A. GULF OF MAINE HADDOCK BENCHMARK STOCK ASSESSMENT FOR 2014

Executive Summary

TOR 1 Estimate catch from all sources including landings and discards. Include recreational discards, as appropriate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data. Investigate the utility of commercial or recreational LPUE as a measure of relative abundance.

Since 1977, fishery removals of Gulf of Maine haddock have ranged from 187 mt to 7,656 mt. Fishery removals over the past five years have ranged from 692 mt to 958 mt. Prior to 1989 there are no direct estimates of commercial discards but discards were hindcast back to 1982 by gear. Prior to 1981 there are no direct estimates of recreational removals and no attempt was made to hindcast recreational catch pre-1981. Over the assessment time series, commercial landings have been the dominant source of fishery removals, constituting 30-100% of the total catch. Commercial discards have been a small component of fishery removals with the exception of a period between 1993 and 1997 when trip limits were 1,000 lb or less. Recreational catch has varied annually from a low of 39 mt in 1981 to a high of 618 mt in 2007. Recreational catches have constituted between <1% and 65% of total annual removals, averaging 17% over the 1977-2013 period.

Currently both the commercial and recreational fisheries are primarily concentrated in the western Gulf of Maine region. Historically, the commercial trawl fishery was more broadly distributed with a large fraction of the landings coming from statistical area 515 in the central Gulf of Maine. The spatial trends in the fishery are partly in response to changes in the distribution of Gulf of Maine haddock, but also reflect changes in the trawl fleet composition and the effects of fishery regulations.

The SAW 59 WG evaluated standardized landings per unit effort (LPUE) indices from both the commercial and recreational fishery and considered their utility as indices of abundance within the Gulf of Maine haddock stock assessment. Over the longer term, there have been a number of regulatory changes (e.g. seasonal closures, trip limits, etc) which call into question the utility of LPUE as an index of haddock biomass. Based on these concerns, the SAW 59 WG recommended that the LPUE indices not be used in the SAW 59 assessment models. It should be noted that sensitivity models were developed that incorporated LPUE indices and these model results are similar to those of the base model, but model diagnostics highlight the poor explanatory power of the LPUE indices (described in Appendix A.2).

TOR 2 Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). If available, consider whether tagging information could be used in estimation of stock size or exploitation rate. Characterize the uncertainty and any bias in these sources of data.

The Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys began in 1968 and 1963 respectively, providing a long time series of fishery independent indices. The

aggregate indices of abundance (numbers/tow) and biomass (weight/tow) have fluctuated over time, primarily in response to episodic recruitment events. The time series is characterized by an early period of high abundance followed by a decline to time series lows in the late-1980s and early 1990s that also coincided with truncation in the population structure. Since the late 1990s the population has generally increased – first in response to the contribution of the 1998 year class, and most recently due to several moderate to strong recruitment events since 2010. These recent large year classes have lead to increases in survey indices that are at, or near, time series highs.

The MADMF bottom trawl survey began in 1978, with two surveys (spring and fall) conducted annually. Age-specific Gulf of Maine haddock indices are not available for this survey. Indices-at-age were constructed by applying age-length info from the NEFSC survey The MADMF survey catches very few older fish and exhibits poor cohort tracking within the survey. Additionally, it shows only marginal cohesion with the NEFSC surveys.

The SAW 59 WG also evaluated data from the Maine-New Hampshire (MENH) inshore groundfish survey which began in the fall of 2000. Age-specific information are only available for the fall survey from 2005 onward, though work is currently being conducted to age available structures from the spring survey. Indices-at-age were constructed by augmenting the available age information with age-length info from the NEFSC survey. The degree of cohort tracking is greater in the MENH survey compared to the MADMF survey. However, similar to the MADMF survey, catches are dominated by young fish. Survey indices show poor agreement with NEFSC survey indices.

Model sensitivities were explored which incorporated the MADMF and MENH survey indices. Generally, model diagnostics for these sensitivities were poor with large residuals on state survey fits. The combination of residual patterns on the indices-at-age fits and poorly estimated selectivity at older ages suggests that there is limited utility in incorporating the older age classes from the state surveys in the tuning of the ASAP model. Attempts to fit only the age-1 indices resulted in neither improved model diagnostics nor markedly different model results. The state surveys were not included in the final population model.

The tagging component of this TOR is described under TOR 3.

TOR 3 Evaluate the hypothesis that haddock migration from Georges Bank influences dynamics of GOM stock. Consider role of potential causal factors such as density dependence and environmental conditions.

Several lines of evidence evaluated by the SAW 59 WG indicate that the mixing rates between the Gulf of Maine and Georges Bank stocks are low. The SAW 59 WG evaluated an in-depth review/analysis of stock mixing prepared by staff from NEFSC, the NEFMC Groundfish Plan Development Team (NEFMC GPDT 2013). The investigation had four primary themes:

- *Literature review of Gulf of Maine/Georges Bank exchange rates.*

- *Revisiting past assertions of recruitment synchrony between the Gulf of Maine and Georges Bank stocks.*
- *Year-class tracking in survey data and Gulf of Maine haddock assessment diagnostics.*
- *Analysis of the consequences of setting catch advice based on movement rate assumptions.*

Based on the work performed by the NEFSC and GPDT, the GPDT concluded that there was no technical basis for adjusting the quota between the two stocks based on the "spillover" of Georges Bank haddock into the Gulf of Maine stock. The SSC agreed with this conclusion noting the significant risk to the Gulf of Maine haddock resource that could occur should an adjustment to the quota be made, particularly given "…the lack of compelling empirical evidence." The SSC further noted that "if fishermen are observing abundance of haddock in the Gulf of Maine that does not seem to comport with the outcomes of the assessment, this might be due to a recent increase since the terminal year of the last assessment update (2010). If so, the appropriate response is to update the Gulf of Maine assessment to see if that change is detected."

In addition to the above work, the SAW 59 WG reviewed a re-analysis of Northeast Consortium Cooperative Haddock Tagging Program data. Between March 2005 and December 2008 the Northeast Consortium Cooperative Haddock Tagging (NCCHT) Program tagged 20,418 haddock in the Georges Bank and Gulf of Maine region. Of the releases 531 recoveries (168 released with two tags) were reported between 2005 and 2010. Miller and Palmer (2014) applied a finite-state continuous time model to the existing NCCHT data to provide estimates of mortality and movement rates. The results of the reanalysis showed poor precision of the natural mortality rate estimate, but the point estimate was consistently between 0.2 and 0.3 for reporting rates ≥ 0.3. The instantaneous migration rates implied greater movement of individuals into the Gulf of Maine than to the Georges Bank stock area given that they survive all sources of mortality and the estimates are not sensitive to the assumed reporting rate. With a reporting rate = 1, the migration rate estimates implied individuals starting in the Gulf of Maine had an approximately 94% probability of being in the Gulf or Maine 1 year later given they survived the interval. Individuals from the Georges Bank region had an approximately 86% probability of being in the Georges Bank region one year later given they survived the interval. Fishing mortality rate estimates were negatively correlated with reporting rates.

The SAW 59 WG found the mortality rates from the reanalysis consistent with other lines of information (e.g., catch-curve analyses, assessment model outputs), but felt that the mixing rate estimates were high and inconsistent with the analyses conducted by the GPDT. The authors stressed that the results are greatly affected by the location, size of fish, and timing of the releases. Many of the releases were near the stock boundaries and in areas closed to groundfishing. The proximity to the stock boundaries might cause migration rates to be greater than the general population if there are substantial portions further away from the stock boundaries and they move at similar speeds and directions. The SAW 59 WG did not feel that the tagging exercises conducted to date had been designed in a way that would allow annual interchange proportions to be estimated reliably.

The SAW 59 WG also examined sensitivity assessment models that allowed for estimation of mixing between stocks. These model results are described under TOR 4, but generally the

estimated annual percent mixing from Georges Bank to the Gulf of Maine from these models was low, and consistent with the PDT analysis. Stock structure cannot be specified conclusively with available information. Directed research designed to expressly determine between-stock movement rates is needed to definitely address the degree of mixing between the two stocks (see TOR8).

TOR 4 Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

The VPA model used for the most recent assessment of Gulf of Maine haddock (2012 AOP) was updated to account for the changes to the data inputs as well as three additional years of catch and survey data. The changes to the input data included:

- *Revisions to commercial landings and reestimated landings-at-age.*
- *Revisions to the commercial discard fleets and reestimated discards-at-age.*
- *Revisions to the recreational catch to convert MRFSS catch to MRIP-equivalents.*
    - *Reestimated recreational landings-at-age.*
    - *Estimation of recreational discards-at-age (not included in prior assessments).*
- *Reestimated survey indices and indices-at-age.*
- *Updated maturity ogive.*

The updated VPA estimated the 2013 spawning stock biomass (SSB_{2013}) at 6,135 mt and average fishing mortality on ages 6-8 ($F_{6\text{-}8(2013)}$) at 0.82. The 2012 AOP VPA assessment estimated SSB_{2010} at 2,868 mt and $F_{6\text{-}8(2010)}$ at 0.82. Comparatively, the updated VPA now estimates SSB_{2010} at 3,070 mt and $F_{6\text{-}8(2010)}$ at 0.82. The general conclusions from the updated VPA are that the updates to the data inputs had only minor impacts on the model results and extending the time series through to 2013 did not change the historical perception of the resource. The more recent data does suggest that two strong year classes have been spawned since 2010. There has been an overall increase in the spawning stock biomass, primarily as result of the 2010 year class moving into the spawning population. The projections from the 2012 AOP update assumed the size of the 2010 year class to be equal to the geometric mean recruitment of the time series; based on the updated VPA, this assumption underestimated the year class size. ***The updated VPA is not the base model for this assessment.***

In this updated assessment, a statistical catch-at-age model (ASAP) represents the new preferred model. While the results of the GARM III and 2012 AOP assessments show that catch-at-age could be constructed to support a defensible VPA model, the amount of imputation required to construct the catch-at-age time series, primarily in the way of commercial discards and recreational catch, introduces questions as to whether this stock would be better assessed using a statistical catch-at-age model where it is not assumed that catch is known exactly. Additional support for exploring a statistical catch-at-age model include: the ability to explore alternative model formulations to counter/lend support to VPA results, and the ability to explicitly handle data uncertainty, particularly with respect to uncertainty in the survey data.

The SAW 59 WGs preferred ASAP model (ASAP_final_temp10) reflects the best model with which to evaluate stock status and provide catch advice. The assessment indicates that total SSB has ranged from 600 mt to 15,178 mt during the assessment time period, with current SSB in 2013 estimated at 4,153 mt (90% CI = 2,690 – 6,043 mt). Currently, total biomass is estimated at 7,749 mt (90% CI = 5,470 – 11,039 mt). The 2013 fully recruited fishing mortality (F_{full}) is estimated at 0.39 (90% CI =0.24 – 1.60).

A retrospective analysis over the years 2006 to 2013 indicated small retrospective error in both F and SSB with no consistent patterns for under/over-estimation. Over the last 7 years, retrospective error resulted in an average of 10% underestimation of SSB and 24% overestimation of fishing mortality. The SAW 59 WG recommended that no correction be made for the retrospective error given the small magnitude and lack of consistent patterns.

The time series mean recruitment (age-1) is around 2.6 million fish. Recruitment patterns of Gulf of Maine haddock are highly episodic, a feature common among many haddock stocks. Several moderate to strong year classes have been spawned in the last fifteen years, including the 1998, 2003, 2010 and most recently, the 2012 year class. ***The size of the 2012 year class is the largest source of uncertainty in this stock assessment, owing to the fact that the estimate is based entirely on only two survey data points.*** *A sensitivity ASAP model (ASAP_final_temp11) was brought forward which placed additional constraint on the estimation of the 2012 year class to illustrate the impacts of 2012 year class size uncertainty on catch projections (see TOR7).*

The SAW 59 WG also evaluated the results from three sensitivity models based on the SCAA statistical catch-at-age methodology (see Appendix 3). All three of the SCAA models achieved results similar to the ASAP_final_temp10 model. The first of the SCAA models considers haddock in the Gulf of Maine to be an isolated stock (SCAA no movement model), which is identical to the WGs preferred ASAP model. The other two incorporate movement into the Gulf of Maine, either permanent or temporary, by haddock from Georges Bank. Under both movement models, the amount of mixing is estimated to be low (<0.8% of the Georges Bank stock annually moving into the Gulf of Maine region). The evidence for such movement from these analyses point to scenarios involving limited movement being of similar plausibility to that of an isolated stock; however, mixing amongst the stocks has limited impact on assessment results. The WG discussed how to interpret the mixing parameter estimates coming from the SCAA movement models. The SCAA movement models do not incorporate specific information to inform the model about migration rates (e.g., tagging); as such, the mixing parameters don't represent actual mixing rates, rather the mixing parameters represent upper bounds on the amount of mixing that could be supported by the data. The mixing parameters are confounded by other parameters or data observation/process error.

Given the limited among of mixing supported by the SCAA models and the robustness of the assessment results to mixing assumptions, The SAW 59 WGs recommended the ASAP model, ASAP_final_temp10, as the preferred model with which to evaluate stock status and provide catch advice – this decision was supported by the SARC.

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

The existing MSY reference points based on a spawning potential ratio (SPR) of 40% were established at GARM III and updated as part of the 2012 AOP update. The overfishing definition is $F_{MSY\text{-}proxy} = F_{40\%} = 0.46$. Maximum sustainable yield and SSB_{MSY} were derived from the median values of long-term projections run at a constant harvest of $F_{40\%} = 0.46$. Projected recruitment was modeled from a cumulative density function (CDF) of VPA model estimated recruitment as well as a hindcast of recruitment between 1963 and 1977. Recruitment events that were a) associated with the large 1962 year class (considered a "bonanza" outlier), or b) when SSB was less than 3,000 mt, were excluded from the recruitment series. The resulting BRP estimates were: SSB_{MSY} = 4,904 mt (90% confidence interval of 2,272 – 10,604 mt), and MSY = 1,117 mt (90% confidence interval of 553 – 2,563 mt). A stock is considered to be overfished if spawning biomass is less than half of SSB_{MSY}; the existing overfished definition is ½ SSB_{MSY} = 2,452 mt.

New reference points were warranted given the changes in data inputs and the assessment model, as well as small changes in the fishery selectivity and weights-at-age. The WG concluded that because Gulf of Maine haddock recruitment events are highly episodic and not well described by traditional stock recruitment relationships, a MSY proxy approach to reference points was warranted. This is the same conclusion reached at GARM III.

The WG saw no compelling reason to select a different F_{MSY} proxy than the $F_{40\%}$ metric that had been adopted previously. While there were differences in the YPR inputs between the 2012 update and the current assessment, these differences were small. The resulting $F_{40\%}$ values were identical (0.46) to the $F_{MSY\text{-}proxy}$ value from the 2012 assessment. Stochastic long-term projections at $F_{40\%}$ were used to determine new recommended biomass-related reference points (proxies for both SSB_{MSY} and MSY). The projection inputs were identical to the YPR inputs.

The WG discussed various ways to project future recruitment. It found the GARM III method to be arbitrary (e.g., excluding very large and very small recruitment events) and instead opted to use a simpler method of using the CDF of the 1977-2011 age-1 recruitments from the preferred ASAP model. Age-1 recruitments in 2012 and 2013 were not included in the cumulative density function due to their greater variance. The resulting biomass reference points and their 90% confidence intervals are SSB_{MSY} = 4,108 mt (1,774 – 7,861 mt) and MSY = 955 mt (421 – 1,807 mt). The overfished biomass threshold of ½ SSB_{MSY} = 2,054 mt.

TOR 6 Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model developed for this peer review. In both cases, evaluate whether the stock is rebuilt (if in a rebuilding plan).

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

   The existing reference points are $F_{MSY\text{-}proxy} = F_{40\%} = 0.46$, $SSB_{MSY} = 4{,}904$ mt (90% confidence interval of 2,272 – 10,604 mt) (½ SSB_{MSY}, or 2,452 mt), and MSY = 1,117 mt (90% confidence interval of 553 – 2,563 mt). The updated VPA model (Model 6, 2013_UPDATE) estimates 2013 SSB at 3,070 mt. This exceeds the existing overfished threshold of 2,452 mt; therefore, the stock is not overfished. The updated estimate of average fishing mortality on ages 6-8 ($F_{6\text{-}8}$) in 2013 is 0.82. This is greater than the overfishing limit of 0.46, and therefore, overfishing is occurring.

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

   The revised reference points are $F_{MSY\text{-}proxy} = F_{40\%} = 0.46$, $SSB_{MSY} = 4{,}108$ mt (90% confidence interval of 1,774 – 7,861 mt) (½ SSB_{MSY}, or 2,054 mt), and MSY = 955 mt (90% confidence interval of 421 – 1,807 mt). The ASAP_final_temp10 model estimates 2013 SSB at 4,153 mt. This is greater than the SSB_{MSY} level of 4,108 mt; therefore, the stock is rebuilt and not overfished. The estimate of 2011 fully recruited fishing mortality (F_{full}) is 0.39. This is less than the overfishing limit of 0.46, and therefore, overfishing is not occurring.

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

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

   The short-term (2014-2017) projection method samples from a cumulative density function derived from ASAP estimated age-1 recruitment from 1977 and 2011 (identical to the recruitment series used for establishing reference points). No retrospective adjustment needed to be applied in the projections.

   Due to the high degree of uncertainty of the size of the 2012 year class, two projection models were developed. The first is based on the preferred population model (ASAP_final_temp10) and the second is based on a sensitivity model that constrained the size of the 2012 year class (ASAP_final_temp11). Both projection models were run under two different assumptions of calendar year 2014 catch – harvest at FMSY (0.46) and an assumed 2014 catch of 500 mt. The fishing year 2014 Gulf of Maine haddock Annual Catch Limit (ACL) is set at 323 mt, though the ACL does not account for recreational

discards. The 500 mt estimate used in the projections was informed by the fishing year 2014 ACL and recent recreational discard amounts.

Catch projections under both models range from 1,271 mt to 2,512 mt between 2015 and 2017. Under all scenarios, spawning stock biomass is not projected to drop below the target biomass level (SSB_{MSY}) through 2017. The increase in biomass above target biomass levels during the projection period reflects the contribution of the 2010 and 2012 year classes to the exploitable biomass.

Recent reviews of historical and contemporary tagging studies suggest that there is movement of fish between the Gulf of Maine and Georges Bank stocks, though there is considerable uncertainty regarding the degree of mixing. Several lines of evidence examined during the SAW/SARC59 assessment indicate that annual percent mixing from Georges Bank to the Gulf of Maine is low, though the mixing scenarios have similar statistical plausibility to that of an isolated stock. While mixing amongst the stocks has limited impacts on stock status, catch projections of the SCAA models (Appendix 3) under constant fishing mortality were found to be sensitive to limited movement for the case where the movement is permanent (SCAA migration model), but much less so when movement was modeled as non-permanent interchange (SCAA sabbatical model). The catch projection results from the most biologically realistic SCAA mixing model (i.e., allows mixing between stocks as opposed to unidirectional movement) are nearly identical to the SCAA model with no mixing and within the 90% confidence intervals of the projections from the preferred ASAP model (Figure A.203).

The SAW 59 WG noted that the evidence for mixing is not conclusive and that the mixing scenarios have similar statistical similar plausibility to that of an isolated stock. Given this, it concluded that the projections based on the ASAP_final_temp10 model should be used for management advice. The SARC agreed with this decision.

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.

Both the WG and SARC concluded that the projections based off the ASAP_final_temp10 model were the 'most realistic'. However, it should be stressed that the absolute size of the 2012 year class is the largest source of uncertainty in this assessment. The risks associated with management actions taken during 2015 – 2017 were examined by undertaking stock projections under two different assumptions of year class size. Under both scenarios the spawning stock biomass is projected to increase well above the target levels and catch can be sustained above MSY levels.

The differences in these two short-term projections in 2014 and 2015 are primarily due to the differences in the size of the 2010 year class between the two different models. However, as the projection horizon increases, and the contribution of the 2012 year class becomes more important and the divergence in catch advice becomes larger (> 600 mt). Based on the estimated selectivity patterns, the 2012 year class is predicted to be 50%

selected by the fishery in 2017 at age-5. Recent changes to the commercial minimum retention size may result in this year class recruiting to the fishery sooner.

The assumption of the catch in 2014 will have limited impacts on stock size and catch advice in the subsequent years, though the two assumed values (catch= $F_{MSY\text{-}proxy}$ and 500 mt) should be re-evaluated once additional information on 2014 catches is available.

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

There are several factors that should be considered when setting catch advice for the Gulf of Maine haddock stock. While these uncertainties have been discussed previously, particular attention should be given to the factors below when determining the appropriate level of scientific uncertainty to prescribe to this stock assessment.

The mortality of haddock discarded in the recreational and commercial fishery is unknown. For trawl and gillnet gear, mortality is likely high and not substantially different than the assumption of 100% used in the assessment. While there is limited information available to suggest that mortality of haddock discarded in the commercial longline fishery may be lower than 100%, given the small magnitude of longline removals, the impacts of this assumption on the assessment results are likely small. However, given the large amount of recreational discards occurring in recent years, the model results and subsequent catch advice could be sensitive to the assumption of 50% discard mortality used in this assessment. While the assessment results were shown to be relatively insensitive to this assumption, it does have implications for management and catch allocation between the commercial and recreational fleets.

Several lines of evidence examined during the SAW/SARC59 assessment indicate that annual percent mixing from Georges Bank to the Gulf of Maine is low; however, stock structure and the specific degree of mixing cannot be specified conclusively with the available information. While the catch projections for the more biologically realistic mixing scenario (non-permanent interchange) were nearly identical to no-movement assumptions, the projections which assumed permanent movement of Georges Bank haddock into the Gulf of Maine were higher than the no movement scenarios. Setting catch advice higher on the presumption that permanent movement of Georges Bank haddock into the Gulf of Maine is occurring, if in fact it is not, could lead to overfishing of the Gulf of Maine stock (NEFMC GPDT 2013).

The absolute size of the 2012 year class is the largest source of uncertainty in this assessment. Based on the estimated selectivity patterns, this year class is predicted to be 50% selected by the fishery in 2017 at age-5. Recent changes to the commercial minimum retention size may result in this year class recruiting to the fishery sooner. Given the high uncertainty with respect to this year class size, the assessment should be updated if future estimates of its size differ significantly from those used in this assessment.

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

The SAW 59 WG reviewed the status of previous research recommendations and proposed new ones to address issues raised during the WG meeting. There were two research recommendation carried forward from GARM III. One of which is no longer relevant due to the switch from a virtual population analysis assessment model to a statistical catch-at-age model. The second one relates to the estimation of haddock discarded in the recreational fishery, a topic which has been partially addressed in TOR 1. The SAW 59 WG reiterated the need for directed field research on this topic.

The WG noted that the haddock tagging experiments conducted to date were not designed to address the issue of between-stock movement rates. Research designed to expressly determine between-stock movement rates is needed to reduce the uncertainty of analytical models that include these rates.

Additionally, the SAW 59 WG proposed five new research recommendations which have broad applicability to many northeast United States groundfish stocks. These include: methods to standardize CPUE indices, development of approaches to incorporate additional stock-recruitment models and autoregressive error into population models, and advance the application of multi-model inference and risk evaluation into the Northeast Region stock assessment process.

SAW 59 Terms of Reference for Gulf of Maine (GOM) haddock

1. Estimate catch from all sources including landings and discards. Include recreational discards, as appropriate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data. Investigate the utility of commercial or recreational LPUE as a measure of relative abundance.

2. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). If available, consider whether tagging information could be used in estimation of stock size or exploitation rate. Characterize the uncertainty and any bias in these sources of data.

3. Evaluate the hypothesis that haddock migration from Georges Bank influences dynamics of GOM stock. Consider role of potential causal factors such as density dependence and environmental conditions.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

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

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

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

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

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

Introduction

The 59th Stock Assessment Workshop Working Group (SAW 59 WG) prepared the assessment report. The working group convened June 2-6, 2014 at the Northeast Fisheries Science Center (NEFSC) in Woods Hole, MA. A complete list of working group participants can be found in Appendix A.1.

Assessment history

Prior to 2002, Gulf of Maine haddock assessments had been conducted (NEFSC 1986,NEFSC 2001) by comparing exploitation rates to biological reference points generated from a surplus production model. The 32nd Stock Assessment Review Committee (SARC) expressed concerns with this approach and suggested that other approaches be explored (NEFSC 2001). In 2002, the Gulf of Maine haddock stock was assessed as part of the first Groundfish Assessment Review Meeting (GARM I, NEFSC 2002a). The 2002 assessment compared survey biomass and exploitation rate indices from 1963 to 2001 (Table 1) to biological reference points (BRPs) generated by the Working Group on Re-estimation of Biological Reference Points for New England Groundfish (NEFSC 2002b). Reference points were established using the index-based model, An Index Method (AIM) available from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/). The reference points were based on a maximum sustainable yield (MSY) level approximated from the average commercial landings between 1959 and 1966 – this period represented a stable period in the landings time series. The fishing mortality (F) reference point (F_{ref}) was set equal to the relative F (Eq. 1) where the replacement ratio equaled 1. The replacement ratio is equal to the biomass index in the current year divided by the average biomass indices from a 3-year centered mean. The biomass reference point (B_{ref}) was estimated by dividing the MSY proxy by F_{ref}. At GARM I, the proxy F_{ref} (exploitation rate index) and $B_{Threshold}$ (1/2 B_{ref}) were estimated at 0.23 and 11.09 kg/tow, respectively. The 2001 exploitation rate was estimated at 0.12 and the 3-year average fall survey biomass index was 10.31 kg/tow. Based on these estimates, the GARM I assessment concluded that the Gulf of Maine haddock stock was overfished, but overfishing was not occurring (Table 2).

(Equation 1)

$$relF_t = \frac{C_t}{\left(\frac{I_{t-1} + I_t + I_{t+1}}{3}\right)}$$

The stock was reassessed again in 2005 as part of GARM II (NEFSC 2005). The same index-based approach used in GARM I was applied in the 2005 assessment. As of 2004, the exploitation rate had increased to 0.18 and the fall biomass index had declined to 5.79 kg/tow. Consequently, stock status remained unchanged. The GARM II review noted the sensitivity of the assessment results to the exclusion of commercial discards and recreational catch. Additionally, the GARM II review made a research recommendation to explore the use of age-structured models in future assessments. Previous assessments had not utilized age-structured models because biological data (length frequencies, age and maturity sampling) were sparse during the late 80s and early- to mid-90s and considered inadequate for use in a virtual population assessment (VPA) analytic assessment (NEFSC 2001).

The Gulf of Maine haddock stock was next assessed in 2008 as part of GARM III (NEFSC 2008). That assessment made several major improvements to the input data and assessment methodologies applied to previous assessments. Notably, commercial discards and recreational landings were included and attempts were made to reconstruct the catch-at-age and survey indices-at-age from 1977 to 2007 from the available biological samples and using hindcasting/imputation procedures. An ADAPT-VPA model was applied to the data, which estimated the 2007 spawning stock biomass at 5,850 mt and average fishing mortality on ages 6-8 was estimated at 0.35. GARM III reference points were based on a yield per recruit analysis, with $F_{40\%}$ (0.43) selected as the fishing mortality reference point ($F_{MSY\text{-}proxy}$). Long-term stochastic projections under a harvest strategy of $F_{40\%}$ were used to estimate proxy values of SSB_{MSY} and MSY of 5,900 mt (1/2 B_{MSY}=$B_{threshold}$=2,950 mt) and 1,360 mt, respectively. As of GARM III, the stock was not overfished and overfishing was not occurring. The stock was considered fully rebuilt due to the fact that the GARM III assessment indicated that spawning stock biomass had exceeded the biomass threshold in 2000.

Most recently, the Gulf of Maine haddock stock was assessed in 2012 (NEFSC 2012). This assessment included data through 2010. The 2012 assessment results were peer reviewed by an Assessment Oversight Panel (AOP) and constituted an update of the benchmark assessment developed at GARM III. Relative to GARM III, the 2010 SSB had declined to 2,868 mt and fishing mortality had increased to 0.82. BRPs were revised using updated estimates of selectivity and weights-at-age. The updated BRPs are shown in Table 2. Based on the results of the 2012 update, the Gulf of Maine haddock stock was declared not overfished, but overfishing was occurring. It should be noted that the projected 2011 spawning stock biomass was estimated to decline below the biomass threshold.

Fisheries Management

Gulf of Maine haddock have been managed under two different management authorities in recent history. Prior to 1977 the stock was managed under an international treaty through the International Commission for the Northwest Atlantic Fisheries (ICNAF). The majority of management measures implemented under ICNAF applied to the greater Subarea 5 which consists of both the 5Y(Gulf of Maine) and 5Z (Georges Bank) Divisions. Fisheries management was primarily controlled through annual total allowable catches (TACs), minimum mesh sizes and spawning closures (Clark et al. 1982). As early as 1951, mesh size regulations were imposed which initially set the minimum codend mesh size at 4.1 inches (114 mm), though these were increased to 5.1 inches (130 mm) in 1974. In response to severe declines in haddock abundance noted during the late 1960s, a 12,000 mt TAC was first implemented in 1970, with subsequent reductions to 6,000 mt in 1972 and then a prohibition on targeted fishing by 1974. The TAC was quickly raised back to 6,000 mt in 1975 under the rationale that establishing some low TAC level would be more effective at controlling fishing mortality compared to prohibiting targeting fishing. Spawning closures were first implemented in 1970, though these were restricted to the Georges Bank region. The Magnuson Fishery Conservation and Management Act (MFMCA) was passed in 1977 and subsequently the management authority of New England groundfish stocks shifted to the New England Fishery Management Council (NEFMC).

The use of TACs continued under the NEFMC authority through 1982. In 1982, the "Interim" Groundfish Fisheries Management Plan (FMP) was implemented, replacing the quota system (TAC) with input controls such as mesh sizes (Table A.3) and minimum retention sizes (Table A.4). The initial Groundfish FMP was implemented in 1985 and largely carried forward the existing measures from the interim FMP. Amendment 4 to the FMP required the use of a Nordmore grate in the northern shrimp fishery as well as placing a prohibition on the retention of groundfish bycatch in the shrimp fishery. Beginning with Amendment 5 (1994), there was a concerted attempt to reduce fishing effort through a days-at-sea (DAS) reduction schedule. Additionally, Amendment 5 brought about mandatory vessel reporting in the way of the Vessel Trip Reports (VTRs). Effort controls were increased under Amendment 7 through further acceleration of the DAS reduction schedule, and the addition of seasonal and year round closures in the Gulf of Maine. Between 1994 and 1999 trip limits ranged from 500 lb to 50,000 lb, in addition to limits on the allowed landings/DAS (Table A.3). Several increases in the minimum mesh sizes occurred, most notably a shift to 6 inch (152 mm) mesh in 1994 followed by increases to 6.5 inch mesh for square rigged trawls in 1999, and a 6.5 inch (165 mm) requirement for all trawl gear in 2000 under Framework 33. In 2004, Amendment 13 implemented mandatory electronic reporting for all primary federally permitted seafood dealers. Amendment 13 also established reference point thresholds for the 18 groundfish stocks as well as formalized rebuilding plans for all overfished stocks ($< ½ SSB_{MSY}$) – at the time, this included Gulf of Maine haddock. Through 2010, a series of framework actions and interim rules placed additional restrictions on DAS usage and seasonal closures on the recreational fishery. The effort controls first adopted in 1994 were frequently changed, making it difficult to isolate the effects of individual regulations. The use of often-changing trip limits led to increased discard rates and may have contributed to high-grading. In response to perceived high bycatch of haddock in the herring fishery, Framework 43 implemented a haddock bycatch cap at 0.2% of the combined total allowable catch of Gulf of Maine and Georges Bank haddock.

In 2010, the groundfish fishery experienced a major management change with the passage of Amendment 16. Amendment 16, with the introduction of annual catch limits (ACLs), represented a return to the use of hard TACs. Additionally, 17 new groundfish sectors were approved and those vessels not members of a groundfish sector were subject to additional cuts in DAS and restrictive trip limits. Vessels fishing under the sector management system were exempt from DAS restrictions and instead, each sector was given a share of the total commercial groundfish sub-ACL. How the catch was divided up amongst sector vessels, or how catch was allocated throughout the year, was left to the discretion of the sector. One of the requirements of Amendment 16 was an increase in the overall level of observer coverage. This was accomplished using observers trained through the existing Northeast Fisheries Observer Program (NEFOP) as well as a new class of observers termed At-Sea Monitors (ASMs). The data collection protocols for ASMs were restricted to catch estimation and the collection of limited biological information (e.g., lengths). The recent shift to a catch share system in 2010 appears to have dramatically reduced discards but it is too soon to fully understand the overall impacts of the sector management system.

Since the passage of Amendment 16, two framework modifications have been made to the FMP with direct impacts on the management of Gulf of Maine haddock. Framework 46, implemented

in August 2011, revised the haddock bycatch cap for the herring fishery to apply to only mid-water trawl gear and establish separate stock specific caps equal to 1% of the acceptable biological catch (ABC) levels of the respective stocks. Framework 48 reduced the commercial minimum size for several groundfish species, including haddock, which was reduced from 18 to 16 inches. The reduced minimum size became effective on July 1, 2013. Around the same time, the National Marine Fisheries Service (NMFS), through an emergency action, increased the recreational minimum retention size from 18 to 21 inches in an attempt to constrain recreational catches to the allocated sub-ACL. It should be noted that the current assessment will only include catch data through December 31, 2013, thus there is insufficient information for this assessment to make inferences about possible changes in selectivity brought about by the recent changes in minimum size regulations.

Biology

Distribution and stock structure

Haddock (*Melanogrammus aeglefinus*) is a demersal gadoid species whose range in United States (US) waters extends from the mid-Atlantic Bight north to the Canadian border (Collette et al. 2002). Globally, haddock occur on both sides of the North Atlantic Ocean, extending southward in the eastern Atlantic to the Bay of Biscay. Within the United States Exclusive Economic Zone (EEZ) there are two recognized stocks of haddock: Gulf of Maine and Georges Bank (Fig. A.1). The existing Gulf of Maine stock complex extends from the northern tip of Cape Cod east to the US/Canadian border and north to the coast of Maine (Fig. A.2, Cargnelli et al. 1999). Several meta-analyses of the life history parameters of haddock in the region have been conducted over the last four decades that generally support the current stock boundaries (Begg 1998, Beg et al. 1999). These investigations have highlighted differences in both the growth and maturation rates between the Gulf of Maine and Georges Bank stocks (Begg 1998, Begg et al. 1999). There are discreet spawning regions within the Gulf of Maine (Ames 1998) which may constitute localized metapopulations. The Gulf of Maine haddock stock may be composed of a seasonal migratory stock and non-migratory stock extending southward into the Nantucket Shoals region (Begg 1998).

Within the Gulf of Maine, haddock tend to move inshore in spring to spawn before returning to the deeper offshore waters in late summer. Peak spawning occurs during March and April and likely fluctuates inter-annually in response to water temperatures (Cargnelli et al.1999). Given that haddock are seldom found below 180 m, the various channels and basins within the Gulf of Maine likely serve as barriers to juvenile and adult dispersal (Begg 1998, Cargnelli et al. 1999). Many of the identified spawning areas of haddock are associated with gravel or sandy substrate (Colton 1972, Ames 1998, Cargnelli et al. 1999). Compared to the Georges Bank region, there are limited areas of suitable habitat in the Gulf of Maine (Clark et al. 1982, NEFSC 2012). This likely explains, in part, the large disparities in stock size between the Georges Bank and Gulf of Maine regions.

Recent reviews of historical and contemporary tagging studies (Begg 1998, NEFMC GPDT 2013) suggest that there is movement of fish between the Gulf of Maine and Georges Bank

stocks, though there is considerable uncertainty regarding the degree of mixing. One recent study provided a crude approximation of 10% (Brodziak et al. 2008a), though subsequent work has shown that mixing rates of that magnitude are unlikely given the maintenance of strong cohort signals within the Gulf of Maine stock, the large disparities in stock sizes and the asynchronous recruitment between the two stocks (NEFMC GPDT 2013). While Brodziak et al. 2008b concluded that recruitment between the two stocks was synchronous based on an examination of NEFSC age-0 bottom trawl survey indices, this analysis was recently revisited (NEFMC GPDT 2013). The updated analysis concluded that the relationship reported in Brodziak et al. 2008b, while significant, was in fact weak, accounting for only 28% of the total recruitment variance. Using a longer time series of survey indices, the updated analysis concluded that there was no apparent synchrony in age-0 survey indices. Distribution of eggs has suggested that the Gulf of Maine and Georges Bank regions constitute distinct groups of haddock (Begg 1998). Survey distributions indicate spatial segregation between the areas of concentration within the two regions (Fig. A.2). The topic of exchange between the Gulf of Maine and Georges Bank regions will be explored in more depth under Terms of Reference 3.

Length-weight relationship

Beginning in 1992, the NEFSC bottom trawl surveys began using digital scales to record individual fish weights. Using these data, the benchmark GARM III assessment (NEFSC 2008) developed seasonal survey-based length-weight (LW) equations as the basis for converting catch weights to numbers-at-age (Equations 2-4). Updated survey-based length weight equations using data through 2013 were compared to the existing length weight equation. Both seasonal (spring/fall) and annual updates were evaluated and showed little difference from those established during GARM III (Fig. A.3). The use of a time-invariant LW equation is only appropriate if the LW relationship has remained stable over time. An examination of the time series of relative condition factor (Froese 2006) by season shows little evidence of pronounced temporal trends (Fig. A.4). Given the results of this comparison, the SAW/SARC 59 assessment will apply the same LW relationships established during GARM III.

(Equation 2) $W_{live\ (kg)} = 0.000007690 \cdot L_{fork\ (cm)}^{3.0622}$ *(spring)*

(Equation 3) $W_{live\ (kg)} = 0.000009870 \cdot L_{fork\ (cm)}^{3.0090}$ *(fall)*

(Equation 4) $W_{live\ (kg)} = 0.000009298 \cdot L_{fork\ (cm)}^{3.0205}$ *(annual)*

There are divergent opinions as to whether it is more appropriate to use a landings-based length-weight equation versus a survey-based length-weight equation to convert catch weights to numbers-at-age. Advocates for a landings-based derivation argue that since the fishery may catch larger (heavier) fish at length, there is the possibility that a survey-based length weight equation may be biased low, particularly at greater lengths. A survey-based approach may be preferred when a large portion of the catch is composed of discards (or some other fraction not sampled such as recreational landings) or when the catch weights-at-age are also used to estimate stock weights due to sparse sampling of older ages in the surveys (missing or highly variable estimates of weights-at-age). In the case of Gulf of Maine haddock, the arguments for a survey-based LW relationship are valid (large fraction of catches not from commercial landings and use of catch weights to estimate stock weights). Currently in the Northeast Region, fishery surveys are the

only source of individual length-weight sampling.

The suitability of applying a survey-based LW equation to commercial landings was evaluated by applying the seasonal LW relationships in equations 2 and 3 to the observed length frequency distributions of commercial biological samples collected between 1977 and 2013. The estimated weights were then compared to the recorded sample weight and the distributions of differences were examined for the presence of bias. Examinations across years showed no evidence of strong temporal trends and across all market categories the interquartile ranges of the differences overlapped the equality line in the majority of years for both the 'scrod' and 'large' landings market categories (Fig. A.5). There was some indication that the estimated weights were greater than the recorded weights for the 'large' market category which could suggest that the survey LW relationships estimate heavier fish at length relative to the true relationship within the commercial landings. Interestingly, using the arguments made against the use of survey-based LW presented above, this is opposite of the expectation.

Since haddock are typically landed in gutted form, a more likely explanation for the discrepancies noted in the 'large' market category is that the current conversion factor for converting gutted haddock to its live weight equivalent is incorrectly specified. A small increase in the established conversion factor of 1.14 would be sufficient to lower the ratios such that the means were more closely aligned with the equality line. There has been an ongoing data collection effort by the NEFSC's Cooperative Research Program to collect information needed to support a re-evaluation of the established conversion factors; however, this work is still in progress and preliminary results are not available.

Growth and maturity

Haddock in the Gulf of Maine reach a maximum size around 75 cm (≈ 5 kg). Comparison of Gulf of Maine and Georges Bank growth curves estimated from time series averages of NEFSC survey data show similar growth patterns (Fig. A.6). This runs contrary to the conclusions of a previous study (Begg et al. 1999), though the growth curves estimated in the Begg et al. (1999) study were highly variable over time and between regions. Gulf of Maine haddock von Bertalanffy growth parameters were reestimated using NEFSC survey data from 1970 to 2013 (Equations 5-6). A summary of the number of ages included in the analysis are presented in Table A.5.

(Equation 5) $L(t)=62.5\cdot(1-e^{-0.41(t-0.05)})$ *(spring)*
(Equation 6) $L(t)=65.8\cdot(1-e^{-0.38(t+0.62)})$ *(fall)*

Density-dependent growth has been observed within the Georges Bank haddock stock, with large cohorts experiencing slower growth (NEFSC 2012). Cohort specific growth was evaluated for four cohorts of Gulf of Maine haddock and compared to the 1997-2013 mean length-at-age (Fig. A.8). These comparisons do show that on average the mean length-at-age of known large cohorts (e.g., 1998 and 2003) tend fall below the 1997-2013 times series mean; however, the differences are not as large as has been observed in the Georges Bank stock. Given the differences observed for the Gulf of Maine stock, it does not appear that large cohorts require special consideration of

density dependent growth when conducting stock projections.

Examination of monthly trends in the mean length of Gulf of Maine haddock landed in the commercial fishery suggests that the majority of somatic growth occurs between April and July, with little growth occurring January through March (Fig. A.9). Examination of mean survey lengths-at-age suggests that fish size-at-age has oscillated about the long-term mean with some indication of decreased growth over the past decade (Fig. A.10). There has been considerable variability in the sampling of Gulf of Maine haddock lengths and ages within the survey due in part to variable survey catches and sampling protocols (Fig. A.11). Some of the interannual variability observed in survey mean lengths-at-age is likely driven by sampling variability.

A logistic regression method (O'Brien et al. 1993) was used to fit maturity-at-age from the NEFSC spring survey data from 1977 to 2013. The number of maturity samples taken per year ranges from 1 to 364 (Table A.6). The trends in annual age-at-50% maturity ($A_{50\%}$; Fig. A.12), is not suggestive of any persistent temporal trends with only small variations around the time series average. Given the absence of persistent trends, and the occasional periods of low sampling, a decision was made to use the of a time-invariant maturity ogive to characterize the maturity schedule of Gulf of Maine haddock. The time series $A_{50\%}$ for male haddock was 1.85 and 2.39 for females (Fig. A.13). The corresponding length-at-50% maturity ($L_{50\%}$) was 30.2 cm and 36.5 cm, respectively. The input to the stock assessment model is based on the female maturity ogive presented in Table A.7. The approach is identical to that used for the GARM III assessment, with the only changes resulting from incorporation of an additional three years of survey data.

The GARM III assessment and subsequent assessment had assumed a spawning time of April 1. This is consistent with the peak period of spawning as inferred from egg distributions in the Gulf of Maine (Cargnelli et al.1999). This assessment will maintain an assumption of April 1 as the peak period of haddock spawning in the Gulf of Maine.

Natural mortality

Previous assessments of Gulf of Maine haddock have assumed a constant, age-invariant rate of instantaneous natural mortality (M) of 0.2 (e.g., NEFSC 2012, NEFSC 2008). While the accuracy of this assumption has not been thoroughly evaluated, it is consistent with the maximum ages observed in both fishery and survey data. Hoenig (1983) demonstrated that total mortality (Z) can be estimated as a function of the maximum observed age (t_{max}) in a population (ibid; Equation 7). This approach was further refined by Hewitt and Hoenig (2005; Equation 8). The maximum age observed in the survey was an age-18 fish in 1976, though more recently, in 2011 an age-22 fish was encountered in the commercial fishery. Generally, the maximum observed age in both the surveys and fishery has been increasing over time (Fig. A.14) – fish from the large 1998 year class continue to consistently be encountered in both surveys and the commercial fishery. Using the Hewitt and Hoenig (2005) approach, Z could be estimated at 0.23 assuming the maximum survey age of 18 or 0.19 assuming the maximum commercial fishery age of 22. The continued existence of the 1998 year class and general increase in the observed maximum age, suggest that total mortality, and by extension, natural mortality is low. Additionally, there is no evidence that natural mortality has increased over time as has been

hypothesized for other gadoid stocks in the Gulf of Maine (NEFSC 2013). This assessment will maintain the assumption of a time invariant M of 0.2.

(Equation 7) $ln(Z) = a + b*ln(t_{max})$
(Equation 8) $Z = 4.22/t_{max}$

Ageing precision

Precision age testing for haddock is conducted six times a year; once for each season of the bottom trawl survey (spring and fall), and once for each quarter of the commercial samples. The precision tests are for both Georges Bank and Gulf of Maine stocks combined. Each precision test consists of a subsample of approximately 100 fish, and measures the consistency of age determination by the age reader. Two accuracy tests for Georges Bank haddock are generally conducted each year using the reference collection of Georges Bank samples (one prior to, and one after the production ageing). Lastly, an annual exchange of Georges Bank age samples is conducted with the Department of Fisheries and Oceans Canada (DFO) staff to compare age assignments between the two age readers (3-4 separate precision tests each year representing a range of sample sources/seasons; n ≈ 50-100 within each test).

Precision testing in the past year has demonstrated high consistency, with agreement levels between 95.9 and 99.0% (CVs range from 0.08 to 0.49%) for each test. The average precision level (5 tests) was 98.4% agreement and CV of 0.25%. These results exceed NEFSC standards for acceptable ageing consistency (>80% agreement, <5% CV); bias is assumed to be minimal in cases where the agreement level exceeds 90%. For samples collected during 2011 to 2013, the precision levels for all tests (17 tests) had an average agreement of 96.3% and an average CV of 0.51%. The best results showed nearly complete agreement (99.0%, 0.08% CV); the worst results were 90.7% agreement and a CV of 1.40%. Since 2011, the average accuracy level has been 93.6% agreement and a CV of 1.99% (5 tests); the best results were 96.4% agreement (May 2012) and a CV of 1.35% (August 2011); the worst results were 91.1% agreement (July 2013) and 2.86% CV (May 2012).

Historically, haddock age reading has been of high quality. Since regular testing began in 2004, precision levels have averaged 94.5% agreement with a CV of 0.73% in 75 tests. Accuracy tests have averaged 86.4% agreement and a CV of 2.26% (34 tests) in the same time period. The 2014 NEFSC/DFO exchange of Georges Bank samples yielded high precision levels. For the three tests conducted so far, the average results were 92.6% agreement and an average CV of 0.92%. One more test is still planned, on the 2014 Canadian spring survey samples (collected in February). Since 2010, when the current Canadian age reader began working with haddock, average annual precision levels in the exchange have been 78.4% (3.34% CV) in 2010, followed by 88.9% (2.43% CV) in 2011, 88.6% (1.81% CV) in 2012, and 81.0% (2.50% CV) in 2013. While the 2014 results were the best in the series and the 2010 results were worst, there is no clear overall trend. Among the five years (2010-2014), the best exchange result was 98.1% (0.38% CV) for NEFSC fall survey samples in the 2014 exchange. The worst result was 62.7% agreement (4.13% CV) for Canadian commercial samples in the 2010 exchange. None of the exchange comparisons revealed any bias. Only four times has the agreement level fallen below

NEFSC ageing standards (80%) in this time period; the CV level has been above NEFSC standards (5%) throughout.

The 2013 age samples were dominated by the 2013, 2012, 2010, 2006, and 2003 year classes. However, these strong year-classes were unlikely to have biased the age reader toward these age groups. Firstly, the QA/QC testing described above has demonstrated that the ages are accurate (as compared with the reference collection) and consistent (both by the NEFSC age reader and in comparison with the Canadian age reader). In addition, all samples are viewed at least twice to confirm the ages. Finally, difficult samples and fish with an atypical age/length combination are more closely examined.

Full testing results and an explanation of the statistics used can be found at http://www.nefsc.noaa.gov/fbp/QA-QC/hd-results.html.

TOR A.1. Estimate catch from all sources including landings and discards. Include recreational discards, as appropriate. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these sources of data. Investigate the utility of commercial or recreational LPUE as a measure of relative abundance.

Overview

In the recent period (1977 to present) total catch has ranged from 187 metric tons (mt) to 7,656 mt (Table A.8, Fig. A.15). Over the last decade, catch has averaged around 1,000 mt. Commercial landings are the predominant source of fishery removals, averaging 80% of the total catch between 1977 and 2013 – though recently, recreational catch has become an increasingly important source of fishery removals. Historical landing records of Gulf of Maine haddock extend back to 1930, though tabled values extend only until 1956 (Clark et al. 1982). The haddock fishery is a relatively new fishery compared to other New England groundfish fisheries with little exploitation prior to the 1900s. Haddock make a poor salt product, as such, the advent of the haddock fishery did not begin until developments in cold storage and distribution could support the fresh (unsalted) fish markets. The levels of commercial landings observed since 1977 are within the range of historical landings. Landings of Gulf of Maine haddock are considerably lower than those from the much larger Georges Banks stock (Fig. A.16).

With the exception of a period from 1994 to 1997, commercial discards of haddock have been less than 50 mt. While direct estimates of commercial discards only extend to 1989, low minimum retention sizes (Table A.4) likely limited the discarding of haddock in the commercial fishery pre-1989. Contemporary estimates of recreational catch from the Marine Recreational Fisheries Statistics Survey (MRFSS) extend back to 1981; however, there were the occasional saltwater angling surveys conducted between 1960 and 1979 which suggest that recreational catch pre-1981 was in the range of 250-400 mt (summarized in Clark et al. 1982). It is unclear whether these estimates represent recreational landings or total catch, though put in the context of commercial landings at the time, represent a minor component of fishery removals, historically.

Commercial landings

In 1982, the United Nations Convention on the Law of the Sea (UNCLOS) defined a country's Exclusive Economic Zone (EEZ) as a zone extending up to 200 nautical miles from a nation's coast. The EEZ defines the region where each country has sovereign rights to marine resources including fisheries. The geographic proximity of the US and Canada in the Gulf of Maine and Georges Bank Regions results in an overlap of each nation's EEZ. Given the importance of these areas with respect to resource extraction (among other reasons), the US and Canada both submitted cases to the International Court of Justice at The Hague, Netherlands seeking clarification. The Court issued a final ruling on October 12, 1984 formally delineating the US and Canadian EEZ. Hereafter, this demarcation line informally became known as the "Hague Line".

Within the Gulf of Maine, the US EEZ splits statistical areas 464, 465 and 467 (Fig. A.17). Prior to Hague line implementation, landings of haddock in US ports from these statistical areas could have been either from the Gulf of Maine or Scotian Shelf (Canadian) stocks. Current in-season management of Gulf of Maine haddock includes catch from these areas against fishery ACLs. Previous assessments have not included these catches. While landings from these statistical areas have been low since 1985 (≈ 3% of total landings, Fig. A.18), these landings have been included in the current assessment to maintain consistency with the existing ACL monitoring programs. No attempt was made to adjust landings prior to 1985 which is consistent with the approach used for Gulf of Maine cod (NEFSC 2013).

Since 1964, when modern catch statistics began, United States (US) domestic commercial landings of Gulf of Maine haddock have ranged from 122 mt to 5,593 mt (Tables A.8 and A.9). Beginning in the mid-1950s and extending until 1986, small amounts of haddock landings were reported by foreign vessels fishing in the Gulf of Maine. Foreign landings averaged less than 10% of the total stock landings during this time period and were dominated by Canadian landings (Clark et al. 1982).

Total US species landings are derived from the weighout reports of commercial seafood dealers and these data are generally considered a census of total landings. While un-reported landings are possible, no estimates exist to evaluate their magnitude. A secondary data source is required to apportion dealer landings to statistical area (stock) and assign basic information on fishing effort (e.g., gear, mesh, tow duration). Prior to 1994, the partitioning of stocks from total haddock landings was accomplished, in part, through a port-interview process conducted by port agents working for the National Marine Fisheries Service (NMFS). When trips were not interviewed, NMFS port agents would attribute area and fishing effort characteristics to the landings using personal knowledge of the fishery and/or information obtained during the interview process about vessels operating in the vicinity of the interviewed captain.

With the implementation of mandatory vessel trip reports (VTRs) in 1994, the port interview process ceased and the area and effort information was obtained directly from the VTRs. Unfortunately, the matching of dealer reports and VTRs has been problematic and secondary allocation procedures are needed to assign the area and effort information to dealer landings. Currently, a standardized procedure is used to assign area and effort from VTRs to dealer-reported landings from 1994 onward (Wigley et al. 2008). The product from this process is stored the NEFSC allocation (AA) database tables. Landings are matched to VTRs in a hierarchal manner, with landings matched at the top tier (level A, direct matching) having a higher confidence in the area and fishing effort attribution than those matched at the lower tiers. The matching rates have improved over time with over 80% of Gulf of Maine haddock landings being matched directly to VTRs since 2010 (Fig. A.19). While there is considerable variability in the matching success throughout the year (Fig. A.20), there are no clear seasonal trends as have been observed with other Gulf of Maine groundfish stocks (e.g., cod, NEFSC 2013). The overall precision associated with the allocation process, in terms of a CV ranges from 0.01 to 0.04 (Table A.10).

An additional area of uncertainty with stock landings stems from the misreporting and/or under

reporting of statistical areas on VTRs. Federal regulations require that a separate VTR logbook sheet be filled out for each statistical area or gear/mesh fished. Vessels fishing in multiple statistical areas frequently under-report the number of statistical areas fished (Palmer and Wigley 2007, 2009 and 2012). Based on comparisons of VTR reports with vessel monitoring system (VMS) data, the impacts of this misreporting on Gulf of Maine haddock landings estimates could be potentially large (>20% underestimation error in terms of landings weight; Palmer and Wigley 2012). In all but 2004, the VMS-based methods estimated higher stock-level landings compared to VTR-based methods. However, a cross validation of the VMS allocation method with observer data between 2004 and 2011 suggests that, for Gulf of Maine haddock, VTR reports achieve stock allocations closer to the observer data more often than VMS-based methods (five out of the eight years compared). Additionally, VTR landings were frequently higher than the observed landings which would seem to invalidate the VMS-based results. While misreporting of stock landings does occur, given these conflicting results, it's difficult to quantify the possible impacts of VTR mis-reporting on the estimation of Gulf of Maine haddock landings. The error rates indicated by the VMS-based methods should be considered an extreme upper bound on the magnitude of error in the landings estimates.

For some species, there may be a component of the catch that does not get reported by seafood dealers. In the case of Gulf of Maine haddock, fish retained by the crew for home consumption are the largest component of commercial landings that would not be reported by seafood dealers. Estimates of home consumption can be derived from VTRs, but these estimates are likely underestimates of total home consumption landings due to incomplete reporting. From 1994 to 2013, home consumption landings averaged 1.6 mt/year, or approximately 0.3% of the total reported dealer landings (Table A.11). Even if these represent underestimates, it is unlikely that home consumption landings represent a significant source of fishery removals. Because of the low magnitude, home consumption estimates are not included in estimates of commercial landings.

Over the past five years, landings of Gulf of Maine haddock have exhibited consistent seasonal trends with peak landings occurring during the month of March (Fig. A.21). The sole exception to these patterns occurred in 2012 when there were large landings in both February and March. The commercial fishery is primarily conducted by vessels fishing trawl, gillnet and benthic longline (Fig. A.22). Gillnet gear contributed a larger fraction of the total landings early in the time series, but in the more recent period, constitutes less than 10% of the landings. The landings contribution of the benthic longline fleet has increased over time and currently ranks second in terms of landings. The primary gear for the exploitation of Gulf of Maine haddock has been, and remains, otter trawl. Over the 1977 to 2013 time period, otter trawl has averaged 77% of the total landings. During one of the GARM III working group meetings a fishing industry member reported that the trawl fishery had shifted to square-rigged mesh in the Gulf of Maine in order better target flatfish and that this shift had lead to a decline in the haddock selectivity of Gulf of Maine trawl fleet (e.g., Robertson and Stewart 1988). There is some evidence of this in the observer data where mesh type has been recorded since 1994. Diamond mesh was the predominant mesh type from 1995 to 1997, but there was a shift towards square mesh in beginning in 1998 (Table A.12), though since 2007, diamond mesh has again been the predominant mesh type in the Gulf of Maine trawl fishery. The mesh size requirements for square and diamond mesh have not always been identical (Table A.3), though a comparison of

the distribution of observed mesh sizes does not indicate large discrepancies (Fig. A.24).

The ports of Gloucester, Portland and Boston have historically been the primary offload ports of Gulf of Maine haddock (Fig. A.25). Portland landings declined sharply in the early 2000s and Gloucester now accounts for over 50-70% of total commercial landings. Unlike other Gulf of Maine groundfish stocks like cod, there are no seasonal trends in the port-level landings (Fig. A.26). Cod landings are sensitive to rolling area closures that cycle clockwise around the western Gulf of Maine from May to June. Haddock landings appear to be less impacted by the seasonal closures.

From the 1980s to 2000 haddock landings came primarily from statistical area 515 in the central Gulf of Maine. However, over the last twenty years, landings have become increasingly concentrated in statistical area 514 in the western Gulf of Maine (Fig. A.27). The shift to statistical area 514 is consistent with an overall concentration of the groundfish fishery in the western Gulf of Maine that has been previously documented (NEFSC 2013). Similar to the seasonal port trends, there are no evident seasonal patterns in the statistical area landings (Fig. A.28).

Using the positional information provided on VTRs (Fig. A.29), annual Lorenz curves were estimated for both the commercial trawl and gillnet fishery based on the cumulative catch by ten minute square (following methods outlined in Wigley 1996). From the Lorenz curve an annual Gini index, or concentration index, can be estimated using Equation (9):

(Equation 9) $$G = A/(A+B)$$

where G is the Gini index, A is the area between 1:1 equality line and B is the area under the Lorenz curve.

Annual Gini indices were developed for both the commercial trawl, gillnet and benthic longline fleet based on the cumulative catch by ten minute square. Both gillnet and longline Gini indices show that these fleet have always been highly concentrated, though the level of concentration has increased between 1994 and 2013 (Fig. A.30); comparatively, the trawl Gini index has increased considerably over the time series from a concentration index of below 0.8 to current levels near 0.95. The concentration in the commercial trawl and gillnet fleet is characterized by a directional shift in the catch-weighted center (centroid) of fishing activity to the southwest (Fig. A.31). The longline fleet has only undergone small-scale changes in its distribution and there are no clear directional shifts in landings centroids. The current center of fishing activity is located in the western Gulf of Maine in the vicinity of 42.6° N x 70.0° W. The concentration of the haddock landings is also evident when comparing the haddock landings by ten minute square in 2013 to the aggregate VTR time series (Fig. A.32).

Landings of Gulf of Maine haddock were dominated by ton class 3 (51-150 tons) and 4 (151-500 tons) vessels until the early 2000s when landings by ton class 2 (5-50 tons) vessels increased sharply (Fig. A.33). It's not clear exactly why the haddock landings increased for the ton class 2 vessels. Similar increases have been observed in the landings of other groundfish species such as cod, were trip limits had a greater impact on larger vessels (NEFSC 2013). In the case of

haddock, while trip limits existed during this period (Table A.3), they were not as limiting as those of other stocks. It could be that since Gulf of Maine haddock has typically not been a target species, the haddock landings patterns are driven by factors un-related to haddock. Similar to port and statistical area, there are no clear seasonal patterns in ton class landings (Fig. A.34).

Commercial landings of Gulf of Maine haddock are classified by four primary market categories: snapper, scrod, large and unclassified (Fig. A.38). There are also medium and extra-large market categories that exist, but these are seldom used by the primary seafood buyers. The snapper market category constitutes fish in the 30-50 cm range and these are generally smaller than the scrod cull (Fig. A.36). The snapper market category largely disappeared in the late 1980s as the minimum retention size increased (Table A.13). However, in July 2013, the minimum retention size in the commercial fishery was reduced to 16 inches and the snapper market category has reemerged. Despite the differences in length frequency distribution, the sparseness of the biological sampling of this market category precludes being able to reliably characterize snapper landings. For this reason, the snapper market category has been combined with the scrod market category. Extra-large has been combined with the large market category and because of the absence of any biological sampling of the medium market category it has been treated as unclassified. Landings of both extra-large and medium market categories are minimal. There has been a general trend over time for landings to shift toward the scrod market category, particularly since 2000 (Fig. A.37). This shift is consistent with the decreases observed in the mean length-at-age noted previously (Fig. A.10). There was a tendency for scrod landings to peak during April and May, though the seasonal patterns changed considerably after July 2013 (Fig. A.38). It's unclear whether the change is due solely to the reductions in minimum size or whether this is reflective of a year class moving into the fishery.

Commercial landings: biosampling

Biological sampling (length and age) of Gulf of Maine haddock prior to 1977 was poor (Table A.14). Sampling intensities less than 200 mt per 100 lengths has traditionally been considered an unofficial NAFO/ICNAF standard (>200 mt/100 lengths). Since 1983 the sampling intensities dropped below that threshold and have remained there. Sampling intensities have been below 20 mt/100 lengths since 2003. Given that age sampling is conducted at the same time as length sampling (but lower density), it is not surprising that the sampling of age structures (otoliths) has followed similar trends as lengths. From 1982 onward the metric tons per 100 ages have been less than 1000 mt with sampling in the last five years less than 50 mt per 100 ages (Table A.15). While the overall sampling intensity for Gulf of Maine haddock has been good, there are a considerable number of calendar year quarters and market category cells with missing or limited biological samples (Table A.16).

For the GARM III assessment, commercial catch-at-age was estimated by aggregating lengths into 2 cm bins. For the AOP 2012 update, the additional years of catch-at-age (2007-2010, 2007 was reestimated due to changes in the landings data since GARM III) were estimated using 1 cm bins. For this assessment a complete update of the catch-at-age was conducted using 1 cm intervals for the entire time series. Catch-at-age was not stratified by gear type since the length frequency distributions of the landings are similar (Fig. A.39) and additional stratification would

increase the level of imputation needed to construct the catch-at-age. This would have been particularly problematic given that sampling was non-existent or limited for sink gillnet and benthic longline in some years (Fig. A.40). Every attempt was made to maintain the market category/quarter stratification, consistent with the design of the biosampling program. However, when the availability of lengths for a particular market/quarter block was low, either a semiannual or annual time block was used. A criterion of 100 lengths per block was applied to the commercial landings for use as an objective basis to decide when it was necessary to bin across quarters. In situations where an annual time block was required, the annual LW relationship (Equation 4) was applied to convert landings in weight to landings-at-length in numbers. When sampling was maintained using quarterly or semi-annual time blocks the appropriate seasonal LW equation was applied (Equations 2 and 3). A summary of the amount of binning that was required is presented in Table A.16.

Total landings-at-age are presented in Table A.17. The bootstrapped generated CVs on the landings-at-age estimates are shown in Table A.18. CVs are generally less than 30% for those ages that make up the majority of the landings (Ages 4-8). Prior to 1984, the calculation of bootstrap CVs were not possible due to the inability to identify individual sampling events in the biosampling database. There is considerable uncertainty in the estimates of landings-at-age among some of the older ages, particularly beyond age-8 where the average CV begins to exceed 30%. Overall, younger ages have become less prevalent in the commercial landings with increases in the minimum retention size (Fig. A.41). There was a noted truncation of the age structure during the early- to mid-1990s, however since the late 1990s the age structure has expanded. The mean weights-at-age of the commercial landings have generally declined over time across all ages, though the declines are greater at older ages (Table A.19).

Commercial landings per unit effort (LPUE)

Commercial catch per unit effort (CPUE) indices have been applied in some groundfish stock assessments (e.g., Mayo et al 1994, NEFSC 2002a), however the practice has been largely discontinued due to major changes occurring in the Gulf of Maine groundfish fishery. The changes include measures to reduce fishing effort, closed areas, changes in mesh size and trip limits in addition to a switch in the fisheries-dependent data collection system from a landings interview/intercept program to a self reported logbook program (Table A.3). All of these issues affect the comparability of CPUEs estimated from post-1994 trends to those from the earlier time series and could cause a disconnect between CPUE and stock abundance. Additionally, these same issues would make standardization of a contemporary catch per unit effort (CPUE) index difficult. Similar issues with commercial catch rate indices have been previously noted (e.g. Harley et al. 2001, Maunder et al. 2006). Despite these concerns about the relationship of CPUE to stock abundance, it is informative to evaluate CPUE indices to gain an understanding of commercial catch patterns, even if these indices are not included in the assessment model.

The only accurate source of total fishery catch (retained and discarded) comes from the Northeast Fisheries Observer Program which began in 1989. This is a shorter time series than available for the dealer data; additionally, there are extended periods of low observer coverage in the twenty plus year time series. For this reason, landings per unit effort (LPUE) indices are

likely to be a more informative source of commercial catch efficiency for Gulf of Maine groundfish. LPUE indices can be extended back to 1964 with the start of the modern commercial dealer data collection program.

An analytical dealer data set was created for the LPUE analysis. A description of the analytical set is included in Palmer (2012). Given that Gulf of Maine haddock landings are dominated by the trawl fleet, only data from commercial trawl trips were considered in this analysis. There is no way to accurately identify which trips in the dealer data constitute 'groundfish' trips with some probability of encountering haddock and which trips were engaged in other fisheries (e.g., fluke) with virtually no probability of encountering haddock. For this reason only trips that landed ≥ 1 lb haddock were included in the model. Nominal Gulf of Maine haddock commercial trawl LPUE (landings per days fished) shows very little trend since the mid-1980s after declining from a peak in 1980 (Fig. A.42).

Standardized LPUE indices were developed using a GLM model. The model included the following factors: year, area, ton class, quarter and depth zone. Factor levels were screened prior to inclusion in the model to evaluate those factors most appropriate for use based on their contribution to the overall haddock landings. The following factor levels were included:

- Area: 511, 512, 513, 514, 515
- Ton class: 23, 24, 25, 31, 32, 33, 41
- Quarter: 1-4
- Depth zone: 1-4

Only main effects were considered in the model to avoid confounding the interpretation of year effects. The year effects presumably provide information on changes in haddock abundance over time, but also likely absorb other factors not included in the model such as changes in technology, management measures and targeting behavior.

LPUE was log transformed (Fig. A.43) such that the linear LPUE model was:

(Equation 10) $$ln(U_i) = \alpha^Y_{y_i} + \alpha^A_{a_i} + \alpha^T_{t_i} + \alpha^Q_{q_i} + \alpha^D_{d_i} + \varepsilon_{y_i a_i t_i q_i d_i}$$

where U_i is landings per unit effort (days fished) and α^Y_{yi} is the coefficient for the year y_i, and similarly the coefficients for area (*A*), ton class (*T*), quarter (*Q*) and depth zone (*D*). Errors were assumed to have a log normal distribution.

The GLM model was run on the years 1977 to 2012. At the time the GLM model was developed the final 2013 commercial dealer data were not available. Standard levels were chosen for each factor as follows: year = 1982, area = 513, ton class = 31, quarter = 1, and depth zone = 4. Model coefficients were retransformed to linear scale after bias correction following Granger and Newbold (1977). To understand the influence of factors on the final GLM model, the model was developed using a stepwise selection process (PROC GLMSELECT, SAS Institute Inc.). While there is an indication of interactions among the factors, interaction terms were not included in this model because of the confounding effects on the interpretation of the year effects. Factors were added based on the adjusted AIC criterion (AIC_C). Factors entered the model in the

following order: ton class, area, depth zone and quarter. Plots of the year coefficients (LPUE index) as factors are added to model show only marginal changes in the nominal LPUE index (Figure A.44). The final LPUE index is provided in Table A.20.

A comparison of the standardized LPUE index to the spawning stock biomass from the 2012 AOP update shows close agreement of the two series until 1994 (Fig. A.45). There were several moderate-to-strong recruitment events between 1993 and 1998 leading to a large increase in spawning biomass between 1994 and 2002 (NEFSC 2012). The LPUE index, while it increased marginally between 1994 and 2009, did not increase consistent with rate of increase in stock size. There was an apparent shift in relationship between LPUE and stock abundance/biomass in the mid-1990s such that after the mid-1990s, LPUE is not informative as an index of stock abundance (Fig. A.46). Based on these results, the commercial LPUE index will not be used in the Gulf of Maine haddock assessment model. This recommendation is consistent with the recommendations of recent SARCs (NEFSC 2013).

Commercial discards

Gulf of Maine Atlantic haddock are primarily discarded in the commercial fishery for three reasons: (1) fish are below the minimum retention size (too small), (2) fish are of poor quality, and (3) retention is prohibited (e.g., non-groundfish fisheries; Table A.21).

Direct sampling of the commercial fishery for discards has been conducted by fisheries observers since 1989. Beginning in May 2010, Amendment 16 created a new class of fisheries observers to support sector management of the northeast US groundfish fishery. These new observers were termed 'at-sea monitors', or ASMs. ASMs are deployed in the same manner as observers certified through the Northeast Fisheries Observer Program (NEFOP; Palmer et al. 2013), but they collect only basic information on fishery catches and length frequency distributions. Between 2010 and 2012, ASM coverage averaged approximately 20% of total groundfish trips whereas regular observer coverage (NEFOP) averaged about 6% (Palmer et al. 2013). A comparison of the estimated discard rates between ASM and NEFOP observers showed no statistical difference for the majority of gears and quarters examined (Wigley et al. 2012). The Gulf of Maine haddock ASM discard rates were statistically indistinguishable from the NEFOP discard rates as evidenced by the fact that the 95% confidence intervals of the difference between estimates include zero (Figs. A.47 – A.49). A comparison of the length frequency distributions showed only small differences (Fig. A.50) when the sampling was sufficient to make comparisons (Table A.22). Given these results, no distinction has been made between data collected by ASM and NEFOP observers with respect to discard estimation.

Beginning with the GARM III assessment, discards were estimated for five commercial gear types: large mesh (≥ 5.5") otter trawl, small mesh (<5.5") otter trawl, sink gillnet, benthic longline and midwater trawl. For this benchmark assessment we have reevaluated the gears for which discards will be estimated and included in the stock assessment model. Using data from 1989 to 2012 (2013 data were not available at the time of the analysis) we conducted a preliminary evaluation of discard estimates and available observer data for six commercial gears: benthic longline, large mesh otter trawl, small mesh otter trawl, shrimp trawl, large mesh (5.5" –

7.0”) sink gillnet and extra-large mesh (>8”) sink gillnet. It should be noted that the large mesh otter trawl gear includes standard otter trawl, Ruhle trawl and haddock separator trawl gears. Previous examinations of VTR data and observer data have shown that there are more trips observed that use these modified gear types than report the gear types on the VTR. This indicates that these gear types are not being accurately reported in the VTR data and no distinction can be made between the modified gear types and the standard otter trawl (NEFSC 2013). However, given that the use of these gear types did not begin until 2009 and the frequency of use is low in the Gulf of Maine, this should have negligible impacts on discard estimates. The mid-water trawl fleet was not included in this preliminary analysis; it was evaluated in a separate analysis which is described later in this section.

The preliminary estimates of discards by fleet showed that three gear types were responsible for the majority of Gulf of Maine haddock discards. Benthic longline, large mesh otter trawl and large mesh sink gillnet, are responsible for, on average, 89% of the Gulf of Maine haddock discards (Table A.23). While the discard estimates from the other gears exceeded 5% contribution to the annual total in some years, the CVs for these years were often large (Table A.24). The three primary gear types all had average CVs across the time series less than 0.5, while average CV of the three minor gear types all exceeded 0.5. The availability of length samples was also considered when deciding which gears to include in the final commercial discard estimates. The available length information for the three minor gear types was sparse and would have required extensive imputation to achieve estimates of discards-at-age (Table A.25). The three major gear types also have some years with limited length observations; the methods used to deal with these issues will be described later in this section. Considering the contribution to total discards, precision of the discard estimates and availability of length samples, this updated assessment will only include discard estimates from the benthic longline, large mesh otter trawl and large mesh sink gillnet gear.

In previous Gulf of Maine haddock assessments, discards had been estimated for the mid-water trawl fleet using the same Standardized Bycatch Reporting Methodology (SBRM) process used for other fleets (Wigley et al. 2007). This method uses observer data to estimate a ratio of discard of species of interest to the kept of all species ($d_{species}/k_{all}$) and then expands the estimated ratios by multiplying by the fleet-wide estimate of the retained catch of all species (K_{all}) that is obtained from dealer data. There are several problems with applying this approach to the mid-water trawl fleet. Since 2006, with the passage of FW 43 to the Multispecies FMP, category 1 herring vessels have been prohibited from discarding haddock. All haddock must be brought to shore, though the regulations prohibit the sale of these haddock for food. The prohibition on the food sale of these landings makes it unlikely that these landings would be reported in the dealer data as commercial landings. Therefore, to accurately account for the haddock removals from the mid-water trawl fleet, a bycatch (retained plus discarded catch) estimate should be used rather than a discard estimate. Secondly, the identification of stock area fished is problematic for paired midwater trawl trips owing to a complication within the analytical dealer database (AA tables). To accurately estimate haddock bycatch by mid-water trawl gear requires the use of VTR data to obtain K_{all} estimates. A separate analysis described in Palmer et al. (2014b) provides a description of the methods and summary of haddock bycatch by the mid-water trawl fleet between 1994 and 2012. Bycatch of haddock is primarily occurring in the Georges Bank region where annual bycatch estimates range from 0 – 281 mt; estimates for Gulf of Maine were less

than, or equal to 4 mt annually. Over all years where haddock bycatch could be estimated, bycatch amount in the mid-water trawl fishery represented approximately 3.0% of the Georges Bank commercial landings and less than 0.1% of Gulf of Maine commercial landings. Bycatch amounts were estimated with moderate to poor precision with CVs ranging from 0.09 to 1.07. Given the small amounts of haddock bycatch occurring in the Gulf of Maine and the poor precision of these estimates, these removals will not be included in this assessment.

The total number of observed trips by gear type are presented in Table A.26. Final estimates of discards ranged from 2 mt in 1990 to a high of 378 mt in 1997 (Table A.27). Since the removal of restrictive trip limits (late 90s), the discarding of small fish seems to peak approximately three years after the spawning of moderate-to-strong year classes. While there are exceptions, large-mesh otter trawl is the major source of haddock discards. The resulting CVs on the discard estimates are variable on a gear-specific basis. At the aggregate level, CVs of total discards average 35%, however since 2010, and the addition of ASM coverage, CVs have been below 20%.

As a means of evaluating the accuracy of the discard estimation procedure, a check was conducted to attempt to estimate total landings using the same methodology used to estimate discards. Instead of estimating a d_{had}/k_{all} ratio, a k_{had}/k_{all} ratio is estimated. When compared to the total Gulf of Maine haddock landings, the results show close agreement with respect to scale and trends, lending support not only to the accuracy of the discard estimation procedure, but also corroborating the commercial landings estimate (Fig. A.51).

Commercial discards: biosampling

Observers collect length and age information from the discarded fraction of the catch (as well as on the retained catch); however, only length samples are currently available. ALKs were created using both commercial landings and NEFSC survey ALK corresponding to the appropriate season (spring/fall). Length sampling extends back to 1989 and with variable coverage over the times series. While the sampling intensity has exceeded the 200 mt/100 lengths threshold since 1992, there are many years with limited length sampling (Table A.29) requiring supplementing of the discard length frequencies be with survey lengths. The length distributions by gear are shown in Figure A.52 on an aggregate basis and by year in Figure A.53. Unlike the commercial landings length frequency distributions, the discard length frequencies vary considerably by gear.

In order to supplement the observer length frequency distributions with lengths from the NEFSC bottom trawl survey, we needed to first estimate gear-specific selectivity ogives for the discard gears under consideration. The selectivity ogives enable gear-specific sub-sampling from the survey length distributions. Gear selectivites were estimated using observer and survey length frequency distributions from 2009-2013. Since the generated selectivity ogives would be applied to length distributions from the Albatross IV time series, the length-frequency distributions from 2009-2013 (Bigelow series) needed to be calibrated using length-specific calibration factors (described under TOR 2). While applying selectivity ogives generated from a 2009-2013 reference period to early years is potentially problematic due to changes in minimum retention sizes, mesh sizes and possession limits, the reference time period was the only period in which

sampling densities of the discard lengths were sufficient to achieve estimates of gear selectivity.

Survey length frequencies were first truncated using the minimum retention size for the year in question (Fig. A.54). Because minimum retention sizes are specified based on total length (in) and survey lengths are recorded in fork length (cm), the retention sizes were converted to fork length (cm) equivalents using Equation 11 (Livingstone 1957). While Pol et al. 2011 developed a similar fork length-total length relationship (Equation 12), the results are nearly identical. The Livingstone 1957 relationship had been used in previous assessments, so it was retained for this benchmark assessment.

(Equation 11) $L_{fork} = 0.944\ L_{total} + 0.58$ *(Livingstone 1957)*
(Equation 12) $L_{fork} = 0.95\ L_{total} + 0.65$ *(Pol et al. 2011)*

Using Pope's (1966) 'alternate tow' approach, the ratios of observed proportion-at-length discarded from the fishery to the proportion-at-length present in the survey are generated. Equation 13 (Wileman et al. 1996) is then fit to the aggregate ratios (across all years) to generate selectivity ogives based on logistic regression (Fig. A.55). A comparison of the estimated length frequency distributions to the observed distributions are shown in Figures A.56 – A.58. The estimated length frequencies pick up the major modes which likely correspond to incoming year classes; however the modal peaks are not identical in all years. A noted feature of the observed discards is that there is often some fraction of discards that are above the minimum retention size, a key violation of this method. While this is problematic, examination of the length distributions over time shows that these occurrences to be infrequent (Fig. A.53). At this time, this method provides the best means with which to impute discard length frequencies. The total number of survey lengths that were 'borrowed' are summarized in Table A.30.

(Equation 13) $$r(l) = \left[\frac{\exp\,(a+bl)}{1+\exp\,(a+bl)}\right]$$

where:

r(l)i is the estimated selectivity at length, *l*
a and *b* are logit linear parameters

When estimating discards at length, attempts were made to maintain the separate semi-annual estimates so that the most appropriate seasonal LW equation could be applied. For some years and gear types this was not possible owing to limited sampling, as evidenced by the need to impute using survey lengths as described above. In these situations an annual time block was used to estimate discards-at-length and an annual LW equation was applied. A criterion of 30 lengths per block was used to provide an objective basis to decide when it was appropriate to bin across semesters. A summary of the time blocks applied in the estimation of discards-at-length is provided in Table A.29.

Commercial discard hindcasting: pre-1989

Direct observations of discards by fishery observers only exist from 1989 to present. The model formulations used in past assessments have started in 1977 owing to the availability of information on the age composition of commercial landings. For the GARM III, and the subsequent 2012 update, commercial discards were estimated in the pre-1989 period using a survey-scaling method (described in Palmer et al. (2008)). One important shortcoming of this approach is that it assumes that all fish from NEFSC surveys below the minimum retention size are selected by the fishery. As shown above, this is not a valid assumption. For this benchmark assessment we have instead applied a survey-filter method (also described in Palmer et al. (2008)). An additional benefit of this method is that it maintains consistency with the method used to impute length frequency distributions in the post-1989 period.

Attempts were made to hindcast discards for only large mesh otter trawl and large mesh gillnet. Because there was a limited longline fishery in the Gulf of Maine from 1982 to 1989 (Fig. A.22), no attempt was made to develop discard hindcast estimates for this gear type. The hindcast estimates could only be extended to 1982 because mesh size cannot be reliably identified in the dealer data prior to 1982. Given that the minimum mesh size was 5.125" from 1977 to 1982, the large mesh trawl gear as defined in the more recent period did not exist.

The survey-filter method requires information on survey numbers at length (N_i), estimates of gear selectivity at length (m_i), a scaling factor (q) and an estimate of total fishery effort (f). Assuming these are available, discard-at-length can be estimated using the following equations:

If:

(Equation 14.a) $C_i/f = q \bullet (N_i \bullet m_i)$, then
(Equation 14.b) $C_i = (q \bullet f) \bullet (N_i \bullet m_i)$ as above.

If :

(Equation 14.c) $K_i = C_i \bullet s_i$, and
(Equation 14.d) $D_i = C_i \bullet (1-s_i)$, then
(Equation 14.e) $D_i = (q \bullet f) \bullet (N_i \bullet m_i) \bullet (1-s_i)$, and
(Equation 14.f) $D_i/f = q \bullet [N_i \bullet m_i \bullet (1-s_i)]$

where:

C_i is the catch retained by a given commercial mesh at length i
f is some estimate of total fishing effort
q is the proportionality constant
N_i is the abundance of fish in the survey at length i
m_i is the proportion of the available population retained by a given mesh at length i
s_i is the proportion of the retained catch kept at length i
K_i is the kept portion of the catch at length i
D_i is the discarded portion of the catch at length i

If it is assumed that the fish discarded pre-1989 were all less than the minimum size, the above equation can be simplified by setting s_i to 0. As noted above, there may be situations where this

assumption does not hold, though it is likely valid for the majority of years. The gear selectivity ogives (m_i) developed above were retained for hindcast estimation. While it was not ideal to use a reference period so far removed from the hindcast period, the limited availability of observer length data necessitated this. As when generating the selectivity ogive, length-based calibration factors were used to convert Bigelow catches at length to Albatross IV equivalents.

By regressing the ratio of observed discards-at-length to the total fishing effort (K_{all} was used similar to the contemporary discard estimates) on the ratio of selectivity-adjusted survey numbers-at-length, the gear-specific scaling factor (q) can be estimated as the slope of the regression line (Equation 14.f, Fig. A.59).

Total discards estimated using the survey-filter approach have similar trends and scales to the direct estimates and are of similar magnitude to those achieved using the survey-scaling method developed in GARM III (Fig. A.60). Since there were no survey length observations within the selectivity window for 1988, no hindcast discard estimate could be generated. Neither the survey-scaling or survey-filter methods suggest that commercial discards were large during this period. For perspective, both approaches estimate total discards at less than 25 mt compared to average commercial landings exceeding 4,000 mt/year for the 1977-1988 period. Regardless of the method used to hindcast discards for the period pre-1989, the impacts on assessment results will be negligible.

Commercial discards-at-age and weights-at-age are presented in Tables A.31 and A.32 respectively. Bubble plots of commercial discards-at-age over time are shown in Fig. A.61.

Discard mortality

The GARM III assessment and the 2012 update both assumed 100% mortality of haddock discarded in the commercial fishery. While considerable work has been done on the mortality of haddock escaping trawl gear (e.g., Ingolfsson et al. 2007) very little work has been done on mortality of haddock captured (brought on board the fishing vessel) and then released. The act of capture and resulting stress of exposure to air, barotraumas, thermal shock, etc. will increase mortality (Hislop and Hemmings 1971, Davis 2002). A recent review of Atlantic cod mortality captured in New England waters estimated discard mortality at 30% for recreational hook and line, 33% for commercial longline gear, 75% for commercial otter trawl and 80% for sink gillnet (NEFSC 2013). Past studies have shown haddock to be less resilient to capture compared to other closely related gadoid species such as cod (Ingolfsson et al. 2007). It is expected that haddock mortalities are higher than those estimated for cod, though absent targeted studies, it is difficult to determine specific mortality rates. There is at least one known study from the Barents Sea that estimates haddock mortality in a pelagic longline fishery from 39-53% (Huse and Soldal 2002). It is however, difficult to apply these results to the Gulf of Maine region, given the differences in geography (seasonal temperature differences) and the gear type (pelagic vs. benthic gear). Given the current discard mortality estimates used for Gulf of Maine cod, and the lower resiliency of haddock, this assessment has assumed a mortality of 100% for haddock discarded by the commercial fishery. For otter trawl and sink gillnet, this is likely close to the true mortality. It's possible that the longline mortality is lower than the 100% assumption and subsequent work should be conducted in the region to better elucidate the true discard mortality.

Recreational landings

There is a large recreational fishery in the Gulf of Maine that, over the last decade, has accounted for approximately 29-86% of the total catch (Table A.8). Previous assessments have used data collected under the Marine Recreational Fisheries Statistical Survey (MRFSS). MRFSS data begin in 1981; however, there were the occasional saltwater angling surveys conducted between 1960 and 1979 that suggest recreational catch pre-1981 was in the range of 250-400 mt (summarized in Clark et al. 1982). It is unclear whether these estimates represent recreational landings or total catch, though put in the context of commercial landings at the time, would represent a much lower fraction of fishery removals compared to the recent period.

Beginning with this current assessment, MRFSS data have been reestimated using revised methodologies consistent with the new Marine Recreational Information Program (MRIP) which has replaced the MRFSS program (NMFS 2012). Since the existing data were collected under the MRFSS program, this assessment report will refer to these as MRFSS data. Beginning in 2012, recreational catch statistics were collected using the MRIP sampling design. The conversion of MRFSS data to MRIP estimates is described below. In general, both MRFSS and MRIP survey methods consist of site interviews to gather catch, effort and biological data from recreational anglers. There are three primary sampling modes: party/charter, private/rental and from shore. Sampling is conducted throughout the year in two-month waves; however in New England waters, wave 1 (January/February) has not been historically sampled. Sampling is stratified by state, mode and wave with samples allocated based on recent estimates of fishing pressure. Survey sampling sites are randomly selected from pre-determined access site lists. The interview procedures vary slightly by mode, but in general anglers are interviewed at assigned access sites on completion of fishing trips and/or during the course of the fishing trip for some party/charter sampling events. Interviews include collection of information on catch composition, effort and length and weight measurements from a random sample of fish from each species. Intercept data are combined with telephone surveys to provide total estimates of catch and effort (ASMFC 1994).

The MRFSS data collection program began in 1979, though estimates of recreationally caught haddock are not available until 1981. Recreational catch data are divided into three components: directly observed landings (A), unobserved landings (B1), and unobserved discards (B2). Catch types A and B1 are collectively referred to as the recreational harvest and B2 catch as recreational releases. Recreational catch is partitioned into Gulf of Maine and Georges Bank stocks using the annual site register lists; catches attributed to intercept/interview sites in Maine and New Hampshire as well as Massachusetts catches from Essex, Suffolk, and Plymouth counties are allocated to the Gulf of Maine stock and catches from Nantucket, Dukes and Bristol counties are assigned to the Georges Bank stock. Catches from Barnstable and Plymouth counties (Massachusetts) are split such that intercept sites bordering Cape Cod Bay are allocated to the Gulf of Maine stock and those on the east and south side of Cape Cod are allocated to the Georges Bank stock (note that there are a few exceptions to this rule where boat access sites occur on the south and east side, but it is known that vessels are catching haddock in Gulf of Maine waters).

Conversion of MRFSS data using MRIP methodologies

In 2012 NMFS released revised MRIP-converted estimates of MRFSS recreational catch extending back to 2004. The revised estimates were based on the application of the MRIP sampling design to the existing MRFSS data. For Gulf of Maine haddock, the revised MRIP estimates ranged from 49-107% of the MRFSS landings estimates and 56-144% of the MRFSS discard estimates (Table A.33). A working group convened in March 2012 recommended applying a ratio estimator to MRFSS data collected pre-2004 to convert the pre-2004 MRFSS data into scales consistent with the revised MRIP estimates. The WG recommended that the ratio estimator be based on the "ratio of means" (summed across all comparison years) rather than based on the "mean of ratios" for individual years (NMFS 2012). Consistent with the recommendations of the WG, that approach has been employed in the current assessment yielding a ratio estimator of 0.83 for AB1 catch and 0.95 for B2 catch (Table A.33).

Total recreational catch has been reestimated since GARM III due to minor updates to the MRFSS data and to accommodate the MRIP re-estimation. Updated catch estimates are presented in Table A.34. The MRFSS data collection program is a numbers based survey and conversion of MRFSS estimates to removals in terms of total biomass can be accomplished in several ways. Consistent with the methodologies used for other groundfish stocks (e.g., cod, NEFSC 2013), catch biomass estimates were developed by using annual length frequency distributions to generate numbers at length and subsequent application of the annual LW equation (Equation 4) to estimate total removals in terms of weight. Since the majority of the recreational catch occurs during the summer months, application of seasonal LW equations from either the spring or fall surveys was not appropriate.

A summary of recreational catch from 1981 to 2013 is presented in Table A.34. Recreational harvests have ranged from 0 to 573 mt, with harvests averaging approximately 290 mt over the past five years. CVs on the harvest estimates have been highly variable, though since 2004 CVs have been below 20%. Releases have ranged from 0 to 414 mt, with the releases increasing sharply over the past five years from only 49 mt in 2009 to the time series high of 414 mt in 2013. The CVs on releases are slightly higher than those of the harvest precision levels; however, they have been below 30% since 2004 with the exception of 2008. Overall the general precision of the release estimates is similar to the commercial discards.

Evaluation of VTR recreational information

While MRFSS/MRIP is the source for official recreational catch estimates, VTRs provide a useful source for understanding some of the finer spatial and temporal trends that cannot be easily determined from the MRFSS/MRIP data. They also help inform the validity of the MRFSS/MRIP sampling scheme and treatment of data. VTR data are only available for the federally permitted party (head boats) and charter modes. Early in the time series party/charter vessels were the predominant source of recreational catch, though the catch by private vessels has increased since 1997 (Fig. A.62). VTRs are not required for the private recreational fleet or

party/charter vessels operating only within state waters (state permitted vessels), thus VTR-based estimates will underestimate the total recreational landings (Fig. A.63). While VTR estimates only provide a sub-component of the total recreational catch, a comparison of VTR catch trends to MRFSS/MRIP provides a validation of the accuracy of the MRFSS/MRIP data (Fig. A.63). The MRFSS program did not historically sample the New England region in wave 1 (January/February); however, an evaluation of VTR data indicates that ≤ 1% of the annual recreational catch occurs during wave 1, with the majority of recreational catch occurring during waves 3 and 4 (May to August; Fig. A.64).

Using the positional information from VTRs (Fig. A.65) the fine scale spatial characteristics of the federally permitted component of the recreational fleet can be described. Unlike the commercial trawl fishery, the recreational fishery has always been highly concentrated, with Gini indices ranging from 0.94 to 0.98 (Fig. A.66). There have been no large scale shifts in the center of recreational effort over time (Fig. A.67). The majority of VTR-reported recreational landings come almost exclusively from the western Gulf of Maine in the vicinity of the Western Gulf of Maine Closed Area (Fig. A.68). Approximately 90% of the total recreational catch comes from federal waters (> 3 mi from shore; Fig. A.69).

Recreational landings-at-age

The numbers-based estimates of recreational landings were converted to numbers-at-age using the length frequency information collected from the MRFSS/MRIP surveys and ALKs borrowed from the NEFSC survey. The length sampling of the recreational harvest was poor prior to 2002 (Table A.35). Generally, recreational harvest included only fish above the minimum retention size (Fig. A.70 and A.71). To supplement the length frequency distributions of the recreational harvest in the years before 2002, lengths were borrowed from the NEFSC surveys, using only lengths above the minimum retention size. Minimum retention sizes were converted to fork-length equivalents using Equation 11 prior to sub-sampling the survey lengths.

Recreational harvest (landings)-at-age are presented in Table A.36 and Figure A.72. The patterns are similar to the commercial landings-at-age with a truncation of the age structure in early 1990s followed by a sharp expansion and evidence of strong cohort signals, particularly of the 1998 and 2003 year classes. Recreational landing weights-at-age are presented in Tables A.37. Similar to the commercial landings, there is a noticeable decline in fish weights over time, particularly since 2000.

Recreational landings per unit effort (LPUE)

Using methods identical to those used to develop a LPUE index for the commercial trawl fleet, a recreational LPUE index was developed using VTR data from 1994 to 2013. LPUE was expressed in terms of number of fish caught per angler hour (number of anglers × fishing time). The un-standardized LPUE shows increasing trends since 1994, with slight declines over the last four years (Fig. A.73). The GLM model included the following factors: year, trip category (party/charter), area, quarter and depth zone. Factor levels were screened prior to inclusion in the

model to evaluate those factors most appropriate for use based on their contribution to the overall haddock landings. The following factor levels were included:

- Area: 511, 512, 513, 514, 515
- Trip category: 2, 3
- Quarter: 1-4
- Depth zone: 1-4

Similar to the commercial trawl LPUE, recreational LPUE estimates were log transformed to normalize the distribution (Fig. A.74). Standard levels were chosen for each factor as follows: year = 1994, area = 514, trip category = 2, quarter = 1, and depth zone = 4.

Factors entered the model in the following order: trip category, depth zone, quarter and area. Plots of the year coefficients (LPUE index) as factors are added to model show only marginal changes in the nominal LPUE index (Figure A.75), with the largest effect coming from the incorporation of trip category. The final LPUE index is provided in Table A.38.

A comparison of the standardized LPUE index to the spawning stock biomass from the 2012 assessment updates shows poor agreement between the two series (Fig. A.76). Spawning stock biomass peaked in 2002 followed by a sharp decline, however recreational LPUE continued to increase until 2006, followed by a general decline until the end of the time series, with the exception of 2009. A scatter plot comparison of the two time series highlights the lack of relationship (Fig. A.77). The recreational fishery was less affected by regulatory changes during the 1994 to 2013 period, so it does not appear that regulatory effects may be responsible for the lack of an apparent relationship between the LPUE and SSB time series. It is possible that SSB is not a good index of the fraction of the resource exploitable by the recreational fishery. For example, the SSB peaked in 2002 when the large 1998 year class would have been four years old (approximate age of 100% maturity) – if these fish were not fully selected by the recreational fishery until they were six to eight years old, then this may explain the delay in the response of the LPUE. Partial recruitment patterns from the 2012 assessment update would seem to support this hypothesis. While there is general concern about the use of LPUE indices as indices of abundance for reasons previously highlighted, there may be utility in exploring the utility of the recreational LPUE index through a sensitivity model.

Recreational discards-at-age

With increases in the minimum recreational retention sizes, the contribution of recreational discards to total recreational catch has been increasing over time (Table A.8, Fig. A.15). In the GARM III, and subsequent 2012 update assessment, recreational discards were reported, but they were not included in the catch-at-age used in the assessment models. The primary reason for the exclusion of discards was the limited length frequency information available on recreational discards at the time the GARM III assessment was conducted. At-sea sampling of the party charter vessels did not begin until 2004 (i9 sampling). Since 2004, sampling has been highly variable, ranging from 14 to 2,343 lengths per year with sampling intensities ranging from 17.7 to 265.3 mt/100 lengths sampled (Table A.35). Overall, the sampling intensity of the recreational

releases is below the level of the recreational harvest.

Because of the increasing importance of recreational discards over time, this benchmark assessment has attempted a hindcast of recreational discards using the available length frequency information and a variant of the survey-filter method used to hindcast commercial discards. Unlike commercial discards, estimates on the magnitude of recreational discards in terms of total numbers are already available from the MRFSS/MRIP data (Table A.34). The survey-filter method was needed only to re-construct the length frequency distributions of recreational discards back in time. Similar to commercial discards, the assumption was made that all discarding was done due to minimum retention sizes. This assumption appears to be valid for the recreational fishery, with very little discarding of legal-sized fish occurring from 2004 to 2013 (Figs. A.78 and A.79). Using the alternate-tow approach used for commercial discards, a gear selectivity ogive was constructed using NEFSC survey catch-at-length below the minimum recreational retention size (Fig. A.80). Because the sampling intensities of the recreational releases were reasonably good during the 2004-2008 period, this period was used as the reference period to construct the selectivity ogive. Using this periods removes any confounding effects of the Bigelow survey calibration when applied to the historical time period. The resulting selectivity ogive is shown in Figure A.81. Comparing the survey-filter length frequency distributions to the observed length frequency distributions showed reasonably close agreement (Fig. A.82).

Application of the generated selectivity ogive to the survey length distributions provided recreational length frequency distributions back to 1981. Unfortunately, due to the sparseness of the survey length information between 1981 and 1994, the number of available lengths were insufficient to characterize the annual length distributions. The survey lengths were aggregated over this period. Because recreational release estimates over this period were low (0-2.6 mt), any errors in the estimation of recreational release catch-at-age should have minimal impacts on the overall catch-at-age.

To our knowledge there are no available scientific studies on the discard mortality of haddock released from the recreational fishery. Efforts were made to reach out people familiar with the recreational haddock fishery to gain a better understanding of likely release mortality. Based on these informal communications, an assumption of 50% mortality seemed reasonable. This is higher than the 30% assumed for Gulf of Maine cod, and consistent with the observations that haddock is a more fragile fish when handled and likely to incur higher release mortality. This assessment will use a baseline assumption of 50% mortality of haddock released in the recreational fishery. Given the large magnitude of recreational releases in the later part of the assessment time series, the discard mortality assumptions for the recreational fishery may be important. Sensitivities of the base assessment model to alternate assumptions will be explored (Appendix 2).

Recreational discards-at-age are presented in Figure A.83 and Tables A.39 (baseline 50% mortality assumption) and Table A.40 (alternate 100% mortality assumption). Several cohorts are evident in the discards-at-age including the 1998, 2003 and 2010 year classes. Recreational release weights-at-age are presented in Table A.41.

Total catch-at-age and mean weight-at-age

Estimates of total catch-at-age were determined by summing the numbers-at-age across all of the catch components: commercial landings, commercial discards, recreational landings and recreational discards. An age-9^+ group was used in the construction of the catch-at-age. This decision was made based on the sparseness of information on older age classes in the middle of the time series during the period of severe truncation of the population age structure and increased CVs on commercial landings-at-age above age-8. The truncation began in the mid-1980s and persisted until the late 1990s. Total catch-at-age is presented in Tables A.42 (baseline 50% recreational release mortality), A.43 (alternate 0% recreational release mortality) and A.44 (alternate 100% recreational release mortality). Bubble plots of the total catch-at-age assuming the baseline 50% mortality are presented in Figure A.84. The updated catch-at-age estimates for this assessment agree closely with those from the 2012 update (Fig. A.85), despite the re-estimation of commercial landings-at-age, revised discard estimation procedures, revised recreational catch estimates and inclusion of recreational discards.

Mean catch weights-at-age were estimated by using a numbers weighted average of the individual catch component's mean weights-at-age. Estimated catch-weights under the range of recreational discard mortality assumptions are presented in Tables A.45 to A.47. Minor imputation of the catch weights at-age was required to fill in gaps in the youngest and oldest ages; a 5-year centered moving average was used to impute missing cells for all but the age-0 weights-at-age, where a time series average was applied. There is evidence of declines in the mean weights-at-age for fish older than age-5 over the last decade (Fig. A.86).

Estimation of January 1/spawning stock weights

Sampling of older age fish in the trawl surveys has historically been low, and use of survey-based weights-at-age to estimate January 1 and spawning stock weights for use as model inputs would require extensive imputation.

January 1 and spawning stock weights were estimated from catch weights using a method described in Rivard (1980, 1982). April 1 is the assumed spawning event in the base model. Given that there is little somatic growth between January 1 and the peak spawning period (Fig.A.9), spawning stock weights were set equal to January 1 weights-at-age. The Rivard method adjusts the catch mean weights-at-age, which are generally presumed to represent mid-year weights, back to January 1. Mean weights at the beginning of the year for a given age class are calculated as the geometric mean of the weight in the same year and of the same cohort in the previous year. No adjustments are made for the plus group calculation. Calculations for the initial and final years and ages are described in Rivard (1980,1982). Since the stock weights should reflect all fish in the population, the catch weights-at-age based on 100% assumption of recreational discard mortality were used to estimate January 1 and spawning stock weights. January 1/spawning stock weights are shown in Table A.48.

Catch-curve analyses

Catch curves were constructed for the aggregate fishery catches (commercial and recreational landings and discards) based on the methods of Robson and Chapman (1961). Catch curves were conducted on a cohort basis rather than an annual basis which removed the confounding effects of differential year class strength on the interpretation of catch curve results. Linear regressions were fit to the log transformed catches of ages 6-11 for the 1978 to 2006 year classes (Fig. A.87). While ages 6-11 may not precisely match the fully recruited ages, it offers a compromise between full selection and having sufficient ages to fit a reliable regression. The slope of the regressions provides a model-independent estimate of cohort *Z*. The analyses suggest time series *Z* estimates around 1.5 early in the time series, dropping to around 0.4 by 1990 and remaining at low levels until the end of the time series (Fig. A.88).

Catch curves can also be useful for making general inferences on the selectivity of both fisheries and surveys. While selectivities can be estimated from the fitting of stock assessment models, it is useful to have model-independent estimates of selectivity that can be used to validate model-based estimates and/or provide some *apriori* understanding of selectivity. A method described in Restrepo et al. (2007) uses the residuals from the log-transformed linear catch curve analysis to infer relative selectivity-at-age. Selectivities are estimated using the ratio of observed to predicted catch proportions and then rescaling the residuals from each curve so that the maximum positive residual equals 1. The distribution of selectivities-at-age from all cohorts was examined to evaluate the time series distributions of catch selectivity at age. While this approach masks any changes that may be occurring in the selectivity across time, it is useful for gaining a general understanding of catch and survey selectivities and evaluating whether there is strong evidence for the presence of domed-selectivity (i.e., lower selectivity at older ages). Examination of the residual patterns from total catch shows full selectivity not occurring until age-6 or 7 and then remaining relatively flat well into the age-9^+ group (Fig. A.89)

TOR A.2. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). If available, consider whether tagging information could be used in estimation of stock size or exploitation rate. Characterize the uncertainty and any bias in these sources of data.

There are three primary fishery independent surveys that operate semiannually in the Gulf of Maine: the NEFSC bottom trawl survey, Massachusetts Department of Marine Fisheries (MADMF) bottom trawl survey and the Maine-New Hampshire (MENH) inshore groundfish survey. All three surveys operate in both the spring and fall with the seasonal timing differing slightly between surveys. The NEFSC survey occurs the earliest of the three spring surveys with MADMF and MENH having similar timing. The MADMF survey occurs first in the fall with the NEFSC and MENH survey having similar timing.

NEFSC bottom trawl survey

The NEFSC spring and fall bottom trawl surveys began in 1968 and 1963, respectively. Together

these two surveys represent the longest regional time series of fishery independent information. All previous Gulf of Maine haddock assessments used only the offshore survey strata (Fig. A.90). Given that haddock tend to be distributed in offshore waters outside of 3 miles (as evidenced by the recreational catch distributions, Fig. A.69), the offshore survey strata likely capture the major haddock distributions in the Gulf of Maine. The NEFSC spring survey in the Gulf of Maine occurs from late April to early May, with some annual variability, but no long-term shifts in survey timing (Fig. A.91). The mean depth of the spring survey is approximately 160 m, with no apparent shifts in the depth distribution over the survey time series. The time series trends of bottom temperature show considerable variability, though no indication of long-term trends (warming or cooling). Since 2010, temperatures have been warmer than average, though episodic departures above the mean were also observed in the early 1970s. The fall survey reaches the Gulf of Maine in late October to early November. Since the sampling design is identical between the spring and fall surveys, the mean depths are similar. Like the spring survey the fall time series trends of bottom temperature show no indication of long-term trends, though temperatures have been above average since 2010.

A frequent criticism of the NEFSC bottom trawl survey is that it does not cover the same areas where the commercial and recreational fisheries catch haddock, and thus 'misses' much of the haddock that exist in the Gulf of Maine. A comparison of the NEFSC spring and fall survey catches to commercial (total observed haddock catches by ten minute square) and recreational activity (total number of recreationally caught haddock by ten minute square) show close agreement between the location of survey and fishery catches (Fig. A.92).

The NEFSC bottom trawl survey has utilized three different vessels and three different door configurations throughout the time series of the survey (Table A.49). To maintain a consistent survey time series, survey indices are converted to 'Albatross IV/Polyvalent door' equivalents using several different conversion factors (Table A.50). The largest change in the survey time series occurred in 2009 when the FSV Albatross IV was decommissioned and replaced by the FSV Henry B. Bigelow. This resulted in changes not only to the vessel and doors, but also to the overall trawl gear and survey protocols (summarized in Table A.51). Calibration experiments to estimate survey differences were conducted in the spring and fall of 2008 (Brown 2009). The results of those experiments were peer reviewed by a panel of external (non-NMFS) experts and summarized in Miller et al. (2010). These results provide annual calibration coefficients both in terms of abundance (numbers) and biomass (weight). Further work by Brooks et al. (2010) developed length-specific abundance calibration coefficients for haddock. This method uses a segmented regression model where a constant conversion factor is applied to fish ≤ 18 cm and ≥ 51 cm, and a constantly decreasing linear regression is fit to fish between 18 and 51 cm (Fig. A.93). A comparison of the converted and unconverted spring and fall survey indices is presented in Figure A.94. It should be noted that while considerable focus has been placed on the Albatross/Bigelow calibration, the effects of door calibration are generally larger than those of the Albatross/Bigelow calibration, in all but the 2013 indices. As will be described below, there were a substantial number of juvenile fish encountered in both the spring and fall 2013 surveys which resulted in large differences between the unconverted and Albatross-converted Bigelow indices.

To evaluate differences in the day/night catchability of haddock, an analysis was conducted to

determine whether there were appreciable differences in survey catchability between daytime and nighttime tows. The results showed that generally, catchability was slightly higher in the daytime tows. However, the trends between day and night tows were similar, and in most years the day/night survey indices fell within the 80% confidence interval (CI) of the aggregate index (Fig. A.95). Splitting by day and night would result in reduced tows and lost strata (Table A.52), which would increase the likelihood that survey indices could be influenced by a single large tow in any year. Given the loss of information that would occur by using only day/night indices, and because of the similarity in the trends, it is appropriate to use both day and night tows to calculate indices for the assessment.

The time series of aggregate survey indices are presented in Table A.53 and the corresponding CVs are presented in Table A.54. Bigelow year indices (2009-2013) are presented using both the station-haul-gear (SHG) criteria that was used in the Albatross IV survey protocols to determine representative hauls as well as the revised tow-operations-gear-acquisition (TOGA) criteria that has been used under the Bigelow survey protocols. The primary difference between the SHG and TOGA criteria is that the TOGA criteria takes advantage of the extensive sensor information collected on the net performance (bottom contact, wing spread, door spread, head rope height, etc.) to determine when a survey tow should be considered 'representative' and included in survey indices. The differences in survey indices between the protocols is variable, though in general, they reflect similar trends. Unconverted Bigelow indices are presented in Table A.55. Note that the unconverted Bigelow indices are only presented using the TOGA tow criteria.

Indices-at-age for both the spring and fall surveys are presented in Tables A.56-67. The tables are as follows:

- Tables A.56-58: Spring abundance (numbers-at-age) using SHG criteria (A.56), TOGA criteria (A.57) and Bigelow-series only (A.58).
- Tables A.59-61: Spring biomass (weight-at-age) using the SHG criteria (A.59), TOGA criteria (A.60) and Bigelow-series only (A.61).
- Tables A.62-64: Fall abundance (numbers-at-age) using SHG criteria (A.62), TOGA criteria (A.63) and Bigelow-series only (A.64).
- Tables A.65-67: Fall biomass (weight-at-age) using SHG criteria (A.65), TOGA criteria (A.66) and Bigelow-series only (A.67).

Plots of the spring and fall survey indices show very strong signals in both the spring and fall surveys, though the fall survey trends tend to be less variable and catches are generally larger (Fig. A.96). The fall survey likely better captures trends in the Gulf of Maine haddock resource since haddock migrate inshore during the spring to spawn, thus the spring survey is likely more susceptible to the timing of spawning and availability within the survey area.

Plots of the numbers-at-age for both the spring and fall survey are shown in Figure. A.97. The plots show approximately four periods of recruitment pulses, corresponding to the peaks in the aggregate survey indices. There was a strong 1963 year class that tracks well in both the fall and spring surveys as well as several moderate recruitment events during the mid-1970s. The period from the mid-1980s to the mid-1990s was characterized by poor recruitment. A strong year class was spawned in 1998, followed by a moderate year class in 2003. The 2010 year class appears to be moderate-to-strong and there are signs of another strong year class in 2012. The fall 2013 age-

0 index is the second largest index on record in the calibrated time series and could be indicative of a strong 2013 year class. It is, however, premature to make any inferences about the strength of the 2013 year class until subsequent observations are collected from additional surveys. Cohorts track well within the spring (Fig. A.98) and fall (Fig. A.99) surveys. Consistent with the earlier statements regarding the overall ability of the surveys to captures trends in the resource, the fall survey tends to do a better job tracking cohorts with strong tracking out to age-8 and strong cohesion between even the age-1 and age-8 indices. The spring survey still does a reasonable job of tracking cohort strength, though the confidence ellipses tend to be larger and the relationship less well defined compared to the fall survey.

There is a general trend towards declining weights-at-age over the last decades consistent with the trends observed in the survey mean lengths (Fig. A.100) and observed in the fishery (Fig. A.86).

NEFSC survey: spatial patterns

Since the 1970s the Gulf of Maine haddock resource has become increasingly concentrated in the western Gulf of Maine (Fig. A.101). There are indications that the haddock population is beginning to repopulate areas in the central and eastern Gulf of Maine over the last decade compared to the population lows during the 1990s. A time series of Gini indices were calculated following the techniques outlined in Wigley (1996). These results support the patterns shown in distribution plots and suggest an overall concentration of the resource over the last fifty years (Fig. A.102). These patterns are similar to the spatial aggregation that has occurred in the commercial fishery that were previously noted.

NEFSC survey: catch-curve analyses

Catch curves were constructed for the NEFSC spring (Fig. A.103) and fall surveys (Fig. A.104) using methods described earlier in this report. Catch curves were conducted on a cohort-basis to avoid the confounding effects of differential year class strength on the interpretation of catch curve results. Linear regressions were fit to the log transformed catches of ages 3-8. The slope of the regressions suggest time series Z estimates on the order of 1.0 early in the time series, declining to around 0.25 late in the time series, though there is considerable variation in both the spring (Fig. A.105) and fall (Fig. A.106) cohort Z estimates.

Selectivity patterns estimated from the catch curve residual patterns suggest nearly flat selectivity across all ages for the spring survey (Fig. A.107) and increasing selectivity until about age-3 in the fall survey (Fig. A.108). The residuals patterns for both surveys do not provide compelling evidence for domed selectivity.

By comparing the ratio of catch-at-age of fishery catch to surveys we can achieve a qualitative understanding of the selectivities of each (e.g., is the fishery likely to have lower selectivity at older ages relative to the survey). While these comparisons do not offer definitive estimates of overall selectivity, they are helpful for gaining an understanding of the relationships in a model-

independent framework (Clark 2013). We've compared the proportion of fish age-6 and older caught in the NEFSC surveys relative to the fishery (Table A.68). The comparison suggest a higher proportion of age-6 fish and a lower proportion of older fish caught in the survey relative to the fishery. These results are likely skewed by the fact that fish are not fully selected to the fishery until age-6 or 7 whereas they are selected to the survey at much younger ages. While there is a general trend for lower selectivity of the older ages in the survey, this trend is not consistent. There are several years where the surveys show greater selectivity for the older ages relative to the fishery. Overall, the results are inconclusive, suggesting that at ages-6 and older there are no appreciable differences in selectivity between the fishery and the NEFSC surveys.

MADMF bottom trawl survey

The MADMF has conducted research bottom trawl surveys during the spring and fall since 1978. A complete description of the MADMF trawl survey is provided in King et al. (2010). The survey strata included in the MADMF survey covers the nearshore habitat within Massachusetts state waters in the southwestern Gulf of Maine (Fig. A.109). The MADMF surveys are conducted in relatively shallow waters (<85 m) and are limited in their spatial extent; as such, they do not provide an index of the total stock resource. Given the limited spatial extent, the MADMF survey may be more susceptible to resource availability due to timing of onshore/offshore seasonal movements (i.e., process error). The MADMF survey occurs in early late April to early May in the spring and in mid September in the fall (Fig. A.110). Similar to the NEFSC surveys there are no indications of time series trends in bottom water temperature. The majority of haddock encountered in the MADMF survey occur in the northern extent of the survey area to the south and north of Cape Ann, though the fall survey has encountered small, but regular, catches of haddock in Cape Cod Bay (Fig. A.111).

The indices from the MADMF survey are relatively flat, with the occasional spike in indices that may correspond to incoming year classes (Table A.69, Fig. A.112). Haddock caught in the MADMF survey have not been aged, though an examination of the catch distribution at length shows that the majority of haddock caught in the spring survey are between 15-30 cm and between 5- 20 cm in the fall (Fig. A.113). Comparing these length distributions to the growth curves from the NEFSC survey (Fig. A.7) would indicate that the MADMF survey is primarily picking up signals of age-1 in the spring and age-0 in the fall.

An ALK constructed from the NEFSC survey utilizing fish collected from both inshore and offshore strata was used to construct MADMF indices-at-age. The inclusion of the offshore strata was necessary to avoid considerable imputation in the age-at-length determination. Abundance (numbers/tow) indices-at-age for the spring and fall surveys are presented in Tables A.70 and A.71 and Figure A.114. Biomass indices-at-age have not been prepared due to the absence of a MADMF-specific LW relationship. Cohort tracking plots show poor tracking of cohorts in the spring survey (Fig. A.115) and only limited tracking between age-0 and age-1 in the fall survey (Fig. A.116).

Because of the limited overlap between the MADMF survey area and the Gulf of Maine haddock distribution, as well as the lack of ageing of the MADMF survey indices, this survey has not been used in previous stock assessment models. Given the noted differences in the timing of the

NEFSC and MADMF surveys, caution is warranted in the use of the MADMF survey indices-at-age in any assessment model.

MENH inshore groundfish trawl survey

The MENH inshore groundfish trawl survey has not been included in previous assessments. The MENH survey began in fall 2000 and has been conducted in the spring and fall annually in the nearshore waters of the Gulf of Maine (Fig. A.117; Sherman et al. 2005). The spring survey occurs around mid-May, slightly later than the NEFSC survey, and the fall survey in late-September/early-October at about the same time as the NEFSC survey (Fig. A.118).

The spatial distribution of catches shows widespread distribution of juvenile (≤ 30 cm) haddock; however, the highest concentrations of adult haddock are found in the southwest region of the Gulf of Maine, consistent with the NEFSC survey observations (Fig. A.119). It's unknown if the nearshore habitat in the eastern Gulf of Maine offers some sort of preferential juvenile habitat that is not exploited by adults or whether there fish in these regions don't survive to adulthood. The distribution plots over time do not show any noticeable trends in the spatial for either the spring (Fig. A.120) or fall (Fig. A.121) surveys. The time series of abundance and biomass indices show a noted increase at the end of the time series (Table A.72, Fig. A.122) which is similar to the increases observed in both the NEFSC and MADMF surveys and may be indicative of recent strong recruitment.

Haddock maturity samples have been taken since 2002 in the spring survey with sampling variable across the time series ranging from 9 to 176 fish per year (Table A.73). Given the limited sampling across time, a time series of maturation-at-age could not be constructed, but a time series averaged maturity ogive was constructed to compare to the NEFSC maturity ogive. The L_{50} for haddock captured in the MENH survey was approximately 28 cm and 20 cm for females and males respectively (Fig. A.123). This compares to 37 cm and 30 cm for males and females in the NEFSC spring survey. It is unknown whether these differences reflect true biological differences or whether there are differences in the macroscopic determination of maturity stage between the two surveys. To our knowledge no comparison has been performed to evaluate whether differences exist in the macroscopic determination of maturity between the two surveys.

The size frequencies from the MENH survey indicate that the survey catches similar size classes to that of the MADMF survey (Fig. A.124). The spring survey catches fish primarily between 15 and 30 cm and the fall survey between 5 and 25 cm. Since 2005, age samples have been collected from the MENH survey, though only the fall survey has been aged (Table A.73). While the age sampling protocol specifies that one otolith be sampled per every one cm length sample (1:1), this has not always been the case due to the lower priority haddock sampling receives in the MENH survey (*S. Sherman pers. comm.*). Owing to the small number of haddock sampled in some years, and the lower priority of haddock age sampling, the number of age samples available in any year ranges from 2 to 117 ages (Table A.73). Assuming growth was similar between the two surveys, the borrowing of the NEFSC ALKs would have minimal impacts. A comparison of the length frequency distributions-at-age shows moderate agreement at ages-0 and

1, though there is insufficient information to make any determination at ages-2 and older (Fig. A.125). Given the noted differences in the maturity-at-length, there is some concern with applying the NEFSC ALKs to the MENH survey.

Abundance (numbers/tow) indices-at-age for the MENH survey are presented in Tables A.75 and A.76 for the spring and fall surveys, respectively. The 1998, 2003 and 2010 year classes are evident in both the spring and fall surveys (Fig. A.126). Biomass indices-at-age have not been prepared because biomass indices-at-length were not readily available. The spring survey exhibits reasonable cohort tracking out to age-5 (Fig. A.127), though the cohort tracking in the fall survey is limited to between age-0 and age-1 (Fig. A.128).

For many of the same reasons discussed for the MADMF survey, caution should be used in using the MENH indices-at-age in an assessment model. The MENH spring survey does appear to have slightly better cohort tracking abilities compared to the MADMF surveys.

Inter-survey comparisons

Inter-survey comparisons show generally good agreement between the spring and fall NEFSC surveys, both in terms of abundance (numbers/tow, Fig. A.129) and biomass (weight/tow, Fig. A.130). Both surveys track reasonably well with the MADMF spring survey, though tracking with the MADMF fall and MENH surveys is poor. Comparison of age-specific indices shows some cohesion between the NEFSC, MADMF and MENH age-1 indices (Fig. A.131) as well as the fall age-0 indices (Fig. A.132); interestingly, there is generally poor agreement between the fall age-1 indices.

TOR A.3. Evaluate the hypothesis that haddock migration from Georges Bank influences dynamics of GOM stock. Consider role of potential causal factors such as density dependence and environmental conditions.

In March of 2013 the Associated Fisheries of Maine (AFM) submitted a problem statement (AFM 2013) to the NEFMC Groundfish Committee requesting that the Committee develop a management strategy that would consider the "spillover" of larger Georges Bank haddock into the smaller Gulf of Maine stock area (see Figure A.133 for a comparison of stock sizes). While the "spillover" concept was not explicitly defined, it was presumed to refer to the density-dependent expansion of an otherwise independent stock across its stock boundary. In response to the AFM problem statement the NEFMC passed the following motion at its April, 2013 meeting:

"To task the PDT and SSC to examine the issue of GB haddock spillover into the GOM stock area, provide an estimate of the amount of spillover when large year classes of GB haddock occur, and provide suggestions as to how the anticipated spill over of the strong 2010 year class can be used to adjust the GOM haddock ABC for FY 2013, 2014 and 2015."

This led to an in-depth review of the available scientific information by the staff from NEFSC, the NEFMC Groundfish Plan Development Team (GPDT) and the NEFMC Scientific and

Statistical Committee (SSC). The investigation had four primary themes which are summarized below. Further details on the analyses can be found in NEFMC GPDT (2013) and the SSC review of the GPDT analyses can be found in NEFMC SSC (2013).

Literature review of Gulf of Maine/Georges Bank exchange rates

There is extensive body of scientific literature on haddock tagging in the northwest Atlantic extending back to the early 1900s. Much of the work was performed with the objective of understanding stock structure and general movement patterns, so while the literature does indicate movement between the Georges Bank and Gulf of Maine regions, the research did not attempt to quantify the magnitude of the movement. More recent tagging studies focused tagging effort around the closed areas (Brodziak and Col 2006) and noted that the vast majority of haddock tagged on Georges Bank remained on the bank but some movement to the Gulf of Maine was observed. The Brodziak and Col (2006) report proposed a ten percent transfer from Georges Bank to the Gulf of Maine; however, any mention of an exchange rate is absent in a later report of the same study written after more tag returns had been received (Brodziak et al., 2008a). Based on the SSC's review of the tagging information it concluded that the Brodziak and Col (2006) ten percent transfer estimate is an upper bound and that the observed movement is likely reflective of movement across certain boundary areas and not indicative of processes operating across the broader stock areas (NEFMC SSC 2013).

There is little evidence from the NMFS trawl survey distribution that supports movement from one stock to the other. The deep central Gulf of Maine basin appears to provide a barrier to juvenile and adult dispersal (Fig. A.2, Begg 1998, Cargnelli et al. 1999), which would support the stock separation evident in the tagging studies. An examination of distribution plots from NEFSC bottom trawl surveys and observer catch data did not show clear evidence of the Georges Bank stock expanding beyond its stock boundaries following periods of strong recruitment (i.e., 2003 and 2010 year classes; Figs. A.134-136).

Based on the GPDT s review of the literature, it conclude that the exchange rates are not well characterized (NEFMC GPDT 2013). This conclusion was supported by the SSC (NEFMC SSC 2013).

Revisiting past assertions of recruitment synchrony between the Gulf of Maine and Georges Bank stocks

Brodziak et al (2008b) and others (Clark et al. 1982) have reported synchrony in the recruitment strength of Georges Bank and Gulf of Maine haddock stocks. A re-evaluation of the Brodziak et al. (2008b) analysis examining the concordance of haddock survey indices-at-ages from the Georges Bank and Gulf of Maine stock areas was conducted. Brodziak et al. (2008b) reported a

significant correlation (R=0.53) between Georges Bank and Gulf of Maine age-0 NEFSC fall bottom trawl survey indices. While there is some synchrony of the recruitment events (covariance of Gulf of Maine recruitment and Georges Bank recruitment) it accounts for only 28% of the total variance, leaving 72% unexplained. Although the correlation is significant, any correlation above 0.3 would be statistically significant given the length of the time series (1963-2004).

Under the hypothesis that older Georges Bank fish spill-over into the Gulf of Maine, it might be expected that younger age Gulf of Maine abundance-at-age indices would not track cohorts at older ages within the Gulf of Maine as well as younger Georges Bank abundance-at-age indices do. Paired comparisons of Kendall rank correlation coefficients indicated that differences between Georges Bank and Gulf of Maine indices were statistically significant. Gulf of Maine indices had higher concordance with older Gulf of Maine indices than Georges Bank indices. Predictions of age-3 abundance in the Gulf of Maine from age-1 abundance of Georges Bank haddock appear to be highly uncertain. The abundance of age-1 fish on Georges Bank does not seem to be a reliable way to predict future cohort strength in the Gulf of Maine.

While the GPDT did note that there was some positive synchrony in year classes, the strength of the association was weak to moderate (explanatory power of only 4-26%), generally explaining a small amount of variation in Gulf of Maine recruitment. Furthermore, some correlation in year class strength could be due to similar environmental conditions influencing the recruitment dynamics of both stocks.

Year-class tracking in survey data and Gulf of Maine haddock assessment diagnostics

The GPDT noted that, if expansion of the Georges Bank stock across its border in response to strong cohorts does occur, then fish from the large 2003 year class on George Bank should have also appeared as a strong cohort in the Gulf of Maine assessment, obscuring cohort tracking in the Gulf of Maine haddock assessment. Spillover of just 1% of the large 2003 GB year class would have approximately doubled the size of the Gulf of Maine 2003 year class and obscured cohort signals within the survey indices. If spillover of Georges Bank haddock were occurring in these large quantities, particularly given the noted asynchrony of the 2003 year class) it would add considerable variability to survey indices, making the tracking of cohorts within the Gulf of Maine stock difficult. The Gulf of Maine haddock indices from the NEFSC bottom trawl surveys show very strong tracking of individual cohorts (Fig. A.96).

Moreover, diagnostic issues should be evident in the assessment model if "spillover" were occurring. Examination of the tracking of cohorts within survey indices at age as well as assessment model diagnostics (survey residuals, retrospective patterns) yielded no evidence to support a spillover of a detectable magnitude. Additionally, maturity, weights-at-age and selectivity difference between the two haddock stocks lends further support to stock separation. The SSC supported the PDT interpretation of these diagnostics.

Analysis of the consequences of setting catch advice based on movement rate assumptions

Projection scenarios conducted by the GPDT reveal that net movement rates greater than 2% of just the 2010 Georges Bank year class into the Gulf of Maine would quickly inundate the Gulf of Maine stock due to the inequalities in stock sizes. Assuming even a relatively small percentage of net movement into the Gulf of Maine would have large negative consequences for the Gulf of Maine stock if spillover is not occurring. These projections suggest that ad-hoc adjustments of quota for spillover would increase the risk of overfishing and spawning biomass declines for the Gulf of Maine stock in 2014 and beyond. The consequences of setting catch based on movement rates, if in fact movement was not occurring, would be severe for the Gulf of Maine stock. The magnitude of the difference in stock sizes and ACLs means that even a small assumed exchange rate could result in fishery catches many times the current Gulf of Maine ACL, and could even approach the entire estimated haddock biomass in the Gulf of Maine.

Conclusions of the GPDT investigation

Based on the work performed by the NEFSC and GPDT, the GPDT concluded that there was no technical basis for adjusting the quota between the two stocks based on the "spillover" of Georges Bank haddock into the Gulf of Maine stock. The SSC agreed with this conclusion noting the significant risk to the Gulf of Maine haddock resource that could occur should an adjustment to the quota be made, particularly given "*...the lack of compelling empirical evidence.*" The SSC further noted that "*if fishermen are observing abundance of haddock in the Gulf of Maine that does not seem to comport with the outcomes of the assessment, this might be due to a recent increase since the terminal year of the last assessment update (2010). If so, the appropriate response is to update the Gulf of Maine assessment to see if that change is detected.*" A GPDT examination of updated survey data suggests the 2010 Gulf of Maine year class may be stronger than the geometric mean assumption used in the 2012 AOP projections. The appropriateness of the geometric mean assumption is discussed in depth in Palmer et al. (2014).

Re-analysis of Northeast Consortium Cooperative Haddock Tagging Program data

Between March 2005 and December 2008 the Northeast Consortium Cooperative Haddock Tagging (NCCHT) Program tagged 20,418 haddock in the Georges Bank and Gulf of Maine region. Of the releases, 531 recoveries (168 released with two tags) were reported between 2005 and 2010 (Fig. A.137). A description of the study design and a summary study results are provided in Brodziak et al. (2008a) and CCCHFA (2009). While the study did have the stated design to describe movement between the Gulf of Maine and Georges Bank stocks, the primary focus of the study was to provide information on fish movements across the boundaries of four areas closed year-round to groundfishing. Tag releases were not distributed proportional to stock

abundance or fishing effort, but released disproportionately inside closed areas (13,122, or 64%, of the releases were inside closed areas).

To date, no formal analysis of the tagging data has attempted to estimate movement rates. Miller and Palmer (2014) applied a finite-state continuous time model to the existing NCCHT data to generate estimates of mortality and movement rates. Overall, model fit was insensitive to the assumed reporting rates, with only an approximate two unit change of the maximized log-likelihood with changes to the assumed reporting rate. Parameter estimates other than those for annual and regional fishing mortality rates were not greatly affected by the assumed reporting rates over a wide range of values. There was poor precision of the natural mortality rate estimate, but the point estimate was consistently between 0.2 and 0.3 for reporting rates ≥ 0.3. The instantaneous migration rates implied greater movement of individuals into the Gulf of Maine than to the Georges Bank stock area given that they survive all sources of mortality and the estimates are not sensitive to the assumed reporting rate. With a reporting rate = 1, the migration rate estimates imply individuals starting in the Gulf of Maine have approximately 94% probability of being in the Gulf or Maine 1 year later given they survived the interval. Individuals starting on Georges Bank have approximately 86% probability of being on Georges Bank one year later given they survived the interval. Fishing mortality rate estimates were negatively correlated with reporting rates. In 2005, fishing mortality was estimated to be greater in the Gulf of Maine than Georges Bank whereas in years 2006 to 2008, estimates were similar for the two stock areas. In 2009 and 2010 estimates for the Georges Bank were greater than the Gulf of Maine.

The authors stressed that the results are greatly affected by the location, size of fish, and timing of the releases. Many of the releases were near the stock boundaries and in areas closed to groundfishing. The proximity to the stock boundaries might cause migration rates to be greater than the general population if there are substantial portions of the populations further away from stock boundaries and they move at similar speeds and directions. Releases in the closed areas may result in lower estimated fishing mortalities than the general population if the fish stay in the vicinity for some time which may be the reason for the lower fishing mortality estimated for unmixed individuals for the first 2 months after release.

The SAW 59 WG found the mortality rates consistent with other lines of information (e.g., catch-curve analyses, assessment model outputs), but felt that the mixing rate estimates were high and inconsistent with the analyses conducted by the GPDT. The SAW 59 WG did not feel that the tagging exercises conducted to date had been designed in a way that would allow annual interchange proportions to be reliably estimated. The SAW 59 WG also examined assessment models that allowed for estimation of mixing between stocks. These model results are described under TOR 4, but generally, the estimated annual percent mixing from Georges Bank to the Gulf of Maine from these models was low (<0.8%), and consistent with the GPDT analysis. Given the conflicting information provided by the NCCTP data, the SAW WG recommended that additional research designed to expressly determine between-stock movement rates is needed (see TOR8).

TOR A.4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series (integrating results from TOR-3), and estimate their uncertainty. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

Update of the 2012 AOP ADAPT-VPA model

There were substantial changes in the underlying data used for the current SAW/SARC 59 assessment compared to the data used in the GARM III and subsequent 2012 AOP assessments. The major changes include: reestimated landings-at-age, modifications to the fleets included in commercial discards, conversion from the MRFSS to MRIP recreational sampling program and calibration of historical MRFSS time series, inclusion of recreational discards and an assumption of 50% discard mortality, new estimates of weights-at-age that reflect landings and discards, minor revisions to the maturity ogive, and updates to the NEFSC survey indices. Additionally, there are three more years of catch and survey information that needed to be incorporated into the model. To fully understand how these data changes impact the VPA update, a bridge was constructed to transition from the 2012 AOP assessment model to a fully updated model.

The 2012 AOP assessment was conducted using the Adaptive Framework Virtual Population Analysis (ADAPT-VPA) model (NOAA Fisheries Toolbox ADAPT-VPA version 3.1.0, 2010). The most recent version of the ADAPT-VPA software is version 3.4.5 (2014). The differences between the VPA model versions primarily affect the usability and graphical interface; there should be no differences in the model calculations. The model formulation used in for the 2012 AOP assessment included an age-9^+ plus group with the 'backward' computation used to estimate the plus group stock size. For the SAW/SARC 59 model formulation, the 'combined' computation will be applied. The difference between the two methods relates to how the fishing mortality is calculated for the plus group. The backward method computes F on the plus-group as the product of the plus group ratio (α) and $F_{A-1,t}$. The stock size for the plus group is then sequentially calculated for years t=1 to T. The backward method can result in the predicted catch of the plus group not matching the observed catches, additionally, since all years are treated independently, impossible stock sizes can result (i.e., $N_{A,t} > \Sigma N_{A-1,t-1} + N_{A,t-1}$). When a low proportion of the population is in the plus group, the impacts of these issues are negligible. The combined computation method address the shortcomings of the backward computation by calculating consistent F and N that adhere to the catch equation and the input ratio of F between the oldest true age and the plus group age. The disadvantage of the combined method is that it disassociates the F on the oldest true age from the younger ages and can result in the F on the oldest true age and the plus group much higher or lower than the other ages. This approach is more appropriate when the plus group abundance is relatively large and the ratio of F between the oldest true age and the plus group age is well determined as is the case as it is in many of the years of the Gulf of Maine haddock time series. See the NOAA Toolbox ADAPT-VPA Version 3.0 Reference Manual for a full description of the methods.

Commercial landings and discards from 1977 to 2010 as well as recreational landings from 1981 to 2007 were accounted for in the model. Tuning indices included the NEFSC spring ages 1-6^+, and NEFSC fall ages 2-8^+ lagged forward by an age and a year (e.g., 2006 age-2 fish become 2007 age-3 fish in the model). The fully recruited F is determined as the unweighted average F

on ages 6 to 8. The terminal year F on age-8 is estimated using the aggregate survivorship of age-6 and 7 fish from year t to t+1. In years prior to the terminal year, F on the oldest age is estimated using stock sizes from ages 6 and 7. Maturity-at-age was estimated from a time series average of the maturity observations from 1977 to 2010. Spawning stock biomass was calculated assuming an April 1 spawning period (0.25 into the calendar year). Natural mortality is assumed age and time invariant at M=0.2.

The general approach used to build the bridge from the 2012 AOP VPA to an updated SAW/SARC 59 VPA was as follows (model numbers correspond to the model summaries presented in Table A.77):

- Model 1: Re-run of the 2012 AOP update of the GARM III VPA model.
- Model 2: Update the ADAPT-VPA software to version 3.4.4.
- Model 3: Modify the plus-group calculation from 'backward' to the 'combined' method.
- Model 4: Include revised catch-at-age estimates of commercial landings, discard and recreational landing (harvest). Update catch WAA.
- Model 5: Include recreational discards-at-age assuming 50% discard mortality. Update catch WAA and stock WAA.
- Model 6: Add three additional years of catch data (2011-2013) and update all NEFSC survey indices-at-age. ***This model represents an updated VPA model.***

The results from the bridge building exercise are presented in Table A.78.

Updating the VPA software had no impact on model results (Fig. A.138-140). Using the combined method to handle the plus group calculations resulted in a rescaling of spawning stock biomass (Fig. A.138) and minor changes in the ages-6 to 8 average fishing mortality ($F_{6\text{-}8}$) time series (Fig. A.139). The combined method resulted in slight improvements in overall model fit as evidenced by the mean squared residual, CVs on the terminal ages and retrospective Mohn's rho values (Table A.78). Updating the catch data and incorporating the recreational discards increased the mean squared residuals and CVs, had variable impacts on the terminal population size and led to an overall decrease in the retrospective pattern; however, there was little impact on the overall assessment results in terms of spawning stock biomass, fishing mortality and age-1 recruitment.

Adding three additional years of data to extend the VPA through 2013 had minimal impacts on the model diagnostics and model results through 2010. The most notable feature of the 2013 update is the presence of what appear to be several strong year classes at the end of the time series, beginning with the 2010 year class (Fig. A.140). The 2012 AOP update did not provide a direct estimate of the 2010 year class owing to the sparseness of the information available to achieve a reliable estimate (a single survey observation). Instead, the 2012 AOP update applied a time series geometric mean to estimate the size of this year class in the t+1 year (see Palmer et al. 2014a for an evaluation of this assumption). With three more years of survey and catch data, it now appears that the 2010 year class was above average. Additionally, both the 2012 and 2013 year classes appear to be above average, though caution should be given to these estimates because of the limited observations available.

The overall retrospective pattern of the 2013 ADAPT-VPA model decreased relative to the previous models (Fig. A.141). The retrospective peels from the 2013 ADAPT-VPA update show variable model retrospective error, with retrospective peels of both spawning stock biomass (Fig. A.142), fishing mortality (Fig. A.143) and age-1 recruitment (Fig. A.144) having positive and negative relative differences over the 7-year peel and no consistent patterning. The survey fits to the final 2013 update of the ADAPT-VPA model do not exhibit strong residual patterns in the fits to either the spring (Fig. A.145.a) and fall (Fig. A.145.b-c) survey indices-at-age. Survey catchabilities (*q*) for the minimum area swept survey indices-at-age were relatively flat across ages in the spring survey and well below those of the fall survey (Fig. A.146). The fall survey *q*s increase with age, with the *q*s on the ages 5-8$^+$ indices exceeding 1 (fit as ages-6 to 9$^+$ lagged forward in the model). These patterns are nearly identical to those of both the GARM III (NEFSC 2008) and 2012 AOP VPA model (NEFSC 2012). While the *q* values on the older ages in fall survey are large, the uncertainty of these estimates is large. Partial recruitment patterns over the past five years are variable, but indicate that haddock in the Gulf of Maine do not fully recruit to the fishery until age-7 (Fig. A.147).

General conclusions from the updated 2013 ADAPT-VPA are:

- Use of the combined method for the plus group calculation had the largest impact on the overall assessment results, with a downward rescaling of spawning stock biomass and variable impacts on the time series of average fishing mortality.

- The updates to the data inputs had only minor impacts on the model results.

- Extending the time series through to 2013 did not change the historical perception of the resource. The more recent data does suggest that there are at least two strong year classes (2010 and 2012) that have been spawned over the past three years beginning in 2010. There has been an overall increase in the spawning stock biomass, primarily as result of the maturation of the 2010 year class. The projections from the 2012 AOP update assumed the size of the 2010 year class to be equal to the geometric mean recruitment of the time series (1.1 million fish). Based on the updated VPA, this assumption underestimated the year class size.

Development of an ASAP statistical catch-at-age model

The 32nd SAW WG concluded that "[t]*here is insufficient length and age sampling of US commercial landings to reliably estimate catch at age required to complete a VPA-based analytical assessment of this stock.*" (NEFSC 2001). While the results of the GARM III and 2012 AOP assessments show that catch-at-age could be constructed to support a defensible VPA model, the amount of imputation required to construct the catch-at-age time series, primarily in the way of commercial discards and recreational catch, brings up questions as to whether this stock would be better assessed using a statistical catch-at-age model where it is not assumed that catch is known exactly. Additional support for exploring a statistical catch-at-age model include: the ability to explore alternative model formulations to counter/lend support to VPA results, ability to estimate a stock-recruit relationship internal to the model, and the ability to explicitly

handle data uncertainty, particularly with respect to uncertainty in the survey data.

The use of a statistical catch-at-age model for the Gulf of Maine haddock assessment was explored. More specifically, the statistical catch-at-age model, ASAP (Age Structured Assessment Program v3.0.17, Legault and Restrepo 1998), which can be obtained from the NOAA Fisheries Toolbox (http://nft.nefsc.noaa.gov/). ASAP is an age-structured model that uses forward computations assuming separability of fishing mortality into year and age components to estimate population sizes given observed catches, catch-at-age, and indices of abundance. Discards can be treated explicitly. The separability assumption is partially relaxed by allowing for fleet-specific computations and by allowing the selectivity-at-age to change in blocks of years. Weights are input for different components of the objective function which allows for configurations ranging from relatively simple age-structured production models to fully parameterized statistical catch-at-age models. The objective function is the sum of the negative log-likelihood of the fit to various model components. Catch-at-age and survey age composition are modeled assuming a multinomial distribution, while most other model components are assumed to have lognormal error. Specifically, lognormal error is assumed for: total catch in weight by fleet, survey indices, stock recruit relationship, and annual deviations in fishing mortality. Recruitment deviations are also assumed to follow a lognormal distribution, with annual deviations estimated as a bounded vector to force them to sum to zero (this centers the predictions on the expected stock recruit relationship). For more technical details, the reader is referred to the technical manual (Legault 2012).

Description of the SAW/SARC 59 ASAP base model

Model sensitivities

In evaluating the ASAP model for SAW/SARC 59, many model configurations were explored. In total, there were over 70 model runs conducted of the ASAP model. Overall, the variability in model results was small (Figure A.148), indicating that assessment results are robust to alternate assumptions and configurations ; however, there is considerable variability of the terminal estimates owing to model uncertainty in the estimation of two potentially large cohorts at the end of the time series. The nature of the sensitivity models fell into two different categories: 1) determining whether an alternate model formulation offered improved fit to the data; and 2) evaluating the sensitivity of the model with respect to a range of assumptions. Table A.79 provides a short summary of the number of models by sensitivity category as well as indicating where in this report a description of those sensitivity models can be found. The process of transitioning from the VPA to the ASAP model and evaluation and fine tuning of the ASAP model is described below. While attempts have been made to describe the development in a linear process, the model development process is inherently non-linear and fraught with dead-ends and second guessing of how the development process could have been better conducted.

Construction of a base ASAP model (ASAP_BASE)

An ASAP model for Gulf of Maine haddock was developed using past experience of ASAP model formulations for other groundfish stocks (e.g., Gulf of Maine cod, NEFSC 2013). Consistent with the VPA model formulation, the base ASAP model (ASAP_BASE) was constructed using an age-9 plus group and including data from only the years where catch-at-age data are available (1977-2013). The age-9^+ group decision is based primarily on the poor precision in estimating catch-at-age beyond age-8 in the commercial fishery (Table A.18) and sparseness of the survey observations at older ages (e.g., Fig. A.97). Unlike the VPA model which was run using calibrated survey indices based on the SHG station selection criteria, the base ASAP model was run using calibrated survey indices based on the TOGA station selection criteria for the Bigelow survey years (2009-2013). This change was done to keep the station selection criteria consistent with the Bigelow sampling protocols. The impacts of this change had negligible impacts on the assessment results (see Appendix A.2).

Fishery catches were modeled as a single fleet, with both commercial and recreational fleets combined. A sensitivity model exploring the treatment of commercial and recreational fleets separately is presented in Appendix 2. Three different fishery selectivity blocks were applied (1977-1988, 1989-2004, 2005-2013). The choice in selectivity blocks was informed by the previous experience with other Gulf of Maine groundfish stocks. The 1988/1989 split corresponds to the start of the at-sea observer program and the direct observation of fishery discards and length frequency information (though length sampling was sparse in the early years). Beginning around 1992, the magnitude of recreational catch began to increase. There were no major regulatory changes specifically in 2004 or 2005 that would give *apriori* expectation for a change in selectivity; however, the recreational minimum size dropped from 23” to 19” between 2002 and 2004 and there was a major change in the commercial dealer reporting system (paper to self-reported electronic) for all federally permitted dealers in 2005 which could have also impacted biological sampling of the commercial fishery. Perhaps more importantly, 2005 corresponds with the point when the declines in mean size-at-age stabilized; size-at-age has remained relatively stable since 2005 (e.g., Fig. A.86). In 2007, the commercial minimum size was reduced from 19” to 18”, with further reductions to 16” in July 2013. Minimum retention sizes were increased to 21” in the recreational fishery in 2013. The selectivity block assumptions were evaluated using several sensitivity models which are described in Appendix A.2.

Base on the partial recruitment patterns from the VPA selectivity-at-age was freely estimated with selectivity fixed at 1.0 for age-7, but allowed to be freely estimated at ages 8 and 9^+. The VPA partial recruitment patterns (Fig. A.147) were suggestive of limited doming of the fishery selectivity. While not conclusive, the catch-curve analysis also provided some indication of lower selectivity at older ages in the fishery (Fig. A.89). Similarly, the two NEFSC surveys were fixed at 1.0 on age-6, though the VPA catchability patterns (Fig. A.147) indicated that maximum selectivity may occur around age-5 in the spring survey and not until age-8 or older in the fall survey. The VPA catchability patterns are not dissimilar to the patterns observed in the catch curve analysis (Figs. A.107-108). The selectivity assumptions applied in the ASAP_BASE model were further evaluated using several sensitivity models described later in this report.

Like many haddock stocks, recruitment of Gulf of Maine haddock is highly episodic and not well described by traditional stock recruitment relationships. Given this, recruitment was modeled as

deviations from the geometric mean (steepness fixed at 1.0). The ASAP model allows the deviations to be constrained by applying a penalty on the deviations. For the base model, the penalty function (lambda) was set at 0.2 and the CVs on the recruitment deviations were set at 0.5 for all years except the final three years, which were set at 0.1. This was an attempt to apply 'shrinkage' to the mean of the terminal year cohorts where there are limited observations available from which to accurately estimate year class size. This decision was based on past experience with Gulf of Maine haddock in a VPA model framework (Palmer et al. 2014a). The treatment of recruitment deviations was subsequently evaluated extensively with this work described later in this report.

The effective sample size (ESS) for the fishery was set at 80 and 15 and 20 for the NEFSC spring and fall surveys, respectively. CVs on the total catch were set at 0.15 for the period prior to recreational catch estimates (1977-1980), 0.10 for the period prior to direct discard estimates (1981-1988) and at 0.05 for the remainder of the catch time series (1989-2013). The CVs on the surveys were initially set equal to the bootstrapped CVs presented in Table A.54. The bootstrapped CVs characterize the sampling, or observation error, but additional process error may be present in the survey indices that are not reflected in the bootstrapped CVs. As with other model assumptions, ESS and CV assumptions were fully evaluated prior to the formulation of the final preferred ASAP model.

Diagnostics and results of the base ASAP model (ASAP_BASE)

A summary of basic model diagnostics for the ASAP_BASE model is provided in Table A.80. Root mean square error (RMSE) values are generally high (with the exception of the catch [Fleet1]), indicating over fitting of the data. Model fits to the fishery catches were good, and improved over time. Fits to catches early in the time period were variable, and not unexpected given larger CV placed on these catches owing to the higher uncertainty. There is some patterning of residuals over time, however the residuals are small. Generally, there is close agreement between modeled and observed catches (Fig. A.149).

The ESS of 80 assumed for the fishery catch-at-age appears reasonable for the later part of the time series, but is likely too high for the early parts of the time series (Fig. A.150), particularly the period in the late 1980s and early 1990s when there was severe truncation in the catch age structure (Fig. A.84) and low landings. Fits to the observed catch-at-age (Fig. A.151.a-c) were relatively good with several modes associated with moderate-to-strong year classes being picked up well (e.g., 1998 and 2003 year classes). There were no large residual runs indicative of year effects; there are however, some small year class effects associated the 1998 and 2003 year classes (Fig. A.152). Fits to the mean catch-at-age suggest that the catch-at-age is being fit too tightly early in the time series (Fig. A.153), consistent with the ESS fits.

Estimated fishery selectivities were flat-topped in the first selectivity block (1977-1988), but slightly domed in blocks 2 (1989-2004) and 3 (2005-2013; Fig. A.154). The selectivity estimates hit several parameter boundaries in blocks 1 and 3 (Table A.81) and will require additional fine tuning. The fishery selectivity parameters are well estimated with CVs ≤ 0.20 on most ages with the exceptions of the youngest and oldest ages. The selectivity trends with decreasing selectivity

on the younger ages through time is consistent with management measures that have gradually increased mesh sizes and minimum retention sizes.

Fits to the NEFSC spring survey index exhibited no strong residual patterning (Fig. A.155). Overall, the model tracks the spring survey index well, though not unexpectedly, large residuals are observed for years with exceptionally low (e.g., 1990) and high (e.g., 2013) survey indices. The input ESS value of 15 were generally supported by the modeled estimates (Fig. A.156), though as noted with the fishery ESS values, the information content in the indices-at-age is variable over time and appears lower in the earlier third part of the time series. There is a decent fit of observed to predicted age compositions with an absence of year- or year class-effects and no large residual blocks (Fig. A.157). Similar to the ESS plot, the fits to the mean age suggest that the current ESS of 15 is likely too high, particularly in the first third of the time series (Fig. A.158).

The models fit the NEFSC fall survey reasonably well (Fig. A.159). Several large outliers are apparent, first around 2000 and most recently in 2011-2013. ESS values of 20 are generally consistent with the modeled estimates, though similar to the catch and spring model ESS estimates, there appears to be lower information content in the late 1980s/early 1990s (Fig. A.160). The fit to the age composition data was generally good, though there is some patterning particularly at the younger ages (< age-3) and in the plus group (Fig. A.161). The overall fit to the mean catch-at-age is reasonable though the RMSE values greater than 2 suggest that the ESS values should be lowered to account for higher uncertainty in the indices-at-age (Fig. A.162).

The NEFSC spring survey exhibits higher selectivity at younger ages relative to the fall survey (Fig. A.163). The selectivities are generally well estimated with CVs less than 0.20 for most ages, though the CV values do suggest that model estimates have hit boundaries for several ages (Table A.81). The selectivity patterns are generally consistent with the catchability patterns from the VPA (Fig. A.147) and the residual patterns from the catch curve analyses (Figs. A.107-108).

Survey catchabilities (q) are presented in Figure A.164. The NEFSC spring survey catchability estimate (q=0.26) is consistent with the catchability estimates from the VPA. The fall survey catchability estimate from the ASAP_BASE model (q=0.99) is considerably lower than the qs on the older ages in the VPA model. Profiling over a range of fall survey q values showed a model preference within the range of 0.8 to 1.0 (Fig. A.165). Within this range, there were minimal impacts on estimates of spawning stock biomass and fishing mortality. Since minimum area swept survey indices were used in the fitting of both the VPA and ASAP model, a q=0.99 could be suggestive that the survey is 100% efficient which is unlikely and indicative of model scaling problems. However, it should be noted that the minimum area swept scaling was performed using a wing spread footprint of 0.012 nm^2 per survey tow for the Albatross survey. If haddock herding occurs between the trawl doors, as has been reported in the literature (e.g., Engås and Godø 1989), survey catchabilities based on a wing spread footprint could represent upper bounds on survey catchability. A sensitivity model using door spread footprint assumption of 0.023 nm^2 per survey tow resulted in estimates of fall q of 0.48 and a spring q of 0.13 with no impacts on model fit or results (Table A.82). The true catchability of the NEFSC surveys are unknown, but with respect to the NEFSC fall catchability estimates, q values within the range of 0.48 to 0.99 are not suggestive of model scaling issues.

Estimates of spawning stock biomass recruitment are similar between the ASAP_BASE model and 2013 update of the VPA model (Fig. A.166). The peak of spawning stock biomass in the early 2000 period is scaled higher in the ASAP model, but the biomass in the early parts of the time series are of equivalent scales. The estimates of the 2010 and 2012 year class are considerably higher in the VPA model; this is expected owing to the shrinkage implemented in the ASAP_BASE model. The notable difference between the ASAP and the VPA models in the fishing mortality patterns. It should be noted that the basis that the fishing mortality basis varies between the two models, with ASAP fishing mortality expressed as the mortality on the fully recruited age classes (F_{full}) and the VPA expressed as the average mortality on ages 6-8 (F_{6-8}). However, the basis for expressing fishing mortality does not explain the differences between the two model runs. Another likely contributing factor to the differences in fishing mortality trends is the inherent difference between the estimation approaches of VPA and statistical catch-at-age models, specifically, the exact fitting of catch within the VPA framework. The largest differences between the two models occurs during the late 1980s/early 1990s when stock sizes were at time series lows (i.e., model variability in estimating fishing mortality on a small population).

Like the VPA model, the ASAP retrospective error was small (Fig. A.166, Table A.80). Coefficients of variation on SSB, F and recruitment have generally been less 0.2 except at the end of the time series where CVs approach or exceed 0.2 (Fig. A.167). Recruitment patterns for the Gulf of Maine haddock stock appear to have an auto-regressive nature with blocks of moderate-to-strong recruitment followed by period of poor recruitment leading to strong residual patterns in the deviations about the geometric mean (Fig. A.168). The periods of lowest recruitment correspond to periods of low spawning stock biomass (Fig. A.166).

Refinements of the ASAP base model

The model runs explored in the following section were intended to fine tune the base ASAP model and further explore issues related to model assumptions and initial configurations evident in the ASAP_BASE model diagnostics described above. Specifically, the model explorations described below address selectivity, the assumed precision of fishery catches, survey process error, and modeling of stock recruitment. Sensitivities not related to the transition from the ASAP_BASE model to the final SAW/SARC 59 model are described in detail in Appendix A.2. A summary of model diagnostics and results from these intermediate models is provided in Tables A.83 and A.85.

<u>ASAP_final_temp1 model</u>: The modeling of stock recruitment relationship, specifically, the amount of constraint applied to recruitment deviations was given considerable attention in several sensitivities described in depth in Appendix 2 and summarized briefly below. Of specific concern was the variability of the estimated sizes of the 2010 and 2012 year classes under a range of model configurations. The base model applied a penalty function (lambda) of 0.2 and set the CVs on the recruitment deviations at 0.5 for all years except the final three years, which were set at 0.1. Within ASAP, the CV value is converted to a variance and standard deviation that are used in the negative log likelihood calculations of the model minimization process

(Legault 2012). The tightening of CV bounds on the terminal recruitment estimates was an attempt to apply 'shrinkage' to the mean of the terminal year cohorts were there are limited observations available from which to accurately estimate year class size.

Several different methods of modeling recruitment deviations were explored: (1) setting the lambda to zero and allowing recruitment estimates to be unconstrained; (2) setting lambda at 1, but then applying some constraint on the recruitment deviations through the adjustment of the CV values. Under option 2, several different configurations were explored: a) hold CVs constant throughout the time series (no shrinkage); b) applying shrinkage over the terminal four years (e.g., those years not fully recruited to the surveys or fishery similar to the approach used the ASAP_BASE model); and c) applying shrinkage to only the terminal year.

A sensitivity analysis was conducted evaluating the retrospective performance of the ASAP model under the four different configurations described above. The performance of the model was evaluated back to 2000 to understand how well the model estimated the size of the large 1998 year class with only three years of information, which is identical to the current situation with respect to being able to estimate the size of the 2010 year class. While the results of the retrospective analysis were not conclusive, this analysis did suggest that within a Gulf of Maine haddock ASAP model, the 'no shrinkage' method offered a lower degree of recruitment estimation error compared to the other methods evaluated.

The specification of the recruitment deviations CVs will affect the level of constraint the model places on recruitment deviations. The sensitivity of the model to recruitment deviation CVs was evaluated by profiling across CV values from 0.6 to 2.4. Based on the profiles of the likelihoods, there is model preference for CVs on the order of 2.0; this is the point when the RMSE on the recruitment deviations approaches 1. Within this range, model results are relatively stable (e.g., 2013 SSB, 2010 and 2012 year class sizes and SSB and F retrospective patterns). One concern with the model runs at the high CVs are the fits to the survey indices; models with high recruitment deviation CVs tend to tightly fit both the 2013 spring and fall survey observations, both of which have large age-1 indices. Based on the model fits to large survey observations earlier in the time series, this degree of fit seems unlikely.

Based on the results of this exploratory work, the ASAP_BASE model was refined by setting a lambda value of 1 and holding the CVs constant at 2.0 for the entire time series (no shrinkage to the mean in the terminal years). Using this revised model configuration (ASAP_final_temp1), the ASAP model was further refined in an iterative fashion.

<u>ASAP_final_temp2 model</u>: Next, the CVs on the fishery catch were increased from the range of 0.05-0.15 used in the ASAP_BASE model (earlier years had higher CVs) to 0.10-0.20 in the ASAP_final_temp2 model (1977-1980=0.20, 1981-1988=0.15, 1989-2013=0.10). The low RMSE value in the ASAP_BASE model motivated this change. This change had minimal effects on the model results, but did increase the catch RMSE from 0.33 to 0.65. While the RMSE value was still less than 1, the revised CV levels approach the maximum level of uncertainty in the catch that is believable.

<u>ASAP_final_temp3 model</u>: The RMSE values on the fits to the survey indices were high (>1.5)

indicating an overfitting of the survey indices. The input survey CVs were initially set equal to the bootstrapped CVs presented in Table A.54. The bootstrapped CVs characterize the sampling error, but additional process error may be present in the survey indices that are not reflected in the bootstrapped CVs. In the ASAP_final_temp3 model, the CVs on the NEFSC spring and fall survey were increased by 0.3 and 0.2, respectively. The increase in survey CVs resulted in the model not fitting more recent survey observations as closely; this in turn impacted terminal estimates in the model with decreases in the estimated size of the 2010 and 2012 year classes and 2013 SSB and increases in 2013 fishing mortality. The RMSE values of the revised model were closer to 1.

ASAP_final_temp4 model: Comparison of input ESS values and model calculated ESS for both the catch-at-age and survey indices-at-age from the ASAP_BASE model indicated that a constant time series ESS value was not appropriate. In the ASAP_BASE model the input ESS on catch was set at 80 and the NEFSC spring and fall trawl surveys were set at 15 and 20, respectively. Using an iterative approach the input ESS values were adjusted in stanzas (5-14 year blocks) to approximately match the model calculated ESS. These adjustments had small impacts on the model results. It should be noted that an attempt was made to adjust the ESS using the stage-2 multiplier approach described in Francis (2011). However, the resulting ESSs were extremely small (e.g., catch ~ 20, surveys ~5) indicating that the information content of the age data was unreasonably low given the strong cohort signals present in the Gulf of Maine haddock data. This approach was not pursued further.

ASAP_final_temp5 model: This model run attempted to address some of the boundary solutions achieved in the selectivity-at-age estimation in the ASAP_BASE model by increasing the fully selected age in the catch selectivity blocks from age-7 to age-8. The fully selected age in the spring survey was adjusted from age-6 to age-4 and the in the fall survey from age-6 to age-8.

ASAP_final_temp6 model: The ASAP_final_temp5 model was still hitting a bound at 1 for the estimated age-9^+ selectivity in blocks 1 and 2 of the catch. In this step, the selectivities were fixed at 1 for these ages (flat top selectivity). A comparison between the selectivity-at-age estimates from the ASAP_BASE and ASAP_final_temp6 models is provided in Table A.84.

The ASAP_final_temp6 model was the preferred model brought forward to the SAW 59 WG. During the SAW 59 WG discussions, the WG remained concerned about the high CV applied to the recruitment deviations (2.0) and the lack of constraint this value provided. In particular, the WG expressed concern over the size of the 2012 year class in the ASAP_final_temp6 model – at 21.5 million fish it would be the largest year class in the assessment time series and more than 50% larger than the 1998 year class, the second largest year class. The WG felt a more conservative approach was warranted given that the size of the 2012 year class was based on only two survey observations (2013 age-1 spring and fall indices-at-age). Using the ASAP_final_temp6 model, the WG revisited some of the early recruitment sensitivities performed on the ASAP_BASE model to evaluate model results at lower CVs and the impacts of 'shrinkage' to the mean on terminal recruitments. Specifically, three different model sensitivities were conducted:

ASAP_final_temp7: The CV on the recruitment deviations was reduced from 2.0 to 1.0.

ASAP_final_temp8: The CV on the recruitment deviations was reduced from 2.0 to 1.0 for the years 1977 to 2010 and to 0.5 for the years 2011 to 2013.

ASAP_final_temp9: The CV on the recruitment deviations was reduced from 2.0 to 1.0 for the years 1977 to 2012 and to 0.5 for 2013.

The results from these sensitivity models are summarized in Table A.85. Overall, the WG was more comfortable with the lower CV on the recruitment deviations; however, the WG felt that the ASAP_final_temp8 ('shrinkage' on 2011-2013 recruitment estimates) put too much constraint on the 2010 year class estimate given that the model had six survey observations in addition to catch information, and therefore should have sufficient information with which to achieve a reliable estimate. The ASAP_final_temp9, which placed a lower CV on only the 2013 estimate (2012 year class at age-1), offered a compromise between the constant CV and 'shrinkage' approaches. Compared to the ASAP_final_temp7 model (constant CV of 1.0) the ASAP_final_temp9 model reduced the size of both the 2012 (46%; 16.7 million to 9.0 million fish) and 2010 (15%; 6.7 million to 5.7 million fish) year classes, and had lower SSB and higher F in 2013.

The WG acknowledged that both the ASAP_final_temp7 and ASAP_final_temp9 models were equally plausible and noted that the size of the 2012 year class represents the largest source of uncertainty in this assessment. However, for the purposes of selecting a 'preferred' model for use in determining stock status, the WG selected the ASAP_final_temp7 as the best option. The WG examined preliminary reference points based on both models and concluded that stock status determination was robust to model selection. The WG recommended that the approach used in the ASAP_final_temp9 model be carried through to catch projections to more fully capture assessment uncertainty (see TOR 7).

Prior to finalizing model selection, the WG made several minor adjustments to both the ASAP_final_temp7 and _temp9 model runs to address concerns with model estimated survey selectivity. There was concern among WG members that the 'saw tooth' nature of the estimated survey selectivity was biologically unrealistic (see Table A.84, the selectivity patterns of ASAP_final_temp7 and _temp9 were identical to those of the temp6 model shown). The WG opted to model survey selectivity as flat-topped with selectivity fixed at 1 for ages-4 and older in the spring survey and ages-6 and older in the fall survey. All other ages were freely estimated. This is identical to the approach taken in the SCAA models discussed later in this TOR. The changes in selectivity had only minor impacts on the model results (Table A.85).

The final models put forward by the SAW 59 WG are:

ASAP_final_temp10 (*preferred*): Recruitment CV set at 1.0 for the entire time series.
ASAP_final_temp11 (*projection sensitivity only*): Recruitment CV set at 1.0 for the years 1977 to 2012 and to 0.5 for 2013.

Diagnostics and results of the preferred ASAP model

RMSE values are improved over those of the ASAP_BASE model. The RMSE of the spring and fall surveys are within the 80% confidence interval of the root mean square error from a normal distribution (Fig. A.169). While the catch RMSE value is well below 1, this is common when fitting catch information and generally, not a concerning model diagnostic. Fits to catches early in the time period were variable, and expected given the larger CV placed on these catches owing to their higher uncertainty. There is some patterning of residuals over time, however the residuals are small and overall, there is close agreement between modeled and observed catches (Fig. A.170).

The ESS adjustments made to the ASAP_BASE model show improved agreement between the input ESS and model calculated ESS (Fig. A.171). Catch ESS varied from 20 in the 1988 to 1992 period to 140 between 2003 and 2013. Overall, fits to the observed catch-at-age were good (Fig. A.172.a-c), with very little residual patterning (Fig. A.173). Fits to the mean catch-at-age suggest that the catch-at-age are reasonably well estimated (Fig. A.174) though there are large residuals between 1989 and 1992 corresponding with a period of low catches and reduced biological sampling.

Fishery selectivities were flat-topped in the first (1977-1988) and second (1989-2004) selectivity blocks, but there is evidence of a slight dome in the third block (2005-2013) (Fig. A.175). As discussed in Appendix 2, the doming in block 3 may reflect the increasing contribution of the recreational fishery to the total catch late in the time series.

Similar to the ASAP_BASE model, the ASAP_final_temp10 model tracks the spring survey index well with no strong residual patterning (Fig. A.176). The adjusted ESS inputs agree with the model calculated ESS values (Fig. A.177). The spring survey input ESS varied from 5 in the 1987 to 1992 period to 25 between 2005 and 2013. There was no concerning patterning of indices-at-age residuals, and overall the model fit the indices-at-age well (Fig. A.178). With the exception of three large outliers (1987, 2002, 2010) the fits to the mean indices-at-age are reasonable (Fig. A.179).

Similarly, the fall survey index was fit well by the model (Fig. A.180). The adjusted ESS inputs agree with the model calculated ESS values (Fig. A.181), with fall ESS varying from 7 in the 1984 to 1997 period to 30 between 1998 and 2008. As with the spring survey indices-at-age, there was little patterning of indices-at-age residuals, with residuals being small overall (Fig. A.182). With the exception of four large outliers (1988, 1992, 2007, 2012) the fits to the mean indices-at-age are reasonable (Fig. A.183).

As with the ASAP_BASE model, the survey selectivities estimated in the ASAP_final_temp10 model show the NEFSC having greater selectivity for younger fish compared to the fall survey (Fig. A.184). The selectivities are generally well estimated with CVs less than 0.20 for most ages (Table A.84). The estimated survey catchability (q=0.25) is nearly identical to the ASAP_BASE model, though the fall survey catchability is about 7% lower (q=0.92) (Fig. A.185). As was discussed previously, while the fall q value approaches 1.0, given possible herding behavior and uncertainty in the true catchability of the survey gear, there is little indication of scaling concerns.

Recruitment of Gulf of Maine haddock is highly episodic. Since 1977 there have been several strong recruitment events. Excluding the 2012 year class, the 1998 year class is the largest observed year class within the assessment time series, estimated at approximately 13.5 million fish (Table A.86, Fig. A.186). The 1998 year class has persisted in the population and lead to a large buildup of fish in the 9^+ age class (Fig. A.187). More recently, moderate-to-large year classes were spawned in 2003 and 2010. The 2003 year class has just recently entered the 9^+ age class. The size of 2010 year class is particularly important in explaining the increase in stock size compared to the previous assessment update in 2012. For the 2012 AOP assessment, the 2010 year class represented the $t+1$ year class (age-1 in 2011, one year beyond the 2010 terminal year of the assessment time series). Due to the limited amount of information available to estimate this year class (a single spring survey observation), this year class was estimated using the geometric mean (see Palmer et al. 2014a for a full discussion). The current estimated size of the 2010 year class is 6.7 million fish, approximately six times larger than the size assumed for the 2012 AOP update. The 2012 year class is estimated to be large, though the actual size of the year class is highly uncertain and represents the greatest area of uncertainty in this assessment.

Total SSB has ranged from 600 mt to 15,178 mt during the assessment time period, with current SSB in 2013 estimated at 4,153 mt (Table A.87, Fig. A.188). Total January 1 biomass in 2013 is estimated at 7,749 mt, with 2,158 mt of exploitable biomass. Fully recruited fishing mortality has ranged from 0.19 to 1.54 (Table A.88). The low fishing mortality on ages-1 through 5 is notable given that the maturity $A_{50\%}$ is approximately 2.4 (Fig. A.13); the current fishery selectivity pattern allows for two to three spawning events on average prior to entering the fishery. The fully recruited fishing mortality in 2013 is estimated at 0.39.

A retrospective analysis of model performance over the years 2006-2013 indicates retrospective error for both F and SSB of 0.30 and -0.15, respectively. The retrospective patterns show a model tendency to underestimate SSB and overestimate F in the earlier peels; more recently, the retrospective error has switched signs (Fig. A.189), suggesting a transient nature to the retrospective error. Overall, the retrospective error is small and the SAW 59 WG recommended that no adjustments be made for the retrospective error when determining stock status determination or when conducting stock projections.

The Hessian-based CVs on SSB have generally been around 0.10 for the majority of the assessment time series, with the exception of the terminal years where CVs increase to around 0.20 (Fig. A.190). Fishing mortality CVs were moderate (>0.20) early in the time series, but decreased over time below 0.15 until about 2010 before increasing at the end of the time series. Age-1 recruitment CVs have been highly variable with the smallest year classes having the greatest degree of uncertainty. The CVs on the 1998 and 2003 year classes are < 0.10 indicating that they are reasonably well estimated. The 2010 year class is less certain with a CV around 0.22 and the 2012 year class is highly uncertain with a CV >0.3. The WG discussed the Hessian-based CVs for the 2012 year class and felt that this value likely does not adequately capture the true uncertainty of this year class.

A MCMC simulation was performed to obtain posterior distributions of the SSB, total B, and F_{full} time series based on 1000 MCMC chains. Two MCMC chains of initial length of five

million were simulated with every five thousandth value saved. The trace of each chain's saved draws suggests good mixing and a sufficient burn-in period (e.g., Fig. A.191 and A.192). The lagged autocorrelations showed decreasing correlation with increased lag with correlations ≤ 0.1 beyond lag-0 indicative of a well mixed MCMC chain (Fig. A.193 and A.194). From the MCMC distributions, 90% posterior probability intervals (PI) were calculated to provide a measure of uncertainty for the model point estimates. Time series plots of the SSB and F_{full} 90% PIs as well as plots of the posterior probability distributions for the SSB, January 1 biomass and F_{full} are shown in Figures A.195 through A.197. The 2013 ASAP_final_temp10 point estimates and the 90% PIs are reported in Table A.89.

The results from the SAW 59 preferred ASAP_final_temp10 model are similar to the model results from the initial ASAP_BASE model (Fig. A.198). The most notable differences are a small negative re-scaling of age-1 recruitment and SSB in the ASAP_final_temp10 model compared to ASAP_BASE. This in turn translates to a slight positive re-scaling of fully recruited fishing mortality.

Description of SCAA model results

Recent reviews of historical and contemporary tagging studies suggest that there is movement of fish between the Gulf of Maine and Georges Bank stocks, though there is considerable uncertainty regarding the degree of mixing. The SAW 59 WG evaluated the results from three sensitivity models which used the SCAA statistical catch-at-age methodology (described in depth in Appendix 3). The first of the SCAA models considers the haddock in the Gulf of Maine to be an isolated stock (SCAA no movement model), which is identical to the WGs preferred ASAP model. The other two models incorporate movement into that area, either permanent or temporary, by haddock from Georges Bank. The WG concluded that the most biologically realistic mixing scenario is one that allows for non-permanent interchange (mixing) between the stocks.

The SCAA permanent migration model estimates the annual proportion of Georges Bank fish moving into the Gulf of Maine region at 0.2% where as the SCAA sabbatical model (non-permanent interchange) estimated the movement at 0.75% annually. The statistical evidence for such movement from these analyses point to scenarios involving limited movement being of similar plausibility to that of an isolated stock; however, mixing amongst the stocks has limited impact on assessment results. All three of the SCAA models achieved similar results to the ASAP_final_temp10 model (Fig. A.199).

The SAW 59 WG discussed how to interpret the mixing parameter estimates coming from the SCAA movement models. The SCAA movement models do not incorporate specific information to inform the model about migration rates (e.g., tagging); as such, the mixing parameters don't represent actual mixing rates, rather the mixing parameters represent upper bounds on the amount of mixing that could be supported by the data. The mixing parameters are confounded by other parameters or data observation/process error. It's unclear how well the SCAA mixing models would perform on simulated data sets from an isolated population – i.e., would the movement models still estimate a non-zero mixing parameter? **Ultimately, the WG supported**

the use of the ASAP_final_temp10 model as the 'preferred' model, but felt that the SCAA projection results should be carried forward as sensitivities to inform catch advice decisions.

The 59th SARC supported the use of the ASAP_final_temp10 model as the preferred model on which to determine stock status and base management advice.

Historical assessment retrospective

A comparison between the results of the final ASAP model to the results of the 2012 AOP and GARM III VPA model is provided in Figure A.200. As discussed earlier when comparing the VPA and ASAP results, the fishing mortality patterns coming out of the two models are different, though these differences are primarily restricted to the pre-2000 period. It should be noted that the comparison of fishing mortality trends between the various assessments are not directly comparable because the calculation basis of the current ASAP model is not identical to the previous VPA models. The VPA outputs reflects an average F over ages 6 to 8 where as the ASAP output reflects the fully recruited fishing mortality. Both model types indicate high fishing mortality early in the time series until about 1998, after which fishing mortality has remained low. The scale and trends of population numbers and biomass has been consistent from assessment to assessment. The 2012 AOP estimates of the 1998 year class were slightly higher than the GARM III and the current SAW/SARC 59 estimates, but these estimation differences were minimized as the 1998 year class aged and contributed less to the overall Gulf of Maine haddock population. This historical "retrospective" examination of past model performance illustrates the general stability of the Gulf of Maine haddock assessment results.

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

The existing MSY reference points based on a spawning potential ratio (SPR) of 40% were established at GARM III (NEFSC 2008) and updated as part of the 2012 AOP update (NEFSC 2012). The inputs to the yield per recruit (YPR) analysis assumed fishery selectivity to be 'flat-topped' beyond the fully selected age (age-7), mean weight and partial recruitment patterns were calculated from an unweighted average of the most recent five years. Maturity and natural mortality were assumed to be time invariant. The overfishing definition was $F_{MSY\text{-}proxy} = F_{40\%} = 0.46$.

Maximum sustainable yield and SSB_{MSY} were derived from the median values of long-term projections (100 years) of the Age Structured Projection Model (AGEPRO, NOAA Fisheries Toolbox, http://nft.nefsc.noaa.gov/) run at a constant harvest of $F_{40\%} = 0.46$. Input vectors for the AGEPRO runs are the same as those used for the YPR analyses. Following on the methods

employed in the GARM III assessment, projected recruitment was determined using the cumulative density function (CDF) of a recruitment series that included both VPA-estimated age-1 recruitment and hindcast recruitment estimates based on NEFSC fall bottom trawl survey age-1 indices. A linear regression was fit to VPA estimates of age-1 recruitment and NEFSC autumn bottom trawl survey indices of abundance of age-1 fish. Using the regression relationship, recruitment was estimated back to the 1962 year class. The 2008 GARM BRP Panel recommended a recruitment series that includes VPA estimated recruitment excluding recruitment estimates for years when SSB was less than 3,000 mt in addition to hindcast recruitment from 1962 to 1976 with the large 1962 year class removed (considered a "bonanza" outlier). The resulting BRP estimates were: SSB_{MSY} = 4,904 mt (90% CI of 2,272 – 10,604 mt), and MSY = 1,117 mt (90% CI of 553 – 2,563 mt). A stock is considered to be overfished if spawning biomass is less than half of SSB_{MSY}; the existing overfished definition is ½ SSB_{MSY} = 2,452 mt.

New reference points are warranted given the changes in data inputs and the assessment model, as well as small changes in the fishery selectivity and weights-at-age.

Ultimately, the WG concluded that because Gulf of Maine haddock recruitment events are highly episodic and not well described by traditional stock recruitment relationships, a MSY proxy approach to reference points was warranted. This is the same conclusion reached at GARM III. A yield per recruit analysis was conducted using 2009-2013 period as representative of future conditions. The WG reached this decision after an inspection of the weights-at-age noting that over this most recent five year periods weights have remained relatively stable. The inputs to the YPR analysis included the time invariant maturity ogive, the time and age invariant natural mortality value (M=0.2), the selectivity-at-age from the third selectivity block as well as the average catch and stock weights from 2009-2013 (Table A.90). The SAW/SARC 59 YPR inputs were not considerably different from those from the 2012 AOP update (Fig. A.201).

A stochastic YPR analysis which incorporated the empirical CVs of the input vectors (natural mortality CV assumed = 0.1) was conducted to better characterize the uncertainty in the proxy fishing mortality rate. After an examination of the YPR results (Table A.91), the WG saw no compelling reason to select a different F_{MSY} proxy than the $F_{40\%}$ metric that had been adopted previously. Because of the similarities in YPR inputs between the 2012 AOP and the current assessment, it is not surprising the $F_{40\%}$ values were identical: $F_{40\%}$ = 0.46 (90% CI of 0.36 – 0.54) (Table A.92).

Stochastic long-term projections (100 years) at $F_{40\%}$ were used to determine new recommended biomass-related reference points (proxies for both SSB_{MSY} and MSY). The projection inputs were identical to the YPR inputs.

The WG discussed various ways to project future recruitment. It found the GARM III method to be arbitrary (e.g., excluding very large and very small recruitment events) and instead opted to use a more straightforward method of using the CDF of the 1977-2011 age-1 recruitments as estimated by the preferred ASAP_final_temp10 model. The 2012 and 2013 recruitment observations were not included in the CDF due to the overall uncertainty in these estimates. *The WG did conduct long-term projections using the full 1977-2013 recruitment series, but these are*

for comparative purposes only.

To approximate the distribution of the SSB and MSY distributions, the long term projections were made from 1000 estimates of numbers at age in 2014, which were estimated by performing MCMC simulation of the ASAP_final_temp10 model (described above under TOR 4). The 2014 age-1 estimates (*t+1*) were based on sampling from the empirical distribution of recruitment estimates from the full assessment times series (1977-2013). Long-term projections are insensitive to the 2014 starting numbers-at-age. All projections were conducted with the AGEPRO software (Age Structured Projection Model v4.2.2).

The resulting biomass reference points and their 90% CI corresponding to $F_{MSY\text{-}proxy} = F_{40\%} = 0.46$ are SSB_{MSY} = 4,108 mt (1,774 – 7,861 mt) and MSY = 955 mt (421 – 1,807 mt). Table A.93 provides a comparison to the sensitivity reference points based on the CDF of 1977-2013 age-1 recruitments. The overfished biomass threshold is ½ SSB_{MSY}, or 2,054 mt.

The SAW 59 WG did discuss other methods for developing reference points for Gulf of Maine haddock. One such approach attempted to examine changes in stock productivity using a Ricker stock recruitment curve with a time-varying productivity parameter (Bell and Hare 2014). The goal of the approach was to examine if there were trends in stock productivity that could be used to inform forecasts of future abundance and in turn inform management decisions. The WG discussed this approach as well other similar approaches (e.g., time-varying/random walk parameter estimation, autoregressive processes) and noted that there was a need to first identify the underlying processes driving productivity shifts. Additionally, the WG noted that additional work was needed before these methods could be incorporated in the stock assessment process. Specifically, the WG noted that in developing these approaches, the robustness and utility of incorporating additional stock-recruitment models needs to be considered (see TOR 8).

TOR A.6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model developed for this peer review. In both cases, evaluate whether the stock is rebuilt (if in a rebuilding plan).

TOR A.6.a. When working with the existing model, update it with new data and evaluate stock status (overfished and overfishing) with respect to the existing BRP estimates.

The existing reference points are $F_{MSY\text{-}proxy} = F_{40\%} = 0.46$, SSB_{MSY} = 4,904 mt (90% CI of 2,272 – 10,604 mt) (½ SSB_{MSY}, or 2,452 mt), and MSY = 1,117 mt (90% CI of 553 – 2,563 mt). The updated VPA model (Model 6, 2013_UPDATE) estimates 2013 SSB at 3,070 mt. This exceeds the existing overfished threshold of 2,452 mt; therefore, the stock is not overfished. The updated estimate of average fishing mortality on ages 6-8 ($F_{6\text{-}8}$) in 2013 is 0.82. This is greater than the overfishing limit of 0.46, and therefore, overfishing is occurring.

TOR A.6.b. Then use the newly proposed model and evaluate stock status with respect to "new" BRPs and their estimates (from TOR-5).

The revised reference points are $F_{MSY\text{-}proxy} = F_{40\%} = 0.46$ (90% CI of 0.36 – 0.54), SSB_{MSY} = 4,108 mt (90% CI of 1,774 – 7,861 mt) (½ SSB_{MSY}, or 2,054 mt), and MSY = 955 mt (90% CI of 421 – 1,807 mt). The ASAP_final_temp10 model estimates 2013 SSB at 4,153 mt. This is greater than the SSB_{MSY} level of 4,108 mt; therefore, the stock is rebuilt and not overfished. The estimate of 2011 fully recruited fishing mortality (F_{full}) is 0.39. This is less than the overfishing limit of 0.46, and therefore, overfishing is not occurring. The stock status determination is robust to model uncertainty (Fig. A.202).

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

TOR A.7.a. Provide numerical annual projections (3 years). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment, migration from Georges Bank).

Identical to the long-term projections used to determine SSB_{MSY} and MSY proxies, the short-term (2015-2017) projection method samples from a cumulative density function derived from ASAP estimated age-1 recruitment between 1977 and 2011. Age-1 recruitments in 2012 and 2013 were not included in the cumulative density function due to their greater variance. Note that the 2014 age-1 estimates ($t+1$) were based on sampling from the empirical distribution of recruitment estimates from the full assessment times series (1977-2013). The WG did examine the sensitivity of the short-term projections to variability in 2014-2017 recruitment assumptions and found results to be robust to the out year recruitment assumptions due to the small differences in median recruitment levels between the two assumptions (1.1 vs. 1.2 million fish, Table A.86) and the limited contribution of these year classes to the spawning stock biomass and fishery yield within the projection window. No retrospective adjustment needed to be applied in the projections.

Due to the high degree of uncertainty of the size of the 2012 year class, two projection models were developed. The first is based on the preferred population model (ASAP_final_temp10) and the second is based on a sensitivity model that constrained the size of the 2012 year class (ASAP_final_temp11). Both projection models were run under two different assumptions of calendar year 2014 catch – harvest at FMSY (0.46) and an assumed 2014 catch of 500 mt. The fishing year 2014 Gulf of Maine haddock Annual Catch Limit (ACL) is set at 323 mt, though the ACL does not account for recreational discards. The 500 mt estimate used in the projections was informed by the fishing year 2014 ACL and recent recreational discard amounts. Because fishing mortality is not allowed to exceed the overfishing limit (i.e., $F_{40\%}$), these projections provide an approach for defining the OFL. Results for the four projections (two models, each with two different 2014 catch assumptions) are provided in table A.94.

The New England Fishery Management Council's Scientific and Statistical Committee have traditionally applied a 75% control rule when recommending Acceptable Biological Catch

(ABC) levels. The above projections were repeated with harvest set at 75% $F_{MSY\text{-}proxy}$ (0.35) to demonstrate example projections for establishing ABC levels. Results for the four projections are provided in table A.95.

Recent reviews of historical and contemporary tagging studies suggest that there is movement of fish between the Gulf of Maine and Georges Bank stocks, though there is considerable uncertainty regarding the degree of mixing. Several lines of evidence examined during the SAW/SARC59 assessment indicate that annual percent mixing from Georges Bank to the Gulf of Maine is low (<0.8%), though the mixing scenarios have similar statistical plausibility to that of an isolated stock. While mixing amongst the stocks has limited impacts on stock status, catch projections of the SCAA models (Appendix 3) under constant fishing mortality were found to be sensitive to limited movement for the case where the movement is permanent (SCAA permanent migration model), but much less so when movement was modeled as non-permanent interchange (SCAA sabbatical model). The WG concluded that of the two mixing scenarios, the most biologically realistic is one that allows for non-permanent interchange between the stocks. The catch projection results from the most realistic SCAA mixing model (i.e., allows mixing between stocks as opposed to unidirectional movement) are nearly identical to the SCAA model with no mixing, with both being within the 90% confidence intervals of the projections from the preferred ASAP model (Figure A.203).

The SAW 59 WG noted that the evidence for mixing is not conclusive and that the mixing scenarios have similar statistical plausibility to that of an isolated stock. **Given this, it concluded that the projections based on the ASAP_final_temp10 model should be used as the preferred model for management advice. This decision was supported by the 59th SARC.**

TOR A.7.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.

The SAW 59 WG determined that the projections based off the ASAP_final_temp10 model were the 'most realistic'. However, it has stressed that the absolute size of the 2012 year class is the largest source of uncertainty in this assessment. The risks associated with management actions taken during 2015 – 2017 were examined by undertaking stock projections under two different assumptions of year class size. Under both scenarios, the spawning stock biomass is projected to increase well above the target levels and catch can be sustained above MSY levels.

The differences in these two short-term projections in 2014 and 2015 are primarily due to the differences in the size of the 2010 year class between the two different models. However, as the projection horizon increases, and the contribution of the 2012 year class becomes more important, the divergence in catch advice becomes larger (> 600 mt). Based on the estimated selectivity patterns, the 2012 year class is predicted to be 50% selected by the fishery in 2017 at age-5. Recent changes to the commercial minimum retention size may result in this year class recruiting to the fishery sooner.

The assumption of the catch in 2014 will have limited impacts on stock size and catch advice in the subsequent years, though the two assumed values (catch= $F_{MSY\text{-}proxy}$ and 500 mt) should be

re-evaluated once additional information on 2014 catches are available.

TOR A.7.c. Describe this stock's vulnerability (see "Appendix to the SAW TORs") to becoming overfished, and how this could affect the choice of ABC.

There are several factors that should be considered when setting catch advice for the Gulf of Maine haddock stock. While these uncertainties have been discussed previously in this report, particular attention should be given to the factors below when determining the appropriate level of scientific uncertainty to prescribe to this stock assessment.

The mortality of haddock discarded in the recreational and commercial fishery is unknown. For trawl and gillnet gear, mortality is likely high and not substantially different than the assumption of 100% used in the assessment. While there is limited information available to suggest that mortality of haddock discarded in the commercial longline fishery may be lower than 100%, given the small magnitude of longline removals, the impacts of this assumption on the assessment results are likely small. However, given the large amount of recreational discards occurring in recent years, the model results and subsequent catch advice could be sensitive to the assumption of 50% discard mortality used in this assessment. While the assessment results were shown to be relatively insensitive to this assumption, it does have implications for management and catch allocation between the commercial and recreational fleets.

Several lines of evidence examined during the SAW/SARC59 assessment indicate that annual percent mixing from Georges Bank to the Gulf of Maine is low (<0.8%), though the mixing scenarios have similar statistical plausibility to that of an isolated stock. While the catch projections for the more biologically realistic mixing scenario (non-permanent interchange) were nearly identical to no-movement assumptions, the projections which assumed permanent movement of Georges Bank haddock into the Gulf of Maine were higher than the no movement scenarios. Setting catch advice higher on the presumption that permanent movement of Georges Bank haddock into the Gulf of Maine is occurring, if in fact it is not, could lead to overfishing of the Gulf of Maine stock (NEFMC GPDT 2013).

The absolute size of the 2012 year class is the largest source of uncertainty in this assessment. Based on the estimated selectivity patterns, this year class is predicted to be 50% selected by the fishery in 2017 at age-5. Recent changes to the commercial minimum retention size may result in this year class recruiting to the fishery sooner. Given the high uncertainty with respect to this year class size, the assessment should be updated if future estimates of its size differ significantly from those used in this assessment.

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

The SAW 59 WG reviewed the status of previous research recommendations and proposed new ones to address issues raised during the WG meeting.

GARM III

- Inverse variance weighting should be investigated as a means to compute the current year's fishing mortality as it has superior statistical characteristics than either the unweighted or weighted (by population) numbers.
    - This research recommendation is no longer relevant for the Gulf of Maine haddock assessment due to the switch from a virtual population analysis assessment model to a statistical catch-at-age model.

- Research should be undertaken on the estimation of the survivorship of haddock released in the recreational fishery.
    - This research recommendation has been partially addressed through the estimation of recreational discards described under TOR 1 and through the model sensitivity runs explored under TOR 4. Directed field studies are needed to better inform the assessment.

SAW 59 WG

- In the Northeast Region, frequent changes in management and the multispecies nature of the fishery hinder the ability to develop useful indices of abundance from fishery data. In stock assessments over the last decade, these problems have resulted in the development of standardized CPUE indices that have no demonstrated utility as indices of stock abundance for assessments of cod, haddock, white hake, yellowtail flounder, summer flounder, scup, or winter flounder. The qualitative properties of the fishery data are generally well described in the assessments. The SAW 59 WG recommends investigation of approaches to consider year/area and other interactions (e.g., at a finer scale than statistical area) in the hopes of developing more useful fishery-based indices of abundance. Given the considerable investment of time that may be required and its potential utility for a range of assessments, this work may be best pursued as research outside the Terms of Reference for any single stock assessment.

- Develop approaches for and evaluate the robustness and utility of incorporating additional stock-recruitment models (e.g., Ricker, time-varying/random walk parameter estimation, autoregressive processes) into the population models used in Northeast Region assessments.

- Develop approaches for and evaluate the robustness and utility of incorporating autoregressive error (e.g., AR1 processes in recruitment and catch-at-age resulting from sampling) in fishery and survey data into the population models used in Northeast Region assessments.

- The SAW 59 WG notes the further advice from the Council SSCs is needed to advance the application of multi-model inference and risk evaluation in Northeast Region stock assessments.

- Practical and logistic problem aside, in the future it would be beneficial to conduct the multiple Northeast Region haddock assessments at the same time, to facilitate comparability of the data and analytical results, especially if models include movement between the stock units.

- The haddock tagging experiments conducted to date were not designed to address the issue of between-stock movement rates. Research designed to expressly determine between-stock movement rates is needed to reduce the uncertainty of analytical models that include these rates.

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Tables

Table A.1. Summary of model inputs and formulations used to assess the Gulf of Maine haddock stock since 2002. There was no accepted analytical assessment prior to 2002.

Year	Meeting	Model	Starting year	Catch data series				Survey series		Plus group
				Commercial landings	Commercial discards	Recreational landings	Recreational discards	NEFSC fall	NEFSC spring	
2002	GARM I	AIM	1963	1963-2001				1963-2001		N/A
2005	GARM II	AIM	1963	1963-2004				1963-2004		N/A
2008	GARM III	VPA	1977	1977-2007	1977-2007	1982-2007		1977-2007	1977-2008	9+
2012	AOP	VPA	1977	1977-2010	1977-2010	1982-2010		1977-2010	1977-2011	9+

Table A.2. Summary of the results of the Gulf of Maine haddock assessments since 2002 and the resulting stock status determinations based on the biological reference points at the time of the assessment. *Notes: [1]F_{ref} = relative F where replacement ratio = 1, B_{ref} = MSY/F_{ref}. Replacement ratio: the biomass index in the current year divided by the average biomass indices from a 3 year centered mean. [2]YPR = Yield per recruit, based on 5yr averages of WAA, MAA and partial recruitment, F SPR basis = 40%. [3]The stock was projected to become overfished in the first year of the projections*

Year	Meeting	$SSB_{terminal}$	Exploitation rate/$F_{terminal}$	Exploitation rate/F note	Reference point basis	B_{ref}	F_{ref}	MSY_{proxy}	Stock status
2002	GARM I	10.31 kg/tow	0.12	Landings/3-yr fall survey avg.	MSY derived avg. 1959-1966 landings[1]	22.17 kg/tow	0.230	5,100 mt	Overfished, overfishing not occuring
2005	GARM II	5.79 kg/tow	0.18	Landings/3-yr fall survey avg.	MSY derived avg. 1959-1966 landings1	22.17 kg/tow	0.230	5,100 mt	Overfished, overfishing not occuring
2008	GARM III	5,850 mt	0.35	$F_{avg6-8, N-Weighted}$	YRP[2]	5900 mt	0.430	1,360 mt	Not overfished, overfishing is not occuring
2012	AOP	2,868 mt	0.82	F_{avg6-8}	YRP[2]	4,904 mt	0.460	1,177 mt	Not overfished, overfishing is occuring[3]

Table A.3. Summary of major regulatory actions that have affected the Gulf of Maine haddock fishery since 1973. For a more detailed summary of regulatory actions, see Nies (2011).

Date	Regulatory action	Cod end minimum mesh size (in)	Miscellaneous	Closures	Differential DAS Counting
01/01/73		4.5			
01/01/77	Groundfish FMP	5.125			
01/01/82					
01/01/83		5.5			
01/01/89					
04/01/92	Shrimp trawl fishery: Nordmore grate regulation, groundfish bycatch prohibited				
05/01/94	Amendment 5	6.0	500 lb trip limit		DAS monitory w/ reduction schedule, mandatory reporting
05/01/96	Amendment 7		Trip limit raised to 1,000 lb/trip		Accelerated DAS reduction
05/01/97	Framework 20				
09/01/97			Trip limits raised to 1,000 lb/day with 10,000/trip maximum		
05/01/98	Framework 25			WGOM (Jeffreys Ledge, Stellwagen Bank)	
06/25/98					
09/01/98			Trip limits raised to 3,000 lb/day with 30,000/trip maximum		
02/01/99	Framework 26			Additional month-block closures for February to April	
05/01/99	Framework 27	6.5 square/6.0 diamond	Trip limit lowered to 2,000 lb/day with 20,000 lb/trip		
05/28/99					
08/03/99	Interim rule				
11/05/99			Trip limit raised to 5,000 lb/day with 50,000 lb/trip		
01/05/00	Framework 31			Additional month-block closures for February	
06/01/00	Framework 33	6.5 square/6.5 diamond			
10/26/00			Daily trip limit removed, total trip limit of 50,000 lb/trip remains in effect		
11/01/00				One month closure of Cashes Ledge	
05/01/02	Interim rule		Trip limits lowered to 3,000 lb/day with 30,000/trip maximum	Additional month-block closures for May - June 2003; Cashes Ledge Closed year round	20% reduction in DAS
06/01/02	Revised interim rule				
07/01/02			Daily limit suspended, 30,000/trip through 9/30/2002 then 50,000/trip thereafter		
08/01/02	Emergency rule				
03/13/03			Haddock possession limit suspended until May 1		
05/01/03			Trip limits lowered to 3,000 lb/day with 30,000/trip maximum		
05/01/04	Amendment 13		Trip limits suspended for remainder of 2004	WGOM, Cashes Ledge and rolling closures continued	Further reduction in DAS
05/01/06	Emergency rule				
11/22/06	FW 42				DAS counted 2:1 in inshore GOM
08/15/06	FW 43		Haddock cap for herring fishery implmented (set at 0.2% of the combined GOM/GBK haddock TAC)		
05/01/09	Interim rule				
05/01/10	Amendment 16			Some changes to rolling closures for sector vessels	DAS counted in 24 -hour blocks; no differential DAS counting except as AMs
05/01/11	Framework 45			Whaleback closure April 1 - June 30 (commercial and recreational)	
09/14/11	Framework 46		Changes to herring haddock cap (1% GOM haddock ABC)		
05/01/12	Framework 47				
05/01/13	Framework 48		Changes to minimum sizes for both commercial and recreationalfisheries (effective July 1)		

Table A.4. Commercial and recreational fishery minimum retention size limits for Gulf of Maine haddock, from 1977 to 2013. Prior to 1977 there were no federal minimum size limits for either fishery. *Note that minimum sizes were changed throughout the year or corresponding to the start of the groundfish fishing year (May 1 – April 30), thus the year/length relationships are approximate.*

Year	Commercial minimum size limit (total length, inches)	Recreational minimum size limit (total length, inches)	Management action
1977	16	15	Groundfish Fishery Management Plan
1978	16	15	
1979	16	15	
1980	16	15	
1981	16	15	
1982	16	15	
1983	17	15	Interim Groundfish Fishery Management Plan
1984	17	15	
1985	17	15	
1986	17	15	
1987	19	17	Amendment 1
1988	19	17	
1989	19	19	
1990	19	19	
1991	19	19	
1992	19	19	
1993	19	19	
1994	19	19	Amendment 5
1995	19	19	
1996	19	19	
1997	19	19	
1998	19	19	
1999	19	19	
2000	19	19	
2001	19	19	
2002	19	23	Framework 33
2003	19	21	Framework 22
2004	19	19	Amendment 13
2005	19	19	
2006	19	19	
2007	18	19	Emergency action (August 10, 2007 through August 10, 2008)
2008	18	19	
2009	18	18	Amendment 16
2010	18	18	
2011	18	18	
2012	18	18	January 6, 2012-April 20, 2012 recreational set at 19 inches as part of AM
2013	16	21	Framework 48, implemented on July 1, 2013

Table A.5. Summary of the number of haddock otoliths sampled from the Northeast Fisheries Science Center (NEFSC) bottom trawl surveys from 1970 to 2013 by season, stock and age. Otoliths that have not been aged are not included in this summary.

Age	Gulf of Maine		Georges Bank	
	Spring	Fall	Spring	Fall
0	1	277		2039
1	541	491	2481	2676
2	542	608	3005	2307
3	505	623	3010	2433
4	342	500	1986	1593
5	262	379	1402	910
6	157	279	931	785
7	112	202	909	587
8	93	169	563	359
9	57	62	307	190
10	44	71	198	83
11	21	38	40	36
12	15	22	33	36
13	13	12	23	14
14	9	7	11	4
15		3	1	1
16			1	1
17			1	
18	1			

Table A.6. Number of Gulf of Maine haddock maturity samples taken from the Northeast Fisheries Science Center (NEFSC) spring survey from 1977 to 2013 by year.

Year	Unknown	Male	Female	Total
1977	6	62	81	149
1978	1	7	21	29
1979		6	13	19
1980	4	28	27	59
1981	12	49	54	115
1982		37	39	76
1983		24	40	64
1984		18	16	34
1985	2	25	38	65
1986		7	19	26
1987	1	1	3	5
1988		6	3	9
1989		7	3	10
1990		1		1
1991		1	3	4
1992	3	1	5	9
1993	1	11	7	19
1994	2	5	13	20
1995	1	5	15	21
1996		4	6	10
1997		26	34	60
1998		5	6	11
1999	18	26	33	77
2000	2	43	38	83
2001	3	35	34	72
2002	7	29	83	119
2003	3	43	71	117
2004	2	10	29	41
2005	1	16	16	33
2006	1	34	56	91
2007		18	19	37
2008		30	27	57
2009	1	33	83	117
2010		40	52	92
2011	5	29	52	86
2012	5	88	128	221
2013	19	167	178	364

Table A.7. Gulf of Maine haddock female maturity ogive. The time series average incorporated data collected the Northeast Fisheries Science Center (NEFSC) spring survey between 1977 and 2013.

Age	Proportion mature	Lower 95% CI	Upper 95% CI
1	0.04	0.02	0.05
2	0.28	0.24	0.33
3	0.81	0.77	0.84
4	0.98	0.97	0.99
5	1.00	1.00	1.00
6	1.00	1.00	1.00
7	1.00	1.00	1.00
8	1.00	1.00	1.00
9	1.00	1.00	1.00
10	1.00	1.00	1.00
11	1.00	1.00	1.00
12	1.00	1.00	1.00
13	1.00	1.00	1.00
14	1.00	1.00	1.00

Table A.8. Estimates of Gulf of Maine haddock catch (mt) by fleet (commercial, recreational) and disposition (landed, discarded) from 1977 to 2013. **Recreational discard estimates do not account for post-release mortality.** *Missing values indicate that estimates are not available for those years.*

Year	US recreational discards (mt)	US recreational harvest (mt)	US commercial discards (mt)	US commercial landings (mt)	Foreign landings (mt)	Total removals	
						100% mortality of recreational discards	50% mortality of recreational discards
1977				3,230.1	26.0	3,256.1	3,256.1
1978				4,382.5	641.0	5,023.5	5,023.5
1979				4,130.6	257.0	4,387.6	4,387.6
1980				6,317.6	203.0	6,520.6	6,520.6
1981	0.0	38.2		5,713.3	513.0	6,264.5	6,264.5
1982	0.0	23.0	6.4	5,634.3	1,278.0	6,941.7	6,941.7
1983	0.0	52.7	6.5	5,593.4	2,003.0	7,655.6	7,655.6
1984	0.6	52.3	11.0	2,792.8	1,245.0	4,101.7	4,101.4
1985	0.0	21.6	16.5	2,259.1	791.0	3,088.2	3,088.2
1986	0.2	51.8	16.4	1,628.9	225.0	1,922.3	1,922.2
1987	0.0	39.2	23.9	846.3	0.0	909.4	909.4
1988	1.3	20.1		418.0	0.0	439.4	438.8
1989	2.6	13.1	5.0	265.1	0.0	285.9	284.6
1990	0.1	5.3	2.0	465.0	0.0	472.4	472.4
1991	0.0	0.3	2.8	443.5	0.0	446.6	446.6
1992	0.0	0.0	8.0	313.4	0.0	321.4	321.4
1993	0.0	0.6	13.3	193.0	0.0	206.9	206.9
1994	0.9	3.3	61.1	121.9	0.0	187.1	186.7
1995	27.4	124.1	87.7	178.2	0.0	417.4	403.7
1996	6.4	5.7	78.2	253.8	0.0	344.2	341.0
1997	10.5	30.2	378.7	623.7	0.0	1,043.2	1,037.9
1998	7.0	45.6	16.6	922.6	0.0	991.9	988.4
1999	9.8	17.8	2.3	569.1	0.0	599.0	594.1
2000	60.4	128.1	27.9	799.3	0.0	1,015.7	985.5
2001	86.8	169.3	12.9	1,006.8	0.0	1,275.8	1,232.4
2002	177.3	135.3	18.6	1,009.2	0.0	1,340.4	1,251.8
2003	257.4	173.9	17.7	1,026.4	0.0	1,475.4	1,346.7
2004	72.9	312.6	11.7	947.2	0.0	1,344.4	1,307.9
2005	72.0	538.1	25.0	977.7	0.0	1,612.7	1,576.7
2006	131.0	447.4	31.5	622.5	0.0	1,232.4	1,166.9
2007	91.4	572.7	46.9	677.9	0.0	1,388.9	1,343.2
2008	144.1	536.6	10.3	542.7	0.0	1,233.6	1,161.6
2009	48.8	408.6	12.3	500.3	0.0	970.0	945.6
2010	37.1	314.0	3.0	622.6	0.0	976.7	958.1
2011	22.4	228.8	5.6	498.6	0.0	755.3	744.2
2012	107.3	251.2	17.7	416.6	0.0	792.7	739.1
2013	413.9	241.1	32.3	212.0	0.0	899.4	692.4

Table A.9. Historical estimates of Gulf of Maine haddock catch (mt) by fleet (commercial, recreational) and disposition from 1956 to 1976. *Estimates of both United States (US) and foreign fleet commercial landings are shown. No estimates of recreational catch or commercial discards are available in the historical period.*

Year	US recreational discards (mt)	US recreational harvest (mt)	US commercial discards (mt)	US commercial landings (mt)	Foreign landings (mt)	Total (mt)
1956				7278.0	29.0	7307.0
1957				6141.0	25.0	6166.0
1958				7082.0	285.0	7367.0
1959				4497.0	163.0	4660.0
1960				4541.0	383.0	4924.0
1961				5297.0	56.0	5353.0
1962				5003.0	107.0	5110.0
1963				4742.0	47.0	4789.0
1964				5378.8	70.0	5448.8
1965				4154.7	159.0	4313.7
1966				4524.0	1125.0	5649.0
1967				4852.2	589.0	5441.2
1968				3417.3	120.0	3537.3
1969				2404.6	290.0	2694.6
1970				1435.8	105.0	1540.8
1971				1190.2	112.0	1302.2
1972				912.2	27.0	939.2
1973				525.9	49.0	574.9
1974				628.8	207.0	835.8
1975				1180.2	83.0	1263.2
1976				1834.5	91.0	1925.5

Table A.10. Coefficients of variation (CV) associated with the landings allocation procedure (AA tables, Wigley et al. 2008) for Gulf of Maine haddock commercial landings.

Year	Overall	A-level		
		B	C	D
1994	0.01	0.03	0.04	0.27
1995	0.01	0.02	0.03	0.15
1996	0.01	0.03	0.03	0.14
1997	0.01	0.03	0.07	0.19
1998	0.01	0.04	0.09	0.13
1999	0.01	0.05	0.06	0.25
2000	0.01	0.03	0.08	0.26
2001	0.01	0.03	0.06	0.18
2002	0.01	0.02	0.07	0.26
2003	0.01	0.04	0.05	0.25
2004	0.01	0.03	0.10	0.06
2005	0.01	0.04	0.07	0.08
2006	0.00	0.02	0.05	0.07
2007	0.00	0.02	0.18	0.09
2008	0.03	0.08	0.24	0.16
2009	0.01	0.05	0.03	0.09
2010	0.02	0.08	0.06	0.25
2011	0.02	0.15	0.20	0.22
2012	0.04	0.15	0.22	0.14
2013	0.01	0.06	0.11	0.24
Average	0.01	0.05	0.09	0.17

Table A.11. Estimates of total United States landings of Gulf of Maine haddock associated with 'non-dealer' transactions from 1994 to 2013. These estimates are obtained from information reported on Vessel Trip Reports (VTRs).

Year	Future sale	Home consumption	Legal sized unmarketable fish (LUMF)	Sold/used for bait	Total	Total dealer reported landings	Percentage of reported dealer landings
1994		0.33			0.33	121.9	0.3
1995		0.81			0.81	178.2	0.5
1996		1.77			1.77	253.8	0.7
1997		0.74			0.74	623.7	0.1
1998		1.25			1.25	922.6	0.1
1999		0.54		0.00	0.54	569.1	0.1
2000		1.82		0.00	1.82	799.3	0.2
2001		2.42		0.01	2.43	1006.8	0.2
2002	0.27	2.56			2.83	1009.2	0.3
2003		2.82			2.82	1026.4	0.3
2004	0.62	2.12		0.02	2.77	947.2	0.3
2005	0.84	1.50		0.02	2.36	977.7	0.2
2006	0.23	1.61			1.89	622.5	0.3
2007		2.30			2.30	677.9	0.3
2008	0.11	0.82			0.93	542.7	0.2
2009	0.02	0.75			0.76	500.3	0.2
2010	0.16	1.66	0.01	0.01	1.85	622.6	0.3
2011	0.46	2.56	0.04	0.01	3.08	498.6	0.6
2012	0.33	1.93	0.01		2.26	416.6	0.5
2013	0.40	0.90	0.00	0.00	1.31	212.0	0.6
Average	0.35	1.56	0.02	0.01	1.74	626.5	0.3

Table A.12. Proportions of observed hauls of otter trawl gear in the Gulf of Maine by mesh type from 1989 to 2013.

Year	Proportion of observed hauls				
	Combination	Diamond	Square	Square/wrapped	Unknown
1989					1.00
1990					1.00
1991					1.00
1992					1.00
1993					1.00
1994		0.37			0.63
1995		0.88	0.12		
1996		0.89	0.11		
1997		0.94	0.06		
1998		0.53	0.48		
1999	0.02	0.43	0.25	0.30	
2000		0.46	0.14	0.40	
2001		0.33	0.20	0.47	
2002	0.01	0.41	0.40	0.18	0.00
2003	0.01	0.59	0.35	0.05	0.00
2004		0.34	0.64		0.01
2005	0.01	0.35	0.63	0.00	0.00
2006		0.49	0.48	0.00	0.03
2007	0.00	0.63	0.36	0.00	
2008		0.68	0.32		
2009		0.61	0.39		
2010	0.01	0.73	0.26		0.00
2011		0.74	0.26	0.00	
2012		0.59	0.41	0.00	
2013		0.67	0.33		

Table A.13. Summary of biological sampling and commercial landings of Gulf of Maine haddock snapper market category fish from 1971 to 2013.

Length samples (no. lengths)					Commercial landings (mt)				
Year	Quarter				Year	Quarter			
	1	2	3	4		1	2	3	4
1971					1971	0.52			
1972					1972				3.39
1973					1973	2.79	1.40	3.41	4.40
1974					1974	14.55	4.77		0.30
1975	64				1975	1.09	3.38	6.53	27.37
1976					1976	1.82	0.44	17.44	148.62
1977		155		52	1977	98.96	85.89	48.68	18.21
1978				89	1978	1.89	4.35	28.90	23.34
1979					1979	18.74	6.38	0.54	1.23
1980		68			1980	3.79	37.60	39.32	6.65
1981		316	406		1981	8.31	32.36	29.47	27.88
1982	221				1982	15.76	1.04	0.33	1.40
1983					1983	0.01	0.09	0.05	
1984					1984				0.20
1985					1985		1.10	0.54	0.03
1986					1986		0.00		
1987					1987		0.25		
1988					1988				
1989					1989				
1990					1990				
1991					1991				
1992					1992				
1993					1993				
1994					1994				
1995					1995				
1996					1996		0.01		0.00
1997					1997				
1998					1998				
1999					1999				
2000					2000		0.03		
2001					2001				
2002					2002				
2003					2003				
2004					2004				
2005					2005				
2006					2006				
2007					2007				
2008					2008				
2009					2009				
2010					2010				
2011					2011				
2012					2012				
2013			122	115	2013			2.5	3.8

Table A.14. Total number of Gulf of Maine haddock lengths taken from commercial landings by quarter and year between 1969 and 2013. Sampling intensity is expressed as metric tons landings per 100 lengths sampled (*200 metric tons per 100 lengths is an unofficial NAFO/ICNAF standard*).

Year	Quarter 1	2	3	4	Total lengths	Commercial landings (mt)	Metric tons/100 lengths
1969		93	341	92	526	2404.6	457.2
1970						1435.8	
1971	86			183	269	1190.2	442.5
1972			74	115	189	912.2	482.7
1973	99		627	205	931	525.9	56.5
1974	207	47			254	628.8	247.6
1975	64	100			164	1180.2	719.6
1976	30		74	108	212	1834.5	865.3
1977	382	708	839	569	2498	3230.1	129.3
1978	372	357	379	203	1311	4382.5	334.3
1979	309		124	166	599	4130.6	689.6
1980	51	494	359	201	1105	6317.6	571.7
1981	53	410	771	1019	2253	5713.3	253.6
1982	576	53	1634	345	2608	5634.3	216.0
1983	561	1176	1759	699	4195	5593.4	133.3
1984	187	173	967	504	1831	2792.8	152.5
1985	700	799	871	735	3105	2259.1	72.8
1986	516	476	1075	475	2542	1628.9	64.1
1987	376	181	689	591	1837	846.3	46.1
1988	352	50	142	202	746	418.0	56.0
1989	291		65	247	603	265.1	44.0
1990	75	50		150	275	465.0	169.1
1991	57	146	395	425	1023	443.5	43.4
1992	228		53	130	411	313.4	76.3
1993	103	110	125		338	193.0	57.1
1994		100	52	516	668	121.9	18.3
1995	256				256	178.2	69.6
1996	77	92	84	527	780	253.8	32.5
1997	120	379	855	613	1967	623.7	31.7
1998	998	160	234	348	1740	922.6	53.0
1999	117		514	313	944	569.1	60.3
2000	965	572	496	495	2528	799.3	31.6
2001	881	201	379	1573	3034	1006.8	33.2
2002	1278	412	247	423	2360	1009.2	42.8
2003	1277	564	1998	1556	5395	1026.4	19.0
2004	2919	2027	363	1052	6361	947.2	14.9
2005	2137	774	1462	1521	5894	977.7	16.6
2006	2121	1222	1022	1131	5496	622.5	11.3
2007	1598	708	1784	1016	5106	677.9	13.3
2008	1355	938	699	436	3428	542.7	15.8
2009	1816	715	277	419	3227	500.3	15.5
2010	1618	453	322	770	3163	622.6	19.7
2011	1664	832	453	652	3601	498.6	13.8
2012	1990	859	291	430	3570	416.6	11.7
2013	1898	1457	883	929	5167	212.0	4.1

Table A.15. Total numbers of Gulf of Maine haddock ages sampled from commercial landings by quarter between 1965 and 2013.

Year	Quarter 1	2	3	4	Total ages	Commercial landings (mt)	Metric tons/100 ages
1965		35	209	102	346	4154.7	1200.8
1966		35	84	14	133	4524.0	3401.5
1967	88	185		53	326	4852.2	1488.4
1968	50	59		35	144	3417.3	2373.1
1969		20	46	15	81	2404.6	2968.7
1970						1435.8	
1971						1190.2	
1972			20	20	40	912.2	2280.6
1973	20		38	40	98	525.9	536.6
1974	40	20			60	628.8	1048.0
1975	15	25			40	1180.2	2950.4
1976	19		20	35	74	1834.5	2479.1
1977	112	195	232	220	759	3230.1	425.6
1978	120	135	89	49	393	4382.5	1115.1
1979	78		25	61	164	4130.6	2518.6
1980	17	97	88	46	248	6317.6	2547.4
1981	14	120	185	227	546	5713.3	1046.4
1982	123	14	359	91	587	5634.3	959.9
1983	155	304	302	153	914	5593.4	612.0
1984	47	52	276	125	500	2792.8	558.6
1985	190	204	230	180	804	2259.1	281.0
1986	118	136	232	116	602	1628.9	270.6
1987	76	38	175	199	488	846.3	173.4
1988	104		32	39	175	418.0	238.9
1989	91		16	42	149	265.1	177.9
1990	43	16		37	96	465.0	484.3
1991	16	32	117	87	252	443.5	176.0
1992	40		15	83	138	313.4	227.1
1993	20	42	49		111	193.0	173.9
1994		26	21	196	243	121.9	50.2
1995	86				86	178.2	207.2
1996	25	13	22	109	169	253.8	150.2
1997	23	101	199	145	468	623.7	133.3
1998	127	45	64	166	402	922.6	229.5
1999	33		143	105	281	569.1	202.5
2000	303	181	171	168	823	799.3	97.1
2001	242	72	121	393	828	1006.8	121.6
2002	555	138	24	158	875	1009.2	115.3
2003	411	178	739	473	1801	1026.4	57.0
2004	783	348	33	82	1246	947.2	76.0
2005	441	170	485	560	1656	977.7	59.0
2006	1078	433	581	480	2572	622.5	24.2
2007	783	338	888	515	2524	677.9	26.9
2008	685	535	373	218	1811	542.7	30.0
2009	993	443	218	248	1902	500.3	26.3
2010	941	192	184	339	1656	622.6	37.6
2011	961	504	236	180	1881	498.6	26.5
2012	880	533	214	243	1870	416.6	22.3
2013	1347	865	461	536	3209	212.0	6.6

Table A.16. Total numbers of Gulf of Maine haddock lengths sampled from commercial landings by market category, quarter and year between 1977 and 2013. *Cells shaded in grey indicate where lengths were aggregated semi-annually. Cells shaded blue indicate where lengths were aggregated annually. Aggregation occurred when length sampling was insufficient; a general criterion of 100 lengths/block was used to determine sampling sufficiency.*

Year	Large (1470)				Scrod (1475)			
	1	2	3	4	1	2	3	4
1977		197	358		382	511	481	569
1978	149	35	200		223	322	179	203
1979	195		124	100	114			66
1980		319	102		51	175	257	201
1981		52	257	638	53	358	514	381
1982	103		1361	104	473	53	273	154
1983	249	868	1317	496	312	308	340	203
1984		79	828	391	187	94	139	113
1985	347	597	573	651	353	202	298	84
1986	283	234	868	271	233	242	207	204
1987	214	102	614	405	162	79	75	186
1988	91		100	202	261	50	42	
1989	192		65	118	99			129
1990	34			100	41	50		50
1991		146	216	213	57		179	212
1992	121			19	107		53	111
1993	Combined 1992 & 1994 and ran annual				103	56	125	
1994		100	52	297				219
1995	62				194			
1996	77		84	427		92		100
1997	120	255	497	355		124	358	258
1998	309	111	78	313	689	49	156	35
1999	117		300	211			214	102
2000	488	313	339	208	477	259	157	287
2001	528	93	313	726	353	108	66	847
2002	930	210		262	348	202	247	161
2003	792	348	1282	1043	485	216	716	513
2004	1898	942	101	601	1021	1085	262	451
2005	1421	325	675	752	716	449	787	769
2006	1193	687	453	617	928	535	569	514
2007	817	348	1016	616	781	360	768	400
2008	789	472	351	141	566	466	348	295
2009	1248	409	142	243	568	306	135	176
2010	1018	214	187	614	600	239	135	156
2011	1050	362	237	344	614	470	216	308
2012	1262	376	171	213	728	483	120	217
2013	1208	706	345	413	690	751	538	516

Table A.17. Total Gulf of Maine haddock commercial landings-at-age (numbers) from 1977 to 2013.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15	Age16	Age17	Age18	Age19	Age20	Age21	Age22	Total
1977	0	39,755	1,762,962	53,167	366,967	184,629	189,299	0	0	0	0	0	0	2,411	0	0	0	0	0	0	0	0	0	2,599,190
1978	0	0	374,650	2,291,417	172,388	363,003	208,654	10,580	0	0	0	5,290	0	0	0	0	0	0	0	0	0	0	0	3,425,982
1979	0	0	67,315	559,608	1,576,962	183,133	99,093	45,294	10,898	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,542,303
1980	0	0	884,750	104,084	755,832	1,366,770	143,816	95,570	27,794	0	0	25,756	0	0	0	0	0	0	0	0	0	0	0	3,404,372
1981	0	2,068	1,598,228	717,686	292,045	340,692	541,941	91,639	116,490	13,327	0	0	0	3,433	9,995	0	0	0	0	0	0	0	0	3,727,544
1982	0	30,106	605,235	1,508,516	618,180	100,219	300,546	476,719	107,236	35,008	19,261	5,206	10,366	0	5,849	0	0	0	0	0	0	0	0	3,822,447
1983	0	0	7,577	818,079	967,850	786,711	147,856	252,137	346,411	54,803	38,544	16,725	5,117	0	0	0	0	0	0	0	0	0	0	3,441,810
1984	0	0	63,736	44,622	588,124	253,782	359,988	61,607	64,176	132,508	3,153	2,775	5,415	2,161	0	0	0	0	0	0	0	0	0	1,582,047
1985	0	0	22,128	319,344	82,516	354,183	151,463	241,319	47,220	19,629	33,631	492	589	0	0	0	0	0	0	0	0	0	0	1,272,514
1986	0	0	0	166,503	340,987	75,330	111,567	84,708	101,115	10,694	3,792	0	0	0	0	0	0	0	0	0	0	0	0	894,696
1987	0	0	3,745	25,377	95,767	46,124	33,013	55,332	32,964	10,723	4,387	252	0	0	0	0	0	0	0	0	0	0	0	307,684
1988	0	0	0	11,539	11,895	52,410	53,781	7,538	13,744	2,772	1,232	0	0	0	0	0	0	0	0	0	0	0	0	154,911
1989	0	0	15,537	2,643	40,660	18,301	22,676	13,959	707	943	0	0	0	0	0	0	0	0	0	0	0	0	0	115,426
1990	0	0	2,018	142,445	1,686	28,564	17,479	27,146	3,794	0	0	0	0	0	0	0	0	0	0	0	0	0	0	223,132
1991	0	0	5,579	15,722	58,569	28,391	27,857	12,628	5,811	3,140	0	0	0	0	0	0	0	0	0	0	0	0	0	157,697
1992	0	0	7,753	92,057	36,323	19,083	2,246	1,134	0	1,895	0	0	0	0	0	0	0	0	0	0	0	0	0	160,491
1993	0	0	10,844	34,040	22,484	9,718	10,571	4,586	1,567	595	186	155	0	0	0	0	0	0	0	0	0	0	0	94,746
1994	0	0	6,274	30,211	10,445	1,674	7,045	3,469	1,138	206	83	153	0	0	0	0	0	0	0	0	0	0	0	60,698
1995	0	0	0	4,993	34,162	8,163	5,440	4,003	4,345	261	686	2,091	0	0	0	0	0	0	0	0	0	0	0	64,144
1996	0	0	3,273	57,790	46,874	14,339	3,775	6,579	5,240	990	0	0	0	0	0	0	0	0	0	0	0	0	0	138,860
1997	0	0	2,281	82,457	117,766	55,455	12,429	4,454	923	790	398	157	0	0	0	0	0	0	0	0	0	0	0	277,110
1998	0	0	11,630	21,006	115,275	180,018	51,089	16,925	8,321	5,514	1,299	547	0	0	0	0	0	0	0	0	0	0	0	411,624
1999	0	0	0	35,907	63,674	93,190	66,255	37,073	6,863	3,851	0	571	1,119	202	0	0	0	0	0	0	0	0	0	308,705
2000	0	0	3,872	36,032	85,996	54,166	108,783	62,046	27,905	14,516	3,111	1,835	1,944	824	1,616	0	0	0	0	0	0	0	0	402,646
2001	0	0	8,684	156,376	106,988	81,810	75,155	71,243	35,344	13,040	6,148	1,284	0	0	0	392	0	0	0	0	0	0	0	556,464
2002	0	0	0	12,751	185,844	92,068	92,509	28,044	60,738	41,761	13,112	3,282	181	0	287	0	0	0	0	0	0	0	0	530,577
2003	0	0	0	2,641	30,433	344,788	69,131	53,244	18,050	28,358	26,095	4,186	1,045	903	178	0	0	0	0	0	0	0	0	579,052
2004	0	0	0	1,847	18,877	42,616	357,654	41,117	24,824	7,245	13,814	17,603	2,279	157	0	0	0	0	0	0	0	0	0	528,033
2005	0	0	0	1,129	17,851	42,303	69,285	316,249	37,353	28,808	9,659	8,093	7,127	1,014	381	0	0	0	0	0	0	0	0	539,252
2006	0	0	0	8,099	294	20,587	36,028	39,908	202,196	23,052	9,071	1,915	3,875	2,126	606	79	0	0	0	0	0	0	0	347,836
2007	0	0	150	1,532	98,378	5,417	26,574	21,756	47,784	192,507	16,300	5,278	1,129	881	1,369	60	0	0	0	0	0	0	0	419,115
2008	0	0	705	21,476	9,102	187,543	1,793	19,203	13,666	20,349	76,643	3,202	3,071	122	0	0	0	0	0	0	0	0	0	356,875
2009	0	0	0	2,184	15,258	5,387	146,364	2,645	18,364	8,603	12,695	61,509	2,519	1,391	275	78	0	0	0	0	0	0	0	277,272
2010	0	0	576	1,600	20,417	28,718	10,619	191,506	2,415	11,366	8,332	10,475	58,600	2,617	292	106	0	81	0	0	0	0	0	347,720
2011	0	0	145	1,474	1,993	26,562	27,024	11,333	122,042	1,241	11,041	9,097	5,616	36,061	1,192	362	103	47	207	0	0	0	18	255,558
2012	0	0	200	8,048	5,398	6,047	33,255	23,118	8,336	92,765	1,506	6,613	5,131	6,442	22,413	944	468	36	123	0	0	0	0	220,843
2013	0	0	1,392	37,916	15,902	7,342	3,697	19,648	11,240	3,166	24,596	757	1,797	929	1,537	5,305	263	73	24	0	0	0	0	135,584

Table A.18. Coefficients of variation (CV) associated with the estimates of Gulf of Maine haddock commercial landings-at-age from 1984 to 2013. Precision estimates of commercial numbers at age could not be estimated prior to 1984. CVvalues greater than 0.3 are shaded grey.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15	Age16	Age17	Age18	Age19	Age20	Age21	Age22
1984			0.25	0.11	0.08	0.09	0.03	0.09	0.13	0.09	0.19	0.33	0.20	0.26									
1985			0.18	0.11	0.15	0.07	0.08	0.04	0.12	0.17	0.16	1.27	0.79										
1986				0.08	0.06	0.05	0.04	0.05	0.08	0.21	0.26												
1987			0.35	0.14	0.06	0.07	0.07	0.06	0.10	0.13	0.25	0.68											
1988				0.32	0.26	0.18	0.26	0.27	0.46	0.60	0.72												
1989			0.60	0.75	0.23	0.29	0.19	0.19	0.91	0.87													
1990			0.84	0.23	0.87	0.33	0.55	0.47	0.80														
1991			0.58	0.37	0.13	0.14	0.15	0.16	0.26	0.67													
1992			0.84	0.17	0.34	0.52	0.71	0.97		1.06													
1993			0.17	0.15	0.15	0.37	0.37	0.31	0.45	0.85	0.88	1.22											
1994			0.16	0.08	0.15	0.27	0.28	0.19	0.34	1.03	0.87	1.00											
1995				0.70	0.13	0.42	0.32	0.38	0.32		0.82	0.46											
1996			0.61	0.25	0.25	0.26	0.33	0.35	0.63	0.69													
1997			1.10	0.14	0.12	0.13	0.26	0.17	0.39	0.29	0.64	1.10											
1998			0.83	0.23	0.12	0.12	0.18	0.35	0.32	0.59	1.23	1.38											
1999				0.26	0.11	0.13	0.18	0.24	0.37	0.51		1.18	0.93	1.23									
2000			0.49	0.23	0.16	0.12	0.14	0.17	0.21	0.46	0.51	0.91	0.65	1.01	0.58								
2001			0.43	0.09	0.09	0.16	0.10	0.13	0.20	0.35	0.57	0.90				1.01							
2002				0.38	0.08	0.13	0.10	0.20	0.13	0.18	0.22	0.42	1.37		1.39								
2003				0.70	0.17	0.04	0.11	0.14	0.19	0.13	0.18	0.44	0.35	0.71	1.27								
2004				0.65	0.47	0.14	0.03	0.12	0.18	0.23	0.23	0.18	0.41	0.94									
2005				0.61	0.25	0.14	0.09	0.03	0.13	0.14	0.24	0.28	0.23	0.68	0.95								
2006				0.26	0.76	0.16	0.13	0.09	0.03	0.12	0.17	0.30	0.22	0.34	0.51	1.34							
2007			1.36	0.51	0.08	0.36	0.14	0.14	0.10	0.04	0.19	0.26	0.50	0.57	0.60	1.28							
2008			1.20	0.34	0.31	0.06	0.44	0.15	0.19	0.17	0.08	0.25	0.50	1.02									
2009				0.55	0.22	0.33	0.05	0.37	0.13	0.18	0.14	0.09	0.29	0.50	0.85	1.35							
2010			1.29	0.97	0.21	0.16	0.25	0.06	0.38	0.18	0.19	0.21	0.13	0.39	0.64	1.38		1.32					
2011			1.35	0.76	0.46	0.15	0.11	0.22	0.05	0.42	0.18	0.17	0.22	0.12	0.45	0.65	1.47	1.48	0.96				1.69
2012			0.77	0.26	0.27	0.25	0.13	0.13	0.21	0.07	0.38	0.22	0.23	0.22	0.14	0.45	0.68	1.43	1.40				
2013			0.50	0.10	0.09	0.13	0.16	0.07	0.09	0.16	0.05	0.32	0.18	0.27	0.22	0.12	0.46	0.83	1.26				
Average			0.70	0.35	0.23	0.19	0.20	0.21	0.27	0.38	0.39	0.59	0.45	0.59	0.69	0.95	0.87	1.26	1.21				1.69

Table A.19. Mean weights-at-age (kg) of commercially landed Gulf of Maine haddock from 1977 to 2013.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15	Age16	Age17	Age18	Age19	Age20	Age21	Age22
1977		0.113	0.757	1.163	2.008	2.558	3.358							4.686									
1978			0.777	1.234	1.684	2.438	3.108	4.642				6.088											
1979			0.774	1.155	1.805	2.261	2.659	2.775	3.587														
1980			0.76	1.168	1.852	2.389	3.354	3.602	4.562			4.204											
1981		0.56	0.685	1.516	1.978	2.64	3.024	3.657	4.18	3.841				3.95	3.984								
1982		0.376	0.623	0.995	2.139	2.598	3.107	3.647	4.13	4.347	4.09	4.642	4.81		3.412								
1983			0.862	1.205	1.728	2.377	2.969	3.372	3.717	4.152	4.316	4.397	3.528										
1984			0.949	1.305	1.809	2.324	3.165	3.928	4.505	4.11	3.95	5.138	2.527	4.642									
1985			1.139	1.102	1.901	2.342	2.653	3.588	4.09	4.479	3.917	6.226	4.976										
1986				1.233	1.464	2.353	2.498	3.061	3.636	4.745	4.191												
1987			1.111	1.805	2.064	2.424	2.608	3.27	4.239	5.007	5.646	6.798											
1988				1.123	1.614	2.558	2.577	3.868	4.606	4.893	5.821												
1989			1.34	2.067	1.835	2.319	2.865	3.548	4.666	4.244													
1990			0.833	1.541	3.331	2.456	3.044	3.734	3.547														
1991			1.637	1.916	2.657	3.027	2.958	3.35	4.433	3.881													
1992			1.415	1.783	1.978	2.656	3.067	2.079		3.45													
1993			1.085	1.635	2.043	2.44	3.015	3.393	3.358	2.948	4.662	3.95											
1994			1.188	1.712	2.162	2.927	2.644	3.254	3.273	2.985	4.707	3.907											
1995				1.854	2.083	2.553	3.614	4.357	5.209	4.825	4.286	6.222											
1996			1.696	1.451	1.884	2.213	3.202	2.494	2.404	3.252													
1997			1.245	2.166	1.975	2.631	3.275	3.168	3.969	4.048	4.508	2.488											
1998			1.225	1.528	1.909	2.25	2.856	3.358	3.162	2.834	2.947	4.871											
1999				1.34	1.615	1.773	1.932	2.294	3.052	3.246		3.368	3.299	4.329									
2000			1.266	1.223	1.547	1.775	2.022	2.421	2.735	2.821	3.625	2.924	3.584	4.514	3.901								
2001			1.153	1.379	1.532	1.825	2.233	2.259	2.467	2.378	2.729	2.24				3.517							
2002				1.227	1.413	1.667	2.179	2.625	2.361	2.597	2.8	3.589	5.788		3.144								
2003				1.028	1.359	1.551	1.851	2.197	2.541	2.593	2.572	2.46	2.843	2.134	4.073								
2004				1.036	1.407	1.429	1.774	1.897	2.11	2.366	2.146	2.295	2.35	3.501									
2005				1.053	1.236	1.591	1.555	1.809	2.047	2.192	2.594	2.316	2.839	2.497	2.488								
2006				1.146	1.329	1.493	1.778	1.638	1.814	2.01	2.164	2.437	2.248	2.332	2.344	2.611							
2007			0.812	1.162	1.236	1.238	1.625	1.681	1.671	1.755	1.864	2.123	3.029	2.398	2.11	3.004							
2008			1.061	1.164	1.238	1.39	1.489	1.792	1.772	1.658	1.786	1.982	2.074	2.987									
2009				1.132	1.242	1.385	1.728	1.677	1.968	2.14	1.986	2.031	2.343	1.775	2.662	2.814							
2010			1.13	0.883	1.16	1.456	1.651	1.762	2.155	2.163	2.237	2.077	2.089	2.253	3.512	2.488		3.745					
2011			0.812	1.165	1.212	1.494	1.696	1.885	2.006	1.987	2.165	2.14	2.023	2.243	2.145	2.521	2.611	2.869	3.198				5.061
2012			0.965	1.14	1.286	1.475	1.564	1.82	1.916	1.995	2.616	2.186	2.113	2.063	2.206	2.727	2.674	3.287	2.869				
2013			0.816	1.014	1.298	1.464	1.635	1.72	1.893	1.937	2.049	1.93	2.243	2.261	2.079	2.226	2.217	2.548	2.611				

Table A.20. Gulf of Maine haddock commercial otter trawl landings per unit effort index (LPUE) from 1977 to 2012. *Note that 2013 commercial landings data were not available at the time the LPUE analysis was conducted.*

Year	Index	Std. Error	Variance	Lower 95% CL	Upper 95% CL
1977	1.064	0.063	0.004	0.938	1.203
1978	1.250	0.066	0.004	1.096	1.420
1979	1.296	0.069	0.005	1.130	1.479
1980	1.488	0.062	0.004	1.315	1.677
1981	1.198	0.066	0.004	1.050	1.362
1982	1.000				
1983	0.820	0.057	0.003	0.733	0.915
1984	0.422	0.057	0.003	0.376	0.471
1985	0.296	0.056	0.003	0.265	0.330
1986	0.230	0.056	0.003	0.206	0.256
1987	0.118	0.060	0.004	0.104	0.132
1988	0.070	0.071	0.005	0.061	0.080
1989	0.062	0.100	0.010	0.050	0.075
1990	0.080	0.087	0.008	0.067	0.094
1991	0.074	0.082	0.007	0.063	0.087
1992	0.046	0.085	0.007	0.039	0.054
1993	0.045	0.088	0.008	0.038	0.053
1994	0.031	0.110	0.012	0.025	0.038
1995	0.032	0.077	0.006	0.028	0.037
1996	0.049	0.068	0.005	0.043	0.056
1997	0.083	0.067	0.005	0.072	0.094
1998	0.111	0.063	0.004	0.098	0.125
1999	0.073	0.070	0.005	0.063	0.083
2000	0.099	0.064	0.004	0.088	0.112
2001	0.147	0.057	0.003	0.132	0.165
2002	0.148	0.054	0.003	0.133	0.164
2003	0.185	0.052	0.003	0.166	0.204
2004	0.220	0.053	0.003	0.198	0.244
2005	0.193	0.053	0.003	0.174	0.214
2006	0.204	0.054	0.003	0.183	0.226
2007	0.227	0.055	0.003	0.204	0.252
2008	0.205	0.055	0.003	0.184	0.229
2009	0.227	0.058	0.003	0.202	0.253
2010	0.160	0.063	0.004	0.141	0.180
2011	0.129	0.056	0.003	0.116	0.144
2012	0.081	0.055	0.003	0.072	0.090

Table A.21. Fractional breakdown of the observed discards of Gulf of Maine haddock by discard reason from 1989 to 2013.

Year	Unknown/ other	No market	Poor quality	Regulatory, no retention	Regulatory, too small
1989	0.51	0.00	0.49	0.00	0.00
1990	0.67	0.00	0.33	0.00	0.00
1991	0.71	0.00	0.29	0.00	0.00
1992	0.82	0.00	0.18	0.00	0.00
1993	0.72	0.14	0.14	0.00	0.00
1994	0.49	0.01	0.00	0.42	0.08
1995	0.09	0.03	0.01	0.56	0.31
1996	0.13	0.03	0.06	0.30	0.48
1997	0.00	0.45	0.00	0.46	0.09
1998	0.83	0.00	0.01	0.00	0.16
1999	0.00	0.07	0.77	0.10	0.06
2000	0.00	0.53	0.21	0.00	0.26
2001	0.00	0.00	0.03	0.00	0.96
2002	0.00	0.05	0.10	0.01	0.84
2003	0.00	0.11	0.08	0.01	0.80
2004	0.00	0.08	0.11	0.32	0.49
2005	0.01	0.02	0.17	0.02	0.78
2006	0.00	0.00	0.03	0.01	0.97
2007	0.00	0.01	0.34	0.01	0.63
2008	0.00	0.00	0.02	0.04	0.93
2009	0.00	0.00	0.17	0.03	0.80
2010	0.00	0.00	0.08	0.08	0.84
2011	0.00	0.00	0.05	0.61	0.34
2012	0.01	0.05	0.06	0.07	0.81
2013	0.00	0.01	0.06	0.14	0.79

Table A.22. Number of Gulf of Maine haddock length observations recorded by certified observers (NEFOP) and at-sea monitors (ASM) by year and gear type. The gear codes listed are as follows: longline (010), otter trawl (050), sink gillnet (100) and mesh type codes are: large mesh (LM), extra-large mesh (ELM).

Year	NEGEAR	Mesh category	NEFOP lengths	ASM lengths
2010	010		1	10
2010	050	LM	25	58
2010	100	ELM	0	1
2010	100	LM	6	31
2011	010		2	51
2011	050	LM	111	418
2011	100	ELM	0	1
2011	100	LM	43	120
2012	010		52	138
2012	050	LM	578	922
2012	100	ELM	0	1
2012	100	LM	305	327
2013	010		16	6
2013	050	LM	282	2032
2013	100	ELM	0	1
2013	100	LM	118	169

Table A.23. Fraction of the total Gulf of Maine haddock estimated discards based on ***preliminary estimates of commercial discards*** by gear type from 1989 to 2012. Gears contributing greater than 5% of the total observed discards in any year are shaded grey. *Note that the 2013 estimates are missing because these data were not available at the time of this analysis.*

Year	Benthic longline	Otter trawl		Shrimp trawl	Sink gillnet		Major gear type contribution	Total estimated discards (mt)
		Small mesh (<5.5")	Large mesh (5.5" - 7.9")		Large mesh (5.5" - 7.9")	Extra-large mesh (≥8")		
1989	0.00	0.00	0.41	0.03	0.57	0.00	0.97	5.1
1990	0.00	0.00	0.06	0.30	0.64	0.00	0.70	2.9
1991	0.14	0.00	0.33	0.07	0.46	0.00	0.93	3.0
1992	0.00	0.00	0.78	0.10	0.12	0.00	0.90	8.9
1993	0.00	0.00	0.67	0.10	0.23	0.00	0.90	14.8
1994	0.00	0.00	0.84	0.04	0.13	0.00	0.96	63.3
1995	0.00	0.01	0.91	0.02	0.06	0.00	0.97	90.1
1996	0.00	0.01	0.73	0.02	0.21	0.02	0.94	83.3
1997	0.00	0.00	1.00	0.00	0.00	0.00	1.00	379.9
1998	0.00	0.00	0.82	0.00	0.18	0.00	1.00	16.6
1999	0.00	0.06	0.44	0.00	0.50	0.00	0.94	2.5
2000	0.00	0.00	0.73	0.00	0.25	0.02	0.98	28.5
2001	0.00	0.25	0.41	0.00	0.34	0.00	0.75	17.3
2002	0.00	0.02	0.37	0.00	0.56	0.04	0.93	20.0
2003	0.28	0.01	0.41	0.00	0.24	0.07	0.93	19.1
2004	0.04	0.05	0.60	0.01	0.23	0.08	0.86	13.6
2005	0.58	0.00	0.25	0.00	0.10	0.06	0.93	26.8
2006	0.20	0.00	0.68	0.01	0.06	0.04	0.95	33.3
2007	0.37	0.01	0.08	0.01	0.50	0.03	0.95	49.3
2008	0.34	0.06	0.34	0.00	0.25	0.00	0.93	11.0
2009	0.30	0.02	0.18	0.03	0.46	0.01	0.94	13.1
2010	0.07	0.08	0.42	0.15	0.21	0.07	0.70	4.3
2011	0.11	0.42	0.23	0.00	0.22	0.02	0.56	9.9
2012	0.16	0.04	0.36	0.25	0.19	0.00	0.71	26.1
2013								
Average	0.11	0.04	0.50	0.05	0.28	0.02	0.89	

Table A.24. ***Preliminary estimates of the coefficients of variation*** (CV) for the Gulf of Maine haddock commercial discard (mt) estimates from 1989 to 2013 by gear. *Note that the 2013 estimates are missing because these data were not available at the time of this analysis.*

Year	Benthic longline	Otter trawl		Shrimp trawl	Sink gillnet		Total
		Small mesh (<5.5")	Large mesh (5.5" - 7.9")		Large mesh (5.5" - 7.9")	Extra-large mesh (≥8")	
1989		0.83	0.84	0.80	0.49		0.72
1990			1.05	0.81	0.43		0.61
1991	1.19		0.56	0.84	0.31		0.44
1992			0.66	0.26	0.24		0.58
1993			0.53	0.21	0.33		0.44
1994			0.38	0.21	0.43		0.35
1995		0.33	0.37	0.25	0.40		0.35
1996		4.07	0.66	0.67	0.54	0.63	0.53
1997			0.96	0.72	1.04		0.95
1998			0.37		0.66		0.33
1999		0.47	1.05		0.53		0.63
2000			0.54		0.50	0.48	0.44
2001		0.70	0.65		0.35		0.37
2002		0.63	0.33		0.39	0.83	0.22
2003	0.45	0.57	0.18		0.23	0.30	0.16
2004	0.37	0.60	0.25	0.69	0.20	0.29	0.17
2005	0.26	0.32	0.18	0.52	0.22	0.19	0.16
2006	0.36	0.43	0.49	0.43	0.24	0.56	0.35
2007	0.39	0.37	0.31	0.69	0.83	0.64	0.39
2008	0.47	0.16	0.41	0.84	0.28	0.62	0.23
2009	0.81	0.73	0.34	0.40	0.27	3.01	0.31
2010	0.40	0.61	0.28	0.41	0.25	0.19	0.16
2011	0.30	0.45	0.11	0.00	0.08	0.14	0.20
2012	0.32	0.25	0.11	0.72	0.06	0.16	0.19
2013							
Average	0.48	0.72	0.48	0.53	0.39	0.62	0.39

Table A.25. Summary of the number of lengths collected from Gulf of Maine haddock discarded in the commercial fishery by gear type and semester from 1989 to 2013.

Year	Benthic longline		Otter trawl				Shrimp trawl		Sink gillnet				Total
			Small mesh (<5.5")		Large mesh (5.5" -				Large mesh (5.5" -		Extra-large mesh		
	1	2	1	2	1	2	1	2	1	2	1	2	
1989					1	8	1						10
1990													
1991										1			1
1992					10	23	7			1			41
1993					8	44	48	1	2	1			104
1994					8	17	88	32	1	18			164
1995				16	217	218	136		7	6			600
1996			21	3	56	32	5	36	25	8		4	190
1997					946	3	7			2	1		959
1998					10				2	2			14
1999				6		5				18			29
2000						17			6	2			25
2001			1		24	18			5				48
2002				40	10	49			35	3			137
2003	105		5	22	96	116			39	43	6	13	445
2004	23			121	41	195	1		55	38	3	26	503
2005	207	7		18	223	237			5	72	9	15	793
2006	140		4	3	219	101	111	2		3		2	585
2007	299			8	124	125	7		13	10	1		587
2008	63				33	185			3	3			287
2009	127			10	80	27		1	91	1			337
2010	11			3	25	58		18	3	34		1	153
2011	36	17		327	78	451	3		53	101		1	1067
2012	137	53	5	5	306	1244	11		130	438	1		2330
2013	22		123	77	1636	720	18		84	116		1	2797

Table A.26. Total number of Gulf of Maine commercial trips (statistical areas 464, 465, 467, 511-515) observed from 1989 to 2013, summarized by gear type. *The 2010-2013 numbers include trips observed by both at-sea monitors and observers.*

Year	Benthic longline	Otter trawl, large mesh (5.5" - 7.9")	Sink gillnet, large mesh (5.5" - 7.9")	Total
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989		38	105	143
1990		26	120	146
1991	3	48	801	852
1992	11	44	896	951
1993	3	17	560	580
1994		6	82	88
1995		24	62	86
1996		11	39	50
1997		5	31	36
1998		6	78	84
1999		27	70	97
2000		80	70	150
2001		112	39	151
2002	1	150	62	213
2003	18	251	254	523
2004	10	251	587	848
2005	58	499	505	1062
2006	36	203	109	348
2007	36	225	92	353
2008	20	254	130	404
2009	35	410	271	716
2010	52	615	1080	1747
2011	80	1014	1382	2476
2012	113	1123	1166	2402
2013	33	642	495	1170

Table A.27. ***Final estimates*** of Gulf of Maine haddock commercial discards (mt) by gear from 1977 to 2013 by gear. Estimates from 1989 to 2011 were estimated using an approach consistent with the Standardized Bycatch Report Methodology (Wigley et al., 2007). Estimates from 1977 to 1988 were hindcast using an approach documented in this report. *Note that hindcast discard estimates could not be obtained pre-1982, and no attempt was made to hindcast discards by longline gear.*

Year	Benthic longline	Otter trawl, large mesh (5.5" - 7.9")	Sink gillnet, large mesh (5.5" - 7.9")	Total
1977				
1978				
1979				
1980				
1981				
1982		0.5	5.9	6.4
1983		1.8	4.6	6.5
1984		4.4	6.6	11.0
1985		9.2	7.3	16.5
1986		8.5	7.9	16.4
1987		10.8	13.1	23.9
1988				
1989		2.1	2.9	5.0
1990		0.2	1.9	2.0
1991	0.4	1.0	1.4	2.8
1992	0.0	7.0	1.1	8.0
1993	0.0	9.9	3.4	13.3
1994		53.1	8.0	61.1
1995		82.0	5.8	87.7
1996		60.9	17.4	78.2
1997		378.5	0.3	378.7
1998		13.7	3.0	16.6
1999		1.1	1.2	2.3
2000		20.8	7.1	27.9
2001		7.1	5.8	12.9
2002		7.5	11.2	18.6
2003	5.3	7.9	4.6	17.7
2004	0.5	8.1	3.1	11.7
2005	15.5	6.8	2.7	25.0
2006	6.7	22.6	2.1	31.5
2007	18.5	3.7	24.7	46.9
2008	3.7	3.8	2.8	10.3
2009	4.0	2.3	6.0	12.3
2010	0.3	1.8	0.9	3.0
2011	1.0	2.3	2.2	5.6
2012	4.5	8.7	4.5	17.7
2013	1.3	28.4	2.6	32.3

Table A.28. ***Final coefficients of variation*** (CV) for the Gulf of Maine haddock commercial discard (mt) estimates from 1977 to 2013 by gear. *CVs are not available for hindcast discards (pre-1989).*

Year	Benthic longline	Otter trawl, large mesh (5.5" - 7.9")	Sink gillnet, large mesh (5.5" - 7.9")	Total
1977				
1978				
1979				
1980				
1981				
1982				
1983				
1984				
1985				
1986				
1987				
1988				
1989		0.84	0.49	0.45
1990		1.05	0.43	0.40
1991	1.19	0.56	0.31	0.31
1992		0.66	0.24	0.58
1993		0.53	0.33	0.40
1994		0.38	0.43	0.33
1995		0.37	0.40	0.35
1996		0.66	0.54	0.53
1997		0.96	1.04	0.95
1998		0.37	0.66	0.32
1999		1.05	0.53	0.56
2000		0.54	0.50	0.42
2001		0.65	0.35	0.39
2002		0.33	0.39	0.27
2003	0.45	0.18	0.23	0.17
2004	0.37	0.25	0.20	0.18
2005	0.26	0.18	0.22	0.17
2006	0.36	0.49	0.24	0.36
2007	0.39	0.31	0.83	0.47
2008	0.47	0.41	0.28	0.24
2009	0.81	0.34	0.27	0.30
2010	0.40	0.28	0.25	0.19
2011	0.30	0.11	0.08	0.08
2012	0.34	0.11	0.06	0.10
2013	0.28	0.16	0.09	0.14
Average	0.47	0.47	0.38	0.35

Table A.29. Length sampling of Gulf of Maine haddock commercial discards from 1989 to 2013 by gear type and semester. Sampling intensity is expressed as metric tons discards per 100 lengths sampled (*200 metric tons per 100 lengths is an unofficial NAFO/ICNAF standard*). Cells shaded grey and blue indicate where discards at length were estimated using annual time blocks. Cells shaded green indicate where discards at length were estimated using semester time blocks. Blue shaded cells indicate where length sampling was determined to be insufficient and augmented with survey length frequencies. A general criterion of 30 lengths/block was used to determine sampling sufficiency.

Year	Benthic longline		Otter trawl, large mesh (5.5" - 7.9")		Sink gillnet, large mesh (5.5" - 7.9")		Total lengths	Total discards (mt)	Metric tons/100 lengths
	1	2	1	2	1	2			
1989			1	8			9	5.0	55.4
1990							0	2.0	
1991						1	1	2.8	280.0
1992			10	23		1	34	8.0	23.6
1993			8	44	2	1	55	13.3	24.2
1994			8	17	1	18	44	61.1	138.8
1995			217	218	7	6	448	87.7	19.6
1996			56	32	25	8	121	78.2	64.7
1997			946	3		2	951	378.7	39.8
1998			10		2	2	14	16.6	118.9
1999				5		18	23	2.3	10.1
2000				17	6	2	25	27.9	111.4
2001			24	18	5		47	12.9	27.5
2002			10	49	35	3	97	18.6	19.2
2003	105		96	116	39	43	399	17.7	4.4
2004	23		41	195	55	38	352	11.7	3.3
2005	207	7	223	237	5	72	751	25.0	3.3
2006	140		219	101		3	463	31.5	6.8
2007	299		124	125	13	10	571	46.9	8.2
2008	63		33	185	3	3	287	10.3	3.6
2009	127		80	27	91	1	326	12.3	3.8
2010	11		25	58	3	34	131	3.0	2.3
2011	36	17	78	451	53	101	736	5.6	0.8
2012	137	53	306	1244	130	438	2308	17.7	0.8
2013	22		1636	720	84	116	2578	32.3	1.3

Table A.30. Summary of length observations borrowed from Northeast Fisheries Science Center (NEFSC) bottom trawl surveys by gear type. See report text for a description of the method used to sub-sample gear-specific lengths from the survey length distributions. The grey shaded cells indicate years when the survey lengths were applied for the estimation of commercial discards at length.

Year	Benthic longline	Otter trawl, large mesh (5.5" - 7.9")	Sink gillnet, large mesh (5.5" - 7.9")
1977	99	348	249
1978	41	94	79
1979	10	40	27
1980	4	53	25
1981	26	89	63
1982	7	21	16
1983	6	38	21
1984	12	33	27
1985	34	61	54
1986	1	1	1
1987	5	5	5
1988	0	0	0
1989	6	11	10
1990		2	1
1991	1	4	4
1992	2	7	3
1993	19	49	38
1994	5	13	11
1995	29	46	44
1996	29	42	38
1997	44	89	70
1998	31	53	44
1999	79	291	188
2000	438	739	670
2001	224	282	268
2002	110	154	135
2003	50	70	64
2004	67	83	83
2005	58	101	86
2006	191	258	244
2007	48	107	86
2008	176	359	313
2009	28	48	41
2010	7	17	10
2011	39	108	79
2012	279	655	533
2013	165	795	456

Table A.31. Total Gulf of Maine haddock commercial discards-at-age (numbers) from 1977 to 2013. *Note that commercial discard estimates are not available pre-1982.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15	Total
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	301	12,883	1,385	0	0	0	0	0	0	0	0	0	0	0	0	14,569
1983	110	10,807	4,266	5,183	0	0	0	0	0	0	0	0	0	0	0	0	20,366
1984	0	1,070	18,321	4,267	1,585	0	0	0	0	0	0	0	0	0	0	0	25,243
1985	0	881	7,054	19,572	2,549	47	0	0	0	0	0	0	0	0	0	0	30,103
1986	0	3,588	10,765	10,765	3,588	3,588	0	0	0	0	0	0	0	0	0	0	32,294
1987	0		15,705	7,437	4,657	632	0	0	0	0	0	0	0	0	0	0	28,431
1988	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1989	0	1,168	5,456	458	497	0	0	0	0	0	0	0	0	0	0	0	7,579
1990	0	6,931	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,931
1991	0	3,130	1,531	501	0	0	0	0	0	0	0	0	0	0	0	0	5,162
1992	0	1,819	5,339	2,314	220	29	0	0	0	0	0	0	0	0	0	0	9,721
1993	0	3,654	9,207	2,175	422	129	351	0	146	95	0	0	0	95	32	0	16,306
1994	69	6,417	16,161	13,226	3,005	1,650	2,076	2,138	573	0	0	245	0	0	0	0	45,560
1995	406	1,983	42,355	32,723	11,912	1,283	530	350	0	0	0	0	0	0	0	0	91,542
1996	0	2,577	19,546	66,865	8,339	1,769	211	404	274	134	0	0	0	0	0	0	100,119
1997	0	821	3,970	75,257	128,867	32,670	5,881	2,145	1,776	553	50	173	0	0	0	0	252,163
1998	965	5,681	7,890	2,360	8,247	2,601	10	0	0	0	0	0	0	0	0	0	27,754
1999	95	3,127	825	632	121	174	128	41	23	12	4	0	0	0	0	0	5,182
2000	0	1,867	32,786	11,083	1,942	734	259	26	11	0	0	3	0	0	0	0	48,711
2001	0	250	4,587	10,752	1,031	209	248	126	2	0	0	0	0	0	0	0	17,205
2002	47	420	1,069	3,644	13,998	1,677	620	104	454	60	0	0	0	0	0	0	22,093
2003	0	112	1,606	2,283	3,959	11,282	1,117	180	123	57	46	4	1	0	0	0	20,770
2004	0	1,251	311	2,048	1,303	2,129	5,394	466	208	18	36	22	2	0	0	0	13,188
2005	0	193	7,692	728	5,858	4,022	4,445	6,986	591	81	10	8	1	0	0	0	30,615
2006	0	80	700	22,304	1,565	3,661	2,189	3,776	5,679	345	22	0	0	0	0	0	40,321
2007	0	7,838	15,443	7,320	37,095	455	1,380	919	1,019	2,022	37	15	0	0	0	0	73,543
2008	0	96	5,695	3,741	310	5,677	89	151	85	120	109	0	0	0	0	0	16,073
2009	0	62	396	3,720	2,895	629	4,774	100	412	22	115	281	3	3	0	0	13,412
2010	27	734	792	484	1,037	412	191	593	0	1	46	4	22	0	0	0	4,343
2011	19	3,040	4,516	1,033	82	1,003	290	41	491	1	0	13	4	5	2	0	10,540
2012	8	1,010	26,796	4,636	965	37	485	85	18	285	5	3	0	8	14	0	34,355
2013	1,175	18,376	12,217	31,242	1,521	232	17	127	42	4	36	2	1	0	1	5	64,998

Table A.32. Mean weights-at-age (kg) of commercially discarded Gulf of Maine haddock from 1977 to 2013. *Note that commercial discard estimates are not available pre-1982.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15
1977																
1978																
1979																
1980																
1981																
1982		0.389	0.438	0.454												
1983	0.048	0.181	0.314	0.610												
1984		0.308	0.420	0.504	0.521											
1985		0.315	0.502	0.562	0.644	0.507										
1986		0.507	0.507	0.507	0.507	0.507										
1987			0.789	0.901	0.901	0.979										
1988																
1989		0.240	0.713	0.799	0.911											
1990		0.295														
1991		0.347	0.821	0.916												
1992		0.448	0.867	0.995	1.078	1.185										
1993		0.364	0.649	0.934	1.931	2.032	3.664		4.111	4.461				4.640	4.286	
1994	0.092	0.362	0.632	1.319	2.281	3.212	3.279	4.234	3.681			3.950				
1995	0.017	0.256	0.717	1.019	1.459	2.575	3.122	3.255								
1996		0.330	0.500	0.752	1.363	2.098	2.326	2.114	2.117	2.488						
1997		0.358	0.759	1.458	1.396	1.823	2.359	2.567	2.565	2.930	3.738	2.632				
1998	0.021	0.250	0.648	0.644	0.790	0.783	1.773									
1999	0.072	0.233	0.468	0.676	0.950	1.026	1.864	2.347	4.111	3.775	3.665					
2000		0.257	0.533	0.659	0.834	0.764	1.148	2.809	3.154			3.331				
2001		0.242	0.667	0.777	0.880	0.997	0.846	0.941	1.639							
2002	0.068	0.121	0.398	0.730	0.892	1.020	1.064	1.066	0.961	1.257						
2003		0.318	0.525	0.593	0.752	0.957	0.996	1.481	1.070	1.858	2.370	1.769	2.814			
2004		0.191	0.381	0.696	0.909	0.962	1.048	1.117	1.863	2.212	1.343	2.365	1.889			
2005		0.173	0.484	0.703	0.828	0.884	0.983	1.033	0.978	1.267	1.336	1.634	2.018			
2006		0.287	0.405	0.701	0.694	0.853	0.858	0.897	1.012	0.943	1.310					
2007		0.243	0.490	0.585	0.752	0.802	0.832	0.843	0.889	0.976	1.170	1.194				
2008		0.289	0.459	0.637	0.899	0.788	0.829	0.851	0.830	0.869	0.985					
2009		0.304	0.565	0.774	0.927	0.944	1.019	0.950	0.976	1.544	1.182	1.319	1.971	1.563		
2010	0.086	0.253	0.450	0.763	0.826	0.887	0.851	1.011		1.353	0.875	1.385	1.261			
2011	0.064	0.268	0.511	0.715	0.975	0.803	0.957	1.011	0.956	1.702	1.466	1.221	1.184	1.398	1.783	
2012	0.064	0.248	0.473	0.668	0.772	1.160	0.936	1.135	1.306	0.982	1.014	1.601		1.236	1.529	
2013	0.076	0.262	0.442	0.651	0.785	0.855	1.134	1.036	1.143	1.567	1.349	1.329	1.575		1.466	1.468

Table A.33. Annual ratios of Marine Recreational Fisheries Statistical Survey (MRFSS) and Marine Recreational Information Program (MRIP) Gulf of Maine haddock catch estimates and aggregate time series ratios (ratio of means) using the 2004 – 2011 period of overlap.

	MRFSS		MRIP			MRIP/MRFSS Ratio	
Year	**Estimated recreational harvest, A + B1 (000s fish)**	**Estimated recreational releases, B2 (000s fish)**	**Estimated recreational harvest, A + B1 (000s fish)**	**Estimated recreational releases, B2 (000s fish)**	**Year**	**Harvest (A+B1)**	**Releases (B2)**
2004	278.5	142.4	199.0	80.4	2004	0.71	0.56
2005	444.7	116.2	355.2	101.8	2005	0.80	0.88
2006	277.9	164.2	296.8	175.1	2006	1.07	1.07
2007	398.2	105.4	402.8	110.6	2007	1.01	1.05
2008	358.5	124.3	342.7	178.4	2008	0.96	1.44
2009	311.6	72.0	265.4	65.4	2009	0.85	0.91
2010	391.5	72.6	190.3	47.0	2010	0.49	0.65
2011	166.3	38.7	139.8	35.5	2011	0.84	0.92
Sum	**2,627**	**835.7**	**2,192.1**	**794.1**	**Ratio**	**0.83**	**0.95**

Table A.34. Estimates of Gulf of Maine haddock recreational catch in numbers (000s) and weight (mt). ***Recreational release estimates do not include any assumptions about discard mortality.***

	Recreational harvest (A+B1)			Recreational releases (B2)		
Year	**Numbers (000s)**	**CV**	**Weight (mt)**	**Numbers (000s)**	**CV**	**Weight (mt)**
1981	19.2	0.34	38.2	0.0		0.0
1982	16.3	0.49	23.0	0.1	1.00	0.0
1983	30.5	0.26	52.7	0.0		0.0
1984	26.2	0.32	52.3	1.6	0.75	0.6
1985	16.2	0.36	21.6	0.1	1.00	0.0
1986	29.1	0.32	51.8	0.4	0.75	0.2
1987	15.7	0.29	39.2	0.0		0.0
1988	6.4	0.31	20.1	2.8	0.58	1.3
1989	5.0	0.42	13.1	4.9	0.44	2.6
1990	1.5	0.48	5.3	0.3	1.00	0.1
1991	0.2	1.46	0.3	0.0		0.0
1992	0.0		0.0	0.0		0.0
1993	0.3	1.99	0.6	0.0		0.0
1994	2.0	0.52	3.3	1.6	0.61	0.9
1995	92.7	0.64	124.1	41.3	0.65	27.4
1996	3.5	0.34	5.7	8.2	0.35	6.4
1997	16.8	0.43	30.2	15.0	0.33	10.5
1998	23.6	0.31	45.6	9.1	0.36	7.0
1999	10.1	0.24	17.8	15.9	0.27	9.8
2000	67.6	0.24	128.1	96.1	0.22	60.4
2001	100.8	0.14	169.3	106.8	0.17	86.8
2002	69.7	0.18	135.3	163.6	0.21	177.3
2003	100.2	0.11	173.9	248.2	0.15	257.4
2004	199.0	0.16	312.6	80.4	0.22	72.9
2005	355.2	0.16	538.1	101.8	0.28	72.0
2006	296.8	0.10	447.4	175.1	0.14	131.0
2007	402.8	0.15	572.7	110.6	0.12	91.4
2008	342.7	0.13	536.6	178.4	0.42	144.1
2009	265.4	0.14	408.6	65.4	0.12	48.8
2010	190.3	0.15	314.0	47.0	0.23	37.1
2011	139.8	0.14	228.8	35.5	0.17	22.4
2012	167.5	0.19	251.2	189.7	0.14	107.3
2013	147.0	0.09	241.1	507.1	0.08	413.9

Table A.35. Length sampling intensity of recreationally caught Gulf of Maine haddock by catch type and year from 1981 to 2013. Sampling intensity is expressed as metric tons of landings per 100 lengths sampled (*200 metric tons per 100 lengths is an unofficial NAFO/ICNAF standard*). In some years recreational length frequencies were supplemented using length observations from the Northeast Fisheries Science Center (NEFSC); see text for a description of the methods used to sub-sample from the survey length distributions. Due to the limited number of survey lengths available to characterize recreational releases between 1981 and 1994, an aggregate length frequency distribution was applied (grey-shaded cells).

	Landings (A)				Releases (B2)			
Year	**Lengths sampled**	**Harvest (A+B1, mt)**	**Metric tons/100 lengths**	**NEFSC survey supplement**	**Lengths sampled**	**Releases (B2, mt)**	**Metric tons/100 lengths**	**NEFSC survey supplement**
1981	13	38.2	293.9	216		0.0		12
1982	2	23.0	1148.2	170		0.0		2
1983	10	52.7	527.4	166		0.0		0
1984	16	52.3	326.8	63		0.6		3
1985	7	21.6	308.4	262		0.0		4
1986	0	51.8		54		0.2		0
1987	6	39.2	652.9	35		0.0		1
1988	2	20.1	1006.2	20		1.3		0
1989	3	13.1	436.9	19		2.6		6
1990	0	5.3		6		0.1		1
1991	0	0.3		4		0.0		1
1992	0	0.0		4		0.0		2
1993	0	0.6		11		0.0		17
1994	4	3.3	81.4	10		0.9		5
1995	153	124.1	81.1			27.4		28
1996	25	5.7	22.9	53		6.4		31
1997	21	30.2	143.9	58		10.5		40
1998	62	45.6	73.6	54		7.0		29
1999	32	17.8	55.6	130		9.8		71
2000	34	128.1	376.7	167		60.4		445
2001	25	169.3	677.4	376		86.8		236
2002	119	135.3	113.7			177.3		551
2003	210	173.9	82.8			257.4		151
2004	2146	312.6	14.6		101	72.9	72.1	
2005	3269	538.1	16.5		140	72.0	51.4	
2006	2473	447.4	18.1		228	131.0	57.5	
2007	2082	572.7	27.5		143	91.4	63.9	
2008	2321	536.6	23.1		106	144.1	135.9	
2009	2366	408.6	17.3		56	48.8	87.1	
2010	1727	314.0	18.2		14	37.1	265.3	
2011	1484	228.8	15.4		29	22.4	77.2	
2012	1753	251.2	14.3		539	107.3	19.9	
2013	1019	241.1	23.7		2343	413.9	17.7	

Table A.36. Total Gulf of Maine haddock harvest (A+B1)-at-age (numbers) from 1977 to 2013. *Note that recreational catch estimates are not available pre-1981.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15	Age16	Age17	Age18	Total
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	6,474	3,934	1,630	2,286	3,123	570	899	122	84	0	0	31	92	0	0	0	0	19,245
1982	0	0	2,454	9,499	2,497	363	426	805	116	76	94	0	16	0	5	0	0	0	0	16,351
1983	0	0	544	13,261	8,458	4,562	768	817	1,642	239	132	85	7	0	0	0	0	0	0	30,515
1984	0	0	6,301	936	8,287	2,876	4,986	591	637	1,507	0	30	19	0	0	0	0	0	0	26,170
1985	0	0	1,018	10,694	880	1,963	581	719	176	68	138	0	10	0	0	0	0	0	0	16,247
1986	0	539	0	6,263	14,207	2,418	2,461	1,644	1,367	204	0	0	0	0	0	0	0	0	0	29,103
1987	0	0	1,119	1,855	5,705	2,053	1,422	1,593	871	642	447	0	0	0	0	0	0	0	0	15,707
1988	0	0	0	266	445	2,342	1,783	97	1,305	145	0	0	0	0	0	0	0	0	0	6,383
1989	0	0	368	61	1,191	1,007	1,288	1,045	57	0	0	0	0	0	0	0	0	0	0	5,017
1990	0	0	0	576	0	256	128	320	256	0	0	0	0	0	0	0	0	0	0	1,536
1991	0	0	43	115	30	7	4	4	0	0	0	0	0	0	0	0	0	0	0	203
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	43	78	59	71	35	0	0	0	0	0	0	0	0	0	0	0	0	286
1994	0	0	515	1,044	150	95	109	68	0	0	0	18	0	0	0	0	0	0	0	1,999
1995	0	0	13,408	48,402	29,610	718	303	303	0	0	0	0	0	0	0	0	0	0	0	92,744
1996	0	0	121	1,560	1,245	255	69	129	85	18	9	0	0	11	0	0	0	0	0	3,502
1997	0	0	202	5,490	7,938	2,012	586	279	89	114	35	10	0	0	0	0	0	0	0	16,755
1998	0	0	875	1,663	8,434	9,962	1,638	508	290	179	18	0	0	0	0	0	0	0	0	23,567
1999	0	0	0	1,484	1,576	3,072	2,461	1,173	263	85	8	0	27	0	0	0	0	0	0	10,149
2000	0	0	554	5,256	16,907	9,977	19,140	9,986	3,895	1,119	382	201	64	84	0	0	0	0	0	67,565
2001	0	0	3,395	34,438	21,048	13,816	10,855	8,892	5,101	2,026	916	191	0	0	0	94	0	0	0	100,772
2002	0	0	0	344	22,898	12,712	13,956	3,854	7,722	6,162	1,471	558	0	0	23	0	0	0	0	69,700
2003	0	0	18	352	4,326	64,000	12,713	7,466	2,564	4,205	3,682	516	273	133	0	0	0	0	0	100,248
2004	0	185	0	1,418	11,735	20,645	129,566	17,109	8,614	2,091	4,159	2,720	697	13	0	0	0	0	0	198,952
2005	0	0	1,671	1,880	21,593	34,865	59,620	203,276	15,698	9,339	2,128	3,263	1,651	197	46	0	0	0	0	355,227
2006	0	0	40	30,887	1,233	24,087	32,982	38,394	149,418	12,705	3,890	608	1,546	795	202	27	0	0	0	296,814
2007	0	0	638	3,164	162,193	5,450	24,982	20,350	38,260	133,950	9,118	3,480	178	551	468	24	0	0	0	402,806
2008	0	0	783	14,041	7,237	167,160	1,605	19,335	15,741	21,632	87,855	4,089	3,192	52	0	0	0	0	0	342,722
2009	0	0	617	12,399	27,983	8,209	141,524	2,558	13,182	4,995	9,486	41,845	1,080	1,377	156	14	0	0	0	265,425
2010	0	0	272	1,752	15,644	21,283	7,892	100,695	1,062	4,866	3,989	4,816	26,701	1,067	184	45	0	14	0	190,282
2011	0	0	2,456	1,976	2,537	22,135	19,859	4,846	57,999	713	4,201	3,959	2,966	15,412	566	124	18	9	26	139,802
2012	0	9	7,854	24,983	10,188	6,127	32,080	14,431	5,383	49,563	438	2,998	1,871	2,743	8,487	201	78	40	6	167,480
2013	0	9	1,358	45,812	16,253	8,189	3,974	18,810	16,395	3,426	30,583	0	0	0	0	2,164	0	0	0	146,973

Table A.37. Mean weights-at-age (kg) of recreationally landed Gulf of Maine haddock from 1977 to 2013. *Note that recreational catch estimates are not available pre-1981.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Age15	Age16	Age17	Age18
1977																			
1978																			
1979																			
1980																			
1981			0.747	1.424	1.943	2.771	3.346	3.729	4.647	3.299	7.943			3.950	3.479				
1982			0.836	1.144	1.691	2.559	2.728	3.143	3.289	4.701	4.040		4.310		2.654				
1983			0.725	1.109	1.619	2.136	3.034	3.803	4.138	4.186	4.630	4.074	2.782						
1984			0.662	1.141	1.638	2.344	3.204	3.415	4.182	3.903		4.825	2.531						
1985			0.855	0.971	1.396	1.824	2.366	3.479	4.171	4.730	3.960		5.014						
1986		0.507		1.287	1.514	2.141	2.379	3.126	3.647	3.998									
1987			0.951	1.447	1.978	2.353	2.624	3.344	4.108	5.329	7.276								
1988				1.442	1.875	2.633	2.735	4.115	5.141	5.208									
1989			1.238	1.994	1.889	2.788	2.845	3.476	3.048										
1990				2.097		1.773	2.654	4.697	6.945										
1991			1.081	1.178	2.099	2.296	2.296	2.296											
1992																			
1993			1.085	1.398	1.960	2.689	2.808												
1994			1.147	1.485	1.971	2.835	2.720	2.977				2.913							
1995			1.281	1.203	1.543	2.115	2.654	2.184											
1996			1.313	1.366	1.705	1.915	2.725	2.502	2.237	3.418	3.479			2.782					
1997			1.211	1.740	1.556	2.271	2.864	3.267	3.601	3.735	3.632	2.531							
1998			1.401	1.591	1.819	1.919	2.431	3.989	2.857	2.291	2.913								
1999				1.353	1.602	1.673	1.911	2.081	2.454	2.573	3.188		2.913						
2000			1.269	1.302	1.627	1.857	1.990	2.193	2.413	2.282	3.671	2.866	3.582	4.115					
2001			1.131	1.294	1.433	1.798	2.225	2.205	2.594	2.444	3.521	2.371				3.479			
2002				1.534	1.604	1.806	2.136	2.478	2.125	2.325	2.358	2.586			3.188				
2003			0.916	1.359	1.559	1.631	1.815	1.970	2.137	2.139	2.216	1.872	2.396	1.971					
2004		0.121		0.976	1.392	1.395	1.558	1.693	1.834	1.939	1.881	2.180	2.133	3.331					
2005			0.718	1.039	1.195	1.438	1.394	1.545	1.770	1.849	2.506	2.109	2.469	2.309	2.531				
2006			0.595	1.084	1.199	1.410	1.554	1.446	1.578	1.748	1.911	2.234	1.911	1.923	2.242	2.654			
2007			0.679	1.050	1.196	1.204	1.462	1.605	1.490	1.621	1.773	1.797	2.754	1.980	2.245	3.048			
2008			0.823	1.129	1.274	1.438	1.677	1.759	1.719	1.629	1.785	2.094	1.896	3.083					
2009			0.678	0.953	1.163	1.285	1.548	1.471	1.779	1.926	1.717	1.818	2.171	1.610	2.544	2.782			
2010			1.113	0.852	1.135	1.387	1.485	1.680	2.077	2.002	2.046	1.889	1.946	2.162	2.220	2.531		3.788	
2011			0.800	1.093	1.188	1.345	1.486	1.627	1.735	1.793	1.919	1.826	1.792	1.974	1.912	2.428	2.654	2.913	2.412
2012		0.393	0.853	1.075	1.164	1.342	1.365	1.626	1.659	1.777	2.352	1.970	2.005	1.762	1.981	2.685	2.720	3.331	2.913
2013		0.507	0.870	1.129	1.461	1.830	1.477	1.662	2.162	1.727	2.189					1.871			

Table A.38. Gulf of Maine haddock recreational VTR landings per unit effort index (LPUE) from 1994 to 2013.

Year	Index	Std. Error	Variance	CV	Lower 95% CL	Upper 95% CL
1994	1.000			0.000		
1995	1.865	0.087	0.008	0.047	1.566	2.205
1996	1.271	0.090	0.008	0.070	1.063	1.509
1997	2.170	0.087	0.008	0.040	1.823	2.563
1998	2.830	0.086	0.007	0.030	2.382	3.338
1999	2.536	0.086	0.007	0.034	2.134	2.991
2000	3.673	0.083	0.007	0.023	3.109	4.311
2001	2.846	0.082	0.007	0.029	2.416	3.329
2002	3.571	0.081	0.007	0.023	3.038	4.170
2003	3.167	0.081	0.007	0.026	2.693	3.700
2004	5.442	0.080	0.006	0.015	4.635	6.348
2005	6.406	0.080	0.006	0.012	5.462	7.467
2006	6.467	0.080	0.006	0.012	5.514	7.538
2007	5.454	0.080	0.006	0.015	4.650	6.356
2008	4.986	0.080	0.006	0.016	4.248	5.814
2009	6.154	0.080	0.006	0.013	5.242	7.178
2010	4.467	0.080	0.006	0.018	3.805	5.209
2011	4.229	0.080	0.006	0.019	3.602	4.934
2012	4.407	0.080	0.006	0.018	3.755	5.140
2013	3.851	0.080	0.006	0.021	3.279	4.493

Table A.39. Total Gulf of Maine haddock recreational dead discards-at-age (numbers) from 1977 to 2013 ***using an assumption of 50% mortality of recreational releases***. *Note that recreational catch estimates are not available pre-1981.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Total
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	20	24	14	0	0	0	0	0	0	0	0	0	0	0	58
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	132	623	48	0	0	0	0	0	0	0	0	0	0	0	803
1985	0	8	19	17	0	0	0	0	0	0	0	0	0	0	0	44
1986	0	151	54	0	0	0	0	0	0	0	0	0	0	0	0	205
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	305	471	637	0	0	0	0	0	0	0	0	0	0	0	1,413
1989	0	222	1,826	315	80	0	0	0	0	0	0	0	0	0	0	2,443
1990	0	76	15	41	0	0	0	0	0	0	0	0	0	0	0	132
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	38	731	50	0	0	0	0	0	0	0	0	0	0	0	819
1995	0	739	15,505	4,430	0	0	0	0	0	0	0	0	0	0	0	20,674
1996	0	212	588	3,290	0	0	0	0	0	0	0	0	0	0	0	4,090
1997	0	852	883	3,550	2,199	0	0	0	0	0	0	0	0	0	0	7,484
1998	0	152	3,357	68	782	185	0	0	0	0	0	0	0	0	0	4,544
1999	0	2,198	2,963	1,447	477	339	341	165	0	0	0	0	0	0	0	7,930
2000	0	488	31,429	13,712	1,932	213	274	0	0	0	0	0	0	0	0	48,048
2001	0	0	12,866	33,558	4,495	935	1,090	483	0	0	0	0	0	0	0	53,427
2002	0	0	1,303	11,082	52,593	10,686	3,328	127	1,516	1,043	108	0	0	0	0	81,786
2003	0	0	9,192	1,671	15,388	86,835	7,525	2,077	814	580	0	0	0	0	0	124,082
2004	0	398	1,592	8,834	1,042	6,592	20,090	978	402	99	157	14	0	0	0	40,198
2005	0	2,909	24,213	2,593	3,999	3,623	5,150	8,381	40	4	0	0	0	0	0	50,912
2006	0	2,381	1,434	62,284	5,367	4,328	514	1,385	9,684	137	17	7	13	2	0	87,553
2007	0	0	8,703	5,319	34,998	77	1,479	187	795	3,671	27	30	0	10	0	55,296
2008	0	1,683	11,293	16,559	2,442	47,245	1,546	3,487	84	1,086	3,735	17	7	0	0	89,184
2009	0	0	2,354	21,927	4,934	844	2,245	31	33	0	78	234	0	10	0	32,690
2010	0	1,678	5,085	9,926	2,508	1,836	411	1,494	0	26	0	105	420	0	0	23,489
2011	0	3,279	12,043	66	122	1,212	195	118	474	5	42	60	0	162	0	17,778
2012	0	1,623	75,709	11,174	3,437	79	1,398	130	65	1,096	21	11	26	13	88	94,870
2013	0	5,595	22,010	202,497	14,427	2,874	1,471	2,493	0	0	2,209	0	0	0	0	253,576

Table A.40. Total Gulf of Maine haddock recreational dead discards-at-age (numbers) from 1977 to 2013 ***using an assumption of 100% mortality of recreational releases***. *Note that recreational catch estimates are not available pre-1981.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14	Total
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	40	47	27	0	0	0	0	0	0	0	0	0	0	0	114
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	263	1,246	95	0	0	0	0	0	0	0	0	0	0	0	1,604
1985	0	16	38	33	0	0	0	0	0	0	0	0	0	0	0	87
1986	0	302	108	0	0	0	0	0	0	0	0	0	0	0	0	410
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	0	609	942	1,274	0	0	0	0	0	0	0	0	0	0	0	2,825
1989	0	444	3,651	629	160	0	0	0	0	0	0	0	0	0	0	4,884
1990	0	152	30	82	0	0	0	0	0	0	0	0	0	0	0	264
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	75	1,462	99	0	0	0	0	0	0	0	0	0	0	0	1,636
1995	0	1,477	31,010	8,860	0	0	0	0	0	0	0	0	0	0	0	41,347
1996	0	423	1,175	6,580	0	0	0	0	0	0	0	0	0	0	0	8,178
1997	0	1,704	1,766	7,100	4,398	0	0	0	0	0	0	0	0	0	0	14,968
1998	0	303	6,713	135	1,564	370	0	0	0	0	0	0	0	0	0	9,085
1999	0	4,396	5,925	2,894	953	677	682	330	0	0	0	0	0	0	0	15,857
2000	0	976	62,857	27,423	3,863	426	547	0	0	0	0	0	0	0	0	96,092
2001	0		25,731	67,115	8,990	1,870	2,180	965	0	0	0	0	0	0	0	106,851
2002	0		2,606	22,163	105,185	21,371	6,655	253	3,032	2,085	216	0	0	0	0	163,566
2003	0		18,384	3,342	30,775	173,669	15,049	4,153	1,628	1,159	0	0	0	0	0	248,159
2004	0	796	3,184	17,668	2,084	13,184	40,180	1,956	803	198	313	27	0	0	0	80,393
2005	0	5,818	48,425	5,186	7,998	7,246	10,299	16,761	79	7	0	0	0	0	0	101,819
2006	0	4,762	2,867	124,568	10,734	8,656	1,028	2,770	19,368	273	33	13	25	4	0	175,101
2007	0		17,405	10,637	69,996	153	2,958	374	1,589	7,341	54	59	0	19	0	110,585
2008	0	3,366	22,586	33,118	4,884	94,489	3,092	6,974	168	2,172	7,469	33	14	0	0	178,365
2009	0		4,708	43,854	9,867	1,688	4,489	61	65	0	155	467	0	19	0	65,373
2010	0	3,355	10,170	19,851	5,015	3,671	821	2,988	0	52	0	210	839	0	0	46,972
2011	0	6,557	24,085	131	243	2,423	390	235	947	9	83	120	0	323	0	35,546
2012	0	3,245	151,417	22,348	6,874	157	2,795	259	130	2,191	41	21	51	25	175	189,729
2013	0	11,189	44,020	404,994	28,853	5,748	2,941	4,985	0	0	4,417	0	0	0	0	507,147

Table A.41. Mean weights-at-age (kg) of recreationally released Gulf of Maine haddock from 1977 to 2013. *Note that recreational catch estimates are not available pre-1981.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14
1977															
1978															
1979															
1980															
1981															
1982		0.357	0.428	0.429											
1983															
1984		0.350	0.412	0.429											
1985		0.347	0.379	0.455											
1986		0.380	0.467												
1987															
1988		0.331	0.412	0.540											
1989		0.307	0.520	0.741	0.865										
1990		0.403	0.621	0.765											
1991															
1992															
1993															
1994		0.288	0.528	0.916											
1995		0.327	0.620	0.869											
1996		0.418	0.650	0.831											
1997		0.350	0.499	0.720	0.890										
1998		0.269	0.766	0.979	0.836	0.927									
1999		0.313	0.651	0.767	0.899	0.891	0.861	0.799							
2000		0.272	0.591	0.680	0.893	0.943	0.951								
2001			0.726	0.829	0.901	0.937	0.812	0.856							
2002			0.535	0.873	1.085	1.206	1.371	1.490	1.301	1.425	1.531				
2003			0.592	0.964	1.005	1.085	1.062	1.173	0.972	1.226					
2004		0.196	0.595	0.761	1.107	0.912	0.980	1.108	1.131	1.152	1.082	1.259			
2005		0.294	0.606	0.580	0.857	0.866	0.913	0.913	1.533	1.589					
2006		0.237	0.504	0.729	0.624	0.863	1.286	1.058	0.964	1.432	1.687	1.911	1.720	1.773	
2007			0.672	0.768	0.845	1.016	0.878	1.182	1.079	0.992	1.358	1.410		1.502	
2008		0.148	0.535	0.743	0.929	0.874	0.845	0.907	1.485	1.083	1.085	1.653	1.972		
2009			0.726	0.702	0.766	0.859	1.020	1.387	1.361		1.244	1.278		1.418	
2010		0.393	0.548	0.758	0.958	0.966	1.113	1.439		1.589		1.589	1.470		
2011		0.408	0.571	1.017	1.061	0.883	1.444	1.194	1.630	2.076	2.076	1.779		1.966	
2012		0.243	0.527	0.669	0.746	1.134	0.897	1.244	2.037	1.103	3.422	2.296	3.201	2.105	3.006
2013		0.351	0.573	0.818	1.065	0.692	1.141	1.168			2.179				

Table A.42. Total catch-at-age (numbers, 000s of fish) of Gulf of Maine haddock from 1977 to 2013 with an age 9^+ group ***assuming 50% mortality of recreational releases. <u>This formulation is used as the 'base' case.</u>*** **Only ages 1 through the 9^+ group are used as assessment model inputs.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9^+
1977	0.0	39.8	1763.0	53.2	367.0	184.6	189.3	0.0	0.0	2.4
1978	0.0	0.0	374.7	2291.4	172.4	363.0	208.7	10.6	0.0	5.3
1979	0.0	0.0	67.3	559.6	1577.0	183.1	99.1	45.3	10.9	0.0
1980	0.0	0.0	884.8	104.1	755.8	1366.8	143.8	95.6	27.8	25.8
1981	0.0	2.1	1604.7	721.6	293.7	343.0	545.1	92.2	117.4	27.1
1982	0.0	30.4	620.6	1519.4	620.7	100.6	301.0	477.5	107.4	75.9
1983	0.1	10.8	12.4	836.5	976.3	791.3	148.6	253.0	348.1	115.7
1984	0.0	1.2	89.0	49.9	598.0	256.7	365.0	62.2	64.8	147.6
1985	0.0	0.9	30.2	349.6	85.9	356.2	152.0	242.0	47.4	54.6
1986	0.0	4.3	10.8	183.5	358.8	81.3	114.0	86.4	102.5	14.7
1987	0.0	0.0	20.6	34.7	106.1	48.8	34.4	56.9	33.8	16.5
1988	0.0	0.3	0.5	12.4	12.3	54.8	55.6	7.6	15.0	4.1
1989	0.0	1.4	23.2	3.5	42.4	19.3	24.0	15.0	0.8	0.9
1990	0.0	7.0	2.0	143.1	1.7	28.8	17.6	27.5	4.1	0.0
1991	0.0	3.1	7.2	16.3	58.6	28.4	27.9	12.6	5.8	3.1
1992	0.0	1.8	13.1	94.4	36.5	19.1	2.2	1.1	0.0	1.9
1993	0.0	3.7	20.1	36.3	23.0	9.9	11.0	4.6	1.7	1.2
1994	0.1	6.5	23.7	44.5	13.6	3.4	9.2	5.7	1.7	0.7
1995	0.4	2.7	71.3	90.5	75.7	10.2	6.3	4.7	4.3	3.0
1996	0.0	2.8	23.5	129.5	56.5	16.4	4.1	7.1	5.6	1.2
1997	0.0	1.7	7.3	166.8	256.8	90.1	18.9	6.9	2.8	2.3
1998	1.0	5.8	23.8	25.1	132.7	192.8	52.7	17.4	8.6	7.6
1999	0.1	5.3	3.8	39.5	65.8	96.8	69.2	38.5	7.1	5.9
2000	0.0	2.4	68.6	66.1	106.8	65.1	128.5	72.1	31.8	25.7
2001	0.0	0.3	29.5	235.1	133.6	96.8	87.3	80.7	40.4	24.1
2002	0.0	0.4	2.4	27.8	275.3	117.1	110.4	32.1	70.4	68.0
2003	0.0	0.1	10.8	6.9	54.1	506.9	90.5	63.0	21.6	70.3
2004	0.0	1.8	1.9	14.1	33.0	72.0	512.7	59.7	34.0	51.1
2005	0.0	3.1	33.6	6.3	49.3	84.8	138.5	534.9	53.7	71.8
2006	0.0	2.5	2.2	123.6	8.5	52.7	71.7	83.5	367.0	61.0
2007	0.0	7.8	24.9	17.3	332.7	11.4	54.4	43.2	87.9	371.1
2008	0.0	1.8	18.5	55.8	19.1	407.6	5.0	42.2	29.6	225.3
2009	0.0	0.1	3.4	40.2	51.1	15.1	294.9	5.3	32.0	146.8
2010	0.0	2.4	6.7	13.8	39.6	52.2	19.1	294.3	3.5	134.2
2011	0.0	6.3	19.2	4.5	4.7	50.9	47.4	16.3	181.0	93.3
2012	0.0	2.6	110.6	48.8	20.0	12.3	67.2	37.8	13.8	204.4
2013	1.2	24.0	37.0	317.5	48.1	18.6	9.2	41.1	27.7	76.9

Table A.43. Total catch-at-age (numbers, 000s of fish) of Gulf of Maine haddock from 1977 to 2013 with an age 9^+ group ***assuming 0% mortality of recreational releases. <u>This formulation is used for model sensitivity only</u>.*** Only *ages 1 through the* 9^+*group are used as assessment model inputs.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9$^+$
1977	0.0	39.8	1763.0	53.2	367.0	184.6	189.3	0.0	0.0	2.4
1978	0.0	0.0	374.7	2291.4	172.4	363.0	208.7	10.6	0.0	5.3
1979	0.0	0.0	67.3	559.6	1577.0	183.1	99.1	45.3	10.9	0.0
1980	0.0	0.0	884.8	104.1	755.8	1366.8	143.8	95.6	27.8	25.8
1981	0.0	2.1	1604.7	721.6	293.7	343.0	545.1	92.2	117.4	27.1
1982	0.0	30.4	620.6	1519.4	620.7	100.6	301.0	477.5	107.4	75.9
1983	0.1	10.8	12.4	836.5	976.3	791.3	148.6	253.0	348.1	115.7
1984	0.0	1.1	88.4	49.8	598.0	256.7	365.0	62.2	64.8	147.6
1985	0.0	0.9	30.2	349.6	85.9	356.2	152.0	242.0	47.4	54.6
1986	0.0	4.1	10.8	183.5	358.8	81.3	114.0	86.4	102.5	14.7
1987	0.0	0.0	20.6	34.7	106.1	48.8	34.4	56.9	33.8	16.5
1988	0.0	0.0	0.0	11.8	12.3	54.8	55.6	7.6	15.0	4.1
1989	0.0	1.2	21.4	3.2	42.3	19.3	24.0	15.0	0.8	0.9
1990	0.0	6.9	2.0	143.0	1.7	28.8	17.6	27.5	4.1	0.0
1991	0.0	3.1	7.2	16.3	58.6	28.4	27.9	12.6	5.8	3.1
1992	0.0	1.8	13.1	94.4	36.5	19.1	2.2	1.1	0.0	1.9
1993	0.0	3.7	20.1	36.3	23.0	9.9	11.0	4.6	1.7	1.2
1994	0.1	6.4	23.0	44.5	13.6	3.4	9.2	5.7	1.7	0.7
1995	0.4	2.0	55.8	86.1	75.7	10.2	6.3	4.7	4.3	3.0
1996	0.0	2.6	22.9	126.2	56.5	16.4	4.1	7.1	5.6	1.2
1997	0.0	0.8	6.5	163.2	254.6	90.1	18.9	6.9	2.8	2.3
1998	1.0	5.7	20.4	25.0	132.0	192.6	52.7	17.4	8.6	7.6
1999	0.1	3.1	0.8	38.0	65.4	96.4	68.8	38.3	7.1	5.9
2000	0.0	1.9	37.2	52.4	104.8	64.9	128.2	72.1	31.8	25.7
2001	0.0	0.3	16.7	201.6	129.1	95.8	86.3	80.3	40.4	24.1
2002	0.0	0.4	1.1	16.7	222.7	106.5	107.1	32.0	68.9	66.9
2003	0.0	0.1	1.6	5.3	38.7	420.1	83.0	60.9	20.7	69.7
2004	0.0	1.4	0.3	5.3	31.9	65.4	492.6	58.7	33.6	50.9
2005	0.0	0.2	9.4	3.7	45.3	81.2	133.4	526.5	53.6	71.8
2006	0.0	0.1	0.7	61.3	3.1	48.3	71.2	82.1	357.3	60.9
2007	0.0	7.8	16.2	12.0	297.7	11.3	52.9	43.0	87.1	367.4
2008	0.0	0.1	7.2	39.3	16.6	360.4	3.5	38.7	29.5	220.4
2009	0.0	0.1	1.0	18.3	46.1	14.2	292.7	5.3	32.0	146.4
2010	0.0	0.7	1.6	3.8	37.1	50.4	18.7	292.8	3.5	133.6
2011	0.0	3.0	7.1	4.5	4.6	49.7	47.2	16.2	180.5	93.0
2012	0.0	1.0	34.9	37.7	16.6	12.2	65.8	37.6	13.7	203.2
2013	1.2	18.4	15.0	115.0	33.7	15.8	7.7	38.6	27.7	74.7

Table A.44. Total catch-at-age (numbers, 000s of fish) of Gulf of Maine haddock from 1977 to 2013 with an age 9^+ group ***assuming 100% mortality of recreational releases. <u>This formulation is used for model sensitivity only</u>.*** Only *ages 1 through the* 9^+*group are used as assessment model inputs.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9$^+$
1977	0.0	39.8	1763.0	53.2	367.0	184.6	189.3	0.0	0.0	2.4
1978	0.0	0.0	374.7	2291.4	172.4	363.0	208.7	10.6	0.0	5.3
1979	0.0	0.0	67.3	559.6	1577.0	183.1	99.1	45.3	10.9	0.0
1980	0.0	0.0	884.8	104.1	755.8	1366.8	143.8	95.6	27.8	25.8
1981	0.0	2.1	1604.7	721.6	293.7	343.0	545.1	92.2	117.4	27.1
1982	0.0	30.4	620.6	1519.4	620.7	100.6	301.0	477.5	107.4	75.9
1983	0.1	10.8	12.4	836.5	976.3	791.3	148.6	253.0	348.1	115.7
1984	0.0	1.3	89.6	49.9	598.0	256.7	365.0	62.2	64.8	147.6
1985	0.0	0.9	30.2	349.6	85.9	356.2	152.0	242.0	47.4	54.6
1986	0.0	4.4	10.9	183.5	358.8	81.3	114.0	86.4	102.5	14.7
1987	0.0	0.0	20.6	34.7	106.1	48.8	34.4	56.9	33.8	16.5
1988	0.0	0.6	0.9	13.1	12.3	54.8	55.6	7.6	15.0	4.1
1989	0.0	1.6	25.0	3.8	42.5	19.3	24.0	15.0	0.8	0.9
1990	0.0	7.1	2.0	143.1	1.7	28.8	17.6	27.5	4.1	0.0
1991	0.0	3.1	7.2	16.3	58.6	28.4	27.9	12.6	5.8	3.1
1992	0.0	1.8	13.1	94.4	36.5	19.1	2.2	1.1	0.0	1.9
1993	0.0	3.7	20.1	36.3	23.0	9.9	11.0	4.6	1.7	1.2
1994	0.1	6.5	24.4	44.6	13.6	3.4	9.2	5.7	1.7	0.7
1995	0.4	3.5	86.8	95.0	75.7	10.2	6.3	4.7	4.3	3.0
1996	0.0	3.0	24.1	132.8	56.5	16.4	4.1	7.1	5.6	1.2
1997	0.0	2.5	8.2	170.3	259.0	90.1	18.9	6.9	2.8	2.3
1998	1.0	6.0	27.1	25.2	133.5	193.0	52.7	17.4	8.6	7.6
1999	0.1	7.5	6.8	40.9	66.3	97.1	69.5	38.6	7.1	5.9
2000	0.0	2.8	100.1	79.8	108.7	65.3	128.7	72.1	31.8	25.7
2001	0.0	0.3	42.4	268.7	138.1	97.7	88.4	81.2	40.4	24.1
2002	0.0	0.4	3.7	38.9	327.9	127.8	113.7	32.3	71.9	69.2
2003	0.0	0.1	20.0	8.6	69.5	593.7	98.0	65.0	22.4	70.8
2004	0.0	2.2	3.5	23.0	34.0	78.6	532.8	60.6	34.4	51.4
2005	0.0	6.0	57.8	8.9	53.3	88.4	143.6	543.3	53.7	71.8
2006	0.0	4.8	3.6	185.9	13.8	57.0	72.2	84.8	376.7	61.2
2007	0.0	7.8	33.6	22.7	367.7	11.5	55.9	43.4	88.7	374.8
2008	0.0	3.5	29.8	72.4	21.5	454.9	6.6	45.7	29.7	230.1
2009	0.0	0.1	5.7	62.2	56.0	15.9	297.2	5.4	32.0	147.1
2010	0.0	4.1	11.8	23.7	42.1	54.1	19.5	295.8	3.5	134.7
2011	0.0	9.6	31.2	4.6	4.9	52.1	47.6	16.5	181.5	93.5
2012	0.0	4.3	186.3	60.0	23.4	12.4	68.6	37.9	13.9	205.7
2013	1.2	29.6	59.0	520.0	62.5	21.5	10.6	43.6	27.7	79.1

Table A.45. Gulf of Maine haddock mean weights-at-age (kg) of the total catch from 1977 to 2013 with an age 9^+ group ***assuming 50% mortality of recreational releases. <u>This formulation is used as the 'base' case</u>.*** Mean catch weights-at-age in the 9^+ group were estimated using a numbers weighted approach. Cells shaded grey were imputed using a 5-year centered moving average, cells shaded blue were imputed using a time series average. **Only ages 1 through the 9^+ group are used as assessment model inputs.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9+
1977	0.061	0.113	0.757	1.163	2.008	2.558	3.358	3.709	3.587	4.686
1978	0.061	0.113	0.777	1.234	1.684	2.438	3.108	4.642	4.075	6.088
1979	0.061	0.337	0.774	1.155	1.805	2.261	2.659	2.775	3.587	4.724
1980	0.061	0.468	0.760	1.168	1.852	2.389	3.354	3.602	4.562	4.204
1981	0.061	0.560	0.685	1.516	1.978	2.641	3.026	3.657	4.184	3.917
1982	0.061	0.376	0.620	0.995	2.137	2.598	3.106	3.646	4.129	4.293
1983	0.048	0.181	0.667	1.200	1.727	2.376	2.969	3.373	3.719	4.215
1984	0.061	0.313	0.816	1.233	1.803	2.324	3.166	3.923	4.502	4.073
1985	0.061	0.315	0.980	1.068	1.859	2.339	2.652	3.588	4.090	4.153
1986	0.061	0.503	0.507	1.192	1.456	2.265	2.495	3.062	3.636	4.592
1987	0.061	0.350	0.856	1.592	2.008	2.402	2.609	3.272	4.236	5.279
1988	0.061	0.331	0.412	1.100	1.623	2.561	2.582	3.871	4.652	5.180
1989	0.061	0.251	1.126	1.779	1.824	2.343	2.864	3.543	4.545	4.244
1990	0.061	0.296	0.831	1.543	3.331	2.450	3.041	3.745	3.762	4.189
1991	0.061	0.347	1.459	1.880	2.657	3.027	2.958	3.350	4.433	3.881
1992	0.061	0.448	1.192	1.764	1.973	2.654	3.067	2.079	3.757	3.450
1993	0.061	0.364	0.885	1.592	2.041	2.436	3.035	3.393	3.422	3.657
1994	0.092	0.362	0.787	1.589	2.186	3.062	2.788	3.620	3.410	3.721
1995	0.017	0.275	0.802	1.156	1.774	2.525	3.526	4.133	5.209	5.665
1996	0.061	0.337	0.674	1.073	1.803	2.196	3.148	2.473	2.387	3.164
1997	0.061	0.354	0.891	1.802	1.662	2.330	2.977	2.985	3.063	3.607
1998	0.021	0.250	0.975	1.448	1.827	2.212	2.843	3.376	3.152	2.988
1999	0.072	0.266	0.611	1.309	1.608	1.765	1.926	2.281	3.033	3.295
2000	0.061	0.260	0.607	1.022	1.535	1.773	2.013	2.390	2.696	3.101
2001	0.061	0.242	0.889	1.260	1.490	1.811	2.210	2.243	2.483	2.532
2002	0.068	0.121	0.473	1.025	1.340	1.631	2.143	2.598	2.303	2.644
2003	0.061	0.318	0.583	0.887	1.230	1.468	1.770	2.134	2.425	2.513
2004	0.061	0.185	0.560	0.809	1.373	1.358	1.681	1.820	2.027	2.208
2005	0.061	0.286	0.583	0.815	1.139	1.464	1.443	1.684	1.954	2.297
2006	0.061	0.238	0.474	0.840	0.745	1.359	1.644	1.507	1.683	2.008
2007	0.061	0.243	0.560	0.777	1.121	1.203	1.510	1.625	1.578	1.714
2008	0.061	0.156	0.544	0.995	1.207	1.341	1.339	1.700	1.740	1.758
2009	0.061	0.304	0.699	0.809	1.135	1.282	1.625	1.563	1.877	1.947
2010	0.086	0.350	0.609	0.785	1.129	1.406	1.563	1.731	2.131	2.069
2011	0.064	0.341	0.588	1.029	1.191	1.401	1.602	1.801	1.915	2.113
2012	0.064	0.246	0.538	0.954	1.106	1.406	1.451	1.742	1.815	1.979
2013	0.076	0.283	0.550	0.870	1.267	1.498	1.486	1.658	2.051	2.104
2009-2013 average	0.070	0.305	0.597	0.890	1.166	1.399	1.545	1.699	1.958	2.043

Table A.46. Gulf of Maine haddock mean weights-at-age (kg) of the total catch from 1977 to 2013 with an age 9^+ group ***assuming 0% mortality of recreational releases. <u>This formulation is used for model sensitivity only</u>.*** Mean catch weights-at-age in the 9^+ group were estimated using a numbers weighted approach. Cells shaded grey were imputed using a 5-year centered moving average, cells shaded blue were imputed using a time series average. **Only ages 1 through the 9^+group are used as assessment model inputs.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9$^+$
1977	0.061	0.113	0.757	1.163	2.008	2.558	3.358	3.709	3.587	4.686
1978	0.061	0.113	0.777	1.234	1.684	2.438	3.108	4.642	4.075	6.088
1979	0.061	0.337	0.774	1.155	1.805	2.261	2.659	2.775	3.587	4.724
1980	0.061	0.468	0.760	1.168	1.852	2.389	3.354	3.602	4.562	4.204
1981	0.061	0.560	0.685	1.516	1.978	2.641	3.026	3.657	4.184	3.917
1982	0.061	0.376	0.620	0.995	2.137	2.598	3.106	3.646	4.129	4.293
1983	0.048	0.181	0.667	1.200	1.727	2.376	2.969	3.373	3.719	4.215
1984	0.061	0.308	0.819	1.233	1.803	2.324	3.166	3.923	4.502	4.073
1985	0.061	0.315	0.981	1.068	1.859	2.339	2.652	3.588	4.090	4.153
1986	0.061	0.507	0.507	1.192	1.456	2.265	2.495	3.062	3.636	4.592
1987	0.061	0.354	0.856	1.592	2.008	2.402	2.609	3.272	4.236	5.279
1988	0.061	0.347	0.844	1.130	1.623	2.561	2.582	3.871	4.652	5.180
1989	0.061	0.240	1.178	1.882	1.826	2.343	2.864	3.543	4.545	4.244
1990	0.061	0.295	0.833	1.543	3.331	2.450	3.041	3.745	3.762	4.189
1991	0.061	0.347	1.459	1.880	2.657	3.027	2.958	3.350	4.433	3.881
1992	0.061	0.448	1.192	1.764	1.973	2.654	3.067	2.079	3.757	3.450
1993	0.061	0.364	0.885	1.592	2.041	2.436	3.035	3.393	3.422	3.657
1994	0.092	0.362	0.796	1.590	2.186	3.062	2.788	3.620	3.410	3.721
1995	0.017	0.256	0.853	1.171	1.774	2.525	3.526	4.133	5.209	5.665
1996	0.061	0.330	0.675	1.080	1.803	2.196	3.148	2.473	2.387	3.164
1997	0.061	0.358	0.945	1.825	1.669	2.330	2.977	2.985	3.063	3.607
1998	0.021	0.250	1.009	1.449	1.833	2.213	2.843	3.376	3.152	2.988
1999	0.072	0.233	0.468	1.329	1.613	1.768	1.931	2.288	3.033	3.295
2000	0.061	0.257	0.620	1.112	1.547	1.776	2.015	2.390	2.696	3.101
2001	0.061	0.242	1.015	1.332	1.511	1.819	2.228	2.251	2.483	2.532
2002	0.068	0.121	0.398	1.125	1.400	1.673	2.167	2.602	2.325	2.665
2003	0.061	0.318	0.529	0.862	1.319	1.547	1.834	2.167	2.482	2.523
2004	0.061	0.182	0.381	0.889	1.381	1.403	1.709	1.831	2.038	2.214
2005	0.061	0.173	0.526	0.978	1.164	1.490	1.464	1.697	1.954	2.297
2006	0.061	0.287	0.415	0.953	0.956	1.403	1.646	1.514	1.702	2.009
2007	0.061	0.243	0.500	0.781	1.154	1.204	1.527	1.627	1.582	1.721
2008	0.061	0.289	0.558	1.101	1.247	1.403	1.559	1.772	1.741	1.773
2009	0.061	0.304	0.634	0.938	1.174	1.308	1.629	1.564	1.877	1.949
2010	0.086	0.253	0.799	0.854	1.140	1.422	1.573	1.732	2.131	2.071
2011	0.064	0.268	0.617	1.030	1.195	1.414	1.603	1.806	1.916	2.114
2012	0.064	0.249	0.561	1.039	1.181	1.407	1.463	1.744	1.814	1.983
2013	0.076	0.262	0.516	0.961	1.353	1.645	1.552	1.689	2.051	2.102
2009-2013 average	0.070	0.267	0.625	0.964	1.209	1.439	1.564	1.707	1.958	2.044

Table A.47. Gulf of Maine haddock mean weights-at-age (kg) of the total catch from 1977 to 2013 with an age 9^+ group ***assuming 100% mortality of recreational releases. <u>This formulation is used for model sensitivity only</u>.*** Mean catch weights-at-age in the 9^+ group were estimated using a numbers weighted approach. Cells shaded grey were imputed using a 5-year centered moving average, cells shaded blue were imputed using a time series average. **Only ages 1 through the 9^+ group are used as assessment model inputs.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9+
1977	0.061	0.113	0.757	1.163	2.008	2.558	3.358	3.709	3.587	4.686
1978	0.061	0.113	0.777	1.234	1.684	2.438	3.108	4.642	4.075	6.088
1979	0.061	0.337	0.774	1.155	1.805	2.261	2.659	2.775	3.587	4.724
1980	0.061	0.468	0.760	1.168	1.852	2.389	3.354	3.602	4.562	4.204
1981	0.061	0.560	0.685	1.516	1.978	2.641	3.026	3.657	4.184	3.917
1982	0.061	0.376	0.620	0.995	2.137	2.598	3.106	3.646	4.129	4.293
1983	0.048	0.181	0.667	1.200	1.727	2.376	2.969	3.373	3.719	4.215
1984	0.061	0.316	0.813	1.232	1.803	2.324	3.166	3.923	4.502	4.073
1985	0.061	0.316	0.980	1.068	1.859	2.339	2.652	3.588	4.090	4.153
1986	0.061	0.498	0.507	1.192	1.456	2.265	2.495	3.062	3.636	4.592
1987	0.061	0.351	0.856	1.592	2.008	2.402	2.609	3.272	4.236	5.279
1988	0.061	0.331	0.412	1.073	1.623	2.561	2.582	3.871	4.652	5.180
1989	0.061	0.259	1.082	1.693	1.822	2.343	2.864	3.543	4.545	4.244
1990	0.061	0.297	0.830	1.543	3.331	2.450	3.041	3.745	3.762	4.189
1991	0.061	0.347	1.459	1.880	2.657	3.027	2.958	3.350	4.433	3.881
1992	0.061	0.448	1.192	1.764	1.973	2.654	3.067	2.079	3.757	3.450
1993	0.061	0.364	0.885	1.592	2.041	2.436	3.035	3.393	3.422	3.657
1994	0.092	0.361	0.780	1.588	2.186	3.062	2.788	3.620	3.410	3.721
1995	0.017	0.286	0.769	1.143	1.774	2.525	3.526	4.133	5.209	5.665
1996	0.061	0.342	0.674	1.067	1.803	2.196	3.148	2.473	2.387	3.164
1997	0.061	0.353	0.849	1.779	1.656	2.330	2.977	2.985	3.063	3.607
1998	0.021	0.251	0.949	1.446	1.822	2.211	2.843	3.376	3.152	2.988
1999	0.072	0.280	0.628	1.290	1.603	1.762	1.921	2.275	3.033	3.295
2000	0.061	0.262	0.602	0.963	1.524	1.771	2.011	2.390	2.696	3.101
2001	0.061	0.242	0.840	1.207	1.471	1.802	2.193	2.234	2.483	2.532
2002	0.068	0.121	0.495	0.981	1.299	1.595	2.120	2.593	2.282	2.624
2003	0.061	0.318	0.587	0.902	1.180	1.412	1.715	2.104	2.372	2.502
2004	0.061	0.187	0.576	0.790	1.364	1.321	1.654	1.808	2.017	2.202
2005	0.061	0.290	0.593	0.747	1.118	1.439	1.424	1.672	1.954	2.297
2006	0.061	0.238	0.486	0.803	0.698	1.321	1.641	1.499	1.664	2.006
2007	0.061	0.243	0.589	0.775	1.095	1.202	1.493	1.623	1.573	1.707
2008	0.061	0.152	0.540	0.937	1.175	1.293	1.223	1.640	1.740	1.744
2009	0.061	0.304	0.710	0.771	1.102	1.260	1.620	1.562	1.876	1.946
2010	0.086	0.368	0.583	0.774	1.118	1.391	1.553	1.729	2.131	2.067
2011	0.064	0.364	0.581	1.029	1.188	1.389	1.602	1.797	1.915	2.113
2012	0.064	0.245	0.533	0.901	1.053	1.404	1.439	1.741	1.817	1.975
2013	0.076	0.296	0.558	0.850	1.220	1.390	1.438	1.630	2.051	2.106
2009-2013 average	0.070	0.315	0.593	0.865	1.137	1.367	1.531	1.692	1.958	2.041

Table A.48. Gulf of Maine haddock mean January 1/spawning stock weights-at-age (kg) from 1977 to 2013 with an age 9^+ group. Weights were estimated from catch weights using Rivard (1980, 1982) approach based on the catch weights under a 100% mortality assumption. **Only ages 1 through the 9^+ group are used as assessment model inputs.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9+
1977	0.045	0.043	0.593	0.967	1.822	2.321	2.856	3.539	3.648	4.686
1978	0.026	0.083	0.296	0.967	1.400	2.213	2.820	3.948	3.888	6.088
1979	0.022	0.143	0.296	0.947	1.492	1.951	2.546	2.937	4.081	4.724
1980	0.020	0.169	0.506	0.951	1.463	2.077	2.754	3.095	3.558	4.204
1981	0.025	0.185	0.566	1.073	1.520	2.212	2.689	3.502	3.882	3.917
1982	0.035	0.151	0.589	0.826	1.800	2.267	2.864	3.322	3.886	4.293
1983	0.019	0.105	0.501	0.863	1.311	2.253	2.777	3.237	3.682	4.215
1984	0.027	0.123	0.384	0.907	1.471	2.003	2.743	3.413	3.897	4.073
1985	0.021	0.139	0.557	0.932	1.513	2.054	2.483	3.370	4.006	4.153
1986	0.025	0.174	0.400	1.081	1.247	2.052	2.416	2.850	3.612	4.592
1987	0.026	0.146	0.653	0.898	1.547	1.870	2.431	2.857	3.602	5.279
1988	0.030	0.142	0.380	0.958	1.607	2.268	2.490	3.178	3.902	5.180
1989	0.028	0.126	0.598	0.835	1.398	1.950	2.708	3.025	4.195	4.244
1990	0.026	0.135	0.464	1.292	2.375	2.113	2.669	3.275	3.651	4.189
1991	0.023	0.146	0.658	1.249	2.025	3.175	2.692	3.192	4.075	3.881
1992	0.025	0.165	0.643	1.604	1.926	2.656	3.047	2.480	3.548	3.450
1993	0.025	0.149	0.630	1.378	1.898	2.192	2.838	3.226	2.667	3.657
1994	0.052	0.148	0.533	1.186	1.866	2.500	2.606	3.315	3.402	3.721
1995	0.004	0.162	0.527	0.944	1.678	2.349	3.286	3.395	4.342	5.665
1996	0.025	0.076	0.439	0.906	1.436	1.974	2.819	2.953	3.141	3.164
1997	0.030	0.147	0.539	1.095	1.329	2.050	2.557	3.065	2.752	3.607
1998	0.006	0.124	0.579	1.108	1.800	1.914	2.574	3.170	3.067	2.988
1999	0.038	0.077	0.397	1.106	1.523	1.792	2.061	2.543	3.200	3.295
2000	0.031	0.137	0.411	0.778	1.402	1.685	1.882	2.143	2.477	3.101
2001	0.043	0.122	0.469	0.852	1.190	1.657	1.971	2.120	2.436	2.532
2002	0.031	0.086	0.346	0.908	1.252	1.532	1.955	2.385	2.258	2.624
2003	0.035	0.147	0.267	0.668	1.076	1.354	1.654	2.112	2.480	2.502
2004	0.028	0.107	0.428	0.681	1.109	1.249	1.528	1.761	2.060	2.202
2005	0.031	0.133	0.333	0.656	0.940	1.401	1.372	1.663	1.880	2.297
2006	0.031	0.121	0.375	0.690	0.722	1.215	1.537	1.461	1.668	2.006
2007	0.039	0.122	0.374	0.614	0.938	0.916	1.404	1.632	1.536	1.707
2008	0.027	0.096	0.362	0.743	0.954	1.190	1.213	1.565	1.681	1.744
2009	0.025	0.136	0.329	0.645	1.016	1.217	1.447	1.382	1.754	1.946
2010	0.042	0.150	0.421	0.741	0.928	1.238	1.399	1.674	1.825	2.067
2011	0.033	0.177	0.462	0.775	0.959	1.246	1.493	1.671	1.820	2.113
2012	0.030	0.125	0.441	0.724	1.041	1.292	1.414	1.670	1.807	1.975
2013	0.042	0.138	0.370	0.673	1.048	1.210	1.421	1.532	1.890	2.106
2009-2013 average	0.034	0.145	0.404	0.712	0.999	1.240	1.435	1.586	1.819	2.041

Table A.49. Summary of vessels and trawl doors used in the Northeast Fisheries Science Center (NEFSC) spring and fall surveys from 1963 to 2013. When survey indices are calibrated to single time series, the calibration is based on Albatross IV, Polyvalent door equivalents. *Note that the spring survey did not begin until 1968.*

Year	Spring	Autumn	Door
1963		Albatross IV	BMV
1964		Albatross IV	BMV
1965		Albatross IV	BMV
1966		Albatross IV	BMV
1967		Albatross IV	BMV
1968	Albatross IV	Albatross IV	BMV
1969	Albatross IV	Albatross IV	BMV
1970	Albatross IV	Albatross IV	BMV
1971	Albatross IV	Albatross IV	BMV
1972	Albatross IV	Albatross IV	BMV
1973	Albatross IV	Albatross IV	BMV
1974	Albatross IV	Albatross IV	BMV
1975	Albatross IV	Albatross IV	BMV
1976	Albatross IV	Albatross IV	BMV
1977	Albatross IV	Delaware II	BMV
1978	Albatross IV	Delaware II	BMV
1979	Albatross IV/Delaware II	Albatross IV/Delaware II	BMV
1980	Albatross IV/Delaware II	Delaware II	BMV
1981	Delaware II	Albatross IV/Delaware II	BMV
1982	Delaware II	Albatross IV	BMV
1983	Albatross IV	Albatross IV	BMV
1984	Albatross IV	Albatross IV	BMV
1985	Albatross IV	Albatross IV	Polyvalent
1986	Albatross IV	Albatross IV	Polyvalent
1987	Albatross IV/Delaware II	Albatross IV	Polyvalent
1988	Albatross IV	Albatross IV/Delaware II	Polyvalent
1989	Delaware II	Delaware II	Polyvalent
1990	Delaware II	Delaware II	Polyvalent
1991	Delaware II	Delaware II	Polyvalent
1992	Albatross IV	Albatross IV	Polyvalent
1993	Albatross IV	Delaware II	Polyvalent
1994	Delaware II	Albatross IV	Polyvalent
1995	Albatross IV	Albatross IV	Polyvalent
1996	Albatross IV	Albatross IV	Polyvalent
1997	Albatross IV	Albatross IV	Polyvalent
1998	Albatross IV	Albatross IV	Polyvalent
1999	Albatross IV	Albatross IV	Polyvalent
2000	Albatross IV	Albatross IV	Polyvalent
2001	Albatross IV	Albatross IV	Polyvalent
2002	Albatross IV	Albatross IV	Polyvalent
2003	Delaware II	Albatross IV	Polyvalent
2004	Albatross IV	Albatross IV	Polyvalent
2005	Albatross IV	Albatross IV	Polyvalent
2006	Albatross IV	Albatross IV	Polyvalent
2007	Albatross IV	Albatross IV	Polyvalent
2008	Albatross IV	Albatross IV	Polyvalent
2009	Henry B. Bigelow	Henry B. Bigelow	PolyIce oval
2010	Henry B. Bigelow	Henry B. Bigelow	PolyIce oval
2011	Henry B. Bigelow	Henry B. Bigelow	PolyIce oval
2012	Henry B. Bigelow	Henry B. Bigelow	PolyIce oval
2013	Henry B. Bigelow	Henry B. Bigelow	PolyIce oval

Table A.50. Summary of survey calibration coefficients for converting survey index values to Albatross IV, Polyvalent door equivalent units.

Calibration type	Index	Length (cm)	Calibration coefficient	CV	Source
Deleware II to Albatross IV	Biomass (weight)	*NA*	0.790	*NA*	Forrester et al., 1997
	Abundance (numbers)	*NA*	0.820	*NA*	
BMV door to Polyvalent door	Biomass (weight)	*NA*	1.510	*NA*	
	Abundance (numbers)	*NA*	1.490	*NA*	
Bigelow to Albatross IV	Biomass (weight), spring	*NA*	0.878	*NA*	Miller et al. 2010
	Biomass (weight), fall	*NA*	1.489	*NA*	
	Abundance (numbers)	≤ 18	2.626	0.07	Brooks et al. 2010
		19	2.581	0.07	
		20	2.535	0.07	
		21	2.489	0.07	
		22	2.444	0.06	
		23	2.398	0.06	
		24	2.352	0.06	
		25	2.307	0.06	
		26	2.261	0.06	
		27	2.216	0.06	
		28	2.170	0.05	
		29	2.124	0.05	
		30	2.079	0.05	
		31	2.033	0.05	
		32	1.988	0.05	
		33	1.942	0.04	
		34	1.896	0.04	
		35	1.851	0.04	
		36	1.805	0.04	
		37	1.759	0.04	
		38	1.714	0.03	
		39	1.668	0.03	
		40	1.623	0.03	
		41	1.577	0.03	
		42	1.531	0.03	
		43	1.486	0.03	
		44	1.440	0.03	
		45	1.394	0.04	
		46	1.349	0.04	
		47	1.303	0.04	
		48	1.258	0.05	
		49	1.212	0.05	
		50	1.166	0.06	
		≥ 51	1.164	0.06	

Table A.51. Summary of the differences in survey protocols between the RV Albatross IV (1963-2008) and the FSV Henry B. Bigelow (2009 - present) surveys. Adapted from Brooks et al. (2010).

Measure	**FSV Henry B Bigelow**	**RV Albatross IV**
Tow speed	3.0 knots SOG	3.8 knots SOG
Tow duration	20min	30 mins
Headrope height	3.5-4m	1-2m
Ground gear (cookies, rock hoppers, etc.)	Rockhopper Sweep Total Length-25.5m Center- 8.9m length, 16” rockhoppers. Wings- 8.2m each 14” rockhoppers	Roller Sweep Total Length-24.5m Center-5m length, 16” rollers. Wings- 9.75m each, 4” cookies.
Mesh	Poly webbing Forward Portion of trawl (jibs, upper and lower wing ends, 1st&2nd side panels, 1st bottom belly)12cm,4mm Square aft to codend:6cm, 2.5mm Codend: 12cm, 4mm dbl. Codend Liner: 2.54cm, knotless	Nylon webbing Body of trawl= 12.7cm Codend- 11.5cm Liner (codend and aft portion of top belly)-1.27cm knotless
Net design	4 Seam, 3 Bridle	Yankee 36 (recent years)
Door type	550 kg PolyIce oval	450 kg polyvalent
Other comments	Wing End to Door distance= 36.5m	Wing End to Door Distance= 9m

Table A.52. Summary of the sampling of Northeast Fisheries Science Center (NEFSC) Gulf of Maine offshore survey strata (26-28, 36-40) broken down by season (spring/fall) and time of day (day/night) between 1963 and spring 2013. The day/night classification is based on sunrise/sunset (zenith angle of 90°50'). This summary applies SHG tow selection criteria between 1963 and 2008 and the TOGA criteria since 2009. *Note that the spring survey did not begin until 1968.*

	Spring						Fall					
Year	Combined		Day		Night		Combined		Day		Night	
	Strata	Stations	Strata	Stations	Strata	Stations	Strata	Stations	Strata	Stations	Strata	Stations
1963							8	41	6	14	8	27
1964							8	37	8	12	8	25
1965							8	38	8	17	8	21
1966							8	37	7	19	7	18
1967							8	38	6	13	8	25
1968	8	39	6	21	8	18	8	39	7	16	8	23
1969	8	40	7	18	7	22	8	40	7	14	8	26
1970	8	40	5	13	7	27	8	42	8	17	8	25
1971	8	46	8	21	8	25	8	44	8	15	8	29
1972	8	43	8	24	8	19	8	43	6	17	7	26
1973	8	37	8	16	8	21	8	43	7	15	8	28
1974	8	40	8	22	8	18	8	46	7	21	7	25
1975	7	43	6	17	6	26	8	54	6	22	7	32
1976	8	53	7	25	7	28	8	44	6	15	8	29
1977	8	56	8	34	8	22	8	60	7	21	8	39
1978	8	52	8	28	8	24	8	101	8	47	7	54
1979	8	61	8	39	7	22	8	103	8	43	8	60
1980	8	39	8	19	6	20	8	41	8	18	8	23
1981	8	42	8	28	8	14	8	42	8	21	8	21
1982	8	42	7	25	7	17	8	43	8	19	8	24
1983	8	42	8	30	5	12	8	36	6	13	7	23
1984	8	39	8	24	8	15	8	40	6	16	7	24
1985	8	37	8	21	7	16	8	42	8	16	8	26
1986	8	41	7	20	8	21	8	42	6	16	7	26
1987	8	36	6	21	6	15	8	40	7	18	8	22
1988	8	42	8	26	7	16	8	41	7	20	7	21
1989	8	41	7	23	8	18	8	40	6	17	6	23
1990	8	41	7	19	8	22	8	41	7	18	8	23
1991	8	39	8	23	7	16	8	42	7	16	8	26
1992	8	41	8	25	7	16	8	40	7	16	8	24
1993	8	40	8	21	7	19	8	40	8	22	7	18
1994	8	42	8	28	7	14	8	40	7	14	8	26
1995	8	42	8	21	7	21	8	45	7	16	8	29
1996	8	41	8	20	8	21	8	42	8	20	7	22
1997	8	42	8	25	8	17	8	41	8	20	8	21
1998	8	63	8	30	8	33	8	56	7	27	8	29
1999	8	41	7	20	8	21	8	60	7	30	8	30
2000	8	42	7	26	7	16	8	41	7	14	8	27
2001	8	41	8	25	7	16	8	43	7	22	7	21
2002	8	44	8	23	8	21	8	38	8	21	8	17
2003	8	41	5	17	7	24	8	40	8	15	7	25
2004	8	39	8	25	7	14	8	37	6	13	7	24
2005	8	40	8	24	5	16	8	40	7	15	8	25
2006	8	48	8	25	8	23	8	47	7	20	7	27
2007	8	39	8	19	8	20	8	42	7	17	7	25
2008	8	40	8	21	8	19	8	42	8	15	8	27
2009	8	55	8	33	7	22	8	40	6	13	7	27
2010	8	51	7	27	8	24	8	37	7	14	8	23
2011	8	43	7	23	7	20	8	35	8	18	8	17
2012	8	60	8	34	8	26	8	48	8	21	8	27
2013	8	53	7	28	8	25	8	48	8	17	8	31
Average		**44**		**24**		**20**		**45**		**19**		**26**

Table A.53. Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl survey indices for Gulf of Maine haddock from 1963 to 2013. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents using both the SHG and TOGA tow selection criteria. *Note that the spring survey did not begin until 1968.*

Year	Calibrated SHG tow criteria				Calibrated, Bigelow TOGA tow criteria			
	Spring		Fall		Spring		Fall	
	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow
1963			69.549	50.697				
1964			14.176	18.386				
1965			17.434	17.739				
1966			10.742	13.103				
1967			12.186	16.871				
1968	6.066	8.107	8.564	17.307				
1969	3.719	6.607	5.451	12.721				
1970	0.906	1.784	2.918	7.354				
1971	0.878	2.523	2.879	8.159				
1972	0.862	0.882	1.984	3.050				
1973	1.312	1.623	4.165	8.591				
1974	1.437	1.061	2.687	3.347				
1975	2.770	3.482	5.533	8.618				
1976	8.326	6.350	6.035	8.041				
1977	6.799	6.725	8.296	8.755				
1978	1.356	1.434	9.775	21.659				
1979	2.870	3.878	6.174	15.568				
1980	2.212	2.672	7.152	9.836				
1981	3.612	3.545	4.456	10.874				
1982	2.047	2.555	2.627	4.164				
1983	3.678	3.571	2.598	5.219				
1984	1.095	1.144	1.696	3.893				
1985	1.773	1.882	4.079	6.149				
1986	0.707	1.284	0.623	1.392				
1987	0.092	0.062	1.035	2.646				
1988	0.187	0.301	0.335	1.476				
1989	0.083	0.124	0.283	0.631				
1990	0.024	0.001	0.145	0.432				
1991	0.074	0.066	0.142	0.120				
1992	0.193	0.272	0.211	0.092				
1993	0.450	0.204	0.866	0.474				
1994	0.402	0.255	0.325	0.218				
1995	0.806	0.351	0.977	1.099				
1996	0.305	0.338	2.407	3.543				
1997	1.935	1.223	2.688	2.424				
1998	0.197	0.113	3.130	2.920				
1999	4.267	1.109	6.730	4.910				
2000	3.610	1.815	16.589	14.033				
2001	2.364	3.205	9.960	11.981				
2002	5.704	2.793	3.920	4.835				
2003	3.191	3.908	4.733	5.359				
2004	1.061	1.199	5.704	7.171				
2005	0.862	0.971	4.132	3.932				
2006	3.151	2.661	3.910	3.945				
2007	0.770	0.675	5.153	4.393				
2008	1.689	1.394	2.266	3.146				
2009	1.521	2.705	1.867	1.154	1.531	2.573	2.017	1.203
2010	1.126	2.349	3.320	2.552	1.630	3.713	2.662	1.339
2011	1.236	1.324	4.885	4.143	1.233	1.259	4.898	4.145
2012	2.720	2.720	5.397	2.880	2.977	2.926	5.397	2.880
2013	12.359	6.218	36.088	12.571	12.380	6.221	36.088	12.571

Table A.54. Coefficients of variation (CV) for the Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl survey indices for Gulf of Maine haddock from 1963 to 2013. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents using both the SHG and TOGA tow selection criteria. *Note that the spring survey did not begin until 1968.*

Year	Calibrated SHG tow criteria				Calibrated, Bigelow TOGA tow criteria			
	Spring		Fall		Spring		Fall	
	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow
1963			0.27	0.15				
1964			0.33	0.17				
1965			0.32	0.20				
1966			0.32	0.26				
1967			0.22	0.24				
1968	0.28	0.24	0.15	0.15				
1969	0.20	0.21	0.23	0.22				
1970	0.23	0.24	0.21	0.21				
1971	0.44	0.41	0.31	0.31				
1972	0.34	0.57	0.24	0.34				
1973	0.24	0.34	0.20	0.30				
1974	0.38	0.42	0.55	0.31				
1975	0.27	0.45	0.26	0.31				
1976	0.35	0.34	0.23	0.28				
1977	0.31	0.37	0.32	0.28				
1978	0.40	0.29	0.18	0.19				
1979	0.22	0.22	0.20	0.22				
1980	0.38	0.41	0.33	0.24				
1981	0.25	0.22	0.18	0.22				
1982	0.31	0.36	0.35	0.28				
1983	0.40	0.42	0.28	0.27				
1984	0.41	0.41	0.26	0.28				
1985	0.38	0.29	0.40	0.28				
1986	0.46	0.50	0.41	0.36				
1987	0.36	0.50	0.32	0.27				
1988	0.52	0.58	0.65	0.71				
1989	0.75	0.82	0.38	0.47				
1990	0.54	0.88	0.37	0.36				
1991	0.53	0.61	0.60	0.71				
1992	0.59	0.95	0.53	0.59				
1993	0.45	0.69	0.72	0.81				
1994	0.34	0.37	0.42	0.86				
1995	0.46	0.45	0.54	0.43				
1996	0.31	0.37	0.37	0.43				
1997	0.40	0.50	0.36	0.28				
1998	0.41	0.44	0.51	0.42				
1999	0.39	0.36	0.30	0.25				
2000	0.41	0.41	0.45	0.41				
2001	0.56	0.65	0.25	0.26				
2002	0.51	0.32	0.35	0.35				
2003	0.25	0.27	0.20	0.23				
2004	0.35	0.39	0.25	0.28				
2005	0.39	0.46	0.19	0.15				
2006	0.45	0.43	0.26	0.21				
2007	0.37	0.33	0.30	0.23				
2008	0.49	0.33	0.31	0.30				
2009	0.30	0.28	0.33	0.26	0.36	0.36	0.35	0.27
2010	0.36	0.37	0.26	0.38	0.35	0.38	0.47	0.62
2011	0.35	0.37	0.46	0.40	0.34	0.38	0.46	0.41
2012	0.44	0.44	0.59	0.71	0.41	0.42	0.58	0.70
2013	0.45	0.32	0.22	0.39	0.44	0.34	0.23	0.38
Average	**0.39**	**0.43**	**0.34**	**0.34**				

Table A.55. Uncalibrated FSV Bigelow survey indices and coefficients of variation (CV) for the Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl survey indices for Gulf of Maine haddock from 2009 to 2013. The TOGA tow selection criteria were used in the calculations of these indices.

Year	Indices				Coefficients of variation (CV)			
	Spring		Fall		Spring		Fall	
	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow	Mean number/tow	Mean weight (kg)/tow
2009	2.046	2.362	3.611	1.541	0.30	0.28	0.38	0.30
2010	2.071	3.262	5.783	3.309	0.33	0.40	0.35	0.48
2011	2.356	1.106	6.722	5.250	0.35	0.39	0.50	0.43
2012	5.555	2.570	10.494	4.287	0.39	0.42	0.54	0.72
2013	29.942	6.997	79.720	17.985	0.44	0.33	0.24	0.37

Table A.56. Northeast Fisheries Science Center (NEFSC) spring survey abundance indices-at-age (numbers/tow) from 1968 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the SHG tow selection criteria.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1968	0.000	0.000	0.000	0.030	0.259	4.342	0.929	0.164	0.212	0.077	0.000	0.053	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.054	0.019	0.244	2.643	0.694	0.029	0.036	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.131	0.633	0.123	0.019	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.024	0.673	0.124	0.032	0.000	0.000	0.000	0.000
1972	0.000	0.584	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.178	0.061	0.016	0.023	0.000	0.000
1973	0.000	0.149	0.764	0.000	0.000	0.000	0.000	0.054	0.000	0.007	0.319	0.019	0.000	0.000	0.000
1974	0.000	0.900	0.088	0.312	0.000	0.022	0.000	0.000	0.031	0.016	0.000	0.070	0.000	0.000	0.000
1975	0.000	0.015	1.973	0.155	0.409	0.000	0.008	0.008	0.065	0.130	0.000	0.000	0.000	0.000	0.008
1976	0.000	5.110	0.115	1.763	0.140	0.961	0.058	0.043	0.000	0.000	0.000	0.000	0.000	0.129	0.008
1977	0.000	1.043	3.383	0.033	1.382	0.399	0.560	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.085	0.682	0.355	0.030	0.204	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.292	0.097	0.702	1.268	0.233	0.135	0.091	0.052	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	1.053	0.153	0.178	0.547	0.219	0.025	0.000	0.000	0.037	0.000	0.000	0.000	0.000	0.000
1981	0.000	1.115	1.094	0.549	0.239	0.349	0.167	0.025	0.034	0.041	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.404	0.933	0.372	0.142	0.069	0.103	0.013	0.013	0.000	0.000	0.000	0.000	0.000
1983	0.085	1.395	0.133	1.087	0.307	0.486	0.000	0.109	0.054	0.000	0.000	0.022	0.000	0.000	0.000
1984	0.000	0.019	0.570	0.054	0.299	0.108	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.013	0.320	1.078	0.055	0.155	0.083	0.050	0.020	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.051	0.000	0.162	0.362	0.000	0.036	0.073	0.023	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.036	0.025	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.043	0.000	0.000	0.015	0.119	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.036	0.012	0.000	0.012	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.012	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.014	0.007	0.007	0.045	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.000	0.085	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.261	0.146	0.000	0.000	0.029	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.074	0.182	0.116	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.000	0.441	0.240	0.079	0.023	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.037	0.146	0.123	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.775	0.210	0.257	0.601	0.070	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.080	0.046	0.000	0.062	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	3.724	0.087	0.160	0.029	0.224	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	1.032	1.170	0.973	0.137	0.124	0.043	0.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.073	0.126	1.093	0.492	0.174	0.193	0.072	0.043	0.098	0.000	0.000	0.000	0.000	0.000
2002	0.000	3.299	0.206	0.600	1.415	0.098	0.027	0.022	0.036	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.359	0.208	0.091	0.108	2.017	0.203	0.121	0.036	0.037	0.012	0.000	0.000	0.000	0.000
2004	0.000	0.115	0.000	0.154	0.022	0.095	0.625	0.036	0.000	0.015	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.010	0.172	0.000	0.099	0.081	0.219	0.253	0.000	0.029	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.179	0.076	1.651	0.318	0.104	0.019	0.201	0.545	0.058	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.156	0.085	0.028	0.242	0.000	0.028	0.029	0.028	0.160	0.000	0.015	0.000	0.000	0.000
2008	0.000	0.043	0.564	0.406	0.000	0.303	0.000	0.027	0.052	0.097	0.197	0.000	0.000	0.000	0.000
2009	0.000	0.030	0.070	0.363	0.191	0.037	0.581	0.000	0.051	0.023	0.042	0.123	0.011	0.000	0.000
2010	0.000	0.103	0.013	0.016	0.116	0.091	0.044	0.478	0.000	0.040	0.024	0.039	0.152	0.000	0.011
2011	0.000	0.527	0.199	0.010	0.000	0.025	0.174	0.000	0.193	0.000	0.018	0.024	0.025	0.042	0.000
2012	0.000	0.505	1.374	0.183	0.050	0.000	0.159	0.083	0.042	0.194	0.000	0.029	0.000	0.032	0.070
2013	0.000	9.438	0.807	1.627	0.135	0.036	0.027	0.116	0.080	0.016	0.070	0.000	0.000	0.000	0.007

Table A.57. Northeast Fisheries Science Center (NEFSC) spring survey abundance indices-at-age (numbers/tow) from 1968 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the TOGA tow selection criteria.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1968	0.000	0.000	0.000	0.030	0.259	4.342	0.929	0.164	0.212	0.077	0.000	0.053	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.054	0.019	0.244	2.643	0.694	0.029	0.036	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.131	0.633	0.123	0.019	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.024	0.024	0.673	0.124	0.032	0.000	0.000	0.000	0.000
1972	0.000	0.584	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.178	0.061	0.016	0.023	0.000	0.000
1973	0.000	0.149	0.764	0.000	0.000	0.000	0.000	0.054	0.000	0.007	0.319	0.019	0.000	0.000	0.000
1974	0.000	0.900	0.088	0.312	0.000	0.022	0.000	0.000	0.031	0.016	0.000	0.070	0.000	0.000	0.000
1975	0.000	0.015	1.973	0.155	0.409	0.000	0.008	0.008	0.065	0.130	0.000	0.000	0.000	0.000	0.008
1976	0.000	5.110	0.115	1.763	0.140	0.961	0.058	0.043	0.000	0.000	0.000	0.000	0.000	0.129	0.008
1977	0.000	1.043	3.383	0.033	1.382	0.399	0.560	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.085	0.682	0.355	0.030	0.204	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.292	0.097	0.702	1.268	0.233	0.135	0.091	0.052	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	1.053	0.153	0.178	0.547	0.219	0.025	0.000	0.000	0.037	0.000	0.000	0.000	0.000	0.000
1981	0.000	1.115	1.094	0.549	0.239	0.349	0.167	0.025	0.034	0.041	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.404	0.933	0.372	0.142	0.069	0.103	0.013	0.013	0.000	0.000	0.000	0.000	0.000
1983	0.085	1.395	0.133	1.087	0.307	0.486	0.000	0.109	0.054	0.000	0.000	0.022	0.000	0.000	0.000
1984	0.000	0.019	0.570	0.054	0.299	0.108	0.000	0.000	0.045	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.013	0.320	1.078	0.055	0.155	0.083	0.050	0.020	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.051	0.000	0.162	0.362	0.000	0.036	0.073	0.023	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.036	0.025	0.031	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.043	0.000	0.000	0.015	0.119	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.036	0.012	0.000	0.012	0.024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.012	0.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.014	0.007	0.007	0.045	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.000	0.085	0.000	0.000	0.109	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.261	0.146	0.000	0.000	0.029	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.074	0.182	0.116	0.030	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.000	0.441	0.240	0.079	0.023	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.037	0.146	0.123	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.775	0.210	0.257	0.601	0.070	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.080	0.046	0.000	0.062	0.009	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	3.724	0.087	0.160	0.029	0.224	0.044	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	1.032	1.170	0.973	0.137	0.124	0.043	0.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.073	0.126	1.093	0.492	0.174	0.193	0.072	0.043	0.098	0.000	0.000	0.000	0.000	0.000
2002	0.000	3.299	0.206	0.600	1.415	0.098	0.027	0.022	0.036	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.359	0.208	0.091	0.108	2.017	0.203	0.121	0.036	0.037	0.012	0.000	0.000	0.000	0.000
2004	0.000	0.115	0.000	0.154	0.022	0.095	0.625	0.036	0.000	0.015	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.010	0.172	0.000	0.099	0.081	0.219	0.253	0.000	0.029	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.179	0.076	1.651	0.318	0.104	0.019	0.201	0.545	0.058	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.156	0.085	0.028	0.242	0.000	0.028	0.029	0.028	0.160	0.000	0.015	0.000	0.000	0.000
2008	0.000	0.043	0.564	0.406	0.000	0.303	0.000	0.027	0.052	0.097	0.197	0.000	0.000	0.000	0.000
2009	0.000	0.032	0.089	0.421	0.219	0.040	0.548	0.000	0.014	0.017	0.037	0.106	0.009	0.000	0.000
2010	0.000	0.103	0.013	0.008	0.131	0.129	0.051	0.787	0.000	0.052	0.045	0.059	0.237	0.000	0.016
2011	0.000	0.555	0.199	0.010	0.000	0.025	0.174	0.000	0.162	0.000	0.018	0.024	0.025	0.042	0.000
2012	0.000	0.532	1.590	0.193	0.049	0.000	0.162	0.084	0.043	0.194	0.000	0.029	0.000	0.032	0.070
2013	0.000	9.459	0.807	1.627	0.135	0.036	0.027	0.116	0.080	0.016	0.070	0.000	0.000	0.000	0.007

Table A.58. Uncalibrated Northeast Fisheries Science Center (NEFSC) FSV Bigelow spring survey abundance indices-at-age (numbers/tow) from 2009 to 2013 for Gulf of Maine haddock. The TOGA tow selection criteria were used in the calculations of these indices.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
2009	0.000	0.077	0.140	0.554	0.245	0.045	0.692	0.000	0.060	0.027	0.049	0.145	0.012	0.000	0.000
2010	0.000	0.258	0.024	0.012	0.165	0.156	0.061	0.920	0.000	0.061	0.052	0.069	0.276	0.000	0.019
2011	0.000	1.385	0.407	0.015	0.000	0.029	0.205	0.000	0.189	0.000	0.021	0.028	0.029	0.049	0.000
2012	0.000	1.313	3.142	0.298	0.071	0.000	0.196	0.100	0.051	0.230	0.000	0.034	0.000	0.038	0.082
2013	0.000	22.971	1.960	4.257	0.269	0.043	0.036	0.172	0.101	0.018	0.104	0.000	0.000	0.000	0.011

Table A.59. Northeast Fisheries Science Center (NEFSC) spring survey biomass indices-at-age (weight/tow) from 1968 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the SHG tow selection criteria. *Note that biomass indices are not used in the current assessment.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1968	0.000	0.000	0.000	0.018	0.141	5.064	1.740	0.348	0.377	0.158	0.000	0.260	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.012	0.013	0.367	4.461	1.632	0.062	0.061	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.333	1.151	0.261	0.039	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.055	1.805	0.500	0.108	0.000	0.000	0.000	0.000
1972	0.000	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.541	0.173	0.071	0.069	0.000	0.000
1973	0.000	0.012	0.279	0.000	0.000	0.000	0.000	0.096	0.000	0.020	1.133	0.083	0.000	0.000	0.000
1974	0.000	0.053	0.037	0.275	0.000	0.030	0.000	0.000	0.122	0.039	0.000	0.505	0.000	0.000	0.000
1975	0.000	0.001	0.980	0.175	0.820	0.000	0.022	0.037	0.390	1.030	0.000	0.000	0.000	0.000	0.027
1976	0.000	0.776	0.045	2.092	0.195	2.421	0.050	0.153	0.000	0.000	0.000	0.000	0.000	0.577	0.043
1977	0.000	0.063	1.671	0.048	2.537	0.927	1.479	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.007	0.275	0.501	0.051	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.017	0.047	0.553	1.930	0.468	0.355	0.292	0.217	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.144	0.096	0.241	1.117	0.591	0.122	0.000	0.000	0.362	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.114	0.519	0.560	0.378	1.076	0.605	0.081	0.094	0.118	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.189	0.977	0.517	0.262	0.161	0.317	0.061	0.072	0.000	0.000	0.000	0.000	0.000
1983	0.003	0.128	0.040	1.181	0.456	0.948	0.000	0.460	0.274	0.000	0.000	0.082	0.000	0.000	0.000
1984	0.000	0.002	0.180	0.047	0.520	0.239	0.000	0.000	0.156	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.001	0.125	0.899	0.079	0.311	0.190	0.197	0.080	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.005	0.000	0.225	0.583	0.000	0.094	0.275	0.103	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.004	0.019	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.003	0.000	0.000	0.035	0.231	0.000	0.000	0.031	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.014	0.009	0.000	0.038	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.001	0.007	0.007	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.000	0.006	0.000	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.026	0.059	0.000	0.000	0.077	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.005	0.072	0.140	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.000	0.017	0.083	0.070	0.027	0.000	0.000	0.000	0.154	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.005	0.099	0.234	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.057	0.097	0.186	0.710	0.126	0.047	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.014	0.024	0.000	0.055	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.293	0.053	0.200	0.078	0.412	0.074	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.087	0.377	0.527	0.220	0.219	0.092	0.293	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.004	0.049	0.995	0.832	0.299	0.434	0.244	0.117	0.231	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.198	0.089	0.508	1.570	0.195	0.083	0.050	0.100	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.015	0.075	0.081	0.078	2.813	0.357	0.268	0.118	0.074	0.029	0.000	0.000	0.000	0.000
2004	0.000	0.008	0.000	0.077	0.024	0.101	0.881	0.076	0.000	0.032	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.000	0.046	0.000	0.108	0.137	0.271	0.355	0.000	0.055	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.012	0.019	0.974	0.223	0.151	0.025	0.287	0.890	0.080	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.012	0.027	0.015	0.230	0.000	0.036	0.047	0.043	0.231	0.000	0.034	0.000	0.000	0.000
2008	0.000	0.005	0.150	0.234	0.000	0.406	0.000	0.044	0.082	0.152	0.322	0.000	0.000	0.000	0.000
2009	0.000	0.003	0.029	0.337	0.295	0.059	1.246	0.000	0.138	0.061	0.147	0.360	0.029	0.000	0.000
2010	0.000	0.012	0.007	0.016	0.176	0.171	0.091	1.130	0.000	0.167	0.058	0.102	0.392	0.000	0.027
2011	0.000	0.065	0.080	0.011	0.000	0.051	0.361	0.000	0.441	0.000	0.054	0.072	0.071	0.120	0.000
2012	0.000	0.076	0.737	0.229	0.066	0.000	0.382	0.246	0.108	0.479	0.000	0.101	0.000	0.069	0.228
2013	0.000	1.883	0.503	2.328	0.278	0.121	0.080	0.373	0.308	0.060	0.261	0.000	0.000	0.000	0.025

Table A.60. Northeast Fisheries Science Center (NEFSC) spring survey biomass indices-at-age (weight/tow) from 1968 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the TOGA tow selection criteria. *Note that biomass indices are not used in the current assessment.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1968	0.000	0.000	0.000	0.018	0.141	5.064	1.740	0.348	0.377	0.158	0.000	0.260	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.012	0.013	0.367	4.461	1.632	0.062	0.061	0.000	0.000	0.000	0.000	0.000
1970	0.000	0.000	0.000	0.000	0.000	0.000	0.333	1.151	0.261	0.039	0.000	0.000	0.000	0.000	0.000
1971	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.055	1.805	0.500	0.108	0.000	0.000	0.000	0.000
1972	0.000	0.028	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.541	0.173	0.071	0.069	0.000	0.000
1973	0.000	0.012	0.279	0.000	0.000	0.000	0.000	0.096	0.000	0.020	1.133	0.083	0.000	0.000	0.000
1974	0.000	0.053	0.037	0.275	0.000	0.030	0.000	0.000	0.122	0.039	0.000	0.505	0.000	0.000	0.000
1975	0.000	0.001	0.980	0.175	0.820	0.000	0.022	0.037	0.390	1.030	0.000	0.000	0.000	0.000	0.027
1976	0.000	0.776	0.045	2.092	0.195	2.421	0.050	0.153	0.000	0.000	0.000	0.000	0.000	0.577	0.043
1977	0.000	0.063	1.671	0.048	2.537	0.927	1.479	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1978	0.000	0.007	0.275	0.501	0.051	0.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.017	0.047	0.553	1.930	0.468	0.355	0.292	0.217	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.000	0.144	0.096	0.241	1.117	0.591	0.122	0.000	0.000	0.362	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.114	0.519	0.560	0.378	1.076	0.605	0.081	0.094	0.118	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.000	0.189	0.977	0.517	0.262	0.161	0.317	0.061	0.072	0.000	0.000	0.000	0.000	0.000
1983	0.003	0.128	0.040	1.181	0.456	0.948	0.000	0.460	0.274	0.000	0.000	0.082	0.000	0.000	0.000
1984	0.000	0.002	0.180	0.047	0.520	0.239	0.000	0.000	0.156	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.001	0.125	0.899	0.079	0.311	0.190	0.197	0.080	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.005	0.000	0.225	0.583	0.000	0.094	0.275	0.103	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.004	0.019	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.003	0.000	0.000	0.035	0.231	0.000	0.000	0.031	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.000	0.014	0.009	0.000	0.038	0.063	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.001	0.007	0.007	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.000	0.006	0.000	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.026	0.059	0.000	0.000	0.077	0.043	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.005	0.072	0.140	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.000	0.017	0.083	0.070	0.027	0.000	0.000	0.000	0.154	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.005	0.099	0.234	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.057	0.097	0.186	0.710	0.126	0.047	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.000	0.014	0.024	0.000	0.055	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.293	0.053	0.200	0.078	0.412	0.074	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.087	0.377	0.527	0.220	0.219	0.092	0.293	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.004	0.049	0.995	0.832	0.299	0.434	0.244	0.117	0.231	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.198	0.089	0.508	1.570	0.195	0.083	0.050	0.100	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.015	0.075	0.081	0.078	2.813	0.357	0.268	0.118	0.074	0.029	0.000	0.000	0.000	0.000
2004	0.000	0.008	0.000	0.077	0.024	0.101	0.881	0.076	0.000	0.032	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.000	0.046	0.000	0.108	0.137	0.271	0.355	0.000	0.055	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.012	0.019	0.974	0.223	0.151	0.025	0.287	0.890	0.080	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.012	0.027	0.015	0.230	0.000	0.036	0.047	0.043	0.231	0.000	0.034	0.000	0.000	0.000
2008	0.000	0.005	0.150	0.234	0.000	0.406	0.000	0.044	0.082	0.152	0.322	0.000	0.000	0.000	0.000
2009	0.000	0.003	0.039	0.395	0.344	0.066	1.177	0.000	0.032	0.045	0.135	0.312	0.026	0.000	0.000
2010	0.000	0.012	0.007	0.008	0.195	0.267	0.106	1.997	0.000	0.199	0.108	0.160	0.617	0.000	0.039
2011	0.000	0.067	0.080	0.011	0.000	0.051	0.364	0.000	0.365	0.000	0.054	0.073	0.072	0.122	0.000
2012	0.000	0.084	0.875	0.240	0.066	0.000	0.398	0.255	0.114	0.488	0.000	0.103	0.000	0.071	0.232
2013	0.000	1.885	0.503	2.329	0.278	0.121	0.080	0.373	0.308	0.060	0.261	0.000	0.000	0.000	0.025

Table A.61. Uncalibrated Northeast Fisheries Science Center (NEFSC) FSV Bigelow spring survey biomass indices-at-age (weight/tow) from 2009 to 2013 for Gulf of Maine haddock. Stations were selected using the TOGA tow selection criteria. *Note that biomass indices are not used in the current assessment.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
2009	0.000	0.005	0.041	0.360	0.262	0.051	1.038	0.000	0.113	0.050	0.120	0.298	0.024	0.000	0.000
2010	0.000	0.022	0.009	0.009	0.181	0.237	0.094	1.737	0.000	0.173	0.094	0.139	0.535	0.000	0.034
2011	0.000	0.113	0.108	0.011	0.000	0.041	0.291	0.000	0.290	0.000	0.043	0.058	0.057	0.096	0.000
2012	0.000	0.122	1.008	0.207	0.057	0.000	0.286	0.181	0.080	0.346	0.000	0.072	0.000	0.051	0.162
2013	0.000	2.297	0.637	2.955	0.269	0.073	0.055	0.272	0.202	0.034	0.185	0.000	0.000	0.000	0.020

Table A.62. Northeast Fisheries Science Center (NEFSC) fall survey abundance indices-at-age (numbers/tow) from 1963 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the SHG tow selection criteria.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1963	35.425	12.307	1.770	2.954	7.037	4.850	1.721	1.287	1.067	0.686	0.362	0.000	0.000	0.085	0.000
1964	0.081	6.194	1.562	0.525	0.989	2.220	1.612	0.851	0.000	0.143	0.000	0.000	0.000	0.000	0.000
1965	0.108	0.666	7.688	5.009	0.305	1.347	1.368	0.646	0.246	0.051	0.000	0.000	0.000	0.000	0.000
1966	0.019	0.162	0.424	6.438	2.390	0.252	0.653	0.327	0.065	0.012	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	1.562	7.924	1.865	0.515	0.068	0.203	0.050	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.235	6.295	1.383	0.237	0.315	0.099	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.040	0.026	0.032	4.061	1.016	0.182	0.011	0.029	0.000	0.000	0.000	0.054
1970	0.000	0.048	0.000	0.000	0.000	0.133	0.151	1.918	0.656	0.000	0.011	0.000	0.000	0.000	0.000
1971	0.268	0.000	0.000	0.000	0.011	0.000	0.170	0.347	1.901	0.139	0.044	0.000	0.000	0.000	0.000
1972	0.000	1.190	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.461	0.201	0.084	0.000	0.000	0.000
1973	1.129	0.022	0.960	0.000	0.371	0.018	0.000	0.059	0.007	0.139	1.177	0.170	0.000	0.022	0.093
1974	0.022	1.660	0.103	0.502	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.306	0.000	0.000	0.030
1975	0.888	0.227	1.850	0.499	1.494	0.000	0.085	0.035	0.000	0.000	0.041	0.064	0.288	0.062	0.000
1976	1.633	1.794	0.097	1.249	0.159	0.921	0.000	0.174	0.000	0.000	0.000	0.000	0.008	0.000	0.000
1977	0.104	3.085	3.425	0.127	1.045	0.120	0.287	0.000	0.000	0.000	0.000	0.020	0.000	0.082	0.000
1978	0.180	0.069	1.550	5.668	0.148	0.762	1.158	0.125	0.000	0.000	0.000	0.000	0.045	0.000	0.071
1979	0.796	0.406	0.088	1.109	2.735	0.477	0.428	0.122	0.000	0.000	0.000	0.013	0.000	0.000	0.000
1980	3.953	0.509	0.292	0.000	0.298	1.062	0.636	0.181	0.129	0.093	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.598	0.470	1.019	0.337	0.800	0.802	0.122	0.309	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.386	0.037	0.586	0.906	0.375	0.049	0.000	0.096	0.096	0.000	0.096	0.000	0.000	0.000	0.000
1983	0.026	0.533	0.051	0.675	0.503	0.401	0.177	0.068	0.164	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.210	0.534	0.000	0.292	0.000	0.413	0.000	0.034	0.214	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.089	0.396	2.794	0.017	0.192	0.134	0.389	0.000	0.000	0.068	0.000	0.000	0.000	0.000
1986	0.000	0.015	0.000	0.076	0.354	0.101	0.018	0.000	0.059	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.029	0.000	0.152	0.102	0.094	0.061	0.301	0.178	0.000	0.118	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.041	0.023	0.092	0.000	0.064	0.115	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.059	0.059	0.019	0.012	0.082	0.033	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.009	0.024	0.000	0.056	0.000	0.000	0.000	0.038	0.019	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.053	0.047	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.043	0.145	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.099	0.467	0.226	0.030	0.030	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.206	0.047	0.000	0.000	0.000	0.000	0.000	0.036	0.000	0.000	0.000	0.036	0.000	0.000	0.000
1995	0.000	0.094	0.604	0.184	0.036	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.000	0.000
1996	0.043	0.127	0.195	1.062	0.618	0.068	0.114	0.071	0.036	0.000	0.036	0.000	0.000	0.036	0.000
1997	0.214	1.328	0.030	0.385	0.578	0.061	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	1.466	0.241	0.416	0.130	0.431	0.303	0.070	0.049	0.025	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.548	3.229	0.594	0.829	0.253	0.478	0.513	0.169	0.059	0.026	0.032	0.000	0.000	0.000	0.000
2000	0.333	0.661	11.306	1.686	1.303	0.425	0.580	0.221	0.074	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.196	0.240	2.297	4.862	0.719	0.808	0.301	0.193	0.293	0.051	0.000	0.000	0.000	0.000	0.000
2002	0.014	0.121	0.014	0.541	2.454	0.342	0.144	0.000	0.215	0.031	0.000	0.045	0.000	0.000	0.000
2003	0.853	0.000	0.267	0.072	0.504	2.466	0.351	0.053	0.000	0.144	0.023	0.000	0.000	0.000	0.000
2004	0.073	0.348	0.029	0.546	0.250	0.828	3.234	0.124	0.156	0.000	0.027	0.090	0.000	0.000	0.000
2005	0.188	0.110	1.593	0.067	0.147	0.300	0.407	1.143	0.088	0.058	0.000	0.019	0.013	0.000	0.000
2006	0.230	0.264	0.083	1.781	0.027	0.205	0.108	0.290	0.848	0.048	0.008	0.000	0.000	0.017	0.000
2007	0.015	1.065	0.848	0.221	2.128	0.061	0.014	0.163	0.114	0.500	0.000	0.025	0.000	0.000	0.000
2008	0.000	0.000	0.404	0.111	0.000	1.045	0.000	0.161	0.114	0.110	0.281	0.000	0.041	0.000	0.000
2009	0.815	0.225	0.080	0.171	0.012	0.038	0.343	0.000	0.043	0.000	0.031	0.108	0.000	0.000	0.000
2010	1.158	0.094	0.072	0.140	0.277	0.593	0.217	0.548	0.000	0.016	0.000	0.030	0.177	0.000	0.000
2011	0.495	1.191	0.835	0.196	0.097	0.850	0.221	0.136	0.747	0.000	0.054	0.000	0.000	0.064	0.000
2012	1.467	0.526	3.291	0.010	0.000	0.020	0.028	0.028	0.000	0.028	0.000	0.000	0.000	0.000	0.000
2013	21.582	5.057	1.815	6.762	0.415	0.260	0.090	0.028	0.000	0.000	0.080	0.000	0.000	0.000	0.000

Table A.63. Northeast Fisheries Science Center (NEFSC) fall survey abundance indices-at-age (numbers/tow) from 1963 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the TOGA tow selection criteria.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1963	35.425	12.307	1.770	2.954	7.037	4.850	1.721	1.287	1.067	0.686	0.362	0.000	0.000	0.085	0.000
1964	0.081	6.194	1.562	0.525	0.989	2.220	1.612	0.851	0.000	0.143	0.000	0.000	0.000	0.000	0.000
1965	0.108	0.666	7.688	5.009	0.305	1.347	1.368	0.646	0.246	0.051	0.000	0.000	0.000	0.000	0.000
1966	0.019	0.162	0.424	6.438	2.390	0.252	0.653	0.327	0.065	0.012	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	1.562	7.924	1.865	0.515	0.068	0.203	0.050	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.235	6.295	1.383	0.237	0.315	0.099	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.040	0.026	0.032	4.061	1.016	0.182	0.011	0.029	0.000	0.000	0.000	0.054
1970	0.000	0.048	0.000	0.000	0.000	0.133	0.151	1.918	0.656	0.000	0.011	0.000	0.000	0.000	0.000
1971	0.268	0.000	0.000	0.000	0.011	0.000	0.170	0.347	1.901	0.139	0.044	0.000	0.000	0.000	0.000
1972	0.000	1.190	0.000	0.000	0.000	0.048	0.000	0.000	0.000	0.461	0.201	0.084	0.000	0.000	0.000
1973	1.129	0.022	0.960	0.000	0.371	0.018	0.000	0.059	0.007	0.139	1.177	0.170	0.000	0.022	0.093
1974	0.022	1.660	0.103	0.502	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.306	0.000	0.000	0.030
1975	0.888	0.227	1.850	0.499	1.494	0.000	0.085	0.035	0.000	0.000	0.041	0.064	0.288	0.062	0.000
1976	1.633	1.794	0.097	1.249	0.159	0.921	0.000	0.174	0.000	0.000	0.000	0.000	0.008	0.000	0.000
1977	0.104	3.085	3.425	0.127	1.045	0.120	0.287	0.000	0.000	0.000	0.000	0.020	0.000	0.082	0.000
1978	0.180	0.069	1.550	5.668	0.148	0.762	1.158	0.125	0.000	0.000	0.000	0.000	0.045	0.000	0.071
1979	0.796	0.406	0.088	1.109	2.735	0.477	0.428	0.122	0.000	0.000	0.000	0.013	0.000	0.000	0.000
1980	3.953	0.509	0.292	0.000	0.298	1.062	0.636	0.181	0.129	0.093	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.598	0.470	1.019	0.337	0.800	0.802	0.122	0.309	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.386	0.037	0.586	0.906	0.375	0.049	0.000	0.096	0.096	0.000	0.096	0.000	0.000	0.000	0.000
1983	0.026	0.533	0.051	0.675	0.503	0.401	0.177	0.068	0.164	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.210	0.534	0.000	0.292	0.000	0.413	0.000	0.034	0.214	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.089	0.396	2.794	0.017	0.192	0.134	0.389	0.000	0.000	0.068	0.000	0.000	0.000	0.000
1986	0.000	0.015	0.000	0.076	0.354	0.101	0.018	0.000	0.059	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.029	0.000	0.152	0.102	0.094	0.061	0.301	0.178	0.000	0.118	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.041	0.023	0.092	0.000	0.064	0.115	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.059	0.059	0.019	0.012	0.082	0.033	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.009	0.024	0.000	0.056	0.000	0.000	0.000	0.038	0.019	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.053	0.047	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.043	0.145	0.000	0.023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.099	0.467	0.226	0.030	0.030	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.206	0.047	0.000	0.000	0.000	0.000	0.000	0.036	0.000	0.000	0.000	0.036	0.000	0.000	0.000
1995	0.000	0.094	0.604	0.184	0.036	0.036	0.000	0.000	0.000	0.000	0.000	0.000	0.023	0.000	0.000
1996	0.043	0.127	0.195	1.062	0.618	0.068	0.114	0.071	0.036	0.000	0.036	0.000	0.000	0.036	0.000
1997	0.214	1.328	0.030	0.385	0.578	0.061	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	1.466	0.241	0.416	0.130	0.431	0.303	0.070	0.049	0.025	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.548	3.229	0.594	0.829	0.253	0.478	0.513	0.169	0.059	0.026	0.032	0.000	0.000	0.000	0.000
2000	0.333	0.661	11.306	1.686	1.303	0.425	0.580	0.221	0.074	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.196	0.240	2.297	4.862	0.719	0.808	0.301	0.193	0.293	0.051	0.000	0.000	0.000	0.000	0.000
2002	0.014	0.121	0.014	0.541	2.454	0.342	0.144	0.000	0.215	0.031	0.000	0.045	0.000	0.000	0.000
2003	0.853	0.000	0.267	0.072	0.504	2.466	0.351	0.053	0.000	0.144	0.023	0.000	0.000	0.000	0.000
2004	0.073	0.348	0.029	0.546	0.250	0.828	3.234	0.124	0.156	0.000	0.027	0.090	0.000	0.000	0.000
2005	0.188	0.110	1.593	0.067	0.147	0.300	0.407	1.143	0.088	0.058	0.000	0.019	0.013	0.000	0.000
2006	0.230	0.264	0.083	1.781	0.027	0.205	0.108	0.290	0.848	0.048	0.008	0.000	0.000	0.017	0.000
2007	0.015	1.065	0.848	0.221	2.128	0.061	0.014	0.163	0.114	0.500	0.000	0.025	0.000	0.000	0.000
2008	0.000	0.000	0.404	0.111	0.000	1.045	0.000	0.161	0.114	0.110	0.281	0.000	0.041	0.000	0.000
2009	0.888	0.258	0.092	0.188	0.012	0.040	0.348	0.000	0.052	0.000	0.031	0.108	0.000	0.000	0.000
2010	1.625	0.034	0.021	0.050	0.168	0.291	0.112	0.240	0.000	0.000	0.000	0.026	0.095	0.000	0.000
2011	0.508	1.191	0.835	0.196	0.097	0.850	0.221	0.136	0.747	0.000	0.054	0.000	0.000	0.064	0.000
2012	1.467	0.526	3.291	0.010	0.000	0.020	0.028	0.028	0.000	0.028	0.000	0.000	0.000	0.000	0.000
2013	21.582	5.057	1.815	6.762	0.415	0.260	0.090	0.028	0.000	0.000	0.080	0.000	0.000	0.000	0.000

Table A.64. Uncalibrated Northeast Fisheries Science Center (NEFSC) FSV Bigelow fall survey abundance indices-at-age (numbers/tow) from 2009 to 2013 for Gulf of Maine haddock. Stations were selected using the TOGA tow selection criteria.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
2009	2.135	0.496	0.138	0.229	0.015	0.048	0.361	0.000	0.050	0.000	0.029	0.111	0.000	0.000	0.000
2010	3.234	0.080	0.109	0.253	0.399	0.754	0.321	0.441	0.000	0.000	0.000	0.030	0.163	0.000	0.000
2011	1.149	1.996	1.095	0.216	0.098	0.903	0.241	0.163	0.745	0.000	0.051	0.000	0.000	0.066	0.000
2012	3.844	1.148	5.371	0.012	0.000	0.023	0.032	0.032	0.000	0.032	0.000	0.000	0.000	0.000	0.000
2013	56.007	10.560	2.949	9.111	0.501	0.370	0.107	0.029	0.000	0.000	0.087	0.000	0.000	0.000	0.000

Table A.65. Northeast Fisheries Science Center (NEFSC) fall survey biomass indices-at-age (weight/tow) from 1963 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the SHG tow selection criteria. *Note that biomass indices are not used in the current assessment.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1963	0.997	3.025	1.418	3.936	12.441	11.214	4.862	4.428	3.738	2.375	1.574	0.000	0.000	0.690	0.000
1964	0.004	1.322	1.134	0.719	1.905	4.854	4.281	3.376	0.000	0.792	0.000	0.000	0.000	0.000	0.000
1965	0.010	0.118	2.985	4.535	0.542	2.920	3.413	2.100	0.875	0.241	0.000	0.000	0.000	0.000	0.000
1966	0.002	0.053	0.255	5.847	3.025	0.653	1.851	1.129	0.247	0.041	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	1.518	10.124	2.887	1.196	0.230	0.722	0.195	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.371	11.415	3.207	0.733	1.176	0.405	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.071	0.040	0.060	8.750	2.988	0.473	0.034	0.080	0.000	0.000	0.000	0.225
1970	0.000	0.011	0.000	0.000	0.000	0.215	0.335	4.803	1.942	0.000	0.049	0.000	0.000	0.000	0.000
1971	0.004	0.000	0.000	0.000	0.021	0.000	0.557	1.322	5.517	0.609	0.129	0.000	0.000	0.000	0.000
1972	0.000	0.320	0.000	0.000	0.000	0.100	0.000	0.000	0.000	1.477	0.765	0.387	0.000	0.000	0.000
1973	0.027	0.004	0.667	0.000	0.883	0.071	0.000	0.220	0.018	0.491	4.841	0.740	0.000	0.118	0.511
1974	0.000	0.484	0.160	0.836	0.193	0.000	0.000	0.000	0.000	0.000	0.000	1.472	0.000	0.000	0.202
1975	0.020	0.076	1.670	1.024	3.413	0.000	0.277	0.109	0.000	0.000	0.239	0.243	1.315	0.233	0.000
1976	0.056	0.814	0.131	2.547	0.449	3.162	0.000	0.853	0.000	0.000	0.000	0.000	0.030	0.000	0.000
1977	0.008	0.902	3.273	0.237	2.613	0.375	0.961	0.000	0.000	0.000	0.000	0.064	0.000	0.323	0.000
1978	0.005	0.029	1.139	10.821	0.483	2.775	5.050	0.729	0.000	0.000	0.000	0.000	0.271	0.000	0.358
1979	0.023	0.136	0.125	2.043	8.674	1.946	1.938	0.597	0.000	0.000	0.000	0.088	0.000	0.000	0.000
1980	0.133	0.175	0.339	0.000	0.800	3.752	2.624	0.721	0.609	0.684	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.169	0.358	1.653	0.882	2.399	3.167	0.667	1.580	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.008	0.012	0.551	1.318	0.906	0.134	0.000	0.386	0.447	0.000	0.403	0.000	0.000	0.000	0.000
1983	0.002	0.113	0.039	1.119	1.046	1.049	0.668	0.460	0.724	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.059	0.375	0.000	0.798	0.000	1.615	0.000	0.202	0.845	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.031	0.355	3.198	0.024	0.417	0.322	1.454	0.000	0.000	0.348	0.000	0.000	0.000	0.000
1986	0.000	0.008	0.000	0.097	0.666	0.309	0.044	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.001	0.000	0.170	0.164	0.190	0.146	0.803	0.597	0.000	0.575	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.119	0.060	0.294	0.000	0.310	0.693	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.015	0.067	0.035	0.032	0.278	0.113	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.007	0.000	0.120	0.000	0.000	0.000	0.162	0.143	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.002	0.018	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.001	0.053	0.000	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.002	0.141	0.192	0.040	0.059	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.003	0.009	0.000	0.000	0.000	0.000	0.000	0.106	0.000	0.000	0.000	0.101	0.000	0.000	0.000
1995	0.000	0.024	0.464	0.255	0.068	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.166	0.000	0.000
1996	0.002	0.052	0.141	1.197	1.129	0.135	0.322	0.220	0.100	0.000	0.137	0.000	0.000	0.110	0.000
1997	0.003	0.305	0.020	0.406	1.185	0.223	0.283	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.030	0.064	0.386	0.245	1.033	0.655	0.205	0.214	0.087	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.017	0.738	0.389	1.047	0.435	0.775	0.985	0.232	0.123	0.060	0.110	0.000	0.000	0.000	0.000
2000	0.012	0.167	6.903	1.860	2.049	0.987	1.323	0.569	0.163	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.003	0.035	1.882	5.298	1.016	1.616	0.682	0.531	0.804	0.114	0.000	0.000	0.000	0.000	0.000
2002	0.001	0.027	0.006	0.467	2.855	0.562	0.326	0.000	0.463	0.051	0.000	0.078	0.000	0.000	0.000
2003	0.021	0.000	0.177	0.086	0.635	3.473	0.546	0.072	0.000	0.284	0.065	0.000	0.000	0.000	0.000
2004	0.001	0.069	0.015	0.427	0.330	1.015	4.598	0.263	0.224	0.000	0.056	0.171	0.000	0.000	0.000
2005	0.006	0.009	0.720	0.037	0.120	0.356	0.575	1.723	0.197	0.115	0.000	0.042	0.033	0.000	0.000
2006	0.005	0.051	0.034	1.514	0.018	0.333	0.147	0.416	1.258	0.113	0.024	0.000	0.000	0.032	0.000
2007	0.000	0.216	0.459	0.178	2.193	0.078	0.030	0.232	0.154	0.807	0.000	0.046	0.000	0.000	0.000
2008	0.000	0.000	0.214	0.126	0.000	1.570	0.000	0.267	0.167	0.171	0.561	0.000	0.070	0.000	0.000
2009	0.031	0.040	0.039	0.144	0.007	0.038	0.530	0.000	0.071	0.000	0.041	0.214	0.000	0.000	0.000
2010	0.051	0.022	0.036	0.106	0.297	0.680	0.209	0.775	0.000	0.043	0.000	0.052	0.281	0.000	0.000
2011	0.012	0.296	0.523	0.217	0.123	1.055	0.266	0.143	1.279	0.000	0.104	0.000	0.000	0.126	0.000
2012	0.073	0.132	2.436	0.019	0.000	0.038	0.045	0.062	0.000	0.076	0.000	0.000	0.000	0.000	0.000
2013	1.429	1.627	1.280	7.043	0.577	0.259	0.117	0.057	0.000	0.000	0.181	0.000	0.000	0.000	0.000

Table A.66. Northeast Fisheries Science Center (NEFSC) fall survey biomass indices-at-age (weight/tow) from 1963 to 2013 for Gulf of Maine haddock. For the FSV Bigelow series (2009-present), indices have been converted to RV Albatross IV equivalents and stations selected using the TOGA tow selection criteria. *Note that biomass indices are not used in the current assessment.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
1963	0.997	3.025	1.418	3.936	12.441	11.214	4.862	4.428	3.738	2.375	1.574	0.000	0.000	0.690	0.000
1964	0.004	1.322	1.134	0.719	1.905	4.854	4.281	3.376	0.000	0.792	0.000	0.000	0.000	0.000	0.000
1965	0.010	0.118	2.985	4.535	0.542	2.920	3.413	2.100	0.875	0.241	0.000	0.000	0.000	0.000	0.000
1966	0.002	0.053	0.255	5.847	3.025	0.653	1.851	1.129	0.247	0.041	0.000	0.000	0.000	0.000	0.000
1967	0.000	0.000	0.000	1.518	10.124	2.887	1.196	0.230	0.722	0.195	0.000	0.000	0.000	0.000	0.000
1968	0.000	0.000	0.000	0.000	0.371	11.415	3.207	0.733	1.176	0.405	0.000	0.000	0.000	0.000	0.000
1969	0.000	0.000	0.000	0.071	0.040	0.060	8.750	2.988	0.473	0.034	0.080	0.000	0.000	0.000	0.225
1970	0.000	0.011	0.000	0.000	0.000	0.215	0.335	4.803	1.942	0.000	0.049	0.000	0.000	0.000	0.000
1971	0.004	0.000	0.000	0.000	0.021	0.000	0.557	1.322	5.517	0.609	0.129	0.000	0.000	0.000	0.000
1972	0.000	0.320	0.000	0.000	0.000	0.100	0.000	0.000	0.000	1.477	0.765	0.387	0.000	0.000	0.000
1973	0.027	0.004	0.667	0.000	0.883	0.071	0.000	0.220	0.018	0.491	4.841	0.740	0.000	0.118	0.511
1974	0.000	0.484	0.160	0.836	0.193	0.000	0.000	0.000	0.000	0.000	0.000	1.472	0.000	0.000	0.202
1975	0.020	0.076	1.670	1.024	3.413	0.000	0.277	0.109	0.000	0.000	0.239	0.243	1.315	0.233	0.000
1976	0.056	0.814	0.131	2.547	0.449	3.162	0.000	0.853	0.000	0.000	0.000	0.000	0.030	0.000	0.000
1977	0.008	0.902	3.273	0.237	2.613	0.375	0.961	0.000	0.000	0.000	0.000	0.064	0.000	0.323	0.000
1978	0.005	0.029	1.139	10.821	0.483	2.775	5.050	0.729	0.000	0.000	0.000	0.000	0.271	0.000	0.358
1979	0.023	0.136	0.125	2.043	8.674	1.946	1.938	0.597	0.000	0.000	0.000	0.088	0.000	0.000	0.000
1980	0.133	0.175	0.339	0.000	0.800	3.752	2.624	0.721	0.609	0.684	0.000	0.000	0.000	0.000	0.000
1981	0.000	0.169	0.358	1.653	0.882	2.399	3.167	0.667	1.580	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.008	0.012	0.551	1.318	0.906	0.134	0.000	0.386	0.447	0.000	0.403	0.000	0.000	0.000	0.000
1983	0.002	0.113	0.039	1.119	1.046	1.049	0.668	0.460	0.724	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.059	0.375	0.000	0.798	0.000	1.615	0.000	0.202	0.845	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.031	0.355	3.198	0.024	0.417	0.322	1.454	0.000	0.000	0.348	0.000	0.000	0.000	0.000
1986	0.000	0.008	0.000	0.097	0.666	0.309	0.044	0.000	0.267	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.001	0.000	0.170	0.164	0.190	0.146	0.803	0.597	0.000	0.575	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.119	0.060	0.294	0.000	0.310	0.693	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.015	0.067	0.035	0.032	0.278	0.113	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.007	0.000	0.120	0.000	0.000	0.000	0.162	0.143	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.002	0.018	0.000	0.000	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.001	0.053	0.000	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.002	0.141	0.192	0.040	0.059	0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.003	0.009	0.000	0.000	0.000	0.000	0.000	0.106	0.000	0.000	0.000	0.101	0.000	0.000	0.000
1995	0.000	0.024	0.464	0.255	0.068	0.121	0.000	0.000	0.000	0.000	0.000	0.000	0.166	0.000	0.000
1996	0.002	0.052	0.141	1.197	1.129	0.135	0.322	0.220	0.100	0.000	0.137	0.000	0.000	0.110	0.000
1997	0.003	0.305	0.020	0.406	1.185	0.223	0.283	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.030	0.064	0.386	0.245	1.033	0.655	0.205	0.214	0.087	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.017	0.738	0.389	1.047	0.435	0.775	0.985	0.232	0.123	0.060	0.110	0.000	0.000	0.000	0.000
2000	0.012	0.167	6.903	1.860	2.049	0.987	1.323	0.569	0.163	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.003	0.035	1.882	5.298	1.016	1.616	0.682	0.531	0.804	0.114	0.000	0.000	0.000	0.000	0.000
2002	0.001	0.027	0.006	0.467	2.855	0.562	0.326	0.000	0.463	0.051	0.000	0.078	0.000	0.000	0.000
2003	0.021	0.000	0.177	0.086	0.635	3.473	0.546	0.072	0.000	0.284	0.065	0.000	0.000	0.000	0.000
2004	0.001	0.069	0.015	0.427	0.330	1.015	4.598	0.263	0.224	0.000	0.056	0.171	0.000	0.000	0.000
2005	0.006	0.009	0.720	0.037	0.120	0.356	0.575	1.723	0.197	0.115	0.000	0.042	0.033	0.000	0.000
2006	0.005	0.051	0.034	1.514	0.018	0.333	0.147	0.416	1.258	0.113	0.024	0.000	0.000	0.032	0.000
2007	0.000	0.216	0.459	0.178	2.193	0.078	0.030	0.232	0.154	0.807	0.000	0.046	0.000	0.000	0.000
2008	0.000	0.000	0.214	0.126	0.000	1.570	0.000	0.267	0.167	0.171	0.561	0.000	0.070	0.000	0.000
2009	0.033	0.046	0.044	0.157	0.007	0.040	0.536	0.000	0.085	0.000	0.041	0.214	0.000	0.000	0.000
2010	0.085	0.005	0.010	0.037	0.205	0.345	0.111	0.333	0.000	0.000	0.000	0.047	0.162	0.000	0.000
2011	0.013	0.296	0.523	0.217	0.123	1.055	0.266	0.143	1.279	0.000	0.104	0.000	0.000	0.126	0.000
2012	0.073	0.132	2.436	0.019	0.000	0.038	0.045	0.062	0.000	0.076	0.000	0.000	0.000	0.000	0.000
2013	1.429	1.627	1.280	7.043	0.577	0.259	0.117	0.057	0.000	0.000	0.181	0.000	0.000	0.000	0.000

Table A.67. Uncalibrated Northeast Fisheries Science Center (NEFSC) FSV Bigelow fall survey biomass indices-at-age (weight/tow) from 2009 to 2013 for Gulf of Maine haddock. Stations were selected using the TOGA tow selection criteria. *Note that biomass indices are not used in the current assessment.*

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14+
2009	0.094	0.098	0.072	0.214	0.011	0.053	0.620	0.000	0.094	0.000	0.043	0.243	0.000	0.000	0.000
2010	0.182	0.012	0.062	0.225	0.491	0.952	0.348	0.686	0.000	0.000	0.000	0.063	0.289	0.000	0.000
2011	0.034	0.558	0.773	0.270	0.140	1.258	0.327	0.190	1.441	0.000	0.111	0.000	0.000	0.148	0.000
2012	0.177	0.262	3.591	0.020	0.000	0.041	0.048	0.067	0.000	0.082	0.000	0.000	0.000	0.000	0.000
2013	3.366	3.031	1.823	8.470	0.617	0.319	0.127	0.055	0.000	0.000	0.178	0.000	0.000	0.000	0.000

Table A.68. Ratio of NEFSC spring and fall survey proportions-at-age to fishery proportion-at-age for ages 6 to age 9^+. Cells shaded grey indicate where the survey proportions-at-age were greater than the proportions observed in the fishery. Unshaded cells indicate where the fishery proportions-at-age were greater relative to the survey. Missing values indicate either where no information was available from the survey (no fish age 6^+) or the fishery proportions at age were zero.

Year	NEFSC spring/fishery compare				NEFSC fall/fishery compare			
	Age6	Age7	Age8	Age9+	Age6	Age7	Age8	Age9+
1977	1.01			0.00	0.75			20.93
1978					0.89	1.89		3.52
1979	0.76	1.13	2.67		1.19	0.74	0.00	
1980	0.83	0.00	0.00	6.74	1.25	0.53	1.31	1.02
1981	0.90	0.81	0.84	4.40	0.93	0.84	1.67	0.00
1982	1.12	1.05	0.57	0.81	0.00	0.67	2.99	4.22
1983	0.00	2.01	0.73	0.91	2.52	0.57	1.00	0.00
1984	0.00	0.00	9.87	0.00	1.10	0.00	0.51	1.40
1985	1.77	0.67	1.36	0.00	0.74	1.35	0.00	1.04
1986	0.77	2.03	0.54	0.00	0.65	0.00	2.37	0.00
1987					2.08	0.74	0.00	1.71
1988	0.00	0.00	5.48	0.00	0.00	3.88	3.51	0.00
1989	1.70	0.00	0.00	0.00	1.08	0.98	0.00	0.00
1990					0.00	1.19	4.04	
1991								
1992								
1993	1.68	0.00	0.00	0.00				
1994					0.00	1.53	0.00	12.28
1995	0.00	0.00	4.21	0.00	0.00	0.00	0.00	6.03
1996					1.71	0.61	0.40	3.82
1997	1.63	0.00	0.00	0.00	1.63	0.00	0.00	0.00
1998					0.80	1.69	1.71	0.00
1999	1.74	0.00	0.00	0.00	1.12	0.66	1.24	1.48
2000	0.50	2.69	0.00	0.00	1.33	0.90	0.69	0.00
2001	1.27	0.51	0.60	2.33	0.96	0.66	2.01	0.59
2002	0.81	2.27	1.69	0.00	0.84	0.00	1.97	0.72
2003	1.35	1.16	0.99	0.42	1.66	0.36	0.00	1.02
2004	1.19	0.59	0.00	0.28	1.14	0.38	0.83	0.41
2005	2.52	0.75	0.00	0.64	1.36	0.99	0.76	0.58
2006	0.19	1.71	1.05	0.67	0.66	1.54	1.02	0.53
2007	1.11	1.43	0.69	1.01	0.18	2.57	0.89	0.96
2008	0.00	0.51	1.42	1.06	0.00	1.63	1.65	0.82
2009	1.22	0.00	0.28	0.76	1.05	0.00	1.43	0.84
2010	0.96	0.97	0.00	1.10	5.57	0.78	0.00	0.86
2011	2.79	0.00	0.68	0.89	1.29	2.29	1.14	0.35
2012	1.27	1.17	1.65	0.83	1.60	2.85	0.00	0.53
2013	1.43	1.38	1.42	0.59	7.68	0.53	0.00	0.82
Cells ≥ 1	**16**	**11**	**10**	**6**	**18**	**11**	**14**	**12**
Total	**29**	**28**	**28**	**28**	**34**	**33**	**32**	**32**
Fraction ≥ 1	**0.55**	**0.39**	**0.36**	**0.21**	**0.53**	**0.33**	**0.44**	**0.38**

Table A.69. Massachusetts Department of Marine Fisheries (MADMF) spring and fall survey indices and coefficients of variation (CV, italicized values in parentheses) from 1978 to 2013 for Gulf of Maine haddock.

Year	Abundance (numbers/tow)				Biomass (kg/tow)			
	Spring		Fall		Spring		Fall	
1978	0.536	*(0.36)*	0.029	*(0.89)*	0.291	*(0.37)*	0.000	*(0.85)*
1979	0.038	*(0.56)*	13.811	*(0.18)*	0.033	*(0.69)*	0.100	*(0.19)*
1980	2.305	*(0.31)*	10.747	*(0.25)*	0.284	*(0.35)*	0.318	*(0.28)*
1981	2.372	*(0.3)*	0.950	*(0.54)*	0.333	*(0.33)*	0.253	*(0.62)*
1982	0.042	*(0.75)*	25.608	*(0.43)*	0.005	*(0.73)*	0.256	*(0.43)*
1983	2.193	*(0.22)*	0.498	*(0.39)*	0.286	*(0.37)*	0.011	*(0.38)*
1984	0.267	*(0.62)*	0.000		0.221	*(0.66)*	0.000	
1985	0.177	*(0.72)*	0.000		0.136	*(0.71)*	0.000	
1986	0.000		0.172	*(0.58)*	0.000		0.000	*(0.61)*
1987	0.017	*(0.9)*	0.756	*(0.31)*	0.002	*(0.9)*	0.004	*(0.25)*
1988	0.021	*(0.87)*	0.105	*(0.72)*	0.041	*(0.86)*	0.000	*(0.71)*
1989	0.043	*(0.87)*	0.014	*(0.87)*	0.010	*(0.85)*	0.003	*(0.88)*
1990	0.000		0.100	*(0.71)*	0.000		0.001	*(0.71)*
1991	0.000		0.068	*(0.62)*	0.000		0.002	*(0.82)*
1992	0.016	*(0.79)*	0.182	*(0.53)*	0.001	*(0.83)*	0.003	*(0.49)*
1993	0.000		0.705	*(0.36)*	0.000		0.007	*(0.38)*
1994	0.025	*(0.72)*	0.244	*(0.42)*	0.002	*(0.7)*	0.022	*(0.69)*
1995	0.172	*(0.57)*	0.158	*(0.36)*	0.007	*(0.54)*	0.006	*(0.45)*
1996	0.000		1.692	*(0.33)*	0.000		0.026	*(0.4)*
1997	0.153	*(0.49)*	0.323	*(0.33)*	0.006	*(0.45)*	0.007	*(0.71)*
1998	0.054	*(0.55)*	9.052	*(0.28)*	0.001	*(0.65)*	0.108	*(0.28)*
1999	0.895	*(0.46)*	1.829	*(0.56)*	0.086	*(0.46)*	0.083	*(0.36)*
2000	0.290	*(0.36)*	0.135	*(0.57)*	0.052	*(0.37)*	0.017	*(0.54)*
2001	0.000		0.951	*(0.62)*	0.000		0.025	*(0.63)*
2002	0.516	*(0.15)*	0.034	*(0.87)*	0.483	*(0.22)*	0.003	*(0.9)*
2003	0.406	*(0.55)*	0.818	*(0.52)*	0.583	*(0.51)*	0.056	*(0.55)*
2004	0.354	*(0.16)*	0.507	*(0.43)*	0.580	*(0.17)*	0.224	*(0.58)*
2005	2.449	*(0.55)*	0.515	*(0.29)*	3.591	*(0.55)*	0.015	*(0.46)*
2006	1.263	*(0.32)*	0.046	*(0.56)*	1.501	*(0.4)*	0.026	*(0.63)*
2007	0.728	*(0.48)*	0.205	*(0.44)*	1.088	*(0.43)*	0.114	*(0.69)*
2008	0.358	*(0.49)*	0.984	*(0.68)*	0.558	*(0.52)*	1.372	*(0.65)*
2009	0.230	*(0.48)*	0.185	*(0.32)*	0.371	*(0.47)*	0.060	*(0.51)*
2010	0.131	*(0.49)*	1.172	*(0.28)*	0.196	*(0.49)*	0.223	*(0.68)*
2011	0.090	*(0.61)*	6.676	*(0.55)*	0.012	*(0.67)*	0.915	*(0.76)*
2012	0.000		0.337	*(0.56)*	0.000		0.005	*(0.63)*
2013	0.159	*(0.5)*	6.191	*(0.33)*	0.013	*(0.53)*	0.134	*(0.31)*
Avg	**0.453**	***(0.52)***	**2.383**	***(0.49)***	**0.299**	***(0.54)***	**0.122**	***(0.56)***
Min	**0.000**	***(0.15)***	**0.000**	***(0.18)***	**0.000**	***(0.17)***	**0.000**	***(0.19)***
Max	**2.449**	***(0.9)***	**25.608**	***(0.89)***	**3.591**	***(0.9)***	**1.372**	***(0.9)***

Table A.70. Massachusetts Department of Marine Fisheries (MADMF) spring survey abundance indices-at-age (numbers/tow) from 1978 to 2013 for Gulf of Maine haddock.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14
1978	0.000	0.000	0.450	0.086	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	0.000	0.013	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	0.386	1.842	0.000	0.014	0.025	0.039	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.000	2.175	0.108	0.058	0.028	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	0.000	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1983	0.051	1.983	0.073	0.057	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.029	0.081	0.081	0.056	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.177	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.000	0.000	0.000	0.000	0.000	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.021	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.000	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.000	0.172	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.000	0.153	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	0.030	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	0.000	0.895	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.000	0.178	0.070	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.000	0.160	0.005	0.072	0.194	0.055	0.012	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.000	0.000	0.000	0.009	0.005	0.348	0.030	0.011	0.000	0.000	0.004	0.000	0.000	0.000	0.000
2004	0.000	0.029	0.000	0.000	0.000	0.005	0.321	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.000	0.000	0.074	0.081	0.206	0.508	1.420	0.000	0.160	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.184	0.000	0.172	0.073	0.117	0.020	0.139	0.519	0.039	0.000	0.000	0.000	0.000	0.000
2007	0.000	0.017	0.000	0.011	0.191	0.000	0.084	0.155	0.095	0.167	0.000	0.009	0.000	0.000	0.000
2008	0.000	0.025	0.000	0.009	0.000	0.167	0.000	0.023	0.021	0.019	0.070	0.025	0.000	0.000	0.000
2009	0.000	0.021	0.000	0.000	0.019	0.022	0.099	0.004	0.011	0.007	0.016	0.030	0.000	0.000	0.000
2010	0.000	0.026	0.000	0.017	0.000	0.000	0.000	0.066	0.000	0.000	0.009	0.000	0.009	0.000	0.004
2011	0.000	0.090	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2012	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2013	0.000	0.159	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A.71. Massachusetts Department of Marine Fisheries (MADMF) fall survey abundance indices-at-age (numbers/tow) from 1978 to 2013 for Gulf of Maine haddock.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12	Age13	Age14
1978	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1979	13.811	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1980	9.815	0.932	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1981	0.068	0.373	0.509	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1982	25.608	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1983	0.444	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1984	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1985	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1986	0.172	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1987	0.756	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1988	0.105	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1989	0.000	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1990	0.100	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1991	0.050	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1992	0.182	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1993	0.705	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1994	0.124	0.120	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1995	0.123	0.034	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1996	1.692	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1997	0.270	0.053	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1998	8.966	0.086	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1999	1.554	0.275	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2000	0.012	0.123	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	0.878	0.074	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.017	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	0.793	0.000	0.000	0.000	0.004	0.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.090	0.319	0.000	0.000	0.000	0.010	0.079	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.424	0.074	0.017	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2006	0.000	0.021	0.000	0.020	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000
2007	0.106	0.025	0.000	0.000	0.031	0.006	0.000	0.000	0.010	0.027	0.000	0.000	0.000	0.000	0.000
2008	0.000	0.000	0.049	0.041	0.000	0.549	0.000	0.045	0.094	0.033	0.148	0.000	0.025	0.000	0.000
2009	0.084	0.076	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2010	1.049	0.000	0.000	0.000	0.000	0.057	0.010	0.032	0.000	0.000	0.000	0.012	0.012	0.000	0.000
2011	2.242	4.433	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2012	0.337	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2013	6.171	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A.72. Maine-New Hampshire (MENH) inshore groundfish survey Gulf of Maine haddock indices and coefficients of variation (CV) from 2000 to 2013. *Note that the spring survey did not begin until 2001.*

Year	Abundance (numbers/tow)				Biomass (kg/tow)			
	Spring	***CV***	**Fall**	***CV***	**Spring**	***CV***	**Fall**	***CV***
2000			4.12	*0.71*			0.71	*1.74*
2001	0.02	*2.00*	3.14	*1.02*	0.00	*2.00*	0.15	*1.06*
2002	4.33	*0.71*	0.29	*0.92*	1.20	*0.58*	0.02	*1.23*
2003	0.70	*0.92*	5.94	*0.94*	0.49	*1.04*	0.55	*0.73*
2004	1.67	*0.71*	2.65	*0.71*	0.26	*0.60*	0.21	*0.80*
2005	0.77	*0.66*	5.75	*0.18*	0.37	*0.71*	0.76	*1.34*
2006	1.58	*1.47*	1.18	*1.27*	0.33	*0.81*	0.43	*2.22*
2007	0.63	*0.50*	0.44	*1.08*	0.38	*0.66*	0.02	*0.53*
2008	0.43	*0.75*	0.68	*0.59*	0.40	*0.75*	0.02	*0.53*
2009	0.61	*0.60*	3.99	*0.67*	0.10	*0.70*	0.17	*0.56*
2010	0.85	*0.69*	10.86	*0.64*	0.19	*0.71*	0.46	*0.68*
2011	6.54	*1.00*	8.02	*0.78*	0.52	*0.88*	0.30	*0.71*
2012	6.56	*2.18*	12.65	*0.67*	0.65	*2.29*	0.78	*0.68*
2013	1.88	*0.41*	24.44	*0.46*	0.26	*0.60*	1.37	*0.57*

Table A.73. Summary of Gulf of Maine haddock age and maturity samples (individual fish) taken by the Maine-New Hampshire (MENH) inshore groundfish survey from 2000 to 2013. *Note that the spring survey did not begin until 2001, though no maturity samples were collected in this first year.*

Season	Year	Maturity	Ages
Fall	2000		
	2001		
	2002		
	2003		
	2004		
	2005	30	6
	2006	53	38
	2007	2	2
	2008	7	5
	2009	3	3
	2010	122	52
	2011	121	54
	2012	203	85
	2013	287	117
Spring	2001		
	2002	100	
	2003	50	
	2004	33	
	2005	40	
	2006	77	
	2007	61	
	2008	37	
	2009	9	
	2010	58	
	2011	176	
	2012	101	
	2013	130	

Table A.74. Summary of age-length information used to construct the Maine-New Hampshire (MENH) inshore groundfish survey indices-at-age for Gulf of Maine haddock. *Note that in spring 2001, only a single 3 cm fish was caught in the MENH survey, there was no corresponding age information from the NEFSC spring survey for this length bin.*

Season	Year	Source ALK		Total ages
		ME/NH	NEFSC	
Fall	2000		80	80
	2001		65	65
	2002		2	2
	2003		67	67
	2004		20	20
	2005	6	81	87
	2006	35	113	148
	2007	1	7	8
	2008	4		4
	2009	3	30	33
	2010	52	62	114
	2011	54	102	156
	2012	85	56	141
	2013	116	256	372
Spring	2001			
	2002		127	127
	2003		63	63
	2004		16	16
	2005		20	20
	2006		70	70
	2007		43	43
	2008		45	45
	2009		40	40
	2010		26	26
	2011		56	56
	2012		134	134
	2013		227	227

Table A.75. Maine-New Hampshire (MENH) spring survey abundance indices-at-age (numbers/tow) from 2001 to 2013 for Gulf of Maine haddock.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12
2001	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.000	3.127	0.115	0.371	0.653	0.027	0.000	0.000	0.025	0.013	0.000	0.000	0.000
2003	0.000	0.000	0.198	0.032	0.121	0.348	0.002	0.000	0.000	0.000	0.000	0.000	0.000
2004	0.000	1.493	0.013	0.064	0.000	0.018	0.083	0.000	0.000	0.000	0.000	0.000	0.000
2005	0.000	0.431	0.113	0.013	0.018	0.027	0.050	0.102	0.000	0.013	0.000	0.000	0.000
2006	0.000	1.356	0.011	0.066	0.008	0.007	0.014	0.036	0.076	0.003	0.000	0.000	0.000
2007	0.000	0.289	0.038	0.039	0.140	0.000	0.023	0.000	0.030	0.068	0.000	0.000	0.000
2008	0.000	0.165	0.039	0.016	0.013	0.115	0.000	0.017	0.002	0.003	0.049	0.010	0.000
2009	0.000	0.551	0.008	0.000	0.016	0.006	0.025	0.003	0.002	0.000	0.000	0.002	0.000
2010	0.000	0.787	0.000	0.000	0.004	0.004	0.019	0.024	0.000	0.002	0.002	0.000	0.014
2011	0.040	6.431	0.020	0.000	0.000	0.000	0.011	0.010	0.027	0.000	0.000	0.000	0.000
2012	0.010	5.742	0.794	0.008	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000
2013	0.194	1.506	0.089	0.078	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.000	0.000

Table A.76. Maine-New Hampshire (MENH) fall survey abundance indices-at-age (numbers/tow) from 2000 to 2013 for Gulf of Maine haddock.

Year	Age0	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9	Age10	Age11	Age12
2000	2.499	1.211	0.256	0.088	0.065	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2001	2.903	0.057	0.128	0.051	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	0.140	0.145	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2003	5.640	0.065	0.016	0.003	0.020	0.172	0.020	0.003	0.000	0.005	0.000	0.000	0.000
2004	1.622	1.008	0.000	0.000	0.000	0.009	0.015	0.000	0.000	0.000	0.000	0.000	0.000
2005	5.182	0.000	0.236	0.012	0.016	0.059	0.075	0.143	0.004	0.020	0.000	0.000	0.000
2006	0.553	0.095	0.026	0.424	0.008	0.008	0.004	0.015	0.045	0.000	0.000	0.000	0.000
2007	0.356	0.079	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2008	0.679	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2009	3.959	0.029	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2010	10.846	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2011	7.708	0.315	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2012	12.178	0.453	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2013	22.848	1.526	0.054	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table A.77. Summary of the Gulf of Maine haddock ADAPT-VPA model formulations used to build a 'bridge' from the GARM III ADAPT-VPA model to the SAW/SARC 59 update. *The (+1) notation indicates that the survey index was lagged forward a year and an age in the model (e.g., age-1 in 1981 becomes age-2 in 1982).*

Model	Type	Version	Model description	Years	Catch	Plus group handling	Partial recruitment	Survey input style	Survey Indices		
										NEFSC	
									Tow evaluation	Spring	Fall
1	VPA	v3.1.0	AOP 2012	1977-2010	Commercial catch, recreational landings (no discards)	Backward calculation	N/A	Age-specific indices	SHG	$1\text{-}6^{+}$	$1\text{-}8^{+}$ (+1)
2	VPA	v.3.4.5	Software update to v3.4.4	1977-2010	Commercial catch, recreational landings (no discards)	Backward calculation	N/A	Age-specific indices	SHG	$1\text{-}6^{+}$	1-8+ (+1)
3	VPA	v.3.4.5	Combined method	1977-2010	Commercial catch, recreational landings (no discards)	Combined method	N/A	Age-specific indices	SHG	$1\text{-}6^{+}$	1-8+ (+1)
4	VPA	v.3.4.5	Fully updated catch info (except recrecreatioal discards), catch WAA matrix updated assuming 0% recreational discard mortality	1977-2010	Commercial catch, recreational landings (no discards)	Combined method	N/A	Age-specific indices	SHG	$1\text{-}6^{+}$	1-8+ (+1)
5	VPA	v.3.4.5	Recreational discards added to catch, catch and stock WAA updated	1977-2010	Commercial catch, recreational catch	Combined method	N/A	Age-specific indices	SHG	$1\text{-}6^{+}$	1-8+ (+1)
6	VPA	v.3.4.5	Add 2011-2013 catch data, update surveys indices (1977-2013)	1977-2013	Commercial catch, recreational catch	Combined method	N/A	Age-specific indices	SHG	$1\text{-}6^{+}$	1-8+ (+1)

Table A.78. Summary of the Gulf of Maine haddock ADAPT-VPA model formulations used to build a 'bridge' from the GARM III ADAPT-VPA model to the SAW/SARC 59 update. Differences in model formulations are summarized in Table A.77.

Model		**1**	**2**	**3**	**4**	**5**	**6**
Model description		**AOP 2012**	**Software update**	**Combined method**	**Updated catch**	**Recreational discard**	**2013 update**
Mean squared residual		1.29	1.29	1.28	1.49	1.48	1.44
CVs on t+1 population numbers	Age2	0.67	0.67	0.66	0.72	0.71	0.86
	Age3	0.52	0.52	0.52	0.56	0.57	0.62
	Age4	0.53	0.53	0.53	0.57	0.60	0.52
	Age5	0.42	0.42	0.42	0.43	0.44	0.50
	Age6	0.47	0.47	0.50	0.47	0.48	0.50
	Age7	0.54	0.54	0.58	0.55	0.56	0.53
	Age8	0.90	0.90	0.71	0.64	0.69	0.88
	Age 9^+	1.14	1.14				
Terminal estimates	$F_{6\text{-}8,\ 2010}$	0.82	0.82	0.58	0.37	0.42	0.36
	$F_{6\text{-}8,\ 2013}$						0.82
	SSB_{2010} (mt)	2,868	2,868	3,146	3,631	3,230	3,070
	SSB_{2013} (mt)						6,135
Retro (Mohns Rho) *7 year 'peels'	F6-8	0.98	0.98	0.70	0.66	0.65	0.52
	SSB	-0.22	-0.22	-0.06	-0.03	-0.04	-0.03
	Recruits (Age1)	4.71	4.71	4.47	3.49	3.08	0.55

Table A.79. Summary of the ASAP model sensitivity runs and location of the run descriptions within this report.

Report location	Order	ASAP sensitivity runs
TOR 4	1	NEFSC fall BTS q-profile
TOR 4	2	Swept area determination (wing vs. door)
Appendix 2	1	Profiling over a range of natural mortality assumptions
Appendix 2	2	SHG/TOGA tow evaluation criteria
Appendix 2	3	Abundance vs. biomass survey indices
Appendix 2	4	Treatment of the Bigelow survey years as independent survey ind
Appendix 2	5	Model performance when tuned to NEFSC survey indices alone
Appendix 2	6	Inclusion of state surveys (MADMF, MENH)
Appendix 2	7	Inclusion of commercial and recreational LPUE indices
Appendix 2	8	Recreational discard mortality
Appendix 2	9	Explicit treatment of catch fleets (commercial, recreational)
Appendix 2	10	Assessment model starting point (1956, 1963)
Appendix 2	11	Selectivity blocks (number, location, selectivity form, etc.)
Appendix 2	12	Catch precision assumptions
Appendix 2	13	Terminal recruitment (handling of recruitment deviations)

Table A.80. Summary diagnostics and results from the base Gulf of Maine haddock ASAP model (ASAP_BASE).

Model		**ASAP_BASE**
Model description		ASAP base run (SHG/TOGA)
Maximum gradient (*conv. criteria* < *1e-4*)		1.10E-05
Number of parameters		125
Objective function		2526
Components of objective function	**Recruit devs**	110
	Suvey age comps	874
	Catch age comps	644
	Index fit	702
	Catch fit	196
RMSE	**Fleet 1**	0.34
	Index 1	2.10
	Index 2	2.00
	Index total	2.05
	Recruit devs	3.91
SSB_{1977} (mt)		9,470
SSB_{2013} (mt)		4,500
$F_{mult,\,2013}$		0.31
Mohn's rho (7 year peel)	**SSB**	-0.03
	F_{mult}	0.05
	Age 1 N	0.18

Table A.81. ASAP_BASE model estimates of selectivity-at-age and corresponding coefficients of variation (CV) for the Gulf of Maine haddock fishery and NEFSC spring and fall surveys.

Block/Index		Selectivity	CV
Fleet block 1 (1977-1988)	1	0.00	0.61
	2	0.22	0.12
	3	0.39	0.11
	4	0.64	0.10
	5	0.65	0.11
	6	0.77	0.12
	7	1.00	
	8	1.00	0.00
	9^+	1.00	0.00
Fleet block 2 (1989-2004)	1	0.01	0.27
	2	0.06	0.16
	3	0.34	0.14
	4	0.55	0.14
	5	0.72	0.14
	6	0.96	0.14
	7	1.00	
	8	0.94	0.21
	9^+	0.67	0.30
Fleet block 3 (2005-2013)	1	0.01	0.42
	2	0.06	0.21
	3	0.22	0.17
	4	0.31	0.17
	5	0.56	0.15
	6	0.77	0.15
	7	1.00	
	8	1.00	0.00
	9^+	0.74	0.19
NEFSC spring	1	0.74	0.13
	2	0.62	0.14
	3	0.79	0.14
	4	1.00	0.00
	5	0.87	0.17
	6	1.00	
	7	0.82	0.25
	8	0.75	0.34
	9^+	0.76	0.30
NEFSC fall	1	0.28	0.14
	2	0.35	0.14
	3	0.60	0.13
	4	0.62	0.14
	5	0.76	0.15
	6	1.00	
	7	1.00	0.00
	8	1.00	0.00
	9^+	0.66	0.25

Table A.82. Comparison of the summary diagnostics from the ASAP base model (ASAP_BASE) which uses survey minimum area swept indices assumption a wing spread footprint of 0.012 nm^2 to a sensitivity run (ASAP_DOOR_SPREAD) assuming a door spread footprint of 0.023 nm^2.

Model		**ASAP_BASE**	**ASAP_DOOR_SPREAD**
Model description		Min area swept indices based on wing spread	Min area swept indices based on door spread
Maximum gradient (*conv. criteria < 1e-4*)		1.10E-05	8.20E-05
Number of parameters		125	125
Objective function		2526	2472
Components of objective function	**Recruit devs**	110	110
	Suvey age comps	874	873
	Catch age comps	644	644
	Index fit	702	648
	Catch fit	196	196
RMSE	**Fleet 1**	0.34	0.34
	Index 1	2.10	2.10
	Index 2	2.00	2.00
	Index total	2.05	2.05
	Recruit devs	3.91	3.91
SSB_{1977} (mt)		9,470	9,469
SSB_{2013} (mt)		4,500	4,500
$F_{mult, 2013}$		0.31	0.31
Mohn's rho (7 year peel)	**SSB**	-0.03	-0.03
	F_{mult}	0.05	0.05
	Age 1 N	0.18	0.18
Survey q	**NEFSC spring**	0.26	0.13
	NEFSC fall	0.99	0.48

Table A.83. Comparison of the summary diagnostics from the ASAP base model (ASAP_BASE) and the various intermediate models used to build the bridge to the ASAP_final_temp6 model.

Model		ASAP_BASE	ASAP_final_temp1	ASAP_final_temp2	ASAP_final_temp3	ASAP_final_temp4	ASAP_final_temp5	ASAP_final_temp6
Description			Modified RecDevs (lambda=1, CV=2.0)	Increased catch CVs (0.1-0.2)	Survey CV adjustments (spring+0.3, fall+0.2)	ESS adjustments to catch and surveys	Selectivity-at-age adjustments	Minor selectivity-at-age adjustments
Maximum gradient (*conv. criteria < 1e-4*)		1.10E-05	7.90E-05	2.90E-05	8.90E-05	5.20E-05	6.80E-05	4.50E-05
Number of parameters		125	125	125	125	125	125	123
Objective function		2526	2705	2728	2690	2389	2386	2386
Components of objective function	Recruit devs	110	332	332	328	328	327	327
	Suvey age comps	874	871	870	869	666	667	667
	Catch age comps	644	640	636	633	539	538	538
	Index fit	702	666	660	633	630	630	630
	Catch fit	196	196	231	227	225	225	225
RMSE	Fleet 1	0.34	0.33	0.65	0.48	0.36	0.36	0.36
	Index 1	2.10	1.91	1.87	1.21	1.18	1.18	1.18
	Index 2	2.00	1.68	1.63	1.17	1.13	1.12	1.12
	Index total	2.05	1.80	1.75	1.19	1.16	1.15	1.15
	Recruit devs	3.91	1.05	1.05	1.01	1.04	1.04	1.04
SSB_{1977} (mt)		9,470	9,476	9,452	9,033	9,634	9,566	9,566
SSB_{2013} (mt)		4,500	6,831	6,681	5,131	4,837	4,671	4,671
$F_{mult, 2013}$		0.31	0.23	0.24	0.31	0.31	0.35	0.35
1998 YC Age-1 (000s)		13,733	13,662	13,431	13,175	14,248	13,900	13,900
2010 YC Age-1 (000s)		5,942	11,150	10,990	8,383	7,465	7,358	7,358
2012 YC Age-1 (000s)		3,998	34,043	33,467	17,954	21,911	21,530	21,530
Mohn's rho (7 year peel)	SSB	-0.03	-0.14	-0.15	-0.21	-0.18	-0.19	-0.19
	F_{mult}	0.05	0.20	0.23	0.38	0.26	0.31	0.31
	Age 1 N	0.18	-0.19	-0.20	-0.24	-0.27	-0.27	-0.27

Table A.84. Comparison of the fleet and index selectivity parameters and the corresponding coefficients of variation (CV) from the Gulf of Maine haddock ASAP_BASE, ASAP_final_temp6, ASAP_temp10 and ASAP_temp11 models.

Block/index	Age	ASAP_BASE		ASAP_final_temp6		ASAP_final_temp10		ASAP_final_temp11	
		Selectivity	CV	Selectivity	CV	Selectivity	CV	Selectivity	CV
Fleet block 1 (1977-1988)	1	0.00	0.61	0.00	0.72	0.00	0.72	0.00	0.72
	2	0.22	0.12	0.20	0.18	0.20	0.18	0.20	0.18
	3	0.39	0.11	0.35	0.17	0.34	0.17	0.34	0.17
	4	0.64	0.10	0.57	0.17	0.56	0.16	0.56	0.16
	5	0.65	0.11	0.55	0.18	0.54	0.17	0.54	0.17
	6	0.77	0.12	0.63	0.19	0.62	0.18	0.62	0.18
	7	1.00		0.75	0.21	0.75	0.21	0.75	0.21
	8	1.00	0.00	1.00		1.00		1.00	
	9^+	1.00	0.00	1.00		1.00		1.00	
Fleet block 2 (1989-2004)	1	0.01	0.27	0.00	0.37	0.00	0.36	0.00	0.36
	2	0.06	0.16	0.04	0.23	0.04	0.22	0.04	0.22
	3	0.34	0.14	0.22	0.21	0.21	0.19	0.21	0.19
	4	0.55	0.14	0.39	0.20	0.37	0.19	0.37	0.19
	5	0.72	0.14	0.57	0.20	0.53	0.19	0.53	0.19
	6	0.96	0.14	0.81	0.19	0.77	0.18	0.77	0.18
	7	1.00		0.88	0.21	0.84	0.21	0.84	0.21
	8	0.94	0.21	1.00		1.00		1.00	
	9^+	0.67	0.30	1.00		1.00		1.00	
Fleet block 3 (2005-2013)	1	0.01	0.42	0.00	0.37	0.00	0.36	0.01	0.34
	2	0.06	0.21	0.05	0.19	0.05	0.19	0.05	0.19
	3	0.22	0.17	0.19	0.15	0.19	0.14	0.19	0.14
	4	0.31	0.17	0.30	0.15	0.30	0.15	0.30	0.15
	5	0.56	0.15	0.53	0.14	0.52	0.13	0.52	0.13
	6	0.77	0.15	0.71	0.13	0.69	0.13	0.69	0.13
	7	1.00		0.83	0.12	0.82	0.12	0.82	0.12
	8	1.00	0.00	1.00		1.00		1.00	
	9^+	0.74	0.19	0.75	0.18	0.83	0.16	0.83	0.16
NEFSC spring	1	0.74	0.13	0.67	0.15	0.74	0.13	0.78	0.13
	2	0.62	0.14	0.68	0.15	0.74	0.14	0.75	0.14
	3	0.79	0.14	0.89	0.15	0.96	0.14	0.95	0.14
	4	1.00	0.00	1.00		1.00		1.00	
	5	0.87	0.17	0.73	0.20	1.00		1.00	
	6	1.00		1.00	0.01	1.00		1.00	
	7	0.82	0.25	0.99	0.23	1.00		1.00	
	8	0.75	0.34	0.82	0.31	1.00		1.00	
	9^+	0.76	0.30	0.90	0.27	1.00		1.00	
NEFSC fall	1	0.28	0.14	0.23	0.25	0.29	0.15	0.29	0.15
	2	0.35	0.14	0.36	0.24	0.45	0.15	0.45	0.14
	3	0.60	0.13	0.51	0.24	0.64	0.14	0.64	0.14
	4	0.62	0.14	0.56	0.24	0.71	0.15	0.71	0.15
	5	0.76	0.15	0.75	0.24	0.94	0.15	0.94	0.15
	6	1.00		0.84	0.25	1.00		1.00	
	7	1.00	0.00	0.71	0.27	1.00		1.00	
	8	1.00	0.00	1.00		1.00		1.00	
	9^+	0.66	0.25	0.55	0.31	1.00		1.00	

Table A.85. Comparison of the summary diagnostics from the ASAP base model (ASAP_BASE) and the ASAP_final_temp6-11 models.

Model		ASAP_BASE	ASAP_final_temp6	ASAP_final_temp7	ASAP_final_temp8	ASAP_final_temp9	ASAP_final_temp10	ASAP_final_temp11
Description			CV_{TS}=2.0	CV_{TS}=1.0	$CV_{1977-2010}$=1.0, $CV_{2011-2013}$=0.5	$CV_{1977-2012}$=1.0, CV_{2013}=0.5	CV_{TS}=1.0, selectivity adjustments from 'temp7' run	$CV_{1977-2012}$=1.0, CV_{2013}=0.5, selectivity identical to 'temp10'
Maximum gradient (*conv. criteria < 1e-4*)		1.10E-05	4.50E-05	2.60E-05	0.000418	0.000261	3.60E-05	8.90E-05
Number of parameters		125	123	123	123	123	115	115
Objective function		2526	2386	2396	2406	2404	2400	2407
Components of objective function	**Recruit devs**	110	327	334	336	336	334	336
	Suvey age comps	874	667	667	667	667	670	671
	Catch age comps	644	538	538	538	538	539	539
	Index fit	702	630	632	639	637	632	636
	Catch fit	196	225	225	226	226	226	226
RMSE	**Fleet 1**	0.34	0.36	0.37	0.38	0.38	0.38	0.39
	Index 1	2.10	1.18	1.20	1.27	1.25	1.20	1.24
	Index 2	2.00	1.12	1.15	1.24	1.21	1.15	1.21
	Index total	2.05	1.15	1.18	1.26	1.23	1.17	1.23
	Recruit devs	3.91	1.04	1.53	1.63	1.60	1.53	1.60
SSB_{1977} (mt)		9,470	9,566	9,473	9,463	9,468	9,438	9,432
SSB_{2013} (mt)		4,500	4,671	4,245	3,021	3,597	4,153	3,517
$F_{mult,2013}$		0.31	0.35	0.38	0.54	0.45	0.39	0.46
1998 YC Age-1 (000s)		13,733	13,900	13,681	13,432	13,546	13,429	13,304
2010 YC Age-1 (000s)		5,942	7,358	6,681	4,749	5,703	6,659	5,685
2012 YC Age-1 (000s)		3,998	21,530	16,698	8,159	9,057	16,565	8,978
Mohn's rho (7 year peel)	**SSB**	-0.03	-0.19	-0.15	-0.07	-0.10	-0.15	-0.10
	F_{mult}	0.05	0.31	0.27	0.18	0.21	0.30	0.24
	Age 1 N	0.18	-0.27	-0.11	0.04	-0.03	-0.10	-0.02

Table A.86. Gulf of Maine haddock January 1 numbers-at-age (000s) from 1977 to 2013 as estimated from the ASAP_final_temp10 model.

Year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9+
1977	5,997	13,897	1,450	2,025	850	463	0	0	46
1978	1,476	4,898	10,203	983	1,217	518	270	0	22
1979	6,048	1,205	3,546	6,748	567	714	289	139	10
1980	6,435	4,941	893	2,441	4,159	354	428	163	74
1981	4,612	5,252	3,505	570	1,331	2,309	186	205	94
1982	774	3,766	3,779	2,295	324	768	1,266	94	128
1983	2,445	632	2,679	2,426	1,261	181	406	611	89
1984	1,043	1,993	415	1,500	1,066	570	75	146	190
1985	282	851	1,369	251	747	543	271	32	114
1986	265	229	559	766	110	337	224	97	39
1987	134	215	138	269	263	39	107	58	24
1988	443	110	147	82	131	131	18	44	27
1989	187	361	77	93	44	72	68	9	27
1990	244	153	289	56	61	27	37	34	16
1991	267	199	119	187	30	28	9	12	13
1992	711	218	154	75	95	12	8	3	6
1993	1,318	579	168	96	38	38	4	2	2
1994	2,903	1,076	458	116	58	20	17	2	1
1995	2,540	2,373	864	341	81	37	11	9	2
1996	1,080	2,075	1,893	623	223	48	19	6	5
1997	2,179	883	1,678	1,458	458	156	31	12	6
1998	2,276	1,780	709	1,247	1,006	292	89	17	10
1999	13,429	1,861	1,436	540	899	685	184	55	16
2000	2,547	10,986	1,510	1,126	409	657	477	126	47
2001	1,121	2,083	8,888	1,167	832	289	435	309	107
2002	1,216	917	1,689	6,938	878	602	198	293	270
2003	219	995	745	1,327	5,283	647	424	137	379
2004	6,281	179	807	585	1,009	3,883	453	293	345
2005	386	5,139	146	636	447	747	2,753	317	433
2006	1,118	316	4,147	113	478	315	501	1,778	473
2007	1,218	915	255	3,243	86	345	218	336	1,457
2008	215	996	735	195	2,379	58	218	131	1,066
2009	301	176	802	565	144	1,634	38	135	736
2010	966	246	142	621	424	102	1,092	24	555
2011	6,659	790	198	109	457	288	65	664	350
2012	2,090	5,443	635	152	80	313	186	40	601
2013	16,565	1,708	4,348	474	108	51	183	102	348

Exclude final 2 years (1977-2011)	
Median recruitment	1,121
Mean recruitment	2,267
Geometric mean	1,137
All years (1977-2013)	
Median recruitment	1,216
Mean recruitment	2,648
Geometric mean	1,242

Table A.87. Gulf of Maine haddock January 1 biomass (mt) and spawning stock biomass (mt) and exploitable biomass from 1977 to 2013 as estimated from the ASAP_final_temp10 model.

Year	January 1 biomass (mt)	Spawning stock biomass (mt)	Exploitable biomass (mt)
1977	17,102	9,438	7,313
1978	18,168	13,392	9,686
1979	19,034	15,178	11,474
1980	19,834	14,400	11,955
1981	19,422	13,675	11,130
1982	17,639	13,068	10,830
1983	13,353	9,895	9,173
1984	8,774	6,618	6,124
1985	6,565	4,796	4,091
1986	3,909	2,735	2,582
1987	1,931	1,456	1,456
1988	1,366	1,049	923
1989	1,072	759	678
1990	1,124	793	621
1991	999	679	484
1992	987	600	329
1993	1,191	610	313
1994	2,026	1,003	483
1995	3,450	1,802	819
1996	4,267	2,962	1,338
1997	6,062	4,568	2,616
1998	7,386	5,646	3,283
1999	7,900	5,606	3,194
2000	11,021	6,607	4,080
2001	13,966	10,840	6,184
2002	15,007	13,206	7,367
2003	12,629	11,341	7,810
2004	11,302	9,641	8,219
2005	10,276	8,098	6,728
2006	8,909	7,443	5,787
2007	7,610	6,427	4,446
2008	6,435	5,464	4,035
2009	5,453	4,771	3,746
2010	4,617	3,904	3,214
2011	4,856	3,062	2,743
2012	5,396	2,961	2,012
2013	7,749	4,153	2,158
Min	987	600	313
Max	19,834	15,178	11,955
Average	8,346	6,180	4,579

Table A.88. Gulf of Maine haddock fishing mortality-at-age and the fully recruited fishing mortality (F_{full}) from 1977 to 2013 as estimated from the ASAP_final_temp10 model.

Year	Age1	Age2	Age3	Age4	Age5	Age6	Age7	Age8	Age9$^+$	F_{full}
1977	0.00	0.11	0.19	0.31	0.30	0.34	0.41	0.55	0.55	0.55
1978	0.00	0.12	0.21	0.35	0.33	0.38	0.46	0.62	0.62	0.62
1979	0.00	0.10	0.17	0.28	0.27	0.31	0.38	0.50	0.50	0.50
1980	0.00	0.14	0.25	0.41	0.39	0.44	0.54	0.72	0.72	0.72
1981	0.00	0.13	0.22	0.37	0.35	0.40	0.49	0.65	0.65	0.65
1982	0.00	0.14	0.24	0.40	0.38	0.44	0.53	0.71	0.71	0.71
1983	0.00	0.22	0.38	0.62	0.59	0.68	0.82	1.10	1.10	1.10
1984	0.00	0.18	0.30	0.50	0.47	0.54	0.66	0.88	0.88	0.88
1985	0.00	0.22	0.38	0.62	0.60	0.68	0.83	1.11	1.11	1.11
1986	0.01	0.31	0.53	0.87	0.83	0.95	1.15	1.54	1.54	1.54
1987	0.00	0.18	0.32	0.52	0.50	0.57	0.69	0.93	0.93	0.93
1988	0.00	0.15	0.26	0.42	0.40	0.46	0.55	0.74	0.74	0.74
1989	0.00	0.03	0.12	0.22	0.31	0.45	0.50	0.59	0.59	0.59
1990	0.00	0.05	0.23	0.41	0.60	0.86	0.94	1.12	1.12	1.12
1991	0.00	0.06	0.27	0.48	0.70	1.00	1.10	1.31	1.31	1.31
1992	0.00	0.06	0.27	0.49	0.70	1.02	1.11	1.32	1.32	1.32
1993	0.00	0.03	0.17	0.30	0.44	0.63	0.69	0.82	0.82	0.82
1994	0.00	0.02	0.09	0.17	0.24	0.35	0.38	0.46	0.46	0.46
1995	0.00	0.03	0.13	0.22	0.33	0.47	0.51	0.61	0.61	0.61
1996	0.00	0.01	0.06	0.11	0.16	0.23	0.25	0.29	0.29	0.29
1997	0.00	0.02	0.10	0.17	0.25	0.36	0.39	0.47	0.47	0.47
1998	0.00	0.01	0.07	0.13	0.18	0.27	0.29	0.35	0.35	0.35
1999	0.00	0.01	0.04	0.08	0.11	0.16	0.18	0.21	0.21	0.21
2000	0.00	0.01	0.06	0.10	0.15	0.21	0.23	0.28	0.28	0.28
2001	0.00	0.01	0.05	0.08	0.12	0.18	0.19	0.23	0.23	0.23
2002	0.00	0.01	0.04	0.07	0.11	0.15	0.17	0.20	0.20	0.20
2003	0.00	0.01	0.04	0.07	0.11	0.16	0.17	0.20	0.20	0.20
2004	0.00	0.01	0.04	0.07	0.10	0.14	0.16	0.19	0.19	0.19
2005	0.00	0.01	0.05	0.09	0.15	0.20	0.24	0.29	0.24	0.29
2006	0.00	0.01	0.05	0.07	0.13	0.17	0.20	0.24	0.20	0.24
2007	0.00	0.02	0.07	0.11	0.19	0.26	0.31	0.37	0.31	0.37
2008	0.00	0.02	0.06	0.10	0.18	0.23	0.28	0.34	0.28	0.34
2009	0.00	0.01	0.06	0.09	0.15	0.20	0.24	0.29	0.24	0.29
2010	0.00	0.02	0.07	0.11	0.19	0.25	0.30	0.36	0.30	0.36
2011	0.00	0.02	0.06	0.10	0.18	0.24	0.28	0.34	0.28	0.34
2012	0.00	0.02	0.09	0.14	0.25	0.34	0.40	0.49	0.41	0.49
2013	0.00	0.02	0.07	0.12	0.20	0.27	0.32	0.39	0.33	0.39

Table A.89. Summary of the Gulf of Maine haddock 2013 point estimates and their corresponding 90% probability intervals for the ASAP_final_temp10 model.

Metric	ASAP point estimate	90% probability interval
SSB_{2013} (mt)	4,153	(2,960 - 6,043)
B_{2013} (mt)	7,749	(5,470 - 11,039)
F_{full}	0.39	(0.24 - 0.60)

Table A.90. Inputs to the Gulf of Maine haddock yield per recruit analysis. Values in italics are the coefficients of variation (CV) used in the stochastic calculations (zero values were replaced with values of 0.001). Natural mortality CVs were assumed.

Age	Catch weights (kg)		Stock weights (kg)		Fishery selectivity		Maturity		Natural mortality	
1	0.30	*0.14*	0.15	*0.14*	0.00	*0.36*	0.04	*0.23*	0.20	*0.10*
2	0.60	*0.11*	0.40	*0.13*	0.05	*0.19*	0.28	*0.08*	0.20	*0.10*
3	0.89	*0.11*	0.71	*0.07*	0.19	*0.14*	0.81	*0.02*	0.20	*0.10*
4	1.17	*0.06*	1.00	*0.05*	0.30	*0.15*	0.98	*0.00*	0.20	*0.10*
5	1.40	*0.05*	1.24	*0.03*	0.52	*0.13*	1.00	*0.00*	0.20	*0.10*
6	1.55	*0.05*	1.43	*0.03*	0.69	*0.13*	1.00	*0.00*	0.20	*0.10*
7	1.70	*0.05*	1.59	*0.08*	0.82	*0.12*	1.00	*0.00*	0.20	*0.10*
8	1.96	*0.07*	1.82	*0.03*	1.00	*0.00*	1.00	*0.00*	0.20	*0.10*
9^+	2.04	*0.04*	2.04	*0.04*	0.83	*0.16*	1.00	*0.00*	0.20	*0.10*

Table A.91. Fishing mortality (F), yield per recruit (YPR) and mean age across a range of percent maximum spawning potential (% MSP) values.

F	YPR (kg)	SSB/R	% MSP	Mean Age	F	YPR (kg)	SSB/R	% MSP	Mean Age
0.00	0.00	5.05	100.0	5.52	0.50	0.48	1.93	38.3	3.10
0.01	0.03	4.86	96.3	5.36	0.51	0.48	1.91	37.9	3.09
0.02	0.06	4.69	92.9	5.22	0.52	0.48	1.89	37.5	3.07
0.03	0.09	4.53	89.7	5.09	0.53	0.49	1.87	37.2	3.06
0.04	0.12	4.38	86.8	4.96	0.54	0.49	1.86	36.8	3.05
0.05	0.14	4.24	84.0	4.85	0.55	0.49	1.84	36.4	3.03
0.06	0.16	4.11	81.5	4.75	0.56	0.49	1.82	36.1	3.02
0.07	0.18	3.99	79.1	4.65	0.57	0.49	1.80	35.8	3.01
0.08	0.20	3.88	76.9	4.56	0.58	0.50	1.79	35.4	3.00
0.09	0.22	3.77	74.8	4.48	0.59	0.50	1.77	35.1	2.99
0.10	0.24	3.68	72.9	4.40	0.60	0.50	1.76	34.8	2.97
0.11	0.25	3.58	71.0	4.33	0.61	0.50	1.74	34.5	2.96
0.12	0.26	3.49	69.3	4.26	0.62	0.50	1.72	34.2	2.95
0.13	0.28	3.41	67.6	4.19	0.63	0.50	1.71	33.9	2.94
0.14	0.29	3.33	66.1	4.13	0.64	0.50	1.70	33.6	2.93
0.15	0.30	3.26	64.6	4.08	0.65	0.51	1.68	33.3	2.92
0.16	0.31	3.19	63.2	4.02	0.66	0.51	1.67	33.0	2.91
0.17	0.32	3.12	61.9	3.97	0.67	0.51	1.65	32.8	2.90
0.18	0.33	3.06	60.6	3.92	0.68	0.51	1.64	32.5	2.89
0.19	0.34	3.00	59.4	3.88	0.69	0.51	1.63	32.3	2.88
0.20	0.35	2.94	58.2	3.83	0.70	0.51	1.61	32.0	2.88
0.21	0.36	2.88	57.2	3.79	0.71	0.51	1.60	31.7	2.87
0.22	0.37	2.83	56.1	3.75	0.72	0.51	1.59	31.5	2.86
0.23	0.37	2.78	55.1	3.71	0.73	0.51	1.58	31.3	2.85
0.24	0.38	2.73	54.1	3.68	0.74	0.52	1.57	31.0	2.84
0.25	0.39	2.69	53.2	3.64	0.75	0.52	1.55	30.8	2.83
0.26	0.39	2.64	52.3	3.61	0.76	0.52	1.54	30.6	2.82
0.27	0.40	2.60	51.5	3.58	0.77	0.52	1.53	30.3	2.82
0.28	0.40	2.56	50.7	3.55	0.78	0.52	1.52	30.1	2.81
0.29	0.41	2.52	49.9	3.52	0.79	0.52	1.51	29.9	2.80
0.30	0.41	2.48	49.1	3.49	0.80	0.52	1.50	29.7	2.79
0.31	0.42	2.44	48.4	3.46	0.81	0.52	1.49	29.5	2.79
0.32	0.42	2.41	47.7	3.44	0.82	0.52	1.48	29.3	2.78
0.33	0.43	2.37	47.0	3.41	0.83	0.52	1.47	29.1	2.77
0.34	0.43	2.34	46.4	3.39	0.84	0.52	1.46	28.9	2.77
0.35	0.44	2.31	45.7	3.37	0.85	0.52	1.45	28.7	2.76
0.36	0.44	2.28	45.1	3.35	0.86	0.52	1.44	28.5	2.75
0.37	0.44	2.25	44.5	3.32	0.87	0.53	1.43	28.3	2.74
0.38	0.45	2.22	44.0	3.30	0.88	0.53	1.42	28.1	2.74
0.39	0.45	2.19	43.4	3.28	0.89	0.53	1.41	28.0	2.73
0.40	0.45	2.16	42.9	3.26	0.90	0.53	1.40	27.8	2.73
0.41	0.46	2.14	42.4	3.24	0.91	0.53	1.39	27.6	2.72
0.42	0.46	2.11	41.9	3.23	0.92	0.53	1.38	27.4	2.71
0.43	0.46	2.09	41.4	3.21	0.93	0.53	1.38	27.3	2.71
0.44	0.47	2.06	40.9	3.19	0.94	0.53	1.37	27.1	2.70
0.45	0.47	2.04	40.4	3.18	0.95	0.53	1.36	26.9	2.69
0.46	0.47	2.02	40.0	3.16	0.96	0.53	1.35	26.8	2.69
0.47	0.47	2.00	39.5	3.14	0.97	0.53	1.34	26.6	2.68
0.48	0.48	1.97	39.1	3.13	0.98	0.53	1.33	26.4	2.68
0.49	0.48	1.95	38.7	3.11	0.99	0.53	1.33	26.3	2.67

Table A.92. Proxy reference points from the Gulf of Maine haddock yield per recruit (YPR) analysis and the corresponding fishing mortality, spawning stock biomass per recruit (SSB/R), biomass per recruit and mean age values. Italicized numbers in parentheses next to the F results indicate the corresponding CVs.

Ref. point	F		YPR (kg)	SSB/R (kg)	Biomass/ Recruit (kg)	Mean Age
F_0	0.00		0.00	5.05	5.79	5.52
$F_{0.1}$	0.38	*(0.10)*	0.45	2.22	2.93	3.31
F_{MAX}	2.31	*(0.23)*	0.55	0.78	1.43	2.27
$F_{40\%}$	0.46	*(0.10)*	0.47	2.02	2.73	3.16

Table A.93. Non-parametric proxy reference points for Gulf of Maine haddock based on the empirical cumulative density functions from two different age-1 recruitment time series: 1977-2011 and 1977-2013. **The SAW 59 WG recommended that the 1977-2011 time series be used for stock status determination.**

Recruitment series	F_{MSY} (proxy)	Fmsy	SSB_{MSY} (mt)	MSY (mt)	Median age1 recruitment
1977-2011	$F_{40\%}$	0.46 (0.36 - 0.54)	4,108 (1,774 - 7,861)	955 (421 - 1,807)	1,121
1977-2013*	$F_{40\%}$	0.46 (0.36 - 0.54)	4,613 (1,936 - 9,903)	1,079 (460 - 2,271)	1,207

* *Sensitivity only*

Table A.94. Short-term projections of total fishery yield and spawning stock biomass for Gulf of Maine haddock based on a harvest scenario of a) fishing at $F_{40\%}$ between 2014 and 2017 and b) an assumed catch of 500 mt in 2014 and fishing at $F_{40\%}$ between 2015 and 2017. Projections are shown based on two different population models to highlight the sensitivity of catch projections to the size of the 2012 year class. Projection results are shown for the base ASAP model (ASAP_final_temp10) and a sensitivity model that constrains the size of the terminal year class (ASAP_final_temp11). Confidence intervals in parentheses are 90% intervals.

Year	Input	ASAP_final_temp10 (1977-2011 recruitment)						
		Catch (mt)		Spawning stock biomass (mt)		Harvest strategy	F_{full}	
2013	Catch input/model result	692		4,153	(2,690 - 6,043)		0.39	(0.24 - 0.60)
2014	Projection	1,085	(713 - 1,605)	6,341	(4,272 - 9,237)	$F_{40\%}$	0.46	
2015	Projection	1,752	(1,140 - 2,633)	10,014	(6,556 - 15,250)	$F_{40\%}$	0.46	
2016	Projection	2,085	(1,367 - 3,181)	10,844	(7,036 - 16,645)	$F_{40\%}$	0.46	
2017	Projection	2,424	(1,567 - 3,755)	9,808	(6,355 - 14,914)	$F_{40\%}$	0.46	
2013	Catch input/model result	692		4,153	(2,690 - 6,043)		0.39	(0.24 - 0.60)
2014	Imputed catch	500		6,472	(4,328 - 9,473)		0.20	(0.13 - 0.31)
2015	Projection	1,871	(1,189 - 2,848)	10,507	(6,788 - 16,090)	$F_{40\%}$	0.46	
2016	Projection	2,189	(1,409 - 3,369)	11,223	(7,223 - 17,291)	$F_{40\%}$	0.46	
2017	Projection	2,512	(1,607 - 3,896)	10,078	(6,487 - 15,332)	$F_{40\%}$	0.46	

Year	Input	ASAP_final_temp11 (1977-2011 recruitment)						
		Catch (mt)		Spawning stock biomass (mt)		Harvest strategy	F_{full}	
2013	Catch input/model result	692		3,643	(2,500 - 5,089)		0.43	(0.28 - 0.67)
2014	Projection	870	(563 - 1,276)	4,961	(3,323 - 7,036)	$F_{40\%}$	0.46	
2015	Projection	1,271	(843 - 1,850)	6,833	(4,620 - 9,805)	$F_{40\%}$	0.46	
2016	Projection	1,456	(989 - 2,104)	7,148	(4,869 - 10,253)	$F_{40\%}$	0.46	
2017	Projection	1,620	(1,099 - 2,376)	6,568	(4,459 - 9,719)	$F_{40\%}$	0.46	
2013	Catch input/model result	692		3,643	(2,500 - 5,089)		0.43	(0.28 - 0.67)
2014	Imputed catch	500		5,050	(3,345 - 7,213)		0.25	(0.17 - 0.40)
2015	Projection	1,350	(863 - 2,011)	7,154	(4,698 - 10,401)	$F_{40\%}$	0.46	
2016	Projection	1,524	(1,004 - 2,239)	7,388	(4,947 - 10,679)	$F_{40\%}$	0.46	
2017	Projection	1,674	(1,113 - 2,473)	6,739	(4,525 - 9,986)	$F_{40\%}$	0.46	

Table A.95. Short-term projections of total fishery yield and spawning stock biomass for Gulf of Maine haddock based on a harvest scenario of a) fishing at 75% $F_{40\%}$ between 2014 and 2017 and b) an assumed catch of 500 mt in 2014 and fishing at 75% $F_{40\%}$ between 2015 and 2017. Projections are shown based on two different population models to highlight the sensitivity of catch projections to the size of the 2012 year class. Projection results are shown for the base ASAP model (ASAP_final_temp10) and a sensitivity model that constrains the size of the terminal year class (ASAP_final_temp11). Confidence intervals in parentheses are 90% intervals.

Year	Input	ASAP_final_temp10 (1977-2011 recruitment)						
		Catch (mt)		Spawning stock biomass (mt)		Harvest strategy	F_{full}	
2013	Catch input/model result	692		4,153	(2,690 - 6,043)		0.39	(0.24 - 0.60)
2014	Projection	844	(554 - 1,250)	6,396	(4,308 - 9,315)	75% of $F_{40\%}$	0.35	
2015	Projection	1,399	(911 - 2,102)	10,313	(6,768 - 15,681)	75% of $F_{40\%}$	0.35	
2016	Projection	1,722	(1,129 - 2,620)	11,463	(7,464 - 17,521)	75% of $F_{40\%}$	0.35	
2017	Projection	2,078	(1,348 - 3,202)	10,747	(6,982 - 16,226)	75% of $F_{40\%}$	0.35	
2013	Catch input/model result	692		4,153	(2,690 - 6,043)		0.39	(0.24 - 0.60)
2014	Imputed catch	500		6,472	(4,328 - 9,473)		0.20	(0.13 - 0.31)
2015	Projection	1,454	(924 - 2,214)	10,605	(6,854 - 16,241)	75% of $F_{40\%}$	0.35	
2016	Projection	1,772	(1,139 - 2,720)	11,709	(7,545 - 18,018)	75% of $F_{40\%}$	0.35	
2017	Projection	2,125	(1,360 - 3,288)	10,923	(7,056 - 16,574)	75% of $F_{40\%}$	0.35	

Year	Input	ASAP_final_temp11 (1977-2011 recruitment)						
		Catch (mt)		Spawning stock biomass (mt)		Harvest strategy	F_{full}	
2013	Catch input/model result	692		3,643	(2,500 - 5,089)		0.43	(0.28 - 0.67)
2014	Projection	677	(438 - 993)	5,008	(3,354 - 7,105)	75% of $F_{40\%}$	0.35	
2015	Projection	1,022	(677 - 1,487)	7,066	(4,781 - 10,116)	75% of $F_{40\%}$	0.35	
2016	Projection	1,213	(822 - 1,754)	7,604	(5,195 - 10,882)	75% of $F_{40\%}$	0.35	
2017	Projection	1,399	(948 - 2,048)	7,235	(4,928 - 10,596)	75% of $F_{40\%}$	0.35	
2013	Catch input/model result	692		3,643	(2,500 - 5,089)		0.43	(0.28 - 0.67)
2014	Imputed catch	500		5,050	(3,345 - 7,213)		0.25	(0.17 - 0.40)
2015	Projection	1,051	(671 - 1,565)	7,230	(4,749 - 10,502)	75% of $F_{40\%}$	0.35	
2016	Projection	1,241	(816 - 1,824)	7,732	(5,182 - 11,165)	75% of $F_{40\%}$	0.35	
2017	Projection	1,423	(944 - 2,102)	7,321	(4,931 - 10,781)	75% of $F_{40\%}$	0.35	

Figures

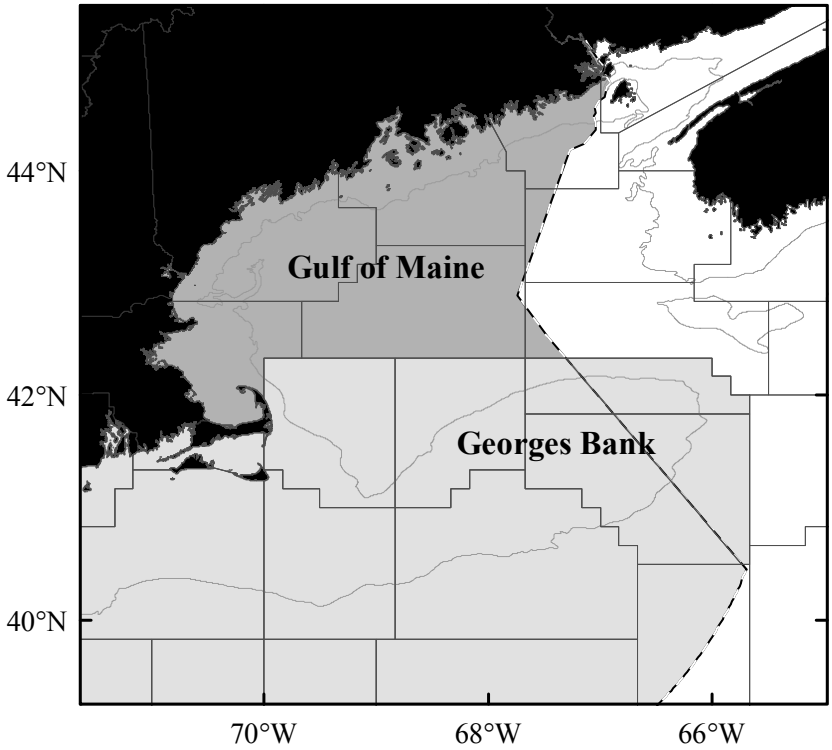


Figure A.1. Map showing the delineation of the Gulf of Maine and Georges Bank haddock (*Melanogrammus aeglefinus*) stocks. The United States exclusive economic zone (EEZ) is indicated by the dashed line.

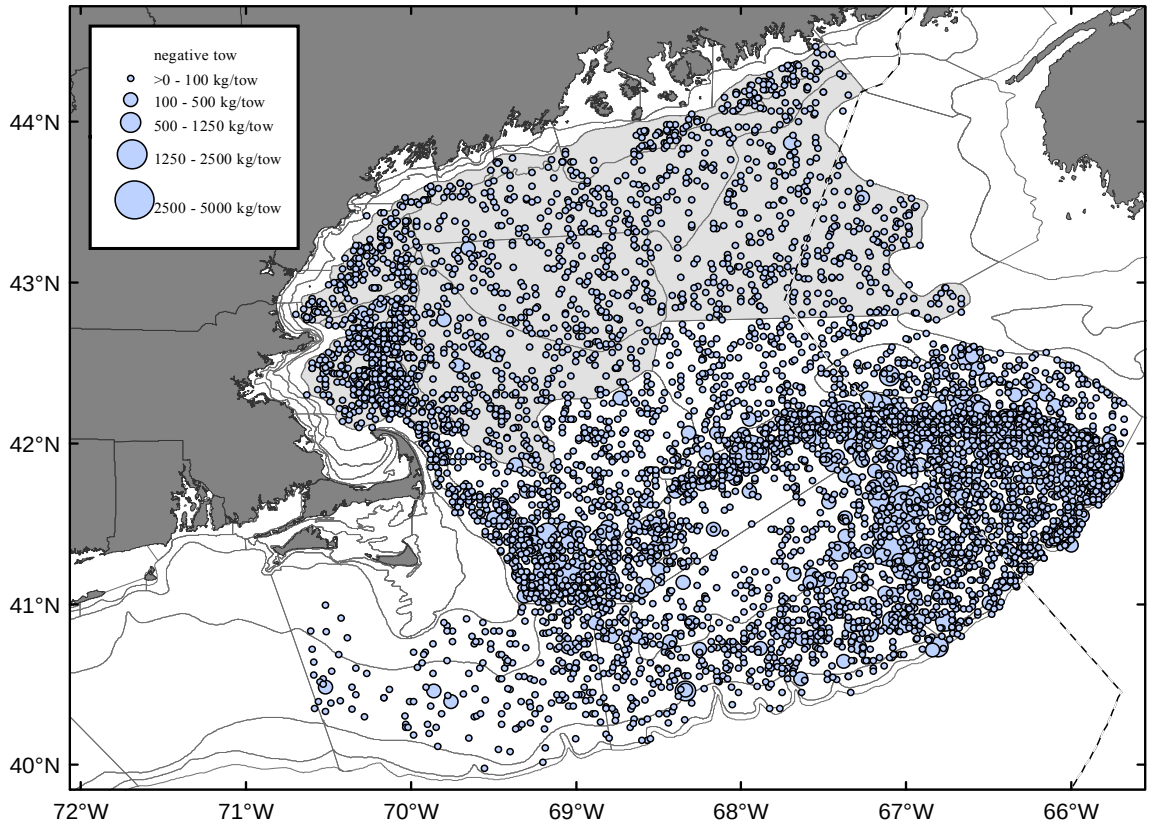


Figure A.2. Distributions of haddock catches from the Northeast Fisheries Science Center's (NEFSC) spring and fall bottom trawl surveys within the Gulf of Maine and Georges Bank regions.

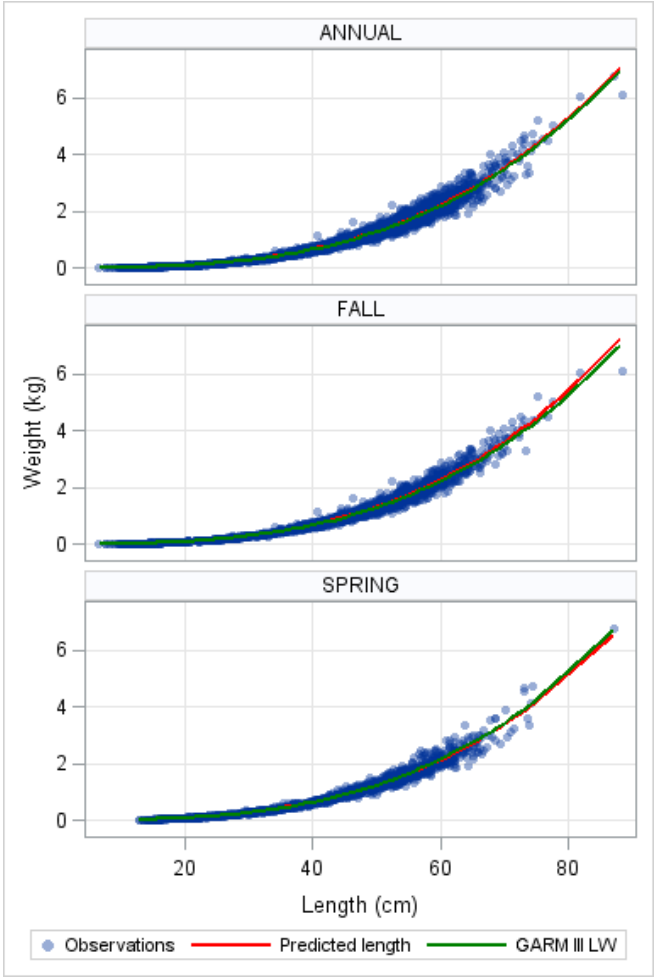


Figure A.3. Gulf of Maine haddock seasonal and annual length-weight (LW) relationships estimated from NEFSC bottom trawl survey data from 1992 to 2013. Re-estimated LW relationships are compared to the corresponding LW equations used for the GARM III assessment.

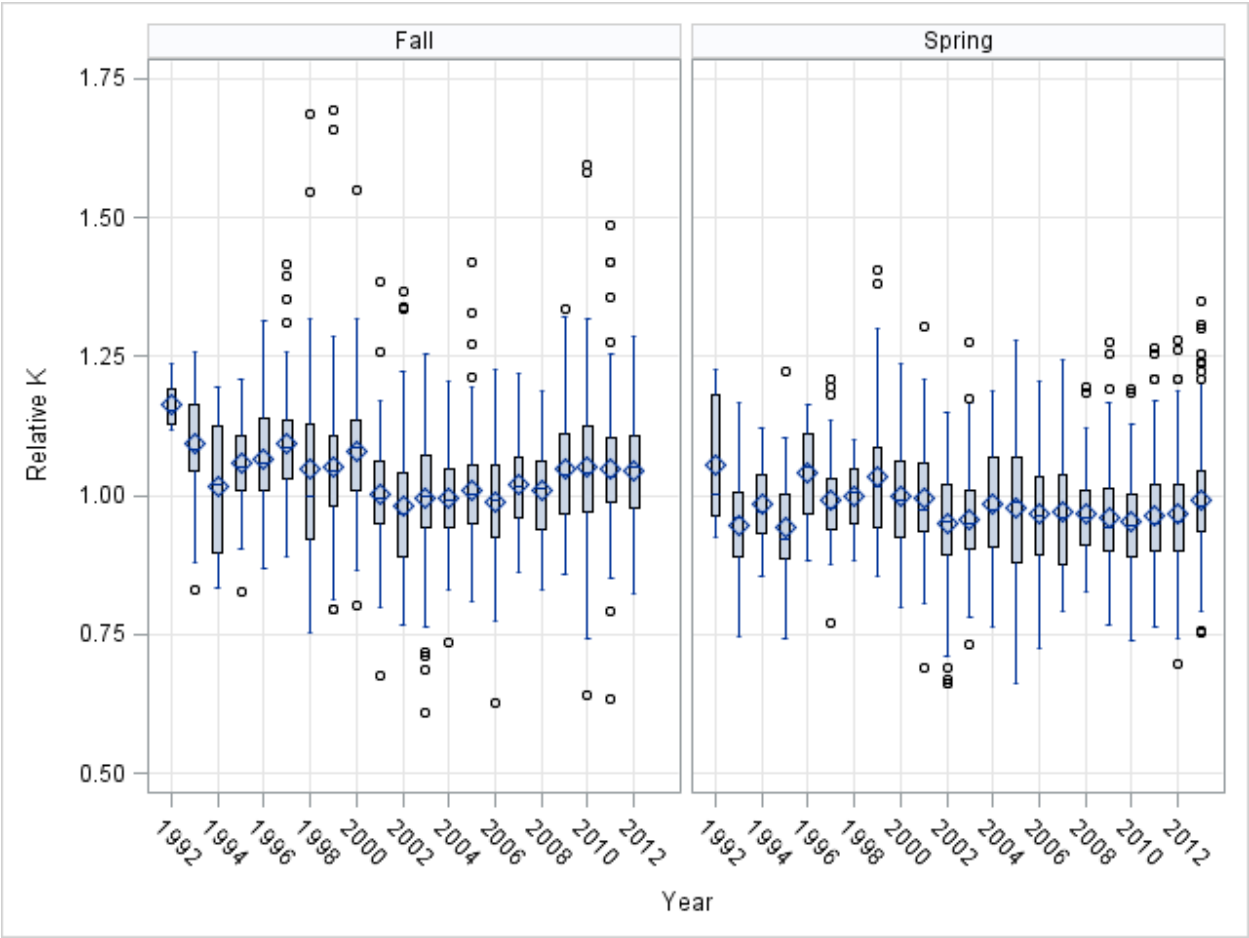


Figure A.4. Annual trends in the seasonal condition factor of Gulf of Maine haddock based on length and weight data collected from the NEFSC bottom trawl survey between 1992 and 2013.

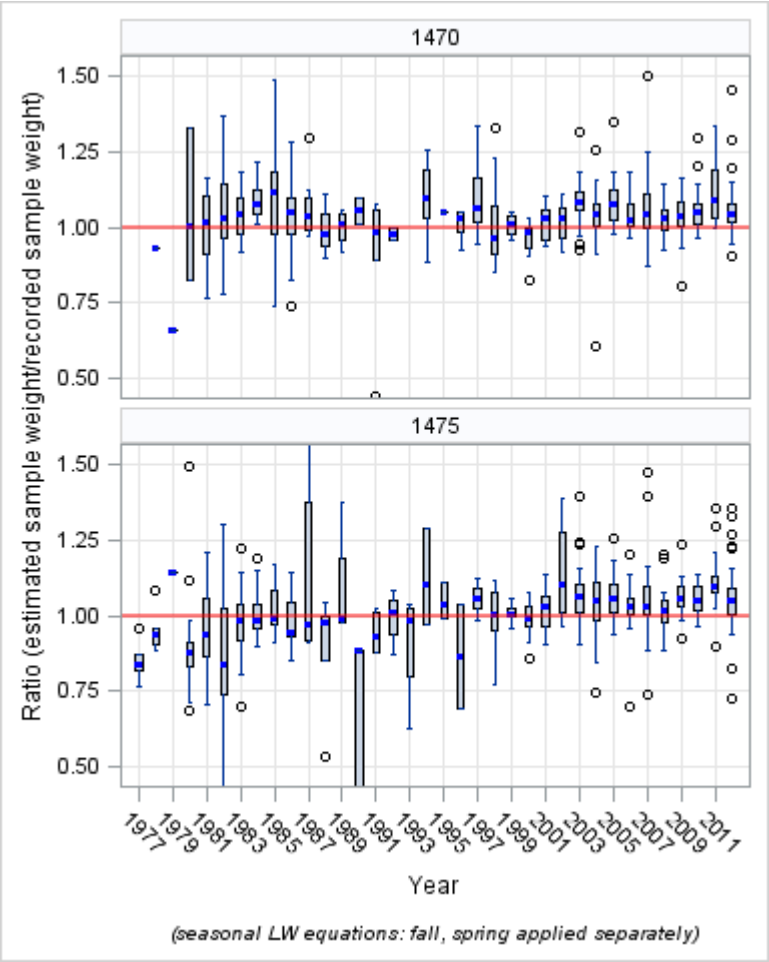


Figure A.5. Distribution of the ratios of estimated commercial biological sample weights to the recorded sample weight by market category (large=1470, scrod=1475) and year using the established gutted-to-live conversion factor of 1.14. Estimated sample weights were obtained by applying the seasonal (spring, fall) length weight equations to the recorded length distribution of the sample. The solid red line indicates the 1.0 equality line.

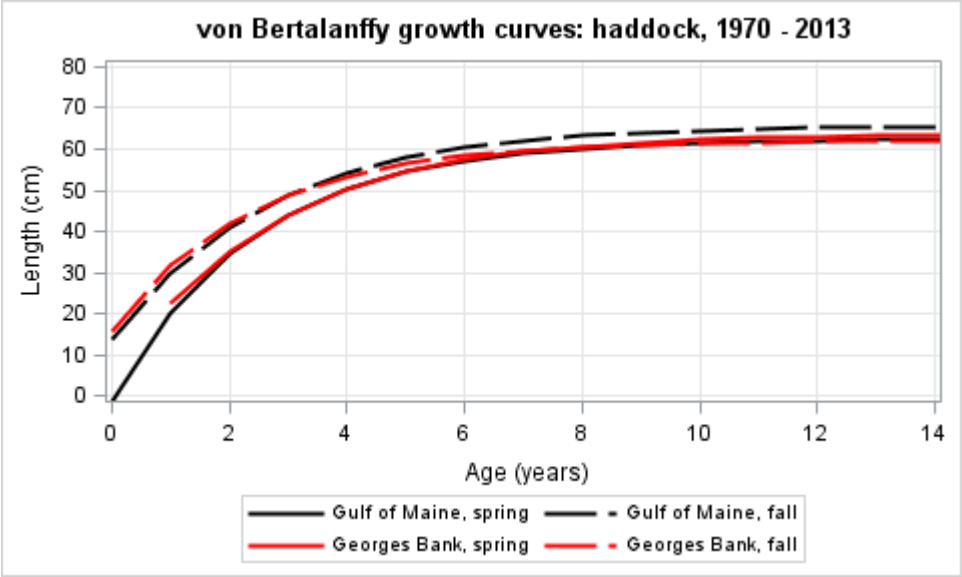


Figure A.6. Comparison of spring and fall von Bertalanffy growth curves for the Gulf of Maine and Georges Banks haddock stocks as estimated from data collected from the Northeast Fisheries Science Center bottom trawl survey between 1970 and 2013.

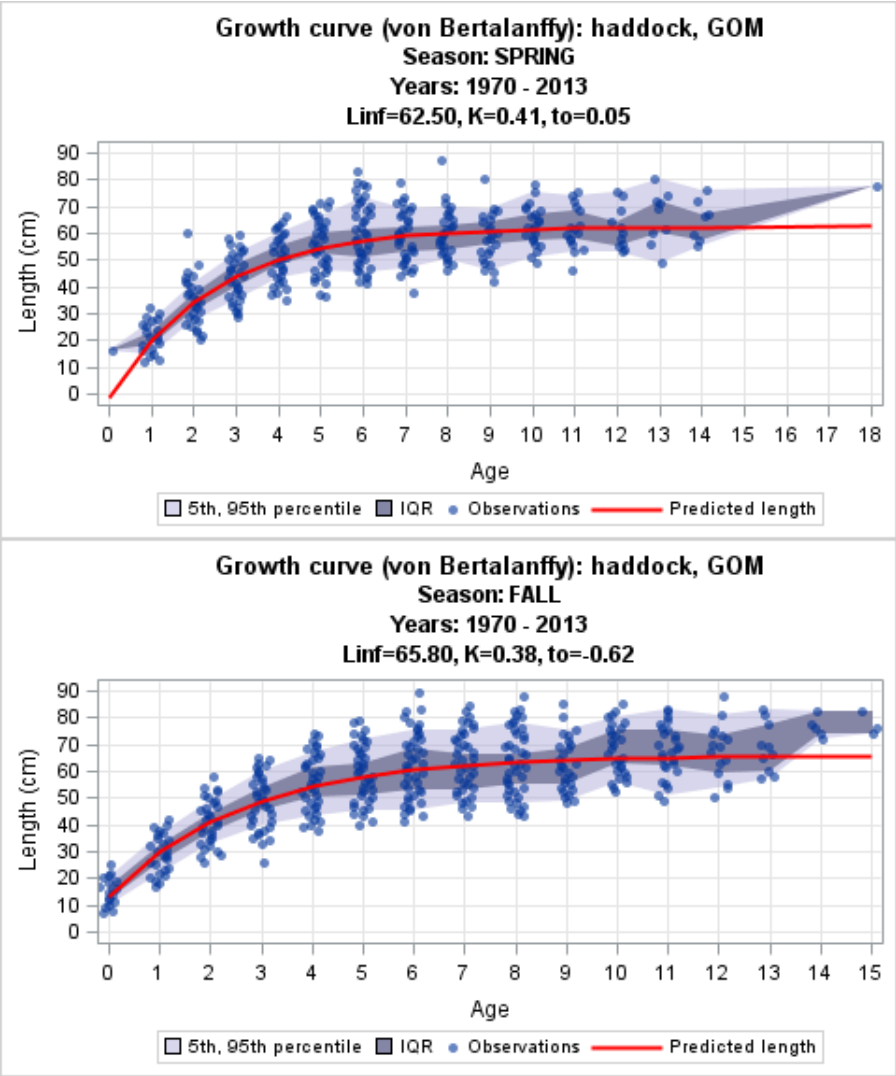


Figure A.7. Gulf of Maine haddock spring (top) and fall (bottom) von Bertalanffy growth curves estimated from data collected from the Northeast Fisheries Science Center bottom trawl survey between 1970 and 2013.

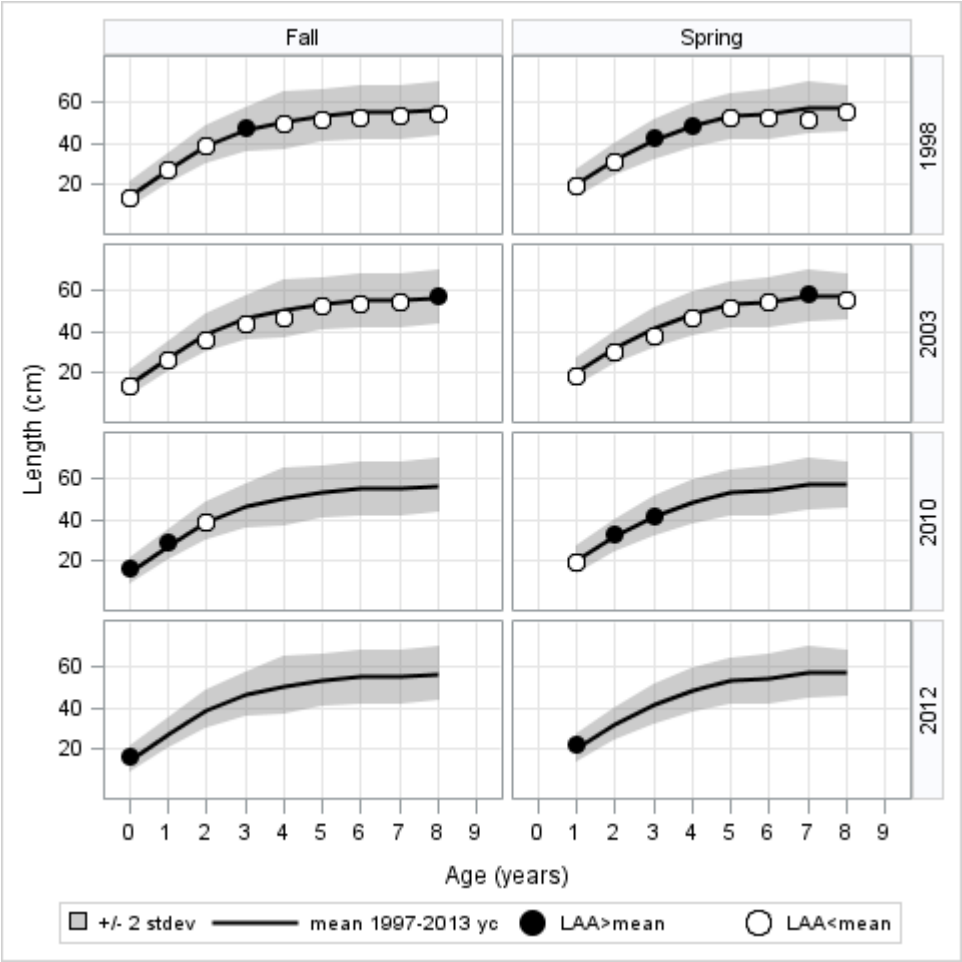


Figure A.8. Mean length-at-age (LAA) of the 1998, 2003, 2010 and 2012 year-classes as estimated from the Northeast Fisheries Science Center's (NEFSC) fall (left) and spring (right) bottom trawl surveys. The mean LAA for each cohort is compared to the 1997-2013 time series average (solid line) ± 2 standard deviations (grey band).

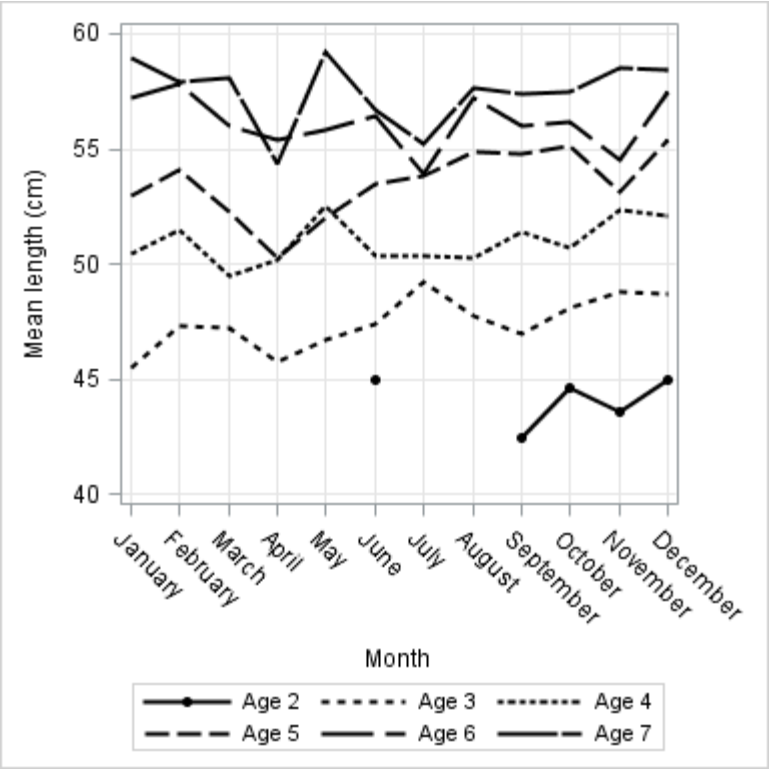


Figure A.9. Mean length-at-age of Gulf of Maine haddock by month as estimated from commercial port samples taken between 2004 and 2013.

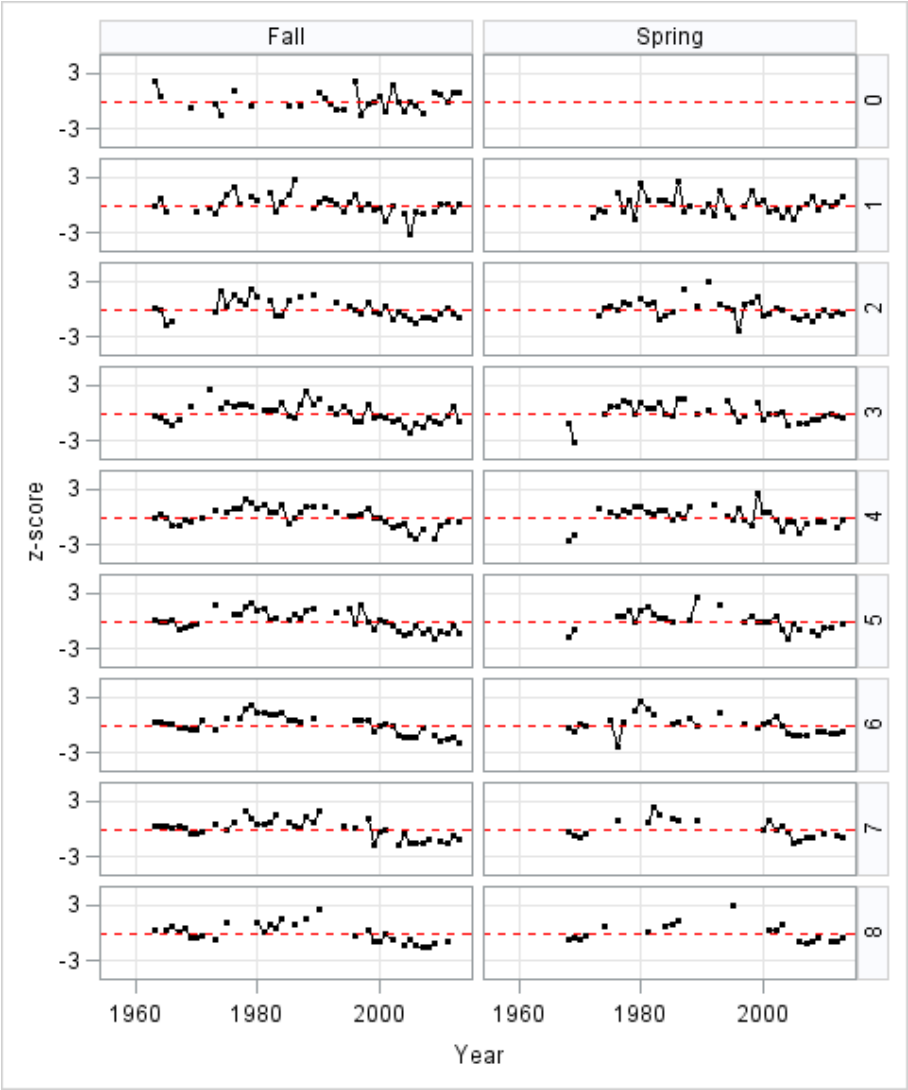


Figure A.10. Average lengths-at-age of Gulf of Maine haddock age 0 to 8 from 1963 to 2013. Survey lengths are based on the average lengths-at-age of haddock sampled from the Northeast Fisheries Science Center spring and fall bottom trawl survey. Average lengths are presented as z-scores ([x-μ]/σ).

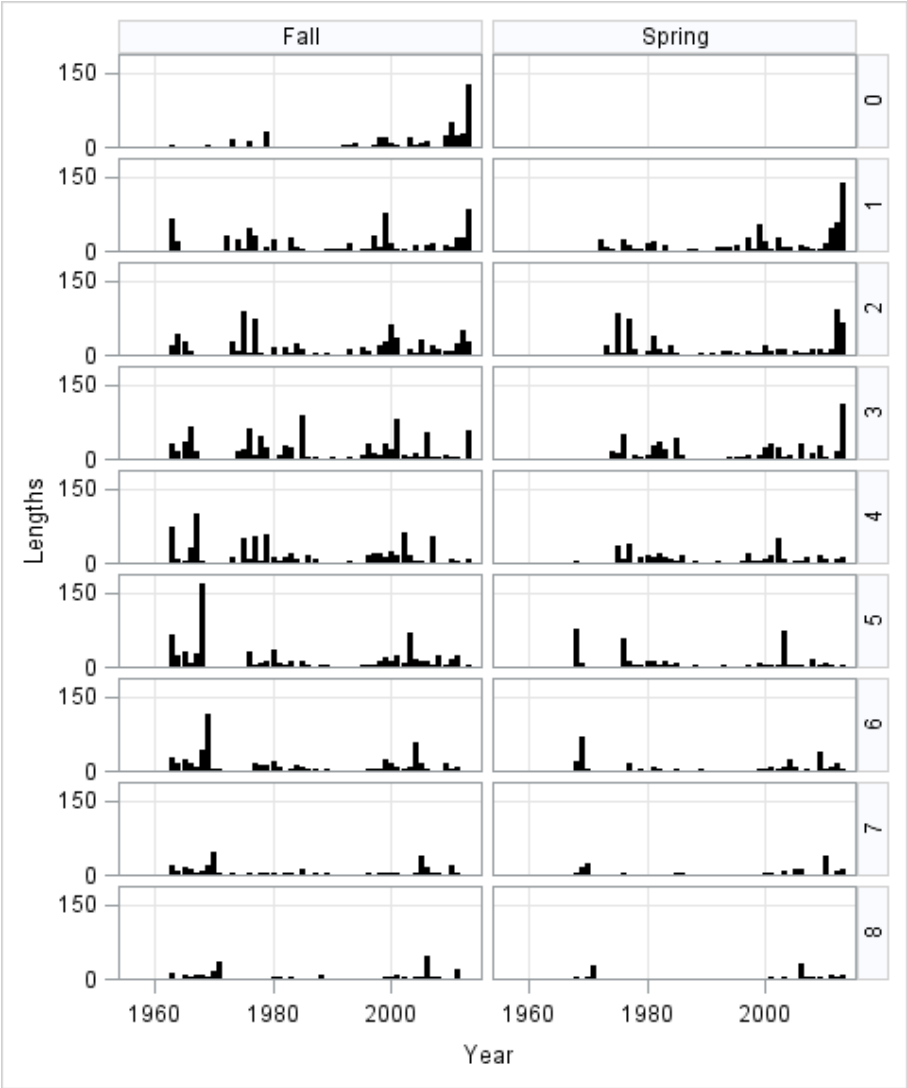


Figure A.11. Number of length measurements of age 0 to 8 Gulf of Maine haddock taken from the Northeast Fisheries Science Center spring and fall bottom trawl survey between 1963 to 2013.

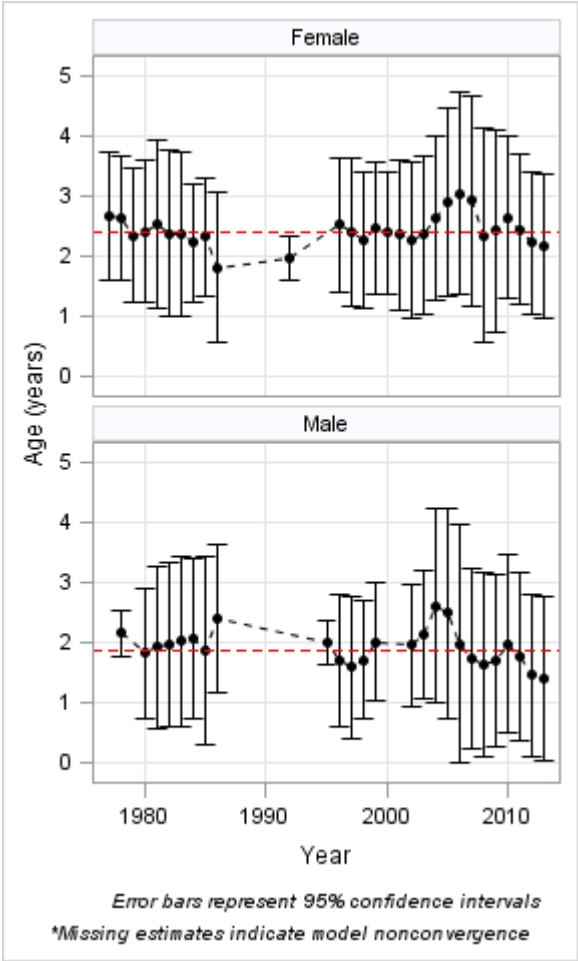


Figure A.12. Annual estimates of age-at-50% maturity ($A_{50\%}$) and the corresponding 95% confidence intervals for female and male Gulf of Maine haddock from 1970 to 2013. Average maturity has been estimated from data collected from the Northeast Fisheries Science Center (NEFSC) spring bottom trawl survey. Years in which the A*50%* could not be estimated are omitted from the plots.

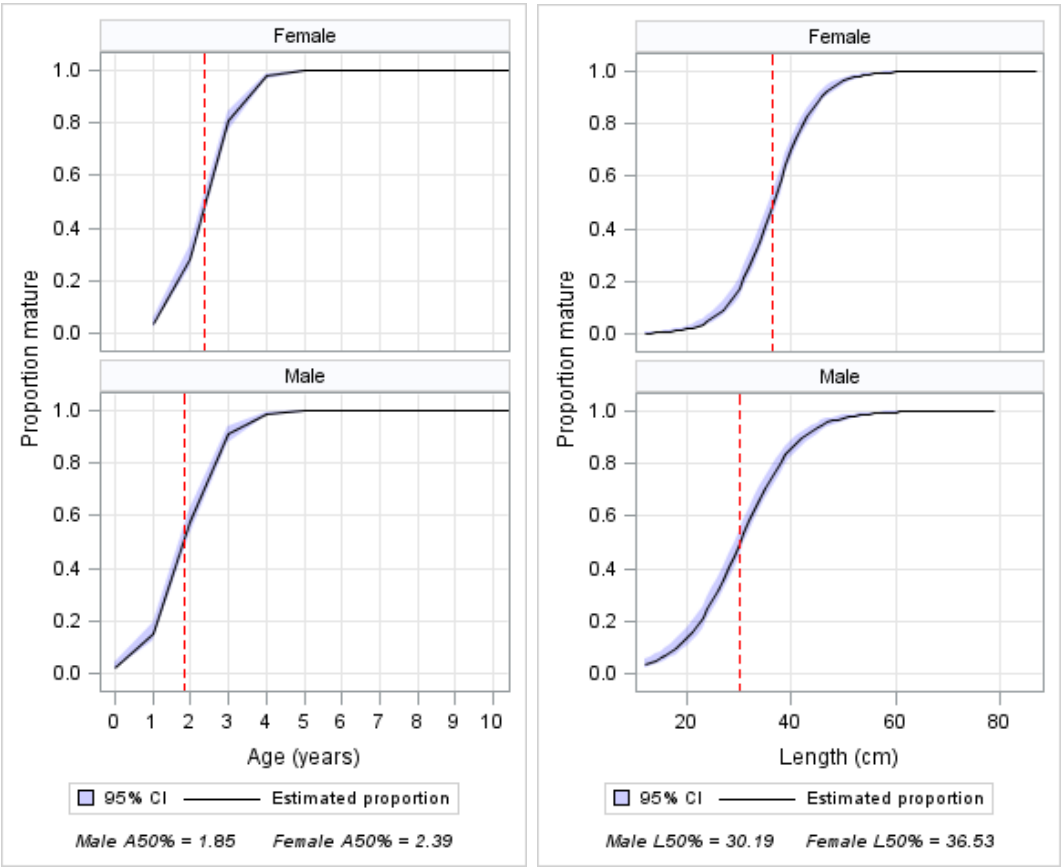


Figure A.13. Age- and length-based maturity ogives for female and male Gulf of Maine haddock based on time series averages of maturity and age information collected from the Northeast Fisheries Science Center (NEFSC) spring bottom trawl survey from 1977 to 2013. The dashed red line indicates the age/length at 50% maturity ($A_{50\%}$, $L_{50\%}$).

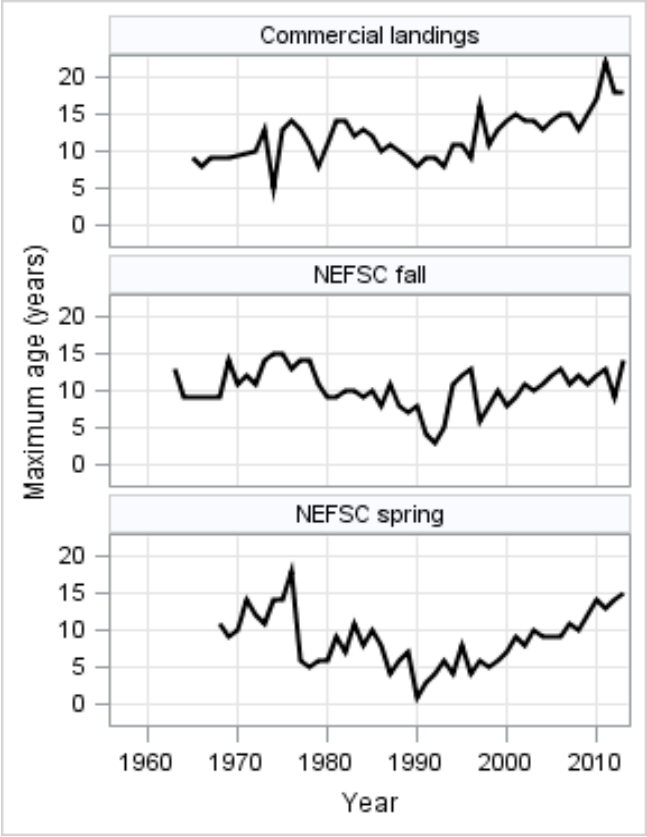


Figure A.14. Maximum age of Gulf of Maine haddock observed from the Northeast Fisheries Science Center (NEFSC) bottom trawl surveys and commercial landings between 1963 and 2013.

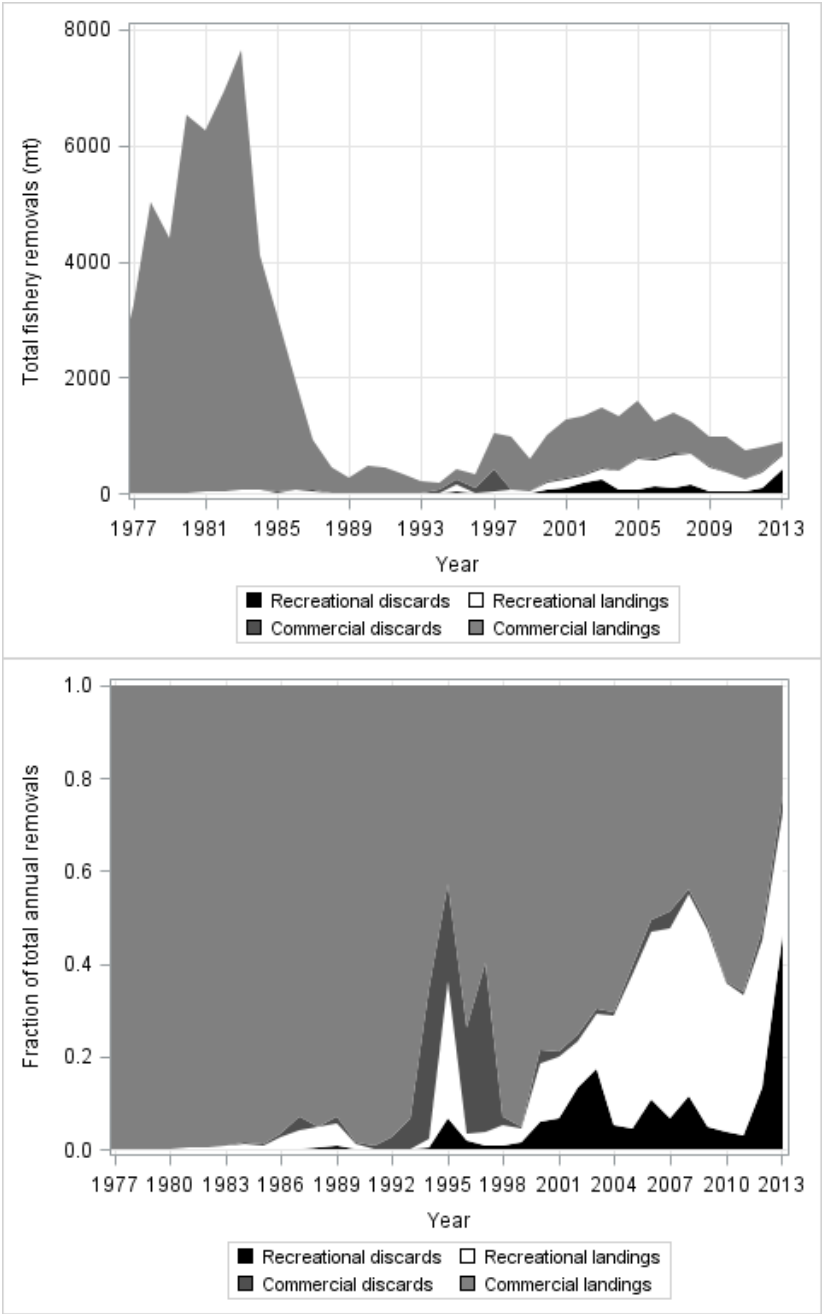


Figure A.15. Total (top) and fractional (as a fraction of the total, bottom) catch of Gulf of Maine haddock from 1977 to 2013 by fleet (commercial and recreational) and disposition (landed, discarded). **Recreational discard estimates shown do not account for post-release survival.**

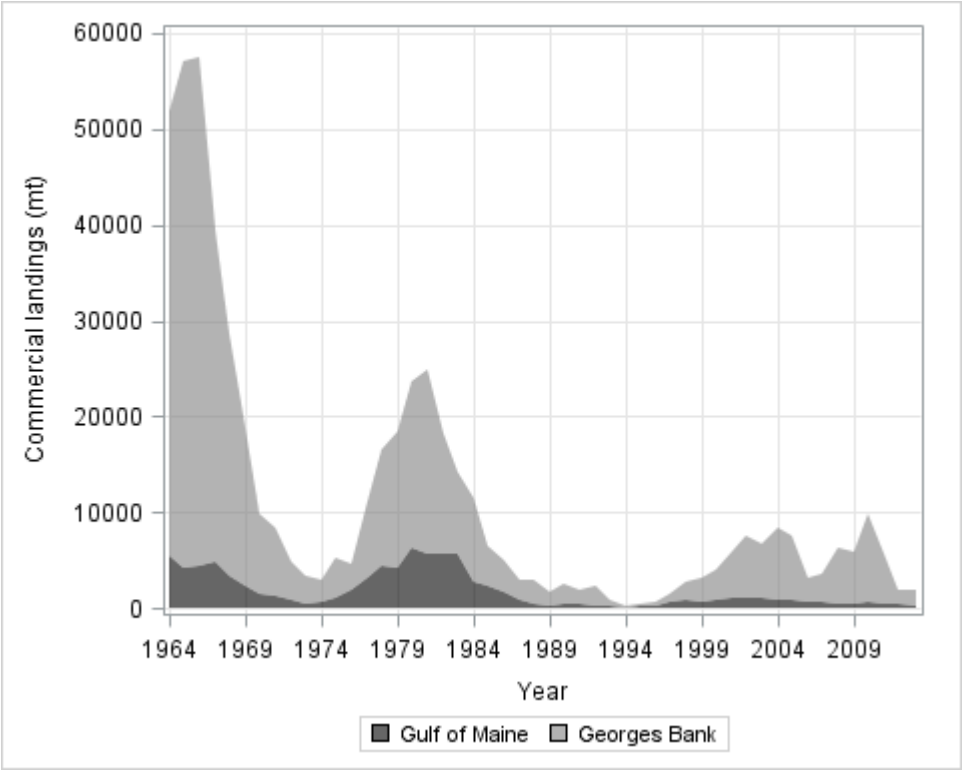


Figure A.16. Total United States commercial landings of Gulf of Maine and Georges Bank haddock from 1964 to 2013.

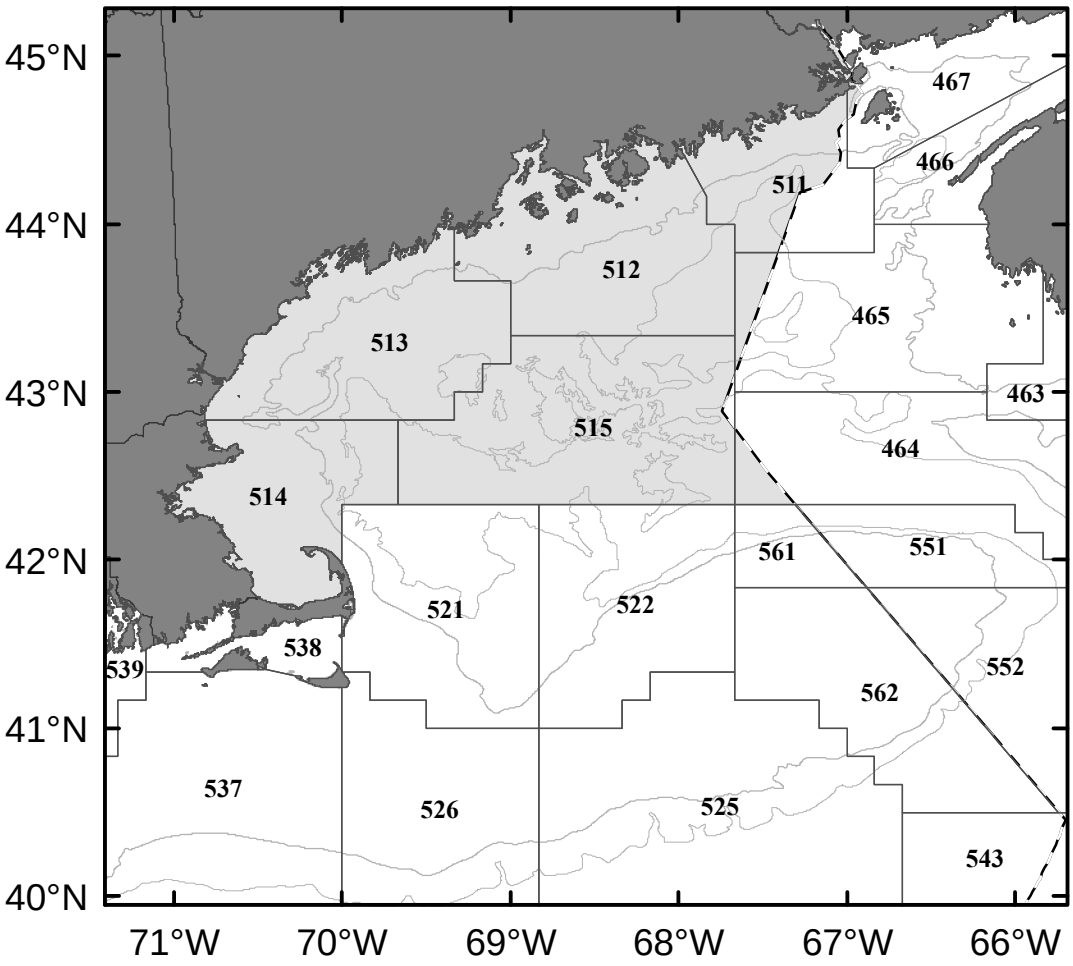


Figure A.17. Map of the Gulf of Maine haddock management area (shaded grey). The United States exclusive economic zone (EEZ) is indicated by the dashed line.

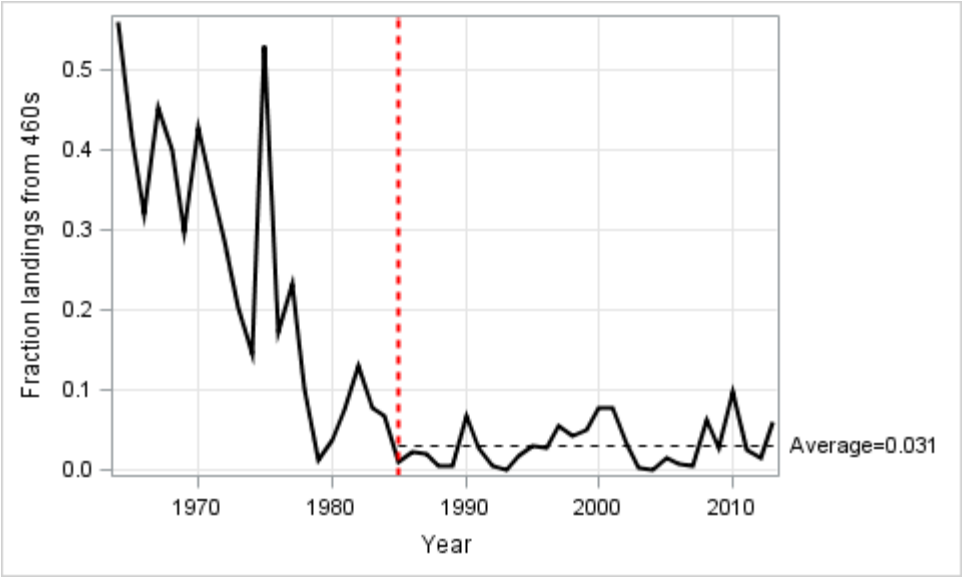


Figure A.18. Percentage of total commercial landings of Gulf of Maine haddock from statistical areas 464, 465 and 467 between 1964 and 2013. The Hague Line, which formally defined the Exclusive Econonimic Zones of the United States and Canada was adopted on October 12, 1984 (dashed red line).

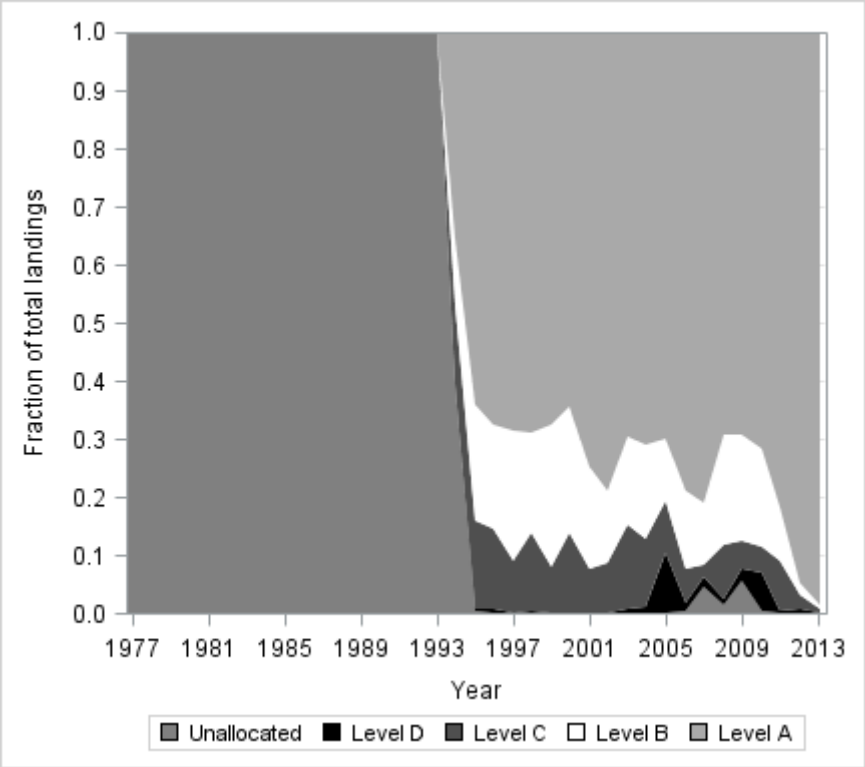


Figure A.19. Fraction of the Gulf of Maine haddock commercial landings by allocation level between 1977 and 2013. Prior to 1994 landings were allocated based on a port interview process. From 1994 onward landings were allocated to statistical area and gear type based on a standardized allocation scheme described in Wigley et al. (2008).

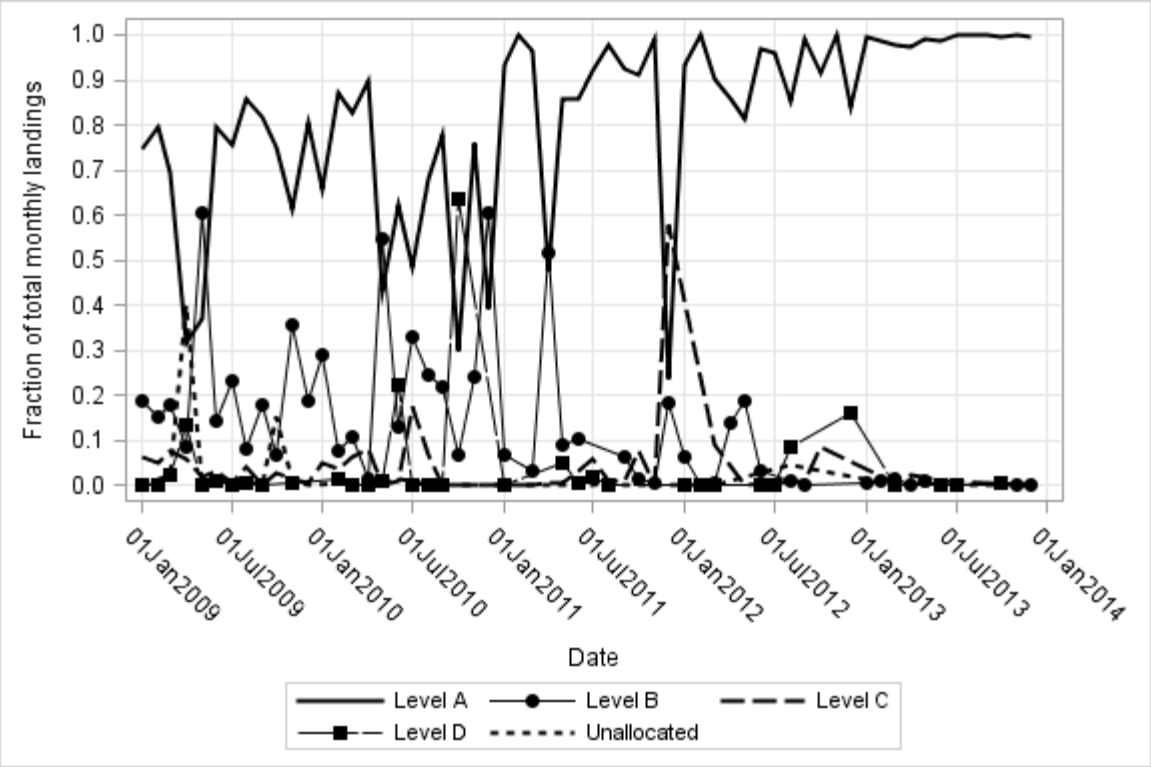


Figure A.20. Fraction of the Gulf of Maine haddock commercial landings by allocation level between 2009 and 2013 by month.

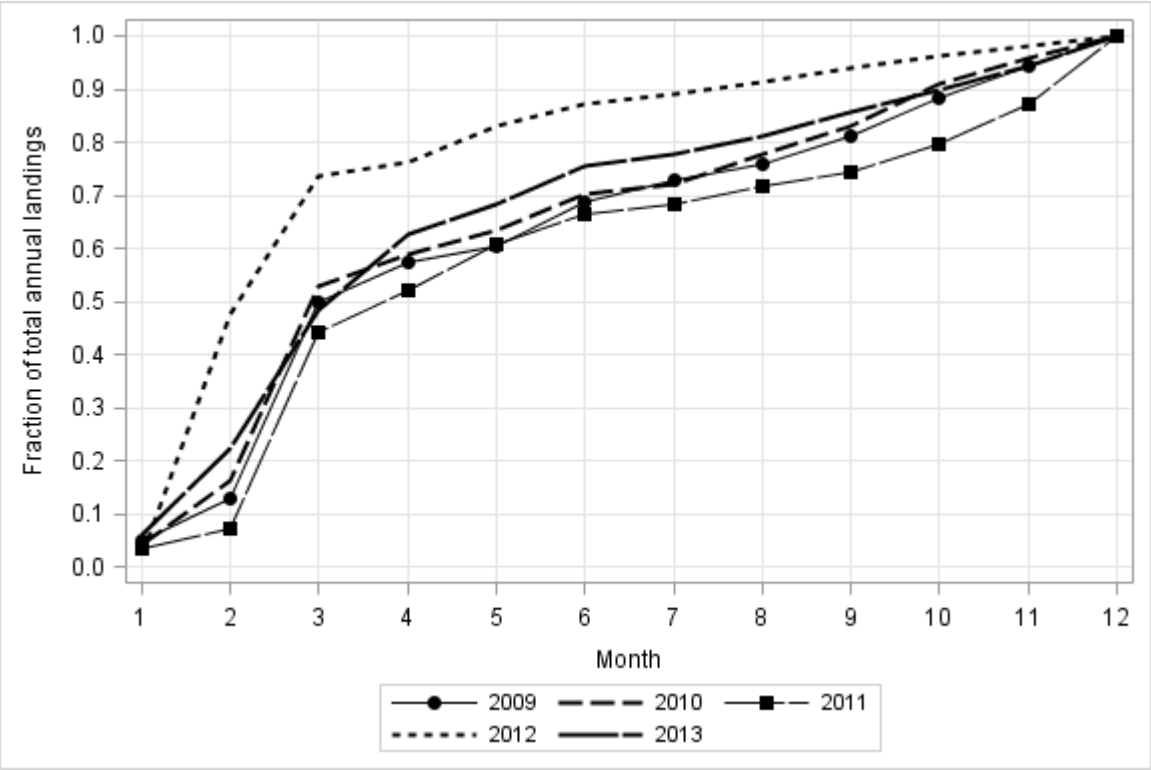


Figure A.21. Cumulative monthly commercial landings of Gulf of Maine haddock by year from 2009 to 2013.

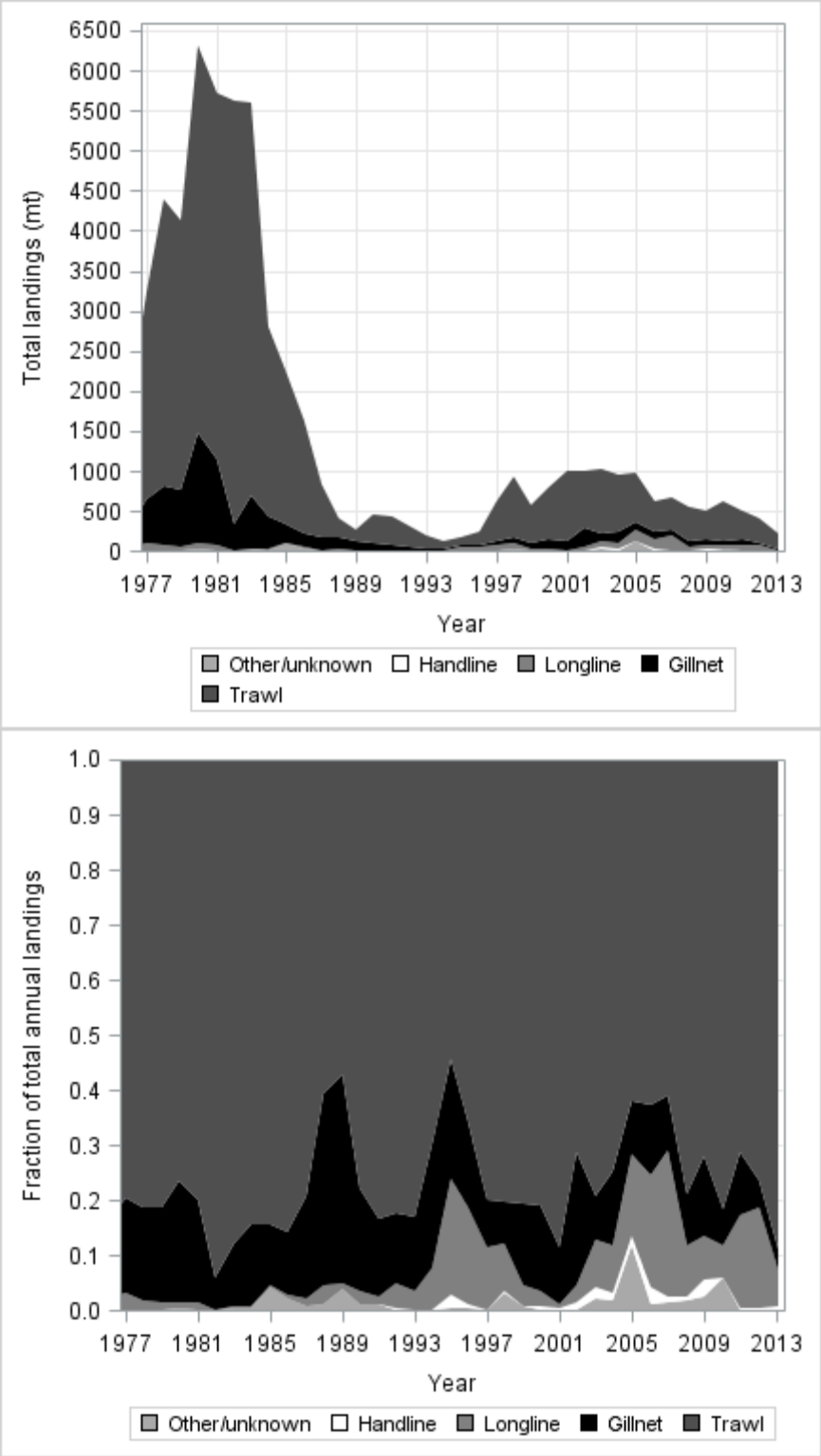


Figure A.22. Total (top) and fractional (as a fraction of the total, bottom) commercial landings of Gulf of Maine haddock by gear from 1977 to 2013.

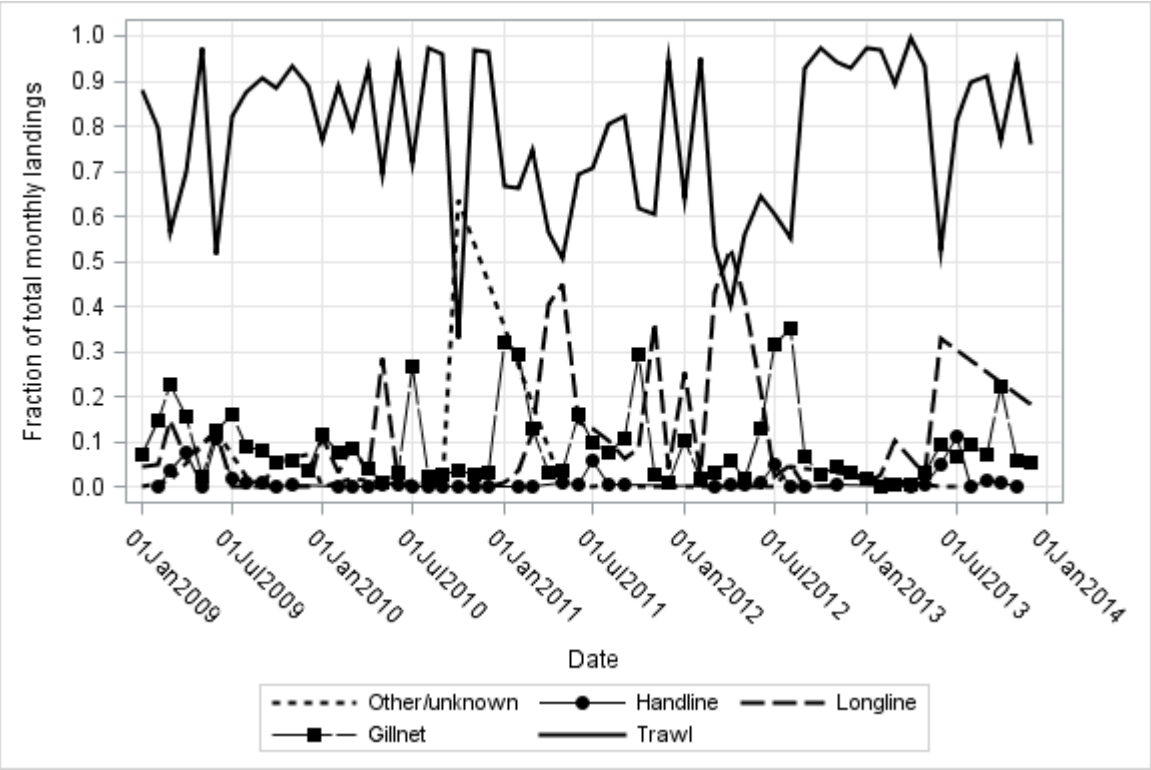


Figure A.23. Monthly commercial landings patterns (as a fraction of the total landings) of Gulf of Maine haddock by gear from 2009 to 2013.

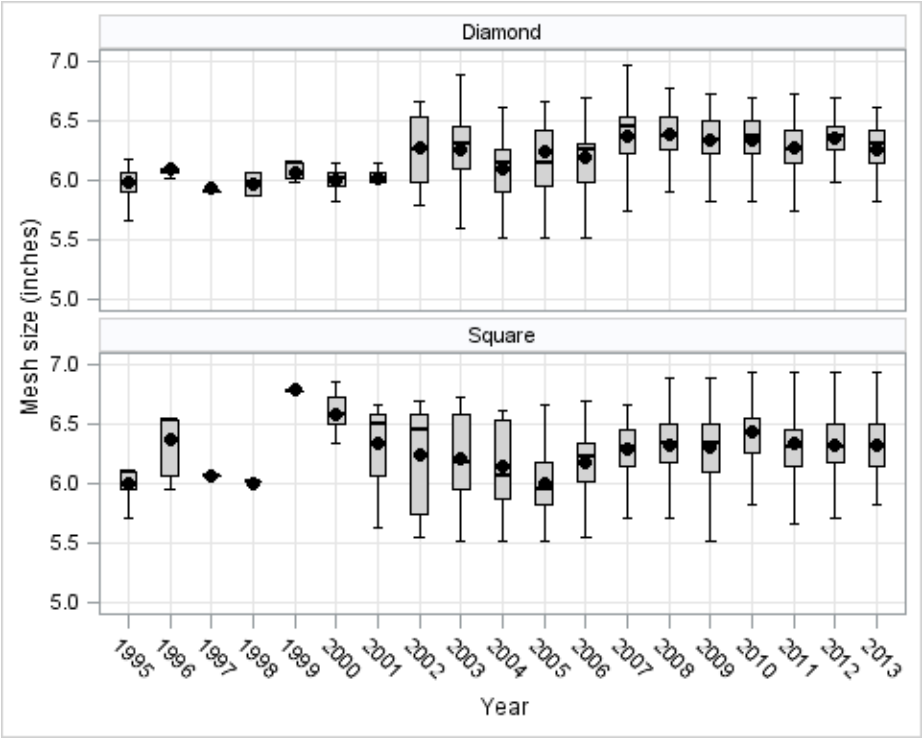


Figure A.24. Distribution of average mesh size for diamond and square hung mesh from observed otter trawl hauls in the Gulf of Maine from 1995 to 2013.

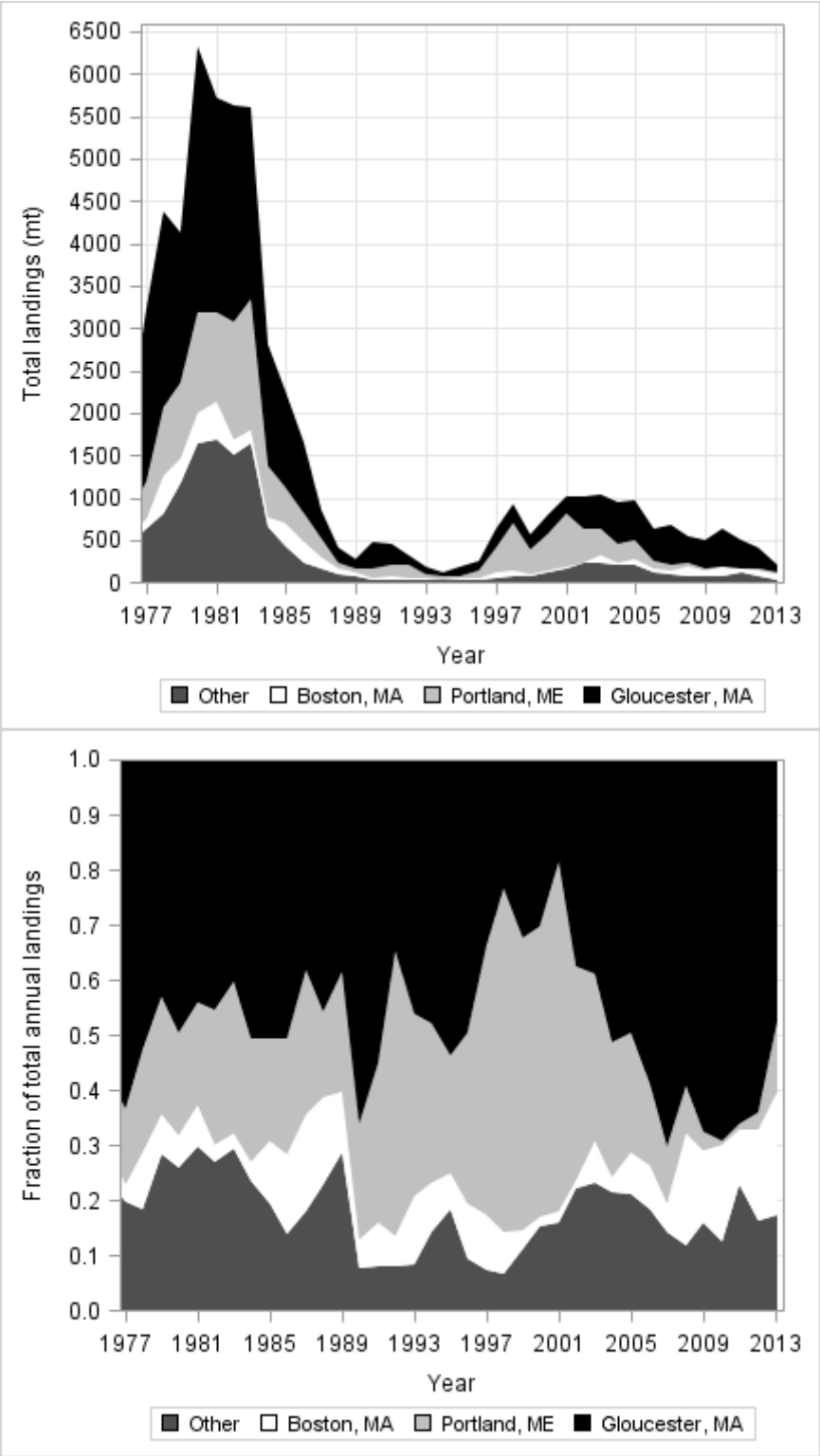


Figure A.25. Total (top) and fractional (as a fraction of the total, bottom) commercial landings of Gulf of Maine haddock by port from 1977 to 2013.

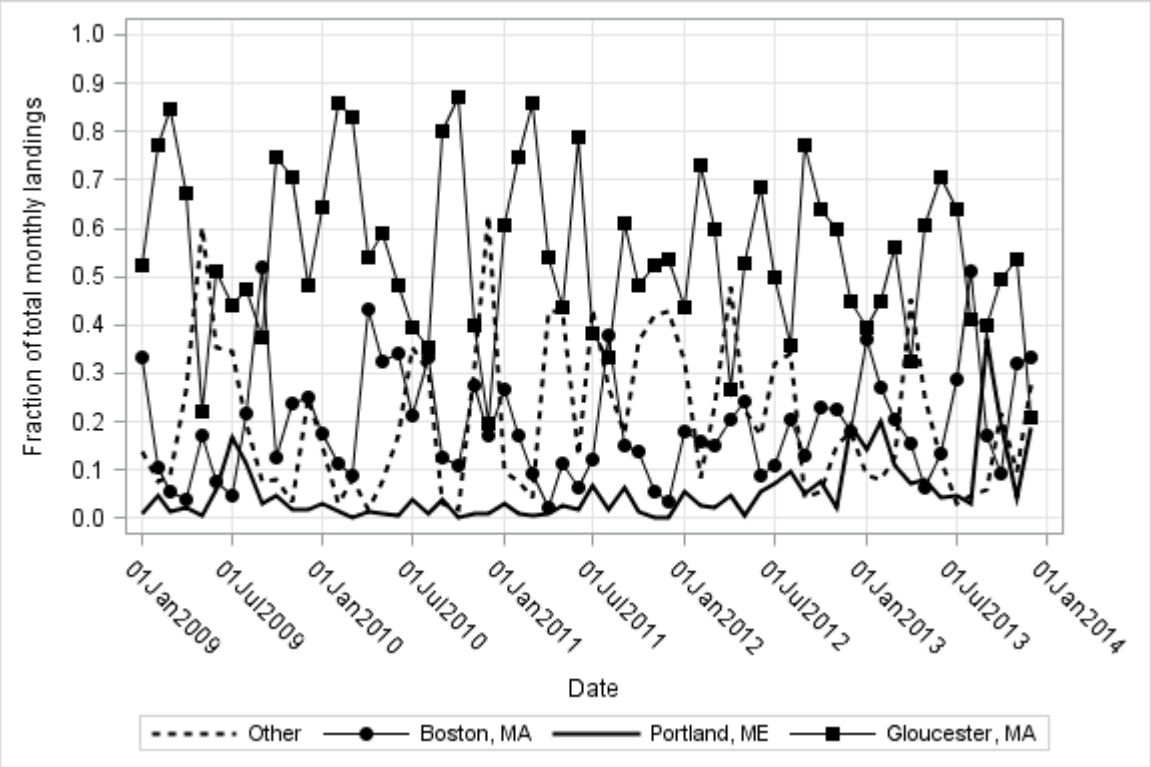


Figure A.26. Monthly commercial landings patterns (as a fraction of the total landings) of Gulf of Maine haddock by port from 2009 to 2013.

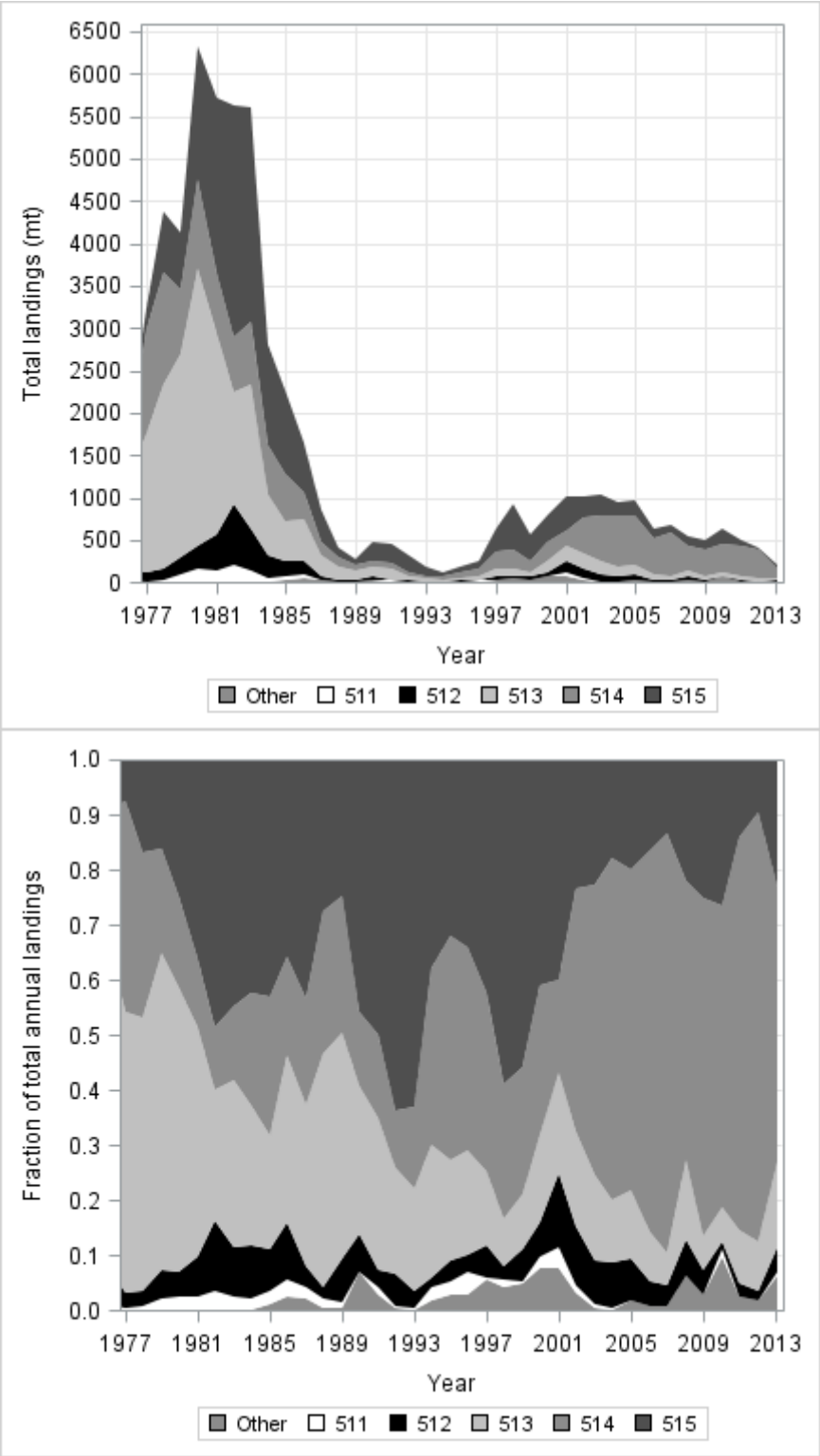


Figure A.27. Total (top) and fractional (as a fraction of the total, bottom) commercial landings of Gulf of Maine haddock by statistical area from 1977 to 2013.

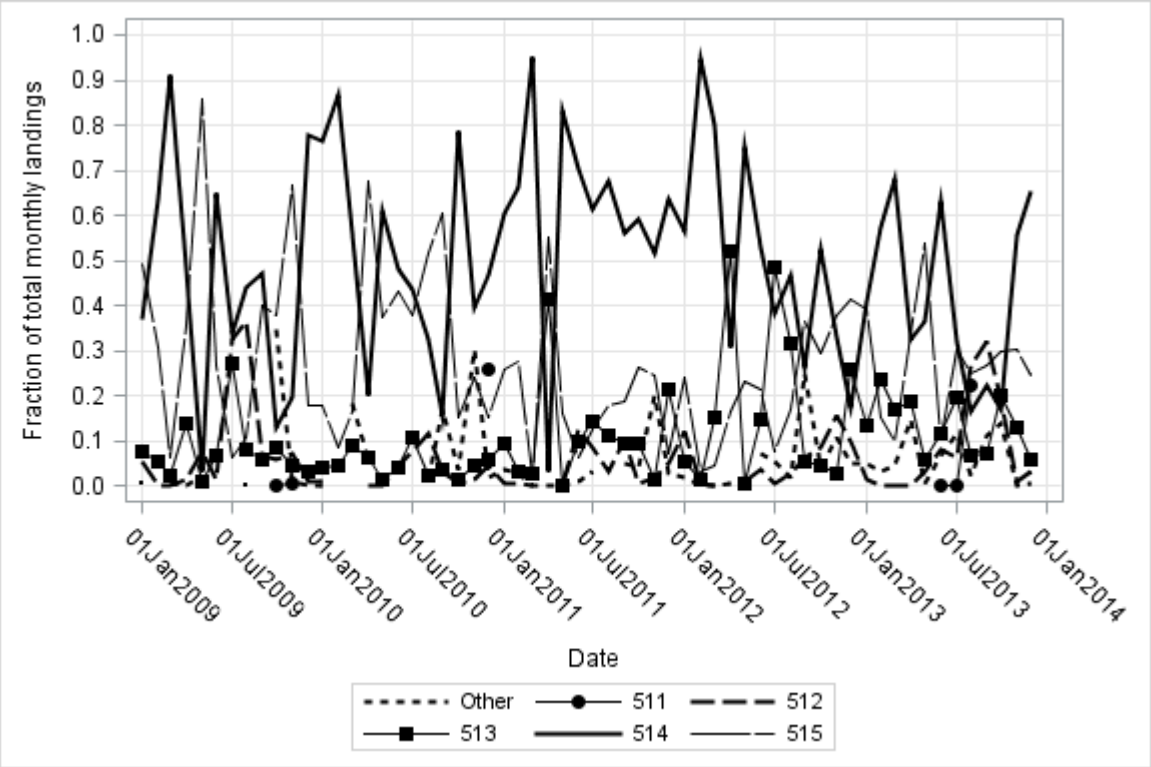


Figure A.28. Monthly commercial landings patterns (as a fraction of the total landings) of Gulf of Maine haddock by statistical area from 2009 to 2013.

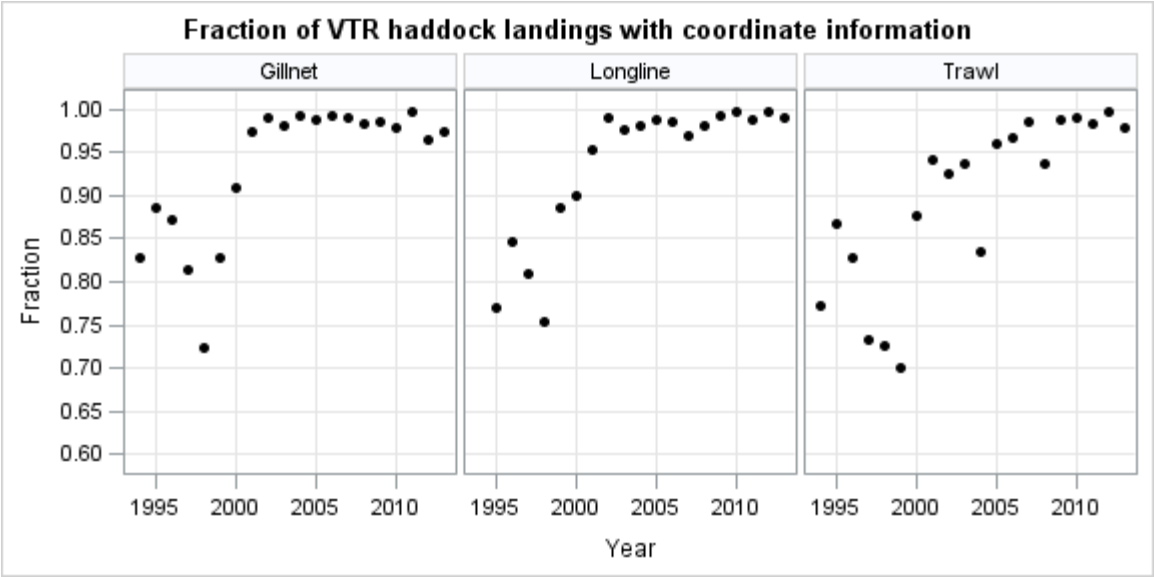


Figure A.29. Fraction of total Gulf of Maine haddock commercial landings reported on vessel trip reports (VTR) with latitude and longitude coordinate information, by gear type from 1994 to 2013.

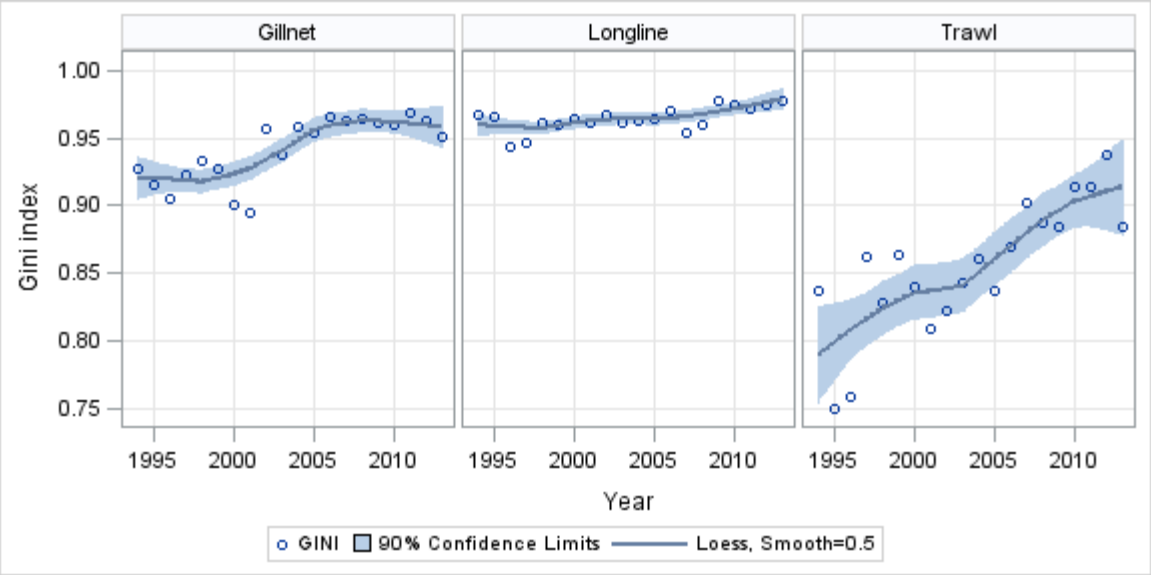


Figure A.30. Gini indices for the Gulf of Maine haddock commercial landings of the sink gillnet, longline and otter trawl fleets from 1994-2013. Indices are based on the spatial distribution of the retained catch reported on vessel trip reports.

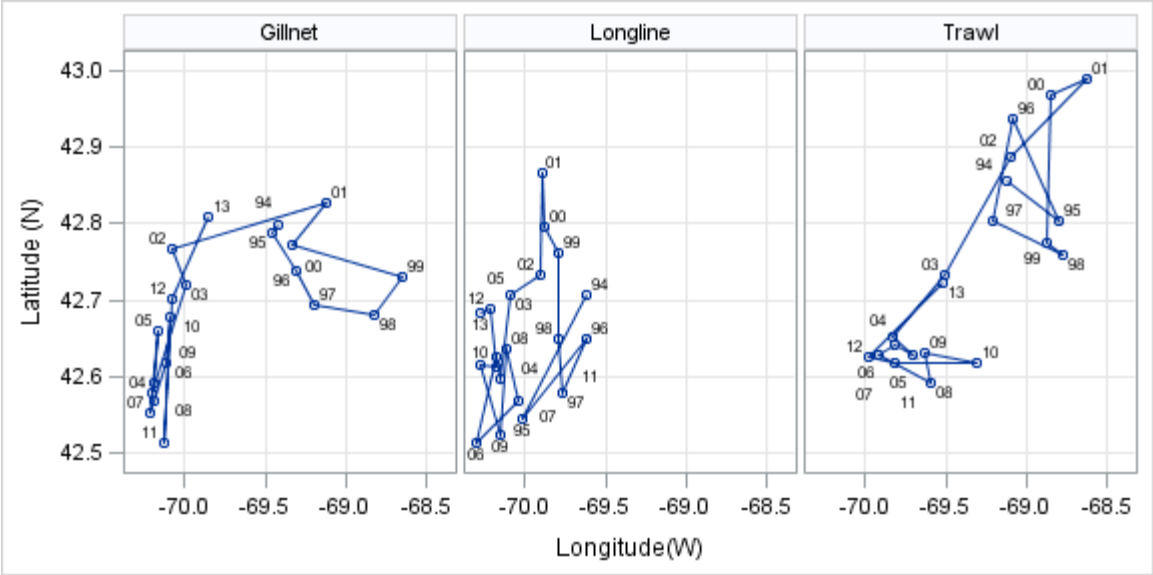


Figure A.31. Landings-weighted mean location (centroid) of Gulf of Maine haddock commercial landings of the sink gillnet, longline and otter trawl fleets from 1994-2013. Centroids are based on the spatial distribution of the retained catch reported on vessel trip reports.

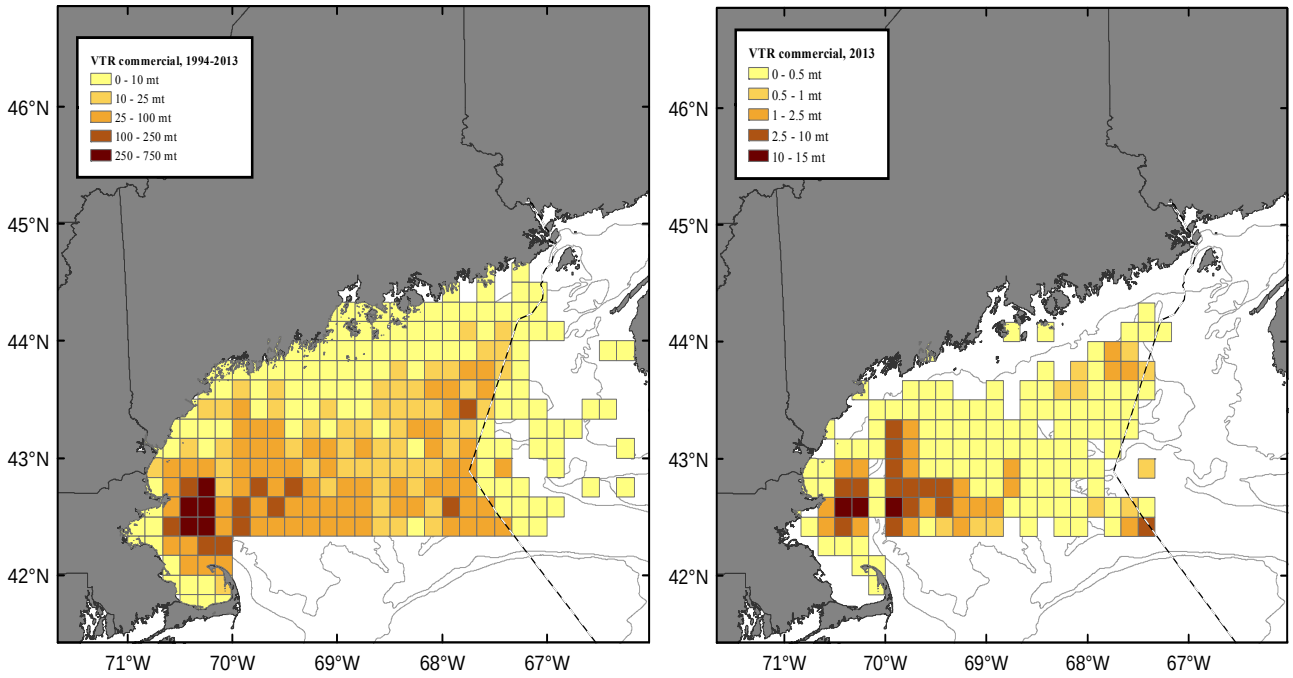


Figure A.32. Comparison of the distribution of Gulf of Maine haddock commercial landings per ten minute square in 2013 (right) to the aggregate distribution from 1994 to 2013 (right).

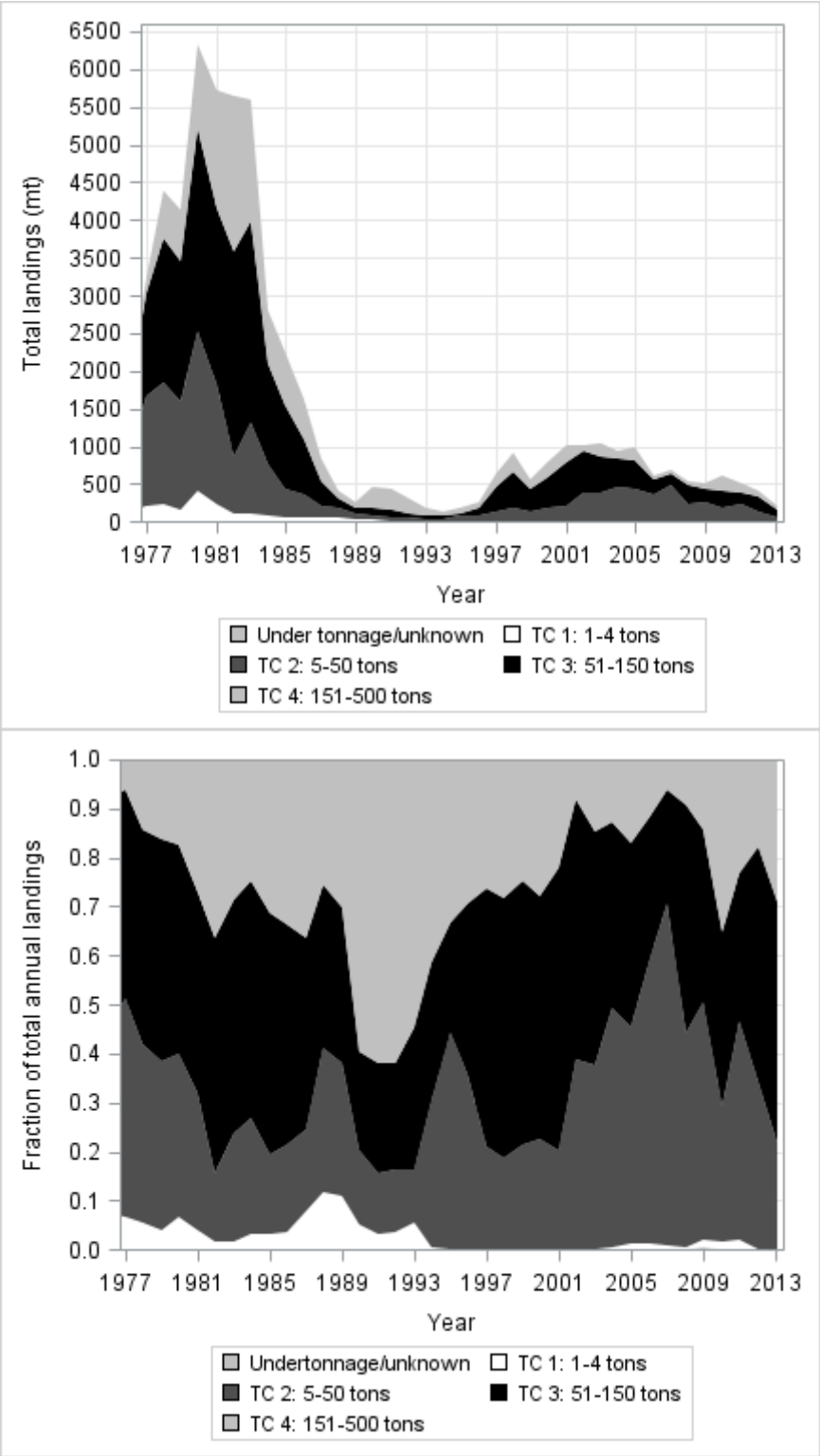


Figure A.33. Total (top) and fractional (as a fraction of the total, bottom) commercial landings of Gulf of Maine haddock by vessel ton class from 1977 to 2013.

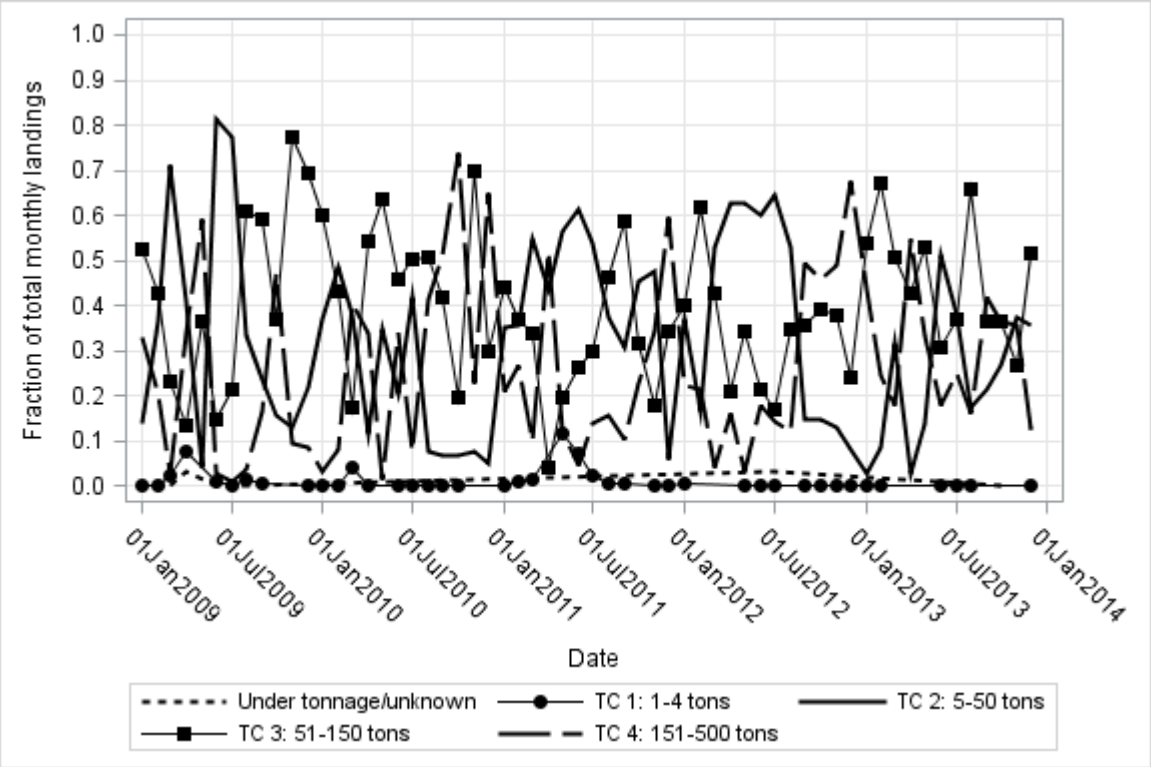


Figure A.34. Monthly commercial landing patterns (as a fraction of the total landings) of Gulf of Maine haddock by ton class from 2009 to 2013.

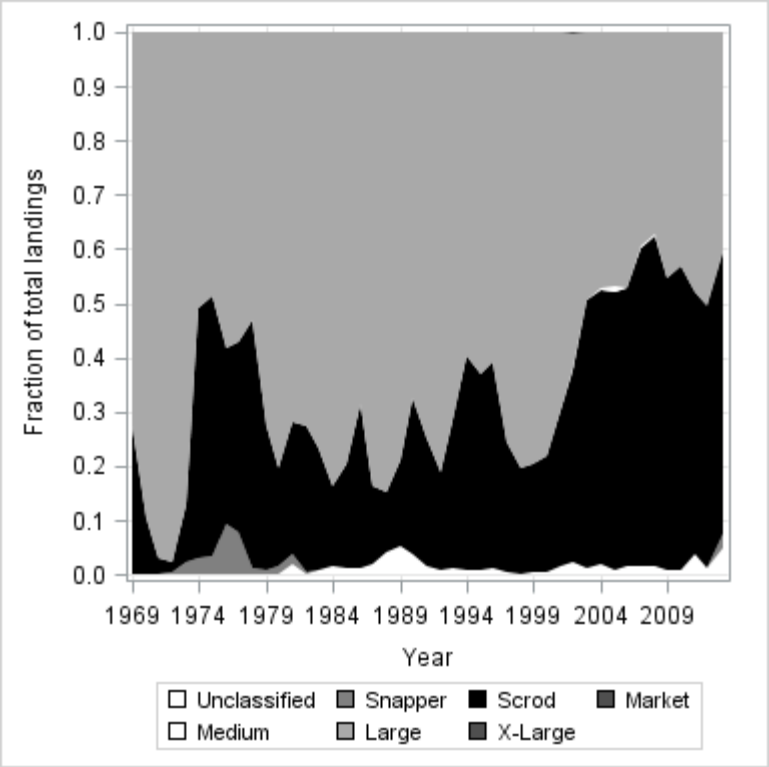


Figure A.35. Fraction of commercial landings of Gulf of Maine haddock by market category from 1969 to 2013.

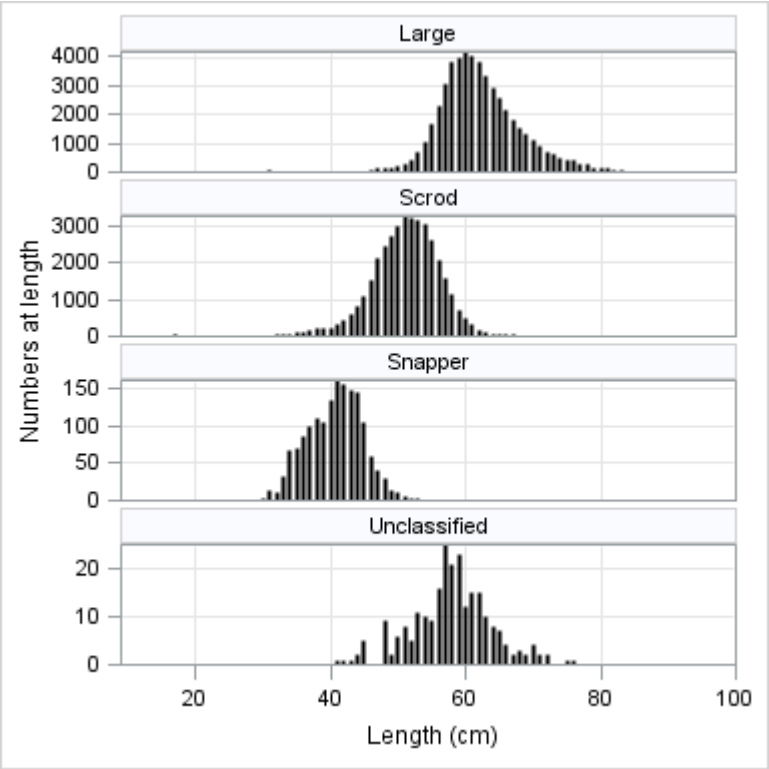


Figure A.36. Length frequency distributions of all reported market categories of Gulf of Maine haddock. Length frequency information has been binned across all years, 1969-2013. *Note that the scales of the y-axis vary by market category.*

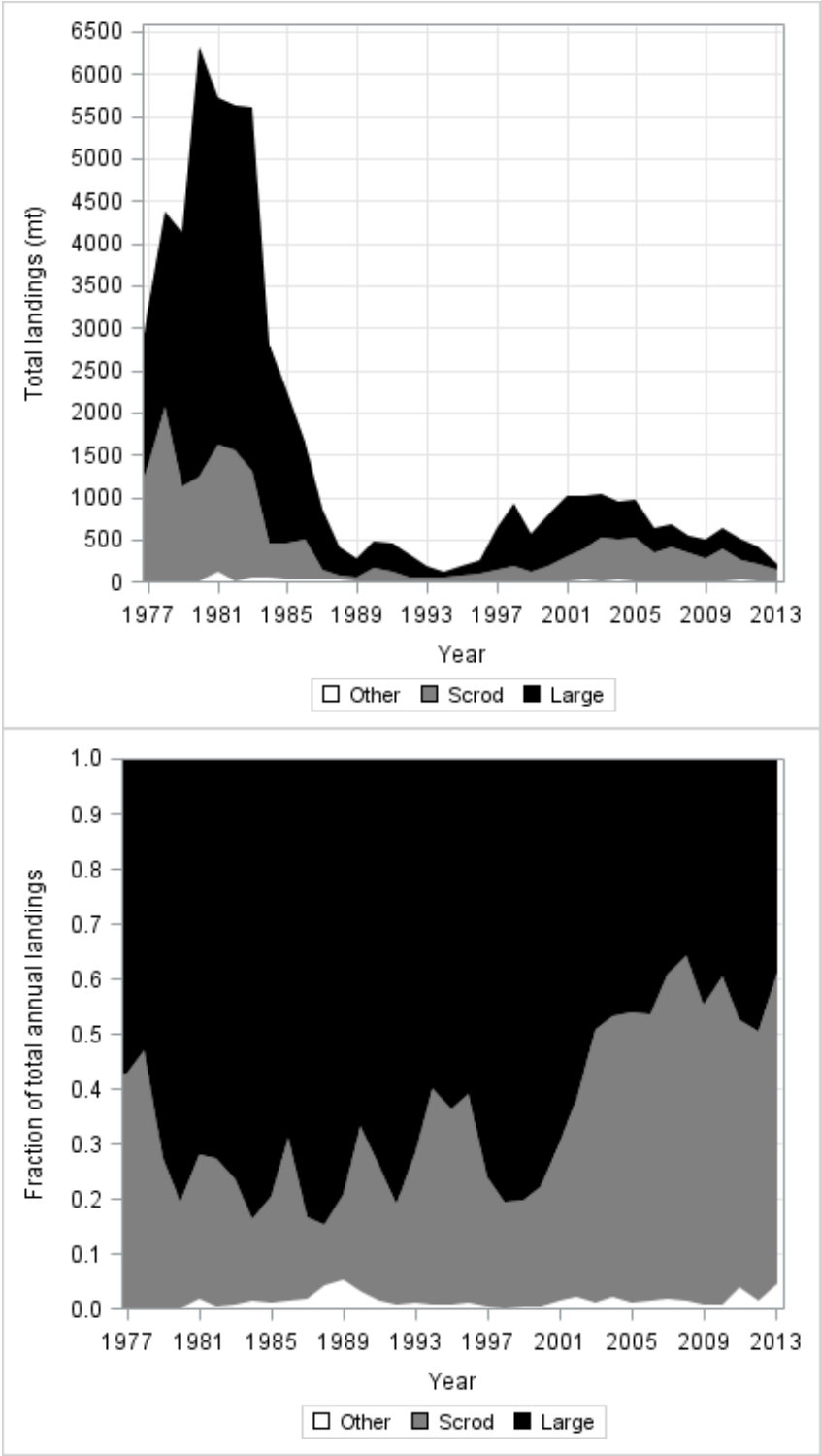


Figure A.37. Total (top) and fractional (as a fraction of the total, bottom) commercial landings of Gulf of Maine haddock by market category from 1977 to 2013. *Note that the snapper and extra-large market categories have been combined with the scrod and large market categories, respectively.*

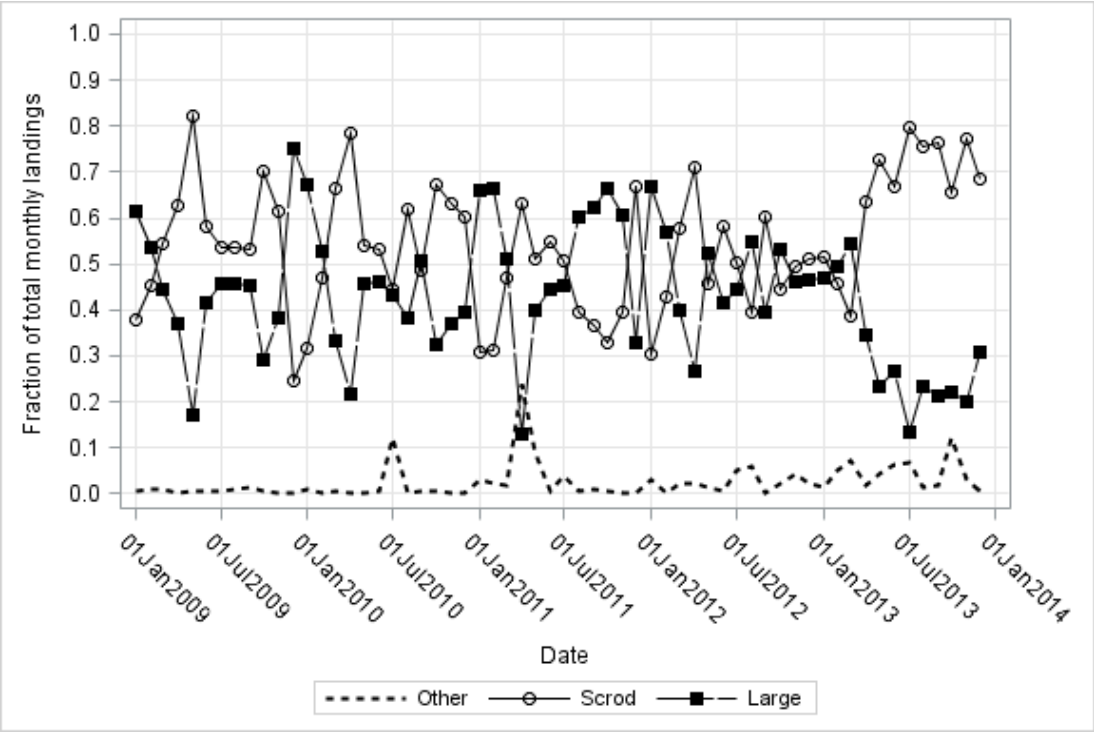


Figure A.38. Monthly commercial landing patterns (as a fraction of the total landings) of Gulf of Maine haddock by market category from 2009 to 2013. *Note that the snapper and extra-large market categories have been combined with the scrod and large market categories, respectively.*

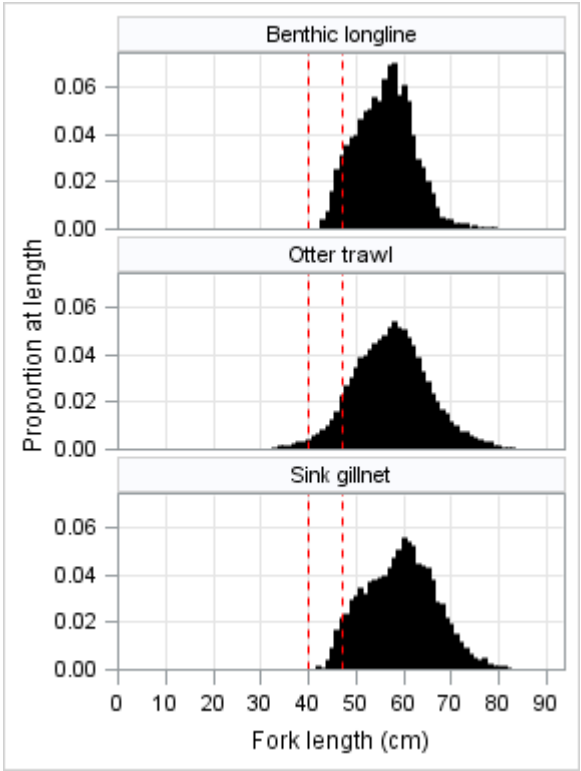


Figure A.39. Gear-specific frequency distributions of landed Gulf of Maine haddock lengths collected by port samplers between 1989 and 2013. The range of commercial minimum retention sizes over the time period is indicated by the dashed red lines.

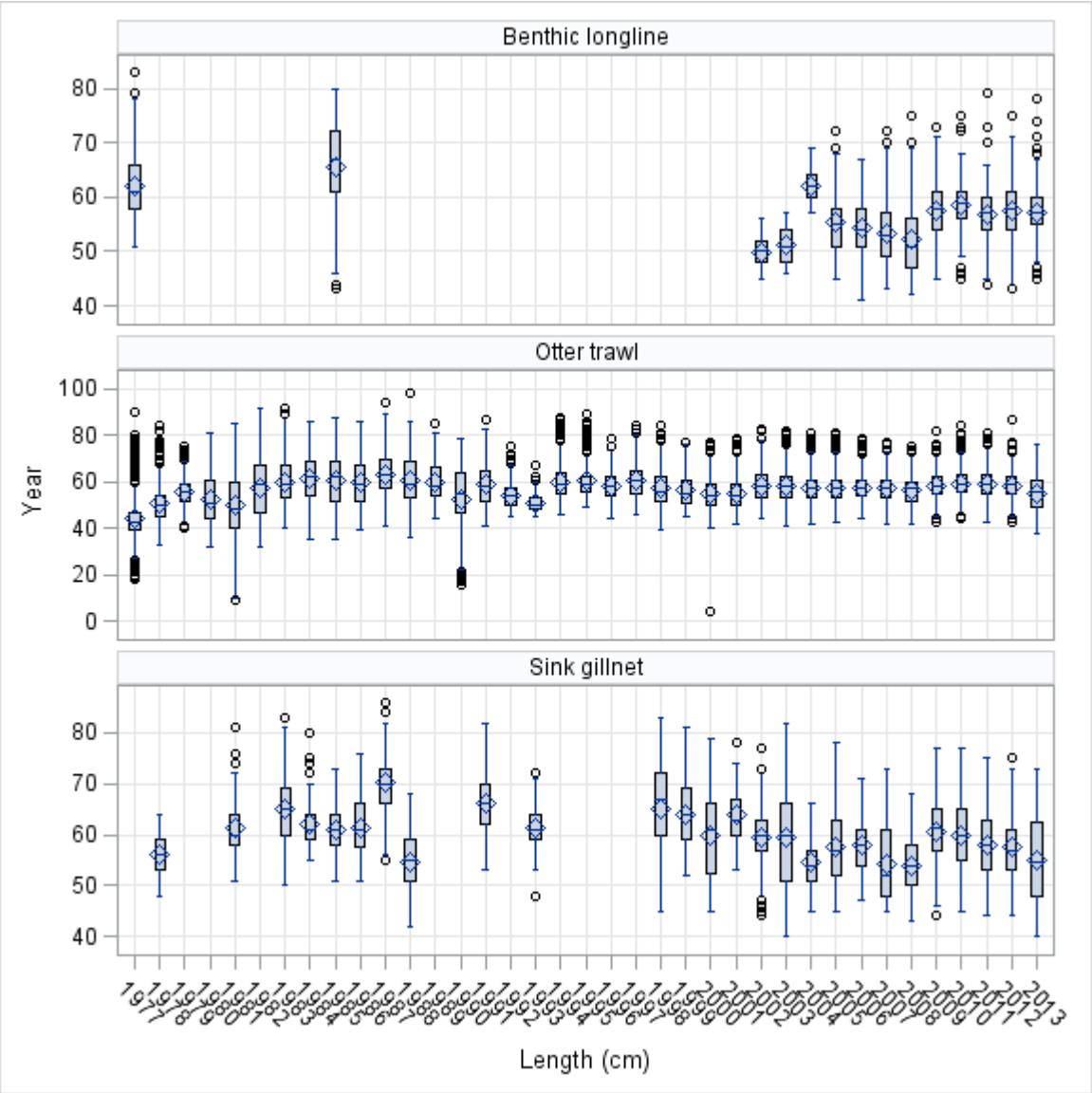


Figure A.40. Box plots showing the length distribution of Gulf of Maine haddock landed by the commercial fishery, by gear type, between 1989 and 2013. Missing years indicate that there were no sampled landings for that gear/year combination.

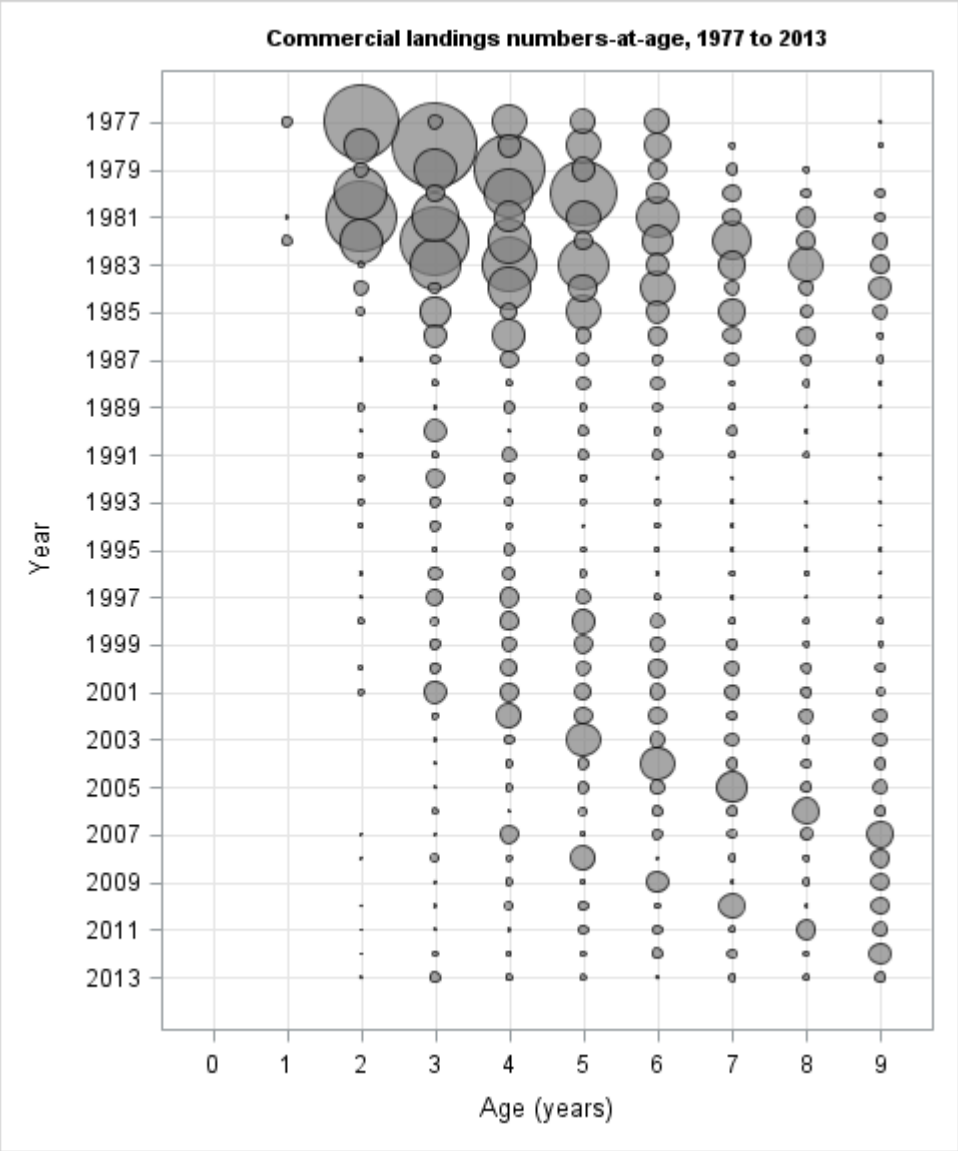


Figure A.41. Commercial landings-at-age of Gulf of Maine haddock from 1977 to 2013.

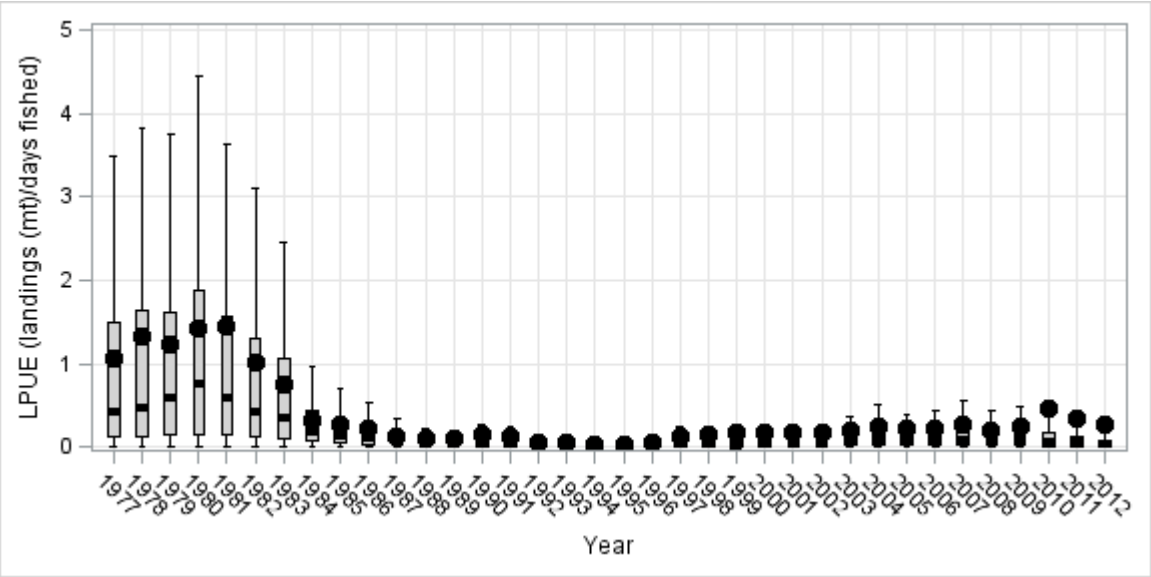


Figure A.42. Box-plot distributions of nominal Gulf of Maine haddock landings (mt) per days fished by the commercial trawl fishery from 1977 to 2012. Commercial dealer and vessel trip report data were used in this analysis and only includes trips that reported landing Gulf of Maine haddock. *Note that commercial dealer data were only available through 2012 at the time of the LPUE analysis.*

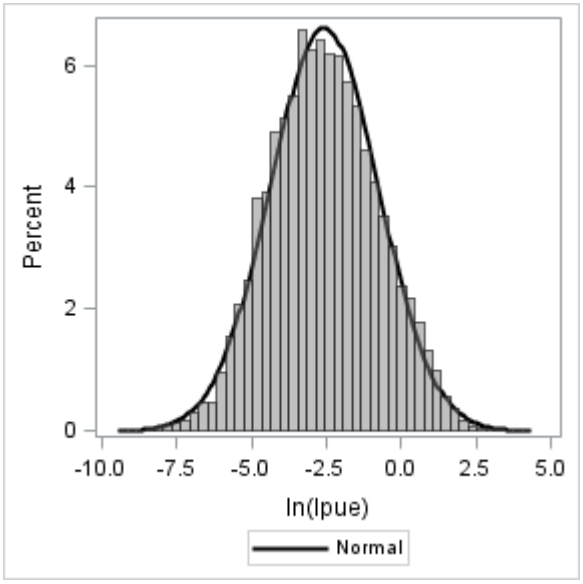


Figure A.43. Distribution of log transformed nominal commercial trawl LPUE.

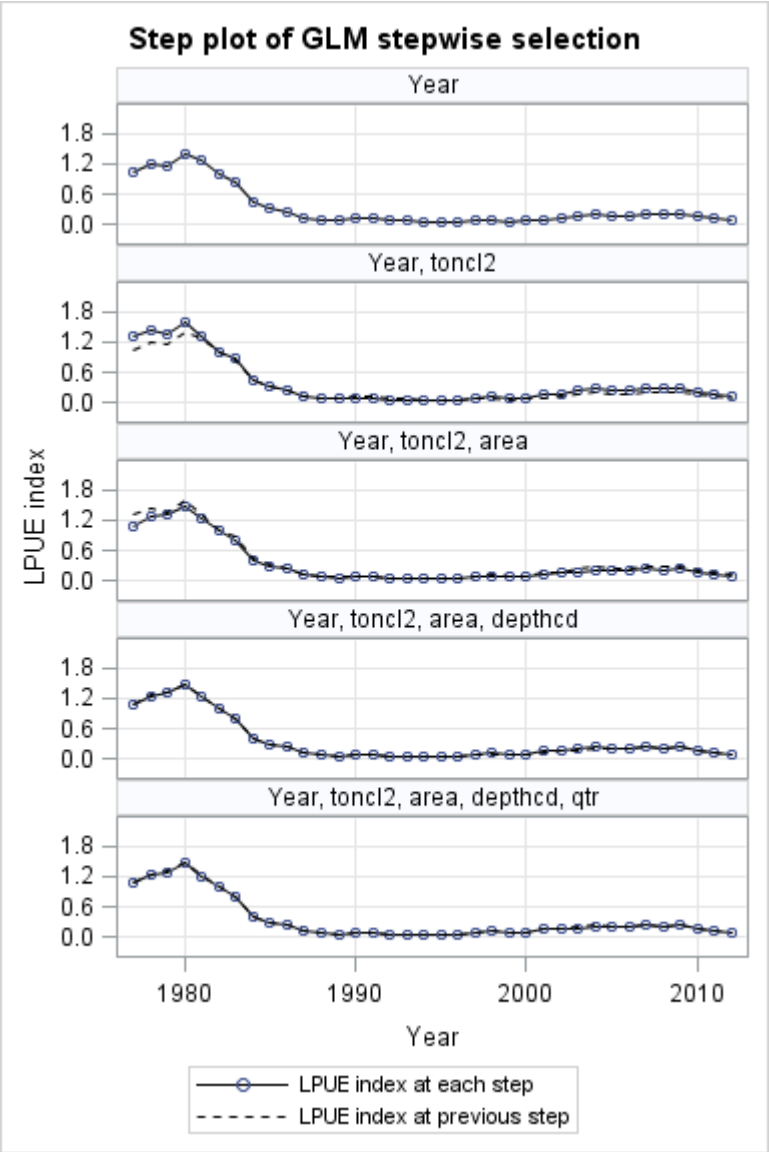


Figure A.44. Step plot of the commercial trawl landings-per-unit-effort (LPUE) standardization model. Each panel shows the standardized abundance index as explanatory variables are added to the model through stepwise selection. The index from previous step is indicated with a dashed line.

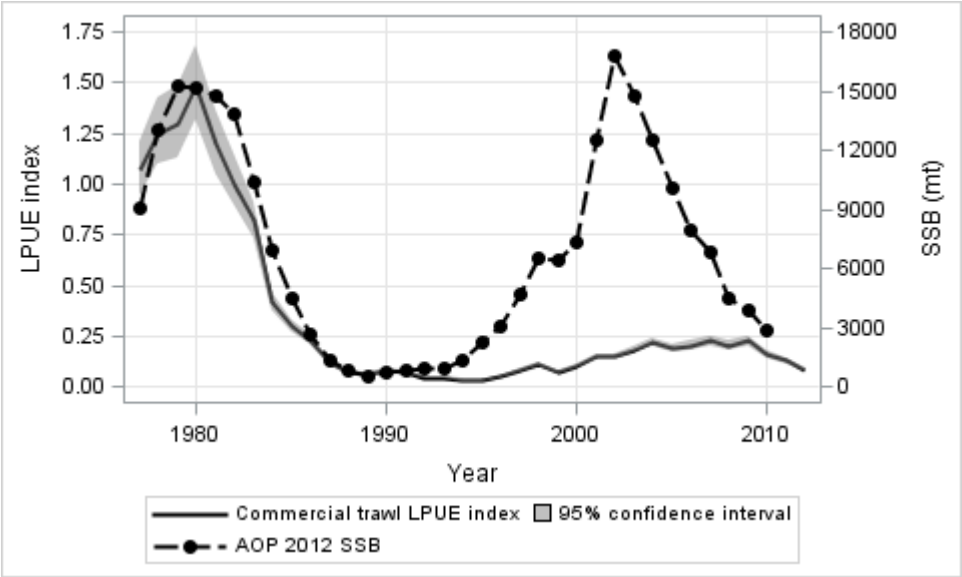


Figure A.45. Time series of the commercial trawl LPUE index overlaid on the spawning stock biomass (SSB) estimate from the AOP 2012 assessment from 1977 to 2012. *Note that the AOP 2012 SSB estimates only extends through 2010 and commercial data were only available through 2012 at the time of the LPUE analysis.*

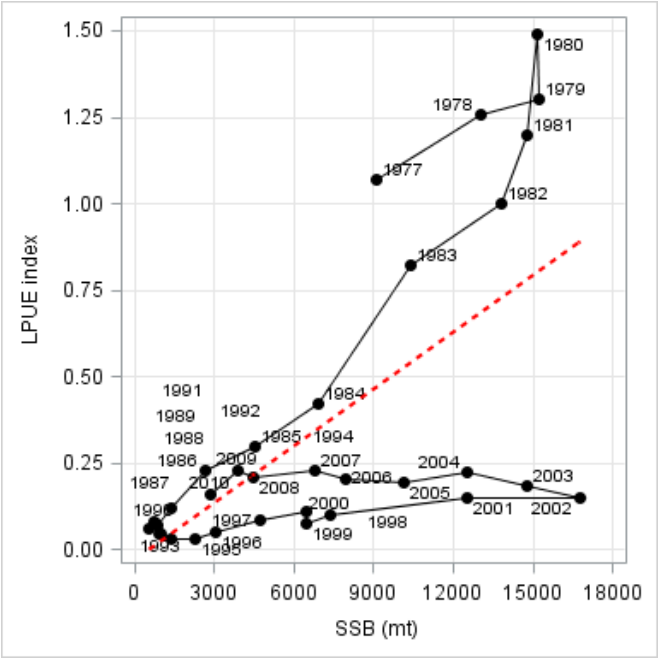


Figure A.46. Linear regression of the commercial trawl LPUE index on the spawning stock biomass (SSB) estimate from the AOP 2012 assessment.

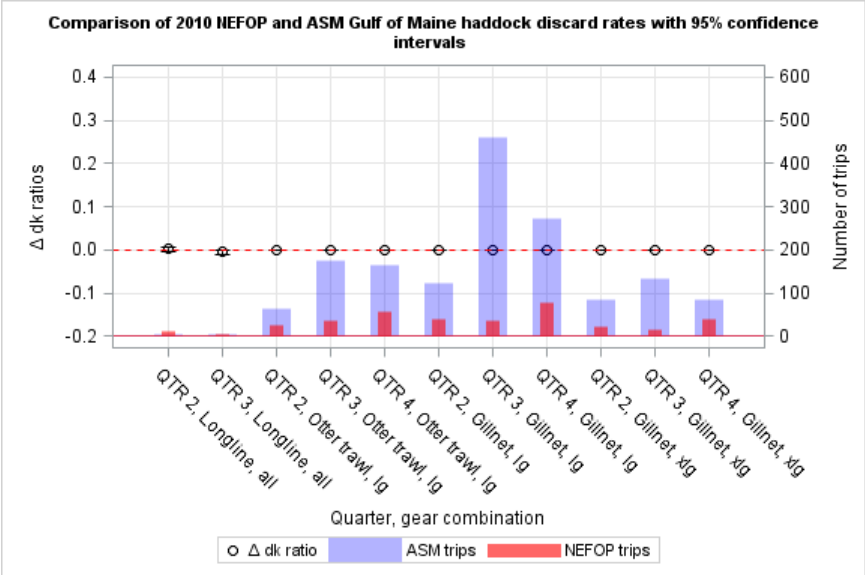


Figure A.47. Differences between the 2010 Gulf of Maine haddock discard rates estimated from data collected by groundfish at-sea monitors (ASMs) and certified observers showing 95% confidence intervals (dots) and the number of trips included in each analysis (bars) broken down by gear-mesh combination and quarter (adapted from Wigley et al. 2012).

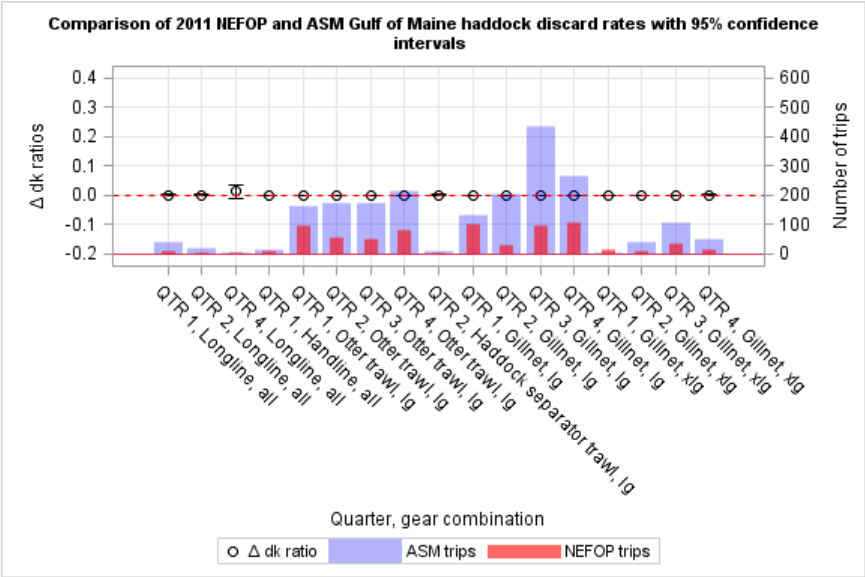


Figure A.48. Differences between the 2011 Gulf of Maine haddock discard rates estimated from data collected by groundfish at-sea monitors (ASMs) and certified observers showing 95% confidence intervals (dots) and the number of trips included in each analysis (bars) broken down by gear-mesh combination and quarter (adapted from Wigley et al. 2012).

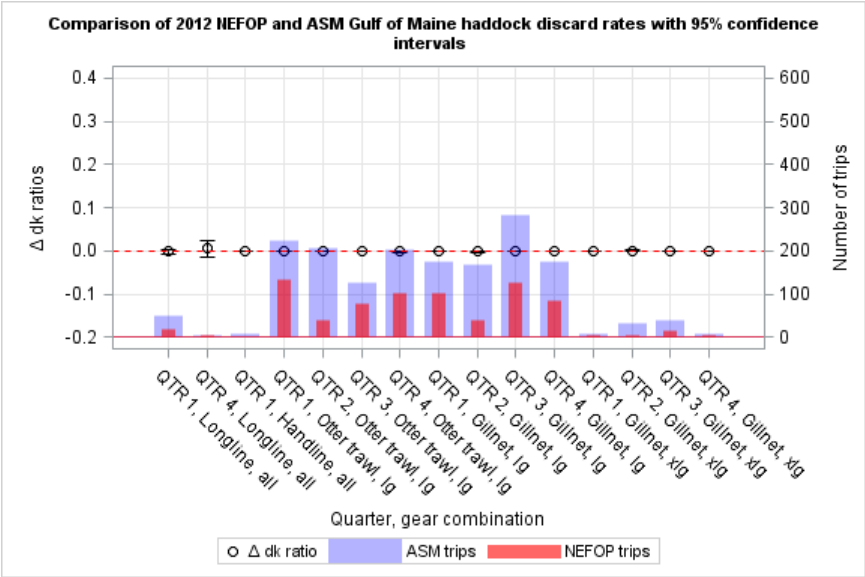


Figure A.49. Differences between the 2012 Gulf of Maine haddock discard rates estimated from data collected by groundfish at-sea monitors (ASMs) and certified observers showing 95% confidence intervals (dots) and the number of trips included in each analysis (bars) broken down by gear-mesh combination and quarter (adapted from Wigley et al. 2012).

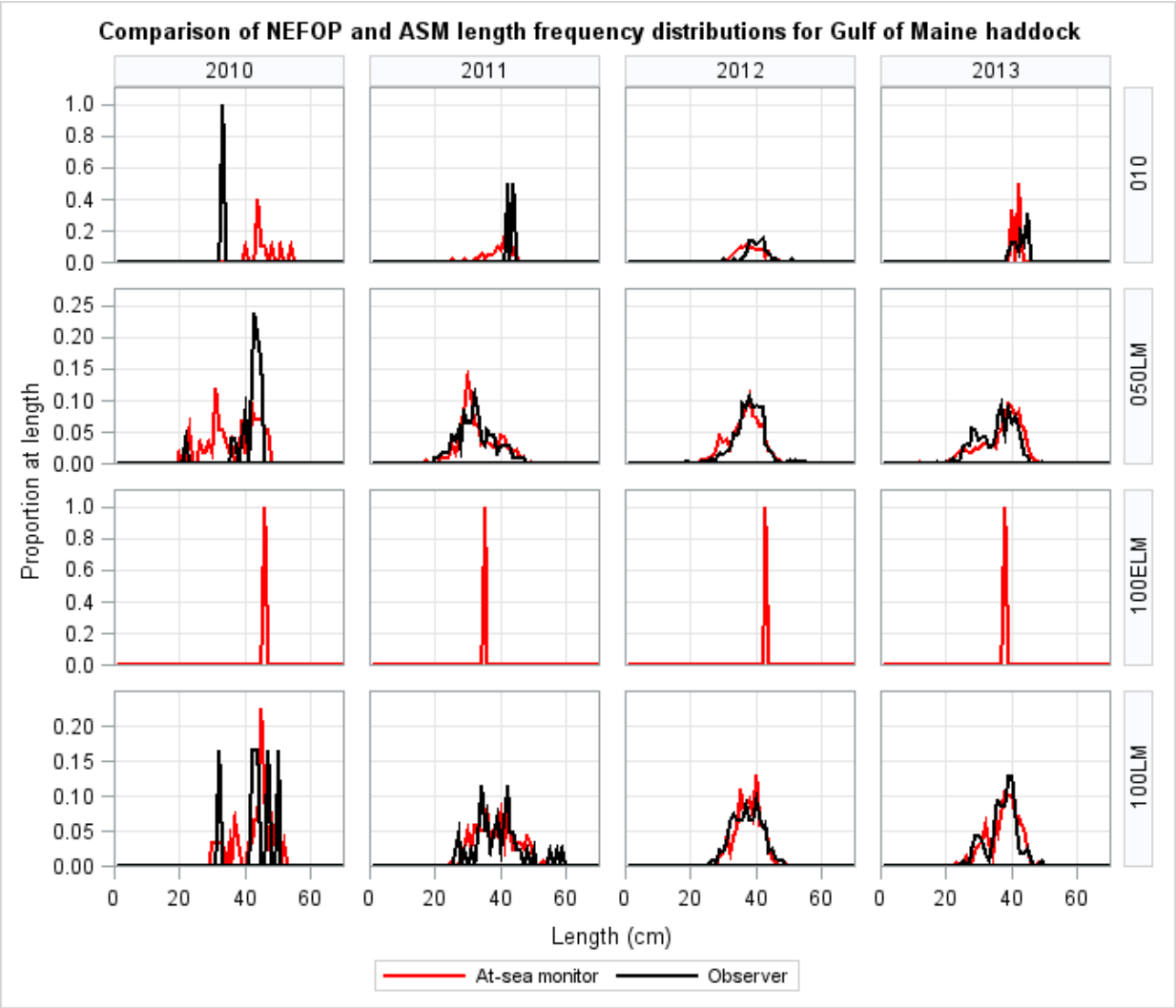


Figure A.50. Length frequency distributions of Gulf of Maine haddock commercials discards estimated from data collected by groundfish at-sea monitors (ASMs) and certified observers between 2010 and 2013. The gear codes displayed on the right hand axis are: longline (010), large mesh otter trawl (050LM), extra-large mesh sink gillnet (100ELM), large-mesh sink gillnet (100LM).

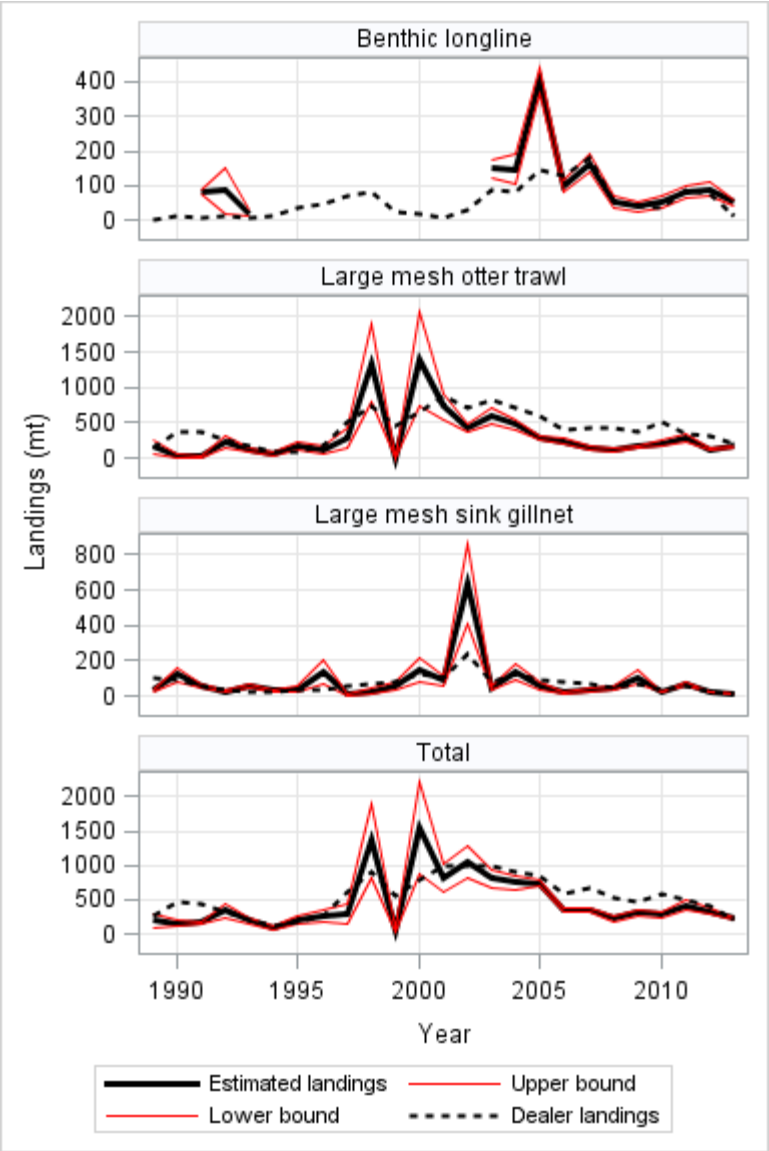


Figure A.51. Comparison of Gulf of Maine haddock landings estimates generated using the Standardized Bycatch Reporting Methodology (SBRM, Wigley et al. 2007) combined ratio approach to the stock landings from the Commercial Fisheries Database AA tables. Landings are shown only for longline, gillnet and otter trawl gears. The comparison provides a cross validation of both the discard estimation and landings allocation procedure.

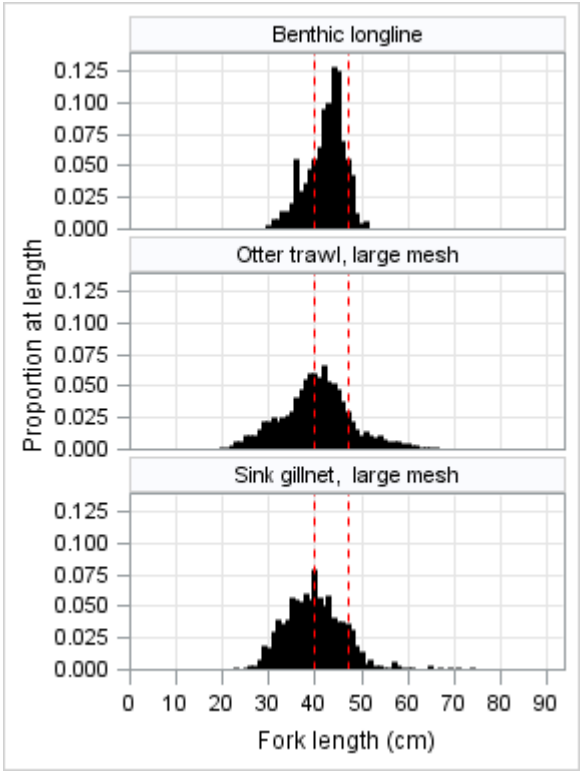


Figure A.52. Gear-specific frequency distribution of discarded Gulf of Maine haddock lengths collected by at-sea observers between 1989 and 2013. The range of commercial minimum retention sizes over the time period is indicated by the dashed red lines.

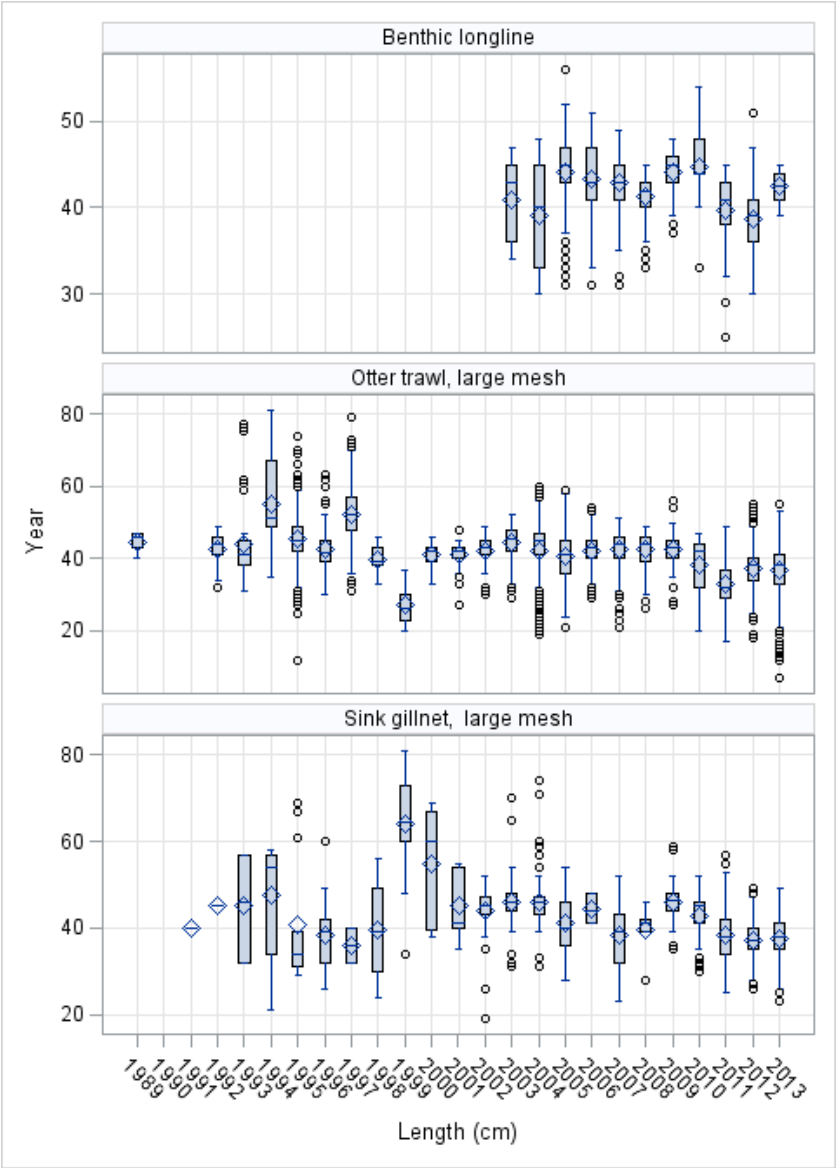


Figure A.53. Box plots showing the length distribution of Gulf of Maine haddock discarded by the commercial fishery by gear type between 1989 and 2013. Missing years indicate that there were either no observed trips for that gear in the Gulf of Maine or no haddock were observed to have been discarded.

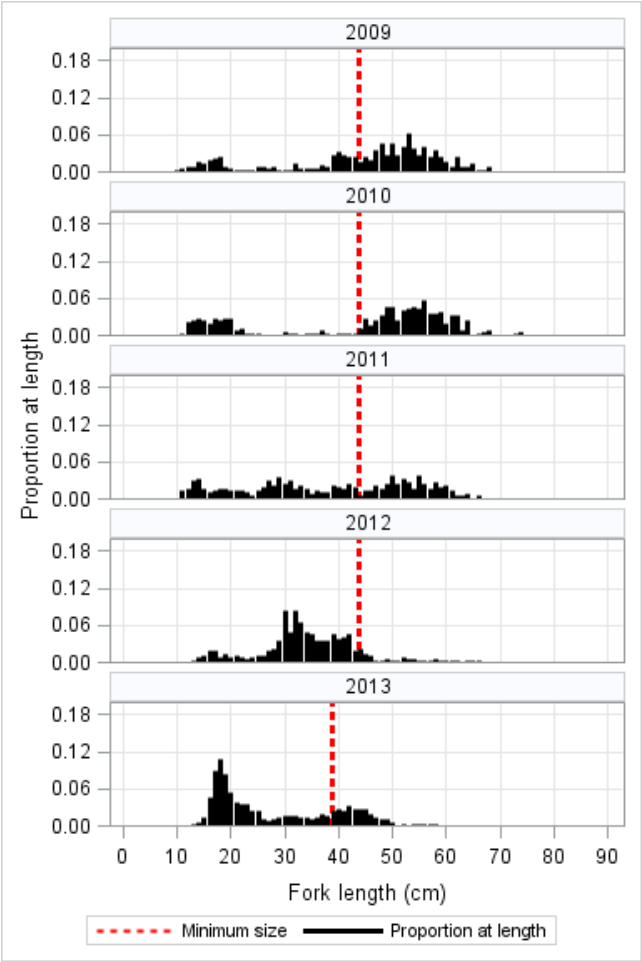


Figure A.54. Frequency distribution of Gulf of Maine haddock lengths collected from Northeast Fisheries Science Center (NEFSC) bottom trawl surveys between 2009 and 2013. The commercial minimum retention size for the specific year is indicated by the dashed red line.

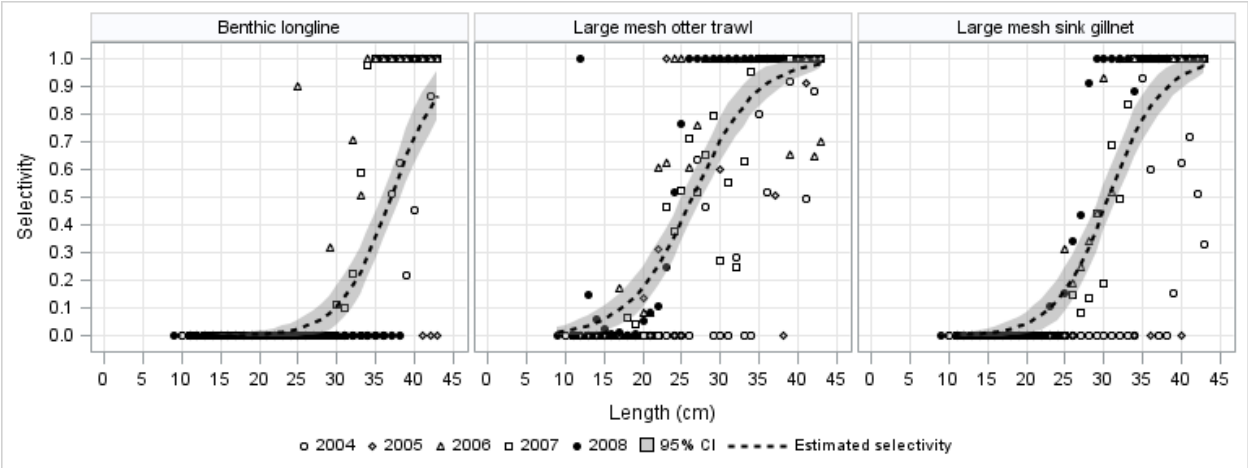


Figure A.55. Estimated selectivity ogives for benthic longline, large mesh (5.5” – 7.9”) otter trawl and sink gillnet and the corresponding 95% confidence intervals (CI) for Gulf of Maine haddock. Selectivity ogives were estimated from the logistic fits to the aggregated annual estimates of selectivity-at-length.

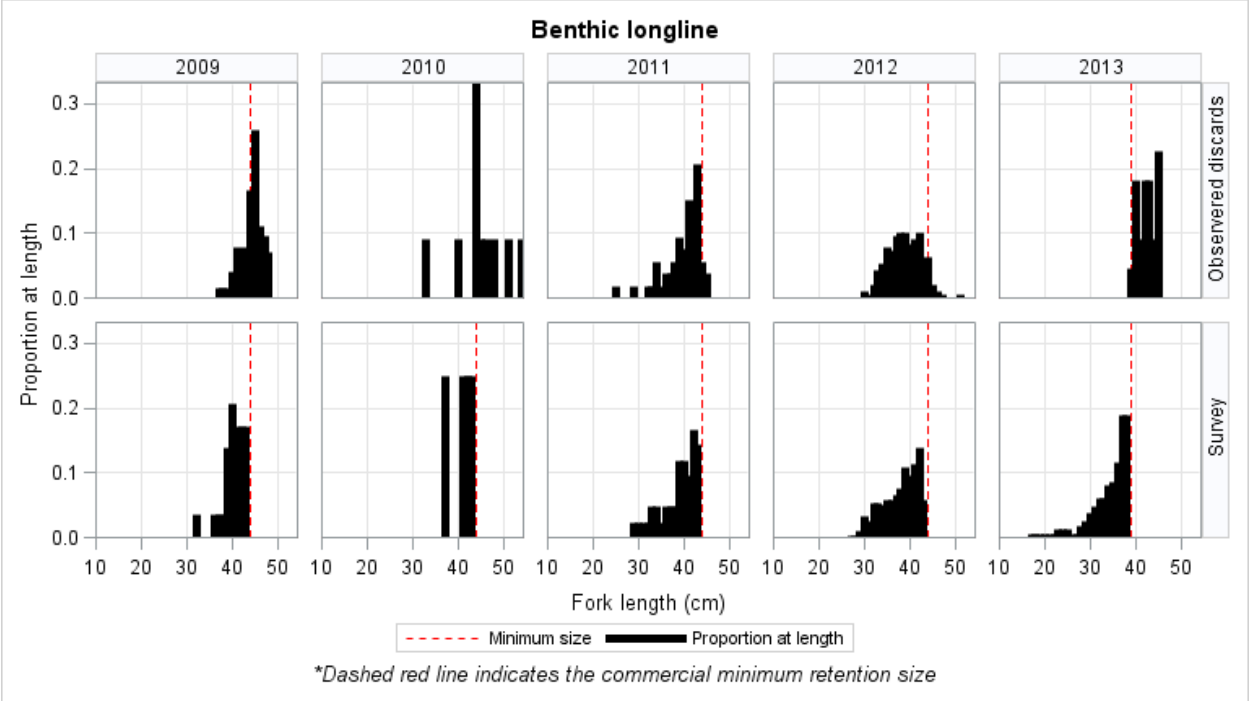


Figure A.56. Comparison of the survey filter-based estimates of discards-at-length for benthic longline gear to the direct observer observations from 2009 to 2013 for Gulf of Maine haddock. The dashed red line represents the commercial minimum retention size for the specific year.

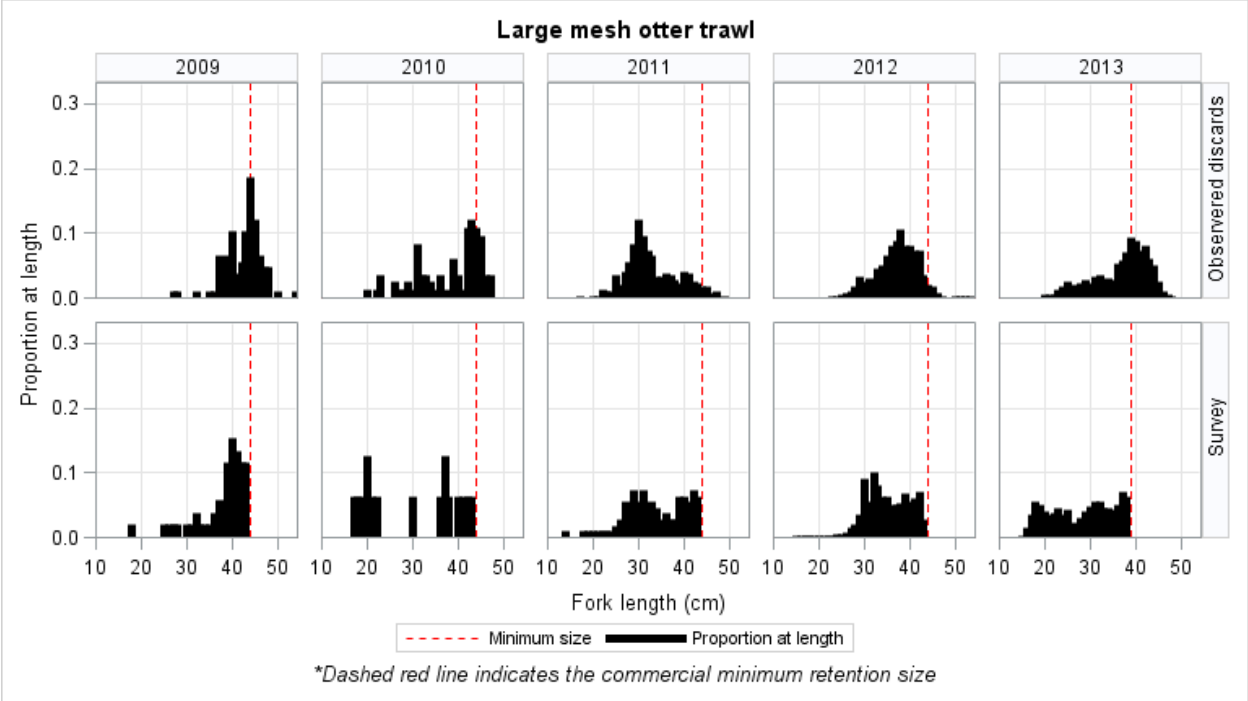


Figure A.57. Comparison of the survey filter-based estimates of discards-at-length for large mesh (5.5" – 7.9") otter trawl gear to the direct observer observations from 2009 to 2013 for Gulf of Maine haddock. The dashed red line represents the commercial minimum retention size for the specific year.

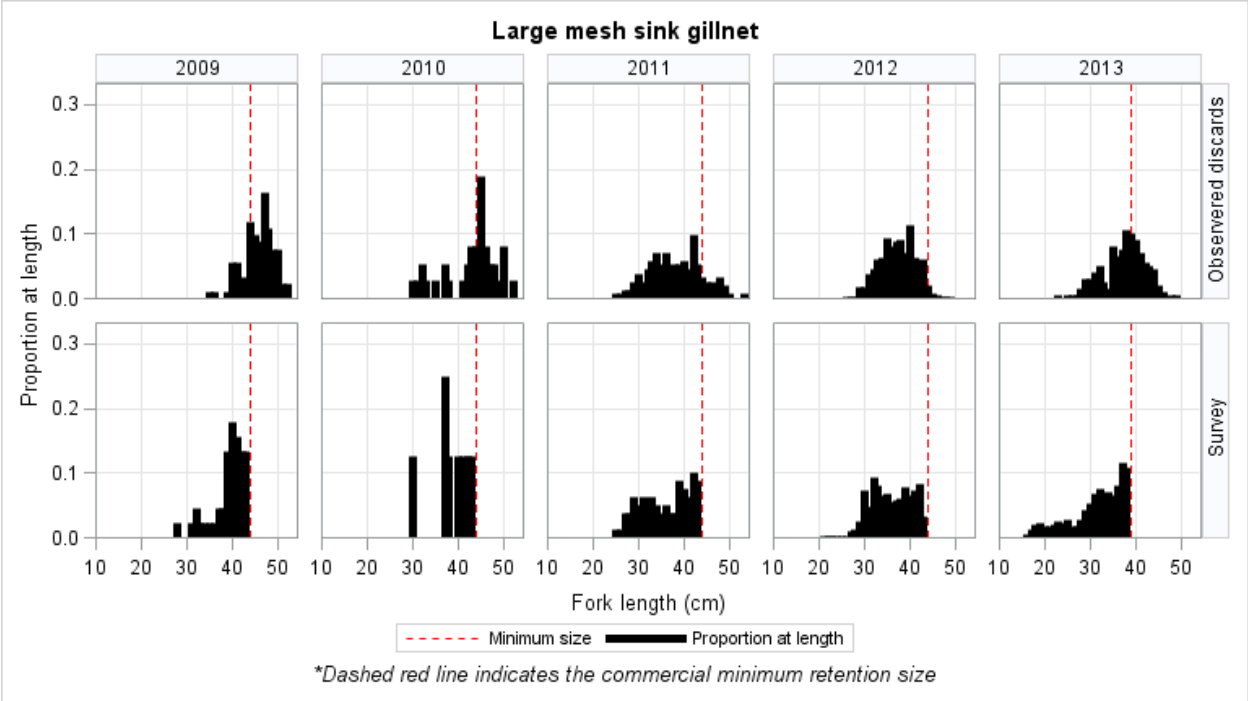


Figure A.58. Comparison of the survey filter-based estimates of discards-at-length for large (5.5" – 7.9") mesh sink gillnet gear to the direct observer observations from 2009 to 2013 for Gulf of Maine haddock. The dashed red line represents the commercial minimum retention size for the specific year.

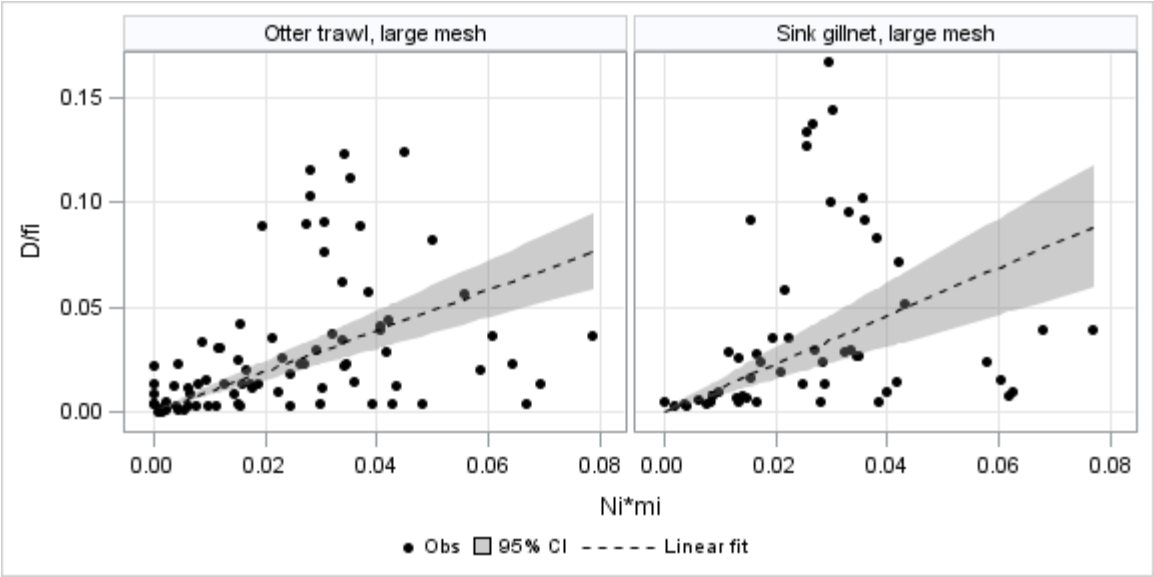


Figure A.59. Plots of the relationship by gear type between fraction of Gulf of Maine haddock observed discarded-at-length (D_i/f) and the estimated number at length from the survey-filter method ($N_i \bullet m_i$) for large mesh (5.5” – 7.9”) otter trawl and large mesh (5.5” – 7.9”) sink gillnet gear. The slope of the relationship (q) is the proportionality constant required to expand the survey-filter estimates of numbers-at-length to estimates of total discards-at-length.

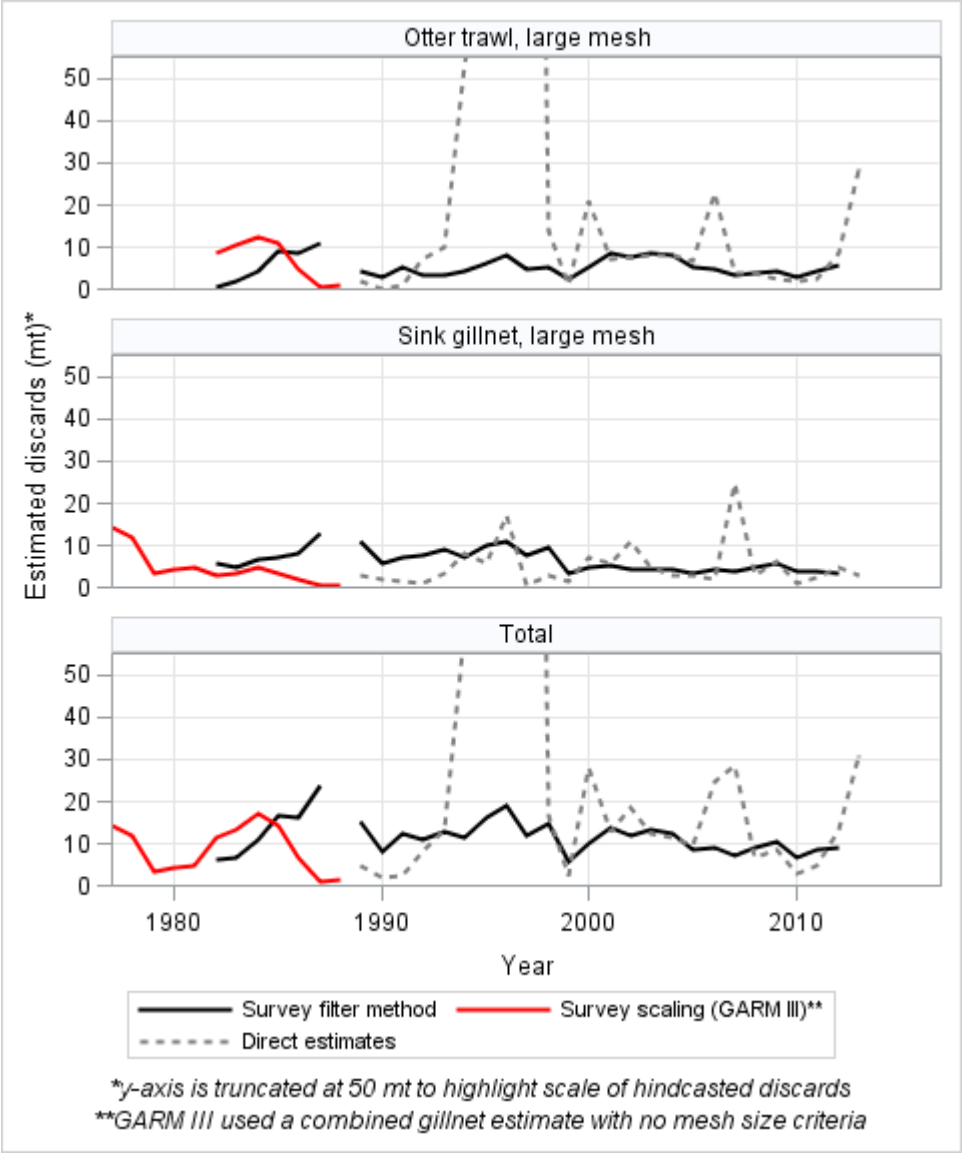


Figure A.60. Comparison of Gulf of Maine haddock discard estimates for large mesh (5.5" – 7.9") otter trawl and sink gillnet gears calculated using the survey-filter hindcast method to the survey scaling method used in GARM III and the direct estimates obtained from 1989 to 2013. *Note that the y-axis has been truncated at 50 mt to preserve scale.*

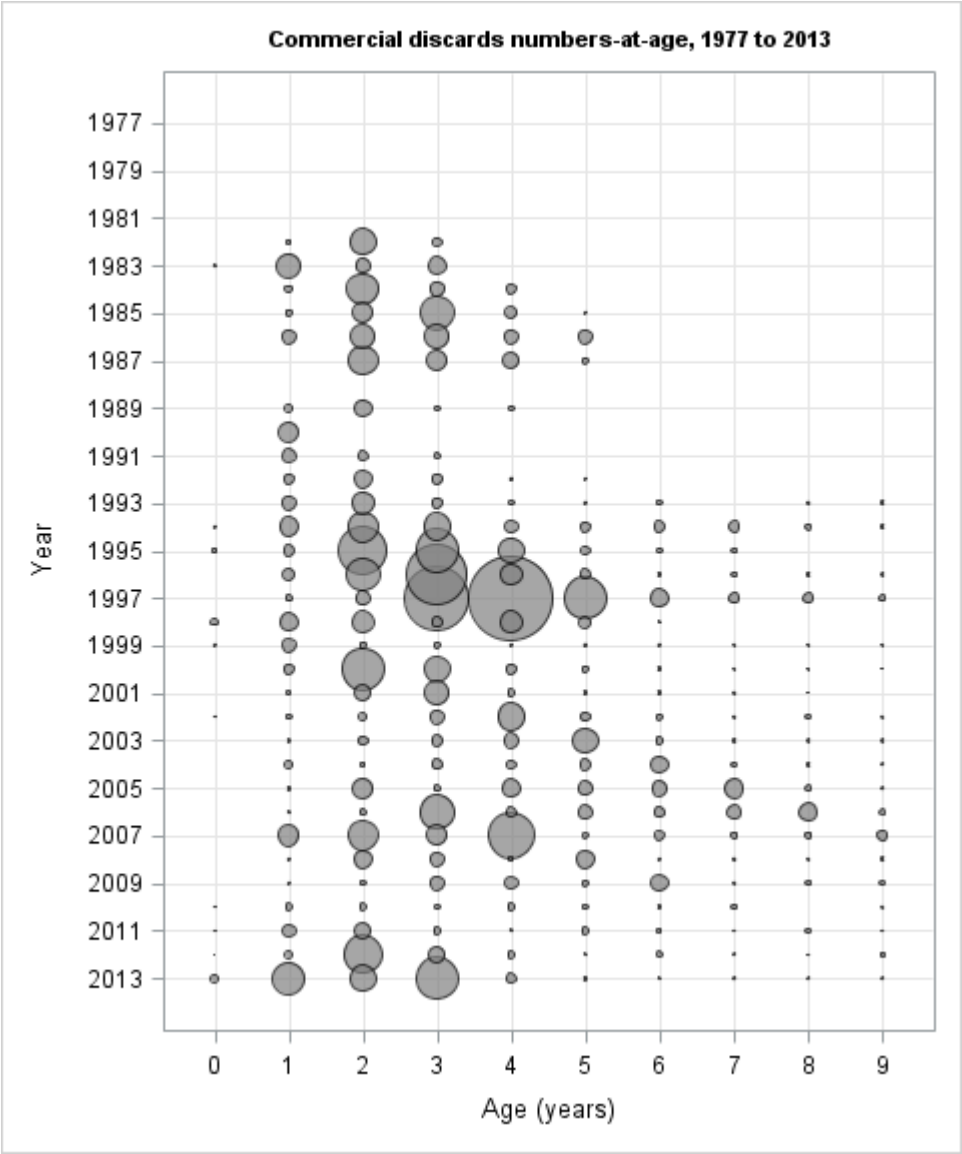


Figure A.61. Commercial discards-at-age of Gulf of Maine haddock from 1977 to 2013. *Note that commercial discards were not estimated pre-1982.*

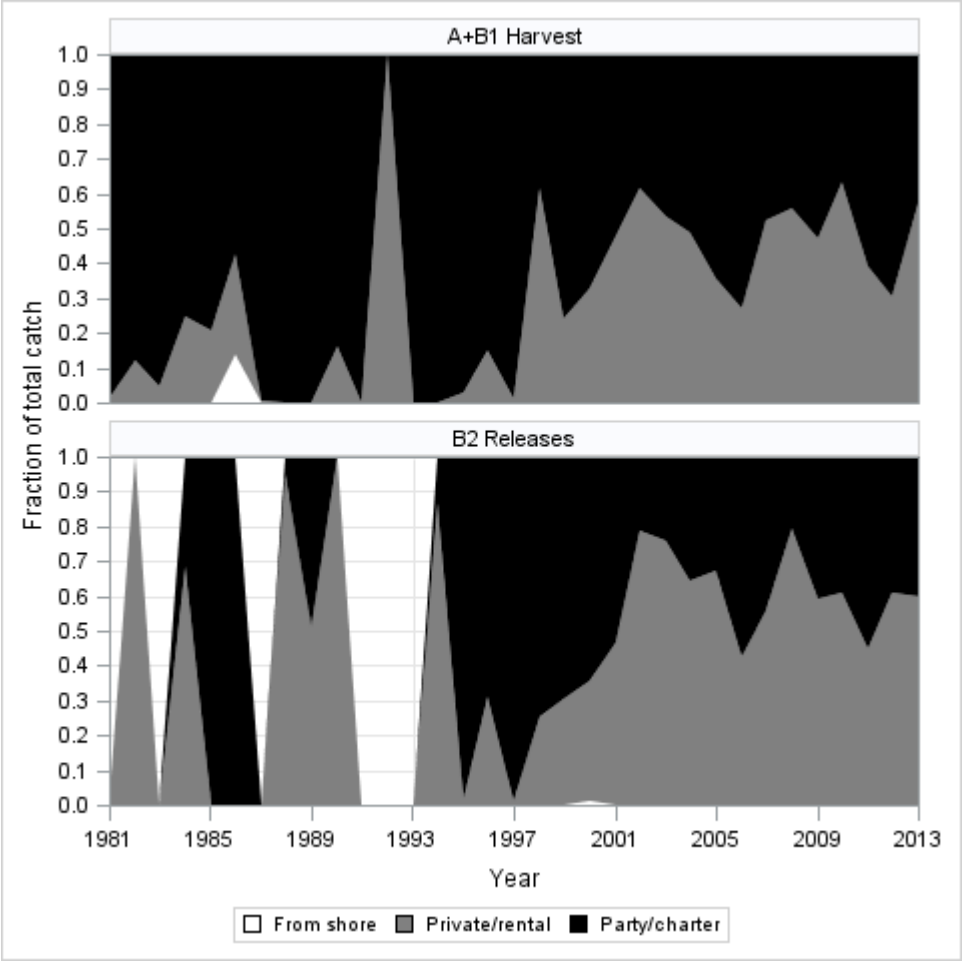


Figure A.62. Fractional distribution of recreational catch of Gulf of Maine haddock by fishing model based on MRFSS/MRIP data.

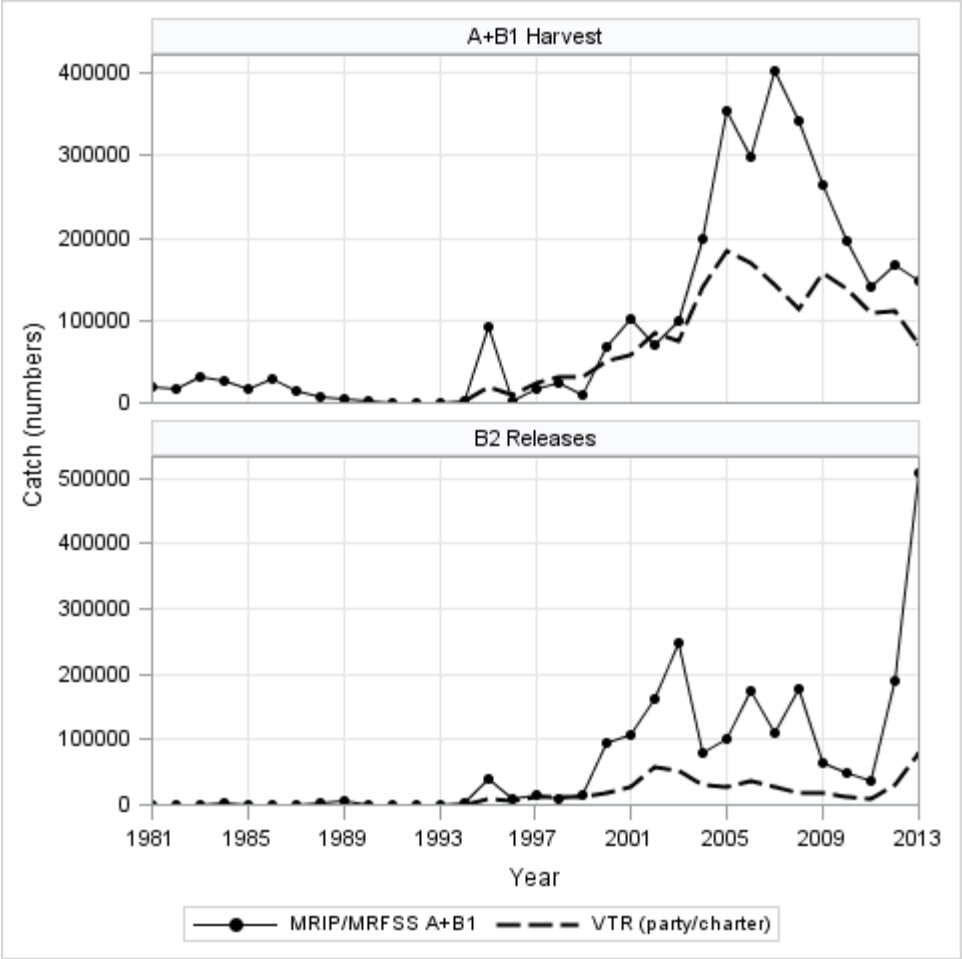


Figure A.63. Comparison of Gulf of Maine haddock recreational harvest (landings) and releases (discards) estimates derived through the Marine Recreational Fisheries Statistics Survey (MRFSS)/Marine Recreational Information Program (MRIP) to recreational landings reported on vessel trip reports (VTRs) between 1981 and 2013. **Note: MRFSS/MRIP data collection began in 1981 and VTR data collection began in 1994.*

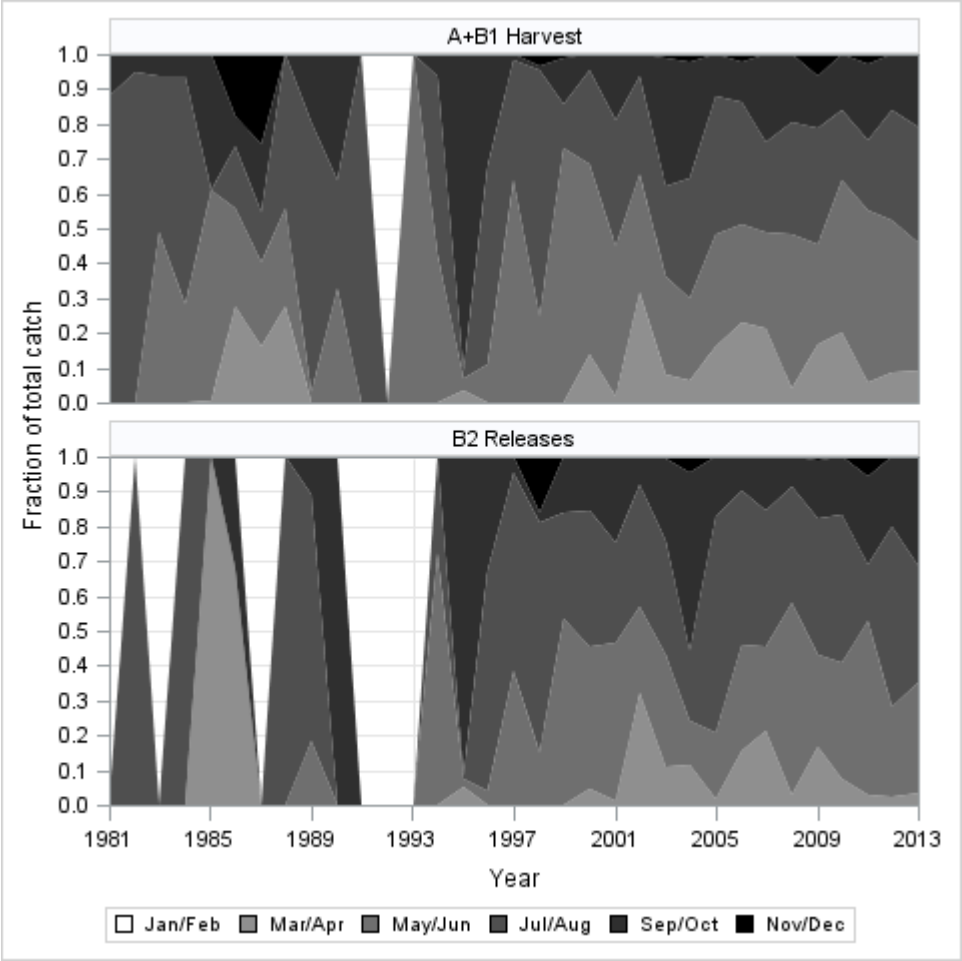


Figure A.64. Fractional distribution of recreational catch of Gulf of Maine haddock by wave (two month time blocks) based on vessel trip report (VTR) data.

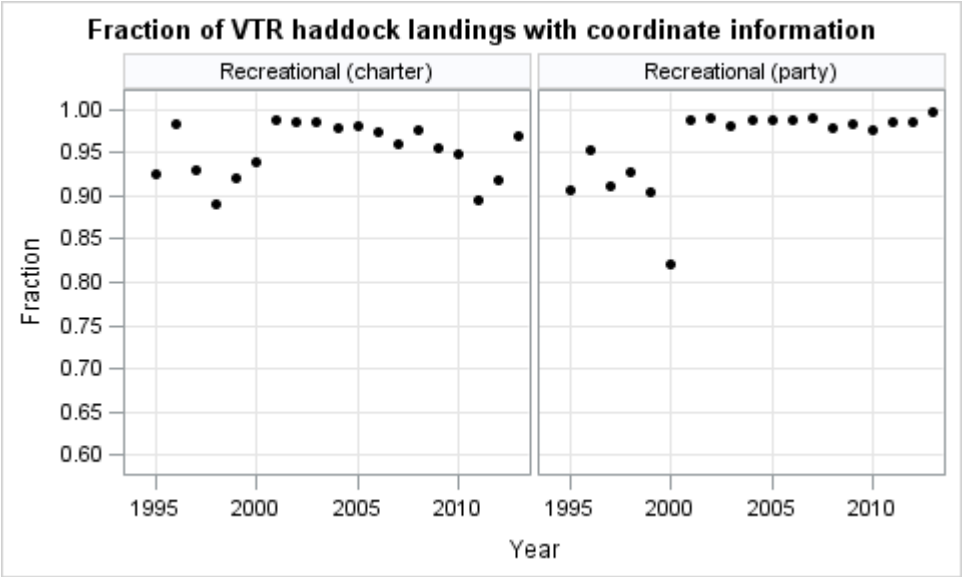


Figure A.65. Fraction of total Gulf of Maine haddock recreational landings reported on vessel trip reports (VTRs) with latitude and longitude coordinate information, by fleet from 1994 to 2013.

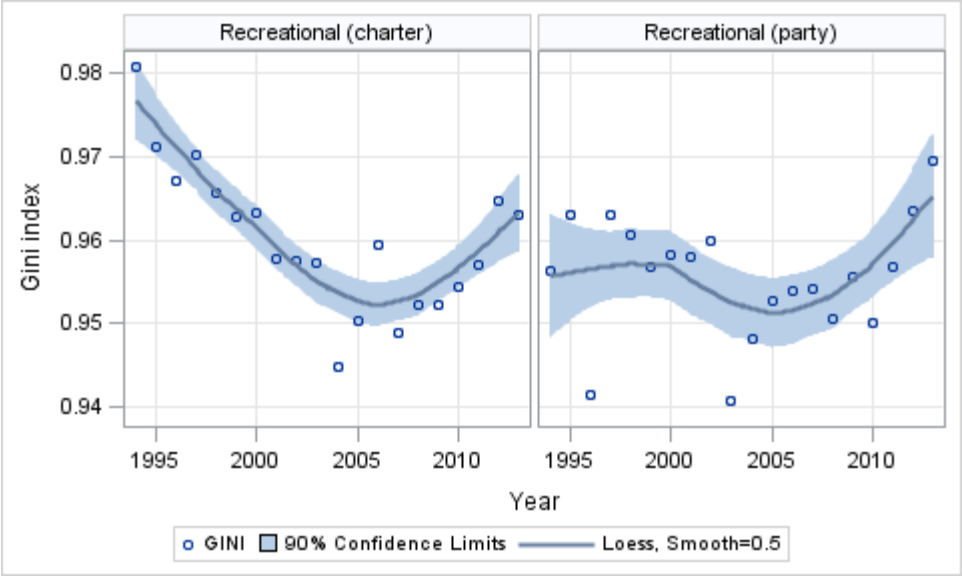


Figure A.66. Gini indices for the Gulf of Maine haddock for the recreational charter and party boat fleets from 1994 to 2013. Indices were based on the spatial distribution of the retained catch reported on vessel trip reports (VTRs).

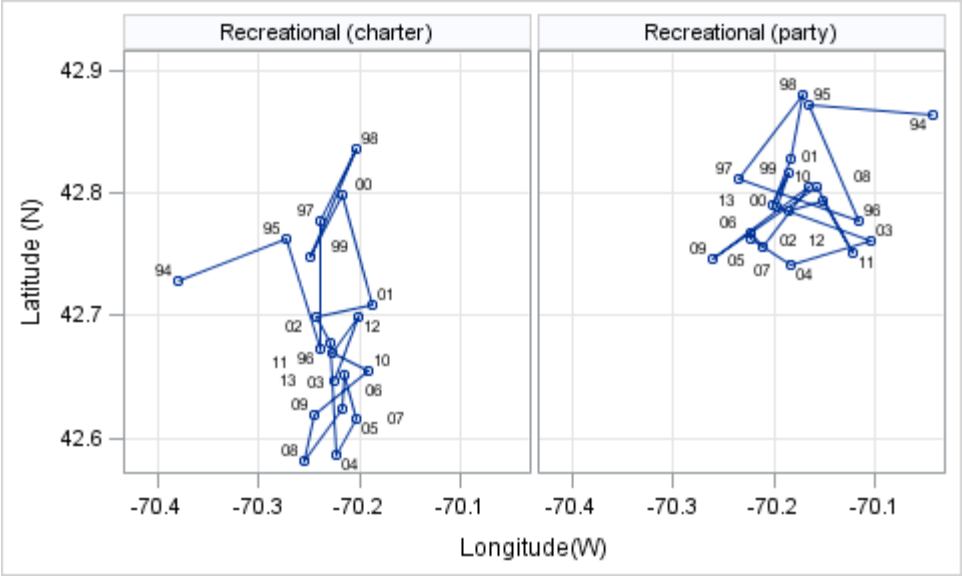


Figure A.67. Landings-weighted mean location (centroid) for the Gulf of Maine haddock recreational charter and party boat fleets from 1994 to 2013. Centroids were calculated using the spatial distribution of the retained catch reported on vessel trip reports (VTRs).

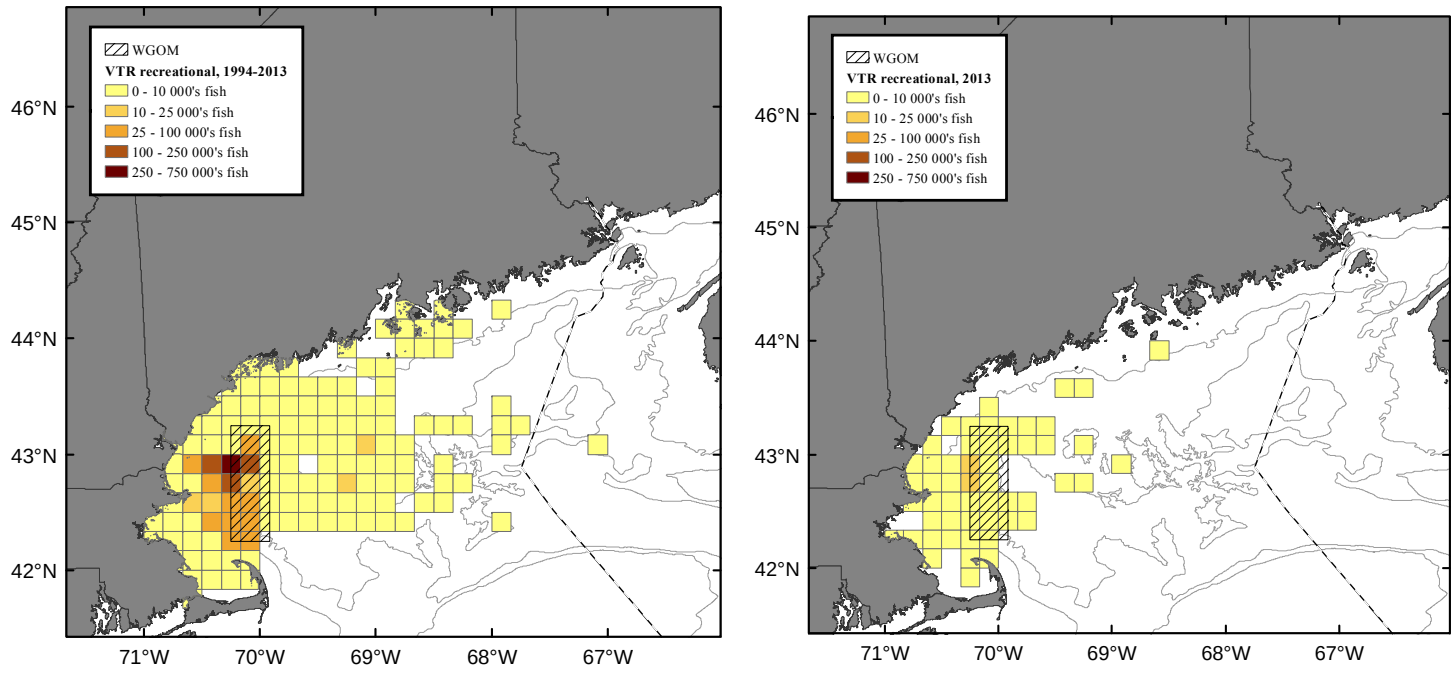


Figure A.68. Comparison of the distribution of Gulf of Maine haddock recreational landings per ten minute square in 2013 (right) to the aggregate distribution from 1994 to 2013 (left). The location of the Western Gulf of Maine (WGOM) closed area is indicated.

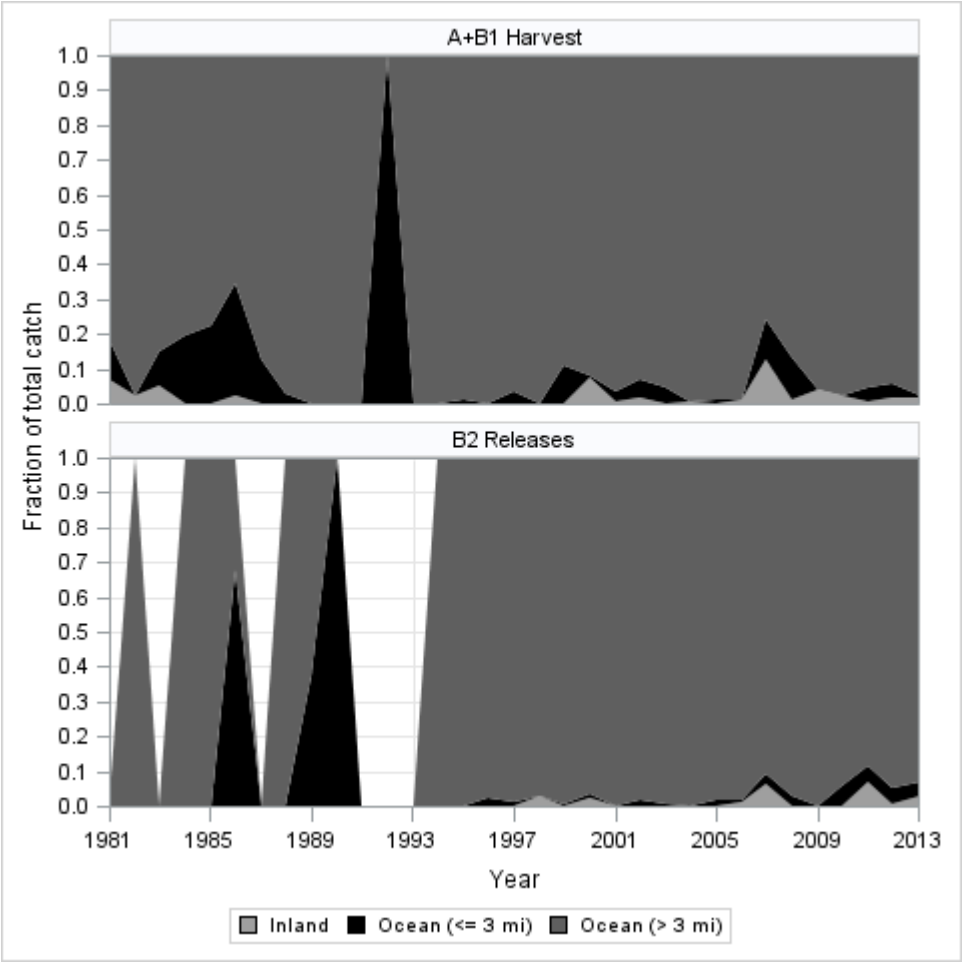


Figure A.69. Fractional distribution of recreational catch of Gulf of Maine haddock by fishing area. This summary uses MRFSS/MRIP data.

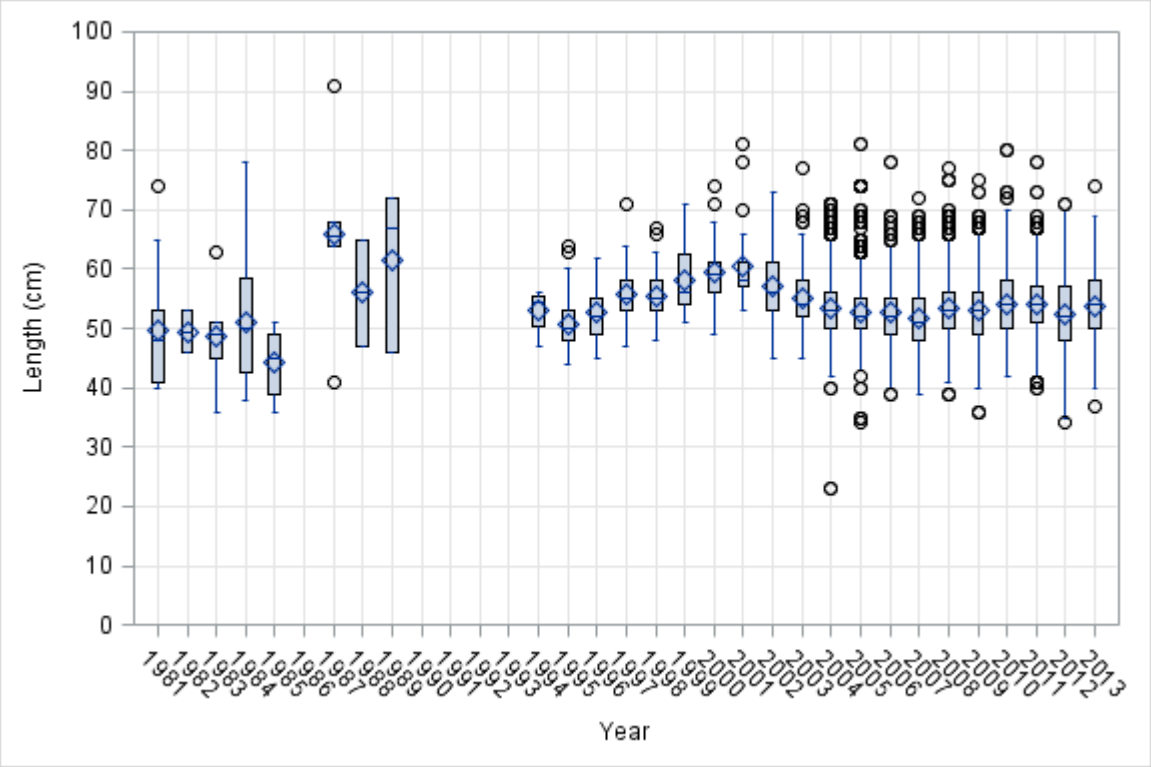


Figure A.70. Box plots showing the length distribution of Gulf of Maine haddock recreational harvest (AB1 catch) between 1981 and 2013.

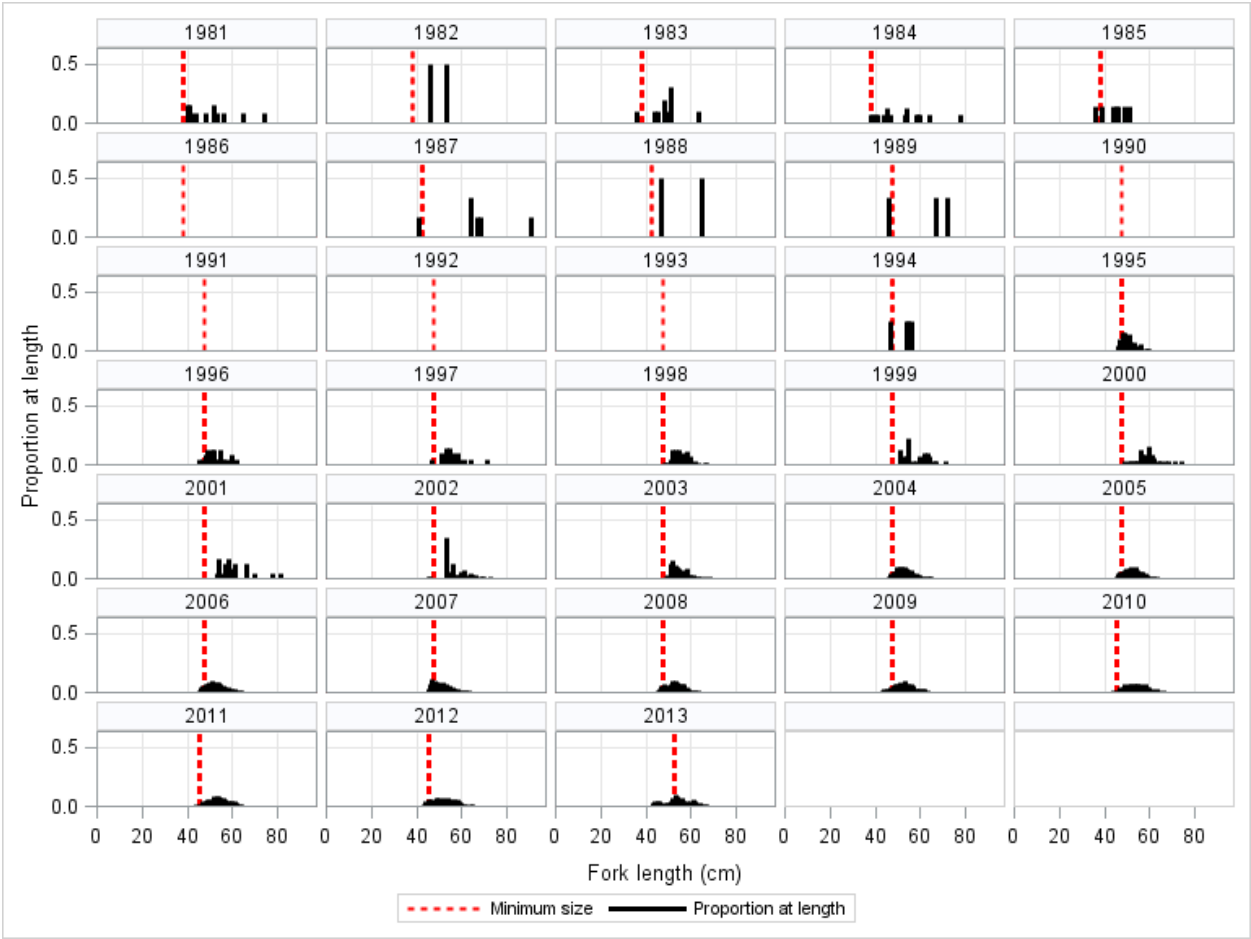


Figure A.71. Length frequency distribution of Gulf of Maine haddock recreational harvest (AB1 catch) between 1981 and 2013. Minimum retention sizes for the specific years are indicated by a dashed red line.

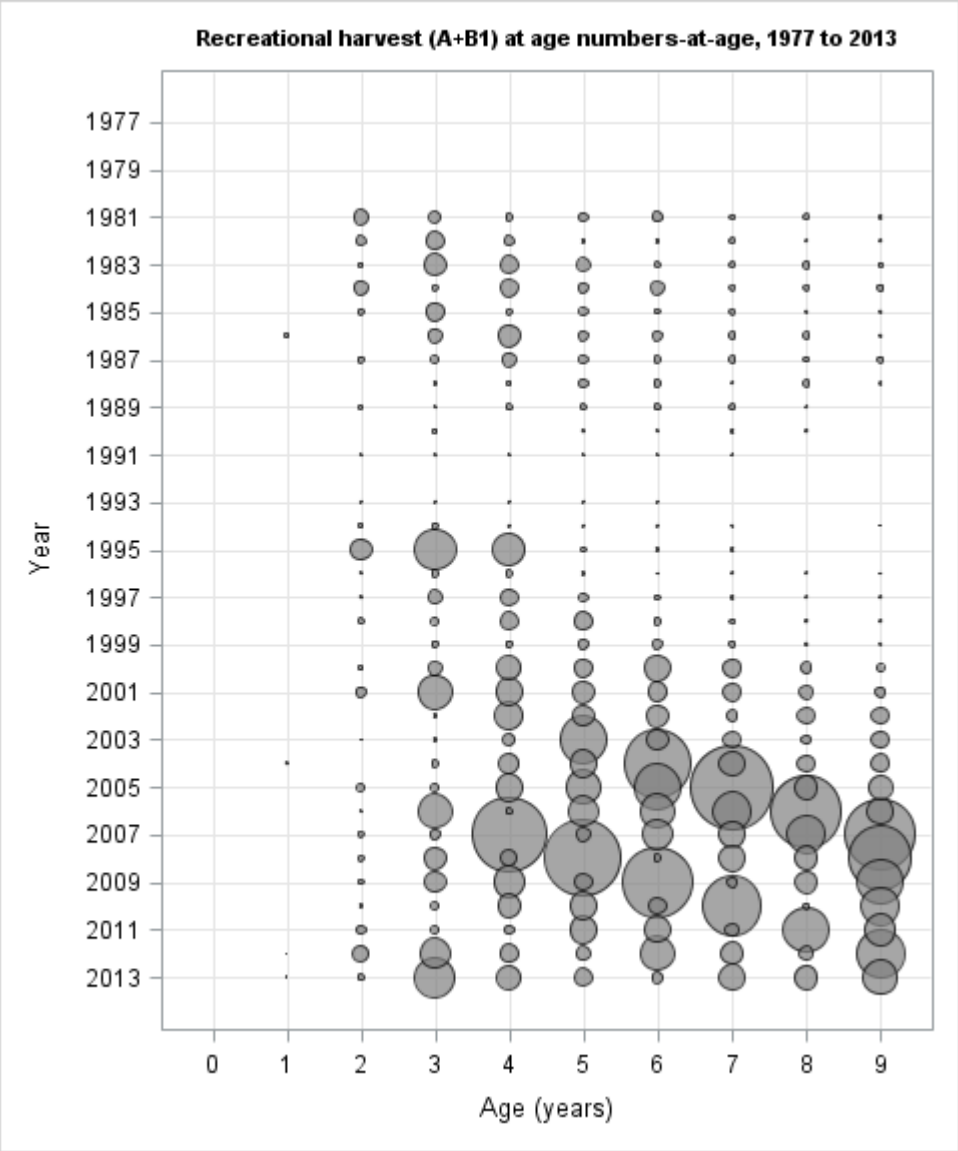


Figure A.72. Recreational harvest (landings)-at-age of Gulf of Maine haddock from 1977 to 2013. *Note that estimates of recreational harvest are not available prior to 1981.*

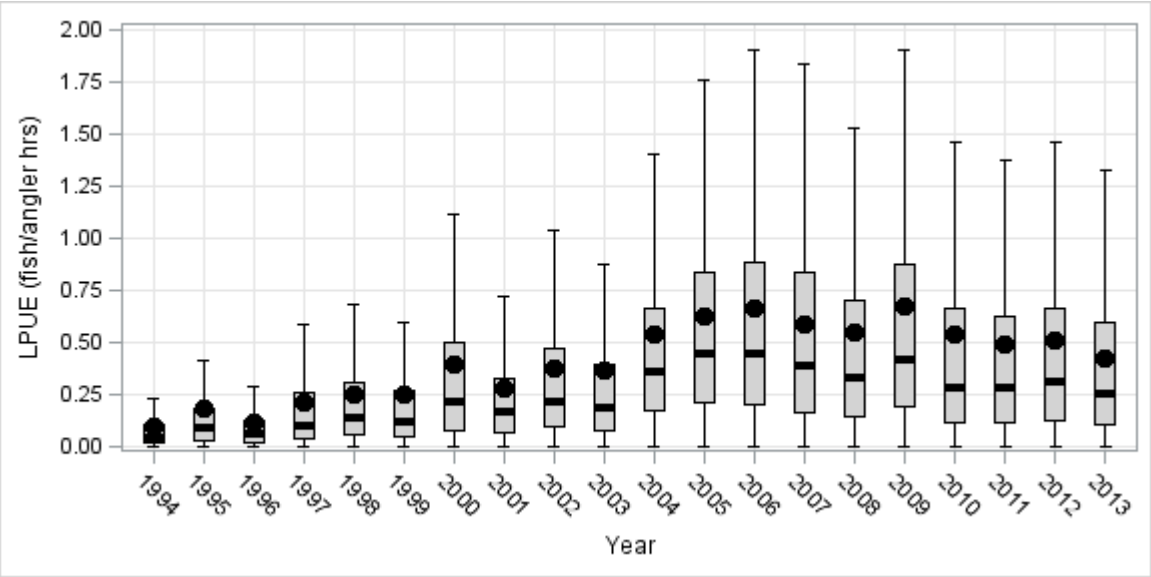


Figure A.73. Box-plot distributions of nominal Gulf of Maine haddock recreational landings (count) per angler hour from 1994 to 2013. Vessel trip report (VTR) data were used in this analysis and only includes trips that reported landing Gulf of Maine haddock.

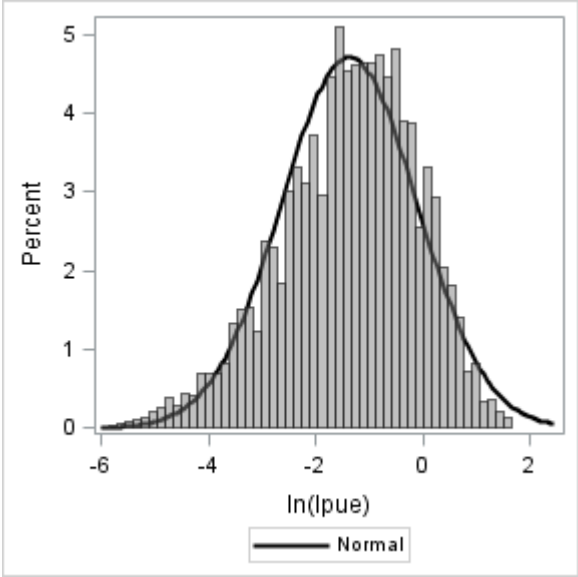


Figure A.74. Distribution of log transformed nominal recreational LPUE.

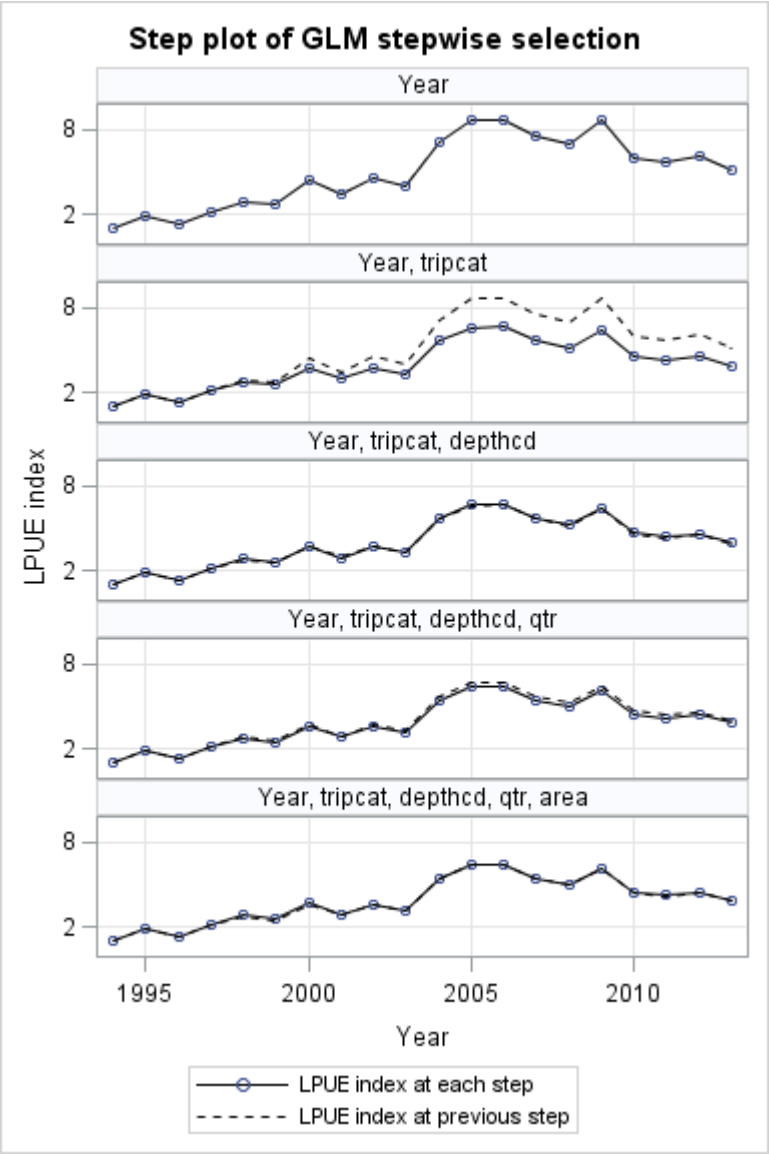


Figure A.75. Step plot of the recreational landings-per-unit-effort (LPUE) standardization model. Each panel shows the standardized abundance index as each explanatory variable is added to the model through stepwise selection. The index from previous step is indicated with a dashed line.

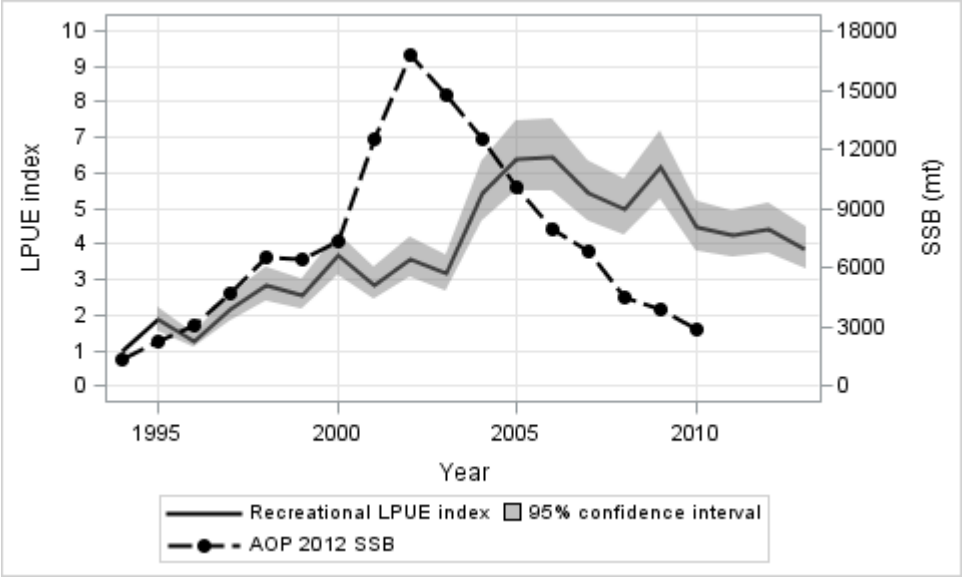


Figure A.76. Time series of the recreational LPUE index overlaid on the AOP 2012 assessment spawning stock biomass (SSB) estimate. *Note that the AOP 2012 SSB estimates only extends through 2010.*

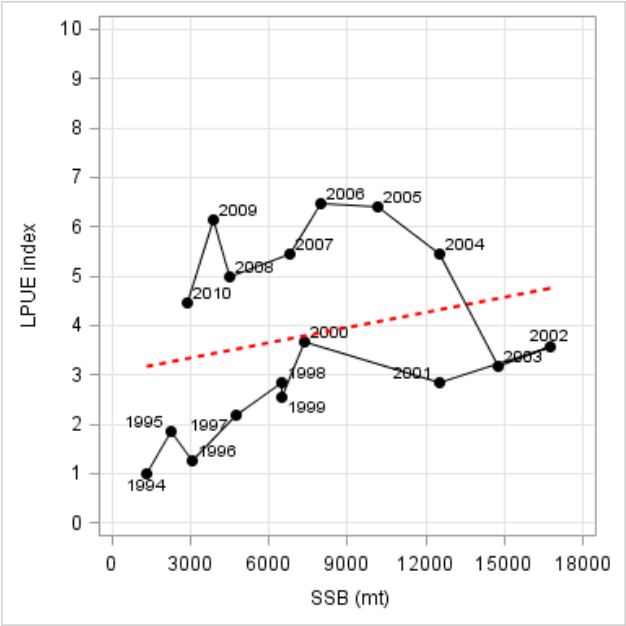


Figure A.77. Linear regression of the recreational LPUE index on spawning stock biomass (SSB) estimate from the AOP 2012 assessment.

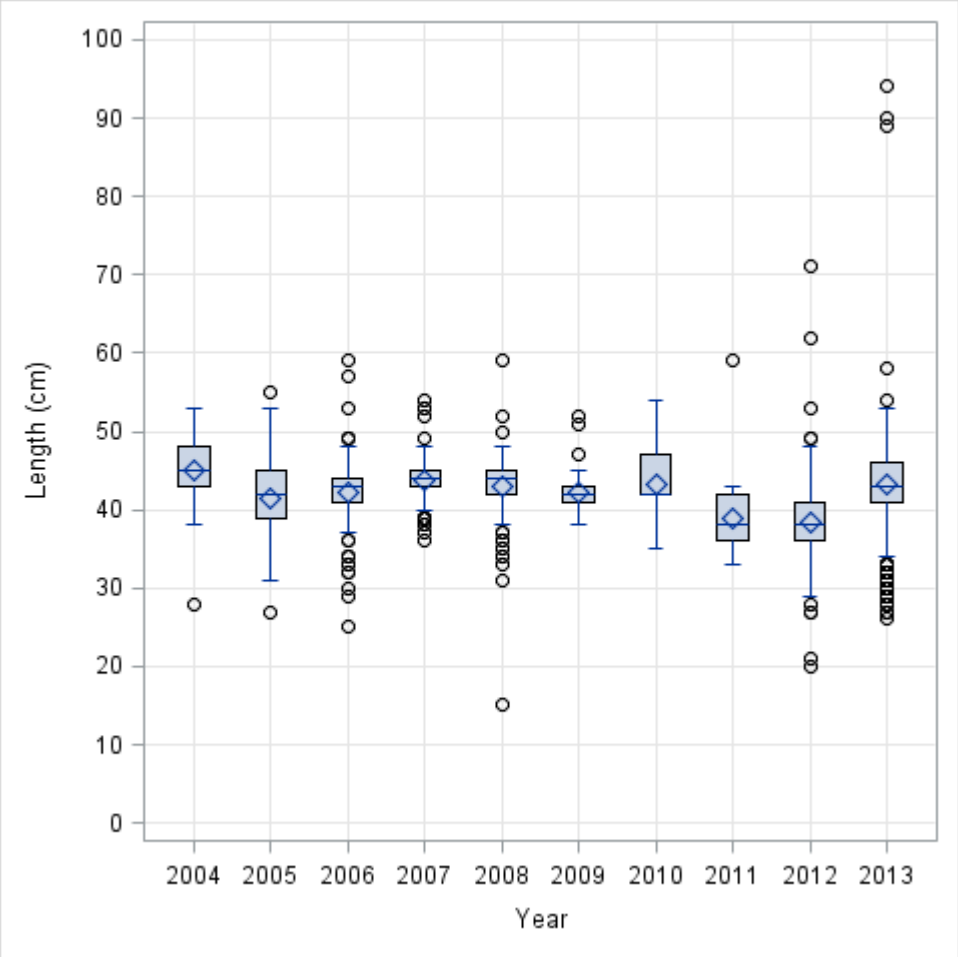


Figure A.78. Box plots showing the length distribution of Gulf of Maine haddock recreational releases (B2 catch) between 2004 and 2013.

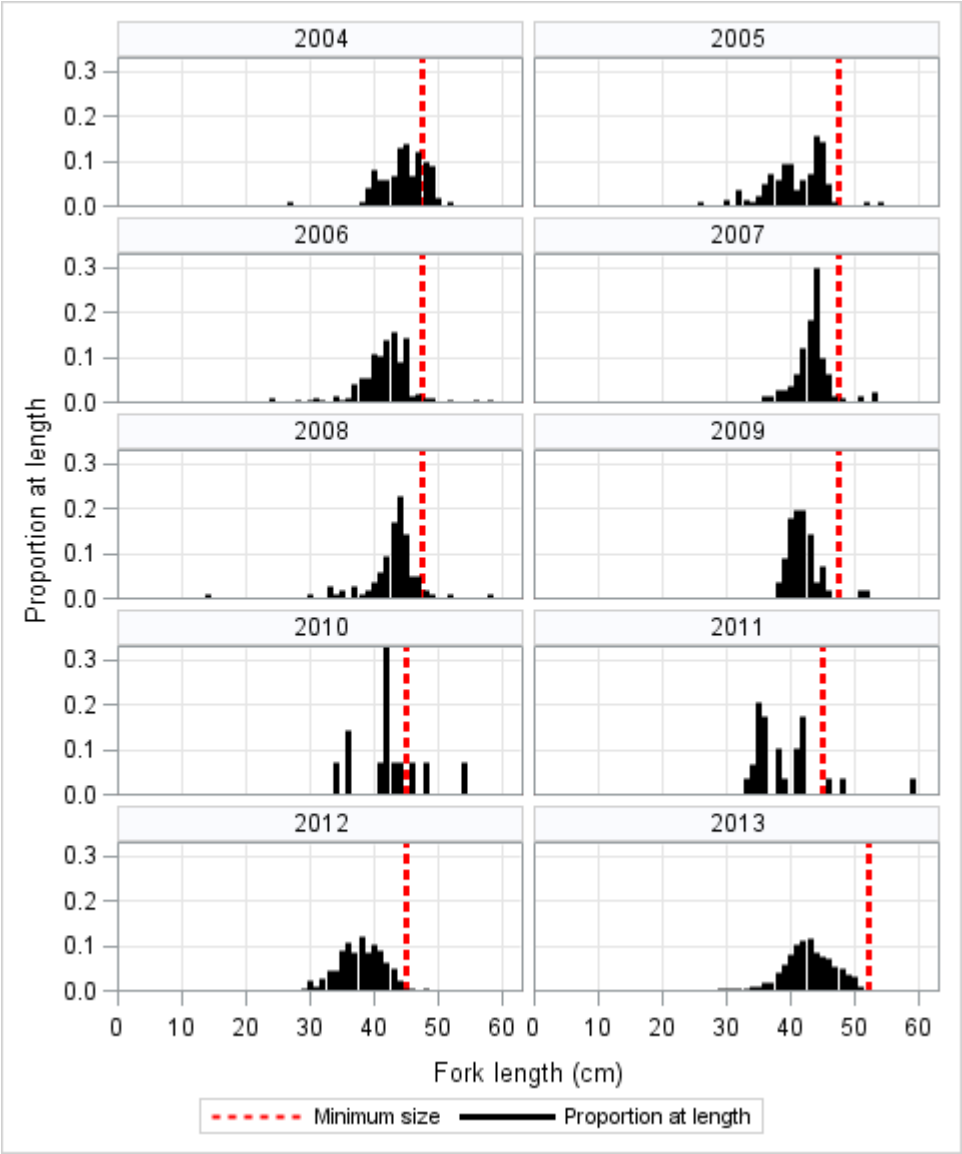


Figure A.79. Length frequency distribution of Gulf of Maine haddock recreational releases (B2 catch) between 2004 and 2013. Minimum retention sizes for the specific years are indicated by a dashed red line.

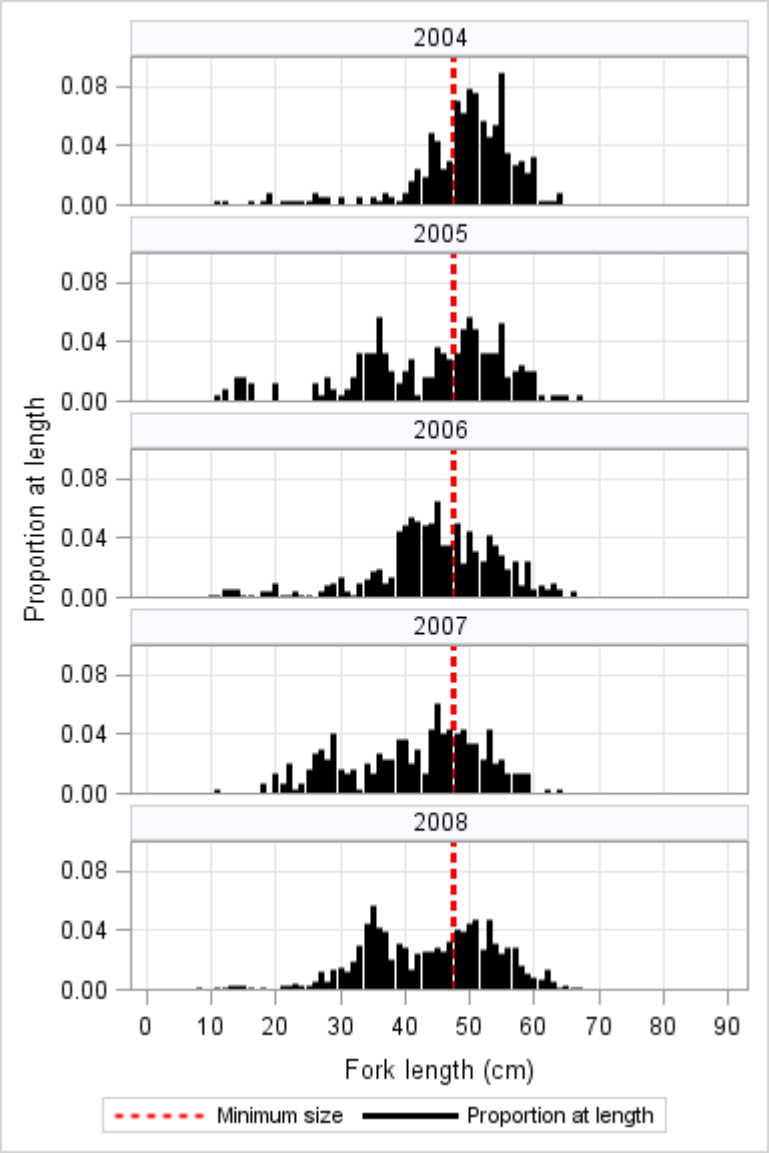


Figure A.80. Frequency distribution of Gulf of Maine haddock lengths collected from Northeast Fisheries Science Center (NEFSC) bottom trawl surveys between 2004 and 2008. The recreational minimum retention size for the specific year is shown by the dashed red line.

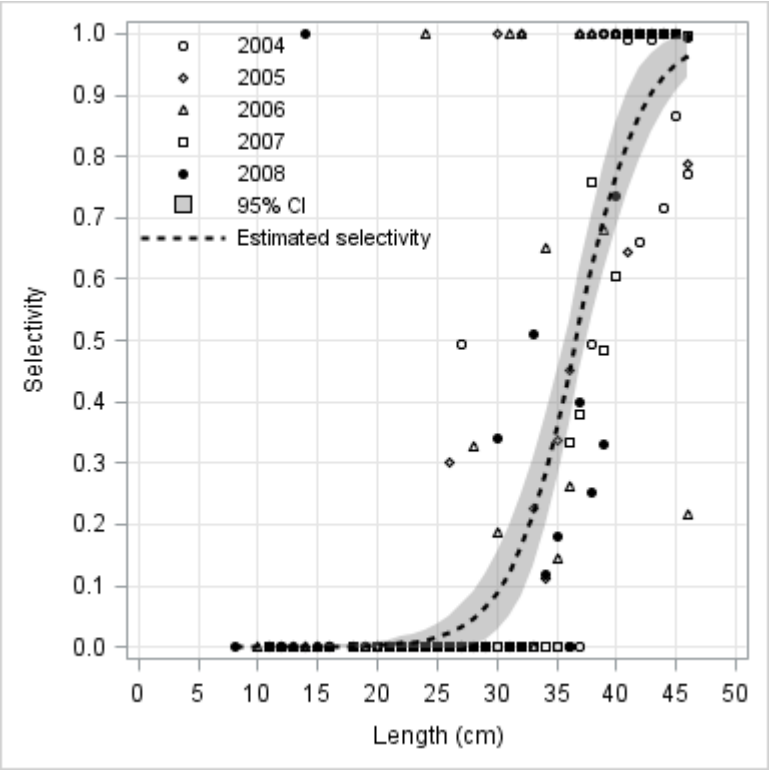


Figure A.81. Estimated selectivity ogives for the recreational fishery and the corresponding 95% confidence intervals (CI) for Gulf of Maine haddock. Selectivity ogives were estimated from the logistic fits to the aggregated annual estimates of selectivity-at-length.

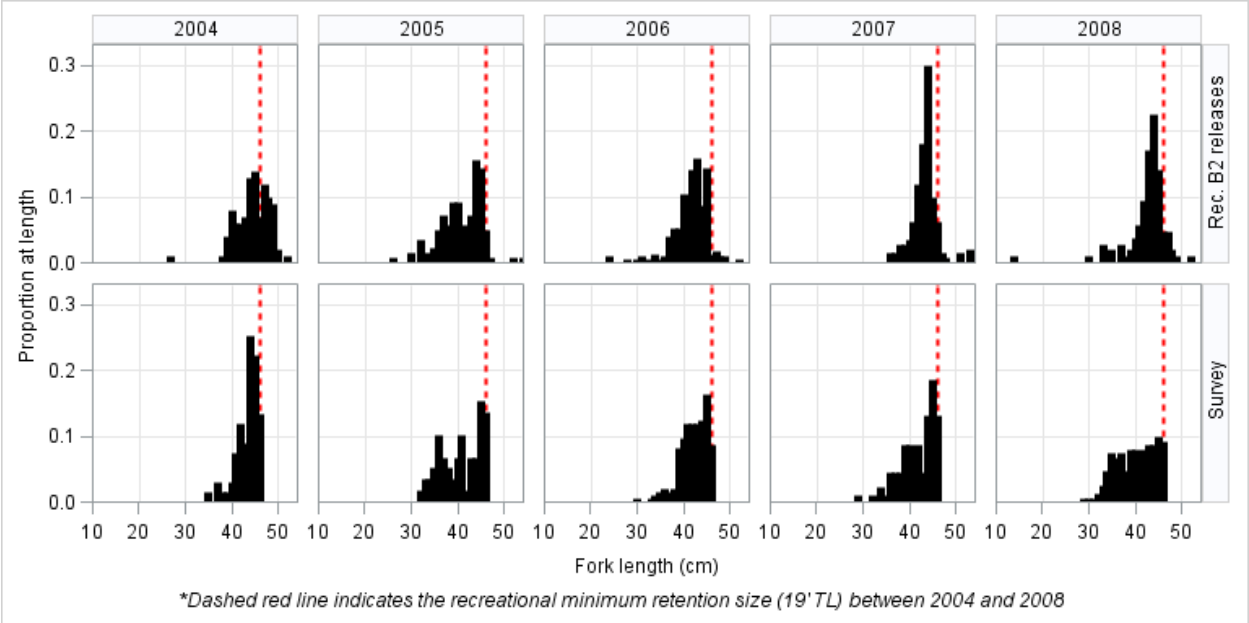


Figure A.82. Comparison of the survey filter-based estimates of discards-at-length for the recreational fishery to the direct observer observations from 2009 to 2013 for Gulf of Maine haddock. The dashed red line represents the commercial minimum retention size for the specific year.

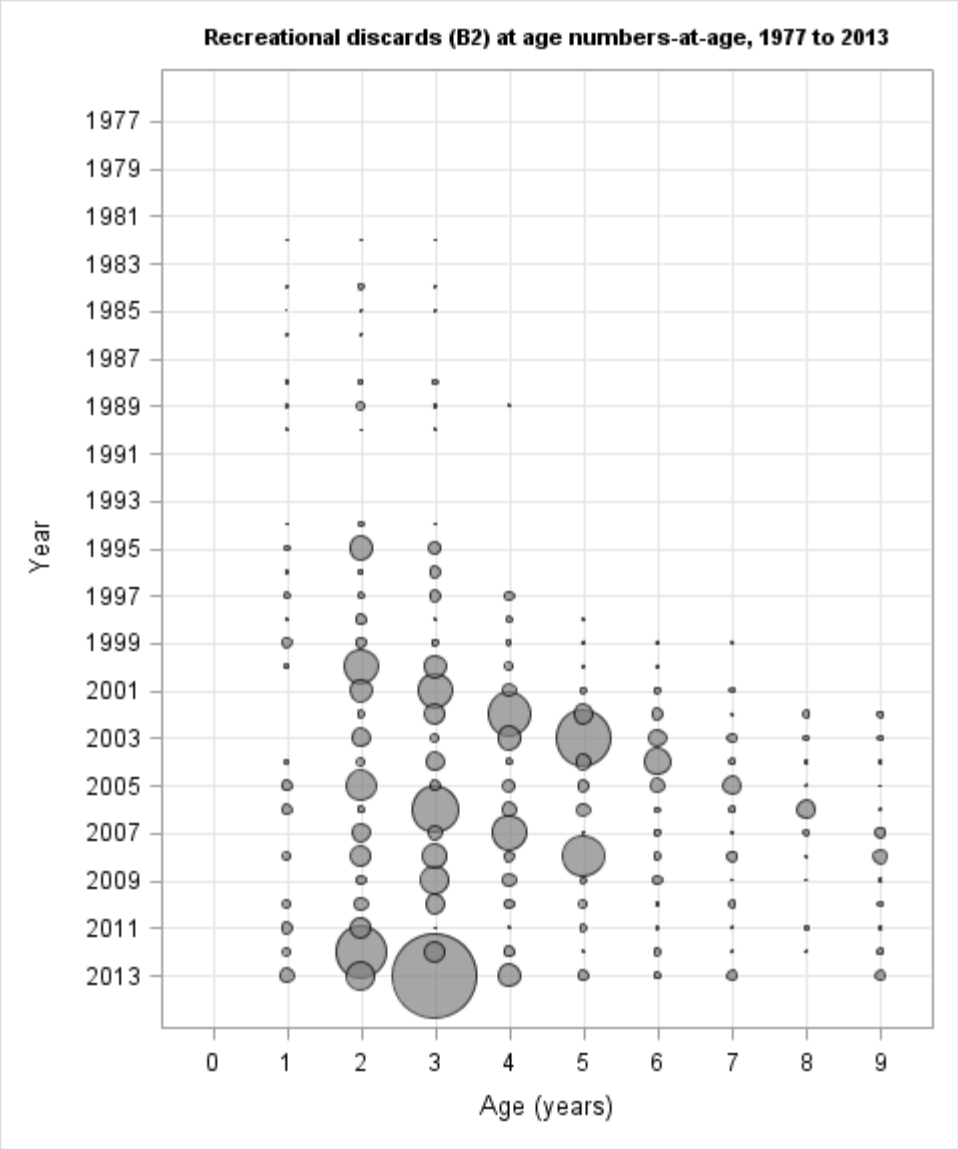


Figure A.83. Recreational discards (releases)-at-age of Gulf of Maine haddock from 1977 to 2013. *Note that estimates of recreational releases are not available prior to 1981.*

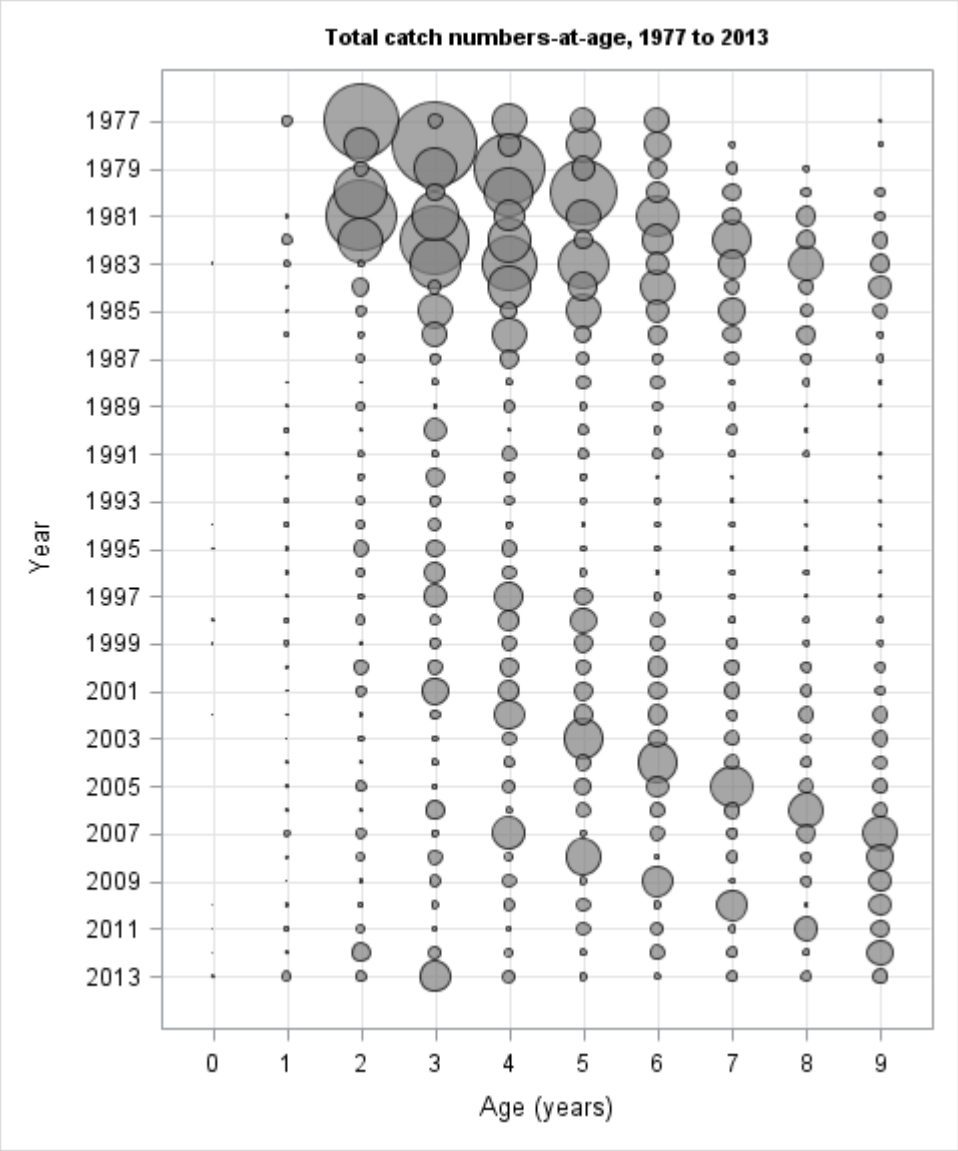


Figure A.84. Total commercial and recreational catch-at-age of Gulf of Maine haddock from 1977 to 2013.

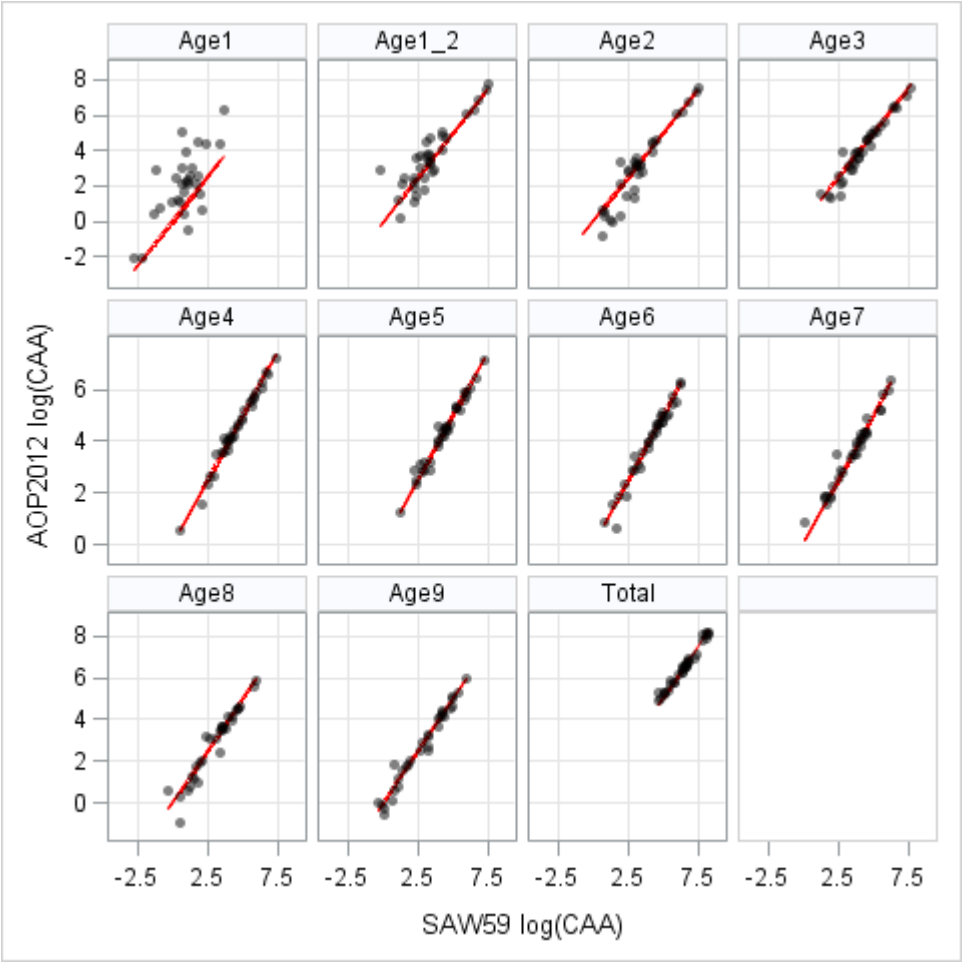
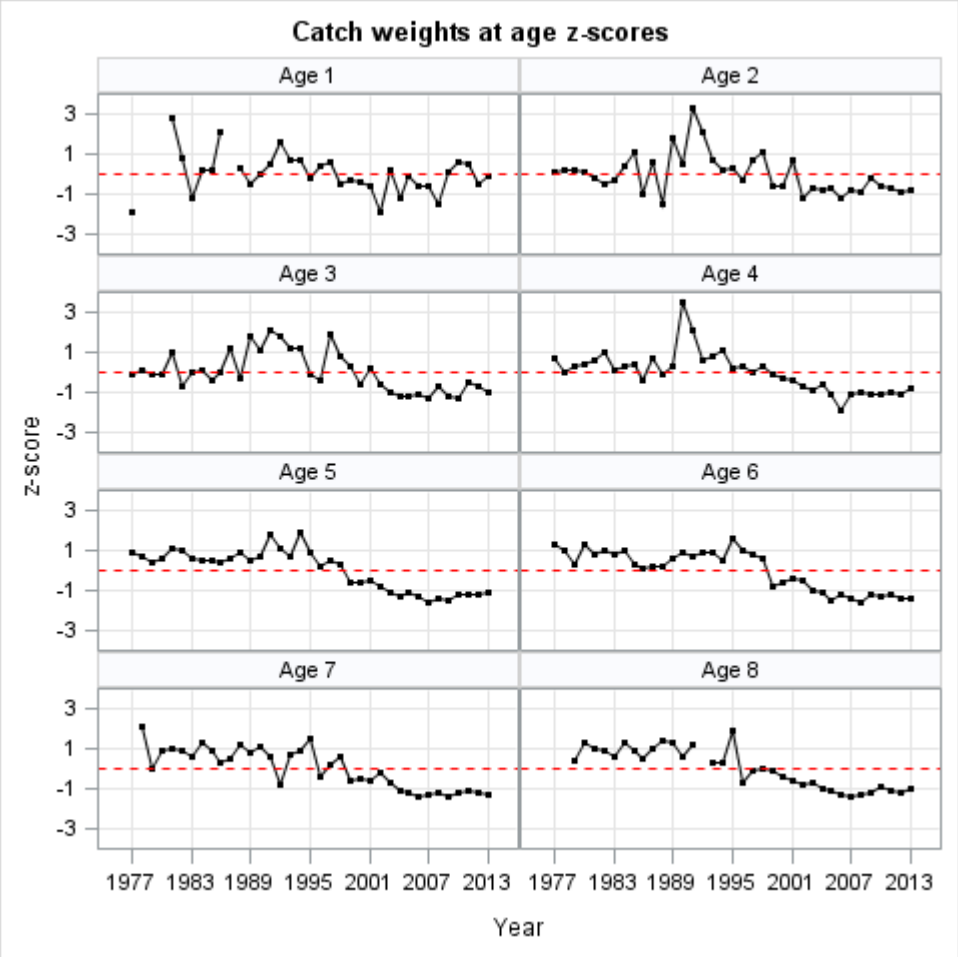


Figure A.85. Comparison of the 2012 AOP estimated catch-at-age to the SAW/SARC 59 updated catch-at-age. *Note that the second plot from the top left corner reflects a comparison of aggregated age-1 and age-2 catch.*



Figue A.86. Average catch weights-at-age of age-1 to age-8 Gulf of Maine haddock from 1977 to 2013. Weights-at-age were estimated using a number weighted average of commercial landing, commercial discard, recreational landings, and recreational discards weights-at-age. Average weights are presented as z-scores ([x-μ]/σ).

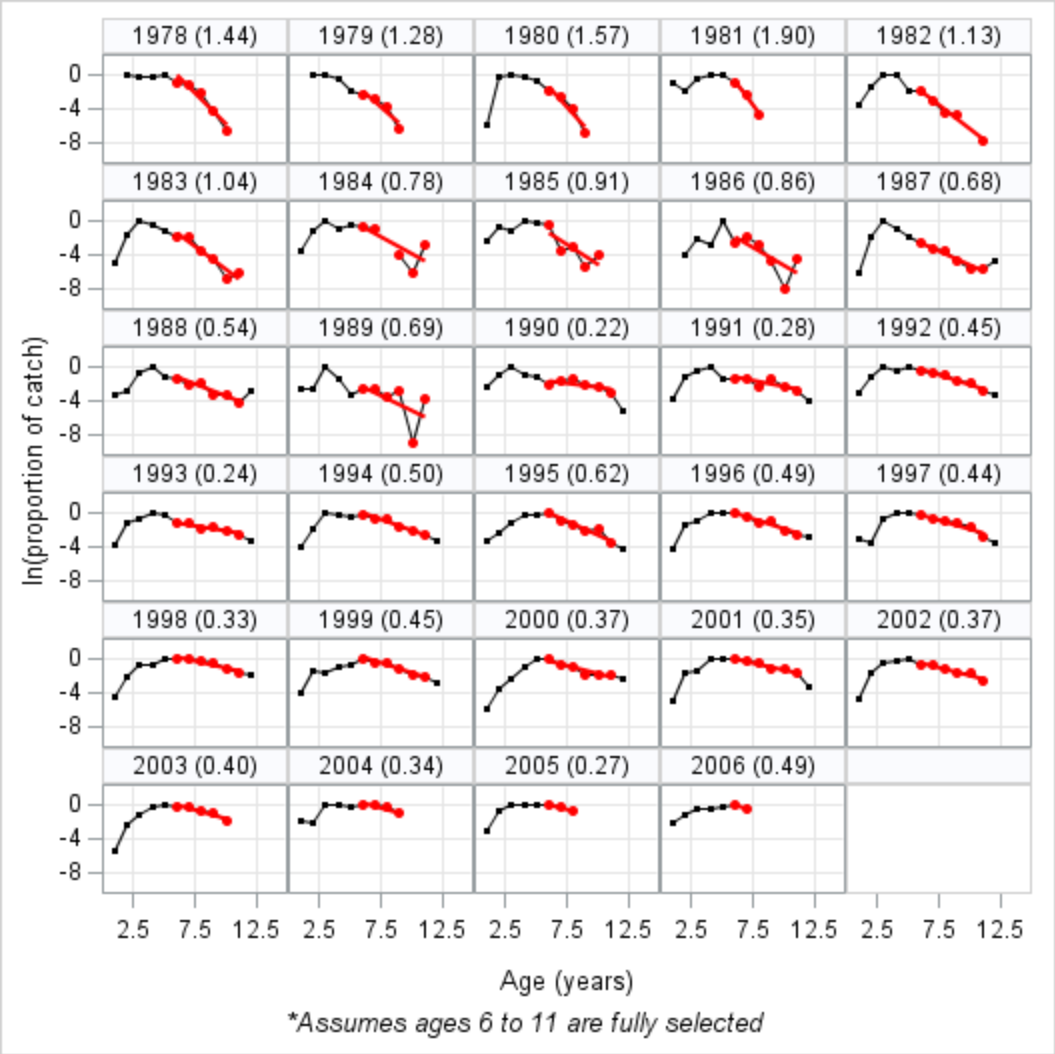


Figure A.87. Gulf of Maine haddock year class curves computed on ages 6-11 (red circles) log-transformed catch (commercial and recreational landings and discards). The corresponding slope of each regression line is shown next to the year class label above each plot.

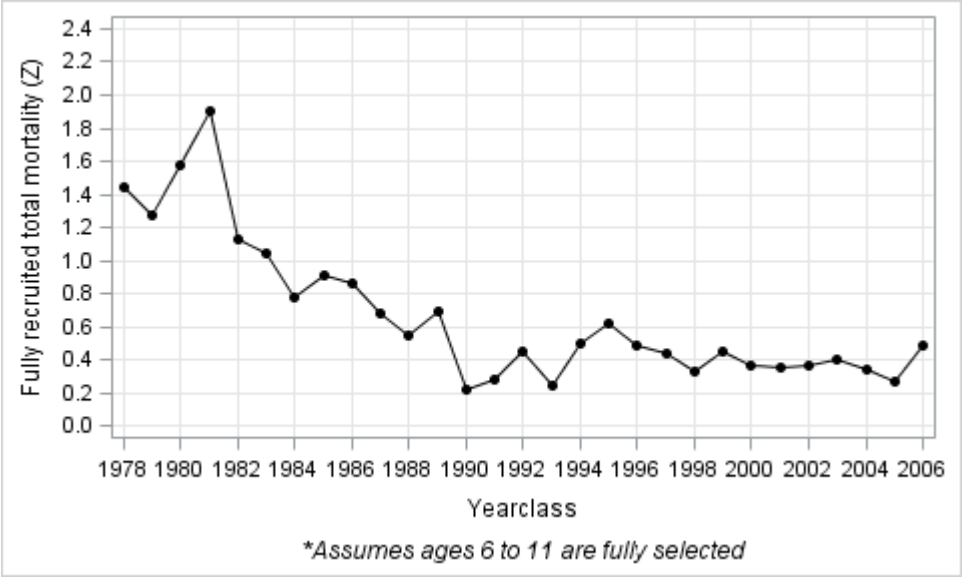


Figure A.88. Annual estimates of Gulf of Maine haddock total mortality (Z) as estimated from the year class curve analsyses for total catch for the 1978 to 2006 year classes.

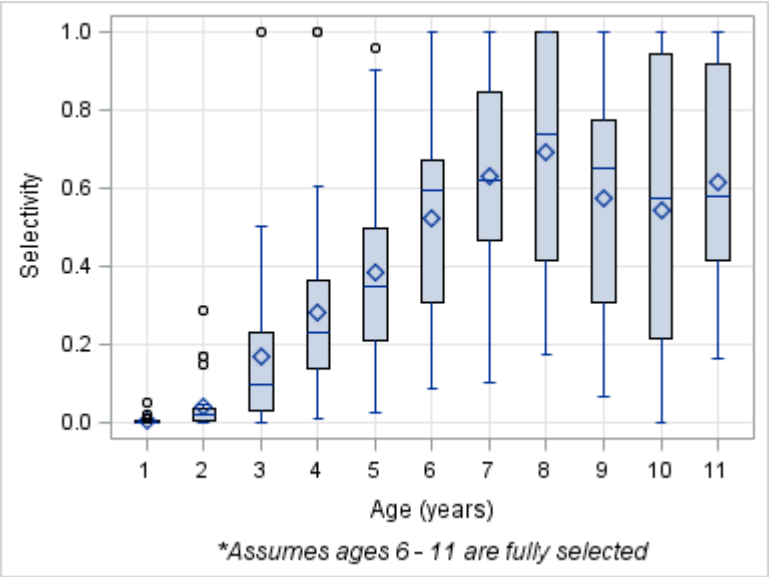
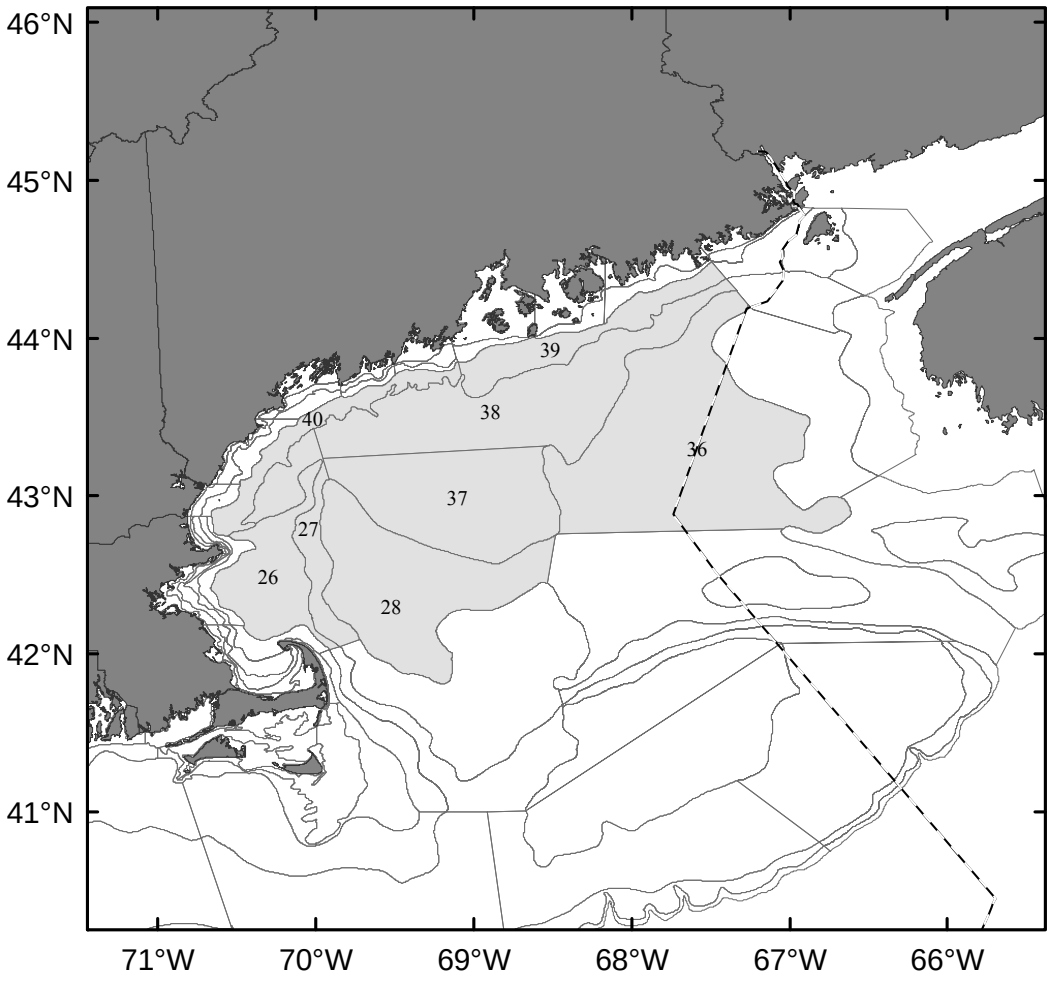
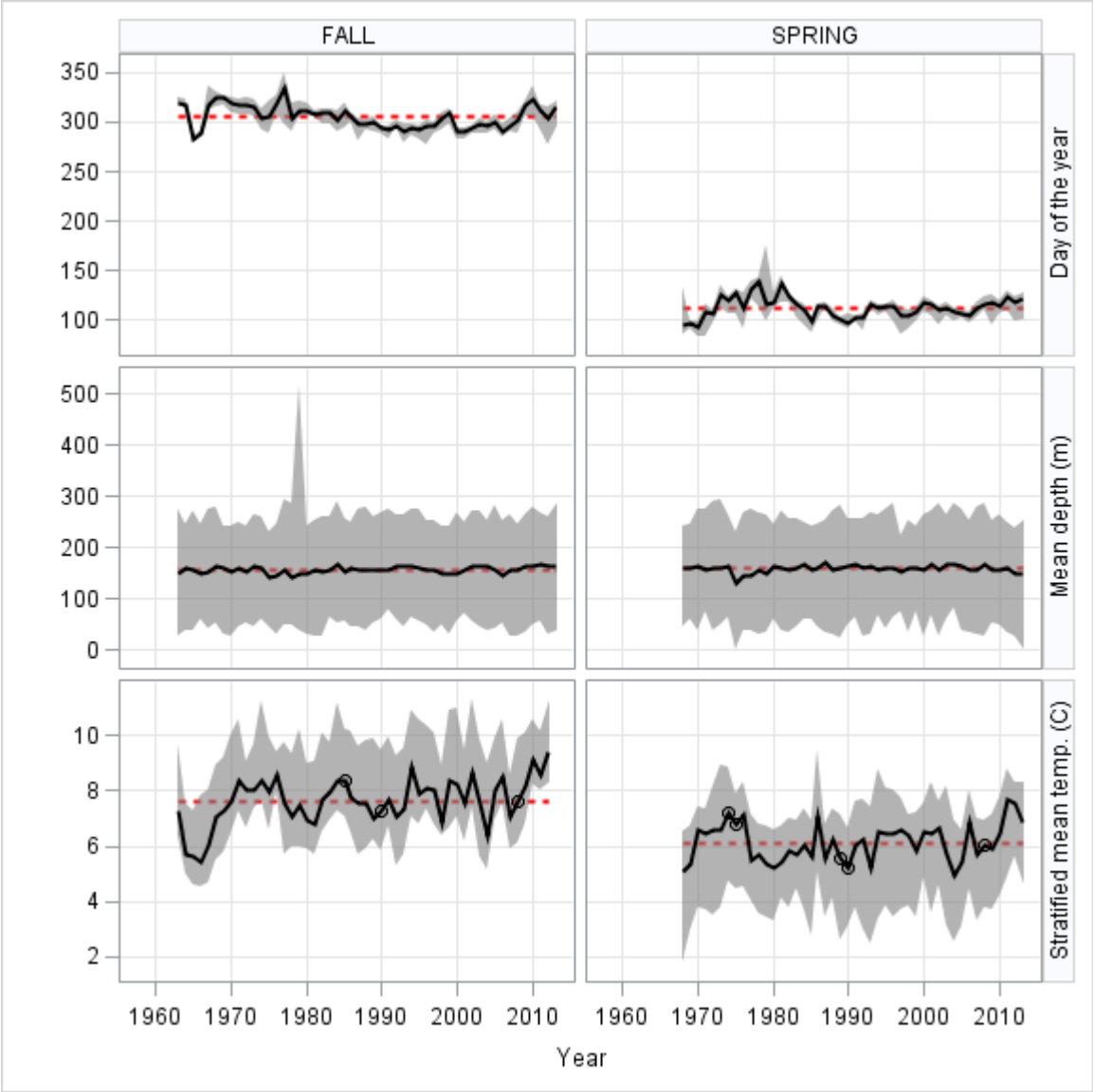


Figure A.89. Distribution of catch selectivity-at-age as estimated from the residuals fits to the Gulf of Maine total catch curve analysis.



Figue A.90. Map of the Notheast Fisheries Science Center (NEFSC) bottom trawl offshore survey strata used to construct NEFSC survey indices for Gulf of Maine haddock stock assessment (shaded grey).



Figue A.91. Mean day of the year, depth and bottom temperature for the Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl surveys in the Gulf of Maine. Shaded areas indicate the range between the minimum and maximum observation. *Day of the year is expressed as Julian days (e.g., January 1 is day 1 and December 31 is day 365/66). Years marked with circles in the mean temperature plot indicate years when not all survey stratum were sampled and therefore the mean temperature may not be representative of the entire survey area.*

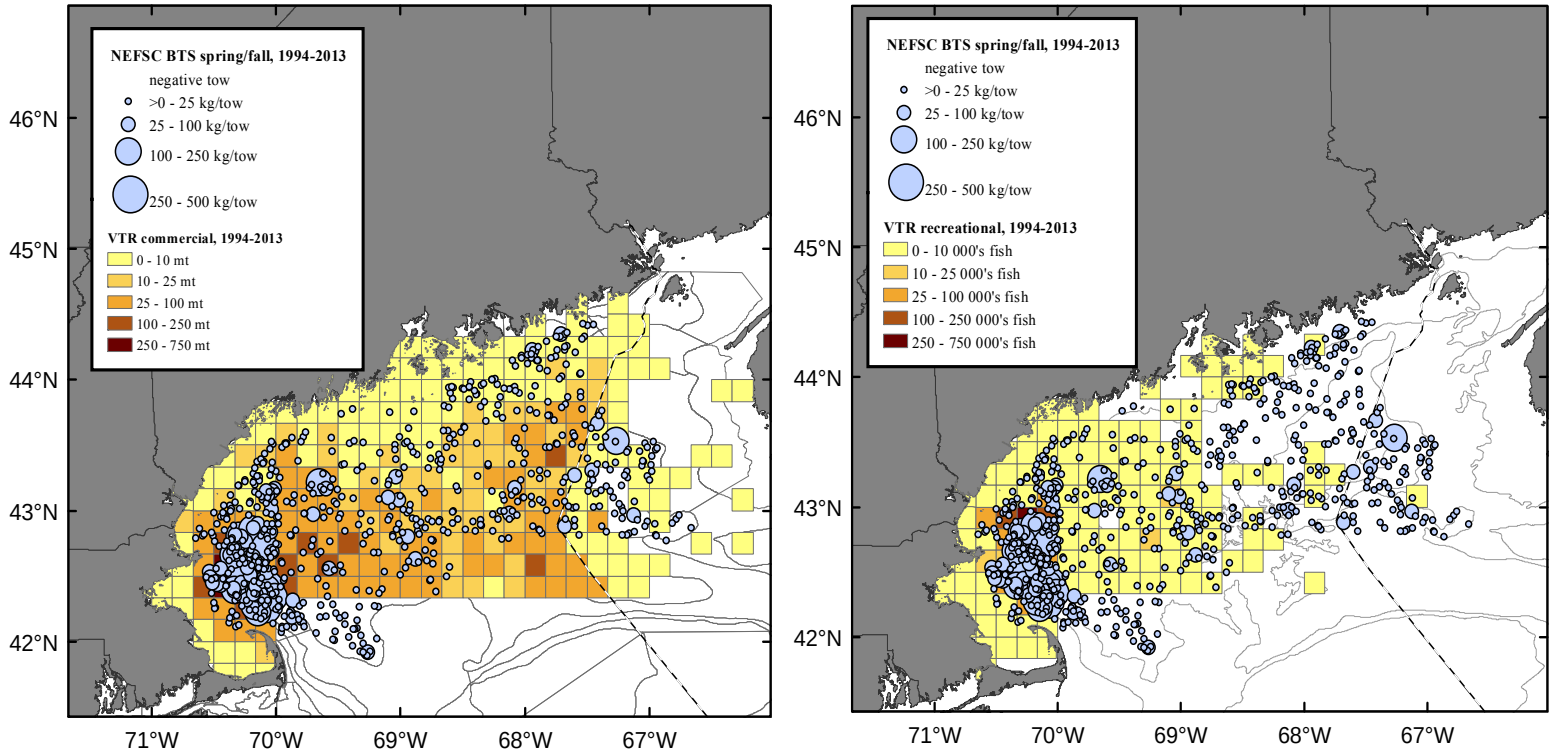


Figure A.92. Spatial overlap of survey catches (kg/tow) of Gulf of Maine haddock from the Northeast Fisheries Science Center (NEFSC) bottom trawl survey (spring and fall combined) and recreational and commercial landings. On the left, NEFSC survey catches from 1994 – 2013 are overlaid on the VTR-reported commercial landings binned to ten minute squares. On the right, NEFSC survey catches from 1994 – 2013 are overlaid on the VTR-reported recreational landings binned to ten minute squares. **Note the different units of measure between the commercial and recreational landings.*

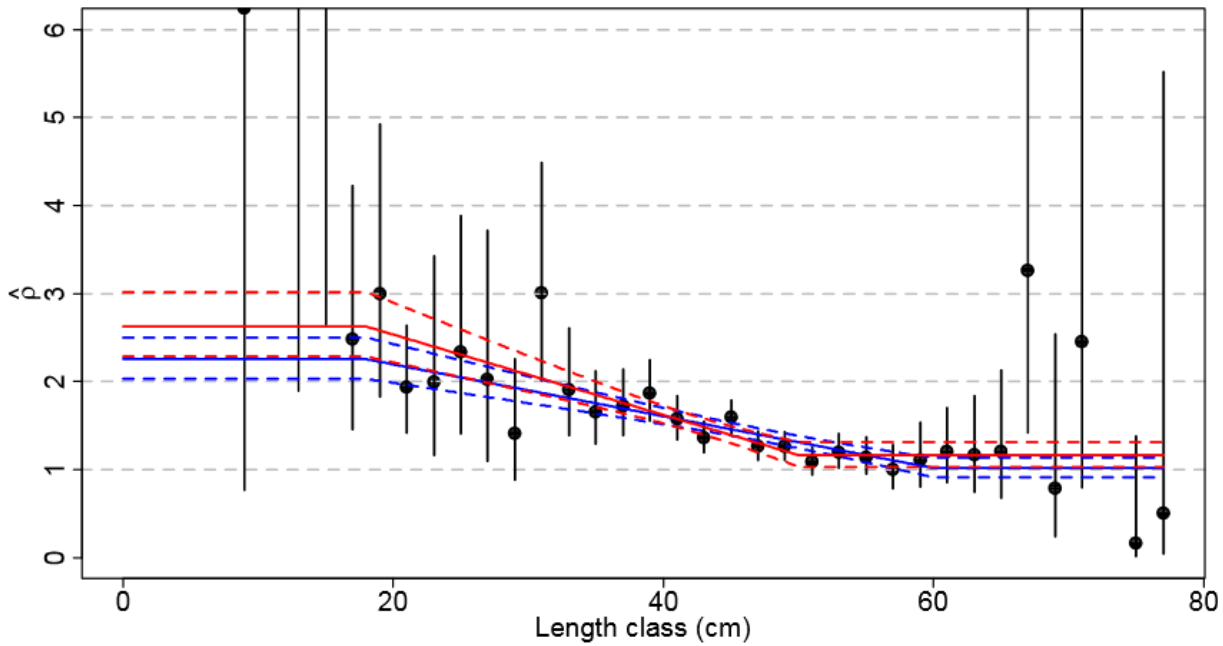


Figure A.93. Beta-binomial based estimates of calibration factors and corresponding 95% confidence intervals by length class (2 cm bins) for haddock. The black points and vertical bars represent results where different calibration factors are estimated for each length class.The blue lines represent results from a segmented regression model where the two points connecting the segments are known (18 and 60 cm) and the red lines represent results from a segmented regression model where the first point (18 cm) is known but the second is estimated. Segmented regression fits are based on data from fish ≥18 cm.

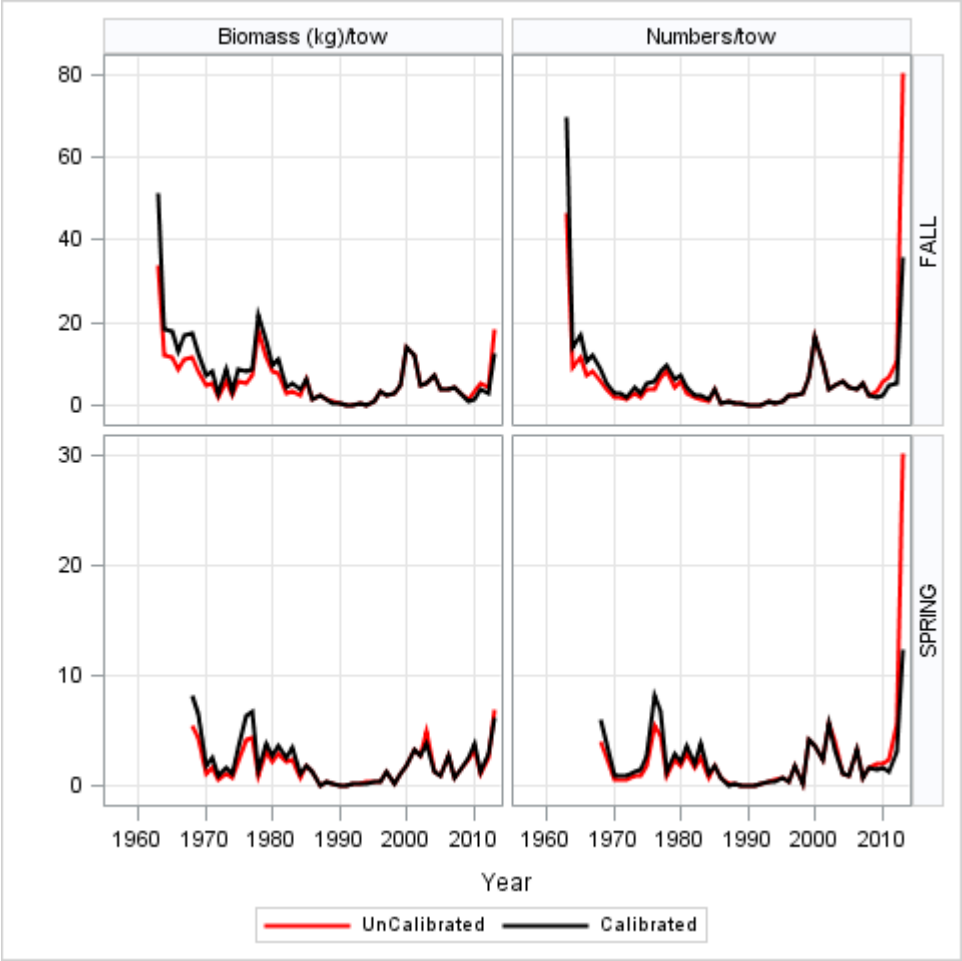


Figure A.94. Northeast Fisheries Science Center spring and fall survey indices of abundance (numbers/tow) and biomass (kg/tow) showing both raw (uncalibrated) and vessel, door and survey calibrated indices over time for Gulf of Maine haddock.

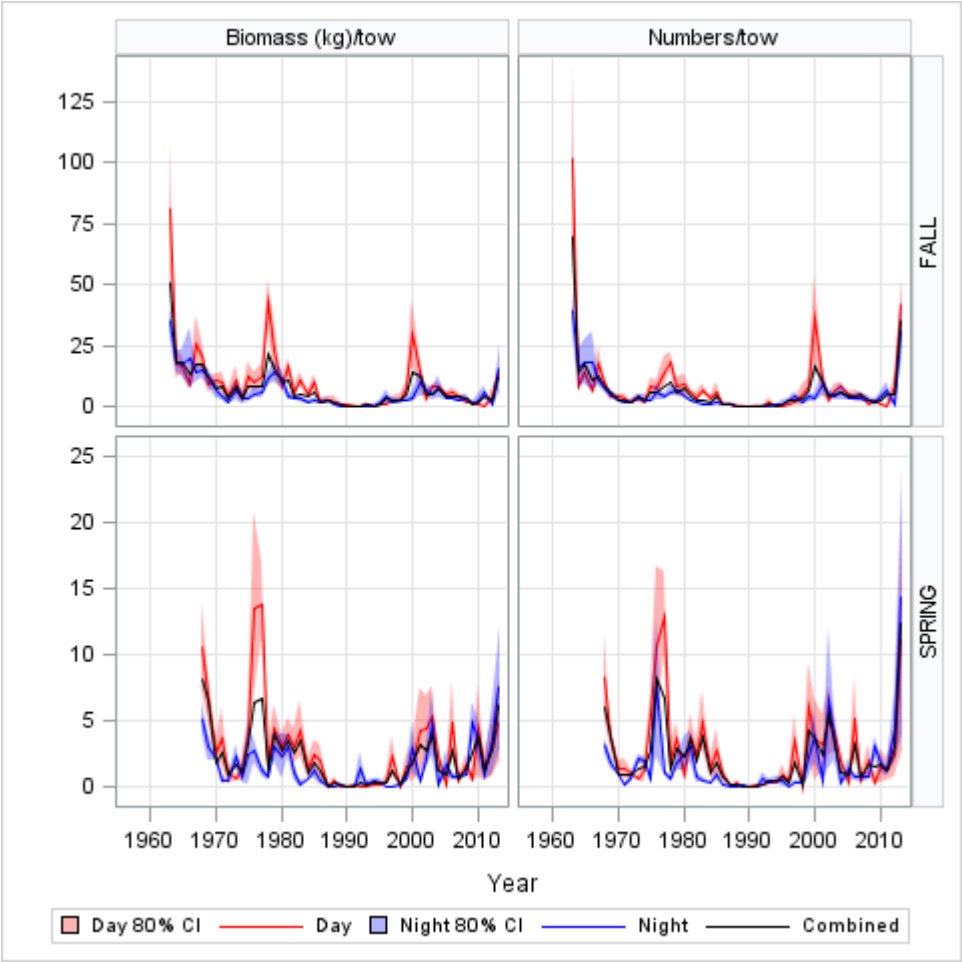


Figure A.95. Northeast Fisheries Science Center spring and fall survey indices of abundance (numbers/tow) and biomass (kg/tow) broken down by day- and night-only tows and the corresponding 80% confidence interval (CI) for Gulf of Maine haddock. The aggregate survey indices are shown in black.

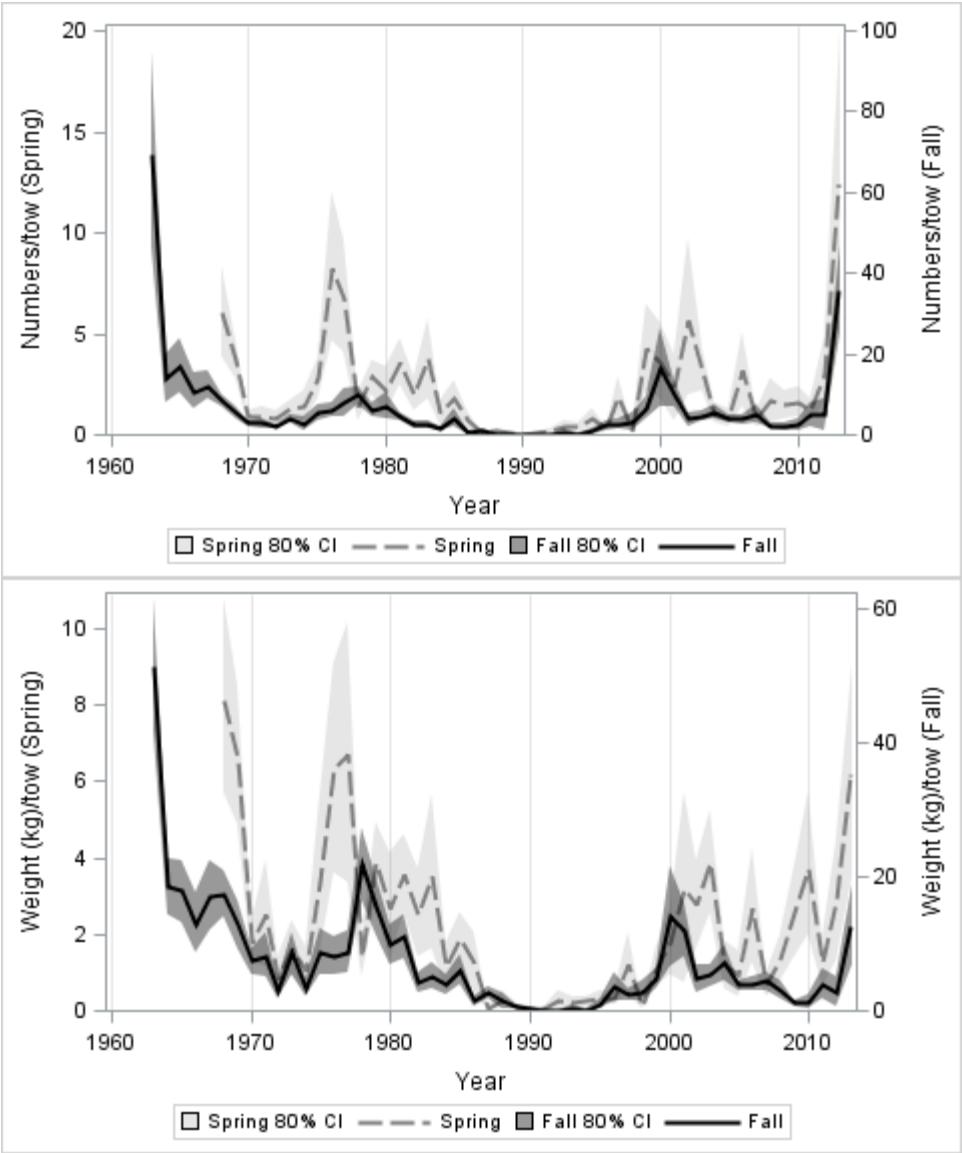


Figure A.96. Northeast Fisheries Science Center (NEFSC) spring and fall bottom trawl survey abundance (numbers/tow) and biomass (kg/tow) indices for Gulf of Maine haddock from 1963 to 2013. The TOGA tow criteria used for years 2009-2013. *Note that the spring survey did not begin until 1968.*

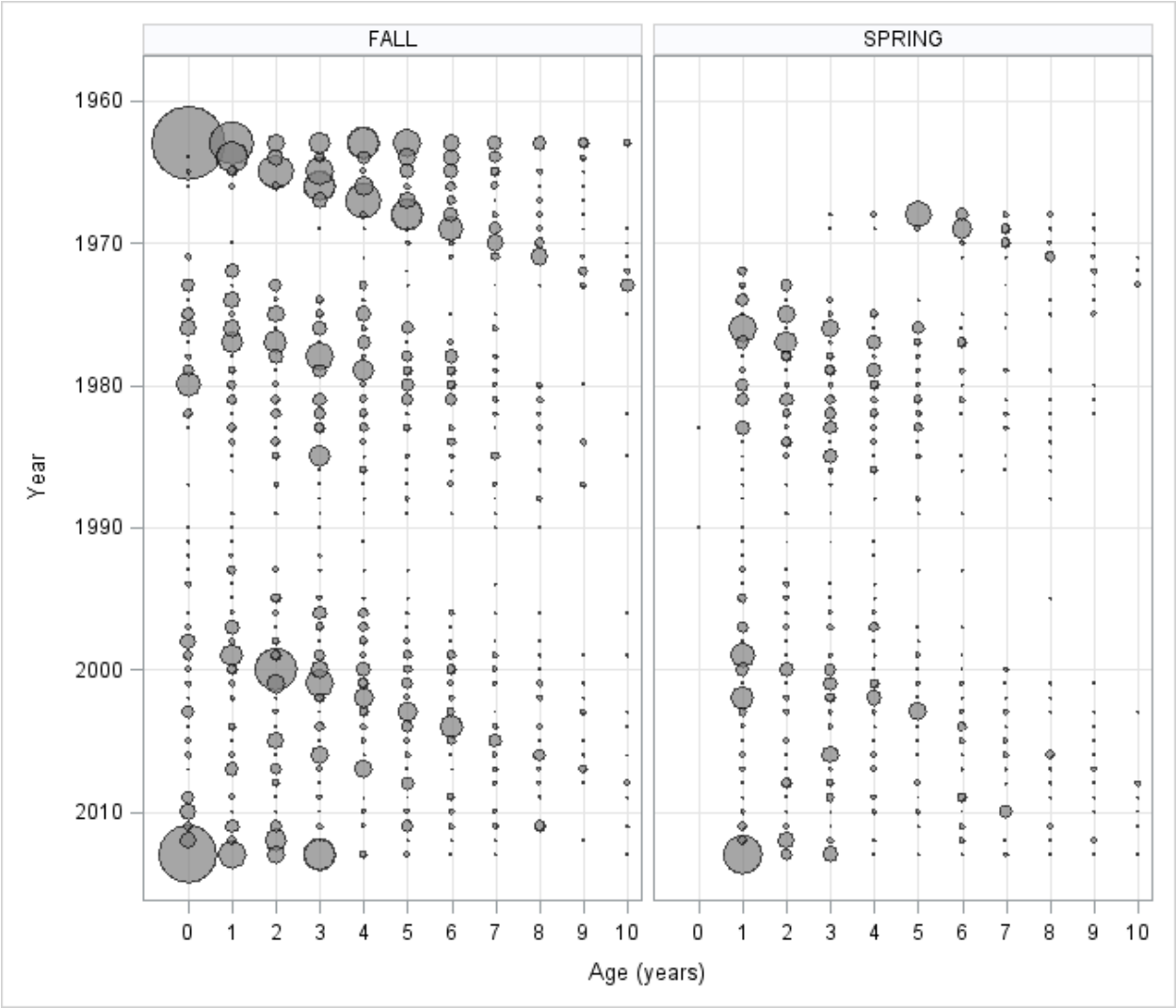


Figure A.97. NEFSC spring and fall bottom trawl survey Gulf of Maine haddock abundance indices-at-age from 1963 to 2013. *Note that the spring survey did not begin until 1968.*

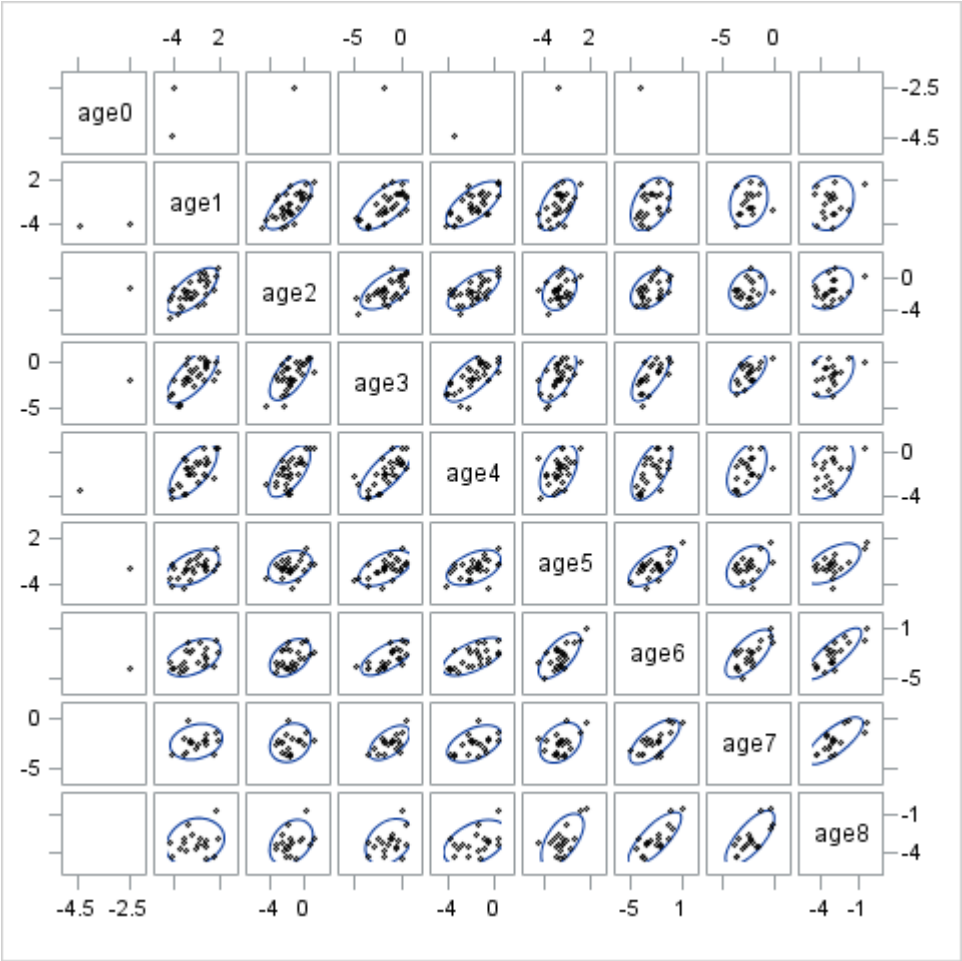


Figure A.98. Scatter plots showing the level of agreement between Northeast Fisheries Science Center (NEFSC) spring bottom trawl survey Gulf of Maine haddock indices-at-age (log transformed) on a cohort basis. The 80% confidence ellipses are shown.

Figure A.99. Scatter plots showing the level of agreement between Northeast Fisheries Science Center (NEFSC) fall bottom trawl survey Gulf of Maine haddock indices-at-age (log transformed) on a cohort basis. The 80% confidence ellipses are shown.

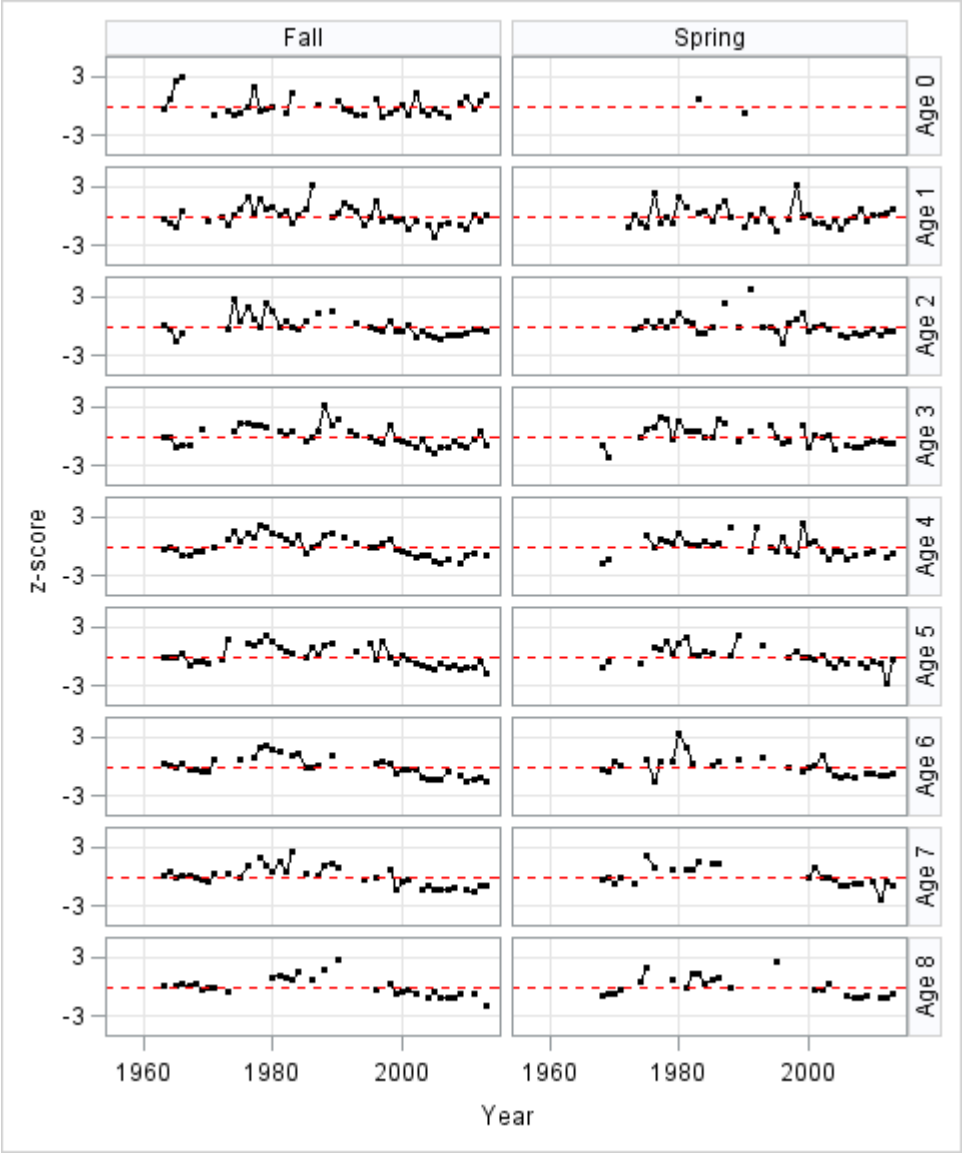


Figure A.100. Average weights-at-age of Gulf of Maine haddock age 0 to 8 from 1963 to 2013. Survey weights are based on the average weights-at-age of haddock sampled from the Northeast Fisheries Science Center spring and fall bottom trawl survey. Average weights are presented as z-scores ([x-μ]/σ).

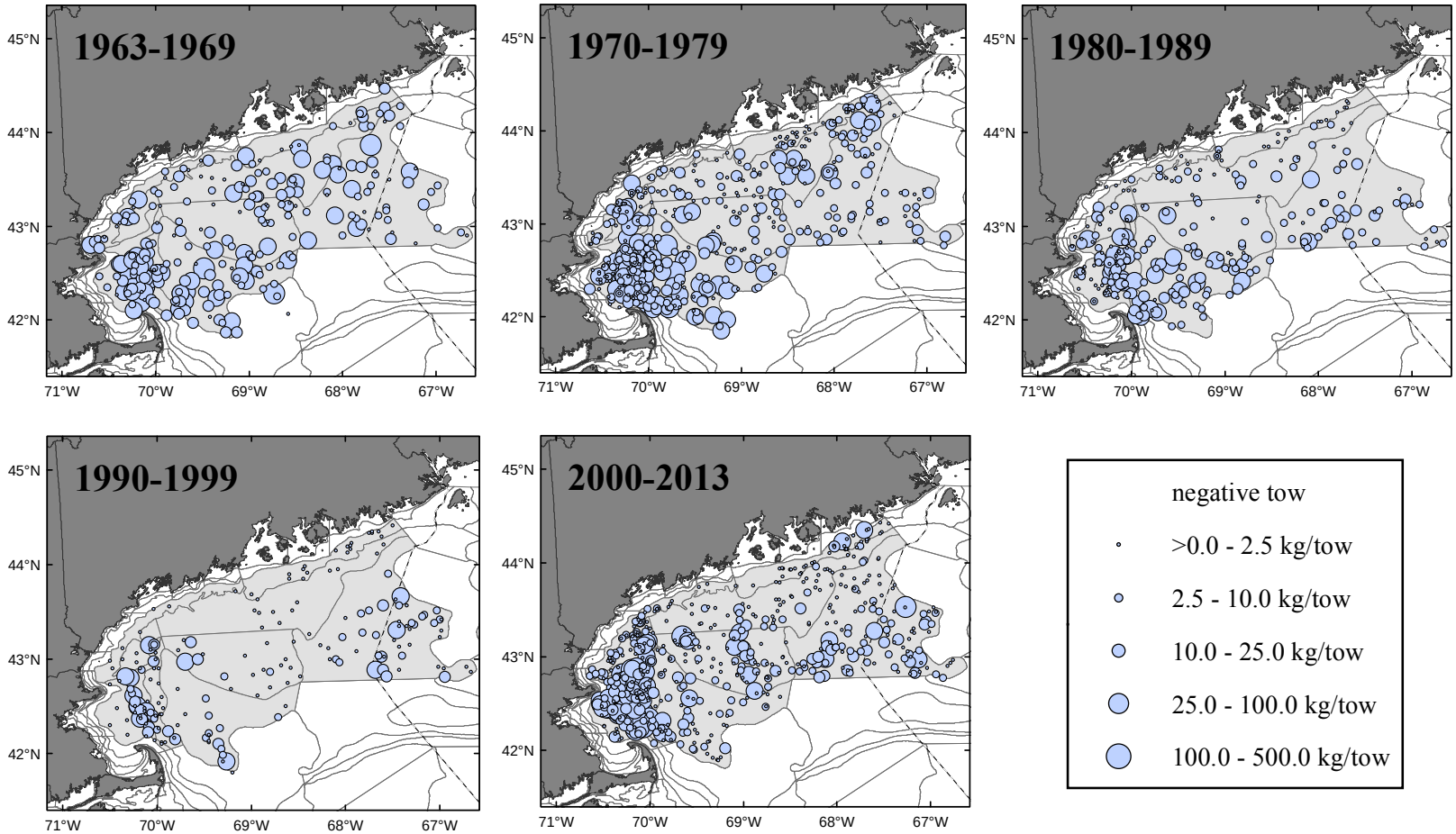


Figure A.101. Spatial distribution of Gulf of Maine haddock catches (numbers/tow) from the Northeast Fisheries Science Center spring bottom trawl survey from 1963 – 2013.

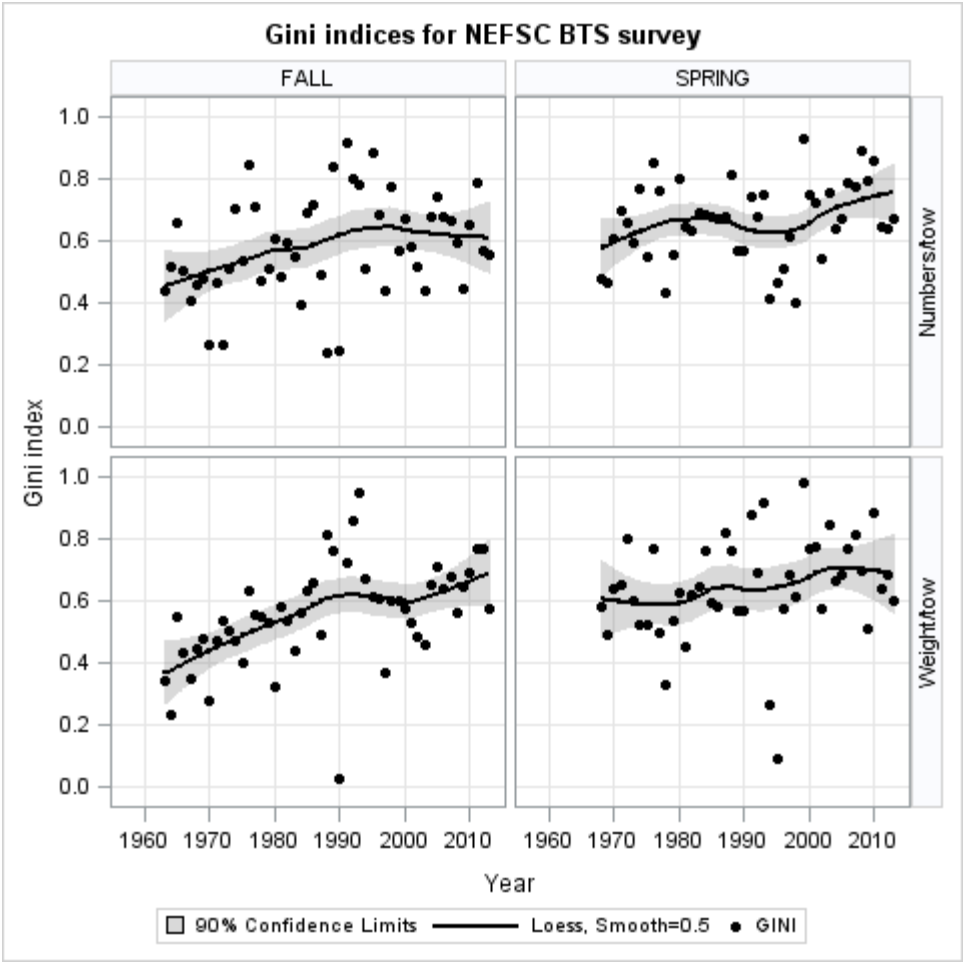


Figure A.102. Gini indices for Gulf of Maine haddock from the Northeast Fisheries Science Center (NEFSC) fall and spring bottom trawl surveys in terms of abundance (numbers/tow) and biomass (kg/tow). A LOESS smooth has been fit to the data with smoothing parameter of 0.5. The LOESS smooth is shown by the solid black line along with the corresponding 90% confidence interval.

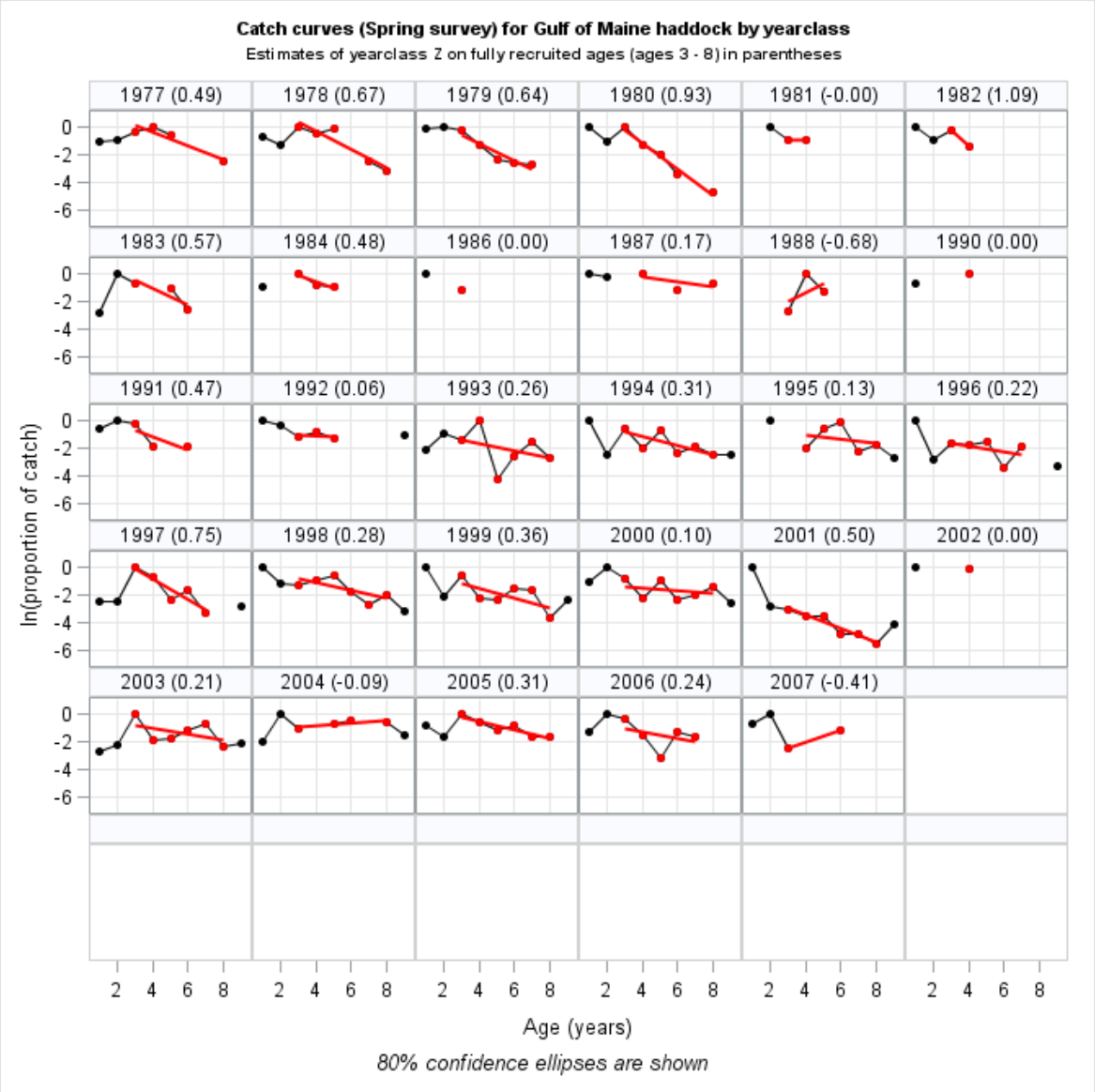


Figure A.103. Gulf of Maine haddock year class curves computed on ages 3-8 (red circles) log-transformed Northeast Fisheries Science Center (NEFSC) spring bottom trawl survey abundance (numbers/tow) indices. The corresponding slope of each regression line is shown next to the year class label above each plot.

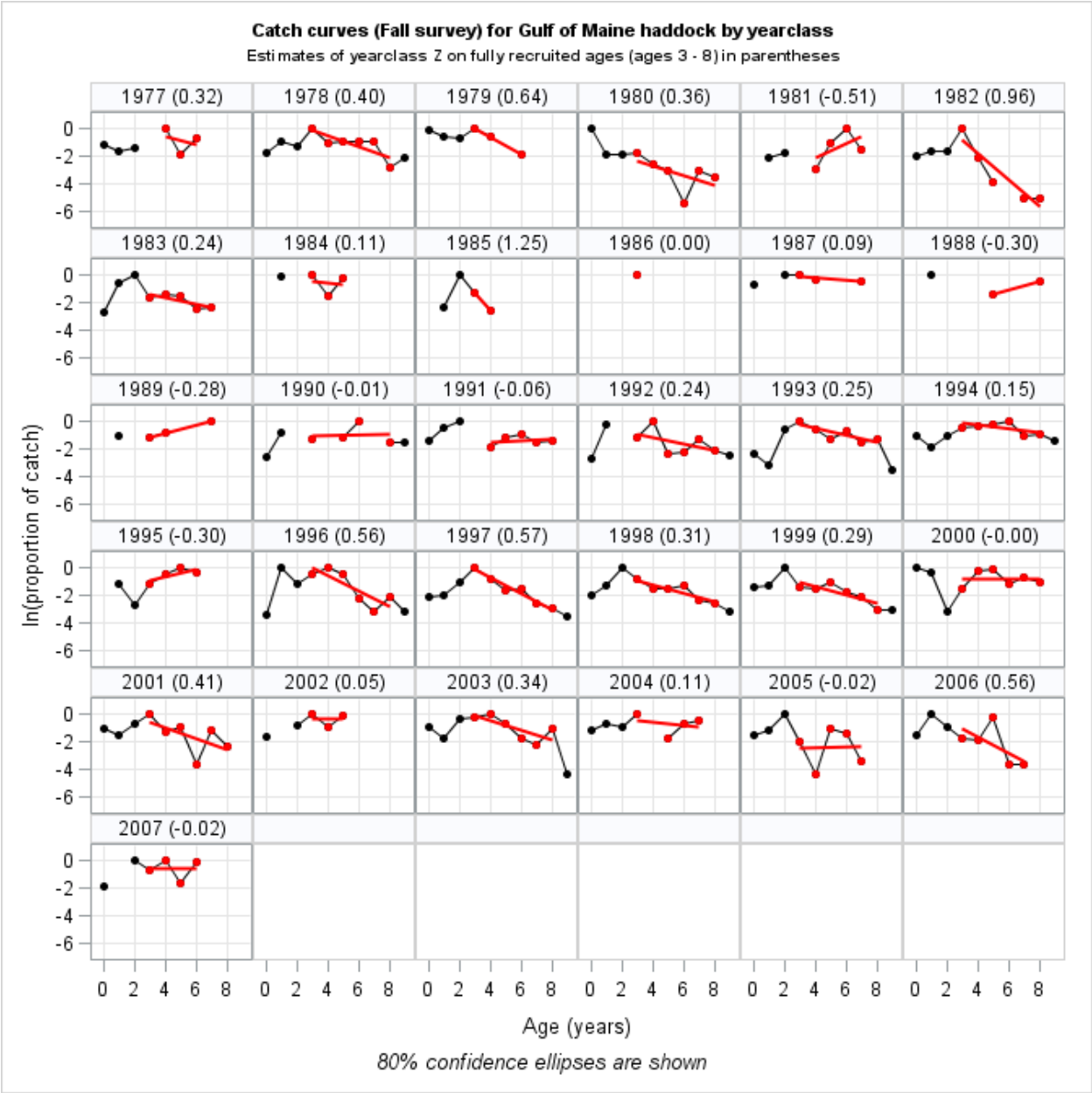


Figure A.104. Gulf of Maine haddock year class curves computed on ages 3-8 (red circles) log-transformed Northeast Fisheries Science Center (NEFSC) fall bottom trawl survey abundance (numbers/tow) indices. The corresponding slope of each regression line is shown next to the year class label above each plot.

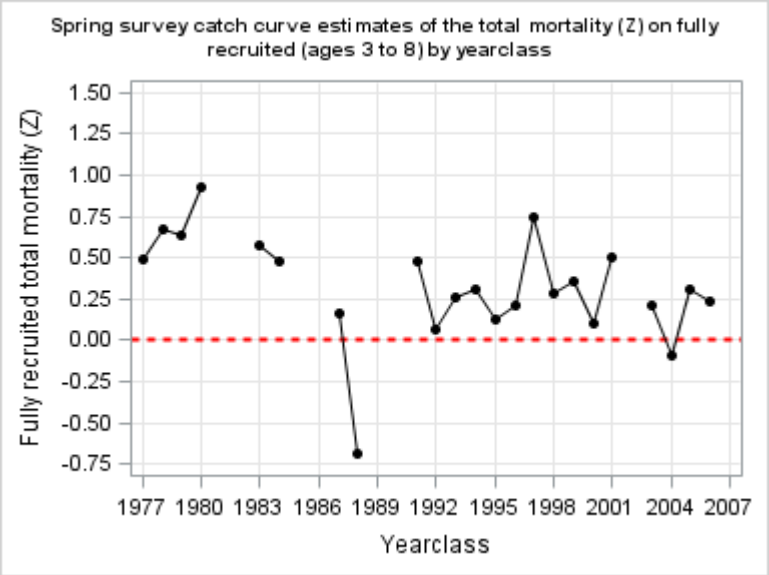


Figure A.105. Plots of the annual estimates of Gulf of Maine haddock total mortality (Z) as estimated from the year class curve analysis for total catch and Northeast Fisheries Science Center (NEFSC) spring bottom trawl surveys.

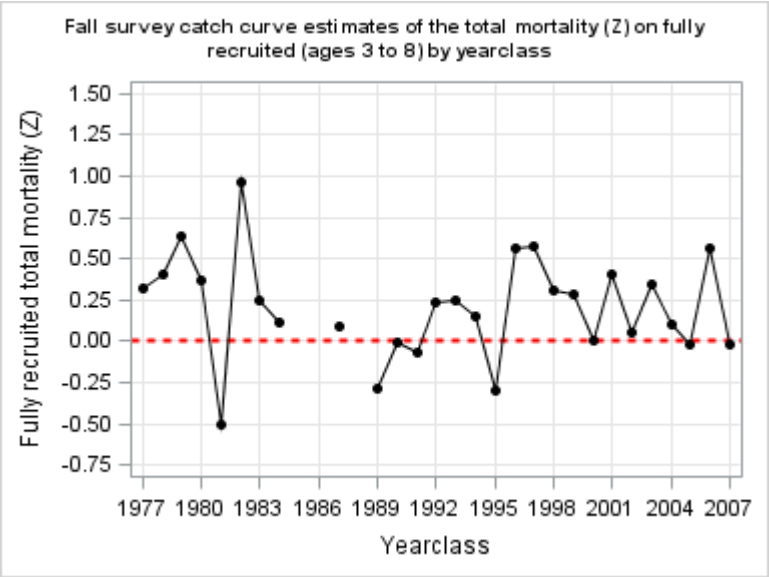


Figure A.106. Plots of the annual estimates of Gulf of Maine haddock total mortality (Z) as estimated from the year class curve analysis for total catch and Northeast Fisheries Science Center (NEFSC) fall bottom trawl surveys.

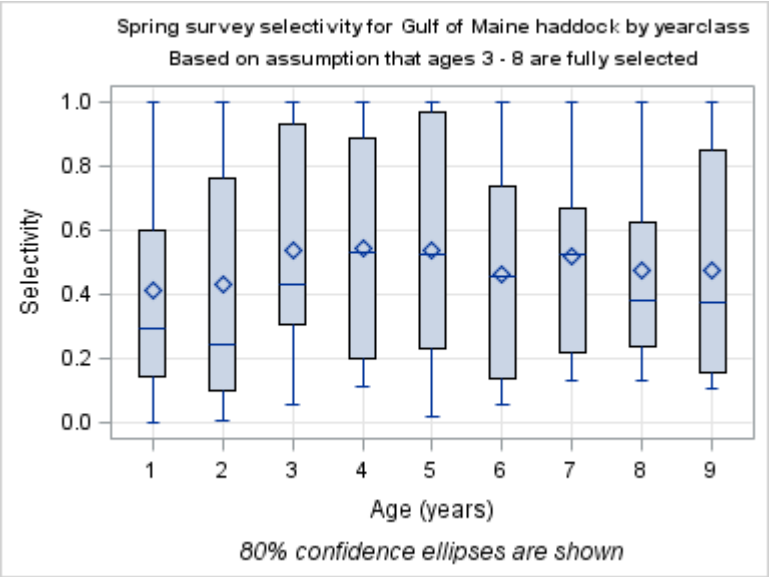


Figure A.107. Distribution of catch selectivity-at-age as estimated from the residuals fits to the Northeast Fisheries Science Center (NEFSC) spring survey indices catch curve analysis for Gulf of Maine haddock.

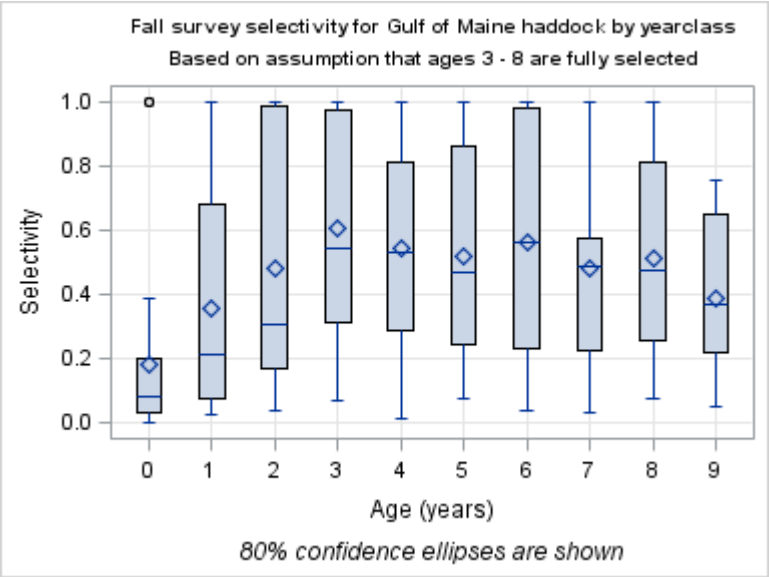


Figure A.108. Distribution of catch selectivity-at-age as estimated from the residuals fits to the Northeast Fisheries Science Center (NEFSC) fall survey indices catch curve analysis for Gulf of Maine haddock.

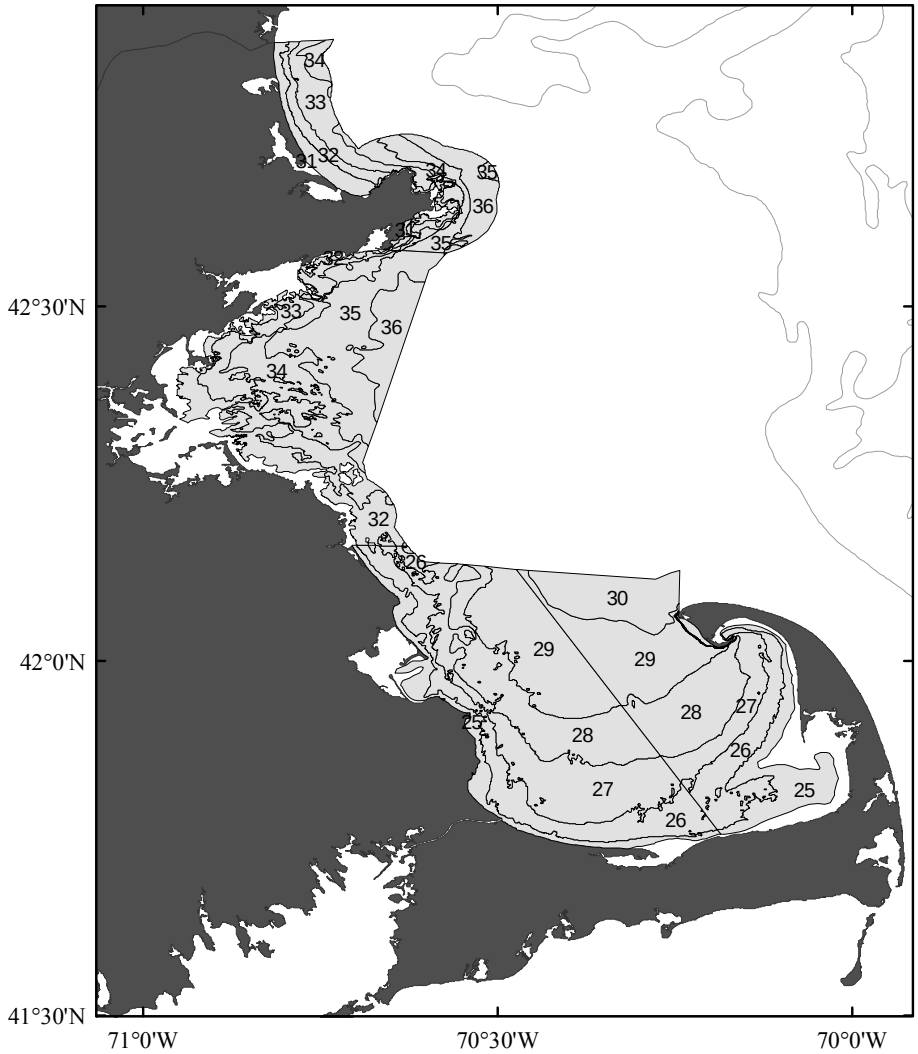


Figure A.109. Map of the Massachusetts Deparment of Marine Fisheries (MADMF) bottom trawl survey strata used to construct MADMF survey indices for Gulf of Maine haddock stock assessment (shaded grey).

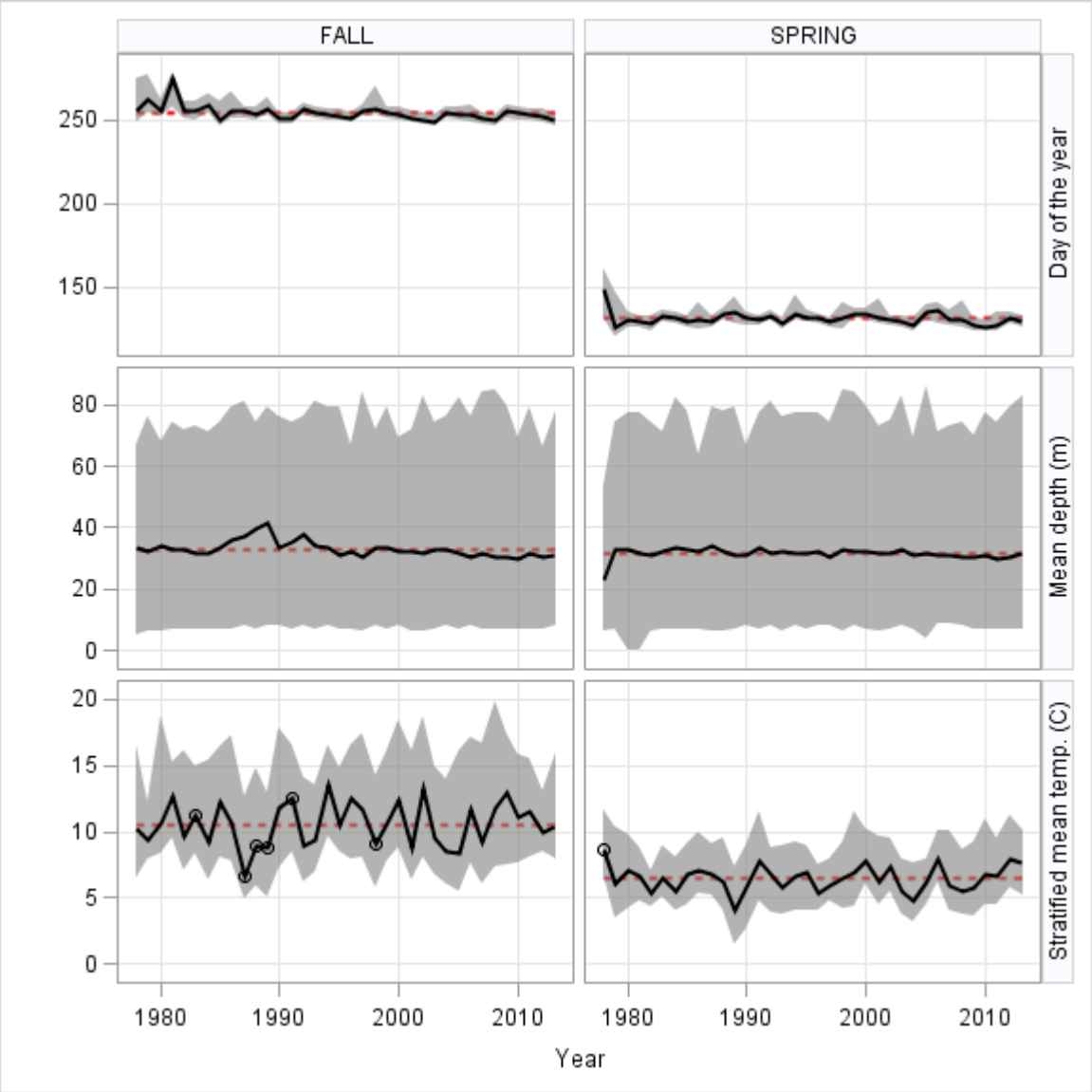


Figure A.110. Mean day of the year, depth and bottom temperature for the Massachusetts Department of Marine Fisheries (MADMF) spring and fall bottom trawl surveys in the Gulf of Maine. Shaded areas indicate the range between the minimum and maximum observation. *Day of the year is expressed as Julian days (e.g., January 1 is day 1 and December 31 is day 365/66). Years marked with circles in the mean temperature plot indicate years when not all survey stratum were sampled and therefore the mean temperature may not be representative of the entire survey area.*

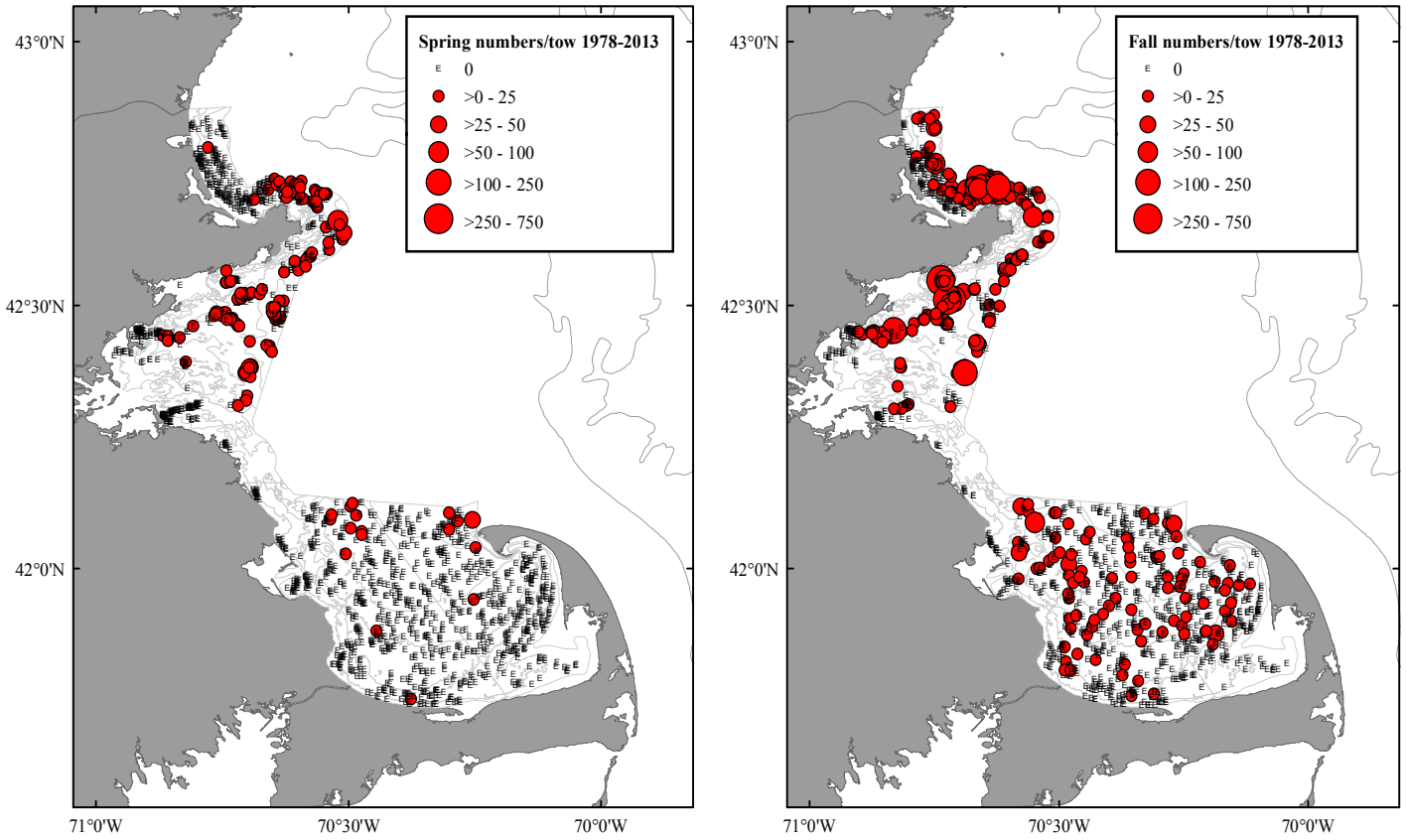


Figure A.111. Spatial distribution of Gulf of Maine haddock catches (numbers/tow) from the the Massachusetts Department of Marine Fisheries (MADMF) spring and fall bottom trawl surveys from 1978 – 2013.

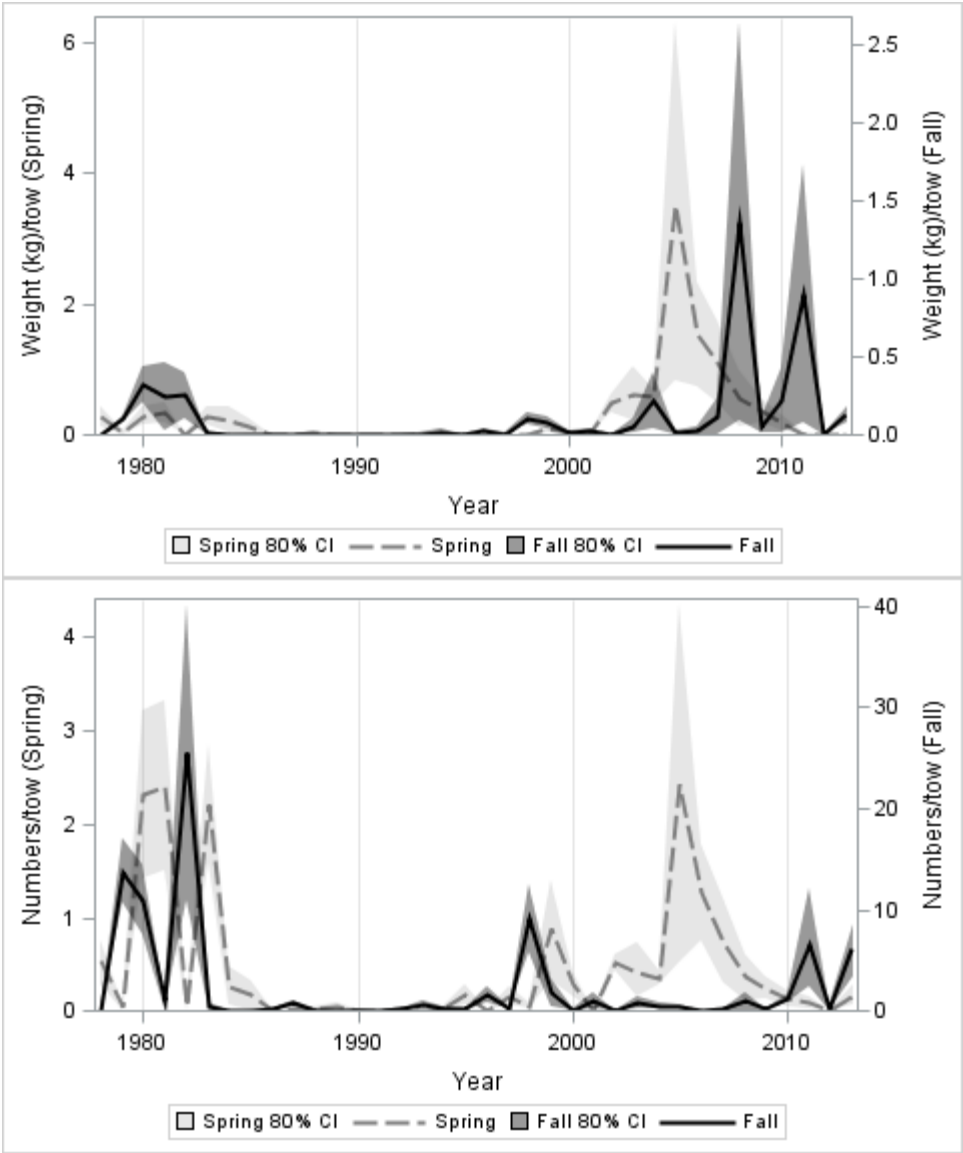


Figure A.112. Massachusetts Department of Marine Fisheries (MADMF) spring and fall bottom trawl survey Gulf of Maine haddock biomass (kg/tow) and abundance (numbers/tow) indices from 1978 to 2013.

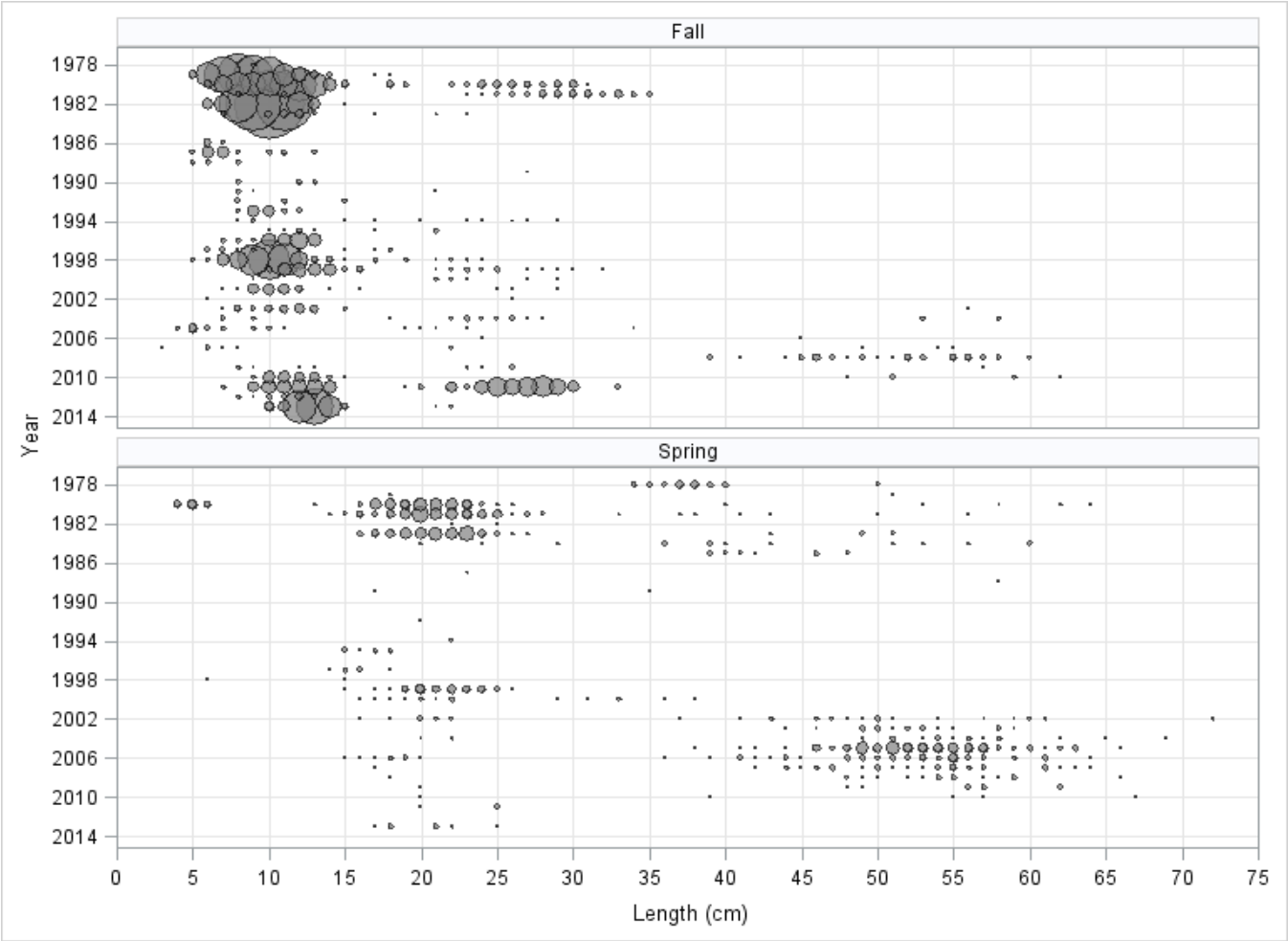


Figure A.113. Gulf of Maine haddock lengths-at-age from the Massachusetts Department of Marine Fisheries (MADMF) spring and fall bottom trawl surveys from 1978-2013.

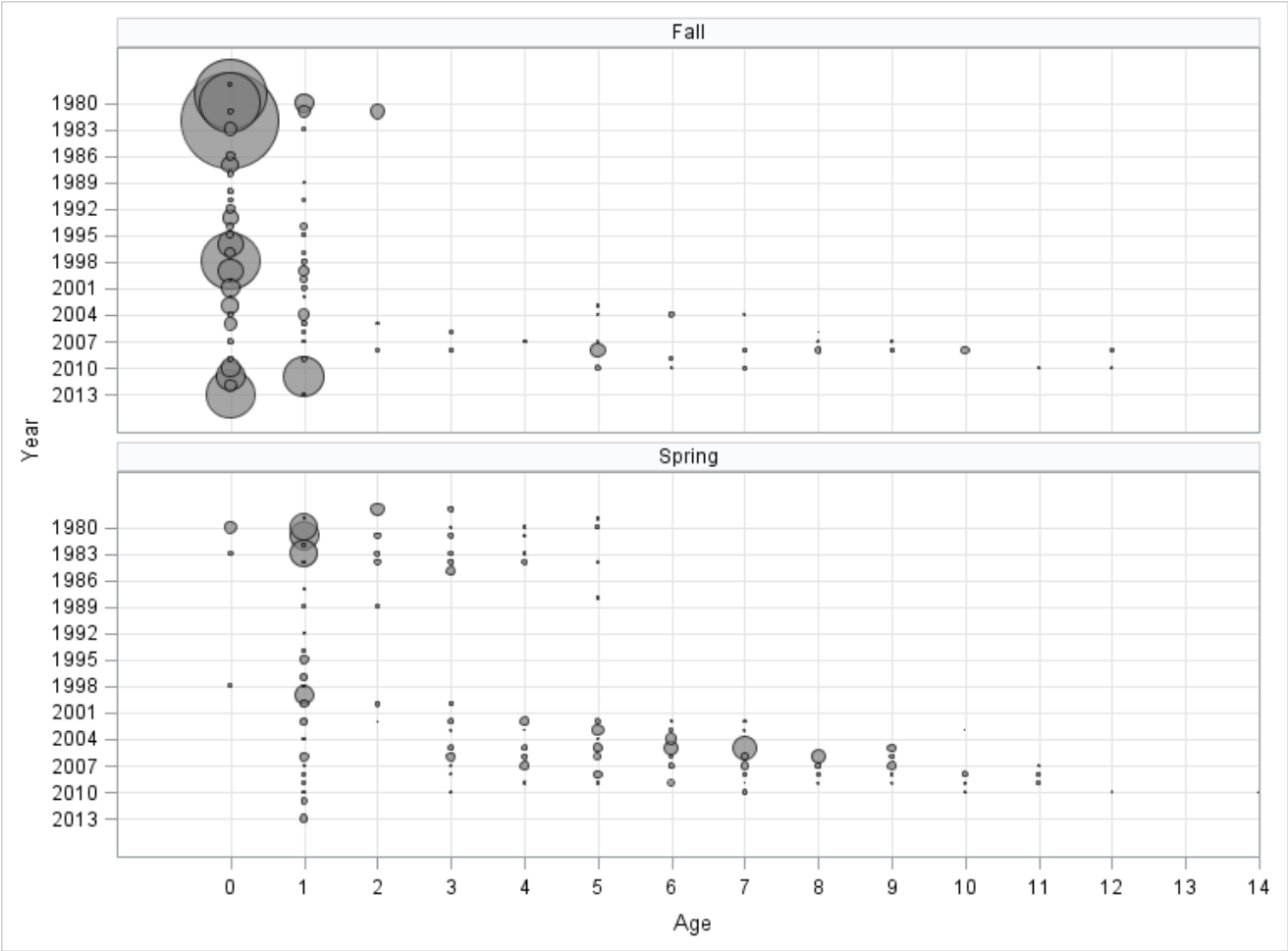


Figure A.114. Gulf of Maine haddock numbers-at-age from Massachusetts Department of Marine Fisheries (MADMF) spring and fall bottom trawl survey from 1978 to 2013. *Note that indices-at-age were constructed from age-length information borrowed from the Northeast Fisheries Science Center survey data.*

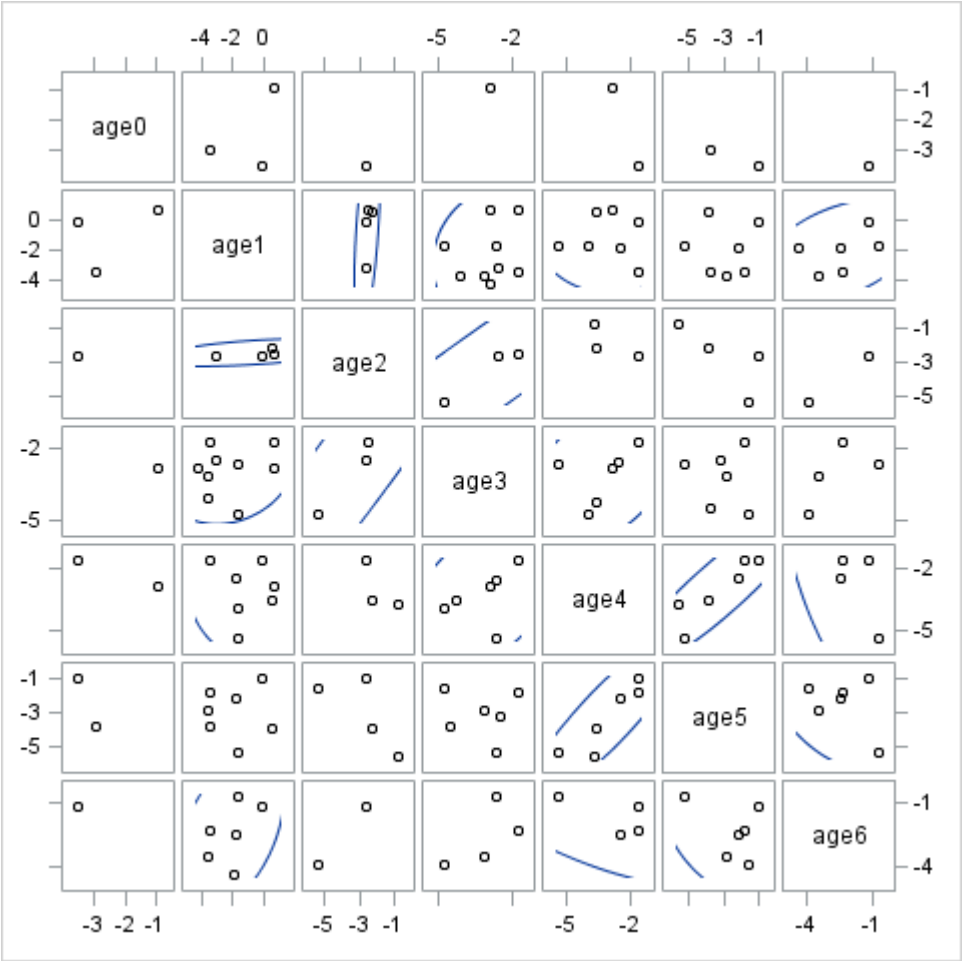


Figure A.115. Scatter plots showing the level of agreement between Massachusetts Department of Marine Fisheries (MADMF) spring bottom trawl survey Gulf of Maine haddock indices-at-age (log transformed) on a cohort basis. The 80% confidence ellipses are shown.

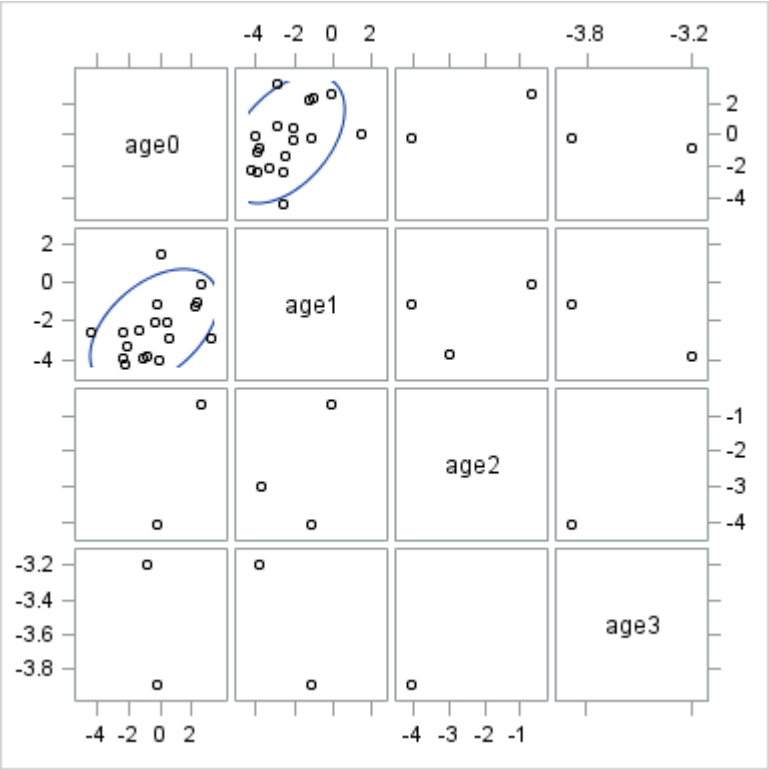


Figure A.116. Scatter plots showing the level of agreement between Massachusetts Department of Marine Fisheries (MADMF) fall bottom trawl survey Gulf of Maine haddock indices-at-age (log transformed) on a cohort basis. The 80% confidence ellipses are shown.

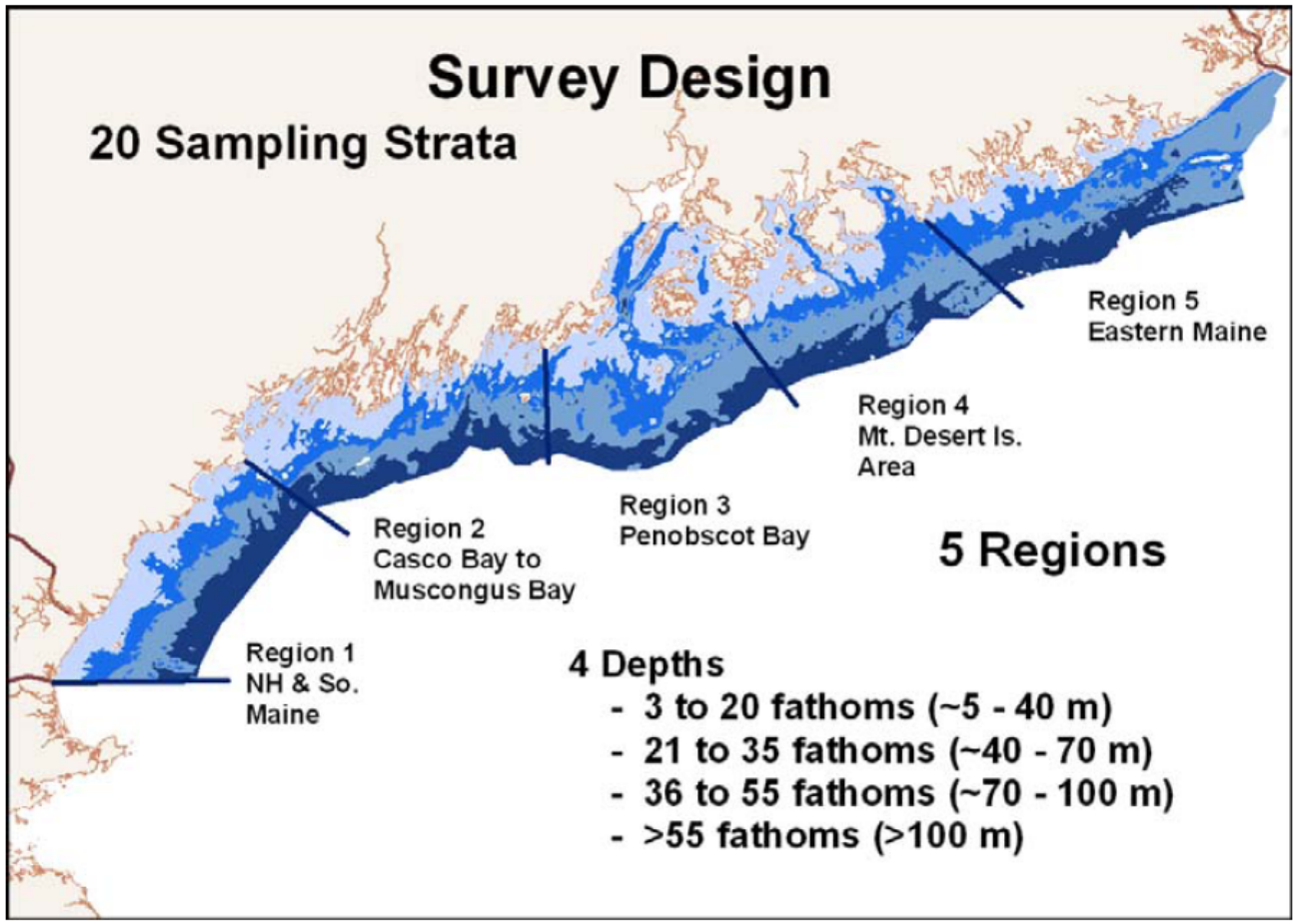


Figure A.117. Map of the Maine-New Hamphire inshore groundfish trawl survey strata set (map from Sherman et al. 2005).

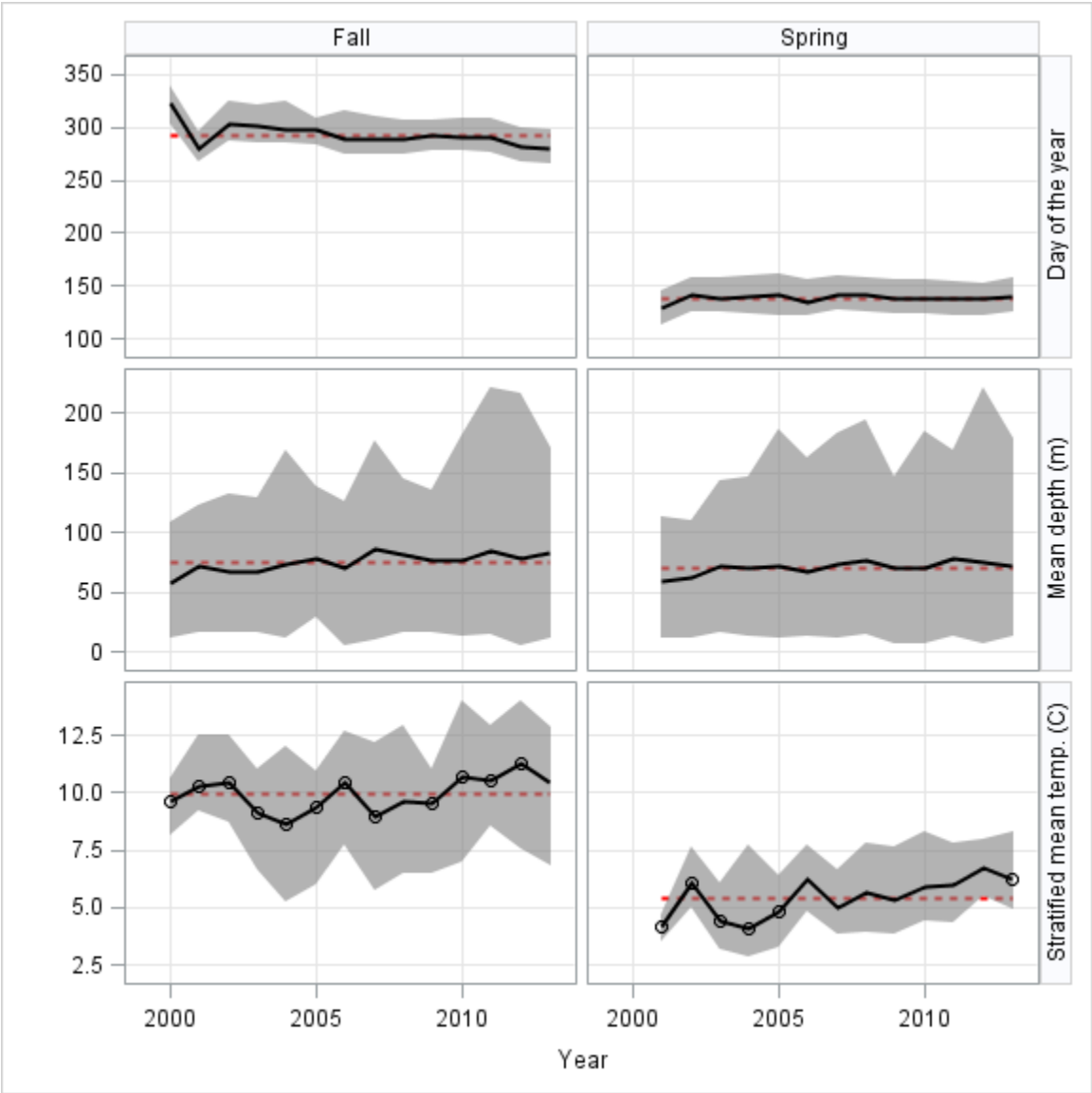


Figure A.118. Mean day of the year, depth and bottom temperature for the Maine-New Hamphire spring and fall inshore groundfish trawl survey. Shaded areas indicate the range between the minimum and maximum observation. *Day of the year is expressed as Julian days (e.g., January 1 is day 1 and December 31 is day 365/66). Years marked with circles in the mean temperature plot indicate years when not all survey stratum were sampled and therefore the mean temperature may not be representative of the entire survey area.*

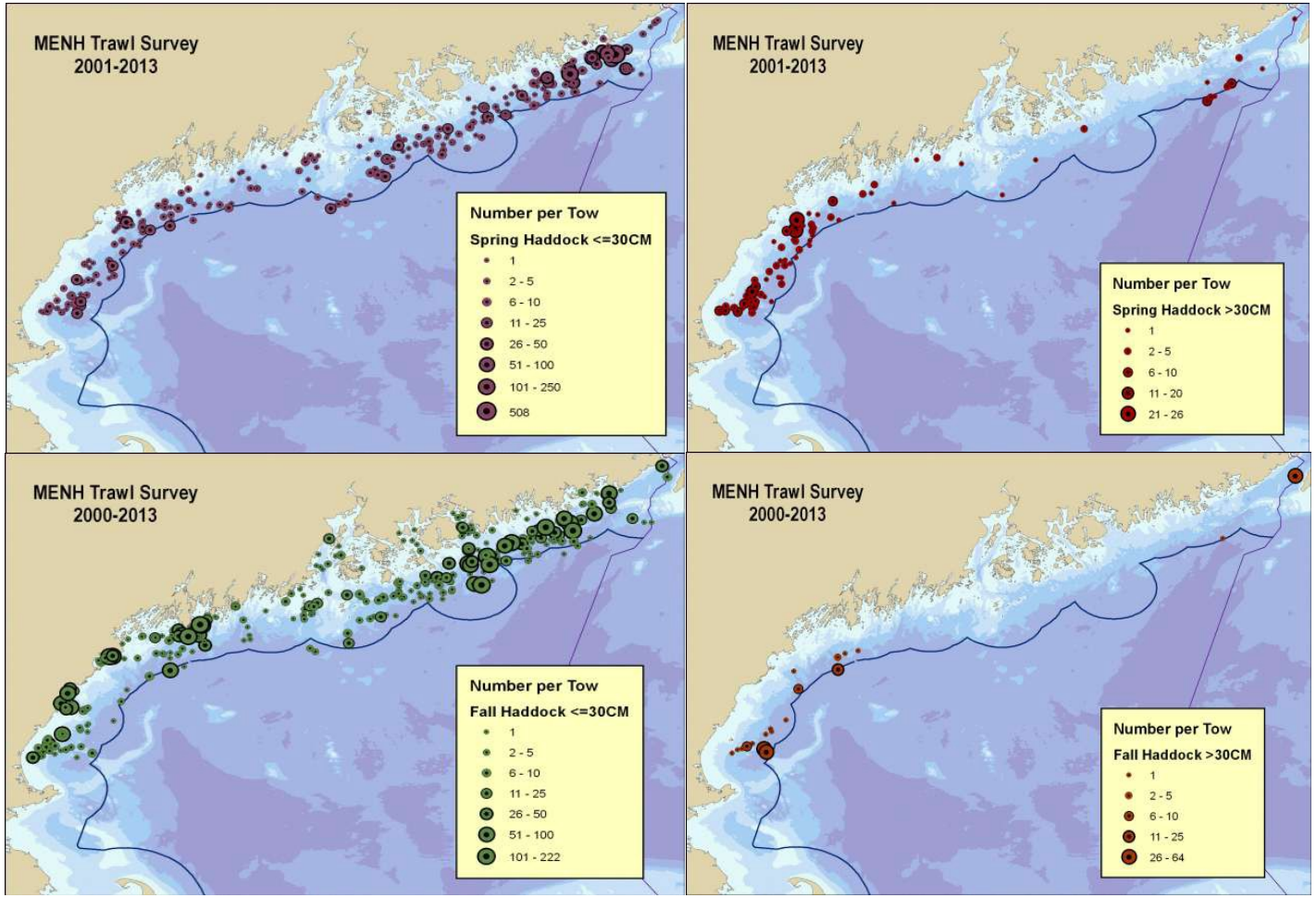


Figure A.119. Spatial distribution of Gulf of Maine haddock catches (numbers/tow) from the spring (top) and fall (bottom) Maine-New Hamphire (MENH) inshore groundfish trawl survey from 2000-2013 for fish ≤30 cm (left) and > 30 cm (right). Maps provided by S. Sherman (pers. comm.).

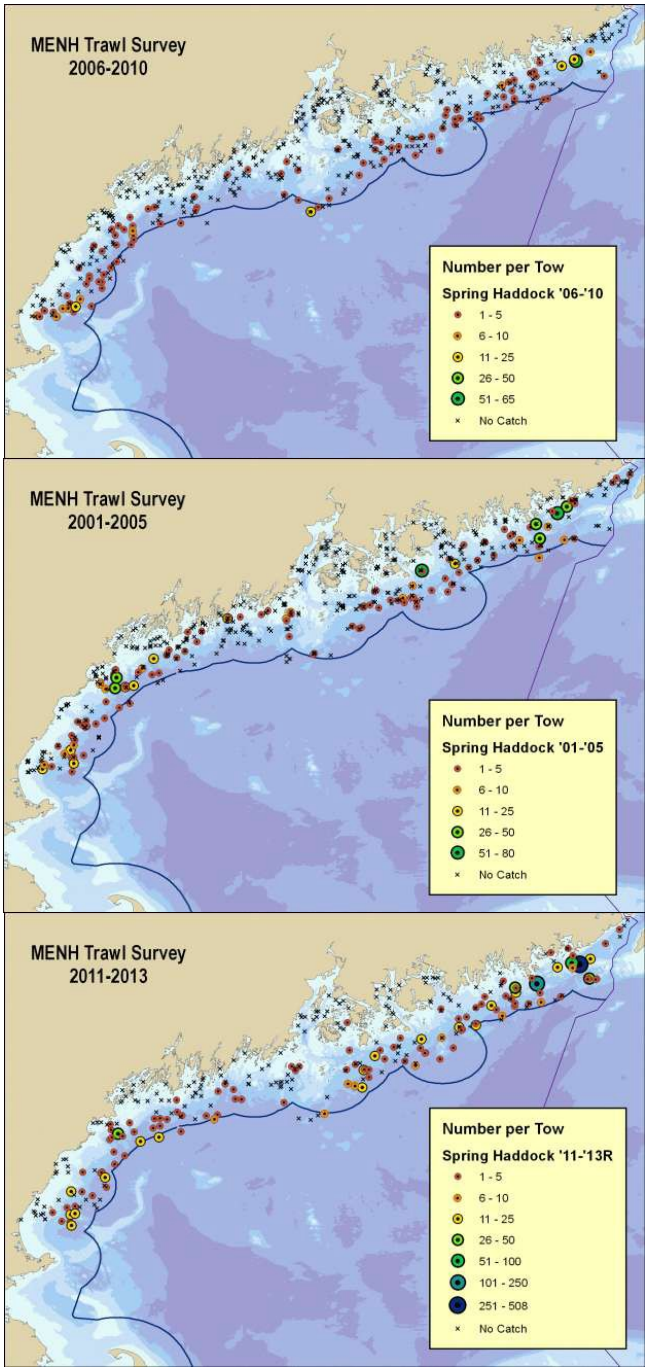


Figure A.120. Spatial distribution of Gulf of Maine haddock catches (numbers/tow) from the spring Maine-New Hamphire (MENH) inshore groundfish trawl survey from 2001-2015 (top), 2006-2010 (middle), and 2011-2013 (bottom). Maps provided by S. Sherman (pers. comm.).

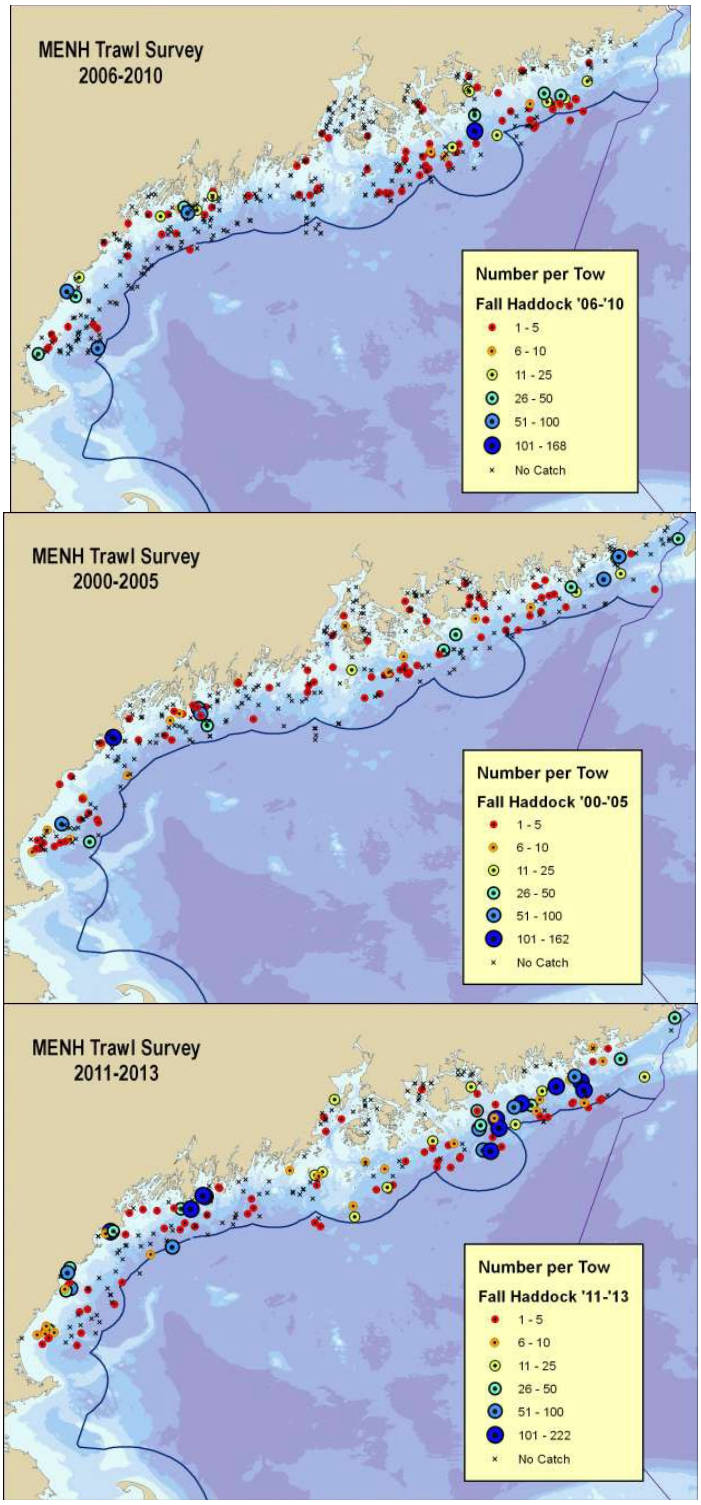


Figure A.121. Spatial distribution of Gulf of Maine haddock catches (numbers/tow) from the fall Maine-New Hamphire (MENH) inshore groundfish trawl survey from 2000-2015 (top), 2006-2010 (middle), and 2011-2013 (bottom). Maps provided by S. Sherman (pers. comm.).

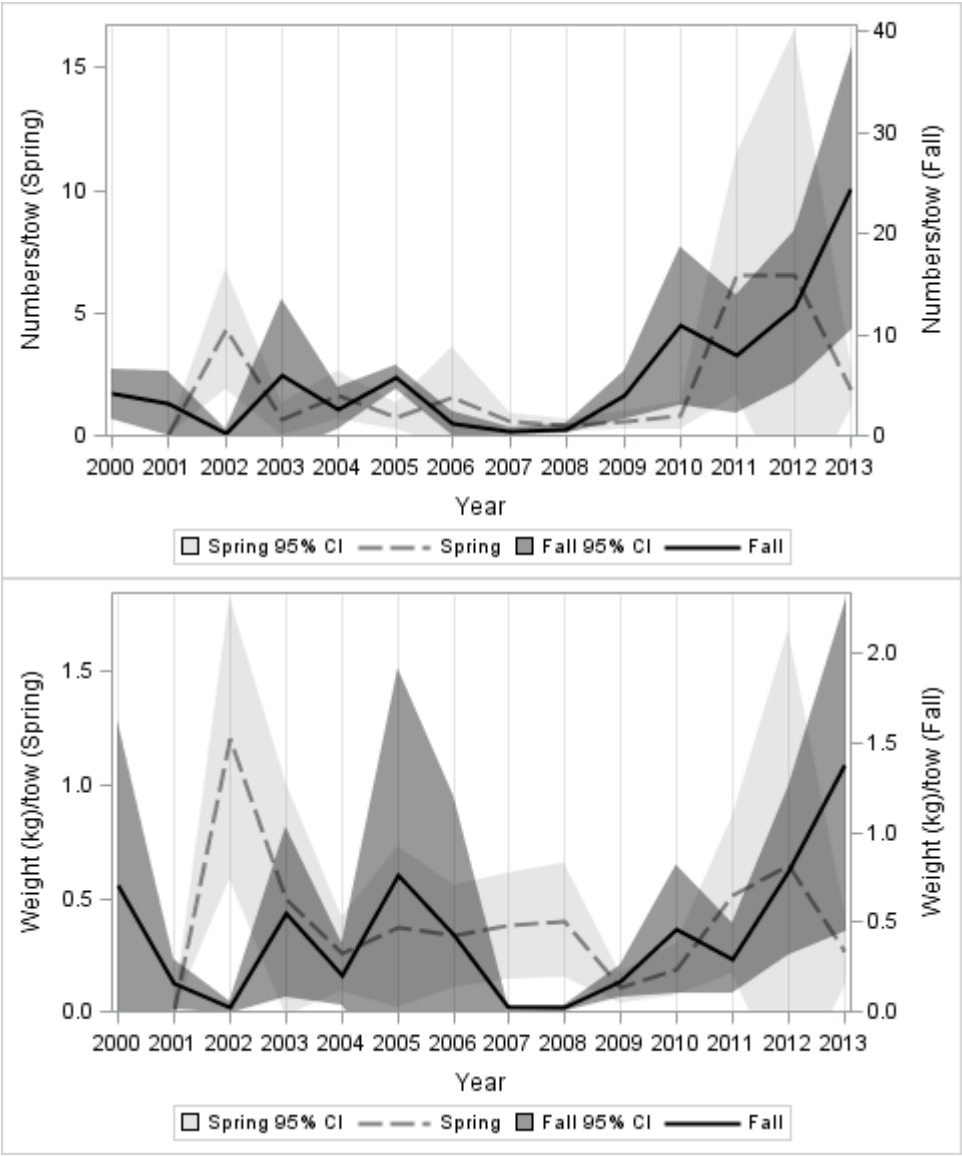


Figure A.122. Maine-New Hamphire inshore (MENH) groundfish trawl survey spring and fall Gulf of Maine haddock biomass (kg/tow) and abundance (numbers/tow) indices from 2000 to 2013. *Note that the spring survey did not begin until 2001.*

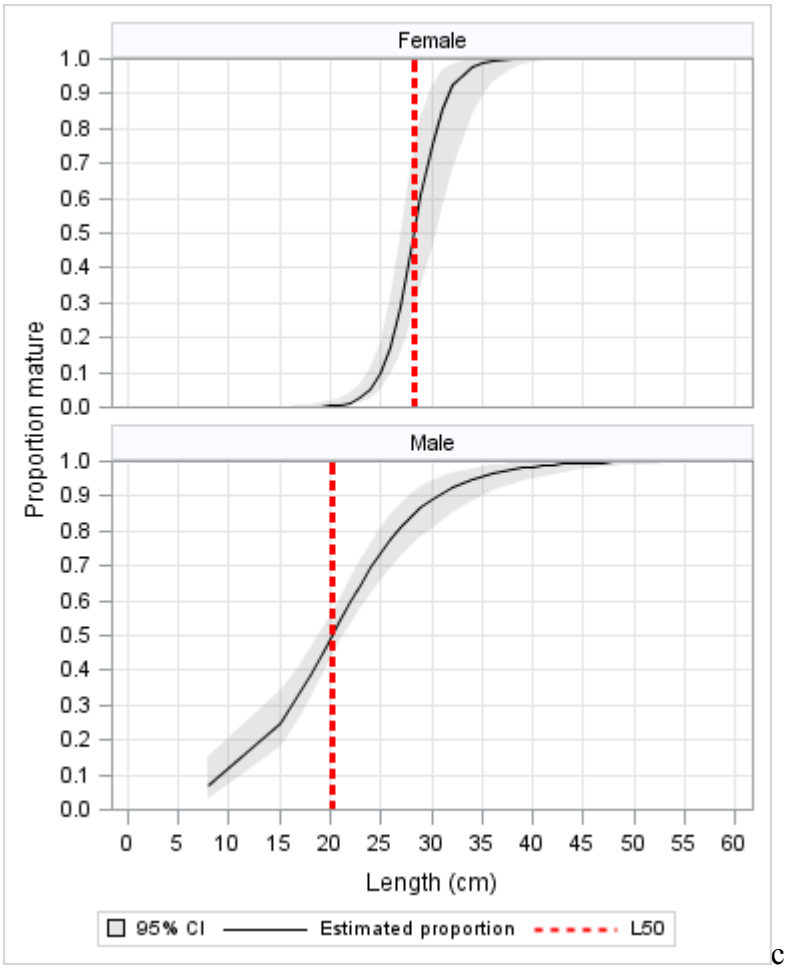


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Figure A.123. Length-based maturity ogives for female (left) and male (right) Gulf of Maine haddock based on time series averages of maturity and length information collected from the Maine-New Hampshire (MENH) spring inshore groundfish trawl survey between 2001 and 2011. The dashed red line indicates the length at 50% maturity.

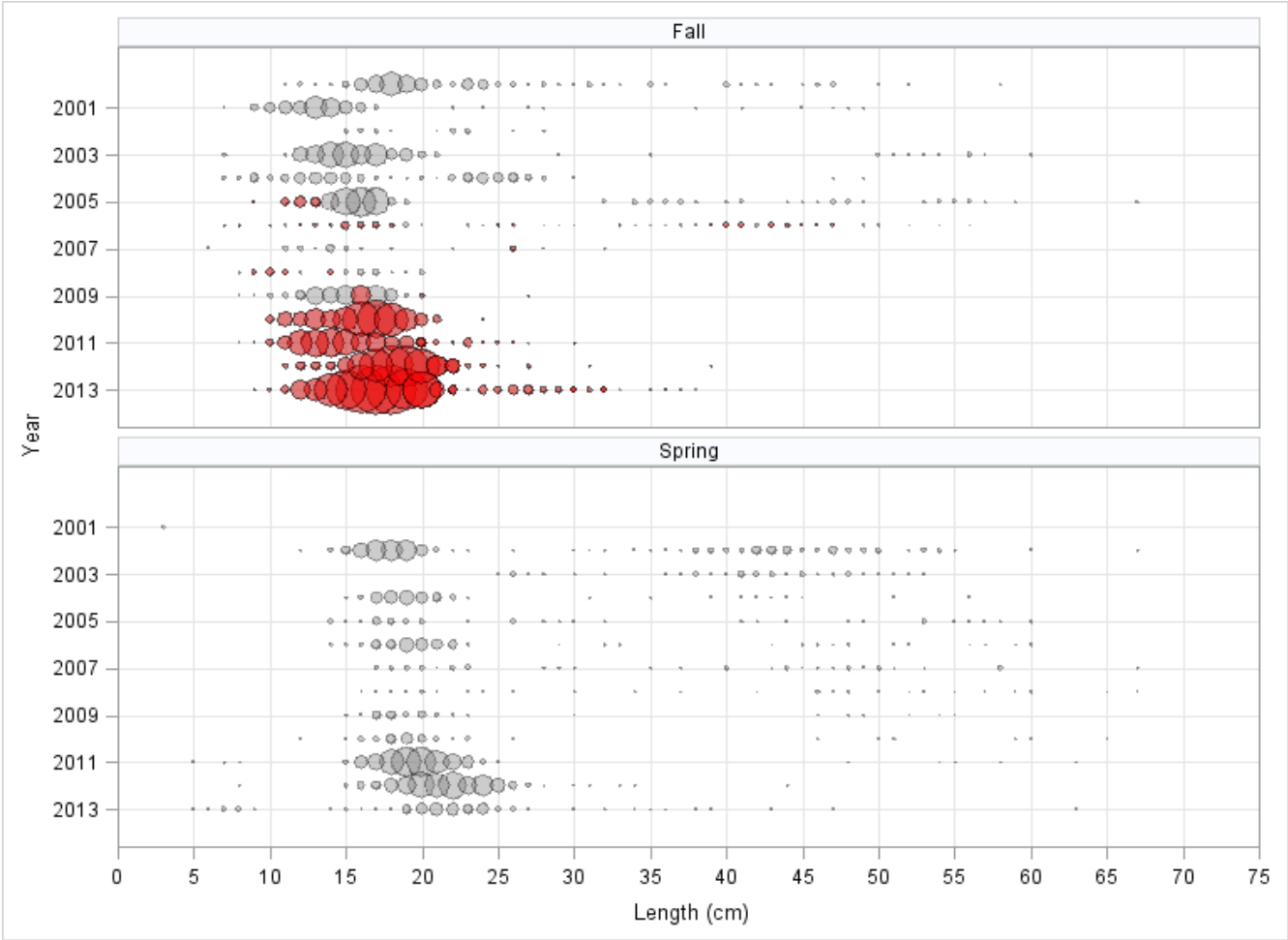

Figure A.124. Length distributions of Gulf of Maine haddock sampled in the Maine-New Hampshire (MENH) inshore groundfish trawl spring (top) and fall (bottom) surveys from 2001 to 2013. The red shaded bubbles indicate the length intervals for which there is age information available directly from the MENH survey.

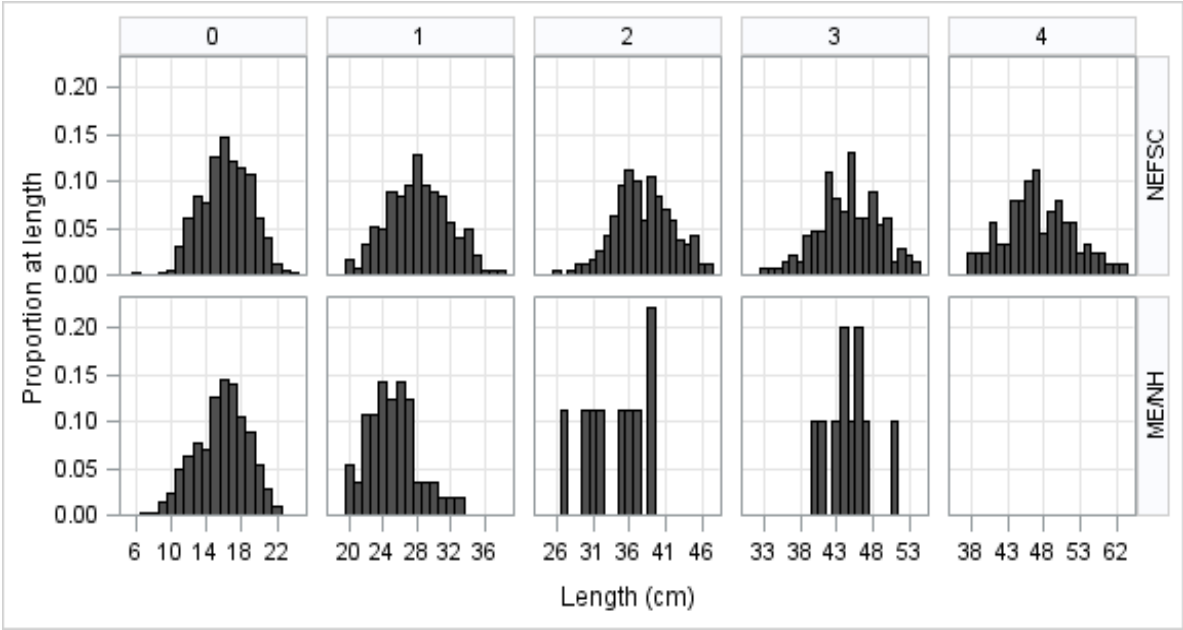

Figure A.125. Comparison of Gulf of Maine haddock length frequency distributions by age class from the Maine-New Hampshire (MENH) and Northeast Fisheries Science Center (NEFSC) fall bottom trawl survey. Data have been aggregated over the years 2005 to 2013.

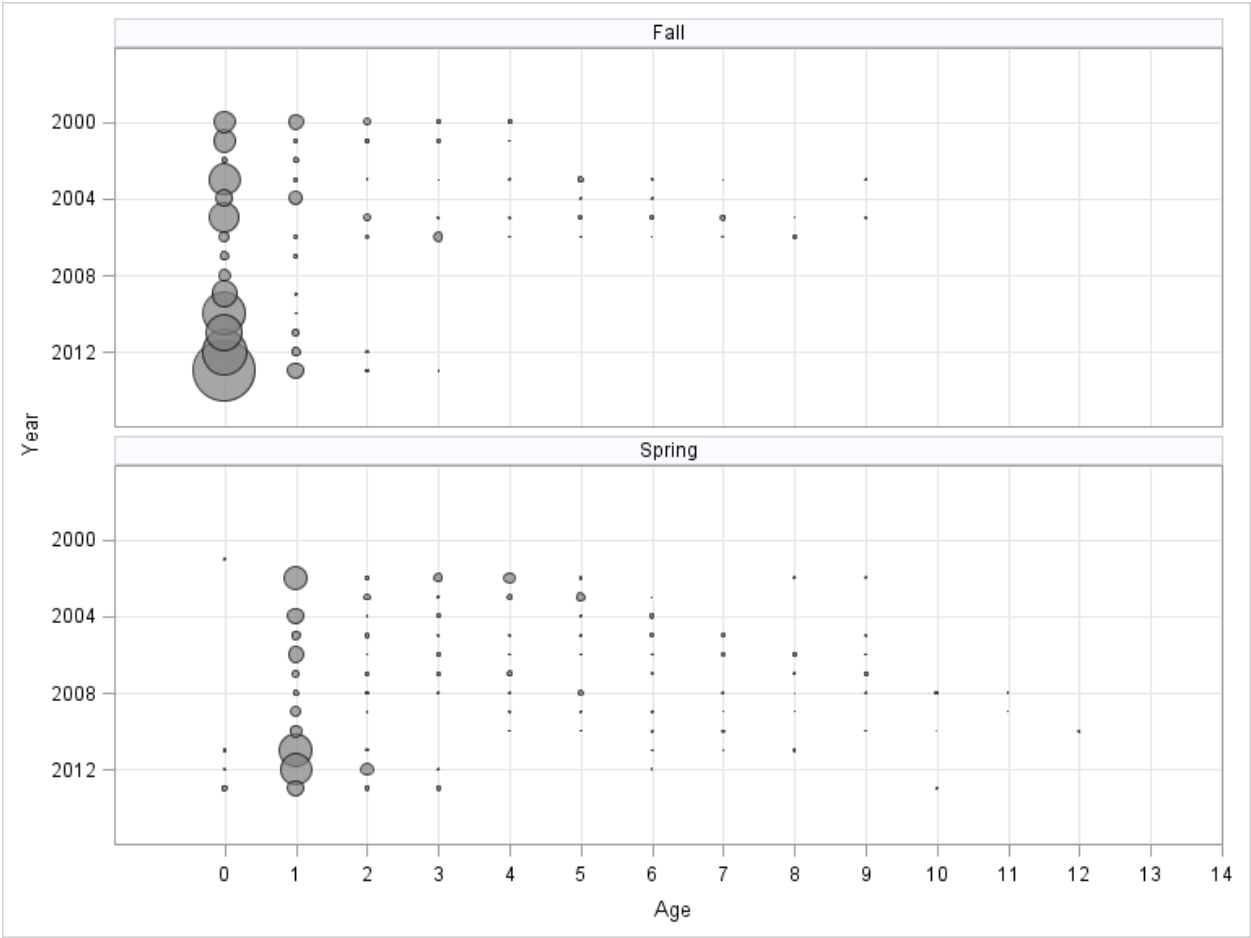

Figure A.126. Gulf of Maine haddock numbers-at-age from Maine-New Hampshire (MENH) spring and fall inshore groundfish trawl survey from 2000 to 2013. *Note: 1) the spring survey did not begin until 2001; 2)* indices-at-age were constructed from age-length information borrowed from the Northeast Fisheries Science Center survey data with the exception of the fall 2005-2013 indices were MENH age-length information was augmented with NEFSC data.

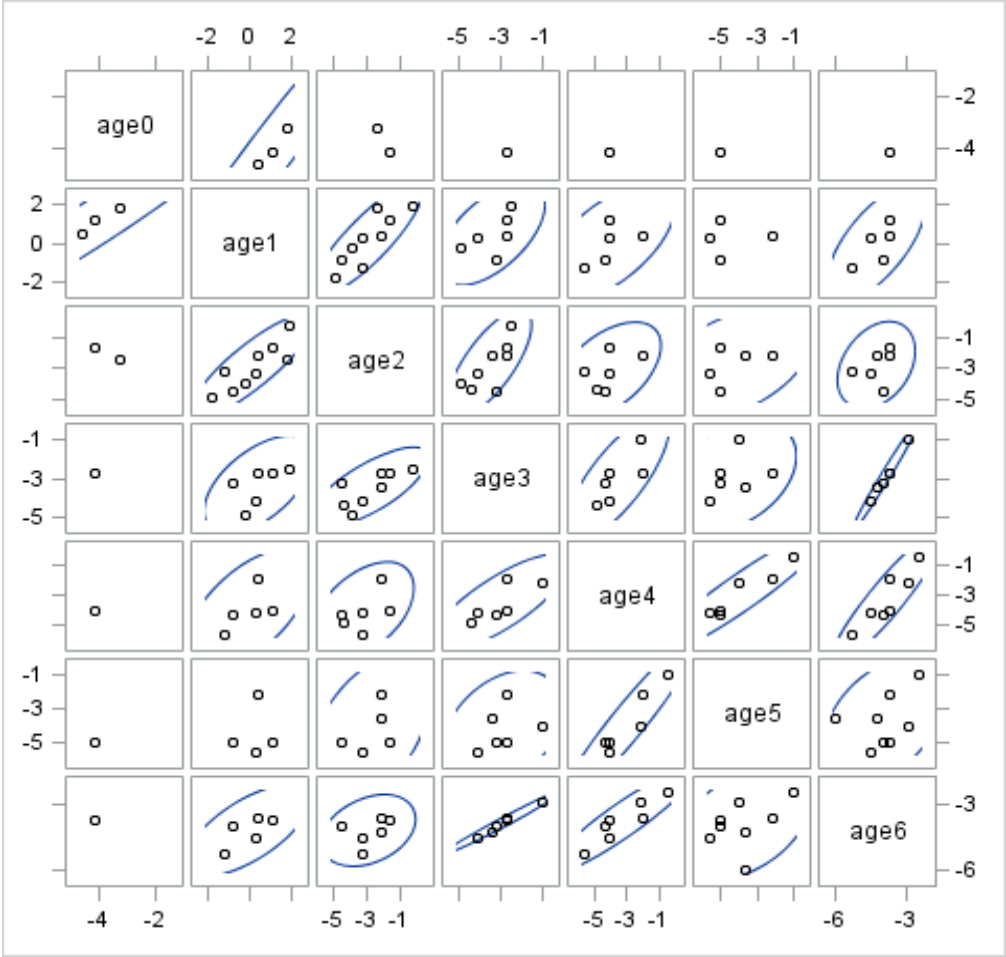

Figure A.127. Scatter plots showing the level of agreement between Massachusetts Maine – New Hampshire (MENH) spring inshore groundfish trawl survey Gulf of Maine haddock indices-at-age (log transformed) on a cohort basis. 80% confidence ellipses are shown.

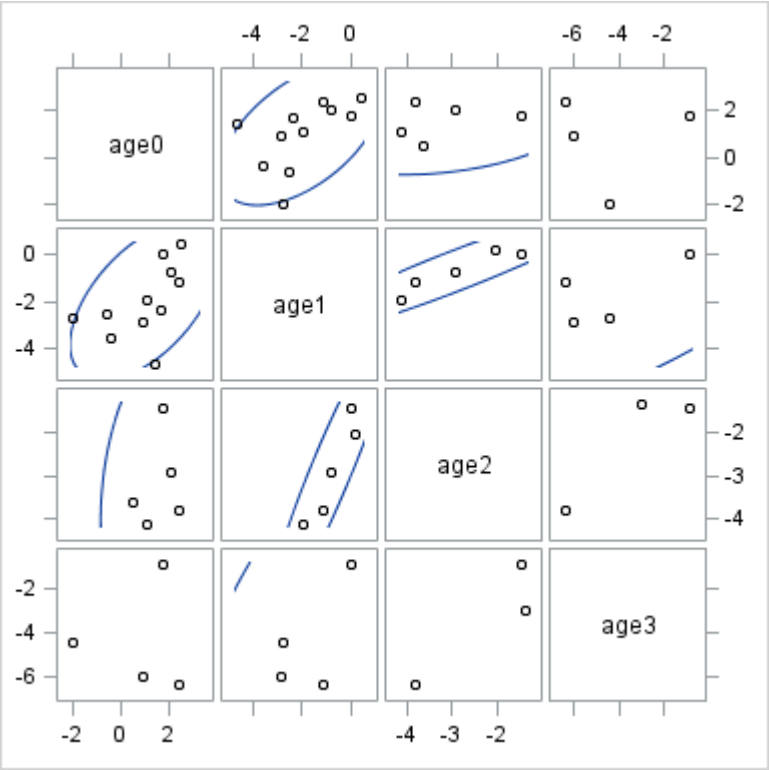

Figure A.128. Scatter plots showing the level of agreement between Maine – New Hampshire (MENH) fall inshore groundfish trawl survey Gulf of Maine haddock indices-at-age (log transformed) on a cohort basis. 80% confidence ellipses are shown.

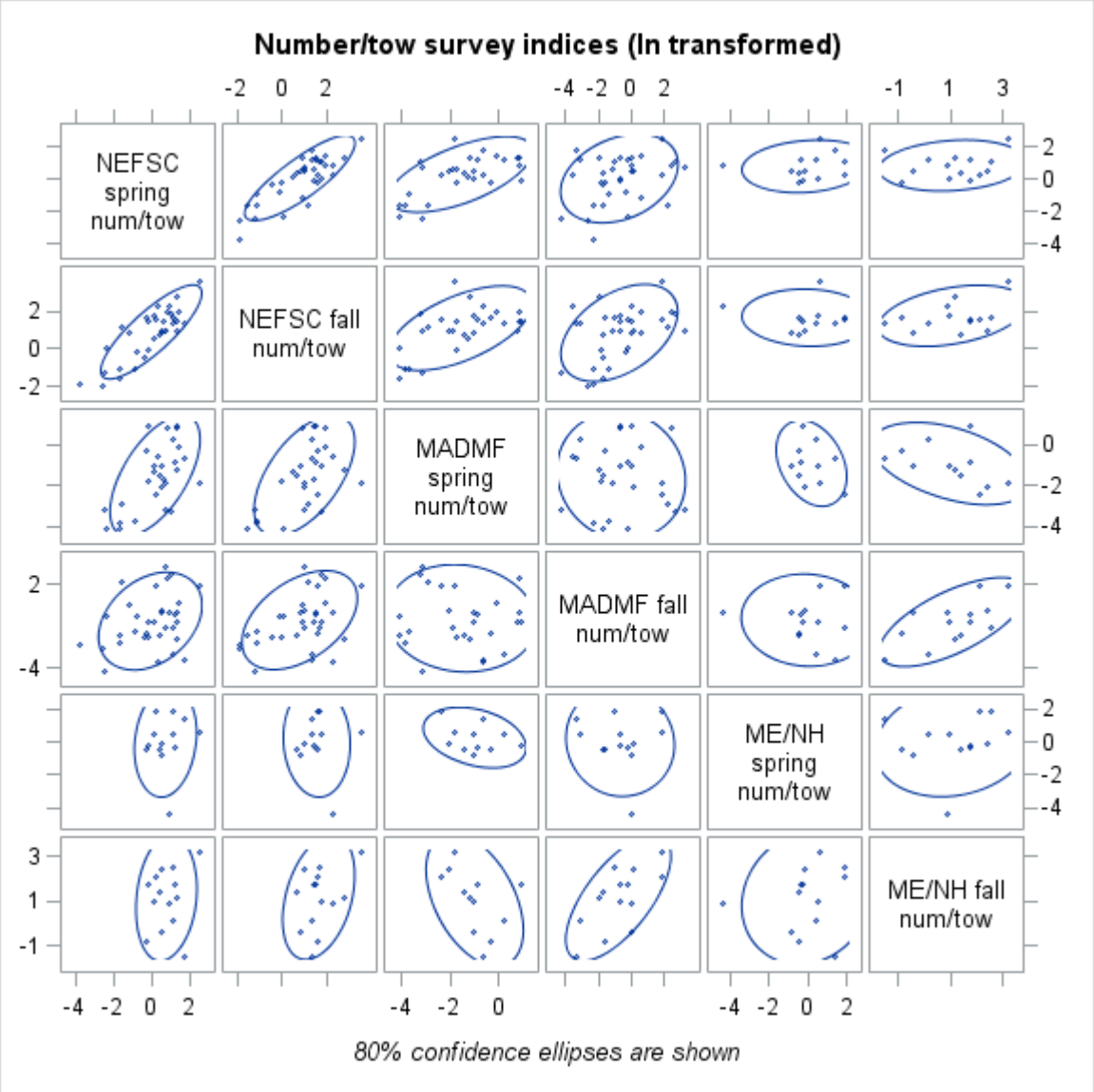

Figure A.129. Scatter plots showing the level of agreement between the Northeast Fisheries Science Center (NEFSC), Massachusetts Department of Marine Fisheries (MADMF) and the Maine – New Hamphire (ME/NH) inshore groundfish trawl survey Gulf of Maine haddock abundance (numbers/tow) indices (log transformed). 80% confidence ellipses are shown.

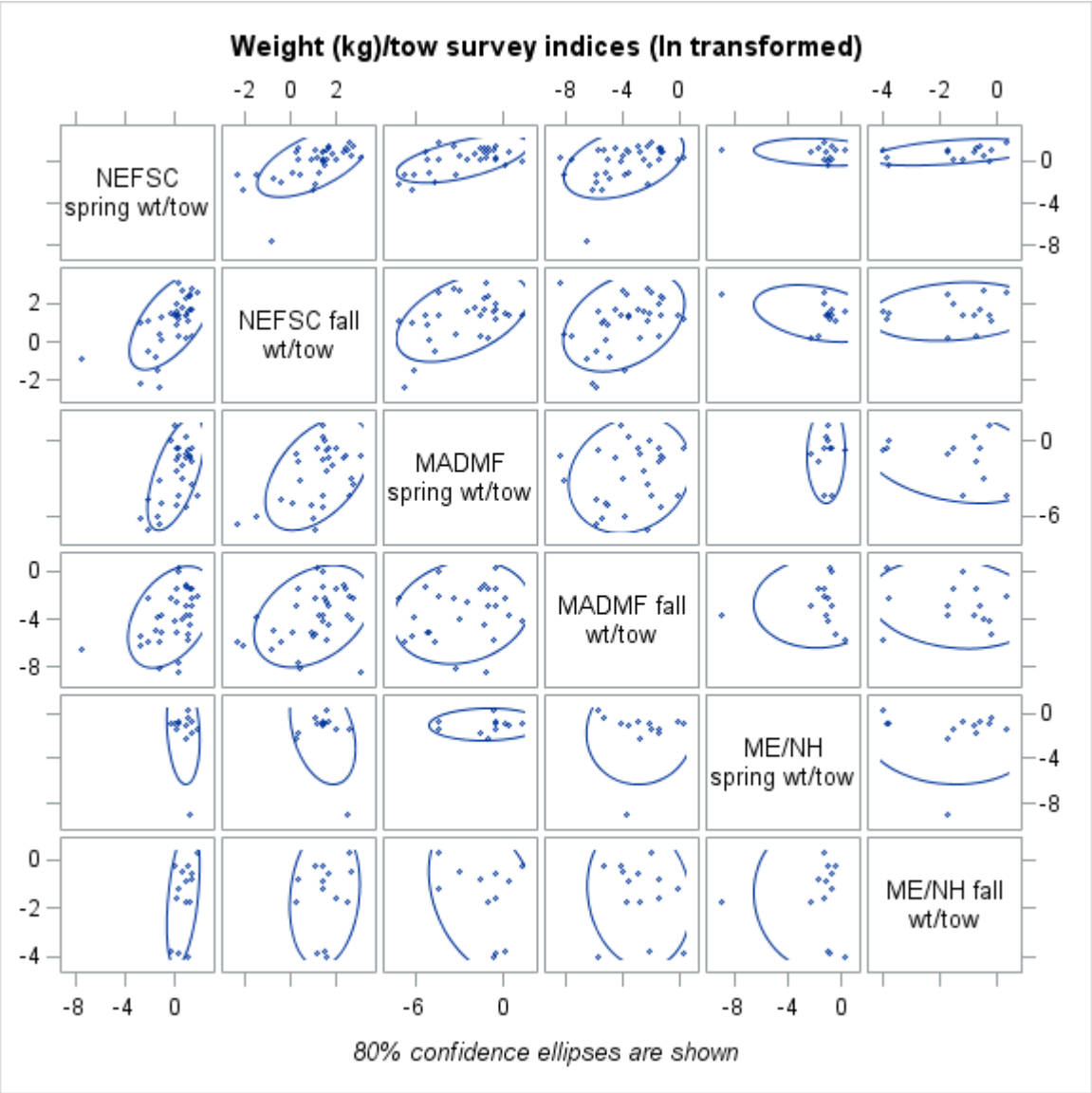

Figure A.130. Scatter plots showing the level of agreement between the Northeast Fisheries Science Center (NEFSC), Massachusetts Department of Marine Fisheries (MADMF) and the Maine – New Hamphire (ME/NH) inshore groundfish trawl survey Gulf of Maine haddock biomass (weight/tow) indices (log transformed). 80% confidence ellipses are shown.

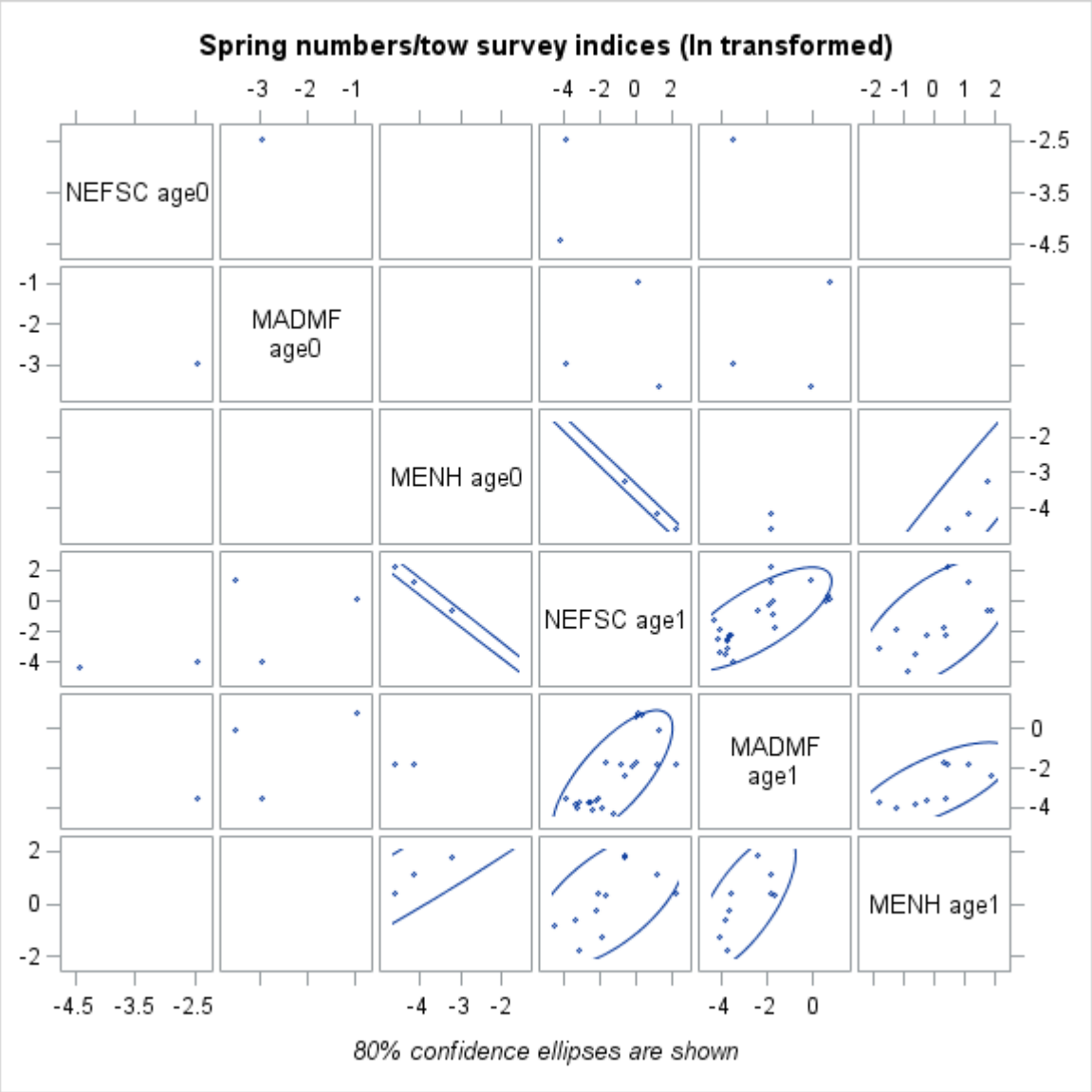

Figure A.131. Scatter plots showing the level of agreement between the Northeast Fisheries Science Center (NEFSC), Massachusetts Department of Marine Fisheries (MADMF) and the Maine – New Hamphire (ME/NH) inshore groundfish trawl survey Gulf of Maine haddock spring abundance (numbers/tow) indices (log transformed) for age-0 and age-1 fish on a cohort basis. 80% confidence ellipses are shown.

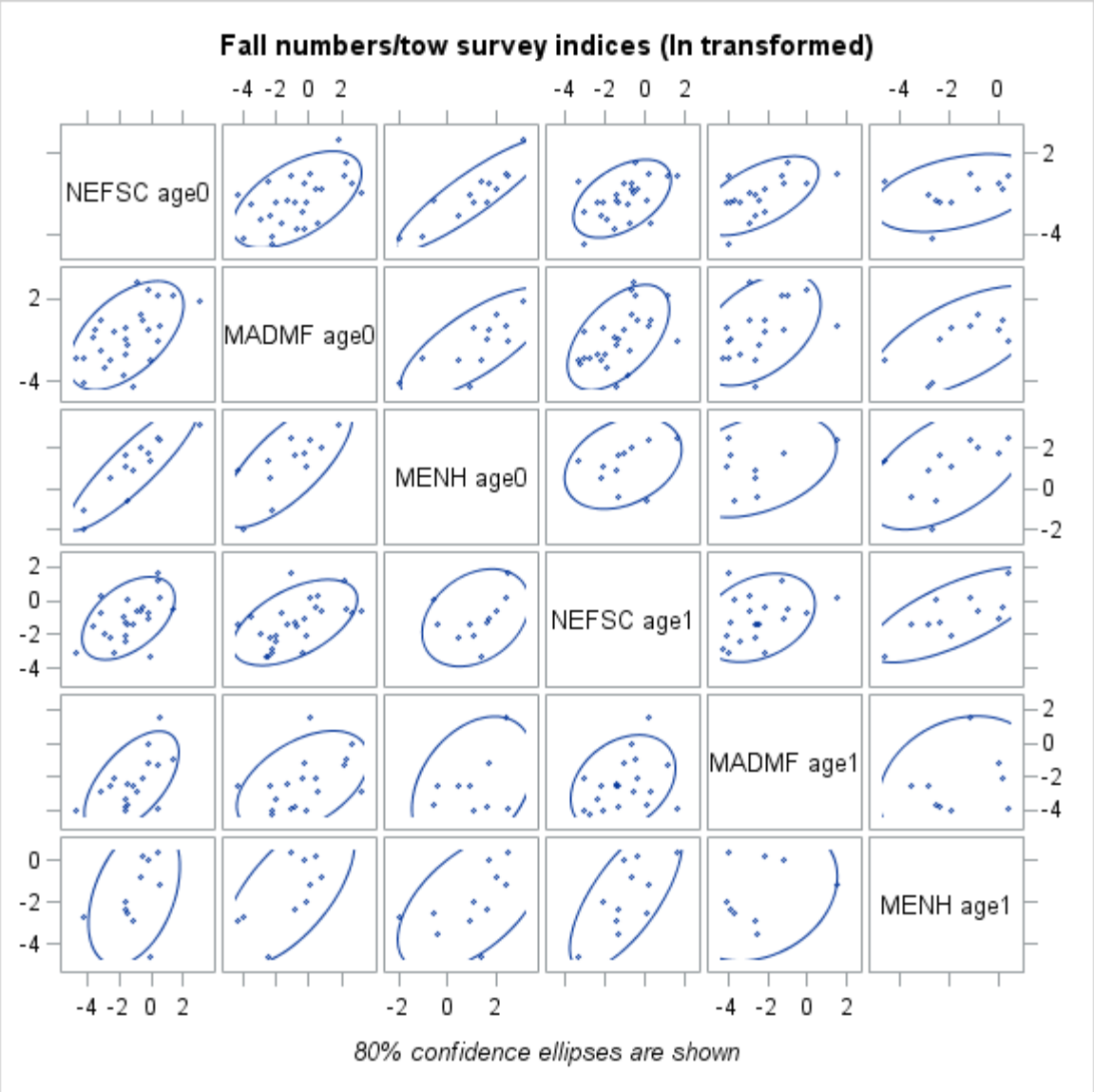

Figure A.132. Scatter plots showing the level of agreement between the Northeast Fisheries Science Center (NEFSC), Massachusetts Department of Marine Fisheries (MADMF) and the Maine – New Hamphire (ME/NH) inshore groundfish trawl survey Gulf of Maine haddock fall abundance (numbers/tow) indices (log transformed) for age-0 and age-1 fish on a cohort basis. 80% confidence ellipses are shown.

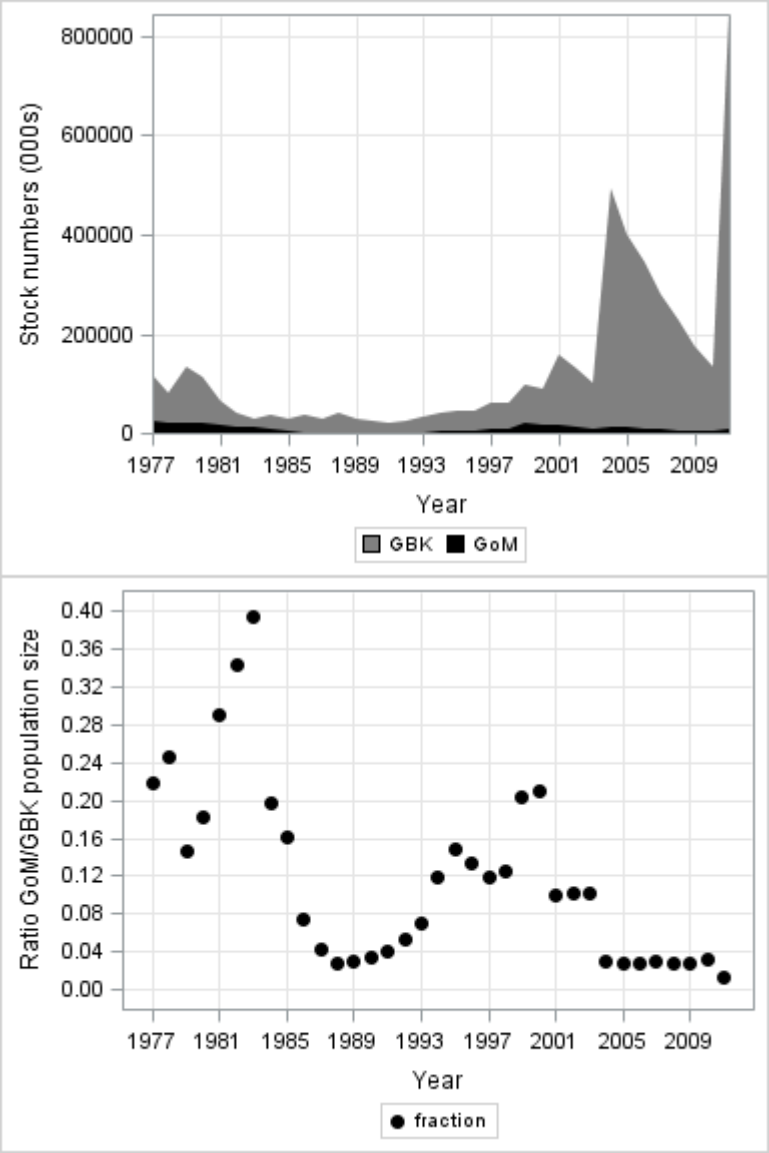

Figure A.133. Georges Bank (GBK) and Gulf of Maine (GoM) haddock population size between 1977 and 2011. The top plot shows the stock population in terms of numbers (000s fish) and the bottom expressed in terms of the ratio of GoM/GBK population in numbers.

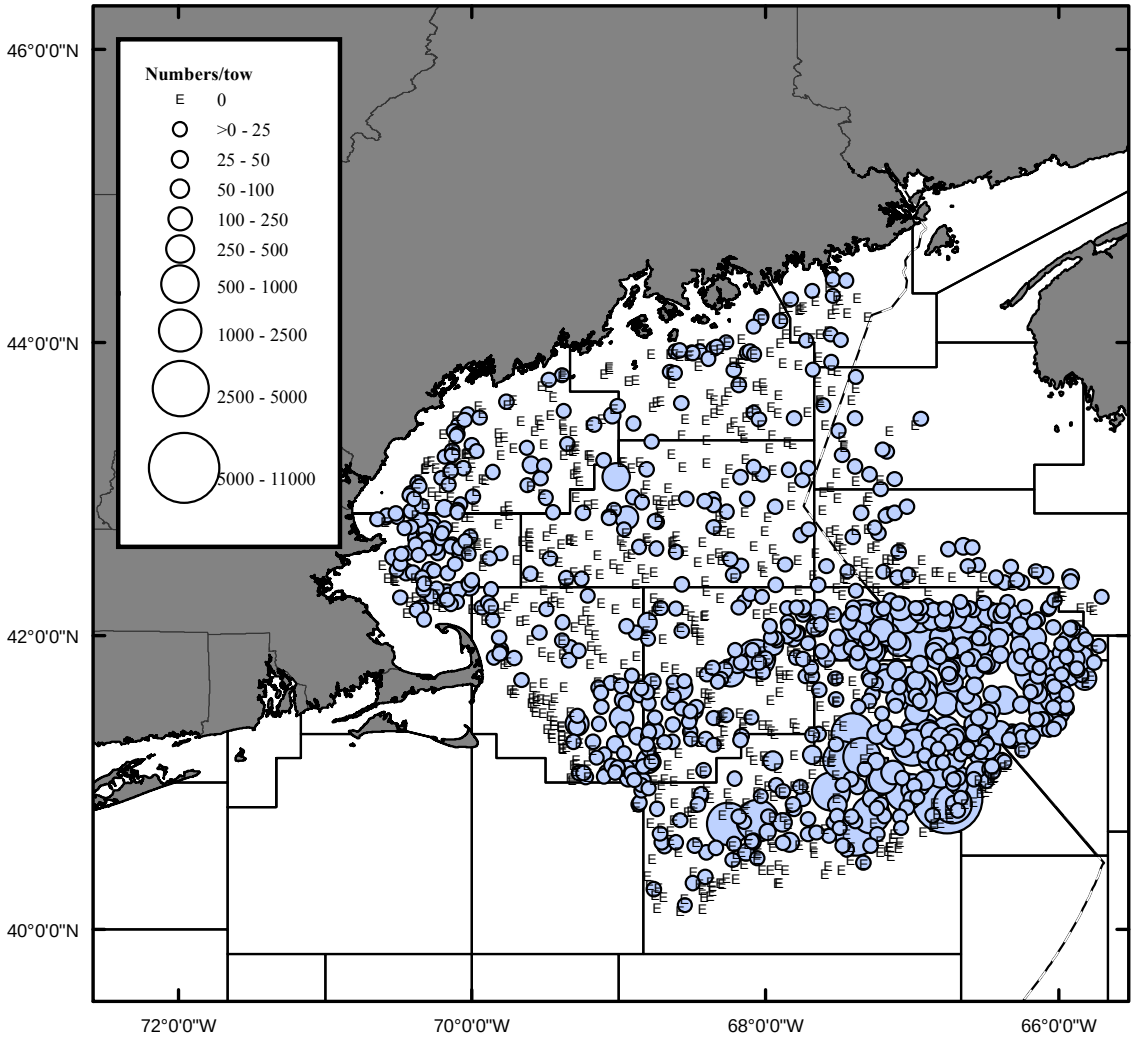

Figure A.134. Distribution plots of catches of haddock from the Northeast Fisheries Science Center spring bottom trawl survey between 2003 and 2013.

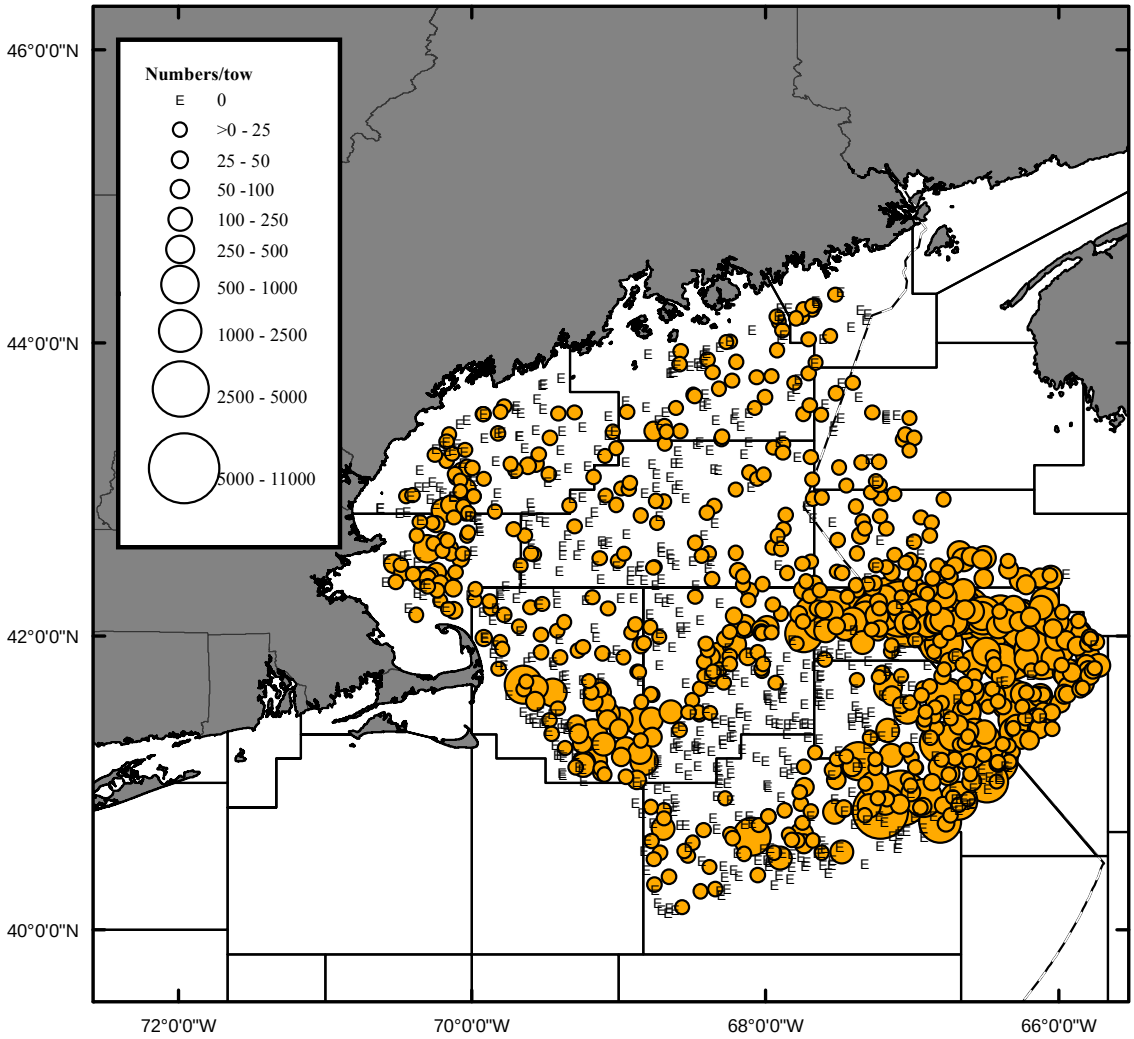

Figure A.135. Distribution plots of catches of haddock from the Northeast Fisheries Science Center fall bottom trawl survey between 2003 and 2012.

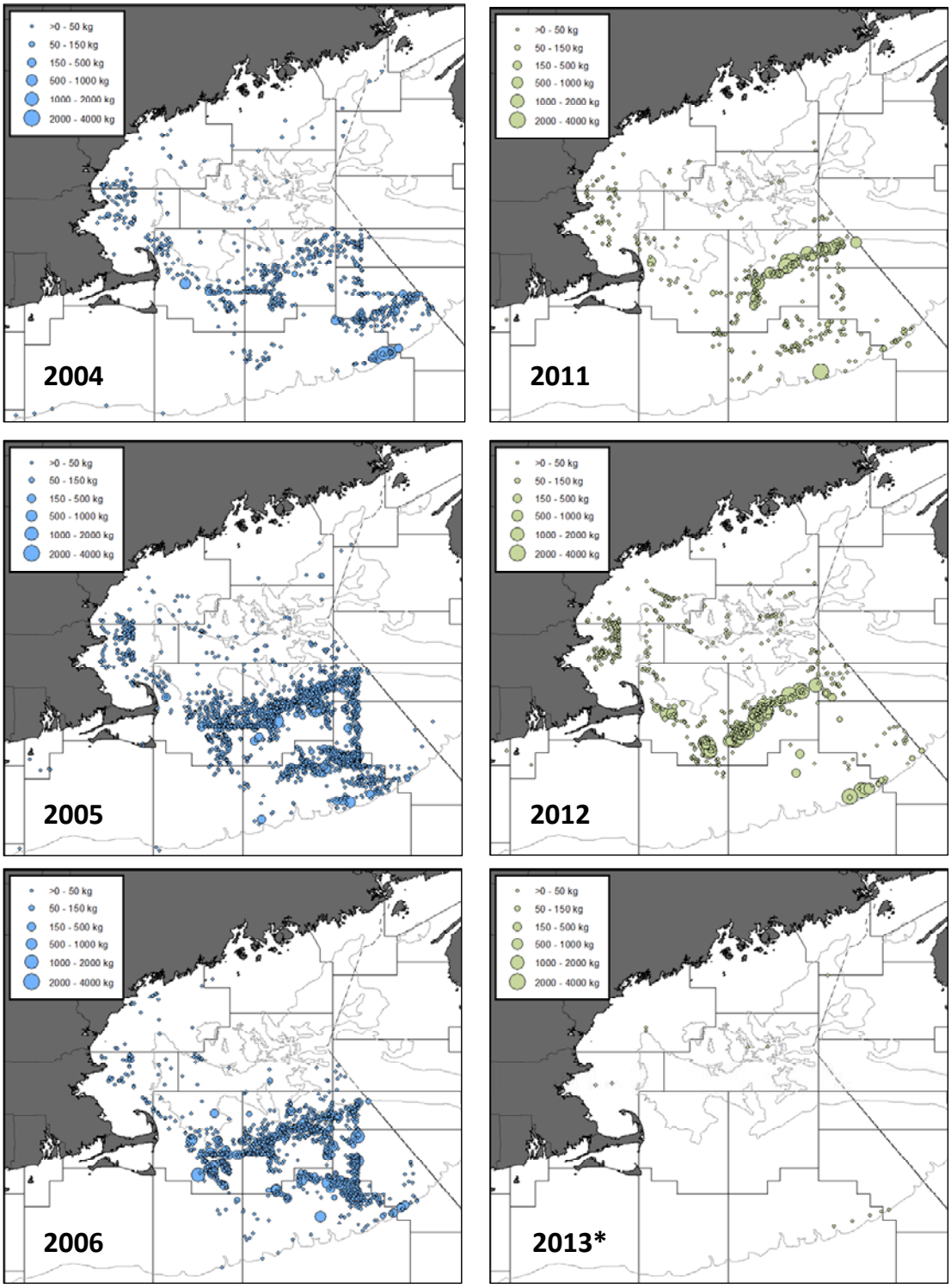

Figure A.136. Distribution plots of catches of haddock less than 46 cm as recorded by fishery observers following the spawning of the 2003 and 2010 year classes on Georges Bank. **Note that at the time of the analysis there was limited information available for 2013.*

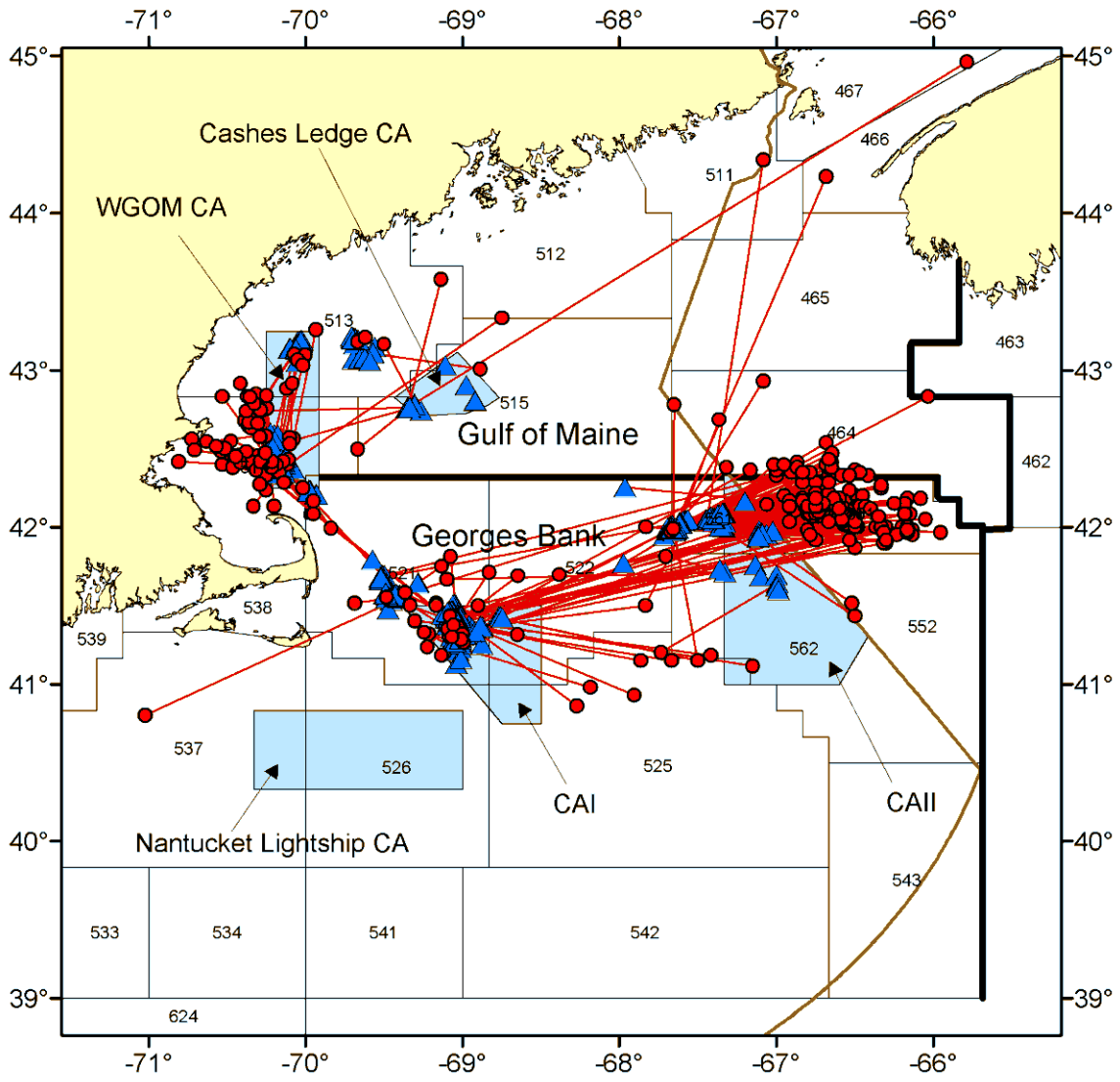

Figure A.137. Plot of release (red circle) and recapture (blue triangle) locations of haddock tagged during the Northeast Consortium Cooperative Haddock Tagging Project reported through September 2, 2008 in relation to Georges Bank and Gulf of Maine haddock stock boundary (solid black line) to the west of the Hague line (light tan line) (Brodziak et al. 2008).

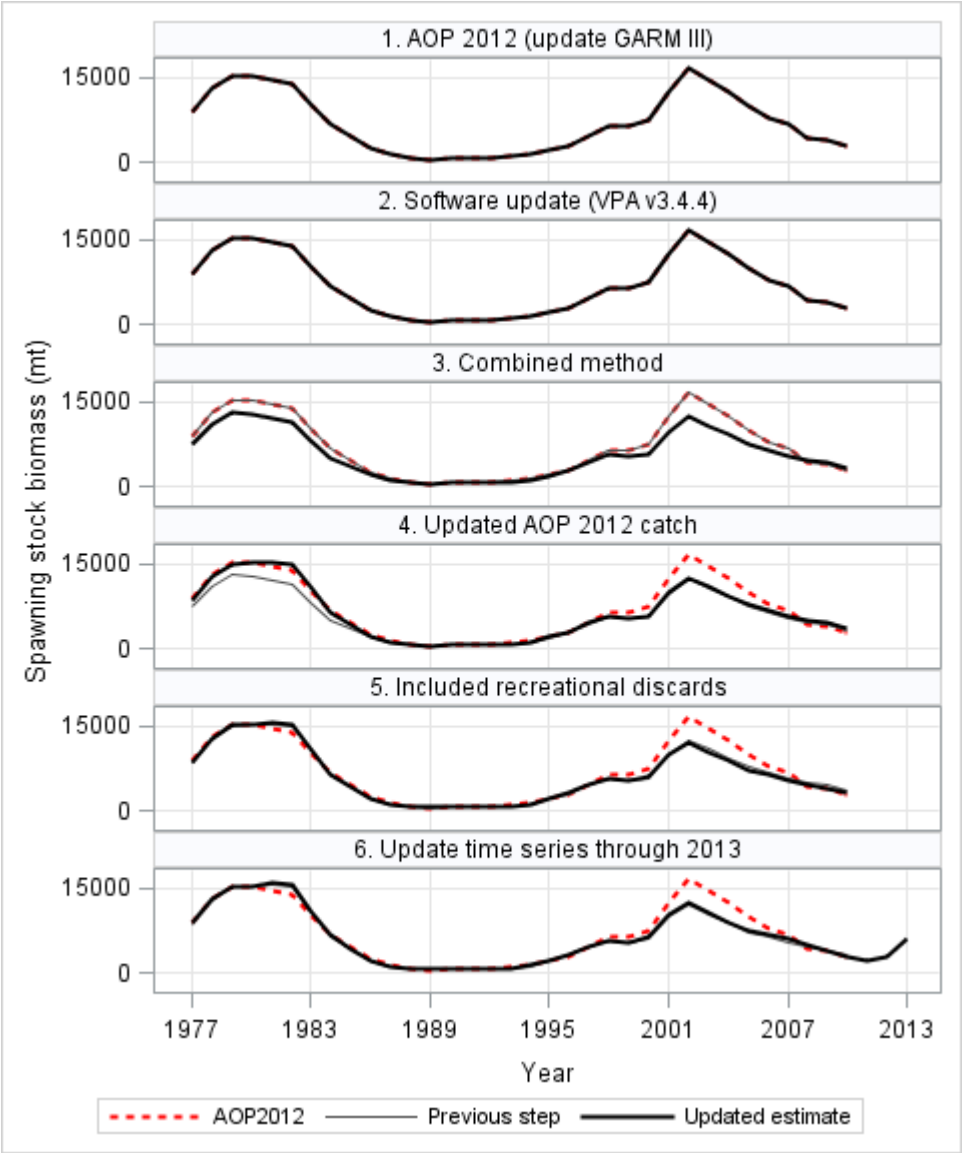

Figure A138. Summary of the impacts of the ADAPT-VPA model update process on the time series of Gulf of Maine haddock spawning stock biomass. The result from each model update is indicated by the solid black line and can be compared to the 2012 AOP result (dashed red line) and the result from the previous model run (grey line).

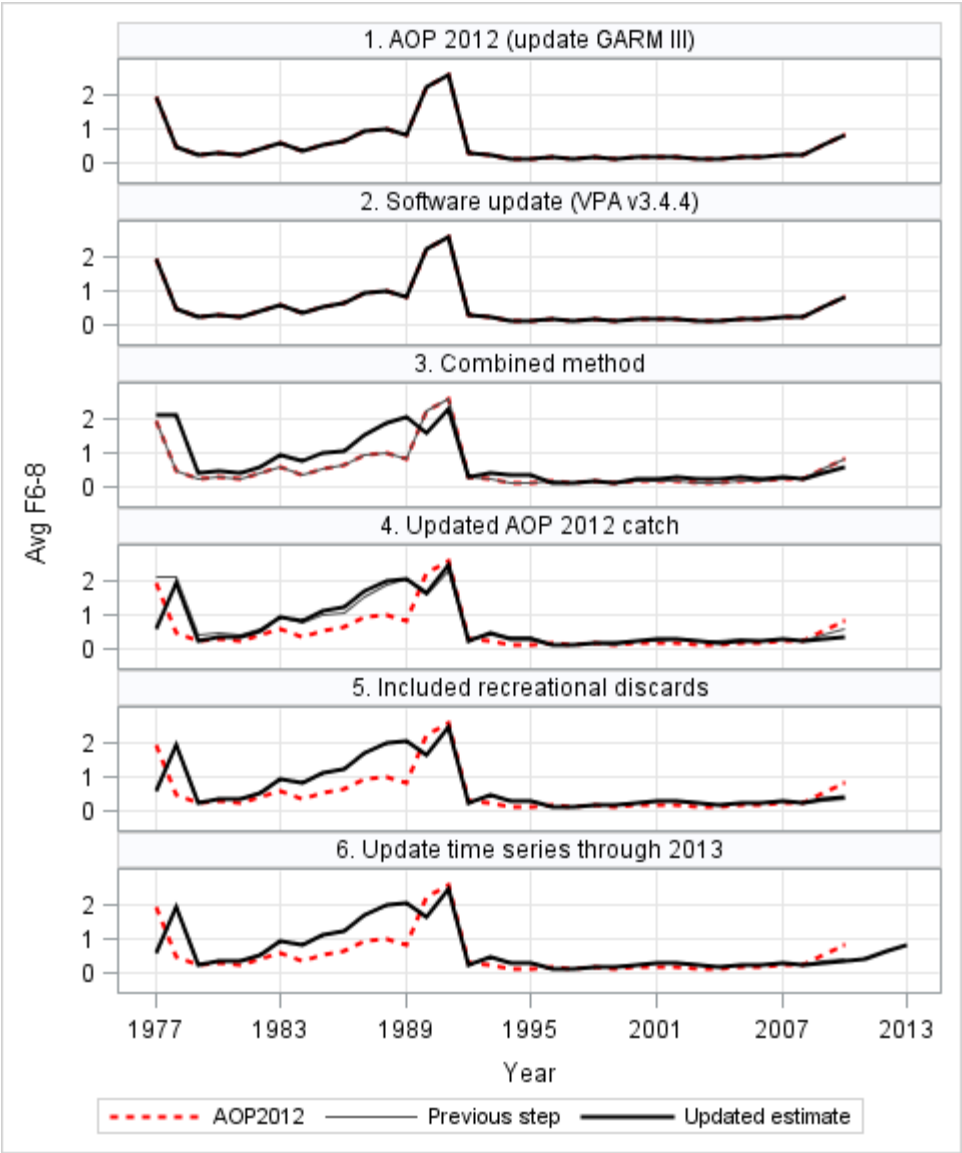

Figure A.139. Summary of the impacts of the ADAPT-VPA model update process on the time series of Gulf of Maine haddock average fishing mortality on ages 6-8. The result from each model update is indicated by the solid black line and can be compared to the 2012 AOP result (dashed red line) and the result from the previous model run (grey line).

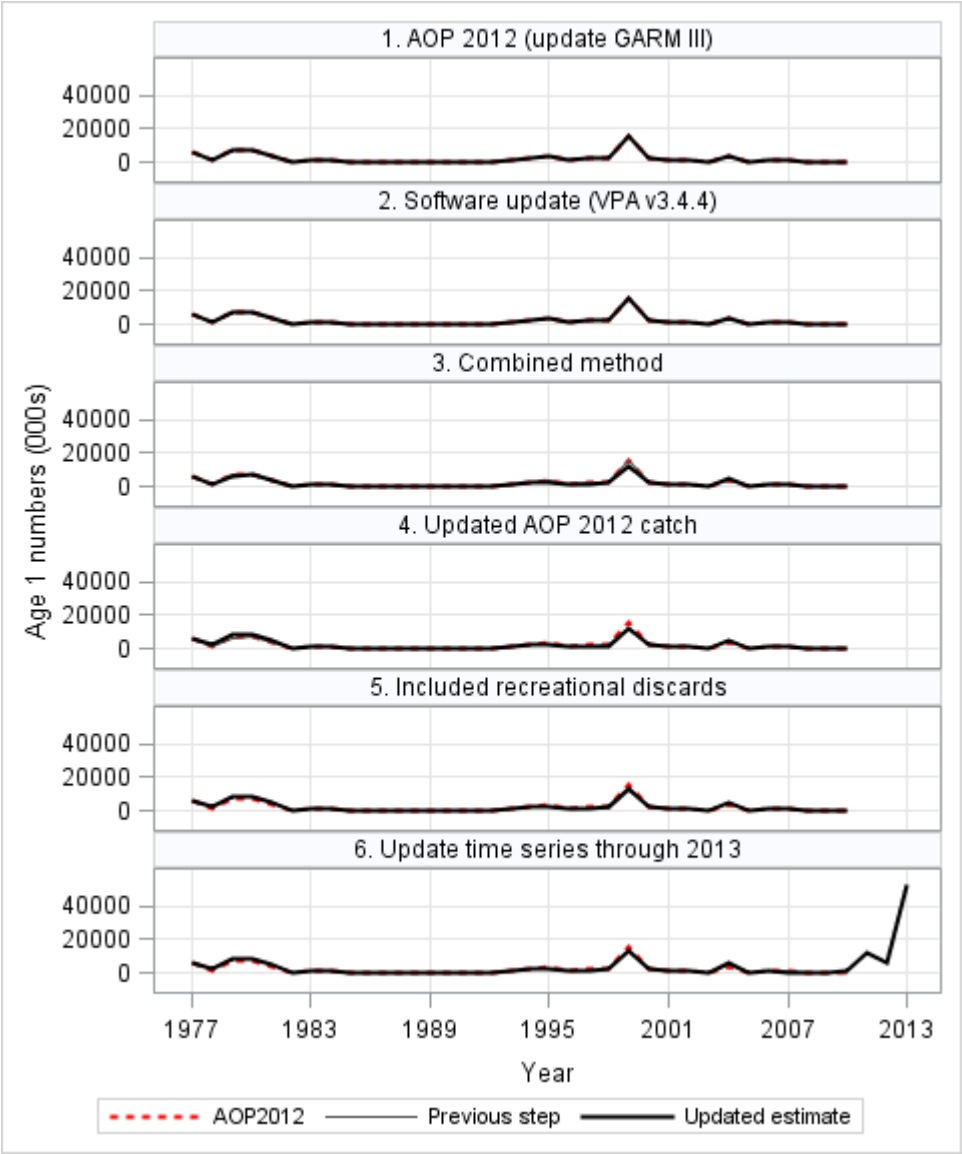

Figure A.140. Summary of the impacts of the ADAPT-VPA model update process on the time series of Gulf of Maine haddock age-1 recrutiment. The result from each model update is indicated by the solid black line and can be compared to the 2012 AOP result (dashed red line) and the result from the previous model run (grey line).

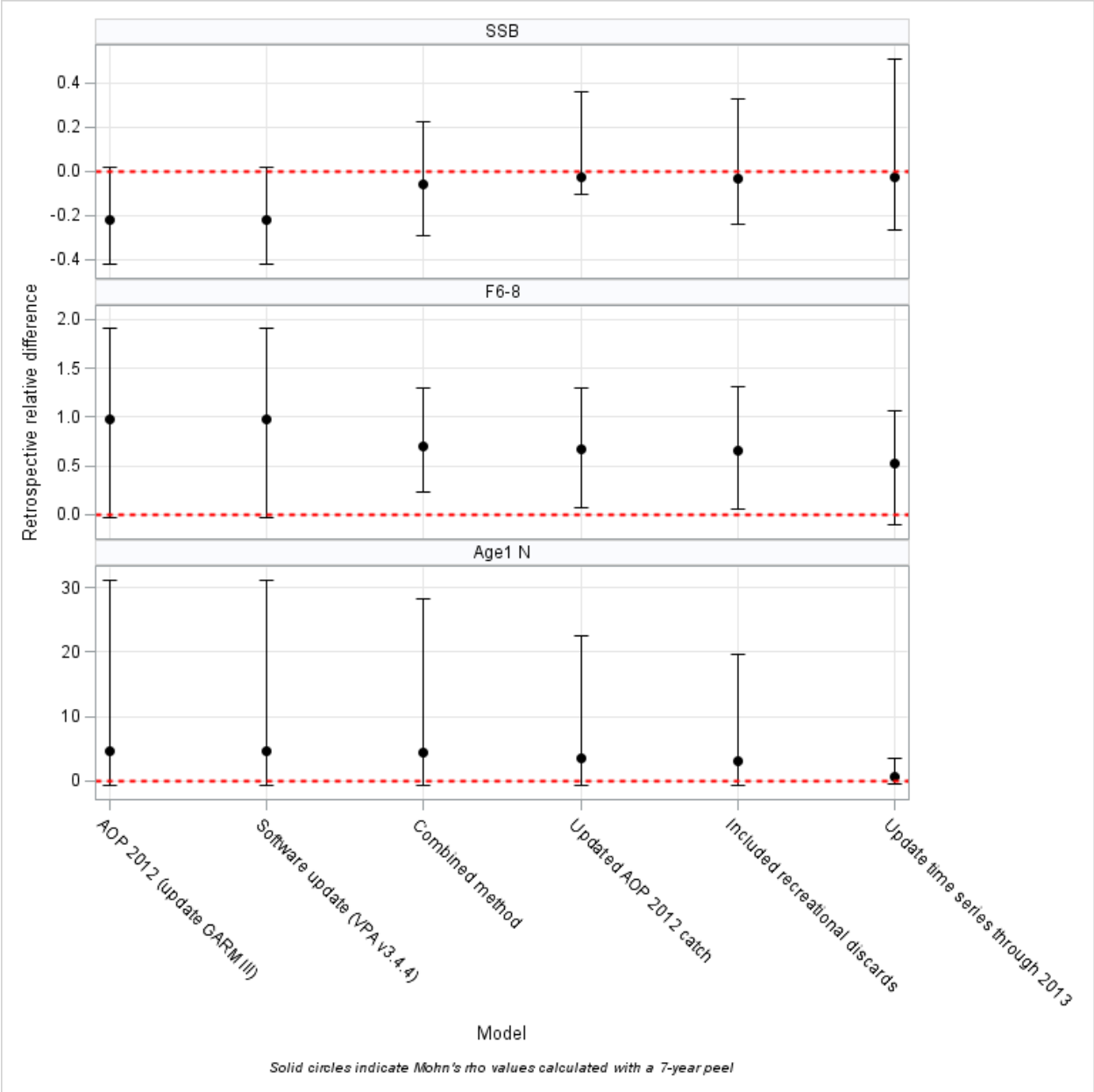

Figure A.141. Summary of the Mohn's rho values (dots) and minimum and maximum observed relative differences resulting from a seven year peel for the six Gulf of Maine haddock ADAPT-VPA model runs used to build the bridge between the 2012 AOP model to an updated SAW/SARC 59 VPA model.

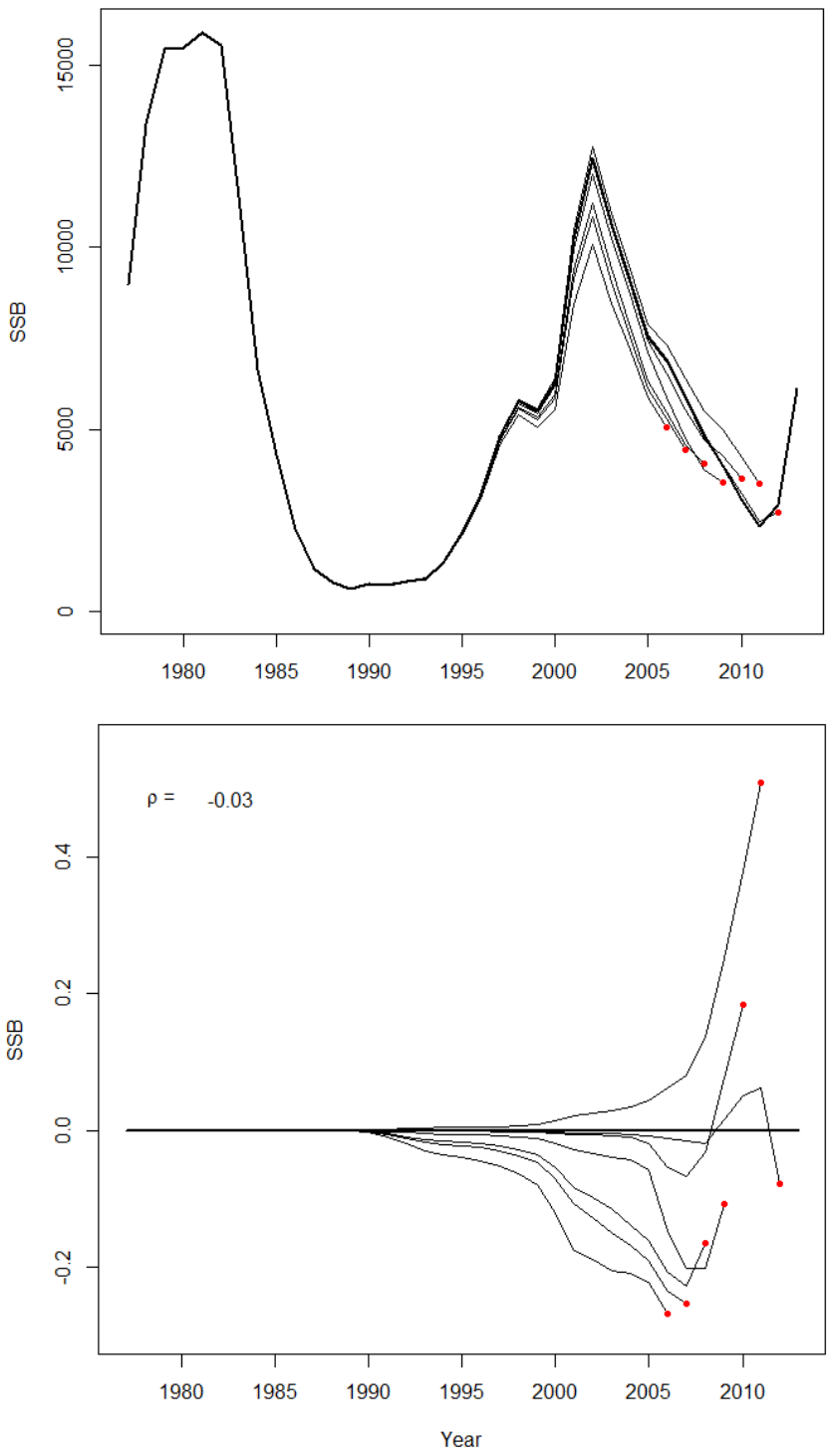

Figure A.142. Retrospective patterns in Gulf of Maine haddock spawning stock biomass (mt) in absolute (top) and relative (bottom) terms from the 2013 update of the ADAPT-VPA model (run 6). A 7-year retrospective peel is shown along with the corresponding Mohn's rho (ρ) value.

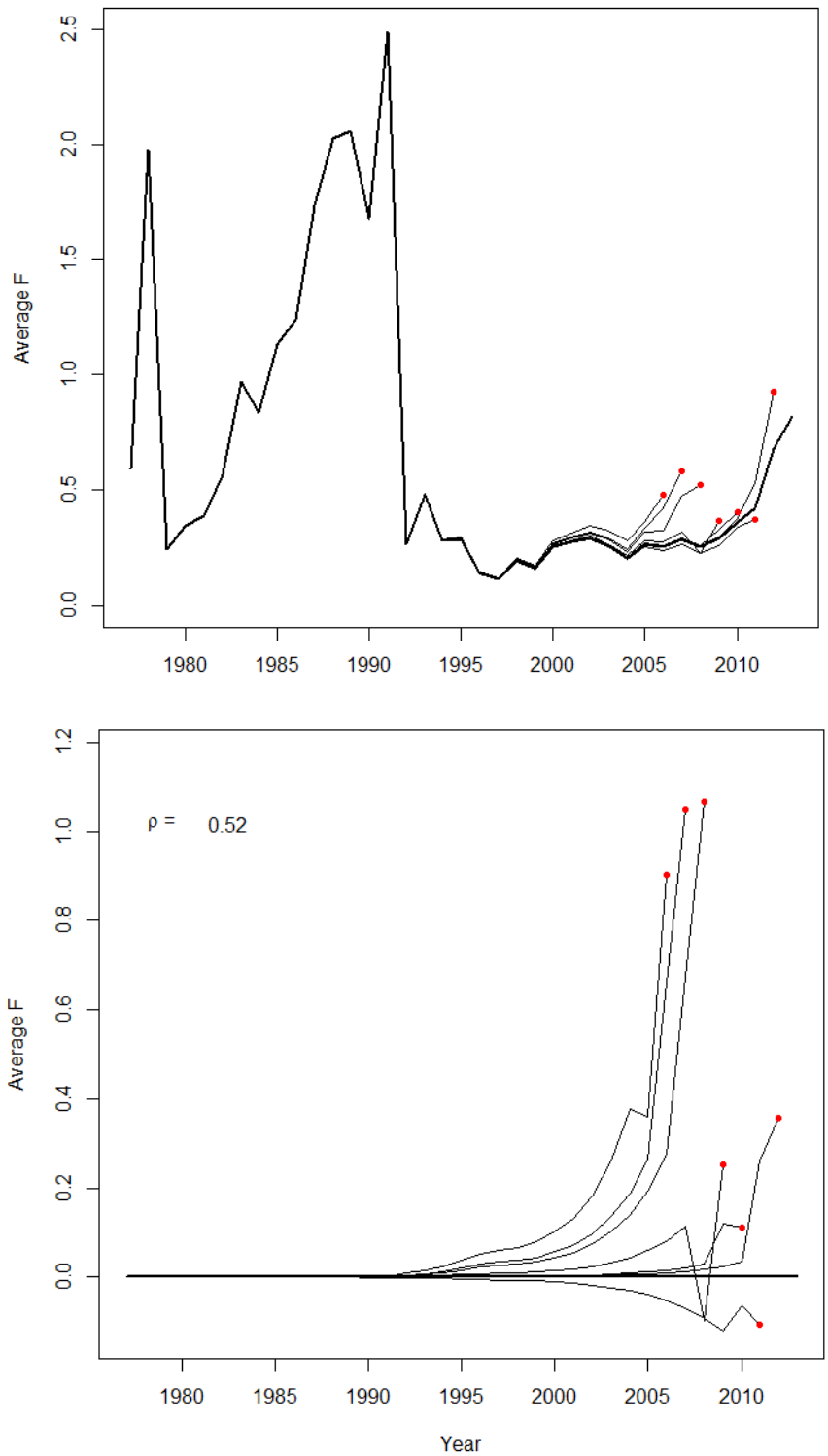

Figure A.143. Retrospective patterns in Gulf of Maine haddock fishing mortality (average ages 6-8) in absolute (top) and relative (bottom) terms from the 2013 update of the ADAPT-VPA model (run 6). A 7-year retrospective peel is shown along with the corresponding Mohn's rho (ρ) value.

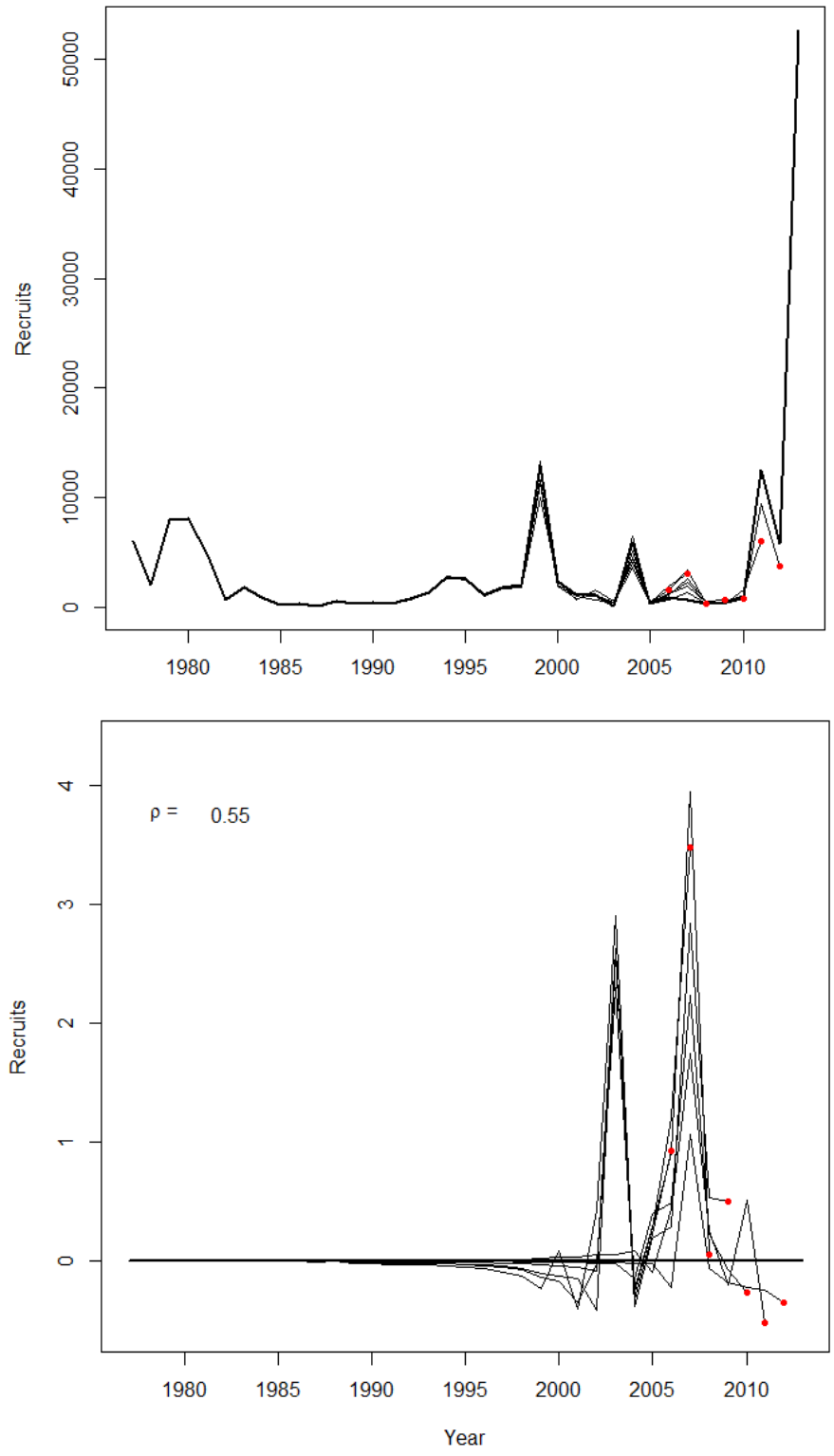

Figure A.144. Retrospective patterns in Gulf of Maine haddock age-1 recruitment (000s) in absolute (top) and relative (bottom) terms from the 2013 update of the ADAPT-VPA model (run 6). A 7-year retrospective peel is shown along with the corresponding Mohn's rho (ρ) value.

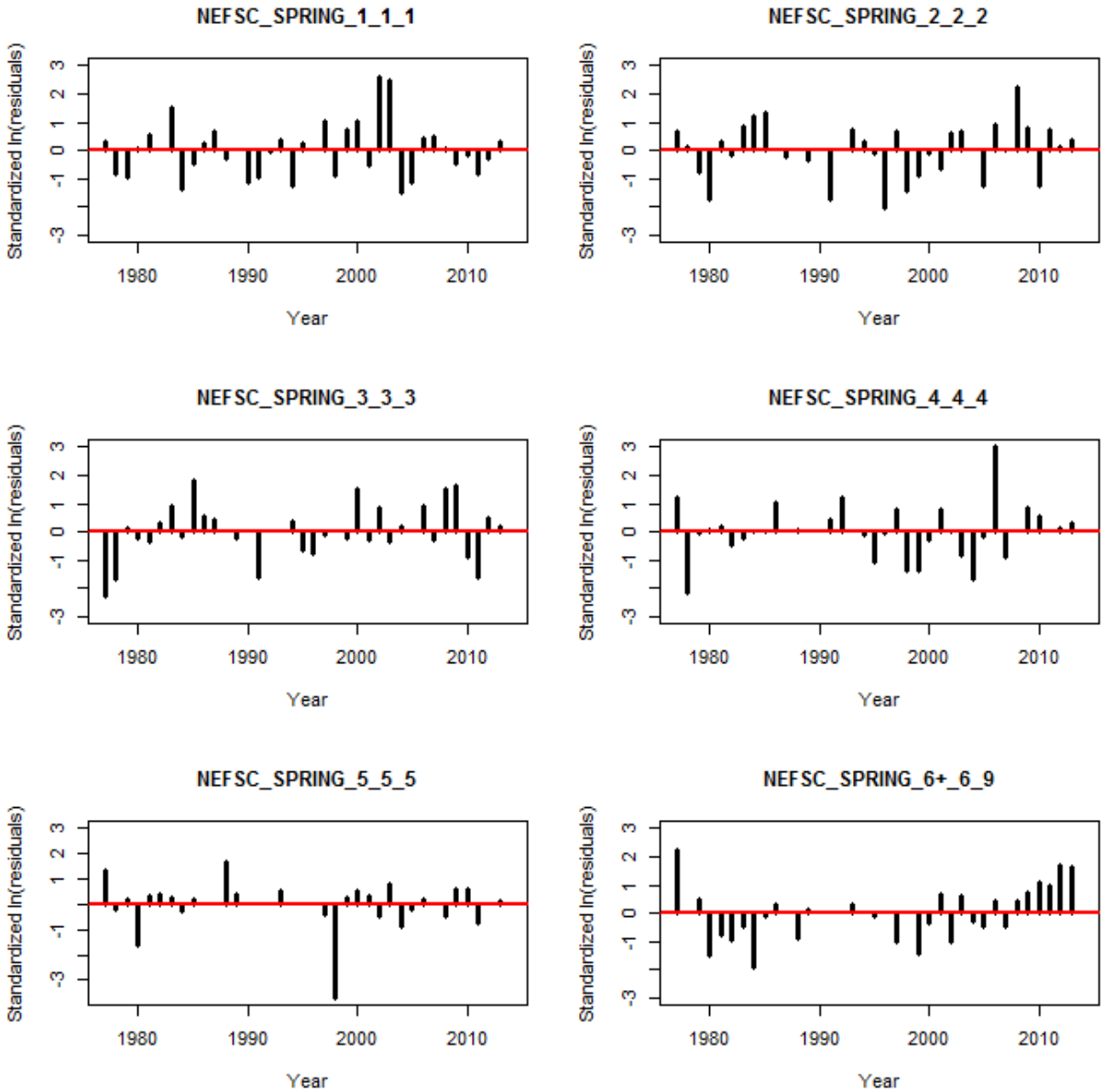

Figure A.145.a. Residuals of the NEFSC survey fits of the 2013 update of the ADAPT-VPA Gulf of Maine haddock assessment model (run 6). Residuals for the NEFSC spring survey age-1 (NEFSC_SPRING_1_1_1) to age-6^+ (NEFSC_SPRING_6+_6_9) are shown.

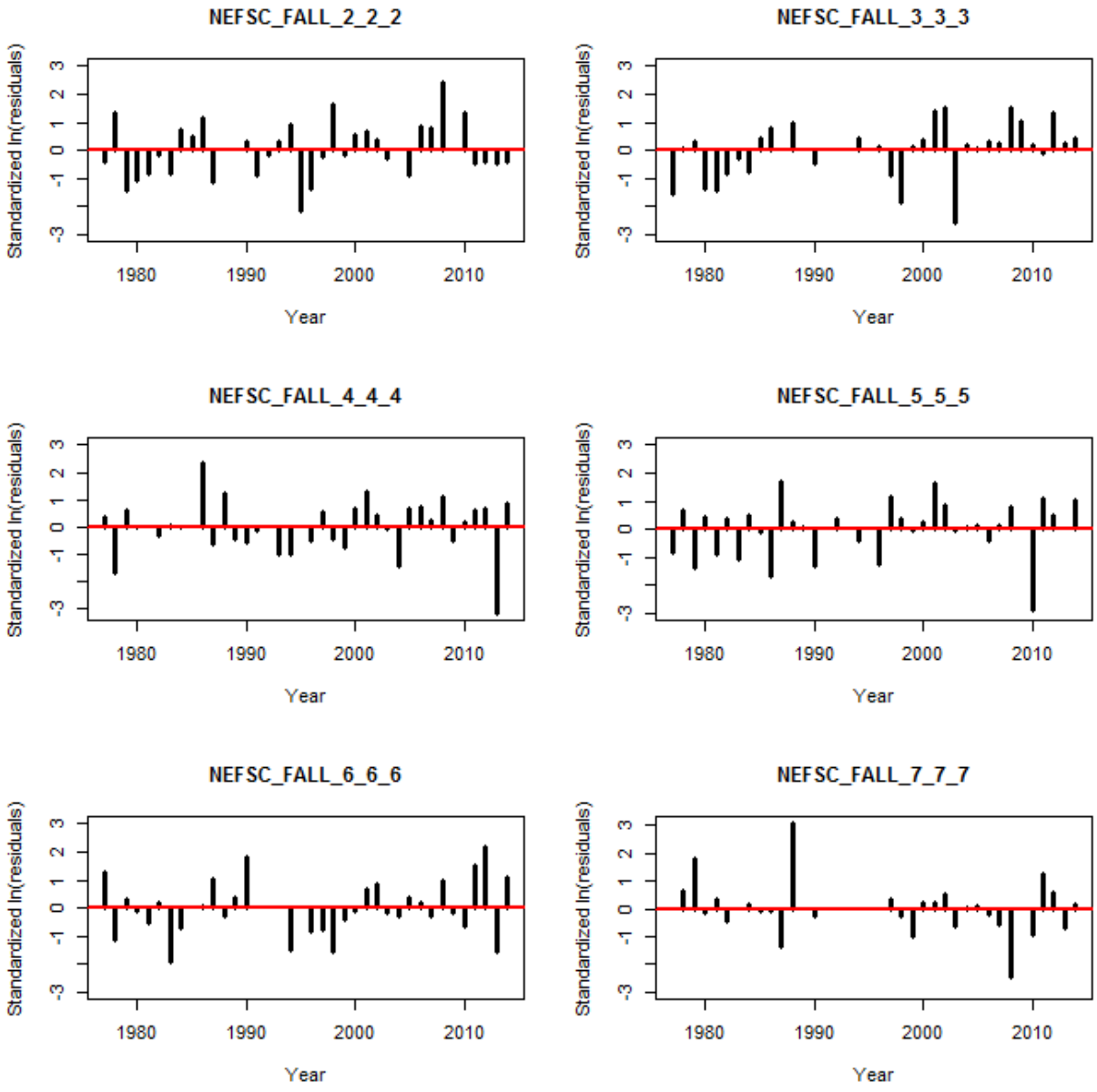

Figure A.145.b. Residuals of the NEFSC survey fits of the 2013 update of the ADAPT-VPA Gulf of Maine haddock assessment model (run 6). Residuals for the NEFSC fall survey age-1 (NEFSC_FALL_2_2_2) to age-6 (NEFSC_FALL_7_7_7) are shown.**Note: fall surveys have been lagged forward a year and an age.*

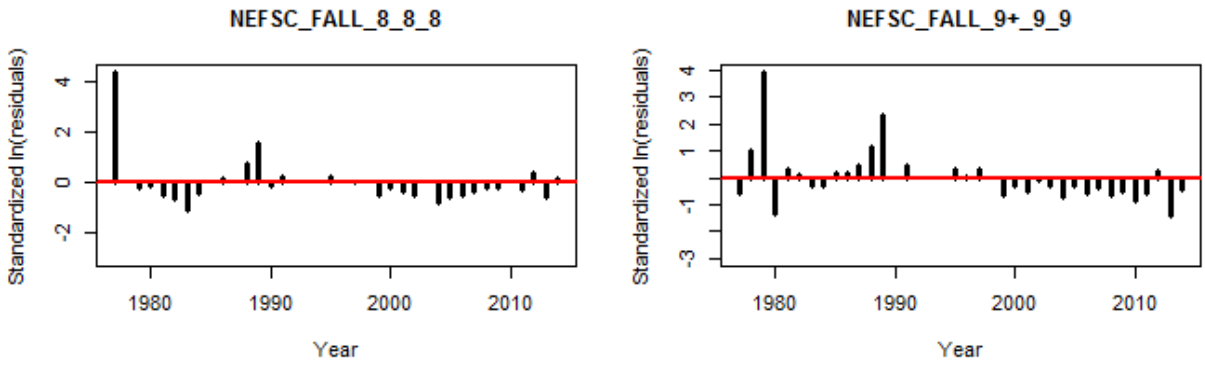

Figure A.145.c. Residuals of the NEFSC survey fits of the 2013 update of the ADAPT-VPA Gulf of Maine haddock assessment model (run 6). Residuals for the NEFSC fall survey ages 7 (NEFSC_FALL_8_8_8) to age 8^+ (NEFSC_FALL_9+_9_9) are shown.**Note: fall surveys have been lagged forward a year and an age.*

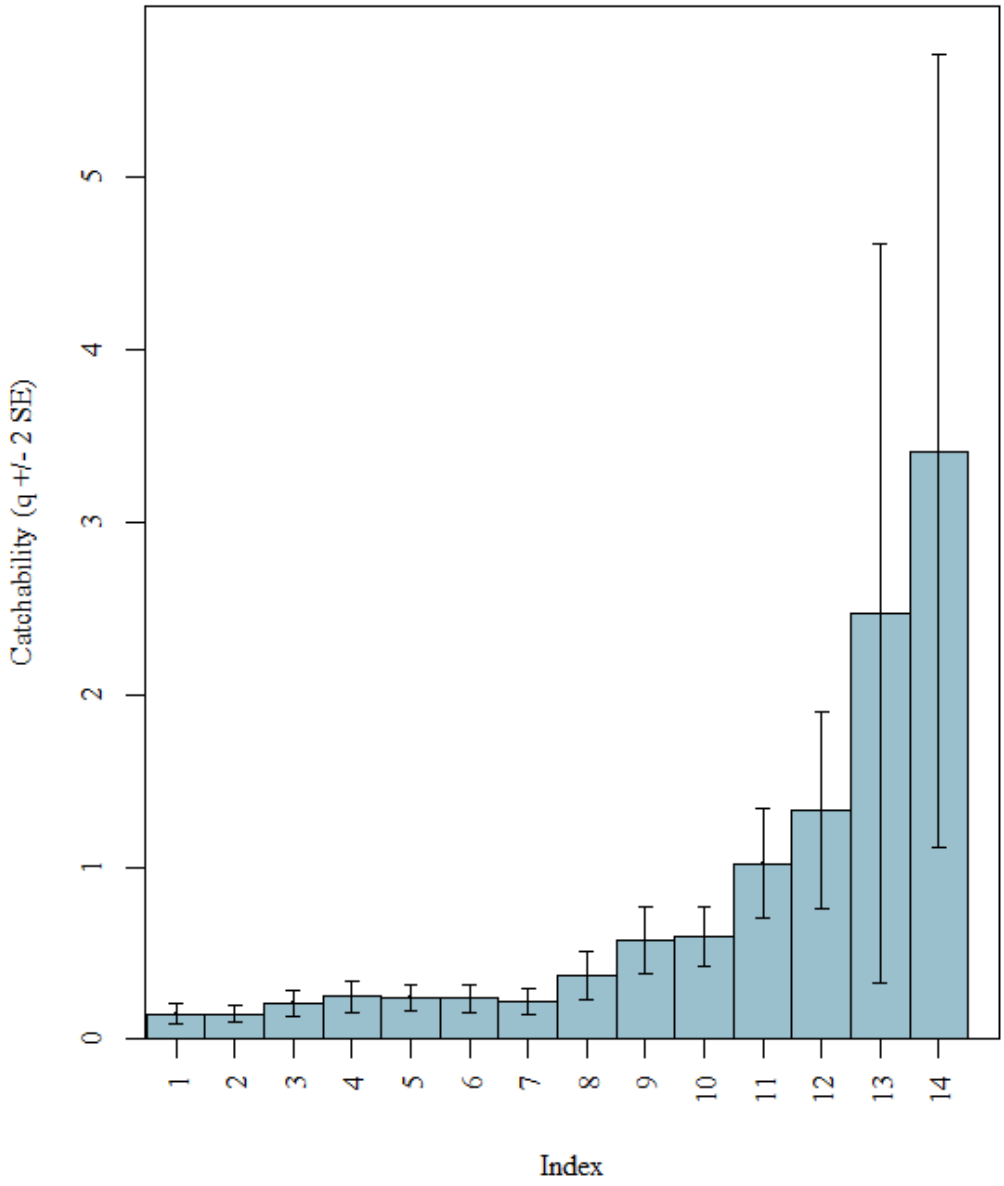

Figure A.146. Patterns in NEFSC survey catchability (q) for the 2013 update of the ADAPT-VPA model (run 6). Indices 1-6=NEFSC spring (ages 2-6^{+}), indices 7-14=NEFSC fall (ages 1-8^{+}).

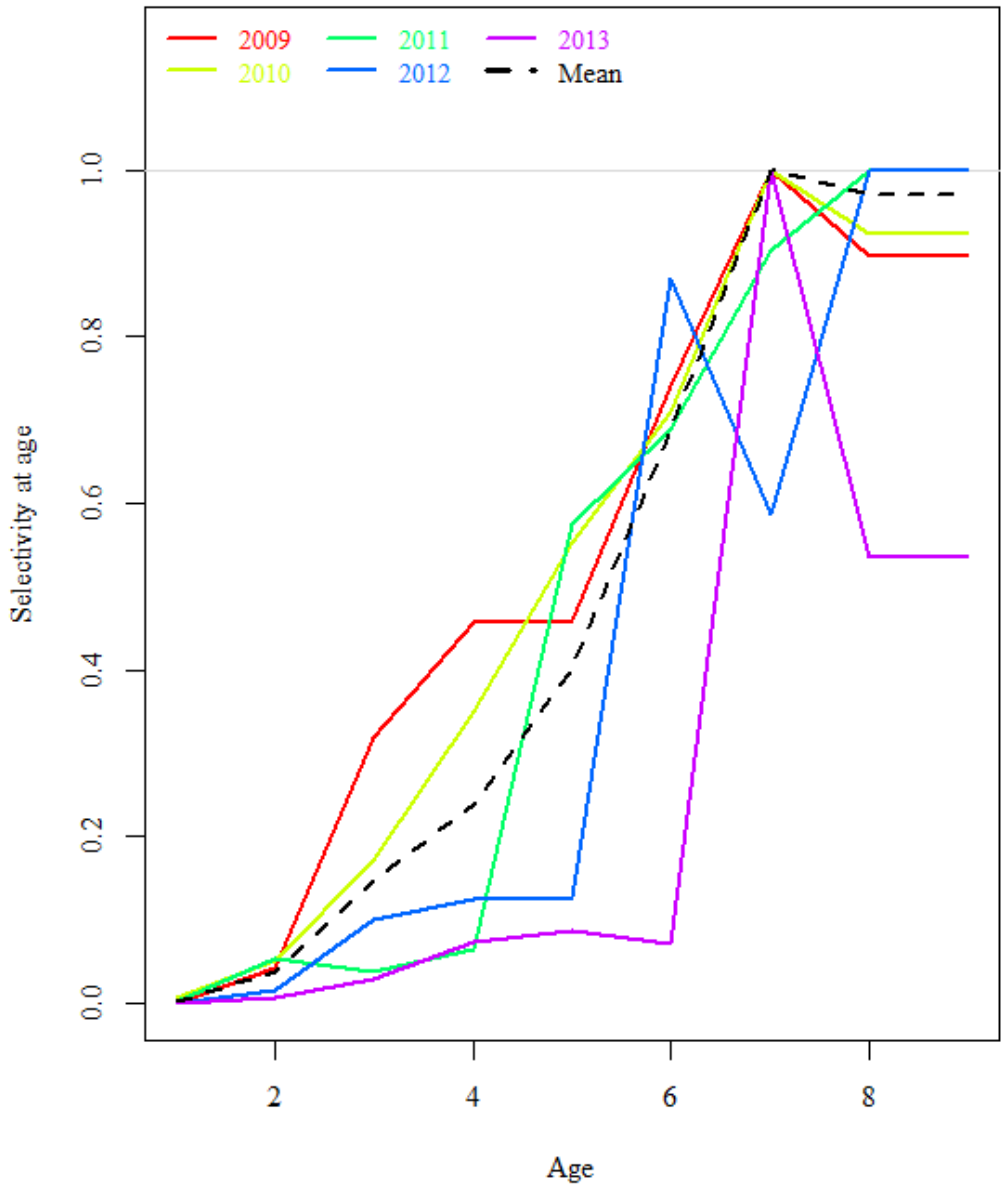

Figure A.147. Catch selectivity patterns for the 2013 update of the ADAPT-VPA Gulf of Maine haddock model (run 6) over the last five years of the model, 2009 through 2013.

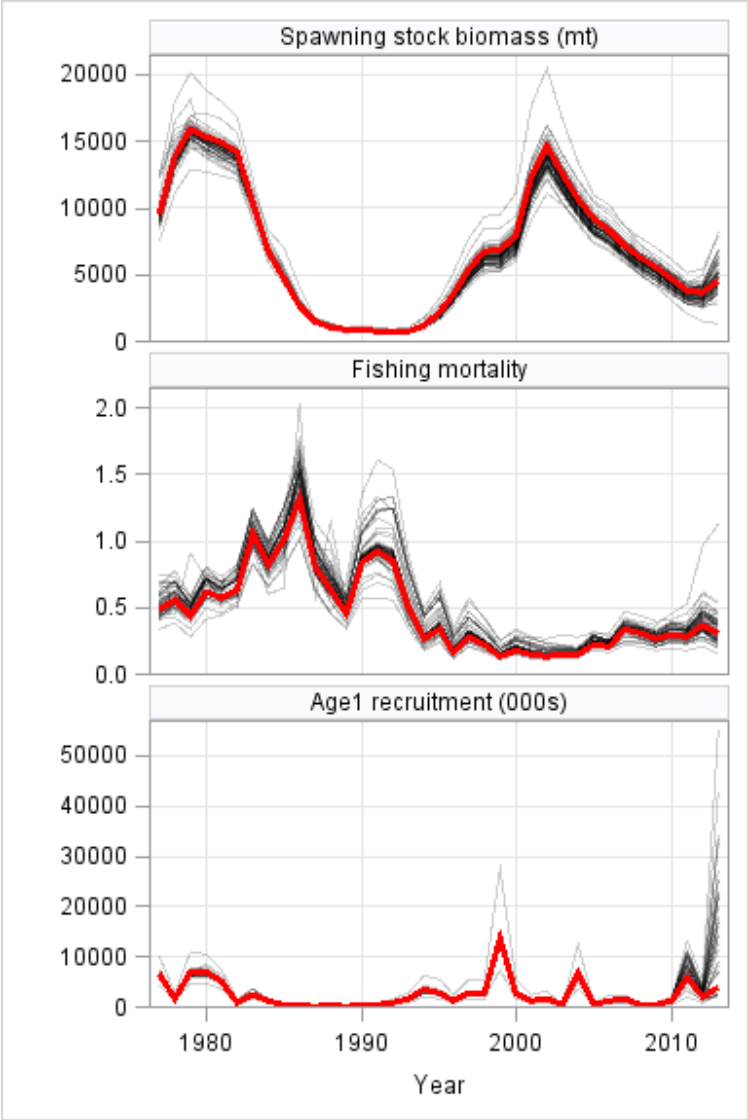

Figure A.148. Estimates of Gulf of Maine haddock spawning stock biomass (top), fishing mortality (middle) and age-1 recruitment (bottom) from the ASAP sensitivity runs conducted (each grey line represents a single sensitivity run). The results of the ASAP_BASE model are shown by a solid red line.

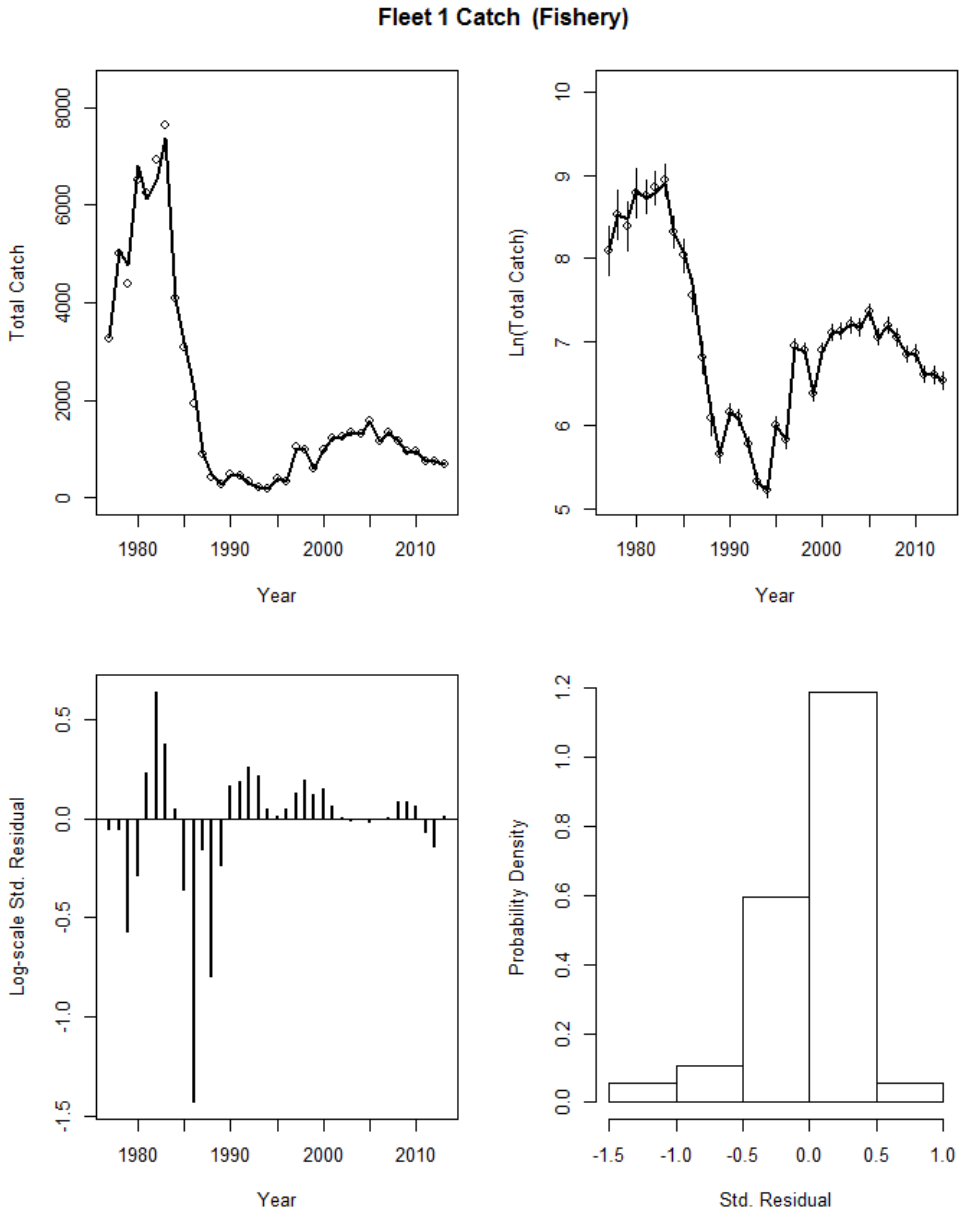

Figure A.149. ASAP_BASE model fit to the total Gulf of Maine haddock fishery catch (Fleet 1).

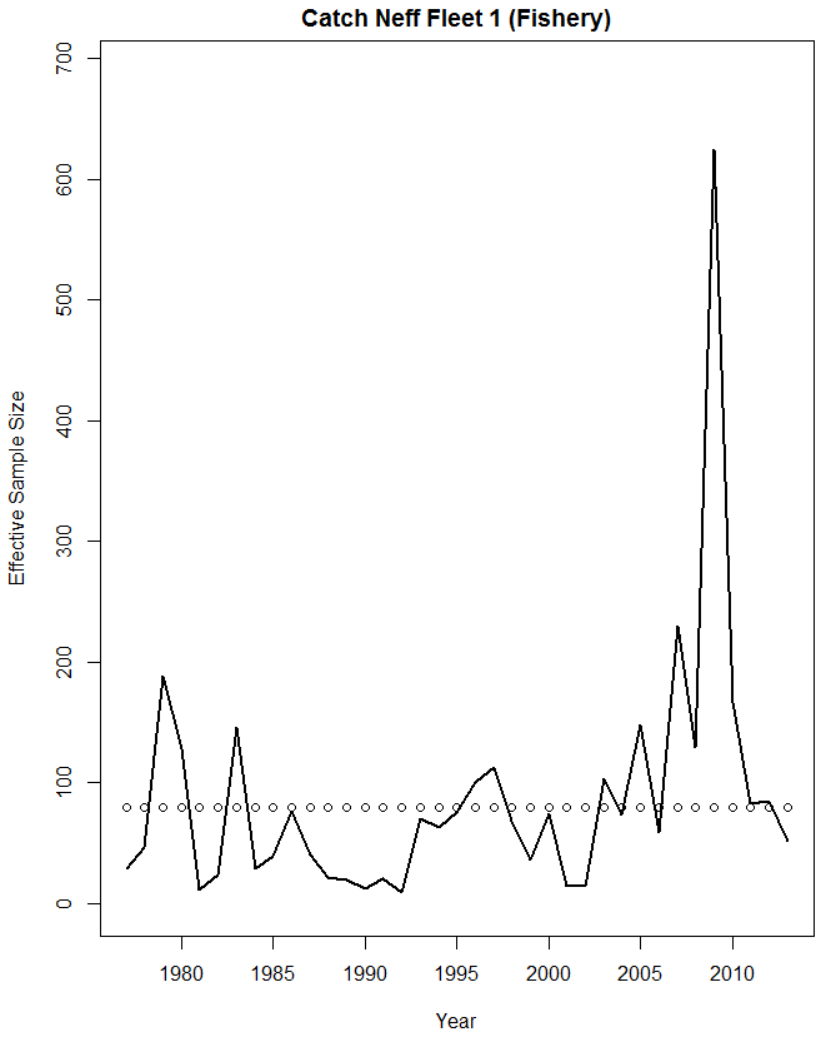

Figure A.150. ASAP_BASE model comparison of input effective sample size versus the model estimated effective sample size for the Gulf of Maine haddock fishery (Fleet 1) catch.

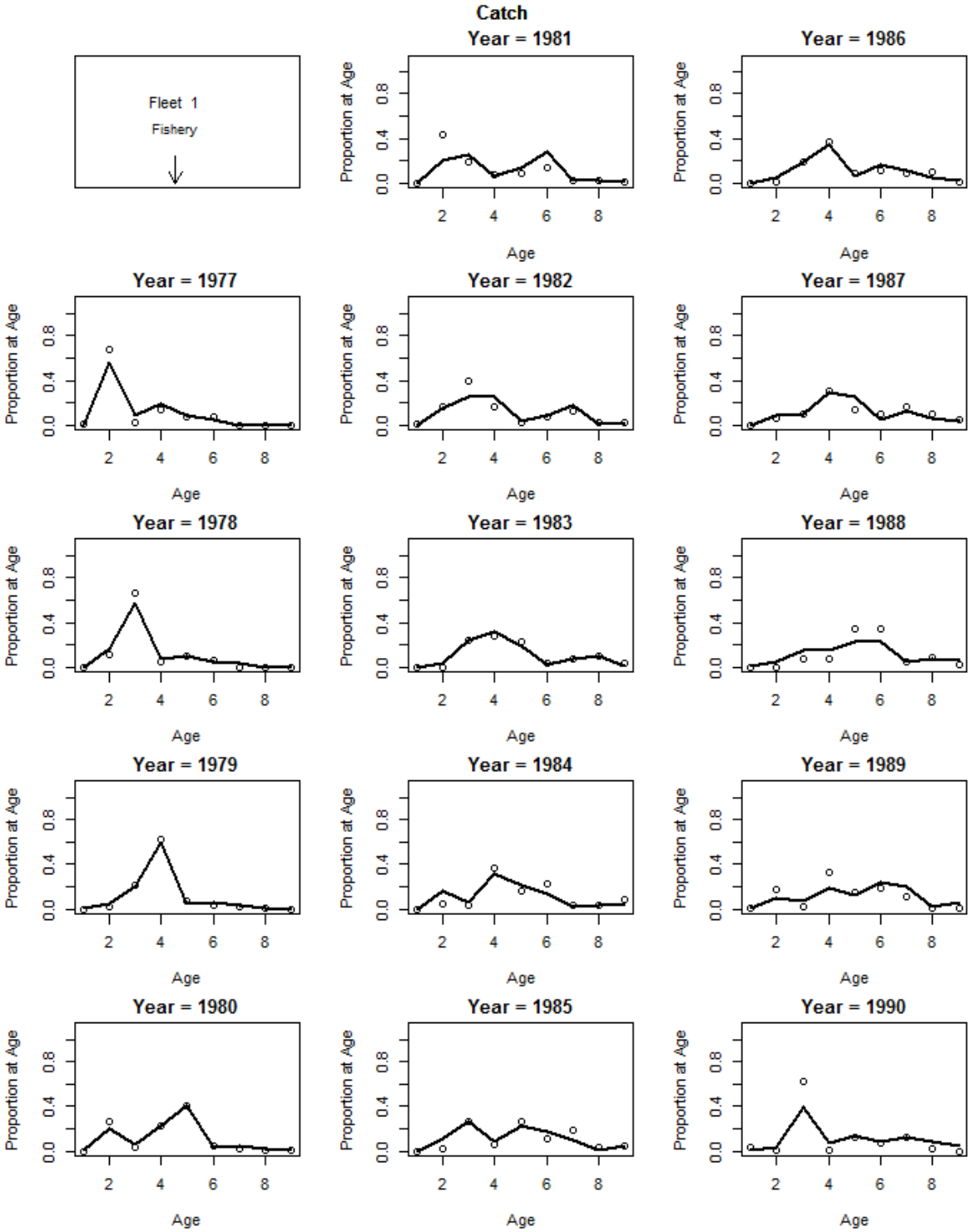

Figure A.151.a. Comparison of the ASAP_BASE estimates of Gulf of Maine haddock proportion-at-age in the fishery to the data estimates.

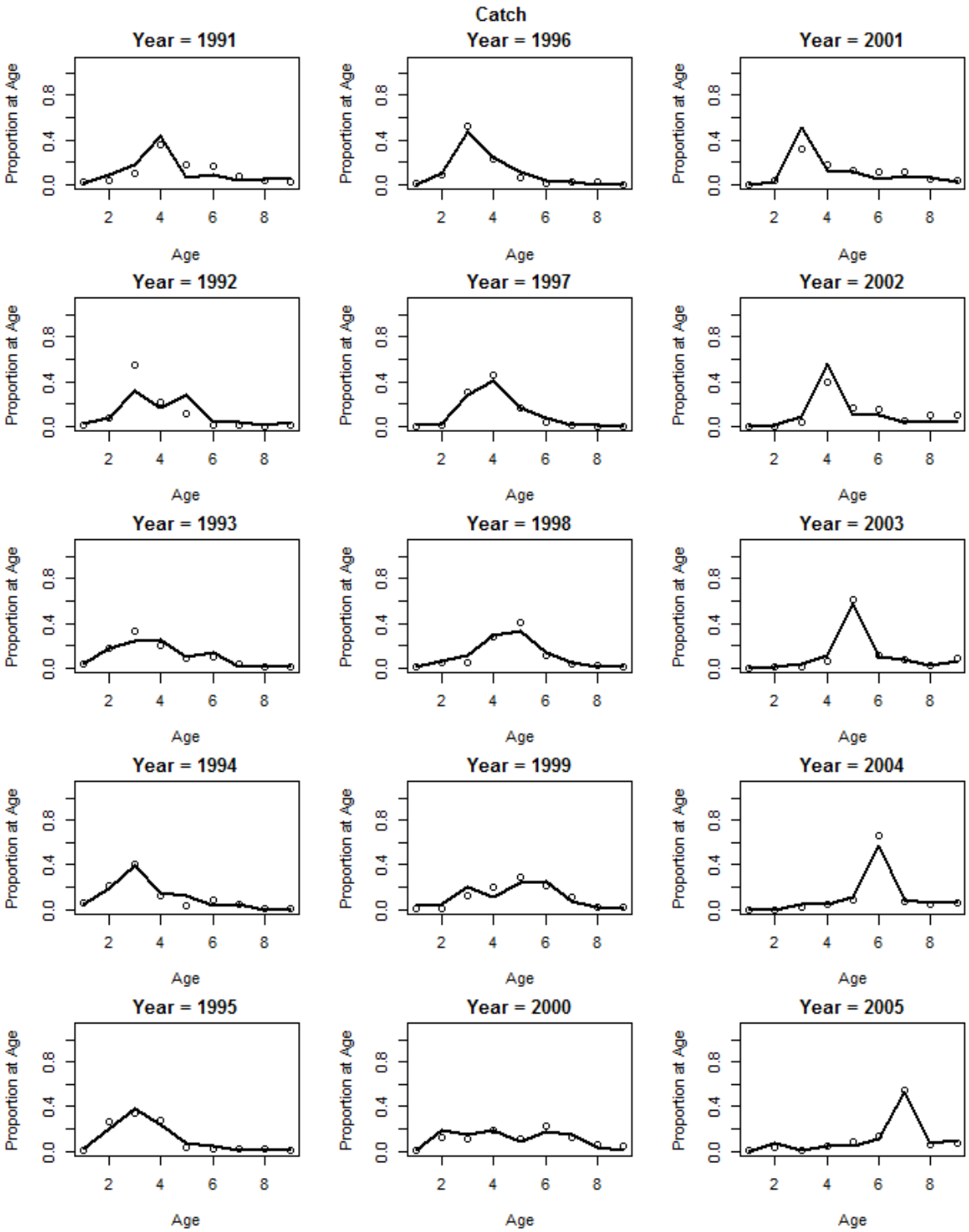

Figure A.151.b. Comparison of the ASAP_BASE estimates of Gulf of Maine haddock proportion-at-age in the fishery to the data estimates.

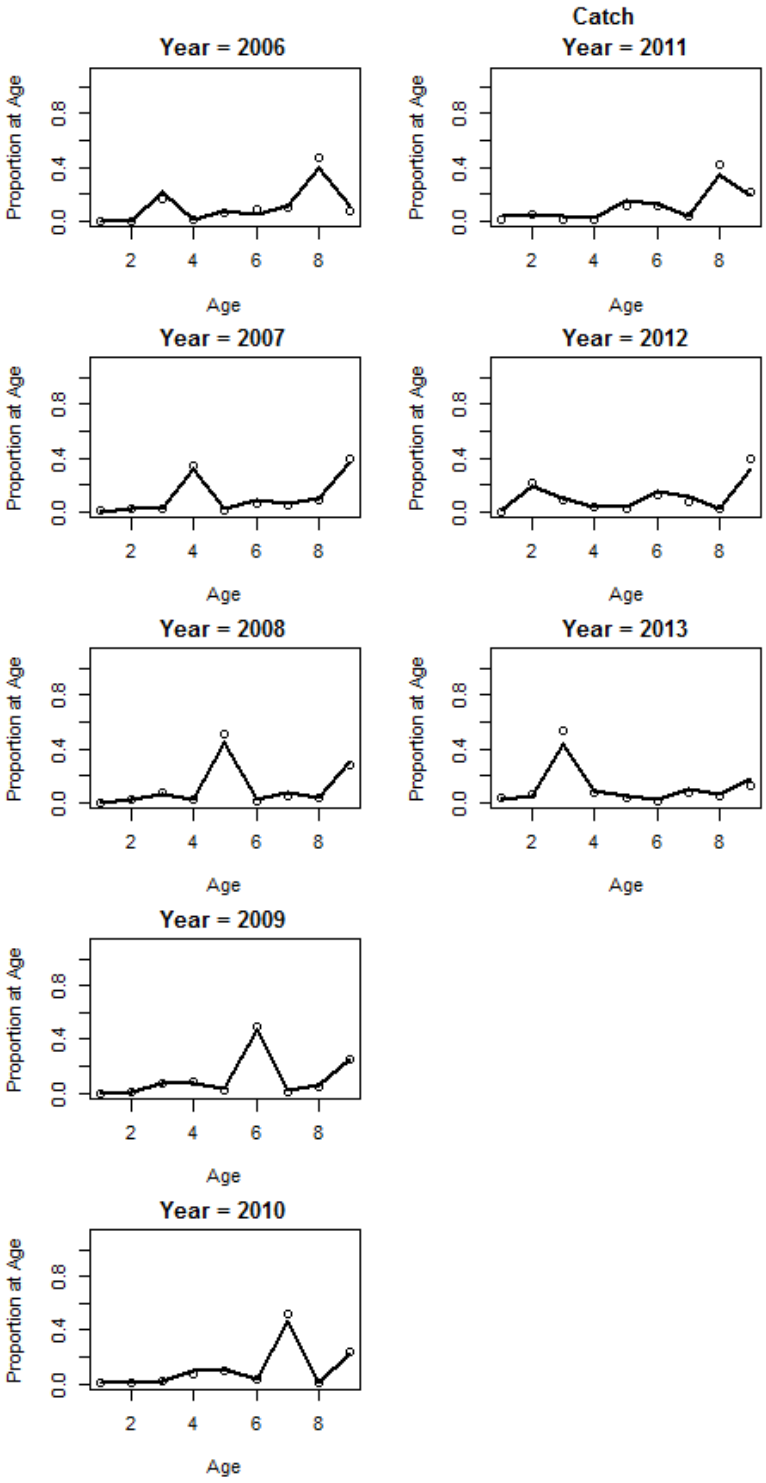

Figure A.151.c. Comparison of the ASAP_BASE estimates of Gulf of Maine haddock proportion-at-age in the fishery to the data estimates.

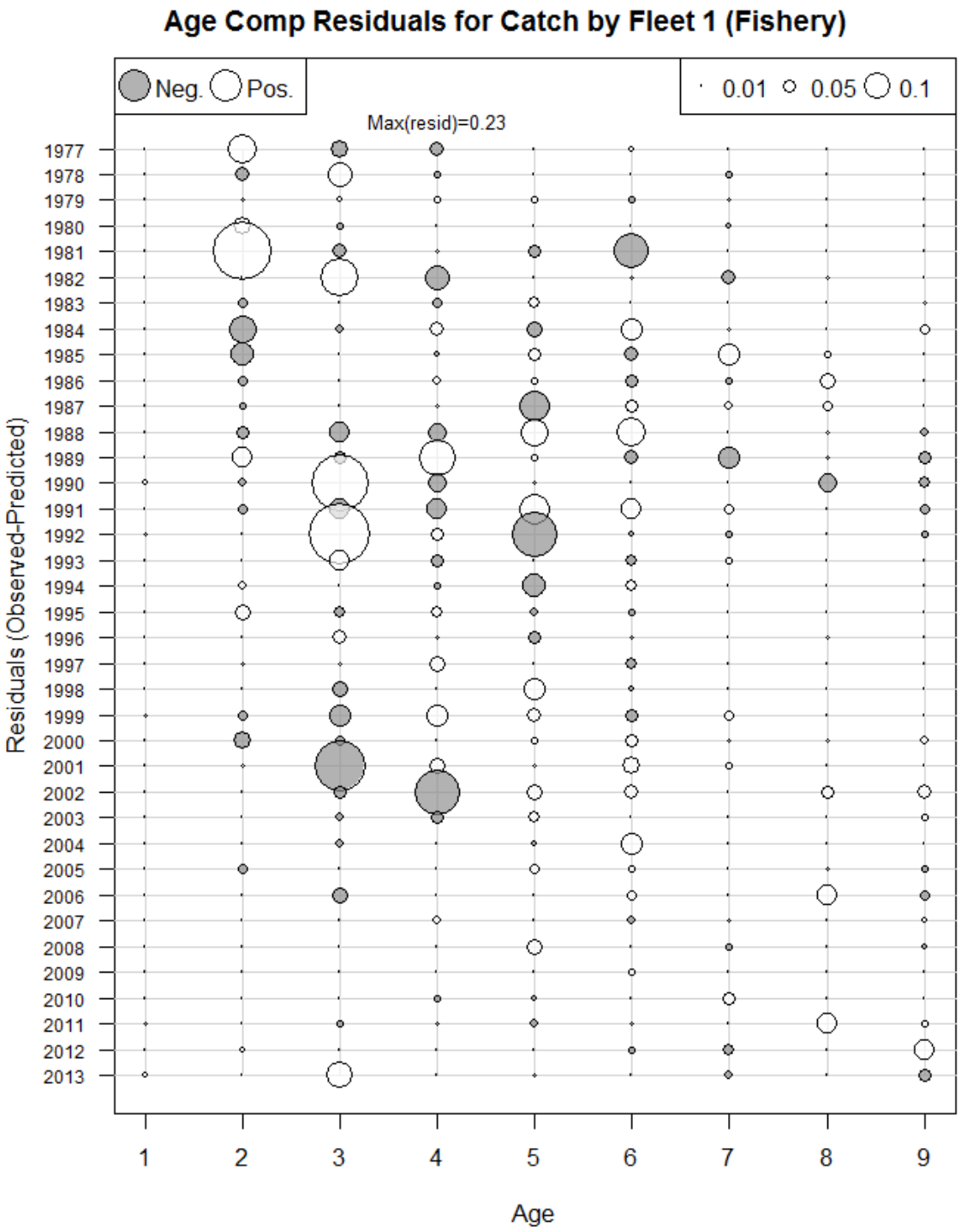

Figure A.152. ASAP_BASE model fit residuals for the Gulf of Maine haddock fishery (Fleet 1) catch-at-age.

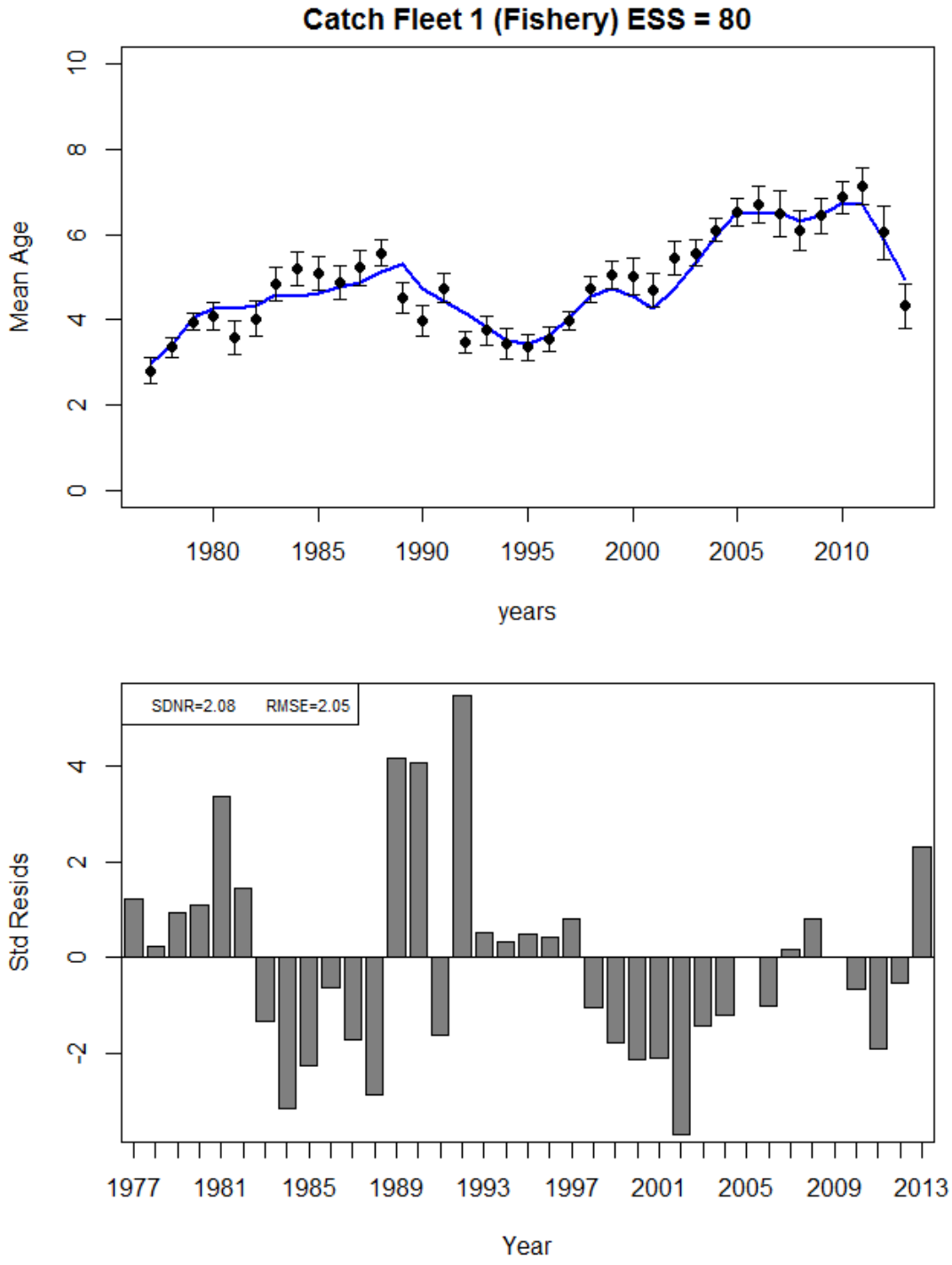

Figure A.153. ASAP_BASE predicted mean age of Gulf of Maine haddock in the fishery (Fleet 1) catch (blue line) compared to observed mean age (top plot) and the residuals about the mean (bottom plot).

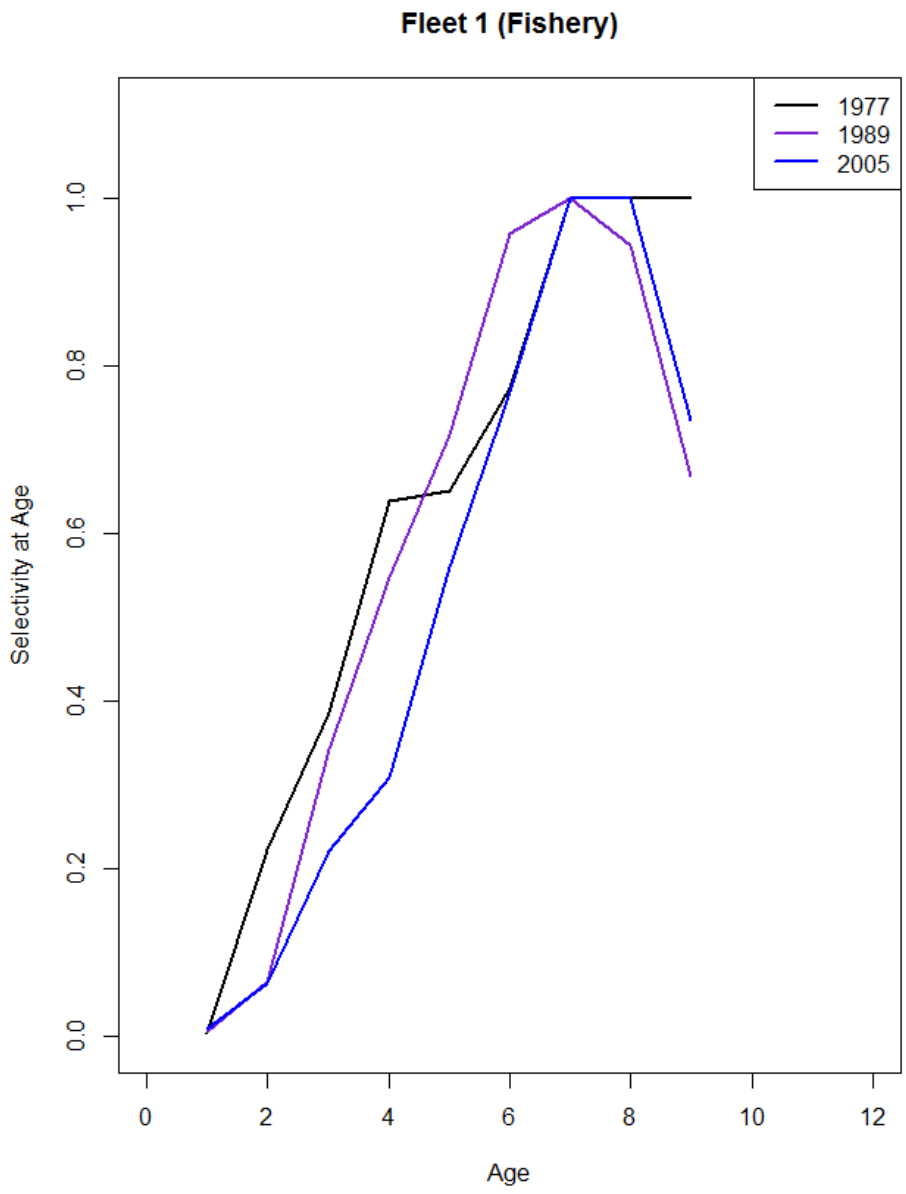

Figure A.154. Gulf of Maine haddock fishery (Fleet 1) selectivity-at-age for block 1 (1977-1988), block 2 (1989-2004) and block 3 (2005-2013) as estimated by the ASAP_BASE model.

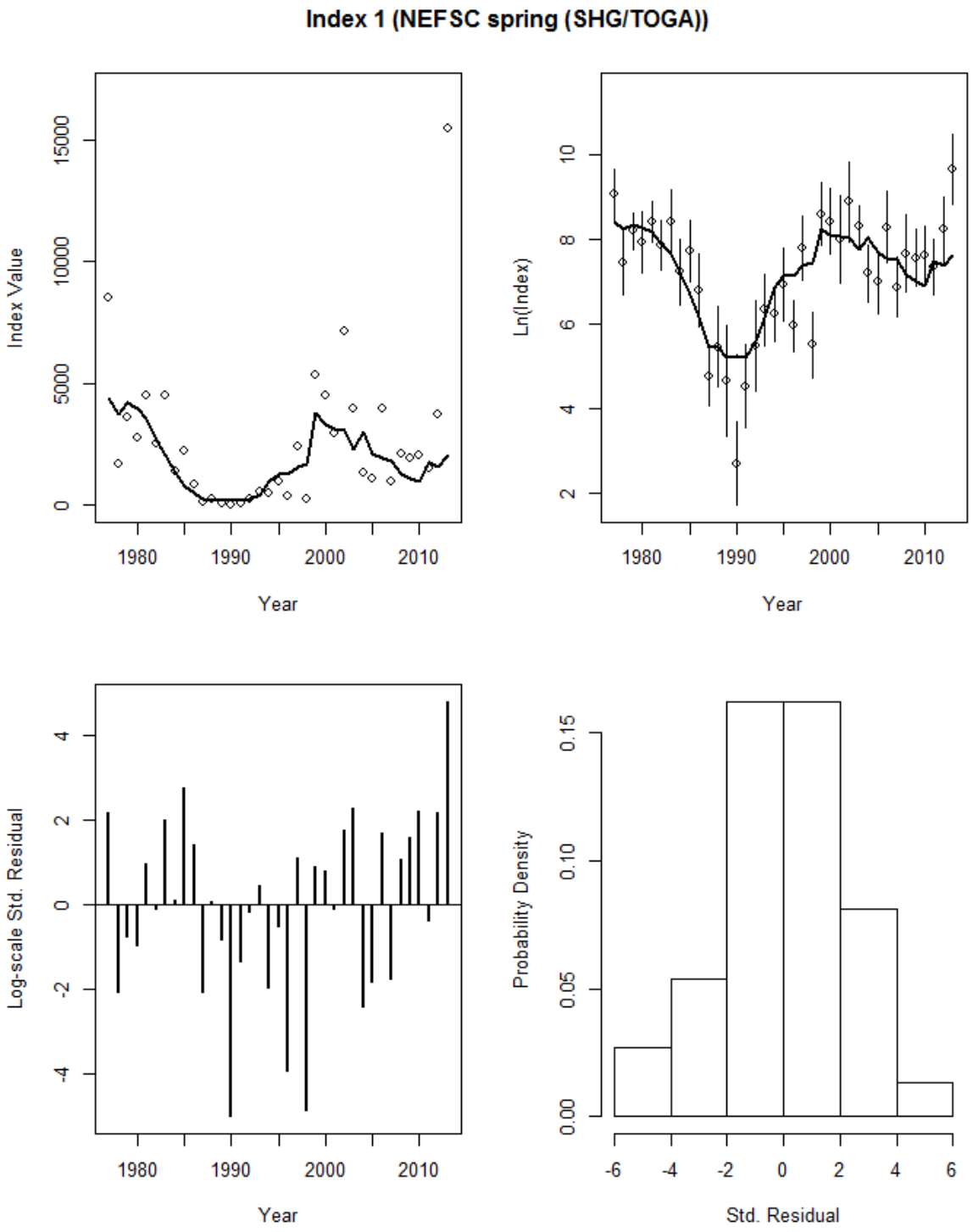

Figure A.155. ASAP_BASE model fit to the NEFSC spring survey Gulf of Maine haddock index (Index 1).

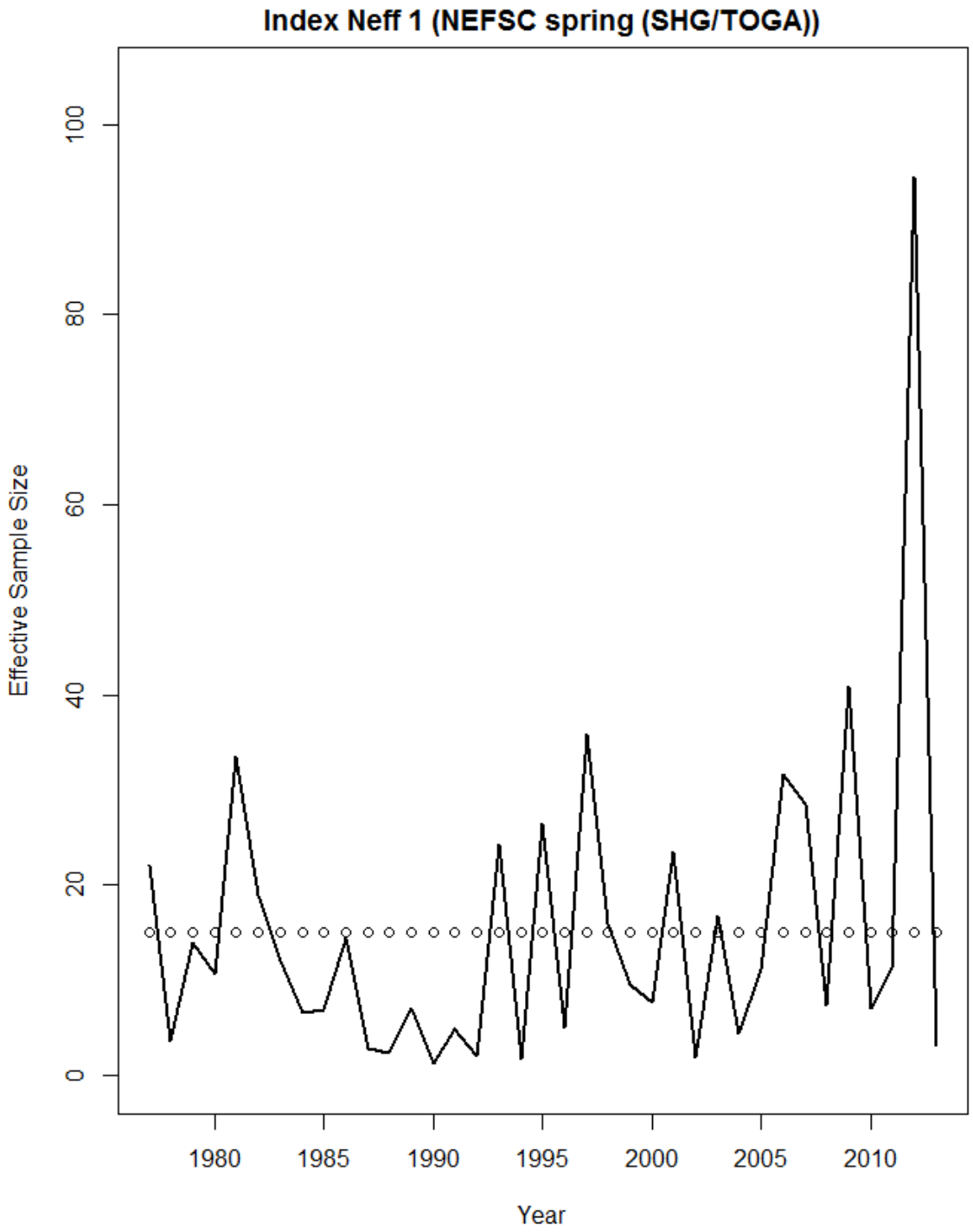

Figure A.156. ASAP_BASE model comparison of input effective sample size versus the model estimated effective sample size for the NEFSC spring survey Gulf of Maine haddock index (Index 1).

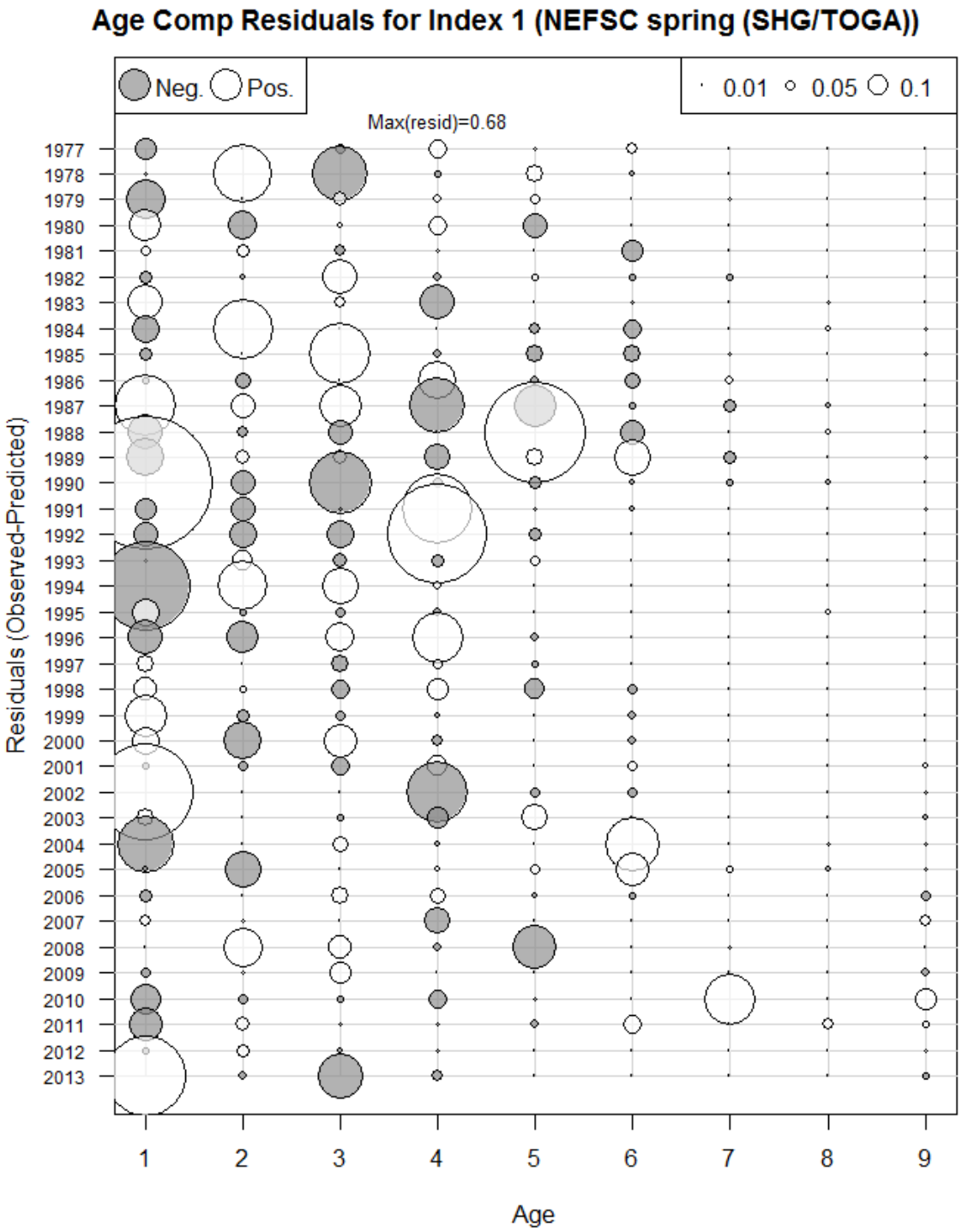

Figure A.157. ASAP_BASE model fit residuals of model fits to the NEFSC spring survey Gulf of Maine haddock indices-at-age (Index 1).

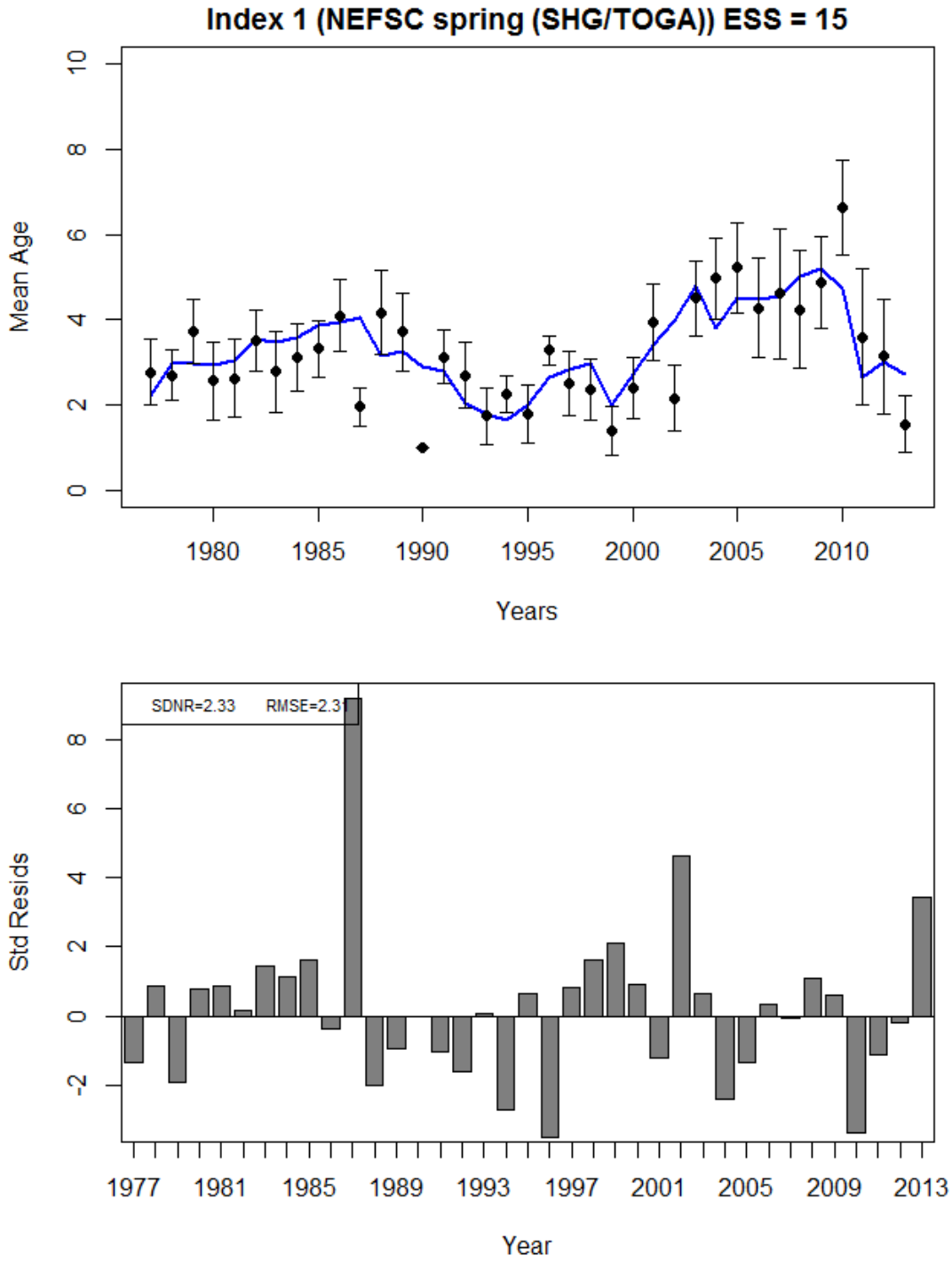

Figure A.158. ASAP_BASE predicted mean age of Gulf of Maine haddock in the NEFSC spring (Index 1) survey (blue line) compared to observed mean age (top plot) and the residuals about the mean (bottom plot).

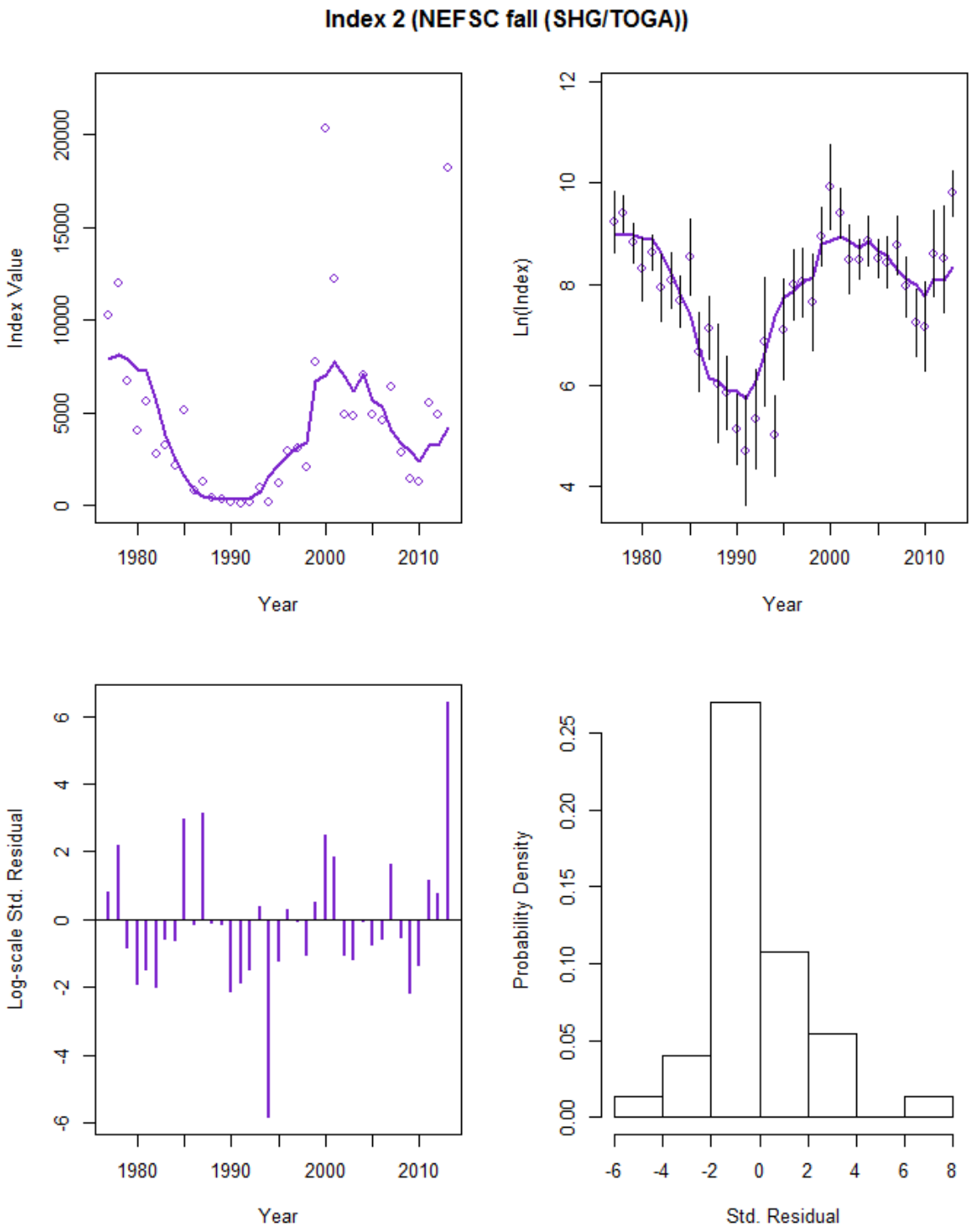

Figure A.159. ASAP_BASE model fit to the NEFSC fall survey Gulf of Maine haddock index (Index 2).

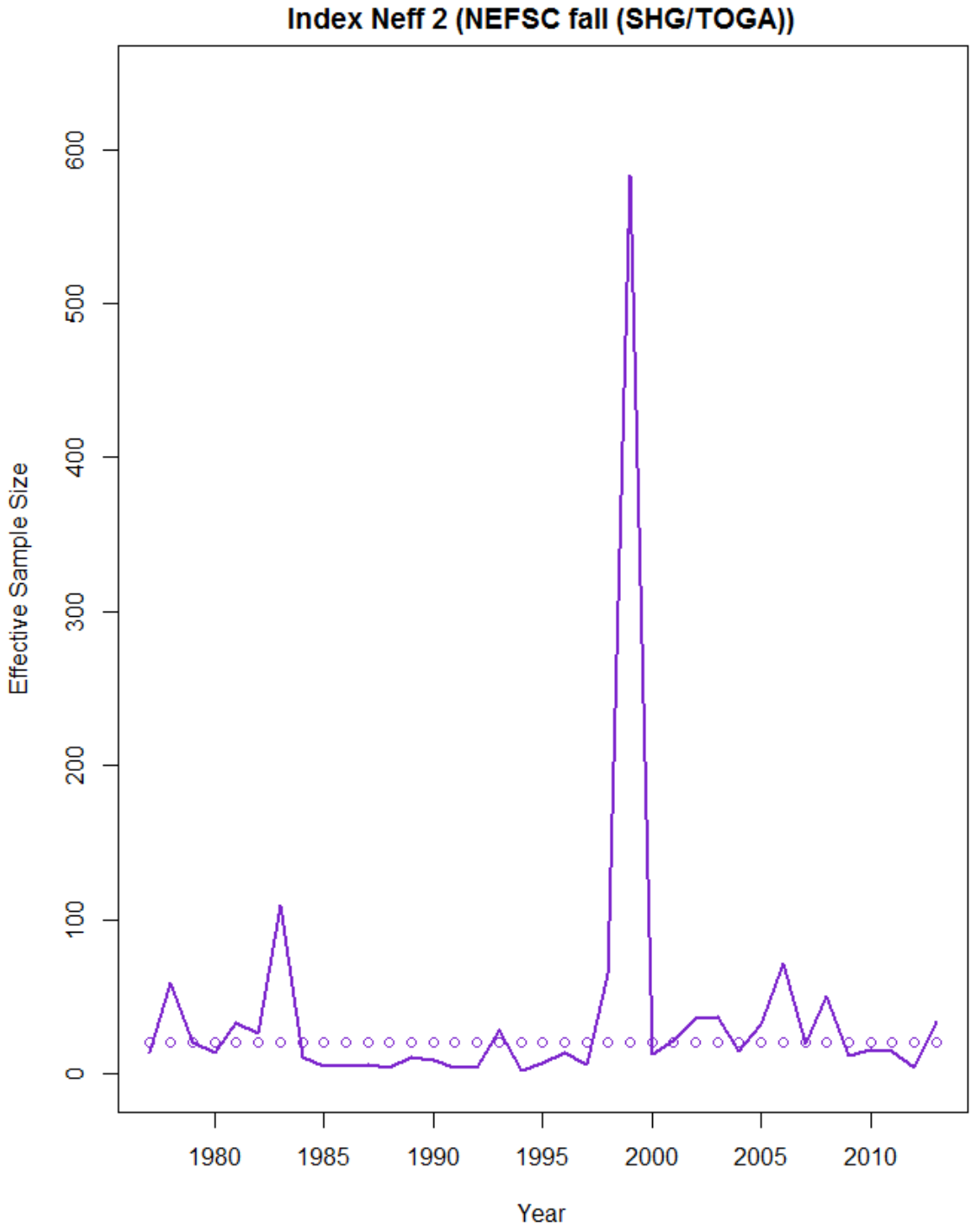

Figure A.160. ASAP_BASE model comparison of input effective sample size versus the model estimated effective sample size for the NEFSC fall survey Gulf of Maine haddock index (Index 2).

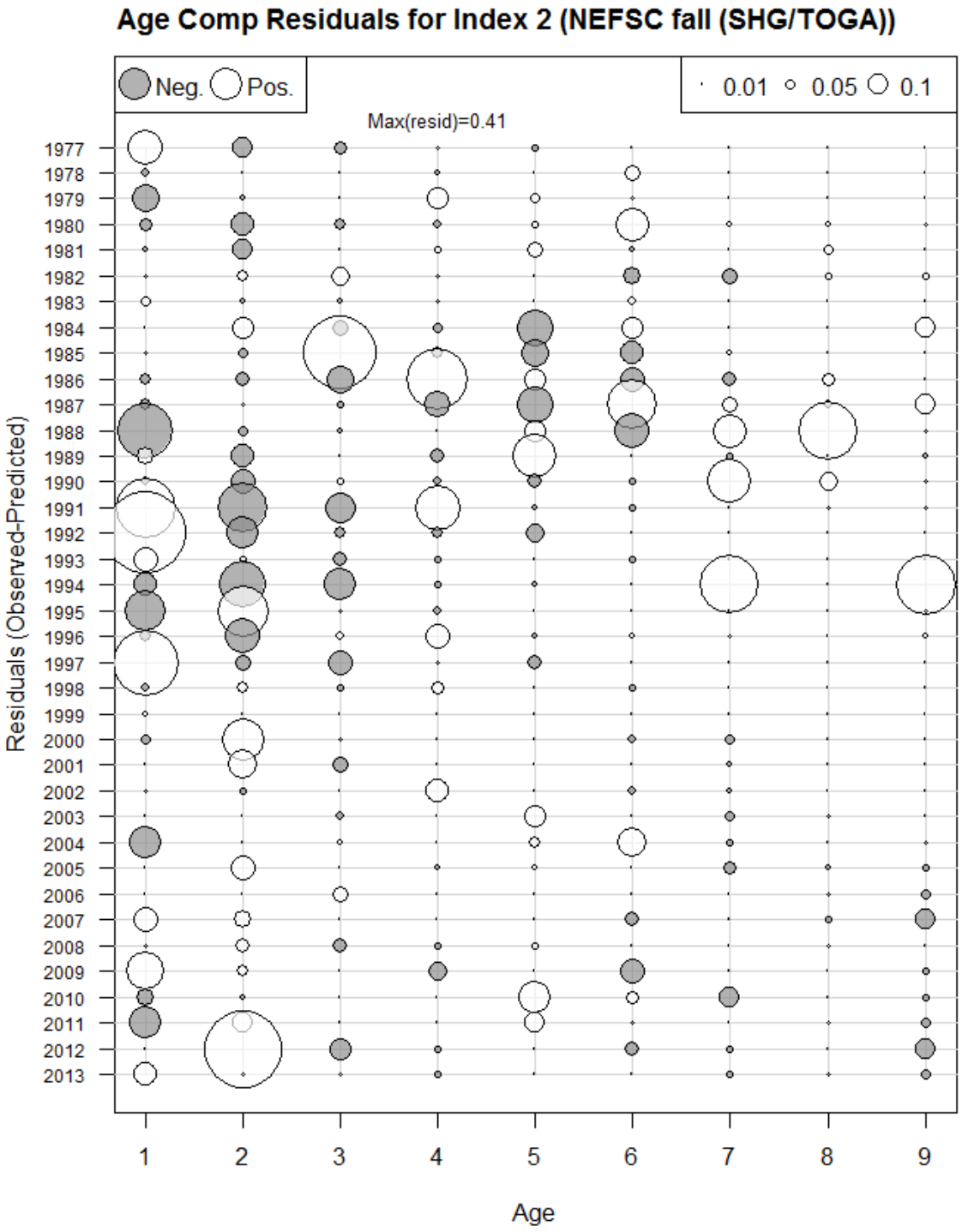

Figure A.161. ASAP_BASE model fit residuals of model fits to the NEFSC fall survey Gulf of Maine haddock indices-at-age (Index 2).

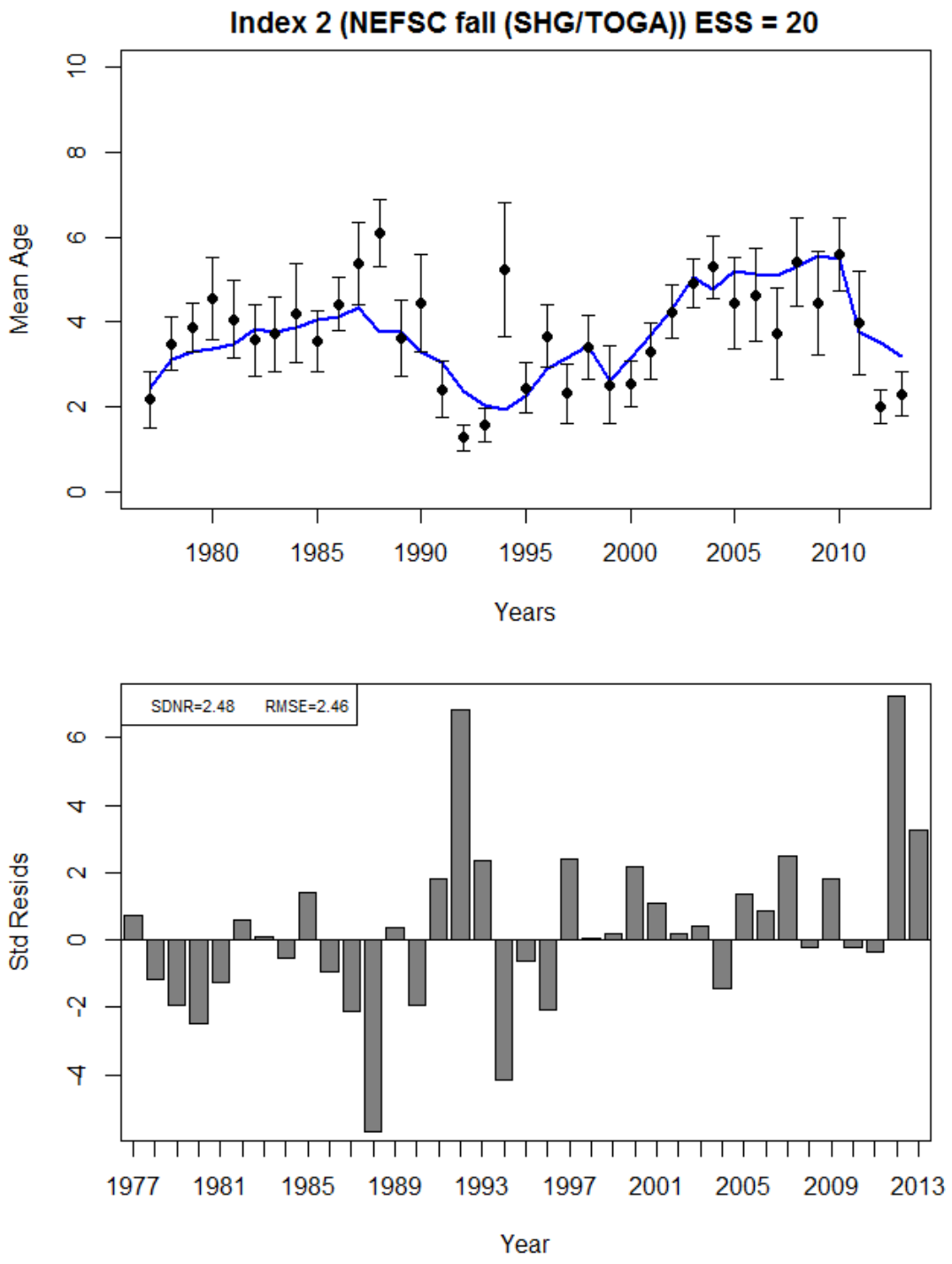

Figure A.162. ASAP_BASE predicted mean age of Gulf of Maine haddock in the NEFSC fall (Index 2) survey (blue line) compared to observed mean age (top plot) and the residuals about the mean (bottom plot).

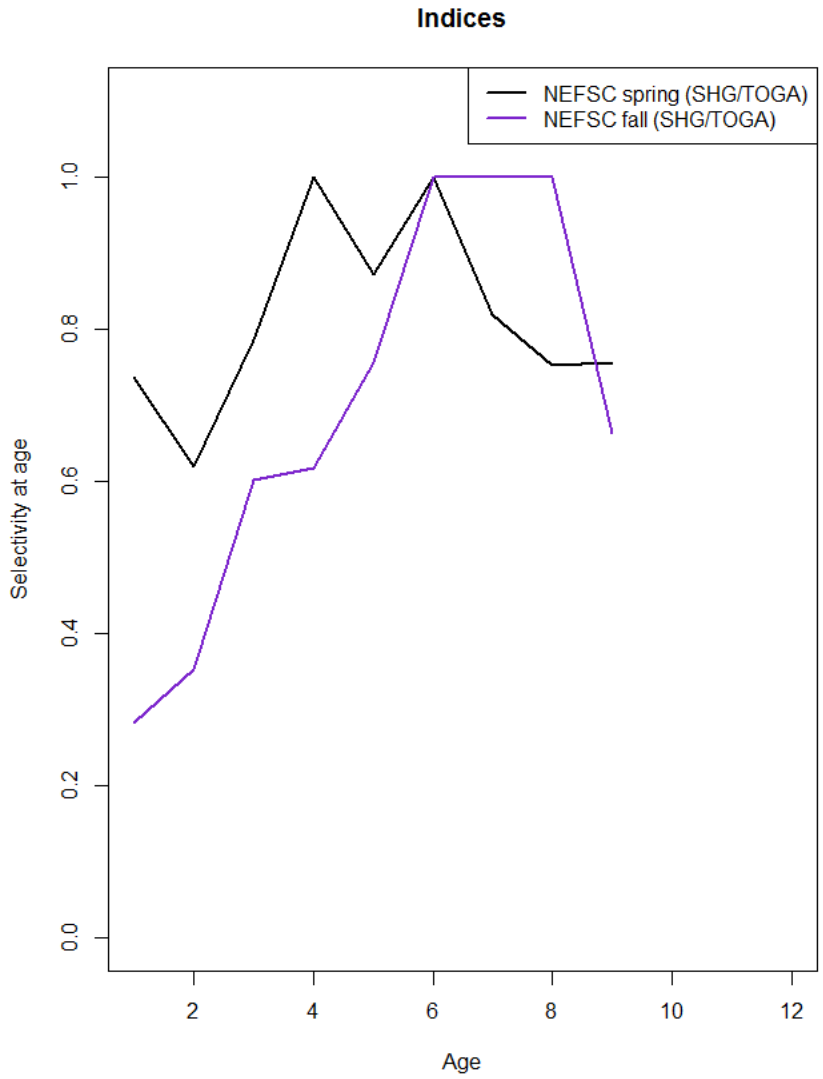

Figure A.163. Gulf of Maine haddock selectivity-at-age for the NEFSC spring (Index 1), and fall (Index 2) from the ASAP_BASE model.

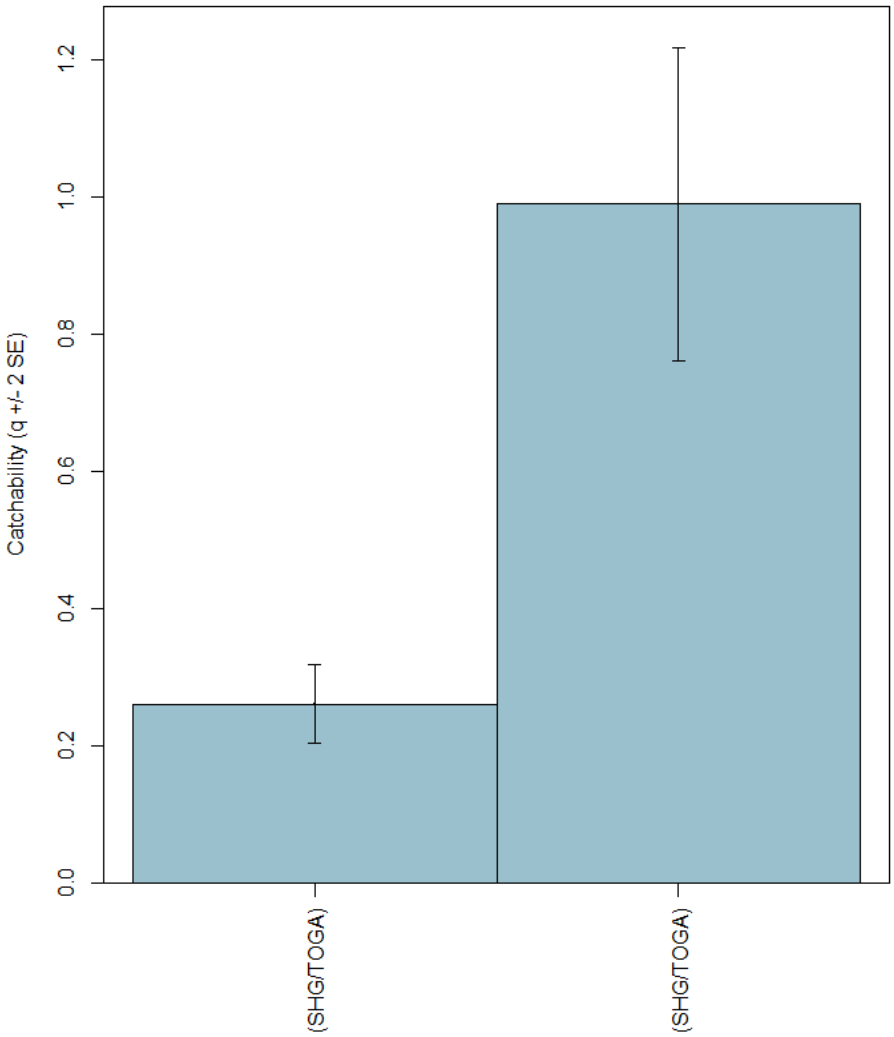

Figure A.164. Gulf of Maine haddock survey catchability, *q*, for the NEFSC spring (Index 1), and fall (Index 2) surveys from the ASAP_BASE model.

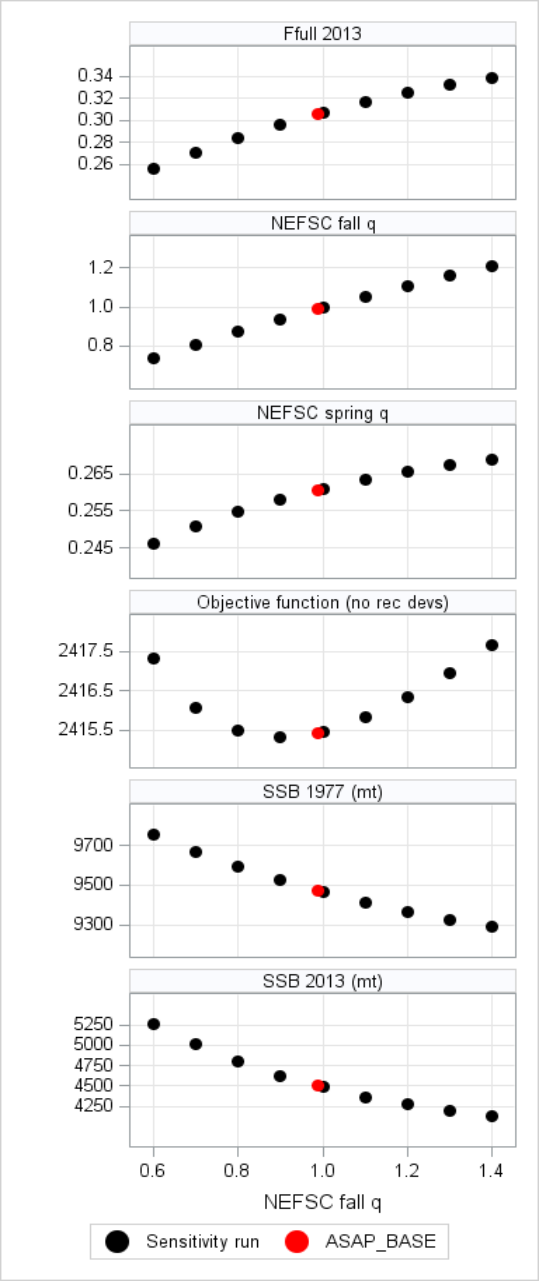

Figure A.165. Sensitivity analysis showing the response of the Gulf of Maine haddock ASAP_BASE model to different assumptions of survey catchability (*q*) of the Northeast Fisheries Science Center fall survey.

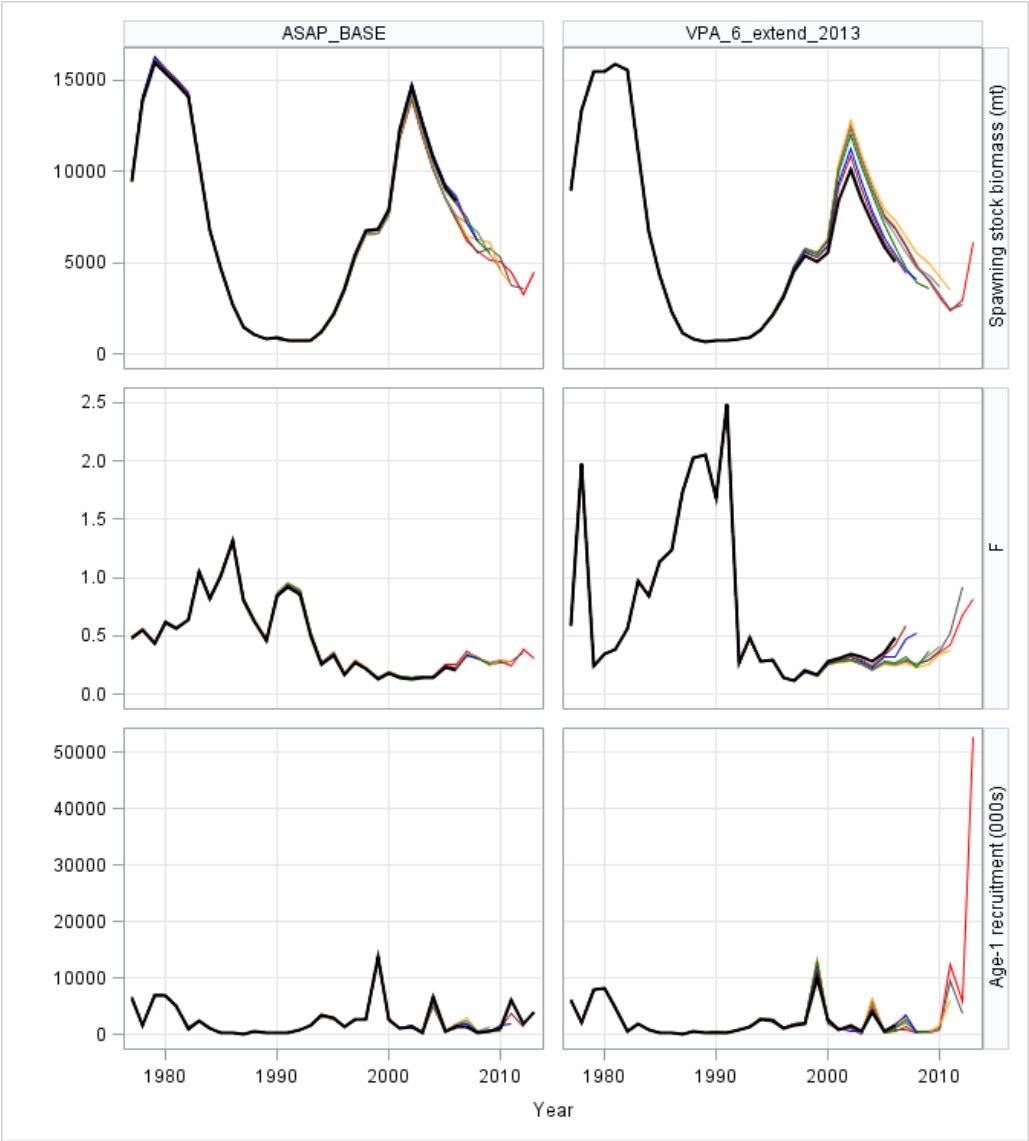

Figure A.166. Comparison of the time series of spawning stock biomass, fishing mortality and recruitment estimates from the 2013 update of the VPA model (VPA_6_extend_2013) to the base ASAP model (ASAP_BASE). Seven years of retrospective peels are shown for both model runs. *Note that the fishing mortality basis is different between the ASAP (F_{full}) and VPA (avg. F_{6-8}) runs.*

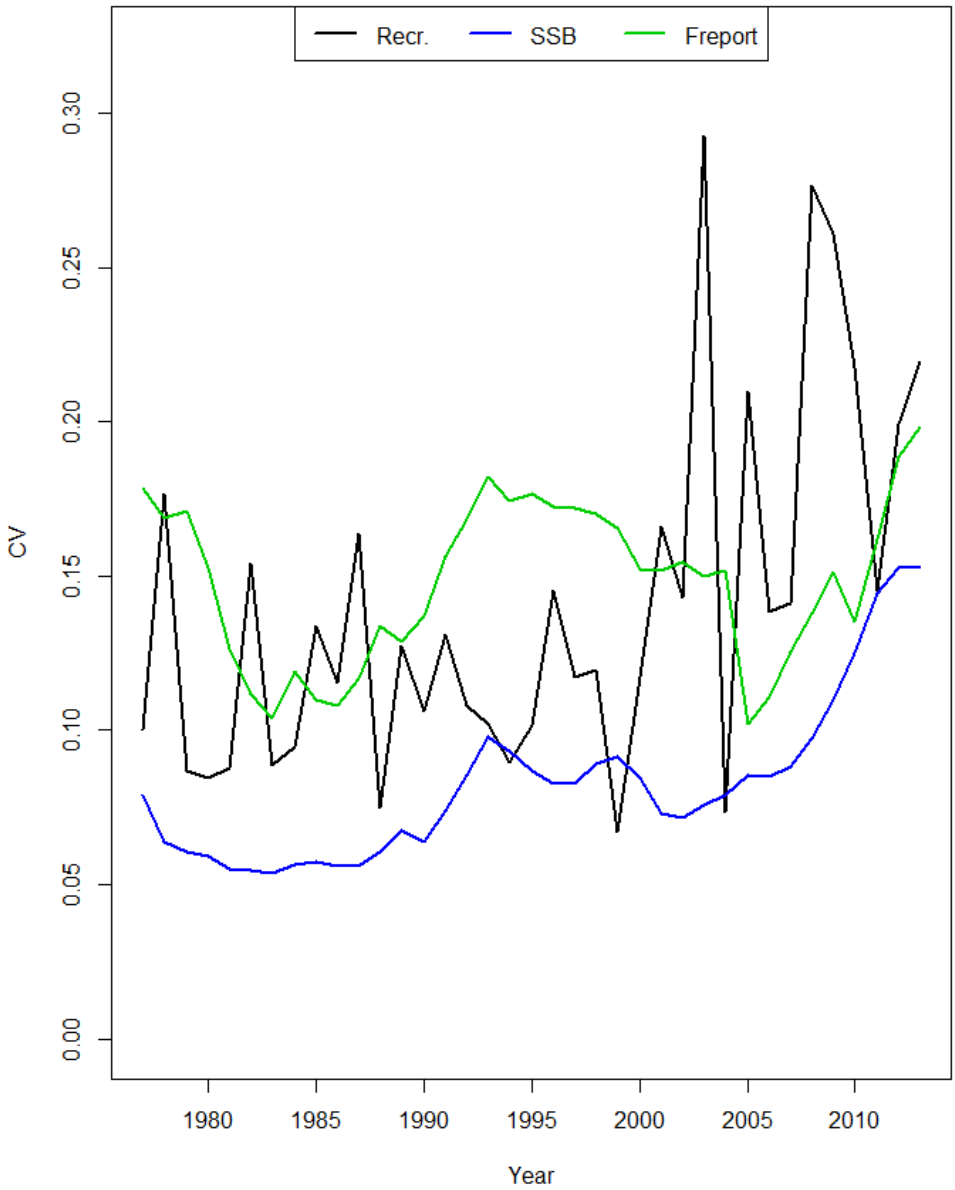

Figure A.167. Hessian-based coefficients of variation (CV) for the ASAP_BASE model estimates of Gulf of Maine haddock spawning stock biomass (SSB), fishing mortality (F_{full}) and age-1 recruitment.

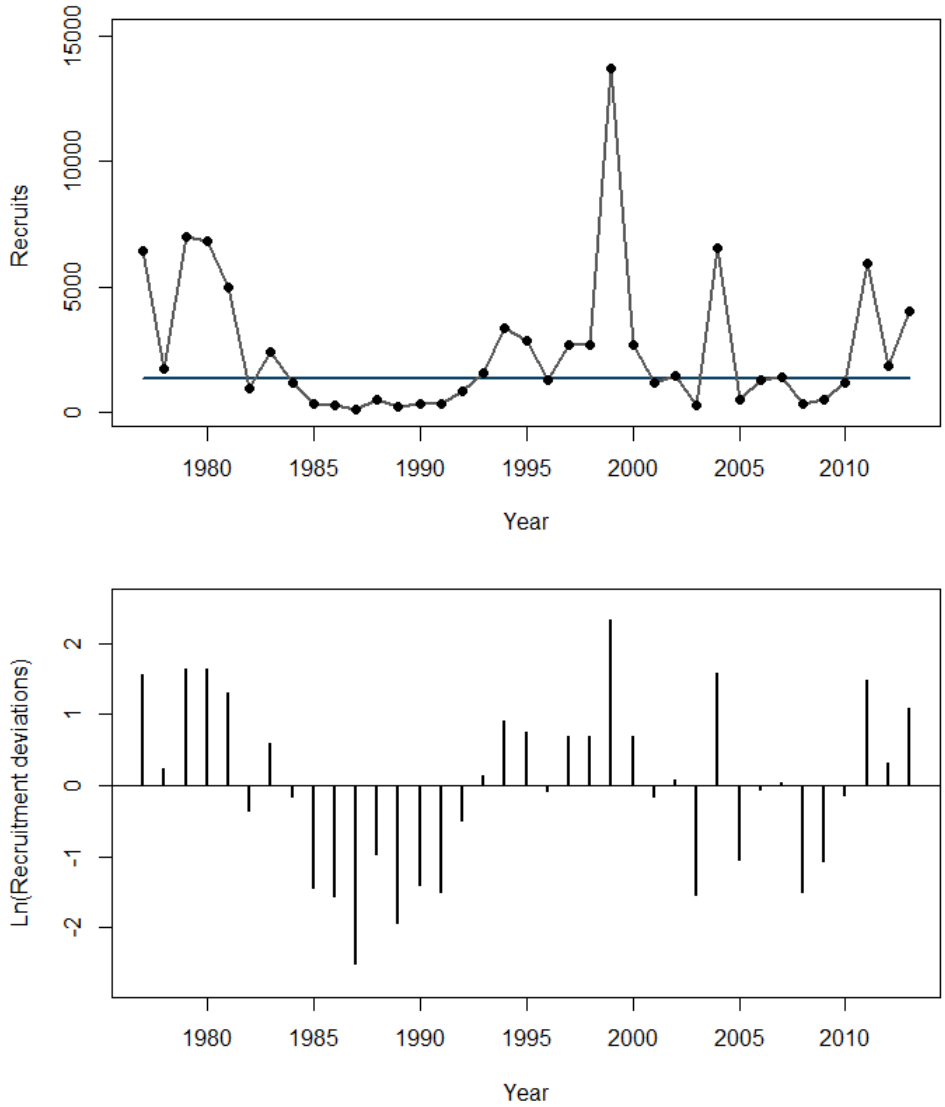

Figure A.168. ASAP_BASE estimated Gulf of Maine haddock age-1 recruitment and recruitment residuals from the geometric mean.

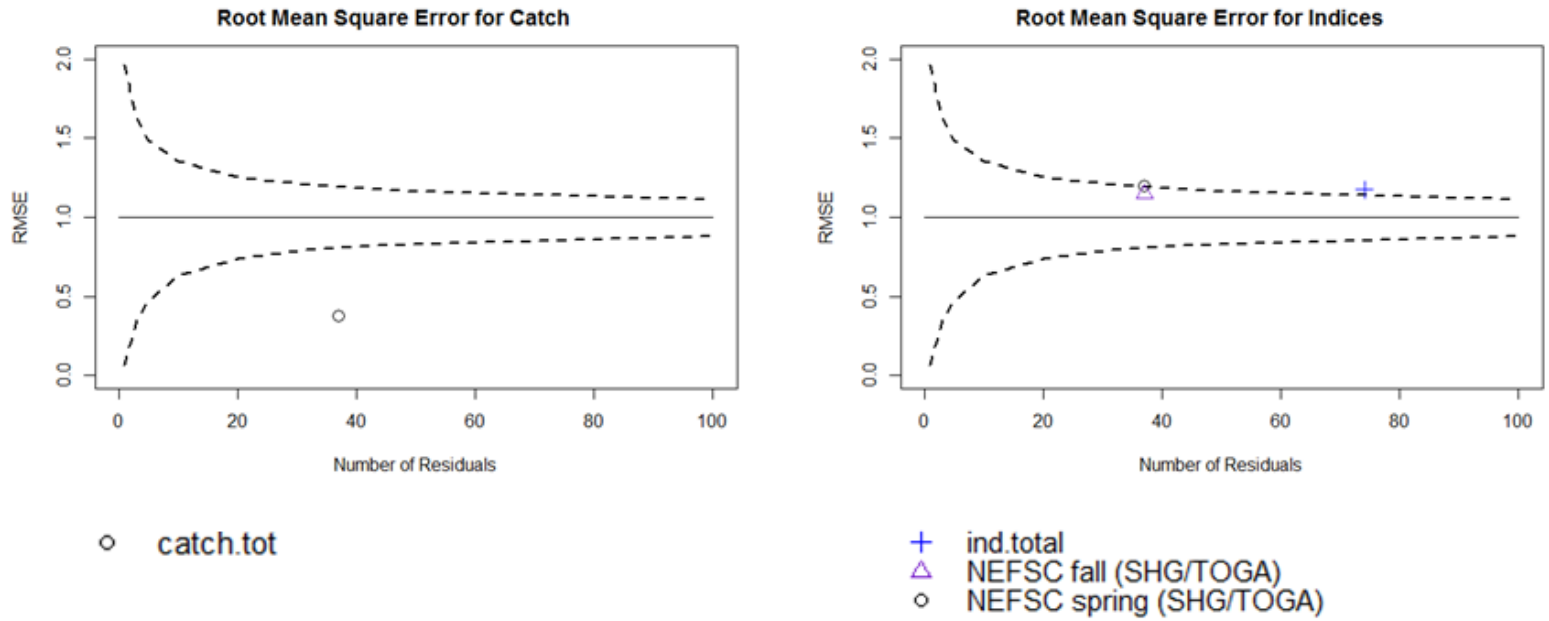

Figure A.169. ASAP_final_temp10 model fit root mean square error (RMSE) values for total catch (left) and survey indices (right) as a function of the number of residuals. The median and 80% confidence interval of the root mean square error from a normal distribution with mean zero and standard deviation one for a range of sample sizes is overlaid on the model RMSE values for reference.

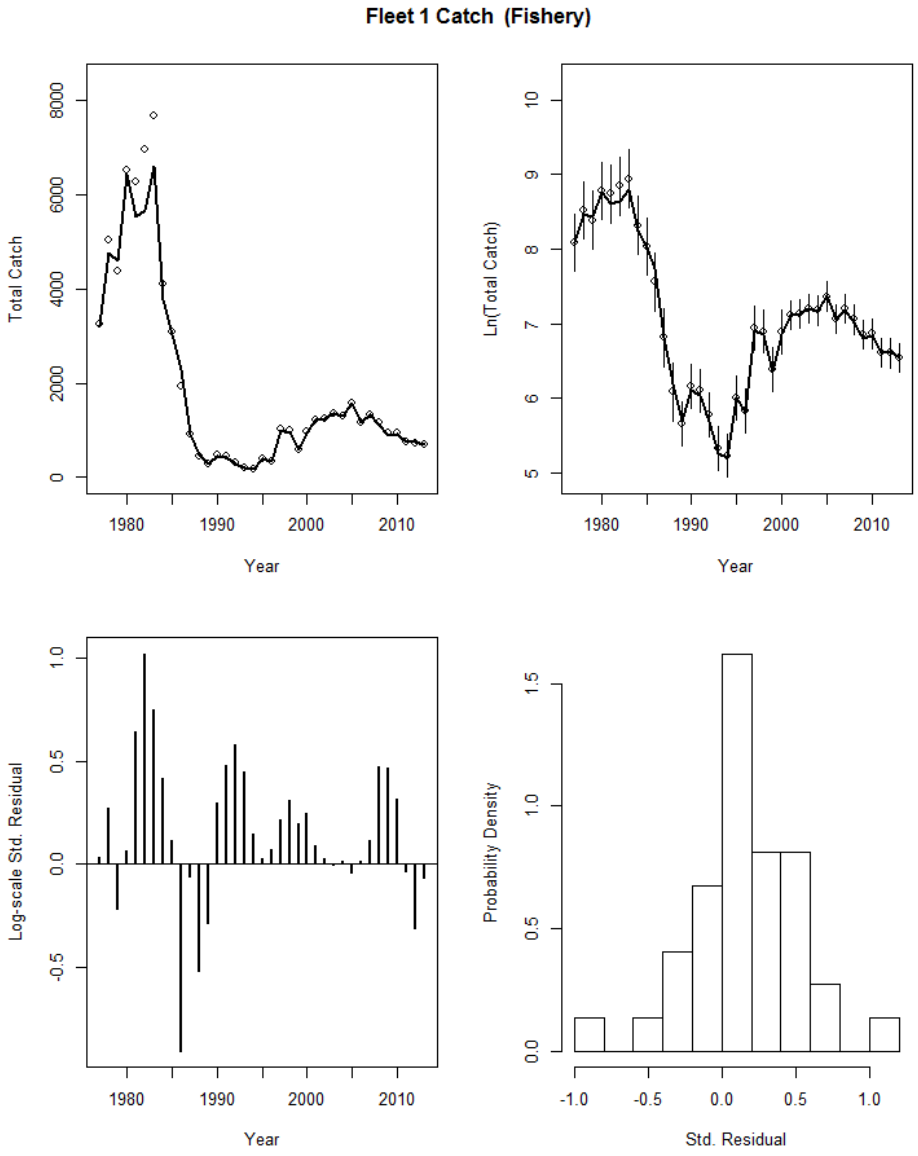

Figure A.170. ASAP_final_temp10 model fit to the total Gulf of Maine haddock fishery catch (Fleet 1).

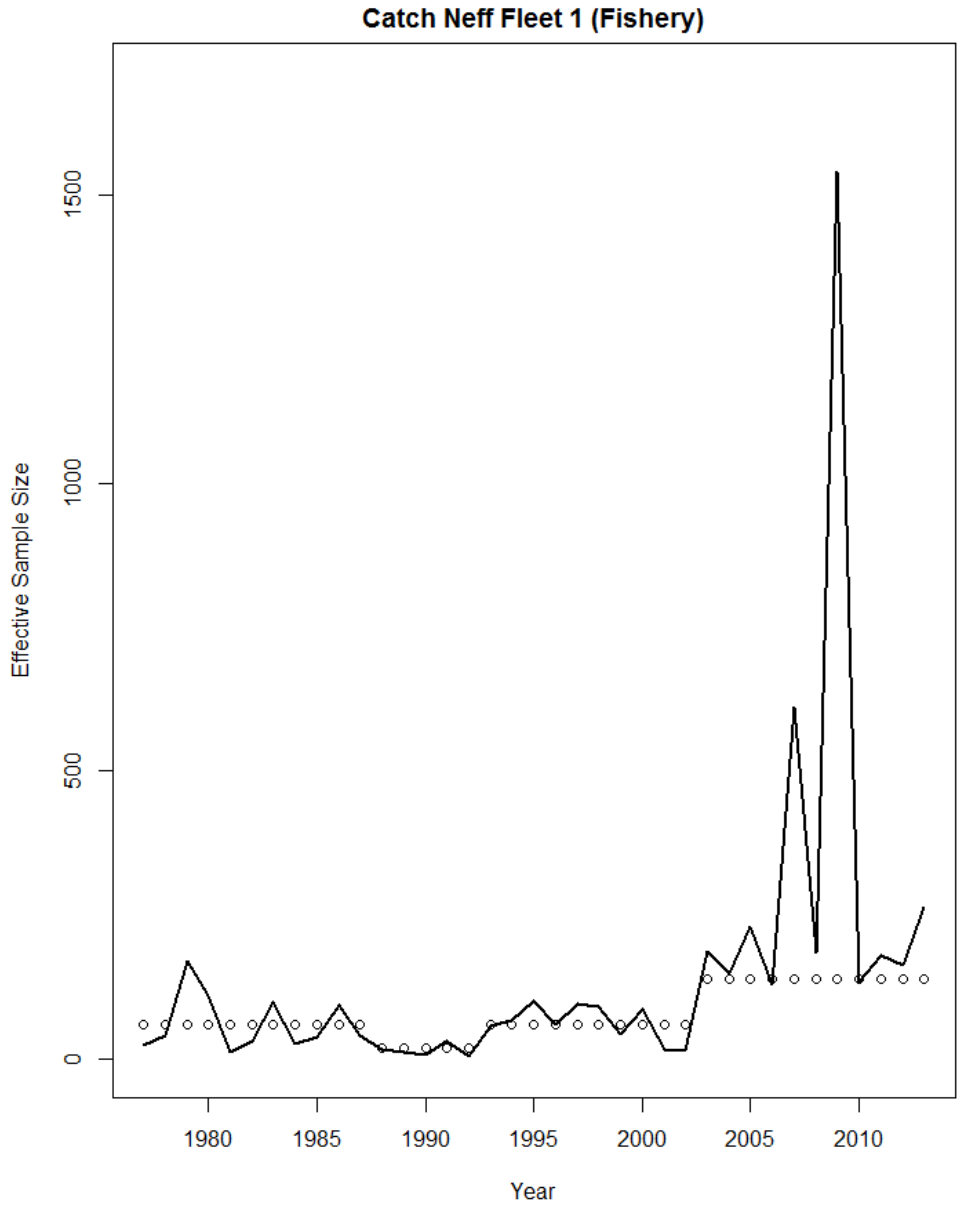

Figure A.171. ASAP_final_temp10 model comparison of input effective sample size versus the model estimated effective sample size for the Gulf of Maine haddock fishery catch (Fleet 1).

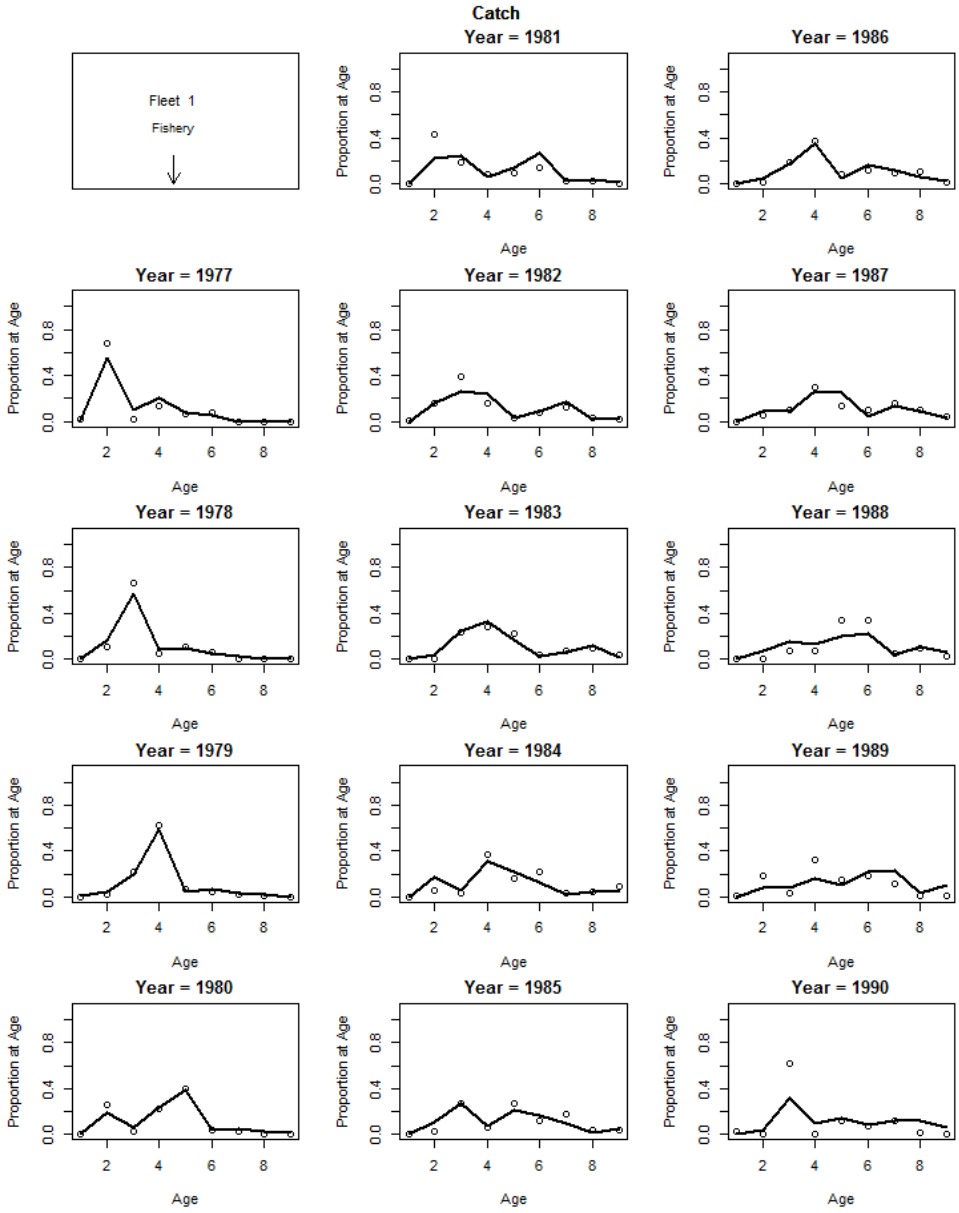

Figure A.172.a. Comparison of the ASAP_final_temp10 model estimates of Gulf of Maine haddock proportion-at-age in the fishery to the data estimates.

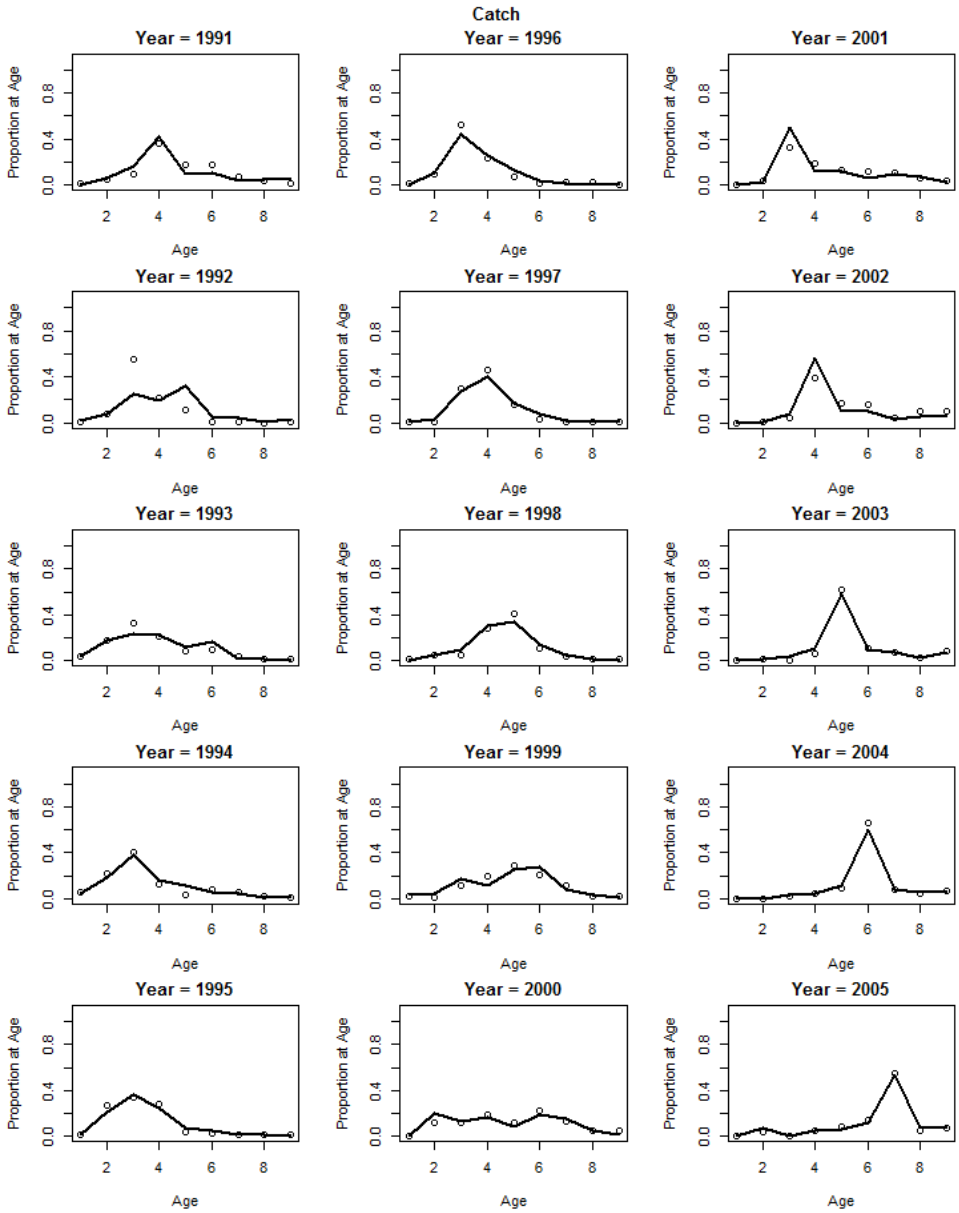

Figure A.172.b. Comparison of the ASAP_final_temp10 model estimates of Gulf of Maine haddock proportion-at-age in the fishery to the data estimates.

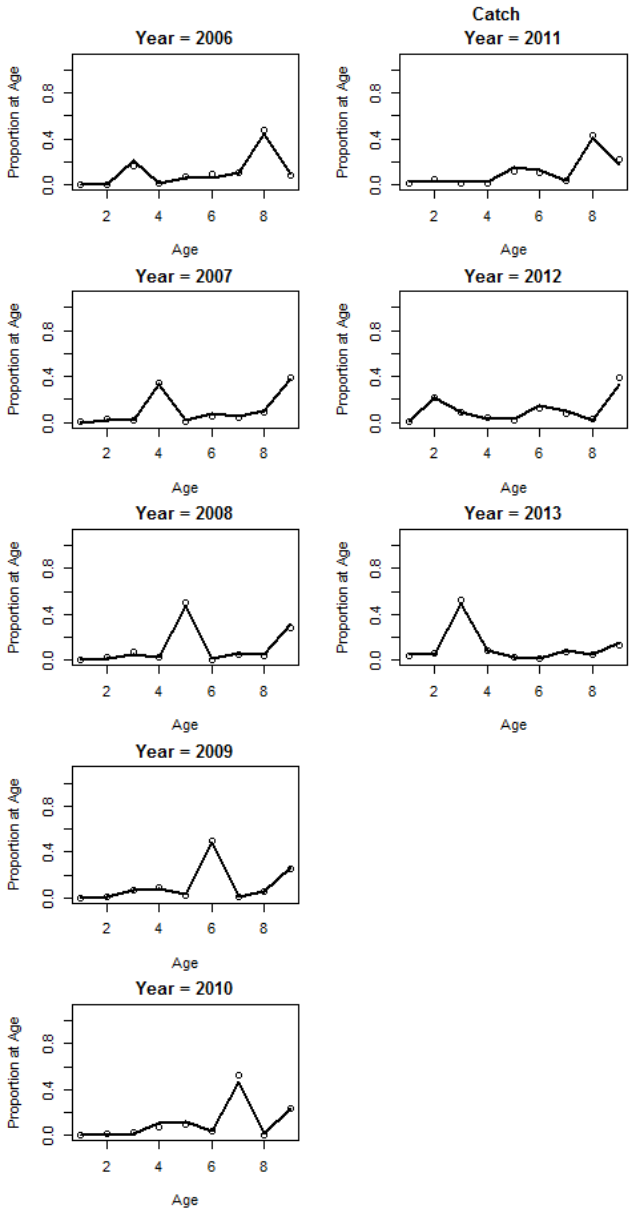

Figure A.172.c. Comparison of the ASAP_final_temp10 model estimates of Gulf of Maine haddock proportion-at-age in the fishery to the data estimates.

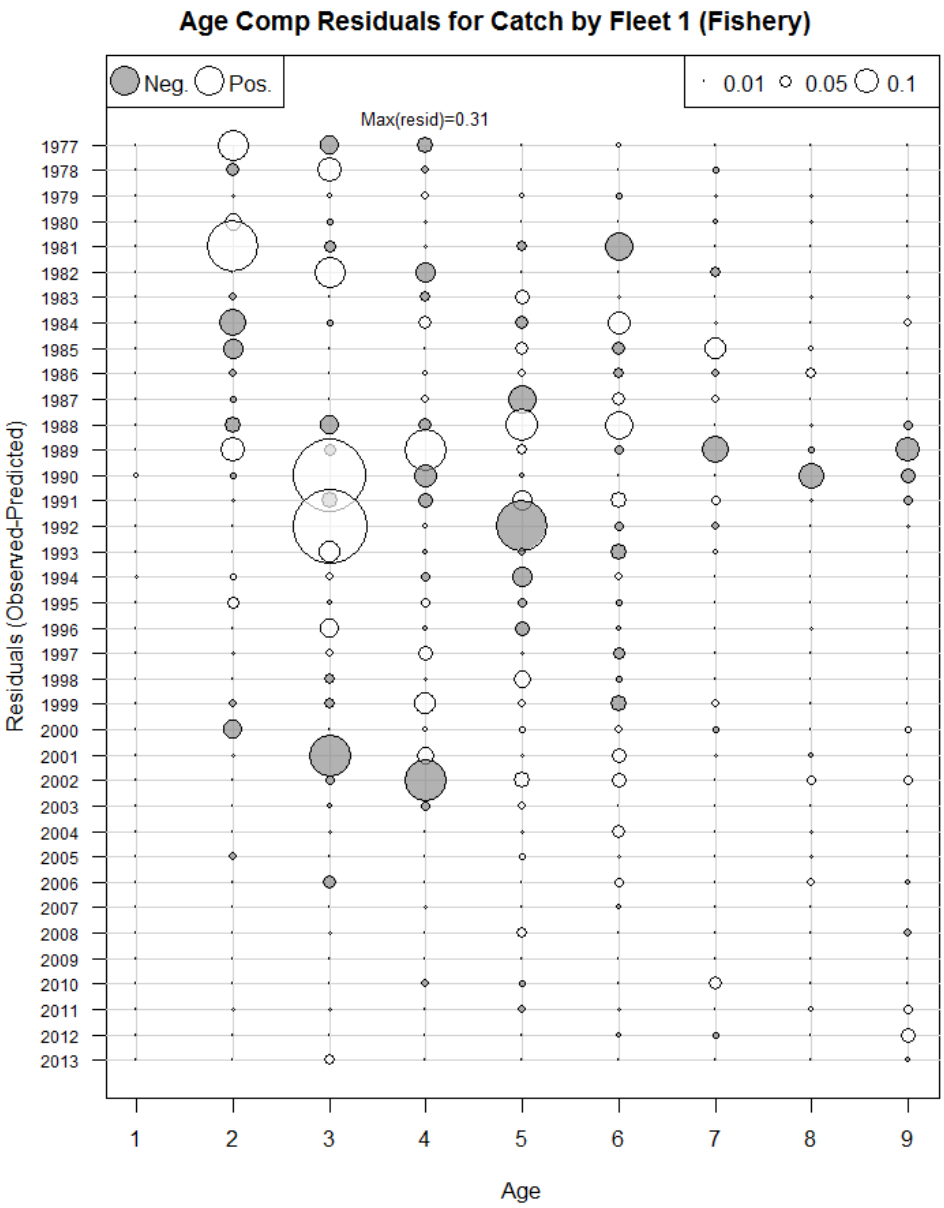

Figure A.173. ASAP_final_temp10 model fit residuals for the Gulf of Maine haddock fishery (Fleet 1) catch-at-age.

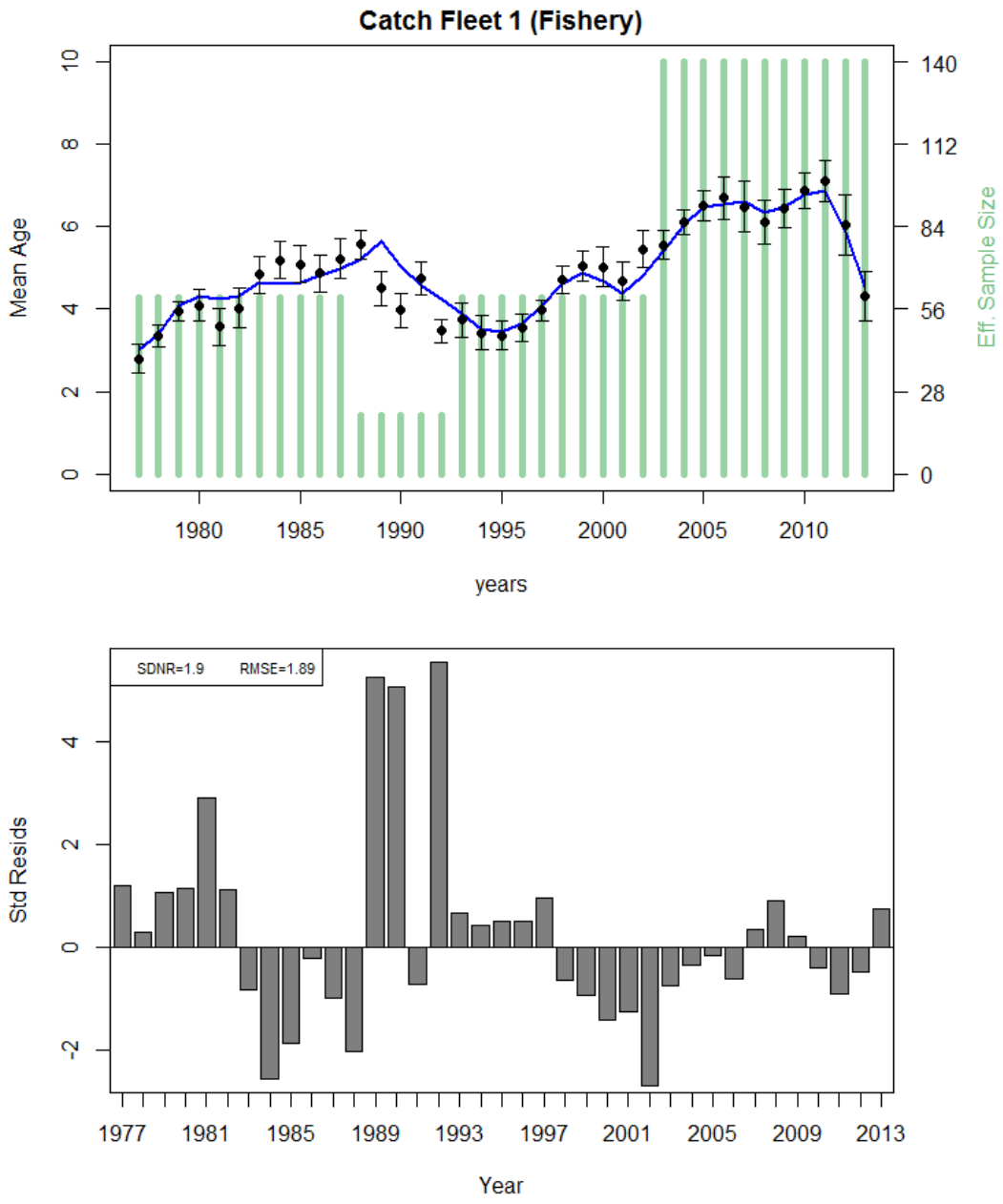

Figure A.174. ASAP_final_temp10 predicted mean age of Gulf of Maine haddock in the fishery (Fleet 1) catch (blue line) compared to observed mean age (top plot) and the residuals about the mean (bottom plot).

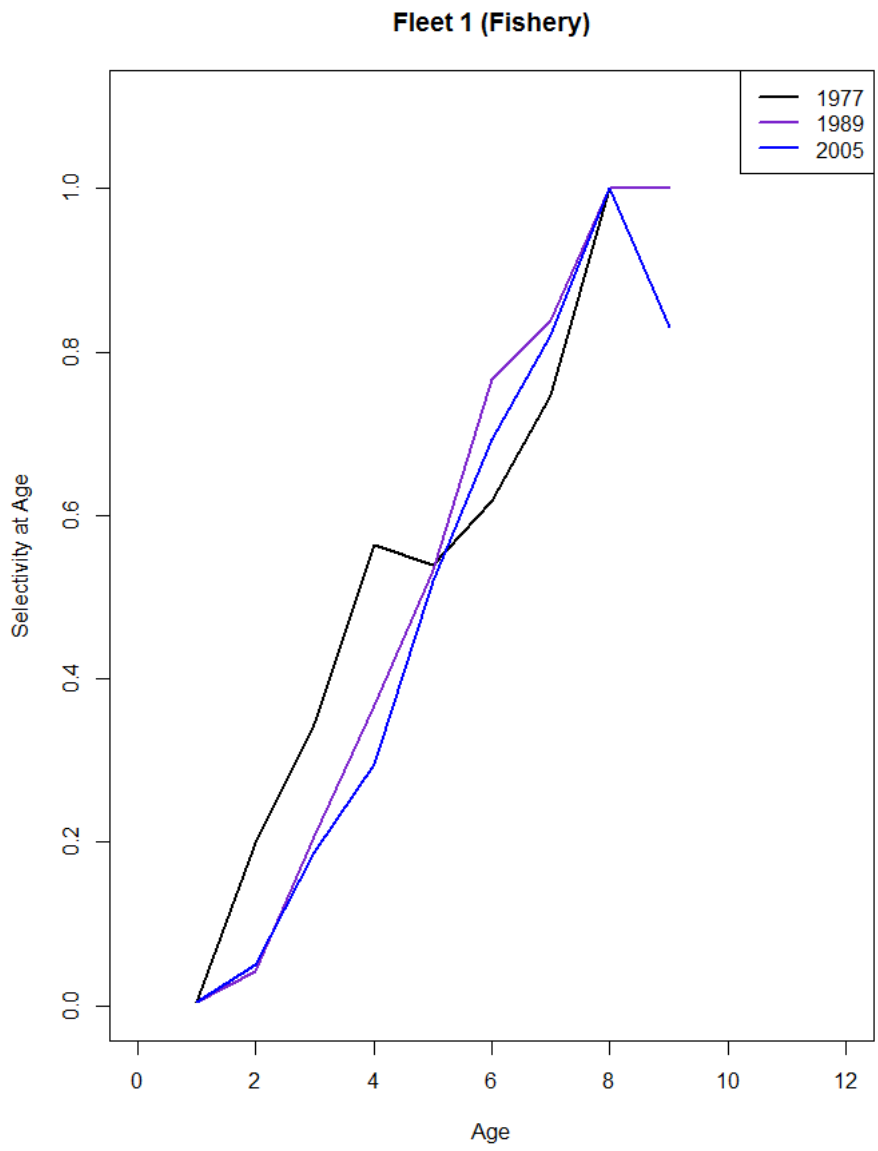

Figure A.175. Gulf of Maine haddock fishery (Fleet 1) selectivity blocks for block 1 (1977-1988), block 2 (1989-2004) and block 3 (2005-2013) as estimated by the ASAP_final_temp10 model.

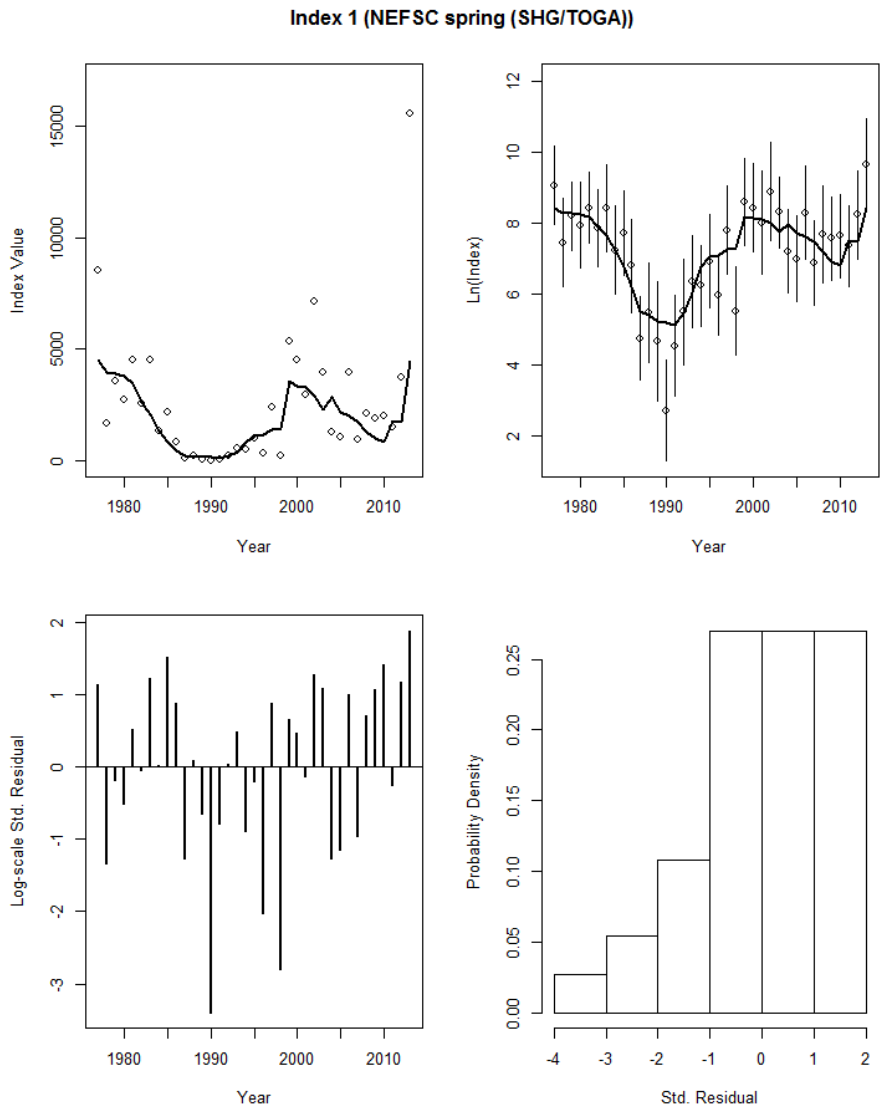

Figure A.176. ASAP_final_temp10 model fit to the NEFSC spring survey Gulf of Maine haddock index (Index 1).

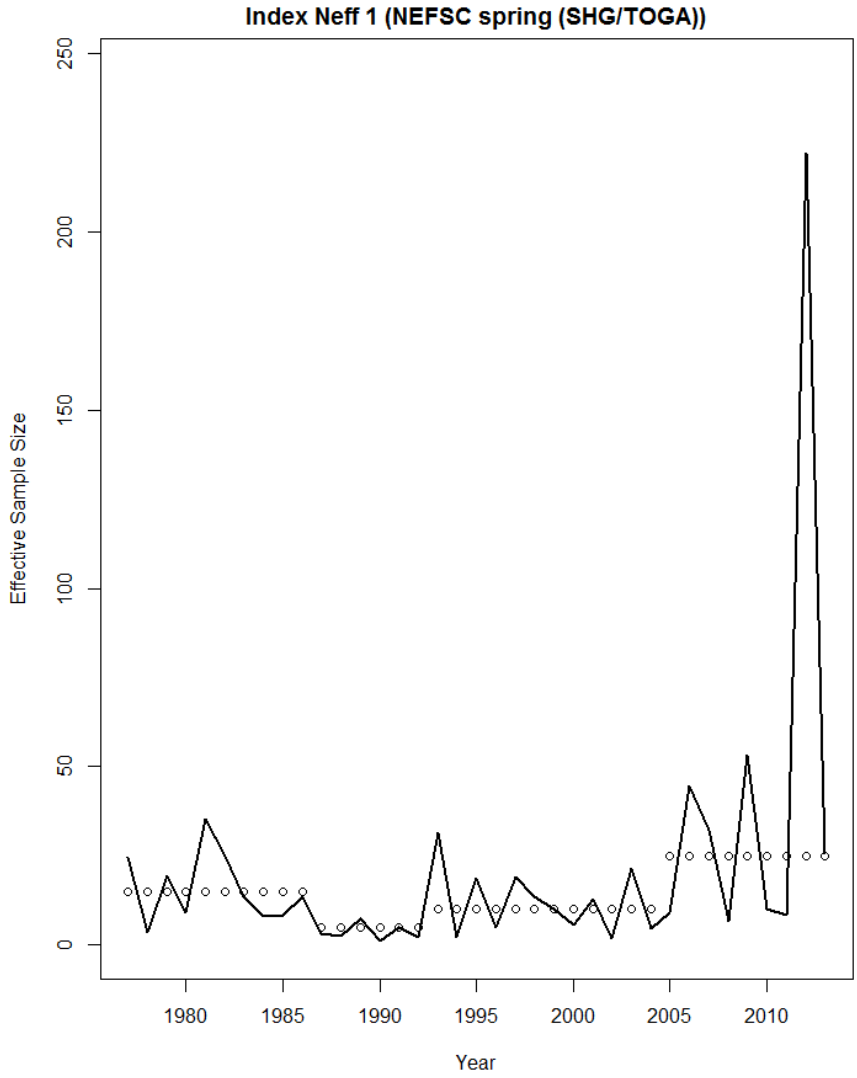

Figure A.177. ASAP_final_temp10 model comparison of input effective sample size versus the model estimated effective sample size for the NEFSC spring survey Gulf of Maine haddock index (Index 1).

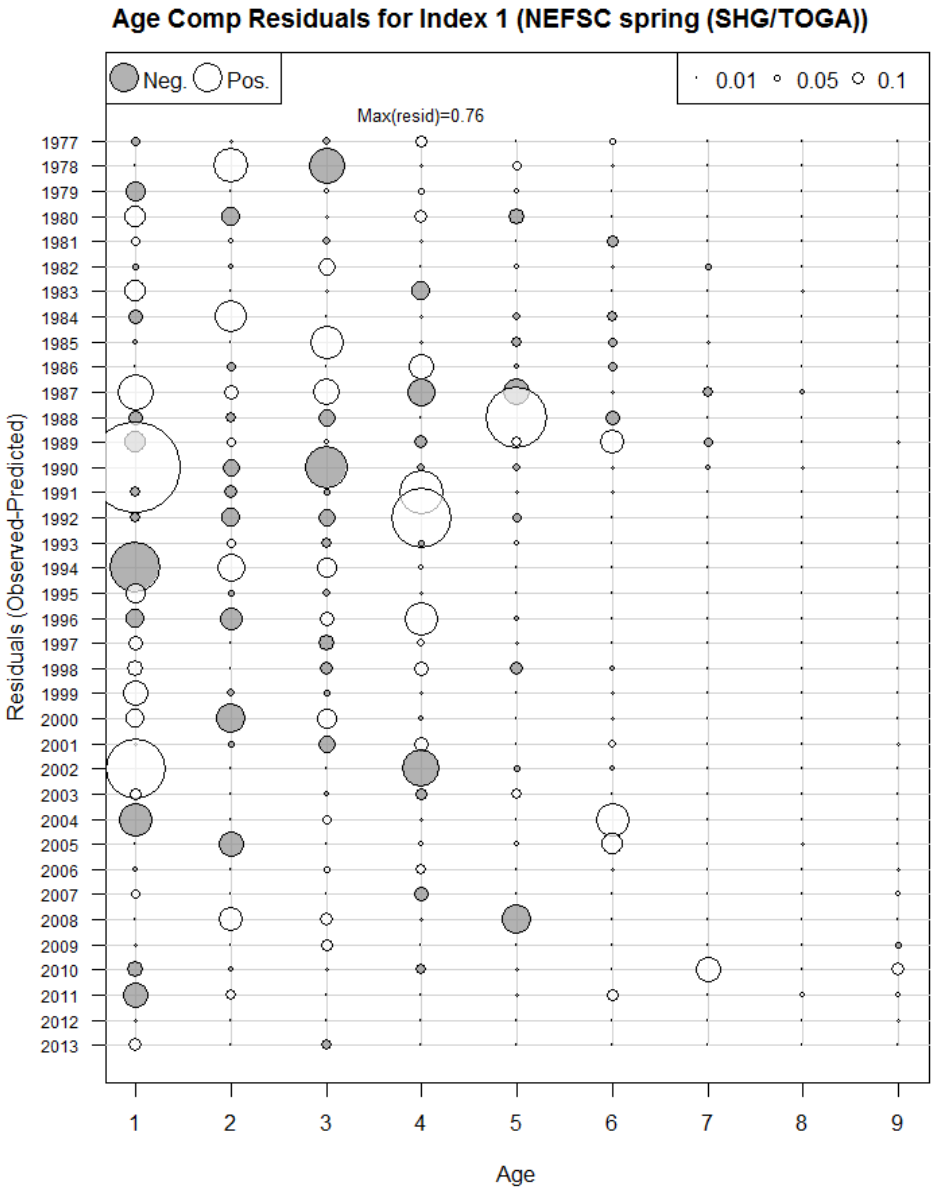

Figure A.178. ASAP_final_temp10 model fit residuals for the NEFSC spring survey Gulf of Maine haddock indices-at-age (Index 1).

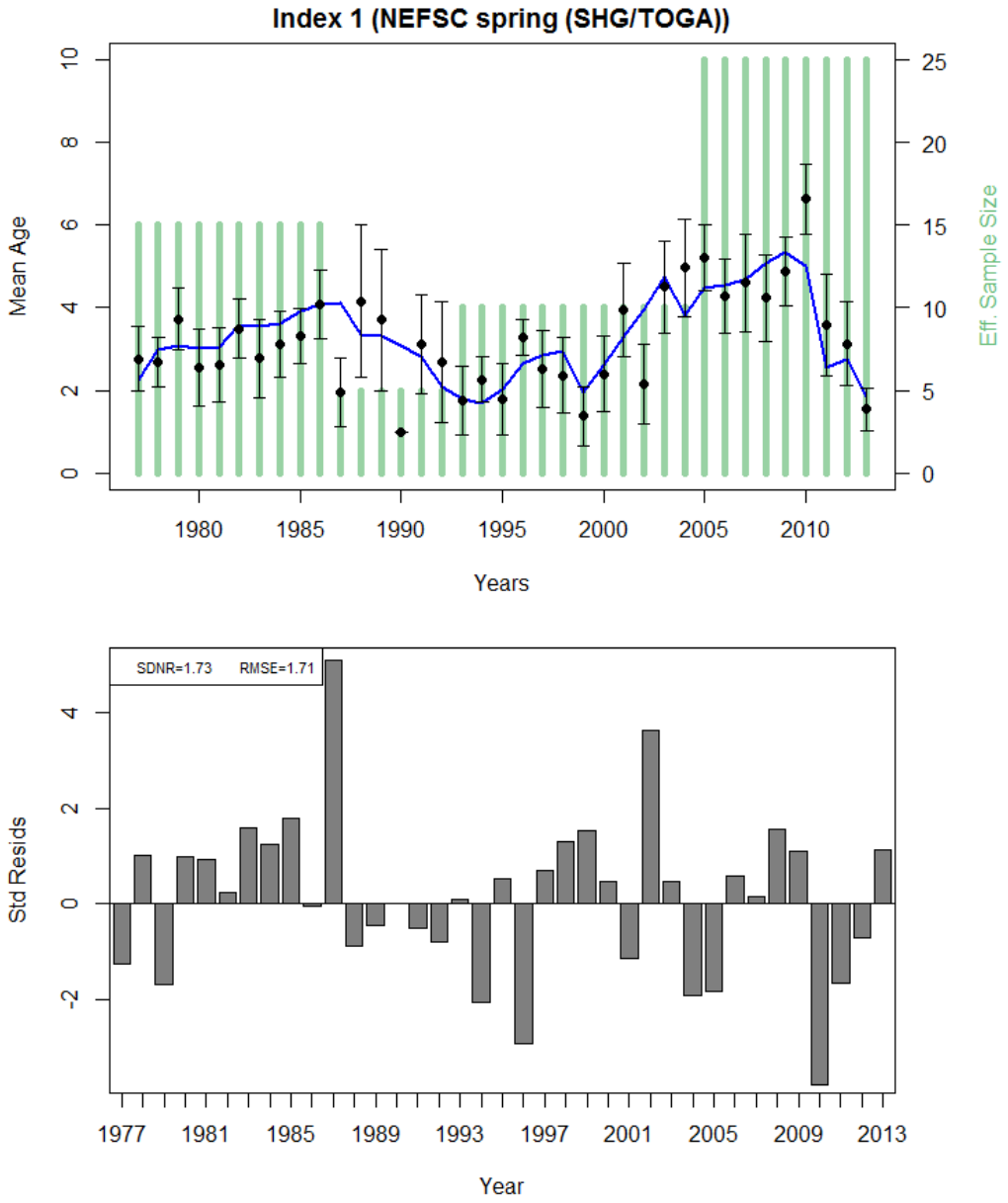

Figure A.179. ASAP_final_temp10 predicted mean age of Gulf of Maine haddock in the NEFSC spring (Index 1) survey (blue line) compared to observed mean age (top plot) and the residuals about the mean (bottom plot).

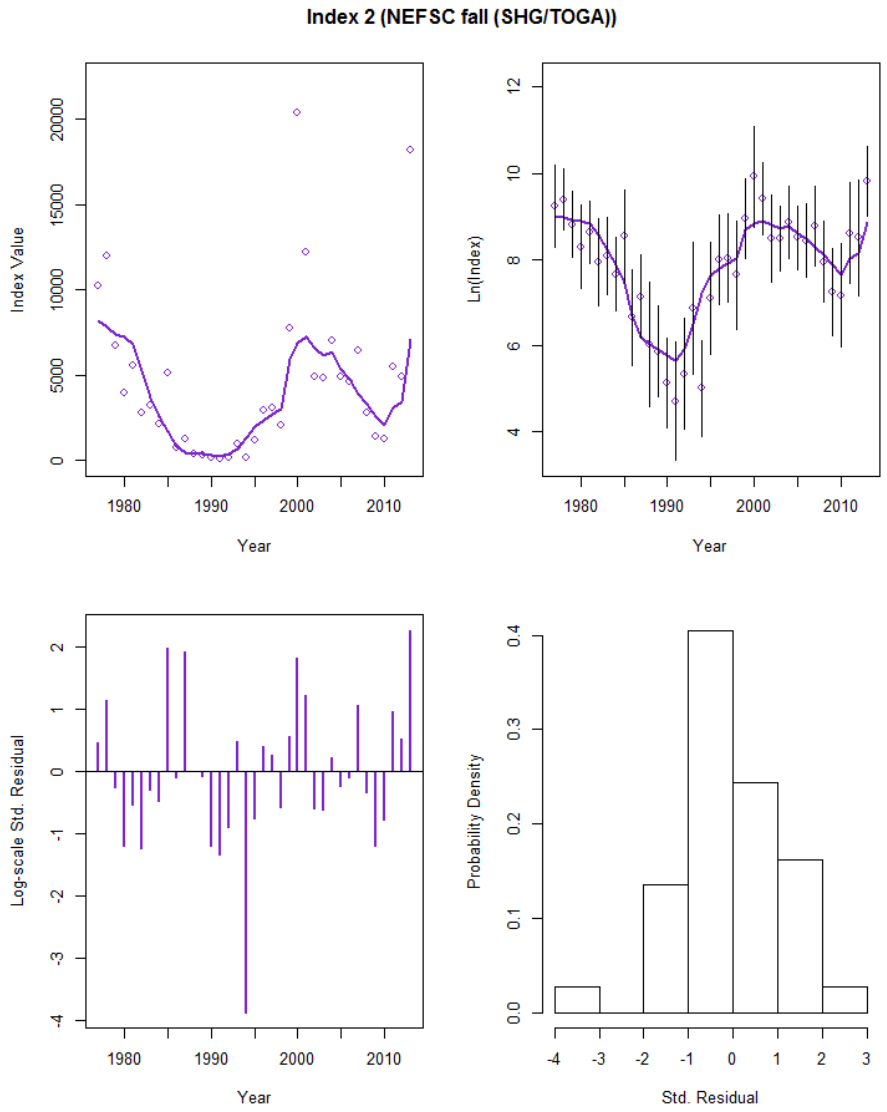

Figure A.180. ASAP_final_temp10 model fit to the NEFSC fall survey Gulf of Maine haddock index (Index 2).

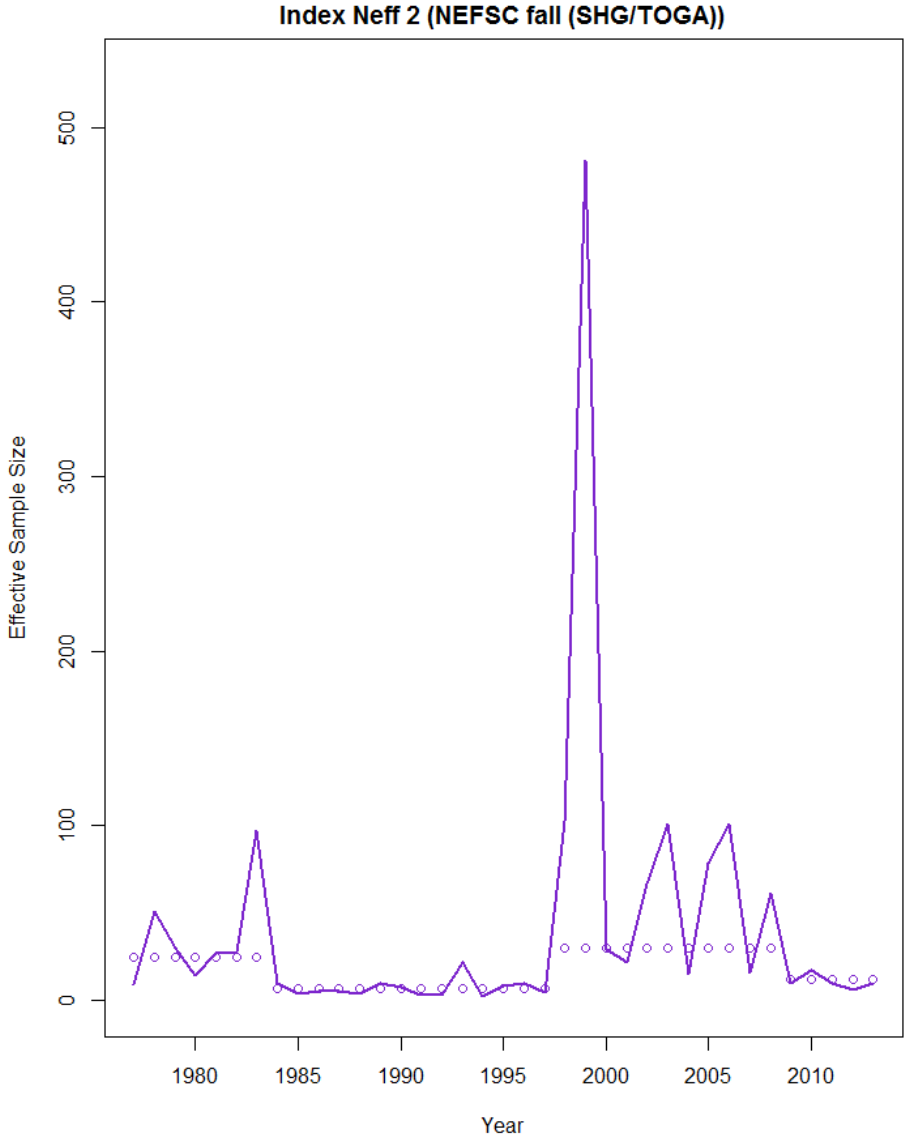

Figure A.181. ASAP_final_temp10 model comparison of input effective sample size versus the model estimated effective sample size for the NEFSC fall survey Gulf of Maine haddock index (Index 2).

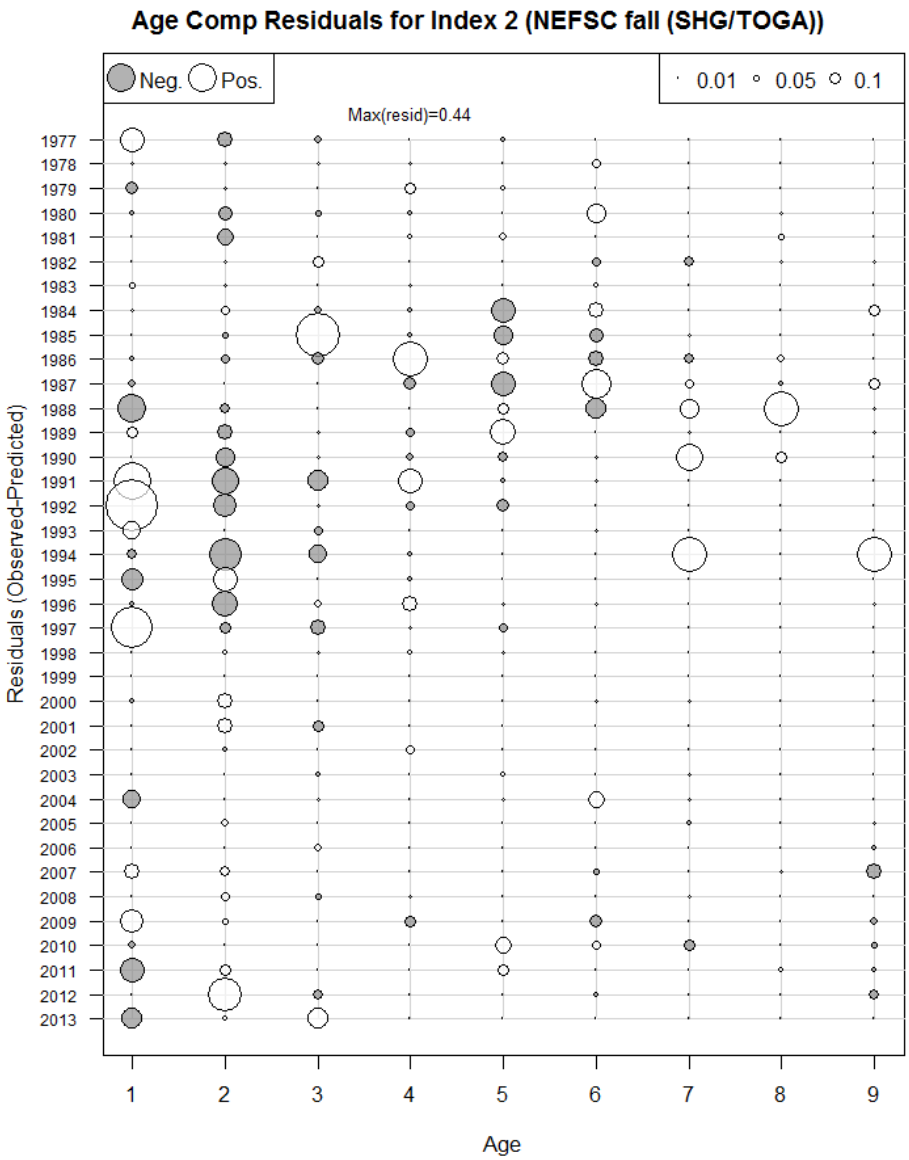

Figure A.182. ASAP_final_temp10 model fit residuals for the NEFSC fall survey Gulf of Maine haddock indices-at-age (Index 2).

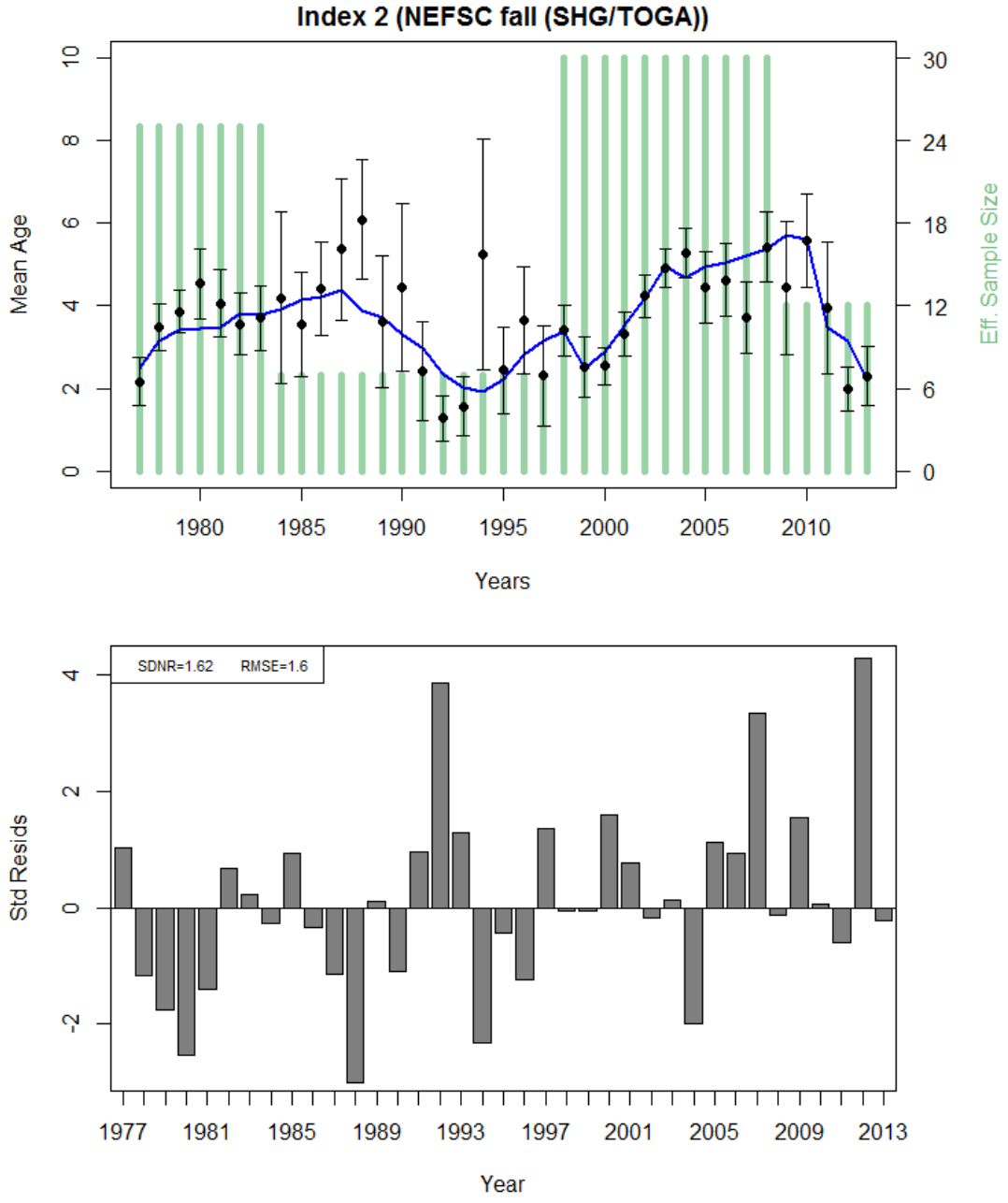

Figure A.183. ASAP_final_temp10 predicted mean age of Gulf of Maine haddock in the NEFSC fall (Index 2) survey (blue line) compared to observed mean age (top plot) and the residuals about the mean (bottom plot).

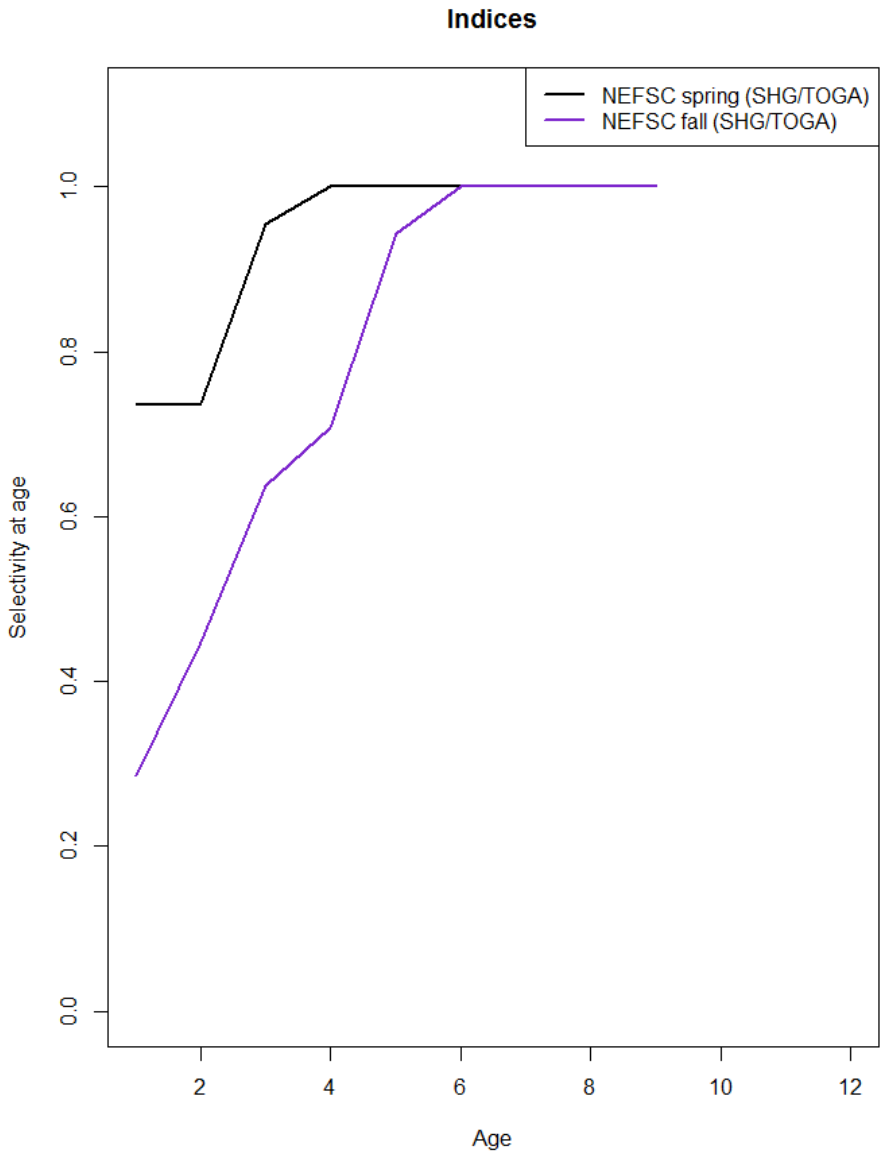

Figure A.184. Gulf of Maine haddock selectivity-at-age for the NEFSC spring (Index 1), and fall (Index 2) from the ASAP_final_temp10 model.

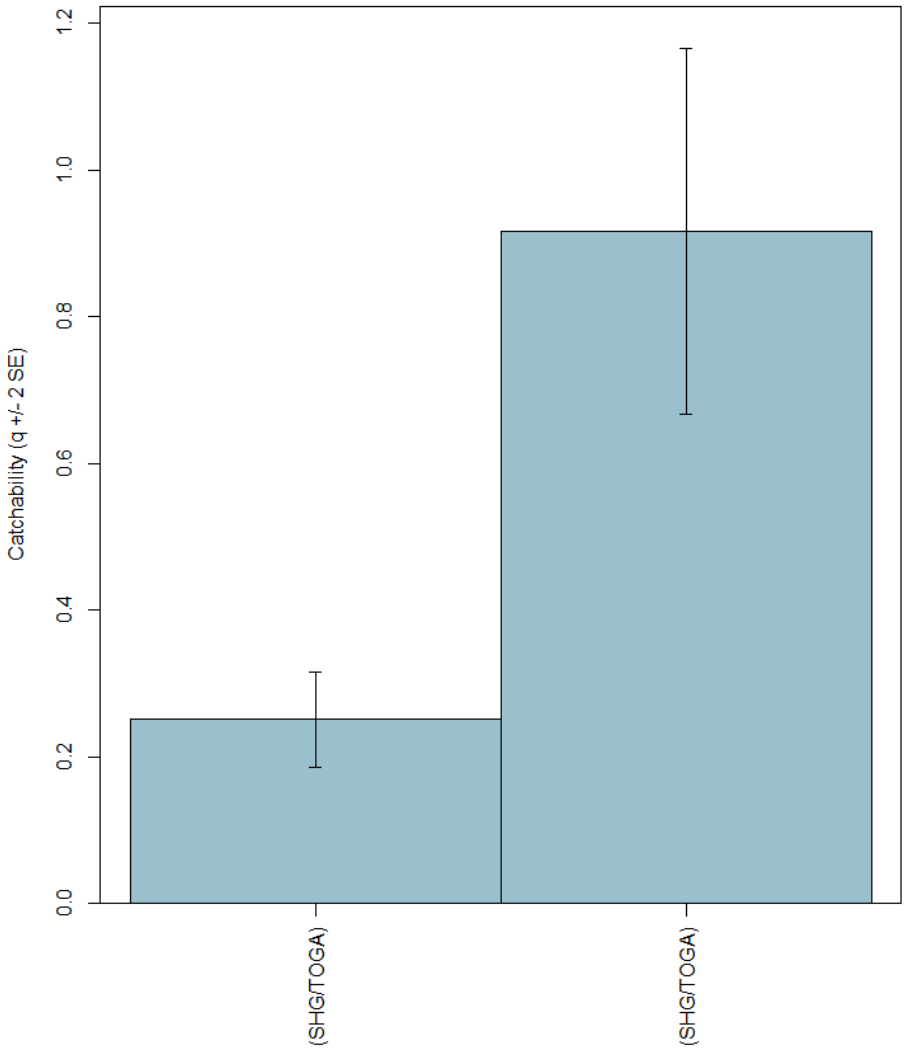

Figure A.185. Gulf of Maine haddock survey catchability, *q*, for the NEFSC spring (Index 1), and fall (Index 2) surveys from the ASAP_final_temp10 model.

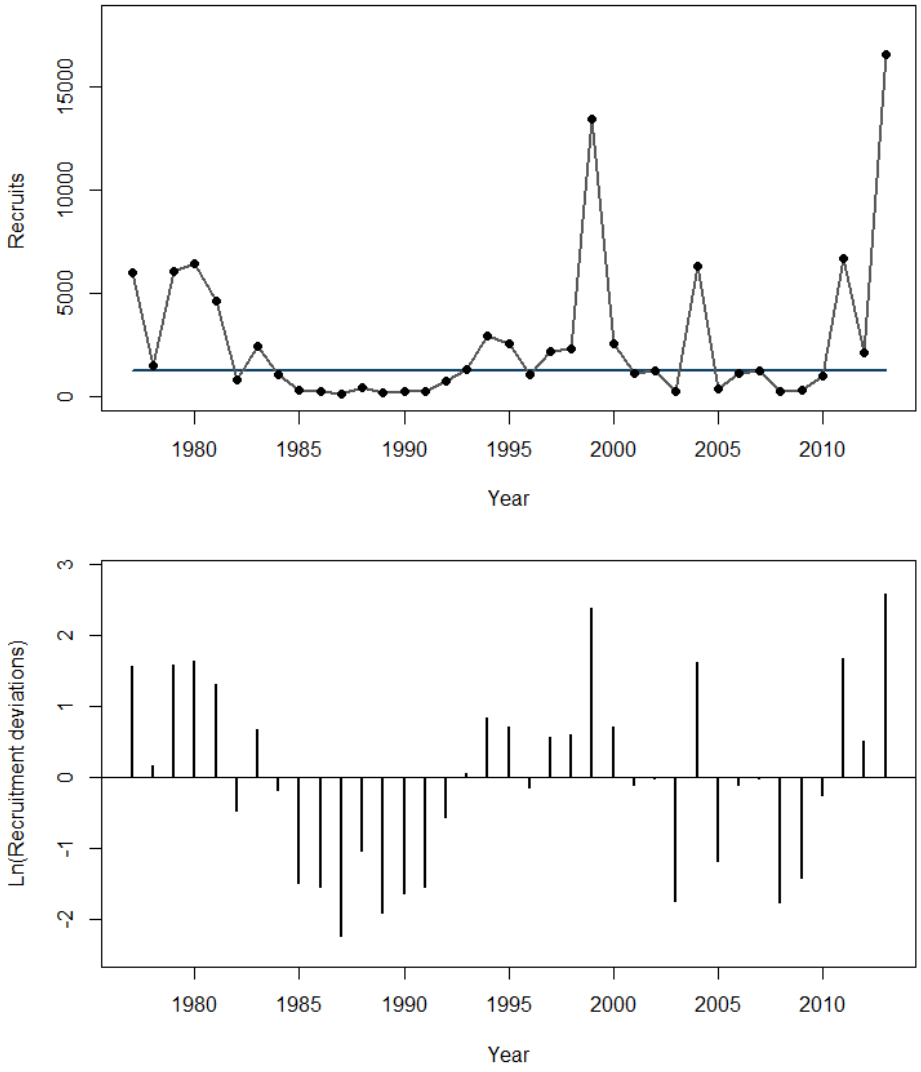

Figure A.186. ASAP_final_temp10 estimated Gulf of Maine haddock age-1 recruitment and recruitment residuals from the geometric mean.

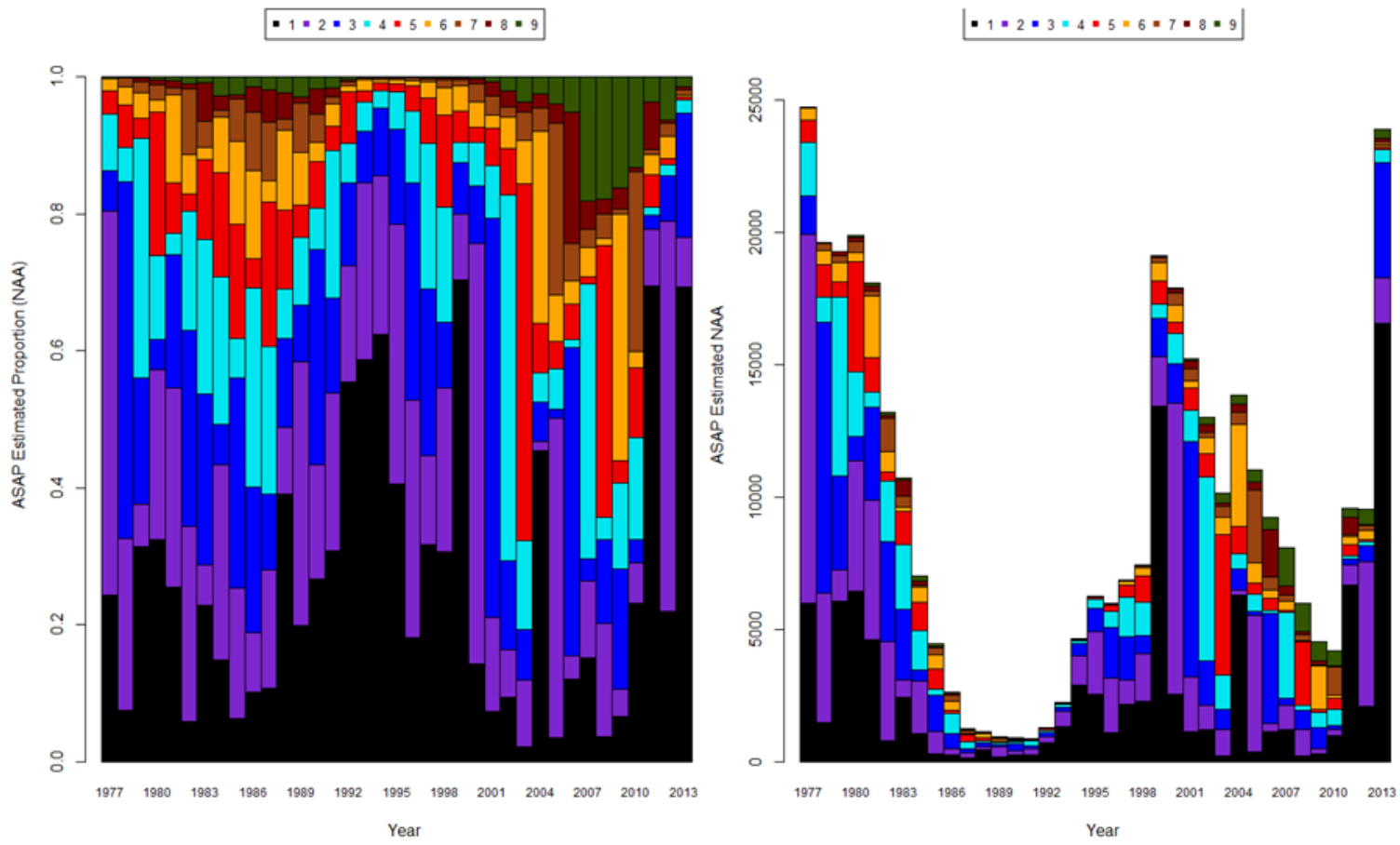

Figure A.187. ASAP_final_temp10 model estimates of Gulf of Maine haddock numbers-at-age in relative (left) terms and absolute (right) numbers (000s).

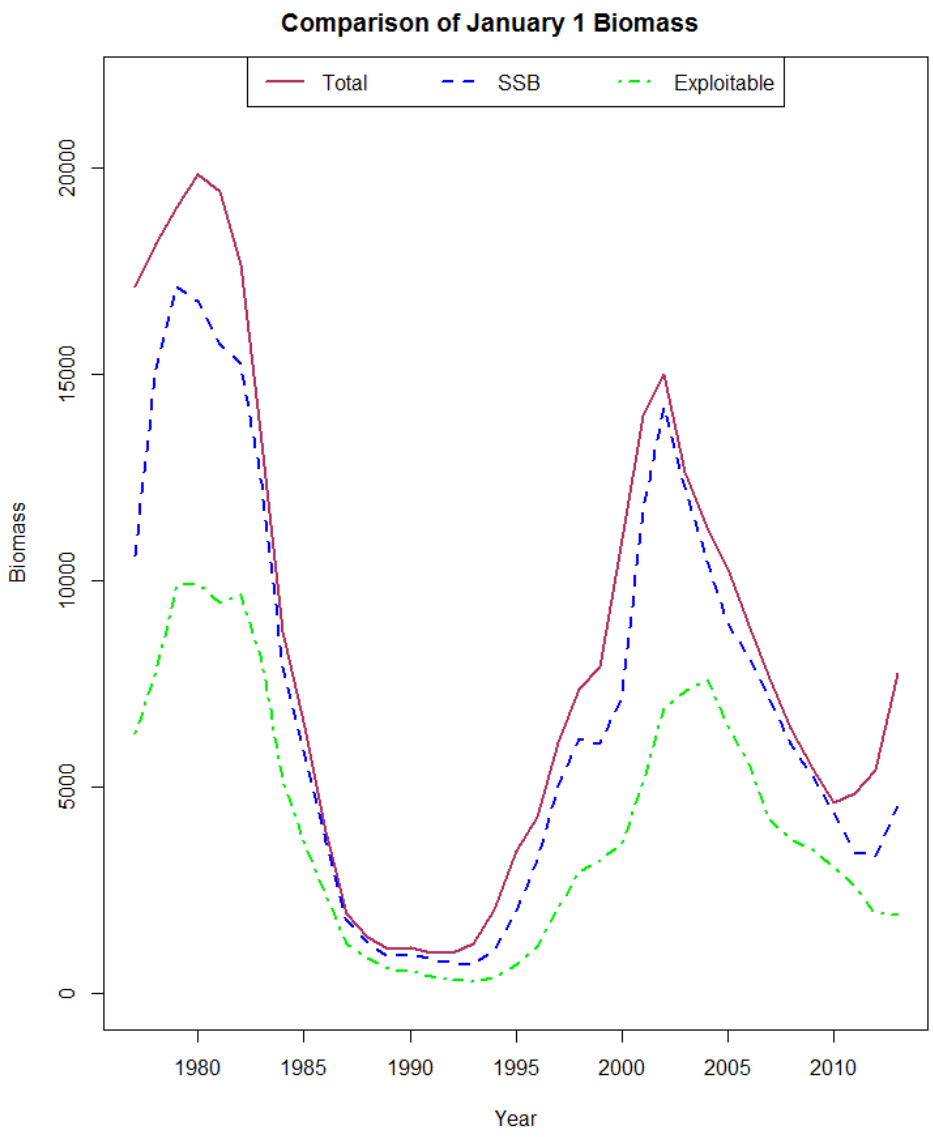

Figure A.188. Comparison of ASAP_final_temp10 model estimates of Gulf of Maine haddock January 1 biomass after application of maturity ogive (SSB) and fleet selectivity ogives (exploitable).

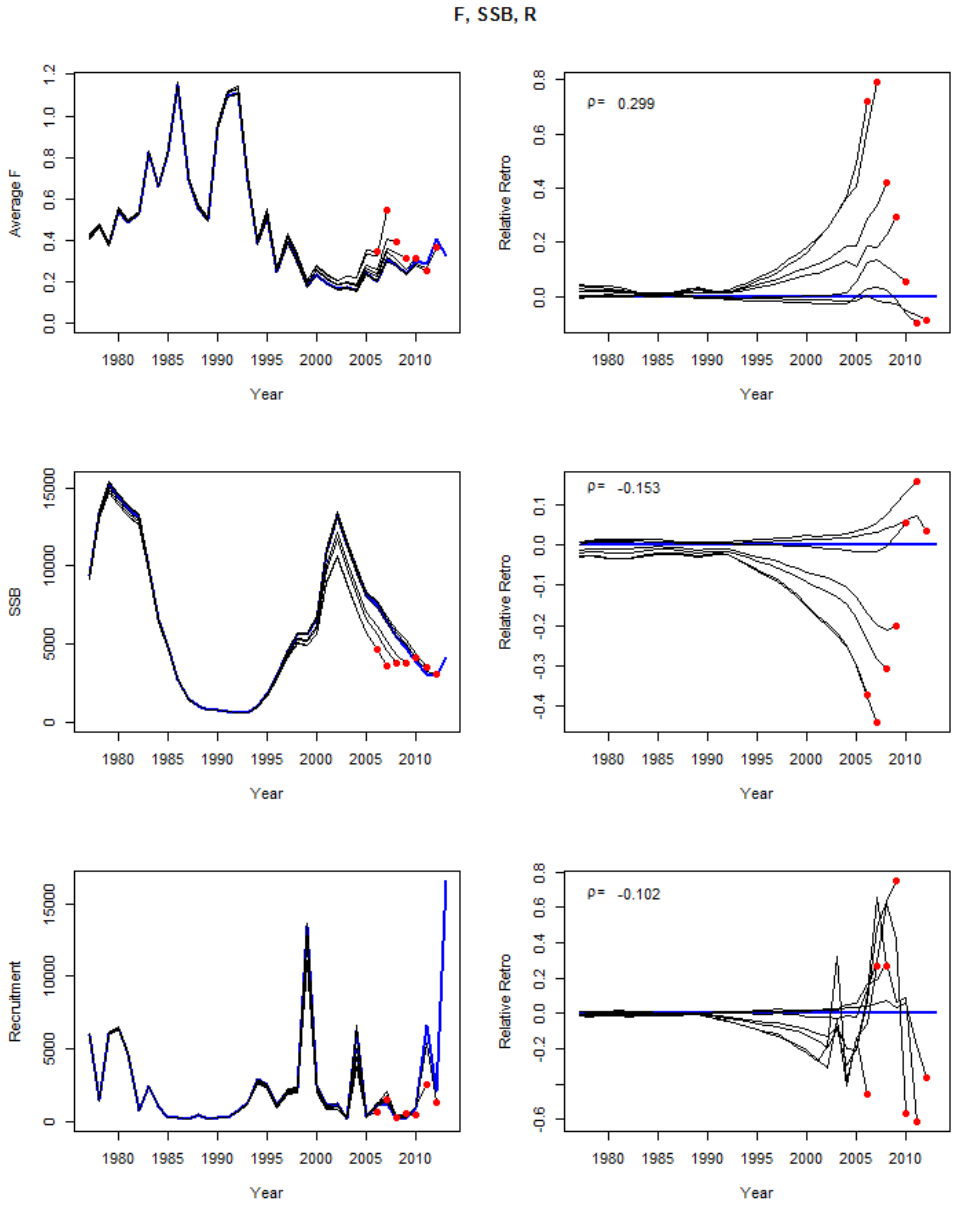

Figure A.189. Model retrospective error patterns for the Gulf of Maine Atlantic haddock ASAP_final_temp10 model. The retrospective error is shown both in absolute (left) and relative (right) terms. The Mohn's rho (ρ) value based on a seven year retrospective peel is indicated in the upper left hand corner of the relative plots.

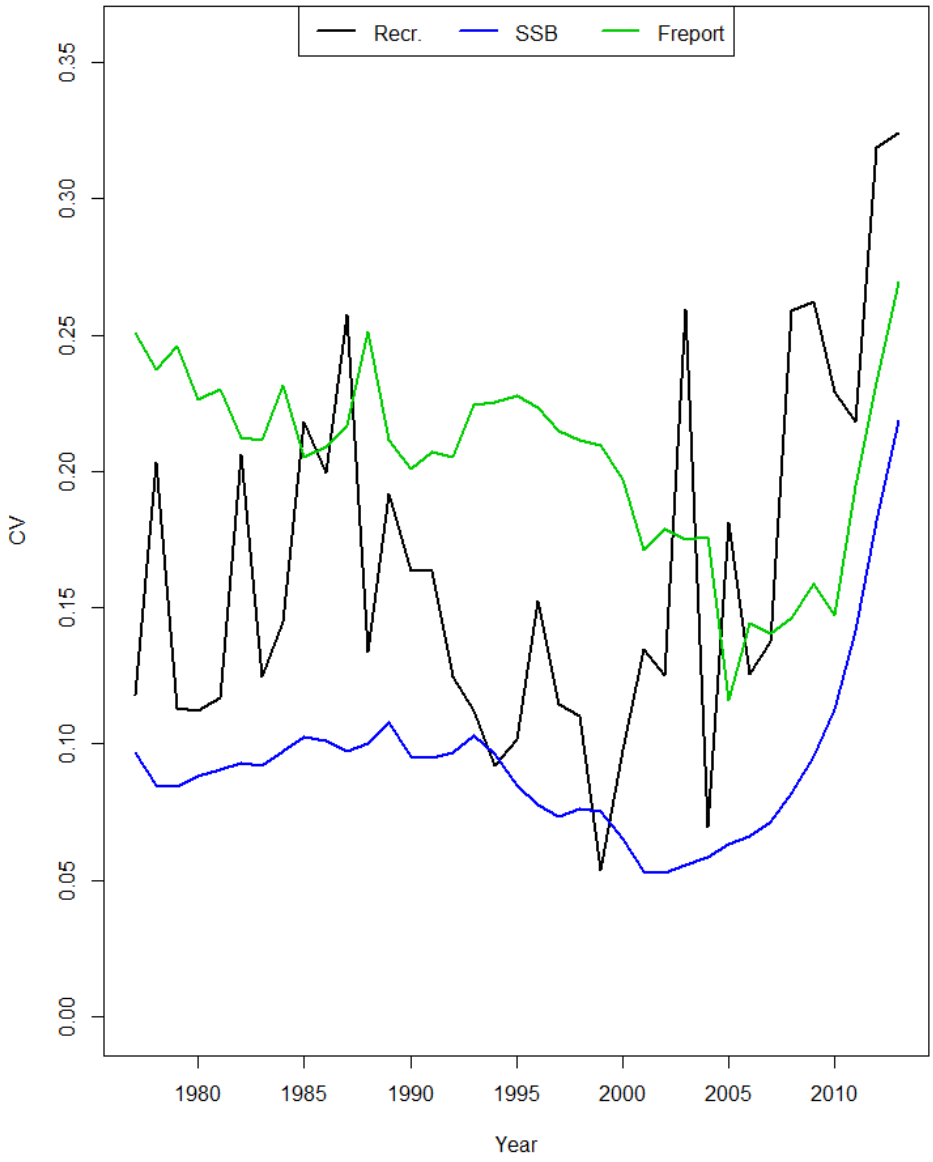

Figure A.190. Hessian-based coefficients of variation (CV) for the ASAP_final_temp10 model estimates of Gulf of Maine haddock spawning stock biomass (SSB), fishing mortality (F_{full}) and age-1 recruitment.

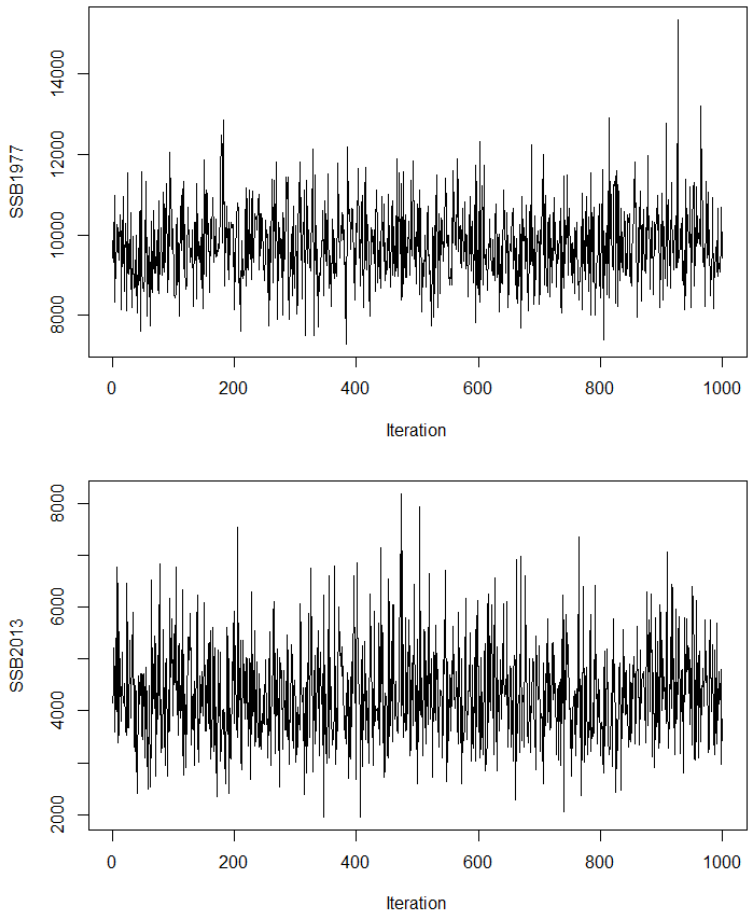

Figure A.191. Trace of MCMC chains for Gulf of Maine haddock 1977 and 2013 spawning stock biomass from the ASAP_final_temp10 model. Each chain had an initial length of 5,000,000 and was thinned at a rate of one out of every 5000th resulting in a final chain length of 1000.

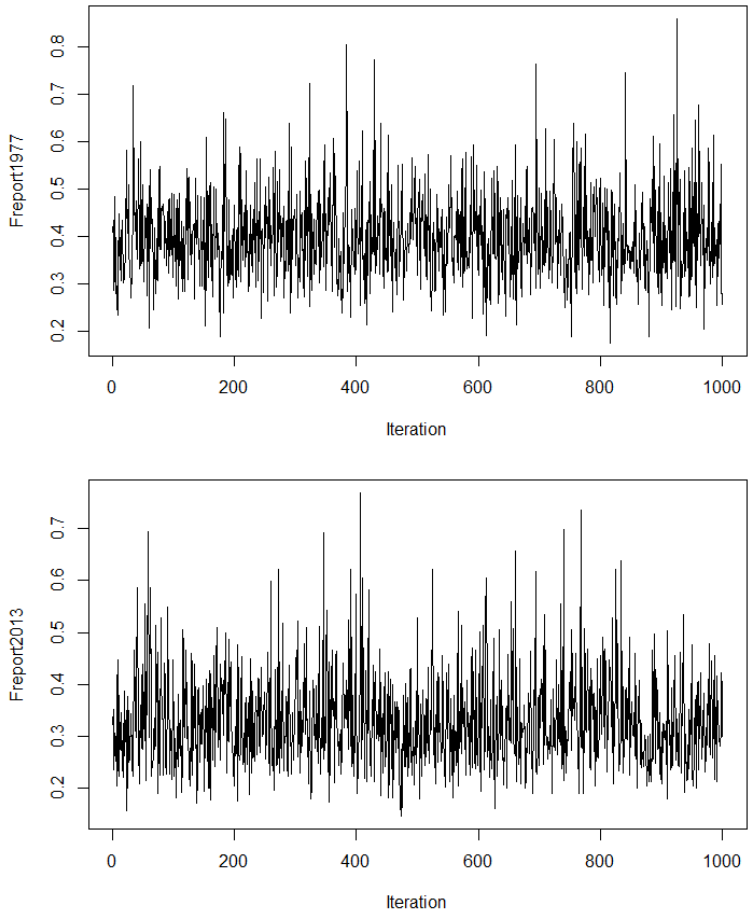

Figure A.192. Trace of MCMC chains for Gulf of Maine haddock 1977 and 2013 fishing mortality from the ASAP_final_temp10 model. Each chain had an initial length of 5,000,000 and was thinned at a rate of one out of every 5000th resulting in a final chain length of 1000.

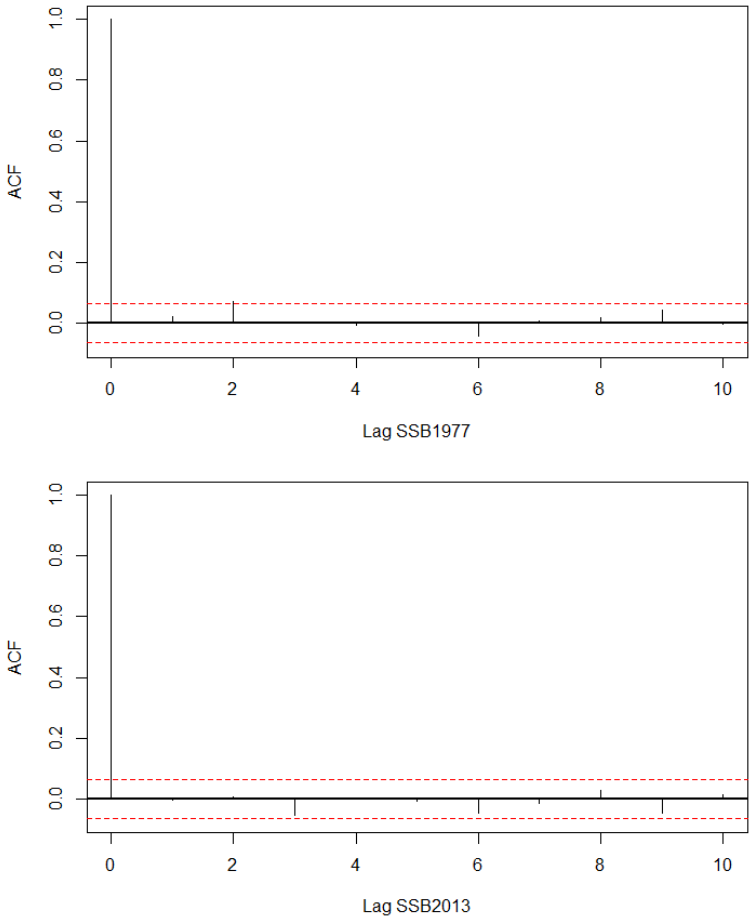

Figure A.193. Autocorrelation within the 1977 and 2013 Gulf of Maine haddock spawning stock biomass (SSB) MCMC chains from the ASAP_final_temp10 model.

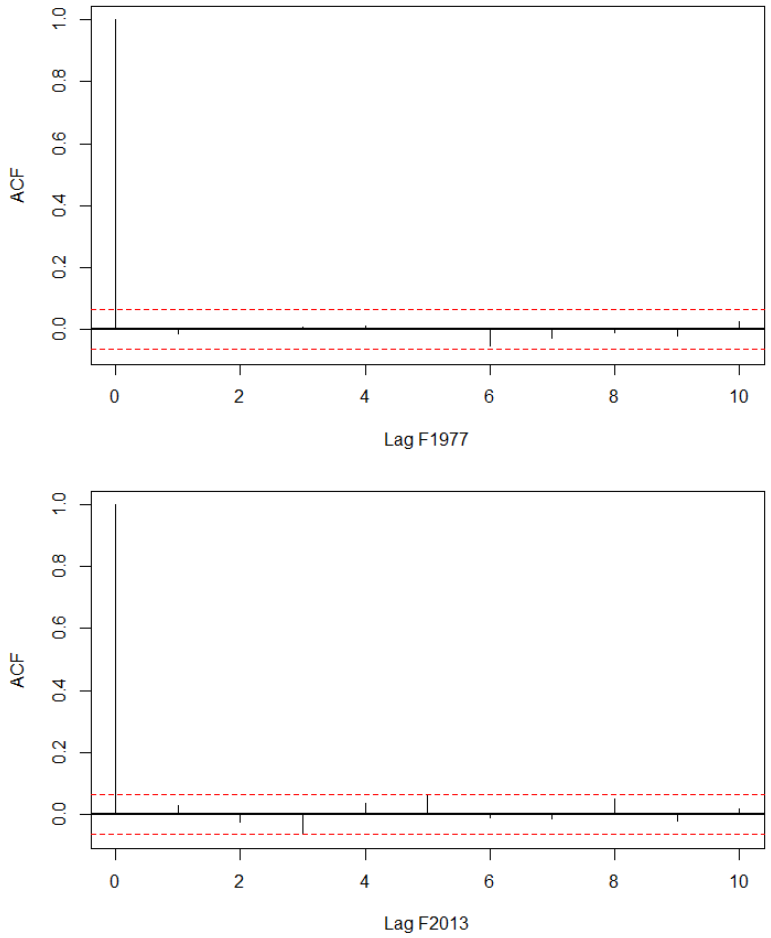

Figure A.194. Autocorrelation within the 1977 and 2013 Gulf of Maine haddock fishing mortality (F) MCMC chains from the ASAP_final_temp10 model.

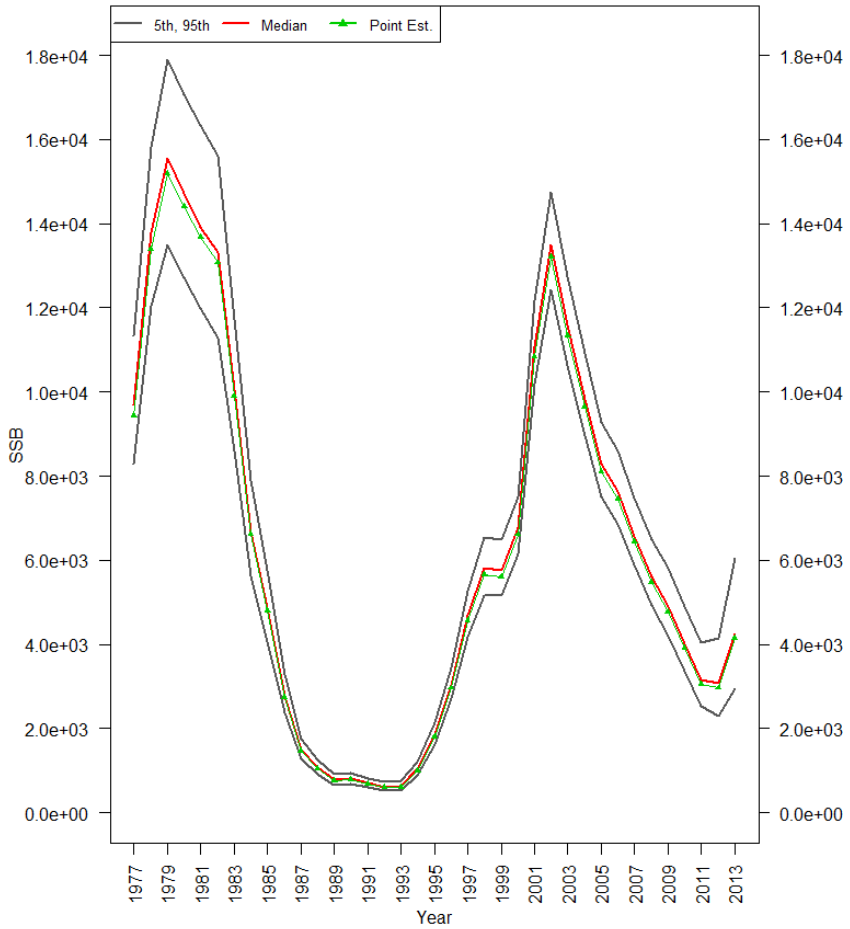

Figure A.195. 90% probability interval for Gulf of Maine haddock spawning stock biomass (SSB) from the ASAP_final_temp10 model. The median value is in red, while the 5th and 95th percentiles are in dark grey. The point estimate from the base model (joint posterior modes) is showin in the thin green line with filled triangles.

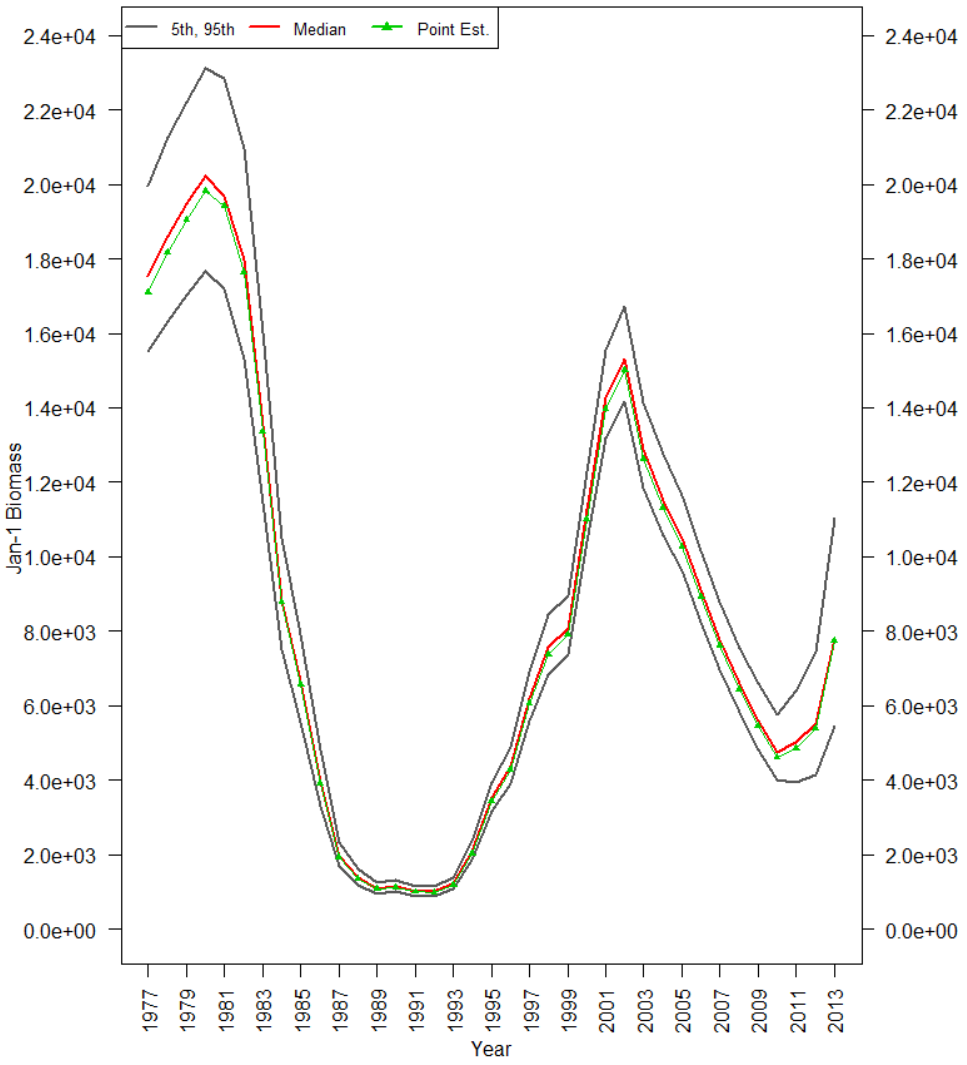

Figure A.196. 90% probability interval for Gulf of Maine haddock January 1 biomass from the ASAP_final_temp10 model. The median value is in red, while the 5th and 95th percentiles are in dark grey. The point estimate from the base model (joint posterior modes) is showin in the thin green line with filled triangles.

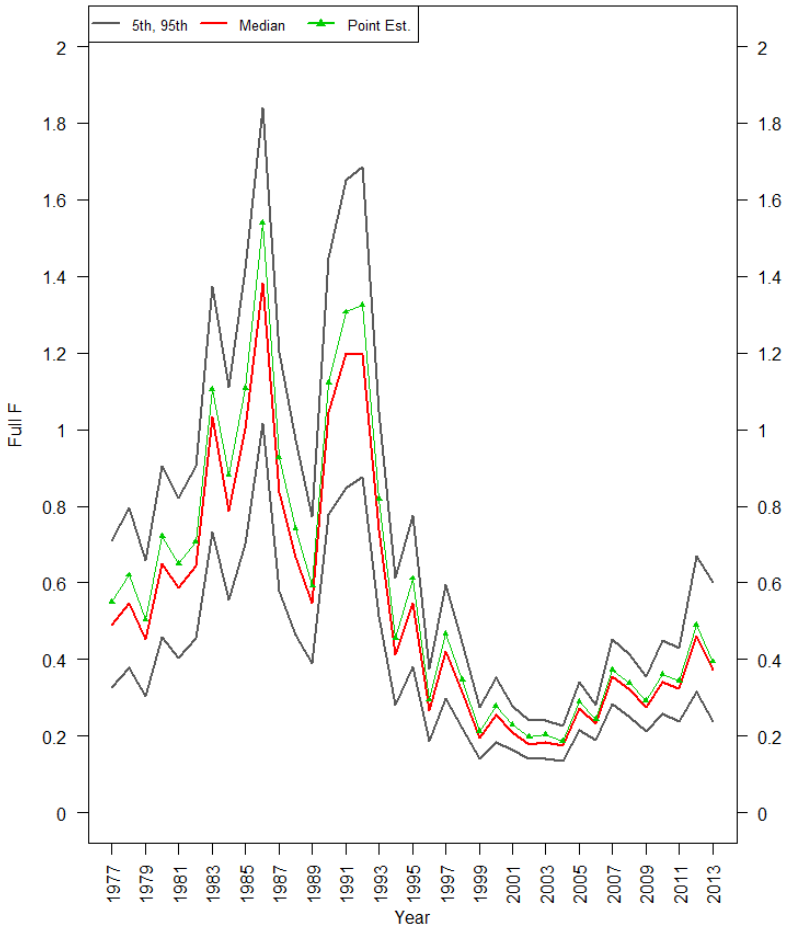

Figure A.197. 90% probability interval for Gulf of Maine haddock fully recruited fishing mortality (Full F or F_{full}) from the ASAP_final_temp10 model. The median value is in red, while the 5th and 95th percentiles are in dark grey. The point estimate from the base model (joint posterior modes) is showin in the thin green line with filled triangles.

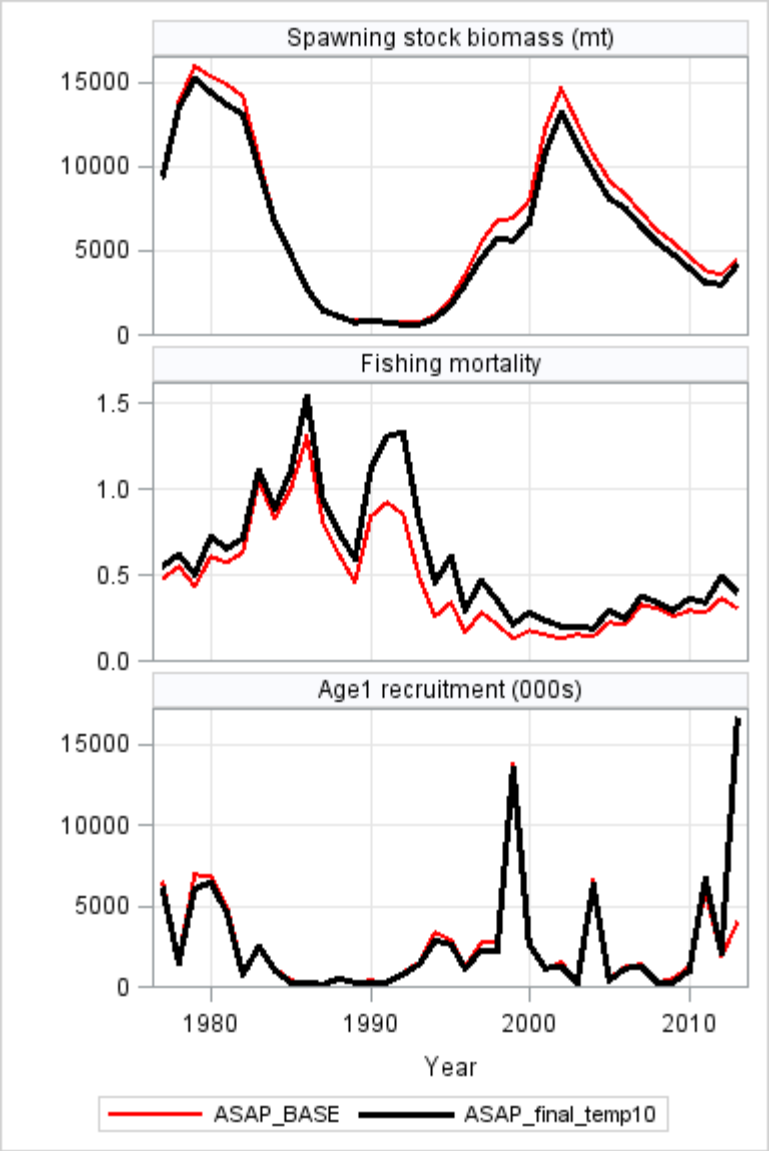

Figure A.198. Comparison of the spawning stock biomass, fully recruited fishing mortality and age-1 recruitment from the ASAP_BASE and ASAP_final_temp10 models.

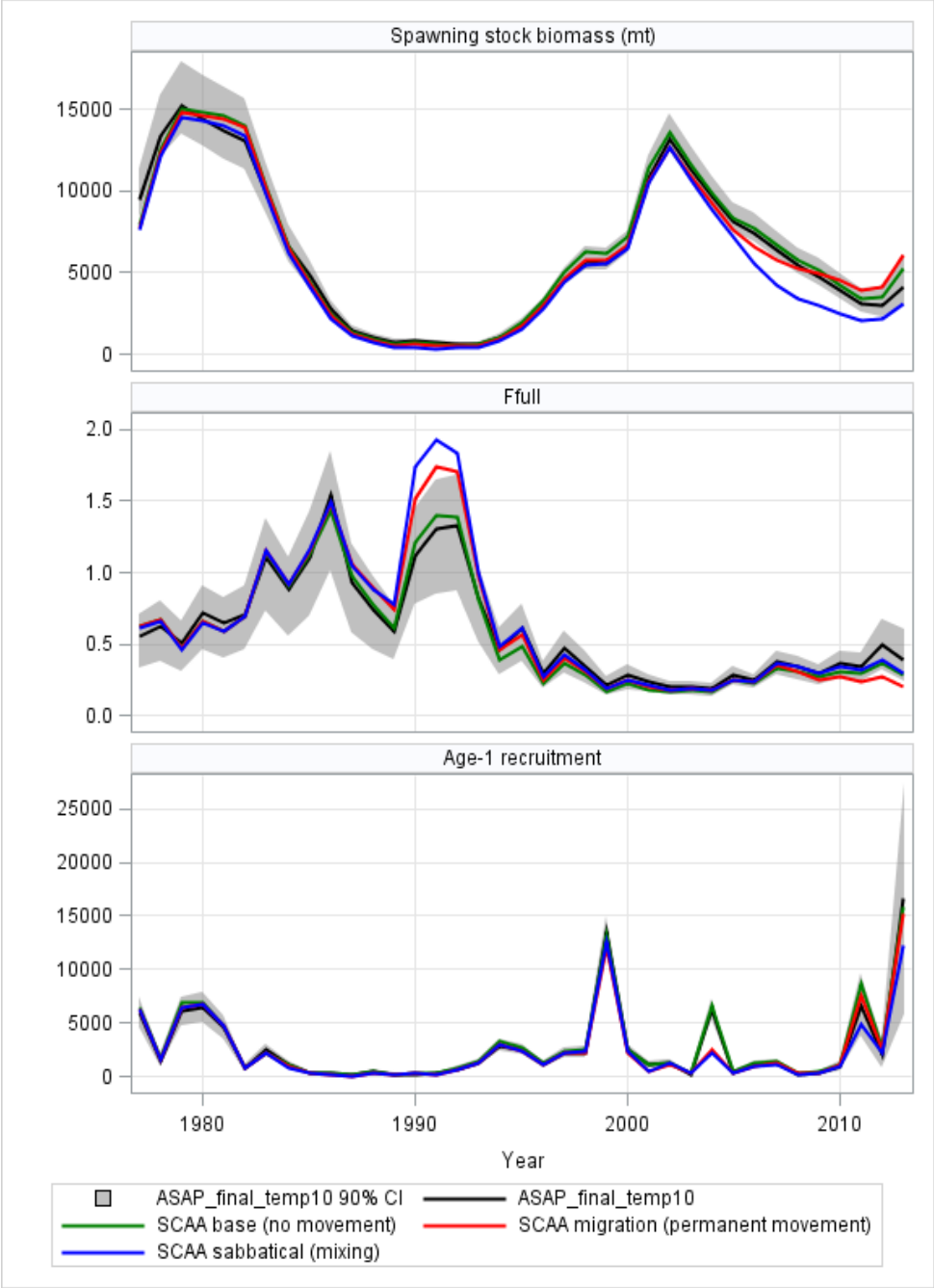

Figure A.199. Comparison of the spawning stock biomass, fully recruited fishing mortality (F_{full}) and age-1 recruitment from the ASAP_final_temp10 model and the SCAA models, two of which incorporate mixing between the Gulf of Maine and Georges Bank stocks. The 90% probability interval from the ASAP_final_temp10 model is indicated by the grey band.

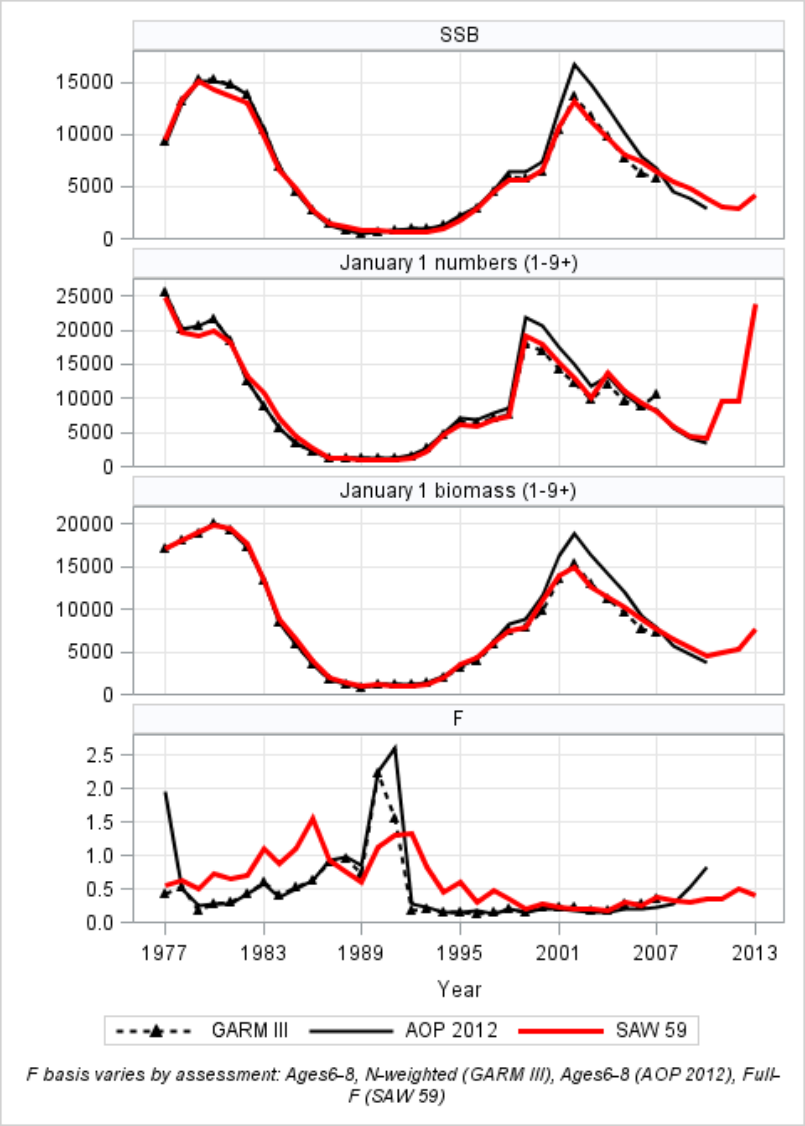

Figure A.200. Comparison of estimates of average spawning stock biomass (SSB), January 1 stock numbers, January 1 stock biomass, and fishing mortality (F) from previous age-based Gulf of Maine haddock stock assessments.**Note that the F basis varies by assessment (see figure footnote).*

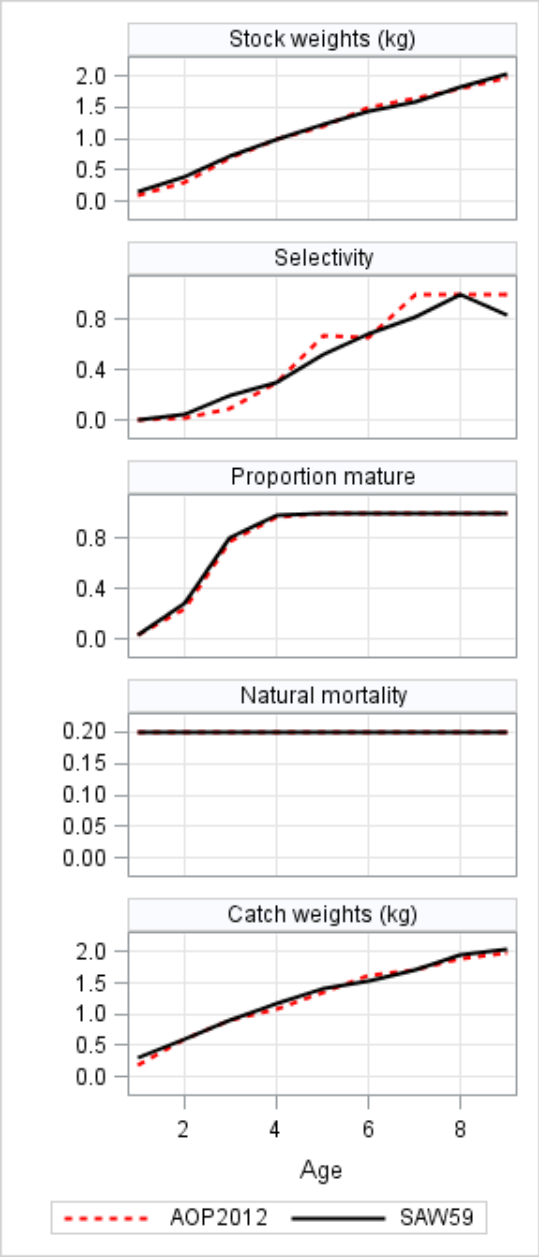

Figure A.201. Comparison of the yield-per-recruit/projection inputs used for the 2012 AOP Gulf of Maine haddock assessment to the current SAW/SARC 59 assessment.

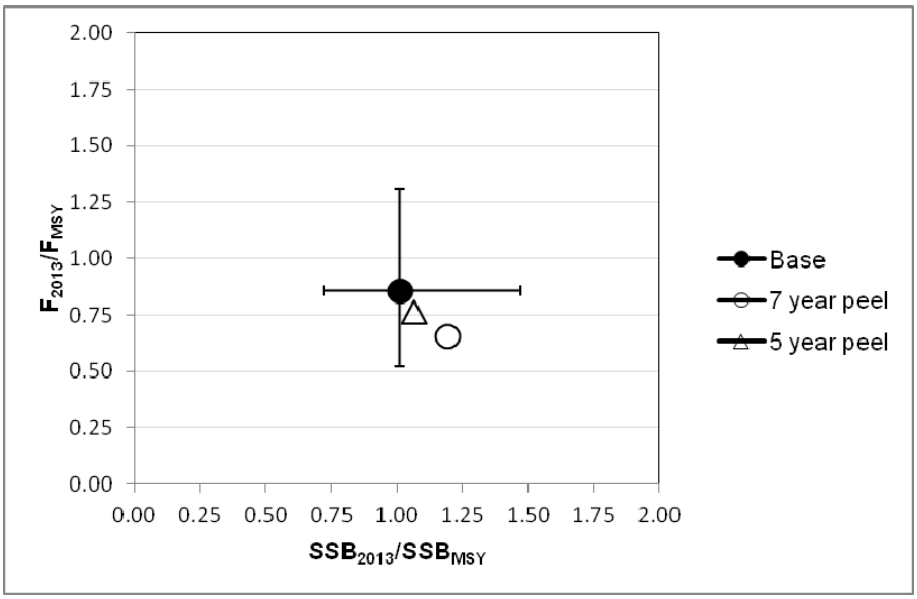

Figure A.202. Comparison of 2013 Gulf of Maine haddock fishing mortality (F_{full}) and spawning stock biomass (SSB) relative to the F_{MSY} ($F_{40\%}$) and SSB_{MSY} proxies both without (solid black circle) and with accounting for retrospective bias based on either a 5-year (open triangle) or 7-year (open circle) retrospective peel. The unadjusted point is shown with the corresponding 90% confidence intervals.

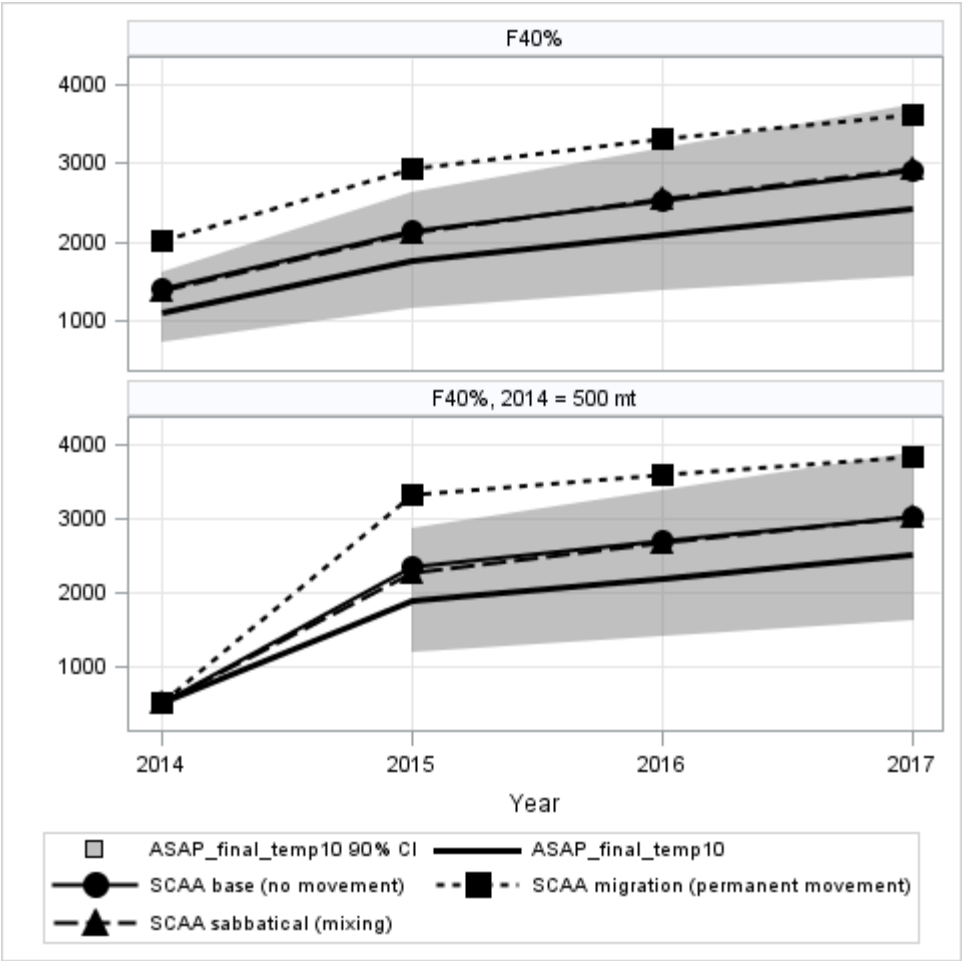

Figure A.203. Short term projections of total fishery yield and spawning stock biomass for Gulf of Maine haddock based on a harvest scenario of a) fishing at $F_{40\%}$ between 2014 and 2017 and b) an assumed catch of 500 mt in 2014 and fishing at $F_{40\%}$ between 2015 and 2017. Projections from the base ASAP model (ASAP_final_temp10) are compared to three alternate runs the from the SCAA model, two of which incorporate mixing between the Gulf of Maine and Georges Bank stocks.