STATE OF DELAWARE
DEPARTMENT OF NATURAL RESOURCES & ENVIRONMENTAL CONTROL
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FISHERIES SECTION

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To: ASMFC Executive Committee
From: John Clark
Date: July 20, 2018
Re: Appeal Criterion 1. Decision not consistent with FMP

Addendum XXX to the Black Sea Bass FMP was approved by the Summer Flounder, Scup, and Black Sea Bass Board at the Winter 2018 meeting, appealed by the Northern Region states in March, then revised by the Board at the Spring 2018 meeting. The action taken at the Spring 2018 meeting by the Black Sea Bass Board on the Addendum in response to the updated 2017 recreational landings and the appeal by the Northern Region states resulted in better management. However, as long as the Executive Committee is reexamining the Appeals criteria, it should take another look at one of the criteria that the Appeals Fact Finding Committee agreed was appropriate for accepting the Northern Region appeal, namely Criterion 1. Decision not consistent with FMP. I think the acceptance of appeal under this criterion by the Appeals Committee could set a troubling precedent for future appeals.

We need to clarify the definition of Criterion 1, Decision not consistent with FMP, because it would seem that many decisions made by ASMFC Boards could be appealed on this criterion if the precedent-setting acceptance of this criterion for Addendum XXX becomes part of the ASMFC management record. This decision is troubling because it is hard to understand how the Board's Addendum XXX decision was not consistent with the FMP. While the Northern Region appeal states that 'The primary objective of Addendum XXX is to address inequities in recreational black sea bass management that resulted from the ad hoc regional management approach in the preceding six years', this was not the primary objective of Addendum XXX, but is instead a selective rewording of Addendum XXX Section 2.1 Statement of the Problem. The Board motion to develop Addendum XXX stated "move to initiate an addendum for 2018 recreational black sea bass management with **options as recommended by the Working Group and Plan Development Team.** Options for regional allocations shall include approaches with uniform regulations (e.g. number of days) and other alternatives to the current North/South regional delineation (MA-NJ/DE-NC) such as those applied for summer flounder, i.e., one – state regions". The

Addendum XXX development process followed the Board motion to the letter. Draft Addendum XXX had management options proposed by the Working Group and Plan Development Team, which were vetted by the Technical Committee. It must be noted that several members of the Working Group were from the Northern Region. These options were approved by the Board for public hearings and the Addendum went through the public hearing process. In my view this Addendum development process was entirely consistent with the FMP. At the Winter 2018 Board Meeting, the Board developed and approved a new management option that was an average of the two of the approved options, which was again consistent with the FMP as the new option fit between the approved options. I certainly understand that, for the Northern Region, these options were not desirable, but that doesn't make them 'not consistent with the FMP'. As a member of the Working Group, I find it disconcerting that the Appeals Committee accepted this appeal under this criterion as the Working Group spent long hours coming up with management options that met the Board's directive for Addendum XXX.

While the resolution of the Addendum XXX appeal situation at the Spring 2018 Board Meeting allowed management to proceed, it wasn't clear whether the ISFMP Policy Board was endorsing the Appeals Committee findings or the appeal was one of several factors in reconsidering the Addendum XXX management options. In the face of this uncertainty, I urge ASMFC to take the following actions:

1. The ISFMP Policy Board need to make clear that Addendum XXX was revised due to the new information received and analyzed between the Winter and Spring 2018 Board Meetings, which fits under Criterion 3: Insufficient/Inaccurate/Incorrect Application of Technical Information, not because the Board accepts the Appeals Committee finding that the appeal was justified under Criterion 1. The version of Addendum XXX approved at the Winter 2018 Board meeting was consistent with the FMP and I think the Policy Board must state that it was consistent. What does seem inconsistent is that just months after ASMFC expressed dismay bordering on outrage over the acceptance by the Secretary of Commerce of the New Jersey summer flounder appeal, we have an ASMFC Appeals Committee accepting an appeal based in part on the grounds that the action taken was not consistent with the FMP, which seems to be a much more ambiguous standard than that used by the Secretary of Commerce to find in New Jersey's favor.

2. As long as we are clarifying other appeal criteria, we need to clarify Criterion 1, if that is possible. My concern and frustration about the Appeals Committee acceptance of the Northern States Addendum XXX appeal on this Criterion is based on recent history. I remind you that Delaware appealed Addendum IV of the Striped Bass Plan on Criterion 1 and was rejected, despite having what I still consider a much stronger case to make on Criterion 1. To refresh the collective memory, Delaware's argument against Addendum IV was that Amendment 6 stated, "*Stock Rebuilding Schedules (2.6.2) If at anytime the Atlantic striped bass population is*

declared overfished and rebuilding needs to occur, the Management Board will determine the rebuilding schedule at that time.", but Addendum IV required a 25% reduction in harvest despite the stock not being declared overfished. If that management decision was consistent with the FMP, yet Addendum XXX was not consistent, then we have a capricious appeal system that will not only increase public skepticism of ASMFC's decision making process, but will further increase the pressure on states to appeal management decisions they find unfavorable. If we keep Criterion 1, we will need to more clearly define conditions that meet this criterion. For example:

'Criterion 1. Decision not consistent with FMP. A decision may be inconsistent with the FMP if it meets any of these conditions:

- Contradicts at least one objective of the FMP
- Contradicts management triggers in the FMP
- Further conditions should be added'

Thank you for your consideration of this request.

B. Atlantic Herring WP-1

June 12, 2018

SARC 65

DRAFT Atlantic Herring Assessment for 2018

By the

Atlantic Herring SAW Working Group

B. Atlantic herring

The SARC 65 Atlantic Herring Working Group conducted a Data meeting (February 6-7, 2018) and a Model meeting (May 2-4, 2018) in the development of this assessment. The SAW/SARC Herring Working Group members are:

Jon Deroba – NEFSC Population Dynamics (Assessment lead)

John Manderson – NEFSC Coop Research

Chris Legault- NEFSC Population Dynamics

Deirdre Boelke – New England Fishery Management Council

Sarah Gaichas – NEFSC Ecosystem Dynamics and Assessment

Matt Cieri –ME DMR

Ashleen Benson – Landmark Fisheries

Gary Shepherd – NEFSC Population Dynamics (WG-Chair)

Executive Summary

TOR B1. Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize uncertainty in these sources of data. Comment on other data sources that were considered but were not included.

US catches were developed for the years 1965-2017 and were a sum of landings and self-reported discards. Discards have only been available since 1996, but were generally less than 1% of landings. Consequently, discards do not represent a significant source of mortality and a lack of historical discards is not considered problematic for the assessment. US catches were developed separately for fixed and mobile gear types. Catches from the New Brunswick, Canada, weir fishery were provided for the years 1965-2017 and were added to the US fixed gear catches for the purposes of assessment.

Total catches during 1964-2017 ranged from 44,613 mt in 1983 to 477,767 mt in 1968. Total catches during the past five years ranged from 50,250 mt in 2017 to 101,622 mt in 2013 and averaged 79,206 mt. Mobile gear catches have been the dominant gear type since about 1995.

TOR B2. Present the survey data being used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, food habits, etc.). Characterize the uncertainty and any bias in these sources of data.

Abundances (i.e., arithmetic mean numbers per tow) from the NMFS spring, fall, and summer shrimp bottom trawl surveys were used in the assessment model along with annual coefficients of variation and age composition when they were available. The trawl door used on the spring and fall surveys changed in 1985 and likely altered the catchability of the survey gear. Consequently, the spring and fall surveys were split into two time series between 1984 and 1985, and these were treated as separate indices in assessment models. The spring and fall surveys also used a different vessel (i.e., the Bigelow) beginning in 2009, and so these surveys were split again to account for this vessel change. Ultimately, the spring and fall surveys had three time stanzas: 1965-1984, 1985-2008, 2009-2017.

An acoustic index collected during the NMFS fall bottom trawl survey was also used as an index of herring abundance. This survey has no age composition data and so selectivity was knife-edged at age-3.

Several other indices of abundance were considered, but not used in the final assessment model. These indices included: NMFS winter survey, Massachusetts state surveys (spring and fall), joint Maine/New Hampshire state surveys (spring and fall), and an index based on food habits data.

TOR B3. Estimate consumption of herring, at various life stages. Characterize the uncertainty of the consumption estimates. Address whether herring distribution has been affected by environmental changes.

Fish food habits data from NEFSC bottom trawl surveys were evaluated for 12 herring predators. From these data, diet composition of herring, per capita consumption, and the amount of herring removed by the 12 predators were calculated. Combined with abundance estimates of these predators, herring consumption was summed across all predators as total herring consumption. Annual removal of herring amounted to 10s to 100s of thousands of mt by these predators. Annual removal ranged from 32,700mt in 1983 to 390,000mt in 2008. Amount of deaths due to input natural mortality in the stock assessment were compared to the estimates of predatory consumption as a general check of scale.

TOR B4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Incorporate ecosystem information from TOR B3 into the assessment model, as appropriate. Include retrospective analyses (both historical and within -model) to allow a comparison with previous assessment results and projections, and to examine model fit.

The base ASAP model made structural changes to the previous assessment (e.g., M, selectivity), included new index time series, and re-evaluated some other relatively minor issues (e.g., weak likelihood penalties). Of particular importance, however, was a change to M. Natural mortality in recent assessments varied by time and age, with values based on a combination of the Hoenig and Lorenzen methods (Hoenig 1983; Lorenzen 1996). In 2012, the natural mortality rates during 1996-2011 were increased from these base rates by 50% to resolve a retrospective pattern and to ensure that the amount of herring deaths due to input M were consistent with observed increases in estimated consumption of herring. In 2015, a retrospective pattern re-emerged and implied levels of consumption were no longer consistent with estimated consumption. Thus, assumptions about time- and age-varying M were reevaluated as part of this assessment. Ultimately, M equaled 0.35 for all years and ages in this assessment.

The base ASAP model estimated SSB in 2017 to be 141,473 mt, with SSB ranging from a minimum of 53,084 mt (1982) to a maximum of 1,352,700 mt (1967) over the entire time series. The base ASAP model estimated total January 1 biomass in 2017 to be 239,470 mt, ranging from a minimum of 169,860 mt (1982) to a maximum of 2,035,800 mt (1967) over the entire time series.

No common age is fully selected in both the mobile and fixed gear fishery. Consequently, the average F between ages 7 and 8 was used for reporting results related to fishing mortality ($F_{7\text{-}8}$), and this includes reference points. These ages are fully selected by the mobile gear fishery, which has accounted for most of the landings in recent years. $F_{7\text{-}8}$ in 2017 equaled 0.45. The all-time low of 0.13 occurred in 1965. The all-time high of 1.04 occurred in 1975.

Age-1 recruitment has been below average since 2013. The all-time high of 1.4 billion fish occurred in 1971. The estimates in 2009 and 2012 are still estimated to be relatively strong cohorts, as in previous assessments. The all-time low of 1.7 million fish occurred in 2016, and the second lowest of 3.9 million fish occurred in 2017. Four of the six lowest recruitment estimates have occurred since 2013 (2013, 2015, 2016, 2017).

The internal relative retrospective pattern suggested consistent overestimation of SSB with Mohn's Rho = 0.15, and underestimation of $F_{7\text{-}8}$ with Mohn's Rho = -0.11. The retrospective pattern for recruitment at age 1 was characterized by both positive and negative peels. The presence of the retrospective pattern was sensitive to the indices of abundance used in the model. The retrospective pattern was not severe enough, however, to warrant an adjustment for stock status determination or projections. Estimating catchability separately for the Bigelow years in 2009-2017 may also be aliasing other causes of the retrospective pattern, and so future herring assessments may have worsening retrospective patterns.

TOR B5. State the existing stock status definitions for "overfished" and "overfishing". Then update or redefine biological reference points (BRPs; point estimates or proxies for B_{MSY},

$B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

The existing MSY reference points were based on the fit of a Beverton-Holt stock-recruitment relationship, estimated internally to the ASAP model, and inputs (e.g., weights-at-age, natural mortality) from the terminal year of the assessment (i.e., 2014). Point estimates of the MSY BRPs equaled: MSY = 77,247 mt, F_{MSY} = 0.24, and SSB_{MSY} = 311,145 mt.

No stock-recruit relationship was able to be estimated in this assessment, therefore $F_{40\%}$ was used as a proxy for F_{MSY} and long-term projections were used to derive other MSY BRP proxies. F_{MSY} proxy = 0.51, SSB_{MSY} proxy = 189,000 mt (½ SSB_{MSY} = 94,500 mt), and MSY proxy = 112,000 mt.

The existing MSY reference points were based on estimates of a Beverton-Holt stock-recruit curve fit internally to the ASAP model. The ability to estimate the stock-recruit curve seems to have deteriorated in this assessment, but the ability of previous models to estimate a stock-recruit curve has also been noted as tenuous. The newly proposed reference points no longer rely on a poorly estimated stock-recruit relationship.

TOR B6. Make a recommendation about what stock status appears to be based on the existing model (from previous peer reviewed accepted assessment) and based on a new model or model formulation developed for this peer review.

a. Update the existing model with new data and evaluate stock status (over fished and overfishing) with respect to the existing BRP estimates.

Given the Working Group's conclusion that MSY reference points based on the estimation of a stock-recruit curve were unjustified, and were likely unjustified in previous assessments, the existing BRPs are not meaningful. Similarly, evaluating stock status of the existing model with updated data to the existing MSY BRPs is not informative.

b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR B5).

The base ASAP model estimated $F_{7\text{-}8}$ in 2017 to be 0.45 and SSB in 2017 was 141,473 mt. Since the retrospective adjusted values do not fall outside of the confidence intervals of the base model estimates, no retrospective adjustment was warranted. A comparison of the base model values to the new MSY proxy reference points suggest that overfishing is not occurring and that the stock is not overfished. The error bars for $F_{7\text{-}8}$, however, included overfishing.

c. Include descriptions of stock status based on simple indicators/metrics.

The estimated numbers at age in 2017 indicate that the population is characterized by more age 6 fish than age 1 and age 2 combined. This result suggests a reliance on the ageing 2011 cohort (age 6 in 2017). If the estimated record low recruitments in recent years hold true, then the SSB is likely to remain relatively low and put the stock at relatively high risk of becoming overfished. Without improved recruitment, the probability of overfishing under recent catch levels is also likely relatively high.

TOR B7. Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (through 2021) and the statistical distribution (i.e., probability density function) of the catch at F_{MSY} or an F_{MSY} proxy (i.e. the overfishing level, OFL) (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).

Short-term projections of future stock status were conducted based on the results of the base ASAP model. The projections did not account for any retrospective pattern because the Mohn's Rho adjusted values for stock status were within the 80% probability intervals of the 2017 point estimates of $F_{7\text{-}8}$ and SSB. If the Allowable Biological Catch (ABC) is fully utilized in 2018 (i.e., 111,000mt), then catch at F_{MSY} proxy in 2019=13,700mt, 2020=31,000mt, and 2021=55,700mt. If only half the ABC is utilized in 2018 (i.e., 55,000mt), then catch at F_{MSY} proxy in 2019=28,900mt, 2020=38,000mt, and 2021=59,400mt. As with the catches, future short-term stock status was also sensitive to the catch specified in 2018.

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.

The Working Group agreed that the 2018 ABC of 111,000mt is unlikely to be fully utilized and that some lower value was more realistic, but that value is likely best determined by a technical group of the New England Fishery Management Council. The projections assumed that future recruitment will approach the mean for the time series (1965-2015). If recruitment continues to be below average, the projected catch increases may be overly optimistic.

c. Describe the stock's vulnerability (see "Appendix to the SARC TORs") to becoming overfished, and how this could affect the choice of ABC (or DEF, possibly even GH&I).

The unknown contributions of the Scotian Shelf (4WX), Gulf of Maine, and Georges Bank stocks can affect the stocks vulnerability to becoming overfished. The vulnerability of the stock has been demonstrated by the historical collapse of the Georges Bank component in the 1980s, which also demonstrated that the multiple spawning groups can be differentially impacted by fishing. Varying contributions from the Scotian Shelf (4WX) stock may also contribute to a retrospective pattern (see below).

In the short-term, the relatively poor recruitments in 2013-2017 will increase the vulnerability of the stock to becoming overfished. The 2016 and 2017 cohorts were imprecisely estimated and so estimates of these cohorts may change significantly in either direction in future assessments, and decisions should likely consider this uncertainty. Growth (i.e., weight at age) also continues to be relatively low when compared to the 1990s, and this seems to be a longer-term feature of the stock that also reduces production. The stock, however, seems to be capable of producing relatively large and small year classes regardless of growth, and so recruitment is likely the more significant driver of short-term vulnerability.

While this assessment had a retrospective pattern that did not warrant adjustments (i.e., via Mohn's Rho), the history of the Atlantic herring stock assessment suggests that resolutions to retrospective patterns are ephemeral, and so future herring assessments may have worsening retrospective patterns. Retrospective patterns are indicative of model misspecification, and this would increase the vulnerability of the stock to becoming overfished.

TOR B8. If possible, make a recommendation about whether there is a need to modify the current stock definition for future assessments.

Previous assessments concluded that there is likely sub-stock structure unaccounted for in the assessment, but that there is no ability to distinguish mixed survey and fishery catches to stock of origin. This lack of information on stock of origin precludes accounting for the sub-stock structure. An attempt was made to use an assessment model (Stock Synthesis) that accounted for stock structure on a coarse level (i.e., inside and outside of Gulf of Maine), but estimating area-specific recruitment and movement rates required unrealistic assumptions and the model generally performed poorly (e.g., poor convergence). The consequences of not accounting for stock structure are unclear, and therefore the need to modify the stock definition is also unclear. More certain, however, is that changing the stock definition and accounting for stock structure in the assessment is currently not possible. Continued research on the topic is warranted.

TOR B9. For any research recommendations listed in SARC and other recent peer reviewed assessment and review panel reports, review, evaluate and report on the status of those research recommendations. Identify new research recommendations.

Research recommendations from previous assessments were reviewed and progress on each updated and documented. Several new research recommendations were developed.

Management Summary and History

Fisheries Management

The Atlantic herring fishery in the Northeastern U.S. operates from Maine to Cape Hatteras, North Carolina and from inshore to offshore waters on the edge of the continental shelf. The herring fishery uses predominantly single and paired mid-water trawl, bottom trawl, purse seine, and to a lesser extent, gillnet gear throughout the entire range. Herring is used primarily in the U.S. as bait for the American lobster and tuna fisheries, but is also frozen whole and canned for human consumption. Herring is managed in federal waters by the New England Fishery Management Council (NEFMC), and in state waters by the Atlantic States Marine Fisheries Commission (ASMFC). Individual states may set different regulations, such as possession/landing restrictions or spawning area closures. If state regulations differ from Federal regulations, herring permit holders must adhere to the more restrictive regulations.

Atlantic herring stocks were first managed in 1972 through the International Commission for the Northwest Atlantic Fisheries (ICNAF). ICNAF regulated the international fishery until the United States withdrew from the organization in 1976 with the passage of the Magnuson Fishery Conservation and Management Act (MSA). The Atlantic Herring Fishery Management Plan (FMP) was one of the first plans developed by the NEFMC, approved in 1978. In 1982, NMFS withdrew the Federal Herring FMP because of conflicts between state and federal regulations, and catch quotas for adult herring in the Gulf of Maine were not enforced in state waters. In the absence of a Federal FMP, Atlantic herring was placed on the prohibited species list, thereby eliminating directed fisheries by foreign nationals or joint ventures in the EEZ and requiring any herring bycatch by such vessels to be discarded.

While directed fishing for Atlantic herring was prohibited in Federal waters in 1983, the herring fishery in State waters was managed through an agreement among the States of Maine, New Hampshire, Massachusetts, and Rhode Island. The final draft of the "Interstate Herring Management Plan of Maine, New Hampshire, Massachusetts, and Rhode Island" was adopted in late 1983 and formally recognized by the Atlantic States Marine Fisheries Commission (ASMFC) in 1987. The primary management tool was spawning closures, but as the size of the resource and fishery grew, this measure was not sufficient. The ASMFC developed the Atlantic Herring Fishery Management Plan in 1993 to address the growth of the herring resource, formalize the allocation process, and lay the foundation for a joint ASMFC-NEFMC management plan.

The New England Council's Herring FMP became effective on January 10, 2001 and included administrative and management measures to ensure effective and sustainable management of the herring resource. The FMP establishes Total Allowable Catches (TACs, now referred to as sub-ACLs, or annual catch limits) for each of four management areas as the primary control on fishing mortality (see Figure B- **1** for current herring management areas). ASMFC adopted Amendment 2 to complement the federal Amendment 1 measures.

The federal FMP has been improved by several subsequent Amendment and Framework actions over the years (Amendments 1-7 and Frameworks 1-4). These actions are described briefly in the bullets below.

- **Framework Adjustment 1 (effective 2002)** set measures for fishing year 2002 and split the TAC for Area 1A into two seasonal components to prevent an early closure of the fishery in 1A.
- **Amendment 1 (effective 200**7) was developed to improve resource conservation, address new scientific information to the extent possible, minimize the potential for excess harvesting capacity in the fishery, and provide a platform to promote long-term economic stability for harvesters, processors, and fishing communities. A limited access program was implemented, management boundaries were adjusted, a seasonal purse seine/fixed gear only area was established for all of Area 1A from June-September, a three-year specifications process was developed, as well as several other adjustments to the management program.
- **Amendment 2 (effective 2008)** was part of an omnibus amendment developed by NMFS to ensure that all FMPs of the Northeast Region comply with the Standardized Bycatch Reporting Methodology (SBRM) requirements of the MSA.
- **Amendment 4 (effective in 2011)** implemented a process for establishing annual catch limits (ACLs) and accountability measures (AMs) in the herring fishery and brought the Herring FMP into compliance with the reauthorized MSA.

- **Framework 2 (effective 2014)** Framework 2 set catch specifications for the herring fishery for the 2013–2015 fishing years and established seasonal splits for management areas 1A and 1B as recommended to NMFS by the Council, and other measures related to specifications.
- **Framework 3 (effective 2014**) to establish a process for setting river herring (alewife and blueback) and shad (American and hickory) catch caps for the herring fishery, including allocations for 2014 and 2015 fishing years.
- **Amendment 5 (effective 2014) to:** Improve the collection of real-time, accurate catch information; enhance the monitoring and sampling of catch at-sea; and address bycatch issues through responsible management by revising several program provisions, expanding vessel requirements to maximize observers' ability to sample catch-at-sea, minimize discarding of unsampled catch, addressing incidental catch of RH/S and revising criteria for MWT vessels in groundfish closed areas.
- **Framework 4 (effective 2016)** to further enhance catch monitoring and address discarding in the herring fishery by establishing requirements for herring dealers and restrictions on vessels when they release catch before it can be sampled by at-sea-observers (known as slippage).
- **Amendment 6 (effective 2016)** was part of an omnibus amendment to establish standards of precision for bycatch estimation for all Northeast fisheries (SBRM Amendment).
- **Amendment 3 (effective 2018)** was part of an omnibus amendment to all New England Council FMPs to address Essential Fish Habitat (EFH) consistent with the MSA.
- **Amendment 7 (scheduled 2018)** to allow the Councils to implement industry-funded monitoring above levels required by SBRM Amendment, including specific measures for an industry funded monitoring program for the herring fishery.
- **Amendment 8 (scheduled 2019)** to implement an ABC control rule and consider measures to address potential localized depletion and user conflicts in the herring fishery.

In general, the herring fishery is managed by a stock-wide annual catch limit (ACL) that is allocated to four distinct management areas (sub-ACLs, also known as management area quotas). The fishery allocations or specifications stem from the sub-ACLs and are currently set every three years. Due to the spatial structure of the Atlantic herring stock complex (multiple stock components that separate to spawn and mix during other times of the year), the total annual catch limit for Atlantic herring (stock-wide ACL/OY) is divided and assigned as sub-ACLs to four management areas (Figure B- **1**). The best available information is used about the proportion of each spawning component of the Atlantic herring stock complex in each area/season and minimizing the risk of overfishing an individual spawning component to the extent practicable.

Other species are caught incidentally in the directed herring fishery. The species composition varies based on gear type, year, season, and area, but some of the species caught include: Atlantic mackerel, haddock, river herring (alewife and blueback herring), shad (American shad and hickory shad), whiting, and spiny dogfish. Due to the high-volume nature of the Atlantic herring fishery, non-target species are often retained once the fish are brought on board and sometimes sold as part of the overall catch if they are not separated. The herring fishery has been allocated a sub-ACL of Georges Bank haddock, and there are also bycatch caps for river herring/shad. The herring fishery is subject to accountability measures for both caps and directed herring fishing is prohibited in specific areas for the remainder of the fishing year when 95% of a bycatch cap is estimated to be caught.

The Atlantic herring stock wide ACL and management area sub-ACLs are tracked/ monitored based on the *total catch – landings and discards*, which is provided and required by herring vessels through the vessel monitoring system (VMS) catch reports and vessel trip reports (VTRs) as well as through Federal/state dealer data. Atlantic herring catch has been variable in recent years, but on average about 90,000 mt for the last decade or so (Table B1- 1). However, the quota allocated to the fishery (stock wide ACL) has decreased during this time. Consequently, the Atlantic herring fishery has become more fully used in recent years, with some exceptions. These exceptions could be related to resource abundance, but there are a variety of factors that have likely caused under harvests of catch limits, including management measures in the plan.

For example, in 2015 the fishery in Area 3 became constrained by the Georges Bank Haddock catch cap accountability measure. Area 3 closed to midwater trawl (MWT) gear during the season, and under 75% of the herring quota was harvested in that area before the haddock cap was reached and directed fishing with MWT gear was prohibited. This closure also had impacts on 2016 catch in Area 3 because the restriction is based on the multispecies fishing year, which is May 1 through April 30. Therefore, directed herring fishing in Area 3 was also prohibited in January 1 – April 30 in 2016, making it more difficult for the fishery to harvest the full allocation in Area 3 in the remaining months of the year. Therefore, the utilization of Area 3 herring quota was potentially impacted by the haddock catch cap in both 2015 and 2016.

In addition, there are other measures in place that have the potential to limit herring landings, especially when they are combined, potentially having cumulative impacts that limit flexibility and reduce the ability for the fishery to harvest the full TAC in each area. For example, there are various seasonal restrictions that limit when vessels can fish in certain areas. Table B- **1** summarizes some of these restrictions by month. Despite these restrictions, the sub-ACL for Area 1A and 1B have been fully harvested in most years. More recently, ASMFC has also placed restrictions on Area 1A that has further reduced flexibility and impacted fishing behavior in that area. In 2018 Addendum 1 to Amendment 3 of the ASMFC plan implemented weekly catch limits and restrictions on carrier vessels in Area 1A, in addition to the days-out measures that control the number of potential harvesting days per week. In 2018, the full Area 1A sub-ACL was not harvested, in part potentially due to the weekly catch limits, as well as implementation of spawning closures that prevent herring fishing by any gear type in different areas within Area 1A.

While bycatch caps have not been reached in many cases, there have certainly been a number of years that the fleet has approached them, and adjusted fishing behavior mid-season to avoid closures. As the fleet approaches the cap, avoidance behaviors have been observed such as moving to new areas and that can impact full utilization of the herring sub-ACLs. In addition to the example explained above for the haddock cap in 2015 and 2016, fishing behavior was impacted in 2017 around Cape Cod when the RH/S cap reached about 80%, vessels voluntarily avoided that area for the remainder of the fishing year to avoid exceeding the cap. Furthermore, fishing behavior and ability to harvest sub-ACLs was definitely impacted in 2018 when the RH/S cap was reached in March closing the MWT herring fishery in all SNE/MA waters. At that time only 20% of the Area 2 herring sub-ACL has been harvested.

In addition to bycatch measures that can impose in-season restrictions on directed herring fishing, the federal herring plan also includes several measures that impose seasonal restrictions for other purposes. For example, Area 1B is closed every year from January 1 through April 30, primarily to provide more herring landings when it is needed most for the bait market, late spring through summer. This quota is a small fraction of the overall herring catch, under 5%, but seasonal closures can limit flexibility and if the fish are not in that area during other months when the area is open, it can potentially impact the ability to harvest the sub-ACL for that area. Similarly, Area1A is closed to all herring fishing in January 1 through May 30, and only open to purse seine gear June 1 – September 30. While the Area 1A sub-ACL is usually fully harvested, these seasonal restrictions, especially when combined with spawning closures imposed by ASMFC, can limit flexibility and potentially impact the ability of the fishery to harvest the full sub-ACL in that area.

Another measure that may also make it more difficult to fully harvest sub-ACLs is the requirement to carry an at-sea observer if a vessel wants to fish in a groundfish closed area. Amendment 5 to the Herring FMP allowed midwater trawl vessels to fish in Closed Areas is a fishery observer is onboard. If observers are not available, herring vessels are prohibited from fishing in those areas (Closed Areas 1 and II). If herring is more concentrated in groundfish closed areas in a particular year or season, and vessels are unable to get observers, it may be more difficult to harvest the Area 3 sub-ACL since those areas cover a relatively large portion of Area 3 where herring are typically found. While some of these restrictions and closed areas have recently changed under the Omnibus Habitat Amendment 2, many of the requirements for herring vessels to carry observers in groundfish closed areas remain the same.

Finally, many herring vessels are active in other fisheries so in some cases, effort in other fisheries can impact when and how much herring fishing occurs during a fishing year. For example, if squid fishing or mackerel fishing is productive, some vessels that have permits in those fisheries will decide to prosecute those fisheries that often have higher revenues and prices. Conditions change every year, and if a herring sub-ACL is not harvested in a particular year, that may not be related to herring resource conditions or herring management restrictions; it is possible that availability or market conditions in other fisheries drives herring fishing activity, at least partially. If herring vessels are focused in other fisheries, i.e. mackerel or squid, herring fishing patterns can be impacted. In summary, herring management is complex, and trends in catch alone may not be reflective of resource conditions. If sub-ACLs are not fully harvested it can be related to resource availability, but there are a web of management measures in place that can inhibit herring fishing activity and full utilization of sub-ACLs.

x = represents no herring fishing

y = represents no midwater trawl gear permitted

z = possible spawning closures, restricts all herring fishing, all gear types

		Sub-Area			
		1A	**1B**	**2**	**3**
Month	**1**	**x**	**x**		
	2	**x**	**x**		
	3	**x**	**x**		
	4	**x**	**x**		
	5	**x**			
	6	**y**			
	7	**y**			
	8	**y, z**			
	9	**y, z**			
	10	**z**			
	11				
	12				

Table B- 1 Summary of spatial and seasonal restrictions that are in place in the Atlantic herring fishery (both NEFMC and ASMFC actions) (Source: Manderson and Sarro (in prep.) Fishing industry perspectives on socio-ecological factors driving Atlantic Mackerel landings in US waters)

Figure B- 1 Atlantic Herring Fishery Management Areas

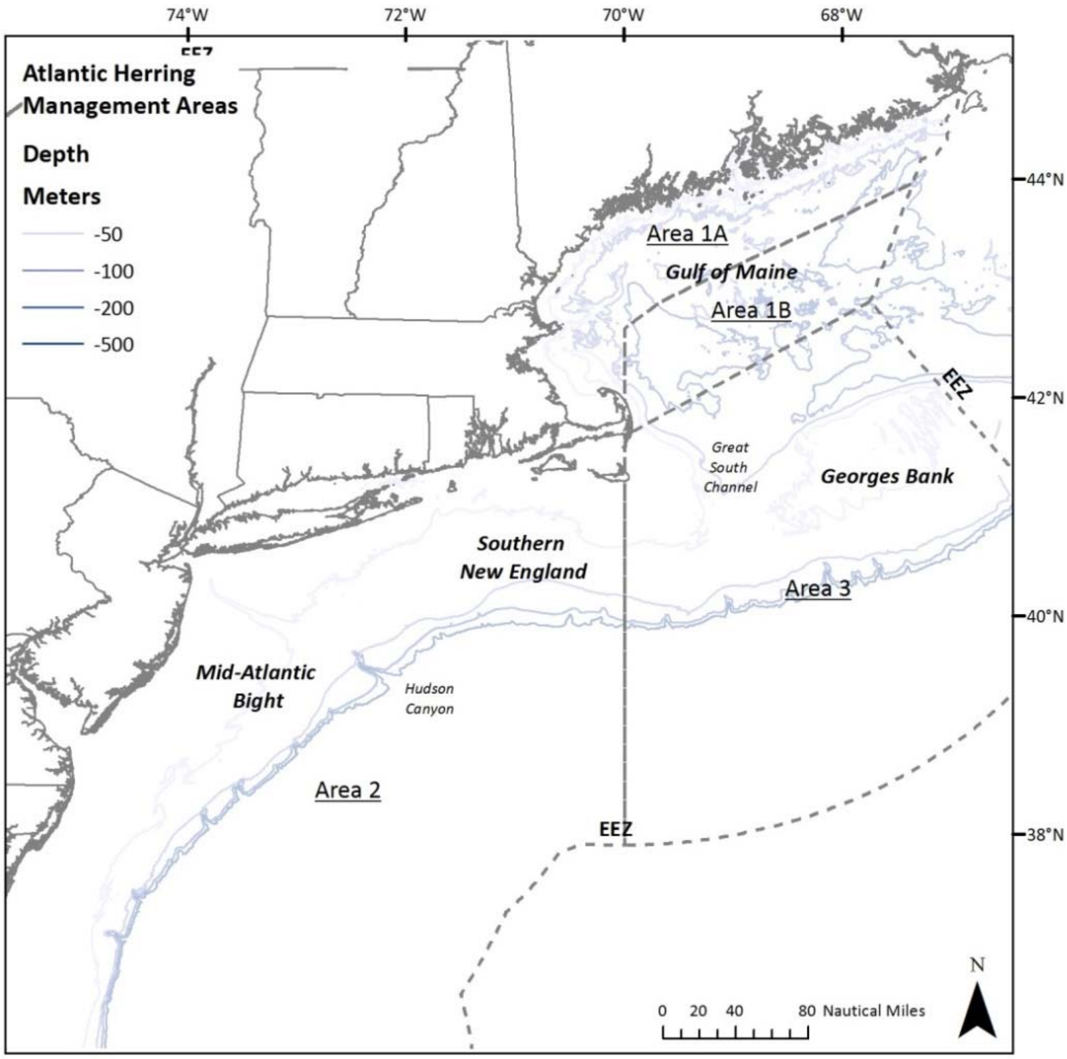
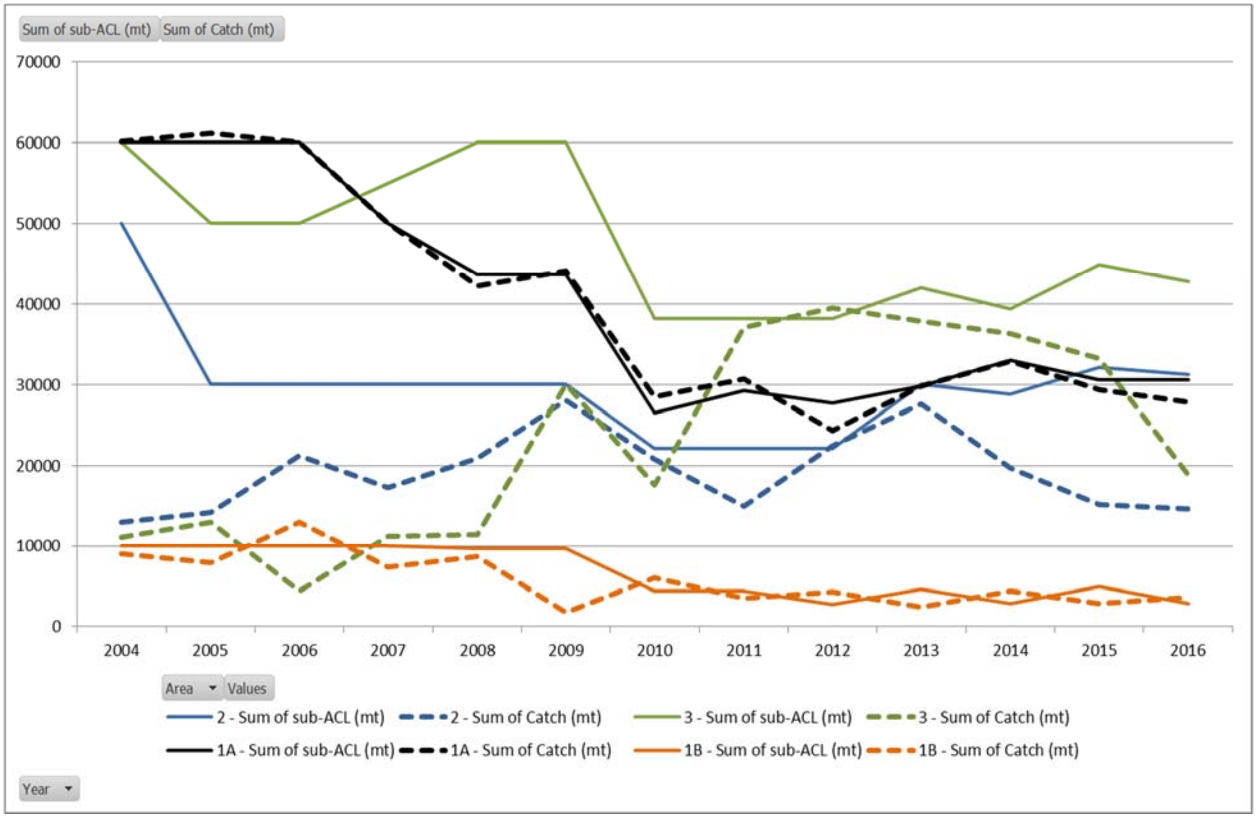


Figure B- 2 Atlantic herring sub-ACLs (solid lines) and estimated catch (dashed lines) by year and management area, 2004-2016



TOR B1: *Estimate catch from all sources including landings and discards. Describe the spatial and temporal distribution of landings, discards and fishing effort. Characterize uncertainty in these sources of data. Comment on other data sources that were considered but were not included.*

Data from the United States

The catch data used to develop the US herring catch at age for 1965 to 2017 comes from a combination of NMFS Dealer reports and Vessel Trip Reports (VTR), NAFO reports, DFO Canada, Maine DMR, and other state landings reports. The reported catch is a sum of landings and self-reported discards, but discard estimates were not available in all years (Table B1- 1; Table B1- 2). Observed discards, however, were generally less than 1% of landings and do not represent a significant source of mortality (Table B1- 2; Wigley et al. 2011). Consequently, a lack of historical estimates of discards is not considered problematic for stock assessments. When data availability permitted, all the calculations used to produce the catch at age data below were done at the level of year, quarter, and gear type. Gear type was defined as either fixed or mobile gear. All trawl gears and purse seines were considered mobile, while all other gears (weirs, fyke nets, pound nets, etc.) were classified as fixed. These two aggregate gear types were used because biological data (e.g., lengths, ages, weights) were insufficient to do calculations on specific gear types. Weight-length relationships were similar between fixed and mobile gears, so data were combined for the gear types to estimate the parameters of this relationship. When no weight-length or length frequency data existed for a unique combination of year, quarter, and gear type, the calculations were then done at the level of year, semester (January-June or July-December), and gear type. Similarly, when no weight-length or length frequency data existed for a unique combination of year, semester, and gear type, the calculations were done at the level of year and gear type. Aggregations to the level of year and gear type were only necessary for 7 years for the fixed gear type (none for mobile gear). For the fixed gear type, no biological data were available in 15 years (1995, 1997, 2000, 2002-2005, 2008-2013, 2016-2017). US catch at age for the fixed gear type was consequently not developed in these years. Age-length keys were developed at the level of year, semester, and gear type. When an observed length had no corresponding age data, age samples for that length from the alternative gear type were used. Any remaining lengths with no corresponding age data were imputed based on a multinomial logistic model fit to the age observations at that length for the given year, semester, and gear type combination (Gerritsen et al., 2006). Data on sampling intensity is provided in Table B1- 3, Table B1- 4, and Table B1- 5.

The Working Group had concerns that the purse seine gear had a selectivity distinct from trawl gears. More specifically, that the purse seine length frequencies were sometimes bi-modal and generally caught some smaller fish than trawl gears (Figure B1- 1; Figure B1- 2). Combining purse seines and trawl gears into the aggregate mobile gear and not accounting for these selectivity differences in an assessment model may induce diagnostic issues (e.g., residual patterns, retrospective patterns), especially since there have been temporal changes in the composition of the catch coming from each gear type (Figure B1- 3). One way to address this concern would be to develop separate catch at age matrices for purse seines and trawls, but a purse seine specific catch at age matrix could not be developed in time for this assessment and it is not clear whether biological data would support such efforts. Consequently, the working group considered some assessment models with time-varying selectivity for the mobile gear fleet as a way to evaluate the necessity of distinguishing between purse seines and trawl gears. The models with time-varying selectivity suggested that modeling purse seines separately from trawls was not supported (see TOR B4 for details).

US catch at age calculations did not include any spatial element because adding this to the stratification scheme resulted in a large number of combinations with little or no biological data (Table B1- 4; Table B1- 5). The gear types are also confounded in space, with nearly all the fixed gear catch coming from the Gulf of Maine (Figure B1- 4). Furthermore, the length frequencies of catches from different gears in the same area are clearly different, while length frequencies from the same gear in different areas are similar (Figure B1- 5; Figure B1- 6); suggesting that accounting for gear type was necessary while spatial differences were relatively inconsequential.

Data from New Brunswick, Canada

Department of Fisheries and Oceans, Canada, personnel (Rabindra Singh) provided catch at age data for the New Brunswick (NB), Canada, weir fishery during 1965-2017 (Table B1- 6). The NB weir fishery uses the same gears as the US fixed gear fishery and have similar age compositions (NEFSC 2012). Furthermore, some US weir operations are located in close geographic proximity to the NB weir fishery. Consequently, the working group agreed that data from the NB weir fishery and the US fixed gear fishery should be combined for the assessment.

Data summaries and assessment inputs

Catch in the mobile gear fishery peaked in the late 1960s and early 70s, largely due to efforts from foreign fleets (Figure B1- 7). Catch in this fishery was relatively stable during the 2000s, and has accounted for most of the Atlantic herring catches in recent years although the contribution has declined for the last four years. Catch in the fixed gear fishery has been variable, but has been relatively low since the mid-1980s (Figure B1- 7).

The US mobile gear fishery catches a relatively broad range of ages and some strong cohorts can be seen for several years (Figure B1- 8; Table B1- 7). In contrast, the fixed gear fishery harvests almost exclusively age 2 herring (Figure B1- 9; Table B1- 8).

A single matrix of catch weights at age was estimated as the catch weighted mean weights at age among the strata used to develop the US catch at age matrices and ultimately among the mobile and fixed gear fisheries (Table B1- 9). Weights at age for spawning stock biomass were estimated as the mean weights at age from the mobile gear fishery in quarter three (i.e., July-September; Table B1- 10). This data was used because the mobile gear fishery is relatively well sampled in all years and quarter three is when herring typically begin spawning. January 1 weights at age were estimated by using a Rivard calculation (Rivard 1982) of the SSB weights at age (Table B1- 11). Any missing weights at age in each matrix were replaced by a time series average from one of three time stanzas: 1965-1985, 1986-1994, or 1995-2017. These three time stanzas were used to accommodate the temporal changes in herring growth, mostly evident for older aged herring (e.g., Figure B1- 10). Since herring beyond age 8 experience relatively little growth, weight at age 8 was used to characterize fish in the plus group (age 8+) in the model.

Maturity at age was developed using samples from commercial catches during quarter three (July to September). Fish caught during this time of year were used because they reflect the maturity condition of herring just prior to or during spawning, and therefore are best for calculations related to spawning stock biomass. Fish of both sexes were included. Fish of unknown maturity were removed from the analysis (codes 0 and 9 in the dataset). Immature fish were defined as those classified as immature I or immature II (codes 1 and 2, respectively in dataset) while all other fish were considered mature (3=ripe, 4=eyed, 5=ripe and running, 6=spent, 7=resting). The observed proportions mature at age from quarter three of each year were input to assessments and used in the calculation of SSB (Table B1- 12). Using predicted proportions at age from a generalized additive model fit to the annual observations was considered (NEFSC 2012), but sample sizes were generally considered large enough that such modeling to reduce the effect of measurement uncertainty was deemed unnecessary (Table B1-13). Microscopic verifications of the maturity classifications was conducted, as was an exploration of the consequences of possible spring or skipped spawning (Appendix B7).

Spatial distribution of fishing effort

The fishery tends to operate as expected given what is known about Atlantic herring migration patterns. In the winter, fishery landings tend to be more southerly than other times of year. As warming occurs through the spring and summer and herring migrate to the north, fishery landings occur more frequently throughout the Gulf of Maine. As fish separate into components to spawn in the fall, fishery landings span the Gulf of Maine and Georges Bank (Figure B1- 11). Also see:
http://noaa.maps.arcgis.com/apps/webappviewer/index.html?id=5d3a684fe2844eedb6beacf1169ca854

Other data sources discussed

The Northeast Fisheries Science Centers (NEFSC) Cooperative Research Branch's Study Fleet pilot program began field-testing data collection with electronic systems in late 2001. The Goals were to (1) to assemble a group of commercial fishermen to collect high resolution (haul-by-haul) self-reported data on catch, effort and environmental conditions during usual fishing operations, (2) develop and implement an electronic data collection system. The program was intended to ultimately provide stock assessment scientists with more precise and accurate fishery-dependent data and to improve the understanding of catch rates and species assemblages through examination of variables such as time of day, temperature, depth, tidal strength, and sediment type (Palmer et al 2007). The Fisheries Logbook and Data Recording Software (FLDRS) was established in 2006 as a product of this pilot work. FLDRS collects information at both the trip and haul level including detailed information of effort, catch and apportionment.

From 2006-2013 the number of vessels using FLDRS while participating in the commercial Atlantic herring fishery varied from 1-7. Most of these vessel participated in the small-mesh bottom trawl fishery off Rhode Island. In late 2014, through collaboration with the Pacific States Marine Fisheries Commission and with cooperation with the Massachusetts Division of Marine, Fisheries Cooperative Research staff deployed FLDRS on the midwater and paired midwater Atlantic herring fleet. This greatly increased the number vessels using FLDRS, the amount of data collected and expanded the spatial extent of coverage. In 2016, vessels reporting haul-by-haul using FLDRS accounted for >40% of the total landings. This and future information should be able address specific research and management questions.

A more detailed description of the program is an Appendix B6.

Table B1- 1 Atlantic herring landings (mt)

Year	US Fixed	New Brunswick Weir	US Mobile	US Fixed + NB Weir (mt)	Total
1965	36440	31682	58161	68122	126282
1966	23178	35602	162022	58780	220802
1967	17458	29928	258306	47386	305692
1968	24565	32111	421091	56676	477767
1969	9007	25643	362148	34650	396798
1970	4316	15070	302107	19386	321493
1971	5712	12136	327980	17848	345828
1972	22800	31893	225726	54693	280419
1973	7475	19053	247025	26528	273553
1974	7040	19020	203462	26060	229522
1975	11954	30816	190689	42770	233459
1976	35606	29207	79732	64813	144545
1977	26947	19973	56665	46920	103585
1978	20309	38842	52423	59151	111574
1979	47292	37828	33756	85120	118876
1980	42325	13526	57120	55851	112971
1981	58739	19080	26883	77819	104702
1982	15113	25963	29334	41076	70411
1983	3861	11383	29369	15244	44613
1984	471	8698	46189	9169	55358
1985	6036	27864	27316	33900	61216
1986	2120	27885	38100	30005	68104
1987	1986	27320	47971	29306	77277
1988	2598	33421	51019	36019	87038
1989	1761	44112	54082	45873	99954
1990	670	38778	54737	39448	94184
1991	2133	24574	78032	26707	104739
1992	3839	31968	88910	35807	124717
1993	2288	31572	74593	33860	108452
1994	539	22242	63161	22781	85943
1995	6	18248	106179	18254	124433
1996	631	15913	116788	16544	133332
1997	275	20551	123824	20826	144651
1998	4889	20092	103734	24981	128715
1999	653	18644	110200	19298	129497
2000	54	16830	109087	16884	125971
2001	27	20210	120548	20237	140785
2002	46	11874	93176	11920	105096
2003	152	9008	102320	9160	111480
2004	96	20685	94628	20781	115409
2005	68	13055	93670	13123	106793
2006	1007	12863	102994	13870	116864
2007	403	30944	81116	31347	112462
2008	31	6448	84650	6479	91129
2009	98	4031	103458	4129	107587
2010	1263	10958	67191	12221	79413
2011	422	3711	82022	4133	86155
2012	9	504	87162	513	87675
2013	9	6431	95182	6440	101622
2014	518	2149	92566	2667	95233
2015	738	146	80465	884	81350
2016	1208	4060	62307	5267	67574
2017	258	2103	47889	2361	50250

Table B1- 2 Atlantic herring discards (mt), landings (mt), and the ratio of the two quantities for the fixed and mobile fleets

Year	Discards (mt)		Landings (mt)		D/L	
	Fixed	**Mobile**	**Fixed**	**Mobile**	**Fixed**	**Mobile**
1996	13	131	666	116609	0.02	0.00
1997	29	225	342	123504	0.08	0.00
1998	7	188	4925	103503	0.00	0.00
1999	5	48	704	110096	0.01	0.00
2000	6	317	62	108756	0.10	0.00
2001	11	539	54	119971	0.21	0.00
2002	3	38	52	93129	0.07	0.00
2003	8	22	159	102284	0.05	0.00
2004	9	477	103	94136	0.08	0.01
2005	3	299	76	93359	0.03	0.00
2006	1	199	1029	102772	0.00	0.00
2007	3	52	418	81045	0.01	0.00
2008	3	526	41	84111	0.07	0.01
2009	2	460	158	102928	0.01	0.00
2010	33	230	1511	66673	0.02	0.00
2011	5	174	582	81683	0.01	0.00
2012	7	145	176	86843	0.04	0.00
2013	3	166	78	94944	0.04	0.00
2014	1	292	533	92259	0.00	0.00
2015	1	83	757	80363	0.00	0.00
2016	2	122	1253	62137	0.00	0.00
2017	0	74	274	47798	0.00	0.00

Table B1- 3 Number of commercial trips sampled for Atlantic herring biological data

	Number of Trips		
Year	Fixed	Mobile	Total
1965	353	13	366
1966	221	29	250
1967	241	66	307
1968	308	14	322
1969	300	25	325
1970	117	40	157
1971	103	91	194
1972	120	103	223
1973	95	69	164
1974	144	146	290
1975	154	131	285
1976	238	150	388
1977	248	106	354
1978	232	276	508
1979	559	121	680
1980	192	268	460
1981	352	100	452
1982	127	105	232
1983	62	134	196
1984	10	161	171
1985	54	88	142
1986	18	56	74
1987	21	79	100
1988	24	77	101
1989	29	68	97
1990	37	107	144
1991	24	99	123
1992	38	126	164
1993	32	125	157
1994	15	75	90
1995	0	124	124
1996	6	137	143
1997	0	213	213
1998	10	173	183
1999	3	206	209
2000	0	195	195
2001	2	214	216
2002	0	200	200
2003	0	155	155
2004	0	141	141
2005	0	186	186
2006	1	211	212
2007	1	147	148
2008	0	125	125
2009	0	123	123
2010	0	119	119
2011	0	119	119
2012	0	120	120
2013	0	132	132
2014	1	142	143
2015	2	119	121
2016	0	93	93
2017	0	103	103

Table B1- 4 Number of Atlantic herring length samples by fleet and spatial area

Year	# Length Samples		Total	# Length Samples		Total
	Fixed	Mobile		Gulf of Maine	Other	
1965	20671	715	21386	21386	0	21386
1966	11123	1401	12524	36766	19888	56654
1967	11410	12263	23673	27583	22156	49739
1968	16521	698	17219	36167	18944	55111
1969	14502	2910	17412	50050	30086	80136
1970	4171	20099	24270	34914	26580	61494
1971	7879	41157	49036	21537	44213	65750
1972	12945	33970	46915	35384	23685	59069
1973	4682	33633	38315	26913	27120	54033
1974	13340	45394	58734	37424	29368	66792
1975	14816	35026	49842	32797	31181	63978
1976	21267	31556	52823	43546	21457	65003
1977	23336	20257	43593	45443	11316	56759
1978	11574	15154	26728	44045	863	44908
1979	28815	8479	37294	37108	186	37294
1980	8867	19448	28315	28115	200	28315
1981	17433	6095	23528	23428	100	23528
1982	6327	6369	12696	12496	200	12696
1983	3100	7915	11015	11015	0	11015
1984	500	9595	10095	10095	0	10095
1985	2700	6288	8988	8888	100	8988
1986	896	3850	4746	4746	0	4746
1987	1050	5344	6394	6394	0	6394
1988	1200	5340	6540	6440	100	6540
1989	1450	4850	6300	6300	0	6300
1990	1847	6727	8574	8574	0	8574
1991	1200	6963	8163	8113	50	8163
1992	1900	9643	11543	11543	0	11543
1993	1671	6265	7936	7879	57	7936
1994	755	3717	4472	4072	400	4472
1995	0	6183	6183	5895	288	6183
1996	300	7181	7481	6483	998	7481
1997	0	10905	10905	8855	2050	10905
1998	500	8656	9156	5517	3639	9156
1999	150	10296	10446	9095	1351	10446
2000	0	9159	9159	6852	2307	9159
2001	100	10078	10178	6252	3926	10178
2002	0	9640	9640	7569	2071	9640
2003	0	7712	7712	4656	3056	7712
2004	0	7099	7099	4658	2441	7099
2005	0	9280	9280	5683	3597	9280
2006	50	11005	11055	5869	5186	11055
2007	45	7730	7775	4984	2791	7775
2008	0	6359	6359	3744	2615	6359
2009	0	6157	6157	3426	2731	6157
2010	0	6127	6127	2737	3390	6127
2011	0	6248	6248	3579	2669	6248
2012	0	6307	6307	2655	3652	6307
2013	0	6676	6676	2255	4421	6676
2014	50	7160	7210	3584	3626	7210
2015	89	5824	5913	3032	2881	5913
2016	0	4868	4868	2850	2018	4868
2017	0	5311	5311	3893	1418	5311

Table B1- 5 Number of Atlantic herring age samples by fleet and spatial area

Year	# Age Samples		Total	# Age Samples		Total
	Fixed	Mobile		Gulf of Maine	Other	
1965	2794	309	3103	3103	0	3103
1966	2337	481	2818	3862	1032	4894
1967	2250	1079	3329	3733	1190	4923
1968	2431	208	2639	3649	976	4625
1969	2149	392	2541	4185	1566	5751
1970	1173	1582	2755	3063	1444	4507
1971	1654	3248	4902	2982	2854	5836
1972	1521	2904	4425	3611	1516	5127
1973	940	2270	3210	2562	1396	3958
1974	1366	3251	4617	3329	1692	5021
1975	1848	2799	4647	3506	1973	5479
1976	1985	2632	4617	4135	1298	5433
1977	2070	2064	4134	4069	785	4854
1978	1272	2584	3856	5013	263	5276
1979	2178	1360	3538	3460	78	3538
1980	1285	2197	3482	3434	48	3482
1981	1370	1166	2536	2488	48	2536
1982	868	1339	2207	2105	102	2207
1983	385	1372	1757	1757	0	1757
1984	102	1971	2073	2073	0	2073
1985	344	1342	1686	1665	21	1686
1986	177	981	1158	1158	0	1158
1987	208	1384	1592	1592	0	1592
1988	202	1260	1462	1418	44	1462
1989	200	983	1183	1183	0	1183
1990	215	1433	1648	1648	0	1648
1991	197	1394	1591	1571	20	1591
1992	284	1887	2171	2171	0	2171
1993	257	1954	2211	2159	52	2211
1994	127	1268	1395	1226	169	1395
1995	0	1582	1582	1474	108	1582
1996	67	1735	1802	1440	362	1802
1997	0	2425	2425	1777	648	2425
1998	112	2059	2171	1281	890	2171
1999	37	2023	2060	1692	368	2060
2000	0	2023	2023	1380	643	2023
2001	41	2394	2435	1410	1025	2435
2002	0	2521	2521	1987	534	2521
2003	0	2146	2146	1206	940	2146
2004	0	1920	1920	1180	740	1920
2005	0	2417	2417	1384	1033	2417
2006	12	2427	2439	1246	1193	2439
2007	11	1829	1840	1085	755	1840
2008	0	1973	1973	1135	838	1973
2009	0	1950	1950	906	1044	1950
2010	0	2115	2115	815	1300	2115
2011	0	1634	1634	861	773	1634
2012	0	1529	1529	660	869	1529
2013	0	1979	1979	518	1461	1979
2014	14	2085	2099	861	1238	2099
2015	25	1547	1572	670	902	1572
2016	0	1332	1332	610	722	1332
2017	0	947	947	511	436	947

Table B1- 6 New Brunswick, Canada, Atlantic herring weir catches (numbers)

	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11+
1965	992000	852368000	65449000	53194000	6897000	240000	116000	77000	0	0	0
1966	3899000	151087000	432061000	49134000	30162000	1182000	28000	13000	22000	29000	0
1967	127374000	194566000	57421000	111164000	12573000	4326000	1170000	119000	3000	0	0
1968	2409000	758766000	51933000	25098000	31655000	3957000	3141000	757000	77000	10000	0
1969	71191000	375586000	101361000	5067000	9845000	7692000	6449000	2025000	300000	3000	0
1970	3553000	348916000	9924000	12598000	6034000	3788000	2356000	893000	61000	10000	0
1971	92253000	183690000	37348000	7925000	3912000	2078000	3068000	1195000	332000	52000	62000
1972	8102000	660547000	6446000	10817000	4226000	2005000	1029000	1161000	354000	34000	11000
1973	31803000	149051000	125965000	14773000	1038000	529000	57000	121000	56000	4000	22000
1974	3259000	246044000	43483000	31147000	1227000	48000	54000	35000	38000	27000	37000
1975	16880000	462977000	57228000	9555000	16380000	2183000	1111000	916000	294000	158000	174000
1976	51791000	199268000	104624000	19989000	14911000	10128000	1601000	366000	457000	193000	112000
1977	459109000	122921000	10305000	20941000	7237000	7050000	4674000	230000	5000	0	1000
1978	213778000	894372000	52125000	3665000	810000	1064000	280000	132000	0	0	0
1979	2396000	423731000	247356000	12236000	822000	841000	479000	1005000	190000	0	0
1980	257995000	5325000	62087000	21615000	924000	125000	124000	67000	57000	63000	0
1981	53336000	294720000	18781000	10199000	5368000	306000	46000	34000	27000	0	0
1982	30210000	395416000	73197000	3199000	1795000	1596000	196000	42000	68000	0	0
1983	2532000	135283000	21684000	7526000	444000	398000	189000	0	0	0	0
1984	14353000	82920000	17292000	5658000	4332000	611000	251000	15000	85000	0	0
1985	20295000	385381000	45879000	17936000	7411000	3507000	304000	71000	73000	0	0
1986	3210000	136292000	119736000	24061000	10636000	4644000	2272000	335000	94000	66000	9000
1987	35677000	129348000	47981000	53150000	22941000	7097000	2472000	606000	173000	96000	0
1988	76053000	347765000	45078000	22366000	38843000	14212000	1680000	101000	247000	1000	9000
1989	26855000	331014000	81410000	21442000	22723000	43020000	11532000	3095000	810000	121000	249000
1990	12576000	454802000	69004000	30689000	6358000	7230000	15031000	3420000	2520000	620000	310000
1991	5530000	338263000	44450000	23618000	9532000	3154000	2620000	3436000	1461000	267000	150000
1992	799000	375772000	97678000	36438000	10378000	3992000	1613000	1360000	558000	245000	44000
1993	1718000	244079000	106099000	37186000	23218000	12260000	4915000	1120000	1101000	864000	175000
1994	1986000	291956000	63902000	9972000	16258000	9332000	3893000	1479000	1080000	544000	334000
1995	57844000	259741000	40122000	14803000	1822000	1567000	1549000	30000	0	0	0
1996	5351000	269431000	22390000	9342000	4302000	1147000	1273000	426000	38000	9000	2000
1997	9309000	216159000	113197000	11333000	3597000	523000	206000	95000	11000	0	0
1998	440000	387723000	36062000	9595000	3404000	1842000	297000	69000	25000	1000	0
1999	167679	106127770	100722414	11903080	9057476	3968746	1365910	154714	3950	3909	8434
2000	1665260	256784705	8082353	7871514	5376908	1416883	521421	101422	190	0	0
2001	1320542	113200008	119194370	8018810	5712883	1823813	588419	95017	101838	2081	0
2002	31858563	180051484	16260128	11528872	3020062	432017	101972	48714	18817	19556	11509
2003	11470685	162210672	15488021	2912807	1987414	456774	128273	27994	27934	13587	12487
2004	6711148	184123131	103911073	18753448	2537258	1751082	305572	358008	92686	31016	45060
2005	1152478	102401310	73912834	19379433	4269372	533907	268965	109207	13692	450	2466
2006	201206756	139578332	25001134	3786465	3705592	1275745	684331	138912	6539	842	1725
2007	6322626	571186007	31093039	2644604	812012	1274805	419924	63163	13985	1667	220
2008	27894408	122185141	19783355	203318	82469	105017	120277	45529	17154	1270	76
2009	12987445	99615384	3302958	141258	3842	1285	832	237	79	0	0
2010	7224	371400620	16967663	522825	463391	29356	21701	28636	16157	5620	612
2011	14254158	44743409	21030320	2153126	262891	61326	3942	0	0	0	0
2012	23399306	4309339	467710	611200	232280	62349	16952	3094	1028	543	287
2013	35483478	126916853	10474516	642836	435504	216325	52156	13511	993	0	253
2014	21037481	38784963	1422384	711520	288369	218518	75676	30661	8797	355	1892
2015	429076	5944638	49852	6985	3867	1622	748	0	748	0	0
2016	832028	61493618	9108761	1707005	657193	253407	145416	180769	15169	5202	0
2017	2427711	13588301	2360908	5096051	1860612	1233993	583536	284588	82045	22132	0

Table B1- 7 Mobile fleet age composition proportions at age

	1	2	3	4	5	6	7	8+
1965	0.001	0.965	0.026	0.008	0.000	0.000	0.000	0.000
1966	0.000	0.416	0.529	0.017	0.027	0.009	0.002	0.000
1967	0.000	0.048	0.213	0.168	0.094	0.138	0.265	0.075
1968	0.011	0.716	0.210	0.039	0.024	0.000	0.000	0.000
1969	0.096	0.257	0.486	0.062	0.013	0.009	0.019	0.058
1970	0.075	0.250	0.111	0.201	0.143	0.074	0.063	0.082
1971	0.053	0.028	0.209	0.182	0.184	0.125	0.084	0.135
1972	0.017	0.234	0.087	0.141	0.182	0.164	0.098	0.077
1973	0.017	0.153	0.524	0.139	0.052	0.038	0.043	0.034
1974	0.008	0.103	0.126	0.629	0.070	0.023	0.021	0.020
1975	0.007	0.025	0.066	0.140	0.635	0.061	0.029	0.037
1976	0.000	0.007	0.176	0.089	0.114	0.545	0.040	0.030
1977	0.013	0.174	0.078	0.264	0.068	0.076	0.293	0.033
1978	0.008	0.201	0.263	0.119	0.191	0.026	0.037	0.155
1979	0.000	0.209	0.332	0.225	0.075	0.092	0.014	0.053
1980	0.001	0.106	0.425	0.363	0.053	0.015	0.022	0.014
1981	0.000	0.107	0.039	0.495	0.299	0.033	0.010	0.017
1982	0.002	0.233	0.200	0.040	0.297	0.186	0.020	0.023
1983	0.033	0.369	0.243	0.191	0.011	0.079	0.062	0.013
1984	0.000	0.222	0.464	0.160	0.107	0.007	0.026	0.013
1985	0.001	0.178	0.157	0.401	0.154	0.086	0.004	0.019
1986	0.005	0.291	0.431	0.105	0.101	0.043	0.019	0.005
1987	0.001	0.155	0.306	0.428	0.057	0.038	0.010	0.005
1988	0.001	0.124	0.230	0.210	0.321	0.077	0.026	0.011
1989	0.000	0.322	0.259	0.106	0.093	0.160	0.041	0.019
1990	0.000	0.172	0.333	0.135	0.066	0.073	0.131	0.089
1991	0.000	0.145	0.281	0.182	0.146	0.074	0.062	0.110
1992	0.000	0.093	0.278	0.166	0.182	0.120	0.066	0.096
1993	0.000	0.128	0.245	0.193	0.181	0.108	0.081	0.064
1994	0.000	0.152	0.236	0.134	0.169	0.159	0.087	0.064
1995	0.003	0.198	0.128	0.069	0.073	0.164	0.198	0.168
1996	0.001	0.267	0.159	0.081	0.103	0.202	0.134	0.052
1997	0.000	0.080	0.551	0.094	0.067	0.084	0.093	0.031
1998	0.000	0.162	0.178	0.425	0.100	0.048	0.050	0.037
1999	0.001	0.148	0.346	0.117	0.228	0.093	0.040	0.028
2000	0.000	0.272	0.070	0.153	0.189	0.231	0.058	0.027
2001	0.000	0.078	0.422	0.065	0.111	0.142	0.141	0.040
2002	0.009	0.091	0.169	0.341	0.131	0.099	0.101	0.059
2003	0.002	0.287	0.193	0.083	0.228	0.079	0.075	0.054
2004	0.001	0.199	0.463	0.112	0.080	0.093	0.041	0.011
2005	0.000	0.064	0.443	0.276	0.080	0.074	0.052	0.011
2006	0.000	0.076	0.292	0.384	0.149	0.044	0.031	0.024
2007	0.000	0.241	0.216	0.201	0.196	0.101	0.029	0.017
2008	0.000	0.020	0.434	0.140	0.121	0.153	0.082	0.049
2009	0.000	0.107	0.135	0.413	0.101	0.096	0.104	0.045
2010	0.000	0.420	0.218	0.089	0.177	0.043	0.034	0.019
2011	0.000	0.049	0.803	0.104	0.022	0.017	0.003	0.003
2012	0.002	0.127	0.049	0.652	0.111	0.024	0.027	0.010
2013	0.000	0.156	0.154	0.085	0.499	0.089	0.012	0.005
2014	0.000	0.073	0.515	0.100	0.049	0.221	0.038	0.004
2015	0.000	0.133	0.100	0.488	0.065	0.063	0.134	0.018
2016	0.000	0.015	0.194	0.158	0.368	0.096	0.062	0.107
2017	0.000	0.014	0.184	0.328	0.118	0.267	0.033	0.057

Table B1- 8 Fixed fleet age composition proportions at age

	1	2	3	4	5	6	7	8+
1965	0.027	0.865	0.066	0.025	0.004	0.000	0.004	0.009
1966	0.032	0.368	0.523	0.042	0.025	0.001	0.003	0.006
1967	0.159	0.487	0.162	0.153	0.022	0.008	0.002	0.008
1968	0.069	0.801	0.085	0.017	0.022	0.002	0.002	0.001
1969	0.120	0.619	0.219	0.009	0.013	0.010	0.008	0.003
1970	0.057	0.848	0.036	0.030	0.013	0.008	0.005	0.002
1971	0.320	0.473	0.123	0.029	0.017	0.014	0.012	0.012
1972	0.008	0.930	0.012	0.013	0.015	0.010	0.008	0.004
1973	0.100	0.460	0.387	0.044	0.005	0.002	0.001	0.001
1974	0.056	0.741	0.126	0.073	0.004	0.000	0.000	0.000
1975	0.055	0.791	0.104	0.017	0.027	0.003	0.001	0.002
1976	0.083	0.635	0.227	0.023	0.017	0.013	0.002	0.001
1977	0.436	0.452	0.060	0.028	0.008	0.008	0.008	0.000
1978	0.154	0.780	0.059	0.003	0.002	0.001	0.000	0.001
1979	0.004	0.764	0.219	0.010	0.001	0.001	0.001	0.001
1980	0.349	0.293	0.290	0.064	0.003	0.000	0.000	0.001
1981	0.042	0.903	0.026	0.016	0.012	0.001	0.000	0.000
1982	0.071	0.809	0.111	0.004	0.003	0.002	0.000	0.000
1983	0.126	0.769	0.077	0.025	0.001	0.001	0.001	0.000
1984	0.152	0.654	0.119	0.039	0.030	0.004	0.002	0.001
1985	0.060	0.823	0.072	0.027	0.011	0.005	0.000	0.000
1986	0.074	0.438	0.364	0.072	0.030	0.013	0.006	0.001
1987	0.187	0.454	0.131	0.140	0.060	0.019	0.007	0.002
1988	0.119	0.688	0.071	0.035	0.061	0.022	0.003	0.001
1989	0.044	0.645	0.141	0.036	0.037	0.071	0.019	0.007
1990	0.020	0.762	0.113	0.049	0.010	0.012	0.024	0.011
1991	0.011	0.806	0.094	0.047	0.019	0.006	0.005	0.011
1992	0.001	0.749	0.164	0.057	0.016	0.006	0.003	0.003
1993	0.003	0.616	0.221	0.073	0.046	0.024	0.010	0.007
1994	0.005	0.741	0.153	0.024	0.039	0.022	0.009	0.008
1995	0.153	0.688	0.106	0.039	0.005	0.004	0.004	0.000
1996	0.018	0.859	0.070	0.029	0.013	0.004	0.004	0.002
1997	0.026	0.610	0.319	0.032	0.010	0.001	0.001	0.000
1998	0.001	0.843	0.082	0.048	0.012	0.007	0.005	0.002
1999	0.001	0.464	0.418	0.052	0.038	0.018	0.006	0.004
2000	0.006	0.911	0.029	0.028	0.019	0.005	0.002	0.000
2001	0.005	0.453	0.477	0.032	0.023	0.007	0.002	0.001
2002	0.131	0.740	0.067	0.047	0.012	0.002	0.000	0.000
2003	0.059	0.833	0.080	0.015	0.010	0.002	0.001	0.000
2004	0.021	0.578	0.326	0.059	0.008	0.005	0.001	0.002
2005	0.006	0.507	0.366	0.096	0.021	0.003	0.001	0.001
2006	0.521	0.363	0.086	0.015	0.010	0.003	0.002	0.000
2007	0.010	0.925	0.056	0.005	0.001	0.002	0.001	0.000
2008	0.164	0.717	0.116	0.001	0.000	0.001	0.001	0.000
2009	0.112	0.858	0.028	0.001	0.000	0.000	0.000	0.000
2010	0.000	0.954	0.044	0.001	0.001	0.000	0.000	0.000
2011	0.173	0.542	0.255	0.026	0.003	0.001	0.000	0.000
2012	0.804	0.148	0.016	0.021	0.008	0.002	0.001	0.000
2013	0.204	0.728	0.060	0.004	0.002	0.001	0.000	0.000
2014	0.297	0.627	0.055	0.011	0.004	0.004	0.001	0.001
2015	0.037	0.514	0.007	0.184	0.038	0.063	0.141	0.015
2016	0.011	0.827	0.122	0.023	0.009	0.003	0.002	0.003
2017	0.088	0.493	0.086	0.185	0.068	0.045	0.021	0.014

Table B1- 9 Catch weights at age (kg)

	1	2	3	4	5	6	7	8+
1965	0.009	0.024	0.055	0.112	0.134	0.272	0.189	0.189
1966	0.011	0.027	0.068	0.142	0.219	0.272	0.189	0.189
1967	0.009	0.028	0.062	0.114	0.170	0.210	0.238	0.351
1968	0.058	0.034	0.068	0.143	0.186	0.239	0.276	0.276
1969	0.010	0.035	0.100	0.137	0.210	0.240	0.288	0.288
1970	0.010	0.044	0.121	0.159	0.186	0.232	0.269	0.413
1971	0.012	0.044	0.129	0.168	0.199	0.242	0.289	0.346
1972	0.026	0.039	0.113	0.175	0.212	0.260	0.292	0.361
1973	0.010	0.044	0.110	0.137	0.219	0.280	0.331	0.370
1974	0.010	0.038	0.103	0.167	0.203	0.271	0.293	0.293
1975	0.016	0.044	0.107	0.177	0.206	0.244	0.288	0.375
1976	0.014	0.036	0.106	0.174	0.205	0.229	0.263	0.333
1977	0.012	0.037	0.094	0.153	0.196	0.227	0.236	0.305
1978	0.011	0.037	0.096	0.158	0.196	0.220	0.239	0.318
1979	0.006	0.031	0.082	0.169	0.216	0.243	0.265	0.294
1980	0.012	0.041	0.097	0.150	0.229	0.265	0.291	0.332
1981	0.010	0.041	0.098	0.177	0.213	0.281	0.310	0.356
1982	0.019	0.042	0.104	0.204	0.229	0.253	0.305	0.367
1983	0.018	0.041	0.124	0.199	0.219	0.283	0.319	0.410
1984	0.014	0.041	0.117	0.154	0.195	0.209	0.291	0.305
1985	0.017	0.036	0.096	0.148	0.162	0.188	0.198	0.220
1986	0.018	0.042	0.101	0.159	0.210	0.236	0.247	0.266
1987	0.011	0.041	0.092	0.137	0.088	0.147	0.145	0.160
1988	0.007	0.031	0.091	0.106	0.123	0.132	0.190	0.208
1989	0.009	0.031	0.066	0.104	0.116	0.133	0.157	0.157
1990	0.004	0.029	0.080	0.138	0.172	0.169	0.179	0.235
1991	0.004	0.036	0.074	0.124	0.150	0.184	0.200	0.244
1992	0.009	0.035	0.073	0.124	0.139	0.164	0.191	0.249
1993	0.003	0.032	0.078	0.119	0.125	0.148	0.183	0.265
1994	0.008	0.029	0.070	0.118	0.134	0.152	0.162	0.166
1995	0.014	0.046	0.090	0.118	0.134	0.149	0.160	0.259
1996	0.024	0.043	0.083	0.120	0.146	0.164	0.179	0.280
1997	0.017	0.045	0.085	0.118	0.146	0.167	0.182	0.182
1998	0.021	0.037	0.080	0.112	0.133	0.158	0.178	0.222
1999	0.026	0.048	0.087	0.116	0.132	0.149	0.176	0.216
2000	0.018	0.060	0.101	0.127	0.147	0.159	0.182	0.244
2001	0.005	0.047	0.089	0.127	0.147	0.161	0.175	0.240
2002	0.020	0.045	0.093	0.121	0.138	0.158	0.169	0.200
2003	0.015	0.052	0.090	0.130	0.149	0.166	0.184	0.207
2004	0.011	0.043	0.092	0.125	0.152	0.166	0.186	0.209
2005	0.019	0.042	0.083	0.123	0.149	0.170	0.188	0.252
2006	0.019	0.066	0.085	0.120	0.147	0.172	0.188	0.198
2007	0.016	0.047	0.085	0.118	0.141	0.161	0.185	0.199
2008	0.016	0.041	0.100	0.131	0.152	0.169	0.180	0.221
2009	0.004	0.047	0.090	0.133	0.156	0.172	0.184	0.206
2010	0.028	0.036	0.072	0.113	0.142	0.162	0.174	0.174
2011	0.019	0.044	0.069	0.100	0.138	0.160	0.189	0.183
2012	0.013	0.049	0.085	0.096	0.109	0.145	0.160	0.184
2013	0.012	0.050	0.070	0.107	0.118	0.129	0.155	0.204
2014	0.012	0.060	0.096	0.106	0.144	0.146	0.150	0.165
2015	0.025	0.043	0.087	0.126	0.136	0.158	0.158	0.206
2016	0.025	0.047	0.068	0.107	0.143	0.151	0.166	0.183
2017	0.014	0.044	0.085	0.114	0.140	0.158	0.167	0.167

Table B1- 10 Spawning stock biomass weights at age (kg)

	1	2	3	4	5	6	7	8+
1965	0.013	0.038	0.095	0.113	0.202	0.265	0.298	0.355
1966	0.016	0.047	0.096	0.170	0.224	0.279	0.302	0.355
1967	0.016	0.043	0.107	0.172	0.206	0.227	0.242	0.371
1968	0.011	0.038	0.069	0.178	0.223	0.265	0.298	0.355
1969	0.011	0.041	0.102	0.134	0.222	0.265	0.298	0.311
1970	0.011	0.061	0.126	0.163	0.191	0.239	0.276	0.419
1971	0.014	0.068	0.144	0.170	0.202	0.248	0.296	0.353
1972	0.031	0.069	0.154	0.197	0.235	0.268	0.289	0.344
1973	0.011	0.051	0.133	0.170	0.238	0.295	0.352	0.379
1974	0.008	0.045	0.124	0.169	0.196	0.270	0.290	0.352
1975	0.015	0.055	0.133	0.188	0.211	0.248	0.295	0.362
1976	0.015	0.088	0.132	0.184	0.210	0.236	0.278	0.371
1977	0.013	0.045	0.131	0.175	0.215	0.243	0.249	0.342
1978	0.032	0.051	0.119	0.178	0.208	0.239	0.252	0.321
1979	0.015	0.073	0.133	0.187	0.229	0.253	0.302	0.389
1980	0.007	0.054	0.104	0.185	0.250	0.294	0.319	0.366
1981	0.015	0.039	0.135	0.192	0.236	0.301	0.339	0.379
1982	0.017	0.050	0.139	0.200	0.240	0.272	0.328	0.368
1983	0.024	0.069	0.144	0.214	0.265	0.297	0.332	0.413
1984	0.007	0.064	0.140	0.193	0.239	0.286	0.313	0.379
1985	0.006	0.047	0.146	0.208	0.237	0.268	0.318	0.269
1986	0.032	0.057	0.116	0.176	0.227	0.252	0.271	0.319
1987	0.010	0.068	0.108	0.159	0.202	0.238	0.256	0.315
1988	0.027	0.066	0.117	0.154	0.192	0.229	0.264	0.316
1989	0.027	0.068	0.116	0.172	0.201	0.234	0.260	0.329
1990	0.024	0.062	0.106	0.156	0.189	0.216	0.233	0.312
1991	0.024	0.063	0.096	0.142	0.171	0.205	0.225	0.306
1992	0.024	0.060	0.102	0.135	0.164	0.190	0.220	0.305
1993	0.024	0.047	0.096	0.137	0.156	0.180	0.209	0.309
1994	0.024	0.054	0.086	0.120	0.138	0.159	0.180	0.307
1995	0.027	0.051	0.095	0.123	0.145	0.162	0.175	0.275
1996	0.028	0.055	0.088	0.125	0.150	0.171	0.188	0.228
1997	0.014	0.059	0.091	0.124	0.150	0.174	0.194	0.222
1998	0.027	0.052	0.092	0.117	0.138	0.164	0.187	0.216
1999	0.026	0.060	0.091	0.123	0.140	0.157	0.186	0.205
2000	0.027	0.065	0.111	0.137	0.156	0.172	0.198	0.221
2001	0.033	0.056	0.099	0.134	0.153	0.166	0.181	0.201
2002	0.030	0.059	0.099	0.126	0.143	0.167	0.183	0.195
2003	0.027	0.059	0.099	0.137	0.153	0.171	0.192	0.198
2004	0.027	0.047	0.091	0.129	0.155	0.173	0.194	0.203
2005	0.027	0.054	0.087	0.131	0.159	0.183	0.199	0.198
2006	0.027	0.062	0.089	0.133	0.163	0.184	0.203	0.204
2007	0.027	0.064	0.106	0.140	0.164	0.184	0.203	0.207
2008	0.027	0.068	0.106	0.135	0.162	0.175	0.188	0.201
2009	0.027	0.057	0.095	0.138	0.159	0.179	0.191	0.209
2010	0.027	0.043	0.089	0.121	0.146	0.169	0.183	0.203
2011	0.027	0.049	0.076	0.110	0.141	0.168	0.183	0.198
2012	0.032	0.049	0.090	0.107	0.123	0.155	0.188	0.198
2013	0.027	0.061	0.090	0.124	0.132	0.144	0.180	0.199
2014	0.027	0.066	0.106	0.119	0.155	0.158	0.165	0.196
2015	0.027	0.057	0.103	0.136	0.148	0.169	0.170	0.195
2016	0.027	0.065	0.080	0.114	0.151	0.158	0.171	0.190
2017	0.027	0.058	0.093	0.121	0.148	0.169	0.186	0.185

Table B1- 11 Jan. 1 Weights at age (kg)

	1	2	3	4	5	6	7	8+
1965	0.007	0.024	0.071	0.080	0.172	0.248	0.287	0.356
1966	0.010	0.025	0.060	0.127	0.159	0.237	0.283	0.352
1967	0.010	0.026	0.071	0.129	0.187	0.226	0.260	0.360
1968	0.006	0.025	0.055	0.138	0.196	0.234	0.260	0.354
1969	0.005	0.021	0.062	0.096	0.199	0.243	0.281	0.326
1970	0.004	0.026	0.072	0.129	0.160	0.230	0.270	0.364
1971	0.006	0.027	0.094	0.146	0.182	0.218	0.266	0.360
1972	0.024	0.031	0.102	0.168	0.200	0.233	0.268	0.345
1973	0.005	0.040	0.096	0.162	0.217	0.263	0.307	0.356
1974	0.003	0.022	0.080	0.150	0.183	0.254	0.293	0.366
1975	0.006	0.021	0.077	0.153	0.189	0.221	0.282	0.353
1976	0.009	0.036	0.085	0.156	0.199	0.223	0.263	0.363
1977	0.007	0.026	0.107	0.152	0.199	0.226	0.242	0.351
1978	0.021	0.026	0.073	0.153	0.191	0.227	0.248	0.324
1979	0.008	0.048	0.082	0.149	0.202	0.229	0.269	0.341
1980	0.003	0.029	0.087	0.157	0.216	0.260	0.284	0.365
1981	0.008	0.017	0.085	0.141	0.209	0.274	0.316	0.370
1982	0.008	0.027	0.074	0.164	0.215	0.253	0.314	0.373
1983	0.015	0.034	0.085	0.173	0.230	0.267	0.301	0.389
1984	0.003	0.039	0.098	0.167	0.226	0.275	0.305	0.395
1985	0.002	0.018	0.097	0.171	0.214	0.253	0.302	0.268
1986	0.022	0.019	0.074	0.160	0.217	0.244	0.270	0.252
1987	0.004	0.047	0.079	0.136	0.189	0.232	0.254	0.312
1988	0.017	0.026	0.089	0.129	0.175	0.215	0.251	0.309
1989	0.018	0.043	0.088	0.142	0.176	0.212	0.244	0.317
1990	0.015	0.041	0.085	0.135	0.180	0.208	0.234	0.314
1991	0.015	0.039	0.077	0.123	0.163	0.197	0.221	0.301
1992	0.017	0.038	0.080	0.114	0.153	0.180	0.212	0.298
1993	0.016	0.034	0.076	0.118	0.145	0.172	0.199	0.298
1994	0.017	0.036	0.064	0.107	0.138	0.158	0.180	0.298
1995	0.019	0.035	0.072	0.103	0.132	0.150	0.167	0.280
1996	0.019	0.039	0.067	0.109	0.136	0.158	0.175	0.237
1997	0.007	0.041	0.071	0.105	0.137	0.162	0.182	0.193
1998	0.018	0.027	0.074	0.103	0.131	0.157	0.180	0.148
1999	0.016	0.040	0.069	0.106	0.128	0.147	0.175	0.211
2000	0.019	0.041	0.082	0.112	0.139	0.155	0.176	0.211
2001	0.025	0.039	0.080	0.122	0.145	0.161	0.176	0.210
2002	0.021	0.044	0.075	0.112	0.138	0.160	0.174	0.198
2003	0.021	0.042	0.076	0.117	0.139	0.156	0.179	0.197
2004	0.019	0.036	0.073	0.113	0.146	0.163	0.182	0.201
2005	0.018	0.038	0.064	0.109	0.143	0.168	0.186	0.202
2006	0.018	0.041	0.069	0.108	0.146	0.171	0.193	0.203
2007	0.017	0.042	0.081	0.112	0.148	0.173	0.193	0.207
2008	0.019	0.043	0.082	0.120	0.151	0.169	0.186	0.205
2009	0.021	0.039	0.080	0.121	0.147	0.170	0.183	0.205
2010	0.020	0.034	0.071	0.107	0.142	0.164	0.181	0.202
2011	0.020	0.036	0.057	0.099	0.131	0.157	0.176	0.202
2012	0.023	0.036	0.066	0.090	0.116	0.148	0.178	0.198
2013	0.017	0.044	0.066	0.106	0.119	0.133	0.167	0.199
2014	0.019	0.042	0.080	0.104	0.139	0.144	0.154	0.198
2015	0.017	0.039	0.082	0.120	0.133	0.162	0.164	0.195
2016	0.018	0.042	0.068	0.108	0.143	0.153	0.170	0.192
2017	0.018	0.040	0.078	0.098	0.130	0.160	0.171	0.187

Table B1- 12 Proportion mature at age

	1	2	3	4	5	6	7	8+
1965	0.0000	0.0529	0.2143	0.8000	1.0000	1.0000	1.0000	1.0000
1966	0.0000	0.0264	0.3082	0.8304	0.9979	0.9993	1.0000	1.0000
1967	0.0000	0.0264	0.3082	0.8304	0.9979	0.9993	1.0000	1.0000
1968	0.0000	0.0264	0.3082	0.8304	0.9979	0.9993	1.0000	1.0000
1969	0.0000	0.0264	0.3082	0.8304	0.9979	0.9993	1.0000	1.0000
1970	0.0000	0.0264	0.3082	0.8304	0.9979	0.9993	1.0000	1.0000
1971	0.0000	0.0000	0.4021	0.8608	0.9959	0.9986	1.0000	1.0000
1972	0.0000	0.0264	0.6241	0.9304	0.9979	0.9993	1.0000	1.0000
1973	0.0000	0.0529	0.8462	1.0000	1.0000	1.0000	1.0000	1.0000
1974	0.0000	0.0264	0.5514	0.9828	1.0000	1.0000	1.0000	1.0000
1975	0.0000	0.0264	0.5514	0.9828	1.0000	1.0000	1.0000	1.0000
1976	0.0000	0.0264	0.5514	0.9828	1.0000	1.0000	1.0000	1.0000
1977	0.0000	0.0000	0.2566	0.9655	1.0000	1.0000	1.0000	1.0000
1978	0.0000	0.0000	0.2722	0.9782	1.0000	0.9762	1.0000	1.0000
1979	0.0000	0.0000	0.4303	0.9944	1.0000	1.0000	1.0000	1.0000
1980	0.0000	0.0529	0.1641	0.9680	1.0000	1.0000	1.0000	1.0000
1981	0.0000	0.0000	0.1485	0.9711	0.9972	1.0000	1.0000	1.0000
1982	0.0000	0.0000	0.6276	1.0000	1.0000	1.0000	1.0000	1.0000
1983	0.0000	0.0000	0.5831	0.9938	1.0000	1.0000	1.0000	1.0000
1984	0.0000	0.0000	0.6102	1.0000	1.0000	1.0000	1.0000	1.0000
1985	0.0000	0.0833	0.7166	0.9947	1.0000	1.0000	1.0000	1.0000
1986	0.0000	0.0000	0.5039	0.9744	1.0000	1.0000	1.0000	1.0000
1987	0.0000	0.2000	0.2986	0.9517	1.0000	1.0000	1.0000	1.0000
1988	0.0000	0.0000	0.2966	0.9769	1.0000	1.0000	1.0000	1.0000
1989	0.0000	0.0000	0.4046	0.9837	1.0000	1.0000	0.9762	1.0000
1990	0.0000	0.0000	0.2378	0.9646	1.0000	1.0000	1.0000	1.0000
1991	0.0000	0.0000	0.2297	0.9701	1.0000	1.0000	1.0000	1.0000
1992	0.0000	0.0529	0.3982	0.9632	1.0000	1.0000	1.0000	1.0000
1993	0.0000	0.0529	0.3186	0.9845	0.9954	1.0000	1.0000	1.0000
1994	0.0000	0.0529	0.1646	0.9082	1.0000	1.0000	1.0000	1.0000
1995	0.0000	0.0529	0.3370	0.8939	1.0000	1.0000	1.0000	1.0000
1996	0.0000	0.0529	0.4500	0.9467	1.0000	1.0000	1.0000	1.0000
1997	0.0000	0.6667	0.8523	1.0000	1.0000	1.0000	1.0000	0.9756
1998	0.0000	0.0529	0.6117	0.9891	1.0000	0.9804	1.0000	1.0000
1999	0.0000	0.0000	0.3548	0.9184	0.9926	1.0000	0.9677	1.0000
2000	0.0000	0.0000	0.6535	0.9919	1.0000	1.0000	1.0000	0.9412
2001	0.0000	0.0000	0.8438	1.0000	1.0000	0.9919	0.9913	1.0000
2002	0.0000	0.0000	0.5252	0.9802	1.0000	1.0000	1.0000	1.0000
2003	0.0000	0.0400	0.5924	0.9552	1.0000	1.0000	1.0000	0.9500
2004	0.0000	0.3333	0.6257	1.0000	1.0000	1.0000	1.0000	1.0000
2005	0.0000	0.5000	0.5662	1.0000	1.0000	1.0000	1.0000	1.0000
2006	0.0000	0.0000	0.3370	0.9927	1.0000	1.0000	1.0000	1.0000
2007	0.0000	0.0063	0.7798	0.9921	1.0000	1.0000	1.0000	1.0000
2008	0.0000	0.0000	0.7890	0.9899	1.0000	1.0000	1.0000	1.0000
2009	0.0000	0.0000	0.7317	1.0000	1.0000	1.0000	1.0000	1.0000
2010	0.0000	0.0087	0.7324	0.9917	1.0000	0.9800	1.0000	1.0000
2011	0.0000	0.0000	0.4842	0.9830	1.0000	1.0000	1.0000	1.0000
2012	0.0000	0.0000	0.6230	0.9906	1.0000	1.0000	1.0000	1.0000
2013	0.0000	0.0660	0.5556	0.9242	0.9973	1.0000	1.0000	1.0000
2014	0.0000	0.0000	0.8817	1.0000	1.0000	1.0000	1.0000	1.0000
2015	0.0000	0.0000	0.6543	0.9965	1.0000	1.0000	1.0000	1.0000
2016	0.0000	0.0000	0.5306	0.7778	1.0000	1.0000	1.0000	1.0000
2017	0.0000	0.0000	0.7765	0.9110	1.0000	1.0000	1.0000	1.0000

Table B1- 13 Number of samples used for maturity at age each year

Year	Maturity Samples
1965	21
1966	0
1967	0
1968	0
1969	0
1970	0
1971	3692
1972	0
1973	84
1974	0
1975	0
1976	0
1977	366
1978	1504
1979	1307
1980	1604
1981	1072
1982	751
1983	993
1984	1107
1985	1037
1986	440
1987	710
1988	468
1989	581
1990	486
1991	674
1992	842
1993	1033
1994	502
1995	804
1996	567
1997	1166
1998	583
1999	640
2000	672
2001	902
2002	998
2003	594
2004	289
2005	959
2006	985
2007	716
2008	744
2009	804
2010	923
2011	1093
2012	851
2013	775
2014	915
2015	602
2016	352
2017	449

Figure B1- 1 Length (cm) composition of Atlantic herring caught by purse seine, midwater trawl, or paired midwater trawl during 2007-2016

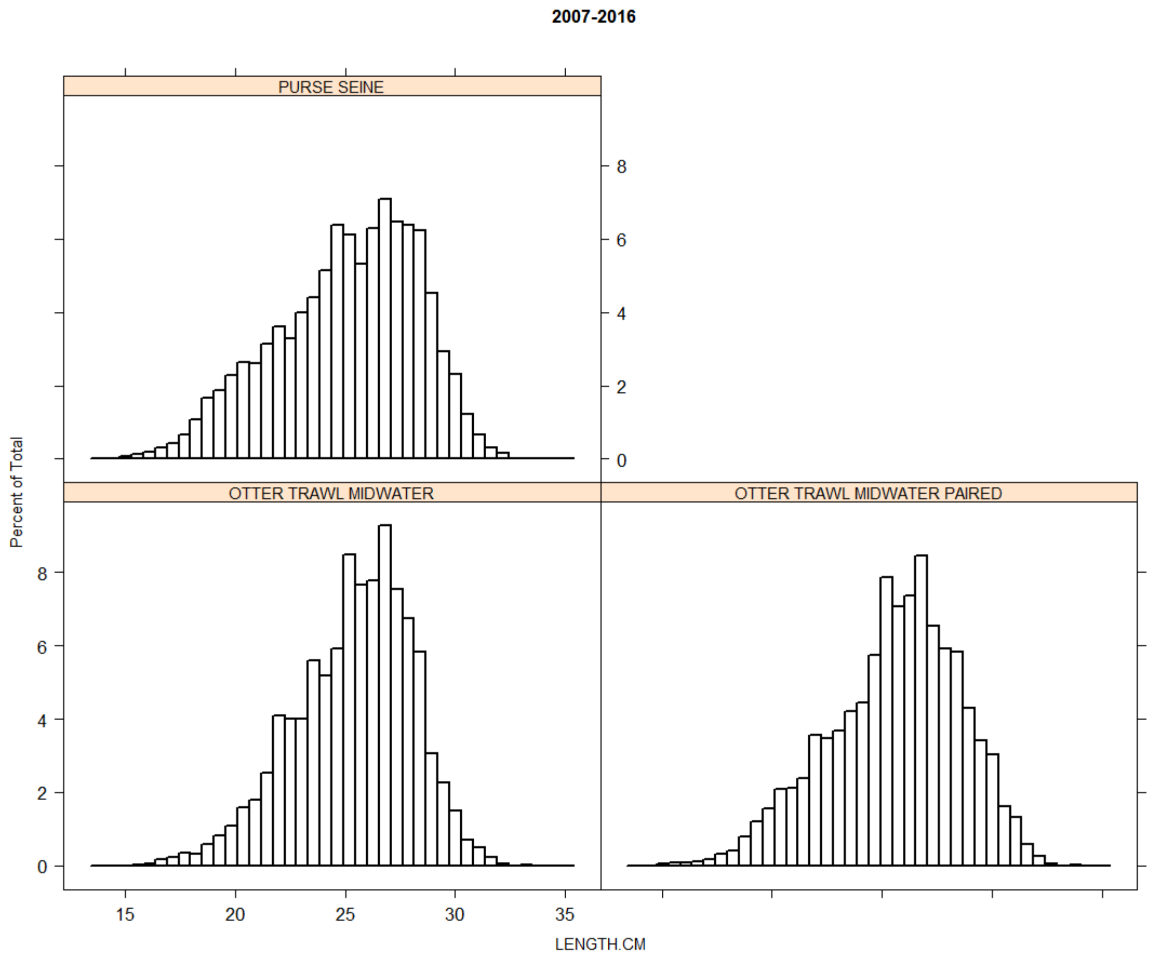


Figure B1- 2 Example of a Atlantic herring bimodal length frequency (cm) observed for the purse seine gear but not midwater trawls (data from 2012)

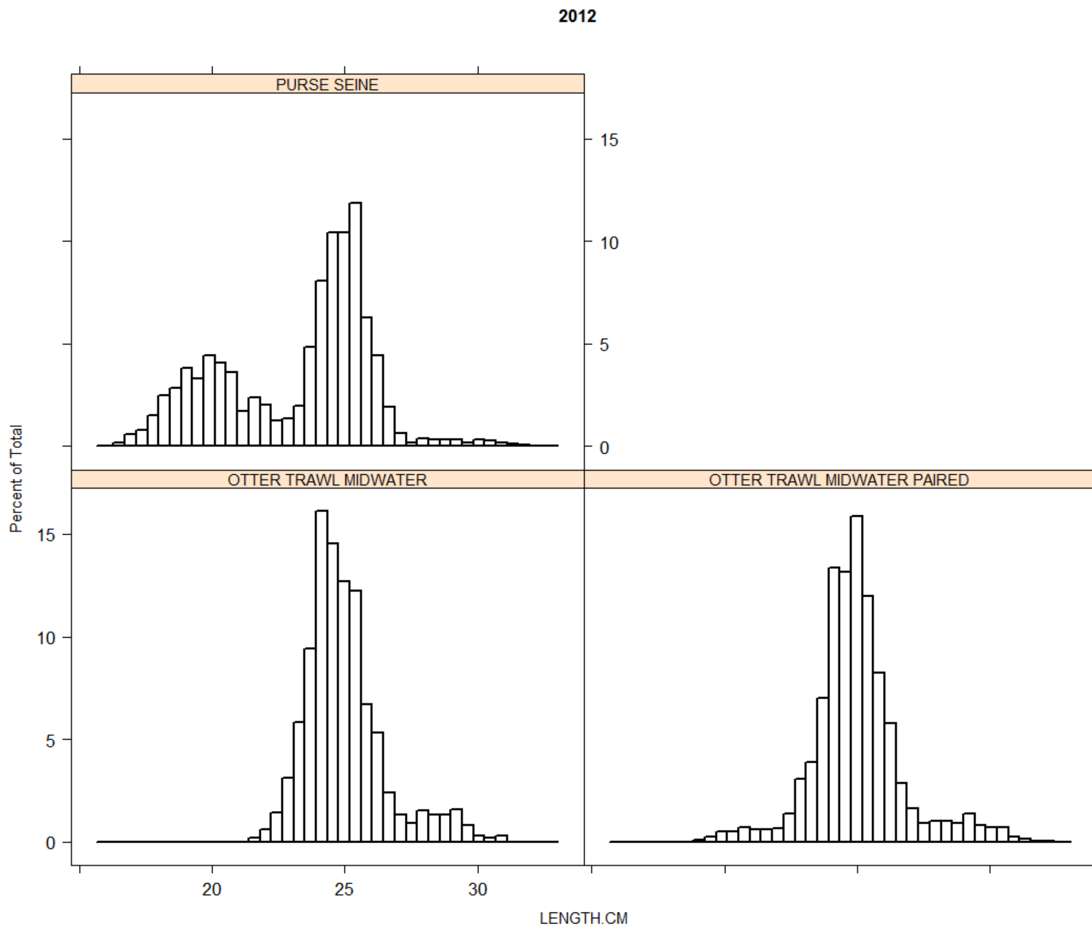


Figure B1- 3 Atlantic herring catch (mt) by purse seine, midwater trawl, and paired midwater trawl

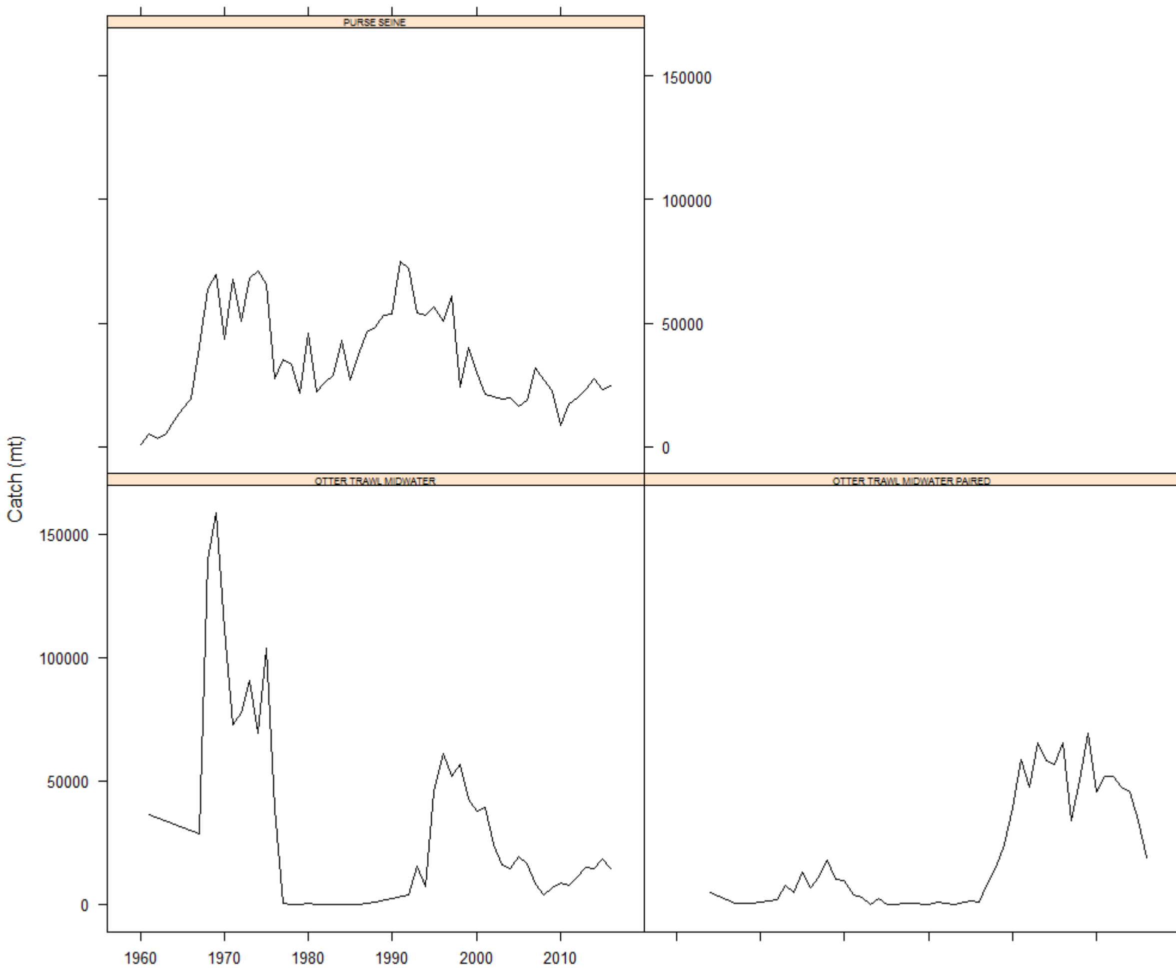


Figure B1- 4 Atlantic herring catch (mt) by mobile and fixed fleets in the Gulf of Maine (GOFM) and outside the GOFM (OTHER)

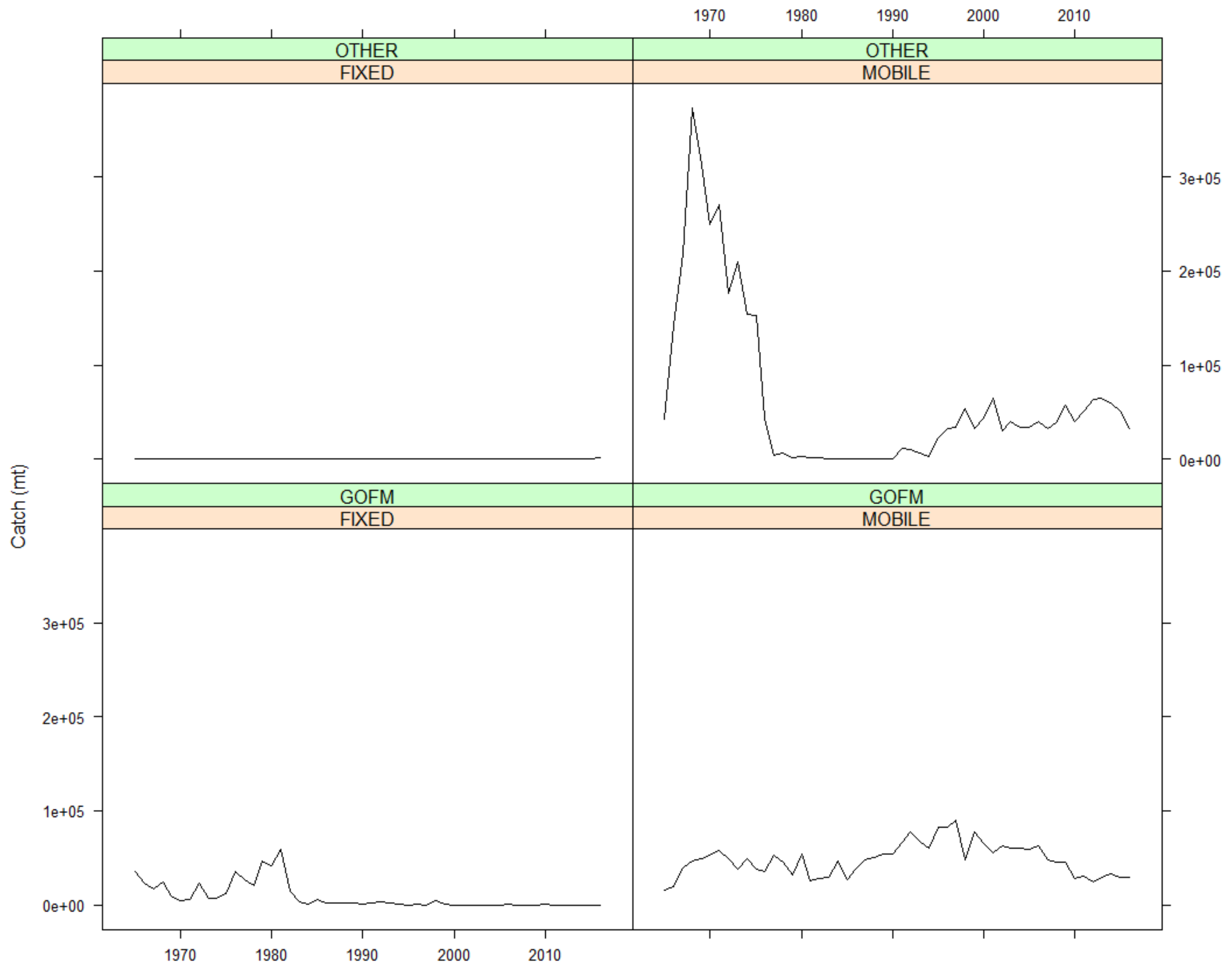


Figure B1- 5 Atlantic herring length composition (cm) of the mobile fleet during 1964-2011 in the Gulf of Maine (GOFM) and all other areas (OTHER)

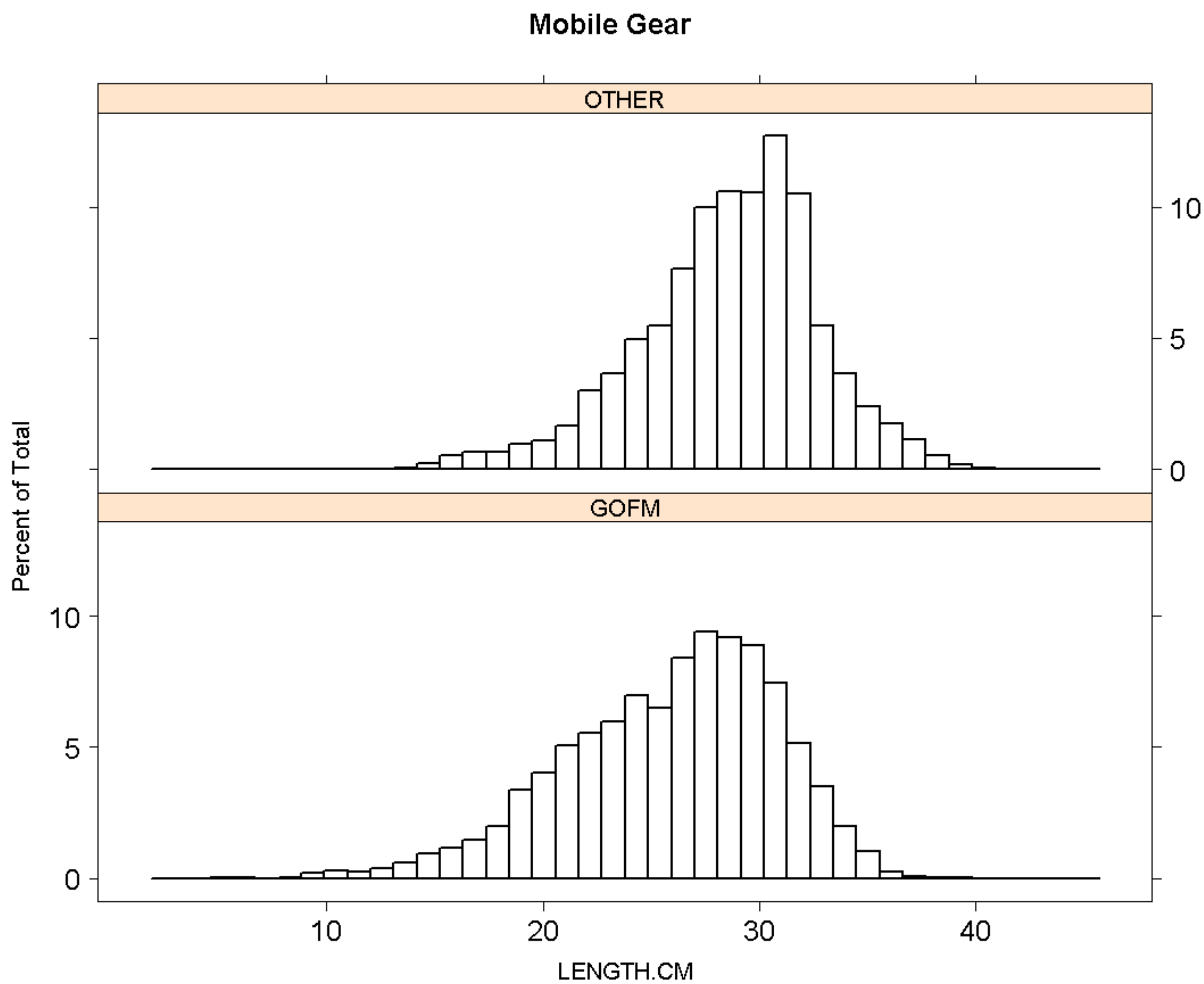


Figure B1- 6 Atlantic herring length composition of the mobile and fixed fleets during 1965-2011 in the Gulf of Maine (GOFM)

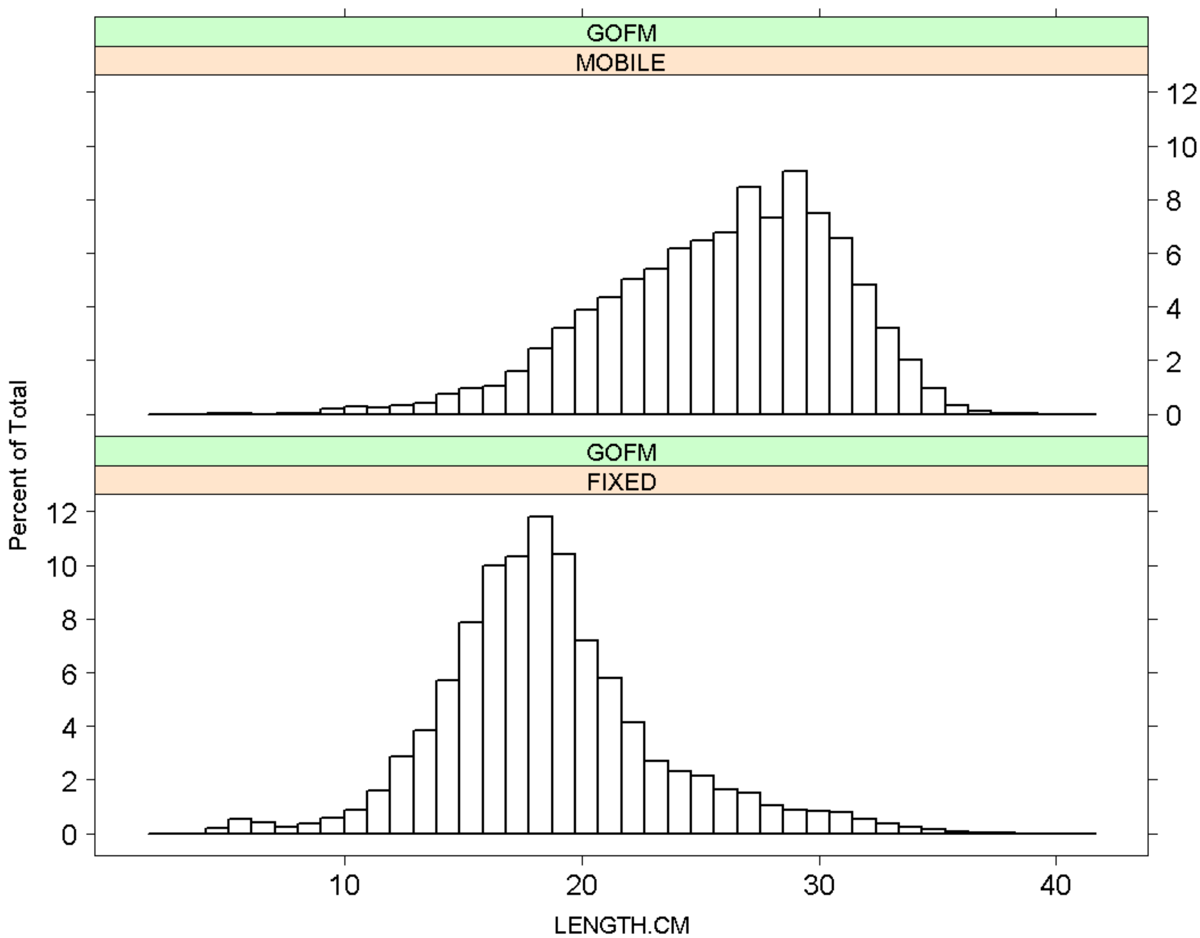


Figure B1- 7 Atlantic herring catch (mt) by the mobile and fixed fleets

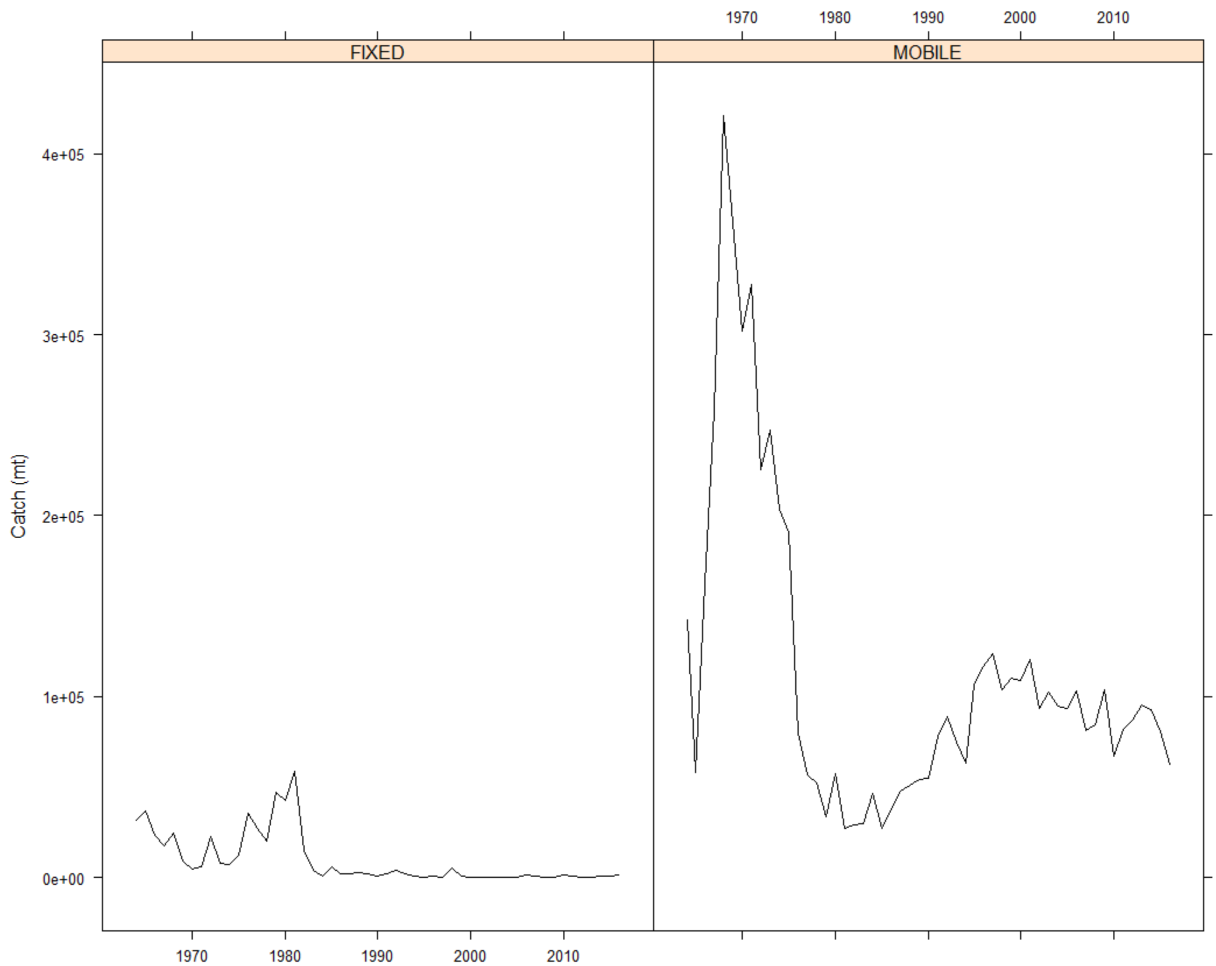


Figure B1- 8 Atlantic herring proportions at age for the mobile fleet

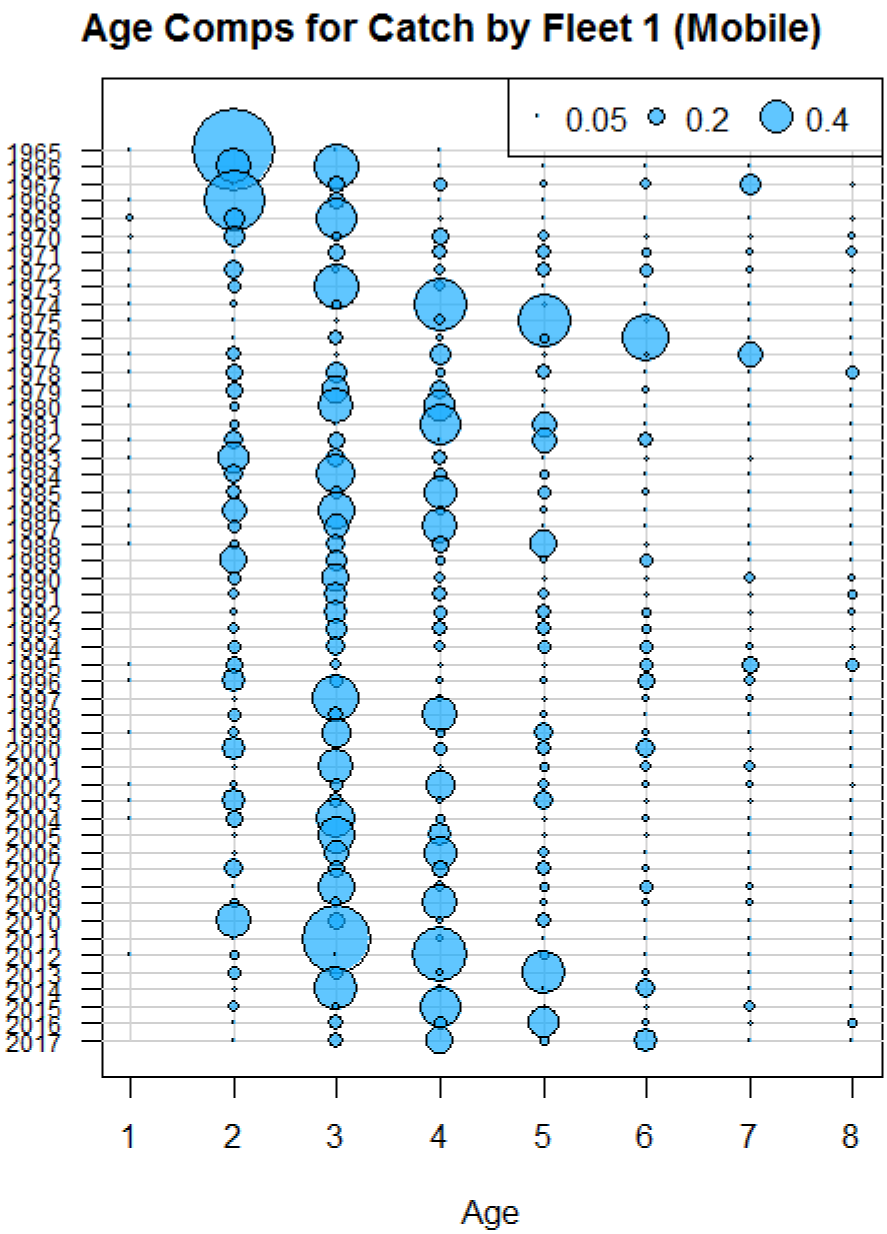


Figure B1- 9 Atlantic herring proportions at age for the fixed fleet

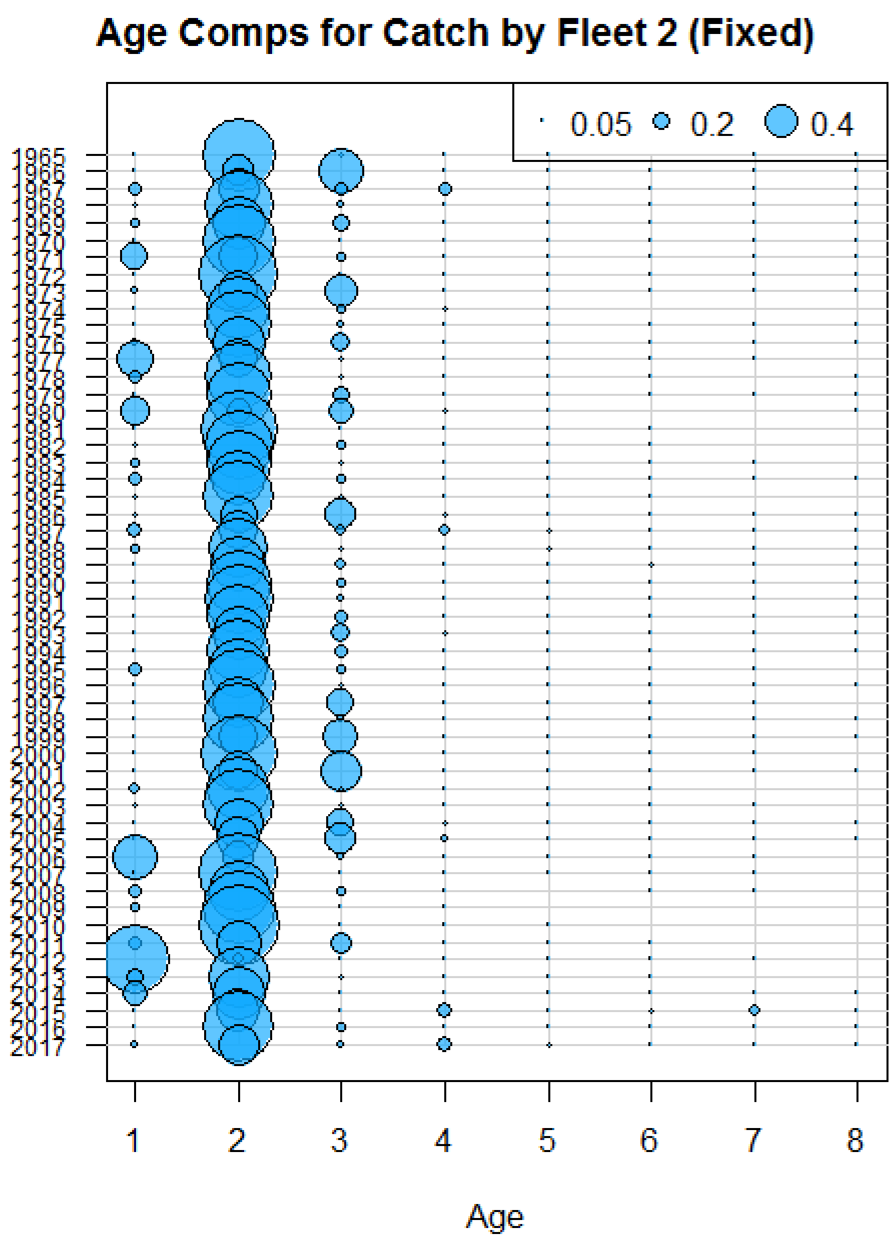


Figure B1- 10 Atlantic herring spawning stock biomass weights (kg) at age

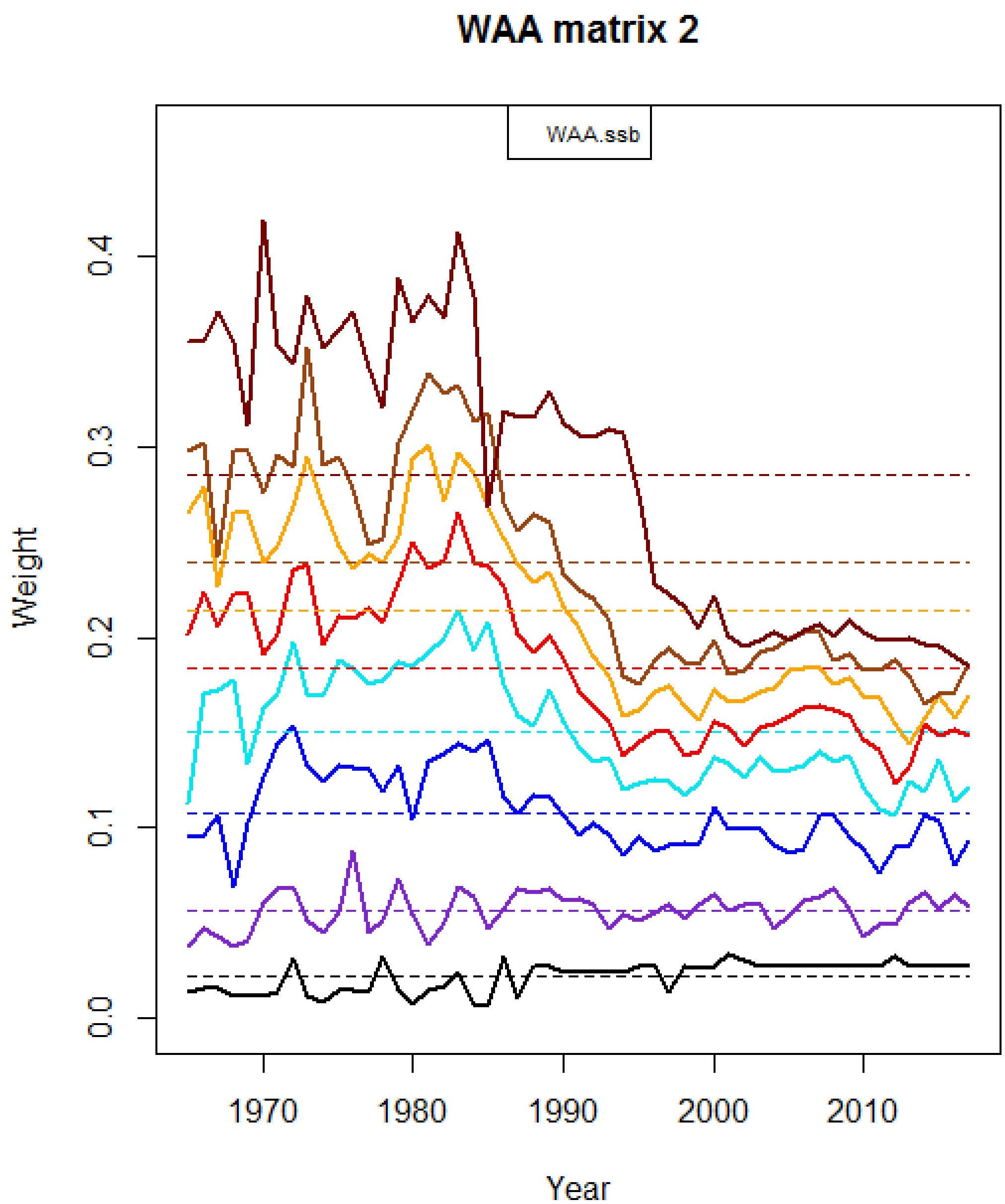
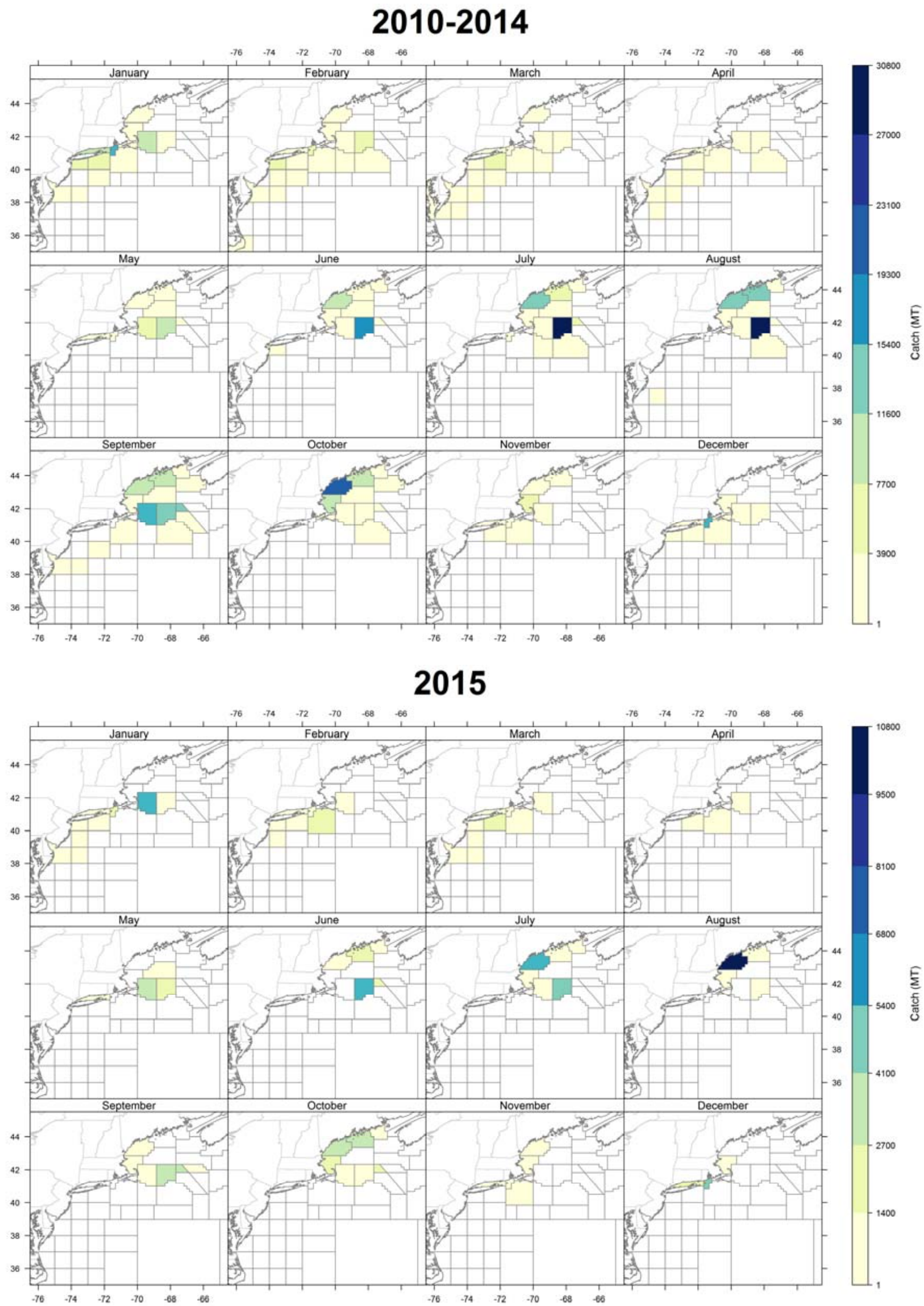
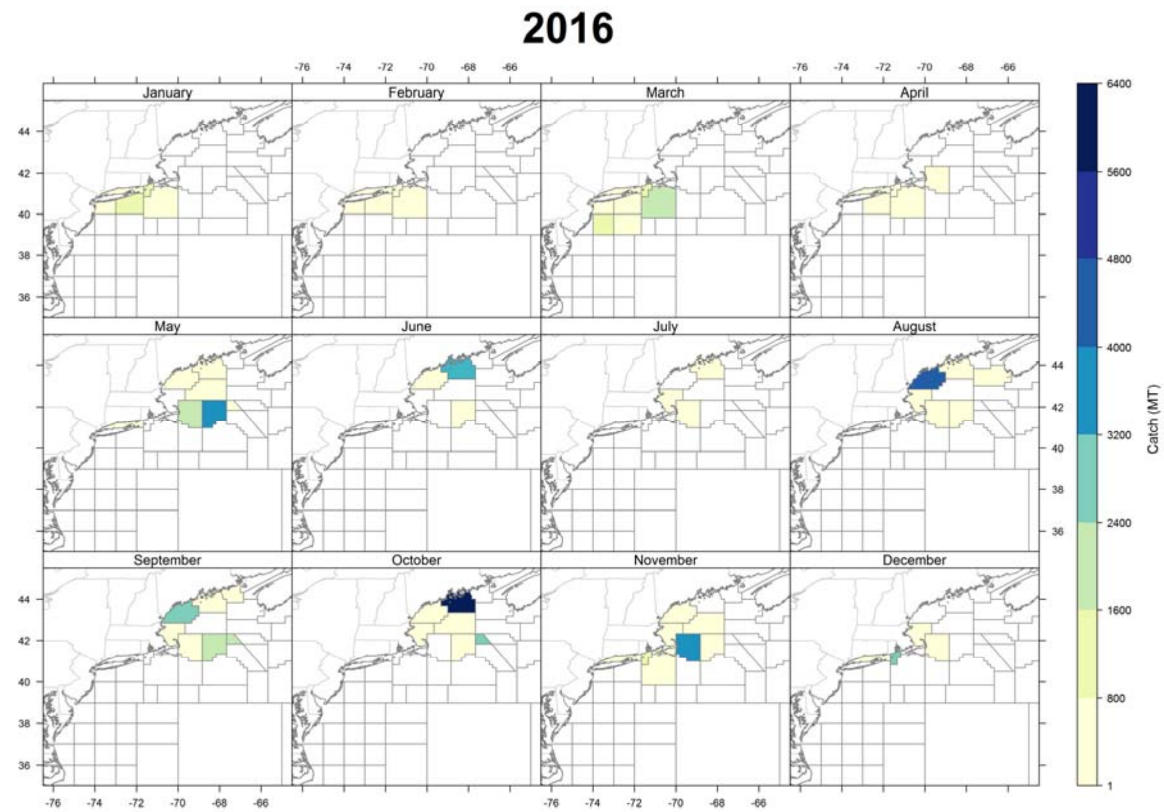


Figure B1- 11 Atlantic herring catch distribution.




2016
January
February
March
April
May
June
July
August
September
October
November
December
Catch (MT)
6400
5600
4800
4000
3200
2400
1600
800
1
-76
-74
-72
-70
-68
-66
44
42
40
38
36

TOR B2: *Present the survey data used in the assessment (e.g., regional indices of abundance, recruitment, state surveys, age-length data, food habits, etc.). Characterize the uncertainty and any bias in these sources of data.*

NMFS bottom trawl surveys

NMFS spring and fall bottom trawl surveys began in 1968 and 1963, respectively, and have continued through 2017. All survey tows in the spring and fall were conducted using the FRV Delaware II, FRV Albatross IV, or FSV Henry B. Bigelow. The Albatross IV was used for most tows in most years prior to 2009. In the spring, however, the Delaware II was responsible for most or all catches in 1973, 1979-1982, 1989-1991, 1994, and 2003. In the fall, the Delaware II was responsible for most or all of the catches in 1977-1978, 1980-1981, 1989-1991, and 1993. The Bigelow has been used exclusively since 2009. To ensure that changes in the indices were more reflective of changes in herring abundance and not due to differences in vessel catchability, Delaware II catches were calibrated to Albatross IV equivalents. Calibration coefficients were based on paired tow experiments (Byrne et al., 1991). Catch numbers from the Delaware II were multiplied by 0.59, and this value was constant among seasons and lengths (Byrne et al. 1991). A range of models used to develop the calibration coefficients for converting Bigelow catches to Albatross IV catches were previously explored and applied in assessment models (Miller et al. 2010; NEFSC 2012). Rather than convert Bigelow catches to Albatross IV equivalents in this assessment, however, the bottom trawl survey index during 2009-2017 (when the Bigelow was used) was treated as a separate survey time series with catchability and selectivity estimated separately from the Albatross IV years. This decision was made because the switch to the Bigelow represents a long-term shift in the survey vessel with known catchability and selectivity differences from previous years. The number of years available for the Bigelow is also now sufficient to estimate relatively precise catchability and selectivity parameters. Treating 2009-2017 as a separate time series was preferred over continued use of the calibration coefficients (Miller et al. 2010; NEFSC 2012) because the calibration coefficients were estimated based on a single year of paired tow experiments and subject to measurement and estimation uncertainties (NEFSC 2012) that are difficult to carry forward into assessment model estimation. Conversely, treating 2009-2017 as a separate time series may allow the estimated difference in catchability to alias other model misspecifications (e.g., the estimated changes in catchability among years may be due to something other than catchability; NEFSC 2008). Thus, while treating 2009-2017 as a separate time series was preferred, assessment models were also run having converted Bigelow catches to Albatross IV equivalents, and these two alternatives were compared and contrasted (see TOR B4). The fall 2017 survey did not cover some survey strata in the mid-Atlantic region (strata 5-12; Figure B2- 1). To account for this inconsistent spatial coverage, a linear regression was fit to the aggregate fall survey indices (arithmetic mean numbers per tow) from 2009-2016 estimated with (dependent variable) and without (independent variable) these strata. This regression was used to calibrate the fall 2017 survey observation (aggregate and at age) to a value assumed equivalent to having sampled the entire survey area. The Working Group noted that the regressions fit to the aggregate indices and indices at age were similar, and that the difference between the uncalibrated and calibrated values (100.9 uncalibrated to 78.6 calibrated) were within the 90%CI of the uncalibrated index. Consequently, this issue was considered relatively inconsequential.

Herring age samples in the spring and fall surveys were collected beginning in 1987. In previous assessments for years prior to 1987, age specific indices were estimated by using age-length keys developed mostly from commercial catch data. Previous assessments, however, have found significant and inexplicable differences in age-length keys from survey and commercial sources and so this practice was abandoned (NEFSC 2012; Appendix B1). Arithmetic mean numbers per tow and associated coefficients of variation in each year were used as indices of Atlantic herring abundance, and age composition since 1987 data was used in assessments Figure B2- 2; Figure B2- 3; Figure B2- 4). As in previous assessments, age-1 survey observations were excluded from the indices because age-1 fish are not selected by the trawl gear, and most observations are thought to be measurement uncertainty as opposed to reflective of changes in herring abundance. Length frequencies were also provided (Figure B2-5).

The trawl doors used on the NMFS spring and fall bottom trawl surveys changed in 1985. Previous assessments have split the spring and fall surveys into separate time series to account for the associated catchability difference caused by the change in trawl doors. This decision was also supported by residual patterns in assessment fit. This practice was continued for this assessment. Ultimately, the spring and fall surveys were each split into three separate series to account for the door change in 1985 and the change to the Bigelow vessel in 2009 (spring: 1968-1984, 1985-2008, 2009-2017; fall: 1963-1984, 1985-2008, 2009-2017).

The NMFS winter survey was conducted during 1992-2007. As in previous assessments, the winter survey was eliminated from consideration as an index of abundance because of concerns over inconsistent spatial coverage among years and lack of fit in previous assessments.

A NMFS summer survey directed at shrimp began in 1983 and has continued through 2017, with the exception of 1984. The spatial extent of this survey is limited to the Gulf of Maine (Figure B2- 6). The working group agreed, however, that fish from the entire complex are mixed in the Gulf of Maine during the summer, and so this survey would be a valid index of the entire stock complex. Age data for Atlantic herring have never been collected on this survey. This survey occurs approximately half way between the spring and fall bottom trawl surveys, however, and so the average of the age-length keys from the spring and fall surveys were used to develop indices at age for the summer survey. Arithmetic mean numbers per tow and associated coefficients of variation in each year were proposed as indices of Atlantic herring abundance (Figure B2- 7; Figure B2- 8). Length frequencies were also provided (Figure B2- 5).

State surveys

Massachusetts Division of Marine Fisheries (MA DMF) spring and fall bottom trawl surveys began in 1977 and have continued uninterrupted through 2017. Joint Maine and New Hampshire spring and fall bottom trawl surveys began in 2001 and 2000, respectively, and have continued uninterrupted through 2017. These surveys cover state waters ≤ 3 nm from shore, and cover a relatively small proportion of the stock, in terms of both spatial coverage and size/age composition. Consequently, the working group agreed that they should not be used for the assessment.

An index from food habits data

An index of herring abundance was developed from stomach contents data collected on the NMFS spring and fall bottom trawl surveys (see TOR B3 for details about stomach contents data collection). The methods were identical to Deroba (2018) and only a brief update and overview were provided here. Data were identical to that in Deroba (2018) except the time series extended through 2016 and some additional observations were added to the years 2012-2014 that had not been previously analyzed. Each stomach observation was essentially treated as a catch-per-effort observation, and a delta approach (hurdle model) was used to develop the index of herring abundance. Separate generalized additive mixed models (GAMMs) were fit to: (i) the amount of herring observed in predator stomachs using only those stomachs in which herring were identified, and (ii) a model of the probability of a stomach containing herring using data from all sampled stomachs. After using a AIC for model selection, the overall best GAMM model for the amount of herring in stomachs with positive herring occurrence included a fixed effect for the product factor of area and season α_{as}, a smooth for predator length $f(l_i)$, and random intercepts for year b_y, predator species m_r, the interaction of year and the product factor of area and season $d_{y,as}$, and the interaction of year, predator species, and the product factor of area and season $g_{y,r,as}$:

$$ln(h_i) = \mu + \alpha_{as} + f(l_i) + b_y + m_r + d_{y,as} + g_{y,r,as} + \varepsilon_i \ .$$

The overall best GAMM model for the probability of a positive herring occurrence included fixed effects for year β_y and the product factor of area and season, smooths for predator length and the amount of herring catch in the tow from which a stomach was sampled $f(c_i)$, and random effects for predator species, and the interaction of predator species and the product factor of area and season $n_{r,as}$:

$$ln\left(\frac{p_i}{(1-p_i)}\right) = \mu + \beta_y + \alpha_{as} + \ f(l_i) + \ f(c_i) + m_r + n_{r,as} \ .$$

An annual index of herring abundance I_y was developed using the year effect coefficients from the GAMM for the amount of herring in stomachs b_y, and the probability of a stomach containing a herring β_y:

$$\hat{h}_y = e^{\mu + b_y};$$

$$\hat{p}_y = \frac{e^{\mu+\beta_y}}{\left(1+e^{\mu+\beta_y}\right)};$$

$$I_y = \hat{h}_y \times \hat{p}_y$$

where μ was the overall model intercept from one of the GAMMs. Estimating measures of uncertainty for this index is not straightforward because methods for combining uncertainty measures from the multistage sampling of the stomachs within the bottom-trawl survey and those from the separate GAMMs have not been developed. Approximate CVs were estimated, however, by summing the year effect variance parameters from each model, and then converting this aggregate variance to a CV for the annual indices of abundance.

The index of abundance was relatively imprecise (Figure B2- 9). The index of abundance was also sensitive to the data used in the GAMM models. Updating the time series through 2016 caused a decrease in the index, mostly in recent years (Figure B2- 10). Eliminating spiny dogfish stomach observations, the most common herring predator in the food habits database, caused a similar change (Figure B2- 11). Removing spiny dogfish had different effects on each of the GAMMs, with the scale of the probability of observing a herring decreasing with the removal of spiny dogfish and the variance among years in the amount of herring in stomachs reducing to near zero (Figure B2- 11). A retrospective analysis of the index of abundance, where one year of data is sequentially dropped from each of the models, was relatively stable (Figure B2- 12). Thus, the models used to derive the index of abundance were insensitive the number of years of data, but relatively sensitive the amount of data contained within each year and throughout the time series. This instability led the Working Group to eliminate the food habits index from consideration in assessment modeling, but assessment sensitivity runs were conducted and further research on this topic was encouraged.

Acoustic index

Water-column acoustic data were collected from 1998 to 2017 during the NEFSC's autumn stratified-random survey along the continental shelf from Cape Hatteras, North Carolina to Canadian waters in the Gulf of Maine (Figure B2- 13). Details of acoustic data acquisition, processing, and post-processing are detailed in Jech and Michaels (2006), Jech and Stroman (2012), Jech (2014), and Jech and Sullivan (2014) but a brief description is provided here.

All echosounders and frequencies were calibrated prior to each survey, and usually near the completion of the cruise using the standard target method (Foote et al., 1987). Transducers were calibrated using either copper (Cu) or tungsten carbide with 6% cobalt binder (WC) spheres, depending on year and conditions. For Cu spheres, a 64-mm diameter Cu sphere was used to calibrate the 18-kHz echosounders, a 60-mm Cu sphere was used to calibrate the 38-kHz echosounders, and a 23-mm Cu sphere was used to calibrate the 120-kHz echosounders. The 38.1-mm diameter WC was used to calibrate the 18, 38, 70 and 200-kHz echosounders.

Water-column acoustic data during the stratified-random bottom survey were collected continuously as the vessel transited between randomly-located trawl-haul sites and during all deployments (Figure B2- 13). Trawl locations were selected randomly within bathymetrically-defined strata for each cruise (Azarovitz et al., 1997). The sampling order was selected by minimizing travel time among trawl locations, thus while locations were random, the order was not. Data from 1998-2005 were collected on the NOAA ship *Albatross IV* (hereafter *Albatross IV*). Data collected from 2009-2012 were collected on the NOAA ship *Henry B. Bigelow* (hereafter *Bigelow*). Data collected during 2007-2008 were collected on both vessels as part of inter-ship comparison surveys (Miller et al., 2010). No data were collected in 2006 and data in 2010 were collected only to 50 m, thus were not used for analysis. An EK500 echosounder collected 12, 38, and 120-kHz data on the *Albatross IV* from 1998-2002. In 2003, the EK500 was replaced with 18-, 38-, and 120-kHz EK60 echosounders. The 12-kHz single-beam, and 18, 38, and 120-kHz split-beam transducers were located downward-looking on the keel. The *Bigelow* collected acoustic data from EK60 echosounders operating at 18, 38, 120, and 200 kHz from 2007-2012 and a 70 kHz EK60 echosounder was added in 2009. Beam angles were 16^{o} for the 12 kHz, 11^{o} for the 18 kHz, and 7^{o} for all other frequencies. The *Albatross IV*'s EK500 was calibrated in 1996, March 2001, and April 2002. The *Albatross IV*'s EK60 was calibrated in 2008, just before decommissioning. Gain settings for years without calibrations were applied from years with calibrations (Jech, 2014). The *Bigelow*'s EK60s were calibrated in spring 2007, and then immediately prior to each survey from 2008-2012. All calibrations followed protocols set from the systematic survey. *Bigelow* 38-kHz gain settings were very stable with ±0.1 dB variation over the calibrations.

Multi-frequency volume backscatter (S_v, dB·re 1 m^{-1}) data were post-processed and classified as described in Jech and Michaels (2006) and Jech (2014) using Myrix Echoview software (v8+; GPO Box 1387 Hobart, Tasmania, Australia, www.echoview.com). Briefly, echograms were scrutinized to remove acoustic and electrical noise, erroneous seafloor detections, data shallower than 10 m, and data deeper than 0.5 m above the sea floor. When 12 or 18, 38, and 120-kHz data were available, the indices of the echogram pixels that contained S_v values greater than -66 dB in all three frequencies were mapped to the 38-kHz echogram and that echogram was used to visually classify Atlantic herring. In cases where only one or two frequency data were available, a modified version of the methods described in Jech and Michaels (2006) was applied (Jech, 2014).

Visual scrutiny of the acoustic data from the stratified-random survey sometimes suggested the presence of Atlantic herring in the water column, but the species composition of the bottom trawl catch co-located or in the immediate vicinity of the acoustic data did not support apportioning acoustic backscatter to Atlantic herring (e.g., Figure B2- 14). In these cases, these aggregations were scrutinized as "unverified" Atlantic herring and used to evaluate the level of uncertainty in examining acoustic data collected during the stratified-random surveys.

After the S_v data were scrutinized for Atlantic herring, area backscattering, also known as nautical area scattering coefficient (NASC, m^2 nmi^{-2}; MacLennan et al. 2002), attributable to Atlantic herring, was generated by vertically integrating throughout the water column and horizontally averaging into 0.5 nmi elementary distance sampling units (EDSU). Geographical location, date, and time were associated with each s_A value. The final water-column data were 38-kHz s_A data classified as Atlantic herring s_A in 0.5 nmi EDSU. Data analyses were done in QGIS (QGIS Development Team, 2018), R statistical package (R Core Team, 2015), and PBS Mapping (Schnute et al., 2004).

The mean s_A ($\overline{s_A}(S_f, y)$) and standard deviation ($SD(S_f, y)$) were calculated annually for each finfish stratum (S_f) for a subset of offshore finfish strata (OS_f) where only offshore strata that had at least one occurrence of acoustic backscatter classified as Atlantic herring among the years were used (Figure B2- 15; Figure B2- 16; Figure B2- 17):

$$\overline{s_A}(S_f, y) = \frac{1}{N(S_f, y)} \sum_{i=1}^{N(S_f, y)} s_A(i) \qquad (1),$$

where the number of s_A values within each stratum were different among stratum and among years (y), and all s_A values were used regardless of activity, i.e., data during steaming and trawls were included. Those mean s_A values for each stratum and year were used to calculate a stratum-area (A_{S_f}) weighted mean ($\overline{s_A}(y)$) and variance ($Var(y)$) for each year:

$$\overline{s_A}(y) = \sum_{j=1}^{M} \frac{A_{S_f}(j)}{A_{OS_f}} \overline{s_A}(j, y) \qquad (2),$$

$$Var(y) = \sum_{j=1}^{M} \left[\left(\frac{A_{S_f}(j)}{A_{OS_f}} \right)^2 \frac{SD_j(S_f, y)^2}{N_j(S_f, y)} \right] \qquad (3),$$

where there were M = 49 offshore strata used in this analysis, j indexes strata, and A_{OS_f} is the total area (nmi^2) of all 49 offshore strata. Table B2- 1 provides the mean and variance estimates for the offshore strata from 1998 to 2017.

Table B2- 1 Stratum-area weighted mean ($\overline{s_A}(y)$) and variance ($Var(y)$) estimates for the offshore strata where acoustic backscatter was classified as Atlantic herring for each year.

Year	Mean	Var
1998	114.85	344.14
1999	78.04	23.84
2000	191.80	2726.22
2001	112.21	120.15
2002	113.92	123.23
2003	33.83	33.05
2004	117.57	1048.22
2005	33.76	11.56
2007	33.08	71.00
2007	32.55	25.76
2008	4.54	0.27
2008	40.74	17.41
2009	52.74	22.92
2011	41.50	76.18
2012	64.65	38.43
2013	51.76	13.61
2014	93.05	68.06
2015	44.15	8.42
2016	40.48	4.54
2017	37.68	19.90

Figure B2- 1 NMFS offshore bottom trawl survey strata

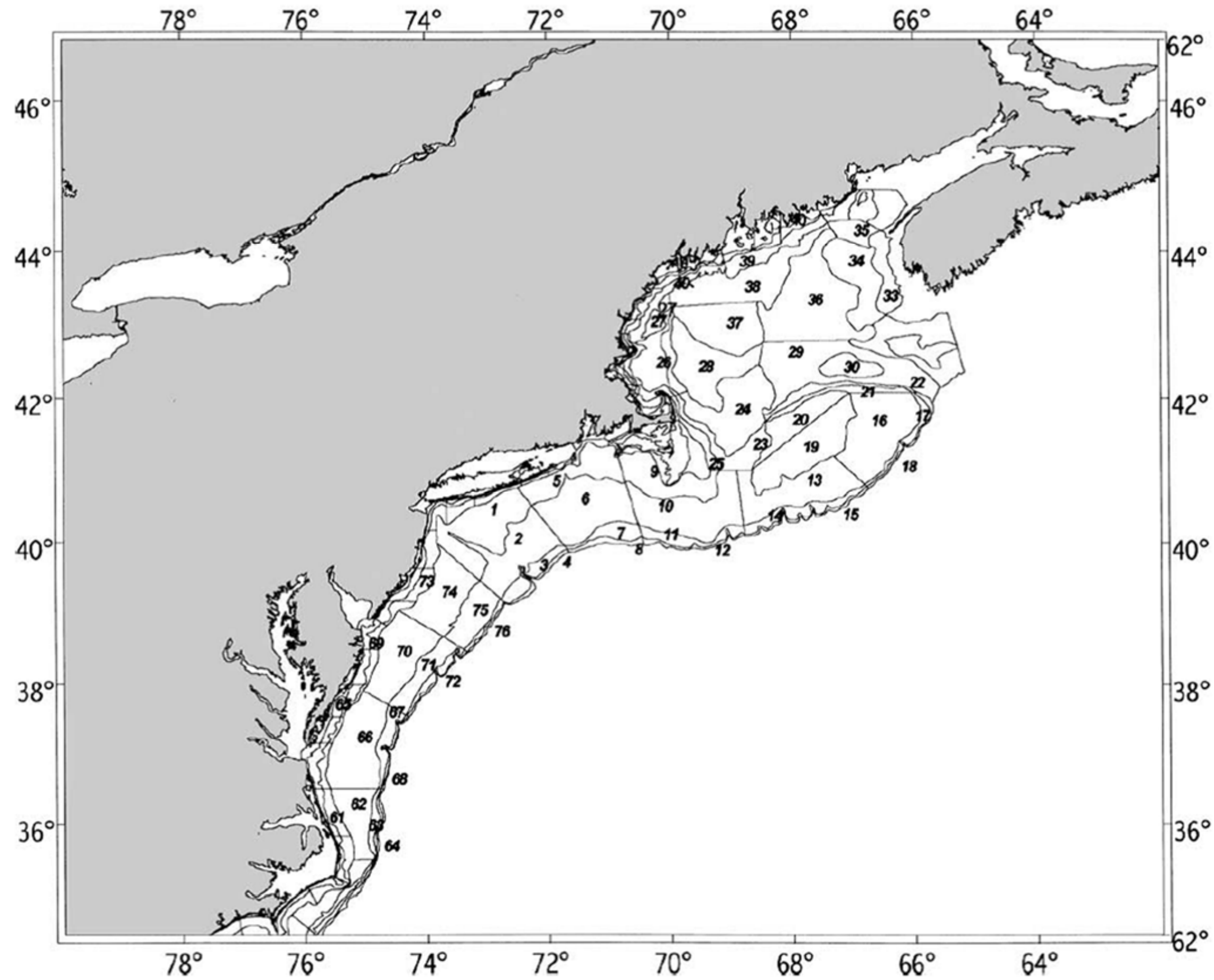
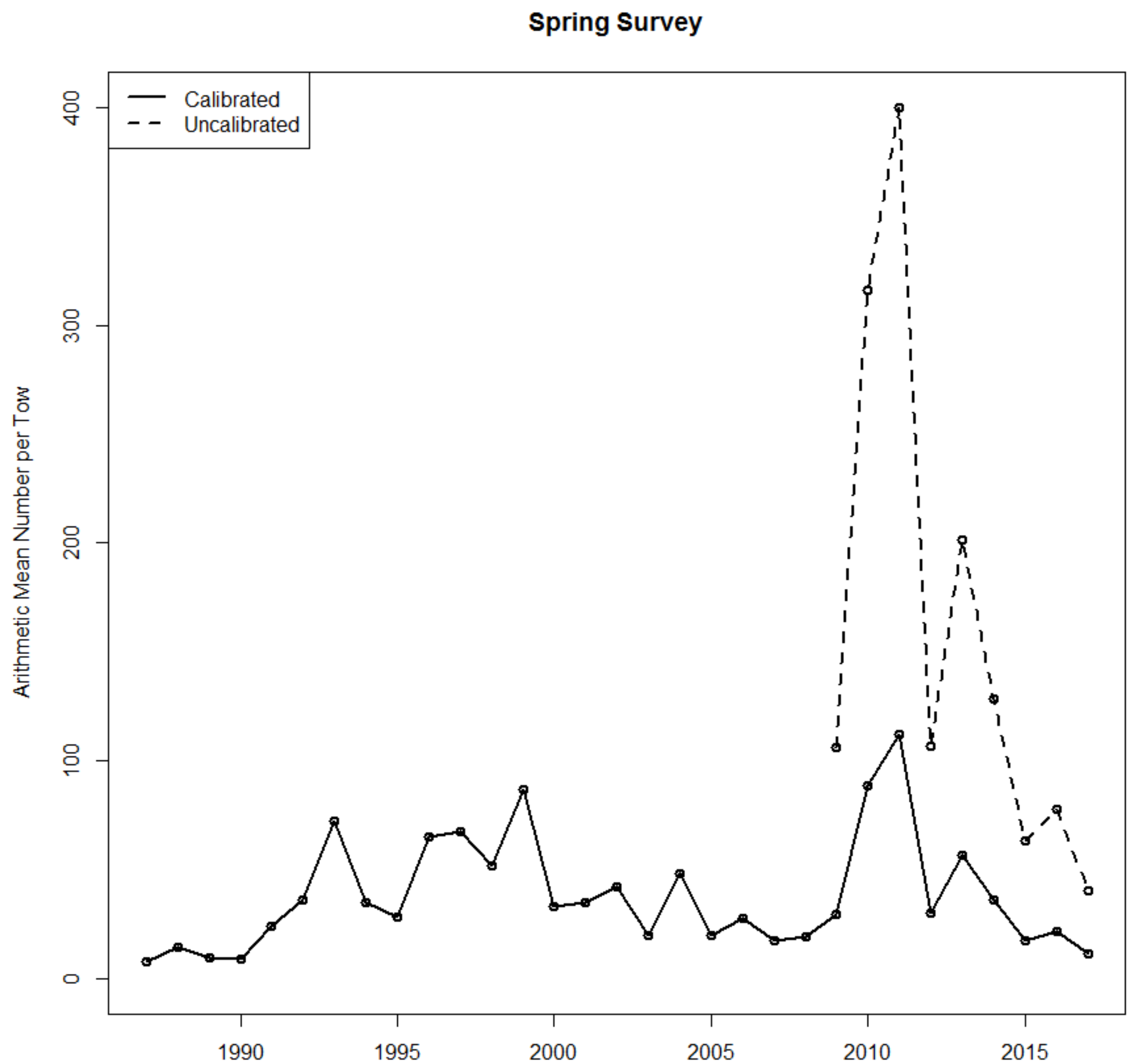


Figure B2- 2 Time series of NMFS spring bottom trawl survey Atlantic herring abundance indices with and without 90%CI.



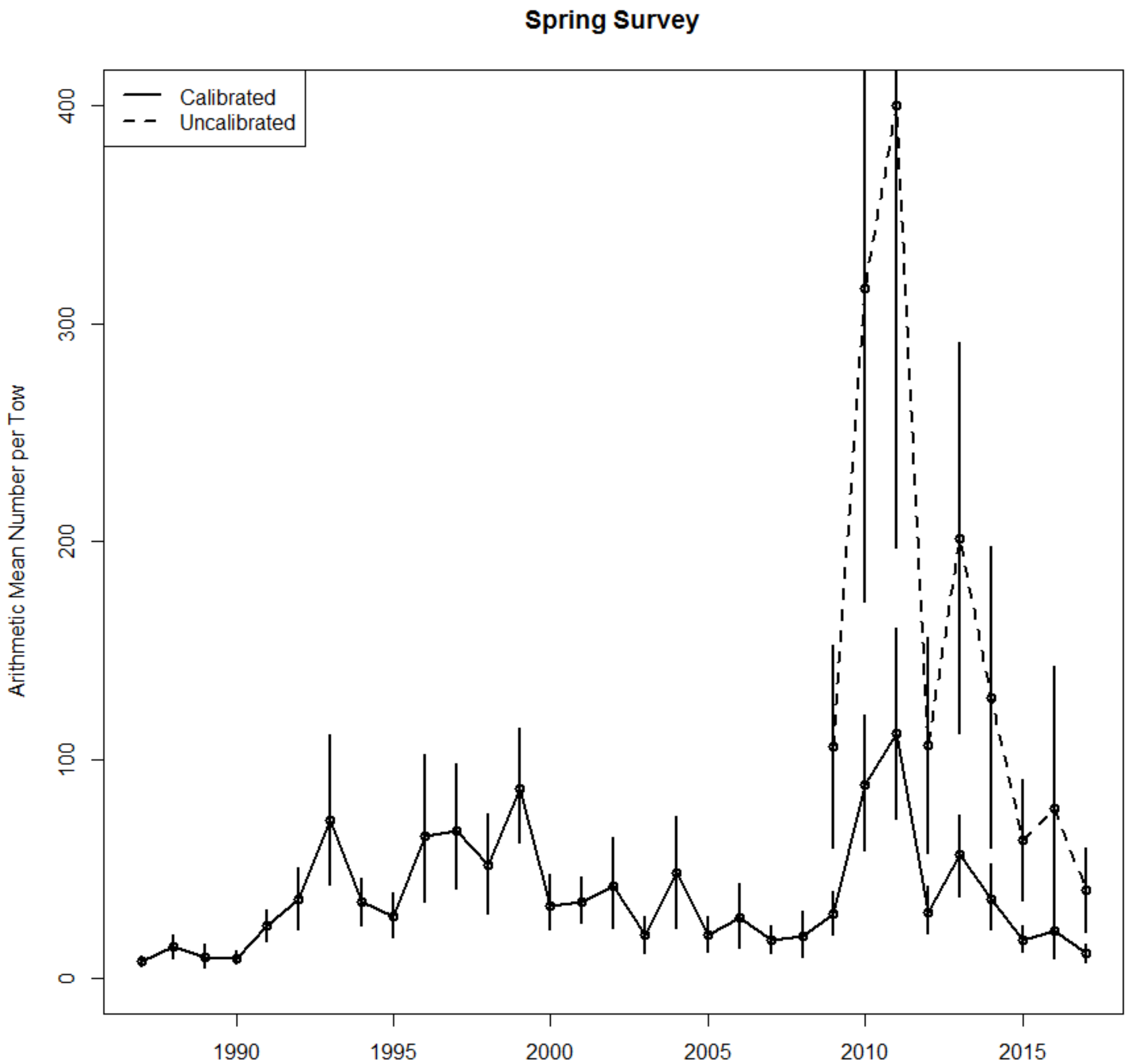
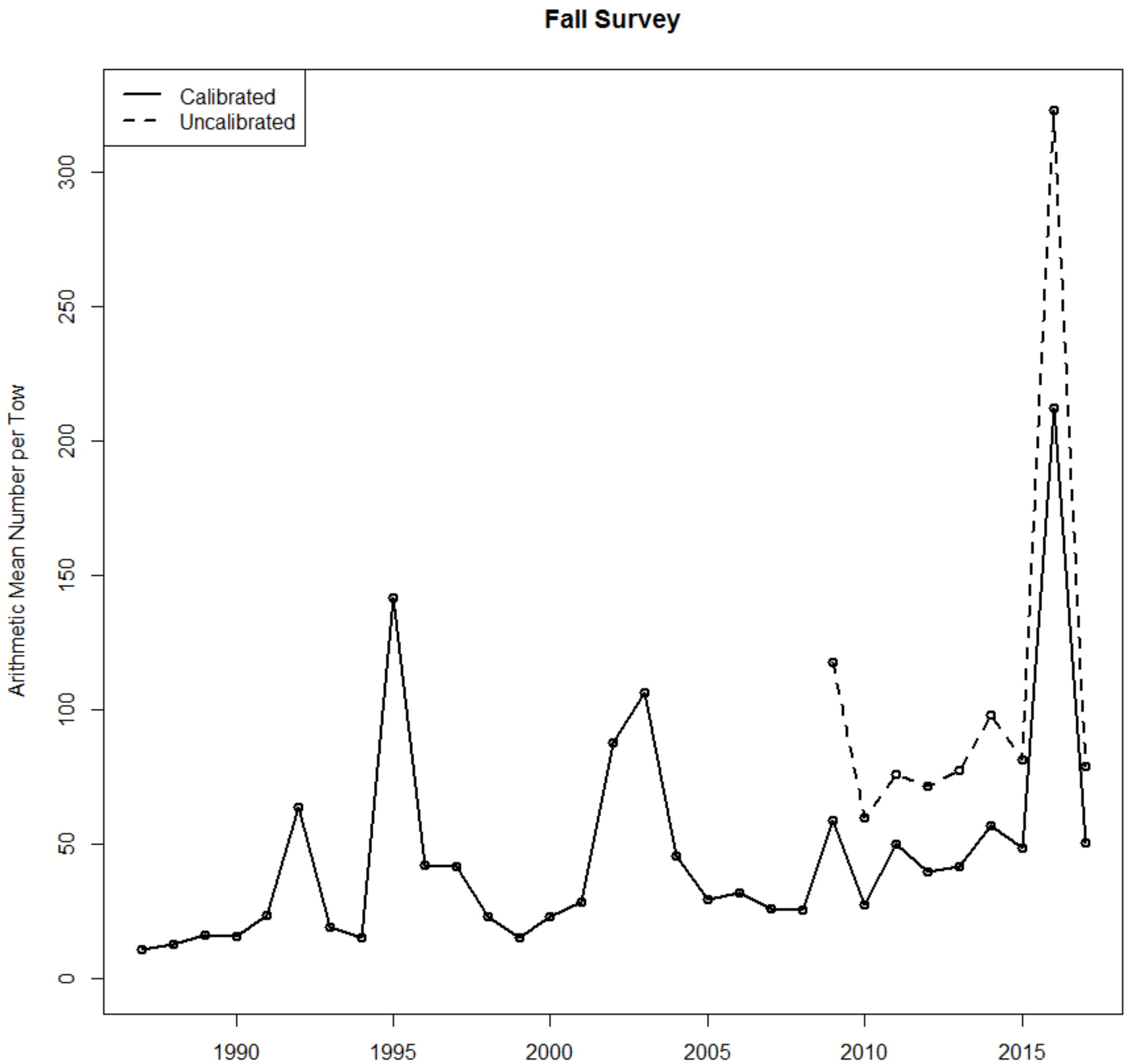

Spring Survey
Calibrated
Uncalibrated
Arithmetic Mean Number per Tow
0
100
200
300
400
1990
1995
2000
2005
2010
2015

Figure B2- 3 Time series of NMFS Fall bottom trawl survey Atlantic herring abundance indices with and without 90%CI



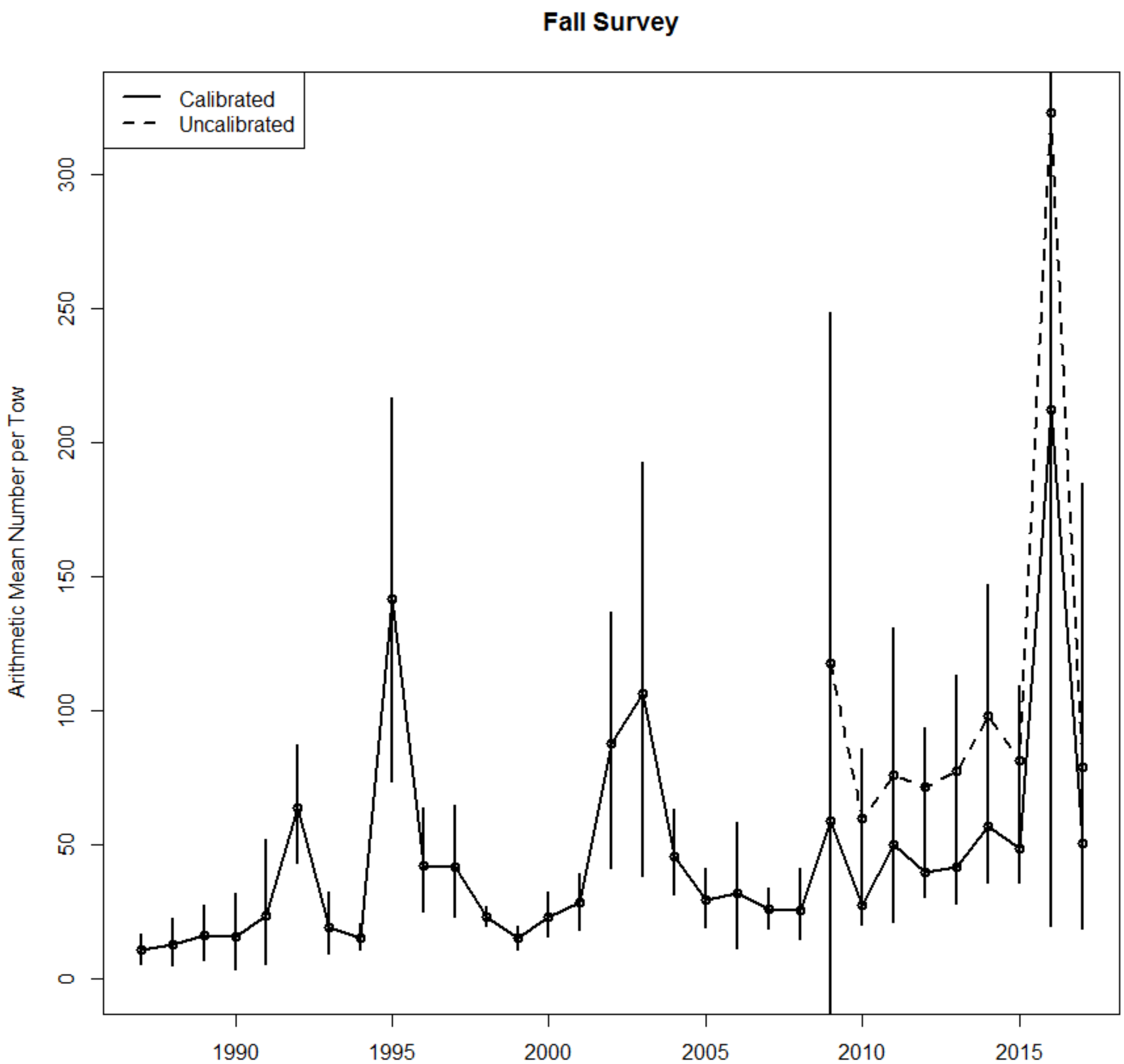
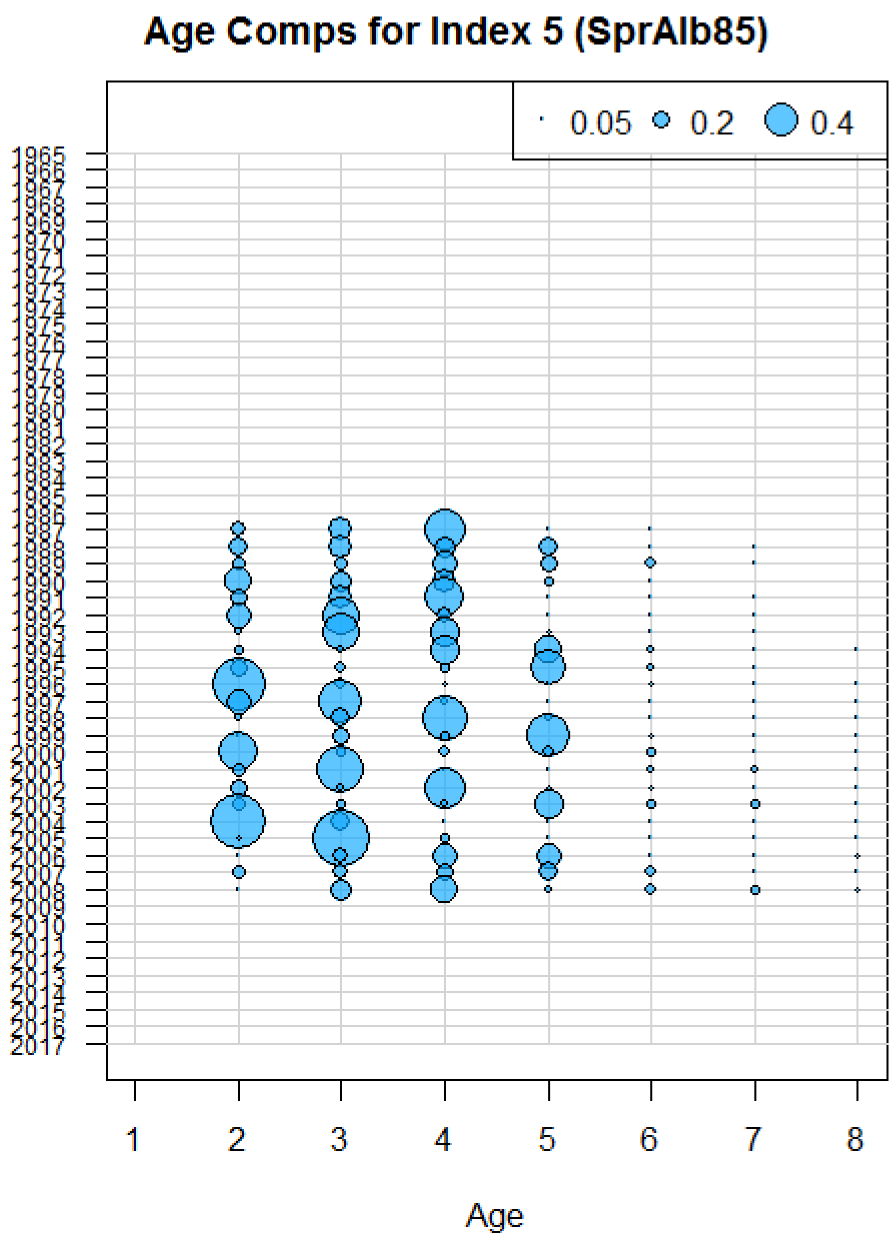
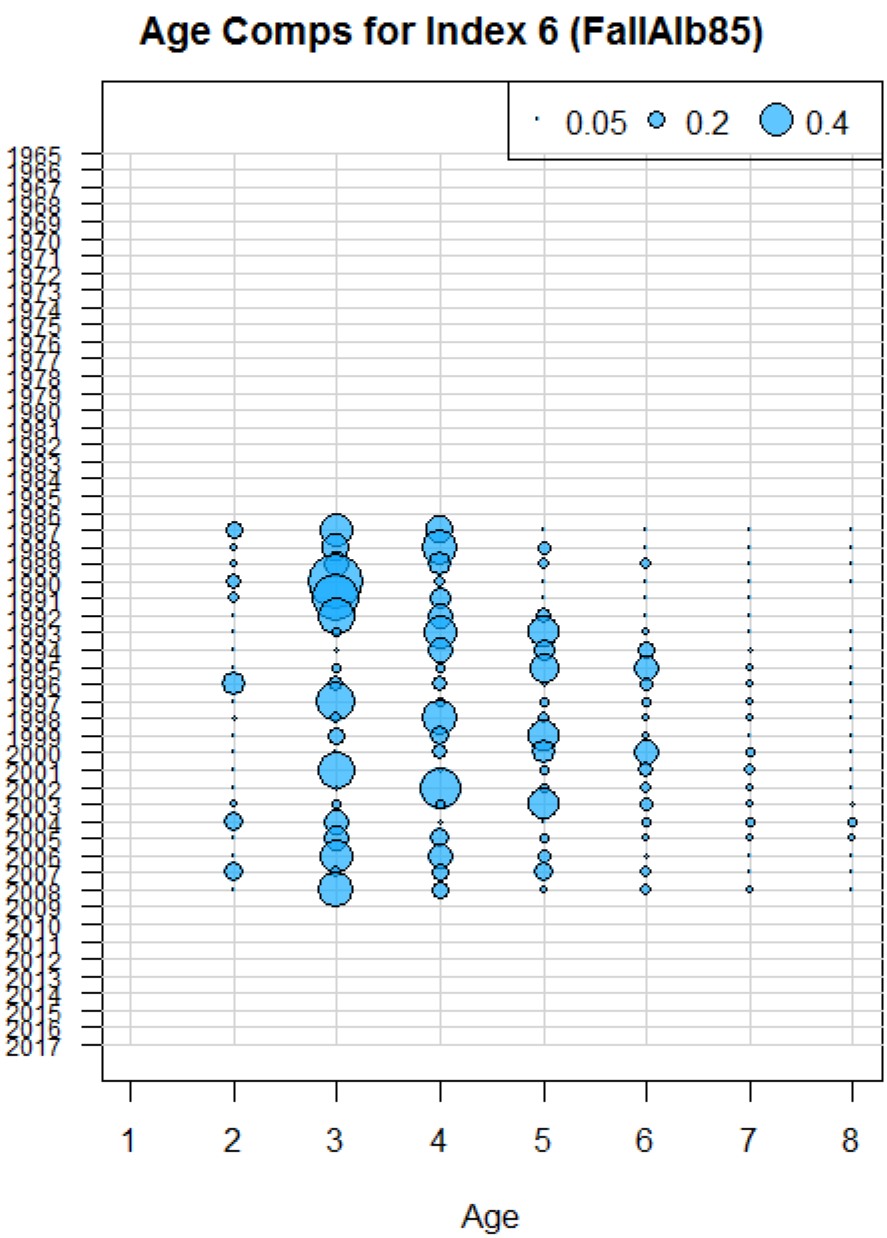
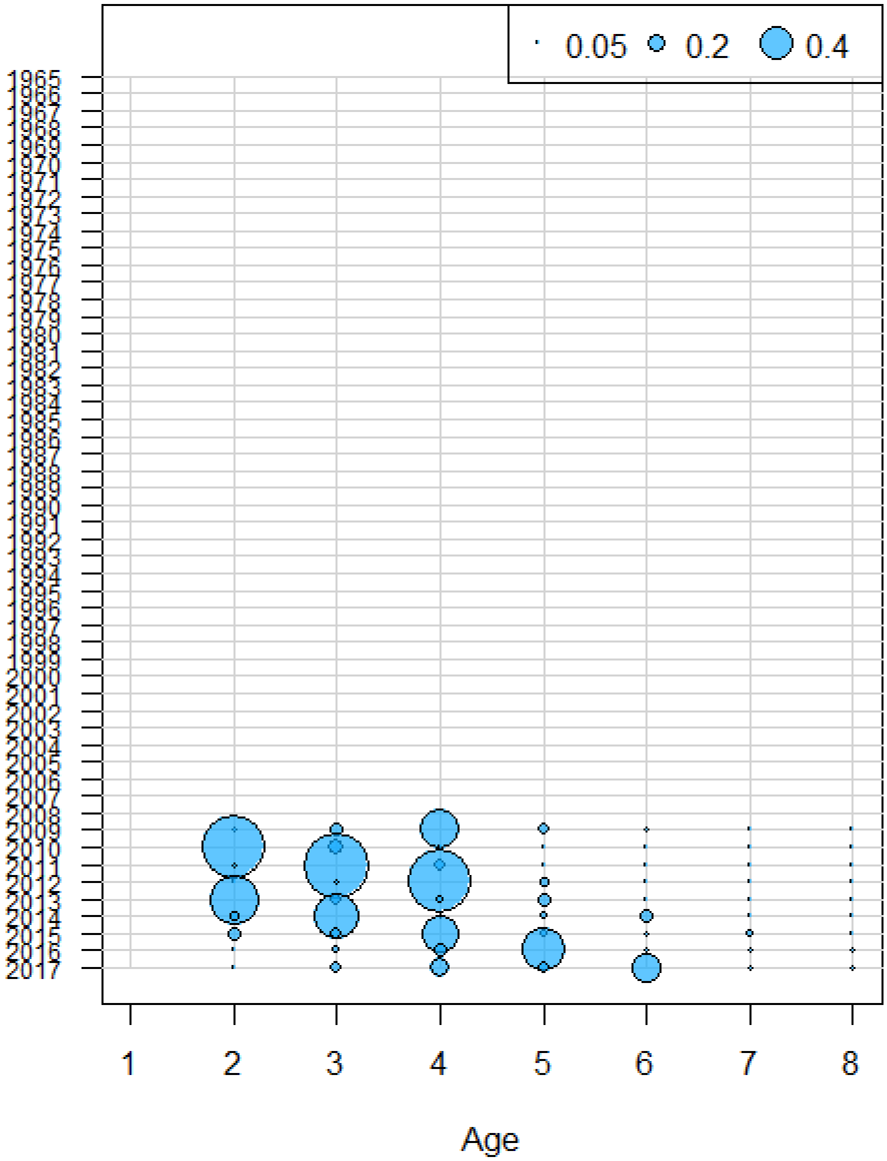

Fall Survey
Calibrated
Uncalibrated
Arithmetic Mean Number per Tow
0
50
100
150
200
250
300
1990
1995
2000
2005
2010
2015

Figure B2- 4 Atlantic herring proportions at age for the spring Albatross years (SprAlb85), spring Bigelow years (SprBig), fall albatross years (FallAlb85), and fall Bigelow years (FallBig)




Age Comps for Index 6 (FallAlb85)
0.05
0.2
0.4
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
1
2
3
4
5
6
7
8
Age

Age Comps for Index 7 (SprBig)



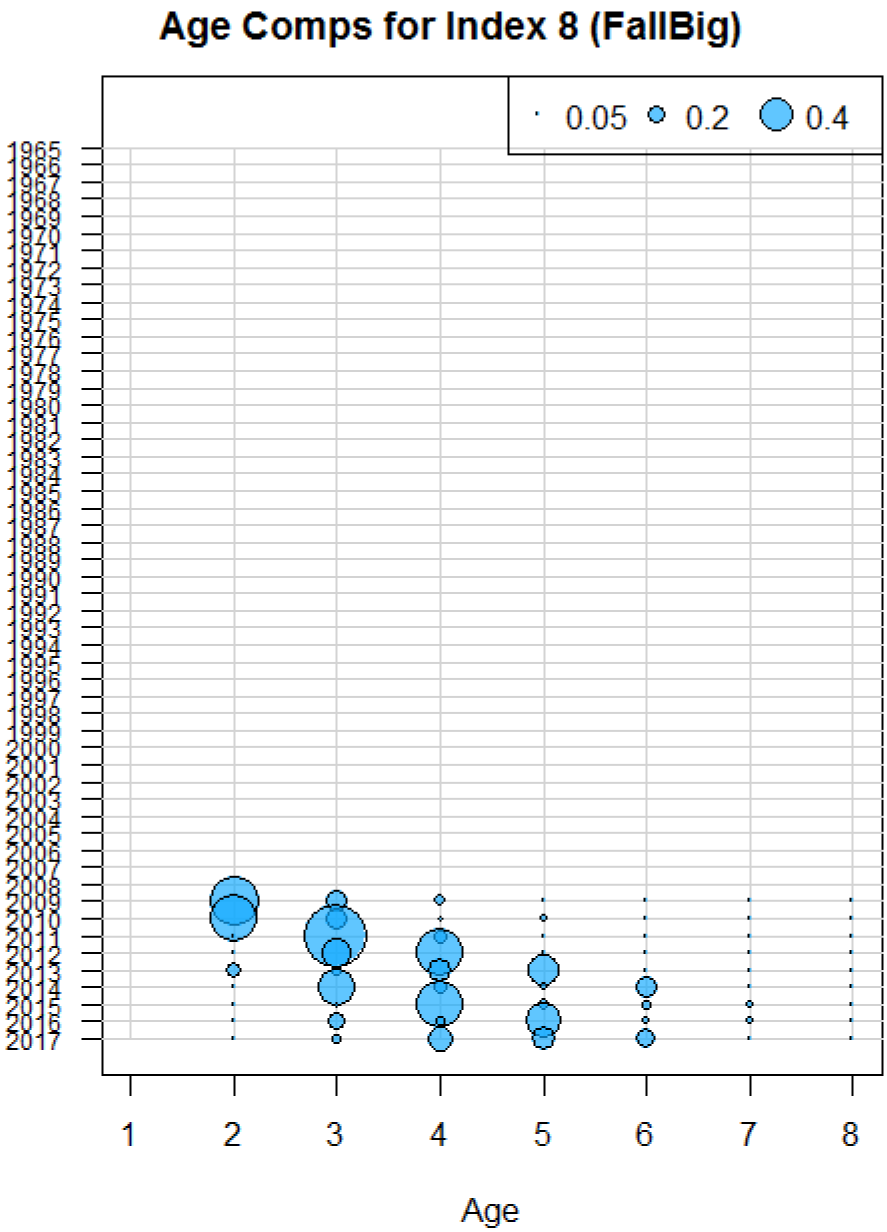
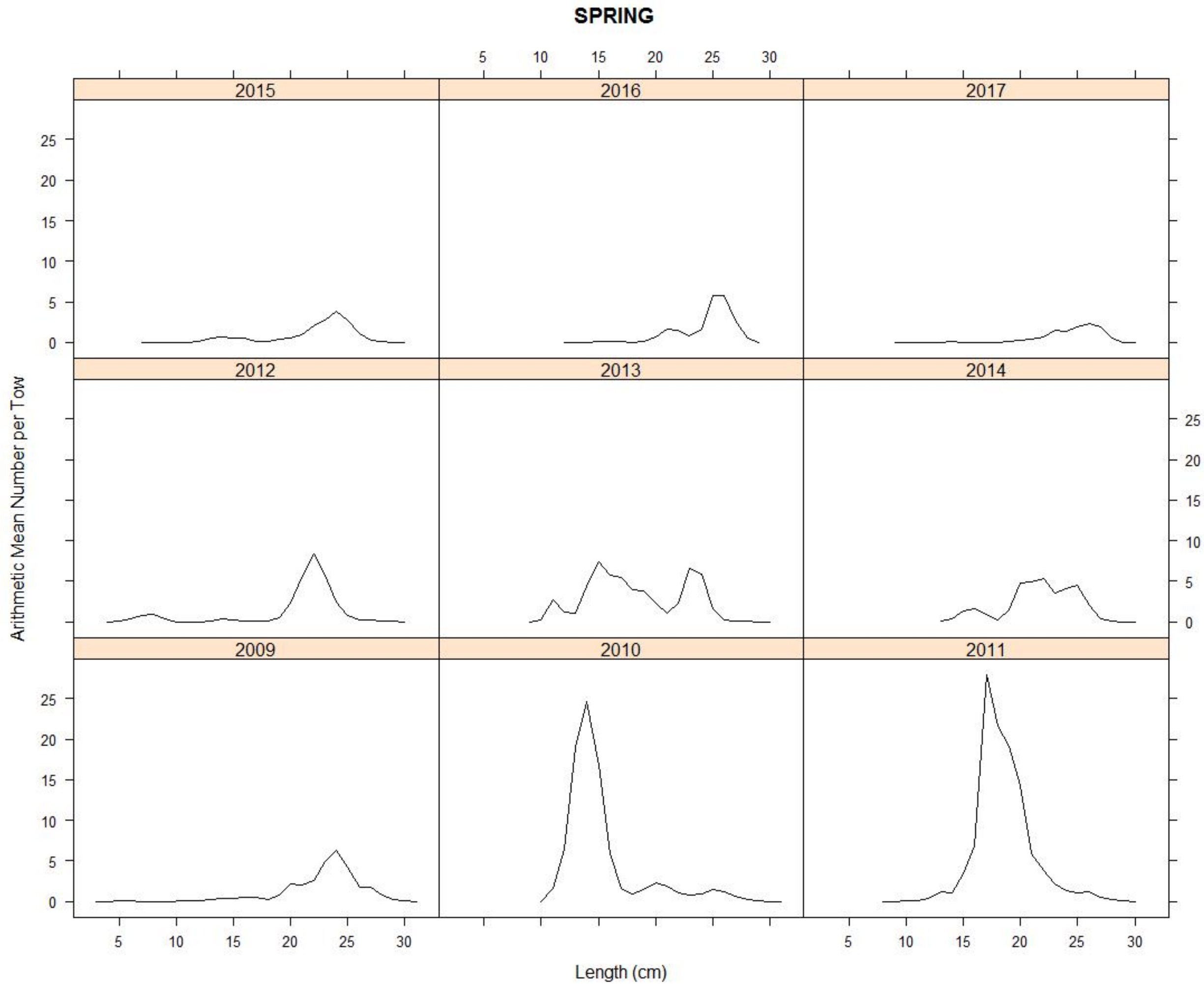
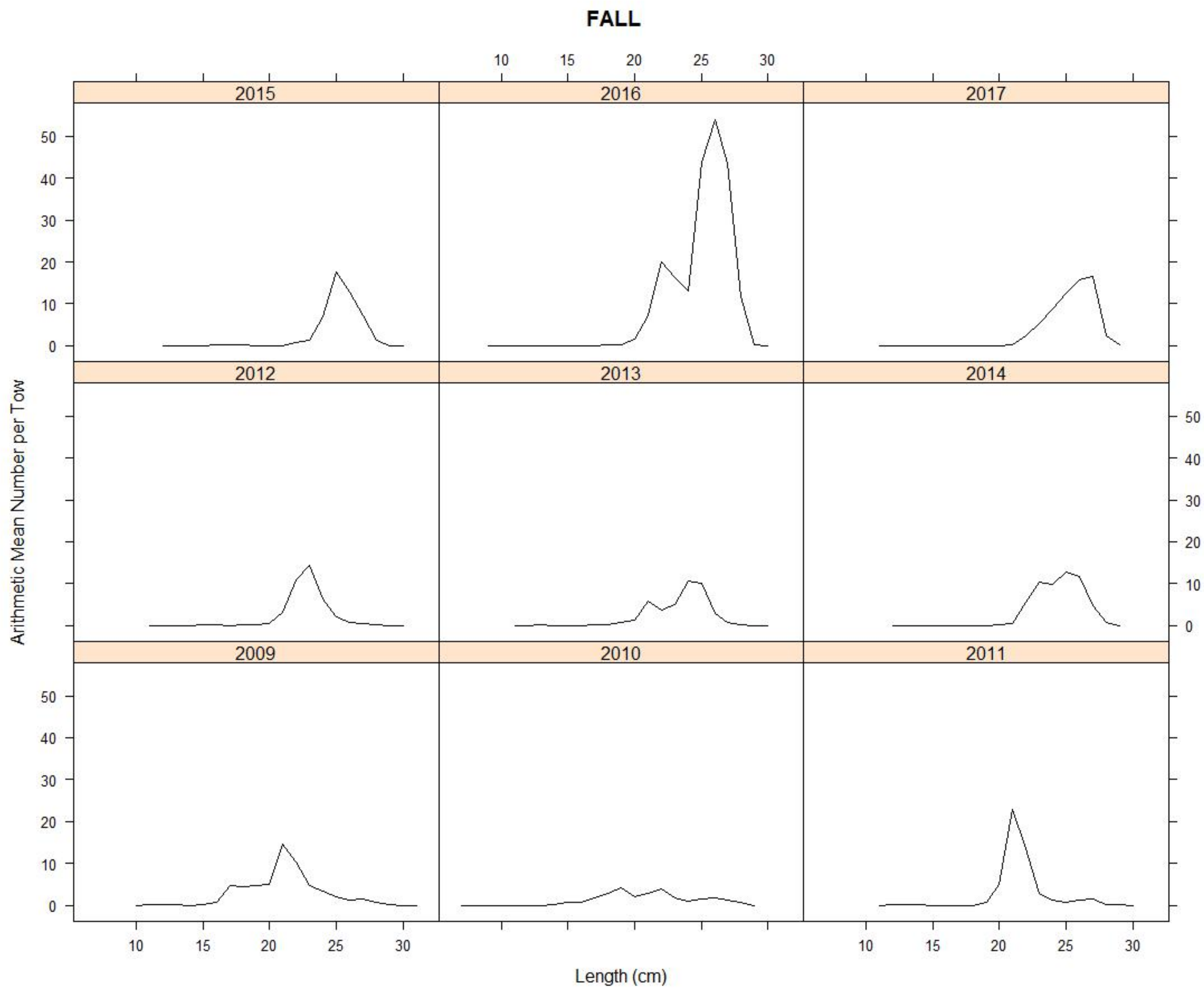

Age Comps for Index 8 (FallBig)
0.05
0.2
0.4
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
1
2
3
4
5
6
7
8
Age

Figure B2- 5 Atlantic herring length frequency from NMFS spring, fall, and summer (shrimp) bottom trawl surveys




FALL
2015
2016
2017
2012
2013
2014
2009
2010
2011
Arithmetic Mean Number per Tow
Length (cm)
0
10
20
30
40
50
10
15
20
25
30

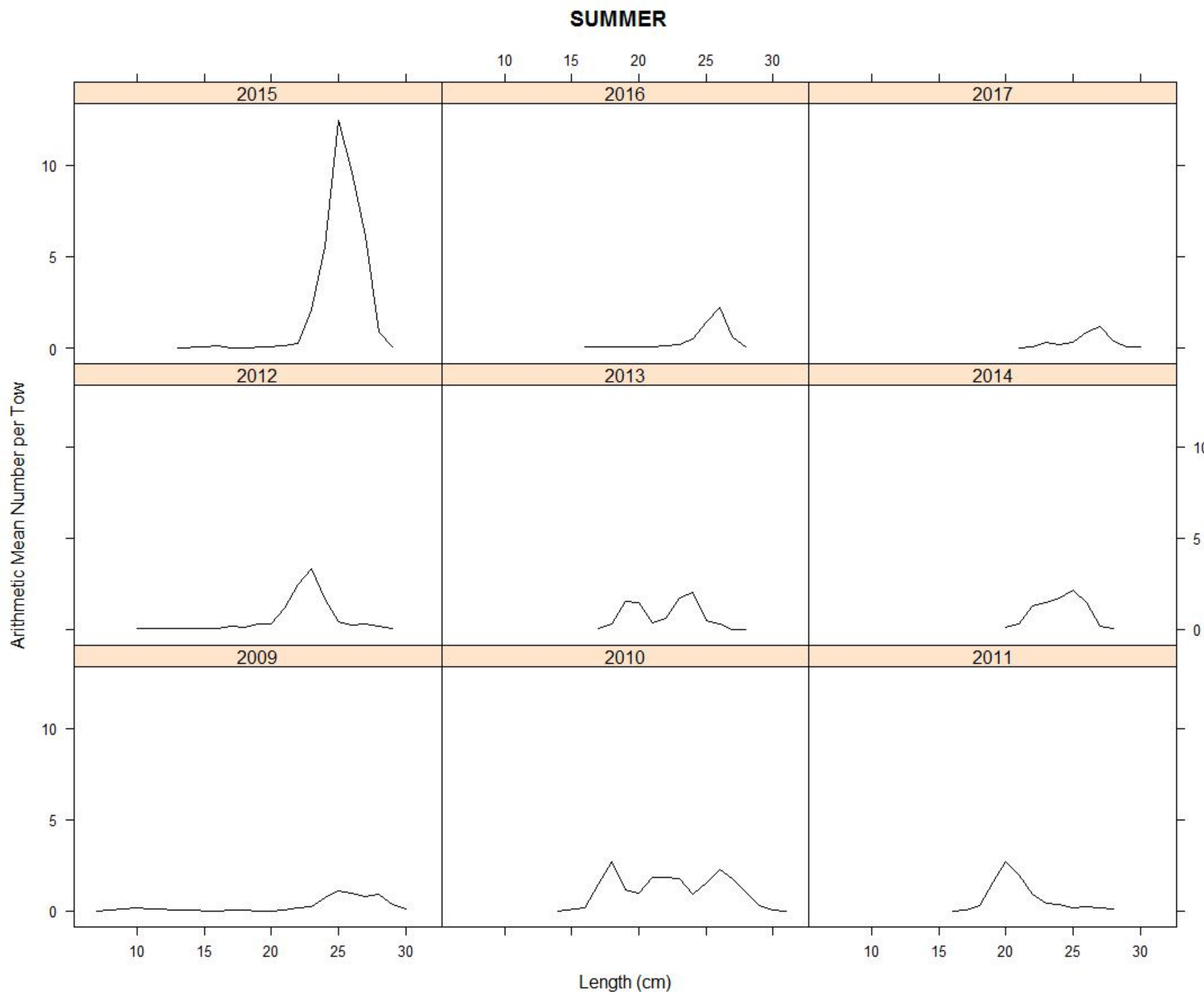

SUMMER
2015
2016
2017
2012
2013
2014
2009
2010
2011
Arithmetic Mean Number per Tow
Length (cm)
0
5
10
15
20
25
30

Figure B2- 6 Location of tows taken during the NMFS summer (shrimp) survey 1983-2017.

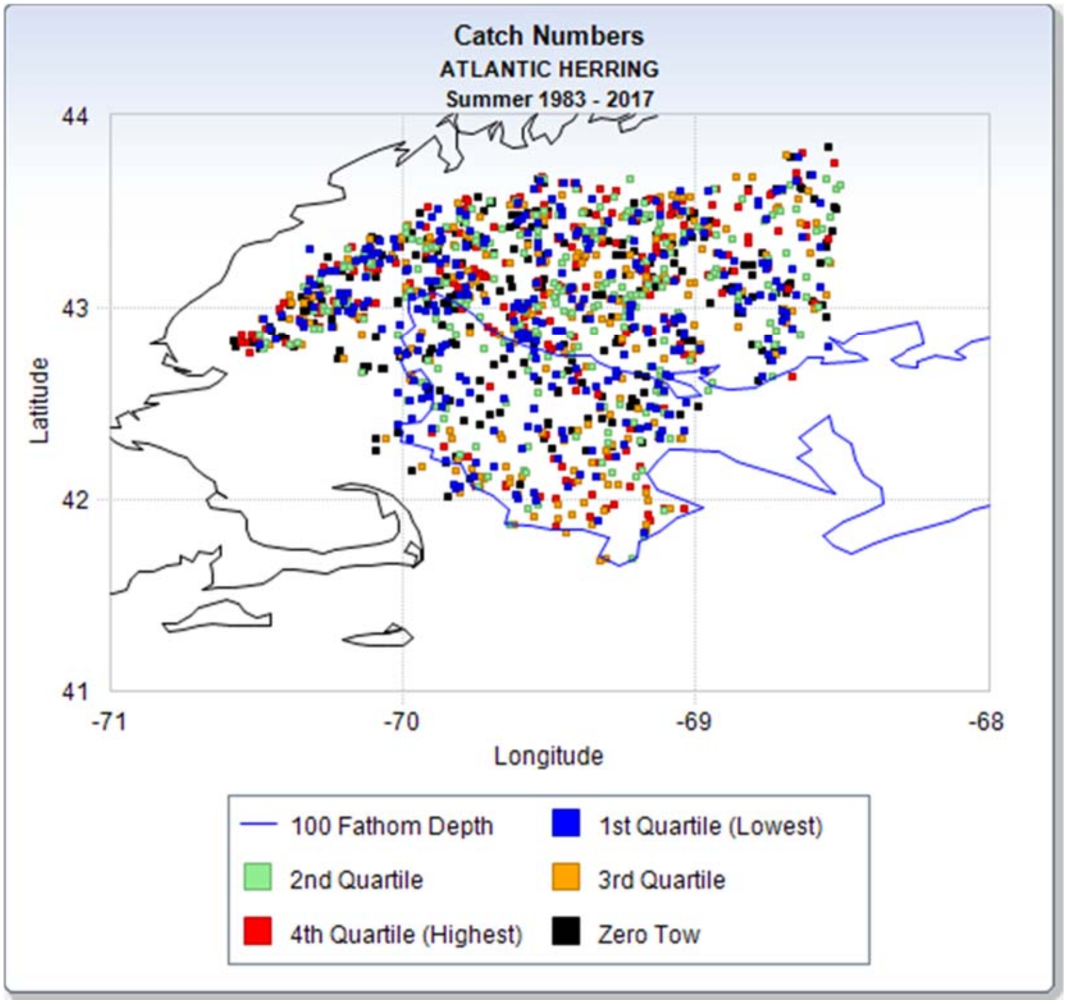


Figure B2- 7 Summer NMFS bottom trawl survey abundance index time series for Atlantic herring with 90%CI

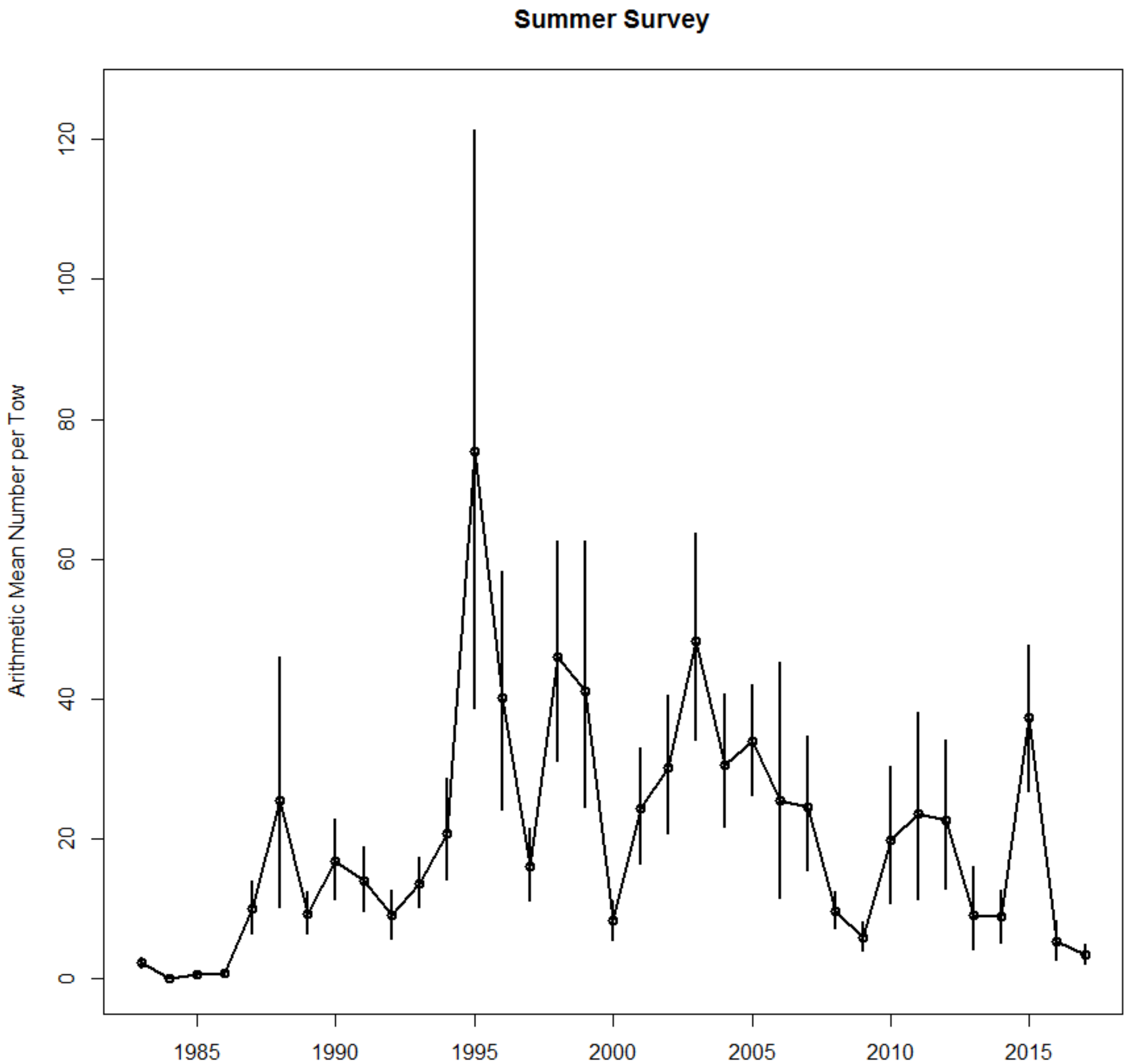


Figure B2- 8 Atlantic herring proportions at age from the NMFS summer (shrimp) survey.

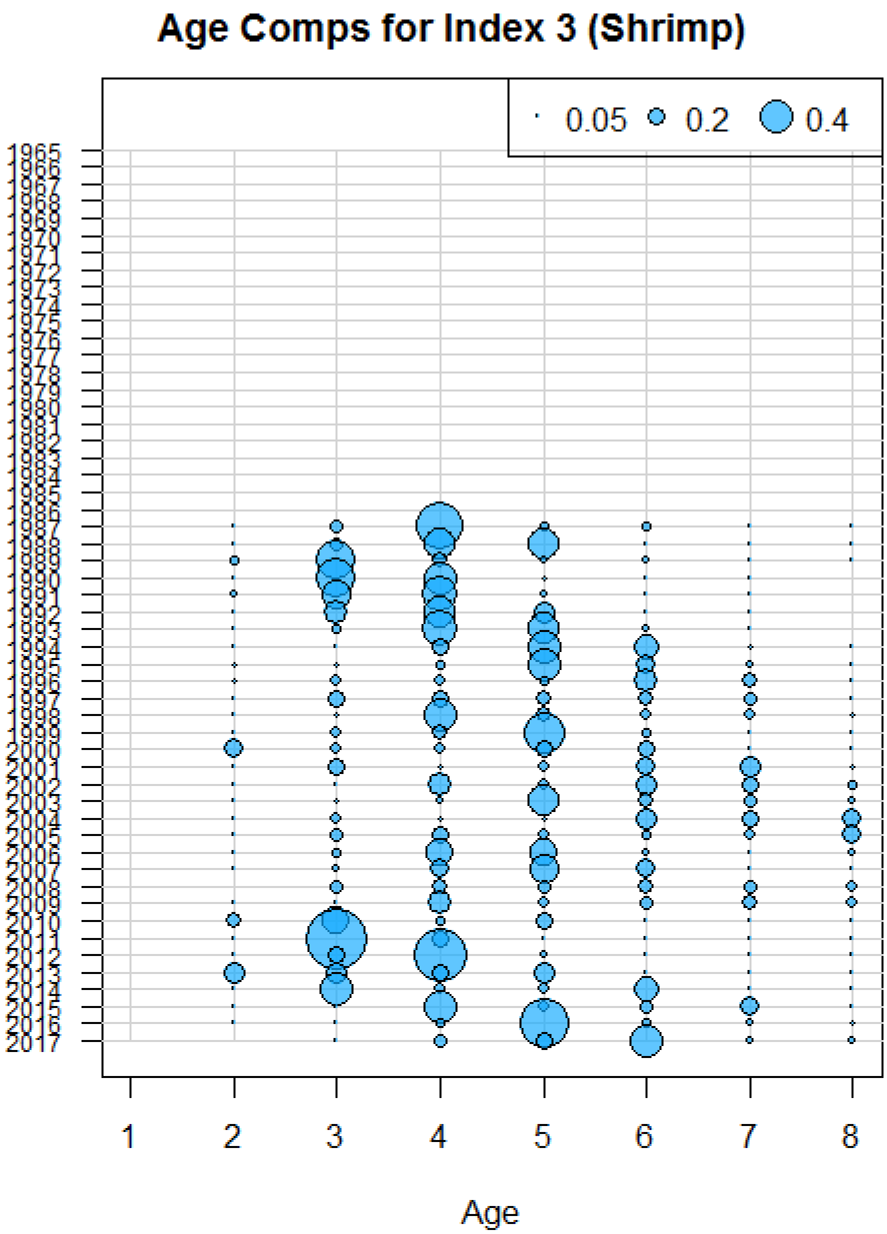


Figure B2- 9 Index of herring abundance derived from NEFSC stomach contents data +/- 2SD

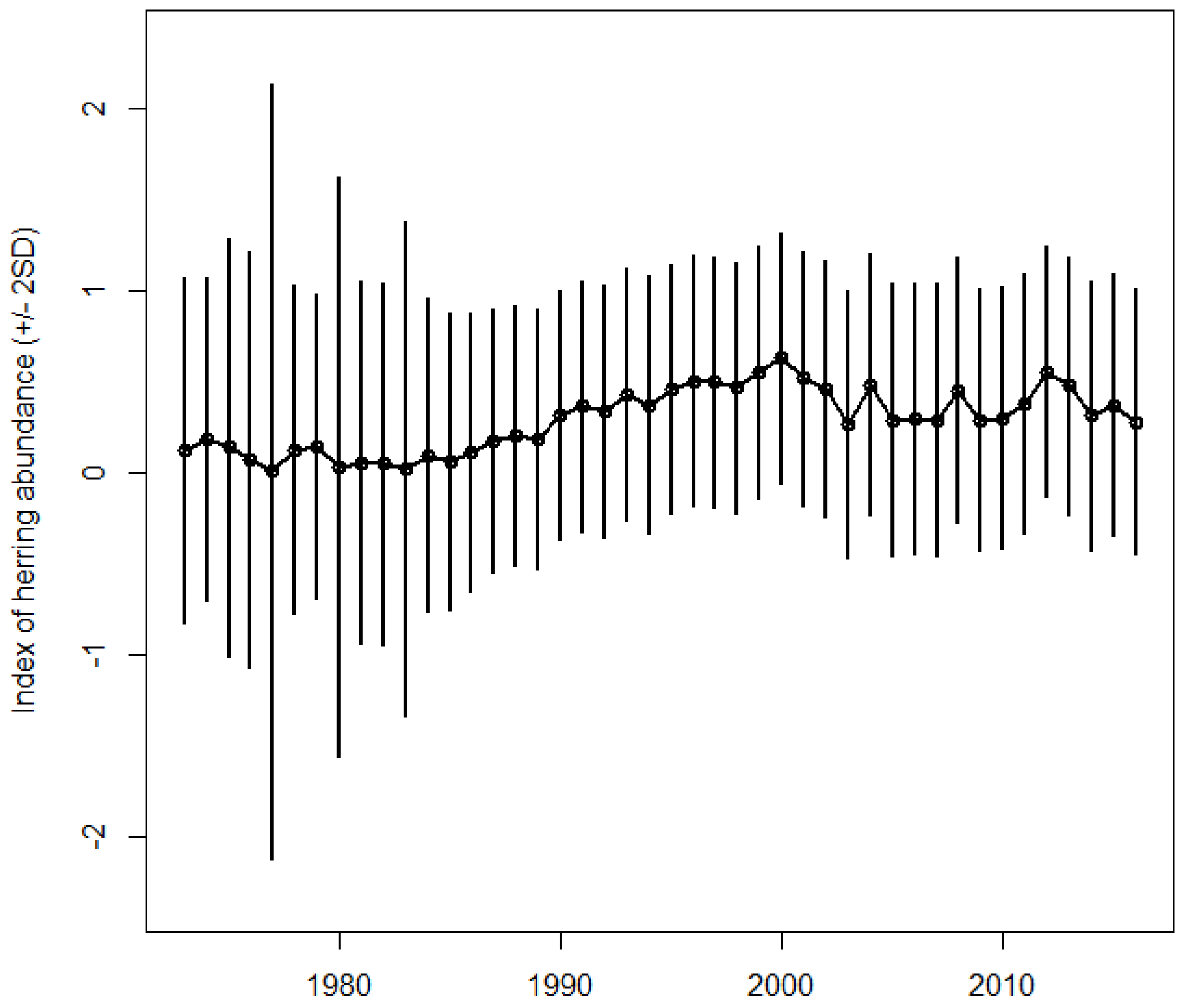


Figure B2- 10 Index of herring abundance derived from stomach contents data using data through 2014 (red) and with revisions to data during 2012-2014 and updated through 2016 (black)

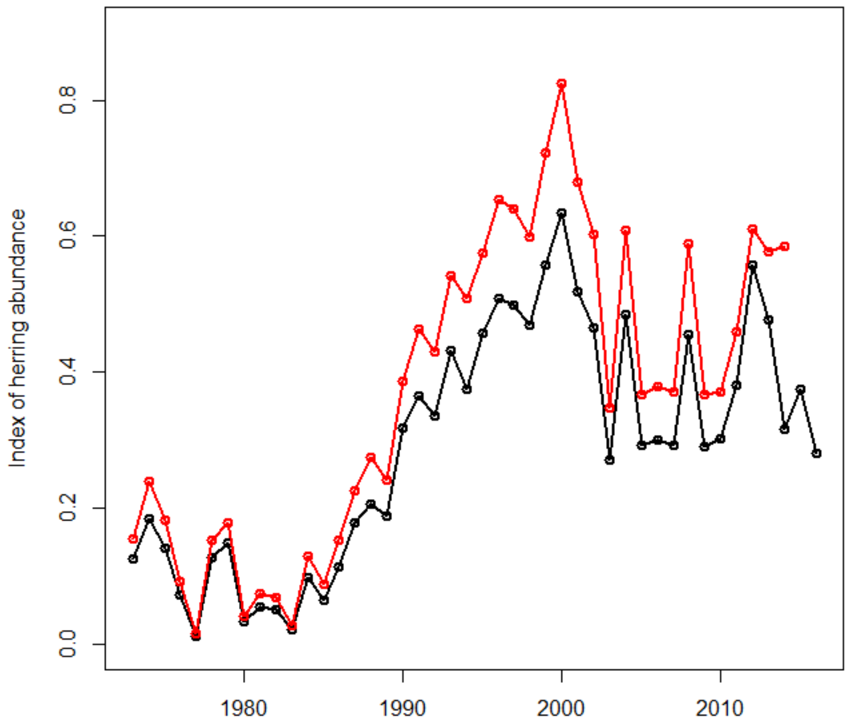
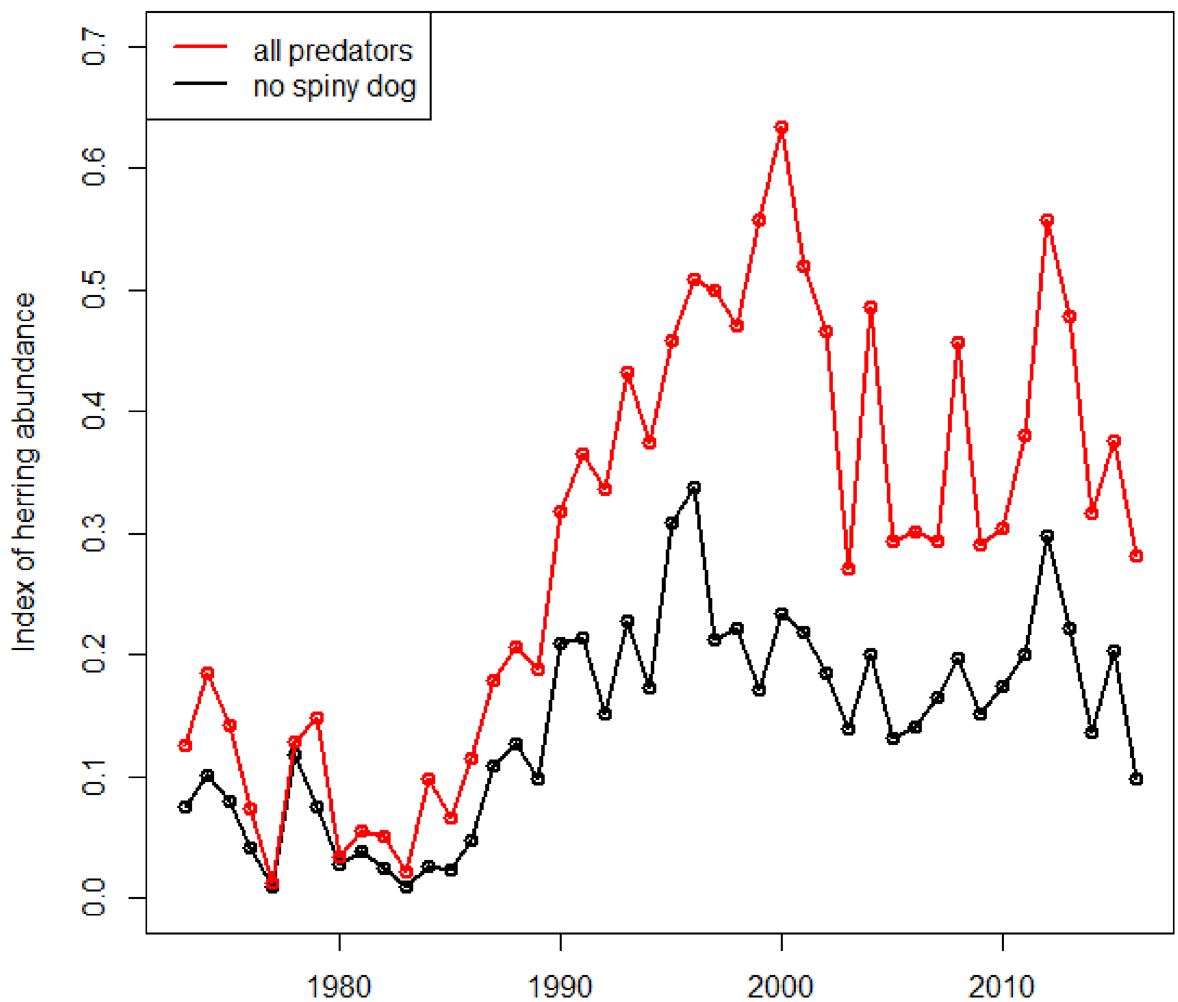
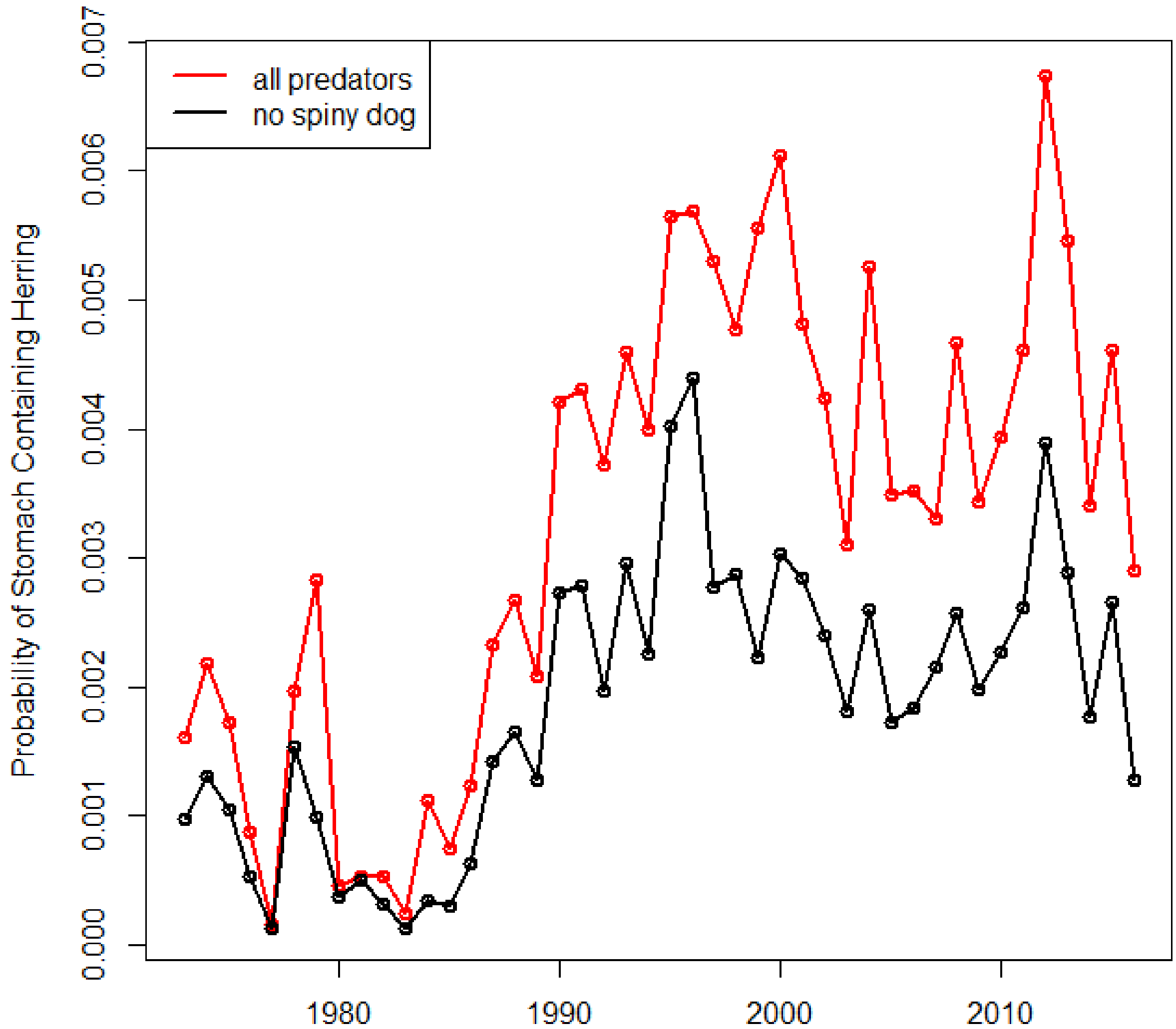


Figure B2- 11 Effect of removing spiny dogfish observations from the index of herring abundance derived from stomach contents data, and the effect on each element of the hurdle model used to create the index




all predators
no spiny dog
Probability of Stomach Containing Herring
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
1980
1990
2000
2010

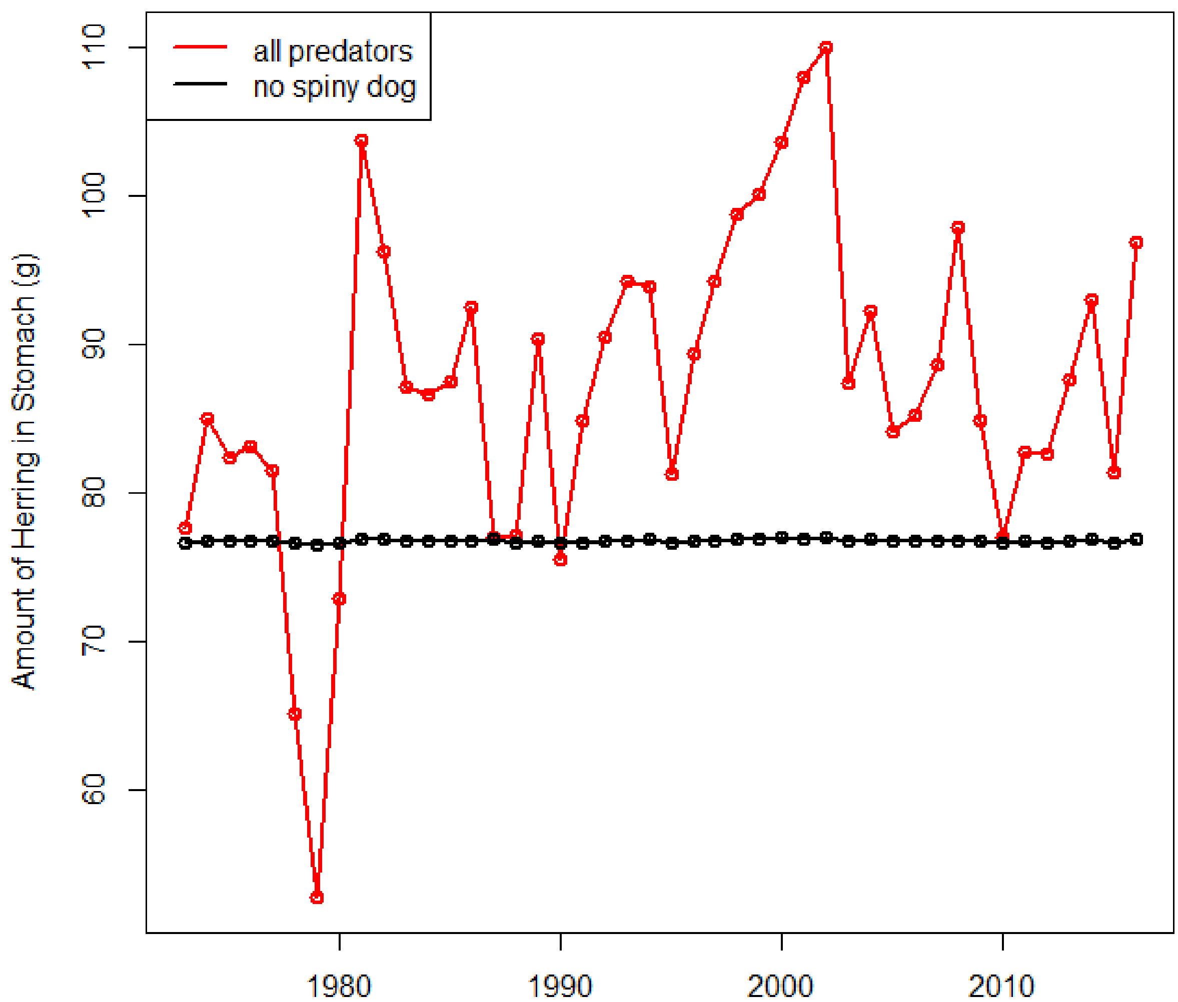

all predators
no spiny dog
Amount of Herring in Stomach (g)
110
100
90
80
70
60
1980
1990
2000
2010

Figure B2- 12 Relative retrospective pattern for the index of herring abundance derived from stomach contents data

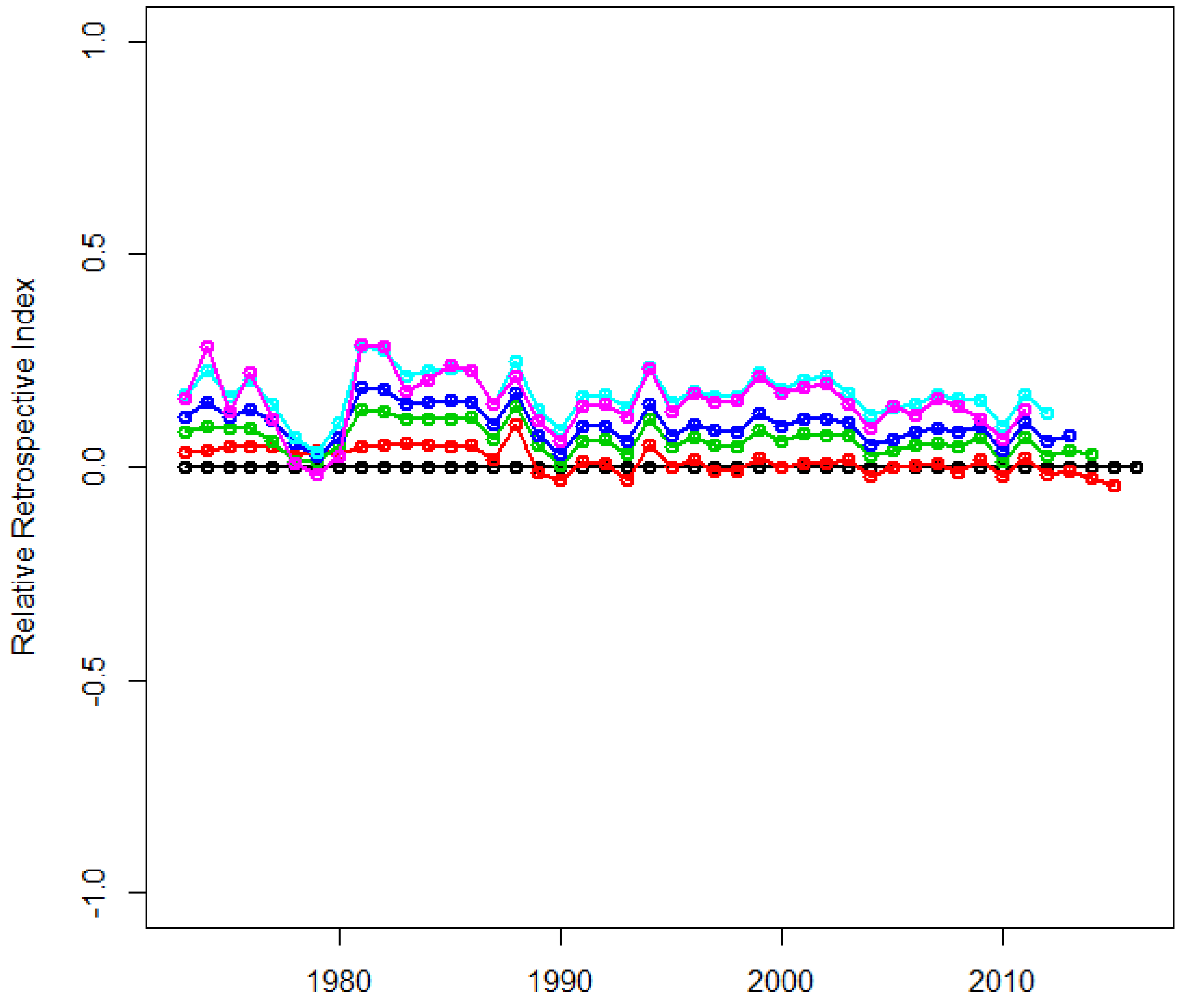


Figure B2- 13 Distribution of acoustic backscatter classified as Atlantic herring along the cruise track during the fall bottom trawl survey in 2016 on the HB Bigelow. Symbol size and color is related to areal acoustic backscatter, s_A (m^2 nmi^{-2}).

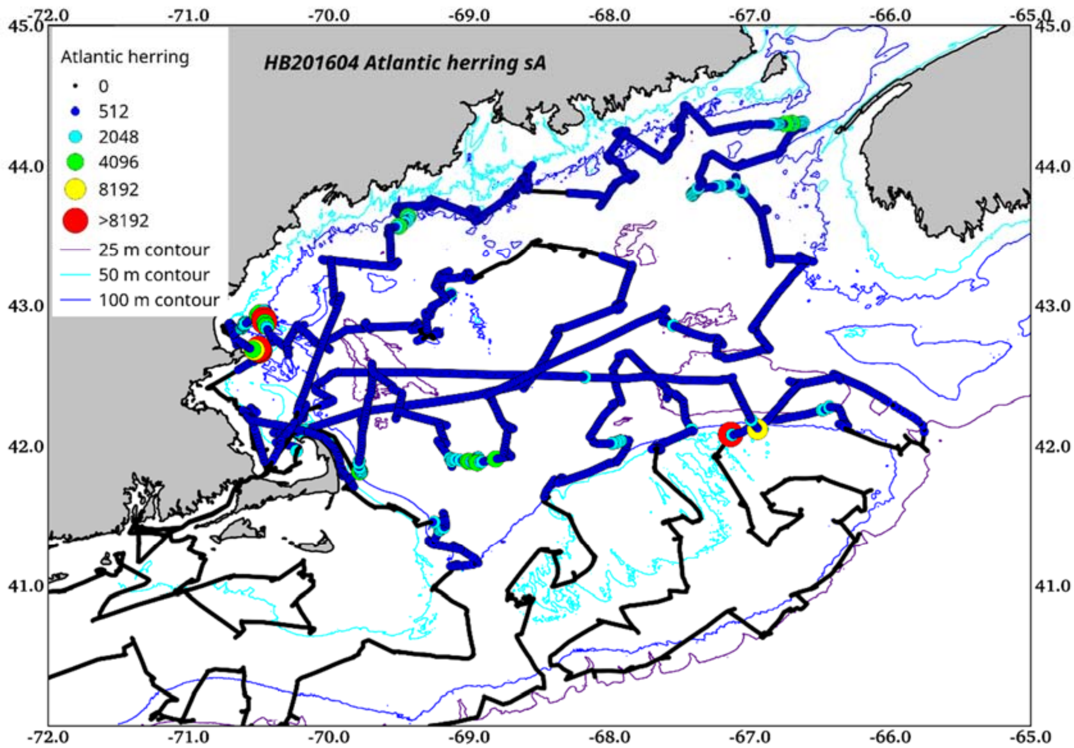


Figure B2- 14 Echogram of acoustic backscatter in the upper water column where the species composition can not be verified because the bottom trawl did not adequately sample these aggregations.

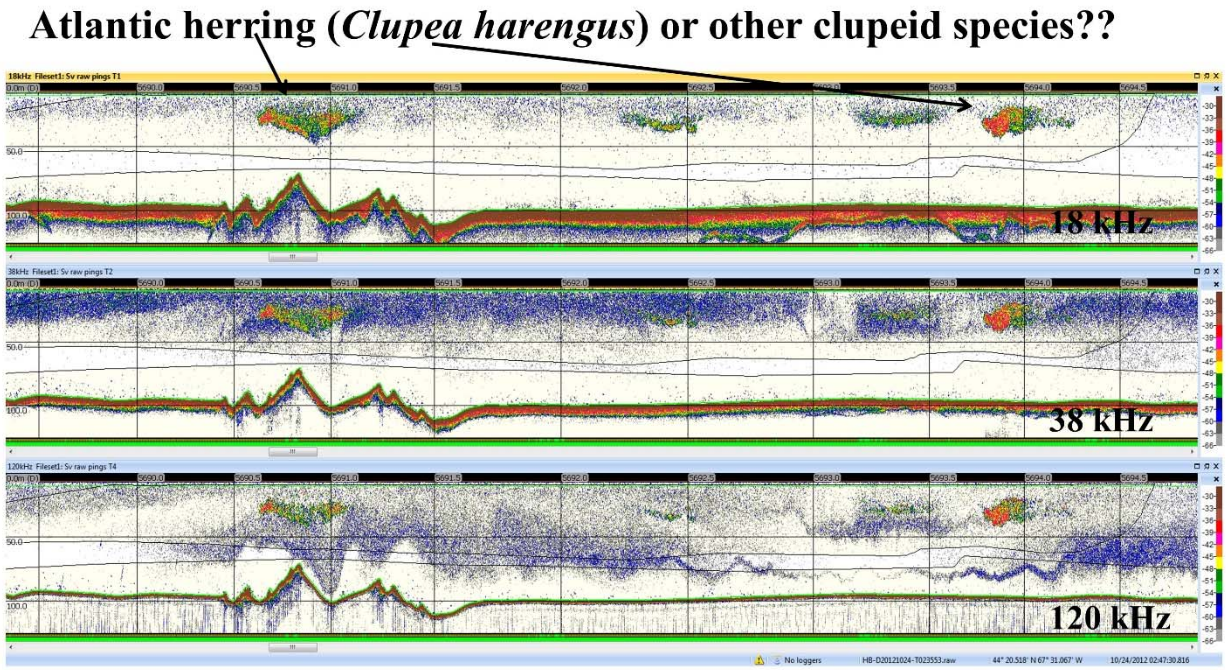


Figure B2- 15 The finfish strata are shown in green. The "acoustic area" encompasses all strata where used to aggregate acoustic backscatter classified as Atlantic herring throughout the years from 1998-2017.

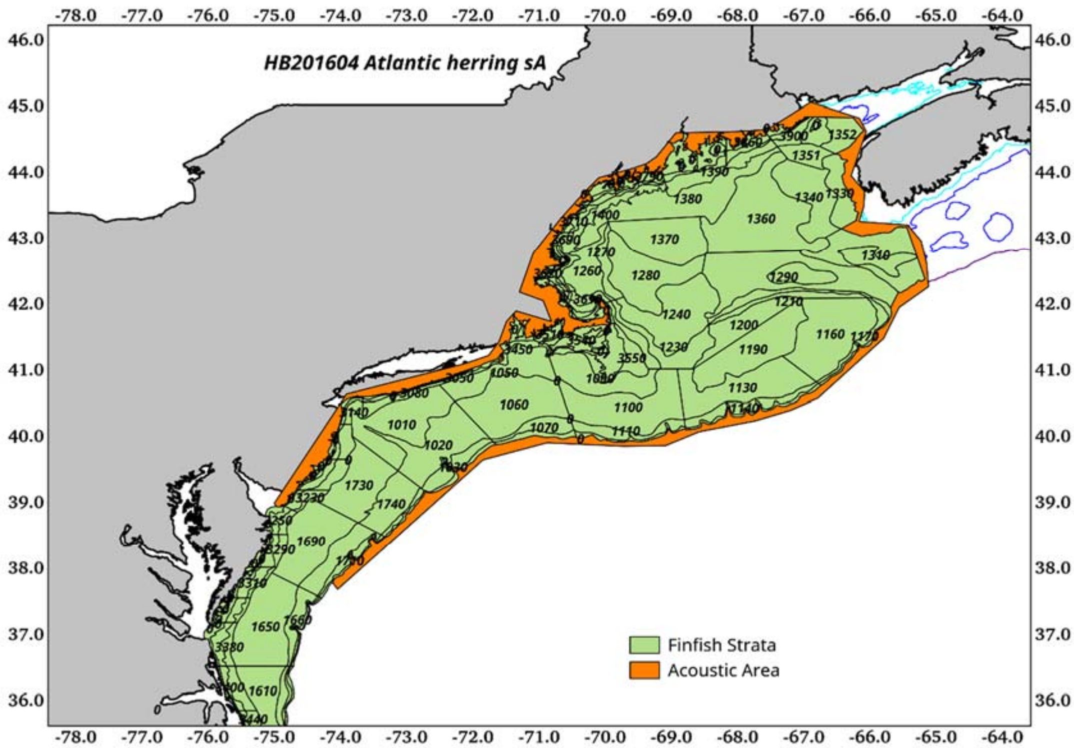


Figure B2- 16 Acoustic backscatter classified as Atlantic herring during the 2016 fall bottom trawl survey on the HB Bigelow overlaid on the finfish strata.

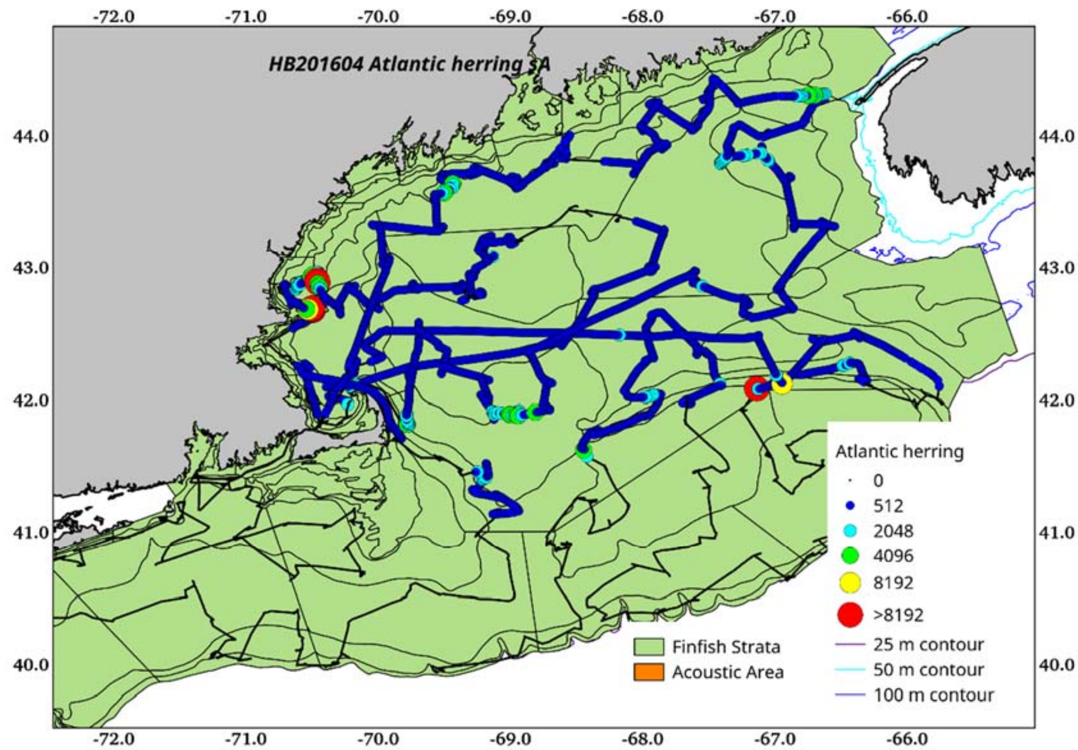
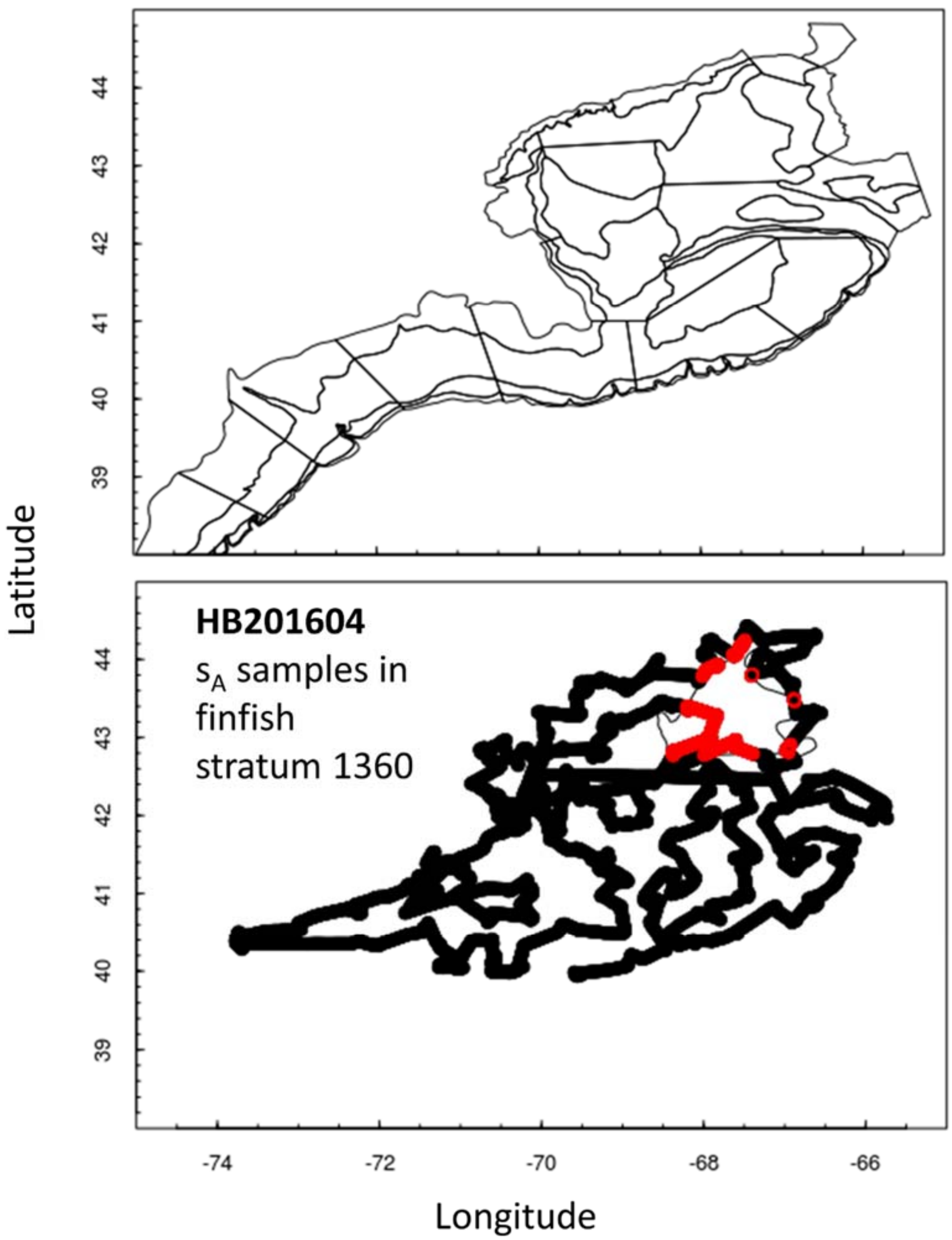


Figure B2- 17 The finfish strata included in the analyses (upper panel) and the entire set of sA samples (black symbols) and sA samples within stratum 1360 (red symbols) during the 2016 bottom trawl survey on the HB Bigelow



TOR B3: *Estimate consumption of herring, at various life stages. Characterize the uncertainty of the consumption estimates. Address whether herring distribution has been affected by environmental changes.*

Estimate consumption of herring, at various life stages. Characterize the uncertainty of the consumption estimates.

Summary

A time series of Atlantic herring consumption was estimated with an evacuation rate model for 12 fish predators of the NE US continental shelf, 1968-2016. Annual removal of herring amounted to 10s to 100s of thousands of MT by these predators.
Herring prey length data indicated adult herring (200+ mm) were primarily targeted, but this may be a result of limited inshore sampling coupled with sporadic inter-annual prey length sampling. Relative to January 1 biomass of herring available in the environment, an annual natural mortality proxy was produced using estimates of herring consumption. The time series average natural mortality was 0.12, reflecting predation of primarily adult herring by these predators.

Introduction

Fish food habits data from NEFSC bottom trawl surveys were evaluated for 12 herring predators (Table B3- 1). From these data, diet composition of herring, per capita consumption, and the amount of herring removed by the 12 predators were calculated. Combined with abundance estimates of these predators, herring consumption was summed across all predators as total herring consumption.

Methods

Every predator that contained Atlantic herring (*Clupea harengus*, and unidentified clupeid remains) was identified. From that original list, a subset of the top 12 predators comprising 94% of the occurrences of all herring predation and were regularly encountered by the sampling survey were included for estimating total herring consumption. Minimum sizes for herring predation were derived from the NEFSC Food Habits Database for each predator (Table B3- 1). Diet data were not restricted by geographic area and were evaluated over the entire northeast U.S. shelf as one geographic unit to match the assessed herring stock structure (see above).

Estimates were calculated on a seasonal basis (two 6 month periods) for each predator and summed per annum. Although food habits data collections for these predators started quantitatively in 1973 (Order Gadiformes only) and extends to the present (through 2016), not all herring predators were sampled during the full extent of this sampling program. Stomach sampling for the non-Gadiformes considered here began in 1977 and extends through 2016. For more details on the food habits sampling protocols and approaches, see Link and Almeida (2000) and Smith and Link (2010). This sampling program was part of the NEFSC bottom trawl survey program; further details of the survey program can be found in Azarovitz (1981), NEFC (1981), and Reid et al. (1999).

Basic Diet Data

Mean amounts of herring eaten ($D_{i,t}$; as observed from diet sampling) for each predator (i) and temporal scheme (t, fall or spring; year) were weighted by the number of fish at length per tow and the total number of fish per tow as part of a two-stage cluster design (See Link and Almeida 2000; Latour et al. 2007). These means included empty stomachs, and units for these estimates are in grams (g).

Numbers of Stomachs

The adequacy of stomach sample sizes were assessed with trophic diversity curves by estimating the mean cumulative Shannon-Wiener diversity of stomach contents plotted as a function of stomach number. The order of stomachs sampled was randomized 100 times, and cumulative diversity curves were constructed for each species focusing on the early 1980s when stomach sampling effort was generally lowest for the entire time series. The criteria for asymptotic diversity was met when the slope of the three proceeding mean cumulative values was ≤ 0.1 which was similar to previous fish trophic studies (e.g. Koen Alonso et al. 2002; Belleggia et al. 2008; Braccini 2008). A minimum sample size approximately equal to 20 stomachs for each predator per year-season emerged as the general cutoff for these asymptotes. Annual estimates of diet compositions of herring were estimated for each predator and season. For all predators, mean amounts of herring consumed ($D_{i,t}$) were not averaged between years with zero stomachs containing herring.

Consumption Rates

To estimate per capita consumption, the gastric evacuation rate method was used (Eggers 1977; Elliott and Persson 1978). There are several approaches for estimating consumption, but this approach was chosen as it was not overly simplistic (as compared to % body weight; Bajkov 1935) or overly complex (as compared to highly parameterized bioenergetics models; Kitchell et al. 1977). Additionally, there has been extensive use of these models (Durbin et al. 1983; Ursin et al 1985; Pennington 1985; Overholtz et al. 1999, 2000; Tsou and Collie 2001a, 2001b; Link and Garrison 2002; Link et al. 2002; Overholtz and Link 2007). Units are in g $year^{-1}$.

Using the evacuation rate model to calculate consumption requires two variables and two parameters. The daily per capita consumption rate of herring, $C_{i,t}$ is calculated as:

$$C_{i,t} = 24 \cdot E_{i,t} \cdot D_{i,t} \quad ,$$

where 24 is the number of hours in a day. The evacuation rate $E_{i,t}$ is:

$$E_{i,t} = \alpha e^{\beta T_{i,t}} \quad ,$$

and is formulated such that estimates of mean herring eaten ($D_{i,t}$) and ambient temperature ($T_{i,t}$) as stratified mean bottom temperature associated with the presence of each predator from the NEFSC bottom trawl surveys (Taylor and Bascuñán 2000; Taylor et al. 2005) are the only data required. The parameters α and β were set as 0.002 and 0.115 for the elasmobranch predators respectively and 0.004 and 0.115 for the teleost predators respectively (Tsou and Collie 2001a, 2001b, Overholtz et al. 1999, 2000).

To evaluate the performance of the evacuation rate method for calculating consumption, a simple sensitivity analysis had been previously executed (NEFSC 2007). The ranges of α and β within those reported for the literature do not appreciably impact consumption estimates (< half an order of magnitude), nor do ranges of *T* which were well within observed values (<< quarter an order of magnitude). An order of magnitude change in the amount of food eaten linearly results in an order of magnitude change in per capita consumption. Variance about any particular species of predator stomach contents has a CV of ~50%. Estimates of abundance, and changes in estimates thereof, are likely going to dominate the scaling of total consumption by a broader range of magnitudes than the parameters and variables requisite for an evacuation method of estimating consumption.

Fish Predator Abundance Estimation

The scaling of total consumption requires information on predator population abundance of sizes actively preying on herring (Table B3- 1). Where age information was available, minimum size was converted to age using the average age at length from Table B3- 1. Abundance estimates were either from assessment models or swept area abundance for each predator (Table B3- 2). Predators with a short time series (data not available 1968 -2016) were extrapolated back using survey indices and their relationship with abundance estimates (Atlantic cod, pollock, summer flounder, and goosefish) or landings using the relationship between landings and abundance (bluefish). Species estimated using swept area abundance (winter and thorny skate, silver and red hake, and sea raven) used an assumed q= 1.0. For Georges Bank cod and goosefish, the most recent assessment model (cod) was not accepted (NEFSC 2015) or ageing method invalidated (goosefish; Richards 2016); thus, abundance data from previously accepted assessments were used and the time series expanded based on the relationship with survey indices.

Scaling Consumption

Following the estimation of consumption rates for each predator and temporal (t) scheme they were scaled up to a seasonal estimate ($C'_{i,t}$) by multiplying the number of days in each half year:

$$C'_{i,t} = C_{i,t} \cdot 182.5 \quad .$$

These were then summed to provide an annual estimate, $C'_{i,\,year}$:

$$C'_{i,year} = C_{i,fall} + C_{i,spring} \quad .$$

and were then scaled by the annual abundance to estimate a total annual amount of herring removed by predator, $C_{i,year}$:

$$C_{i,year} = C'_{i,year} \cdot N_{i,year} \quad .$$

To complement the herring assessment time series prior to 1973, 5-yr averages of annual per capita consumption of herring ($C'_{i,year}$) for the gadiform predators (1973-1977) and non-gadiform predators (1977-1981) were estimated and scaled for each predator by the available abundance data from 1968-1976. The final herring consumption time series was 1968-2016. The total amount of herring removed ($C_{i,year}$) were then summed across all *i* predators to estimate a total amount of herring removed, C_{year}:

$$C_{year} = \sum_i C_{i,year} \quad .$$

The total consumption of herring per predator and total amount of herring removed by all predators are presented as thousands of metric tons year^{-1}.

Prey Lengths of Herring

Prey length data were available for herring consumed by the 12 fish predators considered here. In total, 2,916 length records were collected from 1973-2016. Not all observed herring prey had length data available due to digestion or other sampling constraints; thus, sampling was sporadic year to year. The data were aggregated by decade and kernel density plots produced for each season.

Results and Conclusions

Total consumption of herring by fish predators was variable throughout 1968-2016 with the amount of herring removed equal to 32 MT year^{-1} (minimum) and 390,233 MT year^{-1} (maximum; Figure B3- 1). Years with lesser total amounts of herring predation were earlier in the time series (1968-1987; averaging 61,924 MT year^{-1} compared to later in the time series (1987-2016; averaging 137,051 MT year^{-1}).

Prey length data revealed much of the predation from fishes collected on the bottom trawl survey center on herring around 200 mm or greater for the fall and spring by decade (Figure B3-2). We suspect some of this is due to the bottom trawl survey design focusing on offshore waters and sporadic sampling of prey-lengths per year. It is believed similar or even greater amounts of predation on juvenile herring is likely occurring on this shelf primarily inshore, and in addition to fish predators, by other predators such as birds or marine mammals.
As a proxy for natural mortality due to predation, the proportion of total herring consumption to January 1 biomass of herring from the most recent herring benchmark assessment (NEFSC 2012) was estimated (Figure B3- 3). Here, predation by the 12 predators accounted for approximate proportions of 0.0002 (minimum) and 0.64 (maximum) of the population from 1968-2011. The time series mean of this proxy equaled 0.12. Considering that these estimates largely reflect predation on adult herring, additional work assessing consumption of herring less than 200 mm is warranted, particularly for the inshore waters of this shelf.

Address whether herring distribution has been affected by environmental changes.

Herring distribution at the shelfwide scale has been fairly stable from the 1970's to the present (based on observations from the NEFSC bottom trawl survey). This is in contrast to many New England species, which show significant along-shelf (northeastward) trends in their centers of distribution (see https://www.nefsc.noaa.gov/ecosys/current-conditions/species-dist.html). However, there is evidence that herring are found in deeper survey strata in recent years.

We compared NEFSC trawl survey information to determine whether herring distribution has changed. Comparisons of spring and fall kernel density maps from the 1970's (blue) and the most recent years (red, 2014-2017) shows no substantial change in herring distribution (Figure B3- 4). Further, a time series of the mean along shelf distance from both spring and fall surveys shows no trend over time, indicating that the center of the herring population has remained the same (Figure B3- 5). However, there is a significant long term trend in the mean depth of stations where herring are caught on the survey (Figure B3- 5), which may reflect less herring biomass over shallower Georges Bank and more over deeper Gulf of Maine now than in the past (supported by the kernel density maps).

Atlantic herring's overall climate vulnerability ranking was low in a recent assessment applied to many Northeast U.S. shelf species (Hare et al. 2016). Climate exposure of all Northeast U.S. species including herring was considered high, but Atlantic herring had low biological sensitivity. While the assessment ranked Atlantic herring as having a high potential for distribution shifts due to their low habitat specialization, highly mobile adult stage, and long larval duration with potentially broad dispersal, observations from the NEFSC surveys indicate that a shift has not yet happened.

Table B3- 1 Top 12 predators of Atlantic herring (*Clupea harengus* and unidentified clupeid remains) along with minimum sizes for herring predation from the NEFSC Food Habits Database and average age (where available).

Common Name	Scientific Name	Minimum Size (cm)	Avg. Age (years)
Spiny dogfish	*Squalus acanthias*	29	
Winter skate	*Leucoraja ocellata*	39	
Thorny skate	*Amblyraja radiata*	41	
Silver hake	*Merluccius bilinearis*	13	0.8
Atlantic cod	*Gadus morhua*	16	1.1
Pollock	*Pollachius virens*	19	1.4
White hake	*Urophycis tenuis*	21	0.4
Red hake	*Urophycis chuss*	24	1.3
Summer flounder	*Paralichthys dentatus*	23	0.9
Bluefish	*Pomatomus saltatrix*	17	0.0
Sea raven	*Hemitripterus americanus*	13	
Goosefish	*Lophius americanus*	12	1.2

Table B3- 2 Summary of methods used for determining predator abundances.

Common Name	Method
Spiny dogfish	Model-based estimate
Winter skate	Swept area biomass, fall offshore
Thorny skate	Swept area biomass, fall offshore
Silver hake	Swept area biomass, fall offshore
Atlantic cod	ASAP model, two stocks combined, linear extrapolation
	GB data from previously accepted model used
Pollock	ASAP model and ln curve extrapolation
White hake	Model-based estimate with fall q 2012-13 (last benchmark)
Red hake	Swept area biomass, fall offshore
Summer flounder	ASAP model and ln curve extrapolation
Bluefish	ASAP model and linear extrapolation
Sea raven	Swept area biomass, fall offshore
Goosefish	SCALE model and linear extrapolation
	Ageing method invalidated in 2015, but data from previously accepted model used

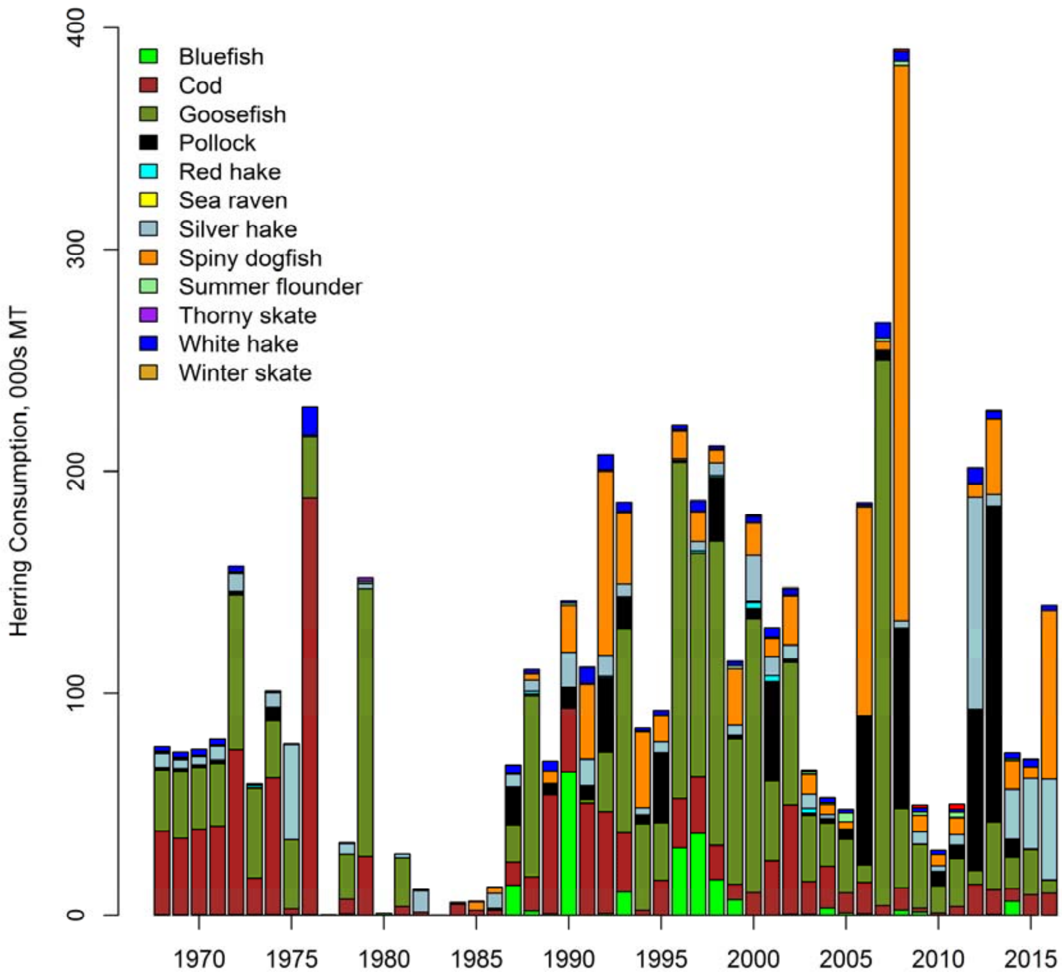


Figure B3- 1 Time series of herring consumption (000s MT) by 12 fish predators.

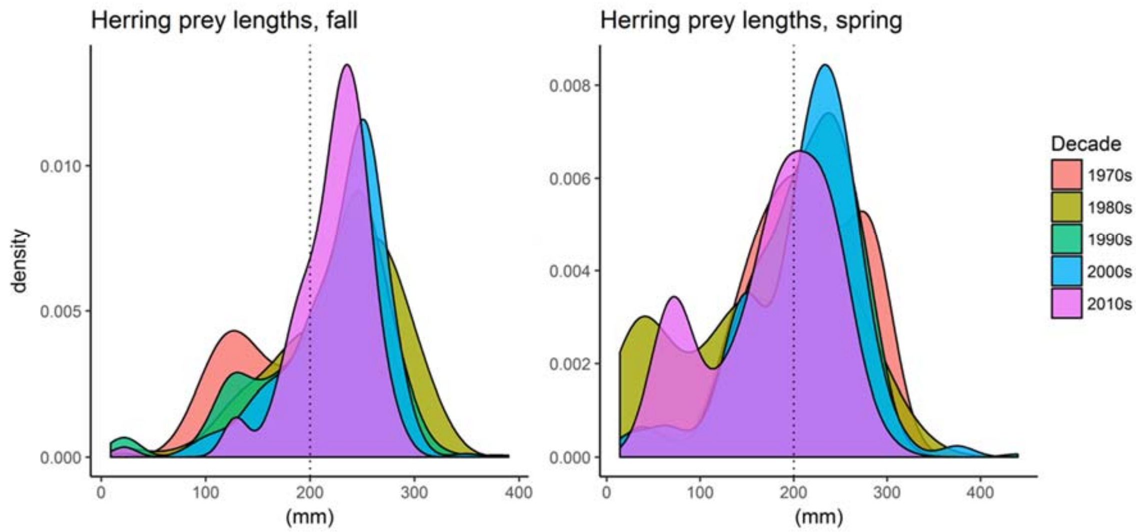


Figure B3- 2 Gaussian kernel density plots of herring prey lengths by decade for the spring and fall, 1973-2016.

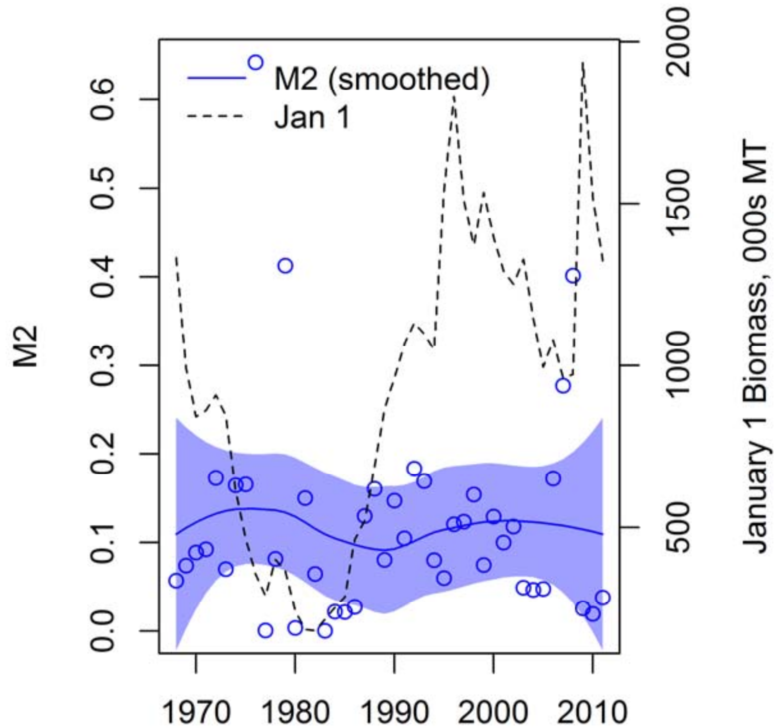


Figure B3- 3 Proxy estimate of natural mortality due to predation (M2) and January 1 biomass of herring, 1968-2011. M2 smoother is loess with span = 0.8 and 95% ci.

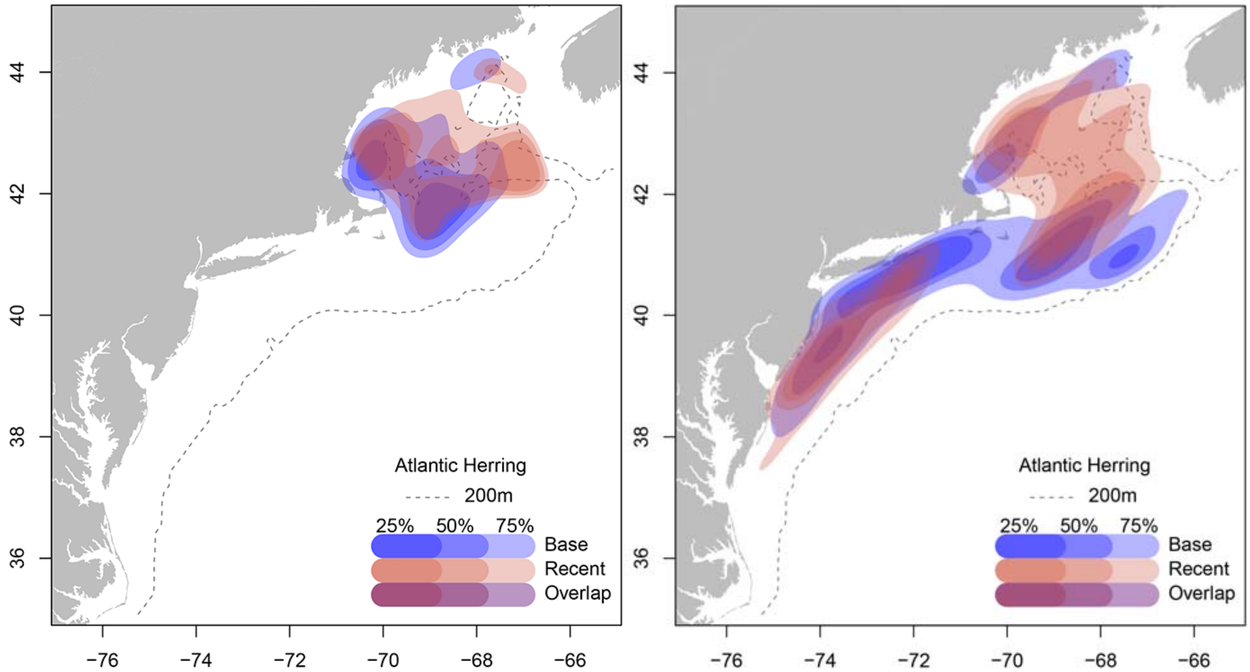


Figure B3- 4 Atlantic herring historical (1970s; blue) and current (2014-2017; red) distribution in the fall (left) and spring (right)

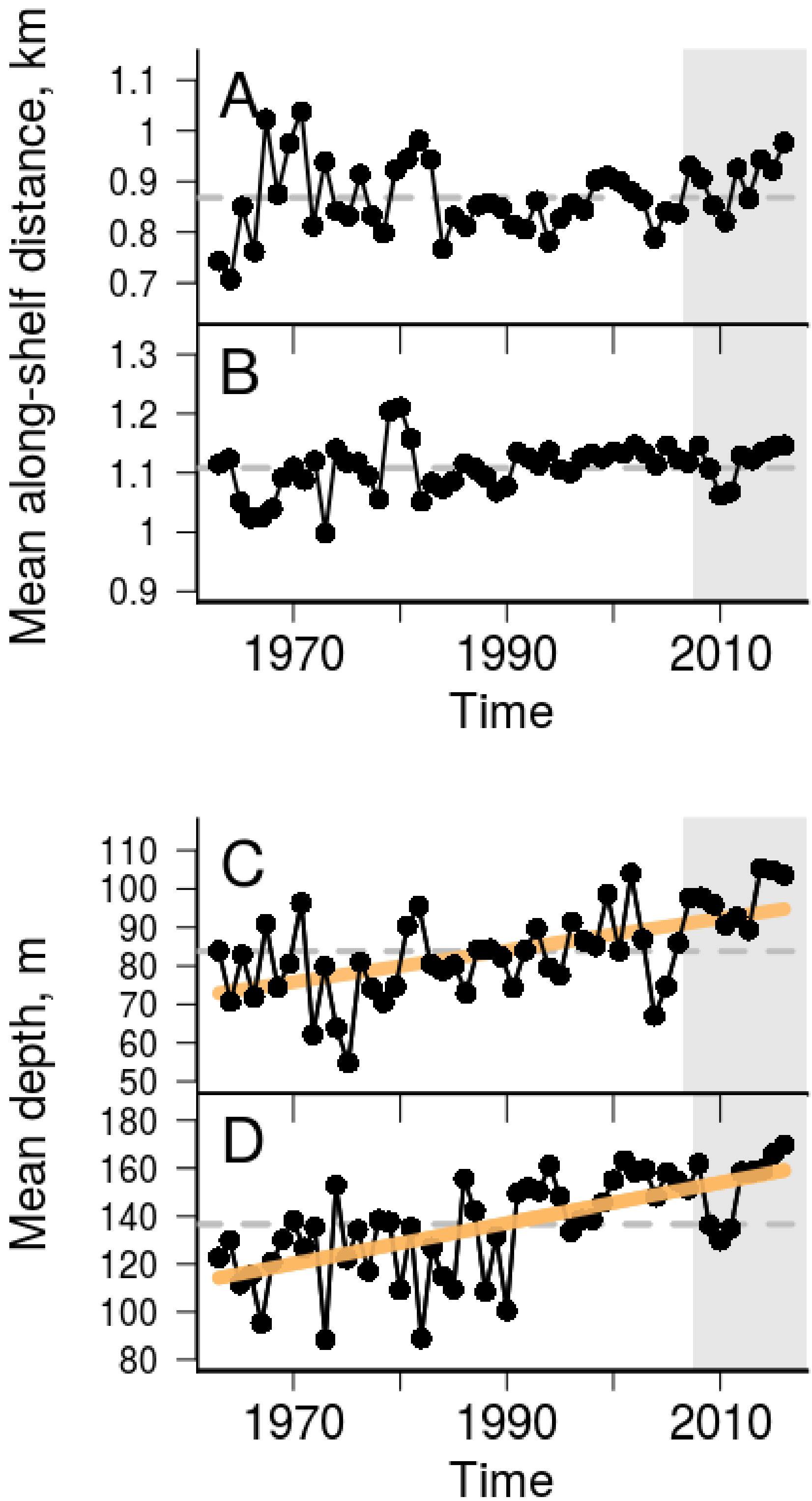


Figure B3- 5 Atlantic herring distribution trends (Along shelf distance in A. Spring, B. Fall, and mean depth in C. Spring, D. Fall)

TOR B4: *Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series, and estimate their uncertainty. Incorporate ecosystem information from TOR B3 into the assessment model, as appropriate. Include retrospective analyses (both historical and within-model) to allow a comparison with previous assessment results and projections, and to examine model fit.*

Update the 2015 ASAP model

The ASAP model formulation (Age Structured Assessment Program, Legault and Restrepo 1998) used in the 2012 (NEFSC 2012) and 2015 (Deroba 2015) stock assessments was updated using data through 2017. A brief description of this model formulation is provided here. The models used two fleets (mobile and fixed) as described above (see TOR B1). Indices of abundance included spring, fall, and summer NMFS bottom trawl surveys. The indices of abundance collected with the Biglow from 2009 to the terminal year of each assessment were calibrated to Albatross IV equivalent catches. Natural mortality was based on a combination of the Hoenig and Lorenzen methods, with the Hoenig method providing the scale of natural mortality and the Lorenzen method defining how natural mortality declined with age (Hoenig 1983; Lorenzen 1996; Brodziak et al. 2011). The natural mortality rates during 1996 to the terminal year of each assessment were increased by 50% from these base rates. In 2012, predatory consumption estimates of Atlantic herring were used in justifying time varying M (i.e., the 50% increase from base rates) that also resolved a retrospective pattern (NEFSC 2012). In the 2015 operational assessment, however, a retrospective pattern re-emerged and predatory consumption estimates no longer supported the time varying M (Deroba 2015). Reconsideration of time varying M is not permissible in an operational assessment, and so this feature was retained in the model, but an adjustment for the retrospective pattern was made for determining stock status and in short-term projections that informed catch specifications. In updating this model formulation through 2017, all model specifications (e.g., selectivity, data weighting, likelihood penalties) were identical to the previous assessments (NEFSC 2012; Deroba 2015), with the exception of a correction to input data. In the course of this assessment, the Working Group discovered that the age 8+ fall NMFS bottom trawl survey data were incorrectly calculated as an age 7+ value. This error was corrected.

Fits to catch, survey trends, and age compositions in the form of residual diagnostics were generally similar between the updated model and the 2015 assessment (results not shown). The updated model also exhibited a retrospective pattern, similar in severity to that of the 2015 assessment (Figure B4- 1).

A comparison of time series trends between the updated model and the 2015 assessment (with the plus group corrected in both models) showed a decrease in scale in the updated model, with the retrospectively adjusted SSB value from the 2015 assessment being similar to the estimate from the updated model (Figure B4- 2).

Review of models considered for this assessment

Three modeling platforms with different data inputs and different model structures were considered to varying degrees during this assessment. Building from previous assessments, the Working Group spent the most time evaluating the ASAP model, which ultimately was used for the base assessment (Legault and Restrepo 1998). A state-space assessment model (SAM; Nielsen and Berg 2014) was also developed. The Working Group was not as familiar with the SAM model as ASAP, and so SAM was ultimately used a point of comparison for ASAP fits. The details of the SAM configuration are in Appendix B2. An attempt was also made at model averaging the ASAP and SAM models (Appendix B3). Largely in response to research recommendations from previous assessments, a Stock Synthesis (SS) model was briefly reviewed (Methot and Wetzel 2013). The research recommendations that the SS model was primarily intended to address were the ability to fit to length composition data (ASAP and SAM cannot) and consideration of stock structure. So, a two area SS model was developed that fit to a broad range of data types, including length and conditional age-at-length composition data. The SS model reviewed by the Working Group during the Model Meeting, May2-4, 2018, had unresolved residual patterns in the composition data. Furthermore, in order to consider the estimation of movement among areas, the SS model assumed that 100% of Atlantic herring from each spatial area returned to their natal location to spawn. The Working Group felt that this assumption was unjustified and likely invalid. Given these concerns, the Working Group did not consider the SS model viable at this time. The Working Group agreed that the consideration of stock structure in the herring assessment may not be reasonable until more information is available on movement rates and the relative size of each sub-stock, which might come from morphometrics, tagging, or some other source. The Working Group recommended the continued consideration of using length composition data, whether through SS or some other model platform. The details of the SS model are in Appendix B4.

Base ASAP model development

The base ASAP model made structural changes to the previous assessment (e.g., M, selectivity), included new index time series, and re-evaluated some other relatively minor issues (e.g., weak likelihood penalties). The reasoning behind some of these modeling choices was described below. Some consequences of the changes to model structure and data inputs were documented in more detail in the *Sensitivities to the base ASAP model* section below.

The base model considered age 1 to an age 8 plus group and covered the time period 1965-2017. The age 8 plus group was based on the difficulties that ASAP had estimating the abundance of age 9 and older herring in the first year (i.e., 1965) and concerns about the reliability of age data for older ages in previous assessments (NEFSC 2012). The model was started in 1965 when catch data from all sources (i.e., US and Canadian weir) was first available.

Estimates of abundance at age in the first year (i.e., 1965) in previous assessments were imprecisely estimated and sometimes caused issues of model non-convergence (NEFSC 2012). To reduce imprecision and help with convergence, these estimates were previously given a relatively weak likelihood penalty for deviating from initial starting guesses. This penalty was removed in the base model, and initial abundances at age were estimated as deviations from an equilibrium age structure (Legault and Restrepo 1998). While these initial abundance estimates were still relatively imprecise (CVs ranging from 0.37-3.09), the imprecision was not considered problematic and the model consistently converged. A model with no likelihood penalty was also considered more parsimonious.

The base ASAP model used age- and time- invariant M = 0.35, which was a value based on the longevity methods of Hoenig (1983). The method assumed a maximum age equal to 14, which was the oldest age ever observed in commercial or survey gear catches and was consistent with maximum ages reported elsewhere (Collette and Klein-MacPhee 2002). Implied amounts of mortality based on the constant M were generally higher or similar to estimates of predatory consumption from stomach contents data (Figure B4- 3). The estimates of predatory consumption from stomach contents are likely underestimates, and so the Working Group was comfortable with implied amounts of mortality from the assessment being higher. The estimates of predatory consumption from stomach contents are also highly imprecise (although largely unquantified), and so the Working Group was satisfied with the general similarity of this comparison, and felt considering changes to M based on this comparison to be unjustified. This constant M was a departure from previous assessments that included age- and time-varying M (NEFSC 2012; Deroba 2015). The 50% increase in M beginning in 1996 was no longer justified given that that this increase in M no longer resolved retrospective patterns in the previous operational assessment (Deroba 2015) and was not needed to create general agreement between estimates of predatory consumption from stomach contents data and the amount of herring implied by the input M. Time-invariant M was also generally supported by a predation pressure index of M (Richards and Jacobson 2016; Appendix B5). The age-variant M based on a combination of the Hoenig and Lorenzen methods (Hoenig 1983; Lorenzen 1996; Brodziak et al 2011) provided a nearly identical fit to using a constant M (Neg. LL = 3773 for constant M and 3774 for age-variant), and so the Working Group agreed to use the more parsimonious constant M. A likelihood profile over time- and age-invariant M values found a minimum at 0.45 (Figure B4- 4).

For the mobile gear fishery, selectivity at age was freely estimated for ages 1-6, while selectivity at ages 7-8 was fixed at 1.0. Preliminary assessment fits were attempted that also estimated selectivity at ages 7 and 8, but estimates were at or near 1.0. The working group agreed that the mobile gear fishery, which is characterized by mostly large scale trawlers and purse seine operations, should have a flat-topped selectivity curve. Previous assessments (NEFSC 2012; Deroba 2015) also fixed the selectivity at ages 5 and 6 to 1.0. Estimating selectivity for these ages, however, improved model fit (Neg. LL improved by 7 units) and reduced some age composition residual patterns (Figure B4- 5).

The fixed gear fishery almost exclusively harvests age 2 fish, while other ages are caught in relatively small proportions (see TOR B1). Consequently, selectivity at age 2 was fixed at 1.0, while selectivity for all other ages was estimated. Previous assessments (NEFSC 2012; Deroba 2015) included a relatively weak likelihood penalty for deviations from initial guesses for each estimated selectivity at age parameter. These penalties were to help with precision and convergence, but were unnecessary for the base model here and so eliminated.

Selectivity at age on the NMFS spring survey during 1968-1984 was fixed and equaled 0.0 at ages 1 and 2, 0.5 at age 3, and 1.0 at ages 4-8. Selectivity-at-age on the NMFS fall survey during 1965-1984 was fixed and equaled 0.0 at ages 1-3, 0.5 at age 4, and 1.0 at ages 5-8. The selectivities for these surveys were fixed because no age composition data was available. The values input for the selectivities were justified in previous assessments by examining length compositions for each survey (see TOR B2). Sensitivity runs excluding these two surveys suggest that the base model is robust to their inclusion/exclusion and selectivity pattern, but that they provide some information for the estimation of initial abundance at age (Figure B4- 6), and so the Working Group agreed that they should be retained.

The NMFS spring survey during 1985-2017 (Albatross and Bigelow vessels) rarely caught any age 1 herring, while the fall frequently caught low proportions of age 1 herring (see TOR B2). In some years, however, a relatively large proportion of age 1 herring were caught.Previous assessments (NEFSC 2012) have found that assessment models would “chase” these signals about year class strength and estimate a relatively high recruitment in those years with high age 1 catches, which created retrospective patterns as more years of data about the given year class revealed a much weaker signal As in previous assessments, this Working Group agreed that the age-1 catches from these surveys were driven more by measurement uncertainty than by true measures of cohort strength. Consequently, age 1 catches from these surveys were discarded from the base ASAP model and selectivity at age 1 fixed to 0.0. For the NMFS spring survey during 1985-2008 (Albatross) and 2009-2017 (Bigelow), selectivity-at-age was freely estimated for ages 2-3 and was fixed and equaled 1.0 for ages 5-8. Age 4 selectivity was initially estimated, but kept hitting the bound of 1.0, which can cause convergence problems, and so this age was fixed at 1.0. For the NMFS fall survey during 1985-2008 (Albatross) and 2009-2017 (Bigelow), selectivity was logistic. Using age based selectivity in the spring resolved age composition residual patterns that were not present in the fall survey, making the more flexible age based alternative unnecessary in the fall (NEFSC 2012). As the NMFS summer survey used an average of the spring and fall NMFS survey age length keys, selectivity at age 1 was also assumed 0.0 in this survey. Otherwise, selectivity followed a logistic pattern.

No age composition data is available to inform selectivity estimation for the acoustic survey (as collected during the fall bottom trawl survey; see TOR B2). While all ages should theoretically be detected by the acoustic survey, some younger ages may be unavailable to the survey if they are not present at the time of sampling, which may be especially true during the fall when spawning occurs. A model with knife-edged selectivity at age 3, informed by the maturity data, provided a better fit than a model with full selection at all ages (Neg. LL better by

7 units). Consequently, the base model assumed knife-edged selectivity at age 3 for the acoustic index.

Input annual effective sample sizes (ESS) for the mobile and fixed gear fishery age composition data were initially set equal to the number of trips sampled for age in each year for each fishery, with a minimum of 5 and maximum of 150. In years for which no age samples were taken from the US fixed gear fishery and the age composition for the fleet relied solely on Canadian data, the ESS was set equal to 5 (the number of Canadian samples was unavailable; NEFSC 2012). Survey input annual ESS were initially set equal to the number of positive survey stations (i.e., stations that captured at least one herring) for each year and survey. All of these ESS were then iteratively reweighted as described for the multinomial distribution in Francis (2011).

The CVs on each survey data point were initially set equal to the CV estimated for a given survey in each year (see TOR B2). These CVs were then adjusted in an iterative fashion until the root mean square error (RMSE) of the standardized residuals for each survey was approximately within the 95% confidence intervals of the RMSE expected at the given sample size (i.e., number of years) for each survey (Figure B4- 7; Table B4- 1). The RMSE in this context was used as a measure of the consistency between the input precision of the survey values (i.e., CVs) and the uncertainty in the fits to a given survey index (i.e., variance of the standardized residuals). An RMSE equal to 1.0 suggests that the input CVs exactly match the uncertainty in the model fit. An RMSE greater than 1.0 suggests that the CVs need to be increased and the opposite for an RMSE less than 1.0. In this assessment, when the RMSE was outside of the 95% confidence intervals of the RMSE expected at the given sample size for a survey, each input CV for that survey was multiplied by the RMSE and the model was refit. For example, if the RMSE equaled 1.5, each CV was multiplied by 1.5 (increasing the CVs by 50%) and the model was refit. This process was repeated until the RMSE agreed with expectations, which usually only required one iteration. CVs were not allowed to exceed 0.95 during this process.

An annual CV of 0.1 was assumed in all years for the catch from both fisheries. Although ad hoc, this value admits some uncertainty in the catches and does not force an exact fit.

Unconstrained annual recruitment deviations were estimated without any penalty for deviating from some underlying mean stock-recruit relationship. Previous assessments have estimated the parameters of a Beverton-Holt stock-recruit relationship, and penalized recruitment for deviating from this underlying curve (NEFSC 2012; Deroba 2015). This practice was not used here because a likelihood profile of steepness revealed that the data provided nearly no information about the correct value of steepness, and the model's ability to estimate steepness seemed to rely solely on a relatively high degree of negative correlation between steepness and unexploited SSB (correlation = -0.96; Figure B4- 8).

Catchability for all surveys was freely estimated.

ASAP base model diagnostics and results

The ASAP base model fit to the fishery catches closely with the scale of residuals being relatively small (Figure B4- 9). The residuals for both fleets, however, were characterized by sequences of positive or negative residuals that were unlikely to have occurred by random chance (Figure B4- 9). The iteratively reweighted ESS for both fisheries led to estimated mean ages in each year that were generally within the 95% confidence intervals of the observed mean ages (Figure B4- 10). Exceptions to this occurred early in the time series for the mobile fleet and in more recent years for the fixed fleet, most often in years with relatively low ESS (Figure B4- 10). Fits to the mobile gear age composition exhibited only a few sequences of patterned residuals (e.g., age 4 from 1989-2002) and had no obvious year class effects (Figure B4- 11). Fits to the fixed gear age composition generally did not exhibit any obvious runs of residuals except for some relatively large residuals for ages $\geq$ 4 during 1986-1991 (Figure B4- 11). The fixed gear fishery caught more fish at these ages during those years than is typical, although still a relatively small amount (TOR B1). Thus, these relatively large residuals are likely not problematic. The mobile gear fishery selectivity increased in a near linear fashion to age-7, when full selection began (Figure B4- 12). The fixed gear fishery selectivity increased from near 0.0 at age 1 to full selection at age 2 and then quickly declined at older ages (Figure B4- 12). Average selectivity was generally less than average maturity at age, with herring maturing prior to full selection (Figure B4- 13).

The ASAP base model fit the survey trends relatively well. With few exceptions, residuals for fits to the survey trends did not exhibit long runs of residuals and residuals were generally centered on zero (Figure B4- 14). The estimated log scale survey indices also generally fell within the 95% confidence intervals of the log scale observations (Figure B4- 14). With rare exception, the iteratively reweighted ESS for the surveys led to estimated mean ages in each year that were generally within the 95% confidence intervals of the observed mean ages (Figure B4- 15). Fits to the survey age compositions also generally did not exhibit patterns, with exceptions being some age effects (e.g., age 8 in the shrimp survey and spring 1985-2008; Figure B4- 16).

The CVs on estimates of catchability (q) among all the surveys ranged from 32% to 55%. The q for the NMFS spring survey between the 1968-1984 period and the 1985-2008 period increased by a factor of 3.8 (0.0000017 to 0.0000064; Figure B4- 17). The q for the NMFS spring survey between the 1985-2008 period and the 2009-2017 period increased by a factor of 5.7 (0.0000064 to 0.000037; Figure B4- 17). The q for the NMFS fall survey between the 1965-1984 period and the 1985-2008 period increased by a factor of 29 (0.00000035 to 0.0000101; Figure B4- 17). The q for the NMFS fall survey between the 1985-2008 period and the 2009-2017 period increased by a factor of 3.43 (0.0000101 to 0.000035; Figure B4- 17). The NMFS shrimp survey q equaled 0.0000099 and the q for the acoustic index equaled 0.000024 (Figure B4- 17). Whether the catchability changes estimated by the base ASAP model in the NMFS spring and fall surveys between the 1985-2008 period and the 2009-2017 period (i.e., Albatross to Bigelow time periods) are aliasing some other factors is unclear. But, a retrospective analysis of the base ASAP model using 17 peels showed the scale of the relative differences in SSB increasing as fewer years of data were used, which includes a general increase in the scale of the relative differences beginning in ~2009 (Figure B4- 18). This result may suggest that some other model mis-specification exists and could be aliased by the modeled changes in catchability. The retrospective pattern is likely to worsen as additional years of data are added to the base ASAP model structure.

No two parameters of the ASAP base model had correlations greater than 0.9 or less than -0.9. Log unexploited SSB was estimated to be 13.2 with a CV of 25%. Time series estimates of SSB, F (averaged over ages 7 and 8), and recruitment were estimated relatively precisely, with the exception of recruitment in 2016 and 2017 that had CVs of 100% and 252%, respectively (Figure B4- 19).

The base ASAP model estimated SSB in 2017 to be 141,473 mt, with SSB ranging from a minimum of 53,084 mt (1982) to a maximum of 1,352,700 mt (1967) over the entire time series (Figure B4- 20; Figure B4- 23; Table B4- 2). The base ASAP model estimated total January 1 biomass in 2017 to be 239,470 mt, ranging from a minimum of 169,860 mt (1982) to a maximum of 2,035,800 mt (1967) over the entire time series (Figure B4- 20; Table B4- 2).

No common age is fully selected in both the mobile and fixed gear fishery. Consequently, the average F between ages 7 and 8 was used for reporting results related to fishing mortality ($F_{7\text{-}8}$), and this includes reference points (see TOR B5). These ages are fully selected by the mobile gear fishery, which has accounted for most of the landings in recent years (TOR B1). $F_{7\text{-}8}$ in 2017 equaled 0.45. The all-time low of 0.13 occurred in 1965 (Figure B4- 23; Table B4- 2). The maximum $F_{7\text{-}8}$ over the time series equaled 1.04 (1975).

Age-1 recruitment has been below average since 2013 (Figure B4- 21; Figure B4- 22; Table B4- 2). The all-time high of 1.4 billion fish occurred in 1971. The estimates in 2009 and 2012 are still estimated to be relatively strong cohorts, as in previous assessments. The all-time low of 1.7 million fish occurred in 2016, and the second lowest of 3.9 million fish occurred in 2017. Four of the six lowest recruitment estimates have occurred since 2013 (2013, 2015, 2016, 2017).

Markov chain Monte Carlo (MCMC) simulation was performed to obtain posterior distributions of SSB and $F_{7\text{-}8}$ time series. An MCMC chain of length 6,000,000 was simulated with every 6000th value saved to create an MCMC chain with length 1,000 for defining the posterior densities. Traces and lag correlation plots for SSB and $F_{7\text{-}8}$ in 1965 and 2017 had no obvious irregularities and chains are presumed to have converged (Figure B4- 24; Figure B4- 25). The posteriors for SSB and $F_{7\text{-}8}$ in 1965 and 2017 are also provided as examples (Figure B4- 27). Time series plots of the 90% probability intervals are in Figure B4- 26while ASAP point estimates and the 80% probability intervals for SSB and $F_{7\text{-}8}$ in 2017 are below:

Metric	ASAP point estimate	80% probability interval
2017 SSB (mt)	141,473	114,281 - 182,138
2017 F7-8	0.45	0.32 - 0.57

Internal retrospective patterns were characterized by using 5 "peels" rather than the 7 peels that is more common because of the relatively few numbers of years available for the NMFS spring and fall bottom trawl surveys during years when only the Bigelow vessel was used (2009-2017). Using 7 peels would require estimating q parameters for these surveys based on 2-3 years of data for the last 2 peels, and this has caused large imprecision and non-convergence in other assessments (Atlantic mackerel; NEFSC 2018). The internal relative retrospective pattern suggested consistent overestimation of SSB with Mohn's Rho = 0.15, and underestimation of F_{7-8} with Mohn's Rho = -0.11 (Figure B4- 28). The retrospective pattern for recruitment at age 1 was characterized by both positive and negative peels, with all of the positive peels greater than 4 (Figure B4- 28). The presence of the retrospective pattern is sensitive to the indices used in the ASAP base model (see sensitivity below with no acoustic index).

Estimates of SSB and fishing mortality among assessments from 1995, 2005, 2009, 2012, 2015, and the current ASAP base model were compared. Exact values from an assessment in 1998 were unavailable, but graphical representations of that assessment were similar in trend and scale as the 1995 assessment. The range of ages over which fishing mortality was calculated differed among assessments, as did selectivity, and therefore F values are not directly comparable, but were still useful for examining temporal trends. Estimates of SSB diverged among assessments more so at the beginning and end of the time series, with more similarity in intermediate years (~1970-1988; Figure B4- 29). Assessments in 1995 and 1998, however, estimated SSB to be about four times higher in the mid-1990s than assessments in 2005-2018 (Figure B4- 29). This contrast can be explained by a switch from a VPA model in 1995 and 1998 to an ASAP model for the other assessments. Estimates of SSB since about 2000 have generally decreased in each subsequent assessment (Figure B4- 29). Estimates of F from all the assessments were similar to that of SSB, except with differences occurring in the opposite direction; F generally increasing since 2000 in each subsequent assessment (Figure B4- 29). Changes in input data (e.g., acoustic index, time varying maturity) and model structure (e.g., M, selectivity) have occurred among assessments, and so the results for SSB and F are not entirely comparable.

ASAP base model sensitivity runs

In each of the sensitivity runs described below, all of the data and settings in the base model were the same as described above, except for the changes required for the given sensitivity run. Results focused on SSB because changes induced by the sensitivity runs were similar for F except in the opposite directions. Results also focused on retrospective patterns, and when appropriate, likelihood values.

ASAP base model sensitivity – M

Amending the ASAP base model to have age- and time-varying M as in previous assessments (NEFSC 2012; Deroba 2015) using the combination of Hoenig and Lorenzen methods (Hoenig 1983; Lorenzen 1996; Brodziak et al 2011) and a 50% increase in those values during 1996-2017, increased the scale of SSB and recruitment (Figure B4- 30). The retrospective pattern was similar between this sensitivity and the base model (Figure B4- 28; Figure B4- 31). The fit of the model was 5 likelihood units better than the base.

Eliminating the 50% increase in M during 1996-2017 and basing M only on the combination of Hoenig and Lorenzen methods, reduced the scale of SSB relative to the base (Figure B4- 32). The retrospective pattern was similar between this sensitivity and the base model (Figure B4- 28; Figure B4- 33). The fit of the model was similar (1likelihood unit worse) to the base.

ASAP base model sensitivity – calibrate Bigelow to Albatross

Calibrating the spring and fall NMFS bottom trawl surveys collected with the Bigelow vessel (2009-2017) to Albatross vessel equivalents using results from the paired tow experiments (Miller et al. 2010; NEFSC 2012) increased the scale of SSB relative to the base (Figure B4- 34). The retrospective pattern was also worse relative to the base, with Mohns's Rho equal to 0.34 for SSB and -0.24 for $F_{7\text{-}8}$ (Figure B4- 28Figure B4- 35). The base ASAP model estimated a 5.7 fold increase in catchability in the spring between the Bigelow and the Albatross, and a 3.4 fold increase in the fall (Figure B4- 36). These changes are 61% larger than the changes in catchability estimated by the paired tow experiments for the spring, and 73% larger for the fall (Figure B4- 36), and this explains the scale shift between the base model and using the paired tow calibrations.

ASAP base model sensitivity –time varying mobile fleet selectivity

The Working Group had concerns that the purse seine gear had a distinct selectivity from trawl gears, but these gears were combined in the mobile gear fleet (see TOR B1). To address this concern, time varying selectivity was added to the mobile gear fleet in the form of separate selectivity blocks for 1965-1990 and 1991-2017, where the break occurs in a year when purse seine catches decreased relative to the trawl gears and remained so. Selectivity at age in both blocks was freely estimated for ages 1-6, but fixed at 1.0 for ages 7-8. The model with 2 selectivity blocks improved model fit by 4 likelihood units over the base model, but also estimated 6 more parameters than the base (AIC would not support the 2 blocks). The model with 2 selectivity blocks also had qualitatively similar residuals as the base, nearly indistinguishable estimates of SSB, and the retrospective patterns were also similar (Figure B4- 28; Figure B4- 37; Figure B4- 38).

ASAP base model sensitivity–drop surveys ("leave one out")

The base ASAP model was re-run with each of the surveys removed from the model. The point estimates of SSB from each of the surveys remained within the 95% confidence intervals of the base run (Figure B4- 39). In more recent years, the base model was most sensitive to the exclusion of the acoustic index, with removing the acoustic index reducing the scale of SSB relative to the base (Figure B4- 39). Exclusion of the acoustic survey also eliminated the retrospective pattern, with peels for SSB and F_{7-8} being both positive and negative (Figure B4- 40). The model was also less precise without the acoustic index, as evidenced by wider confidence intervals on stock status when compared to the base (Figure B4- 41Figure B6- 1). Stock status would also change in a model without the acoustic index, with overfishing occurring (Figure B4- 41).

ASAP base model sensitivity–fit with food habits index of abundance

The base model fit with the addition of the food habits index of abundance provided similar time series estimates of SSB (and F and recruitment) as the base model (Figure B4- 42). The fit to the food habits index was characterized by mostly negative residuals before ~1995 and mostly positive residuals after ~1995, although the estimated indices were generally within the 95% confidence intervals of the log scale observations (Figure B4- 43). The retrospective pattern was similar to the base (not shown).

ASAP base model sensitivity runs–explaining the scale difference from 2015

These sensitivities demonstrate that the shift in scale from the 2015 operational assessment (Deroba 2015) is a combination of: 1) basic data updates, with the retrospectively adjusted SSB value from 2015 being similar to that of the 2015 assessment updated through 2017, 2) treating the NMFS spring and fall bottom trawl surveys in years sampled by the Bigelow (2009-2017) as a separate index time series, 3) using a constant M as opposed to an age- and time-varying M, and 4) to a lesser extent than the other model changes, new data sources such as the acoustic index.

Table B4- 1 Root mean squared error table for the base Atlantic herring ASAP model, after iteratively reweighting

ot Mean Square Error computed from Standardized Residu

Component	# resids	RMSE
catch.fleet1	53	0.141
catch.fleet2	53	0.066
catch.tot	106	0.11
discard.fleet1	0	0
discard.fleet2	0	0
discard.tot	0	0
ind01	17	1.11
ind02	20	1.62
ind03	34	1.27
ind04	18	1.37
ind05	24	1.04
ind06	24	1.2
ind07	9	0.966
ind08	9	1.08
ind.total	155	1.25
N.year1	0	0
Fmult.year1	0	0
Fmult.devs.fleet1	0	0
Fmult.devs.fleet2	0	0
Fmult.devs.total	0	0
recruit.devs	0	0
fleet.sel.params	0	0
index.sel.params	0	0
q.year1	0	0
q.devs	0	0
SR.steepness	0	0
SR.scaler	0	0

Table B4- 2 Time series estimates of Atlantic herring from the base ASAP model

Year	SSB (mt)	Jan.1 Biomass (mt)	Age-1 Recruitment (000s)	F_{7-8}
1965	822530	1684170	5455740	0.13
1966	1158280	1908910	4582210	0.22
1967	1352730	2035820	9893020	0.36
1968	879319	1757780	4584770	0.64
1969	558945	1252230	5314820	0.66
1970	495252	990597	2726970	0.65
1971	309278	939626	14034800	0.97
1972	256642	941744	2487340	0.92
1973	421291	933513	2480520	0.89
1974	358470	694550	3080770	0.84
1975	234402	520342	1870600	1.04
1976	179914	390076	1889890	0.69
1977	107066	290770	5610910	0.70
1978	78307	348807	5312970	0.83
1979	72862	369009	760023	0.60
1980	86845	252059	3951690	0.99
1981	75400	183556	2123520	0.60
1982	53084	169857	1877800	0.64
1983	70978	183135	1371520	0.53
1984	64660	205018	4522510	0.89
1985	72605	212830	3327060	0.57
1986	103420	326508	3045410	0.46
1987	150558	389461	4230370	0.56
1988	253638	481774	6570600	0.61
1989	189046	653702	7616190	0.66
1990	182758	730272	8262200	0.42
1991	302782	834362	6996250	0.43
1992	452094	900893	3420850	0.40
1993	442046	851067	3432600	0.31
1994	389308	751971	4041110	0.26
1995	366549	848662	11221100	0.41
1996	433942	885059	5024520	0.44
1997	310950	861261	4848000	0.44
1998	447860	805422	3131950	0.38
1999	414034	840145	7791940	0.41
2000	394747	833338	2062680	0.37
2001	411161	796936	2067110	0.42
2002	332243	698200	4638660	0.38
2003	264895	684761	5505720	0.47
2004	240243	625565	2896810	0.48
2005	307228	560570	2036360	0.47
2006	260012	557285	4272270	0.58
2007	196392	503615	1229030	0.56
2008	207711	444931	2712310	0.58
2009	139353	577250	10579800	0.94
2010	121661	519530	2364220	0.72
2011	185013	500048	2110360	0.61
2012	243767	602132	6941730	0.60
2013	210106	580801	1370270	0.65
2014	330492	547060	1608170	0.51
2015	264982	471603	776348	0.47
2016	175698	347230	174758	0.47
2017	141473	239472	392286	0.45

Figure B4- 1 Retrospective pattern for the 2015 ASAP operational herring assessment updated using data through 2017

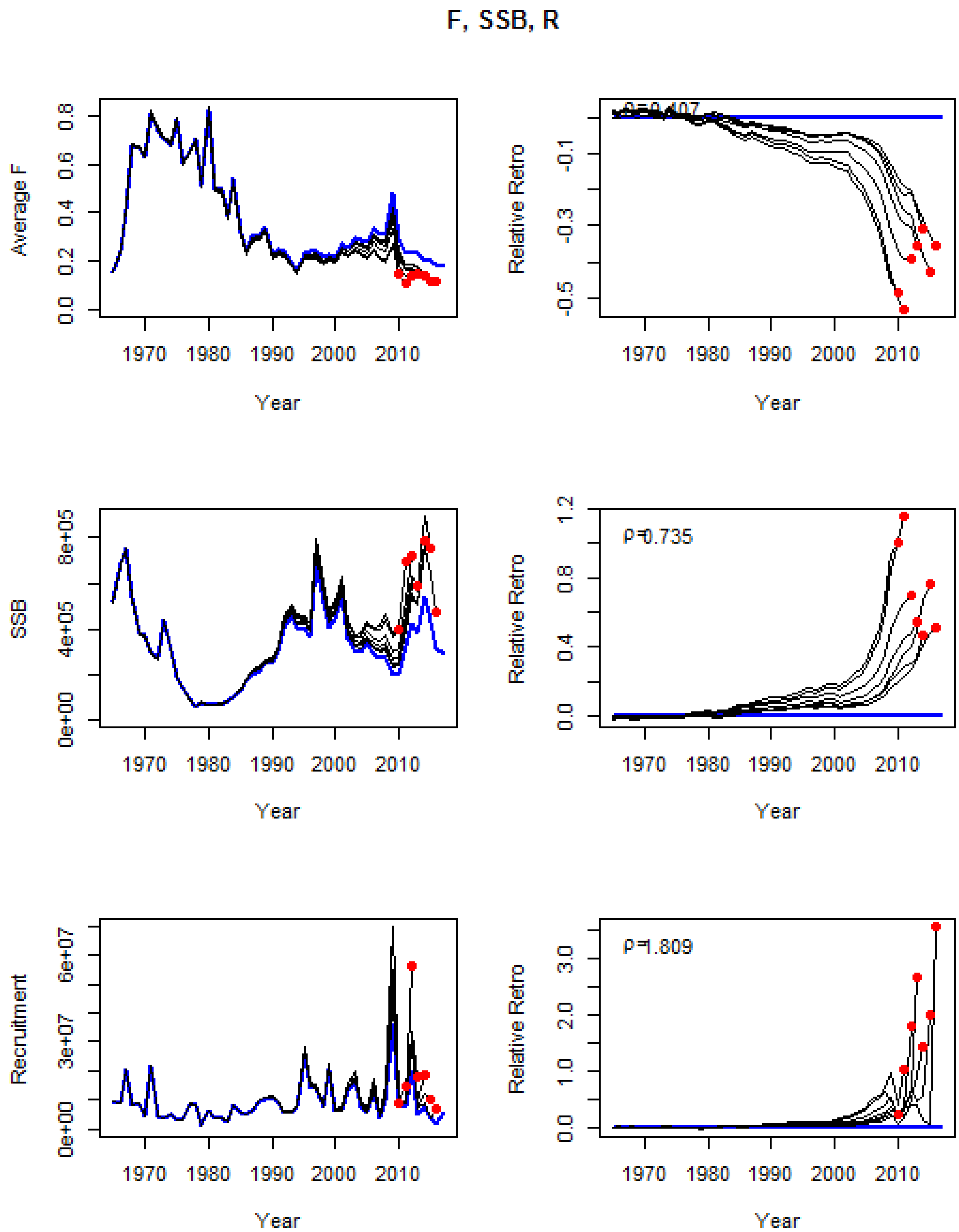


Figure B4- 2 Results of updating the 2015 ASAP operational herring assessment (2015FixFall) with data through 2017 (Run1_2017). The black diamond is the retrospectively adjusted SSB value from 2015.

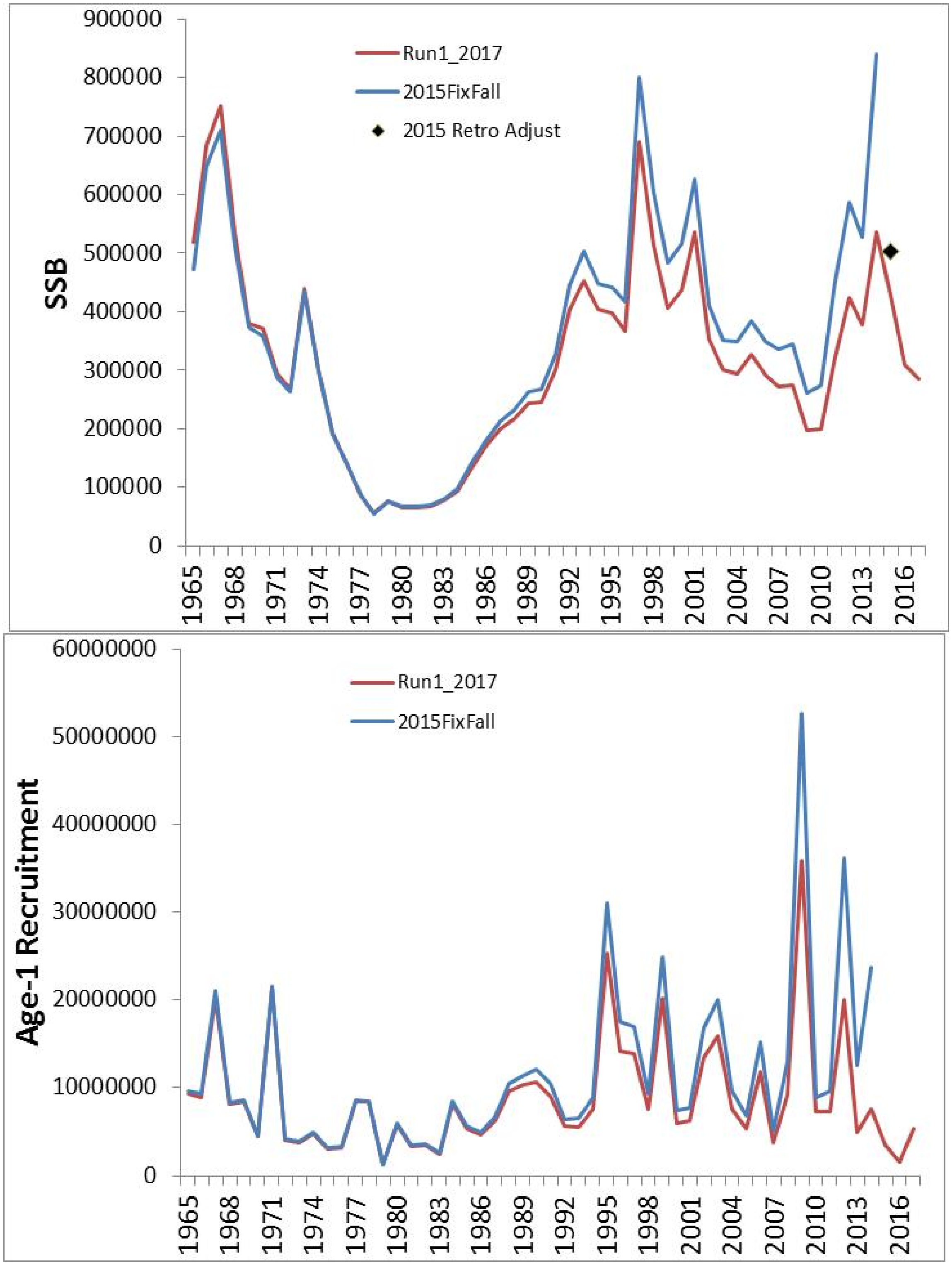


Figure B4- 3 Consumption of Atlantic herring by piscivorous predators as estimated using food habits data (Food Habits), and the amount of herring dying to due natural mortality in the ASAP base model (ASAP)

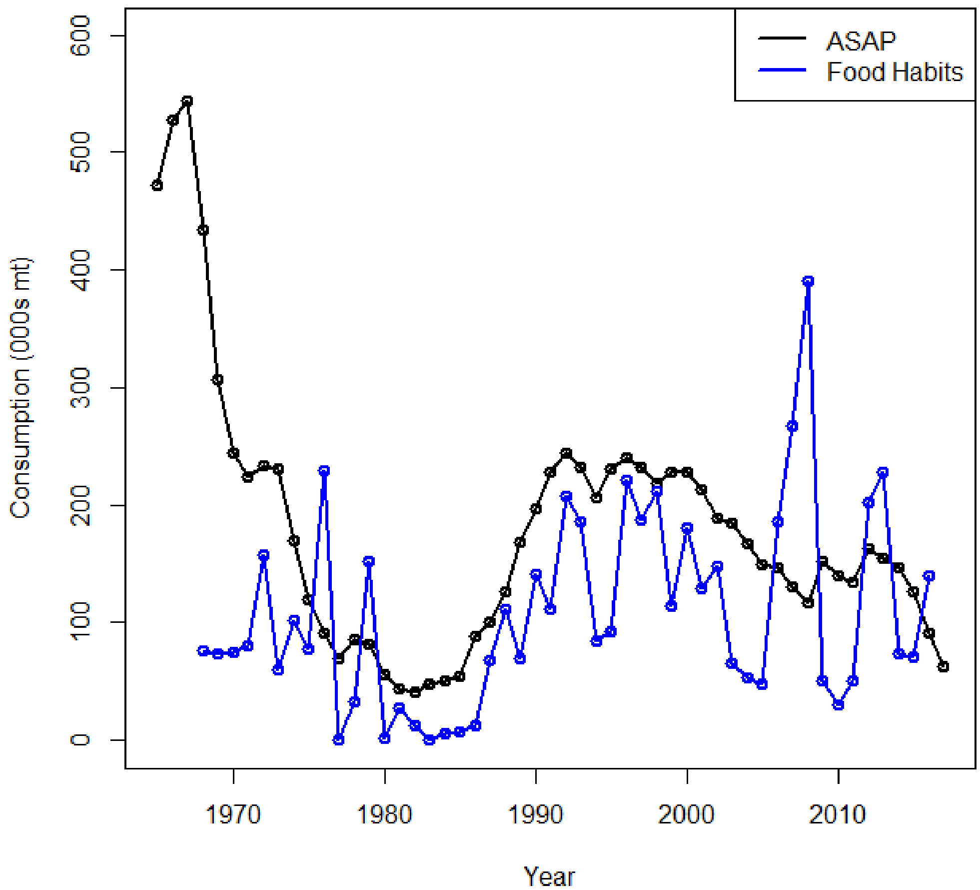
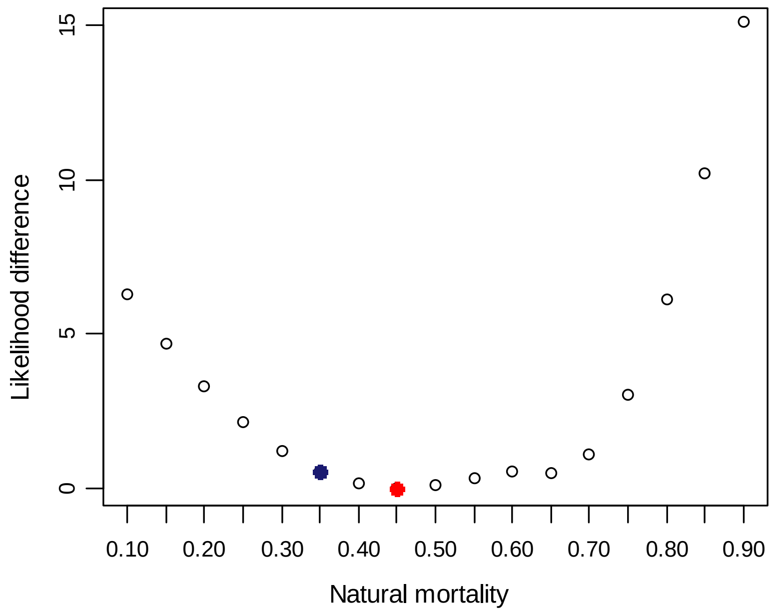


Figure B4- 4 Likelihood profile over time- and age-invariant natural mortality values for the base Atlantic herring ASAP model



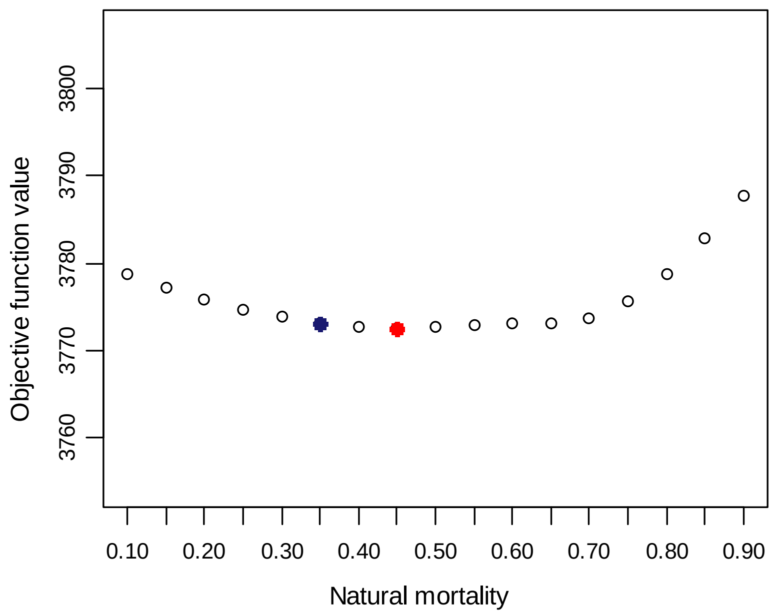
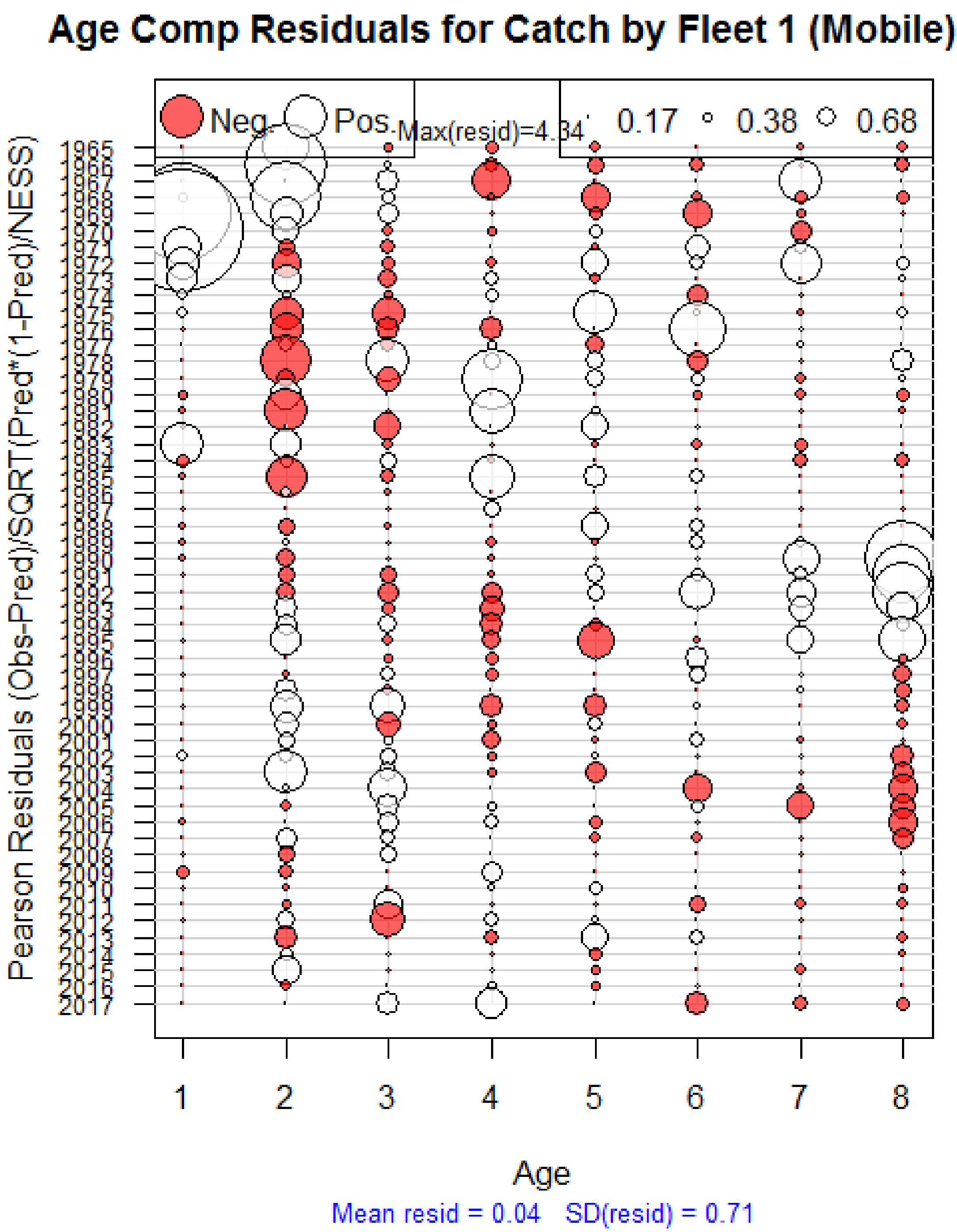


Figure B4- 5 Fits to Atlantic herring age composition for the mobile fleet from the base ASAP model (top panel) and from a fit with the mobile fleet selectivity at ages 5 and 6 fixed at 1.0 (bottom panel)



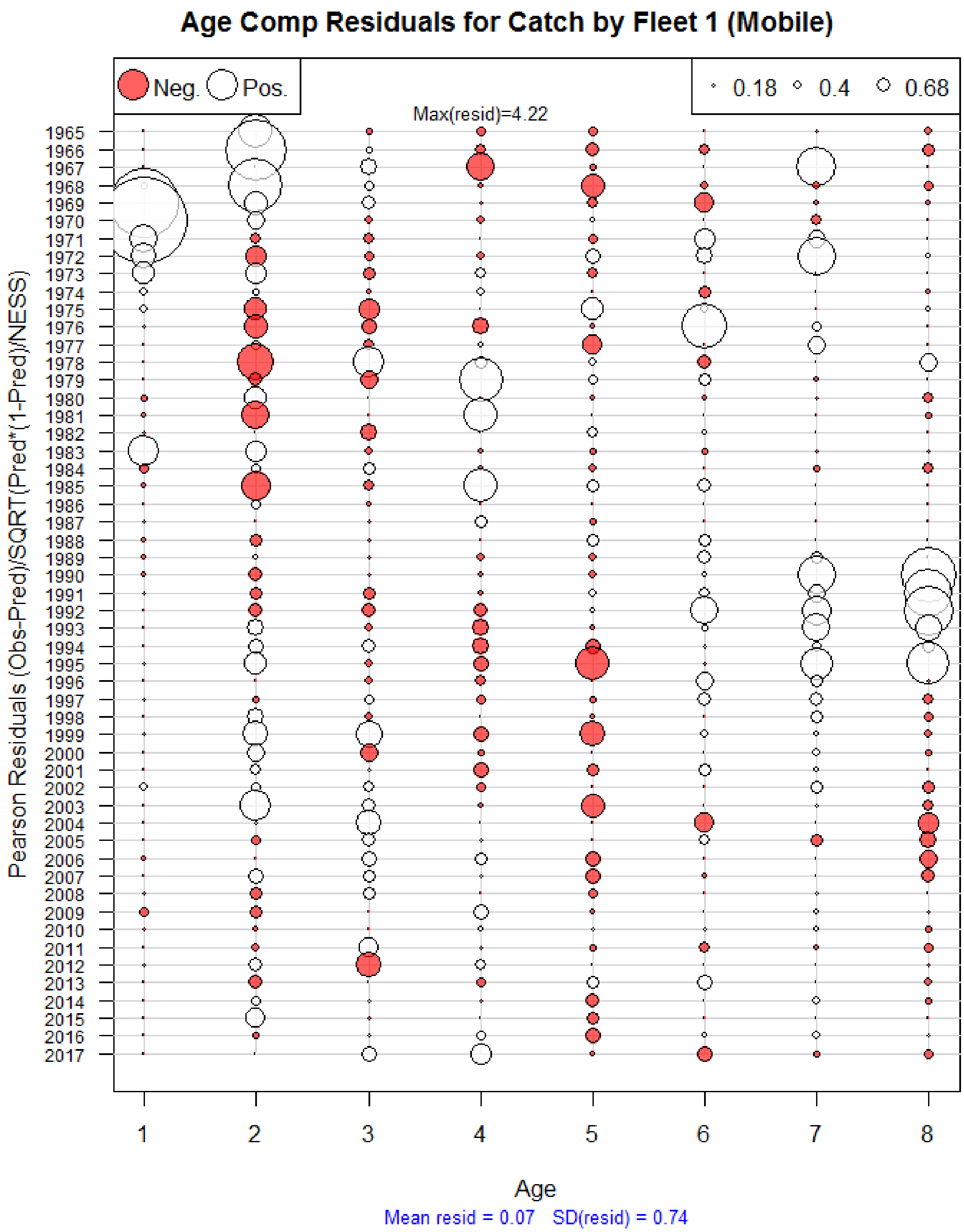
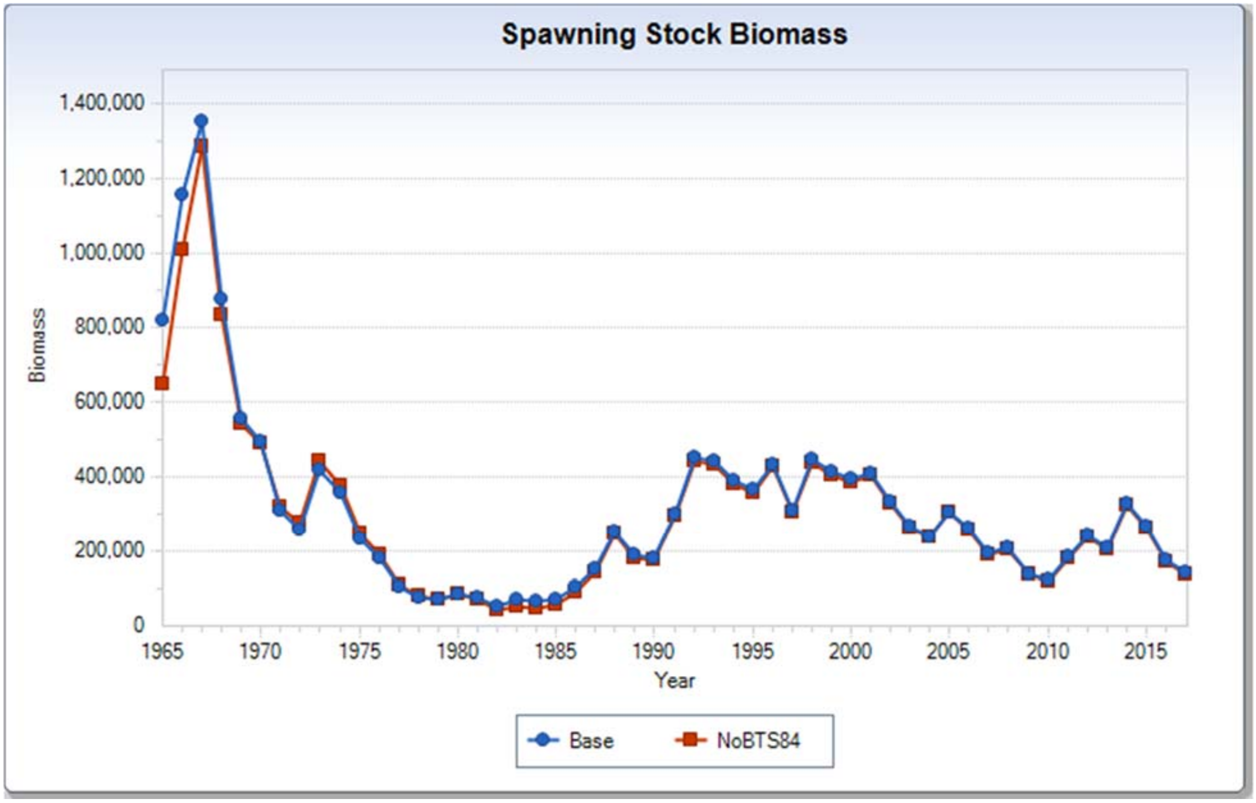

Age Comp Residuals for Catch by Fleet 1 (Mobile)
Neg.
Pos.
0.18
0.4
0.68
Max(resid)=4.22
Pearson Residuals (Obs-Pred)/SQRT(Pred*(1-Pred)/NESS)
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
1
2
3
4
5
6
7
8
Age
Mean resid = 0.07 SD(resid) = 0.74

Figure B4- 6 Effect of inclusion (Base) or exclusion (NoBTS84) of the NMFS spring and fall bottom trawl surveys during ≤1984



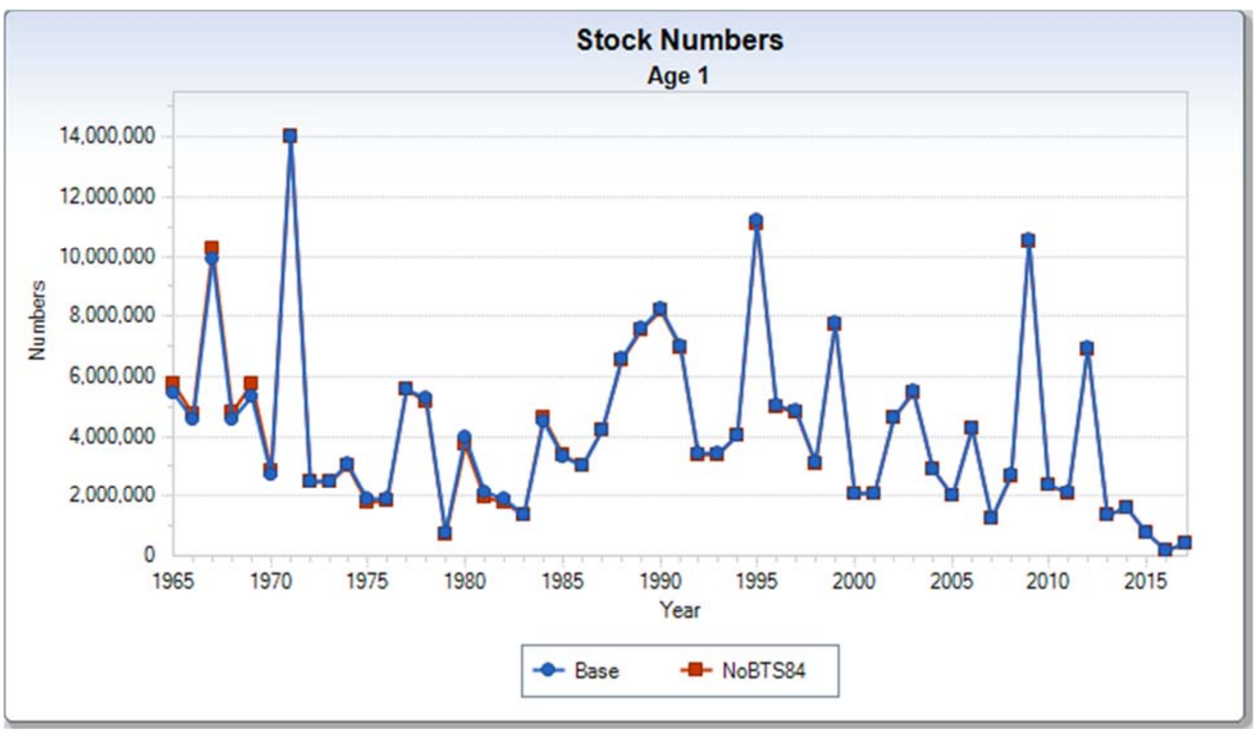


Figure B4- 7 RMSE of the indices after iteratively reweighting in the base ASAP model

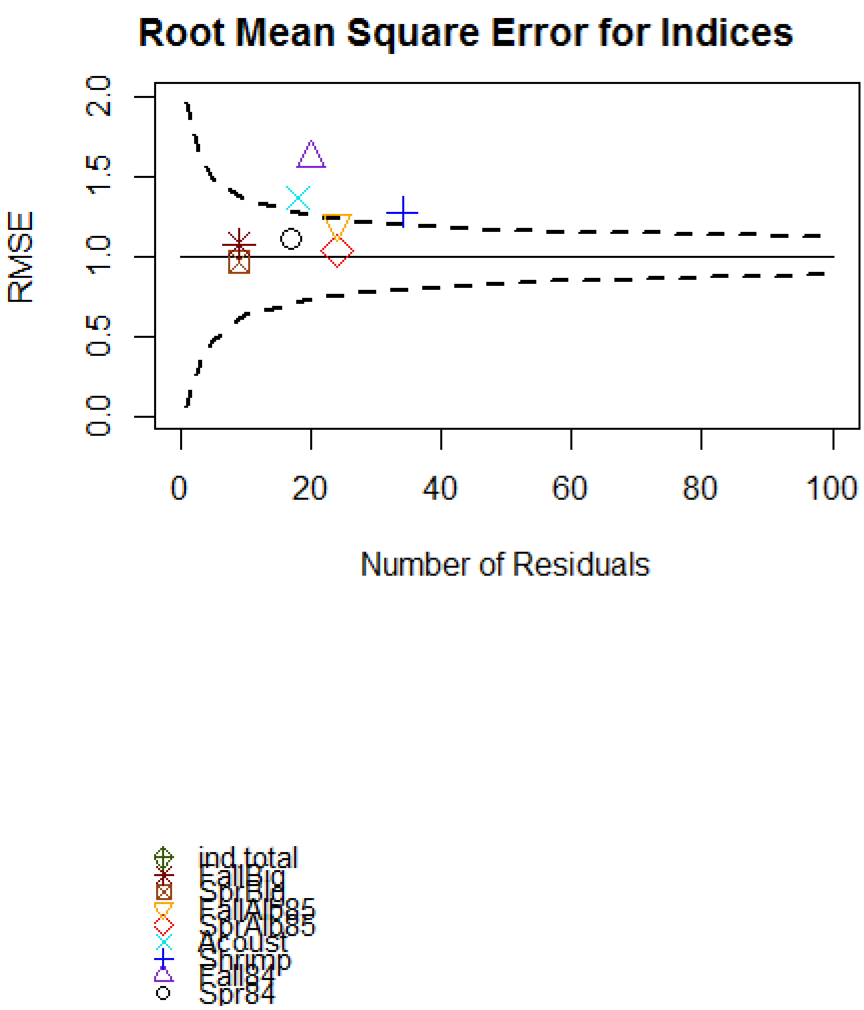


Figure B4- 8 Likelihood profile over steepness for the base ASAP model.

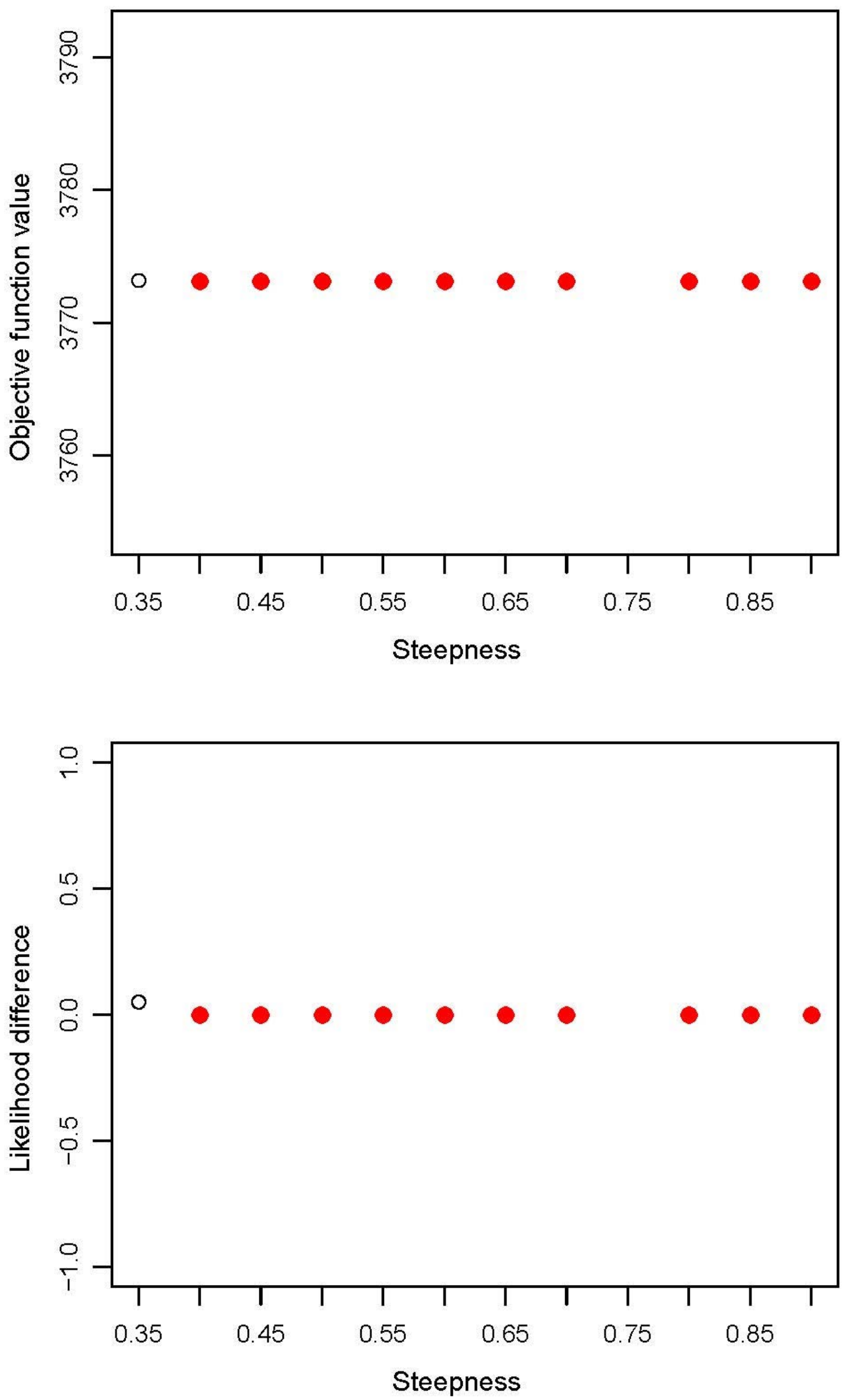
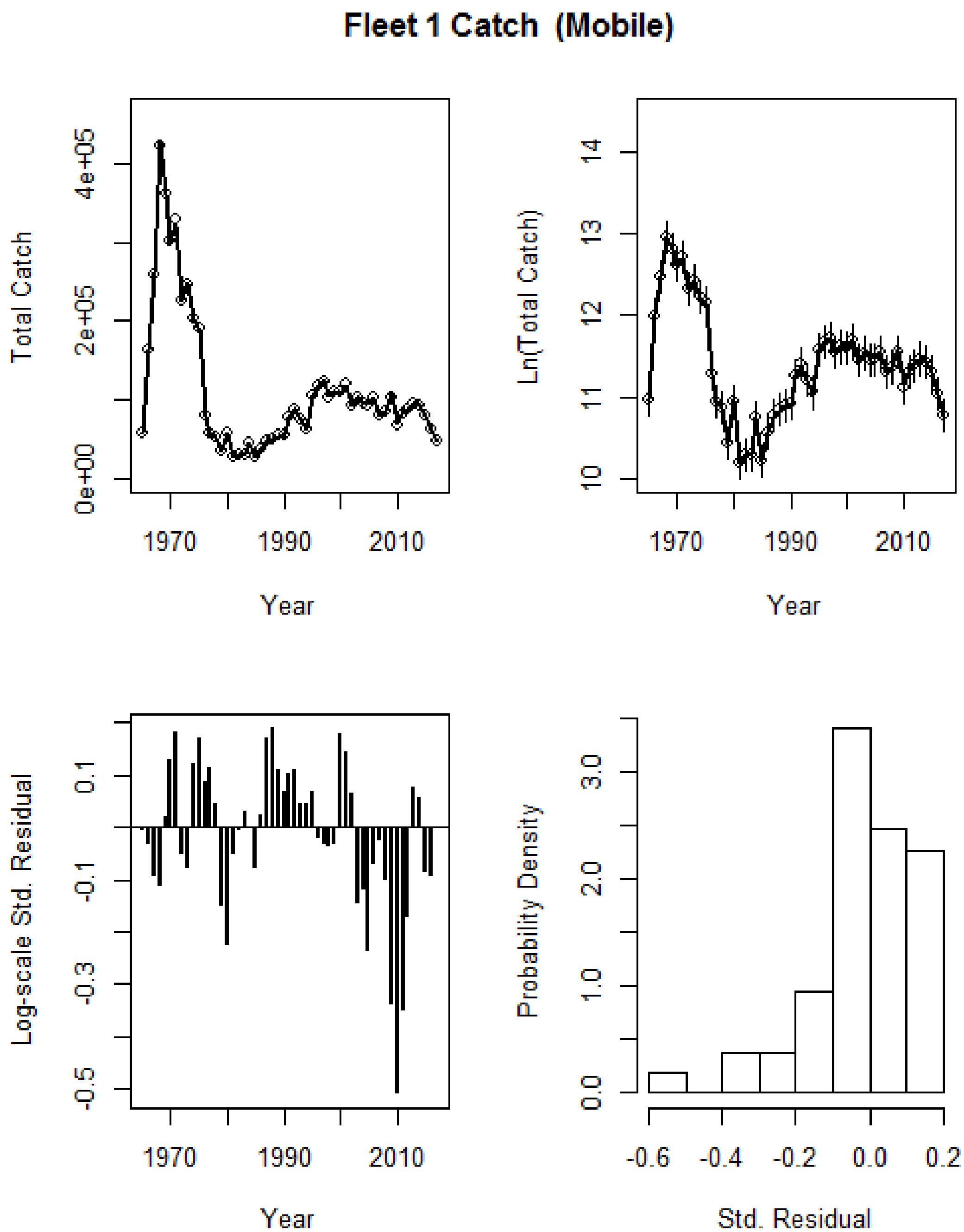
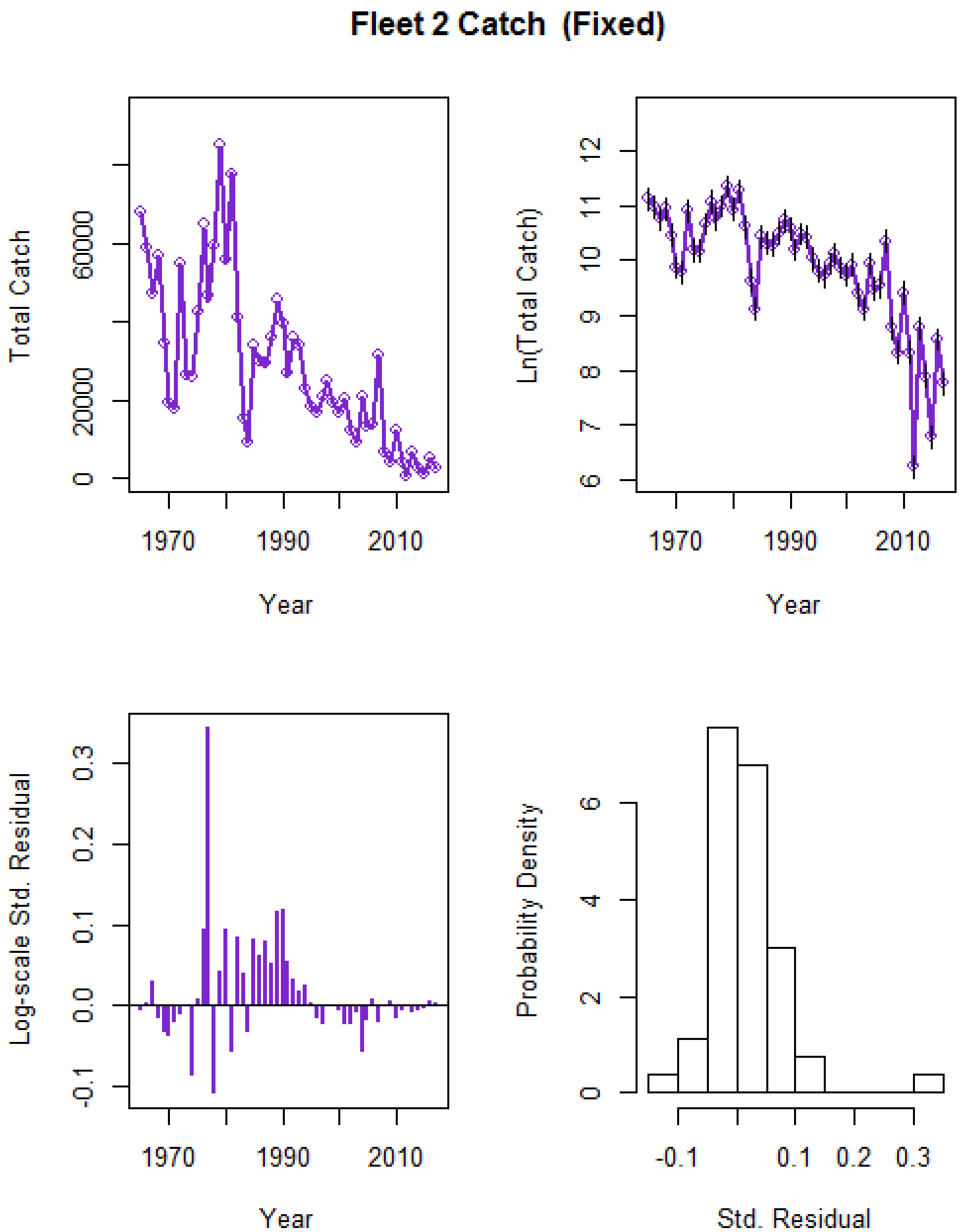


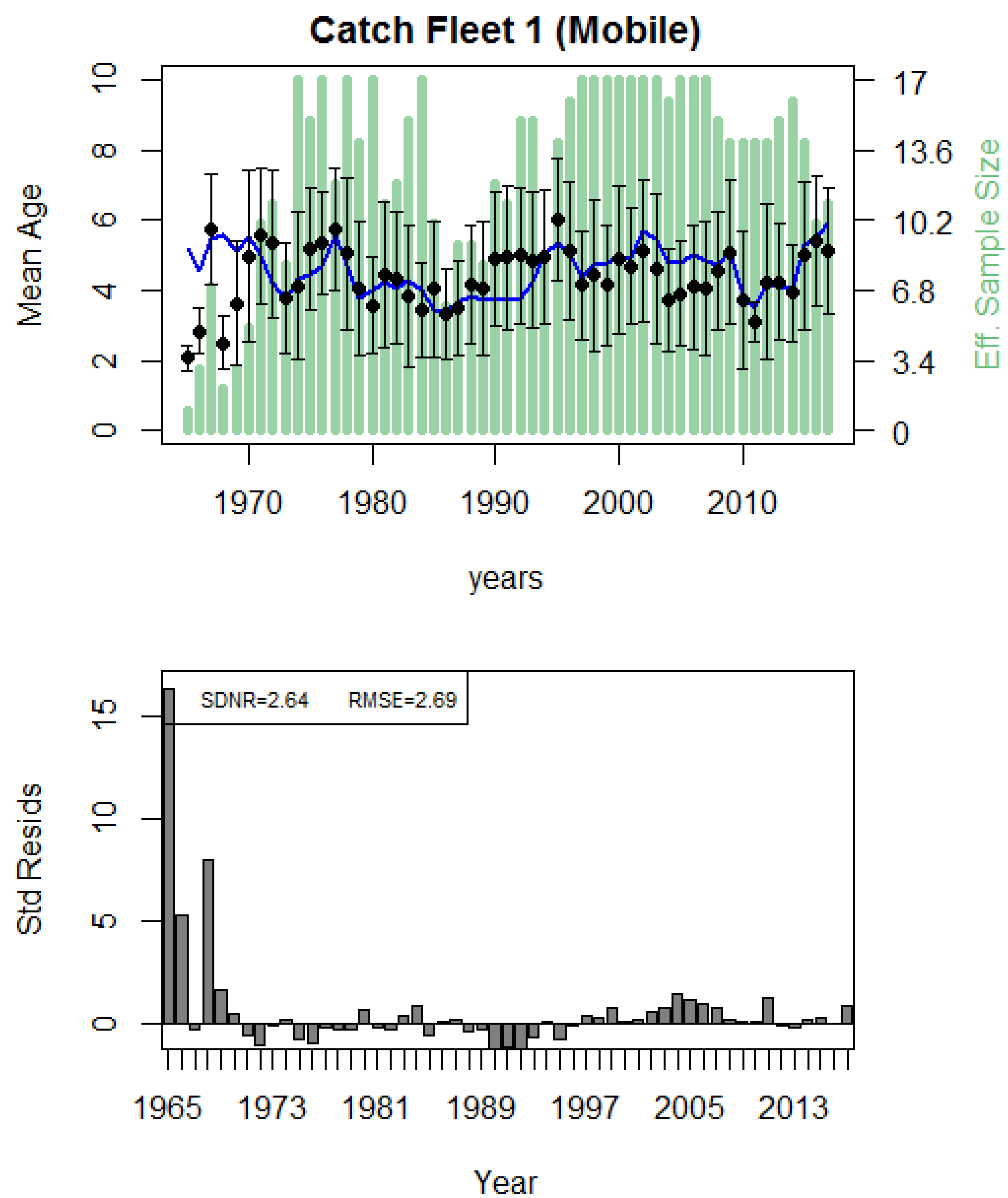
Figure B4- 9 Fits to Atlantic herring catch (mt) for the mobile (top panel) and fixed (bottom panel) fleets from the fit of the base ASAP model

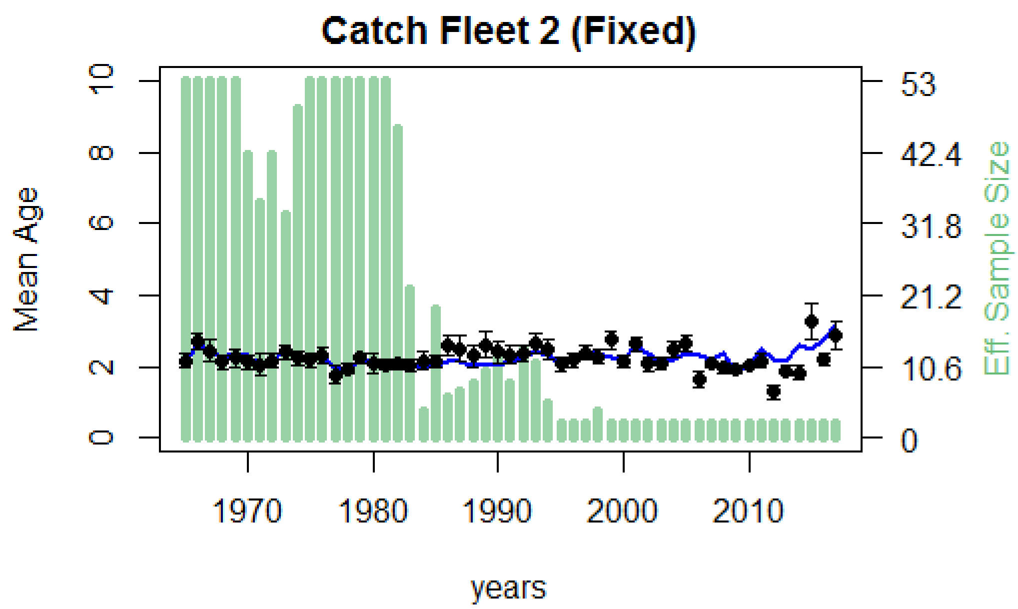




Fleet 2 Catch (Fixed)
Total Catch
0
20000
60000
1970
1990
2010
Year
Ln(Total Catch)
6
7
8
9
10
11
12
1970
1990
2010
Year
Log-scale Std. Residual
-0.1
0.0
0.1
0.2
0.3
1970
1990
2010
Year
Probability Density
0
2
4
6
-0.1
0.1
0.2
0.3
Std. Residual

Figure B4- 10 Fits to Atlantic herring mean age and standardized residuals for the mobile (top panel) and fixed (bottom panel) fleets from the fit of the base ASAP model




Catch Fleet 2 (Fixed)
Mean Age
0
2
4
6
8
10
53
42.4
31.8
21.2
10.6
0
Eff. Sample Size
1970
1980
1990
2000
2010
years

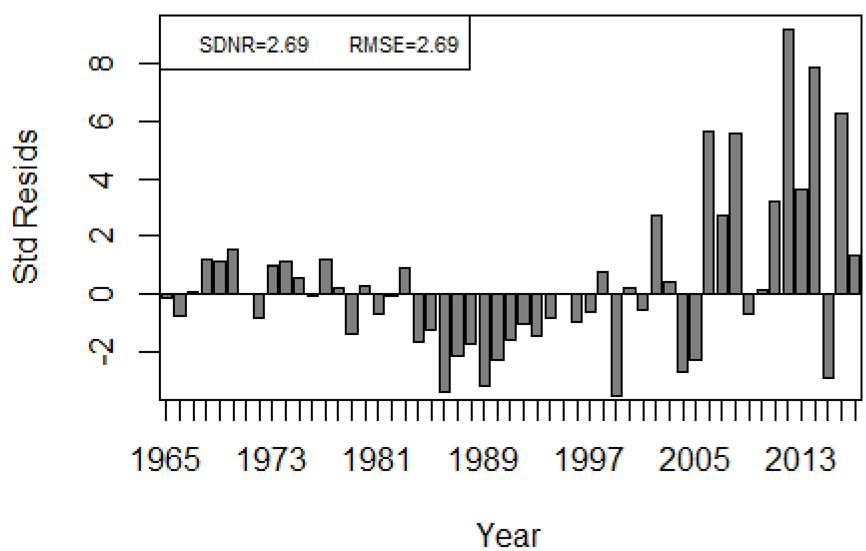
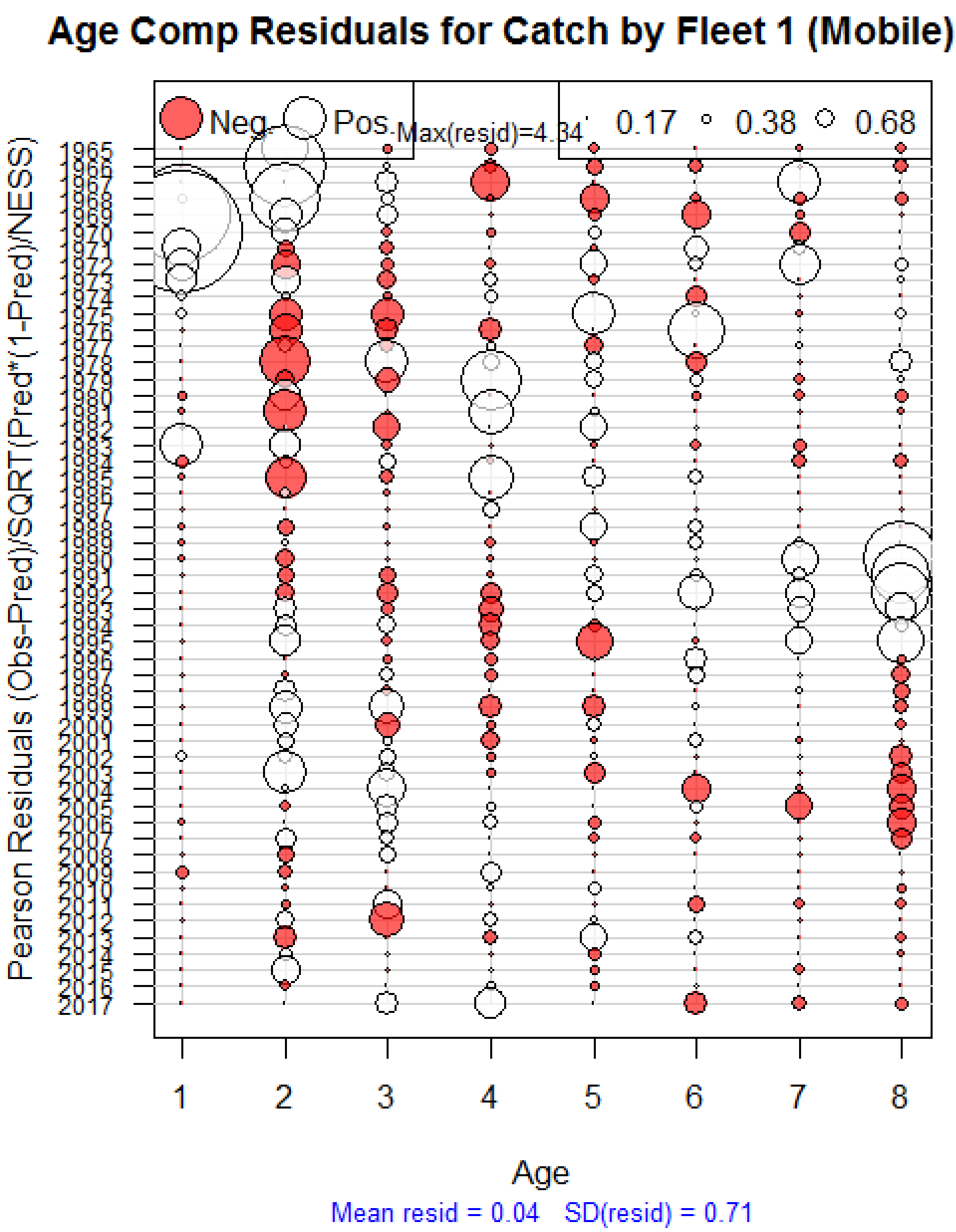

SDNR=2.69 RMSE=2.69
Std Resids
-2
0
2
4
6
8
1965
1973
1981
1989
1997
2005
2013
Year

Figure B4- 11 Fits to the Atlantic herring age compositions for the mobile (top panel) and fixed (bottom panel) fleets from the base ASAP model



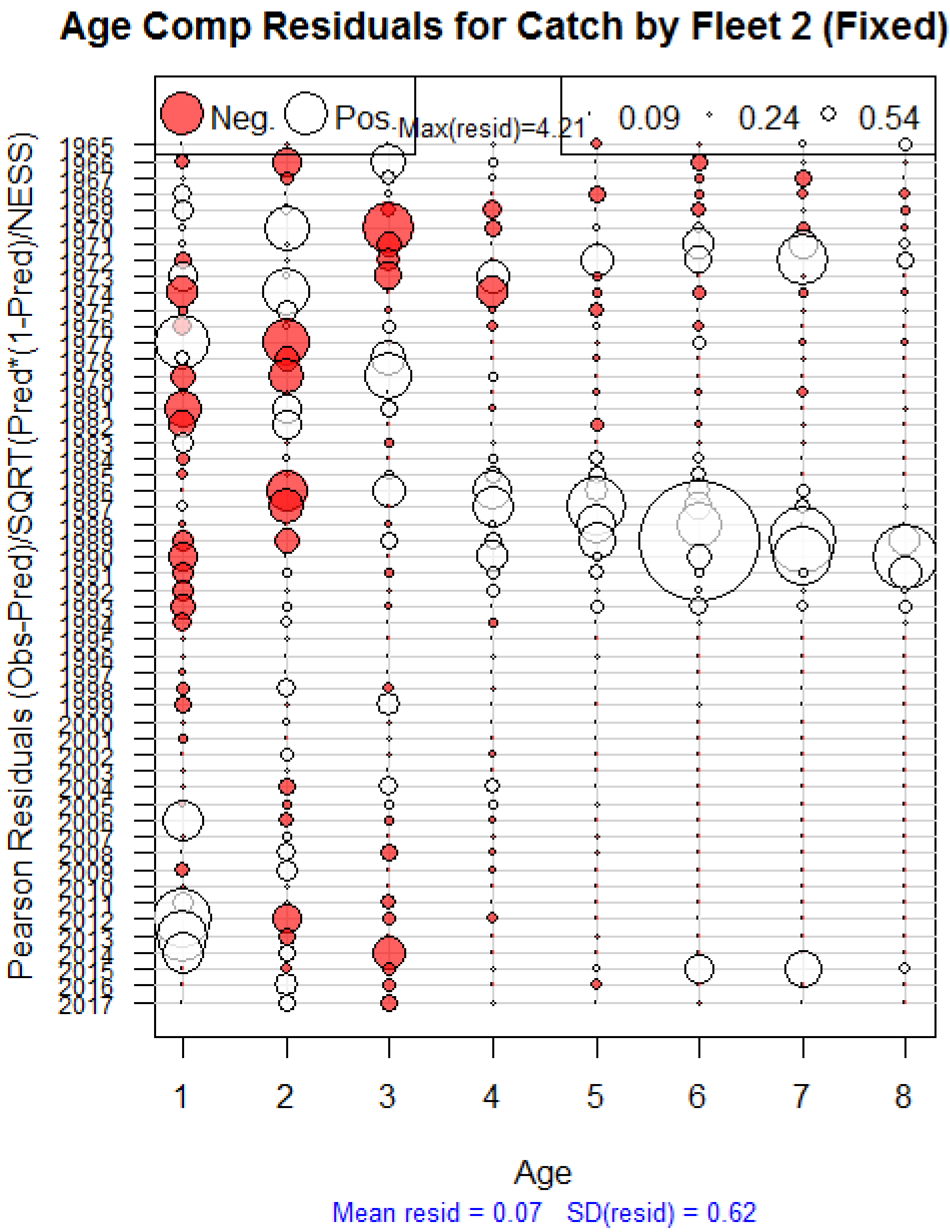
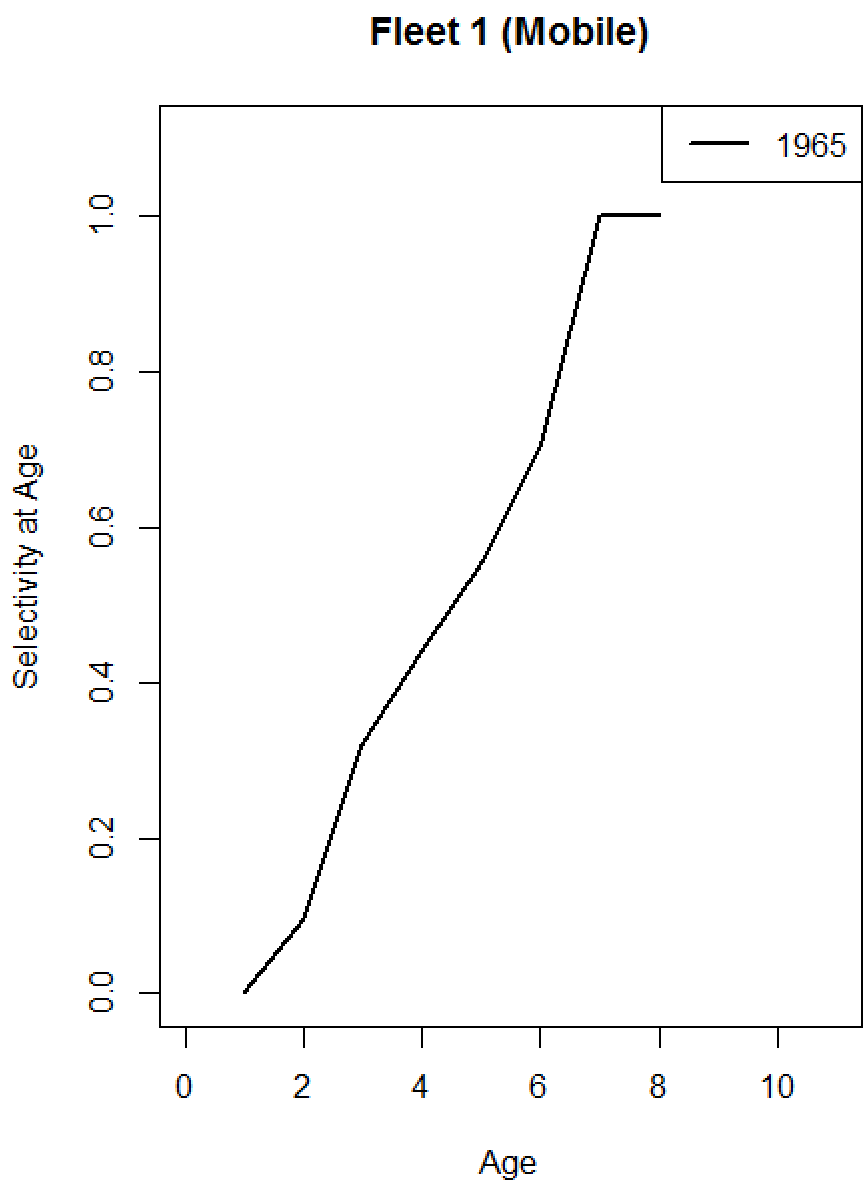
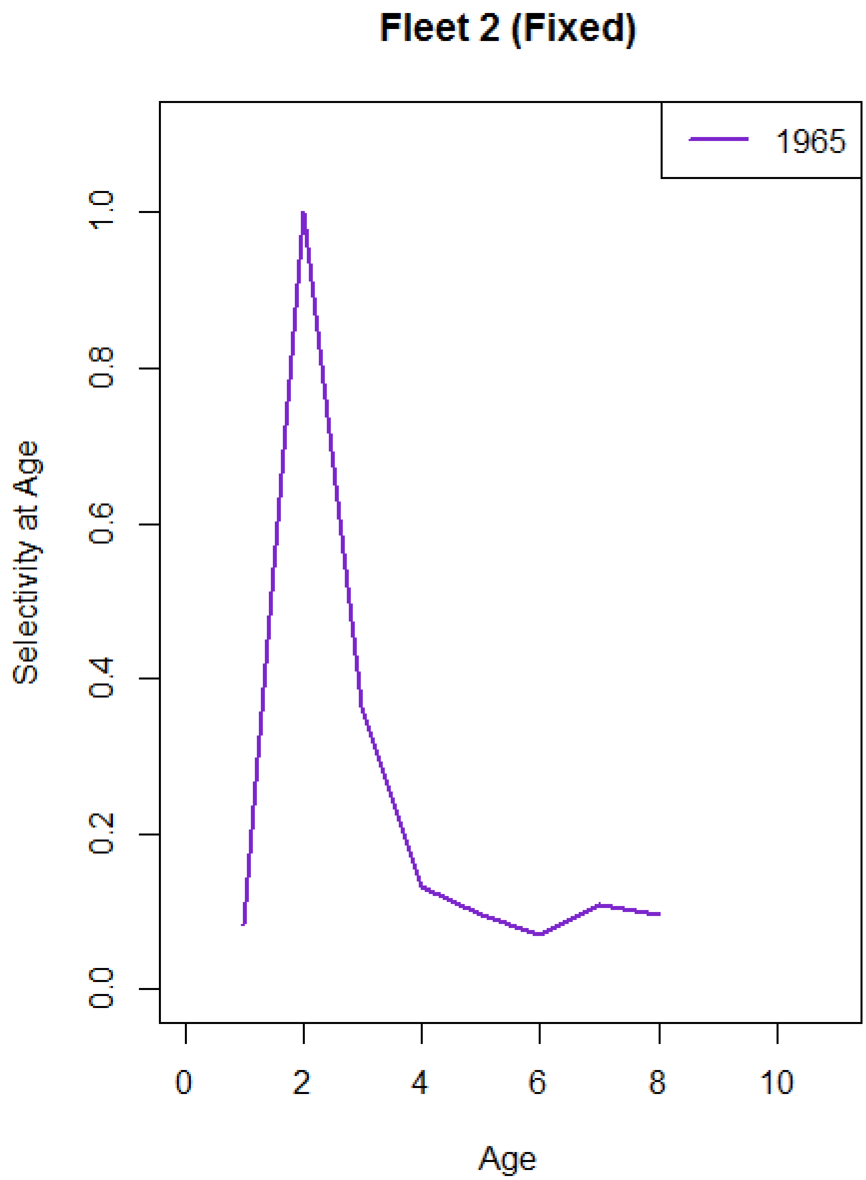

Age Comp Residuals for Catch by Fleet 2 (Fixed)
Neg.
Pos.
Max(resid)=4.21
0.09
0.24
0.54
Pearson Residuals (Obs-Pred)/SQRT(Pred*(1-Pred)/NESS)
Age
Mean resid = 0.07
SD(resid) = 0.62

Figure B4- 12 Selectivity for the mobile (top panel) and fixed (bottom panel) fleets from the base ASAP model





Fleet 2 (Fixed)
1965
Selectivity at Age
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
Age

Figure B4- 13 Average selectivity and terminal year maturity at age from the base ASAP model

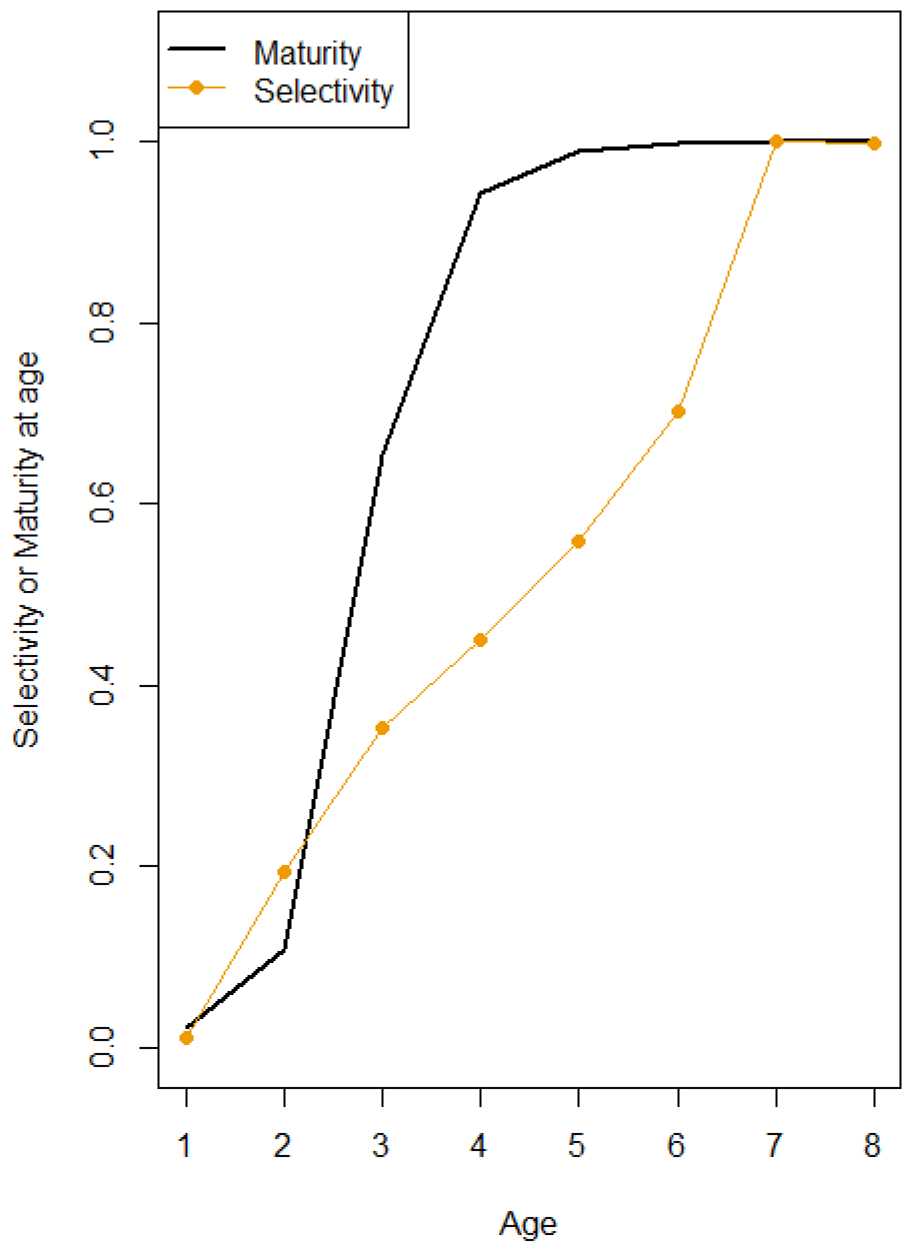
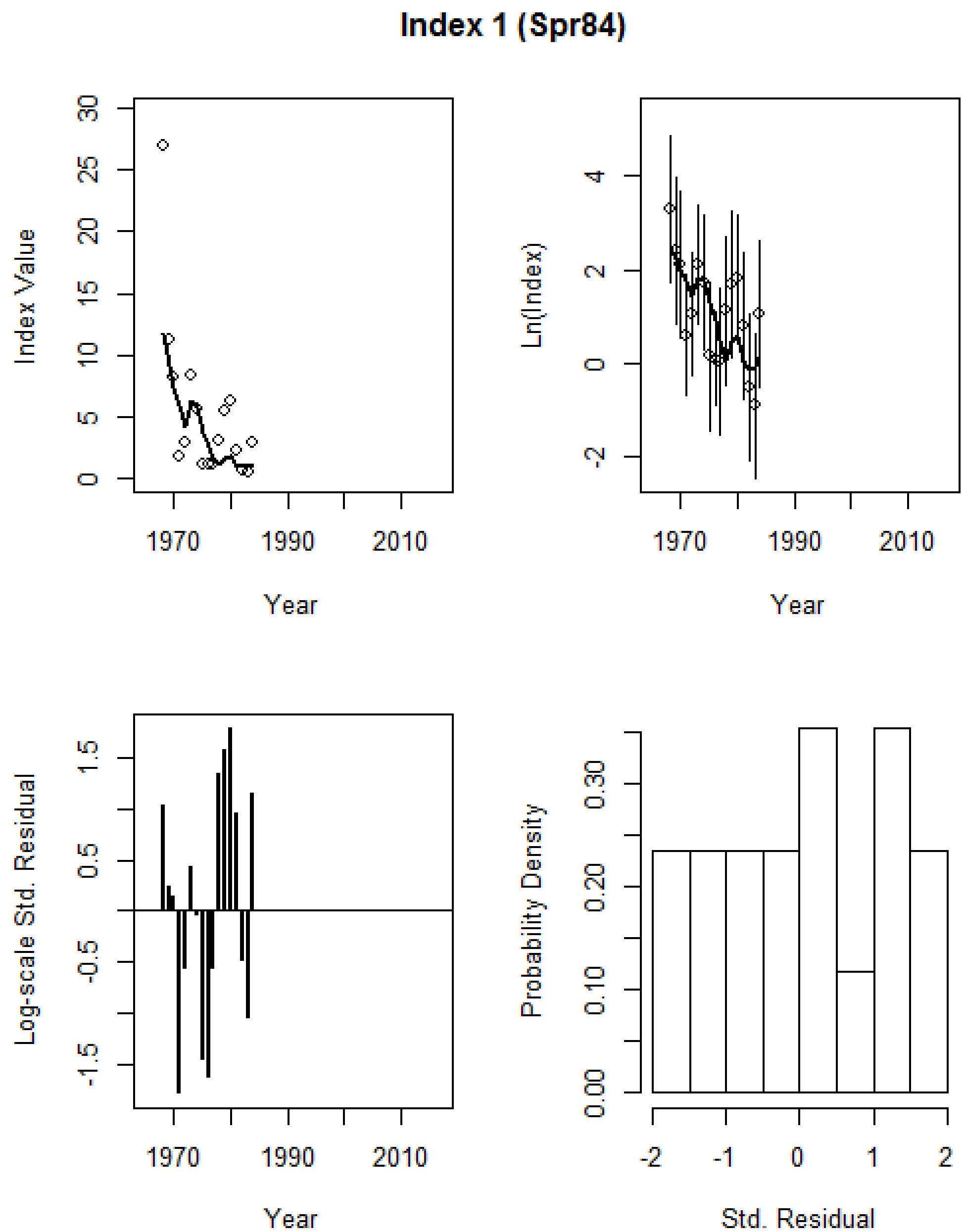
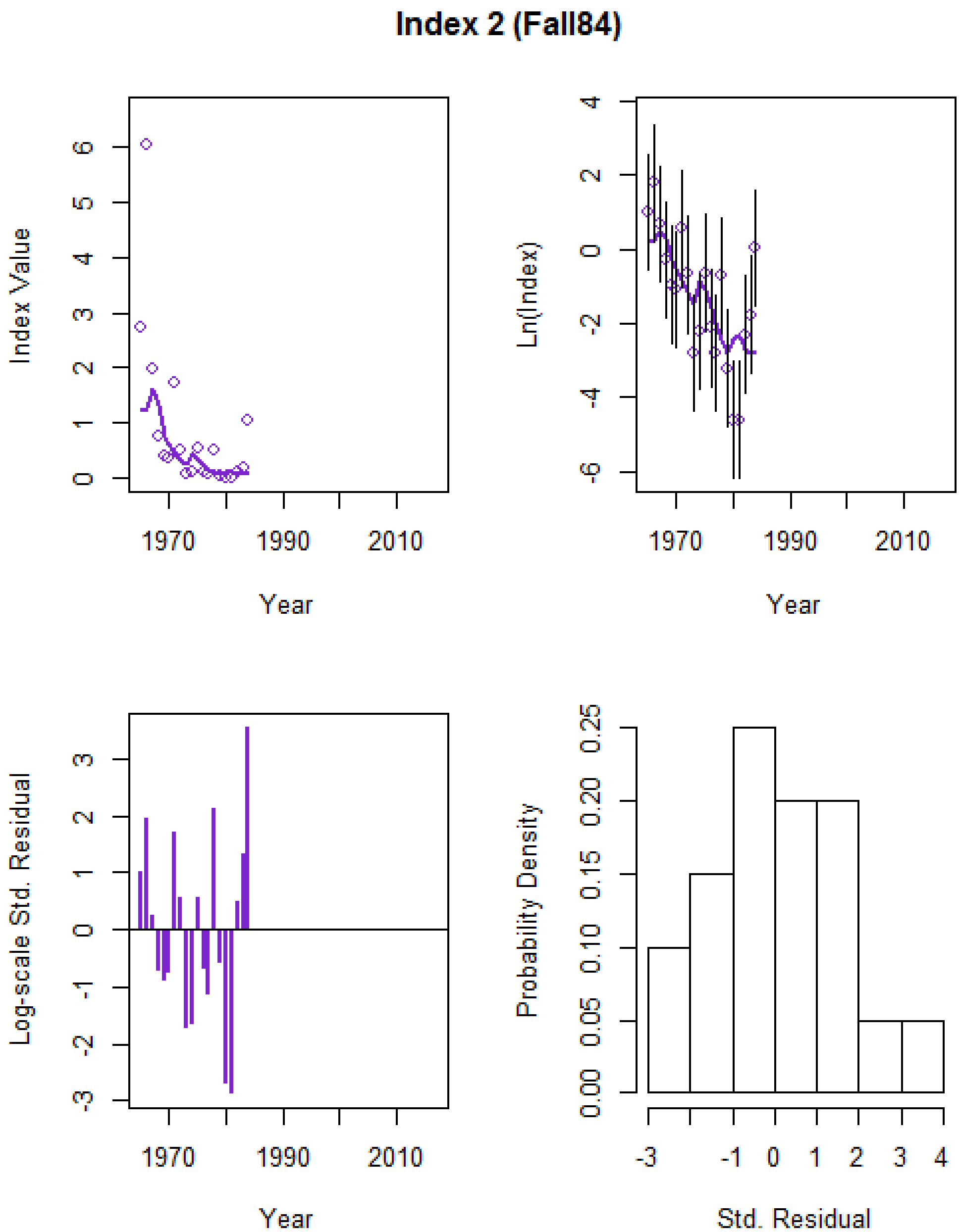
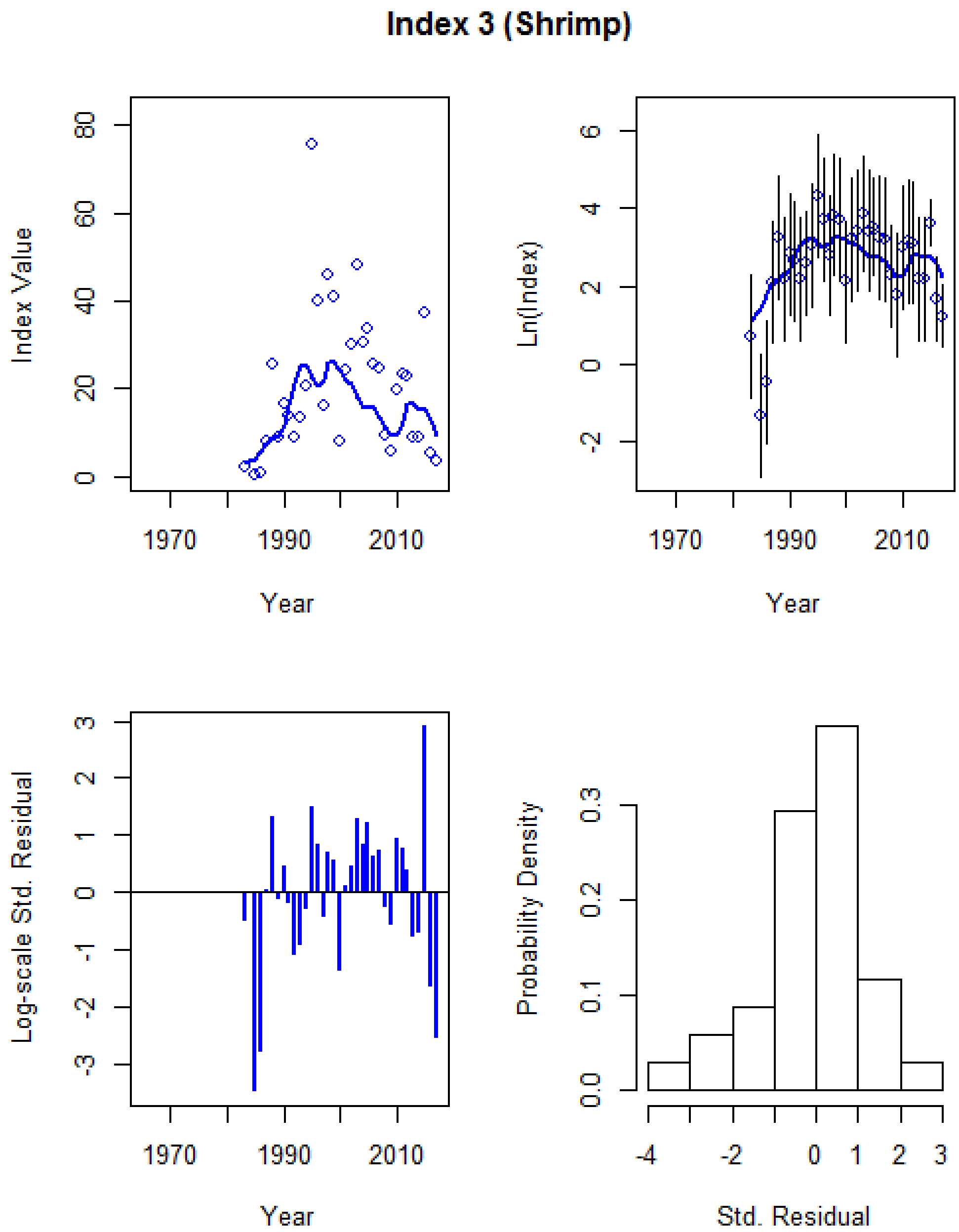
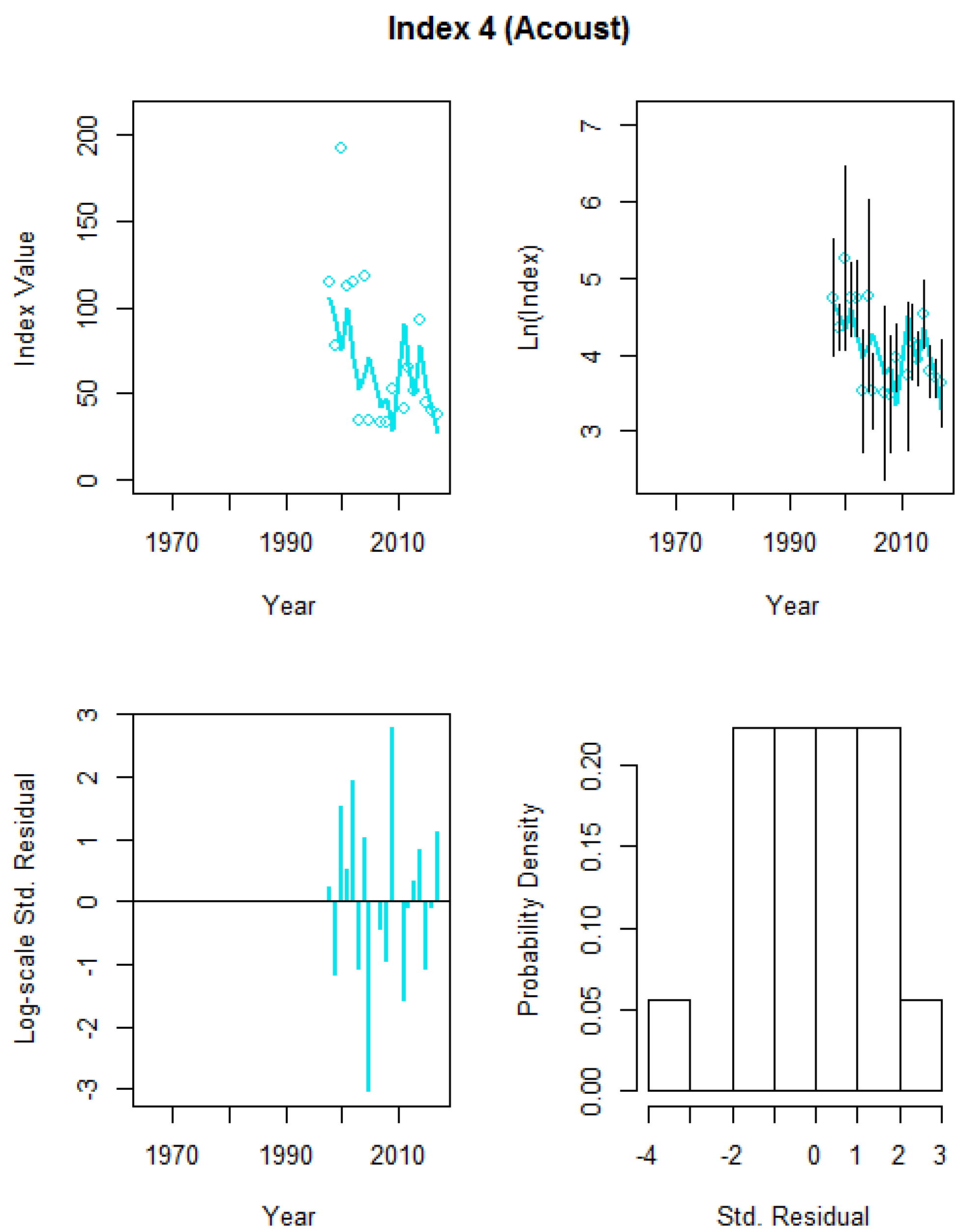


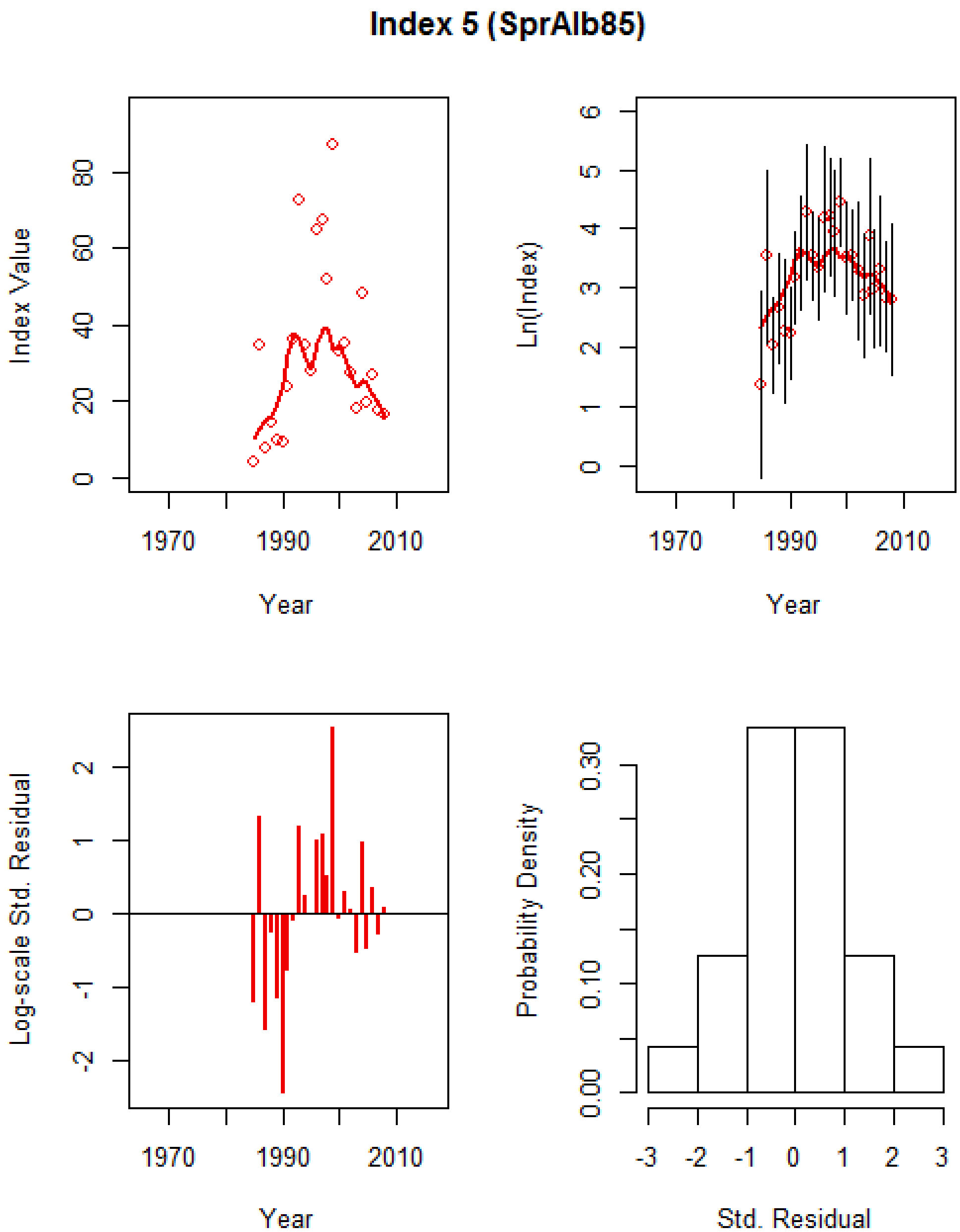
Figure B4- 14 Fits to indices for the base ASAP model (Spr84: Albatross 1965-1984; Fall84: Albatross 1965-1984; Shrimp: NMFS summer/shrimp; Acoust: NMFS acoustic index; Spr85: Albatross 1985-2008; Fall85: Albatross 1985-2008; SprBig: Bigelow 2009-2017; FallBig: Bigelow 2009-2017)



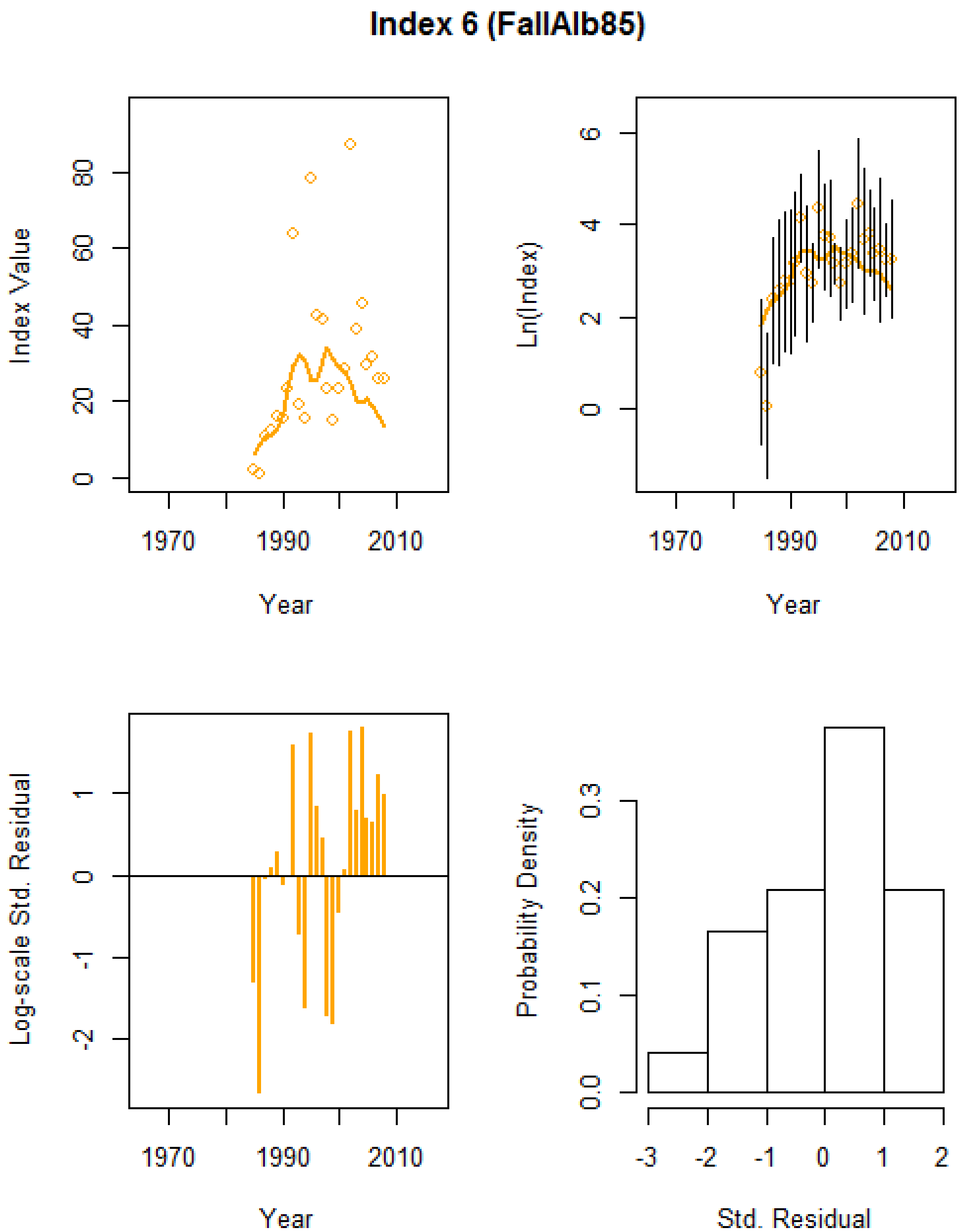

Index 2 (Fall84)
Index Value
Year
Ln(Index)
Year
Log-scale Std. Residual
Year
Probability Density
Std. Residual
1970
1990
2010

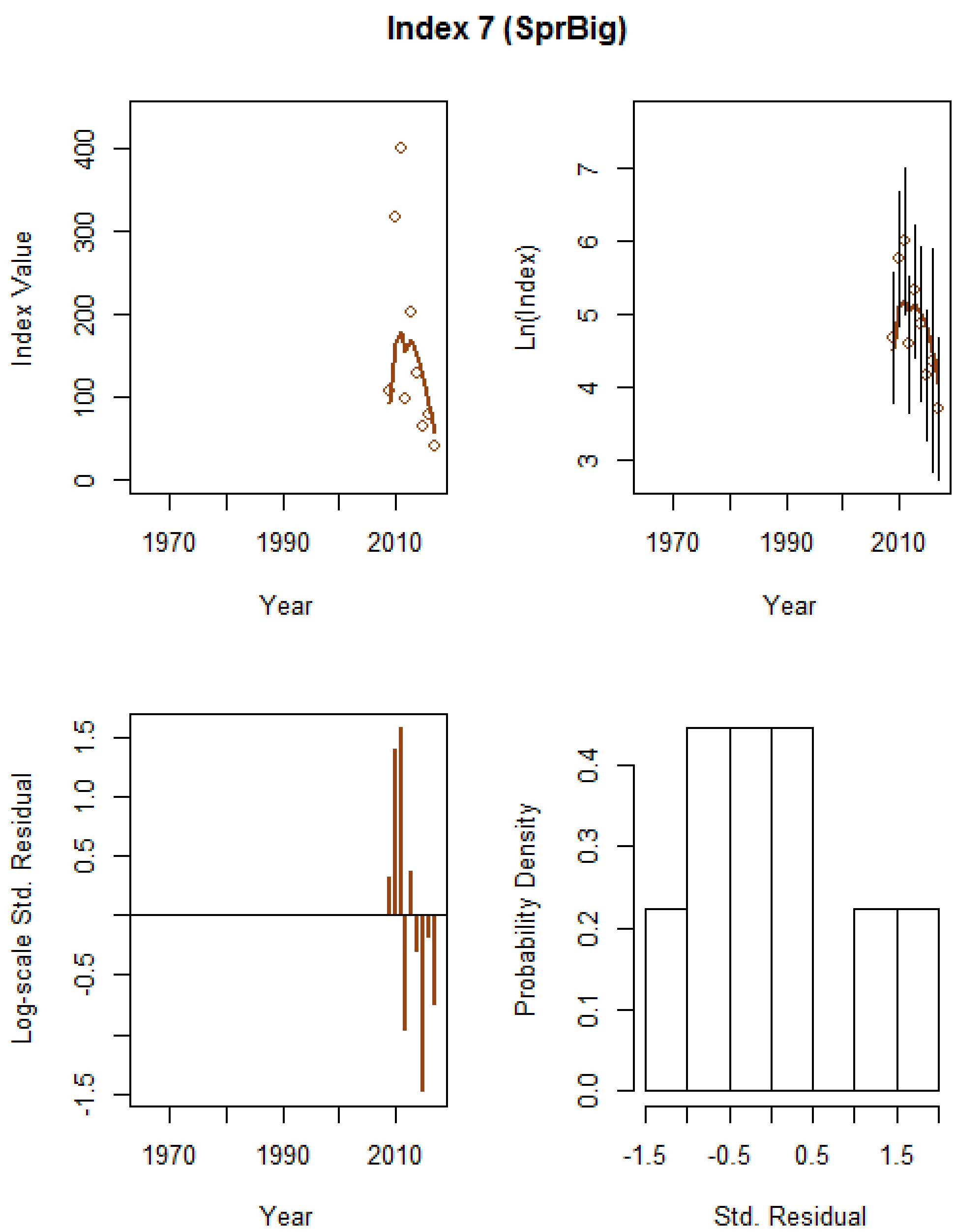

Index 3 (Shrimp)
Index Value
Year
Ln(Index)
Year
Log-scale Std. Residual
Year
Probability Density
Std. Residual


Index 4 (Acoust)
Index Value
0
50
100
150
200
1970
1990
2010
Year
Ln(Index)
3
4
5
6
7
1970
1990
2010
Year
Log-scale Std. Residual
-3
-2
-1
0
1
2
3
1970
1990
2010
Year
Probability Density
0.00
0.05
0.10
0.15
0.20
-4
-2
0
1
2
3
Std. Residual



Index 5 (SprAlb85)
Index Value
0
20
40
60
80
1970
1990
2010
Year
Ln(Index)
0
1
2
3
4
5
6
1970
1990
2010
Year
Log-scale Std. Residual
-2
-1
0
1
2
1970
1990
2010
Year
Probability Density
0.00
0.10
0.20
0.30
-3
-2
-1
0
1
2
3
Std. Residual


Index 6 (FallAlb85)
Index Value
0
20
40
60
80
1970
1990
2010
Year
Ln(Index)
0
2
4
6
Log-scale Std. Residual
-2
-1
0
1
Probability Density
0.0
0.1
0.2
0.3
-3
-2
-1
0
1
2
Std. Residual


Index 7 (SprBig)
Index Value
0
100
200
300
400
1970
1990
2010
Year
Ln(Index)
3
4
5
6
7
1970
1990
2010
Year
Log-scale Std. Residual
-1.5
-0.5
0.5
1.0
1.5
1970
1990
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
-1.5
-0.5
0.5
1.5
Std. Residual

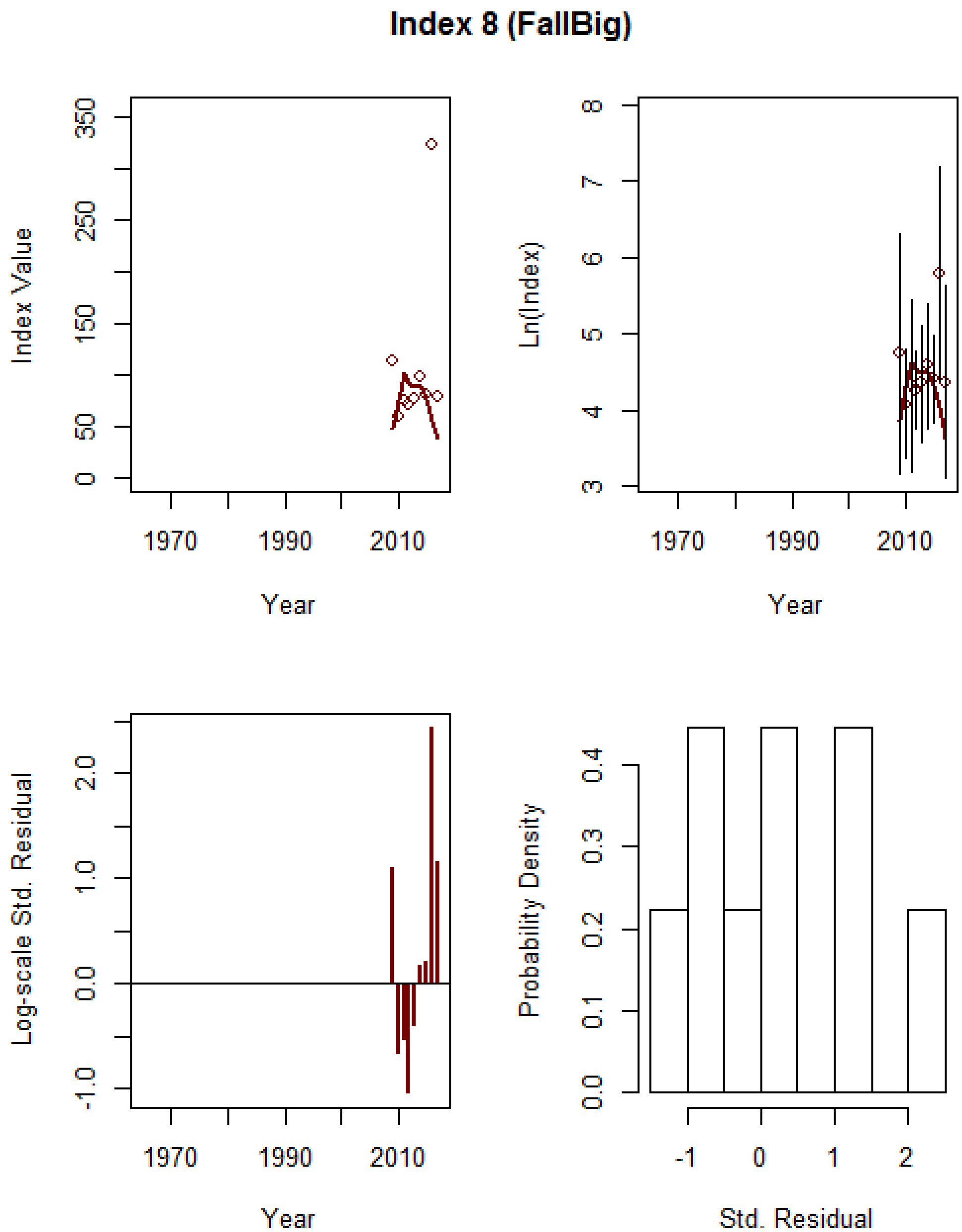
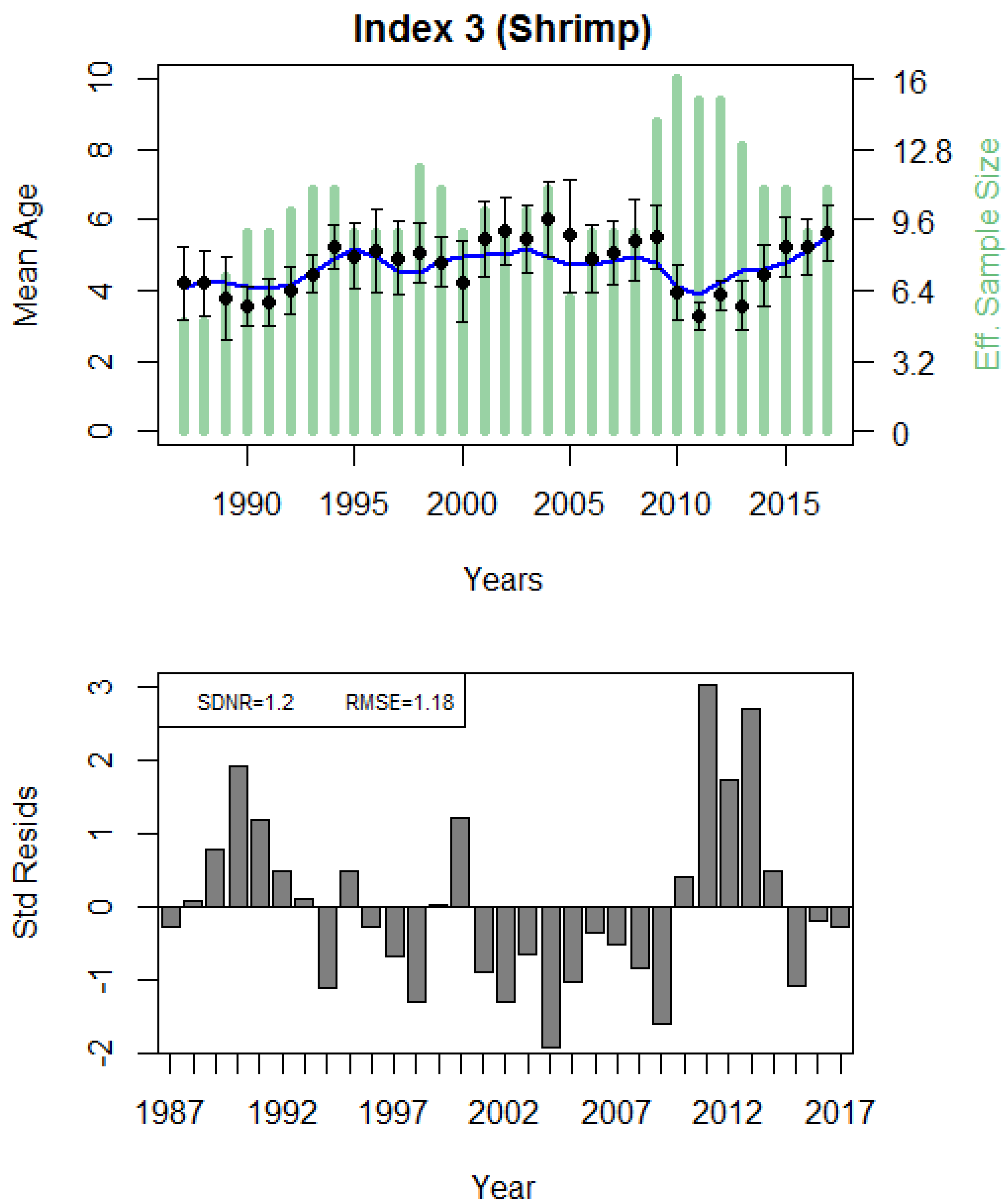
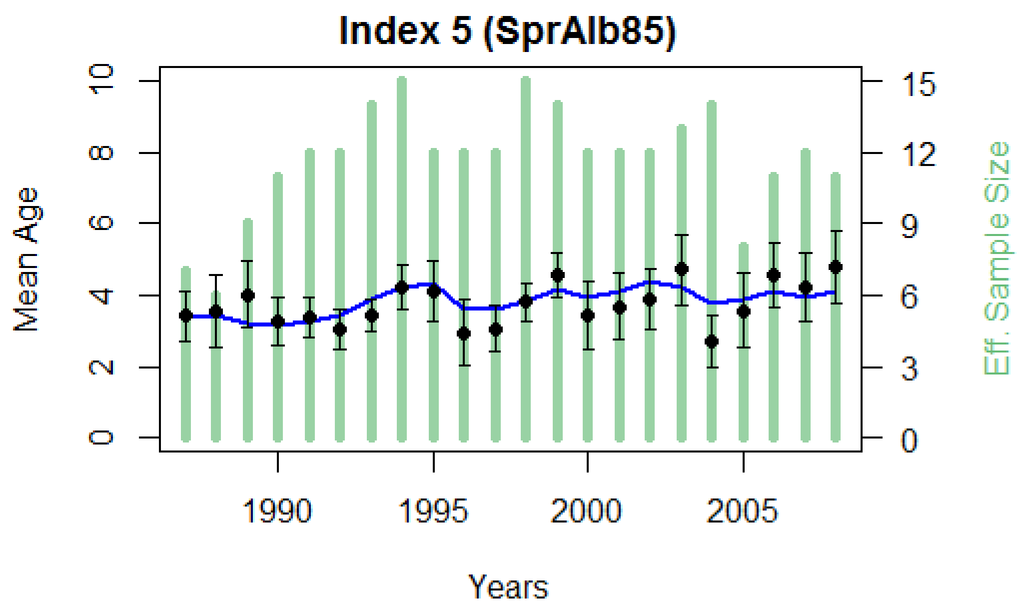
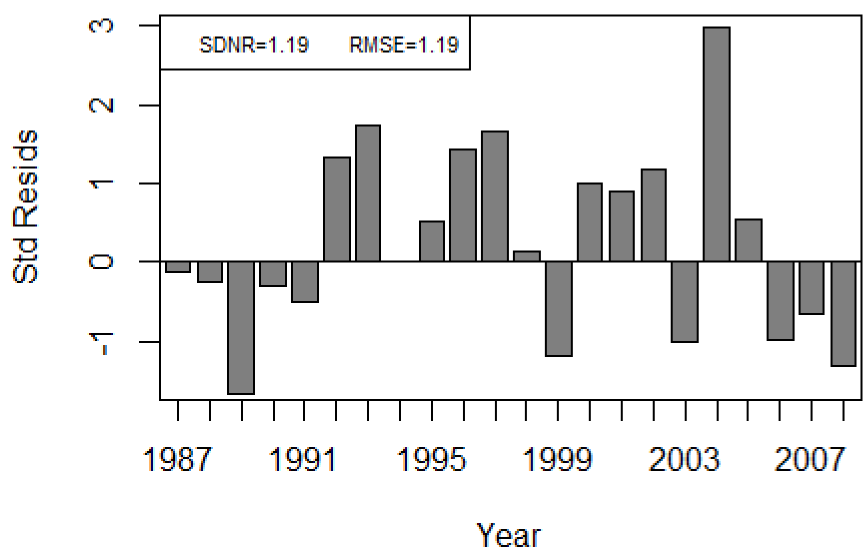
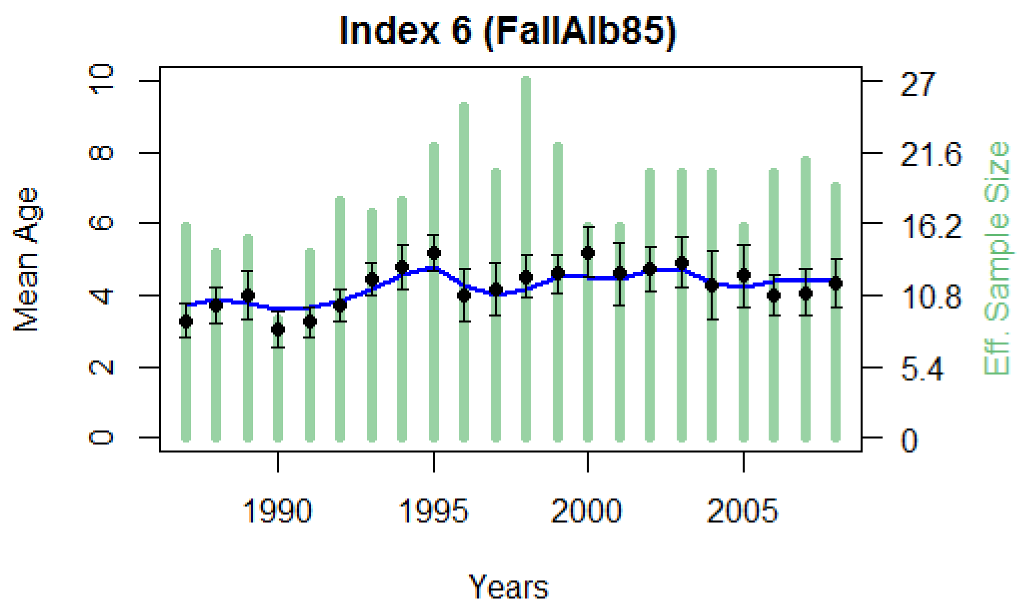

Index 8 (FallBig)
Index Value
0
50
150
250
350
1970
1990
2010
Year
Ln(Index)
3
4
5
6
7
8
1970
1990
2010
Year
Log-scale Std. Residual
-1.0
0.0
1.0
2.0
1970
1990
2010
Year
Probability Density
0.0
0.1
0.2
0.3
0.4
-1
0
1
2
Std. Residual

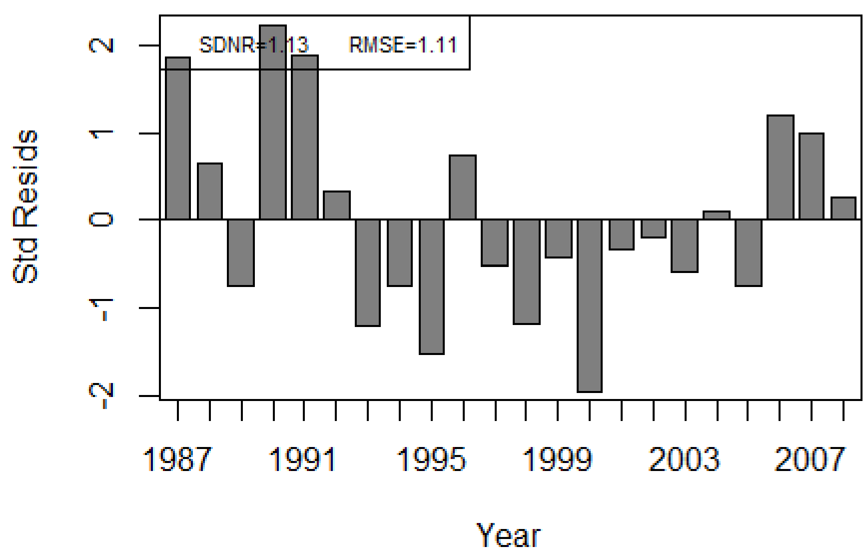
Figure B4- 15 Fits to Atlantic herring mean age for the base ASAP model (Shrimp: NMFS summer/shrimp; Spr85: Albatross 1985-2008; Fall85: Albatross 1985-2008; SprBig: Bigelow 2009-2017; FallBig: Bigelow 2009-2017)

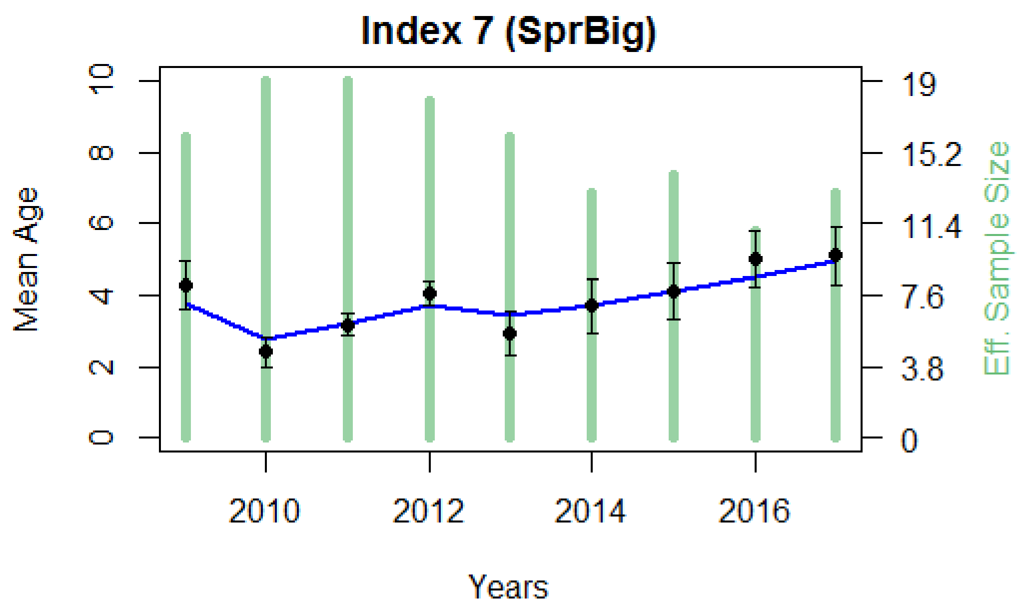


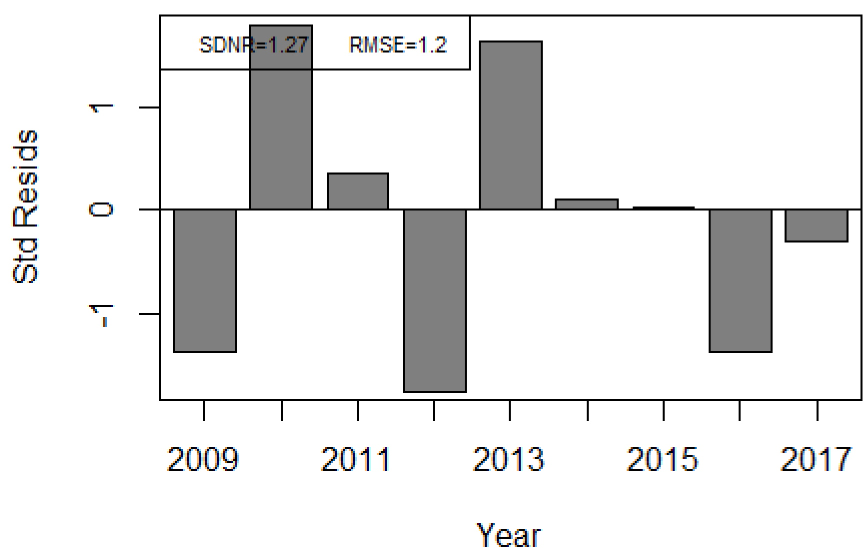

Index 5 (SprAlb85)
Mean Age
Eff. Sample Size
Years
0
2
4
6
8
10
0
3
6
9
12
15
1990
1995
2000
2005

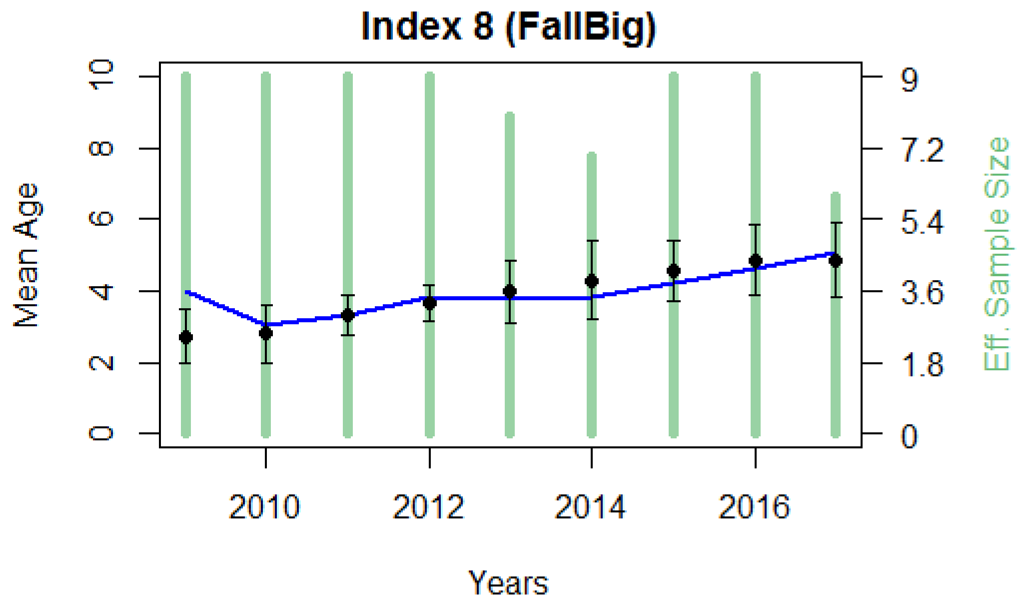

SDNR=1.19 RMSE=1.19
Std Resids
Year
-1
0
1
2
3
1987
1991
1995
1999
2003
2007


Index 6 (FallAlb85)
Mean Age
0
2
4
6
8
10
27
21.6
16.2
10.8
5.4
0
Eff. Sample Size
1990
1995
2000
2005
Years


SDNR=1.13
RMSE=1.11
Std Resids
2
1
0
-1
-2
1987
1991
1995
1999
2003
2007
Year


Index 7 (SprBig)
Mean Age
0
2
4
6
8
10
0
3.8
7.6
11.4
15.2
19
Eff. Sample Size
2010
2012
2014
2016
Years


SDNR=1.27
RMSE=1.2
Std Resids
-1
0
1
2009
2011
2013
2015
2017
Year


Index 8 (FallBig)
Mean Age
0
2
4
6
8
10
9
7.2
5.4
3.6
1.8
0
Eff. Sample Size
2010
2012
2014
2016
Years

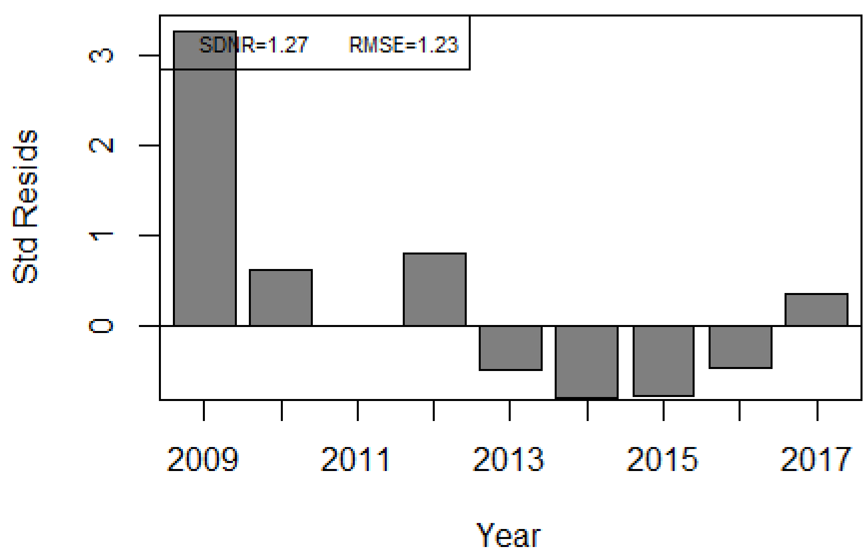
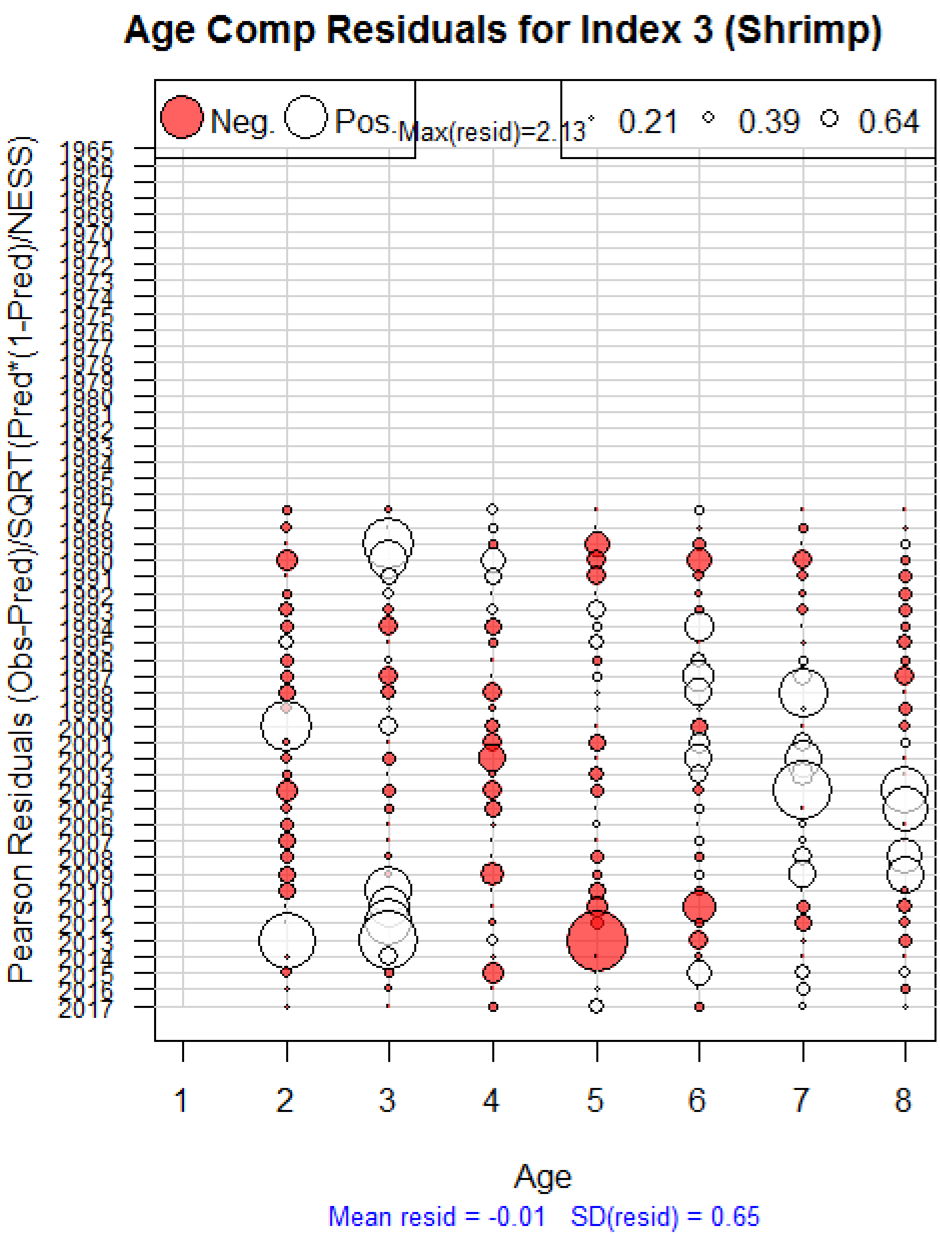
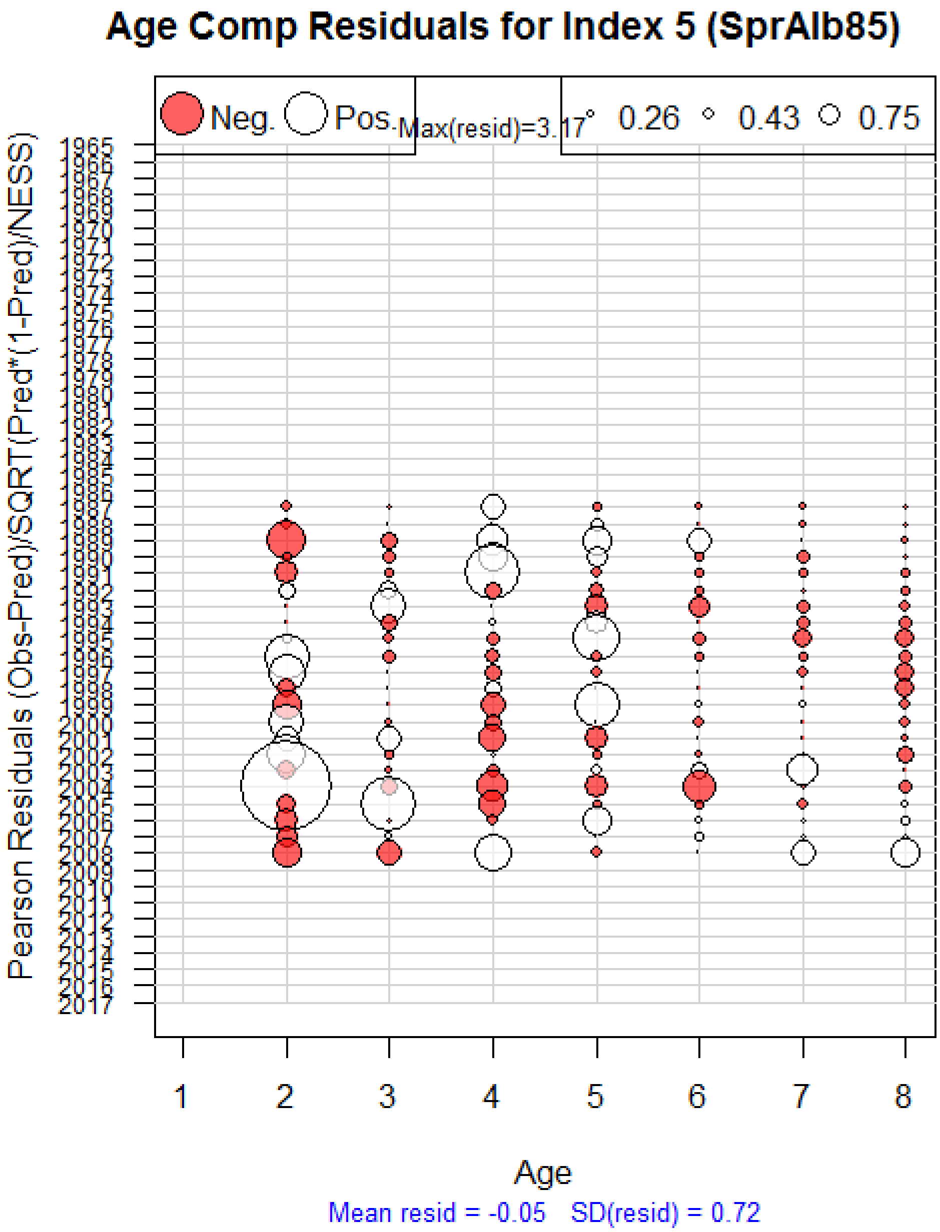
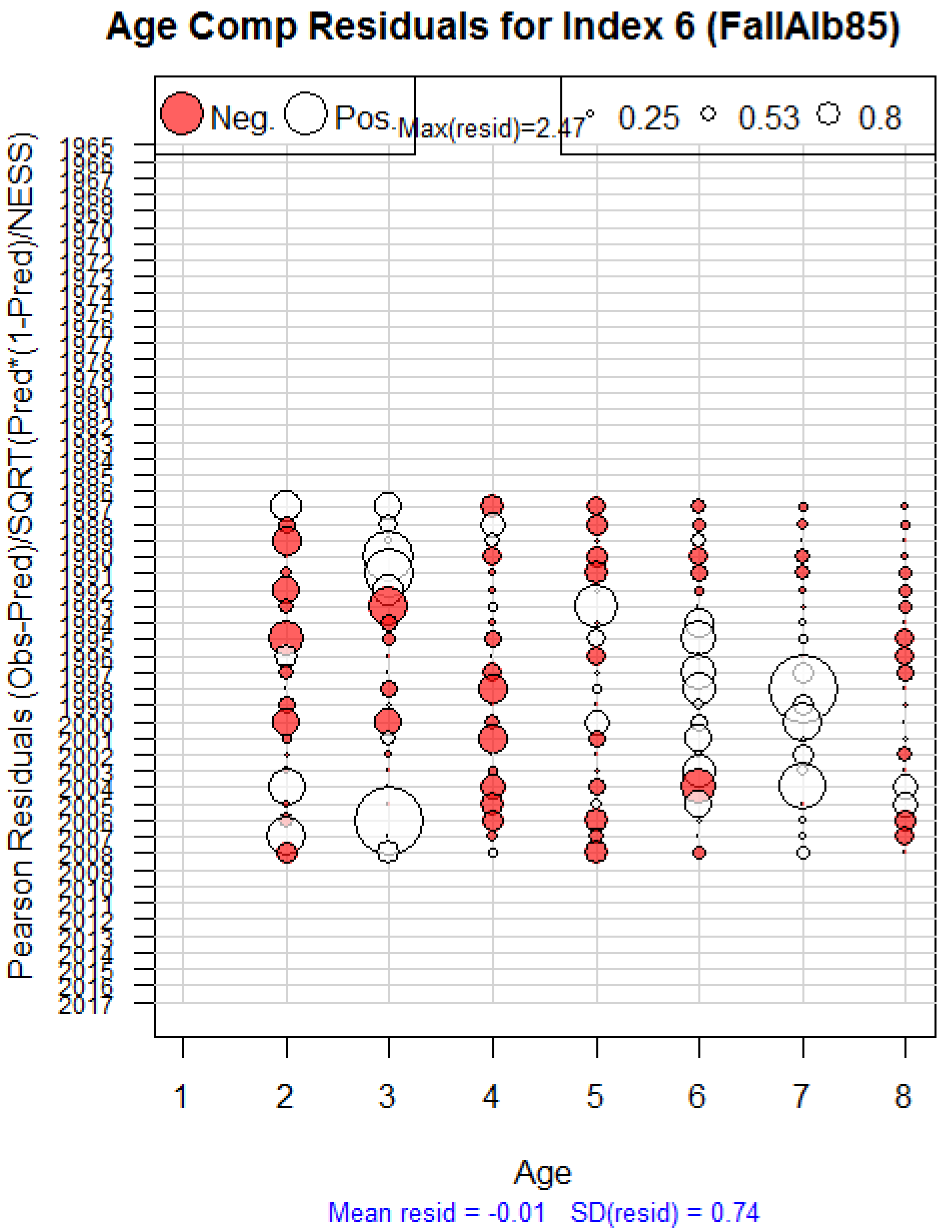
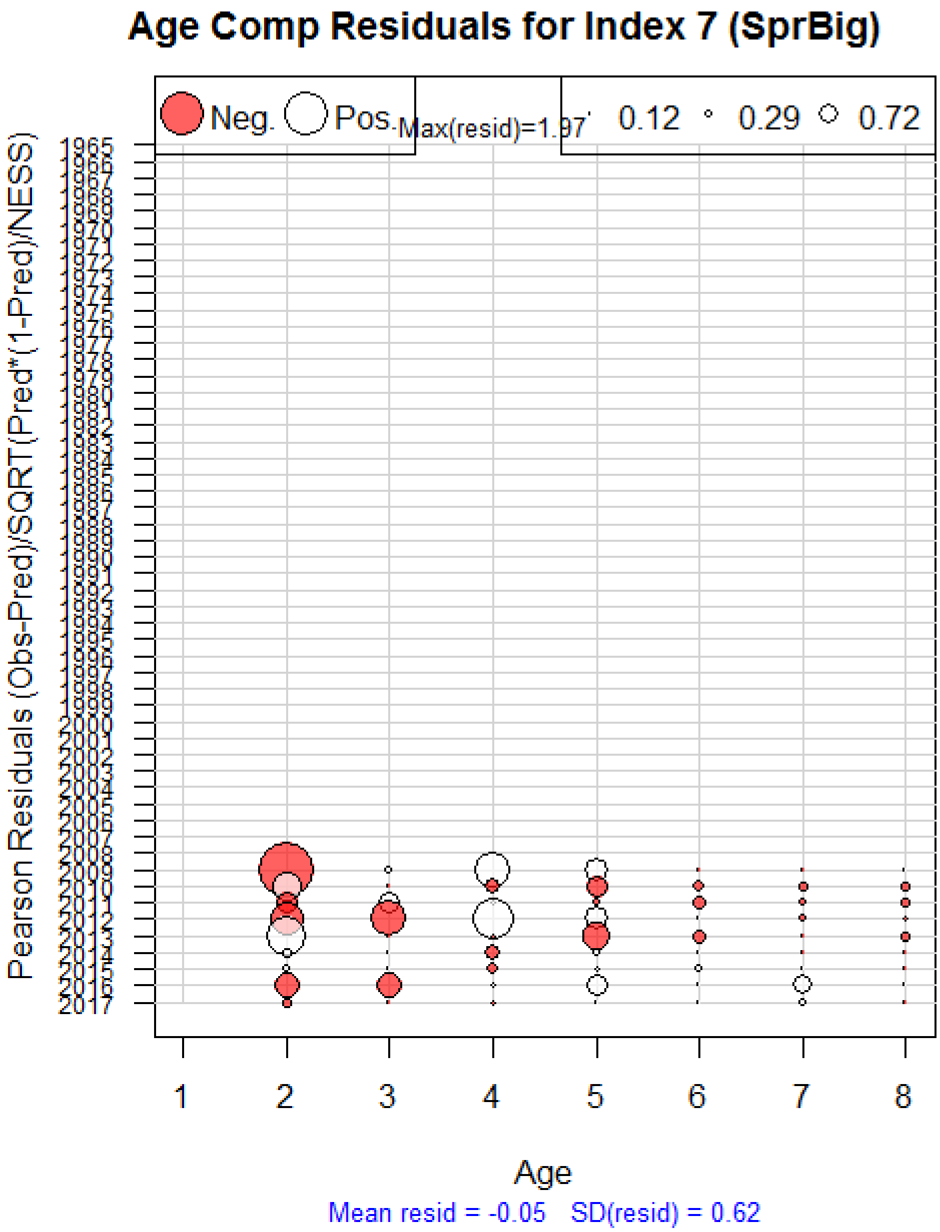

SDNR=1.27
RMSE=1.23
Std Resids
0
1
2
3
2009
2011
2013
2015
2017
Year

Figure B4- 16 Fits to Atlantic herring age compositions for the base ASAP model (Shrimp: NMFS summer/shrimp; Spr85: Albatross 1985-2008; Fall85: Albatross 1985-2008; SprBig: Bigelow 2009-2017; FallBig: Bigelow 2009-2017)




Age Comp Residuals for Index 5 (SprAlb85)
Neg.
Pos.
Max(resid)=3.17
0.26
0.43
0.75
Pearson Residuals (Obs-Pred)/SQRT(Pred*(1-Pred)/NESS)
1965
2017
1
2
3
4
5
6
7
8
Age
Mean resid = -0.05 SD(resid) = 0.72


Age Comp Residuals for Index 6 (FallAlb85)
Neg.
Pos.
Max(resid)=2.47
0.25
0.53
0.8
Pearson Residuals (Obs-Pred)/SQRT(Pred*(1-Pred)/NESS)
1965
2017
1
2
3
4
5
6
7
8
Age
Mean resid = -0.01   SD(resid) = 0.74



Age Comp Residuals for Index 7 (SprBig)
Neg.
Pos.
Max(resid)=1.97
0.12
0.29
0.72
Pearson Residuals (Obs-Pred)/SQRT(Pred*(1-Pred)/NESS)
Age
Mean resid = -0.05 SD(resid) = 0.62

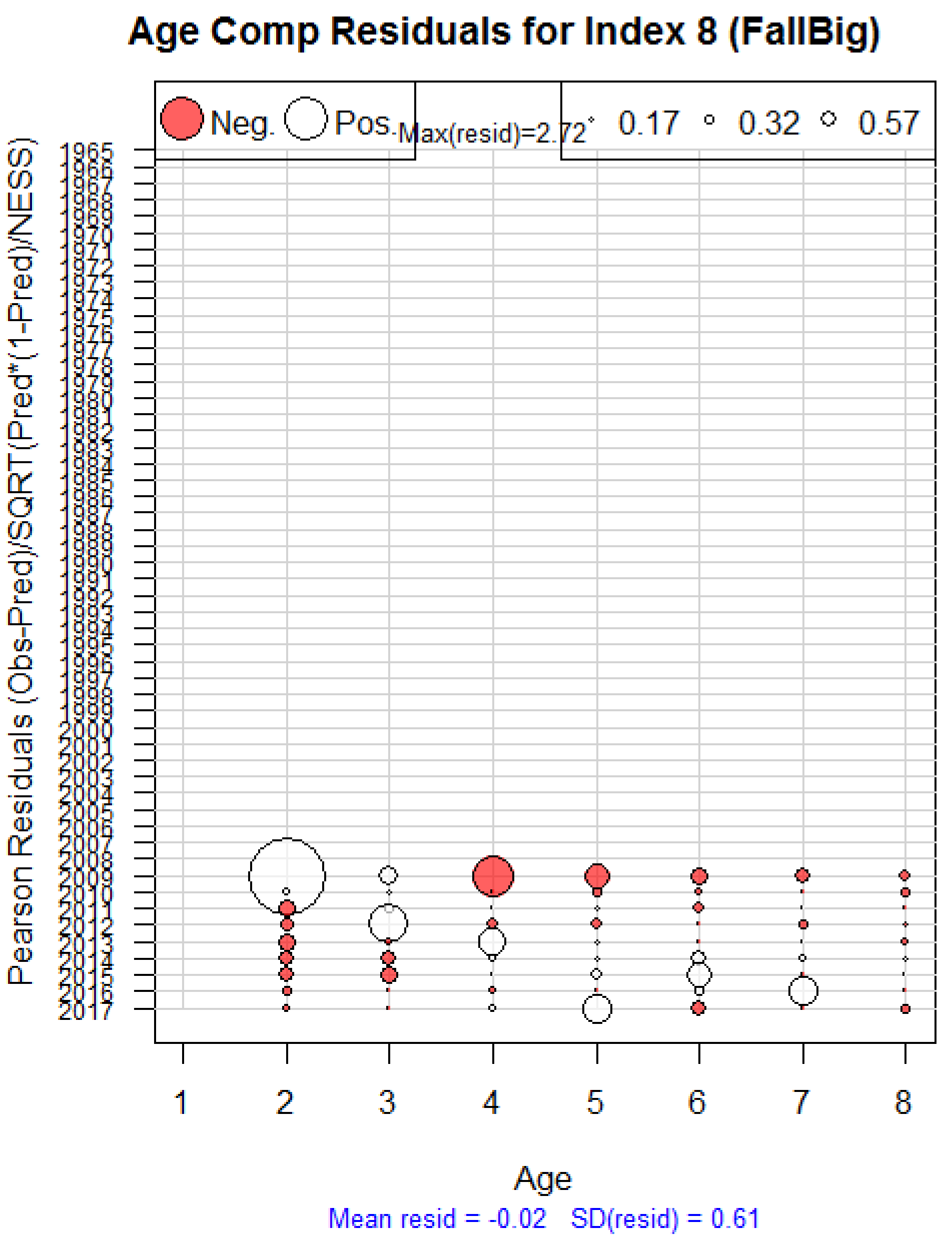

Age Comp Residuals for Index 8 (FallBig)
Neg.
Pos.
Max(resid)=2.72
0.17
0.32
0.57
Pearson Residuals (Obs-Pred)/SQRT(Pred*(1-Pred)/NESS)
Age
1
2
3
4
5
6
7
8
1965
2017
Mean resid = -0.02 SD(resid) = 0.61

Figure B4- 17 Atlantic herring catchability estimates for the indices from the base ASAP model

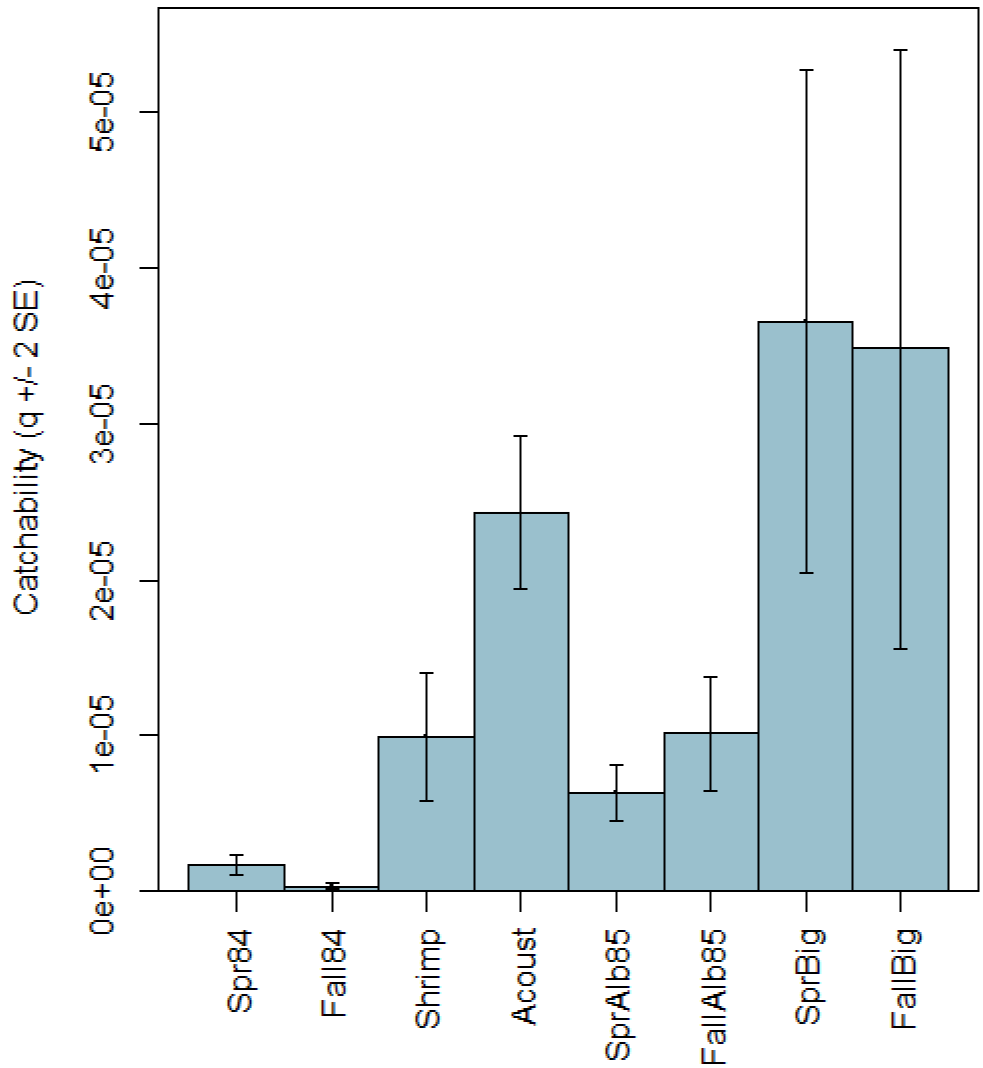


Figure B4- 18 Relative retrospective pattern for Atlantic herring SSB using a 17-year peel for the base ASAP model

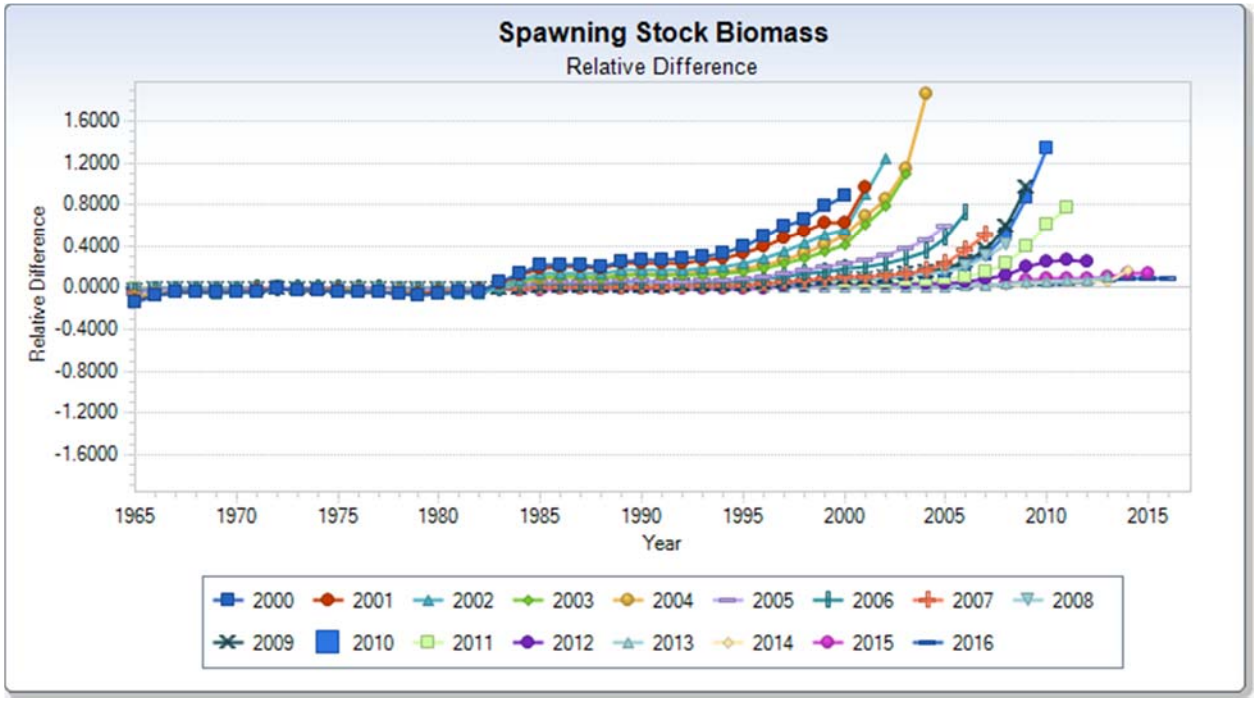


Figure B4- 19 Coefficients of variation of the time series estimates of Atlantic herring recruitment (Recr.), SSB, and F (average F over ages 7 and8) from the base ASAP model

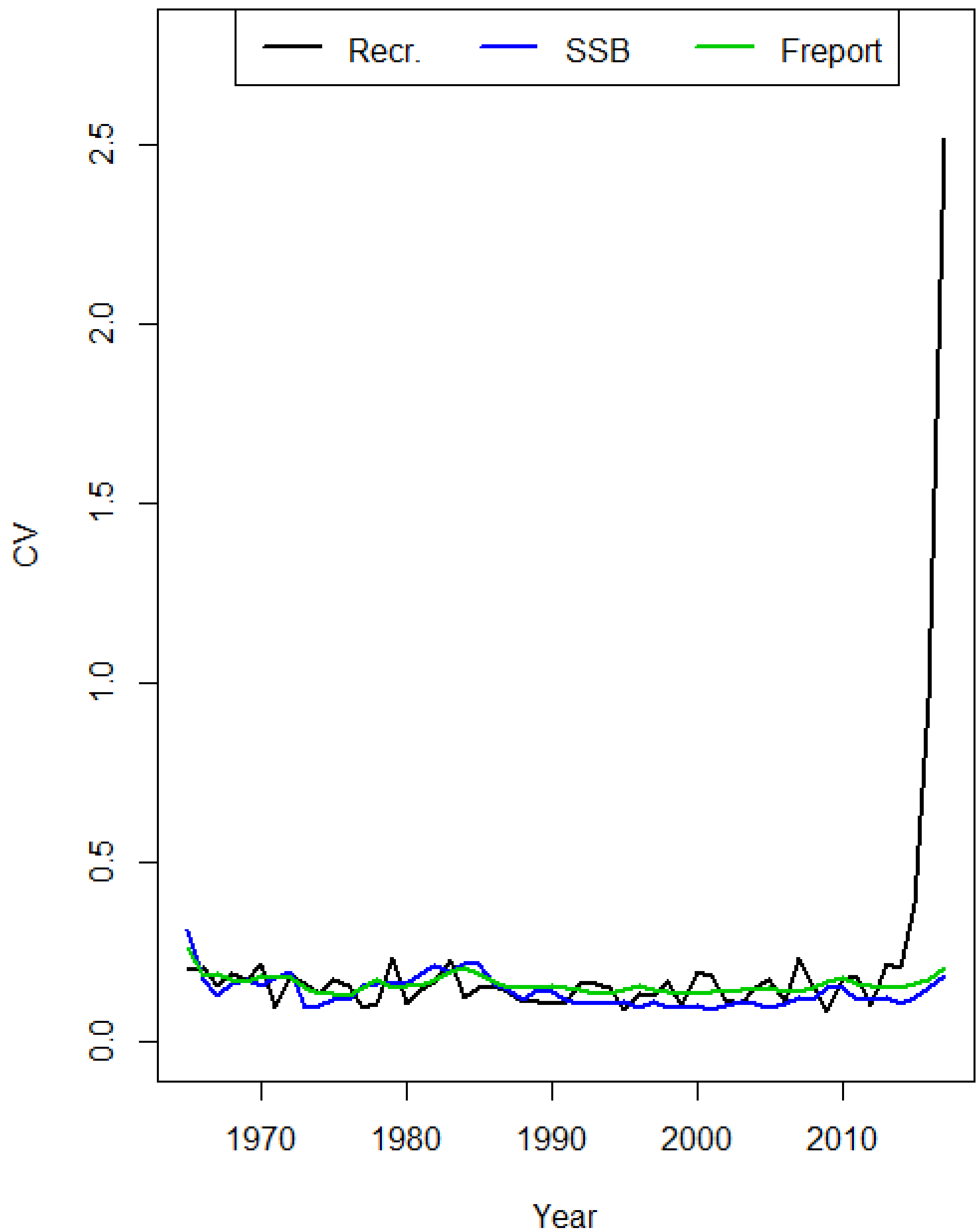


Figure B4- 20 Atlantic herring biomass time series from base ASAP model

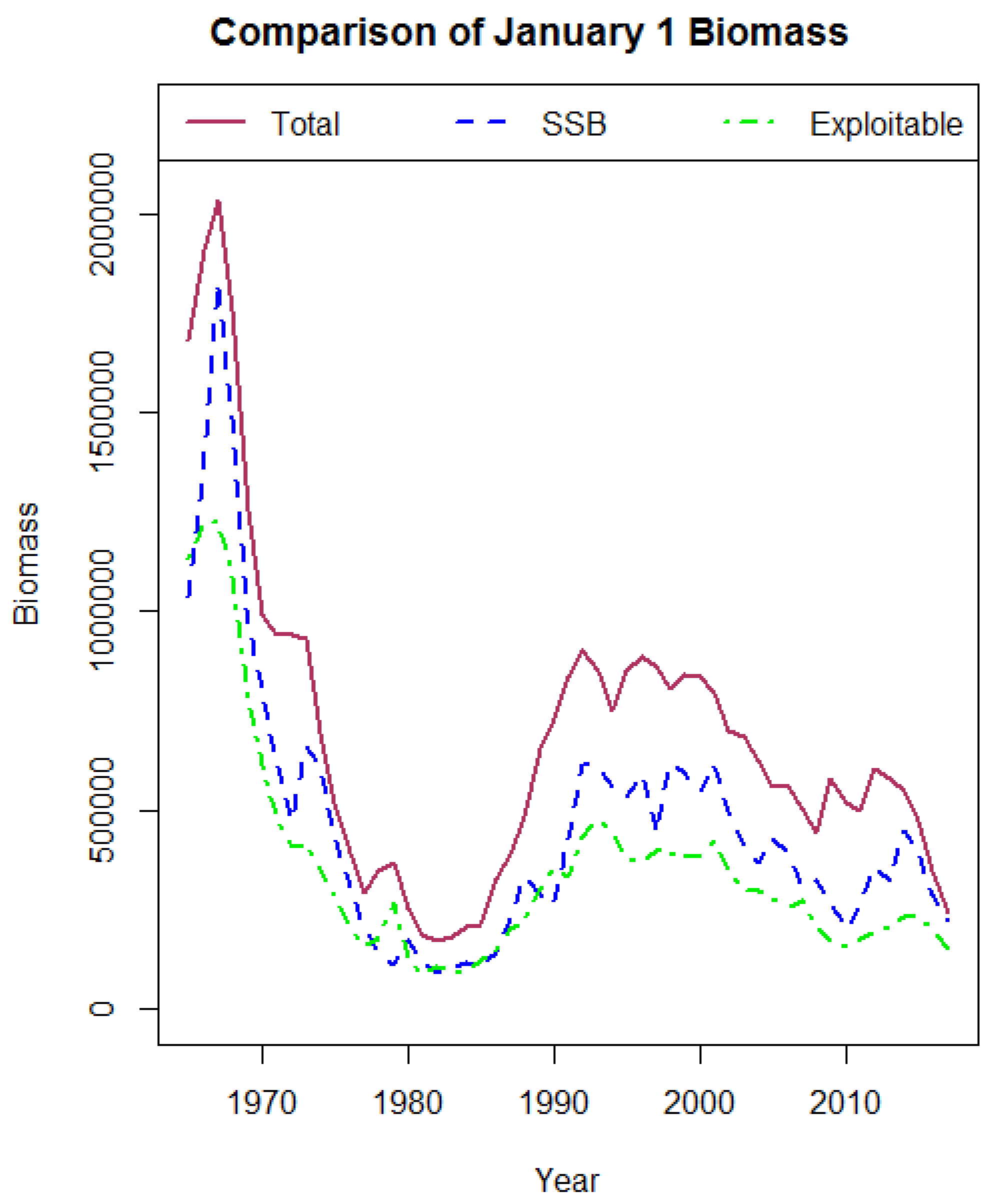


Figure B4- 21 Atlantic herring recruit time series and log-scale deviations from the base ASAP model

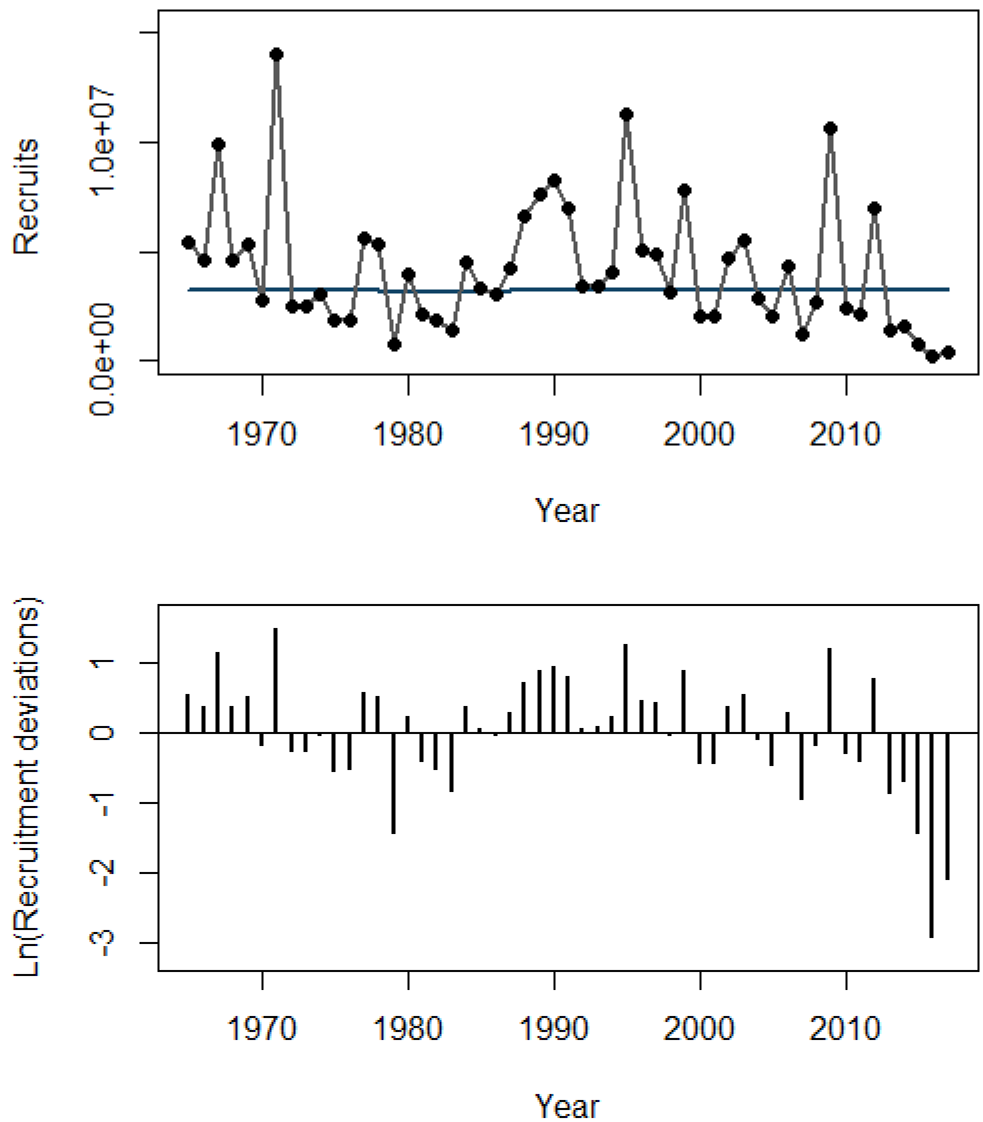


Figure B4- 22 Atlantic herring stock-recruit plot with year of recruitment as points from the base ASAP model

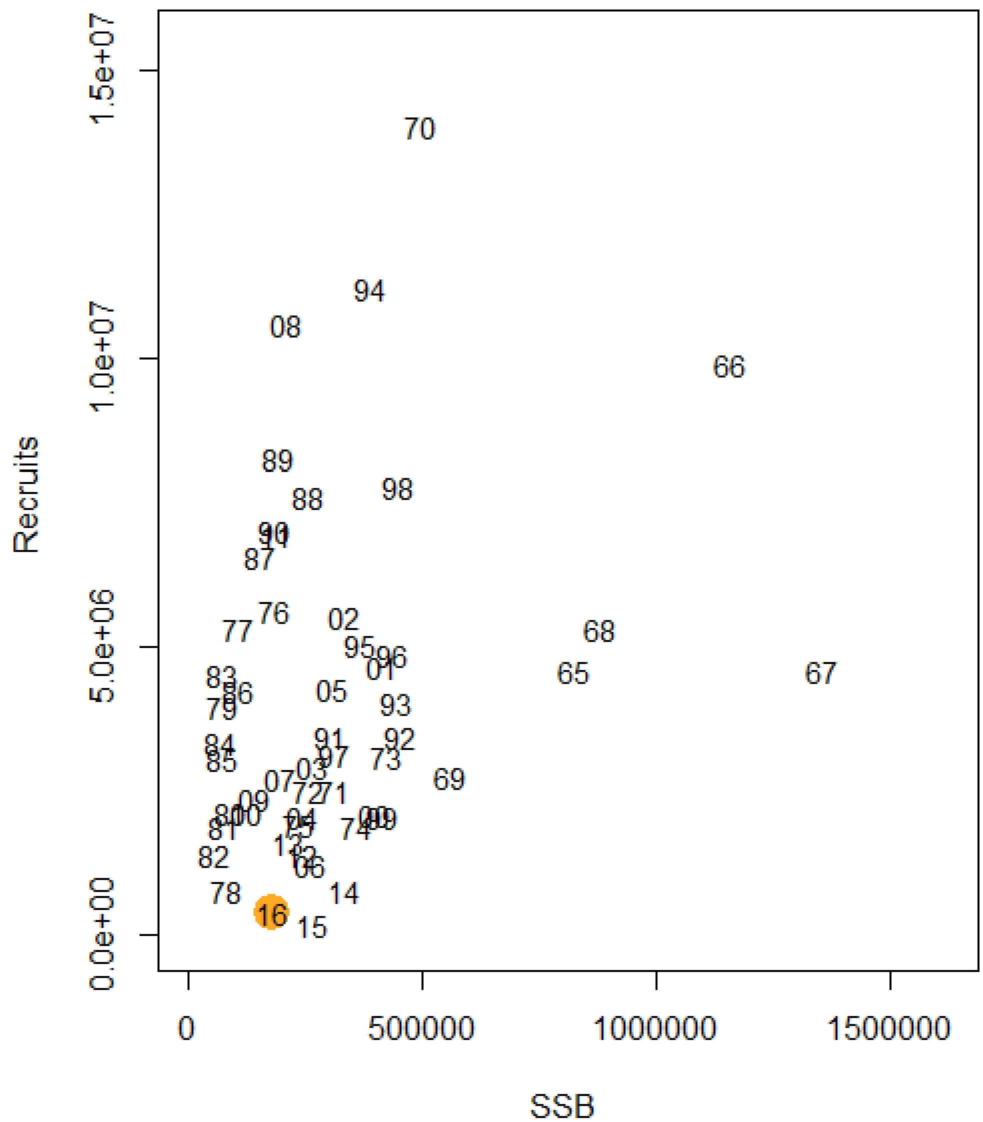


Figure B4- 23 Atlantic herring SSB, fully selected F (F.full) and average F over ages 7-8 (F.report) from the base ASAP model

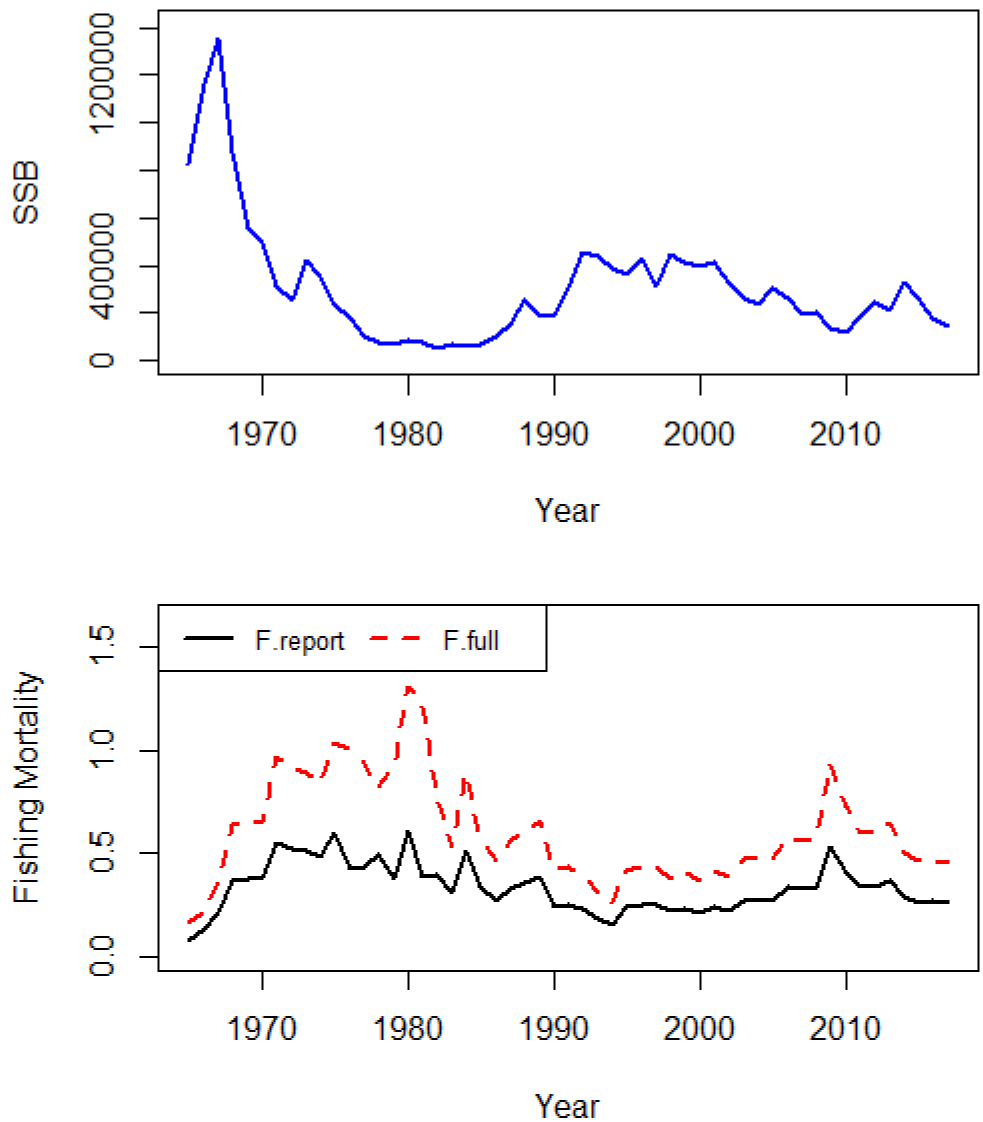
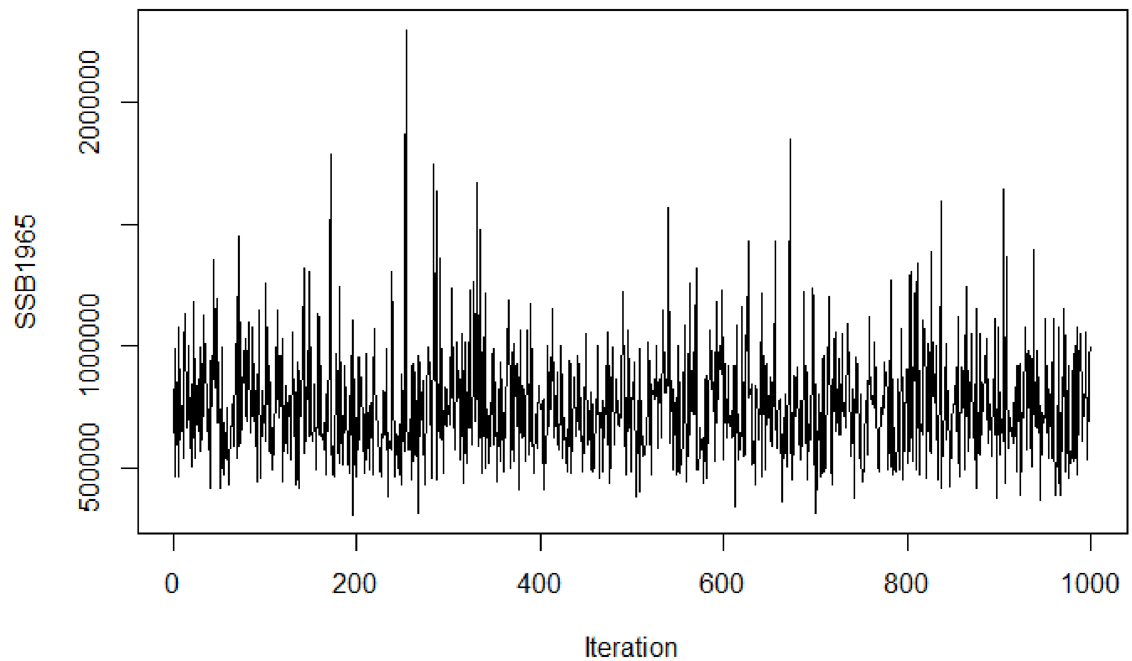
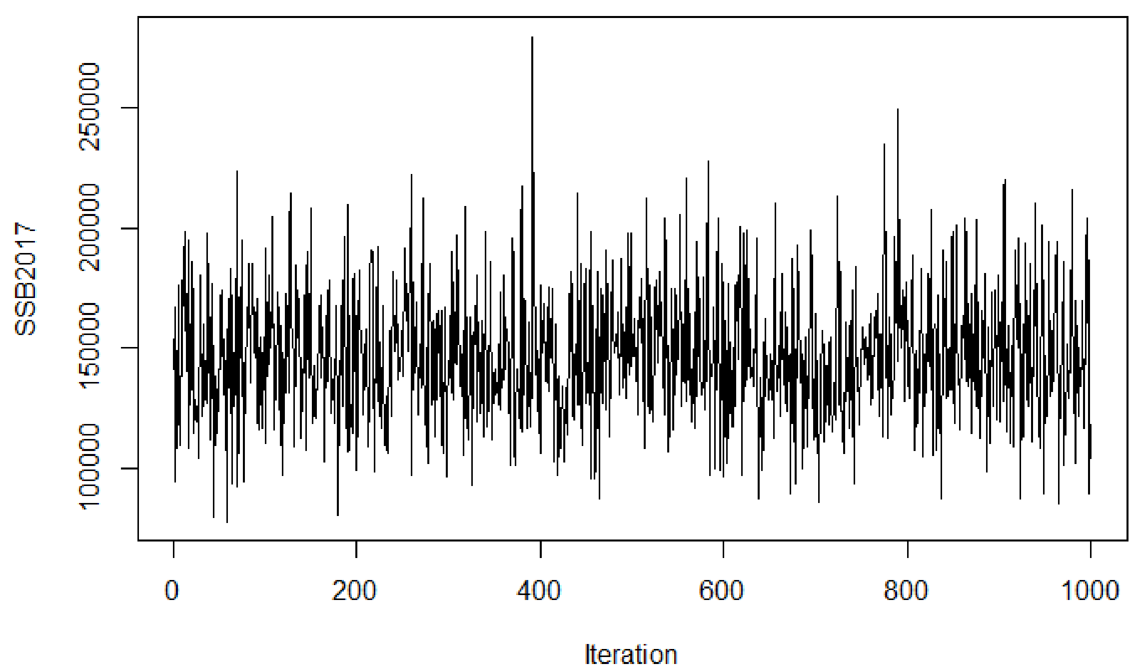
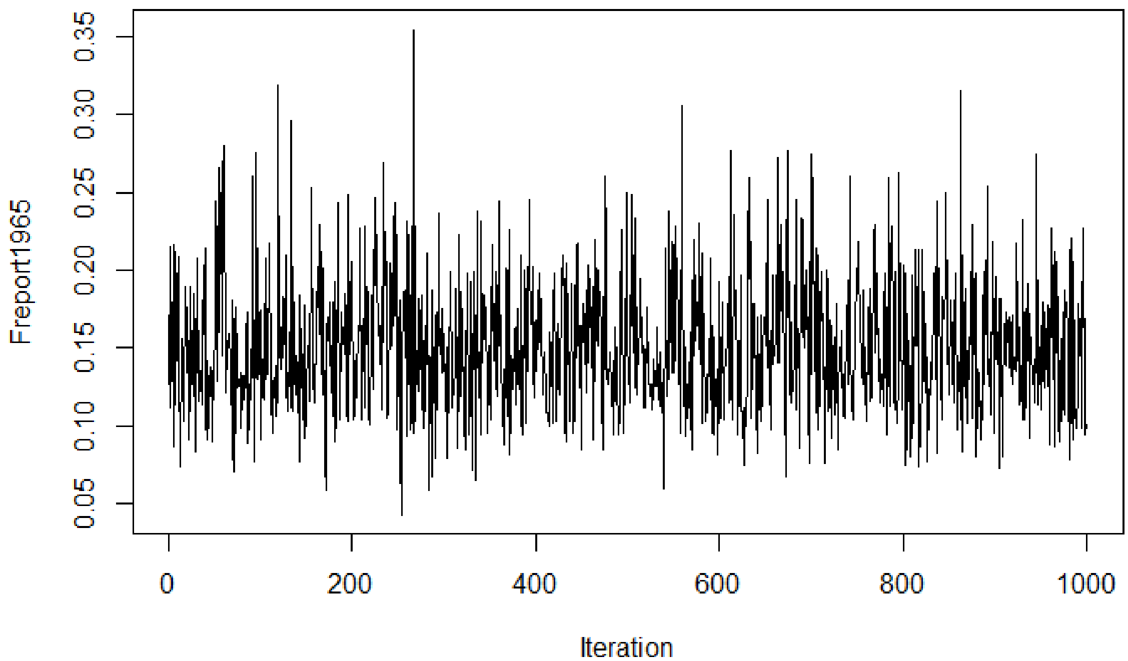


Figure B4- 24 Trace plots for SSB and F in 1965 and 2017 from MCMC of the base ASAP model






Freport1965
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0
200
400
600
800
1000
Iteration

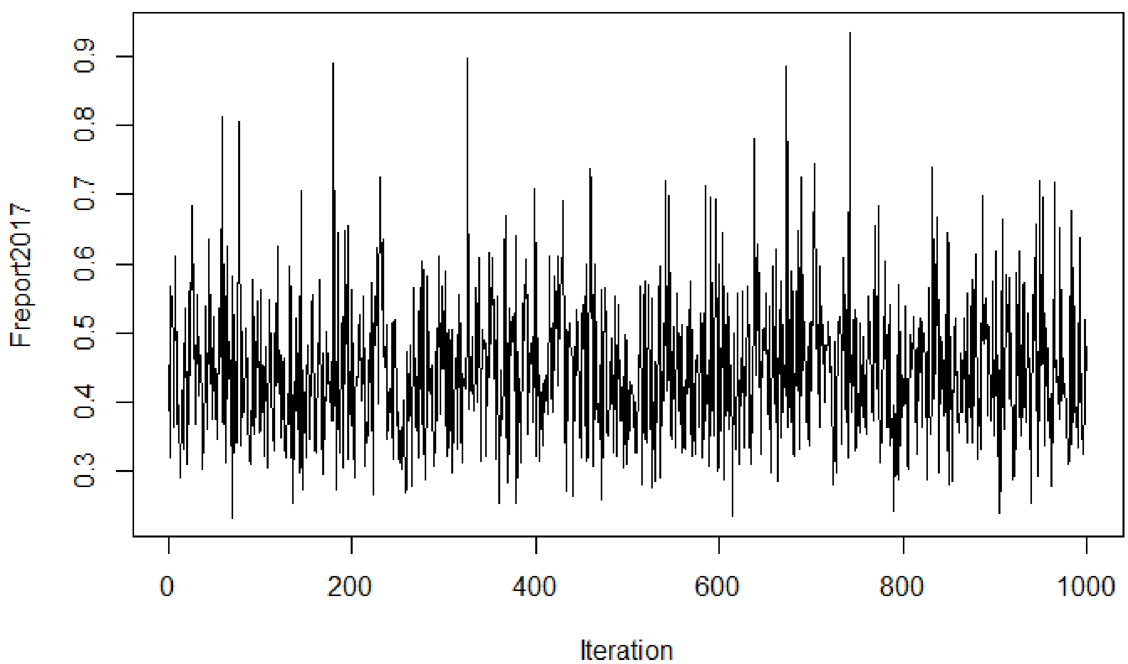
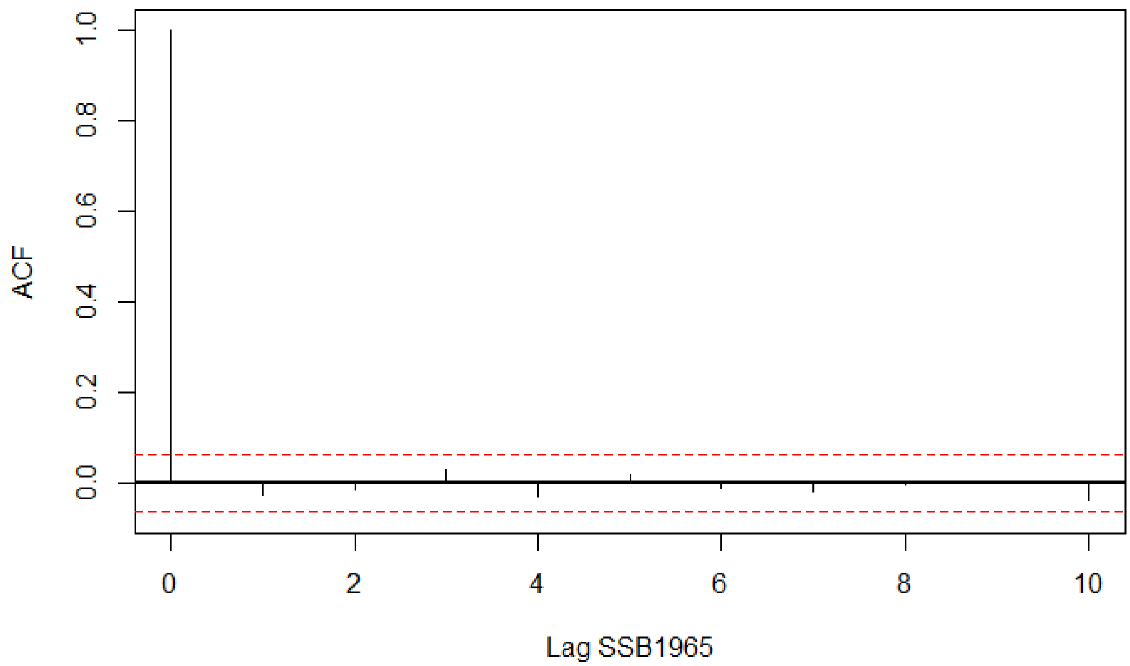
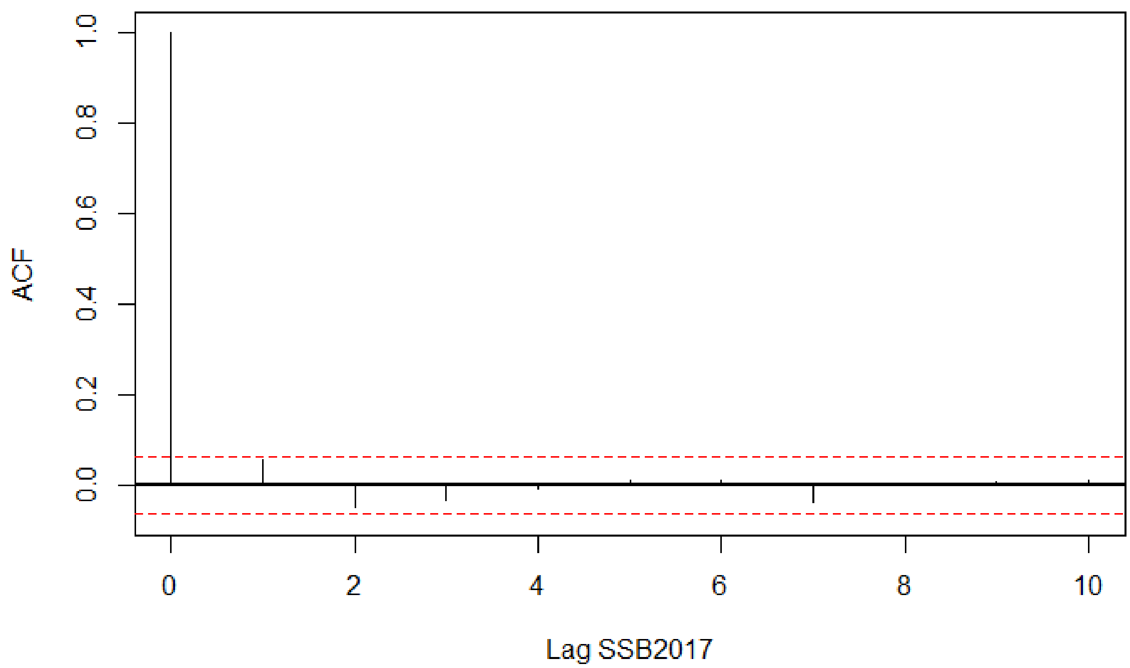
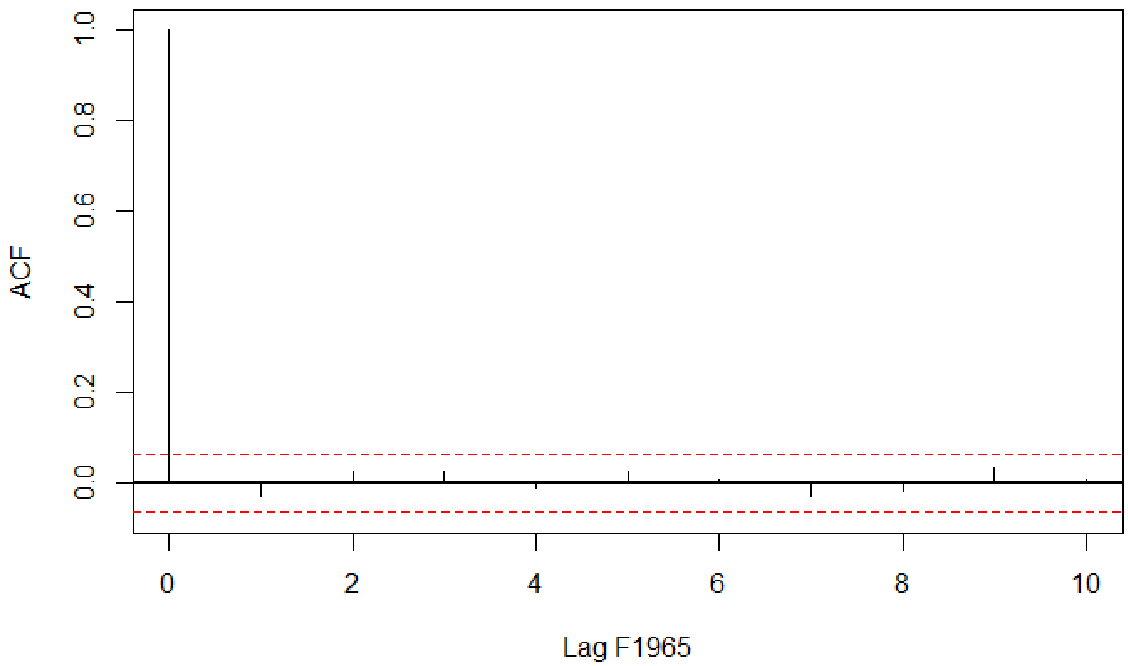

Freport2017
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
200
400
600
800
1000
Iteration

Figure B4- 25 Correlations of lags for SSB and F in 1965 and 2017 from the MCMC of the base ASAP model






ACF
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Lag F1965

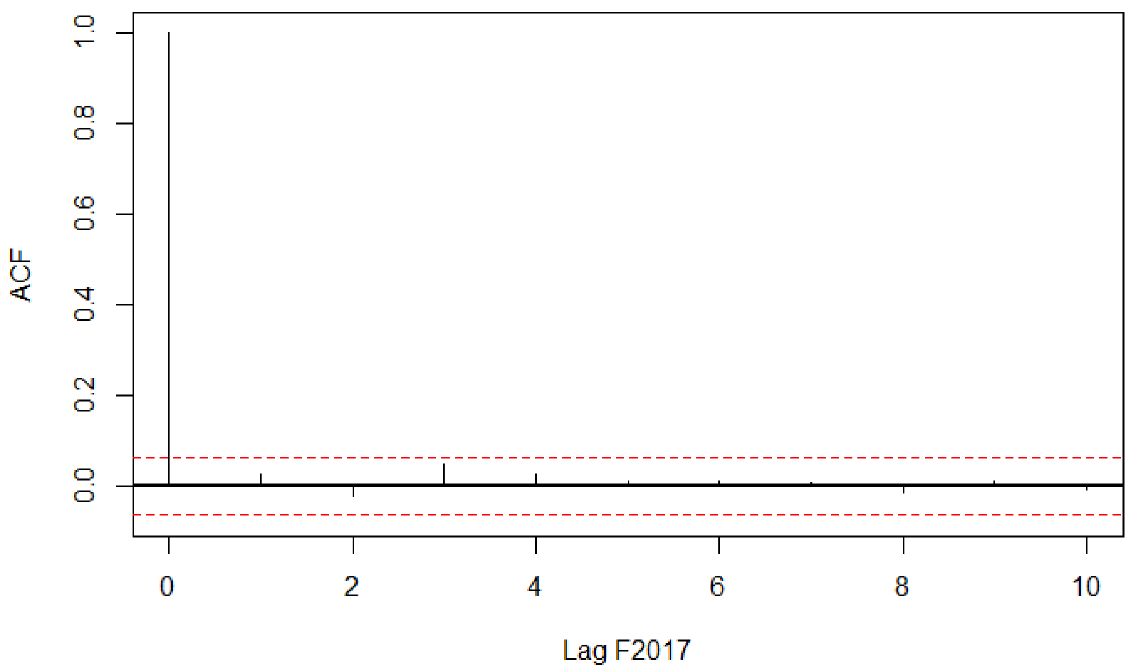
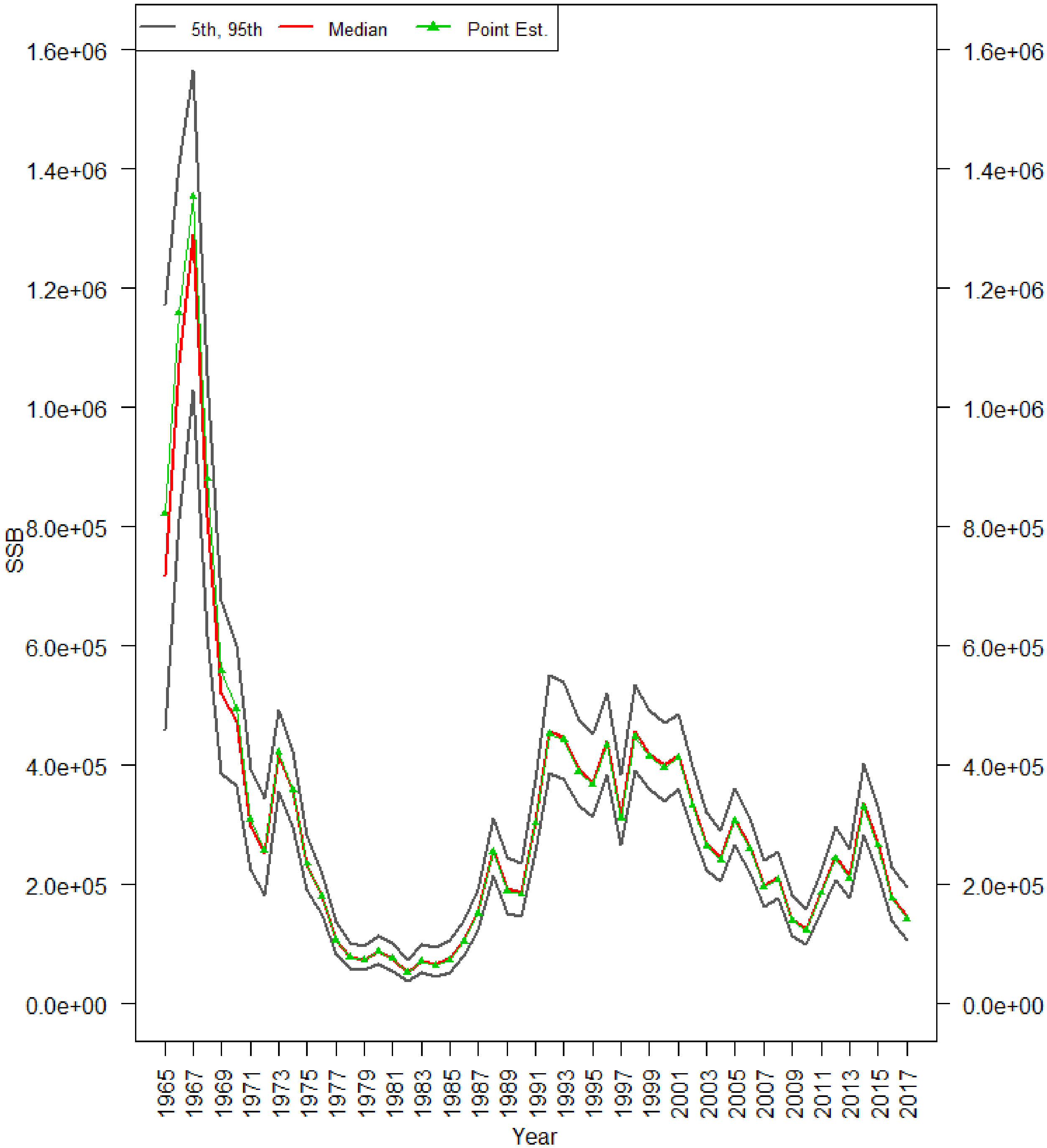

ACF
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
Lag F2017

Figure B4- 26 Point estimates, median, and 90% probability intervals of Atlantic herring SSB and F from the MCMC of the base ASAP model



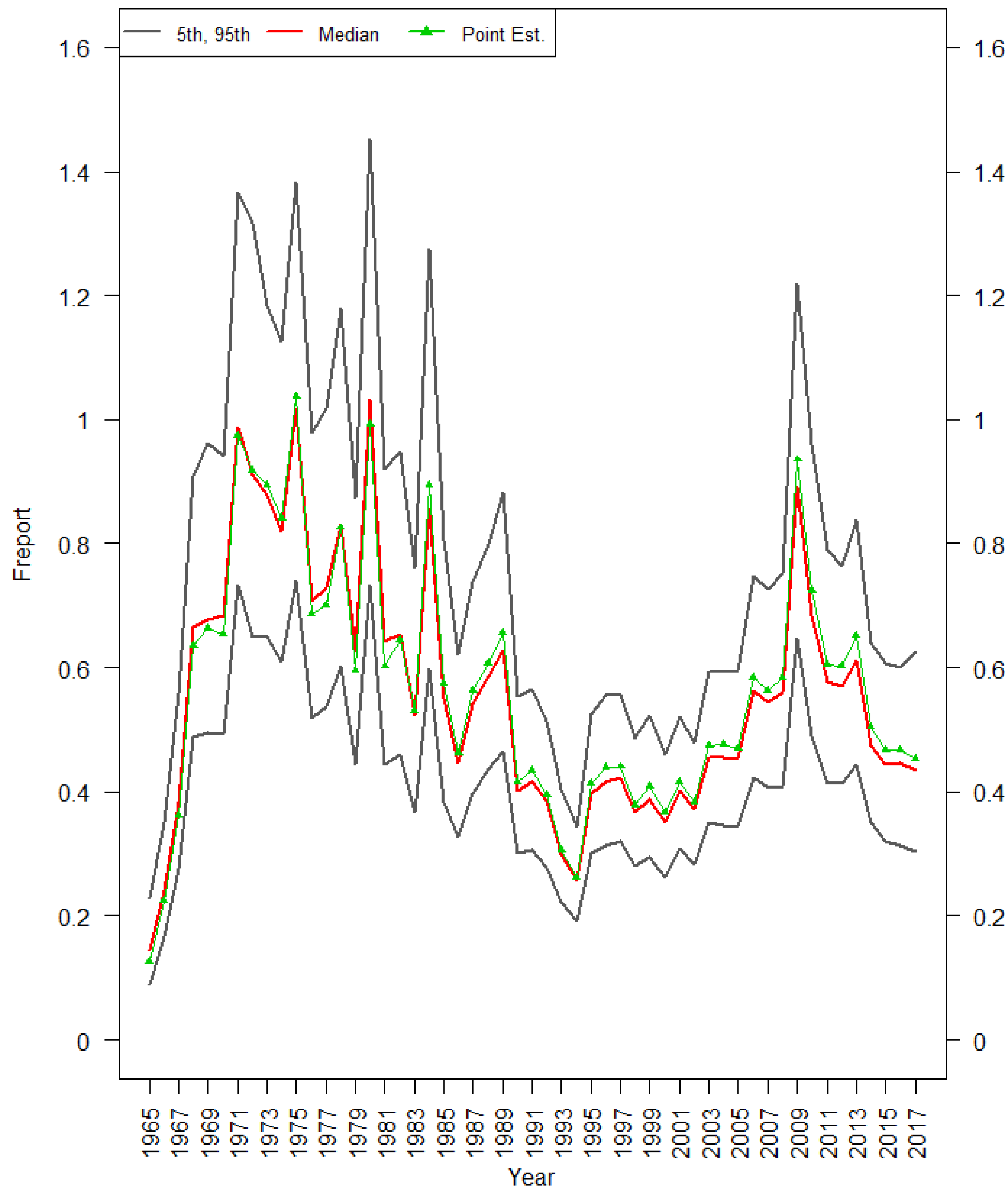
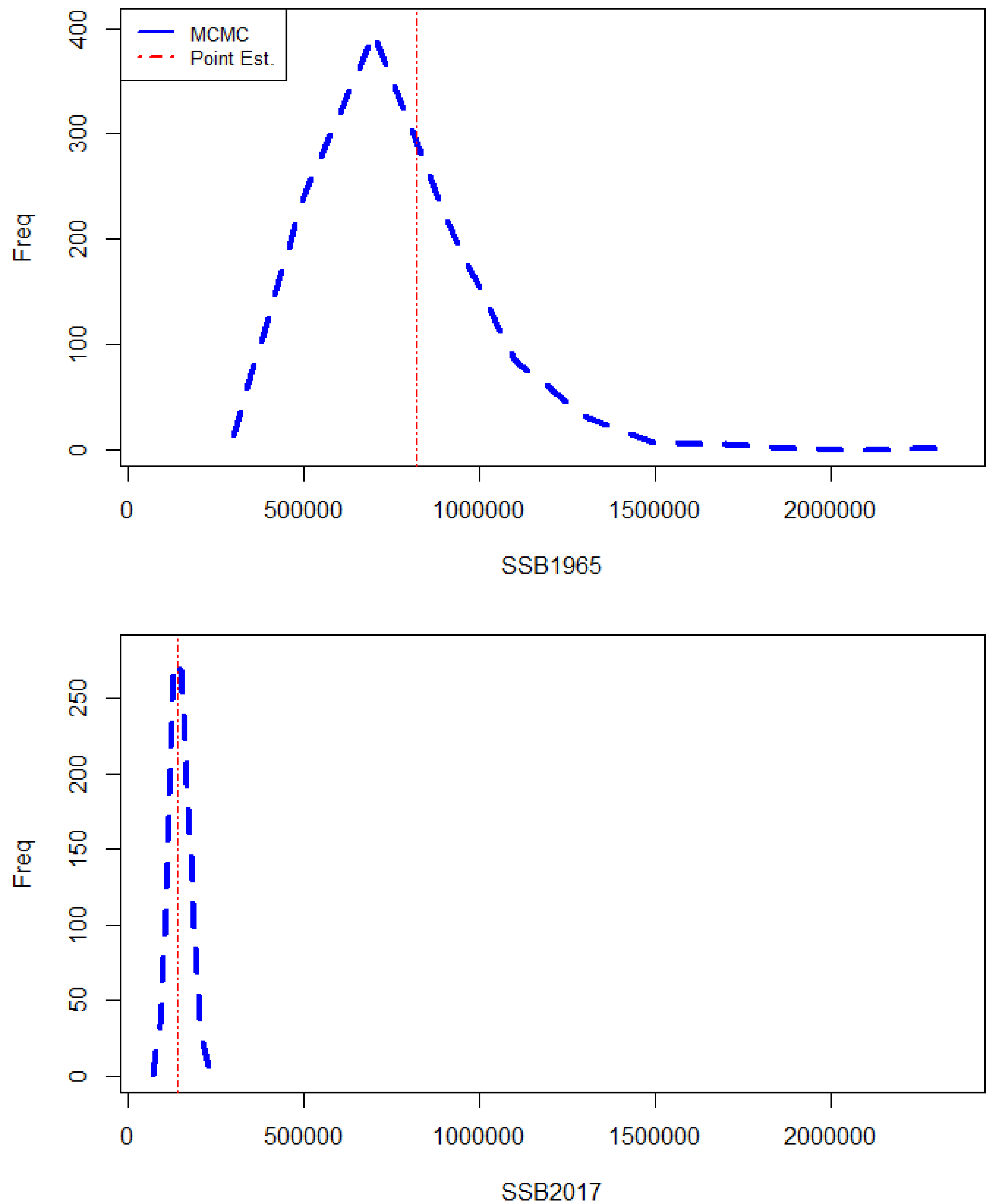
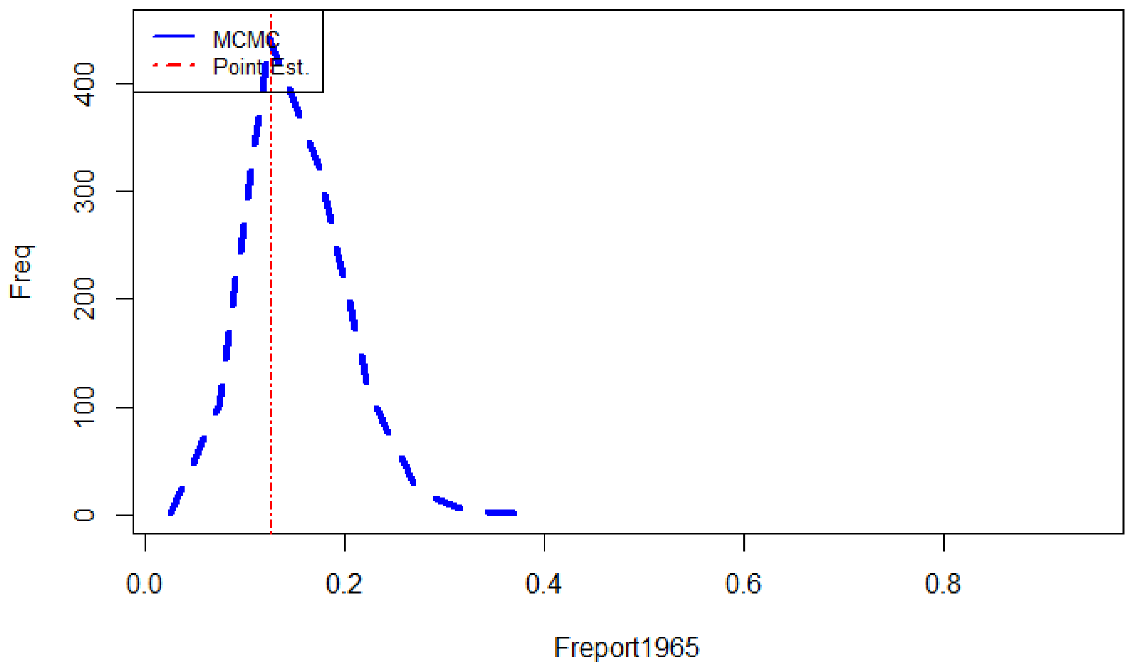
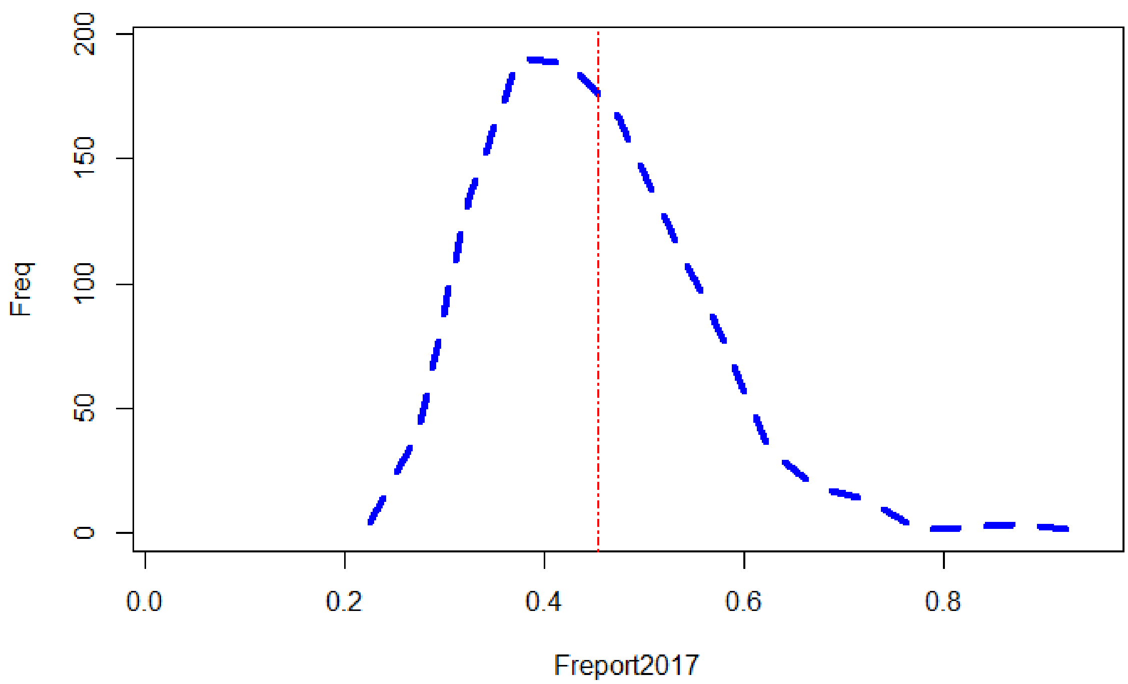

5th, 95th
Median
Point Est.
Freport
Year
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
2017

Figure B4- 27 Posterior density of Atlantic herring SSB and F in 1965 and 2017 from the MCMC of the base ASAP model





MCMC
Point Est.
Freq
0
100
200
300
400
0.0
0.2
0.4
0.6
0.8
Freport1965



Freq
0
50
100
150
200
0.0
0.2
0.4
0.6
0.8
Freport2017

Figure B4- 28 Internal retrospective pattern for F, SSB, and recruitment for the base ASAP model

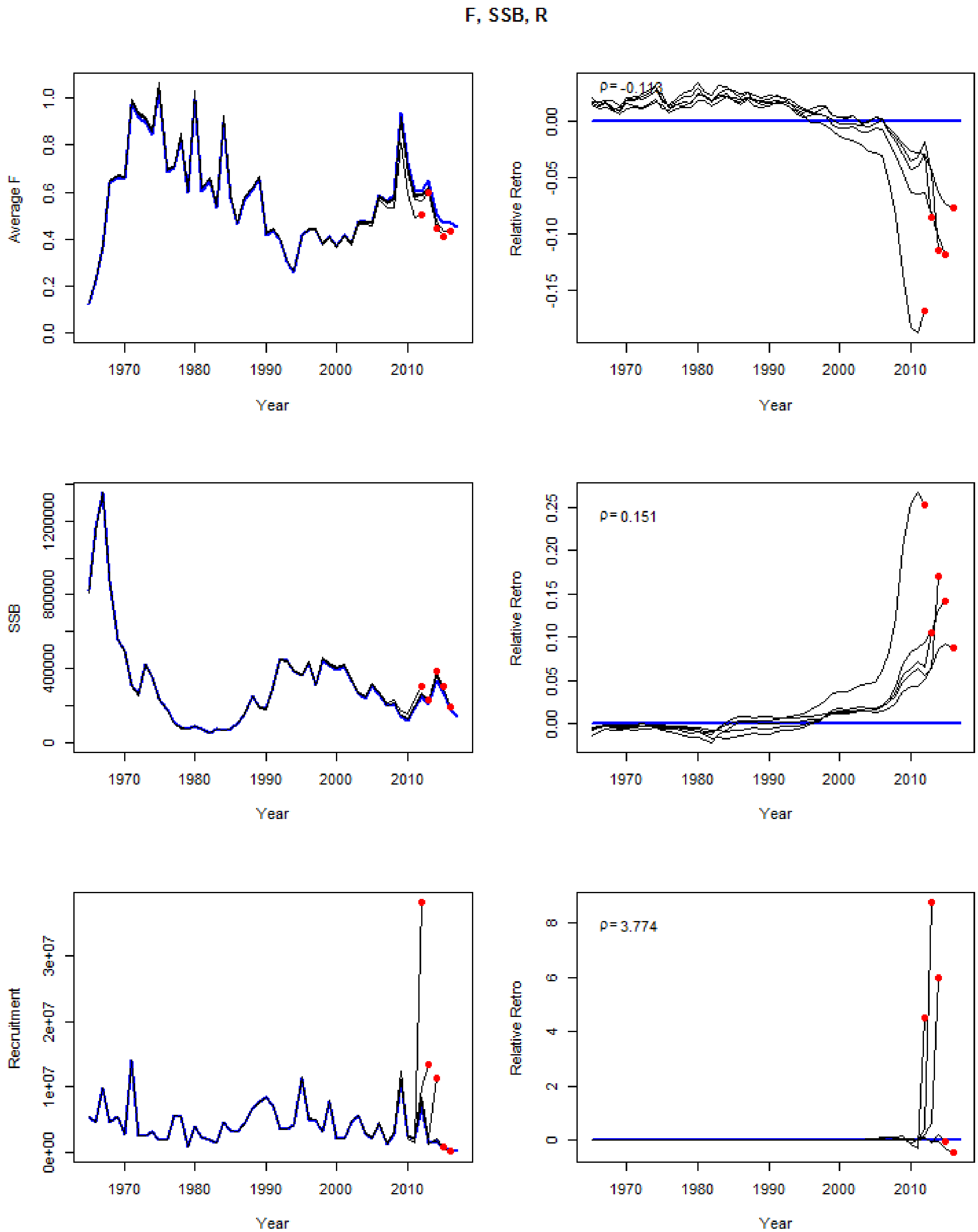
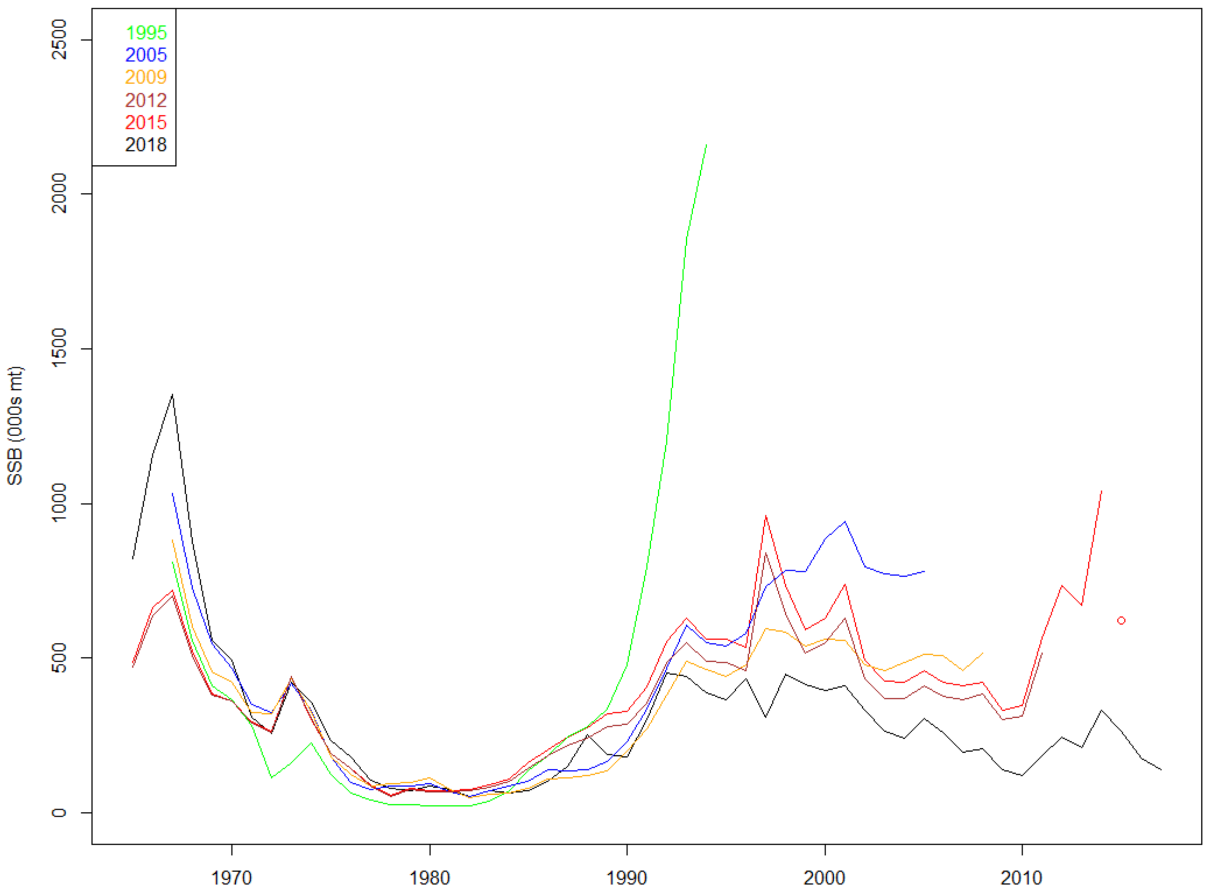
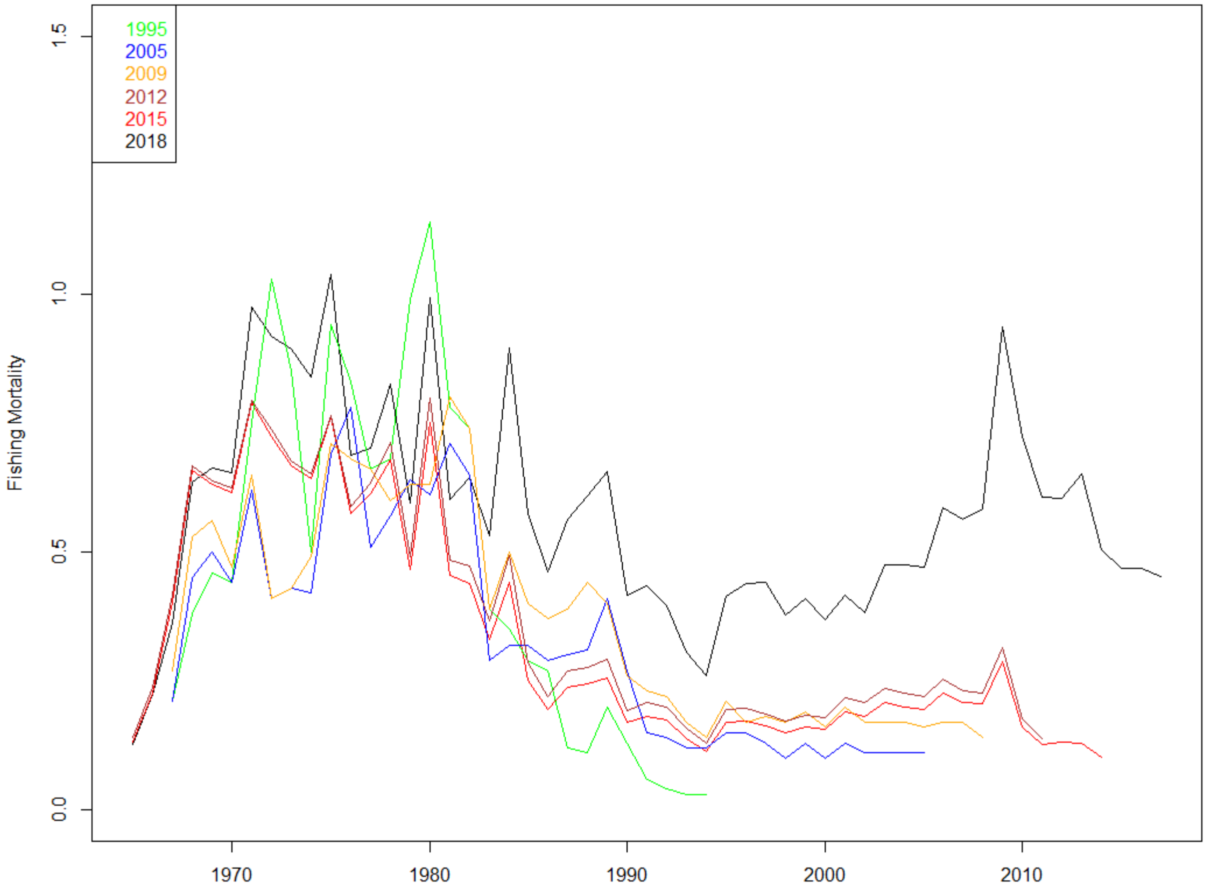


Figure B4- 29 Atlantic herring historic retrospective pattern for SSB, F (not directly comparable), and F rescaled by each time series mean to make the trends more readily comparable





1995
2005
2009
2012
2015
2018
Fishing Mortality
0.0
0.5
1.0
1.5
1970
1980
1990
2000
2010

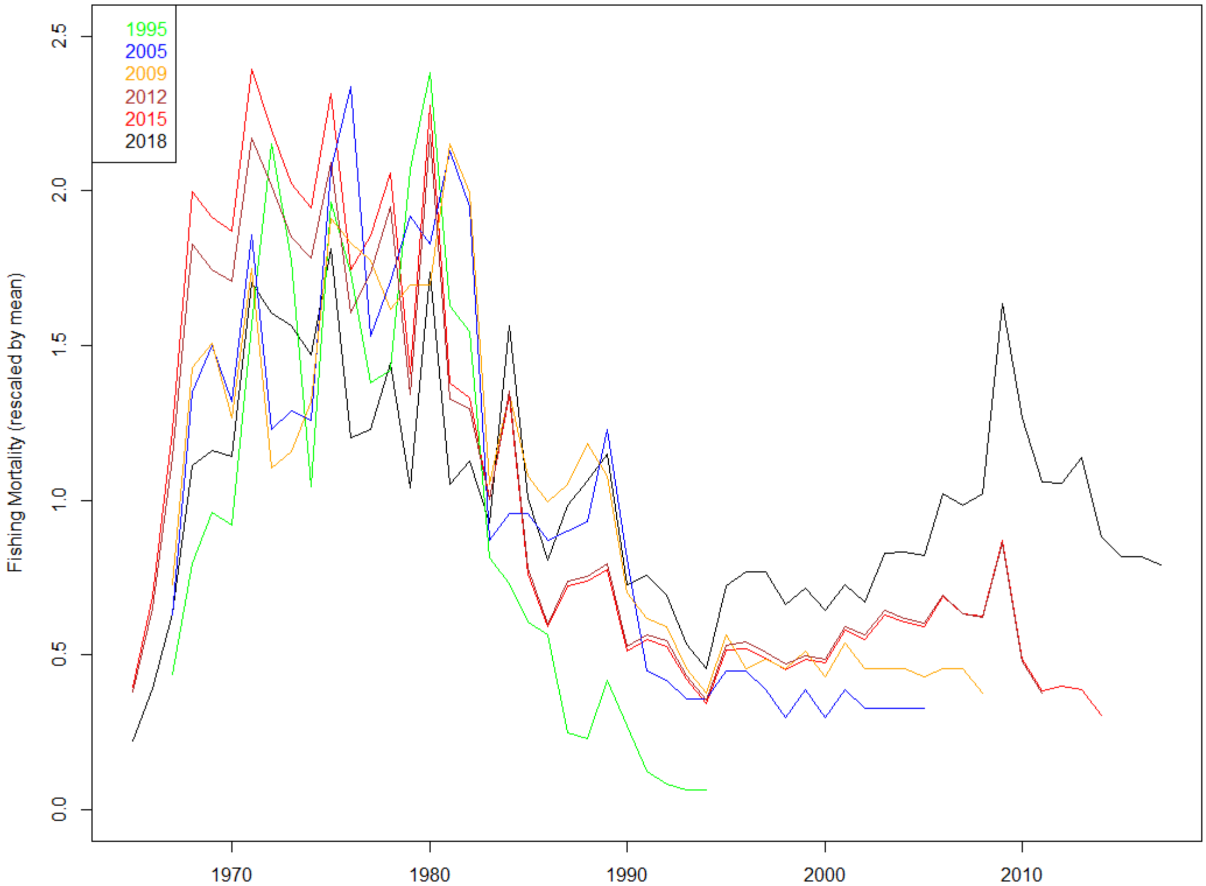

1995
2005
2009
2012
2015
2018
Fishing Mortality (rescaled by mean)
0.0
0.5
1.0
1.5
2.0
2.5
1970
1980
1990
2000
2010

Figure B4- 30 Atlantic herring SSB and recruitment time series for the base ASAP model (Base) and the base model amended to have age- and time-varying M (VaryM)

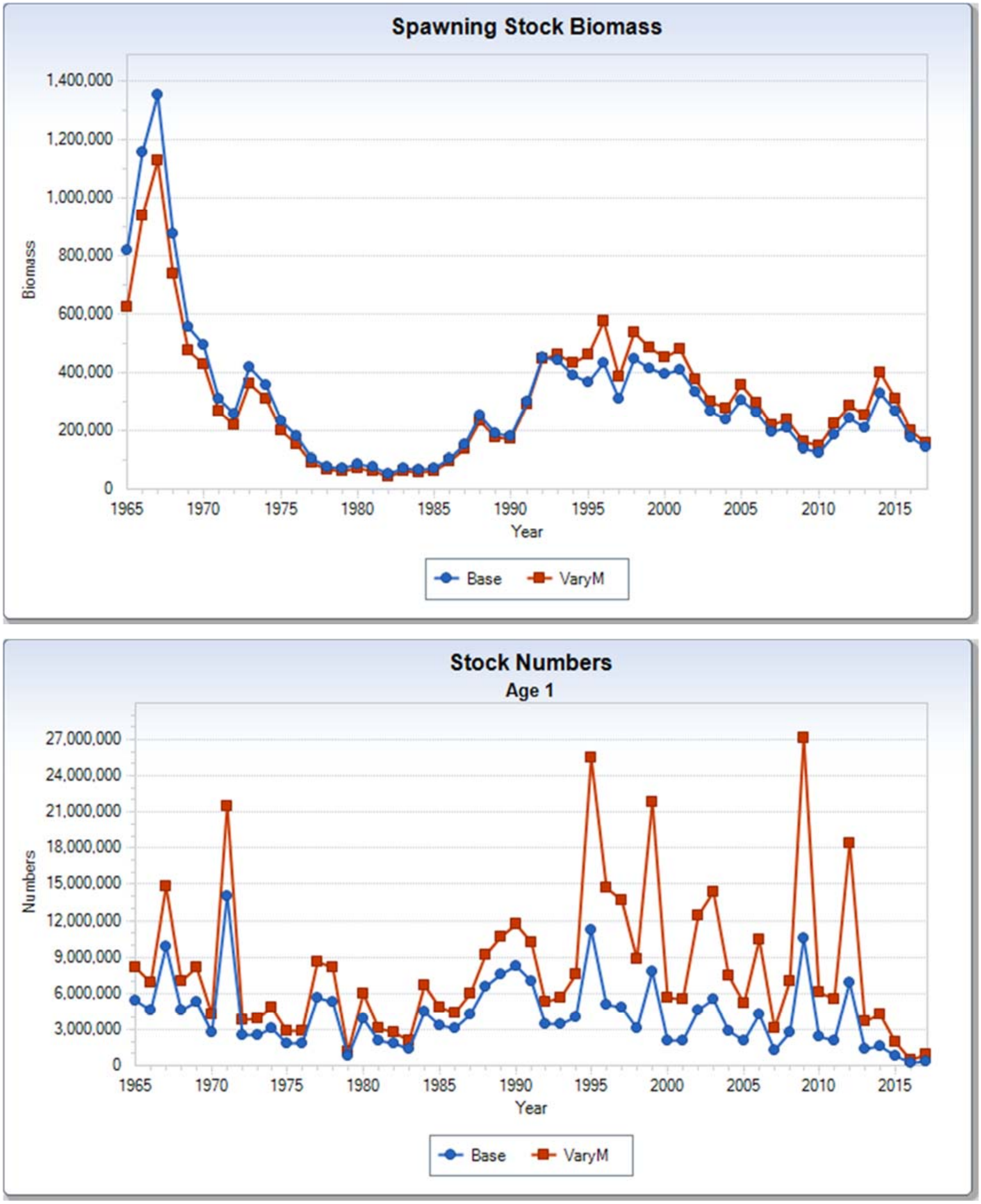


Figure B4- 31 Retrospective patterns for the base model except with age- and time-varying M

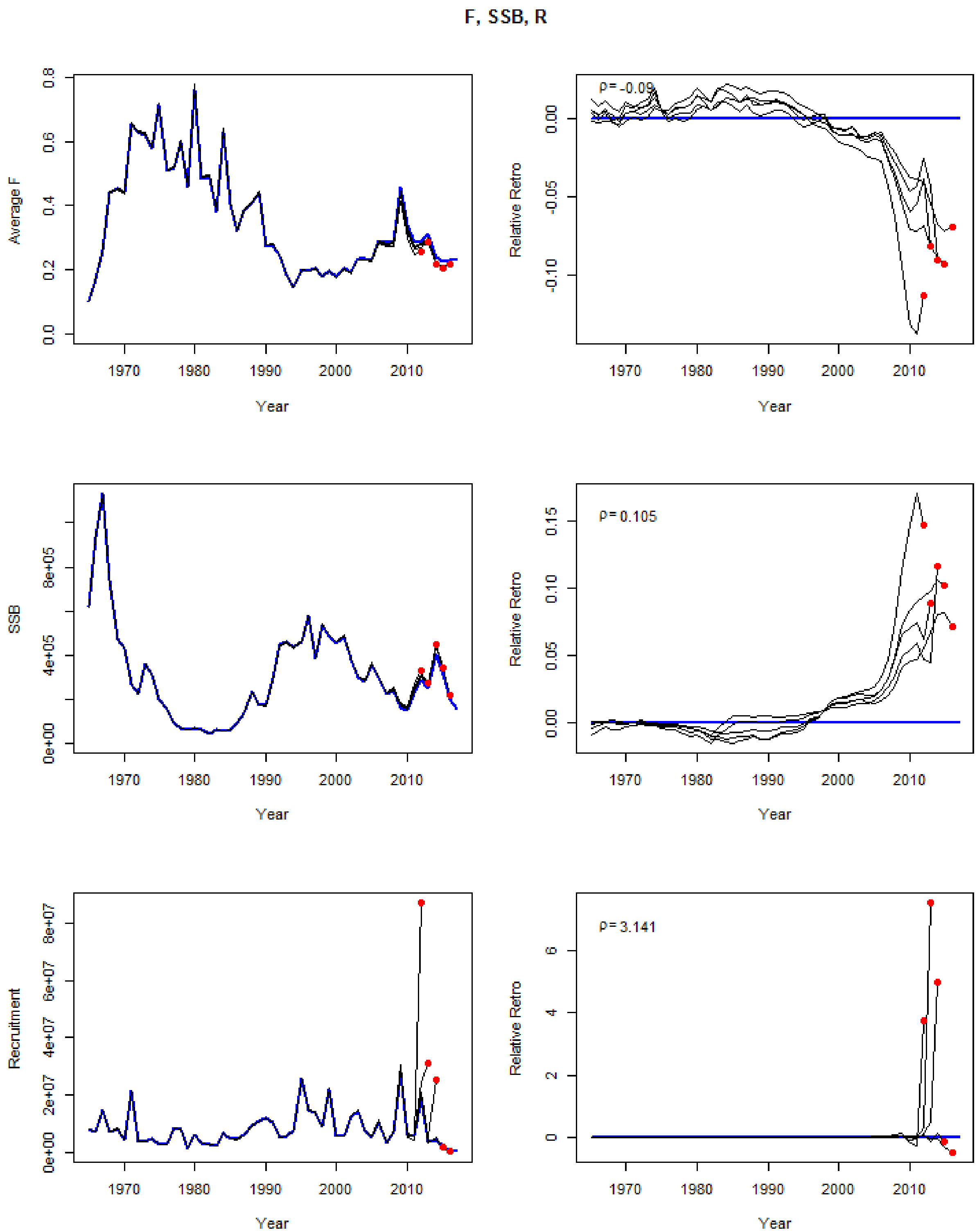
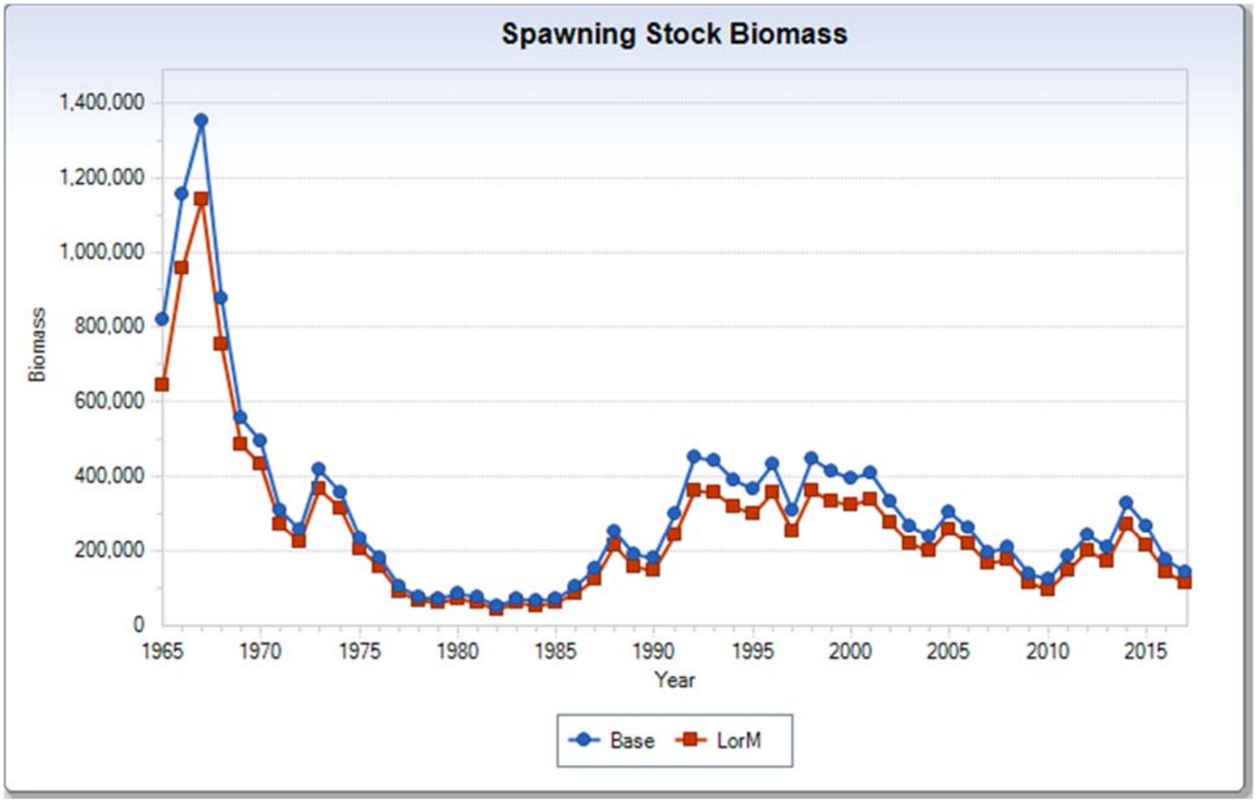


Figure B4- 32 Atlantic herring SSB and recruitment time series for the base ASAP model (Base) and the base model amended to have age-varying M (LorM)



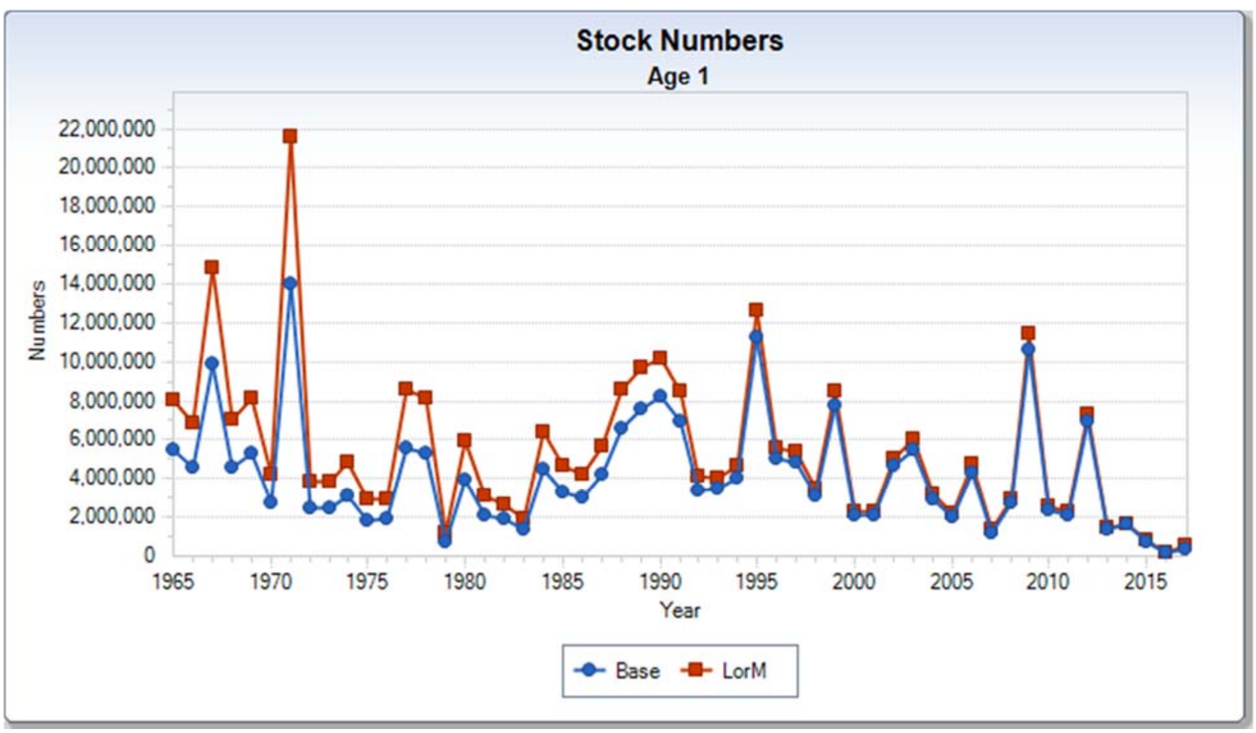


Figure B4- 33 Retrospective pattern for the base model amended to have age-varying M

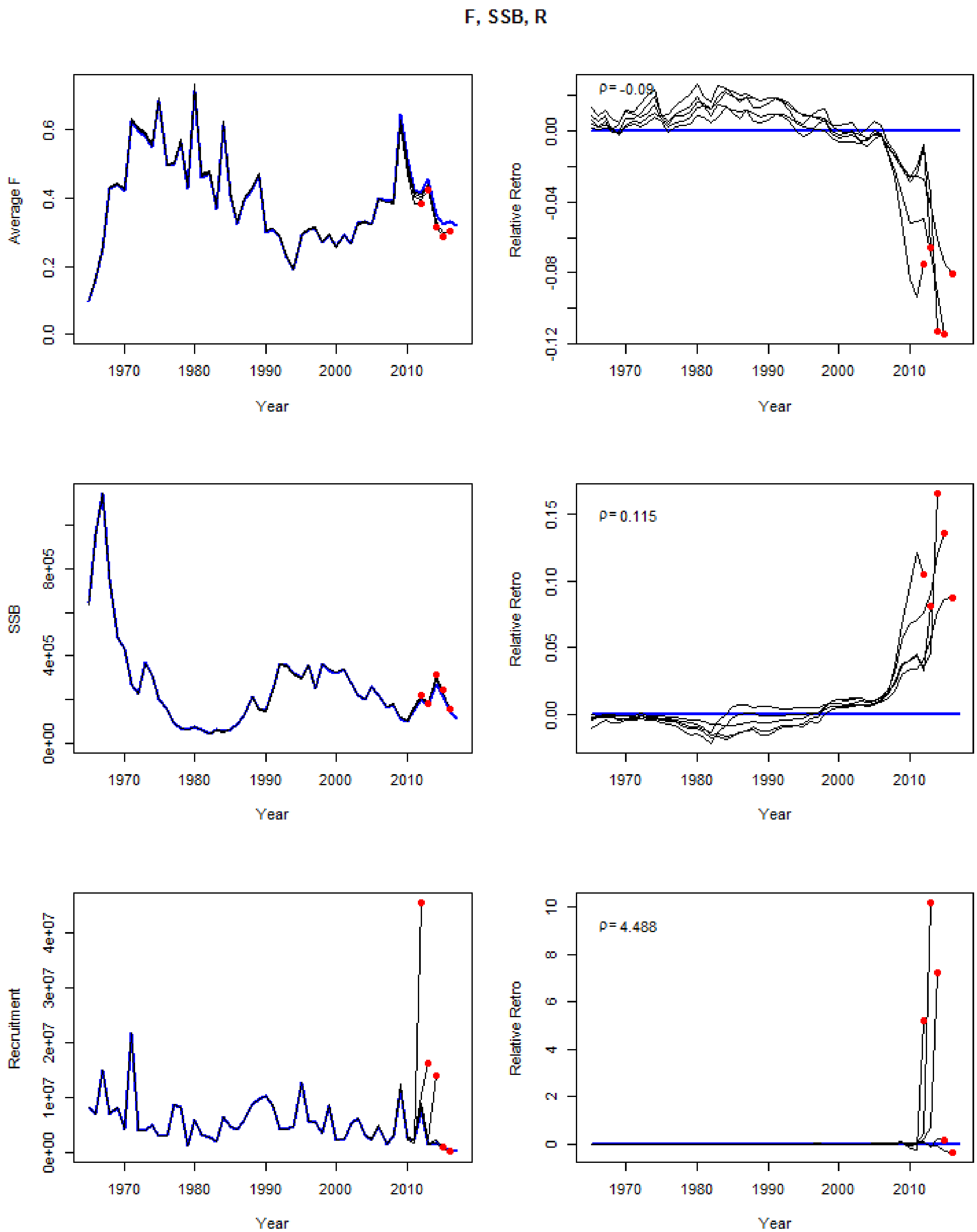
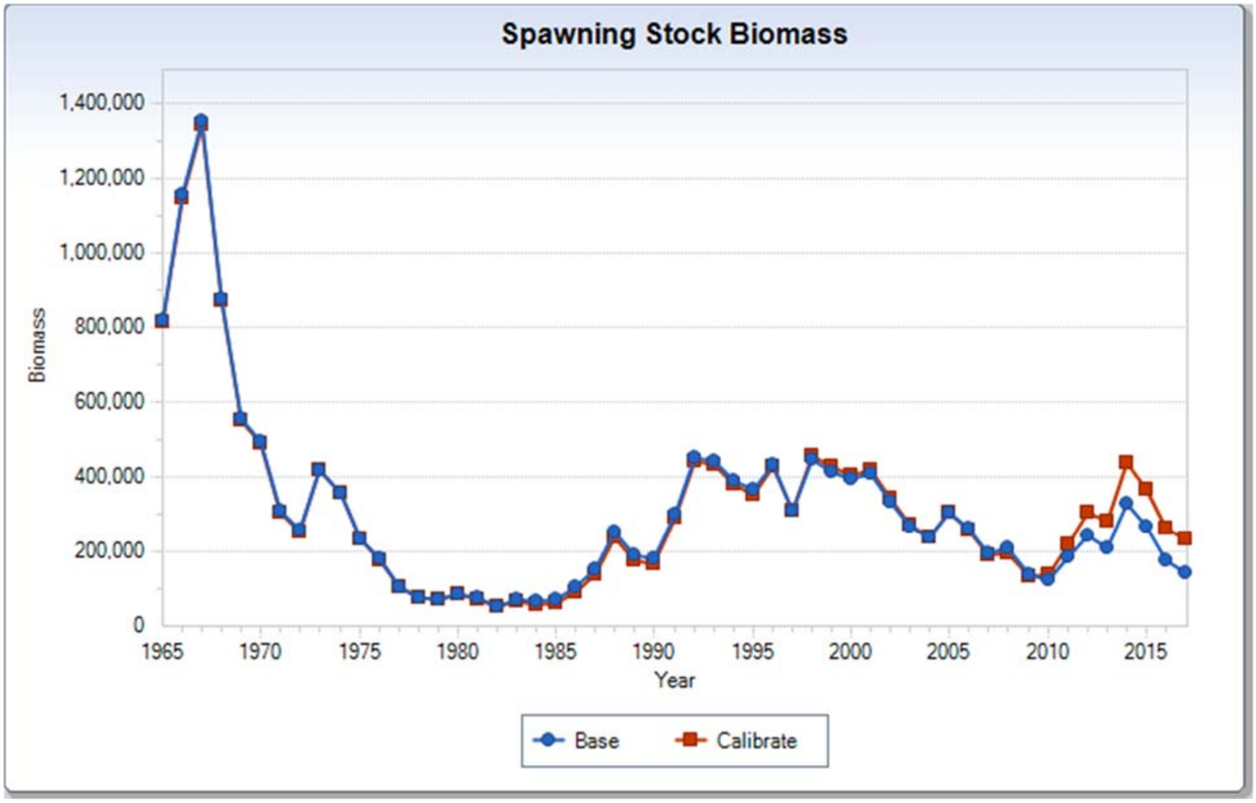


Figure B4- 34 Atlantic herring SSB and recruitment time series for the base ASAP model (Base) and the base model amended to with the NMFS spring and fall Bigelow years (2009-2017) calibrated to Albatross equivalents (Calibrate)



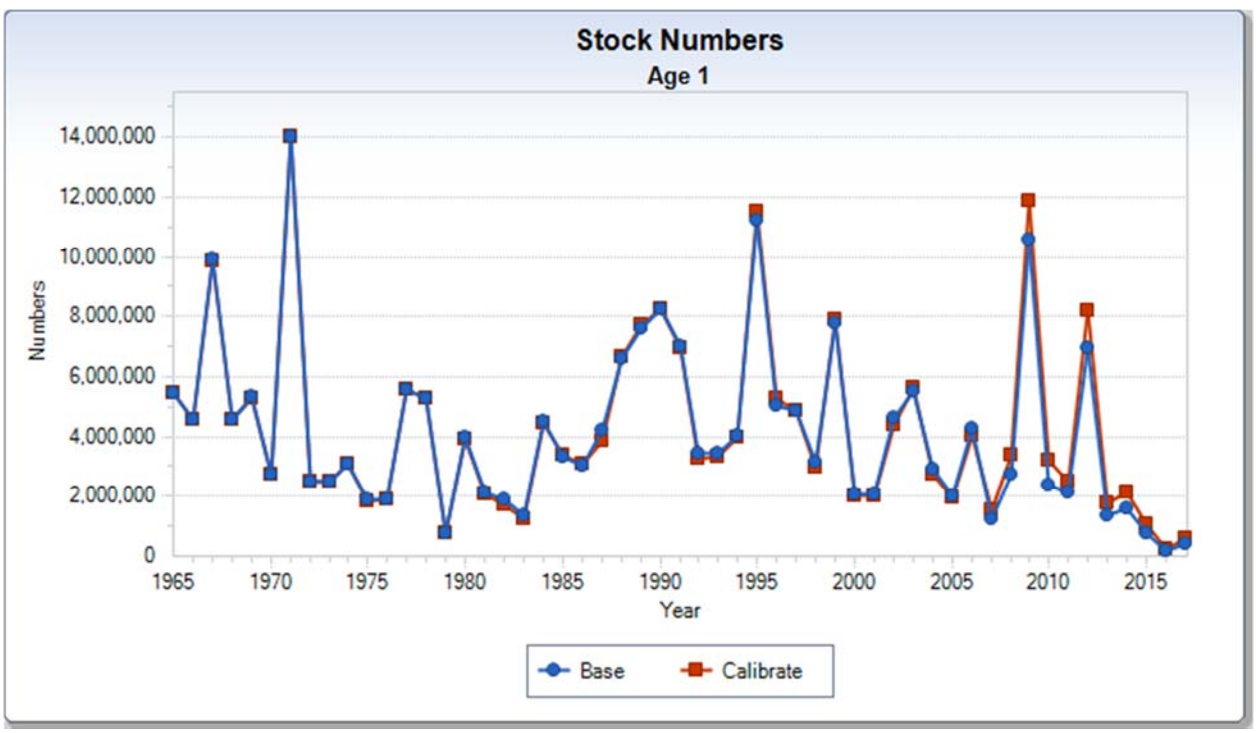


Figure B4- 35 Retrospective pattern for the base model amended to with Bigelow catches (2009-2017) calibrated to Albatross equivalents

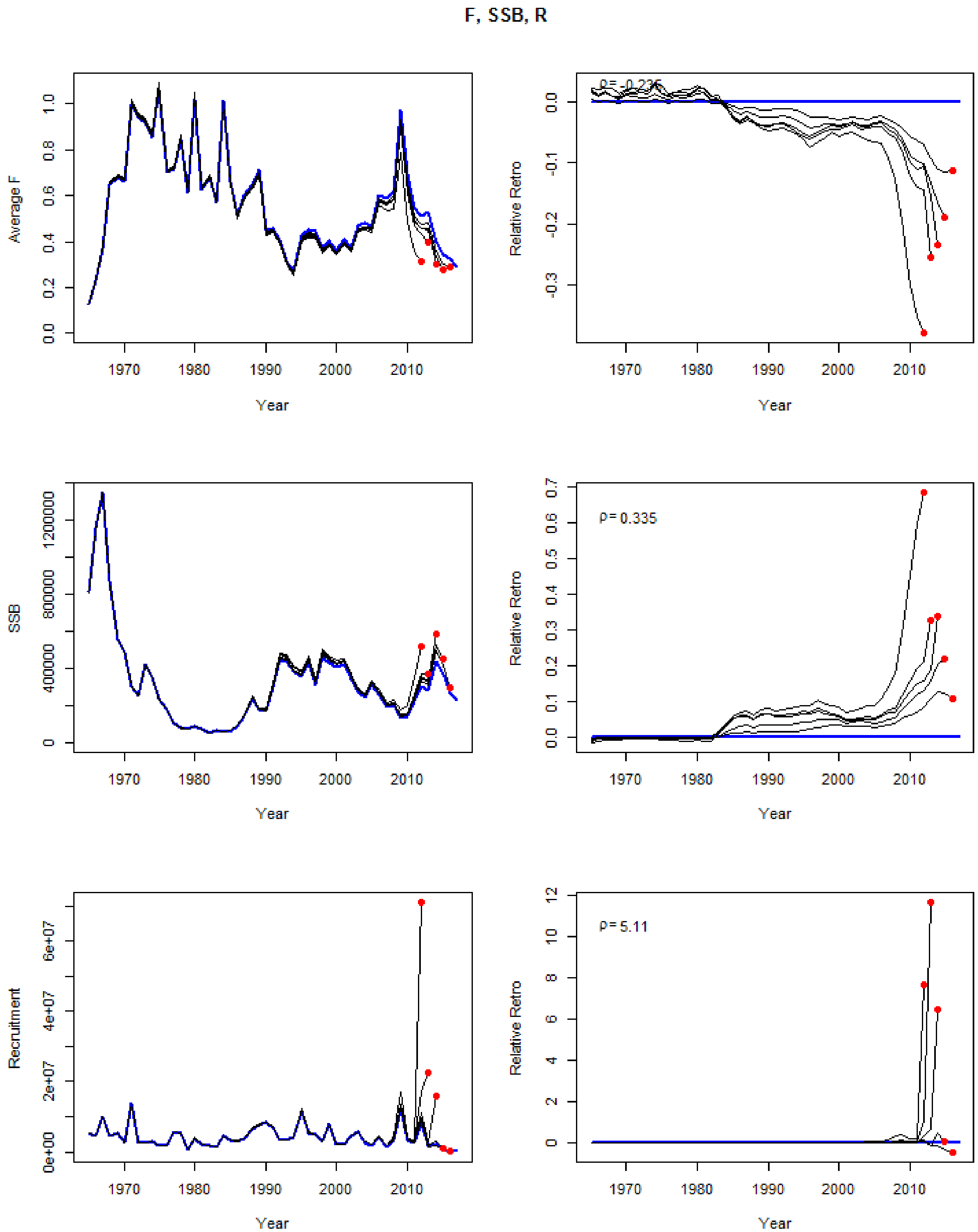


Figure B4- 36 Ratio of Bigelow to Albatross catchability as estimated by ASAP and using paired tow experiments (Conversion Coeff.). Bottom panel is the black bar value divided by the blue bar value in the top panel

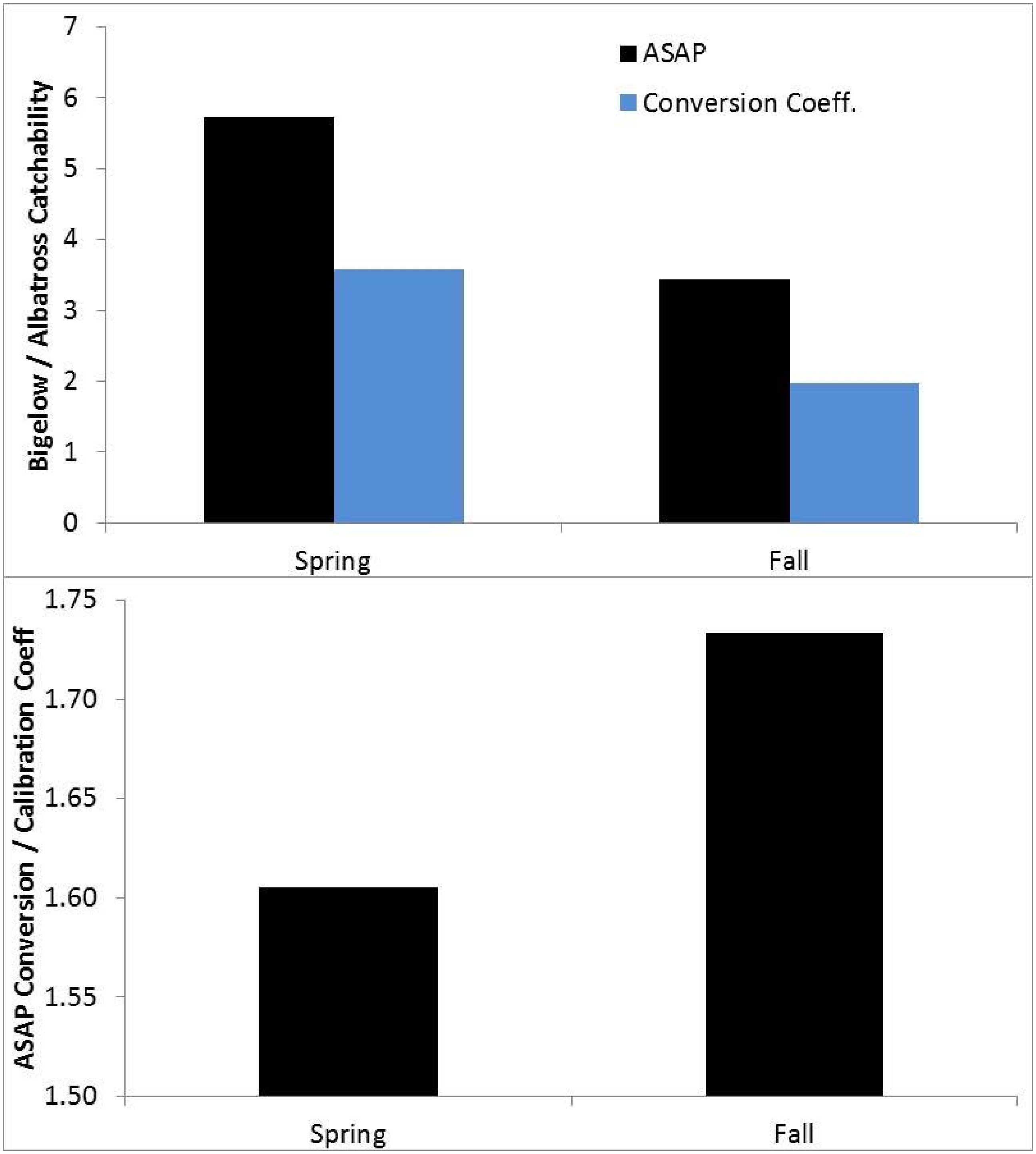
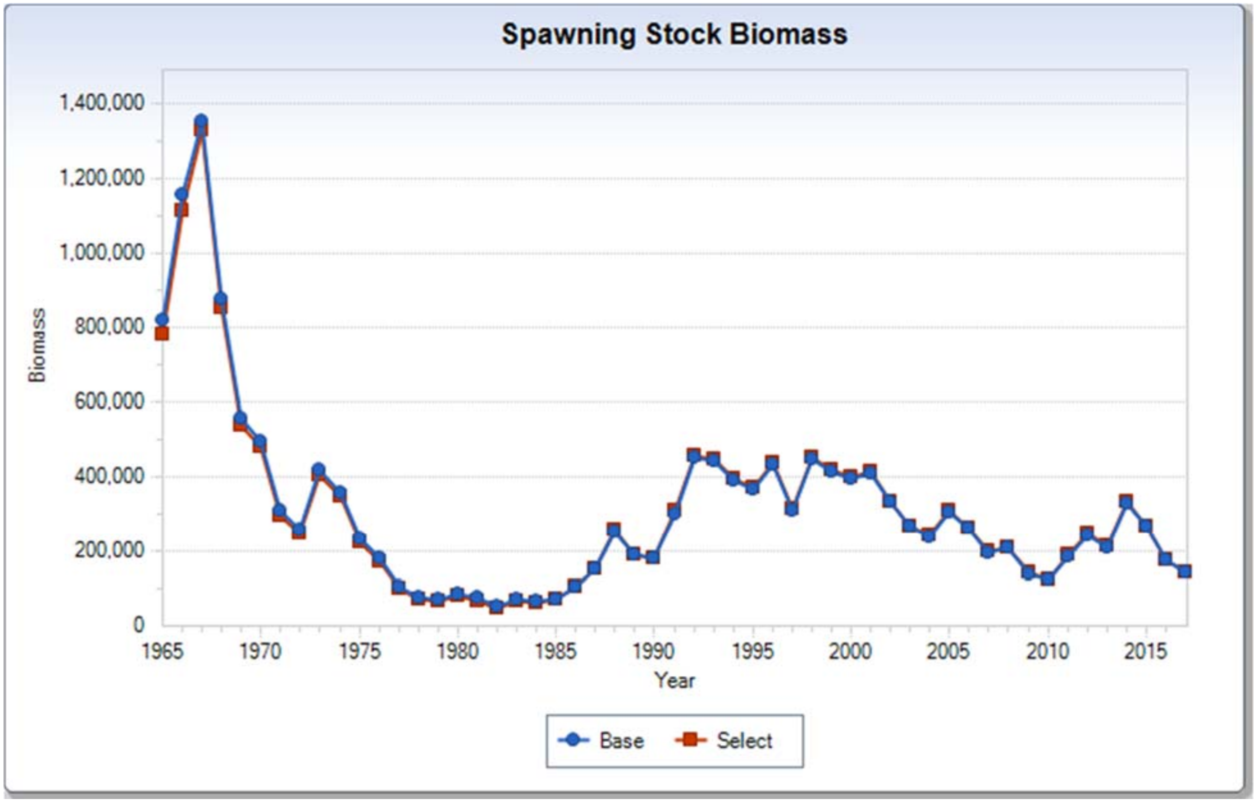


Figure B4- 37 Atlantic herring SSB and recruitment time series for the base ASAP model (Base) and the base model amended with a selectivity block in the mobile fleet (Select)



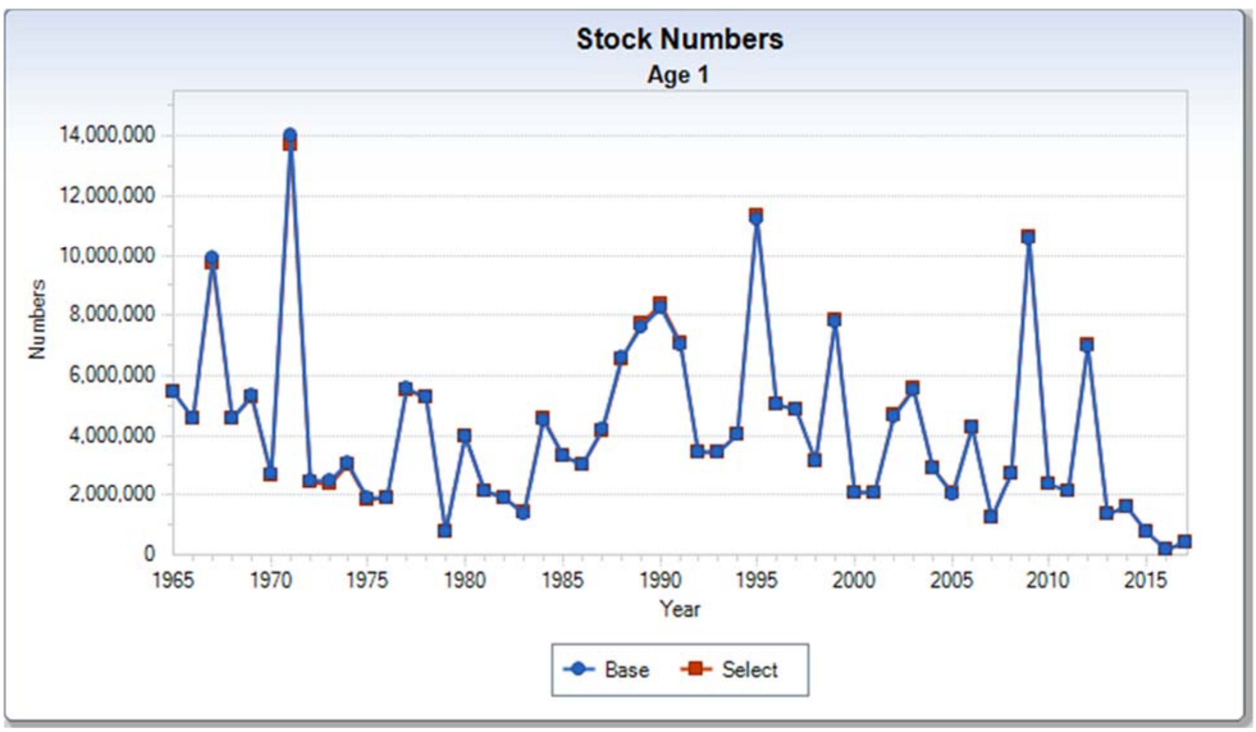


Figure B4- 38 Retrospective pattern for the base model amended with a selectivity block in the mobile fleet

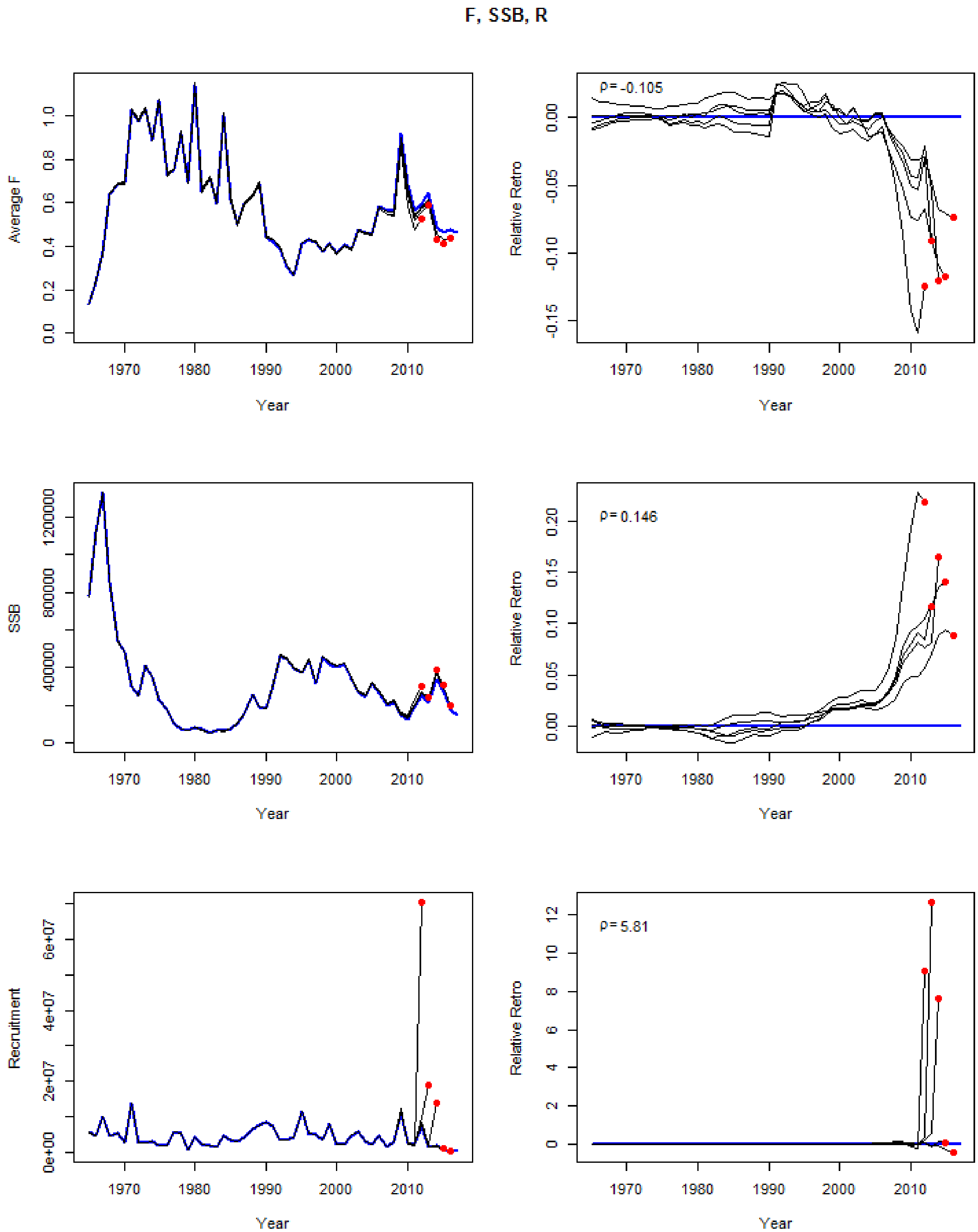
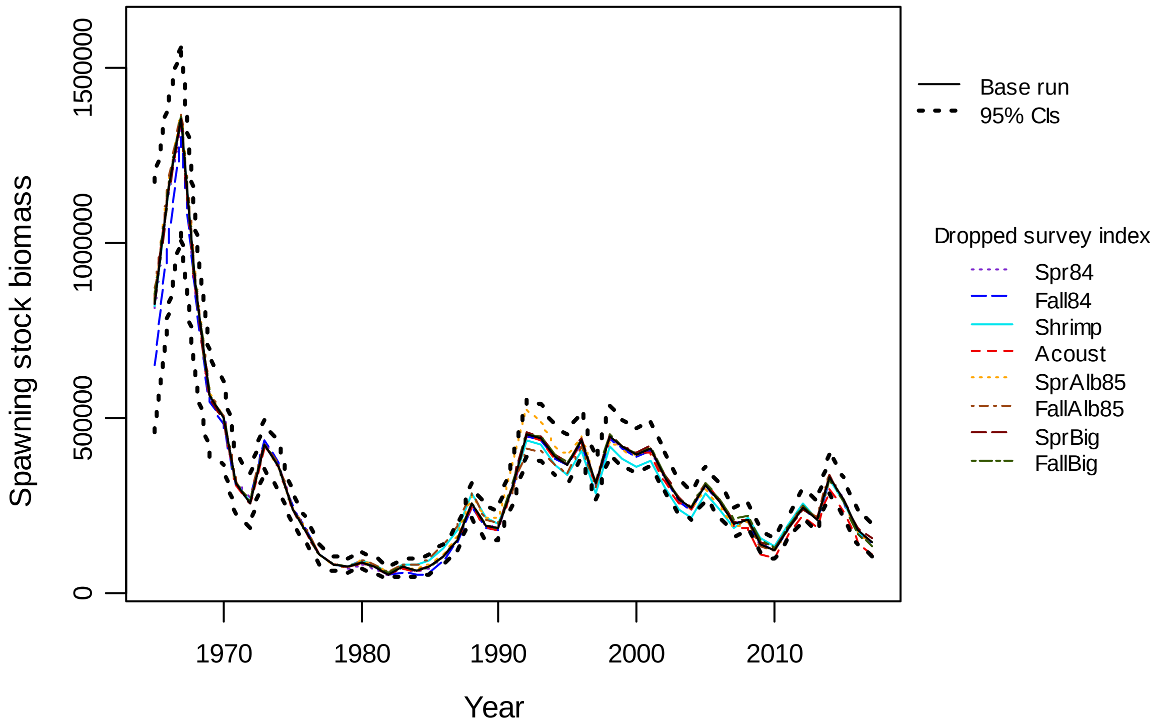


Figure B4- 39 Atlantic herring SSB time series produced by excluding one survey at a time from the base model (top panel) and highlighting the difference between the base and excluding the acoustic index (bottom panel)



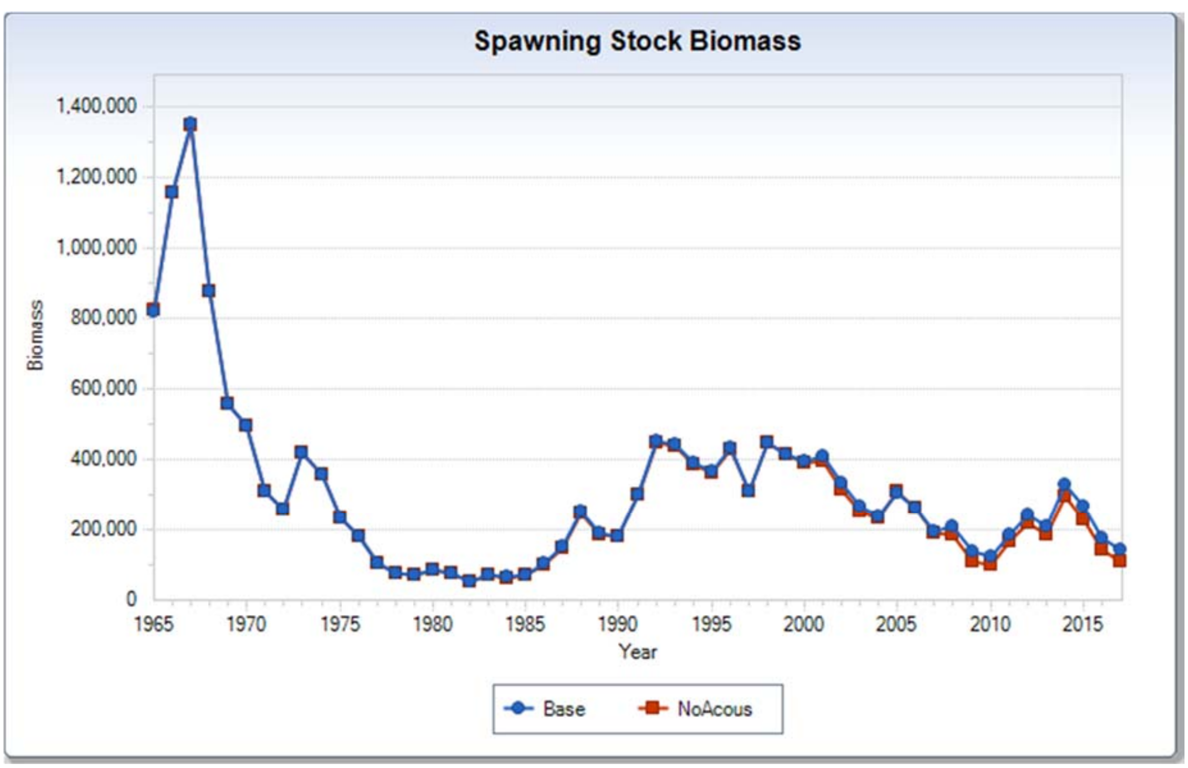


Figure B4- 40 Retrospective pattern for the base model except with the acoustic index excluded from the fit

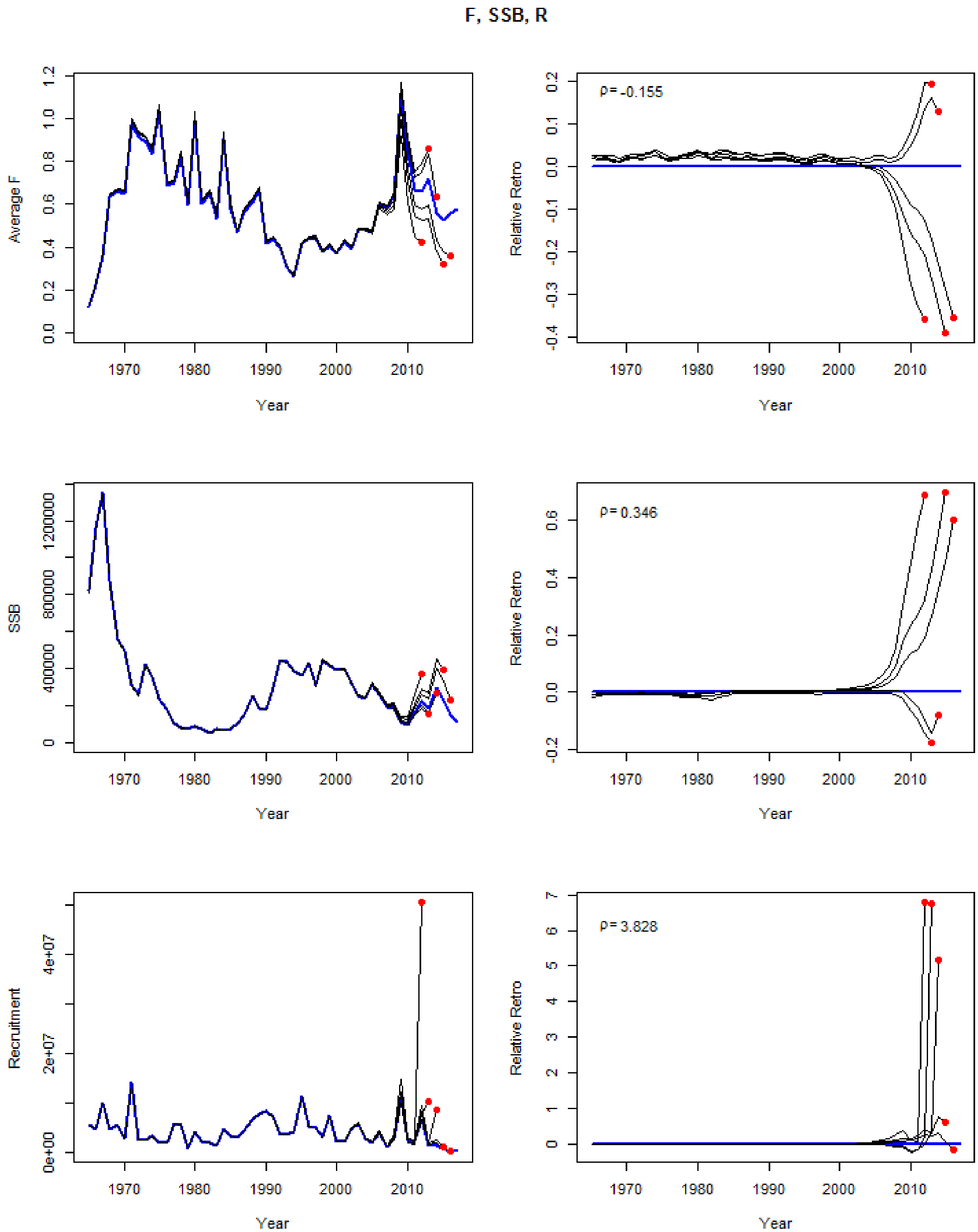


Figure B4- 41 Stock status for the Atlantic herring base model except with the exclusion of the acoustic index from the fit

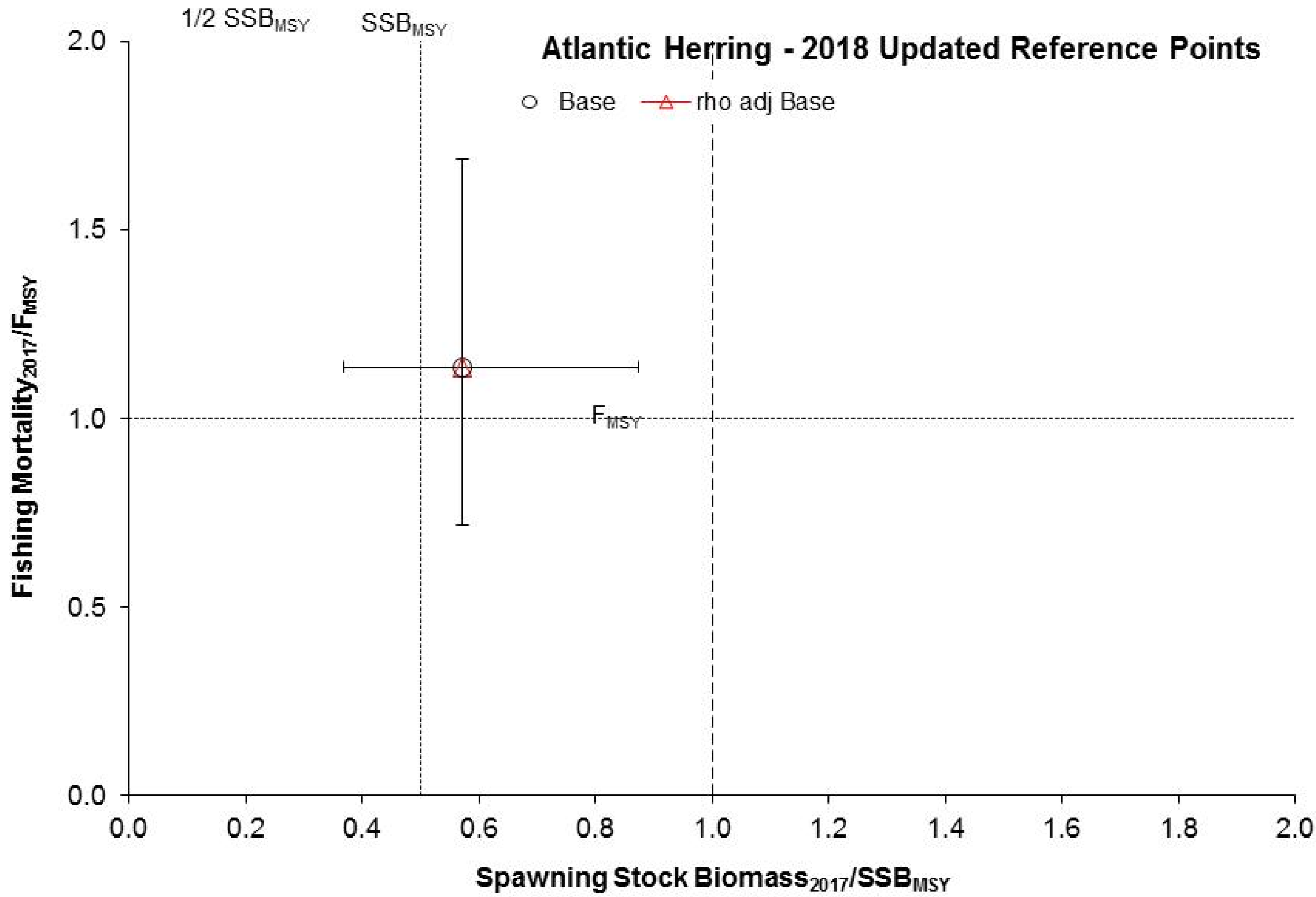


Figure B4- 42 Atlantic herring SSB time series for the base model and the base model with the addition of the index of abundance derived from food habits data

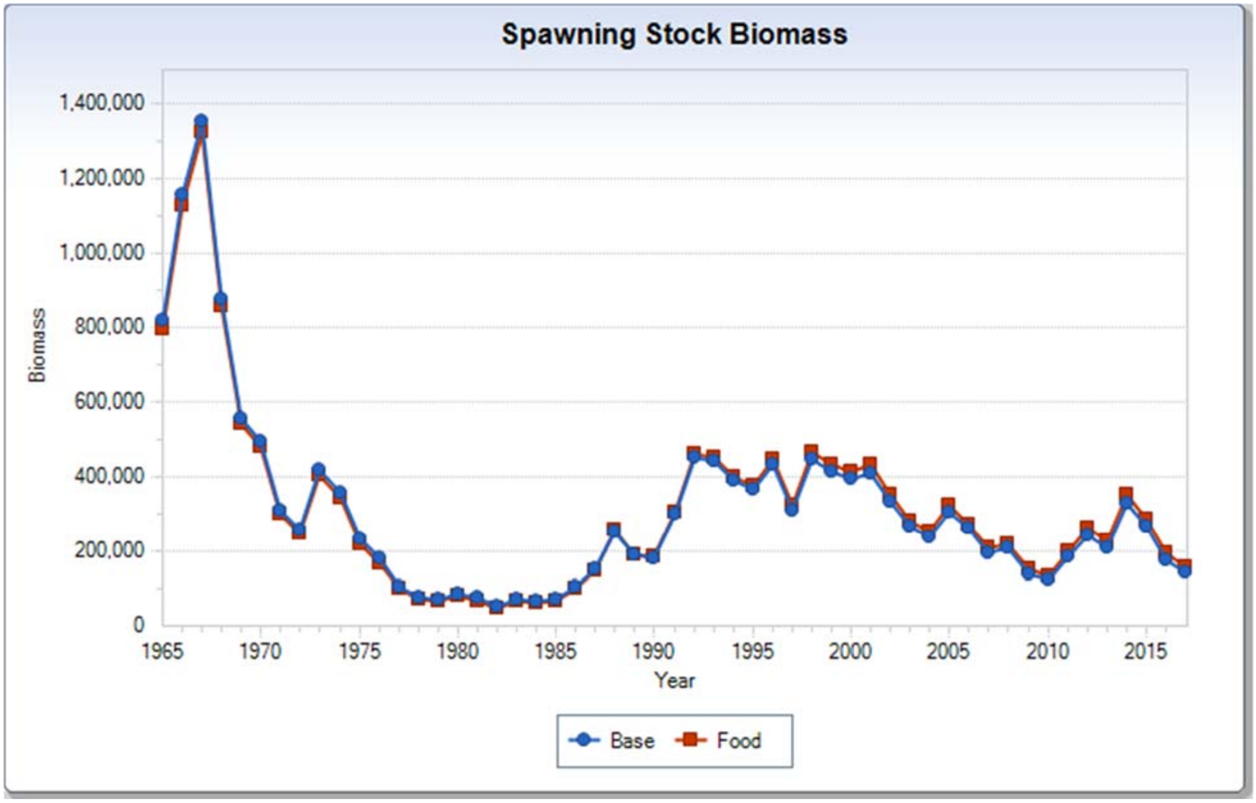
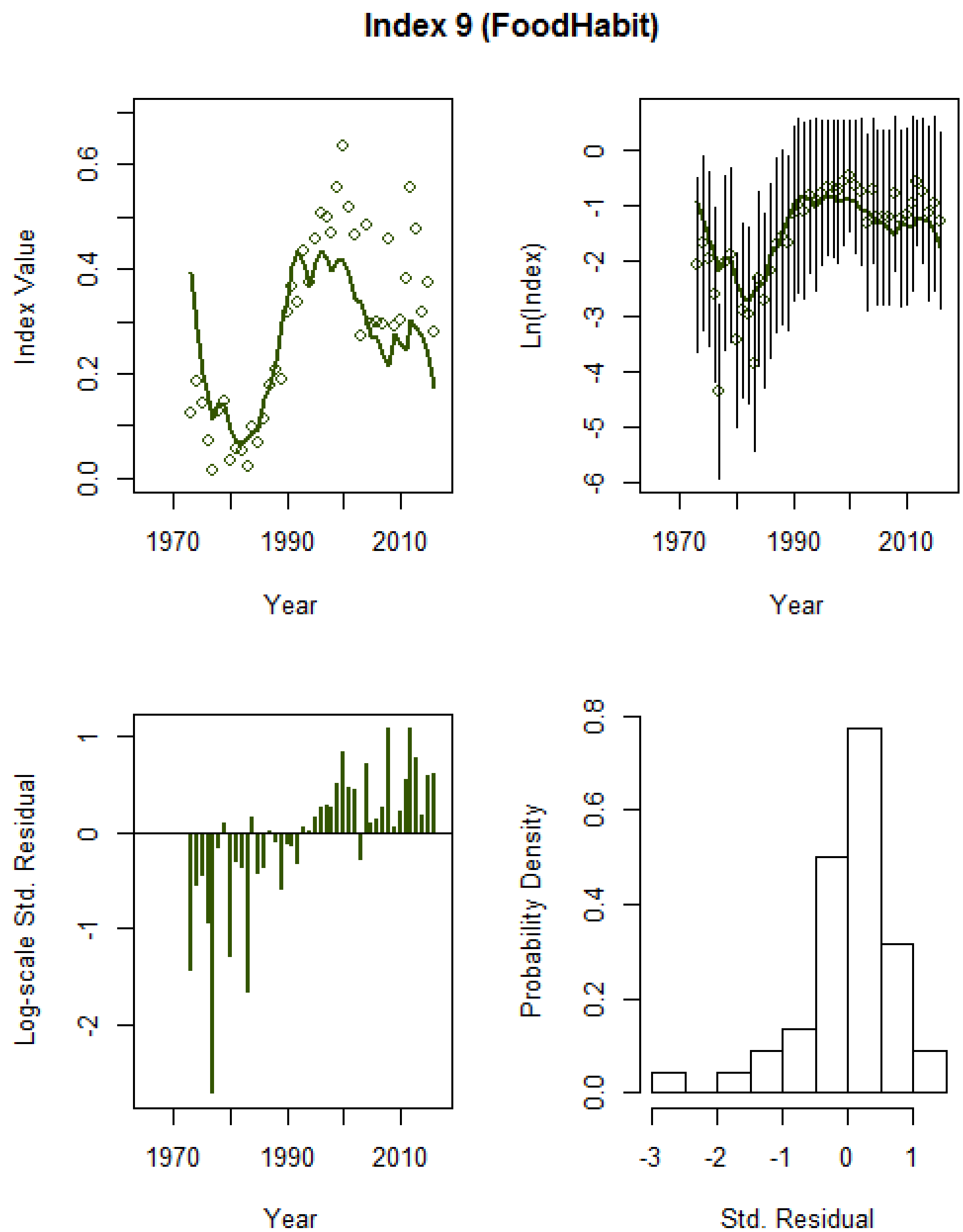


Figure B4- 43 Fit to the food habits index when added to base ASAP model



TOR B5: *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 BRPSs. Comment on the scientific adequacy of existing BRPs and the "new" (i.e. updated, redefined , or alternative) BRPs.*

The existing MSY reference points were based on the fit of a Beverton-Holt stock-recruitment relationship, estimated internally to the ASAP model, and inputs (e.g., weights-at-age, natural mortality) from the terminal year of the assessment (i.e., 2014). Point estimates of the MSY BRPs equaled: MSY = 77,247 mt, F_{MSY} = 0.24, and SSB_{MSY} = 311,145 mt.

No stock-recruit relationship was able to be estimated in the base ASAP model, therefore $F_{40\%}$ was used as a proxy for F_{MSY} and long-term projections were used to derive other MSY BRP proxies. The average of the last five years (2013-2017) of weights at age and maturity at age were used to calculate $F_{40\%}$ and in long-term projections. Selectivity at age equaled the catch weighted average of the selectivities at age from the mobile and fixed fleets over the last five years, which produced selectivity generally similar to the mobile fleet given that this fleet accounts for most of the catch in those years. Recruitment in each year of the projections was drawn from the empirical cumulative distribution of the estimated recruitments from 1965-2015. The estimates of recruitment from 2016-2017 were excluded because they were imprecisely estimated with CVs equal to 95% and 251%, respectively (as a point of comparison the CV for 2015=38%; Figure B4- 19). In drawing recruitments from the empirical distribution, a uniform random value is drawn between 0-1 each year, and the recruitment associated with that probability from the cumulative distribution is applied. Thus, any recruitment between the minimum and maximum in the estimated time series has an equal probability of selection each year. F_{MSY} proxy = 0.51, SSB_{MSY} proxy = 189,000 mt (½ SSB_{MSY} = 94,500 mt), and MSY proxy = 112,000 mt.

Metric	Point Estimate	80% probability interval
F_{MSY}	0.51	NA
SSB_{MSY}	189,000 mt	128,000 – 278,000 mt
MSY	112,000 mt	78,000 – 157,000 mt

The existing MSY reference points were based on estimates of a Beverton-Holt stock-recruit curve fit internally to the ASAP model (NEFSC 2012; Deroba 2015). The ability to estimate the stock-recruit curve seems to have deteriorated in this assessment and was not supported. The deterioration in the models ability to estimate a stock-recruit curve is likely related to changes in model structure, such as in M and various likelihood penalties (see TOR B4). Although, the 2012 assessment (NEFSC 2012) reported similar estimation issues as in this assessment (e.g., flat likelihood profile over steepness; steepness and unfished SSB highly correlated), and so the ability of previous models to estimate a stock-recruit curve was also tenuous. The newly proposed reference points no longer rely on a poorly estimated stock-recruit relationship.

TOR B6: *Make a recommendation about what stock status appears to be based on the existing model (from previous peer reviewed accepted assessment) and based on a new model or model formulation developed for this peer review.*

a. Update the existing model with new data and evaluate stock status (over fished and overfishing) with respect to the existing BRP estimates.

Given the Working Group's conclusion that MSY reference points based on the estimation of a stock-recruit curve were unjustified, and were likely unjustified in previous assessments, the existing BRPs are not meaningful. Similarly, evaluating stock status of the existing model with updated data to the existing MSY BRPs is not informative.

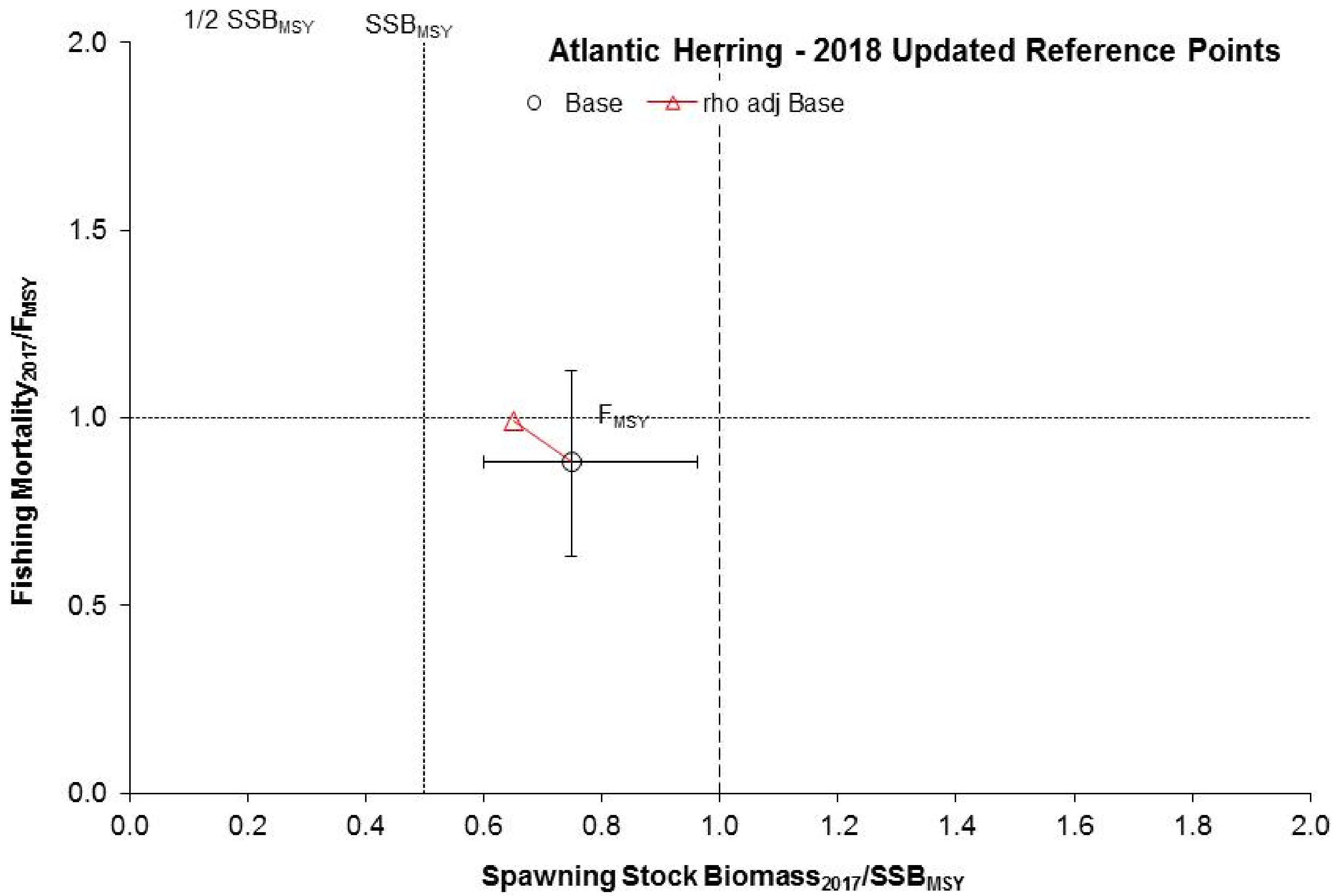
b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR B5).

The base ASAP model estimated F_{7-8} (see TOR B5) in 2017 to be 0.45 and SSB in 2017 was 141,000 mt. Since the retrospective adjusted values do not fall outside of the confidence intervals of the base model estimates, no retrospective adjustment was warranted. A comparison of the base model values to the new MSY proxy reference points suggest that overfishing is not occurring and that the stock is not overfished (Figure B6- 1). The error bars for F_{7-8}, however, included overfishing (Figure B6- 1).

c. Include descriptions of stock status based on simple indicators/metrics.

The estimated numbers at age in 2017 indicate that the population is characterized by more age 6 fish than age 1 and age 2 combined. This result suggests a reliance on the ageing 2011 cohort (age 6 in 2017). If the estimated record low recruitments in recent years hold true, then the SSB is likely to remain relatively low and put the stock at relatively high risk of becoming overfished. Without improved recruitment, the probability of overfishing under recent catch levels is also likely relatively high.

Figure B6- 1 Stock status, "Kobe plot", for the base ASAP model ± 80% CI.



TOR B7: Develop approaches and apply them to conduct stock projections.

a. Provide numerical annual projections (through 2021) and the statistical distribution (i.e. probability density function) of the catch at F_{MSY} *or an* F_{MSY} *proxy (i.e. overfishing level, OFL) (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).*

Short-term projections of future stock status were conducted based on the results of the base ASAP model. The projections did not account for any retrospective pattern because the Mohn's Rho adjusted values for stock status were within the 80% probability intervals of the 2017 point estimates of $F_{7\text{-}8}$ and SSB (Figure B6- 1; TOR B6). Numbers at age for ages 2-8+ in 2018 (the first year of the projection) were drawn from 1000 vectors of numbers at age produced from MCMC simulations of the base ASAP model (see TOR B4 for description of MCMC). Age 1 recruitment in 2018 was drawn from 1000 values, with each value representing the geometric mean of the estimated recruitments for 2013-2017 from each of the 1000 MCMC simulations of the base ASAP model. Age 1 recruitment in 2019-2021 was drawn from the empirical cumulative distribution of the estimated recruitments from 1965-2015 from the base ASAP model (2016 and 2017 were excluded due to imprecision; TOR B5). All other inputs were the same as described in TOR B5.

Projections were repeated with catch in 2018 equal to: 1) the 2018 allowable biological catch (111,000 mt), or 2) half the 2018 allowable biological catch (55,000 mt). Regardless of the catch value in 2018, fishing mortality in 2019-2021 equaled the Fmsy proxy (0.51; TOR B5), and so the row of "Catch (mt)" in the tables below represents the catch at the Fmsy proxy.

	2018	2019	2020	2021
Catch (mt)	111,000	13,700	31,000	55,700
Catch 80% CI	NA	4,000-36,600	16,000-62,700	32,100-95,500
$F_{7\text{-}8}$	1.7	0.51	0.51	0.51
$F_{7\text{-}8}$ 80% CI	0.83-4	NA	NA	NA
SSB (mt)	32,900	19,700	31,700	85,800
SSB 80% CI	4,700-78,600	5,200-58,700	16,500-71,300	47,500-159,000
P(overfishing)	0.95	NA	NA	NA
P(overfished)	0.96	0.94	0.93	0.58

	2018	2019	2020	2021
Catch (mt)	55,000	28,900	38,000	59,400
Catch 80% CI	NA	17,200-53,100	22,700-70,800	35,300-99,600
$F_{7\text{-}8}$	0.58	0.51	0.51	0.51
$F_{7\text{-}8}$ 80% CI	0.4-0.86	NA	NA	NA
SSB (mt)	75,300	43,500	42,600	91,000
SSB 80% CI	46,900-112,100	25,800-86,100	26,400-87,900	52,400-166,100
P(overfishing)	0.69	NA	NA	NA
P(overfished)	0.76	0.92	0.91	0.53

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.

The Working Group agreed that the 2018 ABC of 111,000mt is unlikely to be fully utilized and that a value of 55,000mt is more realistic. The exact value for 2018 catch that should ultimately be used is best left to the Atlantic herring Plan Development Team of the New England Fishery Management Council. Other uncertainties were addressed in TOR B4. The projections assume the future recruitment will approach the mean for the time series. If recruitment continues to be below average, the projected catch increases may be overly optimistic.

c. Describe the stock's vulnerability (see "Appendix to the SARC TORs") to becoming overfished, and how this could affect the choice of ABC (or DEF, possibly even GH&I).

The unknown contributions of the Scotian Shelf (4WX), Gulf of Maine, and Georges Bank stocks can affect the stocks vulnerability to becoming overfished. For example, if the Scotian Shelf stock is contributing a significant amount of fish and that contribution decreases, the vulnerability to overfishing would increase. The vulnerability of the stock has been demonstrated by the historical collapse of the Georges Bank component in the 1980s, which also demonstrated that the multiple spawning groups can be differentially impacted by fishing. Varying contributions from the Scotian Shelf (4WX) stock may also contribute to a retrospective pattern (see below).

In the short-term, the relatively poor recruitments in 2013-2017 will increase the vulnerability of the stock to becoming overfished. The 2016 and 2017 cohorts were imprecisely estimated and so estimates of these cohorts may change significantly in either direction in future assessments, and decisions should likely consider this uncertainty. Growth (i.e., weight at age) also continues to be relatively low when compared to the 1990s, and this seems to be a longer-term feature of the stock that also reduces production. The stock, however, seems to be capable of producing relatively large and small year classes regardless of growth, and so recruitment is likely the more significant driver of short-term vulnerability.

While this assessment had a retrospective pattern that did not warrant adjustments (i.e., via Mohn's Rho), the history of the Atlantic herring stock assessment suggests that resolutions to retrospective patterns are ephemeral (NEFSC 2012; Deroba 2015). Given concerns that estimating catchability separately for the Bigelow years in 2009-2017 may also be aliasing other causes of the retrospective pattern (TOR B2; TOR B4), a safe assumption is that future herring assessments will have worsening retrospective patterns. Retrospective patterns are indicative of model misspecification, and this would increase the vulnerability of the stock to becoming overfished.

TOR B8: *If possible, make a recommendation about whether there is a need to modify the current stock definition for future assessments.*

Previous assessments (NEFSC 2012) concluded that there is likely sub-stock structure unaccounted for in the assessment, but that there is no ability to distinguish mixed survey and fishery catches to stock of origin. This lack of information on stock of origin precludes accounting for the sub-stock structure. In this assessment, a Stock Synthesis model was attempted (Appendix B4) that accounted for stock structure on a coarse level (i.e., Inside Gulf of Maine and Outside Gulf of Maine). In order to attempt this, however, assumptions were required that were likely incorrect, and model diagnostics were poor. The consequences of not accounting for stock structure are unclear, and therefore the need to modify the stock definition is also unclear. More certain, however, is that changing the stock definition and accounting for stock structure in the assessment is currently not possible. Continued research on the topic is warranted (see TOR B9).

TOR B9: *For any research recommendations listed in SARC and other recent peer reviewed assessment and review panel reports, review, evaluate and report on the status of those research recommendations. Identify new research recommendations.*

2018 Atlantic Herring Research recommendations:

- Further research on the use of acoustic technology for inclusion in stock assessment, including information using industry based platforms. Specifically:
    - Investigate methods for converting herring acoustic indices to biomass.
    - Investigate refinements in target strength conversion to abundance estimates in acoustic data
    - Evaluate statistical design implications in acoustic data from surveys and ships of opportunity.
    - Additional research to better understand species identification using acoustic signals
- Investigate use of length data, stock structure and movement within assessment models (e.g. SS3)
- Evaluate data collected in study fleet program for informing assessment data. Development research ideas that can be addressed within the context of the study fleet.
    - Explore fisheries selectivity in greater depth. Perhaps with study fleet and with historical perspective with industry.
- Continue work related to understanding sources of variation in stomach contents, especially as this relates to the (GAMM) models used to develop an index of herring abundance.

General assessment recommendations:

- Develop a list of standards for evaluating data for possible use in stock assessment. Also develop standards for evaluating model diagnostics and inclusion criteria of indices.
- Develop protocols for multi model inference to provide management advice from stock assessments based on NEFSC experience as well as other input (e.g. model averaging approaches).

- Develop simulations to evaluate diagnostics that are useful under different scenarios (e.g. use of likelihoods, retrospective patterns for diagnostics, etc.).

2012 SARC Research Recommendations

a. *More extensive stock composition sampling including all stocks (i.e. Scotian Shelf).*

No additional work completed

b. *Develop (simple) methods to partition stocks in mixed stock fisheries.*

No simple methods completed. Work ongoing using SS3 model to address mixed stock issue.

c. *More extensive monitoring of spawning components.*

Work completed at NEFSC examining extended spawning season in a subset of the mixed stock. Egg survey data analyzed for use as SSB index.

d. *Analyze diet composition of archived mammal stomachs. Improve size selectivity of mammal prey. Also sea birds.*

No work completed for assessment however additional information added to recent herring MSE.

e. *Consider alternative sampling methods such as HabCam.*

No additional work completed.

f. *Research depth preferences of herring.*

Evaluation attempted using Study Fleet information but data incomplete for such analysis.

g. *Simulation study to evaluate ways in which various time series can be evaluated and folded into model.*

On-going work under SEAGRANT funding to Essington and Deroba.

h. *Evaluate use of Length-based models (Stock Synthesis and Chen model).*

SS3 initiated but needs additional work before consideration for use in assessment. Chen model no longer supported.

i. *Develop indices at age from shrimp survey samples.*

Average age-length key developed for application to survey samples. Will make request for a collection of age samples in shrimp survey.

j. *Evaluate prey field to determine what other prey species are available to the predators that could explain some of the annual trends in consumption.*

Some work done regarding sand lance but otherwise not completed.

k. *Develop statistical comparison of consumption estimates and biomass from model M.*

No additional work completed

l. *Consider information on consumption from other sources (i.e. striped bass in other areas) and predators inshore of the survey.*

No additional work completed

m. *Investigate why small herring are not found in the stomachs of predators in the NEFSC food habits database.*

No additional quantitative work completed, however discussions suggest a potential spatial mismatch between our survey coverage and small herring.

n. *Develop an industry-based LPUE or some other abundance index (Industry Based Survey).*

No additional work completed, however ongoing discussion regarding use of acoustic information collected by industry.

o. *Develop objective criteria for inclusion of novel data streams (consumption, acoustic, larval, etc) and how can this be applied.*

Criteria for inclusion already in place, although not completely documented. (see new recommendations).

2012 CIE Research Recommendations

1. *Alternative catch scenarios could be developed to account for uncertainty in the stock boundary, particularly including catches from the Scotian Shelf. This would also allow examination of whether catch underestimation (e.g. inclusion of Scotian shelf catch) can contribute to the reduction in the retrospective pattern and contribute to or explain the need for increased M.*

No additional work completed

2. *Look at the effect of adding a penalty to encourage the NMFS survey trawl door-change q ratios to be similar in spring and fall.*

No indication based on calibration experiment that this is necessary.

3. *Using simulation/estimation methods, evaluate consequences of alternative harvest policies in light of uncertainties in model formulation, presence of retrospective patterns, and incomplete information on magnitude and variability in M (see term of reference 9).*

Considered to some extent in recent MSE work.

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B. Atlantic Herring – List of appendices

Appendix B1.

Otolith exchange text.

Herring ageing: the history and recent exchanges

Jonathan J. Deroba, Eric Robillard, Gary Shepherd, Matt Cieri

Introduction

Estimates of abundance (biomass), fishing mortality (*F*), recruitment, and management quantities (e.g., recommended yield) can be biased when using age-based stock assessments with imprecise or biased age information (Bradford 1991; Eklund et al., 2000; Reeves 2003; Bertignac and Pontual 2007; Yule et al., 2008). Imprecise ageing can cause estimates of abundance or *F* to be biased in scale, but not necessarily trend, while recruitment estimates may be biased in scale and falsely autocorrelated (Bradford 1991; Reeves 2003). Biased age information can cause estimates of abundance, *F*, and recruitment to be biased in scale and trend, and result in inappropriate catch and management advice (Bradford 1991; Eklund et al., 2000; Reeves 2003; Bertignac and Pontual 2007; Yule et al., 2008).

Atlantic herring *Clupea harengus* in the northwest Atlantic Ocean have been assessed using age-based stock assessment models (Anthony 1977; NEFSC 1993; NEFSC 1998; Overholtz et al., 2004). The age-based assessments rely on ages from multiple agencies. Commercial catch samples are aged by the Canadian Department of Fisheries and Oceans (DFO) and the Maine Department of Marine Resources (DMR). Survey catch samples are aged by the US National Marine Fisheries Service (NMFS). Periodic evaluations of the accuracy and precision of herring ageing, however, have revealed disagreements among ageing labs and potential biases (Dery and Chenoweth 1979; Overholtz et al., 2004; Libby et al., 2006). Results of an otolith exchange among agencies conducted during the 2003 stock assessment suggested that age readers from DMR and NMFS were generally in agreement, except for about a 10% difference for fish older than about age-4, with the NMFS reader concluding that fish were younger ("underageing") than the DMR reader (Overholtz et al., 2004). Significant differences of greater than 50% at some older ages were found between the DFO lab and both US facilities, with the DFO concluding that fish were younger than both US readers. An ageing workshop and second otolith exchange were conducted in 2006 (Libby et al., 2006). Generally, agreement among the ageing labs in the second otolith exchange was worse than during the 2003 assessment. Age readers from DMR and NMFS agreed 54% of the time and DMR tended to conclude that fish were younger than NMFS, which is the reverse of the discrepancies found in 2003. Age readers from DFO and NMFS agreed only 39% of the time and DFO generally concluded that fish were younger than NMFS. Similarly, DFO and DMR agreed 58% of the time, with DFO concluding that fish were younger than DMR.

While otolith exchanges provide information on ageing precision and differences among labs, they do not inform accuracy. Using bomb radiocarbon dating to evaluate herring ageing accuracy, Melvin and Campana (2010) concluded that herring aged six and older were often underaged, while ages of younger fish were relatively well determined. The inaccuracy of ageing for older fish is consistent with the results of the otolith exchanges that also found greater disparity at older ages. Since 2003, DFO and DMR have re-aged much of their historical catalogue using techniques agreed to during ageing workshops (Libby et al., 2006), but concerns about herring age accuracy and precision have lingered (NEFSC 2012).

During the 2012 Atlantic herring stock assessment, systematic differences were found between age-length keys (ALKs) from commercial samples aged by the DMR and survey samples aged by NMFS (see below; NEFSC 2012). One possible explanation for these differences is ageing errors. This manuscript describes work that has been done since 2012 to evaluate the potential for ageing errors in the Atlantic herring stock assessment.

Methods

Examinations of ageing data

Prior to the 2012 stock assessment, ALKs for herring from commercial and survey samples were combined to eliminate lengths for which no age data were available (i.e., “fill holes”), increase sample sizes and precision, and allow for survey age compositions to extend prior to 1987, the year when ages were first sampled for herring during NMFS surveys. Combining ALKs among gears, spatial areas, and time, however, can induce bias in the subsequent age compositions and stock assessments (Westrheim and Ricker 1978; Quist et al., 2012; Gerritsen et al., 2006). During the 2012 stock assessment, the practice of combining ALKs from commercial and survey sources was evaluated by plotting the proportion of fish at length assigned to each age by the commercial mobile gear fishery ALK in the first semester of each year (i.e., January-June) with the NMFS spring survey ALK for each year from 1987-2010 (NEFSC 2012). Using only commercial gear samples from the first semester of the year was intended to control for growth within the year that might affect the ALKs. These plots were then visually compared, with general consistency suggesting that ALKs could likely be combined, and inconsistency suggesting that ageing error or some other issue may be problematic and ALKs should not be combined. Consistency between the DMR and NMFS ageing labs was evaluated by plotting the mean age in 5cm length bins in each year estimated from samples collected from the commercial mobile gear fishery in the first semester of each year with mean age estimated using NMFS spring survey samples. The same plots were created using samples collected from the commercial mobile gear fishery in the second semester of each year and the NMFS fall survey. Similarly, samples from all years were combined and mean age in 1 cm length bins was estimated from samples collected from the commercial mobile gear fishery in the first semester and plotted with mean age estimated using NMFS spring survey samples, and a similar plot was created using samples collected from the commercial mobile gear fishery in the second semester of all years and the NMFS fall survey. These plots were visually compared, with consistency suggesting no evidence of ageing error, but systematic differences suggesting the opposite conclusion.

Recent otolith exchanges

To make sure that all labs providing ages followed the same protocols, otoliths exchanges between labs occurred in 2014, 2016 and 2017. The following measures were used to characterize the results of tests of ageing consistency between the labs:

Coefficient of Variation (CV)

The mean coefficient of variation (CV, Campana *et al*. 1995, Chang 1982) is a relatively robust approach to quantifying agreement in fish ages. It yields results which are easier to compare between species and structures. Also, the contribution each fish makes to the CV is relative to the average age assigned to that fish; i.e., a 2-year error in ageing a young fish would increase the measure more than would a 2-year error in an older fish, as the percentage change in age is greater for younger ages.

The CV is based on the differences between the mean age and each given age for each fish, and then these values are averaged over the entire sample set. When two ages are assigned to each fish, the CV is calculated as follows:

$$CV = 100\% \times \frac{1}{N} \sum_{j=1}^{N} \frac{\sqrt{\sum_{i=1}^{2} (X_{ij} - X_j)^2}}{X_j}$$

where X_{ij} is the *i*th age for the *j*th fish, X_j is the mean age of the *j*th fish, and N is the sample size. Campana (2001) indicates that many ageing laboratories around the world view CVs under 5% to be acceptable among species of moderate longevity and ageing complexity. His description applies to all the herring exchanges that have occurred since 2012.

Percent Agreement

The Fishery Biology Program has used this measure since the group's inception, and considers levels of over 80% to be adequate. It is calculated based on the percentage of ages agreed upon relative to the total number aged:

$$\text{Percent Agreement} = 100 \times \frac{\text{Number of agreements}}{N}$$

For this measure, an error in ageing a young fish changes the measure by the same amount as would a similar error for an old fish. Therefore, this statistic is harder to compare between samples sets with different age distributions.

Bowker's Test of Symmetry

For both types of precision test, a Bowker's test (Hoenig *et al.* 1995, Bowker 1948) was used to test for departures from symmetry within the age-frequency table. Such asymmetries indicate the presence of a bias, although the test has low sensitivity when few disagreements exist. Where ages differ from one another, the Bowker's test compares values on the age-frequency table which represent symmetric errors, such as the paired ages (3,4) and (4,3). If all such values are dissimilar, the test will return a significant P value.

This test statistic is calculated as a chi-square variable, as follows:

$$\chi^2 = \sum_{i=1}^{m-1} \sum_{j=i+1}^{m} \frac{(n_{ij} - n_{ji})^2}{n_{ij} + n_{ji}}$$

where m is the maximum age in the data set, and n_{ij} is the number of fish in the *i*th row and *j*th column (Hoenig *et al.* 1995, Bowker 1948). The value of the degrees of freedom is equal to the number of non-zero n_{ij}-n_{ji} comparisons in this calculation, to a maximum of m(m-1)/2.

Results

Examinations of ageing data

All plots of the proportion of fish at length assigned to each age for each year can be found in NEFSC (2012), and so only example plots were provided here. The proportion of fish at length assigned to each age was generally similar between the commercial mobile gear fishery ALK in the first semester of the year and the NMFS spring survey ALK from 1987-1992 (Figure 1-top). The proportion of fish at length assigned to each age was also similar for ages 1-2 during 1993-2010 (Figure 1-bottom). For ages 3 and older, however, the NMFS spring survey ALK generally assigned a larger proportion of fish to each age at smaller lengths and a smaller proportion of fish to each age at larger lengths than the commercial mobile gear fishery ALK during 1993-2010 (Figure 1-bottom).

Mean ages in 5cm length bins were generally similar for the DMR mobile commercial samples and NMFS spring and fall survey samples for the 15-19cm and 20-24cm bins (Figure 2). The exception was between the DMR mobile commercial samples from the second semester and the NMFS fall survey for the 15-19cm length bin during 1987-1991, when the NMFS fall survey mean ages were approximately one year less than the DMR samples (Figure 2).

Mean ages in 5cm length bins differed for the DMR commercial samples and the NMFS spring and fall survey samples for the 25-29cm and 30-35cm bins, and the differences trended among years (Figure 3). Although the severity of differences and trends varied among length bins and seasonal surveys, some patterns were similar. Mean age from the NMFS surveys were less than the mean ages from commercial samples from 1987 until the mid-1990s, similar from the mid-1990s to the early 2000s, and greater than the commercial samples for the remainder of the time series (Figure 3).

Mean ages in 1cm length bins for all years combined (1987-2013) were similar from the smallest bins until about 28cm, after which the survey mean ages were about 1-3 years less than the DMR commercial samples (Figure 4). Mean ages from the DMR commercial samples increased relatively smoothly with length, as might be expected from a von Bertalanffy growth curve, whereas the mean ages from the surveys suggested an irregular increase in age with length beginning at about age-6 (Figure 4).

Recent otolith exchanges

Following Campana's 2001 recommendations, ageing labs around the world consider to have acceptable ages if there is 80% or higher agreement and a CV of 5 % and under. All herring exchanges between the labs fit in this category, with had high percent agreement with low variation (figure 5). Of the seven exchanges, only one had a 73.3% agreement but the CV still met the standard with 3.72%. The average agreement and CV between the 7 exchanges was 83.78% and 2.1% respectively. Bowker's test showed there was a bias between DFO and NEFSC in 2014 and between Maine and NEFSC in 2016. There seemed to be no pattern to the bias has it was two different labs, and were followed by other exchanges in which the bias did not show up.

Conclusions

Results suggest some systematic differences between commercial and survey ages. Consistency among DMR and NMFS ageing labs was also worse for larger and older fish (Figures 1-4), which was consistent with results from previous ageing workshops on herring (Overholtz et al., 2004; Libby et al., 2006) and the work of Melvin and Campana (2010). Results also suggest that the severity of the problem, be it ageing error or some other source, may vary through time. The comparison of the ALKs from commercial and survey sources (Figure 1) and mean age in various length bins (Figures 2-3) show temporal trends. The plots of mean age in various length bins suggest greater ageing discrepancies from about 1987 to the mid-90s, better agreement from the mid-90s to mid-00s, and increased discrepancies in recent years.

This research cannot definitively conclude that ageing error or differences in ageing methods is a problem, but other explanations for the patterns in the data seem unlikely. One alternative is that cohorts of herring school independently of each other, such that the mean age at length of fish from one school would differ from the mean age at length of catch from another school. For this to be a valid explanation, however, the pattern of mean age in 1cm length bins (Figure 4) would require that the NMFS randomized survey systematically misses schools from older cohorts, while a commercial fishery targets schools of older fish. This explanation is unlikely, especially considering that schools of older fish would likely be smaller than schools of younger fish, and therefore inefficient for the fishery to target. This age-based segregation has also never been observed in Atlantic herring in this area. The NMFS survey catches could be detecting signals from cohorts outside of the Georges Bank/Gulf of Maine complex. This explanation, however, is also unlikely because the confounding in the signal does not seem to start until older ages and the fishery operates over much of the same area as the NMFS surveys.

Results of recent otolith exchanges suggest consistent aging methodologies and generally trustworthy ages, regardless of source. Ultimately, combining ALKs from different sources should be abandoned for Atlantic herring, especially in previous years where no explanation is available for discrepancies in the data.

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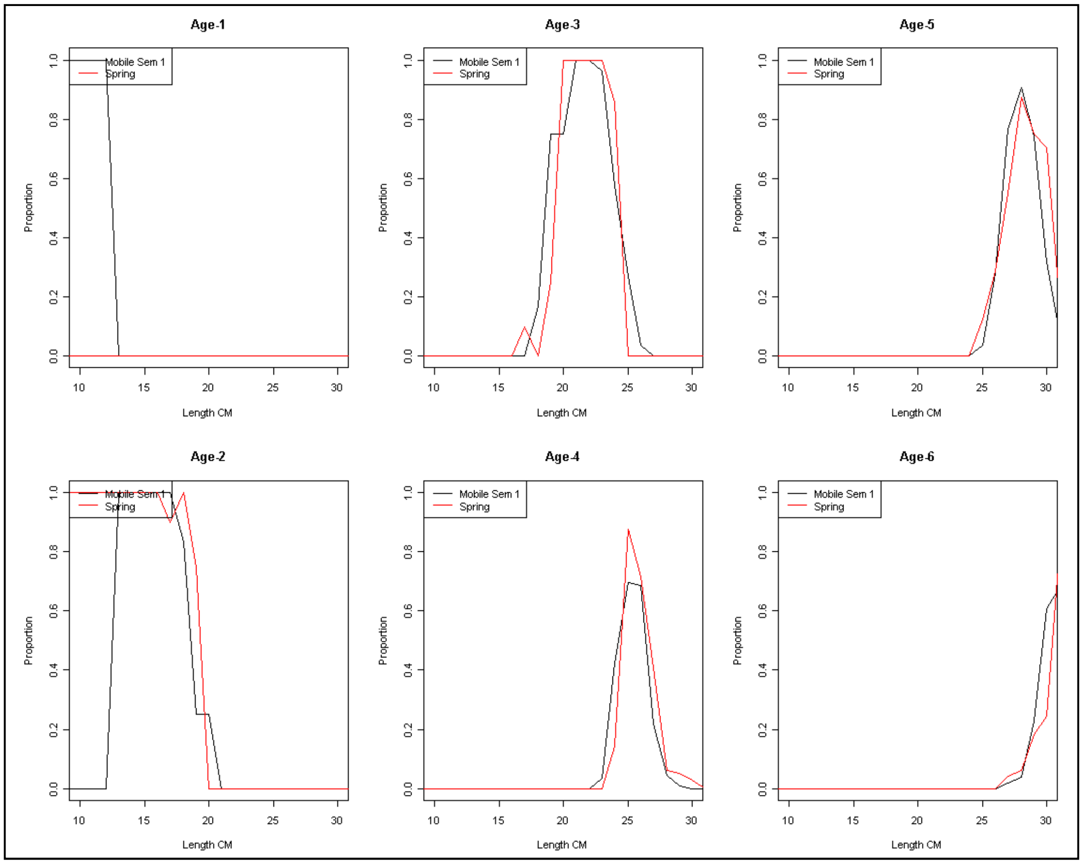
Figure 1. The proportion of fish at length assigned to each age using the commercial mobile gear fishery ALK from semester one of each year (black line) and the NMFS spring survey ALK (red line) in 1988 (top) and 1997 (bottom).



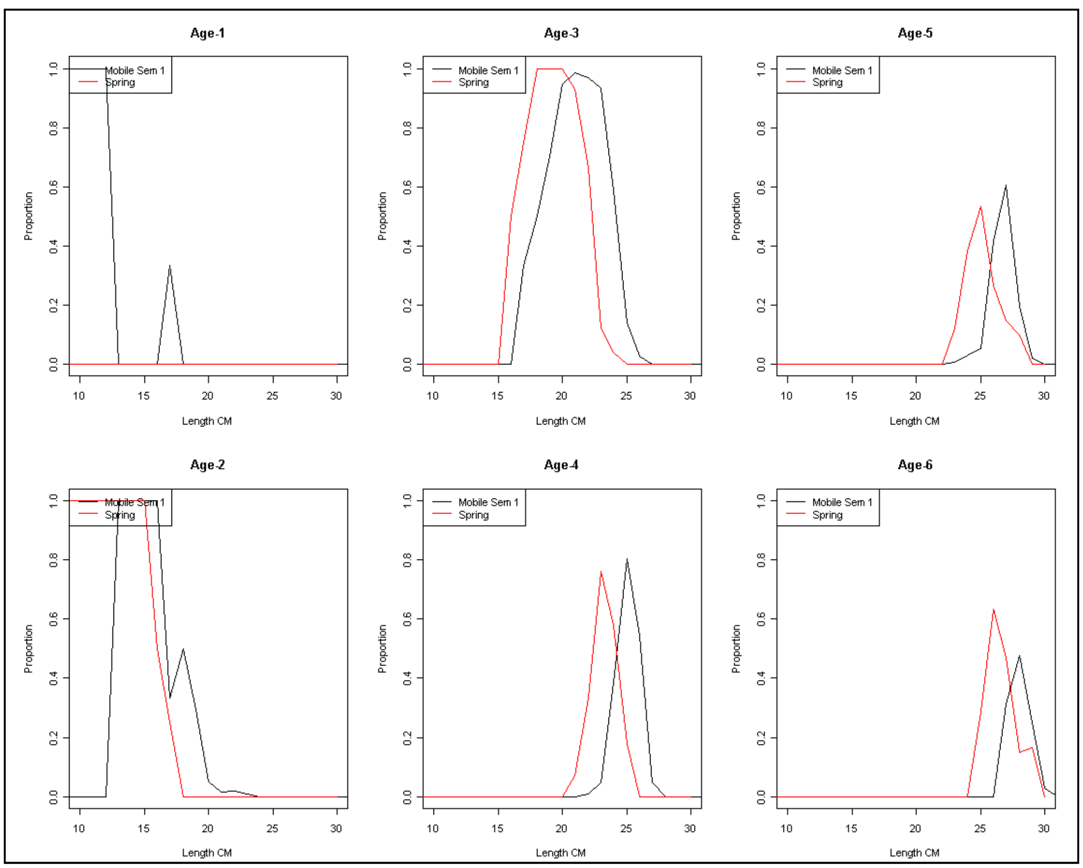
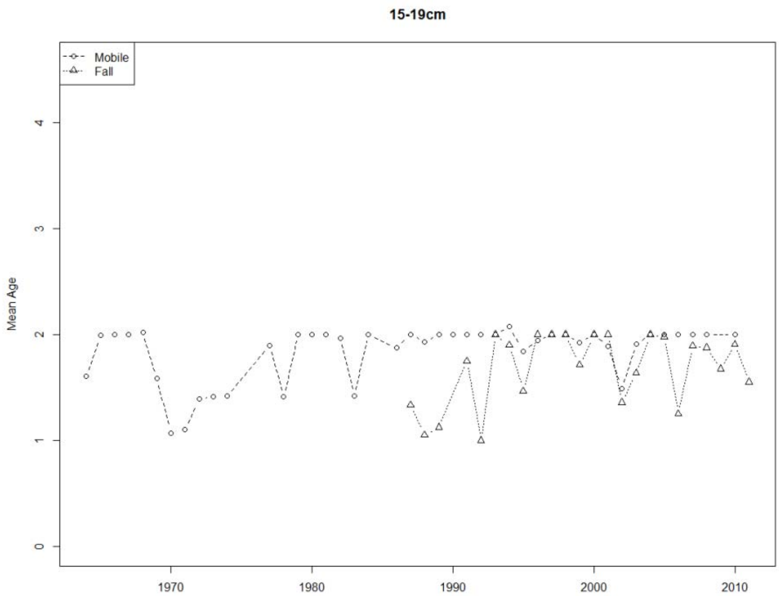
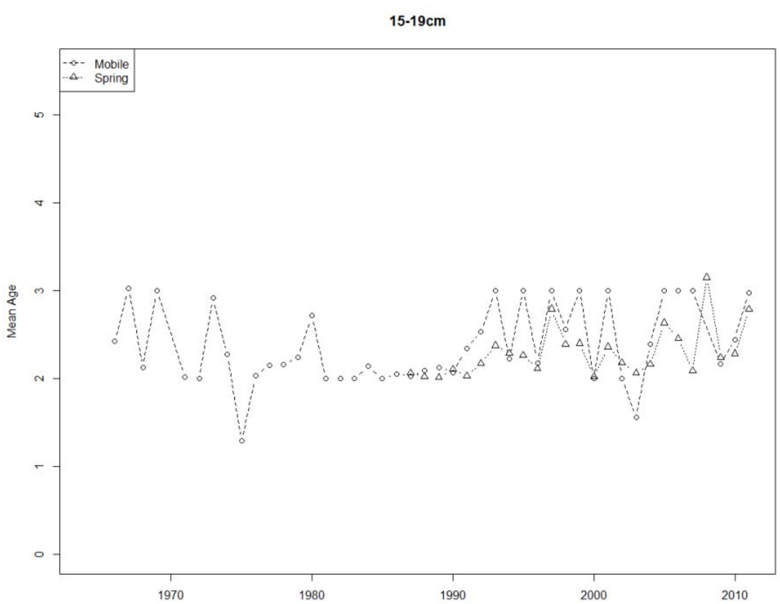
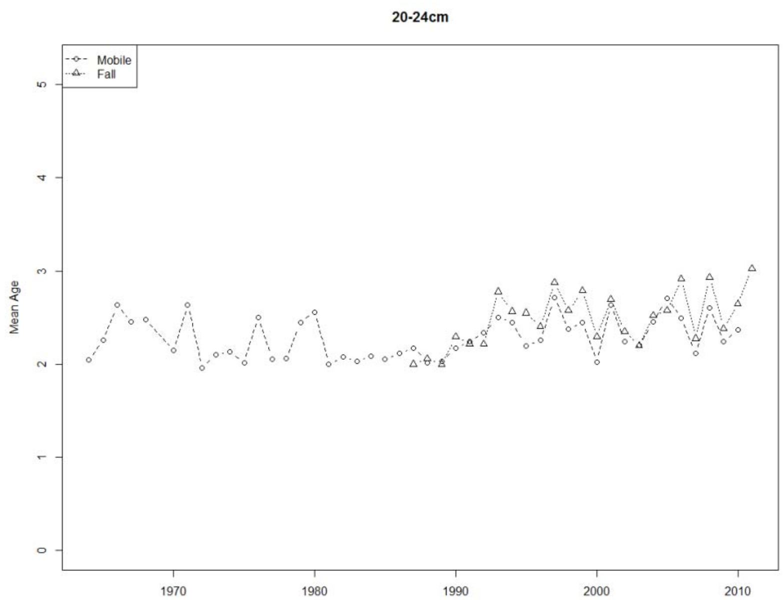


Figure 2. Mean age of herring in 5cm length bins for mobile commercial samples from semester one of each year and NMFS spring survey samples or mobile commercial samples from semester two of each year and NMFS fall survey samples during 1987-2011.






20-24cm
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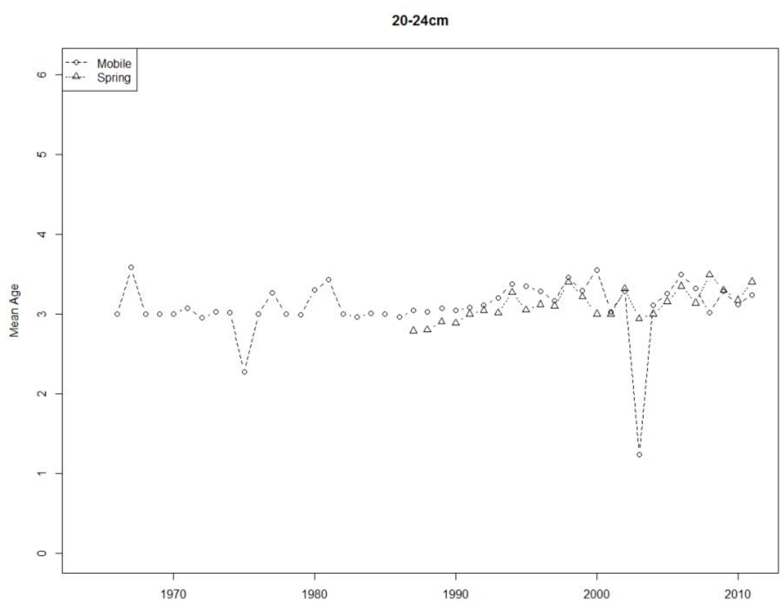
20-24cm
Mobile
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Mean Age
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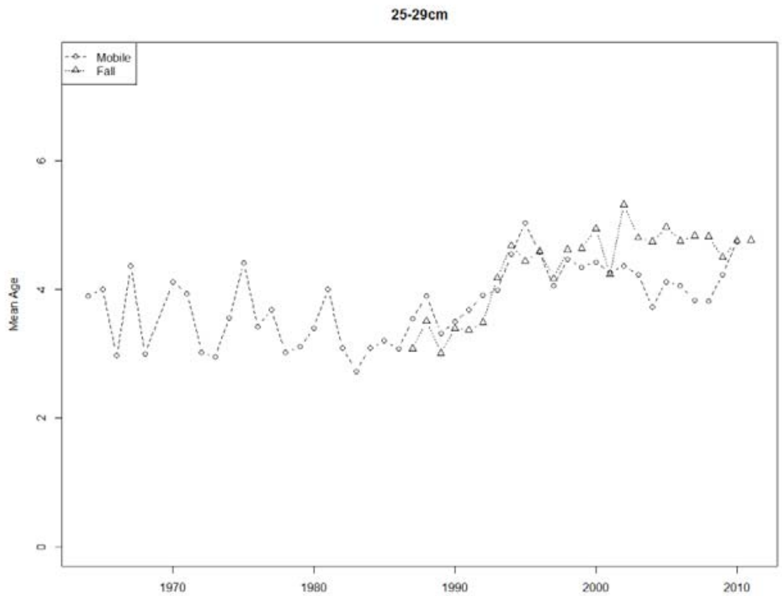
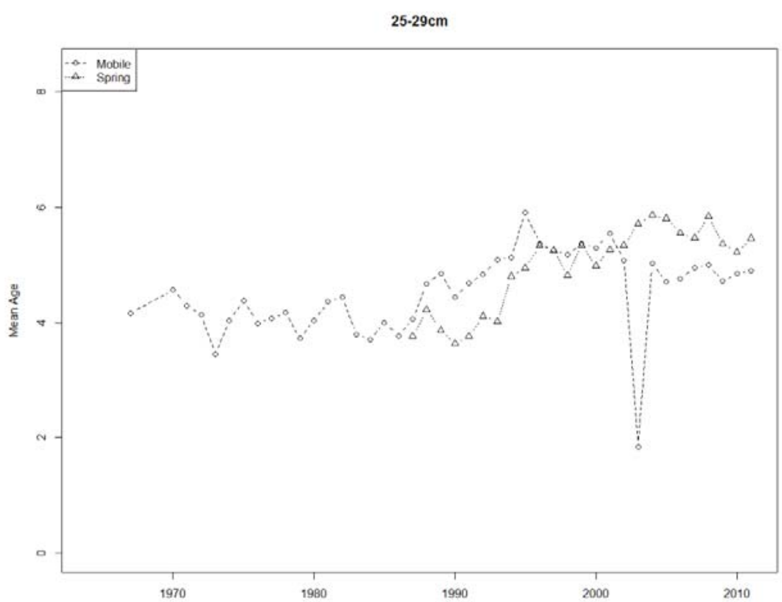
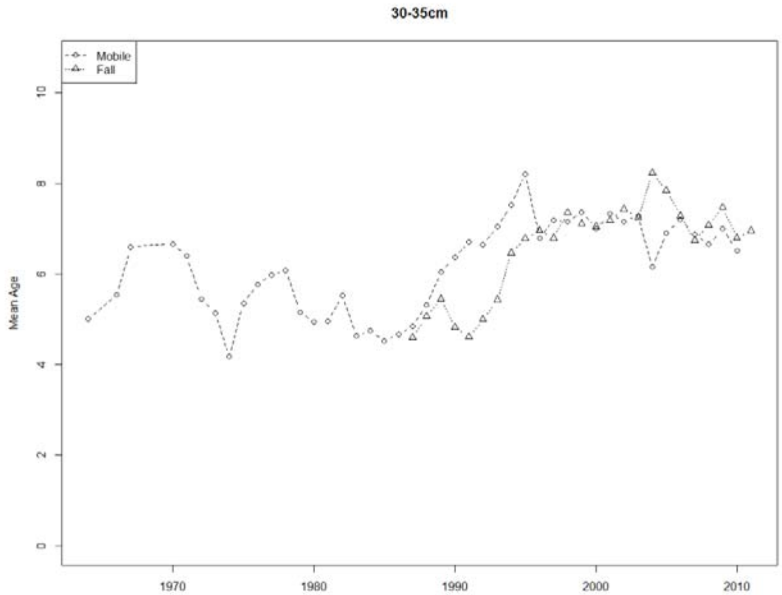
Figure 3. Mean age of herring in 5cm length bins for mobile commercial samples from semester one of each year and NMFS spring survey samples or mobile commercial samples from semester two of each year and NMFS fall survey samples during 1987-2011.






30-35cm
Mobile
Fall
Mean Age
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2000
2010

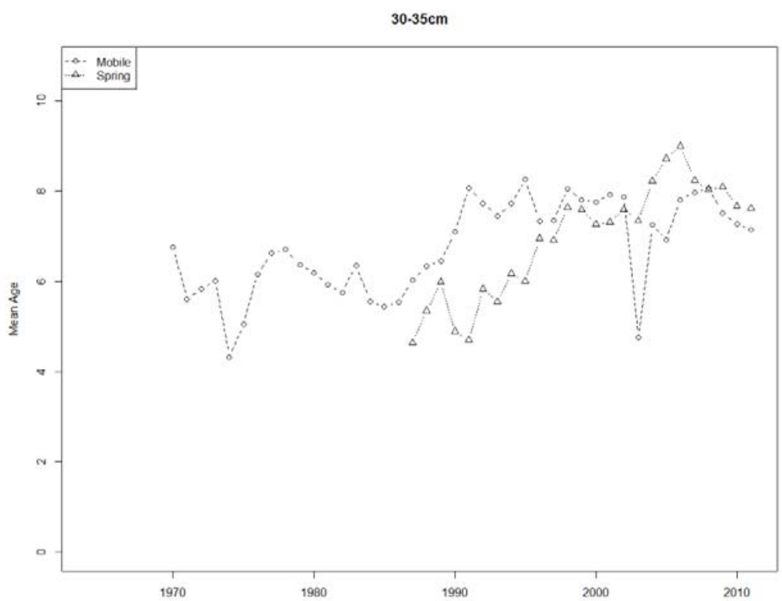

30-35cm
Mobile
Spring
Mean Age
0
2
4
6
8
10
1970
1980
1990
2000
2010

Figure 4. Mean age of herring in 1cm length bins for mobile commercial samples from semester one and NMFS spring survey samples or mobile commercial samples from semester two and NMFS fall survey samples for all years combined from 1987-2013.

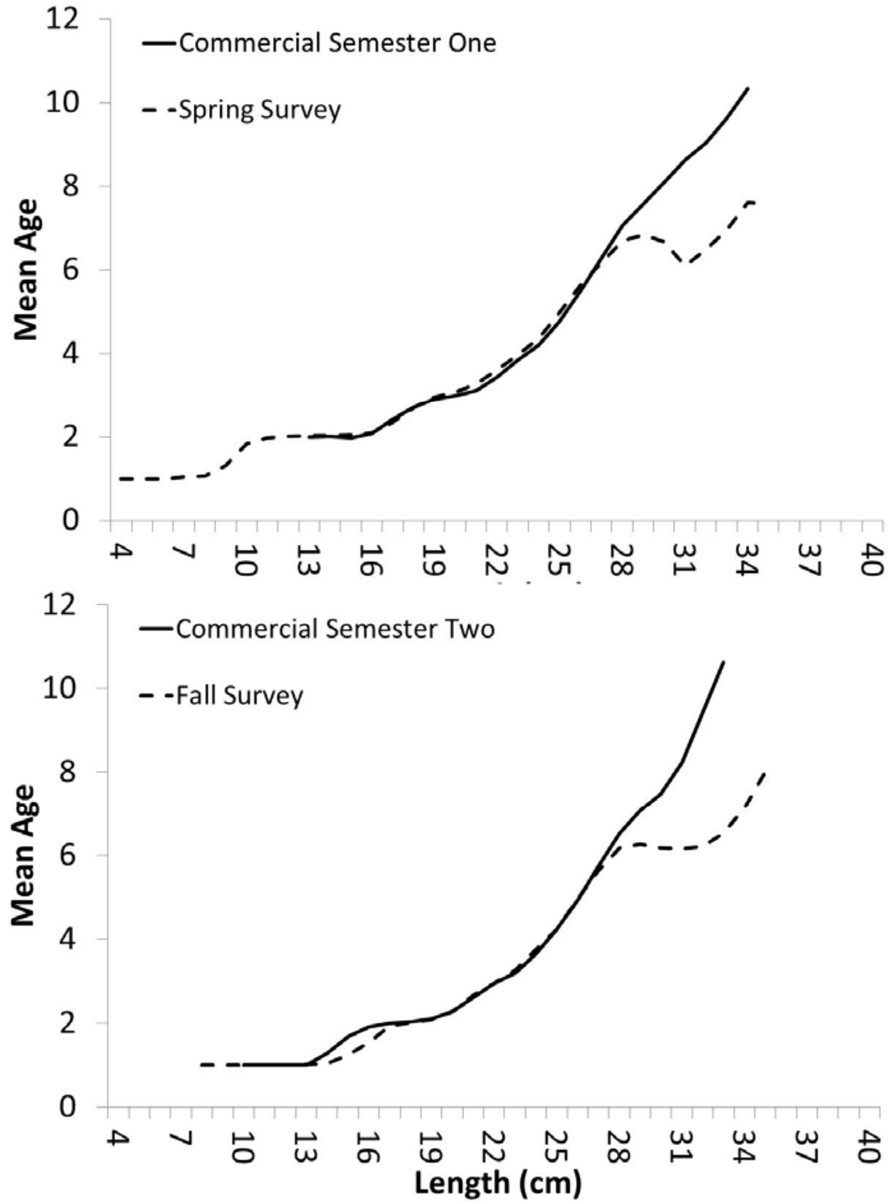


Figure 5. Herring otoliths exchanges between labs

Date	Who	%	CV	Bias
9/29/2014	Maine vs DFO	91.3	1.08	no
9/29/2014	DFO vs NEFSC	80.2	2.8	yes
9/29/2014	Maine vs NEFSC	89	1.57	no
6/1/2016	Maine vs NEFSC	85.6	2.32	yes
7/1/2016	Maine vs NEFSC	73.3	3.72	no
8/1/2017	NEFSC vs Ref	83.3	3.46	no

Appendix B2

A State-Space Stock Assessment Model (SAM) for Gulf of Maine – Georges Bank Atlantic Herring

Jonathan J. Deroba
NOAA NMFS NEFSC
Woods Hole, MA 02543

Introduction

Fish stock assessments rely on observations (e.g., survey indices, catch, age composition) to inform fishing, survival, and reproduction processes (e.g., fishing mortality, selectivity). The observations and the processes are both subject to error. Observations are collected through sampling procedures that are subject to measurement error, while some processes like selectivity and survival are not directly observed and so are subject to process errors not reflected in the observed data.

Stock assessment approaches vary in the degree to which observation and process errors are acknowledged. Virtual population analyses do not allow any observation or process errors because data are assumed perfectly known. Statistical catch-at-age (SCAA) models permit observation errors and limited process error in recruitment, but the extent of the errors are user specified and the models estimate relatively many parameters (e.g., a fishing mortality rate and recruitment for each year). State-space models can separate observation and process errors using relatively few parameters (Nielsen and Berg 2014). This efficiency is achieved by estimating the variances of the assumed distributions for the observation and process errors, and the fishing mortality and abundance states are predictions from the assumed distributions, as opposed to free parameters as in SCAA models.

The objective of this working document was to apply a SAM model to Gulf of Maine – Georges Bank Atlantic herring. I provide an overview of the model here, but details can be found in Nielsen and Berg (2014) and Berg and Nielsen (2016). Notation generally follows that of Nielsen and Berg (2014).

Methods

Observations

Catch and index observations are assumed to have lognormal errors, with separate variance parameters applied to different user selected age groups:

$$\log(C_{a,y}) = \log\left(\frac{F_{a,y}}{Z_{a,y}}(1 - e^{-Z_{a,y}})N_{a,y}\right) + e_{a,y}^{(o)} ;$$

$$e_{a,y}^{(o)} \sim N(0, \hat{\sigma}_{o,a}^2) ;$$

$$\log(I_{a,y}) = \log(\hat{q}N_{a,y}) + e_{a,y}^{(s)} ;$$

$$e_{a,y}^{(s)} \sim N(0, \hat{\sigma}_{s,a}^2) .$$

Age groups were defined to share variance parameters based on AIC and residual patterns.

Processes

SAM allows for process errors in recruitment, survival between sequential ages, and age specific fishing mortality rates. The recruitment and survival processes are assumed to follow lognormal distributions:

$$\log(R_{a=1,y}) = \log\left(f\left(SSB_{y-1}\ or\ R_{a=1,y-1}\right)\right) + \gamma_{a=1,y} ;$$

$$\gamma_{a=1,y} \sim N(0, \hat{\sigma}_R^2) ;$$

$$\log(N_{a,y}) = \log(N_{a-1,y-1}) - F_{a-1,y-1} - M_{a-1,y-1} + \gamma_{a>1,y} ;$$

$$\gamma_{a>1,y} \sim N(0, \hat{\sigma}_{a>1}^2) .$$

Recruitment in all model runs was assumed to follow a random walk. As with the observation variances, age groups were defined to share survival process variance parameters based on AIC and residual patterns.

Fishing mortality rates can be age-specific or groups of ages can be coupled to share fishing mortality rates, and these rates follow a random walk between years. The random walk fishing mortality rates can be correlated among the age couplings, for example, with a correlation of 0.0 producing independent random walks among age couplings and a correlation of 1.0 producing parallel time trajectories in fishing mortality rates among age couplings (i.e., time invariant selectivity). This results in age- and year-specific random walk increments following a multivariate normal distribution:

$$\log(F_{a,y}) = \log(F_{a,y-1}) + \delta_y \ ;$$

$$\delta_y \sim \boldsymbol{N}(0, \widehat{\boldsymbol{E}}) \ .$$

The degree of correlation in the random walks can be fixed at 0.0 (i.e., independent) or estimated, and both were attempted. Age groups were defined to share fishing mortality states and process variances based on AIC and residual patterns.

Input Data

The input data were similar to that used in the ASAP base model, but SAM can only fit to age-based indices or indices of SSB. That is, SAM cannot fit to annual, aggregate index observations with user specified selectivity. Consequently, the SAM model only fit to NMFS spring, fall, and summer (shrimp) bottom trawl surveys for the years 1987-2017. In summary, input data were:

- Catches-at-age for ages 1-8+, with age 8 as a plus group, for the years 1965-2018.
- The NMFS spring and fall bottom trawl surveys for ages 2-8+ from years that used the vessel Albatross, 1987-2008.
- The NMFS spring and fall bottom trawl surveys for ages 2-8+ from years that used the vessel Bigelow, 2009-2017.
- The NMFS summer (shrimp) bottom trawl survey for ages 2-8+ from 1987-2017.
- Natural mortality equaled 0.35 for all ages and years.
- Age- and year-specific maturity was the same as the base ASAP model, as were weights at age.

Results

More than 20 models were run in the development of the SAM model. Presenting the AIC values and diagnostic plots that led to the final model structure would be voluminous. Consequently, only the final model structure is described. Supporting figures are at the end of this document.

Observations

Two separate observation variances were estimated for fishery catches, one that applied to ages 1-6 and another applied to ages 7-8+.

The spring NMFS survey for the Albatross years had separate catchabilities for age 2, 3, 4-6, and 7-8+, and different observation variances for age 2, 3-6, and 7-8+. The fall NMFS survey for the Albatross years had separate catchabilities for age 2, 3, 4, and 5-8+, and different observation variances for age 2-6 and 7-8+. The spring NMFS survey for the Bigelow years had separate catchabilities for age 2, 3, 4, and 5-8+, and different observation variances for age 2-3, 4-8+. The fall NMFS survey for the Bigelow years had separate catchabilities for age 2, 3, 4-6, and 7-8+, and a single observation variance that applied to all ages. The summer NMFS survey had separate catchabilities for age 2, 3, 4, 5, 6, and 7-8+, and different observation variances for age 2, 3-7, and 8+.

Processes

Unique fishing mortality rates were specified for age-1, age-2, age-3, age-4, age-5, age-6, and ages 7-8+. The fishing mortality rates were assumed to follow independent random walks. A model that estimated the degree of correlation among the fishing mortality rates improved the model fit based on log-likelihood, but did not resolve any residual patterns and so this parameter was not estimated.

Separate process variances were estimated for the fishing mortality rates at age 1, 2-4, 5-6, and 7-8+. Process variance in recruitment was estimated separately from a survival process variance shared among ages 2-8+.

Summary of Final SAM Model Structure

- Two fishery catch observation variances (2 parameters).
- Eleven observation variances among all the surveys (11 parameters).
- 22 catchability parameters among all the surveys (22 parameters).
- Four fishing mortality rate process variances (4 parameters).

- Process variance for recruitment and a survival process variance for ages 2-8+ (2 parameters).
- 41 total parameters.

Overview of Final SAM Model Estimates and Results ("Run 13")

The time-varying fishing mortality rates suggested a generally flat-topped selectivity, with ages 7-8+ having the highest fishing mortality rates in most years and age 1 having the lowest selectivity in all years. The fishing mortality rates and subsequent selectivity at ages 2-6, however, were relatively variable. Age-2 had a relatively high selectivity in the 1970s due to higher catches from fixed gear sources during those years, but has since declined as mobile gears have become more dominant. Selectivity at other ages changes through time in a near parallel and cyclic manner.

Fishing mortality rates at age 1 had the largest of the process variances, followed by recruitment. Observation variances differed among ages and data sources.

The model did not exhibit a retrospective pattern. Fitting the model without each of the surveys resulted in time series that were withing the 95% confidence intervals of the base SAM model. Fits to the catch and survey observations varied by data source, with relatively few patterns visible for some inputs (e.g., spring Albatross years), but year effects evident for some surveys (e.g., summer survey). Process residuals did not have any obvious patterns.

Time series estimates of recruitment, fishing mortality rate, and biomass (abundance) were generally similar to the final ASAP run.

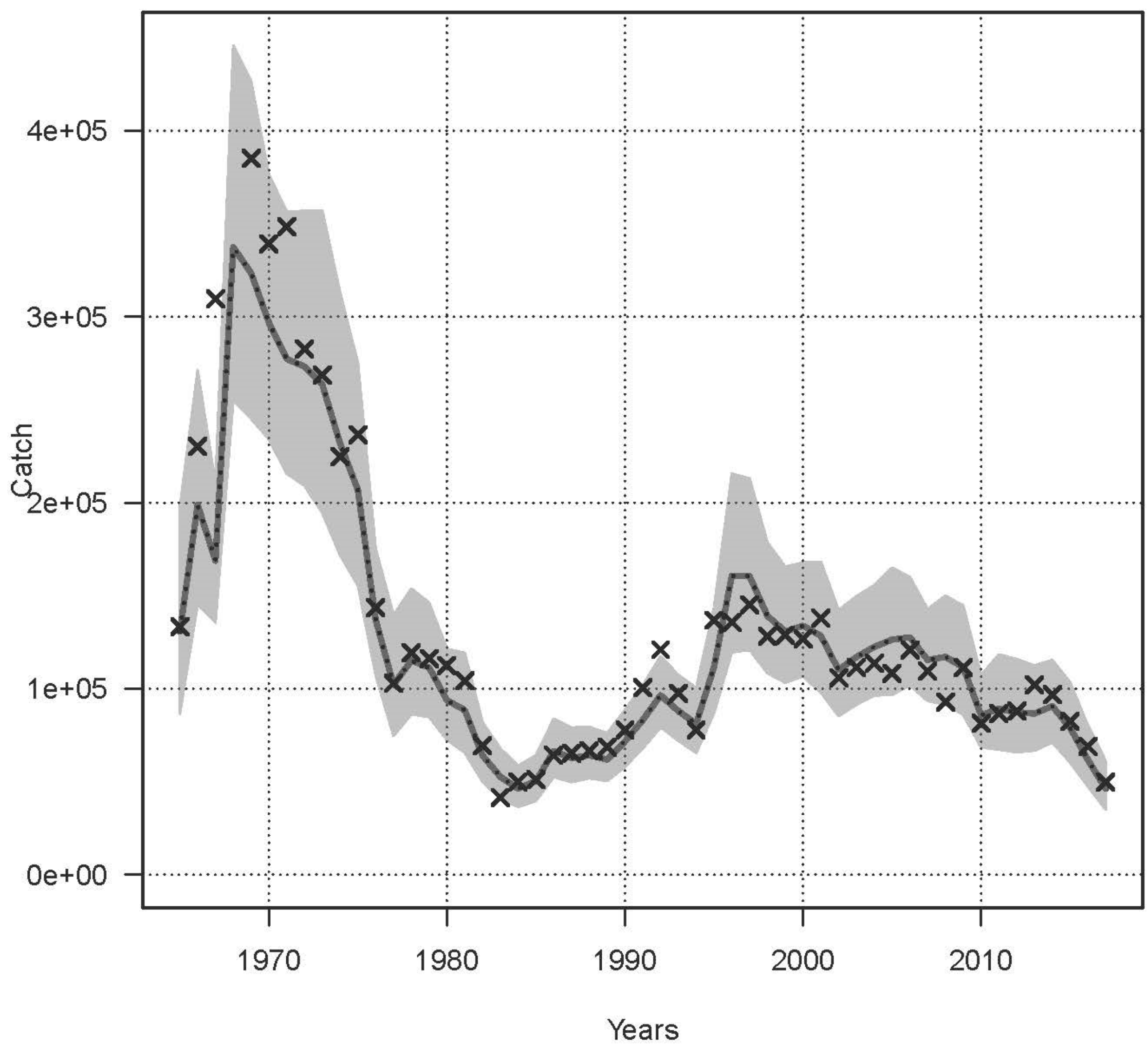
Maximum sustainable yield proxy reference points were calculated using similar methods as for the base ASAP model. More specifically, the 5-year average of life history traits from 2013-2017 (e.g., maturity, weights-at-age) were used to calculate $F_{40\%}$ as an F_{MSY} proxy. Given that selectivity varies through time in the SAM model, the selectivities at age from 2013-2017 were also averaged for purposes of reference point calculation. Consequently, the $F_{40\%}$ value is not identical to that produced by the base ASAP model, nor is the corresponding B_{MSY} proxy. The B_{MSY} proxy was determined for the

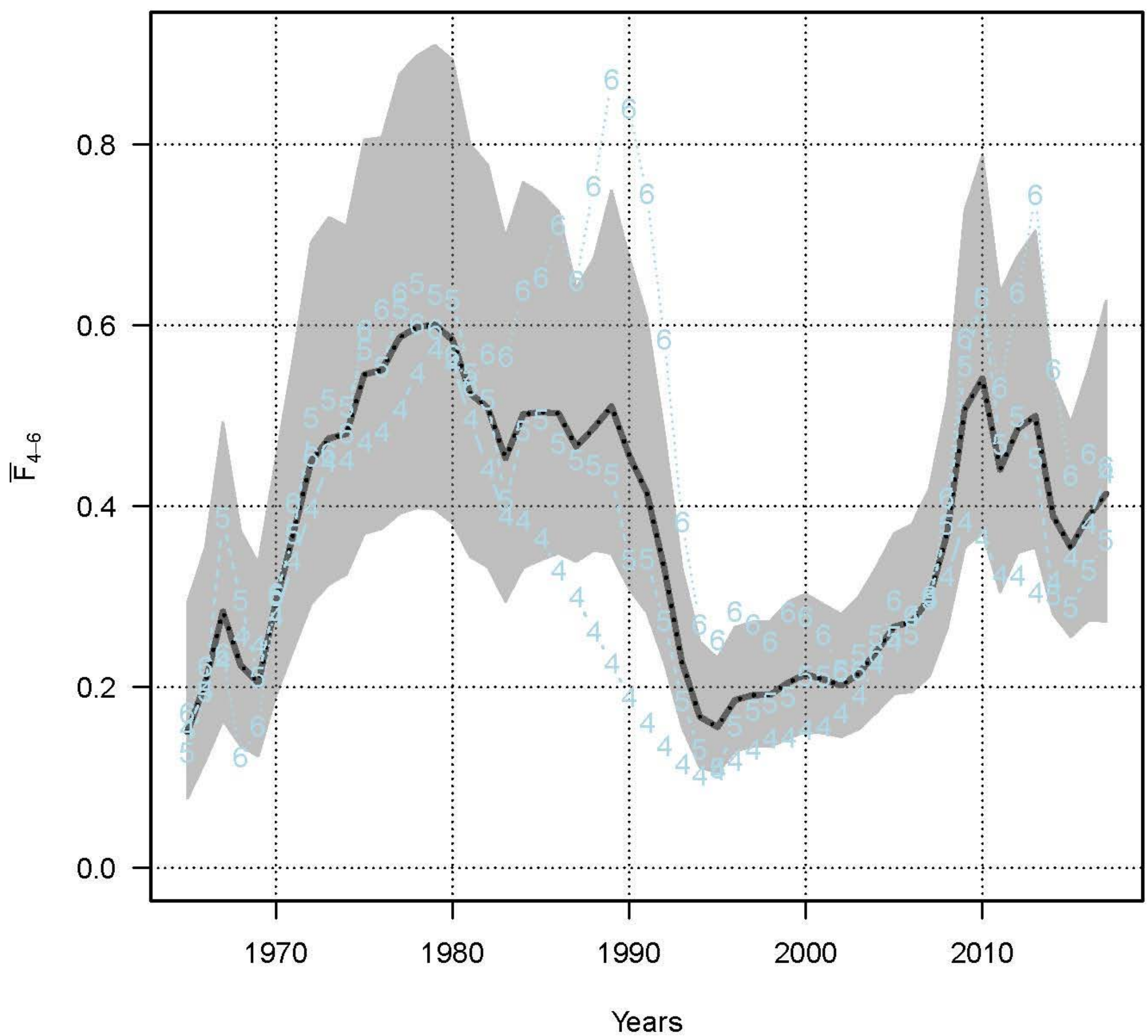
SAM model by conducting a 50 year projection at $F_{40\%}$, which was of sufficient length for the projection to reach equilibrium. Projected recruitments each year were resampled from the full time series of recruitment estimates from the SAM model. Various aspects about how process variance is carried forward in projections for the SAM model were not clear to the Working Group, and best practices for reference point calculation from a state-space model have not been developed. Consequently, the reference points and stock status from the SAM model should be used only for informational purposes and not considered for use in management. The $F_{40\%}$ MSY proxy equaled 0.39 and the corresponding B_{MSY} proxy equaled 197,000mt. Based on the SAM model, the stock is overfished and overfishing is occurring. Measures of uncertainty about stock status, however, were not readily available, but the uncertainty would likely be larger than that from the ASAP model due to the inclusion of process errors in SAM.

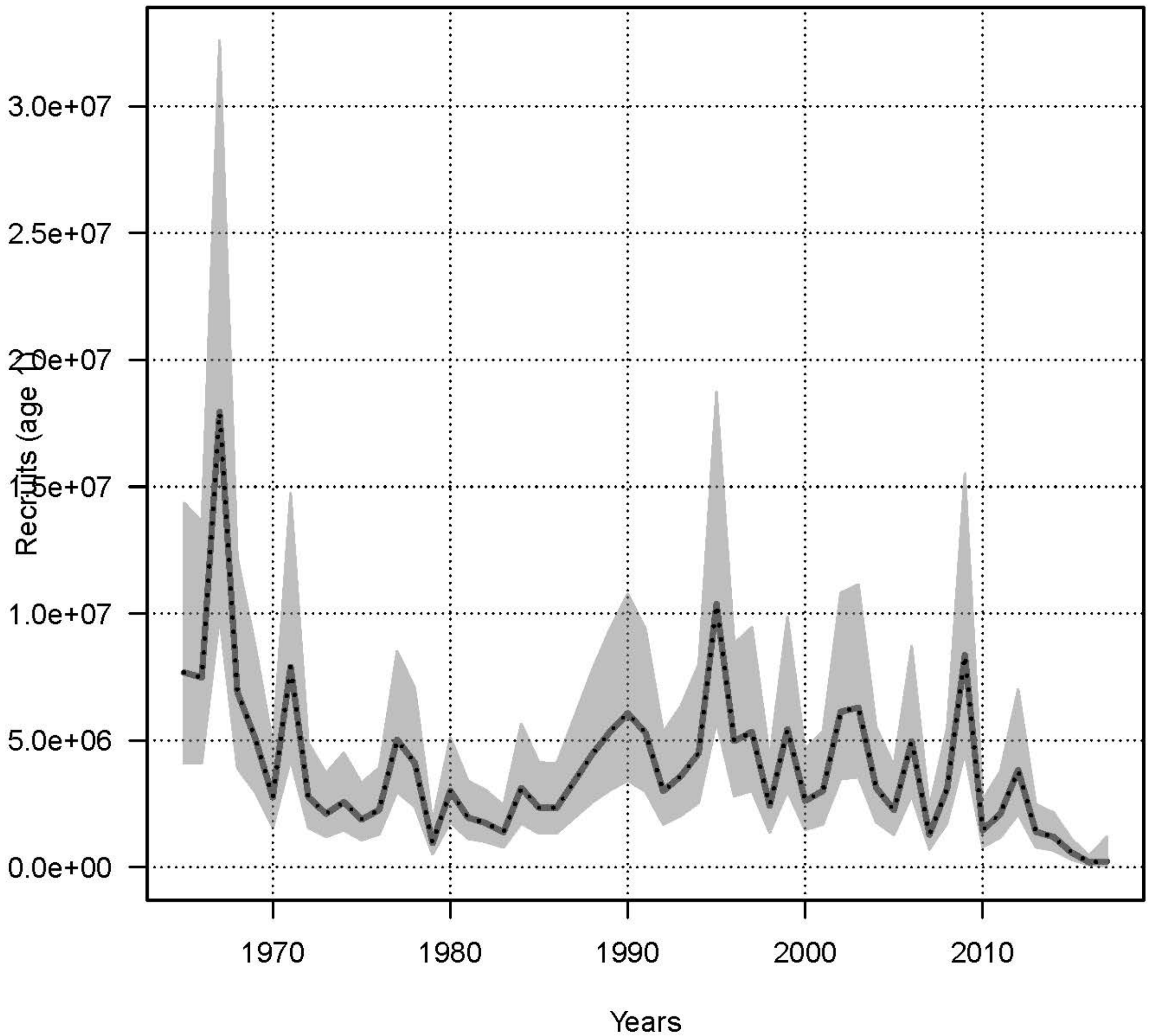
References

Berg, C.W., and Nielsen, A. 2016. Accounting for correlated observations in an age-based state-space stock assessment model. ICES Journal of Marine Science 73: 1788-1797.

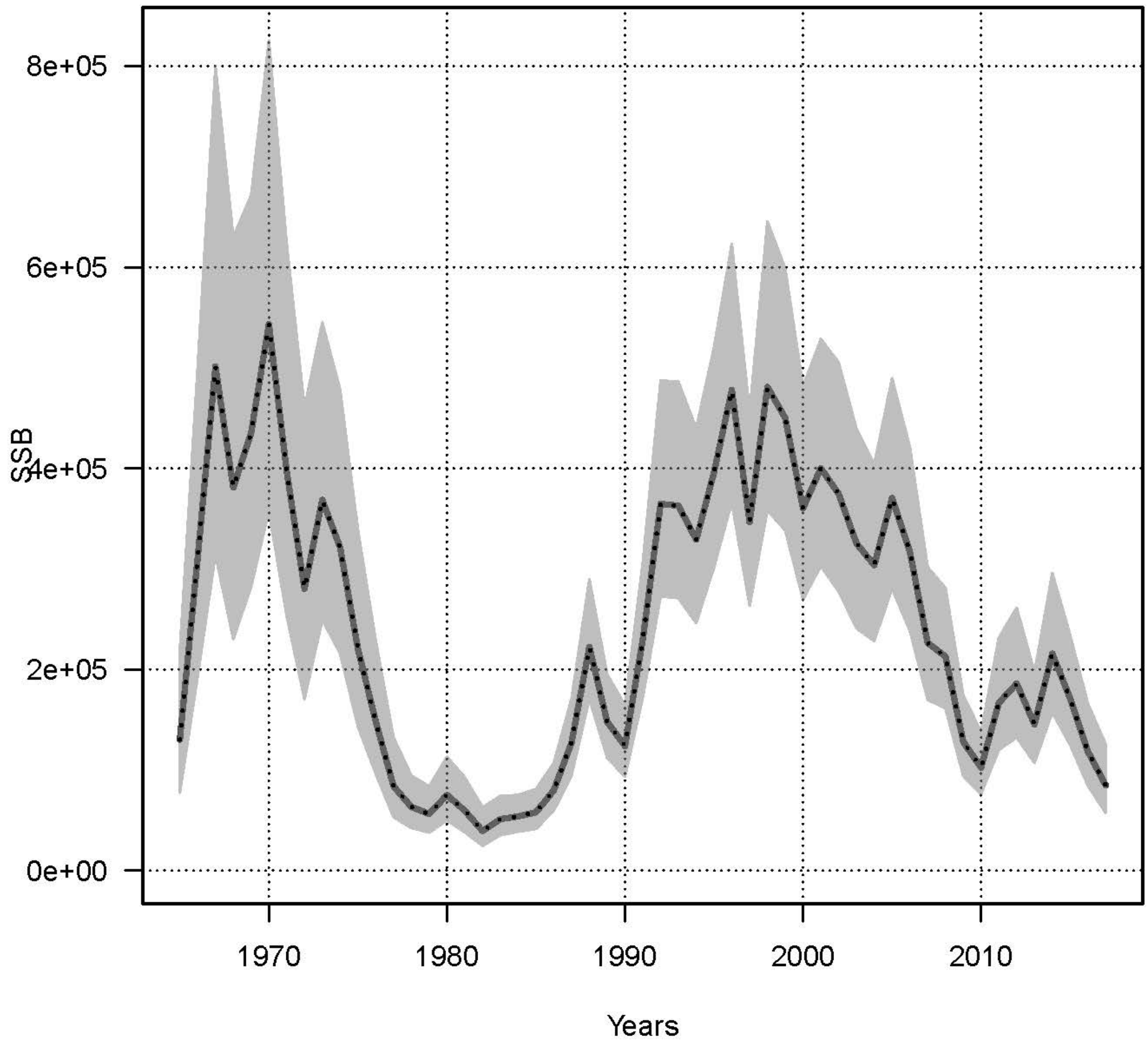
Nielsen, A., and Berg, C.W. 2014. Estimation of time-varying selectivity in stock assessments using state-space models. Fisheries Research 158: 96-101.

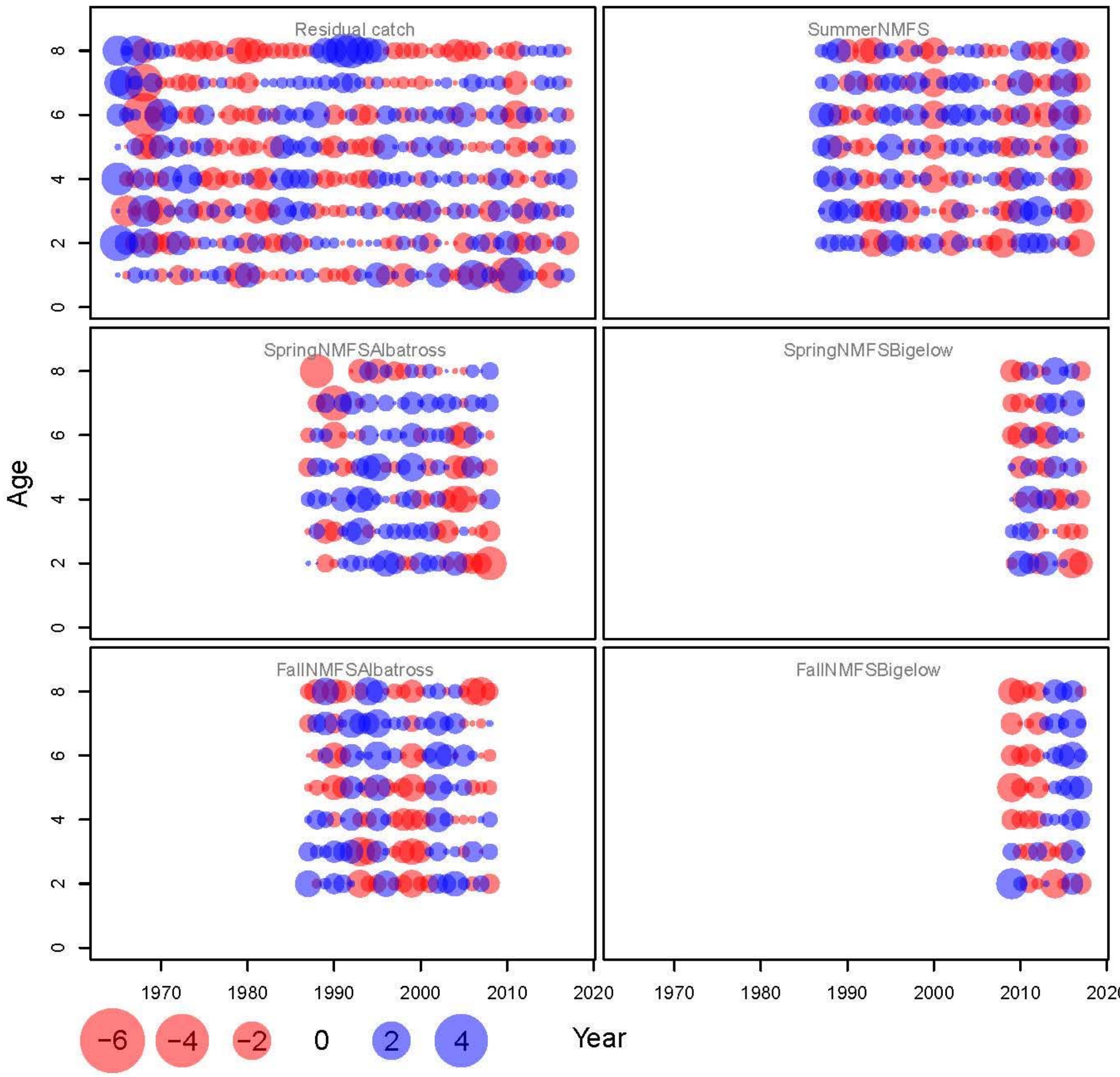

4e+05
3e+05
2e+05
1e+05
0e+00
Catch
1970
1980
1990
2000
2010
Years

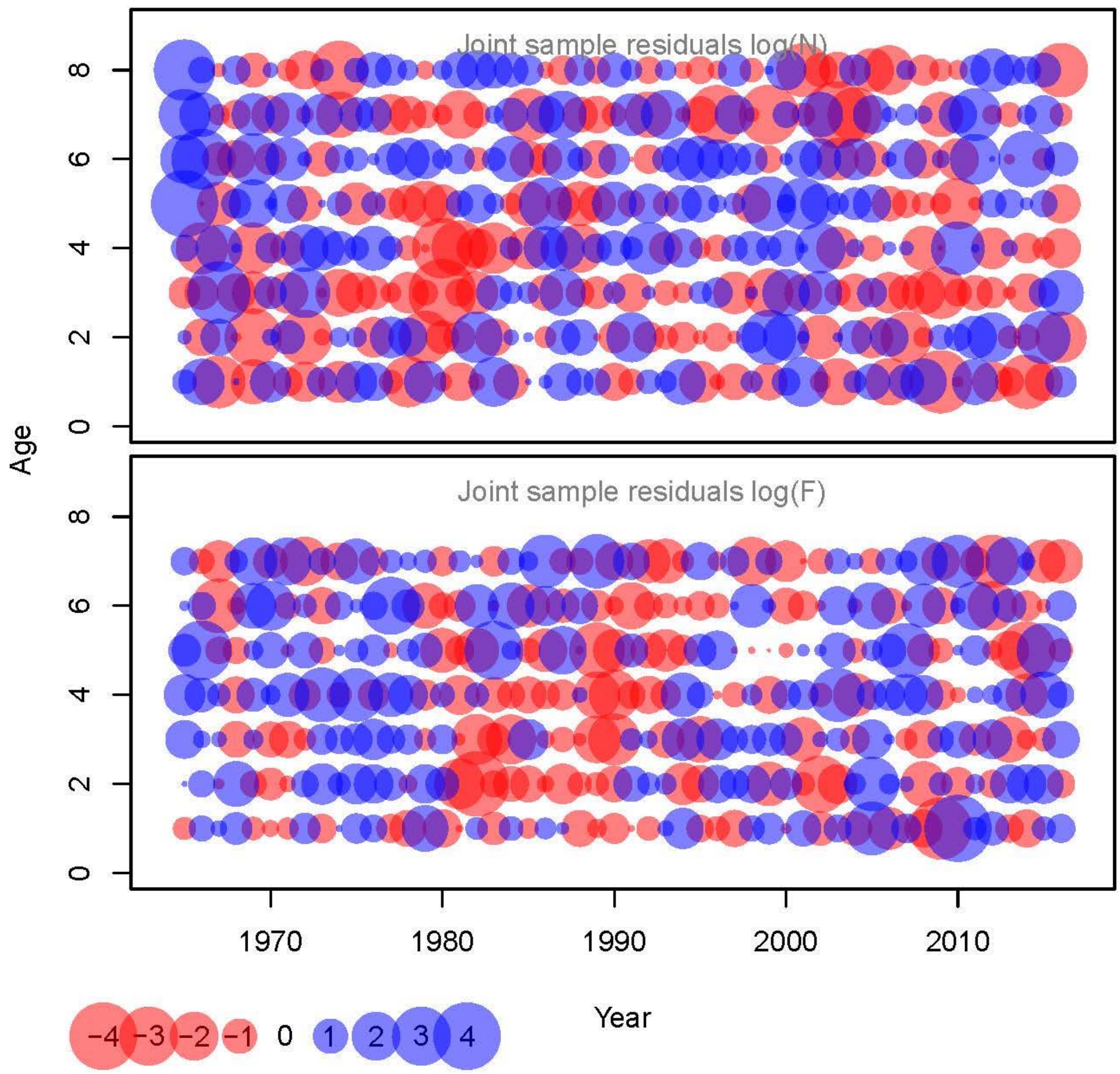

0.8
0.6
0.4
0.2
0.0
$\overline{F}_{4-6}$
1970
1980
1990
2000
2010
Years

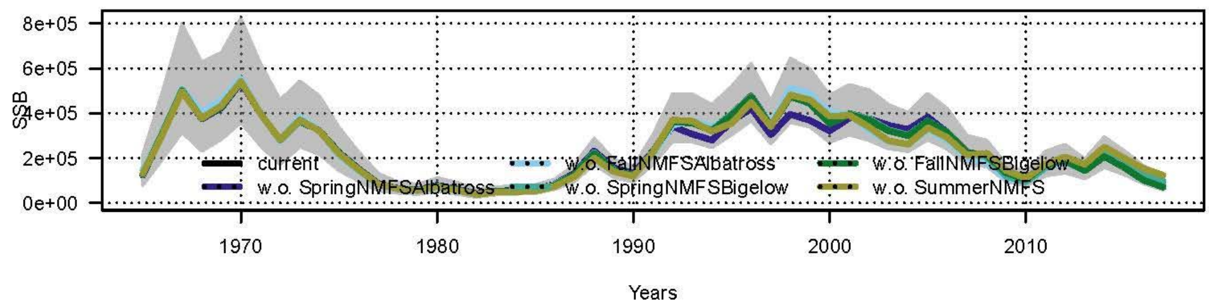


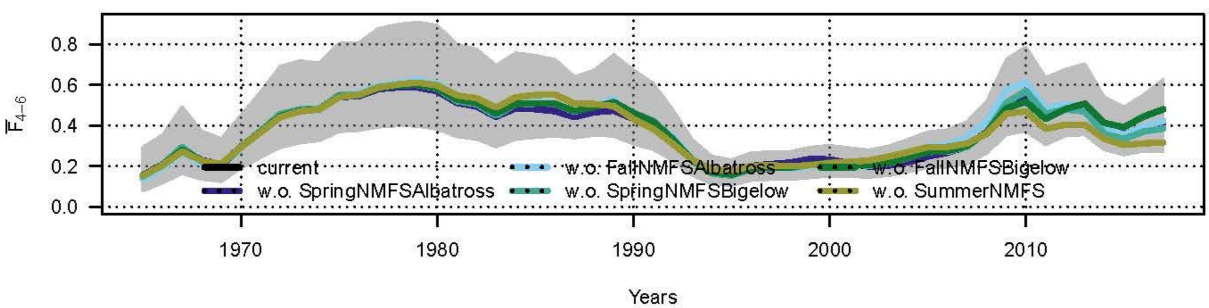
3.0e+07
2.5e+07
2.0e+07
1.5e+07
1.0e+07
5.0e+06
0.0e+00
Recruits (age 1)
1970
1980
1990
2000
2010
Years

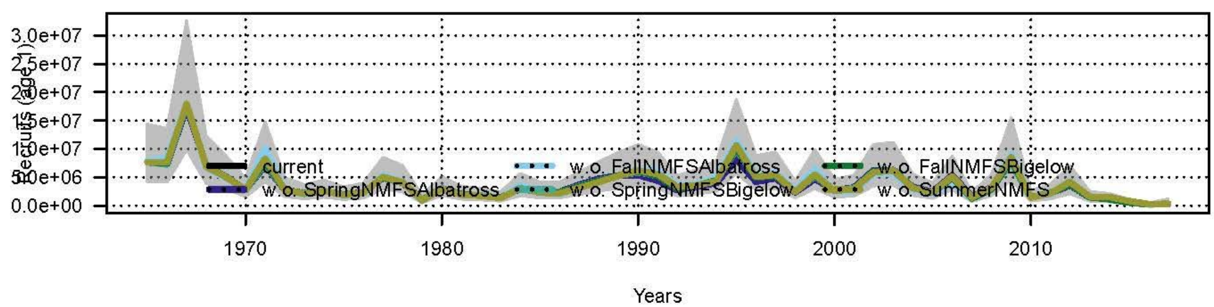

SSB
8e+05
6e+05
4e+05
2e+05
0e+00
1970
1980
1990
2000
2010
Years

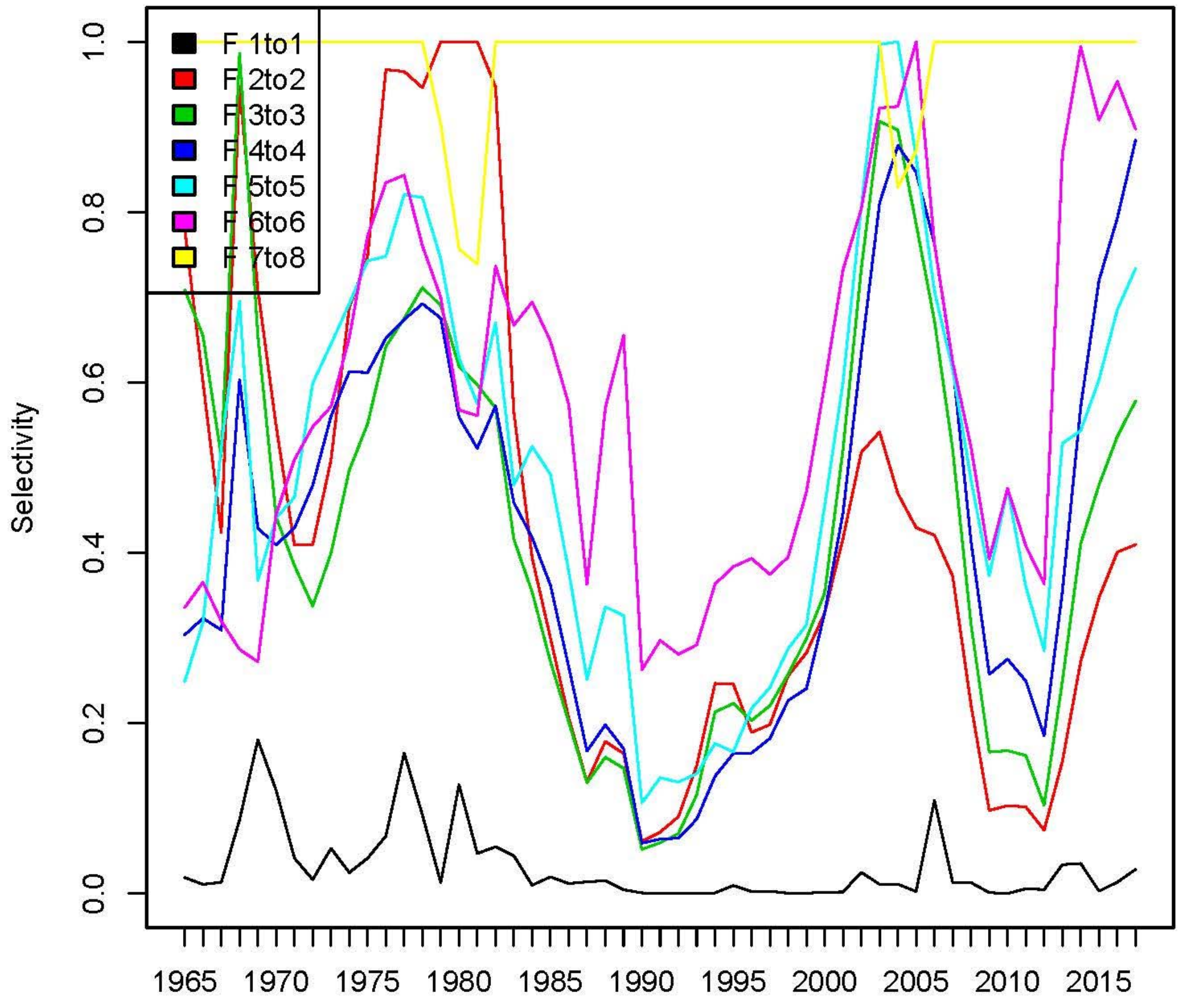

Residual catch
SummerNMFS
SpringNMFSAlbatross
SpringNMFSBigelow
FallNMFSAlbatross
FallNMFSBigelow
Age
0
2
4
6
8
1970
1980
1990
2000
2010
2020
Year
−6
−4
−2
0
2
4

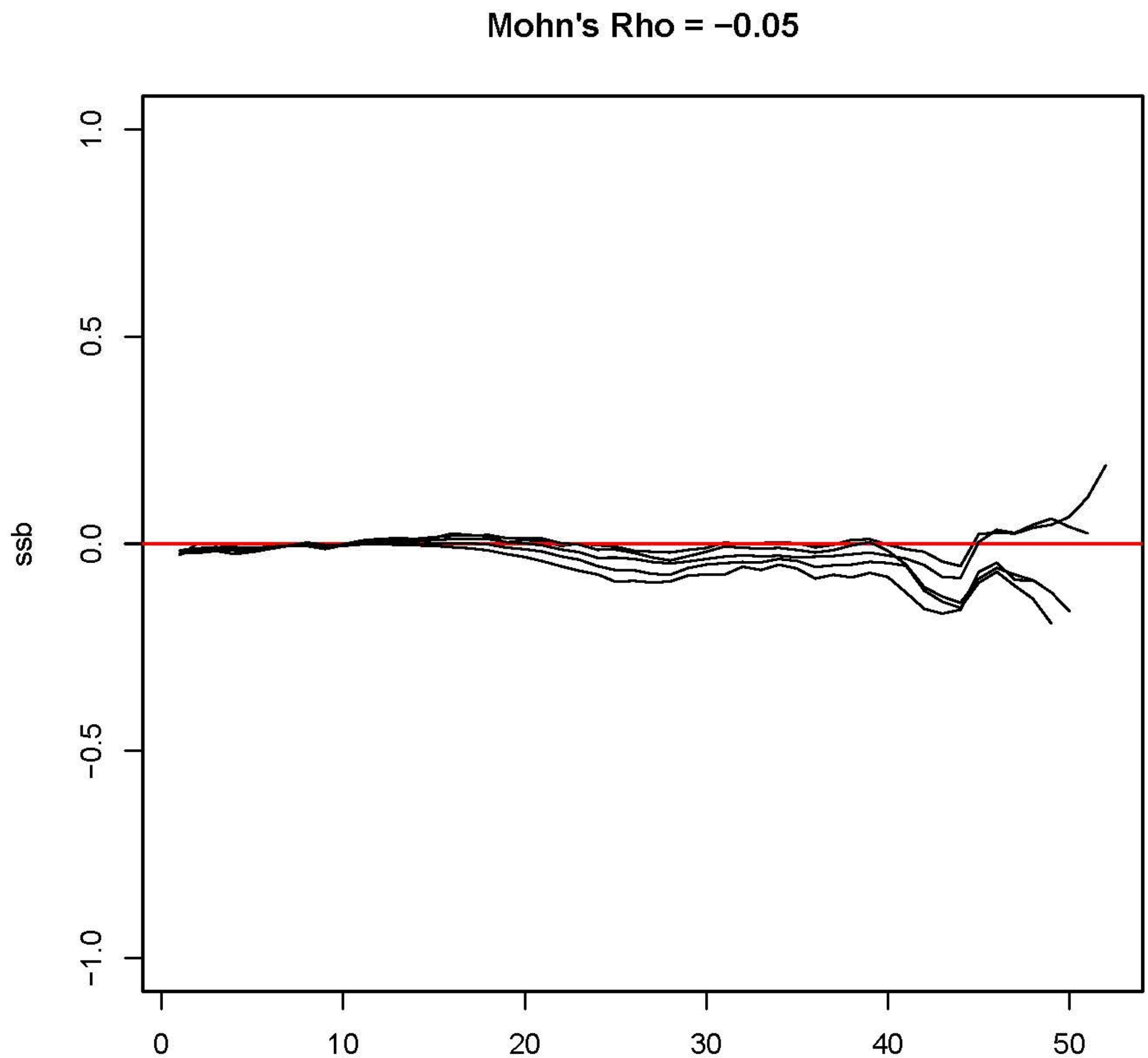

Joint sample residuals log(N)
Joint sample residuals log(F)
Age
Year
0
2
4
6
8
1970
1980
1990
2000
2010
-4
-3
-2
-1
0
1
2
3
4

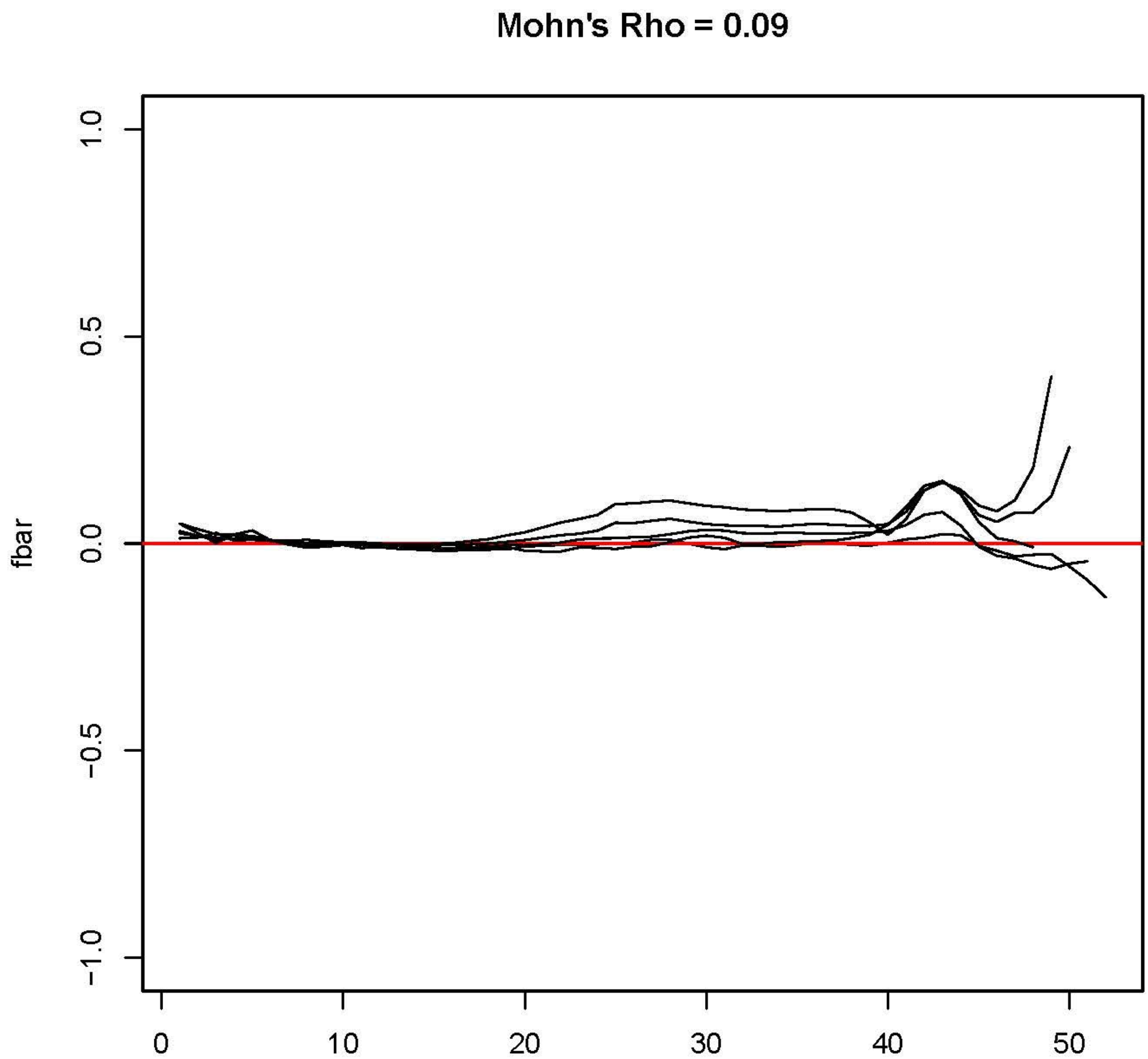

SSB
8e+05
6e+05
4e+05
2e+05
0e+00
current
w.o. SpringNMFSAlbatross
w.o. FallNMFSAlbatross
w.o. SpringNMFSBigelow
w.o. FallNMFSBigelow
w.o. SummerNMFS
1970
1980
1990
2000
2010
Years

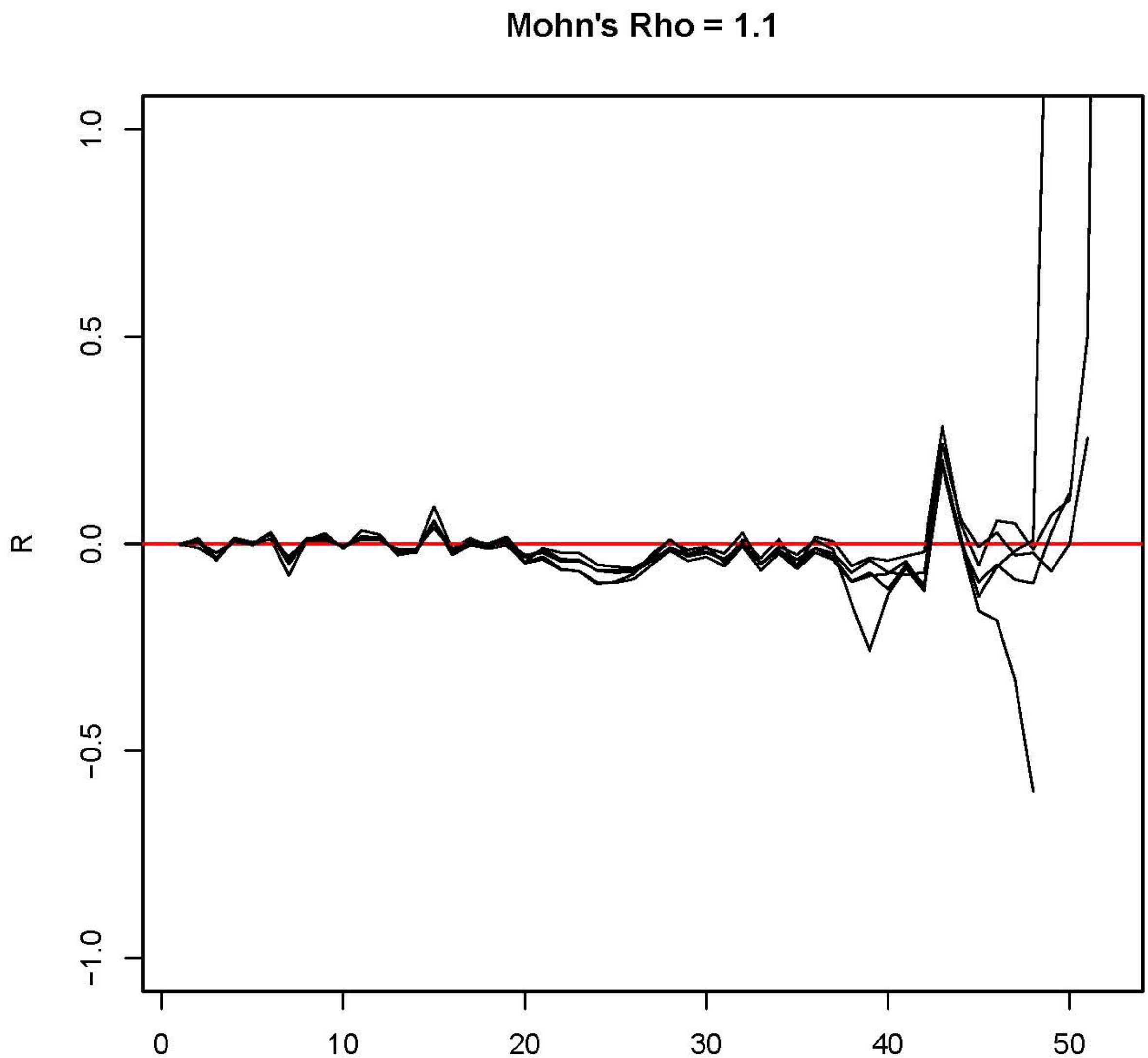

$\overline{F}_{4-6}$
0.8
0.6
0.4
0.2
0.0
current
w.o. SpringNMFSAlbatross
w.o. FallNMFSAlbatross
w.o. SpringNMFSBigelow
w.o. FallNMFSBigelow
w.o. SummerNMFS
1970
1980
1990
2000
2010
Years

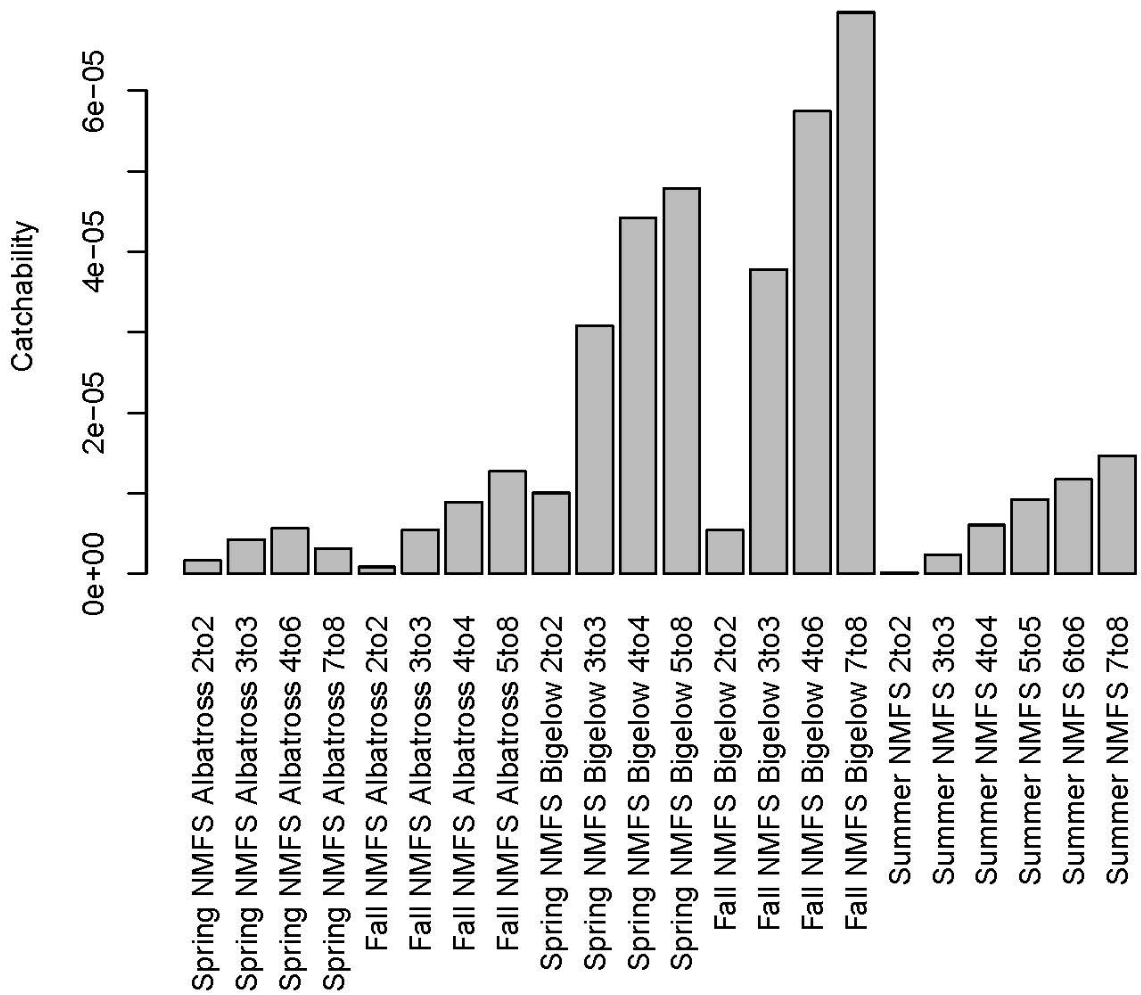

Recruits (age 1)
3.0e+07
2.5e+07
2.0e+07
1.5e+07
1.0e+07
5.0e+06
0.0e+00
current
w.o. SpringNMFSAlbatross
w.o. FallNMFSAlbatross
w.o. SpringNMFSBigelow
w.o. FallNMFSBigelow
w.o. SummerNMFS
1970
1980
1990
2000
2010
Years


F 1to1
F 2to2
F 3to3
F 4to4
F 5to5
F 6to6
F 7to8
Selectivity
0.0
0.2
0.4
0.6
0.8
1.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

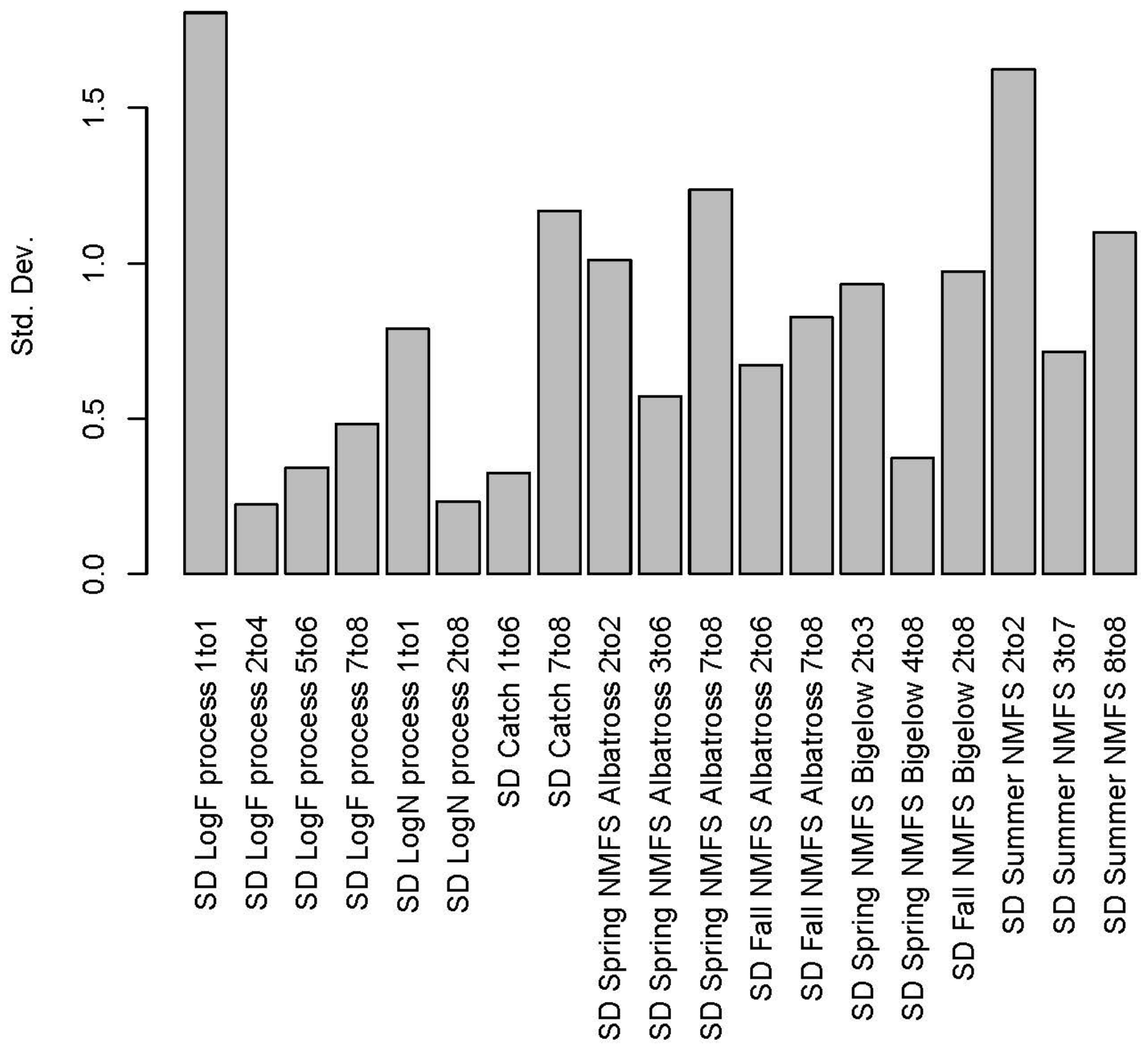

Mohn's Rho = −0.05
ssb
1.0
0.5
0.0
−0.5
−1.0
0
10
20
30
40
50

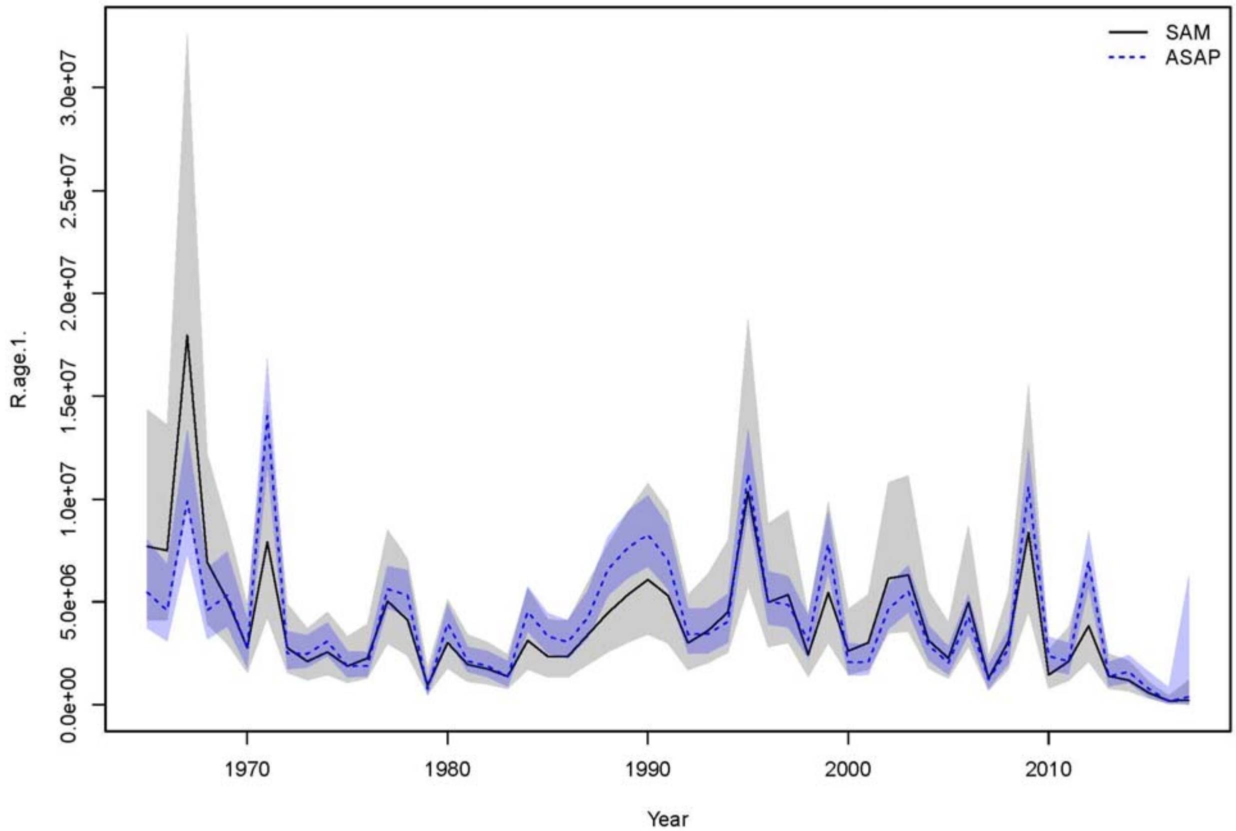

Mohn's Rho = 0.09
fbar
1.0
0.5
0.0
−0.5
−1.0
0
10
20
30
40
50

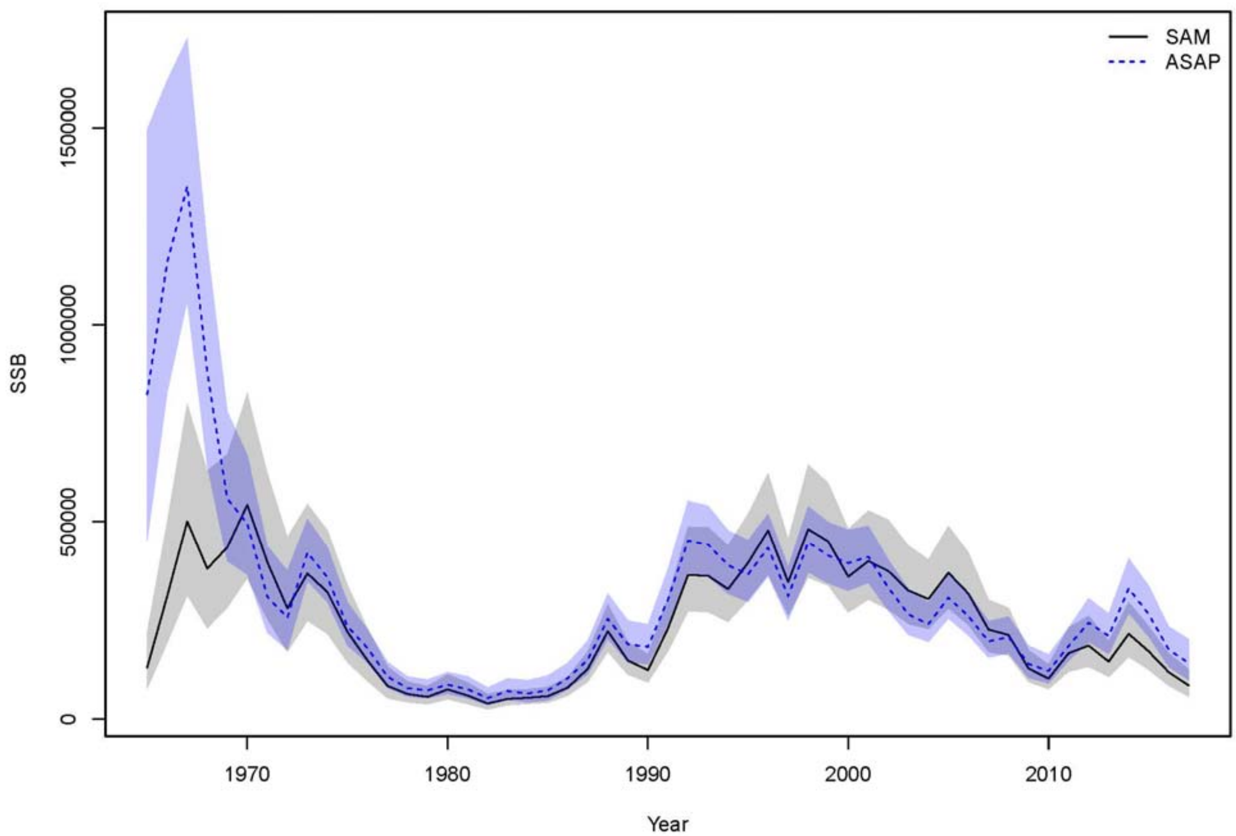

Mohn's Rho = 1.1
R
1.0
0.5
0.0
−0.5
−1.0
0
10
20
30
40
50

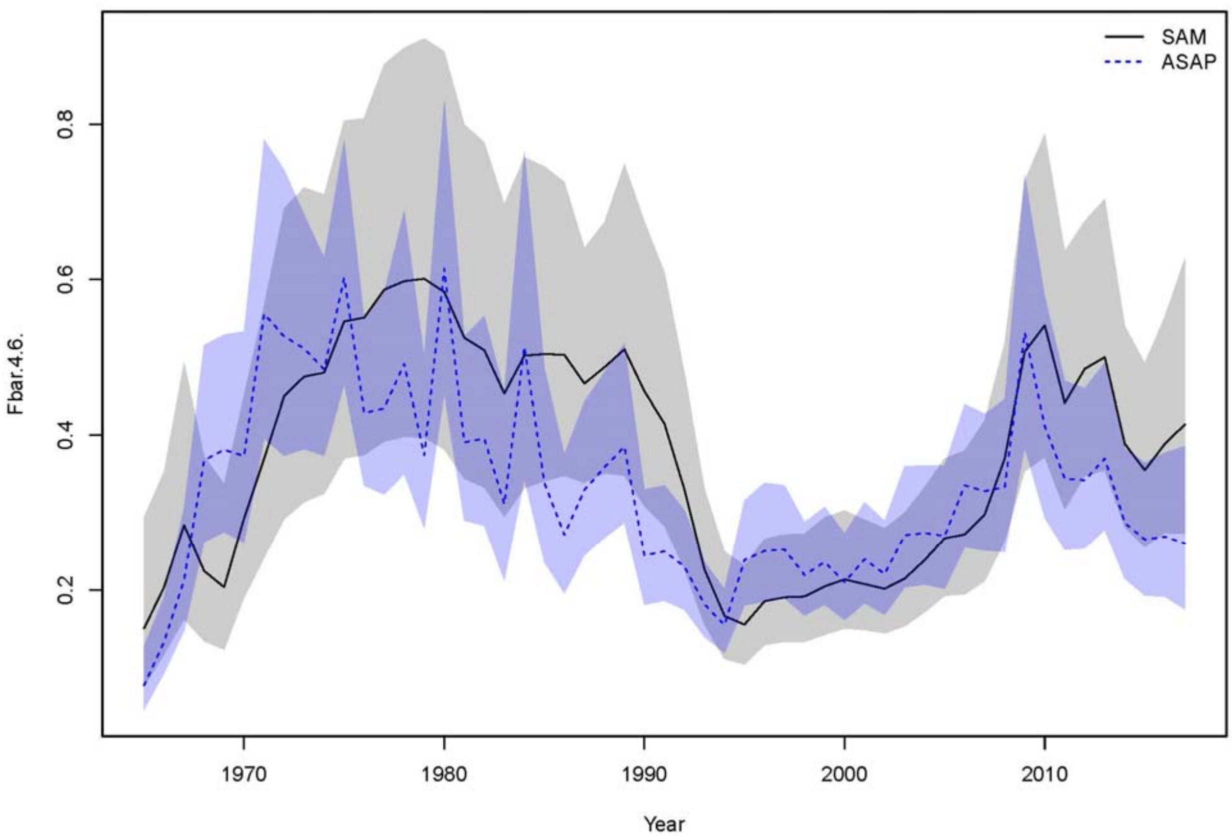


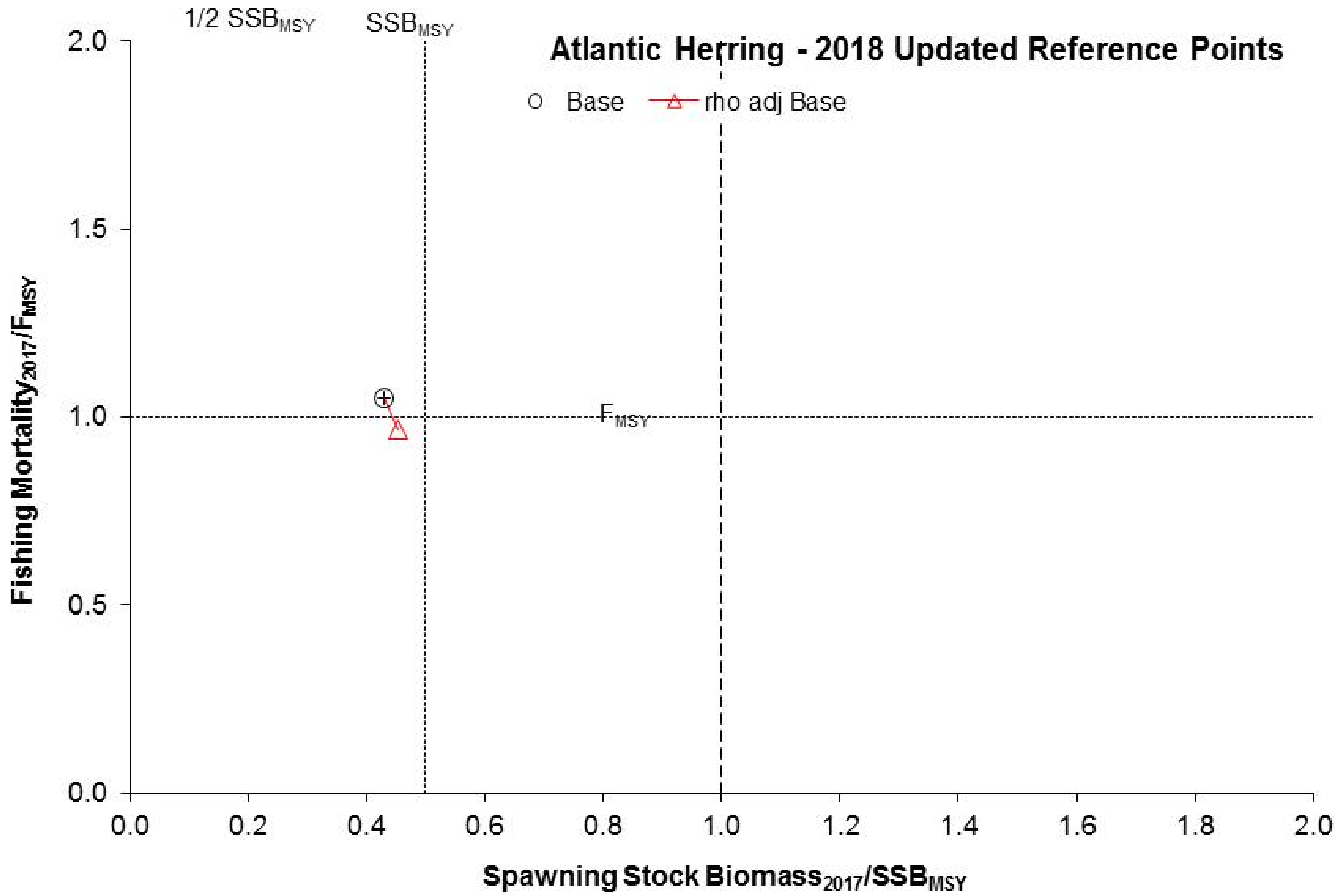
Catchability
0e+00
2e-05
4e-05
6e-05
Spring NMFS Albatross 2to2
Spring NMFS Albatross 3to3
Spring NMFS Albatross 4to6
Spring NMFS Albatross 7to8
Fall NMFS Albatross 2to2
Fall NMFS Albatross 3to3
Fall NMFS Albatross 4to4
Fall NMFS Albatross 5to8
Spring NMFS Bigelow 2to2
Spring NMFS Bigelow 3to3
Spring NMFS Bigelow 4to4
Spring NMFS Bigelow 5to8
Fall NMFS Bigelow 2to2
Fall NMFS Bigelow 3to3
Fall NMFS Bigelow 4to6
Fall NMFS Bigelow 7to8
Summer NMFS 2to2
Summer NMFS 3to3
Summer NMFS 4to4
Summer NMFS 5to5
Summer NMFS 6to6
Summer NMFS 7to8


Std. Dev.
0.0
0.5
1.0
1.5
SD LogF process 1to1
SD LogF process 2to4
SD LogF process 5to6
SD LogF process 7to8
SD LogN process 1to1
SD LogN process 2to8
SD Catch 1to6
SD Catch 7to8
SD Spring NMFS Albatross 2to2
SD Spring NMFS Albatross 3to6
SD Spring NMFS Albatross 7to8
SD Fall NMFS Albatross 2to6
SD Fall NMFS Albatross 7to8
SD Spring NMFS Bigelow 2to3
SD Spring NMFS Bigelow 4to8
SD Fall NMFS Bigelow 2to8
SD Summer NMFS 2to2
SD Summer NMFS 3to7
SD Summer NMFS 8to8


SAM
ASAP
R.age.1.
0.0e+00
5.0e+06
1.0e+07
1.5e+07
2.0e+07
2.5e+07
3.0e+07
1970
1980
1990
2000
2010
Year


SAM
ASAP
SSB
0
500000
1000000
1500000
1970
1980
1990
2000
2010
Year


SAM
ASAP
Fbar.4.6.
0.2
0.4
0.6
0.8
1970
1980
1990
2000
2010
Year



Atlantic Herring - 2018 Updated Reference Points
Base
rho adj Base
1/2 SSB_MSY
SSB_MSY
F_MSY
Fishing Mortality2017/FMSY
Spawning Stock Biomass2017/SSBMSY
0.0
0.5
1.0
1.5
2.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0

Appendix B3

Consideration of a model ensemble – model averaging ASAP and SAM (in prep)

Appendix B4

Two area Stock Synthesis application (In prep).

Appendix B5

Working Paper: Predation Pressure Index to Inform Natural Mortality
Jonathan J. Deroba

Objective

Develop an index of predation pressure (Richards and Jacobson2016) to inform time-varying natural mortality (M) in Atlantic herring.

Methods

Food habits and data to estimate indices of herring predator biomass were collected on NMFS Northeast Fisheries Science Center spring and fall bottom trawl surveys. Details about the methods for sampling food habits data, including the stomach contents data used here, can be found in Link and Almeida (2000) and Smith and Link (2010). Details about bottom trawl survey design and sampling can be found in Grosslein (1969), Azarovitz (1981), and Miller et al. (2010).

A predation pressure index (PPI) was estimated for predators that had at least 10 stomachs containing herring and positive occurrences of herring in at least 0.1% of stomachs, combined among all years and seasons. These criteria were met by 15 predators (Table 1), and the list is similar to that used to estimate annual consumption in recent herring assessments (NEFSC 2012).

A percent frequency of occurrence of herring in predator stomachs was estimated as the percentage of stomachs containing herring (P), combined among years and seasons:

$$P_p = \frac{\sum_y S_{y,p}}{\sum_y T_{y,p}} \times 100;$$

where p is predator, y is year, S is the number of stomachs containing herring (i.e., positive occurrences), and T is the total number of stomachs examined.

Annual indices of predator biomass (B; stratified mean kg per tow) were estimated for the spring and fall bottom trawl surveys for each of the predators (except striped bass and sea raven, see below). Indices for each predator were estimated as in their respective stock assessments (index values were downloaded from the PopDy Branch "ADIOS" system on June 8, 2017). For predators that have indices estimated separately by region or sex (Table 1), values were summed to obtain season specific (spring and fall) annual indices. Sea raven were excluded from the analysis because this species has no stock assessment and indices were unavailable, but they likely account for a relatively small amount of herring predation (NEFSC 2012), and so results and conclusions are likely robust to this omission. Time series of indices of biomass and percent frequency of occurrence began in 1968 in the spring and 1963 in the fall.

The striped bass stock assessment does not use the spring and fall bottom trawl survey data for indices of biomass because the gear does not provide a suitable index. In order to accommodate striped bass in the calculation of PPI, estimates of total striped bass biomass from the stock assessment were rescaled to equal the average of all the other predator biomass indices among seasons and years, and this annual quantity was used for both seasons in the calculation of PPI:

$$B_{y,bass} = \frac{E_y}{\bar{B}};$$

where $B_{y,bass}$ is the value treated as the year specific index of biomass for striped bass in both seasons, $E$is the estimate of total striped bass biomass from the stock assessment, and $\bar{B}$ is the mean index of predator biomass among all other predators, years, and seasons. This rescaling of the striped bass total biomass estimates was done so that the scale of the index values used for striped bass in the calculation of PPI were similar to other predators. The PPI was calculated with and without striped bass included, and results were presented separately. The striped bass stock assessment begins in 1982, and so PPI calculations that included striped bass also began in 1982.

Season and year specific PPI was calculated as the weighted average of the predator indices of biomass (B):

$$PPI_{y,s} = \sum_p B_{y,s,p} \times P_p;$$

where s denotes season (spring or fall).

Time-varying M was calculated by adjusting a base M by annual deviations in PPI from the mean PPI:

$$M_{y,s} = \frac{M_b \times PPI_{y,s}}{\overline{PPI_s}};$$

where M_b was a baseline level of natural mortality, which equaled 0.35 for demonstration purposes, but was derived from Hoenig (1983) and has been used in previous herring stock assessments (NEFSC 2012).

Results

Temporal trends in PPI were similar between seasons, with and without striped bass. Without striped bass, PPI declined from the beginning of each time series, varied without trend below the time series means after ~1990, and increased since ~2010 to near the time series means in the most recent year (Figure 1). With striped bass, PPI has generally varied without trend near the time series means (Figure 1). Results for M were similar to PPI. Without striped bass, M declined from the beginning of each time series, varied without trend below the below the baseline rate after ~1990, and increased since ~2010 to near the baseline level (Figure 2). With striped bass, M generally varied without trend near the baseline level (Figure 2).

Discussion

The 2012 herring stock assessment increased M from 0.35 (averaged among ages) to 0.50 beginning in 1996 (NEFSC 2012). This increase in M eliminated a retrospective pattern and produced generally consistent amounts of consumption between that implied by the input M and that estimated from stomach contents data. These two justifications for increased M no longer held in the 2015 updated herring stock assessment, with a worsened retrospective pattern and consumption of herring implied by the input M being higher than that estimated from stomach contents data (Deroba 2015). The trends in PPI, and subsequent deviations from M_b, were also inconsistent with the increased M rates used in the 2012 and 2015 herring stock assessments.

The PPI and consumption estimates both use some of the same stomach contents data, but suggest different conclusions about variation in M. This inconsistency could be related to caveats in the calculation of PPI, consumption, the herring stock assessment, or a combination. The estimates of consumption, for example, have been criticized as likely to be biased in scale and trend due to reliance on estimates of predatory biomass from stock assessments and other sources with different underlying structural assumptions and uncertainties (Brooks and Deroba 2015). The strength of evidence for an increase in M provided by the estimates of consumption also depends on aspects of the herring assessment itself. Assumptions and input data to the herring assessment determine the scale and trend of the resulting assessment estimates, and estimates of consumption from the stomach contents data are compared to consumption implied by the input M and this requires use of herring assessment estimates. The assumptions and input data for the herring assessment, however, are also subject to uncertainties.

The PPI and consumption calculations also ignore spatial and seasonal variation (other than spring and fall) in the overlap and efficiency of predators and Atlantic herring. The probability of a predator stomach containing herring and the amount of herring in a stomach vary seasonally and spatially (Deroba 2018). Ignoring such variation may cause bias and a false sense of precision in the PPI and consumption estimates.

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Figure 1.—Predation pressure index (PPI) for Atlantic herring calculated in the spring and fall, without (top panel) and with (bottom panel) striped bass. Red horizontal lines are time series means in the spring and fall.

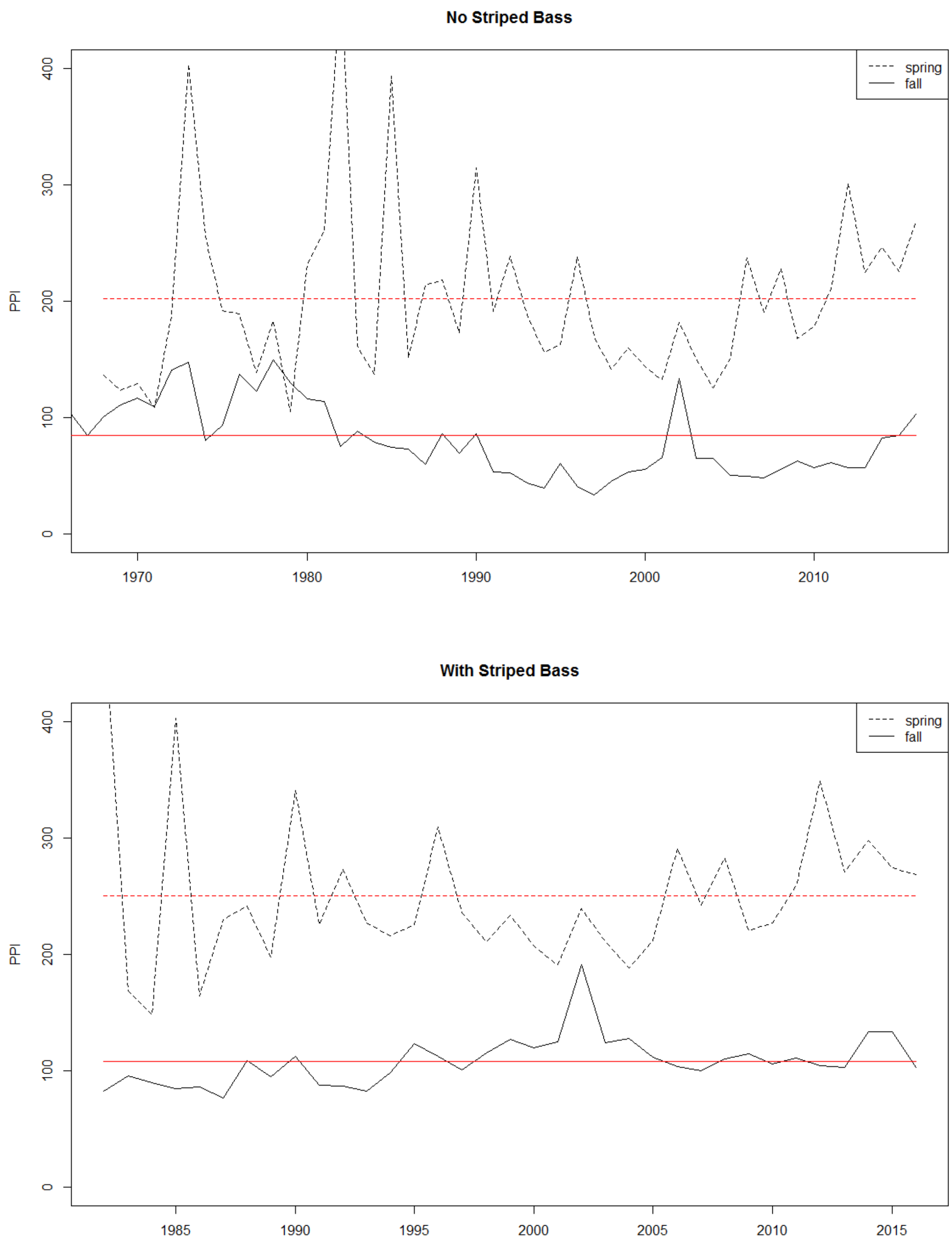

Figure 2.—Natural Mortality (M) for Atlantic herring calculated in the spring and fall, without (top panel) and with (bottom panel) striped bass. Red horizontal lines indicate a baseline M level of 0.35.

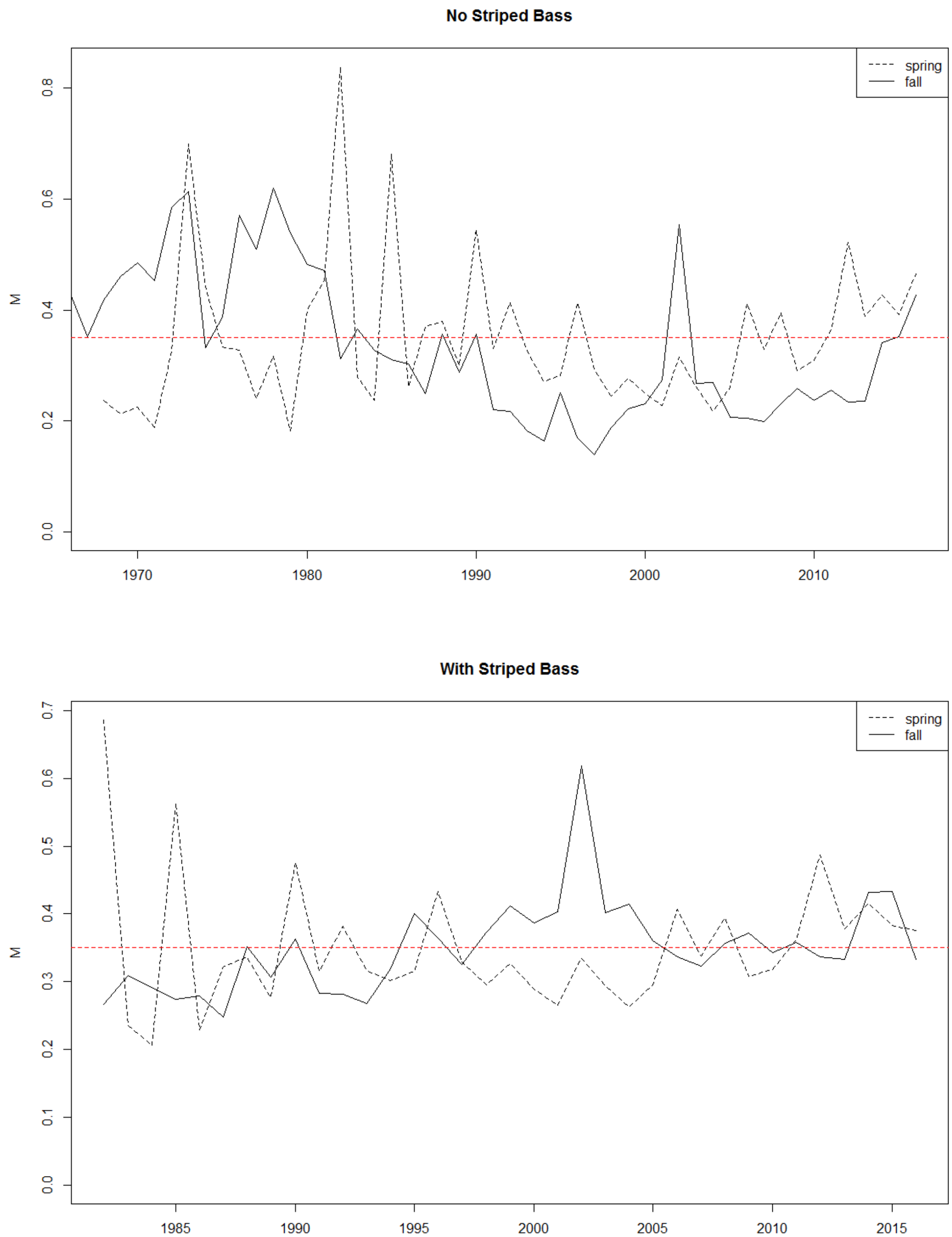

Table 1.—Herring predators that had at least 10 stomachs containing herring and positive occurrences of herring in at least 0.1% of stomachs, combined among all years and seasons, and used to estimate a predation pressure index.

PREDATOR	Region (R) or Sex (S) distinctions
ATLANTIC_COD	R – Georges Bank, Gulf of Maine
ATLANTIC_HALIBUT	NA
BLUEFISH	NA
GOOSEFISH	R – North, South
HADDOCK	R – Georges Bank, Gulf of Maine
POLLOCK	NA
RED_HAKE	R – North, South
SEA_RAVEN	NA
SILVER_HAKE	R – North, South
SPINY_DOGFISH	S – Male, Female, Unidentified
STRIPED_BASS	NA
SUMMER_FLOUNDER	NA
THORNY_SKATE	NA
WHITE_HAKE	NA
WINTER_SKATE	NA

Appendix B6

The NEFSC Study Fleet Program's Fisheries Logbook Data and Recording Software and its use the Atlantic Herring Fishery

Submitted by

Christopher L Sarro – NEFSC Cooperative Research Program

The Northeast Fisheries Science Centers (NEFSC) Cooperative Research Branch's Study Fleet program began development in late 2000. The pilot program had two main goals: 1) assemble a 'study fleet' of commercial New England groundfish vessels capable of providing high resolution (temporal and spatial) self-reported data on catch, effort and environmental conditions while conducting normal fishing operations; and 2) developing and implementing electronic reporting hardware and software for the collection, recording and transferring of more accurate and timely fishery-based data (Palmer et al 2007).

The program was developed to provide stock assessment scientists with fisheries dependent data that could provide more precise estimates of fishing effort and spatially-specific catch and discard rates. The collaborative nature of the program could also provide a means of communication between industry and science for better understanding of factors driving fishing effort and catch, as well as serve as platform for future collaborative projects (Palmer et al 2007).

Phase I began in late 2002, with a fleet of 15 paid participants, to develop an electronic logbook (ELB) and test supporting hardware. Phase II began in September 2004, with 30 participating vessels, to continue developing the ELB and explore satellite communication (Palmer et al 2007). Study Fleet is currently in Phase III, with a fully functioning ELB for data collection and transfer, auditing and utilization of data and enhanced biological sampling. Currently, there are over 40 contracted vessels in Study Fleet with homeports ranging from North Carolina to New Hampshire. Participating vessels range from New Hampshire to North Carolina with concentrations in Cape May, New Jersey and Point Judith, Rhode Island. The majority of vessels fish bottom trawl gear, though there are also gillnet, longline and scallop vessels participating.

The ELB developed for use in the Study Fleet program was the Fisheries Logbook and Data Recording Software (FLDRS). This is free software developed by the NEFSC, which is capable of reporting on the haul-by-haul and subtrip levels. FLDRS is currently on its fourth version with version five in development. On all vessels, FLDRS connects to a GPS unit or satellite compass and polls the unit every 20 seconds for accurate location information. FLDRS can be integrated with the depth sounder for depth information and/or a vessel monitoring system for rapid data transmission via satellite. The newest version of FLDRS is also capable of sending trip and GPS data via email if the software can access a Wi-Fi connection.

Gear-mounted temperature/depth probes are also deployed on vessels. The temperature/depth probes collect temperature and depth data every 90 seconds. Earlier models would poll continually and needed to be downloaded every 30-90 days. Current models are depth triggered and the data is uploaded after each tow to an onboard computer via a Bluetooth connection. Future improvements to FLDRS will allow for email transmission of temperature/depth files as well.

FLDRS can collect data on both the trip and haul levels. On the trip level, FLDRS collects program code, vessel and operator information, sail and landing date and port, number of efforts, aggregated fishing time, catch, apportionment and dealer information. On the haul level, FLDRS also collects fishing gear, tow specific location, duration, depth, statistical area and catch information.

FLDRS is also capable of collecting 'Dynamic Data'. These are additional data elements that are specific to certain gear types or program code. The Herring Program Code was developed with Massachusetts Division of Marine Fisheries (MADMF) to assist with their River Herring Bycatch Avoidance Program. Under the Herring Program Code, captains record which herring management sub-area they intend on fishing, the percent river herring catch and estimated river herring weight if a fisheries observer is present.

During installation, FLDRS is customized to each vessel and its fishing activities. All the various gears that a vessel uses, with the necessary gear characteristics (gear code, sweep length, mesh size and mesh type) are saved in FLDRS. Each gear is also associated with a customized species list of the most common kept and discarded species caught with that particular gear. All dealers that a vessel sells to are added to a dealer list. Finally, vessels' defaults are set up; these are the operator, gear, port, crew size and trip type that populate in the software automatically.

In July 2011, the Greater Atlantic Regional Office (formerly the Northeast Regional Office) approved the use of electronic Vessel Trip Reporting (eVTR) for a segment of the groundfish fleet and was expanded to other fisheries in 2013. FLDRS is now one of six approved eVTR platforms. During 2014-2015, the Cooperative Research Branch collaborated with the Pacific States Marine Fisheries Commission (PSFMC) to expand electronic reporting in the Northeast fisheries. This effort made funding available for up to 120 participating vessels to receive computers, installation, hardware and training in the use of FLDRS. A subset of these vessels also received temperature/depth probes. To date, 234 vessels have used FLDRS for haul-by-haul and subtrip reporting for research and eVTR purposes (Figure 1).

Use of FLDRS in the Atlantic herring Fishery:

Atlantic herring catches start in the Cooperative Research database in 2006. That year only a single vessel landed more than 2,200 lbs of Atlantic herring on an individual trip. The number of participant vessels participating in the Atlantic herring fishery ranged from one in 2006 to seven in 2013 with the vast majority of fishing effort coming from the small-mesh bottom trawl fishery off Rhode Island. Cooperative Research staff, through coordination with MADMF, made a concerted effort to install FLDRS on the mid-water and paired mid-water vessels through the collaboration with the PSMFC. This increase in vessels has greatly increased the amount of data collected from Atlantic herring fishery including fishing effort and the geographic footprint of the fishery. (Figures 2-4).

Midwater gear (both single and paired) is the most commonly occurring gear type in the time series. However, some small-mesh bottom trawl vessels out of Point Judith, RI will report using gear code 097OTM. The summer purse seine fishery in management sub-area 1A is not strongly represented with only one boat reporting using FLRDS in 2016 and two in 2017 (Figure 5). Vessels reporting haul-by-haul using FLDRS represented only 0.23 % of the total Atlantic herring landings in 2006. However, in 2016, vessels using FLDRS accounted for 41 % of the total Atlantic herring landings (Figure 6).

The participation of the commercial Atlantic herring fishery in haul-by-haul reporting has allowed for the collection of detailed information on effort and catch. Cooperative Research is attempting to integrate more of the onboard equipment such as net mensuration equipment for more accurate estimation of fishing time and catch per unit effort. This information combined with future improvements to FLDRS should be able address specific research and management questions.

Cooperative Research staff has fostered a close relationship with the commercial Atlantic herring industry, includes sailing on commercial vessels to examine trends in river herring bycatch and conducting a dedicated study to evaluate a predictive river herring distribution model in the small-mesh bottom trawl fishery. The direct lines of communication between Cooperative Research staff and members of the commercial Atlantic herring industry also provide insight into factors affecting fishing effort beyond availability. Variables such as fuel prices, market forces, seasonal closures, catch caps and availability of other species can influence catch beyond availability of the target species. Providing this information to stock assessment scientists and fisheries managers could prove valuable moving forward.

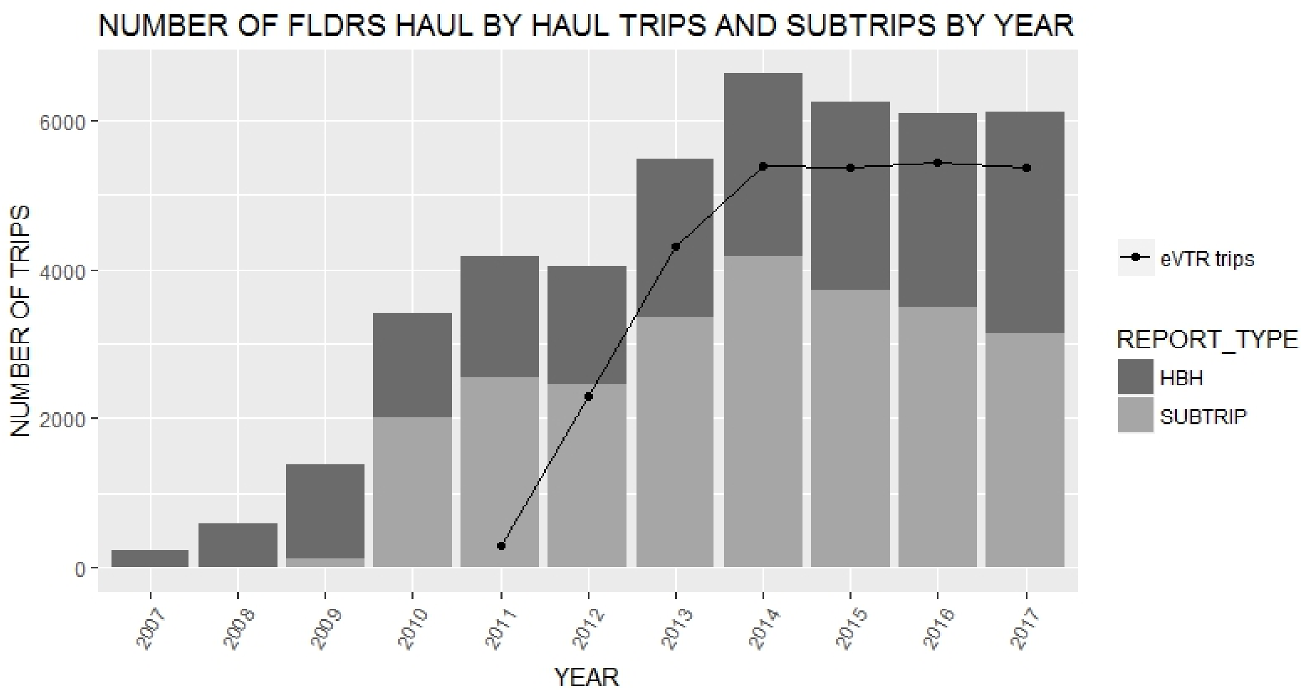

Figure 1: The number of trips (haul-by-haul and subtrip) and eVTRs per year from vessels using FLDRS.

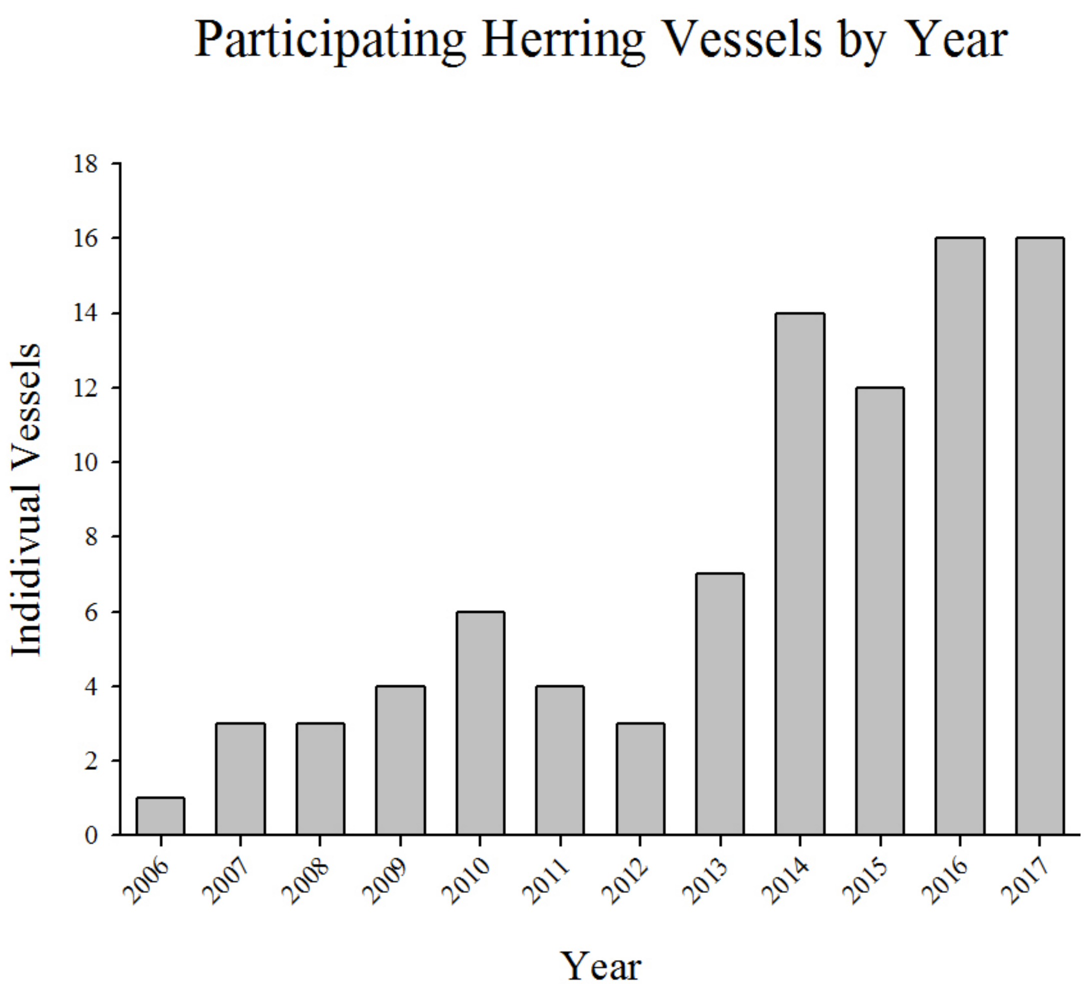

Figure 2: The number of individual vessel permit numbers that reported at least one haul-by-haul trip that landed > 2,200 lbs of Atlantic herring.

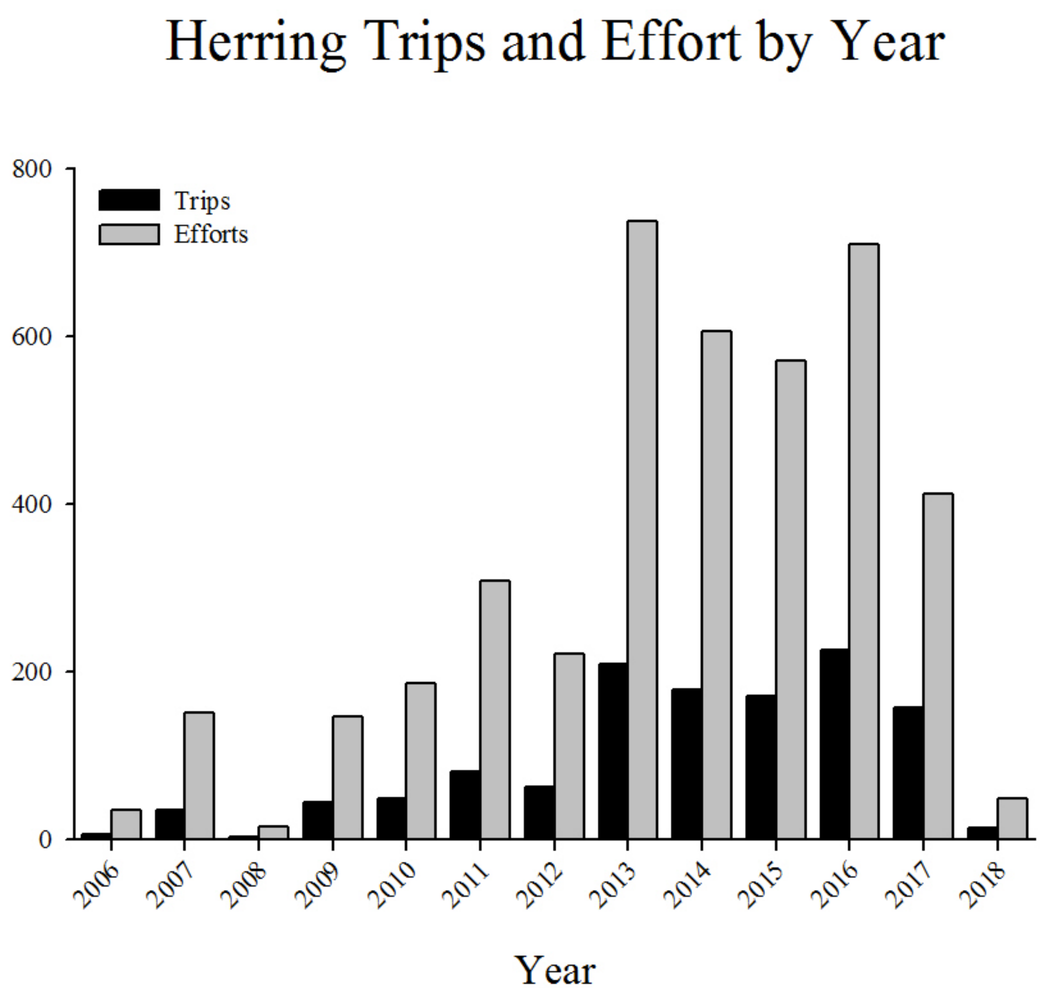

Figure 3: The number of trips and efforts that landed > 2,200 lbs of Atlantic herring. Trips and efforts from paired midwater trawlers were counted together as a single trip or effort.

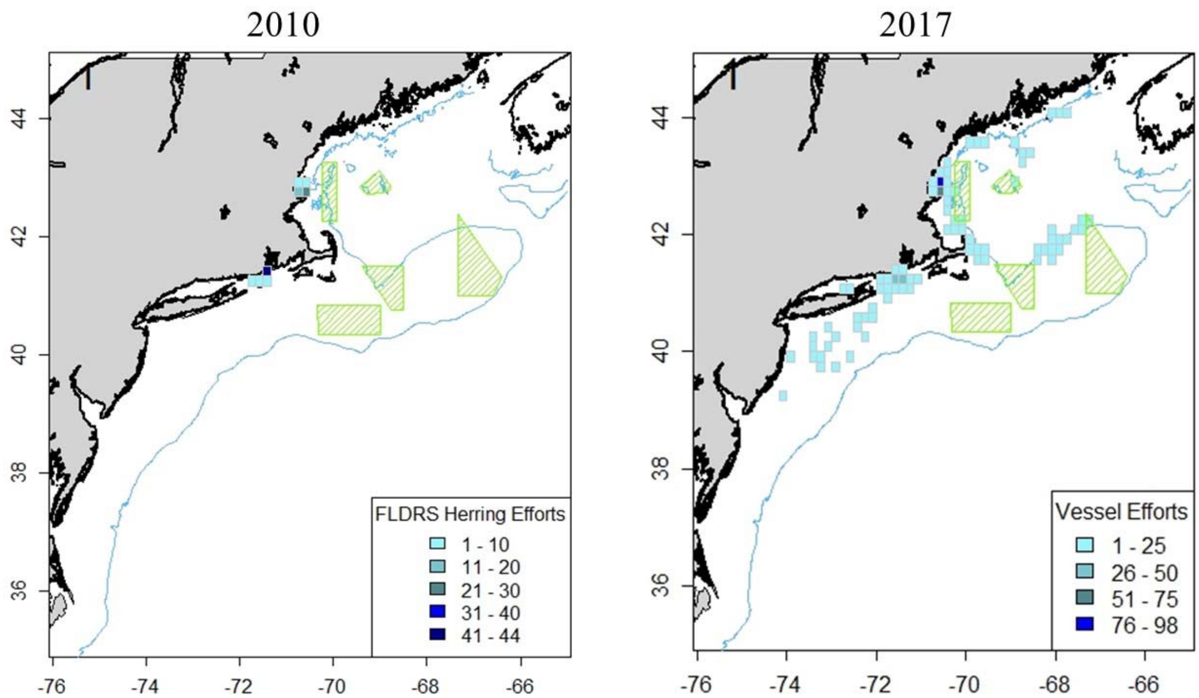

Figure 4: The number of efforts per 10 minute squares on trips landing more than 2,200 lbs of Atlantic herring from Cooperative Research Participants using FLDRS in 2010 and 2017.

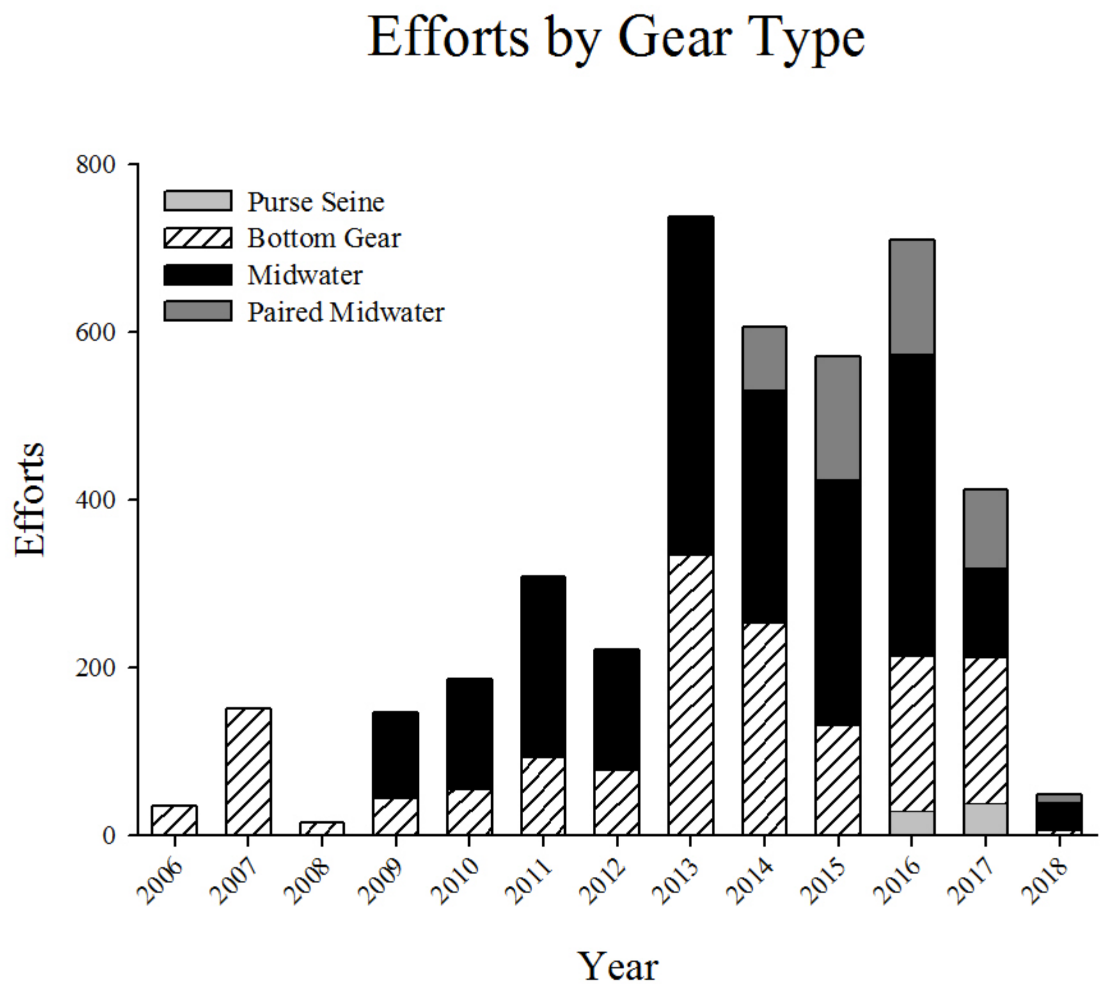

Figure 5: The number of efforts made using the various gear types by year. Bottom gear includes gear codes 090OTO, 092OTF and 092OTR.

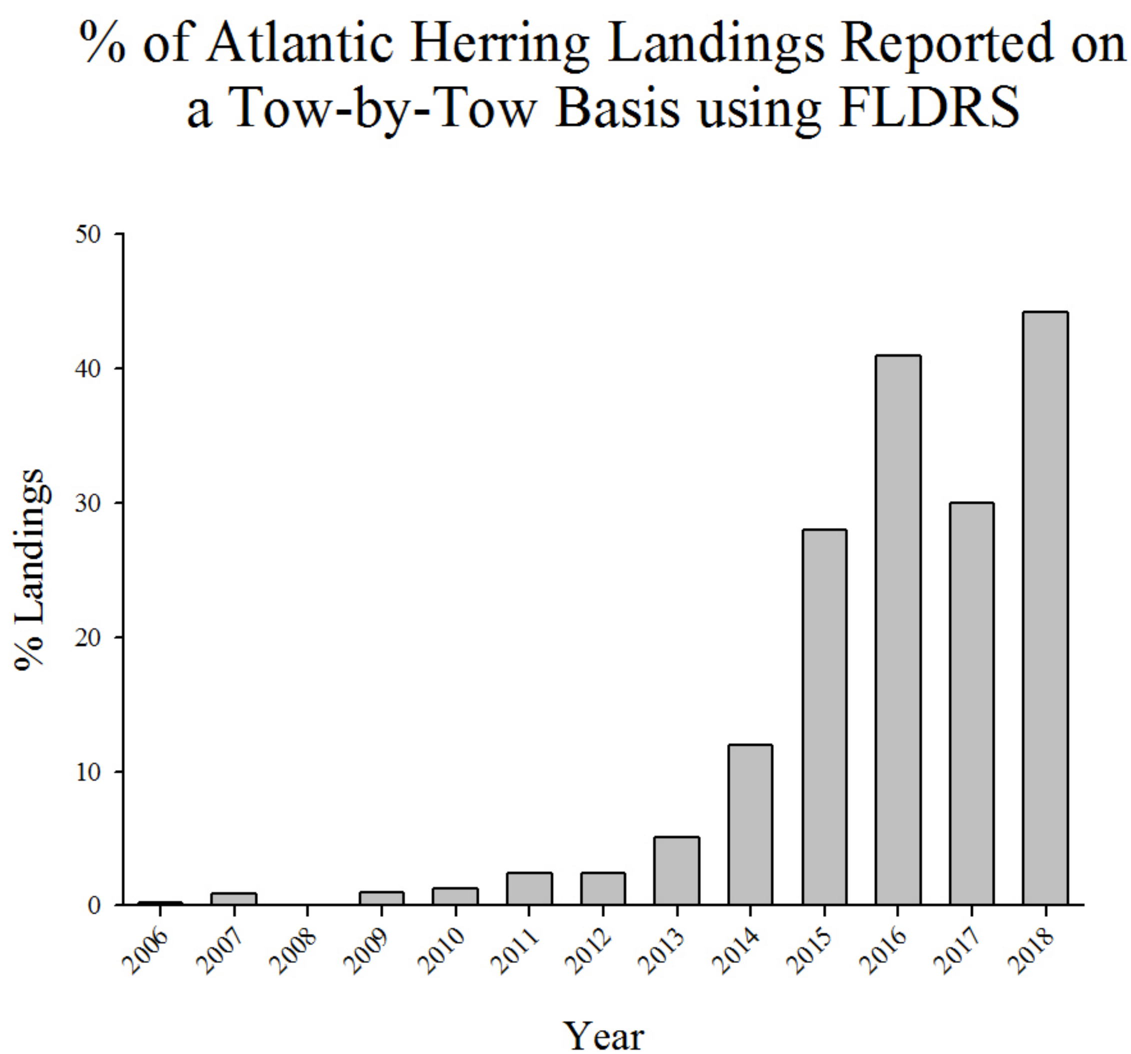

Figure 6: The percentage of Atlantic herring landings from vessels using FLDRS at the haul-by-haul level. The FVTR Apportion table was used to estimate catch and the CFDBS CFDERS tables were used to estimate landings.

References:

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Appendix B7

Working Paper:

Maturity and spawning seasonality of Atlantic herring (*Clupea harengus*) in US waters: QA/QC of data collected from fishery dependent and independent sources, with an evaluation of the consequences of skipped or spring spawning for stock-recruit relationships and stock assessment

Mark J. Wuenschel and Jonathan J. Deroba

Introduction and Objective

Altantic herring (*Clupea harengus*) is of commercial importance throughout its range across the eastern and western north Atlantic. Over this broad geographic range, reproductive plasticity is evident; stock specific size and age at maturity, spawning seasonality, egg sizes, and spawning areas (Iles 1964, van Damme et al. 2009). In addition to the diversity of reproductive strategies, skip spawning (i.e. not all mature fish spawn in every year) has become increasingly apparent in several fish stocks (Rideout and Tomkiewicz 2011, Skjaeraasen 2009, Skjaeraasen 2012), and has been reported for herring in the eastern Atlantic (Engelhard and Heino, 2005, Kennedy et al., 2011, Bucholtz et al. 2013). Although recruitment in the western Atlantic is highly variable (Anthony and Fogarty 1985), a recent evaluation of spawning strategies in the region that considers the possibility of skipped spawning is lacking.

Commercial fishery catch samples from the third quarter of each year (July-September) have been used to define annual maturity ogives for input into Atlantic herring stock assessments (NEFSC 2012; Deroba 2015). During the 2015 Operational Assessment of Atlantic herring (Deroba 2015), systematic differences in the maturity-at-age of herring were found between commercial samples and NMFS fall bottom trawl survey samples, with the commercial samples generally having smaller proportions of herring mature-at-age than the survey, especially for age-3 (Figure 1). The commercial sample based age-3 maturity-at-age also had larger interannual variation than the survey samples. Exploratory analyses by length bins (across ages and for age-3) indicated a similar tendency towards lower proportions mature at length (especially for smaller sizes) in the commercial samples (Figure 2). These differences and the variation in age-3 maturity were a noteworthy uncertainty during the 2015 assessment because: 1) spawning stock biomass at maximum sustainable yield (SSB_{MSY}) varies with age-3 maturity at a constant F_{MSY}, 2) a relatively large year class was age-3 in 2014, the terminal year of the assessment, which contributed to a 2014 SSB that exceeded the SSB_{MSY} reference point by more than two-fold, and 3) the assessment estimates a stock-recruit curve that assumes maturity is known without error in the estimation of SSB each year. While none of these uncertainties or concerns were considered grounds to reject the assessment, incorrectly specifying maturity-at-age could lead to bias in MSY reference points, bias in annual estimates of stock and recruitment, and ultimately to incorrect conclusions about stock status and inappropriate management advice.

One possible source of the differences between the commercial and survey samples is that commercial samples are taken by a port sampler with the State of Maine while the survey samples are taken by NMFS. The State of Maine and NMFS use different maturity classification schemes (Table 1).

The accuracy of macroscopic based maturity determinations for Gulf of Maine and Georges Bank Atlantic herring from both the commercial port samples and fishery-independent samples has not been formally investigated. Inaccuracy of maturity staging of herring using macroscopic criteria has been reported elsewhere (McPherson et al. 2011). Oocyte development and maturity classification of herring based on microscopic characteristics has been documented in other areas (van Damme et al. 2009, McPherson et al. 2011, Kennedy et al., 2011, Bucholtz et al. 2013), but has yet to be applied in the NW Atlantic. In the Gulf of Maine and Georges Bank, Atlantic herring are considered to be fall spawners, with spring spawning reported but not quantified or considered in assessments. An understanding of oocyte development is necessary to determine skipped spawning, especially for ‘resting’ type (Rideout and Tomkiewicz 2011), which is further complicated by the possibility of spring or fall spawning in the region.

Gonad histology is considered the most accurate method for determining maturity. In addition to basic maturity information, histological methods can establish spawning seasonality. Preliminary work has suggested that not all herring spawn in the fall, and so may be either skip spawners or a spring spawning contingent. The occurrence of skip or spring spawning would suggest a violation of the current assumption of all fall spawners in the assessment, and could lead to biased estimates of SSB and reference points. Histological analysis of herring ovaries and the size frequency distributions of developing oocytes indicate whether an individual has spawned recently or is preparing to spawn in the near or more distant future (5-6 months). This information, along with prior studies of oocyte development for the species is used to identify whether apparent 'non-participatory' fish collected in fall are indeed skip spawners or if they spawn in a different season (spring).

In this study we apply histological (microscopic) methods to document oocyte development through the year for both spring and fall spawning herring. Using oocyte stages and other histological characters, we develop criteria to assign maturity stages, spawning seasonality, skipped spawning, and assess the accuracy of macroscopic maturity determinations from both commercial port samples and the fishery-independent surveys in Gulf of Maine and Georges Bank herring. Since the stock assessment of Atlantic herring assumes all mature fish spawn in fall, we then evaluate the implications of observed reproductive diversity on stock-recruit models and the stock assessment.

Methods

Oocyte development and histology-based maturity classification

We obtained gonad samples of Atlantic herring from multiple sources operating at different times of the year. Samples obtained from NEFSC spring and autumn bottom trawl surveys (SBTS and

ABTS, respectively) were processed at sea; maturity classified macroscopically following Burnett et al. 1989 (Table 1), fish weight and gonad weight (+/- 0.1 g). Samples obtained from the NEFSC Cooperative Research Program (Study Fleet) were held on ice and transported to the laboratory where they were processed; fish weight and gonad weight +/- 0.001g, otoliths removed for ageing. Gonad samples were also obtained from the Maine DNR sampling of the commercial catch. The Maine DNR samples were usually frozen (but were fresh in some cases), and processed in the laboratory; maturity classified macroscopically using a different scheme than NEFSC samples (Table 1), fish weight and gonad weight +/- 1 g. In all cases, after weighing the gonad, a small portion was preserved in 10% buffered formalin for histology. Preserved tissue samples were processed following standard protocols; dehydrated in ETOH, embedded in paraffin, thin sectioned and stained with Mallory's trichrome. Histology was viewed with a digital microscope (Nikon Coolscope II) and oocyte were staged following (Brown-Peterson et al., 2011). Additional microscopic characters were recorded; the thickness of the gonad wall, presence and stage of post ovulatory follicles, presence and stage of atresia (Figure 3). Diameters of oocytes (~ 60-80 per fish) sectioned through the nucleus were measured using image analysis (ImageJ) from non-overlapping images from histological sections of representative individuals from each month available. The histological characters and oocyte diameters (Figure 4) from all months sampled were used to develop classification algorithm to assign maturity stages and spawning seasonality (Table 2). The histology-based classifications were compared to macroscopic assessments at-sea for ABTS 2014, ABTS 2015, SBTS 2016, and 2015 Q3 commercial samples. The sampling protocol for histological samples collected on NEFSC surveys for verification was as follows; at each station, after determining maturation stage of individuals sampled for age and growth, one fish of each macroscopic maturity stage was selected for histology sampling until a total of 100 was reached. This protocol ensured histological samples covered all stages encountered, and came from a wide region. Similarly, 100 random histological samples were requested from the third quarter of 2015 sampled by the Maine DMR staff processing the commercial samples with the following objectives; to cover as broad a range in dates, areas, and macroscopic stages as possible, with a preference for fresh (not frozen) samples which produce higher quality histology.

QA/QC of macroscopic maturity estimation.

The accuracy of macroscopic maturity staging for Atlantic herring was assessed for NEFSC surveys (Fall 2014, 2015; spring 2016) and ME DNR (third quarter 2015). The NEFSC Northeast Cooperative Research Program (Study Fleet) collections were used to inform histological characters (oocyte stages, POF persistence) and oocyte size distributions in months not sampled from the other sources and were used solely in the development of classification algorithms (no comparison of macroscopic vs. histologic determinations were performed).

Estimation of spring and/or skipped spawning

Based on the histological characteristics and month of collection, we were able to assign spawning seasonality for mature and maturing fish. For immature fish that have not yet initiated secondary development of oocytes, it was not possible to identify spawning seasonality. The identification of skip spawners is limited to discrete portions of the year, and in the case of Atlantic herring this is further complicated by potential for spring or fall spawners. We established criteria that would indicate skip spawners based on the month of collection, oocyte stages, POFs and atresia (Table 2).

Stock-recruit modeling

Estimates of biomass and recruitment (age-1 abundance) from the 2015 stock assessment (Deroba 2015) were used to evaluate the effect of spring spawning or skipped spawning on estimates of

Beverton-Holt stock-recruit parameters. Beverton-Holt models were fit using three different definitions of spawning stock biomass (*SSB*) that corresponded to spring spawning, skipped spawning, or 100% fall spawning. For spring spawning, some fraction of the stock was assumed to have spawned in May, while the remainder of surviving fish spawned in October. The annual *SSB* related to recruitment in the following year was the sum of the spring and fall spawners:

$$SSB_{y,spr} = SSB_{y,Jan1} * p_s * \exp\left({}^{5}/_{12} * Z_y\right) + SSB_{y,Jan1} * p_f * \exp\left({}^{10}/_{12} * Z_y\right);$$

where $SSB_{y,spr}$ was spawning stock biomass in year *y* and *spr* denoted that the calculation included spring spawners, $SSB_{y,Jan1}$ was spawning stock biomass on January 1, p_s was the fraction of the stock that spawned in spring, $p_f = 1 - p_s$ was the fraction of the stock that spawned in fall, and Z was total instantaneous mortality:

$$Z_y = M + F_y;$$

where M was instantaneous natural mortality, and F was fully-selected instantaneous fishing mortality estimated for each year in the 2015 stock assessment (Deroba 2015). Skipped spawning $\left(SSB_{skip}\right)$ was approximated by not including the spring spawners in the calculation of the annual SSB:

$$SSB_{y,skip} = SSB_{y,Jan1} * p_f * \exp\left({}^{10}/_{12} * Z_y\right).$$

In this context, p_s equates to the proportion of the stock that skips spawning. Fall spawning $\left(SSB_{fall}\right)$, as assumed in recent stock assessments, was calculated as in skipped spawning except with $p_f = 1$:

$$SSB_{y,fall} = SSB_{y,Jan1} * \exp\left({}^{10}/_{12} * Z_y\right).$$

These methods for calculating SSB assumed the same maturity ogive applied in both seasons and ignored within year growth. A Beverton-Holt stock-recruit model was fit using each of the definitions for SSB:

$$R_{y+1} = \frac{\alpha * SSB_{y,x}}{\beta + SSB_{y,x}};$$

where x denoted one of the three definitions of SSB (*spr, skip, or fall*), R was estimated recruitment from 1966-2013 from the 2015 stock assessment (Deroba 2015), and α and β were parameters. This method assumed that the expected recruitment at a given level of SSB was the same in both seasons (i.e., spring spawners were the "same" as fall spawners).

Models were fit using a range of M and $p_s\ (p_f)$ values (Table 3). The mean stock-recruit curve from each fit was plotted, and plots were qualitatively examined for differences.

Sensitivity of the stock assessment

The stock assessment was evaluated for sensitivity to spring spawning and skipped spawning. With the exception of modifying the SSB calculation, all inputs and settings were identical to the 2015 stock assessment (Deroba 2015). The calculation of SSB in the stock assessment was modified as in the case of spring spawning $(SSB_{y,spr})$ and skipped spawning $(SSB_{y,skip})$ in the stock-recruit modeling methods, but the distinction in this case was that the estimation of the stock-recruit relationship was done internal to the assessment model and estimated with all the other associated parameters. Models were fit using a range of $p_s\ (p_f)$ values (Table 3). Time series plots of estimates of SSB, recruitment, and fully-selected fishing mortality were qualitatively examined for differences between the assessment modified for spring or skipped spawning and the 2015 assessment. Values of estimated steepness and unexploited SSB were also compared.

Results and Discussion

Using microscopic verification we found the macroscopic method to be reasonably accurate for Atlantic herring (direct agreement 60-87%), however errors in determination of sex (2-7%) and maturity (0-13%) were evident in all surveys (Tables 4-8). Errors in maturity were highest in the spring survey period. Subtle disagreements (not affecting maturity) between the histologic and macroscopic methods were also evident in all surveys. During spring, many fish classified as resting at sea were undergoing early development which was only visible via histology.

Misclassification of sex occurred in all surveys (summarized in Table 8). Most of these misclassifications occurred for immature fish, where it is more difficult to differentiate sex macroscopically. Additionally, for most individuals during the spring survey period, the gonads are very small, making it more difficult to distinguish males from females macroscopically. This likely led to the higher rates of incorrect maturity in the spring (Table 6), and supports the continued estimation of maturity from samples obtained closest to the main spawning season in fall. The results from the spring also indicate histology was able to identify early developing fish before this was evident macroscopically (ED fish classified as resting at sea). This is not surprising since the characters that define early developing are not readily visible with the naked eye. Several late developing and one spent fish were collected in the spring, a clear indication of spring-early summer spawning. Interestingly, the spent fish was classified as ripe and running at sea. This individual contained advanced and mature oocytes that histology indicated were ‘residual’ (i.e. left over). During winter and spring, the difference in ovary condition between spring and fall spawners is obvious (Figures 5 and 6). Therefore, the estimation of spring spawning from developing and spawning active herring in the spring is considered reliable. Nonetheless, spring spawning was relatively rare (2.5-13%, Table 8). A summary herring maturity from the SBTS time series across regions (Figure 7) indicates a latitudinal trend in the proportion of spring spawning herring (pre-spawning and spawning) encountered. Proportions of spring spawning increased with latitude; 0-10% in the Middle Atlantic Bight, 5-20% on Georges Bank, 10-40% in the Gulf of Maine, and 10-80% on the Scotian Shelf. Although rates of spring spawning were higher on the Scotian Shelf, fewer fish were sampled in that region.

Because of the sampling scheme used, wherein samples were requested across stages, and not in proportion to the stages encountered, the error rates reported here do not depict actual error rates.

To arrive at overall errors in macroscopic classifications in the surveys, one would need to apply stage specific error rates to all fish examined in the surveys. In fall most herring are developing, which is sometimes confused with resting (regenerating), but was never confused with immature. Therefore, proportionally more developing fish in fall would dilute the effect of errors in the rarer stages (i.e. resting), reducing the overall error rate. In a similar vein, although error rates in spring were higher, the late developing and spawning active females were accurately identified, confirming spring spawning in the region. The commercial Q3 collection was the most precise (Table 8), possibly due to being performed by a single experienced technician. In contrast, the NEFSC survey data is collected by multiple individuals per survey, with varying backgrounds and experience levels with respect to herring maturity. Annual training workshops on fish maturity are held at the NEFSC to address this potential source of error.

The spatial distribution of samples from the NEFSC surveys differed from the Q3 commercial samples analyzed by the Maine DNR which were predominately from inshore stat areas (512, 513, 514; Figure 8). Most immature fish remain inshore in fall (i.e. do not undergo spawning migrations offshore), so samples inshore will have more immature fish (overall and at a given age). This is illustrated in maps showing the spatial distribution in age 2 and 3 fish in 2014 and 2015 (Figs 9 and 10). The proportion mature at age 2 and 3 varies in the time series (Deroba 2015), but it appears immature individuals are found closer to shore in fall. In spring Atlantic herring are more widely distributed, including immature individuals (Figure 11). The spatial difference in maturity likely contributes to observed differences in estimated proportions mature at age from survey and commercial data sources in fall. When analysis of survey data is constrained to inshore regions, the differences in maturity decrease (Figure 12).

Stock-recruit modeling

The fits of stock-recruit models with spring spawning and fall spawning were generally similar, but skipped spawning produced higher recruitment at a given level of SSB (Figure 13). Natural mortality had a negligible effect on the fits, especially relative to the fraction of the stock that skipped spawning (p_s in the context of skipped spawning). At low levels of skipped spawning, differences among all fits were generally similar, but the skipped spawning stock-recruit relationships became more distinct at higher levels of skipped spawning (Figure 13).

Sensitivity of the stock assessment

Results for spring spawning were insensitive to the value of p_s, and so only results for $p_s = 0.3$ were reported here. Time series plots were generally similar between the assessment model with spring spawning and the 2015 assessment (Figure 14). Estimates of steepness and unfished SSB were also similar (Table 9). In the case of skipped spawning, differences in the time series plots with the 2015 assessment were only evident for SSB, and SSB was less than the 2015 assessment (Figure 14). The degree of difference increased with the value of p_s, but only results with $p_s = 0.3$ were reported for simplicity (Figure 14). Estimated steepness with skipped spawning was similar to the 2015 assessment, but unfished SSB was less (Table 9). Skipped spawning seems to scale SSB and related reference points, with little other consequences.

This analysis could be improved by accounting for in-season growth and different maturity ogives between seasons. The methods assumed, however, that the maturity and weight-at-age matrices from the fall spawning season also applied in the spring. Spring spawners are less likely to be mature-at-age and have smaller weights-at-age than fall spawners. Consequently, this analysis falsely inflated the contribution that spring spawners would have, and so accounting for these seasonal differences would likely only result in reducing any differences already observed among model fits.

The differences in the stock-recruit modeling between assuming spring spawning or skipped spawning serve to demonstrate the consequence of falsely concluding one mechanism or the other. Results suggest, however, that making such a false conclusion would be of little consequence until the fraction of spring or skipped spawners was relatively high, at which point other indications of spring or skipped spawning would likely become evident in survey or commercial catch samples.

At the levels of possible spring or skipped spawning reported here, the effect on the stock assessment can likely be ignored. Levels of measurement error, process error, and other structural uncertainty also likely far exceed the uncertainty induced by spring or skipped spawning suggested by this analysis, which also supports the conclusion that the effect of spring or skipped spawning can be ignored.

Conclusions

Histological analysis of herring gonads from multiple sources, and inclusion of reproductive diversity in the stock assessment indicated the following:

- error rates of the macroscopic method to determine maturity were low
- there were not any systematic biases between NEFSC and ME DNR maturity methods
- spring spawning was confirmed at low levels
- skipped spawning was not observed
- the spatial distribution of immature herring differs from that of mature herring in fall
- differences in maturity estimated from NEFSC survey and Q3 commercial are likely due to spatial heterogeneity of the population with respect to maturity
- skipped spawning scales SSB and related reference points, with little other consequences
- incorporating observed rates of spring and/or skip spawning had little effect on the stock assessment

Acknowledgments

We thank the following individuals and groups for assisting with the collection and processing of samples: Emilee Tholke, David McElroy, Study fleet staff, Eric Robillard, ME DNR (Mathew Cieri, Lisa Pinkham), agers (Blanche Jackson, Katey Rogers), and NEFSC Ecosystems Survey Branch.

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Table 1. Macroscopic and histological maturity classification schemes used in NEFSC surveys (Table 11 in Burnett et al. 1989) and ME DNR sampling of commercial catch (Table 3B in Burnett et al. 1989). Corresponding histological classes are listed (following Brown-Peterson et al. 2011, with potential skip spawning following Rideout et al. 2005); in some cases multiple stages in one scheme are represented by a single stage in another scheme.

Macroscopic Classes NEFSC	**Macroscopic Classes ME DNR**	**Histological Classes**
Immature	I (Immature) II (Immature will spawn next season)	Immature Immature First Maturing
Developing	III (Ripening, Early stage) IV (Ripening mid stage)	Early Developing Late Developing Spawning Capable Skip Spawning (Reabsorbing)
Ripe Running Ripe	V (Ripe) VI (Spawning)	Spawning Active
Spent	VII (Spent)	Regressing
Resting	VIII (Resting)	Regenerating Skip Spawning (Resting)

Table 2. Microscopic characteristics for each histological maturity stage.

Histological Classes	Characteristics
Immature	Ovaries small with thin ovarian wall and little space between oocytes; only oogonia and PG oocytes present
Immature First Maturing	PG, CA, oocytes present with thin ovarian wall.
Early Developing (repeat)	Ovaries with PG, CA; thick ovarian wall and/or late stage POFs indicating prior spawning.
Late Developing	Enlarging ovaries with Vtg1, Vtg2 oocytes.
Spawning Capable	Large ovaries with Vtg3 oocytes present. Atresia of vitellogenic oocytes may be present. Early stages of OM can be present.
Skip Spawning (Reabsorbing)	Mass atresia of vitellogentic oocytes.
Spawning Active	Oocytes undergoing late GVM, GVBD, hydration, or ovulation.
Regressing	Flaccid ovaries with thick ovarian wall; atresia and recent POFs present. Most advanced oocyte stage is primary growth, with some residual secondary or tertiary growth oocytes possible.
Regenerating	Small ovaries with thick ovarian wall. Late stage atresia or POFs may be present. Only oogonia and PG oocytes present.
Skip Spawning (Resting)	Small ovaries with thick ovarian wall. Only oogonia or PG oocytes present. No indication of participation in proximal spawning season; no secondary or tertiary growth oocytes, recent POFs, or atresia.

Table 3. Range of natural mortality (M) and proportion of spring (p_s) and fall (p_f) spawners evaluated.

M	p_s	p_f
0.20	0.10	0.90
0.35	0.20	0.80
0.50	0.30	0.70

Table 4. QA/QC results for the 2014 fall bottom trawl survey (2015ABTS). In fall IFM fish are not expected to spawn until the following calendar year, so they should not be included in SSB (i.e. not mature). Green cells indicate direct agreement, red cells indicate incorrect maturity.

	Immature	Developing	Ripe	Ripe & Running	Spent	Resting
Immature	8	0	0	0	0	3
Immature First Developing	0	0	0	0	0	0
Early Developing	0	1	0	0	0	2
Late Developing	0	7	6	0	0	0
Spawning Capable	0	1	2	0	0	0
Spawning Active	0	0	0	0	0	0
Regressing	0	1	2	0	0	3
Regenerating	0	4	1	0	0	51
Skip Spawner	0	0	0	0	0	0

Table 5. QA/QC results for the 2015 fall bottom trawl survey (2015ABTS). In fall IFM fish are not expected to spawn until the following calendar year, so they should not be included in SSB (i.e. not mature). Green cells indicate direct agreement, red cells indicate incorrect maturity.

	Immature	Developing	Ripe	Ripe & Running	Spent	Resting
Immature	7	0	0	0	0	0
Immature First Developing	1	0	0	0	0	1
Early Developing	0	0	0	0	0	2
Late Developing	0	14	2	0	0	0
Spawning Capable	0	1	2	0	0	0
Spawning Active	0	0	0	0	0	0
Regressing	0	2	1	0	0	3
Regenerating	3	1	0	1	1	46
Skip Spawner	0	0	0	0	0	0

Table 6. QA/QC results for the 2015 Q3 commercial samples (ME2015 Q3). In fall IFM fish are not expected to spawn until the following calendar year, so they should not be included in SSB (i.e. not mature). Green cells indicate direct agreement, red cells indicate incorrect maturity.

	I	II	III	IV	V	VI	VII	VIII
Immature	2	1	0	0	0	0	0	0
Immature First Developing	0	2	0	0	0	0	0	0
Early Developing	0	2	10	0	0	0	0	0
Late Developing	0	0	34	10	0	1	0	0
Spawning Capable	0	0	1	2	10	7	0	0
Spawning Active	0	0	0	0	0	5	0	0
Regressing	0	0	0	0	0	0	4	0
Regenerating	0	0	0	0	0	0	0	7
Skip Spawner	0	0	0	0	0	0	0	0

Table 7. QA/QC results for the 2016 Spring bottom trawl survey (2016SBTS). In the spring, IFM fish would be expected to spawn in the calendar year (that fall) so they should be included in SSB (i.e. not immature). Green cells indicate direct agreement, red cells indicate incorrect maturity.

	Immature	Developing	Ripe	Ripe & Running	Spent	Resting
Immature	1	0	0	0	0	1
Immature First Developing	5	0	0	0	0	0
Early Developing	4	4	0	0	0	24
Late Developing	0	7	2	0	0	0
Spawning Capable	0	0	0	0	0	0
Spawning Active	0	0	0	0	0	0
Regressing	0	0	0	1	0	0
Regenerating	3	3	0	0	0	40
Skip Spawner	0	0	0	0	0	0

Table 8. Summary of sex and spawning group determinations for the four data sources. For Males the percentages listed in parentheses are the percentage males incorrectly classified as females macroscopically. For females, the percentages listed in parentheses are the percentage of mature females in that spawn group. The direct agreement is the sum of the diagonal green cells for survey (Tables 3-6), and the incorrect maturity is the sum of the red cells in each table. Percentages included for QA/QC are calculated for females only.

Sex	Spawn group	2014 (ABTS)	2015 (ABTS)	ME2015 (Q3)	2016 (SBTS)
Males (incorrect sex)		7 (7.0%)	4 (4.3%)	2 (2.0%)	5 (5.0%)
Females		93 (88.6%)	89 (95.7%)	98 (98.0%)	95 (95.0%)
Mature	Spring	3 (3.7%)	2 (2.5%)	12 (13.0%)	10 (11.4%)
	Fall	78 (96.3%)	77 (97.5%)	81 (87.0%)	78 (88.6%)
	Skip	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Immature	Unknown	11	9	5	7
QA/QC	Direct agreement	68 (73.1%)	69 (77.5%)	85 (86.7%)	57 (60%)
	Incorrect Maturity	3 (3.2%)	3 (3.4%)	0 (0%)	13 (13.6%)

Table 9.—Estimates of unfished spawning stock biomass and steepness from assessment with all fall spawning and 30% spring spawning.

	Fall Spawn Only (2015 Assessment)	With Spring Spawning	Skip Spawning
Unfished SSB	845176	885784	591623
Steepness	0.44	0.43	0.44

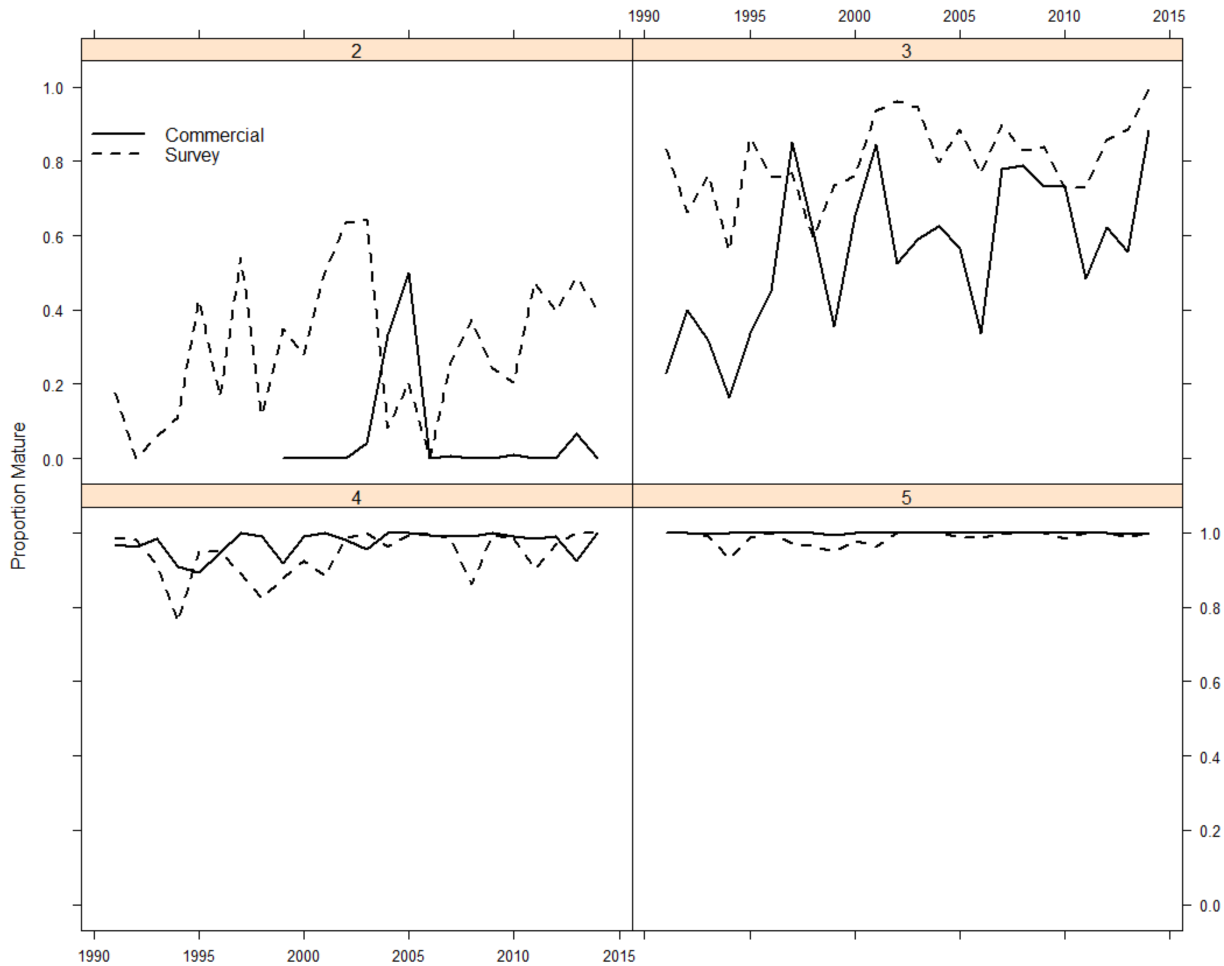


Figure 1. Proportion mature at age (age specified in the "strip" of each panel) from quarter three commercial fishery herring samples and the NMFS fall survey.

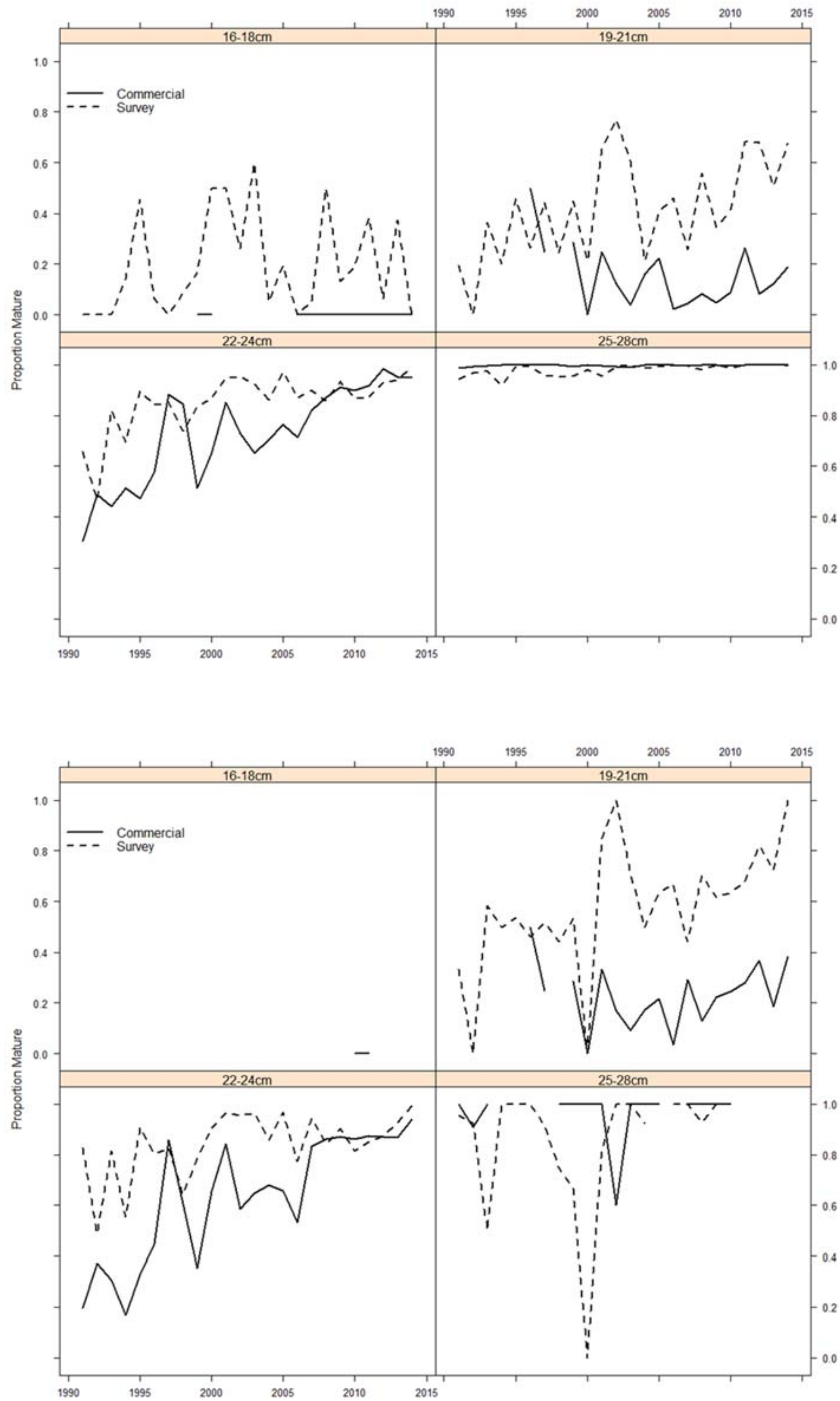


Figure 2. Proportion mature at length (length specified in the “strip” of each panel) for all ages (top) and age-3 (bottom) from quarter three commercial fishery herring samples and the NMFS fall survey.

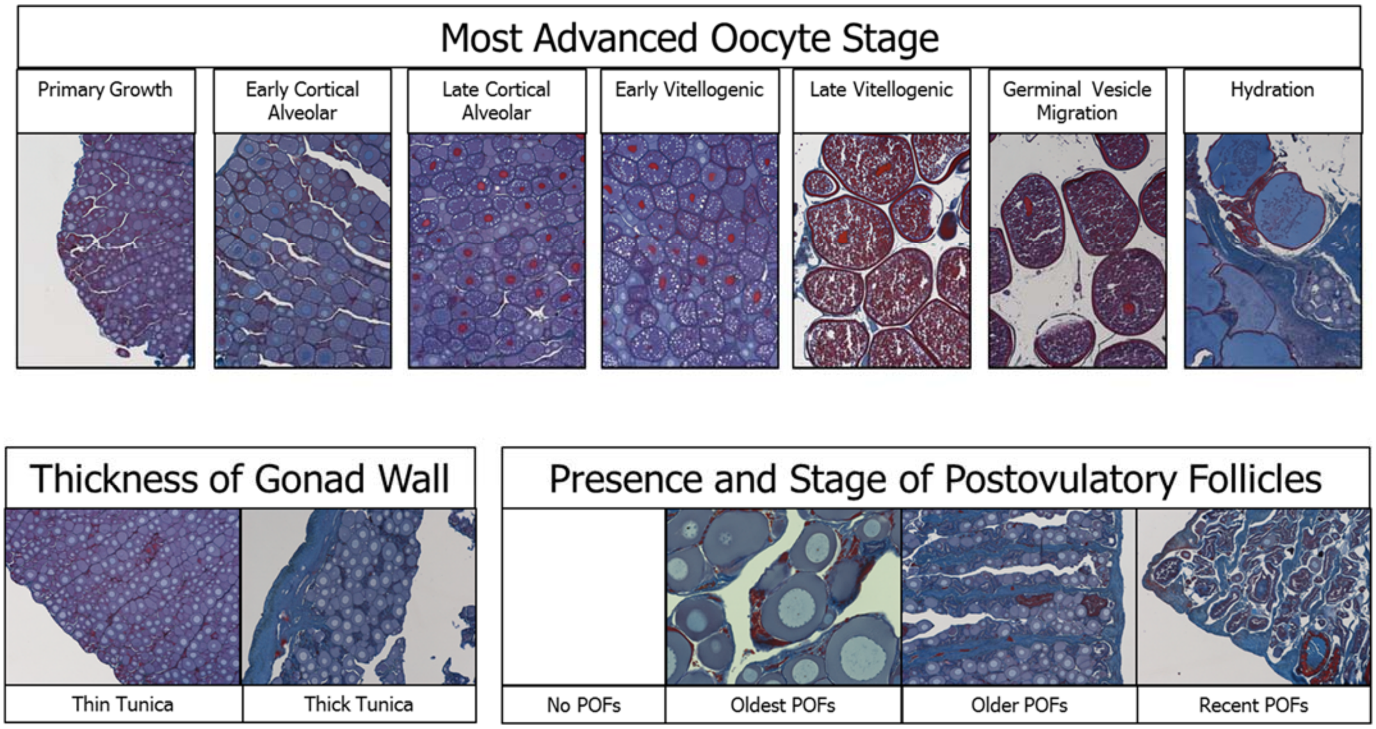


Figure 3. Histological criteria used to assess maturity of Atlantic herring. All images are at the same magnification, except for the 'Oldest POF' which is at a higher magnification.

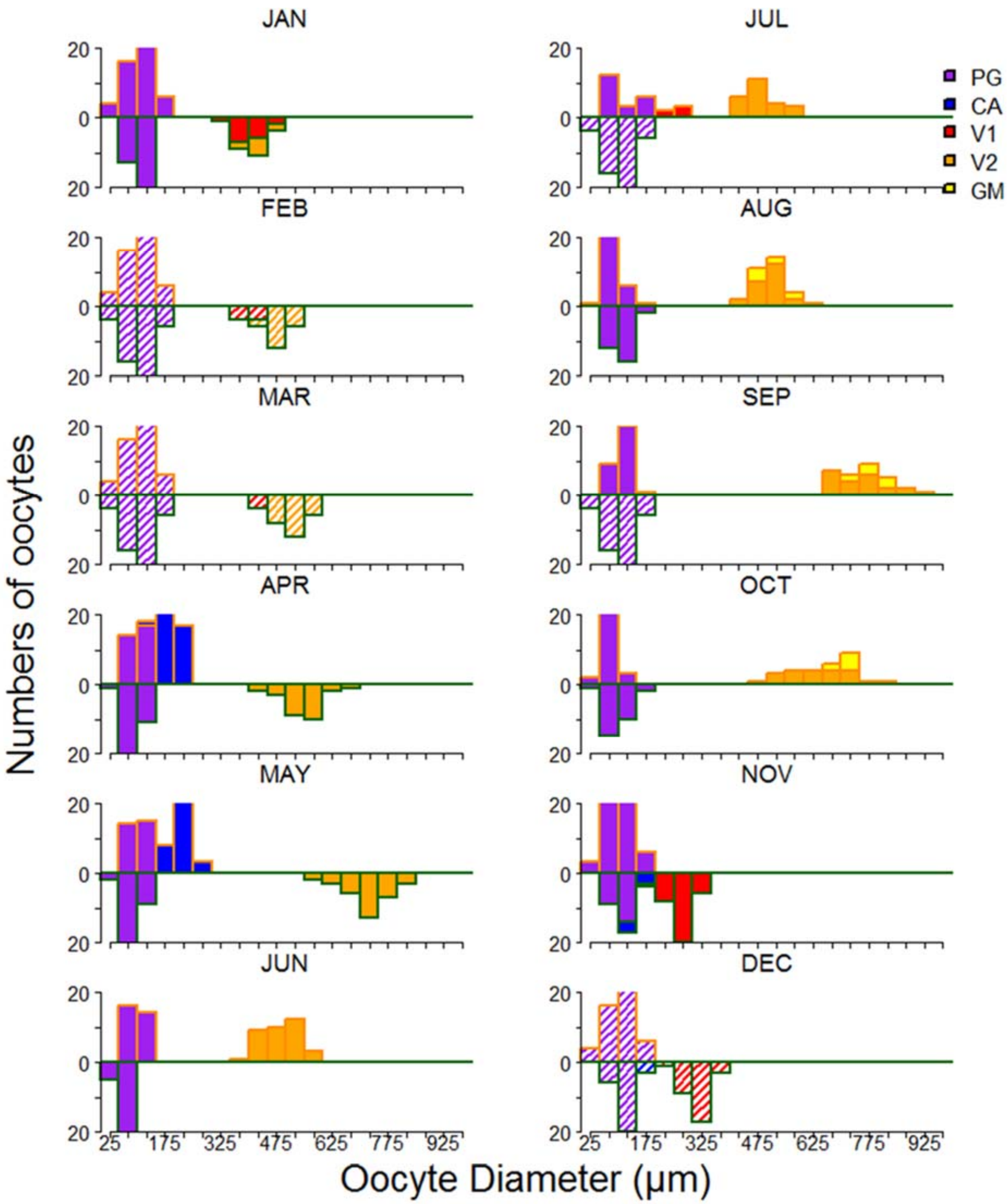


Figure 4. Monthly oocyte size distributions for representative Atlantic Herring (solid bars) or estimated from adjacent months and observed oocyte growth rates (shaded bars). Within each month, the distribution on top represents a fall spawner, and that on the bottom a spring spawner. PG, Primary Growth; CA, Cortical Alveolar; V1, Early Vitellogenic; V2, Late Vitellogenic; GM, Germinal Vesicle Migration.

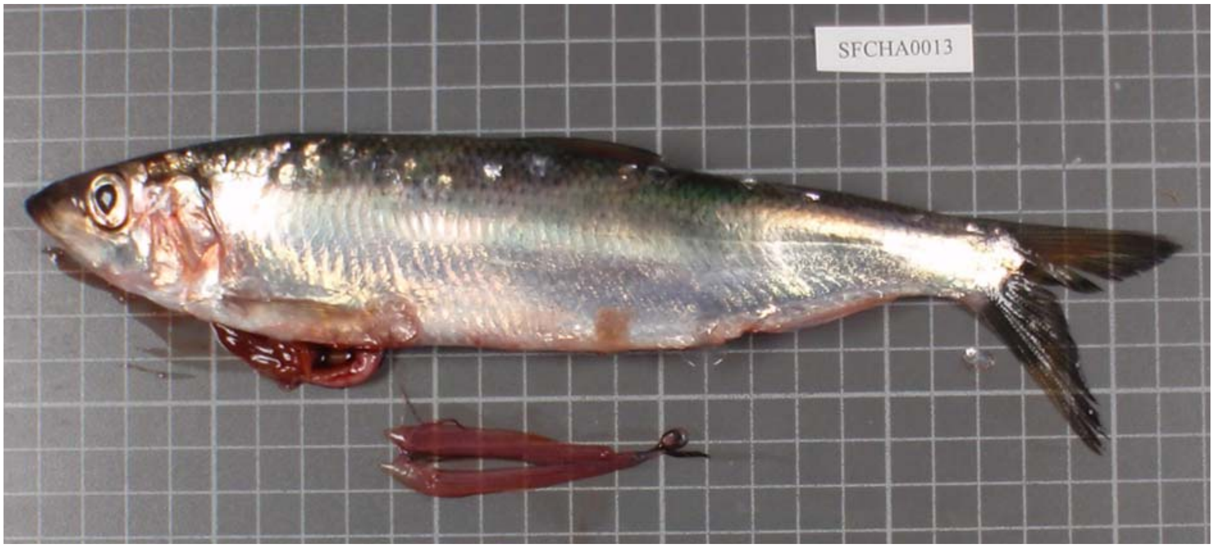


Figure 5. Photographs of herring sampled January 22, 2015 from commercial catch (NEFSC Study Fleet). Top, resting female (Fall spawner); bottom, developing female (Spring spawner).

Figure 6. Herring photographed April 25, 2017 during the NEFSC spring bottom trawl survey. Top, resting female (Fall spawner); Bottom, developing female (Spring spawner).

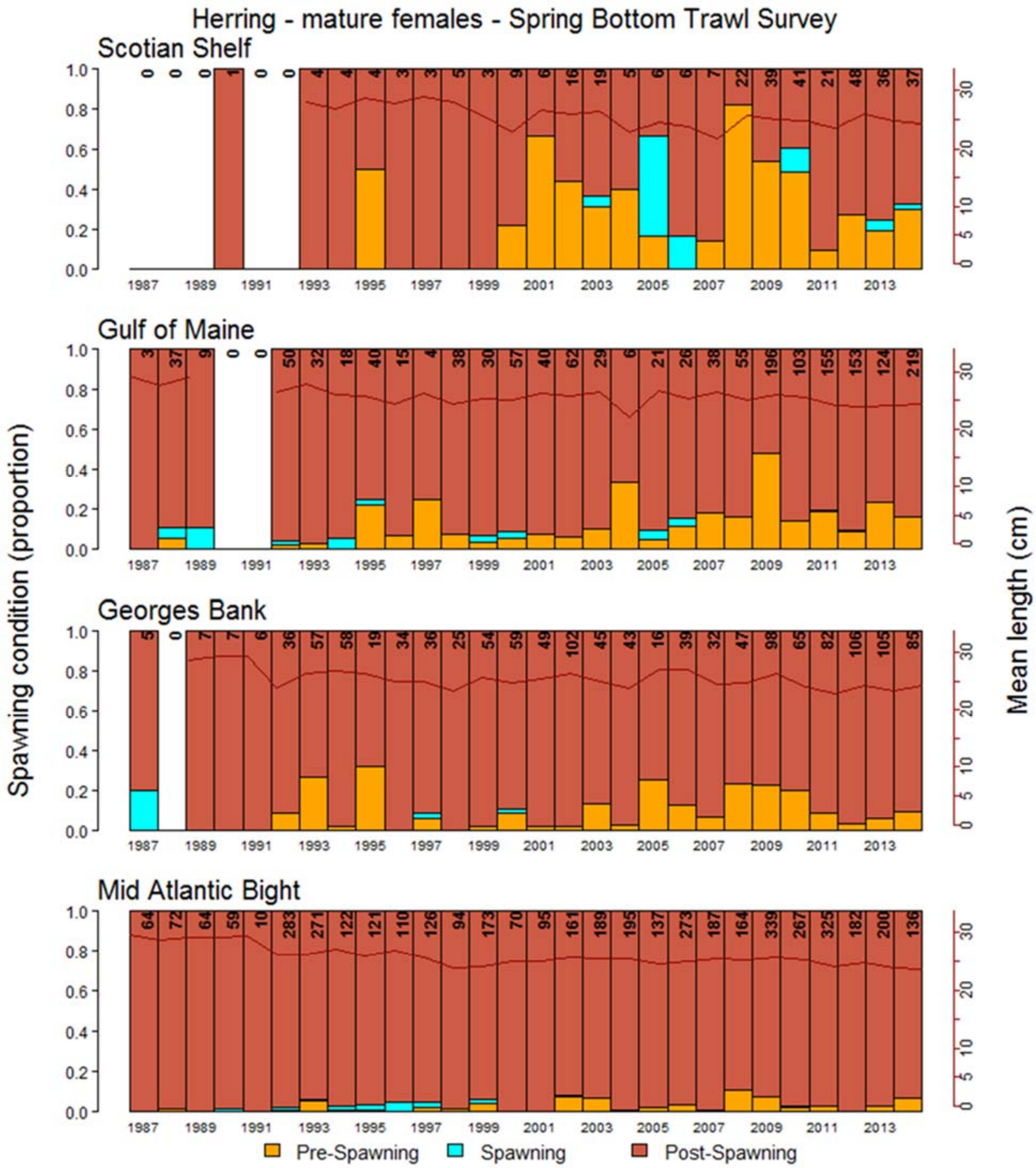
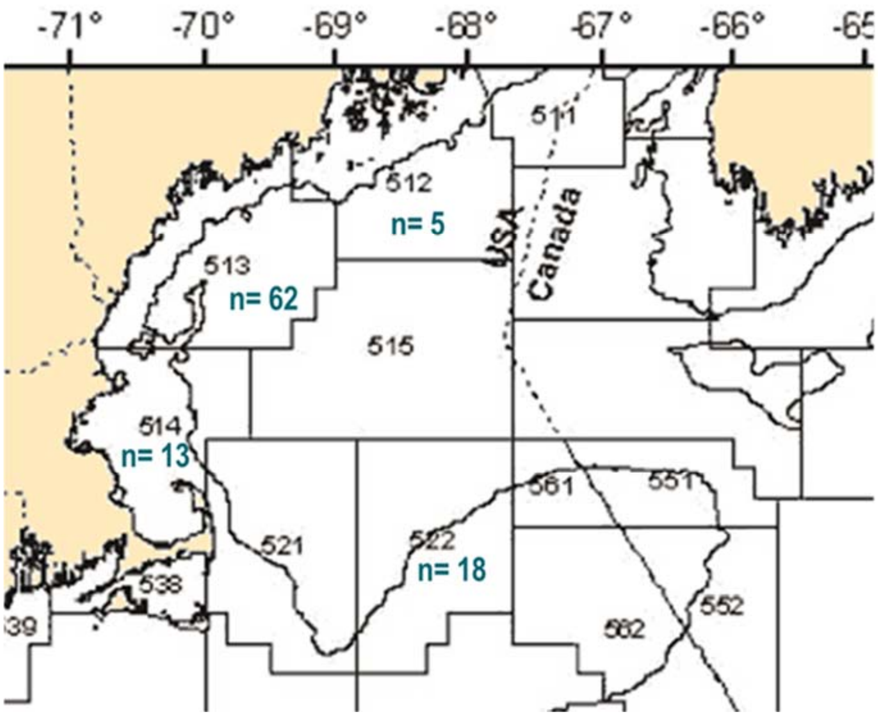


Figure 7. Time series of mature female macroscopic maturity collected on the NEFSC spring bottom trawl survey. For simplification, maturity classes are aggregated to illustrate spawning seasonality (Pre-Spawning = Developing, Spawning = Ripe and Ripe and Running, Post-Spawning = Spent and Resting). Pre-Spawning and Spawning groups represent spring spawning herring.



Stat Area	Sample size
512	5
513	62
514	13
522	18

Figure 8. Distribution and summary of female herring from Q3 commercial that were analyzed histologically.

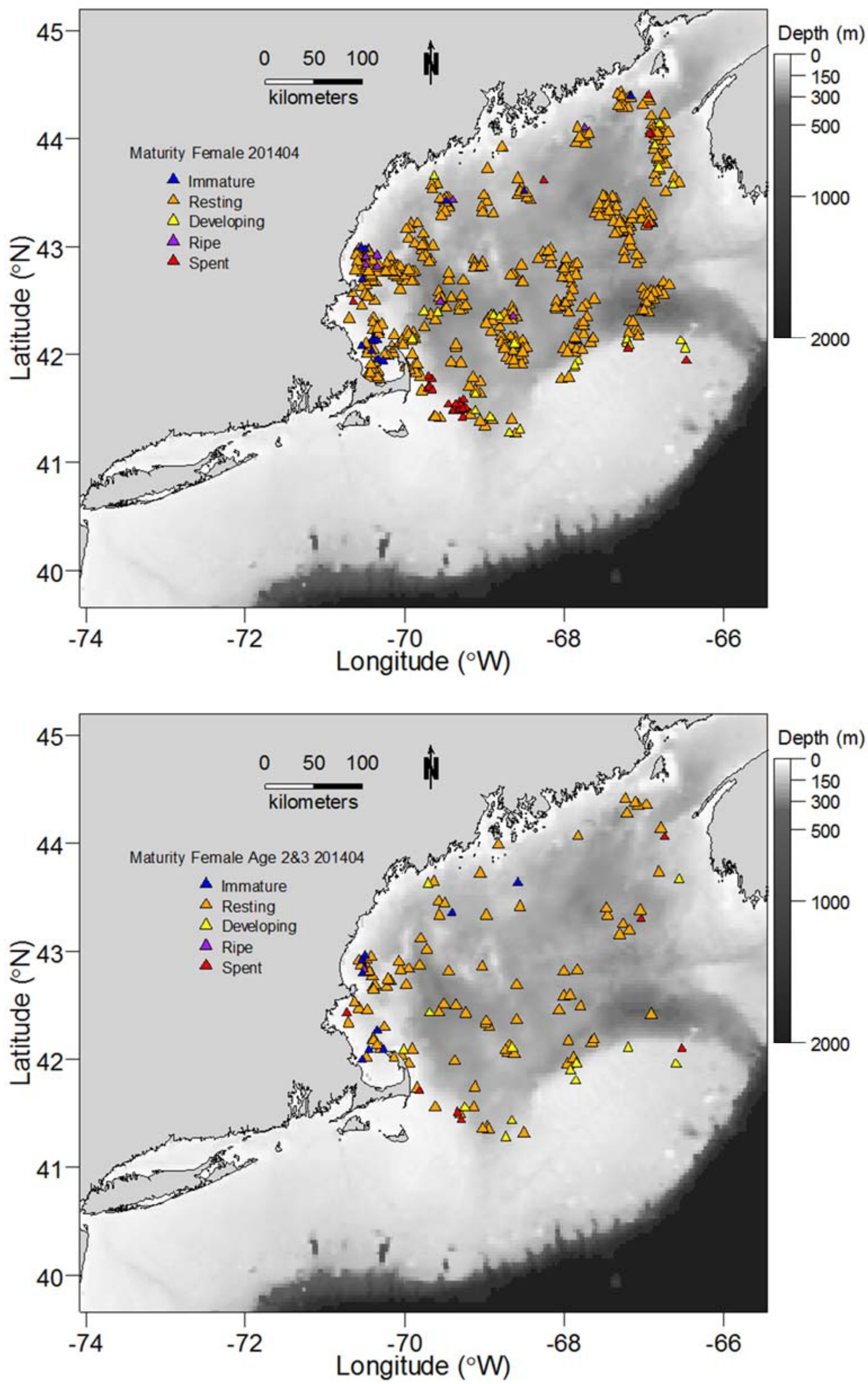
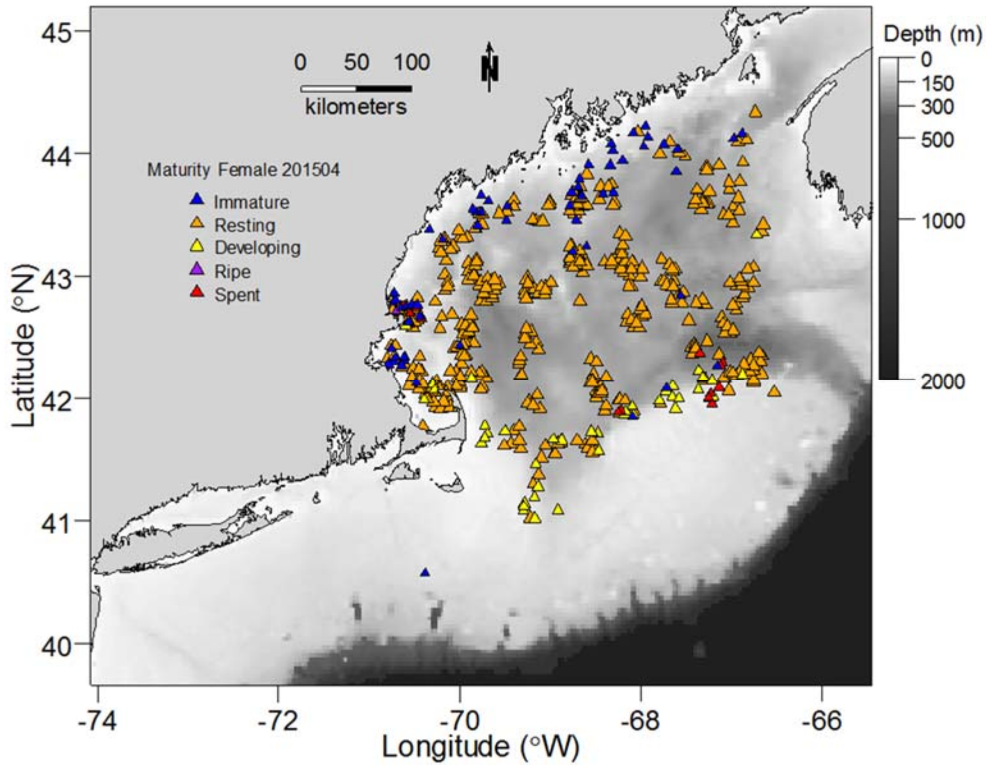


Figure 9. Distribution of all (top) and age 2 and 3 (bottom) females sampled for age, growth and maturity on the 2014 NEFSC fall bottom trawl survey. Points are jittered to reduce over-plotting.


0 50 100
kilometers
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Immature
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Developing
Ripe
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Depth (m)
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41
40
Latitude (°N)
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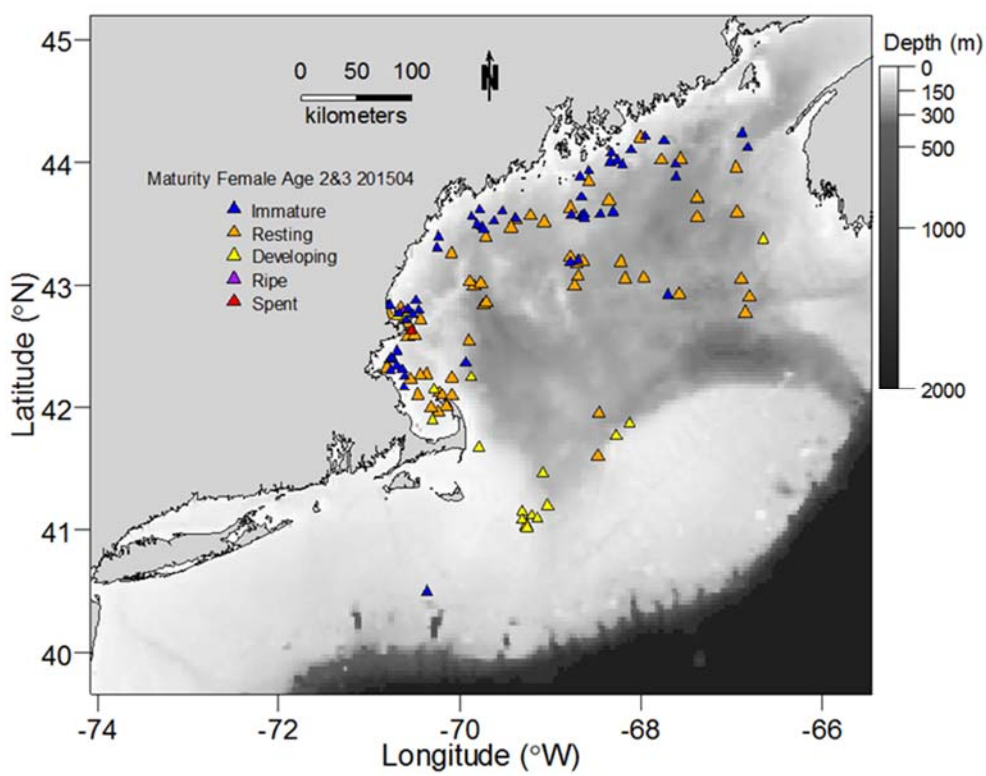
-72
-70
-68
-66
Longitude (°W)


0 50 100
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43
42
41
40
Latitude (°N)
-74
-72
-70
-68
-66
Longitude (°W)

Figure 10. Distribution of all (top) and age 2 and 3 (bottom) females sampled for age, growth and maturity on the 2015 NEFSC fall bottom trawl survey. Points are jittered to reduce over-plotting.

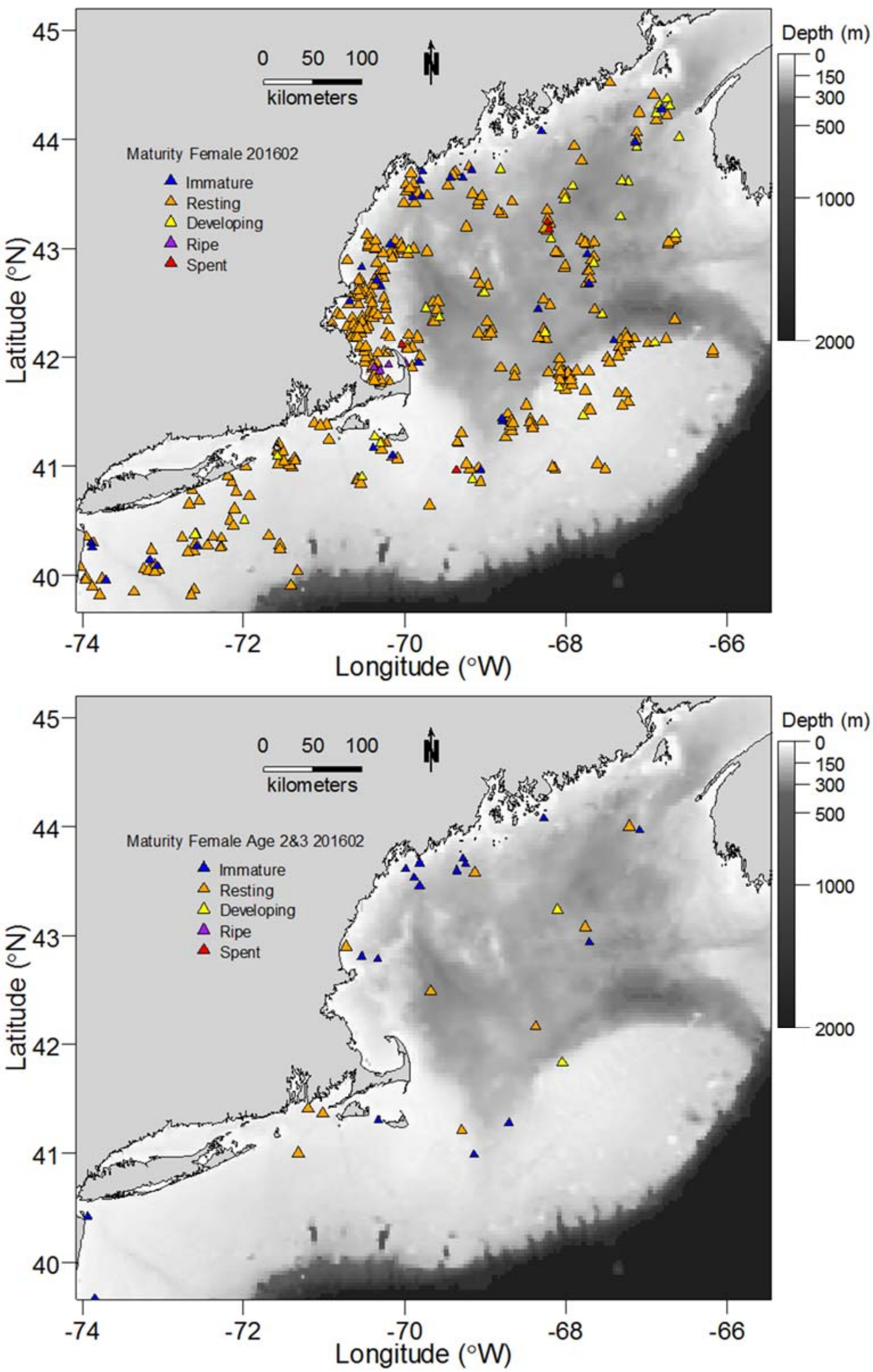


Figure 11. Distribution of all (top) and age 2 and 3 (bottom) females sampled for age, growth and maturity on the 2016 NEFSC spring bottom trawl survey. Points are jittered to reduce over-plotting.

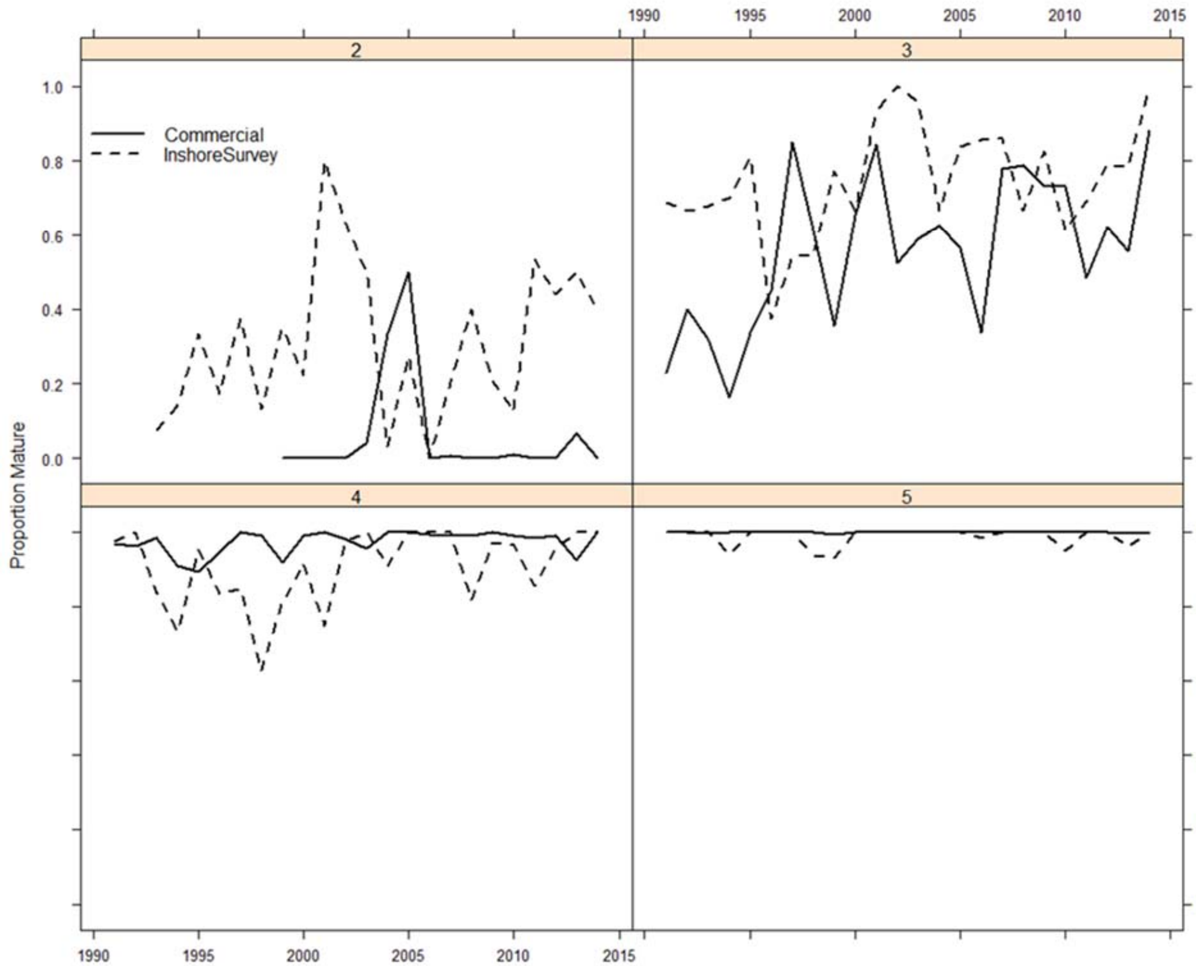


Figure 12. Proportion mature at age (age specified in the "strip" of each panel) from quarter three commercial fishery herring samples and the inshore strata (strata 26-27, 37-40) of the NMFS fall survey.

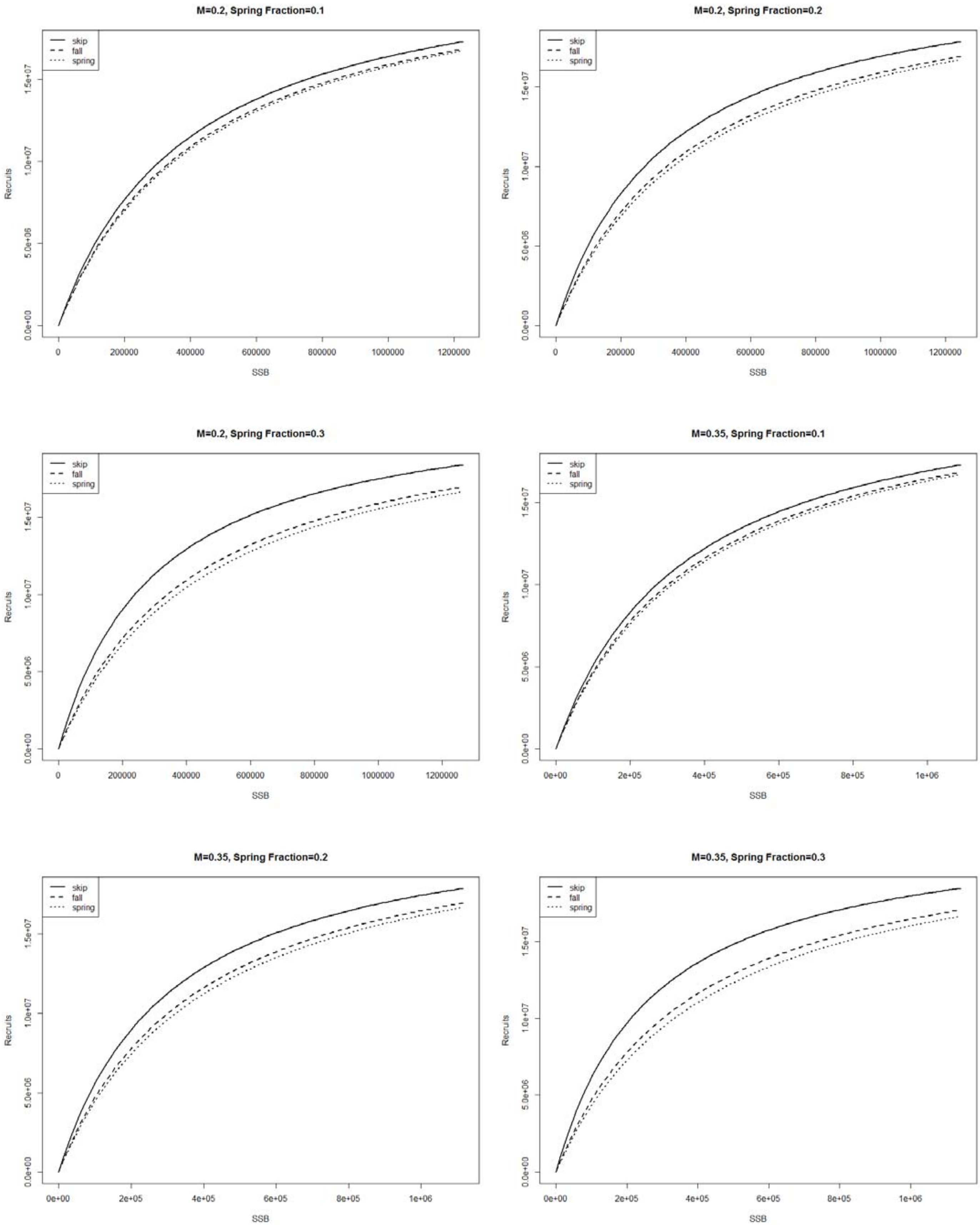
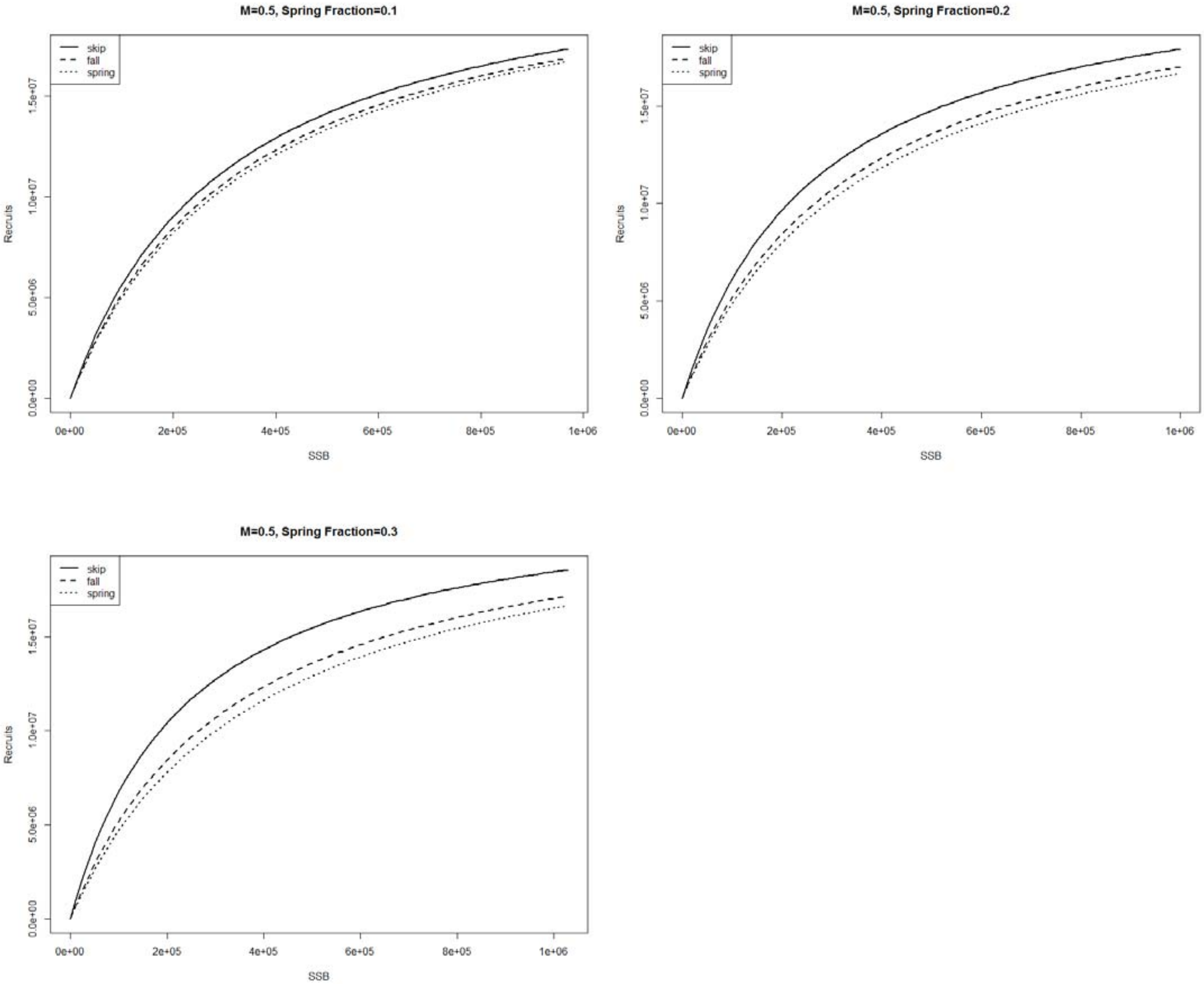
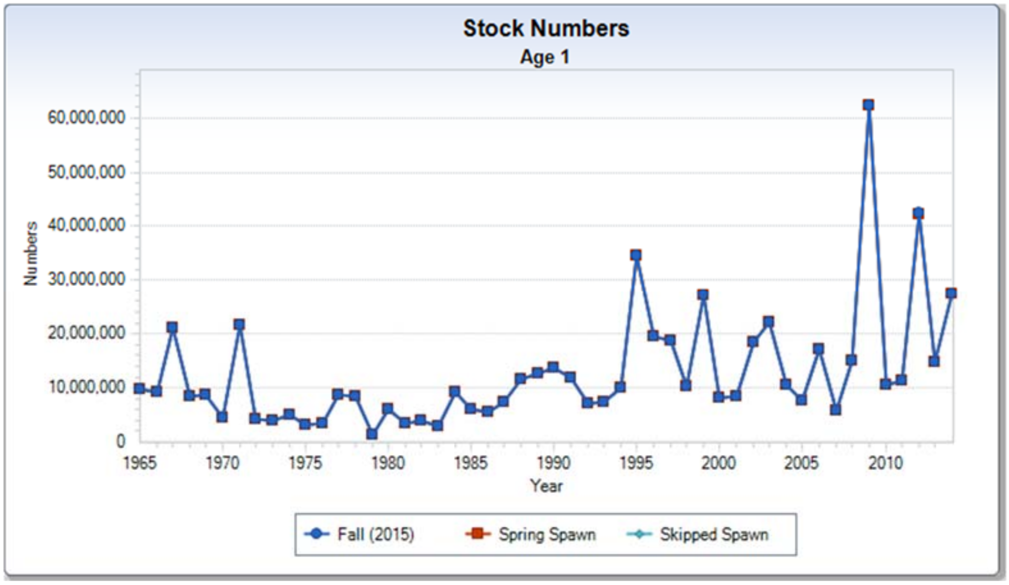


Figure 13.—Beverton-Holt stock-recruit model fits.

Figure 13. (continued)—





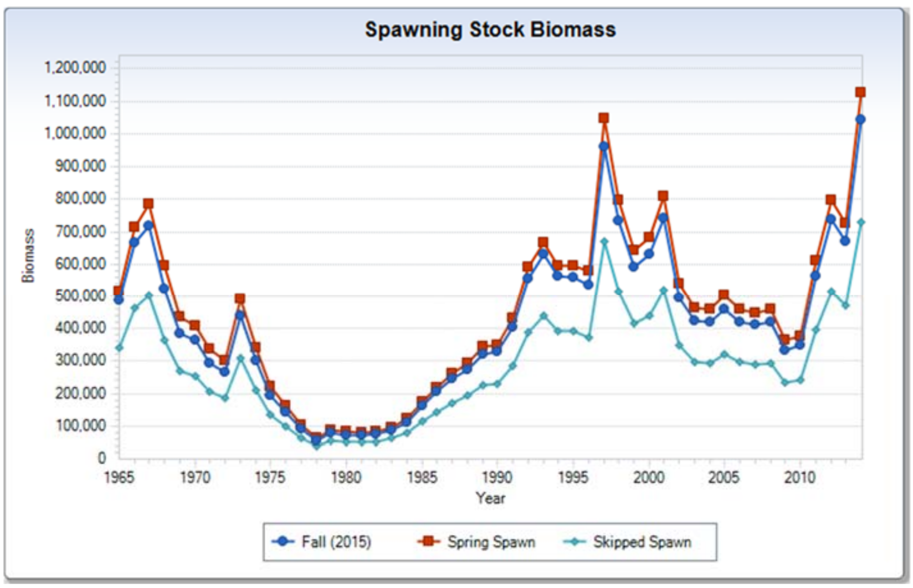


Figure 14.—Time series estimates from stock assessment models assuming all fall spawning and 30% spring or skipped spawning.

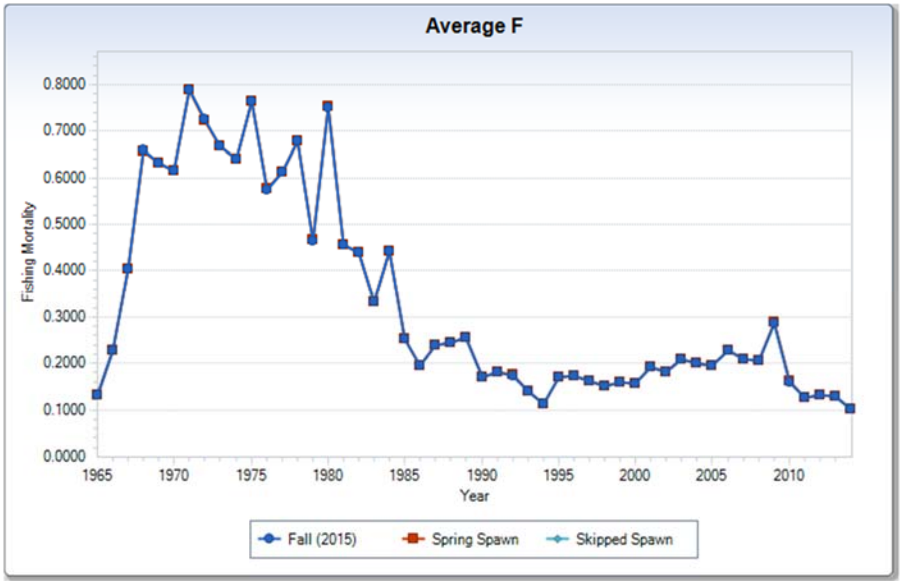


Figure 14.continued.

RECEIVED
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ASMFC

F/V Ocean Spray Partnership
Deake's Wharf
446 Commercial St.
Portland, ME 04101

PROVIDIAN

July 30, 2018

Robert E. Beal
Executive Director
ASMFC
1050 N. Highland Street, Suite 200A-N
Arlington, VA 22201

Robert E. Beal,

We agree with the NEFMC's recommendation to NOAA on the 2018 Sub-Annual Catch limits and to initiate action on the herring specifications for 2019-21. Hopefully, we can mitigate the effect of the possibility of a significant quota reduction. We believe that adjusting the allocation percentages for management areas is the best course of action. Area 1a should be allocated a higher percentage. This allocation would better the herring industry's market and be more beneficial to the Maine lobster industry.

Sincerely,

John-Paul Bilodeau
Regulations and Compliance

(207) 253-5626 Telephone (207) 841-7881 Cell (207) 253-5622 Fax ryan@fvprovidian.net

This letter was received from 217 individuals.

Tina Berger

From: Robert Beal
Sent: Friday, July 20, 2018 3:03 PM
To: Comments
Subject: FW: Uphold menhaden fishing cap that is critical to coastal economies

-----Original Message-----
From: s_choroman@everyactioncustom.com [mailto:s_choroman@everyactioncustom.com]
Sent: Friday, July 20, 2018 3:03 PM
To: Robert Beal <Rbeal@asmfc.org>
Subject: Uphold menhaden fishing cap that is critical to coastal economies

Dear Executive Director Robert Beal,

The recreational fishing community is deeply concerned with the failure of Virginia's legislature to pass legislation consistent with the Chesapeake Bay reduction fishing cap established by the Atlantic States Marine Fisheries Commission (ASMFC) in Amendment 3 to the Atlantic Menhaden Fishery Management Plan. Given the potential economic risks associated with overfishing this cap, I write to encourage you to find Virginia out of compliance with Amendment 3.

Menhaden are a critically important food source for striped bass, bluefish, summer flounder, and other sportfish that keep Americans coming back to Atlantic waters and spending money in coastal communities. In Virginia alone, more than 830,000 anglers contribute at least $2.1 billion annually to the local economy, supporting 18,600 jobs.

In November 2017, the ASMFC approved Amendment 3, which allows an eight-percent increase in the menhaden quota and places a reasonable cap on the level of menhaden harvested in the Chesapeake Bay. This limit, set at 51,000 metric tons, is greater than the average catch of the reduction industry in the Bay over the past five years and more than 30,000 metric tons higher than the 2017 Bay catch.

Given how important the Bay is to recreational and commercial fishermen in Virginia, Maryland, and all along the Atlantic coast, depleted menhaden populations in the Bay pose a real economic risk. Menhaden recruitment in the Bay has been low for more than 20 years, and many fishermen worry that striped bass, for which the Chesapeake is a critical nursery, are malnourished and diseased due to exploitation of Bay menhaden. The new Chesapeake Bay cap poses a minimal overall impact on the reduction fishery, but it is vitally important to the recreational and commercial fisheries that depend on menhaden being available in the Bay for bait harvest and support of predatory species like striped bass.

I respectfully request that the Commission find Virginia out of compliance with Amendment 3 at their August 7, 2018 meeting and, further, that the Commerce Department support this non-compliance determination.

Sincerely,
Mr. Steven Choromanski
10450 Buckeye St Littleton, CO 80125-9100 s_choroman@yahoo.com

From:	foragematters@aol.com
To:	Max Appelman
Cc:	David Blazer; mark.belton@maryland.gov; Megan Ware; Megan Ware; Allison Colden; Jason E. Mcnamee; Nicole Lengyel
Subject:	menhaden assessment questions
Date:	Tuesday, July 17, 2018 1:29:21 PM

Max.....menhaden coordinator ASMFC

I have read much of the material you sent me including the menhaden 2017 stock assessment and the 2017 Review for State compliance. I can't find answers to my question " just where are the menhaden schools the assessments indicates are out there" ?

These are the same basic unanswered questions that I had when I started this. Will you direct me to a member of the staff and/or one of the Commissioners that can answer or attempt to find answers to these questions.

Right now there are many undeniable signs that our Chesapeake Bay wild life are in bad shape .. The rock fish, for example ,depend on menhaden , both juveniles and adults . Rockfish are the species that most of the 400,000 Maryland salt water anglers depend on to enjoy their sport . As I understand it, and as I have experienced it personally, the last two Spring and Fall trophy rock seasons have been a failure . Our DNR just announced the blue crab population is down nearly 50% in two years. Maybe this could be explained by the number of rockfish being caught in
our area that have empty stomachs or just a small crab in them. There are many many other signs of the decline in our Bay fish species . From what I see and hear the majority of our saltwater anglers have quit fishing and if not, take a trip knowing they will only catch a catfish , skate or undersized rock.

The two objective "surveys "of menhaden in the Maryland Bay are the juvenile seine surveys and the pound net harvest. The Chesapeake was once the major nursery for juvenile menhaden on the Atlantic coast, juvenile menhaden that supplied the protein and energy that our young rockfish need to survive and flourish..that juvenile index has been pitifully low for years .I was told the pound net harvest last year showed a sharp drop. Those are facts.

As you know Rhode Island relies on weekly aerial surveys of their menhaden schools to manage menhaden, to count for abundance. From one of the spotter plane log sheet there were 240 schools seen in that small bay one day in June of 2014, the total exceeded 5,000,000 lbs that day . Right now there are very few menhaden in Narragansett Bay and the purse seiner has gone elsewhere . I see in the ASMFC State Compliance Report from 2017 page 10 that the Reduction Fisheries landings in the Virginia Bay were 20,000mt in 2017 which is less that 25% of the Cap plus "rollover" What are the obvious inferences that are being drawn by the ASMFC from that statistic ? How can that situation be reconciled with any thought the menhaden are stable or increasing so far as Maryland and Virginia are concerned ? Isn't it obvious there are drastic changes going on that are not being accounted for ? Isn't it equally obvious the Commission is allowing more and more fish to be taken from a shrinking population coming to Maryland and Virginia ?

We have been flying the Virginia Bay since June . We are hopeful of starting on the Maryland Bay in the near future and building this effort into a weekly survey plan that will yield useful data for the ASMFC in the future , however it is the present I hope is of very real concern to the assessors and the Commission. Perhaps we need to do some thinking out side the box.

As far as the Chesapeake Bay is concerned the Questions remain the same:

(1) After the reduction fishing begins each year what real evidence is there that Maryland receives its " fair, equitable share " of menhaden as required by Section Six paragraph (7) of the ASMFC Charter?
(2) What is the best estimate to date of the amount of menhaden that Maryland's fish and total Bay

wild life need to sustain themselves / grow to abundance in ; a year and in the months of the menhaden season ? Same question for Virginia.

(3) What is the best estimate from all sources available to you of the total amount by weight or number of schools of menhaden that make it from Virginia into Maryland on a monthly basis during the menhaden fishing season?

(4) Using the information you have available what is the usual estimated volume of menhaden or % of menhaden that circulate from the Maryland Bay during the fishing season that are caught in Virginia and thus never return to Maryland.

(5) Considering the more recent menhaden biomass assessment of over 1,000,000 mt is that an estimate for the Atlantic Coast off shore stock or the total stock of menhaden in the Atlantic and in the bays and rivers etc ? If for everything then what is the best estimate of the Atlantic stock ?

(6) Joseph Smith in his article on the Reedville fishery in Marine Fisheries Review (p.7) found that the usual catch size of schools in the Atlantic was from 15-30 t , at least in 2009 . Using that as a basis to start with , I would like to sit down with one of the staff to discuss if it is possible to translate the Atlantic assessment mentioned in (5) into the expected number of menhaden schools that should be in the Atlantic so the public and the Commissioners can determine if the assessment is in the ball park. I believe 100s of thousands of Marylanders and Virginians want and deserve answers to the Questions we have asked . These questions , I believe, are the same basic ones the Menhaden Board promised to answer more that ten years ago !

I am told by people that know that at this time of the year the Atlantic menhaden schools tend to be found from one mile to three -five miles from land . That they tend to be nearest to land in the morning and work off during the day. If these fish are there in anywhere near the amount the assessment says they are they would not be very hard to find. If you or one of the other Commissioners is willing to take some steps toward verification we would be interested is helping in any way we can.

Could you please make this email part of the material the stock assessment subcommittee will see as I would like to see if they will consider the thoughts about verification Thank you

Thomas Lilly for Friends of the Wicomico River (Maryland) 443 235 4465
foragematters@aol.com

American Eel

Activity level: Low

Committee Overlap Score: Medium (SAS overlaps with BERP, Atlantic herring, horseshoe crab)

Committee Task List
• TC –July 2018: review of Maine's aquaculture proposal • TC –July 2018: review of Draft Addendum V • TC – September 1st: Annual compliance reports due

TC Members: Jordan Zimmerman (DE, TC Chair), Ellen Cosby (PRFC, Vice Chair), Lindsey Aubart (GA), Kimberly Bonvechio (FL), Bradford Chase (MA), Chris Adriance (DC), Robert Eckert (NH), Sheila Eyler (USFWS), Alex Haro (USGS), Carol Hoffman (NY), Michael Kaufmann (PA), Wilson Laney (USFWS), Todd Mathes (NC), Patrick McGee (RI), Jennifer Pyle (NJ), Troy Tuckey (VIMS), Danielle Carty (SC), Keith Whiteford (MD), Gail Wippelhauser (ME), Tim Wildman (CT), Kristen Anstead (ASMFC), Kirby Rootes-Murdy (ASMFC)

SAS Members: Greg Hinks (NJ), Bradford Chase (MA), Matt Cieri (ME), Sheila Eyler (USFWS), Laura Lee (NC), John Sweka (USFWS), Troy Tuckey (VIMS), Keith Whiteford (MD), Kristen Anstead (ASMFC), Kirby Rootes-Murdy (ASMFC)

Mr. Martin Gary
Chair, ASMFC American Eel Management Board
1050 N. Highland Street Suite 200 A-N
Arlington, VA 22201

Dear Mr. Gary, July 31, 2018

This letter is to update the Atlantic States Marine Fisheries Commission American Eel Management Board (the Board) on the status of Maryland's 2017 eel harvest given the voluntary reductions put in place for that year. In 2017, Maryland's commercial eel industry requested that the state prohibit the harvest of eels on Saturdays and Sundays from September 1 through November 30, 2017, and close the eel fishery for the entire month of December 2017. Maryland's eel industry made this request in an effort to reduce Maryland's harvest by a sufficient amount to avoid surpassing the coast wide cap in 2017, and thereby avoid firing the management trigger under Addendum IV. With these voluntary measures in place, Maryland's eel harvest declined by an estimated 6.9% (40,308lbs) from 2016 and preliminary estimates of the 2017 coast wide harvest indicate that the cap will not be exceeded for the second year and the trigger under Addendum IV will not be fired.

Although it is likely that the decrease in Maryland eel harvest in 2017 is not due solely to the voluntary fall reductions, this success indicates that it is feasible to manage to a coast wide cap without state specific quotas and also that Maryland's industry stands ready to do its part when and if action is necessary to avoid firing a trigger or to reduce harvest to a cap.
It is our hope that the Board finds this update useful and informative as it deliberates final action on Addendum V.

Sincerely,

Lynn Fegley
Fishing and Boating Services, Maryland Department of Natural Resources
Maryland Administrative Commissioner (Proxy for David Blazer)

Coastal Sharks

Activity level: Low

Committee Overlap Score: low (some overlaps with South Atlantic Board species)

Committee Task List
• TC – August 1st: Annual compliance reports due

TC Members: Bryan Frazier (SC, TC Chair), Carolyn Belcher (GA), Brent Winner (FL), Greg Skomal (MA), Wilson Laney (USFWS), Chris Scott (NY), Lisa Hollensead (NC), Eric Schneider (RI), Greg Hinks (NJ), Jack Musick (VIMS), Angel Willey (MD, Vice Chair), Matt Gates (CT), Karyl Brewster-Geisz (NOAA), Michael Frisk (NY), Enric Cortes (NOAA), Scott Newlin (DE), Julie Neer (SAFMC), Kirby Rootes-Murdy (ASMFC)

Atlantic States Marine Fisheries Commission

DRAFT ADDENDUM V TO THE INTERSTATE FISHERY MANAGEMENT PLAN FOR ATLANTIC COASTAL SHARKS FOR BOARD REVIEW

August 2018

This draft document was developed for Management Board review and discussion. This document is not intended to solicit public comment as part of the Commission/State formal public input process. Comments on this draft document may be given at the appropriate time on the agenda during the scheduled meeting. If approved, a public comment period will be established to solicit input on the issues contained in the document.

ASMFC Vision:
Sustainably Managing Atlantic Coastal Fisheries

Table of Contents

1.0 Introduction

Atlantic shark fisheries from Maine through the east coast of Florida are currently managed through complementary fishery management plans by the Atlantic States Marine Fisheries Commission (Commission) and NOAA Fisheries Highly Migratory Species (HMS) Management Division. The Commission coordinates interstate management of Atlantic sharks in state waters (0-3 miles) via the 2008 Coastal Sharks Interstate Fishery Management Plan (FMP) and Addenda I-IV. Management authority in the Exclusive Economic Zone (3-200 miles from shore) lies with NOAA Fisheries via the 2006 Consolidated Atlantic HMS FMP and Amendments.

The Commission's Coastal Shark Management Board (Board) approved the following motion on May 1, 2018:

Move to initiate an addendum to give the Board the flexibility to implement measures for all species within the Coastal Sharks FMP through Board action.

This Draft Addendum proposes options to allow the Board to streamline the process of state implementation of federal shark regulations so that complementary measures are seamlessly and concurrently implemented at the state and federal level whenever possible.

2.0 Overview

2.1 Statement of Problem

The Commission's Coastal Sharks FMP currently allows for commercial quotas, possession limits, and season dates to be set annually through Board approved specifications. All other changes to commercial or recreational management can only be accomplished through an addendum or emergency action, as outlined in the Adaptive Management Section (4.5) of the FMP (ASMFC 2008). While addenda can be completed in a relatively short period of time (less than 6 months), the timing of the addenda and state implementation can result in inconsistencies between state and federal shark regulations, particularly when NOAA adopts changes through interim emergency rules. Inconsistencies can create confusion for anglers and commercial fishermen, present challenges for law enforcement, and most importantly, undermine the conservation of the resource, particularly when more restrictive measures have been implemented in federal waters based on changes in stock conditions. At times, the States can take up to a year to implement changes while at other times, States never implement any changes.

The only option for the Board to respond quicker than an addendum is through an emergency action, as outlined in the ISFMP Charter. However, there are rigorous criteria that define an emergency action, which are often not met. For example, NOAA Fisheries recently implemented an increase in the recreational size limit for shortfin mako sharks based on new assessment information. While this is an important conservation measure, it does not constitute an emergency action in states waters since the conservation of shortfin mako sharks is not substantially at risk by unanticipated changes in the ecosystem, the stock, or the fishery due to catch in state waters. After deciding not to modify shortfin mako regulations in state waters at the Board Meeting in May 2018, the Board chose to initiate this addendum to allow more flexibility in responding to changes in stock status for shortfin mako and all other shark species under the FMP moving forward.

2.2 Background

The Commission's Coastal Sharks FMP, adopted in 2008, manages coastal sharks as eight different complexes: prohibited, research, non-blacknose small coastal sharks (SCS), blacknose, aggregate large coastal sharks (LCS), hammerhead, pelagic, and smooth dogfish. Over the past 9 years, the FMP has been adapted 4 times through addenda. These addenda have been adopted to match regulatory changes made by NOAA HMS for federal waters and HMS permit holders.

To develop commercial management specifications annually, NOAA Fisheries considers recent year's landings data, stock assessment information, international agreements, and input from the HMS Advisory Panel and the public. As part of the Consolidated HMS FMP, NOAA Fisheries can set regional commercial quotas, possession limits, and season start dates by shark management group. NOAA Fisheries monitors the regional commercial quotas throughout the year and makes adjustments to the season length and possession limit to ensure the quotas are not exceeded.

Generally, NOAA Fisheries will identify commercial specifications (i.e., quota adjustments, season start dates, and starting possession limits) in a proposed rule for HMS permit holders and federal waters management in the fall, with the final rule released in November or December. At this time, NOAA Fisheries does not change recreational measures such as possession or size limits on an annual basis. Rather, as changes to the status of stock for shark species become available, NOAA Fisheries implements changes to both commercial and recreational measures in the regulations (e.g., baseline quota, size limits, baseline possession limits, etc.) to address these stock status changes through a proposed and final rulemaking. Additionally, in rare instances, NOAA Fisheries can implement interim emergency rule measures to respond to the new stock status or other emergencies. For all federal rulemakings, NOAA Fisheries provides at least one opportunity for public comment, although interim emergency rules may be implemented before public comment is considered.

Generally, the Commission follows NOAA Fisheries in setting specifications for the commercial fishery by adopting the same commercial quotas, possession limits, and season start dates by shark management groups. Annually, the Commission reviews the specifications as indicated in the proposed rule in October or early November, often waiting to finalize state waters specifications until after NOAA Fisheries publishes a final rule for federal waters. Some states move to implement changes in their measures for state waters and state permit holders once the final rule is published; others begin the process in the early part of the following year. As part of the Commission's complementary FMP, the Commission follows NOAA Fisheries for in-season changes to the possession limit. A previously noted, recreational management measures currently cannot be adjusted annually through specifications and require an addendum to modify the FMP.

3.0 Proposed Management Program

The proposed management program considers changes to the way the Board makes regulatory adjustments. The options below consider different approaches to how the Board can adjust coastal shark regulations as well as different timing on when this action can occur.

<u>Option 1: Status Quo</u>

If this option is selected, there would be no change to the current management program. Changes to any of the items listed in the Adaptive Management Section of the FMP could only be adjusted through an addendum or emergency action. Both an addendum and emergency action include opportunities for public comment.

<u>Option 2: Adjust All Needed Measures through Annual Specifications</u> *(Modifies Section 4.3.7 of the FMP)*

Under this option, the Board has the authority to annually change the following management measures during the Fall specifications meeting via Board action:

- Recreational size limits
- Recreational possession limits
- Recreational seasons
- Area closures (both recreational and commercial)
- Gear specifications (both recreational and commercial)
- Effort controls (both recreational and commercial)

Prior to setting specifications, the Board may seek input from the Coastal Sharks Technical Committee (TC) and Advisory Panel (AP) on how management measures should be adjusted as part of the annual specifications process, including a review of any new landings and stock assessment information.

Through a motion, the Board can then adopt these regulatory changes. It is important to note that regulatory changes through a specifications process does not require a public hearing or designated public comment period; however, members of the public are welcome to submit comments to the Board ahead of the specifications meeting for consideration. The approval of this option does not preclude the Board from using the addendum process.

Under this option, the Board also can make in-season adjustments to the above measures through a two-thirds vote of the Board as required under the Commission's voting procedures for modifying annual specifications.

Option 3: Adjust Measures on an Ad Hoc Basis as Needed

Under this option, in the event that new scientific information or management changes for federal waters and HMS permit holder becomes available, the Board will consider adjusting the following management measures via Board action on an as needed basis:

- Recreational size limits
- Recreational possession limits
- Recreational seasons
- Area closures (both recreational and commercial)
- Gear specifications (both recreational and commercial)
- Effort controls (both recreational and commercial)

In these circumstances, the Board may seek input from the Coastal Sharks TC and AP on how management measures should be adjusted at any point throughout the fishing season. Through a motion, the Board can then adopt these regulatory changes.

It is important to note that regulatory changes under this option would not require public hearings or a designated public comment period; however, members of the public are welcome to submit comments to the Board ahead of its meeting to consider of adjusting these measures. The approval of this option does not preclude the board from using the addendum process.

4.0 Implementation

TBD

References

Atlantic States Marine Fisheries Commission (ASMFC). 2008. Interstate Fishery Management Plan for Coastal Sharks.

Summer Flounder, Scup, & Black Sea Bass 2018 TC Tasks

Activity level: High

Committee Overlap Score: High (Multi-species committees for this Board)

Committee Task List

- TC- June 1st: Annual compliance reports due
- July 2018: In person meeting to develop recommendations on 2019 specifications (Coastwide Quota and RHLs) for summer flounder, scup and black sea bass
- July 2018: call to update FMP Review and state compliance reports (PRT composed of TC members)
- November 2018: In person meeting to recommend 2019 rec measures for summer flounder, scup, and black sea bass
- 2018 Summer Flounder Benchmark Stock Assessment
    - September 2018: SAW Data/Model/Biological Reference Point (BRP) Meeting
    - October 2018: SAW Data/Model/ BRP Meeting
    - November 2018 2018: Assessment Peer Review

Summer Flounder SAW Working Group: Jeff Brust, Tiffany Cunningham, Jason McNamee, Mark Terceiro

TC Members: Greg Wojcik (CT, TC Chair), Sydney Allhale (VA), Julia Beaty (MAFMC), Peter Clarke (NJ), Tiffany Cunningham (MA, TC Vice Chair), Kiley Dancy (MAFMC), Justin Davis (CT), Steve Doctor (MD), Emily Gilbert (NOAA), Jeff Kipp (ASMFC), John Maniscalco (NY), Jason McNamee (RI), Brandon Muffley (MAFMC), Kirby Rootes-Murdy (ASMFC), Gary Shepherd (NOAA), Caitlin Starks (ASMFC), Mark Terceiro (NOAA), Todd VanMiddlesworth (NC), Richard Wong (DE)

Atlantic States Marine Fisheries Commission

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MEMORANDUM

July 30, 2018

To: Summer Flounder, Scup, and Black Sea Bass Management Board

From: Kirby Rootes-Murdy, Senior FMP Coordinator

RE: Summer Flounder Recreational Management for 2019 and beyond

Addendum XXVIII specified summer flounder recreational management for 2017 and was extended for the 2018 fishing season. Addendum XXVIII expires at the end of this year. Absent a new addendum, the Board will need to consider either coastwide measures or conservation equivalency measures (state-by-state or voluntary regions*) for 2019. The following memo offers background information and potential options for summer flounder recreational management for 2019 and beyond.

Background

Management

Amendment 2 (1993) required each state (Massachusetts through North Carolina) to adopt the same minimum size, possession limit, and season length as established in federal waters for the recreational fishery, allowing only for different timing of open seasons. This set of coastwide measures were intended to uniformly impact the resource and stakeholders in all state and federal waters throughout the management unit.

Over time, the states determined coastwide measures did not provide equitable access to the resource. To address this disparity, the FMP was amended in 2001 (Framework Adjustment 2) to allow for the use of state-specific conservation equivalent measures, which constrains recreational harvest to the same level as under coastwide measures. This adjustment to the FMP created a new process, where the Board and Mid-Atlantic Fishery Management Council (Council) would annually determine whether to manage the fishery with coastwide measures or conservation equivalency (CE); when the latter is chosen, the Board takes the lead in approving state-specific regulations. The Board adopted a series of addenda (Addenda III and IV in 2001, and Addendum VIII in 2004) implementing CE. Estimates of 1998 state recreational harvest established the basis for state recreational harvest targets (Addendum VIII). From 2001-2013, the Board and Council opted to use state-specific CE. This provided states with the flexibility to tailor their regulations—i.e., minimum size, possession, and season limits—to meet the needs and interests of their fishery.

In the immediate years prior to 2014, state-specific management under CE resulted in large variation of measures across the coast, as well as between neighboring states. In 2014, the Board approved Addendum XXV which implemented mandatory regional management measures with the goal of moving away from state allocations under state-specific CE, allowing for more equitable access to the resource, and implementing consistent regulations at the regional level. Since Addendum XXV, there have been

* Voluntary regions were approved as a management tool in 2005 (Addendum XVII)

three addenda (XXVI-XXVIII) that have specified regional measures for summer flounder on an annual or

biennial basis. Addendum XXVIII, approved in February 2017, was the last addendum to specify regional management.

Recreational Data

Recreational management of summer flounder relies on data from NOAA Fisheries' Marine Recreational Information Program (MRIP). MRIP counts and reports marine recreational catch and effort and is driven by data provided by anglers and captains. MRIP replaced the Marine Recreational Fisheries Statistics Survey in 2008, which had been in place since 1979. Detailed information on MRIP can be found at http://www.st.nmfs.noaa.gov/recreational-fisheries/index .

In July 2018, the MRIP released revised catch and effort estimates for the entire time series of data (1981-2017). Theses revisions were based on a calibration from the Coastal Household Telephone Survey to the new, mail-based Fishing Effort Survey and a calibration from the revised Access Point Angler Intercept Survey (APAIS) adjustment outputs.

Specific to summer flounder, changes in the harvest estimates range from a 25% increase to a 210% increase from previous estimates. Historical estimates (1981-2017) are available in both the non-calibrated (old method) and the calibrated (new method) format.

Science

The 2016 assessment update indicated the summer flounder stock was not overfished, but overfishing was occurring. The model estimated spawning stock biomass (SSB) to be 79.9 million pounds in 2015, 58% of SSB_{MSY}= 137.56 million pounds. The fishing mortality rate (F) in 2015 was 0.390, 26% above the F threshold of $F_{MSYPROXY}$= F35% = 0.309. The update also indicated while catch in recent years has not been substantially over the acceptable biological catch (ABC), the projected F has been exceeded and the projected SSB has not been achieved. The 2015 and 2016 updates showed a moderate retrospective pattern where projected F is underestimated and SSB is overestimated.

A benchmark stock assessment is currently underway and scheduled to be completed and peer-reviewed in November 2018. This benchmark assessment will incorporate the entire time series of calibrated MRIP harvest estimates. The Board and Council are scheduled to consider the results of this benchmark assessment and peer review in February 2019.

Next Steps

At their joint August meeting, the Commission and Council will set specifications, including the commercial quota and recreational harvest limit (RHL), based on recent model SSB projections for the 2019 fishing season. The Council's Scientific and Statistical Committee (SSC) provided recommendations for an interim ABC (13.23 million pounds), which resulted in a proposed commercial quota of 7.72 million pounds and a 4.42 million pound recreational harvest limit (RHL) (see Table 1). When the results of the 2018 benchmark assessment and peer review are available (scheduled for early 2019), the Board and Council may reconsider the specifications, including the commercial quota and RHL.

Table 1. Summer Flounder 2018 Specifications and Proposed 2019 Specifications as Derived from the SSC-Recommended ABC of 13.23 million pounds

	Year	
Summer Flounder Landings Limits	2018	2019*
Commercial Quota	6.63 million pounds	7.72 million pounds
Recreational Harvest Limit	4.42 million pounds	5.15 million pounds

Determining 2019 recreational measures, prior to the release of the assessment results, will be complicated due to the possible change in the ABC and associated commercial quota and RHL. Normally, the Technical Committee (TC) would project recreational harvest for waves 5 and 6 in the current year to estimate total harvest. The projected harvest estimate is compared to the next year's RHL to set recreational measures. Because it is likely the ABC and, thus, the RHL will change with the results of the benchmark assessment, the TC would have double the workload if the normal process is followed. Staff is recommending recreational management measures are not set until after the Board and Council consider the results of the benchmark assessment to ensure the TC's workload is manageable.

The following options are available for the Board in considering the process to set 2019 recreational summer flounder measures. Options 1 and 2 appear to provide the most efficient path to set the 2019 measures.

1. <u>Add options to the Draft Black Sea Bass Addendum that would allow summer flounder recreational measures to be set through a specification process.</u> The Draft Addendum currently proposes allowing recreational measures to be set through Board action each year. Instead of taking an addendum out for public comment that does not have actual measures (due to data timing issues, previous addenda have only used example measures), the Board would adopt bag, size and season limits at a Board meeting through the specifications process. Public comment on measures would be collected via the state administrative public process as well at the Board meeting. While ASMFC has had public hearings on measures in the past, the bulk of the comments come from the state administrative process. This is the same public comment process that is used when the Board implements state-by-state measures. The addendum could define specific elements of the specification process (e.g. regions or limiting differences in measures between regions) or leave those elements to be determined each year during the specification setting process.

2. <u>Extend the provisions of Addendum XXVIII for a year</u>. The ISFMP Charter allows the Board to extend the provisions of the FMP for up to a year, specifically:

   The management board/section, by two-thirds vote, may extend, after giving the public one month's notice, the period of effectiveness for any FMP or provision that would otherwise expire for a period of up to six months, and may be extended for an additional six months, if the management board/section is actively working on an amendment or addendum to address the provisions that would otherwise expire. A two-thirds majority will be defined by the entire voting membership, however any abstentions from the federal services would not count when determining the total number of votes.

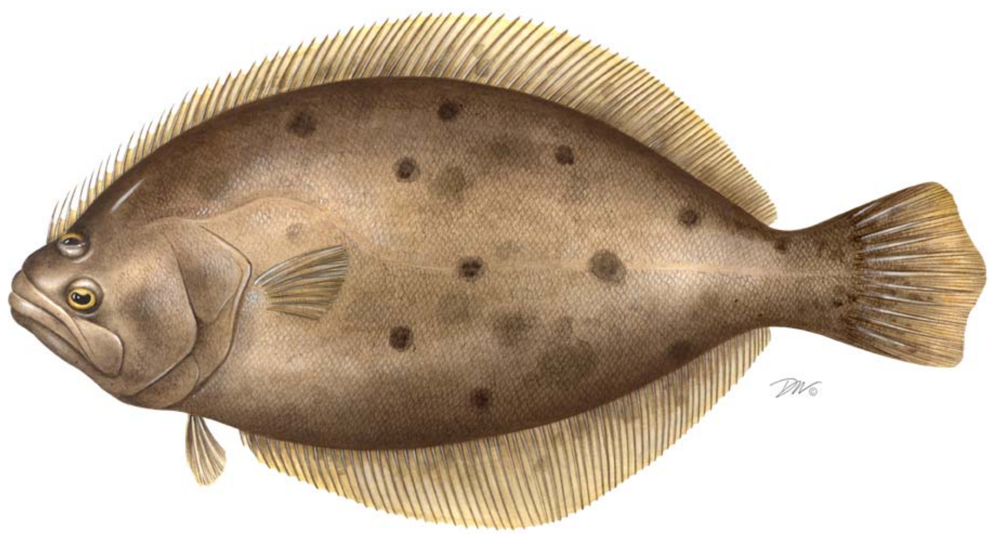
3. Use the voluntary regions tool under CE to establish 2019 regulations. For the past four years, the Board has adopted roughly the same regional boundaries. Under CE a group of states can voluntarily work together to establish a common set of bag, size, and season limits. The difficulty in using this process is that CE is not permitted within a region so differing size and bag limits would not be permitted. States within a region could have differing season start and end dates as long as the total season length was equal.

4. Initiate an addendum that considers recreational management strategies for 2019 and beyond. The Board could draft an addendum, similar to those implemented in previous years, to implement recreational measures in 2019 and beyond. The difficulty in drafting such a management document is the example measures would be based on the 2019 interim RHL. It is likely any measures drafted for public comment would change after the Board and Council considers the benchmark assessment in early 2019, which can be confusing to the public and lead to mistrust by stakeholders. In addition, the TC would have to complete additional analyses after the release of the assessment, doubling their workload.

5. Work within the provision of the FMP. As stated earlier, under the current provisions of the FMP the Board can 1) specify a coastwide set of measures or 2) return to state-specific allocations under CE based on states' recreational harvest in 1998. If the Board chooses state-by-state measures, it will need to determine if the proportion of harvest in 1998 should be based on calibrated or uncalibrated MRIP data.

2018 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN FOR THE 2017 SUMMER FLOUNDER FISHERY

SUMMER FLOUNDER
(Paralichthys dentatus)



Prepared by

Kirby Rootes-Murdy (ASMFC), Chair

Summer Flounder Plan Review Team
Kirby Rootes-Murdy (ASMFC), Chair
Kiley Dancy (MAFMC)
Justin Davis (CT)
Emily Gilbert (NOAA)
Todd VanMiddlesworth (NC DEQ)
Tiffany Vidal (MA)
Jessica Kuesel (ASMFC)

2018 REVIEW OF THE ASMFC FISHERY MANAGEMENT PLAN FOR SUMMER FLOUNDER *(Paralichthys dentatus)*

I. Status of the Fishery Management Plan

The summer flounder (*Paralichthys dentatus*) fishery of the Atlantic Coast is managed jointly by the Atlantic States Marine Fisheries Commission (ASMFC) Summer Flounder, Scup, and Black Sea Bass Management Board (Board) and the Mid-Atlantic Fishery Management Council (MAFMC or Council). The original ASMFC Fishery Management Plan (FMP), established in 1982, recommended a 14" minimum size limit. The MAFMC Plan, prepared in 1988 and based on the ASMFC plan, established a 13" minimum size limit. Since then, seventeen amendments have been developed and approved; it should be noted most but not all amendments have been implemented jointly by the Commission and Council.

The objectives of the FMP have not changed and are to: 1) reduce fishing mortality of summer flounder to ensure overfishing does not occur; 2) reduce fishing mortality on immature summer flounder to increase spawning stock biomass; 3) improve yield from the fishery; 4) promote compatible management regulations between State and Federal jurisdictions; 5) promote uniform and effective enforcement of regulations; and 6) minimize regulations to achieve the stated objectives.

The management unit includes summer flounder in US waters in the western Atlantic Ocean from the southern border of North Carolina northward to the US - Canada border. States and jurisdictions with a declared interest in the summer flounder FMP include all those from North Carolina through Massachusetts except Pennsylvania and the District of Columbia, as well as the National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFWS). An ASMFC Plan Review Team, Technical Committee, species board, and the MAFMC Demersal Committee are actively working on this plan.

Amendment 2 (approved in August 1993) provided a strategy for reducing fishing mortality to the fishing mortality threshold, while avoiding unreasonable impacts on fishermen. Commercial management measures included a moratorium on federal commercial permits, vessel and dealer permitting and reporting requirements, an annual commercial quota, minimum mesh requirements (5.5" diamond or 6" square mesh throughout the entire net), minimum mesh size requirement (200 pounds 11/1-4/30; 100 pounds from 5/1-10/31) with an exemption program. Recreational fishery measures include open access for-hire permit requirements, minimum size limits, possession limits, and seasonal closures.

The management system established under Amendment 2 has been modified by the following amendments, framework actions, and addenda. Amendment 3 (approved in July 1993) revised the mesh requirement exemption program and modified the poundage thresholds for the mesh requirements (change to two seasonal thresholds instead of year-round 100 pounds). Amendment 4 (approved in September 1993) revised the state-specific shares of the coastwide commercial quota allocation in response to a reporting issue in Connecticut. Amendment 5 (approved in December 1993) allows states to transfer or combine their commercial quota shares. Amendment 6 (approved in May 1994) allows properly stowed nets with a codend mesh size less than that stipulated in the plan to be aboard vessels in the summer flounder fishery. Amendment 7 (approved May 1995) adjusted the stock rebuilding schedule and capped the 1996-1997 commercial quotas at 18.51 million pounds. There is no Amendment 8 or 9 to the ASMFC FMP. The Council adopted Scup management measures as Amendment 8 and Black Sea Bass measures as Amendment 9, while the Board adopted separate Scup and Black Sea Bass Management Plans.

Amendment 10, approved by the Board in May 1997, initially sought to examine the commercial quota management system. Its scope was expanded to address a number of federal and state issues in the fishery, including: 1) allow framework adjustments to the minimum mesh size for any portion of the net; 2) require 5.5” diamond or 6” square mesh in the entire net of trawls; 3) continue the federal moratorium on commercial entry; 4) remove the requirement that federally permitted vessels must land summer flounder every year; 5) modify the federal vessel replacement criteria; 6) implement state *de minimis* criteria; 7) prohibit transfer at sea; 8) require states to report summer flounder landings from state waters to the NMFS; and 9) allow states to implement a summer flounder fillet at sea permit system. The amendment also considered alternative commercial quota schemes, including 1) a trimester quota with state-by-state shares during summer, 2) a trimester coastwide quota of equal periods, and 3) a revision to the existing state-by-state allocation formula. Ultimately, the Board and Council decided to maintain the current state-by-state quota allocation system.

Amendment 12, approved by the Board in October 1998, was developed to bring the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan in to compliance with the new and revised National Standards and other required provisions of the Sustainable Fisheries Act. Specifically, the amendment revised the overfishing definitions (National Standard 1) for summer flounder, scup and black sea bass and addressed the new and revised standards relative to the existing management measures (National Standard 8-consider effects on fishing communities, National Standard 9-reduce bycatch, National Standard 10-promote safety at sea). The Amendment also identified essential habitat for summer flounder, scup and black sea bass. Finally, Amendment 12 added a framework adjustment procedure that allows the Council to add or modify management measures through a streamlined public review process. Amendment 12 was partially approved by NMFS on April 28, 1999, with the disapproved measures mostly relating to concerns with essential fish habitat measures that were later addressed.

In December 2000, the Board approved Amendment 13. Although there were some management alternatives included in public hearing drafts of the document that could have resulted in changes to summer flounder management measures, none were approved for implementation. As a result, Amendment 13 had no impact on the summer flounder fishery.

Framework Adjustment 2 to the Summer Flounder, Scup and Black Sea Bass FMP, adopted in January 2001, provided the information and analyses necessary to implement a system of conservation equivalency for the recreational summer flounder fishery. Based on a coastwide recreational harvest limit, Framework 2 allows states to customize summer flounder recreational management measures to address issues associated with the availability of summer flounder on spatial and temporal scales.

Addenda III and IV were approved on January 29, 2001. Addendum IV provides that, upon the recommendation of the relevant monitoring committee and joint consideration with the Council, the Board will make a decision concerning what state regulations will be rather than forward a recommendation to NMFS. The states will then be responsible for implementing the Board’s decision. Addendum III established specifications for the 2001 recreational summer flounder fishery.

The Board approved Addendum VIII in December of 2003. Under this addendum, state-specific targets for recreational landings are derived from the coastwide harvest limit based on each state’s proportion of landings reported in 1998, which was the last year in which states were under a common set of management measures.

The Board approved Addendum XIII in August of 2004. This addendum modifies the FMP such that, within a given year, landings limits for the summer flounder, scup, and/or black sea bass can be specified for up to three years. Multi-year limits do not have to be constant from year to year, but instead are based upon expectations of future stock conditions as indicated by the best available scientific information during the year in which specifications are set.

The Board approved Addendum XV in December of 2004. The addendum was developed to allow for a change in the allocation scheme for the increased commercial quota from 2004 to 2005, approximately 1.3 million pounds, as well as the additional quota from 2004 to 2006, approximately 1.6 million pounds. For the fishing years 2005 and 2006, the associated quota increases were allocated to the following states as a bycatch allocation: 75,000 pounds of summer flounder were allocated each to Maryland, New York, Connecticut, and Massachusetts; 15,000 pounds were allocated to Delaware, 5,000 pounds to Maine, and 90 pounds to New Hampshire.

The Board approved Addendum XVII in August of 2005. Addendum XVII established a program wherein the Board could combine state-by-state recreational allocations into voluntary regions. This is an additional management tool in the management toolbox. This addendum also allowed the averaging or combining of multiple years of data (i.e. landings-per-angler, length-frequency distributions) in analyses to determine the impacts of proposed recreational management programs. The programs also included minimum fish sizes, possession limits, and fishing seasons. The averaging of annual harvest estimates is not allowed if the regional approach is used (i.e. the 1998 based allocations cannot be averaged across multiple years to create new allocations; multi-year averaging can be used to assess management measures).

The Board approved Addendum XVIII in February of 2006. The addendum sought to stabilize recreational fishing rules close to those that existed in 2005, in part, to minimize the drastic reductions that the three states were facing at the time. The addendum allowed the three states (NY, CT, and MA) facing large reductions in their harvest targets to capitalize on harvest opportunities that were foregone by states that chose to maintain their 2005 recreational fishing rules in 2006.

Addendum XIX, approved in August 2007, broadened the descriptions of stock status determination criteria contained within the Summer Flounder, Scup, and Black Sea Bass FMP to allow for greater flexibility in those definitions, while maintaining objective and measurable status determination criteria for identifying when stocks or stock complexes covered by the FMP are overfished. It established acceptable categories of peer-review for stock status determination criteria. When these specific peer-review metrics are met and new or updated information is available, the new or revised stock status determination criteria may be incorporated by the Board directly into the annual management measures for each species, rather than requiring a modification to the FMP.

The Board approved Addendum XXV in February of 2014. The addendum implemented regional conservation equivalency for the 2014 fishing year, and sought to respond to the unintended consequence of using conservation equivalency (e.g., state-specific recreational management measures) such as different measures between neighboring states and across the coast. The addendum established new regional measures that in combination would constrain harvest to coastwide recreational harvest limit. For 2014, the regions were the following: Massachusetts; Rhode Island; Connecticut through New Jersey; Delaware through Virginia; and North Carolina. All states within a region have the same minimum size, bag limit, and season length. A continuation of Addendum XXV was codified in Addendum XXVI by the

Board in February 2015. Addendum XXVI continued the regional management measures established in 2014 through 2015.

The Board approved Addendum XXVII in February 2016. The addendum addressed 2016 recreational summer flounder and black sea bass fisheries management, continuing regional management measures for 2016 and addressing discrepancies in summer flounder management measures within Delaware Bay. The 2016 recreational fishery was divided into six management regions, the same five regions as under Addendum XXV and XXVI, but with New Jersey separated out from New York and Connecticut into its own region, with states within the same region required to implement the same bag, size limits, and season length. By separating New Jersey into its own region, the addendum allowed the state to make regulations different in Delaware Bay than in the rest of the state. Outside of the Delaware Bay, New Jersey regulations stayed consistent with those in New York and Connecticut. Within the Bay, New Jersey regulations consisted of a similar size limit as in Delaware, the same possession limit as Delaware, and the same season as the rest of New Jersey. The line of demarcation for regulation implementation was the COLREGS Demarcation Line.

In February 2017, ASMFC's Summer Flounder, Scup and Black Sea Bass Management Board approved Addendum XXVIII maintaining regional management for the recreational summer flounder fishery through 2017. This Addendum required a one-inch increase in size limit and lowered possession limits to 4 fish or less to reduce fishing pressure on the stock, which was experiencing overfishing.

After submitting a conservation equivalency proposal which was not accepted, the Commission found New Jersey to be out of compliance with Addendum XXVIII in June 2017. ASMFC passed on its recommendation of noncompliance to the Secretary of Commerce. However, the Secretary of Commerce did not agree with the Commission's recommendation and found New Jersey to be in compliance with Addendum XXVIII. This is the first time that the Secretary of Commerce has not agreed with the Commission's recommendation for noncompliance.

II. Status of the Stock

The most recent summer flounder assessment was the June 2016 Stock Assessment Update.

Relative to the biological reference points established during the 2013 benchmark assessment, the stock was not overfished but overfishing was occurring in 2015. Fishing mortality (F) on fully selected age 4 fish ranged between 0.793 and 1.776 from 1982-1996 and then decreased to 0.284 in 2007. Since 2007, the fishing mortality has increased to 0.390 in 2015, 26% above the SAW 57 maximum fishing mortality threshold (F Threshold= F_{MSY}=F35$_{\%}$ = 0.309).

Spawning stock biomass (SSB) decreased from 55.16 million pounds in 1982 to 15.58 million pounds in 1989 and then increased to peaks of 101.48 million pounds in 2003 and 104.73 million pounds in 2010. SSB was estimated to be 36,240 metric tons (mt) = 79.90 million pounds in 2015, 58% of the biomass target reference point = SSBMSY = SSB35% = 62,394 mt = 137.56 million pounds, and 16% above the biomass threshold reference point of ½ SSB_{MSY} proxy = ½ $SSB_{35\%}$ = 31,197 mt =68.78 million lb. A new rebuilding plan would be triggered in the event that estimated biomass falls below the minimum stock size threshold.

Average recruitment from 1982 to 2015 is 41 million fish at age 0. The 1983 and 1985 year classes are the largest in the assessment time series at 75 and 62 million fish, while the 1988 year class is the smallest at only 10 million fish. The update assessment shows that recruitment of age 0 fish was below the time series average each year from 2010 through 2015. The 2015 year class is estimated to be below average at 23 million fish.

III. Status of the Fishery

Commercial landings peaked in 1984 at 37.77 million pounds, and reached a low of 8.8 million pounds in 1997. From 2005 through present, commercial landings have been variable, with two peak years (16.91 million pounds in 2005 and 16.57 million pounds in 2011) that have been followed by steady declines. Over the last five years landings have continued to decline in part due to annual quota limits set in response to the condition of the resource. From 2012-2014, landings exceeded the commercial coastwide quota. 2015 and 2016 commercial landings declined to 10.6 million pounds and 7.76 million pounds, respectively. In both years, approximately 96% of the coastwide quota was harvested. Preliminary landings data were approximately 5.75 million pounds. The principle gear used in the fishery is the otter trawl. Commercial discard losses in the otter trawl and scallop dredge fisheries are estimated from observer data and accounted for 17% of the total commercial catch over the last 10 years.

Recreational harvest from 2005 to present has also shown steady declines in part due to declines in the coastwide recreational harvest limit. From 2009 through 2013 harvest was below the recreational harvest limit (RHL); in 2014 coastwide harvest exceeded the RHL by 5% at 7.39 million pounds. In 2015, the coastwide harvest of 4.72 million pounds was significantly lower than previous years despite similar regulations. In 2016, the coastwide harvest increased to 6.18 million pounds, exceeding the 2016 RHL of 5.42 million pounds by 14%. In 2017, the coastwide harvest decreased to 3.19 million pounds, a 48% reduction from 2016. Recreational discard losses have recently accounted for 20% of the total recreational catch.

IV. Status of Assessment Advice

The 2016 assessment updates indicates that while catch in recent years has not been substantially over the Acceptable Biological Catch, the projected fishing mortality rates have been exceeded and projected spawning stock biomass has not been achieved. These results appear to be largely driven by below average recruitment, an underestimation of the fishing mortality level in the last years of the assessment, and declining biomass indices. Harvest limits were adjusted for 2016 and beyond to address overfishing.

Biological Reference Points (SSB and F estimates updated by the 2016 Stock Assessment Update)

- F Threshold= F_{MSY}=$F35_{\%}$ = 0.309
- Current (2015) F=0.390; overfishing is occurring
- Spawning Stock Biomass (SSB) threshold = 68.8 million pounds
- SSB target = 137.6 million pounds
- Current SSB (2015) =79.9 million pounds; stock is not overfished

V. Status of Research and Monitoring

Several states and NMFS conduct seasonal sampling cruises using an otter trawl to assess the condition of summer flounder populations inshore and in the Exclusive Economic Zone (EEZ). Massachusetts collects sex and maturity samples and local abundance indices from spring and fall otter trawl surveys, as well as young of the year information in its winter flounder juvenile seine survey. The Commonwealth monitored the commercial fishery through the observation of six directed trawl fishery trips, as well as through dealer Integrated Voice Response (IVR) systems and mandatory fishermen's logbook. Rhode Island monitors the commercial quota for summer flounder using an automated IVR system and dealers are required to provide weekly reports through the IVR of summer flounder landings. Connecticut commercial summer flounder landings are monitored through monthly commercial fishermen logbooks, and weekly and monthly dealer reports. These reports contain daily records of fishing and dealer purchase activity. New York conducts a survey of recreational anglers on open boats throughout the marine district to collect additional data on size composition of kept and discarded fish and also conducts a small mesh otter trawl survey in the Peconic Bays that samples summer flounder. New York requires trip level reporting from all of its commercial fishermen and monitors quota through a combination of trip reports and dealer reports. New Jersey collects data from the commercial trawl fishery and conducts an ocean trawl survey from which data on summer flounder are collected and catch-per-unit-of-effort and distribution information are generated for juveniles and adults. Delaware's commercial landings are monitored through a mandatory monthly harvest report from all state-licensed fishermen. Maryland constructs a juvenile index from trawl data collected in the ocean side bays and is also compiling data on population age, sex, and size from summer flounder taken in pound nets. A statewide voluntary angler survey is conducted that records location, time spent fishing, number of fish caught, number kept, and lengths of the first 20 fish caught. Virginia prepares a young-of-the-year index from data collected from beach seine and trawl surveys. North Carolina conducts two otter trawl surveys for juvenile fluke and collects information on age and growth and catch-per-unit-of-effort for the winter trawl fishery, estuarine gill net fishery, pound net fishery, the ocean gill net fishery, commercial gig, and the long haul seine fishery.

VI. Status of Management Measures and Issues

Management measures imposed upon harvesters of summer flounder include an annual commercial quota and recreational harvest limit, minimum sizes, minimum mesh requirements for trawls, permits and administrative fees for dealers and vessels, a moratorium on entry into the commercial fishery, mandated use of sea samplers, monitoring of sea turtles in the southern part of the management unit, and collection of data and record keeping by dealers and processors. Fishing mortality was controlled by a total allowable landings (TAL) from 1993-2009. From 2009 to 2012 an acceptable biological catch (ABC) or total allowable catch (TAC) was specified; starting in 2012 this was expressed only as the ABC. The ABC is further divided into allocations by sector: commercial (60% of the ABC landings) and recreational (40% of the ABC landings). The commercial quota is allocated to each state based on landings during a baseline period (1980-1989), and any overages are subtracted from a state's quota for the following year. The state allocations of the commercial quota are included in Table 1.

Summer Flounder Compliance Criteria

The PRT found no compliance issues.

De Minimis

Delaware requests *de minimis* status. The PRT notes that they meet the requirement of *de minimis*.

COMMERCIAL FISHERY

The following measures may change annually. The 2017 measures are indicated.

<u>Minimum size</u>: 14”
<u>Minimum mesh and threshold</u>: 5.5” diamond, 6” square
<u>Thresholds</u>: 200 pounds in the winter (Nov 1-Apr 30) and 100 lb in the summer (May 1-October 31)
<u>Regulation of mesh beyond the codend</u>: 5.5” diamond or 6” square throughout the mesh

2017 Commercial quota: 5.66 million pounds

The following measures are not subject to annual adjustment.

Quota management provisions: States are required to adopt appropriate measures to manage their quota shares. States may transfer or combine their quota shares as specified in Amendment 5. States must document through a vessel and dealer reporting system all landings that are not otherwise included in the federal monitoring of permit holders. States are required to forward all landings information to the NMFS for inclusion in quota reporting.

Transfer at Sea: States must prohibit permitted summer flounder vessels from transferring summer flounder from one vessel to another at sea. (As specified in Amendment 10)

De minimis status: States having commercial landings less than 0.1% of the coastwide total will be eligible for *de minims* status. (As specified in Amendment 10). Delaware has requested de minimis status and meets the requirements.

RECREATIONAL FISHERY

The Management Board chose to adopt regional management through conservation equivalency for the 2017 recreational fishery under the provisions of Framework 2 (see table 4 for state measures). As such, the Federal recreational bag limit and minimum fish size were waived and the fishing season and vessel owners were subject only to the regulations in their states.

2017 recreational harvest limit: 3.77 million pounds.

OTHER MEASURES

Fillet at sea permit: Party or charter vessels in state waters will be allowed to fillet at sea if they obtain a state issued permit allowing such activity. (As specified in Amendment 10)

Reporting:

1. States must submit a commercial fishery management proposal by October 1 of each year. The proposal must detail the specific management measures that the state intends to use to manage their commercial quota allocation. The proposal must be reviewed and approved by the Management Board.

2. States must submit an annual compliance report to the Chairman of the Summer Flounder Plan Review Team by June 1 of each year. The report must detail the state's management program for the current year and establish proof of compliance with all mandatory management measures and all framework changes specified for the current year. It should include landings information from the previous year, and the results of any monitoring or research program.

This summary of compliance criteria is intended to serve as a quick reference guide. It in no way alters or supersedes compliance criteria as contained in the Summer Flounder FMP and Amendments thereto.

VI. Current State-by-State Implementation of FMP Requirements

The PRT notes that after reviewing state compliance reports, all states are compliant with the FMP requirements with one exception: New Jersey did not include in the state compliance report regulations outlining prohibition of transfers at sea. The PRT did noted that Virginia should clarify in their state compliance report that trawling is prohibited in state waters to avoid confusion with having measures inconsistent with the FMP. The PRT does note that moving forward, state compliance reports should be adjusted in the following three ways:

1) Better language indicating whether all FMP requirements have been implemented, and if not applicable, for them to be noted up front. Many state compliance reports do indicate this clearly.
2) Move a more standardized format of indicating changes to current and future management measures as reflected in state regulations. Many states include more regulatory information than is needed.
3) Landings and survey indices information should be submitted in an excel spreadsheet and compliance reports should be submitted in word documents; this does not preclude a state from including current table or figure of this information, but without the data in a more accessible format, it creates additional work to remove confidential data and update other management documents.

<u>1993 - 2017 Summer Flounder FMP Compliance Schedule</u>

COMMERCIAL:

14" minimum size	3/1/97
Ability to regulate mesh in any portion of the net	1/1/98
5.5” diamond or 6” square mesh throughout entire net	6/3/98
Prohibition of transfer at sea	1/1/98
Mandatory reporting to NMFS of landings from state waters	1/1/98
Small mesh exemption program	1/21/93
Flynet minimum mesh size exemption	1/21/93

RECREATIONAL:

Regional Management Measures under conservation equivalency	2/2017

GENERAL

Submission of annual commercial management plan	10/1/97, annually thereafter
Submission of annual landings and compliance report	6/1/98, annually thereafter

Table 1. State by state allocation for annual commercial quota

State	Allocation (%)
Maine	0.04756%
New Hampshire	0.00046%
Massachusetts	6.82046%
Rhode Island	15.68298%
Connecticut	2.25708%
New York	7.64699%
New Jersey	16.72499%
Delaware	0.01779%
Maryland	2.03910%
Virginia	21.31676%
North Carolina	27.44584%
Total	100%

Table 2. Summer Flounder Commercial Landings by State (2007-2017) in pounds.

Source: ACCSP. 2017. Commercial Landings Summaries (Dealer Reports) for 2007-2016– Non-confidential; generated by J.Kuesel; using ACCSP Data Warehouse, Arlington, VA. & State Compliance Reports for 2017 data (July 2018)

State	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017**
MA	659,784	644,404	731,174	851,889	1,132,192	891,495	859,150	694,777	748,433	585,637	420,342
RI	1,515,684	1,473,439	1,793,891	2,289,379	2,824,032	2,064,076	1,799,394	2,054,951	1,716,095	1,303,001	872,089
CT	205,115	220,510	256,768	308,341	401,377	298,849	280,652	253,442	286,890	185,592	133,759
NY	929,132	832,415	1,119,093	1,330,015	1,483,785	1,237,126	999,206	833,577	829,929	602,527	491,418
NJ	1,697,472	1,540,811	1,798,903	2,165,325	2,830,686	2,268,793	1,995,298	1,826,455	1,681,962	1,294,308	960,149
DE	2,261	1,213	2,952	1,858	836	677	913	1,687	1,349	2,236	1,297
MD	228,809	208,219	213,564	263,302	259,392	139,824	165,134	164,384	187,811	158,970	114,471
VA	1,853,693	1,651,575	1,978,754	2,589,786	4,050,998	4,111,708	4,868,842	2,049,045	2,273, 593	1,560,927	1,200,834
NC	2,670,110	2,406,603	2,859,039	3,310,992	2,854,122	1,090,218	541,542	2,911,750	2,878,753	2,071,089	1,563,045
Total	9,762,060	8,979,189	10,754,138	13,110,887	15,837,420	12,102,766	11,510,131	10,790,068	8,331,222	5,693,198	5,757,404

**2017 Landings are preliminary.

Table 3. Recreational Summer Flounder Harvest by State (2007-2017) in weight (pounds).
Source: "Personal Communication with National Marine Fisheries Service, Statistics Division June 2018"

State	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**
MA	368,084	635,196	121,120	137,611	202,665	175,110	64,365	238,604	146,532	124,411	78,333
RI	553,056	831,062	348,603	458,873	511,544	335,506	372,672	636,207	600,597	269,412	230,371
CT	371,907	567,132	195,883	132,013	186,834	191,119	888,906	391,168	337,194	678,479	298,503
NY	3,249,126	2,738,108	1,449,759	1,612,298	1,718,121	1,760,650	1,954,821	1,668,848	1,569,139	2,281,086	750,333
NJ	2,727,838	2,113,217	2,466,799	1,614,357	2,116,951	3,063,723	3,286,543	3,608,939	1,442,827	2,323,874	1,370,670
DE	330,307	147,895	259,169	159,976	182,733	141,935	159,185	227,913	114,638	230,925	87,826
MD	206,522	169,323	168,025	91,834	55,686	61,514	108,690	179,313	103,613	52,303	77,628
VA	1,311,429	883,168	917,153	789,856	880,639	658,476	449,002	370,230	342,545	191,555	253,008
NC	218,441	64,571	103,867	111,539	100,543	101,642	70,874	67,791	64,065	30,355	41,996
Total	9,336,710	8,149,672	6,030,378	5,108,357	5,955,716	6,489,675	7,355,058	7,389,013	4,721,150	6,057,989	3,188,688

Table 4. 2017 recreational management measures for summer flounder by state.

State	Minimum Size (inches)	Possession Limit	Open Season
Massachusetts	17	4 fish	May 22-September 23
Rhode Island	19	4 fish	May 1-December 31
Connecticut*	19	3 fish	May 17-September 21
*At 41 designated shore sites	17		
New York	19	3 fish	May 17-September 21
New Jersey*	18	3 fish	May 25-September 5
*NJ Pilot shore program 1 site	16	2 fish	May 25-September 5
New Jersey/Delaware Bay COLREGS**	17	3 fish	May 25-September 5
Delaware	17	4 fish	All year
Maryland	17	4 fish	All year
PRFC	17	4 fish	All year
Virginia	17	4 fish	All year
North Carolina	15	4 fish	All Year

*New Jersey east of the COLREGS line at Cape May, NJ will have management measures consistent with the northern region of Connecticut – New York.

**New Jersey west of the COLREGS line at Cape May, NJ inside Delaware Bay will have a similar size limit to the southern region (DE-VA), the same possession limit as the southern region (DE-VA), and the same season length as the northern region of Connecticut – New York.

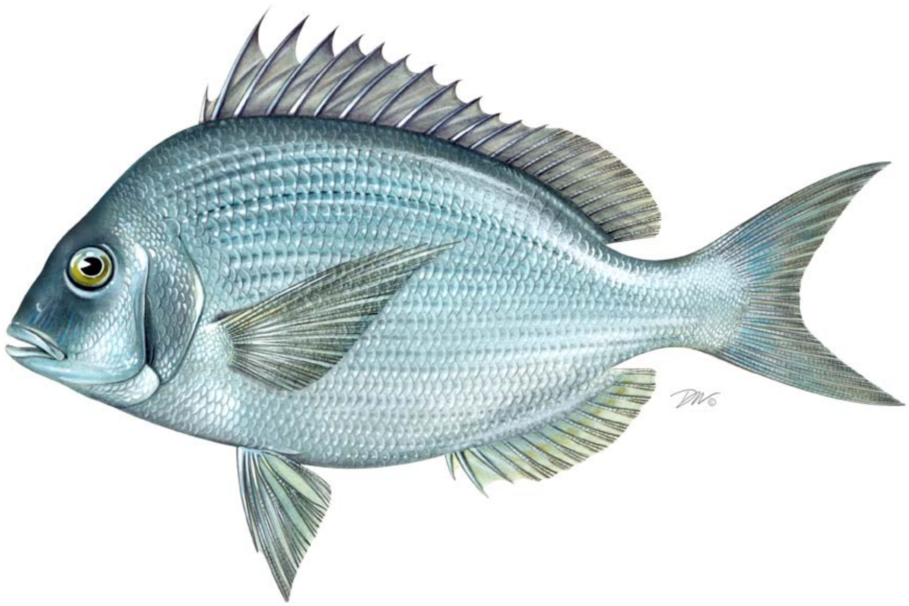
Table 5. 2018 recreational management measures for summer flounder by state.

State	Minimum Size (inches)	Possession Limit	Open Season
Massachusetts	17	5 fish	May 23-October 9
Rhode Island	19	6 fish	May 1-December 31
Connecticut*	19	4 fish	May 4-September 30
*At 45 designated shore sites	17		
New York	19		
New Jersey*	18	3 fish	May 25-September 22
*NJ Pilot shore program 1 site	16	2 fish	
New Jersey/Delaware Bay COLREGS**	17	3 fish	
Delaware	16.5	4 fish	All year
Maryland	17		January 1-March 31
	16.5		April 1-December 31
PRFC	16.5		All year
Virginia	16.6		All year
North Carolina	15	4 fish	All Year

*New Jersey east of the COLREGS line at Cape May, NJ will have management measures consistent with the northern region of Connecticut – New York.

**New Jersey west of the COLREGS line at Cape May, NJ inside Delaware Bay will have a similar size limit to the southern region (DE-VA), the same possession limit as the southern region (DE-VA), and the same season length as the northern region of Connecticut – New York.

2018 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN for the 2017 SCUP FISHERY
SCUP *(Stenotomus chrysops)*



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2018 Review of the Atlantic States Marine Fisheries Commission

Fishery Management Plan for Scup for the 2017 Fishing Year

I. Status of the Fishery Management Plan

States with a declared interest in the Scup FMP are Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina. The Commission's Summer Flounder, Scup, and Black Sea Bass Management Board serves as the species management board, and the Demersal Species Committee guides plan development for the MAFMC. The Summer Flounder, Scup, and Black Sea Bass Technical Committee addresses technical issues. Industry advice is solicited through the Summer Flounder, Scup, and Black Sea Bass Advisory Panel, and annual review and monitoring is the responsibility of the Scup Plan Review Team.

Atlantic States Marine Fisheries Commission (ASMFC or Commission) management of scup was initiated as one component of a multi-species Fishery Management Plan (FMP) addressing summer flounder, scup and black sea bass. The Commission approved the FMP for scup in March 1996. Amendment 12 to the FMP, which established revised overfishing definitions, identification and description of essential fish habitat, and defined the framework adjustment process, was approved by the Commission in October 1998.

The FMP included a seven-year plan for reducing fishing effort and restoring the stock. The primary concerns were excessive discarding of scup and near collapse of the stock. Management measures implemented in the first year of the plan (1996) included: dealer and vessel permitting and reporting, 9-inch commercial minimum size, 4-inch mesh restriction for vessels retaining over 4,000 pounds of scup, and a 7-inch recreational minimum size. The biological reference point to define overfishing when the plan was initially developed was F_{MAX}, or F=0.25. To allow flexibility in addressing unforeseen conditions in the fishery, the plan contained provisions that allow implementation of time and area closures. The plan also specified the option for changes in the recreational minimum size and bag limit, or implementation of a seasonal closure on an annual basis. The original FMP also implemented an annual coastwide Total Allowable Catch (TAC) limit, effective in 1997, from which an annual commercial quota and recreational harvest limit would be derived.

Addendum 1 to the FMP established the quota management procedure for management and distribution of the annual coastwide commercial quota. Addendum 1 also details the state-by-state quota system for the summer period (May through October) that was implemented in 1997. Each state receives a share of the summer quota based on historical commercial landings from 1983-1992.

In June 1997, the Commonwealth of Massachusetts filed a lawsuit against the Secretary of Commerce stating that the historical data used to determine the quota shares underestimated the commercial landings of scup. Massachusetts also stated that the resulting quota share discriminated against Commonwealth of Massachusetts residents. On April 27, 1998, the U.S. District Court voided the state-by-state quota allocations for the summer quota period in the federal FMP, and ordered the Secretary of Commerce to promulgate a regulation that sets forth state-by-state quotas in compliance with the National Standards. The Management Board developed three Emergency Rules to address the quota management during the summer quota period during 1999, 2000 and 2001.

Amendment 12 established a biomass threshold for scup based on the maximum value of the 3-year moving average of the Northeast Fisheries Science Center spring bottom trawl survey index of spawning stock biomass. The Amendment stipulated that the scup stock was considered overfished when the spawning stock biomass index fell below this value. Amendment 12 also defined overfishing for scup to occur when the fishing mortality rate exceeded the threshold fishing mortality. Subsequent addenda modified the reference points.

In 2002, the Board developed Addendum V to avoid the necessity of developing annual Emergency Rules for summer period quota management. Addendum V established state shares of the summer period quota based on historical commercial landings from 1983-1992, including additional landings from Massachusetts added to the National Marine Fisheries Service (NMFS) database in 2000. State shares implemented by this addendum will remain in place until the Board takes direct action to change them.

Another significant change to scup management occurred with the approval of Addendum VII in February 2002. This document established a state specific management program for Massachusetts through New York for the 2002 recreational scup fishery based on the average landings (in number of fish) for 1998-2001. Due to the extremely limited data available, the Board developed specific management measures for the states of New Jersey, Delaware, Maryland, Virginia, and North Carolina. The addendum had no application after 2002. The same addendum language was used verbatim to set management measures for the states of Massachusetts through New York for 2003 through Addendum IX.

Addendum XIX, approved in August 2007, broadened the descriptions of stock status determination criteria contained within the Summer Flounder, Scup, and Black Sea Bass FMP to allow for greater flexibility in those definitions, while maintaining objective and measurable criteria for identifying when stocks are overfished. It established acceptable categories of peer-review for stock status determination criteria. When these specific peer-review metrics are met and new or updated information is available, the new or revised stock status determination criteria may be incorporated by the Commission directly into the annual management measures for each species.

Addendum XX sets policies to reconcile quota overages to address minor inadvertent quota overages. It was approved in November 2009. It streamlines the quota transfers process and establishes clear policies and administrative protocols to guide the allocation of transfers from states with underages to states with overages. It also allows for quota transfers to reconcile quota overages after the year's end.

Addendum XXIX was approved by the Board in May 2017. The Addendum shortens the length of the commercial scup summer period and extends the length of the winter II period. The addendum was developed to allow for the better utilization of the commercial quota, which was under-harvested from 2011-2016. Specifically, the change in quota period length allows for higher possession limits for a longer period of time each year, thus increasing the likelihood the commercial fishery will fully harvest the quota. The quota allocation for each period remains unchanged. While Addendum XXIX is a Commission specific document, the Mid-Atlantic Fishery Management Council (Council) also took the same action through Framework 10. The new quota periods are the following and will be implemented for the 2018 fishing season: Winter 1, January 1-April 30 (120 days); Summer, May 1-September 30 (153 days); Winter II, October 1-December 31 (92 days).

II. Status of the Stock

The most recent stock assessment update for scup took place in 2017. Based on information through 2016, the scup stock was not overfished or experiencing overfishing relative to the reference points defined in the 2015 SAW 60 benchmark assessment. The stock assessment model for scup changed in 2008 from a simple index-based model to a more complex statistical catch at age model. The model now incorporates a broader range of fishery and survey data than was used previously.

Recruitment (i.e., the number of age 0 scup) averaged 121 million fish during 1984-2016. The 1999, 2006, and 2015 year classes are estimated to be the largest of the time series, at 222, 222, and 252 million age 0 fish. Below average recruitment occurred in 2012-2014 and in 2016 (65 million fish).

The fishing mortality reference point is $F_{MSY} = F_{40\%} = 0.220$. $F_{40\%}$ is the rate of fishing that will result in 40% of the spawning potential of an unfished stock. The spawning stock biomass (SSB) target is $SSB_{40\%}$ = 87,302 mt or 192.47 million pounds. The 2017 stock assessment update indicates the F in 2016 was 0.139 and SSB was 397 million pounds, therefore overfishing is not occurring and the stock is rebuilt.

III. Status of the Fishery

Commercial scup landings, which had declined by over 33% to 13.1 million pounds in 1988 from peak landings (approximately 49 million lbs) in 1960, increased to 15.6 million pounds in 1991, then steadily dropped to the lowest value in the time series, 2.7 million pounds in 2000. Since 2001, commercial landings have continued to increase nearly every year to about 17.87 million pounds in 2013. From 2011-2015 commercial landings varied, ranging from 14.88 million lbs in 2012, to 17.87 million pounds in 2013. In 2017, commercial landings were 13.59 million lbs, about 73% of the commercial quota (Table 3). Since 1979 approximately 80% of the commercial landings have been landed in Rhode Island (38%), New Jersey (26%), and New York (16%). Otter trawl is the principal gear, accounting for 65%-90% of commercial landings since 1979.

The recreational fishery for scup is significant, with the greatest proportion of the catches taken in states of Massachusetts through New York. Since 1981, recreational harvest has averaged 32% of total landings (commercial and recreational). From 2005 to 2015, recreational harvest has ranged from 2.69 million lbs in 2005 to 5.11 million lbs in 2013. In 2017, recreational harvest was 5.42 million lbs, about 98% of the recreational harvest limit (Table 4).

IV. Status of Assessment Advice

The 2015 Benchmark Stock Assessment indicated that while the scup biomass is over 200% of the biomass target, the trend moving forward is likely a decline from a recent year's peak. As such, the Board and Council moved to decrease commercial quotas and recreational harvest limits from 2015 levels in 2016 and 2017 based on the biomass projections outlined in the stock assessment. The 2017 Stock Assessment Update indicated the biomass still remains 200% above the biomass target and resource is not experiencing overfishing. Quotas were increased for 2018 and 2019.

V. Status of Research and Monitoring

Commercial landings data are collected by the NMFS Vessel Trip Report system and by state reporting systems. The NEFSC sea sampling program collects commercial discard information. Biological samples (age, length) from the commercial fishery are collected through the NEFSC weighout system, the observer program, and by the state of North Carolina. Recreational landings and discard information is obtained through the Marine Recreational Information Program. The Commonwealth of Massachusetts collected length frequency information for the recreational fishery in 2001 as part of a federally funded effort to monitor the recreational and commercial directed fisheries. One non-directed fishery assumed to have substantial scup bycatch was also monitored. This monitoring effort decreased substantially in 2002 as the study received funding for one year. Fishery-independent abundance indices are available from surveys conducted by the NEFSC, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, and the Virginia Institute of Marine Science. All surveys, with the exception of Delaware's, are included in the species stock assessment.

VI. Management Measures and Developing Issues

Addendum 1 to the Scup FMP specifies the commercial quota management scheme. The annual coastwide quota is divided among three periods. Through 2017, the Winter I period was January through April, the summer period was May through October, and November and December made up Winter II. Starting in 2018, October will be part of the Winter II, rather than the Summer period. During the winter periods, the quota is coastwide and is limited by federal trip limits. The summer allocation is divided into state shares. There is no federal possession limit during the summer period; however, various state possession limits are in effect. When a winter period allocation is landed, the states and NMFS must prohibit landings. When a state lands its summer allocation it is expected to close its fishery. The quota, as well as accompanying trip limits, will be set annually. [Note: The Federal FMP currently contains a coastwide commercial quota during the summer period due to the court decision described in Section I].

In December 2015 the Board and Council approved an adjustment to the threshold to trigger minimum mesh requirements. Starting in 2016, the threshold from November 1 through April 30 was increased from 500 pounds to 1,000 pounds.

In July 2018, Massachusetts and Rhode Island submitted a proposal for the Board and Council to consider changing the current incidental possession limit of 1,000 pounds during October 1-April 30 to 4,000 pounds during April 15-June 15. The goal of this proposal is to eliminate discarding of scup in the small mesh squid fishery. The Board and Council will consider the proposal in August 2018.

Scup FMP Compliance Criteria:

COMMERCIAL FISHERY for 2017

The following management measures may change annually.

Minimum size of possession: 9” Total Length
Minimum mesh: Otter trawls must have a minimum mesh size of 5” for the first 75 meshes from the terminus of the net and a minimum mesh size of 5” throughout the net for codends constructed with fewer than 75 meshes.
Threshold to Trigger Minimum Mesh Requirements: Trawl vessels are subject to the minimum mesh requirements if possessing 1,000 pounds or more of scup from November 1 through April 30, or 200 pounds or more of scup from May 1 through October 31.**
Maximum roller rig trawl roller diameter: 18”
Pot and trap escape vents: 3.1” round, 2.25” square
Pot and trap degradable fastener provisions: a) untreated hemp, jute, or cotton string 3/16” (4.8 mm) or smaller; b) magnesium alloy timed float releases or fasteners; c) ungalvanized, uncoated iron wire of 0.094” (2.4mm) or smaller
Commercial quota: 18.38 million pounds (adjusted for overages)
ASMFC Summer Quota: 7,158,986 lbs (State by State Shares in Table 1)
Winter I and II Quotas and landing limits: Winter I = 8,291,190 lbs; 50,000 lb trip limit, 1,000 lbs trip limits when the quota reaches 80%; Winter II = 5,160,914 lbs, 12,000 pounds initial possession limits; if the winter I quota is not reached, the winter II possession limit increases by 1,500 pounds for every 500,000 pounds of quota not caught during winter I
**Starting in 2016, the threshold to trigger minimum mesh requirements increased from 500 pounds to 1,000 pounds. Starting in 2018, the thresholds by period are adjusted to reflect Addendum XXIX: 1,000 pounds from October 1 through April 30, or 200 pounds or more of scup from May 1 through September 30.
The following required measures are not subject to annual adjustment:

Vessel and dealer permitting requirements: States are required to implement a permit for fishermen fishing exclusively in state waters, and for dealers purchasing exclusively from such fishermen. In addition, states are expected to recognize federal permits in state waters, and are encouraged to establish a moratorium on entry into the fishery.

Vessel and dealer reporting requirements: States are required to implement reporting requirements for state permitted vessels and dealers and to report landings from state waters to NMFS.

Scup pot or trap definition: A scup pot or trap will be defined by the state regulations that apply to the vessels principal port of landing.

Quota management requirements:
Winter I and II: States are required to implement landing limits as specified annually. States are required to notify state and federal permit holders of initial period landing limits, in-period adjustments, and closures. States are required to prohibit fishing for, and landing of, scup when a period quota has been landed, based on projections by NMFS. States must report landings from state waters to NMFS for counting toward the quota

Summer: States are required to implement a plan of trip limits or other measures to manage their summer share of the scup quota. States are required to prohibit fishing for, and landing of, scup when their quota share is landed. States may transfer or combine quota shares. States must report all landings from state waters to NMFS for counting toward the state shares.

RECREATIONAL FISHERY for 2017
Addendum IX (2003) established a state-specific management program for Massachusetts through New York (inclusive), and specific management measures for the states of New Jersey, Delaware, Maryland, Virginia, and North Carolina. The states have continued this approach since 2004.

The following measures may change annually: **2017 Recreational Measures**

2016 Minimum size, possession limits and seasonal closure: Table 5

2017 Recreational Harvest Limit: 5.50 million pounds

2017 Minimum size, possession limits and seasonal closure: Table 5

OTHER MEASURES
Reporting: States are required to submit an annual compliance report to the Chair of the ASMFC Scup Plan Review Team by June 1 of each year. This report should detail the state's management program for the current year and establish proof of compliance with all mandatory management measures. It should include landings information from the previous year, and the results of any monitoring or research programs.

De minimis: States having commercial landings during the summer period that are less than 0.1% of the summer period quota are eligible for *de minimis* consideration. States desiring *de minimis* classification must make a formal request in writing through the Plan Review Team for review and consideration by the Scup Management Board.

This summary of compliance criteria is intended to serve as a quick reference guide. It in no way alters or supersedes compliance criteria as contained in the Scup FMP and any Amendments thereto.

Compliance Issues

The PRT found compliance issues with two states: Massachusetts did not maintain the 5" minimum diamond mesh size or the threshold to trigger minimum mesh requirements (1,000 lbs 11/1 – 4/30 200 lbs from 5/1 – 10/31), allowing squid mesh (1 7/8") vessels to retain directed fishery possession limits for scup from April 23 – June 9 (or longer by Director's declaration). It was identified in the compliance report that this issue was addressed in April 2018; additionally the Board was made aware of it October 2017 and it was addressed in April 2018. The second issue was New Jersey did not specify in their state compliance report the escape vent requirements of 3.1" circular escape vents, 2.25" square escape vent, or rectangular escape vent of equivalent size.

De Minimis

The state of Delaware requests *de minimis* status. The PRT notes Delaware meets the *de minimis* requirements.

VII. State Compliance with Required Measures

Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina are required to comply with the provisions of the Scup FMP. As noted above, the PRT found Massachusetts to have inconsistent minimum mesh size and trigger for minimum mesh size requirements with the FMP in 2017 and New Jersey did not specify the escape vent requirements in their compliance report. All other states implemented regulations in compliance with the requirements approved by the Board.

Scup FMP Compliance Schedule

Commercial Fishery

Management Measures	
Ability to implement and enforce period landing limits	1/1/97
Ability to notify permit holders of landing limits and closures 1/1/97	5/1/97
Ability to close the summer fishery once the state share is harvested	5/1/97
Ability to close the winter fisheries once the period quota is harvested	5/1/97
9" total length minimum size limit	6/30/96
Minimum mesh size of 5" diamond mesh throughout codend	1/1/05

Pot and trap escape vents (min 3.1" square/rectangular; each side at least 2.25" in length), degradable fasteners	6/30/96
Roller diameter restriction (maximum of 18")	6/30/96
Vessel permit and reporting requirements, state	1/1/97
Dealer permit and reporting requirements, state	1/1/97

Recreational Fishery

Management Measures	
Size limit	6/30/96
Possession limit	6/30/96

General

States submit annual monitoring and compliance report	6/1 annually

Annual Specifications

Commercial		
Winter I Landing Limits	11/1/05	1/1/16
Winter II Landing Limits	11/1/05	11/1/16

Recreational

Massachusetts– New York (inclusive)	
State specific minimum size, possession limit and season	3/16
New Jersey – North Carolina (inclusive)	
Federal coastwide minimum size, possession limit and season	12/15

Table 1. 2017 State by State Quota (Summer Period)

State	Share	2017 ASMFC Final Quota
ME	0.00121	8,662
MA	0.21585	1,520,289
RI	0.56189	4,022,592
CT	0.03154	250,773
NY	0.15823	1,132,781
NJ	0.02916	208,785
MD	0.00012	852
VA	0.00165	11,812
NC	0.00025	1,783
Total	0.99991	7,158,986

Table 2. Summary of scup management measures, 2006-2017.

Harvest Limits and Measures	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
ABC (m lbs)	-	-	-	-	-	40.88	38.71	35.99	33.77	31.11	28.40
TAC (m lbs)	13.97	9.9	15.54	17.09	31.92	-	-	-	-	-	
Commercial ACL (m lbs)	-	-	-	-	-	31.89	30.19	28.07	26.35	24.26	22.15
Commercial quota-adjusted (m lbs)*	8.9	5.24	8.37	10.68	20.36	27.91	23.53	21.95	21.23	20.47	18.38
Commercial landing (m lbs)	9.24	5.19	8.20	10.40	15.03	14.88	17.87	15.96	15.85	15.76	13.59
Recreational ACL (m lbs)	-	-	-	-	-	8.99	8.52	7.92	7.43	6.84	6.25
Recreational harvest limit-adjusted (m lbs)*	2.74	1.83	2.59	3.01	5.74	7.55	7.55	7.03	6.8	6.09	5.50
Recreational landings	4.56	3.79	3.23	5.97	3.67	4.17	5.37	4.27	4.41	4.26	5.42
Commercial fish size (in)	9	9	9	9	9	9	9	9	9	9	9
Min. mesh size (in, diamond)	5	5	5	5	5	5	5	5	5	5	5
Mesh threshold (lb)	500/ 200	500/ 200	500/ 200	500/ 200	500/ 200	500/ 200	500/ 200	500/ 200	500/ 200	1,000/200	1,000/200

*2006-2014 commercial quotas and recreational harvest limits were adjustted for the Research Set Aside (RSA) program. The RSA program was suspended for 2015 and beyond.

Table 3. Scup commercial landings by state 2007-2017 in pounds.

Source: ACCSP. 2007-2017. Commercial Landings Summaries; generated by J. Kuesel; using ACCSP Data Warehouse, Arlington, VA.
State Compliance Reports for 2017 data (July 2018)

State	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017**
MA	1,104,316	527,325	718,751	1,030,688	1,243,810	2,005,268	1,094,975	1,185,816	1,380,262	1,535,947	2,564,042
RI	3,892,671	2,133,001	1,785,994	4,298,595	6,335,391	6,309,321	4,689,540	4,450,133	3,732,577	4,395,282	4,214,965
CT	255,884	283,101	203,607	323,757	644,030	905,060	1,194,949	811,106	983,041	946,182	754,672
NY	2,280,112	1,203,661	1,845,908	2,689,443	3,542,538	4,306,621	4,407,231	3,190,433	3,174,868	3,505,824	3,464,423
NJ	1,575,144	773,829	1,528,545	1,550,249	1,966,479	978,531	2,033,083	1,925,591	2,981,572	2,332,900	1,844,570
DE	C	C	C	C	C	C	C	C	C	C	C
MD	C	C	C	C	C	C	C	C	C	C	C
VA	22,579	95,939	211,576	371,376	620,480	339,868	913,113	660,324	509,334	441,257	495,062
NC	66,856	205,703	244,020	102,745	308,883	3,903	28,394	160,399	229,664	111,901	188,852
Total	9,197,562	5,222,559	6,538,401	10,366,853	14,661,611	14,848,572	14,361,285	12,383,802	12,991,318	13,269,293	13,590,397

C= Confidential

**2017 Landings are still preliminary

Table 4. Scup recreational landings, 2007-2017, by state in weight.
Source: State compliance reports. July 2018.

State	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MA	75,860	150,031	874,952	1,023,248	836,156	1,799,446	2,093,144	1,791,306	1,286,537	1,051,147	1,430,263
RI	353,450	632,839	139,576	398,178	567,697	497,505	875,625	1,024,129	591,693	606,528	408,036
CT	108,528	115,821	359,845	1,346,631	1,194,680	922,374	1,070,402	587,336	477,987	843,267	1,019,641
NY	1,596,391	1,450,861	1,460,314	1,990,339	714,789	776,013	1,229,802	975,887	2,020,735	1,533,402	1,919,360
NJ	86,073	72,697	141,861	610,660	42,223	113,332	99,580	48,353	29,500	210,727	643,822*
DE	2,365	1,338	821	0	40	91	0	28	589	1	99
MD	157,360	89,729	36	11	7	0	0	0	204	126*	0*
VA	586	3,920	527	5,284	10,413	2,317	2,471	0	1,846	14,157*	0
NC	0	0	0	0	27	1,939	507	640	88	0	0
Total	**2,380,613**	**2,517,236**	**2,977,932**	**5,374,351**	**3,366,032**	**4,113,017**	**5,371,531**	**4,427,679**	**4,409,179**	**4,245,072**	**4,777,399**

*State estimates for Maryland and Virginia had PSE>50

Table 5. 2017 State Scup Recreational Measures

State	Minimum Size (inches)	Possession Limit	Open Season
Massachusetts For Hire	10	45 fish from May 1- June 30; 30 fish from July 1- Dec 31	May 1- December 31
Private Angler	10	30 fish; private vessels with 6 or more persons aboard are prohibited from possessing more than 150 scup per day	May 1- December 31
Rhode Island For Hire	10	30 fish from May 1-Aug 31 and Nov 1-Dec 31; 45 fish from Sept 1-Oct 31	May 1- December 31
Private Angler	10”; and 9” or greater for shore mode at 3 designated sites	30 fish	May 1- December 31
Connecticut For Hire	10	30 fish from May 1-Aug 31 and Nov 1-Dec 31; 45 fish from Sept 1-Oct 31	May 1- December 31
Private Angler	10; and 9” for shore mode at 46 designated sites	30 fish	May 1- December 31
New York For Hire	10	30 fish from May 1-Aug 31 and Nov 1-Dec 31; 45 fish from Sept 1-Oct 31	May 1- December 31
Private Angler	10	30 fish	May 1- December 31
New Jersey	9	50 fish	Jan 1-Feb 28 and July 1 – December 31
Delaware	8	50 fish	All Year
Maryland	8	50 fish	All Year
Virginia	8	30 fish	All Year
North Carolina	8	50 fish	All Year

Table 6. 2018 State Scup Recreational Measures

State	Minimum Size (inches)	Possession Limit	Open Season
Massachusetts (Private Mode)	9	30 fish; 150 fish/vessel with 5+ anglers on board	May 1-December 31
Massachusetts (For-Hire Only)	9	45 fish	May 1-June 30
		30 fish	July 1-December 31
Rhode Island (Private & Shore)	9	30 fish	May 1-December 31
RI Shore Program (7 designated shore sites)	8		
RI (Party/Charter)	9	30 fish	May 1-August 31; November 1-December 31
		45 fish	September 1-October 31
Connecticut	9	30 fish	May 1-December 31
CT Shore Program (46 designed shore sites)	8		
CT DEEP Registered Party/Charter	9	30 fish	May 1-August 31; November 1-December 31
		45 fish	September 1-October 31
New York	9	30 fish	May 1-December 31
NY (Anglers aboard Licensed Party/Charter Boats)	9	30 fish	May 1-August 31; November 1-December 31
		45 fish	September 1- October 31
New Jersey	9	50 fish	January 1- December 31
Delaware	8	50 fish	January 1-December 31
Maryland	8	50 fish	January 1-December 31
Virginia	8	30 fish	January 1-December 31
North Carolina, North of Cape Hatteras (N of 35° 15’N)	8	50 fish	January 1-December 31

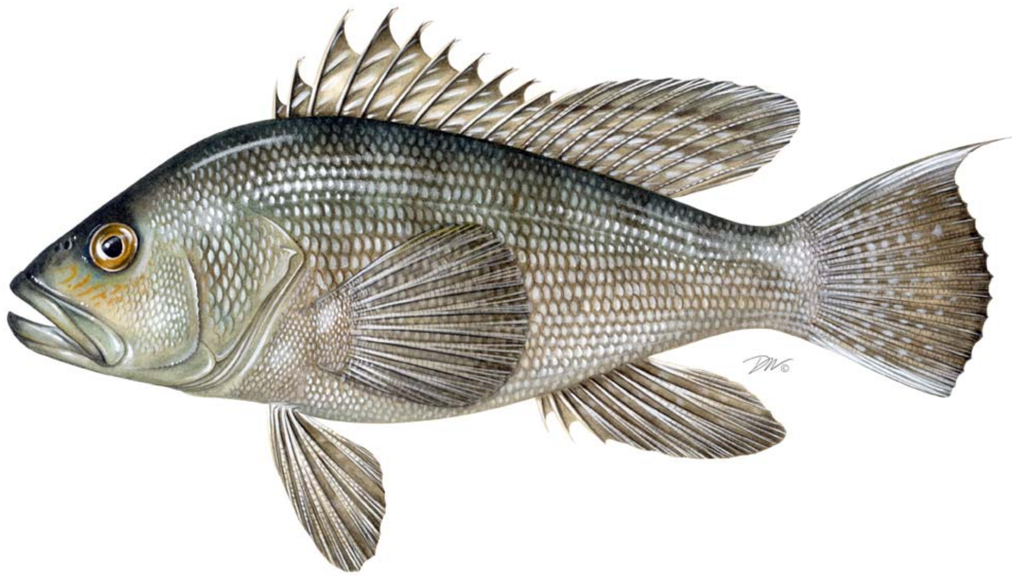
Table 7. Scup Landings by period.

Year	Period	Commercial Quota	Trip Limits	Landings (lbs)	Date Closed	% of Quota Landed
2006	Winter I	3,554,991	30,000/1,000*	3,626,237	--	102
	Summer	4,647,569	--	3,219,929	--	69.3
	Winter II	3,729,581	2,000/1,000	2,115,323	--	56.7
2007	Winter I	4,012,895	30,000/1,000*	3,400,934	--	84.8
	Summer	3,464,914	--	4,254,987	21-Sep	122.8
	Winter II	1,417,991	2,000/1,000	1,590,747	--	112.2
2008	Winter I	2,291,699	30,000/1,000*	2,356,716	--	102.8
	Summer	1,437,558	--	1,935,074	16-Jul	134.6
	Winter II	940,948	2,000/1,000	892,318	--	94.8
2009	Winter I	3,777,443	30,000/1,000*	3,774,583	--	99.9
	Summer	2,930,733	--	3,072,340	--	104.8
	Winter II	1,334,791	2,000/1,000	1,356,961	--	101.7
2010	Winter I	4,964,716	30,000/1,000*	4,740,681	--	95.4
	Summer	4,286,759	--	4,175,206	--	97.4
	Winter II	1,754,325	2,000/1,000	1,482,669	--	84.5
2011	Winter I	6,897,648	30,000/1,000*	5,806,236	--	84.2
	Summer	7,930,504	--	6,642,296	--	83.7
	Winter II	3,245,500	2,000/1,000	2,583,514	--	79.6
2012	Winter I	12,589,558	50,000/1,000*	5,435,576	--	43.2
	Summer	10,870,390	--	6,762,839	--	62.2
	Winter II	11,635,321	8,000	2,685,725	--	23.0
2013	Winter I	10,613,157	50,000/1,000*	7,526,881	--	70.1
	Summer	9,163,877	--	8,215,177	--	89.6
	Winter II	6,932,998	8,000	2,131,981	--	30.7
2014	Winter I	9,900,000	50,000/1,000*	6,238,586	--	62.9
	Summer	8,548,364	--	7,543,741	--	88.2
	Winter II	7,232,471	12,000	2,181,849	--	30.1
2015	Winter I	9,578,008	50,000/1,000*	7,470,126	--	78.1
	Summer	8,269,322	--	7,414,606	--	89.7
	Winter II	5,468,726	12,000	2,145,234	--	39.2
2016	Winter I	9,232,987	50,000/1,000*	6,137,281	--	66.4
	Summer	7,972,176	--	7,240,922	--	90.8
	Winter II	3,262,554	18,000	2,377,558	--	72.6
2017	Winter I	8,291,190	50,000/1,000*	5,653,716	--	68
	Summer	7,458,013	--	7,158,986	--	104
	Winter II	5,160,914	18,000	2,106,598	--	41.0

*The first number indicates the trip limit until 80% of the quota is caught; the second number is the trip limit after that threshold is exceeded.

2018 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN FOR THE 2017 BLACK SEA BASS FISHERY

Black Sea Bass *(Centropristis striata)*



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2018 Review of the Atlantic States Marine Fisheries Commission
Fishery Management Plan for Black Sea Bass

I. Status of the Fishery Management Plan

Atlantic States Marine Fisheries Commission (ASMFC or Commission) management of black sea bass was initiated as one component of a multi-species fishery management plan (FMP) addressing summer flounder, scup, and black sea bass. In 1990, summer flounder was singled out for immediate action under a joint ASMFC and Mid-Atlantic Fishery Management Council (MAFMC or Council) plan. Further action on the scup and black sea bass plan was delayed until 1992 to expedite the summer flounder FMP and subsequent amendments. The joint Black Sea Bass FMP was completed and approved in 1996. The MAFMC approved regulations for black sea bass as Amendment 9 to the Summer Flounder FMP in May 1996.

The management unit of the Black Sea Bass FMP includes all black sea bass in U.S. waters in the western Atlantic Ocean from Cape Hatteras, North Carolina north to the Canadian border. New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Virginia, and North Carolina have declared an interest in black sea bass; Maine and New Hampshire declared interest in 2014, and in 2017 Maine declined interest in the fishery. The Commission's Summer Flounder, Scup, and Black Sea Bass Management Board (or Board) and the MAFMC Demersal Species Committee guide development of the FMP. Technical issues are addressed through the Summer Flounder, Scup, and Black Sea Bass Technical and Monitoring Committees. The Black Sea Bass Plan Review Team conducts annual reviews and monitors compliance, and the Summer Flounder, Scup and Black Sea Bass Advisory Panel provides industry input and advice.

The objectives of the FMP are to reduce fishing mortality to ensure overfishing does not occur, reduce fishing mortality on immature black sea bass to increase spawning stock biomass, improve yield from the fishery, promote compatible regulations among states and between federal and state jurisdictions, promote uniform and effective enforcement, and minimize regulations necessary to achieve the stated objectives. The initial black sea bass FMP (1996) aimed to reduce fishing mortality using a coastwide commercial quota allocated into quarterly periods beginning in 1999, and a recreational harvest limit constrained through the use of minimum size, possession limit, and seasonal closures.

Amendment 12 to the Summer Flounder, Scup, and Black Sea Bass FMP was approved by the Commission in October 1998. The Amendment revised overfishing definitions, identified and described essential fish habitat, and defined the framework adjustment process.

Addendum IV, approved on January 29, 2001, provides that upon the recommendation of the relevant monitoring committee and joint consideration with the Council, the Board will decide state regulations rather than forward a recommendation to NMFS. Addendum IV also made the states responsible for implementing the Board's decisions on regulations.

Starting in 1998, the fishery was subject to lengthy closures and had some significant quota overages in the commercial sector. Fishery closures occurring as a result of exceeded quotas resulted in increased discards of legal sized black sea bass in mixed fisheries for the remainder of the closed period. A significant financial hardship for the fishing industry resulted from a decrease in market demand caused by a fluctuating supply. To address these issues, the Board enacted a series of Emergency Rules in 2001 that established initial possession limits, triggers, and adjusted possession limits. These measures helped reduce the length of fishery closures, but the rapidly changing regulations confused fishermen and added significant administrative burden to the states. To simplify the process for all parties, the Board approved Addendum VI to provide a mechanism for initial possession limits, triggers, and adjusted possession limits to be set during the annual specification setting process without the need for further Emergency Rules.

Amendment 13, approved by ASMFC in May 2002, implemented a federal, annual coastwide commercial quota that is managed in state waters by ASMFC using a state-by-state allocation system. The Amendment was implemented in 2003 and 2004. State-specific commercial shares are listed in Table 1. Amendment 13 also removed the necessity for fishermen who have both a Northeast Region (NER, now referred to as the Greater Atlantic Region) Black Sea Bass permit and a Southeast Region (SER) Snapper Grouper (S/G) permit to relinquish their permits for a six-month period prior to fishing south of Cape Hatteras during a northern closure.

Addendum XII, approved in 2004, continued the use of an annual coastwide commercial quota managed by the ASMFC through a state-by-state allocation system.

Addendum XIII, approved in 2004, modified the FMP so that Total Allowable Landings (TALs) for the summer flounder, scup, and/or black sea bass can be specified for up to three years.

Addendum XIX, approved in 2007, continued the state-by-state black sea bass commercial management measures, without a sunset clause. This addendum also broadened the descriptions of stock status determination criteria contained within the Summer Flounder, Scup, and Black Sea Bass FMP to allow for greater flexibility in those definitions, while maintaining objective and measurable status determination criteria for identifying when stocks or stock complexes covered by the FMP are overfished. It establishes acceptable categories of peer-review for stock status determination criteria. When these specific peer-review metrics are met and new or updated information is available, the new or revised stock status determination criteria may be incorporated by the Commission directly into the annual management measures for each species, rather than requiring a modification to the FMP.

Addendum XX, approved in November 2009, set policies to reconcile commercial quota overages to address minor inadvertent quota overages. It streamlined the quota transfers process and established clear policies and administrative protocols to guide the allocation of transfers from states with underages to states with overages. It also allowed for commercial quota transfers to reconcile quota overages after the year's end.

Addendum XXV continued the use of ad-hoc regional recreational management measure options—originally allowed by Addendum XXI in 2011—to alleviate the differences in state measures for adjacent states along the coast. It was approved in February 2014 and was in place for 2014 and 2015. Northern and southern regions were defined, Massachusetts through New Jersey and Delaware through North Carolina (North of Cape Hatteras), respectively. The addendum allowed northern states to adjust management measures annually to best meet the needs of their state while constraining overall harvest to the coastwide recreational harvest limit (RHL). In years of overages, the northern states, which harvest the largest percentage, adjust their management measures to account for harvest reductions in subsequent years. The southern region states set their management measures consistent with the federal measures. In recent years, these measures have also been adjusted as federal open season dates have been modified.

Addendum XXVII was approved in February 2016. The addendum continued to allow ad-hoc regional management measures for the 2016 black sea bass recreational fishery and the option to continue this management approach in 2017. All states are to agree to the regulations implemented within the region, but those regulations do not need to be consistent across the region. Based on performance in 2015, the northern region was required to reduce harvest through state regulations in order to achieve the required coastwide harvest reduction of 23%.

II. Status of the Stock

The most recent benchmark stock assessment for black sea bass was peer reviewed in December 2016 (SAW-62). The assessment found black sea bass was not overfished nor experiencing overfishing in 2015, the terminal year of the assessment. The assessment used an age-structured assessment model (ASAP) that partitioned the resource into two spatial sub-units separated at approximately Hudson Canyon. This approach was accepted as the best scientific information available for determining stock status for black sea bass; however, it should be noted that the two sub-units were not considered separate stocks by the stock assessment work group, peer review panel, or the MAFMC Scientific and Statistical Committee.

With improved recruitment and declining fishing mortality rates since 2007, spawning stock biomass (SSB) has steadily increased. SSB in 2015 was estimated at 48.9 million lbs (22,176 mt), 2.3 times the SSB target of 21.3 million lbs. Fishing mortality (F) was estimated at 0.27, 25% below the F target ($F_{40\%}$) of 0.36. To account for the fact that black sea bass are protogynous hermaphrodites, changing sex from female to male, the assessment defined SSB as the combined male and female mature biomass. Recruitment at age 1 averaged 24.3 million fish from 1989 to 2015, with peaks in 2000 (1999 cohort) at 37.3 million and at 68.9 million in 2012 (2011 cohort). The large 2011 cohort, which is currently moving through the fishery, was dominant in the northern area and less so in the south. Since 2012, recruitment has been average with a 2014 cohort estimated at 24.9 million fish. The 2017 data update indicated that the 2015 cohort is above average for both the north and south spatial sub-units, but a final recruitment estimate has not yet been generated.

III. Status of the Fishery

The commercial fishery is allocated 49% of the total allowable landings (TAL) for black sea bass. The principle gears used in the fishery are fish pots (or traps), otter trawls, and handlines. After peaking at 21.8 million lbs in 1952, commercial landings markedly decreased in the '60s and have since ranged from 1.17 to 3.85 million lbs since 1981. In 1998, a commercial quota system was incorporated into management and state-by-state shares were introduced in 2003. From 2005-2016 commercial landings remained stable, with a range from 2.87 million lbs in 2005 to 1.17 million lbs in 2009 (Tables 2 and 3). In 2017, commercial landings were approximately 3.85 million lbs, under the coastwide quota of 4.12 million lbs by approximately 6.6% (Tables 2 and 3)[1]. According to the 2018 data update from the Northeast Fisheries Science Center (NEFSC), commercial dead discards in 2017 were 1.78 million lbs (NEFSC 2018). Commercial catch exceeded the 2017 commercial annual catch limit (ACL) of 5.09 million lbs by 13%.

The recreational fishery is allocated 51% of the TAL for black sea bass. After peaking in 1985 at 12.35 million lbs, recreational harvest averaged 3.75 million lbs annually from 1988 to 1997[2]. Recreational harvest limits were put in place in 1998 and harvest ranged from 1.1 to 3.88 million lbs from 1998 to 2014 (Table 4). From 2012-2016, the recreational harvest limit was exceeded annually – by 142%, 9%, 59%, 67%, and 84% respectively. In 2017, the recreational harvest was 4.16 million lbs[3] (3% below the RHL of 4.29 million lbs). Recreational live discards are significantly higher than commercial, ranging from 3 to 10 million fish per year. According to the NEFSC, in 2017 total recreational discards in the management unit were 12.86 million fish. Assuming 15% hook and release mortality, estimated recreational discard losses were projected to be 1.93 million fish, equal to 87.4% of recreational harvest in 2017.

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[1] Prior to the start of the 2019 fishing year, NOAA will review final 2017 catch estimates and determine if any overages occurred. NOAA will publish a notice with final 2019 specifications prior to the start of the fishing year that would account for any overages, if applicable. In February 2018, the Council approved a modification to the commercial summer flounder, scup, and black sea bass accountability measures (AMs). This change, which has not yet been implemented, would eliminate the requirement for pound for pound paybacks of ACL overages when the stock is above the target biomass, as black sea bass is currently. If NMFS approves and implements this change, then ACL overages in 2017 may not require a modification to the 2019 ACLs.

[2] All recreational data included in this report are derived from MRIP data released prior to the July 2, 2018 estimate recalibration based on the new Fishing Effort Survey (FES). New MRIP estimates will be incorporated into an operational assessment in 2019 for management use.

[3] In 2016 and 2017, the Technical Committee identified outliers in MRIP estimates through statistical analyses. The Technical Committee has developed methodologies for analyzing and smoothing MRIP estimates to reduce the impact of MRIP outliers when evaluating harvest and developing recreational measures.

IV. Status of Research and Monitoring

Commercial landings information is collected by the Vessel Trip Reporting system and dealer reports. States are also required to collect and report landings data. Sea sampling data from the NEFSC observer sampling program are used to estimate discards for the trawl and gill net fisheries, and VTR data is used to estimate discards from pots and hand lines if observer data are insufficient. The NEFSC weigh-out program provides commercial age and length information. Recreational landings and discards were estimated through the Marine Recreational Fisheries Statistics Survey (MRFSS) until it was replaced by the Marine Recreational Information Program (MRIP), which has provided recreational landings and discards from 2008 to present. Recreational discards in weight are estimated by the NEFSC. Fishery-dependent surveys are conducted in New York and North Carolina.

Fishery-independent surveys are conducted in Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, and Virginia. The Virginia Game Fish Tagging Program has targeted black sea bass since 1997. Recruitment and stock abundance data are also provided by the NEFSC spring, autumn, and winter trawl surveys.

V. Status of Assessment Advice

The next benchmark stock assessment is tentatively scheduled for 2020. An operational stock assessment or assessment update may be completed in 2019.

VI. Status of Management Measures and Developing Issues

Draft Addendum XXX was initiated by the Board and Council in May 2017, and approved for public comment at the joint ASMFC and MAFMC meeting in December 2017. Addendum XXX was approved for management use in March 2018. The 2018 state recreational measures were then revised in May 2018 following an appeal to the ISFMP Policy Board of the Addendum by the States of MA, RI, CT and NY.

In October 2017, the Board and Council recommended opening a Wave 1 recreational fishery for black sea bass from February 1-28, 2018. 100,000 lbs of black sea bass were allocated to the fishery, to be divided among the participating states according to their historic recreational harvest in Wave 1.

In December 2017, the Council and Board initiated a joint framework action and addendum to consider adding the following management options to the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan:

1. Conservation equivalency for the recreational black sea bass fishery
2. Conservation equivalency rollover for summer flounder
3. Transit provisions for Block Island Sound for recreational and/or commercial fisheries for all three species
4. Slot limits for recreational fisheries for all three species

VII. Black Sea Bass Compliance Criteria

2017 Commercial Fishery Requirements
Minimum size of possession: 11”
Minimum mesh: Nets must possess a minimum of 75 meshes of 4.5” diamond mesh in the codend, or the entire net must have a minimum mesh size of 4.5” throughout; for codends with fewer than 75 meshes, the entire net must have 4.5” diamond mesh or larger throughout
Threshold to trigger minimum mesh requirements: 500 lbs for January-March and 100 lbs for April-December
Maximum roller rig trawl roller diameter: 18”
Pot and trap escape vents: 2 ½” for circular, 2” for square, and 1-3/8 x 5-3/4” for rectangular. Must be 2 vents in the parlor portion of the trap
Pot and trap degradable fastener provisions: a) untreated hemp, jute, or cotton string 3/16” (4.8 mm) or smaller; b) magnesium alloy timed float releases or fasteners; c) ungalvanized, uncoated iron wire of 0.094” (2.4mm) or smaller. The opening covered by a panel affixed with degradable fasteners would be required to be at least 3” x 6”.
Commercial quota: 4.12 million lbs
Pot and trap definition: A black sea bass pot or trap is defined as any pot or trap used by a fisherman to catch and retain black sea bass.

2017 Recreational Fishery Requirements
See Table 6.
Recreational harvest limit: 4.29 million lbs

Other Measures
Reporting: States are required to submit an annual compliance report to the Chair of the Black Sea Bass Plan Review Team by June 1st. The report must detail the state’s management program for the current year and establish proof of compliance with all mandatory management measures. It should include landings information from the previous year, and the results of any monitoring or research programs.

Black Sea Bass FMP Compliance Schedule

Commercial	
11” Size Limit	1/1/02
4.5” diamond minimum mesh throughout codend and threshold provisions	1/1/02
Pot and trap escape vents and degradable fasteners	1/1/97
Maximum 18” roller diameter restriction	1/1/97
States must report to NMFS all landings from state waters	1/1/98
Recreational	
Size Limit	1/1/97
Harvest Limit	1/1/98
Ability to implement possession limits and seasonal closures	1/1/98

General	
Annual compliance report	Annually, 6/1

This summary of compliance criteria is intended to serve as a quick reference guide. It in no way alters or supersedes compliance criteria as contained in the Black Sea Bass FMP and any Amendments thereto. Also, please note that management measures may change annually.

VII. PRT Review

States and jurisdictions required to comply with the provisions of the Black Sea Bass FMP are: New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland, Potomac River Fisheries Commission, Virginia, and North Carolina. All states implemented regulations in compliance with the requirements approved by the Board.

All states appear in compliance with the FMP provisions for fishing year 2017; however, the PRT made the following recommendations:

- *State compliance reports should explicitly list all required regulations and whether they are in compliance with the FMP. Not all 2017 reports included information on the degradable fastener requirement.*
- *Pots/traps should be separated from other types of gear in the commercial harvest by gear tables included in compliance reports.*
- *Compliance reports should be restricted to only the relevant information.*
- *Virginia should note in their compliance report that trawling is prohibited in state waters to make it clear their regulations are in compliance with the FMP.*

VIII. References

NEFSC (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://nefsc.noaa.gov/publications/.

NEFSC (Northeast Fisheries Science Center). 2018. Black Sea Bass 2017 Catch and Survey Information for Stock North of Cape Hatteras, NC - Report to the Mid-Atlantic Science and Statistical Committee. Available at: http://www.mafmc.org/ssc-meetings/2018/july-17-18

Table 1. State by state allocation of annual commercial quota.

State	% Allocation
Maine	0.50%
New Hampshire	0.50%
Massachusetts	13%
Rhode Island	11%
Connecticut	1%
New York	7%
New Jersey	20%
Delaware	5%
Maryland	11%
Virginia	20%
North Carolina	11%

Table 2. Black Sea Bass Commercial Landings by State (2007-2017) in pounds.
Source: State Compliance Reports (June 2018) & ACCSP. 2016-2017.Commercial Landings Summaries (Dealer Reports)-Non-Confidential; generated by J. Kuesel; using ACCSP Data Warehouse, Arlington, VA.

State	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017****
ME											
NH											0
MA	442,136	316,722	148,470	260,181	287,666	248,463	329,223	277,276	347,820	353,602	541,932
RI	356,542	226,925	128,053	241,892	185,709	187,806	237,951	245,268	238,647	294,097	441,899
CT	10,123	15,554	17,854	21,422	20,485	17,677	22,735	27,036	24,591	28,854	43,917
NY	265,940	201,222	123,287	200,463	177,997	153,347	180,947	188,436	151,311	202,336	313,902
NJ	480,112	424,667	204,213	305,294	293,609	310,427	494,075	486,073	468,248	525,615	898,665
DE	63,431	60,700	50,259	76,913	82,436	82,351	104,937	102,279	111,508	95,328	116,066
MD	170,909	159,453	125,643	203,088	182,711	140,861	219,321	235,689	234,707	271,780	364,731
VA	189,875	211,500	164,524	263,563	274,446	391,384	493,153	410,162	422,333	511,608	737,219
NC*	472,931	208,726	176,748	107,996	98,505	61,187	88,242	212,488	241,538	225,405	388,858
Coastwide	2,451,999	2,101,250	1,577,037	1,973,695	1,777,248	1,593,503	2,170,584	2,183,208	2,240,703	2,508,625	3,847,189

** Landings from NC are statewide for 2007 and from north of Cape Hatteras from 2008 forward*
***2017 landings are preliminary*

Table 3. 2016 Commercial Landings and 2017 Black Sea Bass State by State Quotas (pounds)

State	% Allocation	Final 2016 Landings	2017 ASMFC Initial Quota
Maine	0.005	0	20,602
New Hampshire	0.005	0	20,602
Massachusetts	0.13	353,602	535,652
Rhode Island	0.11	294,097	453,244
Connecticut	0.01	28,854	41,204
New York	0.07	202,336	288,428
New Jersey	0.2	525,615	824,080
Delaware	0.05	95,328	206,020
Maryland	0.11	271,780	453,244
Virginia	0.2	511,608	824,080
North Carolina	0.11	225,405	453,244
Coastwide Total	100%	2,508,625	4,120,400
2016 Coastwide Quota		2,702,867	
Overage		None (Under by 194,242)	

* Landings from North Carolina are from North of Cape Hatteras

Table 4. Black Sea Bass Recreational Harvest Estimates by State (2007-2017) in pounds.
Source: "Personal Communication with National Marine Fisheries Service June 2018"

State	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
ME					0	0					
NH				0		4,587	19,227	0	0	0	0
MA	169,852	380,125	621,596	1,052,441	318,383	1,052,049	660,797	1,087,847	718,101	891,440	743,617
RI	65,091	84,536	50,657	246,229	85,903	226,132	144,722	370,531	444,337	564,370	426,405
CT	37,016	90,120	1,025	24,138	13,758	261,164	262,392	586,113	495,675	914,014	825,446
NY	558,204	521,073	878,047	975,624	399,031	545,222	734,729	847,181	1,531,493	2,211,292	770,849
NJ	1,076,467	830,820	768,732	780,115	181,699	993,613	515,176	631,457	428,319	398,481	1,137,317
DE	137,202	27,390	45,496	29,430	46,232	49,966	44,365	30,962	26,893	31,939	75,895
MD	49,046	33,550	40,554	41,507	51,730	42,174	39,170	87,086	78,052	103,995	102,656
VA	60,093	51,421	145,181	24,702	26,747	2,599	33,660	24,433	63,694	70,187	59,988
NC*	21,863	11,489	7,043	16,265	47,310	7,153	9,992	1,180	3,887	1,249	19,448
Coastwide	2,174,834	2,030,524	2,558,331	3,190,451	1,170,793	3,184,659	2,464,230	3,666,790	3,790,451	5,186,967	4,161,621

**Harvest is from north of Hatteras from 2007 to 2017.*

Table 5. Average Weight of Black Sea Bass Recreational Landings by State (2007-2017) in pounds.
Source: "Personal Communication with National Marine Fisheries Service June 2018"

State	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
ME											
NH						1.436	1.565				
MA	1.1366	1.5444	1.4430618	1.4989	1.635	2.024	2.266	2.3799	2.0963	2.2727	2.5253
RI	1.4785	1.6163	1.4082342	1.5348	1.711	2.205	1.937	1.7277	1.9019	2.2158	2.2828
CT	1.5702	1.5083	2.2043011	1.5392	1.642	2.356	2.39	1.4762	1.4992	2.0982	2.2146
NY	1.3625	2.0079	1.5499971	1.7959	1.454	1.696	2.081	1.8058	1.747	2.1415	2.1886
NJ	1.4856	1.4334	1.3177367	1.1348	1.224	1.352	1.492	1.3481	1.3803	1.3539	1.3816
DE	1.473	1.2108	1.2182622	1.3996	1.076	1.245	1.214	1.2966	1.1744	1.3215	1.3067
MD	1.2684	1.2694	1.225863	1.1524	1.09	1.275	1.32	1.2719	1.3543	1.3007	1.4793
VA	1.6622	1.3516	1.2645878	0.8312	1.41	0.638	1.581	1.2995	1.6432	2.4275	1.6674
NC	2.567	1.2284	2.1297248	1.4991	1.527	1.952	1.249	1.6954	1.9771	1.4456	1.4889
Coastwide	1.4235	1.5695	1.4169026	1.4459	1.434	1.699	1.922	1.7313	1.7113	2.0394	1.8866

**Landings are from north of Hatteras from 2007 to 2017.*

Table 6. 2017 recreational management measures for black sea bass by state

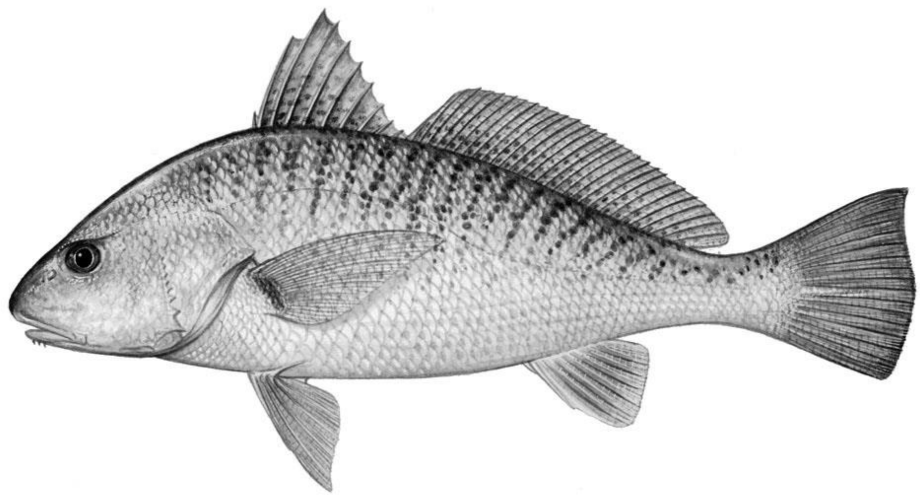
State	Minimum Size (inches)	Possession Limit	Open Season
Maine	13	10 fish	May 19-September 21; October 18-December 31
New Hampshire	13	10 fish	January 1-December 31
Massachusetts	15	5 fish	May 20-August 29
Rhode Island	15	3 fish	May 25-August 31
		7 fish	September 1-September 21; October 22-December 31
Connecticut (Private & Shore)	15	5 fish	May 1-December 31
CT Authorized Party/Charter Monitoring Program Vessels		8 fish	May 1-December 31
New York	15	3 fish	June 27-August 31
		8 fish	September 1-December 31
		10	November 1-December 31
New Jersey	12.5	10 fish	May 26-June 18
		2 fish	July 1-August 31
		15 fish	October 22-December 31
Delaware	12.5	15 fish	May 15-September 21; October 22-December 31
Maryland	12.5	15 fish	May 15-September 21; October 22-December 31
Virginia	12.5	15 fish	May 15-September 21; October 22-December 31
North Carolina, North of Cape Hatteras (N of 35° 15'N)	12.5	15 fish	May 15-September 21; October 22-December 31
Minimum Federal Measures	**12.5**	**15 fish**	**May 15-September 21; October 22-December 31**

Table 7. 2018 recreational management measures for black sea bass by state

State	Minimum Size (inches)	Possession Limit	Open Season
Maine	13	10 fish	May 19-September 21; October 18- December 31
New Hampshire	13	10 fish	January 1-December 31
Massachusetts	15	5 fish	May 19-September 12
Rhode Island	15	3 fish	June 24- August 31
		7 fish	September 1-December 31
Connecticut (Private & Shore)	15	5 fish	May 19-December 31
CT (Authorized party/charter monitoring program vessels)	15	5 fish	May 19-August 31
		7 fish	September 1-December 31
New York	15	3 fish	June 23-August 31
		7 fish	September 1-December 31
New Jersey	12.5	10 fish	May 15-June 22
		2 fish	July 1-August 31
		10 fish	October 8-October 31
	13	15 fish	November 1-December 31
Delaware	12.5	15 fish	May 15-December 31
Maryland	12.5	15 fish	May 15-December 31
Virginia	12.5	15 fish	February 1-28
	12.5	15 fish	May 15-December 31
North Carolina, North of Cape Hatteras (N of 35° 15'N)	12.5	15 fish	February 1-28
	12.5	15 fish	May 15-December 31
Minimum Federal Measures	**12.5**	**15 fish**	**May 15-December 31**

Traffic Light Analysis of Atlantic Croaker (*Micropogonias undulatus)* for the Atlantic States Marine Fisheries Commission Fishery Management Plan Review.

Update for 2017 Fishing Year
&
Proposed Changes to TLA Management Scheme



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*Prepared Analysis and Report

Introduction

Atlantic croaker are managed under Amendment 1 to the Interstate Fishery Management Plan for Atlantic Croaker (2005) and Addendum I (2011). The Amendment does not require any specific measures restricting harvest but encourages states with conservative measures to maintain them. It also implemented a set of management triggers, based on an annual review of certain metrics, to respond to changes in the fishery or resource and initiate a formal stock assessment on an accelerated timeline if necessary. The Addendum revises the management program's biological reference points to assess stock condition on a coastwide basis as recommended by the 2010 stock assessment.

In August 2014, the South Atlantic State/Federal Fisheries Management Board approved Addendum II to Amendment I to the Atlantic Croaker Fishery Management Plan (FMP). The Addendum establishes a new management framework (i.e., Traffic Light Approach or TLA) to evaluate fisheries trends and develop state-specified management actions (i.e., bag limits, size restrictions, time & area closures, and gear restrictions) when harvest and abundance thresholds are exceeded. The TLA is a statistically-robust way to incorporate multiple data sources (both fishery-independent and -dependent) into a single, easily understood metric for management advice. It is often used for data-poor species, or species which are not assessed on a frequent basis, such as blue crabs in North Carolina and snow crabs in the Gulf of St. Lawrence. As such, its serves as an excellent management tool for Atlantic croaker.

The name comes from assigning a color (red, yellow, or green) to categorize relative levels of indicators on the condition of the fish population (abundance metric) or fishery (harvest metric). For example, as harvest or abundance increase relative to their long-term mean, the proportion of green in a given year will increase and as harvest or abundance decrease, the amount of red in that year becomes more predominant. Under the Addendum II, state-specific management action would be initiated when the proportion of red exceeds specified thresholds (30% or 60%), for both harvest and abundance, over three consecutive years.

The current management triggers for Atlantic croaker compare annual changes in various indices (e.g. recent landings and survey information) to review trends in the fisheries. The Atlantic Croaker Technical Committee expressed concern that previous review methodology did not illustrate long-term trends in the stock nor did it include specific management measures to implement in response to declines in the stock or fishery. This resulted in the change to the TLA for annual review of Atlantic croaker. A new stock assessment for Atlantic croaker was completed in 2017 and recommendations for further refinement of the management triggers from the TLA are contained in the second part of this report.

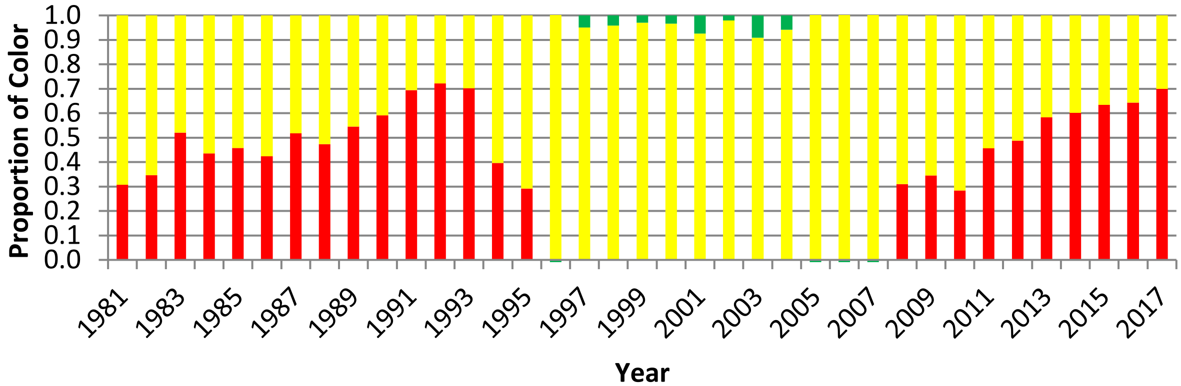
The indices used for the TLA include both commercial and recreational harvest (fishery dependent) and four fishery-independent monitoring surveys that occur in different areas of the Atlantic coast of the United States. The fishery-independent surveys include the Northeast Fisheries Science Center (NMFS) fall ground fish trawl survey, the Virginia Institute of Marine Science (VIMS) trawl survey, the North Carolina Division of Marine Fisheries trawl program 195, and the Southeast Area Monitoring Assessment Program (SEAMAP) trawl survey.

Traffic Light Analysis (Fishery Dependent)

Commercial Landings

- Commercial landings declined 27% in 2017 (1,550 metric tons) from 2016 (2,127 metric tons) and represented the 11th year of decline in commercial croaker landings.
- The TLA for commercial landings has been above the 30% every year since 2011 (Fig. 1) and was the 7th year in a row where landings were above the 30%.
- More concerning is that the red proportion has been above the 60% red threshold for the last four years (2014-2017).
- The three year mean red proportion for croaker has exceeded 30% since 2010 and has exceeded 60% for the last three years. The continued steady decline in croaker landings in recent years represent some of the lowest landings levels in the time series and indicate some management response is required.

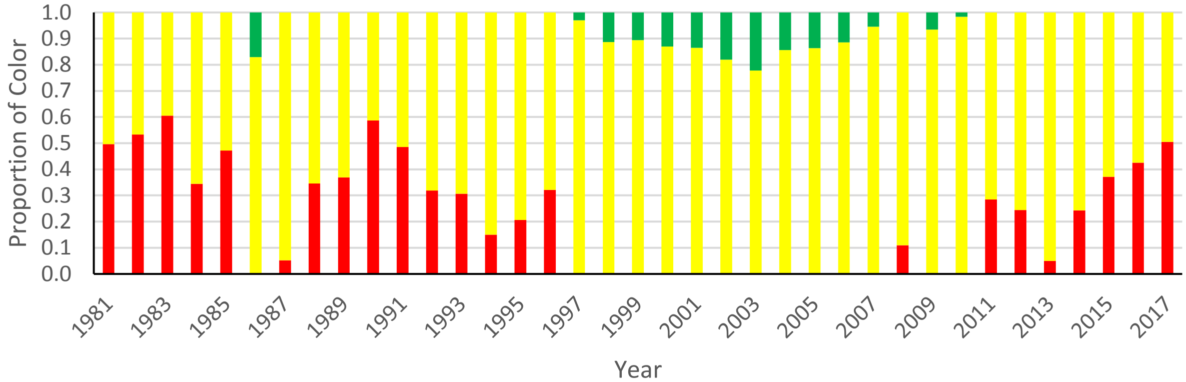
Figure 1. Annual TLA color proportions for Atlantic croaker commercial landings for the Atlantic coast of the US.



Recreational Harvest

- The recreational index this was computed using the newly revised MRIP harvest estimates.
- The recreational harvest index continued to decline, down 18.6% (2,205 metric tons) in 2017 from harvest levels seen in 2016 (2,708 metric tons).
- The recreational harvest level in 2017 (2,205 metric tons) was among the lowest annual harvests in the entire time series (1981-2017).
- Annual percent standard error (PSE) levels were elevated (> 20%) but not quite at the level where considered completely unreliable (> 50%).
- The proportion of red in the TLA was 50.4% in 2017 and 42.5% in 2016 (Fig. 2), indicating the recreational index would have triggered the last two years at the 30% level.
- As with commercial landings, the continued decline in harvest levels for Atlantic croaker in the recreational fishery are also cause for concern indicating management measures may be necessary.

Figure 2. Annual TLA color proportions for Atlantic croaker from Atlantic coast (NJ-FL) recreational harvest of the U.S. based on a 1996-2008 reference period.

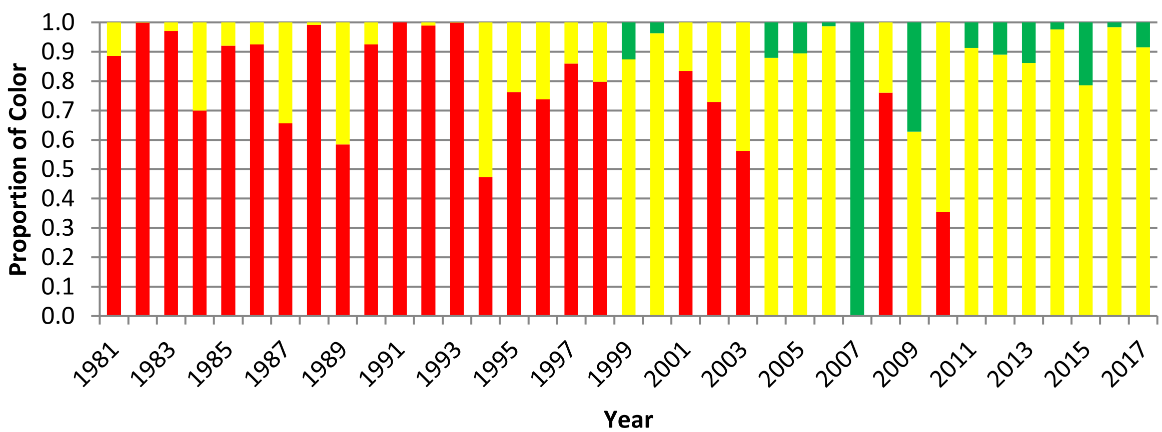


Traffic Light Analysis (Fishery-independent Surveys)

NEFSC/NMFS Fall Groundfish Survey

- The NEFSC/NMFS was not carried out in 2017 due to mechanical problems with the RV Bigelow. In the interim, a placeholder index for 2017 was calculated as the mean for the previous three years (2014-2016) (Fig. 3).
- The index stayed above the long term mean in 2017 using the previous three year average.
- The TLA trigger would not have tripped on the NMFS index in 2017 using the 2014-2016 average.

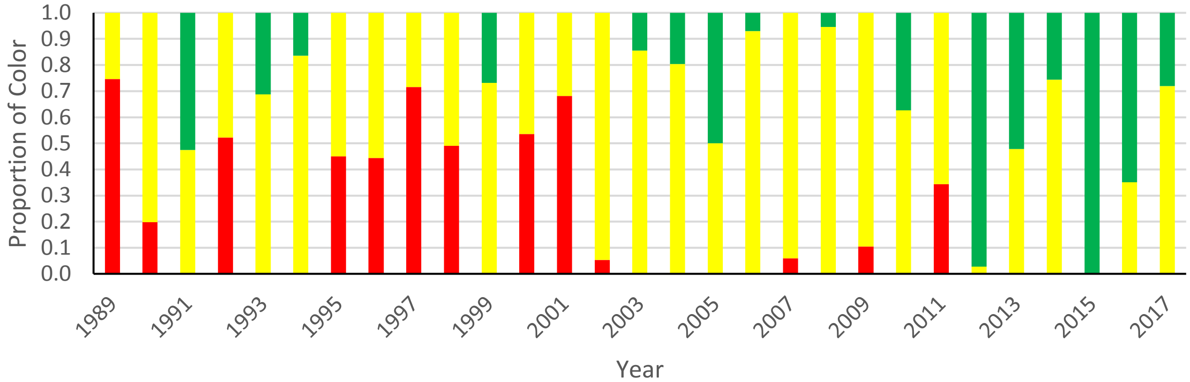
Figure 5. Annual TLA color proportions for Atlantic croaker from NMFS ground-fish trawl survey based on 1996-2008 reference period.



SEAMAP Survey

- The SEAMAP index declined 36.1% in 2017 (8.9 kg/tow) from 2016 (13.9 kg/tow).
- Index values remained above the long term mean so there was no red in the TLA (Fig. 4).
- The TLA trigger for the SEAMAP survey did not trip in 2017.

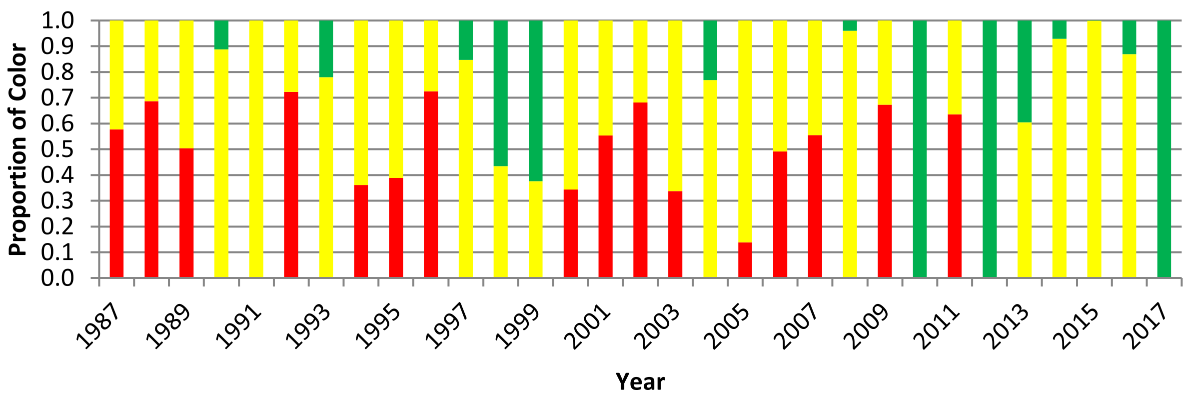
Figure 4. Traffic Light Model for SEAMAP catch data by weight using a 1996-2008 reference period.



North Carolina Program 195

- The North Carolina index increased 217% in 2017 (1,172.3 fish/tow versus 369.8 fish/tow in 2016) and was well above the long term mean resulting in all green in the TLA.
- The high catch level in 2017 was the second highest in the entire time series.

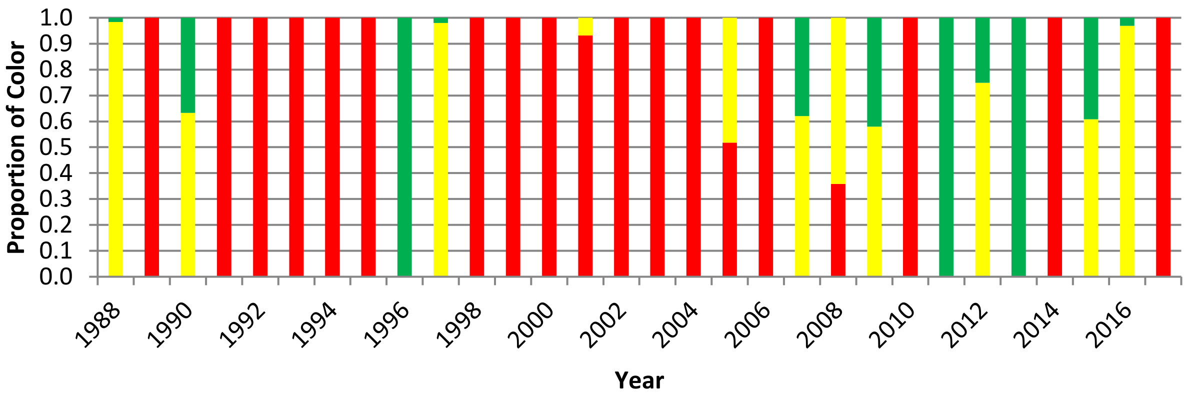
Figure 5. NCDMF Program 195 TLA color proportions for Atlantic croaker using 1996-2008 reference period.



VIMS Survey

- The VIMS index declined significantly (95.3%) in 2017 from 2016 going from 13.2 fish per tow in 2016 to 0.614 fish per tow in 2017. The alternating high variability in annual index values was evident in the alternating proportions of red and green in the TLA for the last 6 years (Fig. 6). High variability in the TLA color proportions was likely due to annual recruitment variations, which would not be uncommon for a juvenile index. However, the index decline in 2017 did represent one of the lowest values in the entire time series.
- The index value was well below the long term mean in 2017 but the three year average red proportion was above 30% in 2017 (44.4%), so the index would have tripped the TLA trigger in 2017.

Figure 6. Annual TLA color proportions for Atlantic croaker from VIMS spring trawl survey using 1996-2008 reference period.

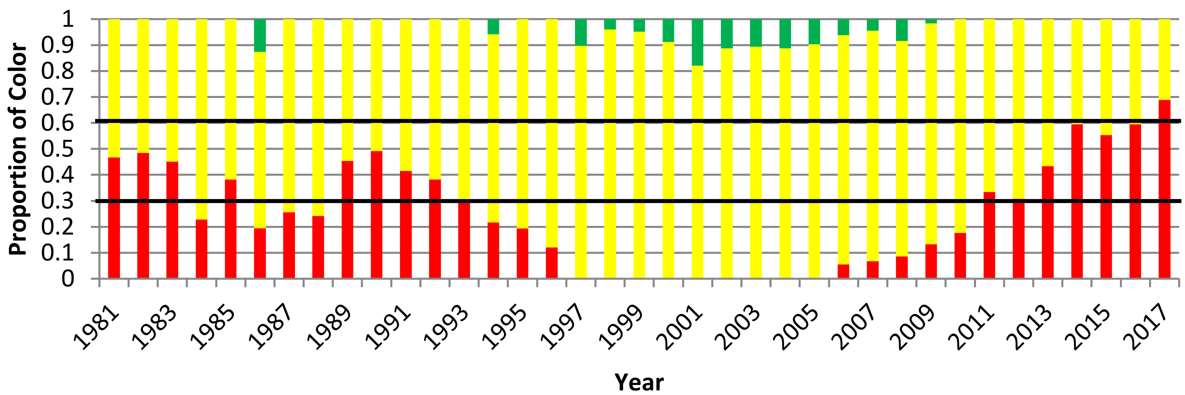


Traffic Light Analysis (Composite Indexes)

Harvest Composite Index

- The harvest composite TLA index indicates that the management response trigger would have been tripped for the fifth year in a row.
- The mean red proportion for the most recent three year time period (2015-2017) was above 60% for two of the three years and averaged 61.2%, which was well above the significant level of concern threshold.
- The important trend to point out is the continuing decline in recreational and commercial landings for Atlantic croaker.

Figure 7. Annual color proportions for harvest composite TLA of Atlantic Croaker recreational and commercial landings



Abundance Composite Characteristic Indexes

The abundance composite TLA index was broken into two components based age composition. The adult composite index was generated from the NMFS and SEAMAP surveys since the majority of Atlantic croaker captured in those surveys were ages 1+. The juvenile composite index was generated from the NC program 195 and VIMS surveys because these two captured primarily young-of-the-year Atlantic croaker.

- Three of the four abundance indexes showed increases in 2017.
- The adult composite TLA characteristic (Fig. 8) showed a trend of declining green proportions over the last three years.

- The juvenile composite TLA characteristic (Fig. 9) in 2017 was unusual in that it only had red and green with no yellow in the index. This was due to the very high survey value for NC195 (100% green) and very low value for VIMS (100% red).

Figure 8. Adult croaker TLA composite characteristic index (NMFS and SEAMAP surveys).

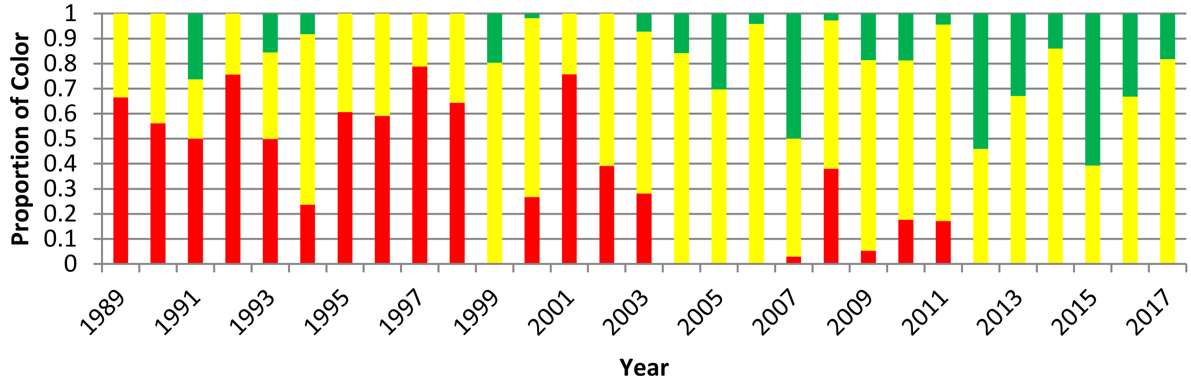
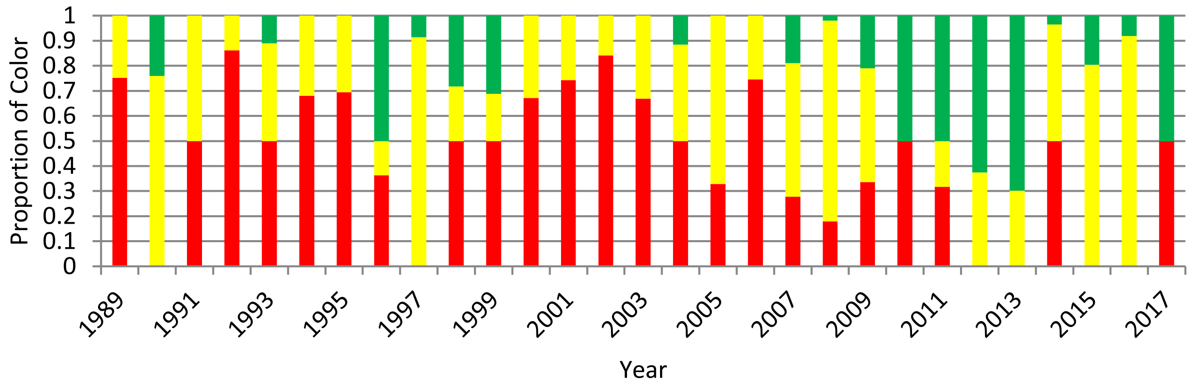


Figure 9. Juvenile croaker TLA composite characteristic index (NC 195 and VIMS surveys).



Neither the adult or juvenile composite characteristic index tripped in either 2017 with red proportions greater than 30% for two of the three terminal years.

- The higher annual variability for the different color proportions in the juvenile composite characteristic (compared to the adult composite characteristic) is likely a reflection of annual recruitment variability rather than population trends.

Summary

The harvest composite TLA tripped in 2017 (for the fifth year in a row) while the abundance TLA composite did not trip. The continued declining trend in the commercial and recreational harvests for the Atlantic coast is a concern since the decline has become greater in the last two years. The recently completed Atlantic croaker stock assessment was not accepted for management use, in part due to the conflicting signals shown by abundance and harvest metrics. The explanation for this discrepancy may lie in differing size and age structures of the different fishery-independent surveys and commercial and recreational landings, with older/larger fish being the more likely target of the fishery. Using an age partitioning approach while examining different (and additional) indices on a regional perspective may allow better refinement of the TLA, providing more synchrony between the harvest and landings metrics for adults as well as juveniles. The next section of this report illustrates this point by presenting both an age structured and regional TLA with additional fishery-independent surveys.

Proposed Changes to Existing Management Traffic Light Approach for Atlantic Croaker

The current Traffic Light Analysis (TLA) approach for Atlantic croaker has not triggered management action to date despite declining trends in commercial and recreational harvest since the early 2000s. There has also been discussion about regional differences and the reliability of data sources with contradictory trends for tracking changes in abundance. Data sources considered in the TLA and assessment were explored in attempts to explain differences in trends and identify potential changes in TLA metrics.

Four options were developed by the TLA subcommittee (TLA-SC) for the Technical Committee's (TC) review. These options were presented for consideration in February 2018 at the Winter Meeting of the South Atlantic Fisheries Management Board (SAB) of the Atlantic States Marine Fisheries Commission (ASMFC). The four options considered included the following:

1. Status Quo (not recommended)
2. Coastwide TLA with Revised Indices
3. Regional TLA with Revised Indices
4. Relative Exploitation

The SAB requested that the TC further explore Option 3 (Regional TLA with Revised Indices) and present a revised TLA using this option along with the current TLA for the Summer Meeting of the ASMFC (August 2018). As decided during previous meetings, the South Atlantic shrimp trawl discards will be included with all options, but for informational purposes only (i.e., cannot trigger management). In addition, as is done in the current TLA, a recruitment metric is included with all options, not as a direct management trigger but for the TC's consideration during annual TLA updates to better inform management. The TLA recruitment metric includes a composite of VIMS and NC Program 195 indices for the following options, although the NMFS-NEFSC trawl and SEAMAP (ages 0 and 1) indices are available too.

The TLA-SC suggests a change in the management triggers so that management action should be considered if 2 of the 3 latest years have tripped based on previous guidelines (30% red represents a moderate concern and 60% red represents a significant concern). Again, these would be based on the adult composite index and the harvest metrics, not the recruitment metric.

For all options, the TC had the responsibility of evaluating informational metrics (recruitment, shrimp trawl discards) during annual TLA updates, especially in years when management action was not triggered, to determine other signs of concern with the population. Under Amendment I, the TC can recommend management action during years when the adopted option does not trigger management.

Option 3. Regional TLA with Revised Indices

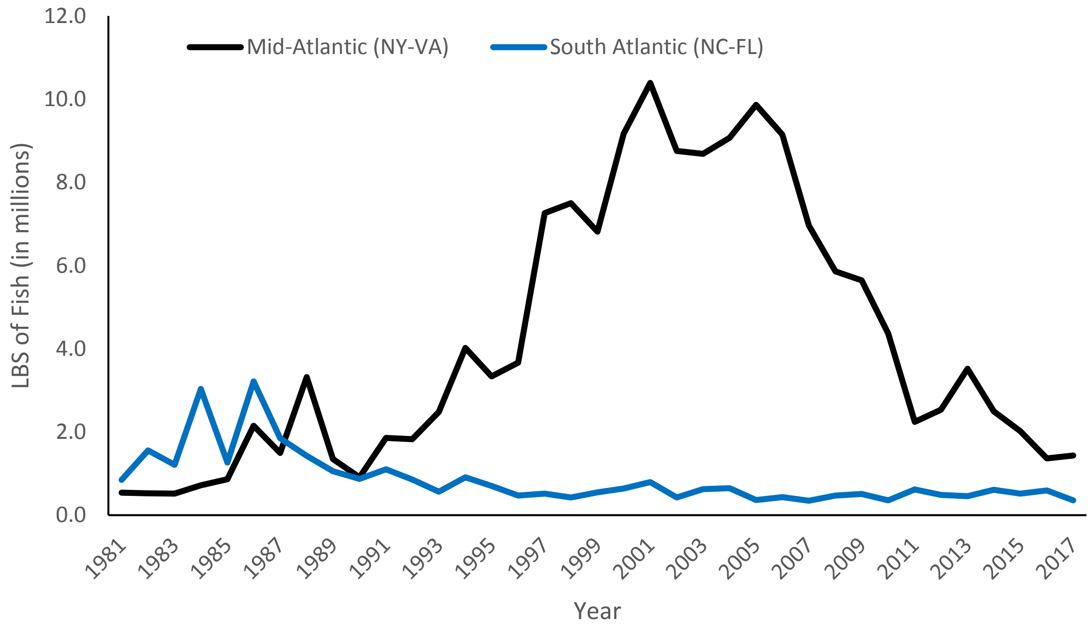
For this option, the TLA-SC revised the abundance indices for Atlantic croaker to split them by age (recruitment indices and age 2+ indices) and region (Mid-Atlantic and South Atlantic) to better reflect the population. Adult indices for the regional TLA would be NMFS-NEFSC (age-2+, excluding NC strata) and ChesMMAP for the Mid-Atlantic and SEAMAP (age-2+) and SC

Trammel survey for the South Atlantic. All adult indices were developed in weight per tow, except the trammel survey. The reference period for the TLA would be based on a 2002-2016 time period since this time frame was covered by all the proposed indices. In addition to an adult index for each region, there would also be regional harvest TLAs for the commercial and recreational fisheries based on annual landings.

Harvest Composite Index

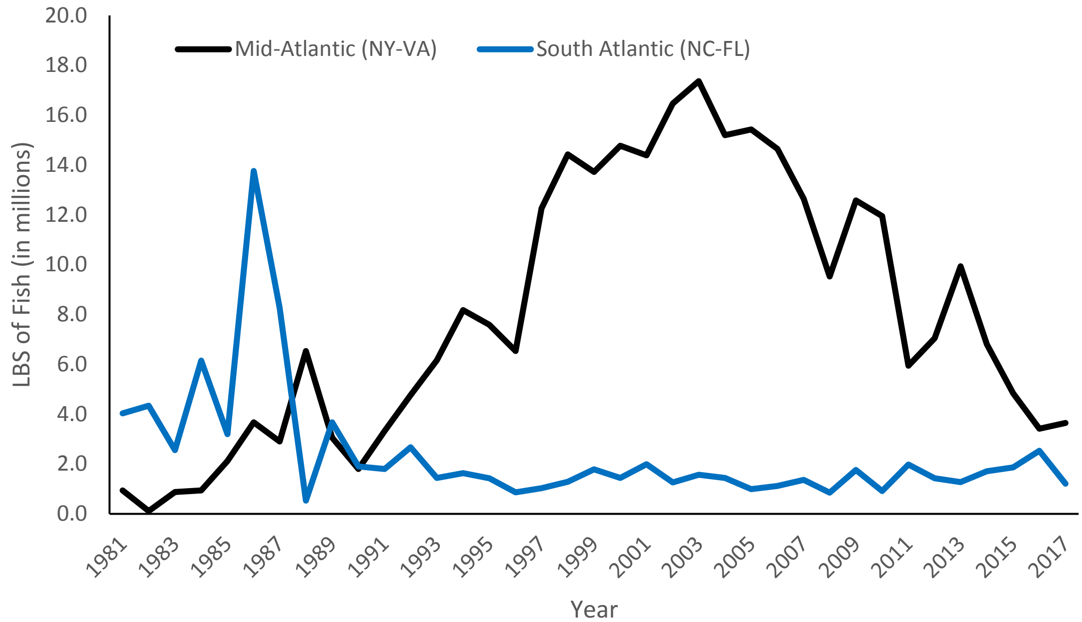
The bulk of coastal commercial landings for Atlantic croaker are driven by trends in the mid-Atlantic (NY-VA) versus relative landings in the South Atlantic region (NC-FL) (Fig. 10). However, the general trend in the south Atlantic has been one of long term decline for Atlantic croaker with the highest landings occurring early in the time series.

Figure 10. Annual commercial landings of Atlantic croaker by region on the Atlantic coast of the United States.



The landings trends for the recreational Atlantic croaker fishery was almost identical to the commercial fishery with general landings trends being driven by the mid-Atlantic coastwide (Fig. 11). As with the commercial landings, the recreational landings in the southern regions showed a general long term decline with the highest landings occurring in the early years of the time series.

Figure 11. Annual recreational harvest by region for Atlantic croaker on the Atlantic coast of the United States.



The harvest composite TLA for both regions mirrored the general trends seen in the annual landings. In the mid-Atlantic, the high proportions of red in recent years were of concern with proportions above 30% since 2011 (Fig. 12). In the south Atlantic, the TLA shows the continued declining trend that has occurred since the early 1990s with red proportions exceeding 30% since 2012 (Fig. 13). The three year average red proportion for the most recent years exceeded 60% for both regions. The management trigger using two out of three years being greater than 30% red would have resulted in the composite harvest metric triggering in both regions from 2012 onward.

Figure 12. Harvest composite TLA for Atlantic croaker from the mid-Atlantic (NJ-VA) using a 2002-2016 reference period.

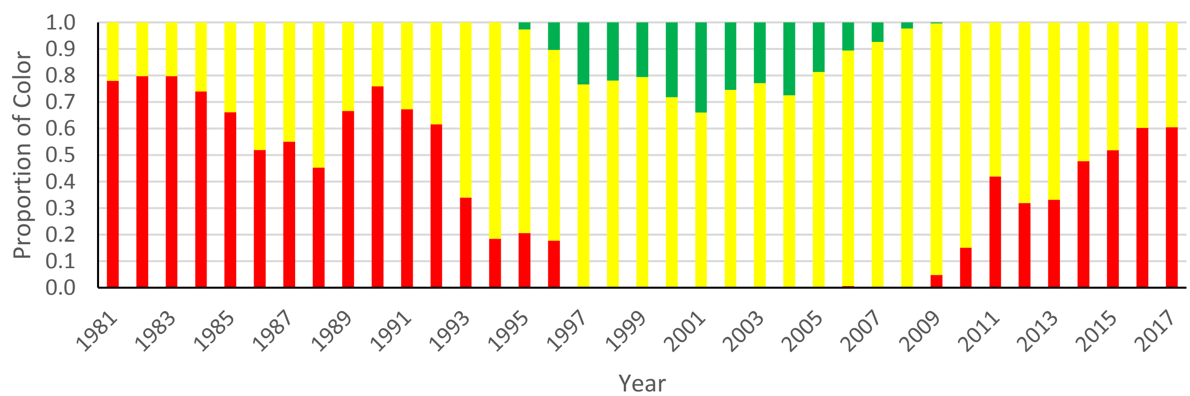
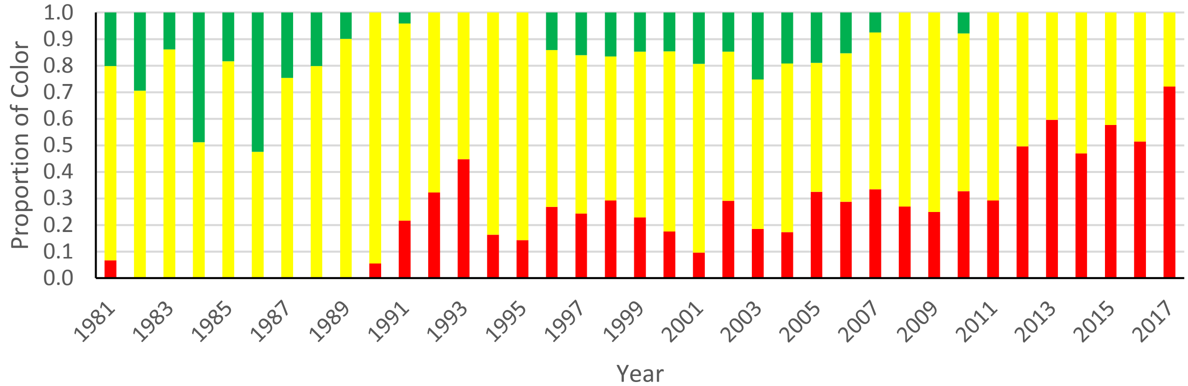


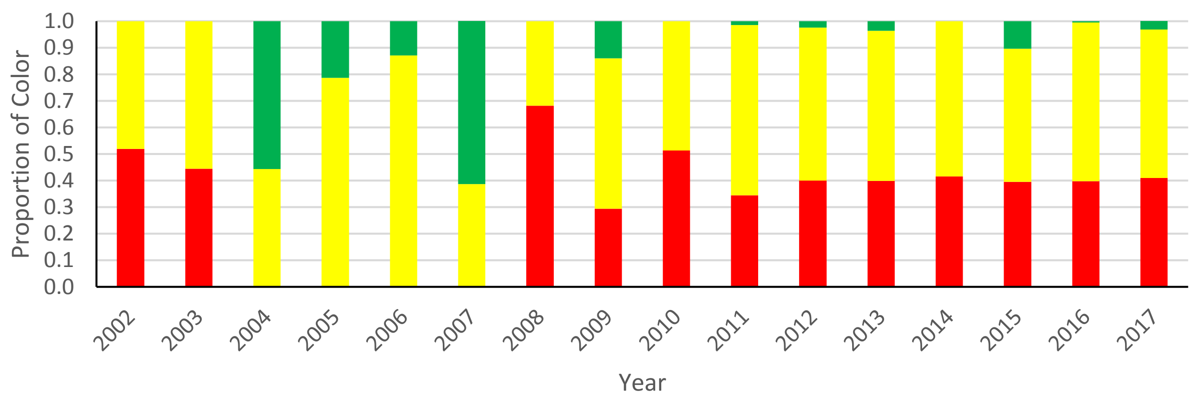
Figure 13. Harvest composite TLA for Atlantic croaker from the south Atlantic (NC-FL) using a 2002-2016 reference period.



Adult Composite Indices

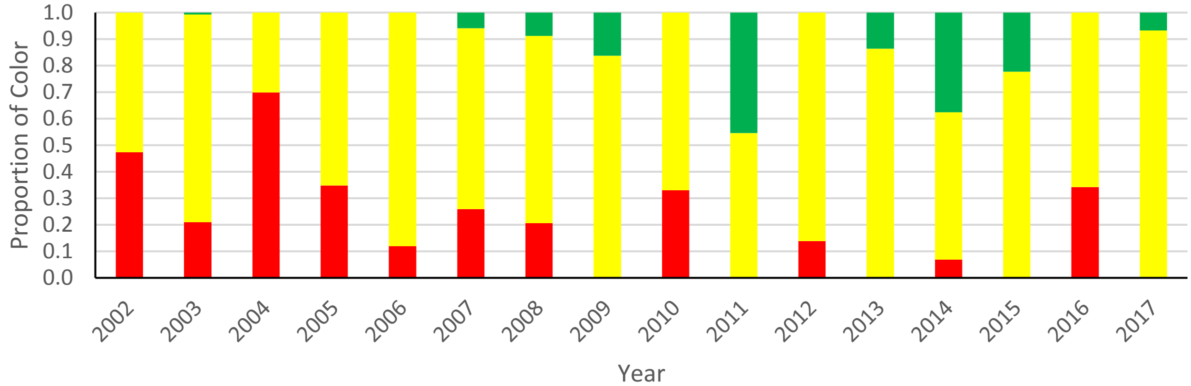
The time period used for the adult composite TLA matched the reference period since that was the year when all the surveys overlapped. In the mid-Atlantic, the TLA illustrated a declining trend since 2007 with red proportions greater than 30% for all years except one (2009) since 2008 (Fig. 14). The high red proportions in recent years was being driven primarily by the ChesMMAP survey which has shown a significant declining trend. Using the 2 out of 3 year rule for red proportions greater than 30%, the mid-Atlantic TLA would have tripped every year since 2010.

Figure 14. Mid-Atlantic adult composite TLA for Atlantic croaker using a 2002-2016 reference period. Indexes included NMFS and ChesMMAP.



In the south Atlantic, the composite TLA has only had one year (2016) with a red proportion greater than 30%. The south Atlantic composite TLA used the spring time frame for the SEAMAP survey and May through September for the SCDNR trammel survey. Both of these surveys catch only adult croaker during these time periods compared to the fall when 1 year olds and some age 0 fish can show up in the catches of either survey. Higher proportions of red in the early 2000s reflected low catch rates in both surveys during this time period. However, the southern region composite TLA did show greater abundance during years (2011-2015) where declining abundance occurred in the mid-Atlantic. However, it should be noted that recreational harvest actually showed an increasing trend in the south Atlantic during these same years. Although the recreational harvest increase was modest, the trends do generally match up with the TLA composite during those years.

Figure 15. South Atlantic adult composite TLA for Atlantic croaker using 2002-2016 reference period. Indexes included SEAMAP and SCDNR trammel survey.



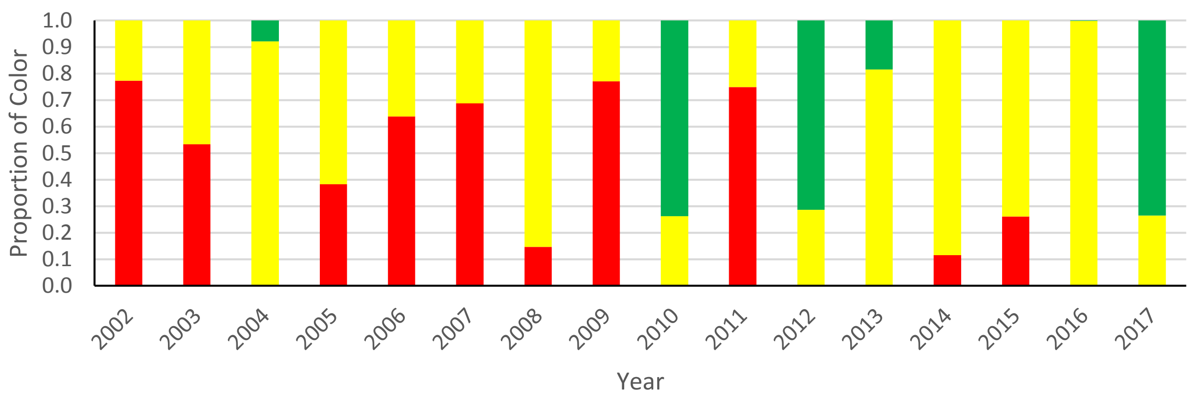
Regional Advisory Indices

Juvenile Composite TLA

The mid-Atlantic composite TLA for juvenile Atlantic croaker showed relatively poor recruitment in most years since 2002 (Fig. 16), which would have certainly contributed to the declining trends seen in adult Atlantic croaker. The TLA red proportions in the mid-Atlantic were above 30% in all but 4 years since 2002.

There was only one juvenile index used for TLA comparisons in the south Atlantic (NC Program 195). The NC195 survey showed relatively poor recruitment in the early to mid 2000's with

Figure 17. South Atlantic juveniile TLA using the North Carolina Program 195 survey with a 2002-2016 reference period.



higher recruitment in recent years. Peak recruitment years in the south Atlantic occurred in 2010, 2012, and 2017. In contrast, the mid-Atlantic juvenile TLA showed poor recruitment in 2010 and 2017 and only moderately better recruitment in 2012.

South Atlantic Shrimp Trawl Discards

Current estimates of relative Atlantic croaker by-catch from the south Atlantic shrimp fishery is only available through 2016 at the writing of this report. This will be amended when the by-catch index for 2017 become available.

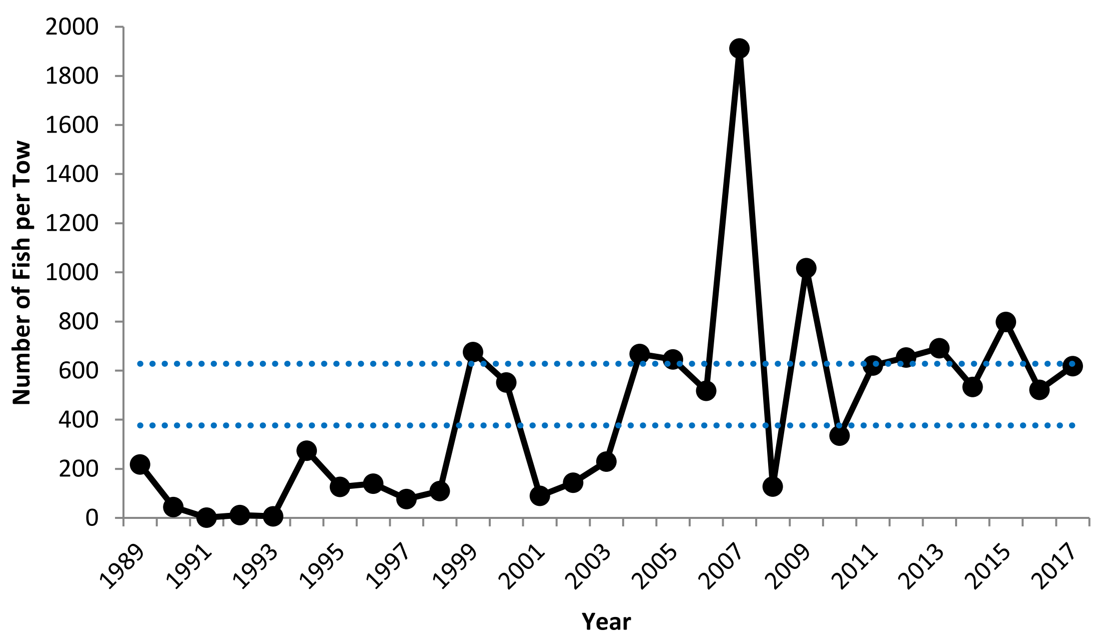
Supplemental Material: Fishery-independent Individual Index TLA's

NMFS

- ❖ Since there was no NMFS sampling along the mid-Atlantic due to mechanical issues on the RV Bigleow, A placeholder index using the three year (2014-2016) was used for the TLA. The TC shall have to decide if the NMFS index should remain in the 2017 index or not be used for this one year. Given the current trends over the last few years with this index, the author suggests using the placeholder proxy for 2017 only as trends have been consistent across the last few years and unless something drastic changes the index it is like to have a minimal impact on the TLA.

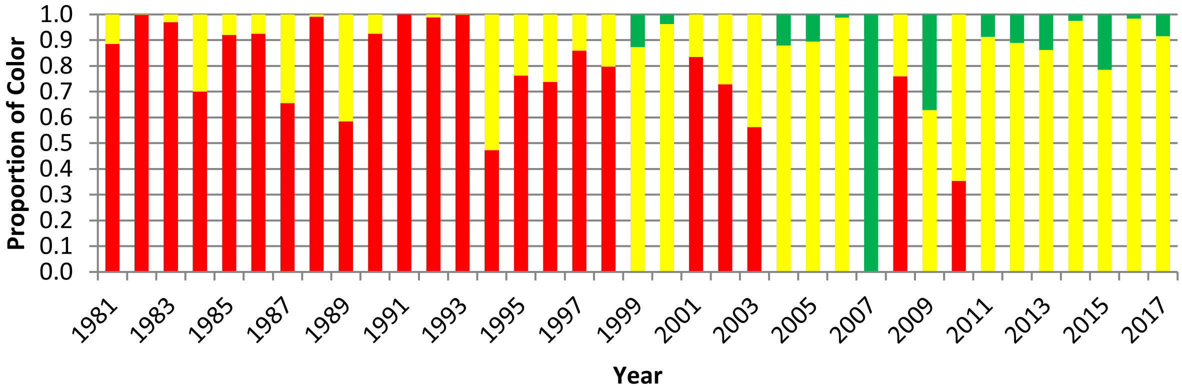
Mean annual CPUE has declined since the peak in 2007 but has remained at or about the long term mean (top blue line on Fig. 18) since 2011 indicating some relative stability in abundance.

Figure 18. Stratified mean annual CPUE for Atlantic croaker for NMFS survey.



This same trend was reflected in the TLA with some green but mostly yellow since 2011. The use of a 3 year mean (2014-2016) as a placeholder should be adequate as it would have taken an extreme drop to effect the index and how it is used in the TLA.

Figure 19. Annual TLA color proportions for Atlantic croaker from NMFS ground-fish trawl survey based on 1996-2008 reference period.



ChesMMAP

The Chesapeake Marine Monitoring Program (ChesMMAP) is a general fish abundance trawl survey run by the Virginia Institute of Marine Science (VIMS) that covers the central portion of the Chesapeake Bay from the mouth up to approximately Aberdeen, MD. Atlantic croaker are one of most abundant species in the survey. ChesMMAP has been in operation since 2002 with 15 years of currently available data. While not as geographically expansive as some of the other larger regional surveys (NMFS, NEAMAP, and SEAMAP), ChesMMAP does cover the full length of the Chesapeake Bay including both Virginia and Maryland.

The overall declining trend in catch of Atlantic croaker was evident in both the adult (age 2+) and juvenile (ages 0-1) indices, although the adult index was higher than the juvenile index (Fig. 20) in the early years of the survey. The series peak for juveniles occurred in 2007 and the series peak for adults occurred in 2004. Since 2008 abundances for both age groups have remained relatively low.

The TLA reflected these trends with high proportions of red since 2008 (Figs. 21 &22). Proportionately, the decline was slightly greater for juveniles than for adults in recent years.

Figure 20. Stratified mean annual CPUE for Atlantic croaker by age group for ChesMMAP.

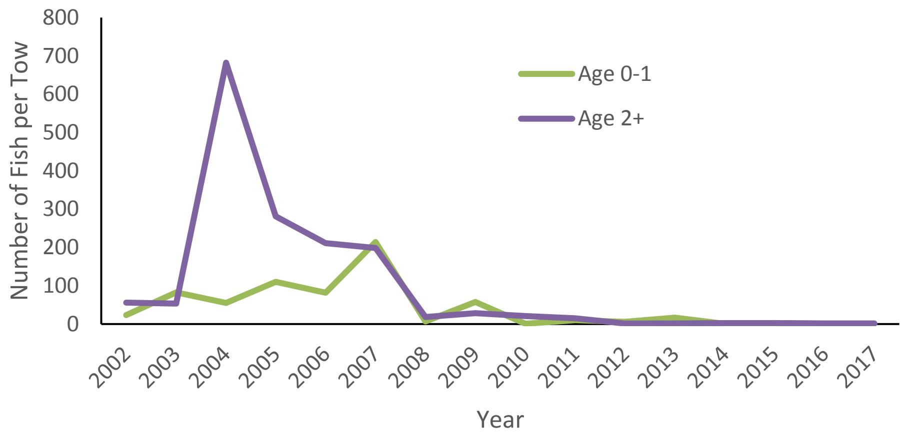


Figure 21. Annual TLA for Atlantic croaker from ChesMMAP for ages 0-1

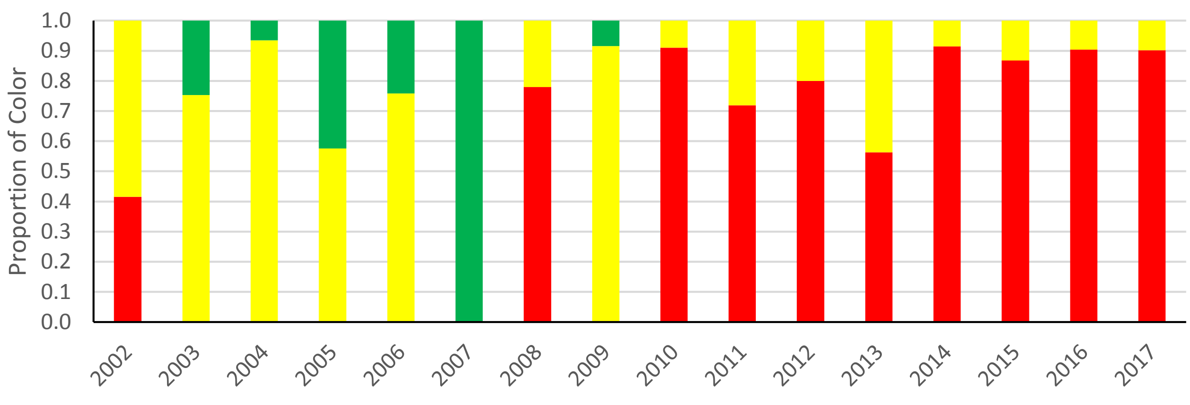
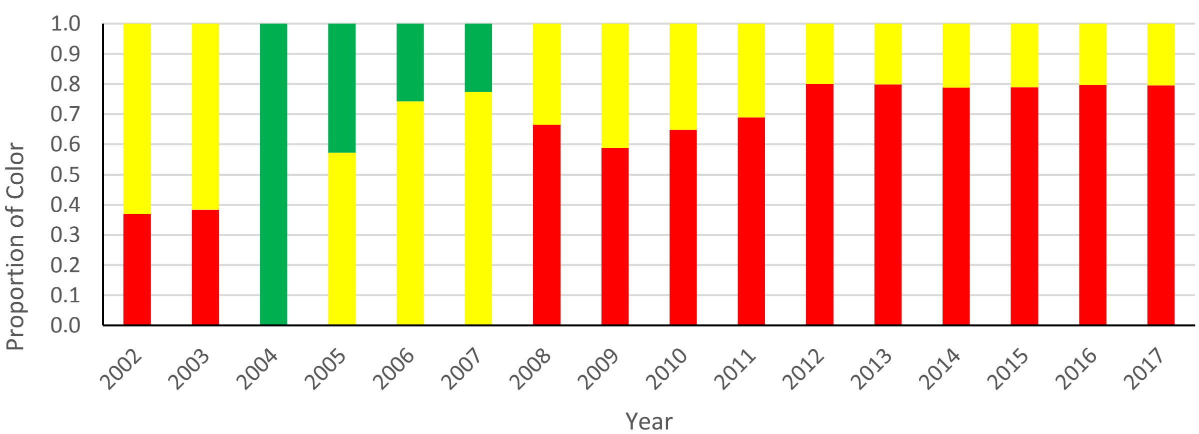


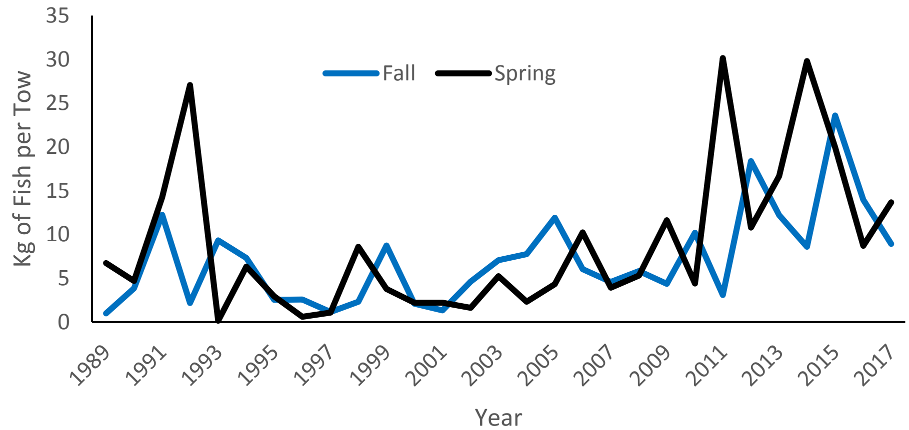
Figure 22. Annual TLA for Atlantic croaker from ChesMMAP for ages 2+



SEAMAP

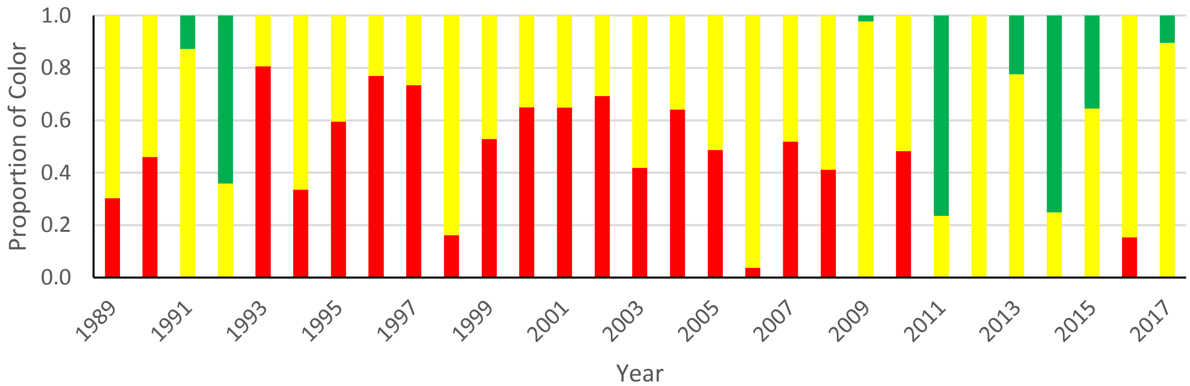
The SEAMAP survey samples during three seasons of the year (spring, summer, and fall) and historically the index used for Atlantic croaker for the trigger management exercises has always been the fall index. The reasons for this were several having to do with the co-occurrence in time frame with other surveys (NMFS), greater abundances in the fall, and higher levels of positive tow intercepts. The fall survey also had the greatest age range sampled for Atlantic croaker with higher numbers of ages 0 and 1. The spring survey had very few age 1 fish and no age 0 fish, therefore the spring survey was a much better index for tracking adult (age 2+) Atlantic croaker. With the proposed age regional and age split TLA, the spring survey would be better for tracking these adult croaker. Additionally, annual CPUE values correlated significantly ($r = 0.731$, $p<0.05$) when the spring index was lagged forward by one year such that peaks in the fall CPUE corresponded to peaks in the following spring CPUE (Fig. 23).

Figure 23. Mean annual CPUE for Atlantic croaker from SEAMAP survey by season.



The TLA for spring showed low abundances from the late 1990s through the mid-2000s (Fig. 24). Since 2009 there has been a generally increasing trend with the two peaks in abundance for the entire time series occurring in 2011 and 2014 being reflected by the high green proportions for those years (Fig. 24).

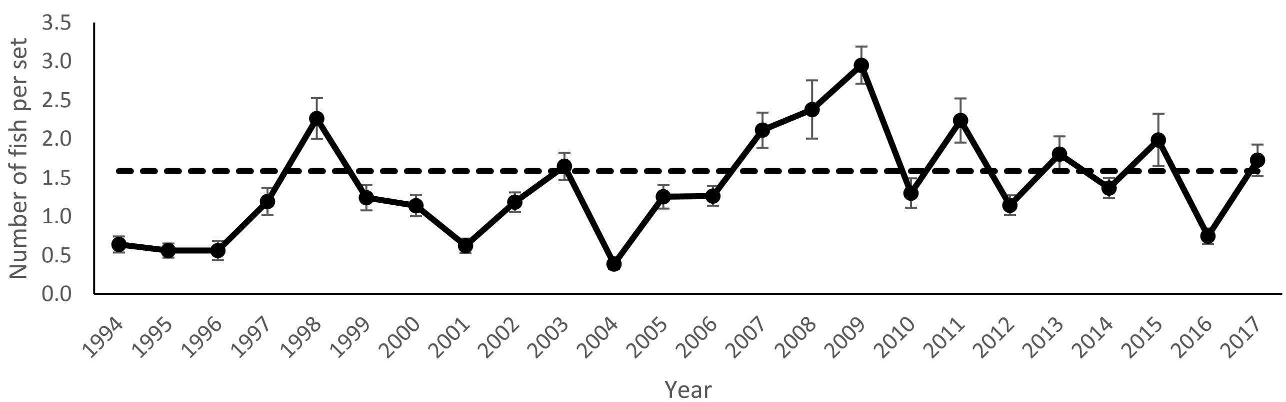
Figure 24. Annual TLA color proportions for adult Atlantic croaker from SEAMAP survey for the spring



SCDNR Trammel Net Survey

The SCDNR trammel net survey is a randomly stratified monthly survey that has been ongoing since 1991. There have been 8 estuarine strata covered during the entire time frame but there is a core group of 5 strata that have been sampled continuously from 1994 through 2017 which are used to calculate the annual abundance index. There were only two years above the long term mean prior to 2007 with a general increasing trend in the index since 2004 and the series peak

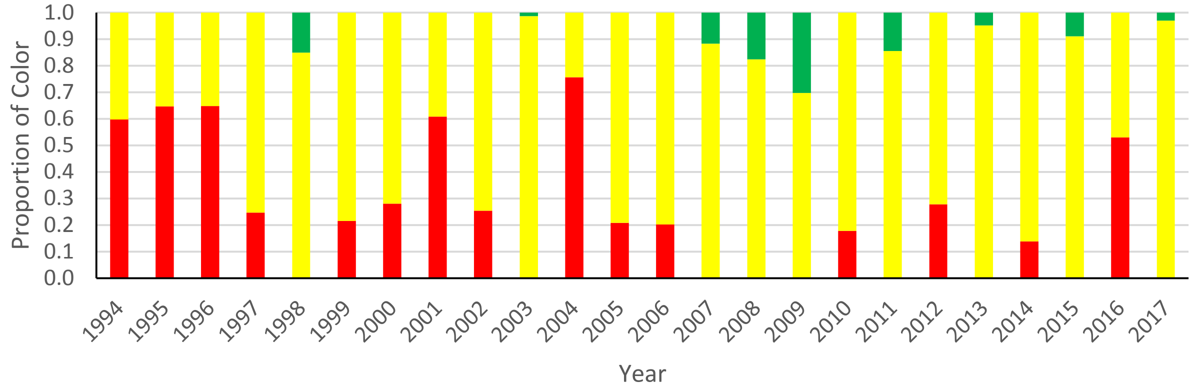
Figure 25. Stratified annual CPUE for Atlantic croaker from core strata from May - Sept. for SCDNR Trammel Net Survey. Error bars are SEM and dashed line is long term mean.



occurring in 2009 (Fig. 25). Since 2007, annual CPUE values have declined although annual values have varied above and below the long term mean.

The TLA mirrored this trend with higher red proportions in the 1990s and early 2000s and higher green proportions from 2007-2009 (Fig. 26). There has been only one year since 2010 that has had a red proportion greater than 30% (2016).

Figure 26. Annual color proportions for TLA of SCDNR trammel survey for Atlantic croaker from core strata.



VIMS Spring Juvenile Fish Survey

The annual CPUE for the VIMS survey stayed below the long term mean in most years prior to 2007 (Fig. 27). There was an increasing trend from 2006-2013 to with two of the three highest CPUE values in the data series. Since 2013 CPUE has declined to the point where 2017 had one of the lowest values in the series.

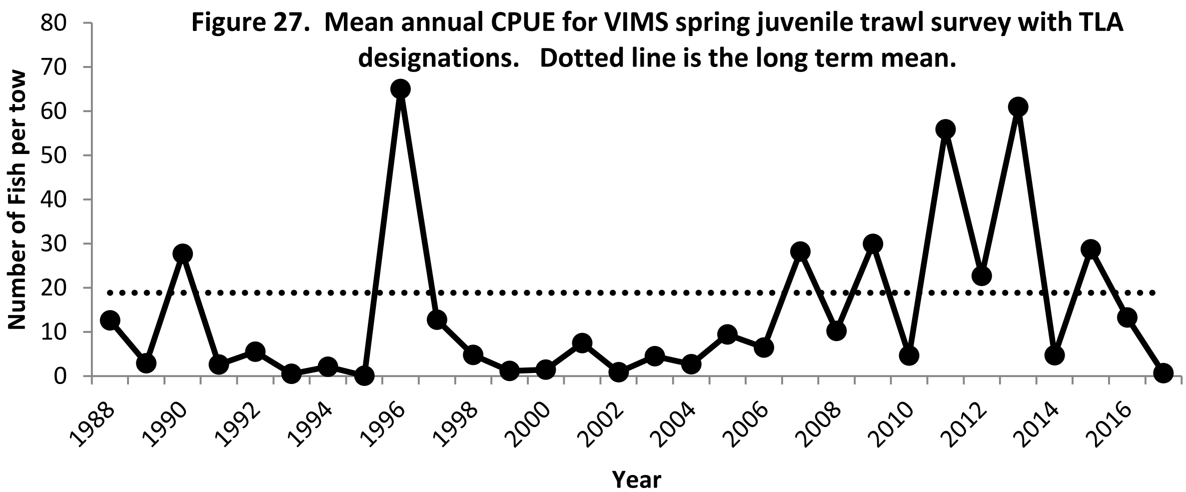
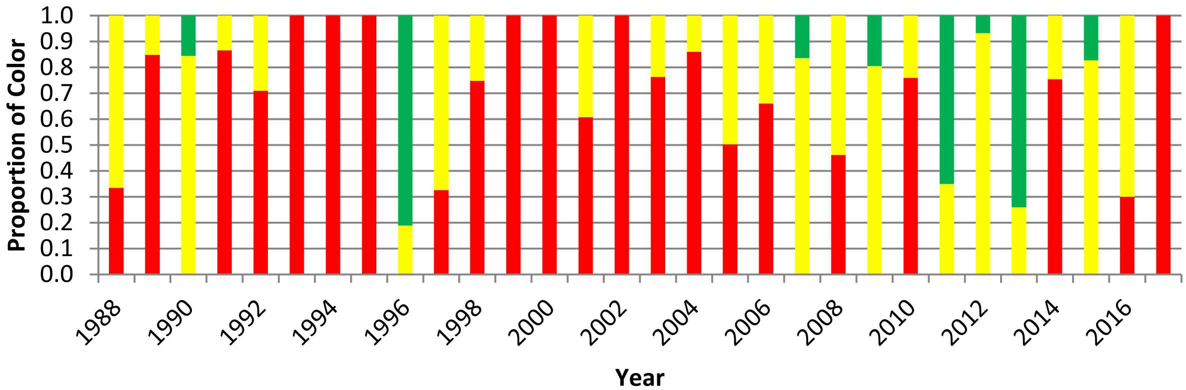


Figure 27. Mean annual CPUE for VIMS spring juvenile trawl survey with TLA designations. Dotted line is the long term mean.

The high proportions of red in the TLA during the early years was a reflection of the reference period encompassing the peak time period in the survey (Fig. 28). While annual TLA proportions have been highly variable since 2010, the index would have tripped in 2017 with red proportions > 30% in 2016 and 2017 (two of the three previous years).

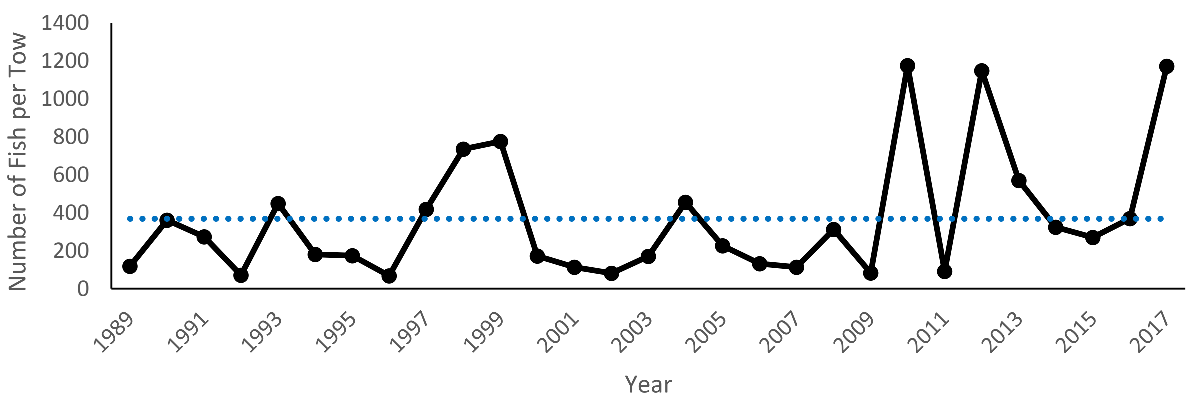
Figure 28. Annual TLA color proportions for Atlantic croaker from VIMS spring trawl survey using 2002-2016 reference period.



North Carolina DMF Program 195

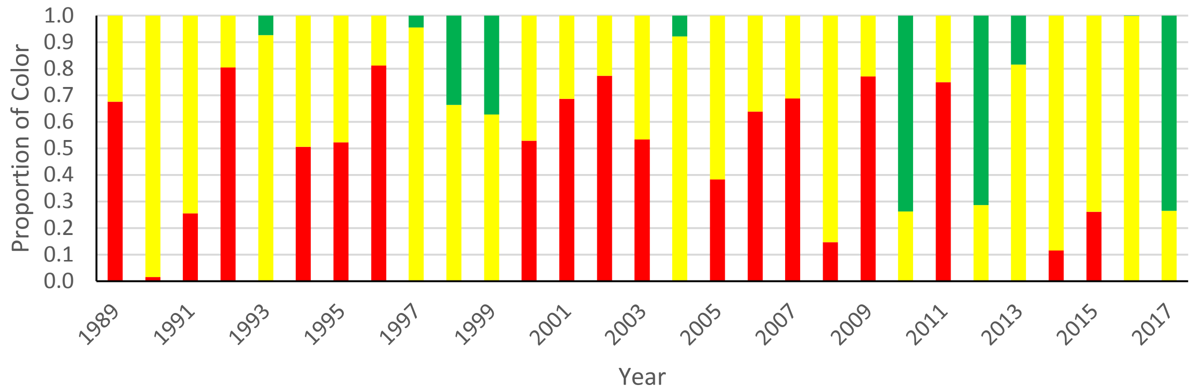
Annual abundance has been on an increasing trend since 2009 with the three highest annual CPUE values occurring since 2010 (Fig. 29). The high degree of annual variability is typical of juvenile fish surveys but the high annual values indicate increased recruitment in recent years.

Figure 29. Stratified mean annual CPUE for Atlantic croaker from NCDMF Program 195. Dotted line is the long term mean for 2002-2016.



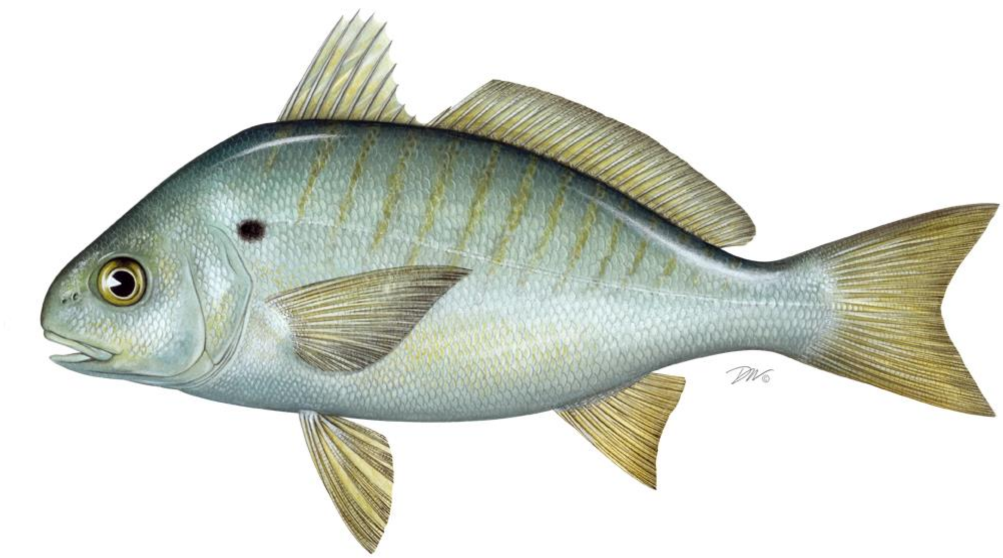
The TLA illustrated this trend with the high proportions of green in 2010, 2012, and 2017 (Fig. 30). This index would not have triggered at the 30% level since 2011. Prior to that it would have triggered most years during the 2000s.

Figure 30. Annual TLA color proportions for NCDMF Program 195 juvenile Atlantic croaker using 2002-2016 reference period



2018 Traffic Light Analysis of Spot (*Leiostomus xanthurus)* for the Atlantic States Marine Fisheries Commission Fishery Management Plan Review.

2017 Fishing Year
&
Proposed Changes to TLA Management Scheme



Plan Review Team
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Introduction

Spot is managed under the Omnibus Amendment for Spot, Spotted Seatrout, and Spanish Mackerel (2011) and Addendum I (2014). The Omnibus Amendment updates all three species plans with requirements of the Commission's ISFMP Charter. The Benchmark Stock Assessment for spot in 2017 was not accepted for management purposes due to the lack of reliable stock biomass and the impact of the shrimp trawl fishery on the population.

Previously, in the absence of a coastwide stock assessment, the South Atlantic Board approved Addendum I to the Spot FMP in 2014. The Addendum establishes use of a Traffic Light Analysis (TLA), similar to that used for Atlantic croaker, to evaluate fisheries trends and develop state-specified management actions (e.g., bag limits, size restrictions, time and area closures, and gear restrictions) when harvest and abundance thresholds are exceeded for two consecutive years. The TLA is a statistically-robust way to incorporate multiple data sources (both fishery-independent and -dependent) into a single, easily understood metric for management advice. It is often used for data-poor species, or species which are not assessed on a frequent basis. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of indicators on the condition of the fish population (abundance metric) or fishery (harvest metric). For example, as harvest or abundance increase relative to their long-term mean, the proportion of green in a given year will increase and as harvest or abundance decrease, the amount of red in that year becomes more predominant. The TLA improves the management approach as it illustrates long-term trends in the stock and includes specific management recommendations in response to declines in the stock or fishery. Under the Addendum, state-specific management action would be initiated when the proportion of red exceeds specified thresholds (30% or 60%), for both harvest and abundance, over two consecutive years.

The current management triggers for spot compare annual changes in various indices (e.g. recent landings and survey information) to review trends in the fisheries. The spot Plan Review Team expressed concern that the previous review methodology did not illustrate long-term trends in the stock nor did it include specific management measures to implement in response to declines in the stock or fishery. The indices used for the TLA include both commercial and recreational harvest (fishery dependent) and three fishery independent monitoring surveys that occur in different areas of the Atlantic coast of the United States. The fishery independent surveys include the Northeast Fisheries Science Center (NMFS) fall ground fish trawl survey, the Maryland Dept. of Natural Resources juvenile striped bass seine survey, and the Southeast Area Monitoring Assessment Program (SEAMAP) trawl survey.

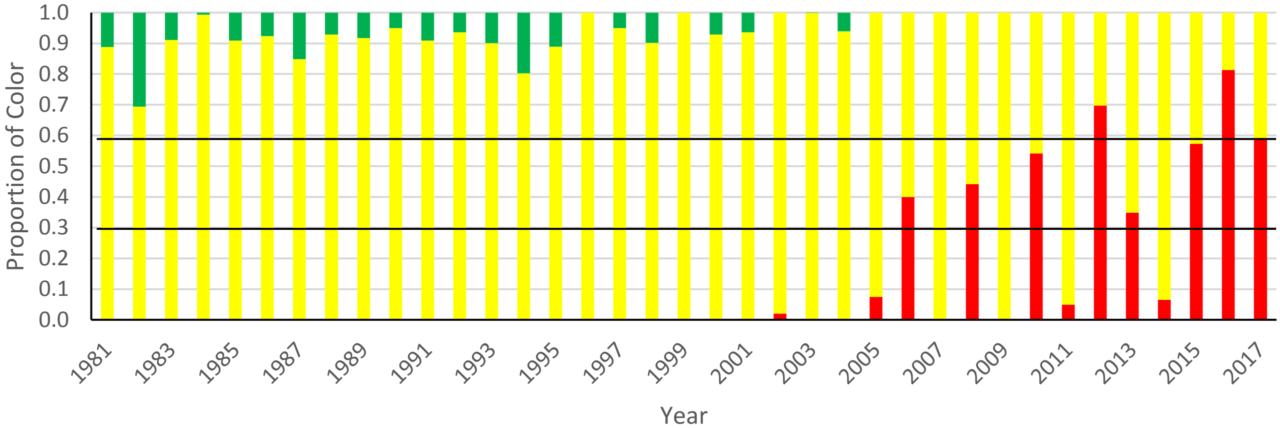
Traffic Light Analysis (Fishery Dependent)

Commercial

- Commercial landings for spot on the Atlantic coast increased 217% in 2017 from 2016. However, landings were still well below the long term mean and the increase in 2017 was up from the time series low which occurred in 2016. Long term, there is still a declining trend in commercial landings that has been occurring since 2003. Total annual landings have declined 90.7% from 2004 to 2016.

- The TLA for commercial landings had relatively stable proportions of green and yellow throughout the 1980s and 1990s but began declining in the early 2000s as evidenced by increasing proportions of red (Fig. 1). The long term mean for the reference time series (1989-2012) was 5,744,635 pounds per year but the average landings since 2010 have dropped to 2,886,785 pounds, with a value of 1,989,804 pounds in 2017.
- The TLA commercial index did trip at the 30% level in 2017.

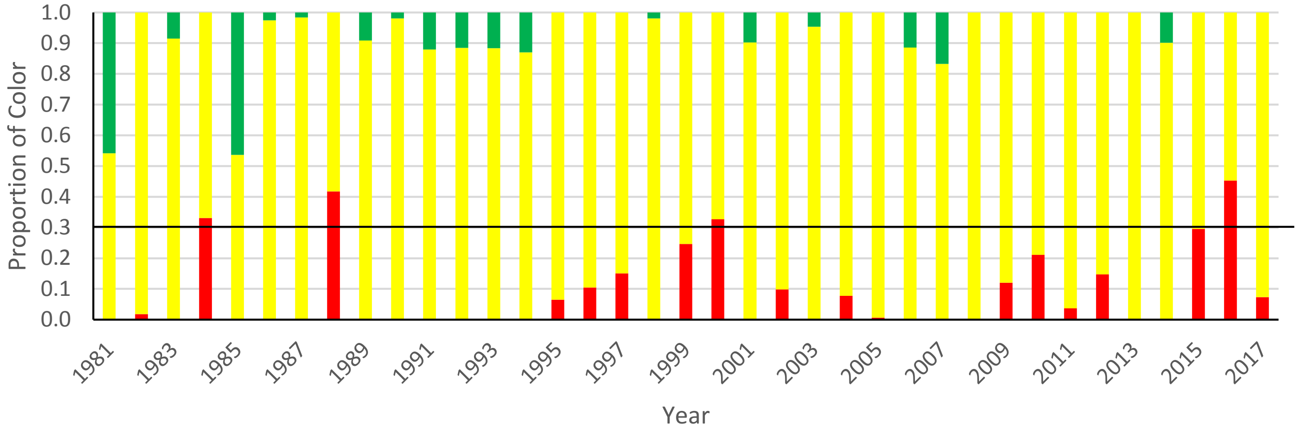
Figure 1. Annual TLA color proportions using 1989-2012 reference period for spot from commercial landings for the Atlantic coast of the US.



Recreational

- The recreational harvest for spot on the Atlantic coast increased 110% from 2016 to 2017, with values of 3,620,388 pounds and 7,636,915 pounds, respectively.
- Annual harvest in the recreational fishery has been below the long term mean (LTM) since 2009 and was still below that threshold in 2017.
- The red proportion of the TLA decreased in 2017 to 7.3%. While the red proportion in 2017 was below the concern threshold, the recreational TLA did trip in 2017 since it was above the 30% threshold for the previous two years (2015-2016).

Figure 2. Atlantic coast TLA for recreational spot harvest on the Atlantic coast of the United States. Note: figure uses revised MRIP estimates (July 2018).

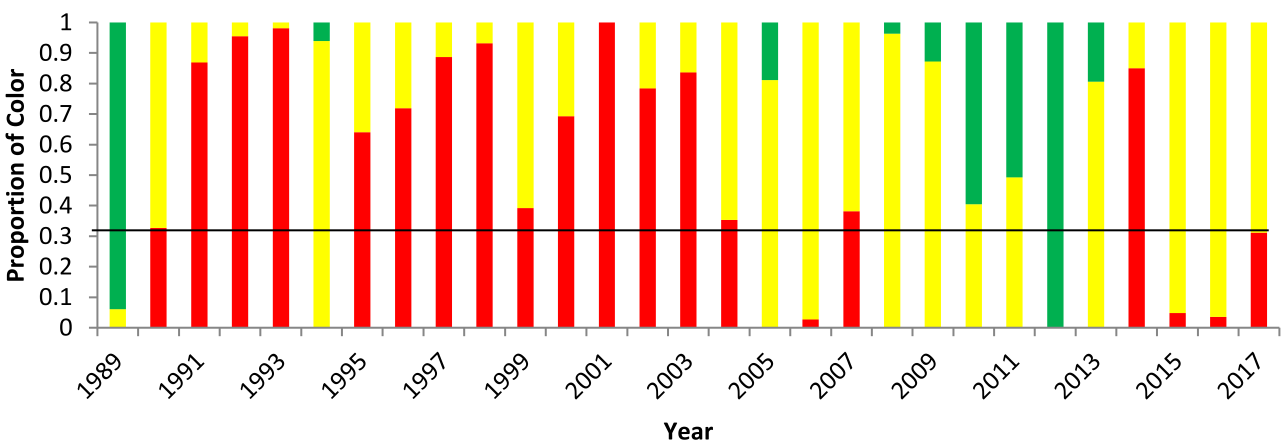


Traffic Light Analysis (Fishery Independent)

NEFSC/NMFS Fall Groundfish Trawl Survey

- The NEFSC/NMFS survey was not carried out in 2017 due to mechanical problems with the RV Bigelow. In the interim, a placeholder index for 2017 was calculated as the mean for the previous three years (2014-2016) (Fig. 3).
- While the red proportion did increase in 2017 using the 3 year placeholder index value, it was still below the 30% threshold.
- The TLA did not trigger in 2017 with the placeholder index

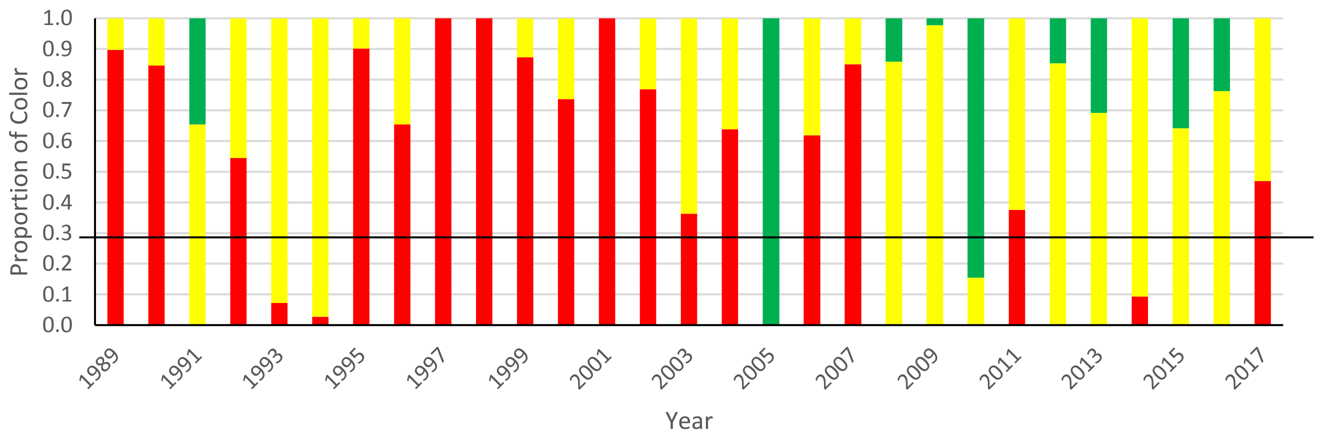
Figure 3. Non-proportioned annual TLA model using 1989-2012 reference time period for Spot from NMFS fall groundfish trawl survey.



SEAMAP Trawl Survey

- The annual CPUE declined 6.9% in 2017 from 2016 and remained above the long term mean (11.3 kg fish per tow).
- The TLA index did not trigger in 2017, and under the current TLA trigger scheme hasn't triggered since 2007.

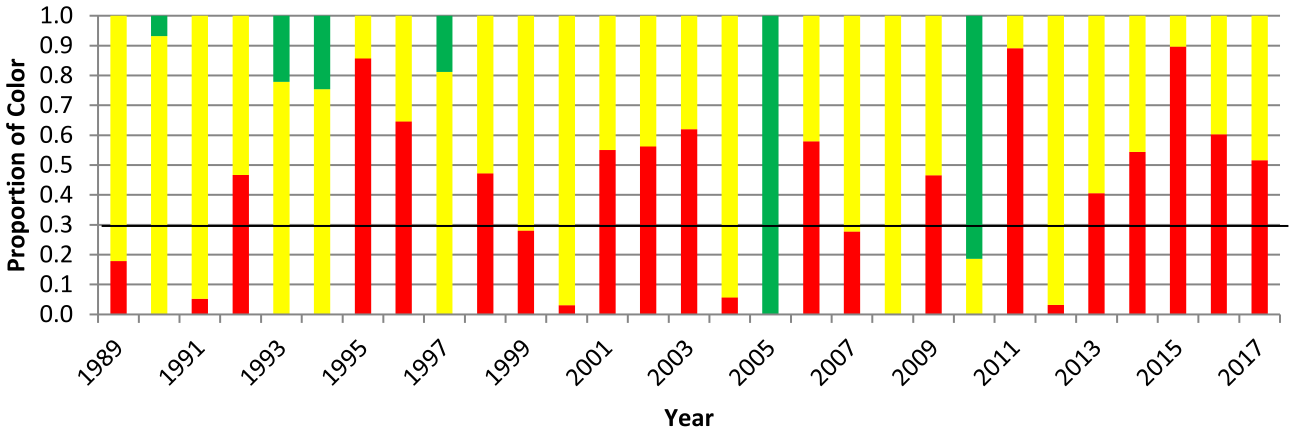
Figure 4. Annual color proportions for spot TLA from the fall SEAMAP survey using a 1989-2012 reference period



Maryland Juvenile Striped Bass Survey

- Since the Maryland survey was the only juvenile index used in the trigger exercise it was used by itself to compare to the other two composite characteristic indices (harvest and abundance).
- The Maryland CPUE increased 24.1% in 2017 from 2016; however the 2015 index value was the lowest in the entire time series and both 2016 and 2017 index values were still quite low (Fig. 5).
- Mean annual CPUE was below the long term mean for the seventh year in a row, indicating annual recruitment and year-class strength remain poor in the Maryland portion of the Chesapeake Bay.
- The TLA trigger did trip in 2017 for the fourth year in a row.
- The index tripping at the 30% level in 2013-2017 indicates cause for concern as the general decline in this index indicates a decline in spot recruitment in Maryland waters has been occurring for the past 20 years.

Figure 5. Annual TLA color proportions for the Maryland seine survey juvenile index using 1989-2012 reference period.

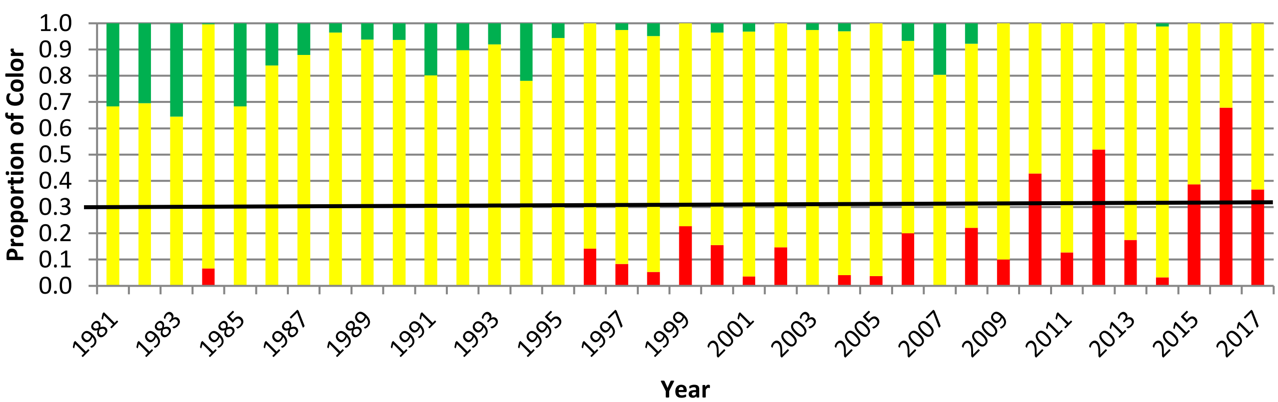


Traffic Light Analysis (Composite Indexes)

Harvest Composite Characteristic Index

- The harvest composite characteristic TLA shows the general decline in landings since 2008, with increasing proportions of red annually (Fig. 6).
- The composite characteristic did trip in 2017 (30% level) with three consecutive years greater than 30%.
- While the red proportion did decline in 2017 it was still above the 30% threshold. This was likely driven more by the decline in commercial landings rather than the recreational harvest.
- The continued declining trend in spot fishery landings was driven primarily by declining landings in the Mid-Atlantic region where the majority of coastwide landings occur.

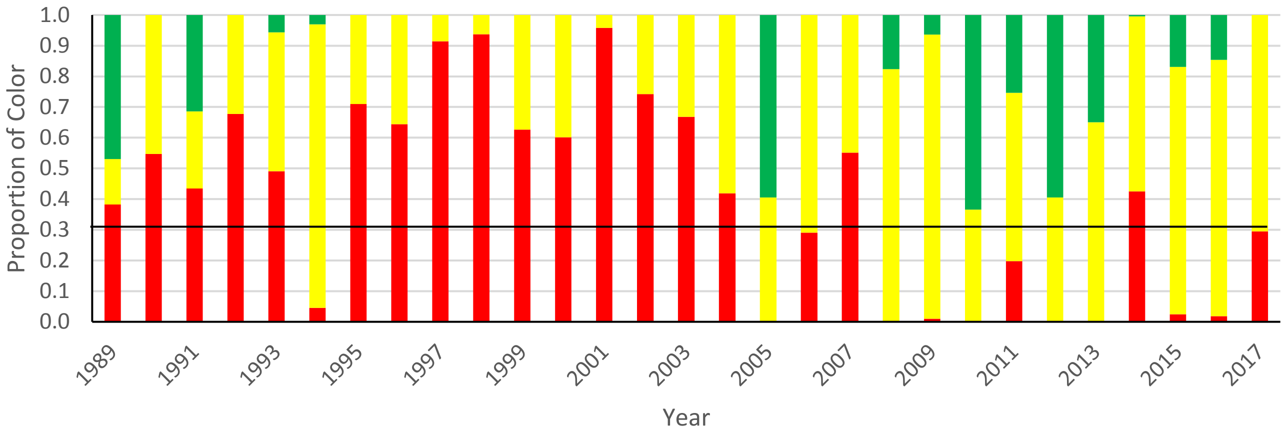
Figure 6. Annual TLA color proportions for harvest composite (commercial and recreational landings) for spot on the Atlantic coast of the US using 1989-2012 reference period.



Abundance Composite Characteristic Index

- The TLA composite characteristic for adult spot (NMFS and SEAMAP surveys) showed a decline from 2016 with a red proportion of 23.3% (Fig. 7).
- The decline in catch levels in the SEAMAP index and the decrease in the NMFS placeholder index would account for this.
- The composite characteristic TLA for the abundance indices did not trigger in 2017.

Figure 7. Annual TLA for spot for composite characteristic of adult fishery independent surveys (NMFS and SEAMAP) using a 1989-2012 reference period.



<u>Summary</u>

The harvest composite characteristic triggered in 2017, mostly due to declines in commercial harvest, while the adult composite index did not and the TLA composite characteristic index for juvenile spot also tripped.

The 2017 Spot Stock Assessment utilized age partitioning in the Catch Survey Analysis model (CSA), separating indices into age 0 and age 1+ (pre-recruits and recruits). The TC suggests considering a similar age partitioning for the TLA as well as a regional approach if it can provide better information on annual changes as well as synchrony between the different indices. The next section of this report outlines the proposed changes to the TLA by the TC for further refinement of the annual trigger exercises.

Proposed Changes to Existing Management Traffic Light Approach for Spot

The current Traffic Light Analysis (TLA) for spot has not triggered management action to date despite declining trends in harvest and indices of abundance to very low values for some areas, particularly since 2014. There has also been discussion about regional differences and the reliability of data sources with contradictory trends for tracking changes in abundance. Data sources considered in the TLA and assessment were explored in attempts to explain differences in trends and identify potential changes in TLA metrics.

Seven recruitment (age-0) indices were evaluated: the SEAMAP trawl index, the NCDMF P195 trawl index, the NMFS trawl index, the ChesMMAP trawl index, the NEAMAP trawl index, the MD seine index, and the VIMS trawl index. Four age-1+ indices were evaluated: the NCDMF P195 trawl index, the NMFS trawl index, the ChesMMAP trawl index, and the NEAMAP trawl index. Nine sources of catch were evaluated: commercial landings, recreational harvest, recreational releases, and recreational total catch, all split between the South Atlantic and Mid-Atlantic (VA-NC border), and South Atlantic shrimp trawl discards.

Four options were developed by the TLA subcommittee (TLA-SC) for the Technical Committee's (TC) review. These options were presented for consideration in February 2018 at the Winter Meeting of the South Atlantic Fisheries Management Board (SAB) of the Atlantic States Marine Fisheries Commission (ASMFC). The four options considered included the following:

1. Status Quo (not recommended)
2. Coastwide TLA with Revised Indices
3. Regional TLA with Revised Indices
4. Relative Exploitation

The SAB requested that the TC further explore Option 3 (Regional TLA with Revised Indices) and present a revised TLA using this option along with the current TLA for the Summer Meeting of the ASMFC (August 2018). As decided during previous meetings, the South Atlantic shrimp trawl discards will be included with all options, but for informational purposes only (i.e., cannot trigger management). In addition, as is done in the current TLA, a recruitment metric is included with all options, not as a direct management trigger but for the TC's consideration during annual TLA updates to better inform management. The TLA recruitment metric includes a composite of VIMS and NC Program 195 indices for the following options, although the NMFS-NEFSC trawl and SEAMAP (ages 0 and 1) indices are available too.

For all options, the PRT has the responsibility of evaluating informational metrics (recruitment, shrimp trawl discards) during annual TLA updates, especially in years when management action is not triggered, to determine other signs of concern with the population. The PRT can recommend management action during years when the adopted option does not trigger management.

Option 3. Regional TLA with Revised Indices

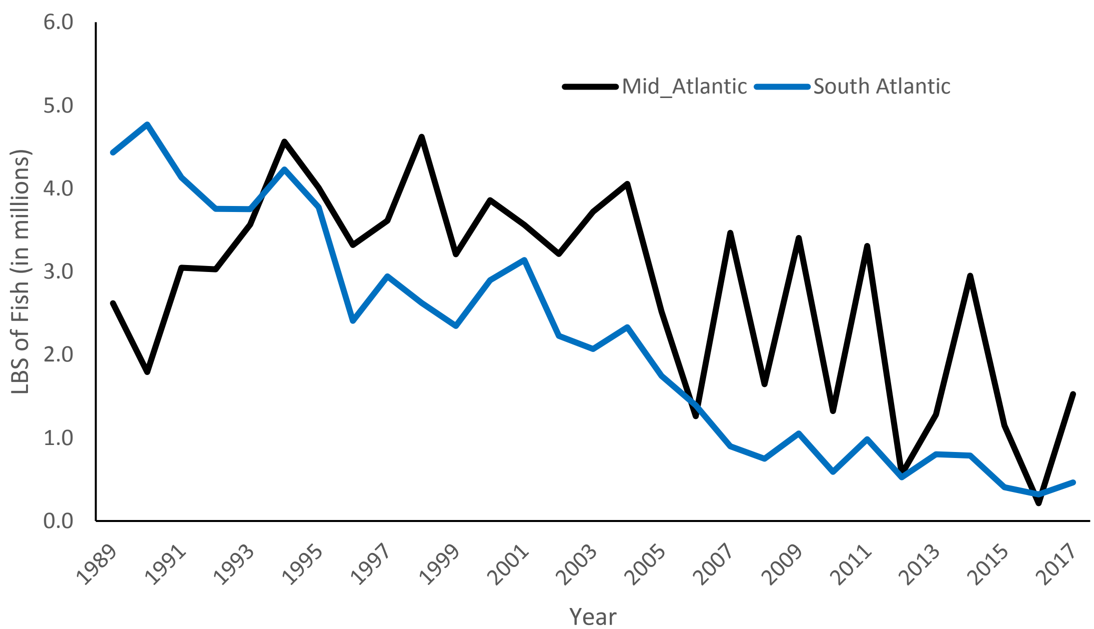
For this option, the TLA-SC revised the abundance indices for spot to split them by age (recruitment indices and age 1+ indices) and region (Mid-Atlantic and South Atlantic) to better reflect the population. Adult indices for the regional TLA would be NMFS-NEFSC (age-1+, excluding NC strata) and ChesMMAP for the Mid-Atlantic and SEAMAP (age-1+) for the South Atlantic. The juvenile advisory indices used would be the Maryland juvenile fish trawl index and ChesMMAP for the Mid-Atlantic and the NCDMF Program 195 for the South Atlantic

The reference period for the TLA would be based on a 2002-2016 time period since this time frame was covered by all the proposed indices. In addition to an adult index for each region, there would also be regional harvest TLAs for the commercial and recreational fisheries based on annual landings. The TLA-SC suggested a change in the management triggers so that management action should be considered if 2 of the 3 latest years have tripped based on previous guidelines (30% red represents a moderate concern and 60% red represents a significant concern). Again, these would be based on the adult composite index and the harvest metrics, not the recruitment metric.

Harvest Composite Index

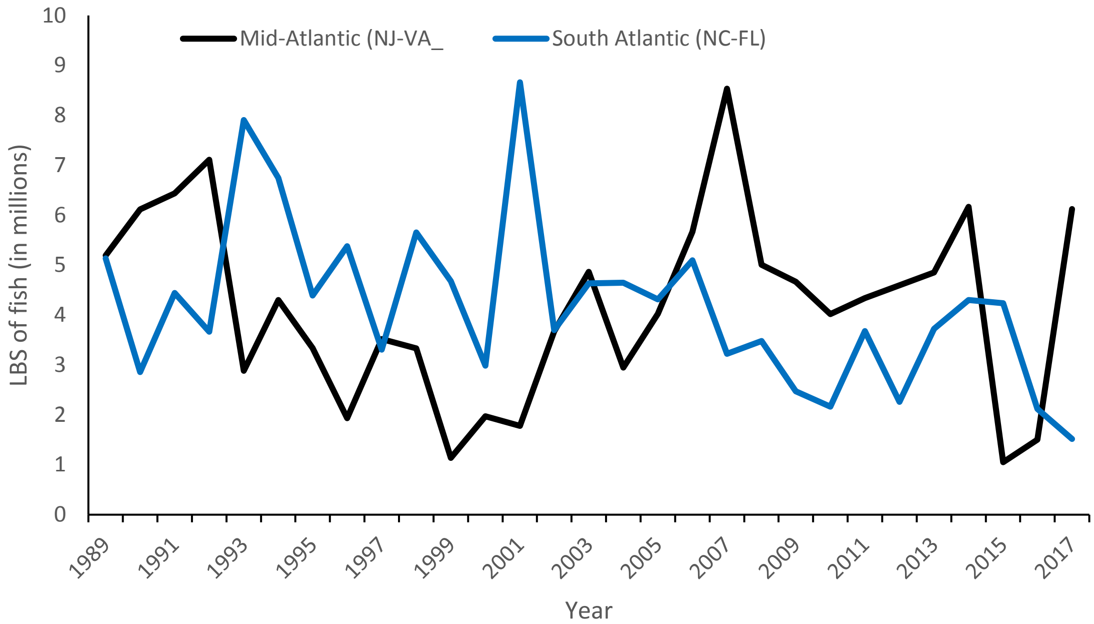
The majority of spot commercial landings occur in the Mid-Atlantic (New Jersey – Virginia), although landings have declined more consistently in the South Atlantic (North Carolina – Florida) (Fig. 8). Landings in the Mid-Atlantic have been highly variable annually over the last ten years with less variation in the South Atlantic.

Figure 8. Annual commercial harvest by region for spot on the Atlantic coast of the United States.



Recreational harvest in the South Atlantic also showed a generally declining trend but nearly as much as the commercial harvest (Fig. 9). Recreational harvest in the Mid-Atlantic showed an increasing trend from 1999 to the series peak in 2007 but has been generally declining since then (Fig. 9).

Figure 9. Annual recreational harvest of spot by region for the Atlantic coast of the United States.



The harvest composite TLA for both regions indicated general decline in harvest in recent years (Figs. 10 and 11). Like the Atlantic coast composite index (Fig. 6) both of the regional composite TLAs would have tripped in both 2016 and 2017 since the red proportions were greater than 30% for two of the three terminal years.

Figure 10. Annual composite TLA color proportions for spot for the Mid-Atlantic (NJ-VA) coast of the United States.

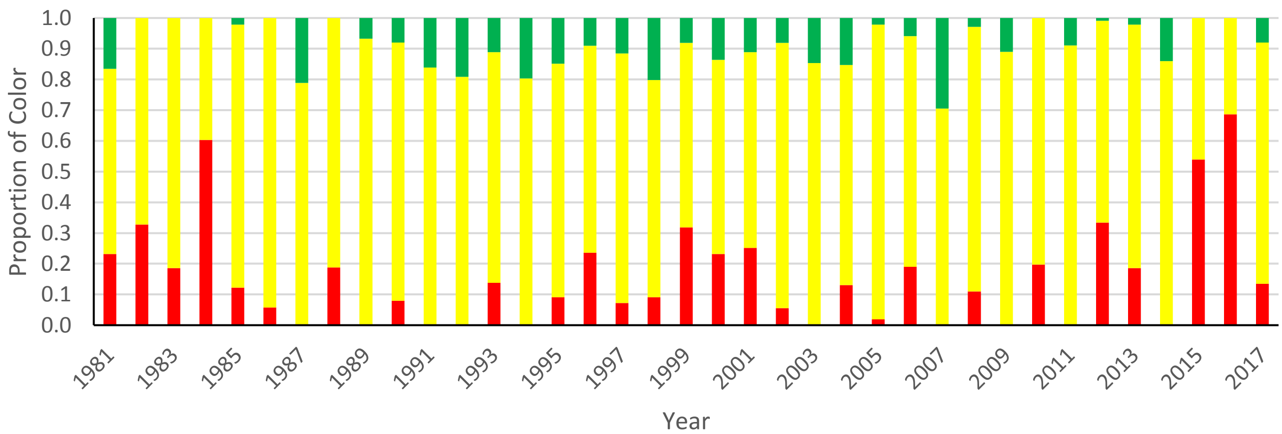
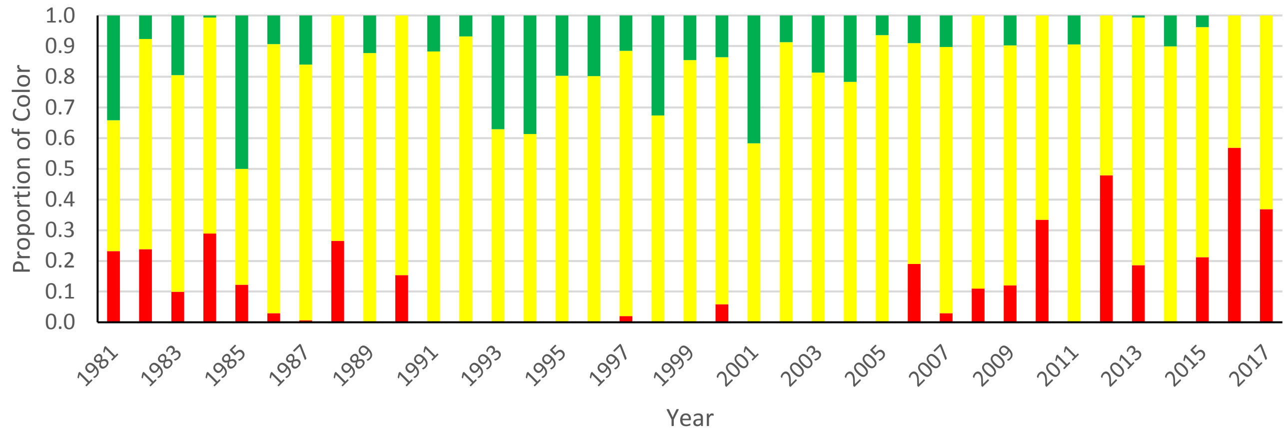


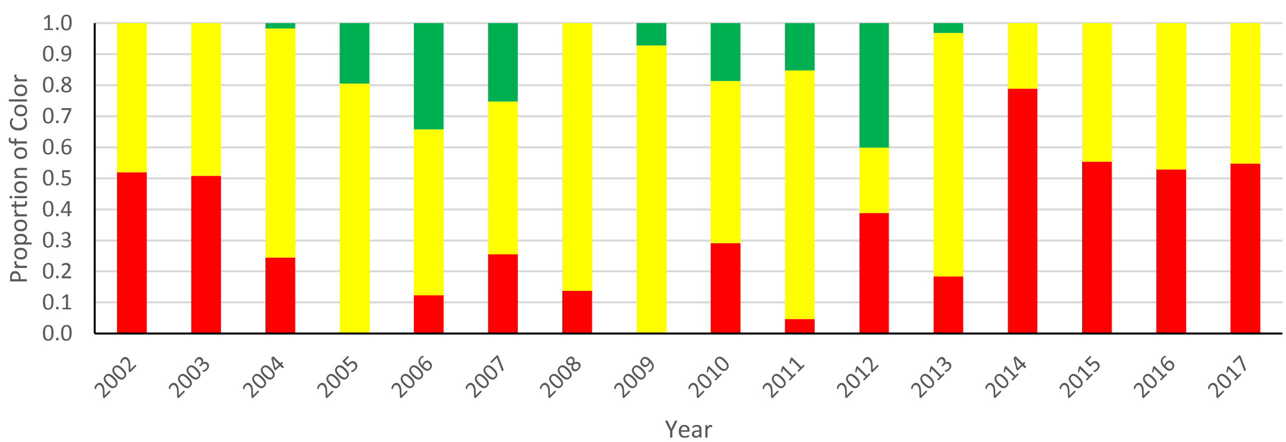
Figure 11. Annual composite TLA color proportions for spot for the South Atlantic (NC-FL) coast of the United States.



Adult Composite Indices

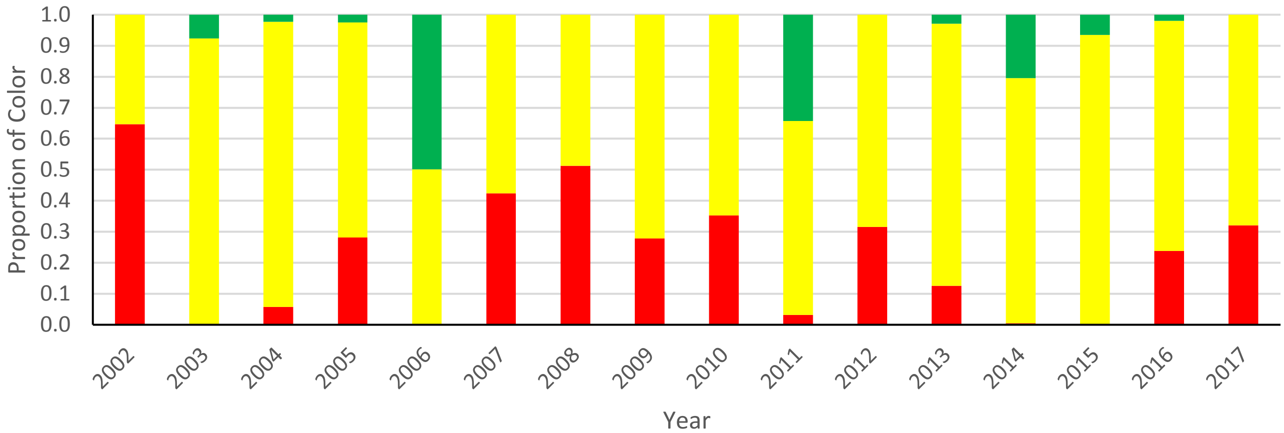
The adult composite index for the Mid-Atlantic used the NMFS and ChesMMAP indices and showed declining abundance since 2009 with the TLA triggering at the 30% level from 2014 through 2017 (Fig. 12). The higher green proportions during mid to late 2000s was due to high green proportions in the NMFS survey where the higher red proportions in the last 6 years was driven by low numbers in the ChesMMAP survey as well as declining catch in the NMFS survey.

Figure 12. Annual composite TLA color proportions for adult spot for the Mid-Atlantic using 2002-2016 reference



The South Atlantic adult composite (SEAMAP and NC195) showed the highest red proportions during the mid-2000s and values approaching the 30% threshold for 2016-2017 (Fig. 13). The composite index would not have triggered at the 30% threshold in the South Atlantic and hasn't since 2008-2010.

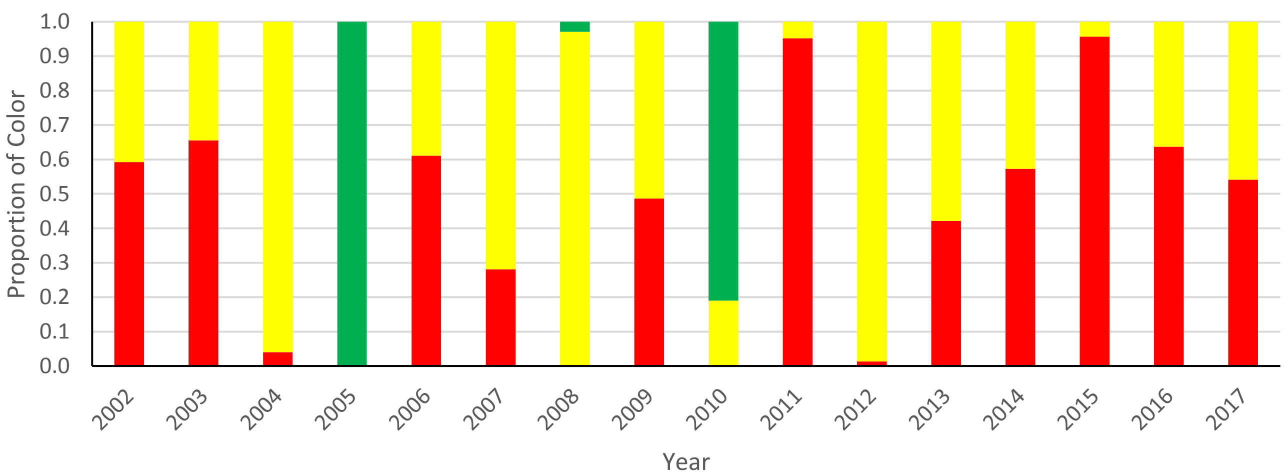
Figure 13. Annual composite TLA color proportions for adult spot for the South Atlantic using 2002-2016 reference period



Juvenile Composite Indices

The Maryland juvenile survey was the only juvenile spot survey available for use with the TLA and there was no juvenile survey available for the South Atlantic. The juvenile TLA showed a similar decline in the last 5-6 years as seen with the adult index with red proportions greater than the 30% threshold. While the juvenile index is not used directly in the trigger exercise, it would have triggered from 2014-2017 at the 30% level and at the 60% level in 2016 and 2017.

Figure 14. Mid-Atlantic (MD Juvenile Survey) TLA using 2002-2016 reference period



South Atlantic Shrimp Trawl Discards

Current estimates of relative spot by-catch from the South Atlantic shrimp fishery are only available through 2016 at the writing of this report. This will be amended when the by-catch index for 2017 become available.

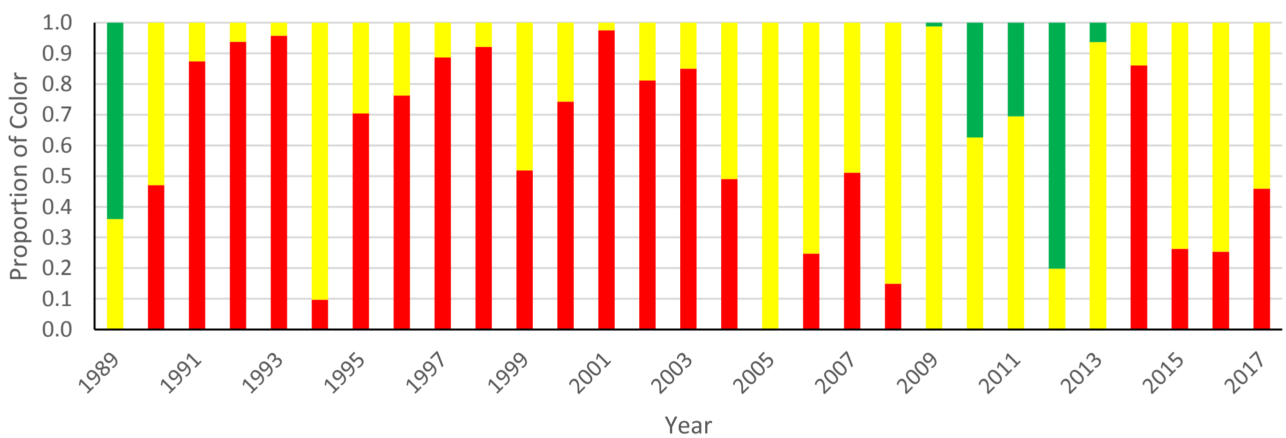
Supplemental Material: Fishery Independent Individual Index TLA's using 2002-2016 reference time period.

NMFS/NEFSC Survey

Since there was no NMFS sampling along the Mid-Atlantic due to mechanical issues on the RV Bigleow, a placeholder index using the three year (2014-2016) was used for the TLA. The TC shall have to decide if the NMFS index should remain in the 2017 index or not be used for this one year. Given the current trends over the last few years with this index, the author suggests using the placeholder proxy for 2017 only as trends have been consistent across the last few years and unless something drastic changes, the index is likely to have a minimal impact on the TLA.

The three-year (2014-2016) mean used for the 2017 placeholder in the NMFS index did exceed the 30% threshold because of the very high red proportion in 2014 and red proportions approaching 30% in 2015-2016.

Figure 15. Annual color proportions for spot TLA from NMFS survey using a 2002-2016 reference period.

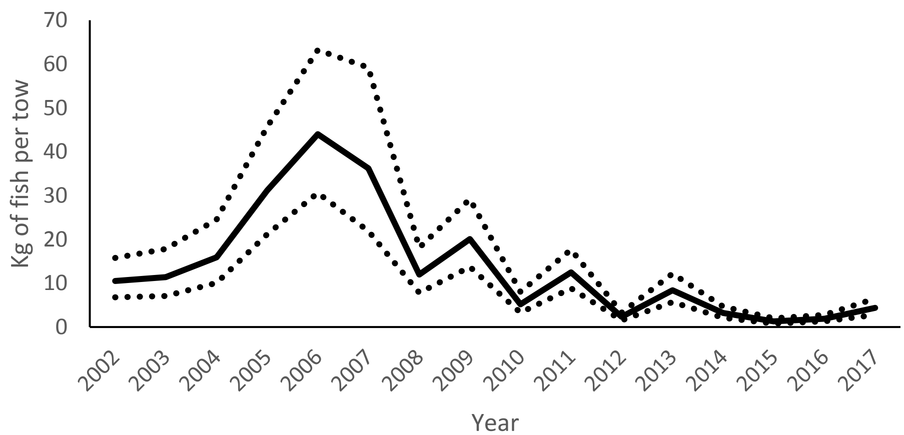


ChesMMAP Survey

The Chesapeake Marine Monitoring Program (ChesMMAP) is a general fish abundance trawl survey run by the Virginia Institute of Marine Science (VIMS) that covers the central portion of the Chesapeake Bay from the mouth up to approximately Aberdeen, MD. Spot are one of most abundant species in the survey. ChesMMAP has been in operation since 2002 with 15 years of currently available data. While not as geographically expansive as some of the other larger regional surveys (NMFS, NEAMAP, and SEAMAP), ChesMMAP does cover the full length of the Chesapeake Bay including both Virginia and Maryland.

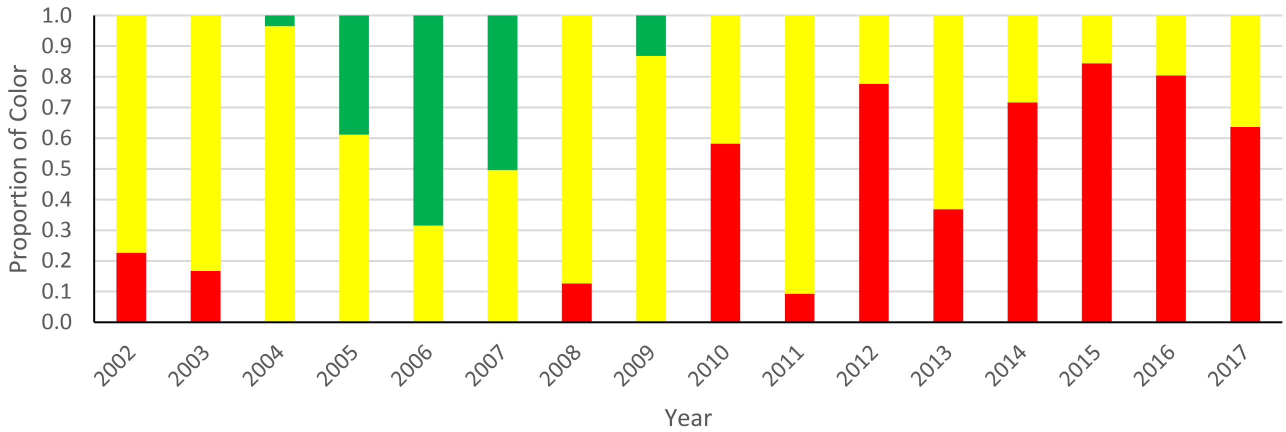
Annual catch levels for spot peaked in 2006 and have declined steadily since then (Fig. 16). Catch level variability was also much higher during the early 2000s versus later years.

Figure 16. Mean annual CPUE for spot from ChesMMAP survey. Dotted lines are 95% CI.



The TLA indicated high red proportions since 2010 when annual CPUE values were lowest (Fig. 17). The TLA would have triggered in 2012 at the 30% threshold and has been above the 60% red threshold since 2014.

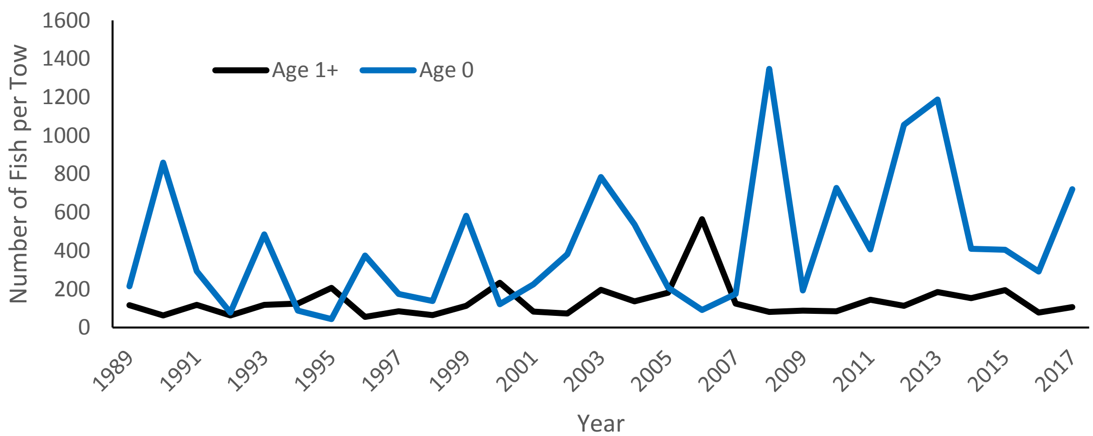
Figure 17. Annual color proportions of TLA for spot from the ChesMMAP survey using a 2002-2016 reference period.



NCDMF Program 195

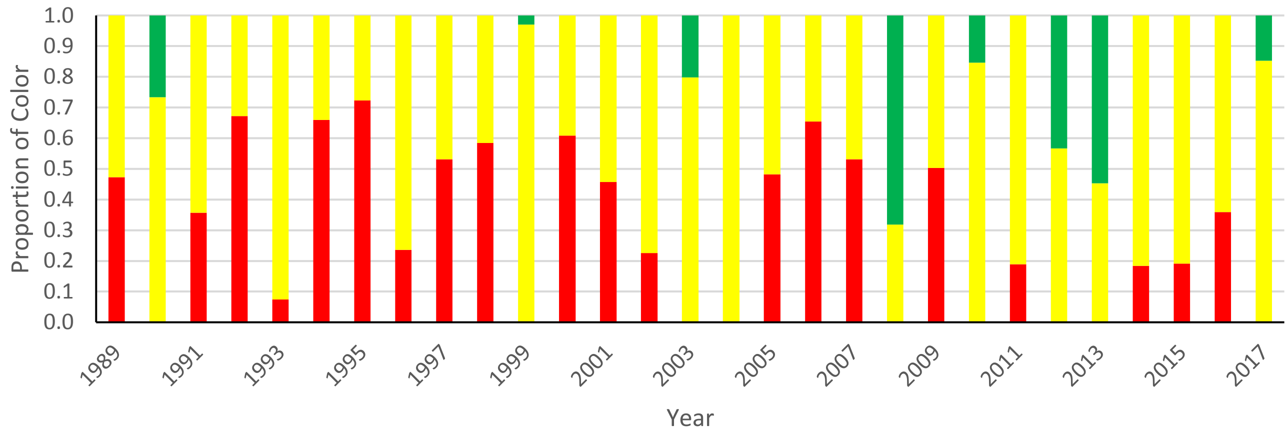
The NC Program 195 index showed a generally increasing trend for age 0 spot over the entire time series but it has declined since 2013 (Fig. 18). Adult spot catch levels remained relatively stable over time with three distinct peaks in 1995, 2000, and 2006.

Figure 18. Stratified mean annual CPUE for spot from NCDMF Program 195 suvey by age group.



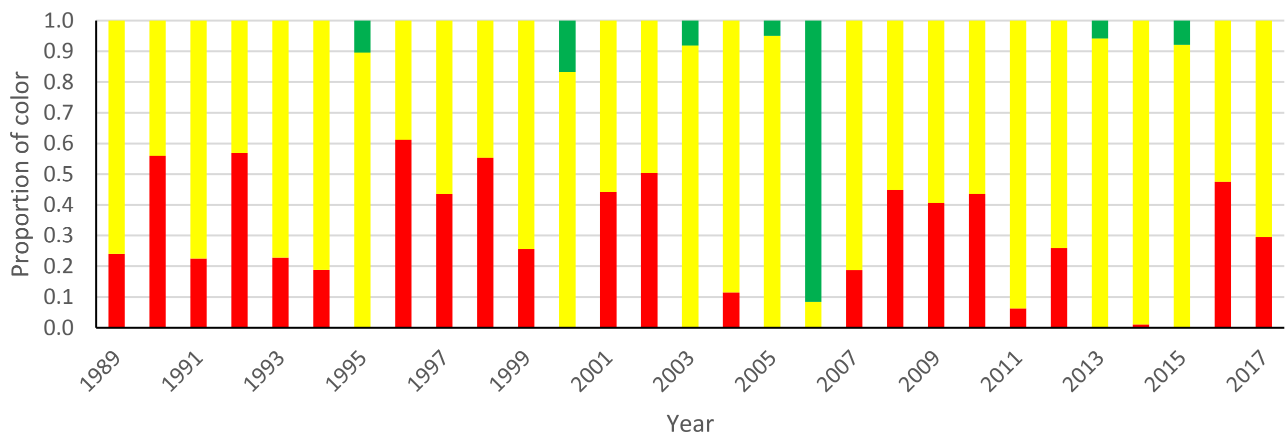
The TLA for juvenile spot (age 0) showed high proportions of red throughout the 1990s and mid 2000s (Fig. 19). Peaks in juvenile abundance occurred in 2008 and 2012-2013 with declines in 2014-2016. The juvenile spot TLA hasn't triggered since 2009.

Figure 19. Annual color proportions for age 0 spot from the NCDMF Program 195 survey using a 2002-2016 reference period.



The TLA for adult spot (age 1+) had only one year with high green proportions (2006) and showed several years (1992, 1997-1998, 2009-2010, and 2017) where the index triggered (Fig. 20).

Figure 20. Annual color proportions for age 1+ spot from the NCDMF Program 195 using a 2002-2016 reference period.



Atlantic States Marine Fisheries Commission

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MEMORANDUM

July 31, 2018

To: **South Atlantic State/Federal Fisheries Management Board**

From: **Atlantic Croaker and Spot Plan Development Team**

Subject: **Recommendations for Management Response to Triggers from Updated Traffic Light Analyses**

At the May 2018 meeting, the South Atlantic State/Federal Fisheries Management Board (Board) tasked the Atlantic Croaker and Spot Plan Development Team (PDT) with exploring potential responses to management triggers that would result from incorporation of TC-recommended updates to the annual Traffic Light Analyses (TLA) for Atlantic croaker and spot. The Board provided guidance on a goal of management measures that would achieve a red level of 35% or less within a two-year timeframe. This goal would only apply to the abundance metric, as the harvest metric would need to be re-evaluated under a new management regime.

The PDT met twice via conference call to address this task. Abundance of Atlantic croaker is strongly associated with environmental variables (Hare and Able 2007, Norcross and Austin 1981), historically expressed through a cyclical pattern in commercial landings. Additionally, the impetus for revision to the TLA was a lack of correlation between current harvest and abundance metrics. Thus, a reduction in harvest would not necessarily be expected to result in a proportional increase in abundance. Atlantic croaker are currently in a low period for commercial harvest, similar to what was previously observed during the early 1980s and followed by an increase into a high period in the late 1990s to early 2000s. Relationships between spot abundance or harvest and environmental variables are not as well-studied as Atlantic croaker, and spot do not exhibit a similar cyclical landings pattern.

Therefore, rather than focusing on a specific numeric goal for percentage red that may not be realistically attainable through management alone, the PDT recommends an alternative goal of initially establishing management measures for both the Atlantic croaker and spot fisheries, which currently have no coastwide management requirements in their respective Fishery Management Plans (FMP). These measures would ideally be suited for long-term management of these species, with the ability for them to be altered in reaction to management triggers from the TLAs. If management action is triggered, as is the case for both species in the Mid-Atlantic region under the updated TLAs, the PDT recommends that measures put in place be re-evaluated as defined in Addendum II to the Atlantic Croaker FMP (after 3 years) and Addendum I to the Spot FMP (after 2 years) to determine if they are eliciting the desired response and evaluate if adjustments should be made. For both Atlantic croaker and spot, the PDT recommends commercial and recreational

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management measures in the form of seasons and trip limits (vessel or bag). Given the close association of Atlantic croaker and spot fisheries, management through an aggregate bag or vessel limit could also be considered. State-level minimum size limits are currently used for commercial and recreational Atlantic croaker fisheries in Delaware and Maryland. Size limits can be a more reliable way to restrict harvest than seasons or an aggregate bag limit due to annual variations in migration timing and masked changes in aggregate bag composition. Determination of whether a coastwide minimum size limit would be useful and an appropriate minimum size would require further discussion and evaluation of size selectivity by gears used for Atlantic croaker throughout the management unit relative to biological information on growth and maturity. Minimum size limits have not been applied to spot at the state level, and may be less useful due to the species' fast growth and early maturity.

The PDT also reviewed literature on movement and connectivity of Atlantic croaker and spot between regions specified by the updated TLA as Mid-Atlantic (New Jersey-Virginia) and South Atlantic (North Carolina-Florida). Although movement literature was sparse, genetic and life history studies, as well as commercial landings trends, suggest connectivity across the VA-NC border. The PDT recognizes that Mid- and South Atlantic regions were designated in the TC's recommendations due to the incorporation of regional abundance indices – such as indices from the Chesapeake Bay Multispecies Monitoring and Assessment Program (ChesMMAP), the South Carolina Department of Natural Resources Trammel Net Survey, and North Carolina Division of Marine Fisheries Program 195 survey – rather than any stock distinction between these regions. Additionally, the 2010 (ASMFC 2010) and 2017 (unpublished) stock assessments for Atlantic croaker and the 2017 (unpublished) stock assessment for spot were conducted for single, coastwide stocks spanning the entire management units (both New Jersey-Florida). Given the connectivity of fish north and south of the VA-NC border, the PDT recommends that any management response to the updated, regional TLA triggers be executed on a coastwide basis. This could be accomplished through an equal response throughout the management unit, or through a form of apportioned response in which all states take on restricted measures, but states of the triggering region enact stricter measures than those of the non-triggering region. For example, if the whole coast were to implement a 100-pound trip limit and the Mid-Atlantic TLA triggers under that management regime, a response could be an 80-pound trip limit in the Mid-Atlantic and a 90-pound trip limit in the South Atlantic.

To summarize, in response to management triggers from the TC-recommended TLA updates, the PDT recommends that long-term commercial and recreational coastwide management measures be established for each species in the form of seasons and/or trip (vessel or bag/possession) limits. These measures should be re-evaluated in three years for Atlantic croaker and two years for spot to determine if they are eliciting the desired response and evaluate if any adjustments should be made. Use of coastwide or area- or gear-specific minimum size limits for Atlantic croaker could be further evaluated if deemed potentially useful from a management perspective.

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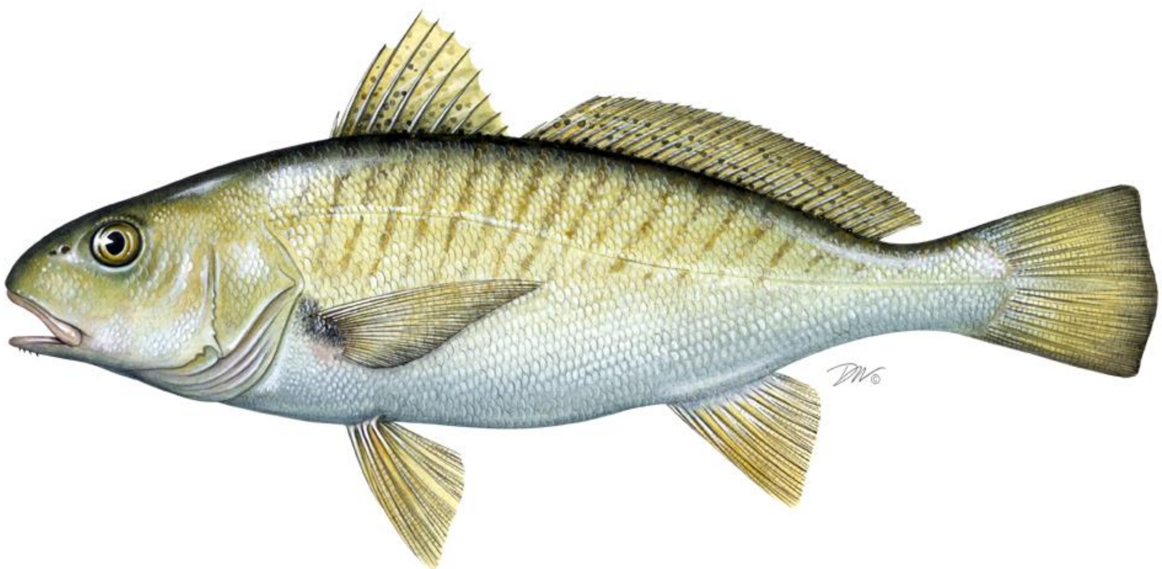
2018 REVIEW OF THE
ATLANTIC STATES MARINE FISHERIES COMMISSION
FISHERY MANAGEMENT PLAN FOR

ATLANTIC CROAKER
(Micropogonias undulatus)

2017 FISHING YEAR



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I. Status of the Fishery Management Plan

Date of FMP Approval:	Original FMP – October 1987
Amendments:	Amendment 1 – November 2005 (implemented January 2006) Addendum I – March 2011 Addendum II – August 2014
Management Areas:	The Atlantic coast distribution of the resource from New Jersey through Florida
Active Boards/Committees:	South Atlantic State/Federal Fisheries Management Board; Atlantic Croaker Technical Committee, Stock Assessment Subcommittee, and Plan Review Team; South Atlantic Species Advisory Panel

The Fishery Management Plan (FMP) for Atlantic Croaker was adopted in 1987 and included the states from Maryland through Florida (ASMFC 1987). In 2004, the South Atlantic State/Federal Fisheries Management Board (Board) found the recommendations in the FMP to be vague, and recommended that an amendment be prepared to define management measures necessary to achieve the goals of the FMP. The Interstate Fisheries Management Program Policy Board also adopted the finding that the original FMP did not contain any management measures that states were required to implement.

In 2002, the Board directed the Atlantic Croaker Technical Committee to conduct the first coastwide stock assessment of the species to prepare for developing an amendment. The Atlantic Croaker Stock Assessment Subcommittee developed a stock assessment in 2003, which was approved by a Southeast Data Assessment Review (SEDAR) panel for use in management in June 2004 (ASMFC 2005a). The Board quickly initiated development of an amendment and, in November 2005, approved Amendment 1 to the Atlantic Croaker FMP (ASMFC 2005b). The amendment was fully implemented by January 1, 2006.

The goal of Amendment 1 is to utilize interstate management to perpetuate the self-sustainable Atlantic croaker resource throughout its range and generate the greatest economic and social benefits from its commercial and recreational harvest and utilization over time. Amendment 1 contains four objectives:

1) Manage the fishing mortality rate for Atlantic croaker to provide adequate spawning potential to sustain long-term abundance of the Atlantic croaker population.
2) Manage the Atlantic croaker stock to maintain the spawning stock biomass above the target biomass levels and restrict fishing mortality to rates below the threshold.
3) Develop a management program for restoring and maintaining essential Atlantic croaker habitat.
4) Develop research priorities that will further refine the Atlantic croaker management program to maximize the biological, social, and economic benefits derived from the Atlantic croaker population.

Amendment 1 expanded the management area to include the states from New Jersey through Florida. Consistent with the stock assessment completed in 2004, the amendment defined two Atlantic coast management regions: the south-Atlantic region, from Florida through South Carolina; and the mid-Atlantic region, from North Carolina through New Jersey.

Amendment 1 established biological reference points (BRPs) to define an overfished and overfishing stock status for the mid-Atlantic region only. Reliable stock estimates and BRPs for the South Atlantic region could not be developed during the 2004 stock assessment due to a lack of data. The BRPs were based on maximum sustainable yield (MSY), and included threshold and target levels of fishing mortality (F) and spawning stock biomass (SSB): F threshold = F_{MSY} (estimated to be 0.39); F target = 0.75 X F_{MSY} (estimated to be 0.29); SSB threshold = 0.7 X SSB_{MSY} (estimated to be 44.65 million pounds); and SSB target = SSB_{MSY} (estimated to be 63.78 million pounds). An SSB estimate below the SSB threshold resulted is an overfished status determination, and an F estimate above the F threshold resulted is an overfishing status determination. The Amendment established that the Board would take action, including a stock rebuilding schedule if necessary, should the BRPs indicate the stock is overfished or overfishing is occurring.

Amendment 1 did not require any specific measures restricting recreational or commercial harvest of Atlantic croaker. States with more conservative measures were encouraged to maintain those regulations (Table 1). The Board was able to revise Amendment 1 through adaptive management, including any regulatory and/or monitoring requirements in subsequent addenda, along with procedures for implementing alternative management programs via conservation equivalency.

The Board initiated Addendum I to Amendment I at its August 2010 meeting, following the updated stock assessment, in order to address the proposed reference points and management unit. The stock assessment evaluated the stock as a coastwide unit, rather than the two management units established within Amendment I. In approving Addendum I, the Board endorsed consolidating the stock into one management unit, as proposed by the stock assessment. In addition, Addendum I established a procedure, similar to other species, by which the Board may approve peer-reviewed BRPs without a full administrative process, such as an amendment or addendum.

In August 2014, the Board approved Addendum II to the Atlantic Croaker FMP. The Addendum established the Traffic Light Approach (TLA) as the new precautionary management framework to evaluate fishery trends and develop management actions. The TLA was originally developed as a management tool for data poor fisheries. The name comes from assigning a color (red, yellow, or green) to categorize relative levels of population indicators. When a population characteristic improves, the proportion of green in the given year increases. Harvest and abundance thresholds of 30% and 60% were established in Addendum II, representing moderate and significant concern for the fishery. If thresholds for both population characteristics achieve or exceed a threshold for a three year period, then management action is enacted.

The TLA framework replaces the management triggers stipulated in Addendum I, which dictated that action should be taken if recreational and commercial landings dropped below 70% of the previous two year average. Those triggers were limited in their ability to illustrate long-term declines or increases in stock abundance. In contrast, the TLA approach is capable of better illustrating trends in the fishery through changes in the proportion of green, yellow, and red coloring. A recent TC report recommends several updates to the current TLA approach, that the Board is currently considering for incorporation (ASMFC 2018).

Addenda I and II did not add or change any management measures or requirements. The only existing requirement is for states to submit an annual compliance report by July 1st of each year that contains commercial and recreational landings as well as results from any monitoring programs that intercept Atlantic croaker.

II. Status of the Stock

The most recent stock assessment, conducted in 2017, upon peer review was not recommended for management use. Therefore, current stock status is unknown, although the Peer Review Panel did not indicate problems in the Atlantic croaker fishery that would require immediate management action. The Peer Review Panel did recommend continued evaluation of the fishery using the annual TLA.

The conclusions of the 2010 stock assessment (ASMFC 2010), which is the most recent assessment that was recommended by peer review for management use, were that Atlantic croaker was not experiencing overfishing and biomass had increased and fishing mortality decreased since the late 1980s. The 2010 assessment was unable to confidently determine stock status, particularly with regards to biomass, due to an inability to adequately estimate removals from discards of the South Atlantic shrimp trawl fishery. Improvements on estimation of these discards were made in the 2017 assessment, allowing the potential for shrimp trawl discards to be included as supplemental information with the annual TLA. Annual monitoring of shrimp trawl fishery discards is important because these discards represent a considerable proportion of Atlantic croaker removals, ranging from 7% to 78% annually during 1988-2008, according to the 2010 assessment (ASMFC 2010).

One of the primary reasons that the 2017 stock assessment did not pass peer review was due to conflicting signals in harvest and abundance metrics. Theoretically, increases in adult abundance should result in more fish available to be caught by the fishery; thus, fishing would be more efficient (greater catch per unit effort) and harvest would increase in a pattern similar to adult abundance. However, several of the most recent abundance indices have shown increases while harvest has declined to some of the lowest levels on record. One factor that has been identified to contribute to overestimates of adult abundance is an increase in the number of juveniles misclassified as adults in surveys that historically have typically caught adults. In response to this conflict, the Atlantic Croaker Technical Committee has recommended several changes to the annual TLA such as additional abundance indices and survey length-composition information so that the TLA abundance metric would more accurately reflect trends in the stock.

III. Status of the Fishery

This report includes updated recreational estimates from the Marine Recreational Information Program's transition to the mail-based Fishing Effort Survey (FES) on July 1, 2018. Therefore, recreational estimates will likely be different from those shown in past FMP Reviews and state compliance reports (due annually on July 1) through 2018. Figure 1 shows coastwide recreational landings including estimates using both the previous Coastal Household Telephone Survey (CHTS) and FES calibration for comparison, but other figures, tables, and text will only show data based on the FES calibration. Data based on either survey can be referenced at: https://www.st.nmfs.noaa.gov/st1/recreational/queries/.

Total Atlantic croaker harvest from New Jersey through the east coast of Florida in 2017 is estimated at 9.0 million pounds (Tables 2 and 3, Figure 2). This represents an 81% decline in total harvest since the peak of 47.4 million pounds in 2003 (85% commercial decline, 74% recreational decline). The commercial and recreational fisheries harvested 46% and 54% of the total, respectively.

Atlantic coast commercial landings of Atlantic croaker exhibit a cyclical pattern, with low harvests in the 1960s to early 1970s and the 1980s to early 1990s, and high harvests in the mid-to-late 1970s and the mid-1990s to early 2000s (Figure 2). Commercial landings increased from a low of 3.7 million pounds in 1991 to 28.6 million pounds in 2001 (Table 2); however, landings have declined every year since 2010 to 4.1 million pounds in 2017, which registers below the 1950-2017 average of 12.1 million pounds. Within the management unit, the majority of 2017 commercial landings came from Virginia (71%) and North Carolina (24%). The Potomac River Fisheries Commission (PRFC) had the next highest level, with 2.8% of coastwide landings.

In 2018, recreational landings estimates from the Marine Recreational Information Program were updated based on effort estimates calibrated from the mail-based Fishing Effort Survey (Figure 1). From 1981-2017, recreational landings of Atlantic croaker from New Jersey through Florida have varied between 9.2 million fish (3.7 million pounds) and 36.2 million fish (17.4 million pounds; Tables 3 and 4, Figure 3). Landings generally increased until 2003, after which they showed a declining trend through 2017. The 2017 landings are estimated at 10.9 million fish and 4.8 million pounds. Virginia was responsible for 70% of the 2017 recreational landings, in numbers of fish, followed by Florida, South Carolina, and North Carolina (9%, 7%, and 6%, respectively).

The number of recreational releases generally increased over the time series until 2013, after which numbers of releases have decreased in every year through 2017 (Figure 3). However, percentage of released recreational catch has shown a slight increasing trend from the 1990s through 2017. In 2017, anglers released approximately 24 million fish, a decline from the 26 million fish released in 2016. Anglers released an estimated 69% of the croaker catch in 2017 (Figure 3).

IV. Status of Assessment Advice

A statistical catch-at-age (SCA) model was used in the 2010 Atlantic croaker stock assessment (ASMFC 2010). This model combines catch-at-age data from the commercial and recreational fisheries with information from fishery-independent surveys and biological information such as growth rates and natural mortality rates to estimate the size of each age class and the exploitation rate of the population. The assessment was peer reviewed by a panel of experts in conjunction with the Southeast Data, Assessment, and Review (SEDAR) process.

The Review Panel was unable to support some of the 2010 assessment results due to uncertainty regarding the estimation of Atlantic croaker discards in the shrimp trawl fishery, and the application of estimates in modeling. Specifically, model-estimated values of stock size, fishing mortality, and biological reference points are too uncertain for use; however, the trends in model-estimated parameters and ratio-based fishing F reference points are considered reliable. Despite the uncertainty in assessment results caused by shrimp trawl bycatch, the Review Panel concluded that it is unlikely that the stock is in trouble. The stock is not experiencing overfishing, biomass has been trending up, commercial catches are stable, and discards from the shrimp trawl fishery have been reduced.

A benchmark stock assessment was conducted in 2017, but was not recommended for management use due to uncertainty in biomass estimates resulting from conflicting signals among abundance indices and catch time series as well as sensitivity of model results to assumptions and model inputs. Because the most recent assessment was not recommended for management use, current stock status is unknown. One noted improvement in this assessment was in the estimation of Atlantic croaker discards by the shrimp trawl fishery. The Review Panel recommended incorporation of shrimp trawl discard estimates into the annual monitoring of Atlantic croaker through the TLA. The TC has recommended several changes to the TLA that would help resolve some of the conflict between harvest and abundance signals. In order to incorporate these changes, the Board would need to initiate an addendum to the Atlantic Croaker FMP.

V. Status of Research and Monitoring

There are no research or monitoring programs required of the states except for the submission of an annual compliance report. The following fishery-dependent (other than catch and effort data) and fishery-independent monitoring programs were reported in the 2017 compliance reports.

Fishery-Dependent Monitoring

- New Jersey: initiated biological monitoring of commercially harvested Atlantic croaker in 2006 in conjunction with ACCSP (2017 n=50 lengths, weights, and ages)
- Delaware: collects trip-based information on pounds landed, area fished, effort, and gear type data through mandatory monthly state logbook reports submitted by fishermen.
- Maryland: commercial pound net fishery biological sampling (2,037 lengths); seafood dealer sampling (767 lengths and 737 weights)
- PRFC: has a mandatory commercial harvest daily reporting system, with reports due weekly.

- Virginia: commercial fishery biological sampling (6,855 length measurements, 6,849 weight measurements, 313 otolith ages, and 690 sex determinations in 2017)
- North Carolina: commercial fishery biological sampling since 1982 for length (2017 n=6,021), weight, otolith, sex determination, and reproductive condition.
- South Carolina: recreational fishery biological sampling via SCDNR State Finfish Survey, MRIP, and a SCDNR-managed mandatory trip reporting system for licensed charter boat operators. In 2013, SCDNR took over its portion of MRIP data collection.
- Georgia: collects biological information, including length, sex, and maturity stage, through the Marine Sportfish Carcass Recovery Project (0 fish in 2017)
- Florida: commercial fishery biological sampling

Fishery-Independent Monitoring

- New Jersey: 3 nearshore ocean (within 12 nm) juvenile trawl surveys (New Jersey Ocean Trawl Survey, 1988-present: 2017 CPUE was well below time-series average but above 2016 value; nearshore Delaware Bay juvenile trawl survey, 1991-present: 2017 survey index was well below time series average; Delaware River juvenile seine survey, 1980-present: 2016 survey index was below time series average)
- Delaware: offshore Delaware Bay adult finfish trawl survey (1990-present; 2017 #/tow = 5.89; 165% increase in relative abundance from 2016 index, below mean for time series); nearshore Delaware Bay juvenile finfish trawl survey (1980-present; 2017 index decreased from 1.17 in 2016 to 0.81; Inland Bays index decreased from 0.43 in 2016 to 0.30 in 2017).
- Maryland: summer gill net survey was initiated in 2013 on lower Choptank (53 fish were captured in 2017); Atlantic coast bays juvenile otter trawl survey (standardized from 1989-present; 2017 GM of 0.38 fish/hectare is the second lowest value of the 29-year time series); Chesapeake Bay juvenile trawl index (standardized from 1989-present; CPUE increased from 0.81 in 2016 to 2.35 in 2017).
- PRFC: Maryland DNR conducts an annual juvenile beach haul seine survey in the Potomac River (1954-present; YOY GM increased from 0.27 in 2016 to 0.35 in 2017).
- Virginia: Virginia Institute of Marine Science (VIMS) Juvenile Finfish and Blue Crab Trawl Survey (1988-present; 2017 index was 15.19, which is down from the 2016 value of 27.41).
- North Carolina: Pamlico Sound juvenile trawl survey (1987-present; 2017 juvenile abundance index (mean number of individuals/tow) was 1,172.3, the second-highest value in the time series)
- South Carolina: estuarine electroshock survey for juveniles (2001-present; 2017 CPUE increased by 80% since 2016, above the long-term mean); SEAMAP shallow water (15-30 ft) trawl survey from Cape Hatteras to Cape Canaveral (1989-present; 2017 CPUE decreased by 36% from 2016; inshore estuarine trammel net survey for adults (May-September, 1991-present; 2017 CPUE increased 178% from 2016); SCECAP estuarine trawl survey (1999-present, primarily targets juveniles, 2017 CPUE decreased from 2016 by 47%).
- Georgia: Marine Sportfish Population Health Survey (trammel and gill net surveys in the Altamaha River Delta and Wassaw estuary, 2002-present; 2017 trammel net index (GM #/standard net set): 0.1, gill net index: 0.4); Ecological Monitoring Survey (trawl, 2003-present; 2017 CPUE (#/tow) decreased from 95.35 in 2016 to 78.8 in 2016).

- Florida: juvenile seine survey (2002-present; 2017 index decreased by 23% from 2016); juvenile trawl survey (2002-present; 2017 index decreased by 9% from 2016); adult haul seine survey (2001-present; 2017 index value increased by 2% from 2016)

The Northeast Fishery Science Center (NEFSC) performs a randomly stratified groundfish survey along the U.S. east coast. Atlantic croaker are one of the main species caught throughout much of the survey area and, since the surveys started in 1972, it provides a long term data set. Regionally, mean CPUE (catch-per-unit-effort) of Atlantic croaker has increased from north to south. Since 1994, there has been an increase in annual catch variability. Catch levels in 2016 decreased 34.6% from 2015 and were above the long term mean. The NEFSC survey was not carried out in 2017 due to mechanical issues with the RV Bigelow. While there will be a survey in 2018, that particular data metric was not available in 2017. In order to maintain the usefulness of the NEFSC index, an initial placeholder value was utilized for 2017 that was calculated as the mean annual catch from the three previous years (2014-2016). The TC has not had a chance to address this specific issue to date and may modify it in the future if a better method or consensus is reached on how to maintain an index value for 2017.

VI. Status of Management Measures and Issues

Fishery Management Plan
Amendment 1 was fully implemented by January 1, 2006, and provided the management plan for the 2009 fishing year. There are no interstate regulatory requirements for Atlantic croaker. Should regulatory requirements be implemented in the future, all state programs must include law enforcement capabilities adequate for successfully implementing the regulations. Addendum I to Amendment 1 was initiated in August 2010 and approved in March 2011, in order to 1) revise the biological reference points to be ratio-based, and 2) remove the distinction of two regions within the management unit, based on the results of the 2010 stock assessment. Addendum II was approved August 2014 and established the TLA management framework for Atlantic croaker in order to better illustrate long-term trends in the fishery.

Traffic Light Approach
Addendum II established the TLA as the new management framework for Atlantic croaker. Under this management program, if thresholds for both population characteristics (harvest and adult abundance) achieve or exceed the proportion of threshold for the specified three year period, management action will be taken.

Analysis of the harvest composite index for 2017 shows that this population characteristic tripped for a fifth consecutive year (Figure 4). Recreational harvest was estimated based on MRIP's mail-based Fishing Effort Survey calibration. The mean proportion of red color from 2014-2016 was 69%, exceeding the 60% threshold. The harvest composite index was comprised of commercial and recreational landings. Both commercial and recreational indices would have individually tripped in 2017 at the 30% level. The TLA for commercial landings was above the 60% threshold in 2017, and has exceeded 60% in three consecutive years.

The abundance composite TLA index was broken into two components based on age composition. The adult composite index was generated from the NEFSC and SEAMAP surveys, since the majority of Atlantic croaker captured in those surveys were ages 1+. The juvenile composite index was generated from the North Carolina (NC) Program 195 and VIMS surveys because these two captured primarily young-of-the-year Atlantic croaker.

Two of four TLA abundance indices showed increases in 2017 with no red proportion. The NEFSC survey was not conducted in 2017 due to mechanical issues with the RV Bigelow. The 2017 value for this index is estimated in this report as the 3-year average of the 2014-2016 index values. The adult composite TLA characteristic (Figure 5) did not trigger in 2017 with no red proportion and no red in the five previous years. The juvenile composite characteristic index (Figure 6) was fifty percent red and fifty percent green, due to a large decrease in the VIMS index and a large increase in the NC Program 195 survey. The higher annual variability for the different color proportions in the juvenile composite characteristic, in comparison to the adult composite characteristic, is likely a reflection annual recruitment variability rather than population trends.

Overall, management triggers were not tripped in 2017 since both population characteristics (harvest and adult abundance) were not above the 30% threshold for the 2015-2017 time period. This continues a trend of disconnect between the harvest and abundance indices since the mid-2000s, with the harvest metric generally decreasing and abundance metric generally increasing.

De Minimis Requests

States are permitted to request *de minimis* status if, for the preceding three years for which data are available, their average commercial landings or recreational landings (by weight) constitute less than 1% of the coastwide commercial or recreational landings for the same three year period. A state may qualify for *de minimis* in either its recreational or commercial sector, or both, but will only qualify for exemptions in the sector(s) that it qualifies for as *de minimis*. Amendment 1 does not include any compliance requirements other than annual state reporting, which is still required of *de minimis* states, thus *de minimis* status does not exempt states from any measures.

In the annual compliance reports, the following states requested *de minimis* status: Delaware (commercial fishery), South Carolina (commercial fishery), Georgia (commercial fishery), and Florida (commercial fishery). The commercial and recreational *de minimis* criteria for 2017 are based on 1% of the average coastwide 2015-2017 landings in each fishery: 58,000 pounds for the commercial fishery and 58,400 pounds for the recreational fishery. The Delaware commercial fishery qualifies for *de minimis* status, but landings are confidential. The South Carolina commercial fishery qualifies for *de minimis* status with a three-year average of 279 pounds. The Georgia commercial fishery qualifies for *de minimis* status with a three-year average of zero pounds. The Florida commercial fishery qualifies for *de minimis* status with a three-year average of 46,441 pounds.

Changes to State Regulations

In 2017, North Carolina enacted several gill net restrictions for coastal waters pertaining to area closures/openings, gear modifications, and attendance rules to avoid interactions with endangered species or bycatch species. These restrictions may indirectly affect the harvest and bycatch of Atlantic croaker and are defined by North Carolina Proclamations: M-24-2017, M-20-2017, M-23-2017, FF-47-2017, M-19-2017, M-18-2017, M-17-2017, M-14-2017, M-13-2017, M-12-2017, M-11-2017, M-10-2017, M-9-2017, M-8-2017, M-7-2017, M-6-2017, M-5-2017, M-4-2017, M-3-2017, M-2-2017, and M-1-2017.

In 2017, the Georgia General Assembly approved the addition of species endorsements to commercial fishing licenses (O.C.G.A 27-2-23 (6) and (11)). Species endorsements regulations were adopted by the Board of Natural Resources in December 2017 and became effective January 2018 (Board of Natural Resources Rule 391-2-4-.17). The endorsements effectively replaced Letters of Authorization.

In Georgia, a new seafood dealer license was also implemented in 2018 through the same 2017 legislation for endorsements (O.C.G.A 27-2-23 (8A)). Seafood dealers are defined as "any person or entity, other than the end-consumer, who purchases seafood products from a harvester unless the harvester is a licensed seafood dealer". Georgia requires seafood dealers and commercial fishermen to be properly licensed as described by O.C.G.A Sections 27-4-118, 27-4-136, and Board of Natural Resources Rule 391-2-4-.09. Commercial harvesters fishing in Georgia waters and/or unloading seafood products must possess a commercial fishing license and the appropriate species endorsements. A harvester is required to have a dealer's license if he is selling his catch to end consumers.

Atlantic Croaker Habitat

In winter of 2017, the ASMFC Habitat Committee released *Atlantic Sciaenid Habitats: A Review of Utilization, Threats, and Recommendations for Conservation, Management, and Research*, which outlines the habitat needs of Atlantic croaker at different life stages (egg, larval, juvenile, adult). This report also highlights threats and uncertainties facing these ecological areas and identifies Habitat Areas of Particular Concern. It can be found online at: http://www.asmfc.org/files/Habitat/HMS14_AtlanticSciaenidHabitats_Winter2017.pdf.

Bycatch Reduction

Atlantic croaker is subject to both direct and indirect fishing mortality. Historically, croaker ranked as one of the most abundant bycatch species of the south Atlantic shrimp trawl fishery, resulting in the original FMP's recommendation that bycatch reduction devices (BRDs) be developed and required in the shrimp trawl fishery. Since then, the states of North Carolina through Florida have all enacted requirements for the use of BRDs in shrimp trawl nets in state waters, reducing croaker bycatch from this fishery (ASMFC 2010). However, bycatch and discard monitoring from the shrimp trawl fishery have historically been inadequate, resulting in a major source of uncertainty for assessing this stock, as well as other important Mid- and South Atlantic species. Most of the discarded croaker are age-0 and thus likely have not yet reached maturity (ASMFC 2010). The North Carolina Division of Marine Fisheries conducted a two-year study, published in 2015, to collect bycatch data from state shrimp trawlers. It found that Atlantic croaker represent between 34-49% of the total observed finfish bycatch by weight in estuarine waters and between 20-42% in ocean waters. The at-net mortality for Atlantic croaker was found to be 23% (Brown 2015). These data will be valuable for incorporating estimates of removals in future stock assessments.

Atlantic croaker are also discarded from other commercial fishing gears, primarily due to market pressures and few restrictions on croaker harvest at the state level. The National Oceanic and Atmospheric Administration (NOAA) Fisheries Pelagic Observer Program provides data to estimate these discards for use in assessments; however, the time series is limited and only discards from gill nets and otter trawls could be estimated for the 2010 assessment based on the available data. Since 1988, estimated discards have fluctuated between 94 and 15,176 mt without trend, averaging 2,503 mt (ASMFC 2010).

Atlantic croaker is also a major component of the scrap/bait fishery. Landings from this fishery are not reported at the species level, except in North Carolina, which has a continuous program in place to sample these landings and enable estimation of croaker scrap landings for use in the stock assessment. As part of the 2010 stock assessment, North Carolina estimated the scrap/bait landings, which have declined in recent years, from a high of 1,569 mt in 1989 to a low of 84 mt in 2008, primarily due to restrictions placed on fisheries producing the highest scrap/bait landings (ASMFC 2010). Regulations instituted by North Carolina include a ban on flynet fishing south of Cape Hatteras, incidental finfish limits for shrimp and crab trawls in inside waters, minimum mesh size restrictions in trawls, and culling panels in long haul seines.

South Carolina has also begun a state monitoring program to account for scrap landings. The state initiated a bait harvester trip ticket program for all commercial bait harvesters licensed in South Carolina. The impetus for this program is to track bait usage of small sciaenid species (croaker, spot, and whiting) as well as other important bait species.

Several states have implemented other commercial gear requirements that further reduce bycatch and bycatch mortality, while others continue to encourage the use of the BRD devices. NOAA Fisheries published a notice on June 24, 2011 for public scoping in the Federal Register to expand the methods for reducing bycatch interactions with sea turtles, which may have additional effects on the bycatch of finfish like Atlantic croaker in trawls (76 FR 37050). Continuing to reduce the quantity of sub-adult croaker harvested should increase spawning stock biomass and yield per recruit.

Atlantic croaker are also subject to recreational discarding. The percentage of Atlantic croaker released alive by recreational anglers has generally increased over time. Discard mortality was estimated to be 10% for the 2010 stock assessment (ASMFC 2010). The use of circle hooks and appropriate handling techniques can help reduce mortality of released fish.

VII. Implementation of FMP Compliance Requirements for 2015

The PRT finds that all states have fulfilled the requirements of Amendment 1.

VIII. Recommendations

Management and Regulatory Recommendations

- Consider initiation of an addendum to incorporate TC-recommended changes to the annual TLA.
- Encourage the use of circle hooks to minimize recreational discard mortality.
- Consider approval of the *de minimis* requests from Delaware, South Carolina, Georgia, and Florida for their commercial fisheries.
- Consider the basic research and monitoring information needed for informed management in light of the budgetary constraints limiting all state governments.

Research and Monitoring Recommendations

<u>High Priority</u>

- Increase observer coverage for commercial discards, particularly the shrimp trawl fishery. Develop a standardized, representative sampling protocol for observers to use to increase the collection of individual lengths and ages of discarded finfish.
- Describe the coast-wide distribution, behavior, and movement of croaker by age, length, and season, with emphasis on collecting larger, older fish.
- Continue state and multi-state fisheries-independent surveys throughout the species range and subsample for individual lengths and ages. Ensure NEFSC trawl survey continues to take lengths and ages. Examine potential factors affecting catchability in long-term fishery independent surveys.
- Investigate environmental covariates in stock assessment models including climate cycles (e.g., Atlantic Multi-decadal Oscillation, AMO, and El Niño Southern Oscillation, El Niño) and recruitment and/or year class strength, spawning stock biomass, stock distribution, maturity schedules, and habitat degradation.
- Continue to develop estimates of length-at-maturity and year-round reproductive dynamics throughout the species range. Assess whether temporal or density-dependent shifts in reproductive dynamics have occurred.
- Re-examine historical ichthyoplankton studies for an indication of the magnitude of estuarine and coastal spawning, as well as for potential inclusion as indices of spawning stock biomass in future assessments. Pursue specific estuarine data sets from the states (NJ, VA, NC, SC, DE, MD) and coastal data sets (MARMAP, EcoMon).
- Investigate the relationship between estuarine nursery areas and their proportional contribution to adult biomass, i.e., are select nursery areas along Atlantic coast ultimately contributing more to SSB than others, reflecting better quality juvenile habitat?

<u>Medium Priority</u>

- Conduct studies of discard mortality for recreational and commercial fisheries by each gear type in regions where removals are highest.

- In the recreational fishery, develop sampling protocol for collecting lengths of discarded finfish and collect otolith age samples from retained fish.
- Encourage fishery-dependent biological sampling, with proportional landings representative of the distribution of the fisheries. Develop and communicate clear protocols on truly representative sampling.
- Quantify effects of BRDs and TEDs implementation in the shrimp trawl fishery by examining their relative catch reduction rates on Atlantic croaker.
- Utilize NOAA Fisheries Ecosystem Indicators bi-annual reports to consider folding indicators into the assessment; identify mechanisms for how environmental indicators affect the stock.
- Encourage efforts to recover historical landings data, determine whether they are available at a finer scale for the earliest years than are currently reported.
- Collect data to develop gear-specific fishing effort estimates and investigate methods to develop historical estimates of effort.
- Develop gear selectivity studies for commercial fisheries with emphasis on age 1+ fish.
- Conduct studies to measure female reproductive output at size and age (fecundity, egg and larval quality) and impact on assessment models and biomass reference points.
- Develop and implement sampling programs for state-specific commercial scrap and bait fisheries in order to monito the relative importance of Atlantic croaker. Incorporate biological data collection into the program.

IX. References

Atlantic States Marine Fisheries Commission (ASMFC). 1987. Fishery Management Plan for Atlantic Croaker. Washington (DC): ASMFC. Fishery Management Report No. 10. 90 p.

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Kevin Brown. 2015. Characterization of the commercial shrimp otter trawl fishery in the estuarine and ocean (0-3 miles) waters of North Carolina. Morehead City (NC): NCDEQ, Division of Marine Fisheries. Abstract.

X. Figures

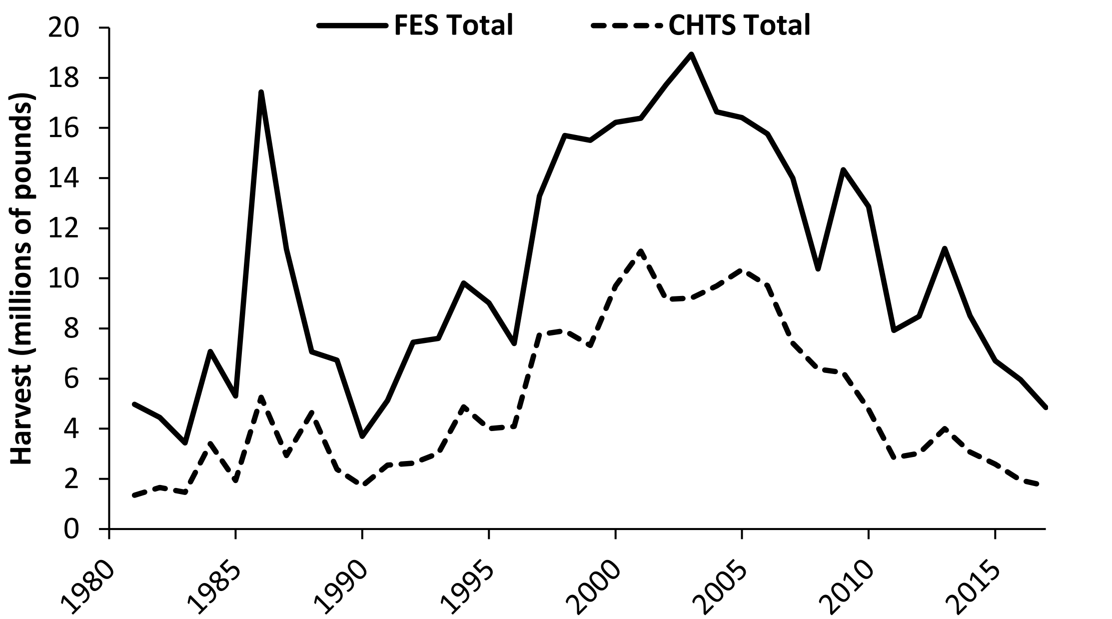


Figure 1. Recreational harvest in pounds, estimated using the Coastal Household Telephone Survey (CHTS) and the mail-based Fishing Effort Survey (FES). (Source: personal communication with NOAA Fisheries, Fisheries Statistics Division. [07/18/2018])

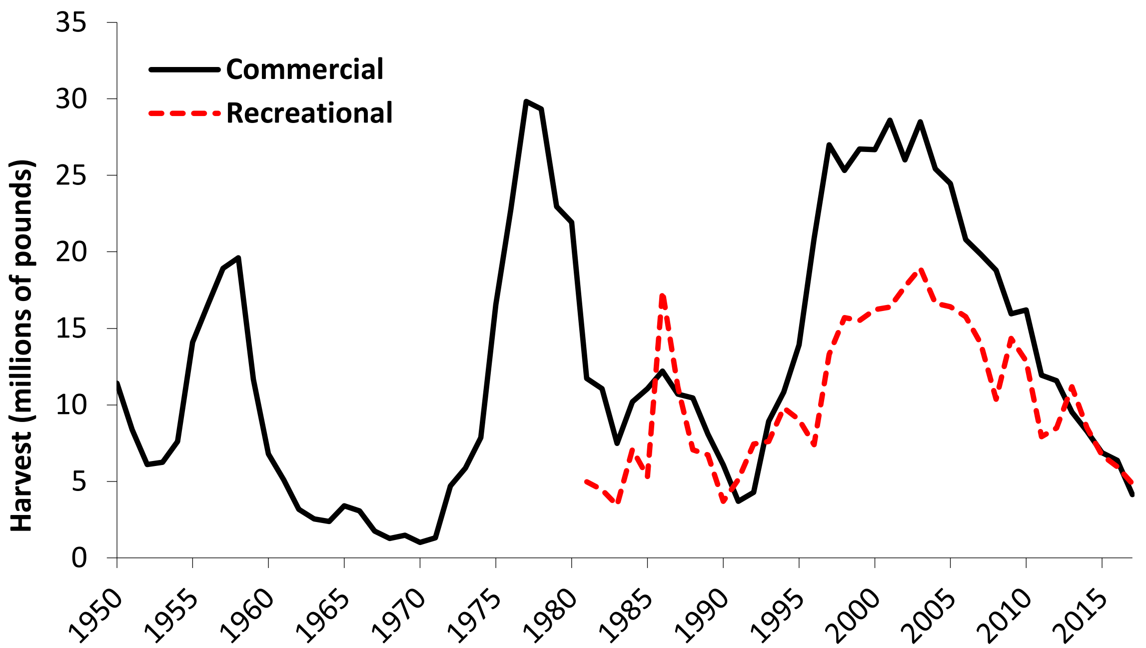


Figure 2. Atlantic croaker commercial and recreational landings (pounds) from 1950-2017. (See Tables 2 and 3 for source information. Commercial landings estimate for 2017 is preliminary. Reliable recreational landings estimates are not available prior to 1981. Recreational landings estimates are based on the mail-based Fishing Effort Survey.)

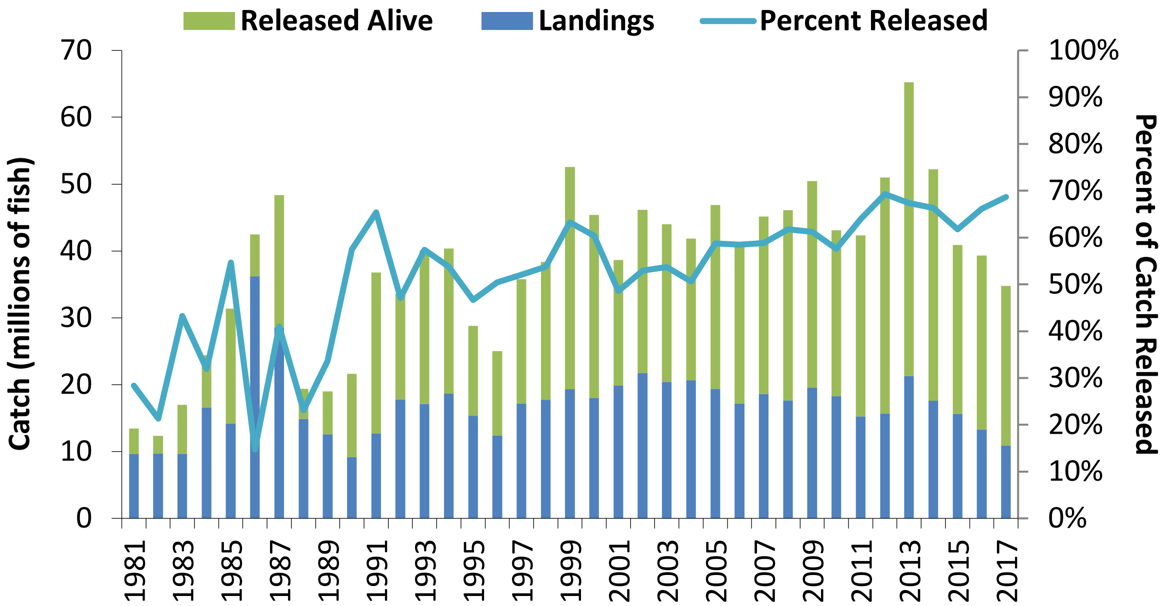


Figure 3. Recreational catch (landings and alive releases, in numbers) and the percent of catch that is released, 1981-2017, based on the mail-based Fishing Effort Survey calibration. (See Tables 4 and 5 for values and source information.)

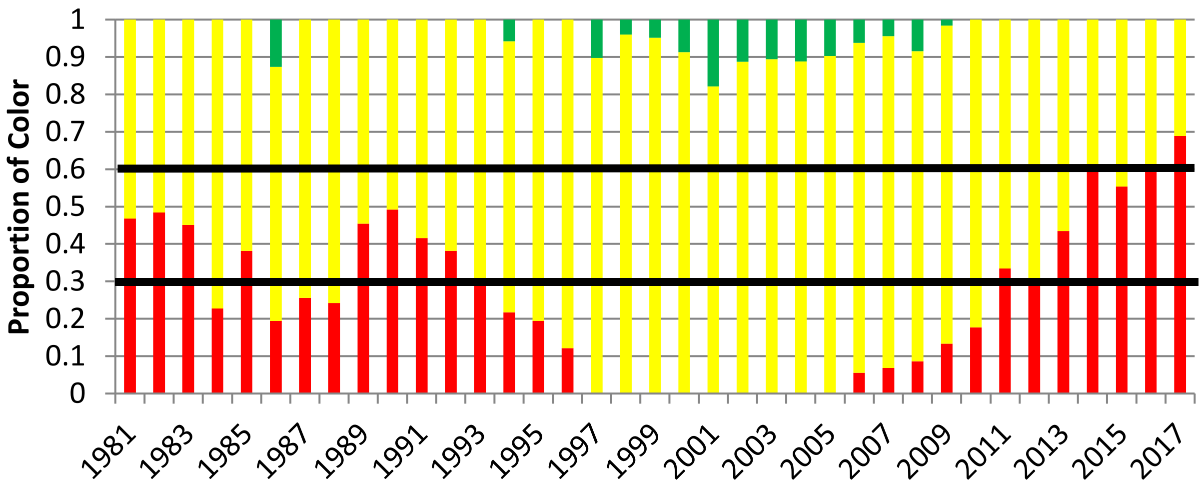


Figure 4. Annual color proportions for the harvest composite TLA of Atlantic croaker recreational and commercial landings.

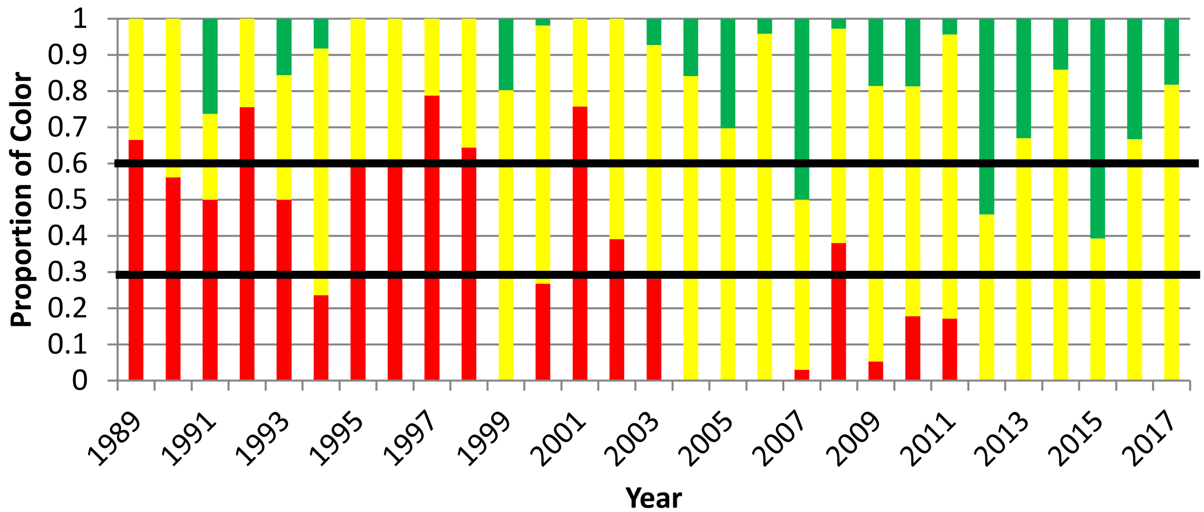


Figure 5. Adult croaker TLA composite characteristic index (NEFSC and SEAMAP surveys). The NEFSC survey was not conducted in 2017 due to mechanical problems with the RV Bigelow. The 3-year average of 2014-2016 values was imputed to estimate the 2017 value for this index.

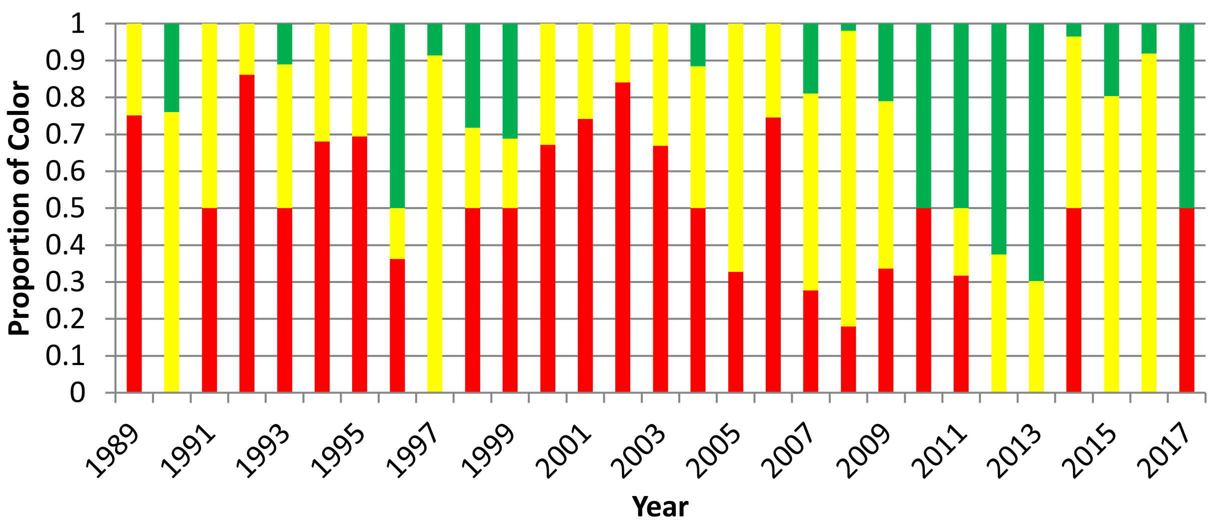


Figure 6. Juvenile croaker TLA composite characteristic index (NC 195 and VIMS surveys).

XI. Tables

Table 1. Summary of state regulations for Atlantic croaker in 2017.

State	Recreational	Commercial
NJ	none	otter/beam trawl mesh restriction for directed croaker harvest (>100 lbs in possession)
DE	8" minimum; recreational gill nets (up to 200 ft.) with license	8" minimum
MD	9" min, 25 fish/day, charter boat logbooks	9" minimum; open 3/16 to 12/31
PRFC	25 fish/day	pound net season: 2/15 to 12/15
VA	none	none
NC	recreational use of commercial gears with license and gear restrictions	
SC	mandatory for-hire logbooks, small Sciaenidae species aggregate bag limit of 50 fish/day	
GA	25 fish/day	25 fish/day limit except for trawlers harvesting shrimp for human consumption (no limit)
FL	none	none

* A commercial fishing license is required to sell croaker in all states with fisheries. For all states, general gear restrictions affect commercial croaker harvest.

Table 2. Commercial harvest (pounds) of Atlantic croaker by state, 2008-2017.
(Estimates for 2017 are preliminary. Sources: 2018 state compliance reports for 2017 fishing year and for years prior to 2017, personal communication with ACCSP, Arlington, VA [07/18/2018], except PRFC [compliance reports only].)

Year	NJ	DE	MD	PRFC	VA	NC	SC	GA	FL	Total
2008	946,339	10,486	608,859	337,062	11,066,482	5,791,766	116	*	30,407	18,791,517
2009	585,552	*	448,589	234,101	8,489,772	6,135,437	75		32,151	15,925,677
2010	342,116	*	542,233	162,571	7,796,179	7,312,159	*		37,229	16,192,487
2011	458,397	*	714,347	243,196	5,415,432	5,054,186	*		47,649	11,933,205
2012	363,381	*	915,432	273,849	6,842,005	3,106,616	*		74,527	11,575,809
2013	332,813	*	820,777	130,285	6,237,602	1,927,938	*		76,463	9,525,878
2014	265,166	*	443,661	177,777	4,697,381	2,629,908	247		45,587	8,259,726
2015	81,311	*	294,038	118,996	4,508,892	1,819,067	*		39,096	6,861,400
2016	55,210	*	101,949	168,889	3,899,990	2,092,135	302		57,538	6,376,012
2017	1,068	*	41,663	114,319	2,933,080	1,007,963	256		42,689	4,141,038

* confidential data

Table 3. Recreational harvest (pounds) of Atlantic croaker by state, 2008-2017. State values are shown using mail-based Fishing Effort Survey (FES)-calibrated estimates, while coastwide totals are shown for both FES estimates and Coastwide Household Telephone Survey (CHTS) estimates. (Source: personal communication with NOAA Fisheries, Fisheries Statistics Division. [07/18/2018])

Year	NJ	DE	MD	VA	NC
2008	911,380	542,545	825,062	7,244,645	275,052
2009	662,763	615,692	3,012,580	8,282,280	359,703
2010	79,889	106,268	2,472,032	9,295,413	638,817
2011	50,153	123,487	1,188,916	4,584,599	360,390
2012	259,645	147,737	1,980,417	4,664,264	307,338
2013	1,637,516	253,447	1,581,384	6,442,166	453,881
2014	750,580	427,615	1,265,217	4,354,046	758,751
2015	263,749	189,320	871,596	3,514,410	557,735
2016	7,133	10,959	407,010	2,998,022	443,728
2017	0	26,429	238,659	3,383,506	237,160

Year	SC	GA	FL	FES Total	CHTS Total
2008	41,864	24,414	503,549	10,368,511	6,372,427
2009	214,212	69,031	1,120,776	14,337,037	6,233,412
2010	27,184	35,593	209,519	12,864,715	4,768,844
2011	583,280	38,219	995,506	7,924,550	2,837,034
2012	30,149	29,815	1,063,337	8,482,702	3,017,384
2013	84,248	89,781	642,887	11,185,310	4,000,931
2014	104,434	138,423	712,090	8,511,156	3,075,053
2015	181,909	248,431	881,185	6,708,335	2,584,350
2016	81,896	116,313	1,893,203	5,958,264	1,949,944
2017	310,621	100,565	555,389	4,852,329	1,715,421

Table 4. Recreational harvest (numbers) of Atlantic croaker by state, 2008-2017. State values are shown using mail-based Fishing Effort Survey (FES)-calibrated estimates, while coastwide totals are shown for both FES estimates and Coastwide Household Telephone Survey (CHTS) estimates. (Source: personal communication with NOAA Fisheries, Fisheries Statistics Division. [07/18/2018])

Year	NJ	DE	MD	VA	NC
2008	1,025,804	639,436	1,057,946	12,901,813	678,638
2009	1,059,267	983,173	2,586,887	10,789,517	958,128
2010	142,887	207,601	2,994,889	12,961,723	1,280,446
2011	91,014	212,613	1,530,723	8,891,276	873,659
2012	830,891	202,283	2,565,599	8,786,350	848,495
2013	2,707,410	530,236	2,308,987	12,517,286	1,300,804
2014	852,733	806,256	2,197,125	9,533,829	1,935,961
2015	339,021	334,676	1,738,576	8,024,381	1,437,019
2016	8,236	24,546	659,318	7,276,719	1,109,570
2017	0	65,575	425,987	7,637,843	666,930

Year	SC	GA	FL	FES Total	CHTS Total
2008	190,181	72,912	1,055,906	17,622,636	10,849,419
2009	733,845	185,129	2,252,473	19,548,419	8,436,509
2010	88,399	121,252	470,168	18,267,365	6,711,636
2011	949,132	129,941	2,593,963	15,272,321	5,109,533
2012	132,264	104,944	2,190,268	15,661,094	5,732,227
2013	336,140	264,984	1,332,465	21,298,312	7,554,404
2014	600,482	289,781	1,359,207	17,575,374	6,218,185
2015	555,263	790,014	2,429,723	15,648,673	5,663,615
2016	268,470	402,254	3,553,777	13,302,890	4,278,373
2017	765,227	371,301	969,146	10,902,009	3,920,875

Table 5. Recreational releases (number) of Atlantic croaker by state, 2008-2017. State values are shown using mail-based Fishing Effort Survey (FES)-calibrated estimates, while coastwide totals are shown for both FES estimates and Coastwide Household Telephone Survey (CHTS) estimates. (Source: personal communication with NOAA Fisheries, Fisheries Statistics Division. [07/18/2018])

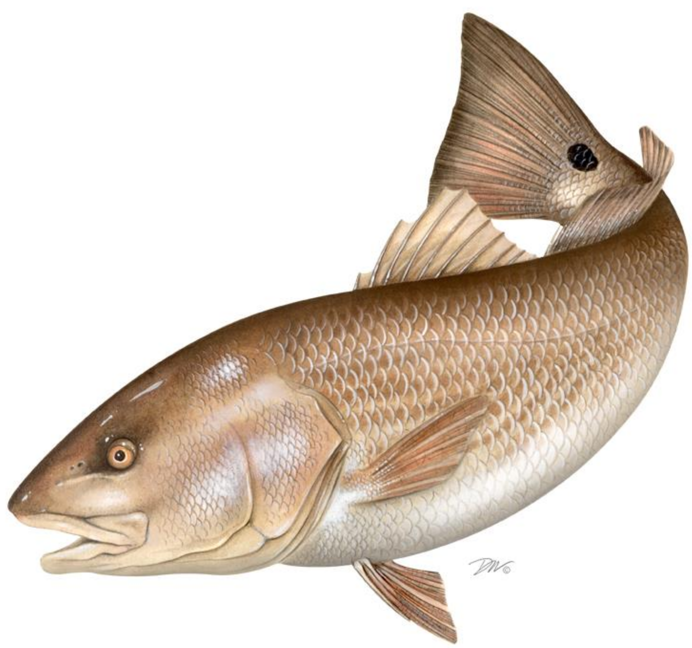
Year	NJ	DE	MD	VA	NC
2008	4,777,481	1,162,992	3,644,105	12,806,082	3,274,873
2009	406,639	1,284,262	2,424,818	16,732,646	5,623,278
2010	380,916	1,056,528	3,060,983	13,470,836	4,571,287
2011	252,419	214,603	937,220	14,160,124	7,005,152
2012	3,336,964	1,036,383	7,090,976	15,140,369	3,878,710
2013	2,980,744	1,811,661	7,557,223	18,480,099	6,729,556
2014	703,031	1,396,970	2,806,693	10,314,405	10,347,332
2015	240,840	309,389	1,236,293	6,815,343	9,632,560
2016	139,085	390,655	726,662	6,993,470	7,254,382
2017	152,540	230,934	2,833,760	8,443,528	4,631,445

Year	SC	GA	FL	FES Total	CHTS Total
2008	531,919	527,977	1,743,548	28,468,977	15,662,602
2009	1,232,519	1,169,782	2,015,296	30,889,240	12,673,959
2010	621,497	651,984	1,014,552	24,828,583	8,469,416
2011	1,187,686	748,696	2,559,976	27,065,876	8,143,558
2012	1,070,703	781,302	2,999,225	35,334,632	10,709,525
2013	3,754,143	1,361,943	1,265,571	43,940,940	13,916,551
2014	4,742,718	2,057,898	2,265,961	34,635,008	9,996,064
2015	3,236,774	1,320,939	2,451,253	25,243,391	7,662,983
2016	5,233,835	1,178,630	4,073,001	25,989,720	6,929,781
2017	4,755,853	1,059,539	1,770,846	23,878,445	6,724,829

2018 REVIEW OF THE ATLANTIC STATES MARINE FISHERIES COMMISSION FISHERY MANAGEMENT PLAN FOR

RED DRUM (*Sciaenops ocellatus*)

2017 FISHING YEAR



The Red Drum Plan Review Team

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I. Status of the Fishery Management Plan

Date of FMP Approval:	Original FMP – October 1984
Amendments:	Amendment 1 – October 1991 Amendment 2 – June 2002 Addendum 1 – August 2013
Management Areas:	The Atlantic coast distribution of the resource from New Jersey through Florida Northern: New Jersey through North Carolina Southern: South Carolina through the east coast of Florida
Active Boards/Committees:	South Atlantic State/Federal Fisheries Management Board, Red Drum Technical Committee, Stock Assessment Subcommittee, Plan Development Team, Plan Review Team, South Atlantic Species Advisory Panel

The Atlantic States Marine Fisheries Commission (ASMFC) adopted an Interstate Fishery Management Plan (FMP) for Red Drum in 1984. The original management unit included the states from Maryland to Florida. In 1988, the Interstate Fisheries Management Program (ISFMP) Policy Board requested that all Atlantic coastal states from Maine to Florida implement the plan's recommended management regulations to prevent development of northern markets for southern fish. The states of New Jersey through Florida are now required to follow the FMP, while Maine through New York (including Pennsylvania) are encouraged to implement consistent provisions to protect the red drum spawning stock.

In 1990, the South Atlantic Fishery Management Council (Council) adopted a FMP for red drum that defined overfishing and optimum yield (OY) consistent with the Magnuson Fishery Conservation and Management Act of 1976. Adoption of this plan prohibited the harvest of red drum in the exclusive economic zone (EEZ), a moratorium that remains in effect today. Recognizing that all harvest would take place in state waters, the Council FMP recommended that states implement measures necessary to achieve the target level of at least 30% escapement.

Consequently, ASMFC initiated Amendment 1 in 1991, which included the goal to attain optimum yield from the fishery over time. Optimum yield was defined as the amount of harvest that could be taken while maintaining the level of spawning stock biomass per recruit (SSBR) at or above 30% of the level which would result if fishing mortality was zero. However, a lack of information on adult stock status resulted in the use of a 30% escapement rate of sub-adult red drum to the off-shore adult spawning stock.

Substantial reductions in fishing mortality were necessary to achieve the escapement rate; however, the lack of data on the status of adult red drum along the Atlantic coast led to the adoption of a phase-in approach with a 10% SSBR goal. In 1991, states implemented or maintained harvest controls necessary to attain the goal.

As hoped, these management measures led to increased escapement rates of juvenile red drum. Escapement estimates for the northern region of New Jersey through North Carolina (18%) and the southern region of South Carolina through Florida (17%) were estimated to be above the 10% phase-in goal, yet still below the ultimate goal of 30% (Vaughan and Carmichael 2000). North Carolina, South Carolina, and Georgia implemented substantive changes to their regulations from 1998-2001 that further restricted harvest.

The Council adopted new definitions of OY and overfishing for red drum in 1998. Optimum yield was redefined as the harvest associated with a 40% static spawning potential ratio (sSPR), overfishing as an sSPR less than 30%, and an overfishing threshold as 10% sSPR. In 1999, the Council recommended that management authority for red drum be transferred to the states through the Commission's Interstate Fishery Management Program (ISFMP) process. This was recommended, in part, due to the inability to accurately determine an overfished status, and therefore stock rebuilding targets and schedules, as required under the revised Sustainable Fisheries Act of 1996. The transfer necessitated the development of an amendment to the interstate FMP in order to include the provisions of the Atlantic Coastal Fisheries Cooperative Management Act.

ASFMC adopted Amendment 2 to the Red Drum FMP in June 2002 (ASMFC 2002), which serves as the current management plan. The goal of Amendment 2 is to achieve and maintain the OY for the Atlantic coast red drum fishery as the amount of harvest that can be taken by U.S. fishermen while maintaining the sSPR at or above 40%. There are four plan objectives:

- Achieve and maintain an escapement rate sufficient to prevent recruitment failure and achieve an sSPR at or above 40%.
- Provide a flexible management system to address incompatibility and inconsistency among state and federal regulations which minimizes regulatory delay while retaining substantial ASMFC, Council, and public input into management decisions; and which can adapt to changes in resource abundance, new scientific information, and changes in fishing patterns among user groups or by area.
- Promote cooperative collection of biological, economic, and sociological data required to effectively monitor and assess the status of the red drum resource and evaluate management efforts.
- Restore the age and size structure of the Atlantic coast red drum population.

The management area extends from New Jersey through the east coast of Florida, and is separated into a northern and southern region at the North Carolina/South Carolina border. The sSPR of 40% is considered a target; an sSPR below 30% (threshold level) results in an overfishing determination for red drum. Amendment 2 required all states within the management unit to implement appropriate recreational bag and size limit combinations needed to attain the target sSPR, and to maintain current, or implement more restrictive, commercial fishery regulations. All states were in compliance by January 1, 2003. See Table 1 for state commercial and recreational regulations in 2017.

Following the approval of Amendment 2 in 2002, the process to transfer management authority to ASMFC began, including an Environmental Assessment and public comment period. The final rule became effective November 5, 2008. It repeals the federal Atlantic Coast Red Drum Fishery Management Plan and transfers management authority of Atlantic red drum in the exclusive economic zone from the South Atlantic Fishery Management Council to the Atlantic States Marine Fisheries Commission.

The Board approved Addendum I to Amendment 2 in August 2013. The Addendum revised the habitat section of Amendment 2 to include current information on red drum spawning habitat and life-stages (egg, larval, juvenile, sub-adult, and adult). It also identified and described the distribution of key habitats and habitats of concern.

II. Status of the Stocks

The 2017 Red Drum Stock Assessment and Peer Review Report indicate overfishing is not occurring for either the northern or southern stock of red drum (ASMFC 2017). The assessment was unable to determine an overfished/not overfished status because population abundance could not be reliably estimated due to limited data for the older fish (ages 4+).

Northern Region (NJ-NC)

Recruitment (age 1 abundance) has varied annually with a large peak occurring in 2012 (Figure 1). The trend in the three-year average sSPR indicates low sSPR early in the time series with increases during 1991 – 1997 and fluctuations thereafter (Figure 2). The average sSPR has been above the overfishing threshold ($F_{30\%}$) since 1994, and at or above the target ($F_{40\%}$) since 1996, except during one year (2002). Fishing pressure and mortality appear to be stabilized near the target fishing mortality. The average sSPR is also likely above the target benchmark.

Southern Region (SC-FL)

Recruitment (age 1 abundance) has fluctuated without apparent trend since 1991 (Figure 1). A high level of uncertainty exists around the three-year average sSPR estimates for the southern region. While the 3-year average sSPR estimate in 2013 was above both the target ($F_{40\%}$) and the overfishing threshold ($F_{30\%}$), indicating that overfishing is not occurring, the high level of uncertainty around this estimate indicates that this conclusion should be considered with extreme caution (Figure 2).

III. Status of the Fishery

In July, 2018, the Marine Recreational Information Program (MRIP) updated recreational catch estimates based on the mail-based Fishing Effort Survey (FES). Previous estimates were made based on the Coastal Household Telephone Survey (CHTS). As current management is based on the most recent stock assessment (2017), which used CHTS-based estimates, these estimates will continue to be used until another stock assessment is conducted. Figure 7 shows coastwide recreational landings including estimates using both the previous CHTS and FES calibrations for comparison, but other figures, tables, and text will only show data based

on the CHTS calibration. Data based on either survey can be referenced at: https://www.st.nmfs.noaa.gov/st1/recreational/queries/.

Total red drum landings from New Jersey through the east coast of Florida in 2017 are estimated at 2.15 million pounds (Tables 2 and 3, Figure 3). This is roughly 100,000 pounds less than was landed in 2016. 2017 total landings are above the previous ten-year (2008-2017) average of 2.01 million pounds. The commercial and recreational fisheries harvested 9% and 91% of the total, respectively. The southern region includes South Carolina through Florida's east coast, while the northern region includes New Jersey through North Carolina. In 2017, 56% of the total landings came from the southern region where the fishery is exclusively recreational, and 44% from the northern region (Figure 4).

Coastwide commercial landings increased significantly this year, but show no long-term temporal trends. In the last 50 years, landings have ranged from approximately 54,000 pounds (in 1997) to 440,000 pounds (in 1980, Figure 3). In 2017, red drum were commercially landed only in Maryland, Virginia, and North Carolina (Table 2). Coastwide commercial harvest increased from 78,785 pounds in 2016 to 194,449 pounds in 2017, with 96% harvested by North Carolina. Historically, North Carolina and Florida shared the majority of commercial harvest, but commercial harvest has been prohibited in Florida under state regulation since January 1988. South Carolina also banned commercial harvest and sale of native caught red drum beginning in 1987, and in 2013 Georgia designated Red Drum Gamefish status, eliminating commercial harvest and sale.

In North Carolina, a daily commercial trip limit and an annual cap of 250,000 pounds with payback of any overage constrain the commercial harvest. Unique to this state, the red drum fishing year extends from September 1 to August 31. In 2008, the Board approved use of this 2008 fishing year to monitor the cap. During the 2009/2010 and the 2013/2014 fishing years, North Carolina had overages of 25,858 pounds and 12,753 pounds, respectively. The commercial harvest for each following fishing year remained well below the adjusted cap allowance, providing sufficient payback.

Recreational harvest of red drum peaked in 1984 at 1.05 million fish (or 2.6 million pounds; Tables 3 and 4). Since 1988, the number has fluctuated without trend between 250,000 and 760,000 fish (800,000 to 2.7 million pounds; Figures 3 and 5). Recreational harvest decreased from 591,333 fish (2.2 million pounds) in 2016 to 541,670 fish (2.0 million pounds) in 2017. The 2017 harvest is greater than the 10-year average (2008-2017) for recreational harvest in numbers (538,441) and pounds (1.8 million). Florida anglers landed the largest share of the coastwide recreational harvest in numbers (40%), followed by North Carolina (21%), Virginia (18%), and South Carolina (14%).

Anglers release far more red drum than they keep; the percent of the catch released has been over 80% during the last decade (Figure 5). Recreational releases show an increasing trend over the time series that has plateaued from around the early 2000s to the present. The proportion of releases in 2017 was 85% (versus 81% in 2016), and the overall number of fish released was

3.0 million in 2017 (Figure 5, Table 5). It is estimated that 8% of released fish die as a result of being caught, resulting in an estimated 241,665 dead discarded fish in 2017 (Table 5). Recreational removals from the fishery are thus estimated to be 783,335 fish in 2017 (Figure 6).

IV. Status of Assessment Advice

Current stock status information comes from the 2017 stock assessment (ASMFC 2017) completed by the ASMFC Red Drum Stock Assessment Subcommittee (SAS) and Technical Committee (TC), peer reviewed by an independent panel of experts through ASMFC's desk review process, and approved by the South Atlantic State-Federal Fisheries Management Board for use in management decisions. Previous interstate management decisions were based on the last coastwide assessment, SEDAR 18 (SAFMC 2009), and prior to 2009, decisions were based on regional assessments conducted by Vaughan and Helser (1990), Vaughan (1992, 1993, 1996), and Vaughan and Carmichael (2000) that reflected the current stock structure, two stocks divided at the North Carolina-South Carolina border. Several states have also conducted state-specific assessments (e.g., Murphy and Munyandorero 2009; Takade and Paramore 2007 [update of Vaughan and Carmichael 2000]).

The 2017 stock assessment uses a statistical catch at age (SCA) model with age-specific data for red drum ages 1 through 7+. This model is similar to that used in the 2009 assessment, with data updated through 2013. Data from 1989-2013 were included from the following sources: commercial and recreational harvest and discard data, fishery-dependent and -independent biological sampling data, tagging data, and fishery-independent survey abundance data.

The Peer Review Panel considered the use of an SCA model appropriate given the types of data available for red drum. For the northern region, the Review Panel agreed that the model was informative of age 1-3 abundance and exploitation rates, but not for older age groups. The model was also found to be informative of annual trends in sSPR and the 2011-2013 average sSPR. For the southern region, the Review Panel agreed that estimates of age 7+ fish seemed to be more consistent with the population biology, leading to a large fraction of biomass being unavailable to exploitation. For both regions, most of the sSPR is contained within the larger, fully mature, age 7+ fish, thus even a small increase in fishing mortality on older red drum (due to harvest or other factors) could quickly lead to a decrease in sSPR and overfishing.

V. Status of Research and Monitoring

No monitoring or research programs are annually required of the states except for the submission of a compliance report. The following fishery-dependent (other than catch and effort data) and fishery-independent monitoring programs were reported in the 2017 reports.

Fishery Dependent Monitoring

- Delaware DFW – Commercial monitoring through mandatory logbook reports.
- Maryland DNR – Commercial pound nets sampled bi-weekly in the Chesapeake Bay from late spring through summer (2017 n=19). Only three of the 24 years of sampling exceeded 20 fish, and no red drum were encountered in ten of the survey years. Seafood dealer

sampling was conducted (2017 n=2). Licensed charter boat captain logbooks are monitored for red drum captures (2017: 48 caught, 17 harvested).

- PRFC – Red drum are harvested incidentally in the commercial pound net and haul seine fisheries. The mandatory commercial harvest daily reporting system, which collects harvest and discards/releases, reported zero red drum released in 2017.
- Virginia MRC – Volunteer anglers have participated since 1995 in the Virginia Game Fish Tagging Program (2017: 1,436 fish tagged, 125 reported recaptures). Carcasses collected through the Marine Sportfish Collection Project since 2007 (2017 n=37).
- North Carolina DMF – Commercial cap monitored through trip ticket program; commercially-landed red drum sampled through biological monitoring program since 1982 (2017: 673 fish measured, primarily gill net).
- South Carolina DNR – State finfish survey conducted in January and February (2017 n=198 caught and 49 harvested, mean catch rate: 1.92 red drum/targeted angler hour). Charter Vessel Trip Reporting (2017 caught: 55,712; release rate: 93.5%). SC Marine Game Fish Tagging Program studies movement patterns, growth rates, and release-mortality rates (in 2017 fish tagged: 4,564; recaptured: 660). SCDNR Sub-Adult Red Drum Tagging Program tags fish caught by the SCDNR electrofishing and trammel net fishery-independent surveys and other fishery-independent sampling efforts (in 2017 fish tagged: 1,191; recaptured: 348). SCDNR Adult Red Drum Tagging Program tags fish caught by the SCDNR inshore fisheries research section longline fishery-independent survey (in 2017 tagged: 409; recaptured: 22). Tournament and freezer fish programs (2017 n=26).
- Georgia CRD – Age, length, and sex data collected through the Marine Sportfish Carcass Recovery Project (2017 n=644 red drum).
- Florida FWC – 7,817 trip interviews in 2017 collected data on total-catch rates and sizes (through MRIP).
- NMFS – Length measurements and recreational catch, harvest, release, and effort data are collected via the Marine Recreational Information Program.

Fishery Independent Monitoring

- New Jersey DFW – Five annual nearshore trawl surveys conducted since 1988, in January/February, April, June, August, and October. Length and weight data, and catch per unit effort (CPUE) in number of fish per tow and biomass per tow recorded for all species. Only two red drum were caught in entire time series (single tow, 2013).
- North Carolina DMF – Seine survey since 1991 produces age-0 abundance index (2016 n=326; CPUE of 2.72, decrease from 2016 CPUE of 5.93). Gill net survey in Pamlico Sound since 2001 characterizes size and age distribution, produces abundance index, improves bycatch estimates, and studies habitat usage (2017 CPUE of 4.12, above long-term average). Longline survey since 2007 produces adult index of abundance and tags fish (2017 n=337; CPUE slightly below long-term average at 4.68 fish per set).
- South Carolina DNR – Estuarine trammel net survey for subadults (2017 CPUE below 10-year average). Electrofishing survey in low salinity estuarine areas for juveniles/subadults (2017 CPUE above 10-year average). Inshore bottom longline survey

for biological data and adult abundance index (409 tagged, 84 sampled for age in 2017). Genetic sub-sampling and tagging conducted during these three surveys.

- Georgia CRD – Estuarine trammel net survey for subadult biological data and abundance index (2017, both areas n=146). Estuarine gill net survey for young-of-year (YOY) biological data and abundance index (2017 both areas n=600). Bottom longline survey for adult biological data and abundance index (2017 n=119 in GA, 9 in NE FL).
- Florida FWC-FWRI – Two seine surveys in northern Indian River Lagoon (IRL) and lower St. Johns River (SJR) for YOY (< 40 mm SL) abundance indices (2017 CPUE higher than 2016). Haul seine survey in these areas and southern IRL for subadult index (2017 CPUE lower than 2016). Age and length data collected during surveys.

VI. Status of Management Measures and Issues

Fishery Management Plan

Amendment 2 was fully implemented by January 1, 2003, providing the management requirements for 2010. Requirements include: recreational regulations designed to achieve at least 40% sSPR, a maximum size limit of 27 inches or less, and current or more stringent commercial regulations. States are also required to have in place law enforcement capabilities adequate to successfully implement their red drum regulations. In August 2013, the Board approved Addendum I to Amendment 2 of the Red Drum FMP. The Addendum revises the habitat section of Amendment 2 to include the most current information on red drum spawning habitat for each life stage (egg, larval, juvenile, sub-adult, and adult). It also identifies the distribution of key habitats and habitats of concern, including potential threats and bottlenecks.

De Minimis Requests

New Jersey and Delaware requested *de minimis* status through the annual reporting process. While Amendment 2 does not include a specific method to determine whether a state qualifies for *de minimis*, the PRT chose to evaluate an individual state's contribution to the fishery by comparing the two-year average of total landings of the state to that of the management unit. New Jersey and Delaware each harvested zero percent of the two-year average total landings. *De minimis* status does not exempt either state from any requirement; it may exempt them from future management measures implemented through addenda to Amendment 2, as determined by the Board.

VII. Implementation of FMP Compliance Requirements for 2017

The PRT finds that all states have implemented the requirements of Amendment 2.

VIII. Recommendations of the Plan Review Team

<u>Management and Regulatory Recommendations</u>

< Consider approval of the *de minimis* requests by New Jersey and Delaware.

< Support a continued moratorium of red drum fishing in the exclusive economic zone.

< Populate the SAS to address assessment recommendations from the Peer Reviewers of the last assessment and the Red Drum TC.

Prioritized Research and Monitoring Recommendations (H) = High, (M) = Medium, (L) = Low

Stock Assessment and Population Dynamics

- Implement surveys (e.g. logbooks, electronic methods, etc.) in each state throughout the management unit to determine the length composition (and age data, if possible) of recreational discards (B2) of red drum. This information has been highlighted as the single largest data gap in previous assessments. (H)
- Further study is needed to determine discard mortality estimates for the Atlantic coast, both for recreational and commercial gears. Additionally, discard estimates should examine the impact of slot-size limit management and explore regulatory discard impacts due to high-grading. Investigate covariates affecting discard mortality (e.g., depth, size, seasonality), and explore methods of determining *in situ* mortality (as opposed to tank studies) and mitigating mortality (e.g. gear types, handling methods, use of descending devices on adults). (H)
- Improve catch/effort estimates and biological sampling from recreational and commercial fisheries for red drum, including increased intercepts of night fisheries for red drum. (H)
- Expand biological sampling based on a statistical analysis to adequately characterize the age/size composition of removals by all statistical strata (gears, states, etc.). (H)
- Each state should develop an on-going red drum tagging program that can be used to estimate both fishing and natural mortality and movements. This should include concurrent evaluations of tag retention, tagging mortality, and angler tag reporting rates. The importance of each state's tagging data to the assessment should be evaluated, including analysis of historical tagging data to determine if existing and historic recreational data sources (e.g., tagging) can be used to evaluate better B2 selectivities. (H)
- Establish programs to provide ongoing estimates of commercial and recreational discard mortality using appropriate statistical methods. Discard estimates should examine the impact of slot-size limit management and explore regulatory discard impacts due to high-grading. (M)
- Evaluate the broader survey needs to identify gaps in current activities and provide for potential expansion and/or standardization between/among current surveys. (M)
- Review all available stock structure data (genetics, tagging, etc.) to determine stock structure and most appropriate management boundaries. (M)

Biological

- Explore methods to effectively sample the adult population in estuarine, nearshore, and open ocean waters, such as in the ongoing red drum long line survey, and to determine the size, age and sex composition of the adults. (H)
- Continue genetic analyses (i.e., SC DNR analyses) to evaluate stock structure and mixing and temporal changes in genetic composition of the red drum population and other applications. (H)
- Refine maturity schedules on a geographic basis. Thoroughly examine the influence of size and age on reproductive function. Investigate the possibility of senescence in female red drum. Archive histological specimens across sizes to look for shifts in maturity schedules and make regional comparisons. Standardize histology reading methods of slides across states conducting such studies. (For reference, see SEDAR 44-DW02). (H)

- Determine habitat preferences, environmental conditions, growth rates, and food habits of larval and juvenile red drum throughout the species range along the Atlantic coast. Assess the effects of environmental factors on stock density/year class strength. Determine whether natural environmental perturbations affect recruitment and modify relationships with spawning stock size. (H)
- Continue tagging studies to determine stock identity, inshore/offshore migration patterns of all life stages (i.e. basic life history research). Specific effort should be given to developing a large-scale program for tagging adult red drum. (M)
- Fully evaluate the effects and effectiveness of using cultured red drum to facilitate higher catch rates along the Atlantic coast. (M)
- Conduct a tagging study using emerging technologies (i.e., acoustic tagging, satellite tagging, genetic tags) to evaluate stock mixing and identify movement of sub-adult fish transitioning to maturity. (M-L)
- Otolith microchemistry analysis should be considered for exploring links between sub-adult estuarine habitats and adult stock structure. (L)

Social (Unless otherwise indicated, the collection of sociological and/or economic data, also sometimes collectively described as "socioeconomic data," would be based on Atlantic Coastal Cooperative Statistics Program [ACCSP] standards.)

- Encourage the NMFS to fund socioeconomic add-on questions to the recreational fisheries survey that are specifically oriented to red drum recreational fishing. (H)
- States with significant fisheries (over 5,000 pounds) should periodically (e.g. every five years) collect socioeconomic data on red drum fisheries through add-ons to the recreational fisheries survey or by other means. (H)
- Using a human dimension analysis perspective, explore Atlantic red drum historical catch-release trends and explanatory factors such as the possible impacts of changes in recreational fishing technology and/or angler behavior on red drum catchability and selectivity over time. (H)
- Conduct applied research to evaluate the various projected (forecasted) social impacts on red drum fishery stakeholders of possible regulatory options (e.g. changing minimum sizes, etc.). (M)

Economic

- Using available secondary data and other information, develop models to estimate the local (community), state and regional level economic impacts (e.g. sales, jobs, income, etc.) of recreational red drum fisheries-related activities including the for-hire sector component (e.g. fishing guides). (H)
- Where appropriate, encourage individual member states to conduct studies to project and evaluate the estimated comparable net economic values associated with current and possible future regulatory regimes that could impact red drum recreational anglers, including those preferring catch and release fishing. (M)
- Using risk adjusted benefit-cost analysis protocols, project the estimated public sector-oriented net economic values over a time for various cultured red drum stocking scenarios compared to possible changes in other fishery management alternatives. (M)

< Encourage NOAA Fisheries to periodically conduct special surveys and related data analysis to determine the economic and operational characteristics of the recreational fishing for-hire component targeting red drum, especially fishing guide-oriented businesses in the South Atlantic states. (M)

Habitat

< Identify spawning areas of red drum in each state from North Carolina to Florida so these areas may be protected from degradation and/or destruction. Explore relationships between spawning activity (e.g. spawning sounds) and environmental parameters (e.g. temperature). (H)

< Identify changes in freshwater inflow on red drum nursery habitats. Quantify the relationship between freshwater inflows and red drum nursery/sub-adult habitats. (H)

< Determine the impacts of dredging and beach re-nourishment on red drum spawning and early life history stages. (M)

< Investigate the concept of estuarine reserves to increase the escapement rate of red drum along the Atlantic coast. (M)

< Identify impacts of water quality, environmental, and ecosystem changes on red drum stock dynamics for potential incorporation into stock assessment models. (M)

< Quantify relationships between red drum production and habitat and implications for future management planning. (L)

< Determine methods for restoring red drum habitat and/or improving existing environmental conditions that adversely affect red drum production. (L)

IX. References

Atlantic States Marine Fisheries Commission (ASMFC). 2002. Amendment 2 to the Interstate Fishery Management Plan for Red Drum. ASMFC, Washington, DC, Fishery Management Report No. 38, 141 p.

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Takade, H and L Paramore. 2007. Stock Status of the Northern Red Drum Stock. North Carolina Division of Marine Fisheries. In-House Report, 60 p.

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Vaughan, DS and TE Helser. 1990. Status of the red drum stock of the Atlantic coast: Stock assessment report for 1989. NOAA Tech. Mem. NMFS-SEFC-263. 117 p.

X. Figures

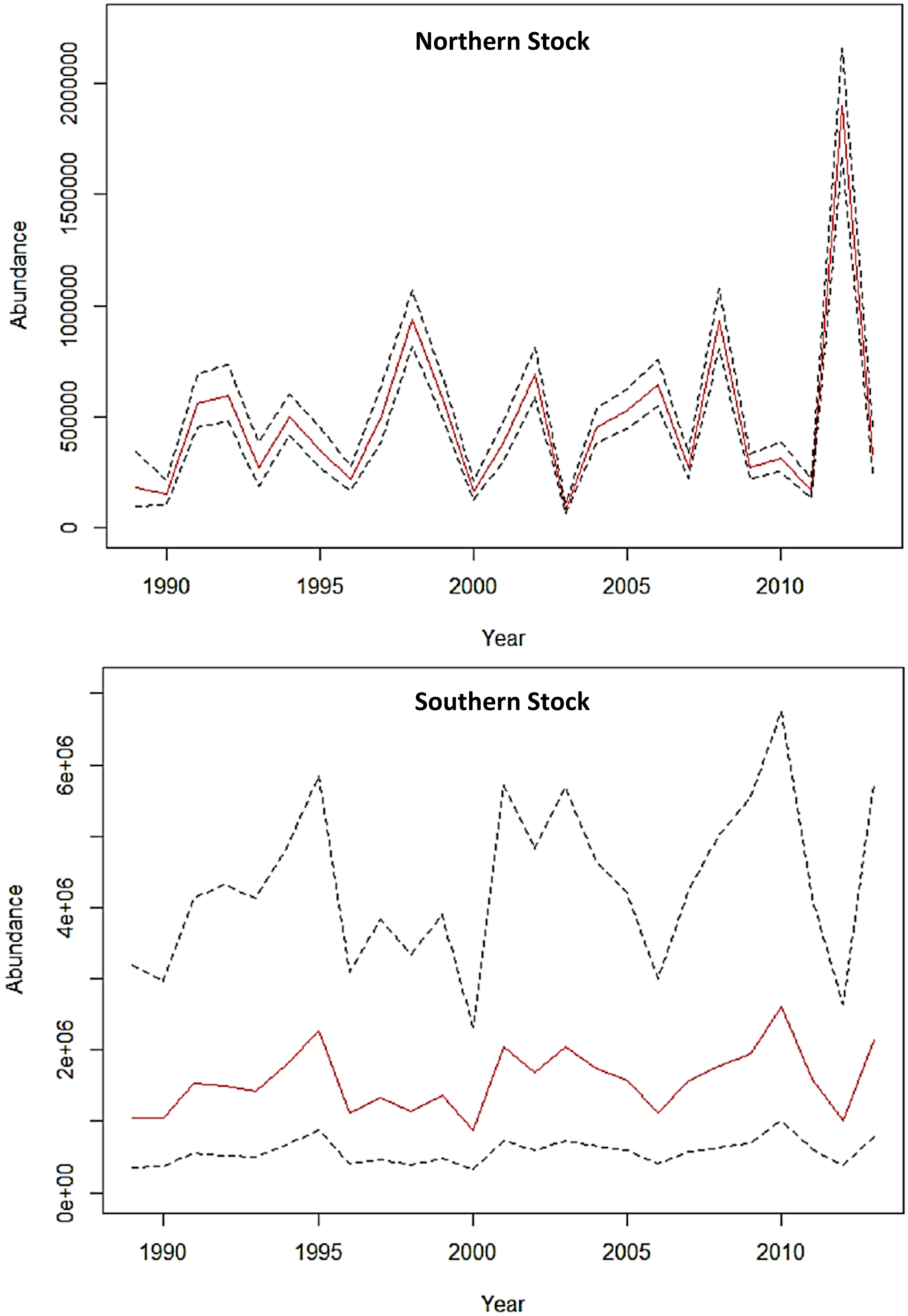

Figure 1. Predicted recruitment (age-1 abundance, red lines) with 95% confidence intervals (dashed black lines) for the northern (top) and southern (bottom) regions (Source: ASMFC 2017).

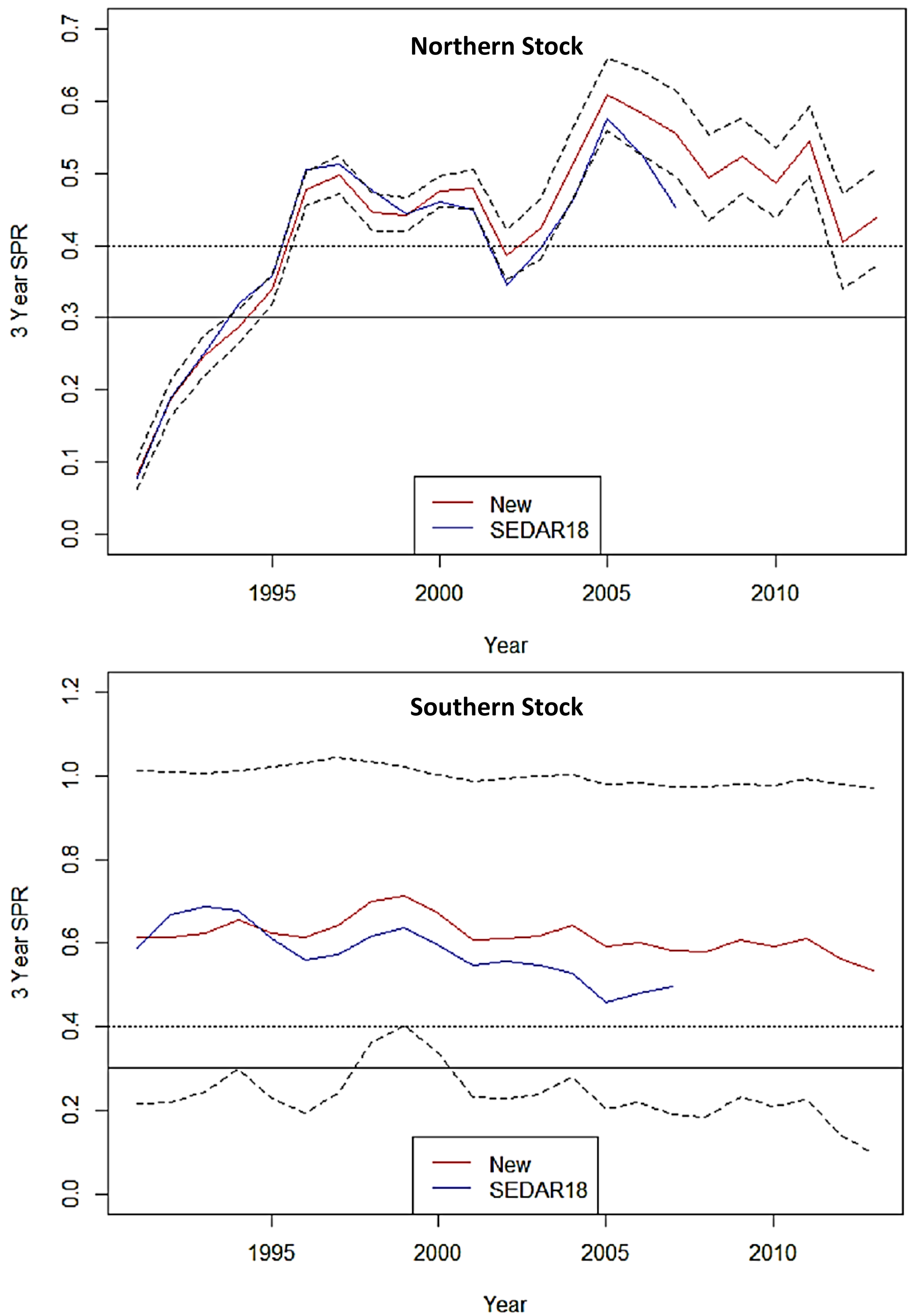

Figure 2. Three year average sSPR (red lines) for the northern (top) and southern (bottom) stocks with 95% confidence intervals (dashed black lines). Point estimates from the previous benchmark assessment (SEDAR18) are included for comparison. The target sSPR (dotted black line) is 40% and the threshold sSPR (solid black line) is 30% (Source: ASMFC 2017)**.**

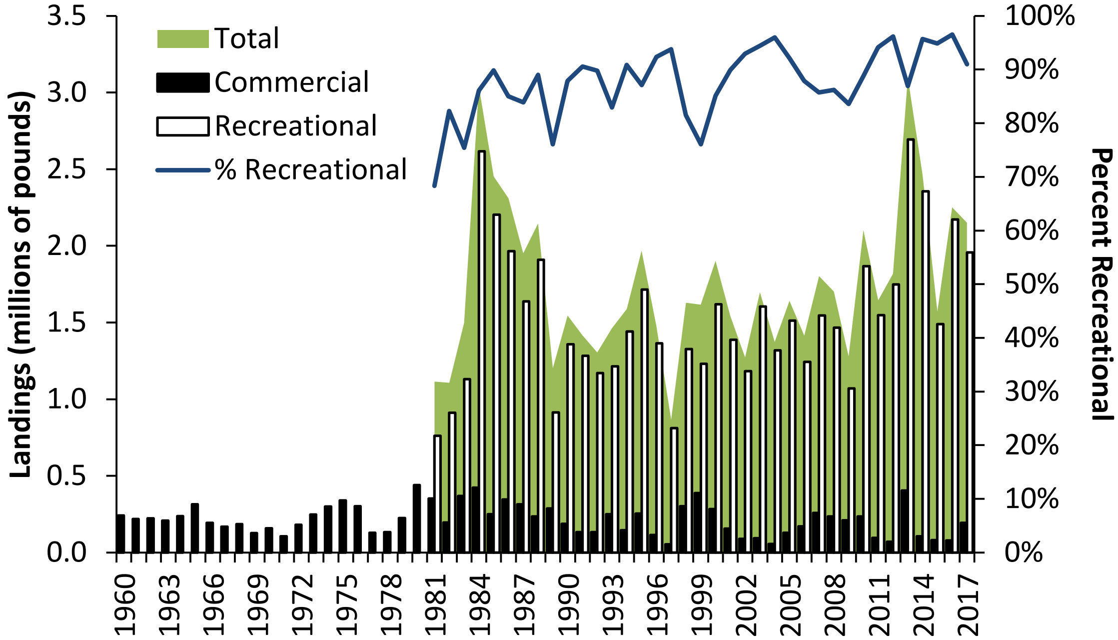

Figure 3. Commercial and recreational landings (pounds) of red drum. Recreational data not available prior to 1981. See Tables 2 and 3 for values and data sources.

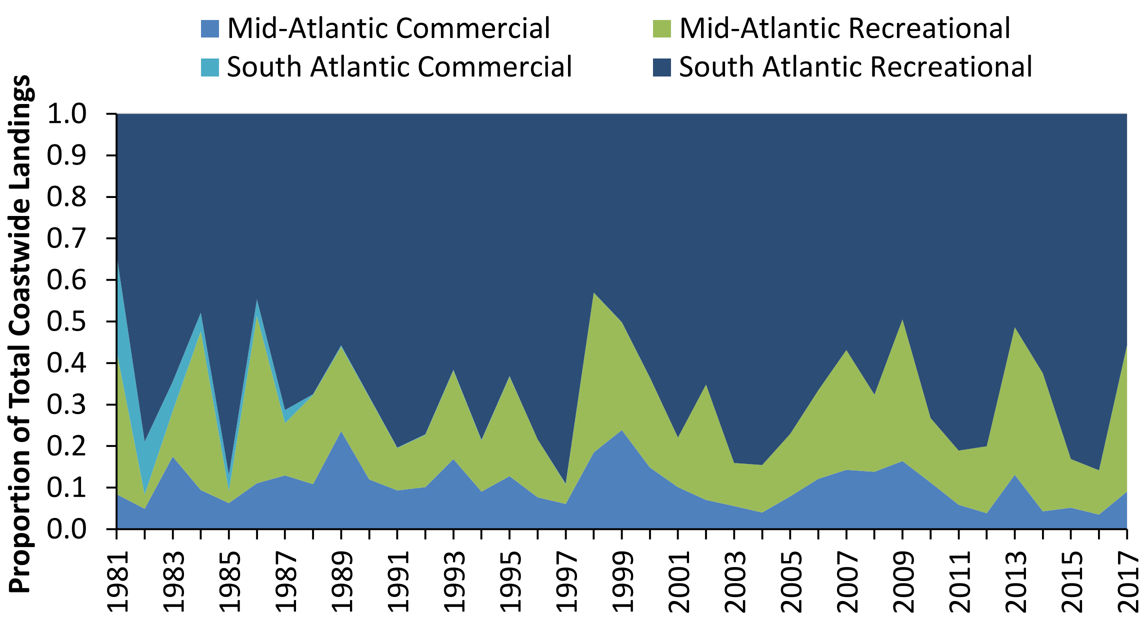

Figure 4. Proportion of regional, sector-specific landings to total coastwide landings (pounds). See Tables 2 and 3 for data sources.

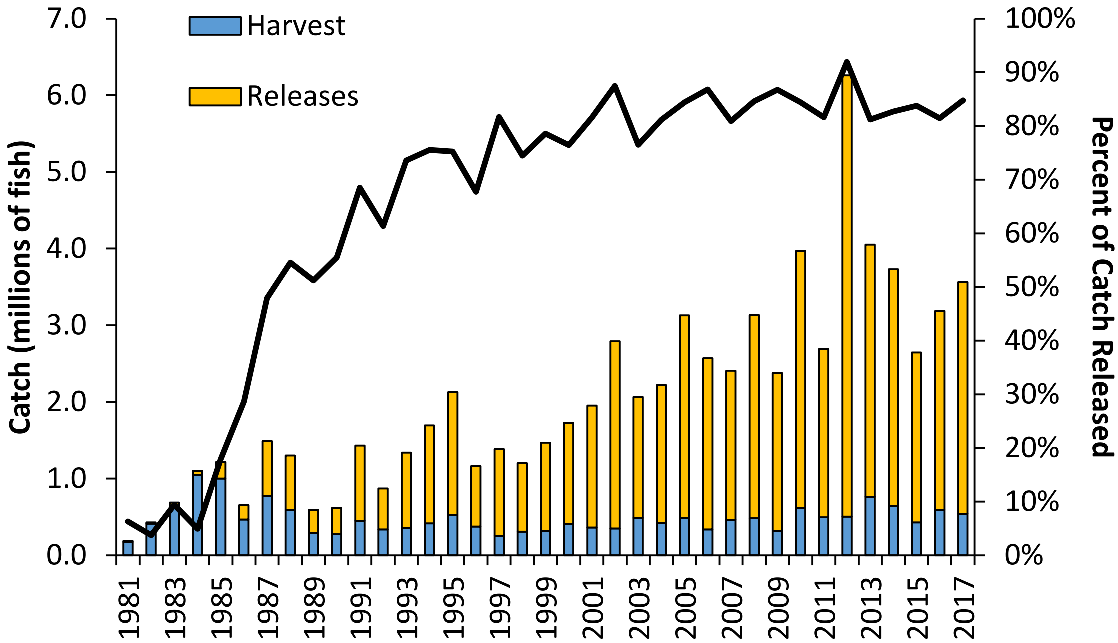

Figure 5. Recreational catch (harvest and alive releases) of red drum (numbers) and the proportion of catch that is released. See Tables 4 and 5 for values and data sources.

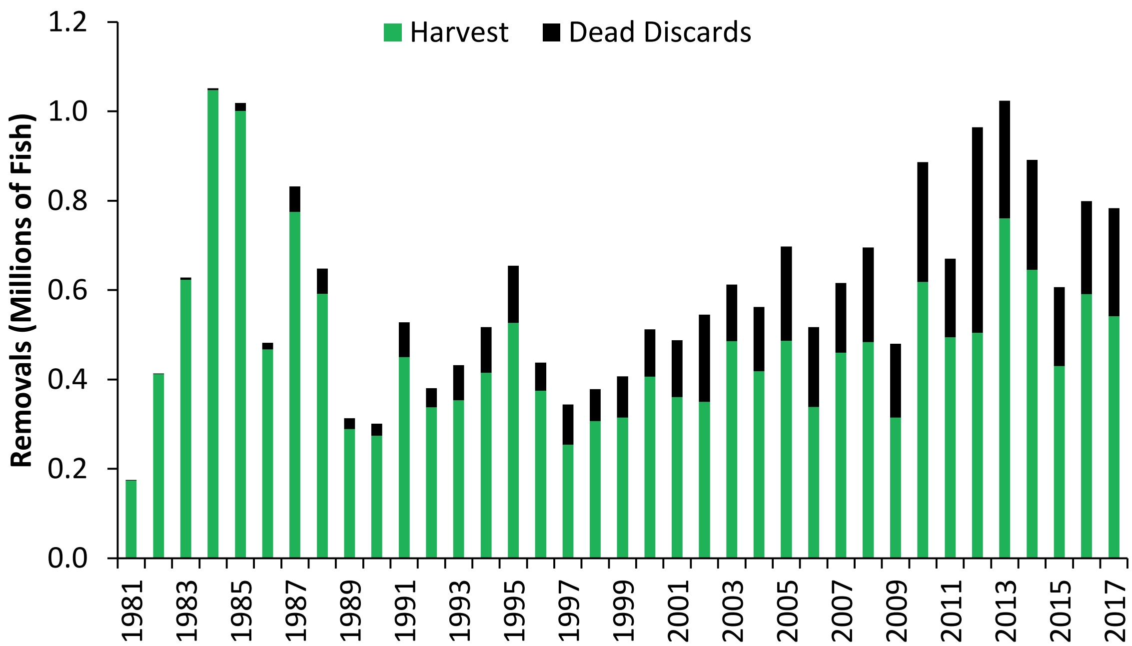

Figure 6. Recreational removals (harvest and dead discards) of red drum (numbers). Dead discards are estimated by applying an 8% discard mortality rate to alive releases. See Tables 4 & 5 for values and data sources.

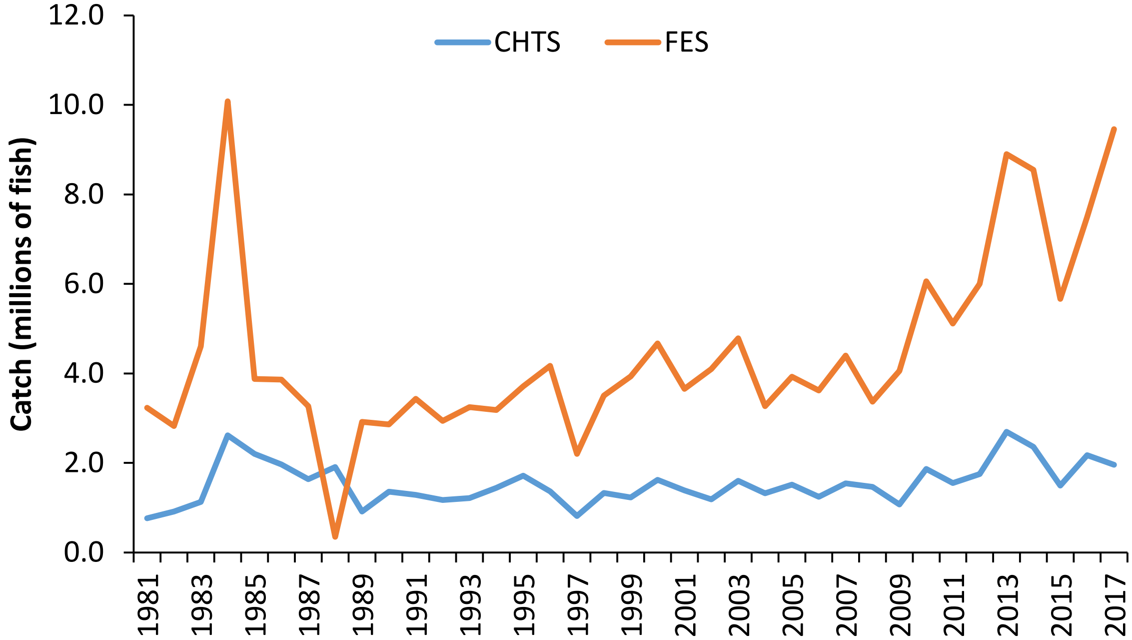

Figure 7. Coastwide comparison of MRIP recreational landings estimates for red drum based on the Coastal Household Telephone Survey (CHTS) and the mail-based Fishing Effort Survey (FES), 1981-2017. FES-calibrated estimates will be used for red drum management once a new stock assessment that incorporates the estimates is completed. (Source: personal communication with MRIP, 2018).

XI. Tables

Table 1. Red drum regulations for 2017. The states of New Jersey through Florida are required to meet the requirements in the FMP; states north of New Jersey are encouraged to follow the regulations. All size limits are total length.

State	Recreational	Commercial
NJ	18" - 27", 1 fish	18" - 27", 1 fish
DE	20" - 27", 5 fish	20" - 27", 5 fish
MD	18" - 27", 1 fish	18" - 25", 5 fish
PRFC	18" - 25", 5 fish	18" - 25", 5 fish
VA	18" - 26", 3 fish	18" - 25", 5 fish
NC	18" - 27", 1 fish	18" - 27"; 250,000 lb harvest cap with overage payback (150,000 lbs Sept 1- April 30; 100,000 lbs May 1-Aug 31); harvest of red drum allowed with 7 fish daily trip limit; red drum must be less than 50% of catch (lbs); small mesh (<5" stretched mesh) gill nets attendance requirement May 1 - November 30. Fishing year: September 1 – August 31.
SC	15" - 23", 3 fish. Gigging allowed March-November	Gamefish Only
GA	14" - 23", 5 fish	Gamefish Only
FL	18" - 27", Northern Region- 2 fish; Southern Region- 1 fish	Sale of native fish prohibited

Table 2. Commercial landings (pounds) of red drum by state, 2008-2017. (Source: personal communication with ACCSP, Arlington, VA, for years prior to 2017 and state compliance reports for 2017, except as noted below.)

Year	NJ	DE	MD	PRFC	VA	NC	SC	GA	FL	Total
2008			*	69	5,138	229,809		*		235,016
2009	*		*	157	9,296	200,296		*		209,749
2010			*	22	3,966	231,828		*		235,816
2011				3	4,397	91,980		*		96,380
2012	*		334	81	2,786	66,519				69,720
2013	*	0	2,752	268	30,137	371,949				405,106
2014	*	0	298	3	14,733	90,647				105,681
2015	0	0	*	0	761	80,282				81,043
2016	0	0	*	0	1,898	76,977	0	0	0	78,875
2017	*	0	1,015	0	6,971	186,463	*	0	0	194,449

Notes: PRFC landings from agency reporting program; * indicates confidential landings.

Table 3. Recreational landings (pounds) of red drum by state, 2008-2017. (Source: personal communication with MRIP for years prior to 2017 and state compliance reports for 2017)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total
2008				84,491	231,551	251,930	247,442	651,672	1,467,086
2009				147,444	288,958	165,892	126,196	341,384	1,069,874
2010				43,126	283,286	447,895	318,264	773,783	1,866,354
2011	2,421				212,245	441,834	229,214	662,811	1,548,524
2012		396	26,788	27,446	238,312	369,333	107,368	978,727	1,748,369
2013		7,153	6,205	410,917	676,050	236,887	129,279	1,226,481	2,692,970
2014				221,685	596,447	242,371	154,332	1,141,154	2,355,988
2015				29,339	154,496	269,787	97,690	939,007	1,490,319
2016				9,682	230,473	144,859	153,368	1,634,141	2,172,523
2017	0	0	1,887	354,719	402,390	278,006	128,973	790,449	1,956,423

Table 4. Recreational landings (numbers) of red drum by state, 2008-2017. (Source: personal communication with MRIP for years prior to 2017 and state compliance reports for 2017)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total
2008				20,847	50,809	119,471	133,107	159,246	483,480
2009				38,670	57,543	70,326	68,857	79,635	315,031
2010				11,076	64,024	172,708	194,826	175,828	618,462
2011	955				45,143	161,503	106,962	180,001	494,564
2012		296	17,869	28,159	52,948	121,068	45,766	238,191	504,297
2013		1,686	2,083	124,088	164,218	97,386	73,827	297,527	760,815
2014				53,672	116,601	103,892	92,869	278,037	645,071
2015				7,792	36,704	106,620	48,172	230,397	429,685
2016				3,510	62,105	62,816	74,702	388,200	591,333
2017			634	70,725	101,473	115,132	66,987	289,056	541,670

Table 5. Recreational alive releases and dead discards (numbers) of red drum by state, 2008-2017. Dead discards are estimated based on an 8% release mortality rate. (Source: personal communication with MRIP for years prior to 2017 and state compliance reports for 2017)

Year	NJ	DE	MD	VA	NC	SC	GA	FL	Total	Dead Discards
2008		75	217	236,787	658,887	552,217	313,743	889,550	2,651,476	212,118
2009			14,754	178,396	429,776	751,123	167,704	521,659	2,063,412	165,073
2010			2,182	28,580	635,876	786,452	483,650	1,414,115	3,350,855	268,068
2011				61,330	207,697	664,291	213,781	1,051,143	2,198,242	175,859
2012		5,876	280,171	2,503,456	1,533,010	543,618	90,237	799,428	5,755,796	460,464
2013		407	2,207	220,305	654,030	673,377	198,722	1,541,541	3,290,589	263,247
2014		41	273	116,215	382,663	635,836	290,101	1,659,671	3,084,800	246,784
2015			779	25,835	334,510	571,433	168,338	1,114,355	2,215,250	177,220
2016		968	15,414	49,819	825,046	337,852	160,031	1,207,481	2,596,611	207,729
2017			6,066	266,236	643,418	581,270	240,613	1,283,206	3,020,809	241,665

South Atlantic Board

Activity level: Moderate

Committee Overlap Score: Moderate (American Eel TC, Horseshoe Crab TC, Shad and River Herring TC, Sturgeon TC, Weakfish TC)

Committee Task List

- Atlantic Croaker and Spot PDT ≈ August: Provide recommendations on management response to triggers from Traffic Light Analyses changes
- Black Drum TC – Summer: Review 2014 benchmark stock assessment research recommendations and make recommendation for 2019 stock assessment
- Cobia PDT ≈ August 2019: Draft Amendment 1 process; current step: develop Draft Public Information Document for Public Comment
- Cobia TC ≈ August: Provide recommendations on how recreational landings should be evaluated
- Cobia TC ≈ August 2018-October 2019: SEDAR 58 stock assessment
- Red Drum SAS - Summer: Develop assessment roadmap and update ASC on progress
- Atlantic Croaker TC - July 1: Compliance Reports Due
- Red Drum TC – July 1: Compliance Reports Due
- Cobia TC – July 1: Compliance Reports Due
- Atlantic Croaker PRT – August 1: Update Traffic Light Analysis
- Spot PRT – August 1: Update Traffic Light Analysis
- Black Drum TC – August 1: Compliance Reports Due
- Spotted Seatrout PRT – September 1: Compliance Reports Due
- Spanish Mackerel PRT – October 1: Compliance Reports Due
- Spot PRT – November 1: Compliance Reports Due

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Black Drum: Harry Rickabaugh (MD, Chair), Jeff Kipp (ASMFC), Michael Schmidtke (ASMFC), Jordan Zimmerman (DE), Ryan Jiorle (VA), Chris Stewart (NC), Chris McDonough (SC), Ryan Harrell (GA), Dustin Addis (FL)

Cobia: Ryan Jiorle (VA, Vice Chair), Michael Schmidtke (ASMFC), Angela Giuliano (MD), Anne Markwith (NC), Mike Denson (SC), Chris Kalinowsky (GA), Christina Wiegand (SAMFC), Michael Larkin (SERO)
Red Drum: Ryan Jiorle (VA, Chair), Jeff Kipp (ASMFC), Michael Schmidtke (ASMFC), Tim Daniels (NJ), Michael Greco (DE), Genine McClair (MD), Lee Paramore (NC), Joey Ballenger (SC), Chris Kalinowsky (GA), Behzad Mahmoudi (FL), Wilson Laney (USFWS), Roger Pugliese (SAFMC)
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Spot (PRT): Michael Schmidtke (ASMFC), Harry Rickabaugh (MD), Ryan Jiorle (VA), Adam Kenyon (VA), Dan Zapf (NC), Chris McDonough (SC), Dawn Franco (GA)
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SAS Members: