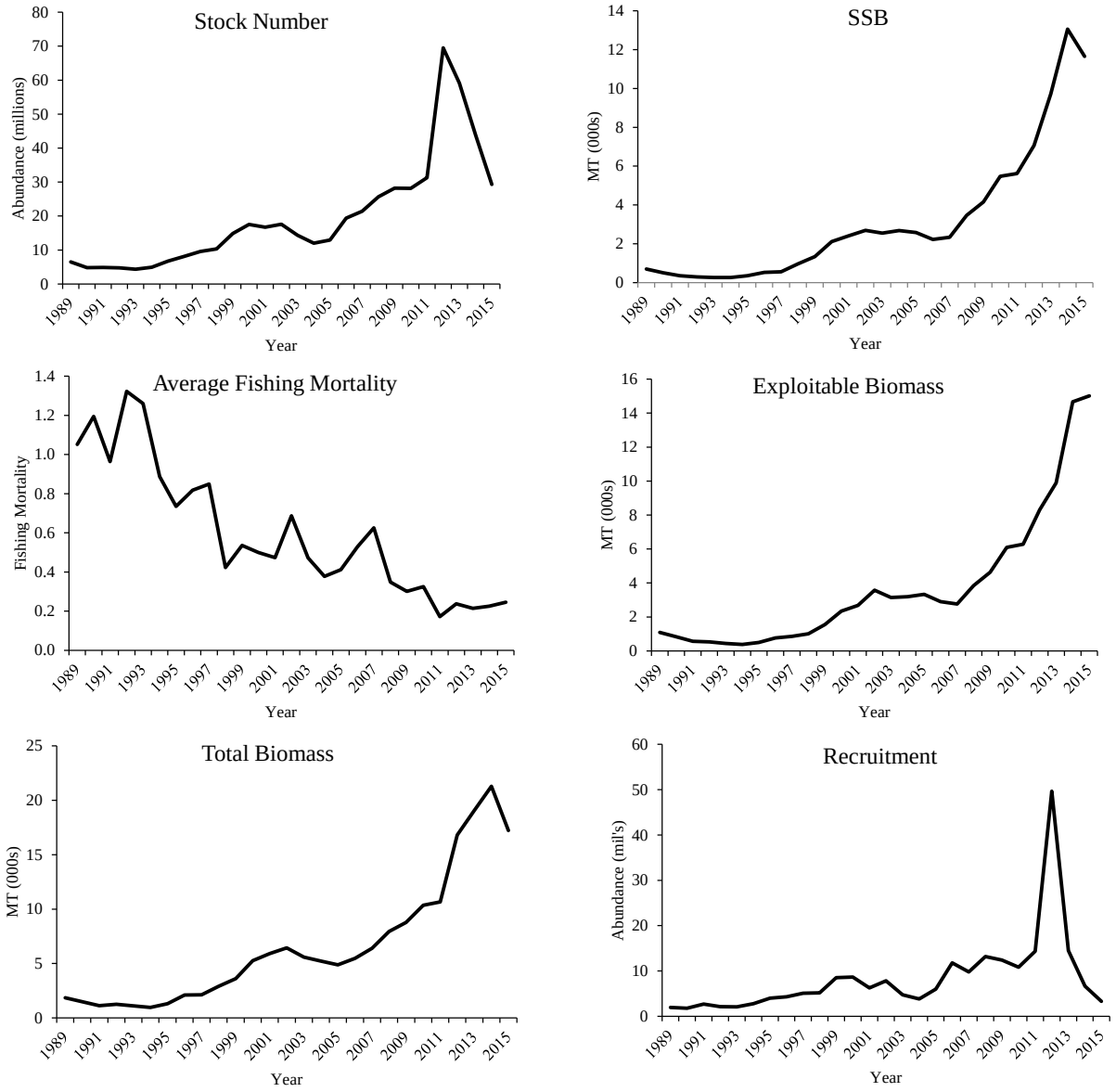

Figure A98. Results of stock number, fishing mortality, total biomass, spawning biomass, exploitable biomass and recruitment from the black sea bass **North** area model.

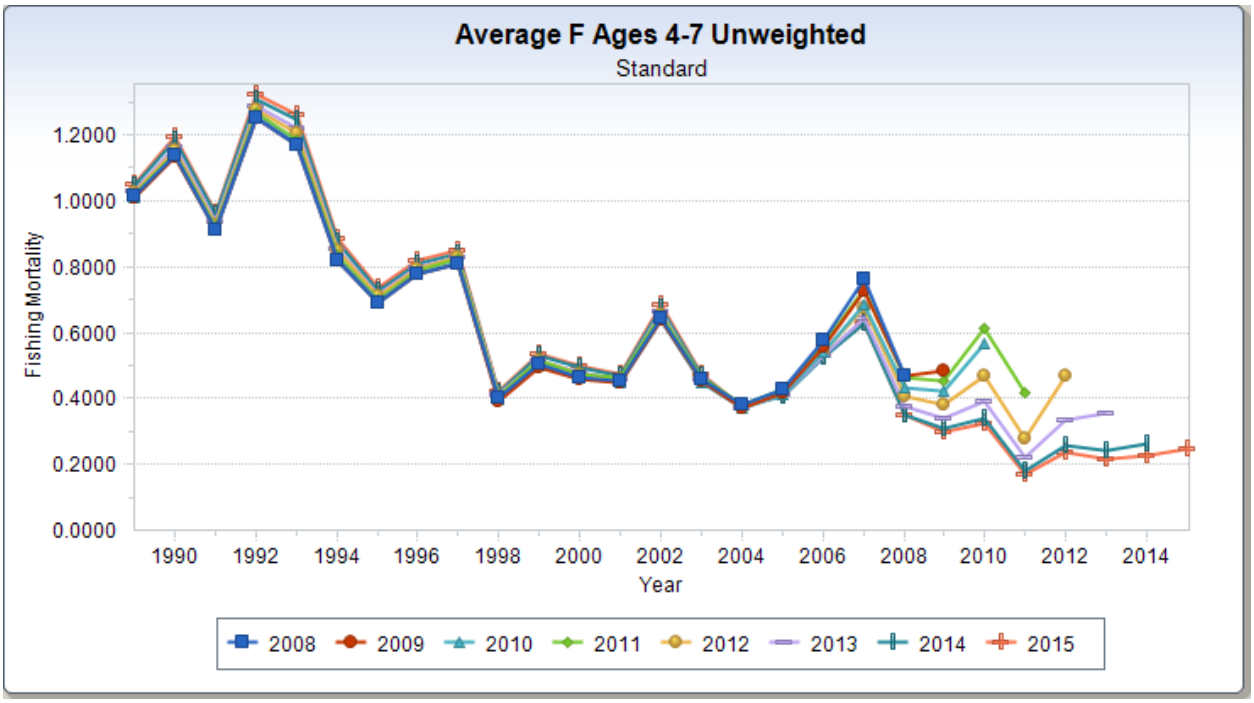

Figure A99. Retrospective pattern in average F estimates from black sea bass ASAP model for **North** area. Mohn's rho = 0.70.

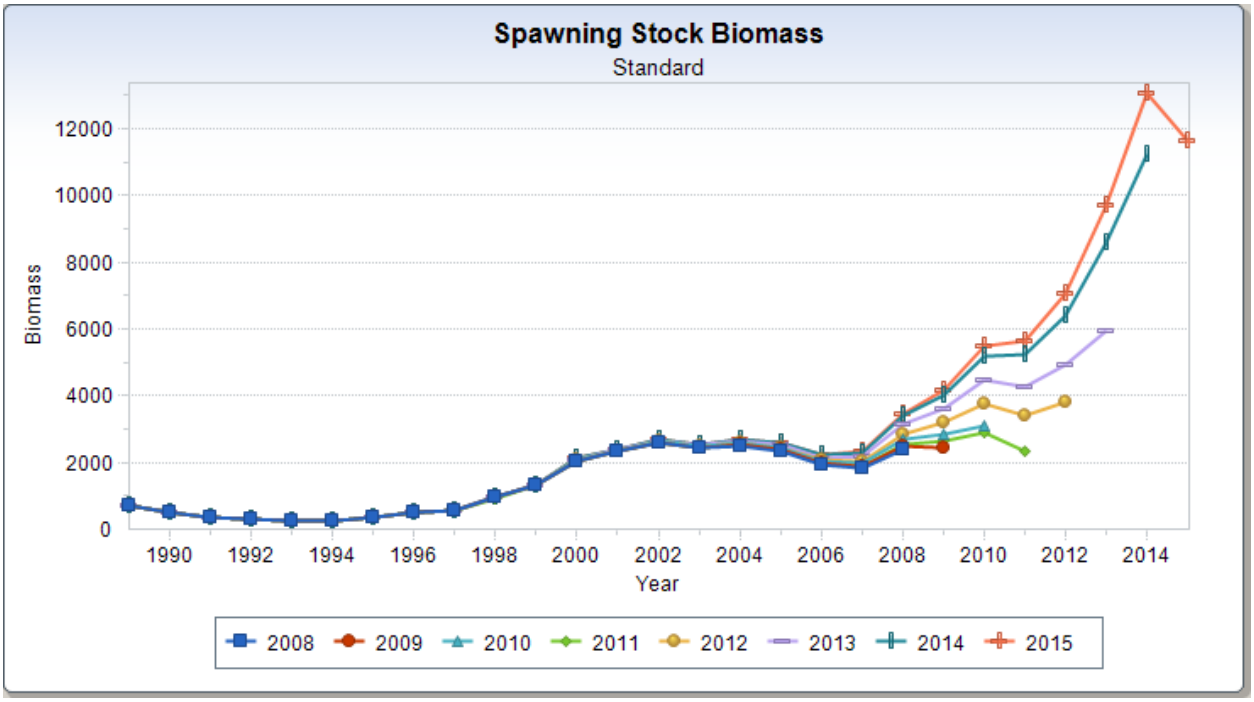

Figure A100. Retrospective pattern in spawning stock biomass (mt) estimates from black sea bass ASAP model for **North** area. Mohn's rho = -0.39

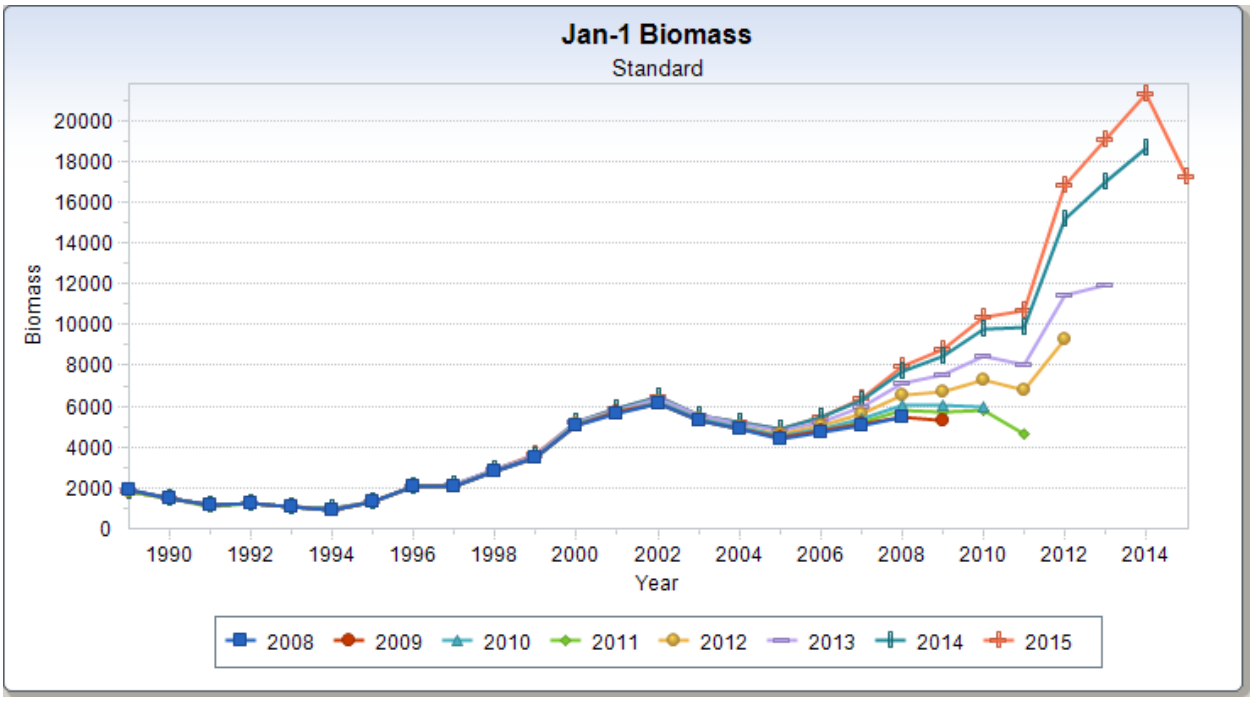

Figure A101. Retrospective pattern in January 1 biomass (mt) estimates from black sea bass ASAP model for **North** area. Mohn's rho = -0.38

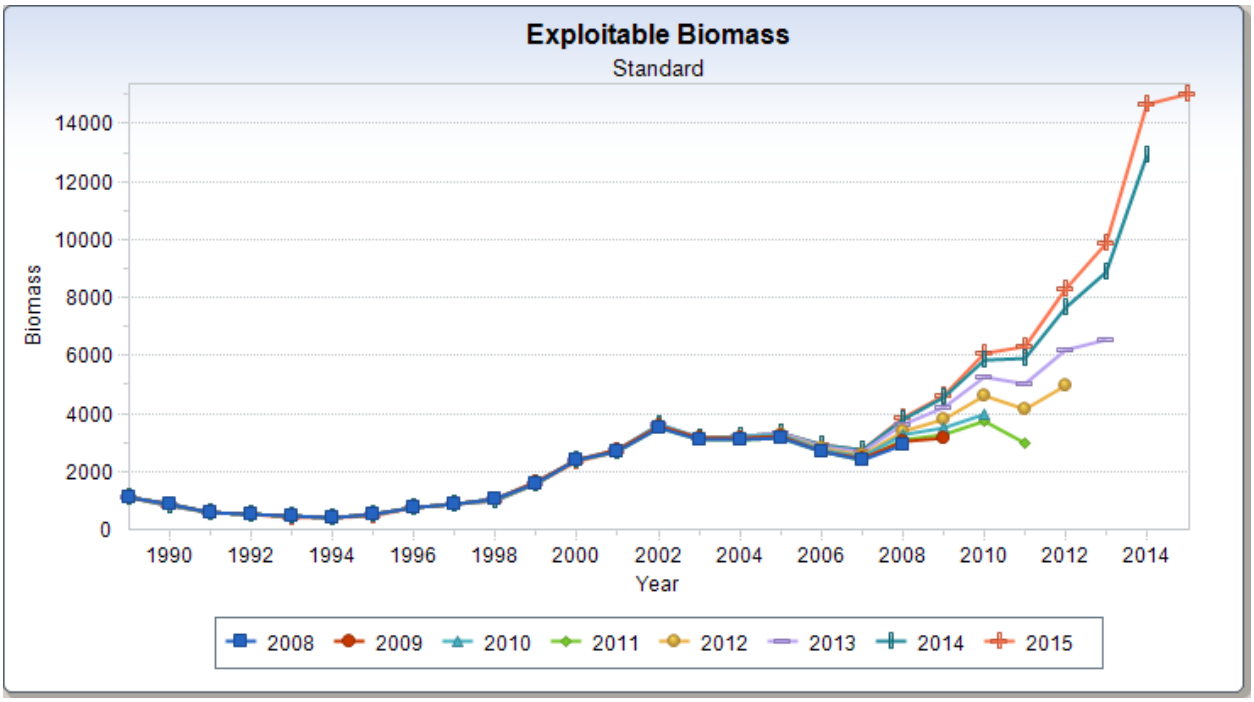

Figure A102. Retrospective pattern in exploitable biomass (mt) estimates from black sea bass ASAP model for **North** area. Mohn's rho = -0.33

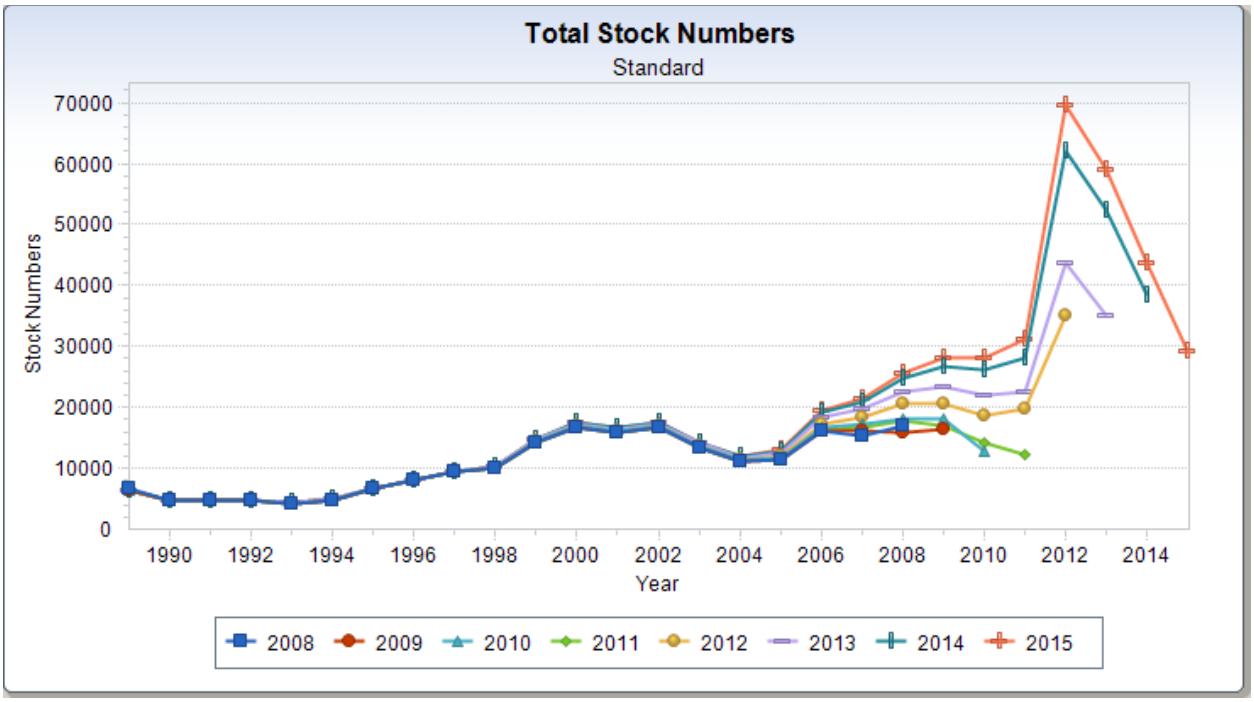

Figure A103. Retrospective pattern in total stock number estimates from black sea bass ASAP model for **North** area. Mohn's rho = -0.42

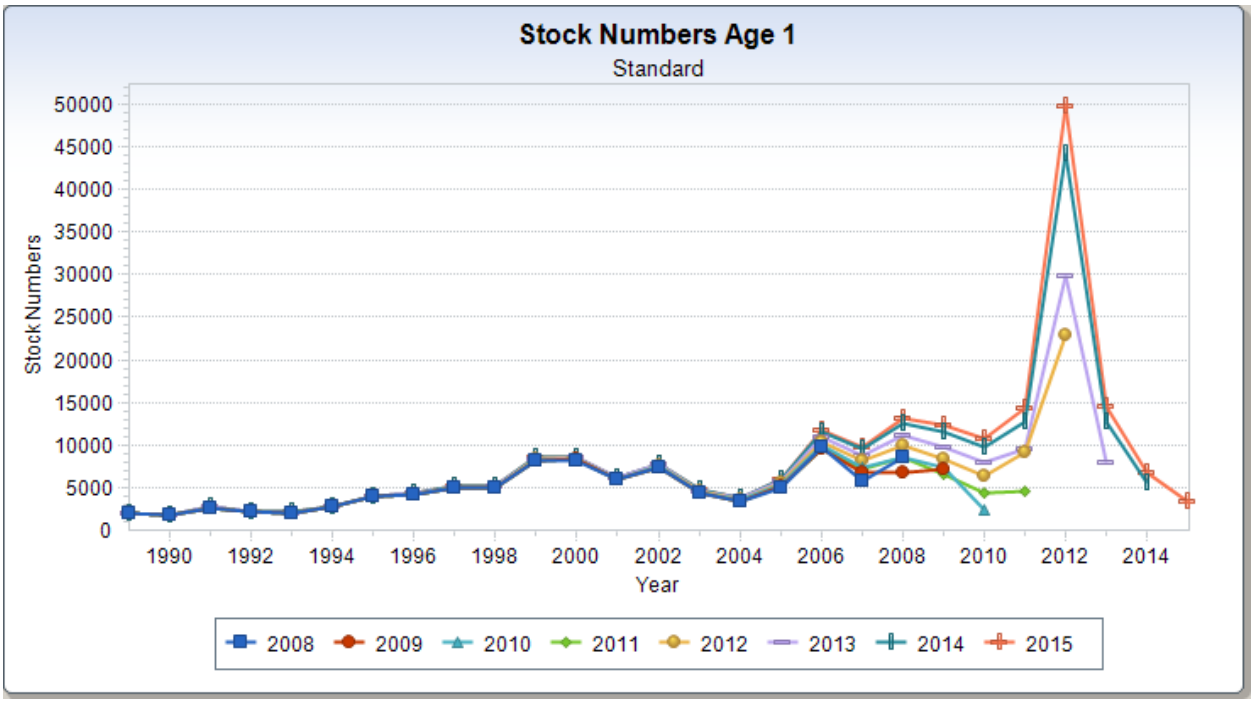

Figure A104. Retrospective pattern in age 1 (recruits) estimates from black sea bass ASAP model for **North** area. Mohn's rho = -0.48

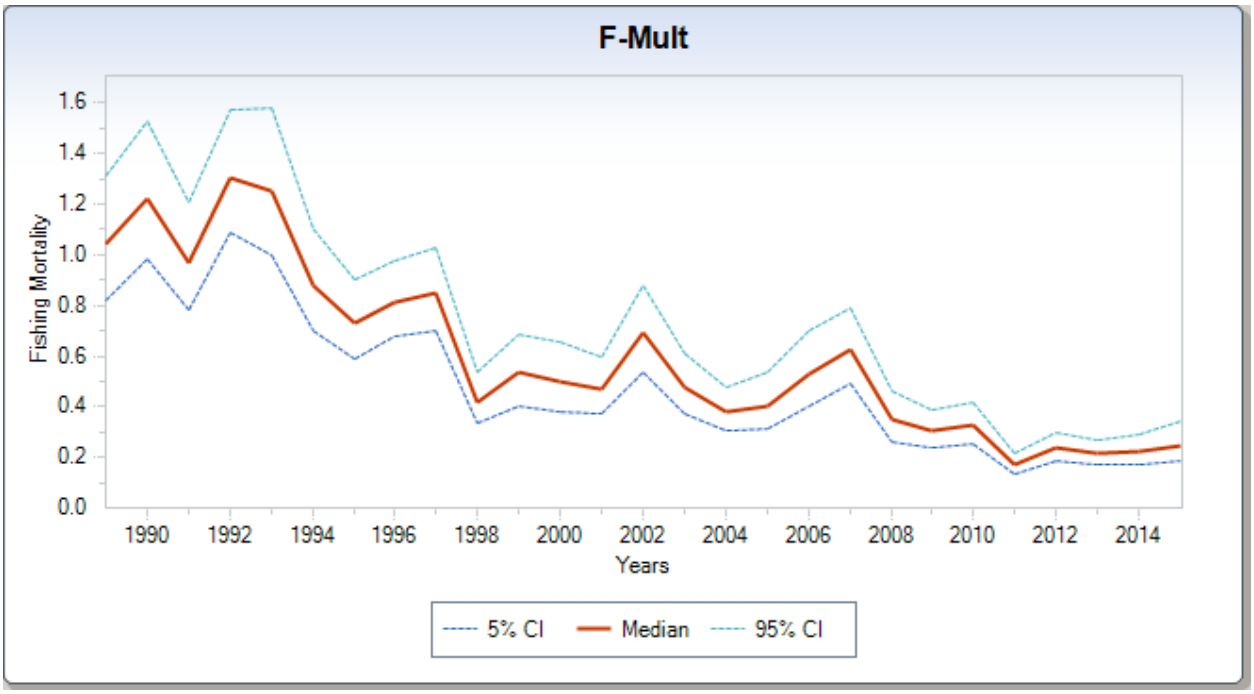

Figure A105. ASAP MCMC estimates of black sea bass Fmult (± 90% CI) from **North** area model.

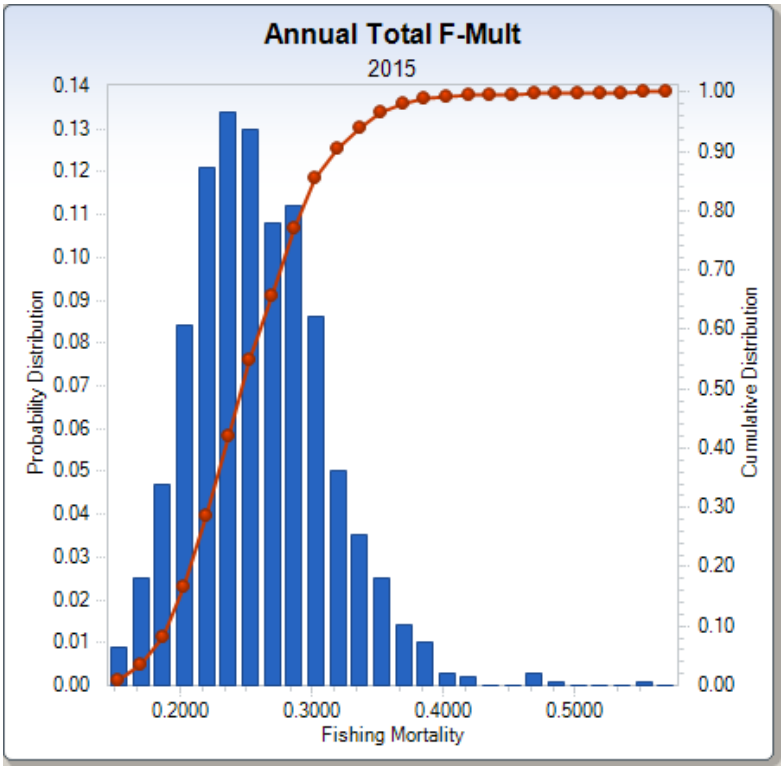

Figure A106. MCMC distribution of 2015 black sea bass F mult estimates from **North** area model.

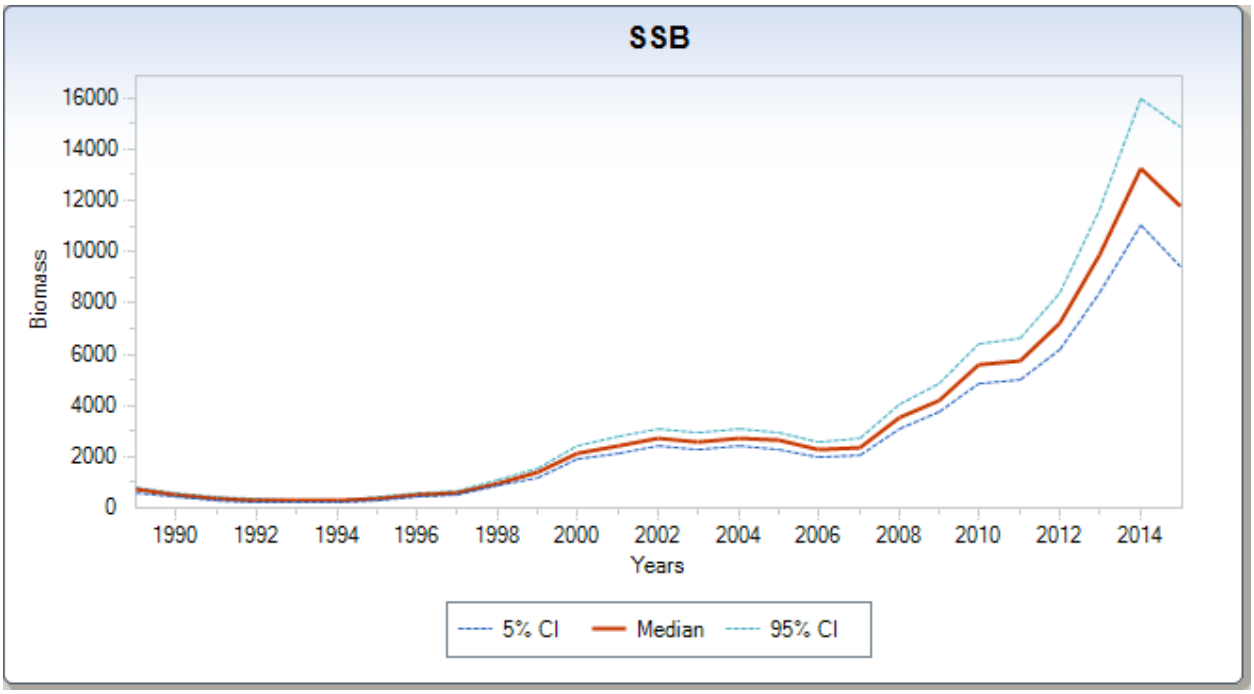

Figure A107. ASAP MCMC estimates of black sea bass spawning stock biomass (mt ± 90% CI) from **North** area model.

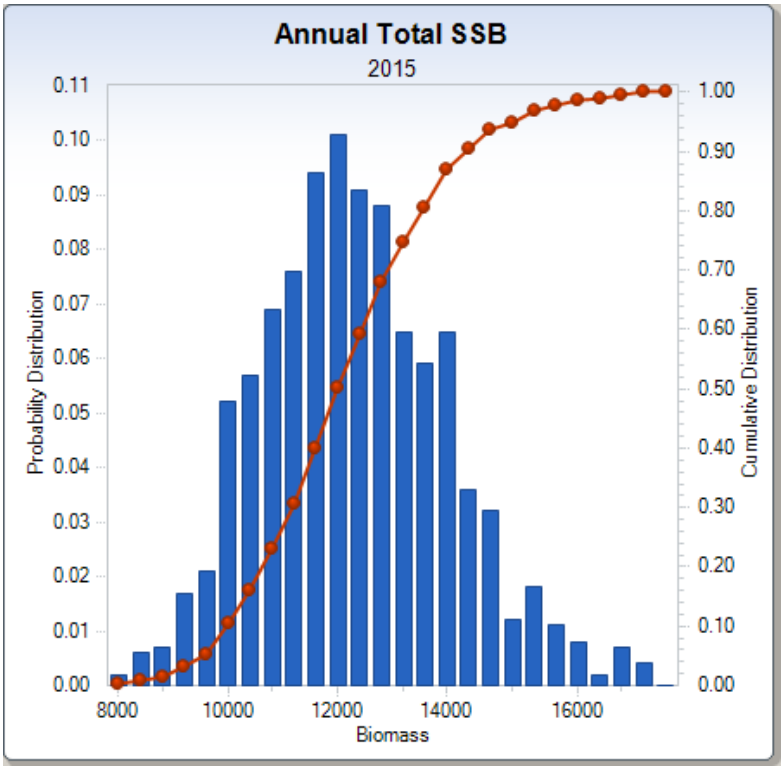

Figure A108. MCMC distribution of 2015 black sea bass spawning stock biomass (mt) estimates from **North** area model.

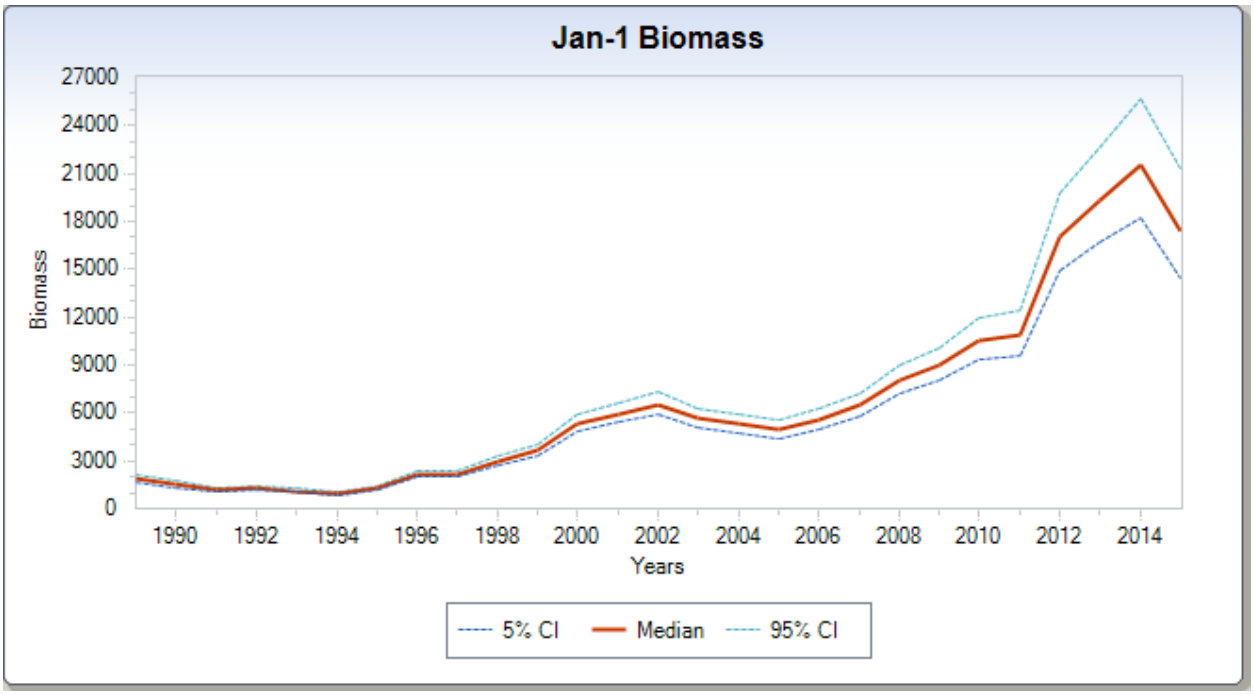

Figure A109. ASAP MCMC estimates of black sea bass Jan 1 biomass (mt ± 90% CI) from **North** area model.

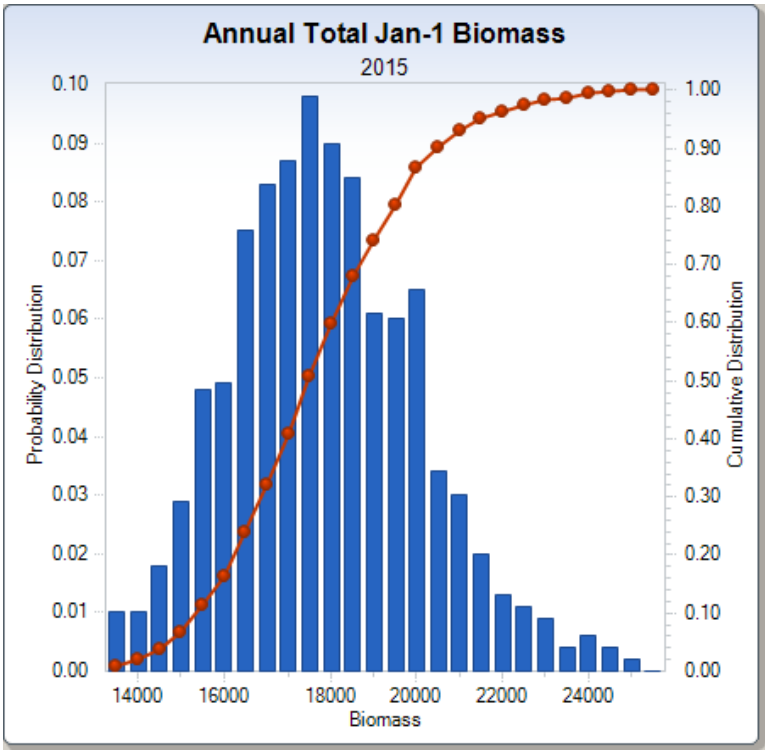

Figure A110. MCMC distribution of 2015 black sea bass total biomass (mt) estimates from **North** area model.

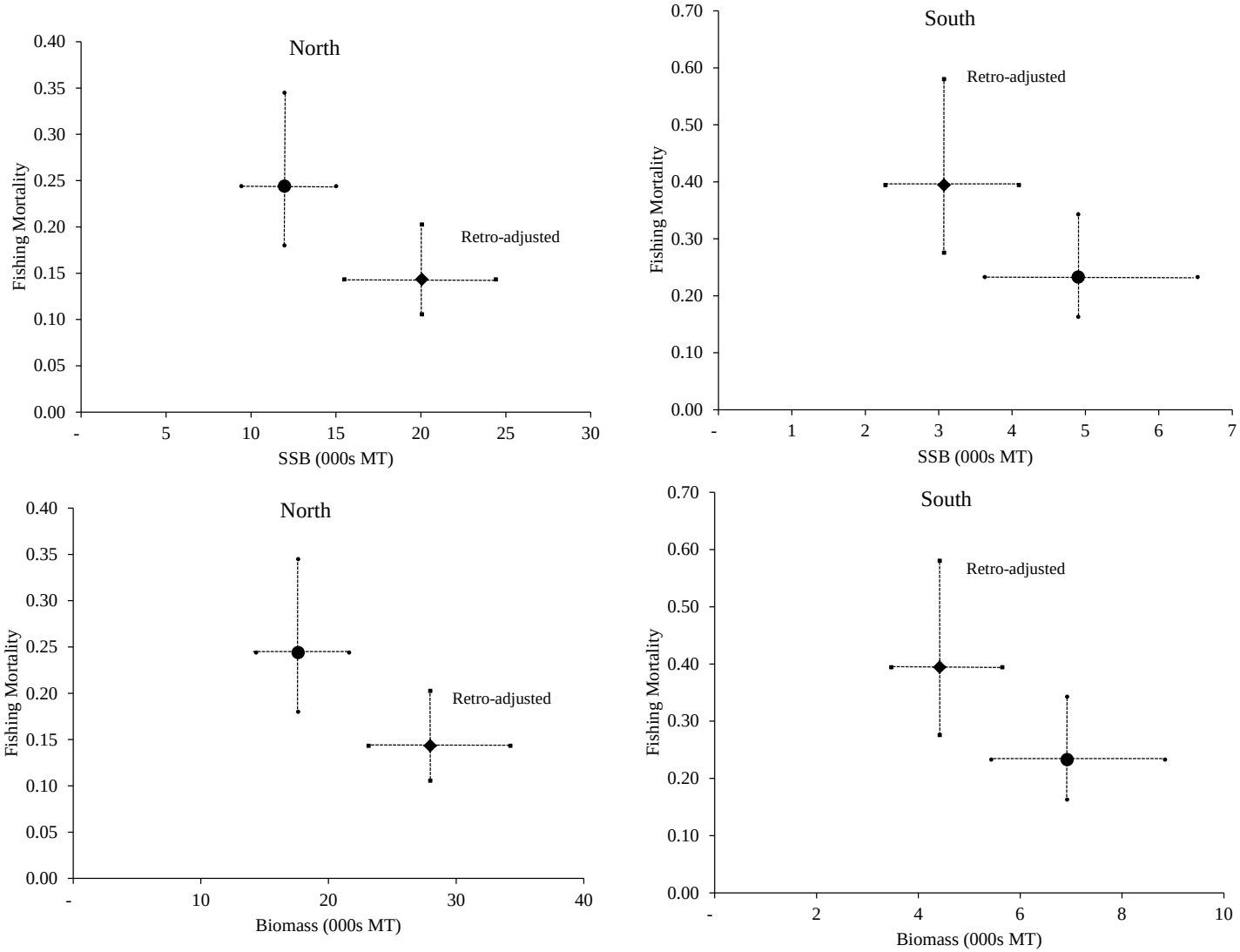

Figure A110a. Black sea bass median fishing mortality and SSB (000s mt) ± 90% CI and fishing morality and total biomass (000s mt) from base estimates and retro-adjusted values for North and South area.

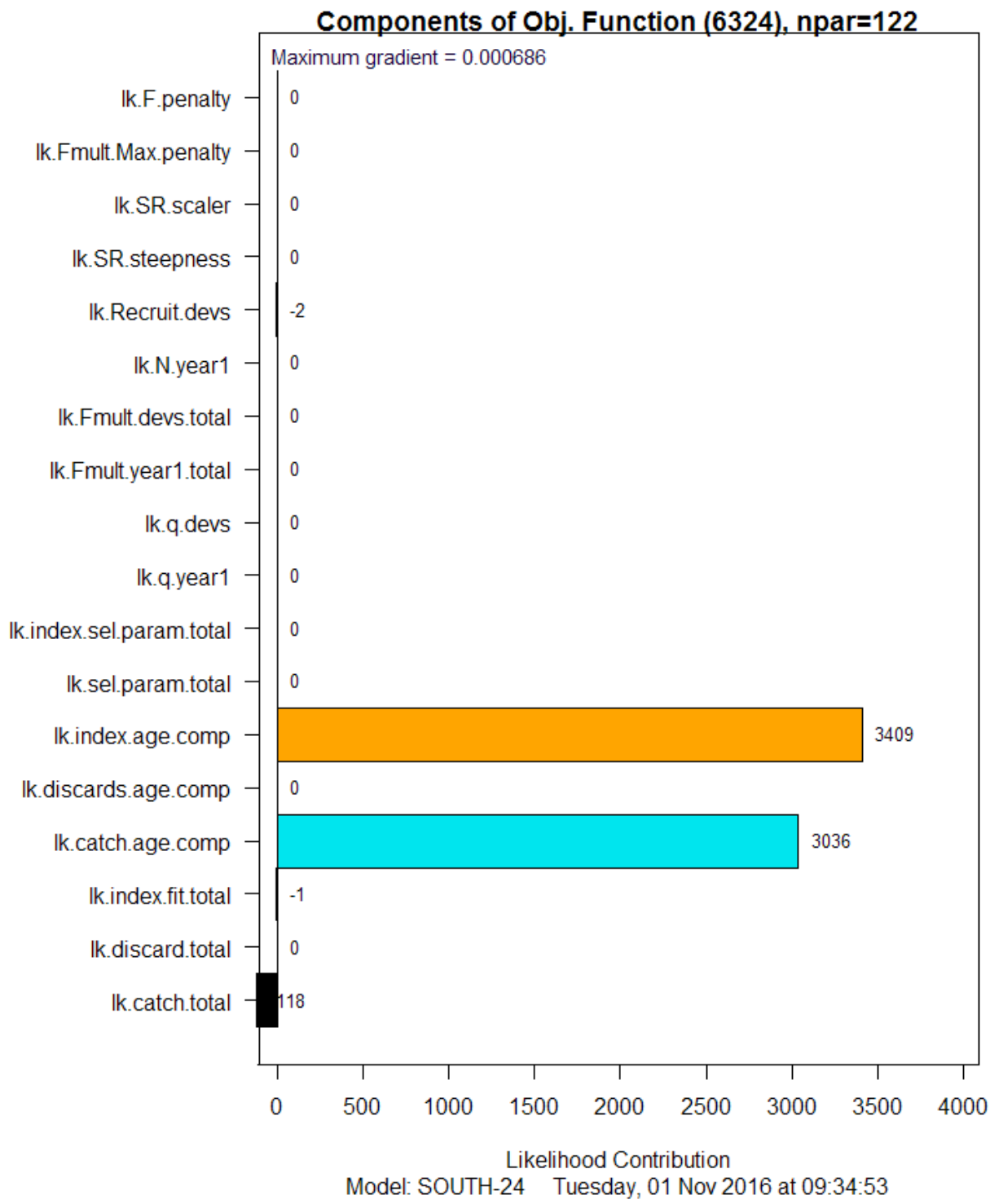

Figure A111. Distribution of objective function components contribution to total likelihood for black sea bass **South** area model.

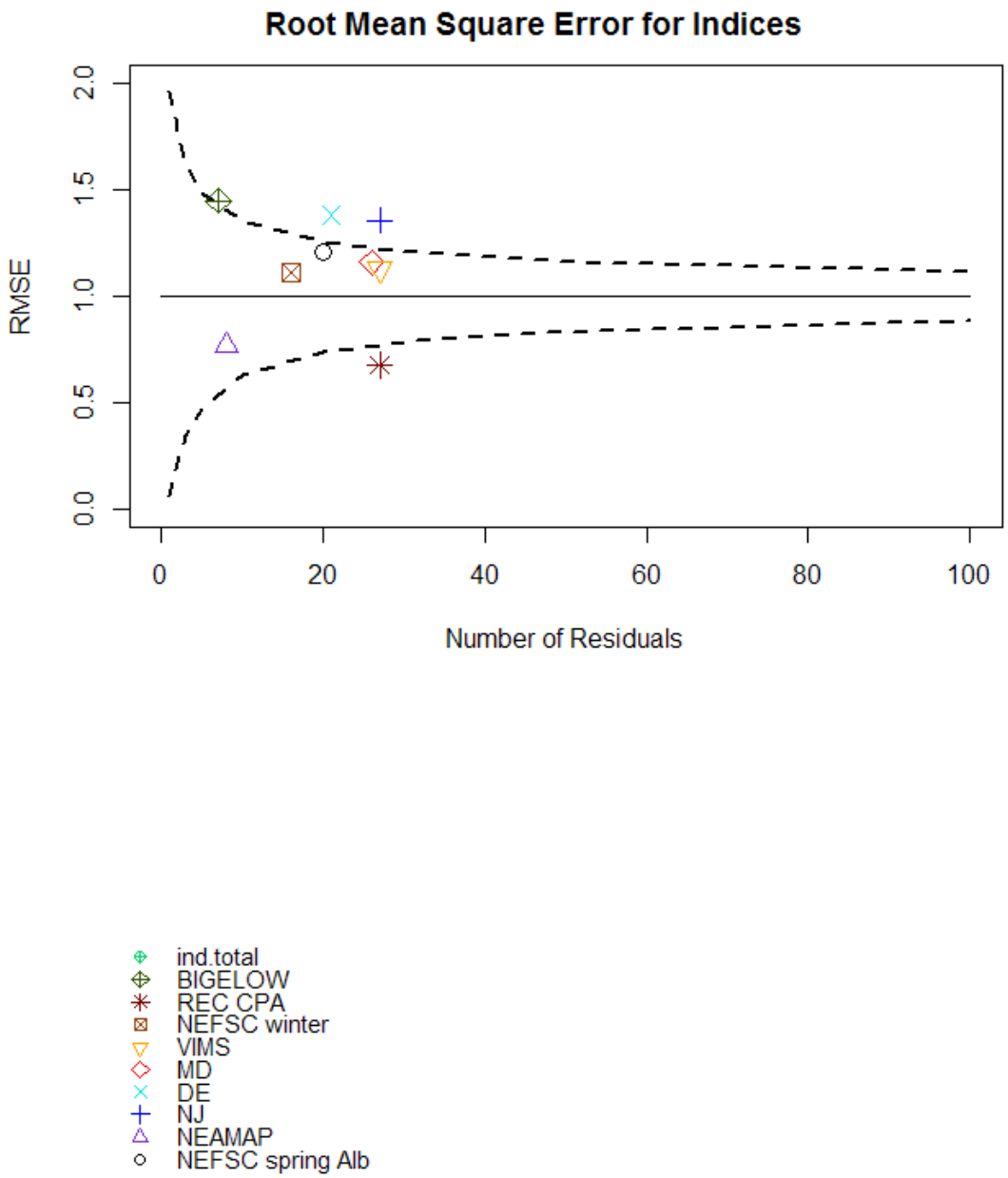

Figure A112. Final Root Mean Square Error (RMSE) values for survey indices in final black sea bass **South** area model.

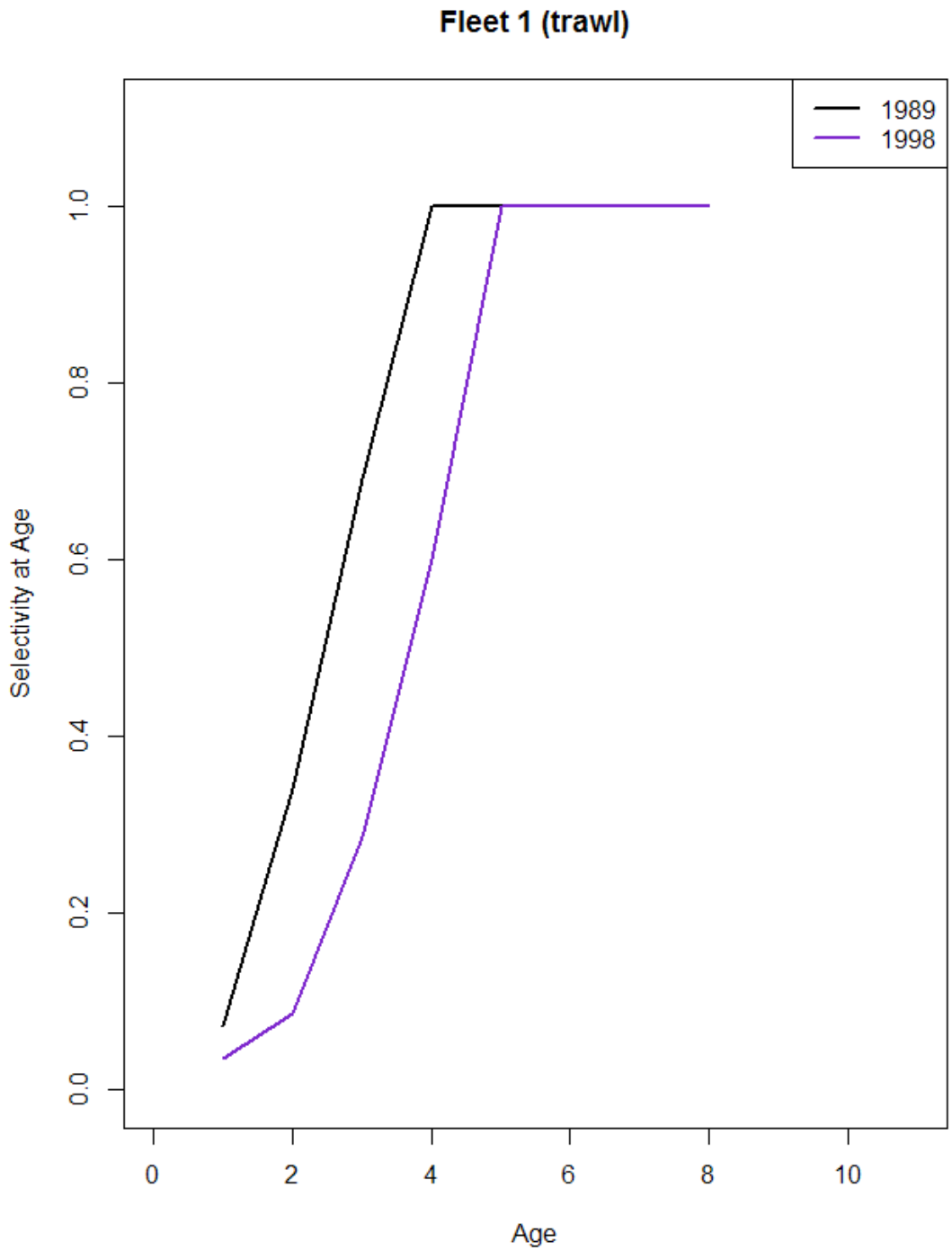

Figure A113. Selectivity at age from trawl fleet in final black sea bass **South** area model.

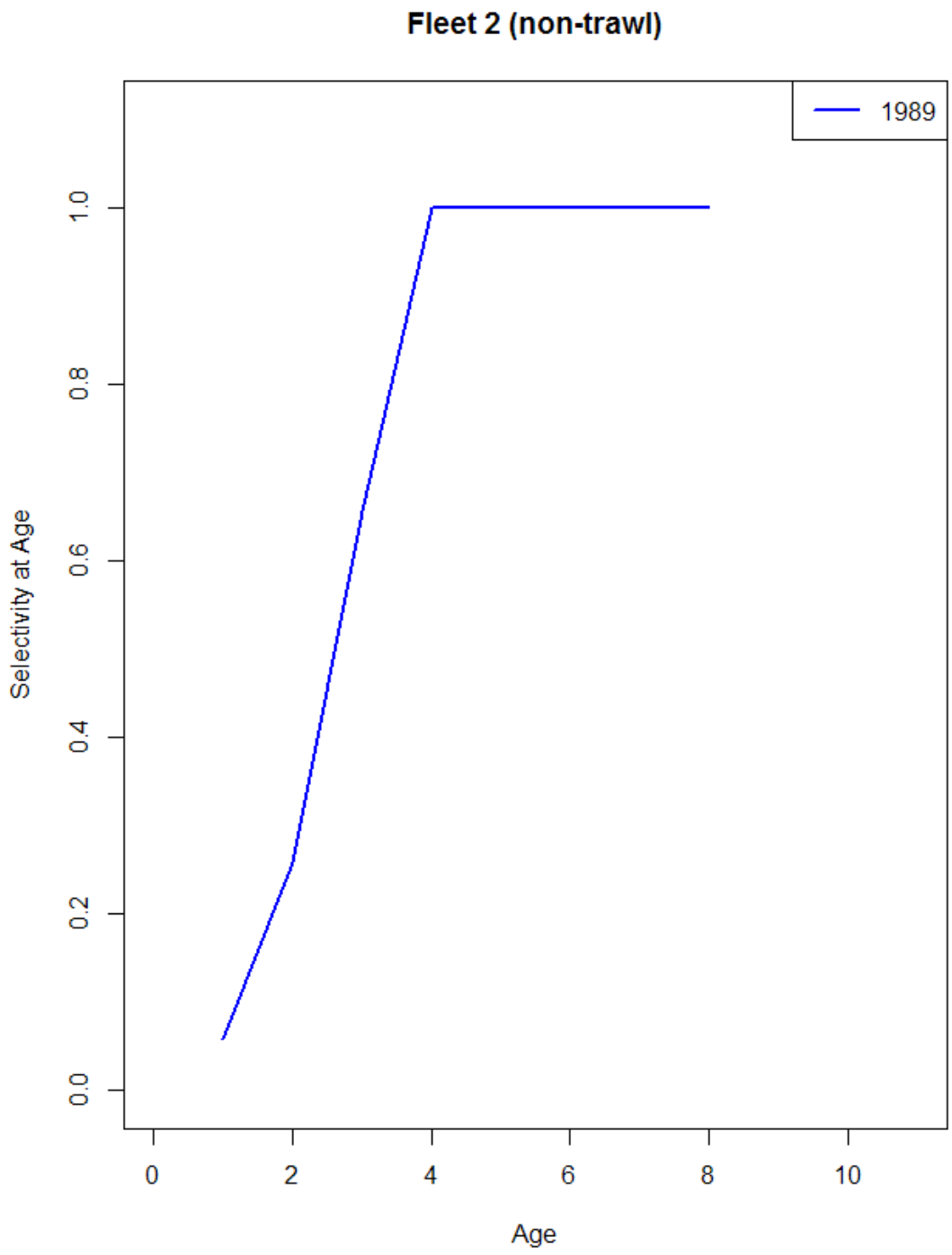

Figure A114. Selectivity at age from non-trawl fleet in final black sea bass **South** area model.

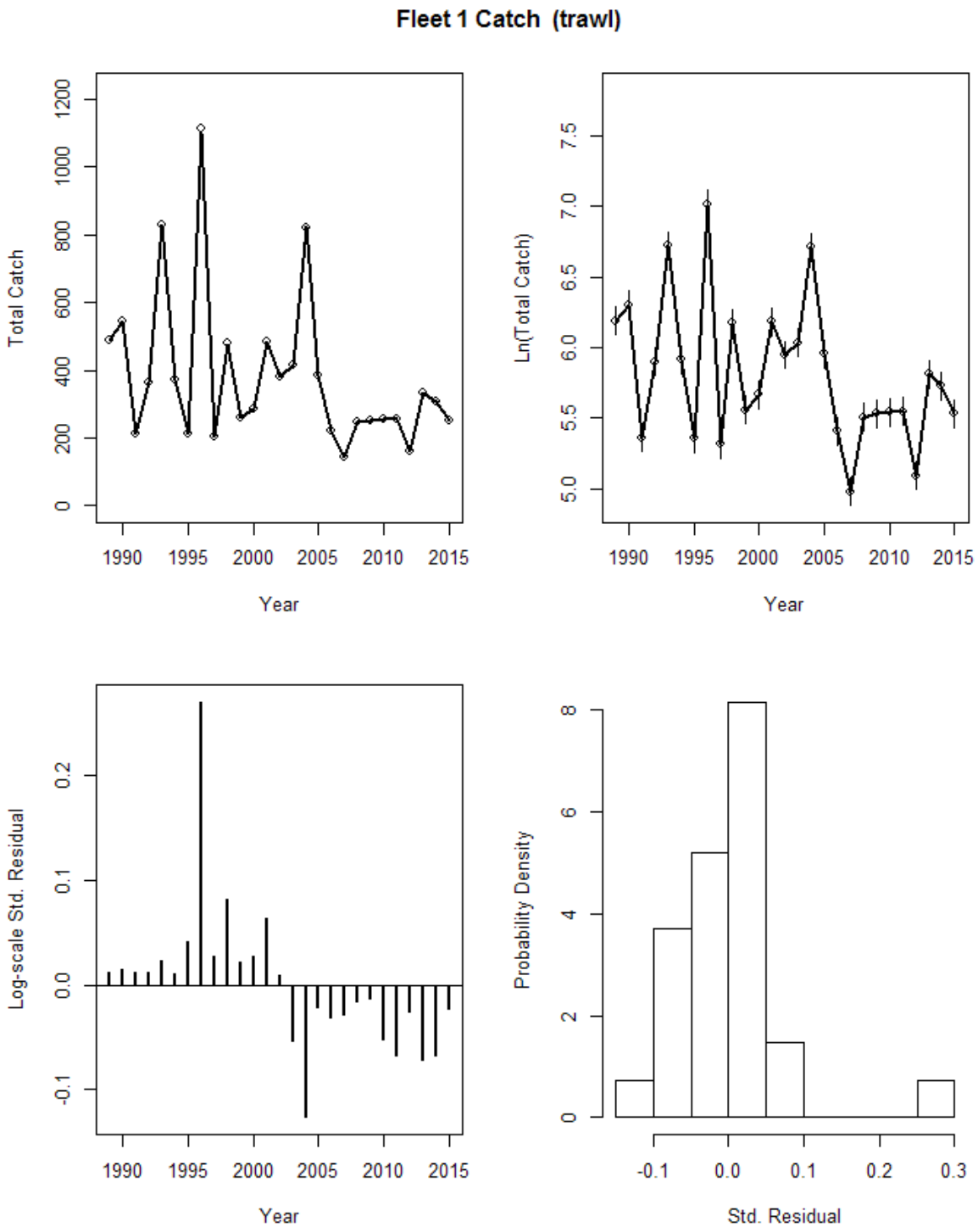

Figure A115. Fit diagnostics for the trawl catch in final black sea bass **South** area model.

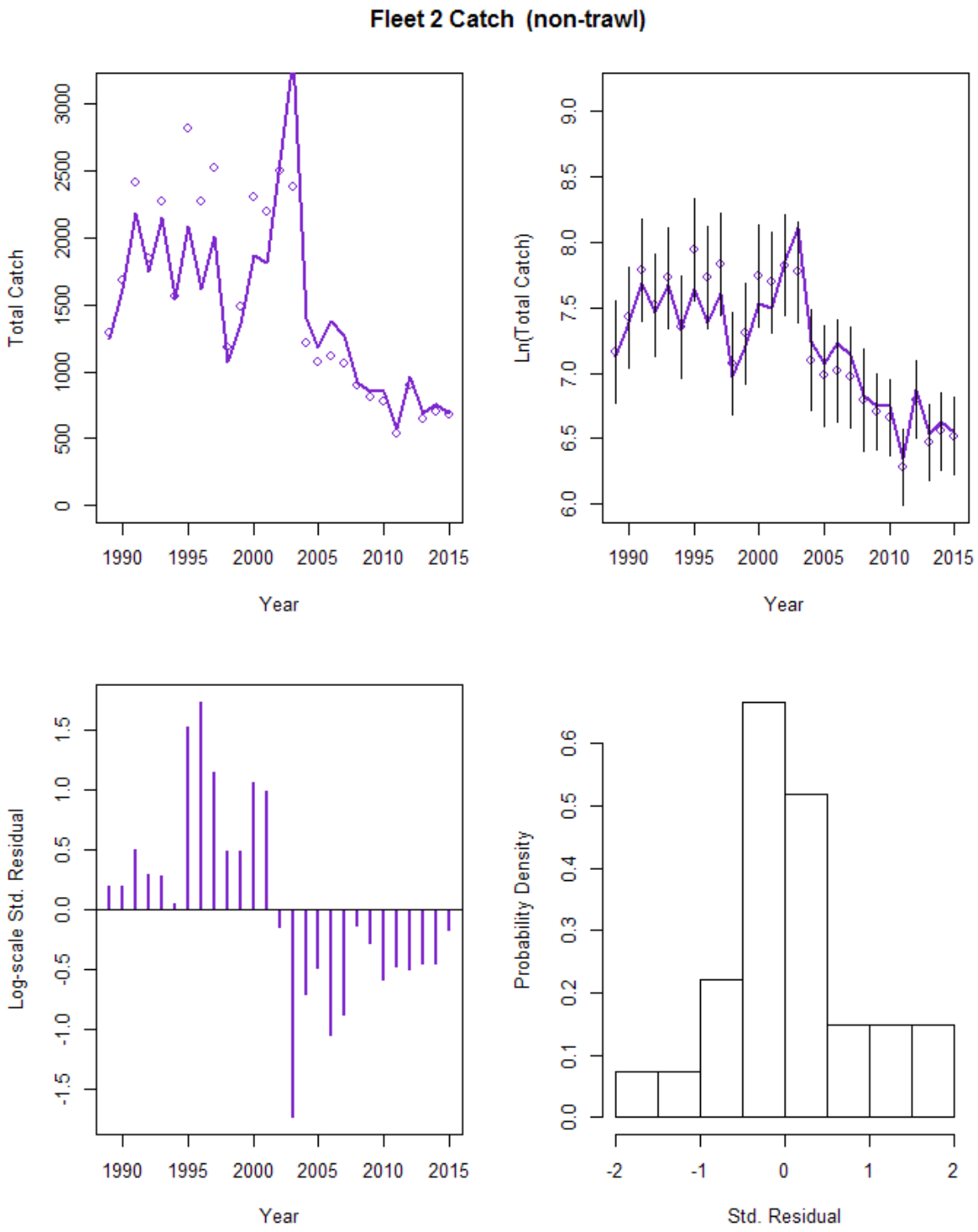

Figure A116. Fit diagnostics for the non-trawl catch in final black sea bass **South** area model.

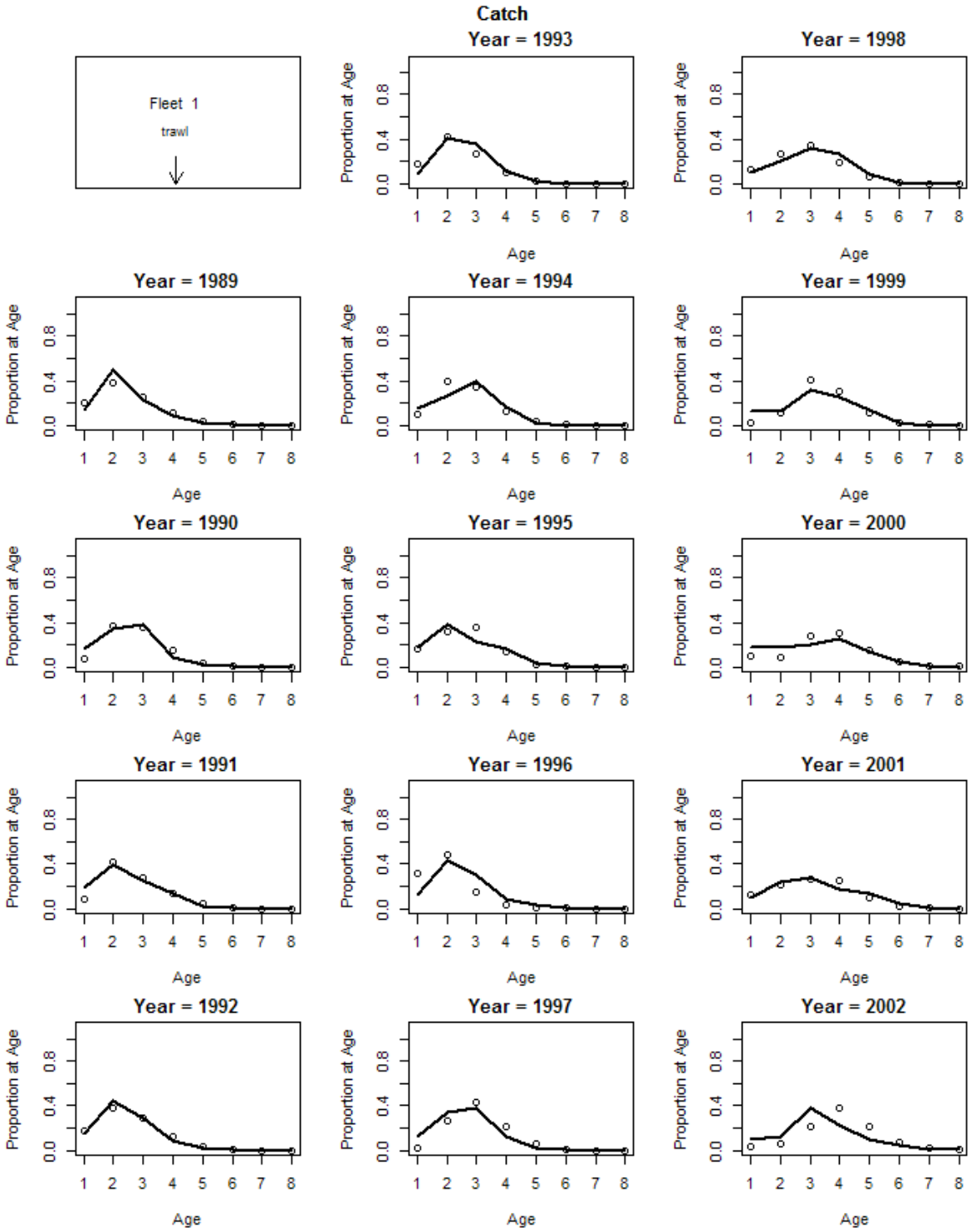

Figure A117. Fits to 1989-2002 trawl catch proportions at age in final black sea bass **South** area model.

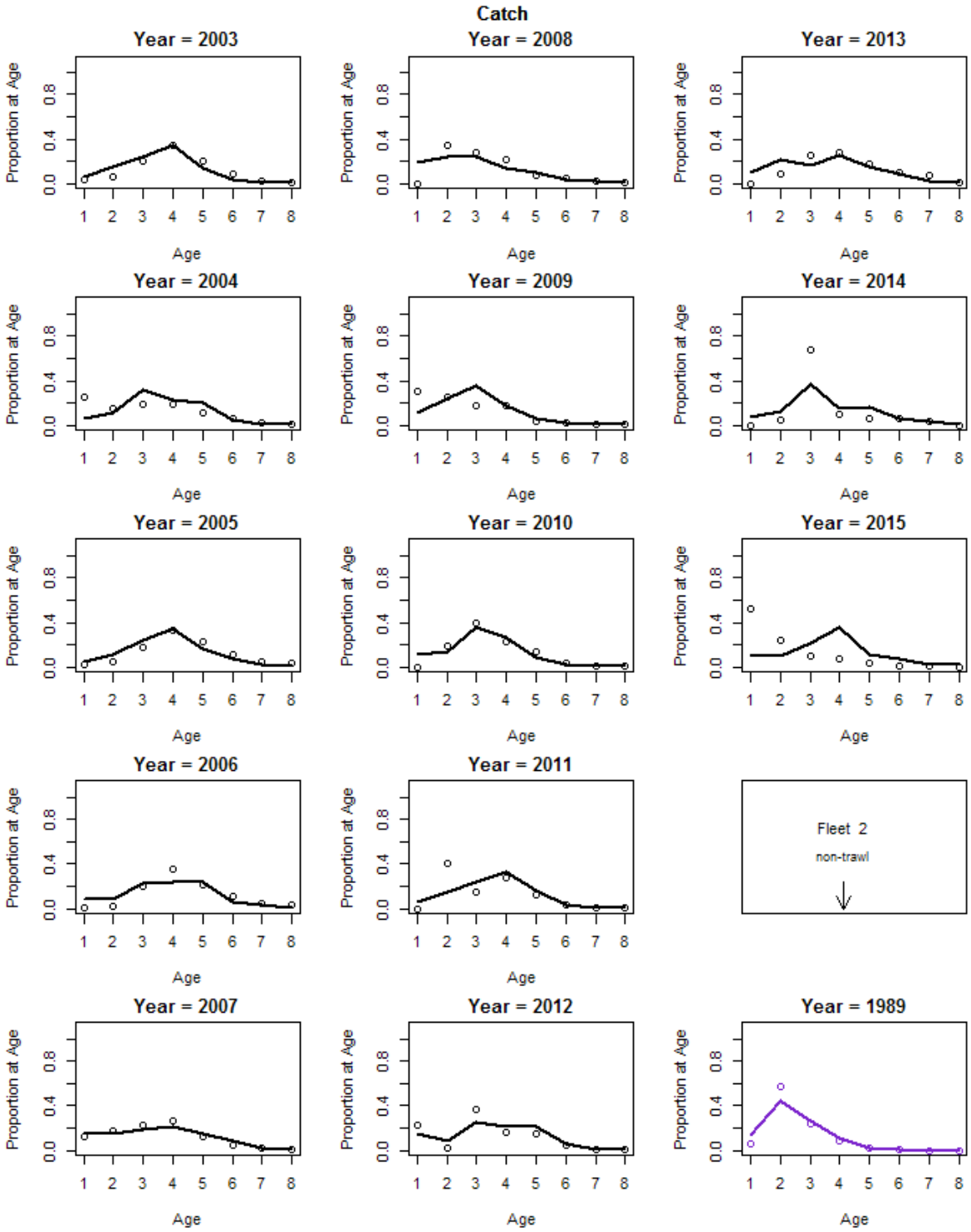

Figure A118. Fits to 2003-2015 trawl catch and 1989 non-trawl catch proportions at age in final black sea bass **South** area model.

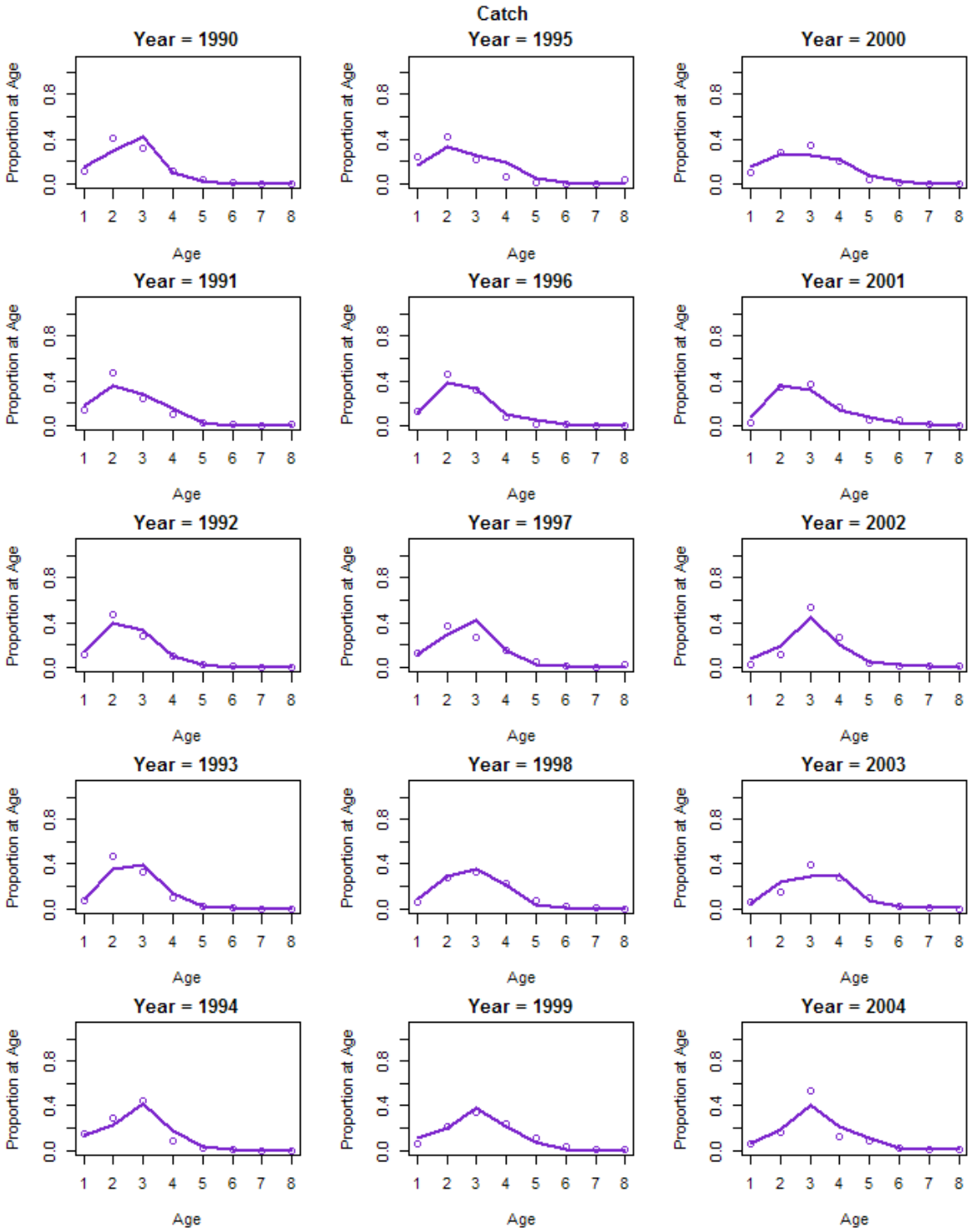

Figure A119. Fits to 1990-2004 trawl catch proportions at age in final black sea bass **South** area model.

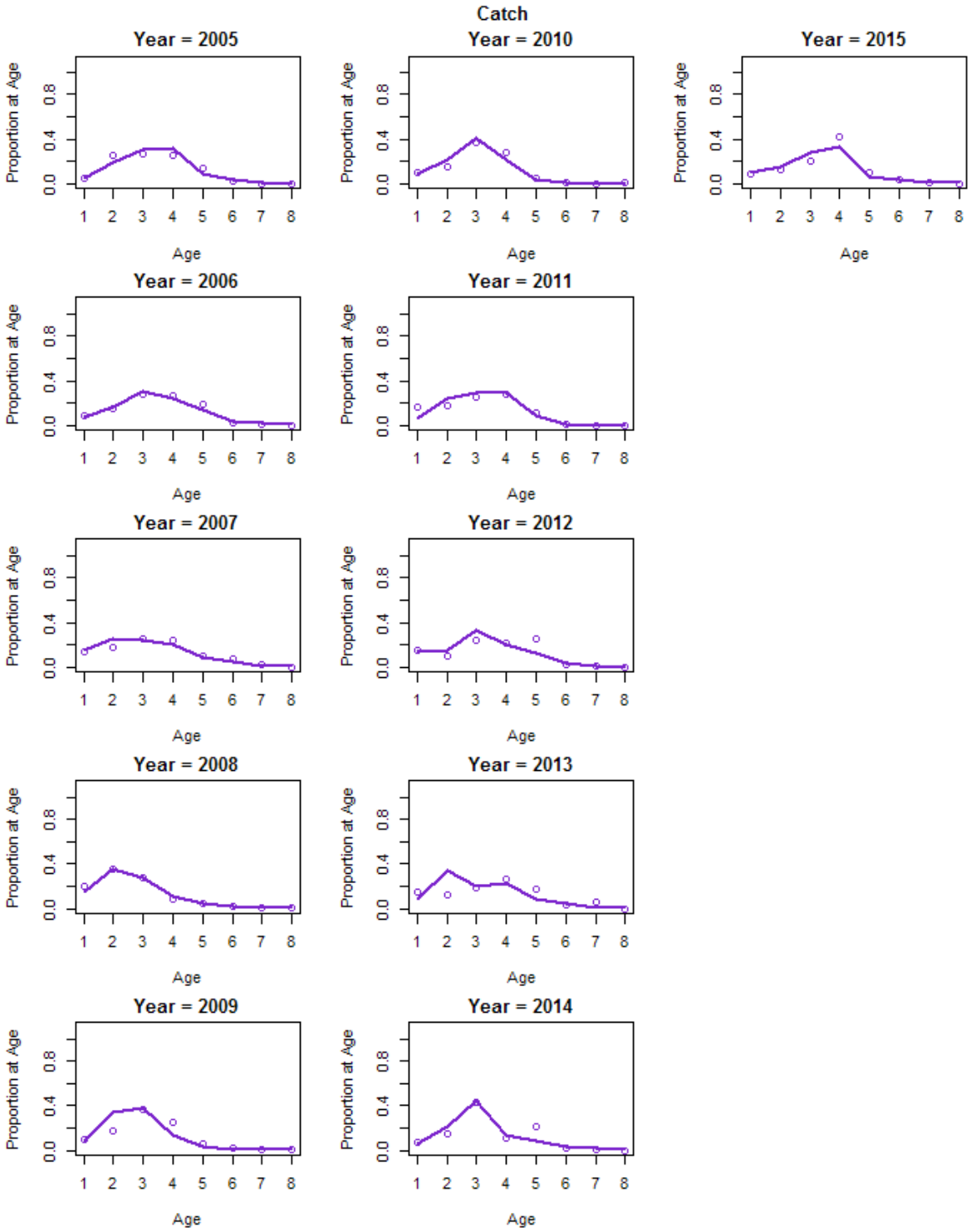

Figure A120. Fits to 2005-2015 trawl catch proportions at age in final black sea bass **South** area model.

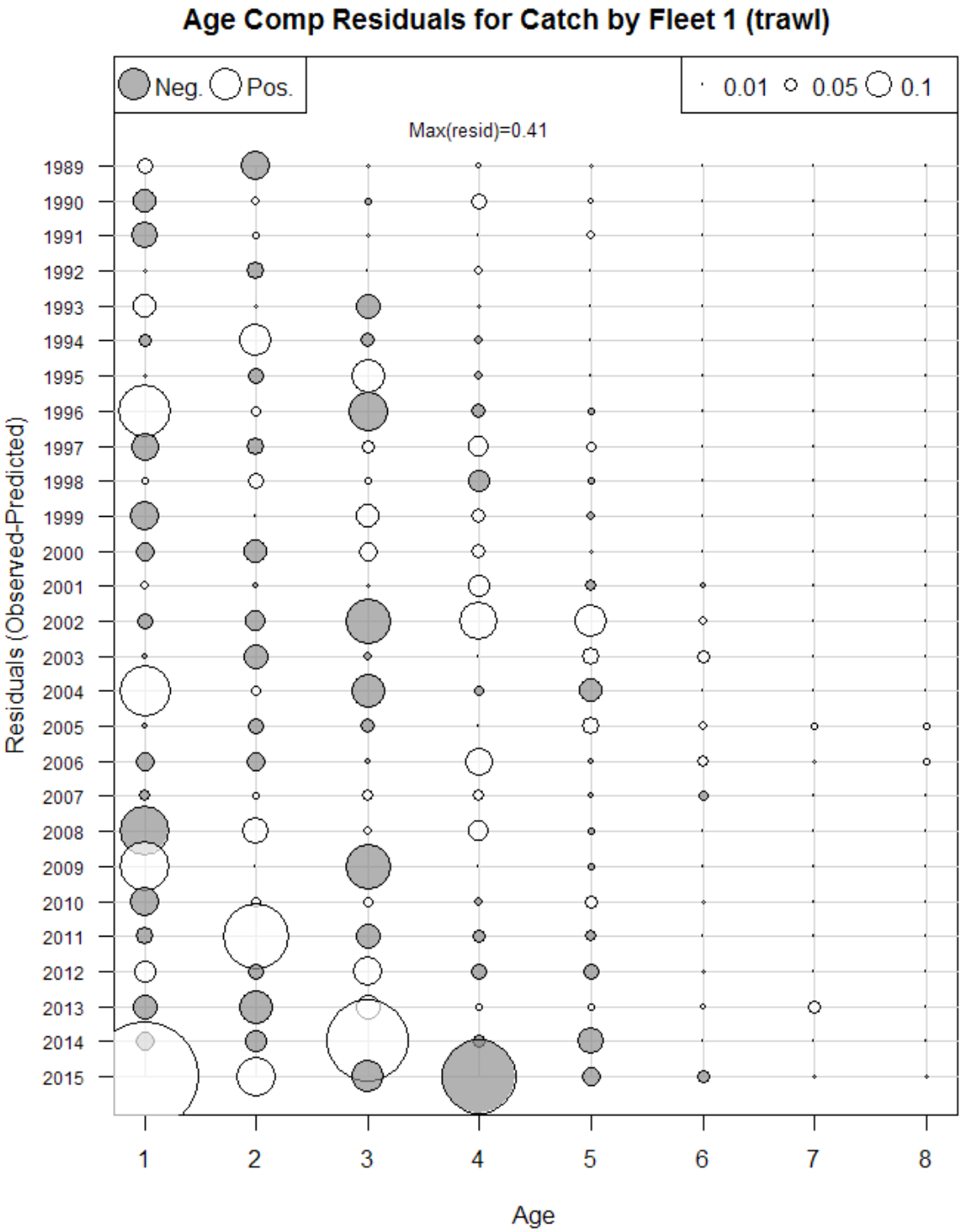

Figure A121. Age composition residuals of proportion at age from black sea bass trawl catch in final **South** area model.

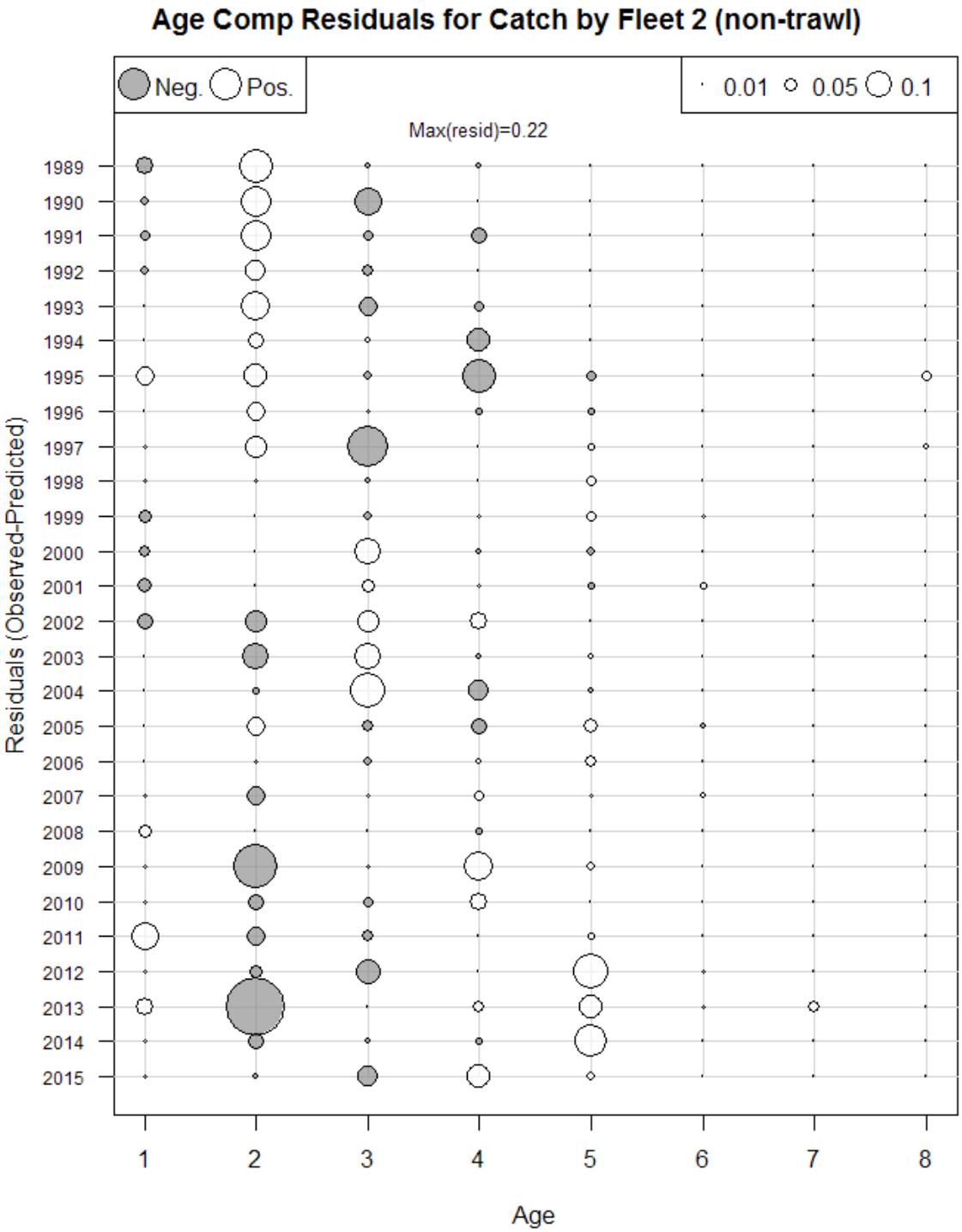

Figure A122. Age composition residuals of proportion at age from non-trawl black sea bass catch in final **South** area model.

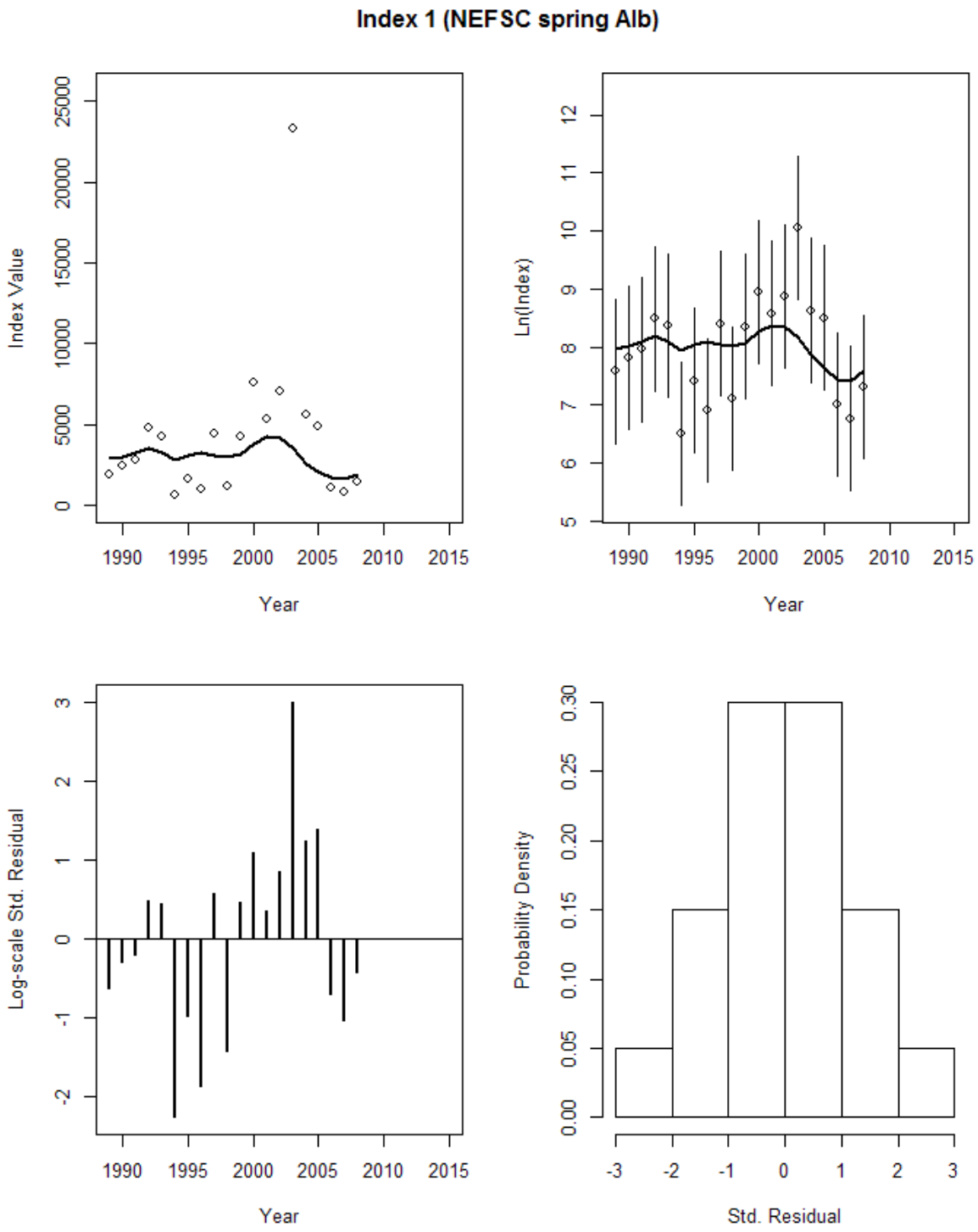

Figure A123. Fit diagnostics for NEFSC spring 1989-2008 (*Albatross*) trawl survey in final black sea bass **South** area model.

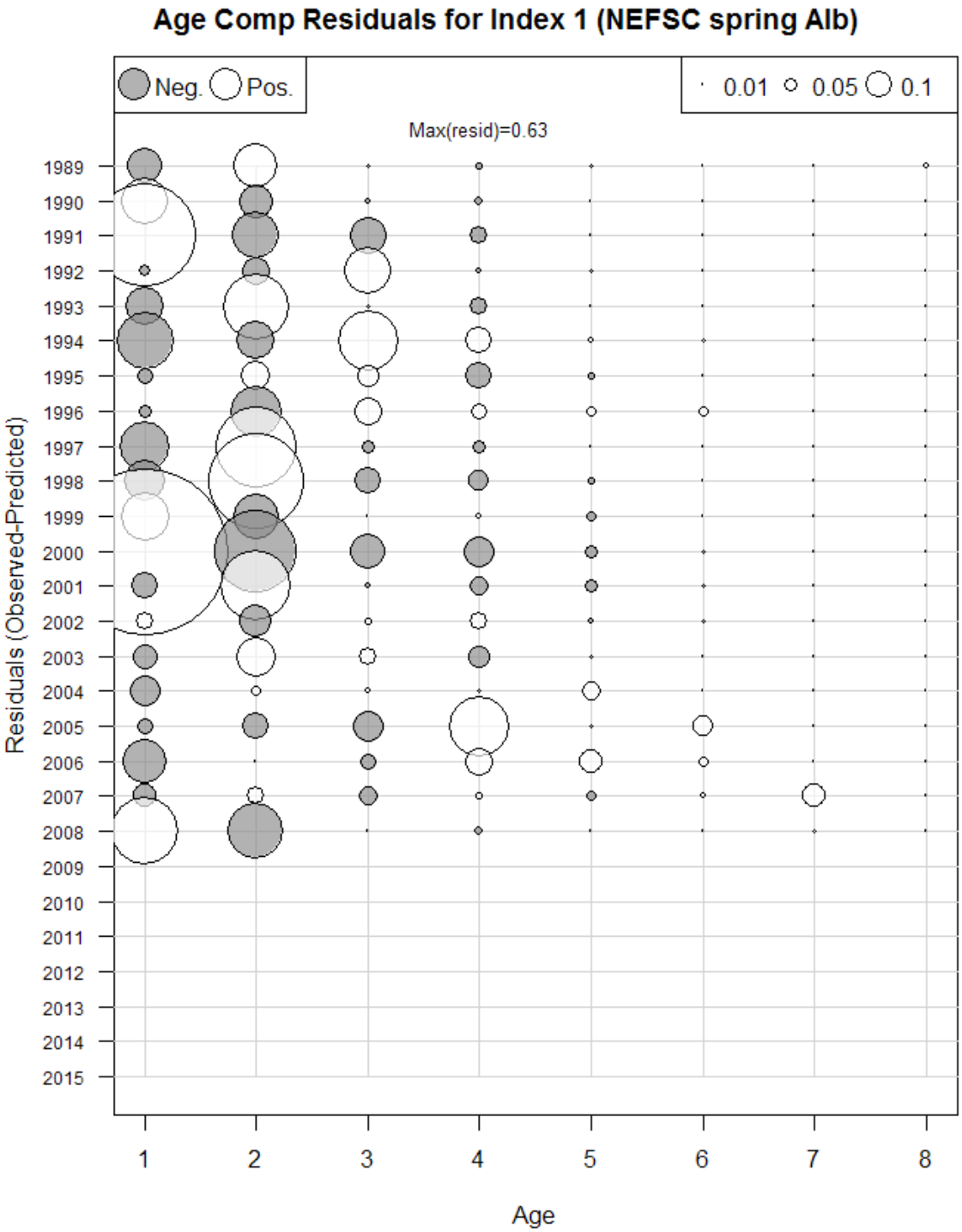

Figure A124. Age composition residuals for NEFSC spring 1989-2008 (*Albatross*) trawl survey in final black sea bass **South** area model.

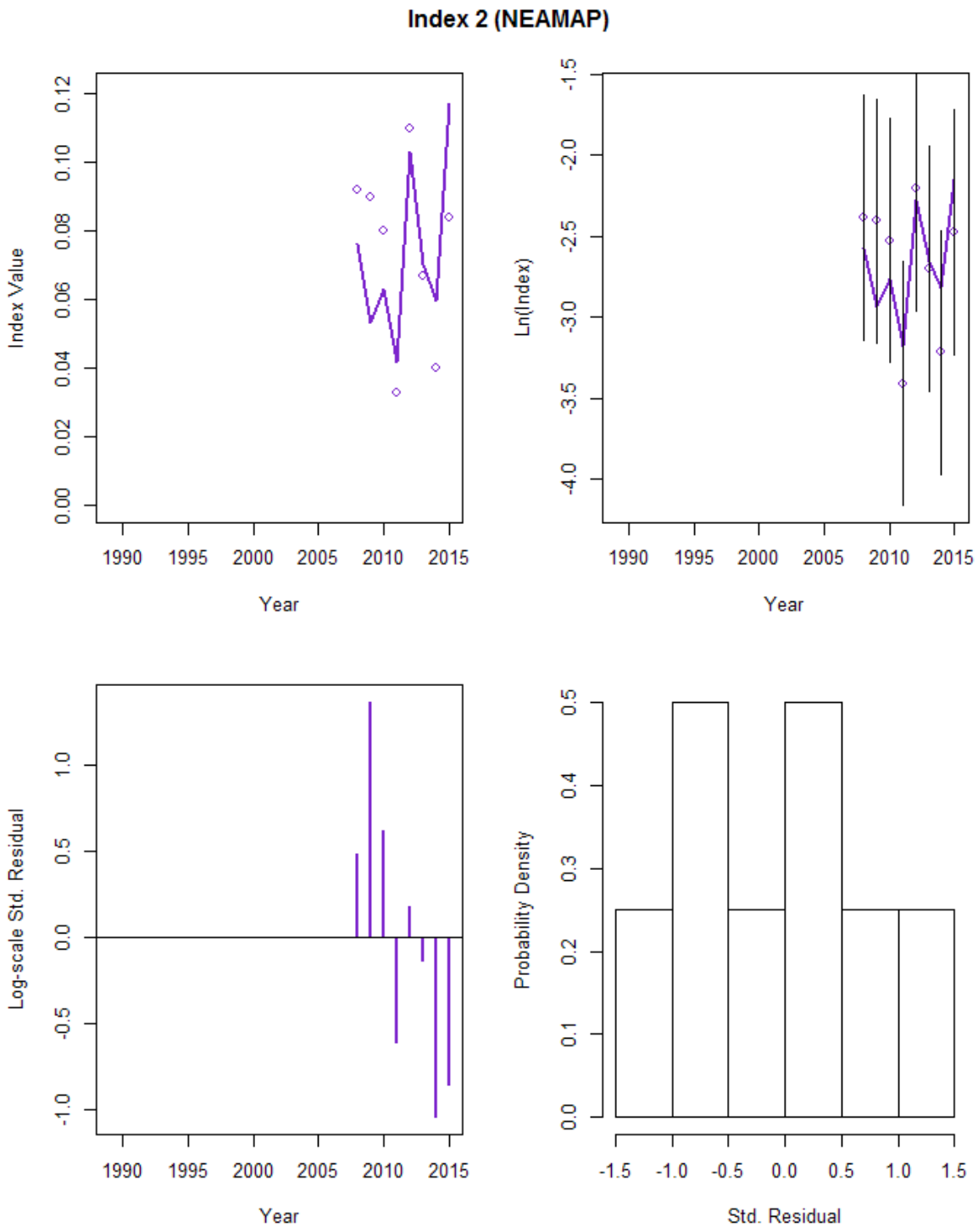

Figure A125. Fit diagnostics for NEAMAP trawl survey in final black sea bass **South** area model.

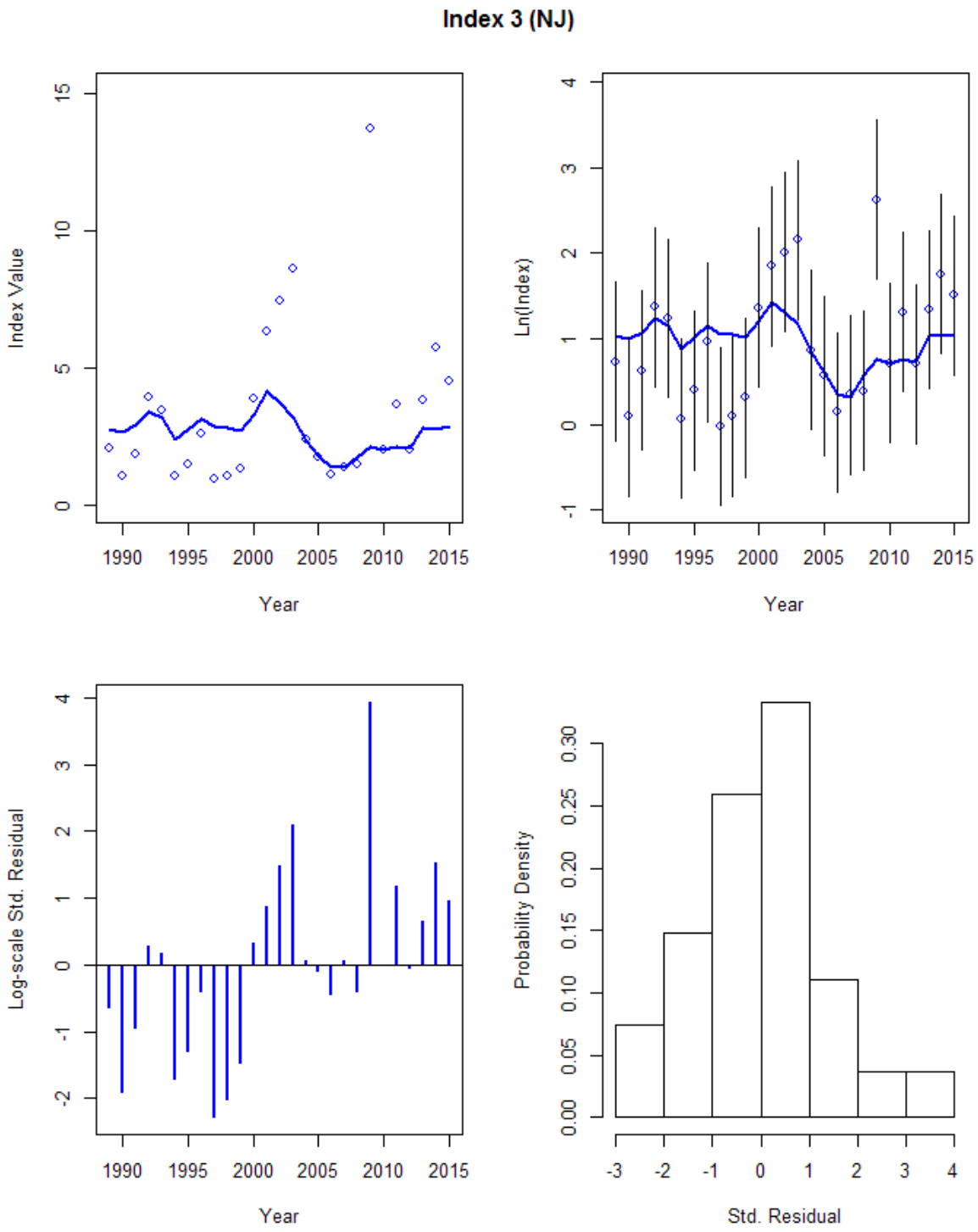

Figure A126. Age composition residuals for NEAMAP trawl survey in final black sea bass **South** area model.

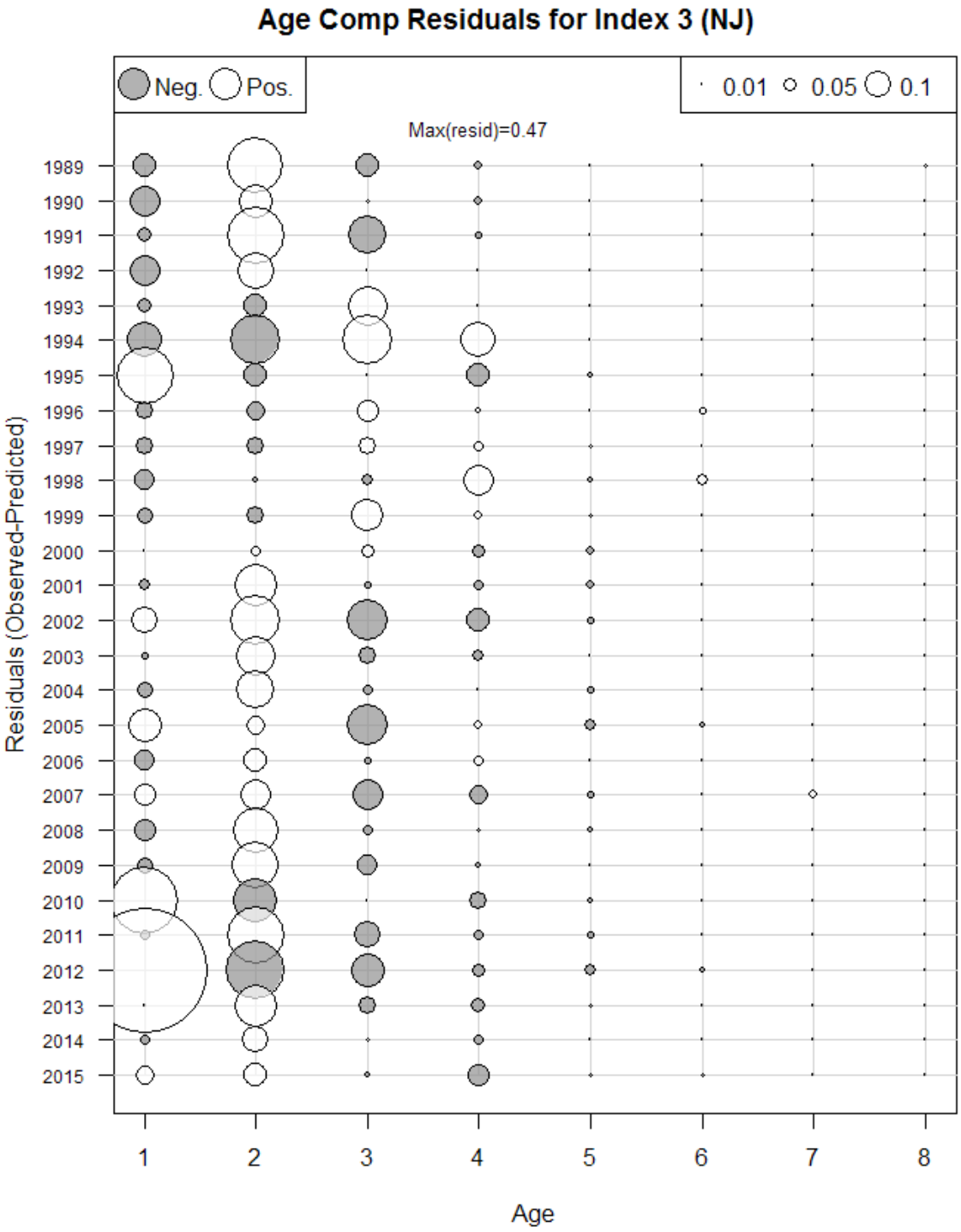

Figure A127. Fit diagnostics for NJ trawl survey in final black sea bass **South** area model.

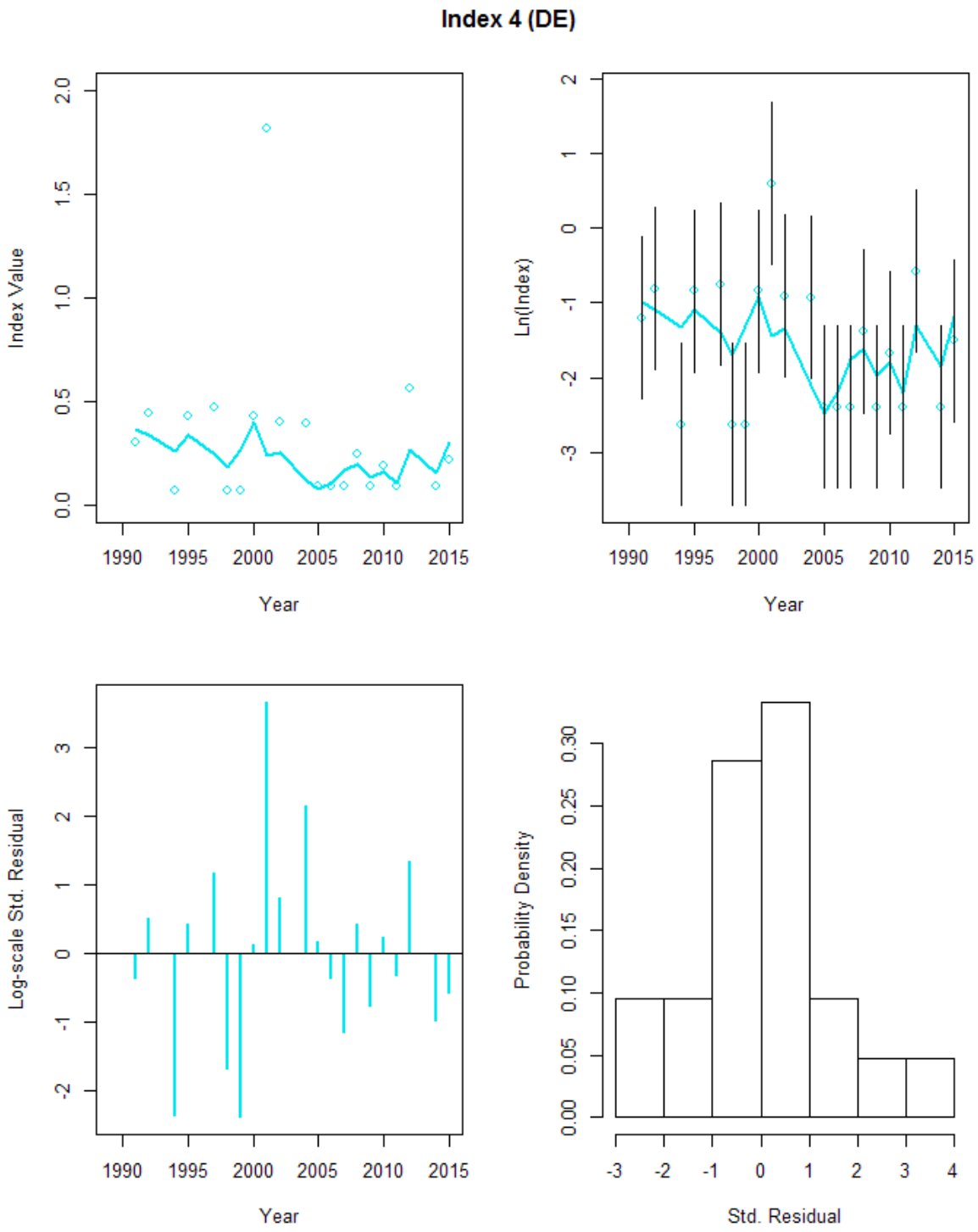

Figure A128. Fit diagnostics for DE trawl survey in final black sea bass **South** area model.

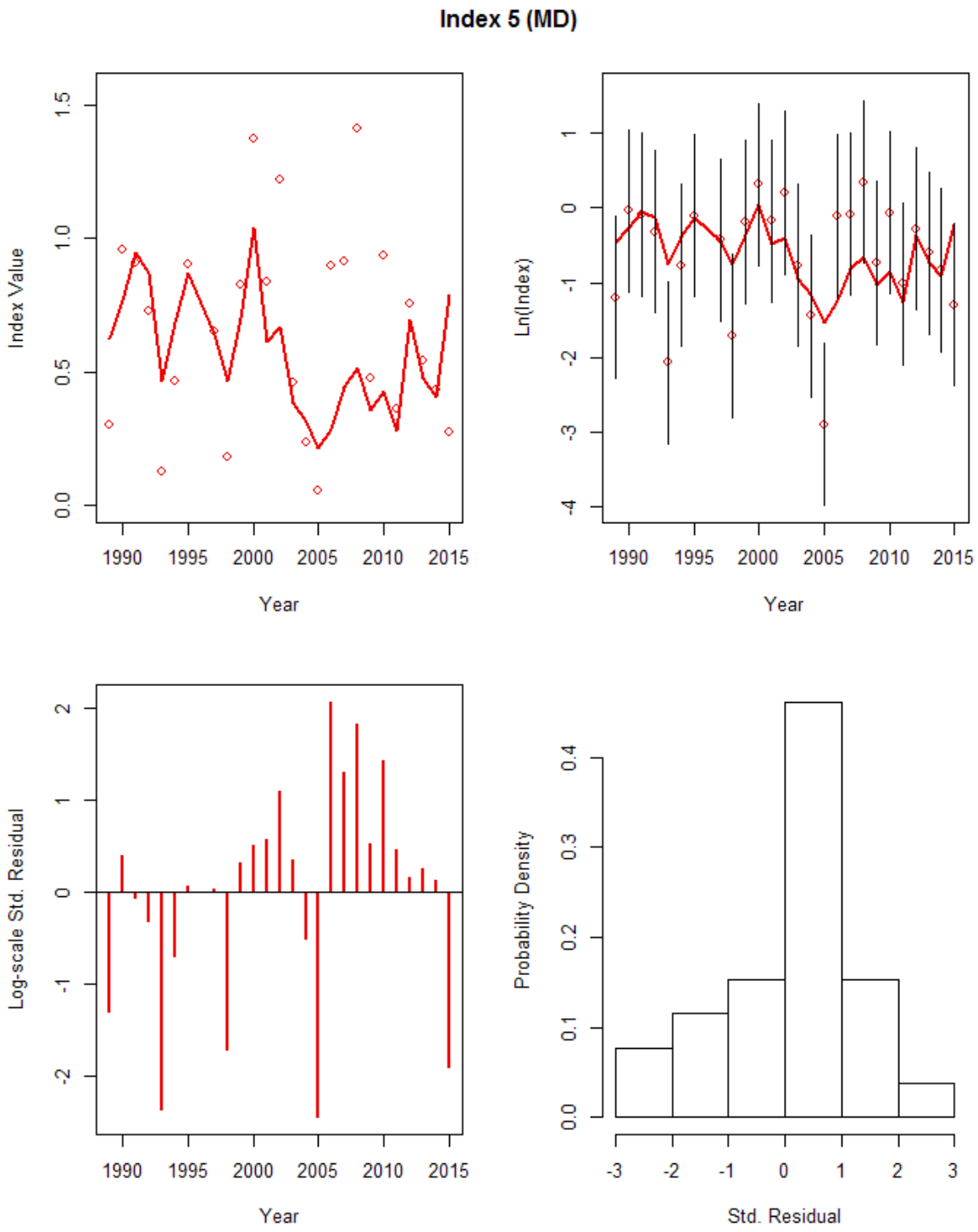

Figure A129. Fit diagnostics for MD trawl survey in final black sea bass **South** area model.

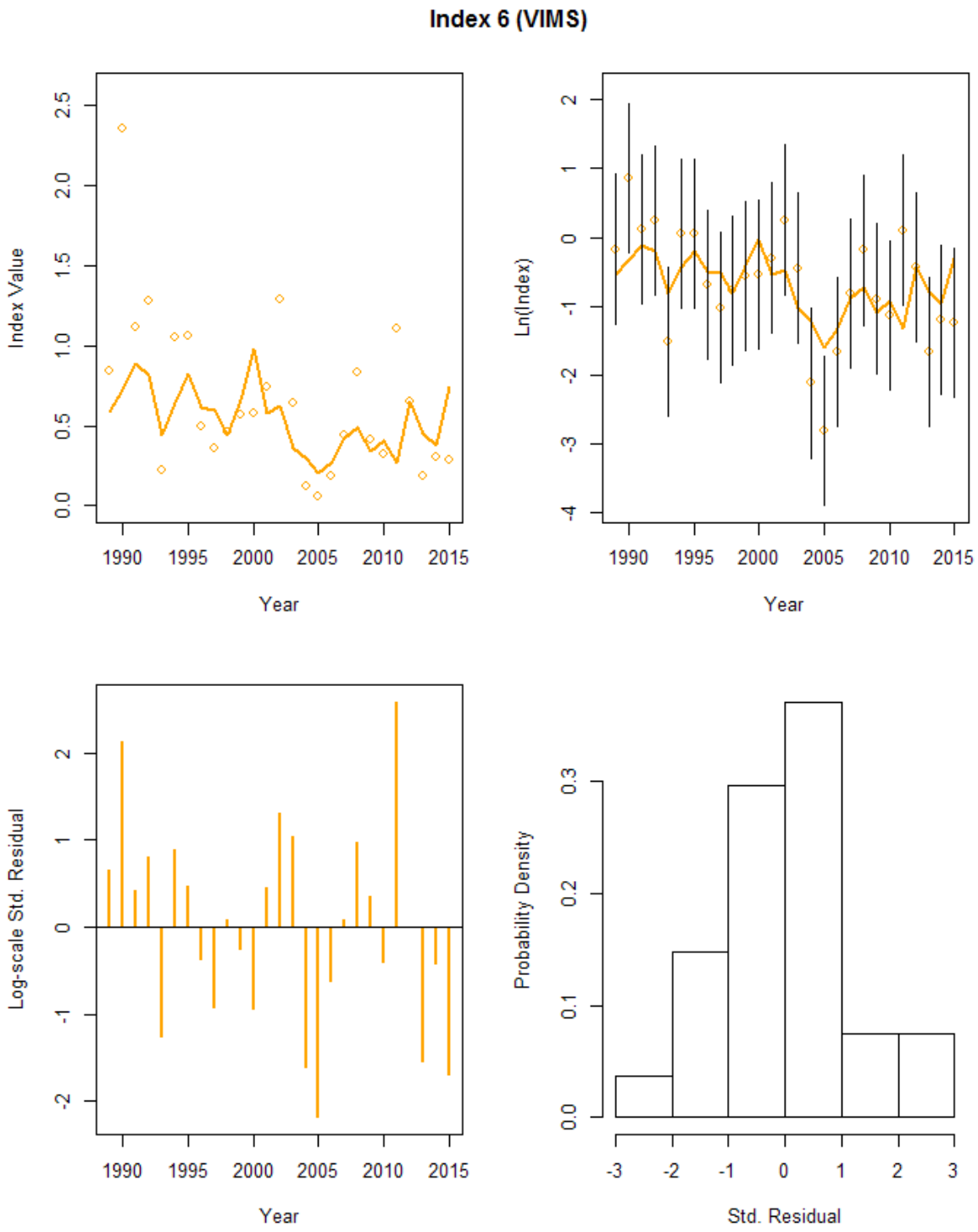

Figure A130. Fit diagnostics for VIMS trawl survey in final black sea bass **South** area model.

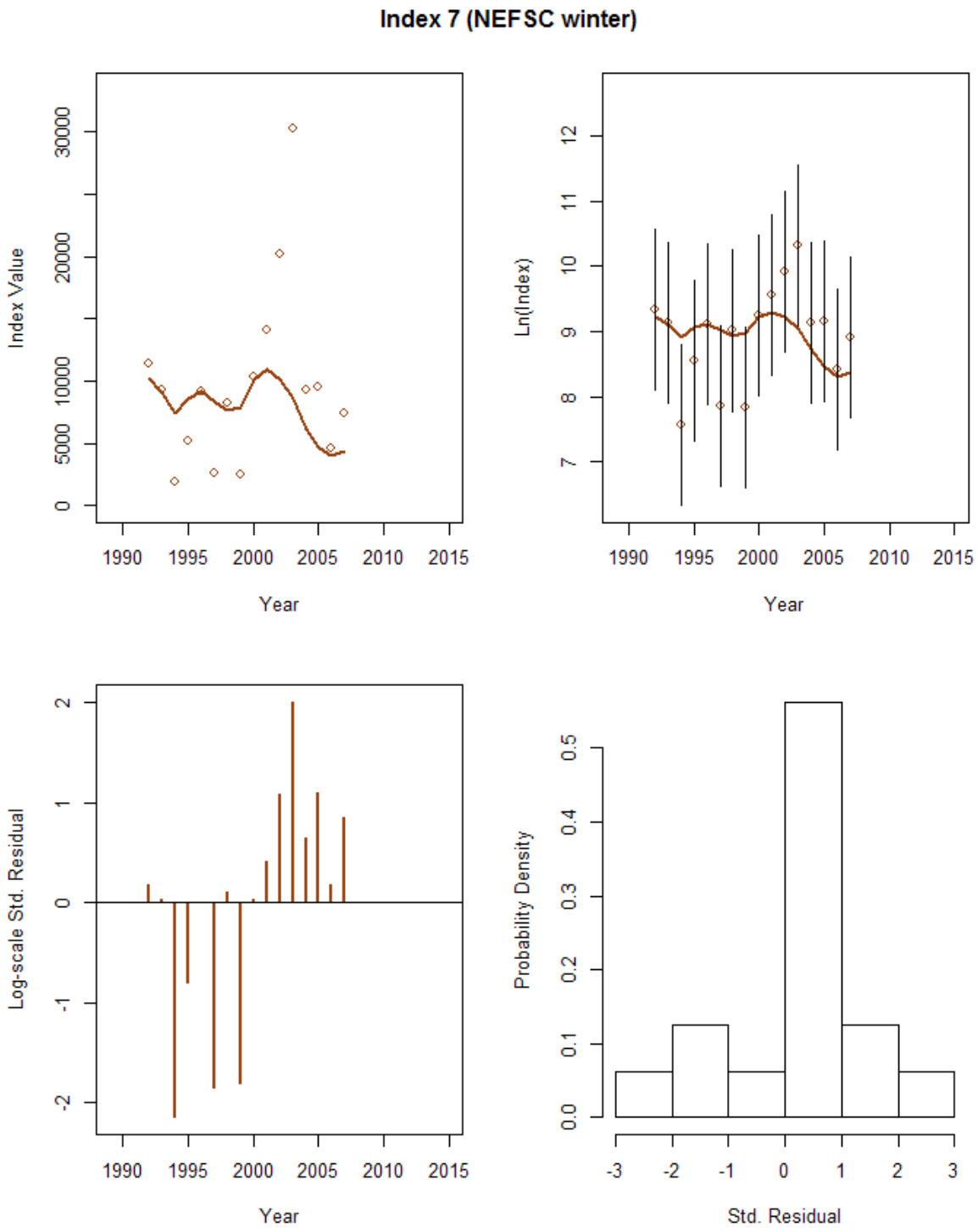

Figure A131. Fit diagnostics for NEFSC winter trawl survey in final black sea bass **South** area model.

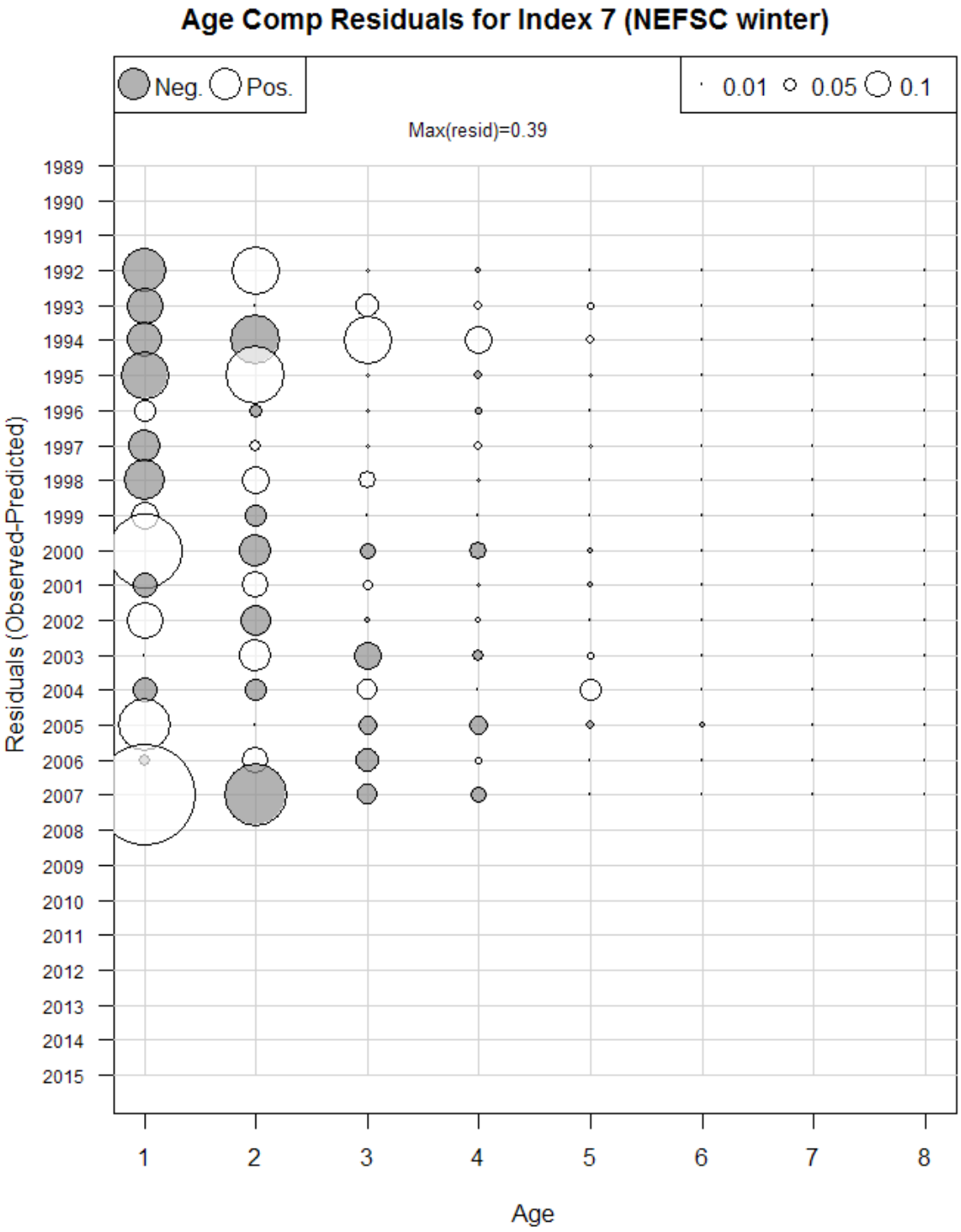

Figure A132. Age composition residuals for NEFSC winter trawl survey in final black sea bass **South** area model.

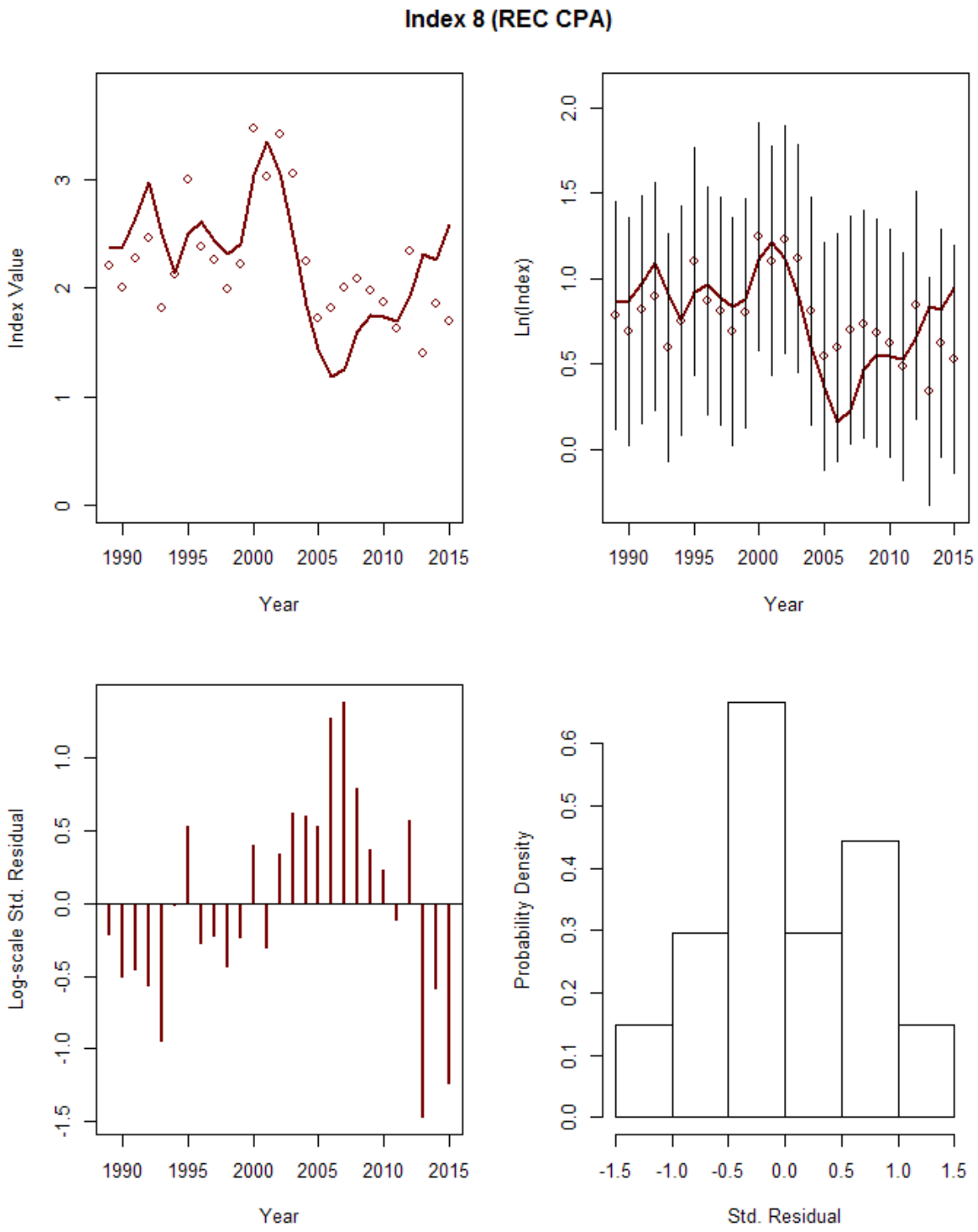

Figure A133. Fit diagnostics for Rec CPA in final black sea bass **South** area model.

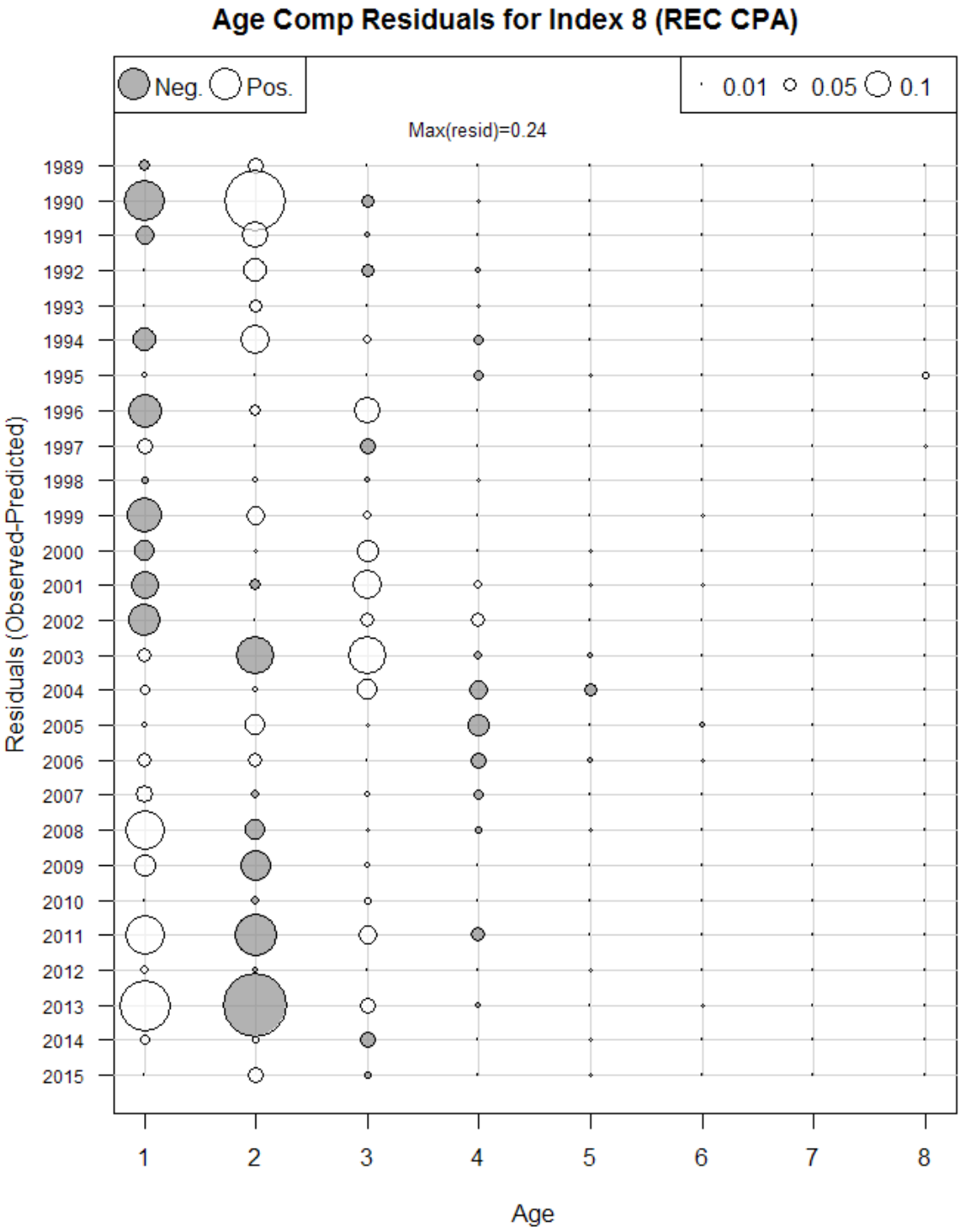

Figure A134. Age composition residuals for Rec CPA in final black sea bass **South** area model.

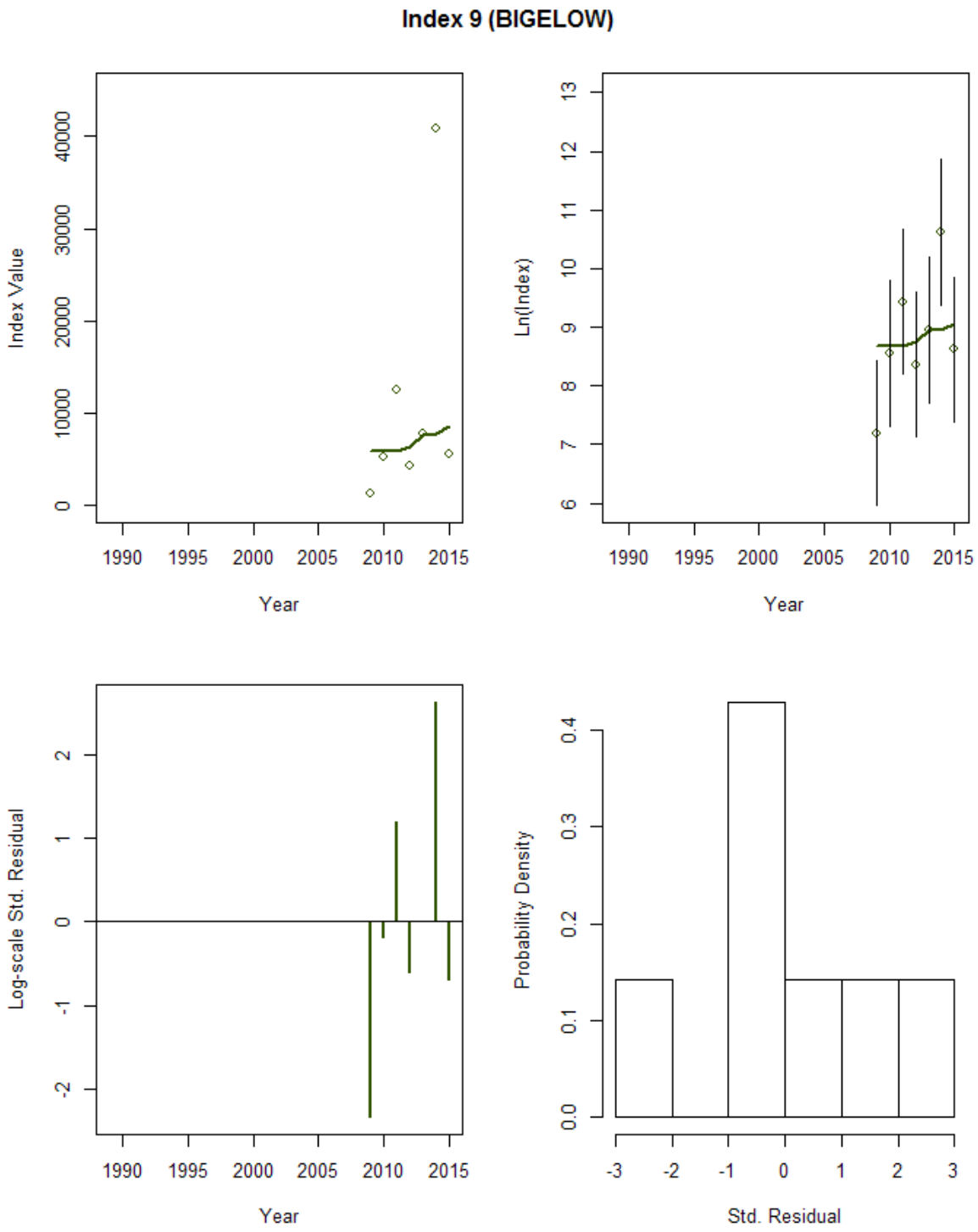

Figure A135. Fit diagnostics for NEFSC spring trawl survey (*Bigelow*) 2008-2015 in final black sea bass **South** area model.

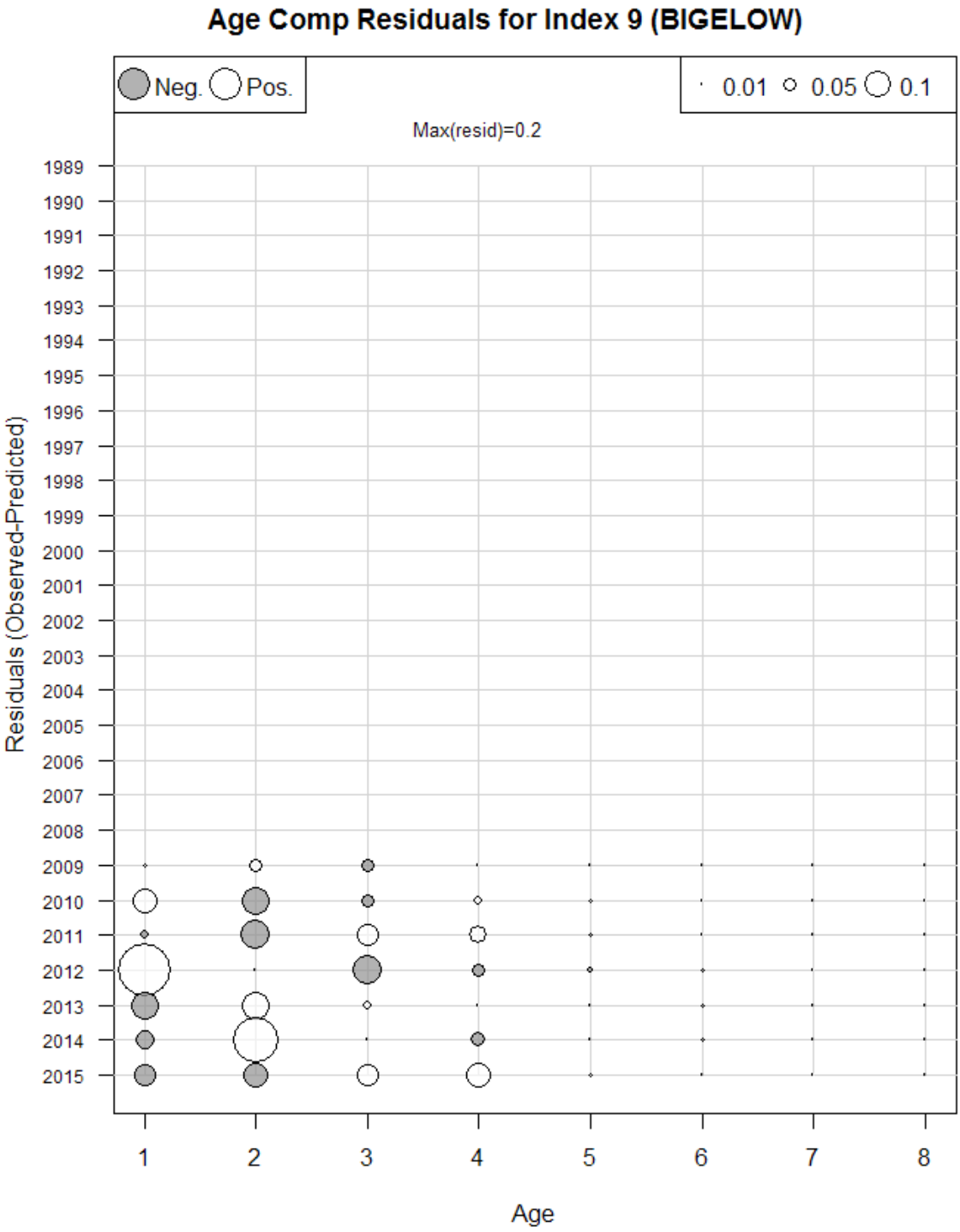

Figure A136. Age composition residuals for NEFSC spring trawl survey (*Bigelow*) 2008-2015 in final black sea bass **South** area model.

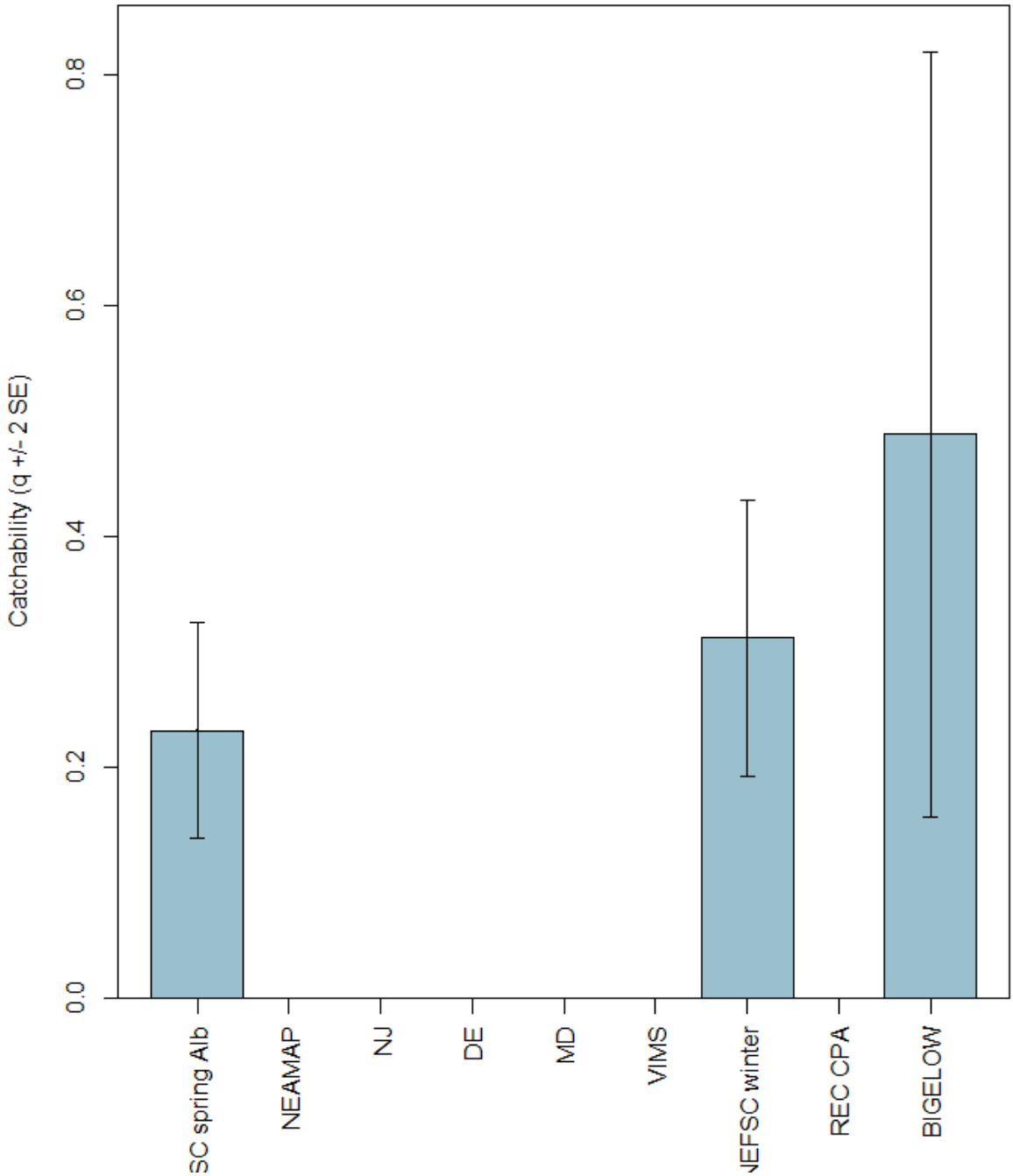

Figure A137. Index catchability estimates from final black sea bass **South** area model.

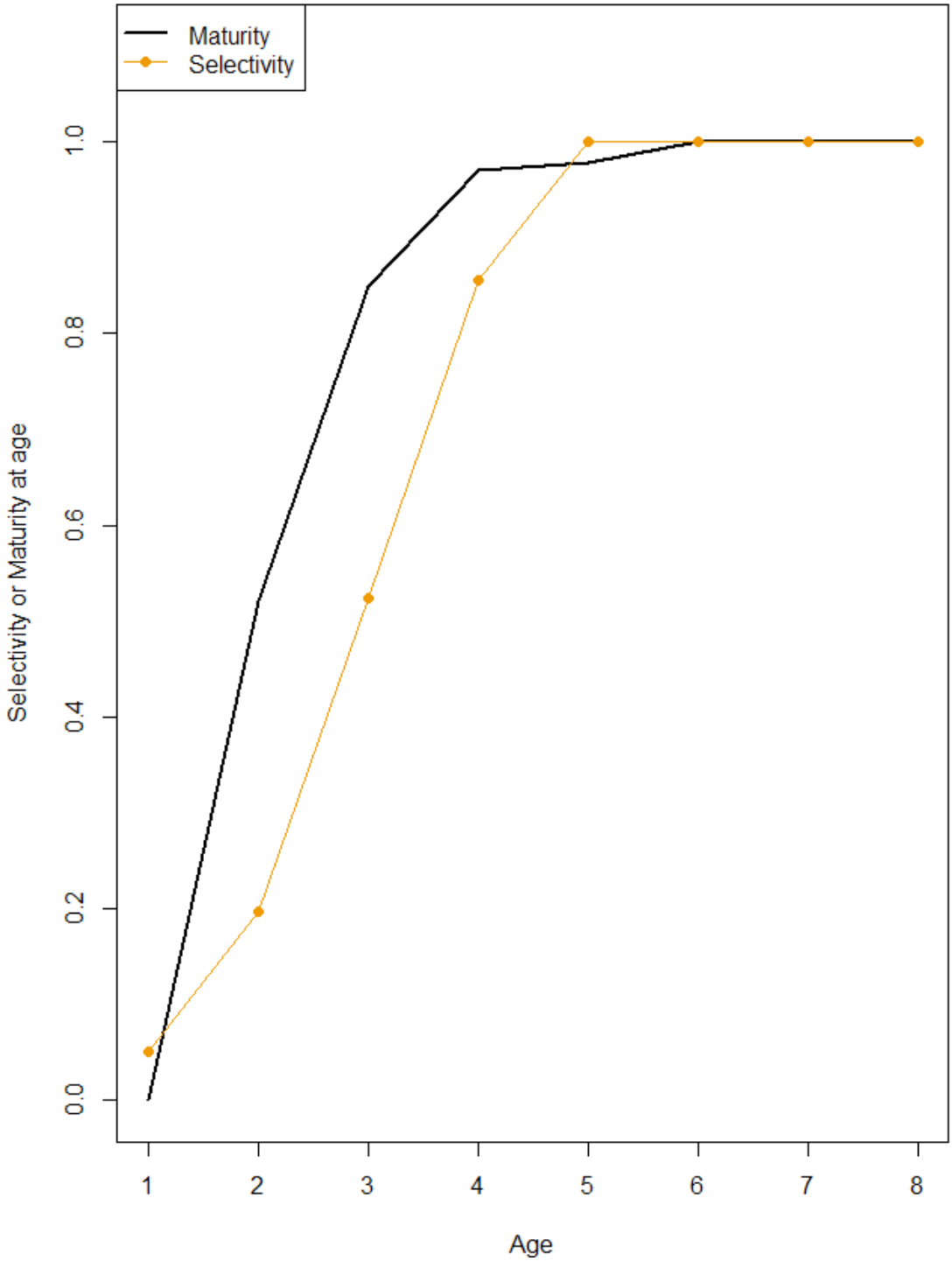

Figure A138. Comparison of maturity and average selectivity at age in final black sea bass **South** area model.

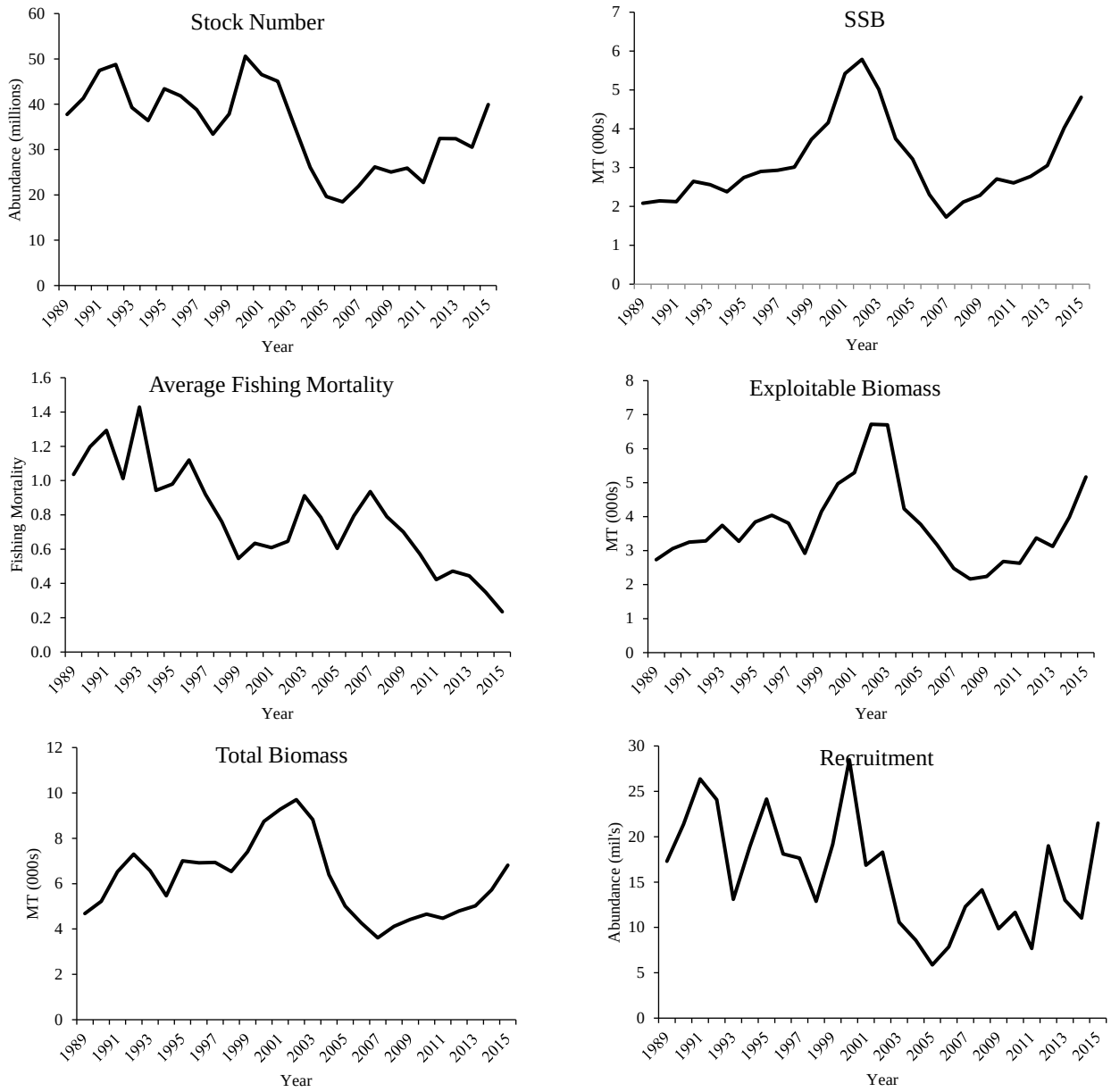

Figure A139. Results of stock number, fishing mortality, total biomass, spawning biomass, exploitable biomass and recruitment from the black sea bass **South** area model.

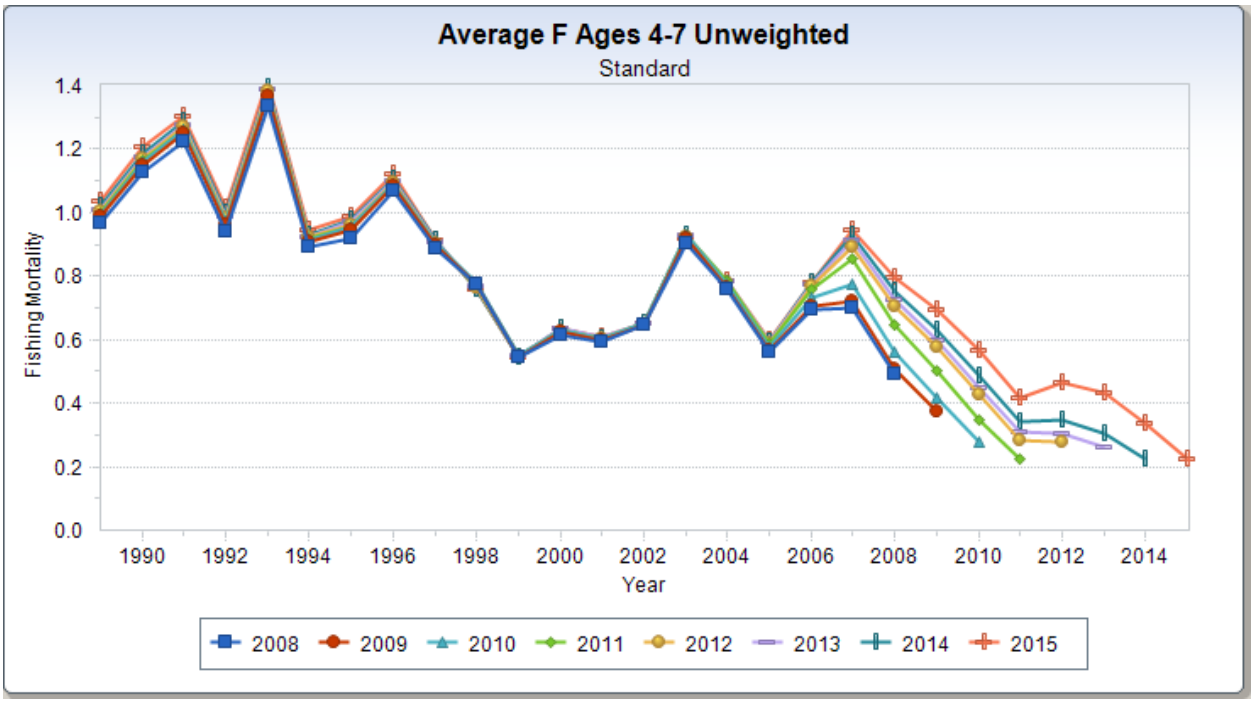

Figure A140. Retrospective pattern in average F estimates from black sea bass ASAP model for **South** area. Mohn's rho = -0.42

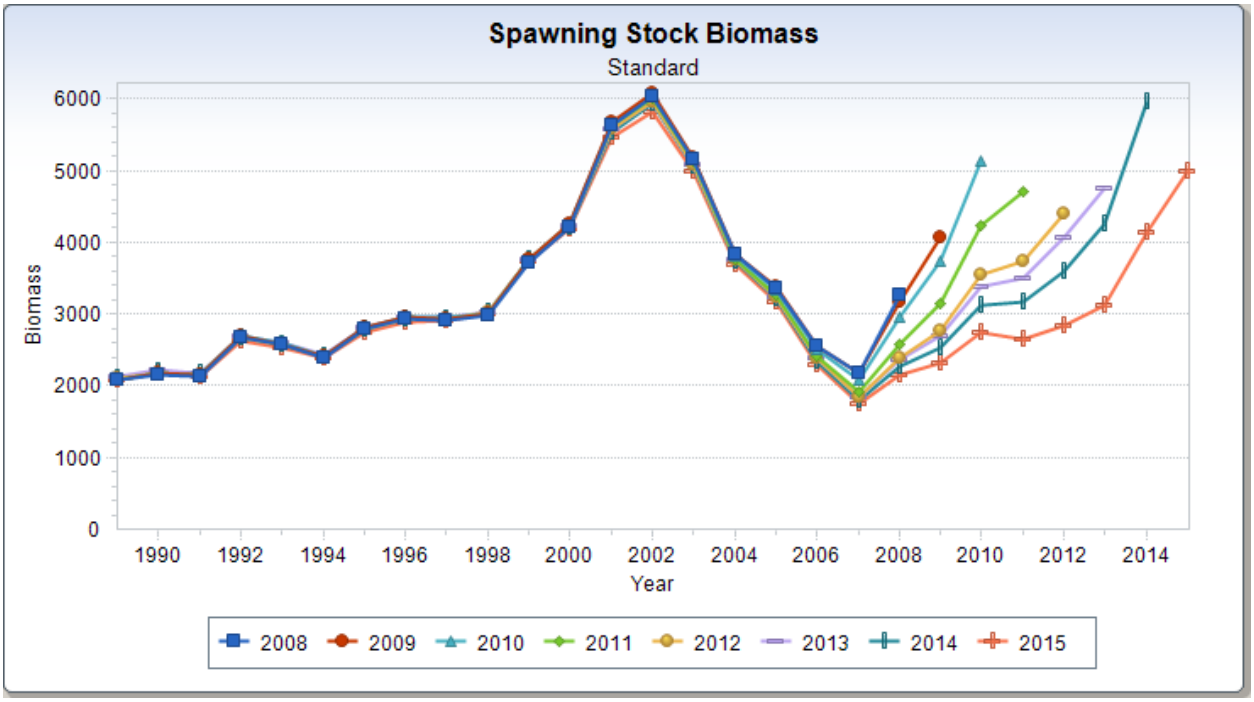

Figure A141. Retrospective pattern in spawning stock biomass (mt) estimates from black sea bass ASAP model for **South** area. Mohn's rho = 0.63

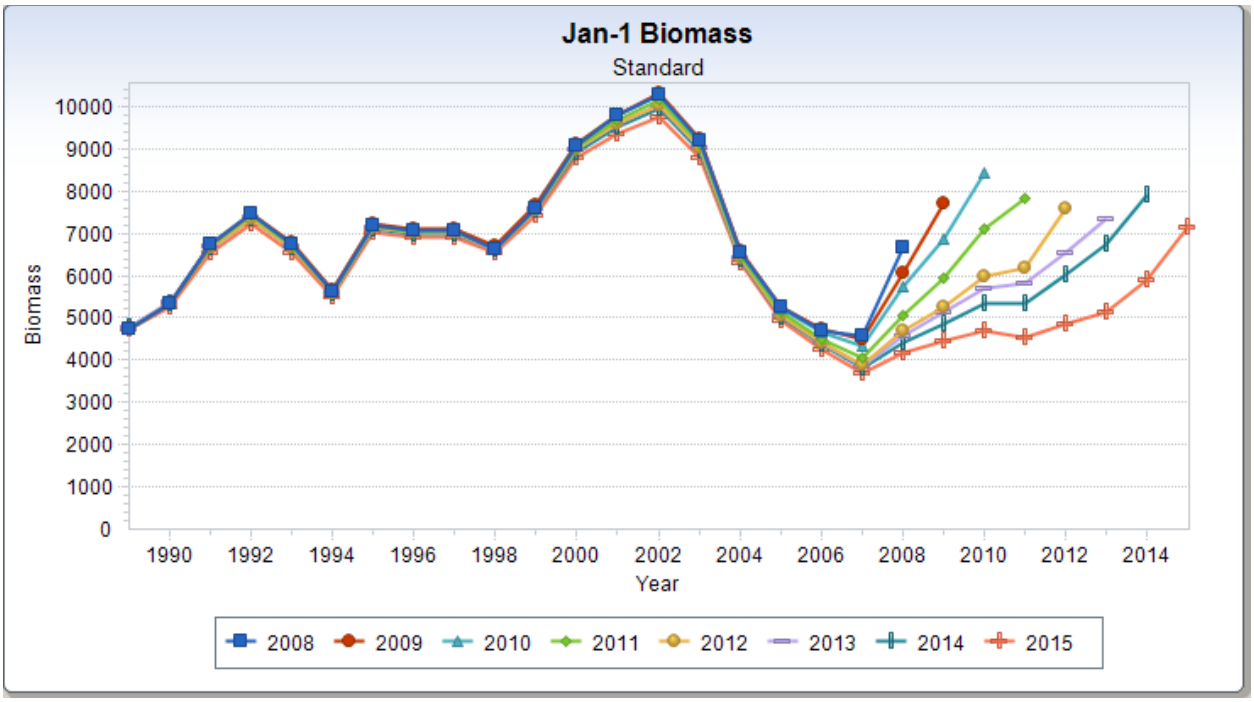

Figure A142. Retrospective pattern in total biomass (mt) estimates from black sea bass ASAP model for **South** area. Mohn's rho = 0.60

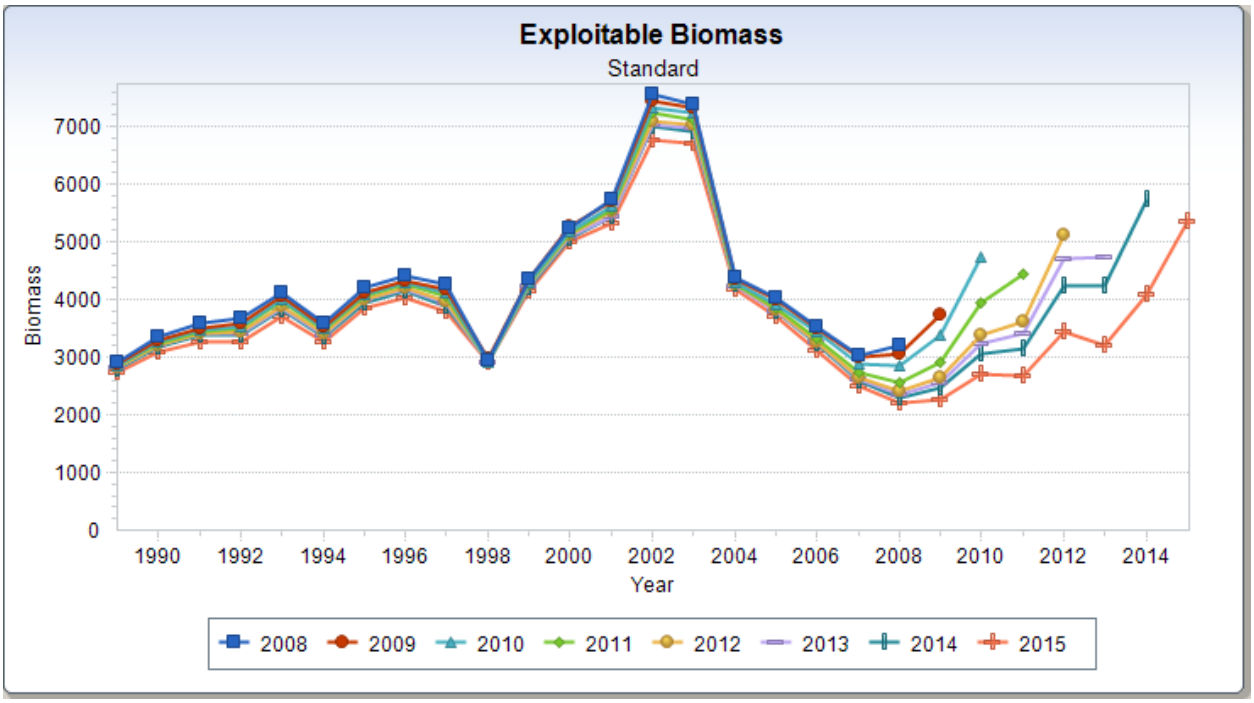

Figure A143. Retrospective pattern in exploitable biomass (mt) estimates from black sea bass ASAP model for **South** area. Mohn's rho = 0.55

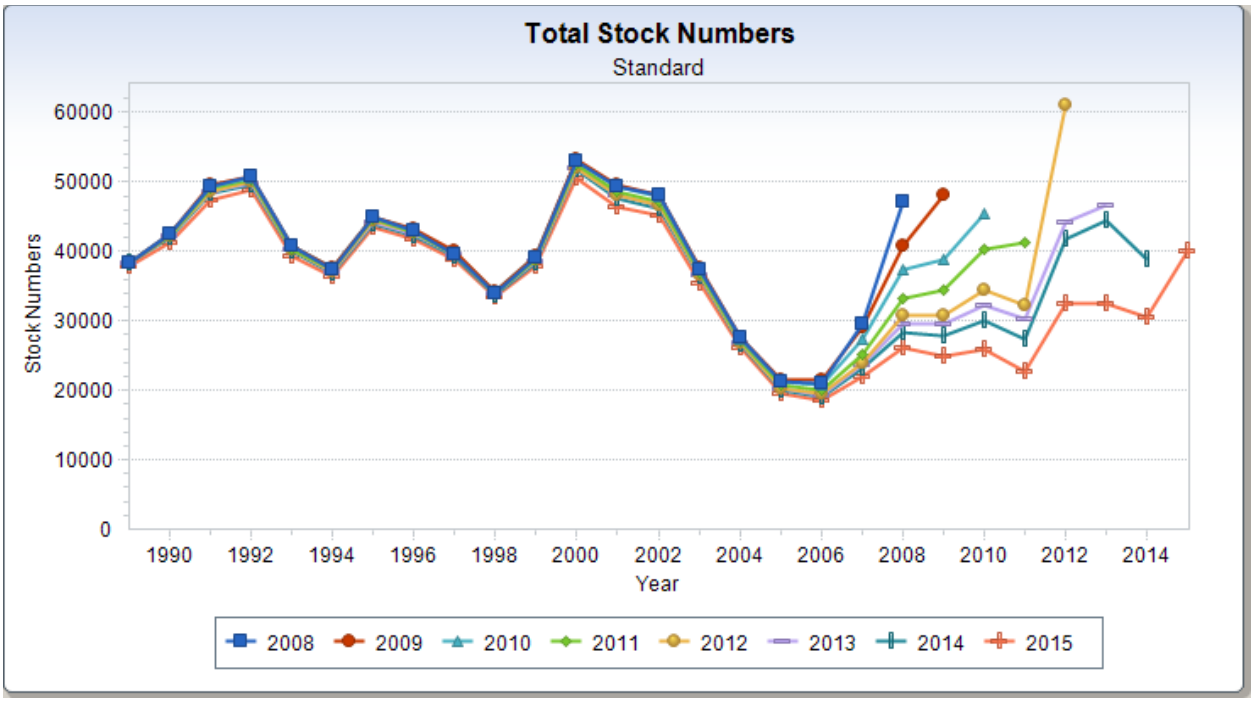

Figure A144. Retrospective pattern in total stock number estimates from black sea bass ASAP model for **South** area. Mohn's rho = 0.70

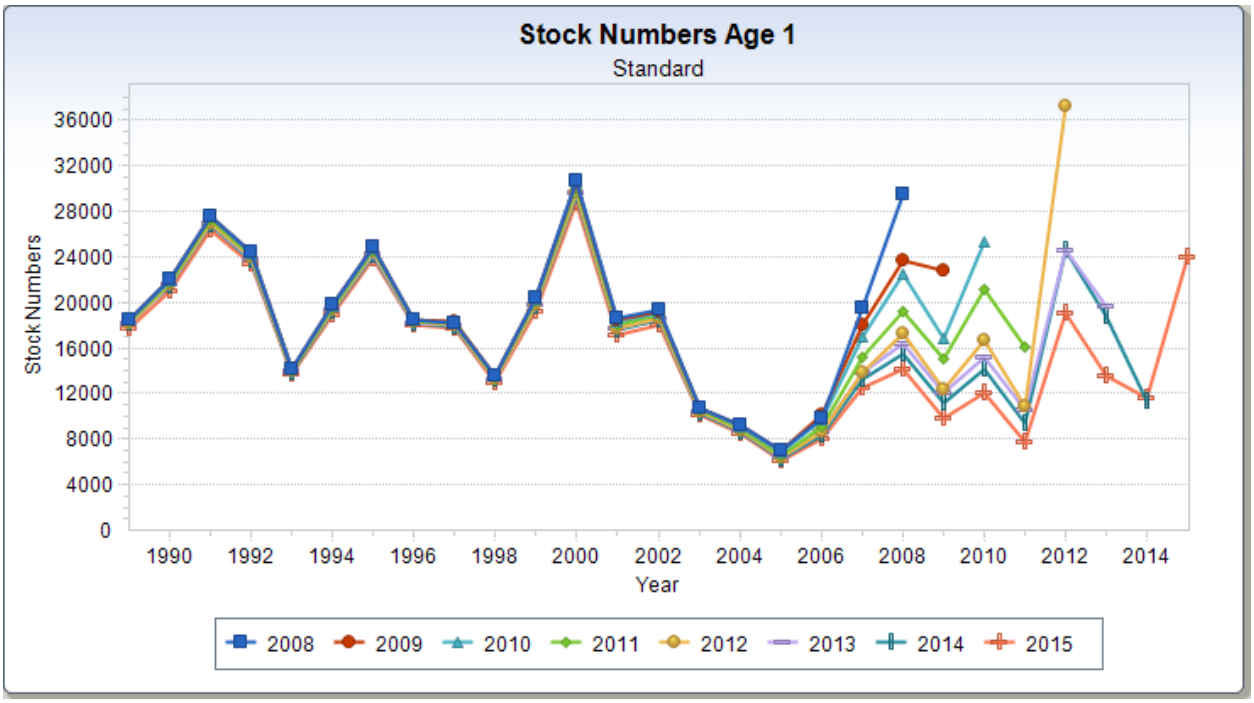

Figure A145 Retrospective pattern in age 1 abundance (recruits) estimates from black sea bass ASAP model for **South** area. Mohn's rho = 0.87

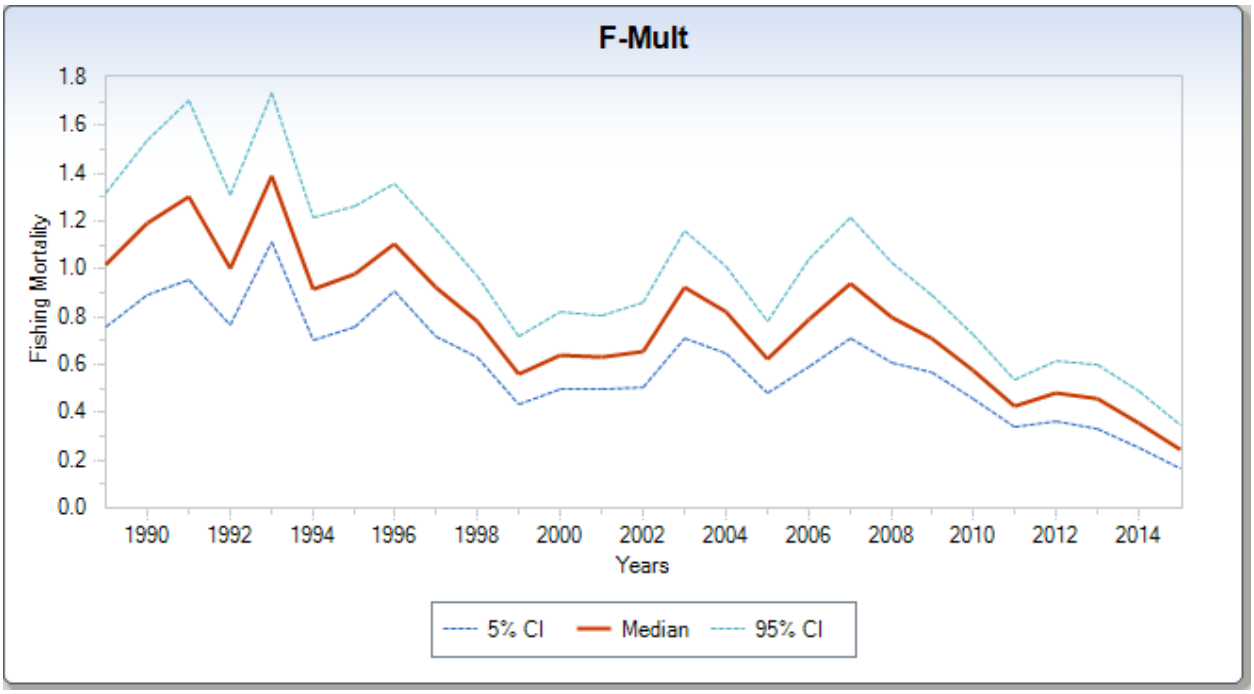

Figure A146. ASAP MCMC estimates of black sea bass F mult (± 90% CI) from **South** area model.

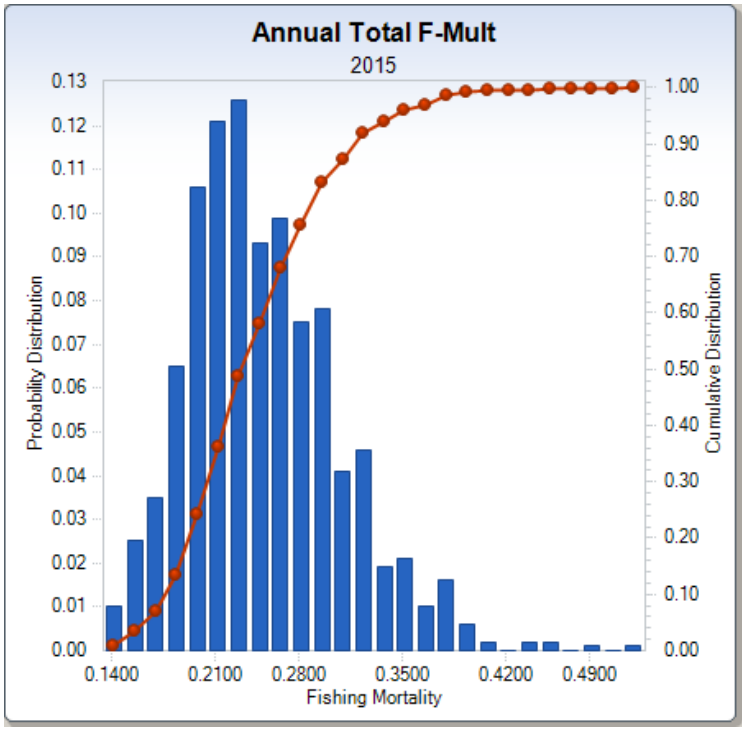

Figure A147. MCMC distribution of 2015 black sea bass F mult estimates from **South** area model.

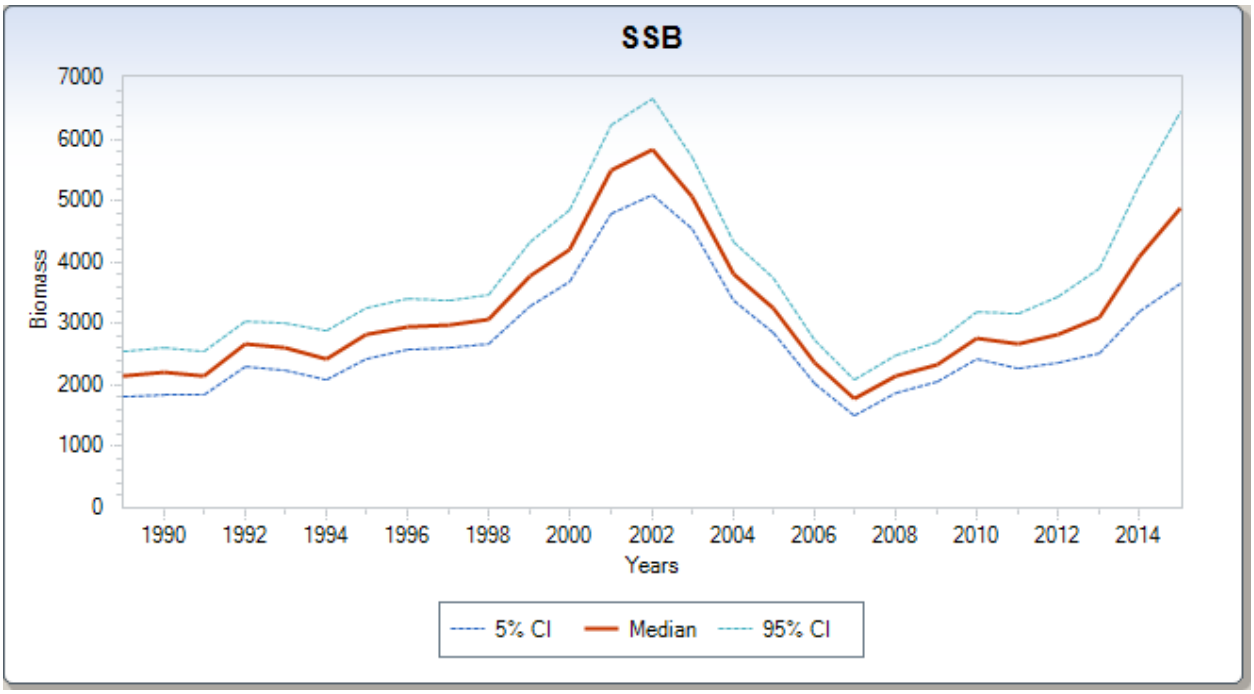

Figure A148. ASAP MCMC estimates of black sea bass spawning stock biomass (mt ± 90% CI) from **South** area model.

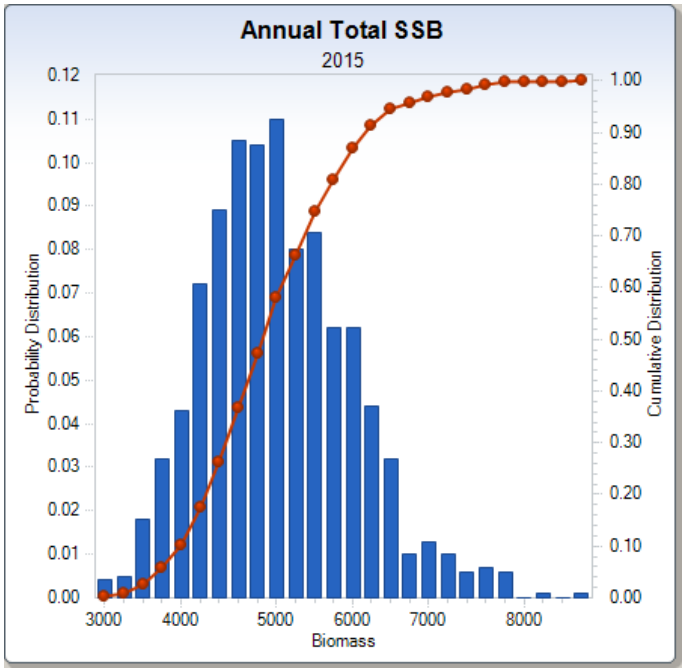

Figure A149. MCMC distribution of 2015 black sea bass spawning stock biomass (mt) estimates from **South** area model.

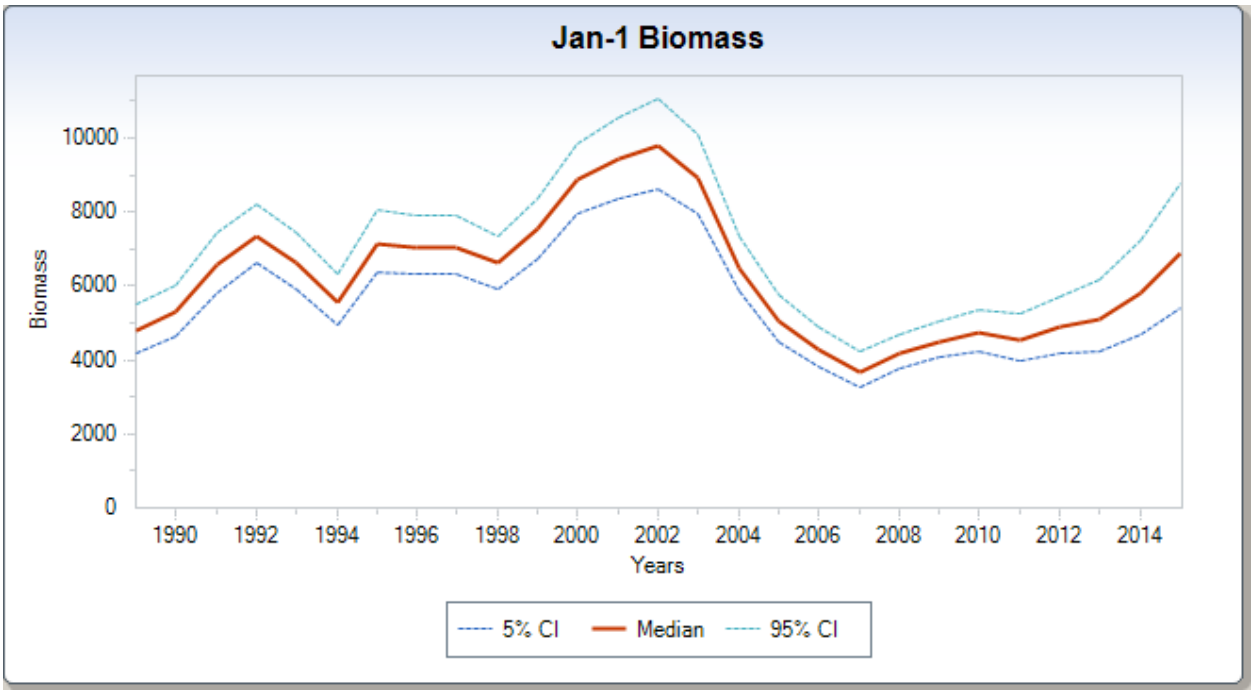

Figure A150. ASAP MCMC estimates of black sea bass total biomass (mt ± 90% CI) from **South** area model.

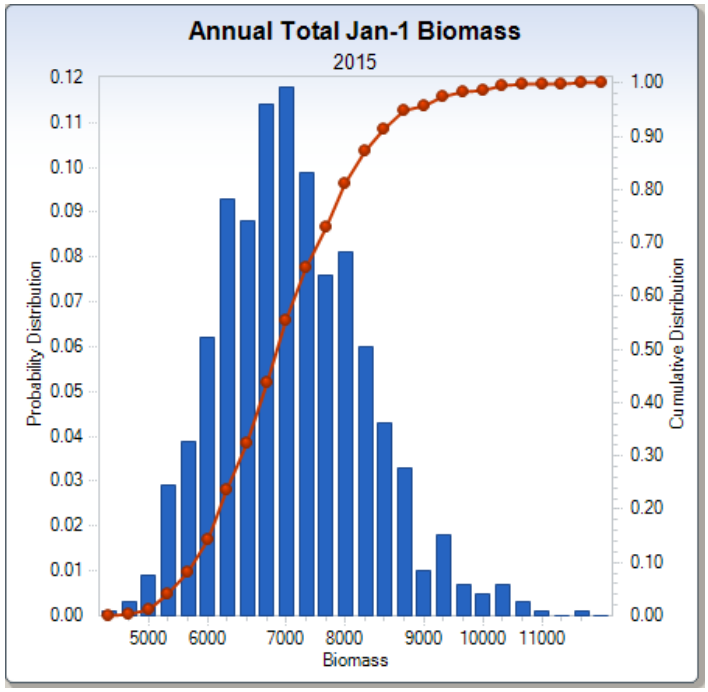

Figure A151. MCMC distribution of 2015 black sea bass total biomass (mt) estimates from **South** area model.

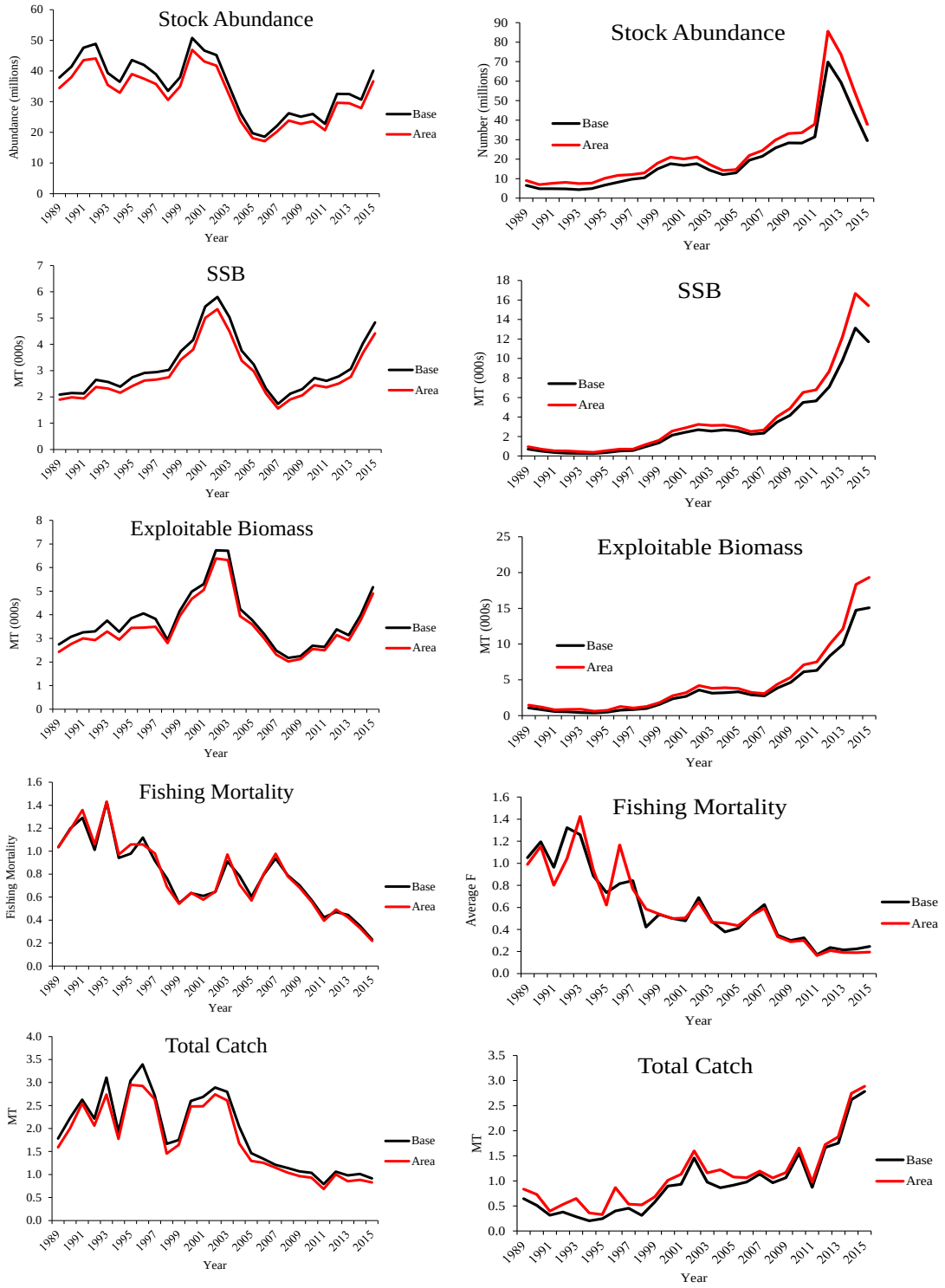

Figure A152. Comparison of black sea bass ASAP model results for base (Combined) area model and Area Exchange model, by region. Base model shown in black, area exchange model in red.

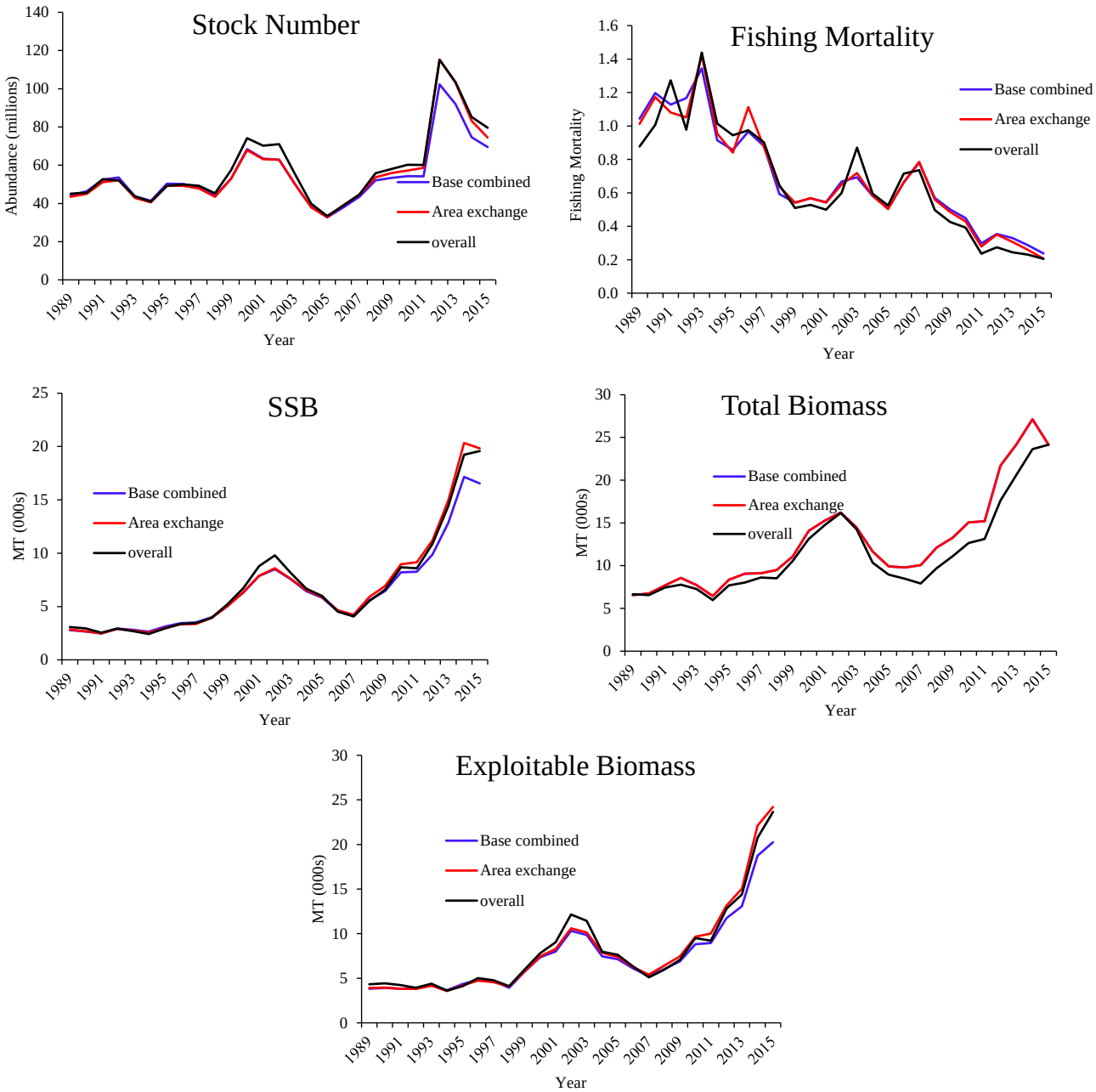

Figure A153. Comparison of black sea bass ASAP model results for Combined area model, Overall single area model and area exchange model. Base (Combined) model shown in blue, Area Exchange model in red and single Overall model in black.

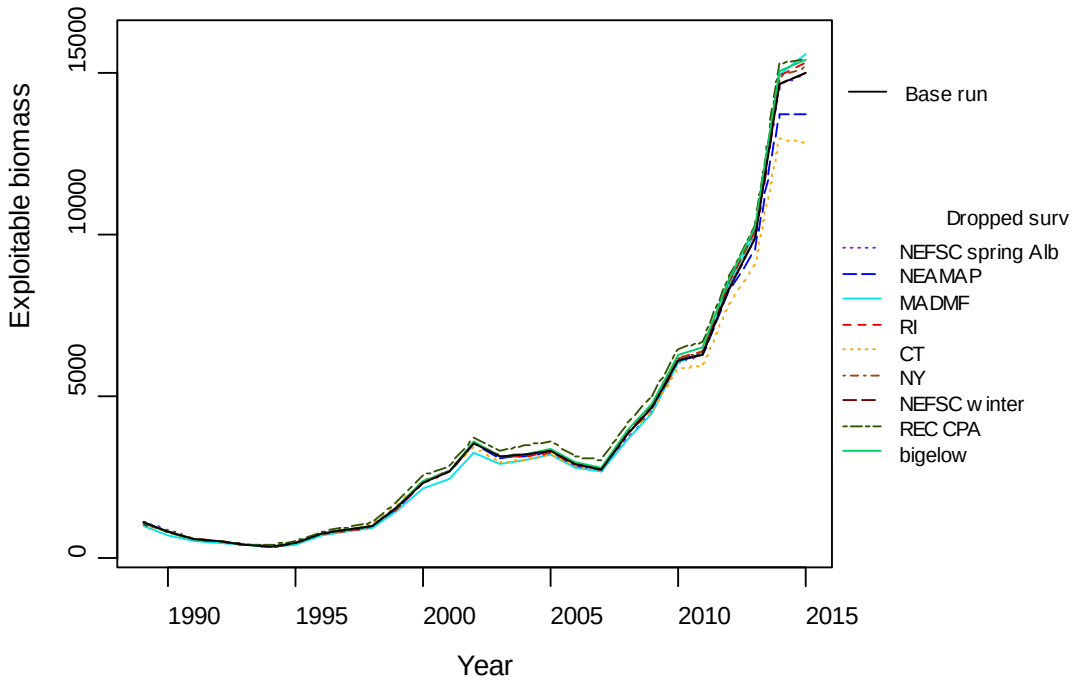

Figure A154. Exploitable biomass (mt) estimates from black sea bass ASAP **North** area model examining sensitivity to indices used in the model.

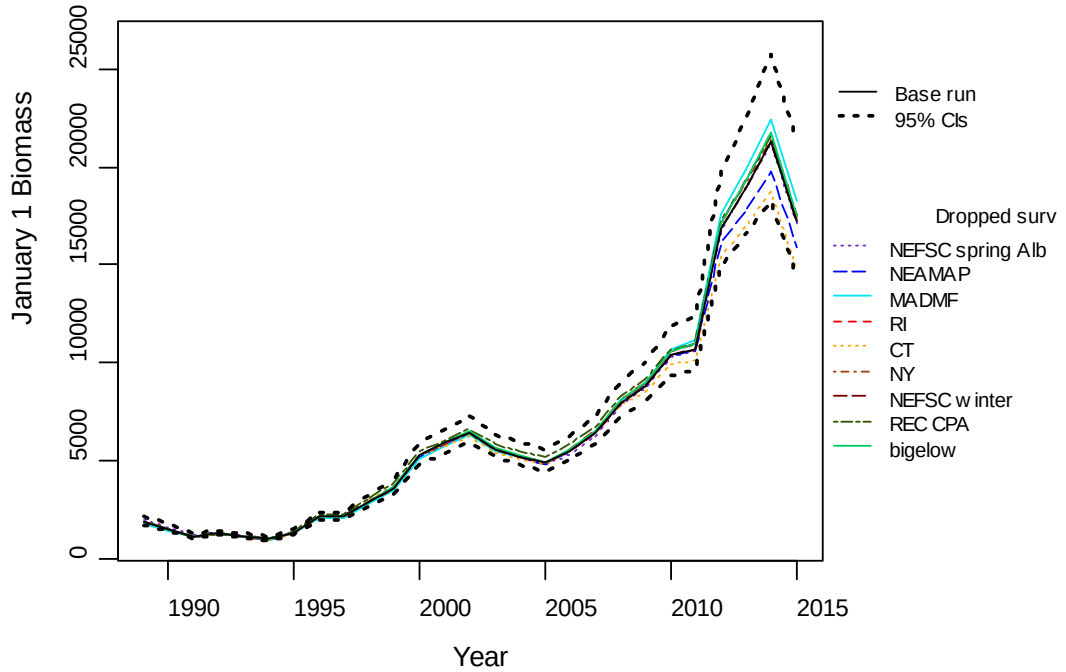

Figure A155. Total biomass (mt) estimates from black sea bass ASAP **North** area model examining sensitivity to indices used in the model.

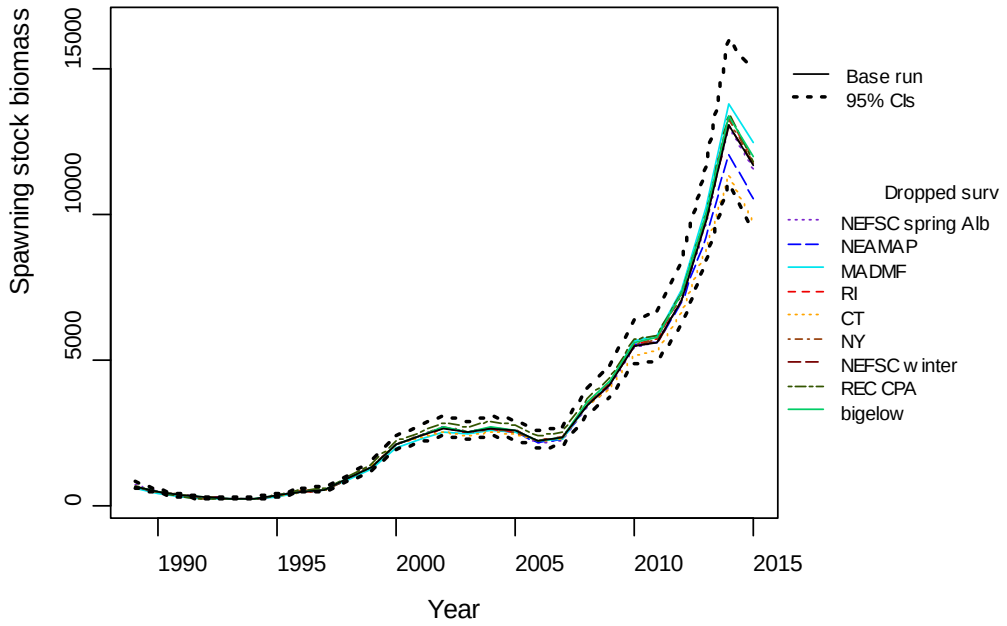

Figure A156. Spawning stock biomass (mt) estimates from black sea bass ASAP **North** area model examining sensitivity to indices used in the model.

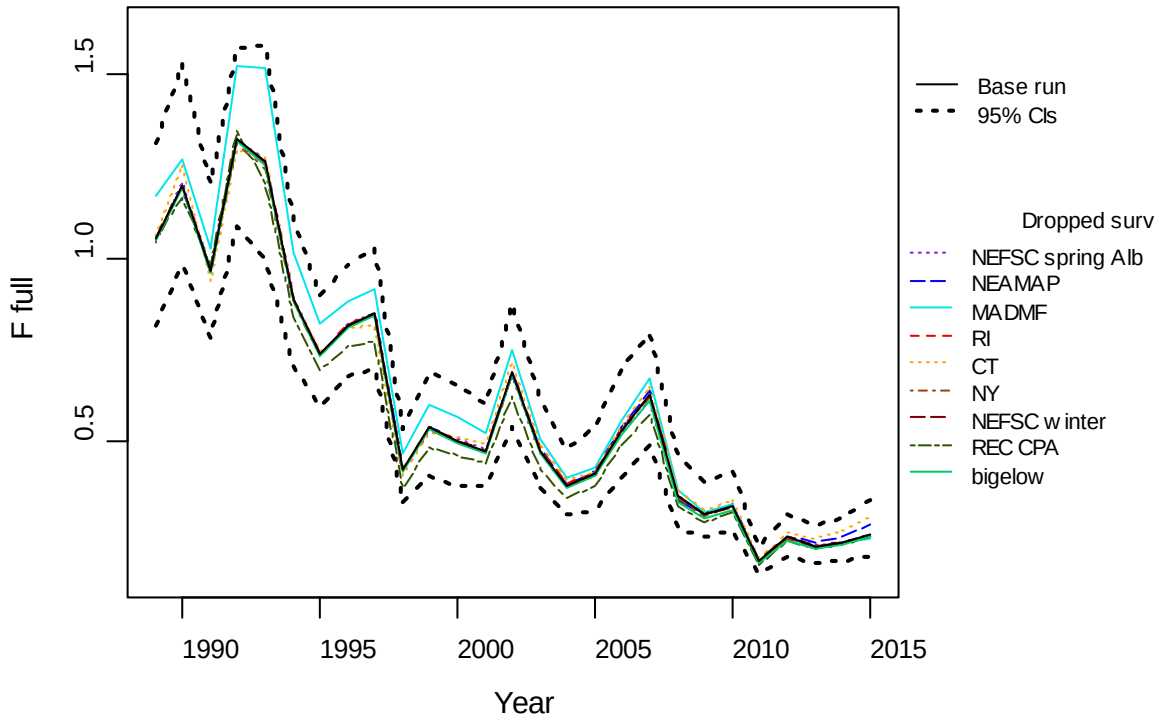

Figure A157. Fishing mortality estimates from black sea bass ASAP **North** area model examining sensitivity to indices used in the model.

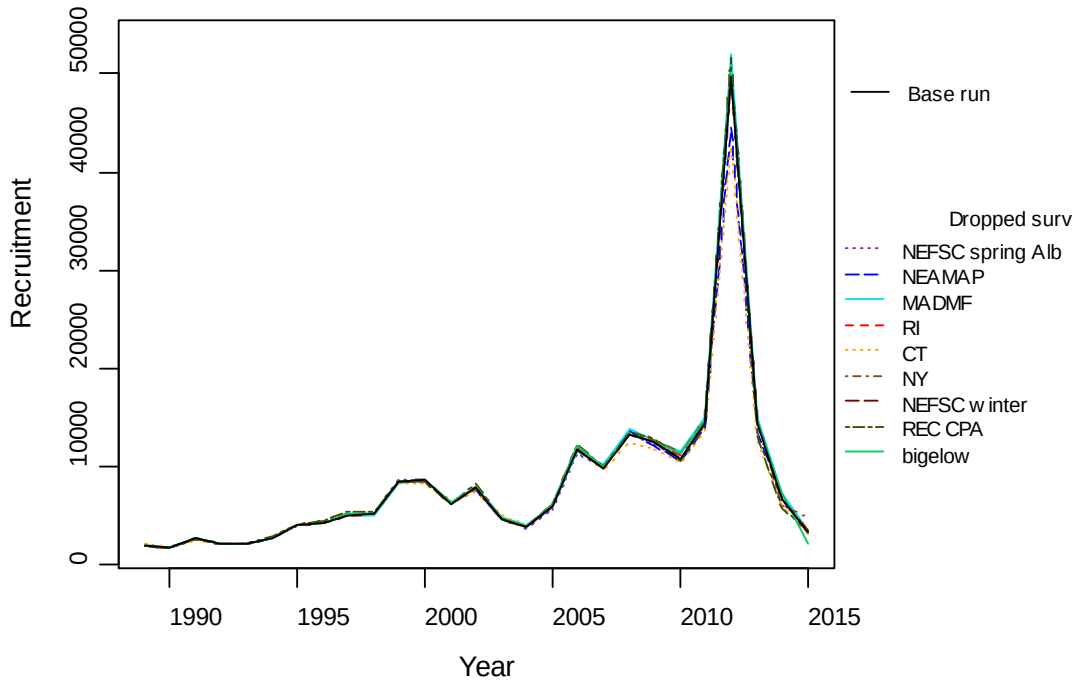

Figure A158. Recruitment (age 1) estimates from black sea bass ASAP **North** area model examining sensitivity to indices used in the model.

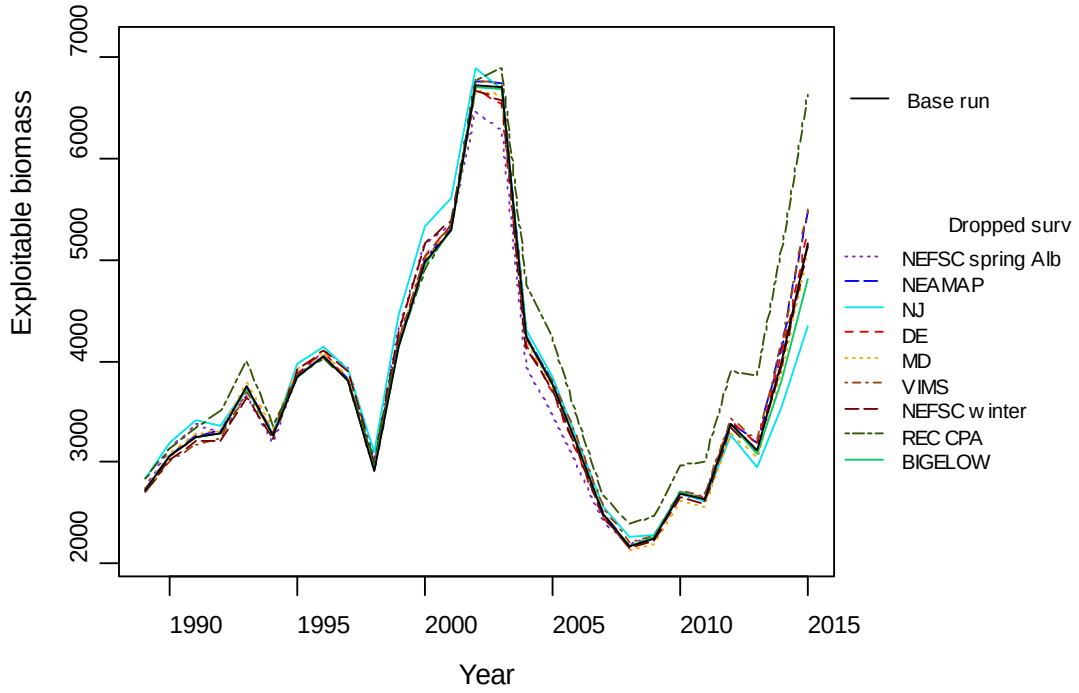

Figure A159. Exploitable biomass (mt) estimates from black sea bass ASAP **South** area model examining sensitivity to indices used in the model.

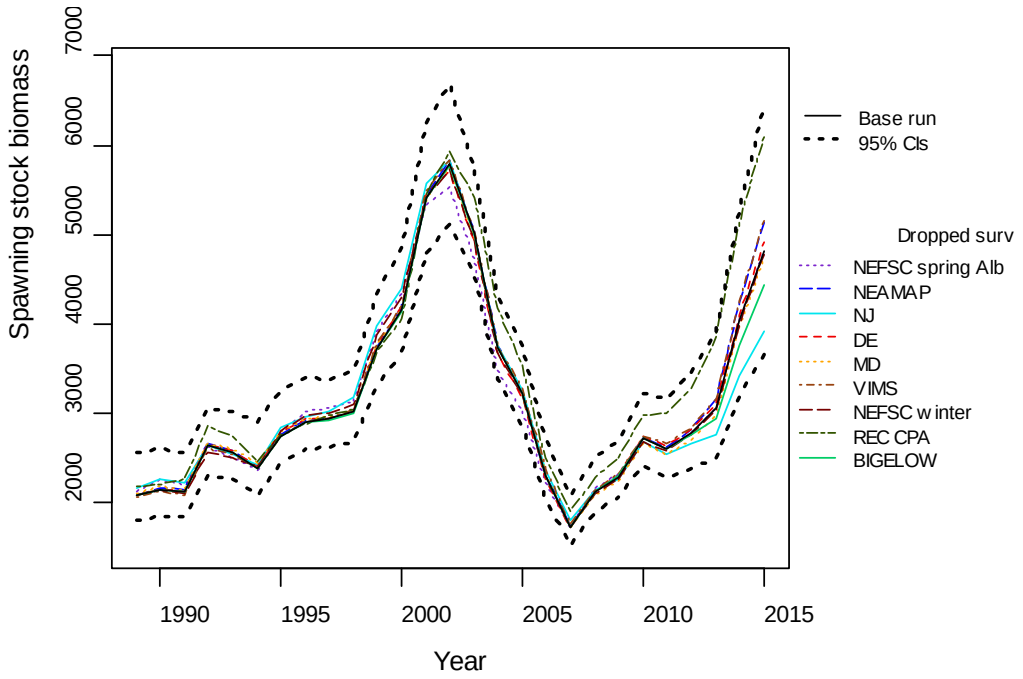

Figure A160. Spawning stock biomass (mt) estimates from black sea bass ASAP **South** area model examining sensitivity to indices used in the model.

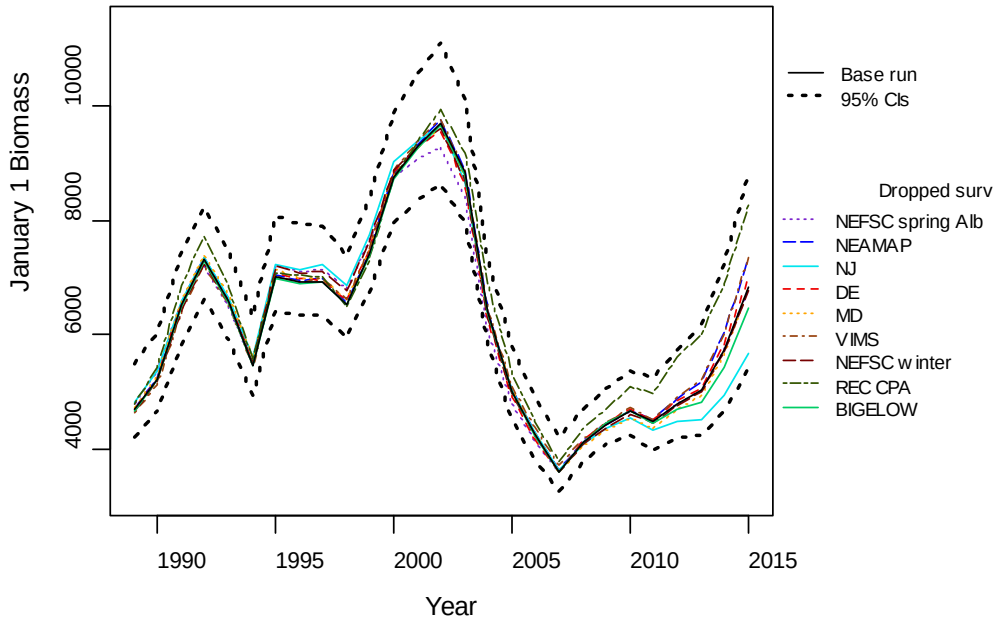

Figure A161. Total biomass (mt) estimates from black sea bass ASAP **South** area model examining sensitivity to indices used in the model.

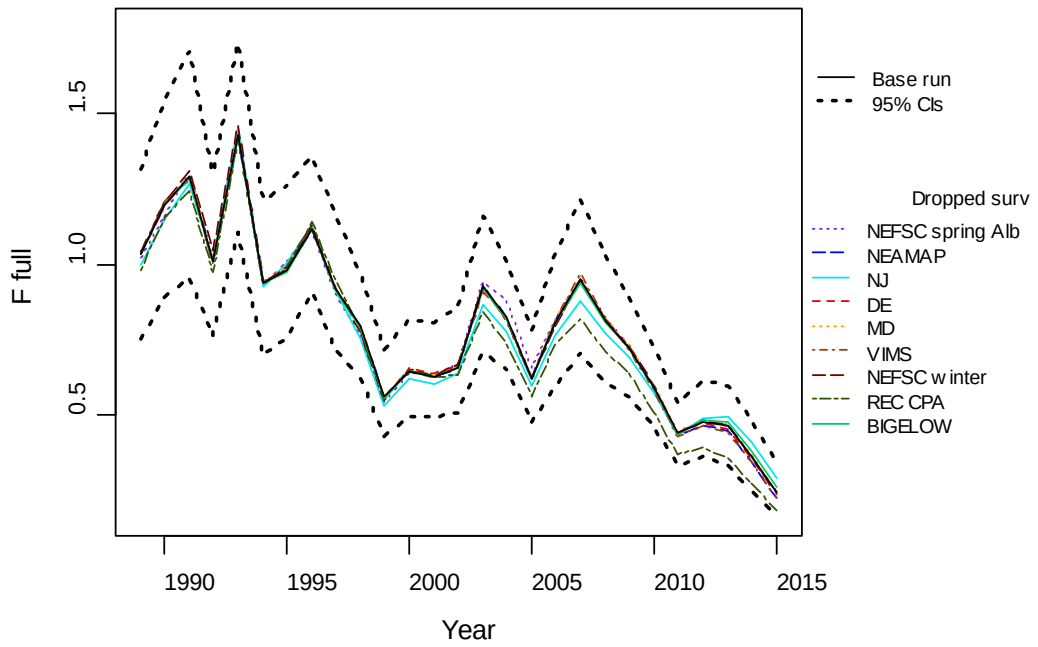

Figure A162. Fishing mortality estimates from black sea bass ASAP **South** area model examining sensitivity to indices used in the model.

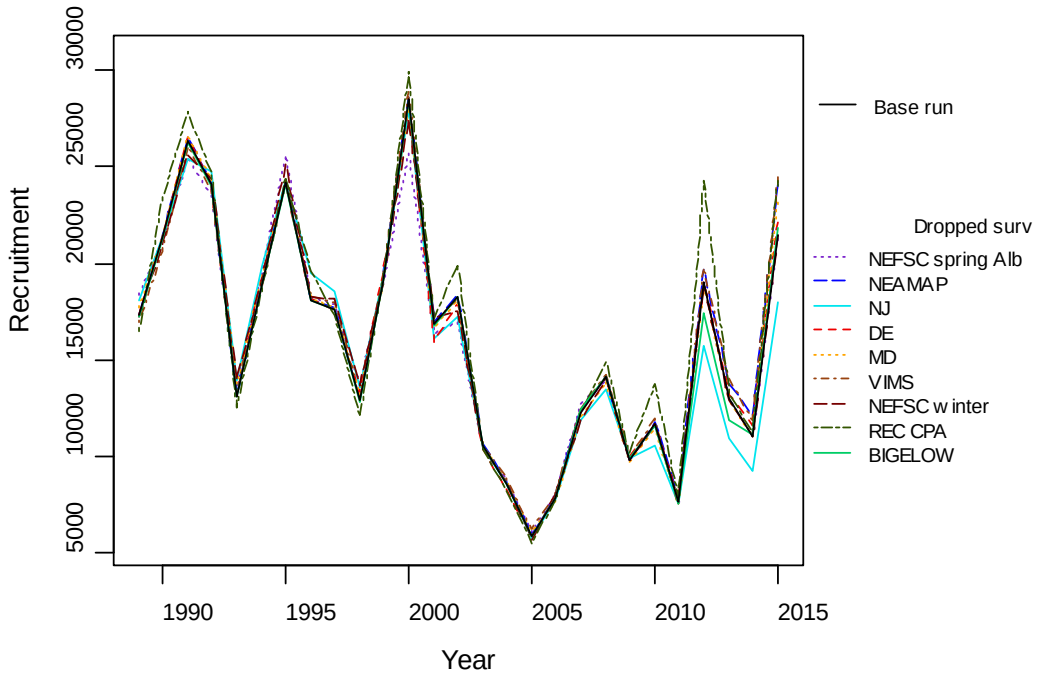

Figure A163. Recruitment (age 1) estimates from black sea bass ASAP **South** area model examining sensitivity to indices used in the model.

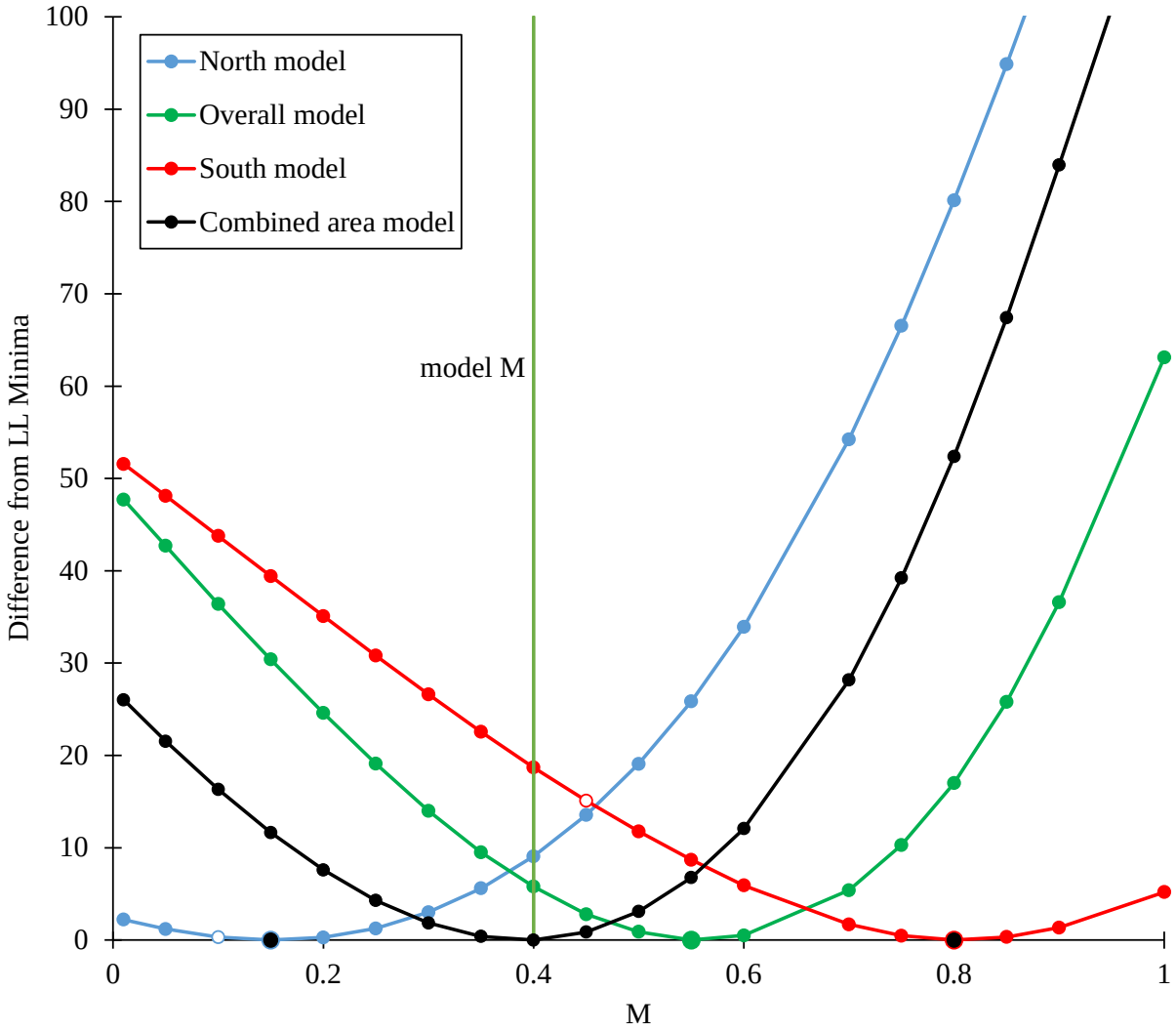

Figure A164. Likelihood profile of varying M estimates in regional black sea bass ASAP models.

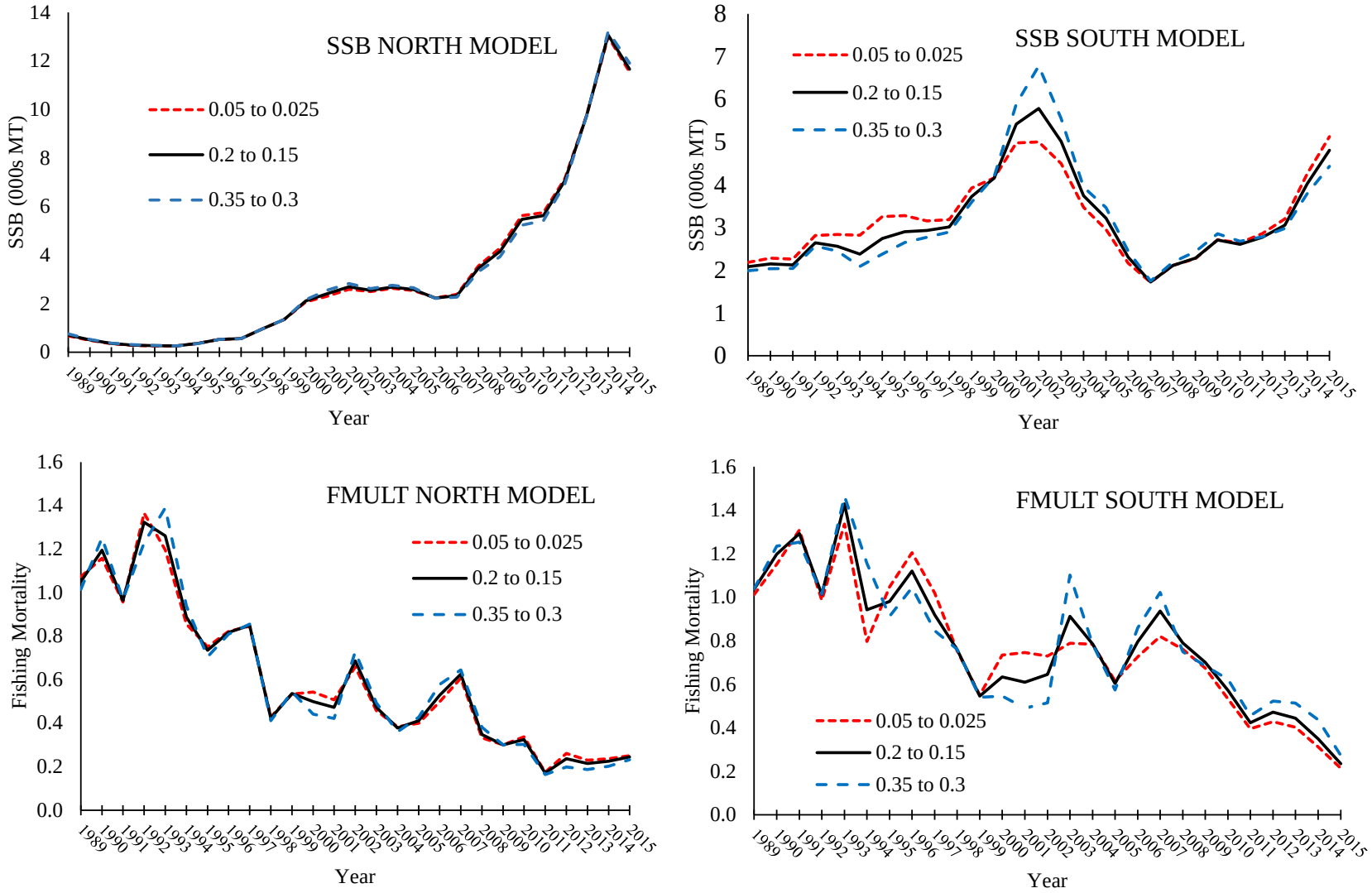

Figure A 165. Sensitivity of CV for non-trawl fleet on the resulting black sea bass spawning biomass and fishing mortality estimates.

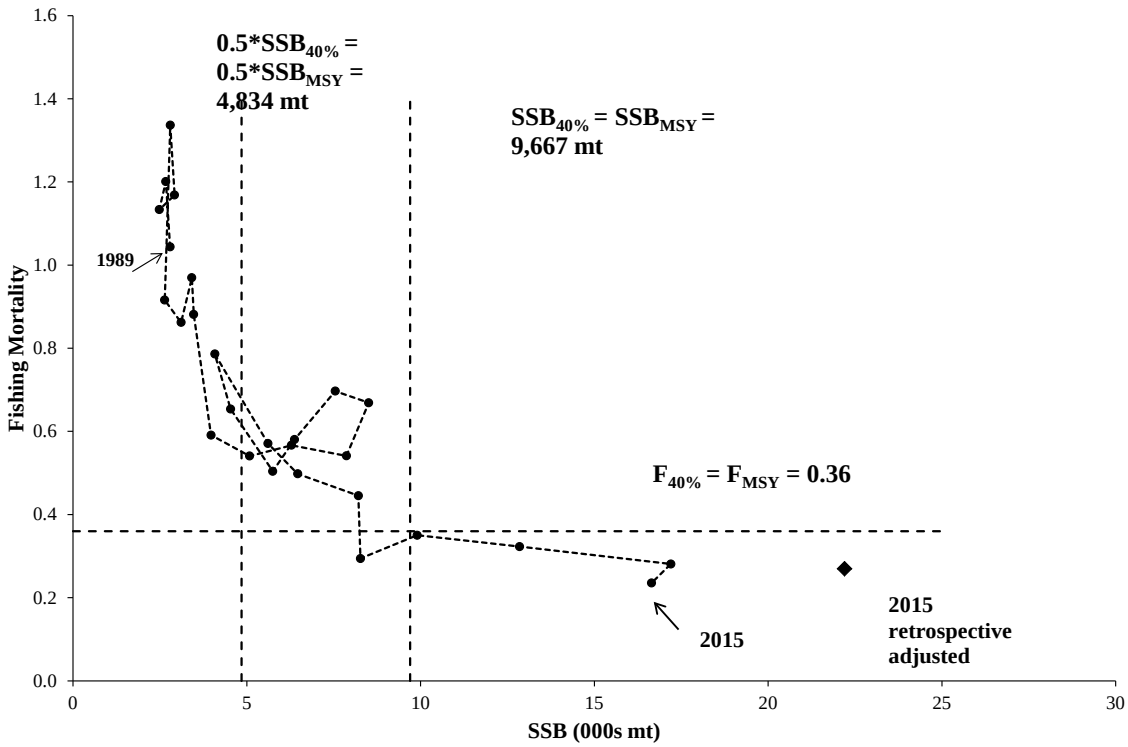

Figure A166. Time series trajectory of black sea bass SSB and F relative to biological reference points.

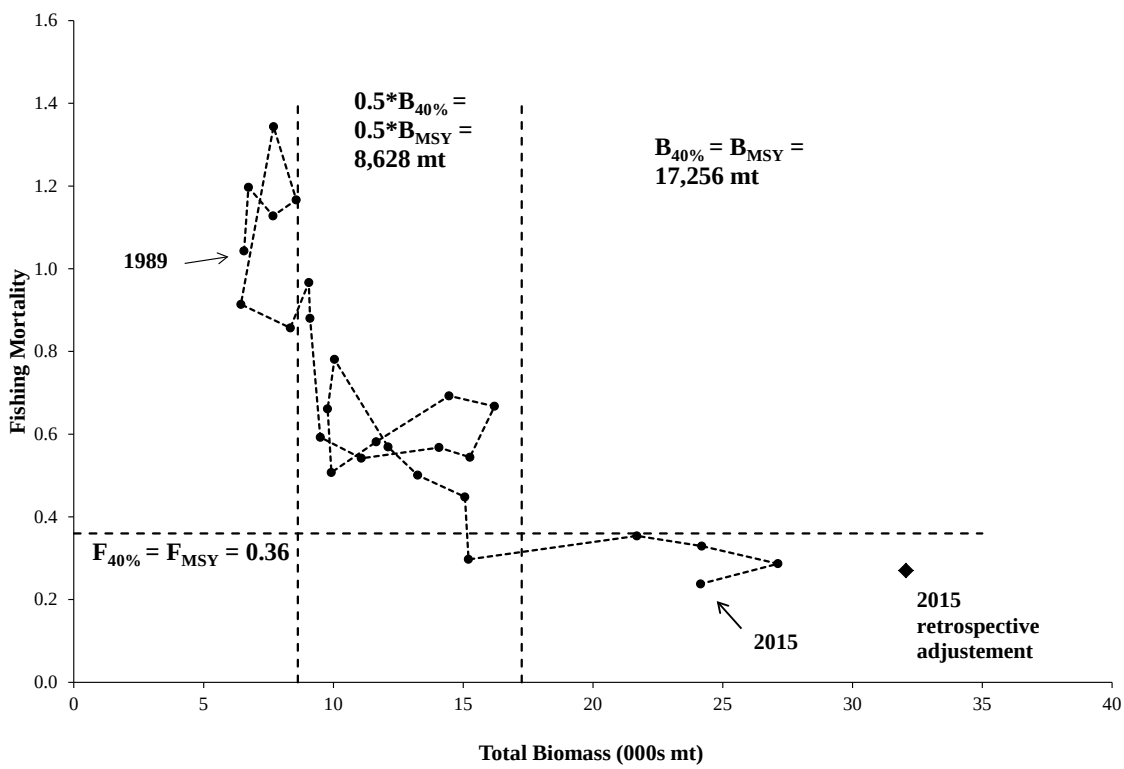

Figure A167. Time series trajectory of black sea bass total biomass and F relative to biological reference points.

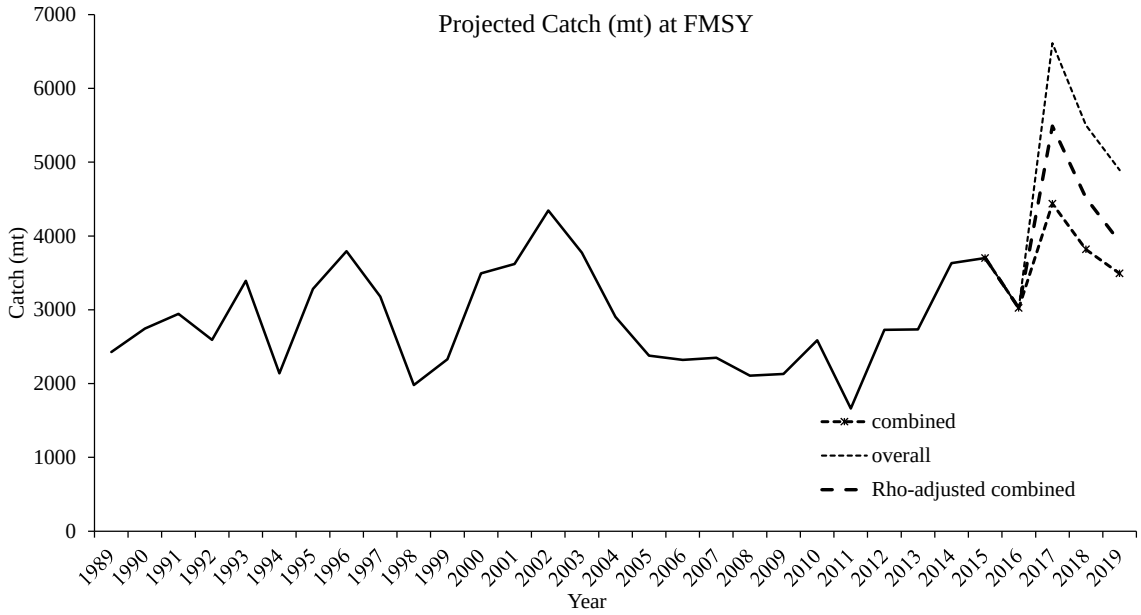

Figure A168. Time series of black sea bass total catch (mt) with 3 year projections at F_{MSY}. Projected catch based on the Overall single area model, the Combined area model and the Combined area model adjusted for retrospective patterns in each area.

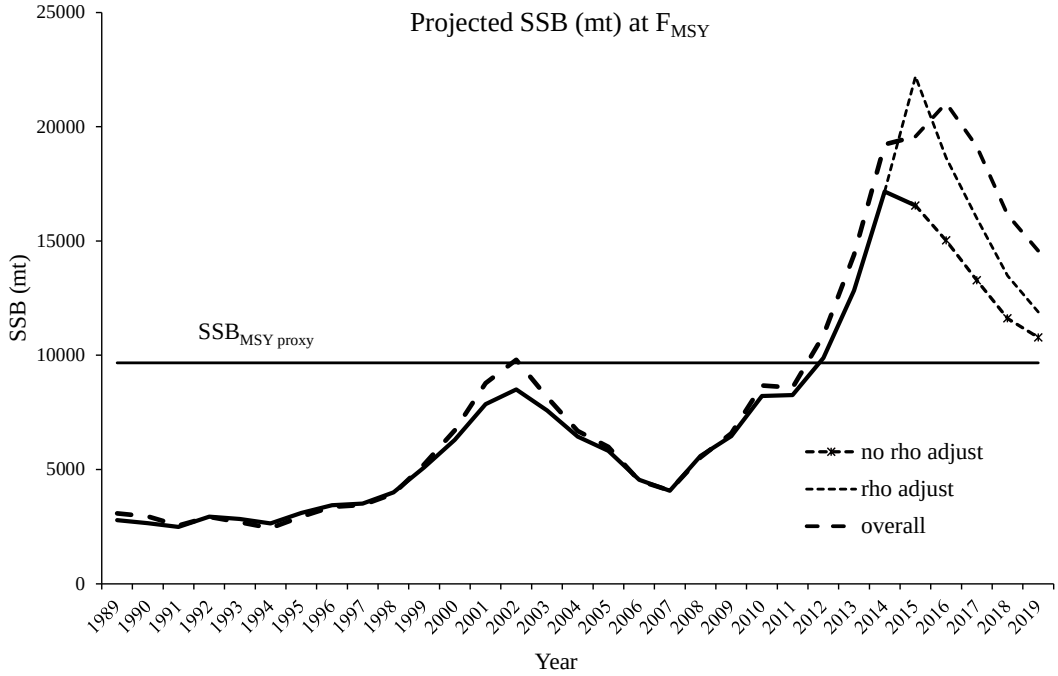

Figure A169. Time series of black sea bass SSB (mt) with 3 year projections at F_{MSY}. Projected SSB based on the Overall single area model, the Combined area model and the Combined area model adjusted for retrospective patterns in each area. $SSB_{MSYproxy}$ reference point shown.

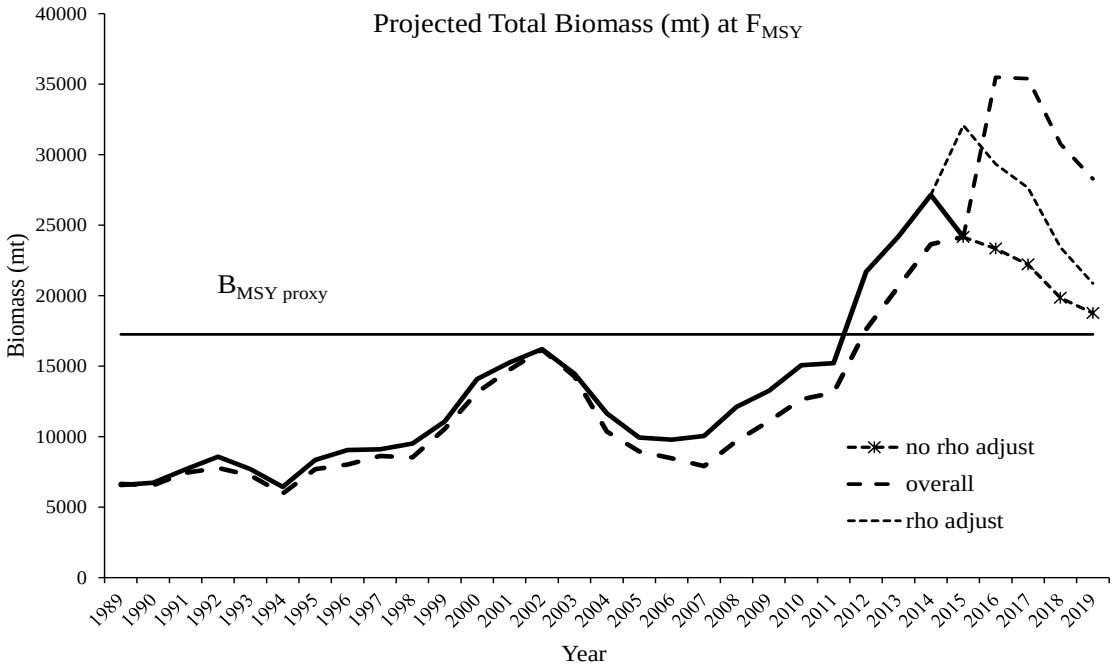

Figure A170. Time series of black sea bass Total Biomass (mt) with 3 year projections at F_{MSY}. Projected Biomass based on the Overall single area model, the Combined area model and the Combined area model adjusted for retrospective patterns in each area. $B_{MSYproxy}$ reference point shown.

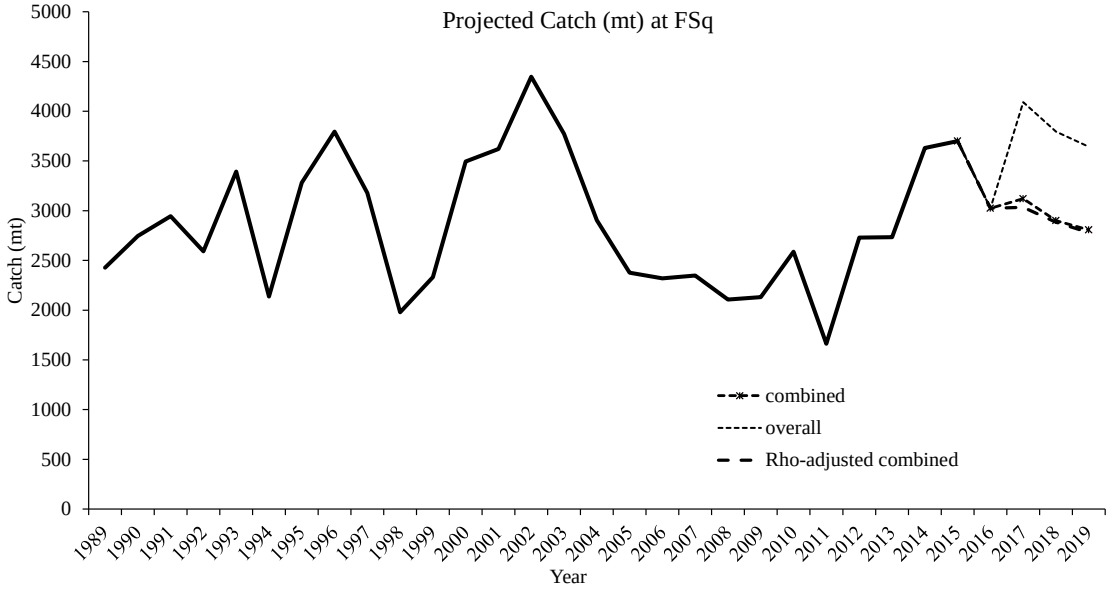

Figure A171. Time series of black sea bass total catch (mt) with 3 year projections at F_{SQ}. Projected catch based on the Overall single area model, the Combined area model and the Combined area model adjusted for retrospective patterns in each area.

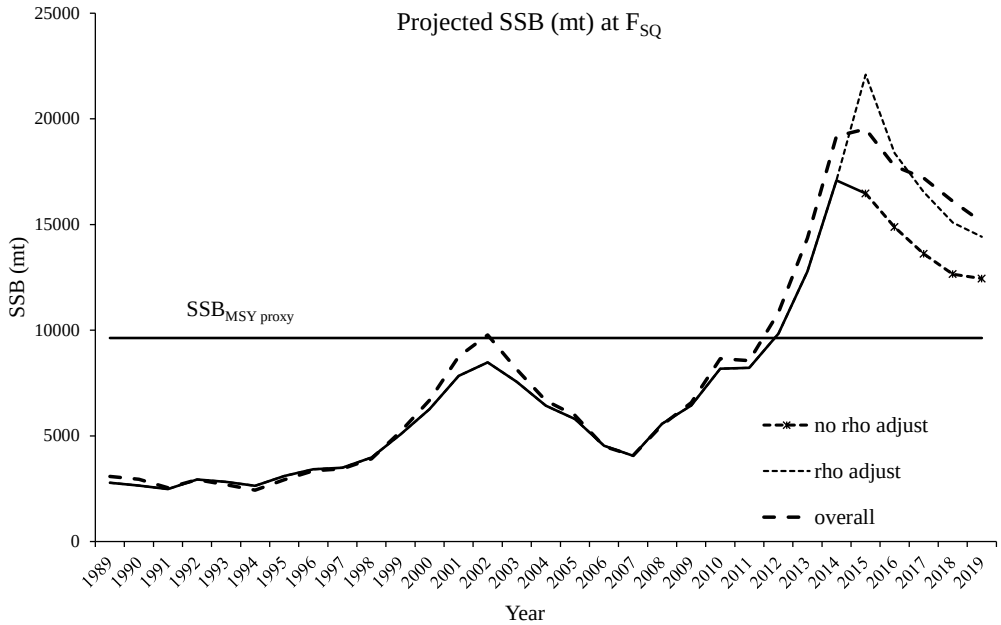

Figure A172. Time series of black sea bass SSB (mt) with 3 year projections at F_{SQ}. Projected SSB based on the Overall single area model, the Combined area model and the Combined area model adjusted for retrospective patterns in each area. $SSB_{MSYproxy}$ reference point shown.

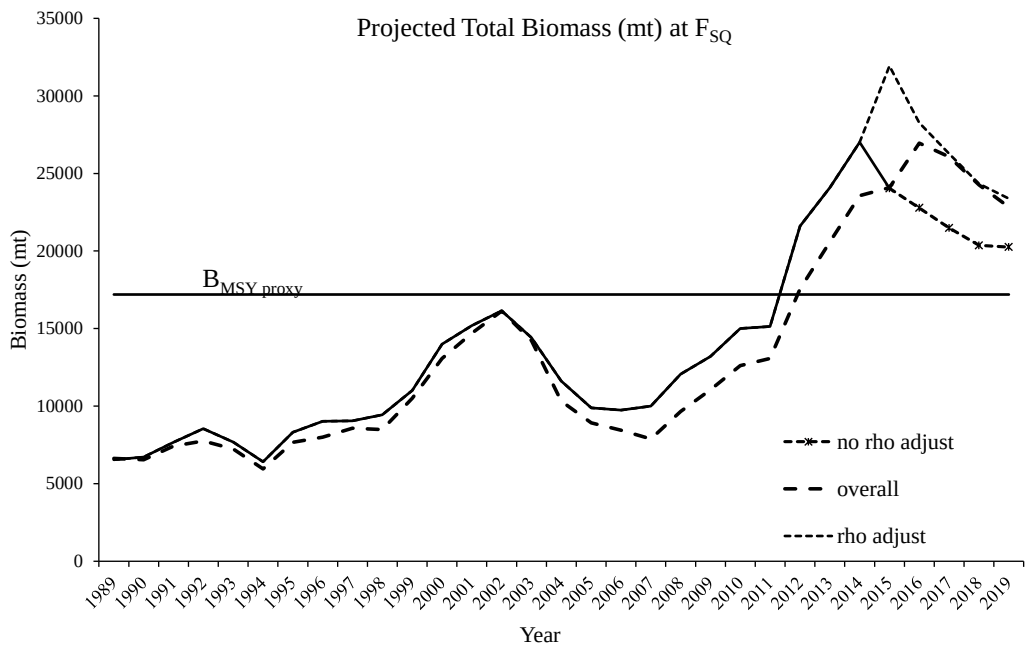

Figure A173. Time series of black sea bass Total Biomass (mt) with 3 year projections at F_{SQ}. Projected Biomass based on the Overall single area model, the Combined area model and the Combined area model adjusted for retrospective patterns in each area. $B_{MSYproxy}$ reference point shown.

Appendix A

The following information is the result of requests for additional information made by CIE reviewers during the SARC.

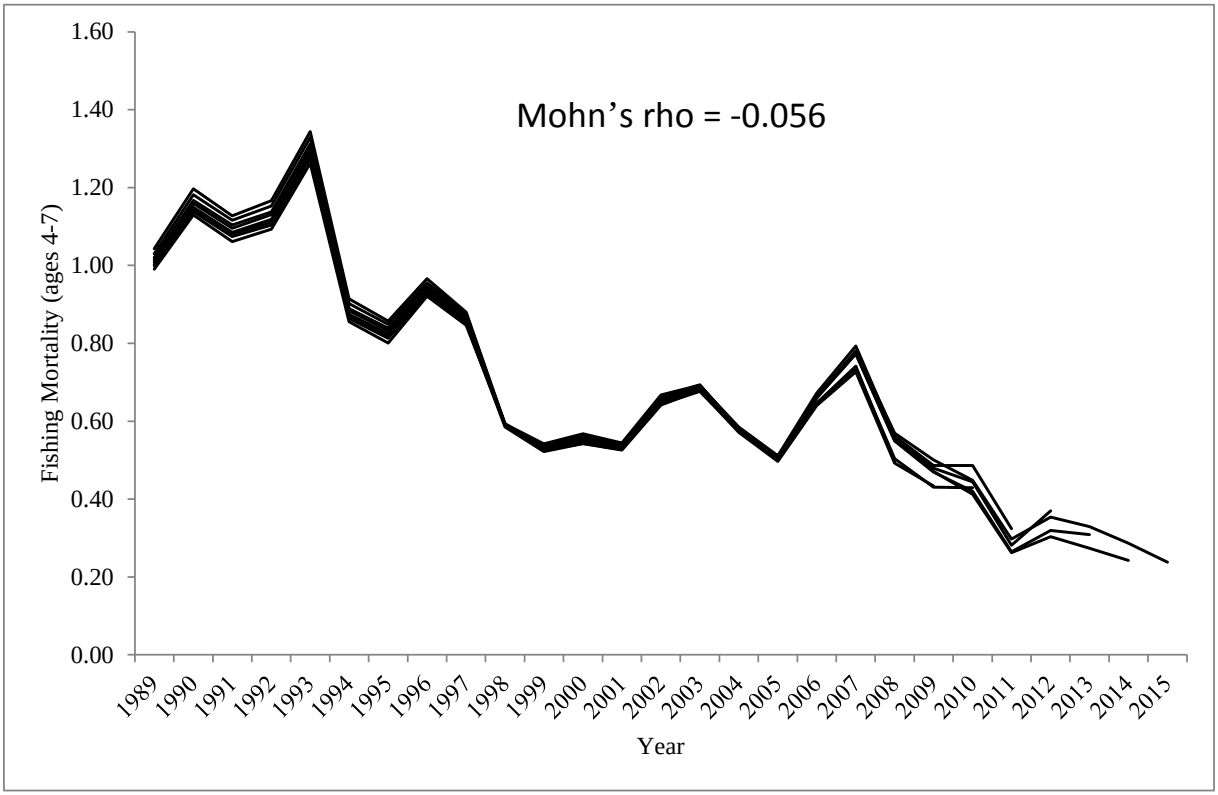

Figure A174. Retrospective pattern of black sea bass fishing mortality from Two Area model combined.

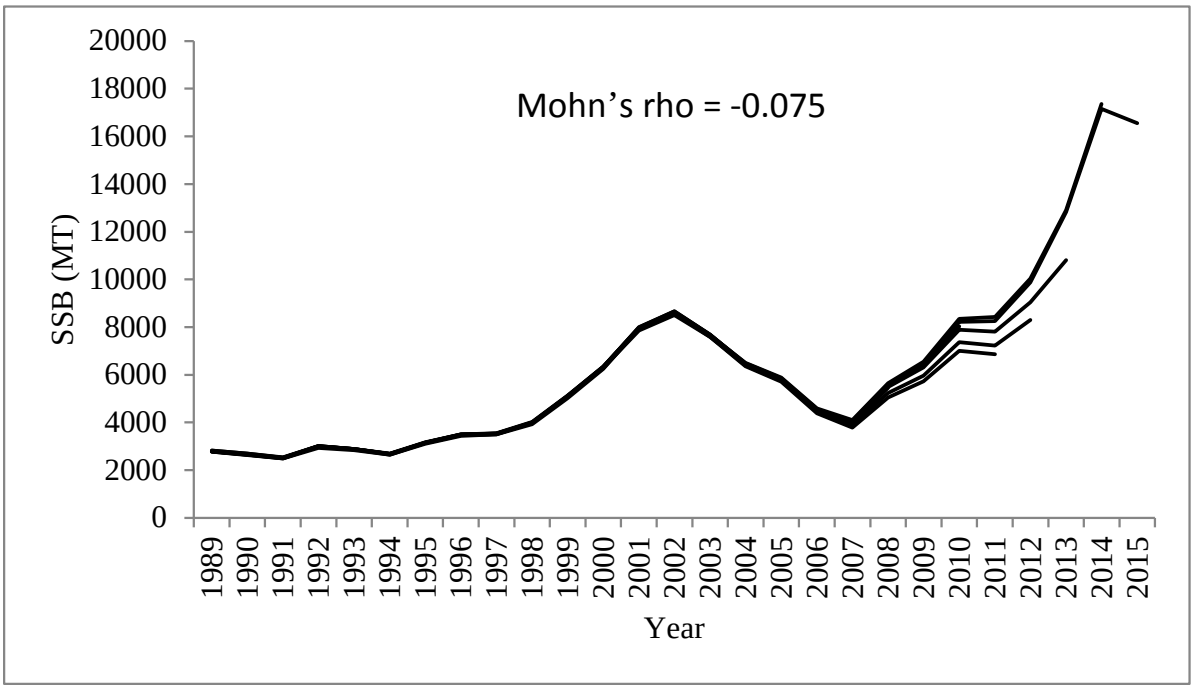

Figure A175. Retrospective pattern of black sea bass SSB (mt) from Two Area model combined.

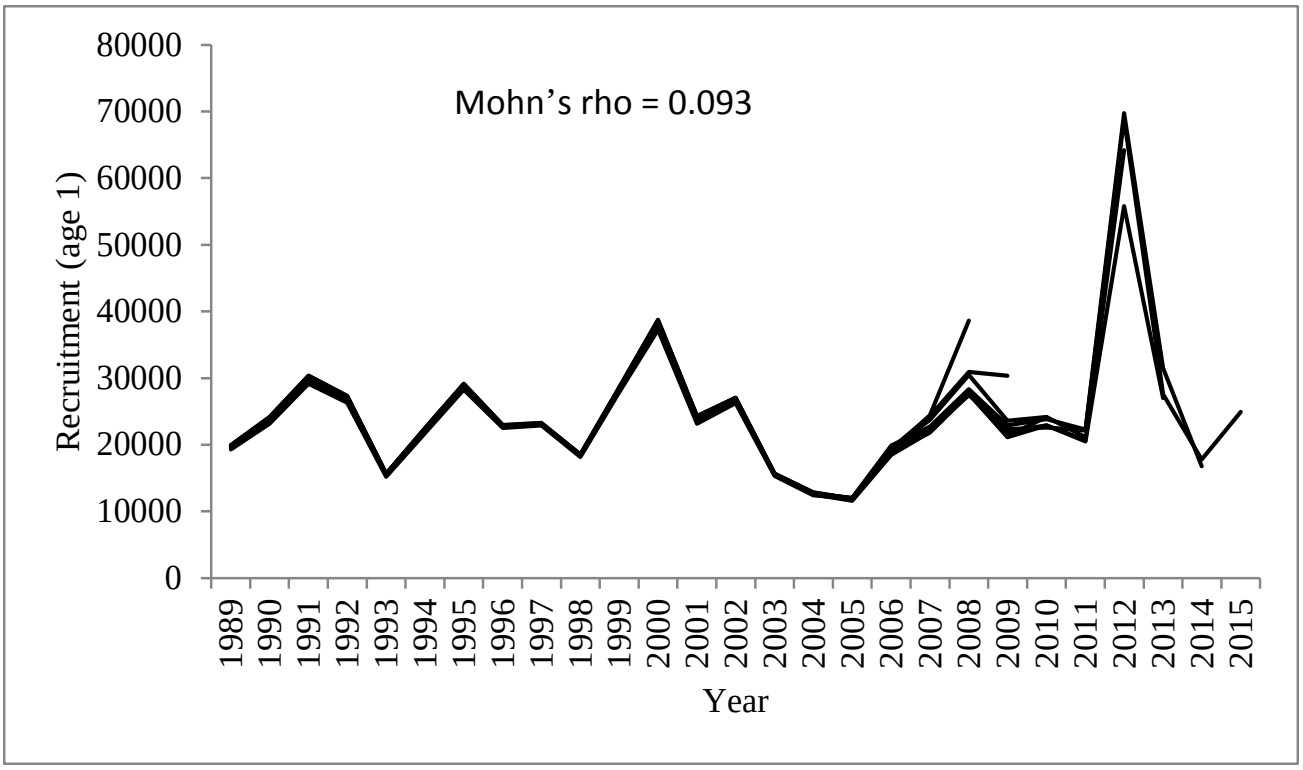

Figure A176. Retrospective pattern of black sea bass age 1 recruitment from Two Area model combined.

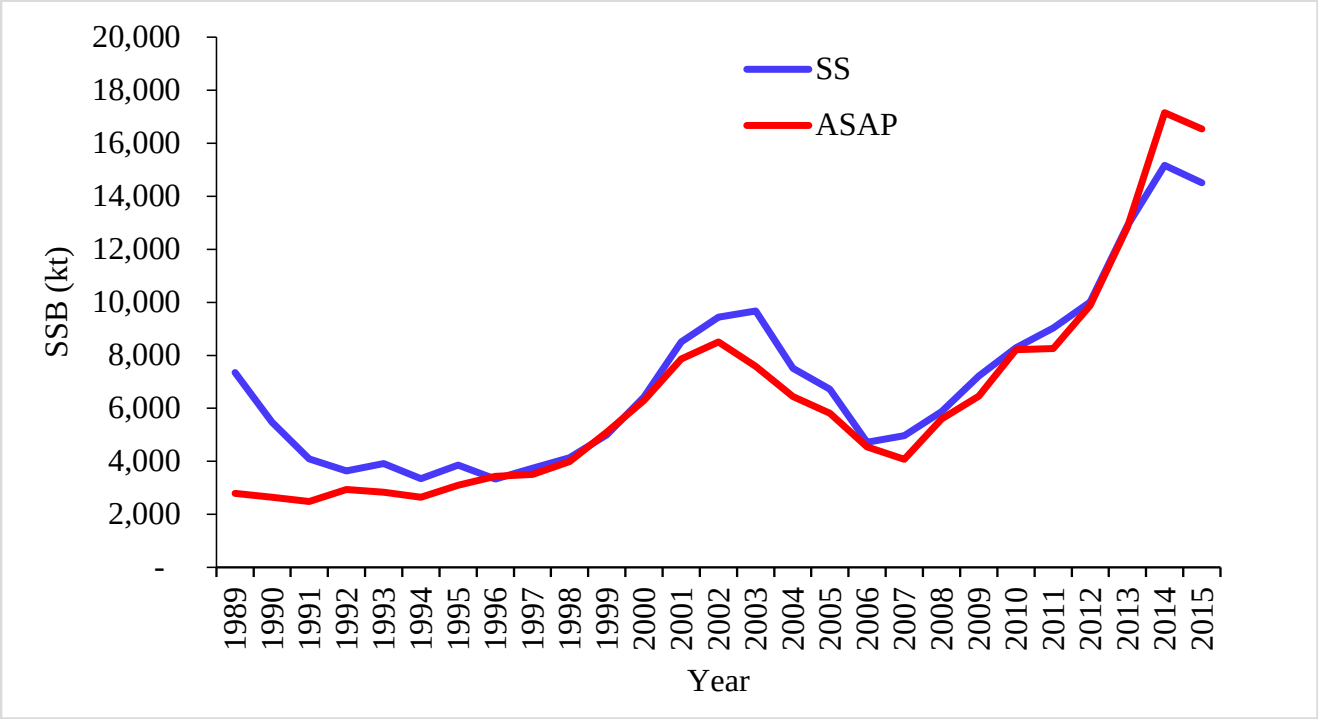

Figure A177. Comparison of black seas bass SSB from the ASAP Two Area model (combined) and Stock Synthesis exploratory model.

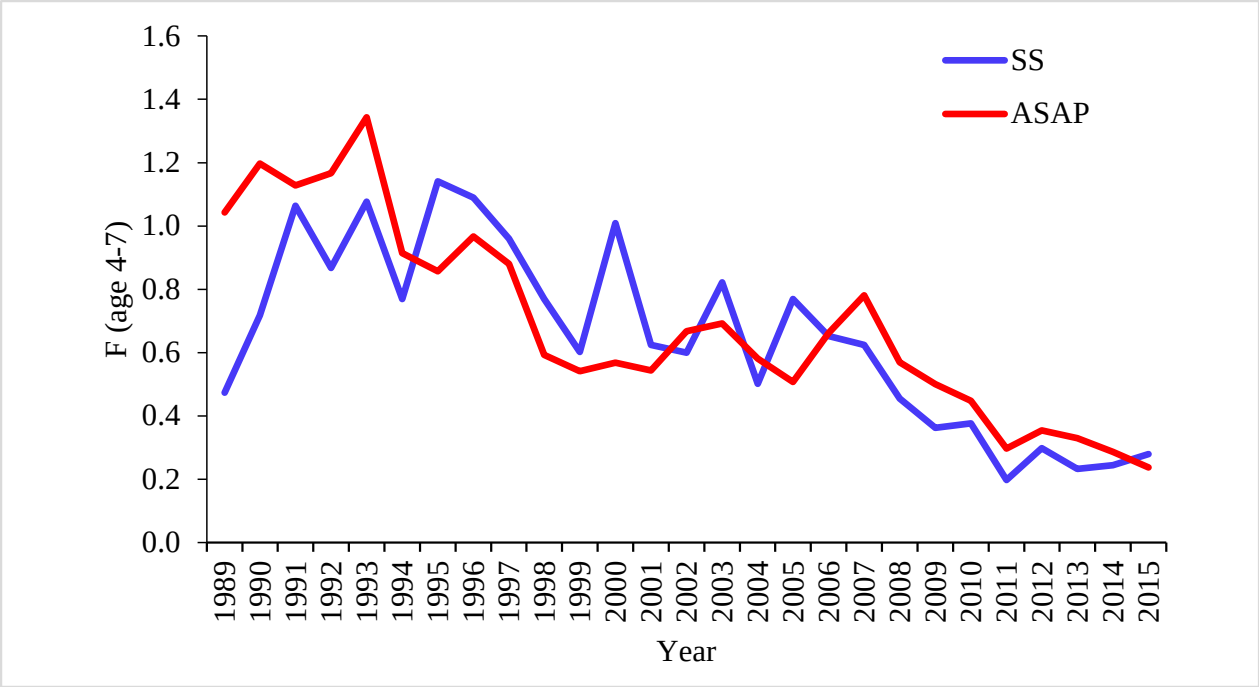

Figure A178. Comparison of black seas bass fishing mortality SSB from the ASAP Two Area model (combined) and Stock Synthesis exploratory model.

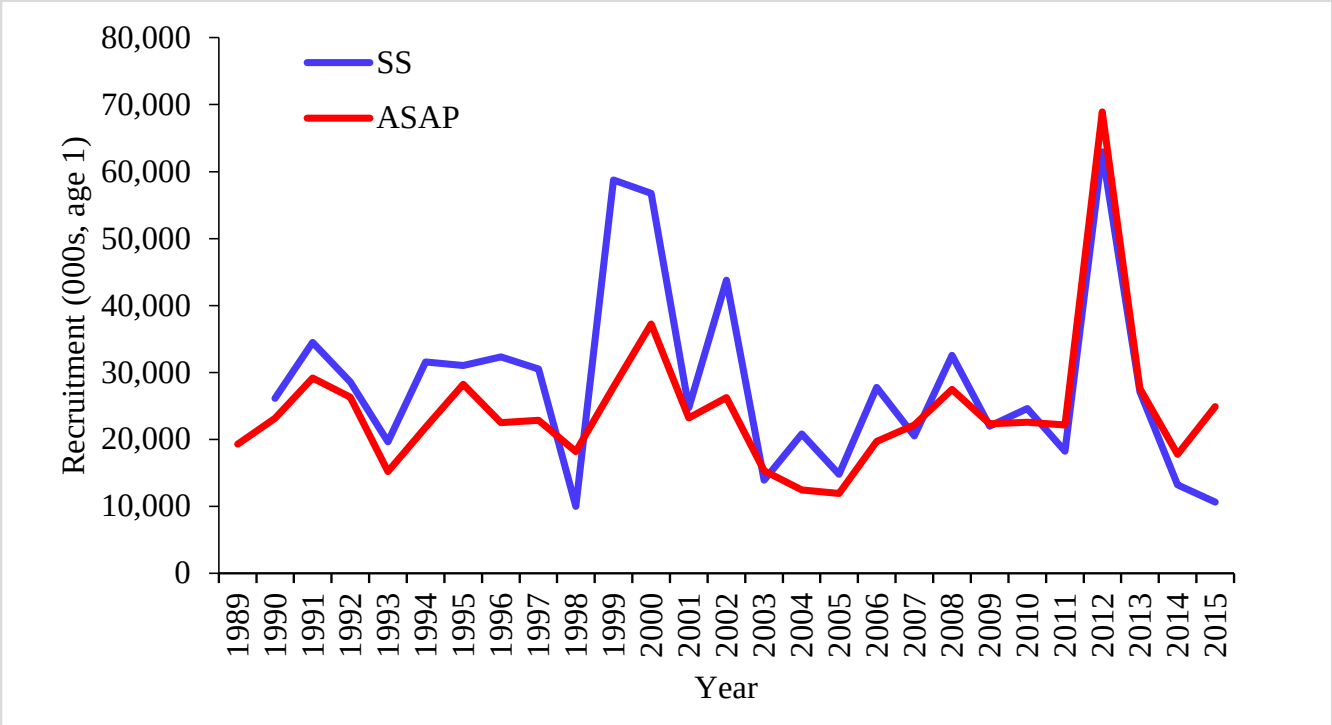

Figure A179. Comparison of black seas bass recruitment SSB from the ASAP Two Area model (combined) and Stock Synthesis exploratory model.

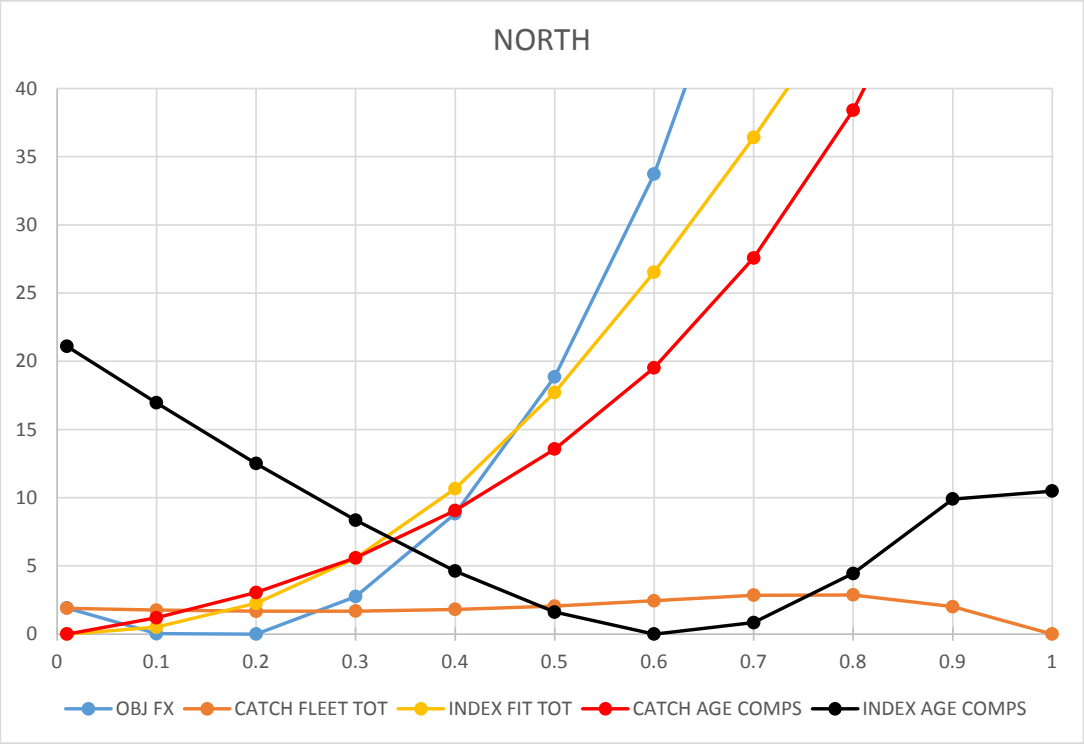

Figure A180. Black sea bass likelihood profiles by component across varying natural mortality values using North ASAP model.

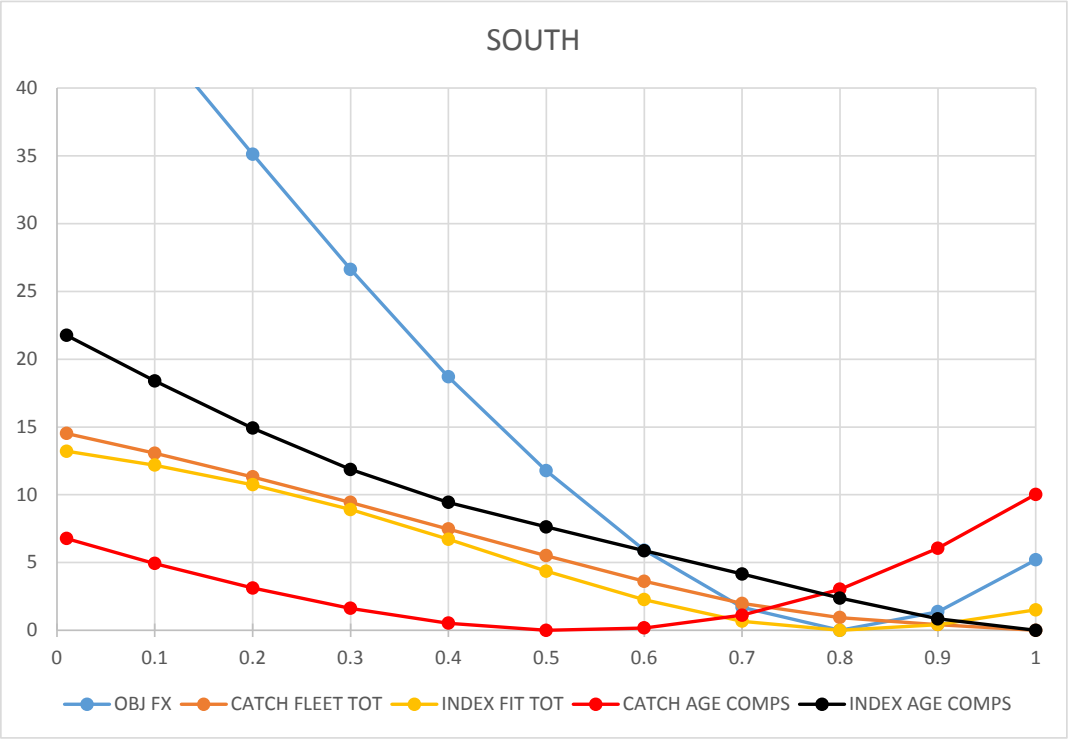

Figure A181. Black sea bass likelihood profiles by component across varying natural mortality values using South ASAP model.

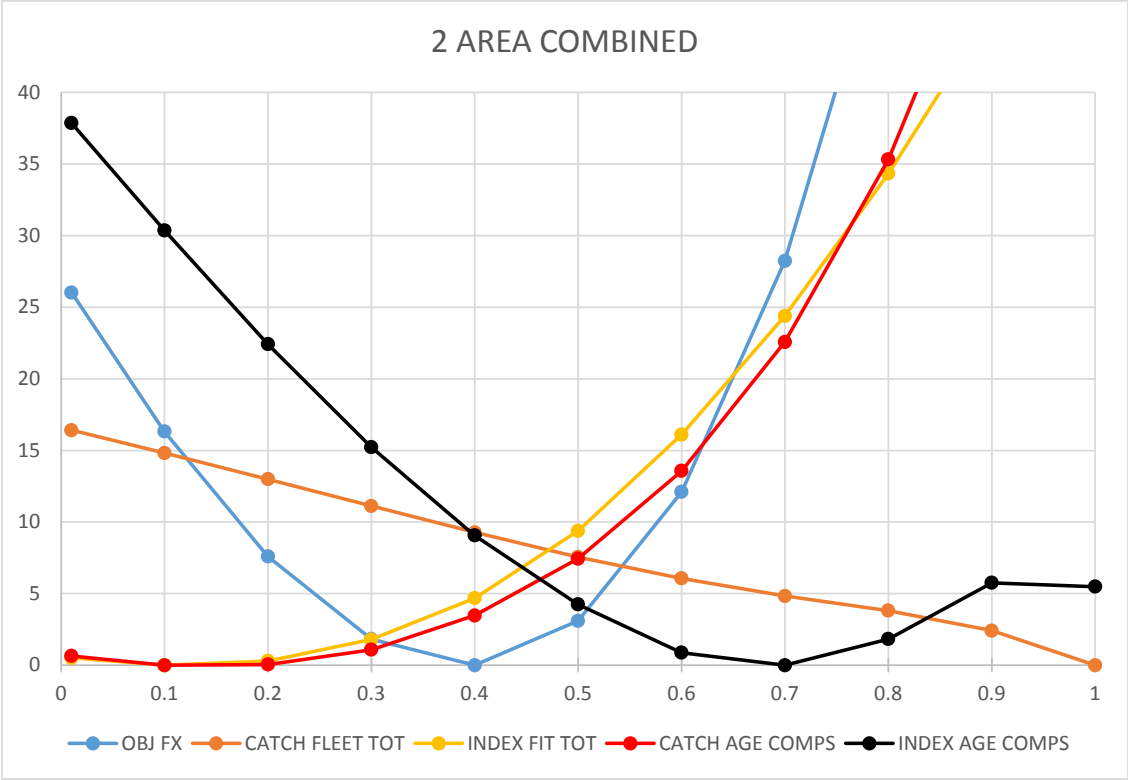

Figure A182. Black sea bass likelihood profiles by component across varying natural mortality values using Two Area combined ASAP model.

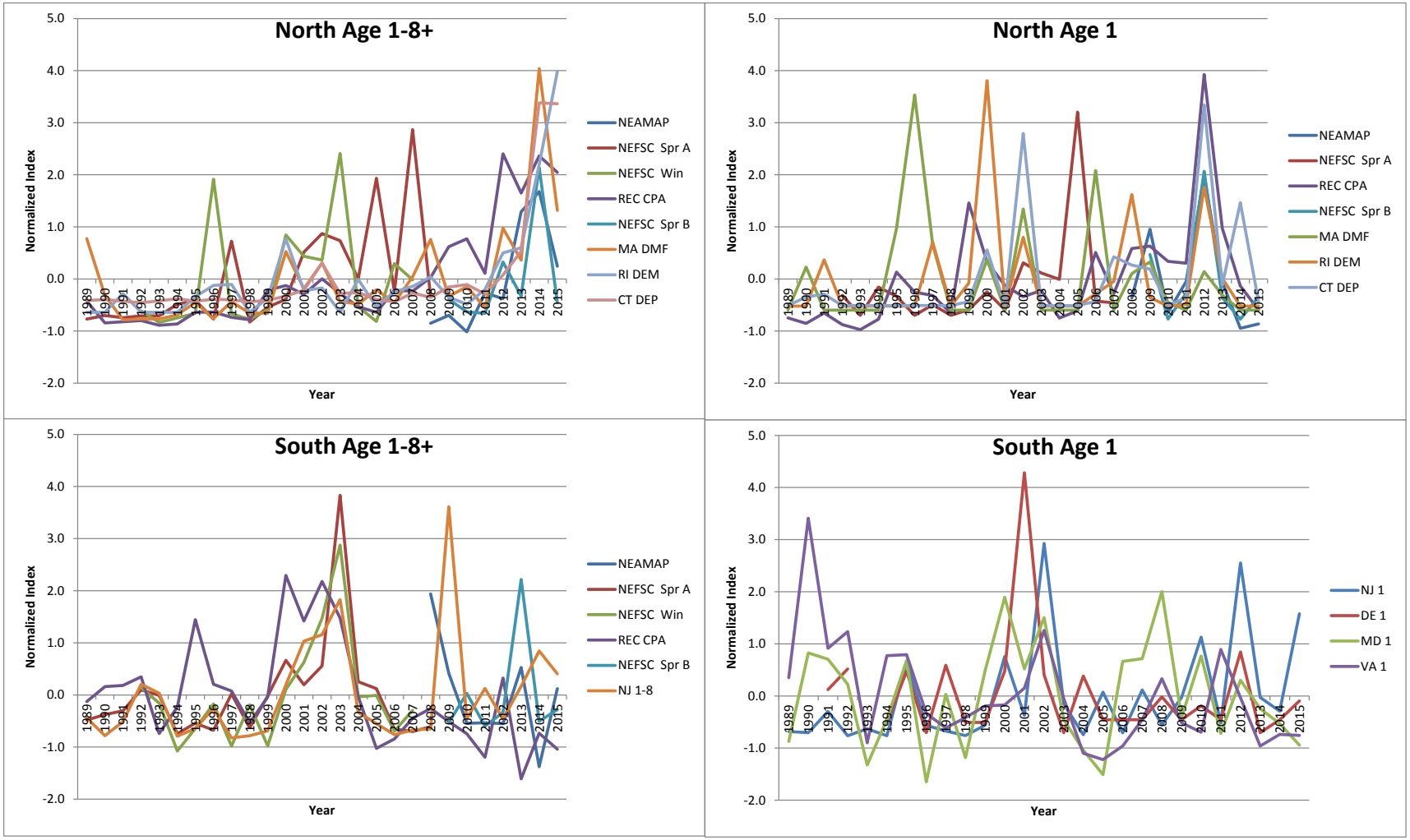

Figure A183. Black sea bass survey standardized indices by area and age groups.

Table A48. Summary of black sea bass survey index rank, CVs, CV multipliers and residual mean square error for overall and regional models.

Rank	**NORTH** Index	Index avg. CV	model CV	CV multiplier	RMSE
1	REC CPA	-	0.40		0.74
2	NEFSC spring Alb	0.65	0.70	1.08	1.49
3	BIGELOW	0.38	0.65	1.71	1.06
3	NEAMAP	0.48	0.30	0.63	1.16
4	MADMF	0.36	0.50	1.39	1.60
4	RI	0.53	0.80	1.51	1.16
4	CT	0.31	0.60	1.94	1.41
5	NY	0.46	0.60	1.30	1.88

Rank	**SOUTH** Index	Index avg. CV	model CV	CV multiplier	RMSE
1	REC CPA	-	0.35		0.68
2	NEFSC spring Alb	0.41	0.70	1.71	1.20
3	BIGELOW	0.36	0.70	1.94	1.45
3	NEFSC winter	0.26	0.70	2.69	1.11
4	NJ	0.32	0.50	1.56	1.36
5	NEAMAP (age 1)	0.22	0.40	1.82	0.77
5	DE	-	0.60		1.38
5	MD	-	0.60		1.16
5	VIMS	0.18	0.60	3.33	1.13

Rank	**OVERALL** Index	Index avg. CV	model CV	CV multiplier	RMSE
1	REC CPA	-	0.5		0.47
2	NEFSC spring Alb	0.38	0.6	1.58	1.23
3	BIGELOW	0.30	0.4	1.33	1.25
3	NEFSC winter	0.25	0.7	2.80	1.00
3	NEAMAP	-	0.4		0.72
4	MADMF	0.36	0.5	1.39	1.97
4	RI	0.53	0.8	1.51	0.96
4	CT	0.31	0.6	1.94	1.85
5	NY	0.46	0.8	1.74	1.65
4	NJ	0.32	0.5	1.56	1.16
5	DE	-	0.6		1.48
5	MD	-	0.4		1.67
5	VIMS	0.18	0.6	3.33	1.31

Ranked by:
Area coverage
Time series length
Ages represented

Retrospective analysis for Black sea bass Stock Synthesis model 'run_164'

Additional analyses requested by SARC 63 review panel Gavin Fay[1]

[1]*Department of Fisheries Oceanography, University of Massachusetts Dartmouth, gfay@umassd.edu*

November 30, 2016

On 11/29/16, the Review panel requested to see retrospective analyses for the 'base' version of the SS black sea bass model.

Retrospective analyses were conducted for the 'run_164' model detailed in WG documents Appendix X. Model peels using data only up to 2008 did not include the Bigelow survey indices or lengths. Note that for some peels some surveys will have a very small number of years of data (e.g. Bigelow, NEAMAP). An eight year peel was used to reflect the same extent of model/data years as the ASAP assessment models (the SS model used the 2016 spring survey data).

Table 1. Mohn's ρ statistics for spawning biomass (SSB), fishing mortality (F), and recruitment (Recruits) based on an eight year peel.

Quantity	Mohn's ρ
SSB	-0.073
F	0.008
Recruits	-0.128

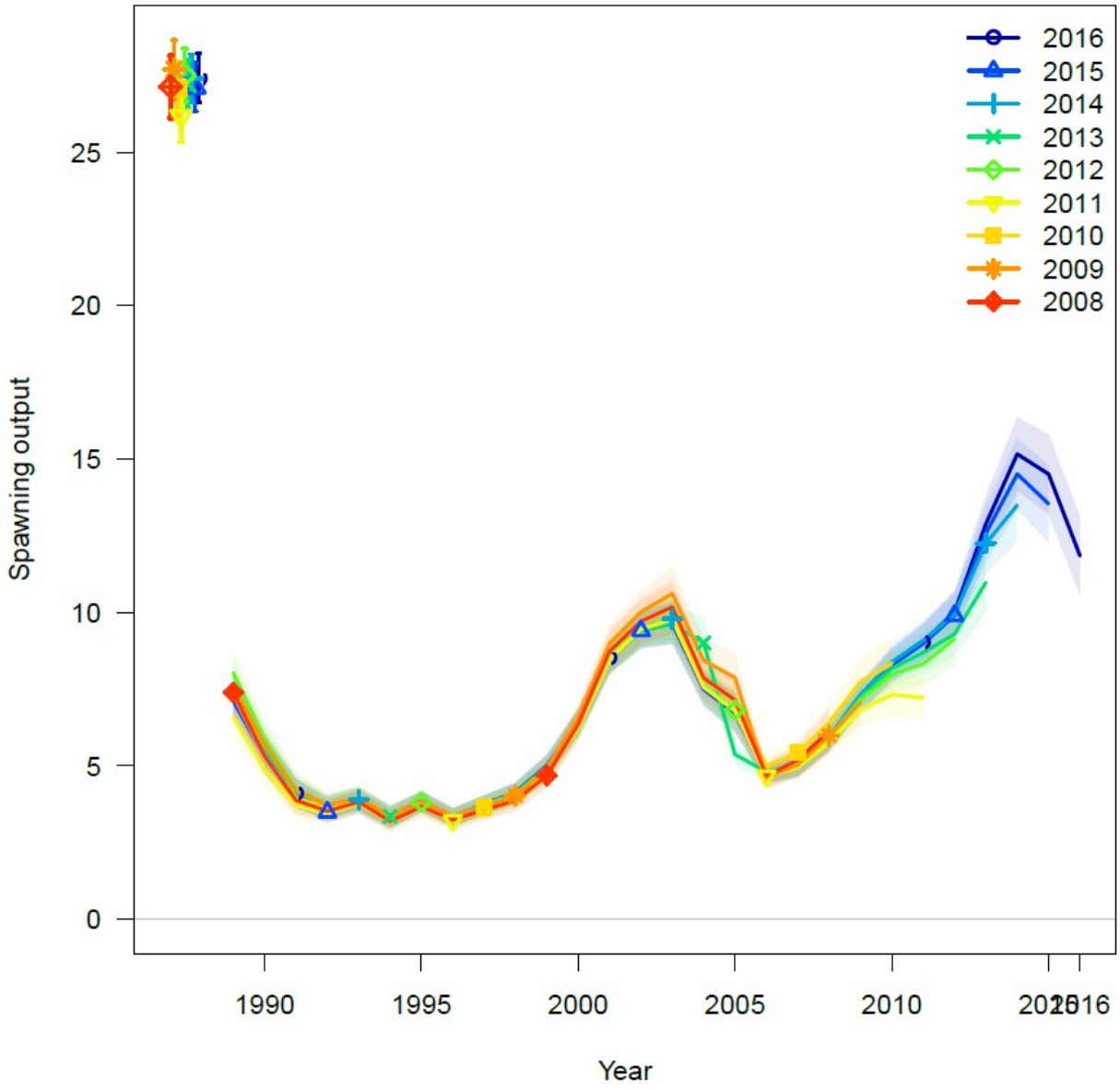

Figure A184. Retrospective analysis for black sea bass spawning biomass in SS exploratory model results

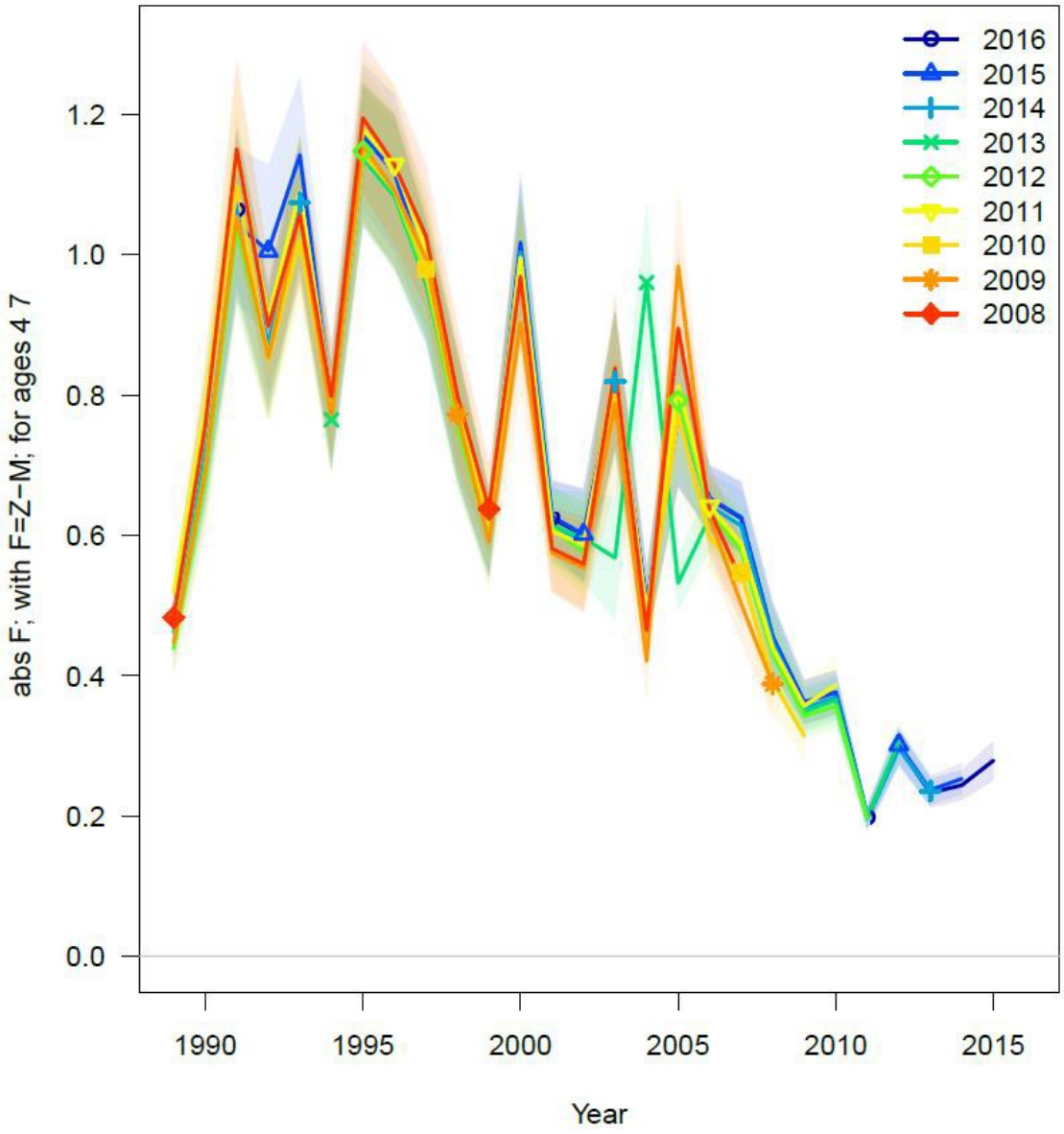

Figure A185. Retrospectives for time series of black sea bass fishing mortality in SS exploratory model results.

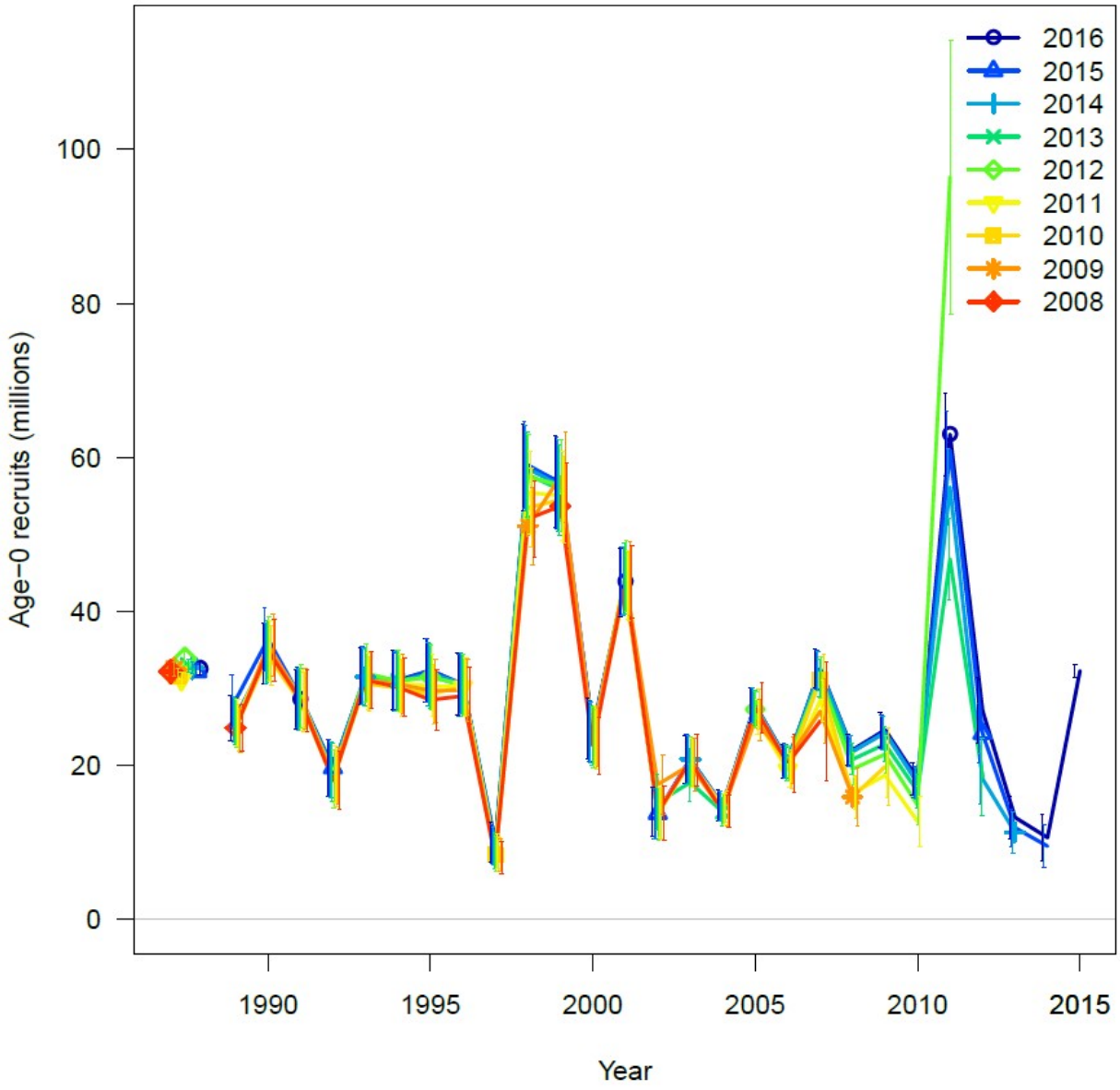

Figure A186. Retrospectives for time series of numbers of black sea bass Age 0 recruits (Recruitment in Table 1) in SS exploratory model results.

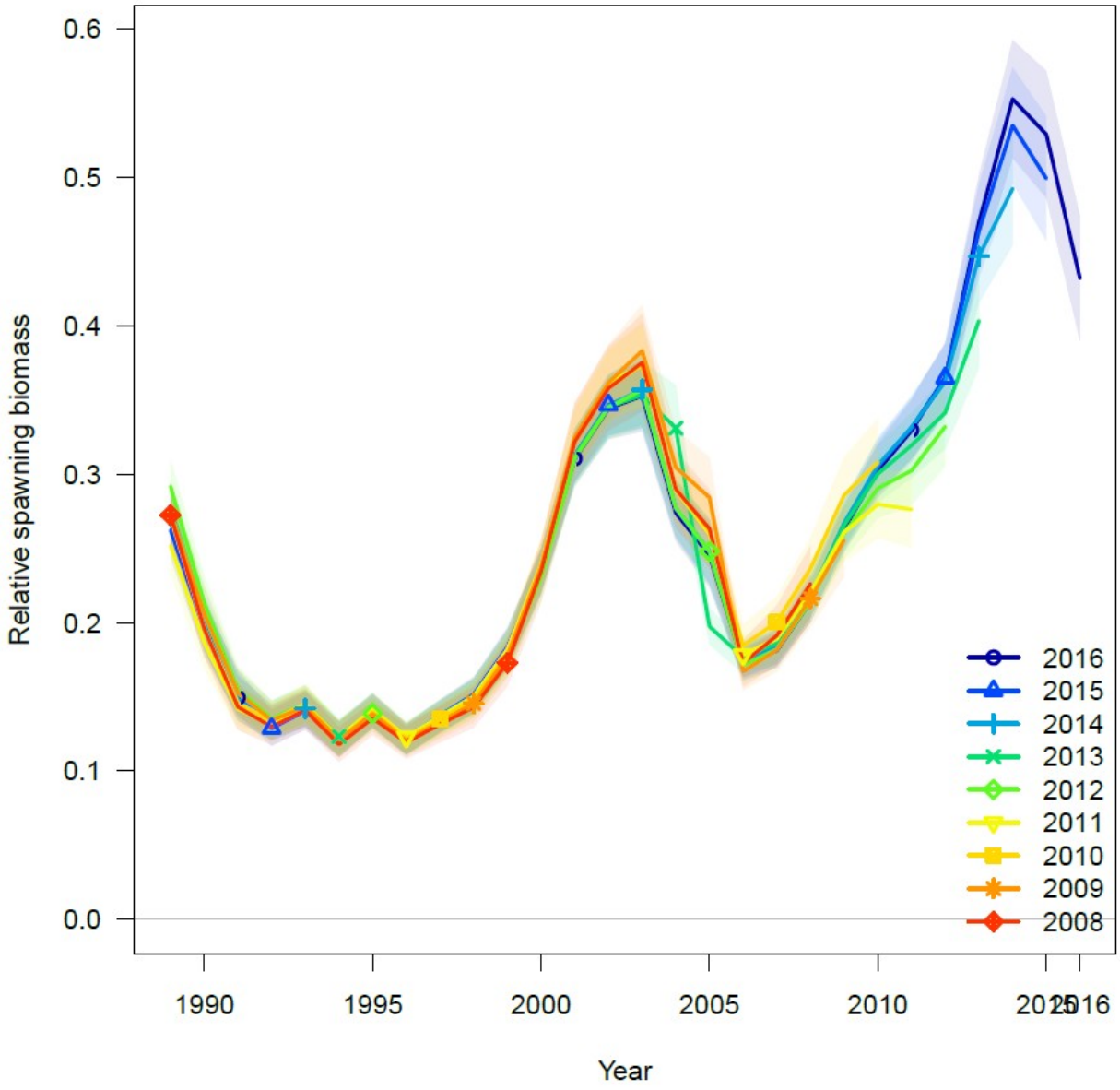

Figure A187. Retrospectives for time series of black sea bass relative spawning biomass (B/B0) in SS exploratory model results.

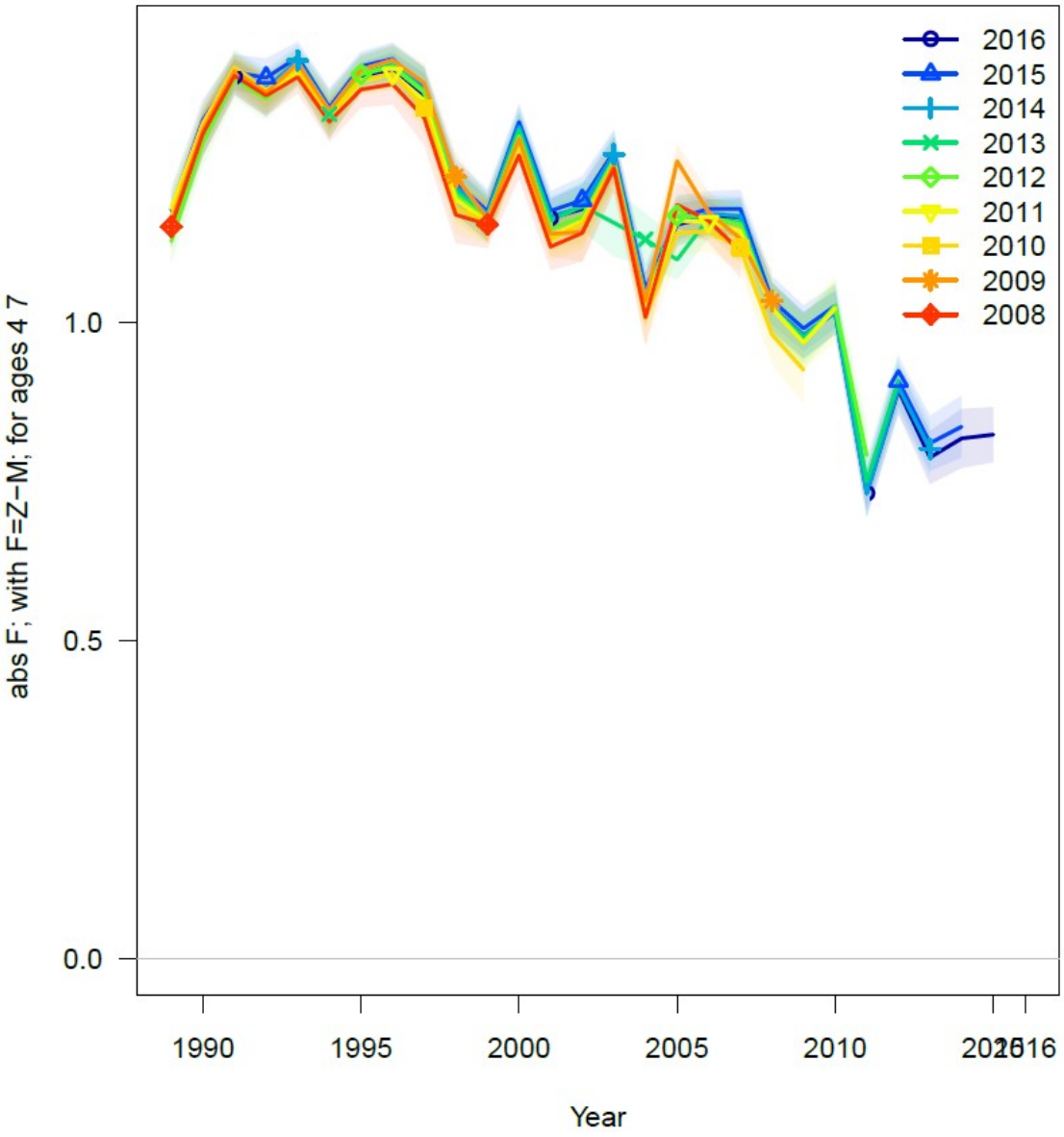

Figure A188. Retrospectives for time series of black sea bass F relative to F40% in SS exploratory model results.

B: STOCK ASSESSMENT OF WITCH FLOUNDER FOR 2016

SAW-62 Editor's Note regarding witch flounder:

The SARC-62 peer review panel did not accept specific applications of the analytical assessment models (e.g., ASAP, VPA, Replacement Yield, SCAA) for witch flounder presented in this report or its appendices. SARC-62 does not recommend that the specific results from those models serve as a basis for fishery management decisions for 2017.

The analytical models and results are included in this report to document the material that the witch flounder SAW Working Group provided to the SARC-62 for peer review.

Text expressing SARC-62 panel opinions has been added *in italics* in the EXECUTIVE SUMMARY and TOR sections of this report to reflect the outcome of the SARC-62 peer review.

The SARC-62 panel is recommending that managers consider using the empirical approach discussed in this document as the basis for developing management advice. The SARC-62 did not fully evaluate the empirical approach during the peer review, and therefore expected additional evaluation of the method, calculations, and results to be made following the peer review.

TERMS OF REFERENCE

B. Witch flounder

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

2. Present available federal, state, and other survey data, indices of relative or absolute abundance, recruitment, etc. Characterize the uncertainty and any bias in these sources of data and compare survey coverage to locations of fishery catches. Select the surveys and indices for use in the assessment.

3. Investigate effects of environmental factors and climate change on recruitment, growth and natural mortality of witch flounder. If quantifiable relationships are identified, consider incorporating these into the stock assessment.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3 if appropriate), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections. Compare F's and SSB's that were projected during the previous assessment to their realized values.

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 (or possibly models, in accord with guidance in attached "Appendix to the SAW Assessment TORs") developed for this peer review. In both cases, evaluate whether the stock is rebuilt.
    a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the updated BRP estimates.
    b. Then use the newly proposed model (or possibly models, in accord with guidance in "Appendix to the SAW Assessment TORs") 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.
    a. Provide numerical annual projections (3 years) and the statistical distribution (e.g., probability density function) of the catch at F_{MSY} or an F_{MSY} proxy (i.e. the overfishing limit, OFL) (see "Appendix to the SAW Assessment TORs"). 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, magnitude and 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. Identify reasonable projection parameters (recruitment, weight-at-age, retrospective adjustments, etc.) to use when setting specifications.

c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC. The choice takes scientific uncertainty into account (see "Appendix to the SAW Assessment TORs").

8. Evaluate the validity of the current stock definition, taking into account what is known about migration, and make a recommendation about whether there is a need to modify the current stock definition for future stock assessments.

9. Review, evaluate and report on the status of research recommendations from the last peer reviewed benchmark stock assessment. Identify new research recommendations.

Appendix to the SAW Assessment TORs: **Clarification of Terms used in the SAW/SARC Terms of Reference**

Guidance to SAW WG about "Number of Models to include in the Assessment Report": In general, for any TOR in which one or more models are explored by the WG, give a detailed presentation of the "best" model, including inputs, outputs, diagnostics of model adequacy, and sensitivity analyses that evaluate robustness of model results to the assumptions. In less detail, describe other models that were evaluated by the WG and explain their strengths, weaknesses and results in relation to the "best" model. If selection of a "best" model is not possible, present alternative models in detail, and summarize the relative utility each model, including a comparison of results. It should be highlighted whether any models represent a minority opinion.

On "Acceptable Biological Catch" (DOC Nat. Stand. Guidel. Fed. Reg., v. 74, no. 11, 1-16-2009):

Acceptable biological catch (ABC) is a level of a stock or stock complex's annual catch that accounts for the scientific uncertainty in the estimate of Overfishing Limit (OFL) and any other scientific uncertainty…" *(p. 3208) [In other words, OFL ≥ ABC.]*

ABC for overfished stocks. For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect the annual catch that is consistent with the schedule of fishing mortality rates in the rebuilding plan. *(p. 3209)*

NMFS expects that in most cases ABC will be reduced from OFL to reduce the probability that overfishing might occur in a year. (p. 3180)

ABC refers to a level of ''catch'' that is ''acceptable'' given the ''biological'' characteristics of the stock or stock complex. As such, Optimal Yield (OY) does not equate with ABC. The specification of OY is required to consider a variety of factors, including social and economic

factors, and the protection of marine ecosystems, which are not part of the ABC concept. (p. 3189)

On "Vulnerability" (DOC Natl. Stand. Guidelines. Fed. Reg., v. 74, no. 11, 1-16-2009):

"Vulnerability. A stock's vulnerability is a combination of its productivity, which depends upon its life history characteristics, and its susceptibility to the fishery. Productivity refers to the capacity of the stock to produce Maximum Sustainable Yield (MSY) and to recover if the population is depleted, and susceptibility is the potential for the stock to be impacted by the fishery, which includes direct captures, as well as indirect impacts to the fishery (e.g., loss of habitat quality)." (p. 3205)

Participation among members of a Stock Assessment Working Group:

Anyone participating in SAW meetings that will be running or presenting results from an assessment model is expected to supply the source code, a compiled executable, an input file with the proposed configuration, and a detailed model description in advance of the model meeting. Source code for NOAA Toolbox programs is available on request. These measures allow transparency and a fair evaluation of differences that emerge between models.

EXECUTIVE SUMMARY

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

USA commercial landings of witch flounder generally increased from the early 1960s, peaking in 1984 at 6,658 mt (14.68 million pounds). Subsequently, landings declined and fluctuated between 2,000 and 3,000 mt (6.6 million pounds) until 2003, when landings further declined. Landings in 2015 were 492 mt (0.11 million pounds), the lowest in the time series. The majority of USA commercial landings come from the western Gulf of Maine and central basin and from the deeper waters north of the South Channel. Witch flounder landings occur throughout the year, with a slight increase during March-July months when witch flounder form dense pre-spawning aggregations. The majority of the landings are taken by otter trawl gear. Trends in landings by market category reveal a sharp decline in LARGE market category fish in the late 1980s.

Total discards from six fisheries ranged between 93 mt (2015) and 774 mt (1991) with a time series mean of 301 mt; coefficients of variation (CVs) ranged between 7% and 40%. The discards estimated in this assessment differ slightly from those estimated in 2015 Operational Assessment that include only three fisheries and did not include the entire stock area. Over the time series, discards average 13% of the total catch. Discard mortality is assumed to be 100%.

There is no recreational fishery for witch flounder.

Annual sampling from 1982 onward ranged between 11 and 133 mt per 100 lengths, exceeding the informal sampling threshold criterion of 200 mt per 100 lengths. However, during the 1990's, sampling was insufficient in some quarters and market categories and it was necessary to pool some quarters for some market categories. Sampling improved by quarter and market category in the late 1990's in which an average 34 mt per 100 lengths was obtained. Commercial age data were available for 1982 to 2015; landed witch flounder ranged in age between 3 and 33 years. The majority of landed fish were ages 6 to 9. The CVs for ages 6 through 9 are generally less than 15%. The age composition reveals a truncated age structure since the mid-1980s, a short-lived expansion in the early 2000s was not sustained.

Total commercial landings in 2015 were 493 mt, commercial discards were estimated to be 93 mt, for a total catch of 585 mt.

Landings per unit effort is described under TOR 2.

TOR 2. Present available federal, state, and other survey data, indices of relative or absolute abundance, recruitment, etc. Characterize the uncertainty and any bias in these sources of data and compare survey coverage to locations of fishery catches. Select the surveys and indices for use in the assessment.

The Northeast Fisheries Science Center (NEFSC) has conducted annual research vessel stratified random bottom trawl surveys during autumn since 1963 and during spring since 1968. The NEFSC survey samples offshore waters between 27 m to 366 m from Cape Hatteras NC to Canadian border. Witch flounder are generally distributed throughout the Gulf of Maine, along the northern edge and southern flank of Georges Bank, and southward along the continental shelf as far south as Cape Hatteras, NC. While NEFSC spring survey indices tend to be more variable

due to pre-spawning aggregations of witch flounder, spring and autumn indices generally display similar trends. NEFSC survey indices generally declined from the early 1960s to record low levels in the late 1980s and early 1990s. There was an increasing trend in the late 1990s to early 2000s followed by a declining trend. In 2015, the survey indices were below their time series means. Age-specific relative abundance from NEFSC spring and autumn 1980-2015 and spring 2016 surveys are derived using annual, seasonal age length keys. A truncation of the age structure occurred in the late-1980s; a slight expansion in age structure occurred in early 2000s but was not sustained.

In 2009, *FS/V Henry B. Bigelow* replaced the *R/V Albatross IV* as the principle vessel conducting the bottom trawl survey. There are no significant vessel, door, or net conversion factors for witch flounder in the NEFSC bottom trawl survey between 1963 and 2008; however, there are significant vessel conversion factors between the *FS/V Bigelow* and the *R/V Albatross IV*. The vessel conversion factor for numbers and weight (spring and autumn) is 3.2572 and has been applied to the 2009 through 2016 NEFSC bottom trawl surveys.

The NEFSC survey strata set was evaluated and no additional strata were identified as contributing to the total catch or improving the precision of the estimates of mean weight per tow. Therefore, the existing strata set of 22-30, 36-40 was retained.

A field experiment was conducted to estimate the relative detectability of witch flounder in the net used in the NEFSC bottom trawl survey and a net with a chain sweep by using a twin net configuration. The goal was to estimate the sweep efficiency of the NEFSC survey trawl. The WG accepted the witch flounder catchability (q) estimates (0.056 for Albatross and 0.291 for Bigelow) from the sweep study and recommended their use in the stock assessment to convert the NEFSC survey relative abundance indices into swept area numbers.

The Commonwealth of Massachusetts Division of Marine Fisheries (MA DMF) began a spring and fall inshore trawl survey in 1978 which complements the NEFSC survey in coastal Massachusetts waters in depths less than 27 m. Witch flounder indices of abundance and biomass from this survey have been presented in previous stock assessments as corroborative information. The percentage of positive tows is low (< 50%) in the spring and fall survey series. Fall survey catch per tow indices varies over the time series with a stratified mean less than 1 fish interspersed with peaks of 2 or 3 fish per tow occurring. Given the sparse length frequency in these seasonal surveys, NEFSC age length keys were not applied. This survey has a spatial coverage confined to the inshore waters of Massachusetts and therefore used as corroborative information only (not included in model).

The Atlantic States Marine Fisheries Commission (ASMFC) has conducted an annual northern shrimp survey during August in the Gulf of Maine since 1983, with catch data for witch flounder available since 1984 onward. There is a high percentage of positive tows in the survey series. Witch flounder age structures are not collected on this survey; however, age-specific relative abundance indices were derived by applying annual NEFSC spring and fall (combined) age-length keys to the length frequency data from the ASMFC survey. Although this survey has limited spatial coverage, much of the juvenile range is covered. This survey appears to provide useful information on relative to trends in abundance, distribution, and recruitment of witch flounder in the Gulf of Maine and could be considered as tuning indices in models

Maine Department of Marine Resources and New Hampshire Fish and Game Department (MENH) have conducted spring and fall bottom trawl surveys along the New Hampshire and Maine coast since fall 2000. Similar to the ASMFC survey, the MENH survey is considered useful in providing a pre-recruit index rather than to characterize the population as whole given the MENH survey catches few witch flounder greater than 30 cm (approximately age 4). Witch

flounder age structures have been collected on this survey; however, ageing has not occurred. Age-specific relative abundance indices were derived by applying annual, season-specific NEFSC age-length keys to the length frequency of the MENH survey. Although this survey has limited spatial coverage, much of the juvenile range is covered. This survey appears to provide useful information on relative to trends in abundance, distribution and recruitment of witch flounder in the Gulf of Maine and could be considered as tuning indices in models.

The WG considered other surveys (NEFSC winter survey; Canadian bottom trawl survey; NEFSC's Cooperative Research Program longline survey; and the MA DMF Industry-Based cod survey) and agreed that the limitations associated with these surveys would prevent their use in models.

The NEFSC spring and fall surveys, MA DMF spring and fall surveys, and ASMFC summer survey exhibit similar trends in which indices are above their time series mean prior to the late 1980s, below the mean during the late 1980s to mid-1990s and remain below or near the mean in the late 1990's and 2000s onward. The MENH seasonal surveys, which have the shortest time series of all surveys considered here, appear to be more variable than the other surveys.

The WG evaluated the **Dealer Report**-based trawl gear landings per unit effort indices (1964-2015 Landings per Day Fished; LPUE), **Vessel Trip Report (VTR)** trawl gear fishery catch per unit effort indices (1994-2015 Catch per Day Fished; CPUE), the **Observer Program** trawl gear fishery catch per unit effort indices (1989-2015 Catch per Day Fished; CPUE), and the NEFSC Cooperative Research Partners **Study Fleet** trawl gear catch per unit effort indices (2007-2015 Catch per Day Fished; CPUE) for their utility as indices of abundance in the witch flounder benchmark stock assessment. For the Dealer data, the WG noted that the utility of the LPUE series as the basis for an index of abundance is limited in that a) it includes only landings and not the total catch including discard, so that the resulting landings rates could be biased low relative to the true abundance of fish, and b) the use of only positive trips that land witch flounder may bias the landings rate as well. For the VTR data, the WG noted that given the low discard rate reported, the total catch reported may be biased low relative to the true total catch. For the Observer data, the WG noted that there may be a bias in fishermen's behavior when an Observer is aboard the vessel that changes the total catch rate in an uncertain and possibly inconsistent manner. The WG also noted that for the Dealer, VTR, and Observer data in particular, the ratio of Days Fished per Trip has 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. During the respective time series there have been a number of spatial, temporal, and catch limit regulatory changes that could bias the commercial fishery catch rate indices relative to the true abundance of witch flounder. The information on these regulatory changes is not part of the commercial fisheries databases and must be developed independently and integrated within the standardization models, and has not been included here. Given the changing regulatory landscape, there likely have been a multitude of changes in fishermen's behavior and strategies over time, and those have not been accounted for here. The increasing sophistication of fishing technology (fish-finding electronics, positioning electronics, fishing gear) is likewise not easy to include in fishery dependent catch rate modeling, and has not been attempted here. The Observer data were further explored to help inform which Dealer LPUE series (10%, 25%, and 40% directed trips) would be the most appropriate to use in a model sensitivity run. Summaries of the Observer haul and trip level data for observed hauls for which witch flounder was reported as the target species indicated no strong justification to select one series over another. For consistency with previous assessments,

the most directed series, LPUE 40%, was selected. The WG agreed to include the commercial LPUE 40% series as a sensitivity run of the assessment model.

TOR 3. Investigate effects of environmental factors and climate change on recruitment, growth and natural mortality of witch flounder. If quantifiable relationships are identified, consider incorporating these into the stock assessment.

An examination of available NEFSC trawl survey data indicated that while there have been some "statistically significant" changes in mean temp and depth of juvenile and adult witch flounder distribution, the slopes of the linear change are not large and movement has been generally within the stock definition strata set. There is also evidence of increases in the mean temperature and depth of the habitat occupied by witch flounder, but a model of changes in "available witch flounder habitat" did not indicate a trend over the time series. Modeling revealed no evidence of temperature influencing recruitment.

TOR 4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3 if appropriate), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections. Compare F's and SSB's that were projected during the previous assessment to their realized values.

> ***SARC-62 Opinions****: The VPA, ASAP, and SCAA age-structured models applied to data for the witch flounder fishery were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice.*
>
> *Based on an empirical area swept method (that includes the results of the NEFSC survey efficiency experiment) conducted by the SAW and examined at the SARC, stock biomass has declined since 2002 and appears to be 16,181 mt Jan-1 surveyable biomass in 2016 and 14,563 mt exploitable biomass in 2016.*
>
> *Survey population biomass was converted to exploitable biomass using a factor of 0.90 based on examination of survey and fishery selectivity patterns from the base ASAP assessment.*
>
> *The relative exploitation rate needed to achieve the recent observed catch is approximately 0.05.*
>
> *The fishery landings and survey catch by age indicate truncation of age structure and a reduction in the number of old fish in the population.*
>
> *The time series of recruitment is not available from the empirical area swept method. All the surveys indicate the 2013 year class is relatively strong. However, this year class is not expected to fully recruit to the*

directed fishery until 2020 at age 7 and should start to appear in the large mesh otter trawl discards in 2017 at age 4. The absolute size of the 2013 year class is uncertain since the estimate is based on only two years of survey observations.

The VPA model used in the 2015 assessment was updated to incorporate re-estimated discards and an additional year of catch, survey, and maturity data. The updated VPA estimated average fishing mortality (F_{8-9}) to be 0.43 and spawning stock biomass to be 3,044 mt in 2015. The 2015 assessment estimated 2014 F_{8-9} to be 0.42 and SSB to be 3,129 mt; however, the updated VPA now estimates 2014 F to be 0.64 and SSB to be 2,480 mt. Including an additional year of data in the VPA model did not change the overall perception of stock. The updated VPA model exhibited a major retrospective pattern that was similar in direction and magnitude as the previous VPA models in which F is underestimated and SSB and recruitment are overestimated. The retrospectively adjusted $F_{8-9,rho}$ in 2015 is estimated to be 0.69 (above the F_{msy} proxy of 0.20). The retrospectively adjusted SSB_{rho} in 2015 is estimated to be 2,035 mt (16% of the SSB_{msy} proxy of 12,499 mt). **The updated VPA is not the base model for this assessment.**

A new statistical catch at age model (ASAP) was developed in this assessment to better account for catch and survey data uncertainty. The ASAP Run 9_5_v2 estimates fully selected fishing mortality (F_{full}) to be 0.16 and SSB to be 5,479 mt in 2015. Age 1 recruitment averaged 9.8 million fish over the 1982-2015 time series. The ASAP model exhibited a major retrospective pattern in which fishing mortality is underestimated and SSB and recruitment are overestimated. The retrospectively adjusted $F_{full,rho}$ is estimated to be 0.29 and SSB_{rho} to be 3,335 mt in 2015.

The WG considered numerous sensitivity runs of the two analytical models (ASAP and another statistical catch at age [SCAA] model, See Appendix B3) and considered several empirical approaches (minimum swept area biomass, replacement yield model, and an empirical approach) in case analytical modeling approaches did not provide defensible results. The WG considered the pros and cons of each approach for determining stock status and catch advice. The age structured models in the accepted final configurations provided calculated NEFSC survey q of approximately 4, exhibited major retrospective patterns requiring rho adjustments, and require very large increase in catch or natural mortality (M) to remove the retrospective errors. The WG noted that these data conflicts have been addressed in the previous accepted and current age structured models explicitly through a rho adjustment, without having to apply potentially implausible scalars of M or catch. **The WG recommends the ASAP Run 9_5_v2 as the preferred model in which to evaluate stock status and provide catch advice.**

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 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.

***SARC-62 Opinions**: The age-structured models applied to data for the witch flounder fishery from 1982-2015 were found to have major retrospective patterns that prevented their use for status evaluation and determination of*

catch advice. Therefore biological reference points are not available.

In 2015 Operational Assessment, the VPA model results were accepted as the basis for the biological reference points and stock status determination for witch flounder (NEFSC 2015). Reference points were calculated using the non-parametric yield and SSB per recruit/long-term projection approach adopted for the New England groundfish stocks (NEFSC 2008). 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 SSB_{msy} (spawning stock biomass at maximum sustainable yield), the cumulative density function was re-sampled from estimates of Age 3 between 1982-2013 to provide future recruitment estimates. Recruitment of witch flounder is not well determined by traditional stock recruitment relationships. Given this, an MSY proxy was used for reference points. $F_{40\%}$ is the proxy used for the overfishing threshold (F_{MSY}). This is consistent with the choice of proxy in the previous assessments (NEFSC 2012, NEFSC 2008). The biological reference points estimated in the 2015 assessment were F_{msy}=$F_{40\%}$=0.28, SSB_{msy}=9,473 mt, and MSY=1,957 mt.

In this assessment, the yield and SSB per recruit calculations (NFT 2013a) used the most recent five year (2011-2015) averages for mean weights, fishery partial recruitment pattern, and maturity ogive. For the estimation of MSY and SSB_{msy}, the cumulative density function was re-sampled from estimates of Age 3 (VPA) or Age 1 (ASAP) between 1982-2015 to provide future recruitment estimates (Table B66 for VPA Run A2 input and Table B67 for ASAP Run 9_5_v2 input). Proxy reference points based on VPA Run A2 and ASAP Run 9_5_v2 are given in Table B68. Stochastic projections at Fmsy=F40% (0.19) were used to determine new biomass-related reference points (proxies for both SSB_{msy} and MSY) based on F40% (Table B69).

Using Run VPA Run A2 and F40%=0.20, biological reference points are estimated to be 12,499 mt for SSB_{msy}, 6,250 mt for $SSB_{threshold}$, and 1,512 mt for MSY (Table B69).

Using ASAP Run 9_5_v2 and F40% = 0.19, biological reference points are estimated to be 12,747 mt for SSBmsy, 6,374 mt for $SSB_{threshold}$, and 1,998 mt for MSY (Table B69). **The 2016 WG recommends the ASAP Run 9_5_v2 model results as the basis for the new biological reference points and stock status determination for witch flounder.**

TOR 6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model (or possibly models, in accord with guidance in attached "Appendix to the SAW Assessment TORs") developed for this peer review. In both cases, evaluate whether the stock is rebuilt.
a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the updated BRP estimates.
b. Then use the newly proposed model (or possibly models, in accord with guidance in "Appendix to the SAW Assessment TORs") and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

> ***SARC-62 Opinions****: The status of the witch flounder stock is unknown with regards to biological reference points. The age-structured models applied to data for the witch flounder fishery from 1982-2015 were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice.*

Based on an empirical analysis (referred to as "empirical area swept method") conducted by the SAW and examined at the SARC, stock biomass has declined since 2002 and appears to be 16,181 mt Jan-1 surveyable biomass in 2016 and 14,563 mt exploitable biomass in 2016. The relative exploitation rate needed to achieve the recent observed catch is approximately 0.05. The SARC-62 did not fully evaluate the empirical approach during the peer review, and therefore expected additional evaluation of the method, calculations, and results to be made following the peer review.

The fishery landings and survey catch by age indicate truncation of age structure and a reduction in the number of old fish in the population.

a) The existing VPA model updated with new data indicates witch flounder stock was overfished and overfishing occurred in 2015. This determination was made on retrospectively adjusted $F_{full,rho}$ and SSB_{rho} in 2015. The retrospective adjustment was required but did not lead to a change in status. The biological reference points used were F_{MSY}=$F_{40\%}$=0.20, SSB_{msy}=12,499 mt, and MSY=1,512 mt. The 2015 $F_{8\text{-}9}$ is estimated to be 0.43 (210% of $F_{40\%}$) and the retrospectively adjusted 2015 $F_{8\text{-}9,rho}$ to be 0.69 (337% of $F_{40\%}$). The 2015 SSB is estimated to be 3,044 mt (24% of SSB_{msy}) and the retrospectively adjusted 2015 SSB_{rho} to be 2,035 mt (16% of SSB_{msy}).

b) The new ASAP model indicates witch flounder stock was overfished and overfishing occurred in 2015. This determination was made on retrospectively adjusted $F_{full,rho}$ and SSB_{rho} in 2015. The retrospective adjustment was required and lead to a change in status of overfishing. The biological reference points used were F_{MSY} proxy=$F_{40\%}$=0.19, SSB_{msy}=12,747 mt, and MSY=1,998 mt. The 2015 F_{full} is estimated to be 0.16 (83% of $F_{40\%}$) and the retrospectively adjusted 2015 $F_{full,rho}$ to be 0.29 (154% of $F_{40\%}$). The 2015 SSB is estimated to be 5,479 mt (43% of SSB_{msy}) and the retrospectively adjusted 2015 SSB_{rho} to be 3,335 mt (26% of SSB_{msy}).

TOR 7. Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (3 years) and the statistical distribution (e.g., probability density function) of the catch at FMSY or an FMSY proxy (i.e. the overfishing level, OFL) (see "Appendix to the SAW Assessment TORs"). 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, magnitude and 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. Identify reasonable projection parameters (recruitment, weight-at-age, retrospective adjustments, etc.) to use when setting specifications.

c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC. The choice takes scientific uncertainty into account (see "Appendix to the SAW Assessment TORs").

SARC-62 Opinions: *The empirical area swept method was used to provide an F_{MSY} proxy for 2017 based on a relative exploitation rate. The SARC-62 did not fully evaluate the empirical approach during the peer review, and therefore expected additional evaluation of the method, calculations, and results to be made following the peer review.*

Stochastic projections were made to provide forecasts of stock size and overfishing limit (OFL) catches in 2017-2019 consistent with the 2016 SAW 62 assessment biological reference points. The WG conducted one projection by assuming recent patterns in the fishery and the most recent maturity ogive. A major source of uncertainty is the retrospective pattern. The past projection was optimistic (outside the confidence bounds for the rho adjusted biomass). Subsequent projections will be conducted by the Groundfish Plan Development Team, when 2016 catch is determined.

The 2016 stock assessment indicates that the stock was below the biomass target and being fished above the fishing mortality threshold in 2015. Witch flounder is slow growing and late maturing and is vulnerable without stringent management regulations in place.

TOR 8. Evaluate the validity of the current stock definition, taking into account what is known about migration, and make a recommendation about whether there is a need to modify the current stock definition for future stock assessments.

Witch flounder are assessed and managed as a unit stock within USA waters; this includes the Gulf of Maine and Georges Bank region as well as areas to the south as far as Cape Hatteras, North Carolina. No tagging studies have been conducted on witch flounder in Gulf of Maine-Georges Bank region. No studies on stock structure have been conducted in the Gulf of Maine-Georges Bank region. A study found biological and yield characteristics of deep water (depth > 366 m) witch flounder south and west of Georges Bank to be slower in growth and the otolith structure was different than the Gulf of Maine-Georges Bank witch flounder suggesting a separate population. Studies of witch flounder on the Grand Banks indicate small independent subpopulations in that region.

Until tagging and/or stock structure analyses are undertaken that reveal subpopulations, the current stock definition should be retained for future stock assessments. Possible future research recommendations include: ageing larval fish to determine transport time; tagging and/or stock structure analyses.

TOR 9. Review, evaluate and report on the status of research recommendations from the last peer reviewed benchmark stock assessment. Identify new research recommendations.

SARC-62 Opinions: *The SARC recommends that witch flounder be put on a research track to address survey catchability and retrospective problems. Such an examination should include other stocks in the region exhibiting major retrospective patterns and survey catchability issues.*

Of the three identified research recommendations made since the last peer reviewed benchmark witch flounder stock assessment (2008 GARM), progress has been made on two recommendations (splitting the survey tuning series and exploring the dome selectivity in the catch and survey). No progress was made on examining the trends in mean weights at age and the possible underlying factors.

The WG developed nine new research recommendations.

WORKING GROUP PROCESS

The Stock Assessment Workshop (SAW) Witch flounder Working Group (WG) met during 13-16 September (Data Meeting) and 4-7 October 2016 (Models Meeting) at the Northeast Fisheries Science Center (NEFSC) to develop the benchmark stock assessment of witch flounder through 2015. The following people were present (in person or via webinar) for all or part of working group discussion.

Jessica Blaylock	NEFSC
Elizabeth Brooks	NEFSC (WG member)
Russell Brown	NEFSC
Doug Butterworth	Univ. of Cape Town (WG member)
Steve Cadrin	SMAST, NEFMC SSC
Richard Canastra	
Jamie Cournane	NEFMC staff (WG member)
Greg DeCelles	MA DMF
Libby Etrie	NEFMC
Vito Giacalone	Northeast Seafood Coalition
Mary Hudson	GMRI
Kevin Friedland	NEFSC
Chris Legault	NEFSC, NEFMC SSC
Brian Linton	NEFSC
John Manderson	NEFSC
Katey Marancik	NEFSC
Michael Martin	NEFSC
Dave McElroy	NEFSC
Tim Miller	NEFSC
Tom Nies	NEFMC staff
Paul Nitschke	NEFSC
Loretta O'Brien	NEFSC
Jackie Odell	Northeast Seafood Coalition
Mike Palmer	NEFSC (WG member)
Charles Perretti	NEFSC
Rebecca Rademeyer	
Maggie Raymond	Associated Fisheries of Maine
David Richardson	NEFSC
Chris Roebuck	F/V Karen Elizabeth
Katherine Sosebee	NEFSC
Mike Simpkins	NEFSC
Mark Terceiro	NEFSC (WG member and chair)
Harvey Walsh	NEFSC (WG member)
Jim Weinberg	NEFSC
Susan Wigley	NEFSC (WG member, assessment lead)
Brooke Wright	SMAST

INTRODUCTION

This assessment of witch flounder in the Gulf of Maine-Georges Bank region and southward presents a benchmark analytical assessment for the 1982-2015 period, estimates 2015 fishing mortality and spawning stock biomass for stock status, updates biological reference points, and provides short-term projections of median catch corresponding to the Overfishing Limit (OFL) for 2017-2019..

Biology

Witch flounder (*Glyptocephalus cynoglossus*) or grey sole is a deep water boreal flatfish occurring on both sides of the North Atlantic. In the Northwest Atlantic, witch flounder are distributed from Labrador to Georges Bank and in the continental slope waters southward to Cape Hatteras, North Carolina. In US waters, the species is predominately in the Gulf of Maine-Georges Bank region (defined by statistical areas [SA] 511-515, 521-522, 525-526, and 561-562; Figure B1), and, in the absence of any stock structure information, is assumed to comprise a single stock unit defined by SA 511-515, 521-22, 525-526, 533-539, 541-543, 561-562, 611-639.

Witch flounder do not undertake seasonal migrations (Bigelow and Schroder 1953; Burnett et al. 1992); however, witch flounder appear to form pre-spawning aggregations in the spring in the western and northern portions of the Gulf of Maine. Spawning is protracted from April to November, with peak during May – August (Bigelow and Schroeder 1953; Colton et al. 1979; Burnett et al. 1992). Using NEFSC bottom trawl survey data collected between 1963 and 1981, Burnett et al. (1992) evaluated witch flounder distribution relative to depth and temperature. Burnett et al. (1992) found that the distributions of juvenile and adult witch flounder were not significantly different for any season with respect to bottom temperature. However, distribution by depth differed for juveniles and adults for all seasons. Burnett et al. (1992) found that adults maintained an annual mean depth of 147 m (fathoms) while juveniles were found at shallower depths in winter and spring and greater depths in summer and fall and this seasonal-difference was attributed to differences in prey distribution associated with differences in diet. Burnett et al. (1992) did note that juveniles do not appear to be adequately sampled by the NEFSC survey gear.

There are no tagging data for witch flounder.

Age and Growth

Age and growth studies (including age validation) by Burnett et al. (1992) indicate that witch flounder is a long-lived, slow-growing, late-maturing species. Witch flounder exhibit sexual dimorphism, with females living longer and growing larger than males. Burnett et al. (1992) derived growth parameters from 1,120 fish that ranged age from 0 (5.3 cm) to 24 (56.8 – 62.1 cm) for males and females using a von Bertalanffy growth model and length-at-age data collected from the NEFSC bottom trawl surveys during 1980 – 1984. Estimated parameters were: for males (n = 626), L_{inf} = 58.04 and k = 0.15; for females (n= 571), L_{inf} = 61.99 cm and k = 0.15.

The largest and oldest fish sampled by the NEFSC surveys were a 73 cm age 24 fish sampled in the 1985 spring survey and a 64 cm age 30 fish sampled in the 1985 fall survey.

In the current assessment, a von Bertalanffy growth model and the 1982 – spring 2016 NEFSC trawl survey length-at-age data were used to derive growth parameters by sex (in which small fish of undetermined sex were grouped with both males and females) and combined sexes. The survey time series data provided parameters for males (n = 5,744) of L_{inf} = 60.7 cm, k = 0.12, with maximum length of 65 cm and age of 25; parameters for females (n = 6,070) of L_{inf} = 64.8 cm, k = 0.12, with maximum length of 73 cm and age of 30; and parameters for sexes combined (n =12,946, including small fish of undetermined sex) of L_{inf} = 59.2 cm and k = 0.15.

The growth curves are generally similar for sexes through about 40 cm and age 7, where the curves begin to diverge due to dimorphic growth (Figure B2). In the most recent stock assessments, ages are grouped together for ages 11 and older (age 11+ "plus group").

Age and growth information is also available from NEFSC commercial port sampling from 1982 – 2015. In the commercial landings, a 70 cm age 14 was sampled in 1986 and 61cm age 33 was sampled in 2005. Commercial length-at-age data are not collected by sex. The 1982-2015 commercial data provided parameters for sexes combined (n=29,865) of L_{inf} = 63.7 cm and k = 0.12. Fish taken from commercial landings are generally the faster growing individuals in the population than those sampled in the NEFSC surveys (Figure B2).

Tests to evaluate ageing precision are conducted by the NEFSC Fishery Biology Program on a regular basis (survey cruise or commercial quarter). There was a change in age reader following the GARM 2008 witch flounder assessment (NEFSC 2008). An extensive age reader comparison (N=251) was performed, resulting in 89% agreement between readers, with a low coefficient of variation (CV) and no bias. Precision tests for the current age reader are quite similar to those of the previous age reader, ranging between 85% and 94% agreement for survey samples, and 76% to 97% from commercial samples. Test results and statistical methods used are given at: http://www.nefsc.noaa.gov/fbp/QA-QC/index.html .

Length-Weight Relationship

Lux (1969) derived length-weight parameters from 188 witch flounder taken from 55 fathoms of water south of Nantucket Shoals in March 1962 by commercial trawlers and research vessels. Lux noted that the length-weight relationship was similar to that of Powles (1967) for witch flounder caught in February of southeast Nova Scotia.

Wilk et al. (1978) derived length-weight parameters, by sex, from 204 witch flounder between sizes of 12 and 55 cm taken from the New York Bight area during 1974 – 1975 from 700 randomly selected otter trawl stations.

Burnett et al. (1992) derived length-weight parameters from 1,652 witch flounder collected between March 1980 and June 1983 during NEFSC bottom trawl survey in the Gulf of Maine and Georges Bank region as well as two commercial sea sampling trips on Stellwagen Bank and in South Channel in spring of 1983. Burnett et al. (1992) reported the length-weight relationships derived in his study closely compared with those of Lux (1969) and Powles (1967).

Wigley et al. (2003b) updated the length-weight parameters used in audits of the NEFSC trawl survey data, using individual length and weight information from 3,778 fish for 1992-1999. There was no significant difference between females and male, however there was significant difference between winter/summer and autumn.

Sherman (ME DMR, pers. comm, July 2016) derived length-weight parameters using Maine-New Hampshire (MENH) inshore trawl survey data from spring 2003 and fall 2005 through 2015.

In the current assessment, individual length and weight information from 8,557 fish

(3,572 males, 4,985 females) sampled during 1992-2016 NEFSC bottom trawl surveys were used to estimate length-weight parameters for comparison with the earlier studies to judge whether changing from the Burnett et al. (1992) parameters would be justified.

A comparison among these studies indicates very little difference in the estimated length-weight relationships from Lux (1969), Wilk et al. (1978), Burnett et al. (1992), Wigley et al. (2003b), and the current examination of the NEFSC trawl survey data. The curves are almost identical through length 42 cm, below which 72% of the fishery catch has occurred, on average, since 1982 (Figures B3 and B4). A 42 cm fish represents roughly an age 7 fish.

WG recommendation: Based on the consistency of these L-W relationships through the majority of the length range of the fishery catch, the Burnett et al. (1992) length-weight parameters were retained for this assessment.

Relative Condition Factor

Individual fish weight collection for witch flounder began on NEFSC surveys in fall 1992. The NEFSC spring and autumn trawl survey sample data were examined for trends in relative condition factor by season using the ratio of observed weight to predicted weight. There are no long-term trends in relative condition factor by season (Figure B5).

Maturity

Witch flounder maturity observations have been collected in the NEFSC research bottom trawl survey since 1977. Macroscopic methods are used to determine maturity stage (see O'Brien et al. 1993 for criteria and maturity stages). The NEFSC spring surveys were used for maturity analyses as these surveys occur closest to and prior to spawning (Halliday 1978). Annually, the number of observations range between 27 and 402 over the 1982 to 2016 time period (Figure B6). Between 1987 and 1993, less than 100 fish were sampled during the spring surveys due to low witch flounder abundance.

Using a method developed and applied for Georges Bank cod (L. O'Brien, NEFSC, pers. comm.), a logistic regression and a 5-year moving window of pooled maturity data from the NEFSC spring survey is used to estimate median age (A_{50}) and length (L_{50}) at maturity. For example, the proportion mature in 1982 was estimated using NEFSC spring maturity data from 1980, 1981, 1982, 1983, and 1984. The 2015 maturity ogive was assumed to be equal to the 2014 ogives, the more recent annual maturity ogive with a full five years of data. In addition to annual maturity ogives, a single ogive using maturity data form the entire time series (1980 to 2016) was also calculated.

For females, median A_{50} has ranged between ages 4.2 and 6.3 years (see table below) and L50 between 29 cm and 38 cm (Table B1). The time series median age is 5.3 years for females and 3.7 years for males and median length is 33.8 cm for females and 27.1 cm for males (Table B2). The NEFSC survey maturity-at-age has remained generally stable over time; however, most recent annual estimates of median A_{50} and L_{50} are slightly below the long term mean (Figure B7). The 2014 median maturity for female witch flounder (using data from 2012 through 2016) is 5.0 years and 32.7 cm (Table B1; Figure B7).

Witch flounder maturity observations have been collected in the Massachusetts Division of Marine Fisheries (MA DMF) during the late 1980s and early 1990s; however, seasonal sample sizes are too sparse to estimate median maturity (Figure B6).

A total of 3, 448 samples (1,588 female and 1,859 male) have been collected in the Maine-New Hampshire inshore survey during spring 2001-2008 and fall 2005-2015 surveys. S. Sherman (ME DMR, pers. comm. July 2016) estimated L_{50} to be 32 cm for females and 23 cm for males (Figures B8 and B9). These estimates are slightly lower than NEFSC estimates.

WG recommendation: *In keeping with the approach from the previous two benchmark assessments (SARC 29 and GARM 2008), annual maturity ogives based on a 5-year moving window of NEFSC 1980- 2016 spring survey data are used with the fishery catch at age to compute SSB in the assessment model. The 5-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.*

Predators and Prey

The NEFSC trawl survey foods habits 1973-2015 database was investigated to identify the most frequent predators of witch flounder. Witch flounder was identified to species as a prey item in 81 predator stomachs of 15 fish species (B. Smith, NEFSC, pers. comm. August 2016). White hake was the predator in 28 cases (35%), followed by goosefish (13 cases; 16%), spiny dogfish (11 cases; 14%), cod (5 cases; 6%) and thorny skate (5 cases; 65). The remaining predators (10 cases; each 4% or less) included Atlantic halibut, red hake, pollock, longhorn sculpin, silver hake, smooth skate, sea raven, barndoor skate, winter skate, and summer flounder. The data are insufficient to calculate total absolute predator consumption of witch flounder.

Witch flounder diet is mainly polychaetes, accounting for more than 70% of the diet (Maurer and Bowman, 1975). The remaining components of the diet include echinoderms (mainly sea cucumbers), crustaceans (mainly amphipods), and mollusks (mainly squid). Bowman and Michaels (1984) and Bowman et al. (2000) have documented similar findings. See Link and Almeida (2000) for details on the food habits sampling program.

Instantaneous natural mortality rate (M)

The instantaneous natural mortality rate (M) for witch flounder has been assumed to be 0.15 in all previous stock assessments based upon an analysis by Burnett (MS 1987) in which estimates of instantaneous total mortality (Z; calculated from catch curves derived from NEFSC spring survey data collected during 1978 -1984, a time period before closed area and effort constraints) were regressed against commercial effort (identified as 'directed' towards witch flounder) in the previous year (calculated using landings per unit effort data of ton class 3 vessels). The slope, q, is the directed catchability coefficient and the intercept is an estimate of M (Gulland, 1983). The regression of annual Z estimates from 1978 – 1984 against commercial effort resulted in M = 0.16. This result was similar to M= 0.15 used by Halliday (1973) for Scotian Shelf witch flounder.

Alternative methods (age constant longevity based and age constant growth/life history based) for estimating M were conducted via an Excel spreadsheet developed by L. Lee and K. Drew (ASMFC, pers. comm. 2016). Longevity based estimators of M are sensitive to critical assumptions which include the value of p, or the small proportion of the population surviving to a given maximum age (t_{max}), and the maximum observed age under no exploitation conditions. Using a maximum age of 33 years, and p = 0.05 and p = 0.015 as the proportion of individuals that survive to t_{max}, age constant longevity based estimates of M range from 0.10 to 0.20 with an

average of 0.16 (Table B2a). Using L_{inf} = 619.9 mm, K= 0.1482, and mean water temperature of 7 degrees C, the age constant growth/life history based estimates of M range from 0.22 to 0.32 with an average of 0.25 (Table B2a). An overall average of M from all alternative methods was 0.20.

WG recommendation: Given the maximum size and age of 73 cm and 33 years, the range of M (0.13 – 0.20) estimated by the empirical methods (based on maximum age) as well methods based on growth/life history, the WG decided there was no compelling reason to change from the previous assumption of M and adopted a value of M=0.15 for all ages and years in the SAW 62 models.

Fishery Management

Witch flounder has been managed under the New England Fishery Management Council's Multi-species Fisheries Management plan since 1987. A brief summary of groundfish management regulations affecting witch flounder is presented in Table B3. Significant changes in regulations include increased minimum size in 1983 and 1987 followed by a decreased minimum size in 2013; increases in mesh size in 1982, 1983, 1994, 1999 and changes to mesh configurations in 1999 and 2002; effort reductions in 1996 and 2002; implementation of closed areas in 1994 and 1998; and implementation of annual catch limits and catch shares in 2010. The western Gulf of Maine area closure, Cashes Ledge area closure, the seasonal rolling closures, and the whiting small mesh exemption area all occur in the Gulf of Maine and overlap the witch flounder distribution (Figures B10-B12). A detailed description of groundfish regulations between 2001 and August 2015 are given in Table B4. The Northeast Multispecies regulations are available online at
https://www.greateratlantic.fisheries.noaa.gov/sustainable/species/multispecies/index.html
NE Multispecies Federal Register documents from 1994 to 2016 are available at:
http://www.greateratlantic.fisheries.noaa.gov/sustainable/species/multispecies/multifr/index.html

Management regulations for the northern shrimp fishery also impact witch flounder (Table B5): significant changes in the northern shrimp fishery include a monthly 10% by-catch limit which restricted the possession of groundfish to 10% by weight of shrimp in the mid-1980's to early 1990s; the implementation of the Nordmore grate to exclude groundfish in 1992; and fishery closures in 1978, 2014 - 2016.

Previous Stock Assessments

Burnett and Clark (1983) provided a preliminary assessment of witch flounder in the Gulf of Maine-Georges Bank region based on analysis of commercial landings and effort and NEFSC and MA DMF research vessel survey data. They reported that witch flounder was an intended component of the mixed trawl fishery and since the 1960s, USA landings had ranged between 1,000 and 6,000 mt and averaged 3,000 mt; total effort had increased and landings of small fish also appeared to be increasing. Survey indices suggested declines in abundance and biomass in the early 1980s with a consistent declining trend following peak landings in the early 1970s. Declines in abundance and biomass were expected in the immediate future if current levels of harvest rates were maintained.

In the early 1980's, Burnett was working on a master's thesis on the population biology of the witch flounder in the Gulf of Maine-Georges Bank region (Burnett MS, 1987; Burnett et

al. 1992) and was in the midst of conducting the first work on witch flounder in the Gulf of Maine-Georges Bank region. Since 1983, stock assessments for witch flounder have been conducted periodically as part of the Northeast Regional Stock Assessment Workshop.

In 1985, at 1st SAW (NEFC 1985) a summary of important assessment issues (terms of reference) were compiled for witch flounder that included: "*Problems of mixed-species effort confounds CPUE analyses for this species; discards of young witch should be examined more fully in the redfish and northern shrimp fisheries; estimates of Z are lacking; valid recruitment estimators have not been developed; ageing past c.a. 9 years is unreliable with scales, but ages 3-9 account for about 90% of landings. Ageing techniques need to be finalized and validated; evaluation of growth and mortality rates (natural, fishing, total) needs to be completed; studies of distribution by size and age may help to elucidate the recruitment mechanisms for this species; recent shifts of large vessel effort to witch may be due to a number of factors including displacement from traditional grounds, and decreases in abundance of other species."(NEFC 1985)*

In 1986 at 2nd SAW (NEFC 1986), witch flounder landings, catch and effort, and research vessel indices summarized by Burnett and Clark (1983) were updated through 1985. The witch flounder stock abundance "*appeared to be declining, based on declining indices of commercial catch-per unit effort and recent general downward trends in research survey abundance indices. Current historically high landing levels do not appear sustainable*" (NEFC 1986). It was noted that preliminary estimates of Z have been developed, ageing techniques using otoliths have been finalized and validated as far as possible, growth rates had been derived, and distribution of ichythoplankton, juveniles and adults has been completed as part of Burnett's thesis.

In 1994, the first virtual population analysis (VPA) was conducted by Wigley and Mayo (1996) and peer reviewed at the 18th SAW (NEFSC 1994). The 1994 assessment included commercial landings and discards at age data through 1993 and age-specific NEFSC spring and autumn abundance indices and age-specific landings per unit effort (LPUE) indices used for calibration. The stock was overexploited and at a low biomass level. Fishing mortality was estimated to be 0.45, and spawning stock biomass (SSB) had fallen to record-low levels in 1993, and the age-structure had become severely truncated.

In 1995 at 21st SAW (NEFSC 1996a 1996b), the northern demersal complex (25 stocks in the Gulf of Maine, Georges Bank and Southern New England region, including witch flounder) were examined using NEFSC and MA DMF research vessel bottom trawl survey biomass trends by species and stock and in aggregate for four species groups. Additional analyses were developed to examine habitat preference, spatial variability, concentration effects, and relationship between survey indices and VPA estimates of mature biomass. Of the 25 stocks examined, 18 (72%) have exhibited significant declines in biomass over the last 10-15 years. The biomass of 13 of these stocks is at or near record-low levels; the biomass of five other stocks remains well below historic levels.

In 1999 at 29th SAW (NEFSC 1999) an analytical assessment (calibrated VPA) of commercial catch (landings plus discards) at age data through 1998 was conducted. Additionally, an exploratory Stock Synthesis analysis was conducted and generally confirmed the VPA results (Wigley et al. 1999). A retrospective analysis was conducted and results indicated that: F was overestimated during 1991-1995, however, average F appeared to be underestimated in 1996-1997 (later described as a "flip-pattern"); estimates of SSB were overestimated in 1994 -1997, yet underestimated in 1991-1993 ("flip-pattern"); and recruitment was consistently estimated with the notable exception of two year classes (1992 and 1993) that were considerably overestimated. Yield and SSB per recruit analyses were updated with an assumed M = 0.15. Revised biological reference points (BRPs) were estimated: F_{msy} = 0.106, B_{msy} 25,000 mt, and MSY = 2,684 mt. Witch flounder was found to be near target biomass (above the overfished

threshold and near B_{msy}) and fishing mortality was projected to decline (slightly lower than the overfishing threshold) in 1999 based on part-year catch statistics.

In 2002, the Groundfish Assessment Review Meeting (GARM I ; NEFSC 2002) was held in which 20 groundfish stock assessments were reviewed, including witch flounder. An analytical assessment (calibrated VPA) of commercial catch (landings plus discards) at age data through 2001 was conducted using the same formulation as the 1999 stock assessment. The retrospective analysis indicated that average fishing mortality (F) was overestimated in the early to mid-1990's and underestimated in the late 1990s, but the 2000 F estimate was initially overestimated; SSB was consistently overestimated since 1994; and a pattern of relatively consistent estimates of the number of age 3 recruits, with the notable exception of the 1992, 1993 and 1996 year classes, which were overestimated. Based on yield and SSB per recruit analyses and the arithmetic mean of the VPA age 3 recruitment (NEFSC 2002), BPRs were estimated to be SSB_{msy} = 19,900 mt; $F_{msy} = F_{40\%}$ = 0.164, and MSY = 2,990 mt. In 2001, spawning stock biomass was slightly above ½ SSB_{msy} (9,950 mt), the overfished threshold, and fishing mortality (F = 0.45) was three times higher than F_{msy}, the overfishing threshold; therefore, witch flounder was not overfished but overfishing was occurring in 2001.

In 2003 at 37th SAW (NEFSC 2003a NEFSC 2003b; Wigley et al. 2003a), an analytical assessment (calibrated VPA) of commercial catch (landings plus discards) at age data was conducted through 2002. An alternative assessment using a statistical catch at age (SCAA) model was also evaluated. Despite differences in model configurations and estimation approach, the SCAA generally confirmed point estimates and trends in the VPA results. Biological reference points were re-estimated as in the NEFSC 2002 work. The yield and SSB per recruit analyses indicate $F_{40\%}$ = 0.23, MSY = 4,375 mt, and SSB_{msy} = 25,240 mt with an assumed M = 0.15. Fully recruited fishing mortality in 2002 was 0.41 (exploitation rate = 31%), nearly double F_{MSY} = 0.23, and SSB was estimated to be 18,300 mt in 2002, 72% of SSB_{msy} (25,200 mt). The witch flounder stock was not overfished, but overfishing was occurring in 2002.

In 2005, the GARM II (NEFSC 2005) was held in which 19 groundfish stocks were assessed and reviewed, including witch flounder. An analytical assessment (calibrated VPA) of commercial catch (landings plus discards) at age data through 2004 was conducted. VPA formulation was the same as the 2003 assessment. Similar to the 2003 stock assessment, the retrospective analysis indicated that: average F was underestimated in the late 1990s and early 2000s; SSB was consistently overestimated; and a pattern of relatively consistent estimates of the number of age 3 recruits, with the notable exception of the 1992, 1993 and 1996 year classes, which were considerably overestimated. Biological reference points were updated based on yield and SSB per recruit analyses and the arithmetic mean of the VPA age 3 recruitment NEFSC 2005), the biological reference points are: SSB_{msy} = 25,248 mt, $F_{msy} = F_{40\%}$ = 0.23, and MSY = 4,375 mt. Witch flounder was not overfished and overfishing was not occurring in 2004.

In 2008, GARM III (NEFSC 2008), consisting of a series of meetings, was held during November 2007-August 2008 in which 19 stocks were reviewed, including witch flounder. An analytical assessment (calibrated VPA) of commercial catch (landings plus discards) at age data through 2007was conducted. VPA analyses were performed for a BASE case and a SPLIT case, where the survey time series were split between 1994 and 1995. This time split corresponded to changes in the commercial reporting methods as well as other regulatory management changes. NEFSC spring and autumn relative abundance indices at age were transformed into swept area absolute abundance indices and used as tuning indices to explore changes in survey catchabilities (q) between the BASE RUN and the SPLIT RUN. In the BASE RUN, the swept area survey q's ranged between 0.02 and 0.21. In the SPLIT RUN, the 1982-1994 series q's ranged between 0.01

and 0.24 and the 1995-2007 q's ranged between 0.05 and 0.30. The magnitude and pattern of increasing survey catchabilities at age for younger fish and a general level pattern at older ages in the BASE and SPLIT runs appear reasonable. The causes of the increased q's between the 1982-1994 and 1995-2007 series in the SPLIT RUN remain unknown. Both VPA formulations have retrospective patterns: the BASE RUN has a consistent pattern while the SPLIT RUN exhibits a 'flip' (change in direction) pattern. The combination of: (1) the contraction of the age structure observed in the survey indices at age and the commercial catch at age; (2) the low NEFSC survey abundance and biomass indices in recent years; and (3) the magnitude of the 2004 year class at age 3 relative to the age 3 abundance indices over the entire time series, indicates a strong 2004 cohort but not exceptional year class, all seem to suggest that the VPA SPLIT RUN more accurately characterizes the witch flounder population. Additionally, the Mohn rho statistics of the VPA SPLIT RUN indicate that the respective pattern is less severe than the VPA BASE RUN. The VPA SPLIT RUN is selected as the final run to use for biological reference point calculations and for stock status determination. The retrospective analysis of the VPA SPLIT RUN indicates a pattern of overestimation of average F prior to 2003 and then underestimation for average F from 2003 onward. A similar "flip" pattern is also evident for SSB, underestimated prior to 2001 and then overestimated from 2001 onward. The retrospective analysis for Age 3 recruits indicates an overestimation prior to 2001 and then an underestimation from 2002 onward. The SPLIT RUN Mohn rho statistics for F, SSB, and Age 3 was -0.02, 0.43 and -0.13, respectively. Biological reference points were estimated via a yield and SSB per recruit analysis using 5-year (2003-2007) averages for partial recruitment, stock weights, catch weights and maturity (2004-2008). Based on yield and SSB per recruit analyses, a proxy of F_{msy} is $F_{40\%MSP}$ = 0.20 for SPLIT RUN. Mean Age 3 recruitment was not used. Long-term (100 year) stochastic projections (AGEPRO v3.1.3) were performed to estimate spawning stock biomass and MSY under equilibrium conditions. The same partial recruitment vectors, mean weights at age, and maturity vectors used in the yield and SSB per recruit analysis were also used in the projections. A constant F scenario was used ($F = F_{msy} = 0.20$). Estimates of Age 3 recruitment used in the projections were derived by re-sampling the cumulative density function based on the empirical observations during 1982 to 2008 (1979 to 2005 year classes) from the SPLIT RUN. The proportions of F and M which occurs before spawning equals 0.1667 (March 1); M equals 0.15. Biological references points for the SPLIT RUN were estimated to be: SSB_{msy} = 11,447 mt; MSY = 2,352 mt. Based on the VPA SPLIT run, the 2007 SSB = 3,434 mt, 30% below SSBMSY (11,447 mt) and 2007 fishing mortality was 0.29, 45% above F_{msy} (F=0.20); therefore, witch flounder was overfished and overfishing occurred in 2007.

The Northeast Groundfish Stock Updates, 2012 Update (NEFSC 2012) was held in February 2012 in which assessments for 13 groundfish stocks were updated and reviewed through 2010, including witch flounder. A small working group was convened prior to the 2012 meeting to discuss candidate models and the application of length-based conversion factors for witch flounder. Length-based conversion factors have not been established for witch flounder. The group concluded that further work was needed before length-based factors were applied; however, the group agreed that a sensitivity run should be conducted using survey indices adjusted with length-based conversion factors derived from a second order polynomial. The VPA formulation was the same the previous assessment (SPLIT RUN configuration). The VPA runs had similar retrospective patterns indicating that average F was underestimated, SSB was overestimated, and Age 3 recruitment exhibited a "flip" (change in direction) pattern (overestimated than underestimated). For this assessment, yield and SSB per recruit analyses were updated using 5-year (2006-2010) averages for partial recruitment, stock weights, catch

weights and maturity (2007-2011). Based on yield and SSB per recruit analyses, a proxy of F_{msy} is $F_{40\%MSP}$ = 0.27 for the SPLIT Run. A long-term (100 year) stochastic projection was performed to estimate spawning stock biomass and MSY under equilibrium conditions. The same partial recruitment, mean weights at age and maturity vectors used in the yield and SSB per recruit analysis were also used in the projections. A constant F scenario was used ($F = F_{msy}$ = 0.27). Estimates of Age 3 recruitment used in the projections were derived by re-sampling the cumulative density function based on the empirical observations during 1982 to 2009 (1979 to 2006 year classes) from the SPLIT RUN. The proportions of F and M which occurs before spawning equals 0.1667 (March 1); M equals 0.15. Based on yield per recruit analyses, BRPs were estimated to be: $F_{msy} = F_{40\%MSP}$ = 0.27. SSB_{msy} = 10,051 mt and MSY = 2,075 mt were estimated using a long-term stochastic projection. The 2010 SSB age structure remains truncated compared to the conditions under MSY. The 2010 SSB was 4,099 mt, 41% below SSB_{msy} (10,051 mt) and 2010 fishing mortality was 0.47, 173% above F_{msy} (F=0.27); therefore, witch flounder was overfished and overfishing occurred in 2010.

Two sensitivity runs (Runs F and G) of the SPLIT RUN were performed during the 2012 Update (NEFSC 2012) where length-based conversion factors from the second order polynomial were applied to the 2009 through 2011 survey indices. Length-specific conversion factors were applied to the entire length range in one run (Run F) while another run (Run G) applied length-specific conversion factors to lengths between 20 and 40 cm and held the conversion factor constant for lengths less than 20 cm and greater than 40 cm (i.e., all lengths less than 20 cm used the 20 cm conversion factor and all lengths greater than 40 cm used the 40 cm conversion factor). The review panel concluded that length-based conversion coefficients require a fuller consideration than can be performed in an update assessment. A research recommendation applicable to several stocks suggested exploring the possibility of refining the calibration factors within the assessment model itself (e.g., splitting the survey tuning series and using the results from the calibration experiment as a prior).

The 2015 Northeast Groundfish Operational Assessments (2015 OA; NEFSC 2015) was held in September 2015 in which 20 groundfish stocks were assessed and reviewed, including witch flounder. An analytical assessment (calibrated VPA) of commercial catch (landings plus discards) at age data through 2014 was conducted. A VPA analyses was performed for the SPLIT case (survey time series was split between 1994 and 1995). The retrospective analysis indicated that model underestimated fishing mortality and overestimated SSB and the magnitude of the retrospective pattern had increased slightly for F and decreased slightly for SSB compared to the 2012 assessment. However, the retrospective pattern for this assessment was considered to be 'major' because the rho adjusted estimates of 2014 SSB (SSB_{rho} = 2,077 mt) and 2014 F (F_{rho} = 0.687) were outside the approximate 90% confidence region around SSB (2,643 - 3,864 mt) and F (0.321 - 0.603). Therefore, a retrospective adjustment was made for both the determination of stock status and for projections of catch in 2016. The retrospective adjustment changed the 2014 SSB from 3,129 mt to 2,077 mt and the 2014 F_{full} from 0.428 to 0.687. The retrospective adjustment did not change stock status; witch flounder was overfished and overfishing occurred in 2014.

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

COMMERCIAL FISHERY LANDINGS

USA commercial landings of witch flounder generally increased from the early 1960s, peaking in 1984 at 6,658 mt (14.68 million pounds; Table B6; Figure B13). Subsequently, landings declined and fluctuated between 2,000 and 3,000 mt (6.6 million pounds) until 2003, when landings further declined. Landings in 2015 were 492 mt (0.11 million pounds), the lowest in the time series (Table B6; Figure B13).

Canadian commercial landings from the Gulf of Maine-Georges Bank region have been minor (not more than 68 mt annually); 2015 landings are estimated to be 1 mt (Table B6).

The majority (> 75%) of USA commercial landings come from the western Gulf of Maine and central basin and from the deeper waters north of the South Channel, specifically, statistical areas 512, 513, 514, 515, 521, and 522 (Table B7; Figure B14). Over the 1982-2015 time series, a shift in statistical areas is apparent. A decline in the percentage of landings occur in statistical areas 513 and 515 while an increase in percentages occur in 514, 521, and 522 (Table B7; Figure B14). Witch flounder landings occur throughout the year, with a slight increase during March - July months when witch flounder form dense pre-spawning aggregations (Burnett et al. 1992; Table B8; Figure B15). The majority (>91%) of the landings are taken by otter trawl gear (Table B9). In recent years, between 3% and 6% of landings are taken by haddock separator trawl. The majority of landings occur in Maine and Massachusetts. Since the mid-1990s, an increasing percentage of witch flounder is landed in Massachusetts (Table B10; Figure B16). Trends in landings by market category reveal a sharp decline in LARGE market category fish in the late 1980s (Table B11; Figure B17). Although culling and grading practices vary by port, witch flounder have historically been landed as either SMALL or LARGE; however, three market categories (PEEWEE, MEDIUM, and JUMBO were added in some ports beginning in 1982. In the mid-1990s, the proportion of witch flounder landings from the PEEWEE market category peaked. In 1983, a minimum size of 33 cm (13 inches) was established for witch flounder. The minimum size was increased to 36 cm (14 inches) in 1987 and reduced back in 33 cm in 2013.

Percentage of landings by ten minute squares of latitude and longitude is given in Figure B18 for the entire time series, by calendar quarter in Figure B19, and in 5-year blocks in Figure B20. Landings generally occur in the western and central Gulf of Maine; seasonal patterns reveal more landings from the southern flank of Georges Bank and southward in quarters 1 and 2 than in quarters 3 and 4. The general pattern of witch flounder landings appears similar over the 5-year time blocks within the Gulf of Maine region. Over the time series, fewer landings are taken from the Mid-Atlantic region. The ten minute squares with the highest percentage of landings varies over time from single squares dispersed in the western and central Gulf of Maine in the 1980s to western Gulf of Maine and along Georges Bank in the late 1990s, to inshore Gulf of Maine between Cape Ann and Cape Cod in the 2000s.

Vessel Trip Report (VTR) commercial landings and number of trips by ten minute square latitude/longitude resolution by 5-year time block with survey weight per tow from NEFSC spring and autumn surveys are presented in Figures B21 and B22, respectively.

COMMERCIAL FISHERY DISCARDS

The Northeast Fisheries Observer Program (NEFOP; formerly known as Domestic Sea Sampling Program and later as Fisheries Observer Program) began in 1989 and has generated varying levels of observer coverage for different fisheries. Prior to the NEFOP, the NEFSC conducted sea sampling on an ad-hoc basis.

Discards were initially estimated in the 1994 assessment (Wigley and Mayo 1996) for the Gulf of Maine northern shrimp fishery and the large (>=5.5 inches) mesh otter trawl fishery in the Gulf of Maine and Georges Bank region only (USA statistical areas: 464, 465, 511, 512, 513, 514, 515, 521-526, 561, and 562; Figure B23). Discard estimation was expanded to include the small mesh (<5.5 inches) fishery in the 2008 witch flounder assessment (NEFSC 2008) and the discard estimation method was updated to use a combined ratio method (Cochran 1963) of d/k_{all} (discarded weight of witch flounder/kept weight of all species) for the large mesh otter trawl fishery. In the 2012 and 2015 assessments, discards were updated using the same methods as the 2008 assessment. Discard mortality is assumed to be 100%.

In the current assessment, a working paper containing several refinements to the discard estimation for 1982-2014 was evaluated by the WG, including: a spatial extent refinement to include the entire stock area; expansion of the discard estimation to include additional gear types (scallop dredge, gillnet, and haddock separator trawl); some gear-specific refinements for large-mesh otter trawl, small-mesh otter trawl and shrimp trawl, and presentation of discard estimation for gillnet, scallop dredge, haddock separator trawl gear.

A summary of the refinements to direct and indirect discard estimation approaches, by gear type and time period, is given in Table B12. Discards in 2015 were estimated using these refined methods.

The number of observed trips by gear type, mesh group and year used in the discard estimation for the current assessment (1982 – 2015) is given in Table B13 for large mesh otter, small mesh otter trawl, shrimp trawl, gillnet, scallop dredge, and haddock separator trawl fisheries. Discards and associated CVs, by gear type, are given in Table B14 and Figures B24.

Large Mesh (>= 5.5 inches) Otter Trawl (LMOT)

Direct Estimation (1989-2015): The NEFOP data from 1989 to 2015 and At-Sea Monitoring (ASM) from 2010 to 2015 are used to derive an annual combined ratio of witch flounder discard weight to kept weight of all species (d/k_{all}) for two regions, CORE (statistical areas: 464, 465, 511, 512, 513, 514, 515, 521-526, 561, and 562) and OTHER (statistical areas: 533, 534, 537-543, 611-639; Table B13; Figure B23). Total annual discard weight is derived by multiplying the d/k_{all} ratio by the kept weight of all species in the commercial landings (Dealer data) for each region and then summing over region.

Indirect Estimation (1982-1988): No observer data are available prior to 1989. Witch flounder discards were indirectly estimated by Wigley and Mayo (1996) for the large mesh otter trawl trips in the Gulf of Maine-Georges Bank (CORE) region based on a method developed by Mayo et al. (1992) that used survey and commercial landings at length data, commercial gear retention ogives, and information on culling practices. Research vessel length frequency data were filtered through commercial gear retention ogives corresponding to the predominant meshes employed in the large mesh fishery (130, 140 and 152 mm) and then through a culling

practice ogive. Due to sparse retention studies for witch flounder, mesh selection ogives were taken from Walsh et al. (1992) for American plaice. Given the high value and low abundance of this species, the culling practice of commercial fishermen was assumed to be knife-edge at the minimum landing size. A semi-annual ratio estimator of survey filtered "kept" index to semi-annual numbers landed was used to expanded the estimated discards survey index to obtain number of fish discarded at length. Estimated numbers at length for both landed and discarded witch flounder in the large mesh otter trawl fishery were derived by season (winter/spring and summer/autumn). A spreadsheet illustrating the method used is presented in Table 19 of Wigley et al. 1999 (and illustrated in Figure 9) for 1993 using the spring survey and commercial landings from quarters 1 and 2. Semi-annual numbers of discard fish at length were apportioned to age using the corresponding season NEFSC age-length key.

To estimate discard weight of witch flounder in the stock area, the annual indirect discard estimates for the CORE region were multiplied by 0.385 (the 1989-2014 average of the ratio of the CORE region discard weight to the OTHER region discard weight) and added to the CORE region discard weight.

Estimated discards over the entire time series are presented in Table B14 and Figure B24. Previously estimated discards are also shown in Appendix Figure B1. Current discard estimates average 198 mt over the time series and the CVs are generally below 30%. In most years, a slight increase in discards occurred when the spatial extent is expanded southward; however, in 1991 and 1992 there is a large increase which appear to be unrelated to observer coverage level in the OTHER region (Table B13).

Small Mesh (<5.5 inch) Otter Trawl (SMOT)

Direct Estimation (1989-2015): The NEFOP data from 1989 to 2015 (except 1994 and 1998) are used to derive an annual combined ratio of witch flounder discard weight to kept weight of all species (d/k_{all}) for each region, CORE and OTHER (Table B13). Total annual discard weight was derived by multiplying the d/k_{all} ratio by the kept weight of all species in the commercial landings (Dealer data) for each region and then summing over region. As mentioned previously, because there was a single observed trip for 1994 and 1998 in the CORE region (Table B13), the average of the discard weight from adjacent years for the CORE region (e.g., 1993 and 1995 were averaged to estimate 1994 for the CORE region) was added to the discard weight of the OTHER region to derive an annual discard estimate for the stock area for these two years.

Indirect Estimation (1982-1988): No observer data are available prior to 1989 (Table B13). Witch flounder discards were indirectly estimated by multiplying the region-specific 1989-2014 (excluding 1994 and 1998 for the CORE region) average of the combined ratio by the region-specific annual kept all weight. Annual region-specific discard estimates were then summed to derive annual discard estimates.

Estimated discards over the entire time series are presented in Table B14 and Figure B24. Previously estimated discards are also show in Appendix Figure B2. Current discard estimates average 78 mt over the time series; the CVs are generally greater than 30%.

Gillnet (GN)

Direct Estimation (1989-2015): The NEFOP data from 1989 to 2015 are used to derive an annual combined ratio of witch flounder discard weight to kept weight of all species (d/k_{all})

for each region, CORE and OTHER (Table B13). Total annual discard weight was derived by multiplying the d/k_{all} ratio by the kept weight of all species in the commercial landings (Dealer data) for each region and then summing over region.

Indirect Estimation (1982-1988): No observer data are available prior to 1989 (Table B13). Witch flounder discards were indirectly estimated by multiplying the region-specific 1989-2014 average of the combined ratio by the region-specific annual kept all weight. Annual region-specific discard estimates were then summed to derive annual discard estimates.

Estimated discards over the entire time series are presented in Table B14 and Figure B24. No previous discards have been used in the stock assessment given the negligible amount. Current discard estimates average 1 mt over the time series and the CVs are greater than 30% early in the time series but are below 30% in recent years.

Scallop Dredge (SD)

Direct Estimation (1992-2015): The NEFOP data from 1992 to 2015 are used to derive an annual combined ratio of witch flounder discard weight to kept weight of all species ($d/k_{al}l$) for each region, CORE and OTHER (Table B13). Total annual discard weight was derived by multiplying the d/k_{all} ratio by the kept weight of all species in the commercial landings (Dealer data) for each region and then summing over region.

Indirect Estimation (1982-1991): Only 2 observed trips are available prior to 1992 (Table B13). Witch flounder discards were indirectly estimated by multiplying the region-specific 1992-2014 mean of the combined ratio by the region-specific annual kept all weight. Annual region-specific discard estimates were then summed to derive annual discard estimates.

Estimated discards over the entire time series are presented in Table B14 and Figure B24. No previous discards have been used in the stock assessment. Current discard estimates average 50 mt over the time series and the CVs are below 30% since the late 1990s.

Haddock Separator Trawl (HS)

Direct Estimation (2010-2015): The NEFOP data from 2010 to 2015 are used to derive an annual combined ratio of witch flounder discard weight to kept weight of all species (d/k_{all}) for each region, CORE and OTHER (Table B13). Total annual discard weight was derived by multiplying the d/kall ratio by the kept weight of all species in the commercial landings (Dealer data) for each region and then summing over region. NEFOP data in 2009 could not be utilized because the commercial landings data does not contain the haddock separator trawl gear code.

Indirect Estimation (1982-2009): No discard estimation is needed for this time period as the haddock separator trawl is a recent gear type. In years leading up to the new gear code, there could be some incorrect gear codes reported in the Vessel Trip Report and used in the commercial landings data. However, a comparison conducted in which haddock separator trawl (negear 057) and large mesh otter trawl (negear 050) are combined reveals negligible impacts on discard estimation (Appendix Figure B3).

Estimated discards for the 5-year time series are presented in Table B14 and Figure B24. Current discard estimates average 1 mt over the time series and the CVs are at or below 30%.

Gulf of Maine Shrimp Trawl (GMSHR)

Discards from the shrimp trawl fishery (primarily associated with the northern shrimp fishery) in the Gulf of Maine have been derived for the CORE area only. In April 1992, a regulation requiring the use of the Nordmore Grate was implemented in the northern shrimp fishery. Small mesh exempted fisheries using shrimp trawls are not required to use a grate. The Vessel Trip Report logbook does not collect information regarding the use of a grate during commercial fishing trips. In 2014 and 2015, the northern shrimp fishery was closed; however, trips using shrimp trawls without grates fished in exempted areas within the Gulf of Maine (fishermen were contacted to confirm the gear used).

Direct Estimation (1989-1997; 2001, 2003-2013): The NEFOP data are used to derive an annual combined ratio of witch flounder discard weight to kept weight of all species (d/k_{all}) for the CORE region (Table B13). Total annual discard weight was derived by multiplying the d/k_{all} ratio by the kept weight of all species in the commercial landings (Dealer data).

Indirect Estimation (1982-1988; 1998-2000, 2002, 2014, 2015): No observer data are available prior to 1989 and between 1998 and 2000, 2002, 2014, and 2015 (Table B13). Witch flounder discards were indirectly estimated by multiplying an average of the combined ratio by the annual kept all weight. For years prior to 1993 and for 2014-2015, 1989-1992 time series was used (years when no grate was required or no northern shrimp fishery in 2014-2015). For years without observer data between 1998 and 2002, a 1993-2013 time series (excluding 2001 and 2011 in which insufficient trips occurred) average combined ratio was used.

The discard estimation methods described above differ from those used in the 2015 Operational Assessment (OA) where discards from the northern shrimp fishery were estimated using the following two methods. When no observer data were available, a regression of age 3 fish in the autumn NEFSC survey and observed discard rates was used to estimate ratios of discard weight to days fished (d/df) ratios. When observer data were available, d/df ratios were calculated by fishing zone (a surrogate for depth). To estimate discard weight, the mean discard ratio (weighted by days fished in each fishing zone) was expanded by the days fished in the northern shrimp fishery.

Discarded weight was translated into numbers of fish at age using observer discard length frequency and NEFSC spring survey age data. When no observer length frequency data were available, an average proportion at age and weighted mean weights over a 5-year time period were used to translate discarded weight into numbers of discarded fish at age (Appendix Figure B4).

Estimated discards over the entire time series from the Gulf of Maine shrimp fishery are presented in Table B14 and Figure B24. Previously estimated discards are also shown in Appendix Figure B5. The previously estimated discards are lower than the re-estimated discards for the1982-1988 time period and the higher for the mid-1990s but remain within the 95% confidence interval of the re-estimated discards.

Total Estimated Discards

Total discards from the six fisheries ranges between 93 mt (2015) and 774 mt (1991) with a time series mean of 301 mt; CVs range between 7% and 40% (Table B14; Figures B25 and B26). The discards estimated in the current assessment differ slightly from those estimated in previous assessments (Figure B26 and Appendix Figure B6) that include only three fisheries. A notably difference occurs in 1991 and is attributable to the spatial extent refinement for the large mesh otter trawl fisheries (the 1991 discard ratio in the OTHER region is 3 times higher than the penultimate discard ratio for this fishery and region).

RECREATIONAL FISHERY CATCH

There is no recreational fishery for witch flounder. The database of the NMFS Marine Recreational Information Program (MRIP) database contains no observations for witch flounder. The Vessel Trip Report database contains 377 witch flounder[1] from 26 party/charter trips during 1996 – 2015, a negligible amount of fish.

COMMERCIAL FISHERY LANDINGS AT LENGTH AND AGE

Commercial length frequency and age sampling data are summarized by market category and calendar quarter (Table B15). Some ports do not cull into "peewee" and "jumbo" categories, and so these categories have been combined into the "small" and "large" categories, respectively. Prior to 1982, sampling was sporadic. Annual sampling from 1982 onward ranged between 11 and 133 mt per 100 lengths, exceeding the informal sampling threshold criterion of 200 mt per 100 lengths. During the 1990's, sampling was insufficient in some quarters and market categories and it was necessary to pool some quarters for some market categories. Sampling improved by quarter and market category in the late 1990's in which an average 34 mt per 100 lengths was obtained. Commercial age data were available for 1982 to 2015; landed witch flounder ranged in age between 3 and 33 years. To estimate landings at age and mean weights at age, quarter, semi-annual or annual age-length keys were applied to corresponding commercial landings length frequency data by market category. Number of fish landed at age, mean weights at age, and mean lengths at age of landed fish are presented in Tables B16, B17, and B18, respectively for ages 0 to 11+ and in Figures B27 and B28 for ages 0 to 14+ and ages 0 to 11+, respectively. The majority of landed fish were ages 6 to 9. The coefficient of variation associated with the numbers of fish at age are given in Table B19; CVs for ages 6 through 9 are generally less than 15%.

COMMERCIAL FISHERY DISCARDS AT LENGTH AND AGE

A summary of the discarded length frequency data collected by the NEFOP is given in Table B20 and Figure B29 by gear type. Witch flounder age structures collected by the NEFOP are not aged; the NEFSC spring and autumn age length data are used.

<u>Large Mesh (>= 5.5 inches) Otter Trawl (LMOT)</u>

Based on NEFOP discard reasons, witch flounder are often discarded due to the minimum size regulation. There is a narrow mode of discarded witch flounder centered at the minimum size (Figure B29). Minimum size regulations for witch flounder have changed over

[1] Upon inspection of the VTRs with the 4 highest counts of witch flounder caught on recreational trips, 3 of the 4 trips had not reported witch flounder; it appears mis-interpretation of hand writing resulted in 171 (45% of 377) witch flounder incorrectly reported as recreational kept fish.

time. In 1983, a minimum size was established at 33 cm (13 inches). In 1987, the minimum size increased to 36 cm (14 inches) and then decreased back to 33 cm in July 2013.

With no new length frequency and age data since the 2015 OA, the numbers of discarded fish at age for the 1982-2014 time period reported in the 2015 OA were re-scaled to the current discard weight using an annual ratio of current discard weight to 2015 OA discard weight. The 2015 OA and the 2015 discards estimated in the current assessment used NEFOP discard length frequency data and NEFSC seasonal age-length keys to translate discarded weight into number of fish discarded at age for the large mesh otter trawl fishery. Witch flounder discarded in the large mesh otter trawl fishery range in age from 1 to 11+, with the majority between ages 4 and 6.

Small Mesh (<5.5 inch) Otter Trawl (SMOT)

In the small mesh otter trawl fishery, witch flounder are often discarded due to no retention regulations and size retention regulations. The overall proportion at length of discarded fish for the small mesh otter trawl fishery appears similar to the large mesh otter trawl fishery (Figure B29). There are some years with insufficient length measurements annually or when partitioned by half year; eight years during the 1989-2014 time period in which the numbers of discarded fish measured for length was less than 100 fish (Table B20).

With limited length frequency data over the entire 1982-2015 time series, the numbers of discarded fish at age from the large mesh otter trawl fishery were rescaled by the annual ratio of small mesh otter trawl discarded weight to the large mesh otter trawl discarded weight.

Gillnet (GN)

In the gillnet fishery, witch flounder are often discarded due to size regulations or for unknown reasons. The length frequency of discarded fish reveals a mode and range similar to large mesh otter trawl (Figure B29). The numbers of fish measured annually for length over the time series is very sparse (Table B20).

With very sparse length frequency data over the entire 1982-2015 time series, the numbers of discarded fish at age from the large mesh otter trawl fishery were rescaled by the annual ratio of gillnet discarded weight to the large mesh otter trawl discarded weight.

Scallop Dredge (SD)

In the scallop dredge fishery, witch flounder are often discarded due to no market or no retention regulations. The length frequency of discarded fish over all years combined reveals a mode and range that is shifted towards larger fish than the large mesh otter trawl (Figure B29). The numbers of fish measured annually for length over the time series varies annually (Table B20).

For years without discarded length frequencies or years with less than 100 fish measured (1982-1995, 1998, 2001, 2002), the annual numbers of discarded fish at age were derived using a combined length frequency over the time series and NEFSC spring and autumn age data combined with commercial landings age data to translate annual discarded weight into number of discarded fish at age for the scallop dredge fishery. Witch flounder discarded in the scallop dredge fishery range in age from 1 to 11+, with the majority at ages 4 to 8.

Haddock Separator Trawl (HS)

In the haddock separator trawl fishery, witch flounder are often discarded due to size retention regulations. The length frequency of discarded fish reveals a mode and range similar to large mesh otter trawl (Figure B29). The numbers of fish measured annually for length over the short time series is limited (Table B20).

With limited length frequency data, the numbers of discarded fish at age from the large mesh otter trawl fishery were rescaled by the annual ratio of haddock separator trawl discarded weight to the large mesh otter trawl discarded weight.

Gulf of Maine Shrimp Trawl (GMSHR)

In the Gulf of Maine shrimp trawl fishery, witch flounder are often discarded due to unknown reasons or quota retention regulations. The length frequency of discarded fish over all years combined reveals a mode and range that is shifted towards smaller fish than fish discarded in the large mesh otter trawl or scallop dredge (Figure B29). The numbers of fish measured annually for length over the time series varies annually (Table B20).

With no new length frequency and age data since the 2015 OA, the numbers of discarded fish at age for the 1989-2013 time period reported in the 2015 OA were re-scaled to the current discard weight using an annual ratio of current discard weight to 2015 OA discard weight.

With no discard length frequency data in 2014 and 2015 from a shrimp trawl fishery that is not using a grate, the numbers of discarded fish at age from the large mesh otter trawl fishery were rescaled by the annual ratio of shrimp trawl discarded weight to the large mesh otter trawl discarded weight based on the assumption that discarded length frequency of witch flounder in shrimp trawl without a grate would be similar that of the small mesh otter trawl fishery.

Witch flounder discarded in the shrimp fishery ranges in age from 0 to 6, with the majority at ages 1 to 3. The estimate discard weight of with flounder from the shrimp fishery is small compared to the otter trawl fishery.

Total Estimated Discards

To form the total numbers of discarded witch flounder at age, the numbers of discarded fish at age in the large mesh otter trawl fishery (rescaled to account the discarded weight from the small mesh otter trawl, gillnet, 2014-2015 Gulf of Maine shrimp trawl, and haddock separator trawl fisheries) was added to the numbers of discarded fish at age in the 1982-2013 the Gulf of Maine shrimp trawl fishery and the numbers of discarded fish at age in scallop dredge fishery. Weighted mean weights and mean lengths at age were derived using numbers of fish as the weighting factor. Numbers of discarded fish at age, mean weight at age, and mean length at age are given in Tables B21, B22, and B23, respectively, and Figure B30.

TOTAL FISHERY CATCH

Total commercial landings in 2015 were 493 mt (1.1 million pounds), commercial discards were estimated to be 93 mt (0.2 million pounds), for a total catch of 585 mt (1.3 million pounds; Table B13).

To form the numbers of fish at age in the catch, the total discarded fish at age was

combined with the numbers of fish in the commercial landings. Weighted mean weights and mean lengths at age were derived using numbers of fish as the weighting factor. Numbers of witch flounder in the catch at age, mean weight at age, and mean length at age are given in Tables B24, B25, and B26, respectively, and Figure B31, B32, and B33.

The age composition data reveal strong 1979-1981 year classes (Figure B31). The 1989 and 1993 year classes also appear to have been strong, however, these cohorts were heavily discarded in both the shrimp and large mesh otter trawl fisheries. The age composition also reveals a truncated age structure since the mid-1980s, and a short-lived expansion in the early 2000s that was not sustained.

WG recommendation: WG members accepted the catch at age as derived.

TERM OF REFERENCE 2: Present available federal, state, and other survey data, indices of relative or absolute abundance, recruitment, etc. Characterize the uncertainty and any bias in these sources of data and compare survey coverage to locations of fishery catches. Select the surveys and indices for use in the assessment.

RESEARCH SURVEY INDICES OF ABUNDANCE

Northeast Fisheries Science Center (NEFSC)

The NEFSC has conducted annual research vessel stratified random bottom trawl surveys during autumn (generally between October and November in northern strata) since 1963 and during spring (generally between March and April) since 1968. The NEFSC survey samples offshore waters between 27 m [15 fm] to 366 m [200 fm] from Cape Hatteras NC to the Canadian border (Figure B34). Details on the survey sampling design are given in Grosslein (1969) and Azarovitz (1981), changes to the survey over time are described in Johnston and Sosebee (2014), and uses of survey data in stock assessments are given in Clark (1981). For witch flounder, strata 22-30, 36-40 (Figure B35) have been used for indices of relative abundance and biomass and have been used in previous peer-reviewed stock assessments as tuning indices in the analytical model (relative indices and/or swept area indices). Table B27 summarizes the square nautical miles of the NEFSC survey area and associated statistical areas.

The annual minimum, maximum, and weighted mean temperature and depth of the strata set over the time series are given in Figures B36 and B37. The weighting factor for mean temperature and mean depth was witch flounder abundance and biomass in tows with positive catches. In spring, bottom temperatures generally range between 3 and 9 degrees with a weighted mean of about 6 degrees. In autumn, bottom temperatures generally range 5 and 11 degrees with a weight mean of about 7.5 degrees. The reduced variability in maximum depth since the mid-1990s onward is attributed to a change in towing protocols for stations with depths greater than or equal to 183 m (Figure B37). Johnston and Sosebee (2014) document "*a more specific depth is randomly chosen among four depth intervals and then trawling was done along that depth contour.*"

The timing of the spring and fall surveys has varied slightly over the time series. In spring of 2014 and 2016, the spring survey was slightly later than the time series mean (Figure B38). The percentage of positive tows in the NEFSC spring and fall survey exhibit similar patterns (Figure B39). The percentage of positive tows was generally greater than 50% prior to a decline in the late 1980's and 1990's when percentages reached time series lows (23% in fall 1987; 24% in spring 1990). Since that time, the percentage of positive tows has increased to above 50% and since 2009 the numbers of positive tows are among the highest in the time series. The recent increase in positive tows is attributed to the change in survey vessel and trawl gear. Gini (concentration) indices of abundance and biomass for spring and fall exhibit similar trends indicating witch flounder are moderately concentrated among the NEFSC survey strata (Figure B40) with a declining trend in concentration over the time series more evident in the spring than fall.

Witch flounder are generally distributed throughout the Gulf of Maine, along the northern edge and southern flank of Georges Bank, and southward along the continental shelf as far south as Cape Hatteras, NC. Distributions of witch flounder abundance in spring 1968-2016 and fall 1963-2015 time series are given in Figures B41 and B42 (animated 5-year moving time block

plots are available on Data Portal). Juveniles are generally distributed in the western Gulf of Maine and along the Mid-Atlantic shelf (Figures B43) with concentrations along the western portion of the Gulf of Maine. As noted earlier, Burnett et al. (1992) found seasonal differences between juveniles and adults. Distribution of survey catches coincides with distributions of commercial landings and trips reported in the Vessel Trip Reports (Figures B21 and B22).

While NEFSC spring survey indices tend to be more variable due to pre-spawning aggregations of witch flounder, spring and autumn indices generally display similar trends. NEFSC survey indices generally declined from the early 1960s to record low levels in the late 1980s and early 1990s. There was an increasing trend in the late 1990s to early 2000s followed by a declining trend (Figure B44). In 2015, the survey indices were below their time series means (Table B28). Uncalibrated Bigelow indices are given in Figure B45.

NEFSC spring and autumn length frequency data are presented in Figures B46 and B47, respectively. The NEFSC survey does not consistently catch small witch flounder; however, occasional strong cohorts are evident in the fall survey between 10-15 cm. Strong cohorts are evident in the other surveys. The length frequency plots also reveal the NEFSC survey consistently caught large witch flounder (greater the 55 cm) in both spring and autumn early in the survey time series; however in recent years, few large fish are caught above 55 cm.

NEFSC spring and autumn age sampling is summarized in Table B29. The maximum age has declined over the time series (Table B29). In the 1980s, the maximum age in the autumn survey was between 20 and 30 years and in recent years, maximum age was between 10 and 15 years.

Age-specific relative abundance from NEFSC spring and autumn 1980-2015 and spring 2016 surveys are given in Table B30 and Figure B48. In the early to mid-1980s, older witch flounder were evident in the survey catches. A truncation of the age structure occurred in the late-1980s; a slight expansion in age structure occurred in early 2000s but was not sustained.

The NEFSC survey data indicate improved recruitment of age 3 fish in 2007, 2011 and 2013 (2004, 2008, and 2013 year classes, respectively; Figure B49); however, only the 2004 year class is evident as a strong year class in the following year.

NEFSC spring and autumn survey mean weights at age are given in Table B31 and Figure B50. Survey mean weights are variable, however, similar declines in mean weights for ages 6-9 were observed during the mid-1990s to 2002 in both the commercial landings and spring and autumn surveys.

Mean lengths at age from NEFSC spring and autumn surveys are presented in Table B32 and for ages 4 to 8 in Figure B51. Mean lengths at age for ages 5 to 7 appear to have increased (approximately 3-5 cm) from 1980 to the late 1980's, and then declined (Figure B1); however, von Bertalanffy growth analyses detected no significant changes in resulting growth parameters over the time period (Wigley et al. 2003a).

Additional NEFSC Survey data explorations

Day-night differences in witch flounder catches were explored; negligible day-night differences were found (Figure B52).

Survey Conversion Factors

There are no significant vessel, door, or net conversion factors for witch flounder in the NEFSC bottom trawl survey between 1963 and 2008. No conversion factors have been applied

to the survey indices for the 1963 through 2008 period.

In 2009, the Fisheries Survey Vessel (*FS/V*) *Henry B. Bigelow* replaced the *R/V Albatross IV* as the principle vessel conducting the bottom trawl survey. The vessel characteristics (size and towing power) as well as fishing gear characteristics differed between the two vessels resulting in different survey catchability. Calibration experiments were conducted to estimate catchability differences during 2008 (Brown 2009), and results of the experiments were peer reviewed in 2009 (Anonymous 2009, Miller et al. 2010). There are significant vessel conversion factors between the *FS/V Bigelow* and the *R/V Albatross IV* for witch flounder (Miller et al. 2010) in the NEFSC bottom trawl survey. The vessel conversion factor for numbers and weight (spring and autumn) is 3.2572 and has been applied to the 2009 through 2016 NEFSC bottom trawl surveys. The *FS/V Bigelow* survey indices were divided by the conversion factor to obtain indices consistent with the *R/V Albatross IV*.

Length-based conversion factors have not been established for witch flounder. A small working group was convened prior to the 2012 Update meeting to discuss candidate models and the application of length-based conversion factors for witch flounder. The group concluded that further work was needed before length-based factors were applied; however, the group agreed that a sensitivity run should be conducted using survey indices adjusted with length-based conversion factors derived from a second order polynomial. Two sensitivity runs (Runs F and G) of the SPLIT RUN were performed during the 2012 Update (NEFSC 2012) where length-based conversion factors from the second order polynomial were applied to the 2009 through 2011 survey indices. Length-specific conversion factors were applied to the entire length range in one run (Run F) while another run (Run G) applied length-specific conversion factors to lengths between 20 and 40 cm and held the conversion factor constant for lengths less than 20 cm and greater than 40 cm (i.e., all lengths less than 20 cm used the 20 cm conversion factor and all lengths greater than 40 cm used the 40 cm conversion factor). The review panel concluded that length-based conversion coefficients require a fuller consideration than can be performed in an update assessment. A research recommendation applicable to several stocks suggested exploring the possibility of refining the calibration factors within the assessment model itself (e.g., splitting the survey tuning series and using the results from the calibration experiment as a prior).

<u>WG recommendation</u>: Continue to use constant conversion factors for Bigelow series as tuning indices in Albatross units; explore use of a "stand alone" Bigelow series without conversion factors (see Term of Reference 4 for a summary of exploratory model configurations).

Alternate NEFSC strata sets

Analyses were conducted in 2003 to examine if the use of additional strata in the NEFSC bottom trawl survey might be appropriate. Burnett and Clark (1983) used NEFSC survey strata set 22, 24, 26-30, and 33-40 in the first witch flounder assessment; however, Burnett (MS 1987) suggested that fish from strata 33, 34 and 35 exhibited different growth rates indicating these fish may be from a different stock inhabiting the western Scotian shelf. Based on this information, Wigley and Mayo (1996) revised the witch flounder survey strata set excluding 33, 34, and 35, and included strata 23 and 25. Following a method developed by Cadrin and King (2003), witch flounder catches for the entire autumn bottom trawl survey time series were examined by individual stratum. The mean number per tow, expanded by the stratum area for each stratum was summed over the time period, and the percentage contribution of each stratum was calculated as well as the percentage of annual stratum sampling which produced no catch.

Results indicate that the current strata set (22-30, 36-40) accounts for approximately 93% of the survey catch and that only minor differences exist between the strata sets used in previous assessments. That analysis also indicated that stratum 6 contributed to the overall witch flounder catch. The stratified mean weight (kg) per tow was calculated for three strata sets: set 1 (22-30, 36-40); set 2 (22, 24, 26-30, 36-40); and set 3 (6, 22, 24, 26-30, 36-40). The trends of these biomass indices (and their variance) are indistinguishable. The inclusion of stratum 6 is not justified due to its geographical discontinuity with the core strata.

In the current assessment, an analysis comparing the current strata set (set 1: 22-30, 36-40) and an alternative set (set 2: 22, 24, 26-30, 36-40) was updated through 2015 and results were similar to those in 2003. The current strata set (22-30, 36-40) accounts for 94% of survey catch (in numbers and weight) and only minor differences exist between the alternative set in percentage of survey catch as well as relative biomass (and associated variance) trends (Table B33 and Figure B53).

The WG also reviewed three additional alternative NEFSC strata sets: (a) the inclusion of strata 33, 34, and 35/351 in the autumn survey series; (b) the inclusion of stratum 34 in the spring and autumn survey series; and (c) the inclusion of strata 2-4, 6-8, 10-18, and 74-76 in the spring and autumn survey series. Each additional alternative strata set was compared with strata set 1 (22-30, 36-40) used in recent assessments. Adding additional strata did not change the trend in abundance or biomass over the time series for the spring or fall surveys (Figures B53a, B53b, B53c).

The WG noted that Burnett et al. 1992 described witch flounder growth differences between Gulf of Maine-Georges Bank region and Scotian Shelf in which the warmer water of the Gulf of Maine (compared to Scotian Shelf) and year-around feeding were factors attributed to the faster growth of the Gulf of Maine-Georges Bank witch flounder. The WG members also noted the Scotian Shelf landings are not included in the catch used in the model, and this was another reason not to include the Scotian Shelf strata in the set.

<u>WG recommendations</u>: Since no additional strata were identified as contributing to the total catch, or improved the precision of the estimates of mean weight per tow, the strata set 22-30, 36-40 was retained.

Witch flounder catchability study

A field experiment was conducted to estimate the survey catchability of witch flounder in the net used in the NEFSC bottom trawl survey and a net with a chain sweep by using a twin net configuration. The goal was to estimate the sweep efficiency of the NEFSC survey trawl. A working paper entitled "Empirical estimates of maximum catchability of Witch Flounder *Glyptocephalus cynoglossus L.* on the Northeast Fisheries Science Center Fall bottom trawl survey" by Hare et al. 2016b describes the field study as well as the analyses used to derive the efficiency of the NEFSC survey net for witch flounder (See Appendix B1 for working paper and supplemental information.)

<u>WG recommendation</u>: The WG accepted the witch flounder catchability (q) estimates (0.056 and 0.291) from the sweep study and recommended their use in the stock assessment to convert the NEFSC survey relative abundance indices into swept area numbers (SWANs).

Massachusetts DMF

The Commonwealth of Massachusetts Division of Marine Fisheries (MA DMF) began spring and fall inshore trawl surveys in 1978 which complement the NEFSC surveys in coastal Massachusetts waters in that depths less than 27 m (the lower depth limit sampled by the NEFSC offshore survey) are sampled (for details see Howe et al. 1981). For witch flounder, strata 25-36 (region 4 and 5; Figure B54) have been used for indices of abundance and biomass and have been presented in previous stock assessments as corroborative information.

The MA DMF spring and fall survey time series has varied little in time of year over the time series (Figure B38). The percentage of positive tows is low (< 50%) in the spring and fall survey series (Figure B39). Gini (concentration) indices of abundance and biomass for the MA DMF surveys indicate witch flounder are generally concentrated and not evenly distributed among the survey strata (Figure B40). The fall gini indices appear similar over time while the spring gini indices indicate witch flounder have become more concentrated from the 1990s onward.

Distributions of witch flounder in the MA DMF surveys (1978 – 2015 time series and 5-year moving time block) are given in Figures B55 and B56.

Relative trends in abundance, biomass, mean length and individual weight of witch flounder in the MA DMF inshore spring and fall surveys are presented in Table B34, Figure B57. Spring survey catch per tow indices indicate declining trends from the late 1970's to time series lows in the mid-1990s; a slight increase is evident in the mid-2000s. The number of fish caught in the fall survey varies from a high of 171 in 2011 to a low of 2 fish in 1996 while the numbers of fish caught in the spring survey are sparser than the fall (Table B35). Fall survey catch per tow indices varies over the time series with a stratified mean less than 1 fish interspersed with peaks of 2 or 3 fish per tow occurring in 1983, 1995, 2002, and 2011 (Figure B57).

The mean length of witch flounder in the MA DMF spring and fall survey has declined from approximately 45 cm to 35 cm over the time series (Figure B58).

MA DMF length frequency data are sparse in the mid-1990s onward, with the exception of spring 2000 (1998 year class) and fall 1995 (1993 year class) and fall 2011; Figures B59 and B60.

Too few age samples are collected during the MA DMF surveys to reliably characterize the age composition (Table B35). Given the sparse length frequency in these seasonal surveys, NEFSC age length keys were not applied.

WG recommendation: This survey has a spatial coverage confined to the inshore waters of Massachusetts. Consider including MA DMF survey as corroborative information only (not included in model).

ASMFC Shrimp Survey

The Northern Shrimp Technical Committee of the Atlantic States Marine Fisheries Commission (ASMFC) has conducted an annual northern shrimp survey during August in the Gulf of Maine since 1983, with catch data for witch flounder available since 1984 onward (for details on the shrimp survey, see Northern Shrimp Survey, see Northern Shrimp Technical Committee MS 1984; Johnston and Sosebee 2014). This survey uses a stratified random sampling design and has consistently sampled strata 1, 3, and 5-8 (Figure B61). For witch flounder, strata 1, 3, 6, and 8 have been used for indices of abundance and biomass and have been presented in previous stock assessments as corroborative information. Comparison of an

alternative strata set (strata 1, 3, 5-8) revealed negligible differences between the original strata set and the alternative set (Figure B62), consequently the original strata set was retained.

The ASMFC survey time series has varied little in time of year over the time series (Figure B38). There is a high percentage of positive tows in the survey series (Figure B39). Gini (concentration) indices of abundance and biomass for this survey indicate witch flounder are distributed evenly among the survey strata (Figure B40).

Distribution of witch flounder survey catches for 1984 – 2015 time series combined is given in Figure B63. Five-year moving time blocks of survey catches are available on the data portal.

Trends in stratified mean abundance and biomass, mean length, and individual weight of witch flounder in the ASMFC shrimp survey are presented in Table B36 and Figure B64. Survey catch per tow indices indicate low abundance in the mid-1980s to mid-1990s, increased abundance in 1999 and early 2000s (a peak in 1999 associated with the strong 1998 and 1999 year classes), followed by a decline to a slightly higher mean than the mid-1980s. The peak in 1999 may also reflect increased availability rather than true abundance in that year.

Length frequency data from the ASMFC shrimp survey (Figure B65) suggests that incoming year classes can be identified prior to their appearance in the NEFSC survey. The ASMFC data might be more useful in providing a pre-recruit index than to characterize the population as whole given the ASMFC survey caught few witch flounder greater than 40 cm. The ASMFC survey data indicate improved recruitment (see length frequency modes at 12 cm, corresponding to age 1 fish) during 1991-1994, 1997, 1999, 2005, and 2014.

Witch flounder age structures are not collected on this survey; however, age-specific relative abundance indices, mean weight at age, and mean length at age were derived by applying annual NEFSC spring and fall (combined) age-length keys to the length frequency data from the ASMFC survey (Tables B37, B38, and B39, respectively; Figures B66 and B67). Any age-length key holes were manually filled in. Mean weight and mean length at age indices reveal similar trends as in other surveys in which mean weights and mean lengths for younger witch flounder fluctuate around the time series mean at age; however, in this survey age 4 and 5 fish exhibit a declining trend in mean weights and length from the mid-1980s to the early 2000s and then increases from the mid-2000s (Figure B68). These age groups represent the younger ages in the NEFSC survey.

WG recommendation: Although this survey has limited spatial coverage, much of the juvenile range is covered. This survey appears to provide useful information on relative to trends in abundance, distribution and recruitment of witch flounder in the Gulf of Maine and could be considered as tuning indices.

Maine-New Hampshire (MENH) Inshore Survey

Maine Department of Marine Resources and New Hampshire Fish and Game Department (MENH) have conducted spring and fall bottom trawl surveys along the New Hampshire and Maine coast since fall 2000. The survey has a stratified random sampling design with a fixed component. Sampling occurs in 5 regions and 4 depth zones that range from 5 fm to greater than 55 fm (Sherman et al. 2005; Figure B69). The distribution of witch flounder survey catches for spring and fall in 5-year time blocks are given in Figures B70-B75.

Relative trends in abundance and biomass of witch flounder in the MENH inshore survey are presented in Table B40 and Figure B76. In the spring, survey catch per tow indices averaged

about 6 fish per tow and 0.3 kg per tow until 2014 when a sharp increase in number of fish occurred (Figure B76). In the fall, a peak in both numbers and biomass occurred in 2001 and subsequently indices averaged about 12 fish per tow and 1 kg per tow.

Length frequency data from the MENH inshore spring and fall survey (Figures B77 and B78, respectively) suggest that incoming year classes may be identified prior to their appearance in the NEFSC survey. Similar to the ASMFC survey, the MENH survey might be useful in providing a pre-recruit index rather than to characterize the population as whole given the MENH survey catches few witch flounder greater than 30 cm (approximately age 4). The MENH inshore survey data indicate improved recruitment (see length frequency modes between 10-15cm, corresponding to age 1 fish) during 2001, 2005, and 2014.

Witch flounder age structures have been collected on this survey; however, ageing has not occurred. Age-specific relative abundance indices, mean weight at age, and mean length at age were derived by applying annual, season-specific NEFSC age-length keys to the length frequency of the MENH survey (Tables B41, B42, and B43, respectively; Figures B79 and B80). Any age-length key holes were manually filled in. The MENH survey catches ages 1 to 11+ ages, with most fish between the ages of 1 and 3. Normalized mean weights revealed a slight increase trend some ages (i.e., age 5) while other ages fluctuated about zero.

WG recommendation: Although this survey has limited spatial coverage, much of the juvenile range is covered. This survey appears to provide useful information on relative trends in abundance, distribution and recruitment of witch flounder in the Gulf of Maine and could be considered as tuning indices.

Other Surveys

- The NEFSC winter survey was conducted between 1992 and 2007 during February in the Georges Bank and Mid-Atlantic region using a stratified random sampling design. In general, there was poor coverage of Georges Bank and deep strata (183 -366 m) were not covered consistently. The following strata were consistently sampled over the 16 year time series: Strata 1-3, 5-7, 9-11; 61, 63, 65-67, 69-71, 73-75 (Figure B34; Johnston and Sosebee 2014). This survey does not sample the core distribution of witch flounder in the Gulf of Maine.

- The Canadian bottom trawl survey samples Georges Bank and does not sample the core distribution of witch flounder in the Gulf of Maine.

- The NEFSC's Cooperative Research Program longline survey uses a random sampling design within bottom trawl survey strata in the central basin of the Gulf of Maine. The longline survey was conducted in 2014 and 2015; no witch flounder have been caught (pers. comm. L. O'Brien August, 2016).

- The MA Division of Marine Fisheries (MA DMF) has conducted an Industry-Based cod survey (IBS) in the Gulf of Maine in 2003 - 2007 and 2016. Plots aggregating the April-May cruises were provided by M. Dean (MA DMF, pers. comm, July 13, 2016). Dean noted that the location of witch flounder appear to fairly similar between IBS1 and IBS2 study areas. A mean catch per tow (kg) was 4.8 kg/tow. Further information about this survey is available online at: http://www.mass.gov/eea/agencies/dfg/dmf/programs-and-projects/industry-based-survey-

for-gulf-of-maine-cod.html
This survey with a mix of random and non-random stations and has a short time series.

WG recommendation: The WG agreed that the limitations associated with these other surveys would prevent their use in the model.

Aggregate research survey trends

Trends in abundance and biomass (normalized to the mean within each survey) for 7 surveys are given in Figures B81 and B82 (by grouped by season). The NEFSC seasonal surveys (spring and fall), MA DMF seasonal surveys (spring and fall), and ASMFC summer survey exhibit similar trends in which indices are above their time series mean prior to the late 1980s, below the mean during the late 1980s to mid-1990s and remain below or near the mean in the late 1990's and 2000s onward. The MENH seasonal surveys, which has the shortest time series of all surveys considered here, is more variable than the other surveys, and fluctuates without trend around the mean for spring, with the fall indices exhibiting a slight downward trend.

WG recommendations: Survey indices appear to generally track one another. Length of time series impacts surveys with shorter time series.

FISHERY DEPENDENT DATA INDICES OF ABUNDANCE (LPUE or CPUE)

Introduction

Recent catch limits for witch flounder are much less than historical catch (NEFSC 2015). Therefore, the assessment relies on indices of stock size to determine whether low catches result from low fishing mortality or low stock size. Scientific surveys can inform relative stock size, but sample size (i.e., the number of survey stations) is often insufficient to detect trends in rebuilding stocks (Pershing 2015), and survey gear may be inefficient for sampling some species (e.g., Reid et al. 2007). Many fishermen are concerned that research trawl survey trends are different than their observed catch rates (NSC 2016).

Fishery catch rates can be evaluated as standardized catch per unit effort (CPUE) to consider fishery-dependent data in stock assessments and potentially supplement survey indices in stock assessment models. There are several potential problems associated with using fishery catch rates as indices of stock size (e.g., Harley et al. 2001, Maunder et al. 2006). However, some changes in fisheries can be addressed through effort standardization (Maunder and Punt 2004). Furthermore, the inspection of CPUE trends can help to reconcile different perceptions and provide valuable ecological information, even if these indices are not included in the assessment model.

The management history of New England groundfish has several distinct periods (Murawski et al. 1999, Murphy et al. 2014):

1) before 1970, essentially unmanaged domestic and distant water fleets,
2) 1970-1981, a period of internationally allocated Total Allowable Catches that were not well enforced,
3) 1982-1995, an input control system (including limited entry, limited days at sea, fishing gear, minimum fish sizes and closed areas) for an exclusively domestic fleet that was based on a

socioeconomic definition of optimum yield (i.e., the Fishery Management Council considered short-term social and economic factors in determining fishery limits),

4) 1996-2009, an input control system for the domestic fleet that was based on achieving maximum sustainable yield (MSY), and
5) an output control and catch share system since 2010.

The fishery-dependent data collection system in the northeast U.S. changed in 1994, transitioning from fishermen interviews in a landings intercept program to self-reported logbooks (i.e., vessel trip reports) to obtain information on fishing effort and location. The frequent changes in management, switch in the fisheries-dependent data collection system, and the multispecies nature of the fishery have hindered the ability to develop useful indices of abundance from fishery data. However, a review of New England groundfish stock assessments recommended that "fishers have a greater trust in the data that they themselves provide, and therefore an effort should be made to validate and use CPUE data" (NRC 1998). Fishermen emphasize the need to examine CPUE data in comparison to survey data, and expressed a willingness to share fine-scale information with scientists and managers on fishing locations and catch rates (Hudson & Joyce 2015). Based on a review of historical use of CPUE in the groundfish assessment process, there are opportunities to reconsider this information for upcoming groundfish assessments which could help to reconcile what fishermen see on the water with the results of analytical analyses (O'Keefe et al. 2015).

Previous assessments of witch flounder included landings per unit effort (LPUE; Wigley & Mayo 1996), but LPUE was excluded from the stock assessment model in 1999 because of uncertainty associated with the effect of the 1994 change in effort reporting on CPUE (e.g., Wigley et al. 1999). The 2015 witch flounder stock assessment has severe retrospective patterns (NEFSC 2015), and fishermen are concerned that the research trawl survey trends do not accurately represent stock abundance trends, because the surveys are not efficient for sampling flatfish (NSC 2016).

The Working Group objective was to develop LPUE/CPUE indices of the witch flounder stock for consideration at the 2016 62nd Northeast Regional Stock Assessment Workshop. The benchmark assessment is expected to consider new information and models for determining stock status and providing catch projections. The consideration of LPUE/CPUE trends will help to quantify fishery-dependent perspectives and possibly to supplement research trawl surveys as indices of stock size.

In discussions following initial reviews of 5 commercial fishery LPUE/CPUE working papers (Cadrin and Wright 2016; Terceiro 2016a, b, c, d) using the NEFSC Dealer, Vessel Trip Report, Observer, and Study Fleet data, the Working Group decided to focus on the commercial Dealer landings data (due to the extended length of time series and large and synoptic sample, in spite of concerns about the lack of inclusion of discards and changing reporting systems over time) as the best candidate for a fishery dependent index of abundance to be used as an assessment model calibration index. The WG decided to revise the data and analysis to include only fish trawls and to consider various thresholds of "directed" of trips (trips with witch flounder accounting for =>10%, =>25%, and =>40% of total trip landings) in further work.

<u>Witch flounder Dealer Data</u>

For witch flounder taken in **"All"** trawl gear trips (all negear "050" to "059", to account for nearly all witch landed), the initial nominal data set for 1964-2015 consisted of 280 million lbs of witch flounder caught on 564 thousand trips, accounting for 678 thousand days fished (DF;

recorded fishing time divided by 24; Terceiro 2016a). The mean total landings lbs per DF (LPUE; LDF) was 416 lbs per DF, with a median of 189, mode of 50, variance of 3 million, standard deviation of 1,724, skewness of 56.4, kurtosis of 8,236, and range from 1 to 338,500 lbs per DF.

These descriptive statistics indicate that the Dealer report Trawl gear landings rate distribution is overdispersed in relation to a normal distribution, as the mean is larger than the mode, the variance is several orders of magnitude larger than the mean, and skewness is larger than zero. The distributions of the observed total landings and LPUE were modeled for three classification variables – calendar quarter (QTR; 1 = Jan-Mar, 2 = Apr-Jun, etc.), 3-digit statistical area (AREA), and vessel tonnage class (TC; binned for vessels < 5 gross registered tons [TC = 1], 5-50 [TC = 2], 51-150 [TC = 3], 151-500 [TC = 4], 501-1000 [TC = 5], and 1001 and larger [TC = 6]), expressed as the cumulative sum or mean of the total landings or LPUE for each class level (Terceiro 2016a).

Modeling Standardized Dealer Report Indices

SAS software version 9 (SAS 2011) was used to develop models of the Dealer Report Trawl Gear landings rate data for witch flounder. The independent variable in this case was the continuous variable total landings per day fished (LPUE; rounded to integer values to be 'discrete' where appropriate), while the classification factors considered were, as noted above, the discrete variables YEAR (the 'year' effect that in a main classification factors only model serves as the index of abundance), calendar quarter (QTR), 3-digit statistical area (AREA), and vessel tonnage class (TC).

The SAS GENMOD procedure was used to fit generalized linear models 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 error (probability) distributions. These include the normal, lognormal, binomial, Poisson, gamma, negative binomial (negbin), and multinomial (McCullagh and Nelder 1989). Given the properties of the Dealer trawl data (e.g., Figures B85-B86), the Dealer landings rate data were modeled using lognormal (for ln-transformed landings rates), gamma, Poisson, and negative binomial (for untransformed landings rates) distributions. The procedure fits a generalized linear model to the data 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 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 fit of the expected error distribution to the data (closer to 1 is better) and is comparable across models for a given error distribution, (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, and across models with the same type of data), (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 (Terceiro 2003, Dick 2004, Maunder and Punt 2004, SAS 2011).

A sequence of models, including from one factor to four factors, were fit and the differences/changes in the goodness of fit diagnostics used to determine the best model under each error distribution assumption. A Type III analysis was used since the results do not depend on the order in which the classification factors are specified. For the discrete variable Poisson and negative binomial error distributions, individual trip catch rate values were rounded to integer values. As noted in the 5 previous working papers, the full-factor (YEAR, QTR, AREA, TC) negative binomial models had the best overall diagnostics and were selected as 'best-fitting.' Therefore in this "Directed" trip work, only full-factor negative binomial models were considered.

Results

For "directed" fish trawl (negear code "050") trips where witch flounder accounted for **40%** or more of the trip reported landings, the data set for 1964-2015 consisted of 44.6 million lbs of witch flounder (**16% of the "All" trip total**) caught on 15,713 trips (**3% of "All" trips**), accounting for 17,109 thousand days fished (DF; recorded fishing time divided by 24; **3% of "All" trips DF**). The mean total landings lbs per DF (LPUE; LDF) was 2,609 lbs per DF (6.3 times the "All" trips lbs per DF), with a median of 2,000, mode of 1,250, variance of 26 million, standard deviation of 5,051, skewness of 21.3, kurtosis of 1,099, and range from 2 to 324,000 lbs per DF. Total reported landings (lbs), trips, days fished, and nominal annual 'directed' LPUE are presented in Table B44 and Figures B83-B84. Model indices (negbin model with Year, Quarter, Area, and Tonnage Class main effects) are presented in Table B45 and Figure B85.

For 'directed' fish trawl (negear code '050') trips where witch flounder accounted for **25%** or more of the trip reported landings, the data set for 1964-2015 consisted of 90.4 million lbs of witch flounder (**32% of the "All" trip total**) caught on 46,953 trips (**8% of "All" trips**), accounting for 45,913 thousand days fished (DF; recorded fishing time divided by 24; **7% of "All" trips DF**). The mean total landings lbs per DF (LPUE; LDF) was 1,969 lbs per DF (4.7 times the "All" trips lbs per DF), with a median of 1,492, mode of 1,250, variance of 15 million, standard deviation of 3,827, skewness of 23.4, kurtosis of 1,464, and range from 2 to 324,000 lbs per DF. Total reported landings (lbs), trips, days fished, and nominal annual 'directed' LPUE are presented in Table B46 and Figures B86-87. Model indices (negbin model with Year, Quarter, Area, and Tonnage Class main effects) are presented in Table B47 and Figure B88.

For "directed" fish trawl (negear code "050") trips where witch flounder accounted for **10%** or more of the trip reported landings, the data set for 1964-2015 consisted of 178.5 million lbs of witch flounder (**64% of the "All" trip total**) caught on 141,321 trips (**25% of "All" trips**), accounting for 147,777 thousand days fished (DF; recorded fishing time divided by 24; **22% of "All" trips DF**). The mean total landings lbs per DF (LPUE; LDF) was 1,969 lbs per DF (4.7 times the "All" trips lbs per DF), with a median of 1,492, mode of 1,250, variance of 15 million, standard deviation of 3,827, skewness of 23.4, kurtosis of 1,464, and range from 2 to 324,000 lbs per DF. Total reported landings (lbs), trips, days fished, and nominal annual 'directed' LPUE are presented in Table B48 and Figures B89-B90. Model indices (negbin model with Year, Quarter, Area, and Tonnage Class main effects) are presented in Table B49 and Figure B91.

Comparison among "Directed" trips LPUE and NEFSC indices

The 'Directed' trips nominal LPUE series are compared Figure B92, the model LPUE series are compared in Figure B93, and the model LPUE series are compared with the NEFSC trawls survey biomass indices in Figure B94. The nominal series have a high degree of

correspondence (Figure B92; r > 0.9), as do the model indices (Figure B93; r >0.9). The model series show similar trends from the early 1970s to the mid-1990s, with the exception of the previously mentioned 'directed' 1992 model index "spike" (Terceiro 2016d); further investigation indicates that this is due to the influence of a few high LPUE trips during a period of relatively low (compared to neighboring years) sample size. All LPUE series show a decrease from the 1960s to the late 1970s, an increase to a peak in the early 1980s, a decrease through the 1980s to the mid-1990s, and then an increase to a peak in the early 2000s. Since 2009, the model series diverge, with the less-directed, but more inclusive 10% model index increasing less (+32%) than the more directed 25% (+48%) and 40% (+64%) series (Figure B93).

When comparing the Dealer LPUE with the trawl survey indices, it should be noted that the survey indices include more young fish (<= 3 years old) than do the Dealer commercial indices based on landed fish, so peaks and valleys may not always exactly coincide due to this "fish growth" lag. The NEFSC trawl surveys series decrease more from the early 1980s to the mid-1990s than do the fishery model indices, while the peak in the early 2000s is comparable at about the respective time series mean (i.e., 1.00). Since the early 2000s peak, the NEFSC trawl survey indices have decreased (spring –71% since 2002; fall –69% since 2001), while the fishery model indices are now at about the same level as in the early 2000s (i.e., at about 1.00 to 1.30 their time series means). Since 2009, the trawl survey spring indices have decreased by –10%, while the fall indices have increased by +17%, and are now at about 40% of their time series means (Figure B94).

*<u>WG recommendation</u>: The Working Group evaluated the **Dealer Report**-based trawl gear landings per unit effort indices (1964-2015 Landings per Day Fished; LPUE, LDF), **Vessel Trip Report (VTR)** trawl gear fishery catch per unit effort indices (1994-2015 Catch per Day Fished; CPUE), the **Observer Program** trawl gear fishery catch per unit effort indices (1989-2015 Catch per Day Fished; CPUE), and the NEFSC Cooperative Research Partners **Study Fleet** trawl gear catch per unit effort indices (2007-2015 Catch per Day Fished; CPUE) for their utility as indices of abundance in the witch flounder benchmark stock assessment.*

For the Dealer data, the Working Group noted that the utility of the LPUE series as the basis for an index of abundance is limited in that a) it includes only landings and not the total catch including discard, so that the resulting landings rates could be biased low relative to the true abundance of fish, and b) the use of only positive trips that land witch flounder may bias the landings rate as well. For the VTR data, the WG noted that given the low discard rate reported, the total catch reported may be biased low relative to the true total catch. For the Observer data, the Working Group noted that there may be a bias in fishermen's behavior when an Observer is aboard the vessel that changes the total catch rate in an uncertain and possibly inconsistent manner. The Working Group also noted that for the Dealer, VTR, and Observer data in particular, the ratio of Days Fished per Trip has 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.

During the respective time series there have been a number of spatial, temporal, and catch limit regulatory changes that could bias the commercial fishery catch rate indices relative to the true abundance of witch flounder. The information on these regulatory changes is not part of the commercial fisheries databases and must be developed independently and integrated within the standardization models, and has not been included here. Given the changing regulatory landscape, there likely have been a multitude of changes in fishermen's behavior and strategies over time, and those have not been accounted for here. The increasing sophistication

of fishing technology (fish-finding electronics, positioning electronics, fishing gear) is likewise not easy to include in fishery dependent catch rate modeling, and has not been attempted here.

The Observer Program data were explored to help inform which LPUE series (10%, 25%, and 40%) would be the most appropriate to use in a model sensitivity run (presentation by WG member M. Palmer). Summaries of Observer Program haul and trip level data for observed hauls for which witch flounder was reported as the target species indicated no strong justification to select one series over another. For consistency with previous assessments, the most directed series, LPUE 40%, was selected.

The Working Group agreed to include the commercial LPUE 40% series as a sensitivity run of the assessment model.

CATCH CURVE ANALYSIS OF FISHERY AND SURVEY CATCH-AT-AGE DATA

The Working Group reviewed a catch curve analysis (Palmer 2016). Catch curves were constructed for the aggregate total fishery catch numbers-at-age (combined landings and discards) and the NEFSC spring and fall bottom trawl survey indices-at-age (number/tow) based on the methods of Robson and Chapman (1961). Catch curves were conducted on a cohort basis rather than an annual basis which removed the confounding effects of differential year class strength on the interpretation of catch curve results. For the total fishery catch-at-age, linear regressions were fit to the log transformed catches of ages 7 to 10 for the 1975 to 2006 year classes (Figure B95) and ages 5 to 9 for the 1975 to 2006 year classes for the NEFSC spring (Figure B96) and fall (Figure B97) surveys. While these age ranges may not precisely match the fully recruited ages, it offers a compromise between full selection and having sufficient ages to fit a reliable regression. The slope of the regressions provides a model-independent estimate of cohort Z. The analyses suggest time series Z estimates averaging around 0.4 to 0.5 in the NEFSC surveys with no clear time series trends while the Z estimates from the total fishery catch were marginally higher with some indication of an increasing trend, particularly after 1983 (Figure B98).

Catch curves can also be useful for making general inferences on the selectivity of both fisheries and surveys. While selectivities can be estimated from the fitting of stock assessment models, it is useful to have model-independent estimates of selectivity that can be used to validate model-based estimates and/or provide some *apriori* understanding of selectivity. A method described in Restrepo et al. (2007) uses the residuals from the log-transformed linear catch curve analysis to infer relative selectivity-at-age. Selectivities are estimated using the ratio of observed to predicted catch proportions and then rescaling the residuals from each curve so that the maximum positive residual equals 1. The distribution of selectivities-at-age from all cohorts was examined to evaluate the time series distributions of catch selectivity at age. While this approach masks any changes that may be occurring in the selectivity across time, it is useful for gaining a general understanding of catch and survey selectivities and evaluating whether there is strong evidence for the presence of domed-selectivity (i.e., lower selectivity at older ages). Examination of the residual patterns suggest full selectivity not occurring until ages 6-8 in the NEFSC surveys and age 8 in the total catch (Figure B99). Both the NEFSC survey and total catch residual distributions suggest that there may be some degree of doming beyond the age of full selectivity.

Comparing the ratio of catch-at-age of fishery catch to surveys can be helpful for gaining a qualitative understanding of the selectivities of each (e.g., is the fishery likely to have lower

selectivity at older ages relative to the survey). While these comparisons do not offer definitive estimates of overall selectivity, they are helpful for gaining an understanding of the relationships in a model-independent framework (Clark 2013). The proportion of fish age-6 to 11+ fish caught in the NEFSC surveys relative to the fishery (Table B50). The comparison suggests a higher proportion of age-6 fish and a lower proportion of older fish (with the exception of the 11+ group) caught in the survey relative to the fishery. These results are likely skewed by the fact that fish are not fully selected to the fishery until age-7 or 8 whereas they are selected to the survey around ages 5 or 6. While there is a general trend for lower selectivity of the older ages in the survey, this trend is not consistent with nearly half of the ratios for age 9 and 10 in the spring survey and age 7 and 10 in the fall survey greater than or equal to 1. The NEFSC surveys appear to capture a higher proportion of fish 11+ relative to the fishery. Overall, the results are inconclusive with no clear evidence of doming being greater in either NEFSC surveys or the fishery.

WG recommendations: *Based on this analysis, there was no clear evidence of doming. Model sensitivity to dome selectivity should be conducted.*

TERM OF REFERENCE 3: Investigate effects of environmental factors and climate change on recruitment, growth and natural mortality of witch flounder. If quantifiable relationships are identified, consider incorporating these into the stock assessment.

The WG considered three working papers: (1) changes in distribution of larval, juvenile and adult witch flounder; (2) estimated witch flounder habitat using random forest models; and (3) environmentally explicit stock-recruitment relationships in witch flounder.

Changes in the Distributions of Larval, Juvenile, and Adult Witch Flounder in the Northeast U.S. Shelf Ecosystem (Walsh et al. 2016)

Background

The spatial distribution of larval and adult witch flounder and seasonal occurrence of larvae in the Northeast U.S. Shelf Ecosystem were examined for distribution changes between two decades (Walsh et al. 2015). Larval witch flounder did not shift significantly spatially or seasonally, but adults shifted significantly deeper in the spring when comparing 1977 – 1987 to 1999 – 2008 (Walsh et al. 2015). The analyses were updated through 2015, and include new analyses of juvenile (< 30 cm) witch flounder.

Methods

Methods were described in Walsh et al. (2015). Briefly, the relative proportion (percent of annual sum) of estimated absolute number of larvae, juveniles, and adults within each of 47 Ecosystem Monitoring (EcoMon) strata were used to examine changes in distribution. The EcoMon strata, which combine some bottom trawl survey strata, were used to allow comparisons to be made among the life stages, and the larval strata were originally developed using the stratum design of the bottom trawl survey. Significant differences of stratum proportions between time periods were calculated using a Kruskal-Wallis chi-square. The stratum-specific Kruskal-Wallis H values were considered a measure of the magnitude of change. Three linear regressions were calculated using the strata Kruskal-Wallis H as the independent variable and along-shelf distance (km), cross-shelf distance (km), and depth (m) values as the dependent variables to test whether distribution changes were coherent in the along-shelf, cross-shelf, and depth dimensions.

For larvae, three bimonthly seasons representing the early (March – April), peak (May – June), and late (July – August) larval seasons were examined. We compared the Marine Resources Monitoring, Assessment and Prediction (MARMAP; 1977 - 1987) and EcoMon (1999 - 2015) programs (Figure B100). Timing of larval occurrence was also examined between the time periods to infer changes in timing of spawning, using similar methods used to examine changes in distribution.

For juveniles and adults, the number of witch flounder caught per tow during the NEFSC bottom trawl surveys were calibrated to Albatross units for collections from 2009 onward. No length based correction used, and the number per tow was divided by 3.257177 (Miller et al. 2010) to transform from Bigelow to Albatross units. For juvenile (< 30 cm) and adult (>= 30 cm) flounder, relative proportions of flounder for each NEFSC bottom survey were calculated: spring (March-April) and fall (September-October). Two 20 year time periods, 1970 - 1989 to 1996 – 2015, were compared.

Changes in the capture of witch flounder during the NEFSC bottom trawl survey by habitat (e.g., bottom water temperature and depth) in the Gulf of Maine region strata used in

previous assessments (NEFSC 2015) were examined. Annual stratified mean bottom temperature (^{o} C) and depth (m) was calculated using stratified mean catch per tow of juvenile and adult witch flounder for survey stations. Years with less than 90 % of stations with bottom temperature data were excluded from the mean bottom temperature analysis. Linear regressions were calculated for juveniles and adults during each survey season to determine if there was a significant change in stratified mean habitat. The p-val, r^2, and slope values reported were bootstraped 1000 times runs across years analyzed.

Results

Witch flounder larval distribution and timing of occurrence changed little over the past four decades (Figure B101). Most change in relative larval proportions among stratum occurred during the late-larval season (Figure B101, subplot C; July – August), with lower proportions in seven strata in the Mid-Atlantic Bight and Southern New England regions from 1999 to 2015. However, no significant change in along-shelf, cross-shelf, or depth dimensions occurred (Figure B101, subplots D-F).

Juvenile witch flounder distribution shifted significantly over the past forty years (Figure B102). Juveniles shifted northward and deeper in the spring, with higher proportions in the Gulf of Maine over the last 20 years (Figure B102, subplots A, C, and E). In the fall, juveniles shifted offshore, with higher proportions along the shelf edge in Southern New England, central Gulf of Maine, and Georges Bank (Figure B102, subplots B and D).

Adult witch flounder distribution shifted significantly over the past four decades (Figure B103). Adults shifted deeper in the spring, with higher proportions during 1999 to 2015 in the central Gulf of Maine and lower proportions in the eastern Gulf (Figure B103, subplots A and E). In the fall, adults shifted offshore, with higher proportions along the shelf edge in Southern New England, central Gulf of Maine, and Georges Bank (Figure B103, subplots B and D).

The changes in juvenile and adult witch flounder distributions resulted in significant changes stratified mean habitat. Water temperatures have generally increased 1 – 1.5 ^{o}C in the ecosystem over the survey time period (Fratantoni et al. 2015). Witch flounder stratified mean bottom water temperature did not significantly change during the spring survey, but linear trends have tracked the increasing average bottom water temperature sampled (Figure B104, subplot A). Adult witch flounder stratified mean bottom water temperature significantly changed (p-val ≤ 0.04, df = 37, $r^2 = 0.24$, slope = 0.03) in the fall survey, and witch flounder were caught at or near average temperatures sampled (Figure B104, subplot B). Witch flounder significantly increased stratified mean depth during the spring and fall surveys (Figure B105) for both juveniles (spring: p-val ≤ 0.001, df = 46, $r^2 = 0.33$, slope = -0.83; fall: p-val ≤ 0.001, df = 51, $r^2 = 0.33$, slope = -0.72) and adults (spring: p-val ≤ 0.002, df = 46, $r^2 = 0.27$, slope = -0.53; fall: p-val ≤ 0.02, df = 51, $r^2 = 0.20$, slope = -0.28). Juvenile and adult witch flounder were collected near or above the mean depth sampled during the bottom trawl surveys before about 1985, but now are caught mostly below the mean depth sampled, particularly for juveniles (Figure B105).

Estimated witch flounder habitat using random forest models by Friedland (NEFSC)

The working group considered a series of Random Forest models of witch flounder habitat based on catches in numbers and weight from the bottom trawl survey. Random Forest is a machine learning method associated with a group of classification and regression trees that are a collection of results from a large number of decision trees based on randomized subsamples of the data (Breiman 2001). It is this subsampling that produces models that are robust to the types

of data used, including highly correlated variables and missing data, resistant to over fitting, and provides measures of variable importance and node proximity (Cutler et al. 2007). In a comparison of supervised learning algorithms, Random Forest was found to be among the top performing models for classification given a range of performance criteria (Caruana and Niculescu-Mizil 2006). Increasingly, this type of classifier is being applied to estimate fish habitats, drawing upon environmental variables to inform model construction (Knudby et al. 2010; Lin et al., 2015).

Regression and classification Random Forest models were fit utilizing a mixture of static and dynamic variables. The regression models estimated habitat based on spring and fall biomass and abundance data. The same model formulation was used in all four models: Log10 (biomass/abundance + 1) ~ soft_sed, bpi_30_250_layer, DEPTH, BOTTEMP, chl_4km_month_1, chl_f_4km_month_1, sst_4km_month_1, sst_f_4km_month_1. The soft_sed, bpi_30_250_layer, DEPTH were static variables and BOTTEMP, chl_4km_month_1, chl_f_4km_month_1, sst_4km_month_1, sst_f_4km_month_1 were dynamic variables. The variables were described in the data meeting with the exception of the dynamic fields of bottom temperature used to develop habitat maps, which were estimated use spline interpolations of the spring and fall survey bottom temperatures by year. The same model formulation was in the classification models except the fits were to spring and fall absence presence (factor 0,1).

The regression models all had good fit diagnostics. All four models had pseudo r^2 greater than 0.86 and mean square error rates (MSE) of ~0.0033 for the biomass models and ~0.014 for the abundance models. DEPTH was the most important variable in all the models with BOTTEMP, bpi_30_250, and soft_sed being high contributors. With a model fit for each of the four models, retrospective data for the years 2000-2015 were assembled and spring/fall biomass/abundance were estimated each year. Figure B106 provides an example of a habitat map, in this case 2000 spring abundance estimates based on the spring model. The biomass model analysis suggests witch flounder habitat declined to low levels in the period 2008 to 2013 and showed some sign of recovery in the most recent years (Figure B107). The classification models fits were satisfactory as seen in the confusion matrices for the models. The OOB (out of bag sample used as classification test samples, which make the error rate a cross-validation estimate) classification error rates were 15.99% and 12.41% for the spring and fall models, respectively. Estimates of absence presence habitat time series were not available.

These types of habitat models and habitat estimates based on other procedures such as generalized additive models (GAMS) can be applied in a number of phases of this and other assessments. They provide a framework to analyze the availability of the species to survey gear based on changes in habitat and thus may provide estimates of catchability. The standard approach to the stratification of survey indices of abundance are based on strata that are in part based on ecological aspects of the ecosystem, i.e., depth. Habitat analyses provide alternative approaches to the way survey data are stratified that represent more natural grouping of tows by habitat. These stratification strategies may also be applied to empirical analyses such as swept area estimates of absolute abundance.

Environmentally explicit stock-recruitment relationships in Witch Flounder (Hare et al. 2016a)

Methods

Recruitment was derived from preliminary ASAP model runs. Three preliminary model runs were examined: Run 9 uses all survey indices (NEFSC, ASMFS, and MENH); Run 10 includes LPUE; Run 15 explores uncertainty in catch.

Fall bottom temperatures were derived from the deeper portions of the Gulf of Maine using temperature observations made on the fall trawl survey.

Environment-recruitment relationships were conducted per Hare et al. (2015). The underlying hypothesis examined was that fall temperature determine the amount of available juvenile habitat and warmer temperature reduces available habitat and recruitment (*sensu* Miller et al. 2016). The recruitment provided in the ASAP model output is for Age 1 fish and it is assumed that recruitment in the model output lagged by 1 year would align with the year of spawning and the corresponding SSB.

Results and Discussion

Based on the analyses conducted, there was no evidence of temperature influencing recruitment (Figures B108-B110).

In general, recruitment was high at low spawning stock biomasses and exhibited no relationship with temperature. Steepness in all model runs was quite high – approaching or equaling 1. The Beverton-Holt relationship without environment had the lowest AIC score for all three model runs.

The shape of the recruitment data suggests that a Ricker stock-recruitment relationship may be appropriate, but the density dependence of such a function would be quite high (depressing recruitment at high spawning stock biomasses).

WG recommendations: An examination of available NEFSC trawl survey data indicated that while there have been some 'statistically significant' changes in mean temperature and depth of juvenile and adult witch flounder distribution, the slopes of the linear change are not large and movement has been within the stock definition strata set. There is also evidence of increases in the mean temperature and depth of the habitat occupied by witch flounder, but a model of changes in 'available witch flounder habitat' did not indicate a trend over the time series. Modeling revealed no evidence of temperature influencing recruitment.

TERM OF REFERENCE 4: Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3 if appropriate), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections. Compare F's and SSB's that were projected during the previous assessment to their realized values.

> ***SARC-62 Opinions****: The VPA, ASAP, and SCAA age-structured models applied to data for the witch flounder fishery were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice.*
>
> *Based on an empirical area swept method (that includes the results of the NEFSC survey efficiency experiment) conducted by the SAW and examined at the SARC, stock biomass has declined since 2002 and appears to be 16,181 mt Jan-1 surveyable biomass in 2016 and 14,563 mt exploitable biomass in 2016.*
>
> *Survey population biomass was converted to exploitable biomass using a factor of 0.90 based on examination of survey and fishery selectivity patterns from the base ASAP assessment.*
>
> *The relative exploitation rate needed to achieve the recent observed catch is approximately 0.05.*
>
> *The fishery landings and survey catch by age indicate truncation of age structure and a reduction in the number of old fish in the population.*
>
> *The time series of recruitment is not available from the empirical area swept method. All the surveys indicate the 2013 year class is relatively strong. However, this year class is not expected to fully recruit to the directed fishery until 2020 at age 7 and should start to appear in the large mesh otter trawl discards in 2017 at age 4. The absolute size of the 2013 year class is uncertain since the estimate is based on only two years of survey observations.*

The WG considered four approaches for estimating annual fishing mortality, recruitment and stock biomass with which to determine stock status and catch advice: (1) minimum estimates of spawning stock biomass; (2) an empirical approach; (3) a replacement yield approach; and (4) three analytical models (VPA, SCAA, and ASAP). A brief overview of each approach is provided followed by the WG discussion on the pros and cons of each approach and why the WG accepted the ASAP model to provide estimates of annual fishing mortality, recruitment, and spawning stock biomass for determining stock status and catch advice.

MINIMUM ESTIMATES OF SPAWNING STOCK BIOMASS FROM NEFSC FALL

SURVEY

The WG reviewed minimum estimates of witch flounder spawning stock biomass using the 2016 experimental estimates of catchability on the NEFSC trawl survey (See Appendix B1for the Hare et al. 2016b working paper and supplement equations.)

A minimum estimate of spawning stock biomass using the survey data and the results of the catchability experiment were developed using the following equation:

$$SSB_t = \sum_{L=1}^{maxL} \frac{(N_{L,t} * W_L * P_{L,t})}{(\delta_L * \rho_L)} * \frac{A}{a}$$

where:

SSB_t = Spawning stock biomass in year t (kg)
N_L= Stratified Mean Number tow^{-1} at Length (L) in year t
W_L= Weight at Length (kg)
P_L= Proportion mature at Length
δ_L = detectability at Length
ρ_L = availability at Length (Set to 1 in this analysis)
A = Total stock area covered by survey (km^2)
a = area covered by a tow (km^2 tow^{-1})

Further information on basic biological parameters is required to implement this equation. The annual parameters used in the stock assessment for the logistic maturity at length equation were:

$$P_L = \frac{1}{1+e^{-(\alpha+\beta L)}}$$

These parameter values for maturity are given below (S.Wigley, NEFSC pers comm):

Maturity parameters used in the evaluation of Spawning Stock Biomass

	2009	2010	2011	2012	2013	2014	2015
a	-9.49773	-10.1677	-9.29966	-9.93273	-10.0779	-10.4224	-10.4224
b	0.289028	0.309791	0.28935	0.304885	0.308803	0.318461	0.318461
L50 (cm)	32.86	32.82	32.14	32.58	32.64	32.73	32.73

The length-weight equation for witch flounder in Burnett et al. 1992 was used ($W_L = aL^b$) where ln(a)=-13.553 and b=3.4384. These values were assumed to be constant across years.

Availability at length (ρ_L) was assumed to be 1 across all age classes. The stock

assessment considers witch flounder present in the Gulf of Maine to be a unit stock, separate from fish off Southern New England (beyond the NEFSC survey strata area). The abundance of witch flounder in the inshore areas of the Gulf of Maine not surveyed by the NEFSC is very low, and thus the assumption that the population occurs completely within the footprint of the trawl survey is reasonable.

Consistent with the stock assessment, the offshore NEFSC trawl strata 22-30 and 36-40 were used. The Area (A) covered by these strata is 75,728 km^2. The analyses focused on data collected by the NEFSC trawl survey since 2009 on the R/V Henry Bigelow. The area covered by an average tow on the NEFSC trawl survey is 0.024 km^2.

Stratified mean number at length (N_L) of witch flounder was calculated using standard approaches for only the fall trawl survey. The rationale for focusing on the fall trawl survey was presented in the September data meeting paper.

Detectability at length (δ_L) was calculated based on the results of the twin trawl experiment (aka sweep study) assuming that the detectability of the chain sweep gear was 1. Two analyses were performed on detectability at length from the catchability experiment, one using a beta-binomial analysis and the other using bootstrapping. The results of the two approaches were very similar. The detectability at length from the 1000 bootstrap runs was used in this analysis. As with previous analyses, we used a weighting factor of 0.57 for the nighttime detectability results and 0.43 for the daytime detectability results to account for the higher proportion of nighttime tows during the fall trawl survey in the Gulf of Maine.
Estimates of minimum spawning stock biomass for the Bigelow survey (2009 to 2015) ranged between 8,100 and 16,600 mt (Table B51).

AN EMPRICAL APPROACH

An empirical approach using witch flounder NEFSC bottom trawl survey data and the survey catchability estimate derived from the recent sweep study (Hare et al. 2016b) was considered by the WG as a backup method to provide catch advice in case modeling approaches did not provide defensible results. The empirical approach used is similar to that used in the Georges Bank yellowtail flounder stock assessment (Legault and Busawon 2016).

The NEFSC spring and autumn time series weight per tow indices (Table B28) were used in which the 2009 – 2016 survey indices were converted to Albatross (ALB) units using a calibration factor of 3.2572 (Miller et al. 2010). Minimum swept area biomass was derived using the witch flounder survey strata set area (22,321 nm^2 converted to 76558.89 km^2), the Albatross net footprint (wing spread; 0.038 km^2), and the Bigelow net footprint (wing spread; 0.024 km^2). Population biomass was derived assuming a Bigelow catchability of 1 and then assuming the chain sweep catchability of 1 (Tables B52 and B53; Figures B111 and B112).

For minimum swept area biomass, the relationship between survey area (*A*) and biomass correlates positively (lower *A* results in lower biomass and higher *A* results in higher biomass); however, the tow footprint (*a*) correlates negatively with biomass (lower *a* results in higher biomass and higher *a* results in lower biomass (Figures B111 and B112, subplots B and C). The Bigelow biomass does not change because the Albatross units account for both the BIG:ALB conversion and the relative size of the tow footprint (5.1572; Tables B52 and B53; Figures B111 and B112, subplots C). The Bigelow and Bigelow to ALB values are identical. The BIG:ALB conversion and the tow footprint impact the joining of the two time series (Figures B111 and B112, subplots D). In the sweep study, the Bigelow catchability is estimated to be 0.291 when

the chain sweep catchability is assumed to be 1. A lower catchability results in a higher biomass and conversely, a higher catchability results in a lower biomass.

To estimate beginning year biomass, a simple average of the NEFSC spring and autumn population biomass estimates is used. To utilize the most recent survey information, the autumn biomass in year t is paired with the spring biomass in year t+1 to provide catch advice for year t+2 (Table B54). Survey population biomass was converted to exploitable biomass using 0.90 based on examination of survey and fishery selectivity patterns from the base ASAP assessment (Table B54; Figure B113). An exploitation rate of 0.16 (based on the ASAP base run Fmsy = F40% = 0.19 and M = 0.15; Table B54) was used to convert exploitable biomass into estimates of the overfishing limit (OFL). The acceptable biological catch (ABC) was estimated using 75% (common practice) of the OFL (Table B54; Figures B114 and B115).

Estimated OFL and ABC are higher than actual annual OFL and ABC that are based on previous assessments and Science and Statistical Committee decisions (Figures B114 and B115). It should be noted that actual catch is calendar year, not fishing year. Historical exploitation rates indicate that an exploitation rate of 0.16 or higher has only occurred three times in the time series (Figure B116) indicating this is too high a value. The working group suggested a value around 0.05, the average of the most recent nine years, would be a more appropriate exploitation rate for this stock given the trends observed in the surveys and the estimated catches. Applying an exploitation rate of 0.05 to the most recent average biomass results in an OFL for 2017 of 728 mt (Table B55, Figures B117 and B118) compared to the OFL for 2017 of 2,330 mt when the exploitation rate is 0.16. Using historical exploitation rates is useful to "ground truth" the choice of exploitation rate. The magnitude (not the trend) of the catch advice will change when choices for q, area, conversions factors, etc. change.

Uncertainties associated with this approach include: the Bigelow to Albatross calibration, the area of the survey, tow footprint, chainsweep:rockhopper calibration, survey conversion between average biomass and exploitable biomass; the exploitation rate apply for catch advice, the appropriate exploitation rate for this stock, and whether any time series smoothing should be applied to the data or catch advice. This approach does not consider the age information and age-based projections cannot be performed using this approach. The working group did not discuss specifics about how to address any of these uncertainties.

REPLACEMENT YIELD MODEL

The "replacement yield" (RY) model is form of an age-aggregated dynamic surplus production model approach using a time series of catches and one or more indices of abundance with associated measures of precision, if available. When applied to witch flounder, the approach utilized catch, the NEFSC spring and autumn bottom trawl survey information and the 40% LPUE series and was conducted with a selection of 3 time periods, 4 values of q and with and without LPUE and NEFSC survey abundance series. See Appendix B2 for Butterworth and Rademeyer's working paper entitled "Replacement Yield Model Assessments of Gulf of Maine-Georges Bank Witch Flounder".

VIRTUAL POPULATION ANALYSIS (VPA) MODEL

The existing assessment model is VPA (Virtual Population Analysis v3.4.4), which can be obtained from the NOAA Fisheries Toolbox (NFT 2014b, http://nft.nefsc.noaa.gov/). As described at the NFT software website, population cohorts are estimated by a backward projection method. Catch is assumed to be measured without error. Population estimates are chosen so as to minimize the sum of squares difference between the population abundance and a set of one or more abundance indices. Catchability coefficients are estimated as functions of population estimates and observed indices. Bootstrapping is used to estimate the precision of all model parameters and all quantities that are functions of model parameters.

The current assessment used VPA v3.4.5 software, the same as used in the previous 2015 Operational Assessment. The VPA formulation was the same as the previous assessment and used USA total catch (landings and discards for ages 3 to 11+; Table B24) through 2015 and NEFSC spring and autumn survey abundance indices (ages 3 to 11+ through 2016 and 2015, respectively, to estimate stock sizes for ages 3 to 10. All indices are given equal weighting. Autumn survey indices are lagged forward one year and one age to calibrate with beginning year population sizes of the subsequent year.

For all VPA runs, NEFSC spring and autumn relative abundance indices at age (Table B30) were transformed into swept area absolute abundance indices (swept area numbers, SWANs in F/V Albatross (ALB) units using the witch flounder survey strata set area of 22,321 nm^2; a trawl swept area [wing spread] of 0.0112 nm^2; survey catchability (q) = 1 for Runs F1 and A1 and q = 0.056 for Run A2) and used as tuning indices to explore changes in model-estimated survey catchabilities. In previous assessments, the SWANs were derived using an assumed survey catchability of 1. The VPA runs for the current assessment used the survey time series with a split between 1994 and 1995 as was done in previous assessments to reduce the retrospective pattern. A flat-top partial recruitment vector is assumed, with full fishing mortality on ages 8 and older (F). The F on ages 10 and 11+ in all years prior to the terminal year is derived from the weighted estimates of Z on ages 8 and 9. Instantaneous rate of natural mortality is assumed to be 0.15. Spawning stock biomass is calculated at time of spawning (March) and mean weights at age calculated by the Rivard method (NFT 2008). Annual maturity ogives are estimated using NEFSC spring maturity at age data through 2016, pooled by 5-year moving time blocks.

Two VPA bridge runs were conducted to step through the changes from the previous assessment accepted run (VPA Run F): (1) VPA Run F1 used the revised catch at age (1982-2014) that incorporated the revised discard estimates; (2) VPA Run A1 incorporated an additional year of data to the catch at age (1982-2015) and maturity ogive. The VPA Run A2 was identical to VPA Run A1 except that it used NEFSC survey swept area numbers (SWANs) derived using the witch flounder survey catchability of 0.056. Although no change to the estimates of F or SSB were expected between VPA Run A1 and VPA Run A2, the comparison was performed to examine changes in the model estimated qs. See Appendix B4 for VPA Run A2 input. No VPA model sensitivities were conducted.

The Working Group reviewed the bridge runs and noted the discard estimation refinement had minimal impact on estimates of F and SSB in the terminal year (Table B56). The VPA diagnostics indicate similar patterns among the runs; however, there was a change in the model-estimated survey catchabilities between Run A1 and A2 as the result of using q=0.056 in the SWANs (Table B56); the qs exceeded 1 in Run A2.

VPA model diagnostics and results are given in Tables B56-B59 and Figures B119-B129. The VPA RUN A2 had a mean square residual of 0.676, the CVs for estimated stock size at age ranged between 29% and 60% (Table B56), and the CVs for survey catchability coefficients (q)

were consistent, ranging from 12% to 43%. In VPA RUN A2, the 1982-1994 series qs ranged between 0.1 and 4.3 and the 1995-2015 qs ranged between 1.3 and 6.8, exceeding the expected q =1 (Figure B119). The pattern of increasing survey catchabilities at age for younger fish and a general level pattern at older ages appeared reasonable; however, the magnitude of the qs indicates a model scaling issue. The cause of the increased q between the 1982-1994 and 1995-2015 series remains unknown.

The model-estimated partial recruitment pattern for the most recent five years is given in Figure B120 and reveals a flat-top selectivity at age pattern for the catch.

Residual patterns from the NEFSC survey tuning indices and indices at age from the VPA RUN A2 are given in Figures B121 and B122. The patterns appear random for most ages; however, for some ages (7 and 10) there appear to be blocks of positive and negative residuals.

Estimates of catch, SSB, F, Age 3 stock size are given in Table B57 and Figure B123 and beginning year stock sizes, F and SSB at age are given in Table B58. Results indicate average fishing mortality (ages 8-9, unweighted) increased from 0.26 in 1982 to 0.70 in 1988, declined to time series low of 0.23 in 1992, increased to a time series high of 1.14 in 1996 and fluctuated until 2012 and then subsequently declined to 0.43 in 2015 (Tables B57 and B58; Figure B123). Spawning stock biomass declined from a time series high of 16,677 mt in 1982 to 3,927 mt in 1996, increased to 6,827 mt in 2000 and then declined to time series low of 2,134 in 2013 mt; SSB remains low at 3,044 mt in 2015 (Tables B57 and B58; Figure B123). Since 1982, recruitment at age 3 has ranged from approximately 3.5 million fish (2007 year class) to 19.1 million fish (1980 year class) with a mean of 9.8 million fish (Tables B57 and B58; Figure B123. The addition of the recent year class to the stock-recruit data continued the negative trend observed in this relationship in the previous assessment (Figure B123). As in previous assessments, the Age 3 stock size in terminal year + 1 (2013 year class) is poorly estimated (60% CV; Table B56).

The retrospective pattern in previous assessment is still present in VPA RUN A2, in which average F was underestimated and SSB was overestimated, and the magnitude of the error was similar to the previous assessment as measured by the Mohn's rho statistic. The Mohn's rho statistic (Mohn 1999) was derived by taking the average of seven (2009 – 2015) relative differences between the quantity (e.g., F, SSB, and Age 3) from the reduced time series assessment and the same quantity from the full assessment. The VPA RUN A2 Mohn's rho statistics for F, SSB and Age 3 was -0.38, +0.50 and +0.69, respectively (Table B56; Figures B123 -B125).

The precision of the 2016 stock size at age, F at age in 2015, and SSB in 2015 from the VPA RUN A2 was evaluated using bootstrap techniques. Bootstrap results of the RUN A2 suggest that the estimates of F and spawning stock biomass are relatively precise with CVs of 19% and 11%, respectively. The 90% confidence interval (CI) for F_{2015}= 0.43 was 0.33 and 0.59, and for SSB_{2015} = 3,044 mt the 90% confidence interval was 2,601 mt and 3,740 mt (Table B59). The range of the bootstrap estimates and the probability of the individual values are presented in Figure B127.

An important source of uncertainty in the VPA Run A2 model is the major retrospective pattern wherein fishing mortality is underestimated and spawning stock biomass and recruitment are overestimated. The 7-year Mohn's rho, relative to SSB, was +0.51 in the 2015 assessment and was +0.50 in the VPA Run A2 and Mohn's rho, relative to F, was -0.38 in the 2015 assessment and was the same in the VPA Run A2 (Table B56). The VPA Run A2 retrospective pattern was considered to be a major retrospective pattern for this model because the rho adjusted estimates of 2015 SSB (SSB_{rho} = 2,035) and 2015 F (F_{rho} = 0.69) were outside the

approximate 90% confidence region around SSB (2,601 – 3,740) and F (0.33-0.59; Table B59; Figure B128).

Comparisons of time series estimates of F, SSB and Age 3 recruitments for VPA Runs F (2015 OA), F1 (bridge run), and A2 (updated model) reveal similar trends among VPA runs (Figure B129).

STATISICAL CATCH AT AGE (SCAA) MODEL

See Appendix B3 for Butterworth and Rademeyer's working paper entitled "Exploratory Catch-at-Age Assessments of Gulf of Maine-Georges Bank Witch Flounder".

AGE STRUCTURED ASSESSMENT PROGRAM (ASAP) MODEL

The new assessment model is ASAP (Age Structured Assessment Program v.3.0.17, Legault and Restrepo 1998), which can be obtained from the NOAA Fisheries Toolbox (NFT 2014a, http://nft.nefsc.noaa.gov/). As described at the NFT software website, 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. Discards can be treated explicitly. 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 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 (Legault and Resprepo 1998).

The WG considered a wide range of sensitivity runs to the base cases of the NEFSC ASAP and Butterworth/Radermayer SCAA models. These included (but were not limited to):

1) split in the NEFSC surveys (SVs) in 1993/1994, a configuration used in previous assessments to allow a change in catchability (q) to reduce the retrospective error in the VPA models used in previous assessments

   WG concluded that the NEFSC SV split in 1993/1994 was no longer effective in reducing the retrospective error, and dropped this aspect from further models.

2) flexibility of the models in fitting "time-blocks" for fishery selection: 1 block (1982-2015), 2 blocks (1982, 1993), and 3 blocks (1982, 1993, 2001-2005 [2005 selected])

WG concluded that the 3 blocks for fishery selectivity provided best model diagnostics, consistent results between ASAP and SCAA, and was roughly coincident with changes in the fishery and management.

3) split in the NEFSC SVs in 2008/2009, a configuration that removes the need to calibrate current Bigelow (BIG) survey indices to the historical Albatross (ALB) series, and to observe the model response in q

   WG considered pros and cons of retaining the ALB calibrated series vs. splitting the NEFSC SVs into independent ALB and BIG series.

   The WG noted several reasons to retain the ALB calibrated series: BIG series too short to stand alone; split perhaps allows too much flexibility, with some counterintuitive results in terms of ALB vs BIG q; limited age structure in short BIG series results in lack of precision in estimates of survey selectivity; effectively includes results of calibration experimental results (ALB to BIG 3.2572).

4) flexibility of the models in fitting fishery selectivity above the age of full (apical) selection, typically age 7 (block 1982-1992) or 8 (1993-2004, 2005-2015)

   WG concluded that the model diagnostics do not strongly support high flexibility to estimate fishery selection above age 7-8. Likewise, analyses external to the analytical models (catch curve analyses, distribution of proportion at length in different bottom types (Wigley 2016), consideration of size at age) do not provide strong evidence for dome shaped fishery selectivity. Going forward, WG elected to use flat top fishery selectivity, and will provide a sensitivity showing the effects of more flexibility for the final model configuration.

5) flexibility of the models in fitting survey selectivity above the age of full (apical) selection, typically age 7 in NEFSC SVs, and younger in the ASMFC shrimp (age 3-4) and MENH trawl surveys age (age 1)

   WG concluded that the model diagnostics do not strongly support high flexibility to estimate NEFSC survey selection above age 7. Likewise, analyses external to the analytical models (catch curve analyses, distribution of proportion at length in different bottom types, consideration of size at age) do not provide strong evidence for dome shaped survey selectivity. Going forward, WG elected to use flat top survey selectivity, and will provide a sensitivity showing the effects of more flexibility for the final model configuration.

6) for NEFSC SVs expanded to swept-area numbers using ALB q = 0.056 and BIG q = 0.291, fixing model aggregate catchability of the NEFSC SVs at 1, to observe the response of other model calculated/estimated parameters and residuals

   WG concluded that fixing NEFSC SV q = 1 was effective in demonstrating model responses, which were comparable for ASAP and SCAA, but did not provide plausible

results for some estimated parameters within the analytical models (i.e., implausible fishery and survey selection patterns).

7) inclusion of fishery LPUE (witch flounder "directed" trips) as an index of stock biomass in model calibration

   The WG included the Dealer data LPUE series to examine the response of the ASAP and SCAA models; models behaved similarly. The WG noted in the Data Meeting that (1) the utility of the Dealer Report data as the basis for an index of abundance is limited in that they 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 land witch flounder may bias the LPUE as well, and may be influenced by management regulations, and (3) the ratio of Days Fished per Trip has 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. Because of the unknown bias concerns, and issues in model diagnostics when the LPUE is included with survey series as calibration indices, the WG elected not to include the Dealer Directed Trips LPUE in final age-structured model development.

8) increase in landings since 1996 by varying scalar factors (up 5 times), to reduce to retrospective error and observe the model response in calculated qs

   The WG found that increasing the catch or M in the ASAP model was effective in reducing the retrospective error in the model. The magnitude of the increase in catch (3.0 to 5.0 times) or M (2.5 to 3.0 times) needed to reduce the retrospective error to a small amount also improved the residual diagnostics for the fishery catch components and marginally improved the residual diagnostics for all surveys, and reduced the NEFSC survey qs. The timing of the "step-increase" in fishery catch informed by large changes in model diagnostics in the early 2000s and was coincident with a change in catch reporting in 2004. Uncertainty in the catch of witch flounder has increased due to recent allegations of catch misreporting currently under litigation. Other than this information, the WG does not currently have access to any publically available independent evidence or justification for such a large unaccounted fishery catch or large increase in M over the last decade. The WG recognizes that such large removals could alias other unknown mortalities.

9) change in the "plus-group" from age 11 and older (11+) to age 9 and older (9+), to examine effects on "post-apical" age selectivity

   The WG examined the response of the ASAP model to this change, and found that the NEFSC SVs q decreased by a small amount, and the decrease in selectivity for the plus group was still large for the run that allowed for this flexibility (down from S = 1.0 at age 8 to about S=0.40 at age 9+). Therefore, this sensitivity run was not very helpful in informing the specification of the fishery selection pattern.

10) for NEFSC SVs expanded to swept-area numbers using ALB q = 0.056 and BIG q = 0.291, use door spread instead of wing spread in the area expansion (reduces SWAN), to observe the response of the model

The WG noted that expansion factor of wings to doors was not sufficient to reduce NEFSC SV qs to the expected value of 1.

The final age structured model configuration (ASAP Base Run) included the following:

1) Three fishery selection blocks: 1982-1992, 1993-2004, 2005-2015
2) CAA ages 1-11+
3) Flat fishery selection with S = 1.0 at age 7+ (1982-1992) and 8+ (1993-2004, 2005-2015)
4) Flat NEFSC SV selection with S = 1.0 at age 7+
5) Use NEFSC SV Albatross calibrated/catchability raised wing-spread SWAN indices in calibration, i.e., no splits and net wing spread
6) Include ASMFC Shrimp indices (with S=1.0 at ages 3 and 4) and ME/NH trawl survey indices (with S=1.0 at age 1) in calibration
7) i.e., ASAP Model 9_5, which became ASAP Run 9_5_v2 (with corrected month from 4 to 10 for MENH autumn; tweaked effective sample size [ESS; Francis 2011]: catch 67, NEFSC spring 46, NEFSC autumn 35, ASMFC summer 30, MENH spring 20, and MENH autumn 24)

See Appendix B5 for ASAP Run 9_5_v2 input.

Sensitivity runs

1) Allow estimation of fishery selection for ages 8+/9+
2) Allow estimation of survey selection for NEFSC SV ages 8+
3) Include Dealer 40% Directed trips LPUE in calibration
4) Any adjustment of SV q prior CVs (lambda for catchability = 1 with CV = 0.001)
5) Effective sample size specification – apply Francis ESS (catch 27; NEFSC spring 21; NEFSC autumn 12; ASMFC summer 11; MENH spring 8, and MENH autumn 14)

Pros and cons of models for catch advice are described in a subsequent section.

ASAP run 9_5_v2 Model Fit Diagnostics

The objective function components that contribute to total likelihood and the fleet and index selectivity parameters (and their associated CVs) for ASAP Run 9_5_v2 are given in Tables B60 and Table B61, respectively. In all ASAP model runs, recruitment was modeled as random deviations from a mean (the stock-recruitment relationship for witch flounder is not well determined). In ASAP Run 9_5_v2, the root mean square errors (RMSE) for catch is close to 1 while the indices are outside the 80% confidence bounds of the median (Figure B13). The CVs for the catch and indices were increased to bring the RMSE closer to the bounds, but avoided excessive down weighting of the indices relative to catch. The CV scalars used are: x1.5 on

NEFSC spring index; x1.75 on NEFSC autumn index; x2.5 on ASMFC index; x2.5 on MENH spring index; and x4 on MENH fall index.

Total catch assumed CV = 0.1. The residuals of total catch revealed a block of positive residuals in early in the time series and a block of negative residuals late in the time series (Figure B131); however, the scale of residuals range between -2 and 2, and a roughly normal distribution of the probability density function of the residuals indicates an adequate fit despite the block pattern. For the age composition of total catch, the input effective sample size for total catch was derived using the median of the model estimated effective sample sizes from a penultimate model run (Figure B132). The total catch age composition residuals are given in Figure B133.

Model building started with one fleet selectivity block and additional blocks were added to break up the runs of positive and negative residuals. The year for the block break was based on the best reduction in the objective function value. As stated above, three fleet selectivity blocks were used: 1982-1992, 1993-2004, and 2005-2015 with full selectivity at ages 7+ for block 1 and 8+ for blocks 2 and 3 (Figure B134). CVs for the model estimated selectivity at age ranged between 10% and 86% for block 1, between 10% and 24% for block 2, and between 10% and 64% for block 3 (Table B61), with higher CV occurring at younger ages.

For ASAP Run 9_5_v2, five tuning indices were used: NEFSC spring (Index 1), NEFSC autumn (Index 2), ASMFC summer (Index 3), MENH spring (Index 4) and MENH autumn (Index 5). Model fit to total indices are given in Figures B135-B139. Generally, for the NEFSC spring and autumn and ASMFC summer indices, the residuals revealed a block of negative residuals in early in the time series and a block of positive residuals late in the time series (Figures B135-B137); however, the scale of residuals generally range between -3 and 3, and a roughly normal distribution of the probability density function of the residuals indicates an adequate fit. The MENH spring and autumn residuals also ranged between -3 and 3, and the pattern of positive and negative residuals blocks are present but not as evident due to the shorter time series of this survey (Figures B138-B139). The input effective sample size for each index was derived using the median of the model estimated effective sample sizes for each index from a penultimate model run (Figure B140). Model fit residuals for indices at age are given in Figures B141-B145. Index selectivity was fixed at 1.0 for ages 7+ for NEFSC spring and autumn, fixed at ages 3 and 4 for ASMFC summer and fixed at age 1 for MENH spring and autumn (Figure B146). The CVs for the model estimated selectivity at age ranged between 8% and 17% for spring and autumn NEFSC indices while CVs for ASMFC and MENH the model estimated selectivity at age ranged between 15% and 167%, with higher CV occurring at older ages (Table B61).

The expected model estimated survey catchability was 1 for the NEFSC spring and autumn indices because the swept area numbers were derived using the witch flounder survey catchability of 0.056; however, the model estimated qs were roughly 4 (Figure B147), indicating a scale issue. This persisted across all runs, except runs in which q was fixed (Table B60). Model estimated q for the other surveys were less than 1; the ASMFC and MENH indices used an assumed q=1 in the derivation of swept area numbers (Figure B147).

ASAP Run 9_5_v2 Model Results

ASAP Run 9_5_v2 model results are presented in Tables B62-B65 and Figures B148-B153. Estimated stock size at age (numbers of fish) from 1982 to 2015 is given in Table B62. Age 1 recruitment ranged between 2.8 and 46.4 million fish with a mean of 14.0 million fish

(Figures B149). A period of above average recruitment occurred in the 1990s and roughly average recruitment since 2009 except in 2014 in which the 2013 year class appears strong (Figure B153). The 2013 year class is uncertain since the estimate is based only on two survey data points. Recruitment CVs are generally less than 15%, except for the 2014 year class (Figure B152). Estimates of biomass (January 1, spawning stock, and exploitable) are given in Table B63 and Figure B153. Spawning stock biomass sharply declined in the 1980s to mid-1990s and has been somewhat stable since (Figure B148); CVs are less than 10% (Figure B154). Catches were 2 to 3 times greater earlier in the time series with older fish landed than later in the time series when fewer older fish are landed. The 2015 SSB is estimated to be 5,479 mt. Witch flounder stock-recruitment relationship is not well determined (Figure B152). Estimated fishing mortality has fluctuated between 0.16 and 1.09 over the time series (Table B64; Figure B148); in recent years, there is a declining trend. The fishing mortality CVs are less 17% (Figure B152). Fishing mortality (F_{full}) was estimated to be 0.16 in 2015.

ASAP 9_5_v2 Retrospective Analyses

An "internal" retrospective analysis for ASAP Run 9_5_v2 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 from terminal years back to 2009. A retrospective pattern was evident in which fishing mortality was underestimated and SSB and Age 1 recruitment was overestimated (Figure B154). The 7-year Mohn's rho was -0.46 for F and 0.64 for SSB. This was considered a major retrospective pattern because the rho adjusted estimates of 2015 F (F_{rho} = 0.29) and 2015 SSB (SSB_{rho}=3,335 mt) were outside the approximate 90% confidence region around F (0.12-0.20) and SSB (4,812-6,511; Table B65). A retrospective pattern has occurred in the previous assessments since 1999.

ASAP Run 9_5_v2 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 sizes in 2016 for future projections. The trace of 1982 and 2015 MCMC chains for both F and SSB (Figures B155-B156, respectively) appear random with negligible autocorrelation (Figures B157-B158) implying the thinning rate of MCMC chains was appropriate. The 1982 and 2015 MCMC distributions about the point estimates are generally centered about the point estimate of F and SSB and appear reasonable (Figures B159-B160).

ASAP Run 9_5_v2 Sensitivity Runs

The Working Group identified five sensitivity runs of ASAP Run 9_5_v2 to evaluate the impacts of: (1) domed fleet selectivity; (2) domed survey selectivity; (3) including LPUE 40% trips as an additional tuning index; (4) fixed q = 1 for NEFSC spring and autumn indices; and (5) down weighting the importance of the catch at age information (Francis ESS). The component contribution to the objective function changed minimally between the base run (Run 9_5_v2) and Sensitivity Runs 1-3 (fleet with domed selectivity [FLEETDOME], NEFSC surveys with domed selectivity [SVDOME], and inclusion of the LPUE 40% trips [LPUE40], respectively; Table B60). However, the contribution of the total catch, catch age composition, total index, and

index age composition differ for Sensitivity Run 4 (in which NEFSC survey q was fixed = 1 [QFIXED] and Sensitivity Run 5 (effective sample size reduced [FRANCIS]; Table B60). The objective function is largest in Sensitivity Run 4 and is smallest for Sensitivity Run 5 in which the importance of the catch at age information has been reduced by adjusting the effective sampling size adjusted downward. Model estimated selectivity at age, and their associated CVs are given in Table B61.

Comparisons of fishing mortality, spawning stock biomass, and stock size (Age 1 and total) estimated from ASAP Run 9_5_v2 and the five sensitivity runs are given in Figures B161-B163. Model results were robust to fishery and NEFSC survey selectivity (Sensitivity Runs 1 and 2). When the LPUE 40% index was included in Sensitivity Run 3, F was slightly higher than the base run between 1982-1999 and lower than the base run between 2000 and 2015, but remained within 2 standard deviations of F in the base run except for year 2010-2015. The SSB of the LPUE 40% Sensitivity Run 3 was lower than the base run early in the time series and higher than the base in later years but remained within 2 standard deviations of the SSB in the base run for all years except 1983-1987 and 2005-2015. When the effective sample size was adjusted downward in Sensitivity Run 5 to reduce the importance of the catch at age information, F was slightly lower and SSB was slightly higher than the base run but both F and SSB generally remained within 2 standard deviations of the base run.

In Sensitivity Run 4 the survey catchability (q) for the NEFSC survey SWAN indices were held fixed at 1 (calculated assuming an ALB efficiency of 0.056, providing freely estimated q of approximately 4). The Sensitivity Run 4 results were, as expected, significantly different from ASAP Run 9_5_v2, with F scaled significantly lower over the entire series and SSB, age 1 recruitment, and total stock numbers scaled higher, especially over the terminal 10 years (Figure B163). This difference in scaling, combined with the presence of the major retrospective pattern, led to further explorations (described below) of the response of the model to possible sources of missing mortality.

Two addition sensitivity analysis were conducted. A likelihood profile over assumed natural mortality was conducted using ASAP Run 9_5_v2 and explorations of missing mortality were conducted using ASAP Run 9_5 (a penultimate run of ASAP Run 9_5_v2).

Likelihood Profile over assumptions for Natural Mortality (M)

The ASAP Run 9_5_v2 model was run over a range of assumed M values from 0.05 to 0.50 (constant at all ages over time) to help determine which assumption for M fit best, given the diagnostic of total minimum log-likelihood (value of the total objective function). Figure B164 shows the likelihood did not find minima within the range of values explored. Given the occurrence of age 15 through 21 year old fish in the 2015 landings, it is unlikely that M would exceed the range of values explored.

Missing Mortality sensitivity runs

The Working Group considered an analysis exploring missing mortality and the response to the mean Mohn's rho value for spawning stock biomass (SSB_{rho}) based on 7 peels (a presentation by C Legault). The ASAP Run 9_5 (a penultimate run to ASAP Run 9_5_v2) was used to determine how the SSB_{rho} changed when morality changed by either increasing natural mortality or by increasing catch. The response of SSB_{rho} over a range of year breaks (1996-2005;

the year in which the increase begins) and over a range of multipliers (from 1.5 to 5.0 by 0.5 steps) for catch or M are summarized in Figures B165-B166. The catch proportions at age do not change as the multipliers changed. The M multiplier was applied to all ages.

The exploratory analysis revealed the SSB_{rho} can be reduced by a variety of combinations of increased catch or increased M over a range of year breaks; however, the NEFSC survey catchability (q) remained an issue. For example, when catch was increased by 4 times starting in 2002, the NEFSC SWAN indices qs ranged between 2.1 and 2.5 (still large compared to the expected qs = 1) and when M was increased by 3 times starting in 1997, the qs ranged between 3.2 and 3.6. Different sources of missing mortality (catch or mortality) produced different trends in SSB and F (Figure B167).

The Working Group concluded that there are many ways to eliminate the retrospective pattern that is present in the witch flounder model; however, all require large changes and while the survey q issue improved by increasing M or catch, a q different from the expected value of 1 still remained.

WORKING GROUP SELECTION OF MODEL for Status and Catch Advice

The Sweep Study document (estimation of NEFSC survey efficiency/catchability; Hare et al. 2016b) provided a useful example of how an absolute estimate of SSB (or another form of stock size) might be computed, and the results provided context for the age structured model results. Since no estimate of exploitable biomass (EB) was directly provided, there is no means from this approach alone to provide advice on the OFL 2017.

The "Empirical Assessment" documentation (i.e., the approach used in the Georges Bank yellowtail flounder TRAC assessment; Legault et al. 2014) incorporates the results of the Sweep Study and uses the two NEFSC survey series and the reported/estimated catch to provide a simple basis for the calculation of OFL for 2017. This approach does not provide biological reference points, does not use a "formal" model framework, does not use the available fishery and SV catch-at-age (CAA) and other biological data, and is strictly deterministic and so does not provide any metrics of uncertainty. Given these constraints, it is not possible to project the impact of catch on stock size.

The RY model is a survey and catch model framework that is simpler than the ASAP and SCAA age structured models that also incorporates the results of the Sweep Study and uses the two NEFSC survey series. This approach can provide model diagnostics to help determine the best model configuration to provide a simple basis for the calculation of catch OFL for 2017. Unfortunately, the WG was unable to sufficiently vet (compared to the work that was done for the ASAP and SCAA age structured models) the RY model performance; e.g., with regard to retrospective errors and impact of the inclusion of the ASMFC and MENH indices. This approach does not provide biomass or F reference points, appears to be sensitive to the times series of data included in the two examples that were examined, and does not use the available fishery and SV CAA and other biological data.

The WG noted that the latter two "simple" models (Empirical, RY) use a subset of the same fishery and survey data used in the more complex ASAP and SCAA age structured models. The Empirical and RY methods do not make some diagnostic issues as obvious, and do not highlight some conflicts in the data. Data conflicts are important for understanding sources of uncertainty and risk. The same conflicts/issues that are of concern in the age structured models (potentially unaccounted for catch, incorrect assumption in the swept area expansions, incorrect

assumption for M) may simply be "masked" in the simple models because they do not include the fishery and survey age structure and so don't explicitly account for fishery and survey selectivity. Witch flounder reaches full maturity at age 8-9, with full recruitment to the fishery at age 7. Age structure may be important for understanding annual dynamics, and for projecting future catches. The Empirical and RY approaches do not explicitly capture these important features.

The WG notes that in previous witch flounder assessments using VPA age structured models, using NEFSC SWAN indices assuming efficiency = 1 and a survey split in 1994/1995, freely estimated NEFSC SV qs were less than 1. These SWANs were proportionally smaller than those used in the current assessment using the Sweep Study results, where ALB efficiency = 0.056 and BIG efficiency = 0.291. With the benefit of the Sweep Study efficiency estimates, the ASAP and SCAA age structured final models examined in this assessment all provide freely estimated values of NEFSC SV q in the range of 4-5, depending on model configuration and weighting, and provided similar diagnostics. Numerous sensitivity runs examining changes in the magnitude of the fishery catch, M, selectivity patterns, and inclusion of fishery CPUE indicated that some configurations could provide a wide range of freely calculated estimates of NEFSC SV qs less than 4.

The WG notes that for many of the age structured model configurations examined, the assessment results do not differ when the survey q is simply a freely estimated parameter, but the resultant high qs and major retrospective errors are diagnostics that indicate some combination of the component input data (e.g., unaccounted catch, incorrect Swept Area Numbers, M) are incorrect. Sensitivity runs that force the models to approach or match the expected NEFSC survey SWAN index q = 1 provided diagnostics that show that models have difficulty reconciling patterns in model starting conditions, catch, aggregate survey trend, and the information on selectivity and magnitude of F provided by the fishery and survey CAA data. In summary, the age structured models in the accepted final configurations provide calculated NEFSC survey q ~ 4.0, exhibit major retrospective patterns requiring rho adjustment, and require very large increase in catch or M to remove the retrospective errors. The WG notes that these data conflicts have been addressed in the previous accepted and current age structured models explicitly through a rho adjustment, without having to apply potentially implausible scalars on M or catch (as has been done in this assessment as sensitivity examples).

The WG recognizes that the new information from the Sweep Study and resultant impacts on the estimation of NEFSC SV q can lead one to question the validity of the ASAP model assumptions and results. A minority of the WG views the ASAP final model freely estimated values of q ~ 4 in the face of the Sweep Study results as a "fatal error" that precludes its direct use for status evaluation and OFL advice. However, a majority of the WG does not feel this diagnostic is sufficient justification to reject the ASAP final model (Run 9_5_v2, adjusted for retrospective error in the terminal year) as the basis for determining stock status and providing advice on 2017 OFL. Therefore, **the WG has used the ASAP final model results as the basis for status evaluation and advice on the 2017 OFL**.

Comparison of VPA and ASAP model results

Trends in fishing mortality, spawning stock biomass for VPA Run A2 and ASAP Run 9_5_v2 (with associated 2 standard deviations) are given in Figure B169. The general pattern over the time series of fluctuating fishing mortality and declining spawning stock biomass are

similar between the two models; however, the VPA Run A2 estimates are not within 2 standard deviations of the ASAP Run9_5_v2 except for a few years throughout the time series.

A HISTORICAL RETROSPECITVE ANALYSIS

A historical retrospective analysis was conducted to allow a comparison with previous assessment results and previous projections using stock assessments from 2008, 20102, 2015 and current assessment model (ASAP Run 9_5_v2). The retrospective pattern is evident for F and SSB (Figure B169). Because the previous projection was conducted in 2015, there was only one year in which there was a projected F and SSB estimate and an estimate from this assessment. The projected estimates of F and SBB from the 2015 assessment are just outside the 90% CI of the retrospective adjusted 2015 estimates F_{rho} and SSB_{rho} from this assessment.

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 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.

> ***SARC-62 Opinions****: The age-structured models applied to data for the witch flounder fishery from 1982-2015 were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice. Therefore biological reference points are not available.*

EXISTING: 2015 Operational Assessment Biological Reference Points

The VPA model results were accepted as the basis for the biological reference points and stock status determination for witch flounder (NEFSC 2015). Reference points were calculated using the non-parametric yield and SSB per recruit/long-term projection approach adopted for the New England groundfish stocks (NEFSC 2008). 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 SSB_{msy} (Spawning Stock Biomass at maximum sustainable yield), the cumulative density function was re-sampled from estimates of Age 3 between 1982-2013 to provide future recruitment estimates. Recruitment of witch flounder is not well determined by traditional stock recruitment relationships. Given this, an MSY proxy was used for reference points. $F_{40\%}$ is the proxy used for the overfishing threshold (F_{msy}). This is consistent with the choice of proxy in the previous assessments (NEFSC 2012, NEFSC 2008). The biological reference points estimated in the 2015 assessment were $F_{msy}=F_{40\%}=0.28$, $SSB_{msy}=9{,}473$ mt, and MSY=1,957 mt.

NEW: 2016 SAW 62 Biological Reference Points

In this assessment, the yield and SSB per recruit calculations (NFT 2013a) used the most recent five year (2011-2015) averages for mean weights, fishery partial recruitment pattern, and maturity ogive. For the estimation of MSY and SSB_{msy}, the cumulative density function was re-sampled from estimates of Age 3 (VPA) or Age 1 (ASAP) between 1982-2015 to provide future recruitment estimates (Table B66 for VPA Run A2 input and Table B67 for ASAP Run 9_5_v2 input). Proxy reference points based on VPA Run A2 and ASAP Run 9_5_v2 are given in Table B68. Stochastic projections at $F_{msy}=F_{40\%}$ (0.19) were used to determine new biomass reference points (proxies for both SSB_{msy} and MSY) based on $F_{40\%}$ (Table B69).

Using Run VPA Run A2 and F40%=0.20, biological reference points are estimated to be 12,499 mt for SSB_{msy}, 6,250 mt for $SSB_{threshold}$, and 1,512 mt for MSY (Table B69).

Using ASAP Run 9_5_v2 and $F_{40\%}$ = 0.19, biological reference points are estimated to be 12,747 mt for SSBmsy, 6,374 mt for $SSB_{threshold}$, and 1,998 mt for MSY (Table B69). **The 2016 WG accepted the ASAP Run 9_5_v2 model results as the basis for the new recommended biological reference points and stock status determination for witch flounder.**

Using ASAP Run 9_5_v2 and F40% = 0.19, biological reference points are estimated to be 12,747 mt for SSBmsy, 6,374 mt for SSBthreshold, and 1,998 mt for MSY (Table B69). The 2016 WG accepted the ASAP Run 9_5_v2 model results as the basis for the new recommended biological reference points and stock status determination for witch flounder.

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 (or possibly models, in accord with guidance in attached "Appendix to the SAW Assessment TORs") developed for this peer review. In both cases, evaluate whether the stock is rebuilt .
a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the updated BRP estimates.
b. Then use the newly proposed model (or possibly models, in accord with guidance in "Appendix to the SAW Assessment TORs") and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

> ***SARC-62 Opinions****: The status of the witch flounder stock is unknown with regards to biological reference points. The age-structured models applied to data for the witch flounder fishery from 1982-2015 were found to have major retrospective patterns that prevented their use for status evaluation and determination of catch advice.*
>
> *Based on an empirical analysis (referred to as "empirical area swept method") conducted by the SAW and examined at the SARC, stock biomass has declined since 2002 and appears to be 16,181 mt Jan-1 surveyable biomass in 2016 and 14,563 mt exploitable biomass in 2016. The relative exploitation rate needed to achieve the recent observed catch is approximately 0.05. The SARC-62 did not fully evaluate the empirical approach during the peer review, and therefore expected additional evaluation of the method, calculations, and results to be made following the peer review.*
>
> *The fishery landings and survey catch by age indicate truncation of age structure and a reduction in the number of old fish in the population.*

2016 UPDATED STOCK STATUS

c) Existing VPA model (VPA Run A2)

Based on the VPA Run A2 model, the witch flounder stock was determined to be overfished and overfishing occurred in 2015. This determination was made on retrospectively adjusted $F_{full,rho}$ and SSB_{rho} in 2015. The retrospective adjustment was required but did not lead to a change in status (Table B69). The biological reference points used were $F_{MSY}=F_{40\%}=0.20$, $SSB_{msy}=12{,}499$ mt, and MSY=1,512 mt. The 2015 F_{8-9} is estimated to be 0.43 (210% of $F_{40\%}$) and the retrospectively adjusted 2015 $F_{8-9,rho}$ to be 0.69 (337% of $F_{40\%}$). The 2015 SSB is estimated to be 3,044 mt (24% of SSB_{msy}) and the retrospectively adjusted 2015 SSB_{rho} to be 2,035 mt (16% of SSB_{msy}).

d) New ASAP model (ASAP Run 9_5_v2)

Based on the ASAP Run 9_5_v2 model, the witch flounder stock was determined to be overfished and overfishing occurred in 2015. This determination was made on retrospectively adjusted $F_{full,rho}$ and SSB_{rho} in 2015. The retrospective adjustment was required and lead to a change in overfishing status (Table B69; Figures B170-B172). The

biological reference points used were F_{msy}=$F_{40\%}$=0.19, SSB_{msy}=12,747 mt, and MSY=1,998 mt. The 2015 F_{full} is estimated to be 0.16 (83% of $F_{40\%}$) and the retrospectively adjusted 2015 $F_{full,rho}$ to be 0.29 (154% of $F_{40\%}$). The 2015 SSB is estimated to be 5,479 mt (43% of SSB_{msy}) and the retrospectively adjusted 2015 SSB_{rho} to be 3,335 mt (26% of SSB_{msy}).

TERM OF REFERENCE 7: Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (3 years) and the statistical distribution (e.g., probability density function) of the catch at FMSY or an FMSY proxy (i.e. the overfishing limit, OFL) (see Appendix). 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, magnitude and 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. Identify reasonable projection parameters (recruitment, weight-at-age, retrospective adjustments, etc.) to use when setting specifications.

c. Describe this stock's vulnerability to becoming overfished, and how this could affect the choice of ABC. The choice takes scientific uncertainty into account (see Appendix).

> ***SARC-62 Opinions:*** *The empirical area swept method was used to provide an F_{MSY} proxy for 2017 based on a relative exploitation rate. The SARC-62 did not fully evaluate the empirical approach during the peer review, and therefore expected additional evaluation of the method, calculations, and results to be made following the peer review.*

A) NUMERICAL ANNUAL PROJECTIONS FOR 2017-2019

Short-term projections of median catch (total fishery yield) and spawning stock biomass (mt) for witch flounder were based on a harvest scenario of an assumed catch of 460 mt in 2016 and fishing at $F_{40\%}$ (0.19) in 2017-2019 to determine the Overfishing Limit (OFL) for 2017-2019. One hundred projections were made for each of the 1000 bootstrapped iterations of 2016 stock sizes from the ASAP Run 9_5_v2 model results using NFT AGEPRO version 4.2.2 (NFT 2013b). Future Age 1 recruitment was generated randomly from a cumulative density function of the updated recruitment series for 1982-2015 (year classes 1981–2014 with mean recruitment = 9.8 million fish). Partial recruitment was taken from the fleet selectivity for time block 2005-2015. Average 2011-2015 mean weights, and maturation ogive representing 2012-2016 maturity data were the same used in the biological reference points based on the ASAP Run 9_5_v2 (Table B67). Projection results based on the ASAP Run 9_5_v2 are shown below and in Figure B173. The SSB retrospective adjustment factor (0.6088) was applied to all ages (1 -11+) of the initial population from ASAP Run 9_5_v2 in these projections. Numbers in parentheses indicate 5th and 95th percentiles.

The probability of SSB falling below the biomass threshold in 2017-2019 fishing at the OFL ($F_{40\%}$ = 0.19), is 96%, 17% and 0%, respectively.

Year	Input	Catch (mt)	SSB (mt)		Harvest Strategy	Ffull	
2016	Catch input	460	4,212	(3,611 - 4,933)		0.14	(0.12 - 0.17)

2017	Projection	762	(650 - 895)	5,452	(4,670 - 6,337)	F40%	0.19
2018	Projection	911	(782 - 1,048)	6,940	(5,977 - 7,933)	F40%	0.19
2019	Projection	1,136	(978 - 1,295)	8,302	(7,136 - 9,528)	F40%	0.19

B) MOST REALISTIC PROJECTIONS

The Working Group conducted one projection by assuming recent patterns in the fishery and the most recent maturity ogive. A major source of uncertainty is the retrospective pattern. The past projection was optimistic (outside the confidence bounds for the rho adjusted biomass in this assessment). Subsequent projections will be conducted by the Groundfish Plan Development Team, when 2016 catch is determined.

C) STOCK VULNERABILITY

The 2016 stock assessment indicates that the stock was below the biomass target and being fished above the fishing mortality threshold in 2015. Witch flounder is slow growing and late maturing and is vulnerable without stringent management regulations in place.

TERM OF REFERENCE 8: Evaluate the validity of the current stock definition, taking into account what is known about migration, and make a recommendation about whether there is a need to modify the current stock definition for future stock assessments.

Witch flounder are assessed and managed as a unit stock within USA waters; this includes the Gulf of Maine and Georges Bank region as well as areas to the south as far as Cape Hatteras, North Carolina.

No tagging studies have been conducted on witch flounder in Gulf of Maine-Georges Bank region.

No studies on stock structure have been conducted in the Gulf of Maine-Georges Bank region. Burnett and Clark (1983) noted that NEFSC spring and autumn survey catch-per-tow data indicate witch flounder in this region are relatively discrete from the western Scotian Shelf or further south.

In the Newfoundland region, Fairbairn (1981), using biochemical systematics for stock separation, suggests that witch flounder in the Newfoundland region exist in relatively small, independent subpopulations with little inter-stock migration.

Bowering and Misra (1981) applied a multivariate statistical method to witch flounder meristics data in the Newfoundland-Labrador area and results indicated seven distinct populations of witch flounder throughout the areas studied (Hawk Channel, Funk Island Bank, Northern Grand Bank, Southwest Slope of Grand Bank, Burgeo-St Pierre Banks, Fortune Bay, and Gulf of St Lawrence). Bowering and Misra (1981) results agreed with those made by Fairbairn (1981) using entirely different techniques.

Wigley and Burnett (2003) compared biological and yield characteristics of deep water (depth > 366 m) witch flounder south and west of Georges Bank and found these fish had slower growth and that otolith structure was different than the Gulf of Maine-Georges Bank witch flounder, suggesting a separate population.

WG recommendation: Until tagging and/or stock structure analyses are undertaken that reveal subpopulations, the current stock definition should be retained for future stock assessments. Possible future research recommendations include: ageing larval fish to determine transport time; tagging and/or stock structure analyses.

TERM OF REFERENCE 9. Review, evaluate and report on the status of research recommendations from the last peer reviewed benchmark stock assessment. Identify new research recommendations.

> ***SARC-62 Opinions:*** *The SARC recommends that witch flounder be put on a research track to address survey catchability and retrospective problems. Such an examination should include other stocks in the region exhibiting major retrospective patterns and survey catchability issues.*

Research recommendations from the last peer reviewed benchmark stock assessment (2008 GARM) are summarized below. Of the 3 research recommendations, progress has been made on two recommendations. The WG developed nine new research recommendations.

Previous Research Recommendations since 2008 GARM benchmark assessment

<u>2008 GARM Benchmark (NEFSC 2008)</u>

The Panel had no specific research recommendations for this stock.

<u>2012 Update (NEFSC 2012)</u>

Two research recommendations, applicable to several stocks were suggested:

1) explore the possibility of refining the calibration factors within the assessment model itself (e.g, splitting the survey tuning series and using the results from the calibration experiment as a prior);

   The WG explored splitting the NEFSC survey tuning series into two separate independent series (Albatross and Bigelow). The WG noted several reasons to retain the ALB calibrated series: BIG series is too short to stand alone; split perhaps allows too much flexibility, with some counterintuitive results in terms of ALB vs BIG q; limited age structure in short BIG series results in lack of precision in estimates of survey selectivity; effectively includes results of calibration experimental results (ALB to BIG 3.2572).

2) continue to examine the trends in mean weights at age and their possible underlying factors.

   No progress.

<u>2015 Operational Assessment (NEFSC 2015)</u>

Research Needs: The Panel recommends that the sources of the retrospective pattern need to be addressed. Considering that retrospective patterns are a common problem, the generic problem may be most appropriately addressed in a research track topic, and all possible sources of the retrospective problem should be investigated (mis-specified natural mortality, changes in natural mortality, under-reported catch, changes in survey catchability and mis-specified

selectivity, etc.). For the next benchmark assessment, the Panel recommended exploring a statistical catch-at-age model to investigate possible doming in the catch selectivity.

> *VPA and ASAP models were considered in this assessment. Sensitivity runs exploring mis-specified M, under-reported catch, survey catchabilities, and mis-specified selectivity in the fleet and survey were conducted but were not accepted as a base run because model diagnostics do not strongly support high flexibility to estimate fishery or survey selection above age 7-8 and the missing mortality (see TOR 4 for a detailed list).*

New Research Recommendations developed by WG

1) Age the archived age structures from the MENH inshore trawl survey for use in the future assessments.

2) Conduct a stock identification study. Components could include: tagging (studies designed for stock id), larval dispersion (transport), morphometrics, meristics, genetics, etc.

3) Conduct larval growth studies to generate larval index of SSB.

4) Conduct tagging studies designed to decrease the uncertainty of estimates/assumption for M, if feasible.

5) Consider a further examination of the appropriate survey area, including environmental and/or habitat preferences (e.g., Friedland working paper), to be used in swept-area expansions.

6) Consider further investigation of the influence of catch-at-age information, as compared to aggregate fishery and survey catches, in the assessment model. Areas of research to consider could include (a) inclusion of ageing error estimates in the assessment model and (b) direct use of age-length keys and length distribution data as data inputs into the assessment model. This is a generic recommendation applicable to all SARC stock assessments.

7) Consider further investigation to maximize the information contained in the survey data, such as the use of new geostatistical /spatial modeling approaches to improve estimates of precision. This is a generic recommendation applicable to all SARC stock assessments.

8) The WG notes that unaccounted catch has been examined as a possible cause for the major retrospective errors in SARC stock assessments. The WG recommends that efforts should be made in all Northeast region fisheries to determine the veracity of currently reported catch statistics and the magnitude of possible unaccounted catch. The WG should then consider using any resulting “hard” evidence of unaccounted catch, as it becomes available, to inform further investigations (e.g., in terms of model performance and diagnostics) of this factor on stock assessment results. This is a generic recommendation applicable to all SARC stock assessments.

9) The WG notes that changes in natural mortality has been examined as a possible cause for the major retrospective errors in SARC stock assessments. The WG recommends that efforts should be made to investigate how M might change or has changed over time in response to biological and environmental factors. This is a generic recommendation applicable to all SARC stock assessments.

ACKNOWLEDGMENTS

The WG members thank C Legault, A Miller, P Nitschke, L O'Brien, C Tholke, S Sherman, and B Smith for their assistance and contributions to this report. We also thank the authors of the working papers for their work and consultations during the meetings. Special thanks to S Emery for the timely preparation of the witch flounder age data.

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TABLES

Table B1. Maturity at age for female witch flounder based on Northeast Fisheries Science Center spring survey maturity data (using a 5 year moving window). 2015 is assumed to be equal to 2014.

	AGE										
Year	1	2	3	4	5	6	7	8	9	10	11+
1982	0.00	0.00	0.01	0.04	0.14	0.40	0.73	0.92	0.98	0.99	1.00
1983	0.00	0.00	0.01	0.06	0.20	0.51	0.82	0.95	0.99	1.00	1.00
1984	0.00	0.00	0.02	0.07	0.24	0.59	0.86	0.97	0.99	1.00	1.00
1985	0.00	0.00	0.01	0.05	0.24	0.68	0.93	0.99	1.00	1.00	1.00
1986	0.00	0.00	0.02	0.09	0.36	0.76	0.95	0.99	1.00	1.00	1.00
1987	0.00	0.02	0.08	0.30	0.68	0.91	0.98	1.00	1.00	1.00	1.00
1988	0.01	0.03	0.14	0.43	0.78	0.94	0.99	1.00	1.00	1.00	1.00
1989	0.00	0.02	0.09	0.32	0.68	0.91	0.98	1.00	1.00	1.00	1.00
1990	0.01	0.02	0.07	0.20	0.46	0.73	0.90	0.97	0.99	1.00	1.00
1991	0.01	0.02	0.07	0.17	0.38	0.64	0.84	0.94	0.98	0.99	1.00
1992	0.01	0.02	0.06	0.17	0.41	0.70	0.89	0.96	0.99	1.00	1.00
1993	0.00	0.01	0.04	0.13	0.35	0.65	0.87	0.96	0.99	1.00	1.00
1994	0.00	0.01	0.04	0.13	0.34	0.64	0.86	0.96	0.99	1.00	1.00
1995	0.00	0.01	0.03	0.13	0.42	0.78	0.95	0.99	1.00	1.00	1.00
1996	0.00	0.00	0.02	0.12	0.45	0.83	0.96	0.99	1.00	1.00	1.00
1997	0.00	0.00	0.01	0.07	0.37	0.81	0.97	1.00	1.00	1.00	1.00
1998	0.00	0.01	0.04	0.13	0.38	0.71	0.91	0.98	0.99	1.00	1.00
1999	0.00	0.01	0.04	0.14	0.36	0.67	0.88	0.96	0.99	1.00	1.00
2000	0.01	0.02	0.05	0.14	0.33	0.59	0.82	0.93	0.98	0.99	1.00
2001	0.01	0.02	0.06	0.15	0.33	0.58	0.79	0.91	0.97	0.99	1.00
2002	0.02	0.04	0.08	0.17	0.32	0.53	0.72	0.86	0.93	0.97	0.99
2003	0.02	0.04	0.09	0.17	0.31	0.49	0.68	0.82	0.91	0.96	0.98
2004	0.03	0.06	0.11	0.19	0.32	0.49	0.66	0.79	0.89	0.94	0.97
2005	0.04	0.07	0.12	0.22	0.35	0.52	0.68	0.80	0.89	0.94	0.97
2006	0.02	0.04	0.09	0.16	0.29	0.45	0.63	0.78	0.88	0.94	0.97
2007	0.02	0.04	0.08	0.17	0.32	0.52	0.71	0.85	0.93	0.97	0.98
2008	0.01	0.03	0.08	0.19	0.37	0.61	0.80	0.92	0.97	0.99	0.99
2009	0.02	0.04	0.11	0.25	0.47	0.71	0.87	0.95	0.98	0.99	1.00
2010	0.01	0.04	0.10	0.24	0.48	0.73	0.89	0.96	0.99	0.99	1.00
2011	0.02	0.05	0.13	0.29	0.53	0.75	0.89	0.96	0.98	0.99	1.00
2012	0.01	0.04	0.11	0.27	0.52	0.76	0.90	0.96	0.99	1.00	1.00
2013	0.01	0.04	0.11	0.27	0.52	0.76	0.91	0.97	0.99	1.00	1.00
2014	0.01	0.03	0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00
2015	0.01	0.03	0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00
TS mean	0.01	0.04	0.09	0.21	0.42	0.65	0.83	0.93	0.97	0.99	1.00

Table B2. Maturity at length (cm) for female witch flounder based on Northeast Fisheries Science Center spring survey maturity data; 2015 is assumed to be equal to 2014.

	Length (cm)																										
Year	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	52	54
1982	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.11	0.20	0.35	0.52	0.69	0.82	0.91	0.95	0.98	0.99	0.99	1.00
1983	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.08	0.16	0.28	0.44	0.62	0.77	0.88	0.94	0.97	0.98	0.99	1.00	1.00
1984	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.05	0.09	0.18	0.32	0.51	0.69	0.83	0.91	0.96	0.98	0.99	1.00	1.00	1.00
1985	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.09	0.19	0.37	0.58	0.77	0.89	0.95	0.98	0.99	1.00	1.00	1.00	1.00
1986	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.13	0.25	0.43	0.63	0.80	0.90	0.95	0.98	0.99	1.00	1.00	1.00	1.00
1987	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.13	0.24	0.41	0.60	0.76	0.87	0.94	0.97	0.99	0.99	1.00	1.00	1.00	1.00	1.00
1988	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.13	0.23	0.38	0.56	0.73	0.85	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1989	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.13	0.21	0.33	0.47	0.62	0.75	0.85	0.91	0.95	0.97	0.98	0.99	1.00	1.00	1.00	1.00
1990	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.08	0.13	0.19	0.27	0.38	0.50	0.62	0.72	0.81	0.87	0.92	0.95	0.97	0.98	0.99	0.99
1991	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.05	0.07	0.10	0.15	0.22	0.31	0.41	0.52	0.63	0.73	0.81	0.87	0.91	0.94	0.96	0.98	0.98
1992	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.04	0.06	0.09	0.14	0.22	0.31	0.42	0.54	0.66	0.76	0.84	0.89	0.93	0.96	0.97	0.98	0.99
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.06	0.10	0.16	0.25	0.36	0.48	0.61	0.73	0.82	0.88	0.93	0.96	0.97	0.98	0.99
1994	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.09	0.15	0.24	0.35	0.48	0.62	0.74	0.83	0.89	0.94	0.96	0.98	0.99	0.99
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.04	0.08	0.17	0.30	0.48	0.67	0.81	0.90	0.95	0.98	0.99	1.00	1.00	1.00	1.00
1996	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.07	0.17	0.35	0.59	0.79	0.91	0.96	0.99	0.99	1.00	1.00	1.00	1.00	1.00
1997	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.11	0.27	0.53	0.77	0.91	0.97	0.99	1.00	1.00	1.00	1.00	1.00	1.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.03	0.06	0.11	0.21	0.36	0.54	0.71	0.84	0.92	0.96	0.98	0.99	1.00	1.00	1.00	1.00
1999	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.12	0.20	0.34	0.50	0.66	0.79	0.88	0.94	0.97	0.98	0.99	1.00	1.00	1.00
2000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.11	0.19	0.30	0.45	0.60	0.74	0.84	0.91	0.95	0.97	0.98	0.99	1.00	1.00
2001	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.13	0.21	0.32	0.46	0.60	0.73	0.83	0.90	0.94	0.97	0.98	0.99	0.99	1.00
2002	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.09	0.14	0.22	0.33	0.45	0.58	0.70	0.80	0.87	0.92	0.95	0.97	0.98	0.99	0.99
2003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.08	0.13	0.20	0.29	0.41	0.54	0.67	0.78	0.85	0.91	0.94	0.97	0.98	0.99	0.99
2004	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.04	0.06	0.10	0.15	0.22	0.31	0.42	0.54	0.66	0.76	0.83	0.89	0.93	0.96	0.97	0.98	0.99
2005	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.07	0.11	0.17	0.24	0.34	0.45	0.57	0.68	0.77	0.85	0.90	0.93	0.96	0.97	0.98	0.99
2006	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.07	0.12	0.18	0.27	0.38	0.50	0.62	0.73	0.82	0.88	0.93	0.95	0.97	0.98	0.99
2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.12	0.19	0.28	0.41	0.55	0.68	0.79	0.87	0.92	0.95	0.97	0.98	0.99	0.99
2008	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.12	0.21	0.33	0.47	0.63	0.76	0.85	0.91	0.95	0.97	0.99	0.99	1.00	1.00
2009	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.12	0.20	0.30	0.44	0.58	0.71	0.82	0.89	0.93	0.96	0.98	0.99	0.99	1.00	1.00
2010	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.06	0.11	0.18	0.29	0.44	0.59	0.73	0.83	0.90	0.94	0.97	0.98	0.99	1.00	1.00	1.00
2011	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.09	0.14	0.23	0.35	0.49	0.63	0.75	0.84	0.91	0.95	0.97	0.98	0.99	0.99	1.00	1.00
2012	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.07	0.12	0.20	0.31	0.46	0.61	0.74	0.84	0.91	0.95	0.97	0.98	0.99	1.00	1.00	1.00
2013	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.04	0.06	0.11	0.19	0.31	0.45	0.60	0.74	0.84	0.91	0.95	0.97	0.98	0.99	1.00	1.00	1.00
2014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.11	0.18	0.30	0.44	0.60	0.74	0.84	0.91	0.95	0.97	0.99	0.99	1.00	1.00	1.00
2015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.06	0.11	0.18	0.30	0.44	0.60	0.74	0.84	0.91	0.95	0.97	0.99	0.99	1.00	1.00	1.00
TS mean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.09	0.16	0.25	0.37	0.51	0.65	0.77	0.86	0.91	0.95	0.97	0.98	0.99	0.99	1.00

Table B2a. Alternative estimates of natural mortality (M) for witch flounder using: t_{max} = 33 years, L_{inf} = 619.9 mm,, K = 0.1482 (L_{inf} and K from Burnett et al. 1992); A50 = 5.3, mean water temperature = 7degrees C.

Estimators	M	Equation
Hoenig 1983 (rule-of-thumb) P = 0.05	0.09	$M = -\ln(P) / t_{max}$
Hoenig 1983 (rule-of-thumb) P = 0.015	0.13	
Hewitt and Hoenig 2005	**0.13**	$\mathbf{M = 4.22 / t_{max}}$
Updated One Parameter t_{max} estimator (Then et al. 2015)	**0.15**	$\mathbf{M = 5.109/t_{max}}$
Hoenig 1983 (regression)	**0.14**	$\mathbf{M = \exp[1.44 - 0.982*\ln(t_{max})]}$
Updated Hoenig 1983 (Then et al. 2015)	**0.16**	$\mathbf{M = \exp[1.717 - 1.01*\ln(t_{max})]}$
Updated Hoenig Non-linear Least Squares (Then et al. 2015)	**0.20**	$\mathbf{M = 4.899*t_{max}^{-0.916}}$
Rikhter and Efanov 1977	0.30	$M = [1.521/(t_{max}^{0.720})] - 0.155$
Charnov & Berrigan 1990	0.07	$M = 2.2/t_{max}$
Jensen's 1st 1996	0.05	$M = 1.65/t_{max}$
Average of all longevity-based estimators	0.14	
Average of estimators w/o Rikhter & Efanov	0.12	
Average of estimators w/o Rikhter & Efanov, P-based	0.13	
Average of estimators w/o estimates >1 or <0.20	0.16	
Average of boldface estimators (age constant, longevity based)	**0.16**	
Pauly 1980	**0.22**	**M = exp[-0.0152 + 0.6543 * ln(K) - 0.279 * ln(L_{inf}/10) + 0.4634 * ln(Temp)]**
Ralston 1987 (linear regression)	**0.32**	**M = 0.0189 + 2.06 * K**
Jensen 1996 (theoretical)	**0.22**	**M = 1.50 * K**
Jensen 1996 (derived from Pauly 1980)	**0.24**	**M = 1.60 * K**
Beverton	0.37	M = 3 * K / [exp(a_50 * K) - 1]
Average of boldface estimators (age constant, Growth/life history based)	**0.25**	
Average All Age Constant preferred estimators	**0.20**	

Table B3. Brief summary of significant changes in management regulations governing the USA commercial fishery for witch flounder (adapted from O'Brien and Brown, 1996), updated by Tom Nies, NEFMC (pers.comm., 2003).

1953-1977	ICNAF era
1953	Minimum mesh in body and codend 4 ½ inches.
1970	Areas 1(A) and 2(B) closed during haddock spawning, from March - April.
1972-1974	Areas 1(A) and 2(B) closure extended to March - May.
1975	Areas 1(A) and 2(B) closures extended to February - May.
1977 - Present	Extended Jurisdiction and National Management
1977	USA Fishery Conservation and Management Act of 1976 (FCMA) in effect.
1977-1982	Fishery Management Plan (FMP) for Atlantic groundfish: Seasonal spawning closures for haddock (Areas 1 and 2), quotas for haddock, etc
1982	**Mesh size 5 1/8 inches (130 mm).**
1982-1985	The 'Interim Plan' for Atlantic groundfish: Eliminated all catch controls, retained closed area and mesh size regulations, implemented minimum landing sizes.
1983	Mesh size increased to 5 ½ inches (140 mm). **Witch flounder minimum size 33 cm.**
1984 October	Hague Line separating USA and Canadian fishing zones in the Gulf of Maine and Georges Bank region.
1985	Fishery Management Plan for the Multispecies Fishery.
1987	**Witch flounder minimum size increased to 36 cm.**
1991	Amendment 4 established overfishing definitions for witch flounder in terms of Fmed (F20%) replacement levels.
1993	Area 2 closure is extended from January 1 - June 30.
1994 January	Amendment 5 implemented: expanded Area 2, Area 1 closure not in effect.
May	**6 inch (152 mm) mesh restriction implemented** (delayed from March 1). Square or diamond mesh allowed.
December	Area 1, Area 2 and Nantucket Lightship Area closed year-around.
1996 July	Amendment 7 implemented: **Days-at-sea (DAS) restrictions**. Haddock trip limits Raised to 1000 pounds
1997 May	Additional scheduled DAS restrictions from Amendment 7 accelerated.
1998 May	Western Gulf of Maine Closure Area adopted: Jeffery's Ledge area closed to all groundfishing. Rolling closures in the western Gulf of Maine.
October	Amendment 9: revised overfishing definitions as required by Sustainable Fisheries Act.

1999 May	**Codend mesh regulations changed to 6-inch diamond mesh, 6 1/2-inch square mesh**.

Table B3 continued. Significant changes in management regulations governing the USA commercial fishery for witch flounder (adapted from O'Brien and Brown, 1996), updated by Tom Nies, NEFMC (pers.comm., 2003).

	Additional rolling closures adopted in the western Gulf of Maine Cashes Ledge seasonal closure adopted Roller gear limited to a maximum of 12 inches in an area of the western Gulf of Maine. Gulf of Maine cod trip limit ranged from 30 to 400 lbs. in this fishing year.
2000 May	May closure implementation on northern Georges Bank. Changes to large mesh permit category, granting additional DAS to vessels using larger than 6-inch diamond / 6-inch square mesh.
2002 June 1	Additional restrictions adopted during this fishing year (result of lawsuit over FW33): Vessels limited to 25% of allocated DAS May to July; Increase in minimum mesh size for trawl vessel to 6 ½ inch diamond/ 6 ½ inch square; Reduced number of rolling closures in the western Gulf of Maine (effective in January 2003, with result there were additional rolling closures in calendar year 2002 compared to calendar year 2001; Cashes Ledge seasonal closure expanded to year-around closure; Increase in GOM cod trip limit to 500 lbs. per day/4,000 lbs per trip; Increase in mesh size for large mesh permit category.
2002 August 1	Reduction in allocated DAS based on past history of use for each permit; Front-loading of DAS clock prohibited; Additional restrictions on number and deployment of gillnets.
2010 May	**Sector management (vessels in sectors are subject to hard TACs)**.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

2001
January 9 – March 17 April 16 – April 30 Northern Shrimp season (61 days)
November 6: Daily haddock possession limit removed (maximum 50,000 lbs.-trip).
2002
February 15-March 11: Northern Shrimp season (25 days with days off)
May 1: Interim rule as a result of FW 33 lawsuit settlement agreement. Continuation of most measures from previous frameworks. DAS: 15 hour minimum charged for all trips over 3 hours Vessels limited to 25 percent of allocation May 1 through July 31, 2002 (only) Prohibition on front-loading DAS Minimum size: Cod 22 in. Gear: GOM Regulated Mesh Area (RMA): 6.5 in. diamond or square codend minimum, 6.5 inch mesh for trip gillnets, 6.5 inch mesh standup (roundfish) or 7 inch mesh tiedown (flatfish) for day gillnets. All areas: day gillnets limited to 50 standup/100 tiedown nets. *Hook gear*: de-hooking devices with spacing of less than six inches prohibited. Closures: WGOM year round closure extended (was to sunset May 1); Cashes Ledge Closed Area (year round); year round Cashes Ledge East and West closure added; add blocks 124/125 May, blocks 132/133 June, Recreational: Cod minimum size 23 in., GOM party/charter limited to 10 fish combined cod/haddock, all areas private recreational limited to 10 cod Possession limits: Remain the same. Haddock possession limit of 3,000 lbs.-DAS/30,000 lbs.-trip through September 30.
June 1: Revised interim rule Minimum size: Cod 19 in. Closures: Year-round Cashes Ledge east and west closures removed Gear: *Hook*: Requirement for six-inch spacing for de-hooking gear removed
July 4: Haddock daily limit suspended. Possession limit of 30,000 lbs.-trip until September 30, 50,000 lbs.-trip thereafter.
August 1: Emergency rule implementing FW 33 lawsuit settlement agreement. DAS: DAS allocation for each permit reduced 20 percent from maximum used FY 1996-2000 (est 71,218 allocated, including carry-over). DAS counted by the minute, except for day gillnet vessels (15 hour minimum). (This change reverted to DAS counting in effect in FY 2001). Prohibition on front-loading DAS clock. Minimum size: Cod 22 in. Gear: *Trawl:* GOM/GB RMAs: 6.5 in. diamond or square codend minimum; Southern New England RMA changed to 70W to 74W (vice 72-30W). 6.5 in. square, 7 in. diamond codend in SNE RMA. *Gillnet:* GOM: Trip gillnets – 6.5 in. mesh/150 nets; Day – 6.5 in./50 standup nets, 7 in./100 tiedown nets (prohibited March-June); GB – 6.5 in./50 nets, SNE – 6.5 in./75 nets; Mid-Atlantic: Trip – 5.5 in. diamond/6 in. square, Day – 5.5 in. diamond/6 in. square. *Hook*: no de-hookers with less than 6 in/. spacing, 12/0 circle hooks or larger; GOM: 2,000 rigged hooks, GB: 3,600 rigged hooks Closures: Add GB seasonal closure areas, May – Blocks 80, 81, 118, 119, 120 (south of 42-20N) Possession limits: *Yellowtail flounder*: SNE/MA: landing/possession of yellowtail flounder prohibited south of 40N. Mar 1 – May 31: 250 lbs./trip, June 1 – February 28: 500 lbs.-DAS/4,000 lbs. – trip. *Cod*: GOM: 500 lbs.-DAS/4,000 lbs./trip. Open access commercial permits limited to 200 lbs. regulated groundfish. Recreational: Cod/haddock: 23 in. minimum size. Party/charter: GOM RMA: April-November, 10 cod/haddock combined per person, Dec-Mar – 10 cod/haddock combined, no more than 5 cod per person per trip. Private: GOM RMA: December-March – 10 cod/haddock combined, no more than 5 cod.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

2003
January 15-February 27: Northern Shrimp season (38 days with days off)
March 13: Haddock possession limit suspended until May 1.
May 1: Haddock possession limit of 3,000 lbs-DAS/30,000 lbs.-trip
May 1: Framework Adjustment 37 Modifications to whiting management measures: extension of Cultivator Shoal whiting fishery by one month (June 15-October 31), changes to default measures, minor changes to Cape Cod Bay Raised Footrope Trawl exemption area.
May 13: Haddock possession limit revised to 30,000 lbs./trip (no daily limit).
July 9: Framework Adjustment 38 Raised footrope trawl whiting fishery in the inshore GOM, July 1 – November 30 each year.
July 28: Final emergency rule implementing FW 33 lawsuit settlement agreement Recreational: Haddock, 21 in. minimum size. Party/charter: GOM: Apr-Nov, 10 cod per person, December-March, 5 cod per person. Private: GOM: December-March, 10 cod/haddock combined, no more than 5 cod. Other areas: 10 cod/haddock combined.
October 7: Haddock possession limit suspended for the remainder of the fishing year.
2004
January 19-March 12: Northern Shrimp season (40 days with days off)
May 1: Implementation of Amendment 13. Measures based on emergency rule and measures in effect prior to interim rule. DAS: DAS for each permit re-categorized. Category 1: 60% of maximum DAS used FY 1996-2001 in years that permit landed 5,000 pounds regulated groundfish (est. 43,000 allocated). Category B: 40% of maximum DAS used FY 1996-2001 in years that permit landed 5,000 pounds regulated groundfish; can only be used in specific programs. DAS leasing and transfer programs allow DAS exchanges between vessels under limited conditions. (200 lbs. of winter flounder can be retained by vessels fishing for fluke west of 72-30 W without using a DAS). Minimum Size: No change from emergency rule (commercial); 22 inch cod, 19 inch haddock (rec) Gear**:** *Trawl*: No change from emergency rule. *Gillnet*: GOM/GB: Day-6.5 in./50 standup nets, no seasonal restriction on tie-down nets; Trip: 6.5 in. mesh/150 nets. SNE/MA: 6.5 in. in. mesh/75 nets. *Hook: GOM:* 2,000 hooks. *GB*: 3,600 hooks Closures: Same as emergency rule, with addition of habitat closed areas; all except Jeffrey Bank and NLCA habitat closed area are within existing year-round closed areas. Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. GB cod: 1,000 lbs.-DAS/10,000 lbs.-trip. *CC/GOM yellowtail flounder*: April, May, October, November - 250 lbs. trip, other months 750 lbs.-DAS/3,000 lbs-trip. *SNE/MA yellowtail flounder*: March –June, 250 lbs. trip, other months 750 lbs.-DAS/3,000 lbs-trip. *Haddock*: 3,000 lbs.-DAS/30,000 lbs.-trip. Special Management Programs: *US/Canada Area*: hard TAC on cod, haddock (SAs 561, 562), yellowtail flounder (SAs 522, 525, 561, 562). Cod possession limit: 500 lbs-DAS/5,000 lbs-trip, not more than 5 percent of catch. No DAS charged to/from SAs 561, 562. Exempted Fisheries: Northern Shrimp fishery area restriction removed; General Category scallop fishery exemption in SAs 537, 538, 539, and 613.
May 14: Haddock possession limit suspended for remainder of the fishing year.
June 1: CAII Yellowtail Flounder Special Access Program Access to CAII south of 41-30N by trawl vessels targeting yellowtail flounder. Limited to 320 trips (total), two trips per vessel per month, yellowtail flounder limited to 30,000 lbs./trip. Authorized use of Category B DAS.
June 23: Amendment 10 to the Atlantic Sea Scallop FMP. 10-in. square mesh twine top required for all scallop dredge vessels in all areas.
September 3: CAII Yellowtail Flounder SAP ends (no trips can begin after this date)

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

November 2: Framework Adjustment 39 (Scallop Framework Adjustment 16) Scallop dredge vessel access to portions of groundfish mortality CAII and NLCA in 2004, CAI and CAII in 2005, and CAI and NLCA in 2006. Season: June 15 through January 31. Possession limits: 1,000 lbs. regulated groundfish, no more than 100 lbs. cod. In NLCA, limited to 250 lbs.-trip yellowtail flounder in June. (Outside of access program, scallop vessels continue to be limited to 300 lbs. regulated groundfish per trip). Yellowtail flounder catch capped at 10 percent of target TAC for the stock.
October 1: Closure of SAs 561 and 562 to all fishing on a multispecies DAS. Prohibition on the possession of yellowtail flounder from SAs 522, 525, 561, 562.
November 19: Framework Adjustment 40A *Closed Area I Haddock SAP* Access to small area of CAI to target haddock using longlines. Limited to 1,000 mt haddock TAC. Season ends December 31. *Eastern US/CA Area Haddock SAP Pilot Program* Access to northern corner of CAII and adjacent area to target haddock using separator trawl. Season: May 1 through December 31. Authorized use of Category B DAS. *Category B (regular) DAS Pilot Program* Vessels can use Category B (regular) DAS to target healthy stocks. Catch (kept and discarded) limited to 100 lbs. of cod, American plaice, white hake, witch flounder, ocean pout, SNE/MA winter flounder and windowpane flounder, 25 lbs.-DAS/250 lbs.-trip of yellowtail flounder. Maximum of 1,000 DAS can be used in each of four quarters from November 1, 2004 through October 31, 2005.
2005
January 14: Eastern US/CA reopened, yellowtail flounder daily poundage limit lifter (maximum remains 15,000 lbs./trip). Cod trip limit of 5,000 lbs./trip in Eastern US/CA area. Vessels fishing in Eastern US/CA area must use haddock separator trawl.
February 9: GB yellowtail flounder trip limit reduced to 5,000 lbs./trip in (entire) US/CA Management Area.
April 1: Eastern US/CA area closed until April 30, 2005, possession of GB yellowtail flounder prohibited in entire US/CA Management Area.
May 1: Eastern US/CA Area reopens at beginning of fishing year. Measures revert to those implemented May 1, 2004.
May 3: Haddock trip limit removed for remainder of the fishing year.
May 26: FW 40B implemented. Changes DAS leasing and transfer program, modifies GB Hook Sector provisions, adopts reporting requirements for herring vessels, modifies trip gillnet provisions. *CAII Yellowtail Flounder SAP* Changes starting date to July 1, reduces trip limit to 10,000 lbs, number of trips per vessel per month is one, process established for adjusting the total number of trips.
June 8: Emergency action to control bycatch of haddock in the herring fishery establishes trip limit and overall TAC.
June 15: Implementation of FW 16 to the Sea Scallop FMP authorizes General Category Scallop vessel participation in scallop access areas. Scallop access areas in CAI and CAII open for all vessels on this date.
June 27: Announcement that no trips will be allowed in the CAII Yellowtail Flounder SAP in FY 2005.
July 12: NE multispecies DAS vessels are limited to one trip per month in the Eastern US/CA area.
July 18: Multispecies DAS vessels are prohibited from fishing in the Category B (regular) DAS program in the GB cod stock area through July 31.
July 27: NE multispecies trawl vessels are required to use a haddock separator trawl when fishing in the Eastern US/CA area.
August 26: Eastern US/CA area is closed to all limited access multispecies DAS vessels because 90

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

percent of the GB cod TAC for the area is projected to be harvested.
September 6: CAI scallop access area is closed to General Category scallop vessels.
September 13: *CAI Hook Gear Haddock SAP* FW 41 to the Northeast Multispecies FMP implemented. This action allows non-sector longline vessels to participate in the CAI Hook Gear Haddock SAP. The October 1 – December 31 season is divided in half, with sector vessels fishing in the first half and non-sector vessels in the second.
October 6: Participation in the Category B (regular) DAS Pilot Program is prohibited because the quarterly allocation of 1,000 DAS is used. The program ends for FY 2005.
October 31: Boundaries of the sea scallop access areas within CAI and the NLCA access areas are adjusted.
December 12: Northern shrimp fishery opens and will remain open through April 30, 2006.
December 21: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is changed from unlimited to 15,000 lbs per trip. The quota for the second period of the CAI Hook Gear Haddock SAP is increased to 536.6 mt.
2006
January 12: The emergency rule allowing Atlantic herring vessels to possess haddock is extended for an additional 180 days.
January 31: Areas within groundfish closed areas that are open to scallop fishing through the scallop access area program close at midnight.
February 7: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is reduced to 1,500 lbs. per DAS up to a maximum of 15,000 lbs.
February 22: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is changed to 15,000 lbs. per trip regardless of trip length.
March 24: The trip limit for NE multispecies vessels fishing for GB yellowtail flounder is increased to an unlimited amount regardless of trip length.
April 30: Northern shrimp fishery season closes at midnight.
May 1: Implementation of an emergency rule to reduce fishing mortality on groundfish stocks while FW 42 is reviewed. Revised regulations are: DAS: DAS charged at the differential rate of 1.4:1 for all areas outside the US/CA area. Minimum Size: No changes for commercial vessels. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 600 lbs-DAS/4,000 lbs.-trip. *GB cod*: 1,000 lbs.-DAS/10,000 lbs.-trip outside of eastern US/CA area. *CC/GOM yellowtail flounder*: May, June October, November - 250 lbs. trip, other months 500 lbs.-DAS/2,000 lbs-trip. *GB yellowtail flounder*: 10,000 lbs. per trip; *GB winter flounder*: 5,000 lbs. per trip; *SNE/MA yellowtail flounder*: March –June, 250 lbs. trip, other months 750 lbs.-DAS/3,000 lbs-trip. White hake: 1,000 lbs.-DAS/10,000 lbs.-trip. *Haddock*: Trip limit removed for duration of emergency action. Special Management Programs: ***Eastern** US/Canada **haddock SAP***: Opening delayed until August 1. Category B (regular) DAS Program: Renewed, with vessels restricted to the US/CA Area, required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Recreational measures: Possession of GOM cod prohibited from November 1 – March 31. Minimum size for GOM cod increased to 24 in. Other: Vessels allowed to fish inside and outside the eastern US/CA area on the same trip.
May 19: Announcement that CAII Yellowtail SAP will not open due to low TAC.
June 19: All trawl vessels fishing in the eastern US/CA area required to use a haddock separator trawl.
July 12: General category scallop vessel access to Nantucket Lightship Close area closed due to catching yellowtail flounder incidental catch TAC.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

July 20: Limited access scallop vessel access to Nantucket Lightship Close area closed due to catching yellowtail flounder incidental catch TAC.
August 11: FW 43 implemented; addresses incidental catch of regulated multispecies by herring vessels. Haddock possession by midwater trawl vessels is allowed subject to a TAC.
September 6: Scallop vessel access to CAII closed due to yellowtail flounder bycatch.
October 1: CAI Hook Gear Haddock SAP opens.
November 22: Implementation of FW 42. Major regulatory changes: DAS: DAS charged at the differential rate of 2:1 for an area in the inshore GOM (for an entire trip if any part of the trip fished in the area) and an area in SNE (only time fishing in the area). Minimum Size: No changes for commercial vessels. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. *CC/GOM yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. *SNE/MA yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. Haddock trip limit unlimited. ***GB Yellowtail flounder: 10,000 lbs/trip. White Hake: 500 lbs-DAS/5,000 lbs-trip (this was an error – FW 42 says 1,000/10,000 per trip).*** Special Management Programs: *US/Canada Area*: Opening delayed until August 1. Prohibition on discarding legal sized fish. Category B (regular) DAS Program: Renewed for all areas. Trawl vessels required to use a haddock separator trawl, limited to 500 days May-June, 1,000 days in other quarters, low trip limits on stocks of concern. Prohibition on discarding legal sized fish. Recreational measures: (same as emergency rule) Possession of GOM cod prohibited from November 1 – March 31. Minimum size for GOM cod increased to 24 in. Other: (same as emergency rule) Vessels allowed to fish inside and outside the eastern US/CA area on the same trip.
December 1: Northern shrimp fishery opens: 151 days, seven days per week.
2007
March 5: Trawl vessels fishing in the eastern US/CA area allowed to use either a haddock separator trawl or a flounder net. GB yellowtail flounder trip limit reduced to 5,000 lbs.-trip for all vessels declaring into the eastern US/CA area.
April 5: Trip limit for GB yellowtail flounder increased to 25,000 lbs.-trip for the entire US/CA area for the remainder of the fishing year (through April 30).
April 25: Eastern U.S./Canada area closed to limited access multispecies vessels (through April 30, 2007).
April 30: Northern shrimp fishery closed at midnight.
May 1: Enforcement protocol for measuring nets changes. For mesh over 4.72 inches (120 mm), weight used with net spade increased to 8 kg (from 5 kg). Eastern U.S./Canada area reopens. No trips are authorized in the CAII yellowtail flounder SAP in 2007. Trip limit for GB yellowtail flounder reduced to 3,000 pounds per trip in the U.S./Canada area. Interim measures adopted for monkfish FMP restrict monkfish trip limits, reduce DAS that can be used in the SFMA, and does not allow carryover of monkfish DAS.
June 15: NLCA and CAI scallop access areas open.
June 20: Eastern US/CA area is closed to limited access multispecies DAS vessels due to cod catch.
July 8: The NLCA scallop access area is closed to General Category Scallop vessels.
July 15: The CAI scallop access area is closed to General Category Scallop vessels.
August 3: NMFS modifies permit renewal requirements for limited access multispecies vessels. Changes limit ability of vessels to fish in state waters outside of the FMP and retain eligibility for a federal limited access permit.
August 9: Minimum size for GB and GOM haddock caught by commercial vessels is reduced to 18

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

inches. Minimum size for all recreational vessels remains at 19 inches.
October 1: CAI Hook Gear Haddock SAP opens for GB Cod Hook Sector vessels.
October 20: The Eastern US/CA area is opened to limited access multispecies DAS vessels. The GB cod possession limit is 1,000 lb/trip for all vessels declared into the Eastern US/CA Area or the Eastern US/CA Area SAP.
November 15: CAI Hook Gear Haddock SAP opens for non-sector vessels.
November 27: GB yellowtail flounder trip limit for vessels fishing in the US/CA management area increased to 7,500 lb/trip.
November 30: Eastern US/CA area closes
December 1: Northern Shrimp fishery opens. Season scheduled for 152 days, seven days per week.
December 11: CAI Hook Gear haddock SAP second period haddock quota increased to 4,789 mt.
2008
January 10: GB yellowtail flounder tip limit in the U.S/Canada management area set at 1,500 lbs./trip
January 24: Harvesting, possessing, and landing GB yellowtail flounder from the entire U.S./Canada management area is prohibited through April 30, 2008 (applies to trips that have not begun prior to announcement).
February 6: Minimum size for both GB and GOM haddock remains at 18 inches total length; extended through August 10, 2008.
March 12: Scallop elephant trunk access area closed to General Category scallop vessels.
April 30: Northern shrimp fishery closes.
May 1: GB yellowtail flounder trip limit set at 5,000 lbs./trip Eastern U.S./Canada area opening delayed until August 1, 2008 for vessels fishing with trawl gear. Eastern U.S./Canada area opened to longline gear but with a cod cap of 33.4 mt.
May 30: CAII yellowtail SAP remains closed (no trips authorized for FY 2008).
August 1: GOM and GB haddock minimum size reverts to 19 inches. Eastern U.S./Canada management area opens to all vessels. U.S./Canada Haddock SAP opens.
August 4: Happy Birthday, U.S. Coast Guard. The Nantucket Lightship Closed Area closed to scallop vessels to prevent exceeding the yellowtail flounder incidental catch cap.
August 13: Haddock rope trawl (later called the Ruhle trawl, previously called the eliminator trawl) approved for use in the Category B (regular) DAS program and the U.S./Canada Haddock SAP.
September 15: Ruhle trawl authorized for use in the Eastern U.S./Canada management area.
October 1: CAI Hook Gear Haddock SAP opens for non-sector vessels.
October 23: GB yellowtail flounder trip limit reduced from 5,000 lbs./trip to 2,500 lbs./trip for vessels fishing in the U.S./Canada management area.
November 15: CAI Hook Gear Haddock SAP opens for GB cod hook sector vessels.
December 1: Northern shrimp fishery opens for 180 days, seven days per week. Closure scheduled for May 29, 2009.
December 23: Landing limit for Eastern GB cod increased to 1,000 lbs./DAS up to a maximum of 10,000 lbs./trip (applies to cod caught in the Eastern U.S./Canada management area).
December 30: Limited access General Category scallop fishery closed.
2009
January 26: NE Multispecies regulations adopted by FW 42 suspended as a result of a court order. No clear explanation of what measures are affected.
February 13: NMFS identifies following measures as NOT impacted by the court order to suspend measures adopted by FW 42: • Recordkeeping and reporting requirements • Gear restrictions • DAS allocations • Time and area closures

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

• Minimum fish sizes • SAPs • Recreational measures • Cape Cod Hook Sector • Some possession limits (GOM cod 800 lbs DAS-4,000 lbs/trip,, GB cod 1,000 lbs./DAS – 10,000 lbs./trip, US/CA area trip limits Confusion continues on what regulations are not in effect.
February 17: Federal court rescinds decision to suspend FW 42 measures and limits suspension to differential DAS counting areas in the GOM and SNE/MA areas, and authorizes submission of DAS leasing requests through March 31, 2009 (vice normal March 1 deadline for such requests).
March 9: Eastern GB cod landing limit reduced to 500 lbs./DAS – 5,000 lbs./trip. GB yellowtail flounder trip limit increased to 5,000 lbs/trip.
April 1: DELMARVA scallop access area closed to General Category scallop vessels.
April 16: Eastern US/CA area closed until May 1.
May 1: Interim rules in effect to reduce overfishing on multispecies stocks until Amendment 16 implemented. Major changes: DAS: DAS allocations reduced according to Amendment 13 schedule. Category A DAS are reduced to 45 percent of the permit's DAS baseline, an 18 percent reduction from the previous year's allocations. Differential DAS area increased in SNE/MA. Minimum Size: Haddock 18 inch minimum size. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. *GB cod*: 1,000 lbs./DAS-10,000 lbs./trip (eastern US/CA area 500 lbs./DAS-5,000 lbs./trip). *CC/GOM yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. *SNE/MA yellowtail flounder*: 250 lbs-DAS/1000 lbs. per trip. Haddock trip limit unlimited. *GB Yellowtail flounder*: 5,000 lbs/trip. *White Hake*: 1000 lbs-DAS/10,000 per trip). GB winter flounder: 5,000 lbs./trip. Witch flounder: 1,000 lbs./DAS-5,000 lbs./trip. Possession *of ocean pout, northern windowpane flounder, and SNE/MA winter flounder* prohibited. Special Management Programs: *US/Canada Area*: Opening delayed until August 1 for trawl vessels. *SNE/MA winter flounder SAP* suspended. State waters winter flounder exemption eliminated. *CAI Hook Gear Haddock SAP* expanded to May 1 to January 31, area increased, no separation between common pool and sector participants. Recreational Measures: GB cod bag limit of n10 cod per person per day for party/charter vessels; retention of GOM cod prohibited from November through April 15; retention of SNE/MA winter flounder prohibited; haddock minimum size reduced to 18 inches. Other: Conservation tax removed from DAS transfers.
May 6: Limited access general category scallop fishery closed to IFQ vessels until June 1.
May 29: Northern shrimp fishery closes.
June 5: GB yellowtail flounder trip limit reduced to 2,500 lbs./trip
June 26: eastern US/CA Area closed to all vessels until August 1 (including fixed gear vessels) to prevent exceeding first quarter GB cod TAC.
June 29: CAII Scallop Access Area closed to prevent exceeding GB yellowtail flounder cap.
July 6: *GB winter flounder* trip limit removed. *White hake* trip limit increased to 2,000 lbs./DAS-10,000 lbs./trip.
July 19: Limited access general category scallop fishery closed to IFQ vessels until September 1.
September 15: Limited access general category scallop fishery closed to IFQ vessels until December 1.
September 17: Use of flounder trawl net prohibited when fishing in the Eastern US/CA area.
November 2: Mid-water trawl vessels fishing in CAI subject to 100 percent observer coverage, prohibition on releasing catch before sampling by observer.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

November 20: In the US/CA management area, trawl vessels required to use a haddock separator trawl or Ruhle trawl south of 41-40N latitude. Any vessel fishing in this area and other areas cannot use any other gear on the same trip. Vessels fishing north of 41-40N for the entire trip can use any legal gear.
December 1: Northern shrimp fishery opens for 180 days; scheduled to close May 29, 2010.
2010
January 12: Limited access general category scallop fishery closed to IFQ scallop vessels
March 1: Limited access general category scallop IFQ program opens. Scallop fishery Elephant Trunk and DELMARVA Access Areas open.
March 11: All multispecies vessels fishing on a Category A DAS allowed to use any legal trawl gear in the Western US/CA Area (statistical areas 522, 525) (lifts restrictions adopted November 20, 2009).
April 13: All multispecies vessels fishing on a Category A DAS allowed to use a flounder trawl net in the Eastern US/CA area.
April 20: Eastern US/CA area (statistical areas 561, 562) closed to multispecies vessels and harvest, possession, and landing of GB yellowtail flounder from entire US/CA area (statistical areas 522, 525, 561, 562) prohibited.
May 1: Implementation of Amendment 16 and Framework 44. Expansion of sector management program to majority of the fishery. Major revisions to common pool measures for permitted vessels not in sectors. Adoption of additional at-sea and dockside monitoring requirements for sector vessels, and new reporting requirements for other vessels. Adoption of new US/CA area TACs. Adoption of annual catch limit (ACL) and accountability measures (AM) for most stocks. No retention of SNE/MA winter flounder, ocean pout, windowpane flounder, Atlantic wolffish. Specific allocations of GOM cod and GOM haddock made to the recreational and commercial groundfish fisheries. Key elements: *Sector Management:* Vessels in sectors subject to hard TACs for most stocks, increased at-sea monitoring (targeting 38 percent of trips), dockside monitoring; not subject to trip limits, some GOM rolling closures, groundfish DAS limits. Permits committed to sectors account for 94 percent or more of available catch except for GOM WFL (84 pct) and SNE/MA YTF (76 pct), and SNE/MA WFL (0%). Total permits committed to sectors: 762. Sector vessels required to retain all legal-sized fish (except limited to one Atlantic halibut, and the five species prohibited). Sectors required to stop fishing in a stock area when a quota (Annual Catch Entitlement, or ACE) for a stock in the area is caught. *Common pool*: Only a small portion of the ACL available to common pool vessels. Major elements of common pool regulations: DAS: Category A DAS allocations reduced to 27.5 percent of the Amendment 13 baseline allocation. All DAS charged in 24 hour increments. Minimum Size: Haddock 18 inch minimum size. Halibut size increased to 41 inches. Gear**:** No changes. Closures: No changes Possession limits: *GOM cod*: 800 lbs-DAS/4,000 lbs.-trip. *GB cod*: 2,000 lbs./DAS-20,000 lbs./trip (eastern US/CA area 500 lbs./DAS-5,000 lbs./trip). *Pollock*: 1,000 lbs./DAS – 10,000 lbs/trip; *CC/GOM yellowtail flounder*: 250 lbs-DAS/1500 lbs. per trip. *SNE/MA yellowtail flounder*: 250 lbs-DAS/1500 lbs. per trip. Haddock trip limit unlimited. *GB Yellowtail flounder*: 2,5000 lbs/trip offshore; 250 lbs./DAS-1,500 lbs./trip inshore. *White Hake*: 2,000 lbs-DAS/10,000 per trip). GB winter flounder: 5,000 lbs./trip. Witch flounder: 1,000 lbs./DAS-10,000 lbs./trip. GB winter flounder: Offshore 5,000 lb./trip. Possession *of ocean pout, windowpane flounder, Atlantic wollffish, and SNE/MA winter flounder* prohibited. Restricted Gear Areas: Areas near CAI and off SNE created to reduce flatfish catches; limited to separator/Ruhle trawls, rope trawl, certain gillnets in these areas. Limited to 500 lbs. of flatfish combined in these areas. Special Management Programs: *US/Canada Area*: Opening delayed until August 1 for trawl vessels. Prohibition on discarding legal sized fish. *SNE/MA winter flounder SAP* suspended. State waters winter flounder exemption eliminated. *CAI Hook Gear Haddock SAP* expanded to January 31, area increased, no separation between common pool and sector participants.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

CAII yellowtail flounder –haddock SAP: SAP opening authorized to target haddock (not GB yellowtail flounder_ subject to specific gear requirements. Opening date August 1. *Adjustments*: RA authorized to make in-season adjustments to trip limits and DAS counting rates. *DAS Leasing and Transfers*: Permits in CPH category allowed to participate in these programs. No conservation tax on transfers. Recreational Measures: GOM cod bag limit of 10 cod per person per day for party/charter vessels; 10 fish bag limit on all cod for private vessels; retention of GOM cod prohibited from November through April 15; retention of SNE/MA winter flounder prohibited; Atlantic wolffish retention prohibited; haddock minimum size reduced to 18 inches. Halibut size increased to 41 inches. No limit on hooks (two hook limit removed).
May 5: Northern shrimp fishery season closes
May 27: Changes to common pool trip limits: GOM haddock: 1,000 lbs./trip GB haddock: 10,000 lbs./trip GOM winter flounder: 250 lbs./trip GB winter flounder: 1,000 lbs./trip (offshore) GB yellowtail flounder: 1,000 lbs./trip (offshore)
June 28: NLCA scallop access area opens
July 15: Pollock ACL revised; increased to 16,553 mt.
July 30: Changes to common pool measures: GB yellowtail flounder: Selective trawl gear required in Eastern US/CA area and Western US/CA area south of 41-40N. GOM cod: 200 lbs./DAS-1,000 lbs./trip
August 6: Changes to common pool measures: Pollock trip limit removed Witch flounder: 130 lbs./trip
August 31: Common pool DAS counting rate set to 2:1 for GOM and GB differential DAS areas.
September 22: Changes to common pool measures: GOM cod: 100 lbs./DAS-1,000 lbs./trip GB yellowtail flounder: 100 lbs./trip White hake: 100 lbs./DAS – 500 lbs./trip US/CA area: Selective trawl gear required to entire US/CA management area
October 18: Handgear A cod trip limit reduced to 50 lbs/trip.
December 1: Northern shrimp season opens
2011
January 24: DELMARVA scallop access area closes to LAGC vessels
February 28: Northern shrimp season closes
March 31: Groundfish common pool trip limit changes. Increase: GB cod 3,000 lbs/DAS, 30,000 lbs/trip' SNE/MA yellowtail flounder 750 lbs/DAS, 3,000 lbs/trip CC/GOM yellowtail flounder 750 lbs/DAS, 3,000 lbs/trip. Decrease: GOM cod 100 lb/trip GOM winter flounder 100 lb/trip
May 1: Start of groundfish fishing year. Common pool trip limits revert to chart (see attached for May 2011). Differential DAS counting areas in GOM and GB. GOM cod spawning area closure adopted off NH, April – June; prohibits all rec and commercial groundfish fishing.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

CAII SAP modified to allow targeting haddock, August 1 – January 31. Gen Cat scallop fishing GSC spawning closure eliminated
August 1: CAI, CAII, and Hudson Canyon scallop access areas open
August 30: Groundfish common pool trip limit reductions. GOM cod: 350 lb/DAS, 1,000 lb/trip GB cod: 300 lb/DAS, 600 lb/trip
September 8: Differential DAS rates reduced for common pool vessels in the offshore GOM and inshore GB differential DAS areas
September 14: Haddock catch cap regulations for herring fishery change. Cap increased to 1% of GB haddock ABC and 1% of GOM haddock ABC. Applies to MIWT gear. Based on catch estimate.
September 19: Dockside monitoring program suspended.
October 1 and 3: Herring Management Areas 1B (Oct 1) and 3 (Oct 3) closed to directed herring fishing due to herring quota being caught
October 3: Handgear B trip limits reduced ot GOM cod 50 lb/trip, GB cod 25 lb/trip
October 27: Herring Management Areas 1A closed to directed herring fishing due to herring quota being caught
November 7-10: Directed herring fishery reopens in Area 3 for 3 days.
November 12: Hudson Canyon scallop access area closes to LAGC vessels

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

May , 2011 trip limits:

Species	Stock Area[1]	A DAS	Handgear A	Handgear B	Eastern US/Canada Haddock SAP[3]	Regular B DAS Program	
						Separator or Ruhle Trawl[3]	Non-Trawl Gear
Cod	GOM	500 lb/DAS, up to 2,000 lb/trip	300 lb/trip	75 lb/trip	1,000 lb/trip	100 lb/DAS, up to 1,000 lb/trip	
	OFF GB, IN GB, and SNE	3,000 lb/DAS, up to 30,000 lb/trip (outside of the Eastern U.S./Canada Area)[2]	300 lb/trip	75 lb/trip			
		500 lb/DAS, up to 5,000 lb/trip (E. U.S./Canada Area)					
		1,000 lb/trip Closed Area I Hook Gear Haddock SAP -or- Closed Area II Yellowtail Flounder/Haddock SAP (for targeting haddock)					
Haddock	GOM	1,000 lb/trip					
	OFF GB, IN GB, and SNE	10,000 lb/trip					
Pollock	All Areas	Unlimited				100 lb/DAS to 1,000 lb/trip	
Redfish	All Areas	Unlimited					
White hake	All Areas	1,500 lb/trip				100 lb/DAS to 1,000 lb/trip	
Atlantic halibut	All Areas	1 fish/trip					
Yellowtail flounder	GOM, IN GB	500 lb/DAS, up to 2,000 lb/trip			NA	25 lb/DAS to 250 lb/trip	
	SNE	500 lb/DAS, up to 2,000 lb/trip					
	OFF GB	2,500 lb/trip			100 lb/DAS, up to 500 lb/trip of all flatfish combined	100 lb/DAS for each stock, up to 500 lb/trip of all flatfish combined	100 lb/DAS, to 1,000 lb/trip
American plaice (dabs)	All Areas	Unlimited			500 lb/trip of all flatfish combined		100 lb/DAS, to 1,000 lb/trip
Witch flounder (gray sole)	All Areas	250 lb/trip					100 lb/DAS, to 250 lb/trip
Winter flounder	OFF GB	1,000 lb/trip			100 lb/trip		100 lb/DAS, to 1,000 lb/trip
	GOM	250 lb/trip			NA	250 lb/trip	
	SNE	**Zero – possession prohibited[4]**					
Windowpane Flounder	All Areas	**Zero – possession prohibited**					
Ocean Pout							
Atlantic Wolffish							

[1] Broad Stock Areas: Gulf of Maine (GOM), Inshore Georges Bank (IN GB), Offshore Georges Bank (OFF GB), and Southern New England (SNE)

[2] Vessel must submit GOM Cod Trip Limit Exemption Form via VMS

[3] Gear performance trip limits of 500 lb all flatfish combined, 500 lb whole monkfish (unless otherwise restricted by trip limits of the monkfish FMP), 500 lb whole skate, and zero lobsters also apply

[4] A vessel may transit the InGB and SNE areas with GOM or OffGB winter flounder on board, provided that fishing gear is properly stowed

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

2012
January 6: Recreational fishery for GOM haddock changes: Decrease: 9 fish possession limit (reduced from unlimited) Increase: Minimum fish size to 19 inches total length (up from 18 inches)
February 7: Commercial groundfish GOM Winter Flounder catch limits change for remainder of the FY 2011 through Emergency Action: Increase: 524 mt (up from 231 mt)
February 20: Directed herring fishery in Area 2 closes due to herring quota being caught
March 8: Groundfish common pool trip limit changes for the remainder of FY 2011. Increase: GB cod: ADAS: 1,500 lbs/DAS up to 4,500 lbs/trip (up from 300 lb/DAS up to 600 lb/trip) GB cod: HB 75 lb/trip (up from 25 lb/trip) SNE/MA yellowtail flounder: ADAS: 1,500 lb/DAS up to 4,500 lb/trip (up from 500 lb/DAS up to 2,000 lb/trip)
April 20: Recreational fishery for GOM haddock changes: Increase: Unlimited fish possession limit (up from 9 fish) Decrease: Minimum fish size to 18 inches total length (down from 19 inches)
May 1: Start of groundfish fishing year. Sectors: Exemptions: - Universal- exempt from trip limits for allocated stocks; exempt from the GB Seasonal Closure Area; exempt from the requirement to use DAS to land GF; can use 6-inch mesh on cod end on haddock separator trawls, rope trawls, and Rhule trawls when on GB; exempt from portions of the GOM Rolling Closure Areas - 20 additional sector by sector exemptions approved for FY 2012 (see table) Common Pool: -Common pool trip limits revert to chart (see attached for May 2012). -DAS counting rate is 1 for common pool on Category A DAS -Common pool trimester TAC -Trawl gear allowed in Eastern US/Canada management area (rather than 8/1 in the past) but still with

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

haddock separator trawl, Rhule trawl, or flounder trawl - FW 47 removed the common pool restricted gear areas in SNE and GB (in place since 5/1/2010) Common Pool and Sectors - FW 47 established AMs for windowpane flounder, ocean pout and Atlantic halibut - FW 47 – by Jan 15th of each FY – re-estimate the expected catch of GB YTF by the scallop fishery – if less than 90% of scallop fishery sub-ACL, then increase the commercial GF fishery sub- ACL for GB YTF Recreational fishery for GOM cod changes: Decrease: Minimum fish size to 19 inches total length (down from 24 inches) 9 fish possession limit (reduced from 10 fish) Small-mesh multispecies (whiting) fishery: ACLs and AMs created for silver hake, red hake, and offshore hake through a Secretarial Amendment
May 7: Sea Scallop Framework 23 implemented, revises the AM closure schedules to better target months with the highest yellowtail flounder catch rates for both Southern New England/Mid-Atlantic and Georges Bank stocks.
June 13: Delmarva closed to scallop fishing for the remained of the fishing year
July 13: Revised catch limits for GB YTF for FY 2012 Increased GF sub-ACL by 150.6 mt and decreased scallop sub-ACL by same amount Scallop revised sub-ACL is 156.9 mt (down from 307.5 mt) Groundfish revised sub-ACL is 368.3 mt (up from 217.7 mt)
August 15: White hake trimester area closed for common pool fishery through August 31
September 20: Northern red hake possession limit through April 30, 2013 Decrease: 400 lb possession limit in the GOM/GB Exemption Area (northern hake stock area)
September 26: Common pool fishery – adjustment to DAS counting rate – differential DAS counting in GOM, GB and SNE/MA due to overages of northern window pane flounder. Atlantic halibut, and southern windowpane flounder
October 7: Directed herring fishery closed in Area 3 due to herring catches, closed through December 31
October 24: Delmarva closed to scallop fishing extended through May 13, 2013
November 5: Directed herring fishery closed in 1A due to herring catches, closed through December 31
December 5: Common pool - Area closed for remainder of trimester 2 to white hake fishing, through December 31

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

December 12: Closure of Elephant Trunk Area for sea scallop vessel through June 10, 2013

Beginning May 1, 2012, common pool vessels are subject to the trip limits listed below. Under FW 44, the Regional Administrator has the authority to revise trip limits for common pool vessels to ensure that ACLs allocated to the common pool are not exceeded.

Species	Minimum Size	Stock Area[1]	A DAS	Handgear A	Handgear B	Regular B DAS Program	
						Separator or Ruhle Trawl[4]	Non-Trawl Gear
Cod	22"	GOM	650 lb/DAS, up to 2,000 lb/trip	300 lb/trip[3]	75 lb/trip[3]	100 lb/DAS, up to 1,000 lb/trip	
		OFF GB, IN GB, and SNE	2,000 lb/DAS, up to 20,000 lb/trip (outside of the Eastern U.S./Canada Area)[2]	300 lb/trip[3]	75 lb/trip[3]		
			500 lb/DAS, up to 5,000 lb/trip (E. U.S./Canada Area)				
			1,000 lb/trip Closed Area I Hook Gear Haddock SAP -or- Closed Area II Yellowtail Flounder/Haddock SAP (for targeting haddock)				
Haddock	18"	GOM	1,000 lb/trip				
		OFF GB, IN GB, and SNE	10,000 lb/trip				
Pollock	19"	All Areas	Unlimited			100 lb/DAS to 1,000 lb/trip	
Redfish	9"	All Areas	Unlimited				
White hake	none	All Areas	1,500 lb/trip			100 lb/DAS to 1,000 lb/trip	
Atlantic halibut	41"	All Areas	1 fish/trip				
Yellowtail flounder	13"	GOM, IN GB	500 lb/DAS, up to 2,000 lb/trip			25 lb/DAS to 250 lb/trip	
		SNE	1,500 lb/DAS, up to 4,500 lb/trip				
		OFF GB	500 lb/trip			100 lb/DAS for each stock, up to 500 lb/trip of all flatfish combined	100 lb/DAS, to 1,000 lb/trip
American plaice (dabs)	14"	All Areas	Unlimited				100 lb/DAS, to 1,000 lb/trip
Witch flounder (gray sole)	14"	All Areas	250 lb/trip				100 lb/DAS, to 250 lb/trip
Winter flounder	12"	OFF GB	1,000 lb/trip				100 lb/DAS, to 1,000 lb/trip
		GOM	250 lb/trip			250 lb/trip	
		IN GB, SNE	Zero – possession prohibited[5]				
Windowpane Flounder		All Areas	Zero – possession prohibited				
Ocean Pout							
Atlantic Wolffish							

[1] Broad Stock Areas: Gulf of Maine (GOM), Inshore Georges Bank (IN GB), Offshore Georges Bank (OFF GB), and Southern New England (SNE)

[2] Vessel must submit GOM Cod Trip Limit Exemption Form via VMS

[3] Unless otherwise revised by the Regional Administrator

[4] Gear performance trip limits of 500 lb all flatfish combined, 500 lb whole monkfish (unless restricted by the monkfish FMP), 500 lb whole skate, and zero lobsters also apply

[5] A vessel may transit the InGB and SNE areas with GOM or OffGB winter flounder on board, provided that fishing gear is properly stowed.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

	Exemption	FGS	NCCS	NEFS II	NEFS III	NEFS IV	NEFS V	NEFS VI	NEFS VII	NEFS VIII	NEFS IX	NEFS X	NEFS XI	NEFS XII	NEFS XIII	PCS	SHS1	SHS 3	TSS
1	120-Day Gillnet Block out of the Fishery	X	X		X			X	X			X	X	X	X	X	X	X	X
2	20-Day Spawning Block	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
3	Limits on the Number of Gillnets for Day Gillnet Vessels	X			X			X	X			X	X	X	X	X	X	X	X
4	Prohibition on a Vessel Hauling Another Vessel's Gillnet Gear	X		X	X			X	X			X	X	X	X	X	X	X	X
5	Limits on the Number of Gillnets that May be Hauled on GB when Fishing on a Groundfish/Monkfish DAS	X			X			X	X			X	X	X	X	X	X	X	X
6	Limits on the Number of Hooks that May be Fished	X	X		X			X	X			X	X	X			X	X	X
7	DAS Leasing Program Length and Horsepower Restrictions	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
8	GOM Sink Gillnet Mesh Exemption January Through April	X			X			X	X			X	X	X	X	X	X	X	X
9	Extension of the GOM Haddock Sink Gillnet Program Through May	X			X			X	X			X	X	X	X	X	X	X	X
10	Prohibition on Discarding	X											X	X			X	X	
11	Daily Catch Reporting by Sector Managers for Sector Vessels that Fish in the CA I Hook Gear Haddock SAP	X	X		X			X	X			X	X	X	X		X	X	X
12	Gear Requirements in the US/CA Management Area	X		X	X		X	X	X	X	X	X	X	X	X		X	X	X
13	Powering VMS While at the Dock*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
14	DSM Requirements for Vessels Fishing West of 72°30' W. Long.	X		X	X		X	X	X	X	X	X	X	X	X		X	X	X
15	DSM Requirements for Handgear A-permitted Sector Vessels	X		X	X			X	X	X		X	X	X	X		X	X	X
16	DSM Requirements for Monkfish Trips in the Monkfish SFMA	X		X	X		X	X	X	X	X	X	X	X	X		X	X	X
17	Prohibition on Fishing Inside and Outside the CA I Hook Gear Haddock SAP While on the Same Trip	X						X	X			X	X	X	X		X	X	X
18	6.5-Inch Minimum Mesh Size Requirement to Allow 6-Inch Mesh for Targeted Redfish Trips	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
19	Prohibition on a Vessel Hauling Another Vessel's Hook Gear	X			X			X	X			X	X	X	X		X	X	
20	Requirement to Declare Intent to Fish in the Eastern US/CA SAP and CA II YT/haddock SAP from the Dock	X		X			X	X	X	X	X	X	X	X	X		X	X	X

* The sector vessel may only powerdown its VMS if the vessel does not hold other permits requiring continuous VMS operation, and must send the VMS powerdown declaration before turning off power to the VMS unit.

2013
February 1: Implementation of the Coastal GOM Consequence Closure Area – due to harbor porpoise bycatch for the Northeast sink gillnet fisheries (shifted from original date of October and November, 2012); to be in place for February and March 2013

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

February 11: Common pool trip limits adjustment for five stocks through April 30 Increase: GOM Cod: A DAS- 2,000 lb/DAS up to 6,000 lb/trip (up from 650lb/DAS up to 2,000 lb/trip) GOM Cod: HB- 200 lb/trip (up from 75 lb/trip) GB Cod: A DAS- 3,000 lb/DAS up to 30,000 lb/trip (up from 2,000 lb/DAS up to 20,000 lb/trip) GB Cod: HB – 125 lb/trip (up from 75 lb/trip) SNE/MA YTF – A DAS- 5,000 lb/DAS up to 15,000 lb/trip (up from 1,500 lb/DAS up to 4,500 lb/trip) Decrease: White Hake: A DAS: 500 lb/trip (down from 1,500 lb/trip) Pollock: A DAS: 10,000 lb/trip (down from unlimited)
February 28: Sector exemption to target redfish with 4.5 inch codend mesh for remainder of FY 2012
April 7: Directed herring fishery closed in Area 2 due to herring catches, through the end of the year
May 1: Start of groundfish fishing year FW 48- Management measures AND FW 50- Specifications for many groundfish stocks for FY 2013-FY 2015 - Catch limits for FYs 2013-2015 for many of the groundfish stocks, including FY 2013 total allowable catches (TACs) for U.S./Canada stocks of Eastern Georges Bank (GB) cod and haddock - revised Southern New England/Mid-Atlantic (SNE/MA) winter flounder rebuilding program and allowance of SNE/MA winter flounder landings - Reductions in the minimum fish size for some species- implemented in July - Scallop fishery allocated a sub-ACL of SNE/MA windowpane flounder beginning in FY 2013 (AMs under development in the Scallop plan) - Scallop sub-ACL for GB YTF will be 16% of the US ABC starting in FY 2014 - Small-mesh fisheries allocated 2% of the US ABC for GB YTF starting in FY 2013; (AMs are under development) - AMs revised/developed for non-allocated stocks of groundfish including Atlantic halibut, wolffish, northern windowpane flounder, southern windowpane flounder, and ocean pout - Changes to sector carryover, this new mechanism specifies that an automatic de minimus amount of carryover will not be counted against ACEs or ACLs in order to provide some incentive for vessels not to risk safety at sea in the last part of the fishing year. - Elimination of dockside monitoring requirements for the groundfish fishery - Changes to reporting in the US/CA area – later changed back and applied retroactively (see below) Also, emergency action to implement FY 2013 catch limits for white hake and GB yellowtail flounder and to reduce FY 2012 Gulf of Maine (GOM) cod carryover Sector Exemptions: Universal ones and 23 additional (see table below) Common Pool GOM cod: Handgear A- 100 lb /trip

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

GOM cod: Handgear B- 25 lb / trip GB cod: Handgear A- 300 lb/trip GB cod: Handgear B – 75 lb / trip Small vessel category- 100 lb each of cod, haddock, and yellowtail per trip. (combined total of 300 lb per trip), and up to the trip limit of the remaining groundfish stocks Common pool trip limits revert to chart (see attached for May 2013). No differential DAS Recreational Fishery changes: -Vessels are allowed to retain and land SNE/MA winter flounder from Federal waters -GOM haddock minimum size has increased to 21 inches; no bag limit. Changes to Eastern US/ Canada Area Quota Monitoring Catch Apportioned by Areas Fished (issued 7-9-2013 and applied retroactively to May 1, 2013) - Changes to how catches for cod, haddock, and yellowtail flounder in the Eastern U.S./Canada Area are tracked. The statistical areas reported on vessel monitoring system (VMS) catch reports and vessel trip reports (VTRs) will be used to apportion catch to specific stock allocations. This change reinstates the practice that was followed by NMFS since the implementation of Amendment 16 in May 2010
May 6: Implementation of A19 to GF FMP that applies to the small-mesh multispecies (whiting fishery) - The specifications for the 2013 and 2014 fishing years - That the red hake trip limit will be 5,000 lb for all areas and all gear types - That the southern whiting trip limit will be 40,000 lb for vessels using 3-inch mesh, or larger, in the Southern New England and Mid-Atlantic Exemption Areas - Changes to the accountability measures for small-mesh multispecies - Changes to the quota structure for the southern area, if landings increase rapidly and - Administrative changes to the specifications and framework adjustment processes for the whiting fishery
May 20: Scallop FW 24 - Changes to YTF AMs in SNE/MA--- seasonal closures based on the percentage of the overage in the year following the overage - SNE/MA windowpane sub-ACLs in the scallop fishery --- allocated in GF FW 50- AM to be developed in the next Scallop FW
July 1: Change in Minimum Fish Sizes for the Commercial Fishery

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

Species	Minimum Size as of May 1, 2013	New Minimum Size as of July 1, 2013
Cod	22	**19**
Haddock	18	**16**
Pollock	19	**19**
Witch flounder (gray sole)	14	**13**
Yellowtail flounder	13	**12**
American plaice (dab)	14	**12**
Atlantic halibut	41	**41**
Winter flounder (blackback)	12	**12**
Redfish	9	**7**

July 16: Common Pool Changes Decrease in trip limit SNE/MA winter flounder – 1,000 lb/trip Trimester Closure for Remainder of Trimester 1 (July 16, 2013-August 31, 2013) for GOM haddock
July 30:Common Pool Closure for remainder of trimester 1 (July 30- August 31, 2013) for GB cod
August 26: Northern red hake possession limit reduced to 400 lb (August 26 – April 30, 2014)
August 28: Changes to Common Pool Trip Limits (August 28 – April 30, 2014) Decrease SNE/MA winter flounder – to 300 lb/trip GOM haddock – to zero lb/trip
October 15: Directed herring fishery closes in herring area 1A until the end of 2013
October 24: Directed herring fishery closed in herring area 3 until the end of 2013
October 30: Common Pool Trip Limit Changes

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

Stock	Permit	Old Possession Limit	New Possession Limit
GOM Cod	A DAS	100 lb/DAS up to 300 lb/trip	**650 lb/DAS up to 2,000 lb/trip**
	Handgear A	100 lb/trip	**300 lb/trip**
	Handgear B	25 lb/trip	**75 lb/trip**
	Category C	100 lb cod within the 300-lb combined trip limit of cod/yellowtail flounder	**300 lb/trip within the 300-lb combined trip limit of cod/yellowtail flounder**
CC/GOM Yellowtail Flounder	A DAS	500 lb /DAS up to 2,000 lb/trip	**2,000 lb/trip**
GOM Winter Flounder	A DAS	500 lb/trip	**2,000 lb/trip**
White Hake	A DAS	500 lb/trip	**1,000 lb /DAS up to 3,000 lb/trip**
Pollock	A DAS	10,000 lb/trip	**Unlimited**

December 31: Sector Exemption allowing vessels into portions of the Nantucket Lightship year-rounder closed area (until the end of FY 2013)

Sector vessels can fish in the Eastern and Western Exemption Areas of the Nantucket Lightship Closed Area under standard at-sea monitoring requirements. Sectors with vessels interested in utilizing this exemption must notify NOAA Fisheries. Prior to fishing in these areas, vessels will need a revised Letter of Authorization (LOA) from their sector manager. Vessels can only fish in these areas if they have a valid LOA on board that includes this exemption. Vessels must call into the Pre-Trip Notification System (PTNS) 48 hours in advance of departure. Vessels that intend to fish in the Eastern or Western Exemption Areas must indicate their intent by writing "N4" in the "Comments" field of their trip start hail and submit the trip start hail prior to departure for each trip into these areas.

When fishing in the Eastern or Western Exemption Areas, gillnet vessels must fish with extra-large mesh gillnets (10" or greater). Pingers must be attached to gillnets when fishing in the Western Exemption Area. Trawl vessels must fish with selective trawl gear, such as the Ruhle or haddock separator trawl. Standard otter trawls and flounder nets are prohibited in these areas.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

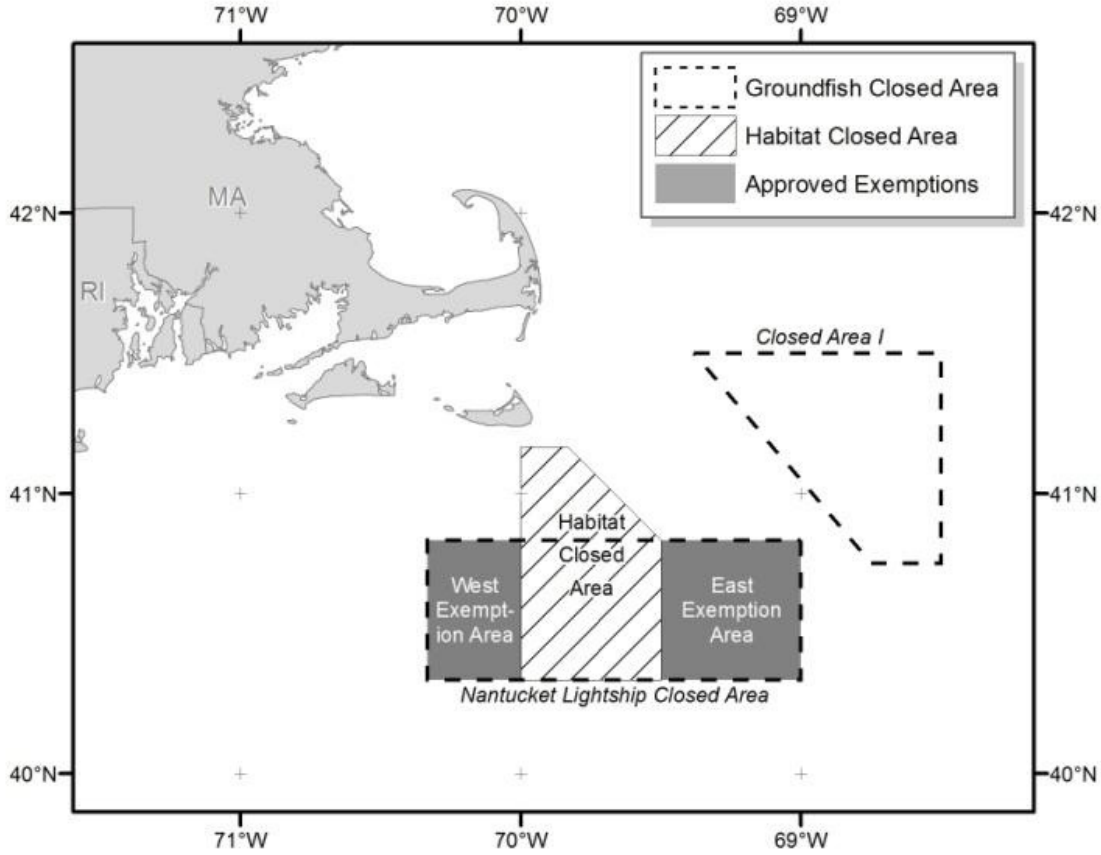

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

What do the exemptions mean?	Exemptions are briefly explained below:
The 120-day gillnet block out of the fishery	A gillnet vessel granted this exemption is not required to declare and take 120 days out of the gillnet fishery in 2013.
The 20-day spawning block	A vessel granted this exemption is not required to stop fishing for groundfish for a 20-day period between March 1 and May 31 of 2013.
The prohibition on hauling another vessel's gillnet gear	This exemption allows multiple vessels participating in the same sector to haul each other's gillnet gear. Each vessel using this exemption must tag each gillnet it intends to haul with one tag.
The number of gillnets that may be hauled on GB when fishing on a groundfish/monkfish DAS	This exemption allows a vessel issued both a groundfish permit and a monkfish permit to haul all of their gillnets on a single GB trip.
The number of hooks that may be fished	A vessel granted this exemption has no limit on the number of hooks they may fish within any of the Regulated Mesh Areas.
The DAS Leasing Program length and horsepower restrictions	Any sector vessel granted this exemption may lease DAS to any other sector vessel also granted this exemption, regardless of a vessel's leasing length and horsepower baseline restrictions.
The prohibition on discarding	A vessel granted this exemption must discard all legal-sized unmarketable fish at sea (not on selected trips), and cannot land unmarketable fish.
Daily catch reporting by sector managers for sectors vessels fishing in the Closed Area (CA) I Hook Gear Haddock Special Access Program (SAP)	This exemption is specific to sector managers, and not to sector vessels. A sector vessel fishing in the CA I Hook Gear Haddock SAP must complete a daily vessel monitoring system (VMS) catch report and submit it directly to us.
Powering a VMS while at the dock	This exemption allows a sector vessel to power down its VMS unit at the dock, after sending a power-down code to us. A vessel with multiple permits requiring VMS (i.e., monkfish, scallop, etc.) must continue to comply with reporting requirements for other fisheries, and may not be able to take advantage of this exemption.
Prohibition on fishing inside and outside the CA I Hook Gear Haddock SAP while on the same trip	A vessel may fish both inside and outside the CA I Hook Gear Haddock SAP on the same trip, but is prohibited from setting or hauling fixed gear across the border of the SAP. The vessel will be required to report via VMS catch from inside the SAP daily either to the sector manager or to us if the sector manager is also exempt from daily reporting requirements for the CA I Hook Gear Haddock SAP. Vessels declared into the CA I Hook Gear Haddock SAP may possess only demersal longline gear or tub trawl gear on the vessel during the trip.
The 6.5-inch minimum mesh size requirement on targeted redfish trips	This exemption allows a vessel to use codends with mesh size as small as 4.5 inches to target redfish, provided an industry-funded monitor is onboard. Sectors wishing to use this exemption must develop an industry-funded monitoring program. NMFS will monitor monthly catch thresholds of 80-percent redfish and a 5-percent groundfish discard limit.
The prohibition on a vessel hauling another vessel's hook gear	This exemption allows multiple vessels participating in the same sector to haul each other's hook gear. Each vessel intending to haul the hook gear must tag the gear consistent with §§ 648.14(k)(6)(ii)(B) and 648.84(a).
The requirement to declare intent to fish in the Eastern U.S./Canada SAP and the CA II Yellowtail flounder/Haddock SAP	This exemption allows a sector vessel to declare its intent to fish in these SAPs while at sea using VMS.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

The limits on the number of gillnets for Day gillnet vessels*	A sector Day gillnet vessel is allowed to fish up to a maximum of 150 nets (any combination of flatfish or roundfish nets), except in: May: Blocks 124 and 125 June: Blocks 132 and 133 Vessels granted this exemption must tag each gillnet with one gillnet tag.
Gear requirements in the U.S./Canada Management Area	This exemption allows for the use of any trawl gear in the U.S./Canada Management Area.
Seasonal restrictions for the Eastern U.S./Canada Haddock SAP	This exemption allows a sector vessel to access the Eastern U.S./Canada Haddock SAP from May 1 to December 31 with any gear approved for use in the Eastern U.S./Canada Area, including the standard otter trawl.
Seasonal restrictions for the CA II Yellowtail Flounder/Haddock SAP	This exemption allows a sector vessel to access the CA II Yellowtail Flounder/Haddock SAP from May 1 to January 31 when using selective gear approved for use in the SAP, or the standard otter trawl.
Sampling Exemption	A vessel participating in a sector granted this exemption may temporarily retain fish for sampling purposes.
Additional Sector Provisions	A sector may include additional provisions in its operations plan. Please consult your sector manager for information on any additional provisions.

*Please not that this exemption has been modified from previous years.

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

Species	Minimum Size	Stock Area[1]	A DAS	Handgear A	Handgear B	Regular B DAS Program	
						Separator or Ruhle Trawl[4]	Non-Trawl Gear
Cod	22"	GOM	100 lb/DAS, up to 300 lb/trip	100 lb/trip[3]	25 lb/trip[3]	100 lb/DAS, up to 300 lb/trip	
		OFF GB, IN GB, and SNE	2,000 lb/DAS, up to 20,000 lb/trip (outside of the Eastern U.S./Canada Area)[2]	300 lb/trip[3]	75 lb/trip[3]	100 lb/DAS to 1,000 lb/trip	
			500 lb/DAS, up to 5,000 lb/trip (E. U.S./Canada Area)				
			1,000 lb/trip Closed Area I Hook Gear Haddock SAP -or- Closed Area II Yellowtail Flounder/Haddock SAP (for targeting haddock)				
Haddock	18"	GOM	100 lb/trip				
		OFF GB, IN GB, and SNE	10,000 lb/trip				
Pollock	19"	All Areas	10,000 lb/trip			100 lb/DAS to 1,000 lb/trip	
Redfish	9"	All Areas	Unlimited				
White hake	none	All Areas	500 lb/trip			100 lb/DAS to 500 lb/trip	
Atlantic halibut	41"	All Areas	1 fish/trip				
Yellowtail flounder	13"	GOM, IN GB	500 lb/DAS, up to 2,000 lb/trip			25 lb/DAS to 250 lb/trip	
		SNE	2,000 lb/DAS, up to 6,000 lb/trip				
		OFF GB	100 lb/trip			500 lb/trip of all flatfish combined. However, may not exceed A-DAS limit for any stock	100 lb/trip
American plaice (dabs)	14"	All Areas	Unlimited				100 lb/DAS, to 1,000 lb/trip
Witch flounder (gray sole)	14"	All Areas	500 lb/trip				100 lb/DAS, to 250 lb/trip
Winter flounder	12"	OFF GB	1,000 lb/trip				100 lb/DAS, to 1,000 lb/trip
		IN GB, SNE	5,000 lb/DAS, up to 15,000 lb/trip				100 lb/DAS, to 1,000 lb/trip
		GOM	500 lb/trip				100 lb/DAS, to 250 lb/trip
Windowpane Flounder		All Areas	Zero – possession prohibited				
Ocean Pout							
Atlantic Wolffish							

[1] Broad Stock Areas: Gulf of Maine (GOM), Inshore Georges Bank (IN GB), Offshore Georges Bank (OFF GB), and Southern New England (SNE)

[2] Vessel must submit GOM Cod Trip Limit Exemption Form via VMS

[3] Unless otherwise revised by the Regional Administrator

[4] Gear performance trip limits of 500 lb all flatfish combined, 500 lb whole monkfish (unless restricted by the monkfish FMP), 500 lb whole skate, and zero lobsters also apply

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

2014	**Bulletin Location**
January 1: Common Pool Trimester 3 Closed for GOM haddock through the end of FY 2013	
April 9: Common Pool GB cod trimester TAC area closed for trimester 3 through end of FY 2013 Decrease: Possession limit and trip limit of GB cod reduced to zero Increase: Possession and trip limit for SNE/MA winter flounder 1,000 lb/DAS and 2,000 lb/trip (from 300/trip)	
May 1- Start of the Groundfishing year Changes in Recreational Measures GOM Cod: - The minimum fish size increases to 21 inches. - The daily per angler bag limit is not changing and remains 9 fish per day. - Possession prohibited (closed season) increases by 2 months: now September 1, 2014 -April 14, 2015. Possession of cod in the GOM regulated mesh area is permitted May 1-August 31, 2014, and April 15-30, 2015. GOM Haddock: - The minimum fish size is not changing and remains 21 inches. - The daily per angler bag limit is decreasing from an unlimited amount to 3 fish per day. - Possession prohibited (closed season) increases by 4 months: September 1-November 30, 2014, and March 1- April 30, 2015. Possession of haddock in the GOM regulated mesh area is permitted May 1-August 31, 2014, and December 1, 2014-February 28, 2015. Common pool Cod Trip Limits-	

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

Permit	Initial FY 2014 GOM Cod Possession/Trip Limit	Initial FY 2014 GB Cod Possession/Trip Limit
Handgear A	200 lb per trip	300 lb per trip
Handgear B	25 lb per trip	75 lb per trip
Small Vessel Category	300 lb of cod, haddock, and yellowtail flounder combined; Maximum of 200 lb of GOM cod and 25 lb per trip of GOM haddock within the 300-lb combined possession limit	

DAS Possession and Landings Limits

Stock	FY 2014 Possession and Landing Limits
GB Cod	2,000 lb per DAS, up to 20,000 lb per trip
GOM Cod	200 lb per DAS, up to 600 lb per trip
GB Haddock	10,000 lb per trip
GOM Haddock	25 lb per trip
GB Yellowtail Flounder	100 lb per trip
SNE/MA Yellowtail Flounder	2,000 lb per DAS, up to 6,000 lb per trip
CC/GOM Yellowtail Flounder	1,000 lb per trip
American plaice	Unlimited
Witch Flounder	500 lb per trip
GB Winter Flounder	1,000 lb per trip
GOM Winter Flounder	1,000 lb per trip
SNE/MA Winter Flounder	1,500 lb per DAS up to 2,000 lb per trip
Redfish	Unlimited
White hake	1,000 lb per trip
Pollock	10,000 lb per trip
Atlantic Halibut	1 fish per trip
Windowpane Flounder	Possession Prohibited
Ocean Pout	
Atlantic Wolffish	

Large AMs implemented for GF fishery (sector and common pool) due to overage in FY 2012 for northern and southern windowpane flounder – requires the use of selective gears to fish in the areas

Sectors
Universal exemptions plus 20 additional

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

FW 51 -Sectors can convert EGB haddock into WGB allocation -FY 2014 catch limits for several stocks - AMs developed for small-mesh fishery for GB YTF – gear-based -rebuilding programs for GOM cod and American plaice extended 10 years until 2024 Also, common pool vessels can fish in the Closed Area II Yellowtail Flounder/Haddock Special Access Program (SAP) to target haddock using a haddock separator trawl, a Ruhle trawl, or hook gear. Vessels may not fish in this SAP using flounder nets. The SAP will close on January 31, 2015. Common pool vessels using trawl gear may fish in the Eastern U.S/Canada Area. Common pool vessels must use a haddock separator trawl, a Ruhle trawl, or a flounder trawl in this area.	
May 24:Directed herring fishery closed in 1B due to herring catches; through December 2014	
Jun16: Scallop FW 25 AMs established for SNE/MA windowpane flounder – gear modification areas for seasons based on the percentage of the overage	
June 30: Sector vessels declared to fish in the Eastern U.S./Canada Area, including the two Eastern U.S./Canada Special Access Programs (SAPs) (the Closed Area II Yellowtail Flounder/Haddock SAP and the Eastern U.S./Canada Haddock SAP) will need to submit daily VMS catch reports.	
July 23: Common pool trip limit adjustment for one stock through April 30, 2015 (end of FY) Increase: SNE/MA winter flounder: A DAS- 3,000 lb/DAS and 6,000 lb/trip (up from 1,500 lb/DAS and 2,000 lb/trip)	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/July/14mulsnemawinterfladjustmentgomcodtrimesterclosurephl.pdf
July 23: Common pool closure through August 31 (Trimester I) Due to GOM Cod catches exceeding Trimester I TAC- no fishing in SRA 513 and 514 (*bulletin was a correction from 7/18/2014*)	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/July/14mulinseason1gomcodtrimesterclosurephlcorrected.pdf
August 5: Northern red hake possession limit reduced to 400 lb. (down from 5,000 lb.) for all vessels	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/July/14mulnrhpossessionlimitreduction.pdf
August 6: Common pool trip limit adjustment for one stock through August 31 (Trimester I) Decrease: American plaice: no possession (down from unlimited)	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/July/14mulinseason2plaiceclosurephl.pdf
August 18: Common pool closure through August 31 (Trimester I) Due to GB cod catches projected to exceed Trimester I TAC- no fishing in SRA 521,522,525, and 561	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/August/140818_inseason_3_trimester_1_gb_cod_closure_phl_final.pdf
August 27: Common pool closure through August 31 (Trimester I) Due to SNE/MA yellowtail flounder catches exceeding Trimester I TAC- no fishing in SRA 537,538,539, and 613	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/August/14mulcommonpoolinseason4and5closurephl.pdf
August 26: Common poll closure through April 30, 2015 (end of FY) Due to EBG cod catches exceeding the common pool TAC – no fishing in US/Canada area including Special Access Programs	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/August/14mulcommonpoolinseason4and5closurephl.pdf
September 23: Directed herring fishery closed in Area 3 due to herring catches, through December 2014	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/September/14herarea3closurephl.pdf

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

October 26: Directed herring fishery closed in Area 1A due to herring catches, through December 2014	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/October/14herarea1aclosurephl.pdf
November 15: Temporary GOM cod and haddock management measures, through May 12, 2015 GOM cod- Temporary Actions: 1) GOM rolling closures replaced with seasonal 30-minute block closures – fishing closed to certain commercial and recreational gear – capable of catching groundfish (gear other than "exempted gear" or gear exempt from current groundfish closed areas) 2) Commercial trip limits- 200-lb trip limit for GOM cod for all sector and common pool in the open areas of the GOM Broad stock area 3) Zero recreational possession – all recreational vessels 4) Commercial fishery declaration change- LA groundfish vessels that declare into GOM BSA can only fish there for that trip 5) Gillnet exemption change- Sector exemption on higher number of gillnets is revoked GOM haddock Increase in catch limit of GOM haddock for the remainder of the FY (April 30, 2015) ACL increases to 641 mt from 323 mt	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/November/14gomhaddockcodphl.pdf
December 29: Clarification of temporary GOM cod and haddock measures, through May 12, 2015 • Gillnet vessels allowed one-time opportunity to change category designation (day versus trip) for the FY • 200-lb trip limit applies to entire GOM BSA	http://www.greateratlantic.fisheries.noaa.gov/nr/2014/December/14mulgomcodcorrectionrulephl.pdf
2015	
January 14: FW 52 implemented Southern windowpane flounder gear restricted area reduced in size –meets FW 52 criteria- to the small AM area (from large AM area) through April 30, 2015 (remainder of FY)	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/January/15mulfw52phl.pdf
January 20: Common pool trip limit adjustment for one stock through April 30, 2015 (end of FY) Decrease: SNE/MA yellowtail flounder: 250 lb/DAS and 500 lb/trip (down from 2,000 lb/DAS and 6,000 lb/trip)	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/January/15mulsnemaytftriplimitadjustphl.pdf
February 26: Clarification of temporary GOM cod and haddock measures, though May 12, 2015 Small mesh Area 1 And 2 exemption areas should have been included on the list of areas exempted from the GOM cod seasonal interim closure areas; vessel fishing a raised footrope trawl with small mesh nets continue to be exempt	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/February/15mulgomcodcorrectionrulephl.pdf
May 1- Start of the Groundfish Fishing Year FW 53 Implemented- Measures for All Vessels (*replaces temporary measures for GOM cod as well*) • FY 2015 catch limits are most groundfish stocks are the same as in FY2014 • GOM haddock catch limit increased, while there were large reductions in GOM cod, GB winter flounder, and GOM winter flounder catch limits • US/CA quotas set for EGB cod and haddock and GB yellowtail flounder for FY 2015 • GOM cod protection measures replace the GOM rolling closures for the commercial groundfish fishery to help protect GOM cod – new areas in winter, modified areas in the spring, opening of some areas • No possession of GOM cod for the recreational fishery to help reduce the incentive to target GOM cod	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/April/15mulfw53phl.pdf

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

• Daily Reporting via VMS required when fishing in the GOM BSA and another BSA on the same trip • Sector carryover provision finalized, in an effort to prevent vessels from misreporting where cod is caught • Default specifications process established in the event of a future management action being delayed Windowpane Flounder AM • Due to the overage of the total catch limit in FY 2014 • Northern windowpane flounder gear restricted area – large in place for FY 2015 – commercial groundfish vessels fishing on a groundfish trip are required to use approved selective trawl gear (haddock separator trawl, Ruhle trawl, mini-Ruhle trawl or rope separator trawl Sector Measures- change to two year plan (first time) • 17 sectors approved to operate in FY 2015 and FY 2016 • All have "universal" exemptions from various regulations • Additional 19 exemptions approved • No trip allocated to CAII Yellowtail Flounder/Haddock SAP for FY 2015 for the purposes of targeting yellowtail flounder. Vessels may fish in the SAP to catch haddock when using a haddock separator trawl, a Ruhle trawl, or hook gear. Vessels may not fish in the SAP using flounder nets. The SAP closes on 1/31/2016 • Eastern US/CA area opens on May 1 for sectors vessels fishing with trawl gear Common Pool Measures • Tables provided with trip limits for FY 2015, trimester TACs, and TAC are closures in the event of closure	

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

Table 5. Initial Fishing Year 2015 Common Pool Possession and Trip Limits

Stock	Possession and Trip Limits
GB Cod (outside Eastern U.S./Canada Area)	2,000 lb/DAS, up to 20,000 lb/trip
GB Cod (inside Eastern U.S./Canada Area)	100 lb/DAS, up to 500 lb/trip
GOM Cod	50 lb/DAS, up to 200 lb/trip
GB Haddock	25,000 lb/trip
GOM Haddock	50 lb/DAS, up to 200 lb/trip
GB Yellowtail Flounder	100 lb/trip
SNE/MA Yellowtail Flounder	2,000 lb/DAS, up to 6,000 lb/trip
CC/GOM Yellowtail Flounder	1,500 lb/DAS up to 3,000 lb/trip
American plaice	Unlimited
Witch Flounder	1,000 lb/trip
GB Winter Flounder	1,000 lb/trip
GOM Winter Flounder	1,000 lb/trip
SNE/MA Winter Flounder	3,000 lb/DAS, up to 6,000 lb/trip
Redfish	Unlimited
White hake	1,500 lb/trip
Pollock	10,000 lb/trip
Atlantic Halibut	1 fish/trip
Windowpane Flounder	Possession Prohibited
Ocean Pout	Possession Prohibited
Atlantic Wolffish	Possession Prohibited

Table 6. Fishing Year 2015 Trip Limits for Handgear and Small Vessel Category Permits

Permit	Initial FY 2015 GOM Cod Possession/Trip Limit	Initial FY 2015 GB Cod Possession/Trip Limit
Handgear A	50 lb per trip	300 lb per trip
Handgear B	25 lb per trip	75 lb per trip
Small Vessel Category	300 lb of cod, haddock, and yellowtail flounder combined; Maximum of 50 lb of GOM cod and 50 lb per trip of GOM haddock within the 300-lb combined possession limit	

- Eastern US/CA Area- common pool vessel can fish in area starting on May 1, must use a haddock separator trawl, a Ruhle trawl, or a flounder trawl in the area
- Common pool can only land cod at a higher possession limit by declaring outside of the GOM BSA and fishing only in the other BSAs, LOA required without a VMS unit

Recreational Fishery Measures

- Within the GOM regulated mesh area:
  - GOM cod – zero retention for entire year
  - GOM haddock- 3 fish/angler daily bag limit, 17 in minimum fish size, and season closed September 1-October 31, 2015 and March 1-April 30, 2016

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

• Measures outside of the GOM regulated mesh area remain unchanged • Recreational fishery may fish in GOM cod protection areas, federally-permitted charter/party vessel must have a LOA to fish those areas	

May 1: Scallop Fishery- Implementation of FW 26
• Catch limits and allocations set for FY 2015 and other management measures
• Access areas:
  ○ CAI, CAII, and NLCA Access Areas closed to scallop fishing for FY 2015
  ▪ Also, NLCA expanded by 158 square miles
  ○ 549 sq mile are in the northwest corner of Elephant Trunk Access Area is closed to scallop fishing
	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/April/15scalla2015specsphl.pdf

May 28: Whiting fishery quotas and management measure for 2015-2017, sets quota for northern silver hake, northern red hake, southern whiting, and southern red hake Also, northern red hake possession limit going forward is 3,000 lb/trip (reduced from 5,000 lb/trip)	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/May/15mulsmallneshspecsphl.pdf
June 23: Common pool closures through August 31 (Trimester I) Due to catches of: • GOM cod- no fishing in SRAs: 513 and 514 (trawl, gillnet, and longline/hook prohibited), • CC/GOM yellowtail flounder – no fishing in SRAs 514 and 521 (trawl and gillnet prohibited), and • American plaice – no fishing in SRAs 512, 513, 514, 515, 522, 525 (trawl prohibited) Also, Common pool trip limit adjustments for two stocks through August 31 (Trimester I) No possession of CC/GOM yellowtail flounder and American plaice for all common pool vessels in all areas (down from 1,500 lb/DAS 3,000lb/trip for CC/GOM yellowtail flounder and unlimited for American plaice)	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/June/15mulinseasonclosuresgomgbgfphl.pdf
July 15: Common pool trip limit adjustment for one stock through April 30, 2016 (end of FY) Decrease: GOM cod: no possession for all common pool vessels	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/June/150615_inseason_1-gom_cod_limit_adjustment_phl_final.pdf
July 29: Common pool closure through August 31 (Trimester I) Due to SNE/MA yellowtail flounder catches for Trimester I TAC – no fishing in SRAs 537,538,539, 613	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/July/15mulsnemaytcommonpoolclosurephl.pdf
August 4: Closure of Mid-Atlantic Scallop Area Access Area for the LA General Category IFQ fleet	http://www.greateratlantic.fisheries.noaa.gov/nr/2015/July/15scallagcmaaclosurephl.pdf
August 12: Northern red hake possession limit reduced to 1,500 lb. (down from 3,000 lb.) for all vessels for the remainder of FY	https://www.greateratlantic.fisheries.noaa.gov/nr/2015/August/15mulnrhlimitphl.pdf
August 17: Updated Annual Catch Limits for Sectors and Common Pool Vessels for Fishing Year 2015 – includes carryover from FY 2014 for sectors (increasing certain sub-ACLs) and reductions to common pool catch limit for Eastern Georges Bank cod, due to overages in FY 2014 (reducing some sub-ACLs), and adjustments to final trimester quotas for the common pool after accounting for sector rosters	https://www.greateratlantic.fisheries.noaa.gov/nr/2015/August/15mulfw53revphl.pdf
August 24: Northern red hake possession limit reduced to 400 lb. (down from 1,500 lb.) for all vessels for the remainder of FY	https://www.greateratlantic.fisheries.noaa.gov/nr/2015/August/15mulrh62reductriggerphl.pdf
September 16: Common Pool Gulf of Maine cod trip and possession limit increased to 25 lb per trip (increasing from no	https://www.greateratlantic.fisheries.noaa.gov

Table B4, continued. Detailed changes in management regulations governing groundfish in the USA commercial fishery between January 2001 and August 2015 (complied by NEFMC staff- T Nies through March 23, 2012 and J Cournane through December 31, 2015).

possession) for remainder of FY	/nr/2015/September/15mulcommonpoolfisheryptriplimitadjustmentphl.pdf
October 22: Atlantic herring fishery herring possession limit reduced to 2,000 lb/day in the Herring Georges Bank haddock Accountability Measure area, due to projected overage of the GB haddock catch cap by the mid-water trawl Atlantic herring fishery. Additionally, the haddock possession limit is reduced to 0 lb in the Herring GB Haddock AM Area for federally permitted Atlantic herring vessels fishing with midwater trawl gear.	https://www.greateratlantic.fisheries.noaa.gov/nr/2015/October/15sfherhadcapclophl.pdf
November 2: Atlantic Herring Management Area 1A Sub-ACL harvested. Atlantic herring catch limited to 2,000 lb per trip/day	https://www.greateratlantic.fisheries.noaa.gov/nr/2015/October/15herarea1aclosurephl.pdf

Table B5. Significant changes in management regulations governing the northern shrimp fishery in the Gulf of Maine.

1972	Adoption of mesh regulations, Establishment of count/pound limits, Establishment of closed areas.
1973	Adoption of interim minimum mesh regulations; mesh size not less than 1.5 inches (38 mm).
1975	**Minimum mesh regulations increased to 1.75 inches (44 mm)**. Harvest restricted to 4,200 mt (9.2 million pounds). Fishery closure from July - September.
1976	Harvest restricted to 2,300 mt (5 million pounds) by season closure and quota management. Open season: January 1 - April 15 1976.
1977	Harvest restricted to 1,600 mt (3.5 million pounds). Open season: January 1 - May 15 1977.
1978	**Closure of fishery**.
1979	Open season: February 1 - March 31, 1979
1980	Open season: February 15 - May 31, 1980
1981	Open season: February 15 - May 31, 1981
1982	Open season: January 1 - April 15, 1982
1983	Open season:
1984	Open season:
1985	Open season:
1986 - 1991	Open season: 183 days, by-catch limit of 10% by weight of groundfish allowed.
1992 April	**Nordmore grate regulation** (max 25 mm space); no bycatch of groundfish allowed, no Sunday fishing
1993	Open season: Dec 15 - May 15, no Sundays, separator gear Dec 15 - Mar 15; grate Apr-May15
1994	Open season: December 15 - April 15
1995	Open season: December 1 - May 31 with 1 day off per week.
1996	Open season: December 1 - May 31 with 1 week off.
1997	Open season: December 1 - May 27 with 4 or 5 day block off per month.
1998	Open season: December 8 - May 22 with 3 weekends of no fishing
1999	Open season: December 1 - May 30, no weekend fishing.
2000	Open season: (51 day season)
2001	Open season: Jan 9 - March17; April 16-30 and no days off (83 day season)
2002	Open season: February 15 - March 11 (25 day season)
2003	Open season: Jan 15 - Feb 27 no Friday fishing (38 day season)
2004	Open season: Jan 19 - March 12, no weekend fishing (40 day season)
2005	Open season: Dec 19-23, 26-30, 2004; Jan 3 - Mar 25,2005 no weekend fishing (70 days)
2006	Open season: Dec 12, 2005 through April 30, 2006 (140 day season)
2007	Open season: Dec 1, 2006 through April 30, 2007 (151 days season)
2008	Open season: Dec 1, 2007 through April 30, 2008 (152 day season)
2009	Open season: Dec 1 2008 through May 29, 2009 (180 day season)
2010	Open season: Dec 1, 2009 – May 5, 2010 (156 day season)
2011	Open season: Dec 1 - Feb 28, 2011 (90 day season)
2012	Open season: Jan 2, 2012 – Feb 17 (21 days); Trap fishery Feb 1-17, 2012 (17 days)

Table B5, continued. Significant changes in management regulations governing the northern shrimp fishery in the Gulf of Maine.

2013	Open season: Jan 22-Apr 12, 2013 (54 days); Trap fishery Feb 5–Apr 12, 2013 (62 days)
2014	Moratorium for 2014 fishing season (Dec 2013– Spring 2014) 0 days
2015	Moratorium for 205 fishing season (Dec 2014 – Spring 2015) 0 days

Table B6. Witch flounder landings, discards, and catch (metric tons, live) by country, 1937-2015 [1937-1959 provisional landings reported in Lange and Lux, 1978; 1960-1963 reported to ICNAF/NAFO (Burnett and Clark, 1983)].

	LANDINGS					
Year	USA Subarea 4, 5 & 6	USA Subarea 3	USA Total	CAN	Other	Total
1937			*5,000*			*5,000*
1938			*3,600*			*3,600*
1939			*3,100*			*3,100*
1940			*3,000*			*3,000*
1941			*2,000*			*2,000*
1942			*1,800*			*1,800*
1943			*1,000*			*1,000*
1944			*1,000*			*1,000*
1945			*1,000*			*1,000*
1946			*1,500*			*1,500*
1947			*1,500*			*1,500*
1948			*1,000*			*1,000*
1949			*3,600*			*3,600*
1950			*3,000*			*3,000*
1951			*2,600*			*2,600*
1952			*3,700*			*3,700*
1953			*4,200*			*4,200*
1954			*4,000*			*4,000*
1955			*2,400*			*2,400*
1956			*2,000*			*2,000*
1957			*1,000*			*1,000*
1958			*1,000*			*1,000*
1959			*1,000*			*1,000*
1960	1,255		1,255			1,255
1961	1,022		1,022	2		1,024
1962	976		976	1		977
1963	1,226		1,226	27	121	1,374
1964	1,381		1,381	37		1,418
1965	2,140		2,140	22	502	2,664
1966	2,935		2,935	68	311	3,314
1967	3,370		3,370	63	249	3,682
1968	2,807		2,807	56	191	3,054
1969	2,542		2,542		1,310	3,852
1970	3,112		3,112	19	130	3,261
1971	3,220		3,220	35	2,860	6,115
1972	2,934		2,934	13	2,568	5,515
1973	2,523		2,523	10	629	3,162
1974	1,839		1,839	9	292	2,140
1975	2,127		2,127	13	217	2,357
1976	1,871		1,871	5	6	1,882
1977	2,469		2,469	11	13	2,493
1978	3,501		3,501	18	6	3,525
1979	2,878		2,878	17		2,895
1980	3,128		3,128	18	1	3,147
1981	3,442		3,442	7		3,449

continued.

Table B6, continued. Witch flounder landings, discards, and catch (metric tons, live). Catch used in assessment models.

	LANDINGS						DISCARDS	CATCH
Year	USA Subarea 4, 5 & 6	USA Subarea 3	USA Total	CAN	Other	Total	USA Subarea 4, 5 & 6	USA Subarea 4, 5 & 6
1982	4,909		4,909	9		4,918	400	5,309
1983	5,998		5,998	45		6,043	411	6,409
1984	6,658		6,658	15		6,673	279	6,937
1985	6,130	255	6,385	46		6,431	210	6,339
1986	4,609	539	5,148	67		5,215	179	4,788
1987	3,451	346	3,798	23		3,821	193	3,644
1988	3,261	358	3,619	45		3,664	190	3,451
1989	2,074	296	2,370	13		2,383	351	2,425
1990	1,476	2	1,479	12		1,491	267	1,744
1991	1,797		1,797	7		1,804	774	2,571
1992	2,245		2,245	7		2,252	507	2,752
1993	2,593	12	2,605	10		2,615	212	2,806
1994	2,659	9	2,668	34		2,702	457	3,115
1995	2,209		2,209	11		2,220	509	2,718
1996	2,086		2,086	10		2,096	306	2,392
1997	1,772		1,772	7		1,779	482	2,254
1998	1,848		1,848	10		1,858	458	2,306
1999	2,121		2,121	19		2,140	370	2,490
2000	2,439		2,439	53		2,492	310	2,749
2001	3,020		3,020	32		3,052	387	3,406
2002	3,188		3,188	39		3,227	282	3,470
2003	3,124		3,124	38		3,163	427	3,551
2004	2,924		2,924	18		2,942	446	3,370
2005	2,652		2,652	10		2,662	264	2,917
2006	1,863		1,863	8		1,872	211	2,075
2007	1,076		1,076	11		1,086	135	1,210
2008	1,009		1,009	3		1,012	127	1,136
2009	954		954	9		963	203	1,157
2010	759		759	5		765	153	912
2011	870		870	3		873	201	1,071
2012	1,038		1,038	2		1,040	219	1,258
2013	686		686	1		687	124	811
2014	570		570	1		570	105	675
2015	492		492	1		493	93	585

Table B7. Proportion of witch flounder landings (metric tons, live) by statistical area or statistical area group, 1982-2015.

	Statistical Area																
												523	524				
Year	464	465	511	512	513	514	515	521	522	525	526	561	562	53	54	6	Total
1982	0.00	0.01	0.03	0.15	0.29	0.09	0.15	0.11	0.06	0.01	0.02	0.02	0.01	0.01	0.00	0.01	1.00
1983	0.00	0.02	0.04	0.21	0.24	0.08	0.17	0.09	0.05	0.01	0.02	0.02	0.01	0.02	0.00	0.01	1.00
1984	0.00	0.02	0.02	0.11	0.23	0.12	0.20	0.12	0.06	0.02	0.03	0.02	0.01	0.02	0.00	0.01	1.00
1985	0.00	0.01	0.04	0.12	0.24	0.11	0.21	0.12	0.08	0.02	0.02	0.02	0.01	0.01	0.00	0.01	1.00
1986	0.00	0.01	0.04	0.17	0.26	0.10	0.17	0.10	0.06	0.01	0.02	0.02	0.00	0.01	0.00	0.01	1.00
1987	0.00	0.00	0.03	0.13	0.30	0.11	0.21	0.10	0.06	0.01	0.01	0.02	0.01	0.00	0.00	0.01	1.00
1988	0.00	0.00	0.03	0.09	0.29	0.11	0.19	0.14	0.06	0.03	0.01	0.02	0.01	0.00	0.00	0.01	1.00
1989	0.00	0.00	0.02	0.08	0.25	0.11	0.18	0.15	0.07	0.03	0.06	0.02	0.01	0.01	0.00	0.02	1.00
1990	0.00	0.00	0.02	0.09	0.29	0.12	0.13	0.11	0.06	0.04	0.05	0.02	0.02	0.03	0.00	0.02	1.00
1991	0.00	0.00	0.01	0.09	0.26	0.11	0.16	0.08	0.08	0.02	0.05	0.02	0.03	0.05	0.00	0.04	1.00
1992	0.00	0.00	0.01	0.10	0.23	0.10	0.15	0.07	0.08	0.03	0.10	0.02	0.02	0.07	0.00	0.03	1.00
1993	0.00	0.00	0.01	0.07	0.22	0.16	0.16	0.07	0.10	0.04	0.05	0.03	0.03	0.04	0.00	0.02	1.00
1994	0.00	0.00	0.01	0.07	0.22	0.16	0.18	0.11	0.13	0.01	0.02	0.02	0.01	0.03	0.00	0.04	1.00
1995	0.00	0.01	0.01	0.05	0.17	0.16	0.20	0.17	0.15	0.01	0.00	0.02	0.01	0.02	0.00	0.02	1.00
1996	0.00	0.00	0.01	0.06	0.20	0.16	0.20	0.16	0.11	0.02	0.00	0.02	0.00	0.02	0.00	0.01	1.00
1997	0.00	0.00	0.01	0.07	0.15	0.15	0.24	0.13	0.15	0.03	0.00	0.03	0.00	0.02	0.00	0.01	1.00
1998	0.00	0.00	0.00	0.08	0.11	0.12	0.25	0.20	0.14	0.02	0.01	0.03	0.00	0.02	0.00	0.01	1.00
1999	0.01	0.00	0.01	0.05	0.11	0.12	0.17	0.22	0.18	0.03	0.01	0.04	0.01	0.02	0.00	0.01	1.00
2000	0.00	0.00	0.01	0.04	0.14	0.18	0.12	0.24	0.17	0.03	0.00	0.02	0.01	0.02	0.00	0.02	1.00
2001	0.00	0.00	0.01	0.04	0.14	0.17	0.12	0.25	0.15	0.02	0.01	0.05	0.00	0.02	0.00	0.01	1.00
2002	0.00	0.00	0.01	0.03	0.16	0.24	0.10	0.21	0.14	0.03	0.00	0.03	0.02	0.01	0.00	0.01	1.00
2003	0.00	0.00	0.00	0.04	0.12	0.31	0.08	0.21	0.13	0.03	0.00	0.03	0.02	0.01	0.00	0.01	1.00
2004	0.00	0.00	0.00	0.07	0.13	0.20	0.11	0.23	0.14	0.02	0.00	0.02	0.04	0.01	0.00	0.01	1.00
2005	0.00	0.00	0.00	0.05	0.14	0.19	0.13	0.23	0.14	0.05	0.00	0.02	0.01	0.01	0.00	0.02	1.00
2006	0.00	0.00	0.00	0.03	0.09	0.17	0.13	0.27	0.16	0.06	0.01	0.02	0.01	0.02	0.00	0.01	1.00
2007	0.00	0.00	0.00	0.05	0.13	0.15	0.12	0.24	0.13	0.09	0.01	0.03	0.02	0.02	0.00	0.02	1.00
2008	0.01	0.00	0.00	0.06	0.13	0.16	0.11	0.23	0.16	0.05	0.00	0.06	0.01	0.01	0.00	0.01	1.00
2009	0.00	0.01	0.01	0.04	0.13	0.19	0.15	0.15	0.19	0.05	0.00	0.05	0.01	0.01	0.00	0.02	1.00
2010	0.01	0.00	0.00	0.02	0.15	0.24	0.14	0.21	0.14	0.04	0.00	0.03	0.01	0.01	0.00	0.00	1.00
2011	0.00	0.00	0.00	0.03	0.09	0.26	0.09	0.26	0.19	0.02	0.00	0.04	0.01	0.00	0.00	0.00	1.00
2012	0.01	0.00	0.00	0.02	0.13	0.30	0.11	0.21	0.18	0.00	0.00	0.03	0.01	0.00	0.00	0.00	1.00
2013	0.01	0.00	0.00	0.03	0.14	0.28	0.16	0.22	0.12	0.01	0.00	0.02	0.00	0.01	0.00	0.00	1.00
2014	0.01	0.00	0.00	0.01	0.10	0.31	0.18	0.21	0.14	0.00	0.00	0.02	0.00	0.01	0.00	0.00	1.00
2015	0.01	0.00	0.00	0.02	0.12	0.35	0.15	0.15	0.16	0.00	0.00	0.03	0.00	0.00	0.00	0.00	1.00

Table B8. Proportion of witch flounder landings (metric tons, live) by month, 1982-2015.

	Month												
Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
1982	0.06	0.06	0.11	0.09	0.10	0.09	0.09	0.08	0.07	0.08	0.08	0.08	1.00
1983	0.09	0.09	0.11	0.12	0.10	0.10	0.07	0.08	0.06	0.06	0.05	0.07	1.00
1984	0.10	0.09	0.11	0.11	0.11	0.09	0.07	0.07	0.06	0.08	0.06	0.06	1.00
1985	0.08	0.08	0.09	0.13	0.12	0.08	0.08	0.07	0.07	0.07	0.05	0.06	1.00
1986	0.08	0.08	0.09	0.14	0.14	0.10	0.09	0.06	0.06	0.06	0.05	0.06	1.00
1987	0.07	0.07	0.10	0.10	0.12	0.11	0.08	0.07	0.07	0.06	0.06	0.08	1.00
1988	0.10	0.09	0.13	0.13	0.15	0.10	0.07	0.05	0.06	0.04	0.04	0.04	1.00
1989	0.08	0.09	0.12	0.13	0.15	0.10	0.08	0.07	0.05	0.05	0.05	0.05	1.00
1990	0.09	0.07	0.08	0.09	0.13	0.11	0.09	0.09	0.06	0.06	0.06	0.06	1.00
1991	0.05	0.04	0.03	0.08	0.13	0.11	0.10	0.09	0.10	0.10	0.07	0.08	1.00
1992	0.06	0.07	0.07	0.14	0.14	0.10	0.07	0.07	0.06	0.07	0.08	0.05	1.00
1993	0.08	0.06	0.10	0.08	0.15	0.11	0.07	0.07	0.06	0.08	0.07	0.06	1.00
1994	0.09	0.08	0.08	0.11	0.10	0.11	0.08	0.08	0.08	0.09	0.06	0.06	1.00
1995	0.07	0.06	0.10	0.11	0.12	0.13	0.09	0.08	0.07	0.08	0.05	0.05	1.00
1996	0.06	0.06	0.07	0.08	0.13	0.12	0.10	0.10	0.07	0.08	0.06	0.07	1.00
1997	0.06	0.08	0.08	0.09	0.10	0.14	0.10	0.08	0.09	0.06	0.05	0.07	1.00
1998	0.05	0.07	0.11	0.12	0.13	0.13	0.09	0.08	0.07	0.06	0.04	0.05	1.00
1999	0.06	0.07	0.09	0.08	0.10	0.16	0.10	0.10	0.05	0.06	0.06	0.07	1.00
2000	0.05	0.08	0.09	0.08	0.07	0.14	0.11	0.10	0.07	0.08	0.07	0.06	1.00
2001	0.09	0.05	0.08	0.11	0.07	0.14	0.11	0.09	0.08	0.06	0.06	0.08	1.00
2002	0.08	0.09	0.09	0.13	0.05	0.10	0.14	0.10	0.08	0.05	0.05	0.04	1.00
2003	0.05	0.08	0.10	0.06	0.07	0.14	0.15	0.09	0.09	0.07	0.06	0.05	1.00
2004	0.06	0.10	0.09	0.08	0.04	0.12	0.11	0.09	0.10	0.06	0.08	0.07	1.00
2005	0.08	0.08	0.11	0.09	0.07	0.12	0.11	0.09	0.07	0.06	0.07	0.05	1.00
2006	0.10	0.14	0.14	0.09	0.06	0.11	0.11	0.06	0.06	0.05	0.04	0.05	1.00
2007	0.08	0.07	0.13	0.08	0.06	0.14	0.12	0.07	0.07	0.07	0.05	0.07	1.00
2008	0.12	0.11	0.09	0.11	0.05	0.11	0.10	0.09	0.06	0.07	0.05	0.06	1.00
2009	0.10	0.09	0.13	0.09	0.04	0.12	0.10	0.08	0.09	0.06	0.04	0.05	1.00
2010	0.12	0.12	0.14	0.10	0.03	0.09	0.07	0.07	0.07	0.07	0.05	0.06	1.00
2011	0.08	0.09	0.09	0.07	0.07	0.12	0.07	0.06	0.10	0.09	0.09	0.08	1.00
2012	0.09	0.10	0.11	0.07	0.06	0.09	0.08	0.08	0.10	0.09	0.06	0.07	1.00
2013	0.13	0.08	0.09	0.12	0.05	0.09	0.09	0.08	0.08	0.09	0.05	0.06	1.00
2014	0.08	0.11	0.13	0.10	0.06	0.09	0.07	0.07	0.09	0.07	0.05	0.07	1.00
2015	0.06	0.04	0.11	0.14	0.06	0.09	0.11	0.08	0.09	0.07	0.06	0.08	1.00

Table B9. Proportion of witch flounder landings (metric tons, live) by gear type, 1982-2015.

	Gear Type							
Year	Otterl Trawl	Haddock Separator Trawl	Shrimp Trawl	Gillnet	Scallop Dredge	Unknown	Other	Total
1982	0.97	0.00	0.01	0.00	0.00	0.00	0.02	1.0
1983	0.96	0.00	0.01	0.00	0.00	0.00	0.03	1.0
1984	0.96	0.00	0.00	0.00	0.00	0.00	0.03	1.0
1985	0.95	0.00	0.01	0.00	0.00	0.00	0.04	1.0
1986	0.95	0.00	0.01	0.00	0.00	0.00	0.04	1.0
1987	0.95	0.00	0.01	0.01	0.00	0.00	0.03	1.0
1988	0.96	0.00	0.01	0.01	0.01	0.00	0.02	1.0
1989	0.95	0.00	0.00	0.02	0.01	0.00	0.03	1.0
1990	0.93	0.00	0.01	0.03	0.02	0.00	0.02	1.0
1991	0.95	0.00	0.00	0.01	0.02	0.00	0.02	1.0
1992	0.96	0.00	0.00	0.01	0.02	0.00	0.01	1.0
1993	0.94	0.00	0.00	0.03	0.02	0.00	0.01	1.0
1994	0.96	0.00	0.00	0.03	0.01	0.00	0.00	1.0
1995	0.97	0.00	0.00	0.02	0.00	0.00	0.01	1.0
1996	0.97	0.00	0.00	0.02	0.00	0.00	0.00	1.0
1997	0.97	0.00	0.00	0.01	0.00	0.00	0.01	1.0
1998	0.97	0.00	0.00	0.02	0.00	0.00	0.01	1.0
1999	0.97	0.00	0.00	0.02	0.00	0.00	0.00	1.0
2000	0.98	0.00	0.00	0.02	0.00	0.00	0.01	1.0
2001	0.98	0.00	0.00	0.01	0.00	0.00	0.00	1.0
2002	0.98	0.00	0.00	0.01	0.00	0.00	0.01	1.0
2003	0.98	0.00	0.00	0.01	0.00	0.00	0.01	1.0
2004	0.97	0.00	0.00	0.01	0.00	0.00	0.02	1.0
2005	0.96	0.00	0.00	0.01	0.00	0.00	0.03	1.0
2006	0.97	0.00	0.00	0.01	0.01	0.00	0.01	1.0
2007	0.98	0.00	0.00	0.01	0.00	0.00	0.00	1.0
2008	0.97	0.00	0.00	0.03	0.00	0.00	0.00	1.0
2009	0.96	0.00	0.00	0.04	0.00	0.00	0.00	1.0
2010	0.93	0.03	0.00	0.03	0.00	0.00	0.01	1.0
2011	0.91	0.05	0.00	0.02	0.00	0.00	0.02	1.0
2012	0.95	0.03	0.00	0.01	0.00	0.00	0.01	1.0
2013	0.94	0.03	0.00	0.02	0.00	0.00	0.02	1.0
2014	0.94	0.04	0.00	0.01	0.00	0.00	0.00	1.0
2015	0.92	0.06	0.00	0.01	0.00	0.00	0.02	1.0

Dealer electronic report implemented in 2004.

Table B10. Proportion of witch flounder landings (metric tons, live) by state, 1982-2015.

	State										
Year	CT	ME	MD	MA	NH	NJ	NY	NC	RI	VA	Total
1982	0.00	0.53	0.00	0.35	0.05	0.01	0.00	0.00	0.05	0.00	1.00
1983	0.00	0.59	0.00	0.34	0.03	0.00	0.00	0.00	0.04	0.00	1.00
1984	0.00	0.44	0.00	0.46	0.04	0.00	0.00	0.00	0.05	0.00	1.00
1985	0.00	0.40	0.00	0.51	0.02	0.00	0.00	0.00	0.06	0.00	1.00
1986	0.00	0.38	0.00	0.56	0.02	0.01	0.00	0.00	0.03	0.00	1.00
1987	0.00	0.56	0.00	0.37	0.03	0.00	0.00	0.00	0.03	0.00	1.00
1988	0.00	0.53	0.00	0.37	0.05	0.01	0.00	0.00	0.05	0.00	1.00
1989	0.00	0.45	0.00	0.43	0.04	0.01	0.00	0.00	0.06	0.00	1.00
1990	0.01	0.41	0.00	0.48	0.02	0.01	0.00	0.00	0.08	0.00	1.00
1991	0.01	0.43	0.00	0.44	0.02	0.01	0.01	0.00	0.08	0.00	1.00
1992	0.01	0.42	0.00	0.43	0.01	0.01	0.01	0.00	0.10	0.00	1.00
1993	0.00	0.48	0.00	0.43	0.01	0.01	0.01	0.00	0.06	0.00	1.00
1994	0.00	0.51	0.00	0.41	0.01	0.01	0.02	0.00	0.04	0.00	1.00
1995	0.00	0.46	0.00	0.50	0.01	0.00	0.01	0.00	0.01	0.00	1.00
1996	0.00	0.50	0.00	0.46	0.01	0.00	0.00	0.00	0.03	0.00	1.00
1997	0.00	0.51	0.00	0.43	0.01	0.00	0.00	0.00	0.05	0.00	1.00
1998	0.00	0.45	0.00	0.48	0.01	0.00	0.00	0.00	0.05	0.00	1.00
1999	0.00	0.42	0.00	0.50	0.01	0.00	0.01	0.00	0.06	0.00	1.00
2000	0.01	0.38	0.00	0.54	0.02	0.01	0.00	0.00	0.04	0.00	1.00
2001	0.00	0.36	0.00	0.58	0.02	0.00	0.00	0.00	0.03	0.00	1.00
2002	0.00	0.34	0.00	0.61	0.03	0.00	0.00	0.00	0.02	0.00	1.00
2003	0.00	0.27	0.00	0.66	0.02	0.01	0.00	0.00	0.03	0.00	1.00
2004	0.00	0.34	0.00	0.60	0.02	0.01	0.00	0.00	0.02	0.00	1.00
2005	0.00	0.32	0.00	0.61	0.02	0.01	0.00	0.00	0.02	0.00	1.00
2006	0.00	0.24	0.00	0.71	0.01	0.00	0.00	0.00	0.04	0.00	1.00
2007	0.00	0.26	0.00	0.66	0.01	0.01	0.00	0.00	0.05	0.00	1.00
2008	0.00	0.16	0.00	0.80	0.01	0.00	0.00	0.00	0.03	0.00	1.00
2009	0.00	0.14	0.00	0.80	0.01	0.00	0.00	0.00	0.04	0.00	1.00
2010	0.00	0.08	0.00	0.89	0.01	0.00	0.00	0.00	0.02	0.00	1.00
2011	0.00	0.07	0.00	0.90	0.01	0.00	0.00	0.00	0.02	0.00	1.00
2012	0.00	0.13	0.00	0.85	0.02	0.00	0.00	0.00	0.01	0.00	1.00
2013	0.00	0.17	0.00	0.82	0.01	0.00	0.00	0.00	0.01	0.00	1.00
2014	0.00	0.12	0.00	0.85	0.01	0.00	0.00	0.00	0.00	0.00	1.00
2015	0.00	0.11	0.00	0.85	0.02	0.00	0.00	0.00	0.01	0.00	1.00

Table B11. Proportion of witch flounder landings (metric tons, live) by market category, 1982-2015.

	Market Category						
Year	PeeWee	Small	Medium	Large	Jumbo	Unclass	Total
1982	0.00	0.26	0.06	0.63	0.00	0.05	1.00
1983	0.01	0.24	0.15	0.58	0.00	0.01	1.00
1984	0.03	0.25	0.20	0.51	0.00	0.01	1.00
1985	0.08	0.28	0.23	0.40	0.00	0.01	1.00
1986	0.05	0.33	0.25	0.34	0.00	0.02	1.00
1987	0.04	0.37	0.26	0.31	0.00	0.03	1.00
1988	0.03	0.34	0.29	0.30	0.01	0.04	1.00
1989	0.03	0.30	0.31	0.31	0.01	0.05	1.00
1990	0.05	0.26	0.30	0.31	0.01	0.06	1.00
1991	0.07	0.33	0.24	0.29	0.01	0.06	1.00
1992	0.12	0.40	0.19	0.23	0.00	0.05	1.00
1993	0.18	0.39	0.18	0.20	0.00	0.05	1.00
1994	0.19	0.44	0.16	0.17	0.00	0.04	1.00
1995	0.26	0.47	0.12	0.13	0.00	0.02	1.00
1996	0.27	0.53	0.10	0.08	0.00	0.02	1.00
1997	0.18	0.64	0.11	0.06	0.00	0.01	1.00
1998	0.13	0.72	0.09	0.05	0.00	0.01	1.00
1999	0.10	0.74	0.10	0.05	0.00	0.01	1.00
2000	0.08	0.77	0.10	0.04	0.00	0.02	1.00
2001	0.09	0.78	0.09	0.03	0.00	0.02	1.00
2002	0.08	0.78	0.10	0.03	0.00	0.01	1.00
2003	0.07	0.79	0.10	0.03	0.00	0.01	1.00
2004	0.09	0.77	0.10	0.03	0.00	0.01	1.00
2005	0.10	0.77	0.09	0.02	0.00	0.02	1.00
2006	0.07	0.81	0.09	0.02	0.00	0.01	1.00
2007	0.06	0.81	0.10	0.02	0.00	0.01	1.00
2008	0.03	0.84	0.10	0.02	0.00	0.01	1.00
2009	0.02	0.86	0.10	0.02	0.00	0.00	1.00
2010	0.00	0.87	0.10	0.02	0.00	0.00	1.00
2011	0.00	0.89	0.09	0.02	0.00	0.00	1.00
2012	0.00	0.90	0.08	0.01	0.00	0.00	1.00
2013	0.00	0.88	0.10	0.02	0.00	0.00	1.00
2014	0.00	0.84	0.12	0.02	0.00	0.00	1.00
2015	0.00	0.87	0.11	0.02	0.00	0.00	1.00

Table B12. Summary of discard estimation approaches used for witch flounder, by gear type, mesh group, and time period. *Abbreviations used: ASM = at-sea monitoring; DAA = numbers of discard fish at age; d/kall (discard/kept weight of all species based on observer data); Kall = kept weight of all species in Dealer data; NEFOP = Northeast Fisheries Observer Program; LF = length frequency of discarded fish.*

Gear Type	What's different from 2015 Update?	Method used for direct discard estimates	Method used for indirect (hindcast) discard estimates[2]	Discard Length Frequency	Age Data Used[3]	Discards-At-Age
Large mesh (>=5.5 inches) otter trawl (LMOT)	Change to spatial extent: using the stock area where "OTHER" region is added.	1989 onward: Combined ratio (d/kall) for two regions within the stock area	1982-1988: Survey filter method (no change from previous stock assessments); however, to account for discards outside the CORE region, the annual indirect discard estimates for the CORE region were multiplied by 0.385 (the 1989-2014 average of the ratio of the CORE region discarded weight to the OTHER region discarded weight) and added to the CORE region discard weight.-	Used NEFOP for 1989-2009; Used NEFOP and ASM from 2010 onward.	NEFSC Spring and Autumn survey	Rescaled existing LMOT DAA
Small mesh (<5.5 inches) otter trawl (SMOT)	Change to spatial extent: using the stock area where "OTHER" region is added. Change to time series: added estimates for 1982-1988	1989 onward: Combined ratio (d/kall) for two region within the stock area. Exception: for GB&GM 1994 and 1998, average of adjacent years was used due to insufficient sample size (1 trip) in those years	1982-1988: Average of 1989-2014 d/kall ratio multiplied by the annual Kall for each region and then summed over regions	Limited NEFOP LF not used		Rescaled revised LMOT DAA

2 Time series used for average discard ratio will not change in subsequent years.
3 As of July 2016, no observer-collected age data are available for witch flounder.

Table B12, continued. Summary of discard estimation approaches used for witch flounder, by gear type, mesh group, and time period. *Abbreviations used: ASM = at-sea monitoring; DAA = numbers of discard fish at age; d/kall (discard/kept weight of all species based on observer data); Kall = kept weight of all species in Dealer data; NEFOP = Northeast Fisheries Observer Program; LF = length frequency of discarded fish.*

Gear Type	What's different from 2015 Update?	Method used for direct discard estimates	Method used for indirect (hindcast) discard estimates[2]	Discard Length Frequency	Age Data Used[3]	Discards-At-Age
Shrimp trawl (SHR) in Gulf of Maine	Change to ratio estimator from d/df by fishing zone to d/k_{all} No change to spatial extent, CORE (GM&GB) only	1989-1997: Combined ratio (d/kall) for CORE (GM&GB area) Notes: 1) Nordmore Grate implemented in April 1992 2) No northern shrimp fishery in 2014, 2015, and 2016; however, shrimp trawling is occurring small mesh exempted fisheries in the Gulf of Maine (separate from northern shrimp fishery); cannot use average ratio w/grate	1982-1988; 2014, 2015 (no grate) Average of 1989-1992 d/kall ratio multiplied by the annual Kall from the CORE region; 1998-2002 (grate): Average of 1993-2013 (excluding 2011) d/kall ratio multiplied by the annual Kall from the CORE region.	NEFOP LF used. Used average proportion at age and weighted average mean weights at age when NEFOP LF was not available	NEFSC Spring Survey	Rescaled existing GMSHR DAA; For 2014-2015, rescaled revised LMOT DAA
Sea scallop dredge (SD)	NEW: gear type added	1992 onward: Combined ratio (d/kall) for two regions within the stock area.	1982-1991: Average of 1992-2014 d/kall ratio multiplied by the annual Kall for each region within the stock area and then summed over regions.	Annual NEFOP LF used. Used combined time series LF when little (<100 fish) or no LF data was available.	NEFSC Spring and Autumn Survey and Commercial	New DAA

Table B12, continued. Summary of discard estimation approaches used for witch flounder, by gear type, mesh group, and time period. *Abbreviations used: ASM = at-sea monitoring; DAA = numbers of discard fish at age; d/kall (discard/kept weight of all species based on observer data); Kall = kept weight of all species in Dealer data; NEFOP = Northeast Fisheries Observer Program; LF = length frequency of discarded fish.*

Gear Type	What's different from 2015 Update?	Method used for direct discard estimates	Method used for indirect (hindcast) discard estimates[2]	Discard Length Frequency	Age Data Used[3]	Discards-At-Age
Gillnet (GN)	NEW: gear type added	1989 onward: Combined ratio (d/kall) for two regions within the stock area.	1982-1988: Average of 1989-2014 d/kall ratio* annual Kall for each area and then sum	NEFOP and ASM, sparse in most years. Combined LF appeared similar to LMOT		Rescaled revised LMOT DAA
Haddock Separator Trawl (HS)	NEW: gear type added	2009 onward: Combined ratio (d/kall) for two regions within the stock area.	No hindcast needed	NEFOP and ASM sparse		Re-scaled LMOT DAA

Table B13. Number of observer trips by gear type, mesh group, and year used in witch flounder discard estimation for the stock area consisting of the CORE region (USA statistical areas: 464, 465, 511, 512, 513, 514, 515, 521-526, 561, 562);and OTHER [statistical areas: 533, 534, 537-543, 611-639]) region. At-Sea Monitoring trips are included for large mesh otter trawl, gillnet haddock separator trawl. Gray shade indicates cells not used.

Large Mesh Otter Trawl

	CORE			OTHER			
YEAR	Q1&2	Q3&4	Total	Q1&2	Q3&4	Total	Total
1989	26	30	56	5	3	8	64
1990	22	24	46	10	7	17	63
1991	28	44	72	6	7	13	85
1992	48	14	62	17	5	22	84
1993	18	15	33	7	16	23	56
1994	20	6	26	18	8	26	52
1995	35	14	49	20	48	68	117
1996	19	5	24	13	23	36	60
1997	12	7	19	12	6	18	37
1998	6	2	8	12	3	15	23
1999	4	29	33	11	4	15	48
2000	55	39	94	21	11	32	126
2001	48	91	139	16	45	61	200
2002	39	168	207	8	42	50	257
2003	182	192	374	13	14	27	401
2004	145	281	426	76	128	204	630
2005	555	547	1102	124	224	348	1450
2006	329	190	519	85	80	165	684
2007	253	276	529	77	167	244	773
2008	311	368	679	114	115	229	908
2009	366	366	732	112	183	295	1027
2010	330	548	878	169	204	373	1251
2011	623	664	1287	232	250	482	1769
2012	716	606	1322	236	133	369	1691
2013	453	360	813	312	188	500	1313
2014	370	422	792	281	318	599	1391
2015	285	290	575	280	219	499	1074

Small Mesh Otter Trawl

	CORE			OTHER			
YEAR	Q1&2	Q3&4	Total	Q1&2	Q3&4	Total	Total
1989	12	33	45	32	43	75	120
1990	4	18	22	36	25	61	83
1991	3	38	41	52	66	118	159
1992	6	22	28	37	31	68	96
1993	5	7	12	22	11	33	45
1994	1	1	2	9	16	25	27
1995	4	30	34	24	46	70	104
1996	3	40	43	32	54	86	129
1997	5	2	7	41	20	61	68
1998	1		1	14	23	37	38
1999	4	11	15	20	21	41	56
2000	3	3	6	24	24	48	54
2001	7	7	14	29	31	60	74
2002	3	46	49	25	24	49	98
2003	16	25	41	49	49	98	139
2004	20	76	96	112	198	310	406
2005	66	91	157	110	151	261	418
2006	28	19	47	90	90	180	227
2007	11	22	33	109	142	251	284
2008	4	16	20	93	85	178	198
2009	11	39	50	166	238	404	454
2010	18	51	69	266	220	486	555
2011	12	42	54	201	238	439	493
2012	11	36	47	155	152	307	354
2013	32	73	105	215	265	480	585
2014	9	79	88	286	334	620	708
2015	20	91	111	237	255	492	603

Shrimp trawl

	CORE		
YEAR	Q1&2	Q3&4	Total
1989	31	9	40
1990	27	4	31
1991	46	7	53
1992	76	6	82
1993	78	4	82
1994	71	6	77
1995	64	9	73
1996	30	5	35
1997	17		17
1998			
1999			
2000			
2001	3		3
2002			
2003	15		15
2004	12		12
2005	17		17
2006	17	3	20
2007	14		14
2008	16	3	19
2009	7	5	12
2010	11	4	15
2011	1		1
2012	19		19
2013	24		24
2014			
2015			

Gillnet

	CORE			OTHER			
YEAR	Q1&2	Q3&4	Total	Q1&2	Q3&4	Total	Total
1989	1	105	106		1	1	107
1990	74	75	149	1	5	6	155
1991	192	763	955	2	3	5	960
1992	403	629	1032	94	61	155	1187
1993	272	347	619	76	78	154	773
1994	69	53	122	120	163	283	405
1995	47	80	127	252	159	411	538
1996	29	45	74	226	125	351	425
1997	20	28	48	238	104	342	390
1998	39	83	122	228	53	281	403
1999	36	66	102	52	35	87	189
2000	59	65	124	59	44	103	227
2001	41	33	74	57	35	92	166
2002	33	67	100	34	40	74	174
2003	112	273	385	50	56	106	491
2004	220	728	948	75	74	149	1097
2005	155	662	817	99	80	179	996
2006	95	80	175	43	35	78	253
2007	43	190	233	58	44	102	335
2008	64	156	220	51	39	90	310
2009	131	195	326	60	31	91	417
2010	307	1364	1671	112	95	207	1878
2011	564	1244	1808	174	82	256	2064
2012	560	900	1460	201	32	233	1693
2013	180	567	747	52	34	86	833
2014	289	830	1119	123	131	254	1373
2015	97	475	572	220	273	493	1065

Scallop Dredge

	CORE			OTHER			
YEAR	Q1&2	Q3&4	Total	Q1&2	Q3&4	Total	Total
1989							
1990							
1991		1	1		1	1	2
1992	4	6	10	4	4	8	18
1993	7	4	11	8	3	11	22
1994	2	5	7	10	9	19	26
1995	1	6	7	14	6	20	27
1996	8	7	15	14	11	25	40
1997	6	5	11	14	5	19	30
1998	2	8	10	7	9	16	26
1999	12	50	62	2	6	8	70
2000	25	203	228	13	15	28	256
2001	17		17	40	48	88	105
2002		13	13	34	53	87	100
2003	6	8	14	44	65	109	123
2004	3	57	60	82	154	236	296
2005	37	73	110	90	131	221	331
2006	35	96	131	10	87	97	228
2007	78	102	180	80	99	179	359
2008	89	123	212	297	135	432	644
2009	43	36	79	330	79	409	488
2010	17	82	99	129	110	239	338
2011	27	110	137	146	106	252	389
2012	67	152	219	167	34	201	420
2013	163	107	270	81	121	202	472
2014	80	111	191	147	134	281	472
2015	112	64	176	174	177	351	527

Haddock Separator Trawl

	CORE		
YEAR	Q1&2	Q3&4	Total
1989			
1990			
1991			
1992			
1993			
1994			
1995			
1996			
1997			
1998			
1999			
2000			
2001			
2002			
2003			
2004			
2005			
2006			
2007			
2008			
2009	1	16	17
2010	40	61	101
2011	73	24	97
2012	13	12	25
2013	6	7	13
2014	23	32	55
2015	31	15	46

Table B14. The number of observed trips, witch flounder discards (in metric tons), and coefficient of variation (CV) by the large-mesh otter trawl, small-mesh otter trawl, gillnet, scallop dredge, haddock separator trawl, and Gulf of Maine shrimp trawl fleets, 1982 – 2015. Time series (TS) means are also given.

	Large Mesh Otter Trawl			Small Mesh Otter Trawl			Gillnet			Scallp Dredge			Haddock Separator Trawl			GM Shrimp Trawl			TOTAL	
YEAR	Trips	MT	CV	Trips	MT	CV	Trips	MT	CV	Trips	MT	CV	Trips	MT	CV	Trips	MT	CV	MT	CV
1982		58.8			279.4			1.1			44.9						15.9		400.1	
1983		206.4			144.8			0.9			41.3						17.4		410.9	
1984		123.0			95.4			1.1			34.5						24.8		278.9	
1985		67.5			76.0			1.0			30.6						34.3		209.5	
1986		16.6			79.6			1.1			39.5						41.7		178.6	
1987		35.6			60.5			1.1			56.7						38.8		192.7	
1988		36.6			63.5			1.2			64.5						24.6		190.3	
1989	64	100.4	0.32	120	150.2	0.40	213	0.3	0.59		73.5					40	26.6	0.25	351.0	0.19
1990	63	105.8	0.58	83	56.1	1.10	160	1.8	0.62		83.2					31	20.5	0.26	267.5	0.33
1991	85	496.2	0.42	159	154.3	0.66	963	2.3	0.15		79.6					53	41.3	0.23	773.7	0.30
1992	84	409.6	0.25	96	70.3	0.33	1187	1.1	0.22	18	12.7	0.70				82	12.9	0.21	506.6	0.20
1993	56	172.9	0.49	45	21.9	0.40	773	1.9	0.29	22	9.3	0.45				82	6.5	0.29	212.5	0.40
1994	52	349.1	0.45	29	26.8		405	1.8	0.54	31	44.5	0.58				77	34.3	0.36	456.6	0.37
1995	117	255.5	0.28	104	122.4	0.39	538	1.8	0.48	33	96.5	0.74				73	32.8	0.15	509.0	0.22
1996	60	158.6	0.53	129	70.8	0.50	425	1.1	0.32	40	31.7	0.67				35	43.8	0.42	306.0	0.31
1997	37	261.1	0.29	73	28.6	2.20	390	5.2	0.40	30	176.8	0.57				34	10.8	0.55	482.5	0.29
1998	29	297.6	0.33	39	81.3		403	1.1	0.50	34	71.2	0.27					7.3		458.4	0.22
1999	48	153.0	0.36	56	134.8	0.89	189	1.2	0.71	76	77.4	0.15					3.2		369.7	0.36
2000	126	128.5	0.22	54	50.8	0.72	227	3.1	0.46	256	122.6	0.12					4.7		309.8	0.16
2001	200	287.1	0.17	74	53.2	0.39	166	0.5	0.87	122	44.2	0.29					1.8		386.7	0.14
2002	257	210.3	0.18	98	33.2	0.48	174	0.5	0.46	113	37.5	0.23					0.7		282.1	0.15
2003	401	281.8	0.12	139	73.0	0.20	491	1.8	0.26	123	70.0	0.28				15	0.1	1.02	426.7	0.10
2004	630	359.5	0.11	406	49.0	0.22	1097	0.3	0.35	296	36.9	0.15				24	0.1	0.97	445.9	0.10
2005	1450	141.7	0.07	418	71.0	0.20	996	0.9	0.32	331	50.5	0.19				34	0.5	0.74	264.4	0.07
2006	684	138.5	0.33	227	57.4	0.57	253	0.2	0.48	228	13.4	0.22				20	1.6	1.26	211.2	0.27
2007	773	58.1	0.14	284	51.1	0.27	335	1.0	0.49	359	22.5	0.24				28	1.9	0.54	134.6	0.13
2008	908	92.1	0.12	198	9.7	0.39	310	0.8	0.32	644	20.4	0.26				19	4.1	0.52	127.2	0.10
2009	1027	118.7	0.12	454	31.1	0.30	417	0.7	0.33	488	51.4	0.15				12	1.3	0.56	203.2	0.09
2010	1251	102.0	0.13	555	27.6	0.27	1878	0.4	0.11	338	18.4	0.28	101	0.9	0.12	15	3.6	0.38	152.9	0.10
2011	1769	68.2	0.07	493	104.7	0.30	2064	0.4	0.13	389	17.1	0.18	97	1.6	0.08	2	8.5		200.6	0.16
2012	1691	78.1	0.07	354	102.5	0.40	1693	0.3	0.10	420	36.7	0.25	25	0.8	0.23	38	1.0	0.49	219.4	0.19
2013	1313	47.7	0.08	585	48.1	0.51	833	0.2	0.15	472	27.8	0.20	13	0.4	0.30	48	0.1	0.46	124.3	0.21
2014	1391	53.0	0.09	708	25.6	0.42	1373	0.1	0.14	472	25.0	0.16	55	1.6	0.34		0.1		105.5	0.12
2015	1074	39.5	0.10	603	24.3	0.35	1065	0.2	0.44	527	26.4	0.17	46	2.2	0.26		0.1		92.8	0.11
TS mean		183.9			75.9			1.1			49.7			1.3			13.8		301.2	

Table B15. Summary of USA commercial witch flounder landings (mt), number of length samples (n), number of fish measured (len) and number of age samples (age) by market category (small, medium, large) and calendar quarter for all gear types, 1981 - 2015. The sampling rate is also given.

		Quarter 1			Quarter 2			Quarter 3			Quarter 4			Total	Sampling Rate
Year		Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	All	(mt/100 lengths)
1981	mt	270	14	536	282	45	704	248	13	617	236	3	475	3443	691
	n	.	.	.	.	1	1	.	1	.	1	.	1	5	
	len	.	.	.	.	101	103	.	89	.	105	.	100	498	
	age	.	.	.	.	.	26	.	25	.	25	.	25	101	
1982	mt	357	30	745	366	97	904	292	182	754	284	210	687	4909	133
	n	5	2	6	1	2	2	2	2	6	3	4	2	37	
	len	527	194	626	126	209	216	189	210	514	307	393	189	3700	
	age	128	55	150	30	55	50	50	50	150	81	105	50	954	
1983	mt	489	296	965	486	328	1104	306	167	790	260	174	633	5998	107
	n	5	2	3	5	1	5	8	3	8	6	3	.	49	
	len	680	232	265	685	96	520	1008	123	981	677	344	.	5611	
	age	135	30	55	131	16	125	152	0	159	180	75	.	1058	
1984	mt	477	379	1100	544	440	1049	408	256	667	437	298	604	6658	103
	n	5	9	4	7	1	7	8	1	2	4	2	1	51	
	len	804	1112	400	970	117	775	1045	106	191	615	243	91	6469	
	age	154	250	76	186	25	180	210	28	53	105	44	25	1336	
1985	mt	477	422	639	711	479	862	527	294	556	437	315	410	6130	83
	n	12	1	2	5	4	7	7	7	6	8	2	4	65	
	len	1530	105	229	657	426	698	795	800	684	824	264	349	7361	
	age	319	29	50	106	77	153	97	138	113	161	25	29	1297	
1986	mt	404	367	381	669	445	605	377	240	356	314	215	239	4611	94
	n	6	3	5	5	4	5	4	3	4	5	3	2	49	
	len	662	307	515	558	410	413	302	364	406	416	337	233	4923	
	age	123	60	89	106	97	129	63	75	100	87	75	52	1056	
1987	mt	356	243	232	442	333	390	299	204	248	300	205	203	3453	105
	n	1	1	2	4	2	3	5	5	4	2	3	2	34	
	len	85	145	200	323	228	316	354	583	400	204	261	178	3277	
	age	25	25	50	77	47	76	78	113	95	48	64	51	749	
1988	mt	432	331	273	441	406	391	185	176	209	141	144	132	3261	71
	n	5	4	5	5	5	3	5	4	3	3	4	3	49	
	len	335	407	465	344	544	429	396	359	295	229	402	356	4561	
	age	70	89	106	71	110	77	70	100	75	61	95	69	993	
1989	mt	235	197	149	260	275	252	99	146	156	87	109	103	2068	115
	n	1	2	2	2	2	1	2	2	1	1	2	.	18	
	len	94	201	222	230	236	27	150	206	100	125	202	.	1793	
	age	25	50	49	50	46	25	40	51	25	25	47	.	433	

Table B15, continued. Summary of commercial port sampling for witch flounder.

		Quarter 1			Quarter 2			Quarter 3			Quarter 4			Total	Sampling Rate
Year		Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	All	(mt/100 lengths)
1990	mt	132	140	109	160	182	149	101	120	130	87	81	86	1476	57
	n	1	2	3	6	3	1	6	2	2	7	2	.	35	
	len	134	199	199	335	296	100	349	247	145	381	201	.	2586	
	age	15	40	45	81	70	25	69	41	50	103	48	.	587	
1991	mt	83	78	59	238	188	169	201	144	185	200	128	124	1798	53
	n	5	2	3	7	2	1	4	2	3	5	4	3	41	
	len	262	224	401	537	239	125	212	165	249	300	410	274	3398	
	age	53	50	80	93	45	25	49	49	52	66	97	58	717	
1992	mt	233	119	83	503	207	177	212	119	138	227	109	116	2245	92
	n	4	2	2	7	1	2	7	1	1	2	.	1	30	
	len	259	241	185	501	125	235	477	121	117	129	.	46	2436	
	age	42	46	52	78	25	25	86	25	25	27	.	23	454	
1993	mt	377	141	111	494	216	163	266	124	150	340	104	107	2593	81
	n	7	1	.	7	1	1	9	1	5	.	.	.	32	
	len	830	100	.	741	107	100	728	85	499	.	.	.	3190	
	age	55	25	.	56	27	26	74	.	73	.	.	.	336	
1994	mt	408	143	98	504	183	153	382	122	116	383	86	80	2659	65
	n	.	.	.	3	5	6	5	5	1	5	3	4	37	
	len	.	.	.	560	532	749	356	648	105	342	368	407	4067	
	age	.	.	.	59	104	134	44	113	26	56	60	82	678	
1995	mt	335	91	77	568	117	100	398	61	70	303	48	40	2209	86
	n	3	3	3	6	3	5	.	.	.	2	.	1	26	
	len	208	348	347	459	367	517	.	.	.	217	.	94	2557	
	age	53	84	89	81	75	135	.	.	.	27	.	25	569	
1996	mt	313	57	36	545	87	60	458	56	44	362	42	27	2086	51
	n	5	2	3	5	2	1	5	4	4	5	3	3	42	
	len	504	218	292	331	240	127	494	464	468	343	277	348	4106	
	age	59	45	78	53	50	26	59	86	101	60	70	69	756	
1997	mt	313	40	25	477	86	41	397	55	27	263	31	16	1772	38
	n	6	3	3	9	4	3	9	3	1	9	1	1	52	
	len	557	350	351	812	418	309	783	308	107	505	128	50	4678	
	age	77	68	70	108	73	77	98	81	20	73	18	23	786	
1998	mt	371	40	18	588	81	31	380	43	20	234	26	14	1848	97
	n	5	2	1	4	1	1	5	3	1	.	.	.	23	
	len	339	206	128	238	88	135	484	186	100	.	.	.	1904	
	age	45	50	19	30	.	29	47	22	.	.	.	.	242	
1999	mt	386	48	19	615	79	31	436	66	30	353	39	17	2121	69
	n	3	.	.	4	.	.	17	2	3	11	1	.	41	
	len	282	.	.	308	.	.	1110	201	306	775	109	.	3091	
	age	15	.	.	62	.	.	143	.	32	91	16	.	359	

Table B15, continued. Summary of commercial sampling port for witch flounder.

		Quarter 1			Quarter 2			Quarter 3			Quarter 4			Total	Sampling Rate
Year		Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	All	(mt/100 lengths)
2000	mt	477	54	17	582	93	27	555	89	28	451	50	16	2439	35
	n	31	2	.	47	.	.	17	1	.	5	5	2	110	
	len	2253	91	.	2445	.	.	994	105	.	308	558	217	6971	
	age	393	10	.	463	.	.	224	20	.	67	92	51	1320	
2001	mt	583	71	17	825	99	30	699	98	28	507	50	13	3020	84
	n	8	4	2	3	3	2	8	2	3	5	3	.	43	
	len	744	422	134	237	352	159	594	209	213	313	232	.	3609	
	age	125	64	42	48	48	64	126	34	46	61	49	.	707	
2002	mt	740	80	18	773	104	26	848	114	29	400	45	9	3188	111
	n	5	1	2	3	5	3	5	2	3	3	2	2	36	
	len	363	121	107	212	518	209	389	150	194	262	226	115	2866	
	age	75	16	50	65	73	64	88	34	62	49	30	49	655	
2003	mt	603	70	17	684	109	30	865	125	36	533	43	10	3124	48
	n	4	6	6	10	5	10	11	6	16	7	7	13	101	
	len	324	423	162	881	482	433	943	531	552	654	632	525	6542	
	age	57	93	60	131	64	174	172	91	246	99	120	191	1498	
2004	mt	613	77	16	599	91	25	757	114	30	545	46	13	2924	34
	n	5	13	23	8	5	8	5	5	2	19	5	15	113	
	len	480	1244	1813	675	549	576	541	356	48	1838	420	83	8623	
	age	73	226	505	151	96	169	58	95	10	49	72	.	1504	
2005	mt	603	69	14	639	101	18	618	96	21	433	34	6	2652	46
	n	15	8	11	10	7	9	8	8	12	9	8	15	120	
	len	727	525	309	798	523	288	542	369	329	512	422	445	5789	
	age	78	65	104	117	113	93	130	92	165	92	99	229	1377	
2006	mt	619	67	14	418	52	8	367	46	12	232	24	4	1863	31
	n	9	6	14	11	5	16	11	5	26	11	5	29	148	
	len	501	538	765	837	433	255	584	268	392	577	444	334	5928	
	age	90	114	246	146	118	119	129	75	282	119	106	238	1782	
2007	mt	264	27	5	267	37	7	227	40	8	173	19	3	1076	23
	n	10	6	40	12	2	12	11	15	24	10	5	19	166	
	len	516	480	400	653	203	304	605	279	237	605	232	177	4691	
	age	106	144	343	132	51	172	136	133	189	107	76	159	1748	

Table B15, continued. Summary of commercial port sampling for witch flounder.

		Quarter 1			Quarter 2			Quarter 3			Quarter 4			Total	Sampling Rate
Year		Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	Small	Med.	Large	All	(mt/100 lengths)
2008	mt	275	34	7	233	28	5	217	33	7	148	18	4	1009	20
	n	13	4	22	13	10	24	13	7	12	13	8	16	155	
	len	649	243	410	819	329	237	578	417	104	749	459	166	5160	
	age	152	83	229	155	190	236	130	69	95	153	178	159	1829	
2009	mt	271	31	5	208	23	4	225	32	8	127	16	4	954	22
	n	12	8	15	14	10	20	10	4	18	10	5	4	130	
	len	642	393	269	722	299	123	575	246	193	572	317	17	4368	
	age	150	163	136	151	139	83	113	100	150	127	74	11	1397	
2010	mt	257	31	5	151	16	3	137	19	6	118	14	3	759	18
	n	10	6	18	12	15	28	12	7	15	13	4	9	149	
	len	537	355	147	656	376	197	685	221	129	672	200	132	4307	
	age	114	106	119	147	178	157	146	134	117	147	77	105	1547	
2011	mt	199	23	3	199	22	5	174	18	4	204	17	3	870	20
	n	13	4	34	13	7	40	10	4	7	18	5	18	173	
	len	674	280	333	696	265	229	499	165	39	864	209	191	4444	
	age	152	100	306	162	119	200	113	97	26	196	82	162	1715	
2012	mt	275	23	3	211	22	4	249	25	6	202	16	2	1038	24
	n	9	8	35	8	8	17	9	9	15	8	12	20	158	
	len	463	512	361	408	456	126	457	419	60	401	411	194	4268	
	age	106	176	327	96	166	115	102	185	59	87	197	161	1777	
2013	mt	185	18	3	156	19	3	149	19	4	113	16	2	686	16
	n	9	10	24	8	11	40	9	14	22	10	8	10	175	
	len	439	315	188	405	539	301	471	454	200	516	429	131	4388	
	age	97	170	173	87	242	282	112	314	200	115	190	130	2112	
2014	mt	147	20	4	123	20	4	130	17	4	83	15	3	570	13
	n	6	8	37	13	6	28	7	5	8	10	10	6	144	
	len	418	442	406	711	413	245	357	304	68	499	445	133	4441	
	age	122	198	389	185	148	212	84	121	65	100	197	77	1898	
2015	mt	84	13	2	129	15	3	128	16	3	85	12	2	492	11
	n	8	13	13	8	9	24	7	8	12	7	6	23	138	
	len	404	453	244	406	682	242	403	438	134	403	274	237	4320	
	age	81	216	174	80	199	202	77	153	124	81	89	206	1682	

Table B16. USA commercial landings at age (thousands of fish), of witch flounder, 1982 – 2015.

	USA Commercial Landings in Numbers (1000's) at Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0.000	0.000	0.000	117.956	826.996	1120.437	1454.997	665.519	656.314	399.691	239.515	1579.156
1983	0.000	0.000	0.000	219.770	768.494	1033.558	1567.084	1589.981	977.665	737.599	510.330	1675.270
1984	0.000	0.000	0.000	90.560	1011.948	1807.892	1733.526	1485.836	1496.831	696.389	374.933	1718.033
1985	0.000	0.000	0.000	0.000	984.926	2026.442	1933.458	1524.630	1247.679	605.893	400.329	1358.960
1986	0.000	0.000	0.000	6.297	298.380	1441.019	2771.482	1566.268	834.563	412.534	222.710	757.894
1987	0.000	0.000	0.000	0.000	81.536	321.742	1276.563	1575.395	871.285	480.812	252.511	489.616
1988	0.000	0.000	0.000	0.000	50.782	175.937	654.465	1382.205	1153.687	401.356	266.604	597.286
1989	0.000	0.000	0.000	0.000	7.311	49.834	315.243	761.556	884.683	350.666	123.749	349.011
1990	0.000	0.000	0.000	0.000	182.989	578.808	257.608	276.000	474.751	336.540	81.986	178.877
1991	0.000	0.000	0.000	0.000	181.620	741.370	525.447	238.501	247.383	295.494	317.192	260.756
1992	0.000	0.000	0.000	0.000	513.307	846.017	942.831	722.606	203.222	179.276	120.982	379.969
1993	0.000	0.000	0.000	0.000	420.946	1019.925	915.000	595.459	583.863	218.136	277.723	389.348
1994	0.000	0.000	0.000	0.000	200.824	1426.042	1283.207	824.896	196.225	537.874	113.220	323.525
1995	0.000	0.000	0.000	0.000	23.690	763.005	1597.441	848.706	267.452	97.221	269.492	156.841
1996	0.000	0.000	0.000	0.000	45.789	467.714	1263.814	1430.462	263.227	215.477	57.049	113.619
1997	0.000	0.000	0.000	0.000	212.263	528.139	1049.873	1014.449	591.550	83.179	49.808	70.112
1998	0.000	0.000	0.000	0.000	18.088	487.900	1213.361	1582.816	370.465	141.333	15.538	70.291
1999	0.000	0.000	0.000	0.000	185.108	585.604	1391.457	1178.041	762.981	251.210	31.564	54.349
2000	0.000	0.000	0.000	0.000	75.399	261.545	1072.941	1671.380	1004.032	558.080	93.128	234.596
2001	0.000	0.000	0.000	0.000	18.818	379.952	931.284	1683.679	1455.521	632.495	427.485	309.590
2002	0.000	0.000	0.000	0.000	169.083	648.709	1233.334	2107.561	1270.087	640.069	94.107	201.165
2003	0.000	0.000	0.000	0.000	56.796	517.734	1222.677	1761.003	1535.660	741.087	433.635	347.046
2004	0.000	0.000	0.000	0.000	188.991	698.164	1224.088	1406.985	1125.257	786.921	314.157	285.748
2005	0.000	0.000	0.000	0.000	75.117	637.816	1702.215	1746.196	818.757	408.731	234.631	132.333
2006	0.000	0.000	0.000	0.000	36.203	177.423	571.714	1519.403	869.549	355.981	132.622	73.041
2007	0.000	0.000	0.000	0.000	15.081	48.657	220.164	851.914	594.807	167.459	96.928	42.698
2008	0.000	0.000	0.000	4.216	58.187	84.196	270.706	578.175	449.514	312.159	111.449	66.523
2009	0.000	0.000	0.000	0.000	35.437	223.560	246.841	476.831	436.592	320.986	73.893	77.017
2010	0.000	0.000	0.000	0.000	0.000	111.761	304.379	275.480	394.673	176.184	231.908	45.569
2011	0.000	0.000	0.000	0.000	21.849	65.402	420.504	535.733	428.548	149.948	80.441	34.307
2012	0.000	0.000	0.000	6.343	10.899	167.066	285.674	721.991	551.611	209.074	84.609	39.359
2013	0.000	0.000	0.000	0.000	25.467	97.572	224.527	411.846	317.429	178.050	81.169	37.055
2014	0.000	0.000	0.000	0.000	12.377	89.581	127.143	254.058	320.617	132.562	47.280	26.032
2015	0.000	0.000	0.000	0.000	10.005	71.521	191.318	242.159	275.114	114.573	34.484	22.997

Table B17. USA commercial landings mean weight (kg) at age of witch flounder, 1982 – 2015. Time series (TS) mean is also given.

	USA Commercial Landings Mean Weight (kg) at Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982				0.216	0.275	0.345	0.424	0.550	0.727	0.886	0.983	1.406
1983				0.195	0.257	0.322	0.410	0.518	0.613	0.795	0.977	1.357
1984				0.212	0.268	0.346	0.422	0.539	0.664	0.817	0.922	1.339
1985					0.253	0.311	0.429	0.565	0.691	0.842	0.964	1.326
1986				0.084	0.227	0.306	0.408	0.533	0.676	0.853	0.975	1.321
1987					0.272	0.342	0.434	0.561	0.686	0.828	0.980	1.303
1988					0.310	0.367	0.435	0.538	0.668	0.819	0.980	1.326
1989					0.260	0.344	0.425	0.574	0.682	0.818	0.968	1.358
1990					0.308	0.323	0.438	0.586	0.688	0.849	1.049	1.454
1991					0.286	0.371	0.443	0.578	0.702	0.836	0.974	1.420
1992					0.328	0.383	0.459	0.614	0.739	0.822	0.882	1.243
1993					0.292	0.364	0.432	0.535	0.666	0.882	1.023	1.335
1994					0.308	0.357	0.430	0.534	0.691	0.832	0.909	1.266
1995					0.284	0.367	0.448	0.561	0.690	0.911	0.974	1.243
1996					0.260	0.355	0.435	0.554	0.708	0.856	0.974	1.232
1997					0.318	0.357	0.407	0.495	0.628	0.871	1.037	1.293
1998					0.235	0.331	0.382	0.492	0.585	0.871	0.978	1.206
1999					0.325	0.355	0.406	0.516	0.584	0.628	0.917	0.872
2000					0.319	0.326	0.376	0.455	0.535	0.624	0.704	0.915
2001					0.291	0.325	0.384	0.468	0.550	0.645	0.647	0.840
2002					0.355	0.344	0.416	0.477	0.553	0.652	0.826	0.941
2003					0.275	0.315	0.355	0.433	0.507	0.567	0.621	0.810
2004					0.288	0.317	0.369	0.451	0.543	0.613	0.698	0.873
2005					0.291	0.327	0.371	0.449	0.558	0.634	0.725	0.909
2006					0.290	0.327	0.372	0.465	0.551	0.655	0.719	0.932
2007					0.292	0.323	0.394	0.480	0.564	0.679	0.742	0.906
2008				0.304	0.313	0.383	0.436	0.485	0.544	0.599	0.649	0.823
2009					0.284	0.330	0.402	0.462	0.562	0.622	0.727	0.677
2010						0.313	0.353	0.442	0.502	0.658	0.620	0.821
2011					0.320	0.338	0.401	0.459	0.552	0.670	0.736	0.891
2012				0.304	0.309	0.350	0.380	0.456	0.551	0.655	0.721	0.882
2013					0.314	0.341	0.381	0.460	0.531	0.632	0.698	0.876
2014					0.284	0.358	0.422	0.491	0.594	0.694	0.771	1.409
2015				0.000	0.267	0.342	0.393	0.477	0.557	0.658	0.767	0.839
TS mean					0.290	0.341	0.408	0.507	0.613	0.743	0.848	1.107

Table B18. USA commercial landings mean length (cm) at age of witch flounder, 1982 – 2015. Time series (TS) mean is also given.

USA Commercial Landings Mean Length (cm) at Age

Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982				32.3	35.0	37.5	39.8	42.9	46.5	49.3	50.9	56.3
1983				31.7	34.3	36.8	39.4	42.2	44.2	47.7	50.7	55.0
1984				32.6	34.9	37.6	39.8	42.7	45.3	48.2	49.9	55.5
1985					34.2	36.3	40.0	43.3	45.9	48.6	50.6	55.3
1986				25.0	33.2	36.2	39.4	42.5	45.6	48.8	50.7	55.3
1987					35.0	37.4	40.1	43.2	45.8	48.4	50.8	55.1
1988					36.4	38.2	40.1	42.7	45.4	48.2	50.8	55.3
1989					34.6	37.5	39.9	43.5	45.6	48.1	50.6	55.7
1990					36.2	36.8	40.2	43.7	45.8	48.7	51.8	56.8
1991					35.4	38.3	40.3	43.3	46.1	48.5	50.6	56.5
1992					37.0	38.7	40.7	44.3	46.8	48.3	49.2	54.2
1993					35.8	38.1	40.0	42.6	45.3	49.3	51.5	55.5
1994					36.0	37.6	39.7	42.3	45.6	48.0	49.1	54.1
1995					35.3	37.9	40.2	42.8	45.4	49.3	50.1	53.8
1996					34.4	37.5	39.8	42.7	45.8	48.4	50.1	53.6
1997					36.4	37.6	39.1	41.3	44.2	48.5	51.1	54.4
1998					33.4	36.8	38.4	41.2	43.3	48.7	50.5	53.4
1999					36.6	37.5	39.0	41.8	43.3	44.3	49.4	48.0
2000					36.4	36.6	38.2	40.3	42.2	44.0	45.7	48.9
2001					35.5	36.6	38.4	40.6	42.5	44.6	44.5	47.9
2002					37.5	37.2	39.3	40.9	42.6	44.6	48.0	49.7
2003					34.9	36.3	37.6	39.8	41.6	42.9	43.9	47.3
2004					35.4	36.4	38.0	40.2	42.4	43.8	45.5	48.5
2005					35.5	36.7	38.0	40.1	42.8	44.3	46.1	49.1
2006					35.4	36.7	38.1	40.6	42.6	44.7	45.9	49.5
2007					35.5	36.6	38.8	41.0	42.9	45.3	46.4	49.1
2008				36.0	36.3	38.3	39.7	41.0	42.4	43.5	44.3	47.8
2009					35.3	36.8	38.8	40.4	42.8	44.1	46.1	45.1
2010						36.2	37.5	39.9	41.4	44.8	44.1	47.7
2011					36.5	37.0	38.9	40.4	42.6	45.1	46.3	48.9
2012				36.0	36.1	37.4	38.3	40.3	42.6	44.8	46.0	48.8
2013					36.3	37.1	38.3	40.4	42.1	44.3	45.6	48.7
2014					35.2	37.6	39.5	41.2	43.6	45.5	46.9	54.0
2015					34.6	37.1	38.6	40.9	42.7	44.8	46.9	47.9
TS mean				32.3	35.5	37.2	39.2	41.7	44.0	46.5	48.3	51.8

Table B19. Coefficient of variation associated with the number of witch flounder landed at age for ages 4 to 11+ for 2003 - 2015.

	Age							
Year	4	5	6	7	8	9	10	11+
2003	0.704	0.286	0.225	0.164	0.131	0.179	0.258	0.166
2004	0.466	0.250	0.160	0.114	0.136	0.142	0.198	0.161
2005	0.495	0.205	0.128	0.087	0.133	0.163	0.181	0.131
2006	0.203	0.123	0.088	0.045	0.020	0.039	0.056	0.074
2007	0.349	0.241	0.142	0.064	0.083	0.129	0.146	0.148
2008	0.430	0.290	0.196	0.087	0.107	0.130	0.170	0.167
2009	0.409	0.195	0.197	0.129	0.101	0.119	0.247	0.419
2010		0.257	0.138	0.119	0.095	0.154	0.109	0.163
2011	0.195	0.125	0.051	0.035	0.025	0.049	0.063	0.063
2012	0.296	0.122	0.083	0.038	0.034	0.050	0.068	0.082
2013	0.226	0.158	0.096	0.049	0.030	0.063	0.059	0.065
2014	0.303	0.121	0.075	0.050	0.057	0.048	0.052	0.063
2015	0.290	0.160	0.103	0.041	0.038	0.067	0.061	0.066

Table B20. The number of witch flounder measured by observers on commercial fishing trips for 6 gear types/mesh groups, 1989 – 2015 from the stock area (except for Gulf of Maine shrimp trawl and haddock separator trawl data that are from the Gulf of Maine-Georges Bank region). No Northeast Fisheries Observer Program discarded length measurements are available prior to 1989.

Year	Large Mesh Otter Trawl	Small Mesh Otter Trawl	Haddock Separator Trawl	Gulf of Maine Shrimp Trawl	Gillnet	Scallop Dredge
1989	491	219	-	877	-	-
1990	64	79	-	171	8	-
1991	195	251	-	1,583	2	-
1992	31	33	-	595	4	-
1993	686	1	-	1,107	6	2
1994	223	176	-	2,208	18	52
1995	2,092	915	-	2,301	9	71
1996	349	12	-	1,096	12	128
1997	732	50	-	268	5	367
1998	204	-	-	-	7	37
1999	548	-	-	-	1	135
2000	191	223	-	-	39	273
2001	511	159	-	-	-	7
2002	3,745	459	-	-	9	2
2003	9,954	914	-	2	63	334
2004	8,067	1,775	-	3	29	630
2005	14,014	1,900	-	33	50	771
2006	5,936	426	-	165	2	126
2007	4,038	797	-	12	42	223
2008	7,690	132	-	66	8	339
2009	6,257	87	57	102	18	660
2010	2,722	228	97	8	140	121
2011	3,894	242	214	-	96	229
2012	3,173	273	39	10	33	467
2013	1,345	177	19	17	25	605
2014	1,698	207	50	-	23	401
2015	1,053	75	68	-	6	555

Table B21. Witch flounder discards at age (thousands of fish), 1982 - 2015.

	Discards in Numbers (1000's) at Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0.240	0.567	5.607	451.642	1812.486	662.967	175.679	14.465	10.673	2.924	1.320	2.592
1983	0.000	0.116	6.857	230.828	1339.408	1145.522	30.639	17.446	9.169	4.265	1.637	2.603
1984	0.000	0.838	2.185	132.071	1130.144	494.143	27.705	11.513	8.456	3.618	1.421	2.150
1985	0.000	1.016	9.966	365.701	571.703	284.877	24.180	11.743	6.683	2.390	1.034	1.909
1986	0.000	1.760	12.411	61.793	402.962	500.513	34.697	16.349	7.644	3.185	1.281	2.302
1987	3.718	33.867	143.655	55.777	252.627	491.324	41.942	27.386	10.157	3.871	1.939	2.968
1988	0.303	10.788	94.744	767.865	237.602	245.194	33.902	32.452	15.265	4.214	2.194	3.411
1989	1.036	17.726	90.404	192.082	1172.740	454.132	29.663	30.829	26.931	6.199	2.000	3.564
1990	0.852	4.058	138.835	367.025	421.474	580.142	26.939	19.383	19.036	10.558	2.973	3.357
1991	4.146	25.191	245.709	1152.467	1413.645	1260.688	487.478	17.705	13.117	7.814	6.618	3.393
1992	1.925	30.959	97.584	196.155	1010.941	685.473	328.930	34.171	1.094	1.141	0.571	0.953
1993	82.165	57.851	79.559	73.256	537.683	366.336	9.067	4.861	2.629	0.431	0.337	0.465
1994	17.200	2921.272	1061.518	100.679	538.078	782.708	88.747	157.062	6.283	10.920	1.473	12.048
1995	2.600	48.453	683.172	864.708	858.059	700.393	315.333	31.210	17.365	6.101	13.230	5.163
1996	16.593	104.175	163.177	390.335	632.735	694.630	120.128	14.489	3.332	2.535	0.685	1.267
1997	7.060	60.908	89.879	129.708	782.005	661.109	354.768	100.231	58.198	7.288	1.924	1.865
1998	20.147	161.403	152.613	347.476	847.700	797.546	272.703	70.044	17.141	10.536	1.017	4.159
1999	8.823	70.386	83.004	147.612	518.891	676.906	113.397	46.287	20.735	9.757	6.506	21.408
2000	12.956	101.892	78.758	132.662	421.838	447.313	150.417	86.883	47.926	27.685	7.656	22.097
2001	4.962	39.078	27.781	61.710	445.771	935.720	267.653	82.586	15.820	7.736	4.396	5.390
2002	1.933	16.311	14.570	37.143	483.675	561.882	158.846	59.586	18.542	9.925	2.987	5.200
2003	0.000	1.989	11.663	42.956	307.983	782.937	514.378	183.154	55.935	23.120	10.627	9.731
2004	0.000	0.760	16.012	48.583	259.672	709.885	571.612	182.926	54.095	26.099	21.773	14.200
2005	0.000	11.001	36.518	30.658	200.261	355.939	294.287	113.117	29.317	16.242	7.825	7.097
2006	0.000	6.972	53.351	126.189	98.257	167.112	375.258	105.261	31.729	13.137	7.446	7.174
2007	0.000	4.753	29.889	144.447	164.555	125.833	90.803	53.738	12.909	7.987	2.410	3.783
2008	0.000	1.200	22.313	51.227	235.041	158.720	81.504	39.118	17.235	4.860	1.778	2.186
2009	0.000	0.622	25.127	40.690	203.255	338.728	93.136	50.581	48.832	17.655	6.780	4.060
2010	0.000	29.170	370.017	80.710	110.939	202.875	239.029	32.885	12.668	6.585	2.328	2.233
2011	0.000	46.436	346.587	245.016	127.164	189.696	251.231	94.749	19.344	12.151	5.678	1.743
2012	0.000	6.487	57.335	161.431	259.412	188.432	194.922	98.803	42.699	12.115	4.256	2.477
2013	0.000	3.497	48.000	43.091	179.335	130.050	72.043	63.249	14.480	7.106	3.040	1.106
2014	0.000	1.778	19.496	134.517	91.653	131.248	54.475	25.966	17.254	4.406	1.308	1.435
2015	0.000	0.367	19.946	94.239	179.622	62.034	58.758	24.813	15.635	7.210	2.075	1.118

Table B22. Witch flounder discard mean weight (kg) at age, 1982 - 2015. Time series (TS) mean is also given.

	Discards Mean Weight (kg) at Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0.000	0.003	0.035	0.050	0.128	0.130	0.206	0.546	0.667	0.847	0.944	1.291
1983		0.008	0.038	0.071	0.132	0.160	0.346	0.535	0.619	0.765	0.966	1.252
1984		0.016	0.039	0.056	0.142	0.168	0.347	0.536	0.641	0.779	0.943	1.269
1985		0.016	0.023	0.128	0.154	0.173	0.361	0.541	0.665	0.808	0.947	1.263
1986		0.017	0.026	0.092	0.126	0.177	0.358	0.543	0.667	0.831	0.940	1.285
1987	0.006	0.015	0.033	0.087	0.131	0.209	0.380	0.543	0.674	0.851	0.989	1.295
1988	0.004	0.006	0.017	0.063	0.165	0.207	0.393	0.522	0.656	0.841	0.995	1.302
1989	0.010	0.012	0.031	0.058	0.151	0.228	0.417	0.529	0.601	0.812	0.941	1.322
1990	0.004	0.011	0.035	0.058	0.160	0.210	0.463	0.569	0.663	0.823	0.875	1.372
1991	0.004	0.014	0.039	0.063	0.161	0.240	0.256	0.563	0.669	0.785	0.895	1.321
1992	0.003	0.007	0.021	0.096	0.188	0.265	0.295	0.397	0.677	0.744	0.874	1.199
1993	0.003	0.009	0.023	0.101	0.200	0.236	0.373	0.450	0.665	0.859	1.016	1.334
1994	0.005	0.004	0.019	0.074	0.180	0.230	0.382	0.484	0.649	0.843	0.867	1.209
1995	0.005	0.007	0.027	0.065	0.154	0.227	0.285	0.561	0.713	0.860	0.927	1.090
1996	0.004	0.019	0.031	0.061	0.128	0.210	0.277	0.572	0.745	0.928	0.989	1.046
1997	0.004	0.023	0.035	0.073	0.163	0.213	0.290	0.521	0.625	0.748	0.854	0.790
1998	0.003	0.006	0.029	0.083	0.167	0.206	0.245	0.384	0.598	0.769	0.965	1.254
1999	0.003	0.006	0.029	0.093	0.167	0.221	0.295	0.481	0.681	0.744	1.053	1.548
2000	0.003	0.006	0.028	0.081	0.149	0.189	0.280	0.378	0.521	0.682	0.847	1.079
2001	0.003	0.006	0.024	0.109	0.167	0.208	0.235	0.308	0.550	0.625	0.718	1.009
2002	0.003	0.007	0.033	0.102	0.172	0.202	0.243	0.325	0.512	0.647	0.692	0.903
2003		0.007	0.032	0.070	0.137	0.196	0.242	0.289	0.408	0.526	0.626	0.868
2004		0.006	0.048	0.099	0.157	0.206	0.244	0.297	0.420	0.539	0.526	0.811
2005		0.019	0.051	0.109	0.170	0.212	0.258	0.329	0.481	0.590	0.704	0.998
2006		0.012	0.051	0.098	0.164	0.203	0.233	0.283	0.386	0.440	0.594	0.877
2007		0.015	0.041	0.115	0.179	0.221	0.251	0.342	0.543	0.663	0.871	1.012
2008		0.004	0.036	0.109	0.171	0.211	0.249	0.334	0.448	0.575	0.639	0.957
2009		0.040	0.044	0.104	0.189	0.222	0.273	0.366	0.420	0.625	0.715	0.931
2010		0.002	0.012	0.081	0.180	0.219	0.238	0.288	0.416	0.486	0.584	0.588
2011		0.002	0.026	0.093	0.183	0.216	0.246	0.281	0.372	0.380	0.493	0.770
2012		0.007	0.039	0.134	0.179	0.220	0.248	0.308	0.395	0.553	0.691	0.894
2013		0.025	0.094	0.147	0.185	0.211	0.252	0.310	0.516	0.613	0.676	0.862
2014		0.025	0.075	0.132	0.183	0.237	0.270	0.386	0.500	0.654	0.703	0.802
2015		0.026	0.062	0.105	0.155	0.198	0.296	0.383	0.494	0.631	0.566	0.917
TS mean	0.004	0.012	0.036	0.090	0.162	0.208	0.295	0.426	0.566	0.702	0.813	1.080

Table B23. Witch flounder discard mean length (cm) at age, 1982 - 2015. Time series (TS) mean is also given.

	Discards Mean Length (cm) at Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982	5.0	8.4	19.2	21.4	28.3	28.5	32.3	42.5	45.0	48.3	49.9	54.4
1983		12.1	19.9	23.5	28.6	30.5	37.3	42.2	44.1	46.9	50.2	53.8
1984		15.4	19.8	21.8	29.3	30.8	37.4	42.3	44.6	47.2	49.9	54.1
1985		15.5	16.9	28.4	30.1	31.0	37.7	42.4	45.0	47.7	49.9	54.0
1986		15.5	17.3	25.3	28.3	31.3	37.6	42.4	45.1	48.1	49.8	54.3
1987	10.6	15.3	19.0	25.1	28.5	32.9	38.3	42.4	45.2	48.4	50.5	54.4
1988	10.2	10.9	15.6	22.6	30.4	32.7	38.7	41.9	44.8	48.2	50.7	54.5
1989	13.6	14.1	18.6	22.3	29.7	33.7	39.3	42.1	43.5	47.7	49.8	54.7
1990	10.5	13.7	19.3	22.1	30.2	32.7	40.6	43.1	45.0	47.8	48.3	55.3
1991	9.7	14.1	19.8	22.6	30.2	34.3	34.8	42.9	45.1	47.2	49.0	54.6
1992	9.3	10.8	16.6	25.3	31.8	35.3	36.2	39.5	45.2	46.4	48.7	53.2
1993	9.2	12.0	16.9	25.9	32.4	34.1	38.5	40.3	45.0	48.6	51.0	54.9
1994	10.7	9.8	15.9	23.2	31.4	33.8	38.8	42.0	45.2	48.4	48.5	54.7
1995	10.9	11.6	17.6	22.6	30.0	33.7	35.7	43.0	46.0	48.6	49.5	51.9
1996	10.0	15.3	18.5	22.6	28.2	32.9	35.5	43.0	46.4	49.6	50.6	51.4
1997	10.2	16.1	19.2	23.7	30.4	32.9	35.7	42.0	44.2	46.8	48.5	47.5
1998	9.4	10.4	17.9	24.9	30.8	32.7	34.2	38.0	43.6	46.7	50.3	53.9
1999	9.4	10.5	18.1	25.5	30.7	33.4	36.3	41.4	45.3	46.6	51.5	57.3
2000	9.4	10.4	17.6	24.5	29.7	31.9	35.5	38.0	41.8	45.2	48.0	51.5
2001	9.4	10.4	17.1	26.6	30.7	32.8	34.0	36.4	42.5	44.0	45.9	50.2
2002	9.4	10.8	18.5	26.1	31.0	32.6	34.2	36.7	41.9	44.5	45.8	46.4
2003		12.5	18.8	23.8	28.9	32.2	34.3	35.9	39.2	42.1	44.1	48.3
2004		12.2	21.3	26.4	30.1	32.7	34.4	36.3	40.1	43.1	42.7	48.0
2005		15.9	21.4	26.8	30.8	33.0	34.9	37.2	41.3	43.7	45.8	50.0
2006		14.0	21.3	26.2	30.5	32.6	34.0	35.7	38.8	39.9	44.0	49.0
2007		15.1	20.0	27.4	31.4	33.4	34.7	37.6	42.7	45.5	48.6	50.9
2008		10.0	19.0	27.0	30.9	33.0	34.5	37.3	40.5	43.0	44.1	49.0
2009		20.3	20.1	26.5	31.8	33.4	35.3	38.0	39.2	44.2	45.6	49.4
2010		13.4	16.0	23.2	31.4	33.3	34.1	35.8	39.6	41.3	43.6	43.7
2011		9.1	17.5	24.3	31.5	33.2	34.4	35.7	38.2	38.4	41.2	47.0
2012		10.2	19.0	28.6	31.3	33.3	34.5	36.5	38.7	42.6	45.5	49.1
2013		16.6	25.9	29.5	31.6	32.9	34.6	36.4	41.9	44.0	45.2	48.5
2014		16.8	24.2	28.6	31.5	34.0	35.1	38.7	41.6	44.9	41.8	38.7
2015		17.9	22.7	26.6	30.0	32.0	36.0	38.5	41.3	44.6	34.2	49.1
TS mean	9.8	13.1	19.0	25.0	30.4	32.7	35.9	39.5	42.9	45.6	47.1	51.1

Table B24. Total USA commercial catch (thousands of fish) at age of witch flounder, 1982 - 2015.

USA Commercial Catch in Numbers (1000's) at Age

Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0.24	0.57	5.61	569.61	2639.52	1783.43	1630.70	679.99	667.00	402.62	240.84	1581.77
1983	0.00	0.12	6.86	450.60	2107.91	2179.09	1597.73	1607.43	986.84	741.87	511.97	1677.88
1984	0.00	0.84	2.19	222.63	2142.12	2302.06	1761.25	1497.37	1505.31	700.02	376.36	1720.20
1985	0.00	1.02	9.97	365.70	1556.64	2311.33	1957.65	1536.38	1254.37	608.29	401.37	1360.88
1986	0.00	1.76	12.41	68.09	701.33	1941.51	2806.15	1582.60	842.20	415.71	223.99	760.19
1987	3.72	33.87	143.66	55.78	334.16	813.07	1318.51	1602.78	881.44	484.68	254.45	492.58
1988	0.30	10.79	94.74	767.85	288.38	421.12	688.36	1414.64	1168.93	405.56	268.79	600.69
1989	1.04	17.73	90.40	192.08	1180.07	503.97	344.91	792.40	911.63	356.87	125.75	352.58
1990	0.85	4.06	138.84	367.03	604.48	1158.98	284.55	295.39	493.80	347.11	84.96	182.24
1991	4.15	25.19	245.71	1152.48	1595.28	2002.07	1012.93	256.21	260.50	303.31	323.81	264.15
1992	1.93	30.96	97.58	196.15	1524.22	1531.46	1271.74	756.76	204.31	180.41	121.55	380.91
1993	82.16	57.85	79.56	73.26	958.62	1386.25	924.06	600.32	586.49	218.57	278.06	389.81
1994	17.20	2921.32	1061.54	100.68	738.92	2208.79	1371.98	981.98	202.51	548.80	114.70	335.58
1995	2.60	48.45	683.18	864.72	881.76	1463.42	1912.80	879.93	284.82	103.32	282.73	162.01
1996	16.59	104.17	163.17	390.33	678.51	1162.32	1383.91	1444.92	266.55	218.01	57.73	114.88
1997	7.06	60.91	89.88	129.71	994.29	1189.27	1404.67	1114.70	649.76	90.47	51.73	71.98
1998	20.15	161.40	152.61	347.47	865.76	1285.41	1486.02	1652.81	387.59	151.86	16.55	74.45
1999	8.82	70.39	83.01	147.62	704.02	1262.55	1504.90	1224.36	783.74	260.98	38.07	75.76
2000	12.96	101.89	78.76	132.66	497.24	708.86	1223.36	1758.27	1051.96	585.77	100.78	256.69
2001	4.96	39.08	27.78	61.71	464.58	1315.66	1198.92	1766.25	1471.32	640.22	431.88	314.98
2002	1.93	16.31	14.57	37.14	652.75	1210.58	1392.17	2167.13	1288.62	649.99	97.09	206.36
2003	0.00	1.99	11.66	42.96	364.78	1300.67	1737.05	1944.15	1591.59	764.21	444.26	356.78
2004	0.00	0.76	16.01	48.58	448.67	1408.06	1795.72	1589.93	1179.36	813.03	335.93	299.95
2005	0.00	11.00	36.52	30.66	275.37	993.73	1996.46	1859.27	848.05	424.96	242.45	139.43
2006	0.00	6.97	53.35	126.19	134.46	344.54	947.00	1624.71	901.30	369.13	140.07	80.22
2007	0.00	4.75	29.89	144.45	179.64	174.49	310.97	905.67	607.73	175.45	99.34	46.48
2008	0.00	1.20	22.31	55.45	293.24	242.92	352.22	617.32	466.77	317.03	113.23	68.71
2009	0.00	0.62	25.13	40.69	238.70	562.30	339.98	527.42	485.43	338.65	80.67	81.08
2010	0.00	29.17	370.01	80.71	110.94	314.63	543.39	308.36	407.33	182.76	234.23	47.80
2011	0.00	46.44	346.60	245.02	149.02	255.11	671.76	630.50	447.91	162.10	86.12	36.05
2012	0.00	6.49	57.34	167.78	270.32	355.50	480.60	820.81	594.32	221.19	88.87	41.84
2013	0.00	3.50	48.00	43.10	204.82	227.64	296.60	475.14	331.94	185.17	84.22	38.17
2014	0.00	1.78	19.50	134.52	104.03	220.84	181.62	280.03	337.88	136.97	48.59	27.47
2015	0.00	0.37	19.95	94.25	189.64	133.57	250.10	266.99	290.77	121.79	36.56	24.12

Table B25. USA commercial catch mean weight (kg) at age of witch flounder, 1982 - 2015. Time series (TS) mean is also given.

	USA Commerical Catch Mean Weight (kg) at Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982	0.000	0.003	0.035	0.085	0.174	0.265	0.401	0.550	0.726	0.886	0.983	1.405
1983		0.008	0.038	0.132	0.178	0.237	0.409	0.518	0.613	0.795	0.977	1.357
1984		0.016	0.039	0.119	0.201	0.308	0.421	0.539	0.664	0.817	0.922	1.339
1985		0.016	0.023	0.128	0.218	0.295	0.428	0.565	0.691	0.842	0.964	1.325
1986		0.017	0.026	0.091	0.172	0.275	0.407	0.533	0.676	0.853	0.975	1.321
1987	0.006	0.015	0.033	0.087	0.168	0.265	0.432	0.561	0.686	0.828	0.980	1.303
1988	0.004	0.006	0.017	0.063	0.192	0.278	0.433	0.538	0.668	0.819	0.980	1.326
1989	0.010	0.012	0.031	0.058	0.151	0.241	0.424	0.572	0.680	0.818	0.968	1.357
1990	0.004	0.011	0.035	0.058	0.205	0.266	0.440	0.585	0.687	0.848	1.043	1.453
1991	0.004	0.014	0.039	0.063	0.176	0.289	0.353	0.577	0.700	0.835	0.972	1.419
1992	0.003	0.007	0.021	0.096	0.235	0.330	0.417	0.604	0.739	0.822	0.882	1.243
1993	0.003	0.009	0.023	0.101	0.240	0.330	0.431	0.534	0.666	0.882	1.023	1.335
1994	0.005	0.004	0.019	0.074	0.215	0.312	0.427	0.526	0.690	0.832	0.908	1.264
1995	0.005	0.007	0.027	0.065	0.158	0.300	0.421	0.561	0.691	0.908	0.972	1.238
1996	0.004	0.019	0.031	0.061	0.137	0.268	0.421	0.554	0.708	0.857	0.974	1.230
1997	0.004	0.023	0.035	0.073	0.196	0.277	0.377	0.497	0.628	0.861	1.030	1.280
1998	0.003	0.006	0.029	0.083	0.168	0.253	0.357	0.487	0.586	0.864	0.977	1.209
1999	0.003	0.006	0.029	0.093	0.208	0.283	0.398	0.515	0.587	0.632	0.940	1.063
2000	0.003	0.006	0.028	0.081	0.175	0.239	0.364	0.451	0.534	0.627	0.715	0.930
2001	0.003	0.006	0.024	0.109	0.172	0.241	0.351	0.461	0.550	0.645	0.648	0.843
2002	0.003	0.007	0.033	0.102	0.220	0.278	0.396	0.473	0.552	0.652	0.822	0.940
2003		0.007	0.032	0.070	0.158	0.244	0.321	0.419	0.504	0.566	0.621	0.811
2004			0.048	0.099	0.212	0.261	0.329	0.433	0.537	0.611	0.687	0.870
2005		0.019	0.051	0.109	0.203	0.286	0.354	0.442	0.555	0.632	0.724	0.914
2006		0.012	0.051	0.098	0.198	0.267	0.317	0.453	0.545	0.647	0.712	0.927
2007		0.015	0.041	0.115	0.188	0.250	0.352	0.472	0.564	0.678	0.745	0.915
2008		0.004	0.036	0.124	0.199	0.270	0.393	0.475	0.540	0.599	0.649	0.827
2009		0.040	0.044	0.104	0.203	0.265	0.367	0.453	0.548	0.622	0.726	0.690
2010		0.002	0.012	0.081	0.180	0.253	0.302	0.426	0.499	0.652	0.620	0.810
2011		0.002	0.026	0.093	0.203	0.247	0.343	0.432	0.544	0.648	0.720	0.885
2012		0.007	0.039	0.140	0.184	0.281	0.327	0.438	0.540	0.649	0.720	0.883
2013		0.025	0.094	0.147	0.201	0.267	0.350	0.440	0.530	0.631	0.697	0.876
2014		0.025	0.075	0.132	0.195	0.286	0.376	0.481	0.589	0.693	0.769	1.377
2015		0.026	0.062	0.105	0.161	0.275	0.370	0.468	0.554	0.656	0.756	0.843
TS mean	0.004	0.012	0.036	0.095	0.190	0.273	0.383	0.501	0.611	0.741	0.847	1.112

Table B26. USA commercial catch mean length (cm) at age of witch flounder, 1982 - 2015. Time series (TS) mean is also given.

	USA Commercial Catch Mean Length (cm) at Age											
Year	0	1	2	3	4	5	6	7	8	9	10	11+
1982	5.0	8.4	19.2	23.6	30.4	34.1	39.0	42.9	46.5	49.3	50.9	56.3
1983		12.1	19.9	27.5	30.7	33.5	39.4	42.2	44.2	47.7	50.7	55.0
1984		15.4	19.8	26.2	31.9	36.1	39.7	42.7	45.3	48.2	49.9	55.5
1985		15.5	16.9	28.4	32.7	35.7	39.9	43.3	45.9	48.6	50.6	55.3
1986		15.5	17.3	25.3	30.4	35.0	39.3	42.5	45.5	48.8	50.7	55.3
1987	10.6	15.3	19.0	25.1	30.1	34.7	40.0	43.1	45.8	48.4	50.8	55.1
1988	10.2	10.9	15.6	22.6	31.5	35.0	40.0	42.7	45.4	48.2	50.8	55.3
1989	13.6	14.1	18.6	22.3	29.8	34.1	39.8	43.4	45.5	48.1	50.6	55.7
1990	10.5	13.7	19.3	22.1	32.0	34.7	40.2	43.7	45.8	48.6	51.6	56.8
1991	9.7	14.1	19.8	22.6	30.8	35.7	37.6	43.3	46.0	48.5	50.6	56.4
1992	9.3	10.8	16.6	25.3	33.5	37.1	39.6	44.1	46.8	48.2	49.2	54.2
1993	9.2	12.0	16.9	25.9	33.9	37.1	40.0	42.5	45.3	49.3	51.5	55.5
1994	10.7	9.8	15.9	23.2	32.7	36.3	39.6	42.2	45.6	48.0	49.1	54.1
1995	10.9	11.6	17.6	22.6	30.1	35.9	39.4	42.8	45.4	49.2	50.1	53.8
1996	10.0	15.3	18.5	22.6	28.6	34.8	39.4	42.7	45.8	48.4	50.1	53.6
1997	10.2	16.1	19.2	23.7	31.7	35.0	38.2	41.4	44.2	48.3	51.0	54.2
1998	9.4	10.4	17.9	24.9	30.9	34.3	37.6	41.1	43.3	48.5	50.4	53.4
1999	9.4	10.5	18.1	25.5	32.3	35.3	38.8	41.8	43.3	44.4	49.8	50.6
2000	9.4	10.4	17.6	24.5	30.7	33.6	37.9	40.2	42.2	44.1	45.8	49.1
2001	9.4	10.4	17.1	26.6	30.9	33.9	37.4	40.4	42.5	44.6	44.5	47.9
2002	9.4	10.8	18.5	26.1	32.7	35.0	38.7	40.8	42.6	44.6	47.9	49.6
2003		12.5	18.8	23.8	29.8	33.8	36.6	39.4	41.5	42.8	43.9	47.3
2004		12.2	21.3	26.4	32.3	34.5	36.8	39.8	42.3	43.8	45.3	48.5
2005		15.9	21.4	26.8	32.1	35.4	37.6	40.0	42.7	44.3	46.1	49.2
2006		14.0	21.3	26.2	31.8	34.7	36.4	40.3	42.4	44.6	45.8	49.4
2007		15.1	20.0	27.4	31.8	34.3	37.6	40.8	42.9	45.3	46.4	49.3
2008		10.0	19.0	27.7	32.0	34.8	38.5	40.8	42.3	43.5	44.3	47.8
2009		20.3	20.1	26.5	32.3	34.8	37.9	40.2	42.4	44.1	46.1	45.3
2010		13.4	16.0	23.2	31.4	34.3	36.0	39.5	41.3	44.6	44.1	47.6
2011		9.1	17.5	24.3	32.2	34.1	37.2	39.7	42.4	44.6	46.0	48.8
2012		10.2	19.0	28.8	31.5	35.3	36.7	39.9	42.3	44.6	46.0	48.8
2013		16.6	25.9	29.5	32.2	34.7	37.4	39.9	42.1	44.3	45.6	48.7
2014		16.8	24.2	28.6	32.0	35.4	38.2	41.0	43.4	45.5	46.8	53.2
2015		17.9	22.7	26.6	30.3	34.7	38.0	40.6	42.7	44.8	46.1	48.0
TS mean	9.8	13.1	19.0	25.4	31.5	34.9	38.4	41.5	43.9	46.4	48.2	51.9

Table B27. Summary of area (square nautical miles) of Northeast Fisheries Science Center survey strata (offshore strata 22-30; 36-40) used in the witch flounder stock assessment and the USA statistical areas associated with the witch flounder stock. The statistical areas that comprise approximately 96% of the landings are denoted with an asterisk (*).

Survey Strata	Area
22	454
23	1,016
24	2,569
25	390
26	1,014
27	720
28	2,249
29	3,245
30	619
36	4,069
37	2,108
38	2,560
39	730
40	578
Total	22,321

USA Stat Areas	Area
464	208
465	258
467	75
511 *	1,313
512 *	3,652
513 *	3,567
514 *	2,573
515 *	4,603
521 *	3,853
522 *	3,663
525 *	7,461
526 *	4,029
533	1,547
534	2,320
537	6,261
538	800
539	742
541	2,320
542	5,402
543	2,281
561 *	765
562 *	3,562
611	1,421
612	1,893
613	3,258
614	1,131
615	2,781
616	3,707
621	3,702
622	2,820
623	2,820
624	5,638
625	5,104
626	2,858
627	2,858
628	2,858
629	3,375
631	3,115
632	2,895
633	2,895
634	2,895
635	3,485
636	2,931
637	2,931
638	2,931
639	3,508
640	6,906
Unit area	141,966
* Areas	39,581

Table B28. Stratified mean number, weight (kg), length (cm), and individual weight (kg) per tow of witch flounder in Northeast Fisheries Science Center offshore spring and autumn bottom trawl surveys in Gulf of Maine-Georges Bank region (strata 22-30,36-40), 1963-2016. Time series means are also given.

	SPRING						AUTUMN					
Year	Number per tow	CV	Weight per tow	CV	Length per tow	Avg. wt. per tow	Number per tow	CV	Weight per tow	CV	Length per tow	Avg. wt. per tow
1963	-		-		-	-	5.52	18.6	3.46	17.2	39.7	0.627
1964	-		-		-	-	2.89	13.6	2.09	17.2	44.2	0.724
1965	-		-		-	-	3.94	14.8	2.29	17.0	40.6	0.580
1966	-		-		-	-	7.89	17.0	4.61	16.2	41.2	0.585
1967	-		-		-	-	3.00	18.0	1.99	27.4	43.7	0.666
1968	4.71	17.8	3.27	21.1	42.3	0.693	4.82	18.2	3.52	19.0	44.8	0.731
1969	3.73	22.1	2.59	22.5	45.3	0.695	5.81	29.2	4.21	19.7	43.5	0.725
1970	6.39	14.3	4.50	13.5	44.7	0.705	4.89	10.7	3.68	12.8	45.0	0.753
1971	2.74	22.0	2.04	26.6	46.5	0.747	4.32	14.6	2.96	14.7	42.1	0.686
1972	5.35	20.1	4.01	21.3	45.8	0.749	3.24	15.3	2.42	16.7	43.9	0.747
1973	8.20	11.8	6.21	14.5	44.8	0.758	3.18	23.4	2.05	23.7	43.6	0.646
1974	6.23	17.9	3.62	18.3	39.3	0.581	2.38	16.7	1.58	19.9	41.0	0.666
1975	3.72	26.2	2.75	32.8	43.9	0.739	1.66	19.1	1.03	25.8	39.8	0.621
1976	5.50	16.8	3.70	22.0	42.3	0.673	1.34	23.6	0.94	21.1	41.9	0.699
1977	4.20	25.6	1.96	20.8	37.2	0.467	5.05	21.3	3.38	15.3	42.0	0.669
1978	3.87	21.4	2.56	18.5	41.7	0.662	4.04	12.3	2.94	10.6	42.8	0.727
1979	3.01	19.5	1.71	16.3	38.2	0.594	1.94	10.3	1.62	11.4	45.2	0.838
1980	8.46	29.8	3.89	15.9	36.0	0.460	2.62	13.8	2.04	16.4	43.7	0.777
1981	8.14	14.5	4.05	19.3	38.0	0.497	3.66	28.5	2.19	20.9	40.4	0.600
1982	3.64	22.2	1.87	17.2	37.2	0.513	0.99	40.5	0.83	40.5	44.7	0.842
1983	6.41	27.0	2.74	22.0	36.3	0.427	4.72	14.2	2.12	13.4	36.7	0.448
1984	3.00	16.1	1.66	17.0	39.9	0.554	4.37	13.9	2.33	16.1	39.7	0.534
1985	5.18	19.3	2.75	19.2	40.3	0.531	2.76	19.7	1.59	23.1	41.9	0.577
1986	2.07	15.8	1.35	17.0	44.1	0.650	1.59	15.5	1.09	14.7	43.3	0.683
1987	1.01	23.2	0.65	25.1	43.4	0.646	0.48	33.0	0.37	27.3	43.9	0.774
1988	1.43	23.3	0.85	27.5	42.3	0.590	1.38	17.3	0.57	19.6	35.2	0.414
1989	1.95	21.7	0.74	20.0	35.8	0.382	0.89	19.6	0.38	26.6	31.4	0.423
1990	0.63	30.3	0.24	30.6	35.2	0.378	2.00	16.4	0.40	18.4	24.7	0.200
1991	1.68	25.0	0.57	21.9	31.5	0.341	2.08	27.6	0.54	27.3	29.2	0.258
1992	1.26	18.2	0.48	23.1	34.8	0.383	0.94	30.0	0.24	37.6	29.5	0.254
1993	1.47	17.7	0.36	20.9	30.3	0.245	5.15	25.0	0.54	22.8	17.0	0.105
1994	3.13	22.6	0.53	28.5	27.4	0.170	2.21	16.4	0.42	26.5	24.9	0.191
1995	1.88	16.9	0.47	19.9	30.6	0.248	4.74	19.6	0.62	20.7	25.7	0.132
1996	1.36	16.9	0.28	19.4	30.5	0.204	5.38	19.1	1.02	21.1	29.7	0.189
1997	2.22	26.7	0.43	28.1	31.0	0.195	5.10	19.6	0.77	21.9	24.9	0.150
1998	4.27	17.5	0.77	18.8	29.0	0.179	3.70	20.1	0.47	23.2	24.2	0.127
1999	3.15	20.5	0.48	20.0	28.1	0.153	5.91	21.9	0.88	21.3	26.3	0.148
2000	3.45	14.0	0.52	12.4	27.3	0.151	6.63	15.2	1.11	17.3	27.1	0.167
2001	4.41	16.3	0.75	13.0	29.5	0.170	7.94	16.2	1.71	16.5	32.3	0.216
2002	8.10	20.3	1.61	16.5	31.4	0.199	4.31	19.0	1.06	20.0	33.2	0.246
2003	5.20	16.1	1.30	14.5	34.2	0.250	2.66	19.0	0.79	18.8	35.4	0.298
2004	3.80	12.6	1.08	13.5	35.5	0.283	3.82	31.8	1.03	31.9	33.3	0.271
2005	3.36	20.3	0.89	22.1	34.6	0.265	1.93	18.5	0.38	16.7	27.8	0.197
2006	3.09	13.9	0.72	11.0	32.2	0.235	2.03	19.3	0.46	20.7	30.5	0.226
2007	2.37	16.5	0.58	14.9	32.9	0.245	2.74	22.8	0.57	23.2	31.6	0.208
2008	7.45	25.0	1.40	21.7	31.3	0.188	2.75	17.1	0.64	19.5	31.2	0.233
*2009	2.34	14.7	0.53	14.8	31.7	0.227	2.18	19.0	0.48	21.0	29.6	0.217
*2010	2.47	13.8	0.54	14.2	30.4	0.218	2.00	16.9	0.36	20.9	28.4	0.182
*2011	2.82	11.4	0.57	12.8	30.3	0.201	3.71	20.6	0.67	22.6	29.3	0.177
*2012	1.82	12.2	0.38	16.8	30.1	0.205	2.19	19.6	0.44	21.6	30.1	0.202
*2013	1.04	13.4	0.22	13.8	30.7	0.209	2.31	17.7	0.35	22.9	24.9	0.152
*2014	2.96	15.2	0.49	16.4	25.7	0.155	2.76	16.8	0.51	18.0	27.8	0.186
*2015	2.77	14.7	0.47	13.6	28.2	0.171	3.16	13.2	0.53	15.5	27.7	0.167
*2016	2.02	11.2	0.38	14.0	30.1	0.188						
TS mean	3.66		1.56		35.5	0.395	3.39		1.42		35.1	0.431

* mean number and mean weight represent adjusted values using constnat conversion factors 3.257177 for numbers and 3.257201 for weight

Table B29. Summary of number of fish caught, age, percentage sampled and maximum age of witch flounder in the Northeast Fisheries Science Center spring and autumn survey (strata 22-30, 36-40), 1980- 2016.

	Spring				Autumn			
Year	Caught	Aged	%sampled	max age	Caught	Aged	% sampled	max age
1980	593	361	60.9	24	189	146	77.2	24
1981	557	209	37.5	23	202	143	70.8	22
1982	245	69	28.2	17	64	53	82.8	24
1983	410	176	42.9	20	359	154	42.9	22
1984	171	124	72.5	20	293	204	69.6	21
1985	269	151	56.1	25	170	116	68.2	30
1986	119	118	99.2	22	129	109	84.5	22
1987	53	53	100.0	24	30	27	90.0	24
1988	74	67	90.5	12	93	82	88.2	20
1989	100	91	91.0	18	59	55	93.2	21
1990	33	27	81.8	16	131	118	90.1	18
1991	93	87	93.5	15	187	107	57.2	11
1992	86	75	87.2	15	79	61	77.2	18
1993	88	81	92.0	19	414	166	40.1	16
1994	196	128	65.3	16	174	102	58.6	21
1995	142	106	74.6	12	352	174	49.4	14
1996	84	72	85.7	11	295	169	57.3	11
1997	129	79	61.2	8	368	243	66.0	12
1998	367	281	76.6	13	359	217	60.4	13
1999	187	138	73.8	10	556	244	43.9	10
2000	231	141	61.0	10	411	224	54.5	12
2001	315	197	62.5	10	475	234	49.3	10
2002	568	289	50.9	21	339	201	59.3	12
2003	310	204	65.8	14	181	146	80.7	18
2004	247	205	83.0	23	191	121	63.4	15
2005	180	142	78.9	13	158	93	58.9	13
2006	209	168	80.4	11	143	115	80.4	11
2007	132	114	86.4	11	168	112	66.7	12
2008	394	202	51.3	10	191	124	64.9	13
2009	648	402	62.0	13	539	324	60.1	11
2010	683	387	56.7	14	434	283	65.2	12
2011	600	379	63.2	14	811	388	47.8	12
2012	514	385	74.9	13	543	331	61.0	12
2013	276	215	77.9	17	575	339	59.0	10
2014	856	486	56.8	9	748	415	55.5	16
2015	671	389	58.0	15	895	480	53.6	14
2016	635	385	60.6	12				

Table B30. Stratified mean number per tow at age of witch flounder in Northeast Fisheries Science Center bottom trawl spring and autumn surveys (strata 22-30, 36-40), 1980 – 2016. Survey conversion factors applied to 2009 onward.

	AGE															
SPRING	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Total
1980	0.000	0.060	0.230	0.950	1.520	0.720	1.200	1.020	0.380	0.400	0.310	0.300	0.120	0.160	1.100	8.46
1981	0.000	0.000	0.050	0.820	0.930	2.000	1.020	0.760	0.670	0.420	0.130	0.200	0.240	0.220	0.900	8.40
1982	0.000	0.044	0.042	0.610	0.484	0.377	0.237	0.608	0.362	0.093	0.259	0.175	0.026	0.033	0.292	3.64
1983	0.000		0.071	0.531	1.262	1.293	0.541	0.716	0.632	0.475	0.214	0.166	0.075	0.054	0.376	6.41
1984	0.000		0.103	0.012	0.307	0.777	0.401	0.310	0.202	0.196	0.115	0.173	0.117	0.023	0.266	3.00
1985	0.000			0.017	0.459	1.057	1.199	0.908	0.412	0.148	0.149	0.044	0.072	0.027	0.691	5.18
1986	0.000				0.044	0.240	0.529	0.412	0.172	0.194	0.079	0.038	0.063	0.055	0.248	2.07
1987	0.000				0.059	0.114	0.133	0.260	0.186	0.010	0.061	0.023			0.163	1.01
1988	0.000	0.023	0.023	0.062		0.072	0.300	0.379	0.239	0.137	0.086	0.084	0.029		0.000	1.43
1989	0.000	0.023	0.013	0.036	1.004	0.106	0.073	0.081	0.328	0.081	0.015	0.056	0.056	0.019	0.056	1.95
1990	0.000	0.008		0.038	0.091	0.320		0.042	0.009	0.050	0.018	0.010	0.011		0.030	0.63
1991	0.000	0.042		0.780	0.108	0.087	0.209	0.033	0.101	0.083	0.138	0.018	0.022		0.064	1.68
1992	0.000	0.055	0.009	0.187	0.373	0.085	0.111	0.152	0.045	0.149	0.015	0.016	0.046		0.019	1.26
1993	0.000	0.149	0.112	0.137	0.472	0.320	0.058	0.085		0.016	0.016		0.068		0.037	1.47
1994	0.000	0.107	0.697	0.541	0.644	0.810	0.164	0.027	0.028	0.070	0.008			0.016	0.016	3.13
1995	0.000	0.041	0.120	0.581	0.316	0.179	0.312	0.116	0.110	0.042		0.038	0.028		0.000	1.88
1996	0.000	0.017	0.036	0.244	0.394	0.346	0.219	0.073				0.032			0.000	1.36
1997	0.000	0.072	0.066	0.152	0.693	0.617	0.438	0.084	0.083	0.014					0.000	2.22
1998	0.000	0.112	1.079	0.712	0.388	0.798	0.713	0.214	0.154	0.076				0.028	0.000	4.27
1999	0.000	0.106	0.376	0.974	0.797	0.483	0.164	0.182	0.031	0.014	0.023				0.000	3.15
2000	0.000	0.007	0.250	1.194	0.693	0.660	0.239	0.253	0.116		0.035				0.000	3.45
2001	0.000	0.105	0.099	0.713	1.476	1.020	0.401	0.293	0.163	0.113	0.028				0.000	4.41
2002	0.000	0.023	0.060	0.897	2.627	2.263	0.822	0.683	0.351	0.192	0.103	0.014		0.029	0.037	8.10
2003	0.000			0.150	0.808	1.646	1.017	0.869	0.387	0.197	0.046	0.060		0.016	0.009	5.20
2004	0.000	0.009	0.060	0.074	0.428	0.649	0.809	0.883	0.368	0.158	0.161	0.135			0.067	3.80
2005	0.000	0.011	0.160	0.146	0.220	0.738	0.760	0.574	0.383	0.245	0.087	0.018		0.021	0.000	3.36
2006	0.000	0.044	0.460	0.347	0.138	0.207	0.683	0.568	0.410	0.145	0.069	0.015			0.000	3.09
2007	0.000		0.178	0.571	0.263	0.241	0.228	0.546	0.154	0.158		0.031			0.000	2.37
2008	0.000	0.011	0.372	0.848	2.834	1.341	0.646	0.724	0.550	0.088	0.036				0.000	7.45
2009	0.000	0.135	0.140	0.290	0.428	0.575	0.206	0.155	0.221	0.120	0.057	0.009	0.004	0.004	0.000	2.34
2010	0.000	0.139	0.451	0.268	0.168	0.420	0.471	0.142	0.102	0.185	0.066	0.031	0.016	0.004	0.010	2.47
2011	0.000	0.035	0.365	0.701	0.268	0.305	0.470	0.283	0.118	0.088	0.115	0.042	0.012	0.010	0.011	2.82
2012	0.000	0.089	0.188	0.387	0.329	0.156	0.232	0.160	0.159	0.075	0.034	0.010		0.006	0.000	1.82
2013	0.000	0.036	0.124	0.139	0.279	0.144	0.087	0.109	0.066	0.031	0.019		0.004		0.002	1.04
2014	0.000	0.576	0.447	0.676	0.264	0.432	0.209	0.137	0.138	0.082					0.000	2.96
2015	0.000	0.032	0.582	0.755	0.461	0.235	0.320	0.152	0.151	0.053	0.020	0.008			0.005	2.77
2016	0.000	0.106	0.083	0.753	0.314	0.364	0.108	0.141	0.086	0.030	0.013	0.006	0.015			2.02

Table B30 continued. Stratified mean number per tow at age of witch flounder.

	AGE															
AUTUMN	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	Total
1980	0.040	0.000	0.020	0.000	0.200	0.260	0.280	0.360	0.170	0.150	0.270	0.040	0.160	0.120	0.570	2.62
1981	0.030	0.070	0.030	0.240	0.440	0.610	0.460	0.270	0.260	0.180	0.210	0.170	0.040	0.130	0.480	3.66
1982	0.020			0.058	0.013	0.027	0.076	0.241	0.132	0.015	0.027	0.032	0.010	0.040	0.302	0.99
1983		0.008	0.011	0.507	1.596	0.758	0.548	0.444	0.084	0.137	0.073	0.114	0.025		0.415	4.72
1984				0.093	0.944	0.991	0.605	0.535	0.310	0.149	0.126	0.073	0.041	0.132	0.375	4.37
1985			0.009	0.059	0.076	0.610	0.684	0.483	0.270	0.103	0.122	0.029	0.015	0.089	0.217	2.76
1986	0.009				0.051	0.267	0.353	0.309	0.160	0.112	0.009	0.010	0.021	0.052	0.238	1.59
1987			0.023		0.011	0.023	0.046	0.192	0.071		0.009			0.023	0.085	0.48
1988		0.007		0.725	0.055	0.012	0.036	0.215	0.048	0.046	0.045	0.079	0.011	0.043	0.055	1.38
1989	0.174	0.018	0.018	0.082	0.301	0.009	0.021	0.017	0.084	0.078	0.024		0.026		0.037	0.89
1990	0.481	0.088	0.137	0.380	0.538	0.188	0.024	0.023	0.023	0.025			0.009	0.055	0.034	2.00
1991	0.224	0.021	0.178	0.661	0.329	0.290	0.145	0.067	0.059	0.030	0.052	0.028			0.000	2.08
1992	0.097	0.029	0.109	0.259	0.224	0.054	0.060			0.019	0.009	0.019		0.019	0.042	0.94
1993	2.541	0.672	0.154	0.544	0.777	0.219	0.058	0.022	0.081		0.019	0.042		0.011	0.014	5.16
1994	0.432	0.156	0.287	0.531	0.165	0.395	0.037	0.106		0.043	0.009		0.005		0.043	2.21
1995	0.512	0.203	0.764	1.624	0.858	0.472	0.229			0.011	0.055				0.009	4.74
1996	0.232	0.091	0.261	0.785	1.988	1.386	0.441	0.066	0.065	0.037		0.033			0.000	5.38
1997	0.892	0.339	0.979	0.522	0.871	0.770	0.383	0.330					0.020		0.000	5.11
1998	0.639	0.082	0.520	1.363	0.465	0.303	0.165	0.110	0.043	0.012					0.000	3.70
1999	0.323	0.521	1.178	1.514	1.044	0.600	0.363	0.275	0.050	0.037	0.009				0.000	5.91
2000	0.943	0.096	0.719	1.408	1.746	0.674	0.589	0.229	0.152	0.050			0.026		0.000	6.63
2001		0.039	0.211	0.953	3.156	1.886	0.813	0.612	0.159	0.058	0.056				0.000	7.94
2002			0.275	0.431	1.475	0.997	0.532	0.331	0.149	0.071		0.046	0.005		0.000	4.31
2003	0.018		0.038	0.075	0.307	0.580	0.770	0.315	0.129	0.222	0.083	0.021	0.046	0.019	0.038	2.66
2004	0.275	0.072	0.014	0.086	0.453	0.987	0.826	0.498	0.355	0.054	0.105	0.072			0.018	3.82
2005	0.132	0.635	0.087	0.023	0.131	0.181	0.269	0.340	0.055	0.052	0.012			0.016	0.000	1.93
2006	0.066	0.103	0.540	0.322	0.046	0.104	0.298	0.286	0.138	0.071	0.042	0.014			0.000	2.03
2007		0.065	0.162	1.206	0.478	0.188	0.220	0.261	0.069	0.078			0.014		0.000	2.74
2008	0.275	0.021	0.095	0.422	0.794	0.273	0.254	0.235	0.302	0.014	0.057			0.008	0.000	2.75
2009	0.094	0.384	0.186	0.198	0.377	0.454	0.153	0.138	0.115	0.068	0.004	0.009			0.000	2.18
2010	0.043	0.402	0.469	0.183	0.212	0.168	0.251	0.051	0.116	0.063	0.019	0.021	0.003		0.000	2.00
2011	0.041	0.229	0.869	1.077	0.402	0.280	0.440	0.180	0.075	0.048	0.060	0.006	0.005		0.000	3.71
2012	0.015	0.261	0.308	0.644	0.315	0.141	0.216	0.135	0.057	0.059	0.032		0.011		0.000	2.19
2013	0.509	0.188	0.486	0.190	0.462	0.238	0.042	0.105	0.057	0.026	0.005				0.000	2.31
2014	0.116	0.683	0.326	0.535	0.236	0.379	0.142	0.140	0.140	0.038	0.008	0.007	0.009		0.005	2.76
2015	0.186	0.150	0.933	0.829	0.331	0.160	0.309	0.131	0.051	0.060	0.014				0.003	3.16

Table B31. Stratified mean weight (kg) per tow at age of witch flounder in Northeast Fisheries Science Center bottom trawl spring and autumn surveys (strata 22-30, 36-40), 1980 – 2016.

	AGE														
SPRING	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1982	-	0.002	0.016	0.048	0.122	0.235	0.317	0.494	0.640	0.864	1.023	1.052	1.595	1.171	1.615
1983	-	-	0.029	0.049	0.107	0.186	0.288	0.443	0.589	0.779	1.089	1.275	0.922	1.328	1.418
1984	-	-	0.026	0.034	0.154	0.223	0.354	0.532	0.565	0.714	1.040	0.998	1.261	1.253	1.543
1985	-	-	-	0.037	0.142	0.235	0.325	0.484	0.627	0.752	0.898	0.886	0.832	1.281	1.409
1986	-	-	-	-	0.112	0.260	0.359	0.474	0.648	0.830	0.988	1.021	1.160	1.305	1.463
1987	-	-	-	-	0.128	0.254	0.464	0.462	0.601	0.689	1.015	0.797	-	-	1.435
1988	-	0.003	0.014	0.036	-	0.218	0.388	0.534	0.669	0.900	1.169	0.977	1.500	-	-
1989	-	0.001	0.014	0.041	0.126	0.204	0.387	0.554	0.595	0.881	0.860	1.041	1.437	0.685	1.645
1990	-	0.003	-	0.039	0.133	0.215	-	0.471	0.872	0.924	1.037	1.069	1.141	-	1.289
1991	-	0.001	-	0.043	0.124	0.278	0.335	0.549	0.806	0.828	1.099	1.111	1.185	-	1.071
1992	-	0.002	0.005	0.052	0.145	0.264	0.364	0.522	0.662	0.877	0.669	0.954	1.431	-	1.314
1993	-	0.002	0.026	0.066	0.151	0.240	0.335	0.412	0.000	0.846	0.846	-	0.867	-	1.617
1994	-	0.005	0.027	0.052	0.148	0.235	0.357	0.468	0.675	0.794	0.781	-	-	1.408	1.408
1995	-	0.003	0.023	0.057	0.109	0.238	0.314	0.545	0.633	0.882	-	1.130	1.504	-	-
1996	-	0.004	0.035	0.056	0.125	0.202	0.317	0.430	-	-	-	1.323	-	-	-
1997	-	0.005	0.018	0.053	0.140	0.173	0.284	0.476	0.543	0.729	-	-	-	-	-
1998	-	0.005	0.040	0.078	0.151	0.218	0.277	0.384	0.507	0.636	-	-	-	0.975	-
1999	-	0.004	0.035	0.082	0.128	0.231	0.313	0.425	0.628	0.556	0.862	-	-	-	-
2000	-	0.003	0.028	0.046	0.116	0.181	0.308	0.379	0.475	-	0.938	-	-	-	-
2001	-	0.002	0.020	0.065	0.105	0.195	0.280	0.340	0.427	0.453	0.609	-	-	-	-
2002	-	0.005	0.025	0.039	0.130	0.186	0.240	0.323	0.462	0.548	0.590	0.454	-	0.592	1.131
2003	-	-	-	0.061	0.113	0.185	0.252	0.343	0.434	0.483	0.504	0.592	-	0.672	0.775
2004	-	0.011	0.023	0.058	0.126	0.190	0.233	0.309	0.387	0.473	0.476	0.568	-	-	0.920
2005	-	0.002	0.029	0.051	0.130	0.186	0.245	0.322	0.404	0.487	0.481	0.827	-	0.576	-
2006	-	0.002	0.032	0.060	0.124	0.197	0.253	0.324	0.407	0.458	0.458	0.630	-	-	-
2007	-	-	0.032	0.085	0.148	0.215	0.273	0.360	0.445	0.567	-	0.639	-	-	-
2008	-	0.001	0.035	0.081	0.133	0.196	0.242	0.316	0.408	0.555	0.603	-	-	-	-
2009	-	0.002	0.031	0.090	0.152	0.206	0.295	0.350	0.438	0.500	0.497	0.610	0.631	1.239	-
2010	-	0.003	0.035	0.068	0.150	0.216	0.271	0.334	0.436	0.510	0.578	0.548	0.757	0.966	0.761
2011	-	0.003	0.036	0.070	0.128	0.204	0.269	0.314	0.413	0.423	0.513	0.601	0.679	0.839	0.613
2012	-	0.003	0.029	0.088	0.143	0.222	0.282	0.357	0.418	0.510	0.541	0.634	-	0.668	-
2013	-	0.004	0.051	0.095	0.163	0.204	0.257	0.336	0.473	0.530	0.612	-	0.891	-	0.891
2014	-	0.005	0.040	0.108	0.172	0.251	0.305	0.388	0.506	0.660	-	-	-	-	-
2015	-	0.003	0.035	0.070	0.156	0.236	0.290	0.374	0.439	0.604	0.741	0.817	-	-	0.834
2016	-	0.009	0.055	0.106	0.145	0.242	0.293	0.363	0.433	0.582	0.641	0.755	0.737	-	-
TS mean		0.003	0.028	0.061	0.134	0.217	0.305	0.415	0.522	0.664	0.768	0.856	1.112	0.997	1.218

Table B31, continue. Stratified mean weight (kg) per tow at age of witch flounder

	AGE														
AUTUMN	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1982	0.000	-	-	0.060	0.149	0.159	0.346	0.547	0.591	0.819	1.005	0.932	1.059	1.133	1.542
1983	-	0.012	0.035	0.088	0.173	0.279	0.427	0.544	0.676	0.876	1.112	1.050	1.034	-	1.701
1984	-	-	-	0.091	0.182	0.264	0.384	0.566	0.685	0.762	0.976	1.045	1.309	1.204	1.659
1985	-	-	0.039	0.097	0.154	0.259	0.388	0.534	0.726	0.855	0.958	1.125	1.254	1.121	1.585
1986	0.001	-	-	-	0.161	0.302	0.383	0.553	0.697	0.924	1.023	1.049	0.892	1.256	1.566
1987	-	-	0.020	-	0.133	0.314	0.417	0.518	0.626	-	0.904	-	-	1.343	1.913
1988	-	0.004	-	0.090	0.188	0.354	0.515	0.547	0.665	0.825	0.912	1.206	1.338	1.269	1.427
1989	0.001	0.016	0.033	0.079	0.189	0.311	0.619	0.669	0.765	0.971	1.097	-	1.310	-	2.266
1990	0.001	0.021	0.028	0.114	0.164	0.317	0.444	0.569	0.772	1.018	-	-	1.587	1.044	1.759
1991	0.001	0.016	0.050	0.108	0.179	0.339	0.526	0.747	0.815	0.766	1.227	1.342	-	-	-
1992	0.001	0.018	0.065	0.124	0.204	0.352	0.385	-	-	0.692	0.920	0.744	-	0.859	1.396
1993	0.001	0.013	0.059	0.142	0.210	0.315	0.523	0.587	0.708	-	1.282	0.990	-	2.043	1.449
1994	0.001	0.019	0.046	0.071	0.212	0.313	0.561	0.589	-	1.191	0.902	-	0.965	-	1.444
1995	0.001	0.021	0.053	0.100	0.150	0.270	0.379	-	-	1.126	0.910	-	-	-	1.275
1996	0.001	0.012	0.032	0.083	0.149	0.233	0.401	0.496	0.736	0.941	-	1.077	-	-	-
1997	0.001	0.020	0.040	0.095	0.170	0.270	0.353	0.503		-	-	-	0.742	-	-
1998	0.001	0.019	0.055	0.093	0.170	0.267	0.394	0.494	0.634	0.533	-	-	-	-	-
1999	0.001	0.018	0.045	0.102	0.167	0.267	0.371	0.493	0.498	0.658	0.641	-	-	-	-
2000	0.001	0.016	0.059	0.099	0.174	0.225	0.351	0.512	0.581	0.677	-	-	0.944	-	-
2001	-	0.013	0.035	0.123	0.168	0.218	0.313	0.413	0.488	0.447	0.694	-	-	-	-
2002	-	-	0.059	0.096	0.182	0.243	0.321	0.476	0.490	0.593	-	0.922	0.935	-	-
2003	0.001	-	0.044	0.075	0.147	0.218	0.275	0.344	0.366	0.491	0.562	0.516	0.604	0.989	0.931
2004	0.001	0.015	0.071	0.117	0.167	0.218	0.291	0.371	0.435	0.586	0.571	0.570	-	-	0.922
2005	0.001	0.019	0.070	0.148	0.190	0.230	0.307	0.405	0.468	0.629	0.642	-	-	0.433	-
2006	-	0.021	0.063	0.091	0.229	0.263	0.286	0.434	0.506	0.557	0.683	0.612	-	-	-
2007	-	0.018	0.060	0.126	0.187	0.246	0.310	0.391	0.597	0.584	-	-	0.996	-	-
2008	0.001	0.019	0.057	0.119	0.183	0.234	0.288	0.465	0.451	0.739	0.651	-	-	1.179	-
2009	0.001	0.023	0.063	0.112	0.213	0.266	0.383	0.487	0.512	0.596	1.014	0.758	-	-	-
2010	0.001	0.024	0.063	0.120	0.187	0.285	0.314	0.391	0.450	0.478	0.512	0.640	0.658	-	-
2011	0.001	0.018	0.070	0.130	0.189	0.270	0.310	0.372	0.503	0.529	0.561	0.978	0.606	-	-
2012	0.001	0.025	0.079	0.139	0.196	0.255	0.335	0.391	0.557	0.648	0.718	-	0.729	-	-
2013	0.001	0.023	0.101	0.151	0.217	0.263	0.370	0.379	0.567	0.614	0.544	-	-	-	-
2014	0.001	0.023	0.073	0.150	0.213	0.303	0.330	0.454	0.520	0.713	0.634	0.500	0.631	-	1.034
2015	0.001	0.030	0.074	0.113	0.206	0.269	0.357	0.431	0.564	0.669	0.622	-	-	-	0.850
TS mean	0.001	0.018	0.055	0.108	0.181	0.270	0.381	0.490	0.588	0.726	0.825	0.892	0.977	1.156	1.454

Table B32. Stratified mean length (cm) per tow at age of witch flounder in Northeast Fisheries Science Center bottom trawl spring and autumn surveys (strata 22-30, 36-40), 1980 – 2016.

	AGE														
SPRING	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1980	-	9.7	16.4	20.6	26.2	30.6	34.8	38.6	40.6	45.0	48.6	49.2	49.3	52.5	55.2
1981	-	-	13.4	20.2	28.5	32.4	35.4	39.7	44.4	49.4	52.4	49.9	54.5	54.1	57.6
1982	-	7.9	15.0	20.7	27.2	32.8	36.1	41.0	44.1	48.2	50.7	51.3	58.0	53.0	58.1
1983	-	-	17.9	20.9	26.5	31.2	35.5	40.2	43.7	47.4	52.5	54.9	50.0	55.6	56.1
1984	-	-	17.4	19.0	29.4	32.6	37.5	42.2	43.0	46.0	51.3	50.6	54.2	54.3	57.4
1985	-	-	-	19.5	28.8	33.5	36.6	41.2	44.4	46.9	49.3	49.3	48.5	55.0	56.3
1986	-	-	-	-	27.3	35.0	38.5	41.7	45.8	49.1	51.8	52.3	54.2	56.1	57.9
1987	-	-	-	-	28.0	34.4	40.9	40.8	44.1	46.0	51.5	48.0	-	-	56.7
1988	-	9.0	15.0	19.5	-	33.1	39.2	43.0	46.0	50.2	54.2	51.2	58.3	-	-
1989	-	7.0	15.0	20.6	28.5	33.0	39.8	44.0	44.9	50.5	50.2	53.1	58.3	47.0	60.7
1990	-	9.0	-	19.8	28.3	32.4	-	40.9	49.0	49.8	51.5	52.0	53.0	-	54.9
1991	-	7.5	-	20.4	27.4	35.3	37.2	43.1	48.2	48.2	52.7	53.0	54.0	-	52.4
1992	-	8.5	11.0	21.7	29.3	35.0	38.4	42.5	45.7	49.3	46.0	51.0	57.3	-	56.0
1993	-	7.9	17.9	23.5	30.0	34.5	38.1	40.5	-	50.0	50.0	-	50.3	-	60.1
1994	-	10.8	17.9	21.5	29.4	33.7	38.1	41.2	46.0	48.2	48.0	-	-	57.0	57.0
1995	-	9.7	17.3	22.4	27.1	34.3	37.2	43.7	45.7	50.3	-	54.0	58.7	-	-
1996	-	9.4	19.6	22.3	28.1	32.5	37.1	40.6	-	-	-	56.3	-	-	-
1997	-	10.8	15.9	22.2	29.5	31.4	36.3	42.3	43.9	48.0	-	-	-	-	-
1998	-	11.0	20.3	24.6	29.9	33.3	35.7	39.1	42.6	45.2	-	-	-	51.7	-
1999	-	10.0	19.5	25.0	28.5	34.0	37.2	40.6	45.5	44.0	50.0	-	-	-	-
2000	-	9.0	18.1	20.9	27.3	31.2	36.5	38.5	41.1	-	50.3	-	-	-	-
2001	-	7.4	15.9	23.5	27.0	32.4	36.0	38.2	40.8	41.5	45.3	-	-	-	-
2002	-	11.0	18.0	20.2	29.0	32.2	34.7	37.8	42.1	44.3	45.1	42.0	-	45.3	54.8
2003	-	-	-	22.8	27.7	32.1	35.2	38.3	41.2	42.5	43.1	45.3	-	47.0	49.0
2004	-	14.0	17.5	22.8	28.6	32.4	34.4	37.4	40.0	42.3	42.3	44.5	-	-	51.3
2005	-	9.0	18.7	22.0	29.1	32.2	35.0	37.9	40.5	42.7	42.6	50.0	-	45.0	-
2006	-	9.0	19.0	23.1	28.5	32.6	35.2	37.8	40.3	41.6	41.7	46.0	-	-	-
2007	-	-	19.0	25.5	30.0	33.4	35.9	38.9	41.4	44.4	-	45.9	-	-	-
2008	-	7.0	19.5	25.2	29.2	32.7	34.9	37.6	40.6	44.4	45.6	-	-	-	-
2009	-	8.9	18.8	25.9	30.2	33.0	36.6	38.5	41.0	42.9	42.7	45.5	46.0	56.0	-
2010	-	9.5	19.4	23.5	29.9	33.4	35.6	37.9	40.9	43.1	44.7	43.7	48.2	52.0	48.5
2011	-	9.5	19.4	24.0	28.5	32.8	35.7	37.4	40.5	40.8	43.1	45.0	47.0	50.0	45.3
2012	-	9.6	18.1	25.3	29.3	33.3	35.8	38.4	40.2	42.6	43.6	45.6	-	46.3	-
2013	-	9.9	21.4	25.8	30.2	32.3	34.7	37.5	41.5	42.9	44.7	-	50.0	-	50.0
2014	-	10.5	20.0	26.7	30.9	34.5	36.5	39.2	42.3	45.5	-	-	-	-	-
2015	-	9.4	19.2	23.5	29.7	33.6	35.9	38.5	40.3	44.4	47.2	48.7	-	-	49.0
2016	-	12.5	22.0	26.8	29.3	34.2	36.2	38.5	40.7	44.2	45.7	47.6	47.5	-	-
TS mean		9.5	17.9	22.6	28.7	33.1	36.5	39.9	42.9	45.8	47.7	49.1	52.5	51.6	54.5

Table B32, continued. Stratified mean length (cm) per tow at age of witch flounder in the Northeast Fisheries Science Center survey.

	AGE														
AUTUMN	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1980	5.5	-	19.5	-	27.3	32.0	34.9	39.1	43.3	47.7	48.8	50.1	51.6	53.7	56.7
1981	5.5	12.6	17.6	23.3	30.6	33.1	38.3	41.4	44.8	47.0	51.4	53.6	52.7	55.0	56.4
1982	5.0	-	-	22.0	28.5	29.2	36.4	41.9	42.8	47.3	50.2	49.1	51.0	52.0	56.8
1983	-	14.0	19.0	24.7	30.1	34.7	39.2	42.2	45.0	48.5	52.0	50.9	51.0	-	58.8
1984	-	-	-	25.1	30.7	34.2	38.2	42.8	45.2	46.6	50.2	51.3	54.8	53.5	58.6
1985	-	-	20.0	26.0	29.7	34.6	38.8	42.7	46.8	49.1	50.8	53.3	55.0	53.1	58.7
1986	6.0	-	-	-	29.7	35.5	38.2	42.4	45.4	49.4	51.0	51.3	49.0	53.9	57.7
1987	-	-	16.0	-	28.0	36.0	39.1	41.6	43.8	-	49.0	-	-	55.0	60.9
1988	-	10.0	-	25.4	31.5	38.0	42.0	42.9	45.6	48.6	50.0	54.3	56.0	55.1	56.8
1989	5.7	15.0	18.5	24.1	31.1	36.0	44.0	45.0	46.7	49.9	52.0	-	54.8	-	64.2
1990	6.2	16.3	17.6	26.7	29.8	36.2	40.0	43.0	47.0	50.9	-	-	58.0	51.2	58.9
1991	5.7	14.9	20.8	26.3	30.5	36.8	41.9	46.4	47.6	46.6	53.5	55.0	-	-	-
1992	5.9	15.8	23.1	27.7	32.1	37.7	37.9	-	-	46.0	50.0	47.0	-	49.0	56.5
1993	5.6	14.2	22.2	28.8	32.2	36.4	42.3	43.6	46.2	-	55.0	51.0	-	63.0	57.0
1994	5.7	16.0	20.9	23.5	32.7	36.6	43.5	44.0	-	54.2	50.0	-	51.0	-	57.2
1995	6.6	16.7	22.0	26.5	29.9	35.5	39.2	-	-	54.0	50.6	-	-	-	56.0
1996	5.5	14.2	18.7	25.0	29.6	33.8	39.6	42.1	47.4	50.5	-	53.0	-	-	-
1997	6.3	16.3	19.8	25.8	30.6	35.1	38.0	42.0	-	-	-	-	47.1	-	-
1998	5.9	15.7	22.0	25.7	30.7	35.0	39.3	41.9	44.9	43.0	-	-	-	-	-
1999	5.5	15.6	20.4	26.1	30.2	34.6	38.2	41.6	41.6	45.1	45.0	-	-	-	-
2000	6.1	15.6	22.6	26.3	31.0	33.4	38.0	42.3	44.1	46.3	-	-	51.0	-	-
2001	-	14.6	18.9	28.0	30.6	33.1	36.7	39.9	41.9	41.0	46.4	-	-	-	-
2002	-	-	22.7	26.0	31.3	34.3	37.2	41.7	41.9	44.6	-	50.5	51.0	-	-
2003	7.0	-	21.0	24.4	29.5	33.2	35.7	38.1	38.8	42.2	43.9	43.0	45.0	52.0	51.0
2004	5.9	15.2	24.0	27.7	30.8	33.3	36.3	38.9	40.7	44.5	43.7	44.0	-	-	50.5
2005	6.0	16.2	24.0	30.0	32.1	34.1	37.1	40.1	41.9	45.6	46.0	-	-	41.0	-
2006	5.0	16.7	23.1	25.6	33.7	35.1	35.9	40.6	42.5	43.5	46.5	45.0	-	-	-
2007	-	16.1	22.8	28.3	31.8	34.4	36.9	39.5	44.6	44.4	-		52.0	-	-
2008	6.3	16.2	22.6	28.0	31.8	34.3	36.3	41.6	41.5	48.0	46.2	-	-	55.0	-
2009	6.6	16.7	22.7	27.2	32.7	34.9	38.9	41.7	42.4	44.3	52.0	47.1	-	-	-
2010	6.2	17.3	23.0	27.7	31.7	35.9	36.6	39.3	41.0	41.8	42.7	45.6	46.0	-	-
2011	6.8	15.6	23.6	28.3	31.8	35.4	36.7	38.9	42.6	42.9	43.6	51.5	44.9	-	-
2012	5.7	17.1	24.4	28.9	32.0	34.5	37.5	39.2	43.5	45.3	46.9	-	47.1	-	-
2013	6.5	16.7	26.1	29.2	32.4	34.6	38.2	38.5	43.3	44.4	43.0	-	-	-	-
2014	6.2	16.7	23.6	29.3	32.6	36.0	37.1	40.7	42.2	46.4	45.0	42.0	44.8	-	51.6
2015	6.5	17.9	23.9	27.0	32.3	34.9	37.9	40.0	43.2	45.6	44.6	-	-	-	49.0
TS mean	6.0	15.6	21.5	26.5	30.9	34.8	38.4	41.4	43.8	46.5	48.3	49.4	50.7	53.0	56.5

Table B33. The sum of the 1963-2015 Northeast Fisheries Science Center autumn mean number per tow of witch flounder weighted by stratum area, by stratum, the percentage of annual stratum sampling which produced no catch (% Zero Catch), and the percentage of stratum contribution (all years) to the total (%Total).

Stratum	Mean number per tow * by stratum area	% Zero Catch	%Total
1	1078.3	96.2%	0.0%
2	5587.6	76.9%	0.1%
3	1364.1	90.4%	0.0%
4	5938.8	59.6%	0.1%
5	0.0	100.0%	0.0%
6	79295.7	40.4%	1.9%
7	413.0	92.3%	0.0%
8	13438.2	55.8%	0.3%
9	2435.2	94.2%	0.1%
10	29912.1	57.7%	0.7%
11	1650.5	86.5%	0.0%
12	5534.7	69.2%	0.1%
13	31040.8	50.0%	0.8%
14	984.0	90.4%	0.0%
15	3675.3	63.5%	0.1%
16	4970.1	76.9%	0.1%
17	777.6	86.5%	0.0%
18	5981.0	51.9%	0.1%
19	0.0	100.0%	0.0%
20	407.0	96.2%	0.0%
21	11949.1	80.8%	0.3%
22	93676.4	3.8%	2.3%
23	17295.3	67.3%	0.4%
24	394334.1	1.9%	9.6%
25	241.4	96.2%	0.0%
26	199469.1	5.8%	4.8%
27	193586.7	0.0%	4.7%
28	143283.3	5.8%	3.5%
29	142583.1	1.9%	3.5%
30	19641.4	38.5%	0.5%
36	421570.3	0.0%	10.2%
37	508560.2	0.0%	12.3%
38	1399696.1	0.0%	34.0%
39	174334.9	1.9%	4.2%
40	179513.0	3.8%	4.4%
61	0.0	100.0%	0.0%
62	0.0	100.0%	0.0%
63	473.0	96.2%	0.0%
64	2122.2	84.6%	0.1%
65	0.0	100.0%	0.0%
66	0.0	100.0%	0.0%
67	43.0	98.1%	0.0%
68	1745.0	57.7%	0.0%
69	405.5	98.1%	0.0%
70	251.5	94.2%	0.0%
71	226.8	94.2%	0.0%
72	15869.9	53.8%	0.4%
73	0.0	100.0%	0.0%
74	1112.6	90.4%	0.0%
75	97.9	94.2%	0.0%
76	2156.4	63.5%	0.1%
Total	4118722.2		100%

set 1: 22-30,36-40	**94.4%**
set 2: 22,24,26-30,36-40	94.0%

Table B34. Stratified mean number, weight (kg), length (cm), and individual weight (kg) per tow of witch flounder in Massachusetts Division of Marine Fisheries inshore spring and autumn trawl surveys in the Cape Cod Bay and Mass. Bay region (Regions 4 and 5), 1978-2016. Time series mean is also given.

	SPRING						AUTUMN					
Year	Number per tow	CV	Weight per tow	CV	Length per tow	Avg. wt. per tow	Number per tow	CV	Weight per tow	CV	Length per tow	Avg. wt. per tow
1978	2.15	26.8	1.52	25.3	44.7	0.704	1.38	18.8	1.26	24.5	46.4	0.908
1979	1.26	25.4	1.32	31.0	48.3	1.046	1.52	48.8	1.08	45.6	42.9	0.708
1980	1.00	37.3	0.93	38.1	44.0	0.932	1.15	32.1	1.12	34.9	46.5	0.966
1981	2.44	36.7	1.83	44.7	40.2	0.747	0.40	71.7	0.23	67.9	41.2	0.589
1982	0.65	39.0	0.47	45.3	44.2	0.728	1.24	55.5	0.64	31.7	37.7	0.511
1983	1.97	34.4	1.02	21.3	36.8	0.519	2.22	30.3	1.46	28.7	44.6	0.658
1984	1.18	27.9	0.76	27.7	40.8	0.645	0.55	34.2	0.37	30.8	43.6	0.674
1985	1.01	21.9	0.73	23.4	43.4	0.720	0.76	44.7	0.50	40.1	43.6	0.655
1986	0.70	18.1	0.65	23.5	47.6	0.934	0.27	31.0	0.24	34.5	46.4	0.893
1987	0.88	42.5	0.73	36.8	45.1	0.821	0.19	34.1	0.13	35.8	44.6	0.713
1988	0.24	21.1	0.20	24.4	45.6	0.844	0.28	57.4	0.16	64.2	39.5	0.579
1989	0.13	40.8	0.05	42.7	34.9	0.369	0.13	49.1	0.06	45.3	38.1	0.491
1990	0.21	63.9	0.17	64.4	44.2	0.809	0.07	51.7	0.03	62.5	36.8	0.436
1991	0.11	52.2	0.04	67.9	34.1	0.393	0.32	34.7	0.19	35.6	41.1	0.604
1992	0.20	52.1	0.12	64.2	40.2	0.583	0.46	41.1	0.25	45.4	40.7	0.557
1993	0.03	82.9	0.01	82.9	33.0	0.200	0.30	40.0	0.15	45.1	40.9	0.500
1994	0.00		0.00				0.38	33.7	0.12	45.9	31.0	0.321
1995	0.10	29.5	0.06	53.9	36.0	0.613	2.41	56.6	0.41	39.5	26.7	0.172
1996	0.02	73.3	0.00	73.3	21.0	0.100	0.04	56.0	0.01	56.0	40.0	0.400
1997	0.05	0.0	0.01	70.3	31.5	0.250	0.51	59.9	0.15	64.1	36.0	0.300
1998	0.00		0.00				0.25	43.0	0.08	40.1	35.2	0.332
1999	0.02	80.4	0.00		11.0	0.000	0.67	34.3	0.17	40.4	33.7	0.251
2000	1.15	25.1	0.10	31.8	23.5	0.089	0.92	27.4	0.24	39.7	31.6	0.266
2001	0.07	41.1	0.02	56.9	33.0	0.250	0.43	20.7	0.12	29.9	33.2	0.275
2002	0.11	42.3	0.03	44.9	33.4	0.253	2.21	18.0	0.70	17.6	36.5	0.317
2003	0.19	11.4	0.04	19.2	30.2	0.217	1.19	26.3	0.53	27.2	39.8	0.445
2004	0.00		0.00	0.0		0.000	0.31	37.1	0.13	40.5	40.5	0.432
2005	0.05	51.7	0.03	54.2	45.5	0.675	0.51	28.2	0.19	28.1	37.8	0.369
2006	0.16	38.9	0.08	44.0	40.9	0.500	0.37	26.6	0.10	21.1	33.0	0.265
2007	0.46	37.5	0.13	43.8	34.6	0.286	0.51	35.0	0.15	28.9	36.8	0.295
2008	0.26	31.7	0.09	41.6	36.6	0.348	1.34	32.5	0.40	27.0	35.2	0.301
2009	0.44	48.0	0.08	43.2	31.1	0.185	1.27	25.5	0.40	40.1	33.4	0.311
2010	0.15	29.0	0.05	33.2	36.9	0.327	1.42	30.4	0.46	30.7	36.1	0.325
2011	0.35	55.0	0.12	53.5	34.9	0.348	3.51	24.9	0.97	25.7	35.1	0.277
2012	0.23	30.9	0.08	39.7	35.5	0.34	0.66	23.9	0.27	26.0	39.2	0.410
2013	0.08	37.2	0.04	38.0	40.7	0.442	0.54	31.0	0.16	38.5	37.0	0.288
2014	0.04	55.7	0.01	59.4	30.5	0.168	0.44	47.0	0.09	38.8	31.7	0.199
2015	0.10	69.1	0.00	69.1	22.5	0.047	1.35	35.91	0.40	34.8	35.3	0.297
2016	0.40	33.4	0.14	36.2	37.7	0.340						
TS mean	0.48	40.1	0.30	43.6	36.5	0.5	0.85	37.6	0.37	38.2	38.1	0.455

Table B35. Number of witch flounder caught, aged and percentage of sampled fish in the Massachusetts Division of Marine Fisheries inshore survey, spring and fall, 1978- 2015 for Regions 4 and 5 (strata 09250 – 09360;).

	Spring				Autumn			
Year	Caught	Aged	%sampled	max age	Caught	Aged	% sampled	max age
1978	73		0		72		0	
1979	66		0		87		0	
1980	57		0		70		0	
1981	132		0		24		0	
1982	38		0		89		0	
1983	102		0		110		0	
1984	71	25	35	14	23	12	52	21
1985	41	8	20	11	50	16	32	14
1986	28	2	7	10	15		0	
1987	50	2	4	8	10	2	20	10
1988	11		0		9		0	
1989	8		0		8		0	
1990	10	1	10	9	4	2	50	10
1991	9		0		21		0	
1992	8	6	75	7	23	13	57	14
1993	2		0		16		0	
1994					25		0	
1995	4		0		101		0	
1996	1		0		2		0	
1997	2		0		12		0	
1998					12		0	
1999	1		0		50		0	
2000	48		0		52		0	
2001	4		0		26		0	
2002	5		0		98		0	
2003	8		0		61		0	
2004					17		0	
2005	2		0		25		0	
2006	8		0		16		0	
2007	24		0		29		0	
2008	11		0		53		0	
2009	19		0		59		0	
2010	8		0		75		0	
2011	15		0		171		0	
2012	10		0		31		0	
2013	4		0		27		0	
2014	2		0		18		0	
2015	4		0		43		0	
2016	17		0					

Table B36. Stratified mean number, weight (kg), length (cm), and individual weight (kg) per tow of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp surveys in the Gulf of Maine (strata set 1, 3, 6, 8), 1984 - 2015. Time series means are also given.

Year	Number per tow	CV	Weight per tow	CV	Length per tow	Avg. wt. per tow
1984	25.30	10.5	8.12	8.8	33.9	0.341
1985	6.69	16.0	2.66	13.5	36.0	0.408
1986	2.63	20.8	0.92	24.1	35.9	0.362
1987	5.19	26.3	1.56	25.2	26.5	0.307
1988	2.58	22.7	0.61	24.7	25.8	0.238
1989	2.92	30.0	0.31	27.1	22.8	0.105
1990	6.66	26.0	1.02	32.3	24.5	0.154
1991	14.94	31.4	1.20	27.1	19.6	0.080
1992	24.28	41.1	1.91	29.8	20.5	0.079
1993	21.42	25.5	0.50	17.0	12.8	0.023
1994	36.36	38.6	2.20	59.1	19.1	0.061
1995	17.95	34.4	1.48	37.1	22.6	0.082
1996	15.45	19.6	1.95	25.6	25.2	0.126
1997	23.19	40.8	1.42	21.0	19.1	0.061
1998	7.35	21.5	0.52	18.3	21.9	0.071
1999	110.07	21.8	5.93	21.1	18.7	0.054
2000	32.43	23.2	3.09	25.1	24.2	0.095
2001	41.52	31.3	5.57	32.2	27.2	0.134
2002	45.25	23.7	7.05	23.3	28.8	0.156
2003	24.06	20.9	4.46	19.8	30.6	0.185
2004	8.75	23.5	1.79	23.4	31.3	0.205
2005	19.77	21.9	2.00	25.4	21.6	0.101
2006	29.98	18.6	2.72	18.3	22.6	0.091
2007	23.10	20.1	2.49	21.4	25.1	0.108
2008	15.19	19.5	2.02	18.0	27.2	0.133
2009	23.21	22.7	3.88	35.9	27.1	0.167
2010	18.13	17.2	1.79	17.2	23.2	0.099
2011	18.29	14.2	2.14	17.2	25.8	0.117
2012	18.62	20.2	2.16	26.7	25.3	0.116
2013	14.59	12.5	1.69	16.8	23.5	0.116
2014	38.27	20.7	2.29	19.2	18.9	0.060
2015	32.33	15.0	3.80	19.1	25.5	0.117
Mean	22.39	23.8	2.50	24.3	24.74	0.14

Table B37. Stratified mean number per tow at age of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp surveys in the Gulf of Maine (strata set 1, 3, 6, 8), 1984 - 2015. NEFSC spring and autumn age length keys used.

	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
1984	0.00	0.33	1.09	2.61	10.15	5.31	1.82	0.91	0.96	0.76	0.40	0.99	25.3
1985	0.00	0.16	0.00	0.30	1.71	2.00	1.16	0.45	0.33	0.19	0.09	0.29	6.7
1986	0.00	0.10	0.08	0.03	0.58	0.43	0.73	0.46	0.12	0.02	0.01	0.07	2.6
1987	0.00	1.94	0.46	0.31	0.65	0.24	0.48	0.49	0.21	0.11	0.07	0.23	5.2
1988	0.17	0.17	0.19	1.35	0.20	0.07	0.05	0.10	0.11	0.06	0.04	0.08	2.6
1989	0.00	0.73	0.43	0.64	0.87	0.11	0.01	0.02	0.05	0.04	0.00	0.02	2.9
1990	0.05	1.95	0.62	1.27	1.66	0.88	0.09	0.01	0.02	0.03	0.03	0.05	6.7
1991	0.03	6.80	0.45	5.89	1.24	0.16	0.06	0.03	0.04	0.07	0.10	0.04	14.9
1992	0.00	8.86	4.91	7.55	2.65	0.05	0.12	0.05	0.00	0.00	0.00	0.07	24.3
1993	0.19	18.94	0.79	0.51	0.69	0.15	0.04	0.04	0.04	0.00	0.00	0.02	21.4
1994	0.04	14.51	8.40	6.54	4.14	2.36	0.22	0.07	0.00	0.00	0.00	0.00	36.3
1995	0.02	2.55	4.90	7.45	2.05	0.57	0.29	0.11	0.02	0.00	0.00	0.00	18.0
1996	0.00	2.97	1.28	3.58	4.23	2.29	0.77	0.25	0.02	0.02	0.00	0.03	15.4
1997	0.00	14.38	4.87	0.32	1.86	1.18	0.39	0.12	0.05	0.00	0.00	0.00	23.2
1998	0.00	1.15	3.15	2.28	0.36	0.23	0.16	0.01	0.00	0.00	0.00	0.00	7.3
1999	0.00	32.47	24.55	32.25	15.30	4.07	0.88	0.33	0.22	0.00	0.00	0.00	110.1
2000	0.00	3.66	6.61	12.45	5.45	2.53	0.94	0.55	0.13	0.03	0.00	0.00	32.4
2001	0.00	1.45	4.03	10.09	16.77	5.98	1.45	0.95	0.46	0.17	0.08	0.08	41.5
2002	0.00	0.77	3.94	9.23	16.65	8.91	2.90	1.81	0.59	0.32	0.05	0.09	45.2
2003	0.00	0.72	0.36	2.04	7.14	7.34	3.63	1.49	0.72	0.31	0.14	0.14	24.1
2004	0.00	0.37	0.63	0.44	1.86	2.07	1.71	1.01	0.40	0.13	0.07	0.04	8.7
2005	0.00	9.98	1.88	0.99	1.60	2.29	1.88	0.81	0.22	0.08	0.04	0.02	19.8
2006	0.00	5.58	13.49	4.59	1.29	1.50	1.68	1.17	0.51	0.15	0.06	0.03	30.0
2007	0.00	1.85	6.19	10.42	1.87	1.09	0.65	0.76	0.23	0.05	0.02	0.00	23.1
2008	0.05	0.84	2.60	3.62	5.64	0.97	0.56	0.43	0.32	0.15	0.03	0.02	15.2
2009	0.02	5.59	2.41	2.74	3.74	4.32	1.53	1.37	0.93	0.37	0.14	0.07	23.2
2010	0.00	4.68	5.62	2.45	1.36	1.56	1.56	0.36	0.31	0.16	0.07	0.02	18.1
2011	0.00	1.23	6.05	6.18	1.72	1.01	1.01	0.49	0.35	0.15	0.09	0.04	18.3
2012	0.00	3.35	4.19	4.95	2.49	1.06	1.15	0.86	0.41	0.11	0.04	0.00	18.6
2013	0.25	4.16	4.36	1.59	2.12	0.82	0.47	0.45	0.22	0.12	0.06	0.01	14.6
2014	0.04	21.16	8.69	4.59	1.22	1.11	0.54	0.42	0.31	0.08	0.04	0.04	38.2
2015	0.10	1.75	11.51	12.19	2.20	1.03	1.58	0.91	0.74	0.26	0.03	0.00	32.3

Table B38. Stratified mean weight (kg) per tow of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey in the Gulf of Maine, strata 1, 3, 6, 8), 1984 - 2015.

Summer	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
1984		0.028	0.048	0.129	0.178	0.268	0.397	0.532	0.706	0.831	0.953	1.389	0.313
1985		0.010		0.066	0.188	0.269	0.377	0.532	0.708	0.838	0.935	2.167	0.398
1986		0.008	0.046	0.086	0.142	0.293	0.431	0.508	0.594	0.818	1.086	1.228	0.361
1987		0.007	0.031	0.059	0.156	0.267	0.439	0.552	0.690	0.894	1.066	1.421	0.258
1988		0.006	0.039	0.072	0.197	0.265	0.407	0.585	0.738	0.904	1.014	1.287	0.198
1989		0.011	0.010	0.061	0.158	0.265	0.447	0.567	0.806	0.872	0.831	1.530	0.116
1990	0.001	0.009	0.048	0.099	0.189	0.254	0.379	0.528	0.670	1.027	1.194	1.395	0.135
1991		0.008	0.060	0.080	0.132	0.292	0.381	0.611	0.800	0.913	1.056	1.150	0.072
1992		0.010	0.063	0.085	0.160	0.308	0.275	0.575	0.599	0.726	0.900	1.651	0.069
1993	0.002	0.006	0.048	0.115	0.182	0.270	0.466	0.565	0.693	0.821	1.058	1.155	0.022
1994	0.001	0.009	0.030	0.058	0.166	0.252	0.390	0.563	0.580	0.577	0.608		0.060
1995	0.002	0.009	0.050	0.076	0.131	0.274	0.410	0.556	0.657	0.657	0.657		0.081
1996		0.009	0.037	0.076	0.144	0.236	0.363	0.491	0.646	1.148	1.150	1.397	0.129
1997		0.013	0.064	0.121	0.180	0.232	0.305	0.511	0.654	0.631	0.709	0.657	0.059
1998		0.013	0.048	0.081	0.146	0.244	0.293	0.289	0.334				0.069
1999	0.001	0.010	0.050	0.088	0.151	0.232	0.325	0.497	0.641	0.685	0.657	1.232	0.075
2000		0.012	0.058	0.070	0.138	0.211	0.292	0.329	0.449	0.568	0.619	0.581	0.097
2001		0.007	0.030	0.094	0.134	0.211	0.306	0.421	0.464	0.514	0.533	0.407	0.140
2002		0.009	0.061	0.072	0.149	0.223	0.300	0.385	0.543	0.651	0.767	0.749	0.167
2003		0.010	0.033	0.069	0.126	0.212	0.277	0.363	0.471	0.514	0.550	0.972	0.203
2004		0.010	0.045	0.081	0.143	0.217	0.291	0.365	0.434	0.473	0.503	0.790	0.224
2005		0.010	0.053	0.067	0.168	0.232	0.297	0.388	0.517	0.582	0.654	0.699	0.108
2006		0.010	0.044	0.072	0.176	0.238	0.288	0.419	0.511	0.587	0.579	0.672	0.097
2007		0.009	0.044	0.105	0.181	0.205	0.338	0.423	0.497	0.579	0.595	0.624	0.114
2008	0.002	0.008	0.050	0.100	0.153	0.226	0.286	0.422	0.498	0.523	0.555	0.775	0.144
2009	0.002	0.012	0.050	0.103	0.192	0.254	0.334	0.384	0.469	0.611	0.661	0.907	0.178
2010		0.013	0.048	0.092	0.168	0.221	0.265	0.371	0.432	0.531	0.573	0.583	0.107
2011		0.017	0.060	0.097	0.155	0.213	0.311	0.431	0.542	0.584	0.611	0.676	0.128
2012		0.018	0.045	0.111	0.165	0.253	0.305	0.388	0.471	0.537	0.611	0.680	0.131
2013	0.001	0.017	0.068	0.094	0.163	0.245	0.306	0.394	0.513	0.637	0.699	0.819	0.111
2014	0.002	0.014	0.040	0.116	0.182	0.267	0.321	0.446	0.550	0.680	0.781	0.885	0.061
2015	0.005	0.028	0.062	0.083	0.157	0.260	0.335	0.438	0.525	0.592	0.613	0.461	0.120
TS mean	0.002	0.012	0.047	0.087	0.161	0.247	0.342	0.463	0.575	0.694	0.767	0.998	0.142

Table B39. Stratified mean length (cm) per tow of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey in the Gulf of Maine, strata 1, 3, 6, 8), 1984 - 2015.

Summer	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
1984		18.0	20.9	27.7	30.5	34.4	38.7	42.3	45.8	48.1	50.0	55.5	33.9
1985		13.4		22.8	31.0	34.5	38.1	42.1	45.9	48.2	49.8	60.8	36.0
1986		12.3	20.3	25.0	28.7	35.4	39.7	41.7	43.6	47.8	51.9	53.9	35.8
1987		12.1	18.4	22.3	29.4	34.4	39.9	42.7	45.5	49.1	51.7	56.0	26.5
1988	5.1	11.2	19.6	23.6	31.5	34.5	38.9	43.3	46.4	49.2	51.0	54.5	26.0
1989		13.7	13.2	22.6	29.7	34.5	40.2	43.0	47.6	48.8	48.1	57.4	22.8
1990	7.0	12.8	20.9	25.7	31.0	33.9	38.2	42.0	45.2	51.0	53.1	55.9	24.5
1991	3.0	12.3	22.3	24.2	27.7	35.4	38.0	43.9	47.5	49.4	51.5	52.8	19.7
1992		13.0	22.2	24.2	29.5	35.8	33.9	43.2	43.8	45.7	48.8	58.7	20.5
1993	7.8	11.1	21.0	26.6	30.7	34.6	40.5	43.0	45.6	48.0	51.6	53.0	12.8
1994	7.0	12.5	17.9	22.0	30.0	33.9	38.5	43.0	43.4	43.3	44.0		19.1
1995	8.0	12.2	21.0	23.7	27.9	34.7	39.1	42.8	45.0	45.0	45.0		22.5
1996		12.8	19.4	23.8	28.8	33.3	37.7	41.2	44.7	52.4	52.4	56.0	25.2
1997		14.3	22.7	27.5	30.7	33.1	35.8	41.6	44.9	44.5	46.0	45.0	19.1
1998		14.3	20.6	24.3	29.0	33.6	35.5	35.3	37.0				21.9
1999	7.0	12.8	21.1	24.9	29.2	33.1	36.6	41.2	44.5	45.5	45.0	54.0	21.5
2000		14.1	22.1	23.2	28.2	32.2	35.5	36.5	40.0	43.0	44.2	43.3	24.2
2001		11.5	17.2	25.3	28.2	32.2	35.9	39.4	40.5	41.7	42.3	38.5	27.2
2002		13.0	22.4	23.2	28.9	32.7	35.6	38.3	42.3	44.6	47.0	46.7	28.8
2003		13.0	18.6	23.1	27.6	32.2	34.9	37.6	40.7	41.7	42.3	49.6	30.6
2004		13.1	20.6	24.0	28.6	32.3	35.4	37.8	39.8	40.7	41.2	46.8	31.3
2005		12.8	21.4	22.7	30.1	33.1	35.6	38.4	41.8	43.3	44.8	45.7	21.6
2006		12.7	20.3	23.5	30.3	33.3	35.2	39.2	41.6	43.3	43.1	45.1	22.6
2007		12.8	20.1	26.3	30.8	31.4	37.0	39.5	41.4	43.3	43.6	44.3	25.1
2008	8.5	12.2	21.2	25.7	29.3	32.9	35.0	39.3	41.3	41.7	42.3	47.2	27.2
2009	8.0	13.0	20.9	26.0	31.2	33.9	36.8	38.3	40.4	43.8	44.5	48.6	27.1
2010		13.8	20.3	24.9	30.0	32.5	34.1	37.9	39.6	42.2	43.2	43.2	23.2
2011		15.0	21.9	25.3	29.4	32.2	35.8	39.5	42.4	43.2	43.8	45.1	25.8
2012		15.2	19.4	26.5	29.8	33.9	35.8	38.5	40.7	42.2	44.0	45.4	25.3
2013	5.5	14.7	23.0	25.2	29.4	33.6	35.8	38.5	41.7	44.4	45.6	48.0	23.5
2014	8.2	14.2	19.4	26.8	30.8	34.4	36.3	40.0	42.6	45.2	47.0	48.7	18.9
2015	10.9	17.5	22.3	24.5	29.2	34.1	36.9	39.8	41.9	43.6	44.1	40.6	25.5
TS mean	7.2	13.3	20.4	24.6	29.6	33.6	36.9	40.3	43.0	45.3	46.5	49.7	24.9

Table B40. Stratified mean catch (in numbers and weight [kg]) per tow and associated standard error of witch flounder in the Maine-New Hampshire inshore trawl survey (strata set 1-4; regions 1-5), spring and fall, 2000 - 2015. Indices for 2000-2002 were re-stratified; fixed stations are excluded.

	SPRING				FALL			
Year	Number per tow	SE	Weight per tow	SE	Number per tow	SE	Weight per tow	SE
2000					3.89	0.56	0.22	0.03
2001	6.96	1.84	0.12	0.03	56.58	4.67	4.18	0.34
2002	4.58	0.86	0.41	0.15	6.29	0.93	0.65	0.13
2003	2.32	0.72	0.24	0.07	7.45	1.16	0.92	0.19
2004	1.42	0.21	0.10	0.02	11.73	1.94	1.41	0.20
2005	8.37	1.33	0.37	0.09	26.20	3.55	0.86	0.10
2006	5.17	1.11	0.24	0.06	12.83	1.37	0.83	0.07
2007	4.37	0.67	0.29	0.04	14.41	2.04	1.47	0.30
2008	4.25	0.60	0.38	0.08	14.78	1.79	1.31	0.23
2009	4.15	0.68	0.23	0.06	10.48	1.08	0.57	0.07
2010	5.17	0.91	0.31	0.06	16.22	1.74	0.81	0.10
2011	5.20	0.63	0.25	0.04	9.79	1.23	0.77	0.12
2012	6.41	1.11	0.36	0.07	3.26	0.40	0.20	0.04
2013	1.54	0.32	0.16	0.04	2.43	0.37	0.18	0.04
2014	28.59	3.45	0.41	0.05	15.62	1.67	0.48	0.05
2015	4.66	0.44	0.18	0.04	13.95	2.38	0.92	0.17
mean	6.21		0.27		14.12		0.99	

Survey indices have been provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016. Annual reports and survey procedures and protocols of the Maine-New Hampshire Inshore Trawl Survey are available online at http://www.maine.gov/dmr/rm/trawl/reports/index.htm

Table B41. Stratified mean number per tow at age of witch flounder in the Maine-New Hampshire inshore trawl survey (strata set 1-4; regions 1-5), spring and fall, 2000 - 2015. Indices for 2000-2002 were re-stratified; fixed stations are excluded. Annual, season-specific Northeast Fisheries Science Center age/length keys used.

SPRING	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
2000													
2001	0.000	4.003	2.611	0.223	0.077	0.000	0.007	0.000	0.014	0.014	0.014	0.000	6.96
2002	0.000	1.073	0.206	1.233	0.995	0.628	0.257	0.174	0.009	0.005	0.005	0.005	4.59
2003	0.000	0.364	0.072	0.410	0.786	0.475	0.127	0.067	0.019	0.000	0.000	0.000	2.32
2004	0.000	0.692	0.231	0.131	0.131	0.118	0.056	0.031	0.013	0.004	0.006	0.011	1.42
2005	0.000	5.246	1.615	0.636	0.117	0.226	0.268	0.117	0.050	0.059	0.033	0.000	8.37
2006	0.000	1.117	2.901	0.703	0.212	0.052	0.062	0.047	0.041	0.021	0.000	0.010	5.17
2007	0.000	1.149	1.560	1.250	0.118	0.083	0.017	0.079	0.035	0.044	0.000	0.031	4.37
2008	0.000	0.917	1.499	0.488	0.675	0.204	0.102	0.221	0.132	0.000	0.000	0.008	4.25
2009	0.000	1.839	1.295	0.452	0.232	0.203	0.037	0.017	0.037	0.025	0.012	0.000	4.15
2010	0.000	1.959	1.581	0.863	0.217	0.264	0.207	0.041	0.010	0.010	0.005	0.005	5.16
2011	0.000	0.608	2.801	1.346	0.146	0.104	0.114	0.047	0.016	0.010	0.005	0.000	5.20
2012	0.000	0.853	3.046	1.738	0.507	0.090	0.083	0.038	0.032	0.013	0.006	0.000	6.41
2013	0.000	0.315	0.498	0.216	0.245	0.089	0.048	0.085	0.022	0.015	0.002	0.011	1.55
2014	0.000	25.274	2.459	0.572	0.114	0.114	0.057	0.029	0.029	0.000	0.000	0.000	28.65
2015	0.000	0.903	2.379	1.220	0.084	0.019	0.028	0.014	0.014	0.000	0.000	0.000	4.66

FALL	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
2000	0.000	0.941	2.276	0.607	0.051	0.008	0.004	0.004	0.000	0.000	0.000	0.000	3.89
2001	0.000	11.373	26.255	6.620	8.261	2.263	1.018	0.622	0.113	0.057	0.000	0.000	56.58
2002	0.000	0.836	1.151	1.182	2.276	0.711	0.132	0.000	0.000	0.000	0.000	0.000	6.29
2003	0.000	1.415	0.208	0.640	1.899	1.631	1.005	0.275	0.127	0.171	0.045	0.045	7.46
2004	0.141	4.551	1.021	1.349	1.150	2.041	0.915	0.270	0.164	0.059	0.023	0.035	11.72
2005	0.000	23.445	2.069	0.210	0.052	0.079	0.105	0.210	0.026	0.000	0.000	0.026	26.22
2006	0.000	5.196	4.709	2.194	0.141	0.154	0.218	0.167	0.013	0.038	0.000	0.000	12.83
2007	0.000	2.940	3.084	5.736	1.225	0.562	0.461	0.303	0.029	0.014	0.000	0.043	14.40
2008	0.015	4.951	3.532	2.956	1.966	0.384	0.502	0.133	0.296	0.015	0.015	0.000	14.76
2009	0.031	7.523	1.310	0.650	0.492	0.346	0.052	0.031	0.021	0.010	0.000	0.000	10.47
2010	0.065	11.291	3.115	0.681	0.389	0.211	0.341	0.032	0.049	0.016	0.000	0.016	16.21
2011	0.029	2.321	4.632	1.939	0.304	0.196	0.255	0.059	0.020	0.010	0.010	0.010	9.78
2012	0.000	2.165	0.589	0.332	0.049	0.023	0.055	0.029	0.010	0.000	0.000	0.000	3.25
2013	0.029	1.208	0.760	0.170	0.168	0.051	0.012	0.017	0.005	0.007	0.002	0.000	2.43
2014	0.016	13.795	1.578	0.203	0.016	0.016	0.000	0.016	0.000	0.000	0.000	0.000	15.64
2015	0.070	3.585	7.031	2.985	0.140	0.042	0.070	0.014	0.000	0.000	0.000	0.000	13.94

Table B42. Stratified mean weight per tow at age of witch flounder in the Maine-New Hampshire inshore trawl survey in the Gulf of Maine (strata set 1-4; regions 1-5), spring and fall, 2000 - 2015. Indices for 2000-2002 were re-stratified; fixed stations are excluded. Northeast Fisheries Science Center seasonal age/length keys used.

Spring	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
2000													
2001		0.005	0.008	0.051	0.105	0.128	0.367	0.367	0.657	0.657	0.608		0.013
2002		0.006	0.022	0.042	0.132	0.216	0.281	0.337	0.467	0.518	0.518	0.518	0.102
2003		0.012	0.047	0.053	0.104	0.176	0.269	0.331	0.437				0.112
2004		0.004	0.046	0.053	0.125	0.162	0.231	0.337	0.438	0.472	0.489	0.505	0.067
2005		0.006	0.029	0.057	0.122	0.219	0.279	0.353	0.452	0.548	0.654		0.044
2006		0.005	0.033	0.062	0.123	0.187	0.267	0.343	0.475	0.562	0.367	0.763	0.049
2007		0.007	0.038	0.087	0.162	0.22	0.294	0.395	0.555	0.617		0.862	0.074
2008		0.004	0.03	0.077	0.14	0.22	0.284	0.364	0.436			0.608	0.094
2009		0.004	0.036	0.073	0.153	0.213	0.302	0.382	0.496	0.545	0.571		0.054
2010		0.005	0.036	0.067	0.134	0.212	0.271	0.328	0.429	0.595	0.693	0.578	0.058
2011		0.005	0.024	0.056	0.14	0.213	0.289	0.356	0.383	0.38	0.418		0.048
2012		0.007	0.027	0.071	0.131	0.199	0.256	0.374	0.443	0.501	0.512	0.562	0.056
2013		0.009	0.048	0.096	0.15	0.213	0.276	0.355	0.448	0.542	0.476	0.821	0.112
2014		0.007	0.023	0.103	0.166	0.252	0.325	0.388	0.517	0.657			0.013
2015		0.005	0.031	0.053	0.109	0.23	0.294	0.384	0.418	0.46			0.038
TS mean		0.006	0.032	0.067	0.133	0.204	0.286	0.360	0.470	0.543	0.531	0.652	0.062

Fall	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
2000		0.019	0.044	0.084	0.141	0.212	0.334	0.334					0.046
2001		0.013	0.026	0.108	0.15	0.228	0.331	0.406	0.474	0.46	0.562		0.07
2002		0.021	0.055	0.092	0.159	0.213	0.287	0.367	0.367				0.118
2003		0.017	0.047	0.075	0.141	0.215	0.269	0.359	0.403	0.517	0.613	0.637	0.169
2004	0.001	0.017	0.056	0.114	0.177	0.222	0.301	0.392	0.465	0.604	0.438	0.567	0.125
2005		0.02	0.061	0.173	0.207	0.261	0.312	0.471	0.476			0.476	0.031
2006		0.019	0.06	0.105	0.192	0.22	0.296	0.42	0.448	0.51			0.065
2007		0.02	0.058	0.114	0.209	0.209	0.334	0.392	0.547	0.518		0.858	0.111
2008		0.018	0.051	0.108	0.186	0.255	0.268	0.395	0.501	0.821	0.778		0.095
2009	0.001	0.025	0.047	0.107	0.199	0.241	0.351	0.465	0.52	0.605		0.562	0.053
2010	0.001	0.023	0.06	0.107	0.188	0.284	0.241	0.349	0.434	0.474	0.476	0.725	0.049
2011	0.001	0.024	0.059	0.1	0.206	0.264	0.3	0.371	0.556	0.44	0.575	0.681	0.078
2012		0.027	0.068	0.113	0.202	0.3	0.374	0.438	0.496	0.367			0.06
2013	0.001	0.023	0.089	0.111	0.182	0.27	0.411	0.37	0.493	0.562	0.562		0.074
2014	0.001	0.024	0.044	0.065	0.208	0.373	0.354	0.485	0.483	0.518		0.518	0.027
2015	0.001	0.025	0.068	0.093	0.18	0.283	0.351	0.394	0.398				0.066
TS mean	0.001	0.021	0.056	0.104	0.183	0.253	0.320	0.401	0.471	0.533	0.572	0.628	0.077

Table B43. Stratified mean length (cm) per tow at age of witch flounder in the Maine-New Hampshire inshore trawl surveys in the Gulf of Maine (strata set 1-4; regions 1-5), spring and fall, 2000 - 2015. Indices for 2000-2002 were re-stratified; fixed stations are excluded. Northeast Fisheries Science Center seasonal age/length keys used.

Spring	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
2000													
2001		10.6	12.6	21.2	26.3	28.0	38.0	38.0	45.0	45.0	44.0		12.1
2002		11.4	16.7	20.0	28.0	32.4	35.1	37.0	40.7	42.0	42.0	42.0	22.9
2003		12.9	21.0	21.2	26.2	30.2	34.6	36.7	39.9				24.8
2004		10.5	20.7	21.3	27.6	29.7	33.2	36.8	40.0	40.8	41.3	41.7	18.5
2005		11.0	18.1	21.8	27.6	32.7	35.0	37.5	40.3	42.6	44.9		15.7
2006		10.8	18.8	22.6	27.6	31.2	34.5	37.2	40.8	42.8	38.0	47.0	18.8
2007		11.6	19.6	24.9	29.9	32.7	35.6	38.6	42.7	44.2		48.7	20.6
2008		10.4	18.2	23.9	28.6	32.7	35.2	37.9	39.9			44.0	21.7
2009		10.4	19.1	23.6	29.1	32.3	35.7	38.3	41.1	42.5	43.0		17.6
2010		10.8	18.8	23.0	28.0	32.1	34.6	36.6	39.5	43.5	45.7	43.0	18.5
2011		10.5	16.5	21.7	28.5	32.2	35.2	37.5	38.4	38.3	39.4	0.0	18.5
2012		11.8	17.0	23.3	28.0	31.6	34.0	38.0	40.0	41.5	41.8	43.0	19.6
2013		12.7	20.7	25.6	29.0	32.2	34.9	37.5	40.2	42.5	41.0	48.0	23.8
2014		11.7	16.5	25.9	30.0	33.9	36.5	38.6	41.7	45.0			12.7
2015		11.1	18.1	21.4	26.0	32.9	35.5	38.3	39.3	40.6			18.0
TS mean		11.2	18.2	22.8	28.0	31.8	35.2	37.6	40.6	42.4	42.1	39.7	18.9

Fall	Age												
Year	0	1	2	3	4	5	6	7	8	9	10	11+	Total
2000		15.9	20.3	24.8	28.7	32.1	37.0	37.0					20.1
2001		14.2	17.4	26.5	29.1	33.0	36.7	39.0	40.9	40.6	43.0		20.8
2002		16.2	21.7	25.0	29.6	32.3	35.3	38.0	38.0				25.9
2003		15.4	20.9	23.9	28.6	32.3	34.6	37.6	39.0	41.9	44.0	44.6	28.1
2004	6.4	15.3	21.9	27.0	30.7	32.8	35.9	38.7	40.6	43.9	40.0	43.0	24.4
2005		16.1	22.3	30.6	32.1	34.3	36.2	40.8	41.0			41.0	17.1
2006		15.7	22.3	26.2	31.5	32.6	35.5	39.4	40.3	41.8			21.0
2007		16.1	22.0	26.9	32.2	31.5	36.9	38.7	42.7	42.0		48.0	25.0
2008	5.0	15.6	21.2	26.4	31.0	34.2	34.3	38.7	41.5	48.0	47.2		23.1
2009	6.7	17.1	20.5	26.3	31.6	33.4	37.2	40.5	41.8	43.9		43.0	19.6
2010	7.0	16.8	22.2	26.3	31.1	35.1	32.7	37.2	39.7	40.8	41.0	46.3	19.3
2011	6.7	17.0	22.0	25.3	31.9	34.4	35.6	38.0	42.8	40.0	42.8	45.3	22.5
2012		17.8	23.0	26.7	31.7	35.6	38.1	39.9	41.4	38.0			20.6
2013	7.0	16.9	25.1	26.5	30.4	34.6	39.0	37.8	41.3	43.0	43.0		21.7
2014	7.0	17.0	20.4	22.6	32.0	37.8	37.4	41.2	41.1	42.0		42.0	17.4
2015	7.5	17.2	23.1	25.4	30.7	35.2	37.4	38.7	38.8				22.2
TS mean	6.7	16.3	21.6	26.0	30.8	33.8	36.2	38.8	40.7	42.1	43.0	44.1	21.8

Table B44. Trends in landings (lbs) for trips in which witch flounder comprise at least 40% or more of the total trip landings, number of trips, days fished, days fished per trip, LPUE of the 40% trips (nominal and scaled), 1969-2015.

Year	Trips 40 Landed Lbs	Trips	Days Fished	DF/Trip	Nominal 40% LPUE	Scaled 40% LPUE
1964	1,002,098	250	185	0.74	5,426	2.08
1965	202,850	8	43	5.15	4,685	1.80
1966	1,392,613	246	357	1.45	3,903	1.50
1967	1,782,883	279	443	1.59	4,024	1.54
1968	2,173,804	412	498	1.21	4,361	1.67
1969	1,473,227	280	323	1.15	4,557	1.75
1970	1,605,073	277	352	1.27	4,560	1.75
1971	2,340,797	393	596	1.51	3,928	1.51
1972	2,208,484	671	664	0.99	3,324	1.27
1973	1,747,907	615	555	0.90	3,148	1.21
1974	779,876	295	231	0.78	3,379	1.30
1975	1,024,094	442	317	0.72	3,236	1.24
1976	673,666	337	188	0.56	3,585	1.37
1977	432,512	220	123	0.56	3,519	1.35
1978	788,823	424	213	0.50	3,710	1.42
1979	383,701	172	120	0.70	3,203	1.23
1980	484,398	268	130	0.49	3,729	1.43
1981	617,158	183	131	0.71	4,729	1.81
1982	913,223	340	214	0.63	4,277	1.64
1983	1,187,732	301	323	1.07	3,678	1.41
1984	1,905,001	666	701	1.05	2,716	1.04
1985	1,620,062	749	803	1.07	2,019	0.77
1986	2,054,683	806	1,038	1.29	1,980	0.76
1987	1,061,519	557	546	0.98	1,945	0.75
1988	1,467,220	585	776	1.33	1,892	0.73
1989	639,629	199	255	1.28	2,504	0.96
1990	118,571	179	100	0.56	1,186	0.45
1991	90,385	105	87	0.82	1,045	0.40
1992	299,486	137	167	1.22	1,790	0.69
1993	329,964	268	271	1.01	1,218	0.47

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Table B44, continued.

Year	Trips 40 Landed Lbs	Trips	Days Fished	DF/Trip	Nominal 40% LPUE	Scaled 40% LPUE
1994	499,124	473	471	1.00	1,060	0.41
1995	450,002	302	437	1.45	1,030	0.39
1996	494,457	293	447	1.53	1,106	0.42
1997	313,016	178	248	1.39	1,265	0.48
1998	589,049	270	389	1.44	1,514	0.58
1999	714,463	474	479	1.01	1,492	0.57
2000	809,664	479	452	0.94	1,792	0.69
2001	1,085,273	418	435	1.04	2,496	0.96
2002	1,510,544	791	542	0.68	2,787	1.07
2003	1,890,138	965	728	0.75	2,596	1.00
2004	982,508	466	406	0.87	2,418	0.93
2005	782,709	550	370	0.67	2,114	0.81
2006	359,100	256	207	0.81	1,732	0.66
2007	227,559	155	112	0.72	2,030	0.78
2008	120,035	80	70	0.88	1,707	0.65
2009	80,864	71	71	1.00	1,142	0.44
2010	83,543	64	60	0.93	1,402	0.54
2011	155,711	116	76	0.66	2,049	0.79
2012	221,601	212	116	0.55	1,919	0.74
2013	160,057	223	95	0.43	1,690	0.65
2014	159,633	167	76	0.45	2,109	0.81
2015	147,234	186	76	0.41	1,940	0.74
Total	44,637,723	17,851	17,109	0.96	2,609	1

Table B45. Landings per unit of effort index (year effect estimates [annual indices of stock biomass] from the negative binomial model) for trips in which witch flounder comprise at least 40% or more of the total trip landings, and associated coefficient of variation (CV), lower and upper 95% confidence intervals of the index and scaled index, (L95CI, U95CI; Scaled L95CI, Scaled U95CI), respectively; 1964-2015.

Year	Trips 40 Index	CV	L95CI	U95CI	Scaled Index	Scaled L95CI	Scaled U95CI
1964	1.593	0.07	1.383	1.835	1.54	1.34	1.78
1965	1.550	0.19	1.077	2.232	1.50	1.04	2.16
1966	1.654	0.07	1.430	1.913	1.60	1.39	1.85
1967	1.864	0.07	1.623	2.140	1.81	1.57	2.07
1968	2.121	0.07	1.859	2.421	2.06	1.80	2.35
1969	1.715	0.07	1.489	1.976	1.66	1.44	1.91
1970	1.812	0.07	1.572	2.090	1.76	1.52	2.03
1971	2.206	0.07	1.926	2.526	2.14	1.87	2.45
1972	1.426	0.07	1.247	1.631	1.38	1.21	1.58
1973	1.248	0.07	1.083	1.437	1.21	1.05	1.39
1974	1.154	0.08	0.991	1.345	1.12	0.96	1.30
1975	1.226	0.07	1.074	1.398	1.19	1.04	1.35
1976	1.381	0.07	1.201	1.588	1.34	1.16	1.54
1977	1.418	0.08	1.212	1.660	1.37	1.17	1.61
1978	1.350	0.08	1.154	1.581	1.31	1.12	1.53
1979	1.192	0.09	0.991	1.432	1.15	0.96	1.39
1980	1.282	0.10	1.059	1.551	1.24	1.03	1.50
1981	1.424	0.09	1.206	1.683	1.38	1.17	1.63
1982	1.515	0.08	1.303	1.762	1.47	1.26	1.71
1983	1.188	0.07	1.028	1.372	1.15	1.00	1.33
1984	0.938	0.06	0.834	1.056	0.91	0.81	1.02
1985	0.730	0.06	0.648	0.823	0.71	0.63	0.80
1986	0.616	0.06	0.545	0.696	0.60	0.53	0.67
1987	0.587	0.07	0.514	0.671	0.57	0.50	0.65
1988	0.509	0.07	0.447	0.580	0.49	0.43	0.56
1989	0.458	0.09	0.385	0.544	0.44	0.37	0.53
1990	0.460	0.11	0.371	0.569	0.45	0.36	0.55
1991	0.612	0.11	0.490	0.764	0.59	0.47	0.74
1992	1.371	0.10	1.126	1.670	1.33	1.09	1.62
1993	0.594	0.08	0.506	0.697	0.58	0.49	0.68

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Table B45, continued.

Year	Trips 40 Index	CV	L95CI	U95CI	Scaled Index	Scaled L95CI	Scaled U95CI
1994	0.412	0.06	0.365	0.465	0.40	0.35	0.45
1995	0.322	0.07	0.282	0.367	0.31	0.27	0.36
1996	0.440	0.07	0.385	0.502	0.43	0.37	0.49
1997	0.463	0.07	0.399	0.536	0.45	0.39	0.52
1998	0.432	0.07	0.378	0.494	0.42	0.37	0.48
1999	0.494	0.06	0.438	0.557	0.48	0.42	0.54
2000	0.662	0.06	0.587	0.747	0.64	0.57	0.72
2001	1.171	0.06	1.035	1.324	1.13	1.00	1.28
2002	1.083	0.06	0.968	1.213	1.05	0.94	1.18
2003	0.852	0.06	0.762	0.951	0.83	0.74	0.92
2004	0.889	0.06	0.788	1.002	0.86	0.76	0.97
2005	0.881	0.06	0.783	0.991	0.85	0.76	0.96
2006	0.648	0.07	0.568	0.740	0.63	0.55	0.72
2007	0.824	0.08	0.705	0.963	0.80	0.68	0.93
2008	0.717	0.09	0.597	0.861	0.69	0.58	0.83
2009	0.610	0.10	0.503	0.739	0.59	0.49	0.72
2010	0.951	0.10	0.779	1.161	0.92	0.75	1.12
2011	1.014	0.08	0.866	1.187	0.98	0.84	1.15
2012	0.809	0.07	0.705	0.929	0.78	0.68	0.90
2013	0.856	0.07	0.748	0.980	0.83	0.72	0.95
2014	0.930	0.07	0.805	1.075	0.90	0.78	1.04
2015	1.000				0.97		

Table B46. Trends in landings (lbs) for trips in which witch flounder comprise at least 25% or more of the total trip landings, number of trips, days fished, days fished per trip, LPUE of the 25% trips (nominal and scaled), 1969-2015.

Year	Trips 25 Landed Lbs	Trips	Days Fished	DF/Trip	Nominal 25% LPUE	Scaled 25% LPUE
1964	1,265,453	426	294	0.69	4,310	2.19
1965	263,515	17	71	4.24	3,722	1.89
1966	2,173,913	584	732	1.25	2,971	1.51
1967	2,571,807	566	794	1.40	3,239	1.65
1968	2,999,423	819	889	1.08	3,375	1.71
1969	2,345,290	569	642	1.13	3,655	1.86
1970	2,403,066	624	671	1.08	3,581	1.82
1971	3,399,044	938	1,083	1.15	3,139	1.59
1972	3,197,444	1,136	1,161	1.02	2,754	1.40
1973	2,665,563	1,270	1,034	0.81	2,577	1.31
1974	1,329,727	631	544	0.86	2,444	1.24
1975	1,591,721	868	638	0.74	2,494	1.27
1976	1,324,854	886	557	0.63	2,377	1.21
1977	1,231,156	746	415	0.56	2,970	1.51
1978	2,048,780	1,293	683	0.53	3,000	1.52
1979	1,031,879	679	417	0.61	2,473	1.26
1980	1,273,034	818	461	0.56	2,764	1.40
1981	1,598,012	792	476	0.60	3,360	1.71
1982	2,899,081	1,090	901	0.83	3,216	1.63
1983	4,179,643	1,326	1,424	1.07	2,936	1.49
1984	5,040,544	2,208	2,199	1.00	2,292	1.16
1985	4,641,865	2,441	2,671	1.09	1,738	0.88
1986	4,125,181	2,368	2,589	1.09	1,594	0.81
1987	2,604,508	1,642	1,802	1.10	1,445	0.73
1988	3,238,526	2,037	2,244	1.10	1,443	0.73
1989	1,336,265	783	856	1.09	1,561	0.79
1990	372,870	540	364	0.67	1,025	0.52
1991	401,925	422	378	0.90	1,063	0.54
1992	780,540	498	631	1.27	1,238	0.63
1993	1,138,998	832	1,087	1.31	1,048	0.53

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Table B46, continued.

Year	Trips 25 Landed Lbs	Trips	Days Fished	DF/Trip	Nominal 25% LPUE	Scaled 25% LPUE
1994	1,405,764	1,191	1,469	1.23	957	0.49
1995	1,067,270	833	1,213	1.46	880	0.45
1996	1,267,622	808	1,360	1.68	932	0.47
1997	893,228	617	886	1.44	1,008	0.51
1998	1,304,009	720	1,101	1.53	1,185	0.60
1999	1,466,550	1,163	1,290	1.11	1,137	0.58
2000	1,722,664	1,112	1,166	1.05	1,478	0.75
2001	2,128,965	1,031	1,179	1.14	1,805	0.92
2002	2,736,010	1,781	1,314	0.74	2,082	1.06
2003	3,084,705	1,874	1,486	0.79	2,076	1.05
2004	2,211,535	1,291	1,181	0.92	1,872	0.95
2005	1,769,039	1,255	1,022	0.81	1,731	0.88
2006	1,019,817	646	698	1.08	1,461	0.74
2007	468,385	389	307	0.79	1,527	0.78
2008	319,107	227	208	0.92	1,532	0.78
2009	282,447	221	226	1.03	1,248	0.63
2010	170,741	152	122	0.80	1,402	0.71
2011	277,894	253	171	0.68	1,625	0.83
2012	503,773	503	317	0.63	1,589	0.81
2013	302,886	406	200	0.49	1,514	0.77
2014	258,248	307	151	0.49	1,707	0.87
2015	251,472	327	140	0.43	1,803	0.92
Total	90,385,758	46,953	45,913	0.98	1,969	1

Table B47. Landings per unit of effort index (year effect estimates [annual indices of stock biomass] from the negative binomial model) for trips in which witch flounder comprise at least 25% or more of the total trip landings, and associated coefficient of variation (CV), lower and upper 95% confidence intervals of the index and scaled index, (L95CI, U95CI; Scaled L95CI, Scaled U95CI), respectively, 1964-2015.

Year	Trips 25 Index	CV	L95CI	U95CI	Scaled Index	Scaled L95CI	Scaled U95CI
1964	1.459	0.05	1.313	1.621	1.6	1.44	1.78
1965	1.404	0.15	1.056	1.865	1.5	1.16	2.04
1966	1.366	0.05	1.233	1.513	1.5	1.35	1.66
1967	1.659	0.05	1.499	1.835	1.8	1.64	2.01
1968	1.824	0.05	1.653	2.012	2.0	1.81	2.21
1969	1.553	0.05	1.403	1.720	1.7	1.54	1.89
1970	1.670	0.05	1.508	1.850	1.8	1.65	2.03
1971	1.858	0.05	1.684	2.049	2.0	1.85	2.25
1972	1.266	0.05	1.150	1.393	1.4	1.26	1.53
1973	1.124	0.05	1.018	1.241	1.2	1.12	1.36
1974	1.029	0.06	0.924	1.147	1.1	1.01	1.26
1975	1.106	0.05	1.005	1.217	1.2	1.10	1.33
1976	1.207	0.05	1.094	1.331	1.3	1.20	1.46
1977	1.301	0.05	1.175	1.440	1.4	1.29	1.58
1978	1.182	0.05	1.071	1.305	1.3	1.17	1.43
1979	1.051	0.06	0.940	1.175	1.2	1.03	1.29
1980	0.998	0.06	0.891	1.117	1.1	0.98	1.23
1981	1.141	0.05	1.033	1.259	1.3	1.13	1.38
1982	1.193	0.05	1.087	1.309	1.3	1.19	1.44
1983	0.998	0.05	0.913	1.092	1.1	1.00	1.20
1984	0.842	0.04	0.776	0.914	0.9	0.85	1.00
1985	0.674	0.04	0.621	0.731	0.7	0.68	0.80
1986	0.582	0.04	0.535	0.634	0.6	0.59	0.69
1987	0.521	0.05	0.477	0.570	0.6	0.52	0.63
1988	0.481	0.05	0.440	0.526	0.5	0.48	0.58
1989	0.415	0.05	0.374	0.460	0.5	0.41	0.50
1990	0.476	0.06	0.420	0.541	0.5	0.46	0.59
1991	0.569	0.07	0.500	0.647	0.6	0.55	0.71
1992	0.794	0.06	0.707	0.891	0.9	0.78	0.98
1993	0.497	0.05	0.450	0.550	0.6	0.49	0.60

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Table B47, continued.

Year	Trips 25 Index	CV	L95CI	U95CI	Scaled Index	Scaled L95CI	Scaled U95CI
1994	0.362	0.04	0.332	0.394	0.4	0.36	0.43
1995	0.282	0.05	0.258	0.308	0.3	0.28	0.34
1996	0.362	0.05	0.331	0.395	0.4	0.36	0.43
1997	0.417	0.05	0.380	0.458	0.5	0.42	0.50
1998	0.387	0.05	0.353	0.424	0.4	0.39	0.46
1999	0.423	0.04	0.389	0.460	0.5	0.43	0.50
2000	0.580	0.04	0.533	0.631	0.6	0.58	0.69
2001	0.878	0.04	0.806	0.957	1.0	0.88	1.05
2002	0.901	0.04	0.831	0.977	1.0	0.91	1.07
2003	0.785	0.04	0.725	0.851	0.9	0.79	0.93
2004	0.734	0.04	0.675	0.798	0.8	0.74	0.87
2005	0.711	0.04	0.654	0.773	0.8	0.72	0.85
2006	0.600	0.05	0.548	0.658	0.7	0.60	0.72
2007	0.787	0.05	0.709	0.872	0.9	0.78	0.96
2008	0.921	0.06	0.820	1.034	1.0	0.90	1.13
2009	0.675	0.06	0.599	0.760	0.7	0.66	0.83
2010	0.931	0.07	0.815	1.063	1.0	0.89	1.17
2011	0.930	0.06	0.832	1.038	1.0	0.91	1.14
2012	0.785	0.05	0.714	0.864	0.9	0.78	0.95
2013	0.819	0.05	0.742	0.904	0.9	0.81	0.99
2014	0.914	0.05	0.824	1.015	1.0	0.90	1.11
2015	1.000				1.1		

Table B48. Trends in landings (lbs) for trips in which witch flounder comprise at least 10% or more of the total trip landings, number of trips, days fished, days fished per trip, LPUE of the 10% trips (nominal and scaled), 1969-2015.

Year	Trips 10 Landed Lbs	Trips	Days Fished	DF/Trip	Nominal 10% LPUE	Scaled 10% LPUE
1964	1,760,255	1,029	742	0.72	2,373	1.96
1965	513,324	84	274	3.25	1,871	1.55
1966	3,124,170	1,370	1,618	1.18	1,930	1.60
1967	3,617,111	1,285	1,684	1.31	2,148	1.78
1968	4,113,350	1,734	1,792	1.03	2,295	1.90
1969	3,382,957	1,520	1,435	0.94	2,358	1.95
1970	3,615,729	2,027	1,769	0.87	2,044	1.69
1971	4,921,749	2,838	2,486	0.88	1,980	1.64
1972	4,541,169	2,577	2,541	0.99	1,788	1.48
1973	3,701,759	2,520	2,073	0.82	1,786	1.48
1974	2,405,000	1,823	1,752	0.96	1,373	1.14
1975	2,868,158	2,153	2,003	0.93	1,432	1.19
1976	2,607,037	2,727	1,952	0.72	1,336	1.11
1977	3,272,216	3,233	1,763	0.55	1,856	1.54
1978	4,645,453	4,385	2,588	0.59	1,795	1.49
1979	3,255,044	3,601	2,198	0.61	1,481	1.23
1980	3,475,554	4,270	2,311	0.54	1,504	1.25
1981	4,291,706	3,833	2,216	0.58	1,936	1.60
1982	6,513,805	4,496	3,537	0.79	1,841	1.52
1983	8,486,977	5,136	4,630	0.90	1,833	1.52
1984	10,350,443	7,069	6,886	0.97	1,503	1.24
1985	9,936,390	7,293	8,229	1.13	1,207	1.00
1986	8,140,190	7,034	7,288	1.04	1,117	0.92
1987	5,713,273	5,321	5,876	1.10	972	0.81
1988	5,765,829	5,366	6,050	1.13	953	0.79
1989	3,024,428	3,053	3,571	1.17	847	0.70
1990	1,263,847	2,246	1,961	0.87	644	0.53
1991	1,544,638	2,019	2,373	1.18	651	0.54
1992	2,391,591	2,439	3,579	1.47	668	0.55
1993	3,234,831	3,476	4,972	1.43	651	0.54

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Table B48, continued.

Year	Trips 10 Landed Lbs	Trips	Days Fished	DF/Trip	Nominal 10% LPUE	Scaled 10% LPUE
1994	3,462,913	3,406	5,466	1.61	634	0.52
1995	2,809,450	3,057	5,206	1.70	540	0.45
1996	2,879,666	2,492	4,592	1.84	627	0.52
1997	2,320,480	2,209	3,414	1.55	680	0.56
1998	2,663,661	2,133	3,364	1.58	792	0.66
1999	3,093,569	2,979	4,172	1.40	742	0.61
2000	3,506,108	2,879	3,719	1.29	943	0.78
2001	4,421,423	2,772	3,795	1.37	1,165	0.96
2002	4,769,417	3,456	3,499	1.01	1,363	1.13
2003	4,700,446	3,453	3,192	0.92	1,472	1.22
2004	4,109,385	2,951	3,153	1.07	1,303	1.08
2005	3,576,863	2,772	2,946	1.06	1,214	1.01
2006	2,553,454	1,633	2,312	1.42	1,105	0.91
2007	1,107,789	1,036	1,099	1.06	1,008	0.84
2008	1,004,091	852	1,033	1.21	972	0.81
2009	939,577	804	986	1.23	953	0.79
2010	649,133	625	628	1.01	1,033	0.86
2011	781,026	803	631	0.79	1,238	1.02
2012	1,123,156	1,148	1,059	0.92	1,060	0.88
2013	619,166	737	604	0.82	1,025	0.85
2014	457,748	591	409	0.69	1,120	0.93
2015	438,232	578	351	0.61	1,249	1.03
Total	178,464,736	141,321	147,777	1.05	1,208	1

Table B49. Landings per unit of effort index (year effect estimates [annual indices of stock biomass] from the negative binomial model) for trips in which witch flounder comprise at least 10% or more of the total trip landings, and associated coefficient of variation (CV), lower and upper 95% confidence intervals of the index and scaled index, (L95CI, U95CI; Scaled L95CI, Scaled U95CI), respectively, 1964-2015.

Year	Trips 10 Index	CV	L95CI	U95CI	Scaled Index	Scaled L95CI	Scaled U95CI
1964	1.204	0.04	1.113	1.303	1.54	1.43	1.67
1965	1.001	0.09	0.846	1.186	1.28	1.09	1.52
1966	1.069	0.04	0.992	1.153	1.37	1.27	1.48
1967	1.414	0.04	1.310	1.526	1.81	1.68	1.96
1968	1.588	0.04	1.471	1.715	2.04	1.89	2.20
1969	1.310	0.04	1.214	1.412	1.68	1.56	1.81
1970	1.345	0.04	1.247	1.451	1.73	1.60	1.86
1971	1.565	0.04	1.453	1.685	2.01	1.86	2.16
1972	1.046	0.04	0.973	1.125	1.34	1.25	1.44
1973	1.024	0.04	0.950	1.104	1.31	1.22	1.42
1974	0.862	0.04	0.797	0.932	1.11	1.02	1.20
1975	0.966	0.04	0.898	1.039	1.24	1.15	1.33
1976	1.007	0.04	0.936	1.084	1.29	1.20	1.39
1977	1.130	0.04	1.052	1.214	1.45	1.35	1.56
1978	0.986	0.04	0.919	1.057	1.26	1.18	1.36
1979	0.847	0.04	0.789	0.909	1.09	1.01	1.17
1980	0.771	0.04	0.718	0.828	0.99	0.92	1.06
1981	0.935	0.03	0.874	1.000	1.20	1.12	1.28
1982	0.936	0.03	0.877	1.000	1.20	1.12	1.28
1983	0.823	0.03	0.772	0.878	1.06	0.99	1.13
1984	0.747	0.03	0.702	0.794	0.96	0.90	1.02
1985	0.607	0.03	0.570	0.645	0.78	0.73	0.83
1986	0.539	0.03	0.506	0.575	0.69	0.65	0.74
1987	0.465	0.03	0.435	0.497	0.60	0.56	0.64
1988	0.441	0.03	0.413	0.472	0.57	0.53	0.60
1989	0.365	0.04	0.340	0.392	0.47	0.44	0.50
1990	0.384	0.04	0.355	0.416	0.49	0.46	0.53
1991	0.416	0.04	0.385	0.449	0.53	0.49	0.58
1992	0.457	0.04	0.425	0.491	0.59	0.54	0.63
1993	0.390	0.04	0.364	0.417	0.50	0.47	0.54

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Table B49, continued.

Year	Trips 10 Index	CV	L95CI	U95CI	Scaled Index	Scaled L95CI	Scaled U95CI
1994	0.311	0.03	0.292	0.332	0.40	0.37	0.43
1995	0.243	0.03	0.228	0.259	0.31	0.29	0.33
1996	0.302	0.03	0.283	0.322	0.39	0.36	0.41
1997	0.330	0.03	0.309	0.352	0.42	0.40	0.45
1998	0.339	0.03	0.317	0.362	0.43	0.41	0.46
1999	0.397	0.03	0.373	0.424	0.51	0.48	0.54
2000	0.503	0.03	0.472	0.536	0.65	0.61	0.69
2001	0.700	0.03	0.656	0.746	0.90	0.84	0.96
2002	0.843	0.03	0.792	0.898	1.08	1.02	1.15
2003	0.767	0.03	0.720	0.817	0.98	0.92	1.05
2004	0.665	0.03	0.624	0.709	0.85	0.80	0.91
2005	0.676	0.03	0.634	0.721	0.87	0.81	0.93
2006	0.582	0.03	0.544	0.623	0.75	0.70	0.80
2007	0.674	0.04	0.626	0.727	0.87	0.80	0.93
2008	0.853	0.04	0.790	0.921	1.09	1.01	1.18
2009	0.760	0.04	0.702	0.822	0.97	0.90	1.05
2010	0.808	0.04	0.743	0.878	1.04	0.95	1.13
2011	0.825	0.04	0.764	0.891	1.06	0.98	1.14
2012	0.696	0.04	0.648	0.748	0.89	0.83	0.96
2013	0.766	0.04	0.709	0.827	0.98	0.91	1.06
2014	0.853	0.04	0.787	0.924	1.09	1.01	1.18
2015	1				1.28		

Table B50. Ratio of witch flounder Northeast Fisheries Science Center (NEFSC) spring and fall survey proportions-at-age to fishery proportion-at-age for ages 6 to age 11^{+}. Cells shaded grey indicates where the survey proportions-at-age were greater than the proportions observed in the fishery. Unshaded cells indicate where the fishery proportions-at-age were greater relative to the survey. Missing values indicate either where the survey index-at-age was zero.

Year	NEFSC spring/fishery						NEFSC fall/fishery					
	Age6	Age7	Age8	Age9	Age10	Age11+	Age6	Age7	Age8	Age9	Age10	Age11+
1982	0.36	2.23	1.35	0.58	2.68	0.83	0.28	2.11	1.18	0.22	0.68	1.44
1983	0.74	0.98	1.40	1.40	0.92	0.88	1.33	1.07	0.33	0.72	0.55	1.28
1984	0.96	0.87	0.56	1.18	1.28	1.41	1.11	1.15	0.66	0.69	1.08	1.16
1985	1.20	1.15	0.64	0.47	0.72	1.19	1.24	1.11	0.76	0.60	1.08	0.91
1986	0.70	0.96	0.76	1.73	1.31	1.97	0.66	1.02	0.99	1.41	0.22	2.22
1987	0.61	0.98	1.27	0.12	1.46	2.28	0.41	1.42	0.96		0.40	2.59
1988	1.58	0.97	0.74	1.23	1.16	0.68	0.41	1.19	0.33	0.90	1.33	2.46
1989	0.80	0.39	1.36	0.86	0.46	1.99	0.62	0.21	0.93	2.21	1.90	1.80
1990		1.42	0.17	1.44	2.06	2.79	0.74	0.68	0.41	0.63		4.71
1991	0.75	0.47	1.41	0.99	1.54	1.42	0.91	1.67	1.44	0.62	1.02	0.68
1992	0.46	1.06	1.16	4.35	0.66	1.12	0.82			1.81	1.31	3.64
1993	0.67	1.53		0.76	0.60	2.90	0.76	0.44	1.68		0.84	2.10
1994	1.29	0.30	1.49	1.38	0.78	1.03	0.40	1.59		1.14	1.16	2.08
1995	0.91	0.74	2.17	2.28		2.30	1.43			1.25	2.30	0.67
1996	1.70	0.54				3.01	1.73	0.25	1.32	0.93		1.56
1997	1.70	0.41	0.70	0.87			1.26	1.37				1.25
1998	1.53	0.41	1.26	1.59		1.21	1.27	0.76	1.25	0.92		
1999	1.02	1.40	0.37	0.52	5.62		1.28	1.19	0.34	0.75	1.31	
2000	1.51	1.11	0.85		2.72		2.29	0.62	0.69	0.40		0.48
2001	1.95	0.97	0.65	1.03	0.38		2.33	1.19	0.37	0.31	0.44	
2002	1.54	0.82	0.71	0.77	2.75	1.01	1.96	0.78	0.59	0.56		1.26
2003	1.54	1.17	0.64	0.68	0.27	0.63	1.85	0.67	0.34	1.21	0.78	1.44
2004	1.05	1.29	0.73	0.45	1.11	1.57	1.44	0.98	0.94	0.21	0.97	0.94
2005	1.00	0.82	1.19	1.52	0.94	0.74	1.00	1.35	0.48	0.91	0.36	0.86
2006	1.55	0.75	0.98	0.84	1.06	0.40	1.51	0.84	0.73	0.92	1.43	0.86
2007	1.41	1.16	0.49	1.73		1.26	2.36	0.96	0.38	1.48		1.04
2008	1.73	1.11	1.12	0.26	0.30		1.60	0.85	1.44	0.10	1.11	0.26
2009	1.45	0.70	1.09	0.85	1.68	0.51	1.72	0.99	0.90	0.76	0.20	0.40
2010	1.46	0.77	0.42	1.70	0.47	2.12	1.52	0.55	0.94	1.12	0.27	1.64
2011	1.24	0.79	0.47	0.97	2.37	3.66	1.64	0.71	0.42	0.73	1.75	0.78
2012	1.61	0.65	0.89	1.13	1.27	1.27	1.98	0.73	0.42	1.17	1.58	1.12
2013	1.31	1.02	0.88	0.75	0.98	0.64	0.85	1.33	1.04	0.84	0.32	
2014	2.06	0.87	0.73	1.07			1.62	1.03	0.86	0.57	0.32	1.58
2015	1.79	0.79	0.73	0.60	0.77	0.74	2.15	0.85	0.31	0.86	0.67	0.25
Cells ≥ 1	23	12	12	15	15	19	22	15	7	9	13	19
Total	33	34	32	32	28	28	34	32	30	31	27	30
Fraction ≥ 1	0.70	0.35	0.38	0.47	0.54	0.68	0.65	0.47	0.23	0.29	0.48	0.63

Table B51. Minimum spawning stock biomass estimates for the R/V Bigelow survey. A_s corresponds to the area (km^2) of the survey and a_s to the area (km^2) of a tow. Index and total area calculations are based on the use of Northeast Fisheries Science Center offshore trawl strata 22-30 and 36-40. All calculations are described in the text. Note that the index weights were calculated first using the stratified mean number per tow and then applying a length-weight conversion.

A_s 75,728 (area of survey associated with the witch flounder strata set using a GIS shapefile.

a_s 0.024 (taken from Hare et al. 2016 working paper)

	Index Total Weight (kg Tow^{-1}) Bigelow Units	Index Mature Weight (kg Tow^{-1}) Bigelow Units	Catchability Mature Numbers	Minimum SSB (mt)
2009	1.370	1.010	0.275 (0.248-0.303)	11,600 (10,500-12,800)
2010	1.070	0.731	0.272 (0.244-0.301)	8,500 (7,700-9,500)
2011	2.240	1.404	0.267 (0.241-0.291)	16,600 (15,200-18,400)
2012	1.435	0.937	0.264 (0.237-0.293)	11,200 (10,100-12,500)
2013	1.121	0.670	0.262 (0.236-0.285)	8,100 (7,400-8,900)
2014	1.672	1.160	0.274 (0.249-0.301)	13,300 (12,100-14,700)
2015	1.640	0.944	0.260 (0.232-0.286)	11,500 (10,400-12,800)

Table B52. The stratified mean weight (kg) per tow indices from the Northeast Fisheries Science Center autumn survey, the minimum swept area biomass (mt), the population biomass estimates assuming Bigelow q = 1 and estimates accounting for the efficiency of the net. Factors used to derive swept area biomass and population biomass estimates are also given.

				2014.708	3189.954		5.157	3.257		0.291		
	kg/tow			minimum swept area biomass (mt)			apply B:A calibration to get population assuming Bigelow q=1			apply Chain sweep:rockhopper conversion to get population		
Year	Albatross	Bigelow	Big to ALB	Albatross	Bigelow	Big to ALB	Albatross	Bigelow	Big to ALB	Albatross	Bigelow	Big to ALB
1963	3.4605			6972			35956			123559		
1964	2.0943			4219			21760			74778		
1965	2.2862			4606			23754			81630		
1966	4.6133			9294			47934			164720		
1967	1.9940			4017			20718			71197		
1968	3.5223			7096			36598			125766		
1969	4.2110			8484			43754			150356		
1970	3.6782			7410			38218			131332		
1971	2.9638			5971			30795			105824		
1972	2.4177			4871			25121			86325		
1973	2.0541			4138			21343			73343		
1974	1.5820			3187			16437			56486		
1975	1.0303			2076			10705			36787		
1976	0.9361			1886			9726			33424		
1977	3.3825			6815			35145			120774		
1978	2.9371			5917			30517			104871		
1979	1.6230			3270			16863			57950		
1980	2.0358			4102			21153			72689		
1981	2.1933			4419			22789			78313		
1982	0.8343			1681			8669			29789		
1983	2.1160			4263			21986			75553		
1984	2.3350			4704			24261			83373		
1985	1.5934			3210			16556			56893		
1986	1.0857			2187			11281			38766		
1987	0.3732			752			3878			13325		
1988	0.5701			1149			5924			20356		
1989	0.3754			756			3901			13404		
1990	0.4004			807			4160			14297		
1991	0.5365			1081			5574			19156		
1992	0.2384			480			2477			8512		
1993	0.5394			1087			5605			19260		
1994	0.4209			848			4373			15028		
1995	0.6243			1258			6487			22291		
1996	1.0203			2056			10601			36430		
1997	0.7679			1547			7979			27418		
1998	0.4697			946			4880			16771		
1999	0.8776			1768			9119			31335		
2000	1.1104			2237			11537			39647		
2001	1.7129			3451			17798			61160		
2002	1.0587			2133			11000			37801		
2003	0.7936			1599			8246			28336		
2004	1.0323			2080			10726			36859		
2005	0.4005			807			4161			14300		
2006	0.4597			926			4776			16414		
2007	0.5699			1148			5921			20349		
2008	0.6400			1289			6650			22852		
2009		1.5572	0.4781		4967	963		4967	4967		17070	17070
2010		1.1610	0.3564		3703	718		3703	3703		12727	12727
2011		2.1818	0.6698		6960	1350		6960	6960		23917	23917
2012		1.4438	0.4433		4606	893		4606	4606		15827	15827
2013		1.1439	0.3512		3649	708		3649	3649		12539	12539
2014		1.6742	0.5140		5341	1036		5341	5341		18353	18353
2015		1.7143	0.5263		5469	1060		5469	5469		18792	18792

Table B53. The stratified mean weight (kg) per tow indices from the Northeast Fisheries Science Center spring survey, the minimum swept area biomass (mt), the population biomass estimates assuming Bigelow q = 1 and estimates accounting for the efficiency of the net. Factors used to derive swept area biomass and population biomass estimates are also given.

				2014.708	3189.954		5.157	3.257		0.291		
	kg/tow			minimum swept area biomass (mt)			apply B:A calibration to get population assuming Bigelow q=1			apply Chain sweep:rockhopper conversion to get population		
Year	Albatross	Bigelow	Big to ALB	Albatross	Bigelow	Big to ALB	Albatross	Bigelow	Big to ALB	Albatross	Bigelow	Big to ALB
1963												
1964												
1965												
1966												
1967												
1968	3.2656			6579			33931			116600		
1969	2.5937			5226			26949			92610		
1970	4.5029			9072			46787			160779		
1971	2.0444			4119			21242			72996		
1972	4.0051			8069			41614			143004		
1973	6.2116			12515			64541			221789		
1974	3.6219			7297			37633			129322		
1975	2.7479			5536			28552			98115		
1976	3.7005			7455			38449			132128		
1977	1.9617			3952			20383			70044		
1978	2.5615			5161			26615			91460		
1979	1.7888			3604			18586			63870		
1980	3.8936			7844			40456			139023		
1981	4.0493			8158			42074			144583		
1982	1.8666			3761			19395			66648		
1983	2.7377			5516			28446			97751		
1984	1.6629			3350			17278			59375		
1985	2.7522			5545			28596			98269		
1986	1.3480			2716			14006			48131		
1987	0.6506			1311			6760			23230		
1988	0.8456			1704			8786			30193		
1989	0.7437			1498			7727			26554		
1990	0.2364			476			2456			8441		
1991	0.5741			1157			5965			20499		
1992	0.4820			971			5008			17210		
1993	0.3595			724			3735			12836		
1994	0.5314			1071			5521			18974		
1995	0.4667			940			4849			16664		
1996	0.2771			558			2879			9894		
1997	0.4332			873			4501			15468		
1998	0.7651			1541			7950			27318		
1999	0.4820			971			5008			17210		
2000	0.5191			1046			5394			18535		
2001	0.7508			1513			7801			26808		
2002	1.6112			3246			16741			57529		
2003	1.2995			2618			13502			46399		
2004	1.0756			2167			11176			38405		
2005	0.8907			1795			9255			31803		
2006	0.7249			1460			7532			25883		
2007	0.5814			1171			6041			20759		
2008	1.4006			2822			14553			50009		
2009		1.7175	0.5273		5479	1062		5479	5479		18828	18828
2010		1.7633	0.5413		5625	1091		5625	5625		19329	19329
2011		1.8462	0.5668		5889	1142		5889	5889		20238	20238
2012		1.2273	0.3768		3915	759		3915	3915		13454	13454
2013		0.7086	0.2175		2260	438		2260	2260		7767	7767
2014		1.5900	0.4882		5072	983		5072	5072		17430	17430
2015		1.5414	0.4732		4917	953		4917	4917		16896	16896
2016		1.2379	0.3801		3949	766		3949	3949		13570	13570

Table B54. Northeast Fisheries Science Center (NEFSC) autumn and spring estimated population biomass (mt), catch advice that includes: average population biomass (mt; representing biomass at the start of the year falling between t and t+1), exploitable biomass (mt), and estimates of the overfishing limit (OFL) and acceptable biological catch (ABC) using an assumed exploitation rate of 0.16. Actual catch, OLF and ABC are given as well as actual exploitation rate.

						0.9	0.16	0.75				
NEFSC AUTUMN year	AUTUMN mt	NEFSC SPRING year	SPRING mt	Catch Advice Year	Avg mt	Exploitable Biomass (mt)	Est. OFL (mt)	Est. ABC (mt)	Actual catch (mt)	Actual OFL (mt)	Actual ABC (mt)	Actual exploitation rate
1967	71,197	1968	116,600	1969	93,899	84,509	13,521	10,141				
1968	125,766	1969	92,610	1970	109,188	98,269	15,723	11,792				
1969	150,356	1970	160,779	1971	155,567	140,011	22,402	16,801				
1970	131,332	1971	72,996	1972	102,164	91,948	14,712	11,034				
1971	105,824	1972	143,004	1973	124,414	111,973	17,916	13,437				
1972	86,325	1973	221,789	1974	154,057	138,651	22,184	16,638				
1973	73,343	1974	129,322	1975	101,332	91,199	14,592	10,944				
1974	56,486	1975	98,115	1976	77,301	69,571	11,131	8,348				
1975	36,787	1976	132,128	1977	84,458	76,012	12,162	9,121				
1976	33,424	1977	70,044	1978	51,734	46,560	7,450	5,587				
1977	120,774	1978	91,460	1979	106,117	95,505	15,281	11,461				
1978	104,871	1979	63,870	1980	84,370	75,933	12,149	9,112				
1979	57,950	1980	139,023	1981	98,487	88,638	14,182	10,637				
1980	72,689	1981	144,583	1982	108,636	97,772	15,644	11,733	5,309			0.073
1981	78,313	1982	66,648	1983	72,481	65,232	10,437	7,828	6,409			0.101
1982	29,789	1983	97,751	1984	63,770	57,393	9,183	6,887	6,937			0.103
1983	75,553	1984	59,375	1985	67,464	60,717	9,715	7,286	6,339			0.070
1984	83,373	1985	98,269	1986	90,821	81,739	13,078	9,809	4,788			0.091
1985	56,893	1986	48,131	1987	52,512	47,261	7,562	5,671	3,644			0.118
1986	38,766	1987	23,230	1988	30,998	27,898	4,464	3,348	3,451			0.159
1987	13,325	1988	30,193	1989	21,759	19,583	3,133	2,350	2,425			0.103
1988	20,356	1989	26,554	1990	23,455	21,109	3,378	2,533	1,744			0.160
1989	13,404	1990	8,441	1991	10,922	9,830	1,573	1,180	2,571			0.148
1990	14,297	1991	20,499	1992	17,398	15,658	2,505	1,879	2,752			0.151
1991	19,156	1992	17,210	1993	18,183	16,365	2,618	1,964	2,806			0.263
1992	8,512	1993	12,836	1994	10,674	9,607	1,537	1,153	3,115			0.163
1993	19,260	1994	18,974	1995	19,117	17,205	2,753	2,065	2,718			0.172
1994	15,028	1995	16,664	1996	15,846	14,262	2,282	1,711	2,392			0.149
1995	22,291	1996	9,894	1997	16,092	14,483	2,317	1,738	2,254			0.087
1996	36,430	1997	15,468	1998	25,949	23,354	3,737	2,802	2,306			0.084
1997	27,418	1998	27,318	1999	27,368	24,631	3,941	2,956	2,490			0.147
1998	16,771	1999	17,210	2000	16,990	15,291	2,447	1,835	2,749			0.110
1999	31,335	2000	18,535	2001	24,935	22,441	3,591	2,693	3,406			0.103
2000	39,647	2001	26,808	2002	33,228	29,905	4,785	3,589	3,470			0.058
2001	61,160	2002	57,529	2003	59,344	53,410	8,546	6,409	3,551			0.084
2002	37,801	2003	46,399	2004	42,100	37,890	6,062	4,547	3,370			0.101
2003	28,336	2004	38,405	2005	33,370	30,033	4,805	3,604	2,917			0.085
2004	36,859	2005	31,803	2006	34,331	30,898	4,944	3,708	2,075			0.103
2005	14,300	2006	25,883	2007	20,092	18,082	2,893	2,170	1,210			0.065
2006	16,414	2007	20,759	2008	18,587	16,728	2,676	2,007	1,136			0.032
2007	20,349	2008	50,009	2009	35,179	31,661	5,066	3,799	1,157			0.056
2008	22,852	2009	18,828	2010	20,840	18,756	3,001	2,251	912	1,239	944	0.050
2009	17,070	2010	19,329	2011	18,199	16,380	2,621	1,966	1,071	1,792	1,369	0.065
2010	12,727	2011	20,238	2012	16,482	14,834	2,373	1,780	1,258	2,141	1,639	0.067
2011	23,917	2012	13,454	2013	18,685	16,817	2,691	2,018	811	1,196	783	0.069
2012	15,827	2013	7,767	2014	11,797	10,617	1,699	1,274	675	1,512	783	0.045
2013	12,539	2014	17,430	2015	14,985	13,486	2,158	1,618	585	1,846	783	0.033
2014	18,353	2015	16,896	2016	17,625	15,862	2,538	1,903		521	460	
2015	18,792	2016	13,570	2017	16,181	14,563	2,330	1,748		732	460	
2016		2017		2018						954	460	

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Table B55. Northeast Fisheries Science Center (NEFSC) autumn and spring estimated population biomass (mt), catch advice that includes: average population biomass (mt; representing biomass at the start of the year), exploitable biomass (mt), and estimates of the overfishing limit (OFL) and acceptable biological catch (ABC) using an assumed exploitation rate of 0.05. Actual catch, OLF and ABC are given as well as actual exploitation rate.

						0.9	0.05	0.75				
NEFSC AUTUMN year	AUTUMN mt	NEFSC SPRING year	SPRING mt	Catch Advice Year	Avg mt	Exploitable Biomass (mt)	Est. OFL (mt)	Est. ABC (mt)	Actual catch (mt)	Actual OFL (mt)	Actual ABC (mt)	Actual exploitation rate
1967	71,197	1968	116,600	1969	93,899	84,509	4,225	3,169				
1968	125,766	1969	92,610	1970	109,188	98,269	4,913	3,685				
1969	150,356	1970	160,779	1971	155,567	140,011	7,001	5,250				
1970	131,332	1971	72,996	1972	102,164	91,948	4,597	3,448				
1971	105,824	1972	143,004	1973	124,414	111,973	5,599	4,199				
1972	86,325	1973	221,789	1974	154,057	138,651	6,933	5,199				
1973	73,343	1974	129,322	1975	101,332	91,199	4,560	3,420				
1974	56,486	1975	98,115	1976	77,301	69,571	3,479	2,609				
1975	36,787	1976	132,128	1977	84,458	76,012	3,801	2,850				
1976	33,424	1977	70,044	1978	51,734	46,560	2,328	1,746				
1977	120,774	1978	91,460	1979	106,117	95,505	4,775	3,581				
1978	104,871	1979	63,870	1980	84,370	75,933	3,797	2,848				
1979	57,950	1980	139,023	1981	98,487	88,638	4,432	3,324				
1980	72,689	1981	144,583	1982	108,636	97,772	4,889	3,666	5,309			0.073
1981	78,313	1982	66,648	1983	72,481	65,232	3,262	2,446	6,409			0.101
1982	29,789	1983	97,751	1984	63,770	57,393	2,870	2,152	6,937			0.103
1983	75,553	1984	59,375	1985	67,464	60,717	3,036	2,277	6,339			0.070
1984	83,373	1985	98,269	1986	90,821	81,739	4,087	3,065	4,788			0.091
1985	56,893	1986	48,131	1987	52,512	47,261	2,363	1,772	3,644			0.118
1986	38,766	1987	23,230	1988	30,998	27,898	1,395	1,046	3,451			0.159
1987	13,325	1988	30,193	1989	21,759	19,583	979	734	2,425			0.103
1988	20,356	1989	26,554	1990	23,455	21,109	1,055	792	1,744			0.160
1989	13,404	1990	8,441	1991	10,922	9,830	492	369	2,571			0.148
1990	14,297	1991	20,499	1992	17,398	15,658	783	587	2,752			0.151
1991	19,156	1992	17,210	1993	18,183	16,365	818	614	2,806			0.263
1992	8,512	1993	12,836	1994	10,674	9,607	480	360	3,115			0.163
1993	19,260	1994	18,974	1995	19,117	17,205	860	645	2,718			0.172
1994	15,028	1995	16,664	1996	15,846	14,262	713	535	2,392			0.149
1995	22,291	1996	9,894	1997	16,092	14,483	724	543	2,254			0.087
1996	36,430	1997	15,468	1998	25,949	23,354	1,168	876	2,306			0.084
1997	27,418	1998	27,318	1999	27,368	24,631	1,232	924	2,490			0.147
1998	16,771	1999	17,210	2000	16,990	15,291	765	573	2,749			0.110
1999	31,335	2000	18,535	2001	24,935	22,441	1,122	842	3,406			0.103
2000	39,647	2001	26,808	2002	33,228	29,905	1,495	1,121	3,470			0.058
2001	61,160	2002	57,529	2003	59,344	53,410	2,670	2,003	3,551			0.084
2002	37,801	2003	46,399	2004	42,100	37,890	1,895	1,421	3,370			0.101
2003	28,336	2004	38,405	2005	33,370	30,033	1,502	1,126	2,917			0.085
2004	36,859	2005	31,803	2006	34,331	30,898	1,545	1,159	2,075			0.103
2005	14,300	2006	25,883	2007	20,092	18,082	904	678	1,210			0.065
2006	16,414	2007	20,759	2008	18,587	16,728	836	627	1,136			0.032
2007	20,349	2008	50,009	2009	35,179	31,661	1,583	1,187	1,157			0.056
2008	22,852	2009	18,828	2010	20,840	18,756	938	703	912	1,239	944	0.050
2009	17,070	2010	19,329	2011	18,199	16,380	819	614	1,071	1,792	1,369	0.065
2010	12,727	2011	20,238	2012	16,482	14,834	742	556	1,258	2,141	1,639	0.067
2011	23,917	2012	13,454	2013	18,685	16,817	841	631	811	1,196	783	0.069
2012	15,827	2013	7,767	2014	11,797	10,617	531	398	675	1,512	783	0.045
2013	12,539	2014	17,430	2015	14,985	13,486	674	506	585	1,846	783	0.033
2014	18,353	2015	16,896	2016	17,625	15,862	793	595		521	460	
2015	18,792	2016	13,570	2017	16,181	14,563	728	546		732	460	
2016		2017		2018						954	460	

Table B56. Parameter estimates (with coefficient of variation [CV]), stock size (N) in '000 of fish, and estimates of terminal F from VPA formulations for witch flounder. *Note: split survey indices are: 1982-1994 and 1995- onward. OA = Operational Assessment; BM = benchmark assessment; CAA = catch at age; DAA = discards at age.*

RUN	F		F1	
	2015 OA SPLIT RUN		2015 OA SPLIT RUN	
Software	NFT VPA 3.4.5	CV	NFT VPA 3.4.5	CV
Catch-At-Age	1982-2014 3-11+		1982-2014 3-11+	
Est.Ages	3-10		3-10	
NMFS-spring	3-11+		3-11+	
NMFS-autumn	3-11+		3-11+	
Residual Sum Sq.	388.609		387.911	
Mean Sq.Residual	0.6842		0.6829	
N3	10,991	0.60	12,029	0.60
N4	8,699	0.43	9,443	0.43
N5	2,816	0.35	3,008	0.36
N6	4,684	0.31	4,900	0.32
N7	2,596	0.29	2,589	0.30
N8	870	0.34	854	0.36
N9	509	0.39	498	0.40
N10	257	0.41	252	0.42
F 3	0.005		0.013	
F 4	0.015		0.032	
F 5	0.027		0.041	
F 6	0.051		0.063	
F 7	0.245		0.265	
F 8	0.463		0.486	
F 9	0.393		0.406	
F10	0.428		0.446	
F11+	0.428		0.446	
2010 Avg F 8-9	0.671		0.661	
2010 SSB (mt)	2,363		2,439	
2010 Age 3 in yr t	3,229		3,644	
2014 Avg F 8-9	**0.428 (.19)**		**0.446**	
2014 SSB (mt)	**3,129 (.12)**		**3,045**	
2014 Age 3 in yr t	**10,160**		**11,116**	
Mohn's rho F8-9	-0.377			
Mohn's rho SSB	0.507			
Mohn's rho Age 3	1.137			
Notes:	Final run used in 2015 OA		re-run of Run F with revised CAA (revised DAA)	

RUN	A1		A2	
	2016 BM SPLIT RUN		2016 BM SPLIT RUN	
Software	NFT VPA 3.4.5	CV	NFT VPA 3.4.5	CV
Catch-At-Age	1982-2015 3-11+		1982-2015 3-11+	
Est.Ages	3-10		3-10	
NMFS-s	3-11+		3-11+	
NMFS-a	3-11+		3-11+	
Residual Sum Sq.	396.087		396.087	
Mean Sq.Residual	0.6759		0.6759	
N3	19,244	0.60	19,244	0.60
N4	8,513	0.42	8,513	0.42
N5	6,014	0.35	6,014	0.35
N6	2,060	0.32	2,060	0.32
N7	3,357	0.29	3,357	0.29
N8	1,542	0.31	1,542	0.31
N9	402	0.38	402	0.38
N10	269	0.40	269	0.40
F 3	0.010		0.010	
F 4	0.029		0.029	
F 5	0.058		0.058	
F 6	0.067		0.067	
F 7	0.149		0.149	
F 8	0.511		0.511	
F 9	0.350		0.350	
F10	0.430		0.430	
F11+	0.430		0.430	
2014 Avg F 8-9	0.643		0.643	
2014 SSB (mt)	2,480		2480	
2014 Age 3 in yr t	8,500		8,500	
2015 Avg F 8-9	**0.430**		**0.430 (.19)**	
2015 SSB (mt)	**3,044**		**3,044 (.11)**	
2015 Age 3 in yr t	**9,992**		**9,992**	
Mohn's rho F8-9			-0.377	
Mohn's rho SSB			0.496	
Mohn's rho Age 3			0.693	
Notes:	2015 CAA, updated maturity ogive, using SWEPT AREA (assumed q = 1)		2015 CAA, updated maturity ogive, using SWEPT AREA (q = 0.056)	

Table B57. Summary of witch flounder spawning stock biomass (mt), fully recruited fishing mortality (F8-9), recruitment (Age 3, millions fish), and year class from VPA SPLIT RUN A2, 1982 to 2015, with Age 3 recruits predicted in 2016.

Year	Catch	SSB (mt)	Avg F8-9	Recruits Age 3	Year Class
1982	5,308	16,677	0.264	17.302	1979
1983	6,409	13,189	0.506	19.122	1980
1984	6,936	11,444	0.631	17.754	1981
1985	6,343	10,382	0.678	9.035	1982
1986	4,793	9,546	0.504	6.053	1983
1987	3,642	8,892	0.605	3.966	1984
1988	3,453	8,365	0.704	11.822	1985
1989	2,422	7,511	0.444	8.145	1986
1990	1,738	6,467	0.258	9.512	1987
1991	2,563	7,029	0.256	10.109	1988
1992	2,750	7,035	0.227	12.838	1989
1993	2,802	5,880	0.441	9.876	1990
1994	3,082	4,475	0.593	14.487	1991
1995	2,699	4,173	0.646	13.141	1992
1996	2,384	3,927	1.104	17.143	1993
1997	2,249	4,195	1.083	15.180	1994
1998	2,299	5,140	0.623	15.574	1995
1999	2,488	6,099	0.519	13.304	1996
2000	2,745	6,827	0.575	12.048	1997
2001	3,406	6,709	0.897	12.789	1998
2002	3,469	6,243	0.543	11.797	1999
2003	3,550	5,560	0.748	8.793	2000
2004	3,368	4,226	0.930	4.739	2001
2005	2,914	3,687	0.857	3.874	2002
2006	2,071	2,600	0.905	3.952	2003
2007	1,209	2,370	0.555	5.644	2004
2008	1,135	2,580	0.651	4.970	2005
2009	1,157	2,662	0.608	4.143	2006
2010	908	2,388	0.678	3.484	2007
2011	1,061	2,282	0.670	5.025	2008
2012	1,255	2,223	0.885	7.297	2009
2013	806	2,132	0.818	3.601	2010
2014	673	2,480	0.643	8.500	2011
2015	584	3,044	0.430	9.992	2012
2016				*19.244*	*2013*
1982 - 2015					
min	584	2,132	0.227	3.484	
max	6,936	16,677	1.104	19.122	
mean	2,784	5,836	0.632	9.853	
Geomean				8.679	
median				9.694	
Mean (1979 to 2011 year classes)				9.849	
2015 Retrospective Adjusted		2,035	0.690		

Table B58. Estimates of beginning year stock size ('000) of fish), instantaneous fishing mortality and spawning stock biomass (mt) for witch flounder estimated from the virtual population analysis, 1982-2015 VPA SPLIT Run A2.

JAN-1 Population Numbers

AGE	1982	1983	1984	1985	1986
3	17302.	19122.	17754.	9035.	6053.
4	14769.	14364.	16041.	15075.	7438.
5	10249.	10272.	10414.	11825.	11534.
6	8038.	7173.	6828.	6837.	8042.
7	4325.	5411.	4698.	4251.	4078.
8	2772.	3094.	3175.	2663.	2243.
9	2106.	1770.	1753.	1350.	1139.
10	1099.	1441.	841.	865.	602.
11	7215.	4722.	3844.	2931.	2044.
Total	67876.	67370.	65348.	54831.	43174.

AGE	1987	1988	1989	1990	1991
3	3966.	11822.	8145.	9512.	10109.
4	5147.	3361.	9464.	6833.	7847.
5	5752.	4121.	2626.	7054.	5321.
6	8133.	4199.	3157.	1795.	5000.
7	4336.	5781.	2978.	2398.	1282.
8	2053.	2256.	3669.	1832.	1791.
9	1155.	956.	869.	2316.	1121.
10	598.	548.	450.	419.	1673.
11	1157.	1226.	1262.	899.	1364.
Total	32296.	34270.	32620.	33059.	35508.

AGE	1992	1993	1994	1995	1996
3	12838.	9876.	14487.	13141.	17143.
4	7634.	10868.	8433.	12376.	10510.
5	5280.	5162.	8467.	6574.	9835.
6	2736.	3132.	3164.	5249.	4307.
7	3368.	1186.	1843.	1461.	2755.
8	866.	2200.	470.	686.	452.
9	1300.	557.	1352.	218.	328.
10	685.	952.	278.	658.	93.
11	2146.	1335.	814.	377.	185.
Total	36853.	35269.	39307.	40740.	45608.

AGE	1997	1998	1999	2000	2001
3	15180.	15574.	13304.	12048.	12789.
4	14393.	12945.	13083.	11314.	10247.
5	8418.	11468.	10341.	10608.	9278.
6	7390.	6145.	8681.	7732.	8474.
7	2431.	5062.	3917.	6080.	5524.
8	1046.	1067.	2833.	2242.	3611.
9	145.	306.	562.	1715.	963.
10	83.	42.	124.	244.	937.
11	116.	190.	246.	620.	683.
Total	49201.	52799.	53091.	52605.	52506.

Table B58, continued.

JAN-1 Population Numbers, continued.

AGE	2002	2003	2004	2005	2006
3	11796.	8793.	4739.	3874.	3952.
4	10951.	10119.	7528.	4034.	3306.
5	8389.	8821.	8371.	6064.	3217.
6	6769.	6101.	6389.	5904.	4301.
7	6185.	4539.	3648.	3842.	3241.
8	3126.	3326.	2119.	1678.	1599.
9	1754.	1505.	1401.	742.	666.
10	244.	911.	593.	461.	250.
11	519.	732.	530.	265.	143.
Total	49734.	44847.	35319.	26865.	20674.

AGE	2007	2008	2009	2010	2011
3	5644.	4970.	4143.	3484.	5025.
4	3284.	4724.	4226.	3529.	2924.
5	2721.	2660.	3794.	3417.	2934.
6	2450.	2180.	2065.	2746.	2649.
7	2827.	1821.	1551.	1463.	1861.
8	1298.	1598.	998.	849.	974.
9	550.	559.	945.	414.	356.
10	235.	312.	190.	501.	188.
11	110.	189.	191.	102.	79.
Total	19118.	19014.	18105.	16503.	16991.

AGE	2012	2013	2014	2015	2016
3	7297.	3601.	8500.	9992.	19244.
4	4098.	6125.	3059.	7191.	8513.
5	2378.	3277.	5082.	2537.	6014.
6	2289.	1718.	2610.	4170.	2060.
7	1660.	1526.	1205.	2078.	3357.
8	1021.	675.	876.	778.	1542.
9	427.	334.	276.	443.	402.
10	158.	164.	118.	112.	269.
11	74.	75.	67.	74.	104.
Total	19403.	17496.	21792.	27375.	41504.

Table B58, continued.

Fishing Mortality Calculated

AGE	1982	1983	1984	1985	1986
3	0.0361	0.0257	0.0136	0.0445	0.0122
4	0.2131	0.1716	0.1549	0.1177	0.1069
5	0.2069	0.2584	0.2708	0.2356	0.1994
6	0.2456	0.2732	0.3239	0.3666	0.4677
7	0.1850	0.3832	0.4177	0.4891	0.5363
8	0.2986	0.4181	0.7055	0.6990	0.5137
9	0.2297	0.5942	0.5569	0.6567	0.4952
10	0.2683	0.4786	0.6501	0.6846	0.5074
11	0.2683	0.4786	0.6501	0.6846	0.5074

AGE	1987	1988	1989	1990	1991
3	0.0153	0.0724	0.0257	0.0424	0.1308
4	0.0724	0.0968	0.1439	0.1000	0.2462
5	0.1648	0.1164	0.2307	0.1942	0.5151
6	0.1914	0.1937	0.1250	0.1867	0.2452
7	0.5035	0.3045	0.3360	0.1420	0.2416
8	0.6140	0.8042	0.3100	0.3412	0.1700
9	0.5951	0.6038	0.5785	0.1756	0.3428
10	0.6072	0.7403	0.3561	0.2454	0.2330
11	0.6072	0.7403	0.3561	0.2454	0.2330

AGE	1992	1993	1994	1995	1996
3	0.0166	0.0080	0.0075	0.0734	0.0248
4	0.2413	0.0997	0.0990	0.0797	0.0720
5	0.3724	0.3396	0.3282	0.2730	0.1359
6	0.6857	0.3801	0.6225	0.4944	0.4220
7	0.2760	0.7759	0.8390	1.0229	0.8188
8	0.2918	0.3368	0.6169	0.5872	0.9866
9	0.1615	0.5443	0.5693	0.7037	1.2215
10	0.2116	0.3754	0.5814	0.6141	1.0787
11	0.2116	0.3754	0.5814	0.6141	1.0787

AGE	1997	1998	1999	2000	2001
3	0.0092	0.0243	0.0120	0.0119	0.0052
4	0.0772	0.0747	0.0597	0.0485	0.0500
5	0.1647	0.1284	0.1407	0.0746	0.1653
6	0.2283	0.3003	0.2061	0.1863	0.1649
7	0.6729	0.4304	0.4078	0.3710	0.4194
8	1.0796	0.4920	0.3518	0.6949	0.5721
9	1.0864	0.7546	0.6854	0.4552	1.2215
10	1.0804	0.5448	0.3999	0.5839	0.6781
11	1.0804	0.5448	0.3999	0.5839	0.6781

Table B58, continued.

Fishing Mortality Calculated, continued.

AGE	2002	2003	2004	2005	2006
3	0.0034	0.0053	0.0111	0.0086	0.0350
4	0.0663	0.0396	0.0663	0.0763	0.0448
5	0.1685	0.1725	0.1993	0.1936	0.1223
6	0.2495	0.3642	0.3586	0.4496	0.2696
7	0.4702	0.6120	0.6267	0.7266	0.7652
8	0.5812	0.7148	0.8986	0.7746	0.9166
9	0.5051	0.7803	0.9614	0.9397	0.8932
10	0.5532	0.7348	0.9231	0.8224	0.9097
11	0.5532	0.7348	0.9231	0.8224	0.9097

AGE	2007	2008	2009	2010	2011
3	0.0279	0.0121	0.0106	0.0253	0.0539
4	0.0607	0.0691	0.0627	0.0344	0.0564
5	0.0715	0.1034	0.1735	0.1043	0.0982
6	0.1467	0.1906	0.1946	0.2389	0.3174
7	0.4204	0.4510	0.4528	0.2565	0.4506
8	0.6930	0.3756	0.7315	0.7178	0.6752
9	0.4178	0.9270	0.4840	0.6390	0.6650
10	0.6029	0.4919	0.6036	0.6913	0.6725
11	0.6029	0.4919	0.6036	0.6913	0.6725

AGE	2012	2013	2014	2015
3	0.0251	0.0130	0.0172	0.0102
4	0.0736	0.0367	0.0373	0.0288
5	0.1751	0.0777	0.0479	0.0583
6	0.2553	0.2051	0.0778	0.0667
7	0.7497	0.4057	0.2869	0.1486
8	0.9665	0.7435	0.5324	0.5104
9	0.8041	0.8919	0.7526	0.3496
10	0.9158	0.7903	0.5810	0.4300
11	0.9158	0.7903	0.5810	0.4300

Table B58, continued.

Average Fishing Mortality For Ages 8-9

Year	Average F	N Weighted	Biomass Wtd	Catch Wtd
1982	0.2641	0.2688	0.2655	0.2727
1983	0.5061	0.4822	0.4935	0.4936
1984	0.6312	0.6526	0.6461	0.6583
1985	0.6779	0.6848	0.6828	0.6852
1986	0.5044	0.5075	0.5065	0.5076
1987	0.6045	0.6072	0.6062	0.6073
1988	0.7040	0.7446	0.7358	0.7526
1989	0.4442	0.3614	0.3702	0.3855
1990	0.2584	0.2487	0.2410	0.2728
1991	0.2564	0.2365	0.2435	0.2629
1992	0.2266	0.2136	0.2090	0.2307
1993	0.4406	0.3787	0.3874	0.3931
1994	0.5931	0.5816	0.5799	0.5822
1995	0.6455	0.6154	0.6216	0.6182
1996	1.1040	1.0854	1.0969	1.0923
1997	1.0830	1.0804	1.0807	1.0804
1998	0.6233	0.5505	0.5658	0.5659
1999	0.5186	0.4070	0.4132	0.4351
2000	0.5750	0.5910	0.5824	0.6092
2001	0.8968	0.7088	0.7274	0.7690
2002	0.5431	0.5538	0.5508	0.5557
2003	0.7476	0.7352	0.7372	0.7361
2004	0.9300	0.9236	0.9260	0.9242
2005	0.8572	0.8252	0.8315	0.8297
2006	0.9049	0.9098	0.9087	0.9098
2007	0.5554	0.6111	0.6001	0.6314
2008	0.6513	0.5184	0.5338	0.5986
2009	0.6078	0.6112	0.6033	0.6298
2010	0.6784	0.6920	0.6879	0.6934
2011	0.6701	0.6725	0.6721	0.6725
2012	0.8853	0.9186	0.9114	0.9225
2013	0.8177	0.7927	0.7992	0.7967
2014	0.6425	0.5852	0.5925	0.5959
2015	0.4300	0.4521	0.4451	0.4630

Table B58, continued.

Spawning Stock Biomass

AGE	1982	1983	1984	1985	1986
3	10.	20.	30.	10.	8.
4	83.	100.	174.	116.	95.
5	288.	390.	545.	648.	959.
6	1062.	1122.	1176.	1549.	1911.
7	1556.	1851.	1726.	1733.	1650.
8	1642.	1552.	1566.	1397.	1229.
9	1635.	1176.	1092.	882.	785.
10	947.	1207.	630.	668.	489.
11	9455.	5770.	4505.	3380.	2420.
Total	16677.	13189.	11444.	10382.	9546.

AGE	1987	1988	1989	1990	1991
3	18.	65.	22.	21.	22.
4	184.	179.	281.	143.	126.
5	792.	664.	361.	614.	441.
6	2410.	1262.	942.	403.	918.
7	1821.	2558.	1339.	1024.	508.
8	1093.	1178.	2055.	1026.	1021.
9	763.	632.	569.	1649.	766.
10	482.	426.	368.	363.	1410.
11	1329.	1401.	1574.	1223.	1816.
Total	8892.	8365.	7511.	6467.	7029.

AGE	1992	1993	1994	1995	1996
3	45.	27.	29.	17.	11.
4	148.	206.	155.	167.	115.
5	478.	464.	727.	654.	868.
6	578.	703.	668.	1333.	1155.
7	1289.	417.	640.	559.	1087.
8	505.	1235.	241.	362.	233.
9	927.	396.	884.	150.	201.
10	553.	800.	220.	521.	71.
11	2511.	1633.	911.	411.	185.
Total	7035.	5880.	4475.	4173.	3927.

AGE	1997	1998	1999	2000	2001
3	7.	32.	35.	33.	57.
4	106.	179.	232.	196.	175.
5	576.	926.	773.	752.	597.
6	1787.	1273.	1739.	1385.	1351.
7	940.	1792.	1347.	1937.	1626.
8	503.	507.	1338.	950.	1451.
9	92.	192.	294.	922.	436.
10	64.	34.	102.	143.	515.
11	121.	204.	239.	511.	502.
Total	4195.	5140.	6099.	6827.	6709.

Table B58, continued.

Spawning Stock Biomass, continued.

AGE	2002	2003	2004	2005	2006
3	75.	31.	35.	37.	24.
4	278.	212.	168.	121.	75.
5	557.	600.	513.	493.	208.
6	1037.	820.	815.	844.	543.
7	1636.	1107.	789.	861.	702.
8	1201.	1153.	667.	564.	512.
9	876.	655.	575.	321.	295.
10	154.	480.	291.	245.	132.
11	430.	502.	374.	200.	108.
Total	6243.	5560.	4226.	3687.	2600.

AGE	2007	2008	2009	2010	2011
3	38.	38.	35.	17.	42.
4	73.	131.	162.	112.	105.
5	187.	213.	388.	356.	315.
6	372.	394.	436.	531.	542.
7	706.	539.	515.	481.	541.
8	485.	680.	418.	335.	392.
9	283.	263.	483.	215.	173.
10	139.	184.	110.	268.	111.
11	87.	139.	116.	72.	61.
Total	2370.	2580.	2662.	2388.	2282.

AGE	2012	2013	2014	2015
3	91.	49.	89.	66.
4	139.	269.	115.	234.
5	280.	364.	578.	278.
6	462.	386.	597.	981.
7	499.	480.	418.	755.
8	393.	272.	386.	349.
9	214.	162.	143.	251.
10	90.	95.	73.	74.
11	55.	56.	81.	57.
Total	2223.	2132.	2480.	3044.

Table B59. Summary of the witch flounder 2015 point estimates and their 90% confidence interval, the retrospective Mohn's rho values, and the retrospectively adjusted estimates for the VPA SPLIT Run A2. The retrospectively adjusted estimates fall outside the confidence region, therefore a major retrospective pattern exists.

	Point Estimate	90% CI		Mohn's Rho value	Rho Adjusted Estimate
F 2015	0.43	0.33	0.59	-0.38	0.69
SSB 2015	3,044	2,601	3,740	0.50	2,035

Table B60. Summary diagnostics and results for the witch flounder ASAP Run 9_5_v2 and five sensitivity runs.

		Base Run	Sensitivity Run 1	Sensitivity Run 2	Sensitivity Run 3	Sensitivity Run 4	Sensitivity Run 5
	Parameters	Run 9_5_v2	Run_9_5_v2 _FLEETDOME	Run_9_5_v2 _SVDOME	Run_9_5_v2 _LPUE40	Run_9_5_v2 _QFIXED	Run_9_5_v2 _FRANCIS
Objective Function Components	N	145	155	153	146	145	145
	total	12953.0	12945.7	12951.1	12985.4	13248.1	5188.4
	catch.total	-58.8	-59.4	-58.9	-50.6	-24.7	-67.8
	index.fit.total	35.4	35.1	35.1	39.9	161.4	23.8
	index.fit.ind01 (NEFSC SPR)	11.2	10.9	11.1	5.7	82.7	7.9
	index.fit.ind02 (NEFSC AUT)	-8.6	-8.4	-8.7	-10.3	48.2	-10.8
	index.fit.ind03 (ASMFC SUM)	10.2	10.0	10.1	7.2	3.9	9.1
	index.fit.ind04 (ME-NH SPR)	5.6	5.6	5.6	5.6	5.4	3.3
	index.fit.ind05 (ME-NH AUT)	17.0	17.0	17.0	18.2	21.2	14.4
	index.fit.ind06 (LPUE40)				13.6		
	catch.age.comp	4716.4	4710.3	4716.7	4720.4	4776.4	1765.3
	index.age.comp	8256.9	8256.7	8255.2	8272.8	8341.3	3467.4
	q.year1	0	0	0	0	-13.77	0
	Recruit.devs	3.1	2.9	3.1	2.8	7.4	-0.2
RMSE	catch.tot	1.07	1.06	1.07	1.28	1.78	0.79
	ind01 (NEFSC SPR)	1.82	1.82	1.82	1.73	2.74	1.77
	ind02 (NEFSC AUT)	1.30	1.31	1.30	1.26	2.24	1.25
	ind03 (ASMFC SUM)	1.40	1.39	1.40	1.33	1.25	1.38
	ind04 (MENH SPR)	1.61	1.61	1.61	1.60	1.60	1.51
	ind05 (MENH AUT)	1.89	1.90	1.89	1.93	2.03	1.81
	ind06 (LPUE40)				1.97		
	ind.total	1.59	1.58	1.58	1.64	2.11	1.53
	recruit.devs	1.30	1.29	1.30	1.29	1.39	1.22
	q.year1	0.00	0.00	0.00	0.00	4010.45	0.00
	NEFSC SPR SV q	4.3	4.1	4.3	3.9	1.0	4.00
	NEFSC AUT SV q	4.5	4.3	4.9	4.2	1.0	3.91
	F in 2015	0.16	0.16	0.16	0.10	0.03	0.12
	SSB in 2015	5,479	5,777	5,520	7,980	23,869	6,385
	Mohn's Rho F	-0.46					
	Mohn's Rho SSB	0.64					
	Rho adjusted F in 2015	0.29					
	Rho adjusted SSB in 2015	3,335					

Table B61. Comparison of fleet and index selectivity parameters and associated coefficients of variation (CV) for the witch flounder ASAP Run 9_5_v2 and 5 sensitivity runs.
Bold values represent fixed values (not estimated). 2015 fishing mortality, spawning stock biomass and Age 1 recruitment is also given at bottom of this page.

		Base Run		Sensitivity Run 1		Sensitivity Run 2		Sensitivity Run 3		Sensitivity Run 4		Sensitivity Run 5	
		Run 9_5_v2		Run_9_5_v2 _FLEETDOME		Run_9_5_v2 _SVDOME		Run_9_5_v2 _LPUE40		Run_9_5_v2 _QFIXED		Run_9_5_v2 _FRANCIS	
Block/Index	Age	Selectivity	CV	Selectivity	CV	Selectivity	CV	Selectivity	CV	Selectivity	CV	Selectivity	CV
Fleet block 1 (1982-1992)	1	0.003	0.86	0.003	0.86	0.003	0.86	0.003	0.86	0.004	0.86	0.003	1.40
	2	0.024	0.33	0.021	0.33	0.024	0.33	0.022	0.33	0.030	0.33	0.024	0.54
	3	0.110	0.17	0.095	0.17	0.110	0.17	0.104	0.17	0.136	0.17	0.111	0.27
	4	0.434	0.11	0.376	0.11	0.435	0.11	0.414	0.10	0.513	0.11	0.441	0.17
	5	0.686	0.10	0.593	0.11	0.687	0.10	0.659	0.10	0.792	0.10	0.689	0.16
	6	0.816	0.11	0.703	0.11	0.816	0.10	0.789	0.10	0.898	0.11	0.806	0.17
	7	**1.000**		**1.000**		**1.000**		**1.000**		**1.000**		**1.000**	
	8	**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**		**1.000**	
	9	**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**		**1.000**	
	10	**1.000**		0.877	0.23	**1.000**		**1.000**		**1.000**		**1.000**	
	11+	**1.000**		0.628	0.15	**1.000**		**1.000**		**1.000**		**1.000**	
Fleet block 2 (1993-2004)	1	0.019	0.21	0.018	0.22	0.019	0.21	0.018	0.21	0.020	0.22	0.019	0.35
	2	0.018	0.24	0.017	0.24	0.018	0.24	0.017	0.23	0.019	0.24	0.018	0.38
	3	0.024	0.22	0.023	0.23	0.024	0.22	0.024	0.22	0.026	0.22	0.024	0.36
	4	0.103	0.13	0.098	0.14	0.104	0.13	0.103	0.13	0.106	0.14	0.105	0.21
	5	0.274	0.11	0.261	0.12	0.277	0.11	0.274	0.11	0.280	0.11	0.282	0.17
	6	0.510	0.10	0.485	0.11	0.514	0.10	0.512	0.10	0.510	0.11	0.522	0.17
	7	0.945	0.11	0.902	0.11	0.953	0.11	0.955	0.11	0.946	0.11	0.947	0.17
	8	**1.000**		**1.000**		**1.000**		**1.000**		**1.000**		**1.000**	
	9	**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**		**1.000**	
	10	**1.000**		0.994	0.24	**1.000**		**1.000**		**1.000**		**1.000**	
	11+	**1.000**		0.728	0.28	**1.000**		**1.000**		**1.000**		**1.000**	
Fleet block 3 (2005-2015)	1	0.001	0.64	0.001	0.64	0.001	0.64	0.002	0.64	0.003	0.64	0.002	1.05
	2	0.019	0.22	0.018	0.22	0.019	0.22	0.022	0.22	0.036	0.22	0.024	0.36
	3	0.036	0.20	0.035	0.20	0.036	0.20	0.040	0.20	0.066	0.20	0.044	0.32
	4	0.082	0.15	0.080	0.16	0.083	0.15	0.091	0.16	0.149	0.16	0.097	0.25
	5	0.153	0.13	0.150	0.14	0.155	0.13	0.171	0.13	0.281	0.13	0.176	0.22
	6	0.301	0.11	0.295	0.12	0.305	0.11	0.338	0.12	0.546	0.11	0.340	0.18
	7	0.666	0.10	0.653	0.11	0.675	0.10	0.741	0.10	1.000	0.00	0.729	0.17
	8	**1.000**		**1.000**		**1.000**		**1.000**		**1.000**		**1.000**	
	9	**1.000**		0.954	0.15	**1.000**		**1.000**		**1.000**		**1.000**	
	10	**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**		**1.000**	
	11+	**1.000**		0.469	0.46	**1.000**		**1.000**		**1.000**		**1.000**	
NEFSC SPR q		4.3	0.27	4.1	0.28	4.3	0.27	3.9	0.27	1.0	0.03	4.0	0.31
NEFSC AUT q		4.5	0.30	4.3	0.31	4.9	0.32	4.2	0.31	1.0	0.03	3.9	0.37
ASMFC SUM q		0.5	0.32	0.5	0.32	0.5	0.32	0.4	0.32	0.3	0.32	0.5	0.35
MENH SPR q		0.2	0.39	0.2	0.39	0.2	0.39	0.1	0.38	0.1	0.39	0.2	0.42
MENH AUT q		0.5	0.39	0.5	0.39	0.5	0.39	0.4	0.39	0.2	0.39	0.5	0.40
LPUE q								0.0	0.22				
Freport		0.16	0.16	0.16	0.16	0.16	0.16	0.10	0.15	0.03	0.13	0.12	0.19
SSB (mt)		5,479	0.09	5,777	0.10	5,520	0.09	7,980	0.08	23,869	0.07	6,385	0.12
Age 1 recruits (000s)		9,246	0.25	9,422	0.25	9,259	0.25	11,011	0.25	19,305	0.25	8,393	0.30

Table B61 continued. Comparison of fleet and index selectivity parameters and associated coefficients of variation (CV) for the witch flounder ASAP Run 9_5_v2 and 5 sensitivity runs. Bold values represent fixed values (not estimated).

		Base Run		Sensitivity Run 1		Sensitivity Run 2		Sensitivity Run 3		Sensitivity Run 4		Sensitivity Run 5	
		Run 9_5_v2		Run_9_5_v2 _FLEETDOME		Run_9_5_v2 _SVDOME		Run_9_5_v2 _LPUE40		Run_9_5_v2 _QFIXED		Run_9_5_v2 _FRANCIS	
Block/Index	Age	Selectivity	CV	Selectivity	CV	Selectivity	CV	Selectivity	CV	Selectivity	CV	Selectivity	CV
NEFSC SPRING	**1**	0.038	0.17	0.039	0.17	0.038	0.17	0.037	0.17	0.072	0.16	0.041	0.25
	2	0.125	0.12	0.128	0.12	0.126	0.12	0.122	0.12	0.239	0.10	0.134	0.17
	3	0.338	0.09	0.344	0.09	0.340	0.09	0.331	0.09	0.655	0.07	0.356	0.13
	4	0.525	0.08	0.534	0.09	0.527	0.08	0.517	0.08	1.000	0.00	0.545	0.12
	5	0.681	0.08	0.692	0.09	0.684	0.08	0.672	0.08	1.000	0.00	0.717	0.12
	6	0.707	0.09	0.717	0.09	0.709	0.09	0.699	0.09	1.000	0.00	0.760	0.13
	7	**1.000**		**1.000**		**1.000**		**1.000**		**1.000**		**1.000**	
	8	**1.000**		**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**	
	9	**1.000**		**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**	
	10	**1.000**		**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**	
	11+	**1.000**		**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**	
NEFSC AUTUMN	1	0.114	0.016	0.116	0.14	0.104	0.14	0.111	0.14	0.222	0.12	0.133	0.23
	2	0.221	0.12	0.226	0.12	0.203	0.13	0.215	0.12	0.435	0.10	0.258	0.20
	3	0.510	0.10	0.522	0.10	0.469	0.11	0.500	0.10	1.000	0.00	0.602	0.17
	4	0.646	0.10	0.660	0.10	0.593	0.11	0.635	0.10	1.000	0.00	0.759	0.17
	5	0.609	0.11	0.621	0.11	0.560	0.12	0.602	0.11	1.000	0.00	0.704	0.18
	6	0.663	0.12	0.675	0.12	0.610	0.12	0.656	0.11	1.000	0.00	0.742	0.20
	7	**1.000**		**1.000**		**1.00**		**1.000**		**1.000**		**1.000**	
	8	**1.000**		**1.000**		0.853	0.16	**1.000**		**1.000**		**1.000**	
	9	**1.000**		**1.000**		0.763	0.21	**1.000**		**1.000**		**1.000**	
	10	**1.000**		**1.000**		0.688	0.27	**1.000**		**1.000**		**1.000**	
	11+	**1.000**		**1.000**		1.000	0.00	**1.000**		**1.000**		**1.000**	
ASMFC SUMMER	1	0.710	0.09	0.710	0.09	0.710	0.09	0.701	0.09	0.687	0.09	0.709	0.14
	2	0.662	0.10	0.662	0.10	0.662	0.10	0.655	0.10	0.645	0.10	0.674	0.16
	3	**1.000**		**1.000**		**1.00**		**1.000**		**1.000**		**1.000**	
	4	**1.000**		**1.000**		**1.00**		**1.000**		**1.000**		**1.000**	
	5	0.699	0.12	0.698	0.12	0.699	0.12	0.708	0.12	0.703	0.12	0.690	0.20
	6	0.579	0.15	0.576	0.15	0.578	0.15	0.589	0.15	0.565	0.15	0.568	0.24
	7	0.558	0.19	0.559	0.19	0.556	0.19	0.570	0.19	0.498	0.19	0.538	0.31
	8	0.520	0.25	0.537	0.25	0.517	0.25	0.527	0.25	0.397	0.25	0.476	0.42
	9	0.415	0.37	0.446	0.37	0.411	0.37	0.421	0.37	0.270	0.37	0.362	0.61
	10	0.333	0.53	0.368	0.53	0.328	0.53	0.343	0.53	0.194	0.53	0.283	0.88
	11+	0.304	0.39	0.236	0.40	0.302	0.39	0.350	0.39	0.166	0.39	0.247	0.65
MENH SPRING	1	**1.000**		**1.000**		**1.00**		**1.000**		**1.000**		**1.000**	
	2	0.925	0.15	0.925	0.15	0.925	0.15	0.929	0.15	0.941	0.15	0.780	0.23
	3	0.613	0.18	0.614	0.18	0.613	0.18	0.623	0.18	0.648	0.18	0.545	0.28
	4	0.344	0.23	0.344	0.23	0.344	0.23	0.354	0.23	0.380	0.22	0.290	0.35
	5	0.225	0.29	0.226	0.29	0.225	0.29	0.235	0.29	0.260	0.28	0.193	0.45
	6	0.132	0.40	0.132	0.40	0.132	0.40	0.138	0.40	0.153	0.40	0.112	0.62
	7	0.160	0.45	0.160	0.45	0.160	0.45	0.167	0.45	0.174	0.45	0.137	0.70
	8	0.133	0.68	0.133	0.68	0.133	0.68	0.134	0.68	0.120	0.68	0.112	1.08
	9	0.125	1.02	0.127	1.02	0.124	1.02	0.119	1.02	0.085	1.02	0.098	1.61
	10	0.100	1.67	0.101	1.67	0.098	1.67	0.091	1.67	0.052	1.67	0.078	2.64
	11+	0.187	1.35	0.141	1.36	0.182	1.35	0.153	1.35	0.053	1.35	0.125	2.13
MENH AUTUMN	1	**1.000**		**1.000**		**1.00**		**1.000**		**1.000**		**1.000**	
	2	0.662	0.13	0.662	0.13	0.662	0.13	0.667	0.13	0.678	0.13	0.657	0.17
	3	0.415	0.16	0.416	0.16	0.415	0.16	0.423	0.16	0.440	0.16	0.413	0.21
	4	0.281	0.20	0.282	0.20	0.281	0.20	0.289	0.20	0.307	0.20	0.278	0.26
	5	0.194	0.26	0.194	0.26	0.194	0.26	0.200	0.26	0.216	0.26	0.193	0.33
	6	0.153	0.33	0.153	0.33	0.153	0.33	0.158	0.33	0.166	0.33	0.153	0.43
	7	0.096	0.53	0.096	0.53	0.096	0.53	0.097	0.53	0.092	0.53	0.093	0.70
	8	0.093	0.78	0.093	0.78	0.092	0.78	0.088	0.78	0.068	0.78	0.084	1.02
	9	0.117	1.03	0.117	1.03	0.115	1.03	0.104	1.03	0.064	1.03	0.100	1.34
	10	0.069	1.95	0.070	1.95	0.068	1.95	0.059	1.95	0.029	1.95	0.057	2.55
	11+	0.119	1.67	0.077	1.69	0.115	1.67	0.090	1.67	0.026	1.67	0.087	2.20
LPUE40	**1**							**0.01**					
	2							**0.03**					
	3							**0.09**					
	4							**0.42**					
	5							**0.56**					
	6							**1.00**					
	7							**1.00**					
	8							**1.00**					
	9							**1.00**					
	10							**1.00**					
	11+							**1.00**					

Table B62. Witch flounder January 1 numbers at age (000s) from 1982 to 2015 estimated from the ASAP Run 9_5_v2.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+
1982	15,151	21,792	20,229	14,059	9,765	7,296	6,007	4,263	1,983	1,865	9,856
1983	6,982	13,033	18,662	17,006	11,026	7,256	5,273	4,173	2,962	1,378	8,143
1984	3,951	6,004	11,136	15,530	12,810	7,686	4,860	3,338	2,642	1,875	6,027
1985	2,860	3,397	5,123	9,203	11,382	8,552	4,891	2,889	1,984	1,570	4,697
1986	12,927	2,459	2,896	4,219	6,650	7,431	5,299	2,814	1,662	1,142	3,606
1987	8,204	11,114	2,097	2,391	3,080	4,414	4,696	3,123	1,658	980	2,798
1988	8,001	7,054	9,488	1,739	1,774	2,096	2,873	2,870	1,909	1,014	2,309
1989	13,380	6,878	6,013	7,808	1,253	1,153	1,292	1,642	1,640	1,091	1,899
1990	14,857	11,505	5,870	4,978	5,763	846	743	780	992	991	1,806
1991	12,158	12,778	9,839	4,906	3,812	4,124	584	489	513	652	1,839
1992	16,213	10,452	10,886	8,079	3,504	2,444	2,500	327	274	288	1,396
1993	24,676	13,935	8,893	8,887	5,639	2,166	1,419	1,328	174	146	894
1994	21,964	20,930	11,828	7,510	7,050	3,908	1,246	579	519	68	406
1995	15,294	18,549	17,692	9,932	5,815	4,581	1,995	407	179	160	146
1996	21,013	12,933	15,699	14,881	7,747	3,853	2,425	697	135	59	102
1997	26,467	17,823	10,977	13,256	11,804	5,367	2,216	988	272	53	63
1998	26,937	22,497	15,159	9,296	10,642	8,443	3,276	1,008	433	119	51
1999	24,813	22,938	19,167	12,866	7,537	7,815	5,410	1,631	486	209	82
2000	16,490	21,178	19,585	16,318	10,569	5,729	5,340	3,035	893	266	159
2001	10,696	14,068	18,076	16,665	13,372	7,983	3,869	2,931	1,623	477	228
2002	5,313	9,112	11,991	15,351	13,547	9,888	5,183	1,974	1,451	803	349
2003	4,435	4,529	7,772	10,193	12,527	10,119	6,540	2,737	1,013	745	591
2004	6,018	3,769	3,852	6,580	8,175	8,937	6,146	2,948	1,189	440	580
2005	13,552	5,102	3,198	3,251	5,208	5,630	5,084	2,454	1,126	454	390
2006	8,097	11,646	4,303	2,647	2,559	3,794	3,489	2,112	708	325	243
2007	6,353	6,960	9,849	3,582	2,110	1,908	2,460	1,602	708	237	191
2008	6,043	5,463	5,927	8,306	2,941	1,663	1,381	1,443	775	343	207
2009	11,334	5,197	4,651	4,996	6,816	2,316	1,201	805	692	372	264
2010	14,651	9,745	4,415	3,905	4,062	5,272	1,615	648	344	296	272
2011	7,788	12,599	8,290	3,715	3,192	3,175	3,753	912	297	157	259
2012	13,916	6,697	10,717	6,975	3,036	2,493	2,257	2,113	415	135	190
2013	18,190	11,965	5,689	8,993	5,665	2,344	1,732	1,207	891	175	137
2014	46,435	15,648	10,222	4,827	7,491	4,587	1,789	1,141	696	514	180
2015	9,246	39,954	13,409	8,724	4,075	6,218	3,675	1,313	774	472	471
Min	2,860										
Max	46,435										
Mean	13,953										
Median	13,154										

Table B63. Witch flounder January 1 biomass (mt), spawning stock biomass (mt), and exploitable biomass (mt) from 1982 to 2015 from the ASAP Run 9_5_v2.

Year	Jan 1 Biomass (mt)	Spawning Stock Biomass (mt)	Exploitable Biomass (mt)
1982	31,689	22,253	29,270
1983	27,547	19,144	25,849
1984	24,644	16,293	23,649
1985	21,071	14,557	20,393
1986	16,489	12,665	16,076
1987	12,846	10,886	13,065
1988	10,418	8,811	10,364
1989	8,199	6,622	7,992
1990	7,701	5,567	7,317
1991	7,746	4,928	6,748
1992	7,133	4,139	6,536
1993	7,440	3,635	4,337
1994	7,194	3,096	3,676
1995	6,770	3,266	3,501
1996	7,378	3,469	3,708
1997	8,933	3,850	4,271
1998	9,975	4,815	5,134
1999	10,947	5,521	6,684
2000	12,282	5,877	6,900
2001	12,715	6,018	7,508
2002	14,030	6,515	8,756
2003	13,195	6,264	8,165
2004	10,424	5,192	7,876
2005	8,390	4,301	5,154
2006	6,147	2,862	3,655
2007	5,041	2,457	2,891
2008	5,139	2,548	2,558
2009	6,030	2,879	2,321
2010	4,988	2,918	2,117
2011	4,765	3,084	2,655
2012	5,488	3,173	2,872
2013	6,478	3,379	2,629
2014	8,975	4,336	3,366
2015	10,627	5,479	4,210
Min	4,765	2,457	2,117
Max	31,689	22,253	29,270
Mean	10,848	6,494	8,006

Table B64. Witch flounder fishing mortality at age and fully recruited fishing mortality (Ffull) from 1982 – 2015 from the ASAP Run 9_5_v2.

Year	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8	Age 9	Age 10	Age 11+	Ffull
1982	0.00	0.01	0.02	0.09	0.15	0.17	0.21	0.21	0.21	0.21	0.21	0.21
1983	0.00	0.01	0.03	0.13	0.21	0.25	0.31	0.31	0.31	0.31	0.31	0.31
1984	0.00	0.01	0.04	0.16	0.25	0.30	0.37	0.37	0.37	0.37	0.37	0.37
1985	0.00	0.01	0.04	0.17	0.28	0.33	0.40	0.40	0.40	0.40	0.40	0.40
1986	0.00	0.01	0.04	0.16	0.26	0.31	0.38	0.38	0.38	0.38	0.38	0.38
1987	0.00	0.01	0.04	0.15	0.23	0.28	0.34	0.34	0.34	0.34	0.34	0.34
1988	0.00	0.01	0.04	0.18	0.28	0.33	0.41	0.41	0.41	0.41	0.41	0.41
1989	0.00	0.01	0.04	0.15	0.24	0.29	0.35	0.35	0.35	0.35	0.35	0.35
1990	0.00	0.01	0.03	0.12	0.18	0.22	0.27	0.27	0.27	0.27	0.27	0.27
1991	0.00	0.01	0.05	0.19	0.29	0.35	0.43	0.43	0.43	0.43	0.43	0.43
1992	0.00	0.01	0.05	0.21	0.33	0.39	0.48	0.48	0.48	0.48	0.48	0.48
1993	0.01	0.01	0.02	0.08	0.22	0.40	0.75	0.79	0.79	0.79	0.79	0.79
1994	0.02	0.02	0.02	0.11	0.28	0.52	0.97	1.02	1.02	1.02	1.02	1.02
1995	0.02	0.02	0.02	0.10	0.26	0.49	0.90	0.95	0.95	0.95	0.95	0.95
1996	0.01	0.01	0.02	0.08	0.22	0.40	0.75	0.79	0.79	0.79	0.79	0.79
1997	0.01	0.01	0.02	0.07	0.19	0.34	0.64	0.67	0.67	0.67	0.67	0.67
1998	0.01	0.01	0.01	0.06	0.16	0.30	0.55	0.58	0.58	0.58	0.58	0.58
1999	0.01	0.01	0.01	0.05	0.12	0.23	0.43	0.45	0.45	0.45	0.45	0.45
2000	0.01	0.01	0.01	0.05	0.13	0.24	0.45	0.48	0.48	0.48	0.48	0.48
2001	0.01	0.01	0.01	0.06	0.15	0.28	0.52	0.55	0.55	0.55	0.55	0.55
2002	0.01	0.01	0.01	0.05	0.14	0.26	0.49	0.52	0.52	0.52	0.52	0.52
2003	0.01	0.01	0.02	0.07	0.19	0.35	0.65	0.68	0.68	0.68	0.68	0.68
2004	0.02	0.01	0.02	0.08	0.22	0.41	0.77	0.81	0.81	0.81	0.81	0.81
2005	0.00	0.02	0.04	0.09	0.17	0.33	0.73	1.09	1.09	1.09	1.09	1.09
2006	0.00	0.02	0.03	0.08	0.14	0.28	0.63	0.94	0.94	0.94	0.94	0.94
2007	0.00	0.01	0.02	0.05	0.09	0.17	0.38	0.58	0.58	0.58	0.58	0.58
2008	0.00	0.01	0.02	0.05	0.09	0.18	0.39	0.59	0.59	0.59	0.59	0.59
2009	0.00	0.01	0.02	0.06	0.11	0.21	0.47	0.70	0.70	0.70	0.70	0.70
2010	0.00	0.01	0.02	0.05	0.10	0.19	0.42	0.63	0.63	0.63	0.63	0.63
2011	0.00	0.01	0.02	0.05	0.10	0.19	0.42	0.64	0.64	0.64	0.64	0.64
2012	0.00	0.01	0.03	0.06	0.11	0.21	0.48	0.71	0.71	0.71	0.71	0.71
2013	0.00	0.01	0.01	0.03	0.06	0.12	0.27	0.40	0.40	0.40	0.40	0.40
2014	0.00	0.00	0.01	0.02	0.04	0.07	0.16	0.24	0.24	0.24	0.24	0.24
2015	0.00	0.00	0.01	0.01	0.02	0.05	0.11	0.16	0.16	0.16	0.16	0.16
Min												0.16
Max												1.09
Mean												0.56

Table B65. Summary of witch flounder 2015 point estimates and their 90% confidence intervals the retrospective Mohn's rho values, and the retrospectively adjusted estimates for ASAP Run 9_5_v2. The retrospectively adjusted estimates fall outside the confidence region, therefore a major retrospective pattern exists.

	Point Estimate	90% CI		Mohn's Rho value	Rho Adjusted Estimate
F2015	0.16	0.12	0.20	-0.46	0.29
SSB 2015	5,479	4,812	6,511	0.64	3,335

Table B66. Witch flounder input vectors for biological reference points (yield and spawning biomass per recruit analyses and long-term stochastic projections) based on VPA SPLIT RUN A2. Average 2010-2015 partial recruitment, average 2011-2015 mean weights (kg), and maturation ogive representing 2012-2016 maturity data are given below. Note: Age 3 recruitment is used.

Age	Partial recruitment	Sel. on M	Mean Stock wts	Mean Catch wts	Mean SpStock wts	Maturity
3	0.030	1.000	0.074	0.124	0.074	0.09
4	0.066	1.000	0.148	0.189	0.148	0.23
5	0.124	1.000	0.229	0.271	0.229	0.49
6	0.233	1.000	0.307	0.353	0.307	0.75
7	0.541	1.000	0.392	0.452	0.392	0.91
8	1.000	1.000	0.494	0.551	0.494	0.97
9	1.000	1.000	0.595	0.656	0.595	0.99
10	1.000	1.000	0.692	0.732	0.692	1.00
11+	1.000	1.000	0.973	0.973	0.973	1.00

Year	Age 3 ('000 fish)	Year class
1982	17,302	1979
1983	19,122	1980
1984	17,754	1981
1985	9,035	1982
1986	6,053	1983
1987	3,966	1984
1988	11,822	1985
1989	8,145	1986
1990	9,512	1987
1991	10,109	1988
1992	12,838	1989
1993	9,876	1990
1994	14,487	1991
1995	13,141	1992
1996	17,143	1993
1997	15,180	1994
1998	15,574	1995
1999	13,304	1996
2000	12,048	1997
2001	12,789	1998
2002	11,797	1999
2003	8,793	2000
2004	4,739	2001
2005	3,874	2002
2006	3,952	2003
2007	5,644	2004
2008	4,970	2005
2009	4,143	2006
2010	3,484	2007
2011	5,025	2008
2012	7,297	2009
2013	3,601	2010
2014	8,500	2011
Mean	9,849	

Table B67. Witch flounder input vectors for biological reference points (yield and spawning biomass per recruit analyses and long-term stochastic projections) based on ASAP Run 9_5_v2. Partial recruitment is the fleet selectivity from time block 2005-2015. Average 2011-2015 mean weights (kg) and maturation ogive representing 2012-2016 maturity data are given below. Note Age 1 recruitment is used in ASAP model.

Age	Partial recruitment	Sel. on M	Mean Stock wts	Mean Catch wts	Mean SpStock wts	Maturity
1	0.001	1.000	0.010	0.017	0.010	0.01
2	0.019	1.000	0.025	0.059	0.025	0.03
3	0.036	1.000	0.074	0.124	0.074	0.09
4	0.082	1.000	0.148	0.189	0.148	0.23
5	0.153	1.000	0.229	0.271	0.229	0.49
6	0.301	1.000	0.307	0.353	0.307	0.75
7	0.666	1.000	0.392	0.452	0.392	0.91
8	1.000	1.000	0.494	0.551	0.494	0.97
9	1.000	1.000	0.595	0.656	0.595	0.99
10	1.000	1.000	0.692	0.732	0.692	1.00
11+	1.000	1.000	0.973	0.973	0.973	1.00

Year	Age 1 ('000 fish)	Year class
1982	15,151	1981
1983	6,982	1982
1984	3,951	1983
1985	2,860	1984
1986	12,927	1985
1987	8,204	1986
1988	8,001	1987
1989	13,380	1988
1990	14,857	1989
1991	12,158	1990
1992	16,213	1991
1993	24,676	1992
1994	21,964	1993
1995	15,294	1994
1996	21,013	1995
1997	26,467	1996
1998	26,937	1997
1999	24,813	1998
2000	16,490	1999
2001	10,696	2000
2002	5,313	2001
2003	4,435	2002
2004	6,018	2003
2005	13,552	2004
2006	8,097	2005
2007	6,353	2006
2008	6,043	2007
2009	11,334	2008
2010	14,651	2009
2011	7,788	2010
2012	13,916	2011
2013	18,190	2012
2014	46,435	2013
2015	9,246	2014
Mean	13,953	

Table B68. Proxy reference points from the witch flounder yield per recruit (YPR) analysis and the corresponding fishing mortality, spawning stock biomass per recruit (SSB/R), biomass per recruit (B/R) and mean age value for the VPA SPLIT Run A2 (top) and ASAP Run 9_5_v2 (bottom).

VPA SPLIT RUN A2

Reference Point	F	YPR (kg)	SSB/R (kg)	B/R (kg)	Mean Age
F-Zero	0.00	0.00	3.19	3.60	9.18
F-01	0.19	0.20	1.32	1.71	6.20
FMax	0.51	0.23	0.70	1.07	5.24
F at 40% MSP	0.20	0.20	1.28	1.67	6.14

ASAP Base Run 9_5_v2

Reference Point	F	YPR (kg)	SSB/R (kg)	B/R (kg)	Mean Age
F-Zero	0.00	0.00	2.37	2.70	7.18
F-01	0.19	0.15	0.96	1.28	4.60
FMax	0.46	0.17	0.51	0.81	3.80
F at 40% MSP	0.19	0.15	0.95	1.26	4.58

Table B69. Witch flounder fully recruited fishing mortality (F), spawning stock biomass (SSB, mt), yield and spawning stock biomass per recruit results and corresponding biological reference points estimated in 2008 GARM, 2012 Update, and 2015 Operational Assessment, and the current 2016 benchmark assessment (VPA SPLIT Run A2 and ASAP Run 9_5_v2). The Fmsy = F40% MSP is based on yield per recruit analyses, while the SSBmsy and MSY estimates are based on long-term stochastic projections. Retrospectively adjusted F and SSB are given for 2015 and 2016 assessments. (*Note: mean recruitment values [Age 3 for VPA and Age 1 for ASAP] are not used in the calculations of SSBmsy and MSY estimates*).

	Fully Recruited F	SSB	Fmsy F40%	Y/R (kg)	SSB/R (kg)	Mean Age 3 Recruitment (fish,millions)	Agepro Projections SSBmsy (mt)	Agepro Projections MSY (mt)
2008 GARM								
SPLIT RUN	0.29	3,434	0.20	0.1943	0.9346	11.1	11,447	2,352
2012 Update								
SPLIT RUN D	0.47	4,099	0.27	0.2069	0.9970	10.0	10,051	2,075
2015 Operational Assessment								
SPLIT RUN F	0.43	3,129	0.28	0.2181	1.1599	9.0	9,473	1,957
Rho Adjusted	0.69	2,077						
2016 Benchmark								
VPA SPLIT RUN A2	0.43	3,044	0.20	0.2044	1.2769	9.8	12,499	1,512
Rho Adjusted	0.69	2,035						
						Mean Age 1		
ASAP Run 9_5_v2	0.16	5,479	0.19	0.1485	0.9463	14.0	12,747	1,998
Rho Adjusted	0.29	3,335						

FIGURES

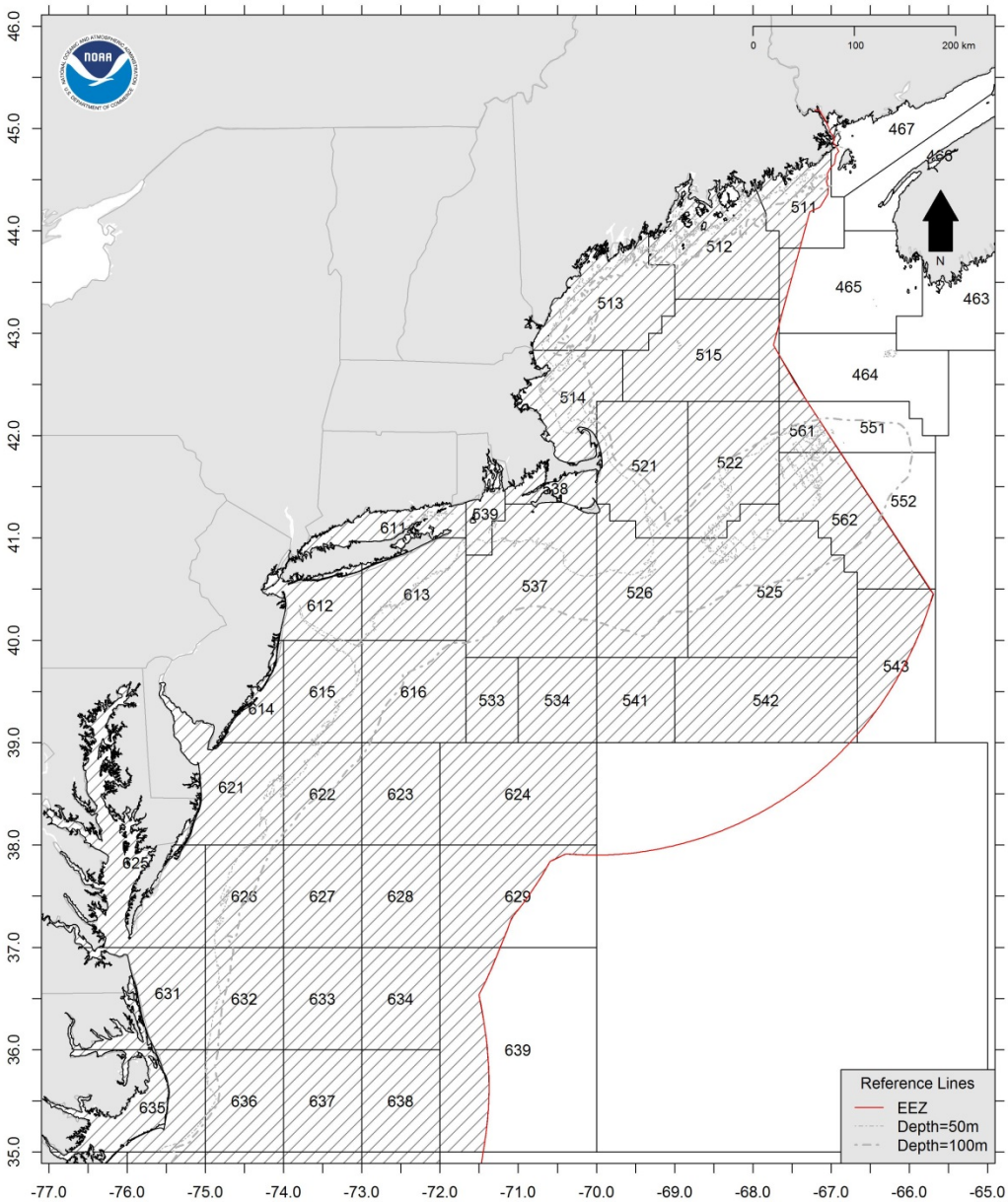

Figure B1. Statistical areas used for reporting commercial fishery statistics. Prior to 1985, statistical areas 551 and 561 comprised statistical area 523 and statistical areas 552 and 562 comprised statistical area 524. Shaded statistical areas delineate witch flounder stock area; Red line represents the U.S. Exclusive Economic Zone.

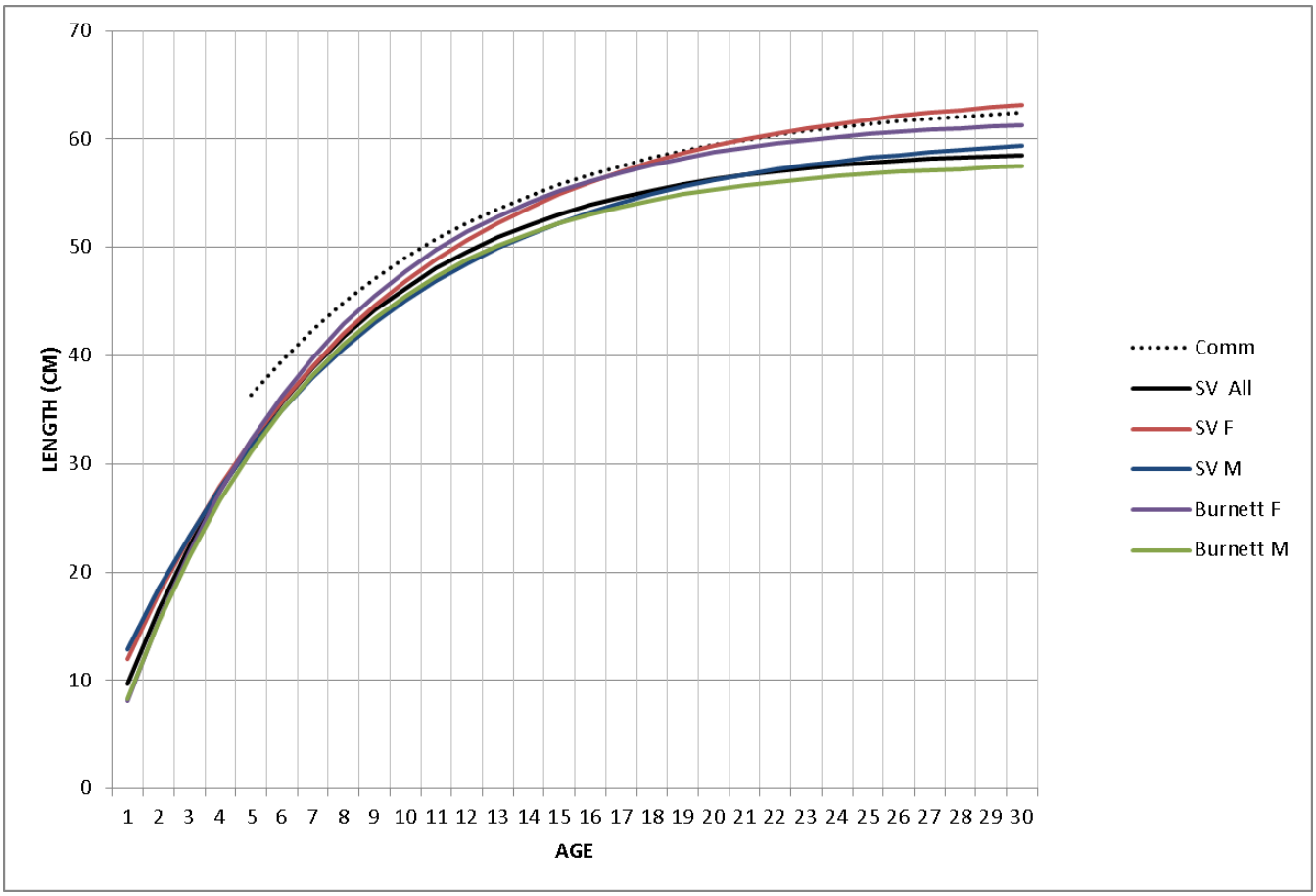

Figure B2. Von Bertalanffy growth curves based on witch flounder length and age data from commercial port sampling (Comm; black dotted line) in which sexes are combined from 1982-2015; Northeast Fisheries Science Center (NEFSC) survey sampling for females (SV F; red solid line), males (SV M; blue solid line) and all sexes combined (SV All; black solid line) from 1982-2015; and NEFSC survey sampling data 1980-1984 via Burnett (MS 1987) for females (Burnett F; purple solid line) and males (Burnett M; green solid line).

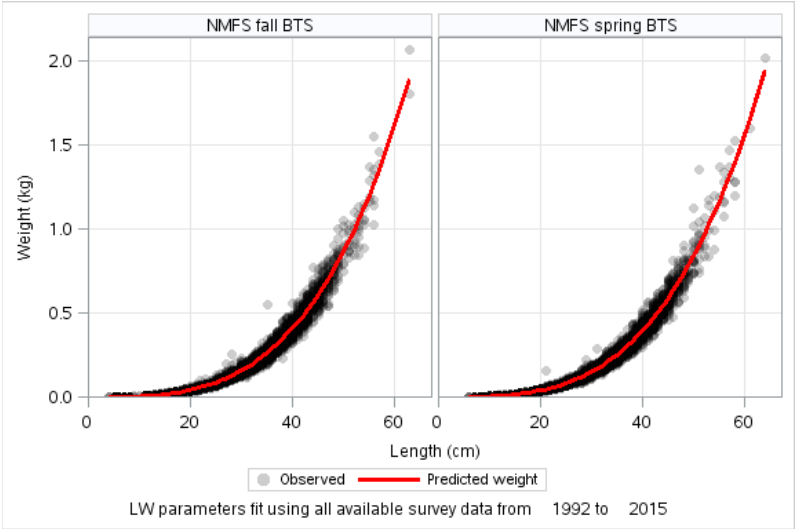

Figure B3. Length-weight relationships of witch flounder based on Northeast Fisheries Science Center research vessel bottom trawl survey for fall (left) and spring (right) for 1992 to 2015.

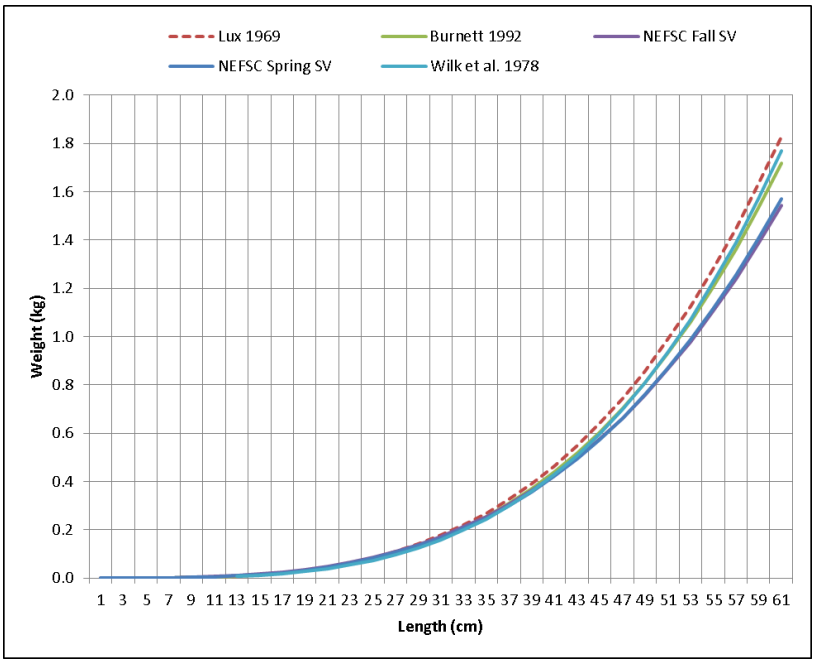

Figure B4. Length-weight relationships of witch flounder from Lux (1969; red dashed line), Burnett et al. (1992; green line), Wilk et al. (1978; light blue line), and1992-2015 Northeast Fisheries Science Center spring survey (blue line) and fall survey (purple line) derived in the current assessment.

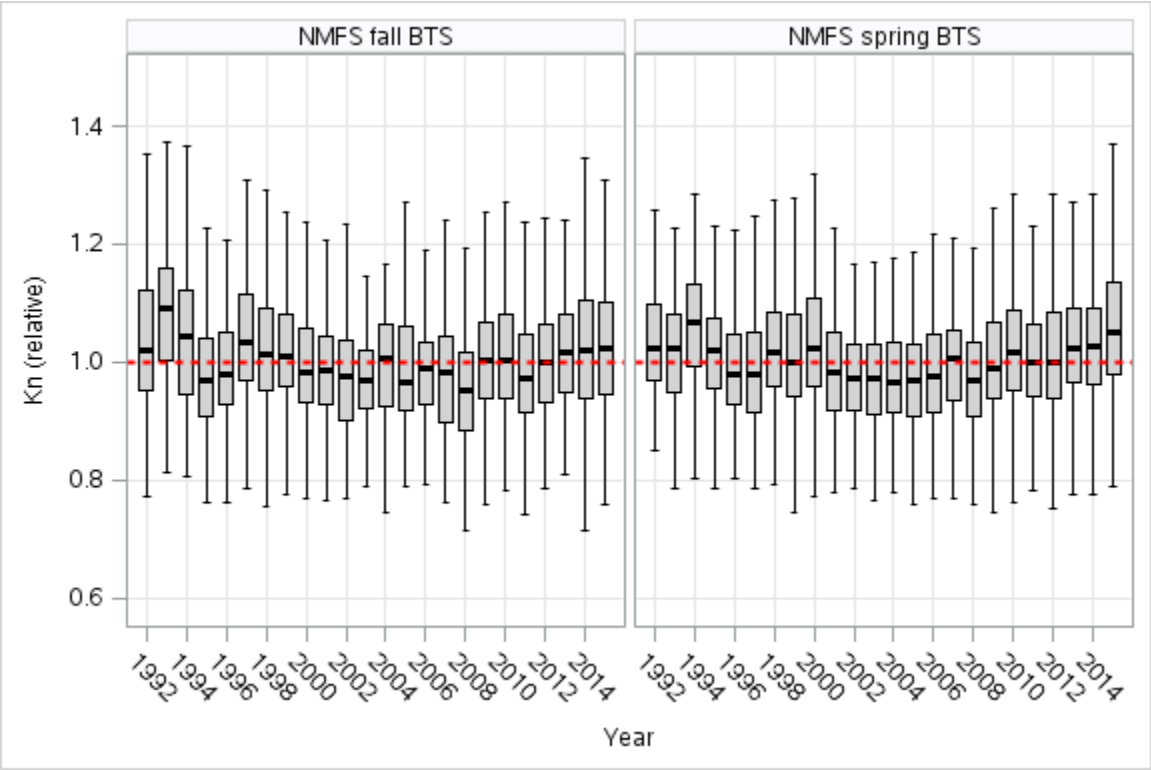

Figure B5. Annual trends in relative condition factor of witch flounder based on length and weight data from the Northeast Fisheries Science Center bottom trawl survey, spring and fall, 1982- 2015.

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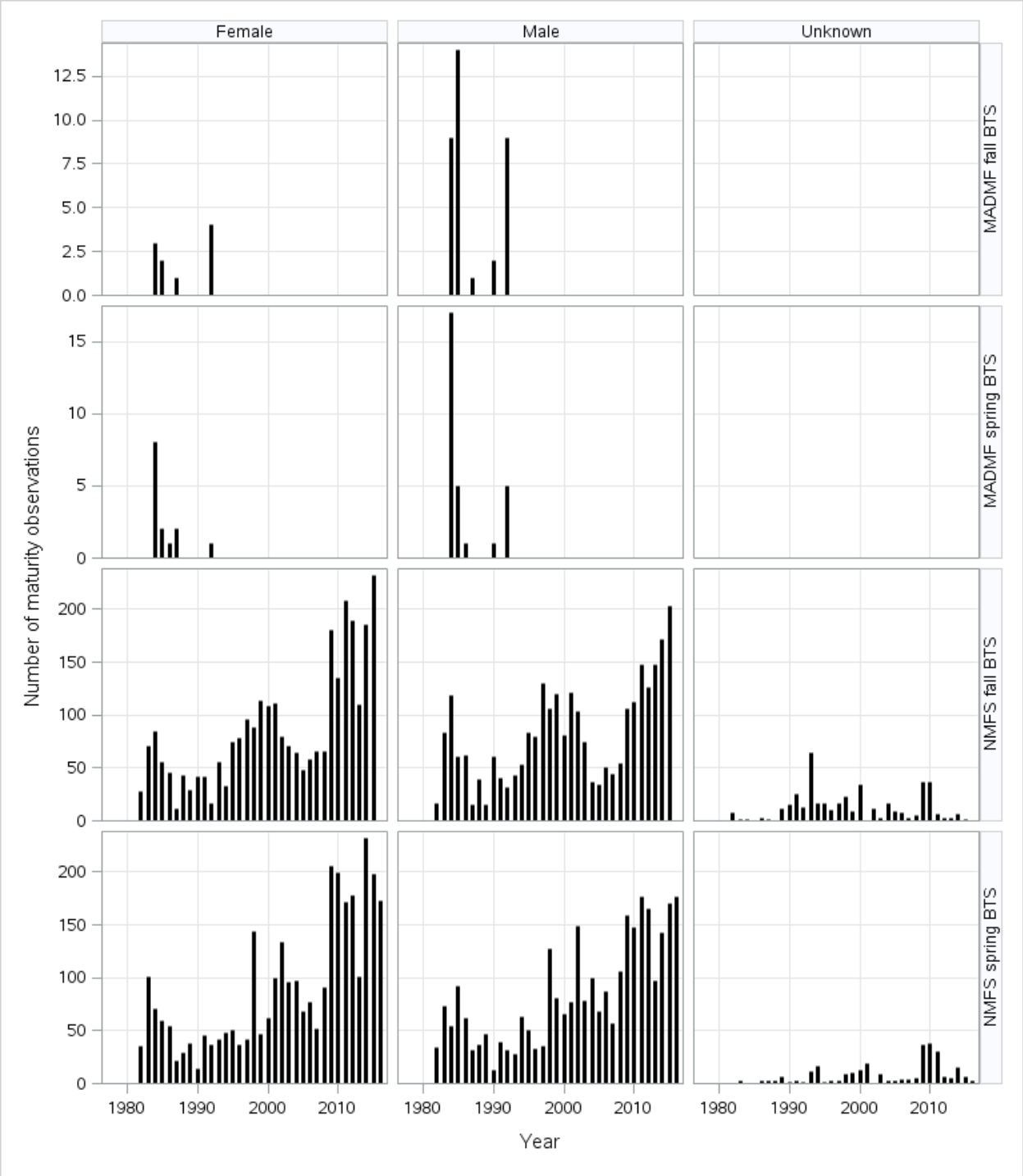


Figure B6. Number of fish with maturity observations, by year and sex, taken during Northeast Fisheries Science Center bottom trawl surveys (spring and fall), Massachusetts Division of Marine Fisheries (spring and fall).

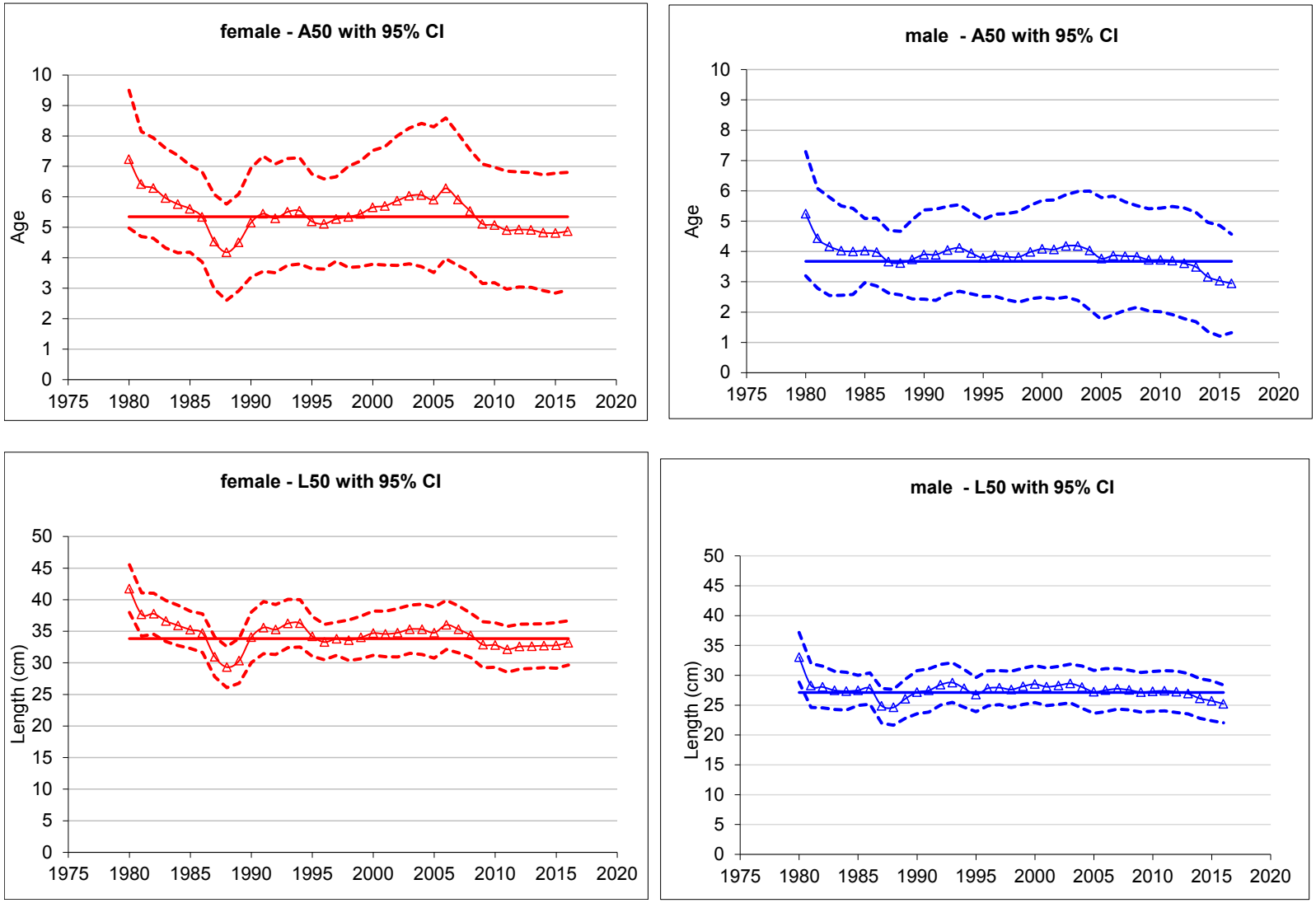


Figure B7. Annual estimates of median age (A50; top) and length (L50; bottom) of female (left) and male (right) witch flounder maturity derived from a five-year moving time block of maturity observations collected during the Northeast Fisheries Science Center spring survey, 1980 – 2016. Time series average is indicated in solid line; dash lines indicate 95% confidence intervals.

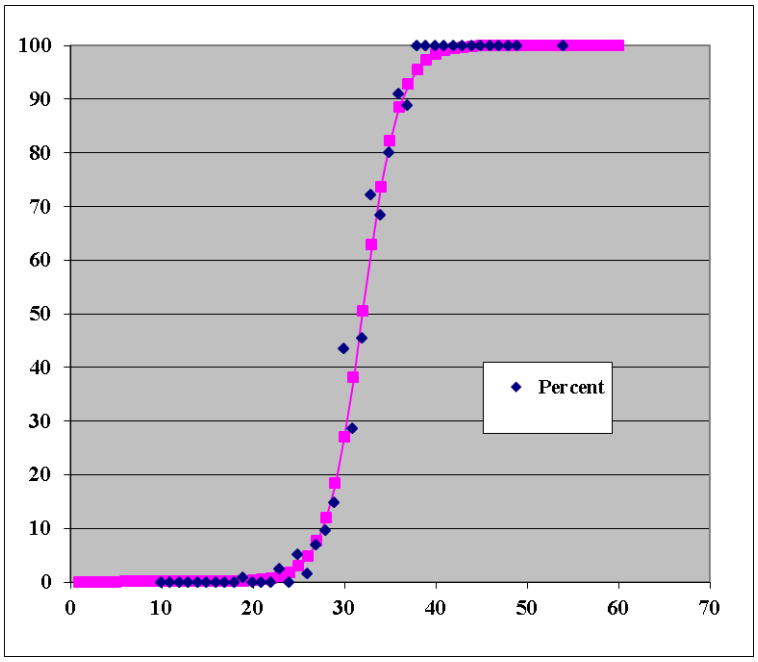


Figure B8. Percent mature at length (cm) of female witch flounder derived from data collected during spring and fall Maine-New Hampshire inshore trawl survey (strata 1-4; regions 1-5). (S. Sherman, ME DMR, pers comm. July 2016)

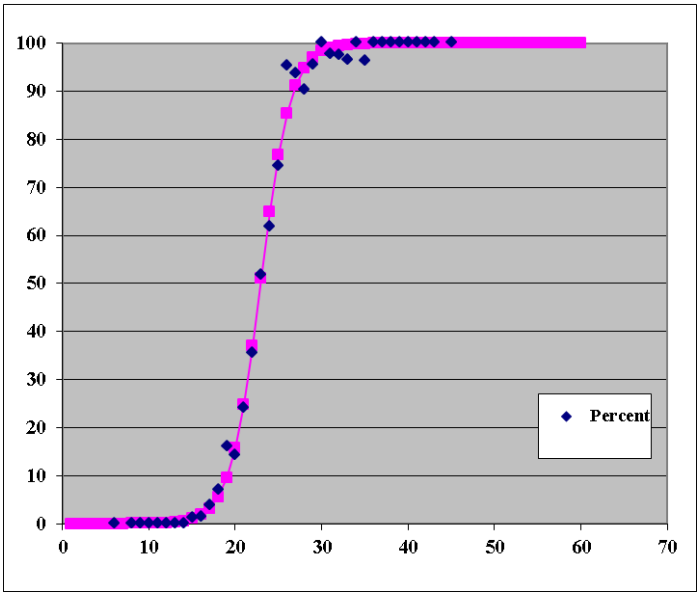
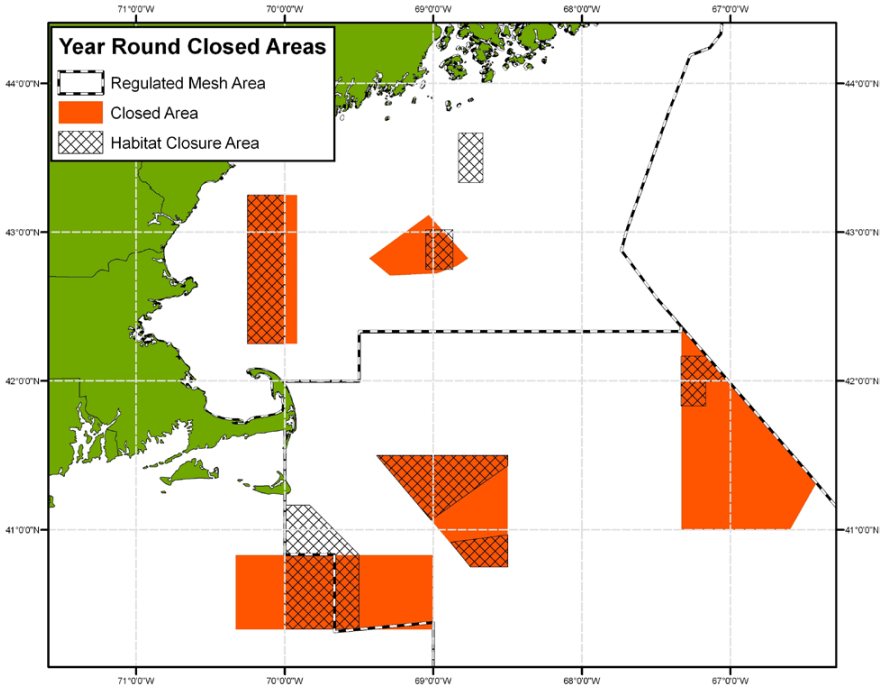


Figure B9. Percent mature at length (cm) of male witch flounder from data collected during spring and fall Maine-New Hampshire inshore trawl survey (strata 1-4; regions 1-5). (S. Sherman, ME DMR, pers comm July 2016)



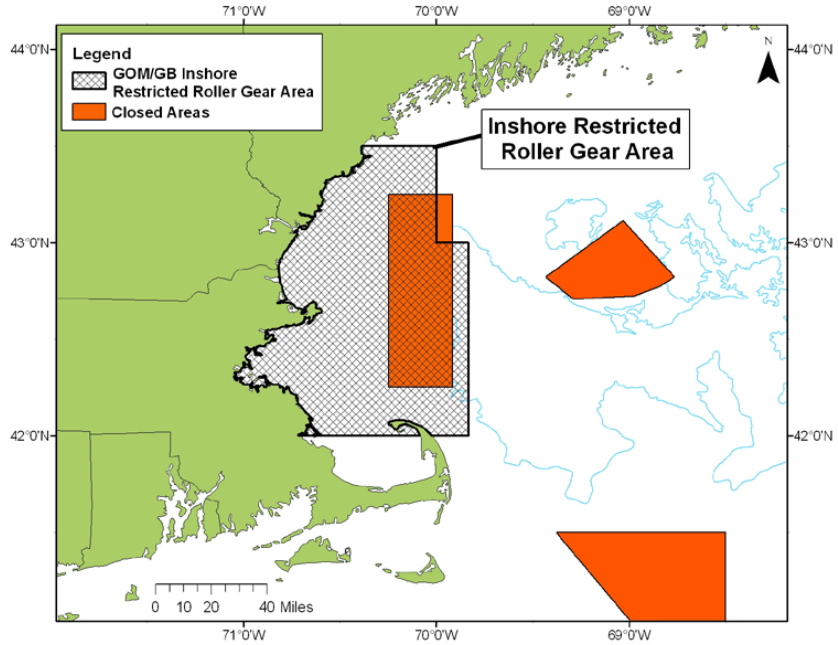


Figure B10. Current (fishing year 2016) year around closed areas (Western Gulf of Maine, Cashes Ledge, Closed Area I, II and Nantucket Lightship Closed Area shown in orange and essential fish habitat areas shown in hatched shading) in the Gulf of Maine and Georges Bank region. Taken from Northeast Multispecies Information Sheet" Closed Area Regulations (April 29, 2016); available online at .
https://www.greateratlantic.fisheries.noaa.gov/regs/infodocs/multsclosedareas.pdf
http://www.greateratlantic.fisheries.noaa.gov/sustainable/species/multispecies/
https://www.greateratlantic.fisheries.noaa.gov/sustainable/species/multispecies/index.html

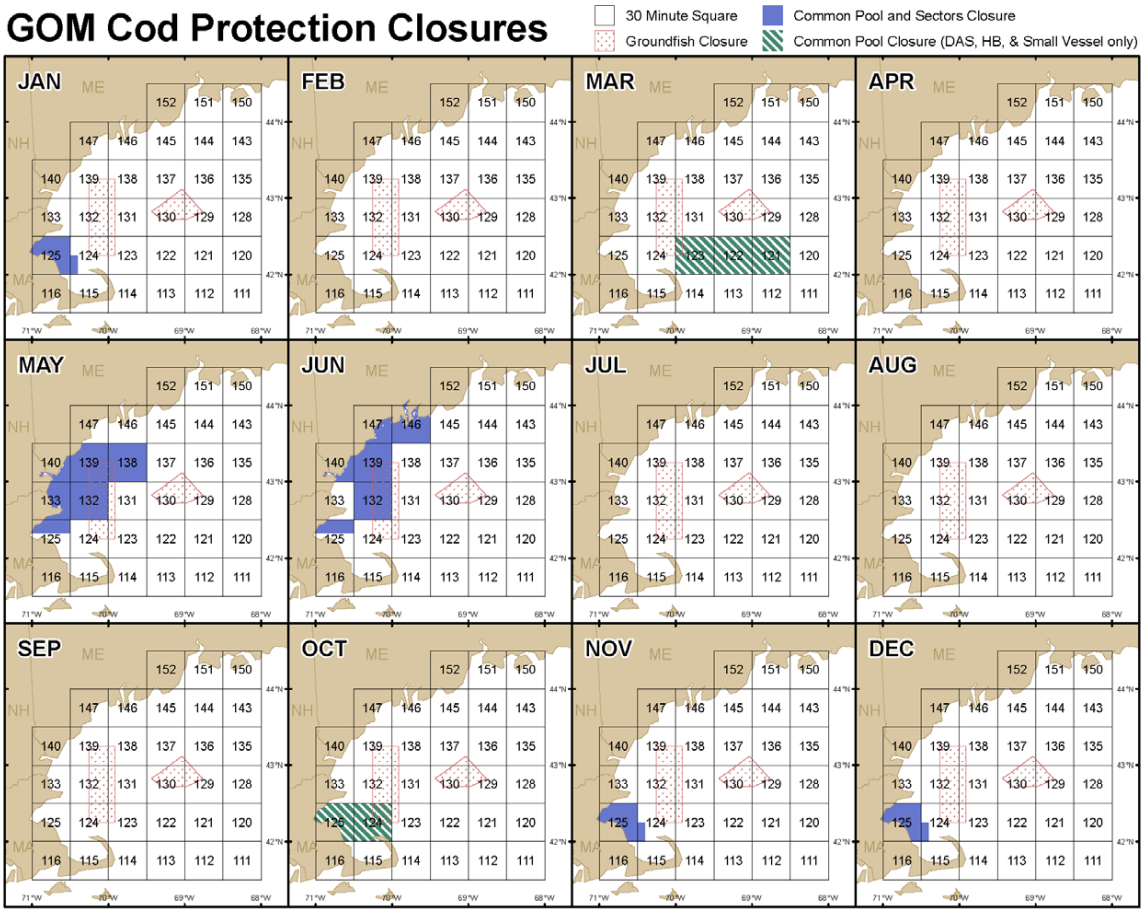


Figure B11. Gulf of Maine cod protection closures in fishing year 2016 to the Northeast Multispecies fishery management plan.

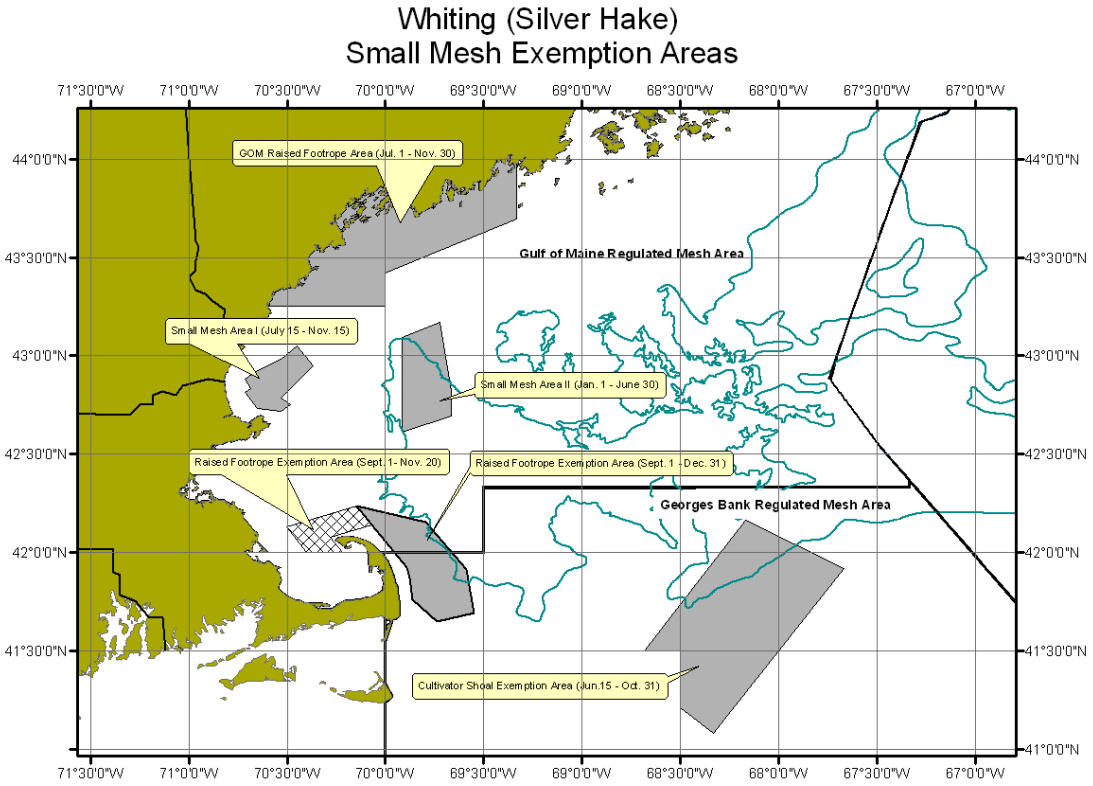


Figure B12. Small mesh exemption area in the Gulf of Maine – Georges Bank region.

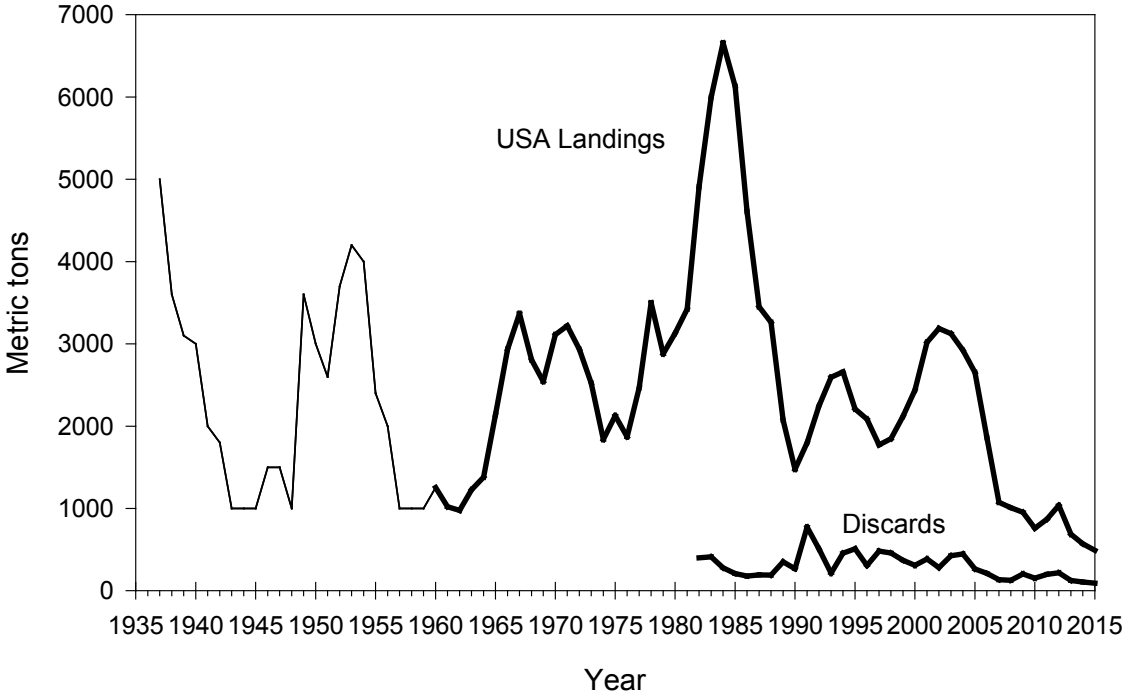


Figure B13. USA witch flounder landings (mt), excluding USA landings from the Grand Banks in the mid-1980's. The thin line represents provisional landings data taken from Lange and Lux (1978). Discards are from the Gulf of Maine shrimp trawl, scallop dredge, gillnet, haddock separator trawl, small-mesh (<5.5 inch) otter trawl and large-mesh (>5.5 inch) otter trawl fisheries.

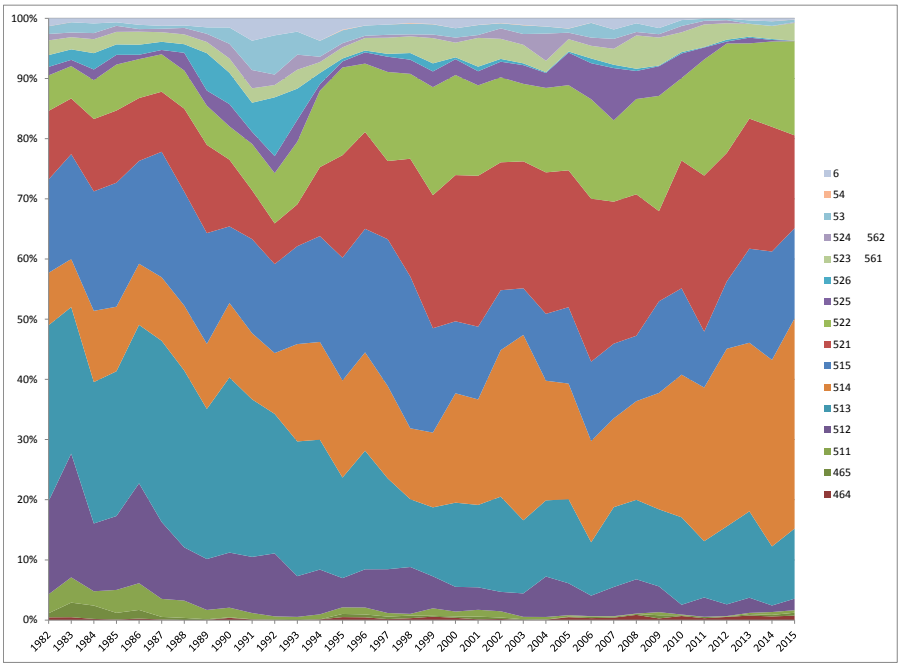


Figure B14. Percentage of witch flounder landings by statistical area, 1982 to 2015.

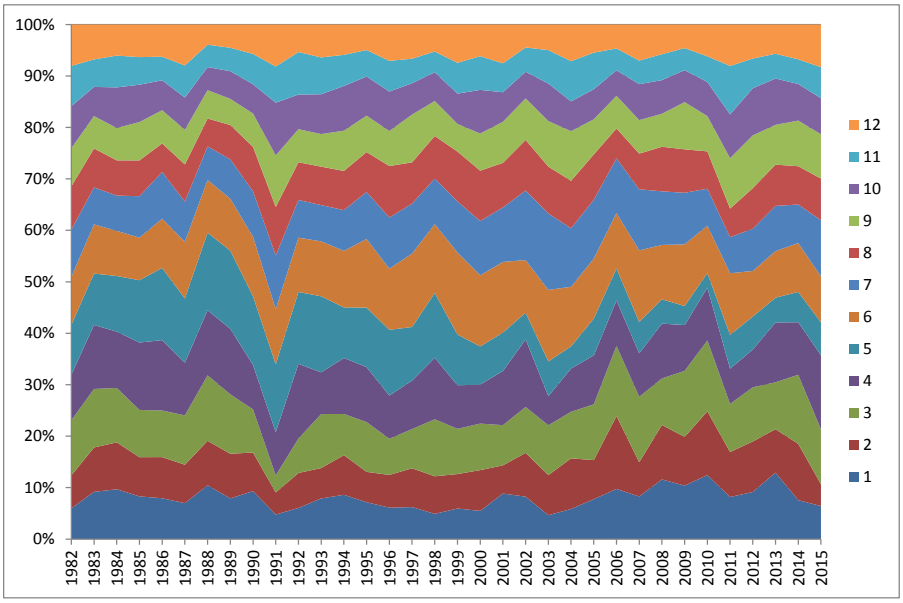


Figure B15. Percentage of witch flounder landings by month, 1982 to 2015.

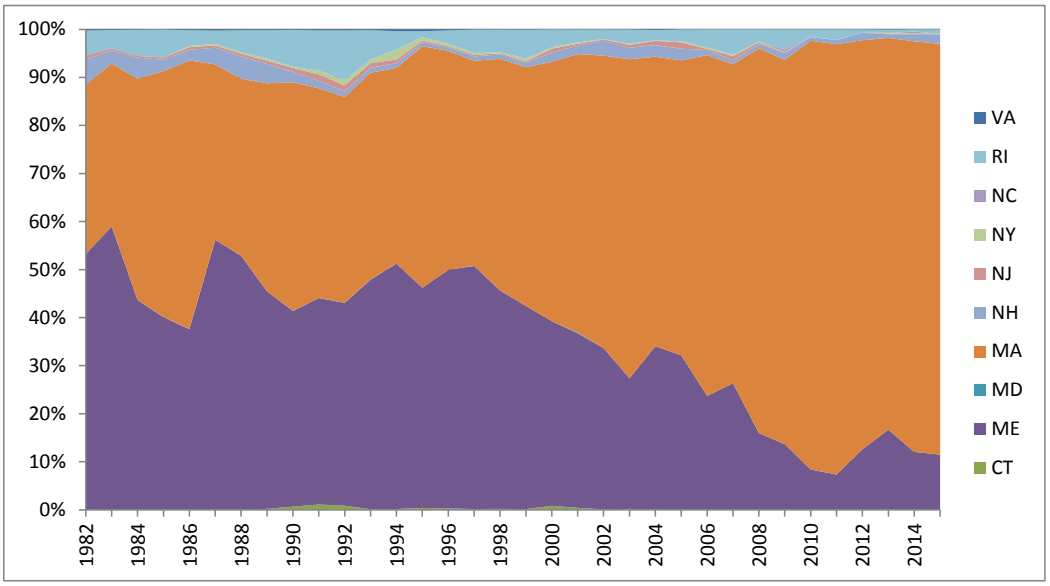


Figure B16. Percentage of witch flounder landings by state, 1982 to 2015.

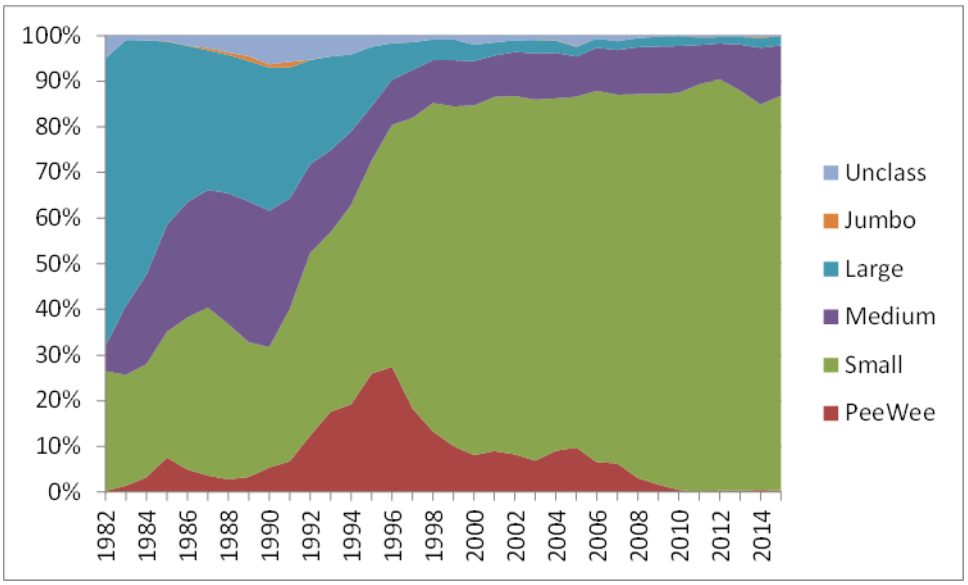


Figure B17. Percentage of witch flounder landings by market category, 1982 to 2015.

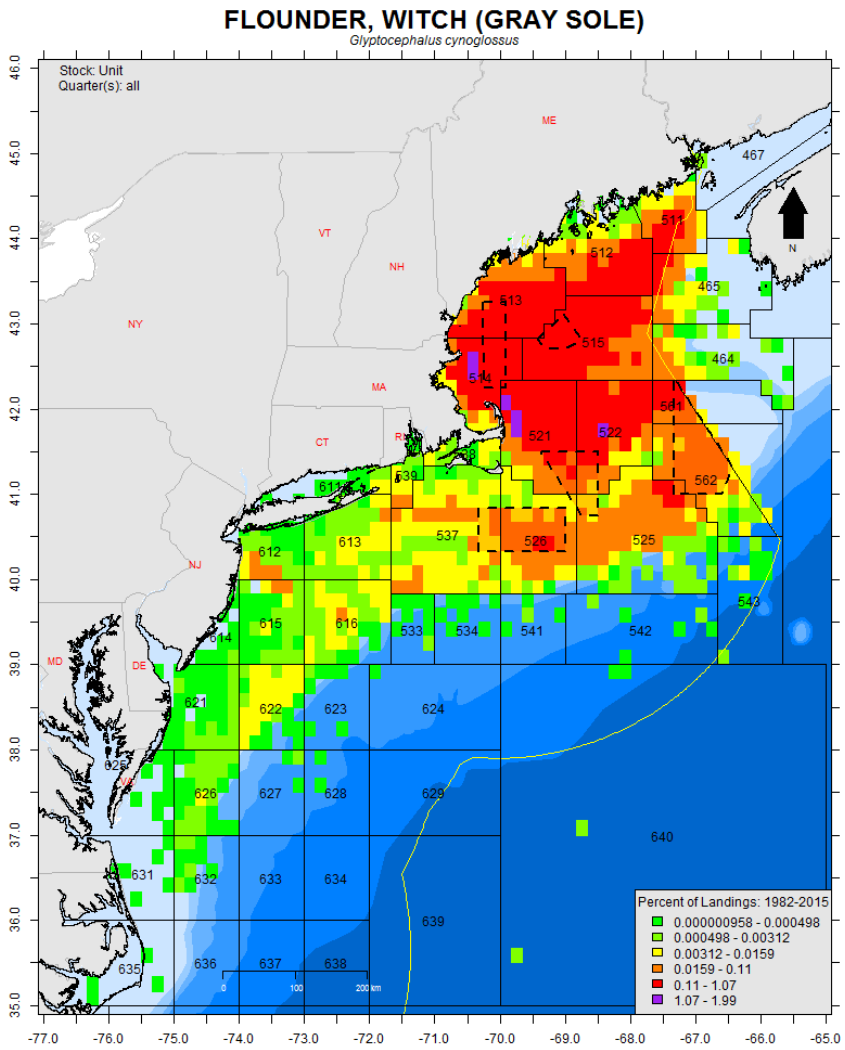


Figure B18. Distribution of commercial landings by ten minute square of latitude/longitude from 1982 – 2015.

This map represents commercial landings for FLOUNDER, WITCH (GRAY SOLE), *Glyptocephalus cynoglossus*. Landings were reported via Dealer reports. Data from 1982 - 1993, have been restricted to interviewed weighout trips (INTV=1), and data from 1994 - 2015 have been restricted to dealer trips matched to a Vessel Trip Report (VTR) (ALEVEL=A) to ensure gear and area information is as accurate as possible.

Landings from all quarters are displayed.

Due to incomplete location data, the map depicts 56.81% of the total catch reported for the species and time frame noted.

Northeast Fisheries Science Center statistical areas are represented by numbered polygons and bathymetry is depicted in blue shading. Groundfish closed areas (dashed borders), and the Exclusive Economic Zone (yellow line) have been overlaid for your reference.

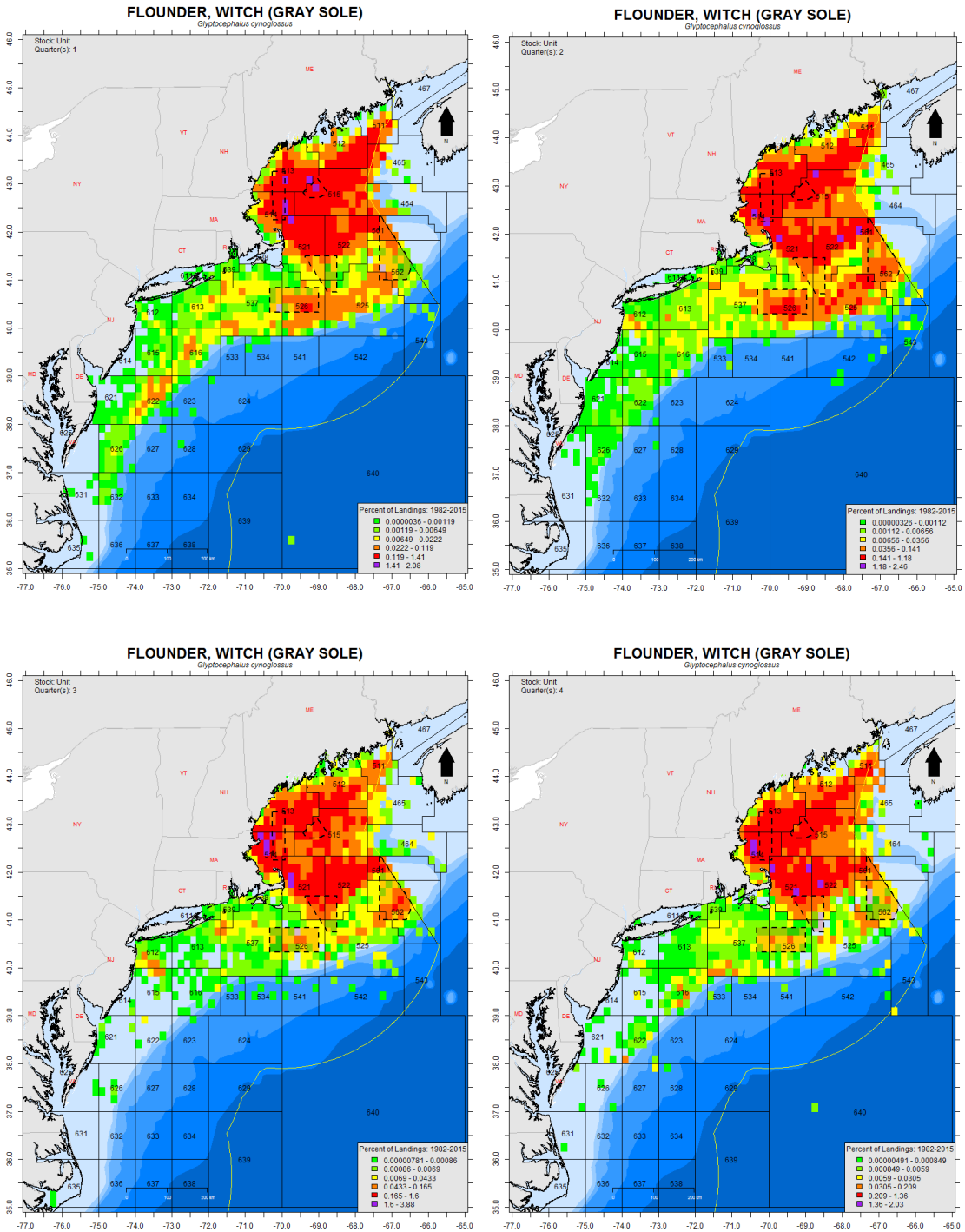


Figure B19. Distribution of witch flounder landing by calendar quarter and ten minute square latitude/longitude with Quarter 1 (top left), Qtr 2 (top right), Qtr 3 (lower left), and Qtr 4 (lower right).

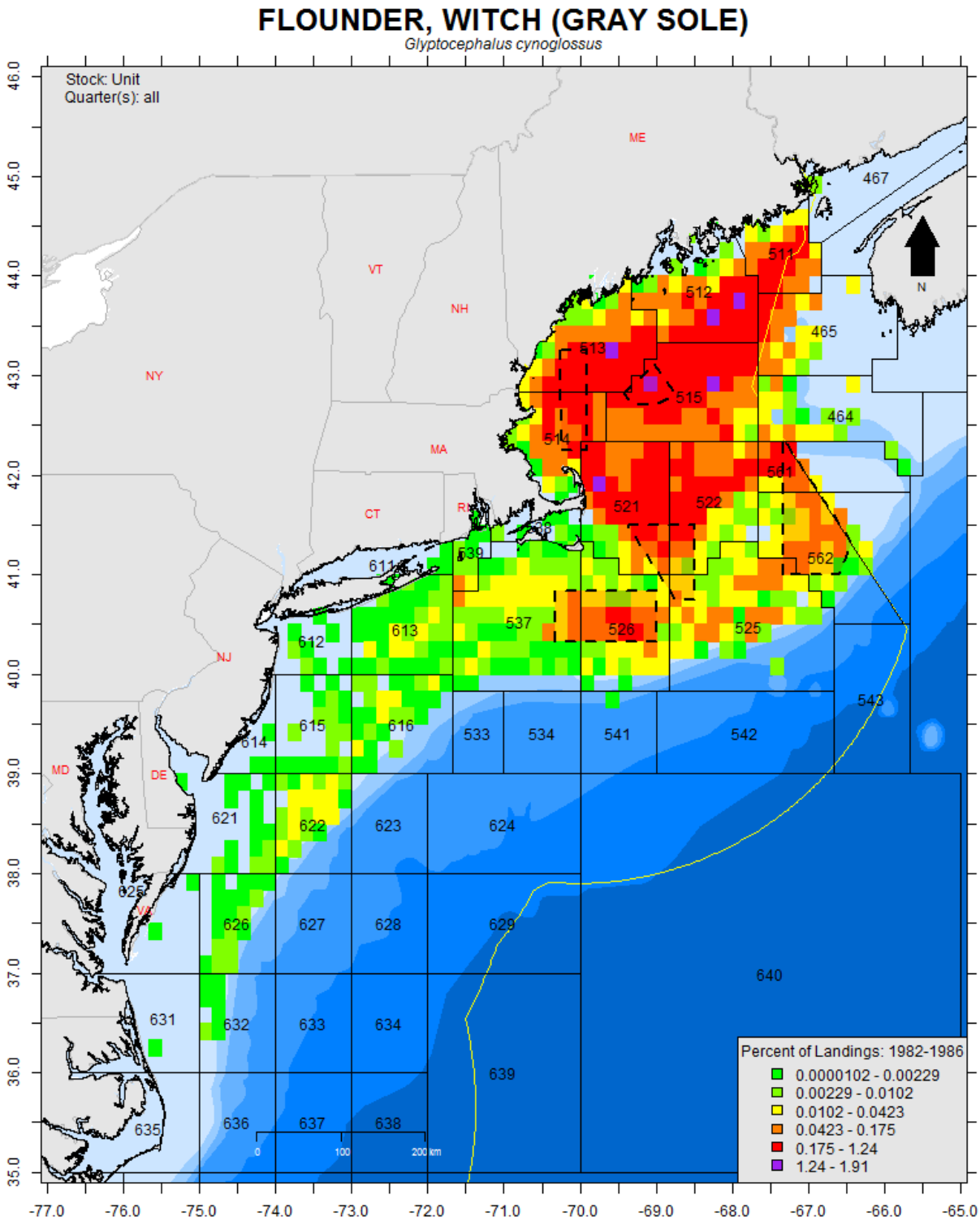


Figure B20. Distribution of witch flounder landing by ten minute square latitude/longitude , 1982 – 1986.

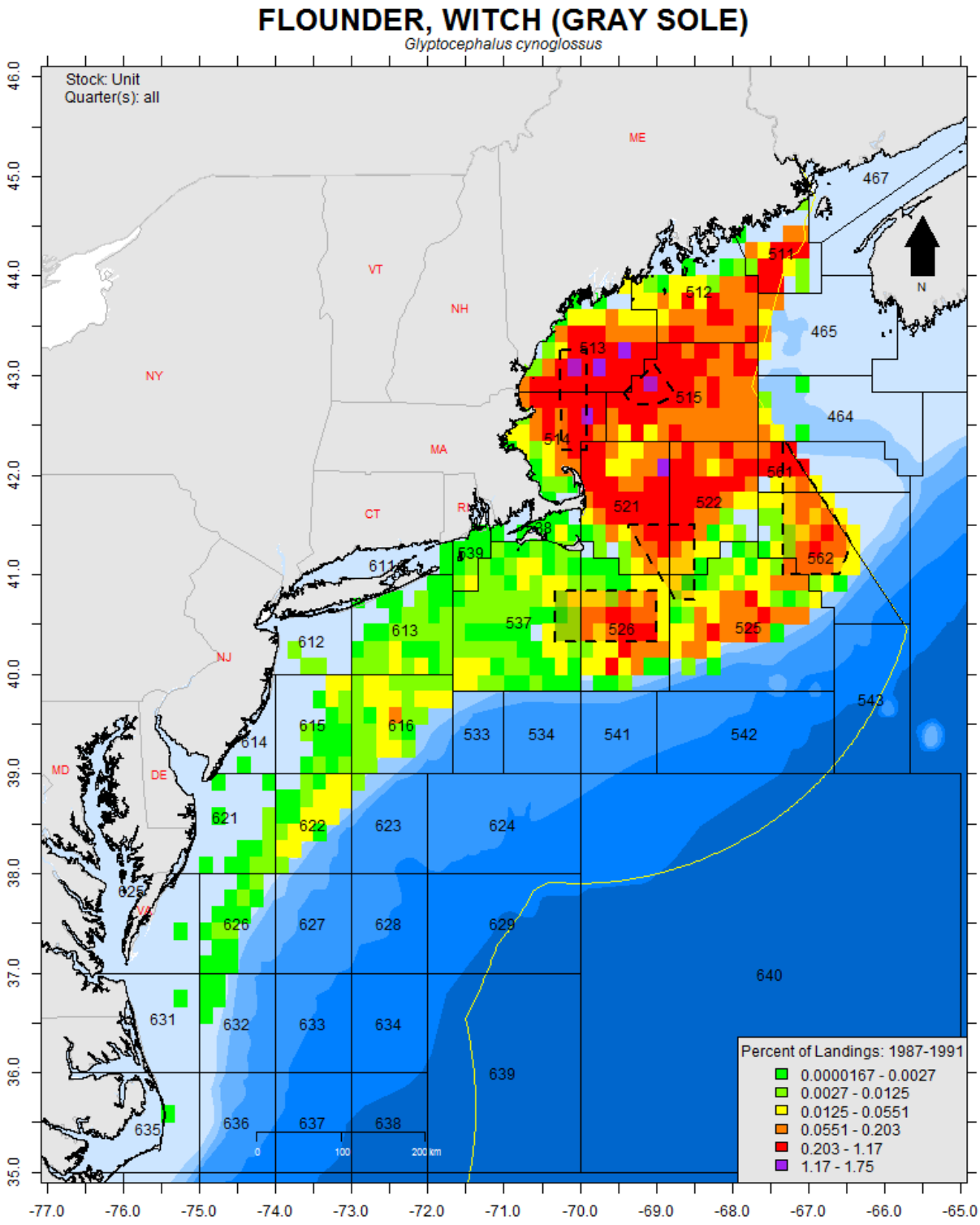


Figure B20 continued. Distribution of witch flounder landing by ten minute square latitude/longitude, 1987 - 1991

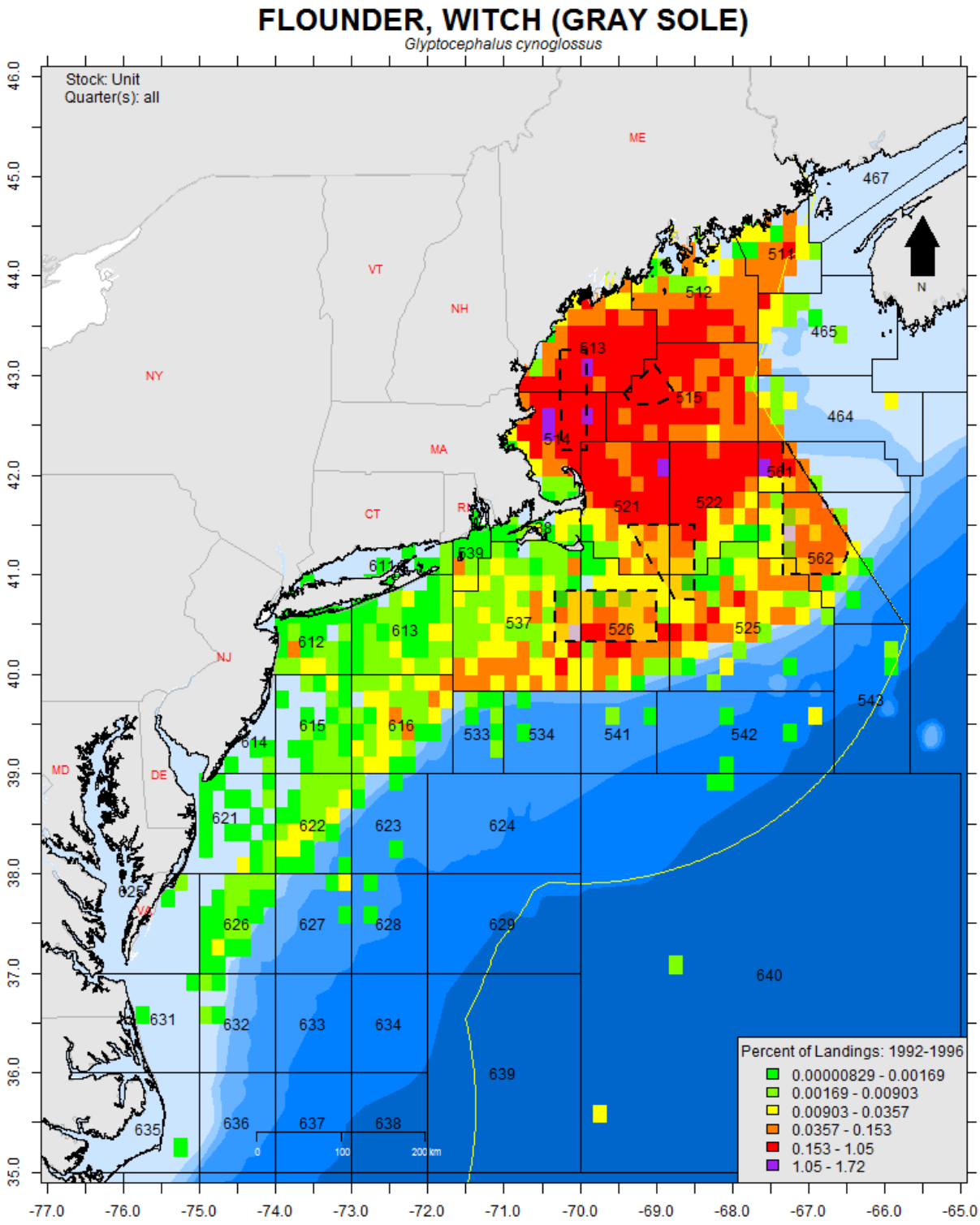


Figure B20 continued. Distribution of witch flounder landing by ten minute square latitude/longitude, 1992 – 1996

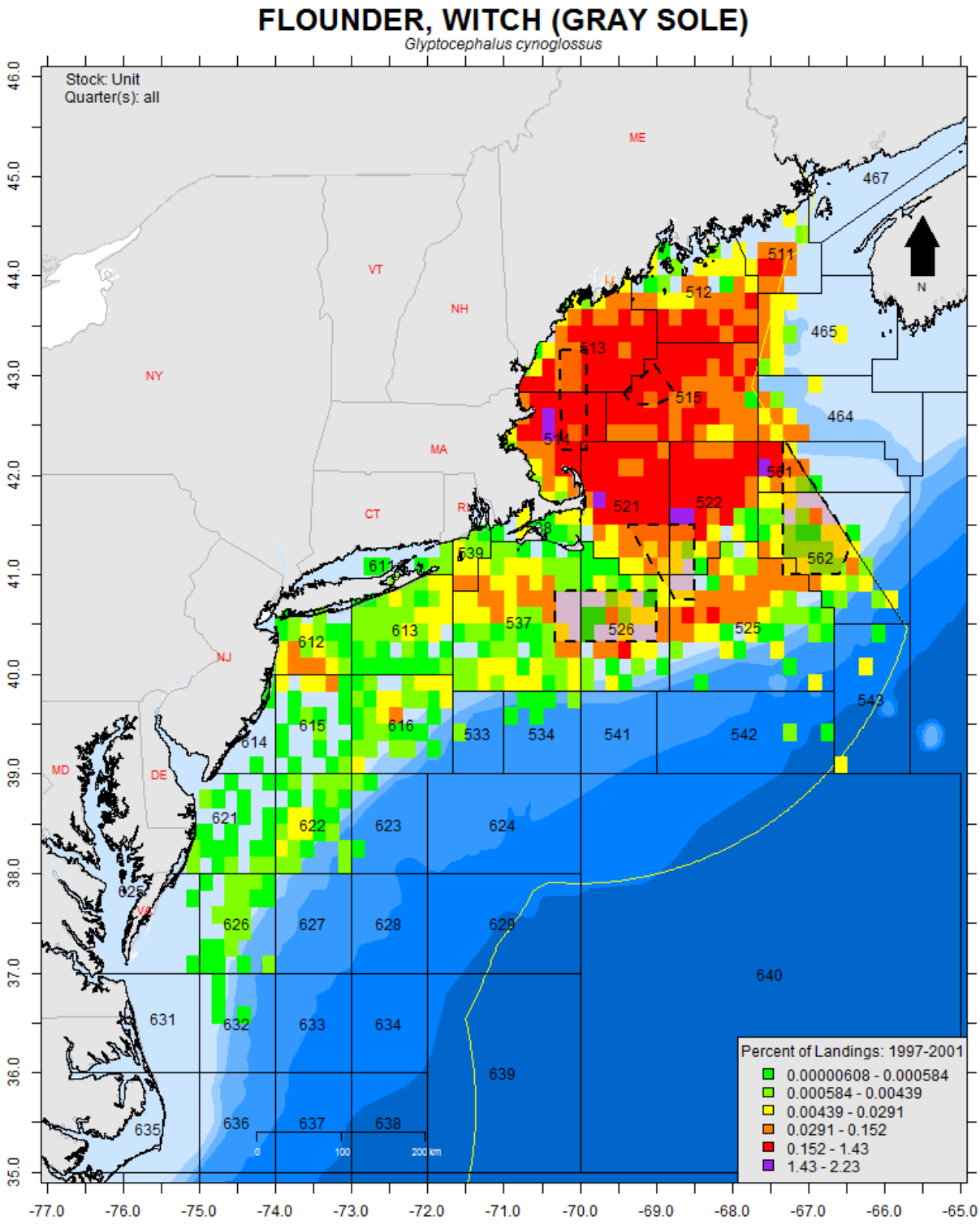


Figure B20 continued. Distribution of witch flounder landing by ten minute square latitude/longitude 1997- 2001.

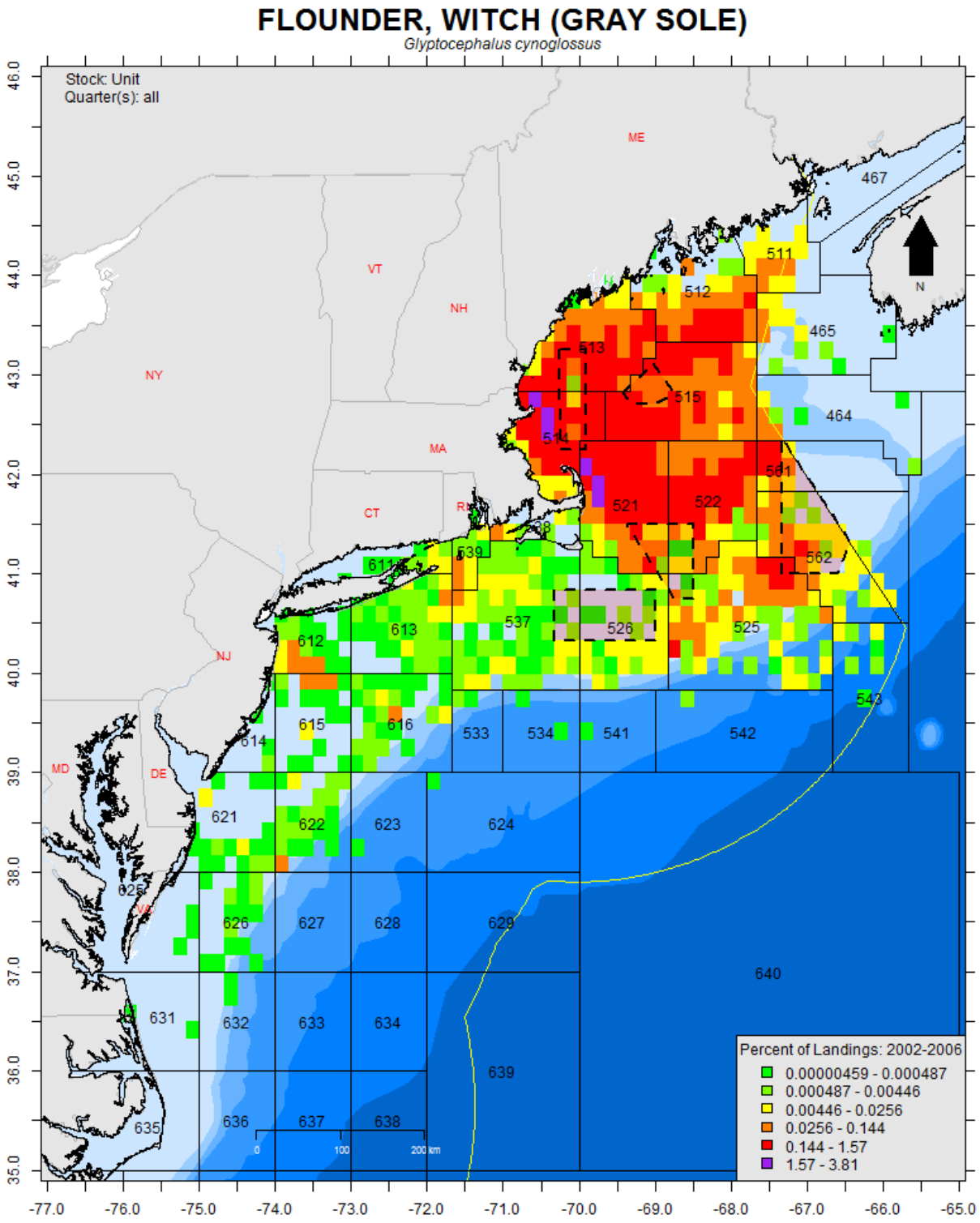


Figure B20 continued. Distribution of witch flounder landing by ten minute square latitude/longitude, 2002-2006.

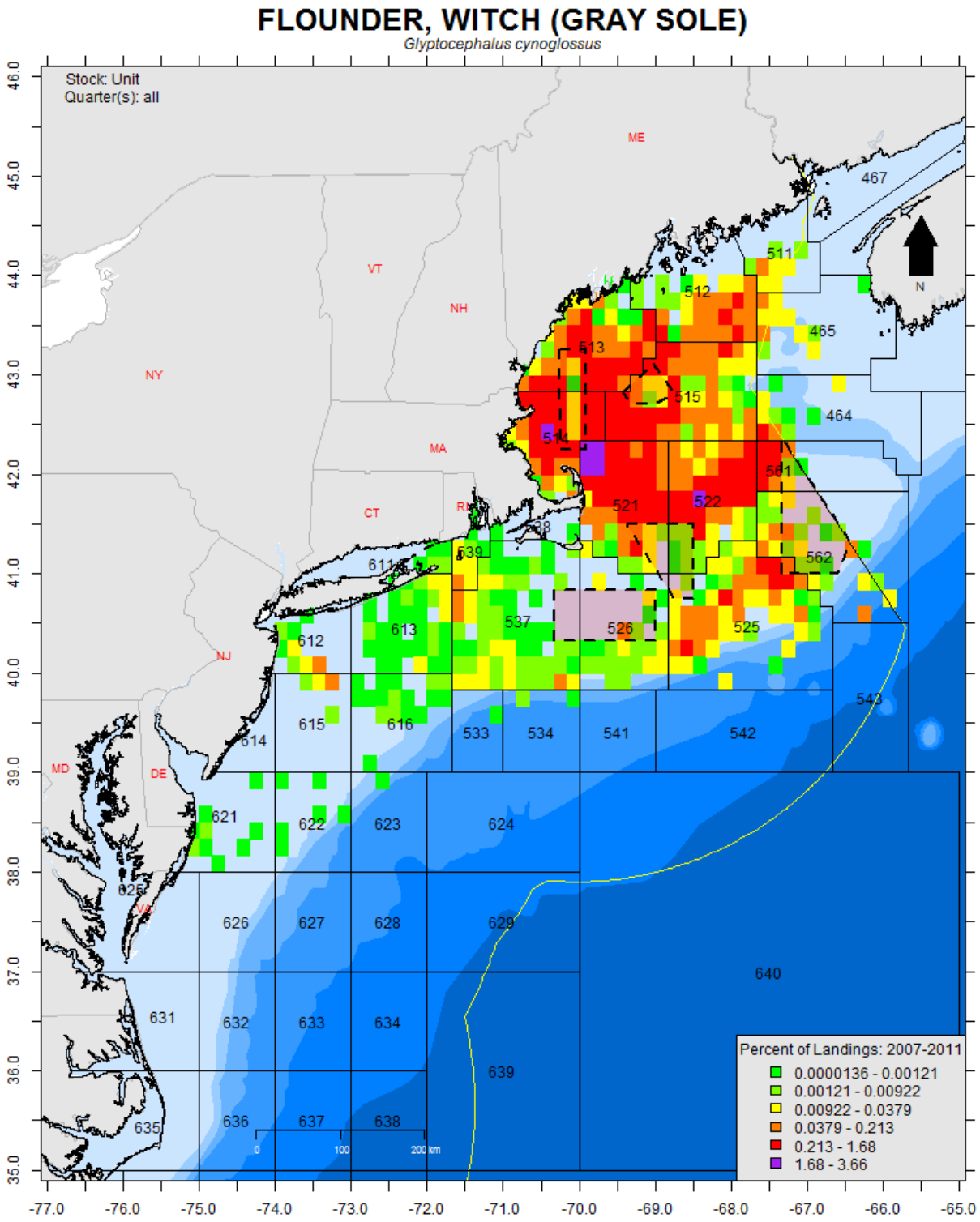


Figure B20 continued. Distribution of witch flounder landing by ten minute square latitude/longitude, 2007-2011.

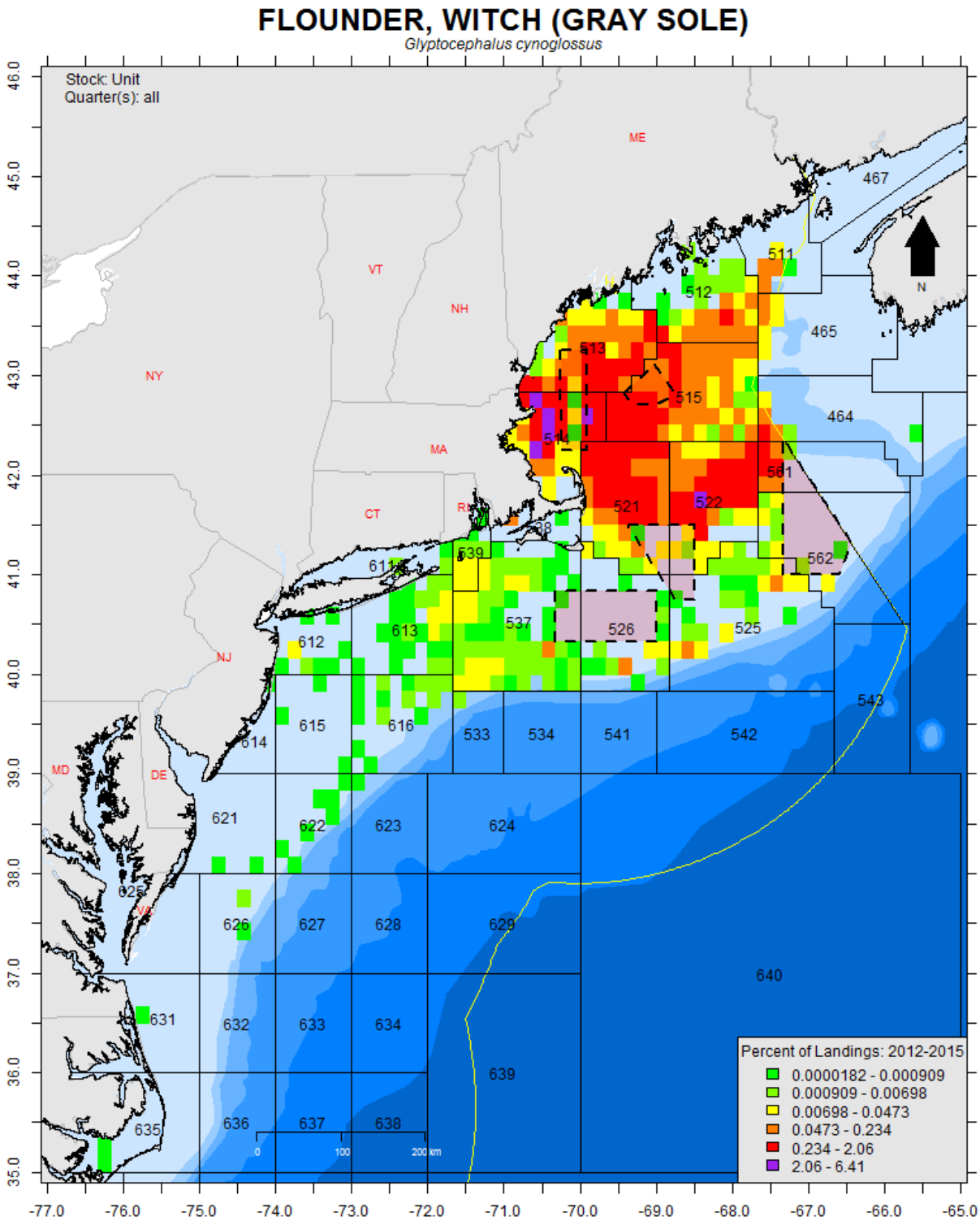


Figure B20 continued. Distribution of witch flounder landing by ten minute square latitude/longitude, 2012 – 2015.

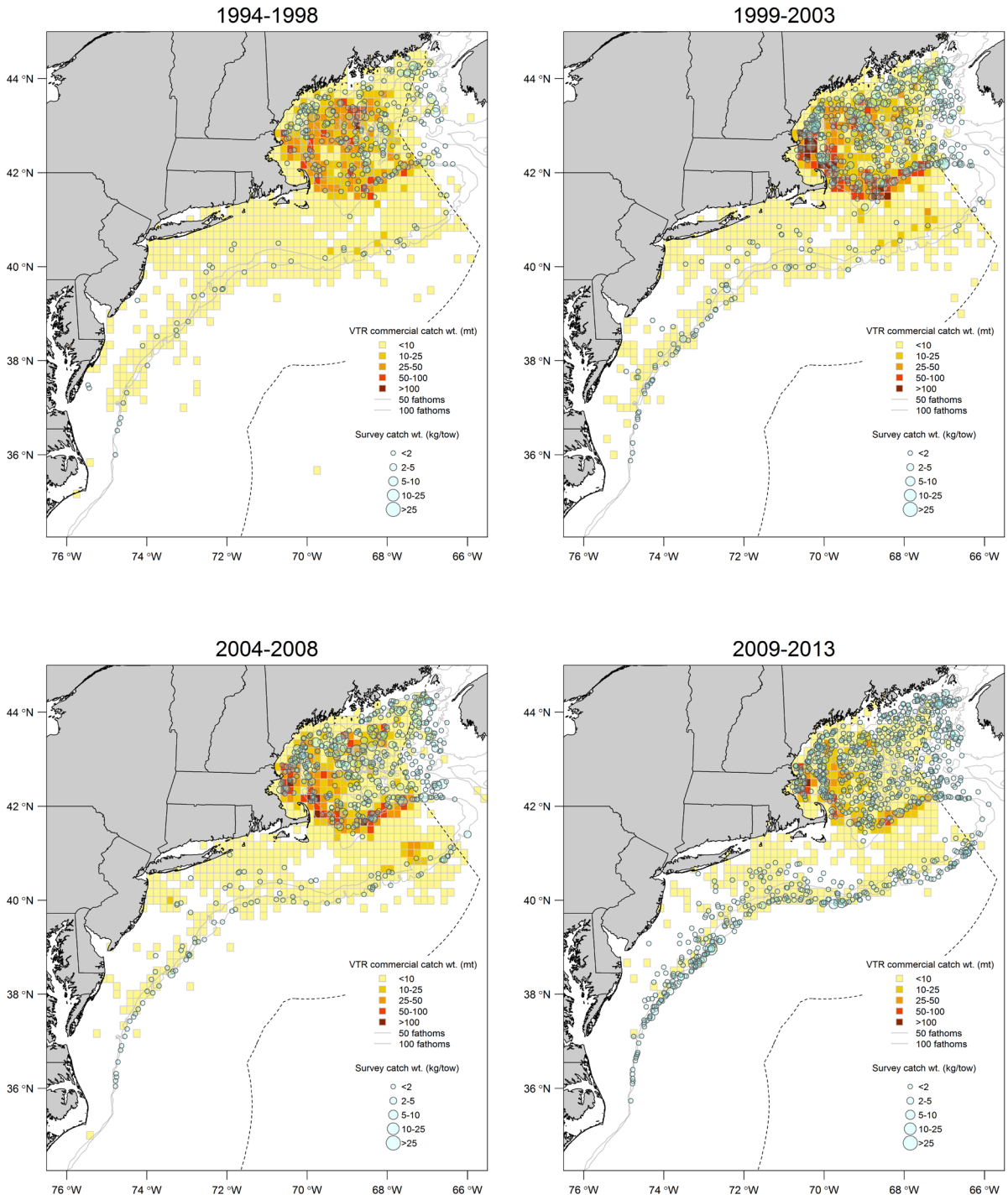


Figure B21. Distribution of commercial trawl catch (landings and discards per trip) as recorded in Vessel Trip Report (VTR) compared with annual Northeast Fisheries Science Center survey catches (kg/tow), by 5-year time blocks (1994-1998, 1999-2003, 2004-2008, 2009-2013; and 2-year block 2014-2015).

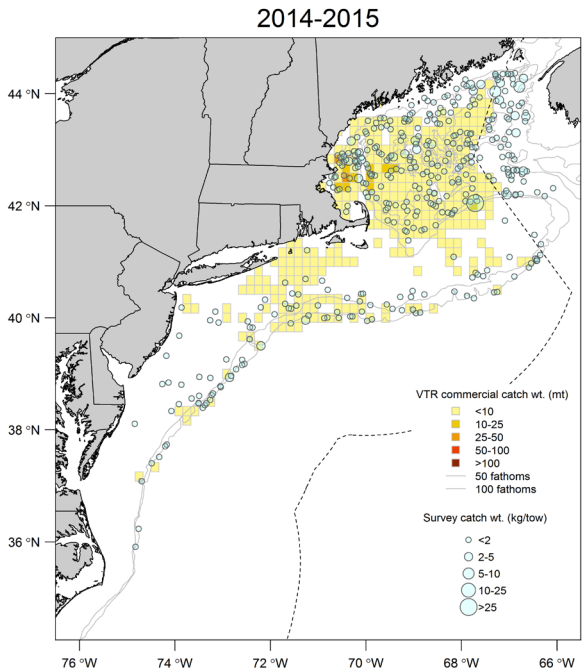


Figure B21, continued. Distribution of commercial trawl catch (landings and discards per trip) as recorded in Vessel Trip Report (VTR) compared with annual Northeast Fisheries Science Center survey catches (kg/tow), by 5-year time blocks.

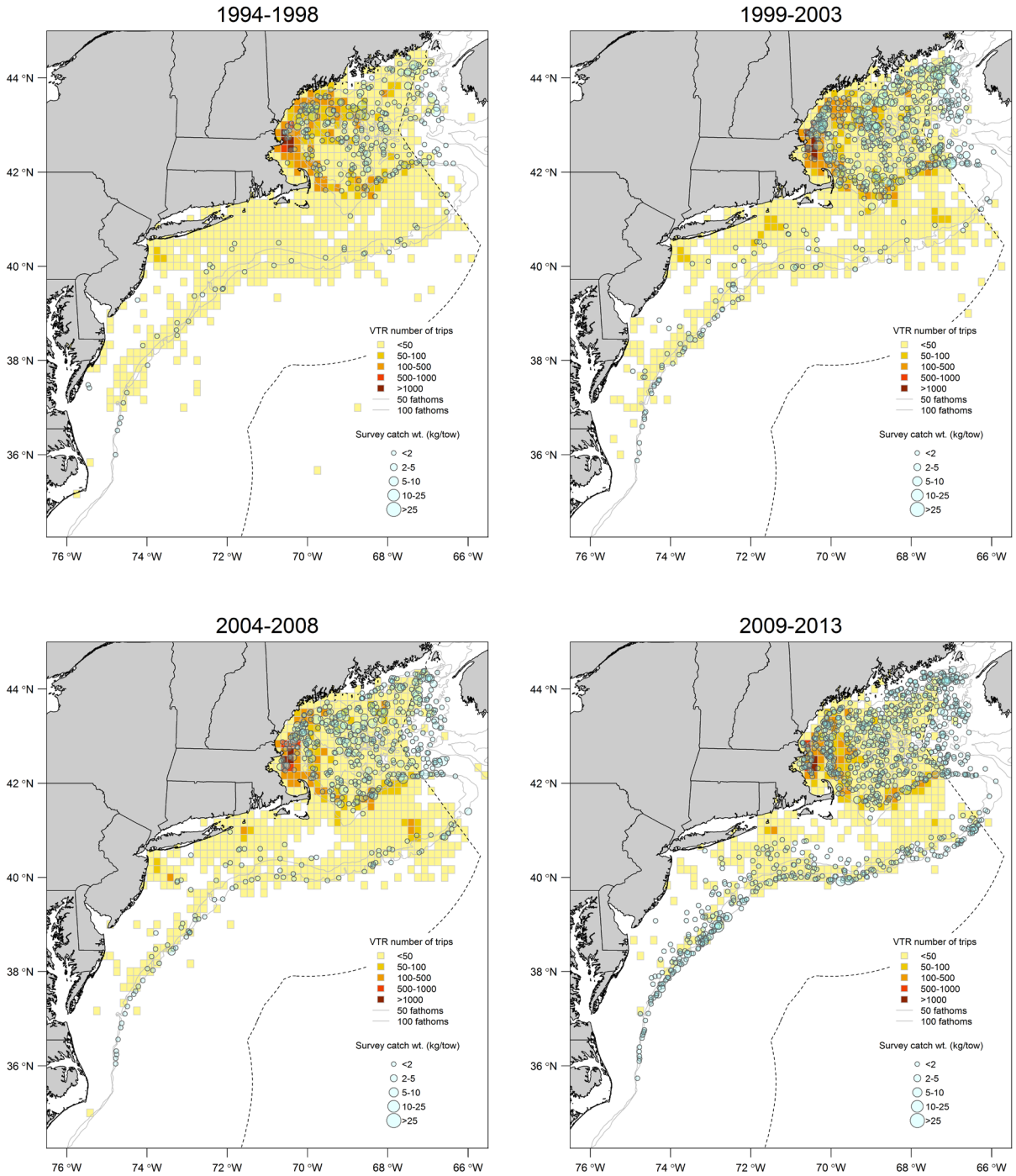


Figure B22. Distribution of commercial trawl trips as recorded in Vessel Trip Report (VTR) compared with annual Northeast Fisheries Science Center survey catches (kg/tow), by 5-year time blocks, (1994-1998, 1999-2003, 2004-2008, 2009-2013; and 2-year block 2014-2015).

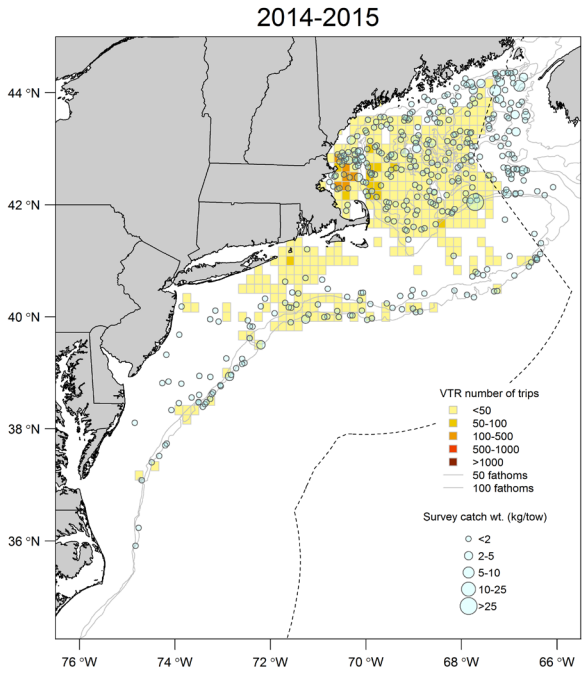


Figure B22, continued. Distribution of commercial trawl trips as recorded in Vessel Trip Report (VTR) compared with annual Northeast Fisheries Science Center survey catches (kg/tow), by 5-year time blocks.

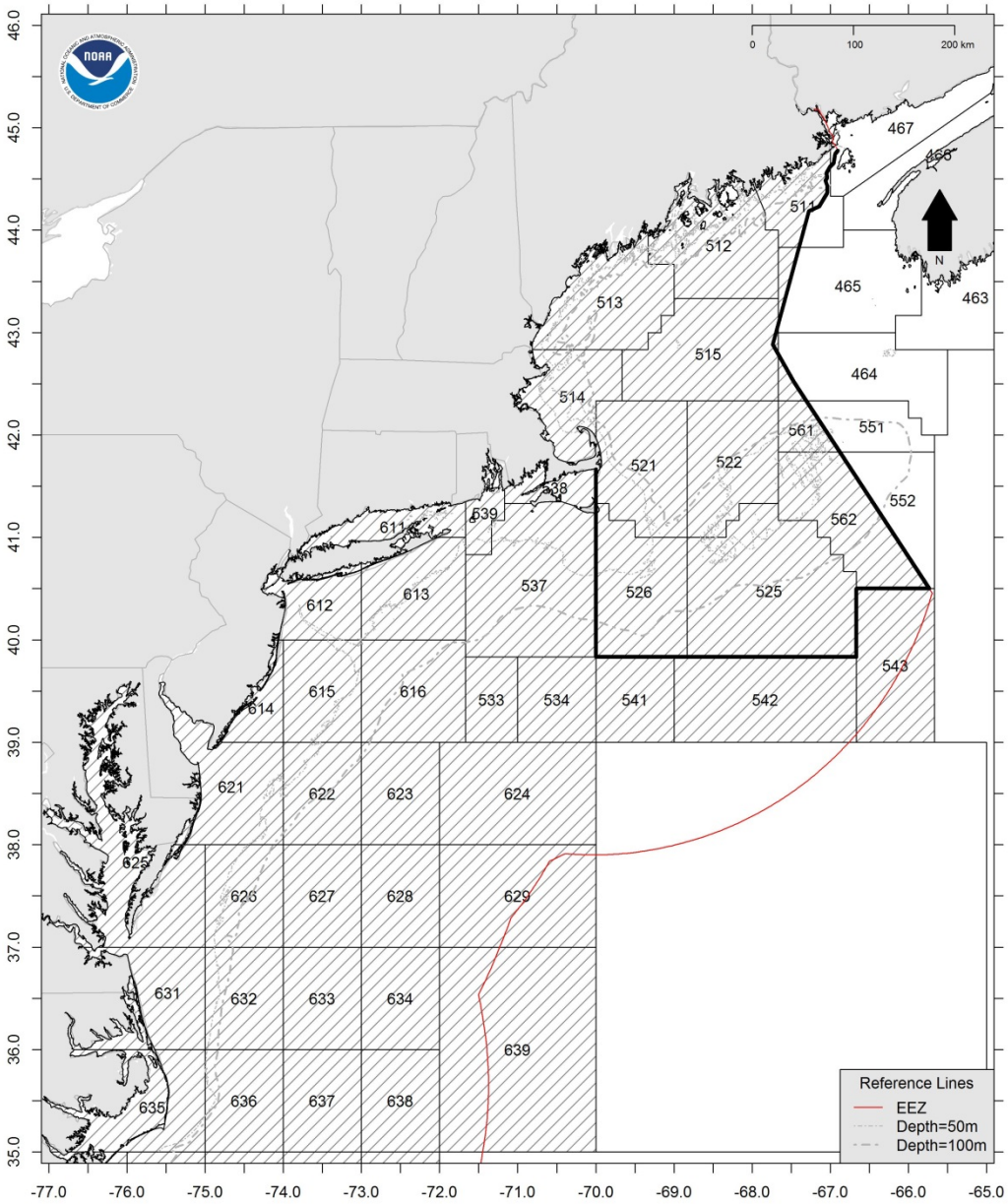


Figure B23. Statistical areas used for reporting commercial fishery statistics. Prior to 1985, statistical areas 551 and 561 comprised statistical area 523 and statistical areas 552 and 562 comprised statistical area 524. Shaded statistical areas indicate witch flounder stock area; Red line represents the U.S. Exclusive Economic Zone; the Gulf of Maine- Georges Bank region (CORE region) is outlined with a bold black line.

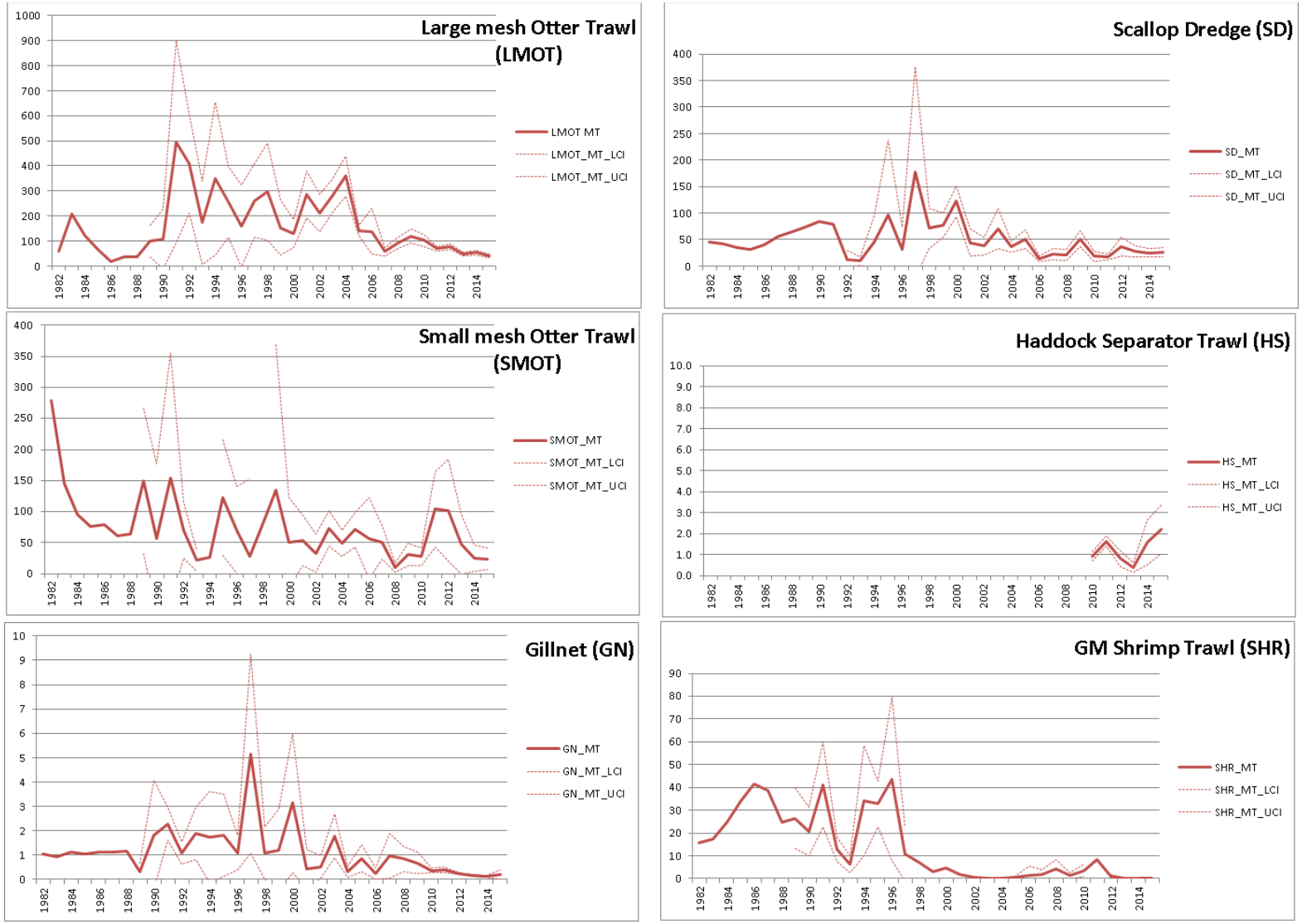


Figure B24. Witch flounder discards, with 95% confidence intervals, for six gear type/mesh groups, 1982 – 2015.

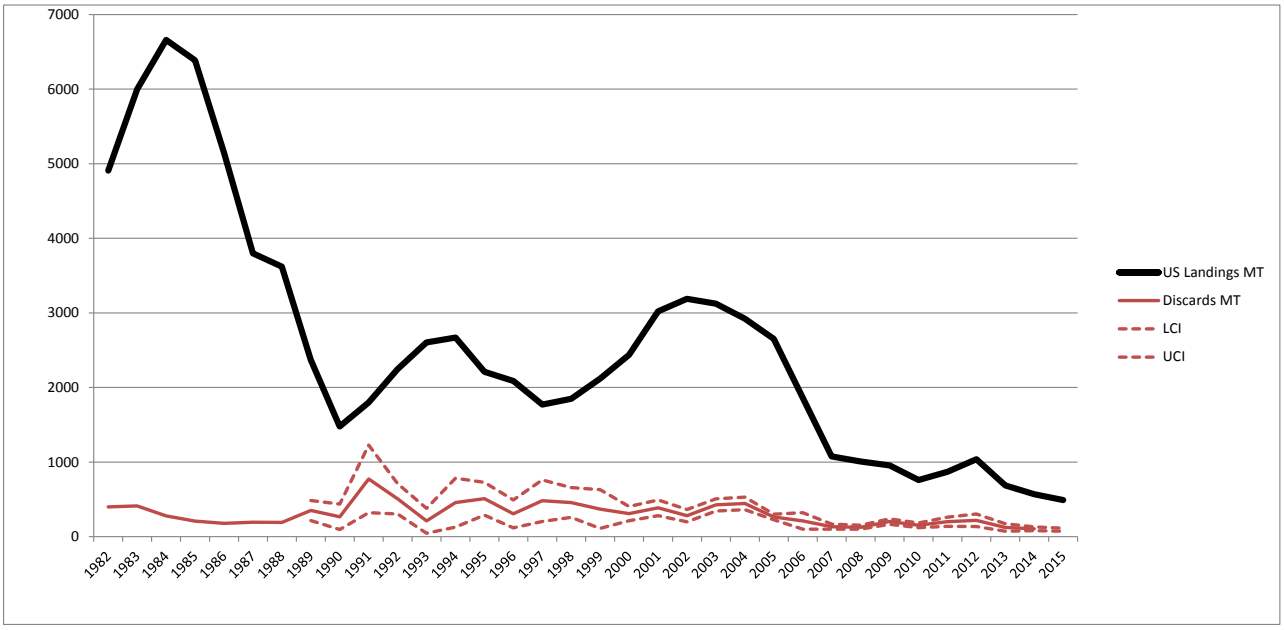


Figure B25. USA landings (mt), excluding USA landings from the Grand Banks in the mid-1980s, and estimated discards with 95% confidential intervals, 1982 - 2015.

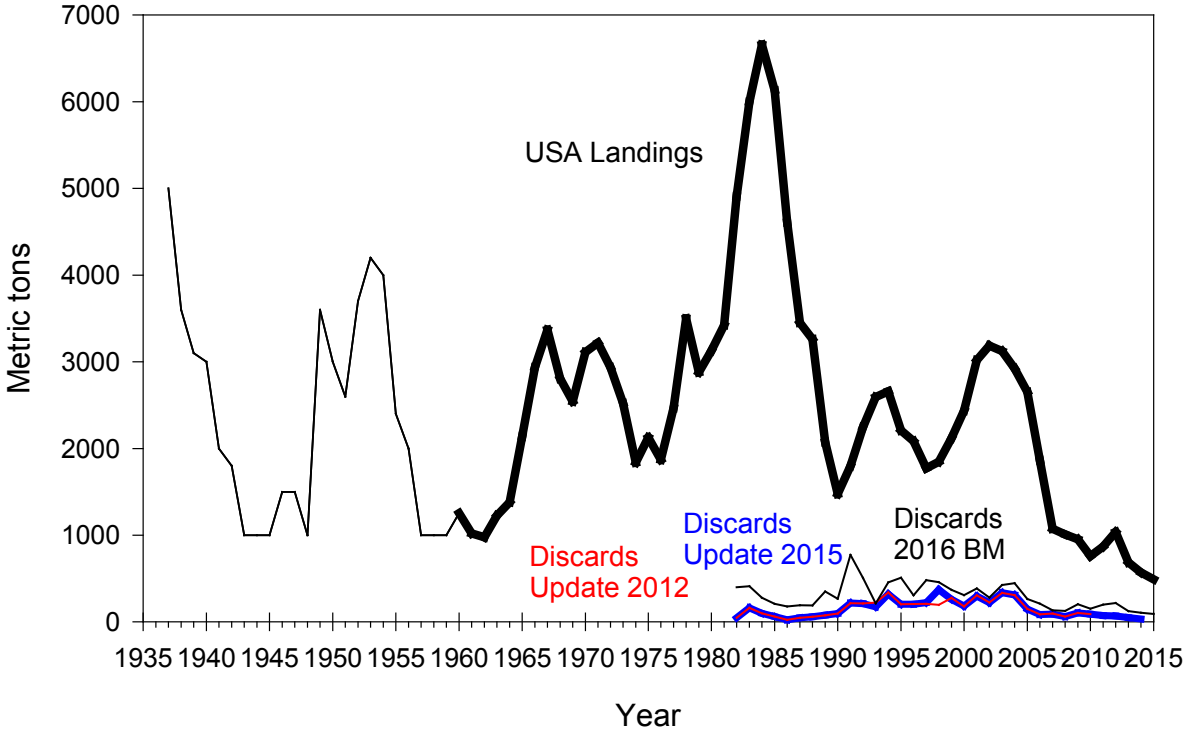


Figure B26. USA witch flounder landings (mt), excluding USA landings from the Grand Banks in the mid-1980's. The thin line represents provisional landings data taken from Lange and Lux (1978). Discards estimated in 2016 (black line) are from six fisheries: shrimp trawl, scallop dredge, gillnet, haddock separator trawl, small-mesh (<5.5 inch) otter trawl and large-mesh (>5.5 inch) otter trawl fisheries; discards estimated for the 2012 Update (red), 2015 Update (blue) are from three fisheries: large mesh otter trawl, small mesh otter trawl and shrimp trawl.

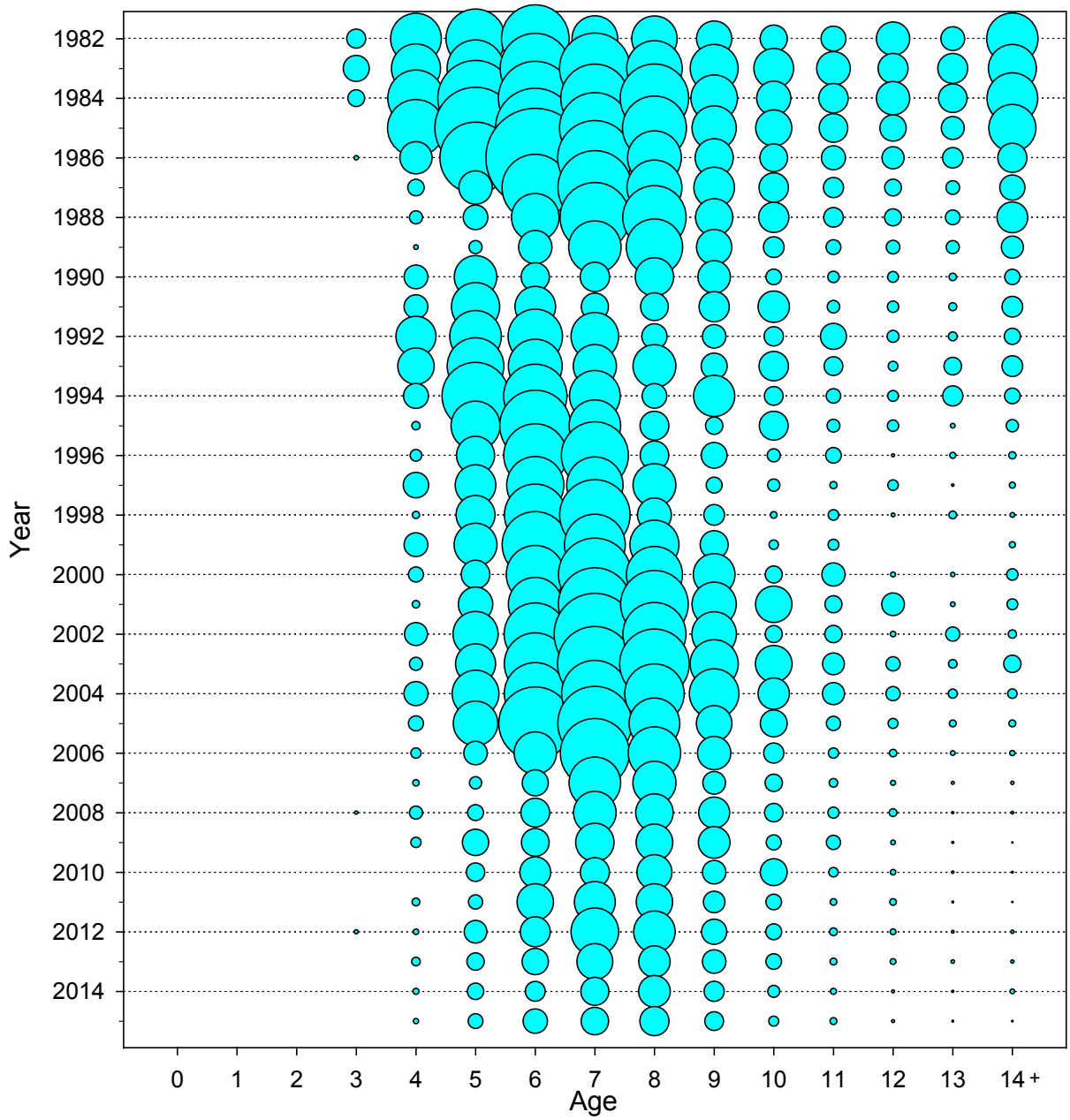


Figure B27. Witch flounder commercial landings at age (in numbers) ages 0 to 14 plus, 1982 to 2015.

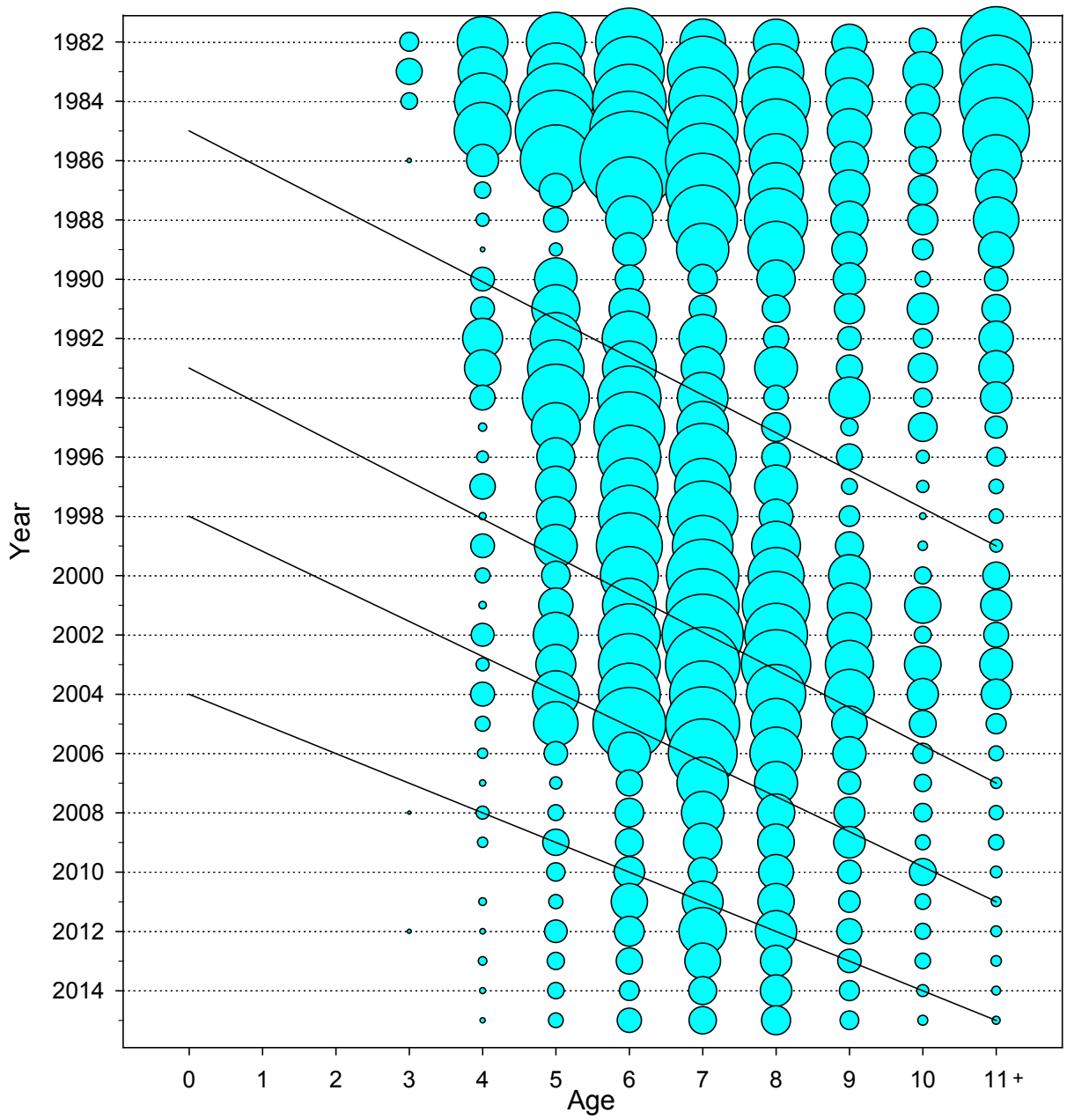


Figure B28. Witch flounder commercial landings at age (in numbers), ages 0 to 11 plus, 1982 to 2015; selected cohorts (1985, 1993, 1998, and 2004 year classes) are indicated with diagonal lines.

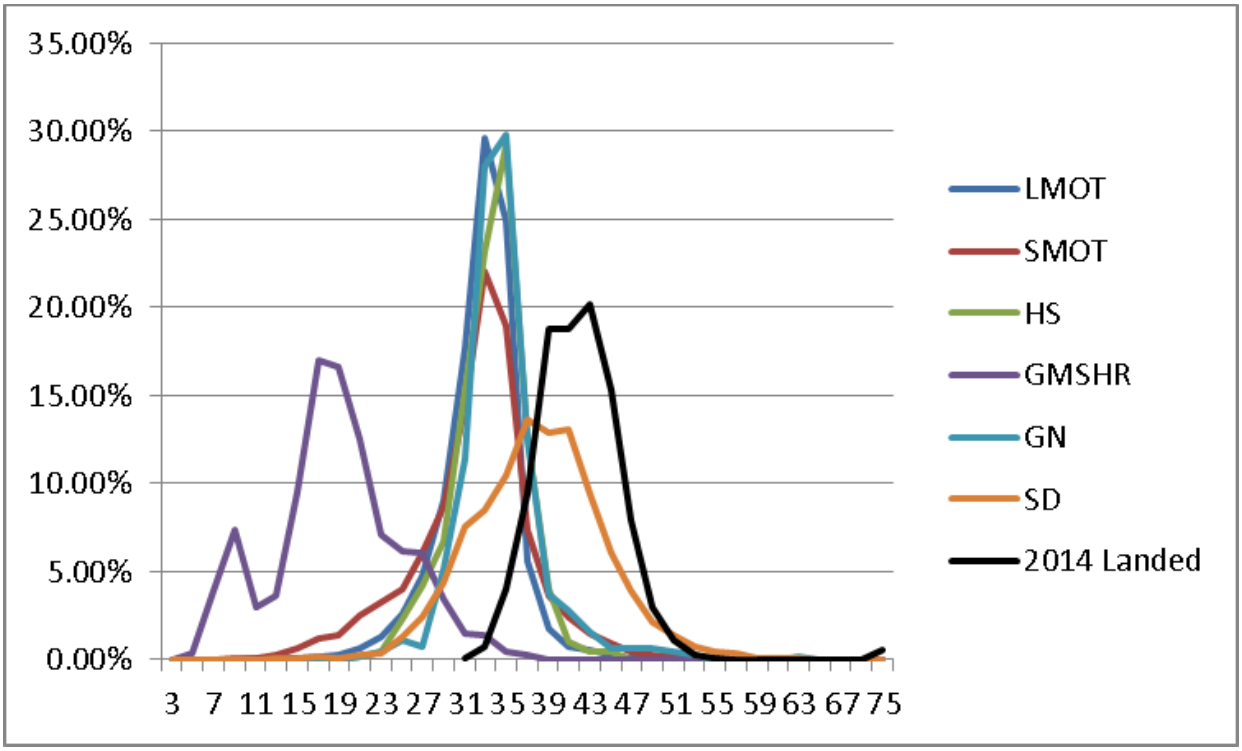


Figure B29. Northeast Fisheries Observer Program proportion at length (cm) of discarded witch flounder for statistical areas in the stock area by six gear types for all years combined. The gear types are: large mesh otter trawl (LMOT), small mesh otter trawl (SMOT), haddock separator trawl (HS), shrimp trawl (GMSHR), gillnet (GN) and scallop dredge (SD). The proportion at length of 2014 landed witch flounder from commercial port sampling is included for reference.

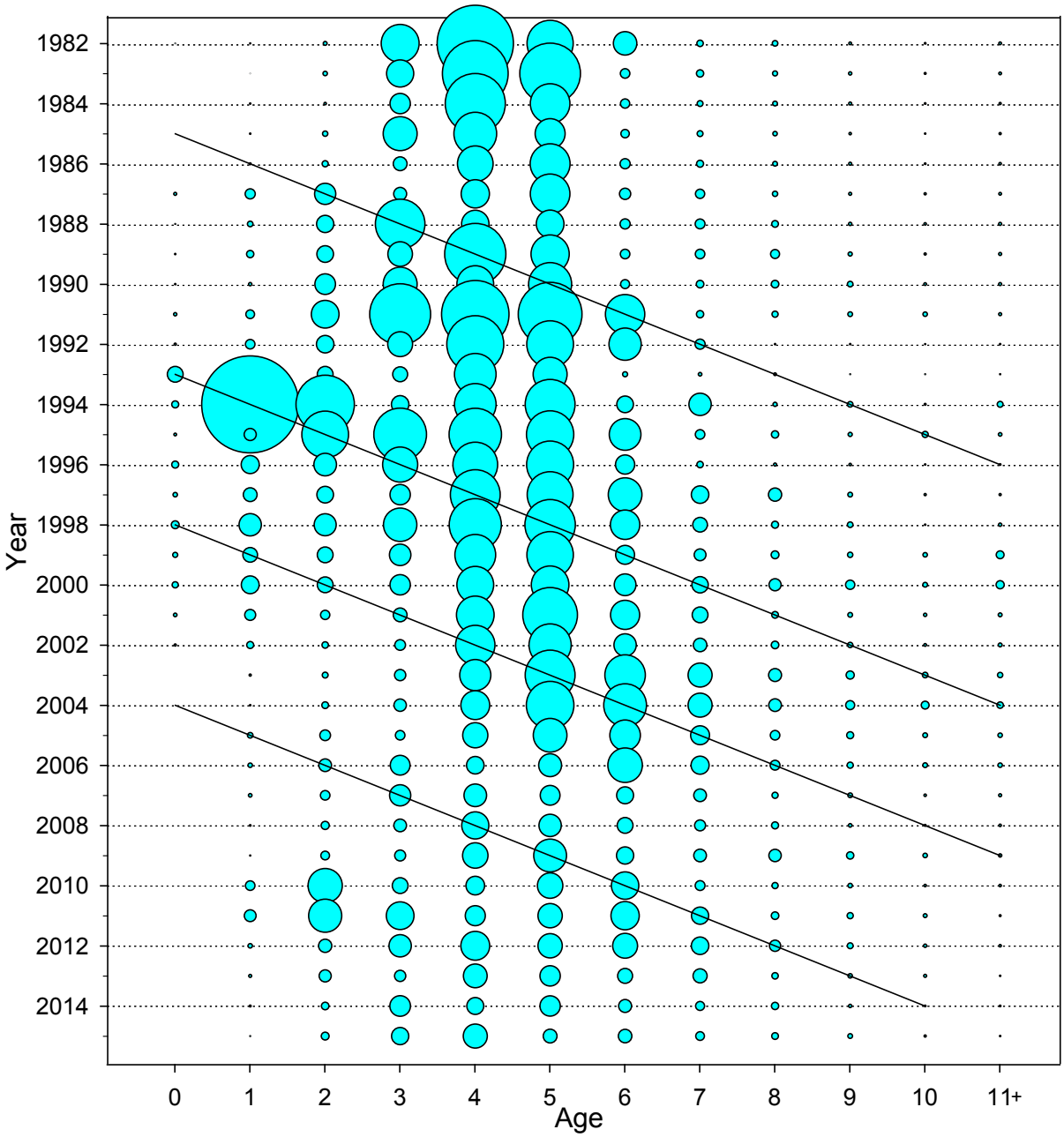


Figure B30. Witch flounder discards at age (in numbers) from six fisheries (large-mesh otter trawl, small mesh otter trawl, Gulf of Maine shrimp trawl, scallop dredge, gillnet, and haddock separator trawl), 1982 to 2015; selected cohorts (1985, 1993, 1998, and 2004 year classes) are indicated with diagonal lines.

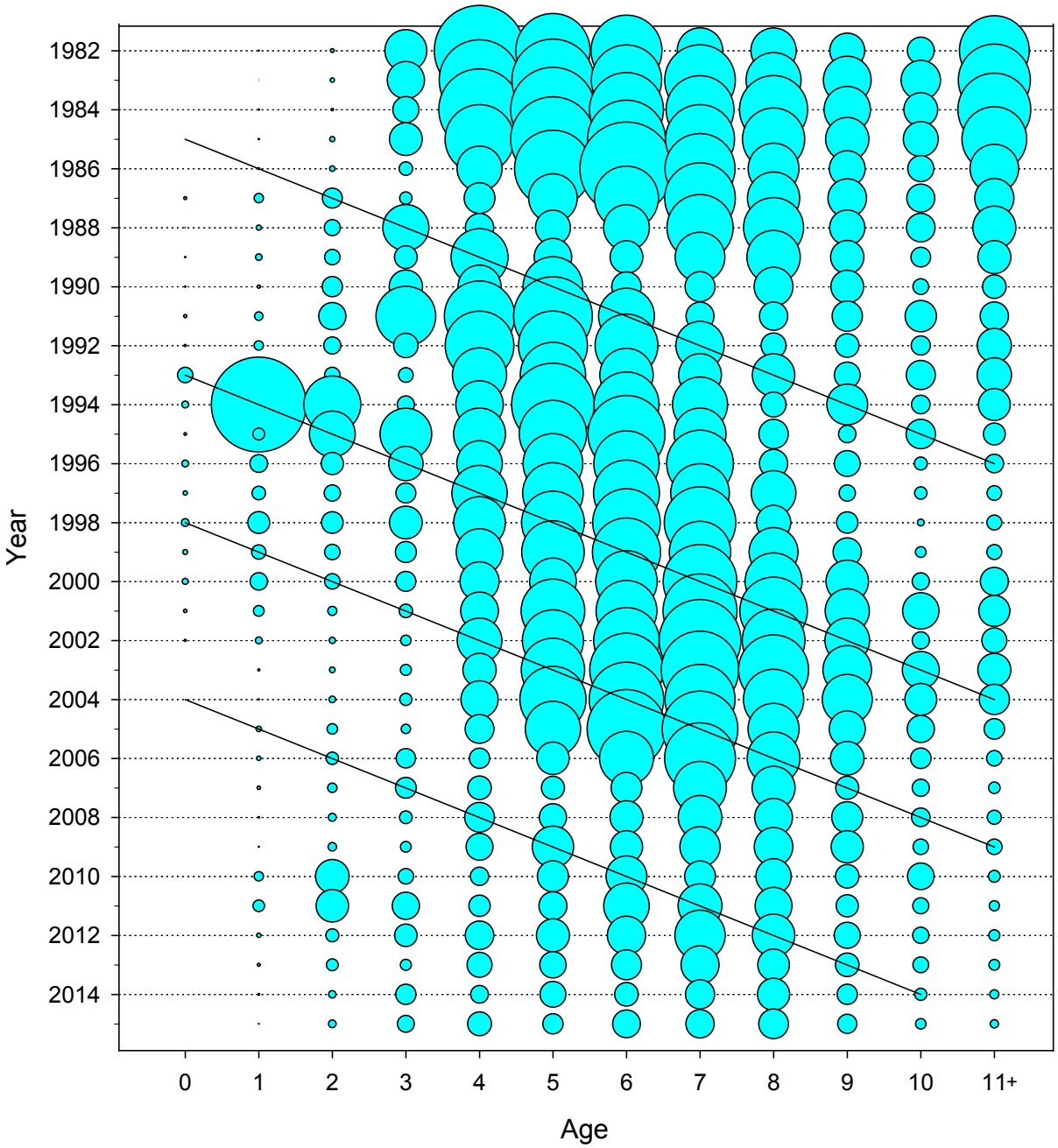


Figure B31. Witch flounder catch at age (in numbers), 1982-2015; selected cohorts (1985, 1993, 1998, and 2004 year classes) are indicated with diagonal lines.

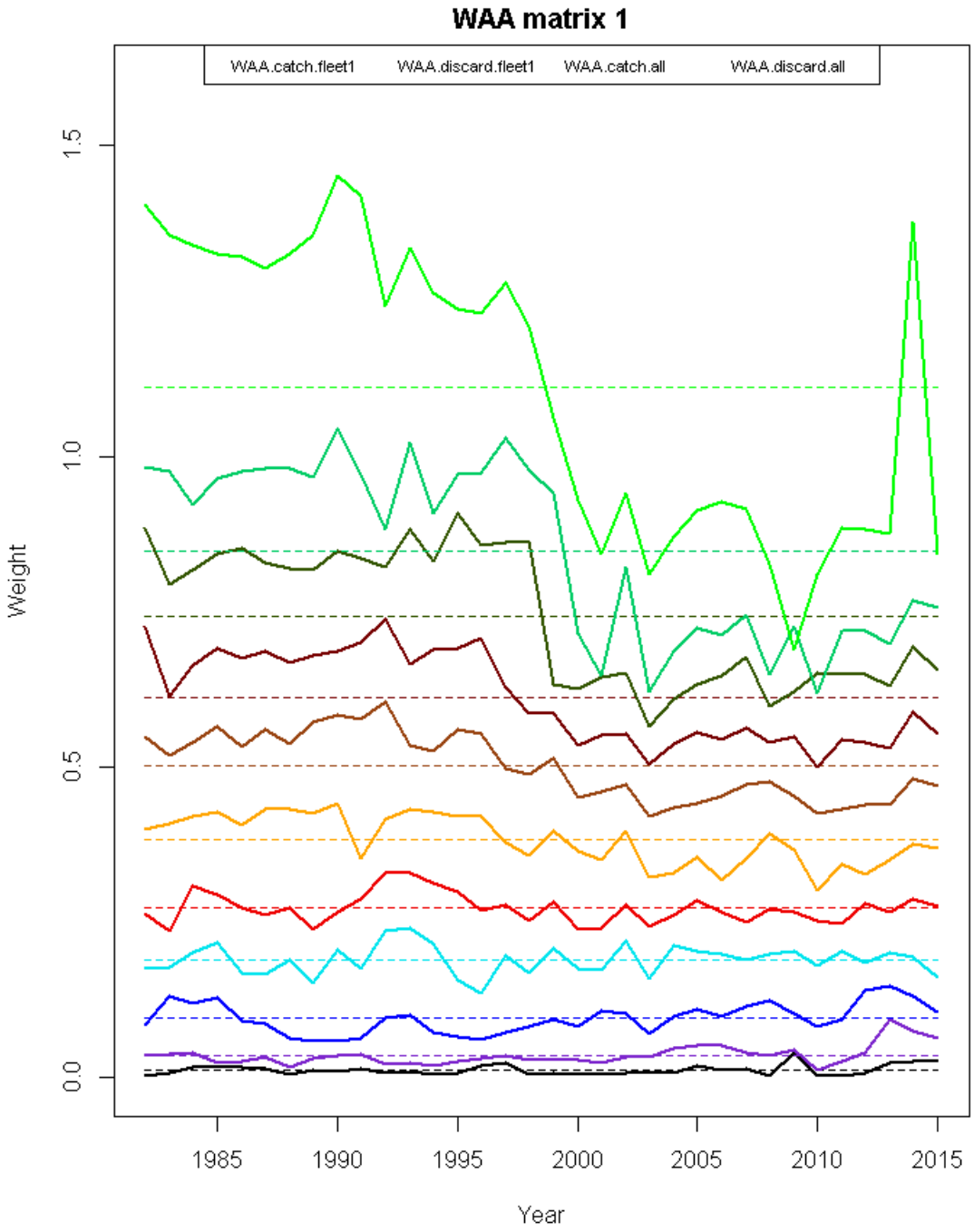


Figure B32. Witch flounder mean weight at age in the catch for ages 1 to 11+, 1982 -2015.

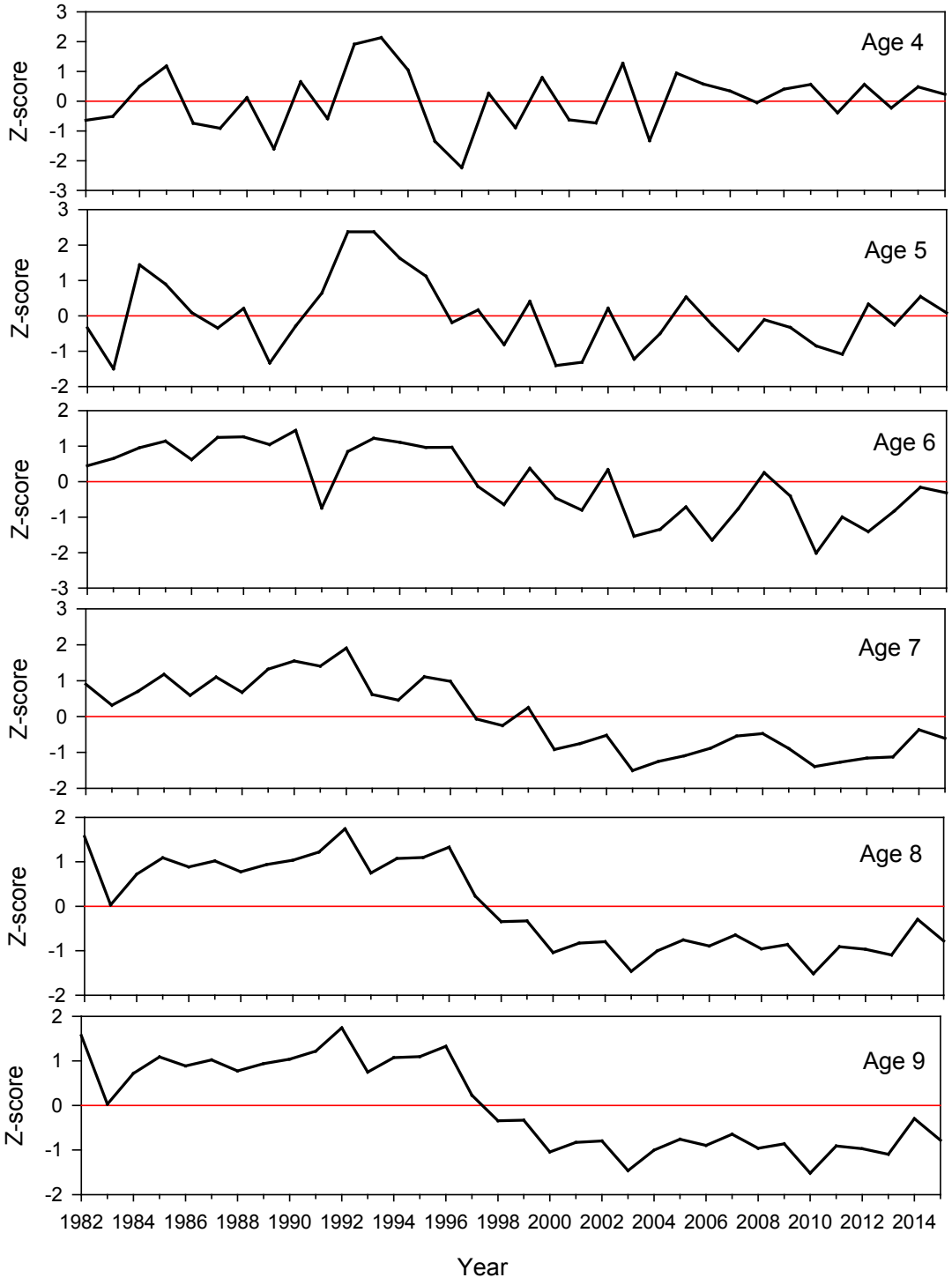


Figure B33. Z-scores of witch flounder mean weight at age in the catch for ages 4 to 9, 1982 - 2015.

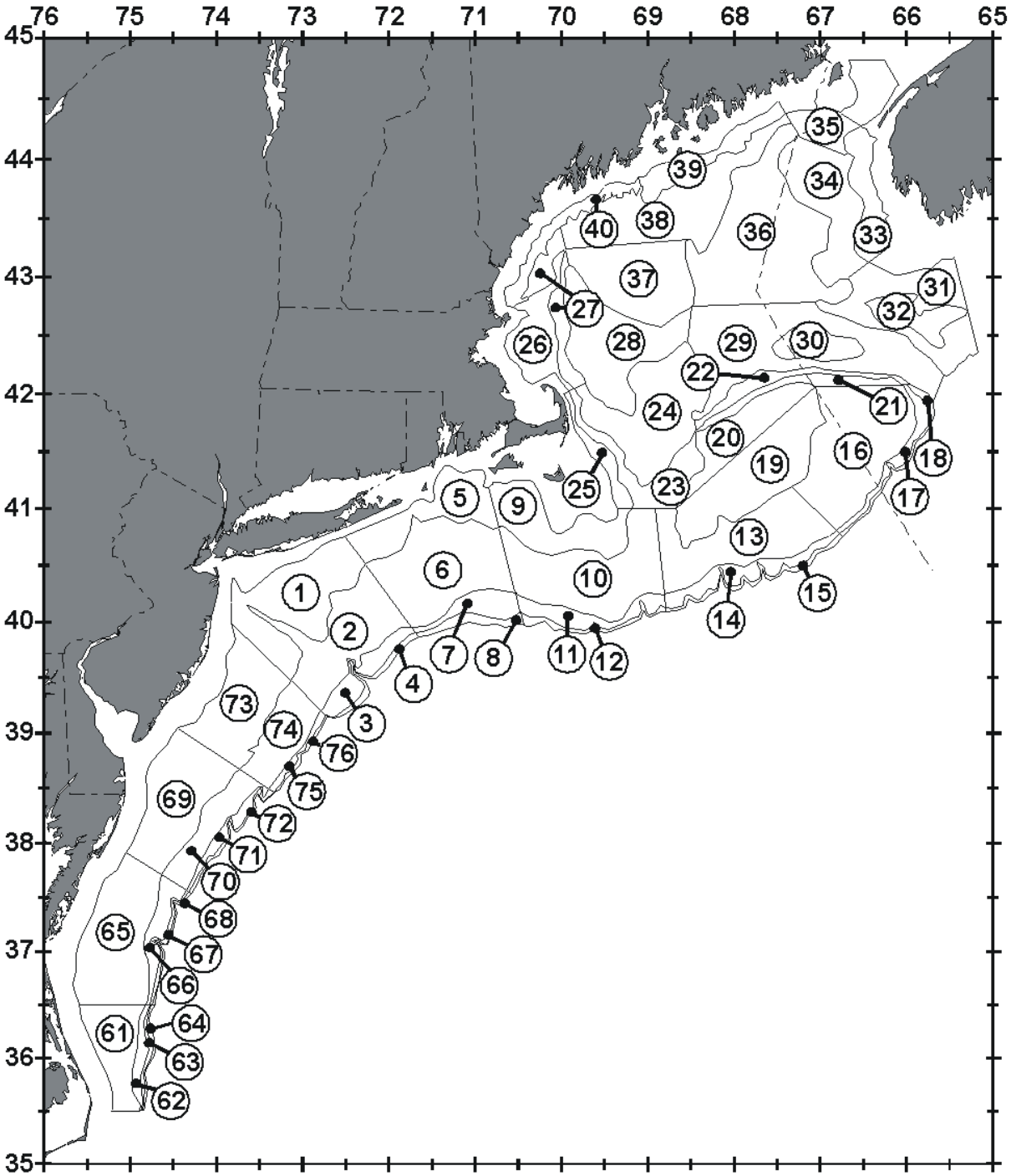


Figure B34. Northeast Fisheries Science Center bottom trawl survey offshore strata 1-76 (depth range 27 to 200 meters).

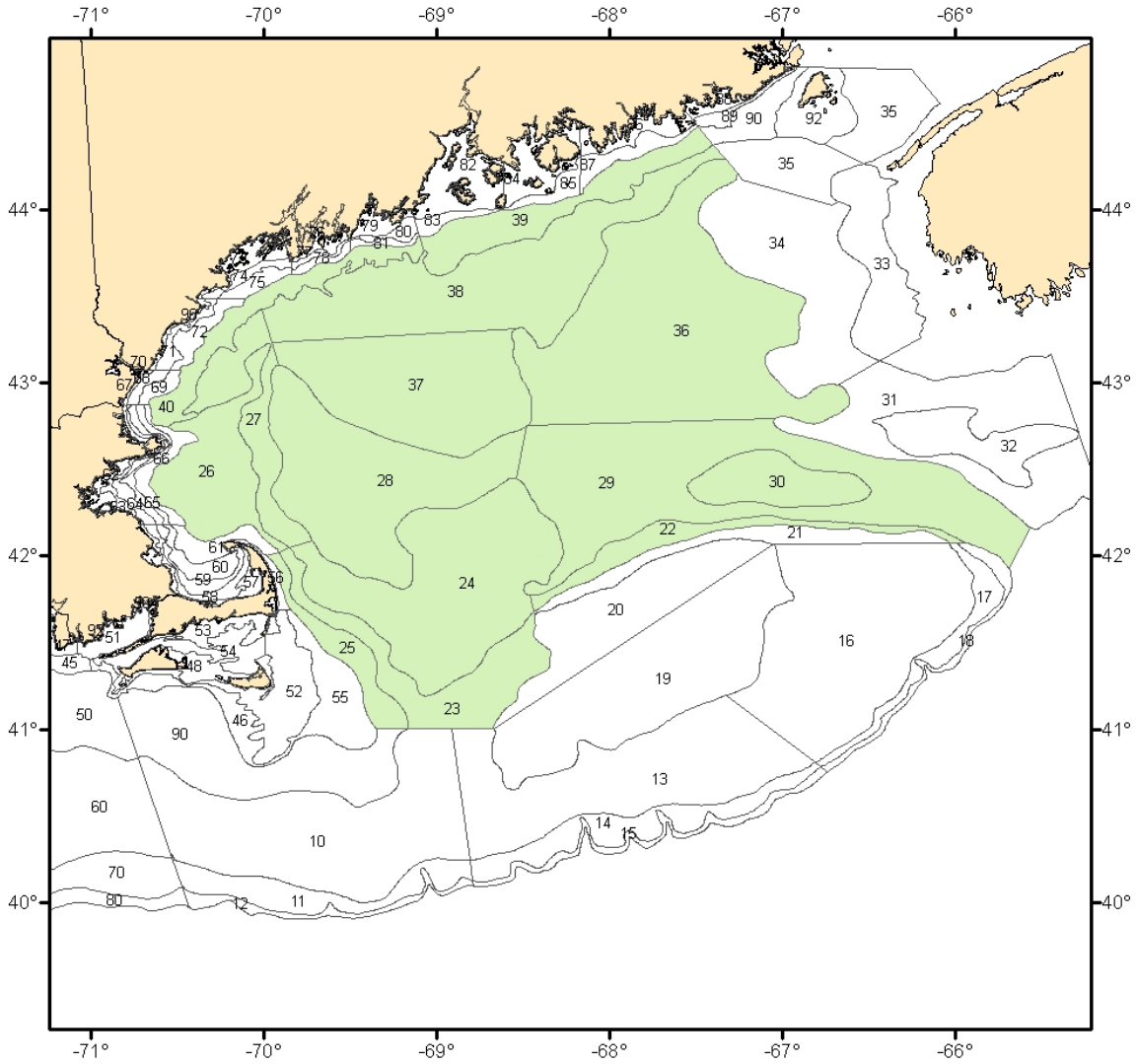
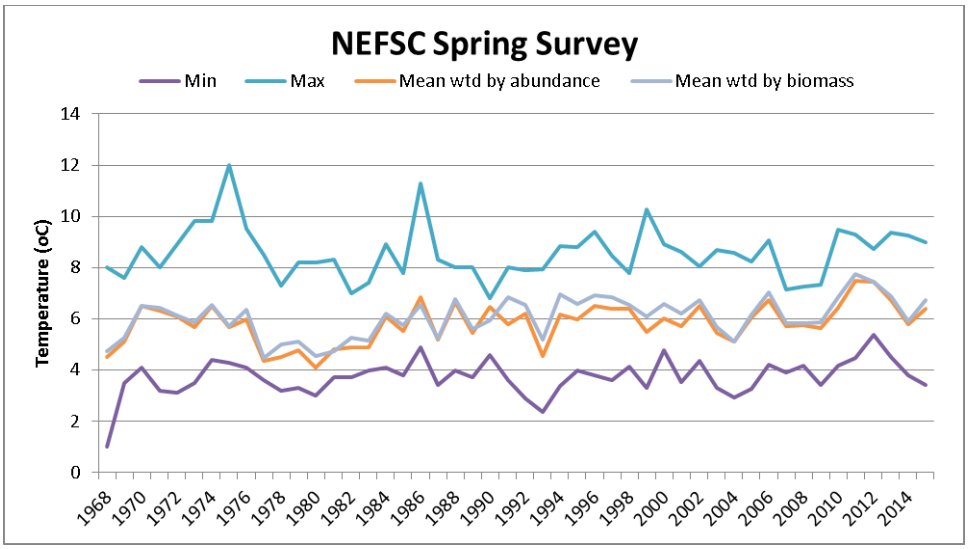


Figure B35. Northeast Fisheries Science Center bottom trawl survey strata (offshore strata 22-30; 36-40) used in the witch flounder stock assessment.



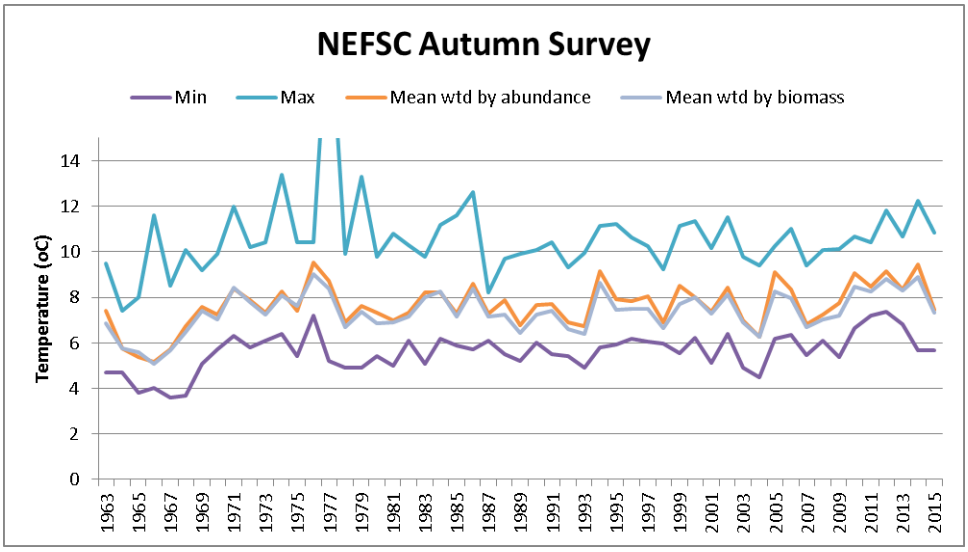
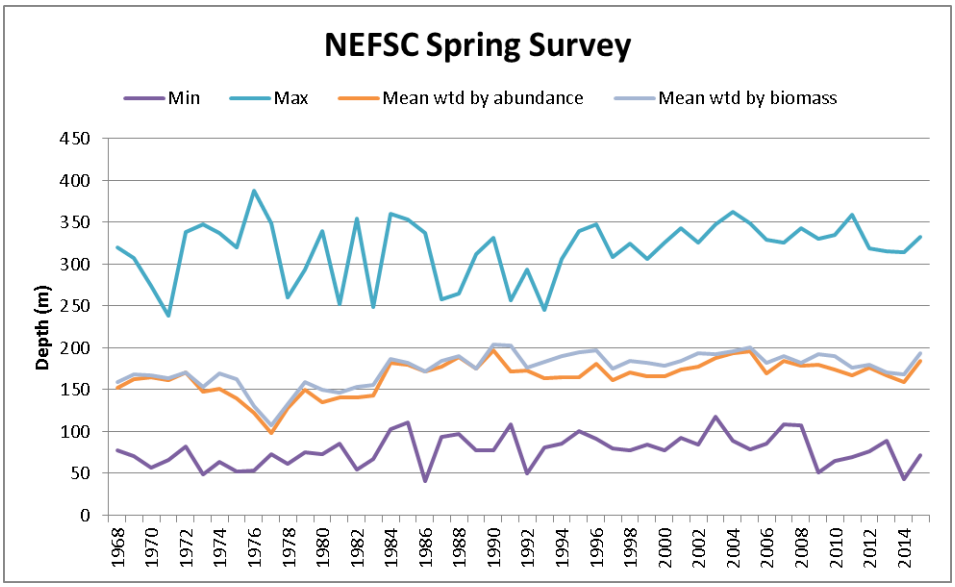


Figure B36. Minimum and maximum bottom temperature (degrees Celsius) of Northeast Fisheries Science Center (NEFSC) spring (top) and autumn (bottom) survey Gulf of Maine–Georges Bank region (strata 22-30, 36-40) and the weighted mean depth (weighted by witch flounder abundance and biomass).



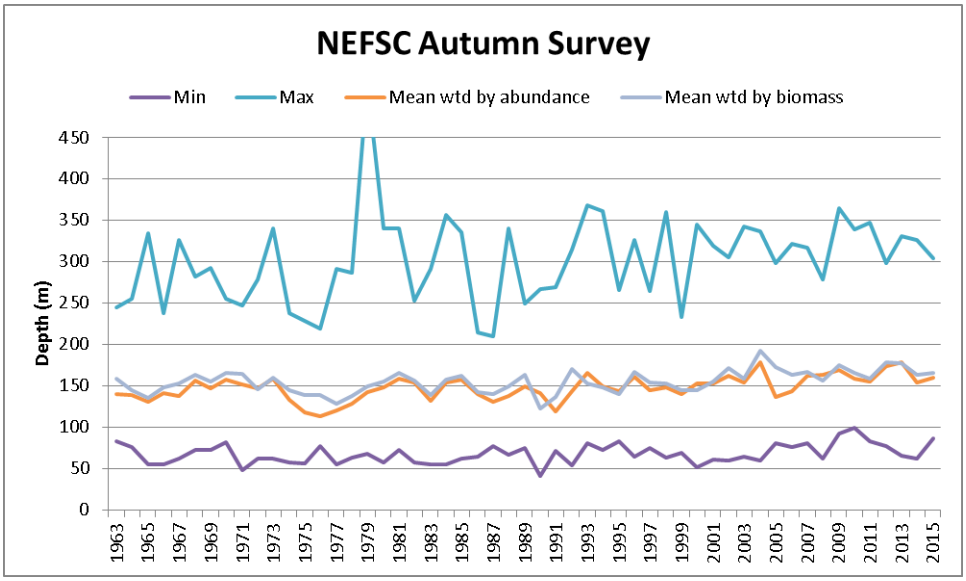


Figure B37. Minimum and maximum depth (m) of Northeast Fisheries Science Center (NEFSC) spring (top) and autumn (bottom) survey in the Gulf of Maine–Georges Bank region (strata 22-30, 36-40) and the weighted mean depth (weighted by witch flounder abundance and biomass).

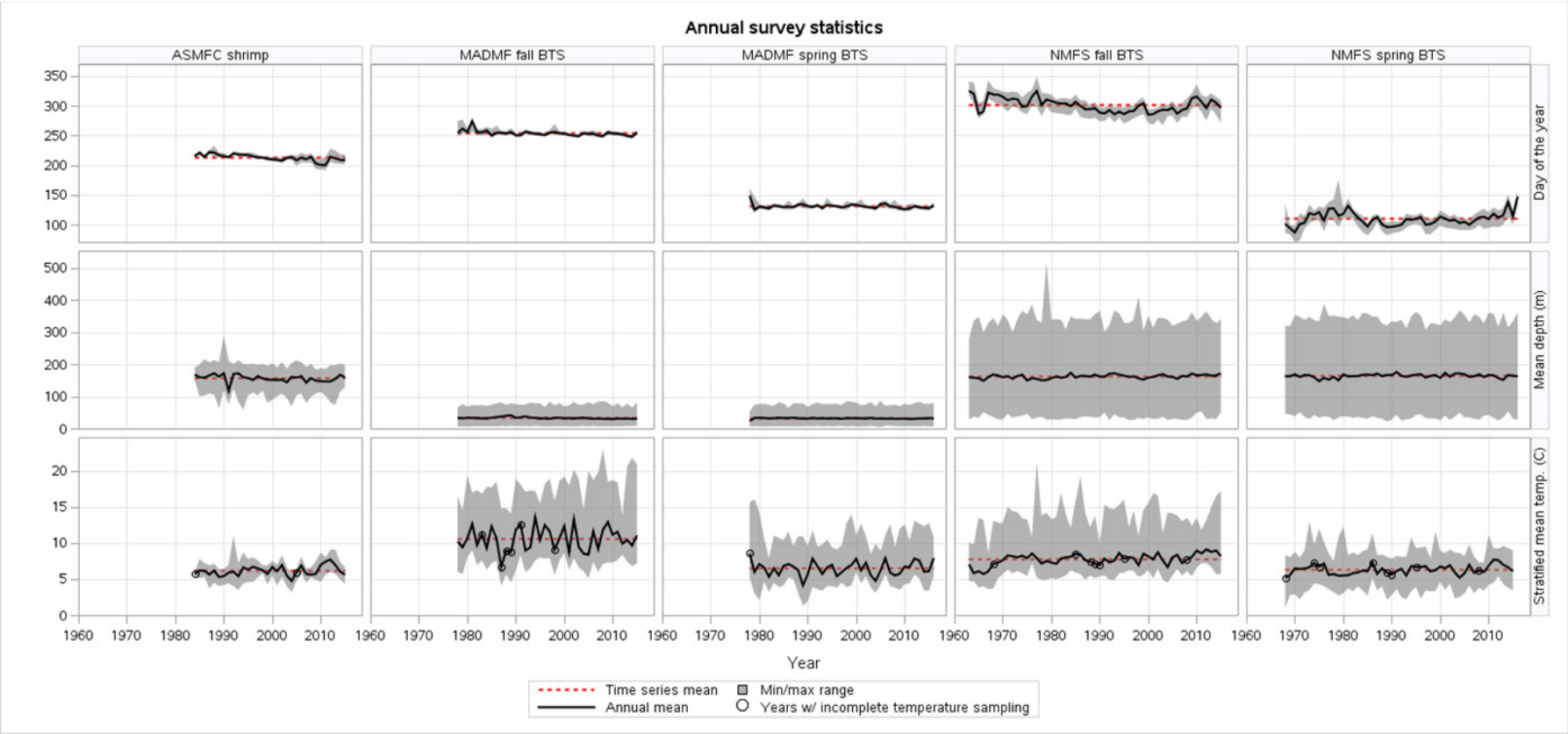


Figure B38. Annual timing (day of year; top row), mean depth (m; middle row), and stratified mean bottom temperature (C; bottom row) for the Atlantic States Marine Fisheries Commission (ASMFC) shrimp survey, Massachusetts Division of Marine Fisheries (MADMF) fall and spring , and Northeast Fisheries Science Center (NEFSC) fall and spring bottom trawl survey (from left to right, respectively). Annual means values (black line), time series mean (red dash line) and minimum/maximum values (gray shading).

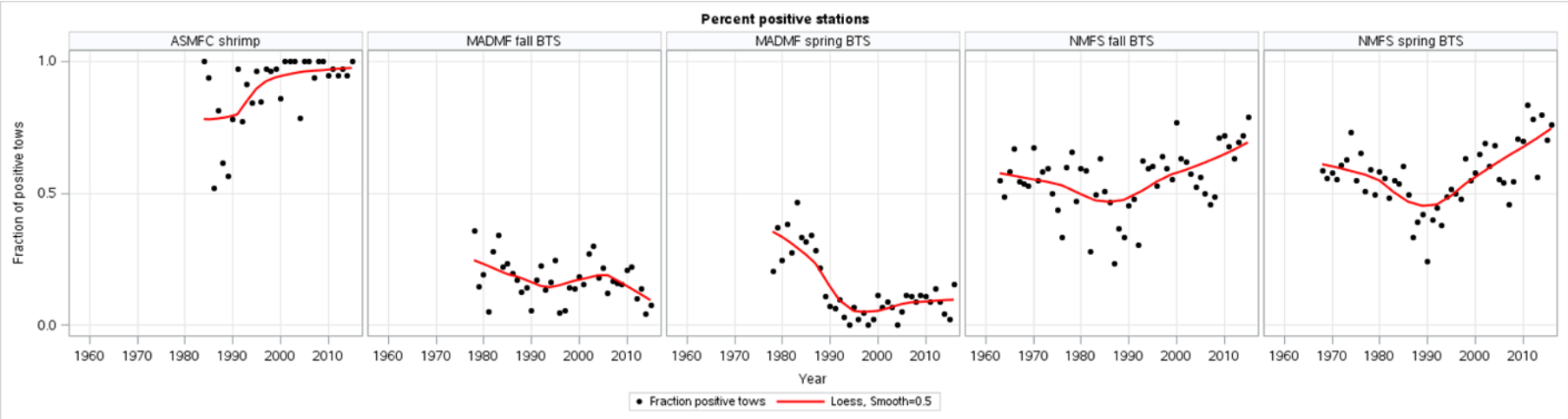


Figure B39. Fraction of survey stations with positive catch of witch flounder in the Atlantic States Marine Fisheries Commission (ASMFC) shrimp survey, Massachusetts Division of Marine Fisheries (MADMF) fall and spring, and Northeast Fisheries Science Center (NEFSC) fall and spring bottom trawl survey (from left to right, respectively). Annual fraction of positive stations (black circles) and loess smooth (0.5; red line) are shown.

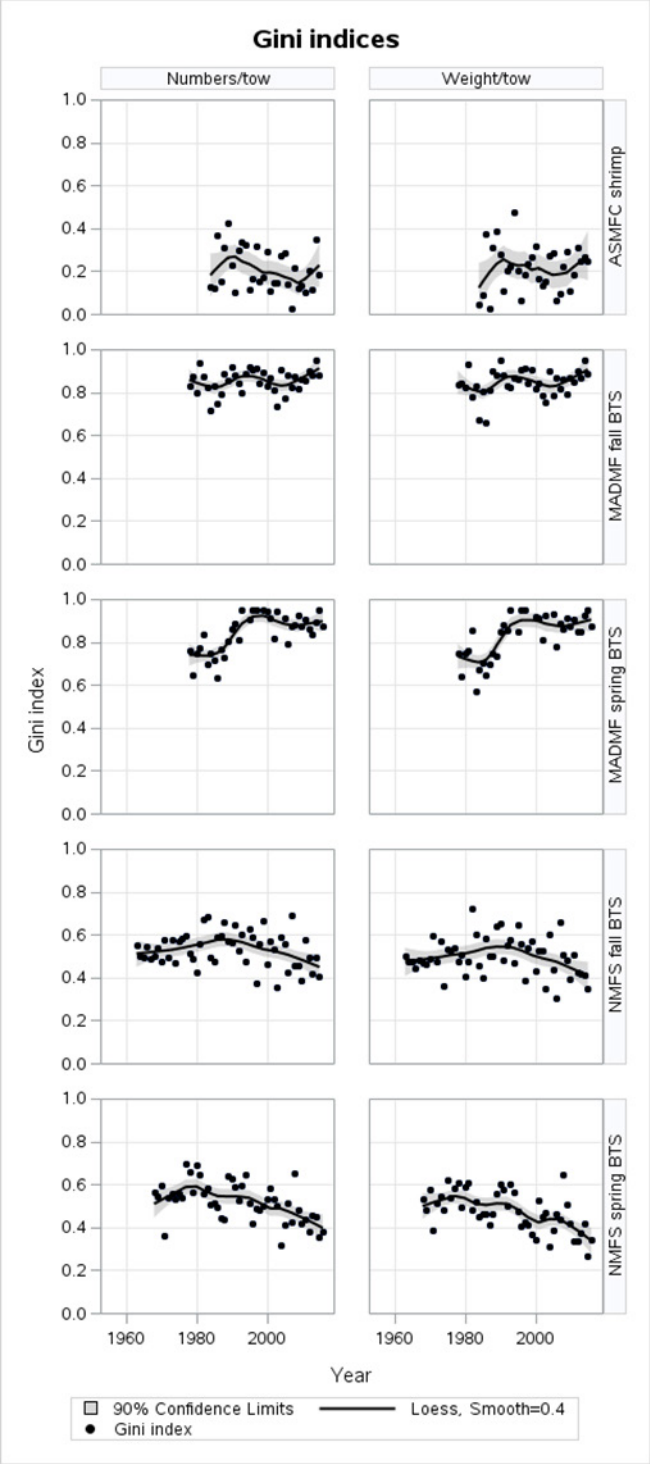


Figure B40. Concentration index (Gini index) of witch flounder (in numbers per tow and weight per tow) in the Atlantic States Marine Fisheries Commission (ASMFC) shrimp survey, Massachusetts Division of Marine Fisheries (MADMF) fall and spring , and Northeast Fisheries Science Center (NEFSC) fall and spring bottom trawl survey (from top to bottom, respectively) . Annual concentration values (black circles) and loess smooth (0.4; black line) are shown.
.

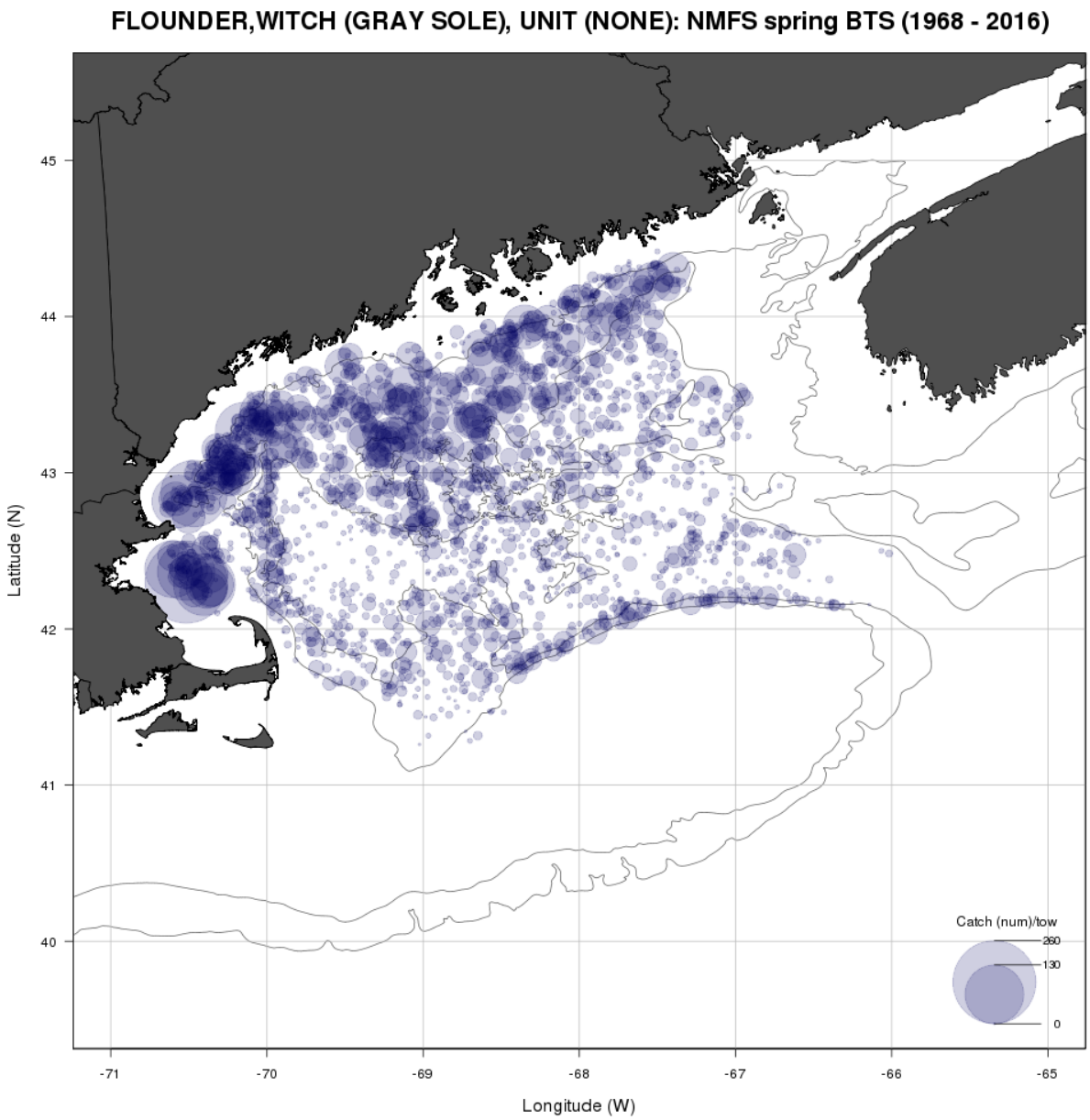


Figure B41. Number per tow of witch flounder in the Northeast Fisheries Science Center spring bottom trawl survey (strata 22-30, 36-40), 1968-2016.

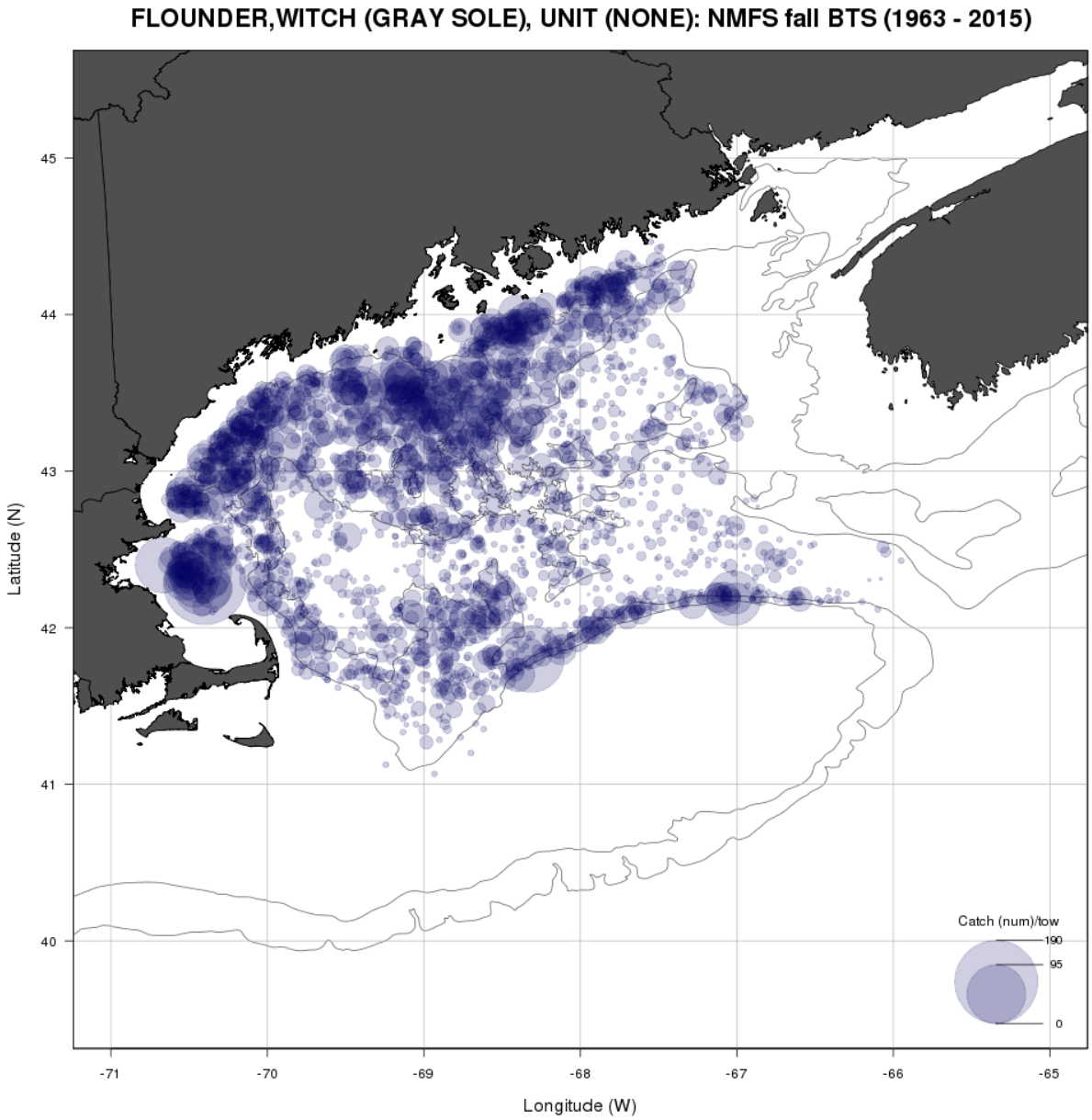


Figure B42. Number per tow of witch flounder in the Northeast Fisheries Science Center autumn bottom trawl survey (strata 22-30, 36-40), 1963-2015.

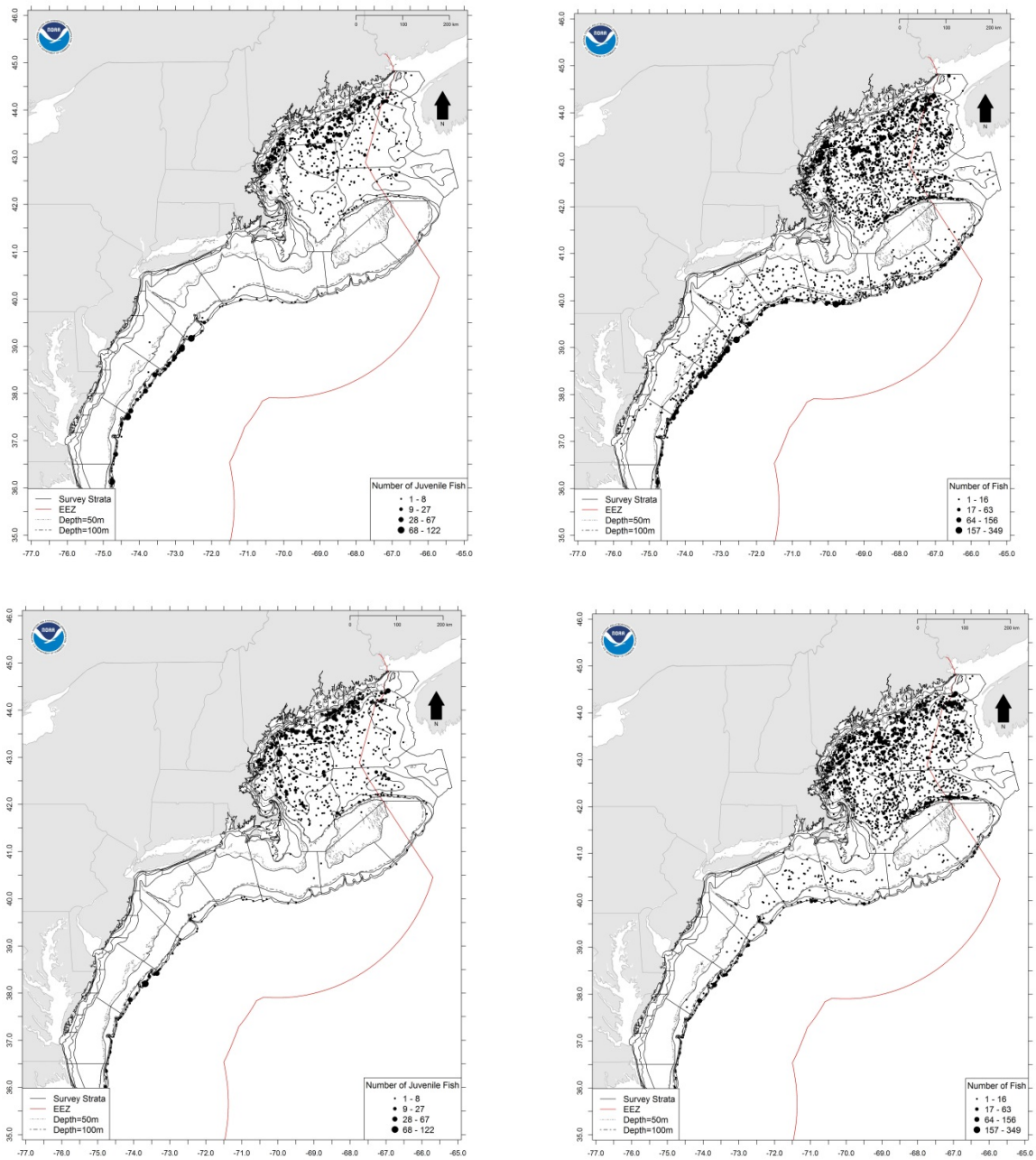


Figure B43. Distribution of juvenile (<25 cm) witch flounder in the Northeast Fisheries Science Center (NEFSC) 1968-2016 spring (top right) and 1963-2015 autumn (bottom right) survey. Distribution of all witch flounder in the NEFSC spring (top left) and autumn (bottom left) survey are also shown.

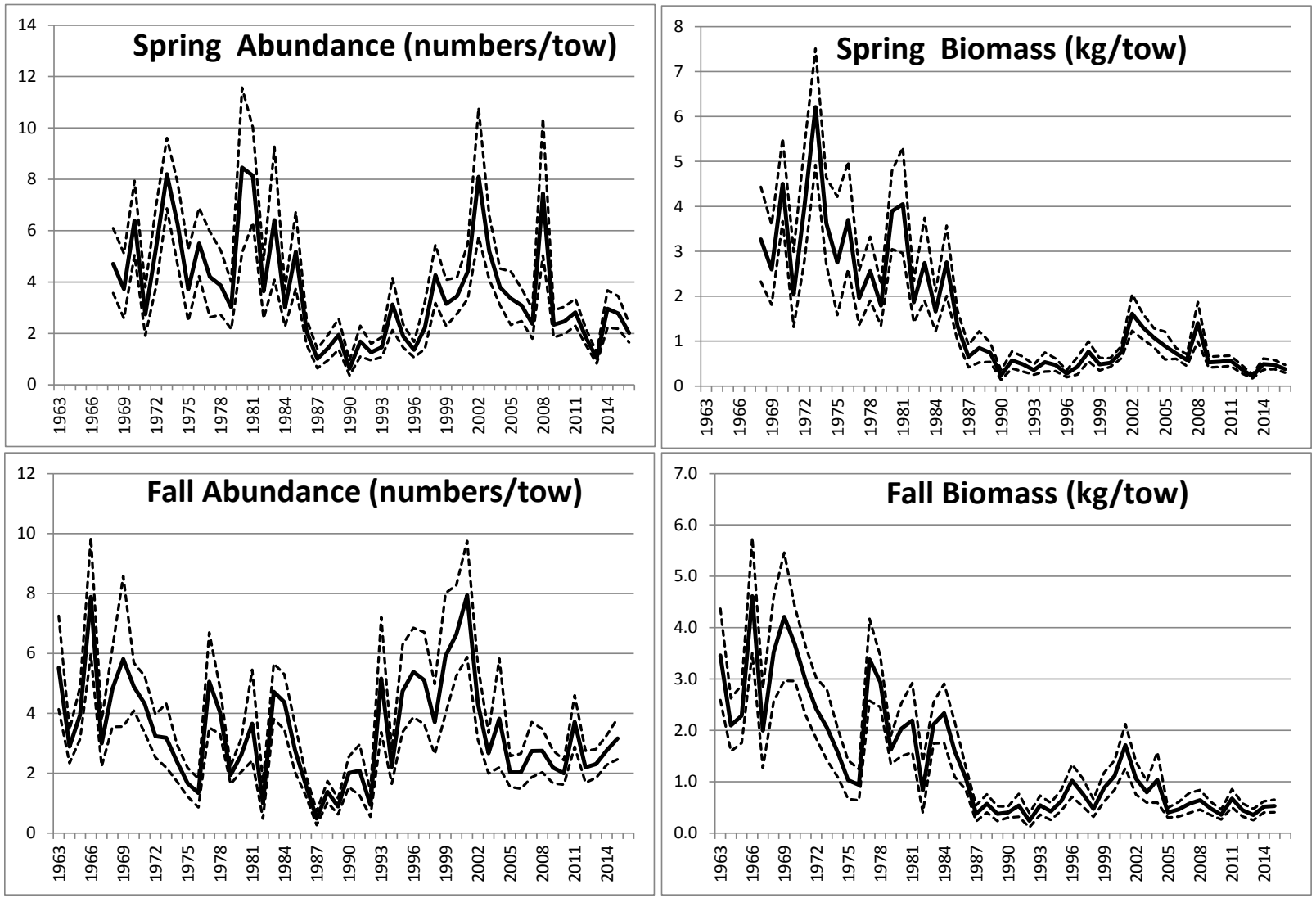


Figure B44. Stratified mean number (left) and weight (kg; right) per tow of witch flounder in the Northeast Fisheries Science Center autumn (bottom) and spring (top) bottom trawl surveys, 1963-2015, spring 2016.

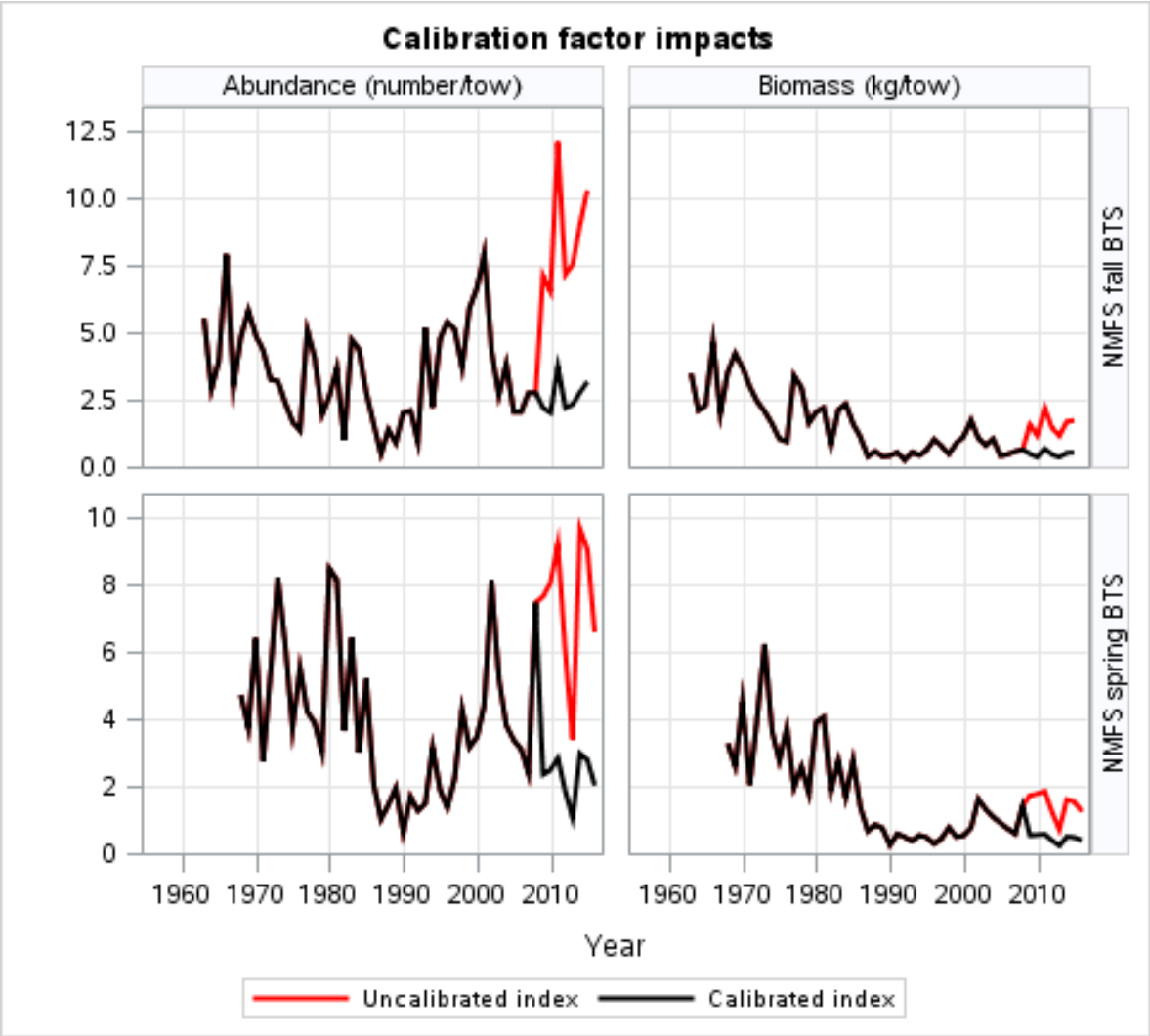


Figure B45. Stratified mean number (left) and weight (kg; right) per tow of witch flounder in the Northeast Fisheries Science Center autumn (top) and spring (bottom) bottom trawl surveys, 1963-2015, spring 2016. Red lines indicate Bigelow uncalibrated indices.

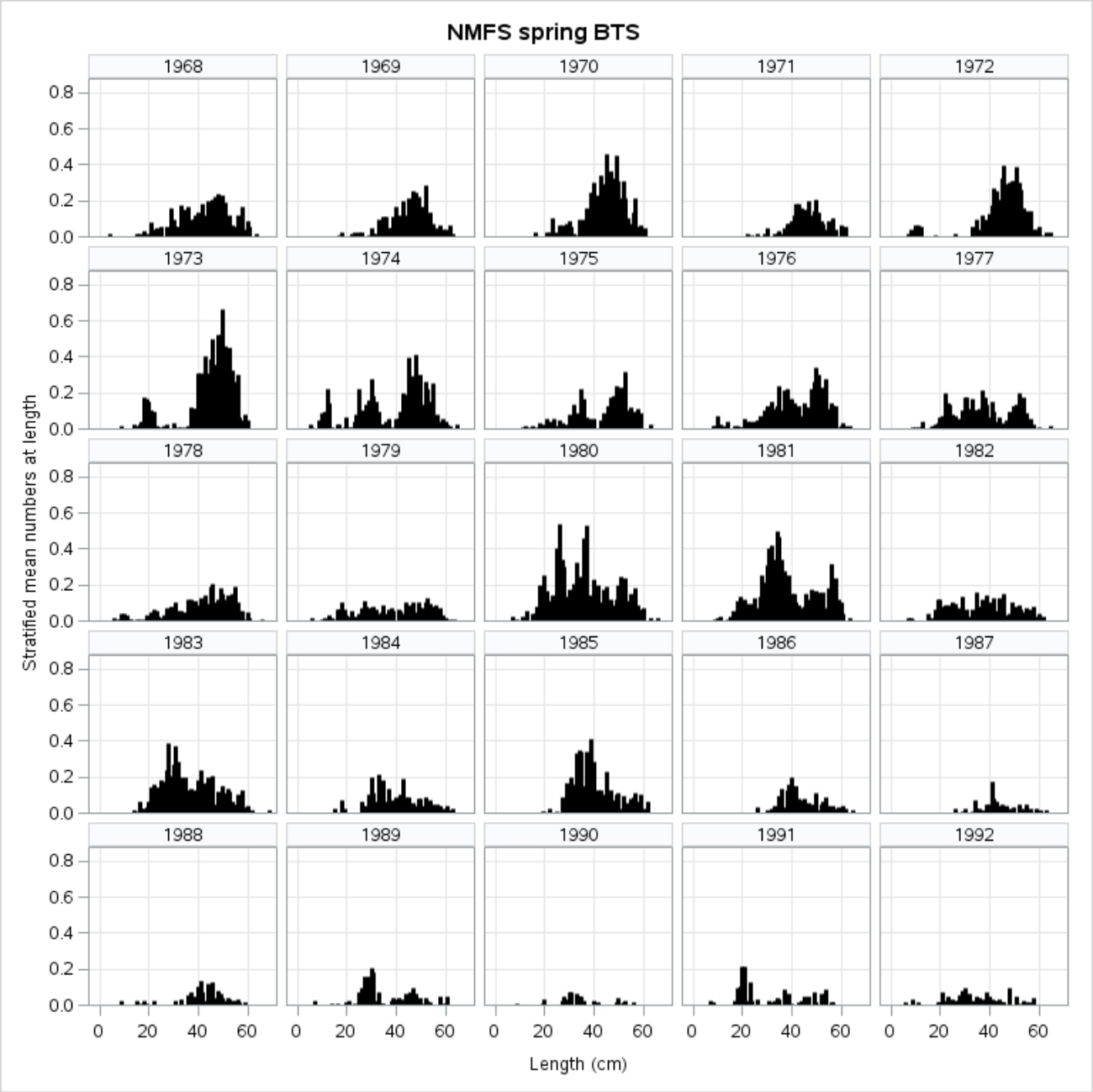


Figure B46. Stratified mean number of witch flounder per tow at length from Northeast Fisheries Science Center spring survey (strata 22-30, 36-40), 1968 – 2016.

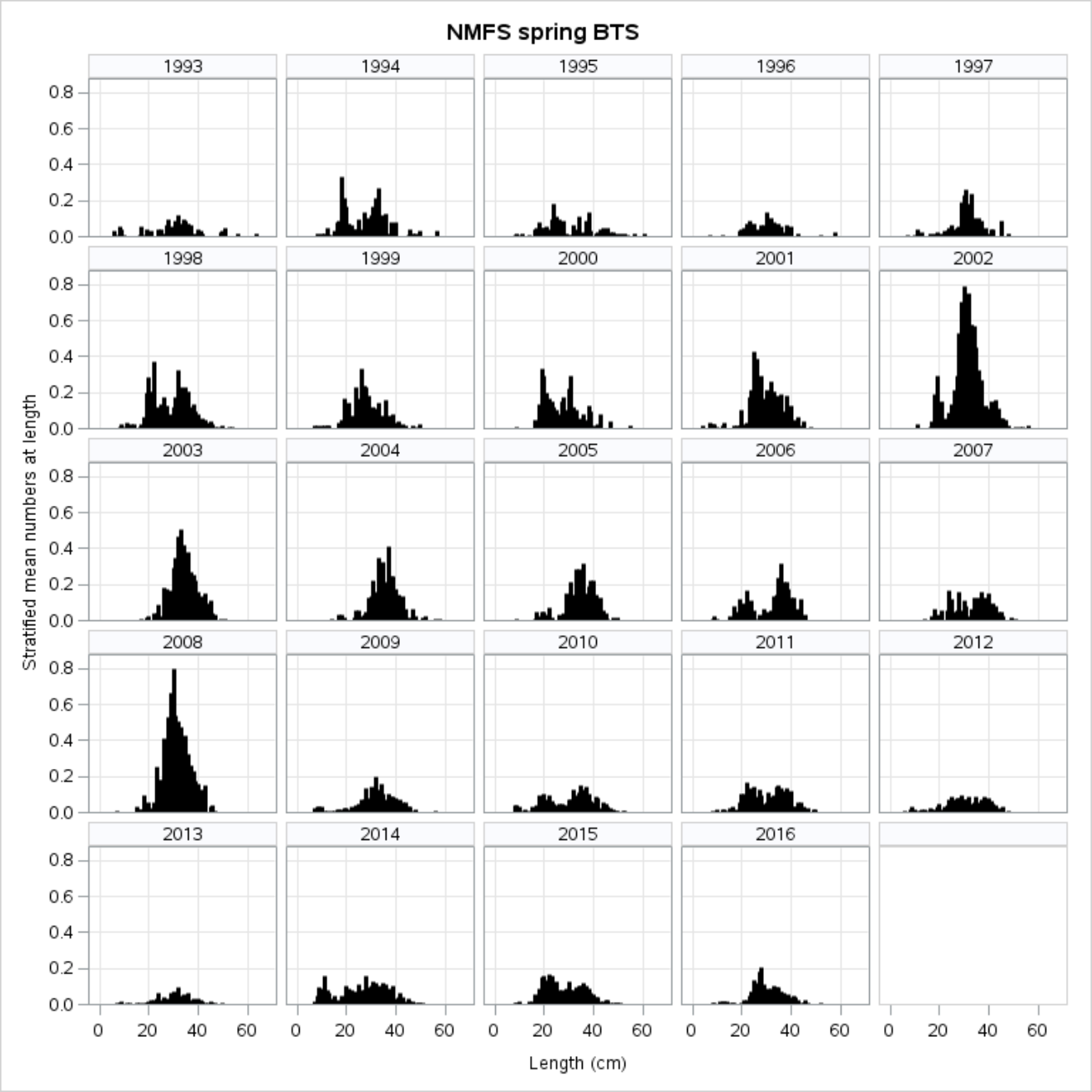


Figure B46, continued. Stratified mean number of witch flounder per tow at length from Northeast Fisheries Science Center spring survey (strata 22-30, 36-40), 1968 – 2016.

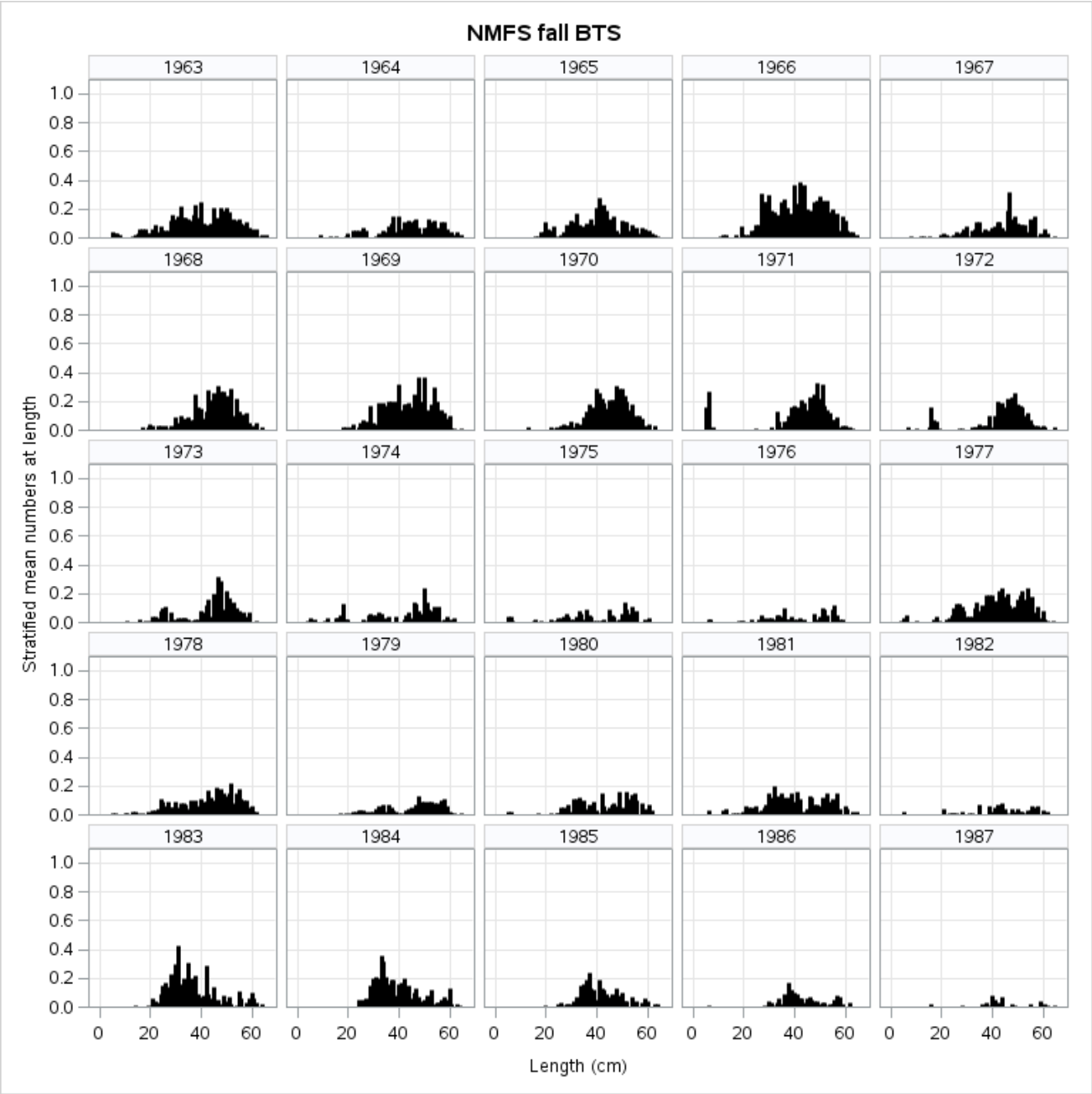


Figure B47. Stratified mean number of witch flounder per tow at length from Northeast Fisheries Science Center autumn survey (strata 22-30, 36-40), 1963 – 2015.

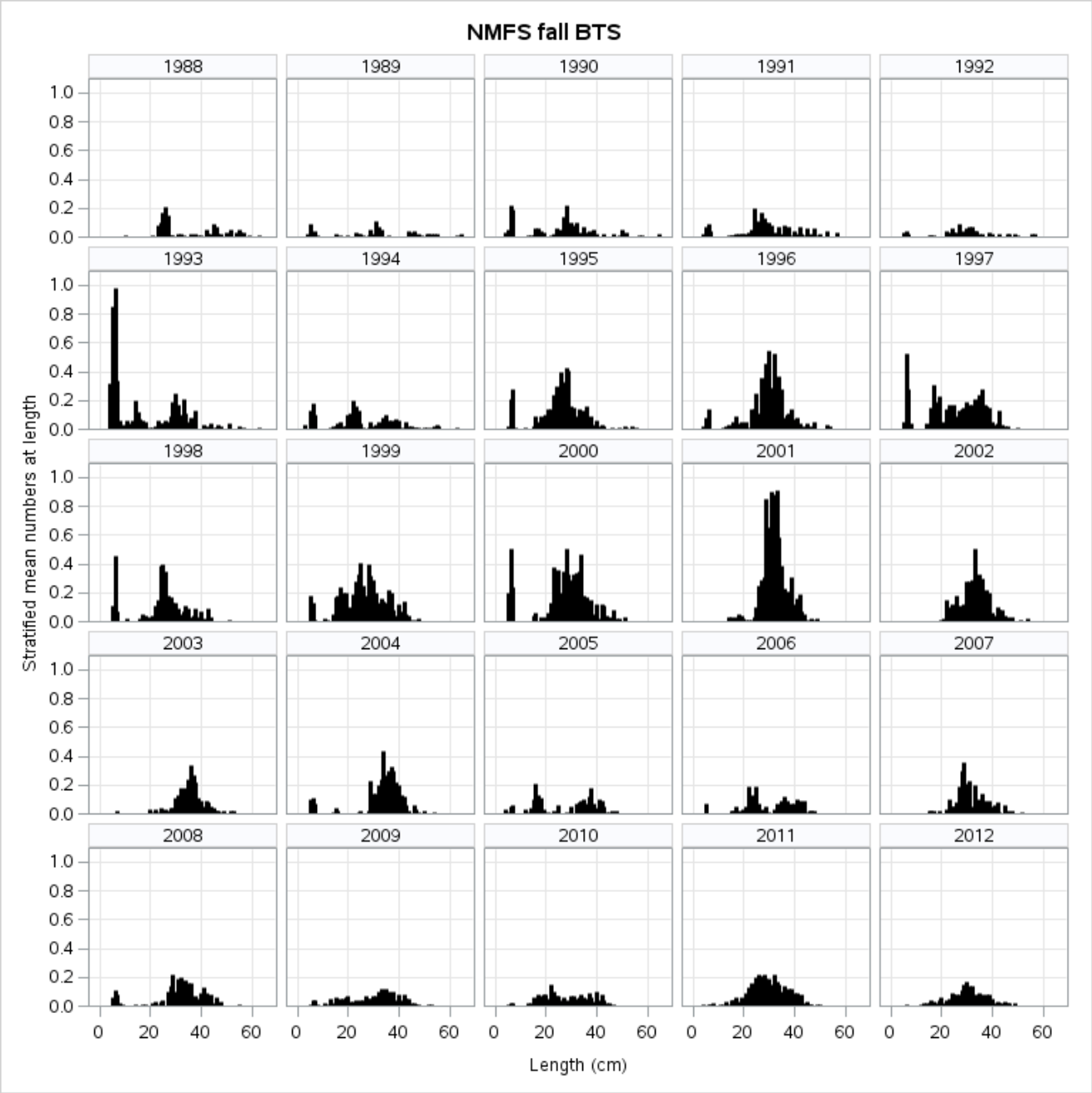


Figure B47, continued. Stratified mean number of witch flounder per tow at length from Northeast Fisheries Science Center autumn survey (strata 22-30, 36-40), 1963 – 2015.

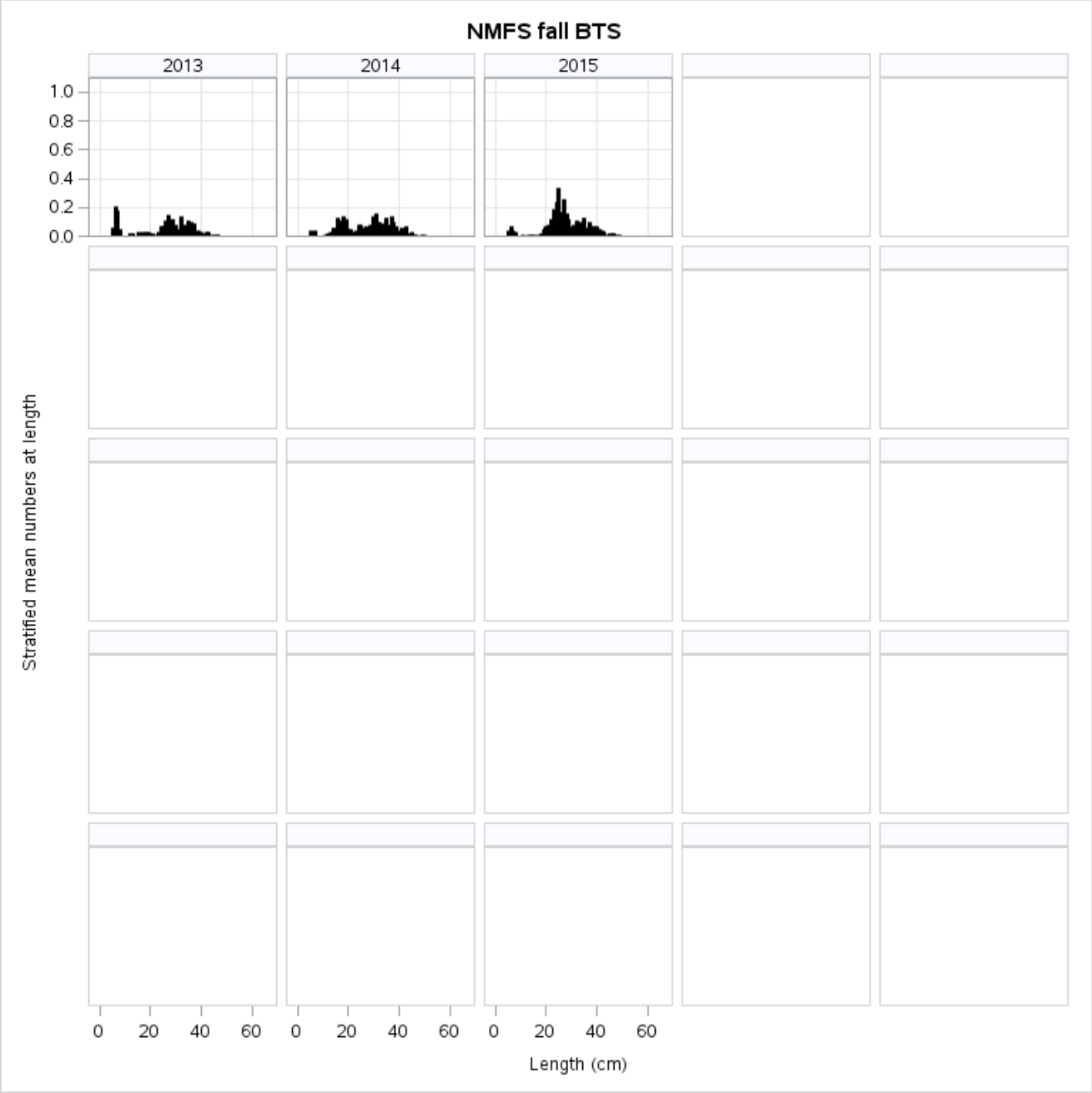


Figure B47, continued. Stratified mean number of witch flounder per tow at length from Northeast Fisheries Science Center autumn survey (strata 22-30, 36-40), 1963 – 2015.

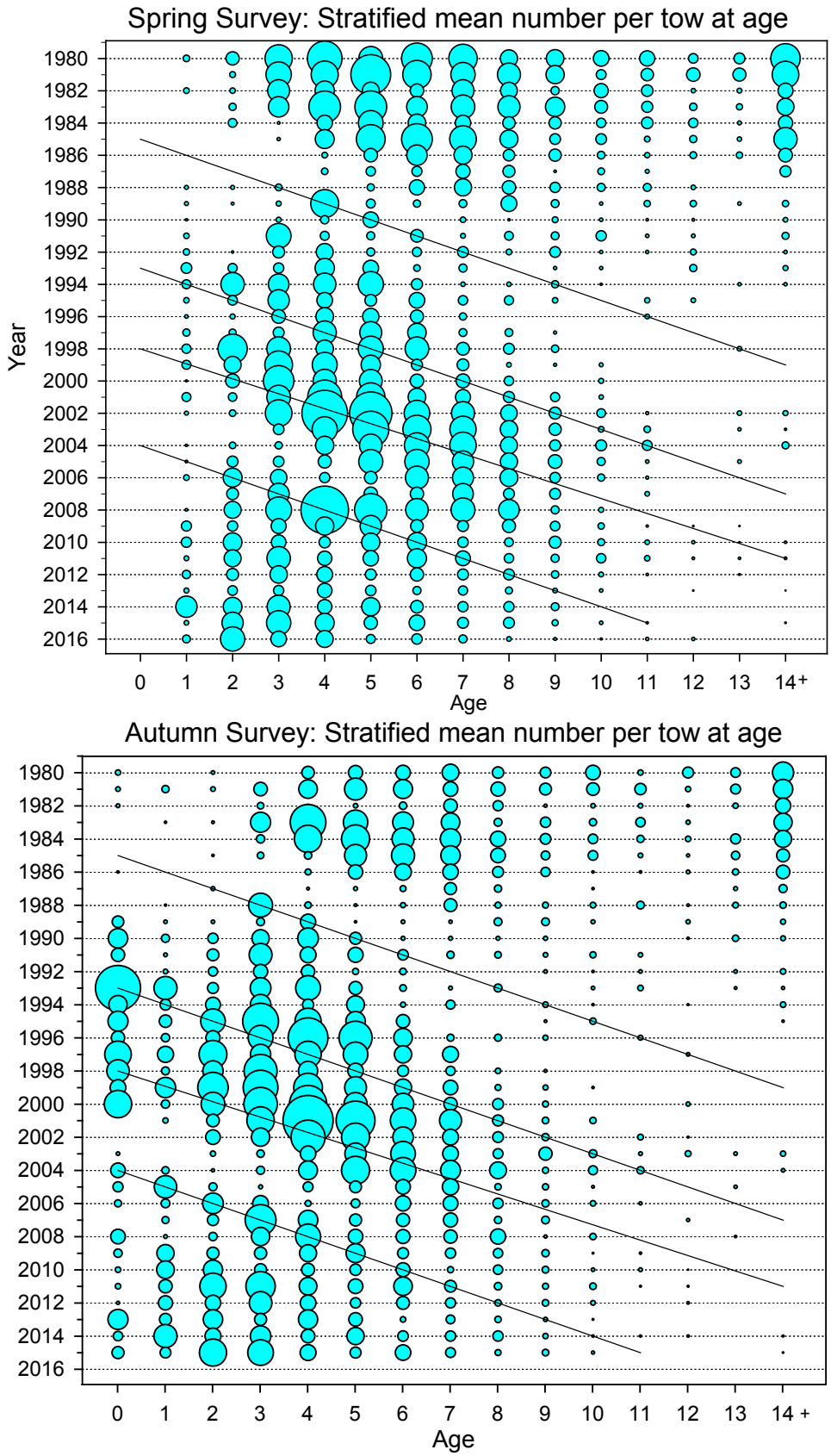


Figure B48. Stratified mean number of witch flounder per tow at age from Northeast Fisheries Science Center spring (top) and autumn (bottom) surveys, 1980 – 2015; spring 2016. Selected cohorts (1985, 1993, 1998, and 2004 year classes) are indicated with diagonal lines.

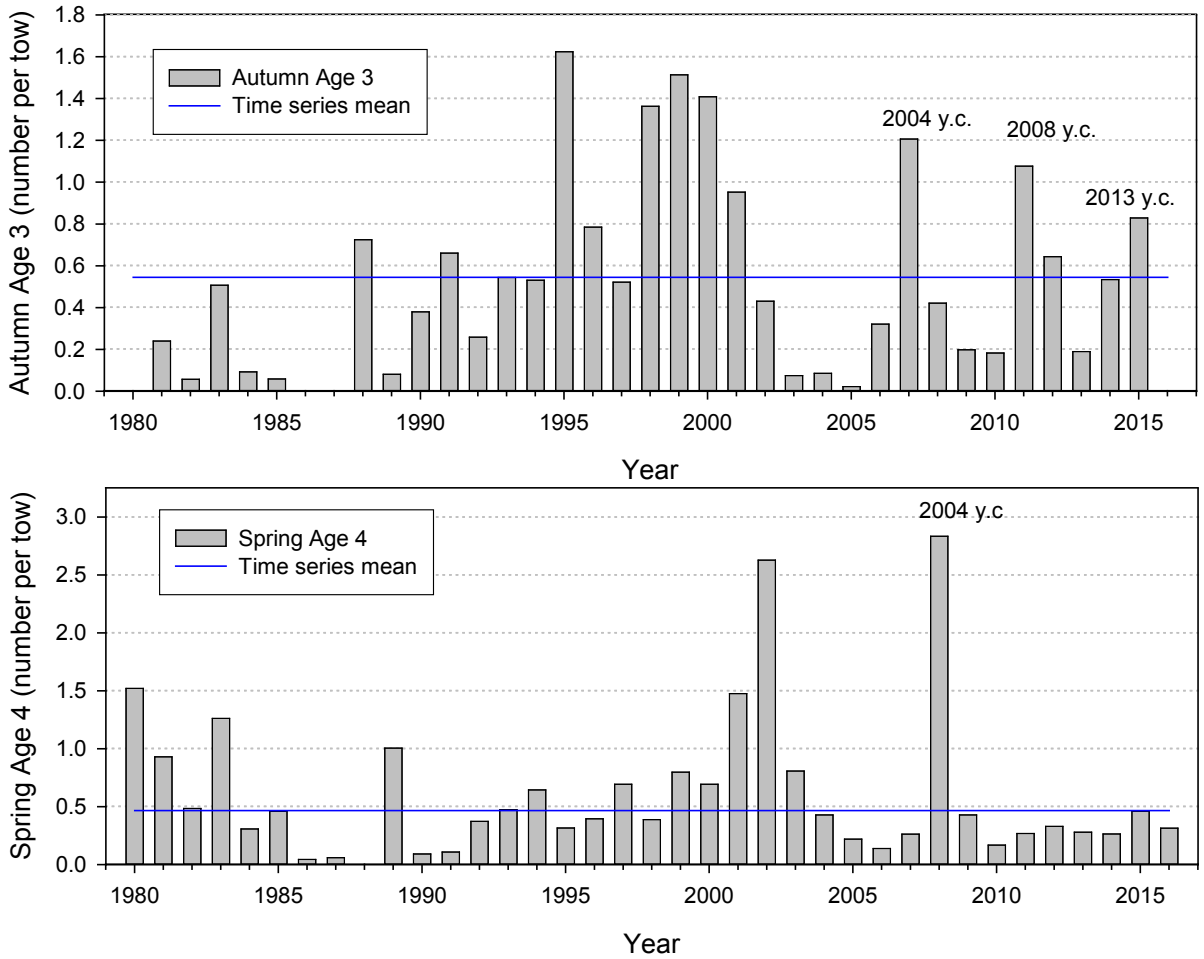


Figure B49. Stratified mean number per tow of age 3 witch flounder in the Northeast Fisheries Science Center autumn survey, 1980- 2015 (top), and age 4 witch flounder in the spring survey, 1980 -2016 (bottom). Constant conversion factor of 3.2572 applied to 2009 – 2016 surveys.

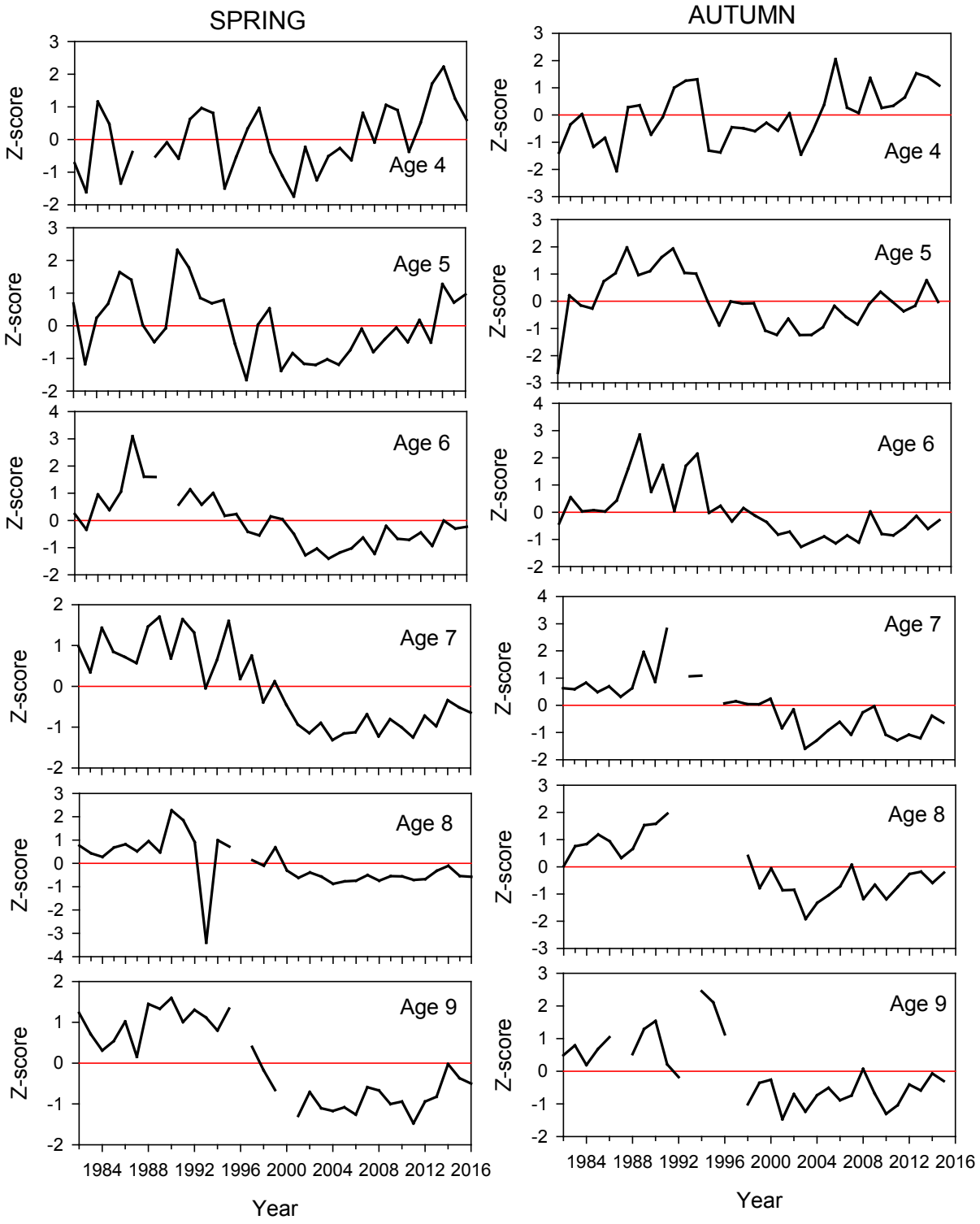
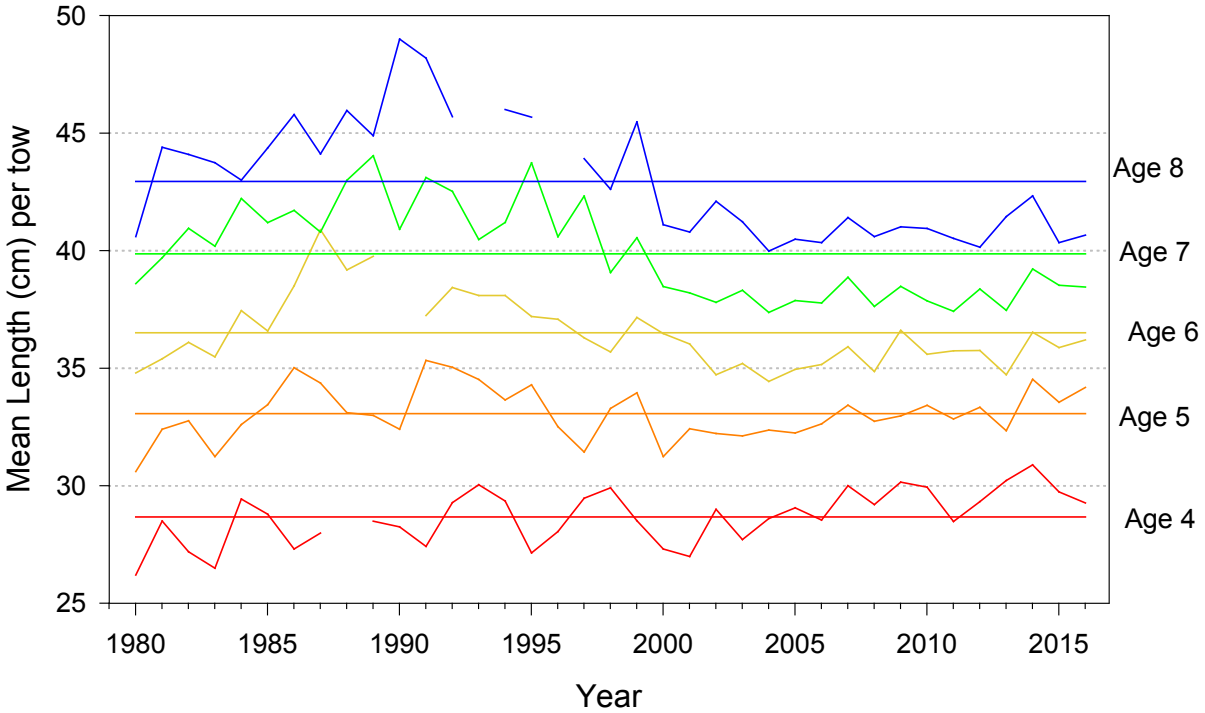


Figure B50. Z-scores of witch flounder mean weight at age (age groups 4 – 9) in the Northeast Fisheries Science Center spring survey (left), 1982-2016 and autumn survey 1982 -2015 (right).



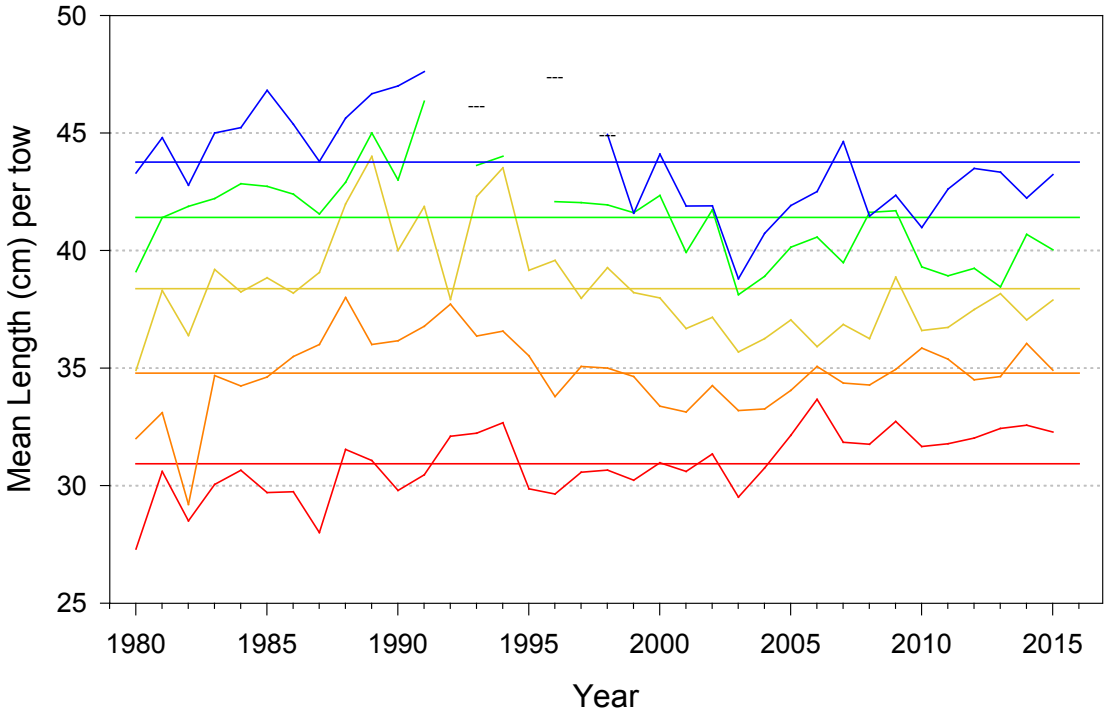
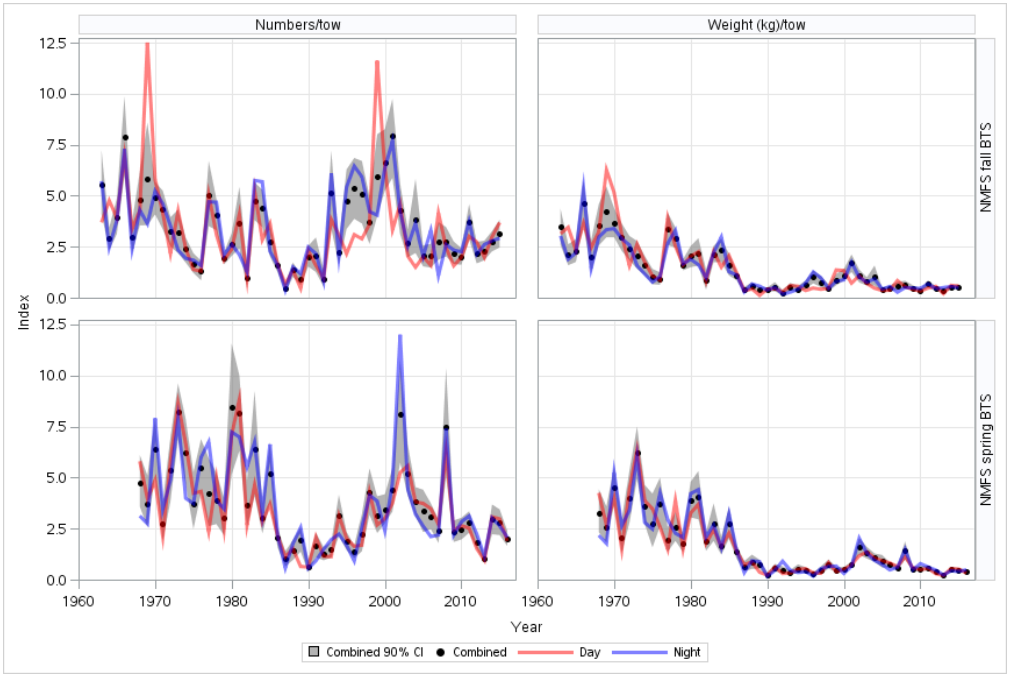


Figure.B51. Stratified mean length (cm) per tow at age of witch flounder in Northeast Fisheries Science Center bottom trawl spring (top) and autumn (bottom) surveys (strata 22-30, 36-40), 1980 – 2016.



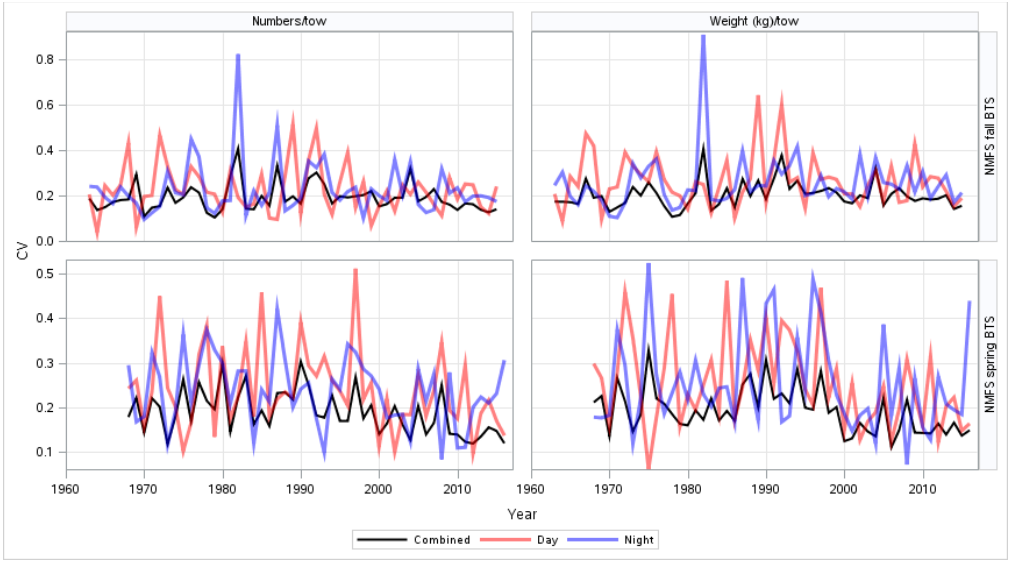


Figure B52. Stratified mean indices (number and weight per tow) of witch flounder from the Northeast Fisheries Science Center surveys broken out by day/night sampling compared with combined mean indices. CV are given in bottom plot.

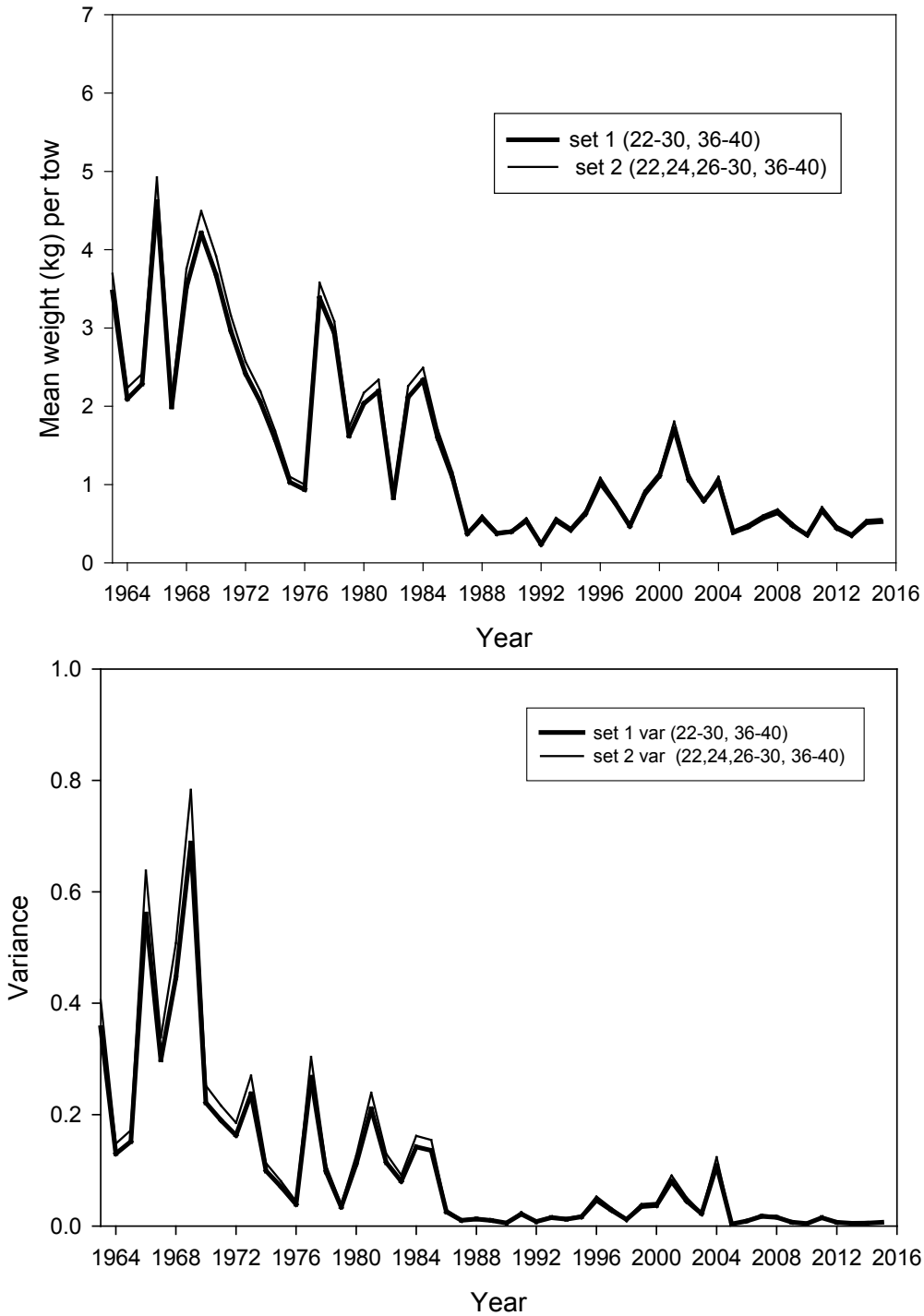


Figure B53. Stratified mean weight per tow (kg; top) and variance (bottom) of witch flounder in the Northeast Fisheries Science Center autumn bottom trawl survey for 2 strata sets in the Gulf of Maine-Georges Bank region, 1963-2015.

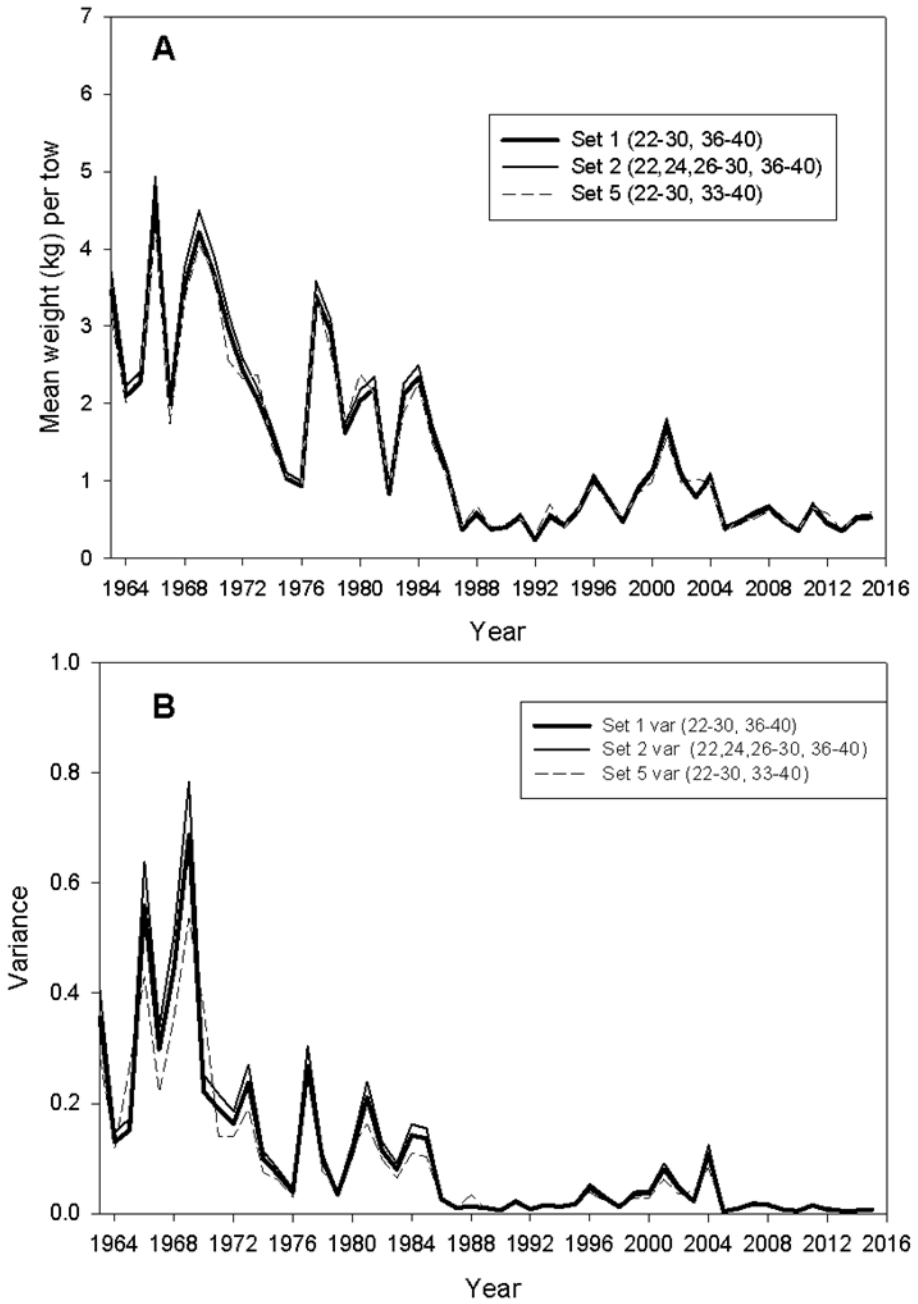


Figure B53a. Stratified mean weight per tow (kg; top) and variance (bottom) of witch flounder in the Northeast Fisheries Science Center autumn bottom trawl survey for 3 strata sets in the Gulf of Maine-Georges Bank region, 1963-2015. Strata set 5 includes strata 33, 34 and 351.

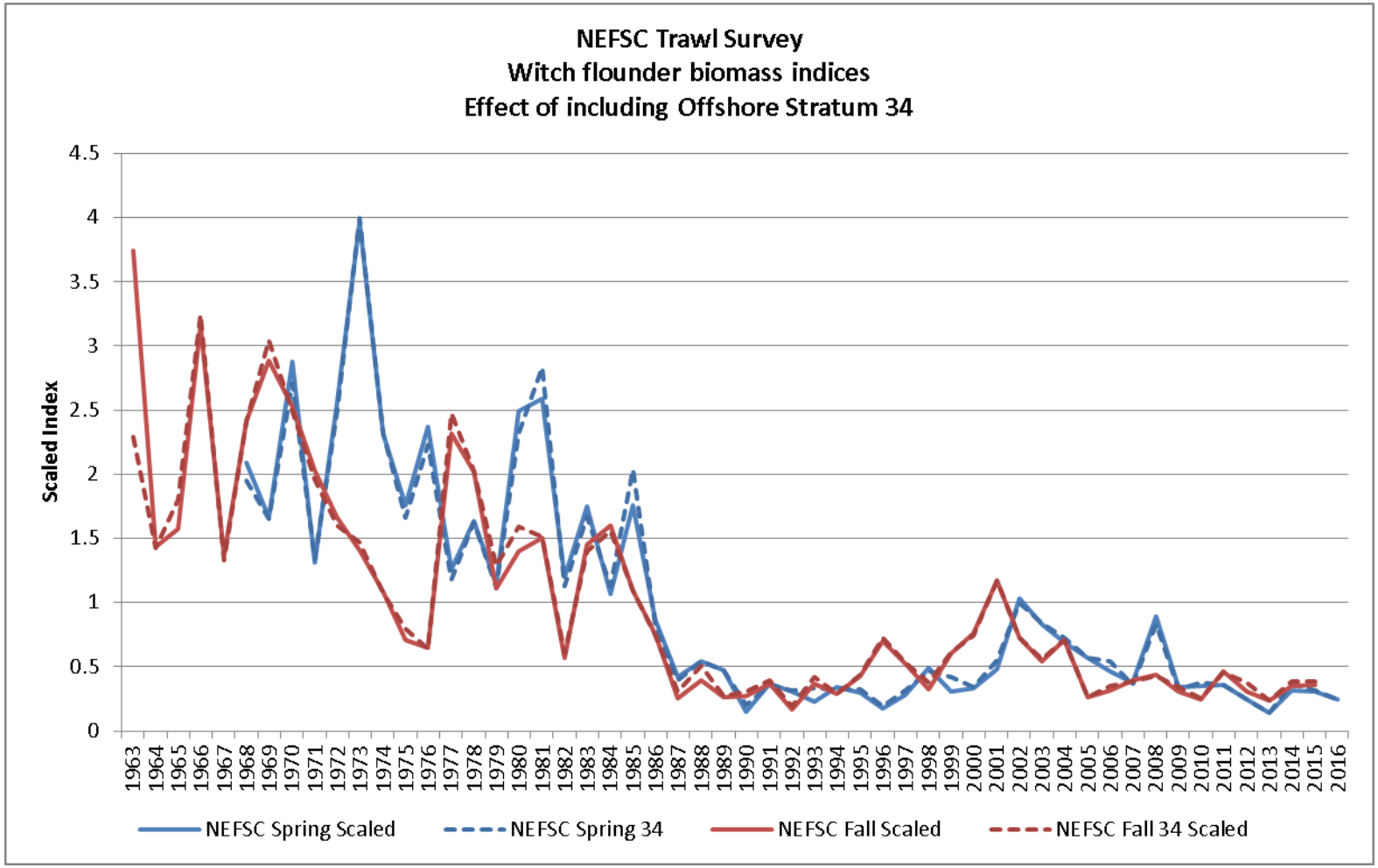


Figure B53b. Stratified mean weight per tow (kg) of witch flounder in the Northeast Fisheries Science Center spring (blue) and autumn (red) bottom trawl survey for 2 strata sets (solid line = set 22-30, 36-40; dashed line = 22-30, 34, 36-40) in the Gulf of Maine-Georges Bank region, 1963-2015.

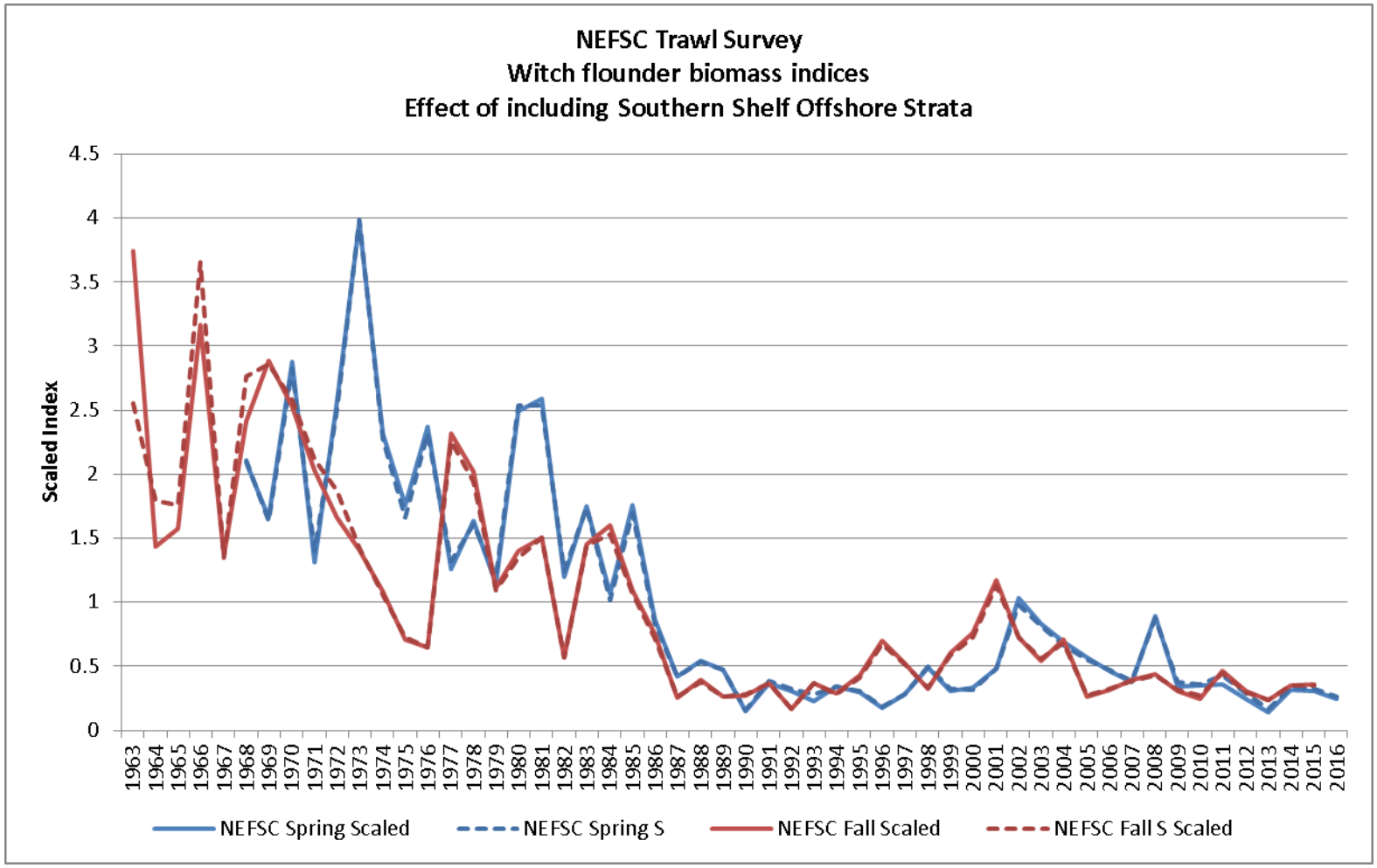


Figure B53c. Stratified mean weight per tow (kg) of witch flounder in the Northeast Fisheries Science Center spring (blue) and autumn (red) bottom trawl survey for 2 strata sets (solid line = set 22-30, 36-40; dashed line = 22-30, 34, 36-40 and southern offshore strata 2-4,6-8,10-18, 74-76) in the Gulf of Maine-Georges Bank and southward, 1963-2015.

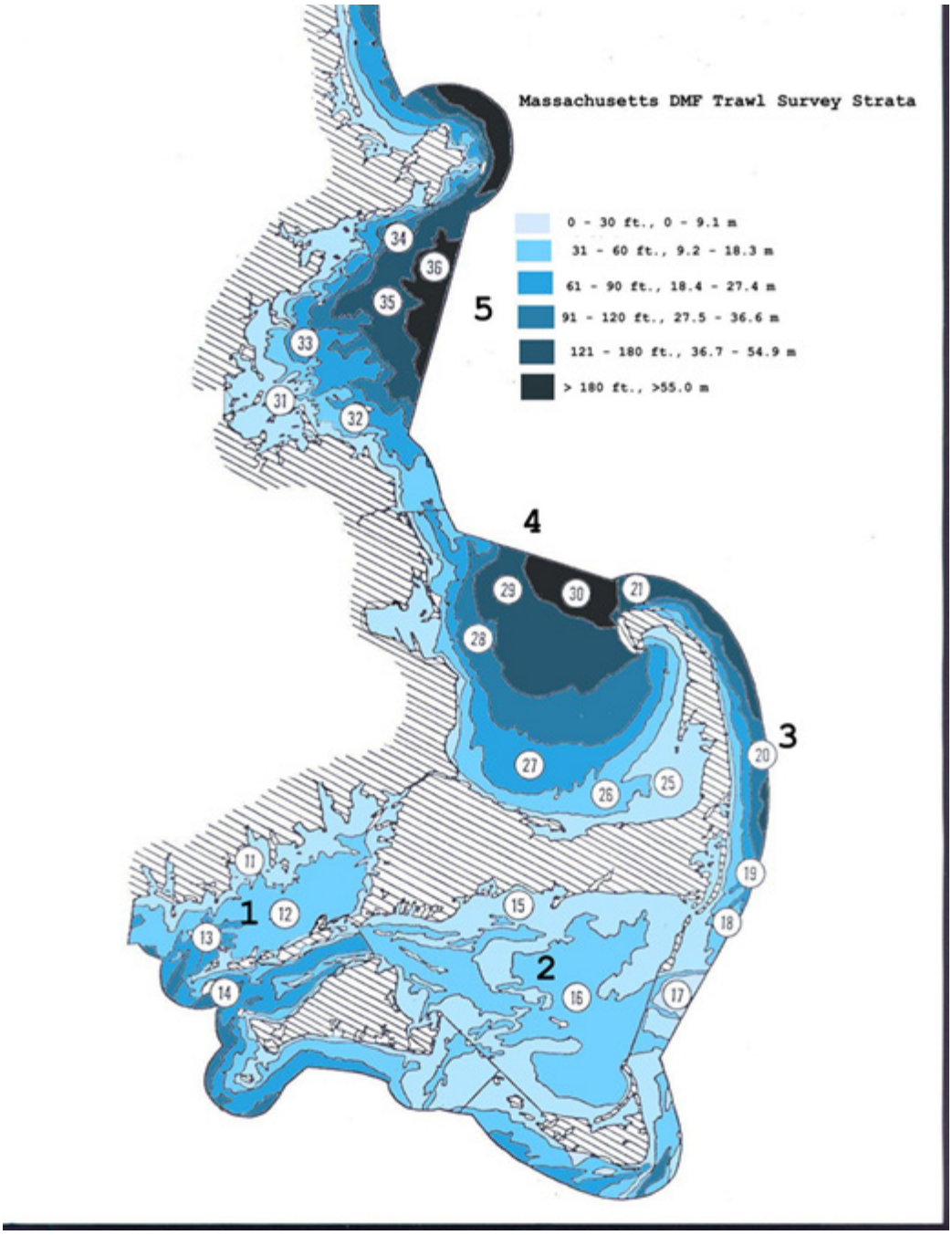


Figure B54. Massachusetts Division of Marine Fisheries inshore bottom trawl survey strata. Cape Cod Bay – Mass Bay region (Regions 4 and 5; strata 25 - 36) are used.

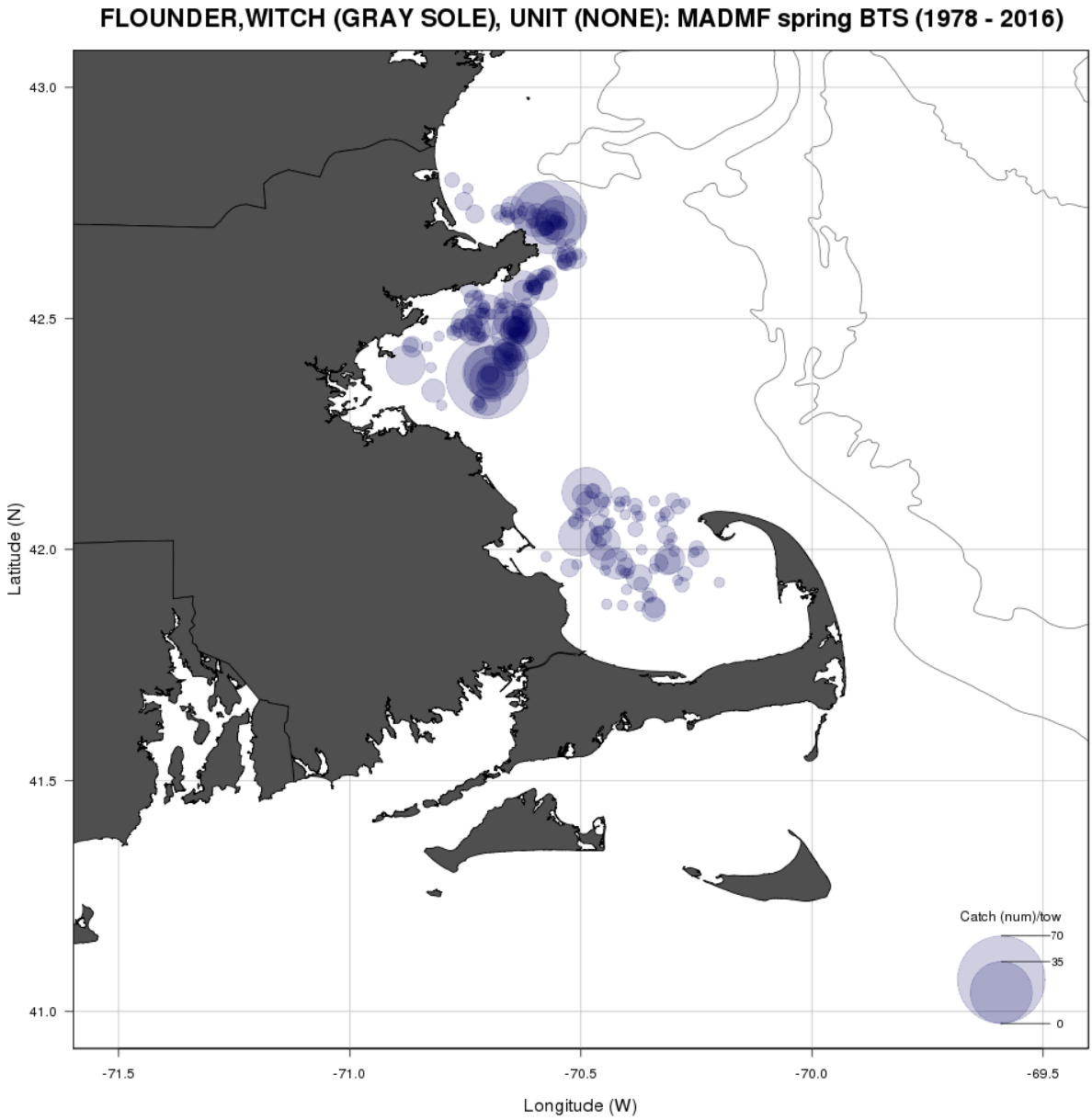


Figure B55. Number per tow of witch flounder in the Massachusetts Division of Marine Fisheries inshore bottom trawl survey strata. Cape Cod Bay – Mass Bay region (Regions 4 and 5; strata 25 - 36), spring 1978-2016.

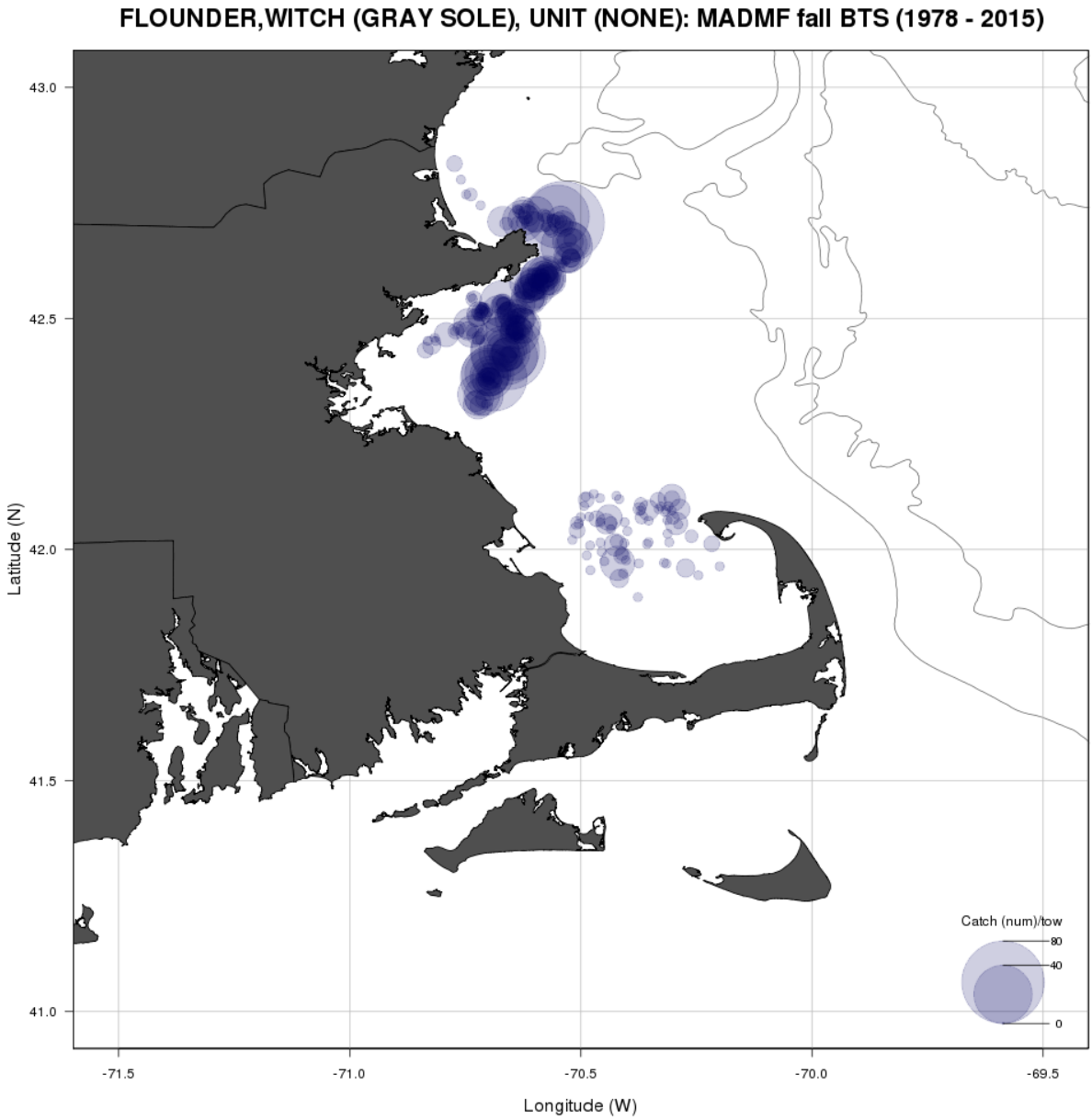


Figure B56. Number per tow of witch flounder in the Massachusetts Division of Marine Fisheries inshore bottom trawl survey strata. Cape Cod Bay – Mass Bay region (Regions 4 and 5; strata 25 - 36), autumn 1978-2015.

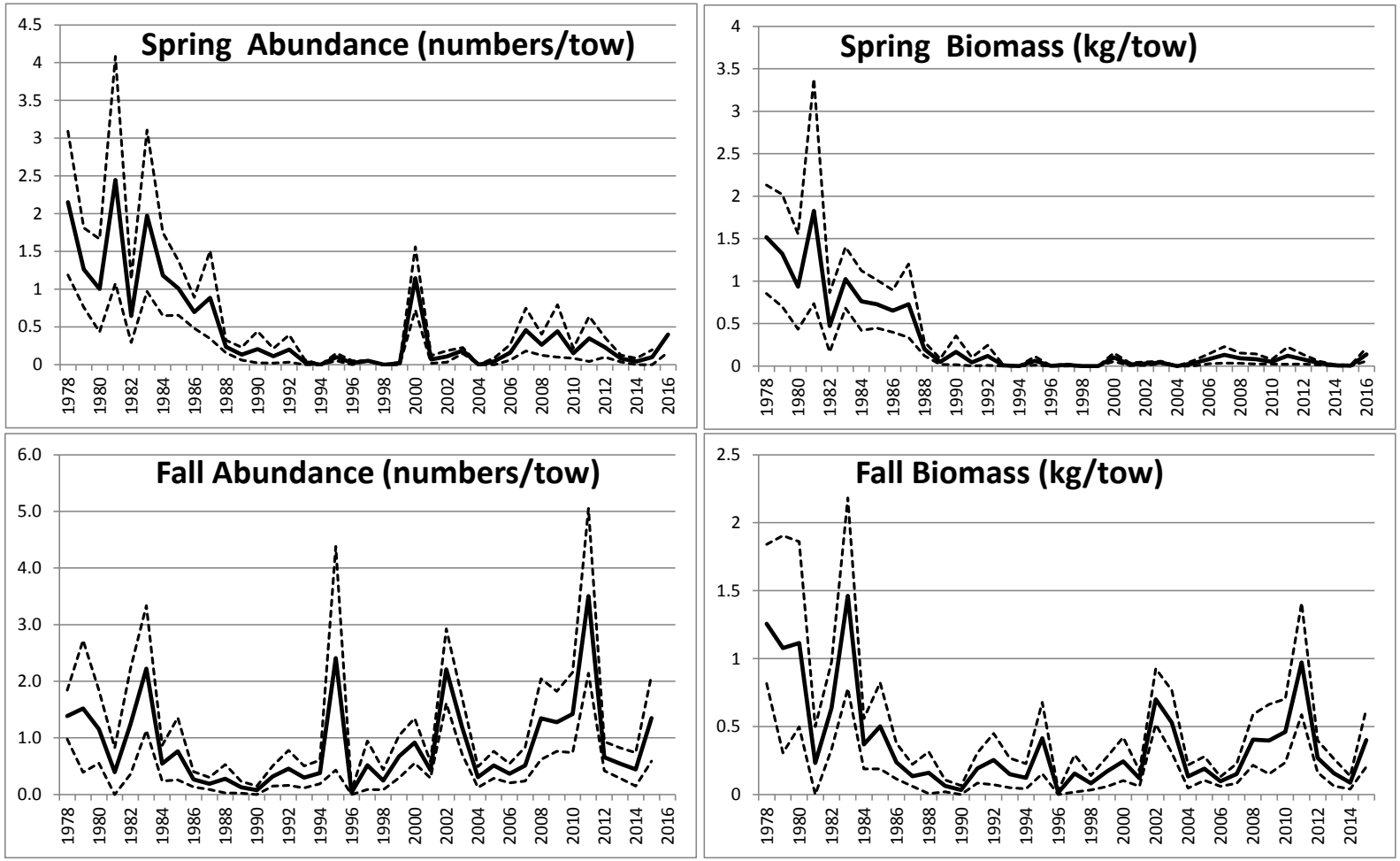


Figure B57. Stratified mean catch per tow, in numbers (left) and weight (right), of witch flounder in the Massachusetts Division of Marine Fisheries spring (top) and autumn (bottom) inshore trawl surveys in Cape Cod Bay – Mass Bay region (Regions 4 and 5), 1978 – 2016. Dashed line indicate the 90% confidence intervals.

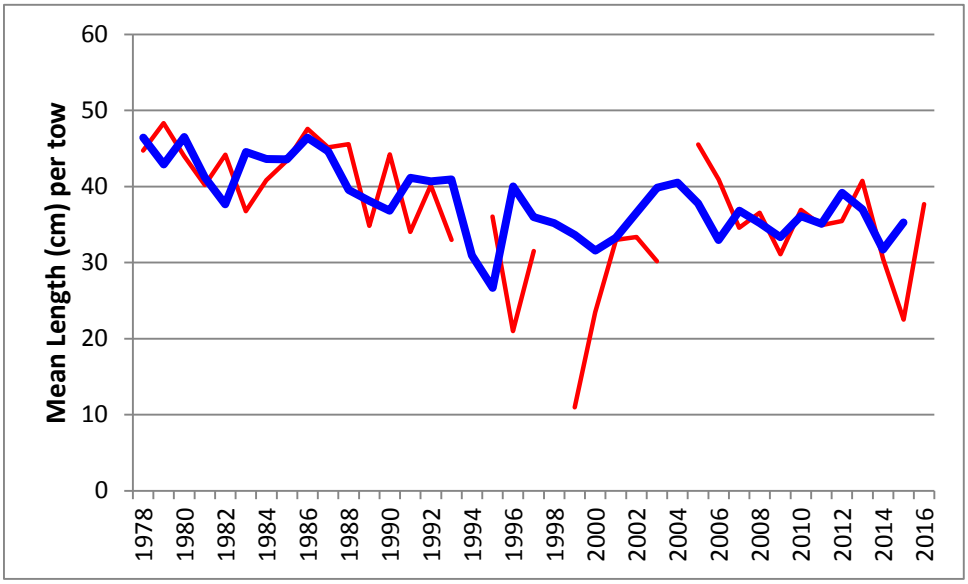


Figure B58. Stratified mean length (cm) per tow of witch flounder in the Massachusetts Division of Marine Fisheries spring (red line) and autumn (blue line) inshore trawl surveys in Cape Cod Bay – Mass Bay region (Regions 4 and 5), 1978 – 2016.

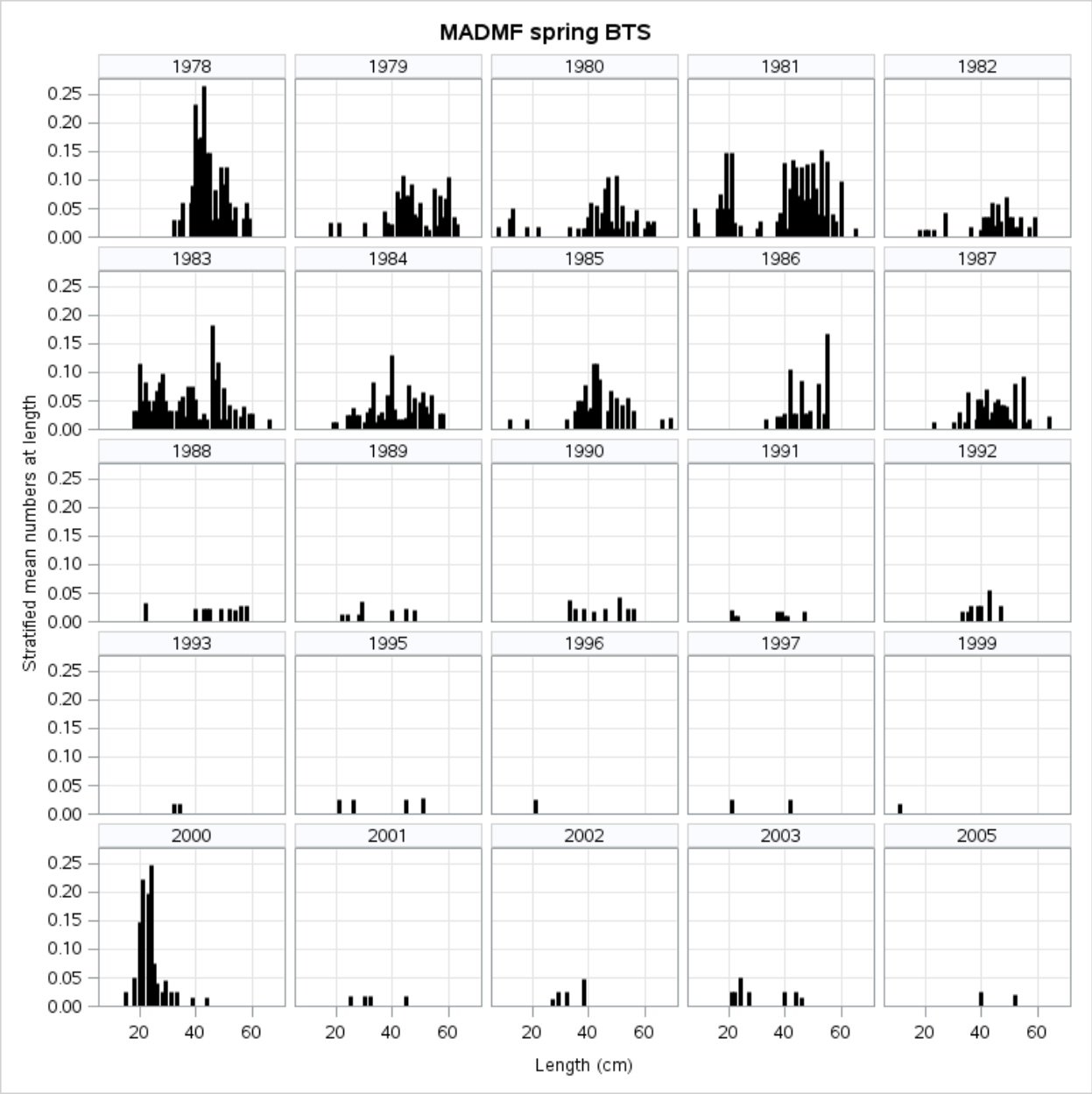


Figure B59. Stratified mean number per tow at length (cm) of witch flounder in the Massachusetts Division of Marine Fisheries spring bottom trawl surveys in Cape Cod Bay – Mass Bay region (Regions 4 and 5), 1978 – 2016.

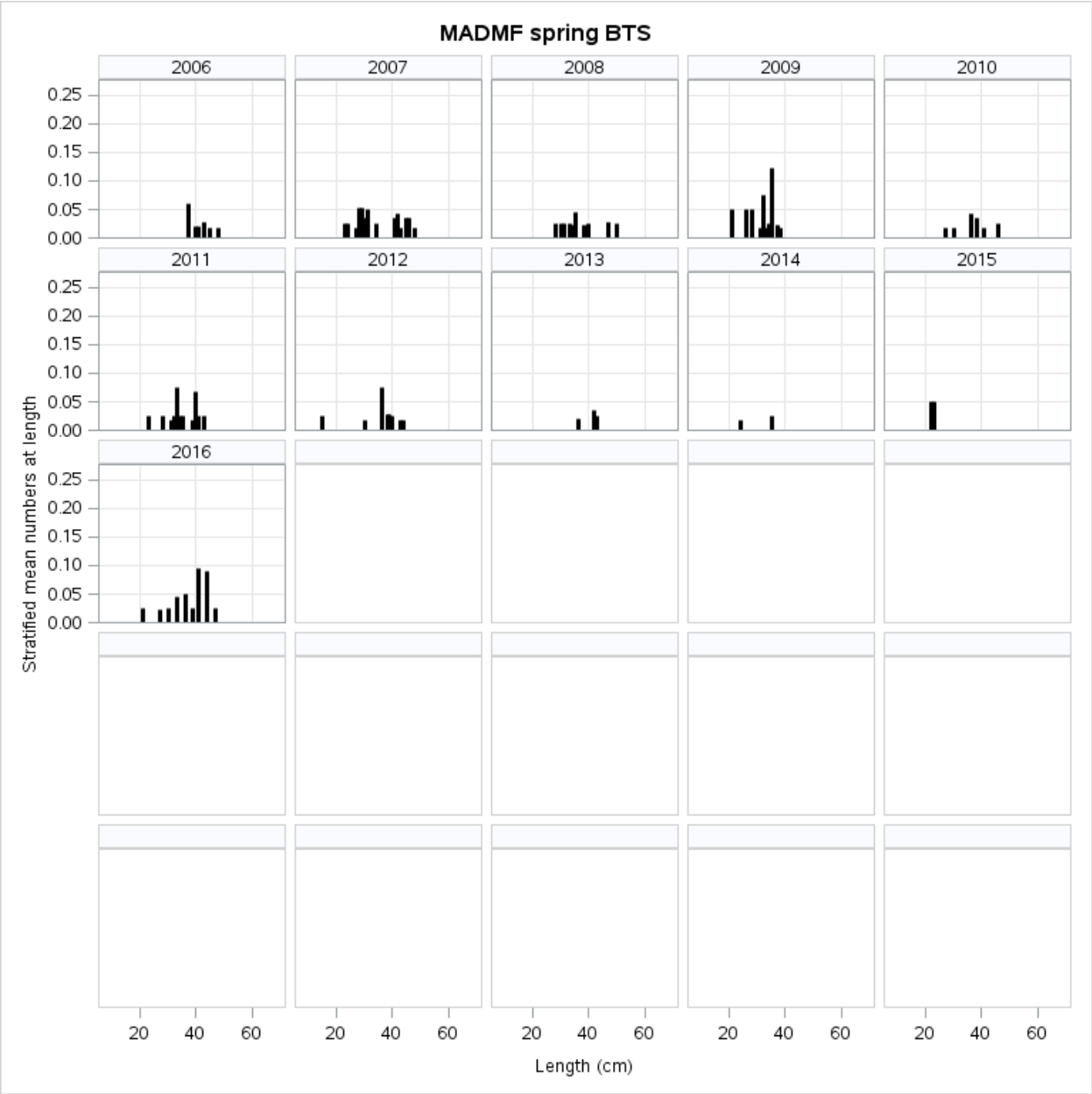


Figure B59, continued. Stratified mean number per tow at length (cm) of witch flounder in the Massachusetts Division of Marine Fisheries spring bottom trawl surveys in Cape Cod Bay – Mass Bay region (Regions 4 and 5), 1978 – 2016.

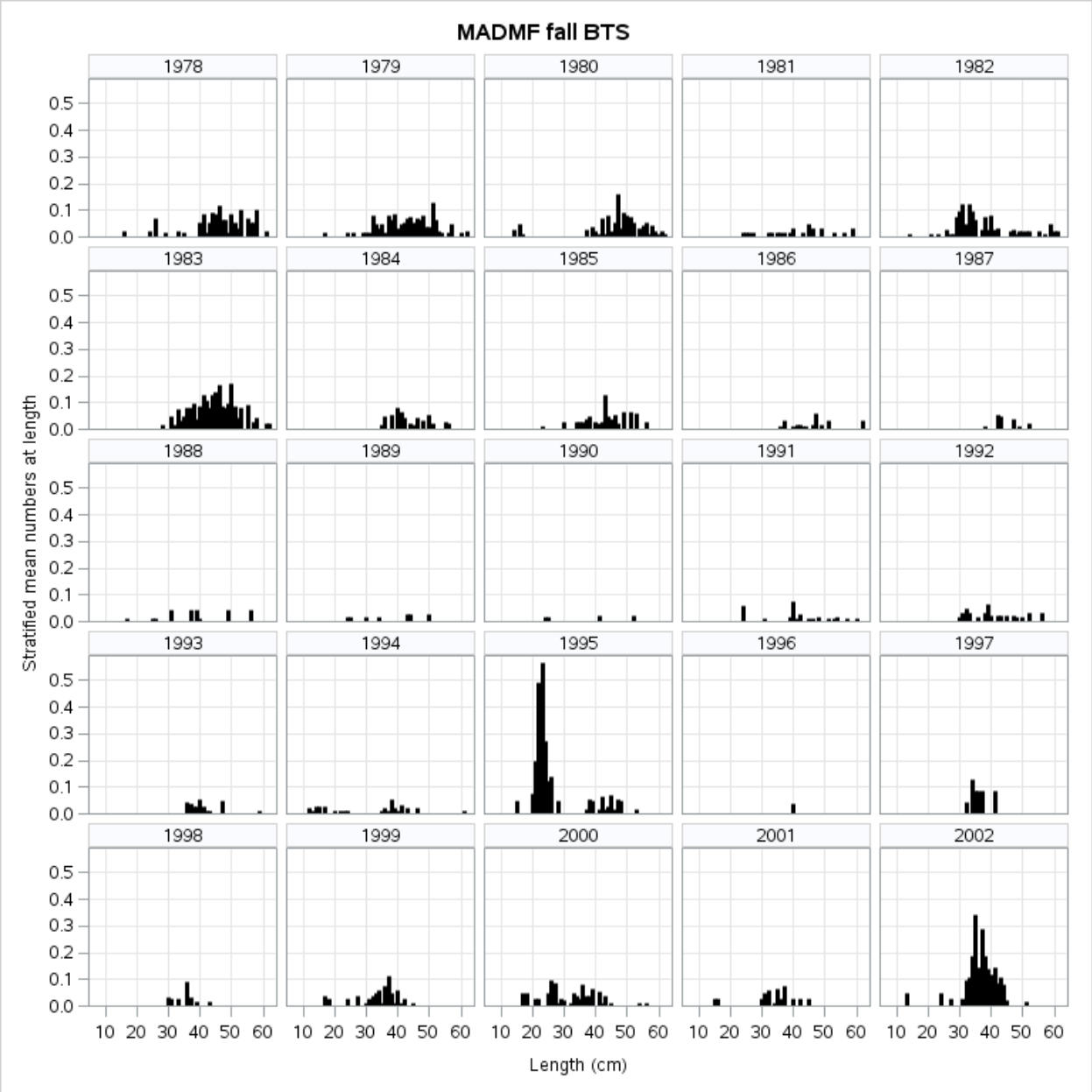


Figure B60. Stratified mean number per tow at length (cm) of witch flounder in the Massachusetts Division of Marine Fisheries autumn bottom trawl surveys in Cape Cod Bay – Mass Bay region (Regions 4 and 5), 1978 – 2015.

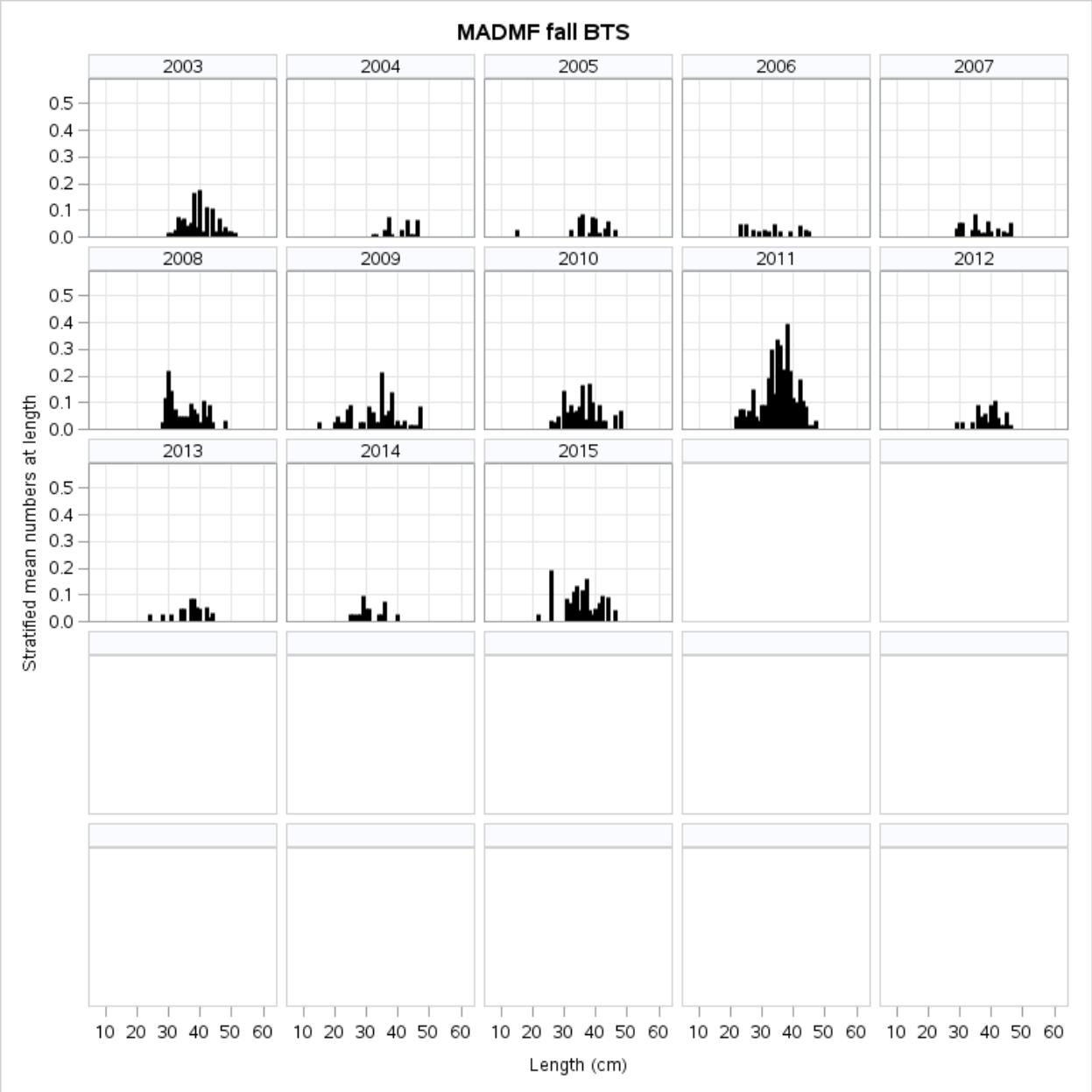


Figure B60, continued. Stratified mean number per tow at length (cm) of witch flounder in the Massachusetts Division of Marine Fisheries autumn bottom trawl surveys in Cape Cod Bay – Mass Bay region (Regions 4 and 5), 1978 – 2015.

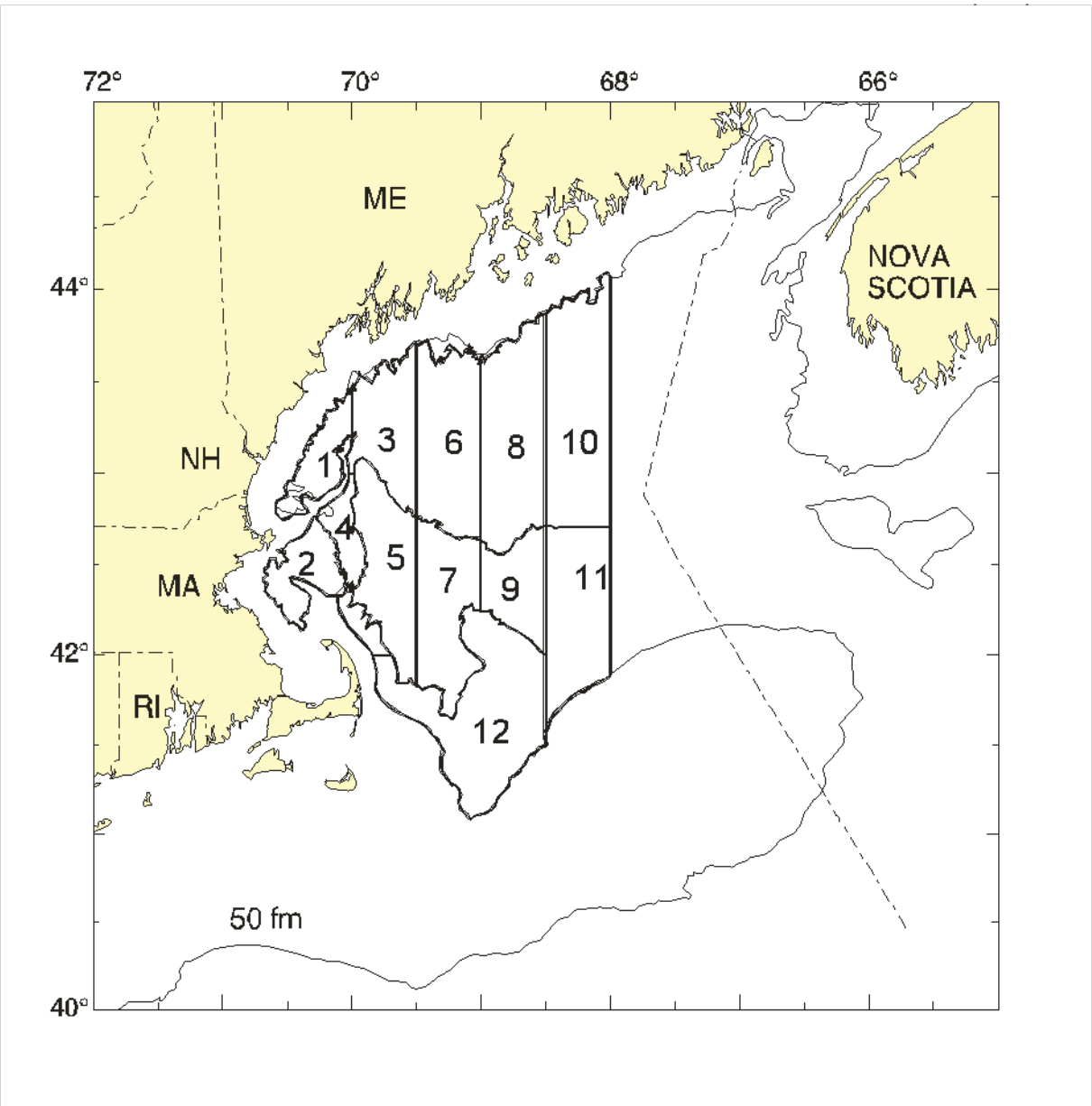


Figure B61. Sampling strata (1, 3, 6, 8) used during the Atlantic States Marine Fisheries Commission summer shrimp trawl survey.

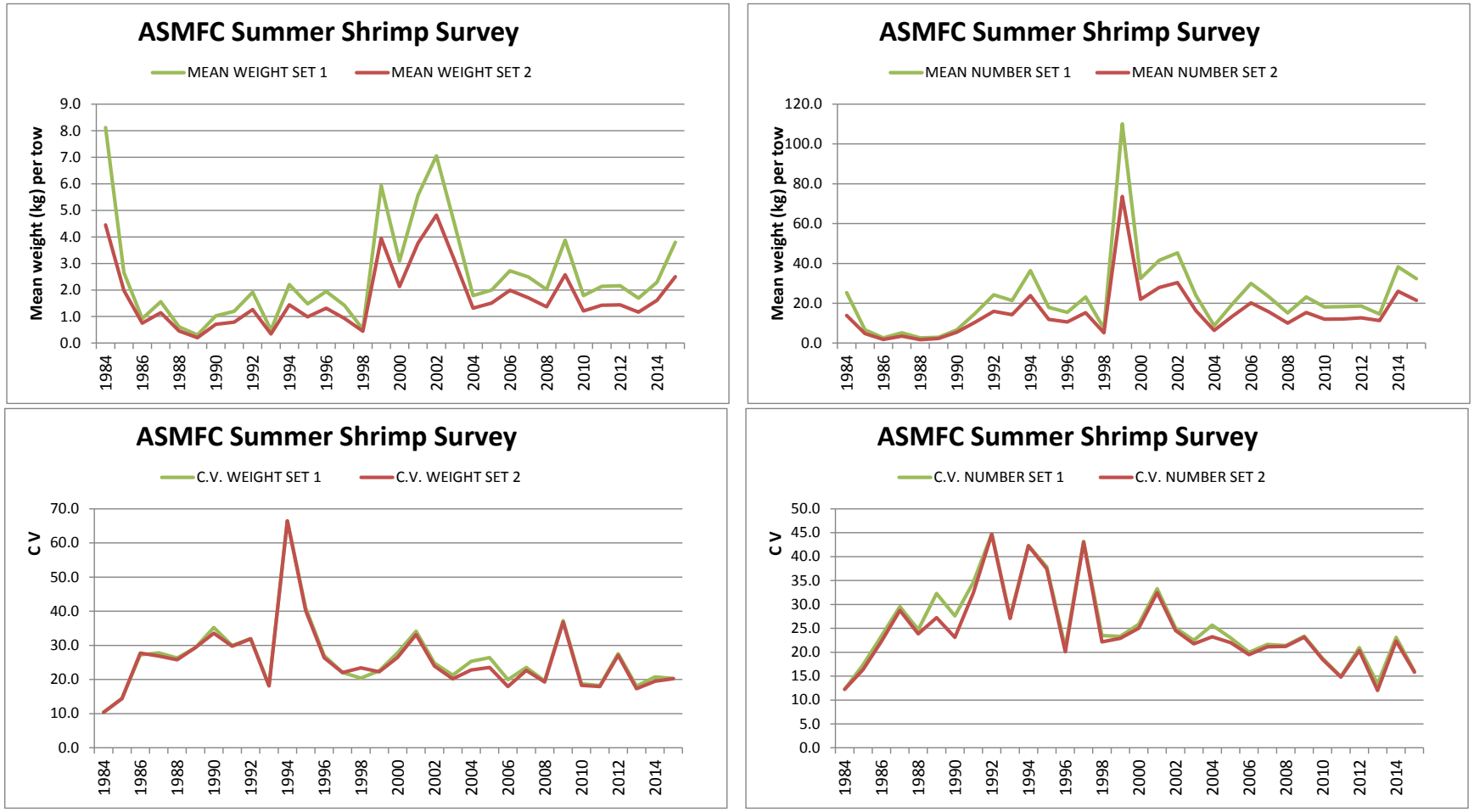


Figure B62. Comparison of stratified mean weight (left) and numbers (right) per tow and their associated coefficient of variation (CV) of two strata sets (set 1 = 1, 3, 6, 8 [green]; set 2 = 1, 3, 5, 6, 7, 8 [red]) in the Atlantic State Marine Fisheries Commission (ASMFC) summer shrimp survey in the Gulf of Maine, 1984 – 2015.

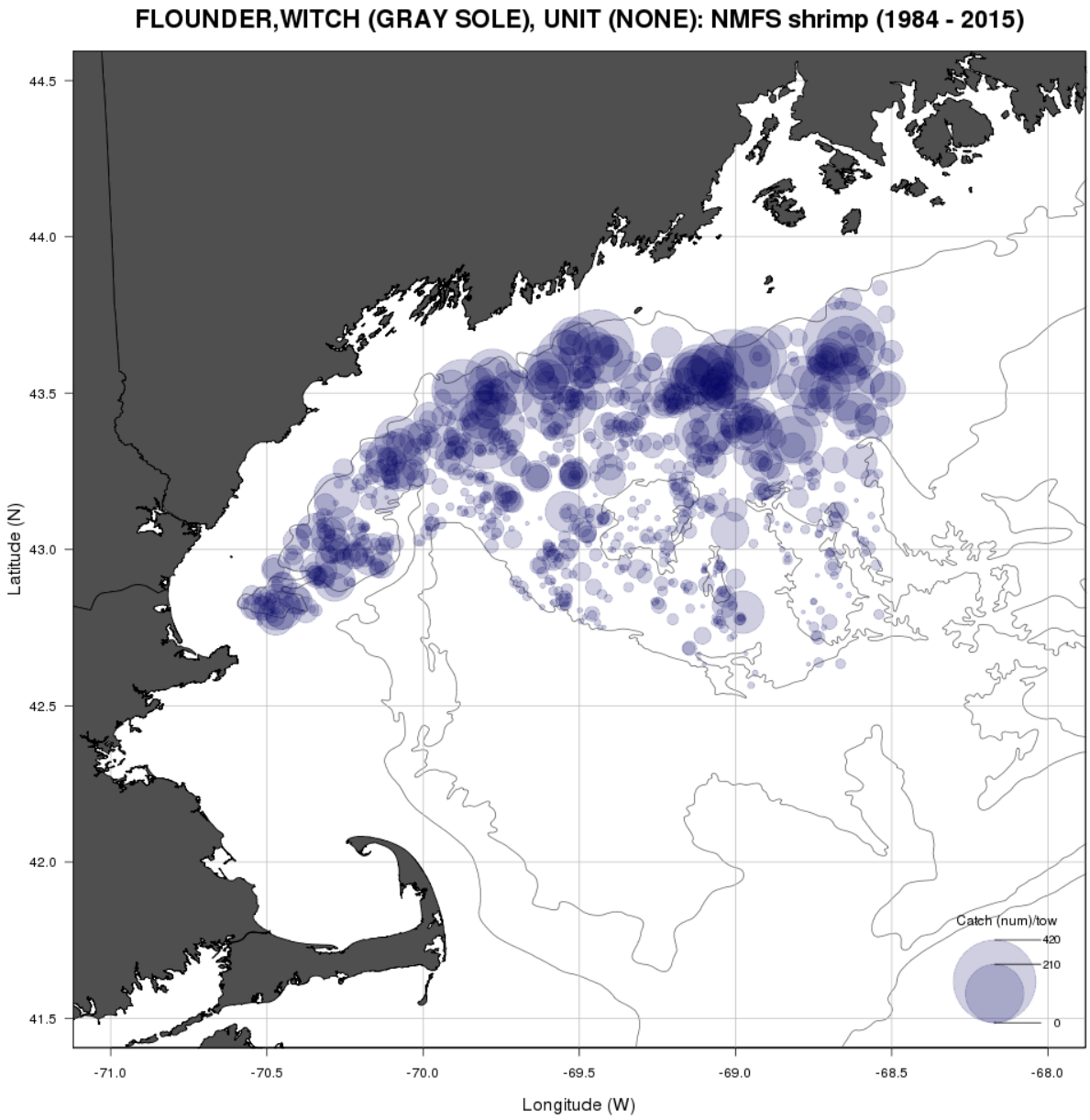


Figure B63. Number per tow of witch flounder in the in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015.

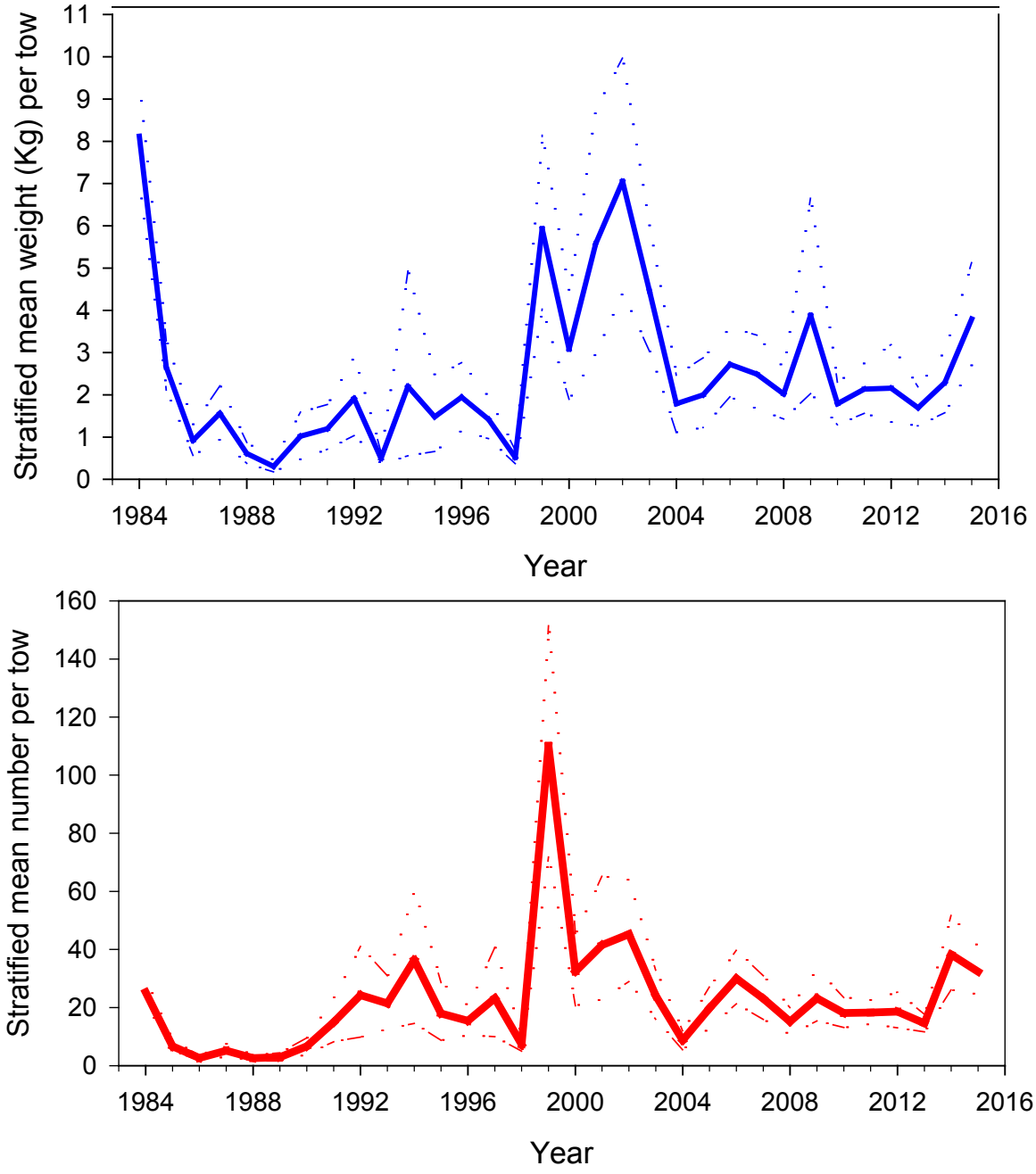


Figure B64. Stratified mean catch per tow, in weight (kg; top) and numbers (bottom), of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015. Dash lines represents 90% confidence intervals.

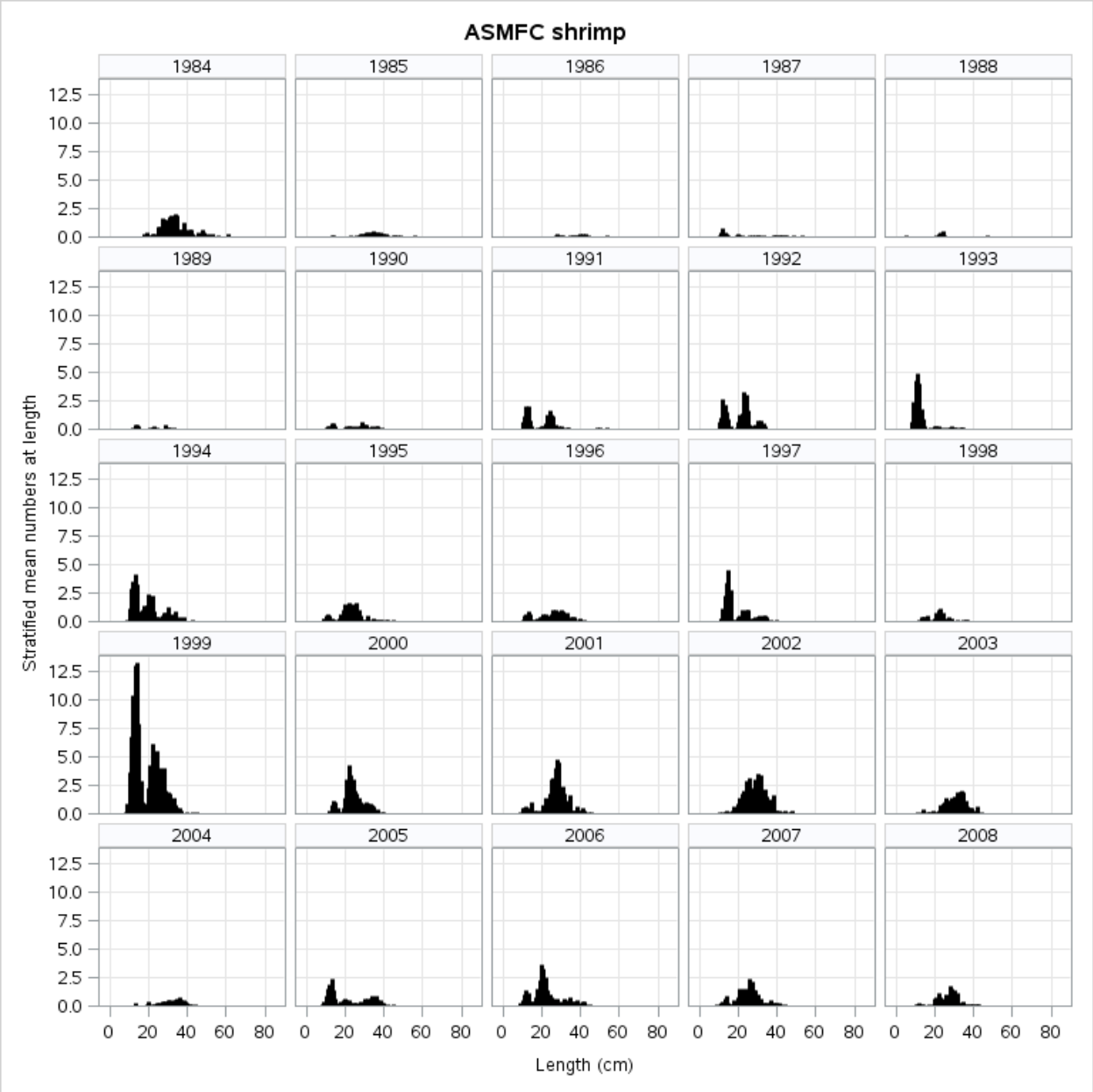


Figure B65. Stratified mean number per tow at length (cm), of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015.

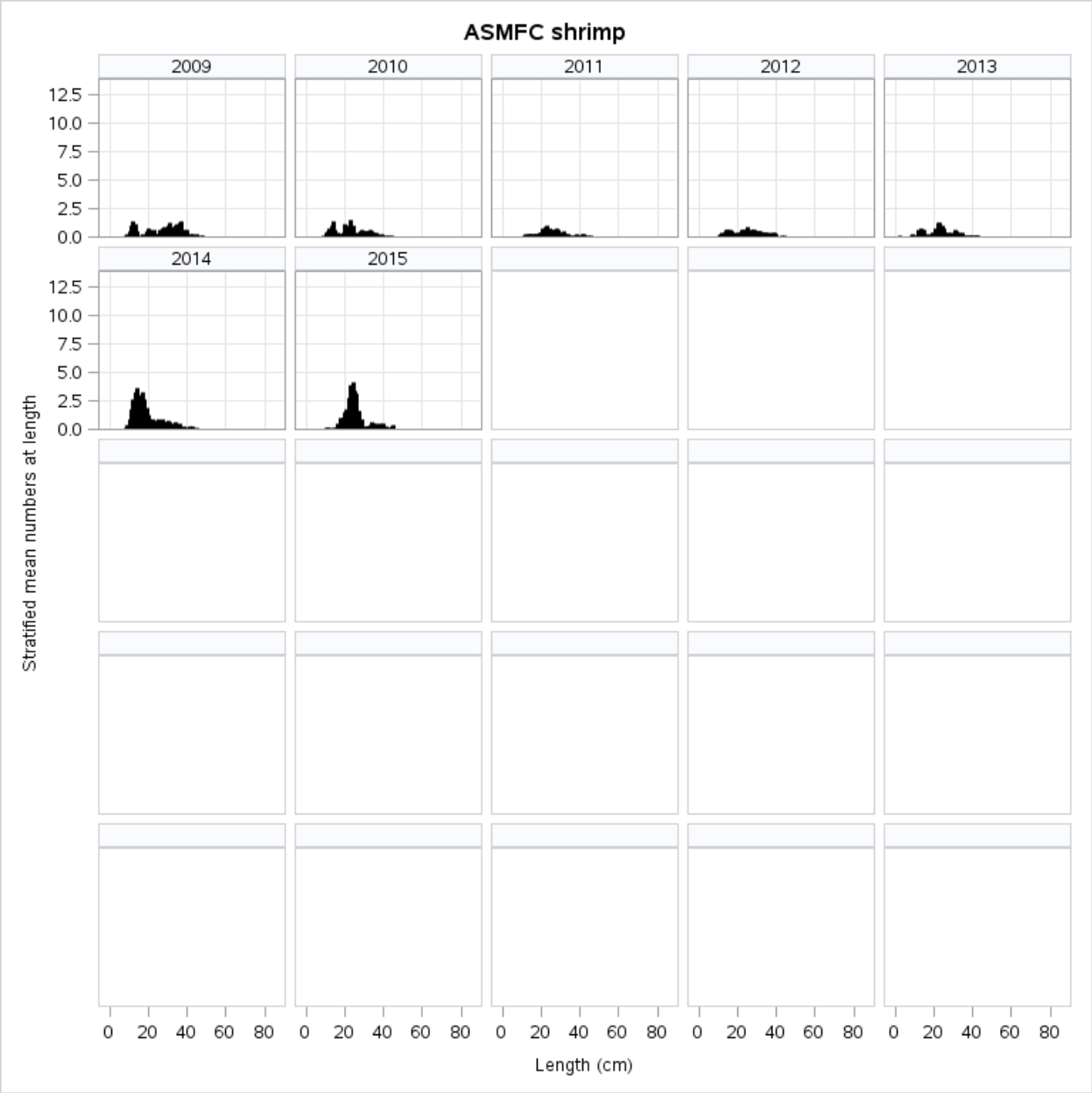


Figure B65, continued. Stratified mean number per tow at length (cm), of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015.

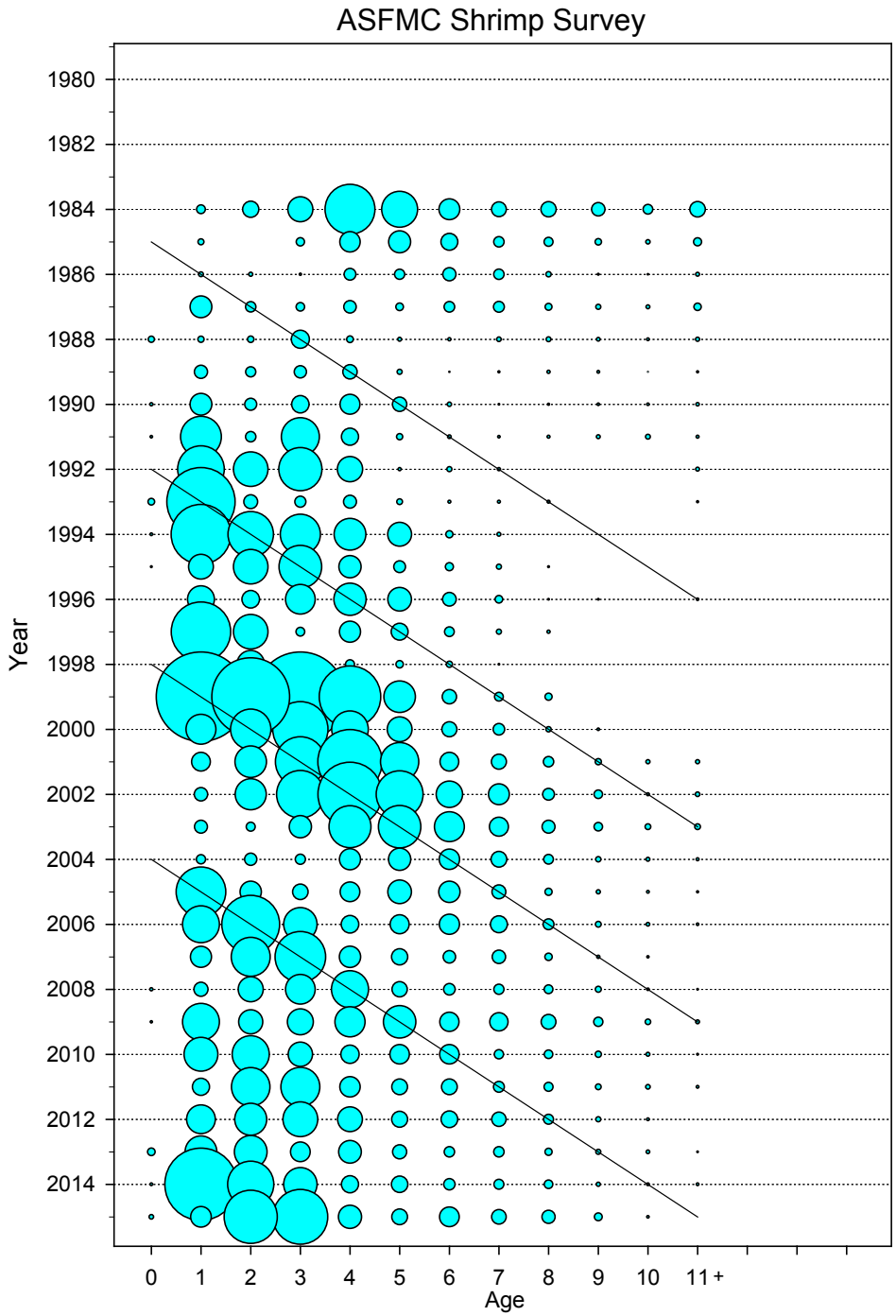


Figure B66. Stratified mean number per tow at age (cm), of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015.

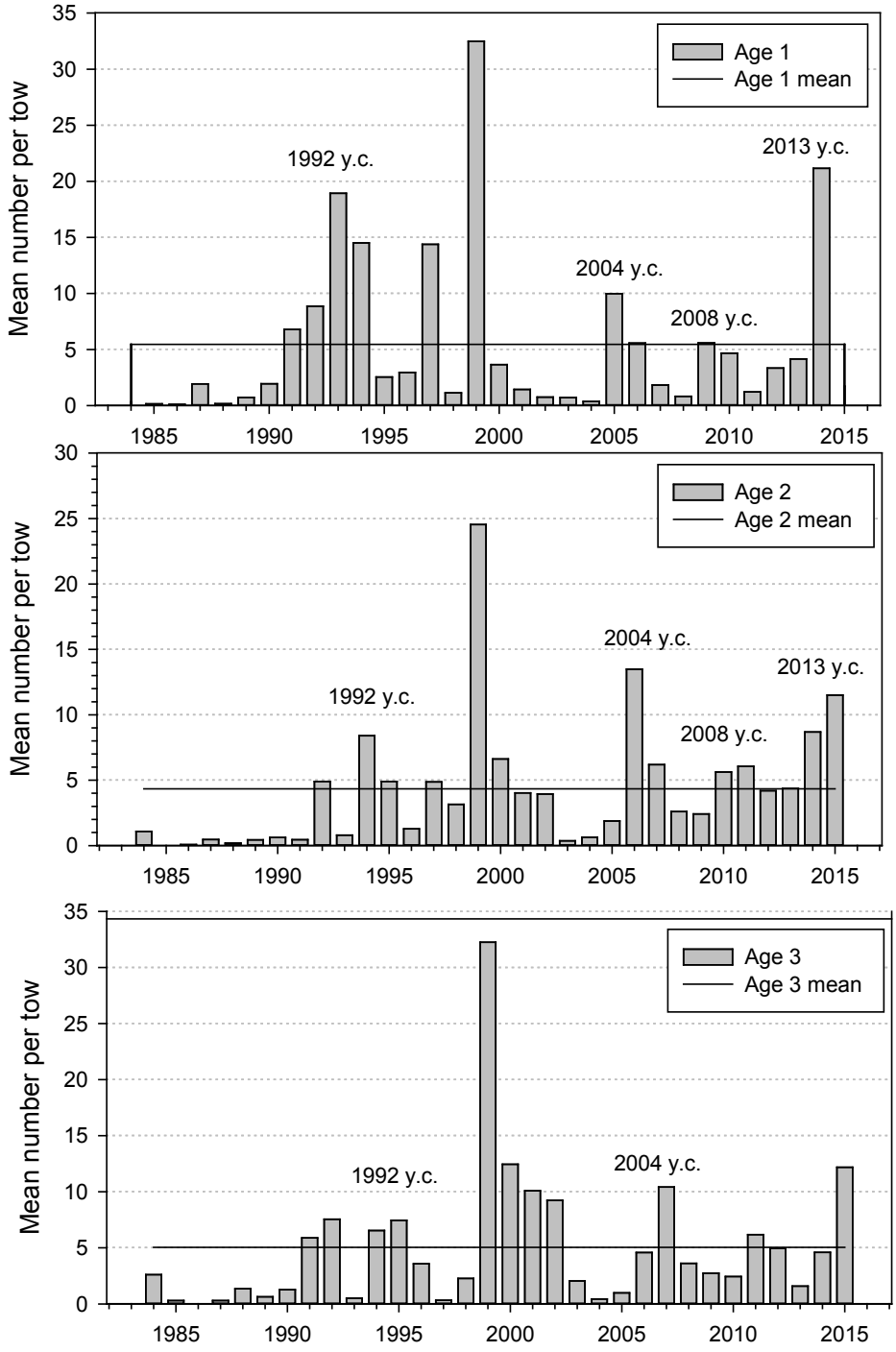


Figure B67. Stratified mean number per tow of age 1 (top), age 2 (middle) and age 3 (bottom) witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015. Time series mean number per tow at age is also given.

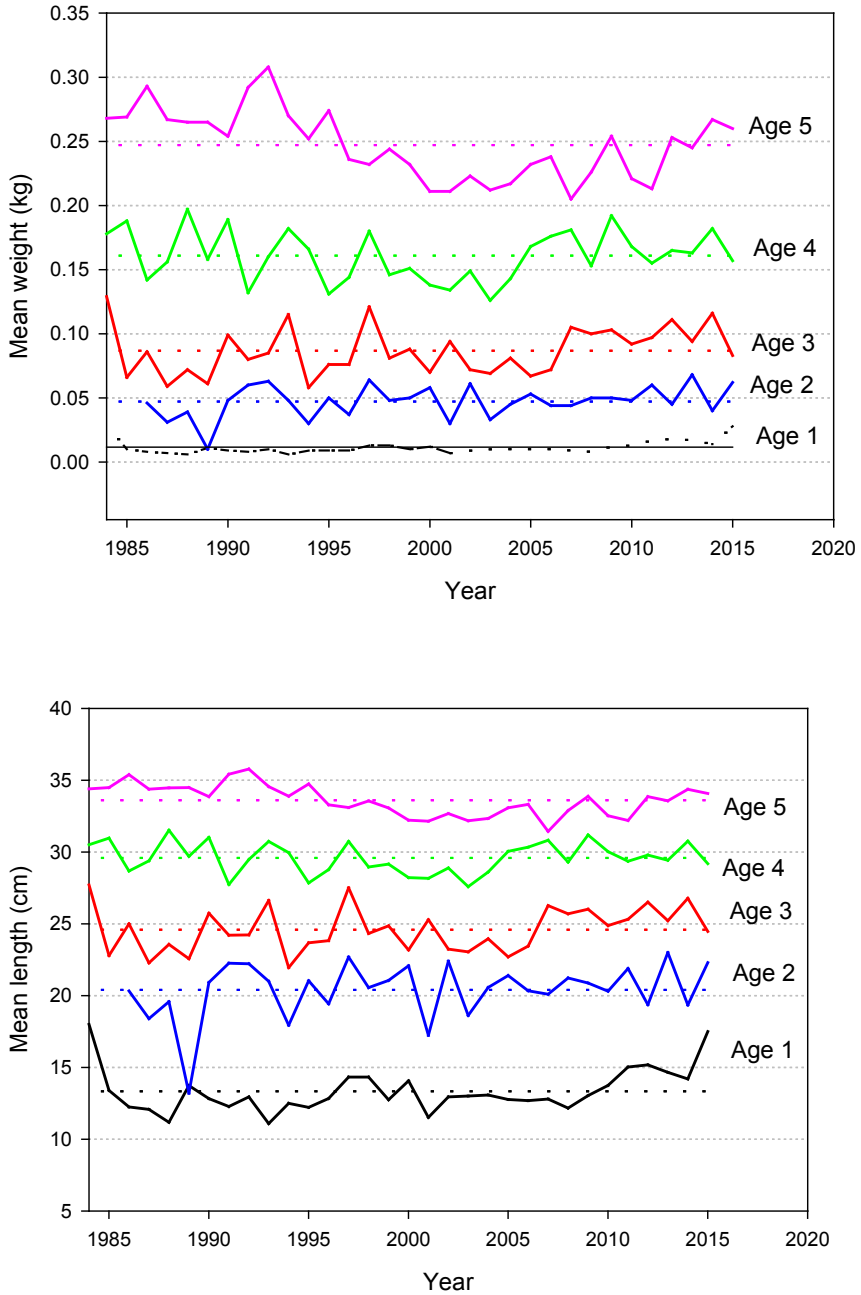


Figure B68. Stratified mean weight (kg; top) and length (cm; bottom) per tow of witch flounder in the Atlantic States Marine Fisheries Commission summer shrimp survey (strata set 1, 3, 6, 8), 1984 - 2015.

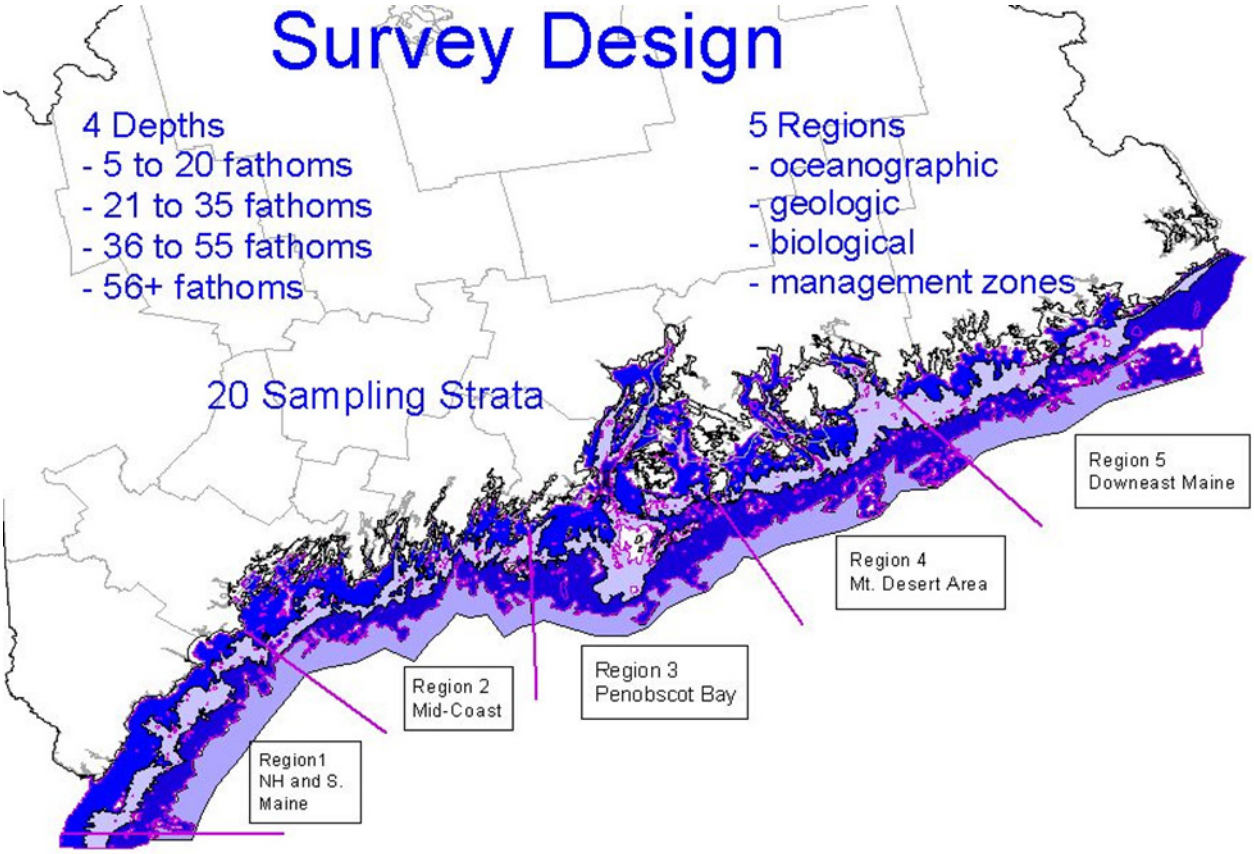


Figure B69. This map shows the 5 regions (each region is bounded by straight purple lines) and 4 depth strata (depicted in blue and purple shading) used in the Maine-New Hampshire Inshore Trawl Survey.

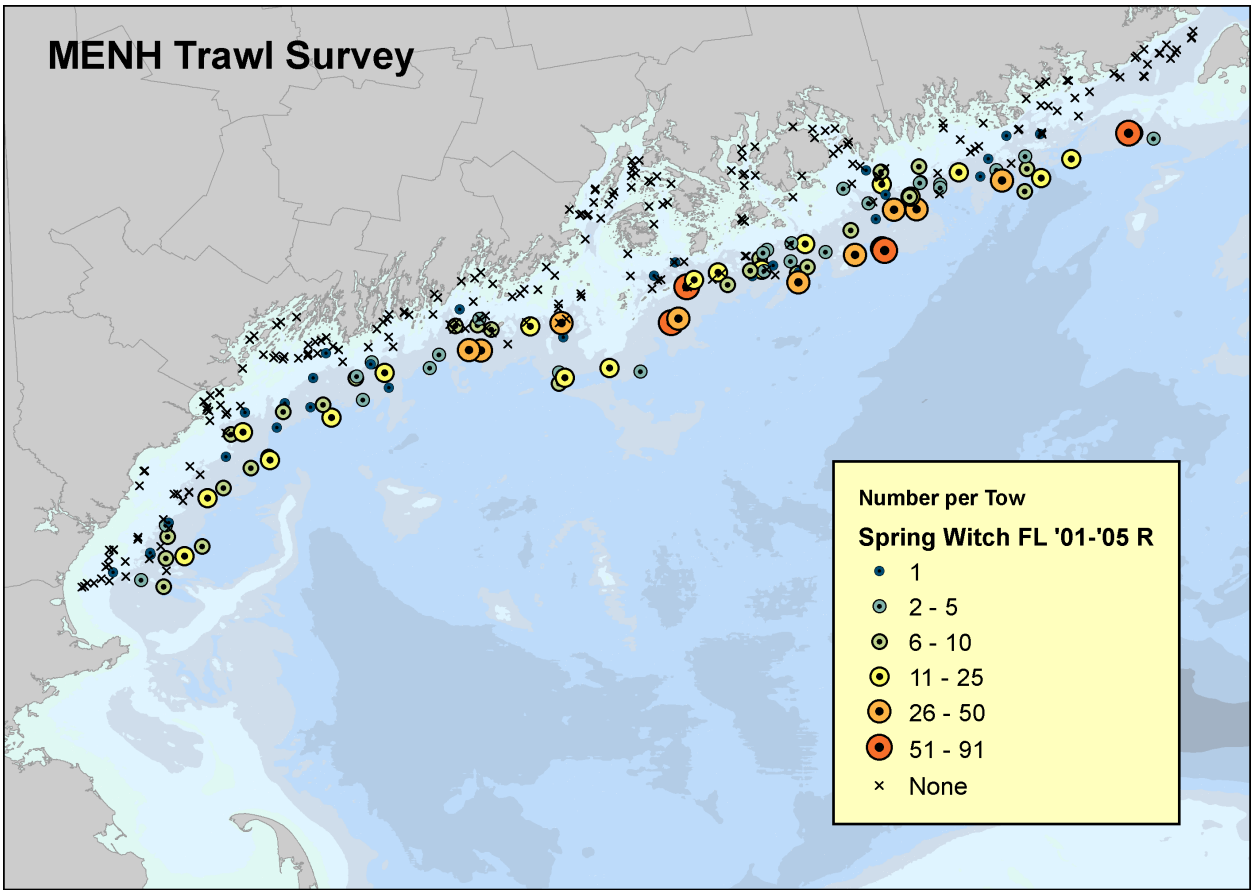


Figure B70. This map depicts survey catches for witch flounder (Glyptocephalus cynoglossus). The color-shaded circles represent number of fish per tow during the 2001-2005 (re-stratified) spring Maine-New Hampshire inshore trawl survey. The black '+' (plus symbol) represent no catch. Bathymetry is depicted in blue and gray shading.

Provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.

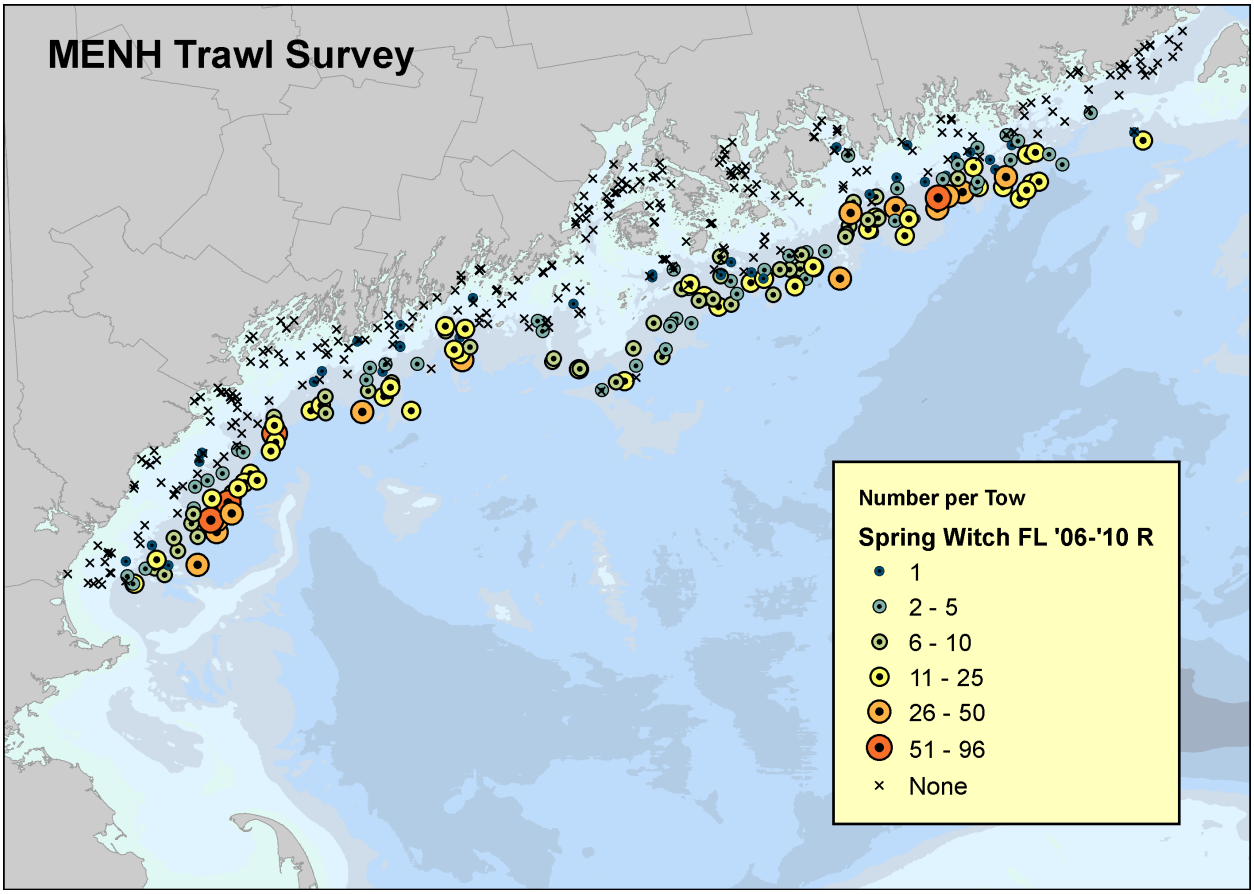


Figure B71. This map depicts survey catches for witch flounder (*Glyptocephalus cynoglossus*). The color-shaded circles represent number of fish per tow during the 2006-2010 (re-stratified) spring Maine-New Hampshire inshore trawl survey. The black '+' (plus symbol) represent no catch. Bathymetry is depicted in blue and gray shading.

Provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.

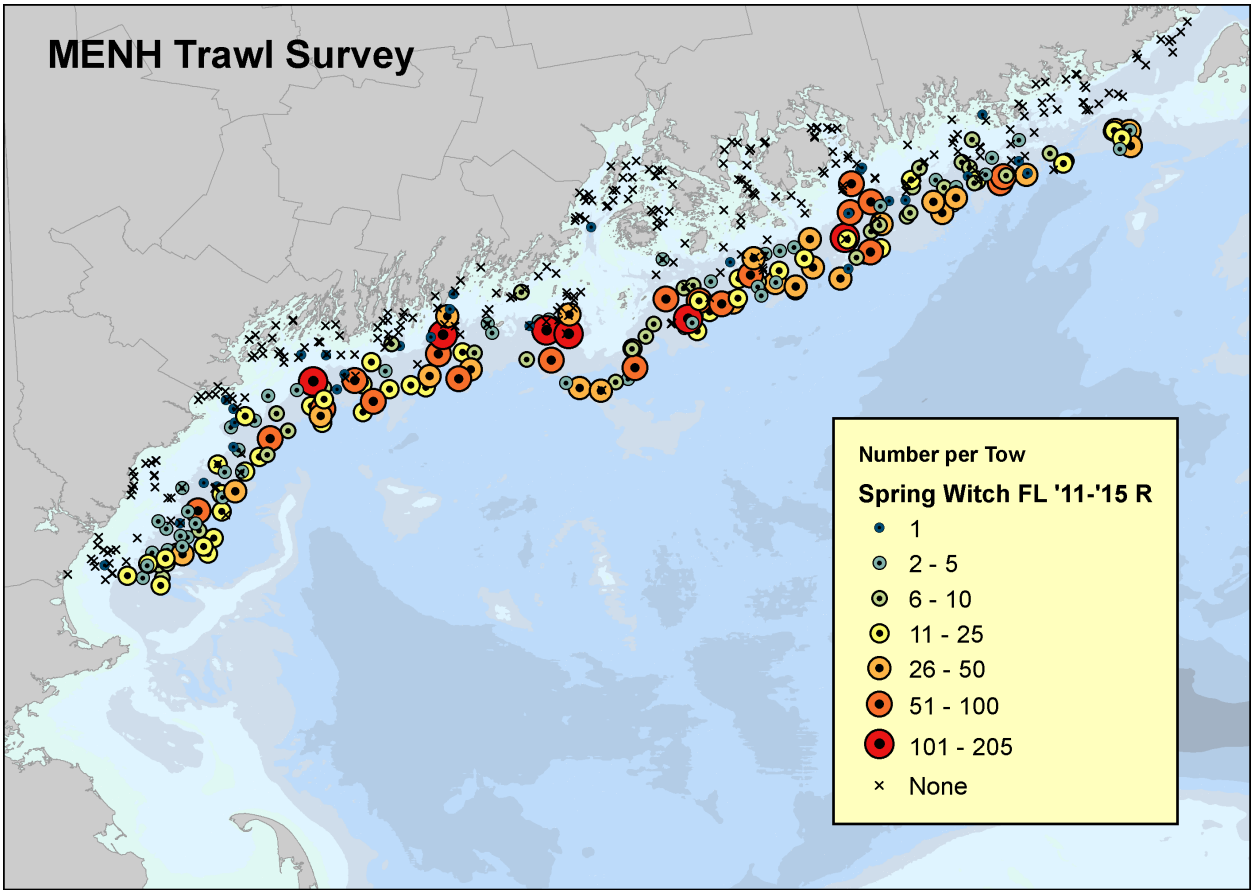


Figure B72. This map depicts survey catches for witch flounder (*Glyptocephalus cynoglossus*). The color-shaded circles represent number of fish per tow during the 2011-2015 (re-stratified) spring Maine-New Hampshire inshore trawl survey. The black '+' (plus symbol) represent no catch. Bathymetry is depicted in blue and gray shading.

Provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.

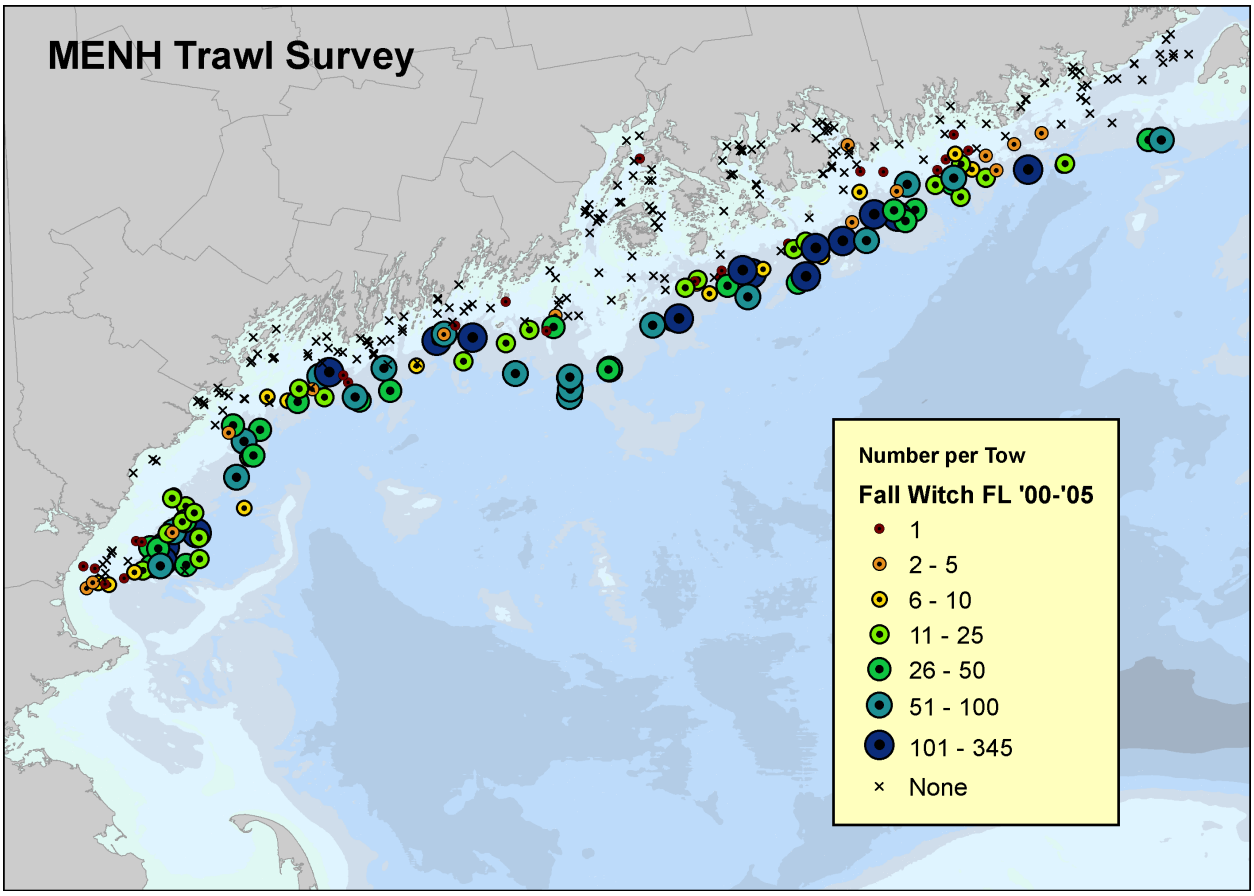


Figure B73. This map depicts survey catches for witch flounder (*Glyptocephalus cynoglossus*). The color-shaded circles represent number of fish per tow during the 2000-2005 (re-stratified) fall Maine-New Hampshire inshore trawl survey. The black '+' (plus symbol) represent no catch. Bathymetry is depicted in blue and gray shading.

Provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.

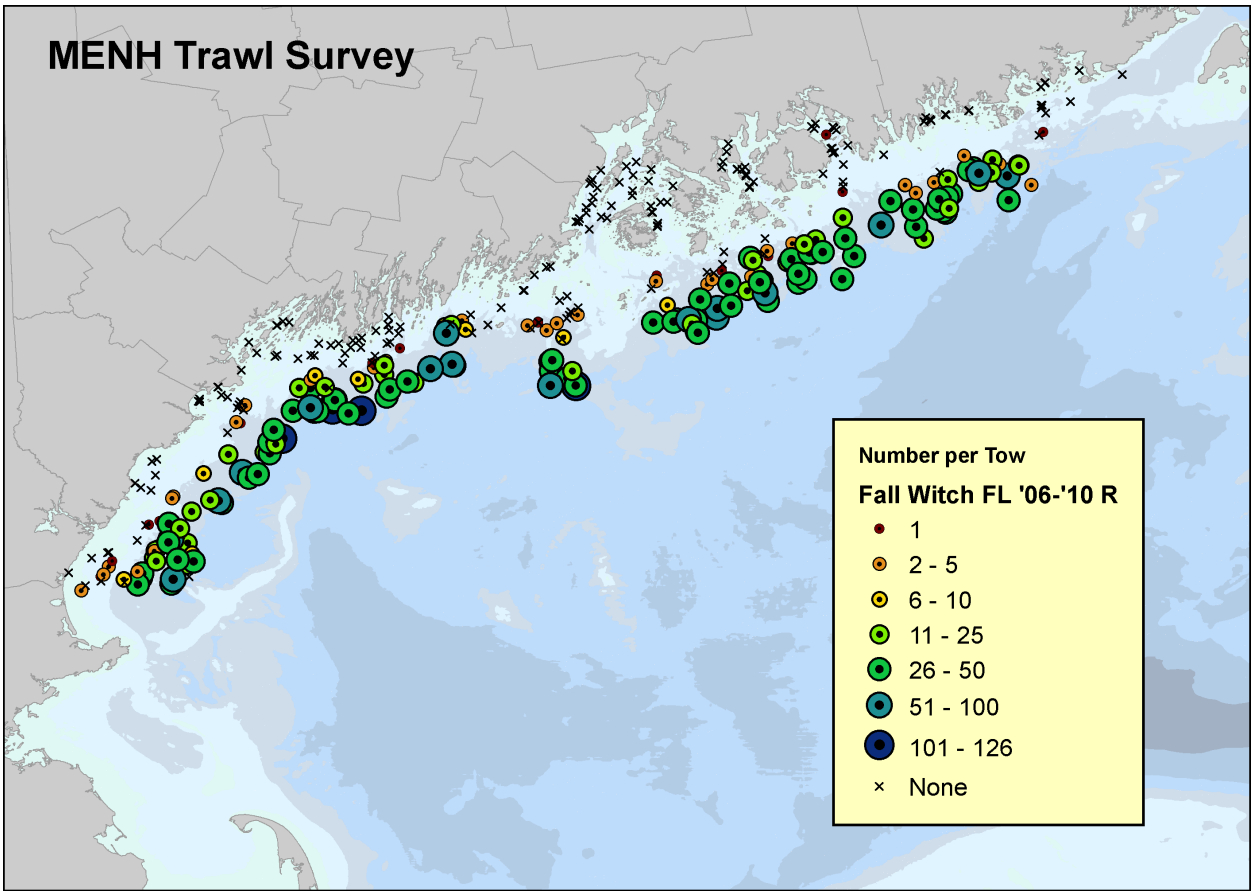


Figure B74. This map depicts survey catches for witch flounder (*Glyptocephalus cynoglossus*). The color-shaded circles represent number of fish per tow during the 2006-2010 (re-stratified) fall Maine-New Hampshire inshore trawl survey. The black '+' (plus symbol) represent no catch. Bathymetry is depicted in blue and gray shading.

Provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.

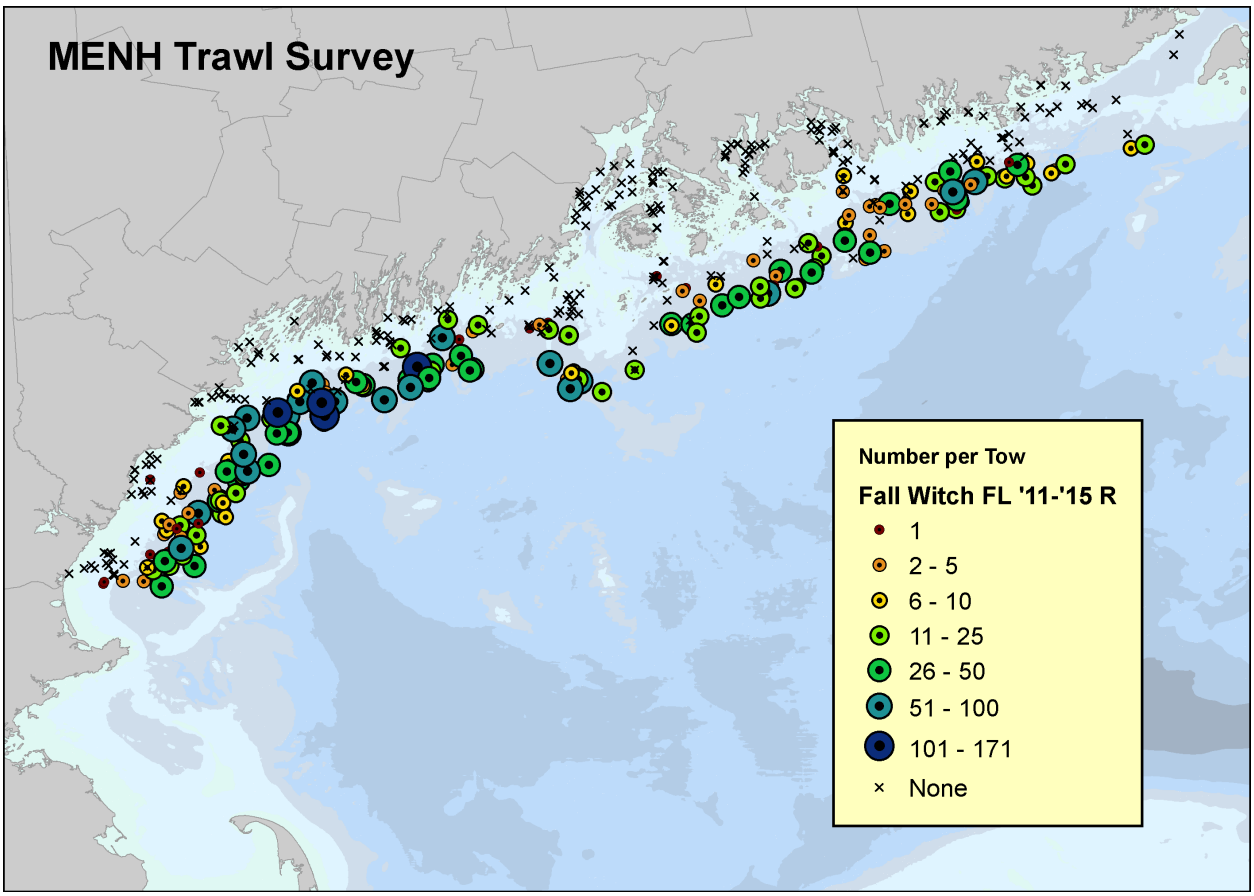
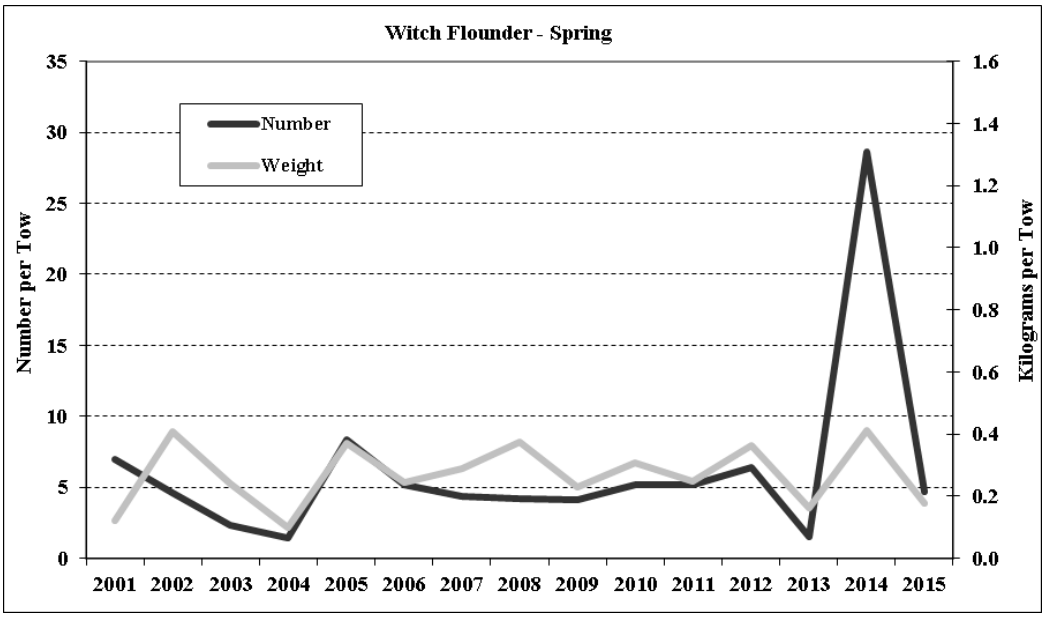


Figure B75. This map depicts survey catches for witch flounder (*Glyptocephalus cynoglossus*). The color-shaded circles represent number of fish per tow during the 2011-2015 (re-stratified) fall Maine-New Hampshire inshore trawl survey. The black '+' (plus symbol) represent no catch. Bathymetry is depicted in blue and gray shading.

Provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.



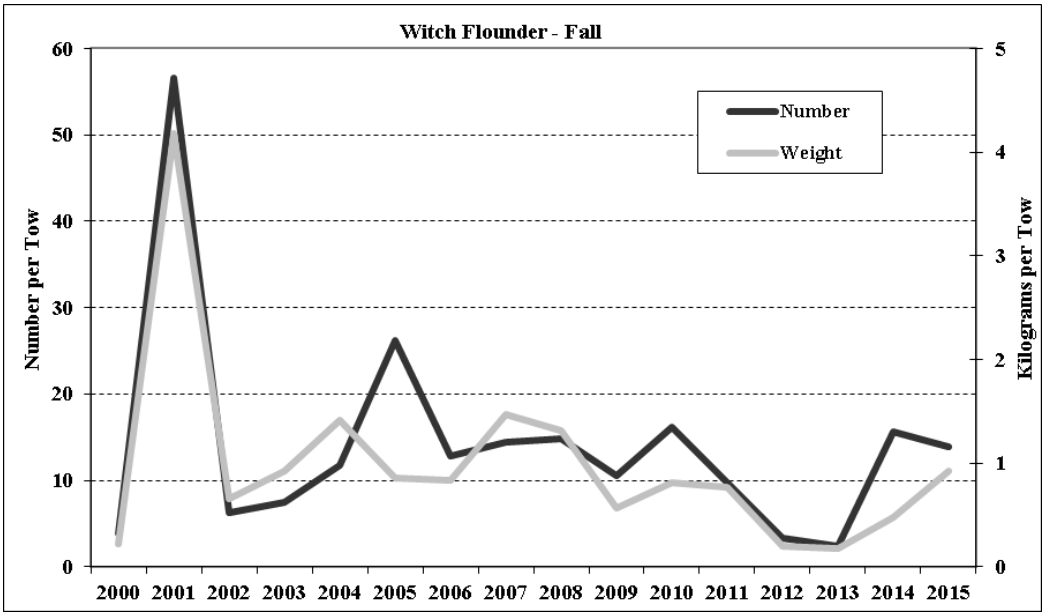


Figure B76. Stratified mean number per tow (black line) and weight (kg) per tow (gray line) of witch flounder in the Maine-New Hampshire inshore trawl survey spring (top) and fall (bottom) survey (strata 1 through 4; regions 1 to 5), 2000-2015. Indices for 2000-2002 were re-stratified; fixed stations are not included.

Survey indices have been provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016. Annual reports and survey procedures and protocols of the Maine-New Hampshire Inshore Trawl Surve, are available online at http://www.maine.gov/dmr/rm/trawl/reports/index.htm

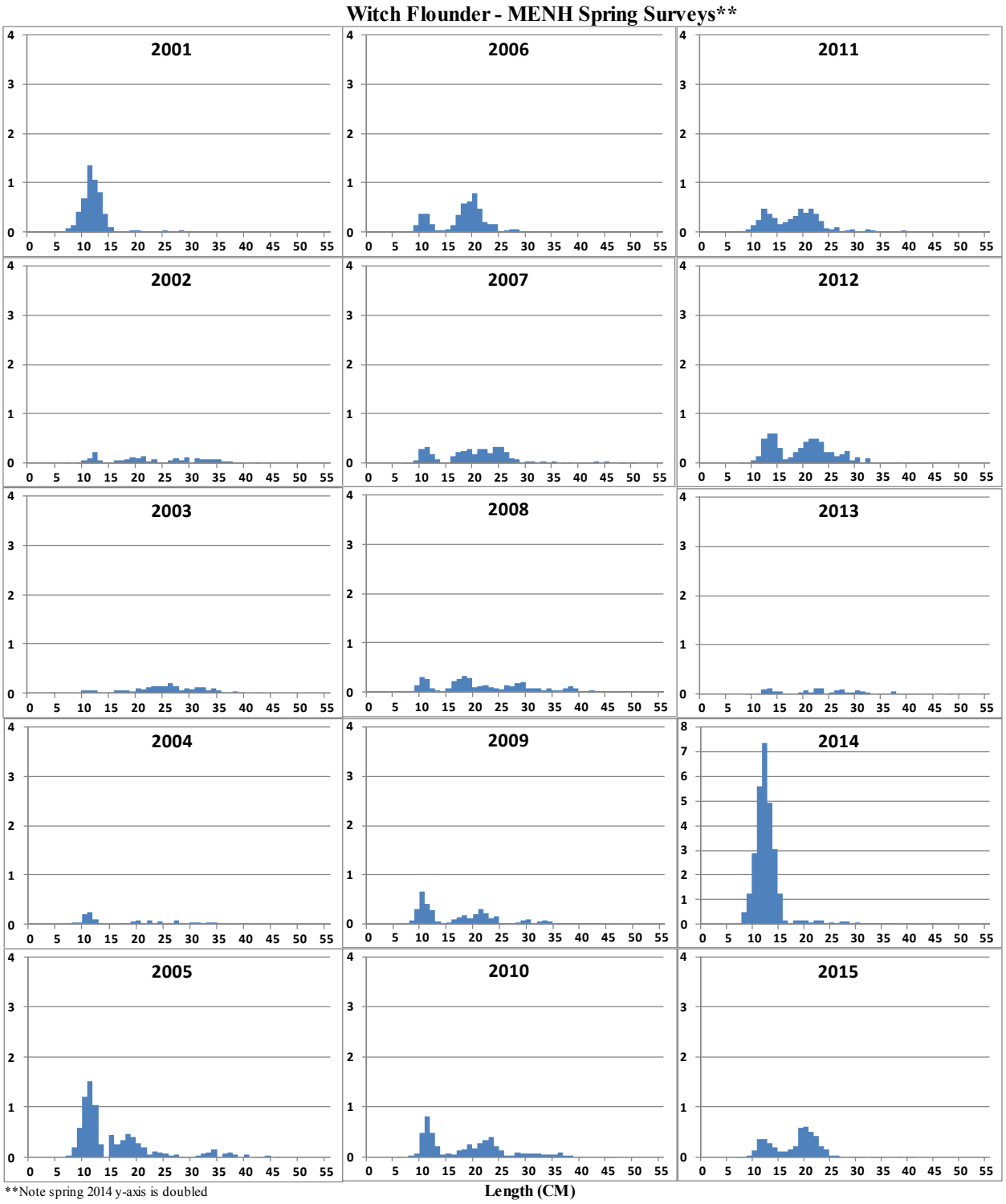


Figure B77. Stratified mean number of fish at length (cm; blue bars) for witch flounder from the 2000-2015 fall Maine-New Hampshire inshore trawl survey (regions 1 through 5; strata 1 through 4). Indices for 2000-2002 were re-stratified; fixed stations are not included.

Survey indices have been provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.

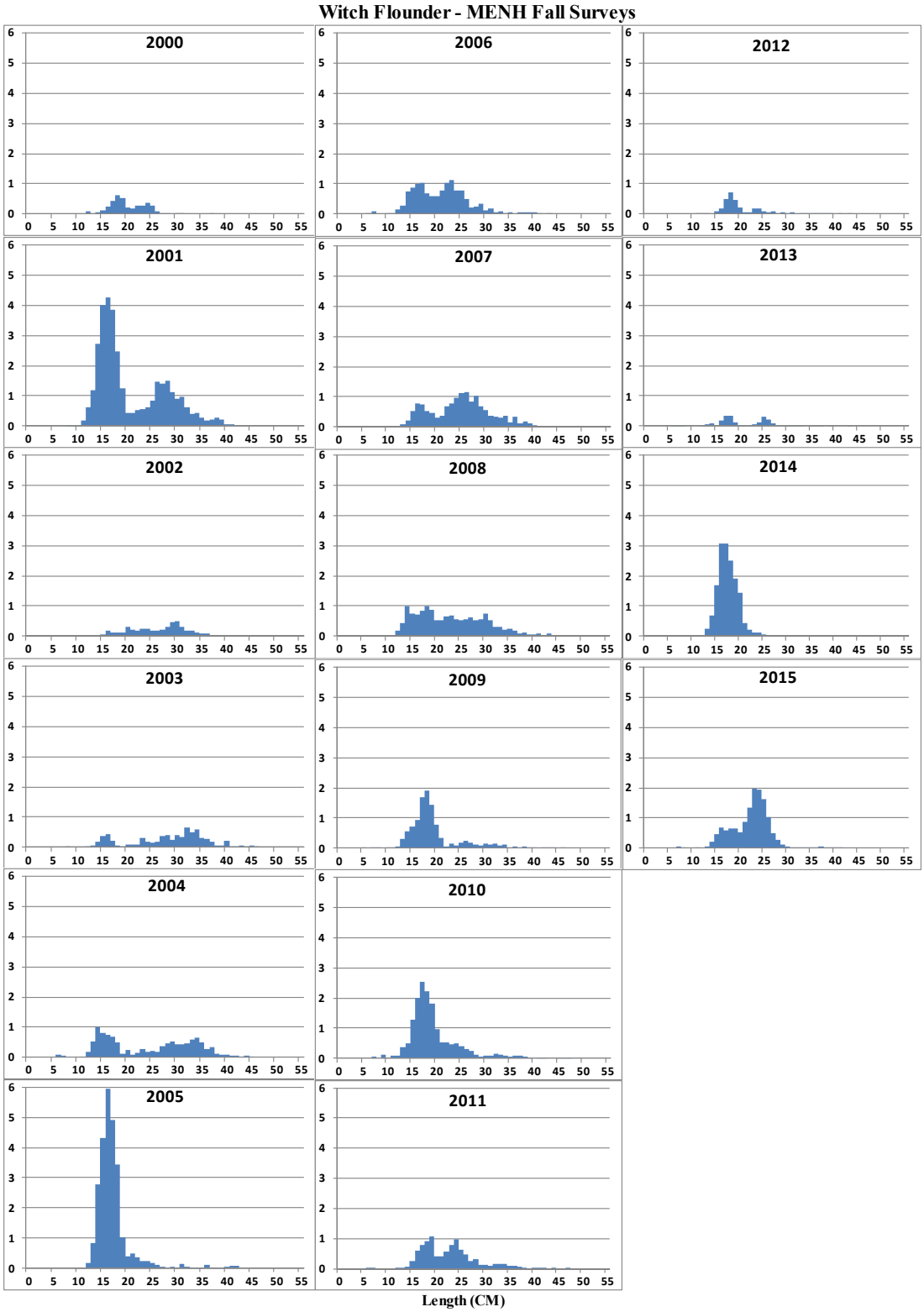


Figure B78. Stratified mean number of fish at length (cm; blue bars) for witch flounder from the 2000-2015 fall Maine-New Hampshire inshore trawl survey (regions 1 through 5; strata 1 through 4). Indices for 2000-2002 were re-stratified; fixed stations are not included.

Survey indices have been provided by Sally Sherman, Maine Department of Marine Resources, pers comm. July 28, 2016.

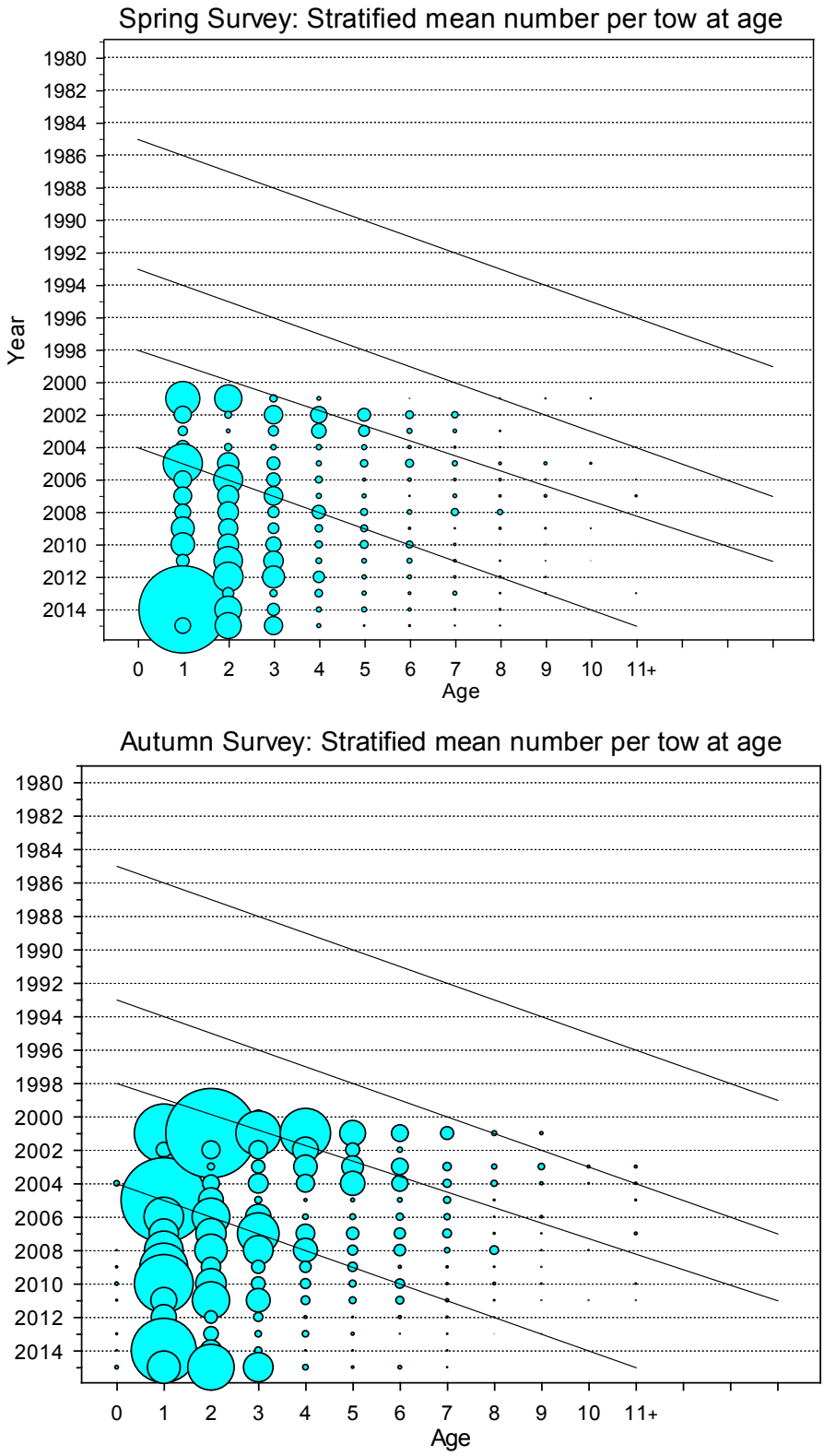


Figure B79. Stratified mean number of fish at age for witch flounder from the 2000-2015 spring (top) and autumn (bottom) Maine-New Hampshire inshore trawl survey (regions 1 through 5; strata 1 through 4). Indices for 2000-2002 were re-stratified; fixed stations are not included; seasonal Northeast Fisheries Science Center survey age/length keys used.

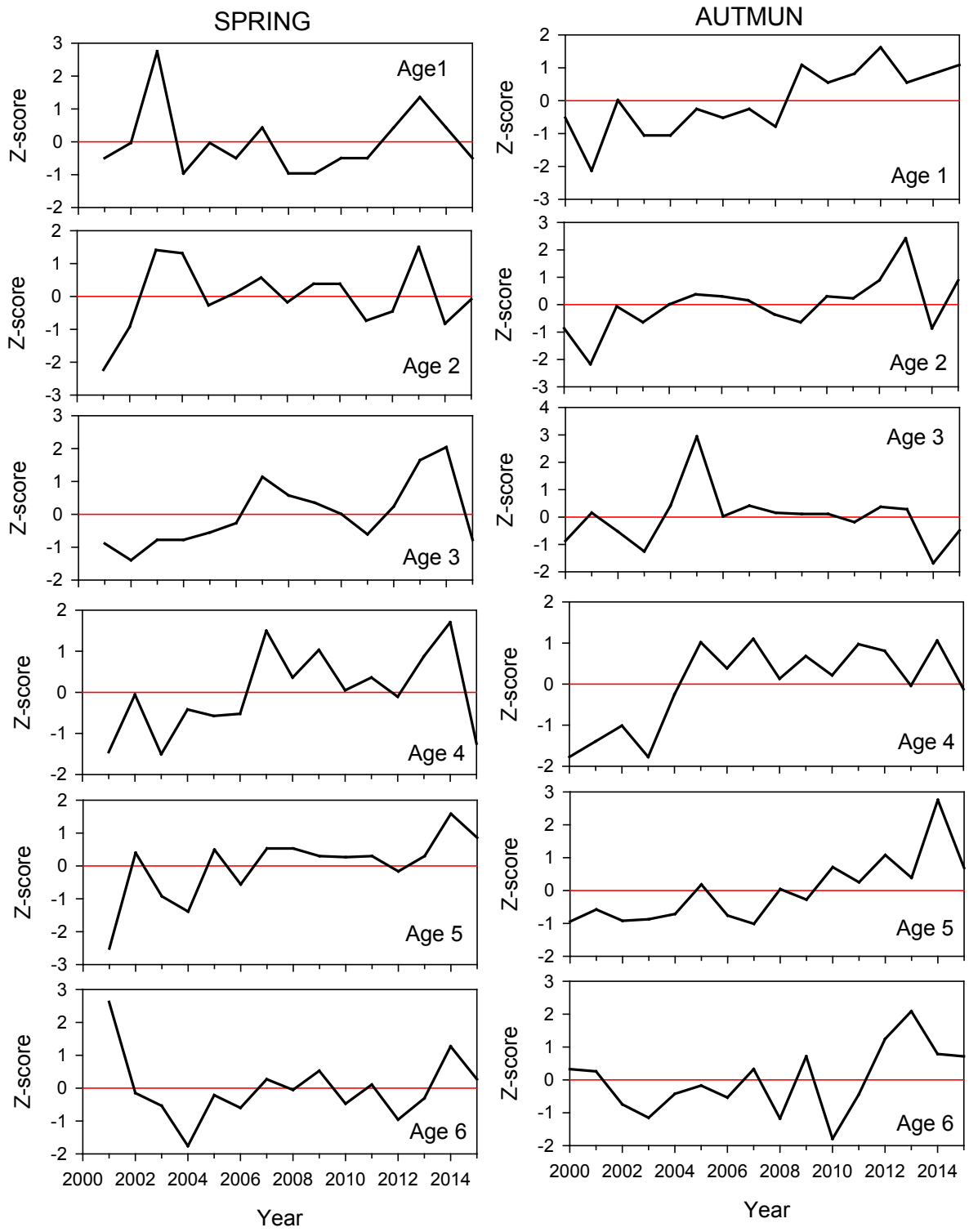


Figure B80. Z-scores of witch flounder mean weight at age (age groups 1-6) in the Maine-New Hampshire inshore trawl survey (regions 1 through 5; strata 1 through 4) spring survey (left), 2001-2016 and autumn survey 2000 -2015 (right).

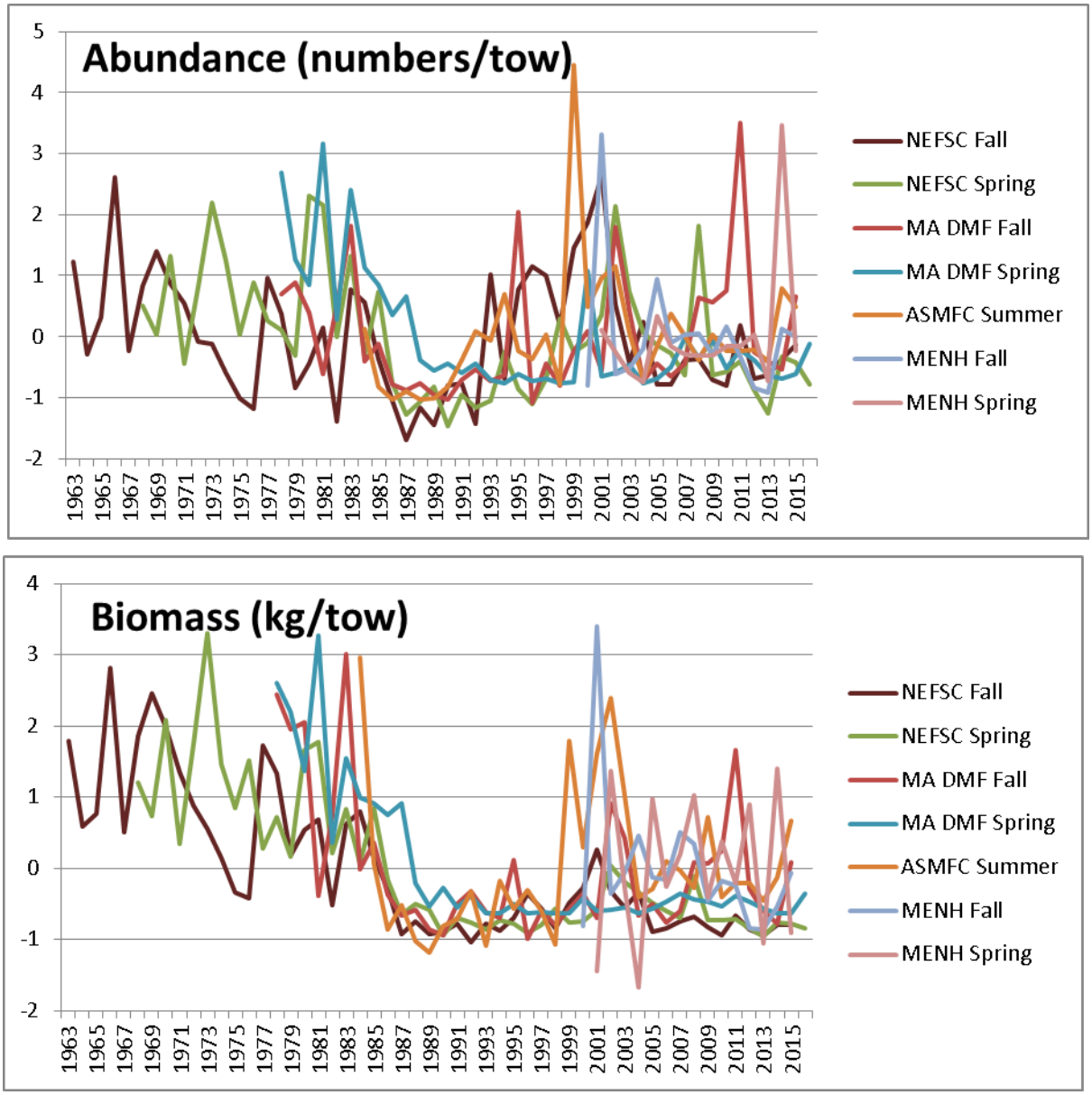


Figure B81. Normalized abundance (stratified mean number per tow; top) and biomass (stratified mean weight per tow; bottom) of witch flounder in the Northeast Fisheries Science Center (NEFSC), Massachusetts Division of Marine Fisheries (MA DMF), Maine-New Hampshire (ME-NH) spring and fall survey series and Atlantic States Marine Fisheries Commission (ASMFC) summer shrimp survey series.

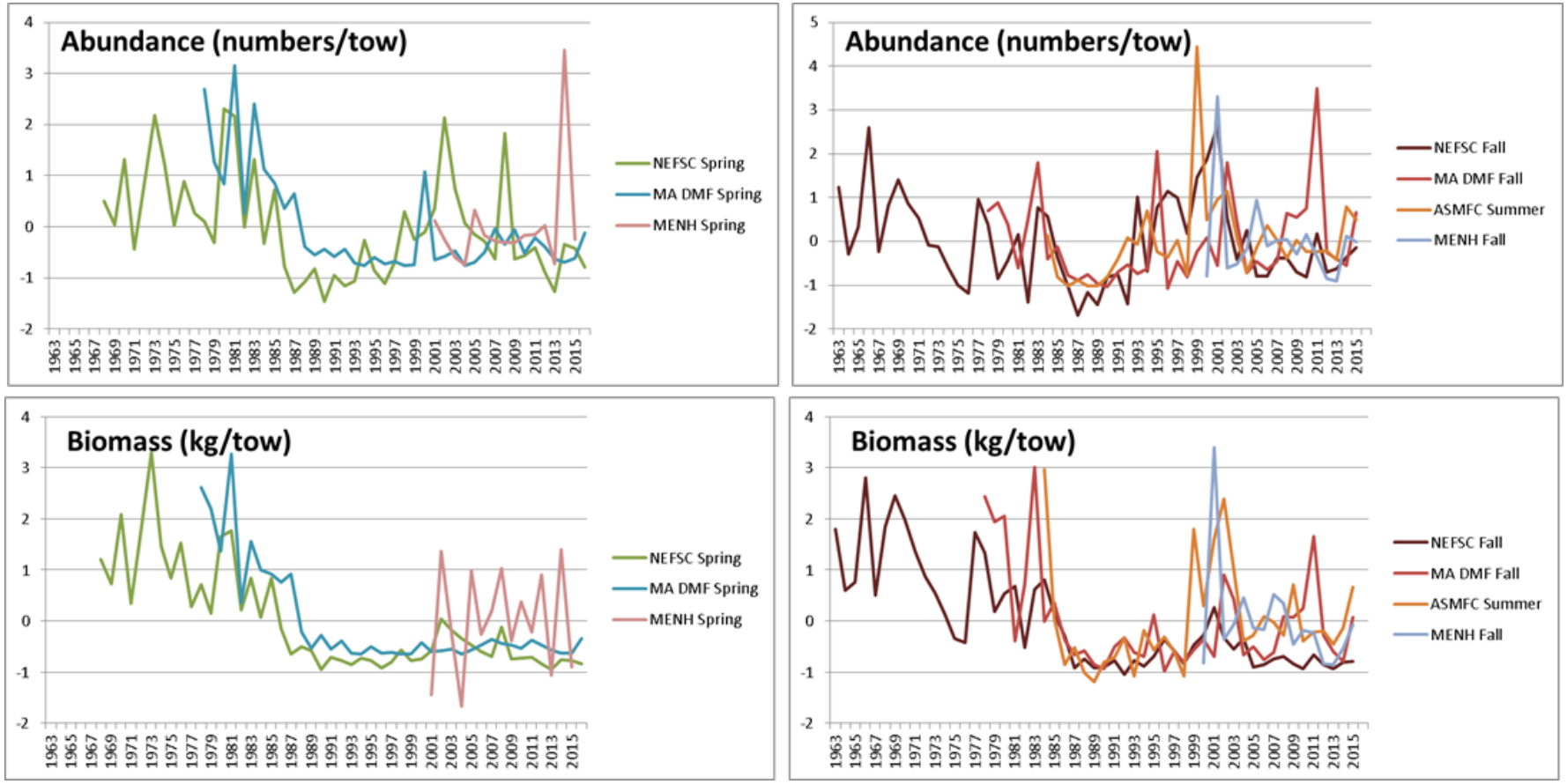


Figure B82. Normalized abundance (stratified mean number per tow; top) and biomass (stratified mean weight per tow; bottom) of witch flounder in the Northeast Fisheries Science Center (NEFSC), Massachusetts Division of Marine Fisheries (MA DMF), Maine-New Hampshire (ME-NH) spring (left) and fall survey series and Atlantic States Marine Fisheries Commission (ASMFC) summer shrimp survey series (right).

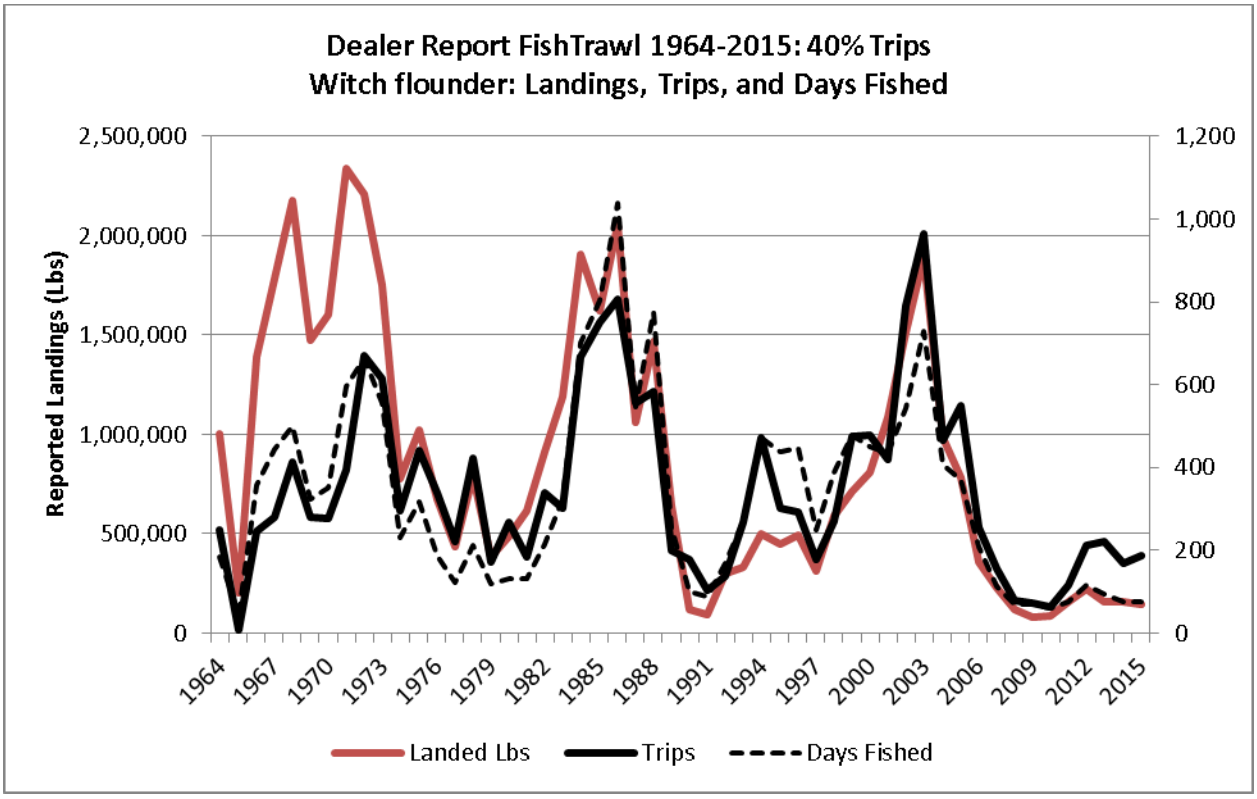


Figure B83. Dealer Report fish trawl gear landings, trips, and days fished for 'directed' (40%) trips.

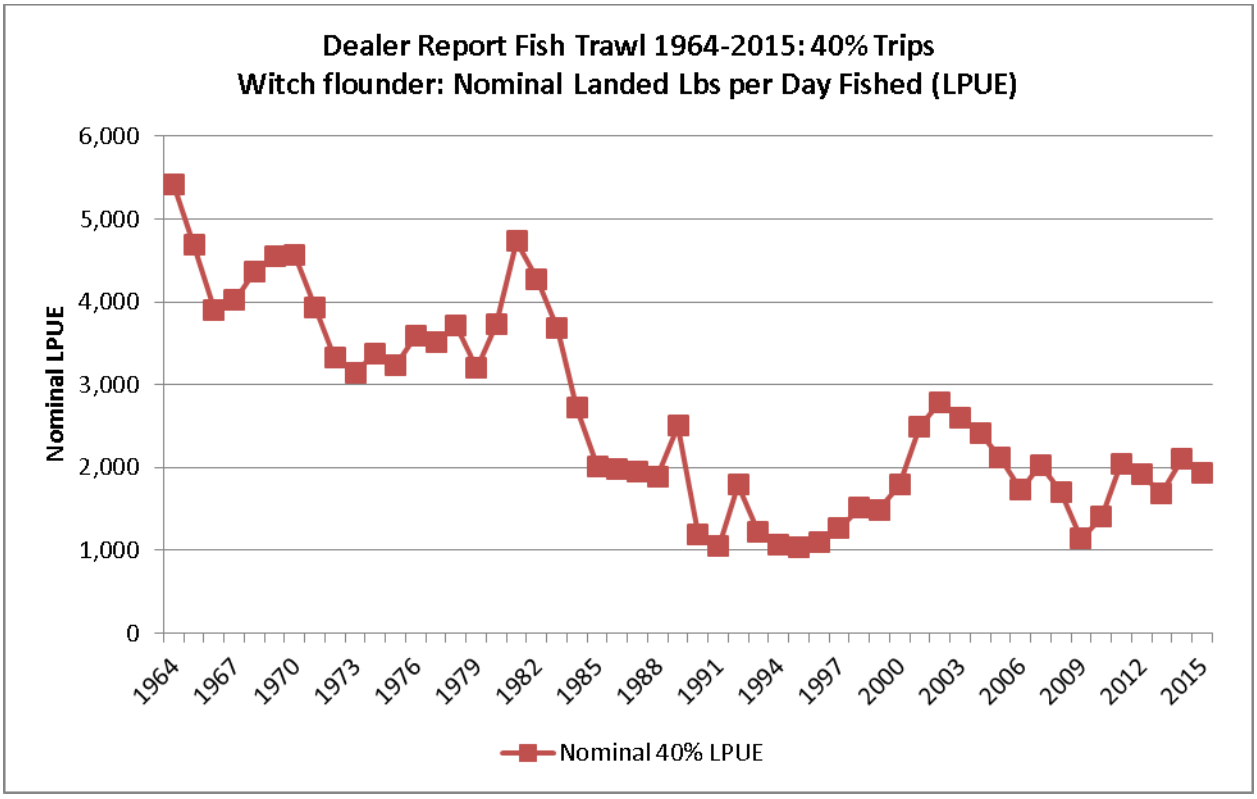


Figure B84. Dealer Report fish trawl gear landed lbs per day fished: nominal landed pounds per day fished (LPUE) for 'directed' (40%) trips.

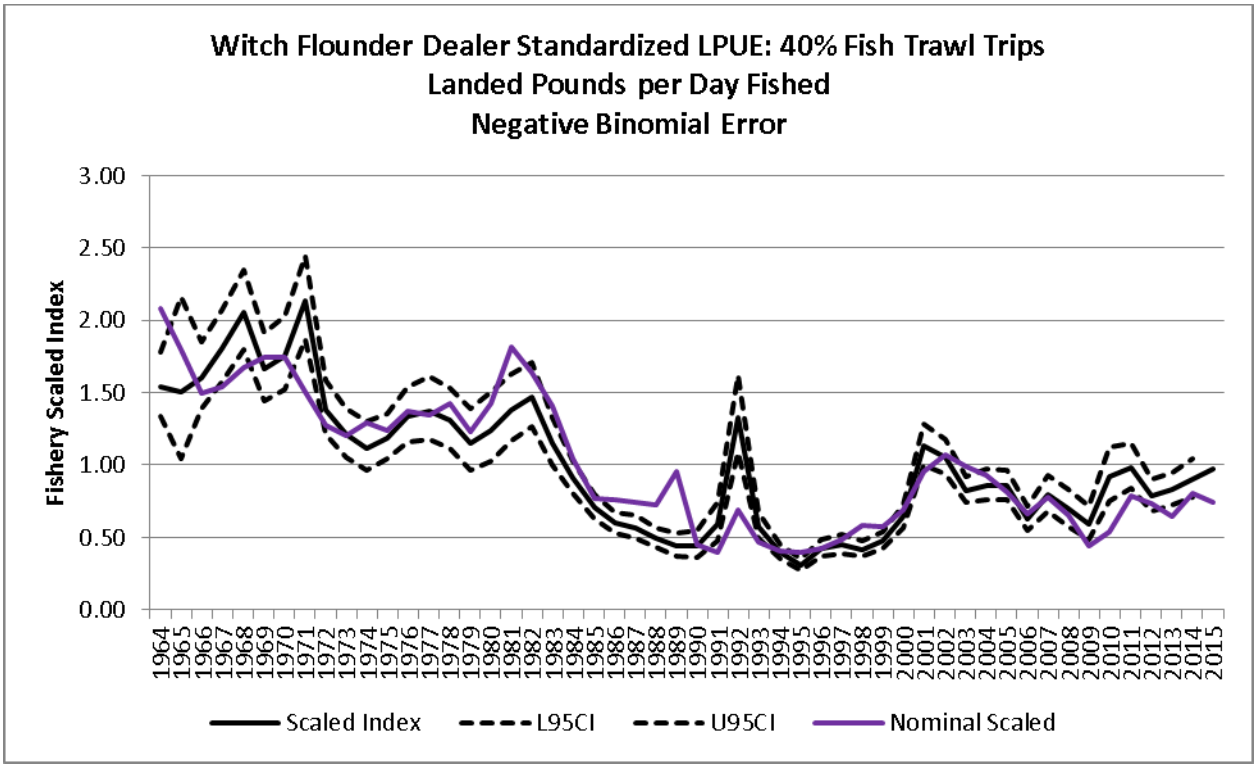


Figure B85. Comparison of the negative binomial model-based indices and the nominal index for fish trawl directed (40%) trips.

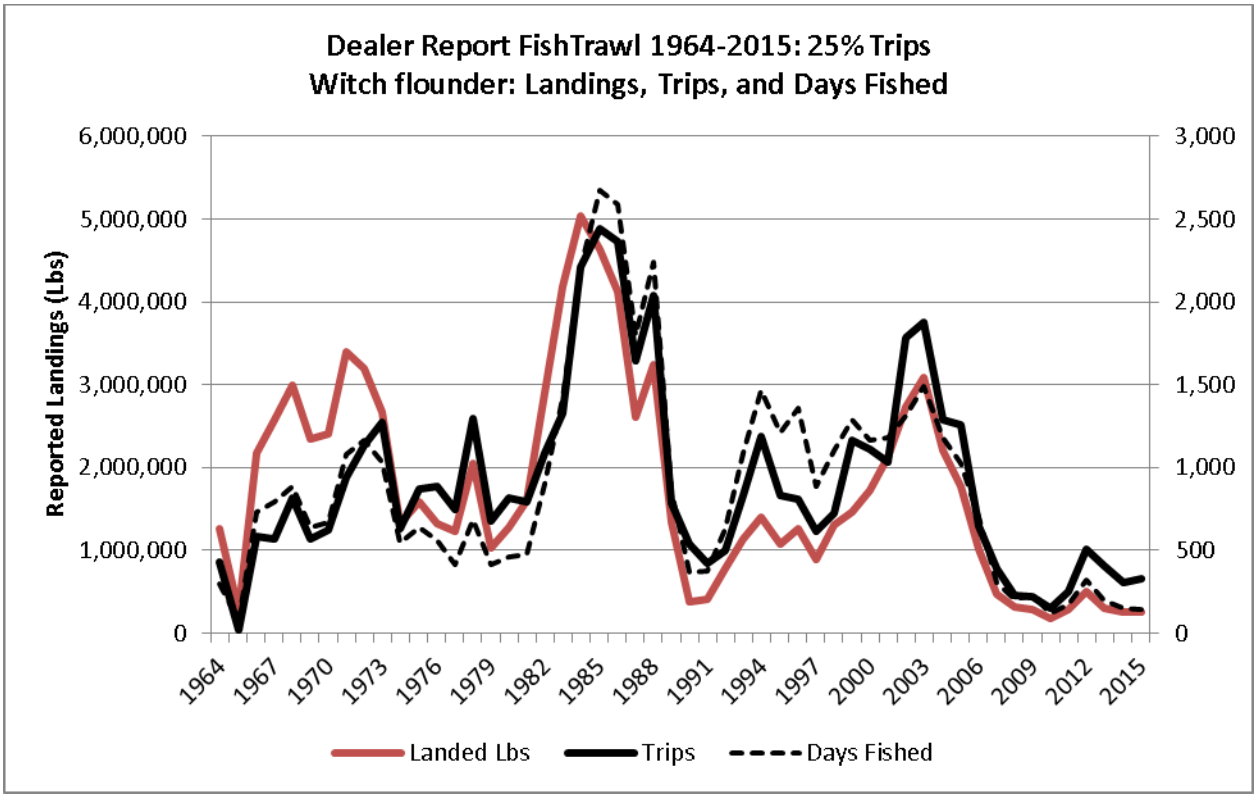


Figure B86. Dealer Report fish trawl gear landings, trips, and days fished for 'directed' (25%) trips.

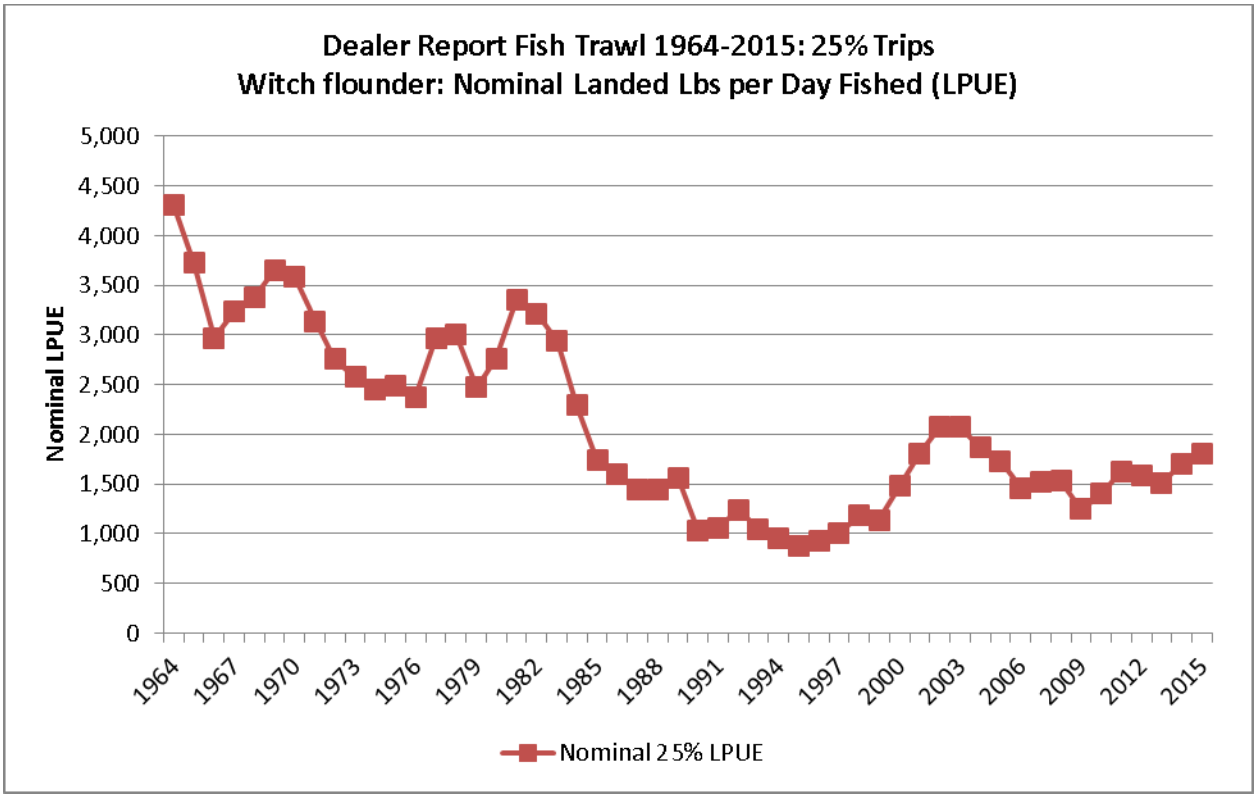


Figure B87. Dealer Report fish trawl gear landed lbs per day fished: nominal landed pounds per day fished (LPUE) for 'directed' (25%) trips.

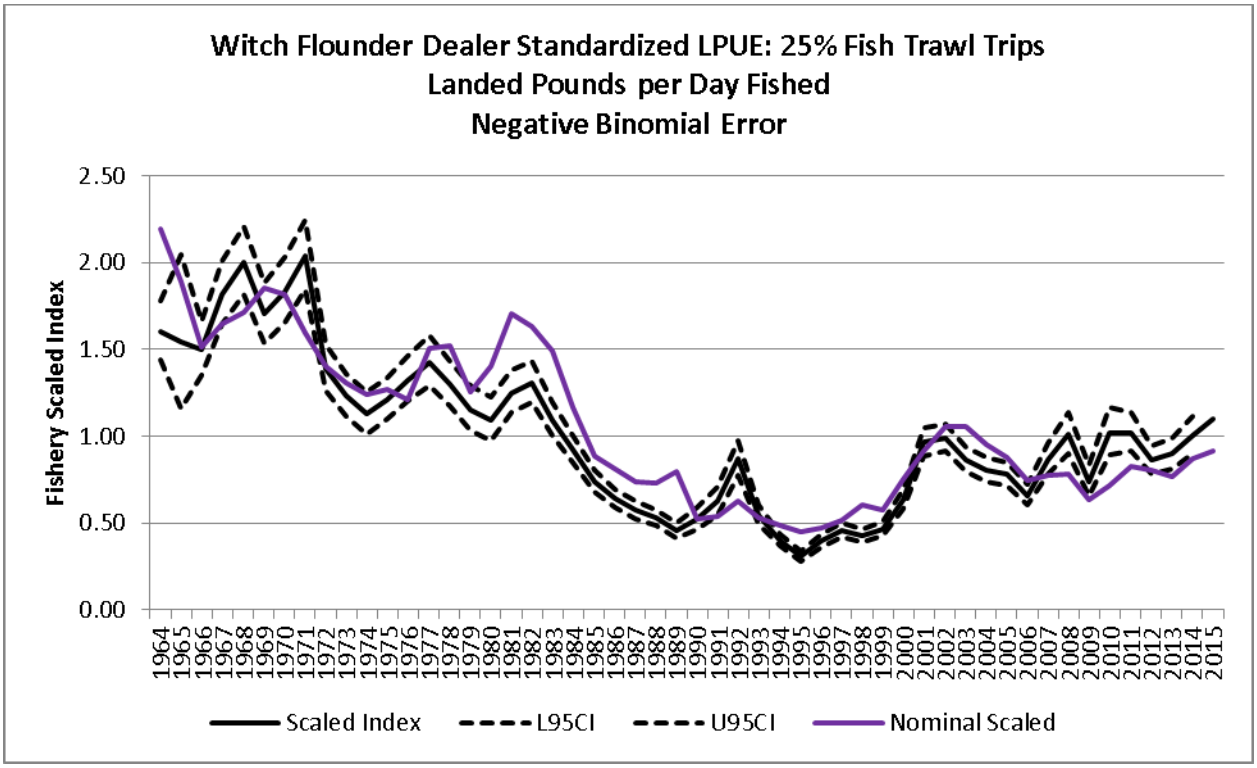


Figure B88. Comparison of the negative binomial model-based indices and the nominal index for fish trawl directed (25%) trips.

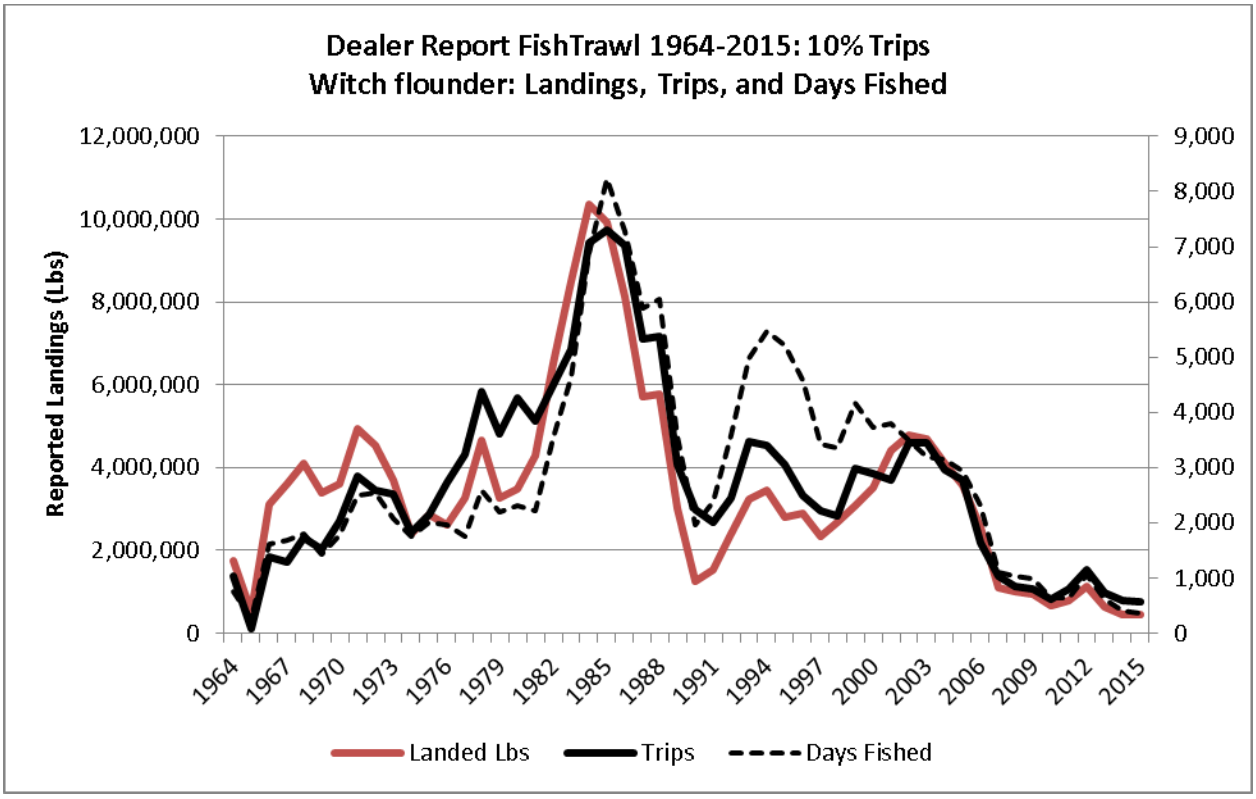


Figure B89. Dealer Report fish trawl gear landings, trips, and days fished for 'directed' (10%) trips.

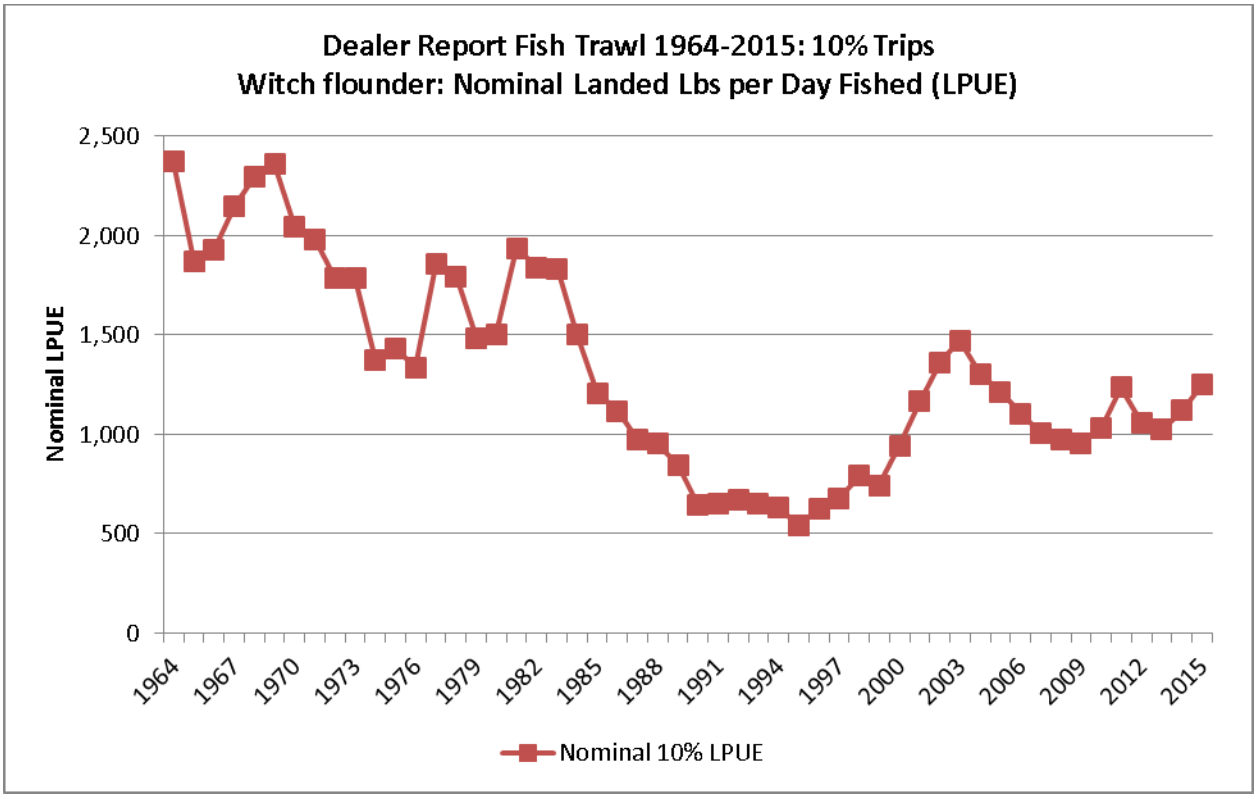


Figure B90. Dealer Report fish trawl gear landed lbs per day fished: nominal landed pounds per day fished (LPUE) for 'directed' (10%) trips.

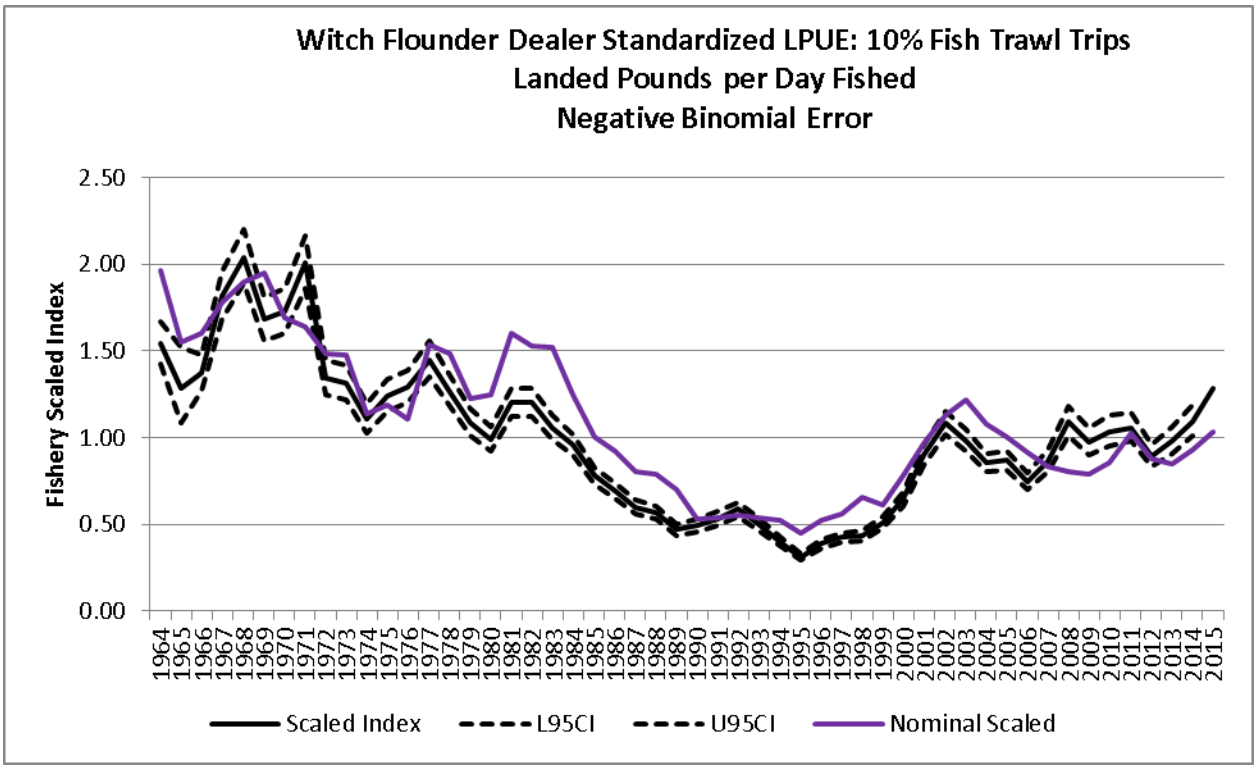


Figure B91. Comparison of the negative binomial model-based indices and the nominal index for fish trawl directed (10%) trips.

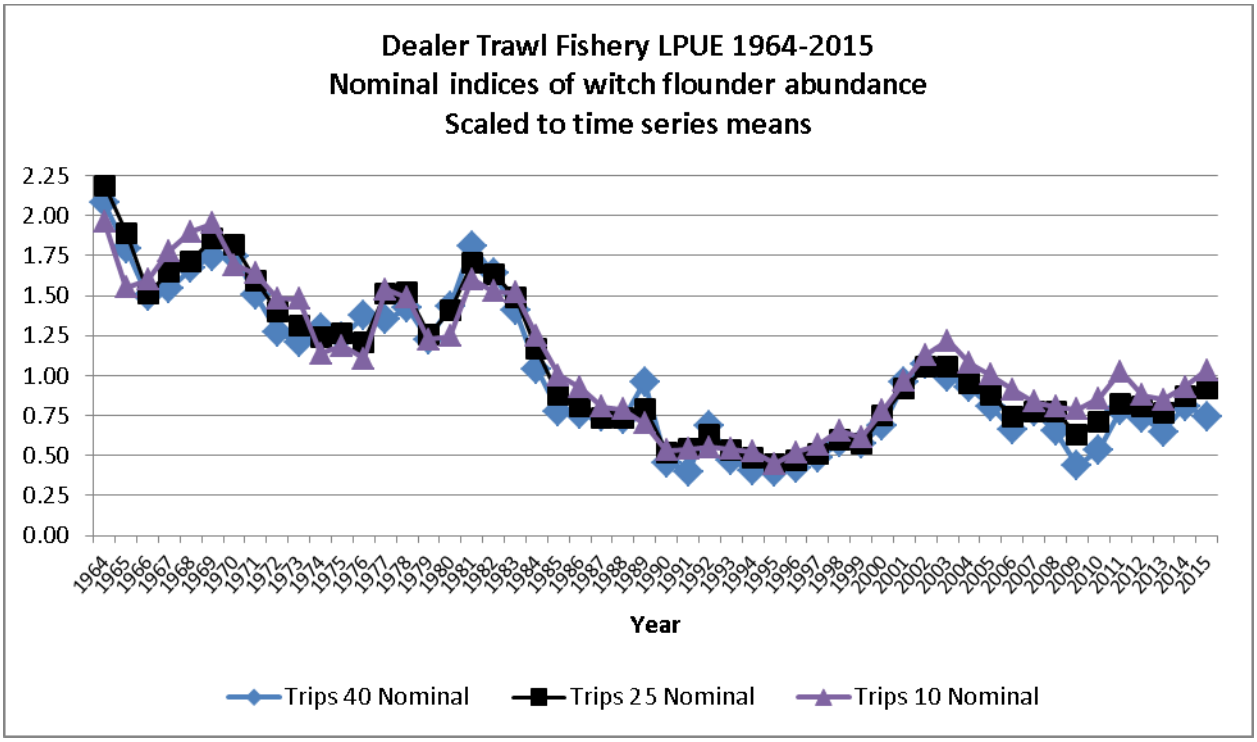


Figure B92. Comparison of nominal scaled landed pounds per day fished (LPUE) for fish trawl directed (10%, 25%, 40%) trips.

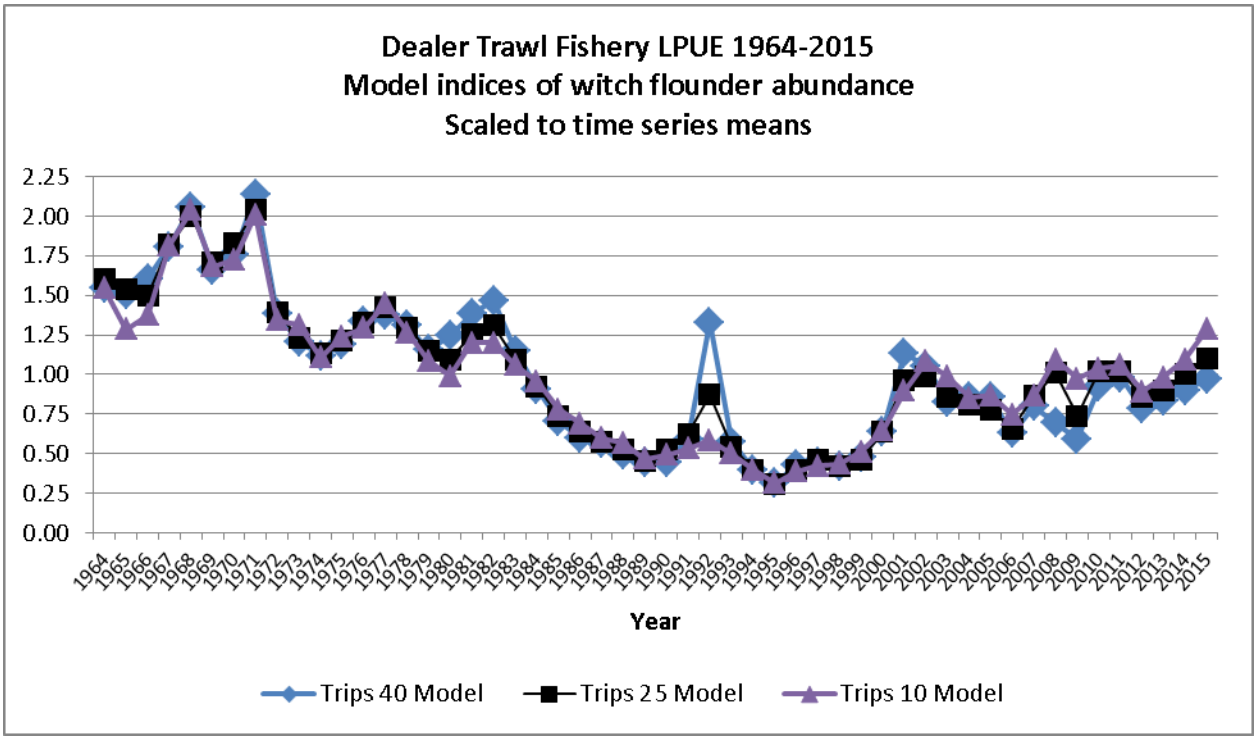


Figure B93. Comparison of negative binomial model scaled landed pounds per day fished (LPUE) for fish trawl directed trips (10%, 25%, 40%).

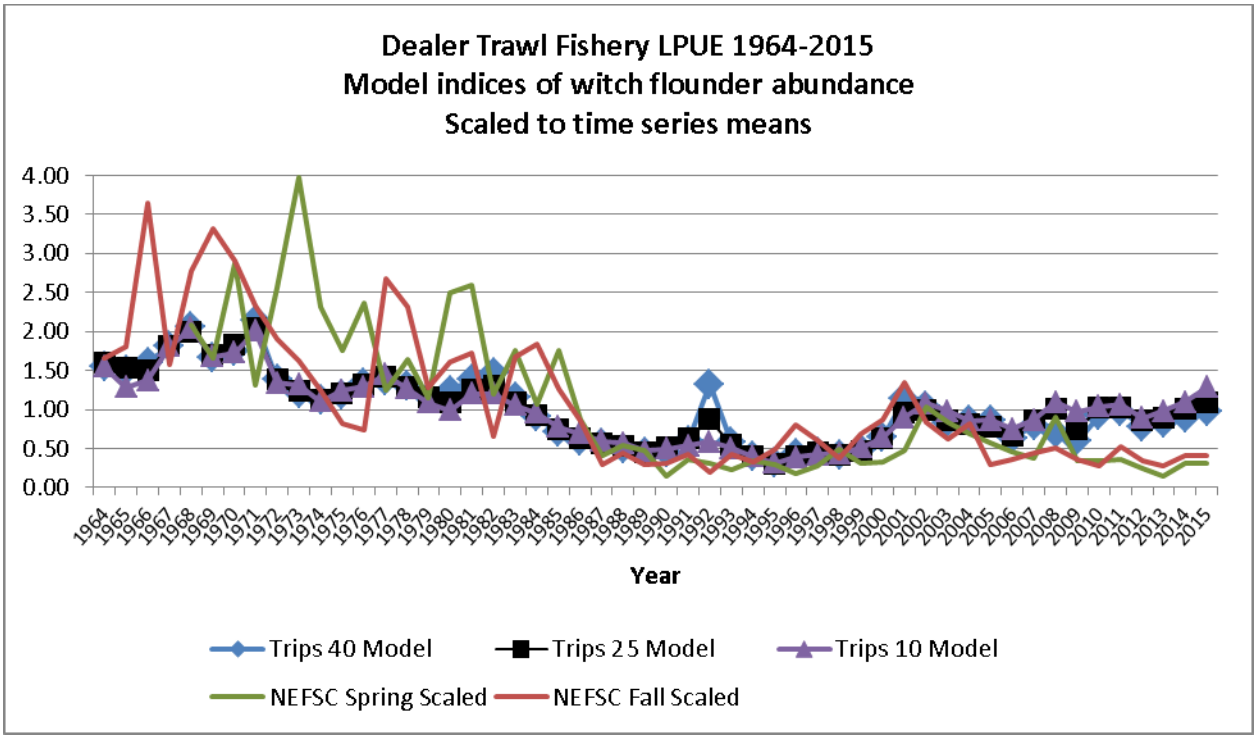


Figure B94. Comparison of negative binomial model scaled landed pounds per day fished (LPUE) for fish trawl directed trips (10%, 25%, 40%) with Northeast Fisheries Science Center (NEFSC) trawl survey Spring and Fall biomass indices.

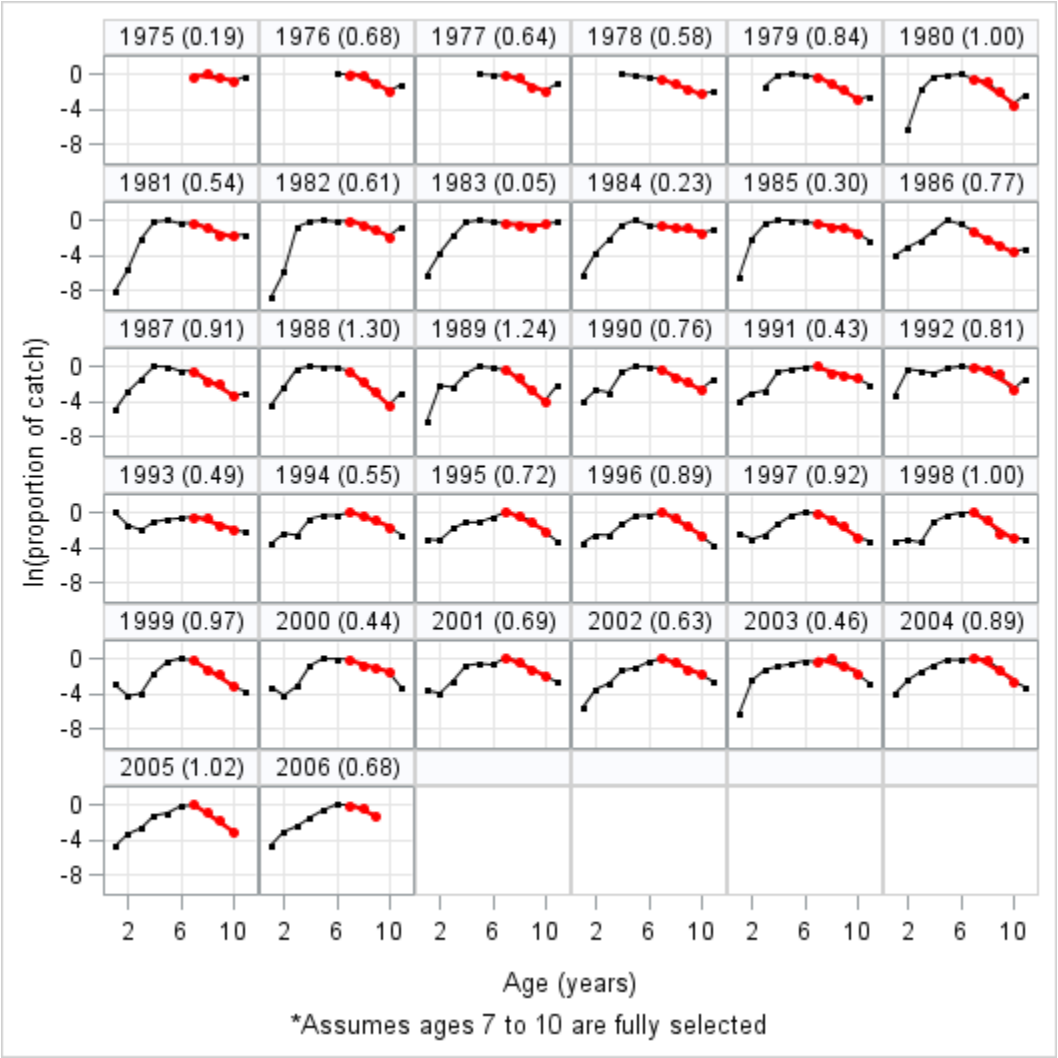


Figure B95. Witch flounder year class catch curves with a linear regression fitted to log-transformed age 7 to 10 (red circles) total fishery catch-at-age data (combined landings and discards). The corresponding slope of each regression line is shown next to the year class label above each plot. *Note that age 11 is a plus group.*

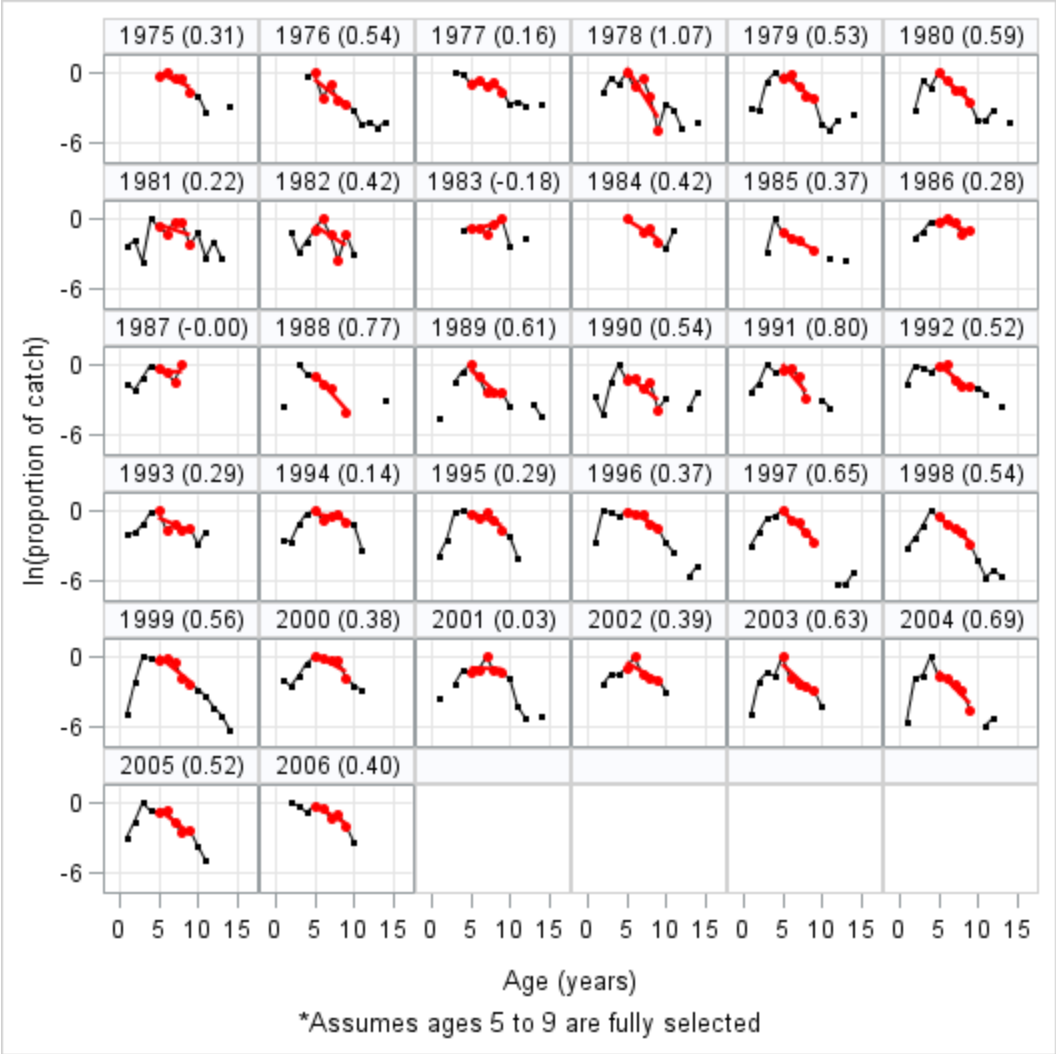


Figure B96. Witch flounder year class catch curves with a linear regression fitted to log-transformed age 5 to 9 (red circles) abundance-at-age (numbers/tow) data from the Northeast Fisheries Science Center spring bottom trawl survey. The corresponding slope of each regression line is shown next to the year class label above each plot. *Note that age 14 is a plus group.*

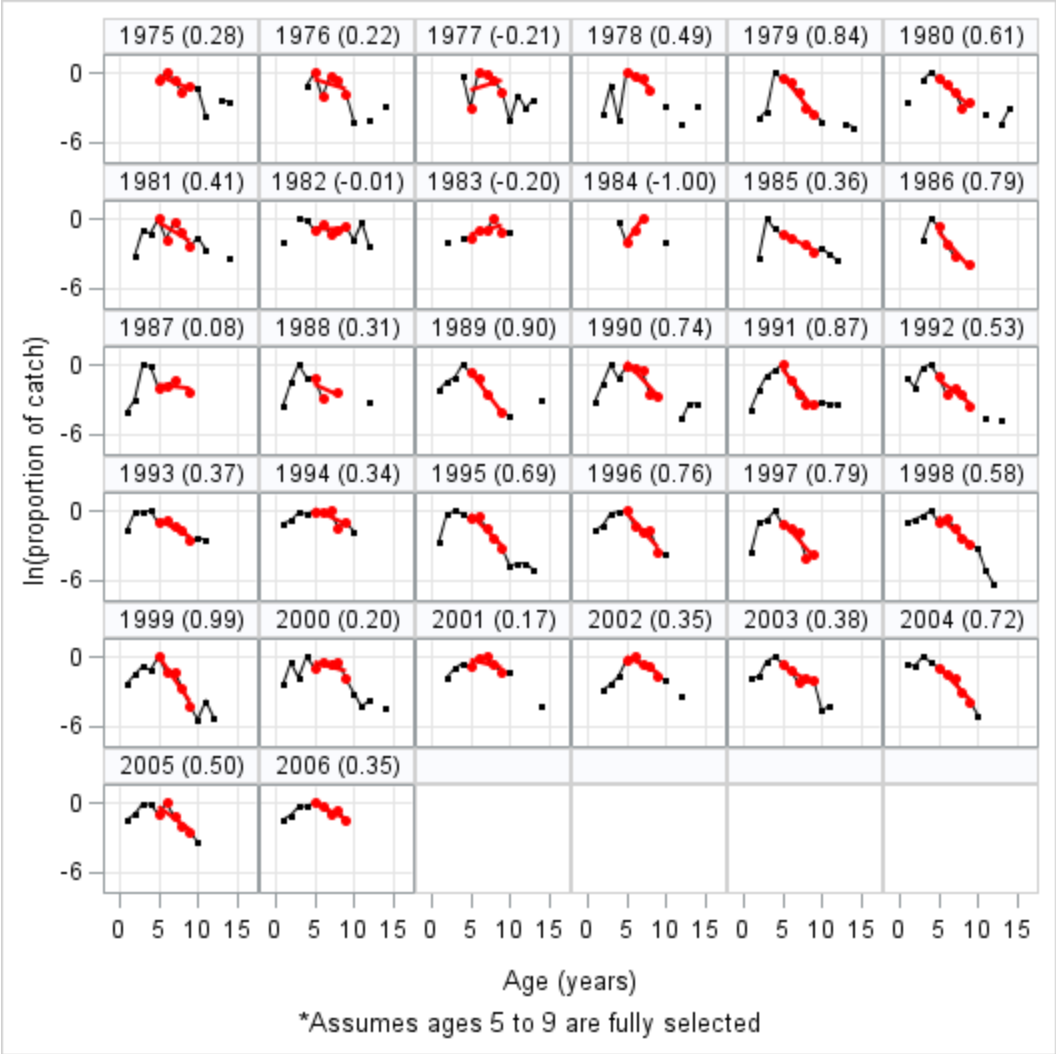


Figure B97. Witch flounder year class catch curves with a linear regression fitted to log-transformed age 5 to 9 (red circles) abundance-at-age (numbers/tow) data from the Northeast Fisheries Science Center fall bottom trawl survey. The corresponding slope of each regression line is shown next to the year class label above each plot. *Note that age 14 is a plus group.*

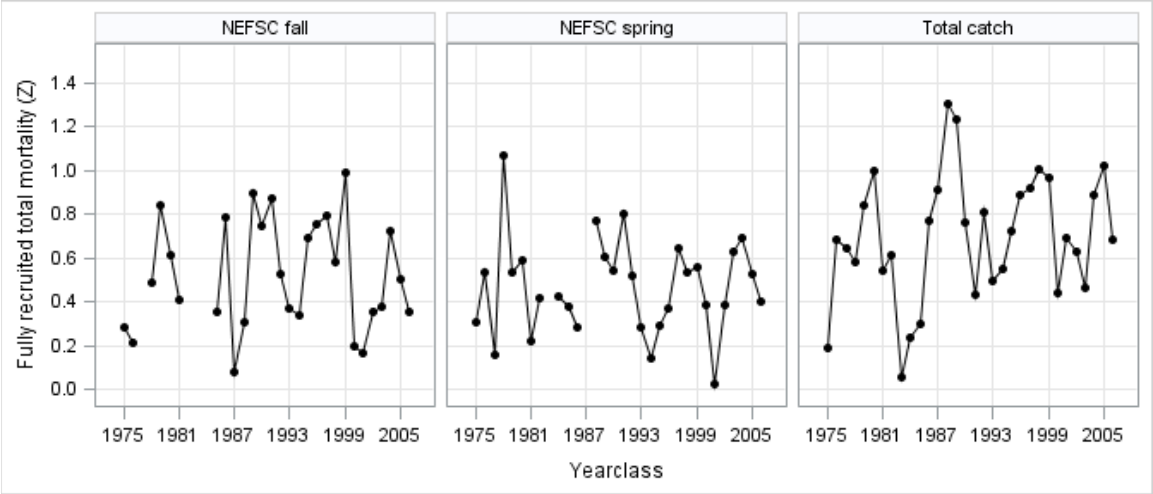


Figure B98. Plots of the annual estimates of witch flounder total mortality (Z) as estimated from the slope of the catch curve analysis of Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys and total catch (landings and discards).

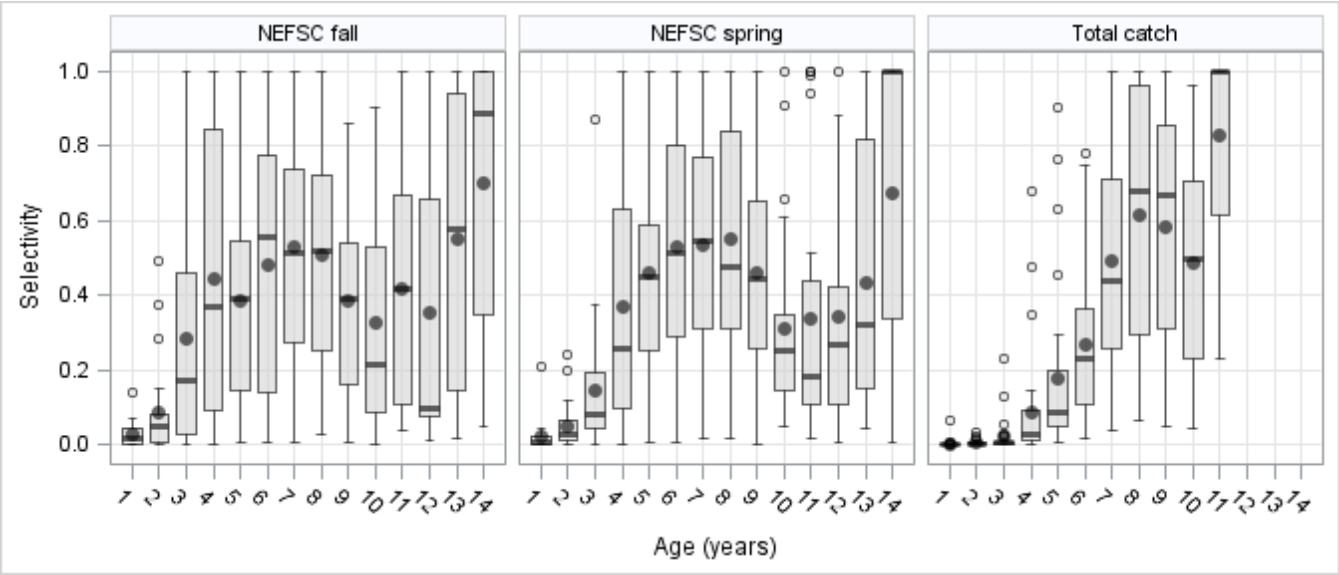


Figure B99. Distribution of catch selectivity-at-age as estimated from the residuals fits to the witch flounder catch curve analysis of Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys and total catch (landings and discards). *Note that age 14 is a plus group in the NEFSC spring and fall survey data and age 11 is a plus group in the total catch data.*

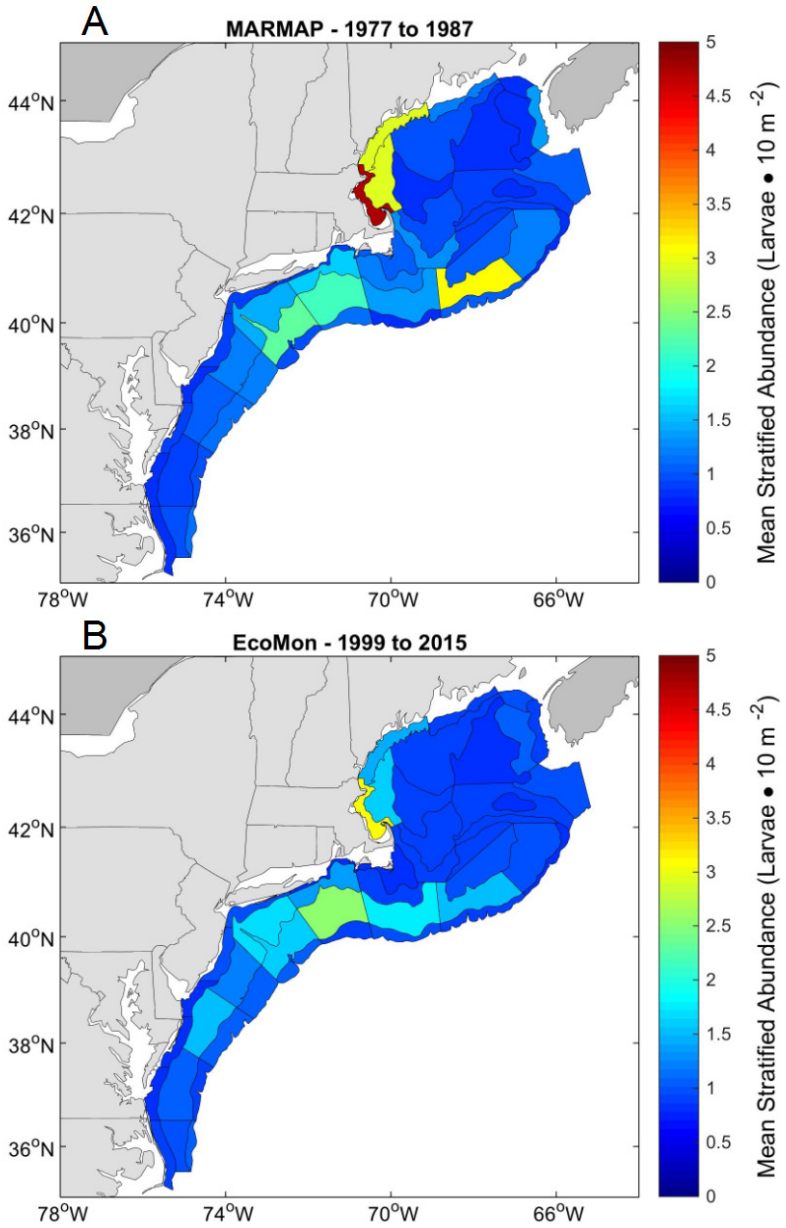


Figure B100. Larval witch flounder (*Glyptocephalus cynoglossus*) stratified mean abundance collected during Marine Resources Monitoring, Assessment and Prediction (MARMAP; A) and Ecosystem Monitoring (EcoMon; B) programs. Larval strata were originally developed using the stratum design of the bottom trawl survey.

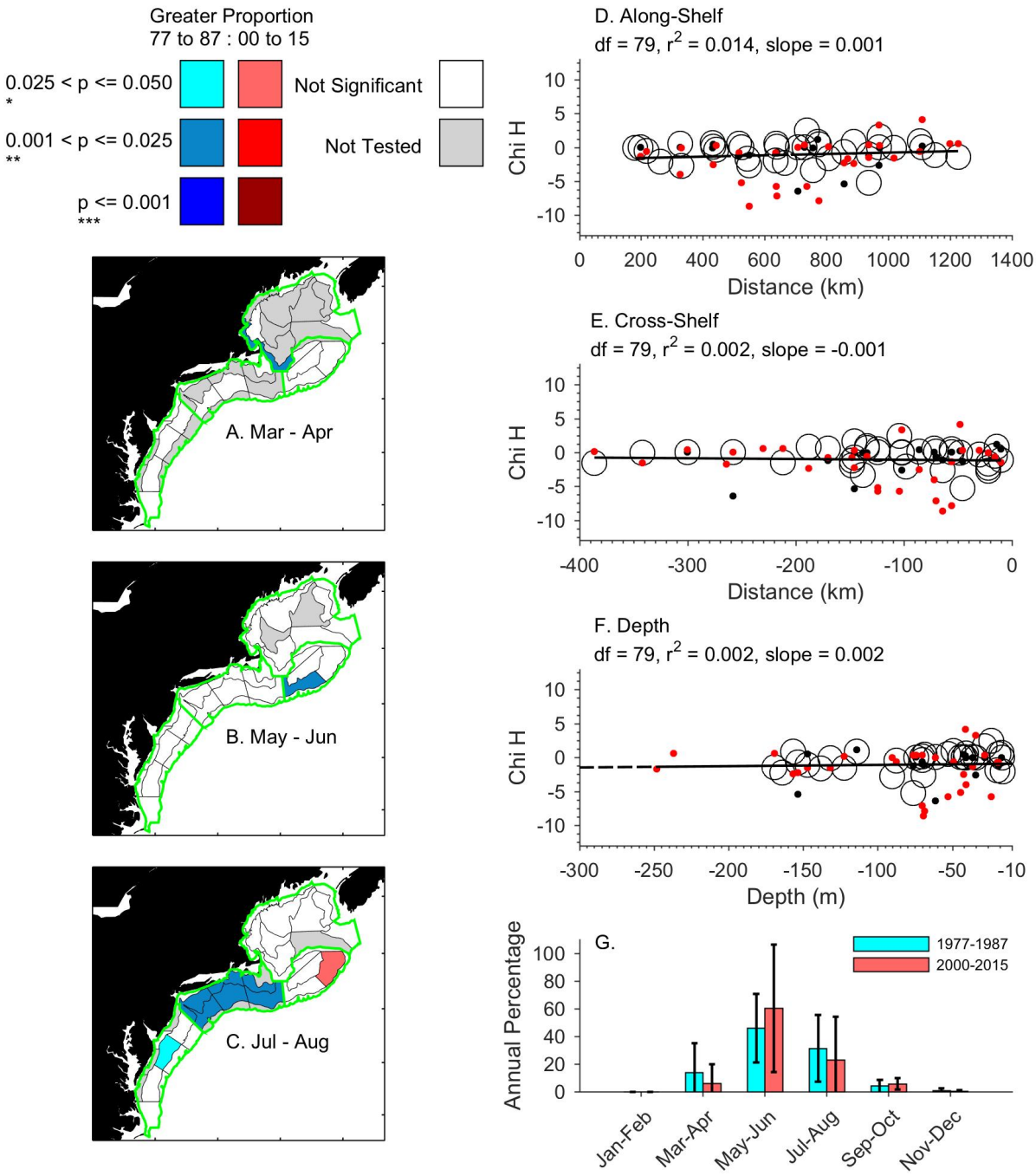


Figure B101. Spatial and seasonal distribution of larval witch flounder (*Glyptocephalus cynoglossus*) in the Northeast U.S. Shelf Ecosystem. Change in spatial distribution of larval in the March – April (A; •), May – June (B; O), and July – August (C; •) were examined in the along-shelf (D), cross-shelf (E), and depth (F) directions. Larval witch flounder did not shift significantly spatially or seasonally (G).

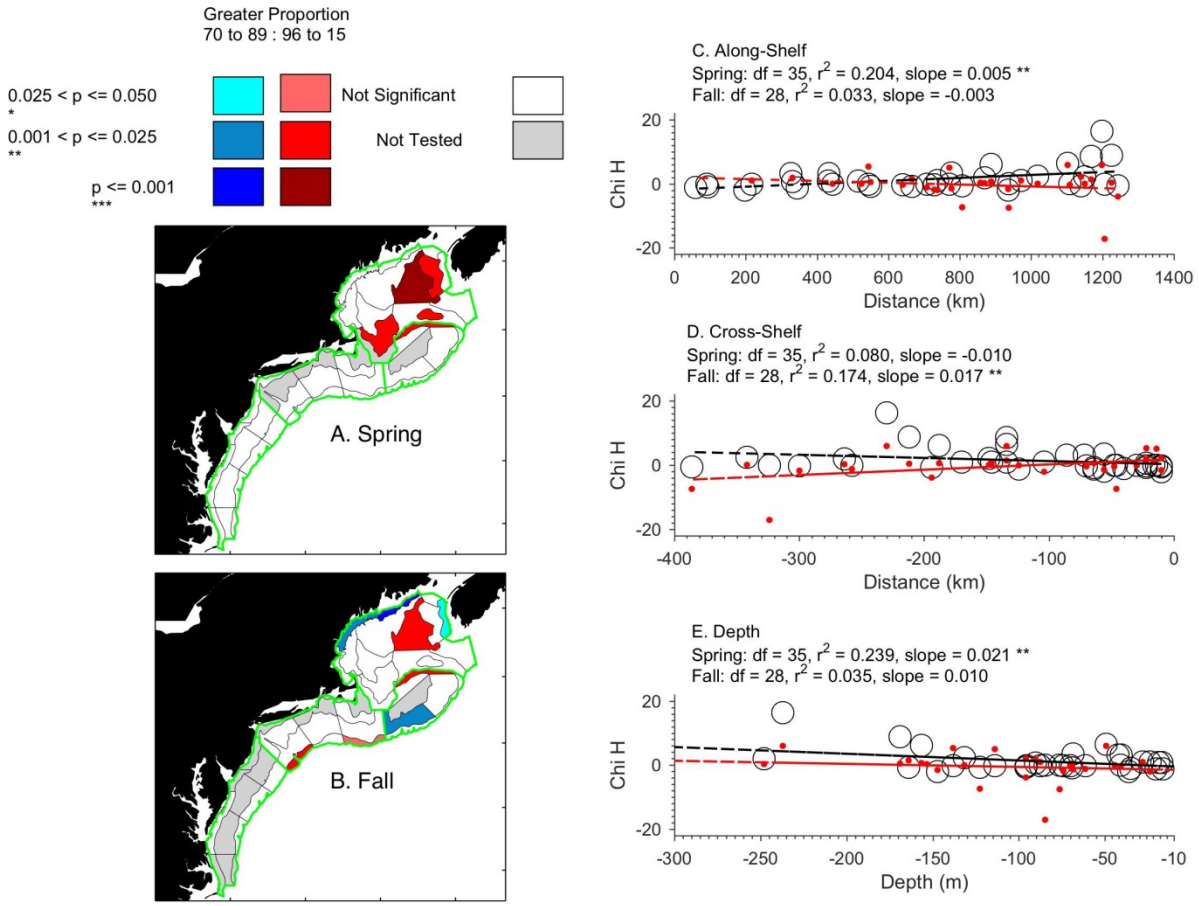


Figure B102. Spatial distribution of juvenile (< 30 cm) witch flounder (*Glyptocephalus cynoglossus*) in the Northeast U.S. Shelf Ecosystem. Change in distribution of juveniles in the spring (A; O) and fall (B; •) were examined in the along-shelf (C), cross-shelf (D), and depth (E) directions. Witch flounder juveniles shifted significantly northward (C) and deeper (E) in the spring, and offshore (D) in the fall.

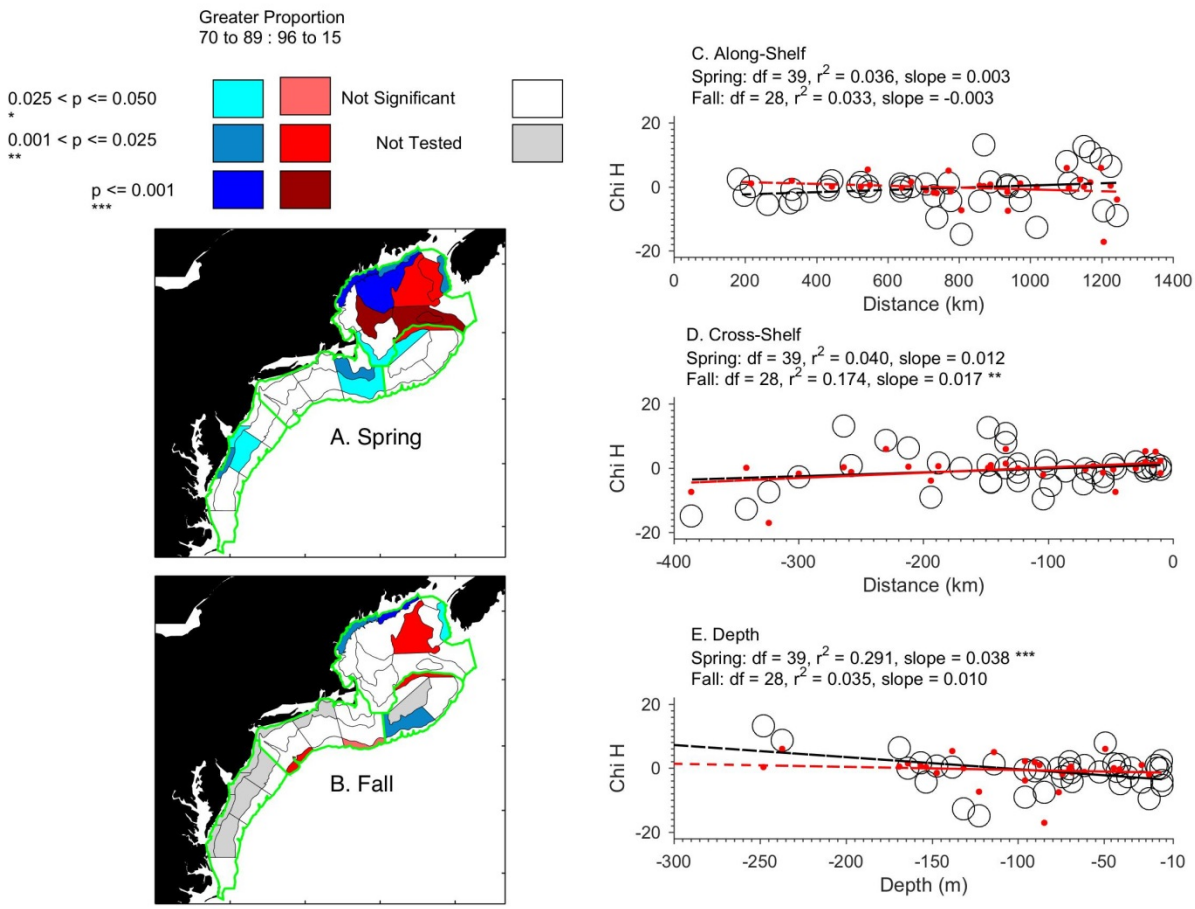


Figure B103. Spatial distribution of adult (>= 30 cm) witch flounder (*Glyptocephalus cynoglossus*) in the Northeast U.S. Shelf Ecosystem. Change in distribution of adults in the spring (A; O) and fall (B; •) were examined in the along-shelf (C), cross-shelf (D), and depth (E) directions. Witch flounder adults shifted significantly deeper (E) in the spring and offshore (D) in the fall.

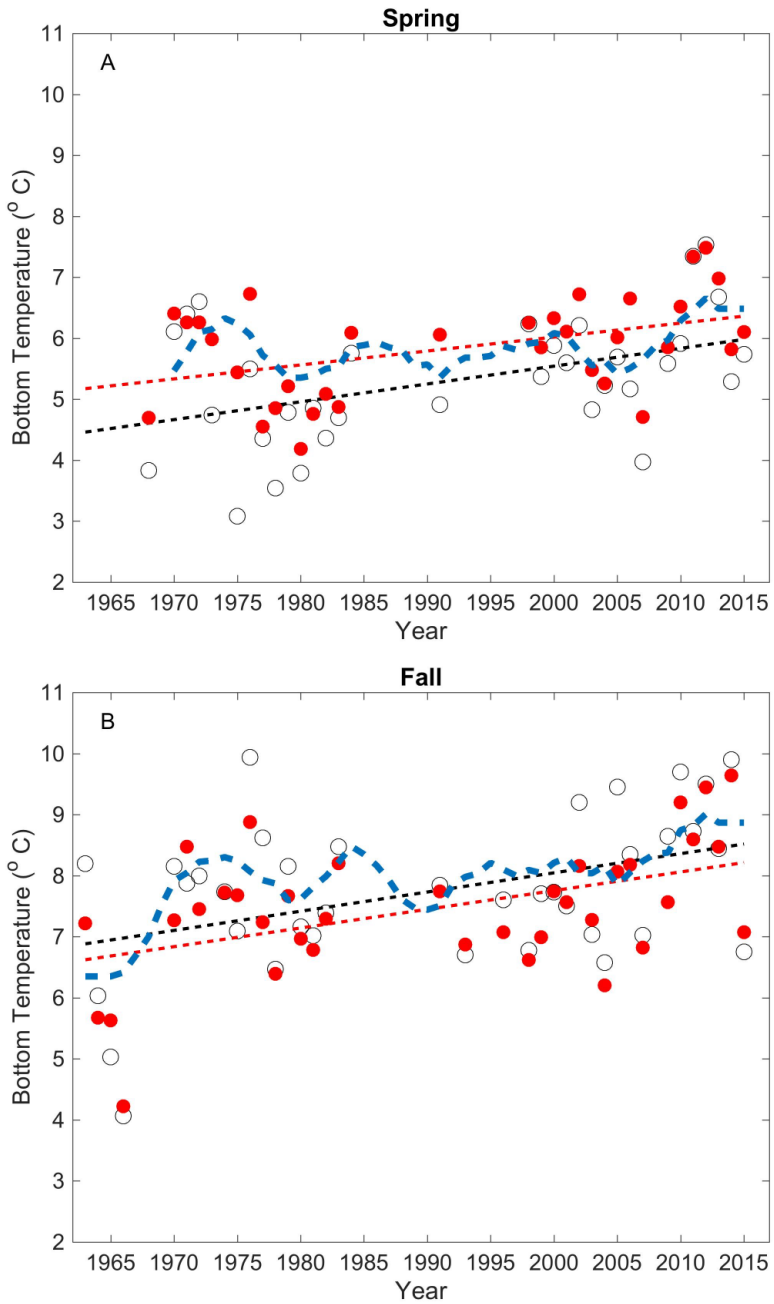


Figure B104. Stratified mean bottom water temperature (symbols) and linear trend (line) of juvenile (< 30 cm; O) and adult witch flounder (>= 30 cm; •) collected in the Gulf of Maine during the Northeast Fisheries Science Center spring (A) and fall (B) bottom trawl surveys. Mean bottom water temperature of all stations sampled in the region is shown as a 5-year moving average (---).

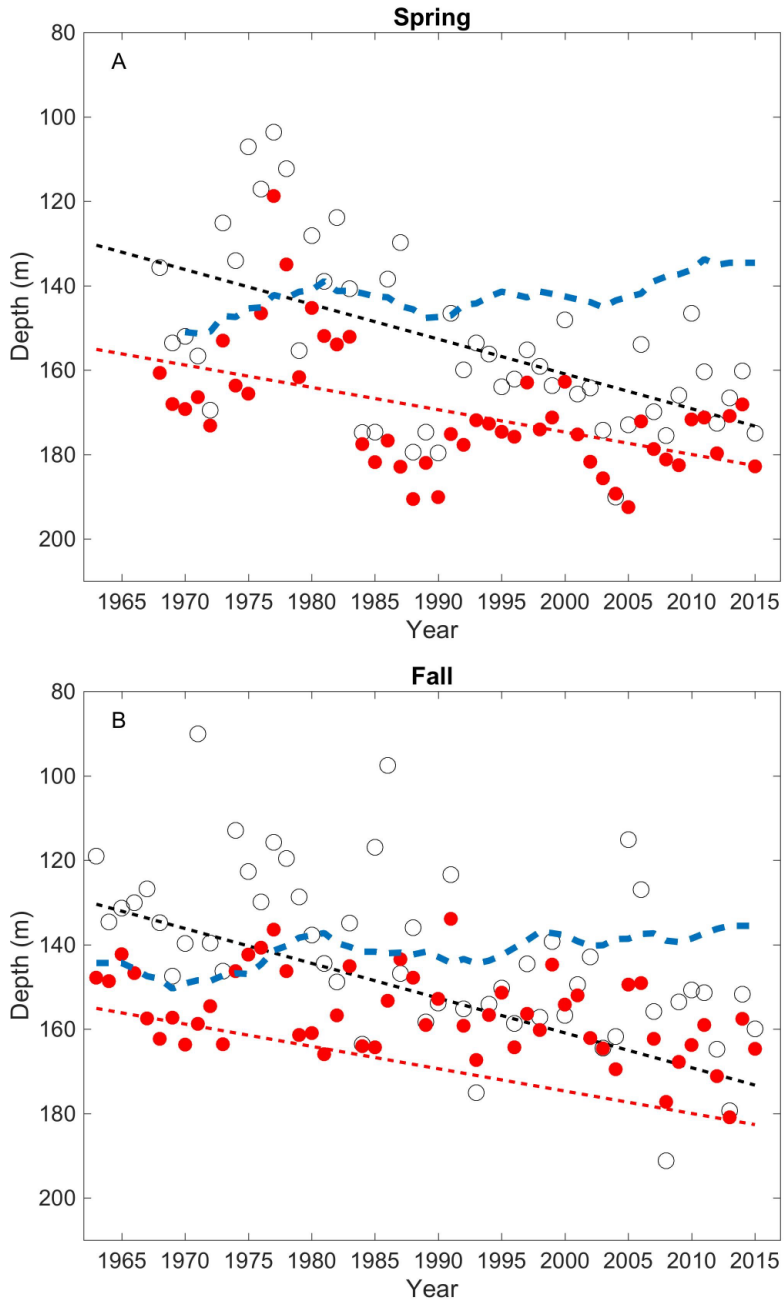


Figure B105. Stratified mean depth (symbols) and linear trend (line) of juvenile (< 30 cm; O) and adult witch flounder (>= 30 cm; •) collected in the Gulf of Maine during the Northeast Fisheries Science Center spring (A) and fall (B) bottom trawl surveys. Mean depth of all stations sampled in the region is shown as a 5-year moving average (---).

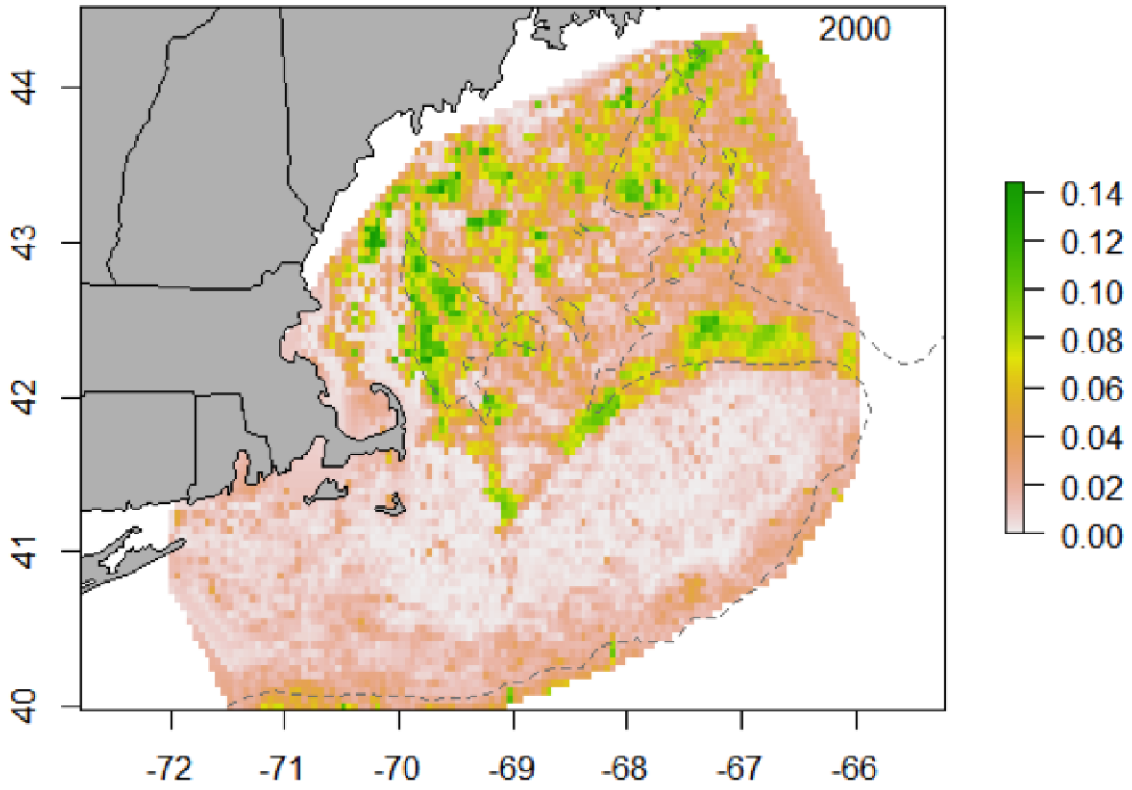


Figure B106. Estimated habitat map of witch flounder spring abundance (log) in the year 2000. Estimates were based on a regression model using Random Forrest models where depth was the most important habitat variable, and bottom temperature, bathymetric position index (BPI) and soft sediments were high contributors.

Figure B107. Trends in mean z-scores of witch flounder biomass based regression model habitat estimates using Random Forrest models were used to visualize changes from 2000 to 2015. A 5-point moving average was applied to the mean z-scores for the spring and fall survey periods.

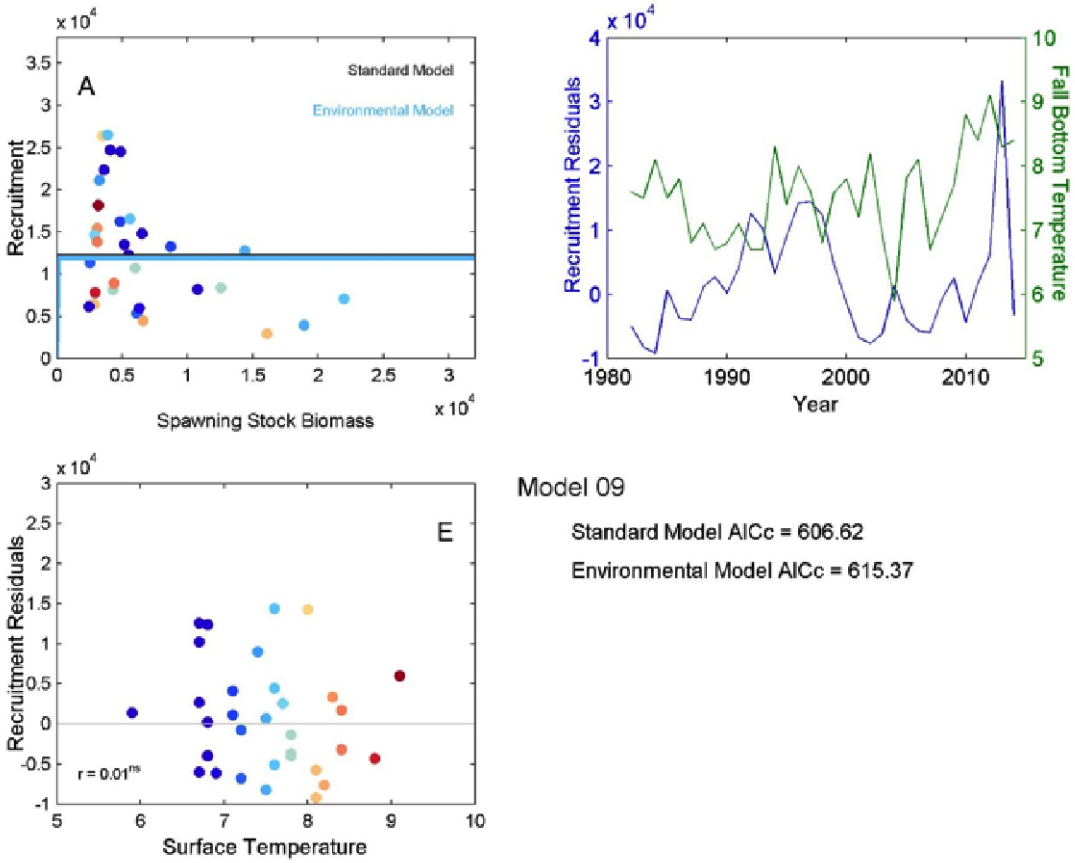


Figure B108. Stock-recruitment analyses for ASAP Model Output 09 using method described in Hare et al. 2016 working paper. ASAP Model Output 09 is the penultimate model run of Run 9_5_v2.

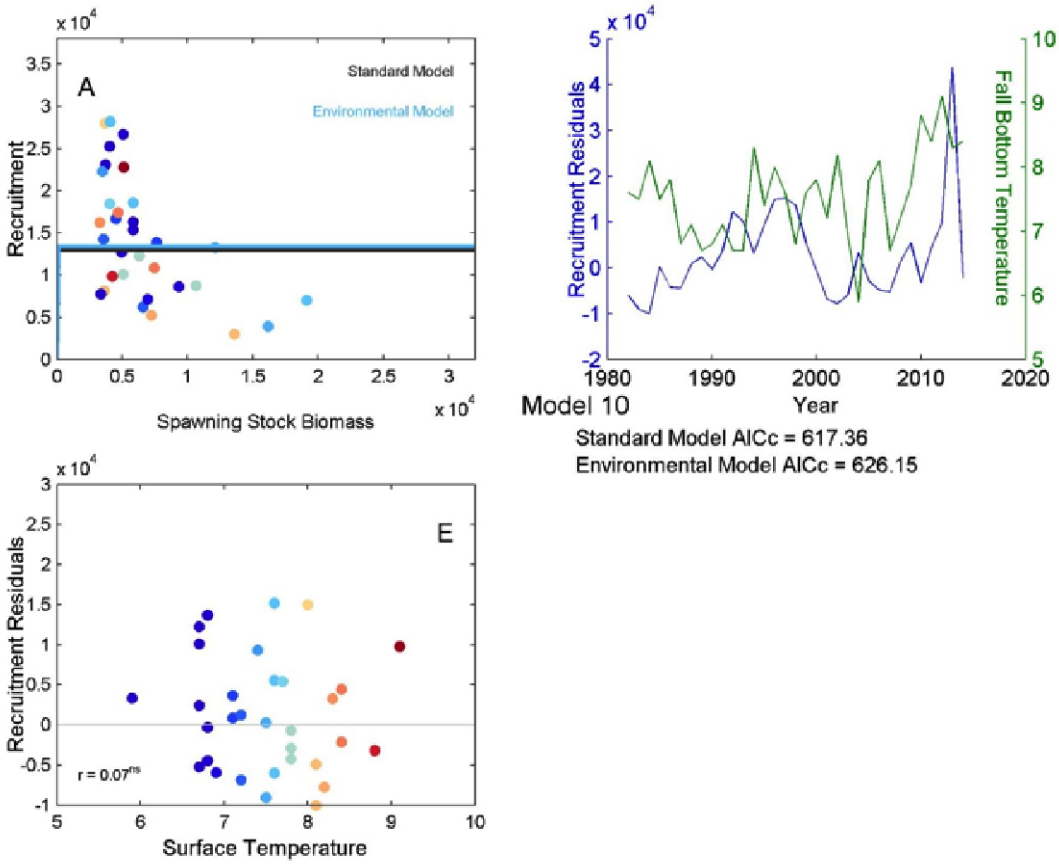


Figure B109. Stock-recruitment analyses for ASAP Model Output 10 using method described in Hare et al. 2016 working paper. ASAP Model Output 10 refers to a sensitivity run incorporating the LPUE40% tuning index.

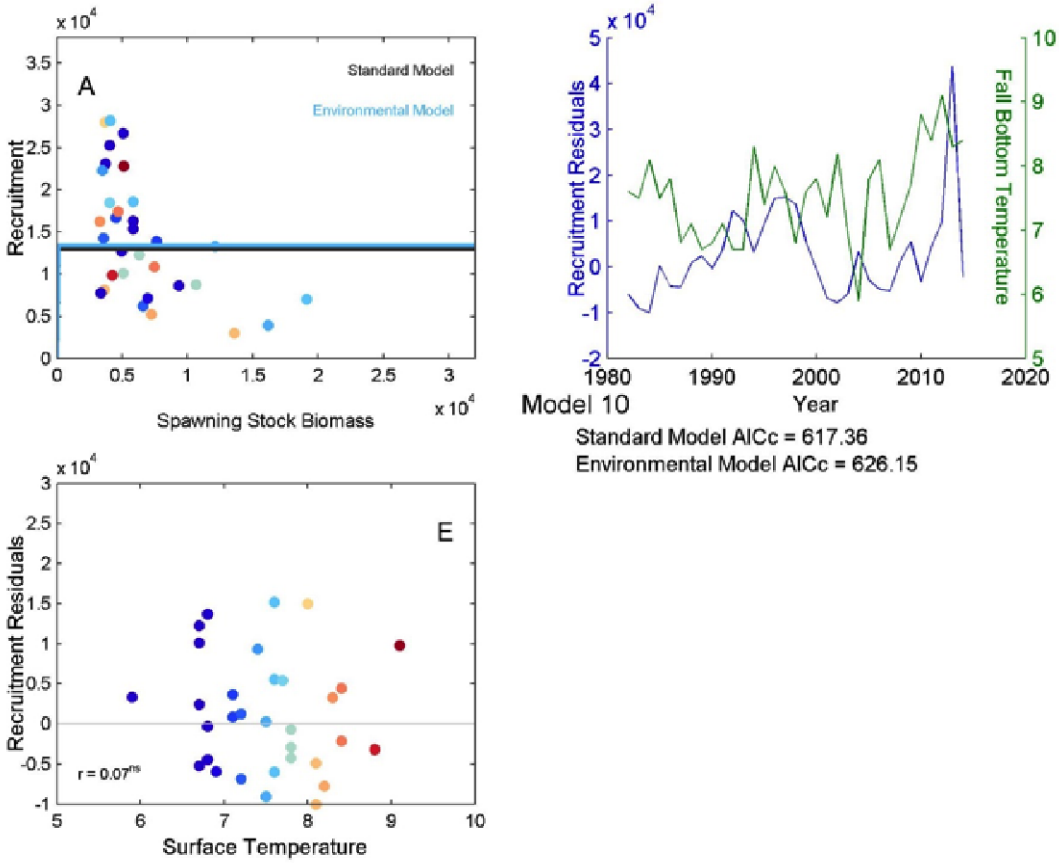


Figure B110. Stock-recruitment analyses for ASAP Model Output 15 using method described in Hare et al. 2016 working paper. ASAP Model Output 15 refers to a ASAP run with a catch multiplier of 4 for 2004 onward.

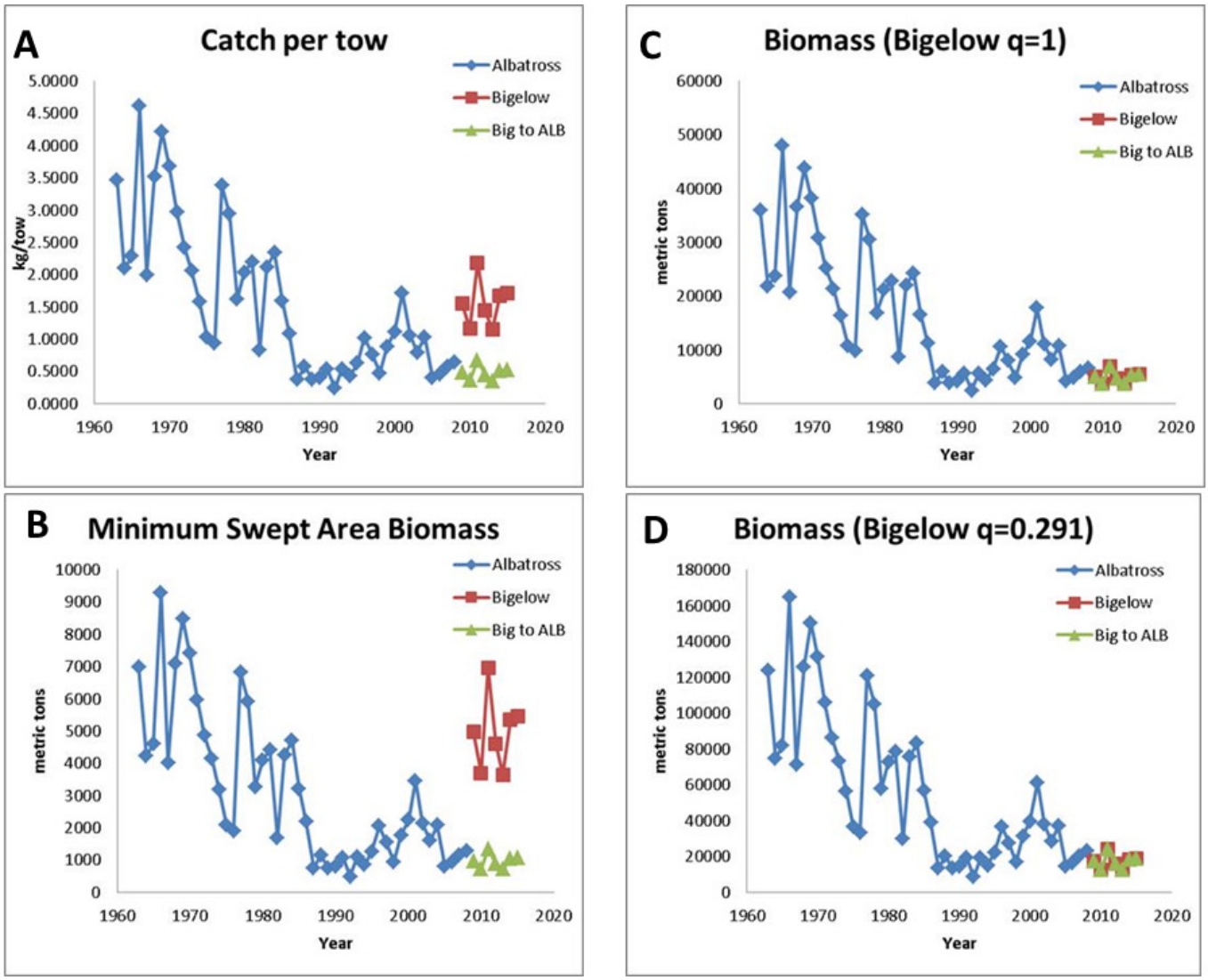


Figure B111. Trends in Northeast Fisheries Science Center autumn survey (kg/tow; A), minimum swept area biomass (mt; B), population biomass (mt; C) and population biomass accounting for net efficiency (mt, D) of witch flounder, 1963 – 2015.

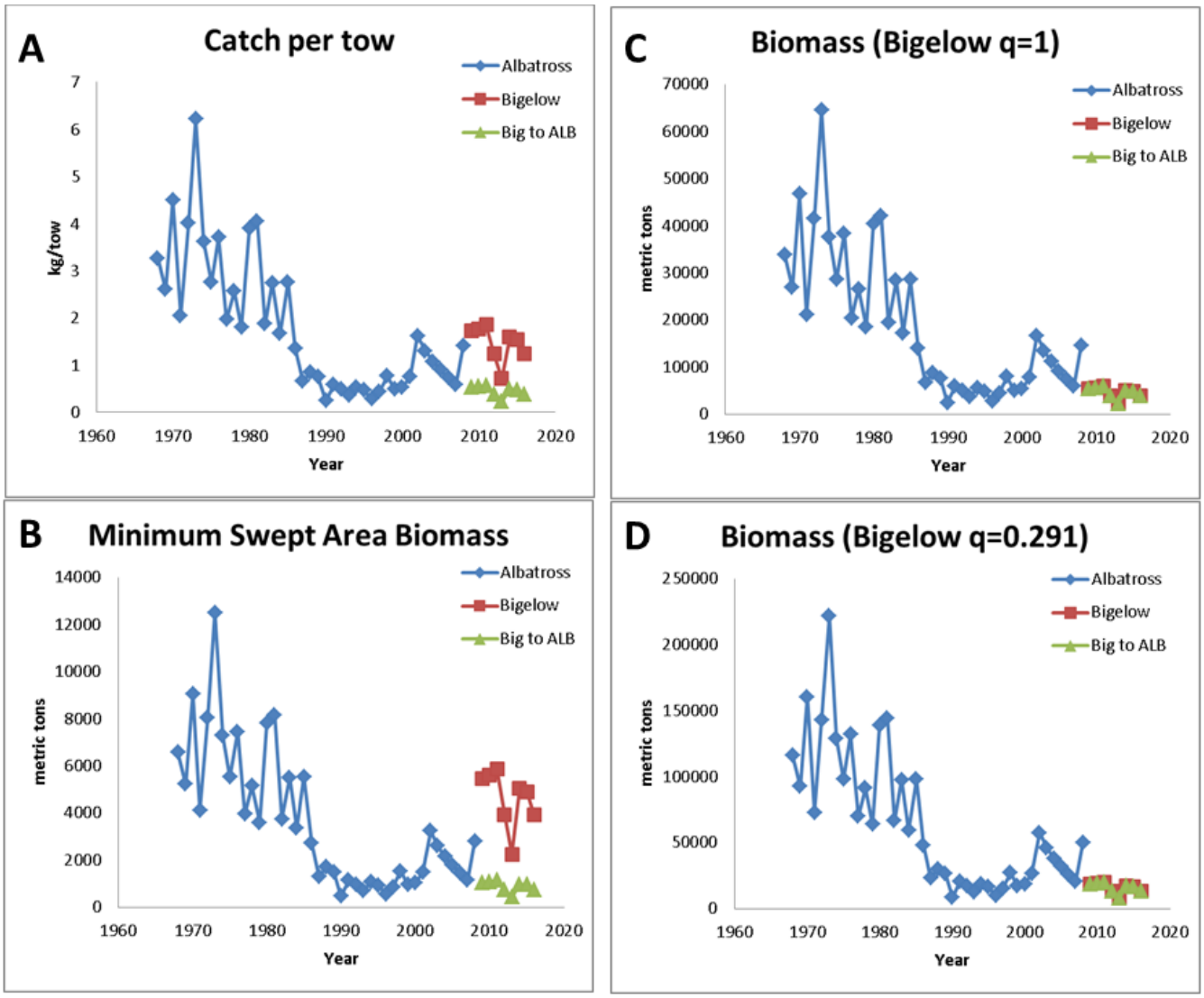


Figure B112. Trends in Northeast Fisheries Science Center spring survey (kg/tow; A), minimum swept area biomass (mt; B), population biomass (mt; C) and population biomass accounting for net efficiency (mt, D) of witch flounder, 1968 - 2016.

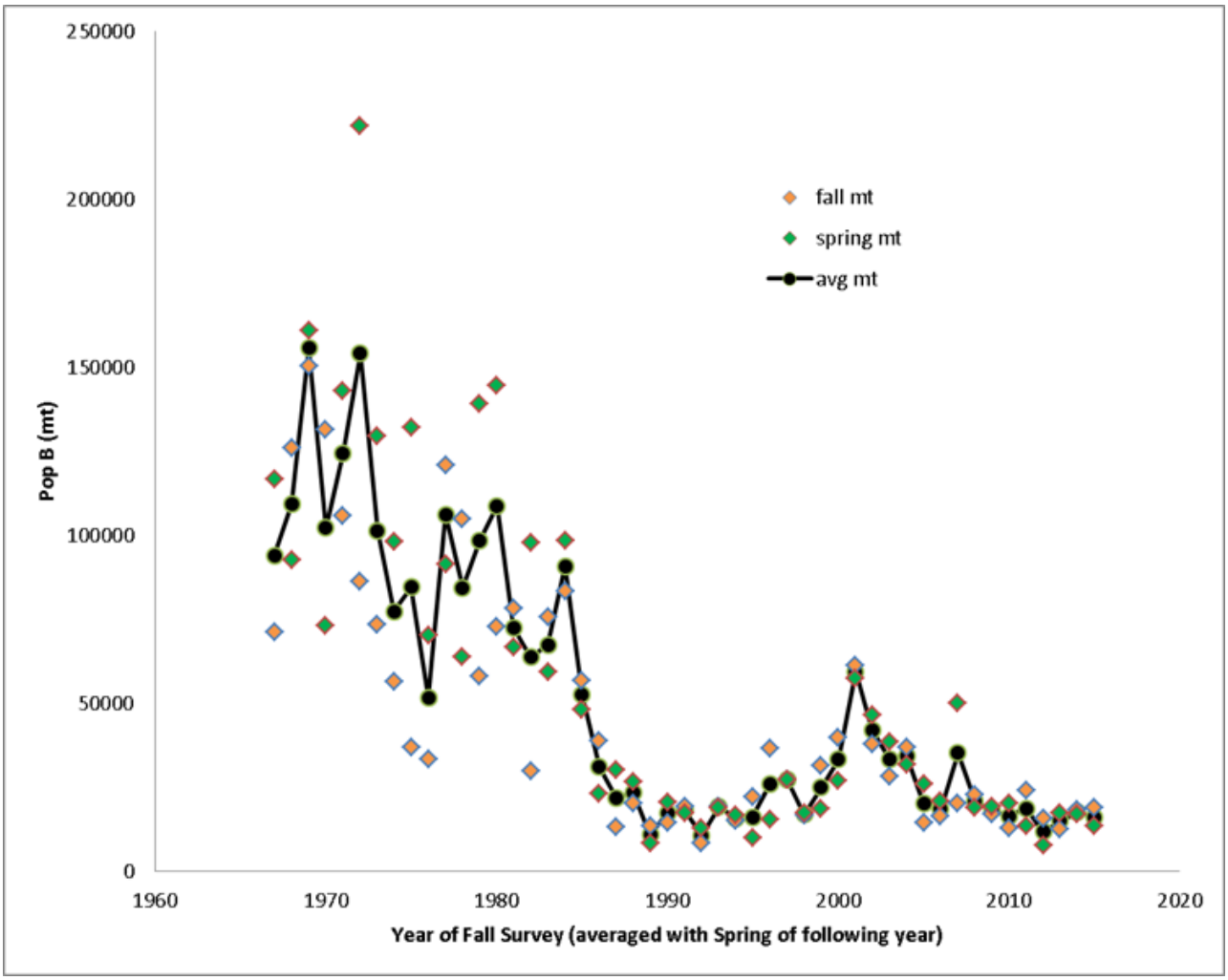


Figure B113. Trends in Northeast Fisheries Science Center autumn (pink diamond) and spring (green diamond) population biomass estimates (mt) and the average population biomass (mt; representing beginning year biomass; black line with solid circles) of witch flounder, 1969 – 2016.

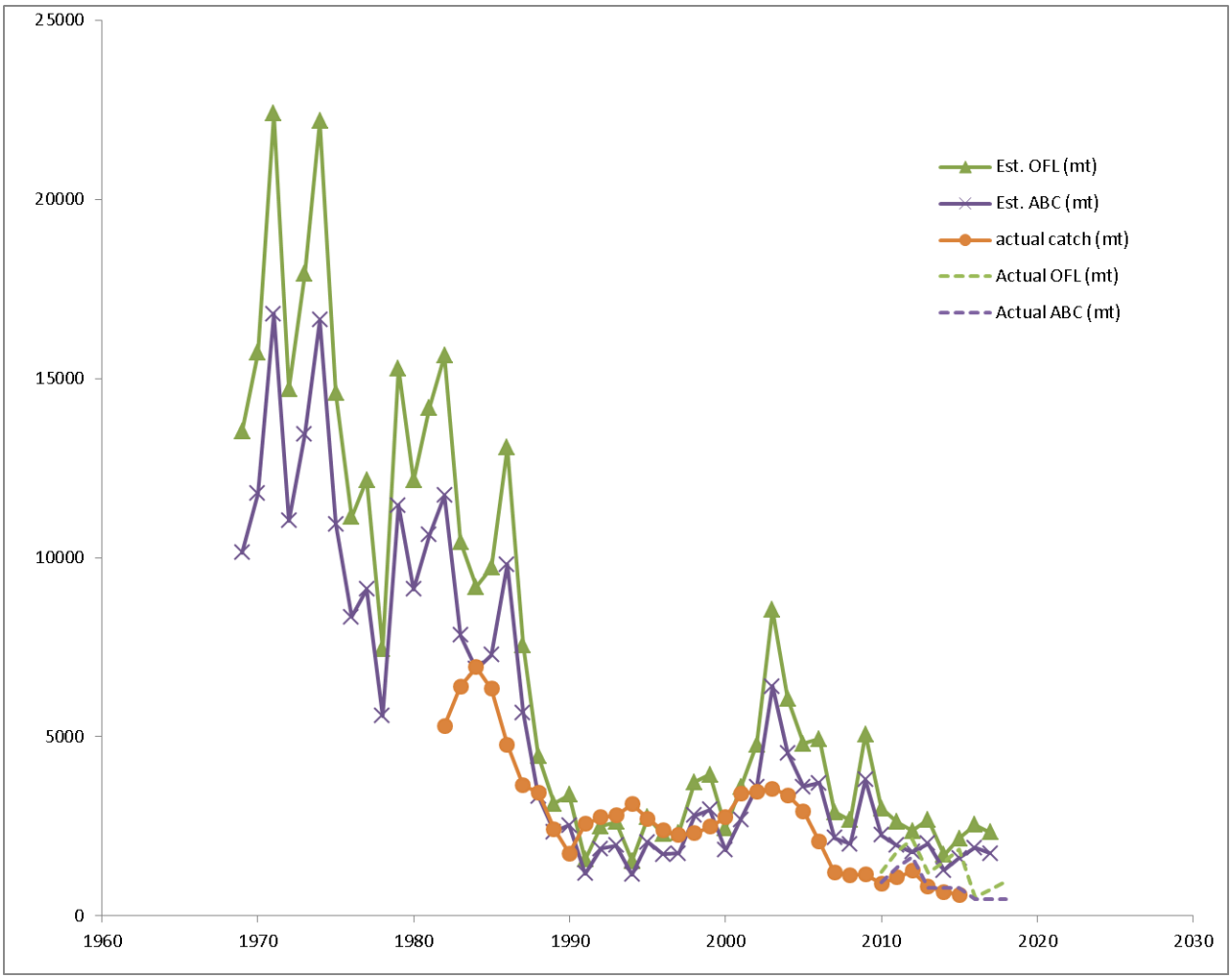


Figure B114. Estimated (solid lines) and actual (dashed lines) overfishing limit biomass (OFL; mt; green lines) and acceptable biological catch (ABC; mt; purple lines) and actual catch (mt; solid line with circles) of witch flounder, 1969 – 2018, using an assumed exploitation rate of 0.16.

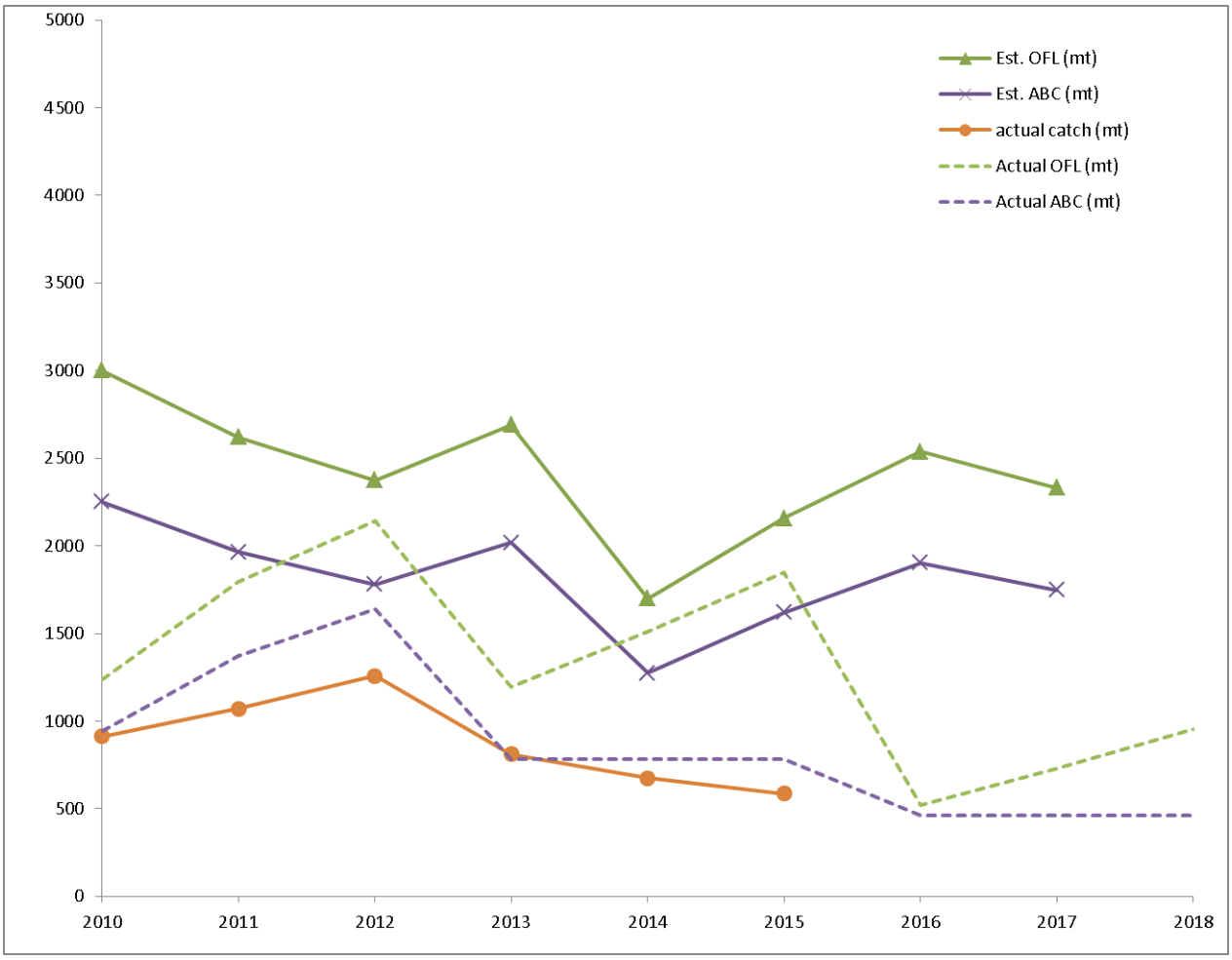


Figure B115. Estimated (solid lines) and actual (dashed lines) overfishing limit biomass (OFL; mt; green lines) and acceptable biological catch (ABC; mt; purple lines) and actual catch (mt; solid line with circles) of witch flounder for 2010 – 2018, using an assumed exploitation rate of 0.16.

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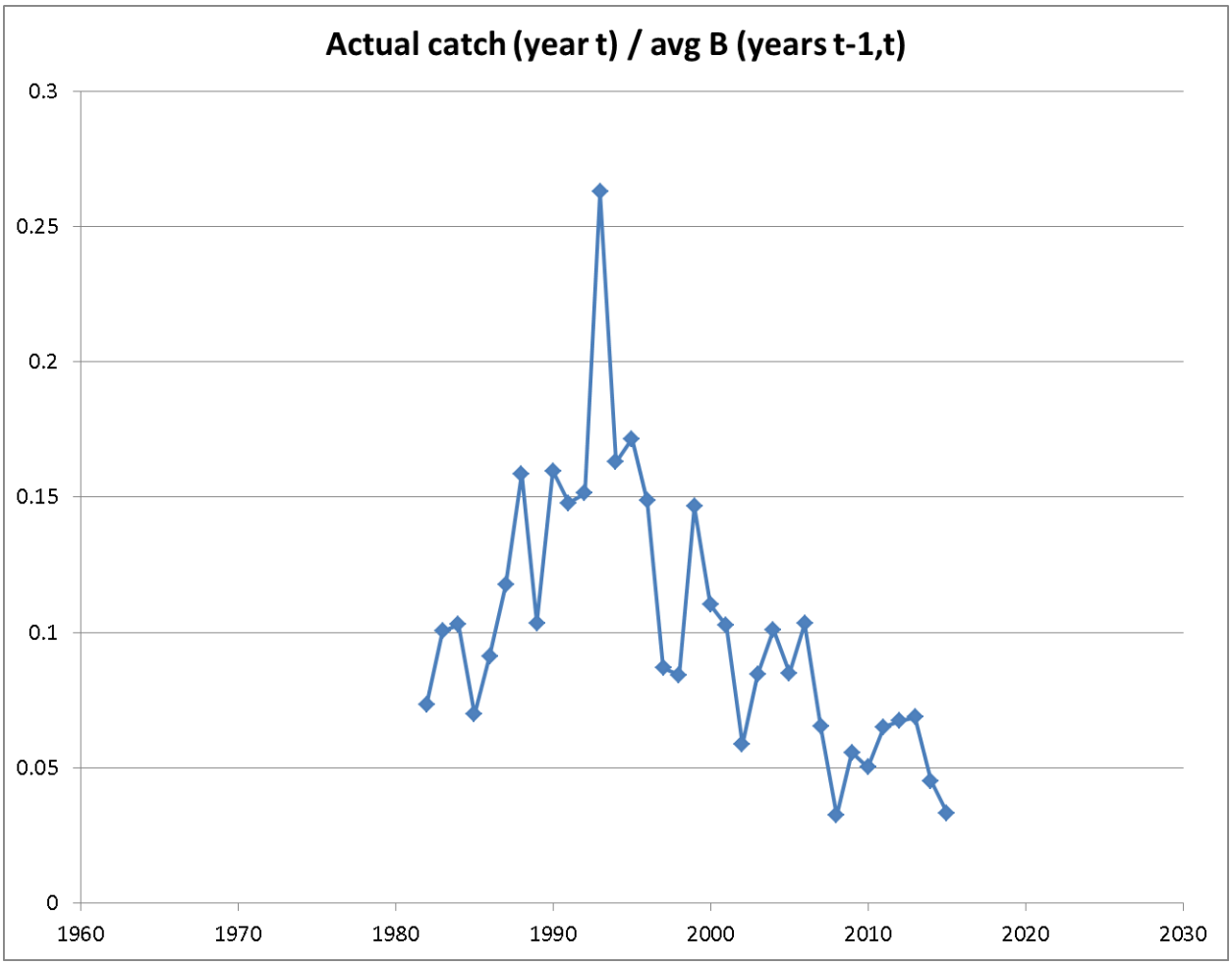


Figure B116. Historical exploitation rates of witch flounder derived from actual catch (year t) divided by average population biomass (years t-1 Autumn and t Spring), 1982 – 2015.

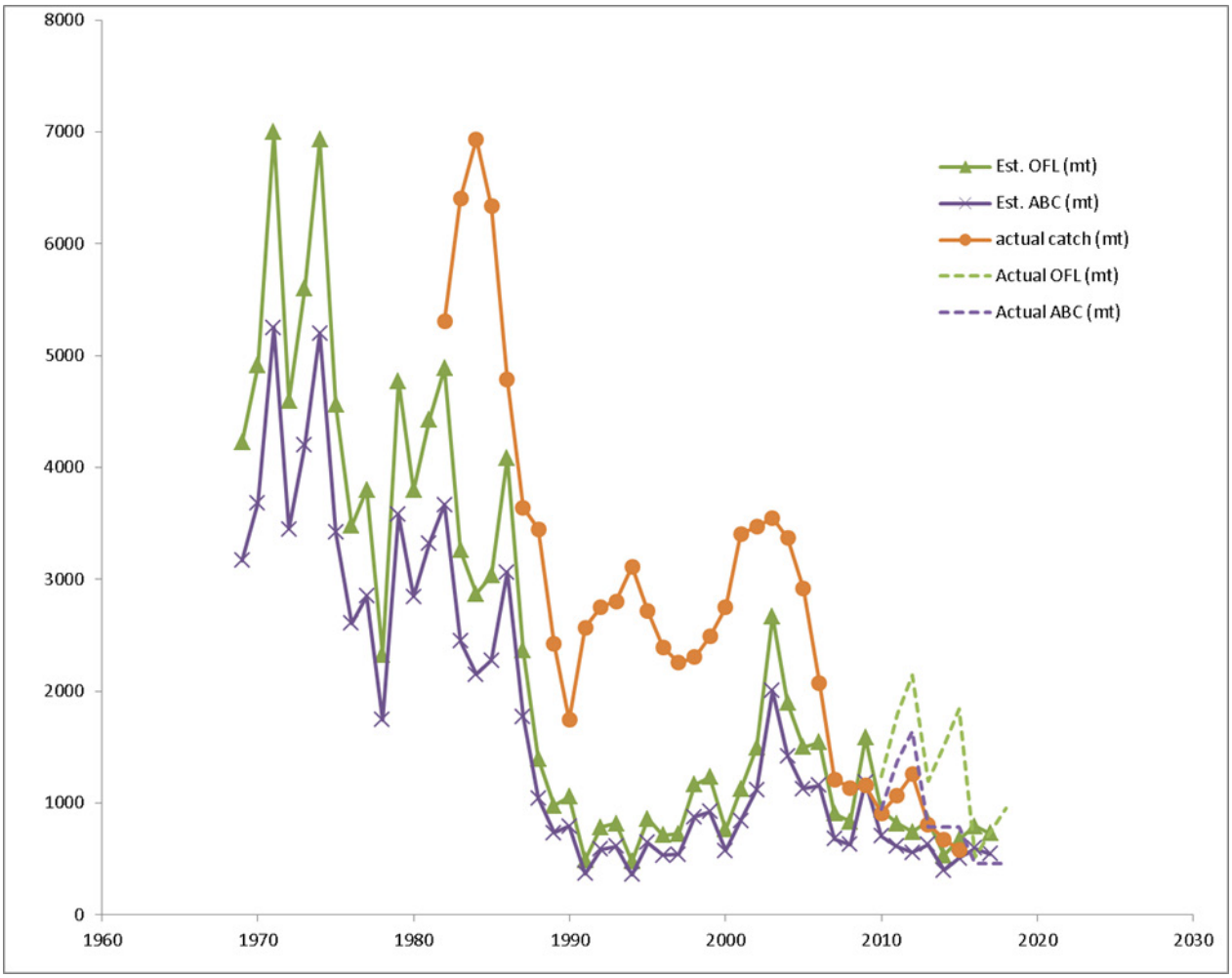


Figure B117. Estimated (solid lines) and actual (dashed lines) overfishing limit biomass (OFL; mt; green lines) and acceptable biological catch (ABC; mt; purple lines) and actual catch (mt; solid line with circles) of witch flounder, 1969 – 2018, using an assumed exploitation rate of 0.05.

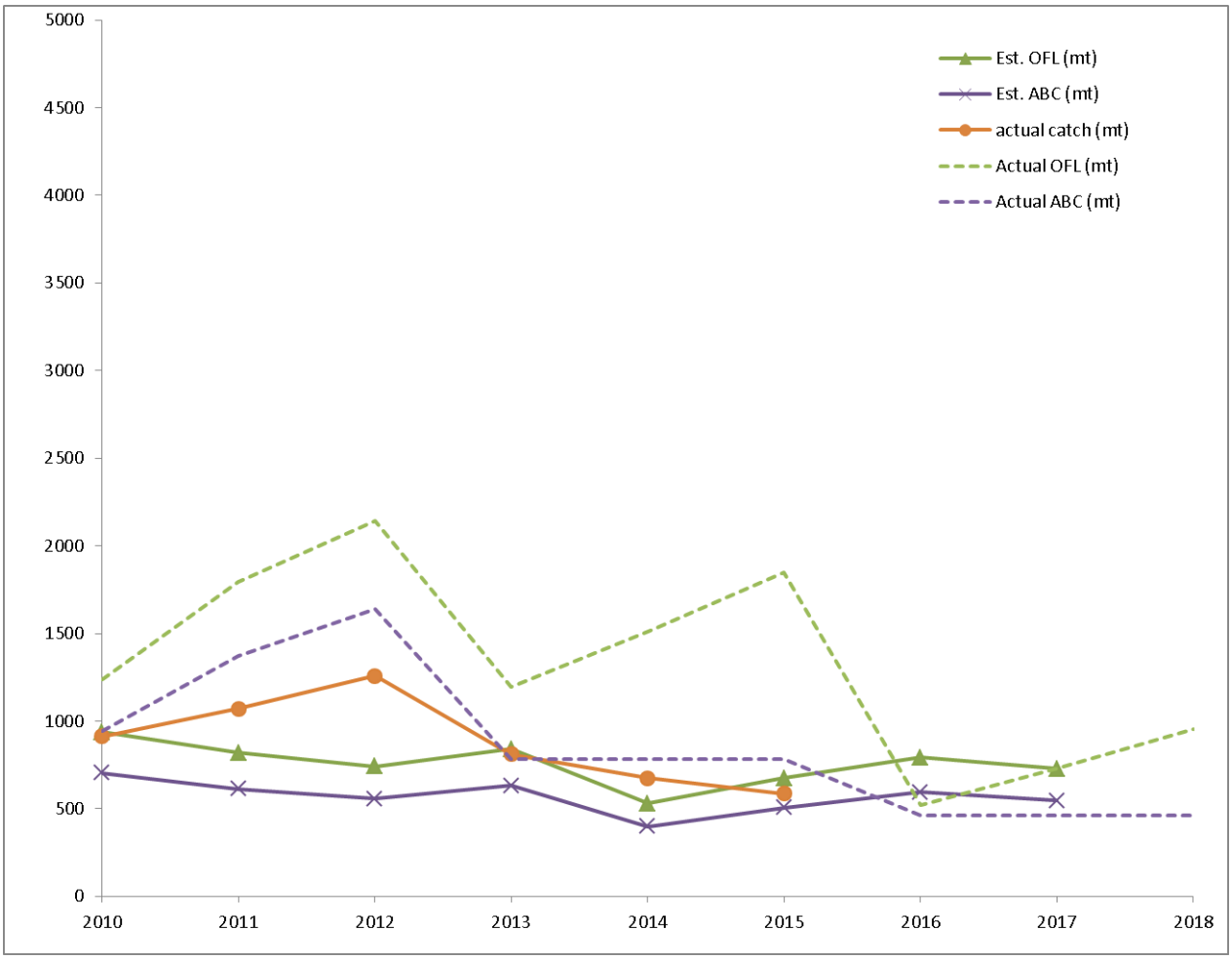


Figure B118. Estimated (solid lines) and actual (dashed lines) overfishing limit biomass (OFL; mt; green lines) and acceptable biological catch (ABC; mt; purple lines) and actual catch (mt; solid line with circles) of witch flounder for 2010 – 2018 using an assumed exploitation rate of 0.05.

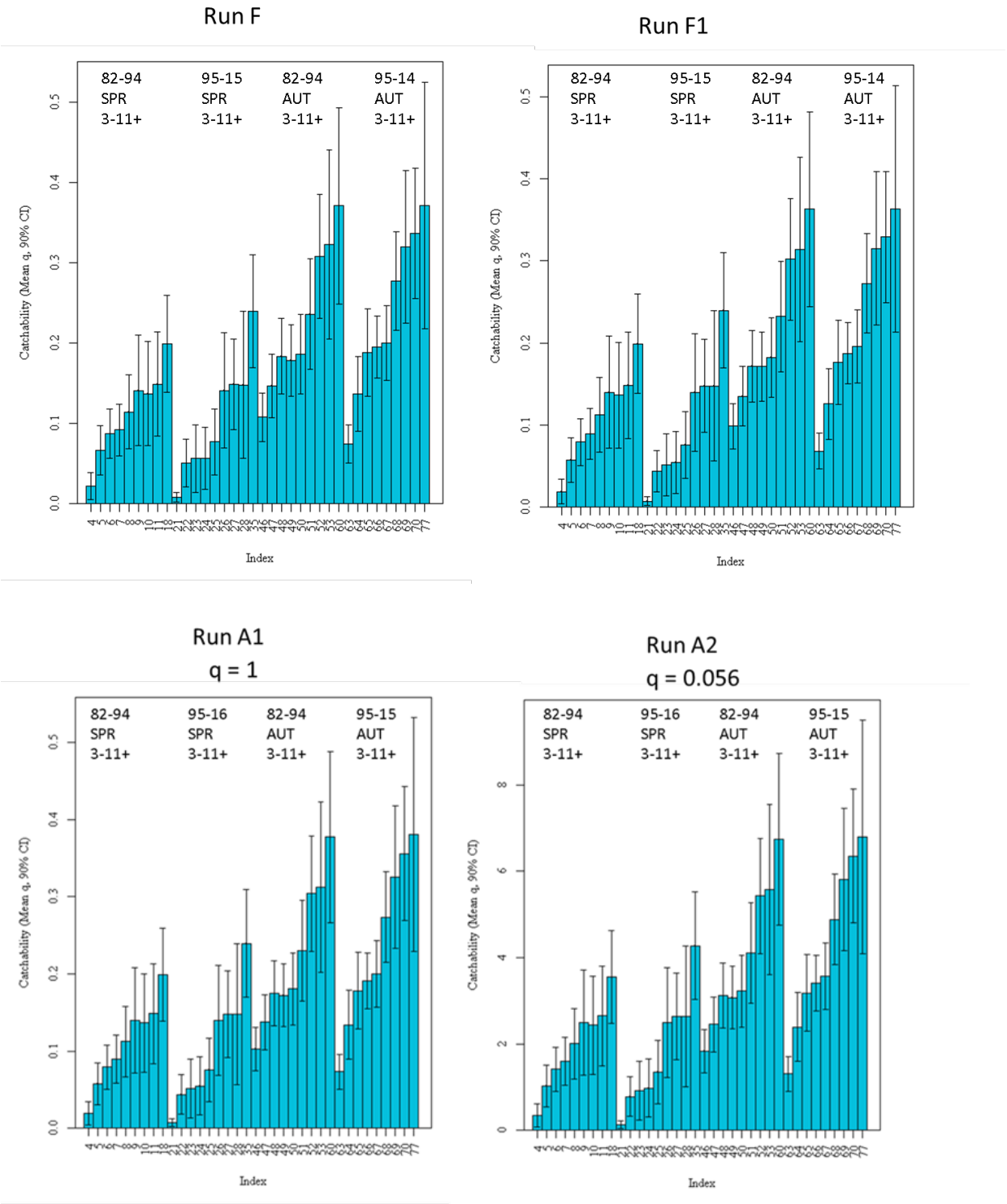


Figure B119. Northeast Fisheries Science Center swept-area survey catchabilities (q) by age (3 to 11+) and season (spring and autumn) from RUN F (2015 OA accepted run; top left), Run F1 (2015 OA with revised catch at age; top right), RUN A1 (q assumed to be 1) and RUN A2 (q = 0.056). Survey tuning indices split between 1994 and 1995.

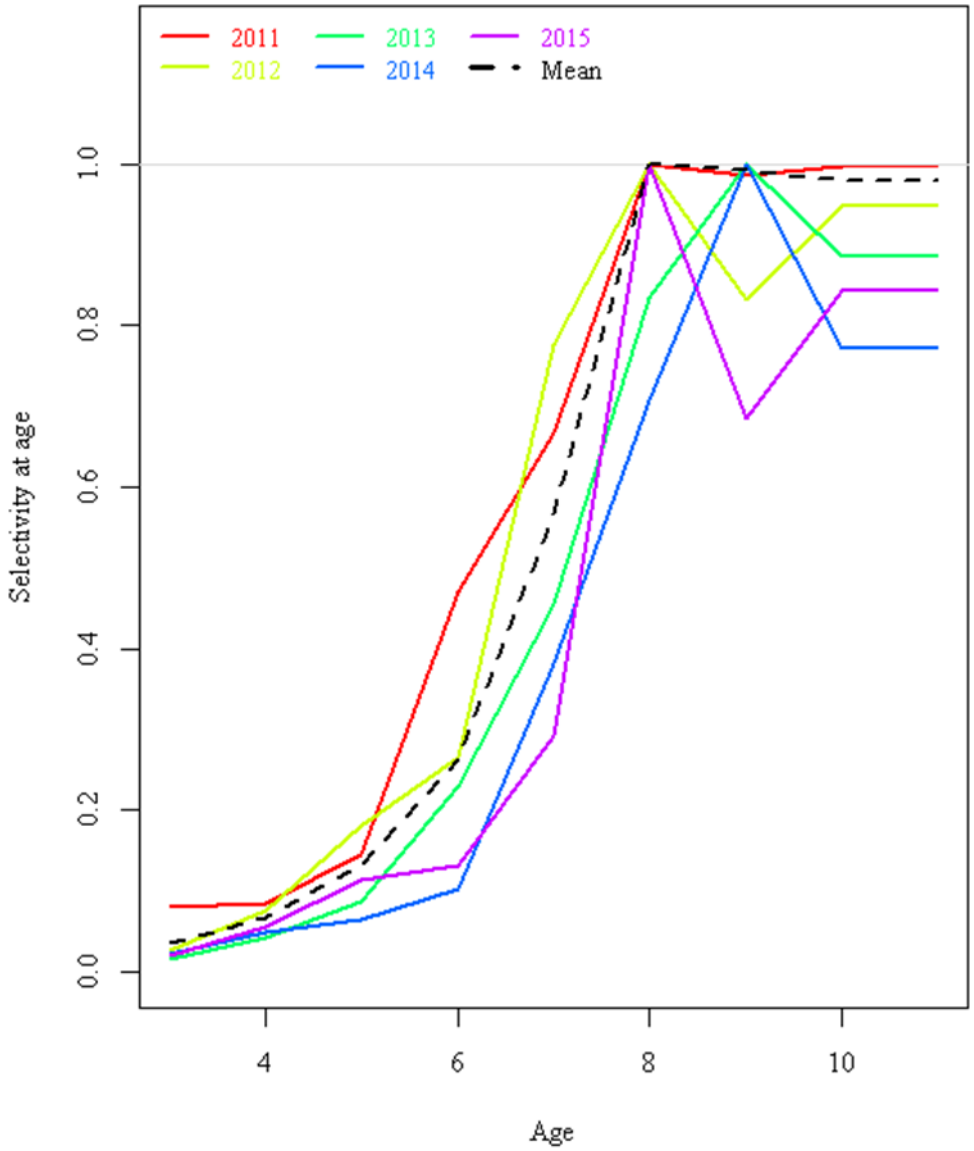


Figure B120. Model-estimated partial recruitment pattern of witch flounder for the five most recent years from Run A2, 1982-2015.

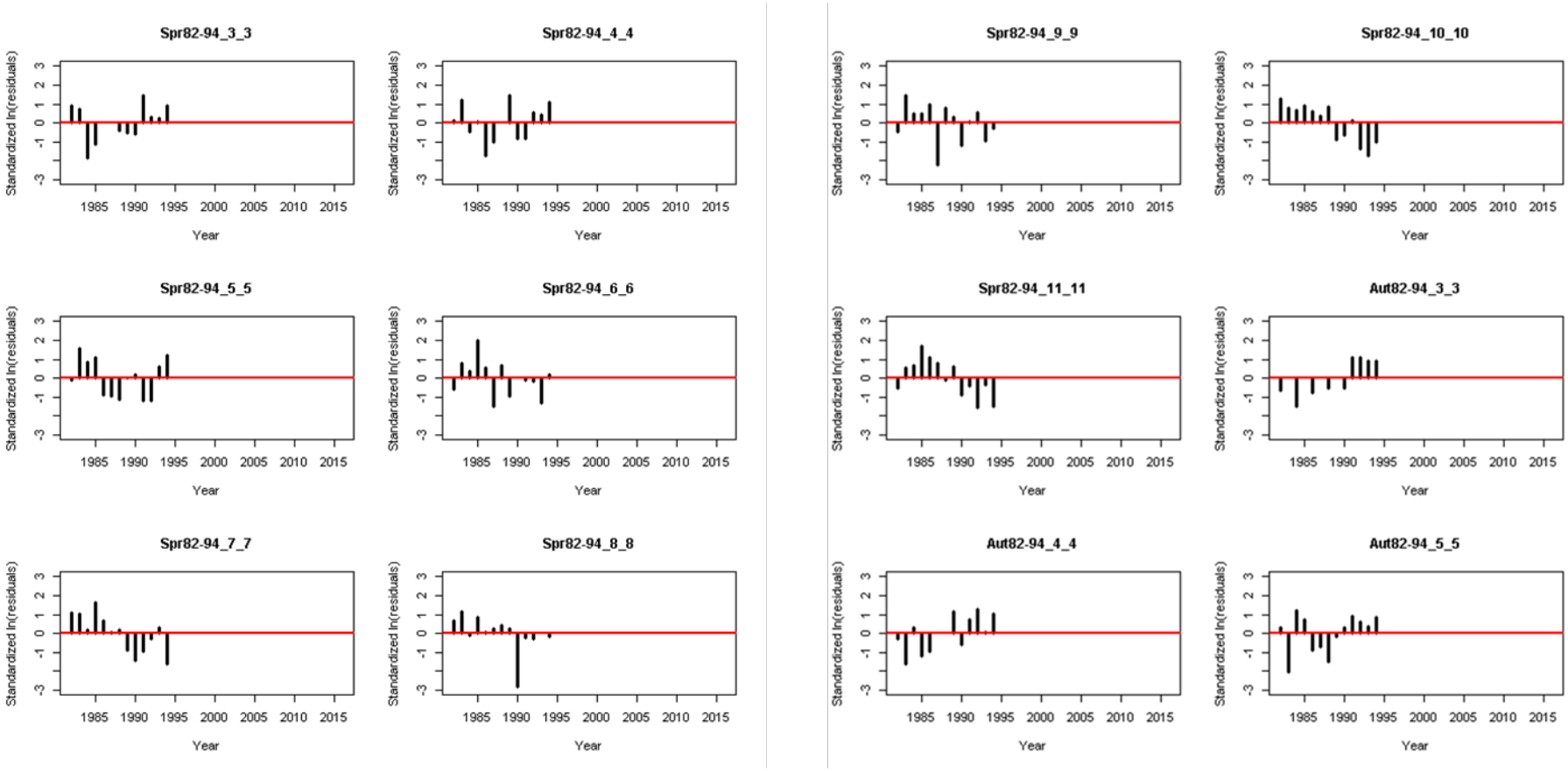


Figure B121. Witch flounder standardized residuals for Northeast Fisheries Science Center spring and autumn survey indices at age from RUN A2, 1982-2015.

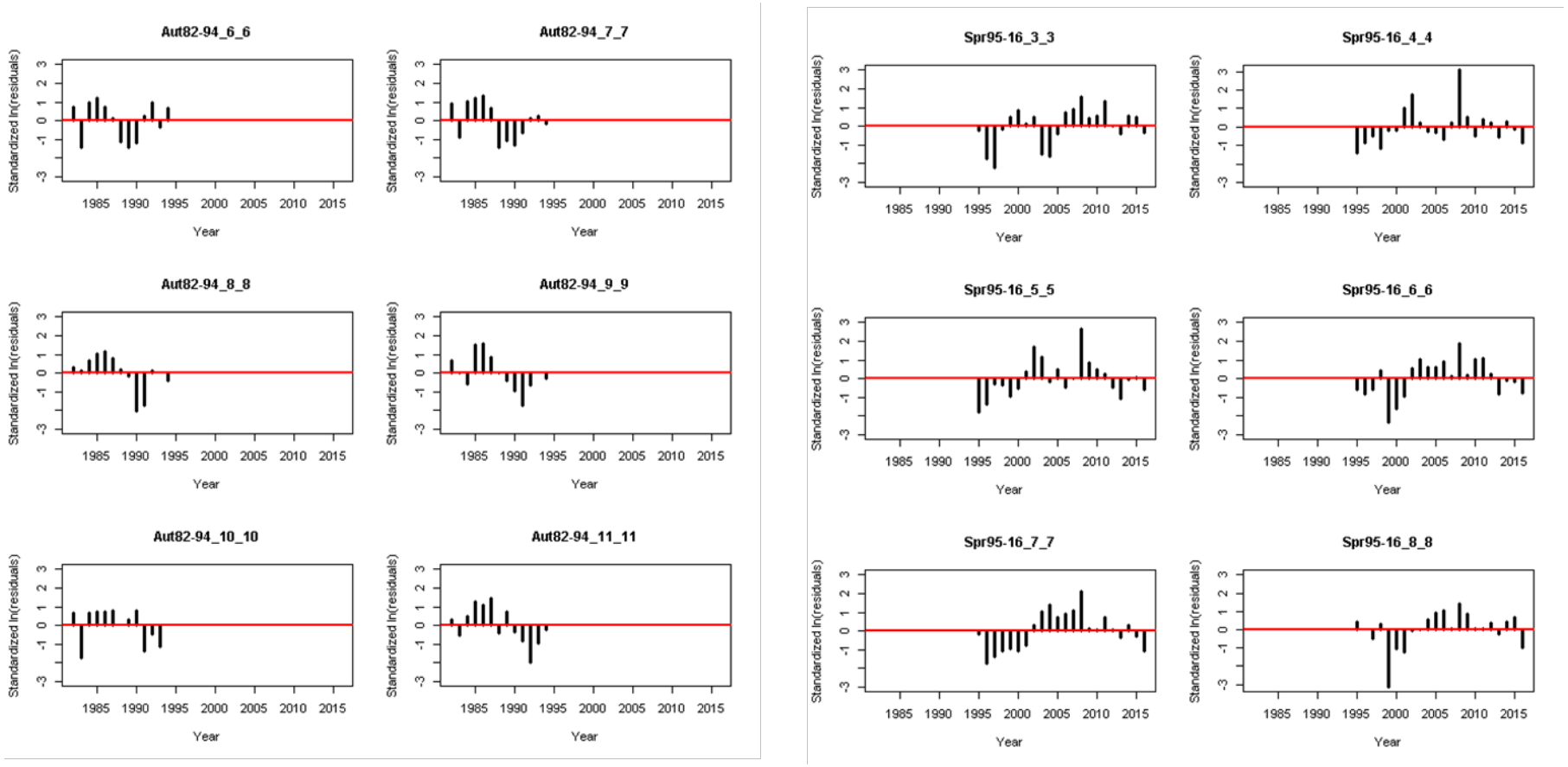


Figure B121, continued. Witch flounder standardized residuals for Northeast Fisheries Science Center spring and autumn survey indices at age (3 to 11+) from RUN A2, 1982-2015.

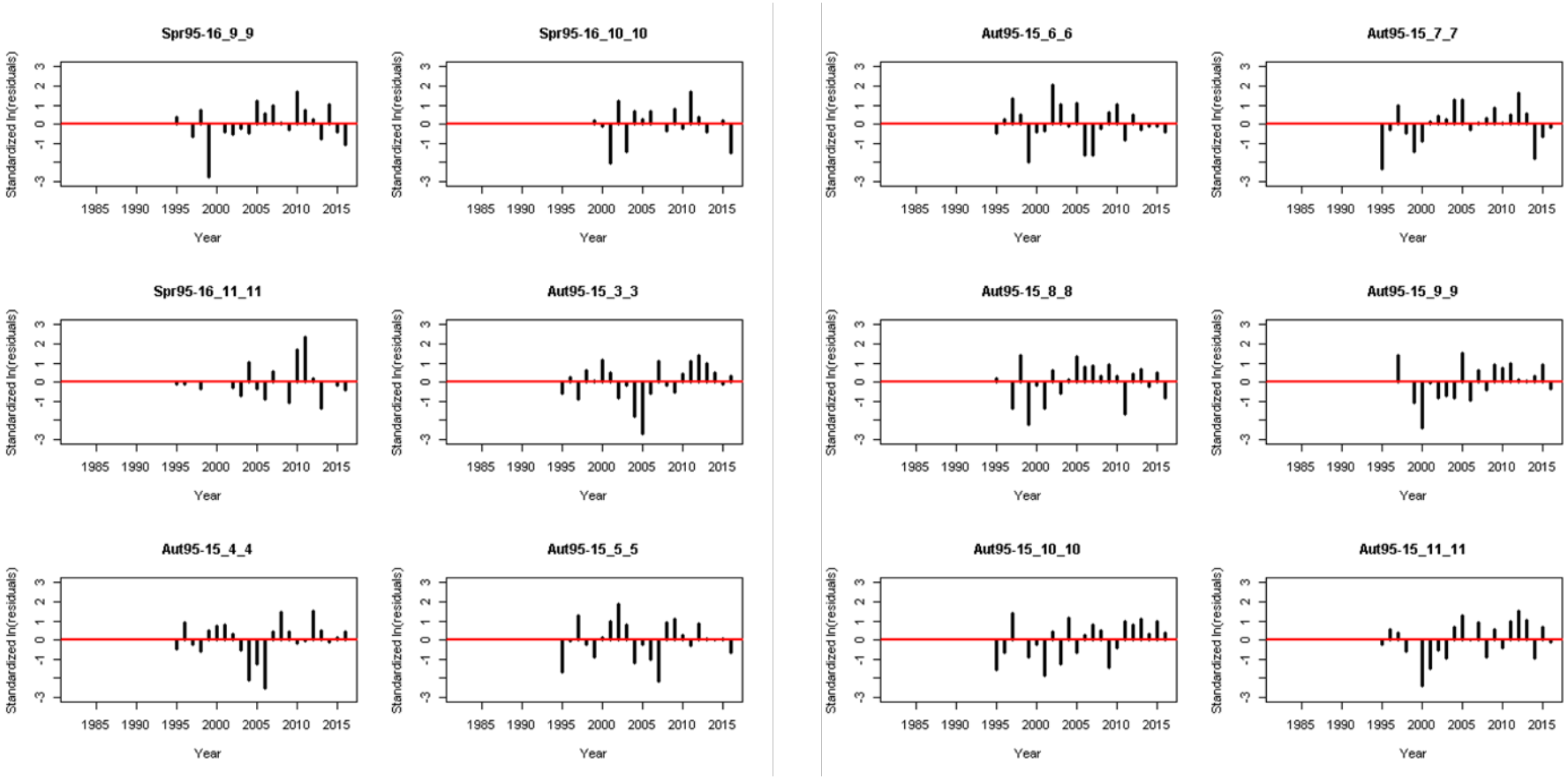


Figure B121, continued. Witch flounder standardized residuals for Northeast Fisheries Science Center spring and autumn survey indices at age (3 to 11+) from RUN A2, 1982-2015.

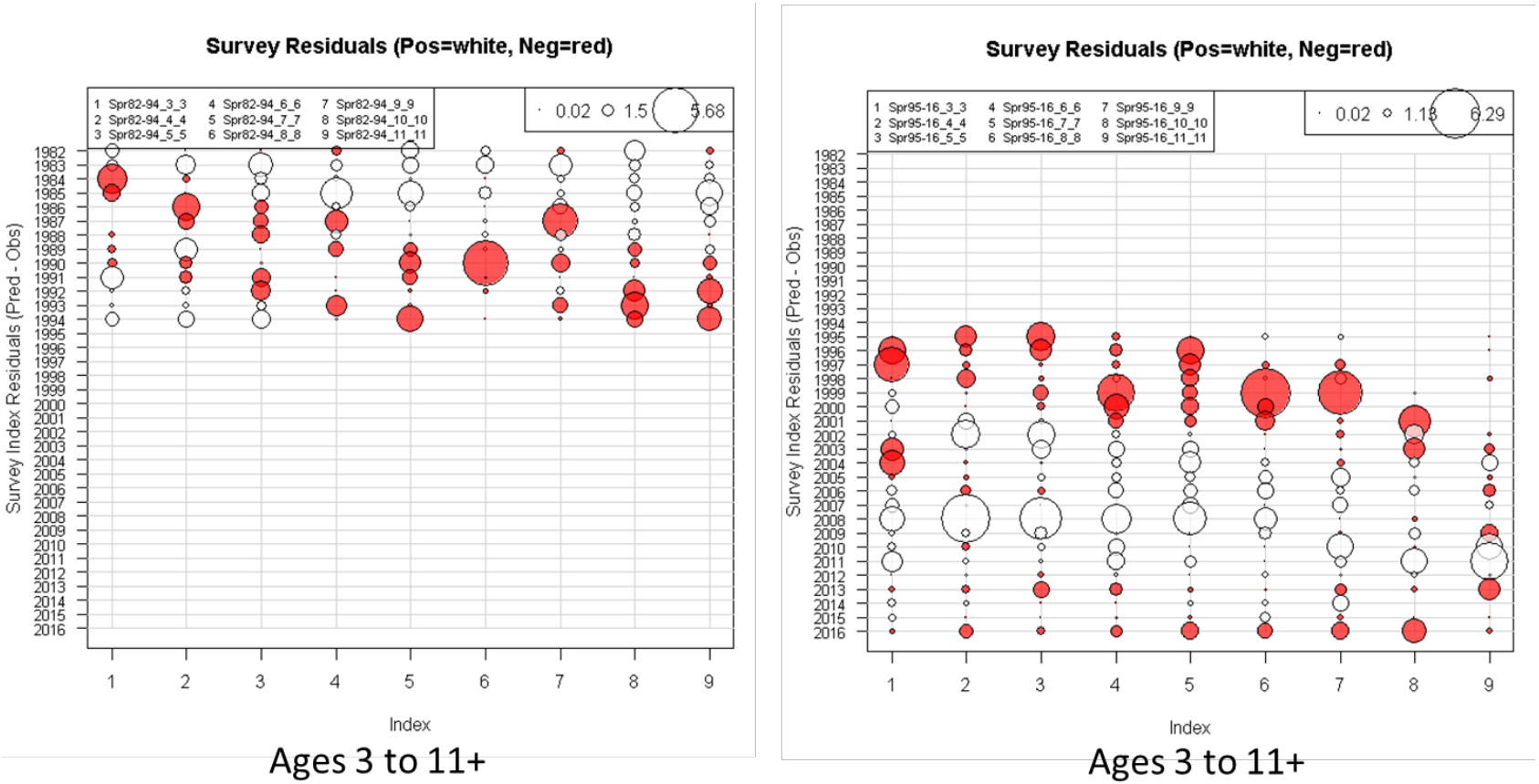
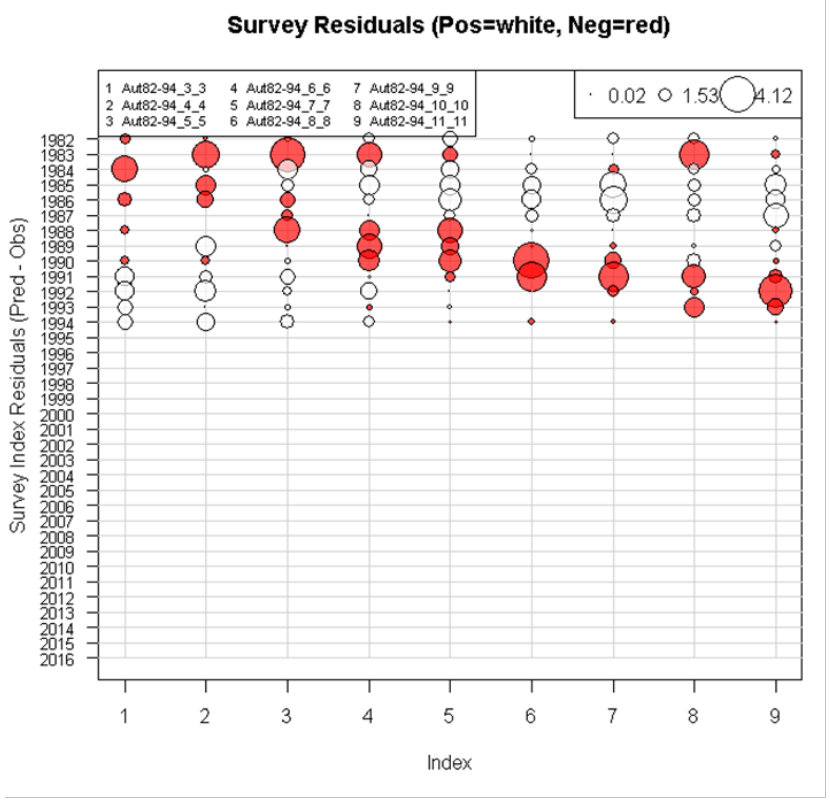
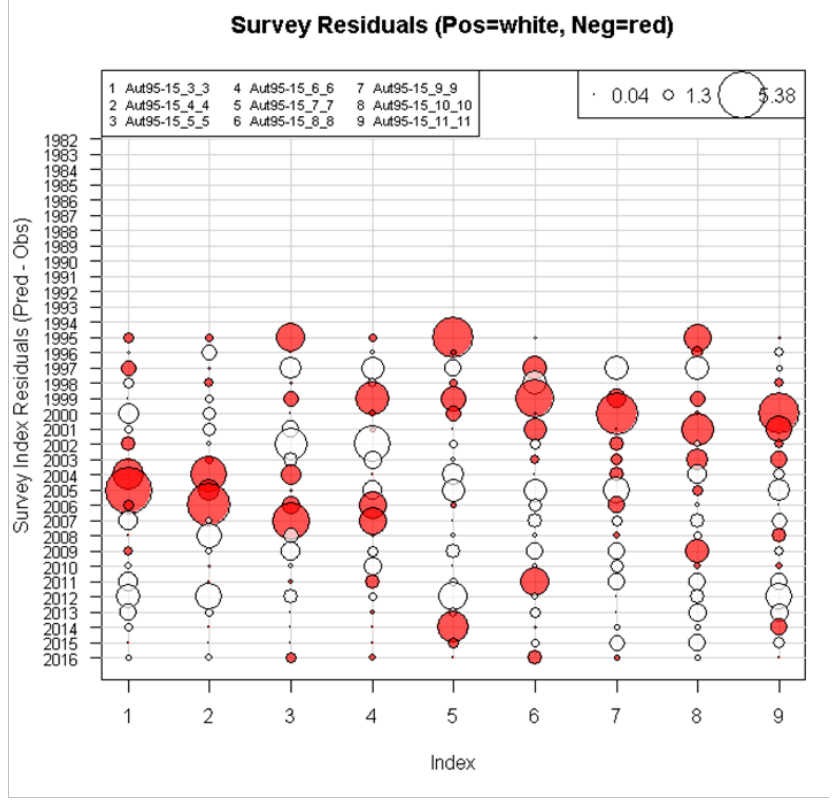


Figure B122. Witch flounder standardized residuals for Northeast Fisheries Science Center spring survey indices at age (3 to 11+) from RUN A2, 1982-2015.



Ages 3 to 11+



Ages 3 to 11+

Figure B122, continued. Witch flounder standardized residuals for Northeast Fisheries Science Center autumn survey indices at age (3 to 11+) from RUN A2, 1982-2015.

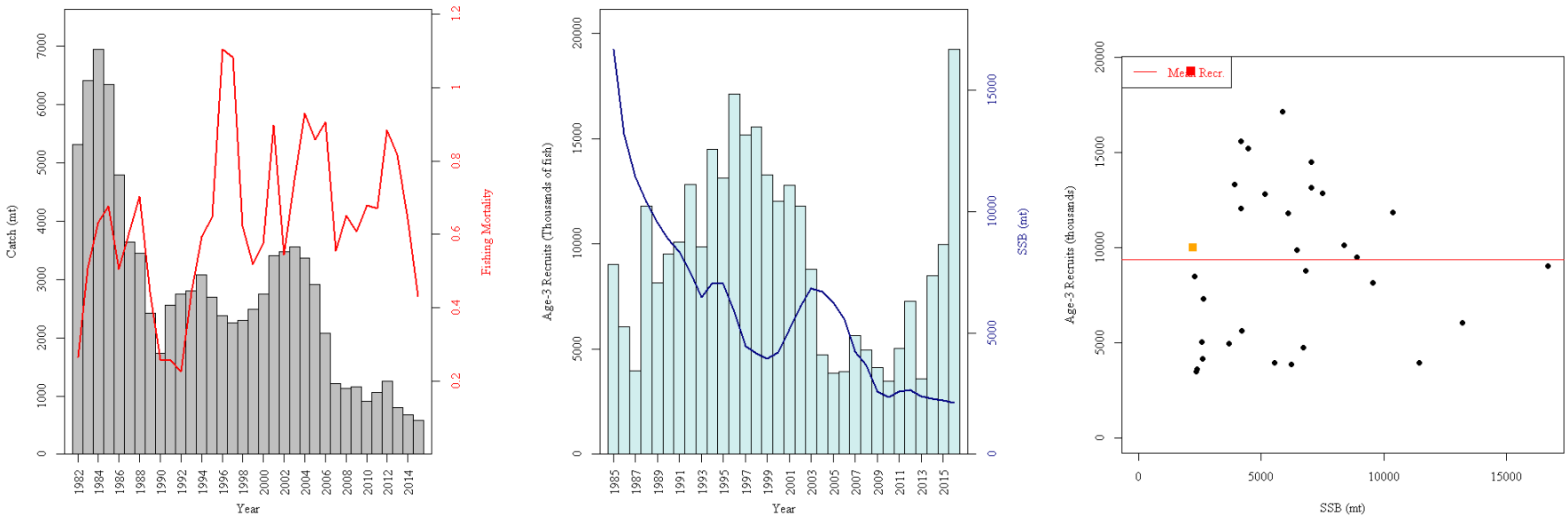


Figure B123. Trends of witch flounder total catch (gray bars) and fishing mortality (red line; left), Age 3 recruitment (light blue bars) and spawning stock biomass (dark blue line; middle), and spawning stock biomass and Age 3 recruits, 1982 – 2014 year classes (right) from RUN A2,1982 -2015. Red horizontal line represents mean recruitments; red and orange squares represent the 2012 and 2013 year classes (Age 3 in 2015 and 2016).

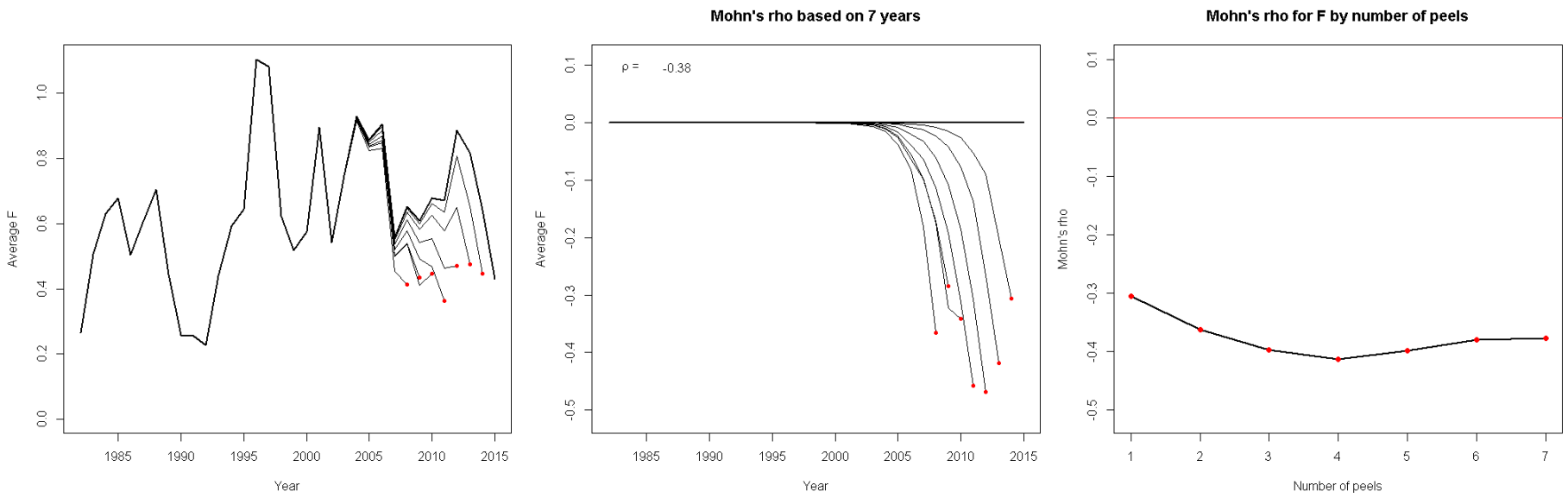


Figure B124. Retrospective analysis results of fishing mortality (left), relative difference of fishing mortality from the terminal year (middle) and Mohn's rho for each peel (right) from RUN A2, 1982 – 2015. Mohn's rho (average relative difference of 7 peels) is -0.38.

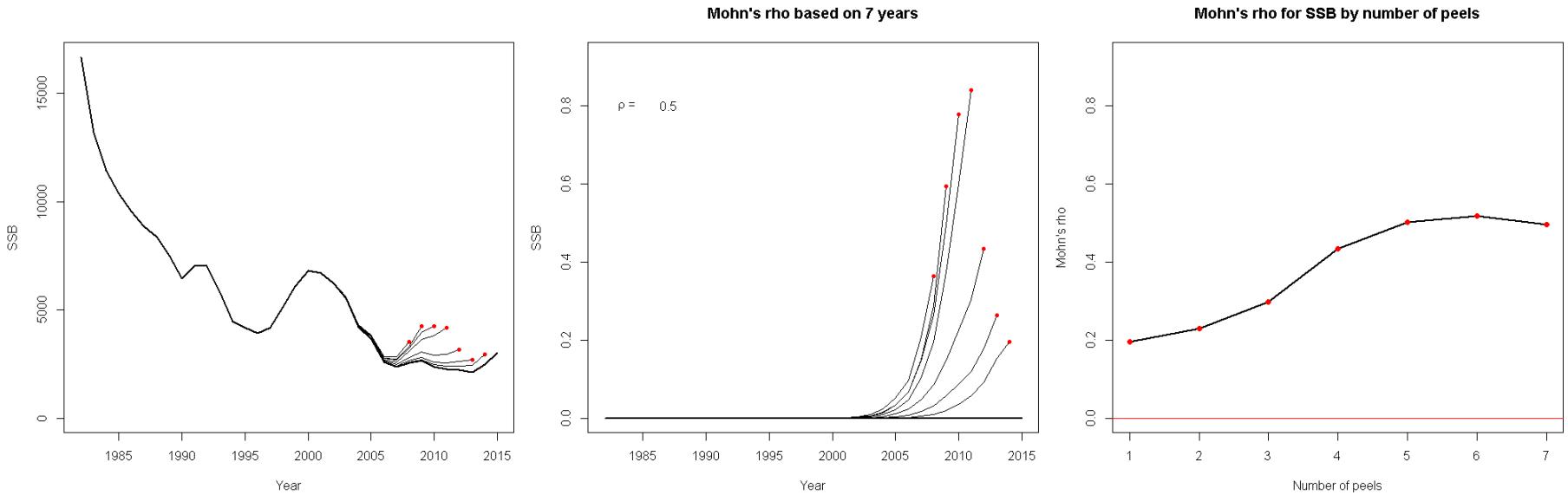


Figure B125. Retrospective analysis results of spawning biomass (left), relative difference of spawning biomass from the terminal year (middle) and Mohn's rho for each peel (right) from RUN A2, 1982 – 2015. Mohn's rho (average relative difference of 7 peels) is 0.50.

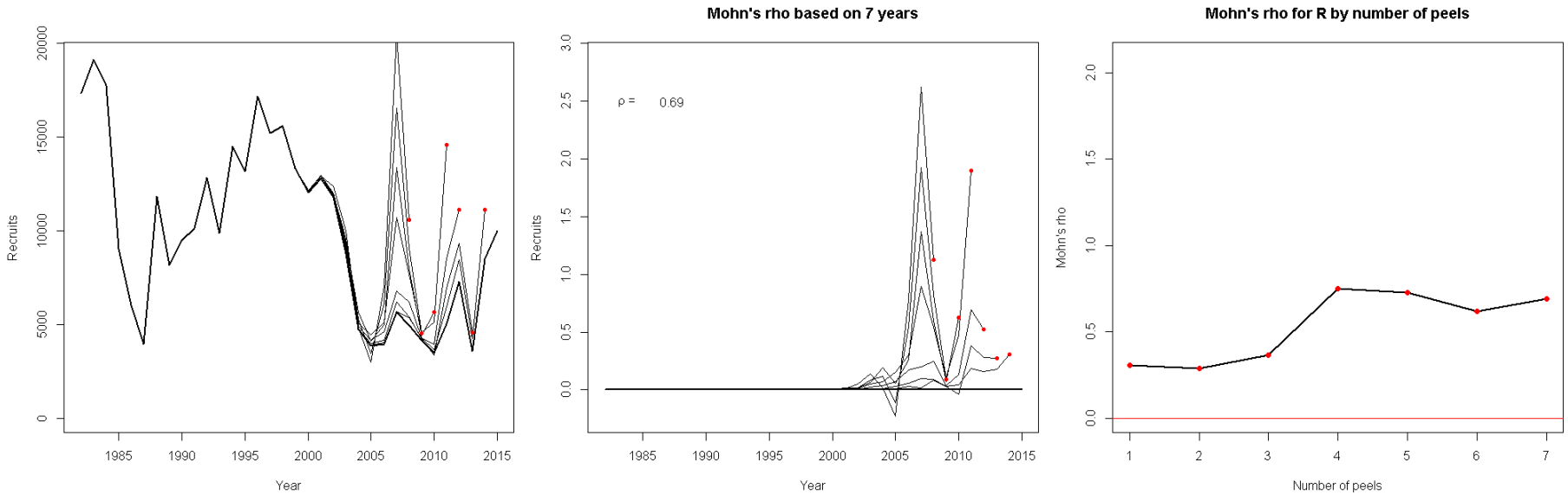
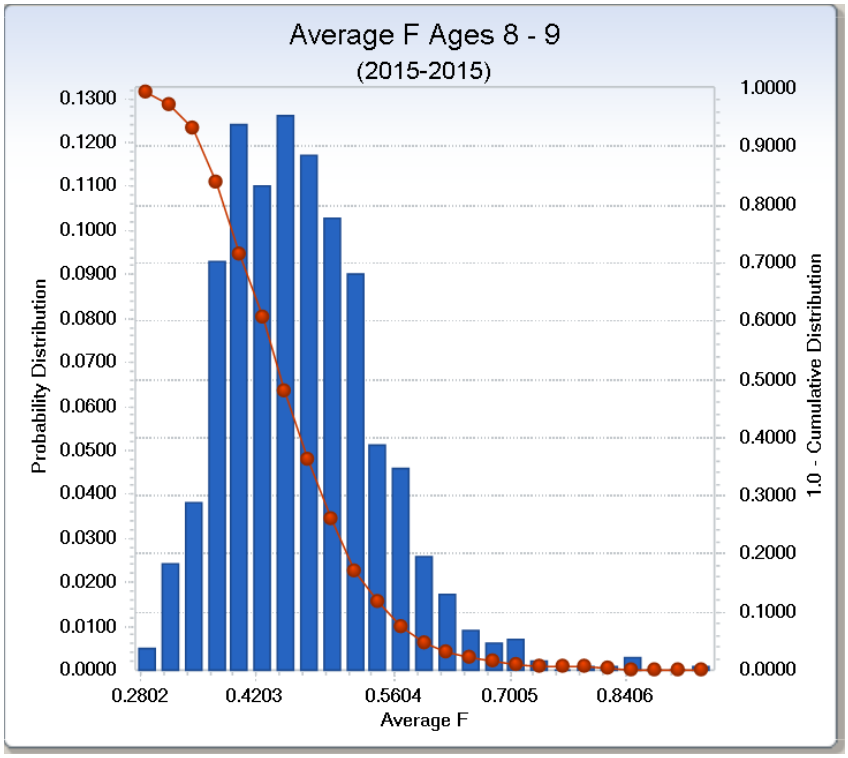


Figure B126. Retrospective analysis results of Age 3 recruitment (left), relative difference of Age 3 recruitment from the terminal year (middle), and Mohn's rho for each peel (right) from RUN A2, 1982 – 2015. Mohn's rho (average relative difference of 7 peels) is 0.693.



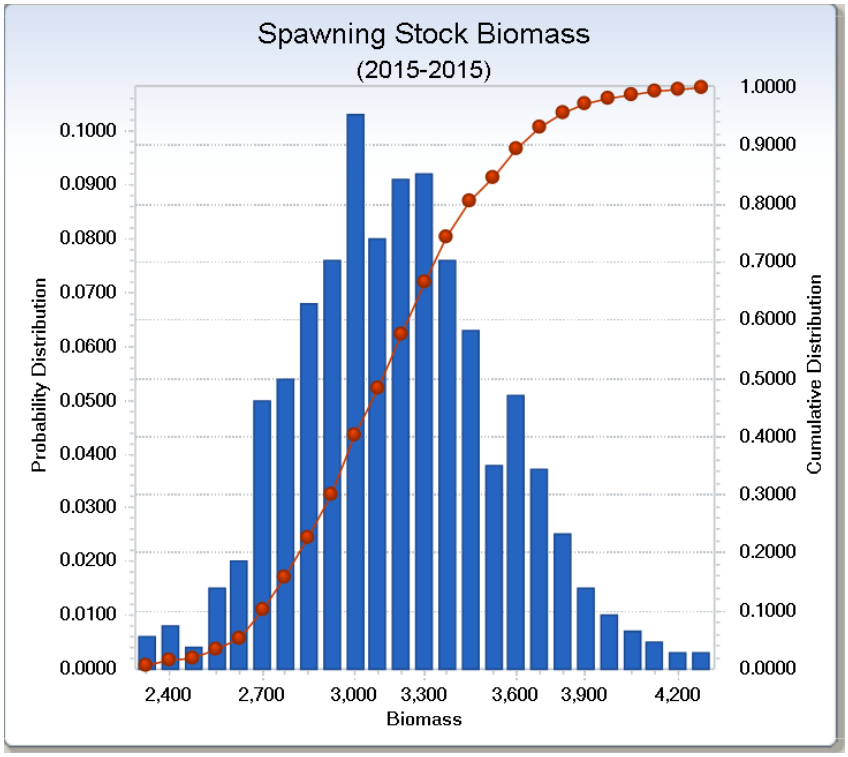
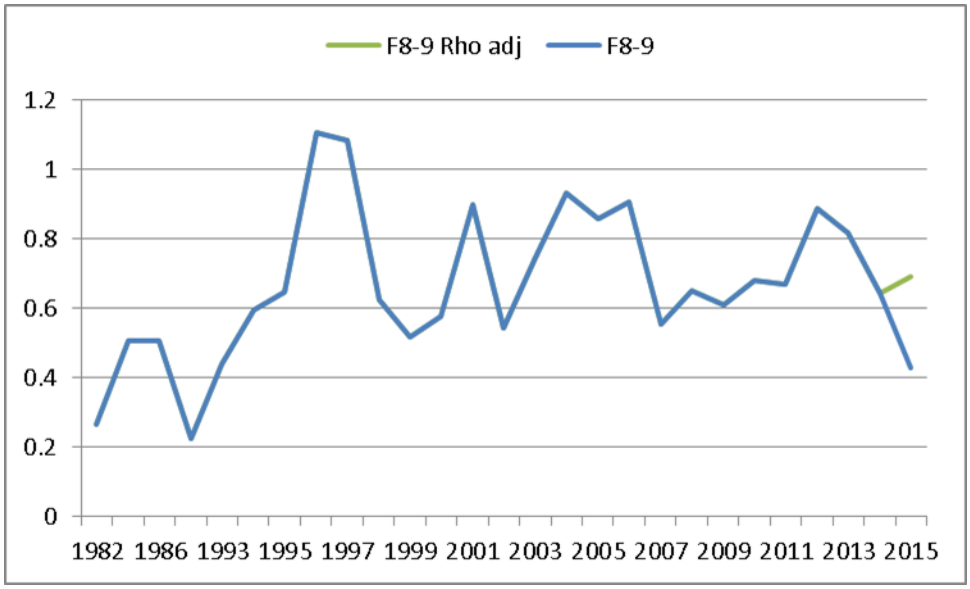


Figure B127. Precision estimates of fishing mortality (top) and spawning stock biomass (mt; bottom) in 2015 from RUN A2. Blue vertical bars display both the range of the bootstrap estimates and the probability of the individual values in the range.



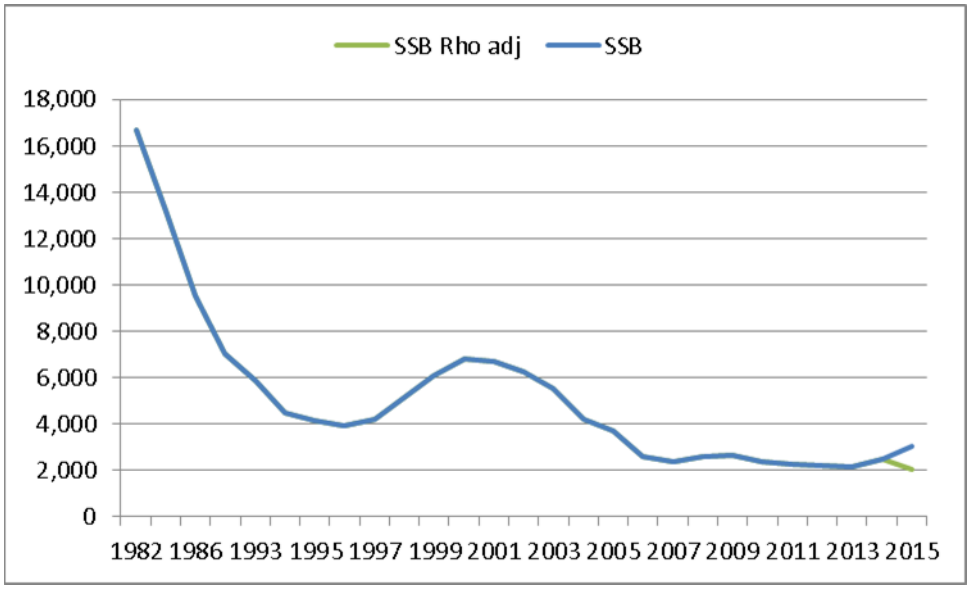
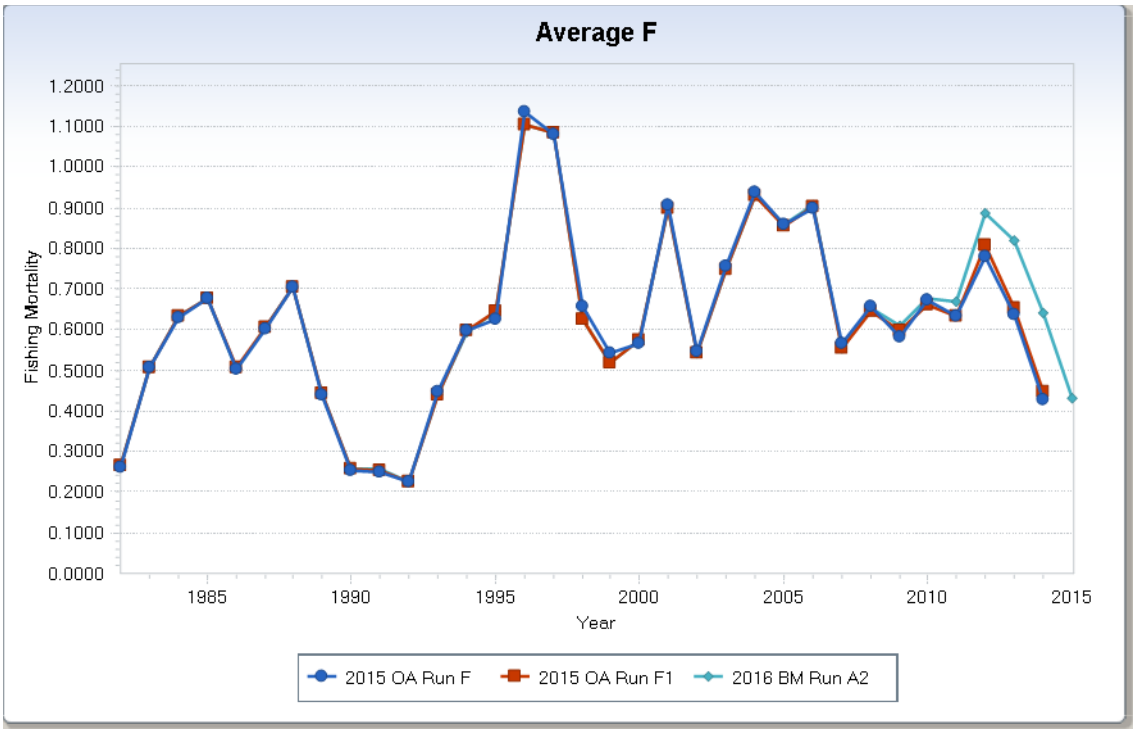


Figure B128 .Trends of witch flounder fishing mortality (top, blue line), and spawning stock biomass (bottom, blue line, mt), with a retrospectively adjusted 2015 values (green line); 1982 – 2015 year classes from RUN A2,1982 -2015.



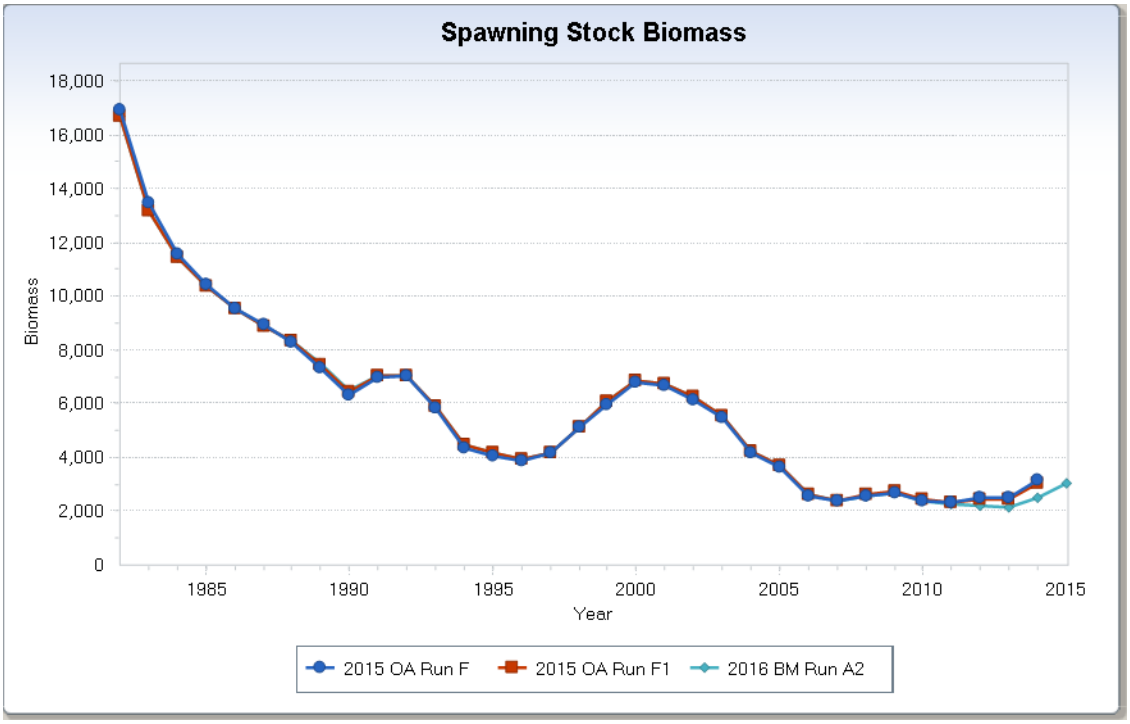


Figure B129. Comparison of trends in average fishing mortality (top), spawning stock biomass (middle),from the 2015 Operational Assessment (OA) RUN F (blue line with circles), 2015 OA with revised catch at age (RUN F1; red line with squares), and the 2016 benchmark (BM) RUN A2 (catch at age through 2015; cyan, small circles).

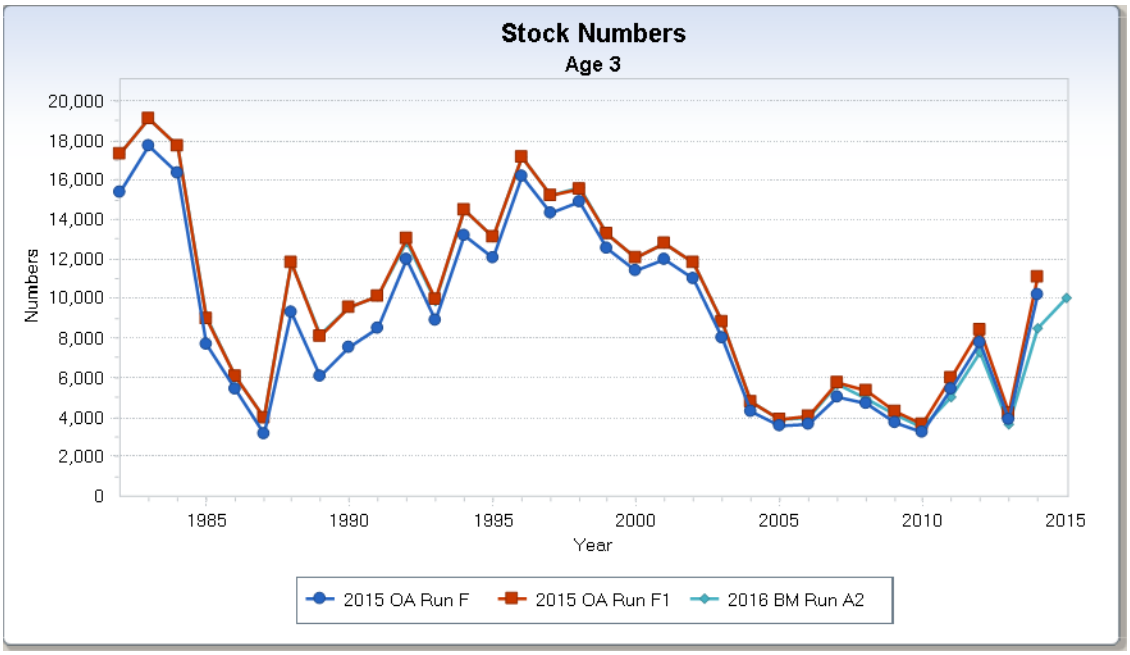
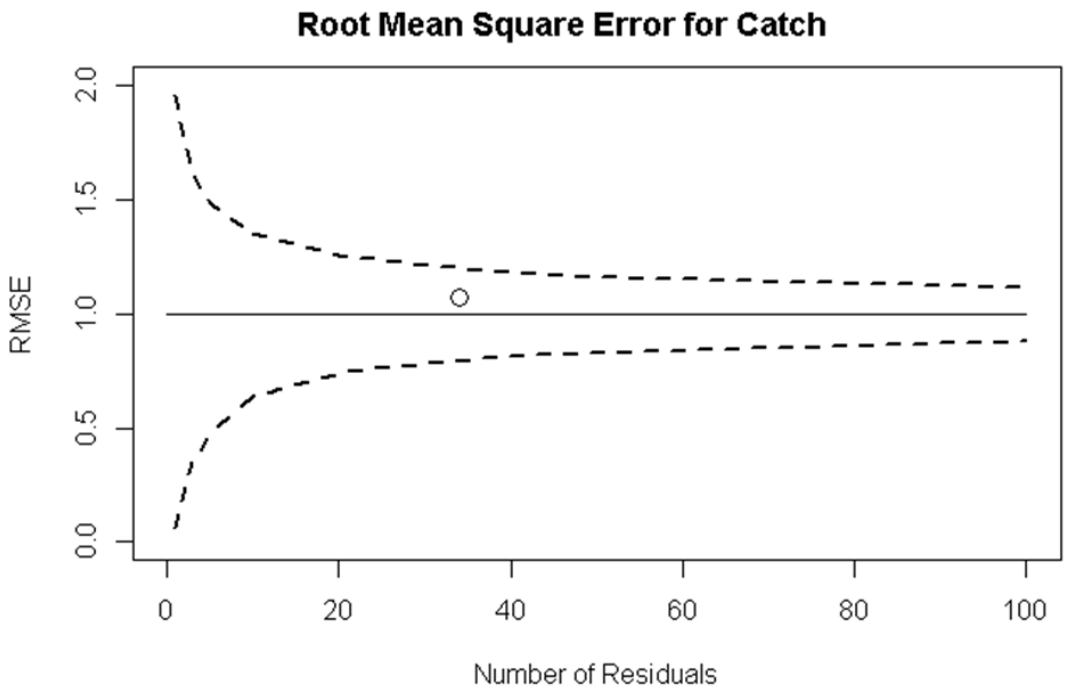


Figure B129 continued. Comparison of Age 3 recruits from the 2015 Operational Assessment (OA) RUN F (blue line with circles), 2015 OA with revised catch at age (RUN F1; red line with squares), and the 2016 benchmark (BM) RUN A2 (catch at age through 2015; cyan, small circles).



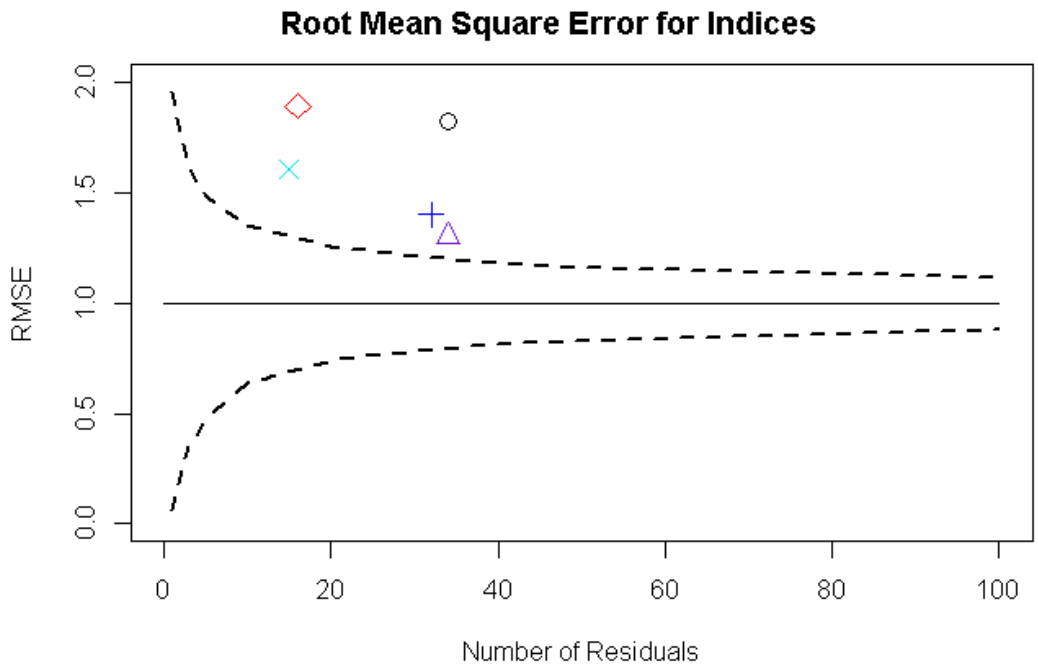


Figure B130. ASAP Run 9_5_v2 model fit root mean square error (RMSE) values for total catch (left) and survey indices (right) as a function of the number of residuals. The median and 80% confidence interval of the root mean square error from a normal distribution with mean zero and standard deviation one for a range of sample sizes is overlaid for reference.

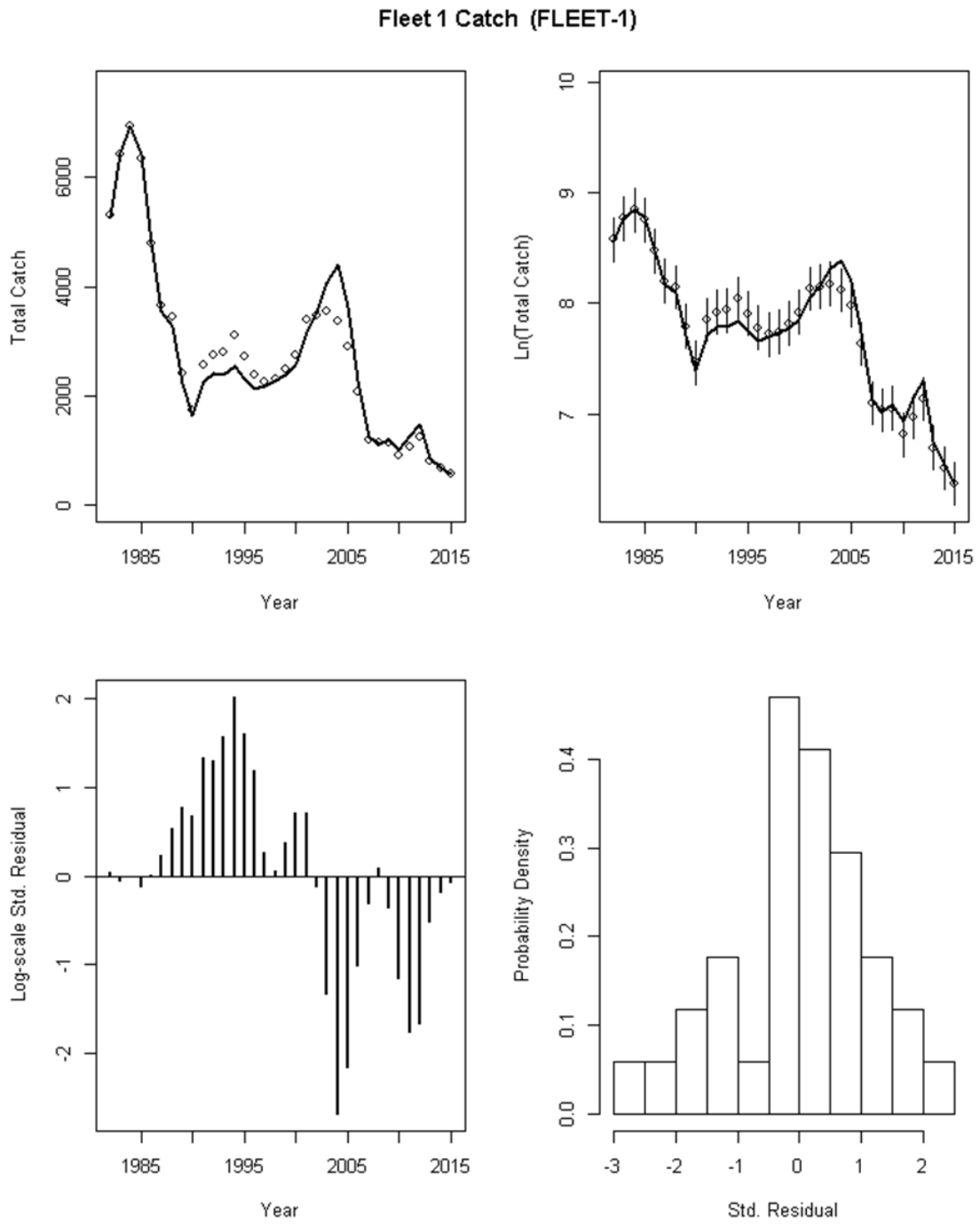


Figure B131. ASAP Run 9_5_v2 model fit to the total witch flounder catch (Fleet 1).

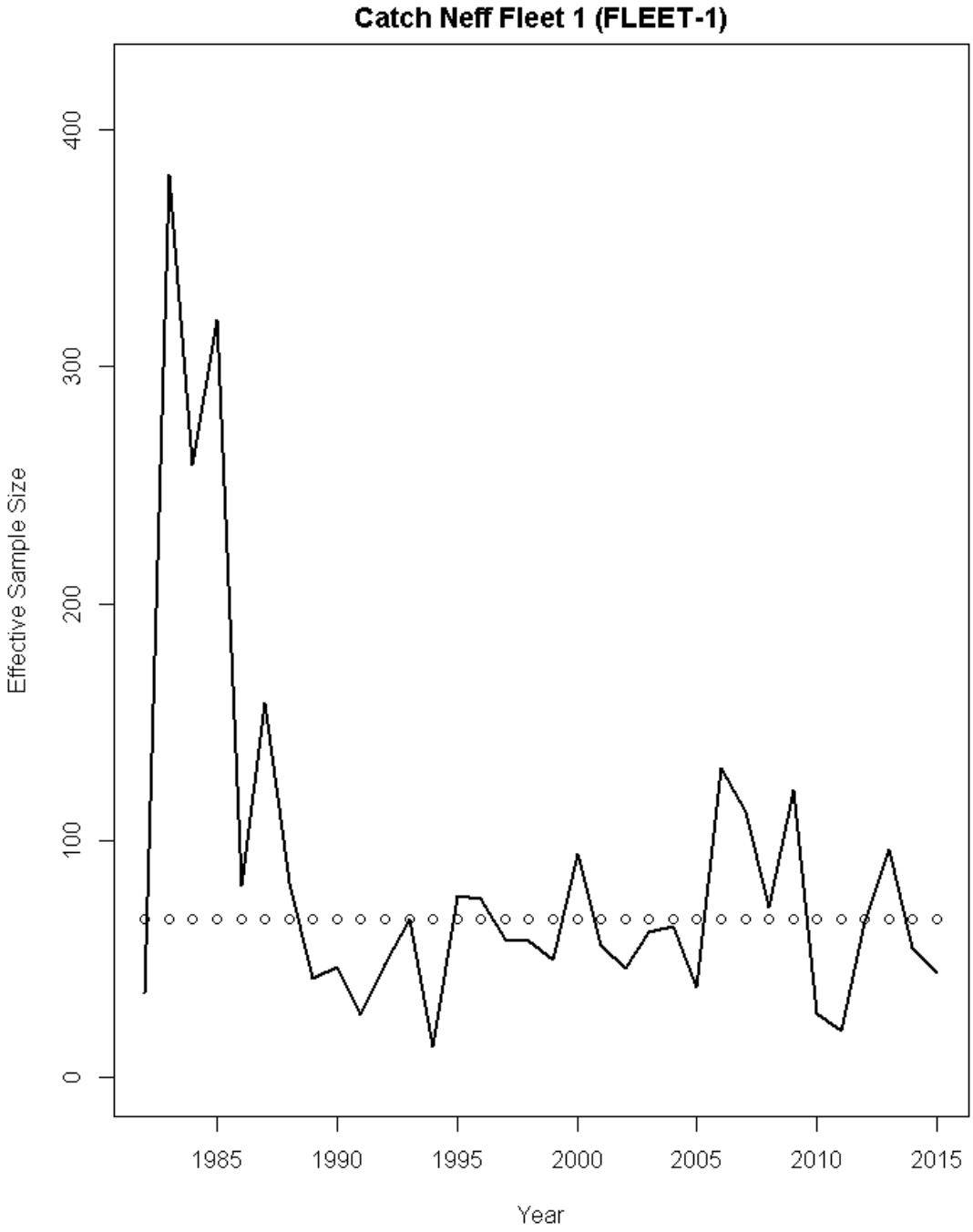


Figure B.132. ASAP Run 9_5_v2 model comparison of input effective sample size vs model estimated effective sample size for witch flounder catch (Fleet 1).

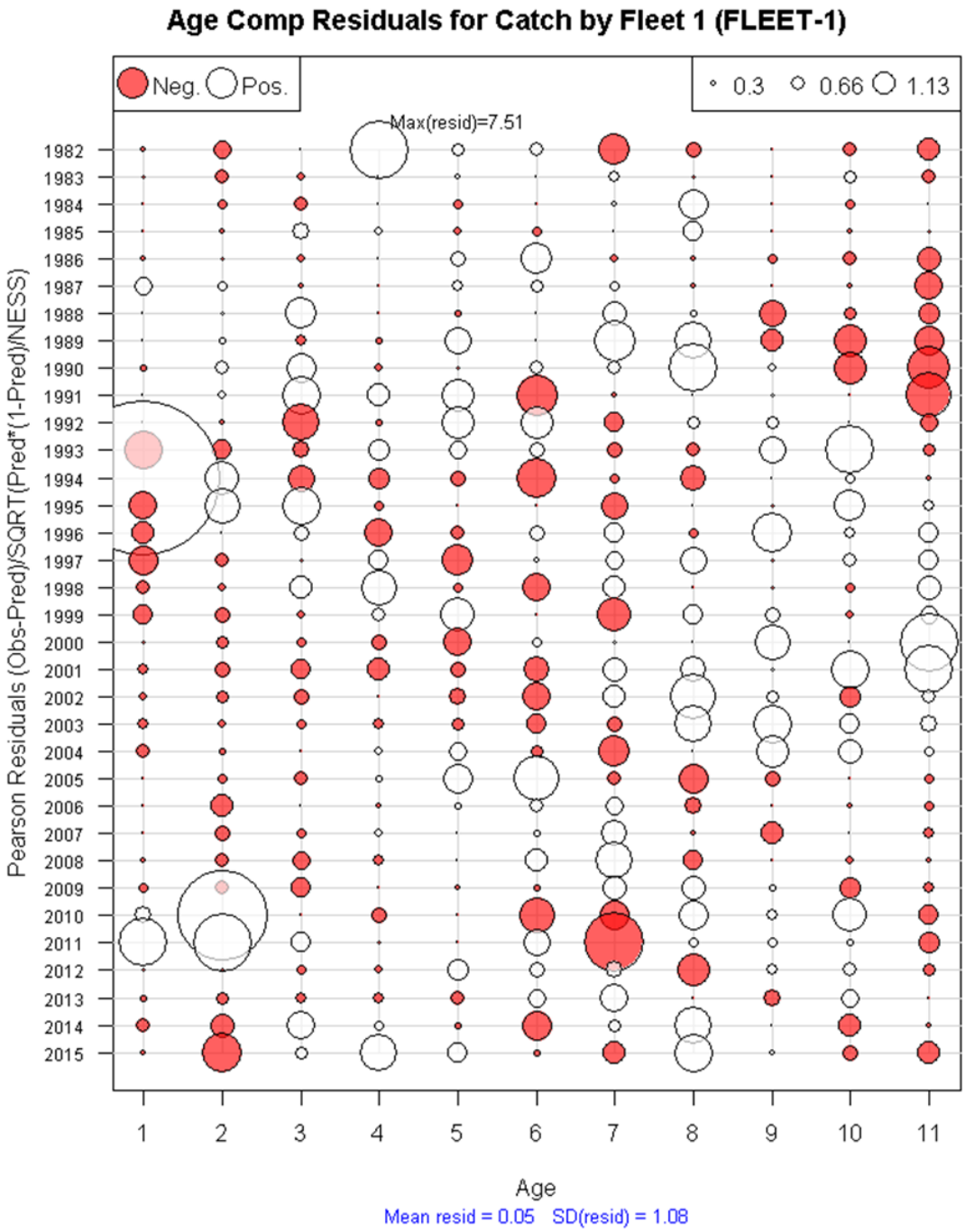


Figure B133. ASAP Run 9_5_v2 model fit residuals for the witch flounder catch (Fleet 1) at age.

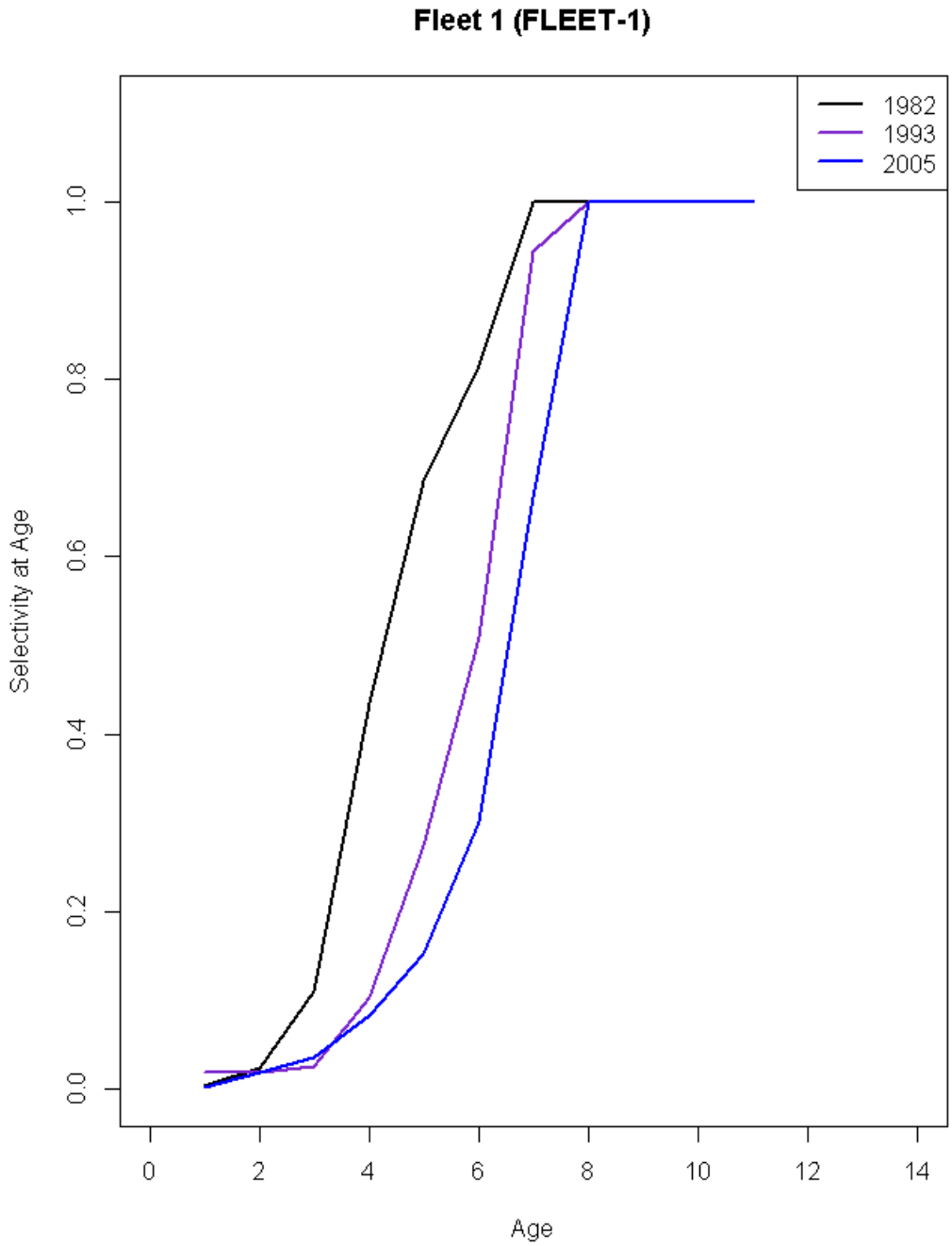


Figure B134. Witch flounder catch (Fleet 1) selectivity at age for block 1 (1982-1992), block 2 (1993-2004) and block 3 (2005-2015) as estimated by the ASAP Run 9_5_v2.

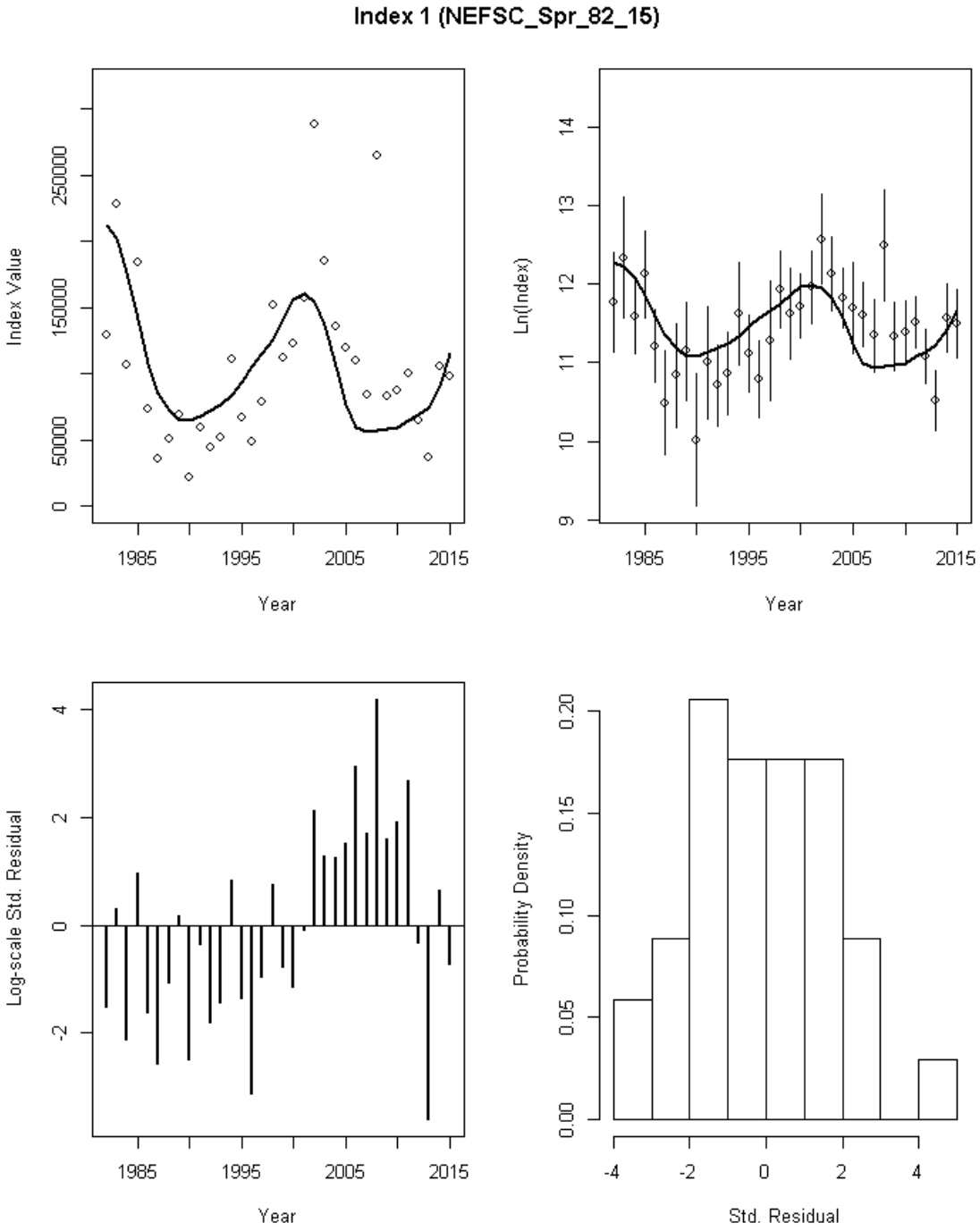


Figure B135. ASAP Run 9_5_v2 mode fit to the Northeast Fisheries Science Center spring survey witch flounder index (Index 1).

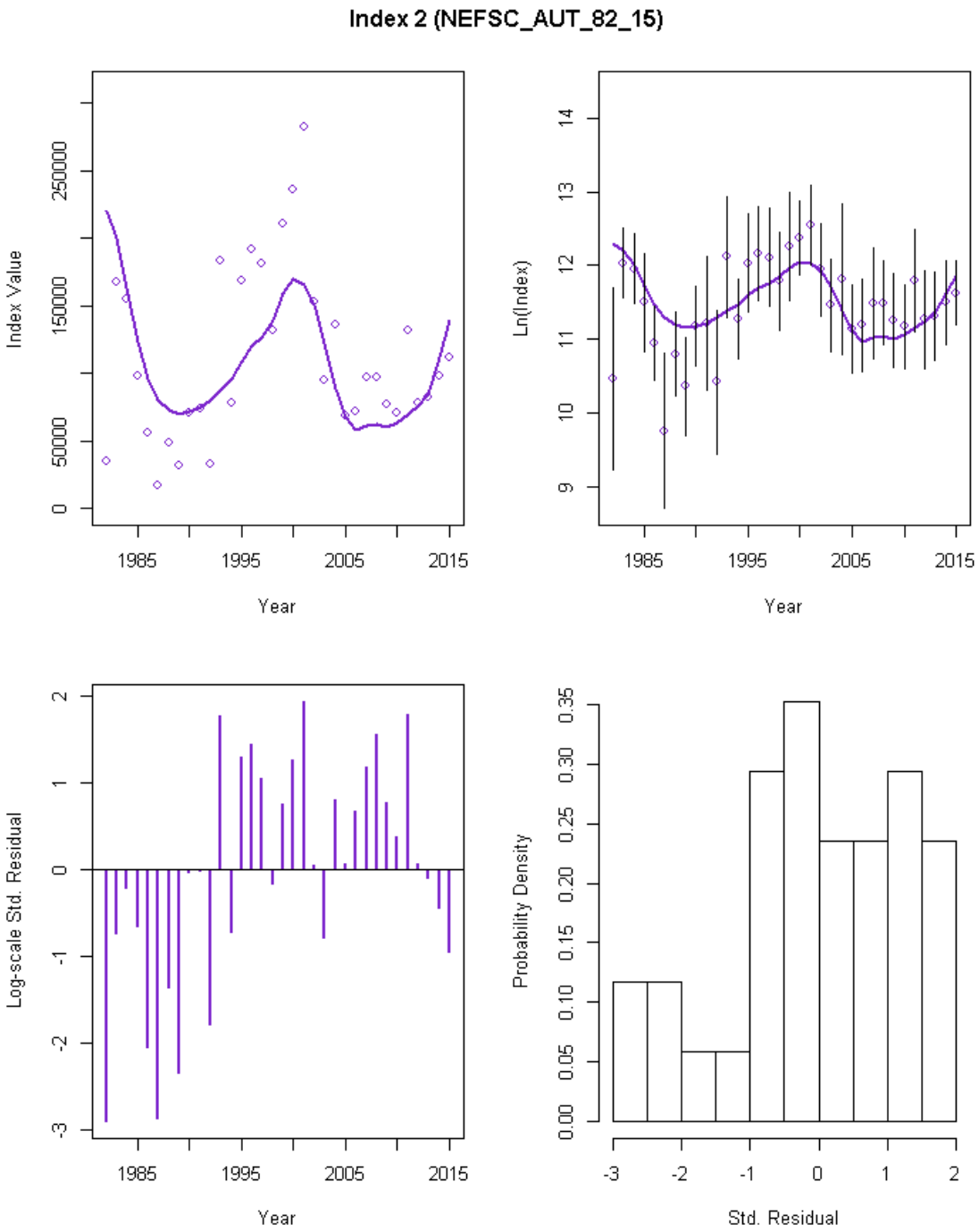


Figure B136. ASAP Run 9_5_v2 mode fit to the Northeast Fisheries Science Center autumn survey witch flounder index (Index 2).

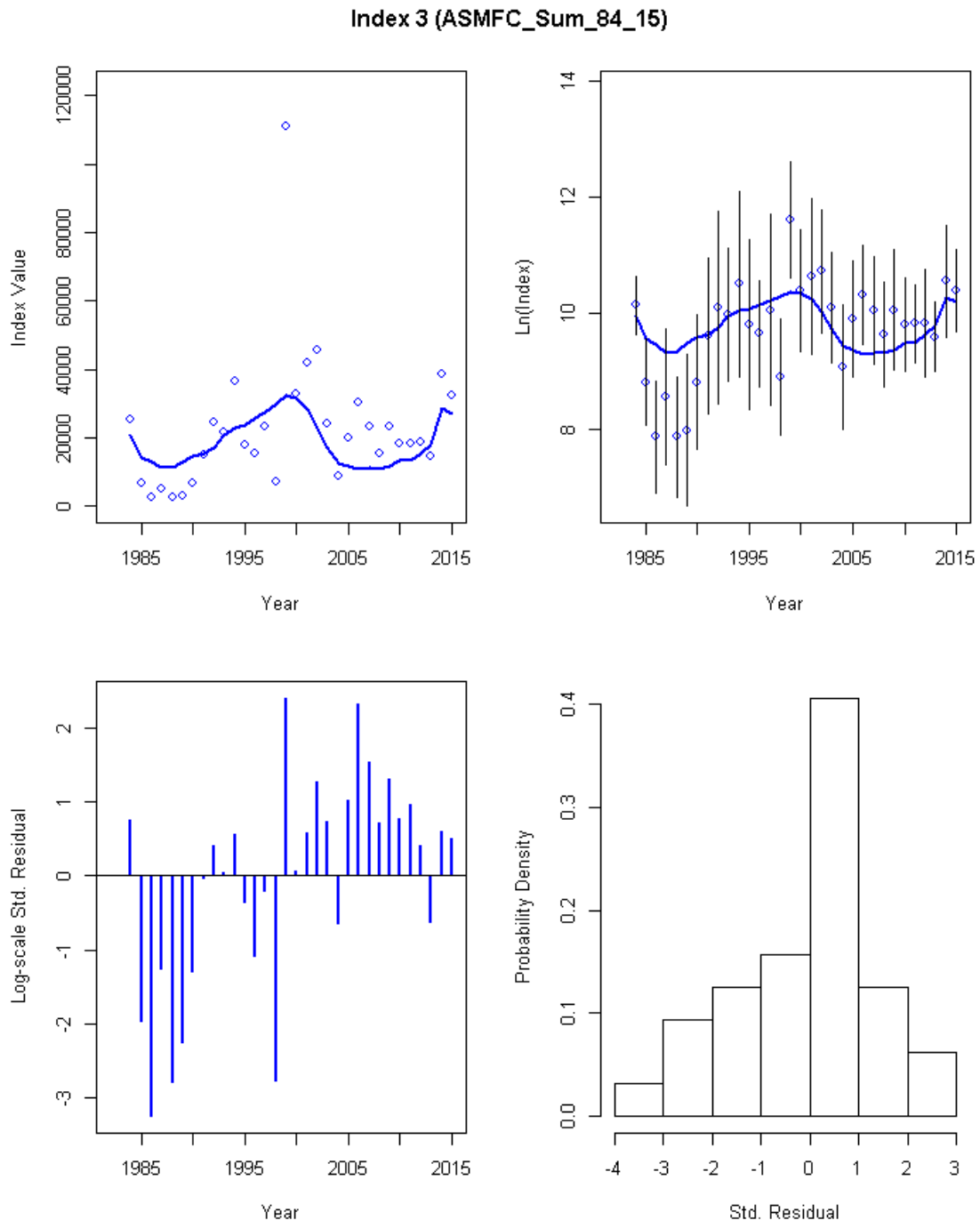


Figure B137. ASAP Run 9_5_v2 mode fit to the Atlantic States Marine Fisheries Commission summer survey witch flounder index (Index 3).

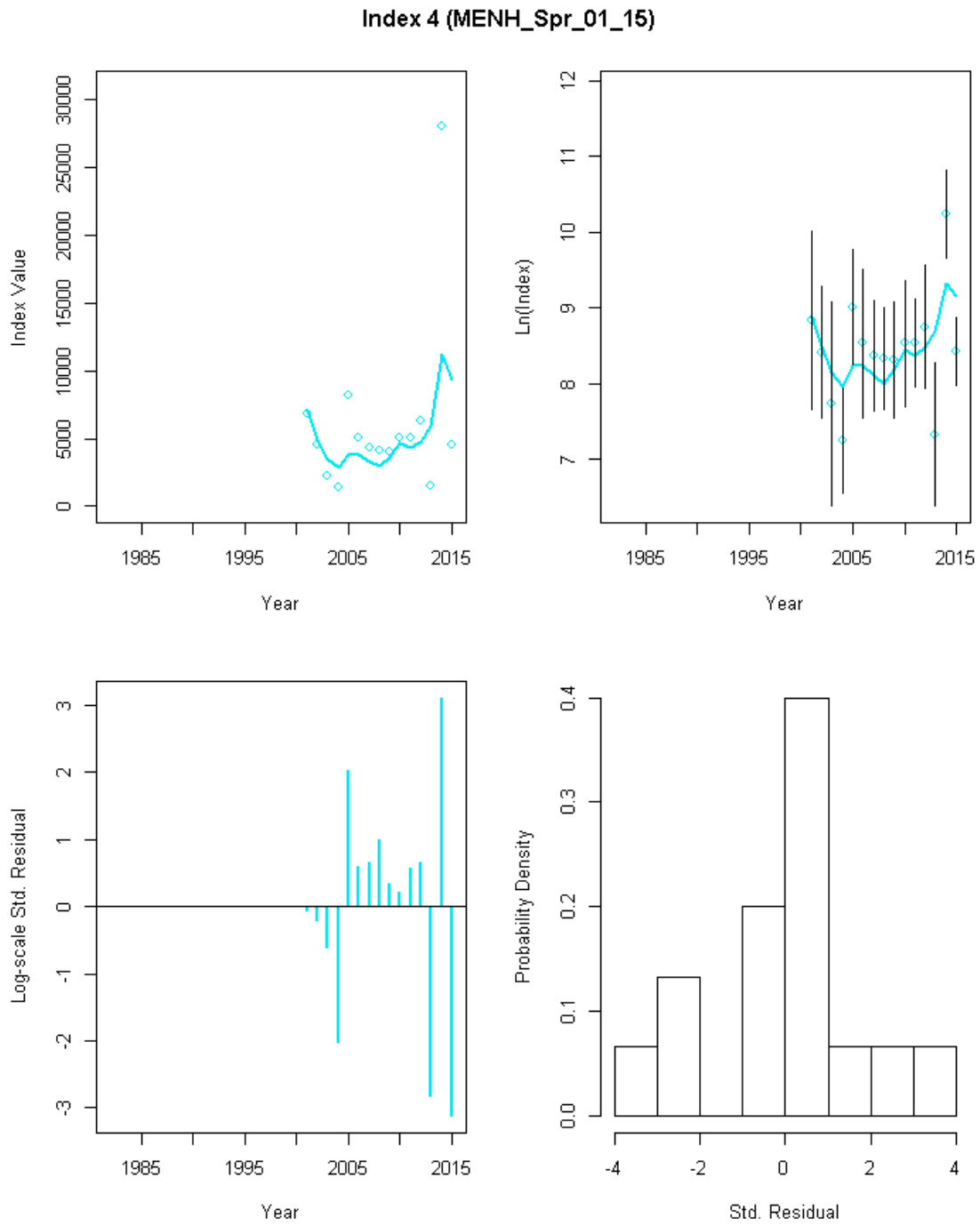


Figure B138. ASAP Run 9_5_v2 mode fit to the Maine-New Hampshire spring survey witch flounder index (Index 4).

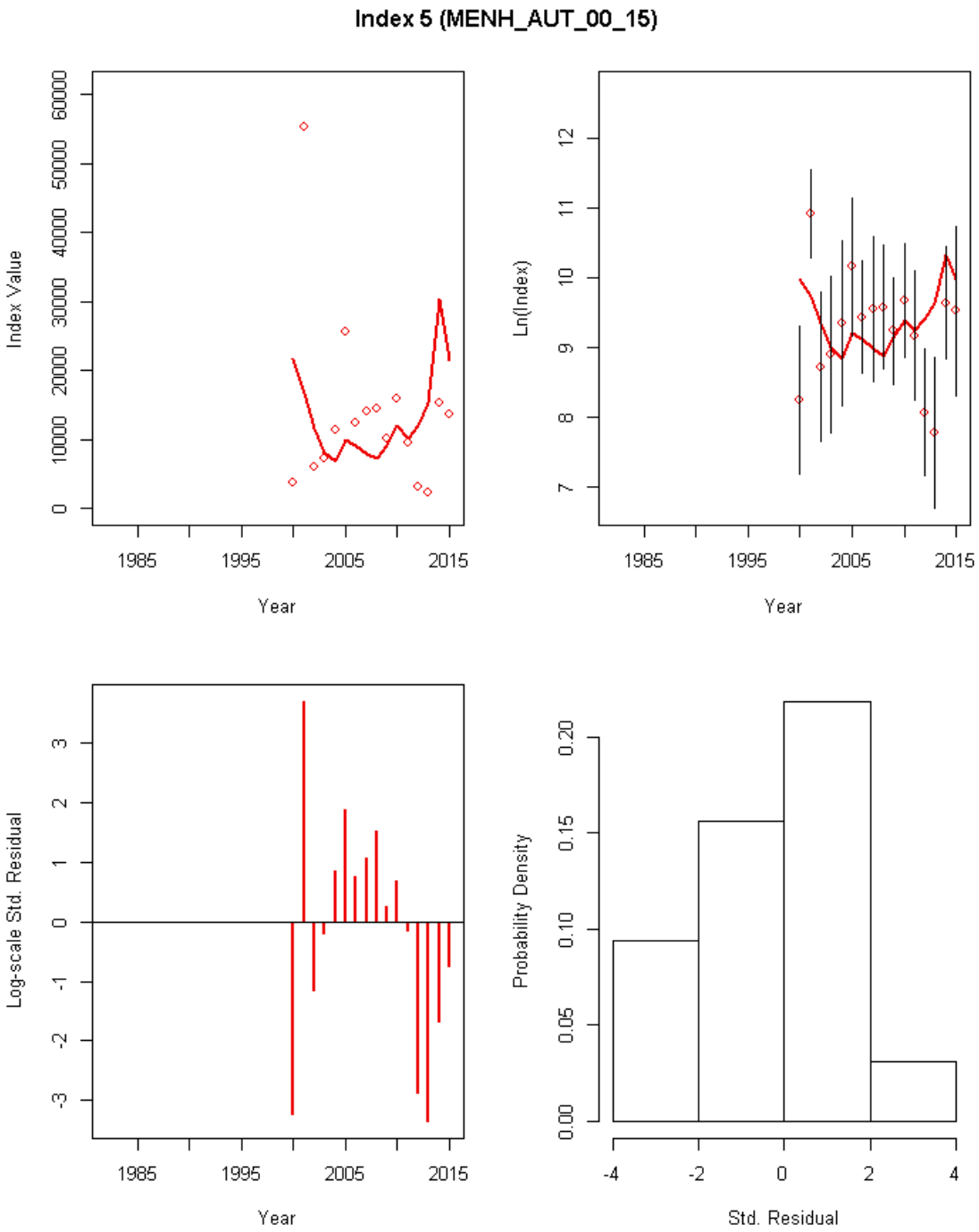


Figure B139. ASAP Run 9_5_v2 model fit to the Maine-New Hampshire autumn survey witch flounder index (Index 5).

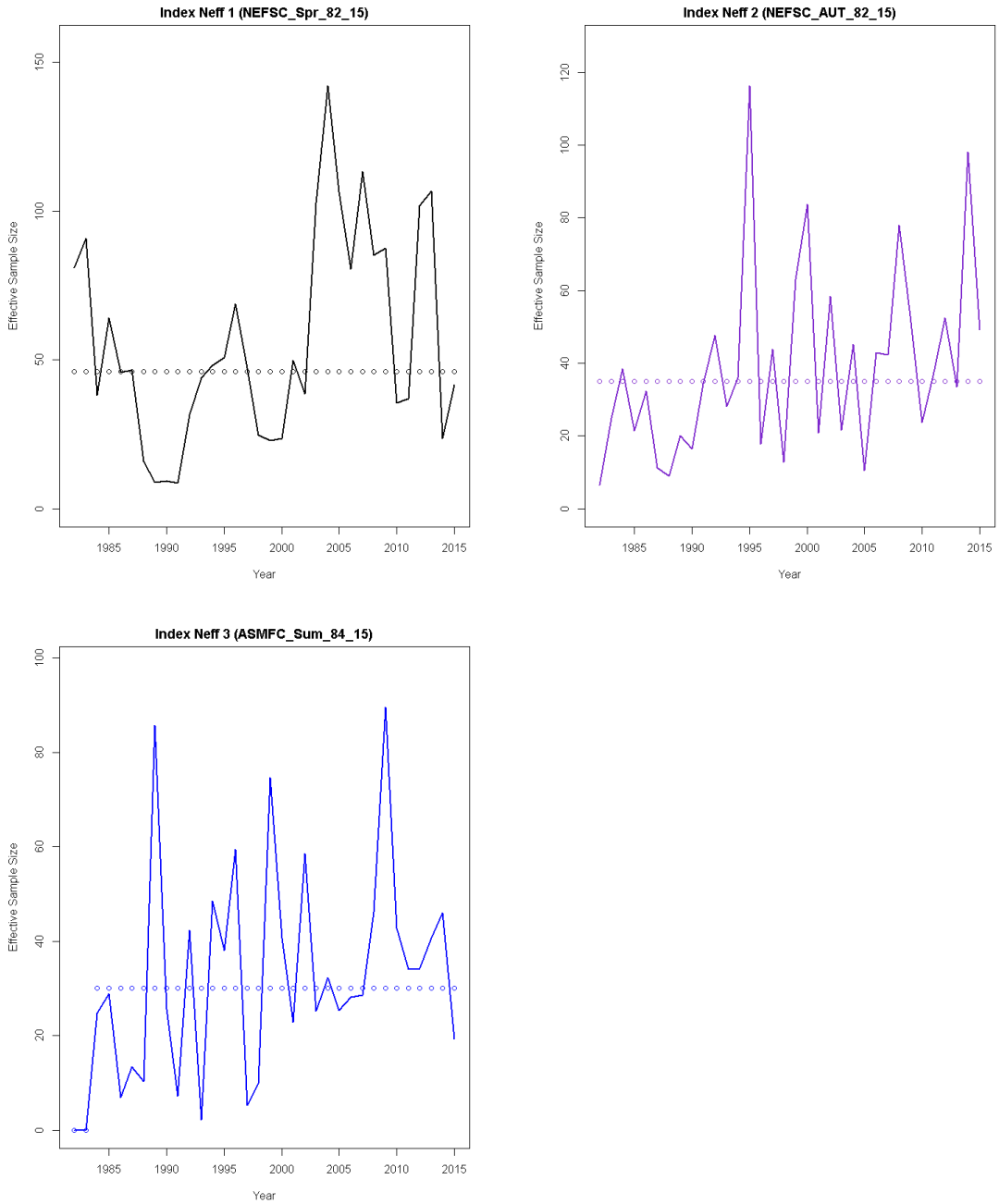


Figure B140. ASAP Run 9_5_v2 model comparison of input effective sample size vs model estimated effective sample size for Northeast Fisheries Science Center spring survey (Index 1) and autumn survey (Index 2), and Atlantic States Marine Fisheries Commission summer survey (Index 3).

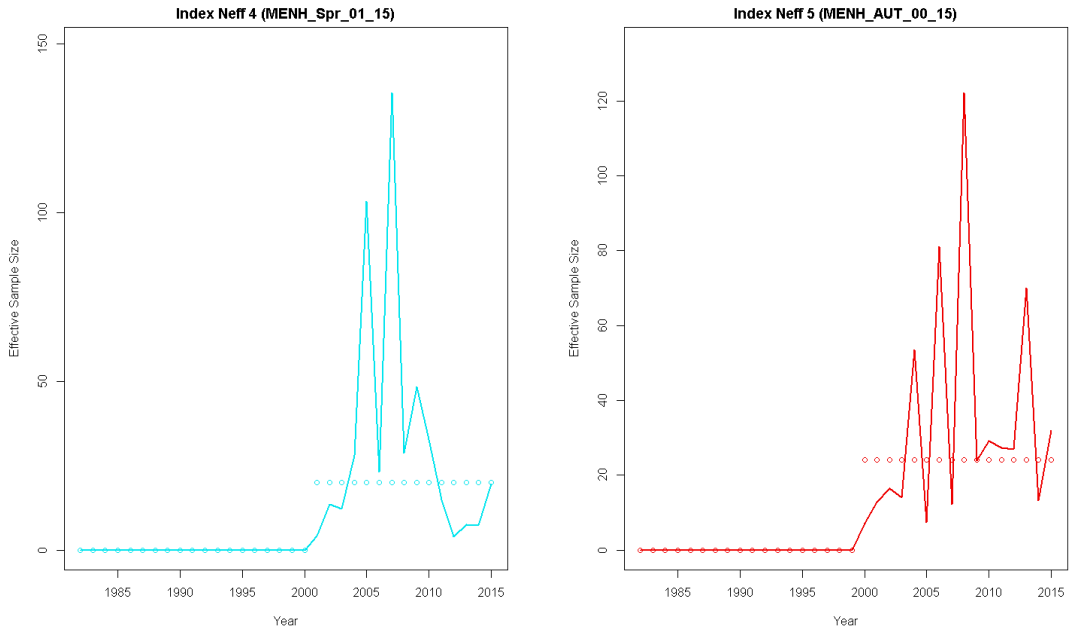


Figure B140, continued. ASAP Run 9_5_v2 model comparison of input effective sample size vs model estimated effective sample size for Maine-New Hampshire spring survey (Index 4) and autumn survey (Index 5).

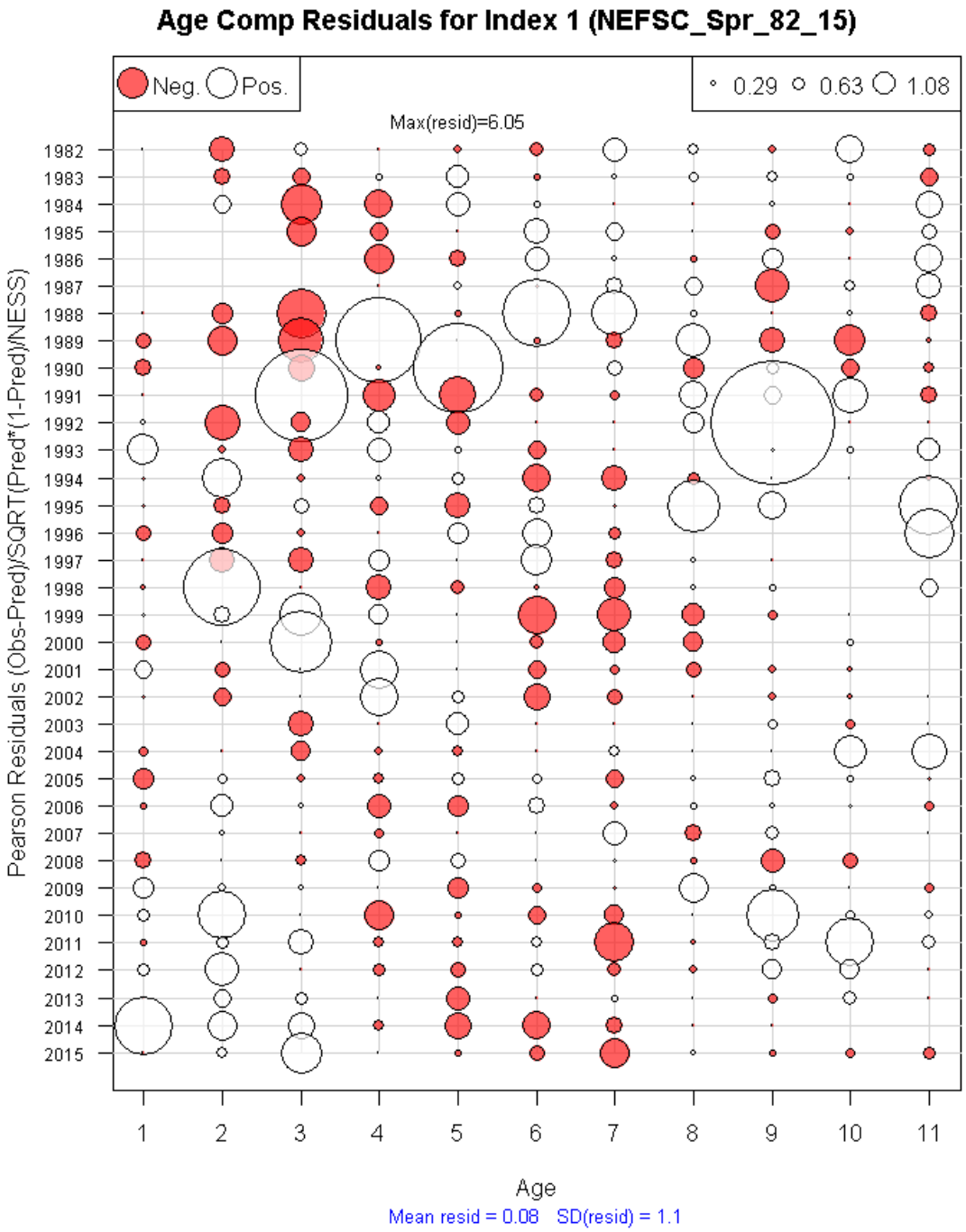


Figure B141. ASAP Run 9_5_v2 model fit residuals for the Northeast Fisheries Science Center spring survey witch flounder indices at age (Index 1).

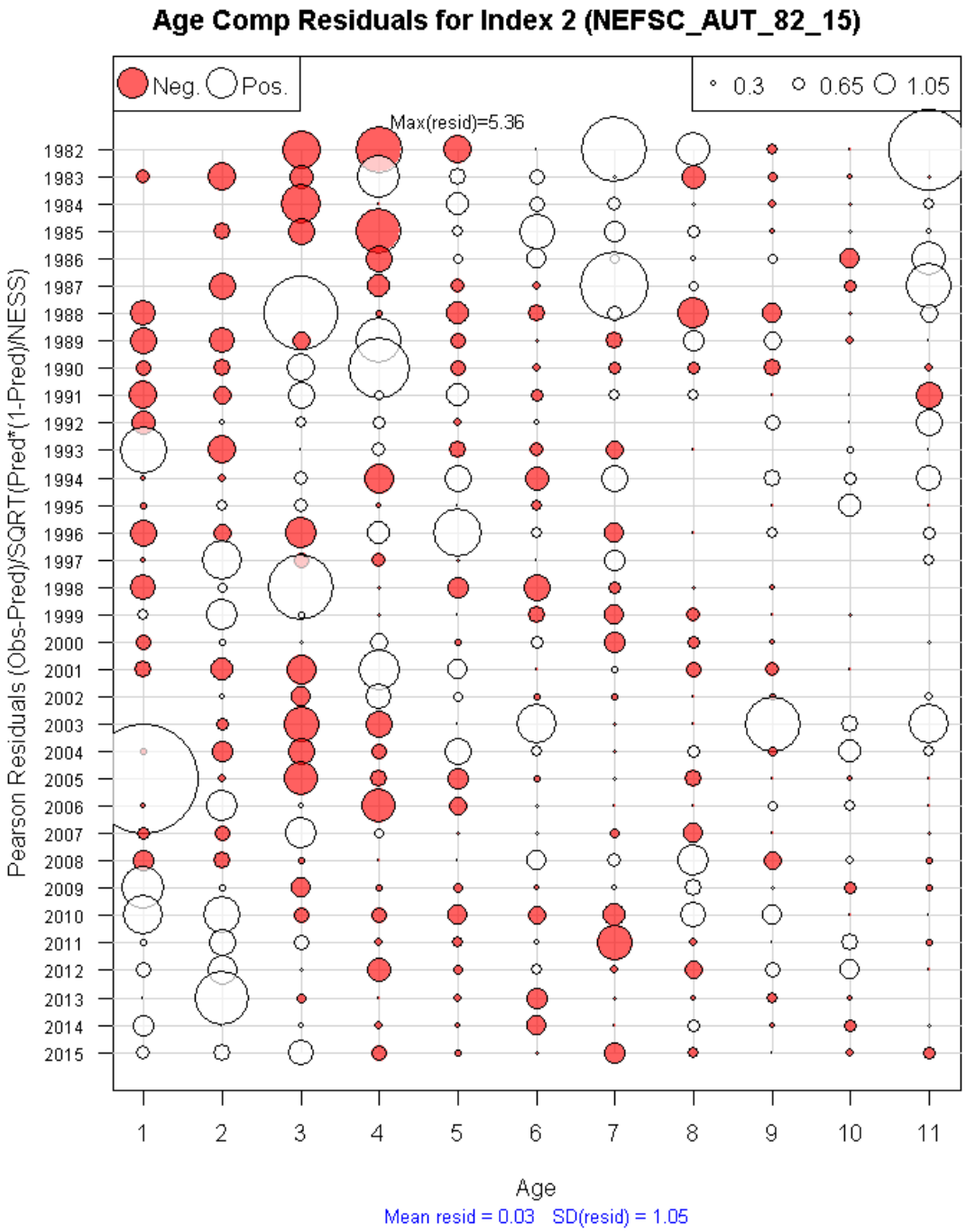


Figure B142. ASAP Run 9_5_v2 model fit residuals for the Northeast Fisheries Science Center autumn survey witch flounder indices at age (Index 2).

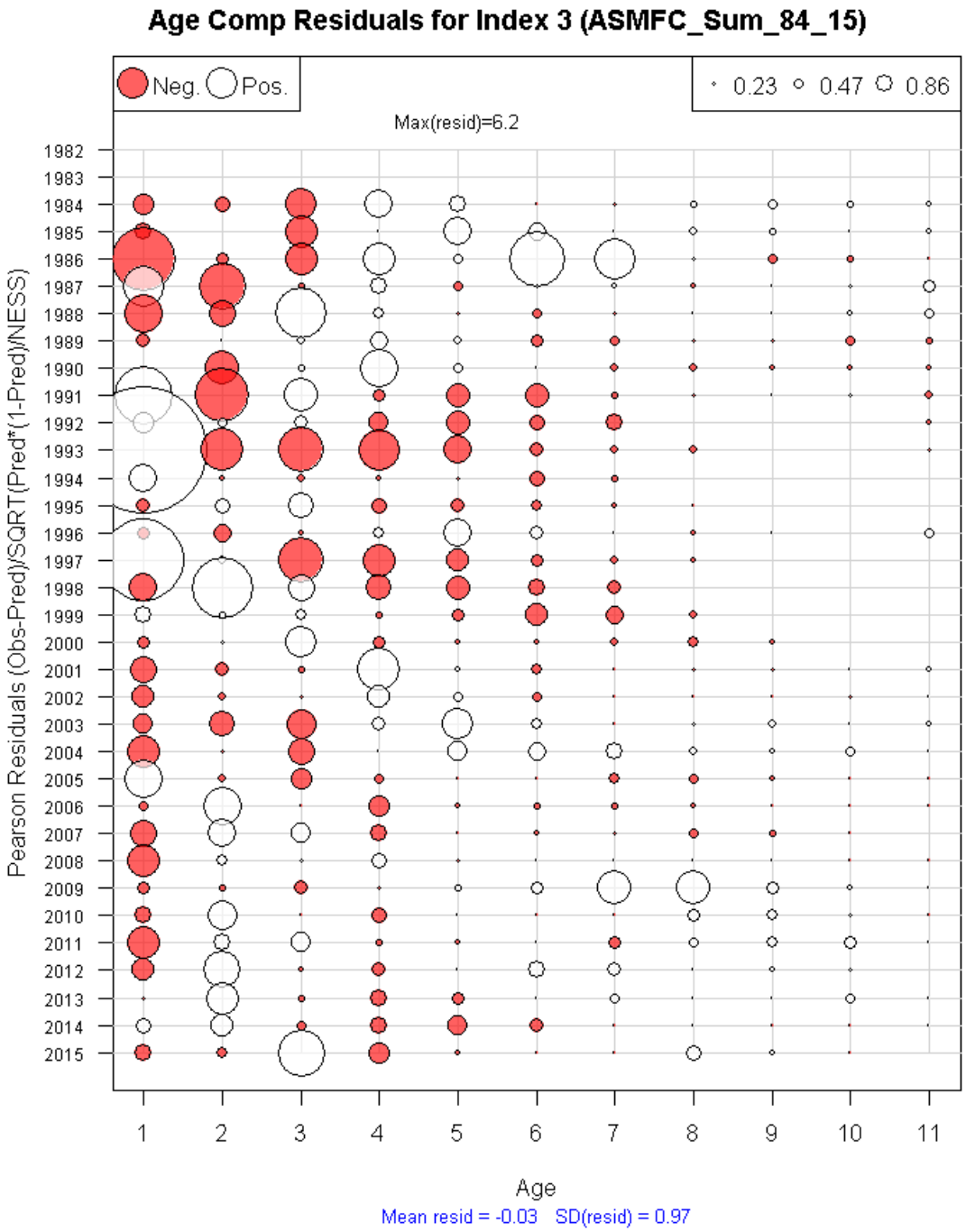


Figure B143. ASAP Run 9_5_v2 model fit residuals for the Atlantic States Marine Fisheries Commission summer survey witch flounder indices at age (Index 3).

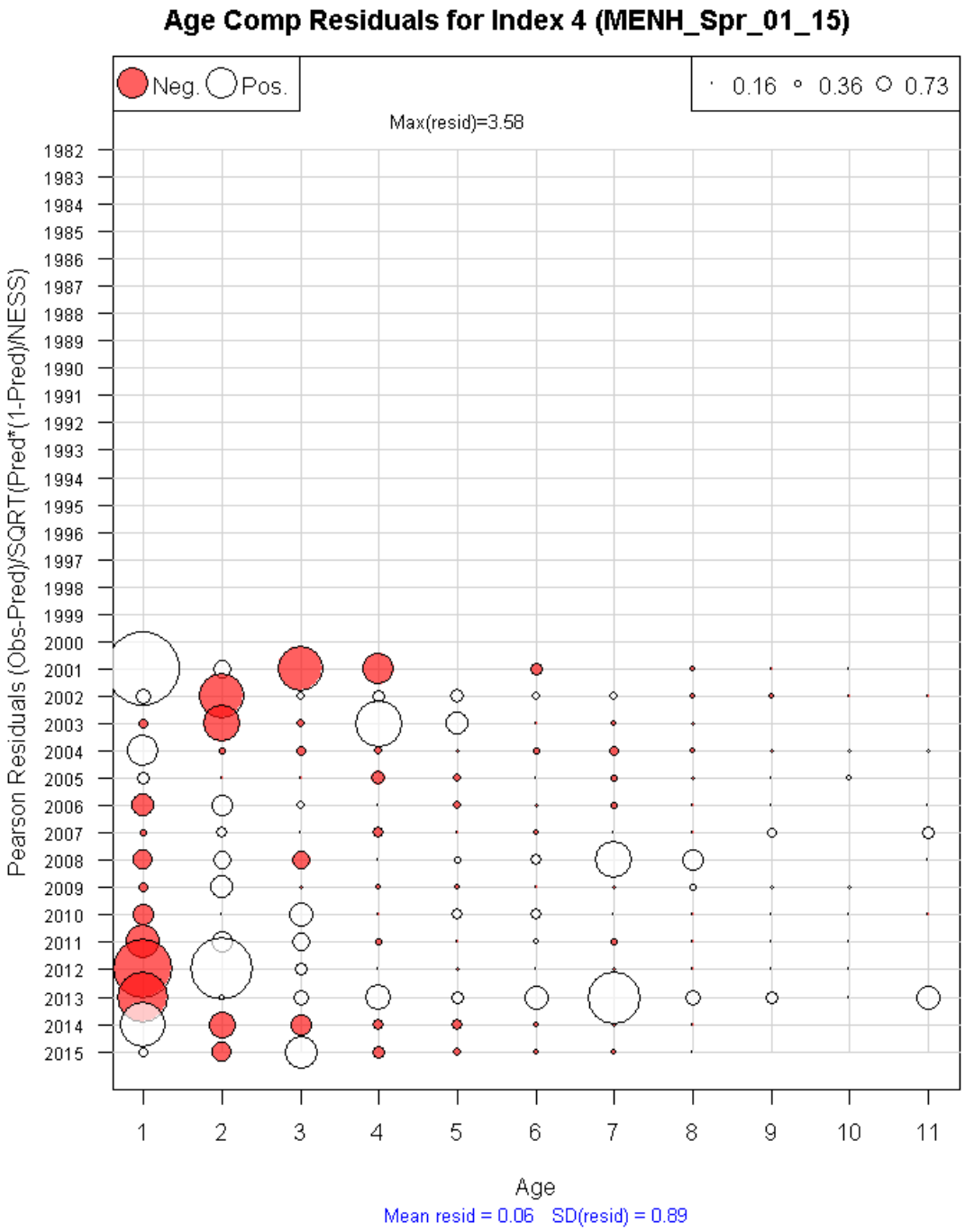


Figure B144. ASAP Run 9_5_v2 model fit residuals for the Maine-New Hampshire spring survey witch flounder indices at age (Index 4).

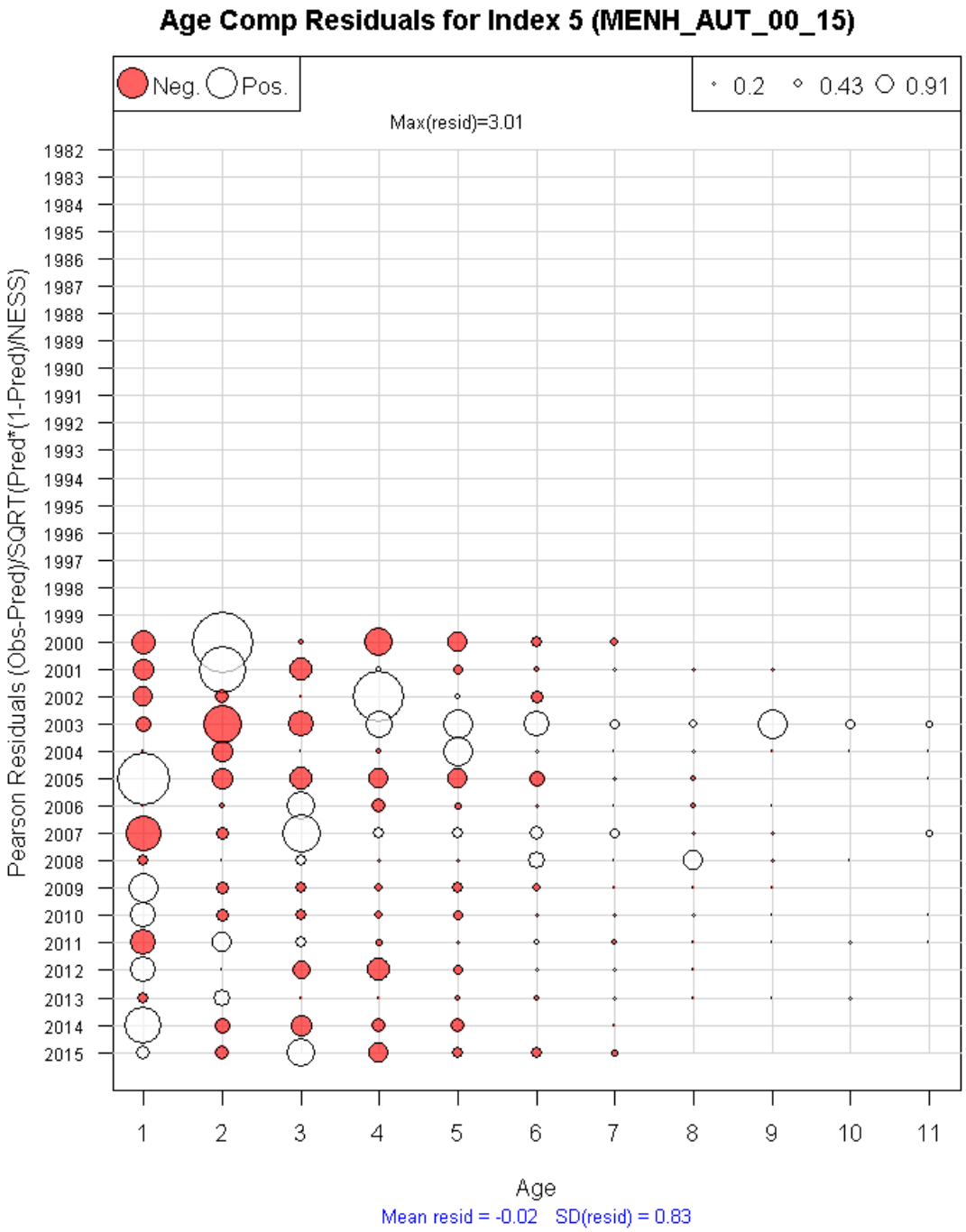


Figure B145. ASAP Run 9_5_v2 model fit residuals for the Maine-New Hampshire autumn survey witch flounder indices at age (Index 5).

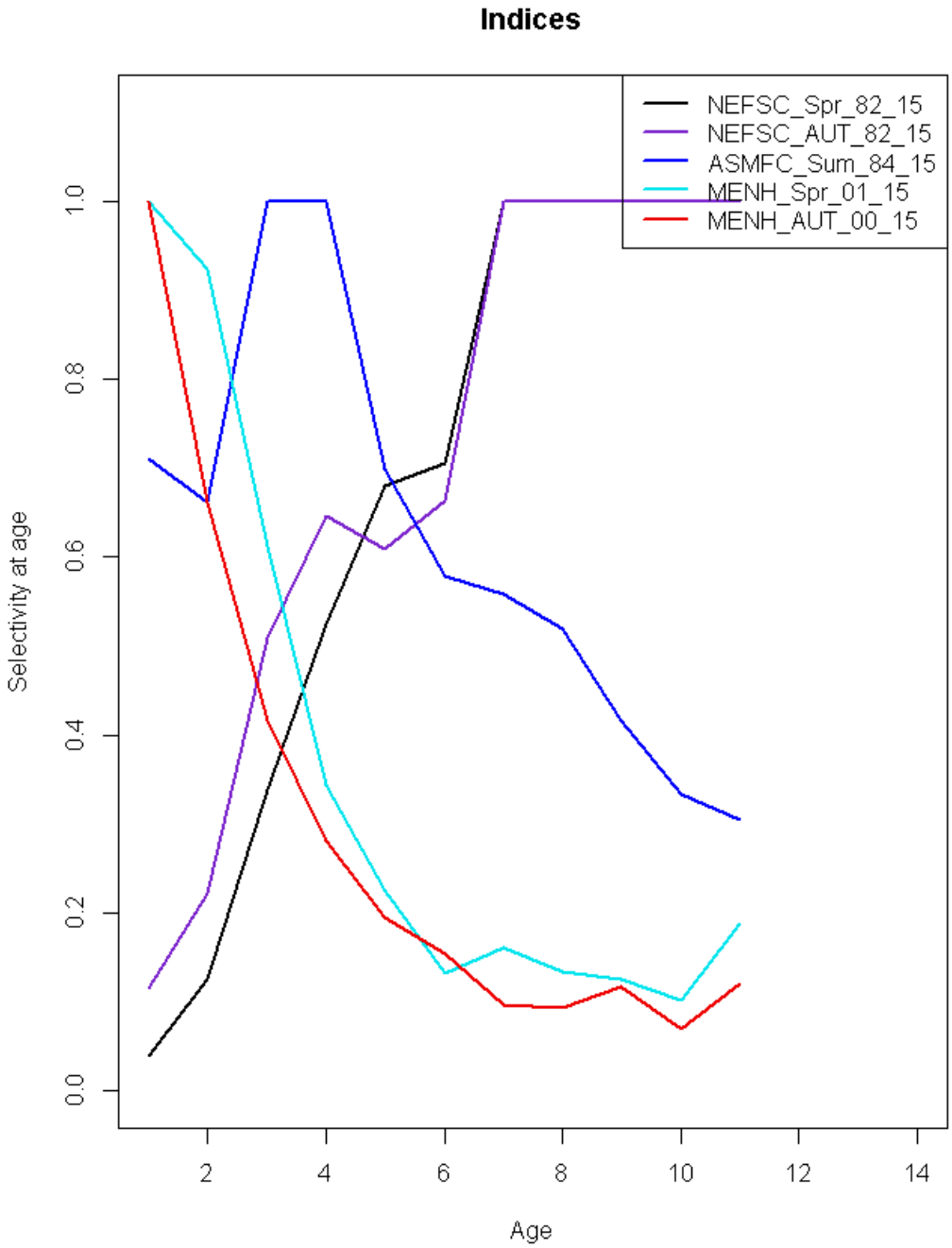


Figure B146. Witch flounder selectivity at age for the Northeast Fisheries Science Center spring (Index 1), autumn (Index 2), Atlantic States Marine Fisheries Commission (Index 3), Maine-New Hampshire spring (Index 4) and autumn (Index 5) surveys from ASAP Run 9_5_2v.

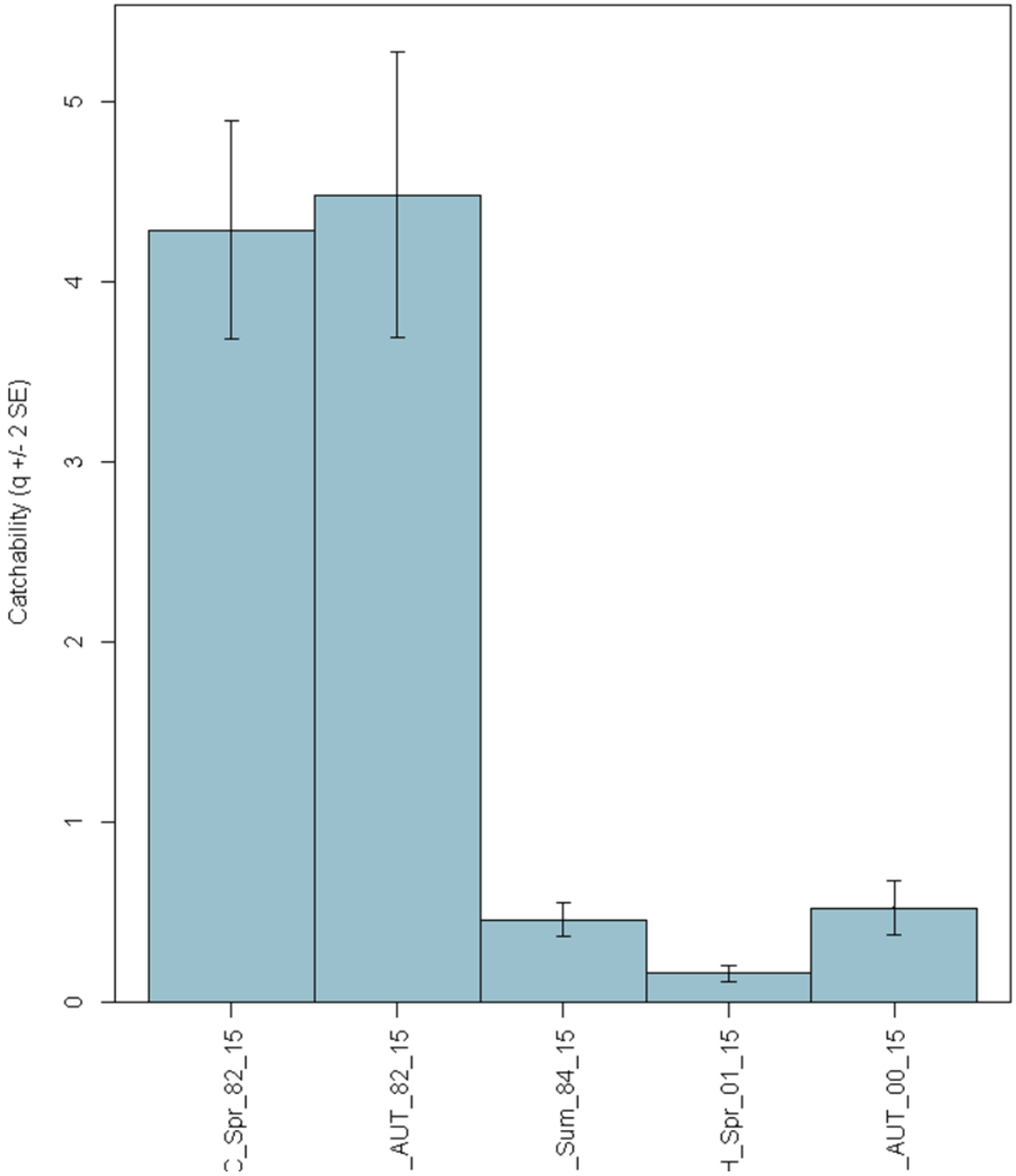


Figure B147. Witch flounder survey catchability, q, for the Northeast Fisheries Science Center spring (Index 1), autumn (Index 2), Atlantic States Marine Fisheries Commission (Index 3), Maine-New Hampshire spring (Index 4) and autumn (Index 5) surveys from ASAP Run 9_5_v2.

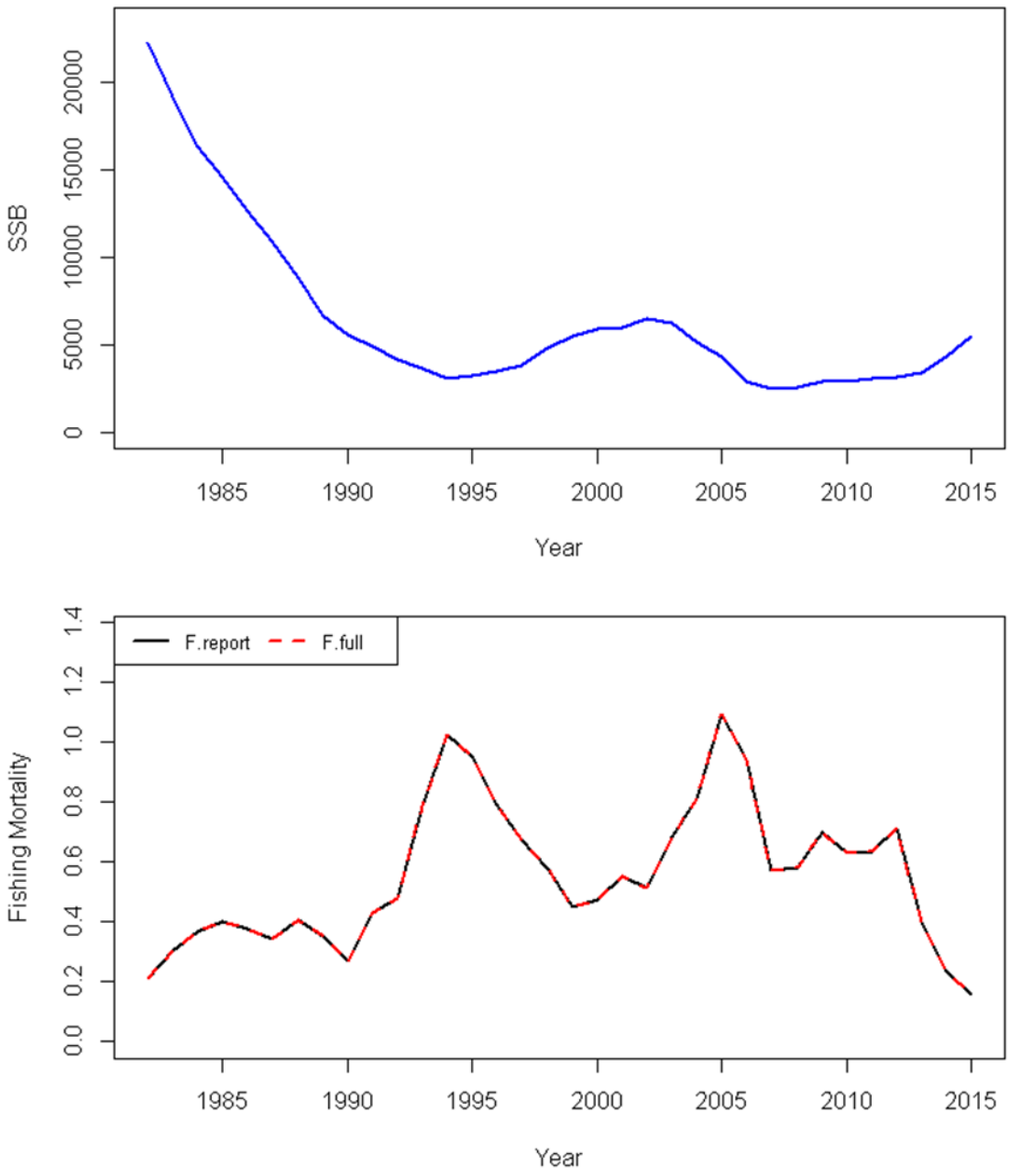


Figure B148. Trends in spawning stock biomass (top) and fishing mortality (bottom) estimates from ASAP Run 9_5_v2, 1982-2015.

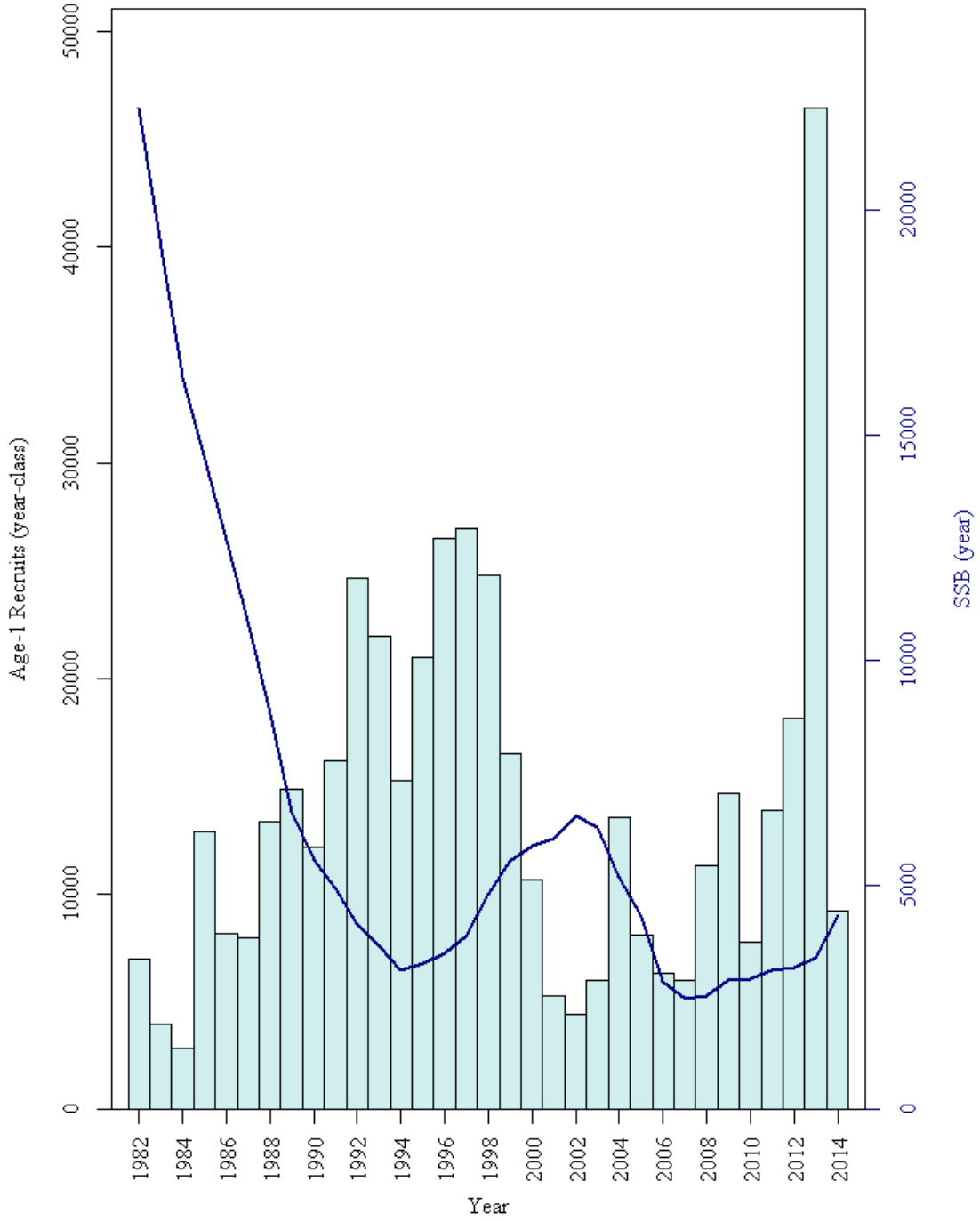


Figure B149. Trends in Age 1 recruitment year class (bars) and spawning stock biomass (mt; line) estimates from ASAP Run 9_5_v2.

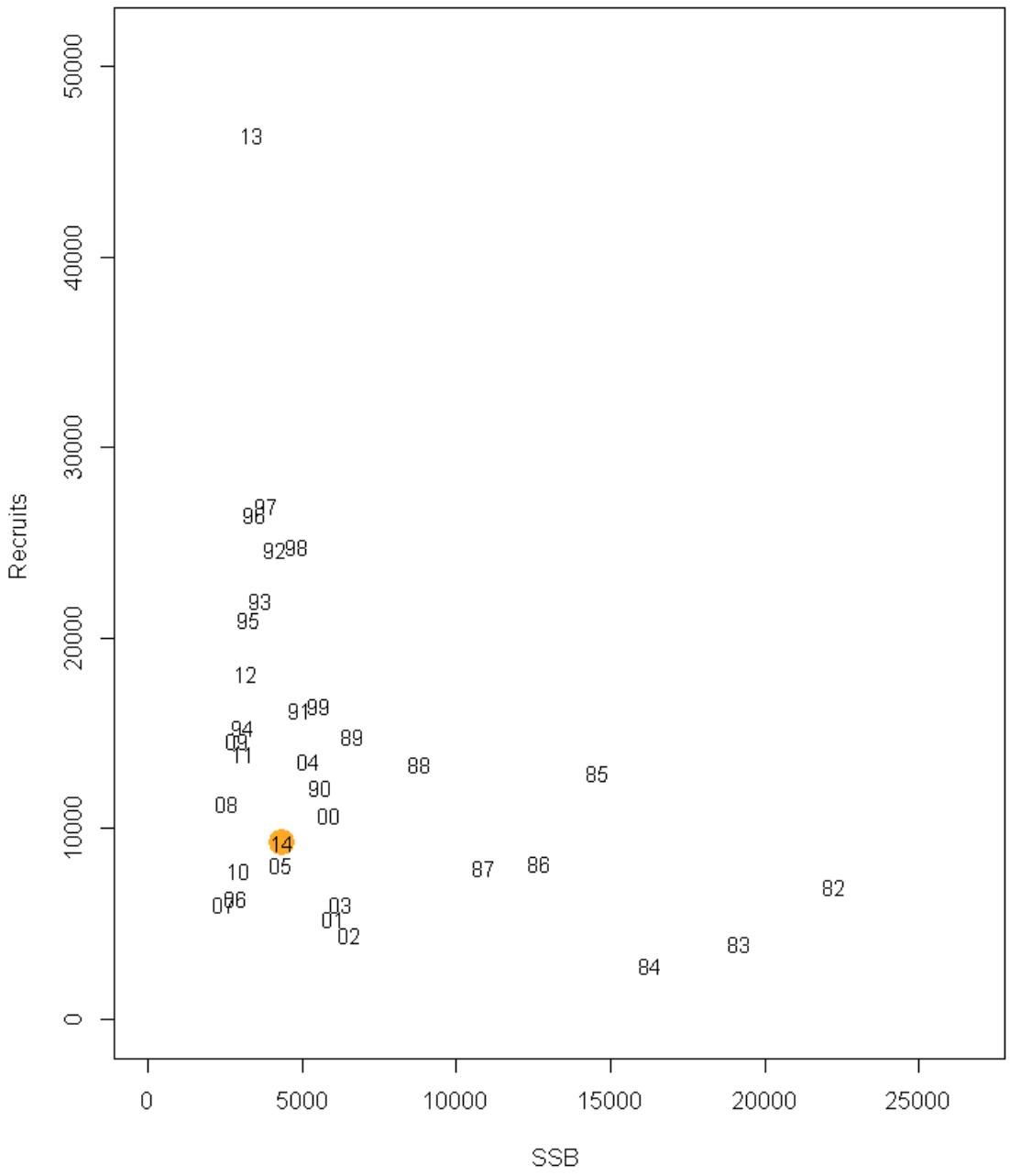


Figure B150. Witch flounder age 1 recruitment (000s) and spawning stock biomass (mt) estimated from ASAP Run 9_5_v2; year classes 1982-2014.

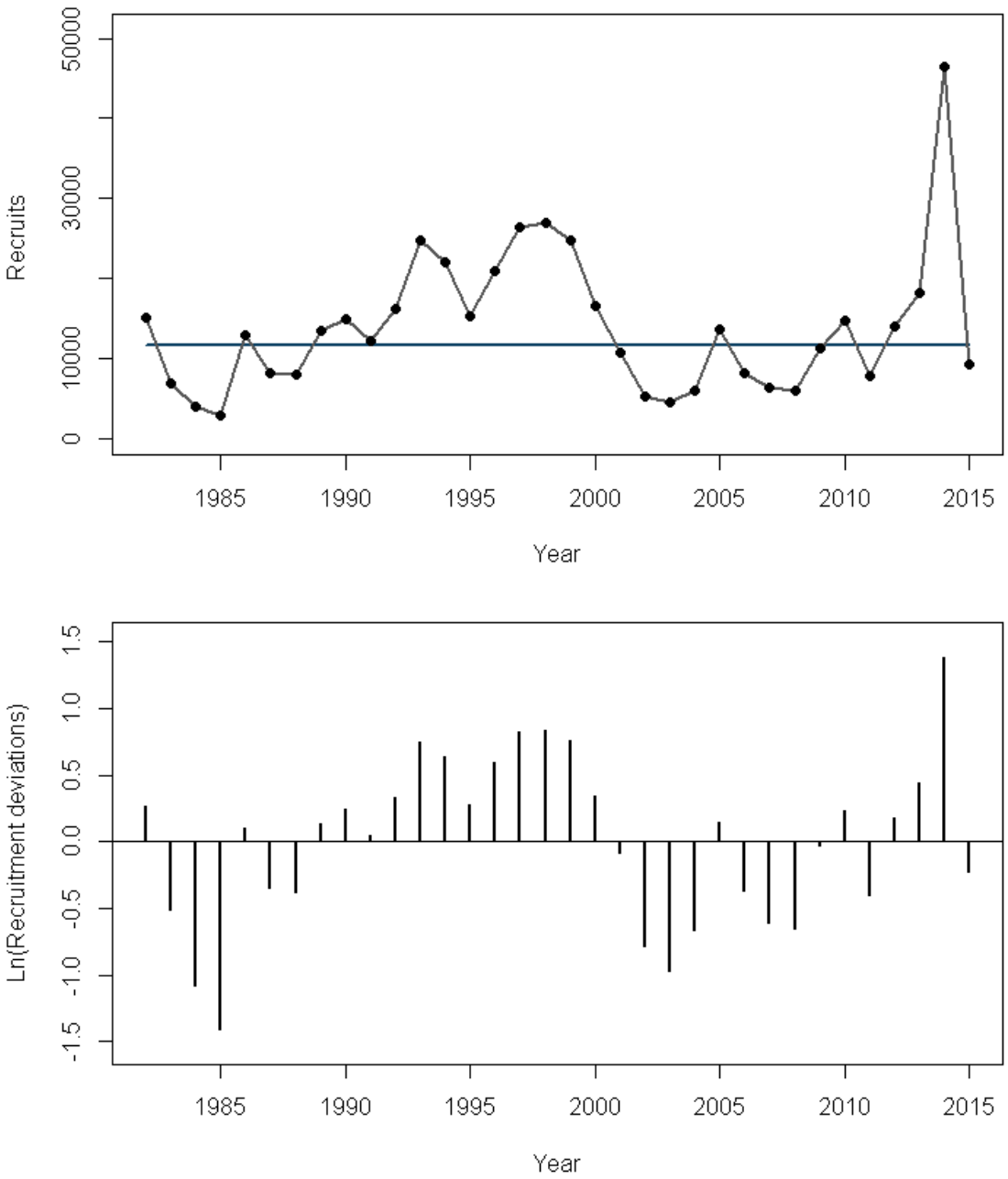


Figure B151. Estimated witch flounder age 1 recruitment (000s) and recruitment residuals from the geometric mean from ASAP Run 9_5_v2.

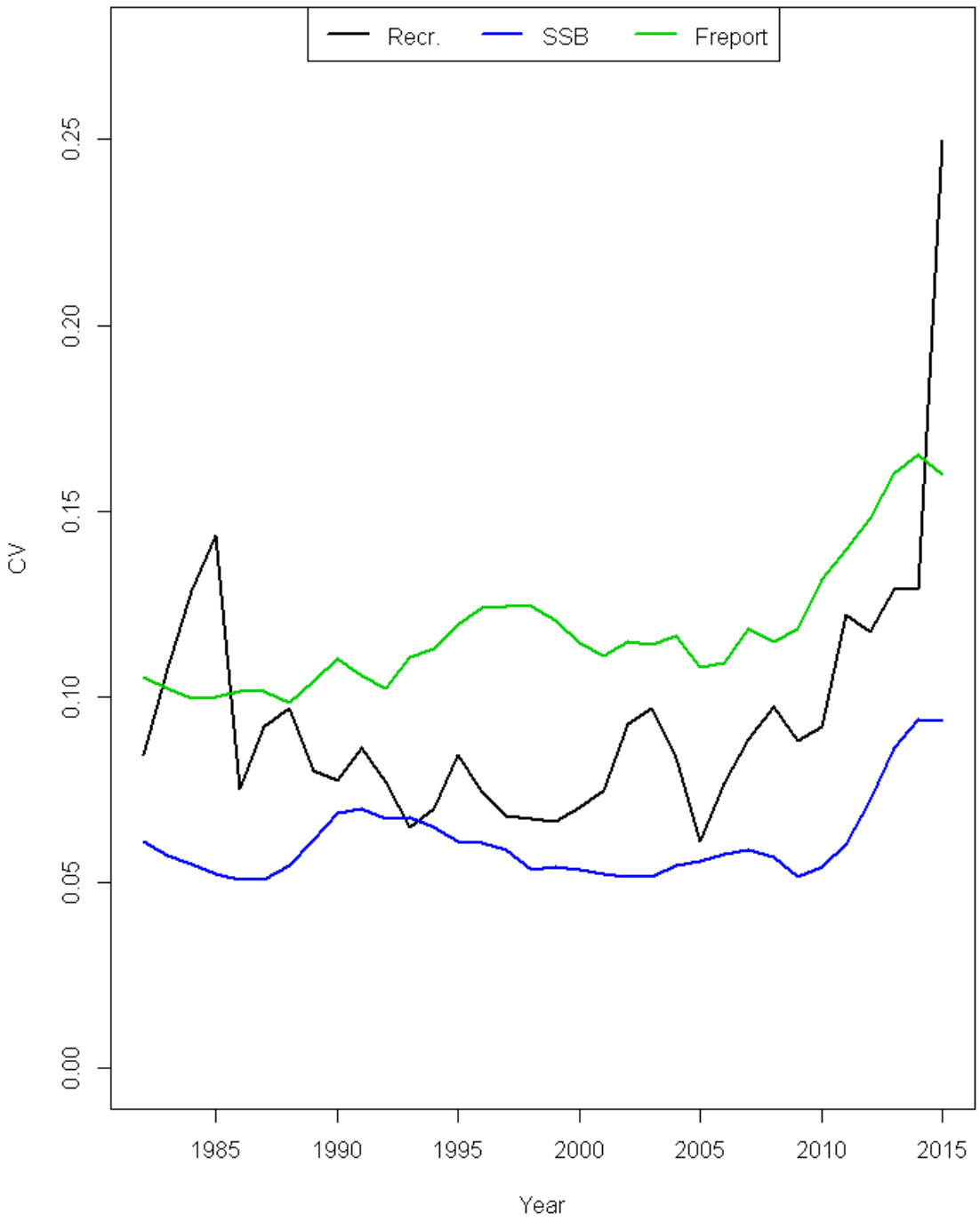


Figure B152. Hessian-based coefficients of variations (CV) estimates of witch flounder spawning stock biomass (SSB), fishing mortality ($F_{report} = F_{full}$) and age 1 recruitment (Recr) from ASAP Run 9_5_v2.

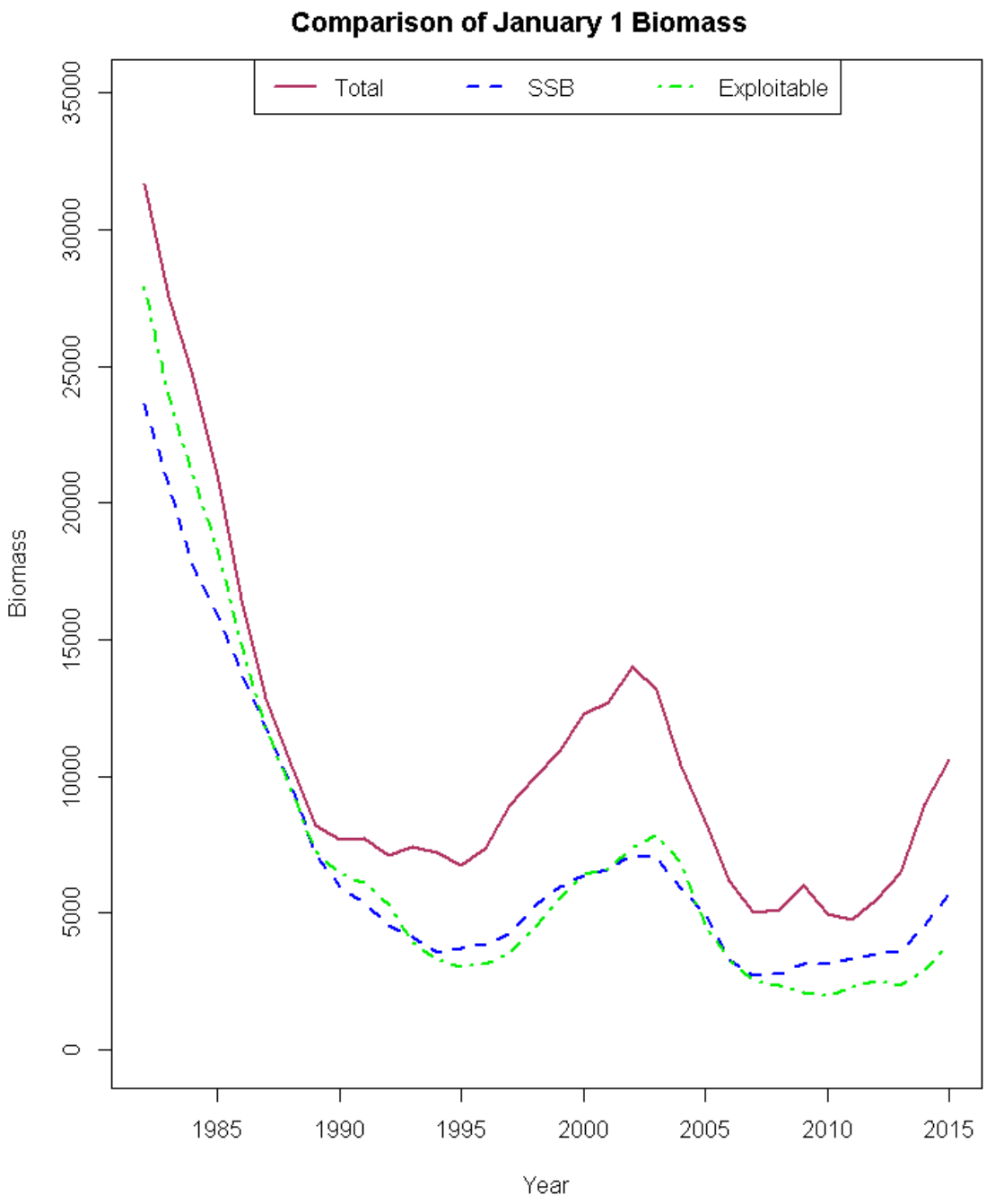


Figure B153. Comparison of ASAP Run 9_5_v2 estimates of witch flounder January 1 biomass after maturity ogive (SSB) and fleet selectivity ogive (exploitable).

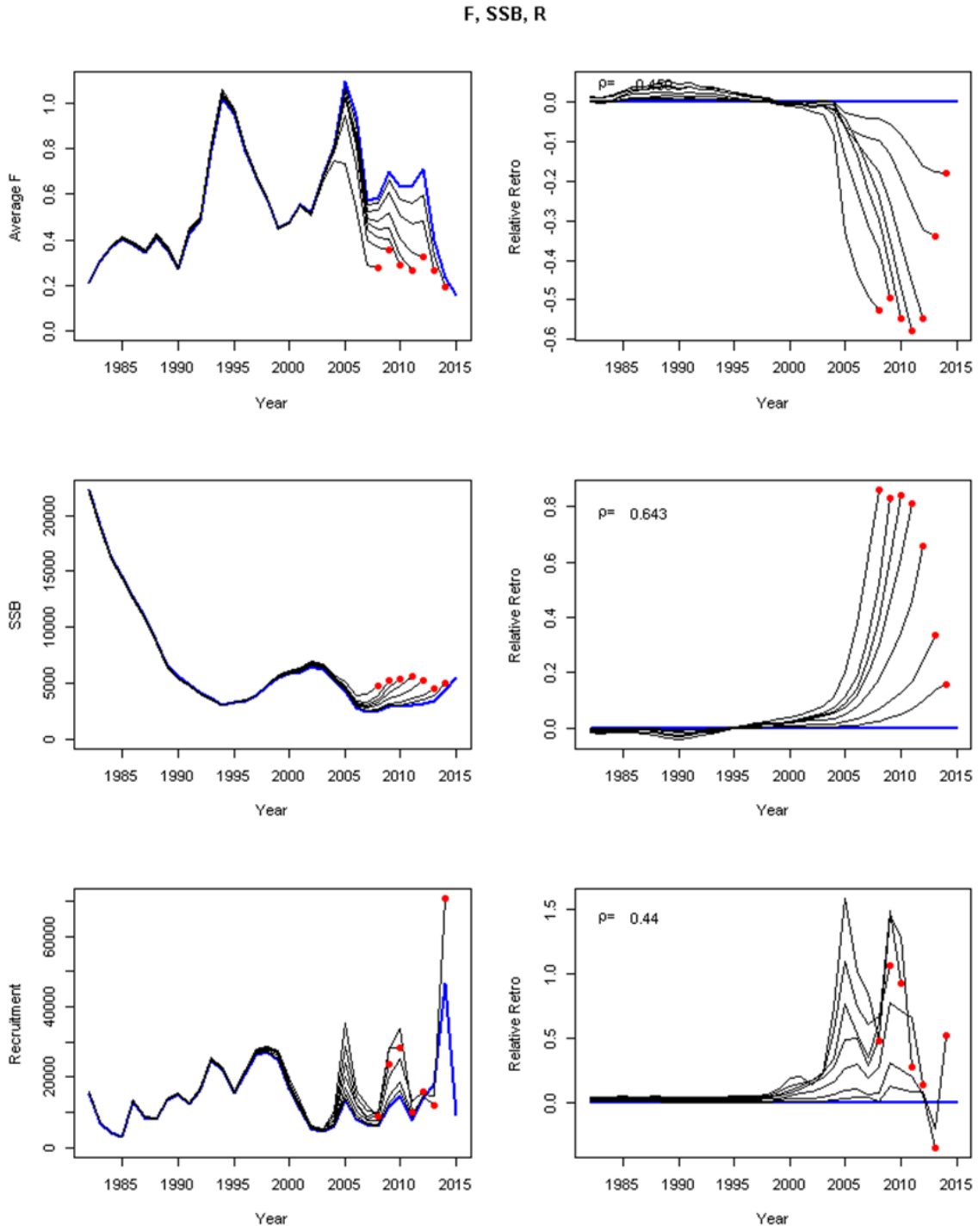


Figure B154. Retrospective patterns (absolute, left; relative, right) for witch flounder fishing mortality (top), spawning stock biomass (SSB; middle) and age 1 recruitment (bottom) from ASAP Run 9_5_v2. The Mohn's rho value based on 7 year peel is indicated.

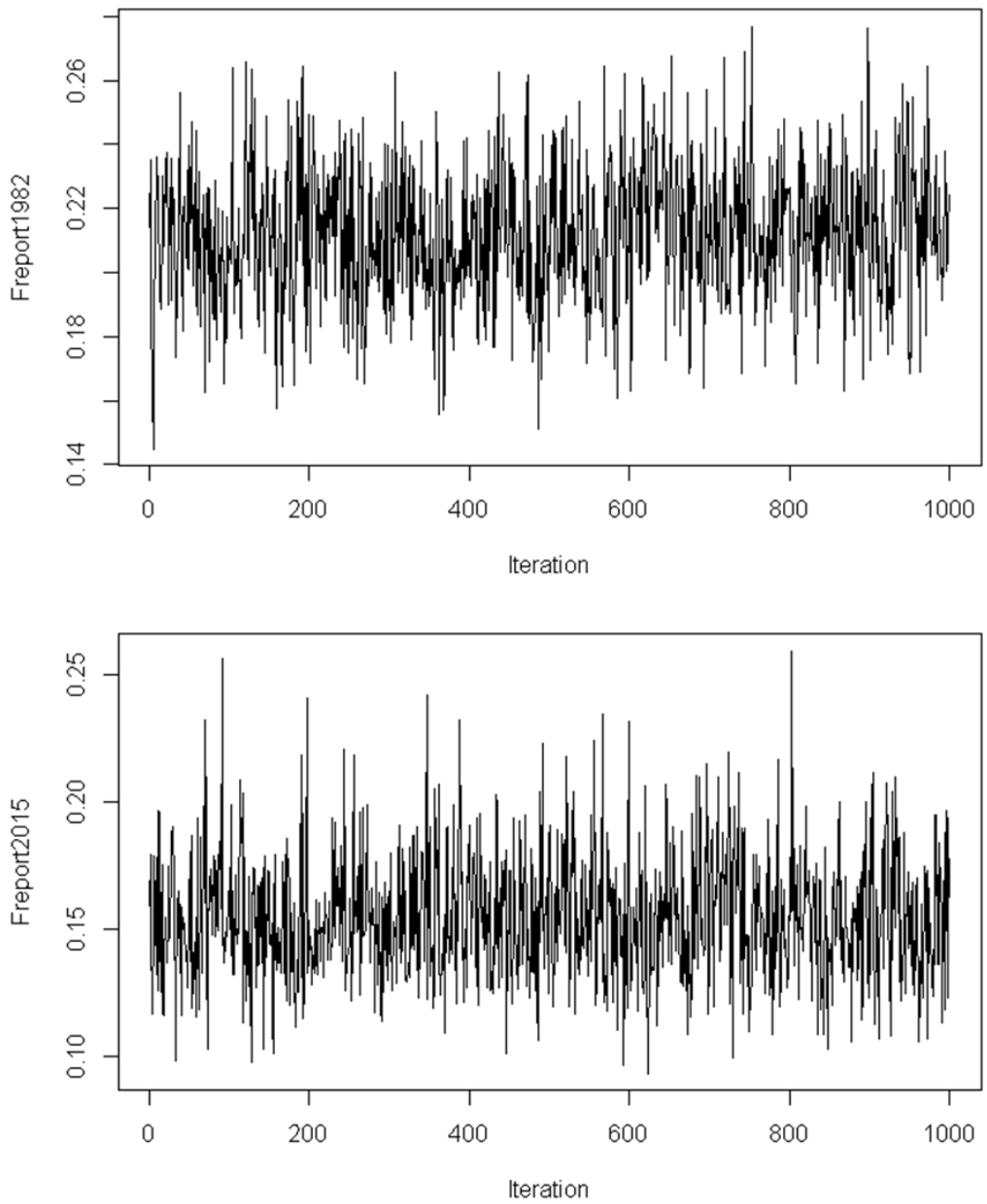


Figure B155. Trace of Monte Carlo Markov chains for witch flounder 1892 (top) and 2015 (bottom) fishing mortality from ASAP RUN 9_5_v2.

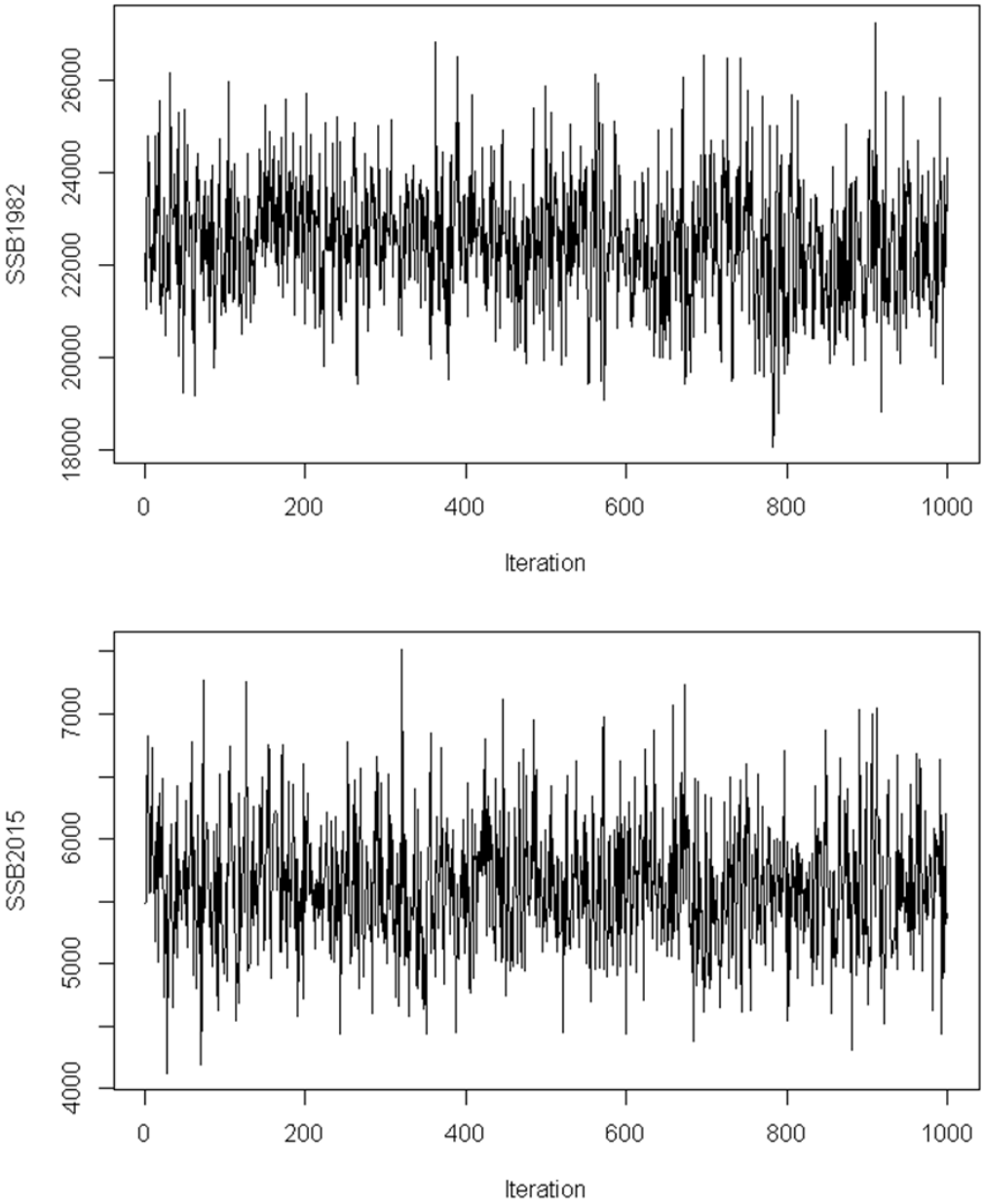


Figure B156. Trace of Monte Carlo Markov chains for witch flounder 1892 (top) and 2015 (bottom) spawning stock biomass from ASAP RUN 9_5_v2.

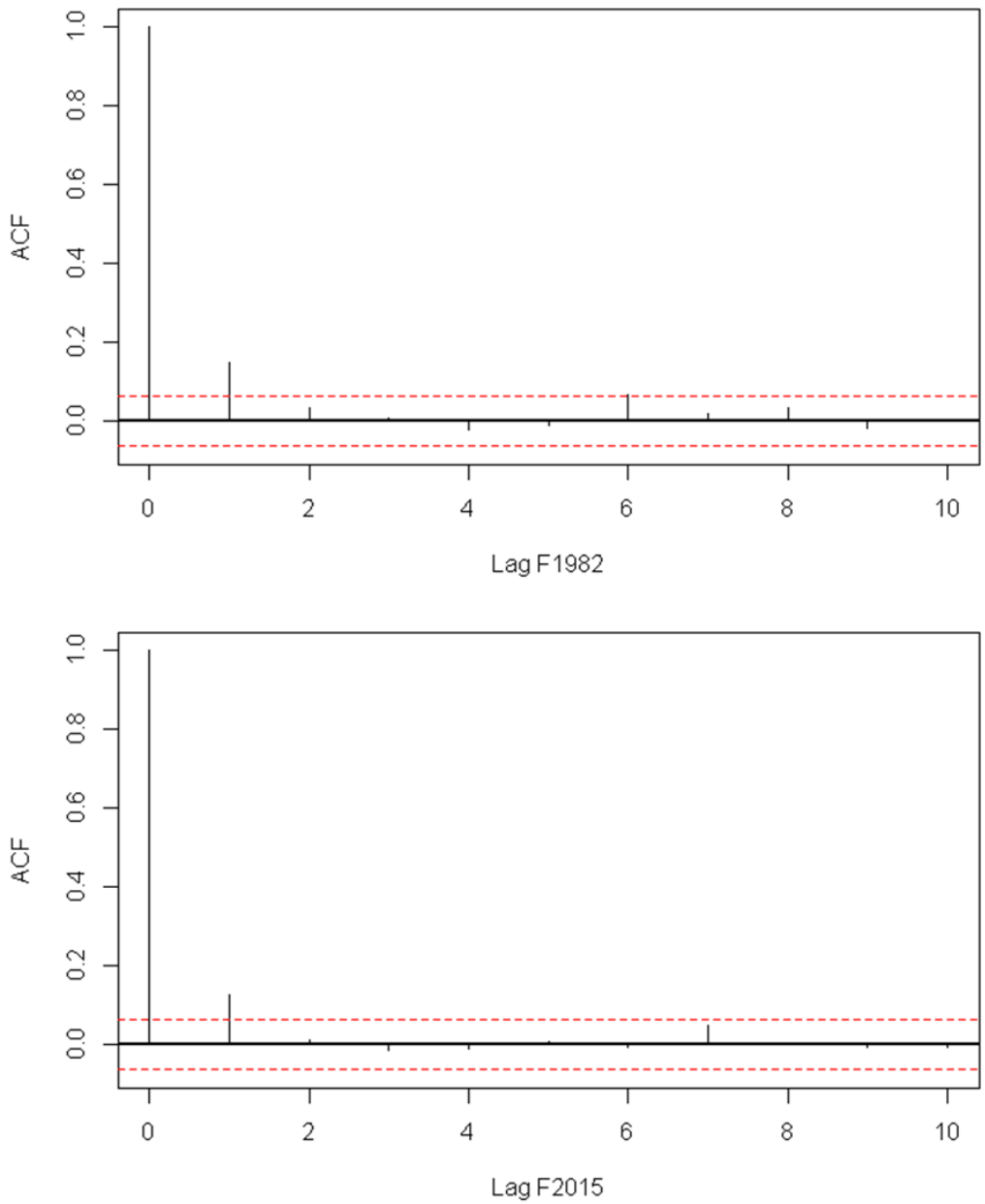


Figure B157. Autocorrelation within the 1982 (top) and 2015 (bottom) witch flounder fishing mortality Monte Carlo Markov chains from ASAP Run 9_5_v2.

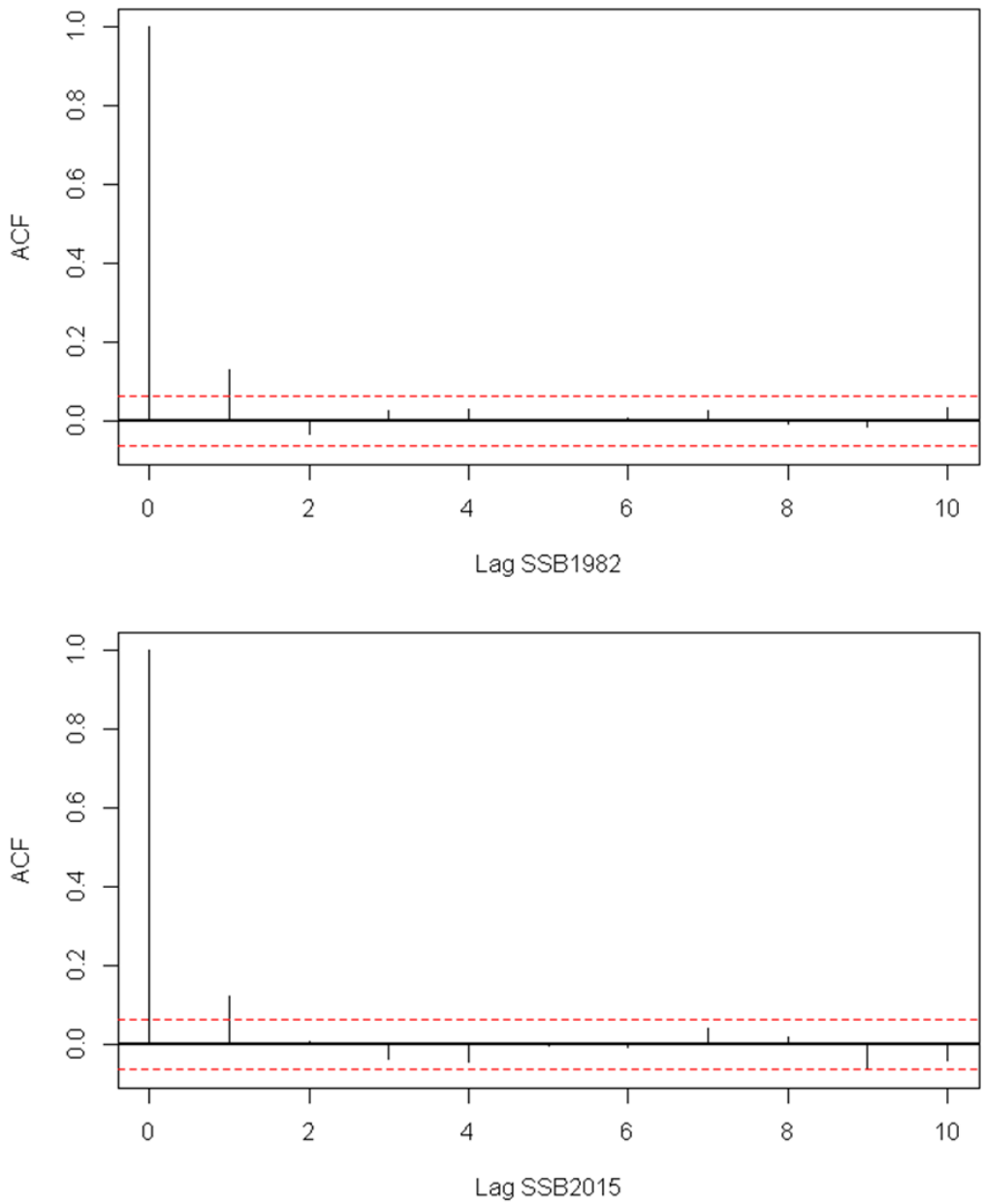


Figure B158. Autocorrelation within the 1982 (top) and 2015 (bottom) witch flounder spawning stock biomass Monte Carlo Markov chains from ASAP Run 9_5_v2.

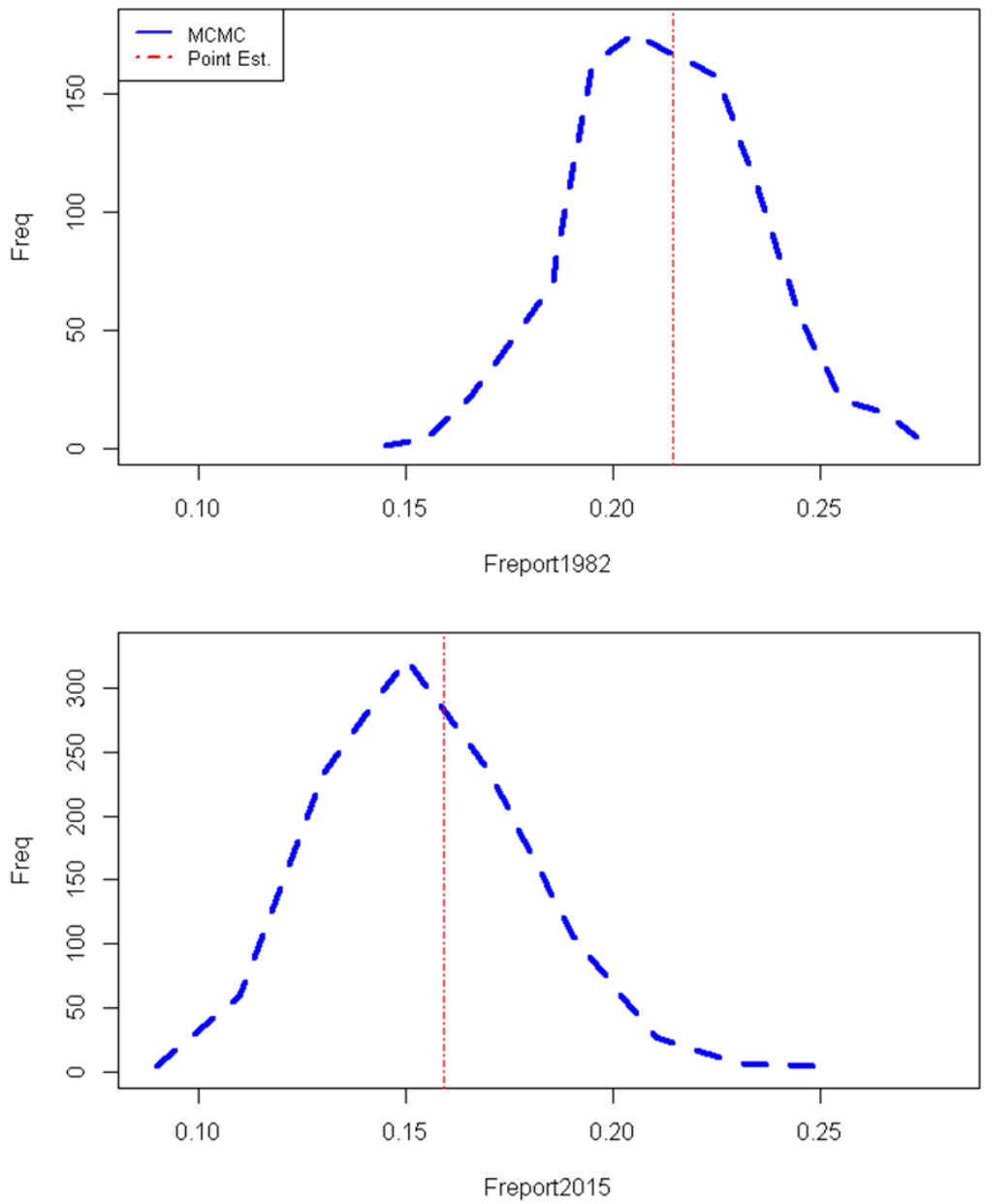


Figure B159. ASAP Run 9_5_v2 point estimates and MCMC distributions of fishing mortality.in 1982 (top) and 2015 (bottom).

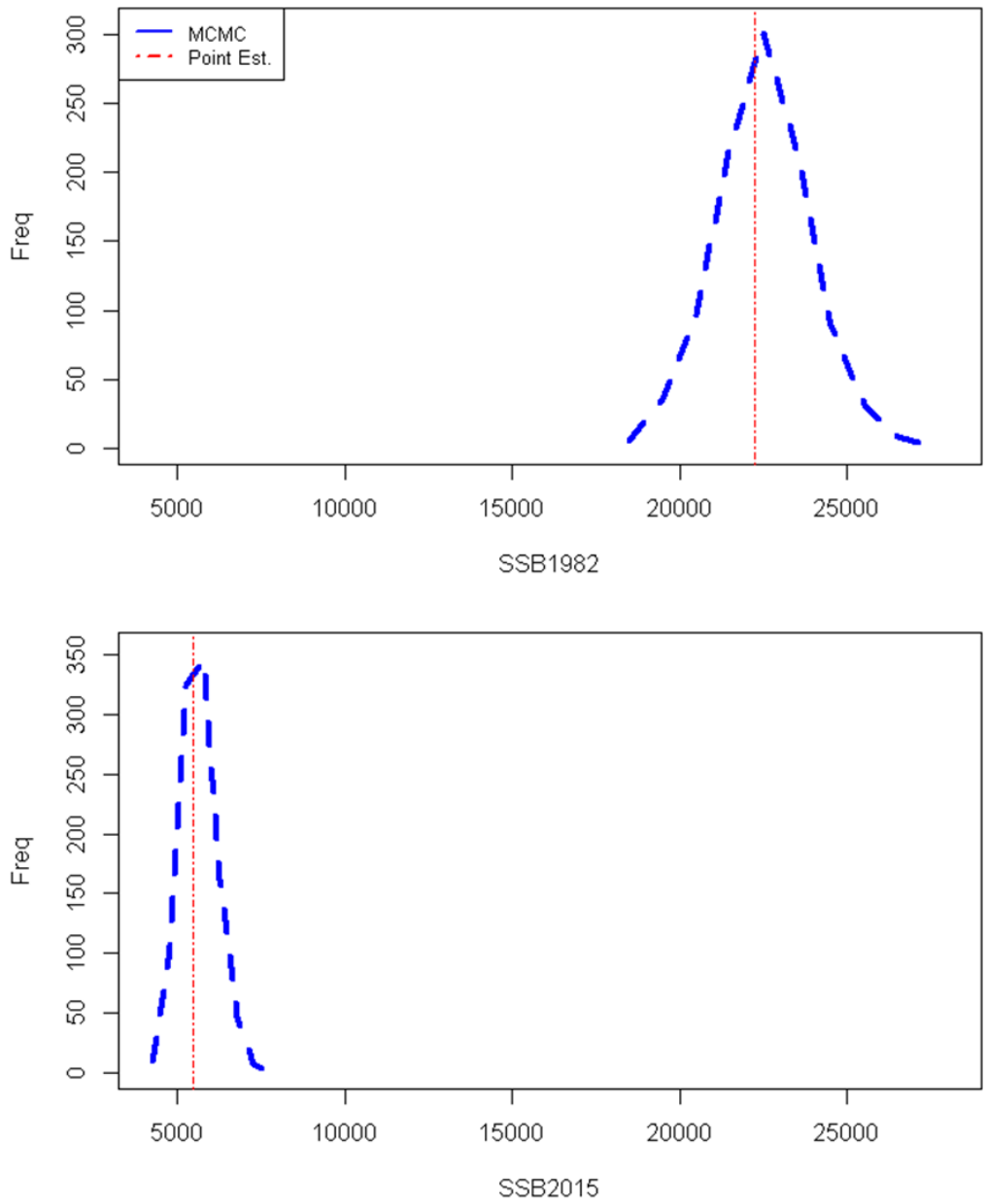
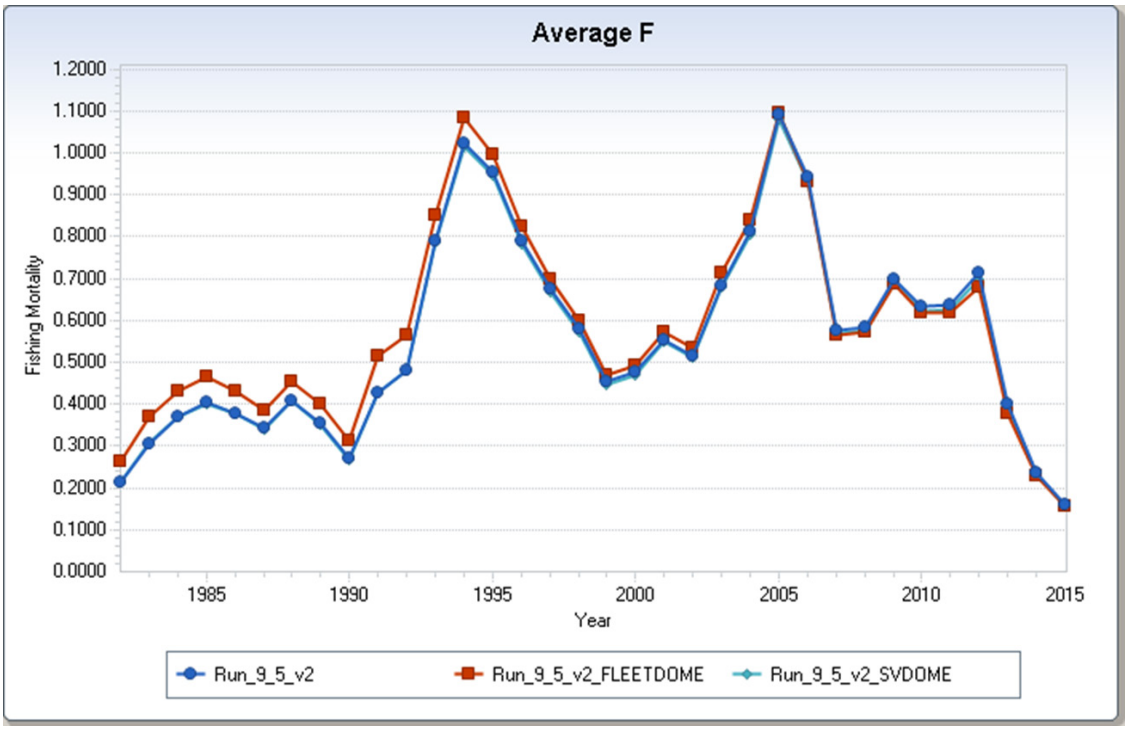


Figure B160. ASAP Run 9_5_v2 point estimates and MCMC distributions of spawning stock biomass (mt) in 1982 (top) and 2015 (bottom).



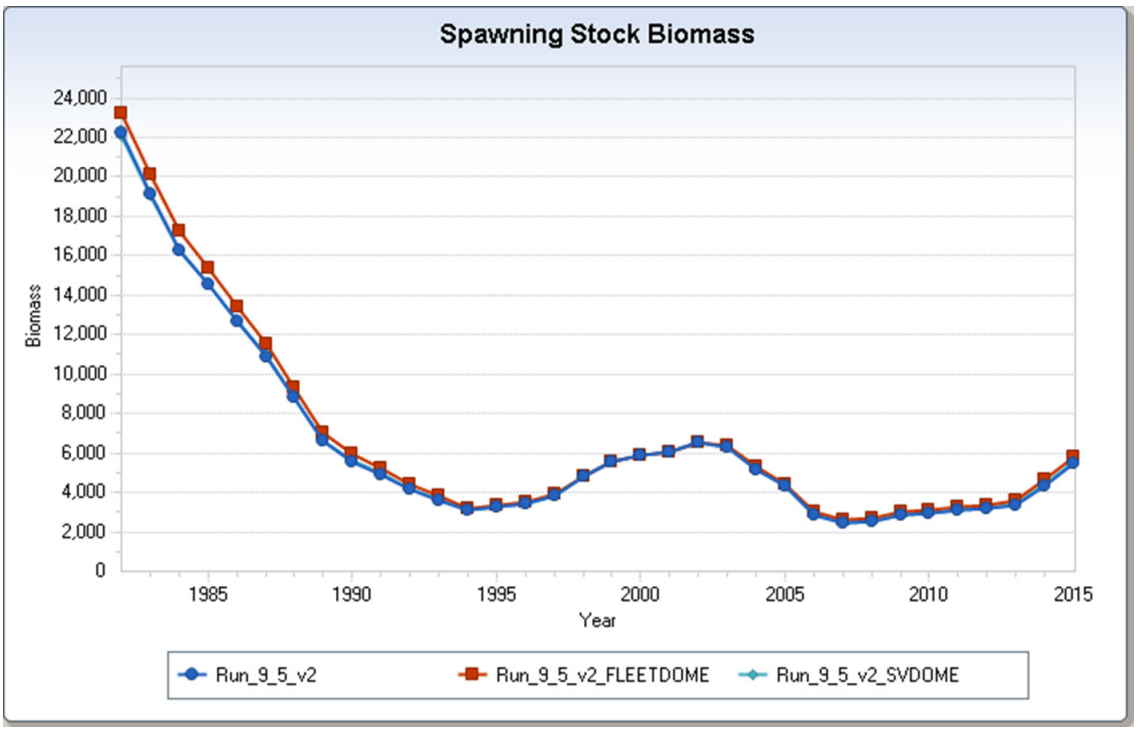
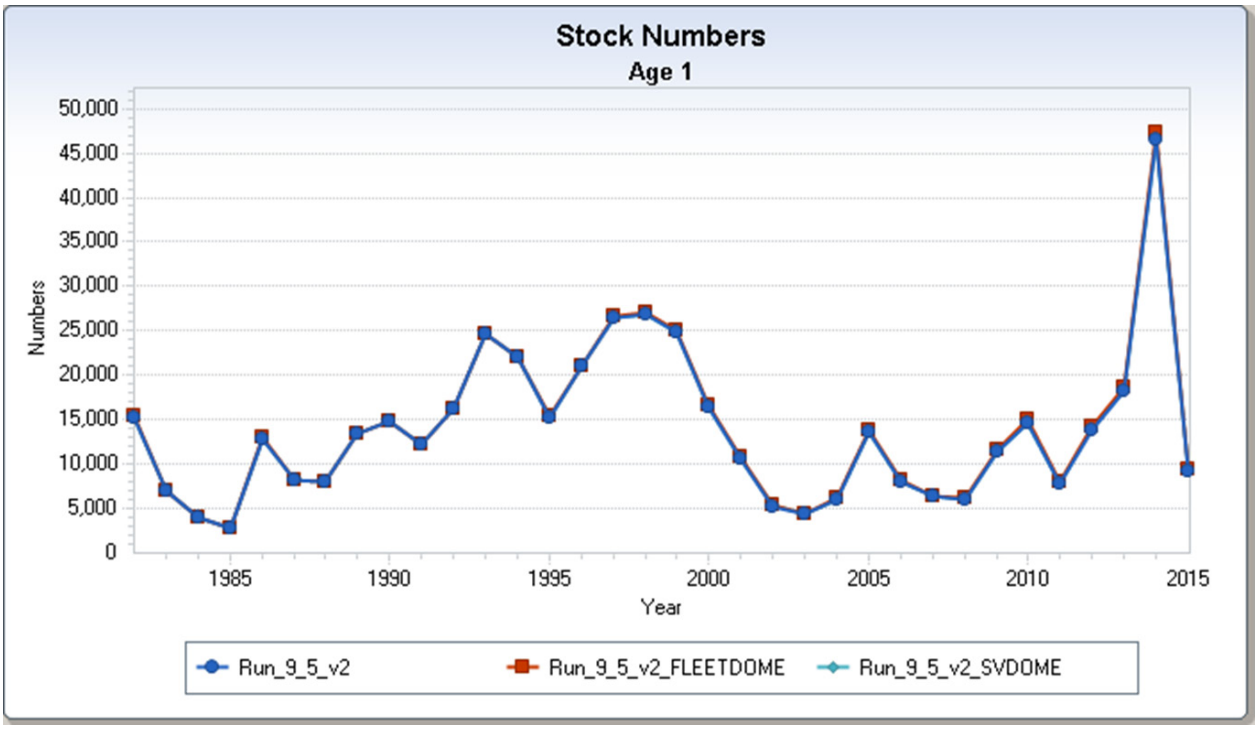


Figure B161. Comparison of witch flounder fishing mortality (top) and spawning stock biomass (mt; bottom) estimated from ASAP Run 9_5_v2, Sensitivity Run 1 (FLEET DOME), and Sensitivity Run 2 (SV DOME).



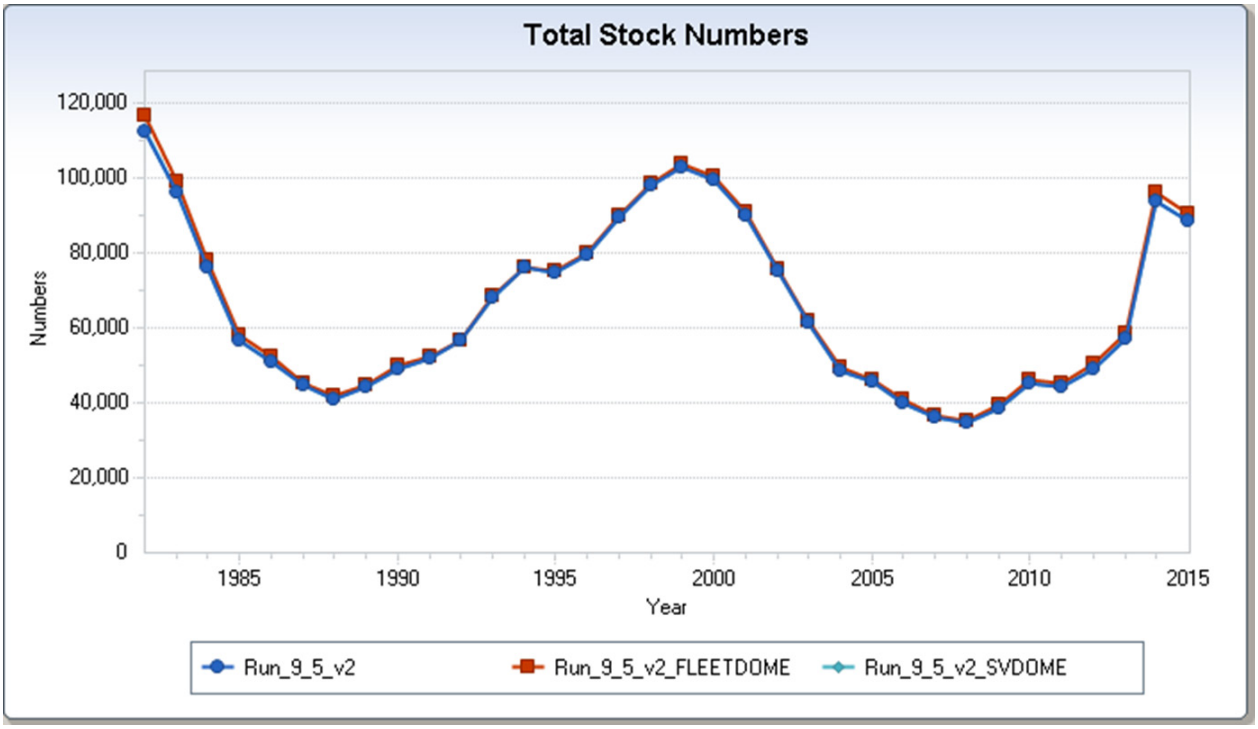
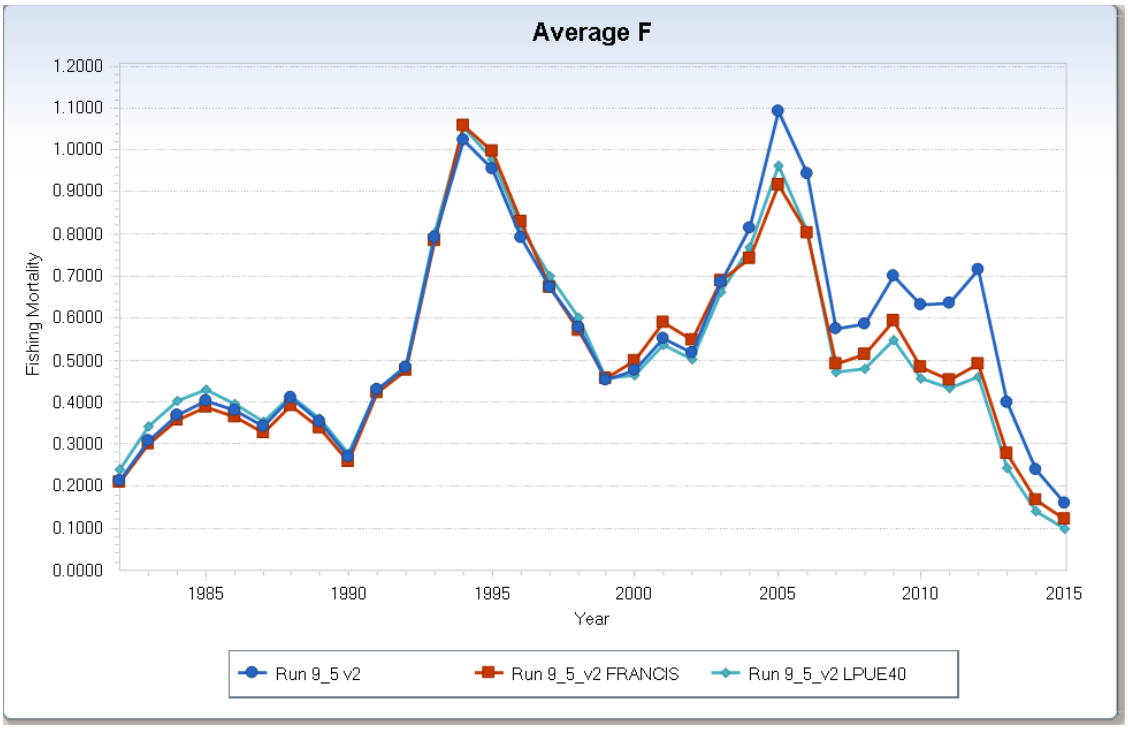


Figure B161, continued. Comparison of witch flounder stock numbers (Age 1, top; Total, bottom) estimated from ASAP Run 9_5_v2, Sensitivity Run 1 (FLEET DOME), and Sensitivity Run 2 (SV DOME).



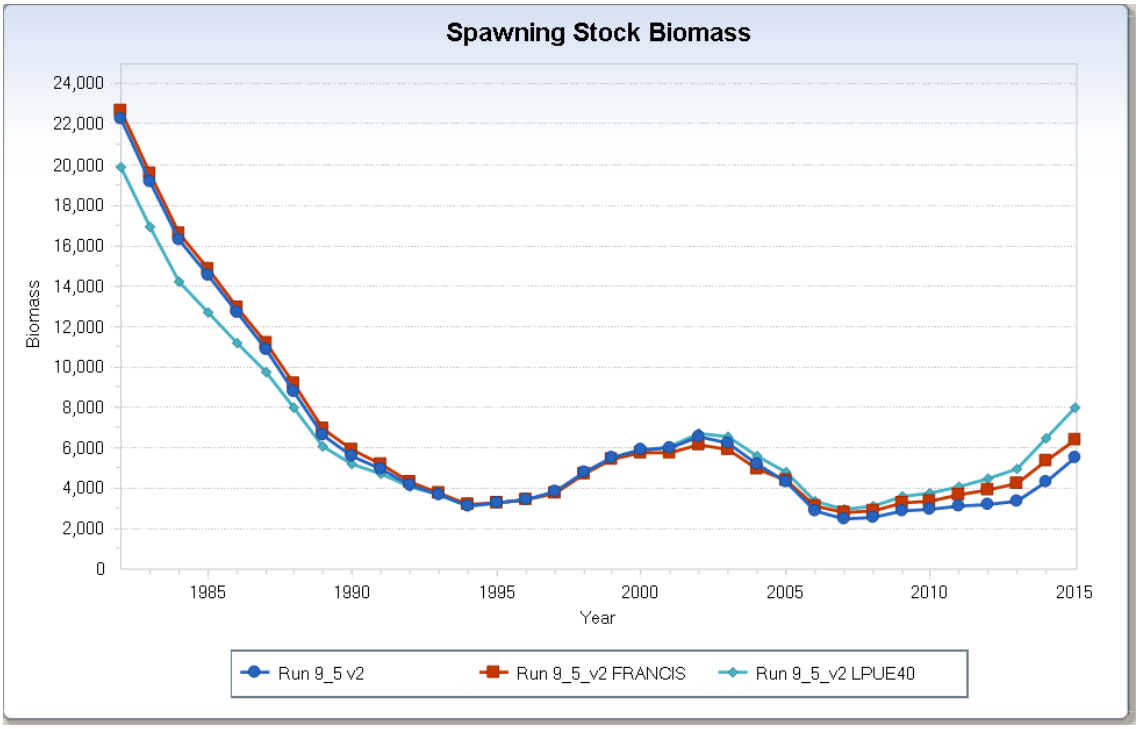
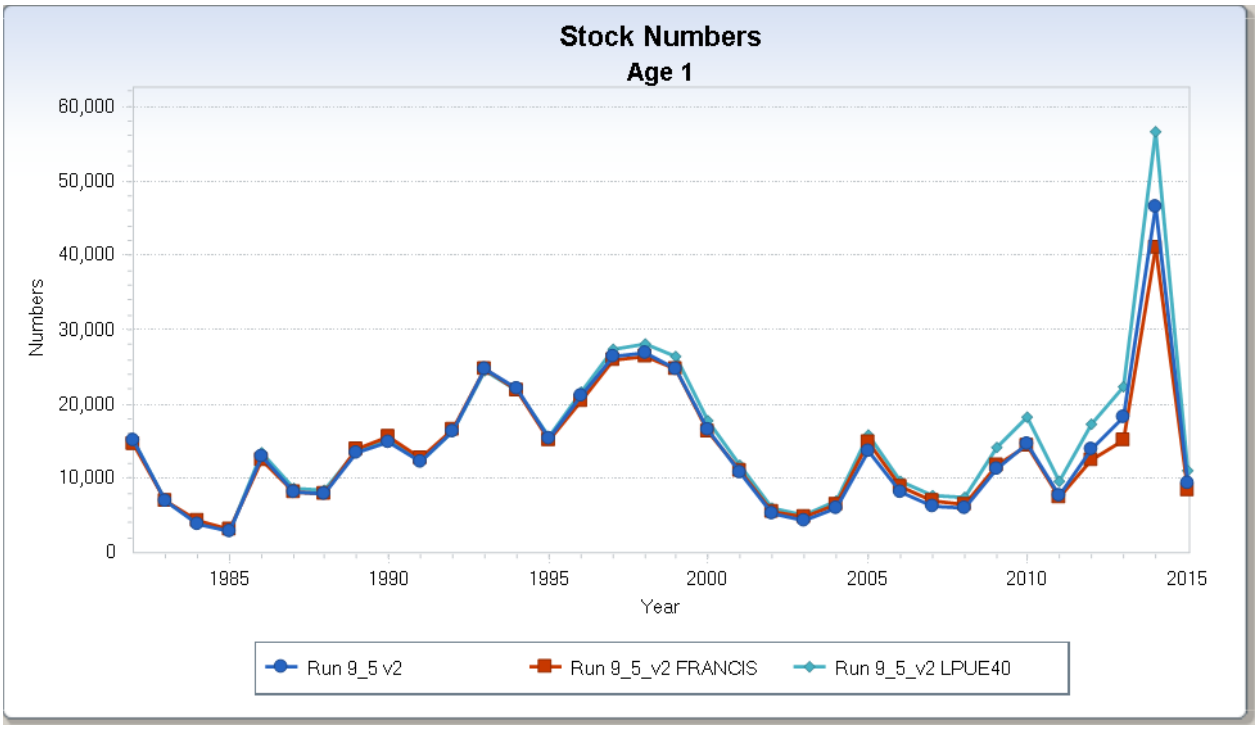


Figure B162. Comparison of witch flounder fishing mortality (top) and spawning stock biomass (mt; bottom) estimated from ASAP Run 9_5_v2, Sensitivity Run 3 (LPUE40) and Sensitivity Run 5 (FRANCIS Effective sample size)



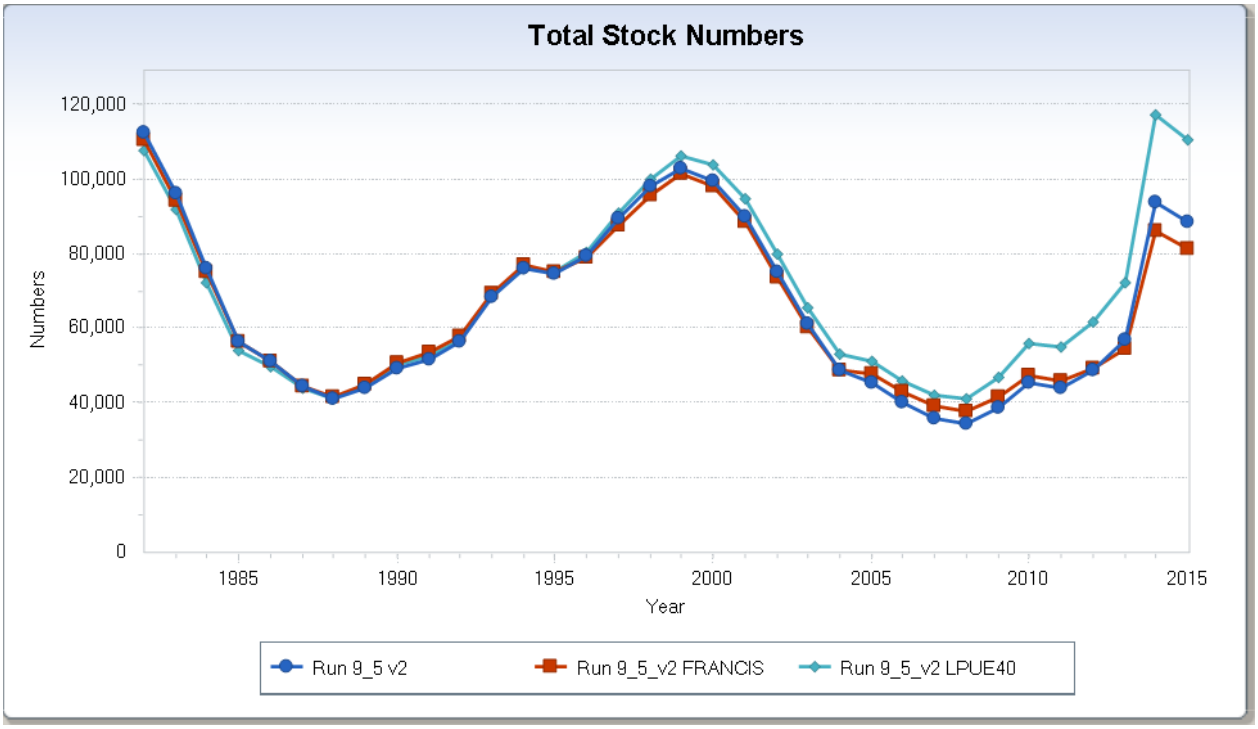
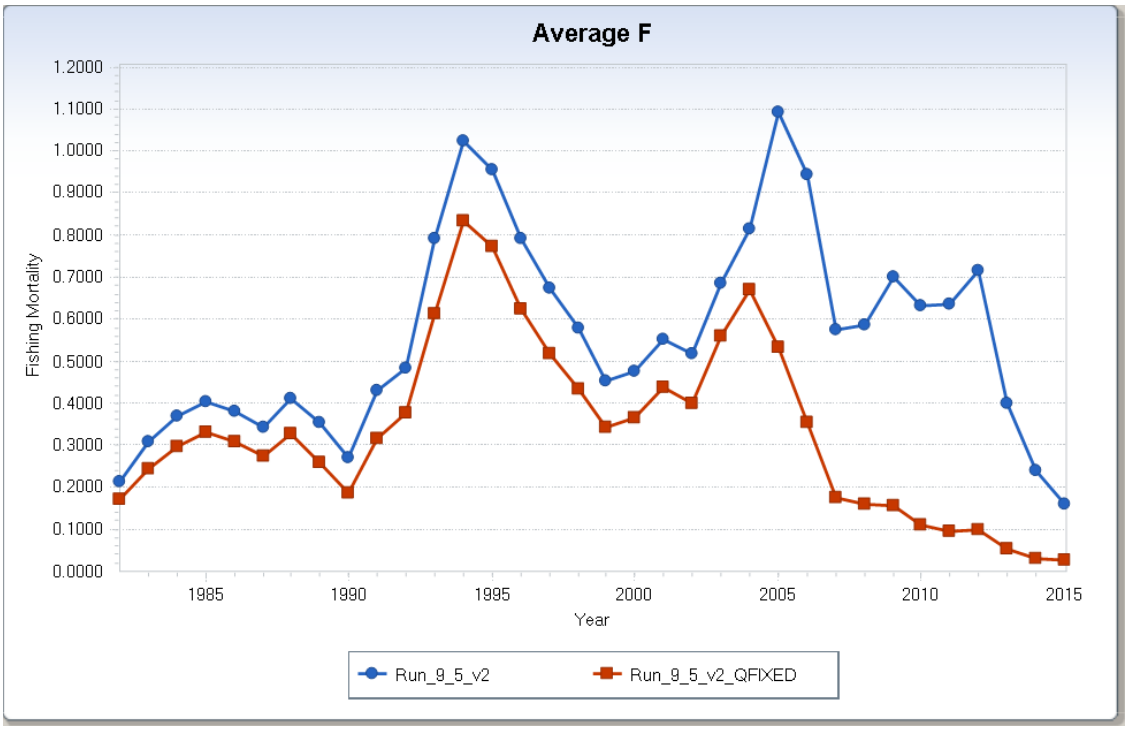


Figure B162, continued. Comparison of witch flounder stock numbers (Age 1, top; Total, bottom) estimated from ASAP Run 9_5_v2, Sensitivity Run 3 (LPUE40) and Sensitivity Run 5 (FRANCIS Effective sample size).



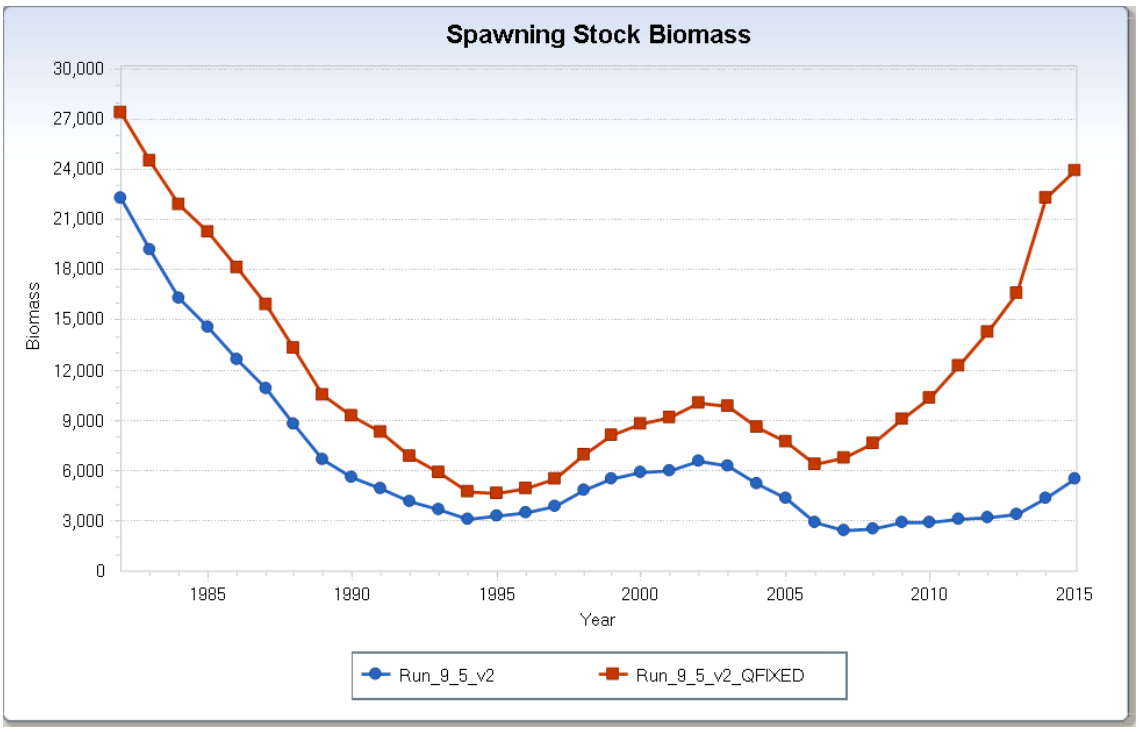
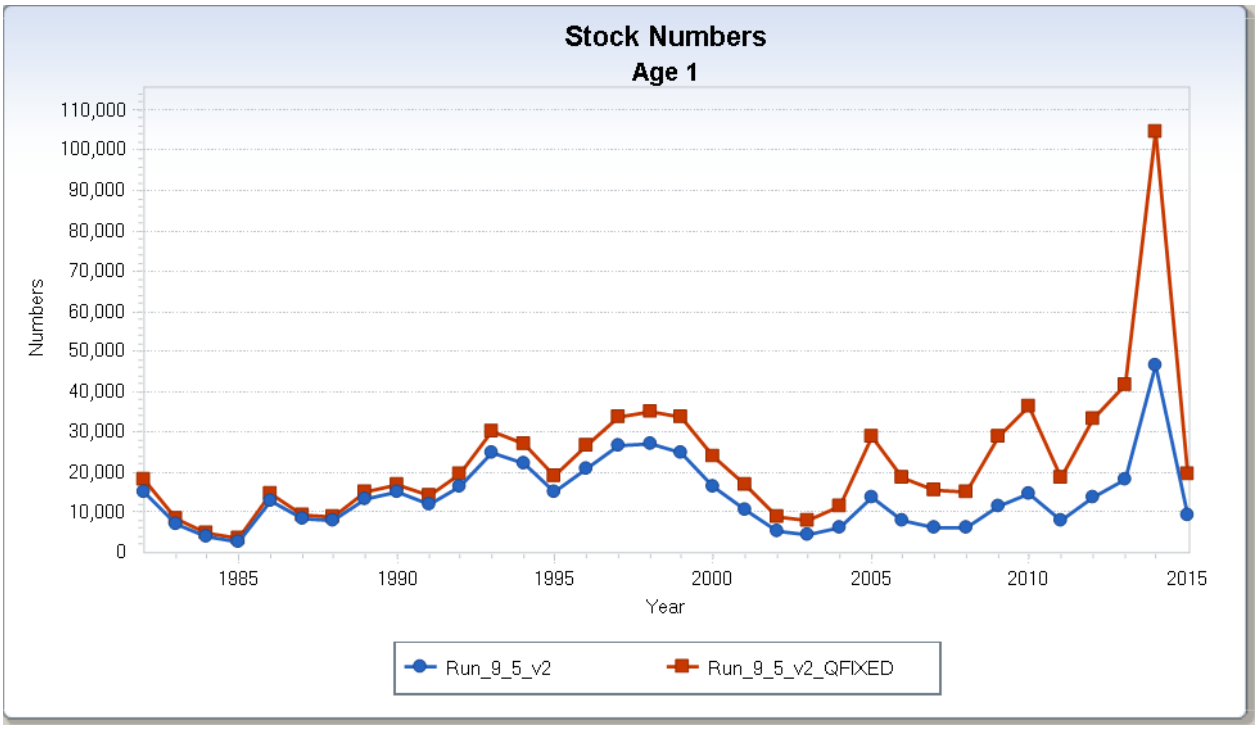


Figure B163. Comparison of witch flounder fishing mortality (top) and spawning stock biomass (mt; bottom) estimated from ASAP Run 9_5_v2 and Sensitivity Run 4 (QFIXED).



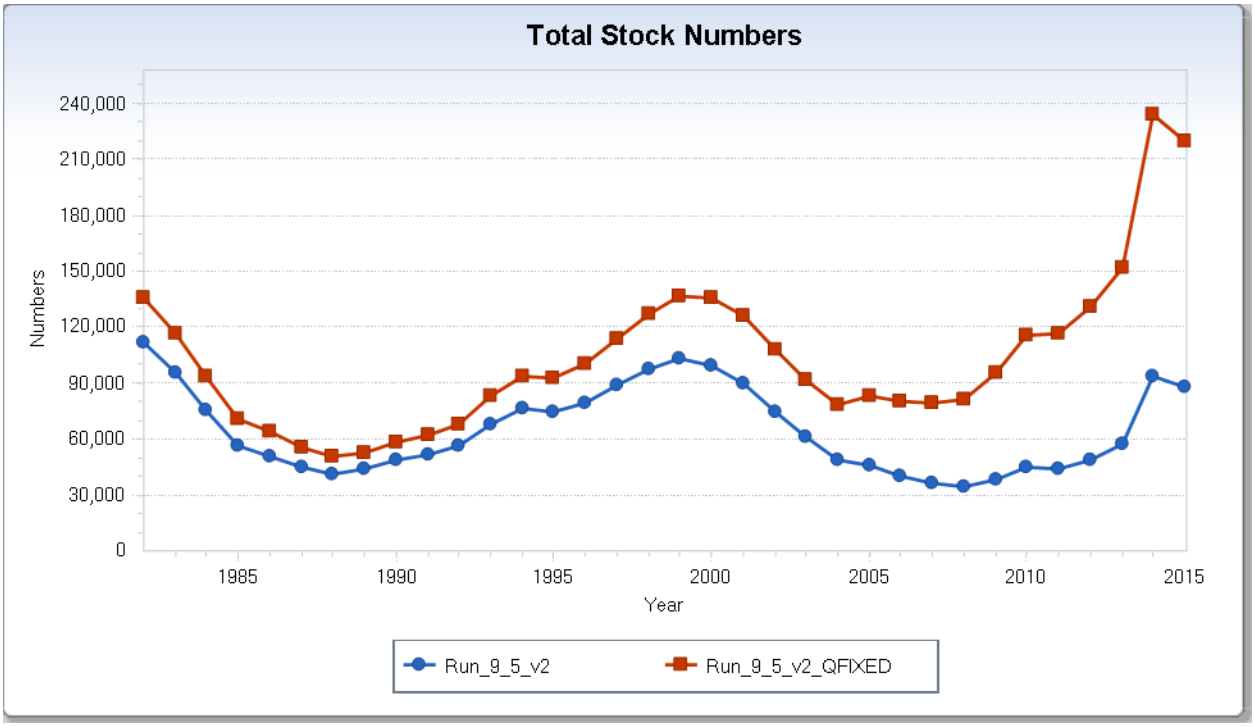


Figure B163, continued. Comparison of witch flounder stock numbers (Age 1, top; Total, bottom) estimated from ASAP Run 9_5_v2 and Sensitivity Run 4 (QFIXED).

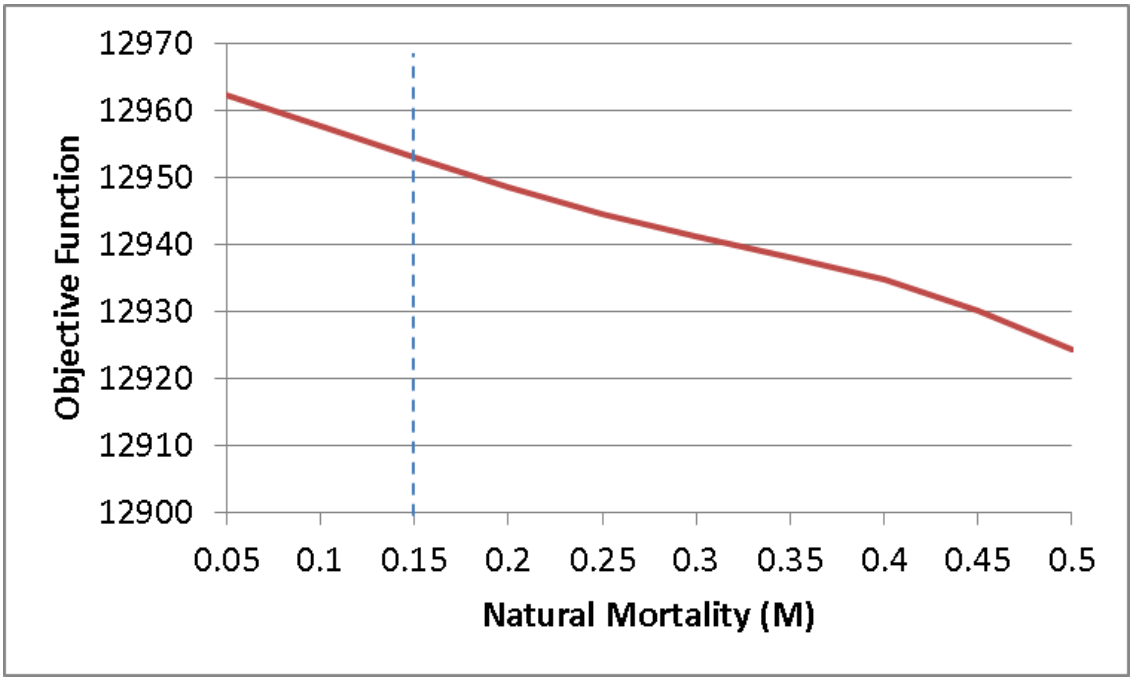


Figure B164. Response of the model objective function to profiling over a range of natural mortality values for ASAP Run 9_5_v2. Blue dashed line indicates M=0.15 assumption applied in ASAP Run 9_5_v2.

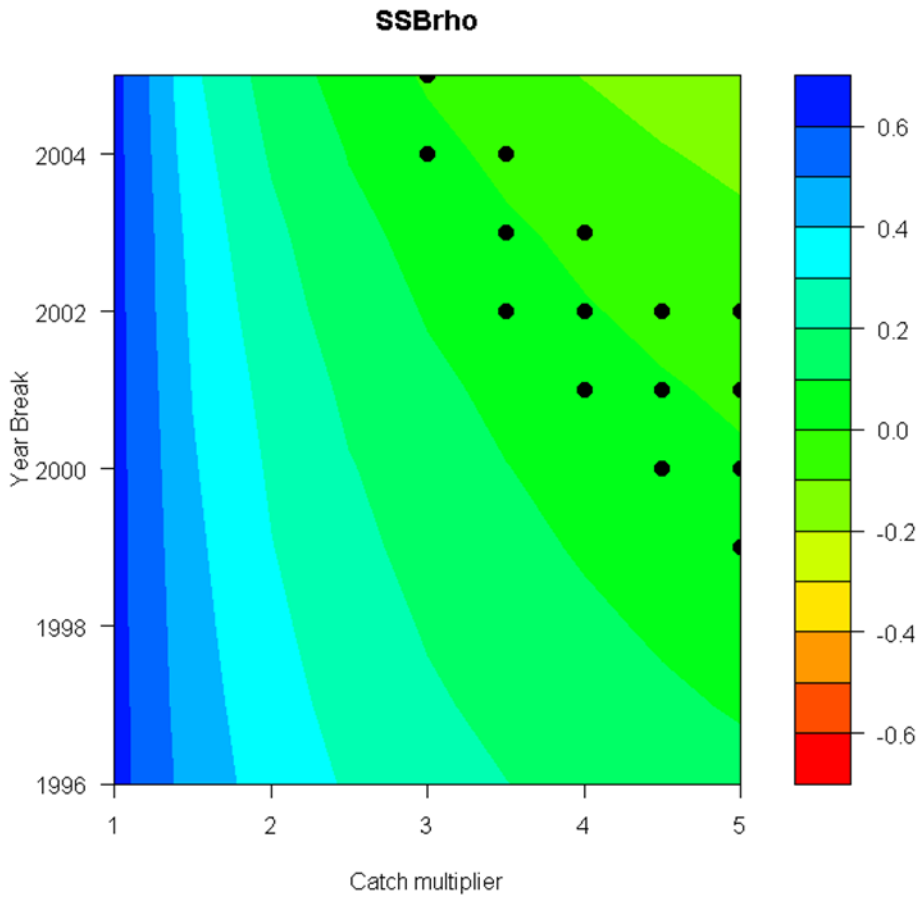


Figure B165. The value of the SSB rho (mean of Mohn's rho value on SSB based on 7 peels; color shading) as the catch multiplier ranges between 1 and 5 (x-axis) and year break (y-axis). The solid black dots denote combinations of year break and catch multiplier that resulted in |SSBrho| < 0.05, indicating multiple ways (combinations of catch multiplier and year break) to eliminate the SSB retrospective pattern in the witch flounder model.

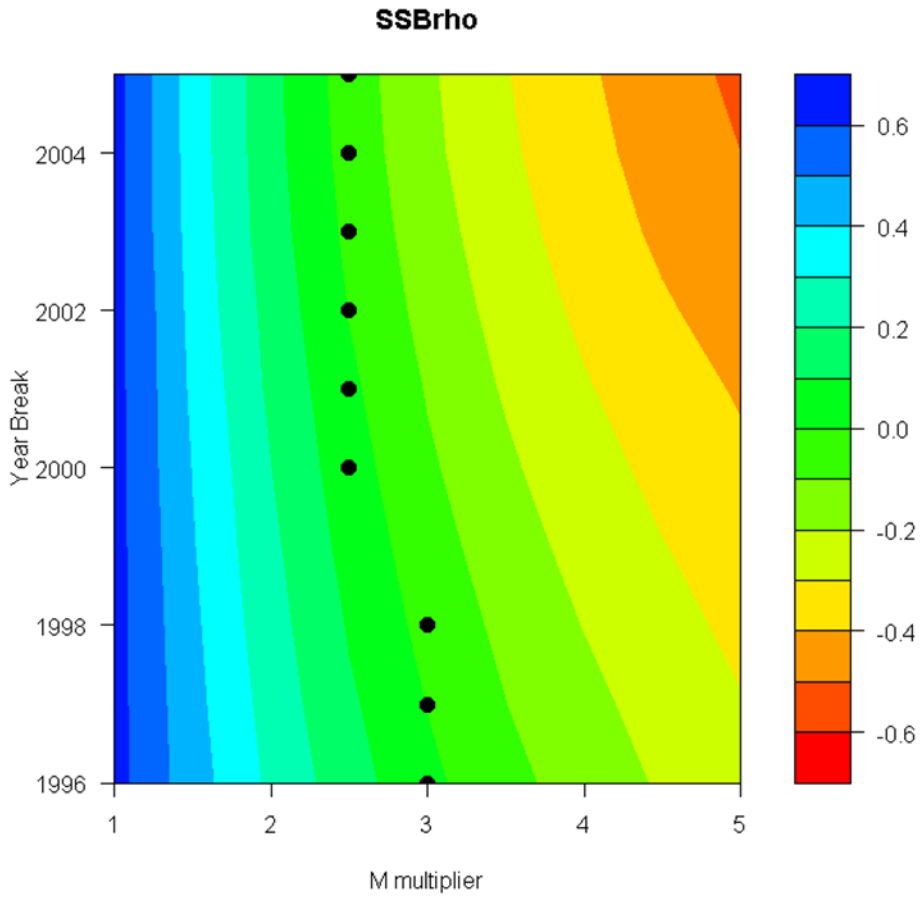
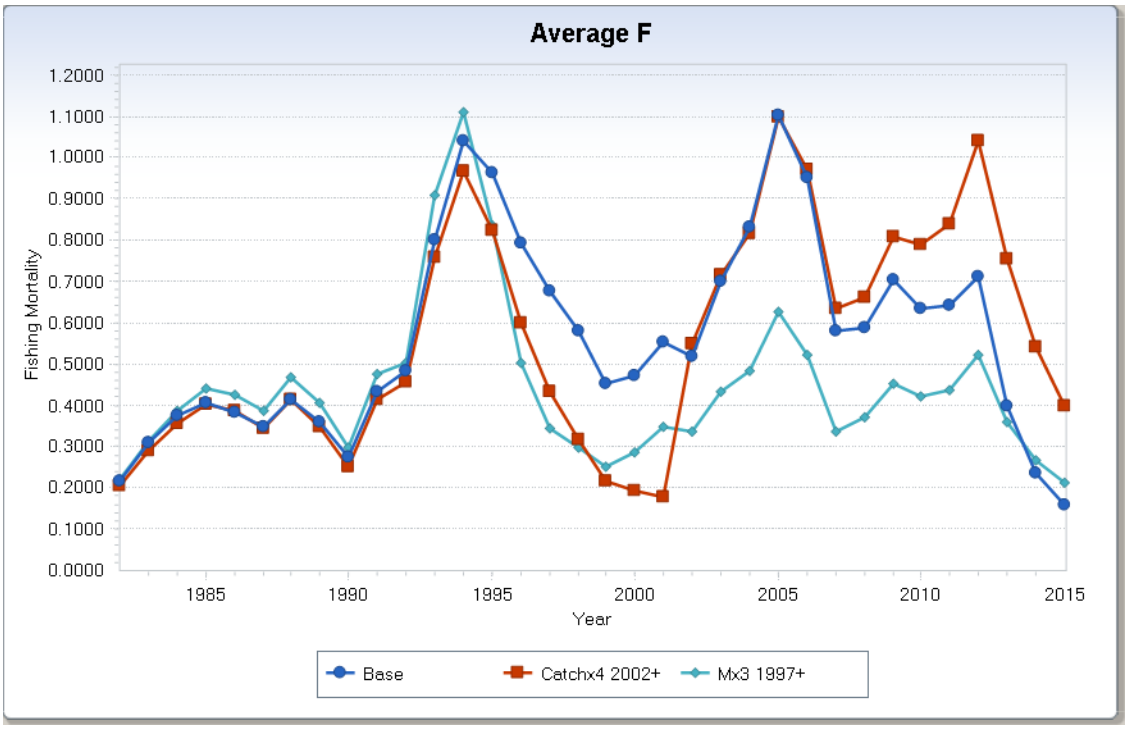


Figure B166. The value of the SSB rho (mean of Mohn's rho value on SSB based on 7 peels; color shading) as the natural mortality (M) multiplier ranges between 1 and 5 (x-axis) and year breaks between 1996 and 2005 (y-axis). The solid black dots denote combinations of year break and M multipliers that resulted in |SSBrho| < 0.05, indicating multiple ways (combinations of M multiplier and year break) to eliminate the SSB retrospective pattern in the witch flounder model.



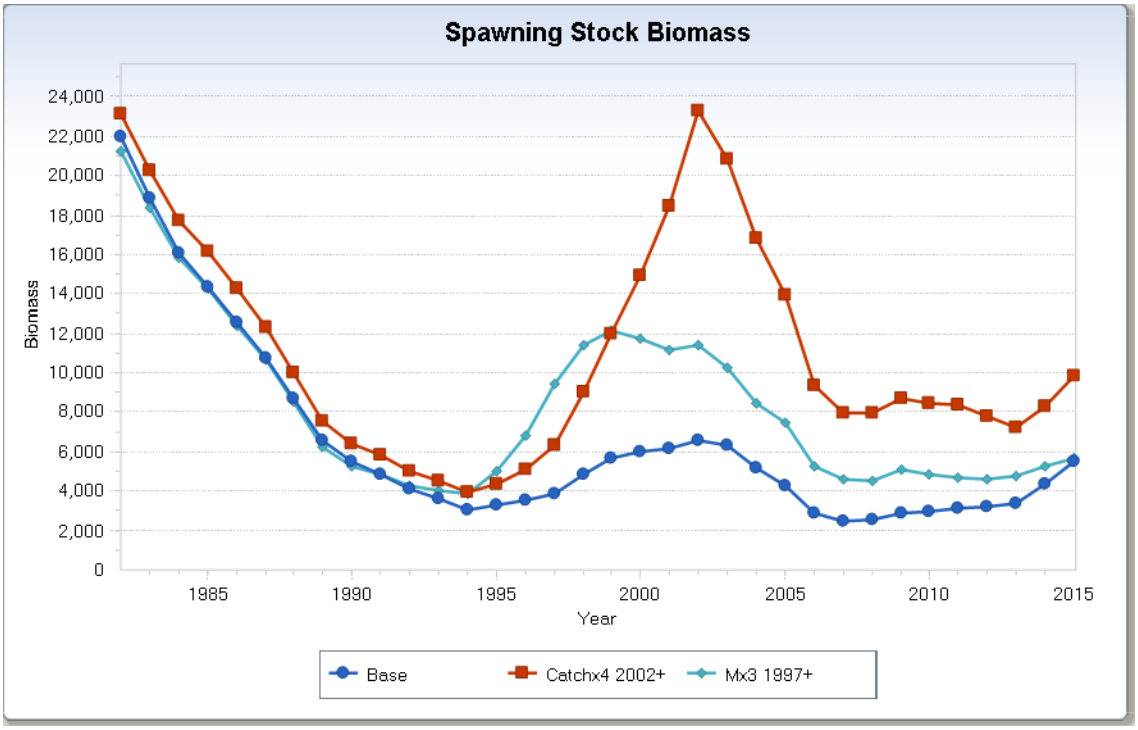


Figure B167. Trends in spawning stock biomass (top) and fishing mortality (bottom) resulting from the ASAP Run 9_5 (Base; blue circle), base run with catch increased by 4 times beginning in 2002 and onward (Catchx4 2002+; red square), and base run with natural mortality increased by 3 times beginning in 1997 and onward (Mx3 1997+; light blue diamond).

Figure B168. Trends in fishing mortality (top) and spawning stock biomass (mt; bottom) estimated from the VPA RUN A2 (dashed line) and ASAP Run 9_5_v2 (solid line) with +/- 2 standard deviation (dotted line).

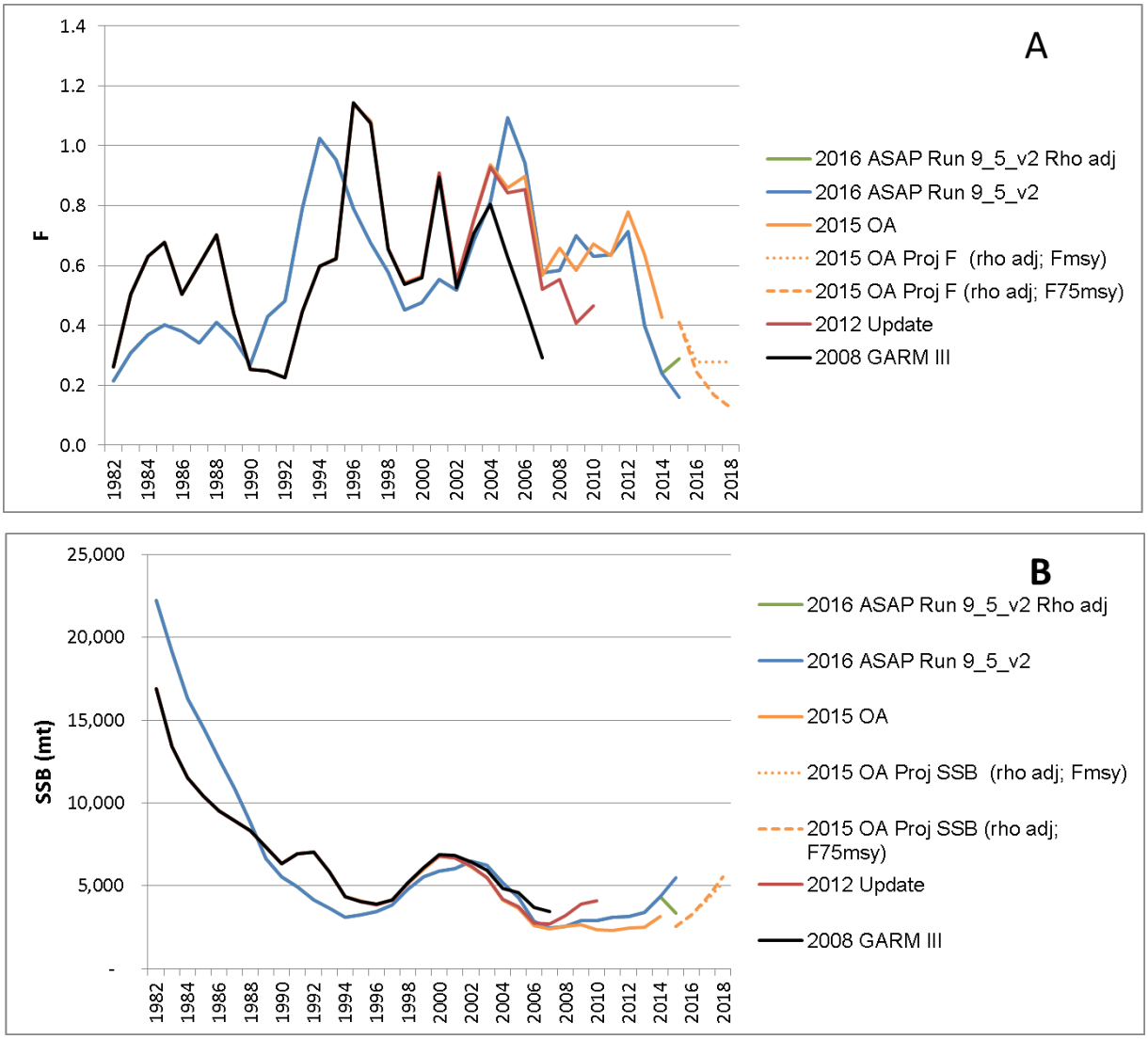


Figure B169. Trends in fishing mortality (top) and spawning stock biomass (mt; bottom) from the 2008 GARM benchmark, 2012 Update, 2015 Operational Assessment (OA), and ASAP Run 9_5_v2 in this assessment (solid lines). The 2015 OA projections are indicated with dashed lines.

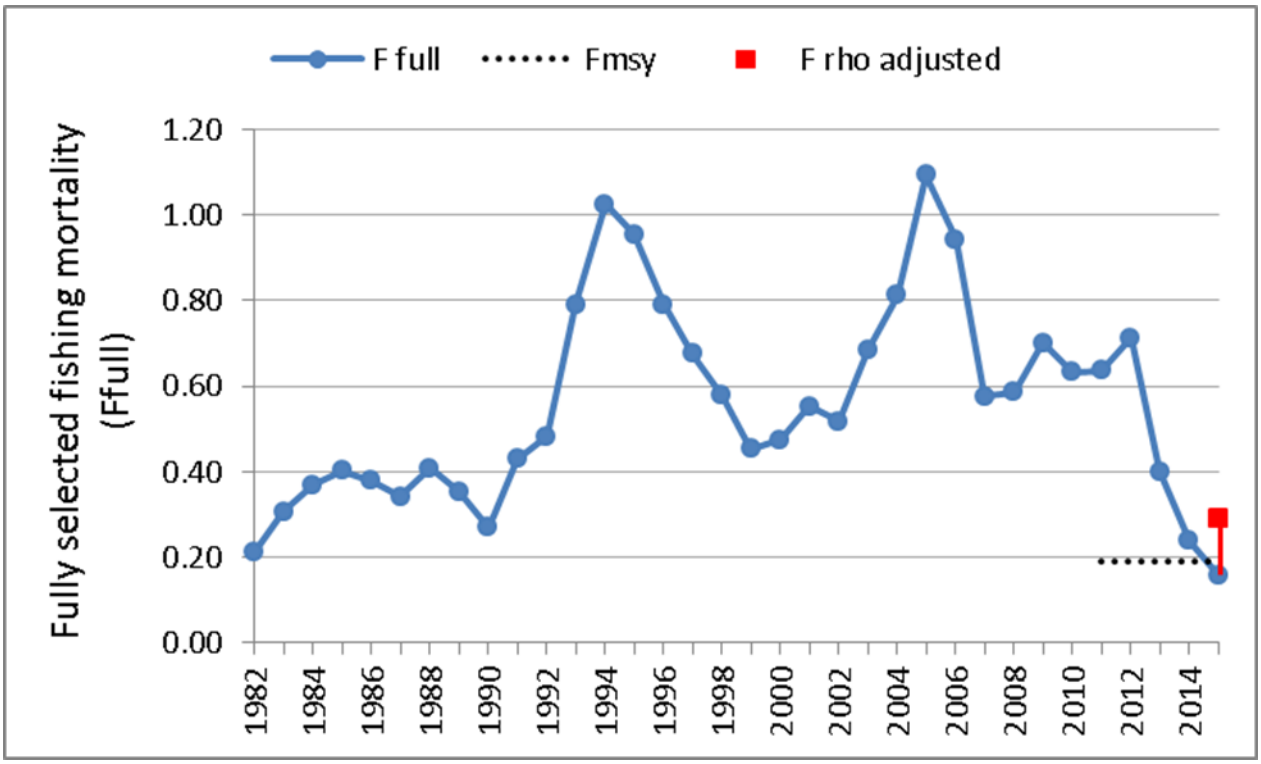


Figure B170**.** Estimated trends in the fully selected fishing mortality (F_{full}; blue line with circle) of witch flounder between 1982 and 2015, and the corresponding F_{MSY} (black dashed line) based on ASAP Run 9_5_v2. The 2015 retrospective adjusted F (F rho adjusted; red square) is also shown.

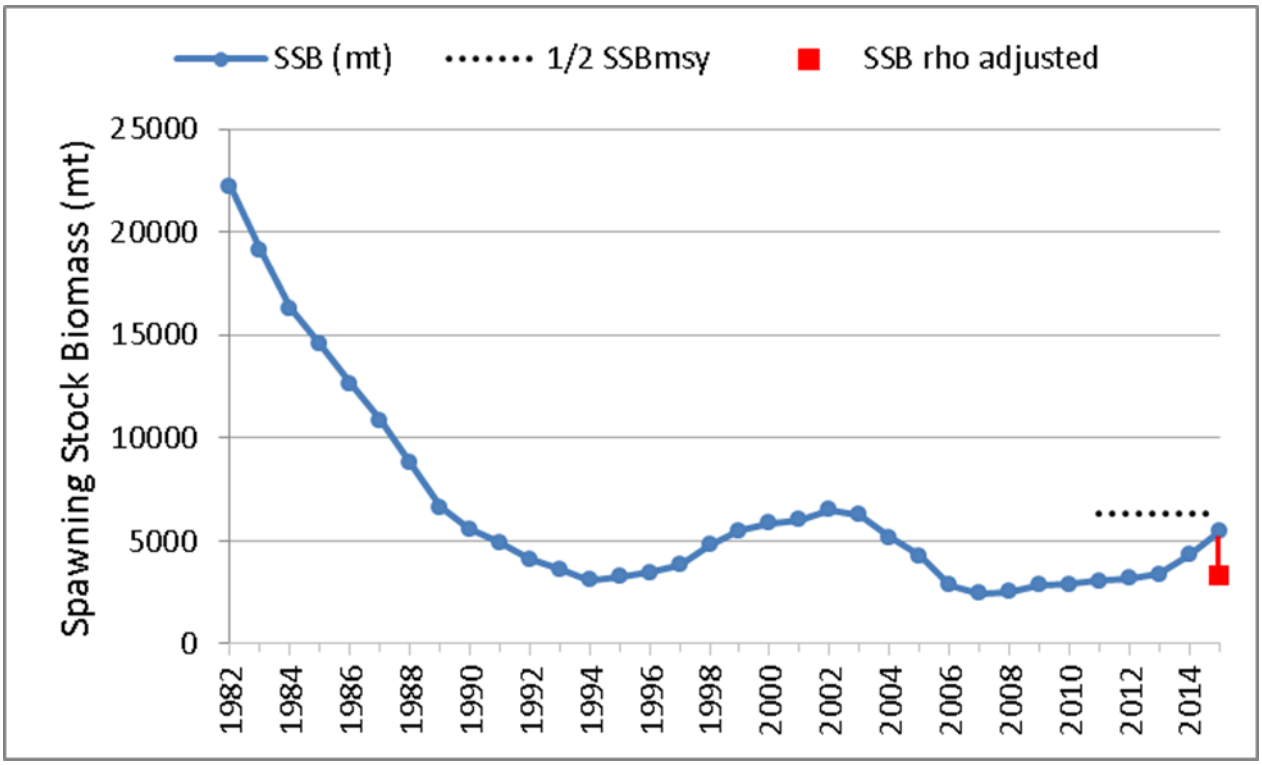


Figure B171. Estimated trends in the spawning stock biomass (mt; blue line with circle) of witch flounder between 1982 and 2015 and the corresponding $SSB_{threshold}$ (1/2 SSB_{MSY}; black dashed line) based on ASAP Run 9_5_v2. The 2015 retrospective adjusted SSB (SSB rho adjusted; red square) is also shown.

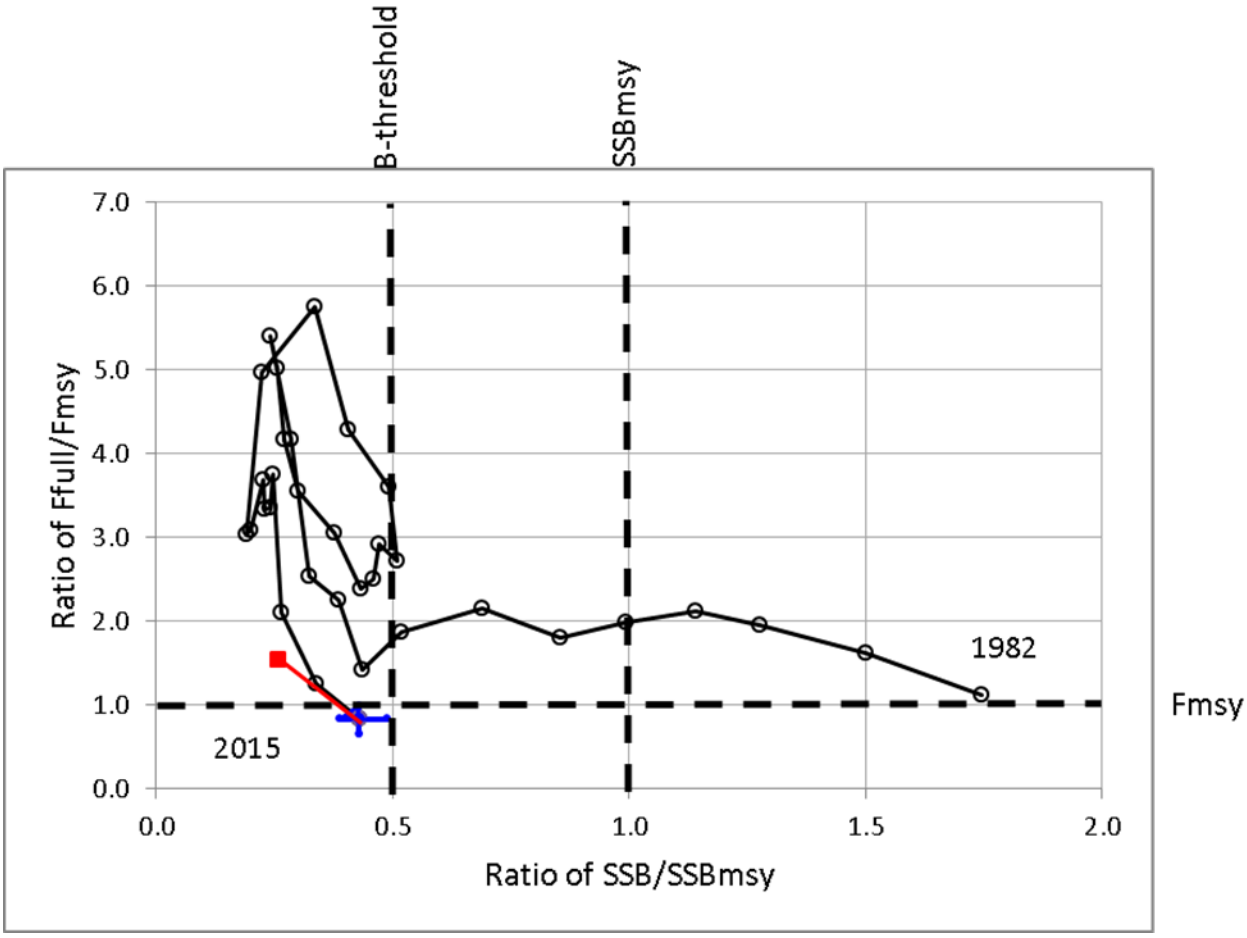
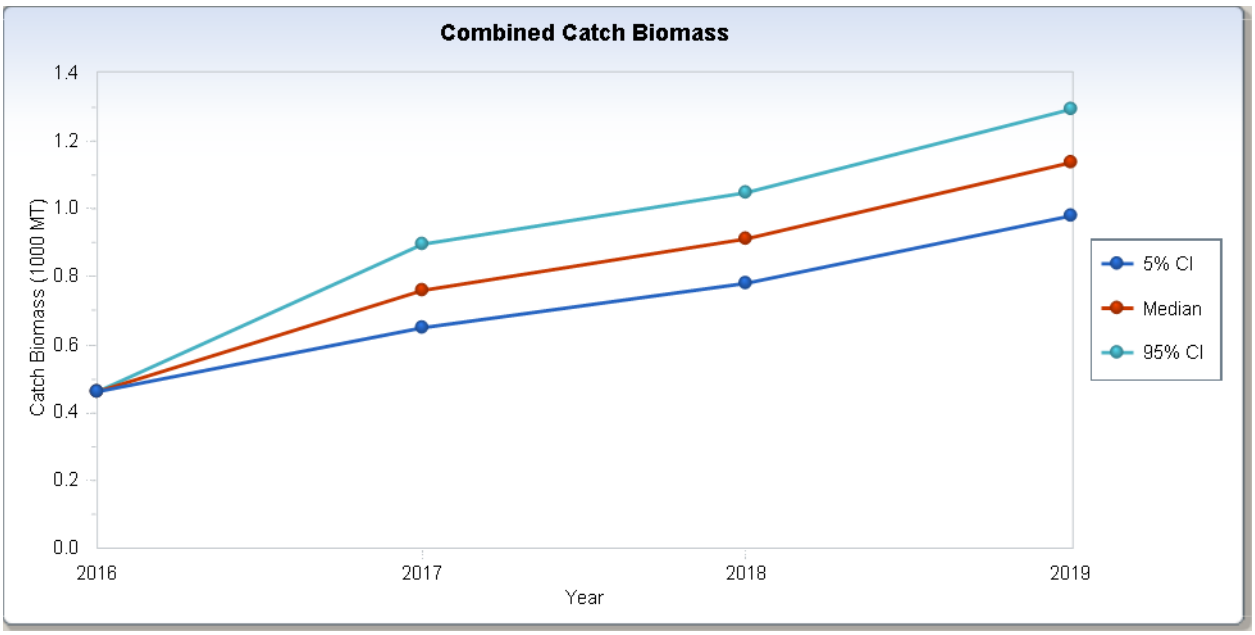


Figure B172. Time series plot of the witch flounder fully selected fishing mortality/F_{MSY} ratio relative to the spawning stock biomass/SSB_{MSY} ratio from 1982 to 2015 (black line with open circles) based on ASAP Run_9_5_v2. The retrospectively adjusted current stock status is indicated with a red solid square; the unadjusted stock status (blue solid circle) along with the corresponding 90% confidence intervals (blue lines) is also shown.



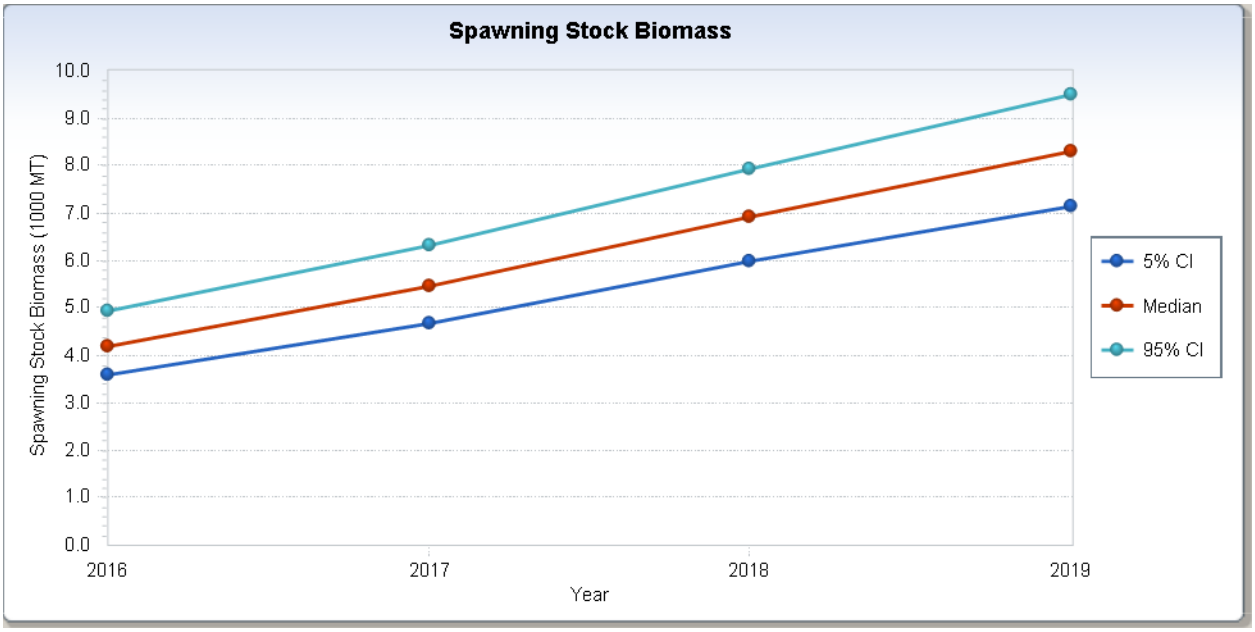
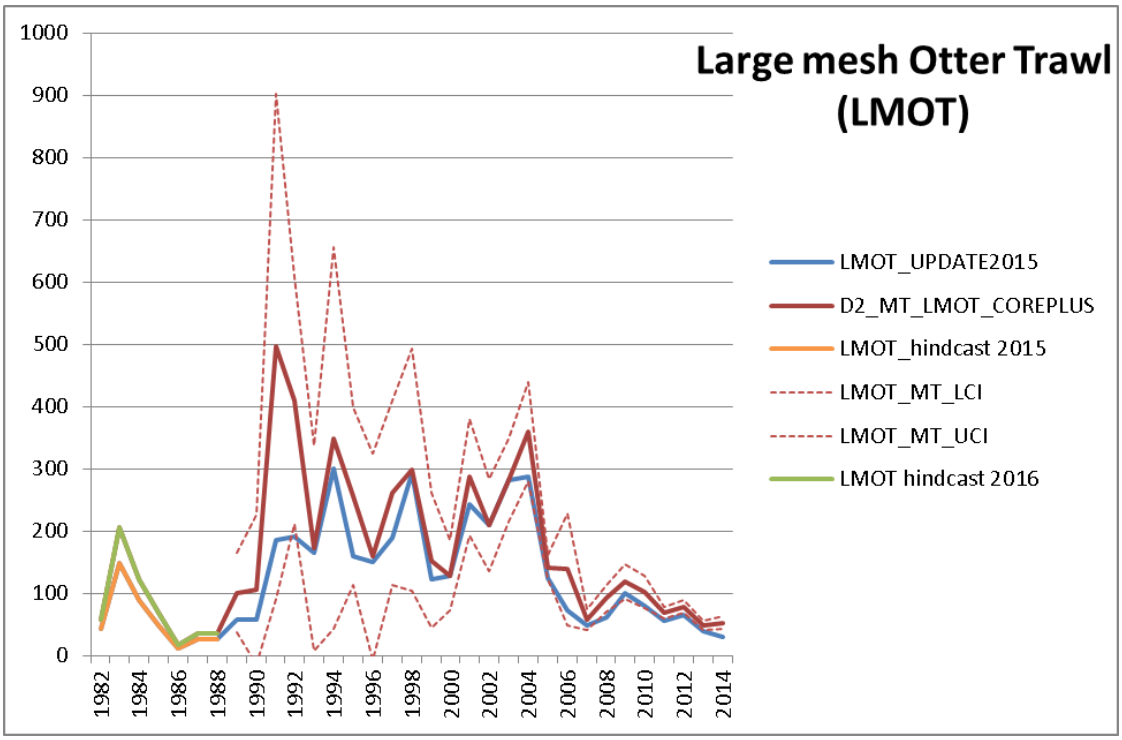
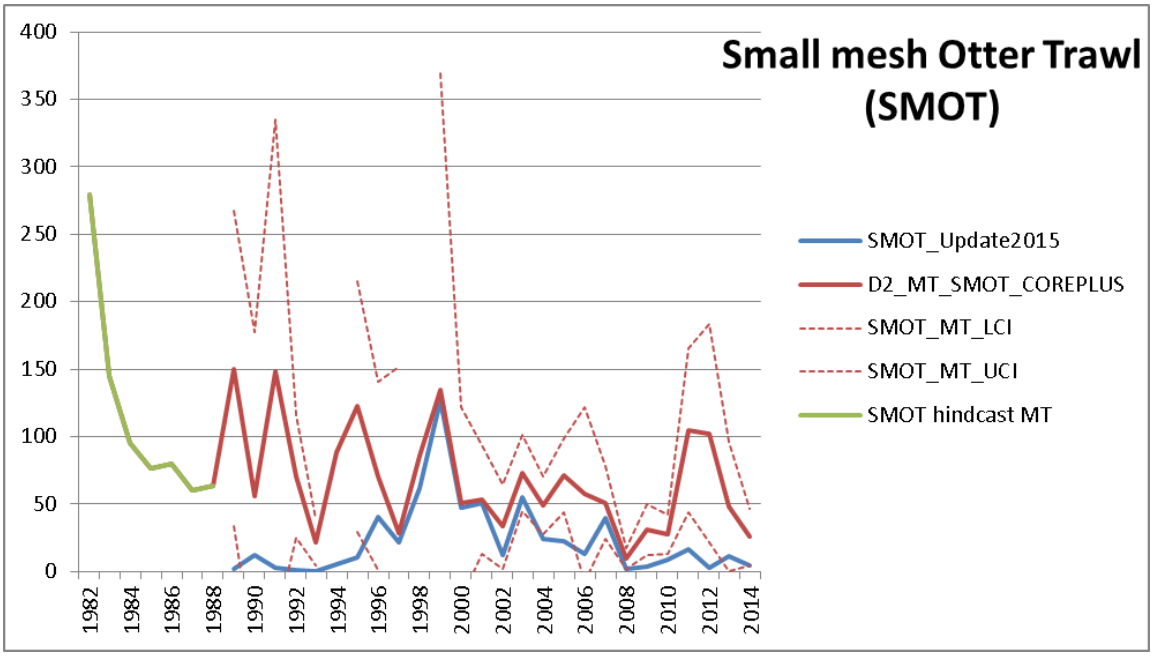


Figure B173**.** Short-term projections of total fishery yield (‘000s mt; top) and spawning stock biomass (‘000 mt; bottom) for witch flounder based on an assumed catch of 460 mt in 2016 and fishing at $F_{40\%}$ between 2017 and 2019. A retrospective adjustment (0.6608) was applied in the projections from ASAP Run_9_5_v2.

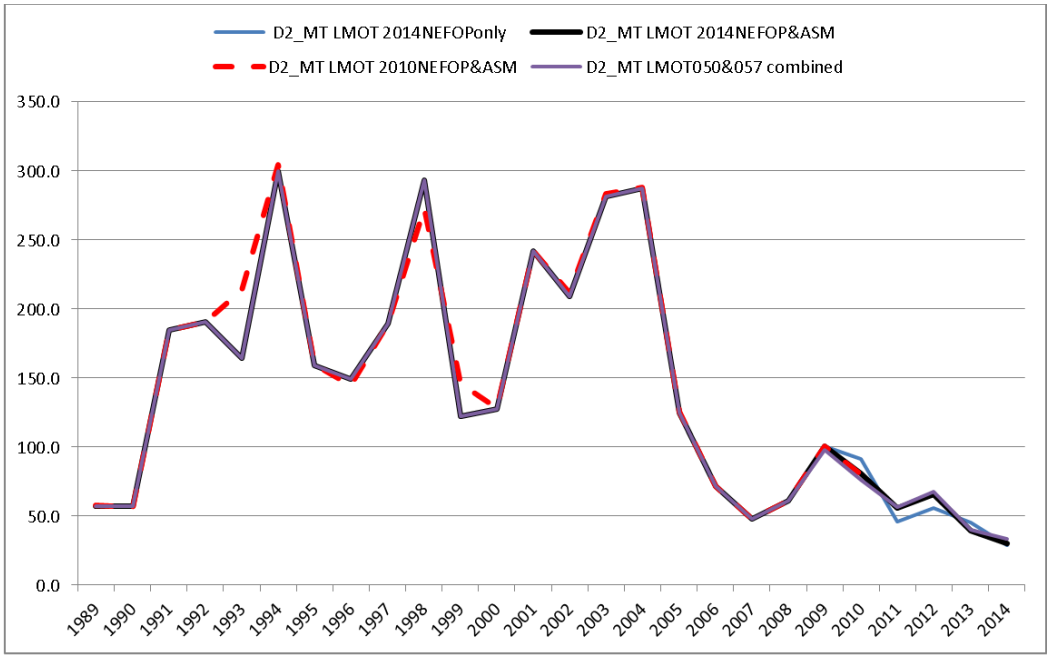
Appendix Figures

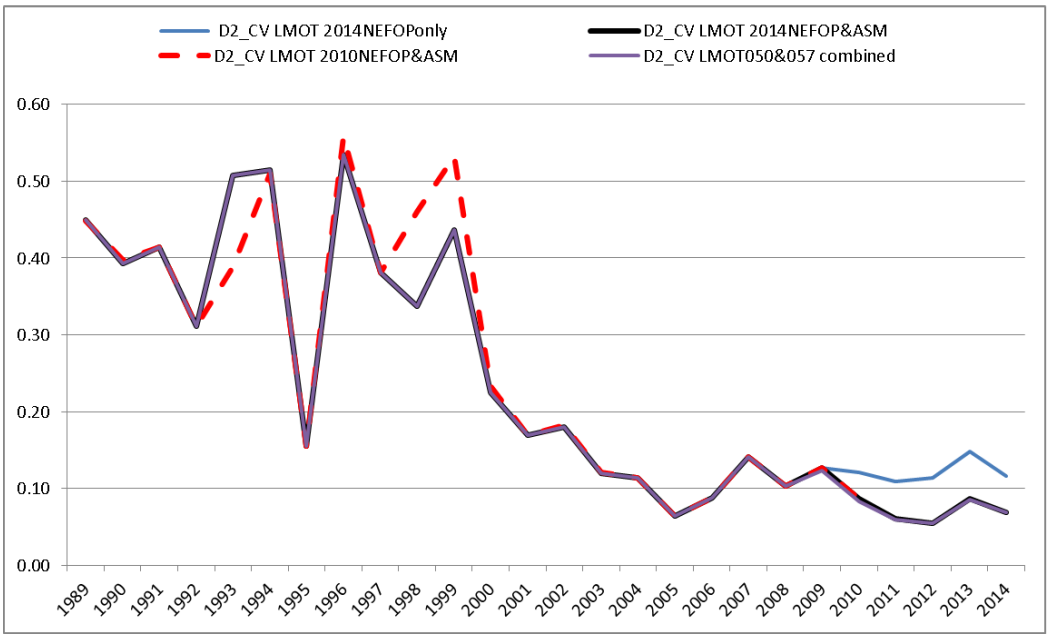


Appendix Figure B1. Witch flounder discards (mt; solid lines) with 95% confidence intervals (dashed lines) in the large mesh otter trawl fishery, 1982-2014.

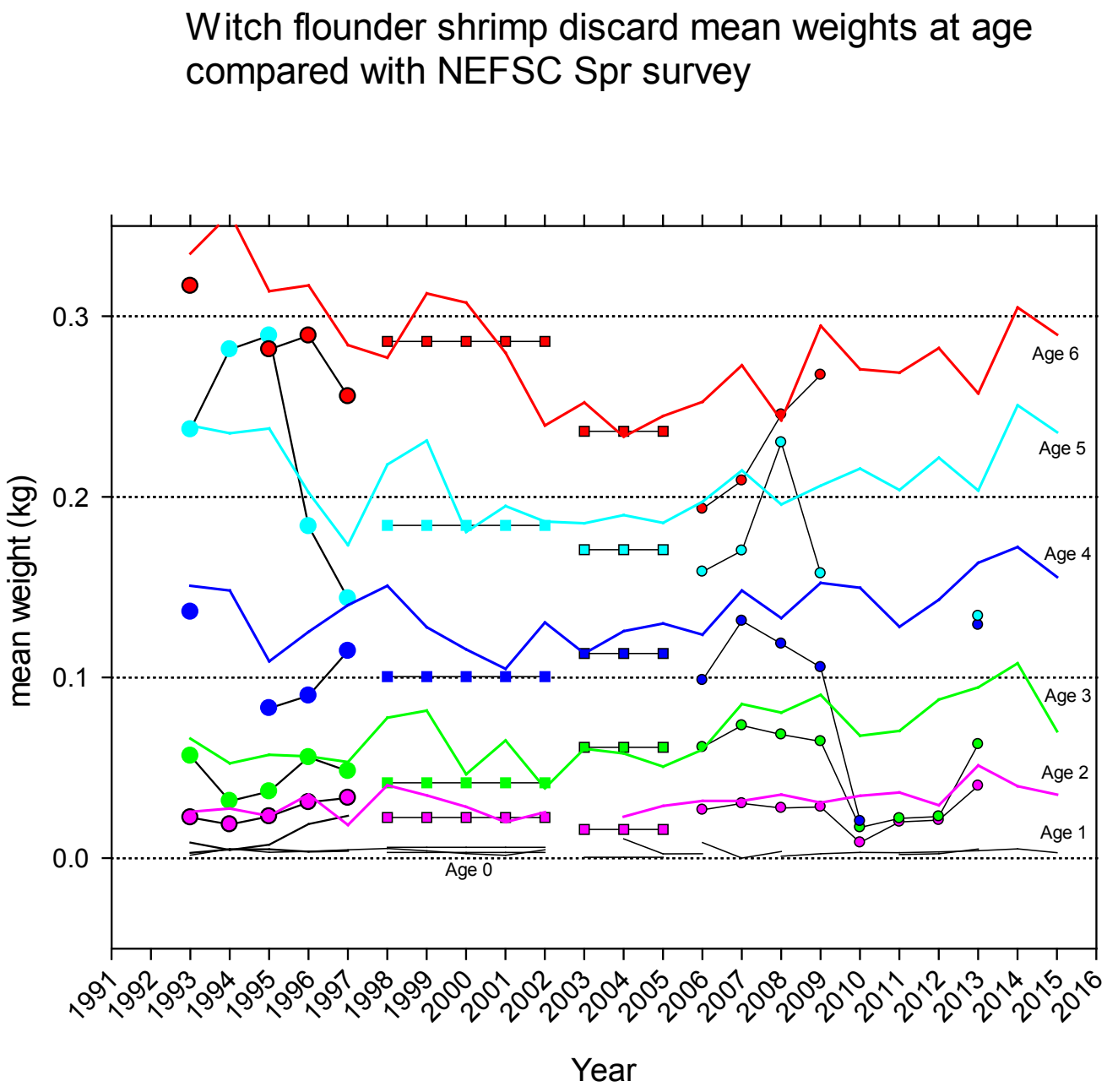


Appendix Figure B1. Witch flounder discards (mt; solid lines) with 95% confidence intervals (dashed lines) in the small mesh otter trawl fishery, 1982-2014.

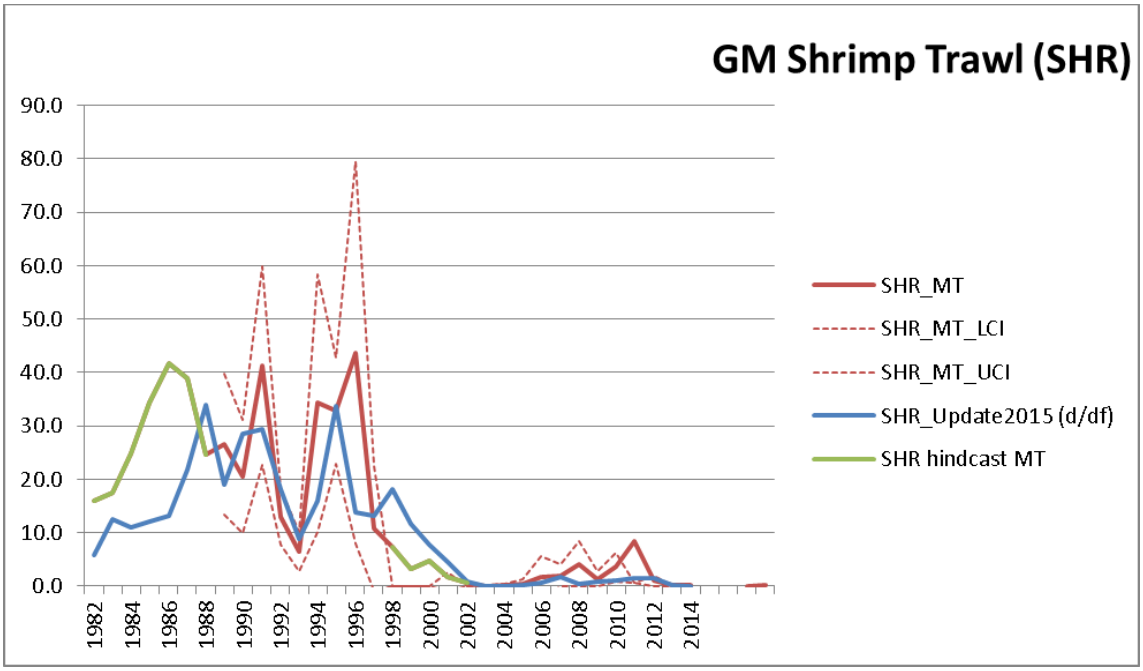




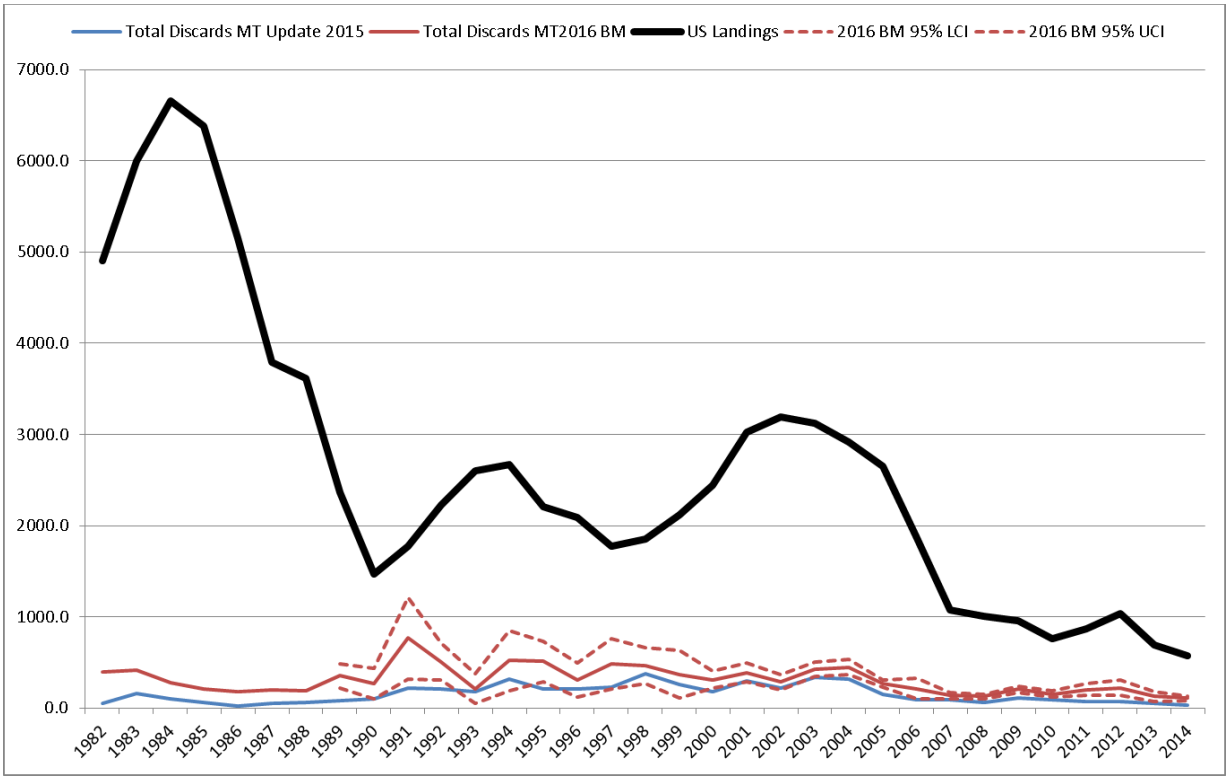
Appendix Figure B2. Comparison of large mesh otter trawl discards derived using Northeast Fisheries Observer Program (NEFOP) and At-Sea Monitoring (ASM) data (black line) and large mesh otter trawl and haddock separator trawl (combined) discards using NEFOP and ASM data (purple line) for the CORE region. Large mesh otter trawl discards using NEFOP only (blue line) and large mesh otter trawl discards using NEFOP and ASM data from the 2012 Update (red dashed line) are also given for perspective.



Appendix Figure B3. Witch flounder mean weight at age for discarded fish in the Gulf of Maine shrimp trawl fishery, 1993 – 2015. Means weights at age derived from Northeast Observer Program discard length frequency and Northeast Fisheries Science Center spring survey age data age are indicated with circles; average mean weights at age for 1989-2002 and 2003-2005 are derived using the 5 year weighted mean weights. Spring survey mean weights at ages (solid lines with no symbol) are also show for comparison purposes only.



Appendix Figure B4. Witch flounder discards (mt; solid lines) with 95% confidence intervals (dashed lines) in the Gulf of Maine shrimp trawl fishery, 1982 to 2014.



Appendix Figure B5. Witch flounder landings (mt; bold solid line) and total discards (mt; blue line) from the 2015 Update and total revised discards (mt; red line) with 95% confidence intervals, 1982 – 2014.

WITCH FLOUNDER APPENDICES

APPENDIX B1 Sweep Study Working Paper with supporting information

APPENDIX B2 Replacement Yield (RY) Model Working Paper

APPENDIX B3 Statistical Catch At Age (SCAA) Model Working Paper

APPENDIX B4 Virtual Population Analysis (VPA) Model Input

APPENDIX B5 Age structured Assessment Program (ASAP) Model Input

APPENDIX B6 Collection of Slides provided during SARC Discussion

APPENDIX B1

Empirical estimates of maximum catchability of Witch Flounder *Glyptocephalus cynoglossus L.* on the Northeast Fisheries Science Center Fall bottom trawl survey

Authors in Alphabetical Order: Jon Hare[1], John Hoey[2], John Manderson[1,2], Michael Martin[3], Phil Politis[3], David Richardson[1,2], Chris Roebuck[4],

1 Oceans and Climate Branch, Northeast Fisheries Science Center
2 Cooperative Research Branch, Northeast Fisheries Science Center
3 Ecosystem Surveys Branch, Northeast Fisheries Science Center
4 Fishing Vessel Karen Elizabeth, Point Judith RI

ABSTRACT

For fisheries research surveys the catchability coefficient (q) defines the relationship between a survey index and population size. Typically, catchability is estimated within a stock assessment model. However, in many situations an empirical estimate of survey gear catchability can provide important information to scale population size during an assessment. We used a gear comparison study with a twin trawler to develop an estimate of maximum catchability of Witch Flounder on the Northeast Fisheries Science Center bottom trawl survey. On average, catch rates in the experimental chain sweep gear were about 4-fold the catch rates of the rockhopper sweep gear used on the standard survey. Both day:night differences and length-specific differences were evident in relative catch efficiencies of the two sweeps. Two separate analytical techniques (beta-binomial models & bootstrapping) provided very similar results; indicating that on a relative scale, the chain sweep was more efficient than the rockhopper sweep during daylight hours and at catching small individuals. Age-specific maximum catchability for the rockhopper survey gear was developed on the assumption of 100% efficiency of the chain sweep between the wings. An asymptote of maximum catchability for the NEFSC survey was reached at age-7 and at a value of 0.291 if survey data is entered into a stock assessment model as Bigelow swept area biomass or 0.056 if entered as Albatross swept area biomass.

INTRODUCTION

Flatfish are dorsoventrally flattened and use cryptic coloration and inactivity on the seafloor or burial in sediments as tactics to evade predators. Flatfish use vision to detect predators at short distances and typically remain within ½ a body length of the seabed when they take flight (Ryer, 2010). Following a brief period of swimming they often resettle on the substrate and may rebury. Their short reactive distance and intimate association with the seabed makes them uniquely susceptible to bottom trawling and specialized trawls have been developed to efficiently capture flatfish (Ryer and Barnett 2006, Ryer 2008, Ryer et al. 2010, Underwood et al. 2015). Flatfish are generally more susceptible to bottom trawls with sweeps that maintain contact with the seabed throughout their length. On commercial trawls, sweeps may also be extended by adding bridles between the net and doors that promote herding of flatfish from beyond net wings.

Fisheries independent bottom trawl surveys are used to assess the size and condition of marine populations, including flatfishes. In multi-species surveys, sampling gear is not optimized for any particular species, but rather is designed to provide representative samples that allow indices of abundance, size and age to be developed for many species. Unlike specialized flatfish trawls, survey trawls often utilize sweeps with discs or other modifications that allow nets to be towed across a wide variety of habitats, even seafloor habitats with complex physical structures. Survey nets may also utilize short bridles that minimize herding and decrease variability in swept area.

Indices of abundance at age and size derived from fisheries independent bottom trawl surveys are scaled to population size using the survey catchability (q) parameter. Catchability is typically estimated internally within population assessment models that incorporate fisheries landings, survey-based estimates of population trends and age structure and life history parameters. However, under many circumstances empirical estimates of survey catchability can provide important information to an assessment, either as a diagnostic of assessment model accuracy or as a direct input into the assessment model. Two sources of observation error are accounted for by the catchability parameter. These are detectability (δ), the proportion of organisms present at a sampling site detected with the sampling method (also termed gear efficiency), and availability, (ρ), the proportion of a population falling within the space-time frame of the survey:

$$q = \delta * \rho$$

Catchability is used in equations to estimate population biomass B_t at time t based on tow swept area in the following manner:

$$B_t = \frac{A}{aq} \mathrm{I}_t$$

Where I_t is the index of stratified mean biomass per sample, a is the area covered by the average sample (e.g. swept area of the tow) and A is the area covered by the survey. The following equation, with the explicit inclusion of detectability and availability, is equivalent:

$$W_t = \frac{A}{a\delta\rho} \mathrm{I}_t$$

Absolute values of detectability are difficult to estimate because accurate abundances of animals in the field are usually not available. However, maximum bounds on detectability can be established by comparing relative abundances (i.e. fish/km^2) of organisms caught in a scientific survey gear versus a gear optimized for a given target species or group of species. Because trawls used in most fishery independent surveys are not specifically designed to maximize capture of flatfish, field comparison of detectability in survey trawls and trawls specialized for the capture of flatfish with respect to sweep differences (but not bridle length) could be used to estimate maximum bounds on detectability, which can then be used to inform population assessments.

The analysis of controlled gear efficiency studies has greatly improved over the last twenty years beginning with the introduction of binomial models conditioned on the total catch of the gears being compared (Fryar, 1991, Millar, 1992). Further improvements have included the addition of smoothed non-parametric size effects through the use of GAM modelling, allowing a greater range of functional forms of this relationship (Munro and Somerton 2001; Fryer et al. 2003; Holst and Revill 2009) and accounting for within-pair extra-binomial variation through the use of beta-binomial models (Miller, 2013).

Witch flounder, *Glyptocaphalus cynoglossus L* , is a pleuronectid flatfish that ranges in the Western North Atlantic from North Carolina USA, to the Gulf of Saint Lawrence and Grand Banks, Canada and in the Eastern North Atlantic from Northern Spain to Norway. The animals mature at between 4 and 10 years of age at lengths of approximately 30 cm,. The animals prefer temperatures of ~7 ^{o}C, and are most abundant at depths ranging from 45 to 370 meters , However

the animals are known to occur >1000 meters deep (see: http://oceanexplorer.noaa.gov/okeanos/explorations/ex1304/dailyupdates/dailyupdates.html). Like most pleuronectids, witch flounder are often inactive, strongly associated with soft bottom habitats, and use burial in sediments to avoid predators.

The NOAA NMFS Northeast Fisheries Science Center bottom trawl survey is the main fisheries-independent source of information describing the abundance, age structure, and condition of witch flounder (along with ~60 other species in US waters) for population assessments. Sampling in the survey is performed using a 4-Seam trawl fitted with a rockhopper sweep made of discs that elevate the footrope ~ 16 cm above the seabed and allow the net to be towed on relatively complex seabeds (Fig. 1). This net was designed with relatively short bridles to minimize herding variability by minimizing the wing to door distance while maintaining the desired mouth opening. This appears to minimize the herding by the bridles of many benthic species including most flatfish. The NEFSC trawl survey occurs in during the Fall (September-November) and Spring (February-April) over periods of approximately 2 months (μ=56 days, 35-101 days) each year.

In this study we use a field experiment to estimate the relative detectability of witch flounder in the same net fitted with the rockhopper sweep routinely used in the NEFSC bottom trawl survey and a chain sweep optimized to capture flatfish. The experiment was performed on a commercial trawler with a twin trawl rig. Our goal was to estimate the sweep efficiency of the standard NEFSC survey trawl and develop a conservative, empirical upper bound for the detectability of witch flounder that could be used for the population assessment of witch flounder on the Northeast US Continental Shelf.

MATERIALS & METHODS

Field Experiment

The field experiment was performed on the FV Karen Elizabeth, a 24 meter twin rigged fishing trawler. The twin trawl rig allowed the vessel to tow two similar nets during each tow, allowing direct comparisons of the gear efficiency (Fig. 1-3). A number of studies have used twin trawl rigs to measure the relative efficiencies of trawls and trawl configurations, including studies focused on flatfishes (Ryer et al, 2010; Engas and Godo, 1989; Walsh, 1992; Munro and Somerton, 2002; Somerton et al., 2007; Ingolfsson & Jorgensen, 2006; Krag et al., 2010). Two 400 x 12 4-Seam trawls as used on the Northeast Fisheries Science Center (NEFSC) fishery independent bottom trawl surveys (for details, see Politis, 2014), were fished on both sides of the twin rig. The inside wings and sweeps of each net were attached by 38 m bridles to the 1134 kg central clump that was towed along the bottom (Fig. 3). The outside wings and sweep of each net were attached by a 38 meter bridles to 84" type 4 Thyborøn doors (weight = 590 kg; area = 3.39 m^2). On the second leg of the field experiment, the bridles were spray painted orange to visually determine what fraction were in consistent contact with the seabed by examining them for abrasion. This allowed us to determine if net spread was the appropriate metric for the estimation of swept area. To ensure consistent trawl geometry for each net irrespective of gear differences or depth, 32 meter restrictor ropes (9/16" Polytron) were connected between each of the doors and the clump. The spreading force of the doors, which are much larger than those used the spring and fall NEFSC trawl surveys (Poly_Ice oval - weight = 550 kg, area = 2.2 m^2), ensured that the restrictor rope remained consistently taut throughout each tow and ensured a wing spread of ~ 13 m for each net. From the attachment points and the likely orientation of the gear during towing, we believe that the restrictor ropes were ~ 1 m off the seafloor at the clump and ~ 1.5 m

at the doors when in fishing configuration. A trawl monitoring system was employed to monitor wing spread using spread sensors sewn into the outer portion of the wings.

The net on one side of the twin trawl was a standard NEFSC bottom trawl fitted with the rockhopper sweep (Politis, 2014). The rockhopper sweep has 30, 40.64 cm x 2.54 cm, 6.35 cm thick discs in the center of the net (total length = 890 cm) and 27, 35.56 cm x 2.54cm, 6.35 cm thick disks in each of the wings (total length = 820 cm). The net is connected to the bolchline which is then connected to the sweep with a wire traveller. The net with the rockhopper had 66, 20cm spherical floats positioned along the headrope and upper wing end extensions (Fig. 1). The net on the other side of the twin rig was fitted with a sweep specifically designed to maximize flatfish capture. The sweep was made with 2 rows of ½ inch (1.25 cm) steel chain (6cm) connected together every other link by 1/2 inch (1.25 cm) shackles (Fig. 2). The 3rd row of ⅝ inch (1.6 cm) chain of the sweep had 5 inch outer diameter x 2 inch hole diameter (12.7 cm x 5 cm) ⅜ inch (1 cm) thick disks at every second link. Every fourth link of the ⅝ chain was attached directly to the footrope of the net with a ½ inch shackle (Fig. 2). The headrope of the net with the chain sweep had 32, 20 cm spherical floats, roughly half the number of the standard survey trawl, to limit the buoyancy of the trawl and maximize seafloor contact.

Sampling was performed on two legs from August 7 through August 21, 2016 around the clock in two areas of the Gulf of Maine where witch flounder are known to occur (Fig 4). The two areas included the northern edge of Georges Bank, and an area off Cape Ann, Massachusetts. Our goal was to perform 25 tows in which witch flounder were caught in at least one net in each tow during the day and night within each region to maximize the precision of estimates of the relative detectability of the nets with the two sweeps. Tows were made in a range of sediment types that included soft mud, sand, coarse gravel and shell hash. Standard tow speed (3 kts) and duration (20 minutes) for the NEFSC survey tows were used and tows were therefore approximately 1nm (1.852 km) long. The scope table used for the NEFSC survey was modified to allow trawl wire in 25 fathom increments, rather than the more precise increments available on the Bigelow. An area of approximately 24,076 m^2 (13m*1852m) was swept by each net during each tow. GPS data were recorded every second aboard the vessel. Temperature and depth sensors (Star Oddi, DST centi-TD) were mounted on the center of the headrope and footrope of each net during leg 2. At the approximate midpoint of sampling in each 7 day leg, the sides on which the nets with sweeps were fished on the twin trawl rig were switched.

All flatfish, skates, and scallops collected in each net in each tow were independently sorted and weighed. The lengths of all flatfish, cod, and monkfish captured in each net were measured when fewer than approximately 150 individuals were present in the catch for that species, otherwise the catch were randomly sub-sampled for length.

Estimates of sweep efficiency by length and day/night were derived via two different methods:

1) The data were fitted under differing assumptions about the mean relative catch efficiency using either the binomial or beta-binomial distribution to model variation both within and between pairs by fish length. The relative performance of the models was compared using Akaike's information criterion (AIC; Akaike 1973).

2) Mean catch ratios with bootstrapped confidence intervals were calculated and a maximum estimate of catchability was derived.

Binomial/Beta-binomial data analysis

The objective of this analysis was to derive a model-based estimate of sweep efficiency for all lengths of fish captured in the experiment. The start of each tow was defined as the winch lock time and the end of the tow was defined as the haul back time. Mean net spread for each tow was

estimated from the net mensuration data. For tows where net spread information was not available, net spread was estimated via a generalized additive model (GAM) using depth, mean vessel speed and sweep type as predictor variables. The distance fished was estimated by first smoothing the gps data with a cubic spline smoother and summing the distances between the smoothed points. The area swept for each tow was calculated as the mean net spread*distance fished. A catch per unit effort (CPUE in numbers) by length was then calculated for each tow.

All of the CPUE length data were then fit following the methods of Miller (2013). A total of 5 conditional binomial (Table 4) and 8 conditional beta-binomial models (Table 5) were fit to the data. The relative performance of all model fits was compared using marginal AIC. The best performing model was selected as the candidate for further analysis. The CPUE length data were then designated as either day or night using the time of the mid-point of the tow for both location and time information as calculated from the AstroCalc4R package (Jacobsen et al, 2011). A similar analysis as described above was performed on each of these subsets of the data and the best performing model chosen.

Development of a maximum estimate of catchability

The objective of this analysis was to develop a maximum estimate of catchability that could be input into the stock assessment model or alternatively could be used to develop a minimum estimate of spawning stock biomass in future analyses. Since the comparative experiment occurred in August which has oceanographic conditions much more similar to the fall versus spring bottom trawl survey, we focused our analyses on obtaining a catchability parameter that could be applied to the NEFSC fall trawl survey. Furthermore, we focused on developing maximum estimates of catchability by age-class, as the assessment models use abundance-at-age data from the surveys rather than abundance-at-length data.

The first step of the analysis involved calculating length-specific (1 cm interval) catch ratios of the chain sweep relative to the rockhopper sweep from the comparative gear experiment. These analyses were done separately for daytime and nighttime tows, with the "suncycle" function in Matlab used to designate tows as daytime or nighttime. We used bootstrapping to develop confidence intervals around these estimates. Paired nets were maintained with the bootstrapping and median ratios and 95% confidence intervals are presented.

Most flatfish exhibit significant night:day catch ratios in the NEFSC trawl survey that will dictate how the comparative gear experiment is analyzed. For example, windowpane is a species for which the night:day ratio on the survey often exceeds the daytime experimental gear:survey gear ratio. In this case the detectability of the daytime experimental tows does not exceed that of the nighttime survey tows. For a species such as windowpane the comparative gear experiment should thus focus on establishing the maximum detectability of the nighttime survey tows (assuming the nighttime comparative gear tows are 100% efficient) and should use the survey data to estimate the relative detectability of the daytime survey tows relative to the nighttime survey tows.

For witch flounder on the NEFSC trawl survey the night:day catch ratio is lower than many flatfish (≈1.4 Night:Day 2009-2014 Fall; 30 cm+ fish) and is similar to the chain sweep: rockhopper sweep efficiency difference between the daytime and nighttime (1.5). We thus assumed that the daytime and nighttime tows with the chain sweep were both equally 100% efficient. The maximum efficiency of the 24-hour survey tows is thus a weighted average of the nighttime efficiency differences of the chain to rockhopper sweep and the daytime efficiency differences of the chain to rockhopper sweep. The average number of daytime and nighttime tows on the fall trawl survey in the strata used for the witch flounder serves as weighting factors.

To obtain estimates of age-specific maximum catchability of the survey on the R/V Bigelow the relative abundance at length of each age-class on the NEFSC fall trawl survey was combined with the length-specific maximum catchability estimates. For the 2009-2015 fall trawl survey on the R/V Bigelow, the stratified mean number per tow at length (strata: 22-30 & 36-40) was first calculated for each year. An age-length key was developed for each year and was applied to the stratified mean number at length to estimate the length-distribution for each age class. To obtain the maximum catchability at age the relative proportion at length for each age class and year was multiplied by the maximum catchability at length for each of the 1000 bootstrap runs of the comparative trawl survey analysis. These products were then summed. The median and 95% confidence intervals of these 1000 bootstrap runs across 7 years are reported as are the annual values.

RESULTS

We successfully completed 118 twin trawl tows of both trawls from August 7 – 21, 2016 (total number of tows = 125). Fifty eight successful tows were made on the west side of Georges Bank during the first leg of the cruise (Aug 7-14; Fig. 4). Three successful tows were also made just east of Cape Cod during this leg. During the second leg of the cruise (Aug 14-21), 57 successful tows were made in the area east of Cape Anne, Massachusetts. Depths of the tows ranged from 40-152 meters.

Spread data indicated that both nets maintained very close to the desired 13 m wing spread on all successful tows. This observation confirmed that the two trawls were maintaining consistent geometry regardless of depth or differential pressure exerted on the trawls due to differences in either sweep or floatation. The chain sweep was much more susceptible to hanging as anticipated, and all but one of the tows with unacceptable performance were due to problems with the chain sweep trawl capturing bottom substrate (rocks, mud etc.).

Witch flounder were the most common and abundant of the 17 species quantitatively sampled during the experiment. They accounted for over 36% of the total measured biomass and were present at all of the sites where tows were performed. American plaice, goosefish, and several skate species were also relatively common). Biomass collected in the chain sweep was higher than the rockhopper sweep for all species occurring in more than 3 tows.

A total of 53,495 witch flounder were caught during the 118 representative tows of the twin trawl, with 43,789 caught in the net with the experimental chain sweep and 10,706 caught in the net with the rockhopper sweep used during the standard NEFSC trawl survey (Table 1). These catch ratios were similar between the leg of the survey that sampled Georges Bank and the leg of the survey that sampled the western Gulf of Maine. Notable length-specific differences were evident in the relative catch rates of the two sweeps during both the day and night (Table 3, Figs. 6-10). The ratio of chain sweep to rockhopper sweep catches were highest for the smallest length classes during both the daytime and nighttime.

Binomial/beta-binomial analysis results

The best fitting model for all data combined is presented in Figure 7. The best fitting model for this data set was beta-binomial model BB3 (Table 4-5). This models also provided the best fit for nighttime tows (Figure 8), while daytime tows were best fit with model BB7 (Figure 8). The results from the binomial/ beta-binomial analysis showed an overall sweep efficiency of .231 for witch flounder for the standard NEFSC rockhopper gear, assuming the chain sweep was 100% efficient. The daytime efficiency estimate was .193, while the nighttime ratio estimate was .271, indicating a catch ratio of ~1.4:1 between day and night catches.

Bootstrapping analysis results

During the Fall, the NEFSC trawl survey on the R/V Bigelow catches on average 1.4 fold the number of witch flounder (30 cm+) during nighttime tows versus during daytime tows. For similarly sized fish the chain sweep was 4.80-fold more efficient than the rockhopper during the daytime and 3.12-fold more efficient than the rockhopper during the nighttime, a difference of 1.53-fold. This implies that the chain sweep had a similar efficiency during both nighttime and daytime. We thus proceeded with an analysis that assumed the chain sweep was 100% efficient during both nighttime and daytime tows. During the fall bottom trawl survey, the Gulf of Maine (strata 22-30 and 36-40) is typically sampled after the fall equinox when there are more nighttime hours than daytime hours. Since the start of the Bigelow time series, ≈43% of tows have been during the day and 57% at night in the Gulf of Maine strata. We used these two values as weighting factors in calculating an aggregate 24-hour estimate of the maximum catchability of the rockhopper gear used during the NEFSC trawl survey; this procedure had the effect of downweighting the higher catch ratio daytime tows.

The maximum catchability of the rockhopper gear increased with age from Age 3 to Age 7 (Table 6 and Figure 11). The maximum catchability was nearly constant for Age 7 to Age 11+ fish. For Age-7 fish the maximum catchability of the rockhopper gear used on the Bigelow was 0.291 with 95% confidence intervals of 0.264-0.321. The calibration of Albatross to Bigelow is 3.257 across all age classes for the number of fish per tow. An Albatross tow sampled 1.6 fold the area of a Bigelow tow (0.038 km^2 versus 0.024 km^2), and thus the Rockhopper net used on the Bigelow survey is estimated to be 5.2-fold as efficient as the net used on the Albatross survey. For Age-7 fish the maximum catchability of the Albatross gear was 0.056 with 95% confidence intervals of 0.051-0.062. All other age classes had lower maximum catchabilities. This maximum catchability value of Age-7 fish not differ much on an interannual basis using annual age-length keys and stratified mean numbers at length.

DISCUSSION

With some notable exceptions (e.g. acoustic surveys, camera surveys of scallops, egg surveys), the primary goal of research surveys is to provide an index of abundance rather than an absolute estimate of abundance. One function of a stock assessment model is to integrate a diverse set of data to determine the scale of the population. However, a variety of factors can make for imprecise scaling of population levels including inaccurate catch data, low fishing mortality rates over the time series, uncertain and time-varying natural mortality, and time-varying catchability on the research survey leading to biased estimates of trend. In these cases, external information can serve a role in population scaling, even if only to establish minimum estimates on stock biomass.

The purpose of this analysis was to establish a maximum bound on catchability of the NEFSC fall trawl survey and data which could be used to obtain a minimum bound on the estimate of spawning stock biomass. We report values of catchability in both Bigelow units and Albatross units. The standard for most NEFSC stock assessments has been to convert the Bigelow trawl survey data to the equivalent values for the Albatross trawl survey. Assuming swept area biomass estimates are the input to the stock assessment, the catchability numbers output by the assessment models are for a tow with the net used on the Albatross survey. For witch flounder, a constant calibration factor across length classes of 3.257 is used to convert the N tow^{-1} of fish on the Bigelow survey to the equivalent for the Albatross survey. Importantly, a Bigelow tow, in addition to catching more witch flounder per tow, is also sampling a smaller area

than an Albatross tow (0.024 km^2 vs 0.038 km^2), a factor that needs to be considered in analyses of catchability. The Albatross maximum catchabilities are thus a factor of 5.2 (3.257*(0.038/0.024)) less than the Bigelow maximum catchabilities. Similarly catchabilities output by the stock assessment model with Albatross swept areas as the input need to be multiplied by 5.2 to obtain the estimated Bigelow survey catchability. If the calibration factors were to be changed in future work (e.g. length specific catchabilities), these changes would need to be accounted for in these analyses of maximum Albatross catchability.

The primary data used in this analysis came from an experiment using a twin trawler and many of the standard tow protocols for the NEFSC survey on the R/V Bigelow. The experimental net used on the other side of twin trawler was similar to the standard bottom trawl survey trawl used on the R/V Bigelow but with roughly half number of floats was reduced and the sweep was modified to optimize flatfish catch by reducing the ability of individuals to pass under the net. As has been shown for past experiments, these modifications resulted in an increased catch rate of flatfish in general. All analyses of this data were based on the assumption that modifying the sweep resulted in the experimental net being 100% efficient (i.e., every fish encountered between the wings of the net is caught), an assumption which is almost certainly incorrect based on previous observations of escapement for a number of flatfish species.

The decision on what value of catchability to input into a stock assessment model depends on the selectivity pattern for the associated survey. The maximum catchability calculated based on the experimental tows increased with age until reaching an asymptote at 0.291 in Bigelow units (0.056 in Albatross units) at Age-7. The Age-7 maximum catchability is recommended as an input to the assessment model. Age-7 maximum catchability is also the highest value for any age class, and thus its use is conservative. A q of 0.291 corresponds to the chain sweep being estimated to be 3.43-fold more efficient than the rockhopper. This value is lower than the catch ratio of 3.99 across all tows on the twin trawl experiment. There are two reasons for this. First, the experimental survey sampled more tows during the day when catch ratios are higher, whereas the analyses used a weighting factor based on the fall survey which samples more nighttime tows in the Gulf of Maine. Second, the aggregate catch ratio includes smaller fish that, on a relative basis, were sampled more effectively by the chain sweep, whereas the recommended q-value is for larger fish more likely to correspond to the asymptotic selectivity of the NEFSC trawl survey.

The analyses presented here assume that bridle herding did not occur, and thus that wing swept area, rather than the door swept area, is the appropriate measure of the area swept by a tow. Herding is a known phenomena for flatfish and many other species when certain types of gear are used (Ramm and Xiao 1995, Somerton and Munro 2001, Somerton et al. 2007, Rose et al. 2009). Our decision to use wing swept area was based on two factors. First, the gear used on the Bigelow survey was specifically designed to minimize herding. On the experimental work, the bridles used during the tows were painted to evaluate whether they were making contact with the bottom and thus were potentially herding flatfish; abrasion from bottom contact would result in the paint wearing off. The paint was not observed to wear off during the tows consistent with the design of the gear and previous work. The second factor underlying our decision to use wing swept area was that published behavioral studies in both the field and lab have indicated reduced and minimal herding of flatfish during nighttime tows (Ryer 2008, Ryer et al. 2010). Most published examples of herding are from daytime studies (Somerton et al 2007, Underwood et al 2015). Use of wing swept area for nighttime tows is consistent with those results. The reason for minimal herding at night is the tendency of fish to rise off the bottom in low light levels rather than engage in directional swimming near to the seafloor as they do during herding at higher light levels (Main and Sangster, 1981; Walsh, 1988, 1991; Walsh and Hickey, 1993; Casey and Myers, 1998; Cadrin and Westbrook, 2004; Ryer and Barnett 2006). This differential behavior is likely to underlie the higher catch rates in survey gear of many flatfish during the night.

The towing of the standard survey bottom trawl differed in a few ways from its deployment on the spring and fall bottom trawl surveys, but we believe that these differences did not have a significant effect on the results. The use of larger doors and the restrictor rope served to fix the net geometry which is likely the biggest potential source of variability in comparative trawl catches. This setup also allowed us to avoid many of the potential problems due to the rather large size difference of the Bigelow and the Karen Elizabeth. The use of the restrictor rope is not believed to have influenced flatfish behavior in front of the trawl as flatfish have been shown to generally not react to trawling induced stimuli until they are in in very close proximity or even contacted by the fishing gear (Ryer et al, 2010). The spread data indicated that the restrictor rope remained taut throughout the towing process (setting, towing, hauling back), so we believe it likely that the restrictor rope was almost always at least 1 m off the bottom at all times. All information indicates that bridle herding was very minimal for flatfish, and therefore the possibility of an increase in herding due to an increase in mud clouds from the use of larger doors was likely a non-factor in the catches that we observed. Similarly, the use of the clump instead of a door was likely not a factor for similar reasons. The use of a modified scope table was likely a very small difference as the amount of wire out never differed (+/-) by more than 13 fm from what the Bigelow scope table prescribes.

A concern raised in previous work is that the results of gear comparison experiments, which are often logistically constrained to certain seafloor types or time of year, may not be broadly applicable to other regions or seasons. We assumed 100% efficiency of the chain sweep in the analyses with the goal of obtaining a maximum efficiency. A catch ratio higher than what we observed in another area would suggest even lower rockhopper catchabilities in that area. In this case the maximum efficiency would be an overestimate. Similarly, if the catch ratios were lower in another unsampled area but the catchabilities of the rockhopper survey gear were assumed to be constant across space, the results would also be valid. Where this caveat is relevant is if the catchabilities of the survey rockhopper gear vary spatially- temporally, and the gear comparison experiment occurred in a low catchability area or time of year for the rockhopper sweep, that is not an equally (on a relative scale) low catchability area for the chain sweep. Empirical data on spatially varying survey catchabilities of the rockhopper sweep is not available. Over the course of the experiment, the gear were towed on a variety of habitats including mud, cobble, shell hash and sand. Additionally, the two study areas in the western Gulf of Maine and northern edge of Georges Bank had similar catch ratios for both the daytime and nightime tows (Table 2). The study was obviously constrained in the time of year in which the work was conducted and temperature has been shown to play a role in catchability for other fish species (Winger et al., 1999; Swain et al., 2000). There is also some evidence that catchability may also be related to density in some species (Godo et al, 1999). We were able to sample in a variety of flatfish densities and the catch ratios remained remarkably consistent so we see no evidence of this behavior in the current study.

The two analyses that were performed differed in several substantial ways from the treatment of the raw data (area-swept estimated vs. raw catches), the analytical methods utilized, and the methodology to derive final results. The fact that the two independent analyses found very similar results (Fig. 10) increases the probability that the results presented here are robust.

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Table 1: Summary data on Witch Flounder (*Glyptocephalus cynoglossus*) catches from the twin trawl experiment aboard the F/V Karen Elizabeth in August of 2016.

	Tows	Rockhopper Sweep Total N	Chain Sweep Total N	Total Catch
Night	43	5,893	19,152	**25,045**
Day	74	4,813	23,637	**28,450**
Total	**117**	**10,706**	**42,789**	**53,495**

Table2 : Total catch numbers and chain sweep to rockhopper catch ratios for tows made during the daytime and at night for each of the two legs of the survey

	Day		Night	
	Leg 1 Georges Bank	Leg 2 WGOM	Leg 1 Georges Bank	Leg 2 WGOM
Chain	9,035	14,592	9,013	10,149
Rockhopper	1,747	3,070	2,653	3,236
Ratio	5.17	4.75	3.40	3.14

Table 3: Summary data on Witch Flounder (*Glyptocephalus cynoglossus*) catches at length from the twin trawl experiment aboard the F/V Karen Elizabeth in August of 2016.

	Night		Day		Total	
Length	Chain Sweep	Rockhopper Sweep	Chain Sweep	Rockhopper Sweep	Chain Sweep	Rockhopper Sweep
<25	254	37	264	33	518	70
25	95	15	129	23	224	38
26	188	47	200	39	388	86
27	539	138	542	84	1081	222
28	759	203	859	172	1618	375
29	1229	291	1223	213	2452	504
30	1428	422	1630	294	3058	716
31	1666	521	1958	363	3624	884
32	1867	500	2073	381	3940	881
33	1604	470	2053	364	3657	834
34	1795	527	2059	417	3854	944
35	1376	473	1673	321	3049	794
36	1434	475	1722	408	3156	883
37	953	277	1119	265	2072	542
38	980	348	1259	300	2239	648
39	667	244	787	236	1454	480
40	697	235	971	238	1668	473
41	370	146	698	155	1068	301
42	303	134	568	119	871	253
43	266	119	526	120	792	239
44	179	86	380	68	559	154
45	147	61	319	57	466	118
46	128	32	213	51	341	83
47	77	24	160	26	237	50
48	54	23	100	28	154	51
49	27	12	74	15	101	27
50	19	10	29	9	48	19
>50	51	23	49	14	100	37

Table 4. Description of relative catch efficiency (ρ)parameterizations for conditional binomial models
fit to data (From Miller 2103)

Model	log(ρ)	Across-pair effects	Pair-specific random effects
BI_0	β_0	Intercept	None
BI_1	$\beta_0 + \delta_{0,j}$	Intercept	Intercept
BI_2	$\mathbf{X}_f^T\boldsymbol{\beta} + \mathbf{X}_r^T\boldsymbol{b}$	Intercept and cubic spline smoother of size	None
BI_3	$\mathbf{X}_f^T\boldsymbol{\beta} + \mathbf{X}_r^T\boldsymbol{b} + \delta_{0,j}$	Intercept and cubic spline smoother of size	Intercept
BI_4	$\mathbf{X}_f^T(\boldsymbol{\beta}_f + \boldsymbol{\delta}_j) + \mathbf{X}_r^T(\boldsymbol{b} + \boldsymbol{\epsilon}_j)$	Intercept and cubic spline smoother of size	Intercept and cubic spline smoother of size

Table 5. Description of relative catch efficiency (ρ)and dispersion (ϕ) parameterizations for conditional beta-binomial models fit to data (From Miller 2103)

Model	log(ρ)	log(ϕ)	Across-pair effects	Pair-specific random effects
BB_0	β_0	γ_0	Intercepts for mean and dispersion	None
BB_1	$\beta_0 + \delta_{0,j}$	γ_0	Intercepts for mean and dispersion	Intercept for mean
BB_2	$\mathbf{X}_f^T\boldsymbol{\beta} + \mathbf{X}_r^T\boldsymbol{b}$	γ_0	Mean and dispersion intercepts and cubic-spline smoother of size for mean	None
BB_3	$\mathbf{X}_f^T\boldsymbol{\beta} + \mathbf{X}_r^T\boldsymbol{b}$	$\mathbf{X}_f^T\boldsymbol{\gamma} + \mathbf{X}_r^T\boldsymbol{g}$	Intercepts and cubic-spline smoothers of size for mean and dispersion	None
BB_4	$\mathbf{X}_f^T\boldsymbol{\beta} + \mathbf{X}_r^T\boldsymbol{b} + \delta_{0,j}$	γ_0	Mean and dispersion intercepts and cubic-spline smoother of size for mean	Intercept for mean
BB_5	$\mathbf{X}_f^T\boldsymbol{\beta} + \mathbf{X}_r^T\boldsymbol{b} + \delta_{0,j}$	$\mathbf{X}_f^T\boldsymbol{\gamma} + \mathbf{X}_r^T\boldsymbol{g}$	Intercepts and cubic-spline smoothers of size for mean and dispersion	Intercept for mean
BB_6	$\mathbf{X}_f^T(\boldsymbol{\beta}_f + \boldsymbol{\delta}_j) + \mathbf{X}_r^T(\boldsymbol{b} + \boldsymbol{\epsilon}_j)$	γ_0	Mean and dispersion intercepts and cubic-spline smoother of size for mean	Intercept and cubic spline smoother for mean
BB_7	$\mathbf{X}_f^T(\boldsymbol{\beta}_f + \boldsymbol{\delta}_j) + \mathbf{X}_r^T(\boldsymbol{b} + \boldsymbol{\epsilon}_j)$	$\mathbf{X}_f^T\boldsymbol{\gamma} + \mathbf{X}_r^T\boldsymbol{g}$	Intercepts and cubic-spline smoothers of size for mean and dispersion	Intercept and cubic spline smoother for mean

Table 6: Age specific maximum catchabilities (q) for the R/V Bigelow survey using the Rockhopper sweep based on the results of the twin trawl experiment. Medians and 95% confidence intervals are presented. R/V Albatross catchabilities are scaled to R/V Bigelow catchabilities using the constant calibration factor across lengths of 3.257 for N fish tow^{-1} and the difference in swept area between the two survey tows (1.6; 0.024 km^2 for the Bigelow and 0.038 km^2 for the Albatross). Age 7 is bolded as it corresponds to the highest maximum q of any age group and may make a suitable input for constraining the assessment model

	Bigelow	Albatross
Age 3	0.170 (0.118-0.228)	0.033 (0.023-0.044)
Age 4	0.235 (0.207-0.264)	0.045 (0.040-0.051)
Age 5	0.252 (0.226-0.281)	0.048 (0.043-0.054)
Age 6	0.281 (0.255-0.312)	0.054 (0.049-0.060)
Age 7	0.291 (0.264-0.321)	0.056 (0.051-0.062)
Age 8	0.273 (0.233-0.311)	0.052 (0.045-0.060)
Age 9	0.255 (0.199-0.305)	0.049 (0.038-0.059)
Age 10	0.251 (0.192-0.309)	0.048 (0.037-0.059)
Age 11+	0.287 (0.149-0.499)	0.055 (0.029-0.096)

Figure 1. Schematic Drawing of the center section of the rockhopper sweep used on the standard NEFSC bottom trawl

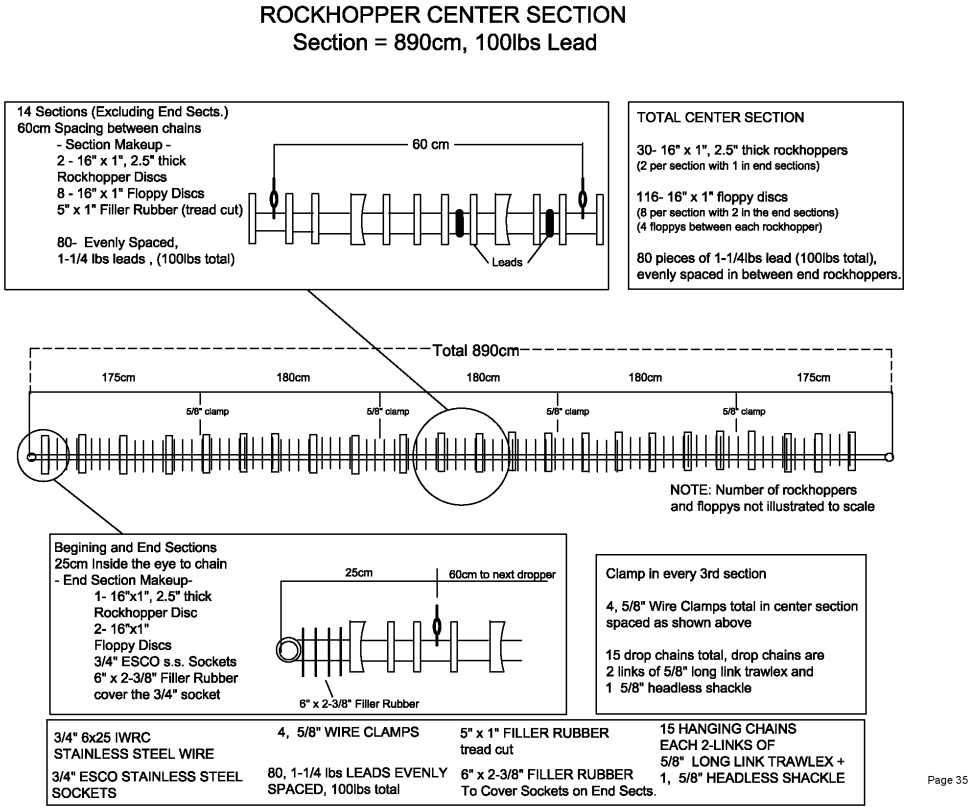


Figure 2. Schematic drawing of the chain sweep used on the experimental net

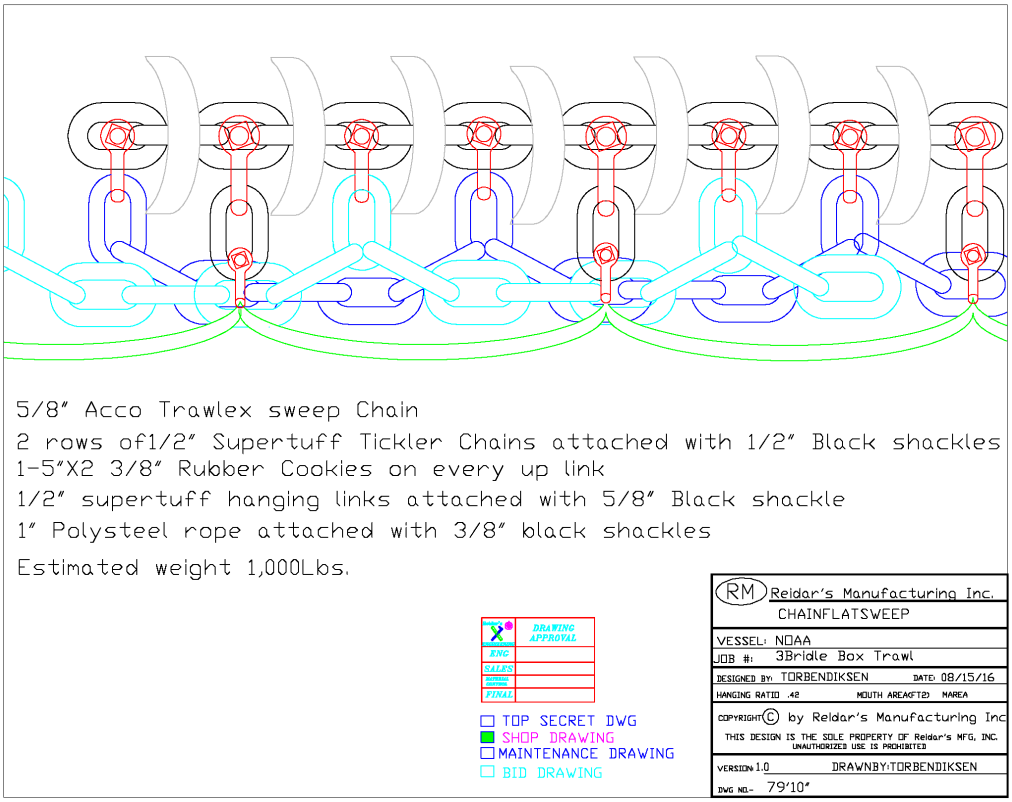


Figure 3. Photo of the rockhopper sweep (left), chain sweep (right) and the clump (center) during the twin trawl experiment.

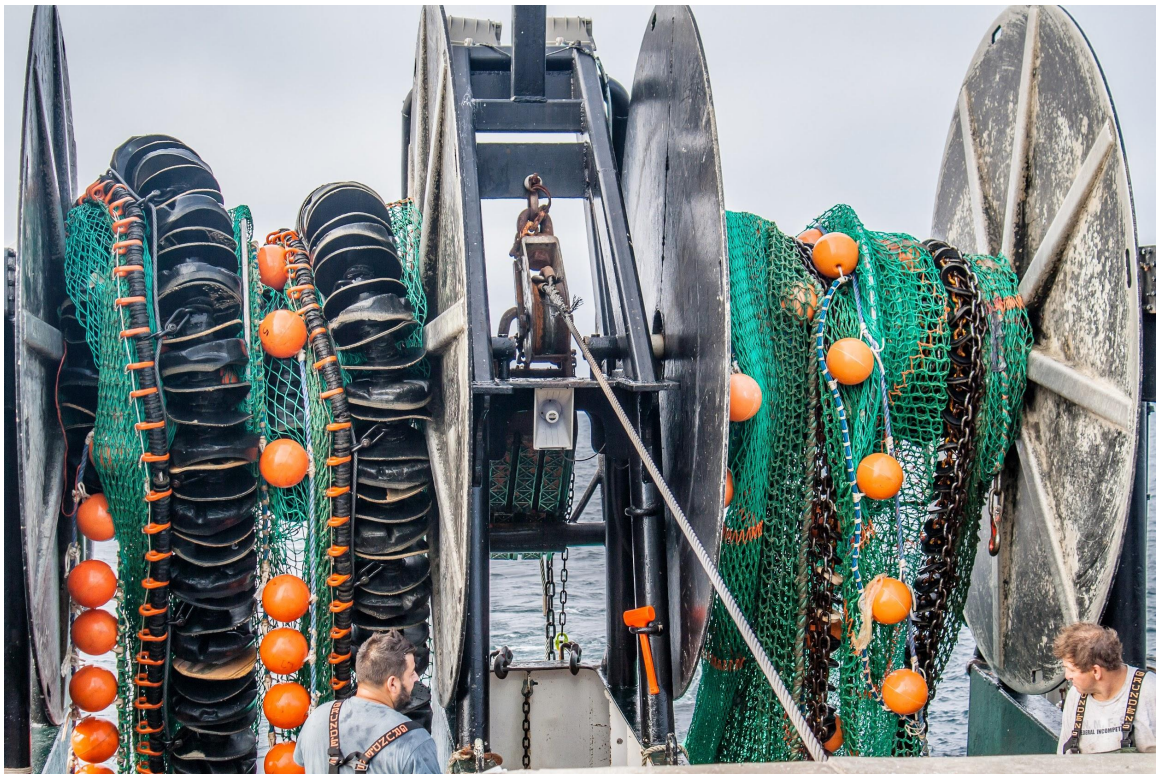
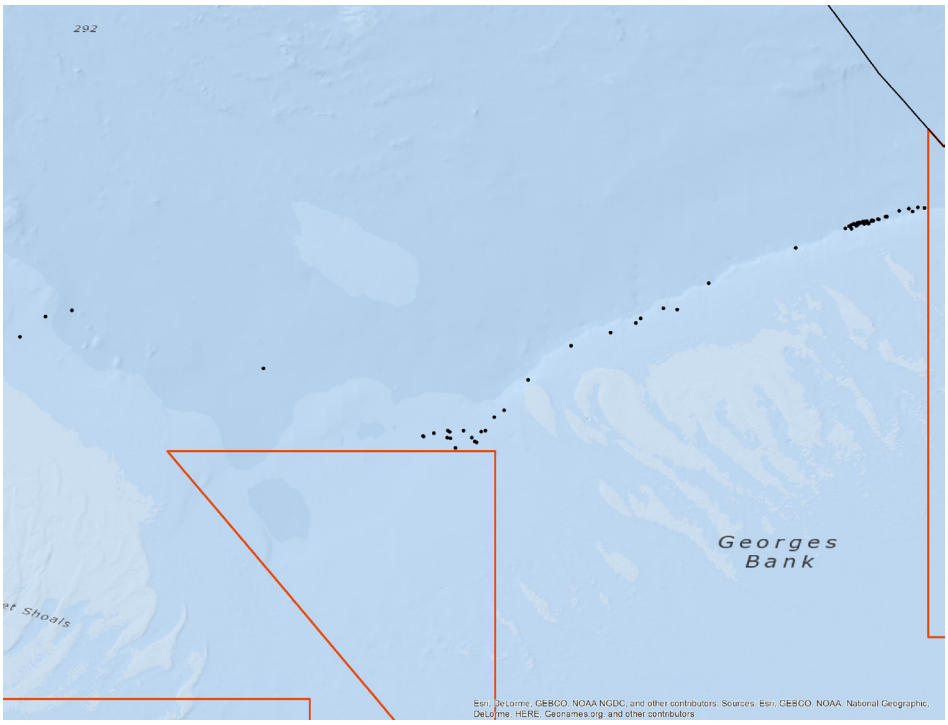


Figure 4. Tow locations during Leg 1 and Leg 2 of the sweep efficiency study



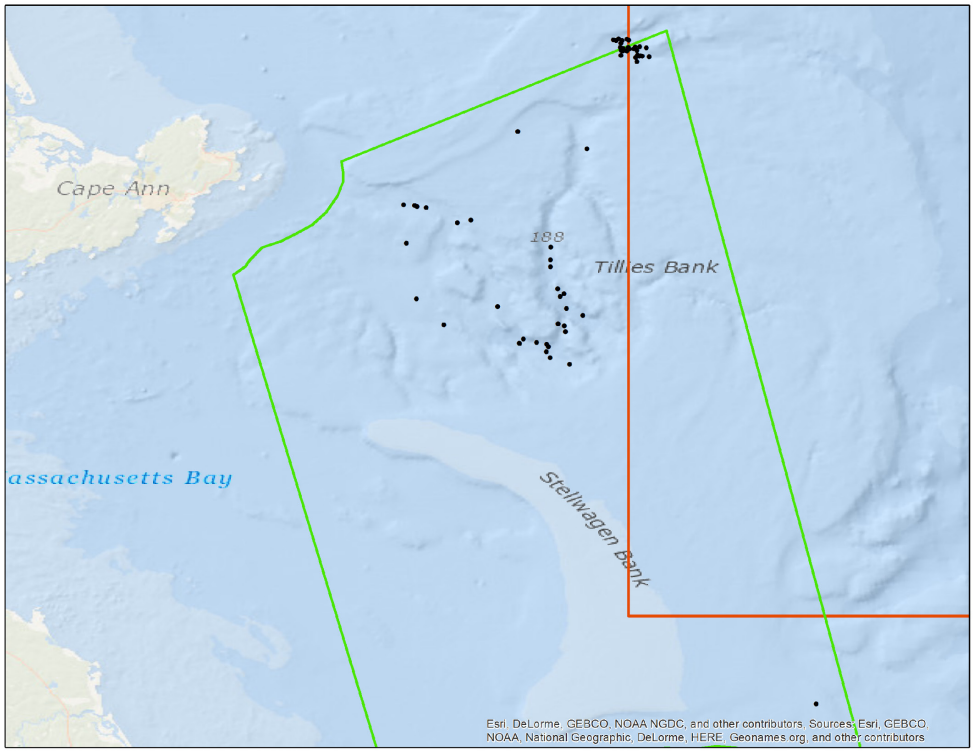


Figure 5. The proportion of all witch flounder captured with the chain sweep for each tow. Red points indicate day tows, while black points indicate night tows.

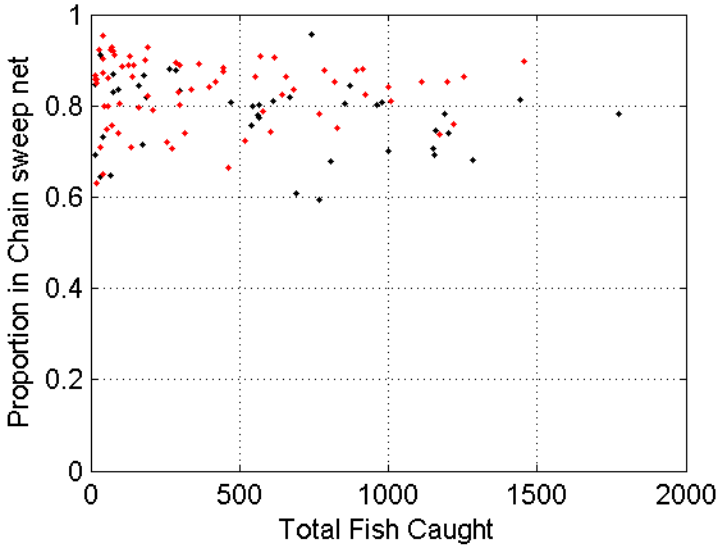


Figure 6. Estimated raw length data expressed as proportion of total witch flounder caught.

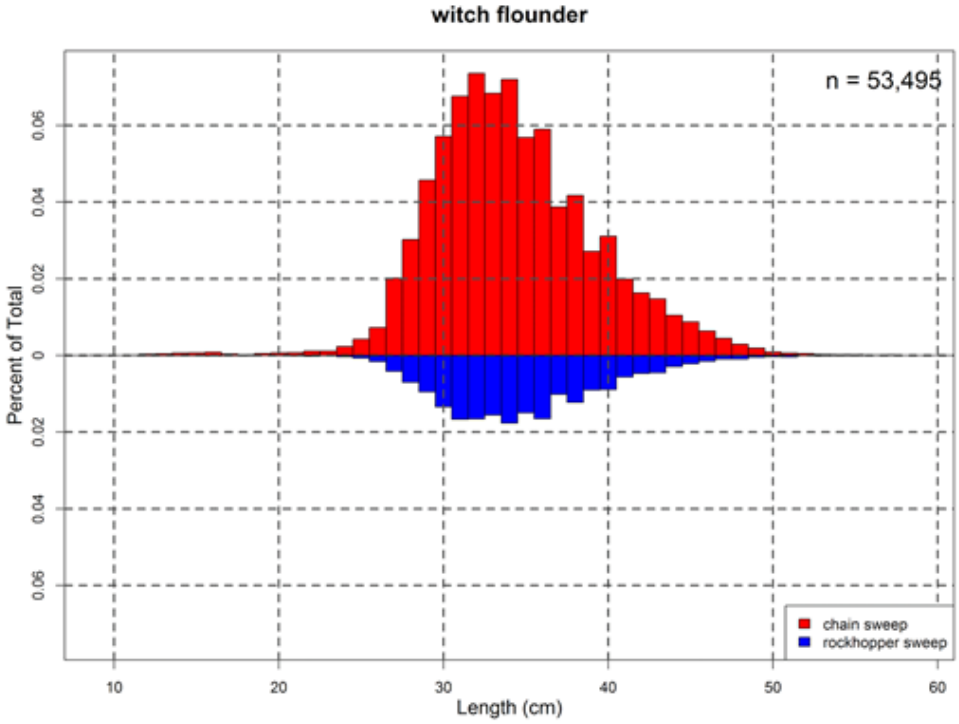


Figure 7. Best model fit for binomial/beta-binomial data analysis using all length CPUE data. The blue area represents 95% confidence intervals

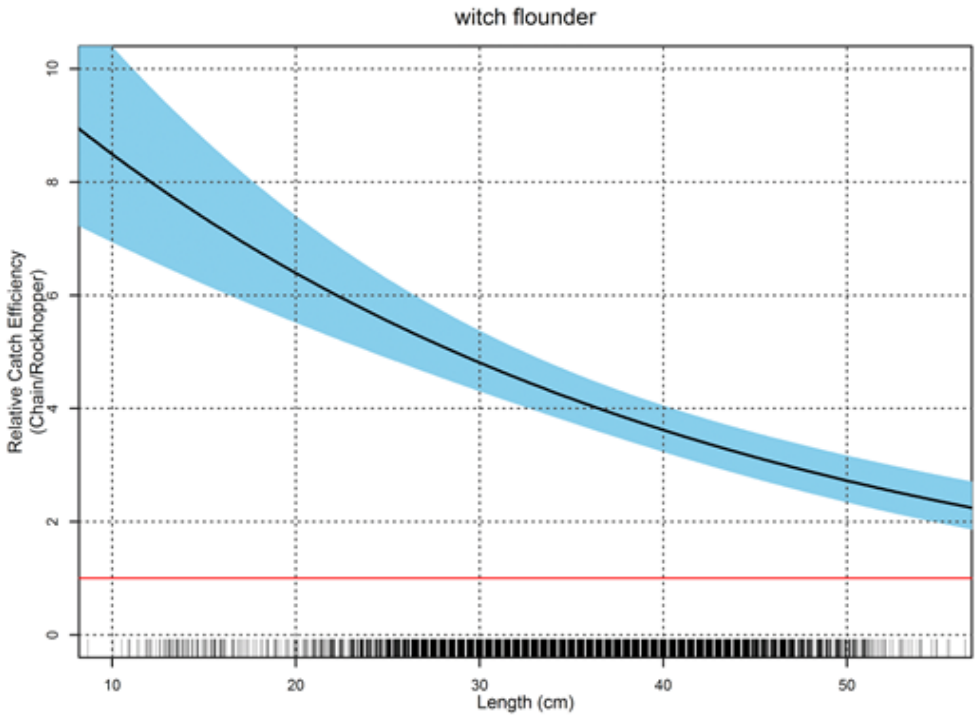


Figure 8. Best model fit for binomial/beta-binomial data analysis using night (top) and day (bottom) length CPUE data only. The blue area represents 95% confidence intervals.

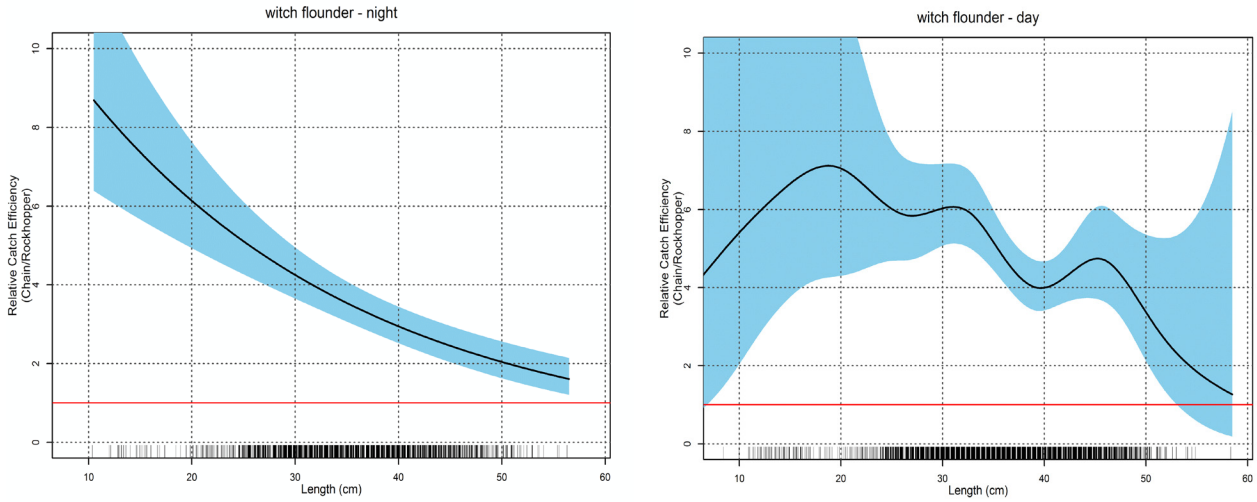


Figure 9: Ratio of chain sweep to rockhopper sweep catches by centimeter length bin during daytime and nighttime tows. Median and 95% confidence intervals of 1000 bootstraps are presented.

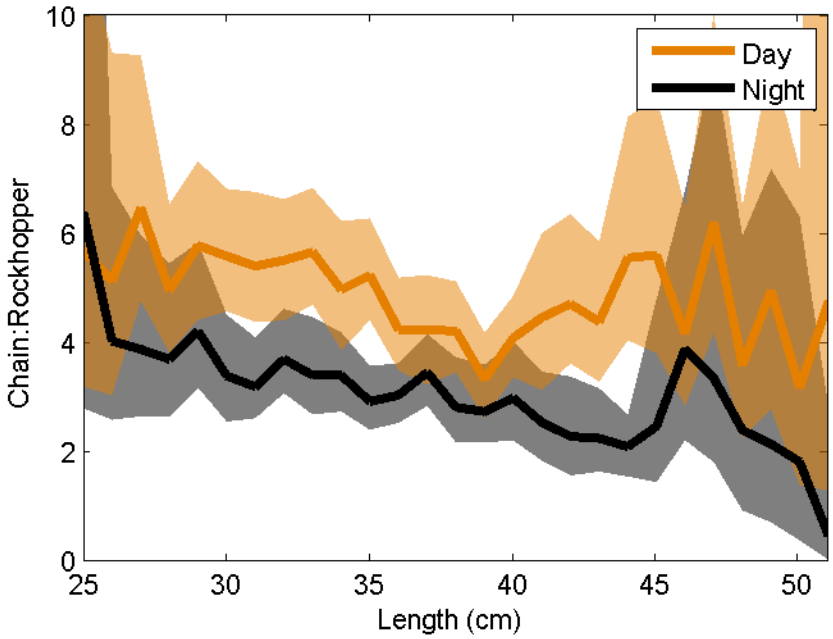


Figure 10: Comparison of the two analytical techniques used to estimate relative gear efficiency by length for both daytime and nighttime tows. See Figures 8 and 9 for details.

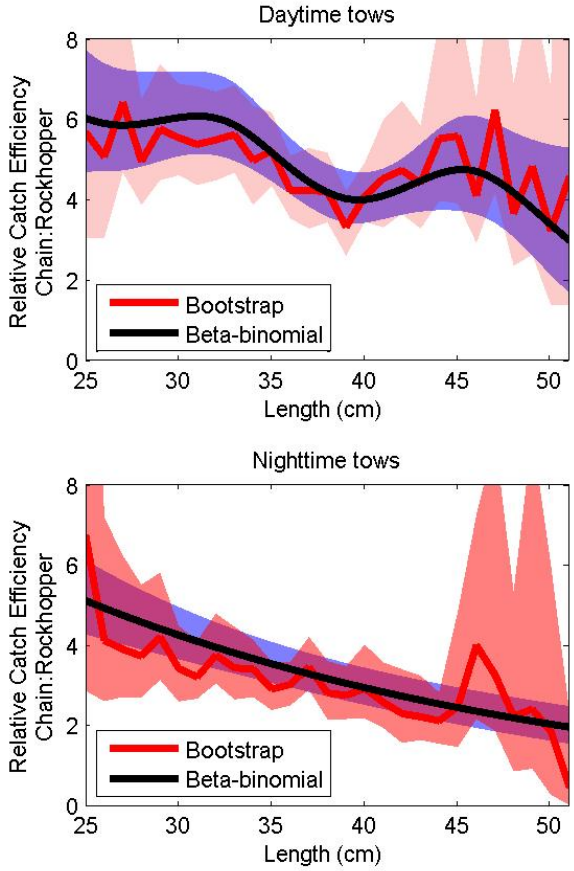
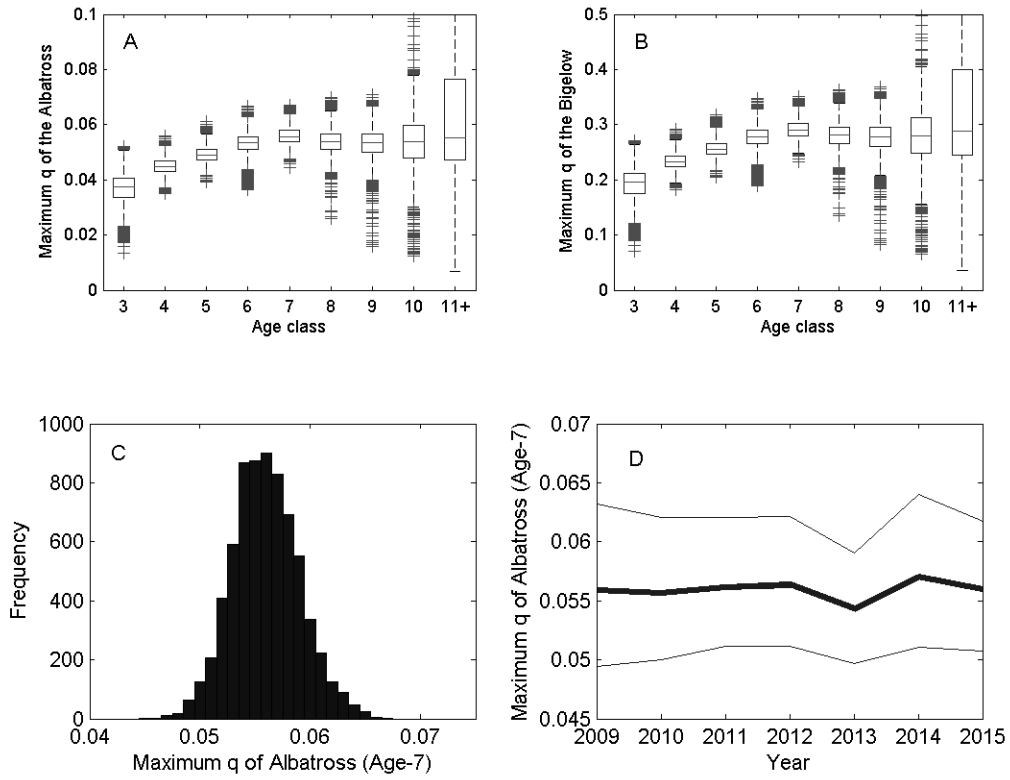


Figure 11: Boxplots of maximum catchability by age class for the A) Albatross tows and B) Bigelow tows. C) Histogram of maximum catchability for Age-7 witch flounder for the fall trawl survey. D) Median and 95% confidence intervals of Age-7 catchability using annual age-length key and stratified mean numbers at length.



Supporting information to the Sweep Study working paper

The relationship between a trawl survey index, catchability and population biomass is generally defined using the following equation:

$$B_t = \frac{1}{q} * \frac{I_t\, A}{a}$$

Where:

I_t: Index value at year t (kg tow^{-1})
B_t: Biomass of the population at year t (kg)
q: catchability
a: area covered by a single trawl (km^2 tow^{-1})
A: area covered by the survey (km^2)
I_tA/a=Swept area biomass

This same equation can be specified for both Bigelow and Albatross Units

$$B_t = \frac{1}{q_{Alb}} * \frac{I_{t,Alb}\, A}{a_{Alb}} = \frac{1}{q_{Big}} * \frac{I_{t,Big}\, A}{a_{Big}}$$

The Area covered by the survey cancels out.

$$\frac{1}{q_{Alb}} * \frac{I_{t,Alb}}{a_{Alb}} = \frac{1}{q_{Big}} * \frac{I_{t,Big}}{a_{Big}}$$

Multiply both sides by $q_{Bigelow}$

$$\frac{q_{Big}}{q_{Alb}} * \frac{I_{t,Alb}}{a_{Alb}} = \frac{I_{t,Big}}{a_{Big}}$$

Multiply both sides by $a_{Albatross}$

$$\frac{q_{Big}}{q_{Alb}} * \frac{I_{t,Alb}}{1} = \frac{I_{t,Big} * a_{Alb}}{a_{Big}}$$

Divide both sides by $I_{t,Alb}$

$$\frac{q_{Big}}{q_{Alb}} = \frac{I_{t,Big}}{I_{t,Alb}} * \frac{a_{Alb}}{a_{Big}}$$

For witch flounder the calibration factor for an individual tow of the Albatross and Bigelow is:

$$I_{t,Big} = 3.257 * I_{t,Alb}$$

This can be substituted into the above equation

$$\frac{q_{Big}}{q_{Alb}} = \frac{3.257 * I_{t,Alb}}{I_{t,Alb}} * \frac{a_{Alb}}{a_{Big}}$$

The $I_{t,Alb}$ cancels out:

$$\frac{q_{Big}}{q_{Alb}} = 3.257 * \frac{a_{Alb}}{a_{Big}}$$

The area of an Albatross tow is 0.038km^2 and the area of a Bigelow tow is 0.024

$$a_{Alb} = 0.038$$

$$a_{Big} = 0.024$$

Substituting those in

$$\frac{q_{Big}}{q_{Alb}} = 3.257 * \frac{0.038}{0.024} = 5.157$$

This is the ratio of catchabilities assuming data is entered into an assessment model as Albatross Swept area numbers (or biomass). That is a catchabilty of 0.2 for the Albatross would be equivalent to a catchability of 1.30 on the Bigelow.

Appendix B2

Replacement Yield Model Assessments of Gulf of Maine-Georges Bank Witch Flounder

Doug S. Butterworth and Rebecca A. Rademeyer

October 2016

Introduction

The "replacement yield" (RY) assessment model is the simplest possible form of an age-aggregated dynamic surplus production model approach. The underlying rationale is that if a resource has been without trend in abundance over a period of time, the (average) annual sustainable yield from the resource over that period is given by the average annual catch. The term "replacement yield" is often used in this context rather than "sustainable yield", with the two being equivalent in an "average over time" sense, as technically RY is that catch which will leave (a specified component of) the resource biomass at the end of a year unchanged from the level at which it started that year. The approach extends naturally to a situation where the resource is trending up or down, in which case the RY will be either greater or less than the past average catch, and to an extent that depends on the size of the trend and the size of the underlying biomass.

This is formalised through a dynamic surplus production model in which the annual natural resource growth is taken to be a constant (here denoted by RY). Only limited information is used to then estimate RY: a time series of catches and of one or more indices of abundance (desirably with associated measures of precision). There are various ways possible to effect the estimation, with the one used here set out in Annex A, together with the specific data considered for implementation in this case. A key consideration is how to handle "estimation" of the index constant of proportionality to biomass q**.** Occasionally there is sufficient contrast in the data to estimate q directly, though more usually some prior has to be assumed or a fixed input value is used (with sensitivity to that value explored). In this application, where the survey indices of abundance available reflect swept area estimates of biomass in terms of tons, the approach has been to set q for those surveys equal to a fixed value on input (which is taken to be the same for both the autumn and spring surveys in question, with the choice q=1 implying those estimates to be unbiased).

The choice of the length of the period of years of data for which the approach is applied involves a trade-off. Since in reality there can be longer term trends in the natural growth of a resource over time, ideally one would want to use a short recent period only to get an RY estimate corresponding closely to that which applies at present. However, the shorter the series, the greater the variance of the RY estimate, so that some compromise decision needs to be made.

By construction the MSY concept is not built into the approach. It could equally be applied to a resource with present abundance either well above or well below B_{MSY}, and would provide

the same output for both. In principle that might not be desirable; in practice however, that aspect is moot as in the circumstances where such an approach might be applied, one would generally be fairly uncertain as to on which side of B_{MSY} the resource biomass was. Regarding MSY-related reference points, at a stretch one might consider the RY estimate a surrogate for MSY. At a further stretch, since the approach provides a time series of (age-aggregated) biomass estimates, one could take the average biomass over the period considered as a surrogate for B_{MSY} , and then the corresponding surrogate for F_{MSY} (considered as an exploitation rate) would be given simply by MSY/ B_{MSY}.

Results and Discussion

Results from the application of the approach to Gulf of Maine-Georges Bank witch flounder are provided in Table 1 for three choices of period (from 1982, from 1996 and from 2006), four choices (1, 2, 3 and 4) for *q*, and with and without inclusion of the LCPUE series as well as the NEFSC survey abundance series. Plots of the model-estimated indices of abundance to show how well they fit the corresponding data are shown in Figures 1-6 for the six combinations of three periods x two data-choice scenarios (with and without LPUE data). Note that "fits" are shown to the LPUE data even when these data are not included – this is because a *q* value for the LPUE series is still implied in such cases (and provided by the limit of including the LPUE data in the likelihood, but with a vanishingly small weight).

Results for RY across these combinations show a number of the features that might have been expected:

- The longer the period the lower the SE.
- Including the extra (LPUE) series reduces the SE.

Features specific to this case are:

- Except for the shortest period considered (that starting in 2006 which is unable to discriminate), the negative log likelihoods for the fits favour *q*=1. These correspond to smaller estimates for RY compared to those for larger *q* values.
- The estimates of RY decrease as the period considered for the computations is reduced in length, suggesting that resource productivity may be lower more recently than further back in time.
- RY estimates that take account also of the LPUE data are larger.

As far as the period *vs* precision trade-off is concerned, the variability in the data is such that when only those from 2006 onwards are considered (see Figures 5 and 6), unsurprisingly standard error estimates for RY are so high as to make them of questionable value. On the other hand, the trend in the RY estimates with period length is such as to query use of the estimates from 1982 onwards. Over the set of results shown then, the best estimates would seem to be those for the intermediate period from 1996 onwards, and for *q*=1. Those yield RY (SE) estimates of 2.09 (0.72) and 1.20 (0.87) thousand tons for respective inclusion and exclusion of the LPUE index data.

Table 1: RY analysis results with Hessian-based CV in parenthesis (except for RY for which SE are given in parenthesis and italics). Estimates of biomass and RY are given in thousand mt (i.e. kt).

(Table is shown on following page due to size constraints)

	1982, with LPUE				1982, no LPUE			
	q=1	q=2	q=3	q=4	q=1	q=2	q=3	q=4
-lnL_total	50.80	51.70	53.61	56.02	15.96	16.98	18.60	20.53
-lnL_surv1	8.93	9.42	10.21	11.16	8.67	9.25	10.10	11.09
-lnL_surv2	7.41	7.86	8.63	9.59	7.29	7.73	8.50	9.43
-lnL_LPUE	34.46	34.42	34.76	35.27	-	-	-	-
-lnL_q1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-lnL_q2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RY	2.57 *(0.30)*	2.69 *(0.17)*	2.73 *(0.12)*	2.75 *(0.09)*	2.23 *(0.41)*	2.52 *(0.22)*	2.63 *(0.15)*	2.69 *(0.11)*
q1	1.00	2.00	3.00	4.00	1.00	2.00	3.00	4.00
q2	1.00	2.00	3.00	4.00	1.00	2.00	3.00	4.00
B_{1982}	40.99 (0.16)	27.93 (0.12)	23.82 (0.10)	21.87 (0.08)	47.34 (0.18)	30.74 (0.15)	25.24 (0.12)	22.58 (0.10)
B_{1996}	22.04 (0.16)	10.56 (0.16)	6.99 (0.16)	5.29 (0.16)	23.49 (0.17)	11.04 (0.17)	7.07 (0.18)	5.18 (0.17)
B_{2006}	18.88 (0.19)	8.54 (0.22)	5.35 (0.24)	3.84 (0.26)	16.84 (0.21)	7.34 (0.26)	4.47 (0.29)	3.14 (0.31)
B_{2015}	31.75 (0.17)	22.43 (0.13)	19.58 (0.11)	18.24 (0.09)	26.56 (0.24)	19.73 (0.18)	17.85 (0.13)	17.01 (0.11)
B_{2015}/B_{1982}	0.77 (0.28)	0.80 (0.22)	0.82 (0.18)	0.83 (0.15)	0.56 (0.38)	0.64 (0.30)	0.71 (0.23)	0.75 (0.19)
B_{2015}/B_{1996}	1.44 (0.20)	2.12 (0.19)	2.80 (0.18)	3.45 (0.17)	1.13 (0.30)	1.79 (0.27)	2.53 (0.24)	3.29 (0.22)
B_{2015}/B_{2006}	1.68 (0.08)	2.63 (0.11)	3.66 (0.15)	4.75 (0.18)	1.58 (0.12)	2.69 (0.13)	3.99 (0.18)	5.42 (0.22)

	1996, with LPUE				1996, no LPUE			
	q=1	q=2	q=3	q=4	q=1	q=2	q=3	q=4
-lnL_total	29.31	30.73	32.60	34.74	8.16	9.13	10.48	12.12
-lnL_surv1	5.06	5.87	6.82	7.87	5.02	5.82	6.78	7.83
-lnL_surv2	3.62	3.86	4.36	5.07	3.15	3.31	3.70	4.28
-lnL_LPUE	20.63	21.01	21.41	21.80	-	-	-	-
-lnL_q1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-lnL_q2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RY	2.09 *(0.72)*	2.17 *(0.44)*	2.22 *(0.36)*	2.27 *(0.32)*	1.20 *(0.87)*	1.59 *(0.53)*	1.72 *(0.43)*	1.79 *(0.40)*
q1	1.00	2.00	3.00	4.00	1.00	2.00	3.00	4.00
q2	1.00	2.00	3.00	4.00	1.00	2.00	3.00	4.00
B_{1982}	-	-	-	-	-	-	-	-
B_{1996}	27.06 (0.30)	15.53 (0.31)	11.72 (0.32)	9.75 (0.34)	35.81 (0.30)	21.05 (0.30)	16.42 (0.30)	14.27 (0.32)
B_{2006}	19.01 (0.21)	8.34 (0.24)	5.06 (0.26)	3.55 (0.28)	18.91 (0.22)	8.09 (0.25)	4.75 (0.28)	3.22 (0.31)
B_{2015}	27.47 (0.28)	17.58 (0.25)	14.77 (0.24)	13.67 (0.22)	19.42 (0.39)	12.13 (0.37)	9.95 (0.37)	8.99 (0.37)
B_{2015}/B_{1982}	-	-	-	-	-	-	-	-
B_{2015}/B_{1996}	1.02 (0.50)	1.13 (0.51)	1.26 (0.52)	1.40 (0.54)	0.54 (0.62)	0.58 (0.63)	0.61 (0.64)	0.63 (0.67)
B_{2015}/B_{2006}	1.45 (0.24)	2.11 (0.26)	2.92 (0.27)	3.86 (0.29)	1.03 (0.40)	1.50 (0.43)	2.10 (0.47)	2.79 (0.51)

	2006, with LPUE				2006, no LPUE			
	q=1	q=2	q=3	q=4	q=1	q=2	q=3	q=4
-lnL_total	13.07	13.08	13.09	13.11	3.15	3.14	3.13	3.13
-lnL_surv1	1.89	1.88	1.87	1.87	1.79	1.78	1.77	1.76
-lnL_surv2	1.31	1.32	1.32	1.33	1.36	1.36	1.37	1.37
-lnL_LPUE	9.86	9.88	9.90	9.92	-	-	-	-
-lnL_q1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-lnL_q2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
RY	0.71 *(1.28)*	0.90 *(0.65)*	0.96 *(0.44)*	0.99 *(0.34)*	0.18 *(1.57)*	0.62 *(0.80)*	0.77 *(0.54)*	0.84 *(0.41)*
q1	1.00	2.00	3.00	4.00	1.00	2.00	3.00	4.00
q2	1.00	2.00	3.00	4.00	1.00	2.00	3.00	4.00
B_{1982}	-	-	-	-	-	-	-	-
B_{1996}	-	-	-	-	-	-	-	-
B_{2006}	20.83 (0.37)	10.91 (0.36)	7.61 (0.35)	5.97 (0.34)	23.40 (0.41)	12.21 (0.39)	8.49 (0.38)	6.64 (0.37)
B_{2015}	16.96 (0.41)	8.69 (0.40)	5.94 (0.40)	4.56 (0.39)	14.69 (0.50)	7.52 (0.49)	5.13 (0.48)	3.93 (0.48)
B_{2015}/B_{1982}	-	-	-	-	-	-	-	-
B_{2015}/B_{1996}	-	-	-	-	-	-	-	-
B_{2015}/B_{2006}	0.81 (0.61)	0.80 (0.60)	0.78 (0.59)	0.76 (0.58)	0.63 (0.76)	0.62 (0.75)	0.60 (0.73)	0.59 (0.72)

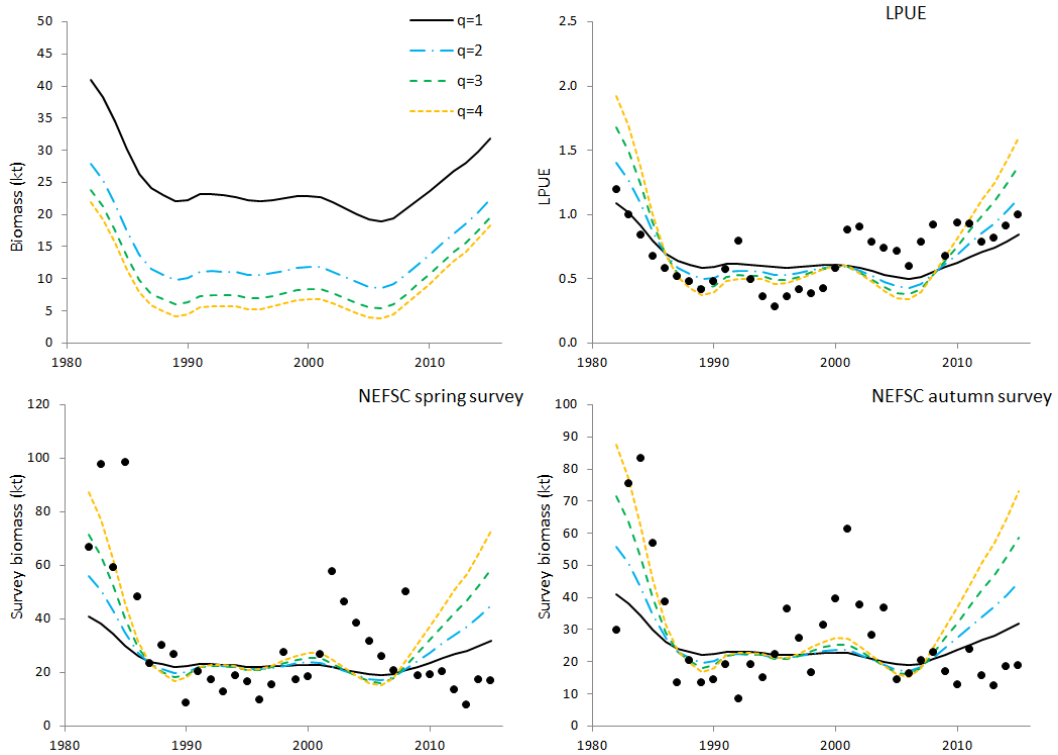


Figure 1: Plots of the estimated biomass trajectories and fits to the abundance indices for the "With LPUE, 1982 start" scenario.

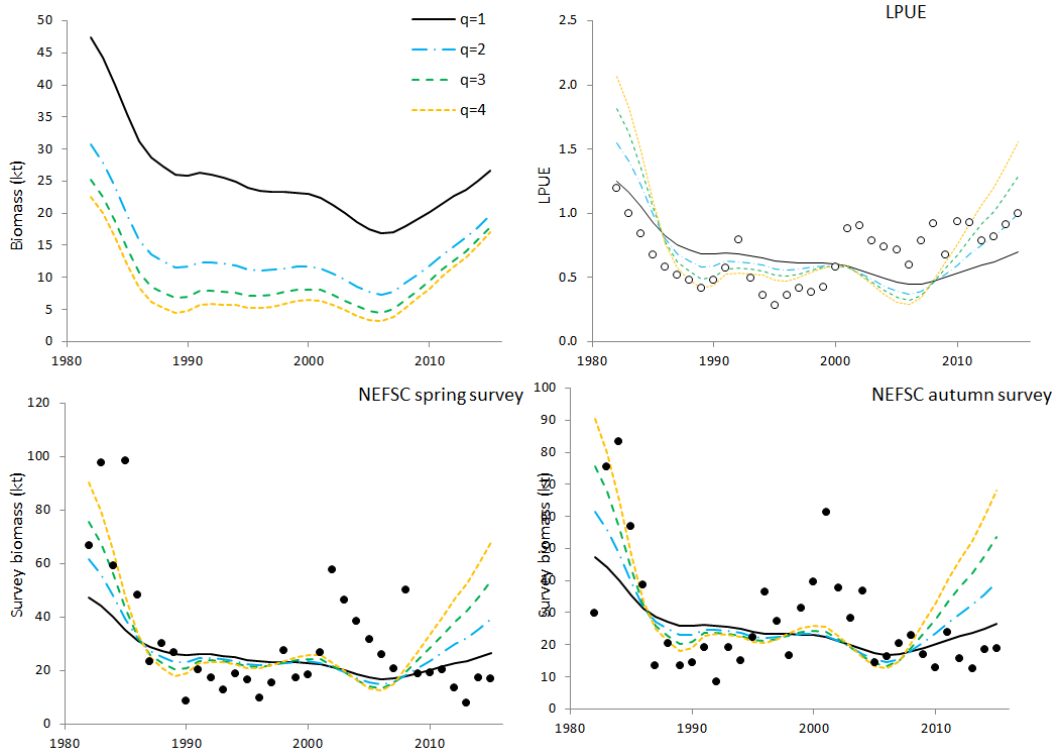


Figure 2: Plots of the estimated biomass trajectories and fits to the abundance indices for the "No LPUE, 1982 start" scenario. Note that the fits shown to the LPUE index are implied by an estimate of q^{LPUE} external to the basic model fitting procedure.

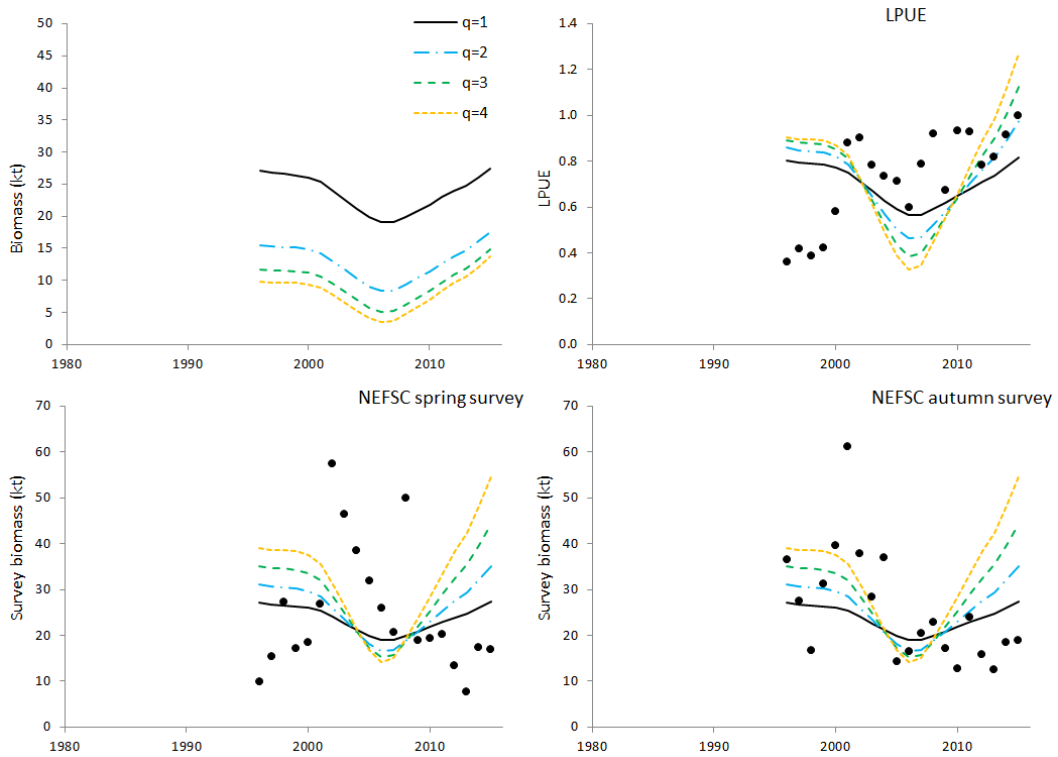


Figure 3: Plots of the estimated biomass trajectories and fits to the abundance indices for the "With LPUE, 1996 start" scenario.

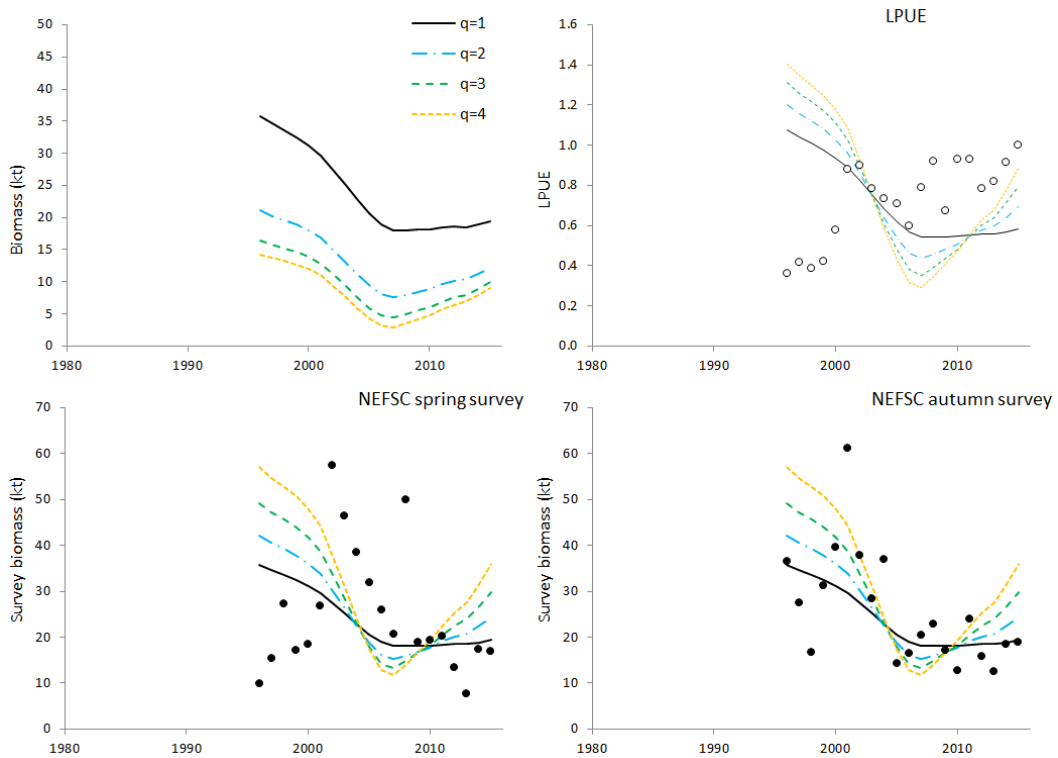


Figure 4: Plots of the estimated biomass trajectories and fits to the abundance indices for the "No LPUE, 1996 start" scenario.

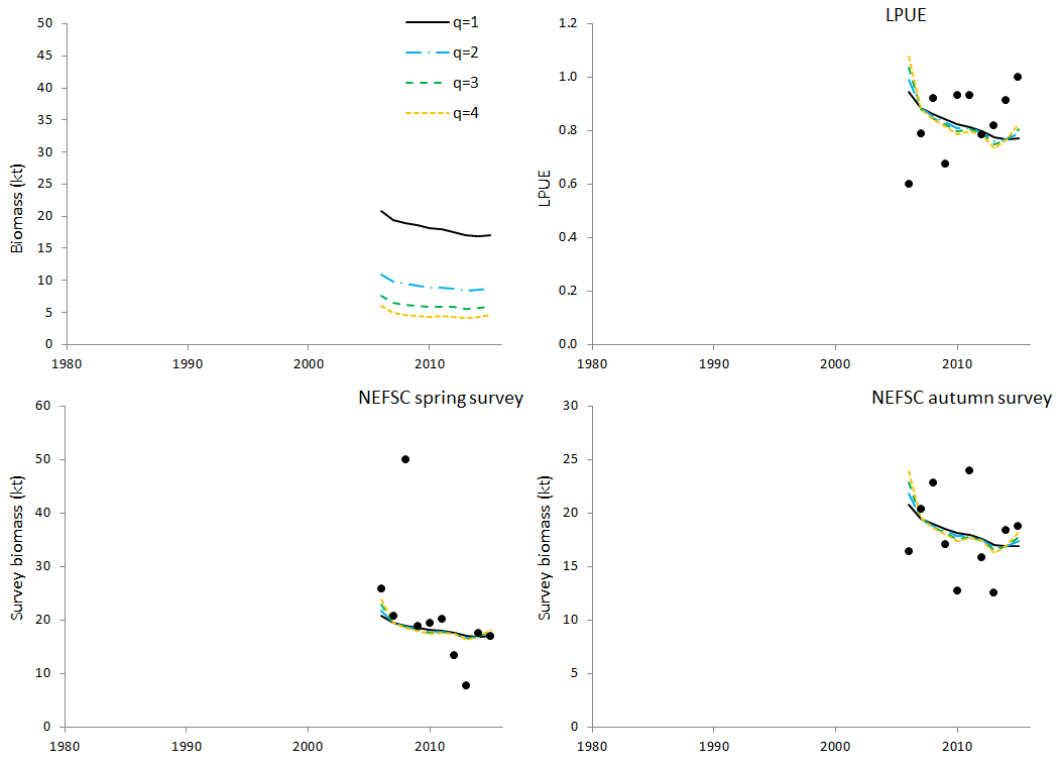


Figure 5: Plots of the estimated biomass trajectories and fits to the abundance indices for the "With LPUE, 2006 start" scenario.

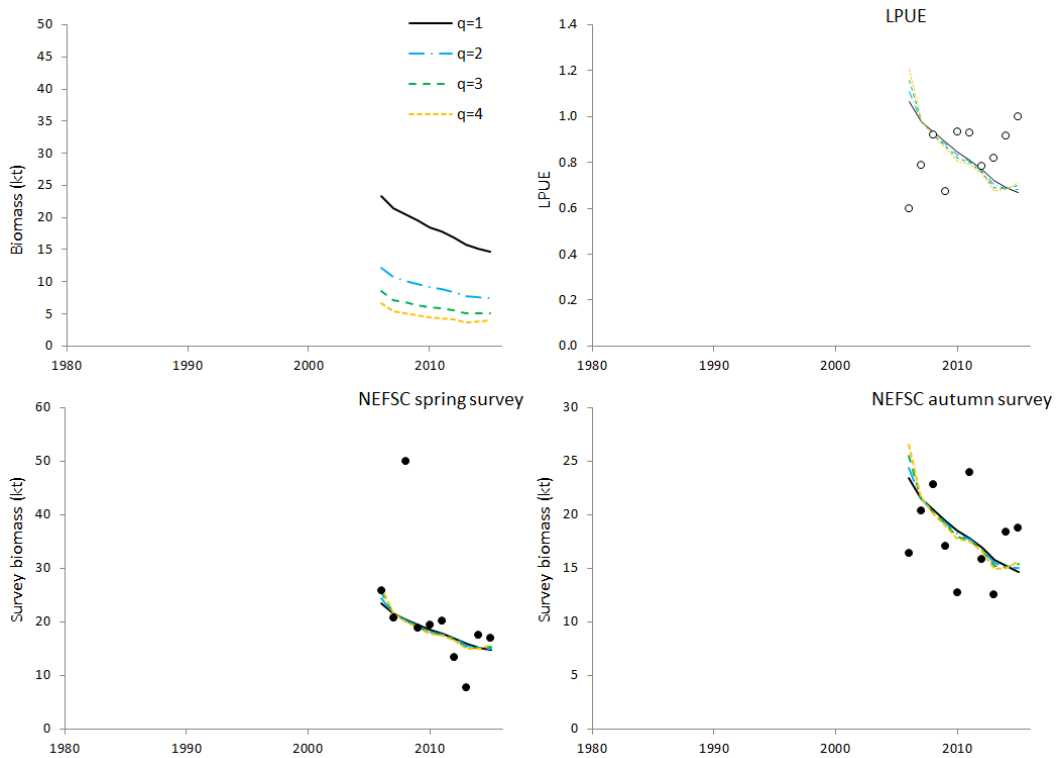


Figure 6: Plots of the estimated biomass trajectories and fits to the abundance indices for the "No LPUE, 2006 start" scenario.

APPENDIX B2: ANNEX A - REPLACEMENT YIELD MODEL

THE POPULATION DYNAMICS

The resource dynamics are modelled by the following equation:

$$B_{y+1} = B_y + RY - C_y \qquad \text{(A.1)}$$

where:

- B_y is the biomass at the start of year *y*,
- C_y is the catch in year *y*, and
- RY is the replacement yield in year *y*, which is assumed to be constant over the period considered.

THE LIKELIHOOD FUNCTION

The model is fitted to survey abundance indices. Contributions by each of these to the negative of the log-likelihood ($-lnL$) are as follows.

Survey abundance data

The likelihood is calculated assuming that the observed abundance indices are log-normally distributed about their expected value:

$$I_y^i = \hat{I}_y^i e^{\varepsilon_y^i} \quad \text{or} \quad \varepsilon_y^i = ln\left(I_y^i\right) - ln\left(\hat{I}_y^i\right) \qquad \text{(A.2)}$$

where:

- I_y^i is the abundance index for year *y* and survey series *i*,
- $\hat{I}_y^i = \hat{q}^i \hat{B}_y$ is the corresponding model estimated value,
- $\hat{q}^i$ is a constant of proportionality (catchability) for abundance index *i*, and
- ε_y^i is the observation error for survey *i* in year *y*, which is assumed to be normally distributed: $N\left(0, \left(\sigma_y^i\right)^2\right)$.

For the surveys, an estimate of the CV is available for each survey and the associated σ_y^i are given by $ln\left(1 + \left(CV_y^i\right)^2\right)$, where the CV_y^i are the coefficients of variation of the resource abundance estimate for index *i* for year *y*. These CVs are input and include the additional variance estimated in the SCAA Final BC (see Appendix B3). They are given in Table A1.

The contribution of the survey abundance data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-lnL^{surv} = \sum_{iy}\left\{ln\left(\sigma_y^i\right) + \frac{\left(\varepsilon_y^i\right)^2}{2\left(\sigma_y^i\right)^2}\right\} \qquad \text{(A.3)}$$

LPUE data

As for the survey abundance data, the likelihood is calculated assuming that the LPUE index is lognormally distributed about its expected value:

$$I_y^{LPUE} = \hat{I}_y^{LPUE} e^{\varepsilon_y^{LPUE}} \quad \text{or} \quad \varepsilon_y^{LPUE} = ln\left(I_y^{LPUE}\right) - ln\left(\hat{I}_y^{LPUE}\right) \qquad \text{(A.4)}$$

where

I_y^{LPUE} is the LPUE index in year y,
$\hat{I}_y^{LPUE} = \hat{q}^{LPUE}\hat{B}_y$ is the corresponding model estimate, where
$\hat{q}^{LPUE}$ is the constant of proportionality for the LPUE index.

The contribution of the LPUE index data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-lnL^{LPUE} = \sum_y \left\{ ln\left(\sigma_y^{LPUE}\right) + \frac{\left(\varepsilon_y^{LPUE}\right)^2}{2\left(\sigma_y^{LPUE}\right)^2} \right\} \quad \text{(A5)}$$

The coefficient of proportionality $\hat{q}^{LPUE}$ for is estimated by its maximum likelihood value:

$$ln\hat{q}^{LPUE} = \frac{1}{n_{LPUE}} \sum_y \left(lnI_y^{LPUE} - ln\hat{B}_y\right) \quad \text{(A6)}$$

***q* prior**

A very tight prior is included for the catchability coefficient q^i for each survey abundance index i so that these are basically fixed:

$$ln\left(q^i\right) \sim N\left(lnq^{mean}, \sigma_{lnq^{mean}}^2\right) \quad \text{(A.7)}$$

with $\sigma_{\sigma_{lnq^{mean}}^2} = 0.05$.

Table A1: Total catch (mt), NEFSC spring and autumn surveys swept area biomass estimates (mt) and LPUE each with CV. These CVs are from SCAA final BC results for the NEFSC series (see Appendix B3) and from a corresponding fit with LPUE replacing those series in the log likelihood.

	Total catch	NEFSC spring survey		NEFSC autumn survey		LPUE (40% trips)	
	(mt)	Swept area biomass (mt)	CV	Swept area biomass (mt)	CV	LPUE	CV
1982	5309	66648	0.554	29789	0.531	1.193	0.320
1983	6409	97751	0.575	75553	0.553	0.998	0.320
1984	6937	59375	0.532	83373	0.509	0.842	0.320
1985	6339	98269	0.543	56893	0.520	0.674	0.320
1986	4788	48131	0.531	38766	0.508	0.582	0.320
1987	3644	23230	0.558	13325	0.535	0.521	0.320
1988	3451	30193	0.558	20356	0.536	0.481	0.320
1989	2425	26554	0.552	13404	0.529	0.415	0.320
1990	1744	8441	0.591	14297	0.570	0.476	0.320
1991	2571	20499	0.566	19156	0.543	0.569	0.320
1992	2752	17210	0.539	8512	0.516	0.794	0.320
1993	2806	12836	0.537	19260	0.514	0.497	0.320
1994	3115	18974	0.556	15028	0.533	0.362	0.320
1995	2718	16664	0.535	22291	0.511	0.282	0.320
1996	2393	9894	0.535	36430	0.511	0.362	0.320
1997	2254	15468	0.573	27418	0.551	0.417	0.320
1998	2306	27318	0.537	16771	0.513	0.387	0.320
1999	2490	17210	0.547	31335	0.524	0.423	0.320
2000	2749	18535	0.526	39647	0.502	0.580	0.320
2001	3406	26808	0.533	61160	0.509	0.878	0.320
2002	3470	57529	0.547	37801	0.523	0.901	0.320
2003	3551	46399	0.532	28336	0.509	0.785	0.320
2004	3370	38405	0.523	36859	0.499	0.734	0.320
2005	2917	31803	0.547	14300	0.523	0.711	0.320
2006	2075	25883	0.526	16414	0.502	0.600	0.320
2007	1210	20759	0.534	20349	0.510	0.787	0.320
2008	1136	50009	0.566	22852	0.543	0.921	0.320
2009	1157	18828	0.528	17070	0.504	0.675	0.320
2010	912	19329	0.526	12727	0.502	0.931	0.320
2011	1071	20238	0.520	23917	0.496	0.930	0.320
2012	1258	13454	0.522	15827	0.498	0.785	0.320
2013	811	7767	0.525	12539	0.501	0.819	0.320
2014	675	17430	0.530	18353	0.506	0.914	0.320
2015	585	16896	0.528	18792	0.504	1.000	0.320

Appendix B3

Exploratory Catch-at-Age Assessments of Gulf of Maine-Georges Bank Witch Flounder

Doug S. Butterworth and Rebecca A. Rademeyer

October 2016

Summary

Exploratory Statistical Catch-at-Age assessments of the Gulf of Maine-Georges Bank witch flounder stock indicate possibly unrealistically high q values (in the range of 3-5) for surveys, suggesting substantial herding by the net. If q is forced to be lower, the primary lack of fit that arises originates from the larger numbers of 11+ fish predicted compared to observed for the spring survey. All of treating the *Albatross* and *Bigelow* abundance index series as independent, including LPUE data, and forcing a lower value for q suggest the resource at present to be larger and of better status relative to pristine. Even if both the first two of these factors are incorporated, however, a strong retrospective pattern remains. During the meeting, a further base case run was developed to mimic the specifications agreed for the ASAP base case run as closely as possible, and some sensitivities to that also run. Of interest is that for a combination of the sensitivity factors (allowing selectivity doming, including LPUE data and downweighting the proportions-at-age data) the retrospective pattern is considerably reduced (especially for spawning biomass), the survey indices are fit better, and values of q drop, approaching 3.

Introduction

The initial section of this paper provides exploratory assessments of the Gulf of Maine-Georges Bank witch flounder stock. Their purpose is not to advocate a specific "best assessment" choice, but rather to show the sensitivity of results to some key factors under discussion relating to assumptions and input choices for this assessment. These include the following.

- Whether to assume a change in survey catchability in the mid-1990s.
- The catchability difference between the *Albatross* and the *Bigelow*.
- The use of LPUE data.
- The large estimates of survey catchability q under standard model assumptions.

A subsequent section reports on further analyses developed during the October SAW WG meeting in the light of discussions there.

Data and Methodology

The data used for the assessments reported in this paper are as kindly provided by Susan Wigley (NEFSC) for the period 1982-2015 and are given in Annex A.

The algebraic details of the methods used for the SCAA assessments are similar to those of previous assessments of New England groundfish by the authors (e.g. Butterworth and Rademeyer 2012), and are set out in Annex B. Important assumptions for Base Case assessment model runs are as follows.

- The Baranov catch equation is used.
- Natural mortality M is age-independent and equal to 0.15.
- Recruitment is independent of spawning stock size (i.e. an extreme case of the Beverton-Holt relationship with steepness h =1), and assumed log normal variability of a magnitude

specified as σ_R = 0.5 in a penalty function added to the negative log likelihood minimised in the model fitting process.

- A parsimonious parametrisation of the starting numbers-at-age estimated in the model fit.
- Essentially free estimation of both commercial and survey selectivity-at-age, except that the survey is considered flat above ages 7 and 8 for the spring and autumn surveys respectively.
- A "sqrt(p)" formulation for fitting to information on proportions-at-age in the survey and commercial catches.
- Survey indices of abundance are fitted to (selectivity-weighted) numbers (though in scenarios include the LPUE series this is fitted to mass in the form of exploitable biomass).
- Estimation of additional variation in excess of survey sampling error for the surveys.

Convenient groupings of alternative assessment runs have been attempted to aid understanding of the impacts of different changes. The first set (Table 1) considers two Base Cases – BC1 with no survey catchability change after 1994, and BC2 with such a change – as well as runs forcing the survey catchabilities to be 1 and fitting to the LPUE (the series taking 25% of the catch being witch flounder to be reflective of directed effort is used) instead of the survey abundance indices (and their age-composition data). The second set (Table 2) takes BC1 and BC2 and addresses the impact on each of including one or both of the LPUE data in the fit and treating the *Albatross* and *Bigelow* survey series as independent (i.e. taking no account of the calibration factor for their catchabilities estimated from a trawl experiment, though still assuming the same selectivities for surveys in the same season by each vessel).

Results

Table 1 lists estimates of primary parameters and management-related quantities for the Gulf of Maine-Georges' Bank witch flounder for the first set of "single factor" runs. Results for an "ASAP-test_run_2" kindly provided by Susan Wigley are also included for convenient comparison, but not intending to imply that they might be Wigley's preferred ASAP run.

Figures 1-5 give plots of fits and diagnostics for the Table 1 runs. In the interests of brevity, not all statistics are plotted for every run, and CAA comparison plots in particular have been omitted if not considered to be particularly informative. Figure1 shows results for the BC1 run for spawning biomass, recruitment at ages1 and 3, a stock-recruitment plot with a time-series of residuals, and estimated selectivities-at-age, with comparisons where straightforward to the near-equivalently specified example ASAP run. Figure 2 shows BC1 fits to abundance and CAA data. Figures 3 and 4 show similar results comparing the BC1, q=1 and fit to the LPUE series results, though here the fits shown to the CAA data are for the survey q=1 scenario. Figure 5 provides a less extensive comparison of the BC1 and BC2 set of results, where the latter allows for a survey catchability change after 1994.

Table 2 provides the results for BC1 and BC2 together with their variants that include one or both of fitting to the LPUE data and treating the *Albatross* and *Bigelow* series as without any information on relative catchability. Figures 6 (for BC1) and Figure 7 (for BC2) provide comparisons across these variants in a similar format to Figure 5.

Results for further sensitivities based on SCAA BC3 are developed as follows:

1. "SCAA BC3": *Albatross* and *Bigelow* survey series split, including LPUE.
2. "SCAA BC3 Dome surveys": Survey selectivities are freely estimated to age 11+ for both spring and autumn surveys (instead of flat from ages 7 and 8 for the spring and autumn survey respectively).

3. "SCAA BC3 W_{CAA}=0.30": Downweighting of the contribution of the CAA data (both survey and commercial) to –lnL by a multiplicative factor of 0.3 instead of 1.
4. "SCAA BC3 calibration": Addition of a term to -lnL to take account of the *Albatross/Bigelow* experimental calibration estimate as:

$$-lnL^{calib} = \sum_i \left[ln\left(q^{Big}\right) - ln(q^{Alb}) - \Delta lnq\right]^2 / 2\sigma^2_{\Delta lnq} \quad (1)$$

with

$$\Delta lnq = ln(3.257) = 1.181$$

and

$$\sigma_{\Delta lnq} = 0.336/3.257 = 0.103$$

5. "SCAA BC3 split LPUE": the LPUE series is split into five series following major management changes which may have compromised comparability over time (the choice of break point is not always obvious, but the following approximation has been used:1982-1986, 1987-1994, 1995-2001, 2002-2009 and 2010-2015).

Table 3 lists estimates of primary parameters and management-related quantities for these further five sensitivity runs. Furthermore Hessian-based CVs are given for SCAA BC3 in Table 3. Figures 8-10 give plots of fits and diagnostics for the Table 3 runs, while Figure 11 plots the retrospective analysis for SCAA BC3.

Discussion

The discussion below is limited to listing a few key observations from the results with brief commentary.

1) The SCAA BC1 results are quite similar to those for the near equivalently specified example ASAP run, both reflecting domed commercial selectivity (Figure 1).

2) Both BC1 and BC2 indicate high survey *q* values, ranging from about 3 to 5 (Table 1), which indicates an extent of herding by the survey net whose plausibility might be open to question – hence inclusion of run forcing the survey *q* values to 1.

3) BC1 displays a systematic lack of fit to the LPUE data (not taken into account in this fit of the model), with the LPUE data being too low in the 1980s, and too high around 2010 (Figure 2).

4) Fitting to the LPUE instead of the survey index results in a larger and less depleted (relative to pristine) spawning biomass, and these effects are larger still if the survey catchabilities *q* are forced to equal 1 (Table 1 and Figure 3).

5) From the –lnL contributions in Table 1, it is clear to the main reason that the BC1 (BC2 would be similar) model fit "wants" high *q* values is in the fit to the survey CAA. Comparison of the residual plots for the CAA data in Figure 2 for BC1 and Figure 4 for *q*=1 show that this stems primarily from the spring survey, with the *q*=1 results predicting a far higher fraction of older (11+) fish.

6) BC1 (no survey catchability change in the mid-1990s) indicates a more positive recent status and trend for the resource than BC2 (Table 1 and Figure 5).

7) When the possibility of one or both of taking account of the LPUE data and treating the *Albatross* and *Bigelow* index series as independent is admitted (BC3), estimates of current spawning biomass and of status relative to pristine improve (Table 3 and Figures 6 and 7).

8) Both the domed selectivity and the downweighted CAA variants show higher current spawning biomasses and less depletion below pristine than BC3, and correspondingly lower survey *q* values which though still greater than 1 might be considered more realistic (Table 3 and Figure 8).

9) These last two variants fit the LPUE series better. The domed selectivity fit to the CAA data is slightly better for the commercial data but slightly worse for the surveys, but the downweighted CAA variant predicts too many 11+ fish for the autumn survey compared to the data (Table 3 and Figure 9).

10) The other two variants (calibration and split LPUE) show the opposite effects, with lower current spawning biomasses and greater depletion below pristine than BC3, and correspondingly higher survey *q* values (Table 3 and Figure 10).

11) Biomass related quantities for BC3 have Hessian-based CV estimates of about 20% (Table 3).

12) The retrospective pattern remains for BC3 (Figure 11).

DEVELOPED DURING SAW WG MEETING

These further runs with their results were developed and presented during the SAW WG meeting. They reflect a "final (SCAA) BC" which was structured to match the specifications for the final ASAP Base case run as closely as possible given certain different structures of these two approaches, together with some sensitivities to that run. Note that these runs do not include any survey selectivity change between 1994 and 1995.

Results

Table 4 lists estimates of primary parameters and management-related quantities for the SCAA final BC and six sensitivities to that. The sensitivities are:

- sens1: domed fishery and survey selectivities;
- sens2: domed survey only;
- sens3: dome fishery only;
- sens4: including LPUE (the 40% trips series) in the fit;
- sens5: *Bigelow/Albatross* calibration factor halved (i.e. 3.257 is reduced to 2.129, half-way towards 1) ; and
- sens6: downweighting of the CAA data in terms of output from an ASAP run, which resulted in setting W_{CAA} equal to 0.36 for commercial, 0.54 for spring survey and 0.34 for autumn survey CAA data; this is on the basis of application of an estimation procedure by Francis (2011) which attempts to take correlations amongst these data into account

Figures 12-14 provide plots of fits and diagnostics for the Table 4 runs.

Table 5 lists estimates of primary parameters and management related quantities for a further sensitivity run sens7 and two further variants to sens7, all based on the final BC. Sens7 includes dome selectivities for both the fishery and the surveys, fits to LPUE (40% trips series) and downweights the CAA data as for sens 6. Sens8 and sens9 restrict *q* to a maximum of 2 and 1 respectively.

Figures 15-17 give plots of fits and diagnostics for the Table 5 runs, while Figure 18 plots the retrospective analysis for sens7.

Discussion

Again the discussion below is limited to listing a few key observations from these within-WG-meeting results with brief commentary.

1) The first six sensitivities show little difference in results from those for the final BC. The current spawning biomass as a fraction of *K* is about 0.2, increasing slightly only for sens4 (including the LCPUE data) and for sens5 (halving the calibration factor). All survey *q* values remain above 4 (Table 4 and Figures 12-14).

2) Sens7, which includes three of the sensitivity factors together (dome selectivities for both the fishery and the surveys, fits to LPUE (40% trips series) and downweighting the CAA data as for sens6) shows more appreciable differences from the final BC: the current spawning biomass increases by about 50%, and relative to *K* from about 0.2 to 0.4. The fits to the survey indices of abundance improve, and the survey *q* values drop to approach 3 (Table 5 and Figures15-17).

3) If the survey *q* is forced to be 2 or less (sens8), the –lnL deteriorates by only some 1.5 units, the current spawning biomass is estimated to be higher still as is its ratio to *K*, and the fits to the survey indices of abundance improve still further. However the 1982 spawning biomass is estimated to be above *K*, this being primarily a reflection of estimation of a large 11+ abundance in this (assessment-commencing) year. Forcing *q* to be 1 or less (sens9) reflects all these same features to a greater extent (Table 5 and Figure 17).

4) The retrospective pattern for sens7 (Figure 18) is appreciably reduced (compared, say, to that for BC3 in Figure 11). This is particularly the case for spawning biomass for which there is very little indication of pattern, though for apical fishing mortality some systematic pattern remains.

References

Butterworth DS and Rademeyer RA. 2012. Applications of Statistical Catch-at-Age Assessment Methodology to Gulf of Maine cod, October 2012.Document presented to SAW/SARC 55 Working Group on Gulf of Maine and Georges Bank cod Modeling Meeting, 15-19 October, 2012. 40pp.

Francis RICC. 2011. Data weighting in statistical stock assessments models. Can. J. Fish. Aquat. Sci. 68: 1124-1138.

Table 1: Negative log-likelihood components and estimates of abundance and related quantities for witch flounder for the ASAP run "test_run_2", and several Base Case and "single factor" SCAA runs. Biomass units in this and all following tables are thousand mt unless otherwise indicated. For the run fitting to commercial LPUE and CAA data only, the implied *q* values for the surveys are shown in *italics*. Note that overall –lnL values are not comparable for run including the LPUE data.

	ASAP	SCAA BC1	SCAA BC2	SCAA B1 q=1	SCAA B1 CPUE only
-lnL: overall		-1634.0	-1665.0	-1508.2	-659.3
-lnL: survey		54.8	35.8	42.1	-
-lnL: LPUE		-	-	-	-0.8
-lnL: comCAA		-584.7	-583.2	-607.6	-631.7
-lnL: survCAA		-1096.7	-1107.0	-930.0	-0.1
-lnL: RecRes		37.0	34.2	33.7	19.1
-lnL: Catch		-44.5	-44.7	-46.7	-45.9
K^{sp}		31.38	28.53	78.71	43.35
B^{sp}_{1982}	24.81	23.63	24.24	89.20	35.37
B^{sp}_{2015}	6.77	6.58	4.31	58.55	21.33
B^{sp}_{2015}/K^{sp}		0.21	0.15	0.74	0.49
$B^{sp}_{2015}/B^{sp}_{1982}$	0.27	0.28	0.18	0.66	0.60
q:					
NEFSC spring: 1972-1994			2.85		*2.45*
NEFSC spring: 1995-2008	3.84	4.15	5.33	1.00	*2.77*
Bigelow spring: 2009-2015					
NEFSC aut: 1982-1994			2.70		*2.12*
NEFSC aut: 1995+	4.13	4.50	6.35	1.00	*3.03*
Bigelow aut.: 2009-2015					

Table 2: Negative log-likelihood components and estimates of abundance and related quantities for witch flounder for variants of the two Base Case SCAA runs. Note that overall –lnL values are not comparable for runs including the LPUE data.

	SCAA BC1	SCAA BC1 split Alb/Big	SCAA BC1 incl. LPUE	SCAA BC1 split Alb/Big, incl. LPUE = BC3	SCAA BC2	SCAA BC2 split Alb/Big	SCAA BC2 incl. LPUE	SCAA BC2 split Alb/Big, incl. LPUE
-lnL: overall	-1634.0	-1655.1	-1608.8	-1629.9	-1665.0	-1678.2	-1634.4	-1651.9
-lnL: survey	54.8	55.9	53.4	54.3	35.8	-	38.1	38.1
-lnL: LPUE	-	-	22.1	21.3	-	37.6	27.9	22.8
-lnL: comCAA	-584.7	-589.2	-590.4	-594.1	-583.2	-587.8	-588.4	-592.7
-lnL: survCAA	-1096.7	-1114.2	-1087.2	-1108.5	-1107.0	-1118.9	-1101.8	-1114.1
-lnL: RecRes	37.0	37.4	37.5	41.7	34.2	36.3	34.3	39.3
-lnL: Catch	-44.5	-45.1	-44.3	-44.7	-44.7	-45.3	-44.6	-45.2
K^{sp}	31.38	32.07	33.88	36.54	28.53	31.58	30.46	35.30
B^{sp}_{1982}	23.63	23.68	23.30	23.46	24.24	24.06	23.99	23.87
B^{sp}_{2015}	6.58	6.71	8.93	10.86	4.31	6.33	5.69	9.54
B^{sp}_{2015}/K^{sp}	0.21	0.21	0.26	0.30	0.15	0.20	0.19	0.27
$B^{sp}_{2015}/B^{sp}_{1982}$	0.28	0.28	0.38	0.46	0.18	0.26	0.24	0.40
q:								
NEFSC spring: 1972-1994	4.15	4.11	3.85	3.94	2.85	2.91	2.85	2.90
NEFSC spring: 1995-2008					5.33	5.45	4.87	5.14
Bigelow spring: 2009-2015		4.10		2.82		4.19		3.07
NEFSC aut: 1982-1994	4.50	4.21	4.24	3.91	2.70	2.65	2.62	2.50
NEFSC aut: 1995+					6.35	6.36	5.60	5.61
Bigelow aut.: 2009-2015		4.21		2.76		4.36		2.97

Table 3: Negative log-likelihood components and estimates of abundance and related quantities for the SCAA BC3 run and several variants thereof. Biomass units are thousand mt. For the run fitting to commercial LPUE and CAA data only, the implied *q* values for the surveys are shown in italics. For SCAA BC3, the Hessian-based CVs are given in parenthesis.

	SCAA BC3		SCAA BC3 Dome surveys	SCAA BC3 W_{CAA}=0.3	SCAA BC3 with calib. in likelihood	SCAA BC3 split CPUE
-lnL: overall	-1629.9		-1641.2	-463.0	-1580.9	-1654.8
-lnL: survey	54.3		45.4	36.7	50.6	55.1
-lnL: calib	-		-	-	14.2	-
-lnL: LPUE	21.3		9.5	-5.0	40.6	-1.8
-lnL: comCAA	-594.1		-598.5	-181.9	-586.4	-590.4
-lnL: survCAA	-1108.5		-1096.2	-288.3	-1092.2	-1109.2
-lnL: RecRes	41.7		44.5	21.9	36.6	35.9
-lnL: Catch	-44.7		-46.0	-46.3	-44.4	-44.4
K^{sp}	36.54	(0.11)	43.73	42.29	24.50	31.27
B^{sp}_{1982}	23.46	(0.07)	51.46	28.64	23.72	24.12
B^{sp}_{2015}	10.86	(0.19)	20.08	19.97	1.98	6.05
B^{sp}_{2015}/K^{sp}	0.30	(0.17)	0.46	0.47	0.08	0.19
$B^{sp}_{2015}/B^{sp}_{1982}$	0.46	(0.21)	0.39	0.70	0.08	0.25
q:						
NEFSC spring: 1972-1994 NEFSC spring: 1995-2008	3.94	(0.07)	3.35	2.43	4.04	4.06
Bigelow spring: 2009-2015	2.82	(0.17)	1.82	1.53	8.57	4.31
NEFSC aut: 1982-1994 NEFSC aut: 1995+	3.91	(0.11)	2.99	2.82	4.42	4.15
Bigelow aut.: 2009-2015	2.76	(0.19)	1.66	2.00	10.20	4.45

Table 4: Negative log-likelihood components and estimates of abundance and related quantities for witch flounder for SCAA Final BC and sens1 to sens6.

	BC	sens1	sens2	sens3	sens4	sens5	sens6
	Final BC	Dome fishery and survey	Dome survey	Dome fishery	Include 40% LPUE	Calibration factor halved	Downweighting CAA
-lnL: overall	-1686.8	-1690.5	-1686.8	-1690.5	-1650.5	-1684.4	-675.5
-lnL: survey	56.2	56.0	56.2	56.0	55.1	57.9	54.7
-lnL: LPUE	-				34.4		
-lnL: comCAA	-655.2	-658.5	-655.2	-658.5	-654.8	-655.1	-233.4
-lnL: survCAA	-1079.0	-1078.9	-1079.0	-1078.9	-1077.5	-1080.9	-481.2
-lnL: RecRes	34.8	34.8	34.8	34.8	35.4	37.2	30.0
-lnL: Catch	-43.7	-43.8	-43.7	-43.8	-43.0	-43.6	-45.6
K^{sp}	31.44	31.80	31.44	31.80	32.74	33.42	30.67
B^{sp}_{1982}	21.25	21.74	21.25	21.74	20.66	21.20	21.40
B^{sp}_{2015}	6.41	6.77	6.41	6.77	7.55	8.24	6.16
B^{sp}_{2015}/K^{sp}	0.20	0.21	0.20	0.21	0.23	0.25	0.20
$B^{sp}_{2015}/B^{sp}_{1982}$	0.30	0.31	0.30	0.31	0.37	0.39	0.29
ϕ	0.12	0.14	0.12	0.14	0.12	0.12	0.12
1982 N-at-age ($\times 10^6$)							
$N_{1,1982}$	17.14	17.29	17.14	17.29	16.95	17.11	16.61
$N_{2,1982}$	21.25	21.64	21.25	21.64	20.98	21.23	20.44
$N_{3,1982}$	20.28	20.76	20.28	20.76	20.02	20.26	20.27
$N_{4,1982}$	15.27	15.75	15.27	15.75	15.08	15.23	14.92
$N_{5,1982}$	9.39	9.68	9.39	9.68	9.25	9.36	9.23
$N_{6,1982}$	7.43	7.63	7.43	7.63	7.32	7.40	7.33
$N_{7,1982}$	5.79	5.93	5.79	5.93	5.72	5.77	5.74
$N_{8,1982}$	4.39	4.37	4.39	4.37	4.32	4.37	4.36
$N_{9,1982}$	3.33	3.27	3.33	3.27	3.26	3.32	3.32
$N_{10,1982}$	2.52	2.47	2.52	2.47	2.46	2.51	2.53
$N_{11+,1982}$	7.89	8.25	7.89	8.25	7.60	7.88	8.05
q:							
NEFSC spring	4.39	4.26	4.39	4.26	4.29	4.65	4.33
NEFSC autumn	4.75	4.60	4.75	4.60	4.62	5.01	4.44

Table 5: Negative log-likelihood components and estimates of abundance and related quantities for witch flounder for SCAA Final BC, and sens7 to sens9.

	BC	sens7	sens8	sens9
	Final BC	Both dome, incl. LPUE, down. CAA	sens7 + q=2	sens7 + q=1
-lnL: overall	-1686.8	-656.2	-654.7	-651.8
-lnL: survey	56.2	41.0	37.4	36.6
-lnL: LPUE	-	9.1	7.8	8.7
-lnL: comCAA	-655.2	-229.5	-223.0	-221.2
-lnL: survCAA	-1079.0	-457.6	-458.7	-458.8
-lnL: RecRes	34.8	27.2	28.5	30.0
-lnL: Catch	-43.7	-46.4	-46.7	-46.9
K^{sp}	31.44	37.13	50.72	81.92
B^{sp}_{1982}	21.25	31.85	83.36	157.22
B^{sp}_{2015}	6.41	14.78	29.98	62.93
B^{sp}_{2015}/K^{sp}	0.20	0.40	0.59	0.77
$B^{sp}_{2015}/B^{sp}_{1982}$	0.30	0.46	0.36	0.40
F_{2015}	0.138	0.071	0.047	0.026
ϕ	0.12	0.13	0.00	0.00
1982 N-at-age ($\times 10^6$)				
$N_{1,1982}$	17.14	16.54	20.68	30.51
$N_{2,1982}$	21.25	21.32	27.69	40.88
$N_{3,1982}$	20.28	21.35	28.47	42.36
$N_{4,1982}$	15.27	16.18	21.84	33.20
$N_{5,1982}$	9.39	10.08	14.75	27.71
$N_{6,1982}$	7.43	8.12	12.69	23.85
$N_{7,1982}$	5.79	6.50	10.93	20.53
$N_{8,1982}$	4.39	4.84	9.40	17.67
$N_{9,1982}$	3.33	3.77	8.09	15.21
$N_{10,1982}$	2.52	3.02	6.97	13.09
$N_{11+,1982}$	7.89	14.51	43.04	80.88
q:				
NEFSC spring	4.39	3.36	2.00	1.00
NEFSC autumn	4.75	3.18	1.75	0.95

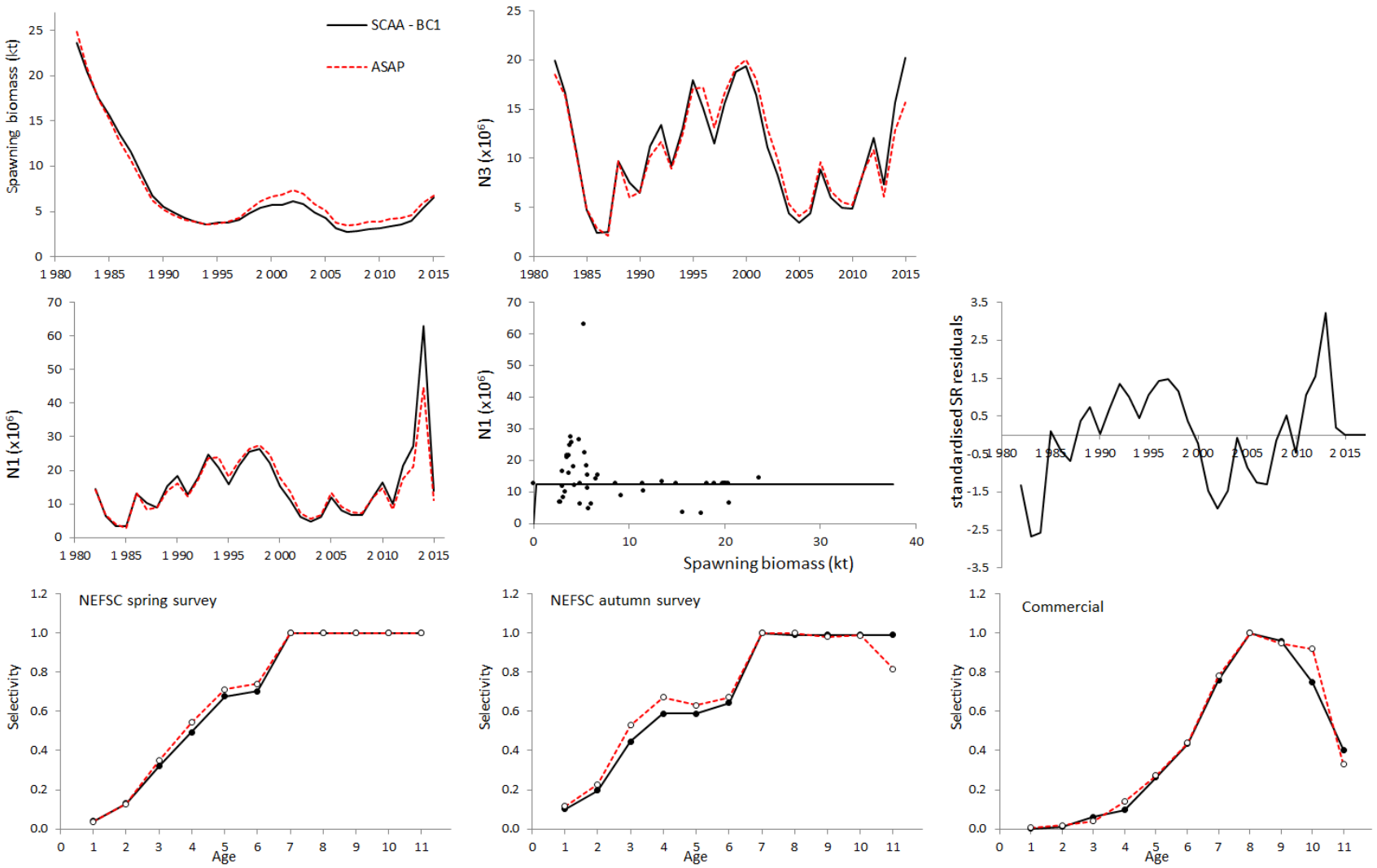


Figure 1: Comparison of the **SCAA BC1** results with the **ASAP run "test_run2"** .

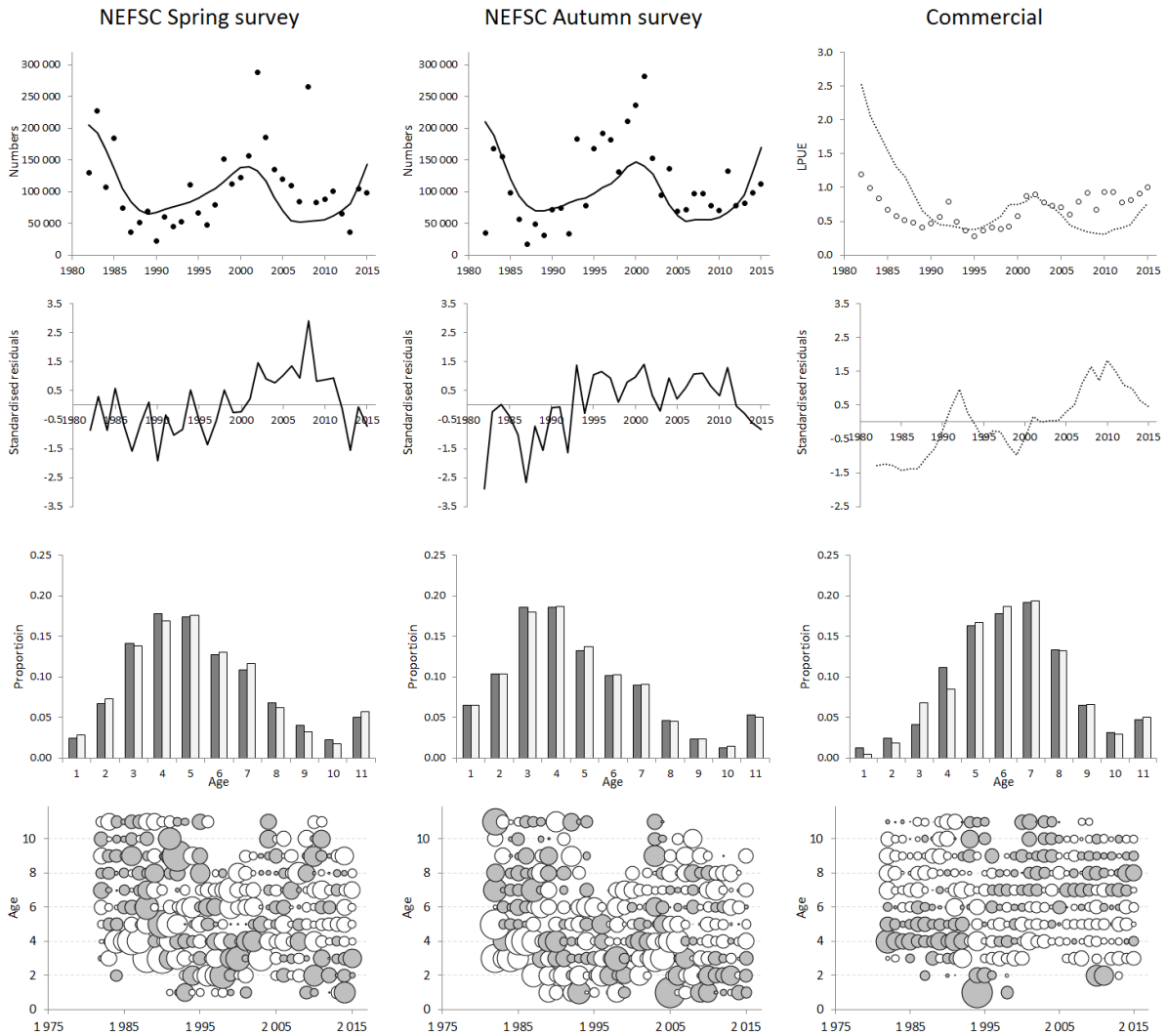


Figure 2: Fit to the survey series and survey and commercial catch-at-age data (averaged over all the years for which data is available – third row – and bubble plots of residuals, with grey bubbles representing positive residuals – bottom row) for the **SCAA BC1** run.

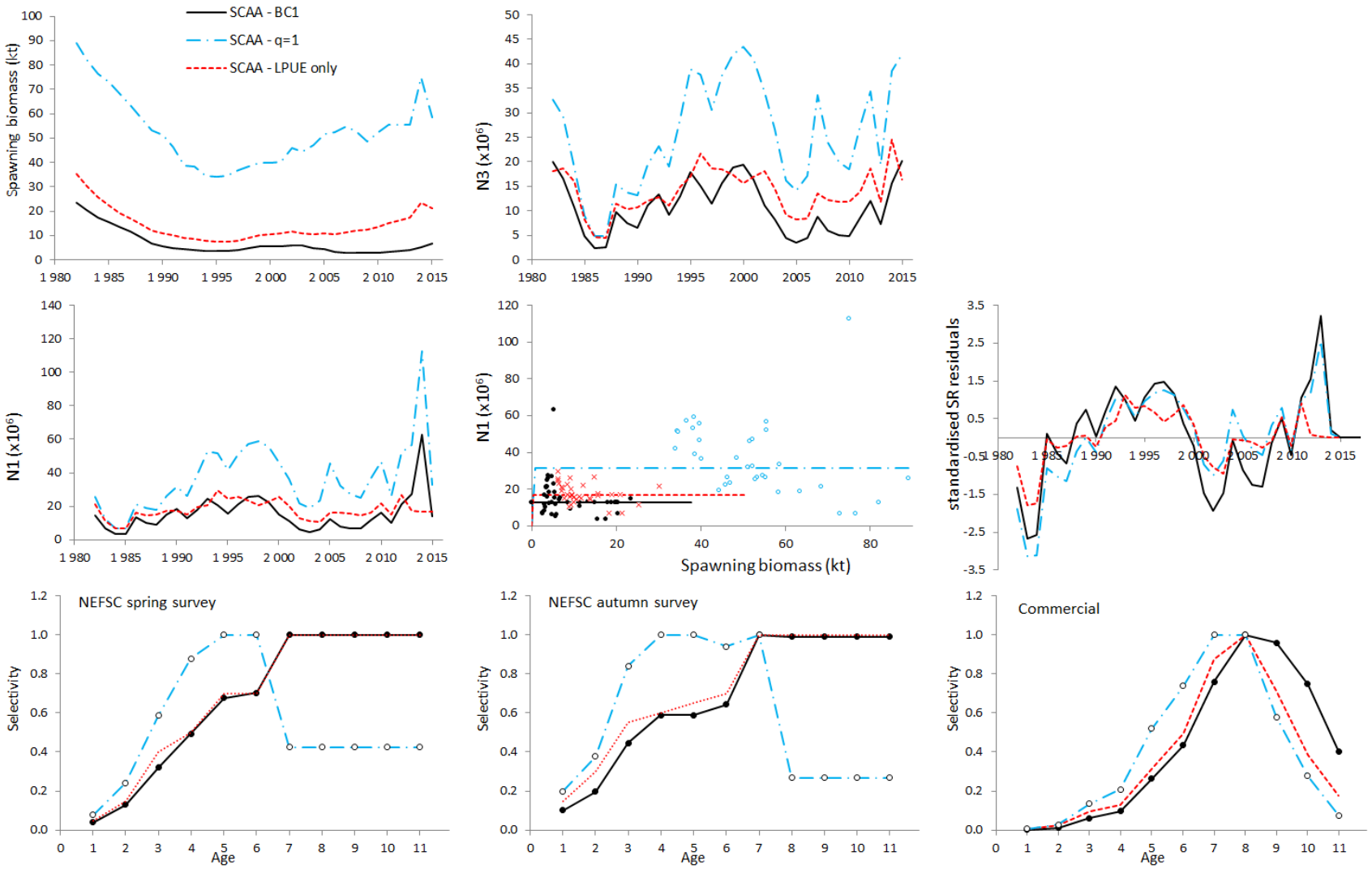


Figure 3: Comparison of the **SCAA BC1** results with the **SCAA q=1** and **SCAA LPUE only**.

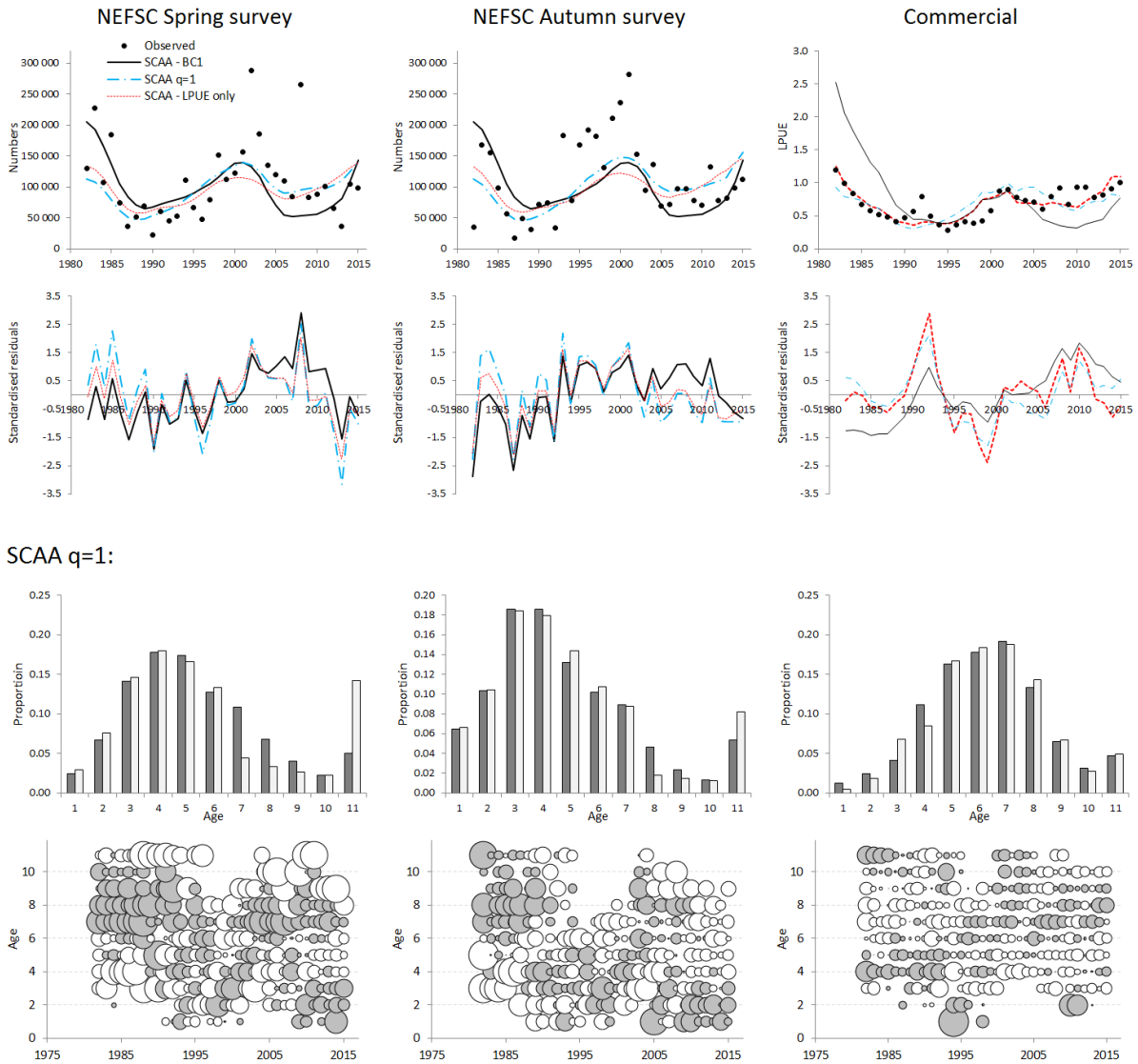


Figure 4: Fit to the survey and CPUE series for the **SCAA BC1**, **q=1** and **LPUE only** runs and survey and commercial catch-at-age data (averaged over all the years for which data is available – third row – and bubble plots of residuals, with grey bubbles representing positive residuals – bottom
row) for SCAA *q*=1.

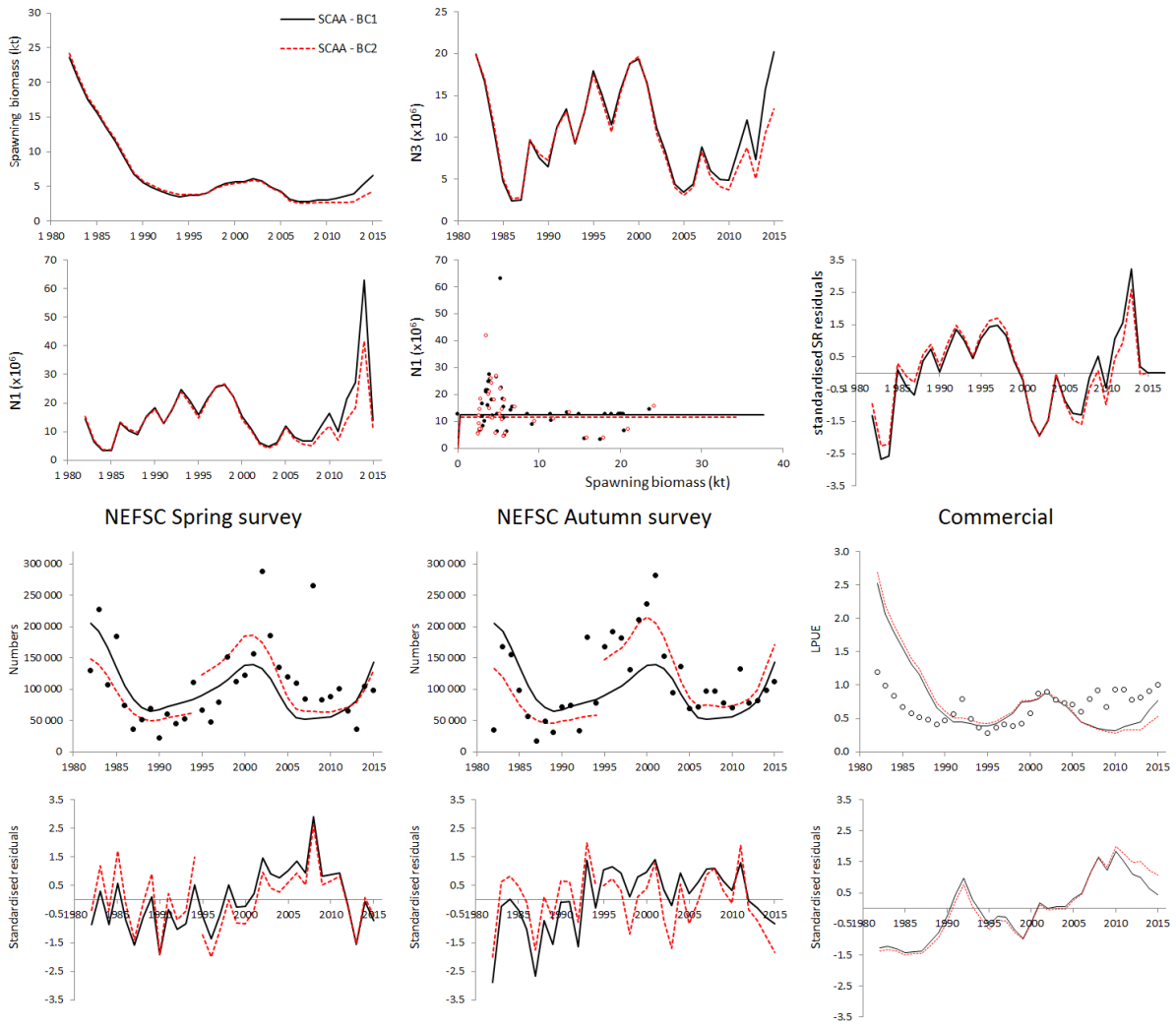


Figure 5: Comparison of the **SCAA BC1** and **SCAA BC2** results.

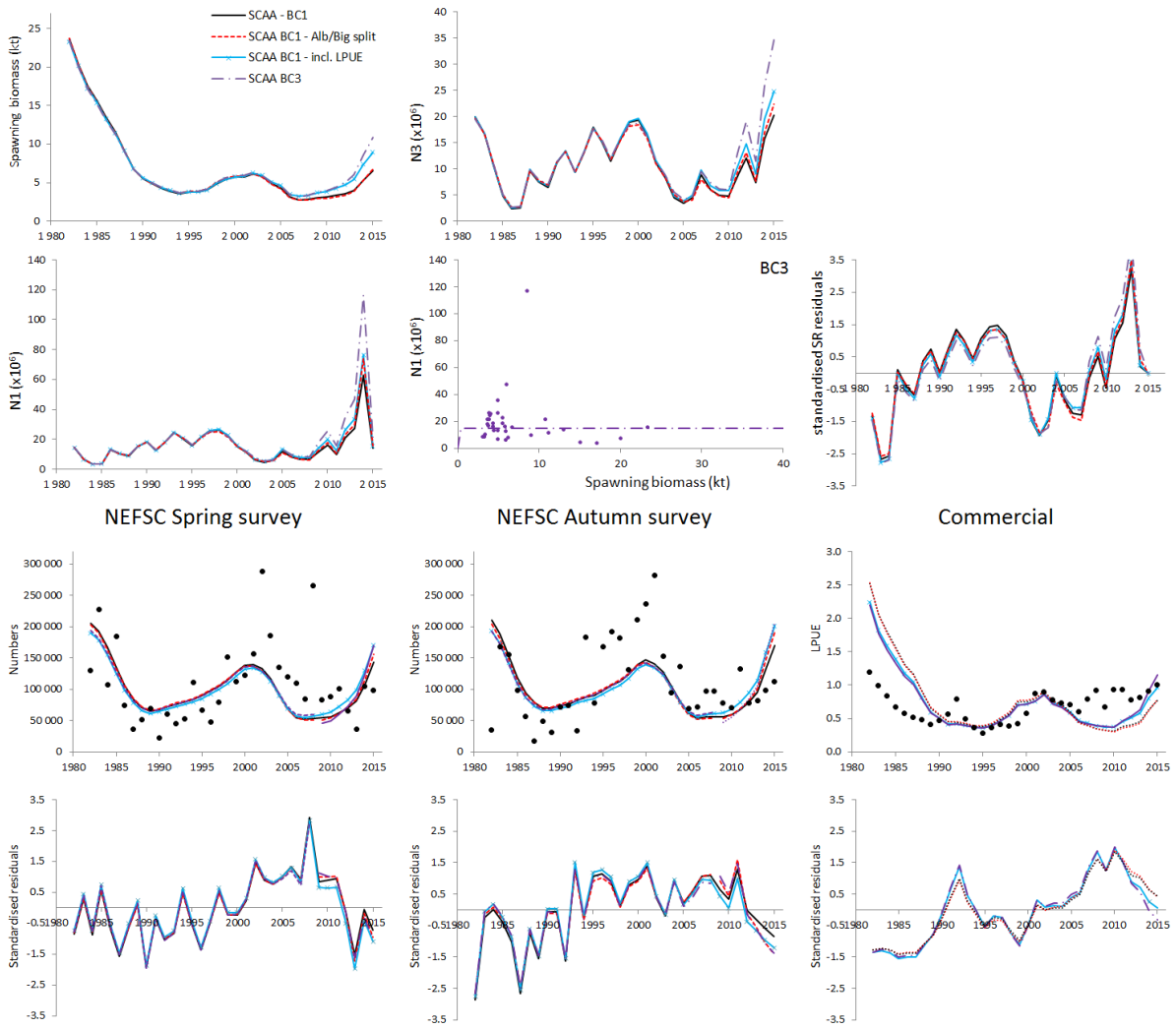


Figure 6: Comparison of the **SCAA BC1** (in black) and **Alb/Big split** (in red), **including LPUE** (in blue) and **BC3** (Alb/Big split and including CPUE, in purple) results.

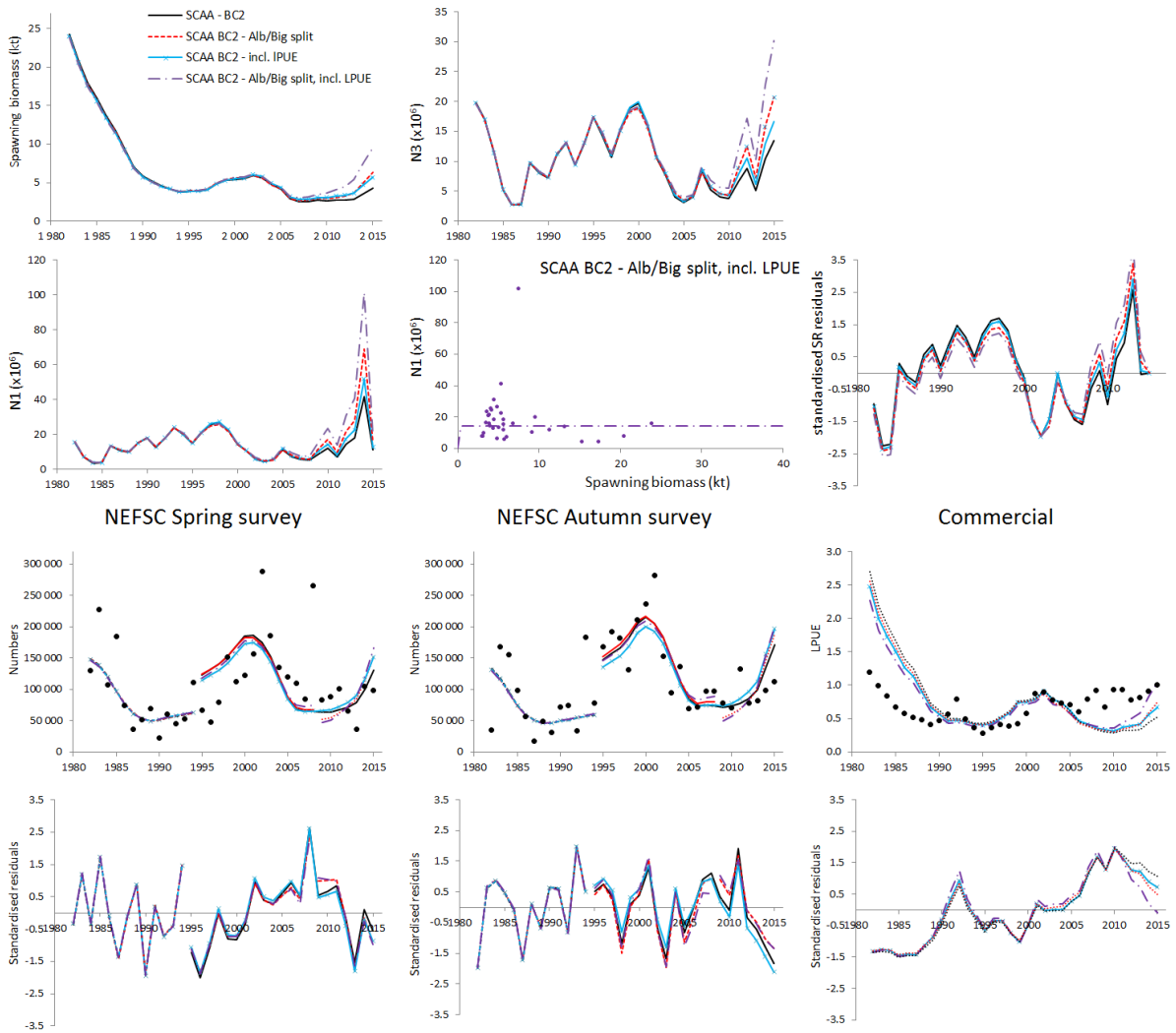


Figure 7: Comparison of the **SCAA BC2** (in black) and **Alb/Big split** (in red), **including LPUE** (in blue) and **BC3** (Alb/Big split and including CPUE, in purple) results.

Figure 8: Comparison of the **SCAA BC3** (in black) and **survey dome** (in red), and $\mathbf{W_{CAA}=0.3}$ (in blue) results.

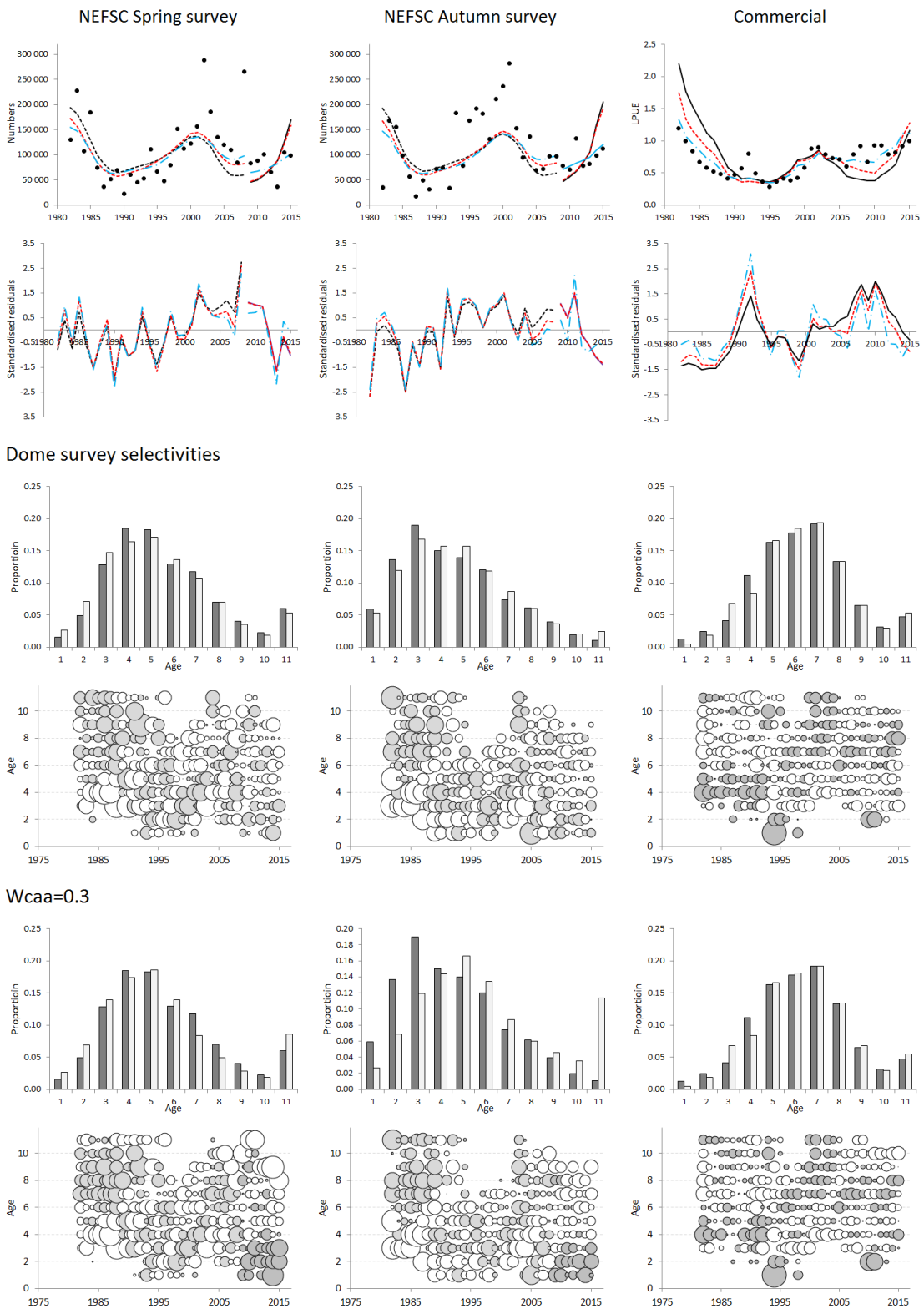


Figure 9: Fit to the survey series for **SCAA B3** (in black), with **dome survey selectivities** (in red) and **downweighting the CAA data** (W_{CAA}=0.3, in blue) and survey and commercial catch-at-age data (averaged over all the years for which data is available – third row – and bubble plots of residuals, with grey bubbles representing positive residuals – bottom row) for the **dome survey** and **downweighting the CAA data** runs.

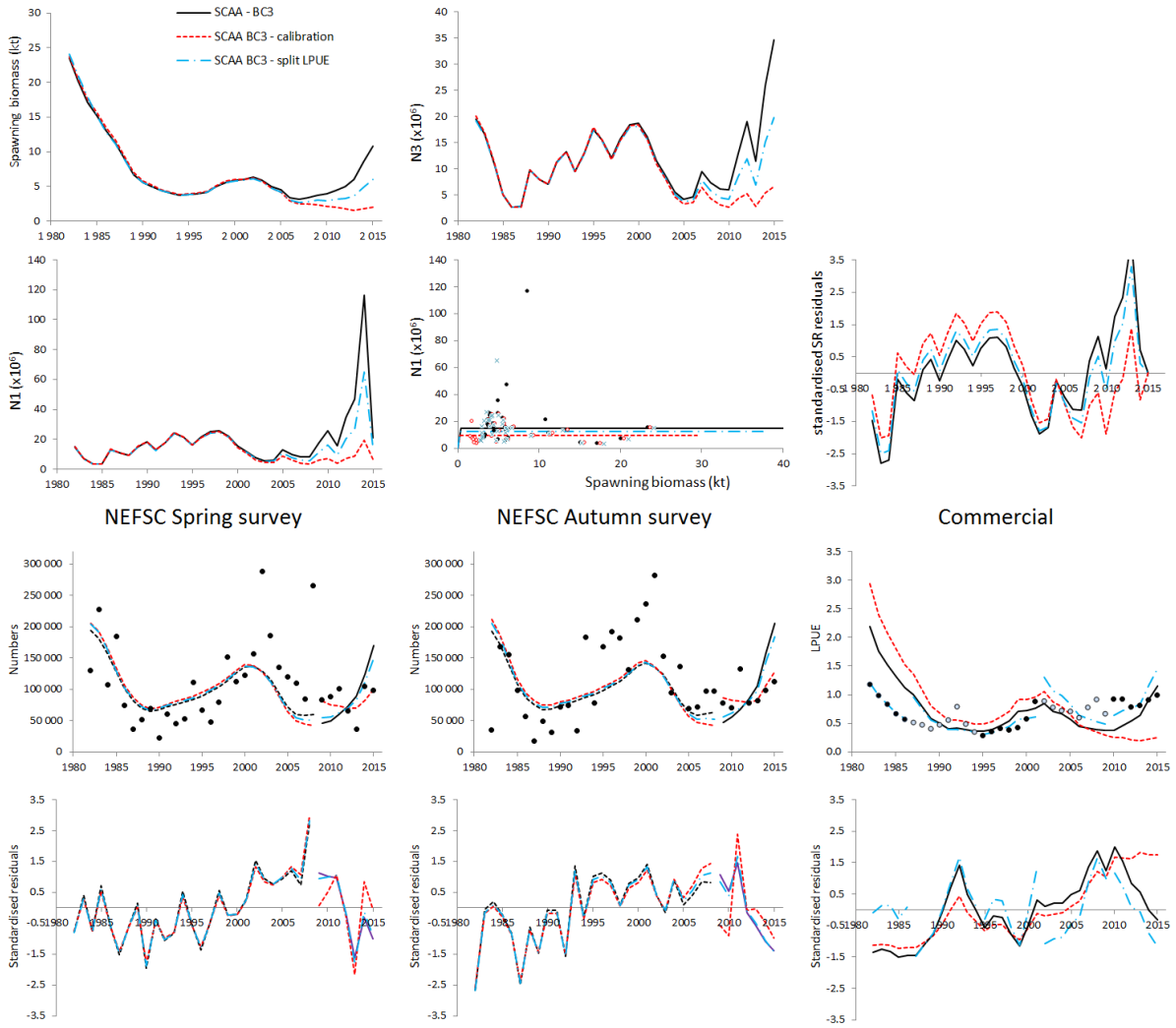


Figure 10: Comparison of the **SCAA BC3** (in black) and **calibration** (in red), and **split LPUE** (in blue) results.

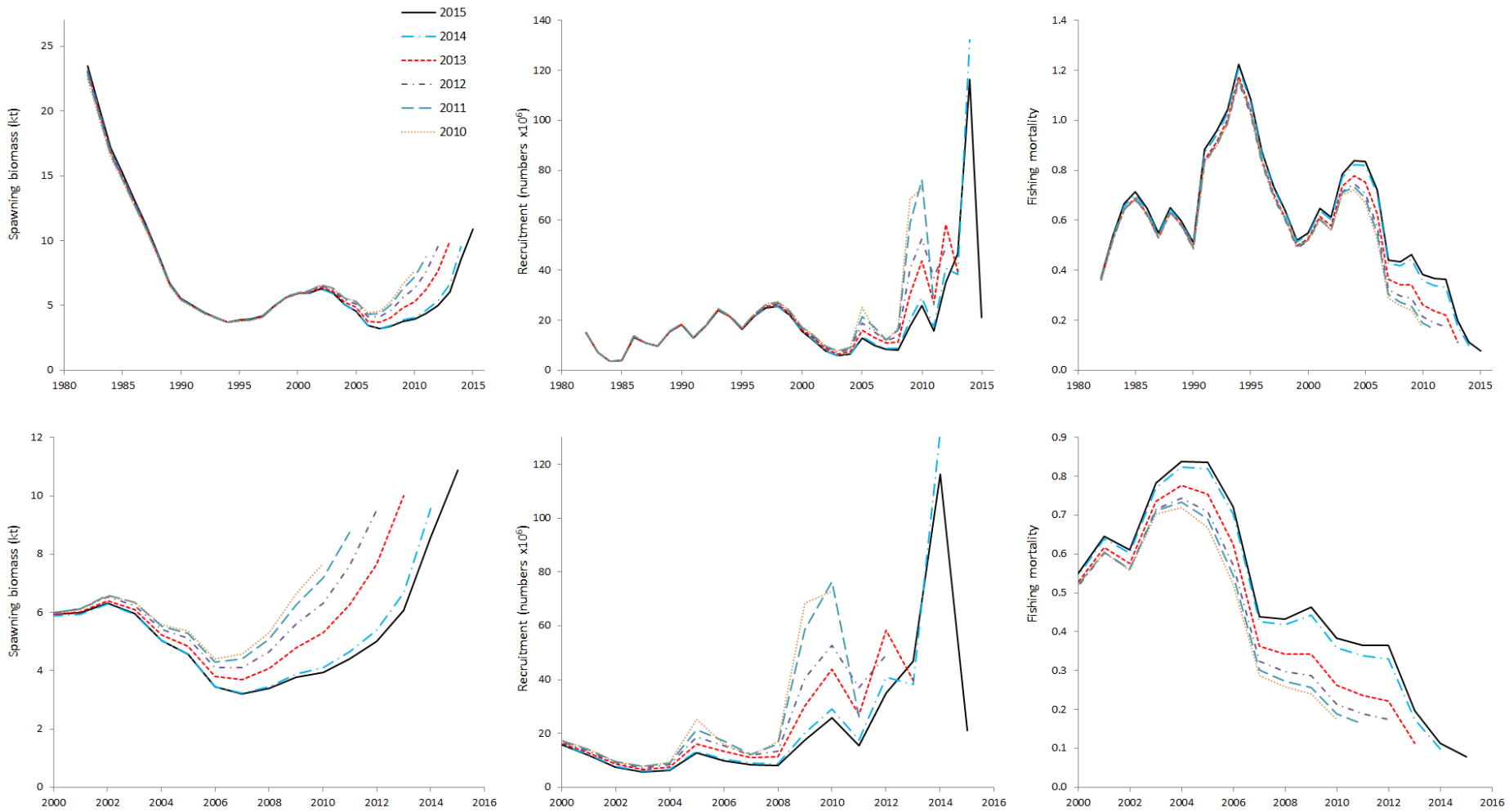


Figure 11: Retrospective plots of spawning biomass, recruitment and (apical – age 8) fishing mortality for SCAA BC3. The bottom row replicates the top row but with different scales.

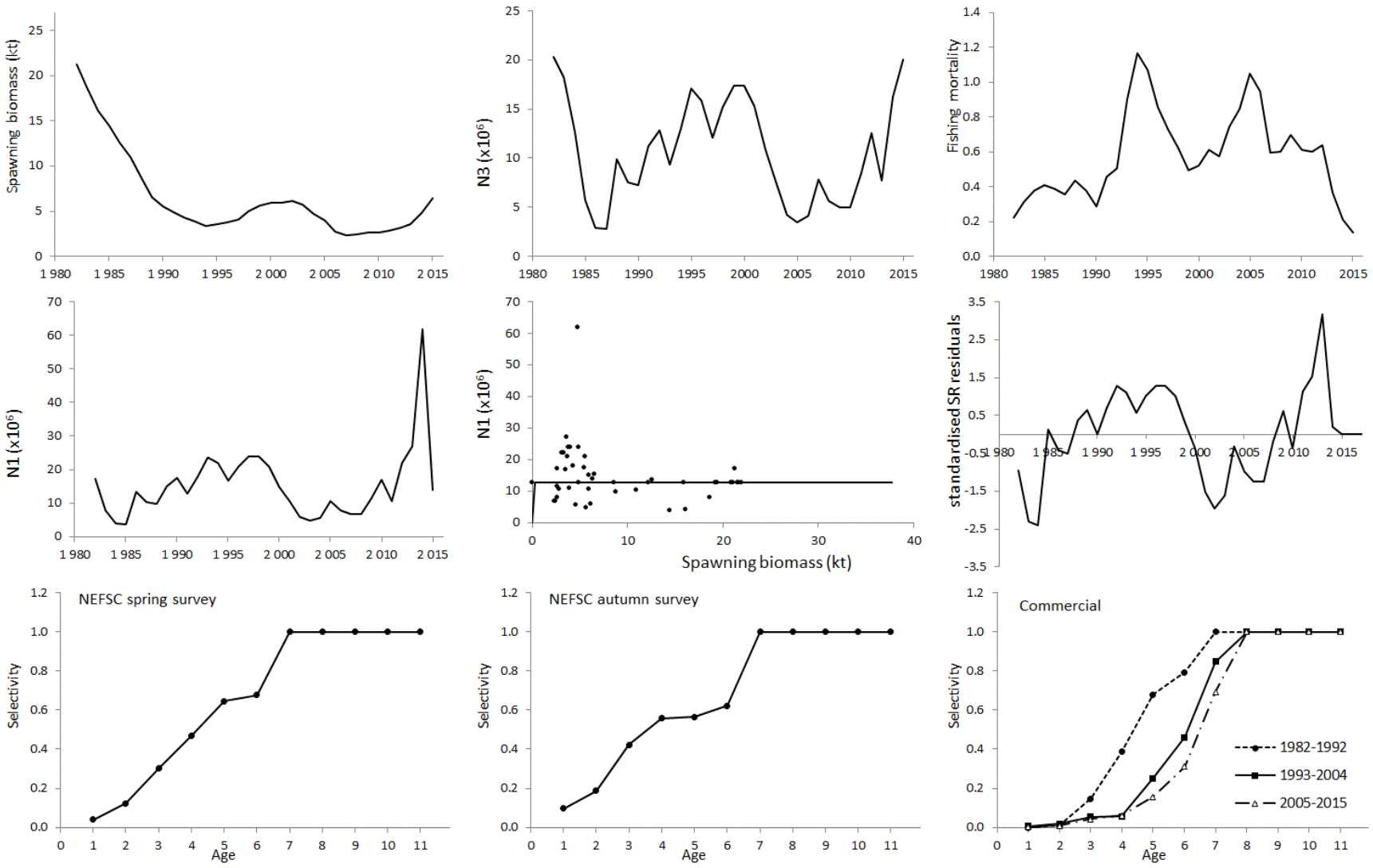


Figure 12: **SCAA Final BC** results.

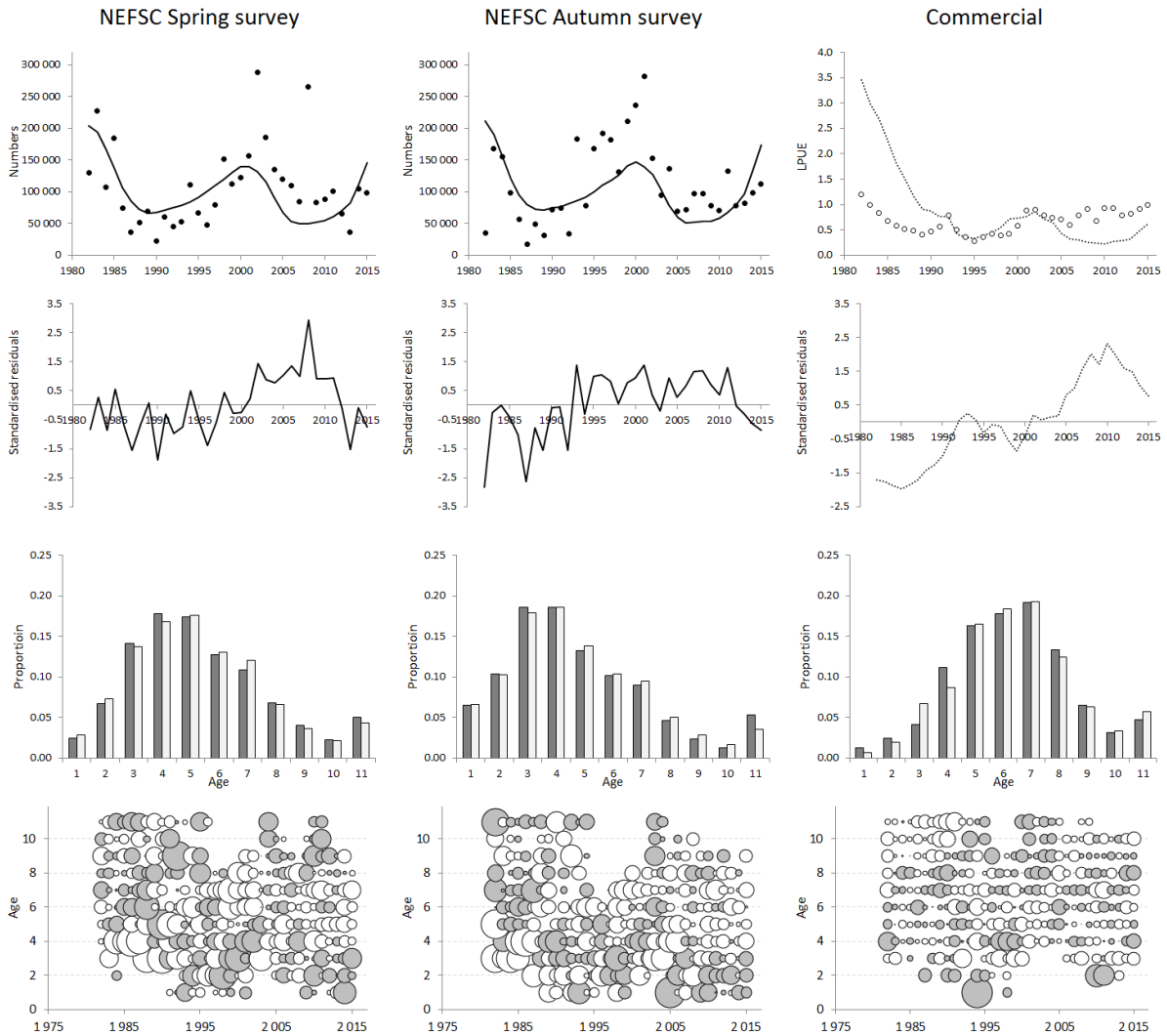


Figure 13: Fit to the survey series and survey and commercial catch-at-age data (averaged over all the years for which data is available – third row – and bubble plots of residuals, with grey bubbles representing positive residuals – bottom row) for the **SCAA Final BC** run.

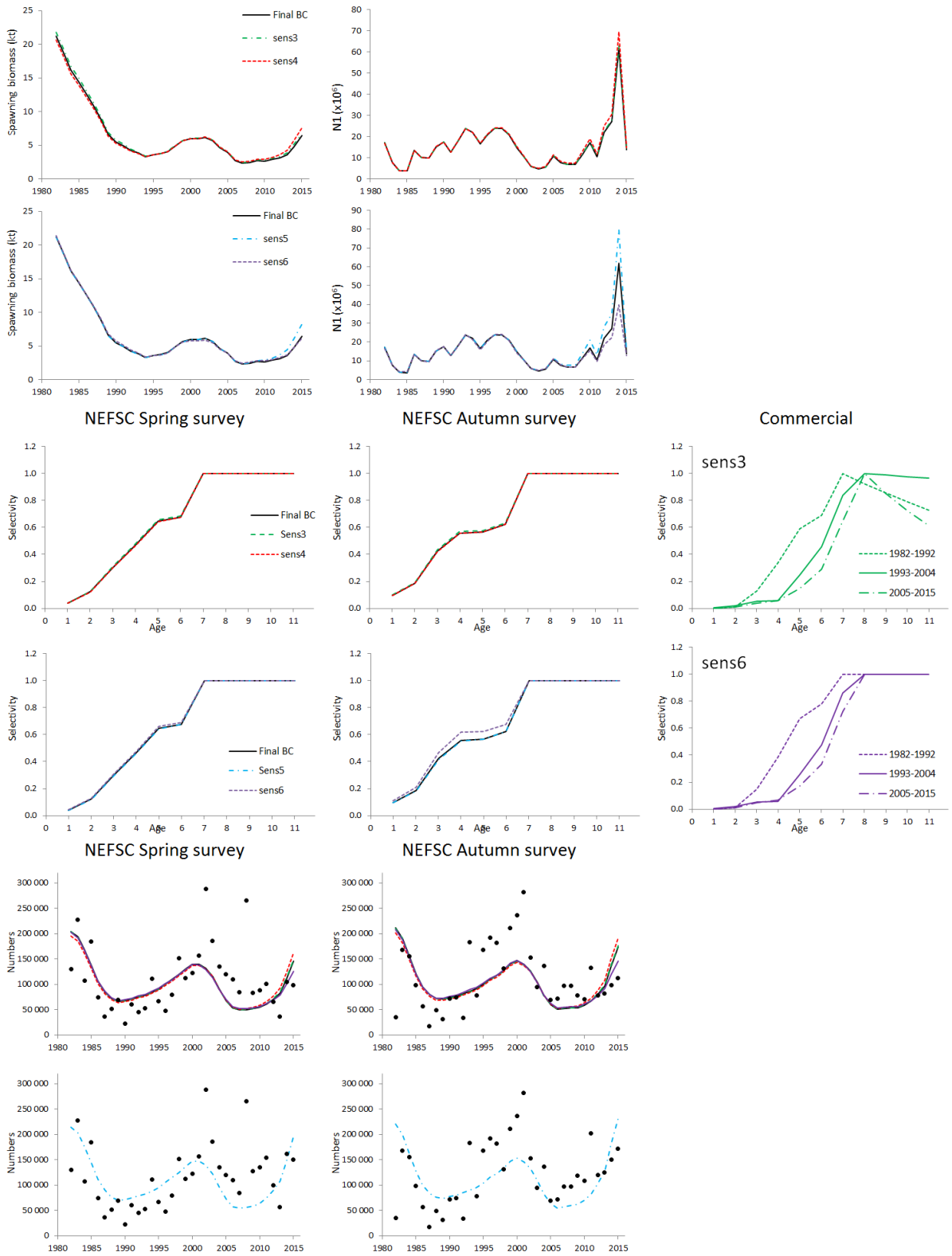


Figure 14: Comparison of the **SCAA Final BC** and four sensitivities: "sens3" (domed fishery and flat survey selectivities), "sens4" (including 40% LPUE), "sens5" (calibration factor halved) and "sens6" (downweighting the CAA data).

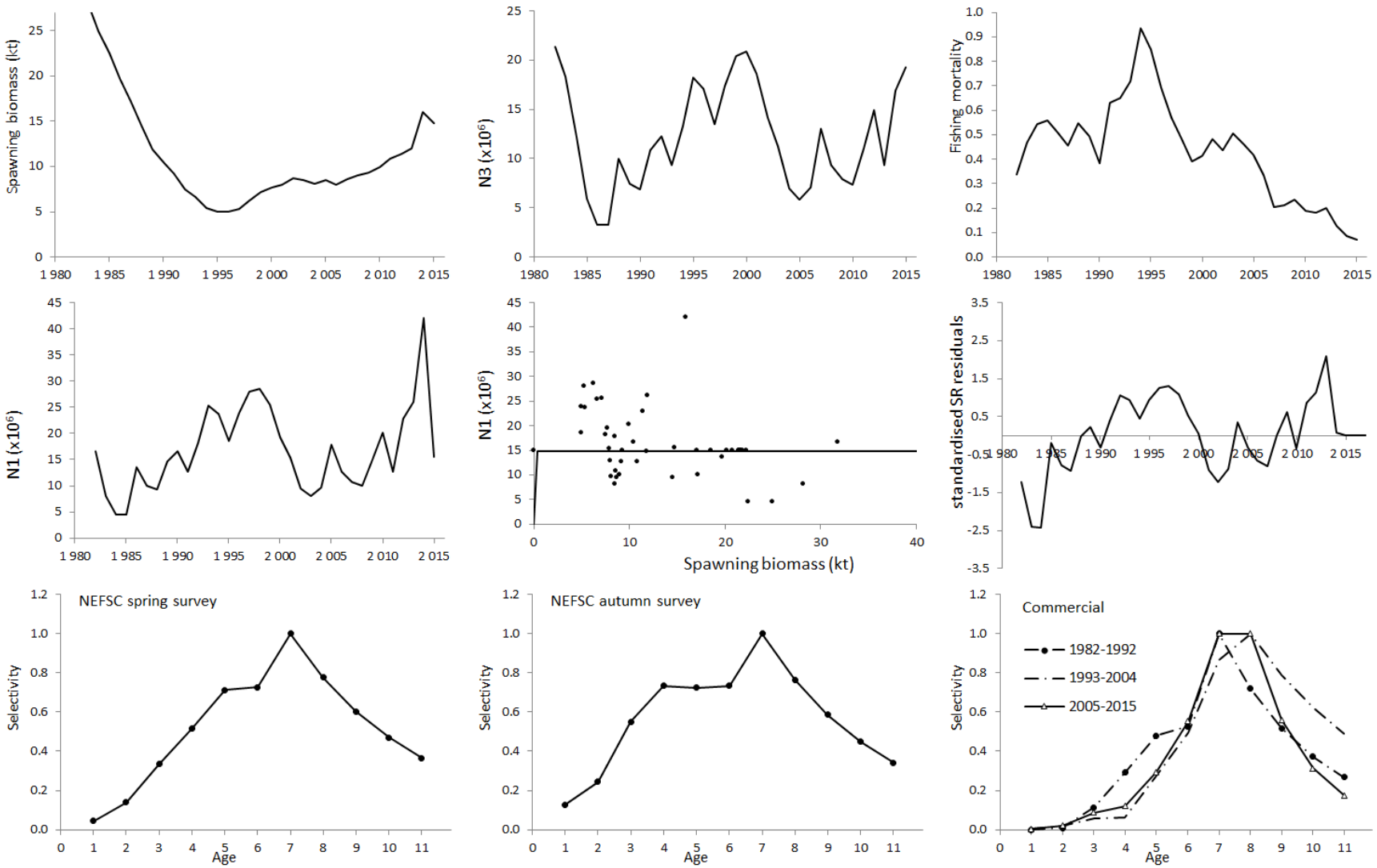


Figure 15: **SCAA sens7** (domed fishery and survey selectivities, including LPUE and downweighting the CAA data) results. Fishing mortality is apical (for age 7).

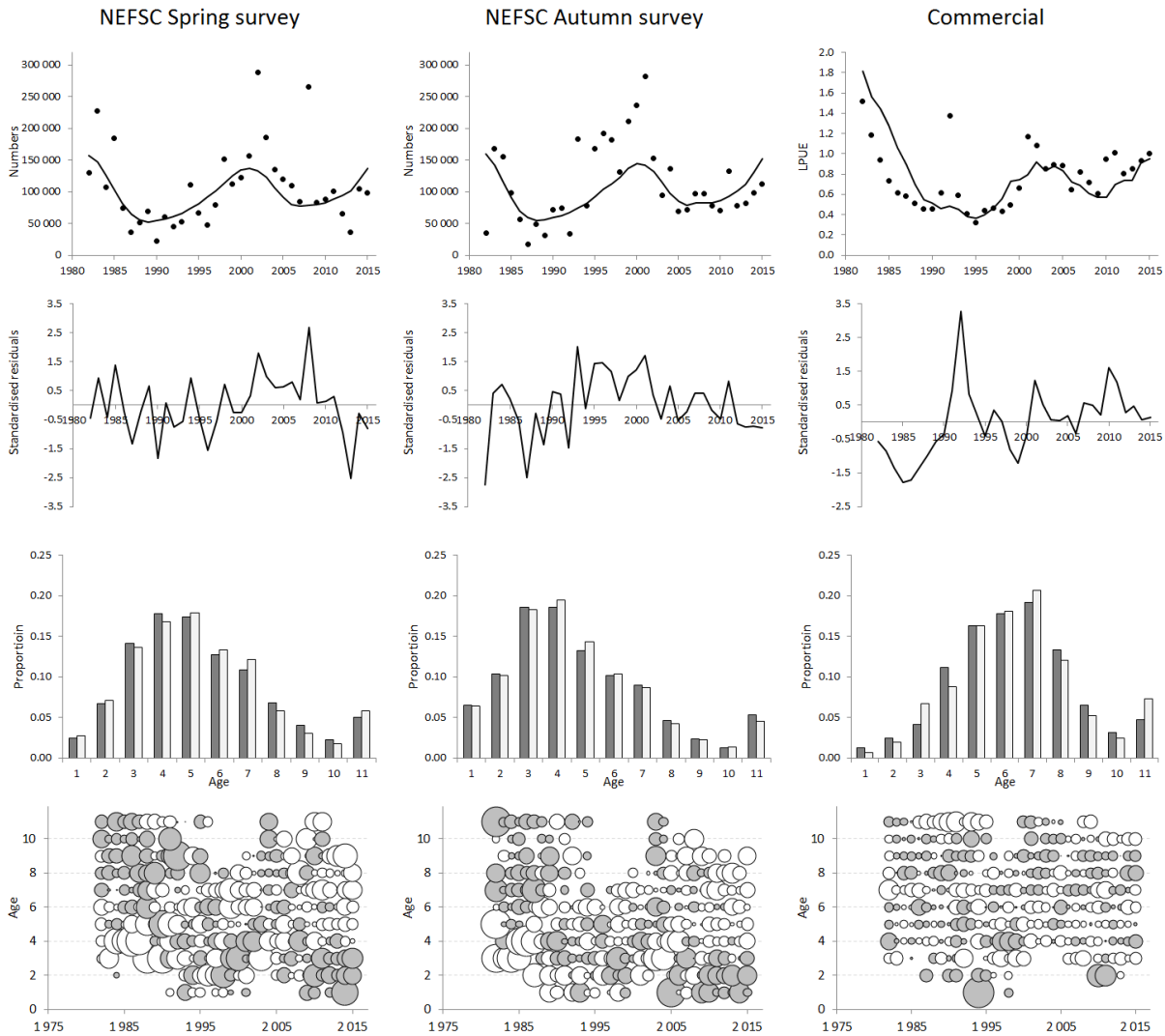


Figure 16: Fit to the survey series and survey and commercial catch-at-age data (averaged over all the years for which data is available – third row – and bubble plots of residuals, with grey bubbles representing positive residuals – bottom row) for the **SCAA sens7** run.

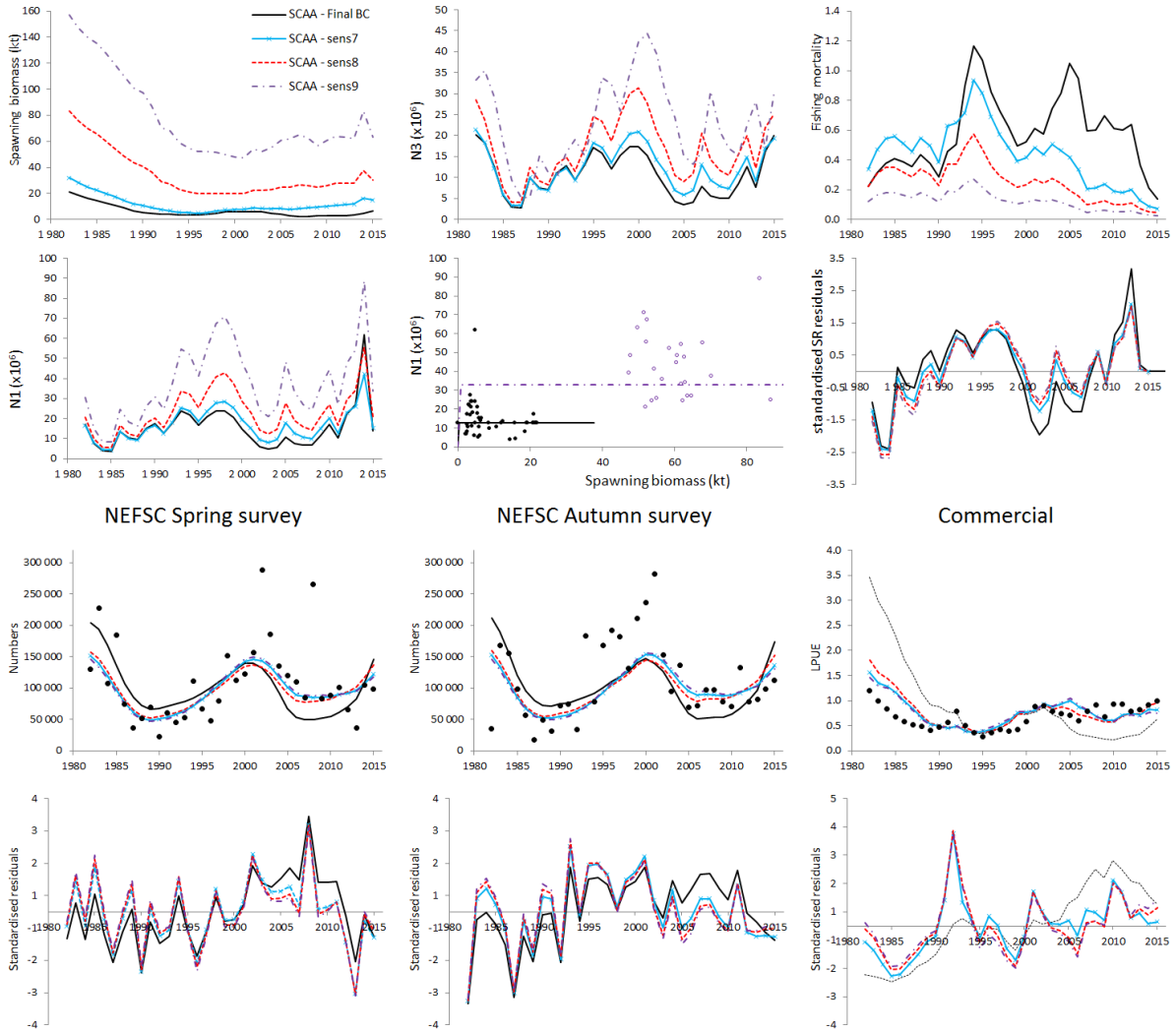


Figure 17: Comparison of the **SCAA Final BC** (in black) and **sens7** (in red, domed fishery and survey selectivities, including LPUE and downweighting the CAA data), sens8 (in blue, as sens7 but with q<=2) and sens9 (in purple, as sens7 but with q<=1) results. Fishing mortality is apical (for age 7).

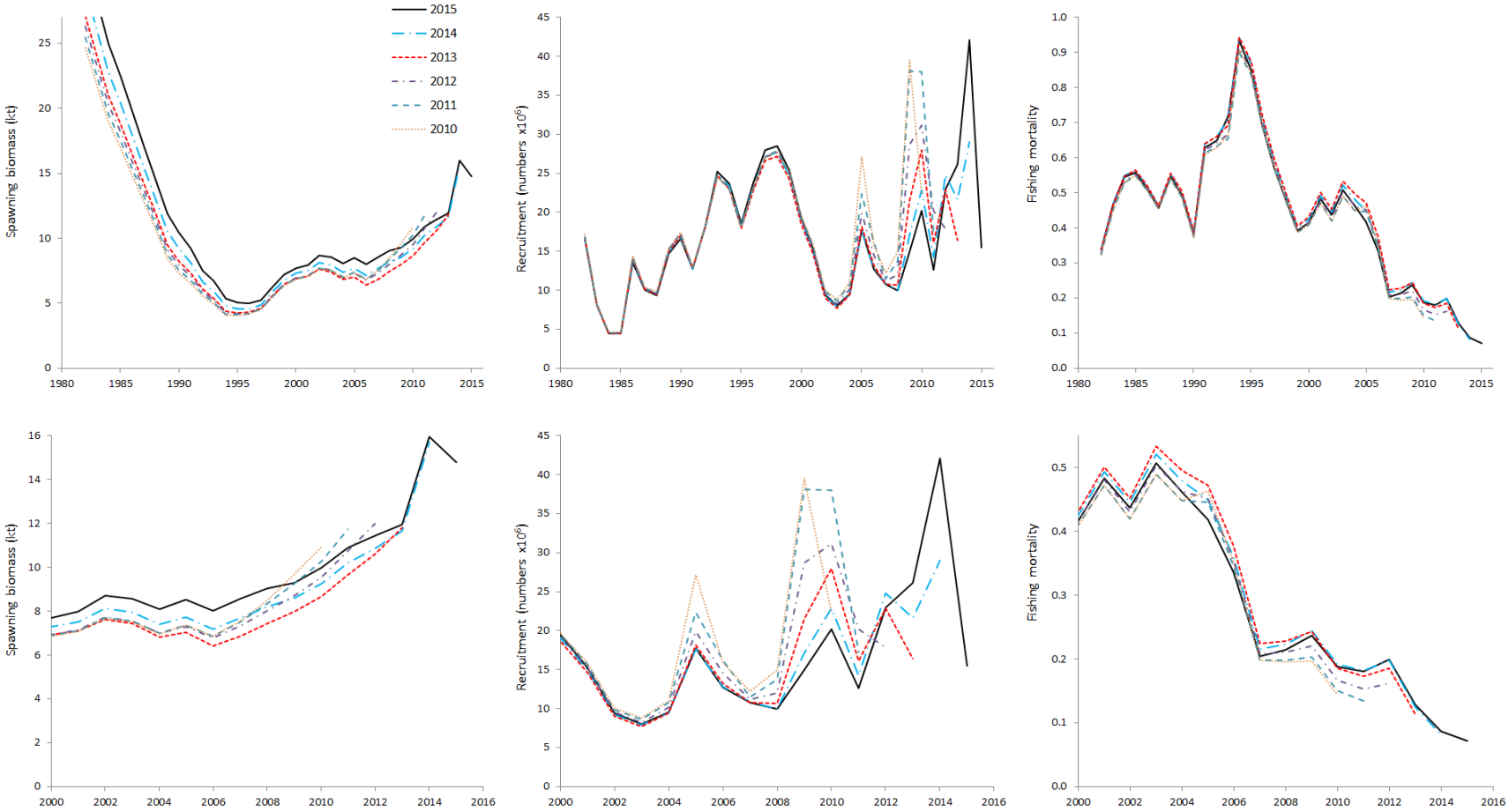


Figure 18: Retrospective plots of spawning biomass, recruitment and (apical – age 7) fishing mortality for SCAA sens7 (domed fishery and survey selectivities, including LPUE and downweighting the CAA data). The bottom row replicates the top row but with different scales.

APPENDIX B3 - Annex A - Data

Table A1: Maturity-at-age (proportions) for witch flounder.

Maturity at age					AGE						
Year	1	2	3	4	5	6	7	8	9	10	11+
1982	0.00	0.00	0.01	0.04	0.14	0.40	0.73	0.92	0.98	0.99	1.00
1983	0.00	0.00	0.01	0.06	0.20	0.51	0.82	0.95	0.99	1.00	1.00
1984	0.00	0.00	0.02	0.07	0.24	0.59	0.86	0.97	0.99	1.00	1.00
1985	0.00	0.00	0.01	0.05	0.24	0.68	0.93	0.99	1.00	1.00	1.00
1986	0.00	0.00	0.02	0.09	0.36	0.76	0.95	0.99	1.00	1.00	1.00
1987	0.00	0.02	0.08	0.30	0.68	0.91	0.98	1.00	1.00	1.00	1.00
1988	0.01	0.03	0.14	0.43	0.78	0.94	0.99	1.00	1.00	1.00	1.00
1989	0.00	0.02	0.09	0.32	0.68	0.91	0.98	1.00	1.00	1.00	1.00
1990	0.01	0.02	0.07	0.20	0.46	0.73	0.90	0.97	0.99	1.00	1.00
1991	0.01	0.02	0.07	0.17	0.38	0.64	0.84	0.94	0.98	0.99	1.00
1992	0.01	0.02	0.06	0.17	0.41	0.70	0.89	0.96	0.99	1.00	1.00
1993	0.00	0.01	0.04	0.13	0.35	0.65	0.87	0.96	0.99	1.00	1.00
1994	0.00	0.01	0.04	0.13	0.34	0.64	0.86	0.96	0.99	1.00	1.00
1995	0.00	0.01	0.03	0.13	0.42	0.78	0.95	0.99	1.00	1.00	1.00
1996	0.00	0.00	0.02	0.12	0.45	0.83	0.96	0.99	1.00	1.00	1.00
1997	0.00	0.00	0.01	0.07	0.37	0.81	0.97	1.00	1.00	1.00	1.00
1998	0.00	0.01	0.04	0.13	0.38	0.71	0.91	0.98	0.99	1.00	1.00
1999	0.00	0.01	0.04	0.14	0.36	0.67	0.88	0.96	0.99	1.00	1.00
2000	0.01	0.02	0.05	0.14	0.33	0.59	0.82	0.93	0.98	0.99	1.00
2001	0.01	0.02	0.06	0.15	0.33	0.58	0.79	0.91	0.97	0.99	1.00
2002	0.02	0.04	0.08	0.17	0.32	0.53	0.72	0.86	0.93	0.97	1.00
2003	0.02	0.04	0.09	0.17	0.31	0.49	0.68	0.82	0.91	0.96	1.00
2004	0.03	0.06	0.11	0.19	0.32	0.49	0.66	0.79	0.89	0.94	1.00
2005	0.04	0.07	0.12	0.22	0.35	0.52	0.68	0.80	0.89	0.94	1.00
2006	0.02	0.04	0.09	0.16	0.29	0.45	0.63	0.78	0.88	0.94	1.00
2007	0.02	0.04	0.08	0.17	0.32	0.52	0.71	0.85	0.93	0.97	1.00
2008	0.01	0.03	0.08	0.19	0.37	0.61	0.80	0.92	0.97	0.99	1.00
2009	0.02	0.04	0.11	0.25	0.47	0.71	0.87	0.95	0.98	0.99	1.00
2010	0.01	0.04	0.10	0.24	0.48	0.73	0.89	0.96	0.99	0.99	1.00
2011	0.02	0.05	0.13	0.29	0.53	0.75	0.89	0.96	0.98	0.99	1.00
2012	0.01	0.04	0.11	0.27	0.52	0.76	0.90	0.96	0.99	1.00	1.00
2013	0.01	0.04	0.11	0.27	0.52	0.76	0.91	0.97	0.99	1.00	1.00
2014	0.01	0.03	0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00
2015	0.01	0.03	0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00

Table A2: Catch and SSB mean weight-at-age for witch flounder in kg.

Catch mean weights						AGE					
Year	1	2	3	4	5	6	7	8	9	10	11+
1982	0.0029	0.0347	0.0847	0.1744	0.2649	0.4005	0.5499	0.7260	0.8857	0.9828	1.4054
1983	0.0078	0.0380	0.1317	0.1775	0.2370	0.4088	0.5182	0.6131	0.7948	0.9770	1.3573
1984	0.0161	0.0391	0.1192	0.2015	0.3078	0.4208	0.5390	0.6639	0.8168	0.9221	1.3393
1985	0.0163	0.0235	0.1281	0.2168	0.2940	0.4282	0.5648	0.6909	0.8419	0.9640	1.3254
1986	0.0165	0.0255	0.0910	0.1692	0.2727	0.4074	0.5331	0.6759	0.8528	0.9748	1.3208
1987	0.0151	0.0328	0.0873	0.1654	0.2618	0.4323	0.5607	0.6859	0.8282	0.9801	1.3030
1988	0.0061	0.0170	0.0629	0.1902	0.2740	0.4329	0.5376	0.6678	0.8192	0.9801	1.3255
1989	0.0123	0.0313	0.0580	0.1514	0.2395	0.4243	0.5722	0.6796	0.8179	0.9676	1.3574
1990	0.0106	0.0355	0.0580	0.2051	0.2662	0.4404	0.5849	0.6870	0.8482	1.0429	1.4527
1991	0.0139	0.0386	0.0632	0.1756	0.2885	0.3530	0.5770	0.7003	0.8347	0.9724	1.4185
1992	0.0066	0.0209	0.0961	0.2351	0.3302	0.4165	0.6042	0.7387	0.8215	0.8820	1.2430
1993	0.0086	0.0226	0.1005	0.2403	0.3302	0.4314	0.5343	0.6660	0.8820	1.0230	1.3353
1994	0.0045	0.0187	0.0736	0.2144	0.3122	0.4269	0.5260	0.6897	0.8322	0.9085	1.2636
1995	0.0074	0.0269	0.0646	0.1576	0.3001	0.4212	0.5610	0.6914	0.9080	0.9718	1.2377
1996	0.0189	0.0311	0.0607	0.1365	0.2685	0.4213	0.5542	0.7085	0.8568	0.9742	1.2295
1997	0.0234	0.0354	0.0733	0.1959	0.2771	0.3774	0.4973	0.6277	0.8611	1.0302	1.2800
1998	0.0060	0.0287	0.0830	0.1685	0.2535	0.3569	0.4874	0.5856	0.8640	0.9772	1.2088
1999	0.0062	0.0292	0.0930	0.2084	0.2829	0.3976	0.5147	0.5866	0.6324	0.9402	1.0631
2000	0.0060	0.0279	0.0810	0.1747	0.2393	0.3642	0.4512	0.5344	0.6267	0.7149	0.9296
2001	0.0060	0.0245	0.1088	0.1722	0.2415	0.3507	0.4605	0.5500	0.6448	0.6477	0.8431
2002	0.0068	0.0329	0.1024	0.2198	0.2783	0.3963	0.4728	0.5524	0.6519	0.8219	0.9400
2003	0.0072	0.0324	0.0695	0.1582	0.2437	0.3214	0.4195	0.5035	0.5658	0.6211	0.8112
2004	0.0064	0.0479	0.0986	0.2120	0.2611	0.3291	0.4333	0.5374	0.6106	0.6869	0.8701
2005	0.0188	0.0514	0.1090	0.2033	0.2859	0.3543	0.4417	0.5553	0.6323	0.7243	0.9135
2006	0.0121	0.0509	0.0975	0.1978	0.2669	0.3170	0.4532	0.5452	0.6474	0.7124	0.9272
2007	0.0154	0.0410	0.1147	0.1884	0.2495	0.3522	0.4718	0.5636	0.6783	0.7451	0.9149
2008	0.0036	0.0358	0.1241	0.1991	0.2705	0.3928	0.4754	0.5405	0.5986	0.6489	0.8268
2009	0.0402	0.0444	0.1036	0.2030	0.2652	0.3666	0.4528	0.5477	0.6222	0.7260	0.6897
2010	0.0025	0.0116	0.0808	0.1803	0.2526	0.3024	0.4256	0.4993	0.6518	0.6196	0.8102
2011	0.0024	0.0262	0.0933	0.2030	0.2469	0.3430	0.4322	0.5442	0.6483	0.7199	0.8851
2012	0.0065	0.0388	0.1402	0.1843	0.2811	0.3266	0.4382	0.5398	0.6494	0.7195	0.8828
2013	0.0245	0.0941	0.1472	0.2010	0.2669	0.3498	0.4400	0.5304	0.6313	0.6972	0.8755
2014	0.0254	0.0754	0.1319	0.1951	0.2862	0.3764	0.4812	0.5892	0.6927	0.7692	1.3769
2015	0.0264	0.0624	0.1054	0.1612	0.2751	0.3701	0.4683	0.5536	0.6564	0.7556	0.8428

SSB mean weights at age						AGE					
Year	1	2	3	4	5	6	7	8	9	10	11+
1982	0.0008	0.0178	0.0585	0.1496	0.2132	0.3521	0.5208	0.6939	0.8433	0.9330	1.4054
1983	0.0035	0.0105	0.0676	0.1226	0.2033	0.3291	0.4556	0.5806	0.7596	0.9302	1.3573
1984	0.0133	0.0175	0.0673	0.1629	0.2337	0.3158	0.4694	0.5865	0.7077	0.8561	1.3393
1985	0.0130	0.0195	0.0708	0.1608	0.2434	0.3630	0.4875	0.6102	0.7476	0.8874	1.3254
1986	0.0117	0.0204	0.0462	0.1472	0.2431	0.3461	0.4778	0.6179	0.7676	0.9059	1.3208
1987	0.0142	0.0233	0.0472	0.1227	0.2105	0.3433	0.4779	0.6047	0.7482	0.9142	1.3030
1988	0.0027	0.0160	0.0454	0.1289	0.2129	0.3366	0.4821	0.6119	0.7496	0.9010	1.3255
1989	0.0072	0.0138	0.0314	0.0976	0.2134	0.3410	0.4977	0.6044	0.7390	0.8903	1.3574
1990	0.0056	0.0209	0.0426	0.1091	0.2008	0.3248	0.4982	0.6270	0.7592	0.9236	1.4527
1991	0.0113	0.0202	0.0474	0.1009	0.2433	0.3065	0.5041	0.6400	0.7573	0.9082	1.4185
1992	0.0036	0.0170	0.0609	0.1219	0.2408	0.3466	0.4618	0.6529	0.7585	0.8580	1.2430
1993	0.0058	0.0122	0.0458	0.1520	0.2786	0.3774	0.4717	0.6343	0.8072	0.9167	1.3353
1994	0.0018	0.0127	0.0408	0.1468	0.2739	0.3754	0.4764	0.6070	0.7445	0.8952	1.2636
1995	0.0036	0.0110	0.0348	0.1077	0.2537	0.3626	0.4894	0.6031	0.7914	0.8993	1.2377
1996	0.0138	0.0152	0.0404	0.0939	0.2057	0.3556	0.4831	0.6305	0.7697	0.9405	1.2295
1997	0.0211	0.0259	0.0477	0.1090	0.1945	0.3183	0.4577	0.5898	0.7811	0.9395	1.2800
1998	0.0027	0.0259	0.0542	0.1111	0.2228	0.3145	0.4289	0.5396	0.7364	0.9173	1.2088
1999	0.0029	0.0132	0.0517	0.1315	0.2183	0.3175	0.4286	0.5347	0.6086	0.9013	1.0631
2000	0.0030	0.0132	0.0486	0.1275	0.2233	0.3210	0.4236	0.5245	0.6063	0.6724	0.9296
2001	0.0026	0.0121	0.0551	0.1181	0.2054	0.2897	0.4095	0.4982	0.5870	0.6371	0.8431
2002	0.0031	0.0140	0.0501	0.1546	0.2189	0.3094	0.4072	0.5044	0.5988	0.7280	0.9400
2003	0.0028	0.0148	0.0478	0.1273	0.2314	0.2991	0.4077	0.4879	0.5591	0.6363	0.8112
2004	0.0023	0.0186	0.0565	0.1214	0.2032	0.2832	0.3732	0.4748	0.5545	0.6234	0.8701
2005	0.0114	0.0181	0.0723	0.1416	0.2462	0.3042	0.3813	0.4905	0.5829	0.6650	0.9135
2006	0.0066	0.0309	0.0708	0.1468	0.2329	0.3010	0.4007	0.4907	0.5996	0.6712	0.9272
2007	0.0101	0.0223	0.0764	0.1355	0.2222	0.3066	0.3867	0.5054	0.6081	0.6945	0.9149
2008	0.0010	0.0235	0.0713	0.1511	0.2257	0.3131	0.4092	0.5050	0.5808	0.6634	0.8268
2009	0.0748	0.0126	0.0609	0.1587	0.2298	0.3149	0.4217	0.5103	0.5799	0.6592	0.6897
2010	0.0008	0.0216	0.0599	0.1367	0.2264	0.2832	0.3950	0.4755	0.5975	0.6209	0.8102
2011	0.0006	0.0081	0.0329	0.1281	0.2110	0.2943	0.3615	0.4813	0.5689	0.6850	0.8851
2012	0.0017	0.0096	0.0606	0.1311	0.2389	0.2840	0.3877	0.4830	0.5945	0.6830	0.8828
2013	0.0140	0.0247	0.0756	0.1679	0.2218	0.3136	0.3791	0.4821	0.5838	0.6729	0.8755
2014	0.0162	0.0430	0.1114	0.1695	0.2398	0.3170	0.4103	0.5092	0.6061	0.6968	1.3769
2015	0.0175	0.0398	0.0891	0.1458	0.2317	0.3255	0.4198	0.5161	0.6219	0.7235	0.8428

Table A3: Commercial catch-at-age (numbers) and total catch in metric tons.

	USA Commercial Catch in Numbers (1000's) at Age											
						Age						Total weight
Year	1	2	3	4	5	6	7	8	9	10	11+	(MT)
1982	0.567	5.607	569.606	2639.517	1783.427	1630.697	679.992	666.996	402.621	240.837	1581.769	5308.91
1983	0.116	6.857	450.599	2107.911	2179.089	1597.730	1607.434	986.839	741.867	511.969	1677.879	6408.60
1984	0.838	2.185	222.633	2142.118	2302.064	1761.252	1497.367	1505.305	700.016	376.358	1720.203	6936.86
1985	1.016	9.966	365.703	1556.639	2311.335	1957.652	1536.384	1254.371	608.287	401.366	1360.878	6339.35
1986	1.760	12.411	68.090	701.335	1941.511	2806.150	1582.601	842.199	415.715	223.989	760.189	4787.66
1987	33.867	143.655	55.777	334.163	813.067	1318.507	1602.784	881.442	484.684	254.450	492.585	3644.02
1988	10.788	94.742	767.854	288.380	421.124	688.357	1414.635	1168.934	405.564	268.794	600.688	3451.38
1989	17.726	90.405	192.085	1180.069	503.974	344.911	792.398	911.628	356.871	125.750	352.580	2424.98
1990	4.058	138.838	367.034	604.478	1158.980	284.554	295.391	493.800	347.107	84.961	182.239	1743.82
1991	25.191	245.711	1152.476	1595.278	2002.075	1012.933	256.209	260.502	303.311	323.813	264.151	2571.13
1992	30.959	97.582	196.151	1524.221	1531.463	1271.739	756.764	204.313	180.413	121.551	380.915	2751.97
1993	57.850	79.558	73.255	958.623	1386.252	924.061	600.316	586.487	218.566	278.058	389.811	2805.73
1994	2921.323	1061.537	100.681	738.916	2208.789	1371.979	981.975	202.511	548.804	114.695	335.580	3115.31
1995	48.454	683.181	864.719	881.761	1463.417	1912.799	879.927	284.820	103.323	282.725	162.006	2717.99
1996	104.172	163.173	390.327	678.510	1162.319	1383.912	1444.920	266.553	218.007	57.733	114.883	2392.45
1997	60.909	89.881	129.710	994.288	1189.272	1404.670	1114.704	649.761	90.470	51.734	71.978	2254.24
1998	161.398	152.609	347.466	865.764	1285.410	1486.022	1652.813	387.595	151.864	16.555	74.448	2306.24
1999	70.388	83.006	147.616	704.019	1262.546	1504.897	1224.363	783.738	260.975	38.072	75.759	2490.21
2000	101.892	78.759	132.663	497.238	708.860	1223.361	1758.267	1051.961	585.766	100.785	256.693	2748.76
2001	39.078	27.781	61.710	464.584	1315.658	1198.923	1766.246	1471.324	640.224	431.876	314.977	3406.43
2002	16.311	14.570	37.143	652.752	1210.582	1392.170	2167.130	1288.619	649.988	97.094	206.364	3470.39
2003	1.989	11.663	42.955	364.779	1300.668	1737.052	1944.153	1591.591	764.205	444.261	356.777	3550.97
2004	0.760	16.012	48.583	448.668	1408.064	1795.719	1589.928	1179.364	813.028	335.933	299.951	3370.06
2005	11.001	36.517	30.657	275.372	993.733	1996.458	1859.272	848.055	424.964	242.450	139.426	2916.83
2006	6.972	53.352	126.192	134.464	344.545	946.998	1624.709	901.303	369.128	140.072	80.217	2074.69
2007	4.753	29.889	144.450	179.640	174.494	310.973	905.672	607.730	175.451	99.340	46.482	1210.13
2008	1.200	22.313	55.445	293.238	242.925	352.223	617.315	466.765	317.030	113.232	68.711	1135.94
2009	0.622	25.127	40.691	238.696	562.298	339.983	527.421	485.433	338.646	80.674	81.078	1157.43
2010	29.169	370.005	80.707	110.936	314.626	543.392	308.355	407.329	182.763	234.229	47.800	912.33
2011	46.437	346.598	245.024	149.018	255.107	671.757	630.503	447.907	162.104	86.122	36.051	1070.97
2012	6.487	57.336	167.776	270.315	355.504	480.603	820.808	594.319	221.193	88.867	41.837	1257.51
2013	3.498	48.004	43.095	204.821	227.644	296.599	475.140	331.940	185.173	84.216	38.165	810.76
2014	1.778	19.497	134.520	104.032	220.835	181.621	280.031	337.879	136.972	48.589	27.467	675.03
2015	0.367	19.947	94.246	189.642	133.565	250.096	266.993	290.772	121.793	36.562	24.117	584.97

Table A4: Swept area NEFSC spring and autumn abundance indices, in Albacore and Bigelow units.

	SWEPT AREA (using q=0.056) ALB units				SWEPT AREA (using q=0.291) BIG units			
	NEFSC SPRING 82-15		NEFSC AUTUMN 82-15		NEFSC SPRING 09-15		NEFSC AUTUMN 09-15	
Year	number of fish (1000's)	CV	number of fish (1000's)	CV	number of fish (1000's)	CV	number of fish (1000's)	CV
1982	129606.3	0.222	35252.9	0.405				
1983	227996.6	0.270	167921.8	0.142				
1984	106806.6	0.161	155613.9	0.139				
1985	184410.5	0.193	98346.6	0.197				
1986	73755.0	0.158	56589.0	0.155				
1987	35842.4	0.232	17164.6	0.330				
1988	51019.4	0.233	48960.6	0.173				
1989	69222.5	0.217	31594.7	0.196				
1990	22280.8	0.303	71335.4	0.164				
1991	59922.2	0.250	74125.9	0.276				
1992	44844.1	0.182	33440.8	0.300				
1993	52284.2	0.177	183434.3	0.250				
1994	111366.2	0.226	78606.8	0.164				
1995	66998.9	0.169	168542.1	0.196				
1996	48353.2	0.169	191619.0	0.191				
1997	78953.1	0.267	181668.8	0.196				
1998	152102.7	0.175	131720.9	0.201				
1999	112072.3	0.205	210496.1	0.219				
2000	122631.3	0.140	235959.9	0.152				
2001	156908.6	0.163	282569.2	0.162				
2002	288301.8	0.203	153417.0	0.190				
2003	185206.3	0.161	94667.4	0.190				
2004	135215.4	0.126	135788.0	0.318				
2005	119655.8	0.203	68773.0	0.185				
2006	109855.5	0.139	72240.0	0.193				
2007	84329.7	0.165	97526.6	0.228				
2008	265119.9	0.250	97791.4	0.171				
2009	83344.3	0.147	77611.0	0.190	83585.8	0.147	77835.9	0.171
2010	87963.7	0.138	71166.0	0.169	88218.5	0.138	71372.2	0.190
2011	100384.0	0.114	132068.3	0.206	100674.8	0.114	132450.9	0.169
2012	64898.9	0.122	78020.3	0.196	65086.9	0.122	78246.3	0.206
2013	36990.5	0.134	82070.2	0.177	37097.7	0.134	82308.0	0.196
2014	105369.9	0.152	98359.0	0.168	105675.2	0.152	98644.0	0.177
2015	98629.5	0.147	112338.1	0.132	98915.2	0.147	112663.6	0.168

Table A5: Stratified mean number per tow at age of witch flounder in NEFSC spring and autumn surveys.

	NEFSC SPRING 82-15 (ALB units)					Age					
Year	1	2	3	4	5	6	7	8	9	10	11+
1982	0.0442	0.0418	0.6096	0.4838	0.3766	0.2367	0.6084	0.3621	0.0932	0.2593	0.5269
1983	0.0000	0.0710	0.5312	1.2615	1.2933	0.5410	0.7163	0.6324	0.4754	0.2141	0.6712
1984	0.0000	0.1032	0.0115	0.3071	0.7774	0.4013	0.3096	0.2017	0.1961	0.1147	0.5791
1985	0.0000	0.0000	0.0167	0.4592	1.0572	1.1994	0.9077	0.4121	0.1478	0.1487	0.8335
1986	0.0000	0.0000	0.0000	0.0439	0.2403	0.5286	0.4118	0.1719	0.1942	0.0792	0.4032
1987	0.0000	0.0000	0.0000	0.0589	0.1139	0.1328	0.2595	0.1855	0.0095	0.0614	0.1862
1988	0.0228	0.0229	0.0620	0.0000	0.0724	0.3000	0.3790	0.2386	0.1372	0.0863	0.1127
1989	0.0229	0.0130	0.0360	1.0044	0.1055	0.0728	0.0812	0.3275	0.0812	0.0152	0.1858
1990	0.0081	0.0000	0.0375	0.0913	0.3196	0.0000	0.0421	0.0087	0.0504	0.0176	0.0512
1991	0.0418	0.0000	0.7803	0.1084	0.0871	0.2087	0.0329	0.1008	0.0828	0.1377	0.1036
1992	0.0545	0.0087	0.1869	0.3727	0.0852	0.1106	0.1519	0.0450	0.1486	0.0153	0.0812
1993	0.1485	0.1122	0.1373	0.4723	0.3196	0.0577	0.0854	0.0000	0.0155	0.0155	0.1055
1994	0.1073	0.6974	0.5409	0.6436	0.8104	0.1644	0.0269	0.0281	0.0704	0.0083	0.0320
1995	0.0405	0.1198	0.5812	0.3157	0.1789	0.3119	0.1162	0.1102	0.0420	0.0000	0.0665
1996	0.0168	0.0356	0.2436	0.3944	0.3456	0.2185	0.0725	0.0000	0.0000	0.0000	0.0320
1997	0.0721	0.0663	0.1521	0.6926	0.6169	0.4375	0.0842	0.0827	0.0144	0.0000	0.0000
1998	0.1121	1.0788	0.7123	0.3881	0.7980	0.7131	0.2143	0.1536	0.0758	0.0000	0.0284
1999	0.1058	0.3758	0.9738	0.7970	0.4825	0.1643	0.1824	0.0306	0.0144	0.0228	0.0000
2000	0.0065	0.2504	1.1938	0.6925	0.6595	0.2393	0.2527	0.1159	0.0000	0.0354	0.0000
2001	0.1051	0.0988	0.7126	1.4758	1.0199	0.4008	0.2930	0.1629	0.1128	0.0281	0.0000
2002	0.0229	0.0599	0.8972	2.6274	2.2633	0.8223	0.6832	0.3507	0.1915	0.1027	0.0802
2003	0.0000	0.0000	0.1498	0.8079	1.6464	1.0167	0.8686	0.3871	0.1969	0.0455	0.0855
2004	0.0092	0.0601	0.0738	0.4280	0.6485	0.8090	0.8828	0.3683	0.1581	0.1607	0.2017
2005	0.0109	0.1600	0.1464	0.2195	0.7375	0.7602	0.5744	0.3832	0.2450	0.0865	0.0392
2006	0.0435	0.4604	0.3473	0.1380	0.2072	0.6833	0.5681	0.4101	0.1451	0.0688	0.0151
2007	0.0000	0.1778	0.5707	0.2627	0.2413	0.2284	0.5462	0.1536	0.1584	0.0000	0.0306
2008	0.0109	0.3722	0.8475	2.8342	1.3407	0.6455	0.7243	0.5501	0.0882	0.0364	0.0000
2009	0.1349	0.1395	0.2897	0.4283	0.5745	0.2058	0.1552	0.2206	0.1204	0.0566	0.0172
2010	0.1389	0.4514	0.2682	0.1681	0.4199	0.4712	0.1417	0.1016	0.1849	0.0657	0.0604
2011	0.0349	0.3652	0.7009	0.2677	0.3045	0.4695	0.2827	0.1176	0.0883	0.1150	0.0744
2012	0.0894	0.1875	0.3870	0.3293	0.1559	0.2321	0.1597	0.1585	0.0753	0.0339	0.0160
2013	0.0356	0.1239	0.1391	0.2793	0.1444	0.0870	0.1090	0.0655	0.0312	0.0186	0.0055
2014	0.5757	0.4474	0.6763	0.2635	0.4316	0.2091	0.1365	0.1383	0.0823	0.0000	0.0000
2015	0.0316	0.5818	0.7549	0.4608	0.2345	0.3200	0.1516	0.1511	0.0526	0.0201	0.0127

	NEFSC AUTUMN 82-15 (ALB units)					Age					
Year	1	2	3	4	5	6	7	8	9	10	11+
1982	0.0000	0.0000	0.0575	0.0131	0.0270	0.0757	0.2409	0.1323	0.0146	0.0274	0.3825
1983	0.0081	0.0109	0.5071	1.5958	0.7575	0.5480	0.4442	0.0837	0.1373	0.0730	0.5529
1984	0.0000	0.0000	0.0933	0.9437	0.9913	0.6049	0.5348	0.3097	0.1489	0.1256	0.6210
1985	0.0000	0.0086	0.0588	0.0757	0.6102	0.6840	0.4825	0.2698	0.1027	0.1222	0.3497
1986	0.0000	0.0000	0.0000	0.0510	0.2665	0.3533	0.3085	0.1598	0.1120	0.0093	0.3217
1987	0.0000	0.0229	0.0000	0.0109	0.0229	0.0457	0.1921	0.0714	0.0000	0.0086	0.1077
1988	0.0065	0.0000	0.7247	0.0545	0.0115	0.0356	0.2148	0.0484	0.0463	0.0454	0.1880
1989	0.0182	0.0182	0.0817	0.3006	0.0091	0.0211	0.0166	0.0838	0.0784	0.0237	0.0629
1990	0.0881	0.1369	0.3801	0.5379	0.1881	0.0240	0.0229	0.0229	0.0251	0.0000	0.0981
1991	0.0211	0.1776	0.6610	0.3292	0.2899	0.1449	0.0673	0.0591	0.0296	0.0518	0.0281
1992	0.0293	0.1092	0.2585	0.2236	0.0536	0.0604	0.0000	0.0000	0.0189	0.0092	0.0804
1993	0.6718	0.1542	0.5442	0.7771	0.2194	0.0579	0.0217	0.0814	0.0000	0.0192	0.0675
1994	0.1559	0.2872	0.5314	0.1652	0.3952	0.0370	0.1061	0.0000	0.0425	0.0091	0.0476
1995	0.2027	0.7643	1.6238	0.8576	0.4722	0.2291	0.0000	0.0000	0.0108	0.0545	0.0091
1996	0.0914	0.2608	0.7853	1.9876	1.3861	0.4412	0.0655	0.0648	0.0373	0.0000	0.0330
1997	0.3389	0.9789	0.5223	0.8709	0.7696	0.3831	0.3296	0.0000	0.0000	0.0000	0.0195
1998	0.0817	0.5199	1.3626	0.4652	0.3030	0.1652	0.1102	0.0425	0.0123	0.0000	0.0000
1999	0.5213	1.1781	1.5137	1.0439	0.5997	0.3634	0.2754	0.0498	0.0370	0.0094	0.0000
2000	0.0957	0.7187	1.4082	1.7460	0.6739	0.5891	0.2294	0.1517	0.0495	0.0000	0.0260
2001	0.0393	0.2105	0.9525	3.1557	1.8858	0.8130	0.6119	0.1586	0.0575	0.0556	0.0000
2002	0.0000	0.2748	0.4309	1.4752	0.9971	0.5319	0.3307	0.1485	0.0711	0.0000	0.0507
2003	0.0000	0.0383	0.0752	0.3067	0.5804	0.7696	0.3150	0.1286	0.2223	0.0828	0.1235
2004	0.0723	0.0144	0.0863	0.4529	0.9866	0.8263	0.4978	0.3550	0.0541	0.1048	0.0901
2005	0.6350	0.0868	0.0229	0.1309	0.1809	0.2693	0.3399	0.0548	0.0522	0.0117	0.0162
2006	0.1029	0.5398	0.3217	0.0460	0.1043	0.2982	0.2864	0.1379	0.0710	0.0420	0.0144
2007	0.0650	0.1615	1.2063	0.4776	0.1880	0.2198	0.2609	0.0691	0.0777	0.0000	0.0144
2008	0.0212	0.0952	0.4220	0.7936	0.2730	0.2537	0.2345	0.3022	0.0136	0.0565	0.0081
2009	0.3842	0.1863	0.1984	0.3770	0.4540	0.1534	0.1379	0.1152	0.0677	0.0043	0.0085
2010	0.4016	0.4686	0.1833	0.2115	0.1678	0.2512	0.0514	0.1162	0.0625	0.0193	0.0238
2011	0.2285	0.8690	1.0769	0.4022	0.2800	0.4395	0.1801	0.0751	0.0475	0.0604	0.0112
2012	0.2612	0.3079	0.6442	0.3154	0.1407	0.2156	0.1347	0.0571	0.0586	0.0318	0.0106
2013	0.1878	0.4858	0.1902	0.4620	0.2378	0.0420	0.1046	0.0572	0.0258	0.0045	0.0000
2014	0.6832	0.3263	0.5346	0.2361	0.3794	0.1419	0.1395	0.1402	0.0379	0.0076	0.0209
2015	0.1501	0.9330	0.8293	0.3310	0.1604	0.3086	0.1306	0.0512	0.0599	0.0140	0.0034

Table A6: >25% target LPUE

LPUE Year	**Trips 25** Index	CV
1982	1.193	0.05
1983	0.998	0.05
1984	0.842	0.04
1985	0.674	0.04
1986	0.582	0.04
1987	0.521	0.05
1988	0.481	0.05
1989	0.415	0.05
1990	0.476	0.06
1991	0.569	0.07
1992	0.794	0.06
1993	0.497	0.05
1994	0.362	0.04
1995	0.282	0.05
1996	0.362	0.05
1997	0.417	0.05
1998	0.387	0.05
1999	0.423	0.04
2000	0.580	0.04
2001	0.878	0.04
2002	0.901	0.04
2003	0.785	0.04
2004	0.734	0.04
2005	0.711	0.04
2006	0.600	0.05
2007	0.787	0.05
2008	0.921	0.06
2009	0.675	0.06
2010	0.931	0.07
2011	0.930	0.06
2012	0.785	0.05
2013	0.819	0.05
2014	0.914	0.05
2015	1.000	

APPENDIX B3 - Annex B

Algebraic details of the Statistical Catch-at-Age Model

The text following sets out the equations and other general specifications of the Statistical Catch-at-Age assessment model applied to witch flounder, followed by details of the contributions to the (penalised) log-likelihood function from the different sources of data available and assumptions concerning the stock-recruitment relationship. Quasi-Newton minimization is applied to minimize the total negative log-likelihood function to estimate parameter values (the package AD Model Builder™, Otter Research, Ltd is used for this purpose).

Where options are provided under a particular section, the section concludes with a statement in **bold** as to which option was selected for the iinitial Base Case (BC) runs considered in the main text.

B.1. Population dynamics

B.1.1 Numbers-at-age

The resource dynamics are modelled by the following set of population dynamics equations:

$$N_{y+1,1} = R_{y+1} \quad \text{(B1)}$$

$$N_{y+1,a+1} = N_{y,a} e^{-Z_{y,a}} \qquad \text{for } 1 \le a \le m-2 \qquad \text{(B2)}$$

$$N_{y+1,m} = N_{y,m-1} e^{-Z_{y,m-1}} + N_{y,m} e^{-Z_{y,m}} \qquad \text{(B3)}$$

where

$N_{y,a}$ is the number of fish of age *a* at the start of fishing year *y*,

R_y is the recruitment (number of 1-year-old fish) at the start of year *y*,

m is the maximum age considered (taken to be a plus-group, where here *m* = 11),

$Z_{y,a} = F_y S_{y,a} + M_{y,a}$ is the total mortality in year *y* on fish of age *a*, where

$M_{y,a}$ denotes the natural mortality rate for fish of age *a* in year *y* (taken here to be year- and age-independent),

F_y is the fishing mortality of a fully selected age class in year *y* , and

$S_{y,a}$ is the commercial selectivity at age *a* for year *y*.

B.1.2. Recruitment

The number of recruits (i.e. new 1-year olds) at the start of year *y* is assumed to be related to the spawning biomass by a Beverton-Holt stock-recruitment relationship, allowing for annual fluctuation about the deterministic relationship.

$$R_y = \frac{\alpha B_{y-1}^{sp}}{\beta + B_{y-1}^{sp}} e^{(\varsigma_y - (\sigma_R)^2/2)} \qquad \text{(B4)}$$

where

α and β are spawning biomass-recruitment relationship parameters,

ς_y reflects fluctuation about the expected recruitment for year *y*, which is assumed to be normally distributed with standard deviation σ_R (which is input in the applications considered here); these residuals are treated as estimable parameters in the model fitting process,

B_y^{sp} is the spawning biomass at the start of year *y*, computed as:

$$B_y^{sp} = \sum_{a=1}^{m} w_y^{sp} f_{y,a} N_{y,a} e^{-Z_{y,a}\mu_{spawn}} \quad \text{(B5)}$$

where spawning for the witch flounder stock under consideration is taken to occur on the 1st of March, i.e. μ_{spawn} = 0.1667,

$f_{y,a}$ is the proportion of fish of age *a* which are (reproductively) mature in year *y* (see Table A1), and

w_y^{sp} is the mean weight of fish of age *a* that are mature in year *y* (see Table A2).

Further, for the Beverton-Holt relationship, the parameters α and β parameters are related to steepness *h* and the deterministic pristine spawning biomass B_0^{sp} by the equations:

$$\alpha = \frac{4hR_0}{5h-1} \quad \text{and} \quad \beta = \frac{B_0^{sp}(1-h)}{(5h-1)}$$

For the Base Cases, the Beverton-Holt form with *h* fixed at 1.0 has been used.

B.1.3. Total catch and catches-at-age

The total catch by mass in year *y* is given by:

$$C_y = \sum_{a=1}^{m} w_{y,a}^{mid} C_{y,a} = \sum_{a=1}^{m} w_{y,a}^{mid} N_{y,a} S_{y,a} F_y \left(1-e^{-Z_{y,a}}\right) / Z_{y,a} \quad \text{(B7)}$$

where

$w_{y,a}^{mid}$ denotes the (middle of the fishing year) mean weight of fish of age *a* landed in year *y* (see Table A2),

$C_{y,a}$ is the catch-at-age, i.e. the number of fish of age *a*, caught in year *y*.

B.1.4. Initial conditions

As the first year for which data are available for witch flounder considered clearly does not correspond to the first year of (appreciable) exploitation, one cannot necessarily make the conventional assumption in the application of SCAA's that this initial year reflects a population (and its age-structure) at pre-exploitation equilibrium

For the first year (y_0) considered in the model therefore, the numbers-at-age are estimated directly for ages 1 to a^{est}, with a parameter ϕ mimicking recent average fishing mortality for ages above a^{est}, i.e.:

$$N_{y_0,a} = N_{\text{start},a} \quad \text{for } 1 \le a \le a^{est} \quad \text{(B13)}$$

and

$$N_{\text{start},a} = N_{\text{start},a-1} e^{-M_{a-1}} (1-\phi S_{y_0,a-1}) \quad \text{for } a^{est} < a \le m-1 \quad \text{(B14)}$$

$$N_{\text{start},m} = N_{\text{start},m-1} e^{-M_{m-1}} (1-\phi S_{y_0,m-1}) \Big/ (1-e^{-M_m}(1-\phi S_{y_0,m})) \quad \text{(B15)}$$

where

$$S_a = \sum_f S_{y0,a}^f C_{y0}^{obs,f} \Big/ \sum_f C_{y0}^{obs,f} \quad \text{(B16)}$$

For the Base Cases a^{est}=5. Thus the abundances of the first five ages plus the value of the parameter ϕ are estimated; there is insufficient information content in the data to allow all elements of the starting numbers-at-age vector to be estimated with reasonable precision.

B.2. The (penalised) likelihood function

The model can be fit to (a subset of) fleet-specific catches, survey abundance indices, CPUE and commercial and survey catch-at-age to estimate model parameters (these may include residuals about the stock-recruitment function, facilitated through the incorporation of a penalty function described below). Contributions by each of these to the negative of the (penalised) log-likelihood ($-\ell\mathrm{nL}$) are as follows.

B.2.1. Survey abundance data

The likelihood is calculated assuming that a survey index is lognormally distributed about its expected value:

$$I_y^{obs,i} = I_y^i \exp\left(\varepsilon_y^i\right) \quad \text{or} \quad \varepsilon_y^i = \ell\mathrm{n}\left(I_y^{obs,i}\right) - \ell\mathrm{n}\left(I_y^i\right) \quad \text{(B17)}$$

where

$I_y^{obs,i}$ is the survey index for survey *i* in year *y* (see Table A4),

$I_y^i = \hat{q}^i \widetilde{N}_y^i$ is the corresponding model estimate, where

$\hat{q}^i$ is the constant of proportionality (catchability) for the survey series *i*,

$$\widetilde{N}_y^i = \sum_{a=1}^{m} S_a^i N_{y,a} e^{-Z_{y,a} T^i/12}$$

where,

S_a^i is the selectivity at age for index *i*,

T^i is the month in which the survey takes place (4 and 10 for the spring and autumn surveys respectively), and

ε_y^i from $N\left(0,\left(\sigma_y^i\right)^2\right)$.

The contribution of the survey abundance data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell\mathrm{n}\, L^{\text{survey}} = \sum_i \sum_y \left\{ \ell\mathrm{n}\left(\sqrt{\left(\sigma_y^i\right)^2 + \left(\sigma_{Add}^i\right)^2}\right) + \left(\varepsilon_y^i\right)^2 / \left[2\left(\left(\sigma_y^i\right)^2 + \left(\sigma_{Add}^i\right)^2\right)\right]\right\} \quad \text{(B18)}$$

where

σ_y^i is the standard deviation of the residuals for the logarithm of survey *i* in year *y* (which is input), and

σ_{Add}^i is the square root of the additional variance for survey series *i*, which is estimated in the model fitting procedure.

The catchability coefficient q^i for survey index *i* is estimated by its maximum likelihood value:

$$\ell n\, \hat{q}^i = 1/n_i \sum_y \left(\ln I_y^i - \ln \widetilde{N}_y^i\right) \quad \text{(B19)}$$

B.2.2. LPUE series

As for the survey indices, the likelihood is calculated assuming that the LPUE index is lognormally distributed about its expected value:

$$I_y^{obs,LPUE} = I_y^{LPUE} \exp\left(\varepsilon_y^{LPUE}\right) \quad \text{or} \quad \varepsilon_y^{LPUE} = \ell\mathrm{n}\left(I_y^{obs,LPUE}\right) - \ell\mathrm{n}\left(I_y^{LPUE}\right) \quad \text{(B20)}$$

where

$I_y^{obs,LPUE}$ is the LPUE index in year *y* (see Table A6),

$I_y^{LPUE} = \hat{q}^{CPUE} B_y^{\text{ex}}$ is the corresponding model estimate, where

$\hat{q}^{LPUE}$ is the constant of proportionality for the LPUE index,

$$B_y^{ex} = \sum_{a=1}^{m} w_{y,a}^{\text{mid}} S_{y,a} N_{y,a} e^{-Z_{y,a}/2} \quad \text{(B21)}$$

where,

ε_y^{LPUE} from $N\left(0,\left(\sigma^{LPUE}\right)^2\right)$,

with $\hat{\sigma}^{LPUE}$ estimated in the fitting procedure by its maximum likelihood value:

$$\hat{\sigma}^{LPUE} = \sqrt{1/n_{LPUE}\sum_y\left(\ell\text{n}(I_y^{LPUE}) - \ell\text{n}(q^{LPUE}\widehat{B}_y^{ex})\right)^2} \qquad \text{(B22)}$$

The contribution of the LPUE index data to the negative of the log-likelihood function (after removal of constants) is then given by:

$$-\ell\text{n}\,L^{\text{LPUE}} = \sum_y\left\{\ell\text{n}\left(\sigma_y^{LPUE}\right) + \left(\varepsilon_y^{LPUE}\right)^2 / \left[2\left(\sigma_y^{LPUE}\right)^2\right]\right\} \qquad \text{(B23)}$$

The coefficient of proportionality q^{LPUE} for is estimated by its maximum likelihood value:

$$\ell n\,\hat{q}^{LPUE} = 1/n_{LPUE}\sum_y\left(\ln I_y^{LPUE} - \ln B_y^{ex}\right) \qquad \text{(B24)}$$

B.2.3. Commercial catches-at-age

The contribution of the catch-at-age data to the negative of the log-likelihood function under the assumption of a "sqrt(p)" formulation, which mimics a multinomial form for the error distribution by forcing a near-equivalent variance-mean relationship for the error distributions:

$$-\ell\text{n}\,L^{\text{CAA}} = W_{CAA}\sum_y\sum_a\left[\ell n\left(\sigma_{CAA}\right) + \left(\sqrt{p_{y,a}^{obs}} - \sqrt{\hat{p}_{y,a}}\right)^2 / 2\left(\sigma_{CAA}\right)^2\right] \qquad \text{(B25)}$$

where

$p_{y,a}^{obs} = C_{y,a}^{obs} / \sum_{a'} C_{y,a'}^{obs}$ is the observed proportion of fish caught in year *y* by fleet *f* that are of age *a* (see Table A3),

$\hat{p}_{y,a} = C_{y,a} / \sum_{a'} C_{y,a'}$ is the model-predicted proportion of fish caught in year *y* that are of age *a*,

where

$$C_{y,a} = N_{y,a}\;S_{y,a}\,F_y\left(1 - e^{-Z_{y,a}}\right)\Big/ Z_{y,a} \qquad \text{(B26)}$$

and

σ_{CAA} is the standard deviation associated with the catch-at-age data, which is estimated in the fitting procedure by:

$$\hat{\sigma}_{CAA} = \sqrt{\sum_y\sum_a\left(\sqrt{p_{y,a}^{obs}} - \sqrt{\hat{p}_{y,a}}\right)^2 \Big/ \sum_y\sum_a 1} \qquad \text{(B27)}$$

Minus and plus groups are year dependent and are chosen so that any proportion is greater than 2%.

The W_{CAA} factor can be selected on input to downweight the contributions of these data to the negative log likelihood, to account for their possible non-independence.

For the Base Cases, the sqrt(p) formulation has been used with W_{CAA} = 1 (i.e. no downweighting).

B.2.4. Survey catches-at-age

The survey catches-at-age are incorporated into the negative of the log-likelihood in an analogous manner to the commercial catches-at-age (equation (B25) where:

$p_{y,a}^i = C_{y,a}^i / \sum_{a'} C_{y,a'}^i$ is the observed proportion of fish of age *a* in year *y* for survey *I* (see Table A5),

$\hat{p}_{y,a}^i$ is the expected proportion of fish of age *a* in year *y* in the survey *i*, given by:

$$\hat{p}^{i}_{y,a} = S^{i}_{a} N_{y,a} e^{-Z_{y,a}T^{i}/12} \Big/ \sum_{a'=1}^{m} S^{i}_{a'} N_{y,a'} e^{-Z_{y,a'}T^{i}/12} \quad . \qquad \text{(B28)}$$

As for the commercial data, the minus and plus groups are year dependent and are chosen so that any proportion is greater than 2%.

B.2.5. Stock-recruitment function residuals

The stock-recruitment residuals are assumed to be lognormally distributed. Thus, the contribution of the recruitment residuals to the negative of the (now penalised) log-likelihood function is given by:

$$-\ell n L^{\text{pen}} = \sum_{y=y_1}^{y_2} \left[\varepsilon_y^2 / 2\sigma_{\text{R}}^2 \right] \qquad \text{(B29)}$$

where

*y*1 and *y*2 are the first and last years over which these residuals are included (the full period of the assessment is used here)

ε_y from $N\left(0,(\sigma_R)^2\right)$,

σ_{R} is the standard deviation of the log-residuals, which is input.

For the Base Cases, σ_{R} has been set to 0.5.

B.2.6. Catches

$$-\ell n L^{\text{Catch}} = \sum_{y} \left[\frac{\ell n\, C_y^{obs,} - \ell n\, C_y}{2\sigma_{\text{C}}^2} \right] \qquad \text{(B30)}$$

where

C_y^{obs} is the observed catch in year *y* ,

C_y is the predicted catch in year *y* (equation B7), and

σ_{C} is the CV input: 0.1 throughout.

B.3. Estimation of precision

Where quoted, CV's or 90% probability interval estimates are based on the Hessian.

B.4. Model parameters

B.4.1 Natural mortality

Natural mortality is taken to be age and year independent at 0.15 yr-1.

APPENDIX B4: VPA Run A2 Input file (WITCH15_SPLIT_RUN_A2.DAT)

```
VPA/ADAPT V 3.0
##
MODEL ID
WITCH 2015 SPLIT RUN A2  (swept area q= 0.056; all in ALB units)
PARAM
34  9  78  36  8  1982  3  0  123456
PARTIAL RECRUIT
0.0128  0.0324  0.0905  0.4274  0.5685  1.0000  1.0000  1.0000
AGE ESTIMATE
3  4  5  6  7  8  9  10
STOCK ESTIMATE
10000.  10000.  10000.  10000.  10000.  10000.  10000.  9000.
STOCK MIN-MAX
1.0000E+00  1.0000E+06
F-PLUS
1.00000*34
AGES-F
8-10
AGES-SUMMARY
8-9
MFSPAWN
0.1667  0.1667
CATCH AT AGE
569.61          2639.52         1783.43         1630.70         679.99          667.00          402.62          240.84          1581.77
450.60          2107.91         2179.09         1597.73         1607.43         986.84          741.87          511.97          1677.88
222.63          2142.12         2302.06         1761.25         1497.37         1505.31         700.02          376.36          1720.20
365.70          1556.64         2311.33         1957.65         1536.38         1254.37         608.29          401.37          1360.88
68.09           701.33          1941.51         2806.15         1582.60         842.20          415.71          223.99          760.19
55.78           334.16          813.07          1318.51         1602.78         881.44          484.68          254.45          492.58
767.85          288.38          421.12          688.36          1414.64         1168.93         405.56          268.79          600.69
192.08          1180.07         503.97          344.91          792.40          911.63          356.87          125.75          352.58
367.03          604.48          1158.98         284.55          295.39          493.80          347.11          84.96           182.24
1152.48         1595.28         2002.07         1012.93         256.21          260.50          303.31          323.81          264.15
196.15          1524.22         1531.46         1271.74         756.76          204.31          180.41          121.55          380.91
73.26           958.62          1386.25         924.06          600.32          586.49          218.57          278.06          389.81
100.68          738.92          2208.79         1371.98         981.98          202.51          548.80          114.70          335.58
864.72          881.76          1463.42         1912.80         879.93          284.82          103.32          282.73          162.01
390.33          678.51          1162.32         1383.91         1444.92         266.55          218.01          57.73           114.88
129.71          994.29          1189.27         1404.67         1114.70         649.76          90.47           51.73           71.98
347.47          865.76          1285.41         1486.02         1652.81         387.59          151.86          16.55           74.45
147.62          704.02          1262.55         1504.90         1224.36         783.74          260.98          38.07           75.76
132.66          497.24          708.86          1223.36         1758.27         1051.96         585.77          100.78          256.69
61.71           464.58          1315.66         1198.92         1766.25         1471.32         640.22          431.88          314.98
37.14           652.75          1210.58         1392.17         2167.13         1288.62         649.99          97.09           206.36
42.96           364.78          1300.67         1737.05         1944.15         1591.59         764.21          444.26          356.78
48.58           448.67          1408.06         1795.72         1589.93         1179.36         813.03          335.93          299.95
30.66           275.37          993.73          1996.46         1859.27         848.05          424.96          242.45          139.43
126.19          134.46          344.54          947.00          1624.71         901.30          369.13          140.07          80.22
144.45          179.64          174.49          310.97          905.67          607.73          175.45          99.34           46.48
55.45           293.24          242.92          352.22          617.32          466.77          317.03          113.23          68.71
40.69           238.70          562.30          339.98          527.42          485.43          338.65          80.67           81.08
80.71           110.94          314.63          543.39          308.36          407.33          182.76          234.23          47.80
245.02          149.02          255.11          671.76          630.50          447.91          162.10          86.12           36.05
167.78          270.32          355.50          480.60          820.81          594.32          221.19          88.87           41.84
43.10           204.82          227.64          296.60          475.14          331.94          185.17          84.22           38.17
134.52          104.03          220.84          181.62          280.03          337.88          136.97          48.59           27.47
94.25           189.64          133.57          250.10          266.99          290.77          121.79          36.56           24.12
WEIGHT AT AGE
0.085           0.174           0.265           0.401           0.550           0.726           0.886           0.983           1.405
0.132           0.178           0.237           0.409           0.518           0.613           0.795           0.977           1.357
0.119           0.201           0.308           0.421           0.539           0.664           0.817           0.922           1.339
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0.128	0.218	0.295	0.428	0.565	0.691	0.842	0.964	1.325
0.091	0.172	0.275	0.407	0.533	0.676	0.853	0.975	1.321
0.087	0.168	0.265	0.432	0.561	0.686	0.828	0.980	1.303
0.063	0.192	0.278	0.433	0.538	0.668	0.819	0.980	1.326
0.058	0.151	0.241	0.424	0.572	0.680	0.818	0.968	1.357
0.058	0.205	0.266	0.440	0.585	0.687	0.848	1.043	1.453
0.063	0.176	0.289	0.353	0.577	0.700	0.835	0.972	1.419
0.096	0.235	0.330	0.417	0.604	0.739	0.822	0.882	1.243
0.101	0.240	0.330	0.431	0.534	0.666	0.882	1.023	1.335
0.074	0.215	0.312	0.427	0.526	0.690	0.832	0.908	1.264
0.065	0.158	0.300	0.421	0.561	0.691	0.908	0.972	1.238
0.061	0.137	0.268	0.421	0.554	0.708	0.857	0.974	1.230
0.073	0.196	0.277	0.377	0.497	0.628	0.861	1.030	1.280
0.083	0.168	0.253	0.357	0.487	0.586	0.864	0.977	1.209
0.093	0.208	0.283	0.398	0.515	0.587	0.632	0.940	1.063
0.081	0.175	0.239	0.364	0.451	0.534	0.627	0.715	0.930
0.109	0.172	0.241	0.351	0.461	0.550	0.645	0.648	0.843
0.102	0.220	0.278	0.396	0.473	0.552	0.652	0.822	0.940
0.070	0.158	0.244	0.321	0.419	0.504	0.566	0.621	0.811
0.099	0.212	0.261	0.329	0.433	0.537	0.611	0.687	0.870
0.109	0.203	0.286	0.354	0.442	0.555	0.632	0.724	0.914
0.098	0.198	0.267	0.317	0.453	0.545	0.647	0.712	0.927
0.115	0.188	0.250	0.352	0.472	0.564	0.678	0.745	0.915
0.124	0.199	0.270	0.393	0.475	0.540	0.599	0.649	0.827
0.104	0.203	0.265	0.367	0.453	0.548	0.622	0.726	0.690
0.081	0.180	0.253	0.302	0.426	0.499	0.652	0.620	0.810
0.093	0.203	0.247	0.343	0.432	0.544	0.648	0.720	0.885
0.140	0.184	0.281	0.327	0.438	0.540	0.649	0.720	0.883
0.147	0.201	0.267	0.350	0.440	0.530	0.631	0.697	0.876
0.132	0.195	0.286	0.376	0.481	0.589	0.693	0.769	1.377
0.105	0.161	0.275	0.370	0.468	0.554	0.656	0.756	0.843
BIOMASS								
0.0587	0.1491	0.2133	0.3528	0.5210	0.6938	0.8437	0.9332	1.4050
0.1070	0.1230	0.2031	0.3292	0.4558	0.5806	0.7597	0.9304	1.3570
0.0879	0.1629	0.2341	0.3159	0.4695	0.5865	0.7077	0.8561	1.3390
0.1104	0.1611	0.2435	0.3631	0.4877	0.6103	0.7477	0.8875	1.3250
0.0670	0.1484	0.2448	0.3465	0.4776	0.6180	0.7677	0.9061	1.3210
0.0586	0.1236	0.2135	0.3447	0.4778	0.6047	0.7481	0.9143	1.3030
0.0407	0.1292	0.2161	0.3387	0.4821	0.6122	0.7496	0.9008	1.3260
0.0309	0.0975	0.2151	0.3433	0.4977	0.6048	0.7392	0.8904	1.3570
0.0333	0.1090	0.2004	0.3256	0.4980	0.6269	0.7594	0.9237	1.4530
0.0326	0.1010	0.2434	0.3064	0.5039	0.6399	0.7574	0.9079	1.4190
0.0607	0.1217	0.2410	0.3471	0.4617	0.6530	0.7586	0.8582	1.2430
0.0692	0.1518	0.2785	0.3771	0.4719	0.6342	0.8073	0.9170	1.3350
0.0506	0.1474	0.2736	0.3754	0.4761	0.6070	0.7444	0.8949	1.2640
0.0448	0.1081	0.2540	0.3624	0.4894	0.6029	0.7915	0.8993	1.2380
0.0340	0.0944	0.2058	0.3554	0.4829	0.6302	0.7695	0.9404	1.2300
0.0481	0.1093	0.1948	0.3179	0.4574	0.5898	0.7808	0.9395	1.2800
0.0524	0.1107	0.2227	0.3145	0.4285	0.5397	0.7366	0.9172	1.2090
0.0678	0.1314	0.2180	0.3173	0.4288	0.5347	0.6086	0.9012	1.0630
0.0556	0.1276	0.2230	0.3210	0.4237	0.5244	0.6067	0.6722	0.9300
0.0767	0.1180	0.2054	0.2896	0.4096	0.4980	0.5869	0.6374	0.8430
0.0820	0.1549	0.2187	0.3089	0.4075	0.5045	0.5988	0.7281	0.9400
0.0402	0.1269	0.2317	0.2987	0.4073	0.4883	0.5590	0.6363	0.8110
0.0691	0.1218	0.2031	0.2833	0.3728	0.4743	0.5549	0.6236	0.8700
0.0809	0.1418	0.2462	0.3040	0.3813	0.4902	0.5826	0.6651	0.9140
0.0708	0.1469	0.2328	0.3011	0.4005	0.4908	0.5992	0.6708	0.9270
0.0874	0.1357	0.2225	0.3066	0.3868	0.5055	0.6079	0.6943	0.9150
0.0969	0.1513	0.2253	0.3134	0.4089	0.5049	0.5812	0.6633	0.8270
0.0791	0.1587	0.2296	0.3148	0.4219	0.5102	0.5796	0.6594	0.6900
0.0512	0.1368	0.2266	0.2829	0.3954	0.4754	0.5977	0.6210	0.8100
0.0661	0.1282	0.2109	0.2946	0.3612	0.4814	0.5686	0.6852	0.8850
0.1168	0.1308	0.2388	0.2842	0.3876	0.4830	0.5942	0.6831	0.8830
0.1276	0.1677	0.2216	0.3136	0.3793	0.4818	0.5837	0.6726	0.8760
0.1195	0.1693	0.2398	0.3168	0.4103	0.5091	0.6060	0.6966	1.3770
0.0756	0.1458	0.2316	0.3253	0.4195	0.5162	0.6216	0.7238	0.8430

0.0756	0.1458	0.2316	0.3253	0.4195	0.5162	0.6216	0.7238	0.8430
SSB								
0.0587	0.1491	0.2133	0.3528	0.5210	0.6938	0.8437	0.9332	1.4050
0.1070	0.1230	0.2031	0.3292	0.4558	0.5806	0.7597	0.9304	1.3570
0.0879	0.1629	0.2341	0.3159	0.4695	0.5865	0.7077	0.8561	1.3390
0.1104	0.1611	0.2435	0.3631	0.4877	0.6103	0.7477	0.8875	1.3250
0.0670	0.1484	0.2448	0.3465	0.4776	0.6180	0.7677	0.9061	1.3210
0.0586	0.1236	0.2135	0.3447	0.4778	0.6047	0.7481	0.9143	1.3030
0.0407	0.1292	0.2161	0.3387	0.4821	0.6122	0.7496	0.9008	1.3260
0.0309	0.0975	0.2151	0.3433	0.4977	0.6048	0.7392	0.8904	1.3570
0.0333	0.1090	0.2004	0.3256	0.4980	0.6269	0.7594	0.9237	1.4530
0.0326	0.1010	0.2434	0.3064	0.5039	0.6399	0.7574	0.9079	1.4190
0.0607	0.1217	0.2410	0.3471	0.4617	0.6530	0.7586	0.8582	1.2430
0.0692	0.1518	0.2785	0.3771	0.4719	0.6342	0.8073	0.9170	1.3350
0.0506	0.1474	0.2736	0.3754	0.4761	0.6070	0.7444	0.8949	1.2640
0.0448	0.1081	0.2540	0.3624	0.4894	0.6029	0.7915	0.8993	1.2380
0.0340	0.0944	0.2058	0.3554	0.4829	0.6302	0.7695	0.9404	1.2300
0.0481	0.1093	0.1948	0.3179	0.4574	0.5898	0.7808	0.9395	1.2800
0.0524	0.1107	0.2227	0.3145	0.4285	0.5397	0.7366	0.9172	1.2090
0.0678	0.1314	0.2180	0.3173	0.4288	0.5347	0.6086	0.9012	1.0630
0.0556	0.1276	0.2230	0.3210	0.4237	0.5244	0.6067	0.6722	0.9300
0.0767	0.1180	0.2054	0.2896	0.4096	0.4980	0.5869	0.6374	0.8430
0.0820	0.1549	0.2187	0.3089	0.4075	0.5045	0.5988	0.7281	0.9400
0.0402	0.1269	0.2317	0.2987	0.4073	0.4883	0.5590	0.6363	0.8110
0.0691	0.1218	0.2031	0.2833	0.3728	0.4743	0.5549	0.6236	0.8700
0.0809	0.1418	0.2462	0.3040	0.3813	0.4902	0.5826	0.6651	0.9140
0.0708	0.1469	0.2328	0.3011	0.4005	0.4908	0.5992	0.6708	0.9270
0.0874	0.1357	0.2225	0.3066	0.3868	0.5055	0.6079	0.6943	0.9150
0.0969	0.1513	0.2253	0.3134	0.4089	0.5049	0.5812	0.6633	0.8270
0.0791	0.1587	0.2296	0.3148	0.4219	0.5102	0.5796	0.6594	0.6900
0.0512	0.1368	0.2266	0.2829	0.3954	0.4754	0.5977	0.6210	0.8100
0.0661	0.1282	0.2109	0.2946	0.3612	0.4814	0.5686	0.6852	0.8850
0.1168	0.1308	0.2388	0.2842	0.3876	0.4830	0.5942	0.6831	0.8830
0.1276	0.1677	0.2216	0.3136	0.3793	0.4818	0.5837	0.6726	0.8760
0.1195	0.1693	0.2398	0.3168	0.4103	0.5091	0.6060	0.6966	1.3770
0.0756	0.1458	0.2316	0.3253	0.4195	0.5162	0.6216	0.7238	0.8430
M MATRIX								
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150

0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
MATURITY								
0.01	0.04	0.14	0.40	0.73	0.92	0.98	0.99	1.00
0.01	0.06	0.20	0.51	0.82	0.95	0.99	1.00	1.00
0.02	0.07	0.24	0.59	0.86	0.97	0.99	1.00	1.00
0.01	0.05	0.24	0.68	0.93	0.99	1.00	1.00	1.00
0.02	0.09	0.36	0.76	0.95	0.99	1.00	1.00	1.00
0.08	0.30	0.68	0.91	0.98	1.00	1.00	1.00	1.00
0.14	0.43	0.78	0.94	0.99	1.00	1.00	1.00	1.00
0.09	0.32	0.68	0.91	0.98	1.00	1.00	1.00	1.00
0.07	0.20	0.46	0.73	0.90	0.97	0.99	1.00	1.00
0.07	0.17	0.38	0.64	0.84	0.94	0.98	0.99	1.00
0.06	0.17	0.41	0.70	0.89	0.96	0.99	1.00	1.00
0.04	0.13	0.35	0.65	0.87	0.96	0.99	1.00	1.00
0.04	0.13	0.34	0.64	0.86	0.96	0.99	1.00	1.00
0.03	0.13	0.42	0.78	0.95	0.99	1.00	1.00	1.00
0.02	0.12	0.45	0.83	0.96	0.99	1.00	1.00	1.00
0.01	0.07	0.37	0.81	0.97	1.00	1.00	1.00	1.00
0.04	0.13	0.38	0.71	0.91	0.98	0.99	1.00	1.00
0.04	0.14	0.36	0.67	0.88	0.96	0.99	1.00	1.00
0.05	0.14	0.33	0.59	0.82	0.93	0.98	0.99	1.00
0.06	0.15	0.33	0.58	0.79	0.91	0.97	0.99	1.00
0.08	0.17	0.32	0.53	0.72	0.86	0.93	0.97	0.99
0.09	0.17	0.31	0.49	0.68	0.82	0.91	0.96	0.98
0.11	0.19	0.32	0.49	0.66	0.79	0.89	0.94	0.97
0.12	0.22	0.35	0.52	0.68	0.80	0.89	0.94	0.97
0.09	0.16	0.29	0.45	0.63	0.78	0.88	0.94	0.97
0.08	0.17	0.32	0.52	0.71	0.85	0.93	0.97	0.98
0.08	0.19	0.37	0.61	0.80	0.92	0.97	0.99	0.99
0.11	0.25	0.47	0.71	0.87	0.95	0.98	0.99	1.00
0.10	0.24	0.48	0.73	0.89	0.96	0.99	0.99	1.00
0.13	0.29	0.53	0.75	0.89	0.96	0.98	0.99	1.00
0.11	0.27	0.52	0.76	0.90	0.96	0.99	1.00	1.00
0.11	0.27	0.52	0.76	0.91	0.97	0.99	1.00	1.00
0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00
0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00
SURVEY INDEX								
Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94
Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94	Spr82-94	Aut82-94	Aut82-94
Aut82-94	Aut82-94	Aut82-94	Aut82-94	Aut82-94	Aut82-94	Aut82-94	Aut82-94	Aut82-94
Aut82-94	Aut82-94	Aut82-94	LPUEAS	LPUEAS	LPUEAS	LPUEAS	LPUEAS	LPUEAS
Spr95-16	Spr95-16	Spr95-16	Spr95-16	Spr95-16	Spr95-16	Spr95-16	Spr95-16	Spr95-16
Spr95-16	Spr95-16	Spr95-16	Spr95-16	Spr95-16	Aut95-15	Aut95-15	Aut95-15	Aut95-15
Aut95-15	Aut95-15	Aut95-15	Aut95-15	Aut95-15	Aut95-15	Aut95-15	Aut95-15	Aut95-15
Aut95-15								

0	1	2	3	4	5	6	7	8	9	10	11
12	13	14:11	9:11	10:11	11	1	2	3	4	5	6
7	8	9	10	11	12	13	14	15:11	10:11	11	12:11
7	8	9	10	10:11	11	0	1	2	3	4	5
6	7	8	9	10	11	12	13	14:11	9:11	10:11	11
1	2	3	4	5	6	7	8	9	10	11	12
13	14	15:11	10:11	11	12:11						
1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN
1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN
1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN
MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN
1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN
1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN
1-JAN	1-JAN	1-JAN	1-JAN	1-JAN	1-JAN						
NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
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NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER
NUMBER	NUMBER	NUMBER	NUMBER	NUMBER	NUMBER						
0	1573.004145	1487.592156	21694.64541	17217.63361	13402.56473	8423.757494	21651.93941	12886.53396	3316.83227	9228.053731	
6227.957589	935.9730548	1185.091358	10402.46859	31296.37659	27979.54432	18751.49059	1067.649872	2491.183036	1067.649872	8541.19898	
15658.8648	21708.88074	16370.63138	9608.848852	9252.965561	6405.899235	7473.549107	6050.015944	1423.533163	4626.482781	17082.39796	
43061.87819	36655.97895	29182.42985	0.040	0.040	0.024	0.014	0.109	0.095	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	0	2526.771365	18904.52041	44894.67714	46026.386	19253.28603	25491.92012	22506.05931	16918.69165	7619.461256	
5911.22146	2683.360013	1903.975606	13388.3294	48425.03938	31506.34774	23886.88648	722.4430804	0	0	2046.328922	
466.207111	960.8848852	2694.036511	8573.228476	4708.335938	519.5896046	975.1202168	1138.826531	338.0891263	1405.738999	10729.88122	
15107.2457	14587.65609	13612.53587	0.088	0.054	0.041	0.028	0.121	0.093	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	0	3672.715561	409.2657844	10929.17586	27666.36703	14281.59646	11018.14668	7178.165976	6978.871333	4081.981346	
6171.016263	4156.716837	804.2962372	9477.172034	31670.05405	24691.18272	20609.20137	0	288.2654656	387.912787	18046.84168	
56791.85555	26958.15928	19502.40434	15808.33578	2978.743144	4886.277583	2597.948023	4049.951849	871.9140625	0	14754.92124	
27161.01276	22274.73517	19676.78715	0.071	0.071	0.033	0.018	0.100	0.082	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	0	0	594.3250957	16342.16071	37623.98151	42684.6419	32303.52631	14665.95041	5259.955038	5291.984534	
1558.768814	2544.565529	960.8848852	24598.65306	40214.81186	34954.85682	29662.87229	0	0	0	3320.391103	
33584.70615	35278.71062	21527.38026	19032.63839	11021.70552	5299.1022	4469.894133	2594.38919	1455.562659	4708.335938	13342.06457	
31869.34869	26570.24649	22100.35236	0.069	0.057	0.028	0.018	0.080	0.062	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	0	0	0	1562.327647	8551.875478	18811.99075	14655.27392	6117.633769	6911.253508	2818.595663	
1363.033004	2227.829401	1946.681601	8811.670281	24079.06346	17167.80995	14349.21429	0	0	306.0596301	2092.59375	
2694.036511	21715.99841	24342.41709	17171.36878	9601.731186	3654.921397	4348.893814	1021.385045	523.1484375	3174.478954	7726.226244	
20449.05389	16794.13249	12445.23868	0.082	0.044	0.022	0.012	0.051	0.040	0	0	0
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0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	0	0	0	2096.152583	4053.510682	4726.130102	9235.171397	6601.635045	338.0891263	2185.123406	
811.4139031	0	0	5815.132972	9149.759407	8811.670281	6626.546875	323.8537946	0	0	0	
1815.004783	9484.2897	12573.35666	10978.99952	5687.014987	3985.892857	330.9714605	370.1186224	761.5902423	1861.269611	8455.78699	
15765.62978	11779.73693	11448.76547	0.090	0.050	0.028	0.015	0.043	0.028	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	811.4139031	814.972736	2206.476403	0	2576.595026	10676.49872	13487.97672	8491.375319	4882.71875	3071.2728	
2989.419643	1021.385045	0	0	11964.79624	7082.077487	4010.804688	0	0	814.972736	0	
387.912787	814.972736	1626.386639	6836.518017	2541.006696	0	306.0596301	0	0	811.4139031	3021.449139	
4138.922672	4138.922672	3832.863042	0.082	0.069	0.024	0.016	0.051	0.036	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	814.972736	462.6482781	1281.179847	35744.91773	3754.568718	2590.830357	2889.772321	11655.17777	2889.772321	540.942602	
1992.946429	1975.152264	661.9429209	1982.26993	10043.02647	7153.254145	6612.311543	0	231.324139	0	25790.86209	
1939.563935	409.2657844	1266.944515	7644.373087	1722.475128	1647.739636	1615.71014	2822.154496	380.7951212	1533.856983	1953.799267	
9954.055644	8306.316008	6690.605867	0.050	0.059	0.023	0.008	0.031	0.023	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	288.2654656	0	1334.562341	3249.214445	11374.02997	0	1498.268654	309.618463	1793.651786	626.3545918	
338.0891263	405.7069515	0	1078.326371	4242.128827	2448.477041	1822.122449	6188.810427	647.7075893	647.7075893	2907.566486	
10697.85172	323.8537946	750.9137436	590.7662628	2982.301977	2790.125	843.4433992	0	911.0612245	0	1327.444675	
5872.074298	3081.949298	2238.505899	0.019	0.033	0.023	0.006	0.018	0.012	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	1487.592156	0	27769.57318	3857.774872	3099.743463	7427.284279	1170.856027	3587.303571	2946.713648	4900.512915	
637.0310906	779.3844069	0	2270.535395	11534.17746	8587.463807	3686.950893	17103.75096	3135.331792	4872.042251	13527.12388	
19142.96221	6694.1647	854.119898	814.972736	814.972736	893.2670599	0	0	323.8537946	1950.240434	1217.120855	
4384.482143	3491.215083	3491.215083	0.014	0.015	0.018	0.019	0.034	0.015	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	1939.563935	309.618463	6651.458705	13263.77025	3032.125638	3936.069196	5405.867188	1601.474809	5288.425702	544.5014349	
576.5309311	1640.621971	0	672.6194196	8722.699458	3434.273756	2889.772321	7961.109216	750.9137436	6320.487245	23523.88552	
11715.67793	10317.0566	5156.748884	2395.094547	2103.270249	1053.414541	1843.475446	1000.032047	0	0	0	
3896.922034	2843.507494	1000.032047	0.037	0.011	0.009	0.006	0.026	0.020	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0			
0	5284.866869	3993.010523	4886.277583	16808.36783	11374.02997	2053.446588	3039.243304	0	551.6191008	551.6191008	0
2434.241709	0	1320.327009	4857.80692	4306.187819	3754.568718	3434.273756	1042.738042	3886.245536	9199.583068	7957.550383	
1907.534439	2149.535077	0	0	672.6194196	327.4126276	683.2959184	0	683.2959184	1494.709821	3861.333705	
3188.714286	2861.301658	0.032	0.031	0.012	0.015	0.035	0.021	0	0	0	0
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0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0				
0	3818.62771	24819.3007	19249.7272	22904.6486	28840.78189	5850.721301	957.3260523	1000.032047	2505.418367	295.3831314	0
0	569.4132653	569.4132653	3939.628029	1434.209662	1138.826531	90419.2677	23908.23948	5487.720344	19367.16869	27655.69053	
7808.079401	2060.564254	772.2667411	2896.889987	0	683.2959184	1484.033323	0	405.7069515	512.4719388	3085.508131	
3085.508131	2402.212213	0.000	0.000	0.000	0.000	0.000	0.000	0	0	0	0
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0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	1441.327328	4263.481824	20683.93686	11235.23549	
6366.752073	11099.99984	4135.363839	3921.833865	1494.709821	0	1355.915338	1010.708546	0	0	3861.333705	
2366.623884	2366.623884	15367.0405	5548.220504	10220.96811	18911.63807	5879.191964	14064.50765	1316.768176	3775.921716	0	
1512.503986	323.8537946	0	181.5004783	0	1512.503986	3530.362245	2017.858259	1694.004464			
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	597.8839286	1266.944515	8669.316964	14036.03699	
12299.32653	7776.049904	2580.153858	0	0	0	1138.826531	0	0	0	1138.826531	
1138.826531	1138.826531	18217.66566	7213.754305	27200.15992	57788.32876	30520.55102	16804.80899	8153.286193	0	0	
384.3539541	1939.563935	0	0	0	323.8537946	2647.771684	2263.41773	323.8537946			
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	2565.918527	2359.506218	5412.984853	24648.47672	
21954.44021	15569.89397	2996.537309	2943.154815	512.4719388	0	0	0	0	0	512.4719388	0
0	8245.815848	3252.773278	9281.436224	27947.51483	70735.36288	49328.98294	15701.57079	2331.035555	2306.123724	1327.444675	0
1174.41486	0	0	0	2501.859534	1174.41486	1174.41486					
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	3989.45169	38392.68941	25349.5668	13811.83052	
28399.48661	25378.03747	7626.578922	5466.367347	2697.595344	0	0	0	1010.708546	0	3708.30389	
1010.708546	1010.708546	31751.90721	12060.88473	34837.41534	18587.78428	30993.8758	27388.77806	13633.88887	11729.91327	0	0
0	0	693.9724171	0	0	693.9724171	693.9724171	693.9724171				
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	3765.245217	13374.09407	34655.91486	28363.89828	
17171.36878	5847.162468	6491.311224	1089.00287	512.4719388	811.4139031	0	0	0	0	1323.885842	
811.4139031	0	22740.94228	2907.566486	18502.37229	48492.65721	16555.69069	10783.26371	5879.191964	3921.833865	1512.503986	
437.7364477	0	0	0	0	0	437.7364477	0	0			

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0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	231.324139	8911.317602	42485.34726	24644.91789	
23470.50303	8516.287149	8993.170759	4124.687341	0	1259.826849	0	0	0	0	1259.826849	
1259.826849	0	11491.47146	18552.19595	41926.61049	53870.05373	37150.65673	21342.32095	12932.79879	9801.025829	1772.298788	
1316.768176	334.5302934	0	0	0	0	1651.298469	334.5302934	0			
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0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	3740.333386	3516.126913	25360.2433	52521.25606	
36296.53683	14263.8023	10427.38042	5797.338807	4014.36352	1000.032047	0	0	0	0	5014.395568	
1000.032047	0	33542.00016	3405.803093	25577.33211	50115.48501	62137.22258	23982.97497	20965.08466	8163.962691	5398.749522	
1761.62229	0	0	925.2965561	0	0	2686.918846	925.2965561	925.2965561			
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0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	814.972736	2131.740912	31929.84885	93504.77583	
80547.06521	29264.283	24313.94643	12480.82701	6815.165019	3654.921397	494.6777742	0	1032.061543	1327.444675	13324.27041	
6509.105389	2854.183992	0	1398.621333	7491.343272	33897.88345	112306.0901	67112.47098	28933.31154	21776.49857	5644.308992	
2046.328922	1978.711097	0	0	0	0	4025.040019	1978.711097	0			
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0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	0	0	5331.131696	28751.81107	
58592.625	36182.65418	30912.02264	13776.24219	7007.341996	1619.268973	2145.976244	0	569.4132653	327.4126276	11669.41311	
4662.07111	3042.802136	0	0	9779.672832	15335.011	52499.90306	35485.12293	18929.43224	11769.06043	5284.866869	
2530.330198	0	1622.827806	181.5004783	0	0	4334.658482	1804.328284	1804.328284			
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0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	327.4126276	2138.858578	2626.418686	15231.80485	
23079.03141	28790.95823	31417.37691	13107.1816	5626.514828	5719.044483	4804.424426	0	0	2373.74155	18523.72529	
12897.21046	7178.165976	647.7075893	0	1363.033004	2676.242347	10914.94053	20655.4662	27388.77806	11210.32366	4576.65912	
7911.285555	2946.713648	736.678412	1629.945472	683.2959184	1345.238839	15253.15784	7341.87229	4395.158642			
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0.000	0.000	0.000	0.000	0.000	0.000	0	387.912787	5694.132653	5210.131378	7811.638233	
26246.3927	27054.24777	20441.93622	13637.4477	8719.140625	3078.390466	647.7075893	0	747.3549107	0	13192.59359	
4473.452966	1395.0625	9801.025829	2573.036193	512.4719388	3071.2728	16117.95424	35111.44547	29406.63632	17715.87022	12633.85682	
1925.328603	3729.656888	2551.683195	0	0	654.8252551	8861.493941	6936.165338	3206.50845			
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0	0	0	0	0	0	0	0	0	0	0	0
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0.000	0.000	0.000	0.000	0.000	0.000	0	1548.092315	16384.86671	12359.82669	4911.189413	
7373.901786	24317.50526	20217.72975	14594.77376	5163.86655	2448.477041	537.3837691	0	0	0	8149.72736	
2985.86081	537.3837691	4711.89477	22598.58897	3089.066964	814.972736	4658.512277	6437.928731	9583.937022	12096.47305	1950.240434	
1857.710778	416.3834503	0	0	576.5309311	0	2850.625159	992.9143814	576.5309311			
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	0	6327.604911	20310.25941	9349.05405	
8587.463807	8128.374362	19438.34534	5466.367347	5637.191327	0	1089.00287	0	0	0	6726.194196	
1089.00287	1089.00287	2338.153221	3662.039063	19210.58004	11448.76547	1637.063138	3711.862723	10612.43973	10192.49745	4907.63058	
2526.771365	1494.709821	512.4719388	0	0	0	4533.953125	2007.18176	512.4719388			
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	387.912787	13245.97608	30161.1089	100864.4423	
47713.2728	22972.26642	25776.62675	19577.13983	3138.890625	1295.415179	0	0	0	0	4434.305804	
1295.415179	0	0	2313.24139	5747.515147	42930.20137	16996.98597	6690.605867	7822.314732	9284.995057	2459.15354	
2765.21317	0	0	512.4719388	0	0	3277.685108	512.4719388	512.4719388			
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0

0.000	0.000	0.000	0.000	0.000	0.000	0	4800.865593	4964.571907	10309.93893	15242.48135
20445.49506	7324.078125	5523.308673	7850.785395	4284.834821	2014.299426	316.7361288	149.4709821	145.9121492	0	6911.253508
2626.418686	612.1192602	9776.113999	754.4725765	3388.008929	15018.27487	28242.89796	9715.613839	9028.759088	8345.46317	10754.79305
484.0012755	2010.740593	0	0	288.2654656	0	2783.007334	2299.006059	288.2654656		
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	4943.218909	16064.57175	9544.78986	5982.398119
14943.53938	16769.22066	5042.866231	3615.774235	6580.282047	2338.153221	1110.355867	555.1779337	145.9121492	338.0891263	11067.97034
4487.688297	2149.535077	3352.420599	13673.03603	6630.105708	7060.72449	13416.80006	16157.1014	5459.249681	4907.63058	4099.77551
2409.329879	153.0298151	302.5007972	0	0	0	2864.860491	455.5306122	302.5007972		
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	1242.032685	12996.85778	24943.85985	9526.995695
10836.64621	16708.7205	10060.82063	4185.1875	3142.449458	4092.657844	1487.592156	419.9422832	338.0891263	402.1481186	9882.878986
6740.429528	2647.771684	1516.062819	14292.27296	16676.69101	6523.340721	7526.931601	5971.72162	8939.788265	1829.240115	4135.363839
2224.270568	686.8547513	758.0314094	88.9708227	0	0	3758.127551	1533.856983	847.0022321		
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	3181.59662	6672.811703	13772.68335	11719.23677
5548.220504	8260.05118	5683.456154	5640.750159	2679.80118	1206.444356	355.8832908	0	213.5299745	0	4455.658801
1775.857621	569.4132653	1473.356824	8131.933195	30926.25797	38325.07159	14313.62596	9964.732143	15641.07063	6409.458068	2672.683514
1690.445631	2149.535077	213.5299745	185.0593112	0	0	4238.569994	2548.124362	398.5892857		
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	1266.944515	4409.393973	4950.336575	9939.820313
5138.954719	3096.18463	3879.12787	2331.035555	1110.355867	661.9429209	0	131.6768176	0	64.05899235	1968.034598
857.6787309	195.7358099	526.7072704	9295.671556	10957.64652	22926.00159	11224.55899	5007.277902	7672.84375	4793.747927	2032.093591
2085.476084	1131.708865	0	377.2362883	0	0	3594.421237	1508.945153	377.2362883		
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	20488.20105	15922.21843	24068.38696	9377.524713
15359.92283	7441.519611	4857.80692	4921.865912	2928.919483	0	0	0	0	0	2928.919483	0
0	18096.66534	6683.488202	17288.81027	6768.900191	16441.80804	8462.904656	1494.709821	3722.539222	2035.652423	918.1788903
160.1474809	0	0	0	0	1078.326371	160.1474809	0			
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	1124.591199	20705.28986	26865.62962	16399.10204
8345.46317	11388.26531	5395.190689	5377.396524	1871.94611	715.3254145	284.7066327	0	0	167.2651467	3039.243304
1167.297194	451.9717793	4135.363839	24313.94643	11612.47178	19025.52073	8402.404496	13502.21205	5049.983897	4964.571907	4989.483737
1348.797672	270.471301	249.1183036	306.0596301	0	188.6181441	2363.065051	1014.267379	743.7960778		
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0.000	0.000	0.000	0.000	0.000	0.000	0	3765.245217	2968.066645	26812.24713	11160.5
12957.71062	3836.421875	5017.954401	3053.478635	1078.326371	444.8541135	220.6476403	540.942602	0	0	1206.444356
761.5902423	540.942602	6608.75271	5341.808195	33203.91103	29513.40131	11779.73693	5708.367985	10982.55835	4647.835778	1822.122449
2131.740912	498.2366071	0	0	0	121.0003189	2750.977838	619.236926	121.0003189		

CHECKED INDEX
4 5 6 7 8 9 10 11 18 21 22 23 24 25 26 27 28 35 46 47 48 49 50 51 52 53 60 63 64 65 66 67 68 69 70 77
CHECKED RETRO
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
1 1 1 1 1 1 1 1 1 1
OPTIONS
1 0 0 1 1 1 0 1 0 1
XPARM
80 1

APPENDIX B5

ASAP INPUT FILE: Run_9Mc_FLAT_q056_5_v2.DAT (aka Run 9_5_v2)

```
# ASAP VERSION 3.0
# WITCH 2015 Run 9Mc FLAT q=0.056 5 SV indices
#
# ASAP GUI 15 AUG 2012
#
# Number of Years
34
# First Year
1982
# Number of Ages
11
# Number of Fleets
1
# Number of Sensitivity Blocks
3
# Number of Available Survey Indices
15
# Natural Mortality
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
# Fecundity Option
0
# Fraction of year that elapses prior to SSB calculation (0=Jan-1)
```

```
0.1667
# Maturity
0.00	0.00	0.01	0.04	0.14	0.40	0.73	0.92	0.98	0.99	1.00
0.00	0.00	0.01	0.06	0.20	0.51	0.82	0.95	0.99	1.00	1.00
0.00	0.00	0.02	0.07	0.24	0.59	0.86	0.97	0.99	1.00	1.00
0.00	0.00	0.01	0.05	0.24	0.68	0.93	0.99	1.00	1.00	1.00
0.00	0.00	0.02	0.09	0.36	0.76	0.95	0.99	1.00	1.00	1.00
0.00	0.02	0.08	0.30	0.68	0.91	0.98	1.00	1.00	1.00	1.00
0.01	0.03	0.14	0.43	0.78	0.94	0.99	1.00	1.00	1.00	1.00
0.00	0.02	0.09	0.32	0.68	0.91	0.98	1.00	1.00	1.00	1.00
0.01	0.02	0.07	0.20	0.46	0.73	0.90	0.97	0.99	1.00	1.00
0.01	0.02	0.07	0.17	0.38	0.64	0.84	0.94	0.98	0.99	1.00
0.01	0.02	0.06	0.17	0.41	0.70	0.89	0.96	0.99	1.00	1.00
0.00	0.01	0.04	0.13	0.35	0.65	0.87	0.96	0.99	1.00	1.00
0.00	0.01	0.04	0.13	0.34	0.64	0.86	0.96	0.99	1.00	1.00
0.00	0.01	0.03	0.13	0.42	0.78	0.95	0.99	1.00	1.00	1.00
0.00	0.00	0.02	0.12	0.45	0.83	0.96	0.99	1.00	1.00	1.00
0.00	0.00	0.01	0.07	0.37	0.81	0.97	1.00	1.00	1.00	1.00
0.00	0.01	0.04	0.13	0.38	0.71	0.91	0.98	0.99	1.00	1.00
0.00	0.01	0.04	0.14	0.36	0.67	0.88	0.96	0.99	1.00	1.00
0.01	0.02	0.05	0.14	0.33	0.59	0.82	0.93	0.98	0.99	1.00
0.01	0.02	0.06	0.15	0.33	0.58	0.79	0.91	0.97	0.99	1.00
0.02	0.04	0.08	0.17	0.32	0.53	0.72	0.86	0.93	0.97	1.00
0.02	0.04	0.09	0.17	0.31	0.49	0.68	0.82	0.91	0.96	1.00
0.03	0.06	0.11	0.19	0.32	0.49	0.66	0.79	0.89	0.94	1.00
0.04	0.07	0.12	0.22	0.35	0.52	0.68	0.80	0.89	0.94	1.00
0.02	0.04	0.09	0.16	0.29	0.45	0.63	0.78	0.88	0.94	1.00
0.02	0.04	0.08	0.17	0.32	0.52	0.71	0.85	0.93	0.97	1.00
0.01	0.03	0.08	0.19	0.37	0.61	0.80	0.92	0.97	0.99	1.00
0.02	0.04	0.11	0.25	0.47	0.71	0.87	0.95	0.98	0.99	1.00
0.01	0.04	0.10	0.24	0.48	0.73	0.89	0.96	0.99	0.99	1.00
0.02	0.05	0.13	0.29	0.53	0.75	0.89	0.96	0.98	0.99	1.00
0.01	0.04	0.11	0.27	0.52	0.76	0.90	0.96	0.99	1.00	1.00
0.01	0.04	0.11	0.27	0.52	0.76	0.91	0.97	0.99	1.00	1.00
0.01	0.03	0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00
0.01	0.03	0.09	0.23	0.49	0.75	0.91	0.97	0.99	1.00	1.00
# Number of Weights at Age Matrices
3
# Weight Matrix - 1
0.0029	0.0347	0.0847	0.1744	0.2649	0.4005	0.5499	0.726	0.8857	0.9828	1.4054
0.0078	0.038	0.1317	0.1775	0.237	0.4088	0.5182	0.6131	0.7948	0.977	1.3573
0.0161	0.0391	0.1192	0.2015	0.3078	0.4208	0.539	0.6639	0.8168	0.9221	1.3393
0.0163	0.0235	0.1281	0.2168	0.294	0.4282	0.5648	0.6909	0.8419	0.964	1.3254
0.0165	0.0255	0.091	0.1692	0.2727	0.4074	0.5331	0.6759	0.8528	0.9748	1.3208
0.0151	0.0328	0.0873	0.1654	0.2618	0.4323	0.5607	0.6859	0.8282	0.9801	1.303
0.0061	0.017	0.0629	0.1902	0.274	0.4329	0.5376	0.6678	0.8192	0.9801	1.3255
0.0123	0.0313	0.058	0.1514	0.2395	0.4243	0.5722	0.6796	0.8179	0.9676	1.3574
0.0106	0.0355	0.058	0.2051	0.2662	0.4404	0.5849	0.687	0.8482	1.0429	1.4527
0.0139	0.0386	0.0632	0.1756	0.2885	0.353	0.577	0.7003	0.8347	0.9724	1.4185
0.0066	0.0209	0.0961	0.2351	0.3302	0.4165	0.6042	0.7387	0.8215	0.882	1.243
0.0086	0.0226	0.1005	0.2403	0.3302	0.4314	0.5343	0.666	0.882	1.023	1.3353
0.0045	0.0187	0.0736	0.2144	0.3122	0.4269	0.526	0.6897	0.8322	0.9085	1.2636
0.0074	0.0269	0.0646	0.1576	0.3001	0.4212	0.561	0.6914	0.908	0.9718	1.2377
0.0189	0.0311	0.0607	0.1365	0.2685	0.4213	0.5542	0.7085	0.8568	0.9742	1.2295
0.0234	0.0354	0.0733	0.1959	0.2771	0.3774	0.4973	0.6277	0.8611	1.0302	1.28
0.006	0.0287	0.083	0.1685	0.2535	0.3569	0.4874	0.5856	0.864	0.9772	1.2088
0.0062	0.0292	0.093	0.2084	0.2829	0.3976	0.5147	0.5866	0.6324	0.9402	1.0631
0.006	0.0279	0.081	0.1747	0.2393	0.3642	0.4512	0.5344	0.6267	0.7149	0.9296
0.006	0.0245	0.1088	0.1722	0.2415	0.3507	0.4605	0.55	0.6448	0.6477	0.8431
0.0068	0.0329	0.1024	0.2198	0.2783	0.3963	0.4728	0.5524	0.6519	0.8219	0.94
0.0072	0.0324	0.0695	0.1582	0.2437	0.3214	0.4195	0.5035	0.5658	0.6211	0.8112
0.0064	0.0479	0.0986	0.212	0.2611	0.3291	0.4333	0.5374	0.6106	0.6869	0.8701
0.0188	0.0514	0.109	0.2033	0.2859	0.3543	0.4417	0.5553	0.6323	0.7243	0.9135
0.0121	0.0509	0.0975	0.1978	0.2669	0.317	0.4532	0.5452	0.6474	0.7124	0.9272
0.0154	0.041	0.1147	0.1884	0.2495	0.3522	0.4718	0.5636	0.6783	0.7451	0.9149
0.0036	0.0358	0.1241	0.1991	0.2705	0.3928	0.4754	0.5405	0.5986	0.6489	0.8268
```

0.0402	0.0444	0.1036	0.203	0.2652	0.3666	0.4528	0.5477	0.6222	0.726	0.6897
0.0025	0.0116	0.0808	0.1803	0.2526	0.3024	0.4256	0.4993	0.6518	0.6196	0.8102
0.0024	0.0262	0.0933	0.203	0.2469	0.343	0.4322	0.5442	0.6483	0.7199	0.8851
0.0065	0.0388	0.1402	0.1843	0.2811	0.3266	0.4382	0.5398	0.6494	0.7195	0.8828
0.0245	0.0941	0.1472	0.201	0.2669	0.3498	0.44	0.5304	0.6313	0.6972	0.8755
0.0254	0.0754	0.1319	0.1951	0.2862	0.3764	0.4812	0.5892	0.6927	0.7692	1.3769
0.0264	0.0624	0.1054	0.1612	0.2751	0.3701	0.4683	0.5536	0.6564	0.7556	0.8428
# Weight Matrix - 2										
0.0008	0.0178	0.0585	0.1496	0.2132	0.3521	0.5208	0.6939	0.8433	0.933	1.4054
0.0035	0.0105	0.0676	0.1226	0.2033	0.3291	0.4556	0.5806	0.7596	0.9302	1.3573
0.0133	0.0175	0.0673	0.1629	0.2337	0.3158	0.4694	0.5865	0.7077	0.8561	1.3393
0.013	0.0195	0.0708	0.1608	0.2434	0.363	0.4875	0.6102	0.7476	0.8874	1.3254
0.0117	0.0204	0.0462	0.1472	0.2431	0.3461	0.4778	0.6179	0.7676	0.9059	1.3208
0.0142	0.0233	0.0472	0.1227	0.2105	0.3433	0.4779	0.6047	0.7482	0.9142	1.303
0.0027	0.016	0.0454	0.1289	0.2129	0.3366	0.4821	0.6119	0.7496	0.901	1.3255
0.0072	0.0138	0.0314	0.0976	0.2134	0.341	0.4977	0.6044	0.739	0.8903	1.3574
0.0056	0.0209	0.0426	0.1091	0.2008	0.3248	0.4982	0.627	0.7592	0.9236	1.4527
0.0113	0.0202	0.0474	0.1009	0.2433	0.3065	0.5041	0.64	0.7573	0.9082	1.4185
0.0036	0.017	0.0609	0.1219	0.2408	0.3466	0.4618	0.6529	0.7585	0.858	1.243
0.0058	0.0122	0.0458	0.152	0.2786	0.3774	0.4717	0.6343	0.8072	0.9167	1.3353
0.0018	0.0127	0.0408	0.1468	0.2739	0.3754	0.4764	0.607	0.7445	0.8952	1.2636
0.0036	0.011	0.0348	0.1077	0.2537	0.3626	0.4894	0.6031	0.7914	0.8993	1.2377
0.0138	0.0152	0.0404	0.0939	0.2057	0.3556	0.4831	0.6305	0.7697	0.9405	1.2295
0.0211	0.0259	0.0477	0.109	0.1945	0.3183	0.4577	0.5898	0.7811	0.9395	1.28
0.0027	0.0259	0.0542	0.1111	0.2228	0.3145	0.4289	0.5396	0.7364	0.9173	1.2088
0.0029	0.0132	0.0517	0.1315	0.2183	0.3175	0.4286	0.5347	0.6086	0.9013	1.0631
0.003	0.0132	0.0486	0.1275	0.2233	0.321	0.4236	0.5245	0.6063	0.6724	0.9296
0.0026	0.0121	0.0551	0.1181	0.2054	0.2897	0.4095	0.4982	0.587	0.6371	0.8431
0.0031	0.014	0.0501	0.1546	0.2189	0.3094	0.4072	0.5044	0.5988	0.728	0.94
0.0028	0.0148	0.0478	0.1273	0.2314	0.2991	0.4077	0.4879	0.5591	0.6363	0.8112
0.0023	0.0186	0.0565	0.1214	0.2032	0.2832	0.3732	0.4748	0.5545	0.6234	0.8701
0.0114	0.0181	0.0723	0.1416	0.2462	0.3042	0.3813	0.4905	0.5829	0.665	0.9135
0.0066	0.0309	0.0708	0.1468	0.2329	0.301	0.4007	0.4907	0.5996	0.6712	0.9272
0.0101	0.0223	0.0764	0.1355	0.2222	0.3066	0.3867	0.5054	0.6081	0.6945	0.9149
0.001	0.0235	0.0713	0.1511	0.2257	0.3131	0.4092	0.505	0.5808	0.6634	0.8268
0.0748	0.0126	0.0609	0.1587	0.2298	0.3149	0.4217	0.5103	0.5799	0.6592	0.6897
0.0008	0.0216	0.0599	0.1367	0.2264	0.2832	0.395	0.4755	0.5975	0.6209	0.8102
0.0006	0.0081	0.0329	0.1281	0.211	0.2943	0.3615	0.4813	0.5689	0.685	0.8851
0.0017	0.0096	0.0606	0.1311	0.2389	0.284	0.3877	0.483	0.5945	0.683	0.8828
0.014	0.0247	0.0756	0.1679	0.2218	0.3136	0.3791	0.4821	0.5838	0.6729	0.8755
0.0162	0.043	0.1114	0.1695	0.2398	0.317	0.4103	0.5092	0.6061	0.6968	1.3769
0.0175	0.0398	0.0891	0.1458	0.2317	0.3255	0.4198	0.5161	0.6219	0.7235	0.8428
# Weight Matrix - 3										
0.0008	0.0178	0.0585	0.1496	0.2132	0.3521	0.5208	0.6939	0.8433	0.933	1.4054
0.0035	0.0105	0.0676	0.1226	0.2033	0.3291	0.4556	0.5806	0.7596	0.9302	1.3573
0.0133	0.0175	0.0673	0.1629	0.2337	0.3158	0.4694	0.5865	0.7077	0.8561	1.3393
0.013	0.0195	0.0708	0.1608	0.2434	0.363	0.4875	0.6102	0.7476	0.8874	1.3254
0.0117	0.0204	0.0462	0.1472	0.2431	0.3461	0.4778	0.6179	0.7676	0.9059	1.3208
0.0142	0.0233	0.0472	0.1227	0.2105	0.3433	0.4779	0.6047	0.7482	0.9142	1.303
0.0027	0.016	0.0454	0.1289	0.2129	0.3366	0.4821	0.6119	0.7496	0.901	1.3255
0.0072	0.0138	0.0314	0.0976	0.2134	0.341	0.4977	0.6044	0.739	0.8903	1.3574
0.0056	0.0209	0.0426	0.1091	0.2008	0.3248	0.4982	0.627	0.7592	0.9236	1.4527
0.0113	0.0202	0.0474	0.1009	0.2433	0.3065	0.5041	0.64	0.7573	0.9082	1.4185
0.0036	0.017	0.0609	0.1219	0.2408	0.3466	0.4618	0.6529	0.7585	0.858	1.243
0.0058	0.0122	0.0458	0.152	0.2786	0.3774	0.4717	0.6343	0.8072	0.9167	1.3353
0.0018	0.0127	0.0408	0.1468	0.2739	0.3754	0.4764	0.607	0.7445	0.8952	1.2636
0.0036	0.011	0.0348	0.1077	0.2537	0.3626	0.4894	0.6031	0.7914	0.8993	1.2377
0.0138	0.0152	0.0404	0.0939	0.2057	0.3556	0.4831	0.6305	0.7697	0.9405	1.2295
0.0211	0.0259	0.0477	0.109	0.1945	0.3183	0.4577	0.5898	0.7811	0.9395	1.28
0.0027	0.0259	0.0542	0.1111	0.2228	0.3145	0.4289	0.5396	0.7364	0.9173	1.2088
0.0029	0.0132	0.0517	0.1315	0.2183	0.3175	0.4286	0.5347	0.6086	0.9013	1.0631
0.003	0.0132	0.0486	0.1275	0.2233	0.321	0.4236	0.5245	0.6063	0.6724	0.9296
0.0026	0.0121	0.0551	0.1181	0.2054	0.2897	0.4095	0.4982	0.587	0.6371	0.8431
0.0031	0.014	0.0501	0.1546	0.2189	0.3094	0.4072	0.5044	0.5988	0.728	0.94
0.0028	0.0148	0.0478	0.1273	0.2314	0.2991	0.4077	0.4879	0.5591	0.6363	0.8112
0.0023	0.0186	0.0565	0.1214	0.2032	0.2832	0.3732	0.4748	0.5545	0.6234	0.8701

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0.0114          0.0181          0.0723          0.1416          0.2462          0.3042          0.3813          0.4905          0.5829          0.665           0.9135
0.0066          0.0309          0.0708          0.1468          0.2329          0.301           0.4007          0.4907          0.5996          0.6712          0.9272
0.0101          0.0223          0.0764          0.1355          0.2222          0.3066          0.3867          0.5054          0.6081          0.6945          0.9149
0.001           0.0235          0.0713          0.1511          0.2257          0.3131          0.4092          0.505           0.5808          0.6634          0.8268
0.0748          0.0126          0.0609          0.1587          0.2298          0.3149          0.4217          0.5103          0.5799          0.6592          0.6897
0.0008          0.0216          0.0599          0.1367          0.2264          0.2832          0.395           0.4755          0.5975          0.6209          0.8102
0.0006          0.0081          0.0329          0.1281          0.211           0.2943          0.3615          0.4813          0.5689          0.685           0.8851
0.0017          0.0096          0.0606          0.1311          0.2389          0.284           0.3877          0.483           0.5945          0.683           0.8828
0.014           0.0247          0.0756          0.1679          0.2218          0.3136          0.3791          0.4821          0.5838          0.6729          0.8755
0.0162          0.043           0.1114          0.1695          0.2398          0.317           0.4103          0.5092          0.6061          0.6968          1.3769
0.0175          0.0398          0.0891          0.1458          0.2317          0.3255          0.4198          0.5161          0.6219          0.7235          0.8428
# Weights at Age Pointers
1
1
1
1
2
3
# Selectivity Block Assignment
# Fleet 1 Selectivity Block Assignment
1
1
1
1
1
1
1
1
1
1
1
1
2
2
2
2
2
2
2
2
2
2
2
2
2
3
3
3
3
3
3
3
3
3
3
3
3
# Selectivity Options for each block 1=by age, 2=logisitic, 3=double logistic
1  1  1
# Selectivity Block #1 Data
0.0128          3               0               0.001
0.0324          3               0               0.001
0.0905          2               0               0.001
0.4274          2               0               0.001
0.5685          1               0               0.001
1               1               0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
```

```
1               -1              0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Selectivity Block #2 Data
0.0128          3               0               0.001
0.0324          3               0               0.001
0.0905          2               0               0.001
0.4274          2               0               0.001
0.5685          1               0               0.001
1               1               0               0.001
1               1               0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Selectivity Block #3 Data
0.0128          3               0               0.001
0.0324          3               0               0.001
0.0905          2               0               0.001
0.4274          2               0               0.001
0.5685          1               0               0.001
1               1               0               0.001
1               1               0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
0               0               0               0
# Fleet Start Age
1
# Fleet End Age
11
# Age Range for Average F
8  9
# Average F report option (1=unweighted, 2=Nweighted, 3=Bweighted)
1
# Use Likelihood constants? (1=yes)
0
# Release Mortality by Fleet
0
# Catch Data
# Fleet-1 Catch Data
0.566518513     5.606896798     569.5981556     2639.481958     1783.403138     1630.675411     679.983411      666.9871226     402.6155269     240.8343007     1581.748404     5308.91
0.116177956     6.857221798     450.5973005     2107.90245      2179.080081     1597.723803     1607.427084     986.8348926     741.8635887     511.966894      1677.872498     6408.6
0.838380655     2.185406352     222.6301786     2142.092193     2302.035858     1761.230949     1497.348759     1505.286895     700.007297      376.3530914     1720.182366     6936.86
1.015753207     9.965520903     365.7008725     1556.628491     2311.318715     1957.638347     1536.373152     1254.362264     608.2823974     401.3635824     1360.868563     6339.35
1.759635083     12.41089533     68.09041265     701.3418818     1941.531422     2806.179365     1582.617308     842.2078847     415.7188211     223.9912619     760.1965004     4787.66
33.86662621     143.6551884     55.77651227     334.1625336     813.0656645     1318.505502     1602.781574     881.4412398     484.6832354     254.4499612     492.5838813     3644.02
10.78820732     94.74357502     767.8653244     288.3840725     421.1306251     688.3676776     1414.656367     1168.951673     405.5703073     268.7980538     600.6968875     3451.38
17.72595644     90.40362571     192.0820682     1180.051228     503.9660508     344.9061225     792.3855222     911.6141959     356.8653662     125.7483688     352.5751012     2424.98
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4.057884043	138.8346915	367.025043	604.4629287	1158.950118	284.5470462	295.3837099	493.7878809	347.0980393	84.95913663	182.2345289	1743.82
25.19055714	245.7090434	1152.466719	1595.264994	2002.057613	1012.924893	256.2065785	260.4996796	303.3080607	323.8106356	264.1486552	2571.13
30.95943444	97.58360527	196.1549177	1524.248027	1531.489858	1271.761385	756.7777667	204.3168193	180.4165135	121.5528104	380.9215561	2751.97
57.85051286	79.55883776	73.25551783	958.6290864	1386.261087	924.0665432	600.3199594	586.4912542	218.5672894	278.0599751	389.8135989	2805.73
2921.271717	1061.518089	100.679145	738.902567	2208.750097	1371.954518	981.9579347	202.507532	548.7938629	114.693097	335.5738155	3115.31
48.45326453	683.1718811	864.7083219	881.7493384	1463.398548	1912.774219	879.9160383	284.8164719	103.3216994	282.721779	162.0040639	2717.99
104.1746542	163.1766293	390.3351983	678.5243706	1162.344534	1383.942426	1444.951529	266.5591162	218.0118546	57.73416481	114.8853537	2392.45
60.90776757	89.87894276	129.7077765	994.2676063	1189.248206	1404.641148	1114.680887	649.7475448	90.46795431	51.73249464	71.97692922	2254.24
161.4026217	152.6128551	347.4758727	865.7882732	1285.445701	1486.063998	1652.859337	387.6056722	151.8683347	16.55538629	74.45057258	2306.24
70.38551956	83.00390412	147.611678	703.9989504	1262.50931	1504.85351	1224.32768	783.7153937	260.967839	38.07073568	75.75675053	2490.21
101.8922714	78.75849953	132.6624118	497.2366386	708.8587655	1223.358007	1758.263005	1051.958297	585.7652409	100.7845164	256.6927806	2748.76
39.07799272	27.78083041	61.71019168	464.5888759	1315.672518	1198.936464	1766.265374	1471.340874	640.2307985	431.8807056	314.9804279	3406.43
16.31075742	14.56986134	37.14289183	652.7574322	1210.591501	1392.180533	2167.146504	1288.628799	649.9935861	97.09431959	206.3652549	3470.39
1.988534468	11.66328438	42.95557055	364.7793471	1300.670773	1737.055187	1944.156714	1591.59472	764.2070753	444.2615617	356.7772915	3550.97
0.760215681	16.01190584	48.58261398	448.6634368	1408.049171	1795.699657	1589.910478	1179.35169	813.0197443	335.9293917	299.9477194	3370.06
11.00124183	36.5176549	30.65752308	275.3779597	993.7544804	1996.502163	1859.312813	848.0733451	424.9728742	242.4556927	139.4294502	2916.83
6.972188858	53.35072062	126.1888042	134.4603515	344.5351545	946.97154	1624.664124	901.2781392	369.1180224	140.0685266	80.21459694	2074.69
4.752548331	29.88859912	144.4465546	179.6354318	174.4900102	310.9662426	905.6517095	607.7158517	175.4466076	99.3382131	46.48095228	1210.13
1.199930136	22.31259473	55.44322035	293.2277612	242.9158454	352.2098826	617.2928024	466.7484145	317.0190633	113.2277235	68.70899443	1135.94
0.621694892	25.12655048	40.6898391	238.691698	562.2878709	339.9770371	527.4118467	485.4242232	338.6406063	80.67286008	81.07612141	1157.43
29.16985646	370.0167012	80.70951109	110.9393807	314.6351574	543.4086136	308.3646314	407.3418629	182.7682003	234.2361632	47.80195442	912.33
46.43556927	346.5866982	245.0159323	149.012945	255.0982937	671.7348363	630.4828031	447.8921715	162.0988992	86.11875644	36.05002037	1070.97
6.487267651	57.33537102	167.7732065	270.3110203	355.4977896	480.595299	820.7949123	594.3093117	221.1890239	88.86556431	41.83632831	1257.51
3.497294934	47.99980573	43.09117501	204.8013083	227.621825	296.5701184	475.0947227	331.9083305	185.1555633	84.2083784	38.16160025	810.76
1.777519053	19.49641694	134.5170815	104.0296137	220.8298589	181.6170745	280.0243038	337.8709016	136.9684638	48.58806756	27.4666024	675.03
0.366926536	19.9456269	94.23889088	189.6269459	133.5545375	250.0763716	266.97185	290.7486523	121.7831234	36.55909766	24.11499246	584.97

Discards
Fleet-1 Discards Data

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

Release Proportion
Fleet-1 Release Data

0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0

```
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0
# Survey Index Data
# Aggregate Index Units
2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
# Age Proportion Index Units
2  2  2  2  2  2  2  2  2  2  2  2  2  2  2
# Weight at Age Matrix
3  3  3  3  3  3  3  3  3  3  3  3  3  3  3
# Index Month
4  10  4  4  10  10  4  4  10  10  8  4  10  4  10
# Index Selectivity Link to Fleet
-1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1  -1
# Index Selectivity Options 1=by age, 2=logisitic, 3=double logistic
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
# Index Start Age
1  1  1  1  1  1  1  1  1  1  1  1  1  1  1
# Index End Age
11  11  11  11  11  11  11  11  11  11  11  11  11  11  11
# Estimate Proportion (Yes=1)
1  1  0  0  0  0  0  0  0  0  1  1  1  0  0
# Use Index (Yes=1)
1  1  0  0  0  0  0  0  0  0  1  1  1  0  0
# Index-1 Selectivity Data
0.1	3	0	0.001
0.15	3	0	0.001
0.2	3	0	0.001
0.25	3	0	0.001
0.4	1	0	0.001
0.6	1	0	0.001
1	-1	0	0.001
1	-1	0	0.001
1	-1	0	0.001
1	-1	0	0.001
1	-1	0	0.001
0	-1	0	0
```

```
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-2 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-3 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-4 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-5 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
```

```
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-6 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-7 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-8 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-9 Selectivity Data
```

```
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-10 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-11 Selectivity Data
0.6             3               0               0.001
0.6             3               0               0.001
1               -1              0               0.001
1               -1              0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-12 Selectivity Data
1               -1              0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
0               -1              0               0
```

```
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-13 Selectivity Data
1               -1              0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
1               3               0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-14 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-15 Selectivity Data
0.1             3               0               0.001
0.15            3               0               0.001
0.2             3               0               0.001
0.25            3               0               0.001
0.4             1               0               0.001
0.6             1               0               0.001
0.7             1               0               0.001
0.8             1               0               0.001
0.9             1               0               0.001
0.95            1               0               0.001
1               -1              0               0.001
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
0               -1              0               0
# Index-1 Data
1982  129606.2886     0.33            1573.004145     1487.592156     21694.64541     17217.63361     13402.56473     8423.757494     21651.93941     12886.53396     3316.83227      9228.053731
18751.49059     46
1983  227996.6303     0.405           0               2526.771365     18904.52041     44894.67714     46026.386       19253.28603     25491.92012     22506.05931     16918.69165     7619.461256
23886.88648     46
1984  106806.6256     0.24            0               3672.715561     409.2657844     10929.17586     27666.36703     14281.59646     11018.14668     7178.165976     6978.871333     4081.981346
20609.20137     46
```

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1985  184410.536      0.285           0               0               594.3250957     16342.16071     37623.98151     42684.6419      32303.52631     14665.95041     5259.955038     5291.984534
29662.87229     46
1986  73755.03261     0.24            0               0               0               1562.327647     8551.875478     18811.99075     14655.27392     6117.633769     6911.253508     2818.595663
14349.21429     46
1987  35842.42975     0.345           0               0               0               2096.152583     4053.510682     4726.130102     9235.171397     6601.635045     338.0891263     2185.123406
6626.546875     46
1988  51019.42857     0.345           811.4139031     814.972736      2206.476403     0               2576.595026     10676.49872     13487.97672     8491.375319     4882.71875      3071.2728
4010.804688     46
1989  69222.50301     0.33            814.972736      462.6482781     1281.179847     35744.91773     3754.568718     2590.830357     2889.772321     11655.17777     2889.772321     540.942602
6612.311543     46
1990  22280.78519     0.45            288.2654656     0               1334.562341     3249.214445     11374.02997     0               1498.268654     309.618463      1793.651786     626.3545918
1822.122449     46
1991  59922.20497     0.375           1487.592156     0               27769.57318     3857.774872     3099.743463     7427.284279     1170.856027     3587.303571     2946.713648     4900.512915
3686.950893     46
1992  44844.14171     0.27            1939.563935     309.618463      6651.458705     13263.77025     3032.125638     3936.069196     5405.867188     1601.474809     5288.425702     544.5014349
2889.772321     46
1993  52284.23779     0.27            5284.866869     3993.010523     4886.277583     16808.36783     11374.02997     2053.446588     3039.243304     0               551.6191008     551.6191008
3754.568718     46
1994  111366.2023     0.345           3818.62771      24819.3007      19249.7272      22904.6486      28840.78189     5850.721301     957.3260523     1000.032047     2505.418367     295.3831314
1138.826531     46
1995  66998.94421     0.255           1441.327328     4263.481824     20683.93686     11235.23549     6366.752073     11099.99984     4135.363839     3921.833865     1494.709821     0
2366.623884     46
1996  48353.15096     0.255           597.8839286     1266.944515     8669.316964     14036.03699     12299.32653     7776.049904     2580.153858     0               0               0
1138.826531     46
1997  78953.06395     0.405           2565.918527     2359.506218     5412.984853     24648.47672     21954.44021     15569.89397     2996.537309     2943.154815     512.4719388     0               0
46
1998  152102.7391     0.255           3989.45169      38392.68941     25349.5668      13811.83052     28399.48661     25378.03747     7626.578922     5466.367347     2697.595344     0
1010.708546     46
1999  112072.2748     0.3             3765.245217     13374.09407     34655.91486     28363.89828     17171.36878     5847.162468     6491.311224     1089.00287      512.4719388     811.4139031     0
46
2000  122631.332      0.21            231.324139      8911.317602     42485.34726     24644.91789     23470.50303     8516.287149     8993.170759     4124.687341     0               1259.826849     0
46
2001  156908.587      0.24            3740.333386     3516.126913     25360.2433      52521.25606     36296.53683     14263.8023      10427.38042     5797.338807     4014.36352      1000.032047     0
46
2002  288301.7657     0.3             814.972736      2131.740912     31929.84885     93504.77583     80547.06521     29264.283       24313.94643     12480.82701     6815.165019     3654.921397
2854.183992     46
2003  185206.291      0.24            0               0               5331.131696     28751.81107     58592.625       36182.65418     30912.02264     13776.24219     7007.341996     1619.268973
3042.802136     46
2004  135215.3652     0.195           327.4126276     2138.858578     2626.418686     15231.80485     23079.03141     28790.95823     31417.37691     13107.1816      5626.514828     5719.044483
7178.165976     46
2005  119655.7918     0.3             387.912787      5694.132653     5210.131378     7811.638233     26246.3927      27054.24777     20441.93622     13637.4477      8719.140625     3078.390466
1395.0625       46
2006  109855.4777     0.21            1548.092315     16384.86671     12359.82669     4911.189413     7373.901786     24317.50526     20217.72975     14594.77376     5163.86655      2448.477041
537.3837691     46
2007  84329.74871     0.24            0               6327.604911     20310.25941     9349.05405      8587.463807     8128.374362     19438.34534     5466.367347     5637.191327     0
1089.00287      46
2008  265119.884      0.375           387.912787      13245.97608     30161.1089      100864.4423     47713.2728      22972.26642     25776.62675     19577.13983     3138.890625     1295.415179     0
46
2009  83344.30788     0.225           4800.865593     4964.571907     10309.93893     15242.48135     20445.49506     7324.078125     5523.308673     7850.785395     4284.834821     2014.299426
612.1192602     46
2010  87963.67299     0.21            4943.218909     16064.57175     9544.78986      5982.398119     14943.53938     16769.22066     5042.866231     3615.774235     6580.282047     2338.153221
2149.535077     46
2011  100383.9998     0.165           1242.032685     12996.85778     24943.85985     9526.995695     10836.64621     16708.7205      10060.82063     4185.1875       3142.449458     4092.657844
2647.771684     46
2012  64898.87691     0.18            3181.59662      6672.811703     13772.68335     11719.23677     5548.220504     8260.05118      5683.456154     5640.750159     2679.80118      1206.444356
569.4132653     46
2013  36990.50925     0.195           1266.944515     4409.393973     4950.336575     9939.820313     5138.954719     3096.18463      3879.12787      2331.035555     1110.355867     661.9429209
195.7358099     46
2014  105369.9247     0.225           20488.20105     15922.21843     24068.38696     9377.524713     15359.92283     7441.519611     4857.80692      4921.865912     2928.919483     0               0
46
2015  98629.49522     0.225           1124.591199     20705.28986     26865.62962     16399.10204     8345.46317      11388.26531     5395.190689     5377.396524     1871.94611      715.3254145
451.9717793     46
# Index-2 Data
1982  35252.87349     0.7             0               0               2046.328922     466.207111      960.8848852     2694.036511     8573.228476     4708.335938     519.5896046     975.1202168
13612.53587     35
```

1983	167921.7514	0.245	288.2654656	387.912787	18046.84168	56791.85555	26958.15928	19502.40434	15808.33578	2978.743144	4886.277583	2597.948023	19676.78715	35
1984	155613.8836	0.245	0	0	3320.391103	33584.70615	35278.71062	21527.38026	19032.63839	11021.70552	5299.1022	4469.894133	22100.35236	35
1985	98346.568	0.35	0	306.0596301	2092.59375	2694.036511	21715.99841	24342.41709	17171.36878	9601.731186	3654.921397	4348.893814	12445.23868	35
1986	56589.00207	0.2625	0	0	0	1815.004783	9484.2897	12573.35666	10978.99952	5687.014987	3985.892857	330.9714605	11448.76547	35
1987	17164.57141	0.5775	0	814.972736	0	387.912787	814.972736	1626.386639	6836.518017	2541.006696	0	306.0596301	3832.863042	35
1988	48960.64373	0.2975	231.324139	0	25790.86209	1939.563935	409.2657844	1266.944515	7644.373087	1722.475128	1647.739636	1615.71014	6690.605867	35
1989	31594.74915	0.35	647.7075893	647.7075893	2907.566486	10697.85172	323.8537946	750.9137436	590.7662628	2982.301977	2790.125	843.4433992	2238.505899	35
1990	71335.38211	0.28	3135.331792	4872.042251	13527.12388	19142.96221	6694.1647	854.119898	814.972736	814.972736	893.2670599	0	3491.215083	35
1991	74125.86299	0.49	750.9137436	6320.487245	23523.88552	11715.67793	10317.0566	5156.748884	2395.094547	2103.270249	1053.414541	1843.475446	1000.032047	35
1992	33440.75136	0.525	1042.738042	3886.245536	9199.583068	7957.550383	1907.534439	2149.535077	0	0	672.6194196	327.4126276	2861.301658	35
1993	183434.3481	0.4375	23908.23948	5487.720344	19367.16869	27655.69053	7808.079401	2060.564254	772.2667411	2896.889987	0	683.2959184	2402.212213	35
1994	78606.78951	0.28	5548.220504	10220.96811	18911.63807	5879.191964	14064.50765	1316.768176	3775.921716	0	1512.503986	323.8537946	1694.004464	35
1995	168542.0559	0.35	7213.754305	27200.15992	57788.32876	30520.55102	16804.80899	8153.286193	0	0	384.3539541	1939.563935	323.8537946	35
1996	191618.952	0.3325	3252.773278	9281.436224	27947.51483	70735.36288	49328.98294	15701.57079	2331.035555	2306.123724	1327.444675	0	1174.41486	35
1997	181668.8111	0.35	12060.88473	34837.41534	18587.78428	30993.8758	27388.77806	13633.88887	11729.91327	0	0	0	693.9724171	35
1998	131720.9471	0.35	2907.566486	18502.37229	48492.65721	16555.69069	10783.26371	5879.191964	3921.833865	1512.503986	437.7364477	0	0	35
1999	210496.0694	0.385	18552.19595	41926.61049	53870.05373	37150.65673	21342.32095	12932.79879	9801.025829	1772.298788	1316.768176	334.5302934	0	35
2000	235959.8748	0.2625	3405.803093	25577.33211	50115.48501	62137.22258	23982.97497	20965.08466	8163.962691	5398.749522	1761.62229	0	925.2965561	35
2001	282569.1976	0.28	1398.621333	7491.343272	33897.88345	112306.0901	67112.47098	28933.31154	21776.49857	5644.308992	2046.328922	1978.711097	0	35
2002	153417.0161	0.3325	0	9779.672832	15335.011	52499.90306	35485.12293	18929.43224	11769.06043	5284.866869	2530.330198	0	1804.328284	35
2003	94667.44654	0.3325	0	1363.033004	2676.242347	10914.94053	20655.4662	27388.77806	11210.32366	4576.65912	7911.285555	2946.713648	4395.158642	35
2004	135787.9814	0.56	2573.036193	512.4719388	3071.2728	16117.95424	35111.44547	29406.63632	17715.87022	12633.85682	1925.328603	3729.656888	3206.50845	35
2005	68773.02242	0.315	22598.58897	3089.066964	814.972736	4658.512277	6437.928731	9583.937022	12096.47305	1950.240434	1857.710778	416.3834503	576.5309311	35
2006	72240.03744	0.3325	3662.039063	19210.58004	11448.76547	1637.063138	3711.862723	10612.43973	10192.49745	4907.63058	2526.771365	1494.709821	512.4719388	35
2007	97526.6129	0.4025	2313.24139	5747.515147	42930.20137	16996.98597	6690.605867	7822.314732	9284.995057	2459.15354	2765.21317	0	512.4719388	35
2008	97791.39007	0.2975	754.4725765	3388.008929	15018.27487	28242.89796	9715.613839	9028.759088	8345.46317	10754.79305	484.0012755	2010.740593	288.2654656	35
2009	77611.02806	0.3325	13673.03603	6630.105708	7060.72449	13416.80006	16157.1014	5459.249681	4907.63058	4099.77551	2409.329879	153.0298151	302.5007972	35
2010	71165.98166	0.2975	14292.27296	16676.69101	6523.340721	7526.931601	5971.72162	8939.788265	1829.240115	4135.363839	2224.270568	686.8547513	847.0022321	35
2011	132068.2892	0.3675	8131.933195	30926.25797	38325.07159	14313.62596	9964.732143	15641.07063	6409.458068	2672.683514	1690.445631	2149.535077	398.5892857	35
2012	78020.29385	0.35	9295.671556	10957.64652	22926.00159	11224.55899	5007.277902	7672.84375	4793.747927	2032.093591	2085.476084	1131.708865	377.2362883	35
2013	82070.2457	0.315	6683.488202	17288.81027	6768.900191	16441.80804	8462.904656	1494.709821	3722.539222	2035.652423	918.1788903	160.1474809	0	35
2014	98359.02392	0.2975	24313.94643	11612.47178	19025.52073	8402.404496	13502.21205	5049.983897	4964.571907	4989.483737	1348.797672	270.471301	743.7960778	35
2015	112338.1196	0.2275	5341.808195	33203.91103	29513.40131	11779.73693	5708.367985	10982.55835	4647.835778	1822.122449	2131.740912	498.2366071	121.0003189	35

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# Index-3 Data
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1983  6.407          0.27           0              0              0              0              0              0              0              0              0              0              0
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1984  3.001          0.161          0              0              0              0              0              0              0              0              0              0              0
0
1985  5.182          0.193          0              0              0              0              0              0              0              0              0              0              0
0
1986  2.072          0.158          0              0              0              0              0              0              0              0              0              0              0
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1987  1.007          0.232          0              0              0              0              0              0              0              0              0              0              0
0
1988  1.434          0.233          0              0              0              0              0              0              0              0              0              0              0
0
1989  1.945          0.217          0              0              0              0              0              0              0              0              0              0              0
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1990  0.626          0.303          0              0              0              0              0              0              0              0              0              0              0
0
1991  1.684          0.25           0              0              0              0              0              0              0              0              0              0              0
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1992  1.26           0.182          0              0              0              0              0              0              0              0              0              0              0
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1993  1.469          0.177          0              0              0              0              0              0              0              0              0              0              0
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1994  3.129          0.226          0              0              0              0              0              0              0              0              0              0              0
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2012  0              0              0              0              0              0              0              0              0              0              0              0              0
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2013  0              0              0              0              0              0              0              0              0              0              0              0              0
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# Index-4 Data
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1984  0          0          0          0          0          0          0          0          0          0          0          0          0
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1985  0          0          0          0          0          0          0          0          0          0          0          0          0
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1986  0          0          0          0          0          0          0          0          0          0          0          0          0
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1987  0          0          0          0          0          0          0          0          0          0          0          0          0
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1988  0          0          0          0          0          0          0          0          0          0          0          0          0
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1989  0          0          0          0          0          0          0          0          0          0          0          0          0
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1990  0          0          0          0          0          0          0          0          0          0          0          0          0
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1993  0          0          0          0          0          0          0          0          0          0          0          0          0
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1994  0          0          0          0          0          0          0          0          0          0          0          0          0
0
1995  1.883      0.169      0.0405     0.1198     0.5812     0.3157     0.1789     0.3119     0.1162     0.1102     0.042      0          0.0665
50
1996  1.359      0.169      0.0168     0.0356     0.2436     0.3944     0.3456     0.2185     0.0725     0          0          0          0.032
50
1997  2.219      0.267      0.0721     0.0663     0.1521     0.6926     0.6169     0.4375     0.0842     0.0827     0.0144     0          0
50
1998  4.274      0.175      0.1121     1.0788     0.7123     0.3881     0.798      0.7131     0.2143     0.1536     0.0758     0          0.0284
50
1999  3.149      0.205      0.1058     0.3758     0.9738     0.797      0.4825     0.1643     0.1824     0.0306     0.0144     0.0228     0
50
2000  3.446      0.14       0.0065     0.2504     1.1938     0.6925     0.6595     0.2393     0.2527     0.1159     0          0.0354     0
50
2001  4.409      0.163      0.1051     0.0988     0.7126     1.4758     1.0199     0.4008     0.293      0.1629     0.1128     0.0281     0
50
2002  8.101      0.203      0.0229     0.0599     0.8972     2.6274     2.2633     0.8223     0.6832     0.3507     0.1915     0.1027     0.0802
50
2003  5.204      0.161      0          0          0.1498     0.8079     1.6464     1.0167     0.8686     0.3871     0.1969     0.0455     0.0855
50
2004  3.799      0.126      0.0092     0.0601     0.0738     0.428      0.6485     0.809      0.8828     0.3683     0.1581     0.1607     0.2017
50
2005  3.362      0.203      0.0109     0.16       0.1464     0.2195     0.7375     0.7602     0.5744     0.3832     0.245      0.0865     0.0392
50
2006  3.087      0.139      0.0435     0.4604     0.3473     0.138      0.2072     0.6833     0.5681     0.4101     0.1451     0.0688     0.0151
50
2007  2.37       0.165      0          0.1778     0.5707     0.2627     0.2413     0.2284     0.5462     0.1536     0.1584     0          0.0306
50
2008  7.45       0.25       0.0109     0.3722     0.8475     2.8342     1.3407     0.6455     0.7243     0.5501     0.0882     0.0364     0
50
2009  2.342      0.147      0.1349     0.1395     0.2897     0.4283     0.5745     0.2058     0.1552     0.2206     0.1204     0.0566     0.0172
50
2010  2.472      0.138      0.1389     0.4514     0.2682     0.1681     0.4199     0.4712     0.1417     0.1016     0.1849     0.0657     0.0604
50
2011  2.821      0.114      0.0349     0.3652     0.7009     0.2677     0.3045     0.4695     0.2827     0.1176     0.0883     0.115      0.0744
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2012  1.824          0.122          0.0894         0.1875         0.387          0.3293         0.1559         0.2321         0.1597         0.1585         0.0753         0.0339         0.016
50
2013  1.039          0.134          0.0356         0.1239         0.1391         0.2793         0.1444         0.087          0.109          0.0655         0.0312         0.0186         0.0055
50
2014  2.961          0.152          0.5757         0.4474         0.6763         0.2635         0.4316         0.2091         0.1365         0.1383         0.0823         0              0
50
2015  2.771          0.147          0.0316         0.5818         0.7549         0.4608         0.2345         0.32           0.1516         0.1511         0.0526         0.0201         0.0127
50
# Index-5 Data
1982  0.991          0.405          0              0              0.0575         0.0131         0.027          0.0757         0.2409         0.1323         0.0146         0.0274         0.3825
50
1983  4.718          0.142          0.0081         0.0109         0.5071         1.5958         0.7575         0.548          0.4442         0.0837         0.1373         0.073          0.5529
50
1984  4.373          0.139          0              0              0.0933         0.9437         0.9913         0.6049         0.5348         0.3097         0.1489         0.1256         0.621
50
1985  2.763          0.197          0              0.0086         0.0588         0.0757         0.6102         0.684          0.4825         0.2698         0.1027         0.1222         0.3497
50
1986  1.59           0.155          0              0              0              0.051          0.2665         0.3533         0.3085         0.1598         0.112          0.0093         0.3217
50
1987  0.482          0.33           0              0.0229         0              0.0109         0.0229         0.0457         0.1921         0.0714         0              0.0086         0.1077
50
1988  1.376          0.173          0.0065         0              0.7247         0.0545         0.0115         0.0356         0.2148         0.0484         0.0463         0.0454         0.188
50
1989  0.888          0.196          0.0182         0.0182         0.0817         0.3006         0.0091         0.0211         0.0166         0.0838         0.0784         0.0237         0.0629
50
1990  2.004          0.164          0.0881         0.1369         0.3801         0.5379         0.1881         0.024          0.0229         0.0229         0.0251         0              0.0981
50
1991  2.083          0.276          0.0211         0.1776         0.661          0.3292         0.2899         0.1449         0.0673         0.0591         0.0296         0.0518         0.0281
50
1992  0.94           0.3            0.0293         0.1092         0.2585         0.2236         0.0536         0.0604         0              0              0.0189         0.0092         0.0804
50
1993  5.154          0.25           0.6718         0.1542         0.5442         0.7771         0.2194         0.0579         0.0217         0.0814         0              0.0192         0.0675
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1994  2.209          0.164          0.1559         0.2872         0.5314         0.1652         0.3952         0.037          0.1061         0              0.0425         0.0091         0.0476
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2012	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0

Index-6 Data

1982	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	4.736	0.196	0.2027	0.7643	1.6238	0.8576	0.4722	0.2291	0	0	0.0108	0.0545	0.0091
1996	5.384	0.191	0.0914	0.2608	0.7853	1.9876	1.3861	0.4412	0.0655	0.0648	0.0373	0	0.033
1997	5.105	0.196	0.3389	0.9789	0.5223	0.8709	0.7696	0.3831	0.3296	0	0	0	0.0195
1998	3.701	0.201	0.0817	0.5199	1.3626	0.4652	0.303	0.1652	0.1102	0.0425	0.0123	0	0
1999	5.915	0.219	0.5213	1.1781	1.5137	1.0439	0.5997	0.3634	0.2754	0.0498	0.037	0.0094	0
2000	6.63	0.152	0.0957	0.7187	1.4082	1.746	0.6739	0.5891	0.2294	0.1517	0.0495	0	0.026
2001	7.94	0.162	0.0393	0.2105	0.9525	3.1557	1.8858	0.813	0.6119	0.1586	0.0575	0.0556	0
2002	4.311	0.19	0	0.2748	0.4309	1.4752	0.9971	0.5319	0.3307	0.1485	0.0711	0	0.0507
2003	2.66	0.19	0	0.0383	0.0752	0.3067	0.5804	0.7696	0.315	0.1286	0.2223	0.0828	0.1235
2004	3.816	0.318	0.0723	0.0144	0.0863	0.4529	0.9866	0.8263	0.4978	0.355	0.0541	0.1048	0.0901
2005	1.932	0.185	0.635	0.0868	0.0229	0.1309	0.1809	0.2693	0.3399	0.0548	0.0522	0.0117	0.0162
2006	2.03	0.193	0.1029	0.5398	0.3217	0.046	0.1043	0.2982	0.2864	0.1379	0.071	0.042	0.0144
2007	2.74	0.228	0.065	0.1615	1.2063	0.4776	0.188	0.2198	0.2609	0.0691	0.0777	0	0.0144

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2008  2.748          0.171          0.0212         0.0952         0.422          0.7936         0.273          0.2537         0.2345         0.3022         0.0136         0.0565         0.0081
50
2009  2.181          0.19           0.3842         0.1863         0.1984         0.377          0.454          0.1534         0.1379         0.1152         0.0677         0.0043         0.0085
50
2010  2              0.169          0.4016         0.4686         0.1833         0.2115         0.1678         0.2512         0.0514         0.1162         0.0625         0.0193         0.0238
50
2011  3.711          0.206          0.2285         0.869          1.0769         0.4022         0.28           0.4395         0.1801         0.0751         0.0475         0.0604         0.0112
50
2012  2.192          0.196          0.2612         0.3079         0.6442         0.3154         0.1407         0.2156         0.1347         0.0571         0.0586         0.0318         0.0106
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2013  2.306          0.177          0.1878         0.4858         0.1902         0.462          0.2378         0.042          0.1046         0.0572         0.0258         0.0045         0
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2014  2.764          0.168          0.6832         0.3263         0.5346         0.2361         0.3794         0.1419         0.1395         0.1402         0.0379         0.0076         0.0209
50
2015  3.157          0.132          0.1501         0.933          0.8293         0.331          0.1604         0.3086         0.1306         0.0512         0.0599         0.014          0.0034
50
# Index-7 Data
1982  3.642          0.222          0.0442         0.0418         0.6096         0.4838         0.3766         0.2367         0.6084         0.3621         0.0932         0.2593         0.5269
50
1983  6.407          0.27           0              0.071          0.5312         1.2615         1.2933         0.541          0.7163         0.6324         0.4754         0.2141         0.6712
50
1984  3.001          0.161          0              0.1032         0.0115         0.3071         0.7774         0.4013         0.3096         0.2017         0.1961         0.1147         0.5791
50
1985  5.182          0.193          0              0              0.0167         0.4592         1.0572         1.1994         0.9077         0.4121         0.1478         0.1487         0.8335
50
1986  2.072          0.158          0              0              0              0.0439         0.2403         0.5286         0.4118         0.1719         0.1942         0.0792         0.4032
50
1987  1.007          0.232          0              0              0              0.0589         0.1139         0.1328         0.2595         0.1855         0.0095         0.0614         0.1862
50
1988  1.434          0.233          0.0228         0.0229         0.062          0              0.0724         0.3            0.379          0.2386         0.1372         0.0863         0.1127
50
1989  1.945          0.217          0.0229         0.013          0.036          1.0044         0.1055         0.0728         0.0812         0.3275         0.0812         0.0152         0.1858
50
1990  0.626          0.303          0.0081         0              0.0375         0.0913         0.3196         0              0.0421         0.0087         0.0504         0.0176         0.0512
50
1991  1.684          0.25           0.0418         0              0.7803         0.1084         0.0871         0.2087         0.0329         0.1008         0.0828         0.1377         0.1036
50
1992  1.26           0.182          0.0545         0.0087         0.1869         0.3727         0.0852         0.1106         0.1519         0.045          0.1486         0.0153         0.0812
50
1993  1.469          0.177          0.1485         0.1122         0.1373         0.4723         0.3196         0.0577         0.0854         0              0.0155         0.0155         0.1055
50
1994  3.129          0.226          0.1073         0.6974         0.5409         0.6436         0.8104         0.1644         0.0269         0.0281         0.0704         0.0083         0.032
50
1995  1.883          0.169          0.0405         0.1198         0.5812         0.3157         0.1789         0.3119         0.1162         0.1102         0.042          0              0.0665
50
1996  1.359          0.169          0.0168         0.0356         0.2436         0.3944         0.3456         0.2185         0.0725         0              0              0              0.032
50
1997  2.219          0.267          0.0721         0.0663         0.1521         0.6926         0.6169         0.4375         0.0842         0.0827         0.0144         0              0
50
1998  4.274          0.175          0.1121         1.0788         0.7123         0.3881         0.798          0.7131         0.2143         0.1536         0.0758         0              0.0284
50
1999  3.149          0.205          0.1058         0.3758         0.9738         0.797          0.4825         0.1643         0.1824         0.0306         0.0144         0.0228         0
50
2000  3.446          0.14           0.0065         0.2504         1.1938         0.6925         0.6595         0.2393         0.2527         0.1159         0              0.0354         0
50
2001  4.409          0.163          0.1051         0.0988         0.7126         1.4758         1.0199         0.4008         0.293          0.1629         0.1128         0.0281         0
50
2002  8.101          0.203          0.0229         0.0599         0.8972         2.6274         2.2633         0.8223         0.6832         0.3507         0.1915         0.1027         0.0802
50
2003  5.204          0.161          0              0              0.1498         0.8079         1.6464         1.0167         0.8686         0.3871         0.1969         0.0455         0.0855
50
2004  3.799          0.126          0.0092         0.0601         0.0738         0.428          0.6485         0.809          0.8828         0.3683         0.1581         0.1607         0.2017
50
2005  3.362          0.203          0.0109         0.16           0.1464         0.2195         0.7375         0.7602         0.5744         0.3832         0.245          0.0865         0.0392
50
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2006  3.087          0.139          0.0435         0.4604         0.3473         0.138          0.2072         0.6833         0.5681         0.4101         0.1451         0.0688         0.0151
50
2007  2.37           0.165          0              0.1778         0.5707         0.2627         0.2413         0.2284         0.5462         0.1536         0.1584         0              0.0306
50
2008  7.45           0.25           0.0109         0.3722         0.8475         2.8342         1.3407         0.6455         0.7243         0.5501         0.0882         0.0364         0
50
2009  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2010  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2011  0              0              0              0              0              0              0              0              0              0              0              0              0
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2012  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2013  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2014  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2015  0              0              0              0              0              0              0              0              0              0              0              0              0
0
# Index-8 Data
1982  0              0              0              0              0              0              0              0              0              0              0              0              0
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1983  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1984  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1985  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1986  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1987  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1988  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1989  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1990  0              0              0              0              0              0              0              0              0              0              0              0              0
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1992  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1993  0              0              0              0              0              0              0              0              0              0              0              0              0
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1994  0              0              0              0              0              0              0              0              0              0              0              0              0
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1995  0              0              0              0              0              0              0              0              0              0              0              0              0
0
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1998  0              0              0              0              0              0              0              0              0              0              0              0              0
0
1999  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2000  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2001  0              0              0              0              0              0              0              0              0              0              0              0              0
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2002  0              0              0              0              0              0              0              0              0              0              0              0              0
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2003  0              0              0              0              0              0              0              0              0              0              0              0              0
0
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2004  0          0          0          0          0          0          0          0          0          0          0          0          0
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2005  0          0          0          0          0          0          0          0          0          0          0          0          0
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2006  0          0          0          0          0          0          0          0          0          0          0          0          0
0
2007  0          0          0          0          0          0          0          0          0          0          0          0          0
0
2008  0          0          0          0          0          0          0          0          0          0          0          0          0
0
2009  7.628      0.147      0.439      0.454      0.944      1.395      1.871      0.67       0.506      0.719      0.392      0.184      0.056
50
2010  8.051      0.138      0.452      1.47       0.874      0.548      1.368      1.535      0.462      0.331      0.602      0.214      0.197
50
2011  9.188      0.114      0.114      1.19       2.283      0.872      0.992      1.529      0.921      0.383      0.288      0.375      0.242
50
2012  5.94       0.122      0.291      0.611      1.261      1.073      0.508      0.756      0.52       0.516      0.245      0.11       0.052
50
2013  3.386      0.134      0.116      0.404      0.453      0.91       0.47       0.283      0.355      0.213      0.102      0.061      0.018
50
2014  9.644      0.152      1.875      1.457      2.203      0.858      1.406      0.681      0.445      0.45       0.268      0          0
50
2015  9.027      0.147      0.103      1.895      2.459      1.501      0.764      1.042      0.494      0.492      0.171      0.065      0.041
50
# Index-9 Data
1982  0.99       0.4        0          0          0.058      0.013      0.027      0.076      0.241      0.132      0.015      0.027      0.383
50
1983  4.72       0.14       0.008      0.011      0.507      1.596      0.758      0.548      0.444      0.084      0.137      0.073      0.553
50
1984  4.37       0.14       0          0          0.093      0.944      0.991      0.605      0.535      0.31       0.149      0.126      0.621
50
1985  2.76       0.2        0          0.009      0.059      0.076      0.61       0.684      0.483      0.27       0.103      0.122      0.35
50
1986  1.59       0.15       0          0          0          0.051      0.267      0.353      0.309      0.16       0.112      0.009      0.322
50
1987  0.48       0.33       0          0.023      0          0.011      0.023      0.046      0.192      0.071      0          0.009      0.108
50
1988  1.38       0.17       0.007      0          0.725      0.055      0.012      0.036      0.215      0.048      0.046      0.045      0.188
50
1989  0.89       0.2        0.018      0.018      0.082      0.301      0.009      0.021      0.017      0.084      0.078      0.024      0.063
50
1990  2          0.16       0.088      0.137      0.38       0.538      0.188      0.024      0.023      0.023      0.025      0          0.098
50
1991  2.08       0.28       0.021      0.178      0.661      0.329      0.29       0.145      0.067      0.059      0.03       0.052      0.028
50
1992  0.94       0.3        0.029      0.109      0.259      0.224      0.054      0.06       0          0          0.019      0.009      0.08
50
1993  5.15       0.25       0.672      0.154      0.544      0.777      0.219      0.058      0.022      0.081      0          0.019      0.068
50
1994  2.21       0.16       0.156      0.287      0.531      0.165      0.395      0.037      0.106      0          0.043      0.009      0.048
50
1995  4.74       0.2        0.2027     0.7643     1.6238     0.8576     0.4722     0.2291     0          0          0.0108     0.0545     0.0091
50
1996  5.38       0.19       0.0914     0.2608     0.7853     1.9876     1.3861     0.4412     0.0655     0.0648     0.0373     0          0.033
50
1997  5.1        0.2        0.3389     0.9789     0.5223     0.8709     0.7696     0.3831     0.3296     0          0          0          0.0195
50
1998  3.7        0.2        0.0817     0.5199     1.3626     0.4652     0.303      0.1652     0.1102     0.0425     0.0123     0          0
50
1999  5.91       0.22       0.5213     1.1781     1.5137     1.0439     0.5997     0.3634     0.2754     0.0498     0.037      0.0094     0
50
2000  6.63       0.15       0.0957     0.7187     1.4082     1.746      0.6739     0.5891     0.2294     0.1517     0.0495     0          0.026
50
2001  7.94       0.16       0.0393     0.2105     0.9525     3.1557     1.8858     0.813      0.6119     0.1586     0.0575     0.0556     0
50
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2002  4.31          0.19          0             0.2748        0.4309        1.4752        0.9971        0.5319        0.3307        0.1485        0.0711        0             0.0507
50
2003  2.66          0.19          0             0.0383        0.0752        0.3067        0.5804        0.7696        0.315         0.1286        0.2223        0.0828        0.1235
50
2004  3.82          0.32          0.0723        0.0144        0.0863        0.4529        0.9866        0.8263        0.4978        0.355         0.0541        0.1048        0.0901
50
2005  1.93          0.18          0.635         0.0868        0.0229        0.1309        0.1809        0.2693        0.3399        0.0548        0.0522        0.0117        0.0162
50
2006  2.03          0.19          0.1029        0.5398        0.3217        0.046         0.1043        0.2982        0.2864        0.1379        0.071         0.042         0.0144
50
2007  2.74          0.23          0.065         0.1615        1.2063        0.4776        0.188         0.2198        0.2609        0.0691        0.0777        0             0.0144
50
2008  2.75          0.17          0.0212        0.0952        0.422         0.7936        0.273         0.2537        0.2345        0.3022        0.0136        0.0565        0.0081
50
2009  0             0             0             0             0             0             0             0             0             0             0             0             0
0
2010  0             0             0             0             0             0             0             0             0             0             0             0             0
0
2011  0             0             0             0             0             0             0             0             0             0             0             0             0
0
2012  0             0             0             0             0             0             0             0             0             0             0             0             0
0
2013  0             0             0             0             0             0             0             0             0             0             0             0             0
0
2014  0             0             0             0             0             0             0             0             0             0             0             0             0
0
2015  0             0             0             0             0             0             0             0             0             0             0             0             0
0
# Index-10 Data
1982  0             0             0             0             0             0             0             0             0             0             0             0             0
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1983  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1984  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1985  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1986  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1987  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1988  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1989  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1990  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1991  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1992  0             0             0             0             0             0             0             0             0             0             0             0             0
0
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1994  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1995  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1996  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1997  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1998  0             0             0             0             0             0             0             0             0             0             0             0             0
0
1999  0             0             0             0             0             0             0             0             0             0             0             0             0
0
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0
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0
2005  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2006  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2007  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2008  0              0              0              0              0              0              0              0              0              0              0              0              0
0
2009  7.103251602    0.17           1.251407403    0.606812075    0.646223917    1.227955729    1.478758358    0.499650952    0.449164708    0.37522679     0.220510883    0.014005861
0.027686005    50
2010  6.513376847    0.19           1.308082283    1.526313142    0.597040544    0.688892936    0.546554301    0.818202862    0.167418898    0.378483967    0.203573563    0.062863516
0.077520813    50
2011  12.08738385    0.17           0.744264945    2.830486813    3.507653911    1.310036589    0.91200956     1.431529292    0.586617578    0.244613993    0.154715908    0.196733491
0.036480382    50
2012  7.140709137    0.21           0.850774632    1.002884798    2.098273423    1.027313626    0.458284804    0.702247361    0.438741742    0.185984807    0.190870572    0.103578229
0.034526076    50
2013  7.51137588     0.2            0.611697841    1.582336587    0.619515065    1.504815774    0.774556691    0.136801434    0.340700714    0.186310524    0.084035167    0.014657297    0
50
2014  9.002185793    0.18           2.225303326    1.062816855    1.741286824    0.76901949     1.235772954    0.462193416    0.454376192    0.456656215    0.123447008    0.024754545
0.068074999    50
2015  10.28160492    0.17           0.488902268    3.038946141    2.701176886    1.078125587    0.522451191    1.005164822    0.425387316    0.166767462    0.195104902    0.045600478
0.011074402    50
# Index-11 Data
1982  -999           0              0              0              0              0              0              0              0              0              0              0              0
0
1983  -999           0              0              0              0              0              0              0              0              0              0              0              0
0
1984  25508.7        0.26           331.6          1097           2627.6         10229.9        5357.3         1836.8         918.4          969.4          765.4          408.1          994.9
30
1985  6755.3         0.4            161.8          0              303.4          1725.8         2015.7         1173           458.5          337.1          188.7          87.6           289.9
30
1986  2621.5         0.52           103.2          76.8           26.5           585.1          428.9          736            466            124.4          15.9           10.6           68.9
30
1987  5242.9         0.66           1957.5         460.6          308.8          654.3          246            481.5          497.3          209.3          115.1          73.3           230.3
30
1988  2621.5         0.57           171.9          192.8          1364.8         200.5          75.5           46.9           96.4           106.8          59.9           36.5           80.8
30
1989  2923.9         0.75           738.7          435.6          644.6          877.1          108.9          8.9            20.6           47.1           38.2           2.9            20.6
30
1990  6755.3         0.65           1966.5         624.2          1281.9         1671.2         885.9          87.2           13.4           20.2           33.6           26.8           53.7
30
1991  15022.9        0.78           6854.8         452            5935.8         1250.4         165.8          60.3           30.1           45.2           75.3           105.5          45.2
30
1992  24500.5        1.03           8936.7         4945.8         7614.6         2668.7         49             122.4          49             0              0              0              73.5
30
1993  21576.6        0.64           19093.1        799.1          518.3          691.2          151.2          43.2           43.2           43.2           0              0              21.6
30
1994  36599.5        0.97           14626.4        8467.9         6598.4         4179           2382.8         219.9          73.3           0              0              0              0
30
1995  18148.5        0.86           2570.3         4941.5         7511.9         2063.5         579.2          289.6          108.6          18.1           0              0              0
30
1996  15527.1        0.49           2990.6         1292.8         3613.6         4267.7         2305.2         778.8          249.2          15.5           15.5           0              31.2
30
1997  23391.4        1.02           14499.3        4911.1         327.4          1870.9         1192.7         397.6          117            46.8           0              0              0
30
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1998  7360.2          0.54            1155.6          3177.8          2296.3          363             229.7           162.9           14.8            0               0               0               0
30
1999  111008.3        0.55            32739.5         24748.8         32517.5         15426.4         4106.3          887.9           332.9           221.9           0               0               0
30
2000  32667.3         0.58            3694.3          6669.5          12554.3         5492.5          2550.1          948.2           555.7           130.8           32.7            0               0
30
2001  41842.4         0.78            1465.2          4060.7          10172.7         16912.8         6028.3          1465.2          962.9           460.5           167.5           83.7            83.7
30
2002  45572.9         0.59            775.5           3969            9306.7          16788.6         8987.3          2919.8          1824.8          593.1           319.3           45.6            91.2
30
2003  24298.8         0.52            727.7           363.9           2061.7          7203.8          7397.8          3662.6          1503.8          727.7           315.3           145.5           145.5
30
2004  8771.8          0.59            370.4           635.1           441             1878.9          2090.6          1728.9          1014.4          405.7           132.3           70.6            44.1
30
2005  19963.4         0.55            10066.7         1893.7          996.7           1614.6          2312.3          1893.7          817.3           219.3           79.8            39.8            20
30
2006  30247.5         0.46            5622.9          13603.7         4625.2          1299.9          1511.6          1693            1178.9          513.9           151.1           60.5            30.2
30
2007  23290.6         0.5             1863.1          6241.7          10503.6         1886.4          1094.7          652.1           768.6           232.9           46.6            23.3            0
30
2008  15325.4         0.49            842.4           2619.1          3645.3          5682.5          980.2           566.7           428.9           321.6           153.2           30.7            15.3
30
2009  23391.4         0.57            5640.3          2433.9          2761.6          3767.9          4353            1544.6          1380.8          936.2           374.5           140.4           70.2
30
2010  18249.3         0.43            4715.5          5665.9          2467.4          1370.8          1571.9          1571.9          365.5           310.7           164.4           73.1            18.2
30
2011  18451           0.35            1235.7          6104.7          6233.8          1733.7          1014.4          1014.4          498             350.5           147.5           92.3            36.9
30
2012  18753.5         0.5             3378.4          4223.2          4992.7          2515.1          1069.9          1163.7          863.4           412.9           112.6           37.5            0
30
2013  14720.5         0.31            4193.6          4399.6          1603.8          2133.6          824             470.9           456.1           220.7           117.8           58.9            14.7
30
2014  38515.2         0.52            21339           8759.4          4630.5          1234.8          1119.1          540.2           424.5           308.7           77.1            38.6            38.6
30
2015  32566.5         0.37            1760.4          11605.8         12290.4         2216.8          1043.2          1597.5          912.8           749.8           260.8           32.6            0
30
# Index-12 Data
1982  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1983  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1984  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1985  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1986  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1987  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1988  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1989  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1990  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1991  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1992  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1993  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1994  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
1995  -999            0               0               0               0               0               0               0               0               0               0               0               0
0
```

```
1996  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1997  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1998  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1999  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
2000  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
2001  6805.3        0.6596975     3914.2        2552.8        217.8         74.9          0             6.8           0             13.6          13.6          13.6          0
20
2002  4488          0.4669        1049          201.7         1205.9        972.8         614.1         251           170.3         9             4.5           4.5           4.5
20
2003  2268.4        0.7812025     355.7         70.2          401.1         768.1         464.5         124.6         65.7          18.1          0             0             0
20
2004  1388.4        0.363355      676.9         225.6         128.1         128.1         115.6         54.3          30.6          12.5          4.2           5.6           11.1
20
2005  8184          0.39707       5129.2        1578.8        621.7         114.5         220.9         261.8         114.5         49.1          57.3          32.7          0
20
2006  5055.1        0.53571       1092          2836          687.5         207.3         50.6          60.7          45.5          40.4          20.2          0             10.1
20
2007  4272.9        0.38576       1123.8        1525.5        1222.1        115.4         81.2          17.1          76.9          34.2          42.7          0             29.9
20
2008  4155.5        0.355075      896.8         1465.6        477.5         660.2         199.3         99.6          215.9         128.7         0             0             8.3
20
2009  4057.8        0.407255      1797.9        1266.2        442.4         227.3         198.9         36.5          16.2          36.5          24.4          12.2          0
20
2010  5045.3        0.4423975     1915.1        1546.2        843.8         212.2         257.7         202.1         40.4          10.1          10.1          5.1           5.1
20
2011  5084.4        0.302         594.6         2739.2        1316.3        142.3         101.6         111.8         45.7          15.2          10.2          5.1           0
20
2012  6267.5        0.43449       833.9         2978          1699.1        495.3         87.8          81.5          37.6          31.3          12.5          6.3           0
20
2013  1515.6        0.5127875     307.7         487.1         211.1         239.8         87.5          46.8          82.9          21.1          15.1          1.5           10.6
20
2014  28013.3       0.3019525     24712         2404.1        559.1         111.8         111.8         55.9          28            28            0             0             0
20
2015  4556.4        0.2338725     883           2326          1192.6        81.9          18.2          27.3          13.7          13.7          0             0             0
20
# Index-13 Data
1982  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1983  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1984  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1985  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1986  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1987  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1988  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1989  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1990  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1991  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1992  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1993  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
```

```
1994  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1995  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1996  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1997  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1998  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
1999  -999          0             0             0             0             0             0             0             0             0             0             0             0
0
2000  3803.6        0.58          920.5         2225.1        593.4         49.4          7.6           3.8           3.8           0             0             0             0
24
2001  55325.8       0.33          11120.5       25671.2       6473.1        8077.6        2213          995.9         608.6         110.7         55.3          0             0
24
2002  6148          0.59          817.7         1125.1        1155.8        2225.6        694.7         129.1         0             0             0             0             0
24
2003  7280.1        0.62          1383.2        203.8         626.1         1856.4        1594.3        982.8         269.4         123.8         167.4         43.7          43.7
24
2004  11469.2       0.66          4450.1        997.8         1319          1124          1995.6        894.6         263.8         160.6         57.3          22.9          34.4
24
2005  25613.3       0.54          22923.9       2023.5        204.9         51.2          76.8          102.5         204.9         25.6          0             0             25.6
24
2006  12544.9       0.43          5080.7        4604          2145.2        138           150.5         213.3         163.1         12.5          37.6          0             0
24
2007  14092.7       0.57          2874.9        3015.8        5608.9        1197.9        549.6         451           295.9         28.2          14.1          0             42.3
24
2008  14450.3       0.48          4840.9        3453.6        2890.1        1921.9        375.7         491.3         130.1         289           14.5          14.5          0
24
2009  10244.5       0.41          7355.6        1280.6        635.2         481.5         338.1         51.2          30.7          20.5          10.2          0             0
24
2010  15862.1       0.43          11040         3045.5        666.2         380.7         206.2         333.1         31.7          47.6          15.9          0             15.9
24
2011  9575.5        0.5           2269.4        4529.2        1896          296.8         191.5         249           57.5          19.2          9.6           9.6           9.6
24
2012  3183.9        0.49          2117.3        576.3         324.8         47.8          22.3          54.1          28.7          9.6           0             0             0
24
2013  2380.6        0.6           1180.8        742.8         166.6         164.3         50            11.9          16.7          4.8           7.1           2.4           0
24
2014  15276.1       0.43          13488.8       1542.9        198.6         15.3          15.3          0             15.3          0             0             0             0
24
2015  13640.7       0.68          3505.7        6874.9        2919.1        136.4         40.9          68.2          13.6          0             0             0             0
24
# Index-14 Data
1982  0             0.39          0             0             0             0             0             0             0             0             0             0             0
0
1983  1.973         0.34          0             0             0             0             0             0             0             0             0             0             0
0
1984  1.182         0.28          0             0             0             0             0             0             0             0             0             0             0
0
1985  1.009         0.22          0             0             0             0             0             0             0             0             0             0             0
0
1986  0.698         0.18          0             0             0             0             0             0             0             0             0             0             0
0
1987  0.884         0.42          0             0             0             0             0             0             0             0             0             0             0
0
1988  0.236         0.21          0             0             0             0             0             0             0             0             0             0             0
0
1989  0.132         0.41          0             0             0             0             0             0             0             0             0             0             0
0
1990  0.207         0.64          0             0             0             0             0             0             0             0             0             0             0
0
1991  0.111         0.52          0             0             0             0             0             0             0             0             0             0             0
0
```

```
1992  0.2          0.52         0            0            0            0            0            0            0            0            0            0            0
0
1993  0.033        0.83         0            0            0            0            0            0            0            0            0            0            0
0
1994  0            0            0            0            0            0            0            0            0            0            0            0            0
0
1995  0.1          0.29         0            0            0            0            0            0            0            0            0            0            0
0
1996  0.025        0.73         0            0            0            0            0            0            0            0            0            0            0
0
1997  0.049        0            0            0            0            0            0            0            0            0            0            0            0
0
1998  0            0            0            0            0            0            0            0            0            0            0            0            0
0
1999  0.016        0.8          0            0            0            0            0            0            0            0            0            0            0
0
2000  1.146        0.25         0            0            0            0            0            0            0            0            0            0            0
0
2001  0.069        0.41         0            0            0            0            0            0            0            0            0            0            0
0
2002  0.109        0.42         0            0            0            0            0            0            0            0            0            0            0
0
2003  0.186        0.11         0            0            0            0            0            0            0            0            0            0            0
0
2004  0            0            0            0            0            0            0            0            0            0            0            0            0
0
2005  0.045        0.52         0            0            0            0            0            0            0            0            0            0            0
0
2006  0.161        0.39         0            0            0            0            0            0            0            0            0            0            0
0
2007  0.456        0.38         0            0            0            0            0            0            0            0            0            0            0
0
2008  0.263        0.32         0            0            0            0            0            0            0            0            0            0            0
0
2009  0.44         0.48         0            0            0            0            0            0            0            0            0            0            0
0
2010  0.152        0.29         0            0            0            0            0            0            0            0            0            0            0
0
2011  0.347        0.55         0            0            0            0            0            0            0            0            0            0            0
0
2012  0.23         0.31         0            0            0            0            0            0            0            0            0            0            0
0
2013  0.08         0.37         0            0            0            0            0            0            0            0            0            0            0
0
2014  0.042        0.56         0            0            0            0            0            0            0            0            0            0            0
0
2015  0.098        0.69         0            0            0            0            0            0            0            0            0            0            0
0
# Index-15 Data
1982  1.244        0.55         0            0            0            0            0            0            0            0            0            0            0
0
1983  2.222        0.3          0            0            0            0            0            0            0            0            0            0            0
0
1984  0.546        0.34         0            0            0            0            0            0            0            0            0            0            0
0
1985  0.764        0.45         0            0            0            0            0            0            0            0            0            0            0
0
1986  0.266        0.31         0            0            0            0            0            0            0            0            0            0            0
0
1987  0.187        0.34         0            0            0            0            0            0            0            0            0            0            0
0
1988  0.276        0.57         0            0            0            0            0            0            0            0            0            0            0
0
1989  0.129        0.49         0            0            0            0            0            0            0            0            0            0            0
0
```

```
1990  0.074  0.52  0  0  0  0  0  0  0  0  0  0  0
0
1991  0.318  0.35  0  0  0  0  0  0  0  0  0  0  0
0
1992  0.455  0.41  0  0  0  0  0  0  0  0  0  0  0
0
1993  0.297  0.4  0  0  0  0  0  0  0  0  0  0  0
0
1994  0.38  0.34  0  0  0  0  0  0  0  0  0  0  0
0
1995  2.407  0.57  0  0  0  0  0  0  0  0  0  0  0
0
1996  0.037  0.56  0  0  0  0  0  0  0  0  0  0  0
0
1997  0.515  0.6  0  0  0  0  0  0  0  0  0  0  0
0
1998  0.245  0.43  0  0  0  0  0  0  0  0  0  0  0
0
1999  0.674  0.34  0  0  0  0  0  0  0  0  0  0  0
0
2000  0.917  0.27  0  0  0  0  0  0  0  0  0  0  0
0
2001  0.432  0.21  0  0  0  0  0  0  0  0  0  0  0
0
2002  2.21  0.18  0  0  0  0  0  0  0  0  0  0  0
0
2003  1.186  0.26  0  0  0  0  0  0  0  0  0  0  0
0
2004  0.307  0.37  0  0  0  0  0  0  0  0  0  0  0
0
2005  0.514  0.28  0  0  0  0  0  0  0  0  0  0  0
0
2006  0.365  0.27  0  0  0  0  0  0  0  0  0  0  0
0
2007  0.514  0.35  0  0  0  0  0  0  0  0  0  0  0
0
2008  1.344  0.32  0  0  0  0  0  0  0  0  0  0  0
0
2009  1.275  0.25  0  0  0  0  0  0  0  0  0  0  0
0
2010  1.422  0.3  0  0  0  0  0  0  0  0  0  0  0
0
2011  3.505  0.25  0  0  0  0  0  0  0  0  0  0  0
0
2012  0.658  0.24  0  0  0  0  0  0  0  0  0  0  0
0
2013  0.545  0.31  0  0  0  0  0  0  0  0  0  0  0
0
2014  0.443  0.47  0  0  0  0  0  0  0  0  0  0  0
0
2015  1.35  0.36  0  0  0  0  0  0  0  0  0  0  0
0
# Phase Control
# Phase for F mult in 1st Year
1
# Phase for F mult Deviations
3
# Phase for Recruitment Deviations
3
# Phase for N in 1st Year
2
# Phase for Catchability in 1st Year
1
# Phase for Catchability Deviations
-5
# Phase for Stock Recruitment Relationship
```

```
1
# Phase for Steepness
-1
# Recruitment CV by Year
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
# Lambdas by Index
1  1  0  0  0  0  0  0  0  0  1  1  1  0  0
# Lambda for Total Catch in Weight by Fleet
1
# Lambda for Total Discards at Age by Fleet
0
# Catch Total CV by Year and Fleet
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
```

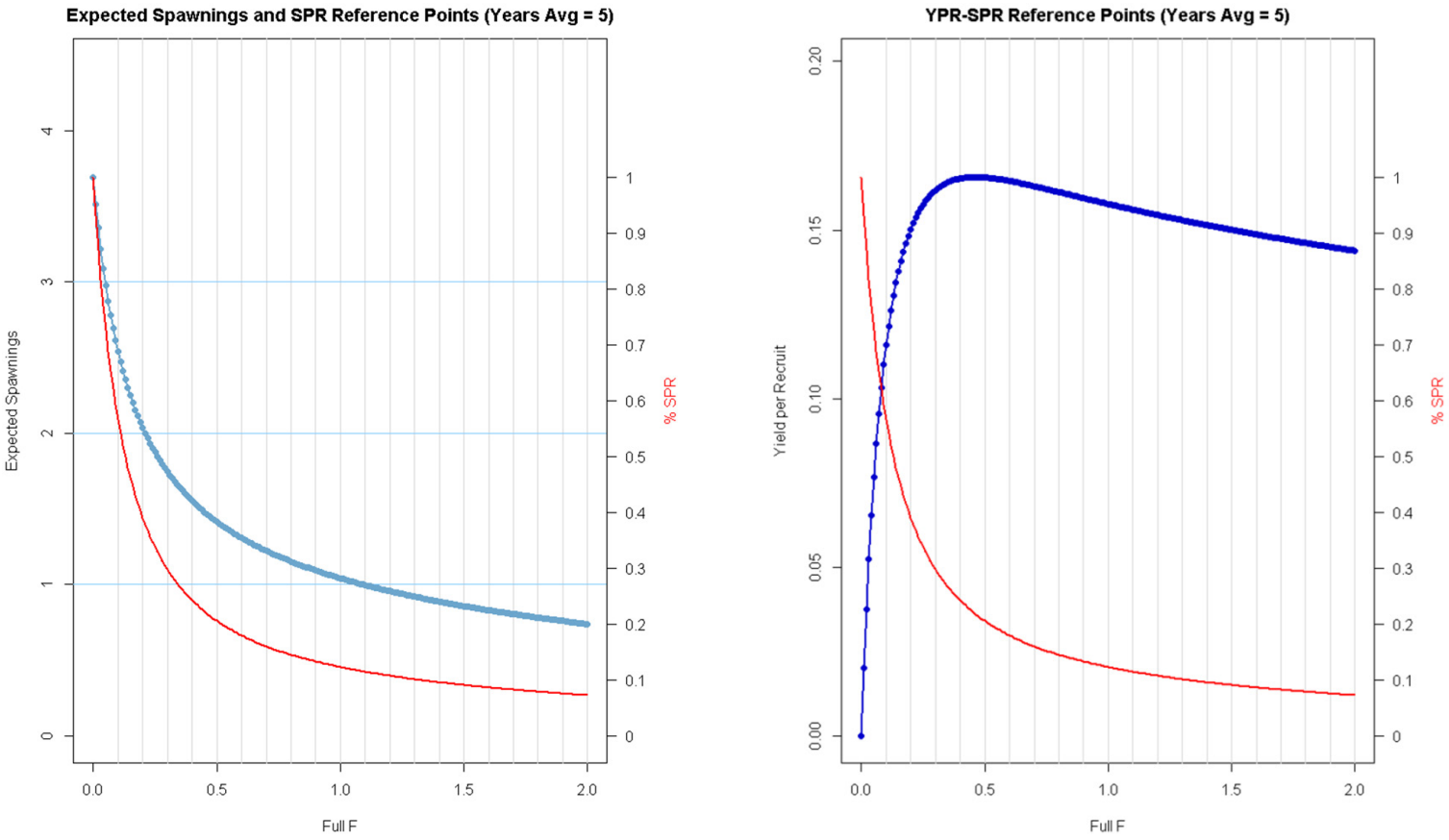
```
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
# Discard Total CV by Year and Fleet
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
0.1
# Catch Effective Sample Size by Year and Fleet
67
67
67
67
67
67
67
67
67
67
67
67
67
67
67
67
67
67
```

```
67
67
67
67
67
67
67
67
67
67
67
67
67
67
67
67
67
# Discard Effective Sample Size by Year and Fleet
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
# Lambda for F Mult in First year by Fleet
0
# CV for F Mult in First year by Fleet
0.1
# Lambda for F Mult Deviations by Fleet
0
# CV for F Mult Deviations by Fleet
0.1
# Lambda for N in 1st Year Deviations
0
# CV for N in 1st Year Deviations
0.1
# Lambda for Recruitment Deviations
1
```

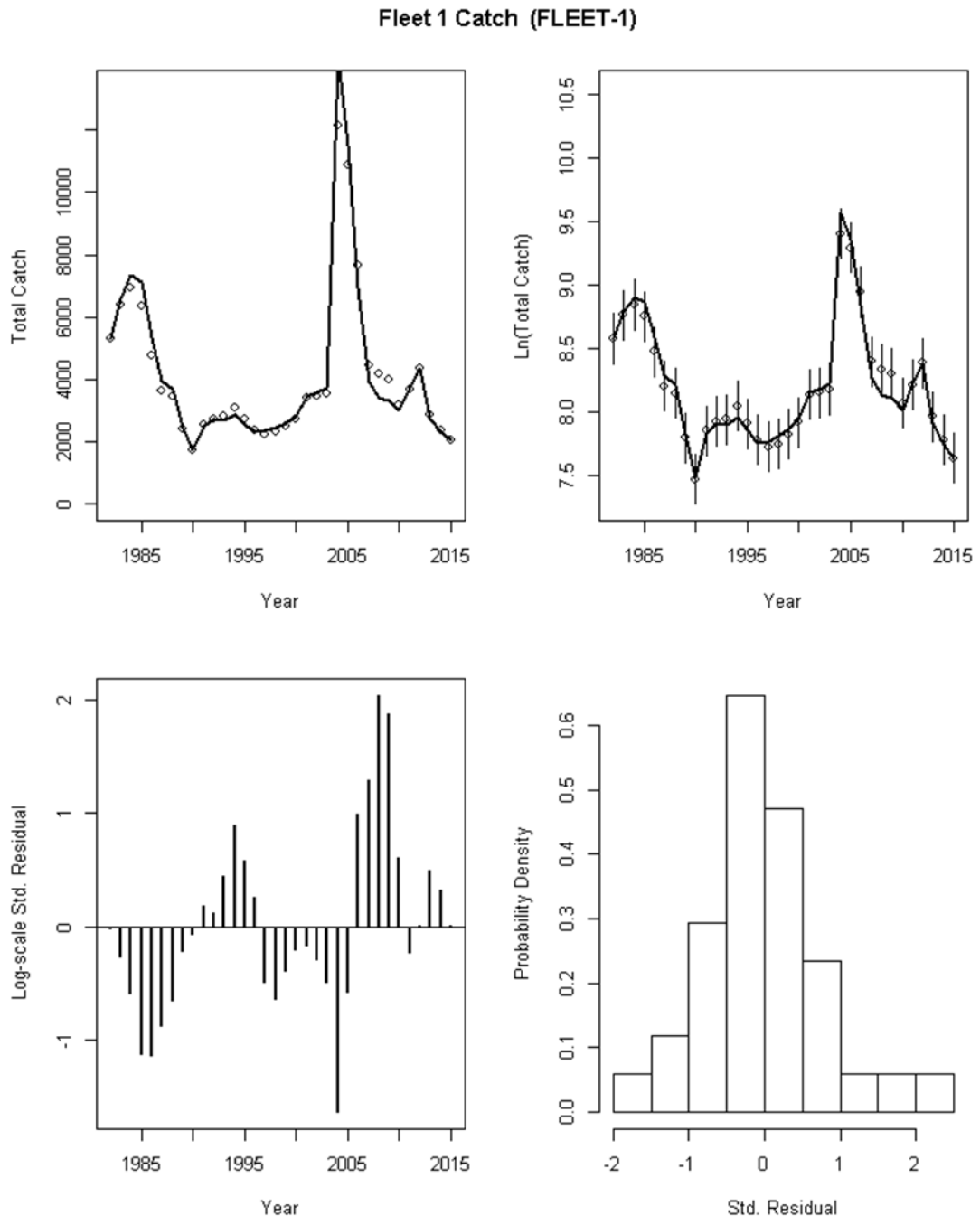
```
# Lambda for Catchability in First year by Index
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
# CV for Catchability in First year by Index
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
# Lambda for Catchability Deviations by Index
0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
# CV for Catchability Deviations by Index
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
# Lambda for Deviation from Initial Steepness
0
# CV for Deviation from Initial Steepness
0.1
# Lambda for Deviation from Unexploited Stock Size
0
# CV for Deviation from Unexploited Stock Size
0.1
# NAA Deviations Flag
1
# Initial Numbers at Age in 1st Year
10000  10000  10000  10000  10000  10000  10000  10000  10000  10000  10000
# Initial F Mult in 1st Year by Fleet
0.2
# Initial Catchabilty by Index
0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001  0.001
# Stock Recruitment Flag
1
# Initial Unexploited Stock
10000
# Initial Steepness
1
# Maximum F
5.0
# Ignore Guesses (Yes=1)
0
# Projection Control
# Do Projections (Yes=1)
0
# Fleet Directed Flag
1
# Final Year in Projection
2016
# Projection Data by Year
2016     -1         3     -99        1
# Do MCMC (Yes=1)
0
# MCMC Year Option
1
# MCMC Iterations
1000
# MCMC Thinning Factor
500
# MCMC Random Seed
12345678
# Agepro R Option
0
# Agepro R Option Start Year
2011
# Agepro R Option End Year
2015
# Export R Flag
1
# Test Value
-23456
######
###### FINIS ######
# Fleet Names
```

```
#$FLEET-1
# Survey Names
#$NEFSC_Spr_82_15
#$NEFSC_AUT_82_15
#$NEFSC_Spr_82_94
#$NEFSC_Spr_95_15
#$NEFSC_AUT_82_94
#$NEFSC_AUT_95_15
#$NEFSC_Spr_82_08
#$NEFSC_Spr_09_15
#$NEFSC_AUT_82_08
#$NEFSC_AUT_09_15
#$ASMFC_Sum_84_15
#$MENH_Spr_01_15
#$MENH_AUT_00_15
#$MADMF_SPR_82-15
#$MADMF_AUT_82-15
#
```

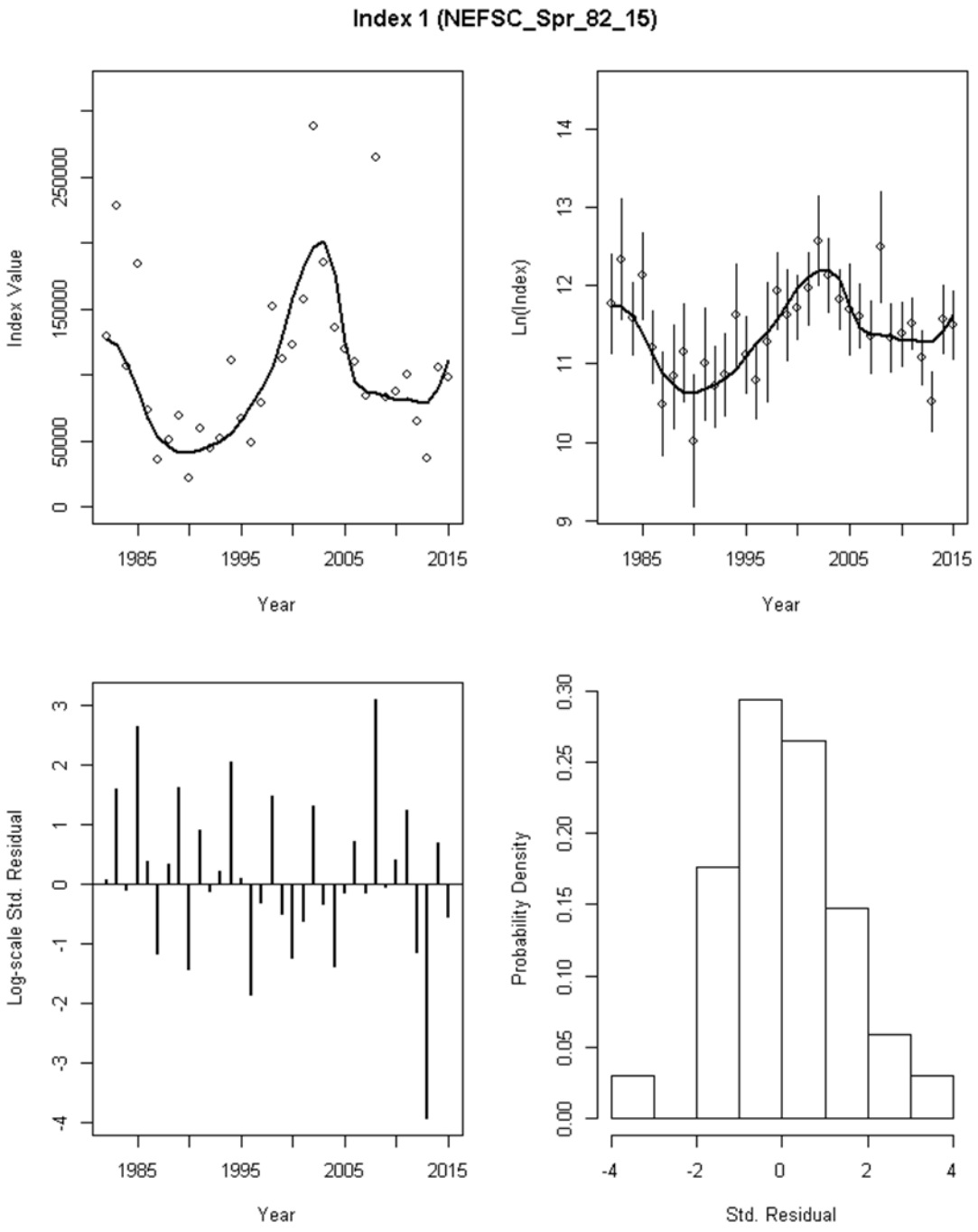
APPENDIX B6: Collection of Slides provided during the SARC discussion



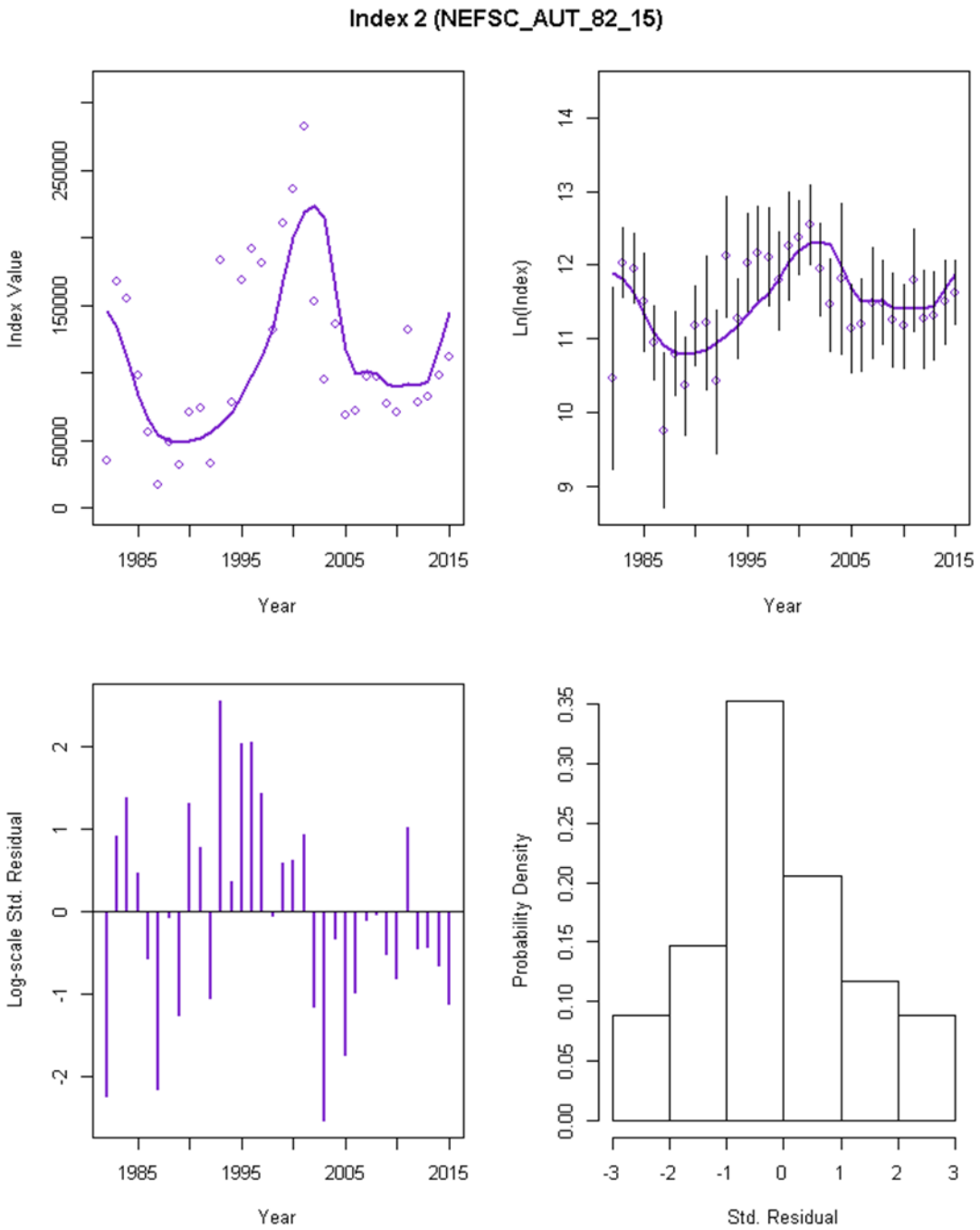
Appendix B6 Figure 1. Number of expected spawning and spawning per recruit reference points (left) and yield per recruit (right) from witch flounder; taken from ASAP Run 9_5_v2.



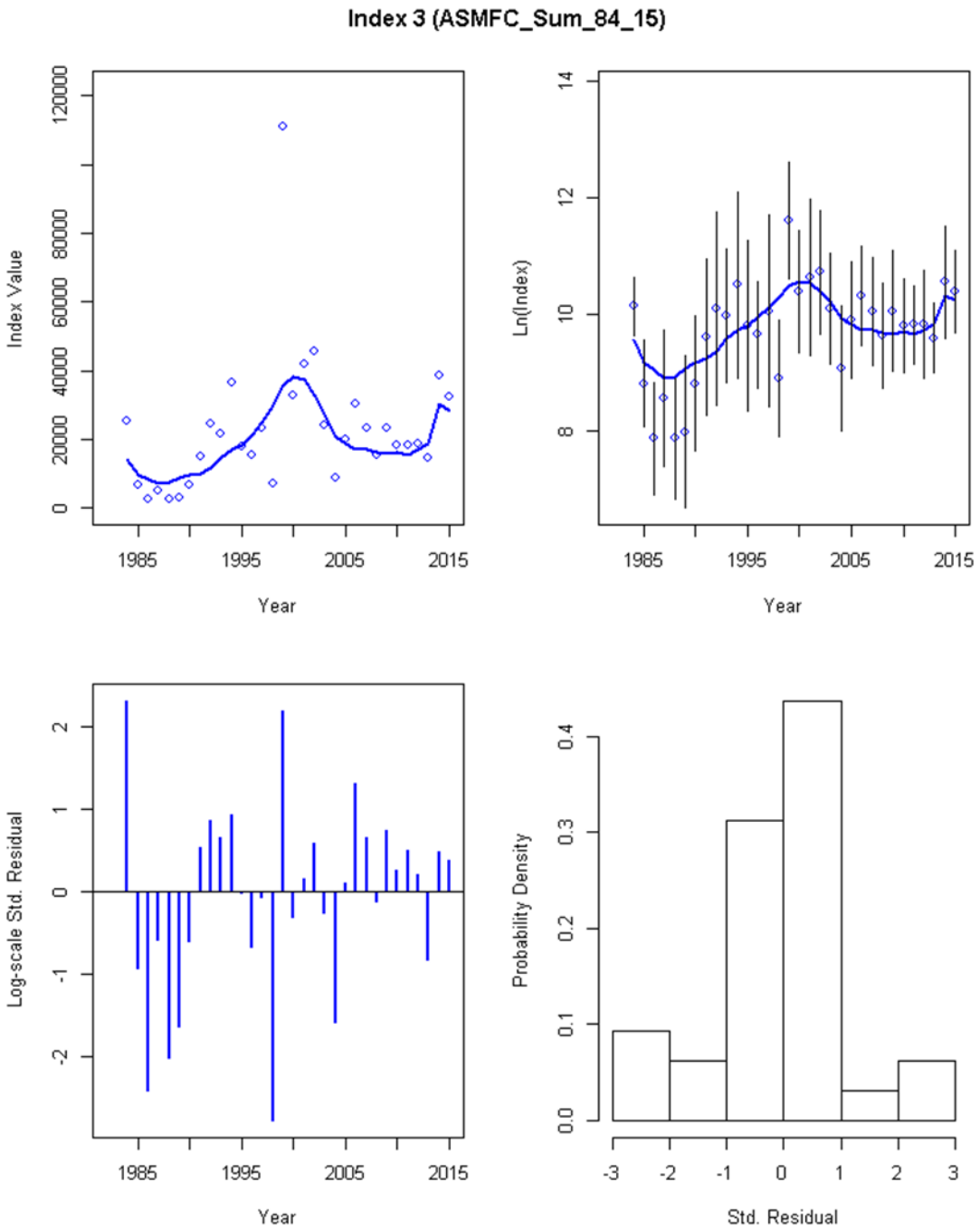
Appendix B6 Figure 2. Model fit to the total witch flounder catch (Fleet 1) from ASAP Run 15 catchx4 for 2004 onward.



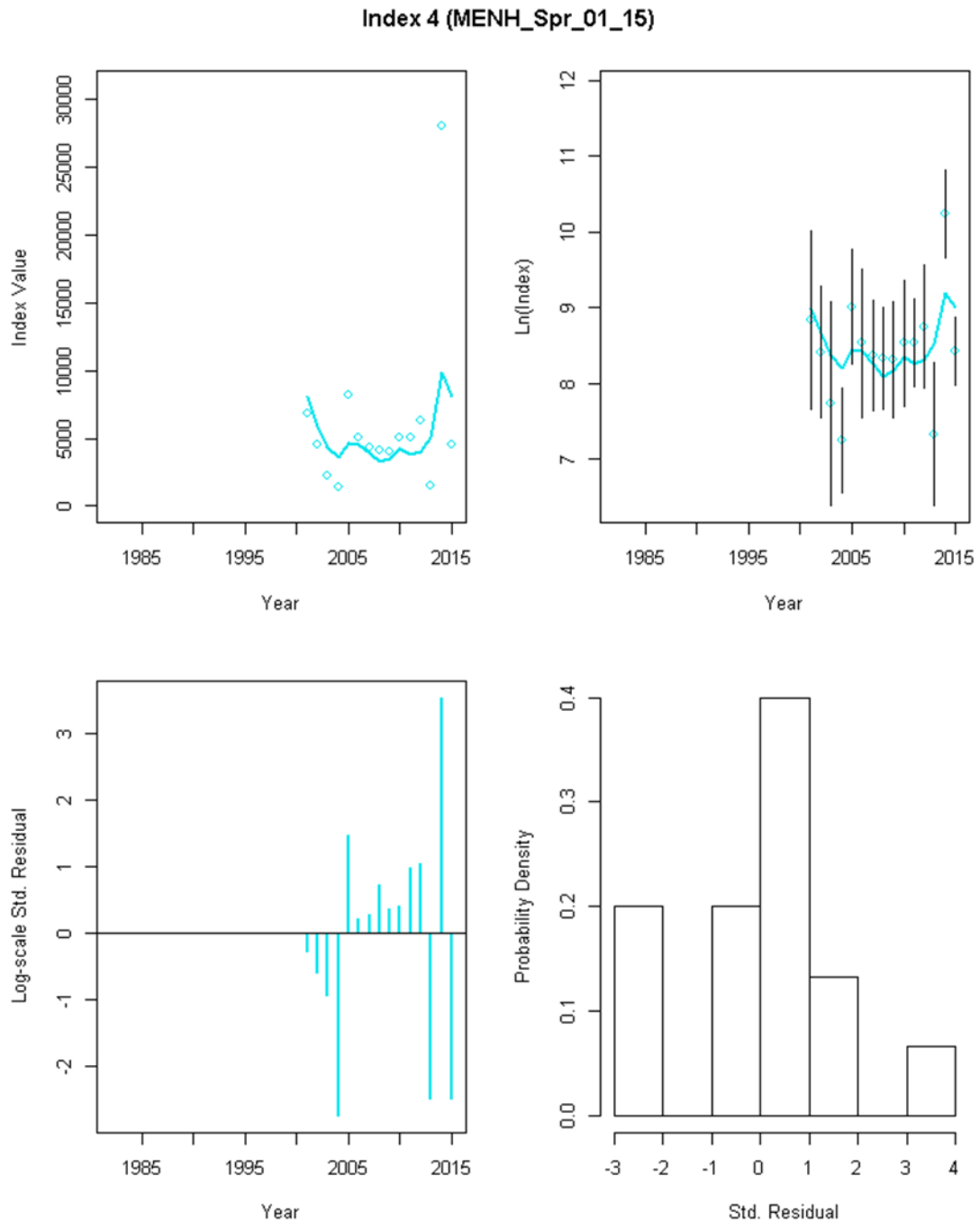
Appendix B6 Figure 3. Model fit to the Northeast Fisheries Science Center spring survey witch flounder index (Index1) from ASAP Run 15 catchx4 for 2004 onward.



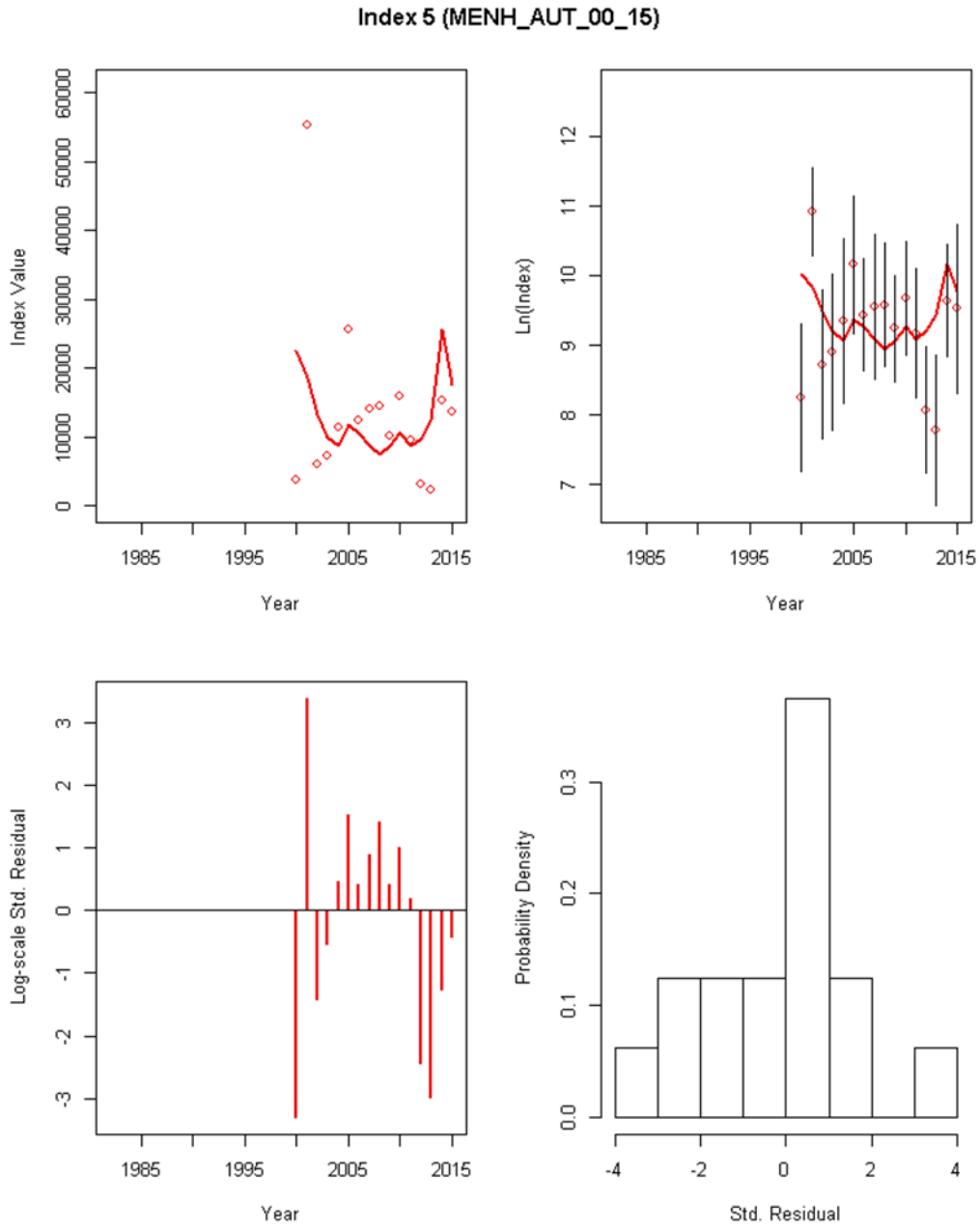
Appendix B6 Figure 4. Model fit to the Northeast Fisheries Science Center autumn survey witch flounder index (Index2) from ASAP Run 15 catchx4 for 2004 onward.



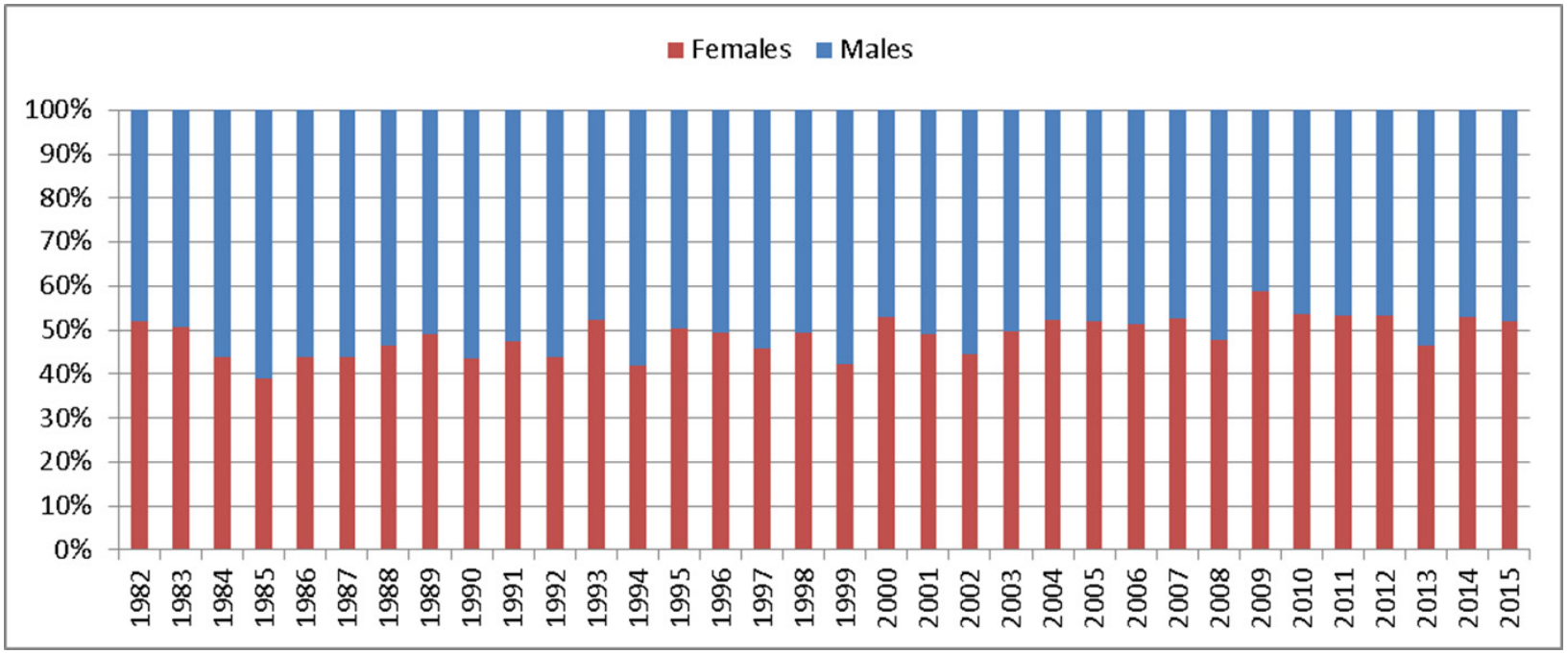
Appendix B6 Figure 5. Model fit to the Atlantic States Marine Fisheries Commission summer survey witch flounder index (Index3) from ASAP Run 15 catchx4 for 2004 onward.



Appendix B6 Figure 6. Model fit to the Maine_New Hampshire inshore spring survey witch flounder index (Index4) from ASAP Run 15 catchx4 for 2004 onward.



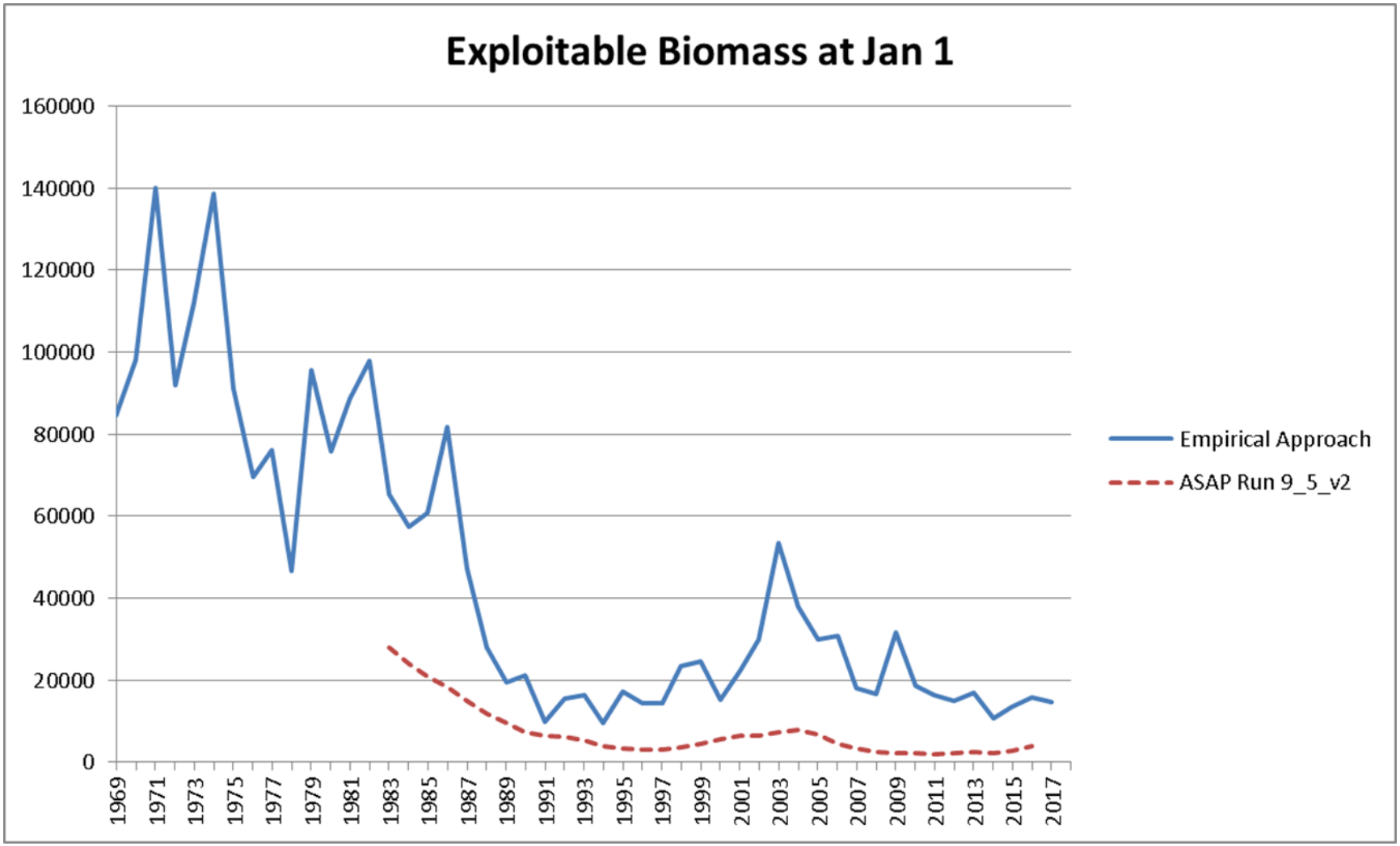
Appendix B6 Figure 7. Model fit to the Maine_New Hampshire inshore autumn survey witch flounder index (Index5) from ASAP Run 15 catchx4 for 2004 onward.



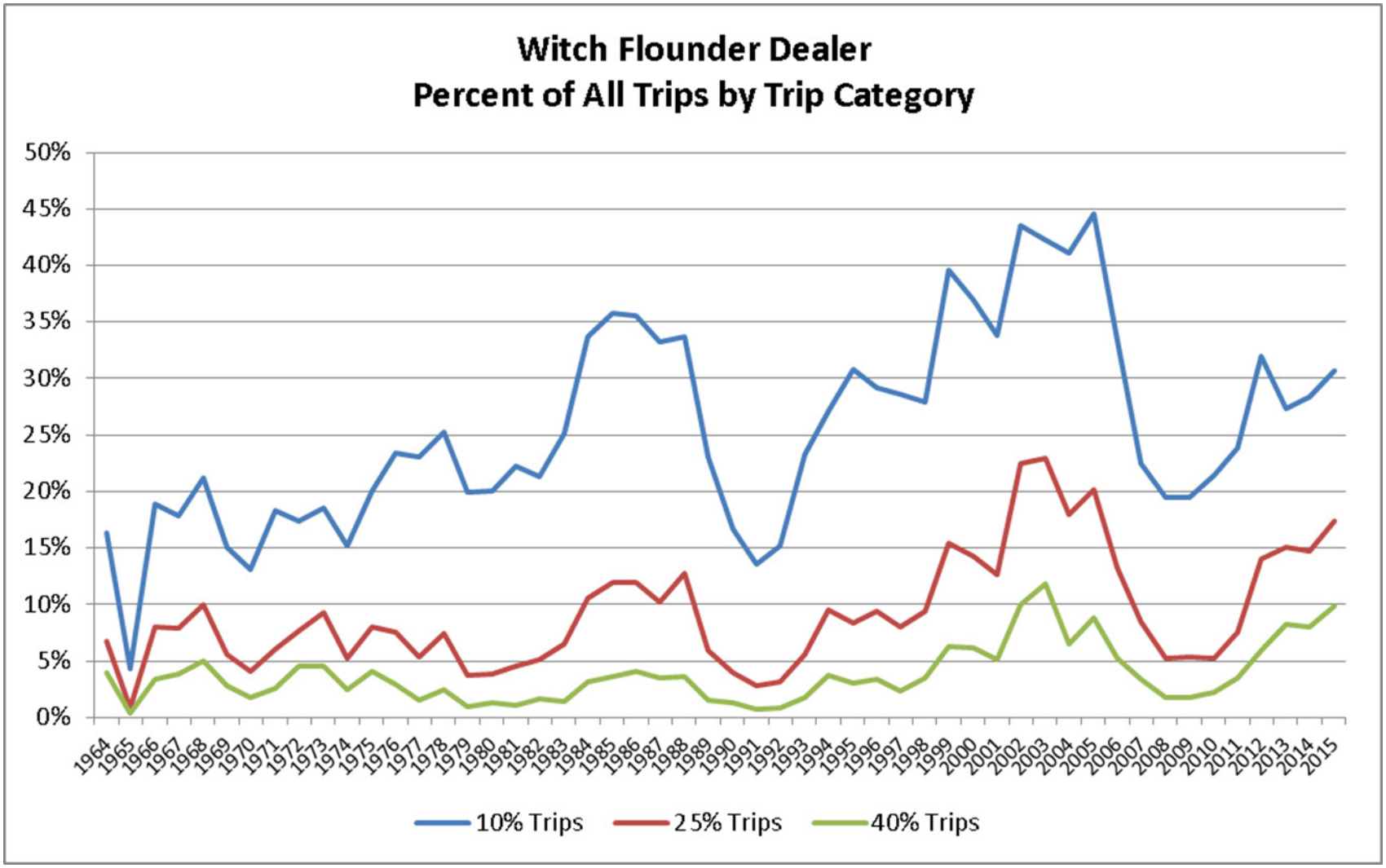
Appendix B6 Figure 8. Witch flounder sex ratio based on Northeast Fisheries Science Center spring and autumn survey data, 1982-2015.

	ASAP RhoAdjust (unadjust)	ASAP CAT4X	ASAP M3X	SWEEP	Legualt Empirical	RY4	RY1	ASAP q=1
SSB15	3335 (5,520)	9,517	5,514	11,500	N/A	N/A	N/A	24,859
EB15	2563 (4,700)			N/A	14,563	8,990	19,420	25,064
F15	0.29 (0.16)	0.4	0.21	N/A	F= ?, (mu = 0.03)	F= ?, mu= 0.2	mu= 0.06	0.025
R15		19 mil	35 mil	N/A	N/A	N/A	N/A	22 mil
NEC Qs	ALBq=~4.0	ALBq=~2.5	ALBq=~3.0	BIGq=~0.3	BIGq=~0.3	ALBq= ~4.0	ALBq= ~1.0	ALBq=~1.0
F40	0.19	0.19	0.15	N/A	mu10yravg = (mu = 0.05)	N/A	N/A	
SSB40	12,747	28,511	7,300	N/A	N/A	N/A	N/A	
MSY40	1,998	4,481 (1,120)	646	N/A	N/A	1,790	1,200	
FMSY (OFL17)	762	2,100 (525)	563	N/A	728	1,790	1,200	

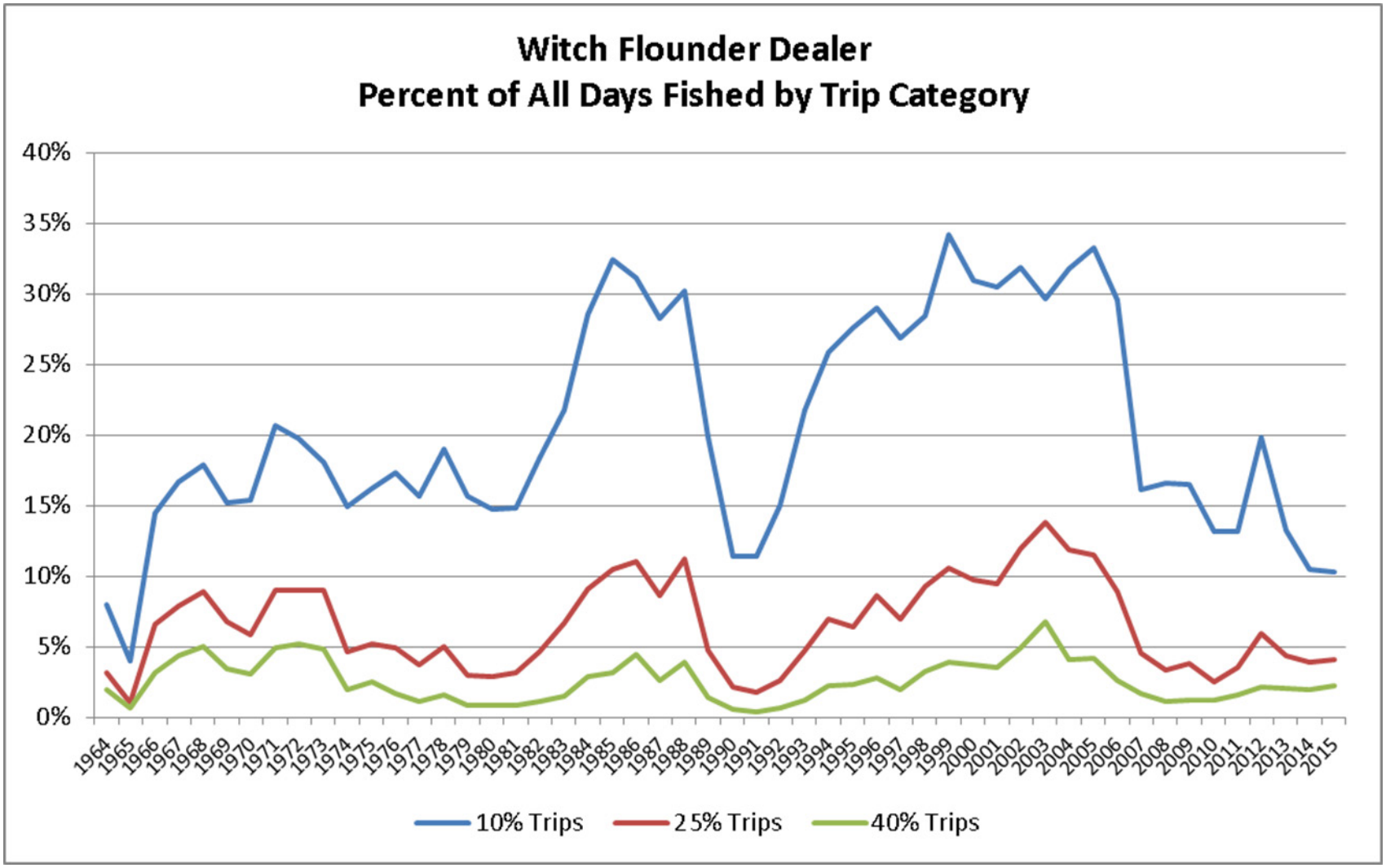
Appendix B6 Figure 9. Witch flounder model result summary compiled during the Model Meeting on the white board in the Conference Room. *Note: some values may not represent final results.*



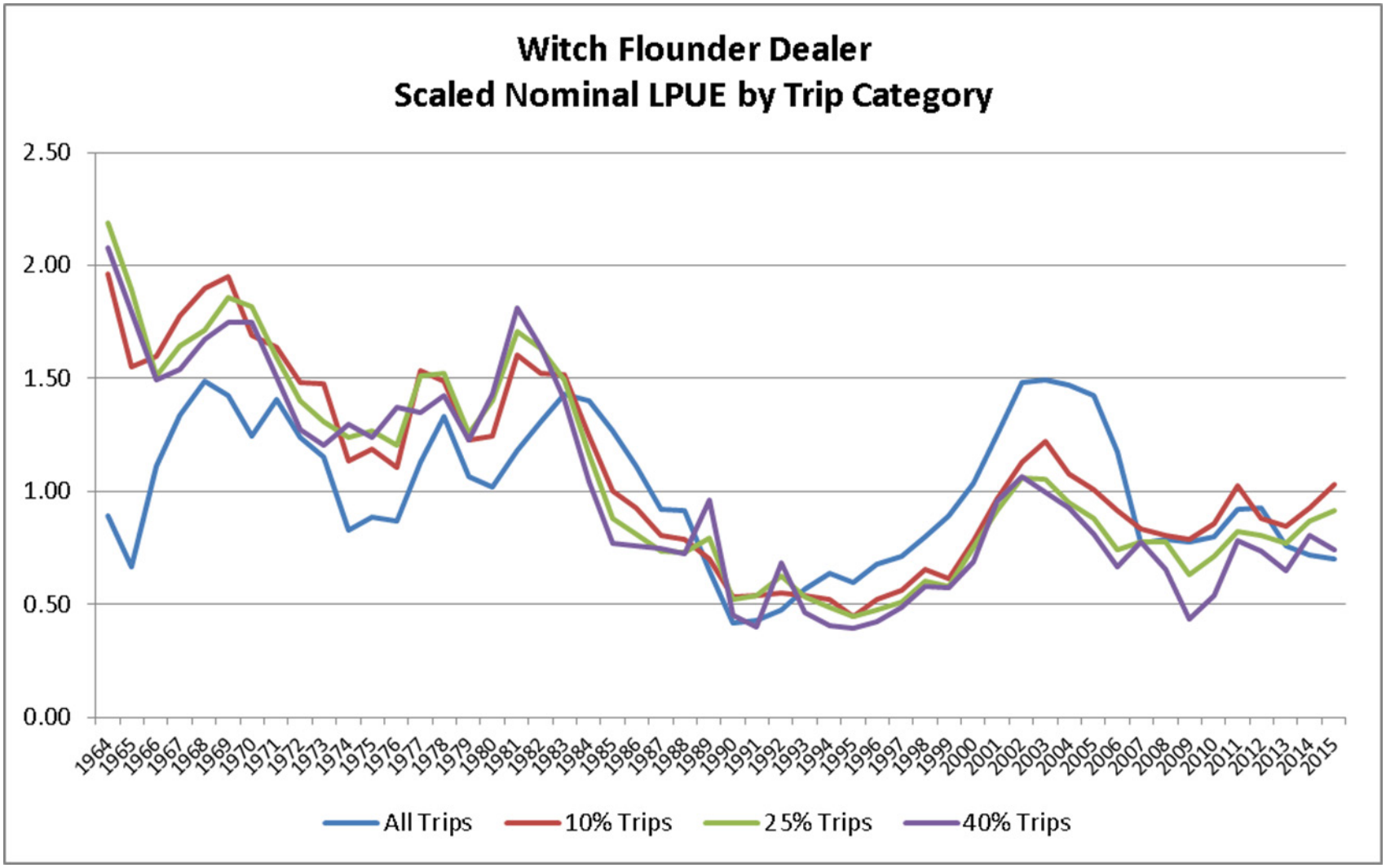
Appendix B6 Figure 10. Comparison of witch flounder January-1 exploitable biomass from Empirical Approach and ASAP Run 9_5_v2.



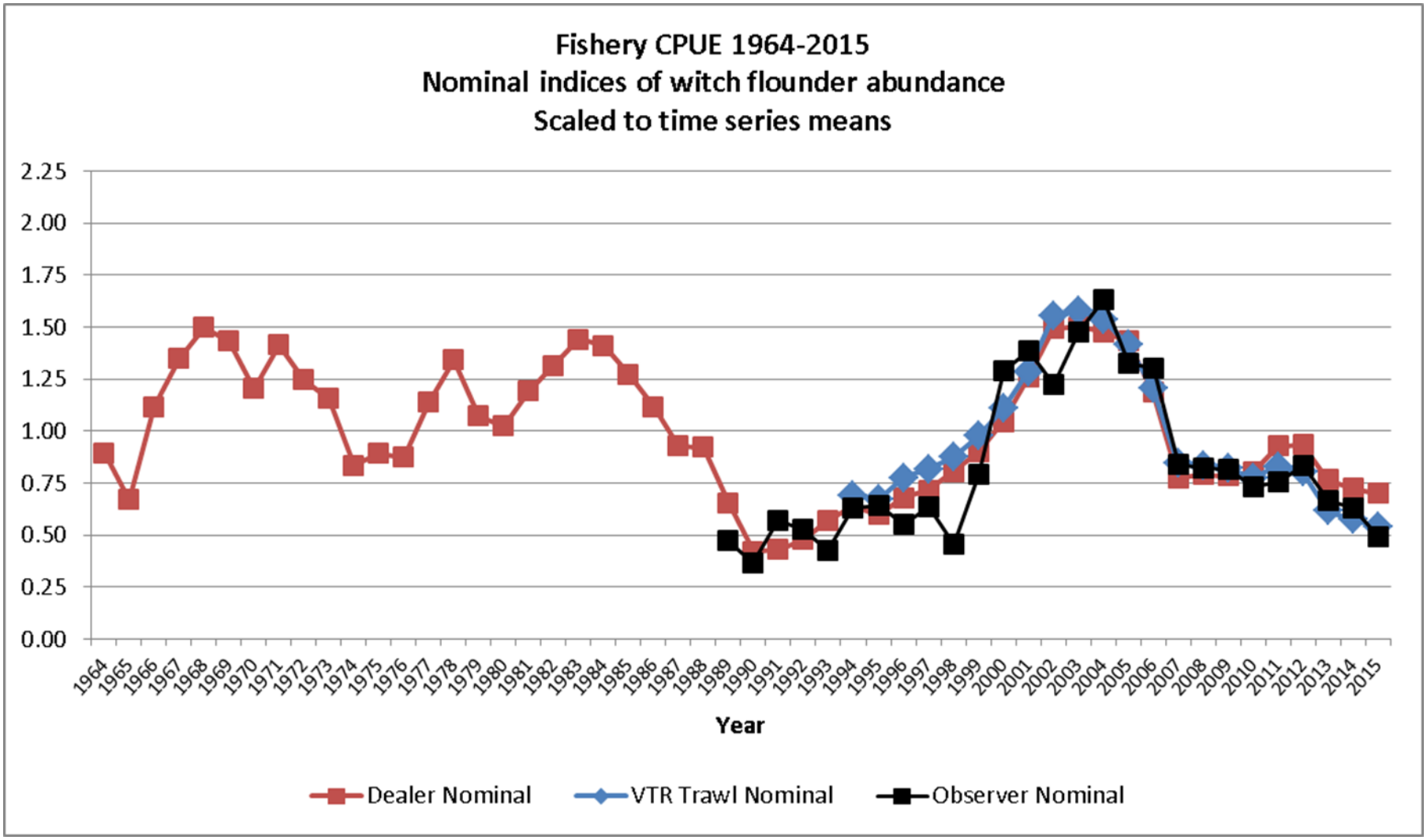
Appendix B6 Figure 11. Trends in percentage of all trips, by trip category (10%, 25% and 40% directed trips) for witch flounder.



Appendix B6 Figure 12. Trends in percentage of all days fished, by trip category (10%, 25% and 40% directed trips) for witch flounder.



Appendix B6 Figure 13. Trends in scaled nominal landings per days fished (LPUE), by trip category (10%, 25% and 40% directed trips, and all trips) for witch flounder.



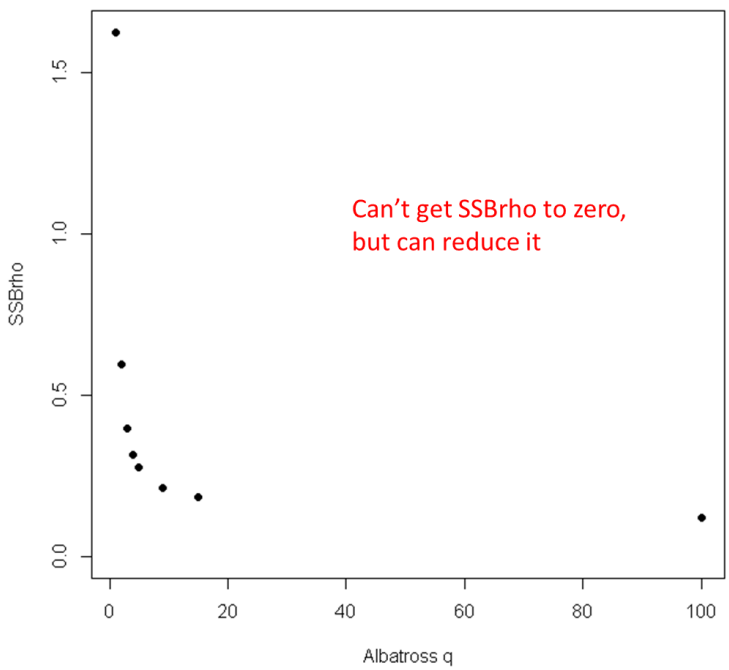
Appendix B6 Figure 14. Trends in nominal witch flounder fishery catch per day fished (CPUE) by data set (Dealer, Vessel Trip Report, and Observer).

Witch Flounder Albatross-Bigelow Calibration Exploration

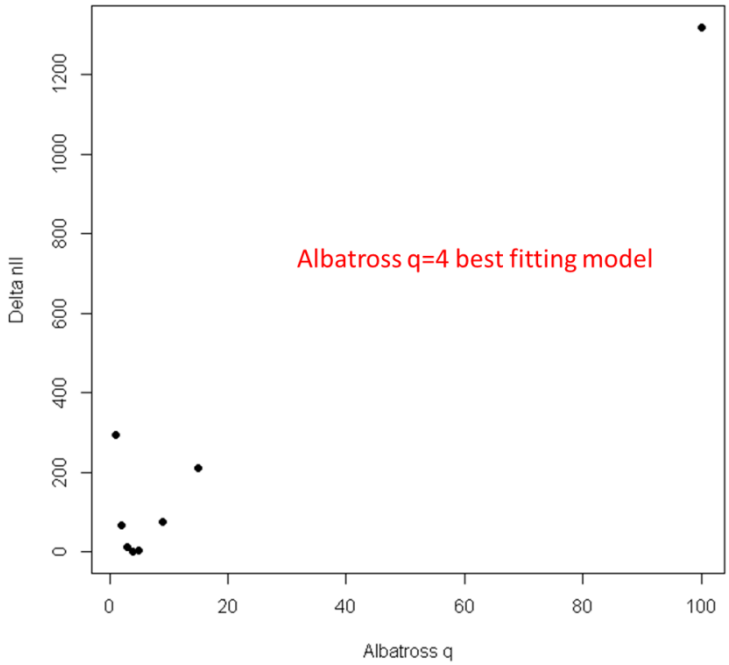
What was done

- Started with final witch flounder run
- Separated Albatross and Bigelow series
  - Each is converted so that q = 1 for both is expected
- Fixed Bigelow q at 1
- Fixed Albatross q at range of values
- Examined SSBrho and other metrics

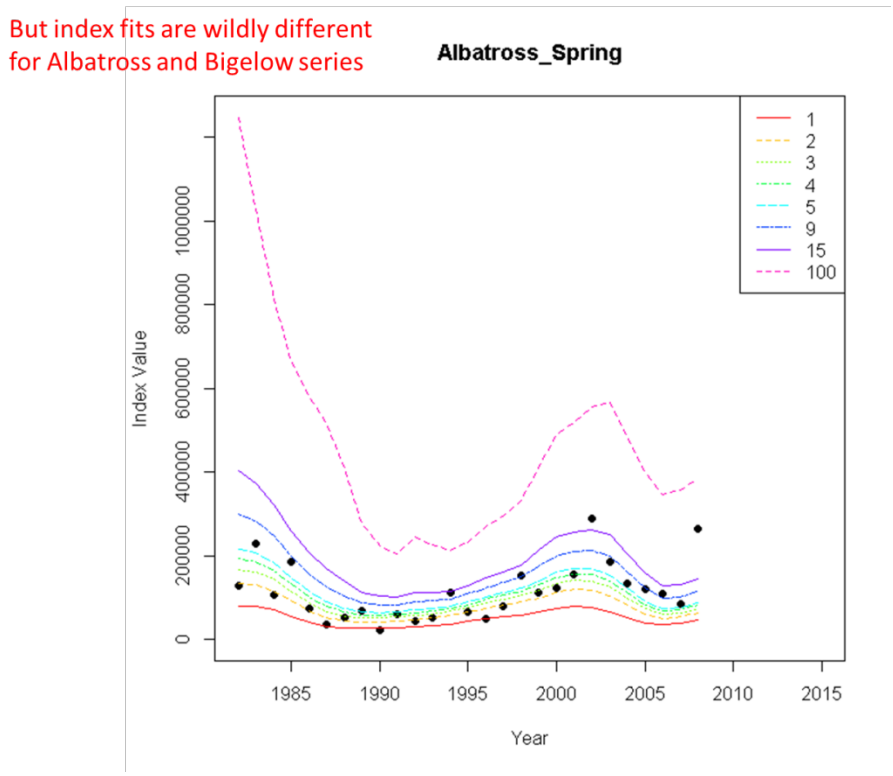
Appendix B6 Figure 15. Steps taken for the witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault).



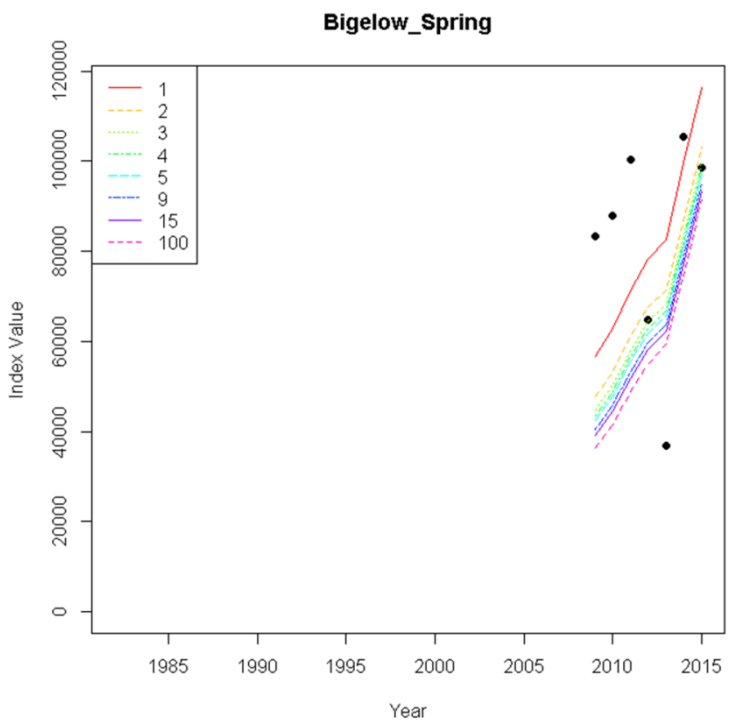
Appendix B6 Figure 16. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault).



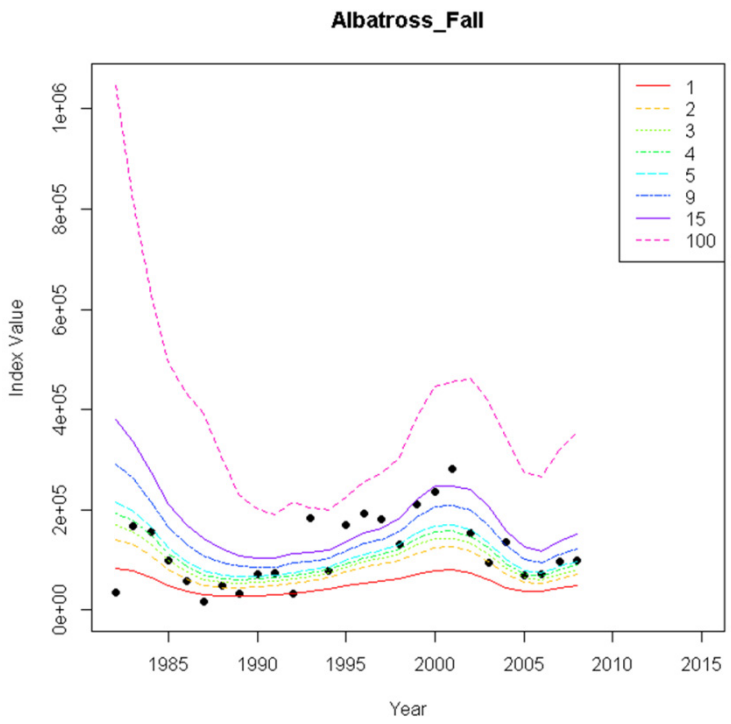
Appendix B6 Figure 17. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault).



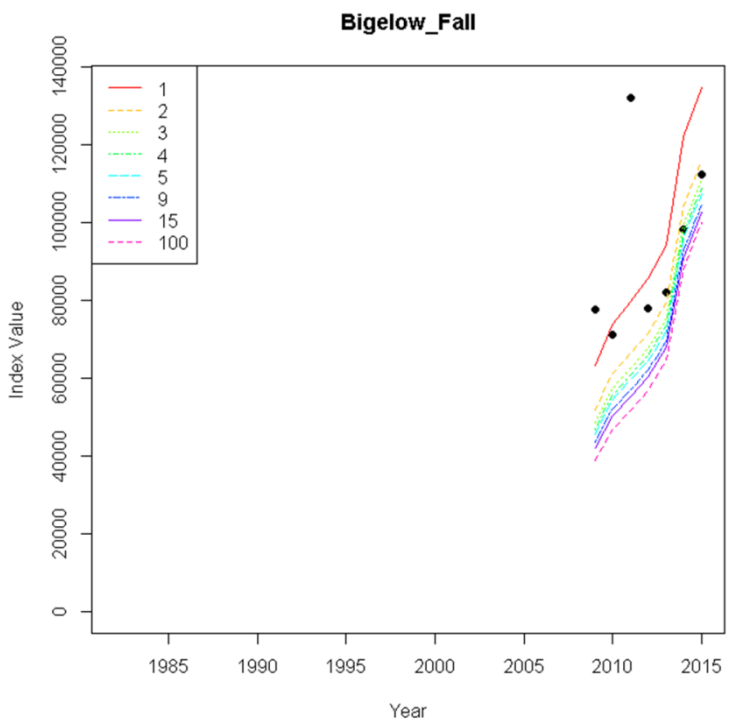
Appendix B6 Figure 18. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault).



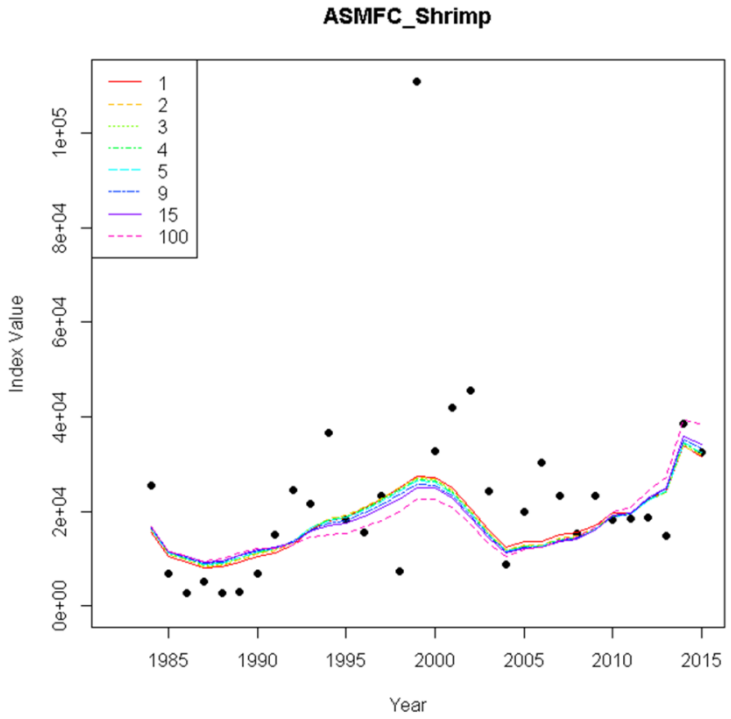
Appendix B6 Figure 19. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault).



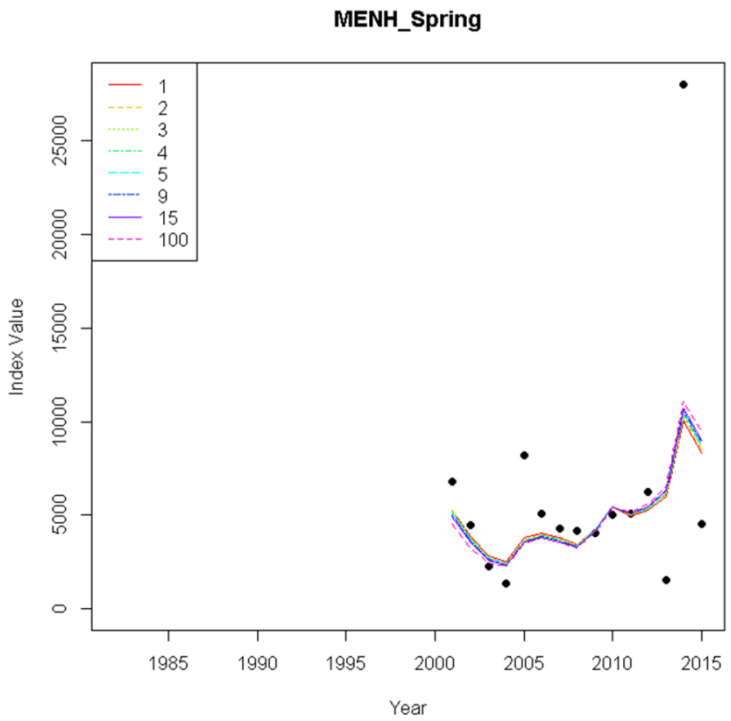
Appendix B6 Figure 20. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault).



Appendix B6 Figure 21. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault).



Appendix B6 Figure 22. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault)



Appendix B6 Figure 23. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault)

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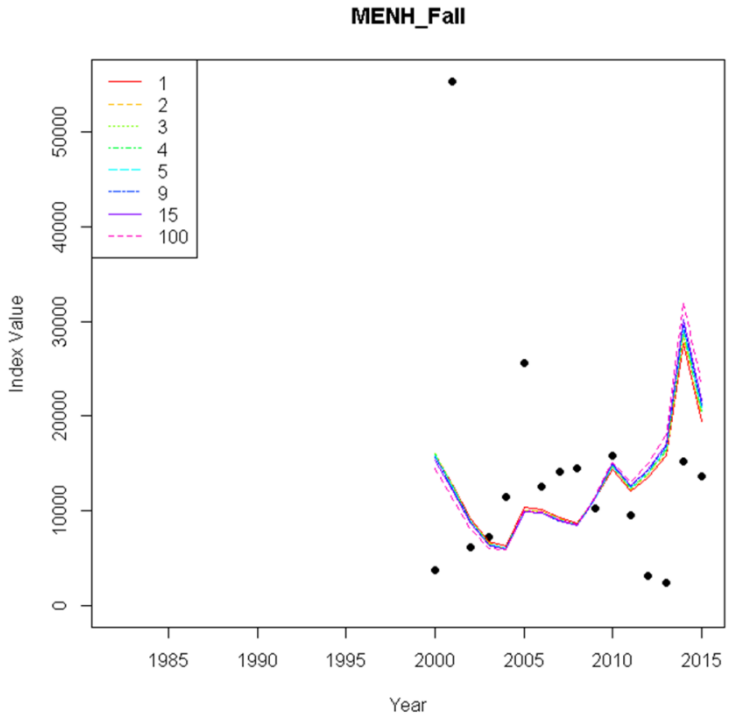

Appendix B6 Figure 24. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault)

Take home messages

- Changing survey q can reduce retrospective pattern
- Doing so for witch flounder at Albatross-Bigelow transition requires Albatross to have higher catchability than Bigelow (when Bigelow q fixed at 1)
  - This contradicts experimental evidence
- Could be explored more in future, but does not appear promising

Appendix B6 Figure 25. Witch flounder Albatross-Bigelow calibration Exploration (presentation by Chris Legault)

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