Summary Report of the 59th Northeast Regional Stock Assessment Review Committee (SARC 59)

Stock Assessment Review Committee (SARC) Meeting
15-18 July 2014
Northeast Fisheries Science Center
Wood's Hole, Massachusetts

Prepared by the Stock Assessment Review Committee
Benchmark Assessments for Gulf of Maine Haddock and Atlantic Sea Scallop
(SAW/SARC 59)

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1. Introduction

1.1 Background

The 59th SARC (Stock Assessment Review Committee) met in the Aquarium Conference Room at NOAA's Northeast Fisheries Science Center in Woods Hole, MA during 15-18 July 2014 to review stock assessments for Gulf of Maine haddock and Atlantic sea scallop. The review committee was composed of three scientists appointed by the Center for Independent Experts: Panayiota Apostolaki , Vivian Haist, Dr Coby Needle, and J.-J. Maguire who chaired the review committee as a member of the New England Fisheries Management Council Scientific and Statistical Committee.

The SARC was assisted by the NEFSC Stock Assessment Workshop (SAW) Chairman, Dr. James Weinberg, Ms. Anne O'Brian, and Dr. Paul Rago. Supporting documentation for the Gulf of Maine haddock assessment was prepared by the Gulf of Maine Haddock SAW 59 Working Group, and presentations at the meeting on Gulf of Maine haddock were made by Dr. Mark Terceiro (NEFSC). Materials for the Atlantic sea scallop assessment were prepared by the Invertebrate Working Group and presentations were made by Dr. Dvora Hart. Jon Deroba, Chuck Adams, Toni Chute, Brian Linton, Alicia Miller, Toni Wood and Burton Shank, all from the NEFSC acted as rapporteurs. A total of 26 people participated in the SARC 59 meeting.

1.2 Review of Activities and SARC Process

Before the meeting, assessment documents and supporting materials were made available to the SARC Panel via a server on the NEFSC website. On the morning of July 15, 2014, before the meeting, the SARC panel met with Drs. Weinberg and Rago to review and discuss the meeting agenda, reporting requirements, and meeting logistics. During the SARC meeting, background and working documents were available electronically and in print. The meeting opened on the morning of Tuesday July 15, with welcoming remarks and comments on the agenda by Dr Weinberg and J.-J. Maguire. Participants and audience members introduced themselves. Following introductions, sessions on July 15 were devoted to presentation and discussion of the Gulf of Maine haddock assessment. The Atlantic sea scallop assessment and discussion sessions were conducted on the morning and afternoon of July 16, followed by continued discussion of the Gulf of Maine haddock assessment in the late afternoon.

Follow-up discussion on the Atlantic sea scallop assessment took place on the morning of 17 July. The morning (Gulf of Maine haddock) and afternoon (Atlantic sea scallop) of July 17 were devoted to drafting the Assessment Summary Reports and hearing results of the follow-up Atlantic sea scallop analyses. The SARC Panel spent the final day, July 18, deliberating on whether the SAW WGs had addressed Terms of Reference (ToR) in each of the assessments and drafting elements of this Panel Summary Report.

The SARC Panel and SAW WGs worked collectively during the meeting to reach agreement and consensus on the two assessments. The meeting was collegial.

The Assessment Summary Report for Gulf of Maine haddock and Atlantic sea scallop, with contributions by the NEFSC staff and the SARC Panel, were agreed during the session on Thursday July 17, 2014. The SARC Panel completed drafting this Summary Report by correspondence, evaluating each ToR that had been addressed by the SAW WGs. The SARC Chair compiled and edited the draft Summary Report, which was distributed to the Panel for final review before being submitted to the NEFSC. Additionally, each of the CIE Panelists drafted and submitted an independent reviewer's report to the Center for Independent Experts.

Mike Palmer while theoretically on leave contributed remotely. Chris Legault was very helpful with the drafting of the Assessment Summaries for both species.

The SARC Panel agreed that each of the assessments (Gulf of Maine haddock and Atlantic sea scallop) was effective in delineating stock status, determining biological reference points (*BRP*s) and proxies, and in projecting probable short-term trends in stock biomass, fishing mortality, and catches. Issues and concerns related to each of the stock assessments are discussed below. The SARC process was effective in structuring a critical review of the work of the SAW WGs and in identifying areas of concern and needs for additional work in future assessments.

2. Review of Gulf of Maine Haddock

2.1 Synopsis of Panel Review

The SARC Panel agreed with the SAW 59 WG's conclusion that the Gulf of Maine haddock stock was not overfished and that overfishing was not occurring in 2013.

Given the increased importance of recreational catch (and discards), it would be important to have empirical estimates of the survival of discards in the recreational fishery.

Considerable effort was spent on estimation of LPUE for commercial and recreational fisheries. During this work, it became clear that continued changes in fishing practices, gear and location, along with the possibility of hyper-aggregation, mean that LPUE for GoM haddock is not a reliable indicator of stock status or dynamics. The review panel considers that future methodological work in this area should be carried out generically, rather than on a species-by-species basis, and that LPUE estimation for GoM haddock in particular need not be reconsidered for a number of years.

This was the first GoM haddock assessment to use the ASAP model, and many runs were conducted to investigate alternative approaches and assumptions to find a suitable base case. The basis for selecting a final model appears appropriate. The ASAP assessment assumed a constant natural mortality rate of 0.2, consistent with previous GoM assessments. Using the final model run proposed as the basis for the assessment (ASAP_final_temp10) and profiling on M, one of the SARC 59 Panel members found that fit improved as M decreased. This should be investigated further in future assessments.

The SARC 59 Panel felt the stock assessment working group (SAW) had done a thorough job in exploring uncertainty in the assessment results, and the final selected base model provides an appropriate basis for informing management decisions.

The Gulf of Maine haddock stock was not overfished and overfishing was not occurring in 2013. Spawning stock biomass (SSB) in 2013 is estimated to be 4,153 mt which is 101% of the SSBMSY proxy (4,108 mt). The 2013 fully selected fishing mortality is estimated to be 0.39 which is below the FMSY proxy (0.46).

2.2 Evaluation of Terms of Reference for Gulf of Maine Haddock

A. Gulf of Maine 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.

This ToR was met.

GoM haddock catch data consist of four components: commercial landings, commercial discards, recreational landings and recreational discards. A great deal of work was presented at SARC 59 on the estimation of commercial discards, although these are a small component of the overall catch. While this was also true historically of recreational landings and discards, the recreational catch, including discards, is now a very significant part of the overall removals.

Recreational discards were included in the assessment for the first time at SARC 59, based on surveys conducted by the National Marine Fisheries Service. However, recreational discard mortality remains unknown, and there are no studies planned to address this uncertainty. Two sets of results were presented assuming recreational discard mortality of 50% or 100%, with 50% mortality being chosen for the final run, but this choice is essentially *ad hoc* and provides a key source of uncertainty in the assessment. In the future, it will be important to collect empirical data and estimate post-release survival from the recreational fishery.

The only full time-series of catch data exists for commercial landings. For the other three components, there are varying amounts of imputation and inference used to generate time-series estimates of equal length. It may be more appropriate in future to run the assessment only for those years for which real data exist (from around 1989 onwards). The pattern of historical stock development means that there is no real benefit to extending the time series further back than this, and an assessment based only on observed data is likely to be more justifiable.

Age data are only collected for the commercial landings component of the catch, and for the surveys. The age compositions of the remaining catch components are inferred by the application of a combination of the survey and commercial age-length keys (ALKs) to length measurements. There is a potential for this to cause bias in age compositions, particularly for the recreational fishery for which the gear used and areas fished are considerably different to the commercial fishery. It may be that the ALKs are similar between components, but it would be inappropriate to assume this on the basis of limited evidence, and the review panel recommends that a trial programme of age-reading from the recreational fishery be carried out to determine if the recreational ALKs are different or not. Length or survey based assessment methods should also be considered (at least comparatively).

The draft report did not contain sufficient information on the methodology of the recreational landings and discards sampling programme. This was addressed during the SARC 59 meeting to the satisfaction of the review panel and additional text was inserted in the final report.

Weights-at-age in the catch data show considerable reductions over time for older fish, with sharp declines followed by more stability in the most recent 5 years. No hypothesis was proposed to explain this, and it does not seem to be related to commensurate changes in maturity (as is the case for many gadoids in European waters). The review panel queried whether there may be spatial differences in weights-at-age that might cause changes in the whole-stock weights-at-age through spatially heterogeneous exploitation and sampling, and recommends that this possibility be considered in future work.

The spatial distribution of catches was illustrated through maps, time-series plots of the centres of distribution of catches, and Gini indices (which measure the concentration of catch locations). There was less spatial information provided about fishing effort, and it may be that VTR-derived fishing locations are not very reliable due to the inconsistent way in which they are recorded. More use could be made of VMS data for this purpose, given that nearly 100% of the relevant commercial vessels are fitted with these systems since 2006. Uncertainty in catch data was expressed through estimated CVs.

Following a review panel request, a table was produced giving the ratio of SARC 59 catch estimates to the previous catch estimates. As expected, there were relatively large differences at ages 1 and 2, but as the catches are small at these ages the changes do not make a large difference to the assessment results.

Considerable effort was spent on estimation of LPUE for commercial and recreational fisheries. During this work, it became clear that changes in fishing practices, gear and location, along with the possibility of hyper-aggregation, mean that LPUE for GoM haddock is not a reliable indicator of stock status or dynamics. The review panel considers that future methodological work in this area should be carried out generically, rather than on a species-by-species basis, and that LPUE estimation for GoM haddock in particular need not be reconsidered for a number of years.

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.

This ToR was met. Attempts were made to estimate exploitation rates from tagging data under TOR 3.
The NEFSC spring and fall surveys are both considered to be consistent and independent surveys in the assessment. However, for both there have been significant changes over time in vessel, net and door characteristics, and the use of conversion factors to try and ensure consistency may not be appropriate. Given that there are now five years of data from the *Bigelow* series, it would be possible to treat that as a separate index. This was tried as an alternative assessment run, making no significant difference to the outcome. However, this would not address the changes in the net and trawl doors, and an alternative approach would be to develop priors on net, door and vessel effects for the model estimation.
The MADMF and MENH series are principally inshore surveys that do not cover the full extent of the GoM haddock stock, and do not track cohorts well through time. Attempts to use the age 1 and 2 data from them as indices of recruitment were reported in Appendix 2 showing poor diagnostics and little impact on results.
The report hypothesized a westerly concentration of the stock over time, as evidenced by survey distribution maps (Figure A.101). The review panel did not find this conclusion convincing, as the plot for 1970-1979 looked very similar to the plot for 2000-2013, and the Gini index (Figure A.102) did not support the hypothesis either. While the stock seemed to have been more concentrated in the western part of the area, this does not seem be the case for the most recent decade or so.

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.

This ToR was partially met.

Much of the evidence provided in the assessment report for this ToR was rather circumstantial, and the review panel concluded that it would not be possible to determine a mixing rate on the basis of the evidence provided. If concerns about mixing rates and stock structure remain, biological analyses such as directed tagging studies, egg dispersal modeling, genetic differentiation determination or otolith microchemistry analysis would be needed to determine the degree of mixing, and hence stock identity.

In terms of management, the conclusion of low mixing between separate stocks is probably appropriate. In terms of scientific evaluation of mixing or stock structure, the review panel concluded that more work would be required to reach firm conclusions.

The tagging studies presented investigated whether haddock from within closed areas were likely to move outside such areas. Around 20,000 tags were applied, and only around 500 returned. This could indicate a very high tagging mortality, and the way in which haddock tagging is carried out in future will need to be carefully considered.

Potential causal factors such as density dependence or environmental conditions were not considered in detail.

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.

This ToR was met.

A statistical catch-age model (ASAP) was used to reconstruct the GoM haddock stock and estimate recruitment, stock biomass and fishing mortality rates. The previous benchmark assessment had used a VPA catch-age model which was updated to provide a bridge to the new approach. For the ASAP assessment, a single fleet representing commercial and recreational catch and discards was modeled. The model was fitted to the NEFSC spring and fall bottom trawl survey data. An alternative statistical catch-age model (SCAA) was used to explore assumptions about movement between the GoM and GB haddock stocks.

This was the first GoM haddock assessment to use the ASAP model, and many runs were conducted to investigate alternative approaches and assumptions to find a suitable base case. The primary model components explored to develop the base case were data weighting, including weighting of at-age data and total catch, and constraints on recruitment deviations to restrict the magnitude of apparently strong recent year-classes. The basis for selecting a final model appears appropriate. The single "fleet" fishery age composition data consists of both commercial and recreational fishery discards and landings, and there have been many changes in fisheries regulations that would affect the selectivity of the fisheries, whereas the trawl surveys should have relatively stable selectivity (other than the recent change to the RV *Bigelow*). However, the weighting approach used (iterative re-weighting for effective sample size) should ensure consistency in the weights with the ability of the model to fit the various data sources so there is no reason to believe the final weightings are inappropriate.

The ASAP assessment assumed a constant natural mortality rate of 0.2, consistent with previous GoM assessments. This value was justified based on the maximum observed age in catch and survey data, and equations that use the maximum age (i.e. Hoenig, 1983; Hewitt and Hoenig, 2005). Those equations, however, provide estimates of total mortality (Z), not natural mortality (M).

A likelihood profile on M, conducted with the original ASAP Base run (ASAP_BASE), indicated an improvement in fit of 6 negative log-likelihood units when M was fixed at 0.1 rather than 0.2. Runs with lower M were not explored further in the assessment, although a decrease of 2 negative log-likelihood units or greater is considered significant with either a likelihood ratio test or the AIC criterion. Using the final model run proposed as the basis for the assessment (ASAP_final_temp10) and profiling on M, one of the SARC 59 Panel members found a decrease of 18 negative log-likelihood units when M was changed from 0.2 to 0.1, and a preference for even lower values of M. When a particularly large at-age residual was removed from the data (plus group for the 1994 fall trawl survey) the model fit improved by 30 negative log-likelihood units with an *M* of 0.1 rather than 0.2.

The model clearly shows a preference for lower *M*, and it appears that the trawl survey data provide the basis for this preference (rather than aliasing for some other model mis-specification). Survey-based estimates of year- and age-specific *Z* for ages assumed to be fully selected indicate fairly low rates (<0.25) of total mortality in recent years. While the SARC 59 felt that there was reasonable support for a lower *M*, they did not think it would be possible to explore this fully in the time available. *M* is likely age-dependent and potentially variable over time, and estimation of *M* will be confounded with survey selectivity assumptions. The Panel recommends that future GoM haddock assessments evaluate alternative assumptions about *M*. In particular, the George Bank multi-species VPA may be informative about age and time-varying *M*.

As indicated above, in the final ASAP model selected for the assessment, a single fleet representing commercial and recreational catch and discards was modeled. One of the sensitivity runs had separated the commercial and recreational fleets. While the overall results were very similar, this run indicated different age-selectivity for the two fleets. The SARC 59 panel suggests that having separate fleets in the ASAP assessment for the commercial and recreational data would be a better approach for future GoM haddock assessments.

Uncertainty in the stock assessment was explored through sensitivity runs and by estimating the marginal posterior distributions of key parameters using Markov-chain Monte-Carlo simulation (McMC). The range of sensitivity runs explored was extensive and included: alternative methods for calculating survey indices; inclusion/exclusion of survey indices including the state surveys; treating the RV Bigelow trawl time series as separate indices; inclusion of LPUE indices; alternative recreational discard mortality assumptions; alternative starting years; explicit treatment of catch fleets; and different terminal recruitment assumptions. Overall, model results were relatively insensitive to the alternative model configurations indicating that conclusions about stock status are robust to these uncertainties. The SARC 59 Panel felt the stock assessment working group (SAW) had done a thorough job in exploring uncertainty in the assessment results, and the final selected base model provides an appropriate basis for informing management decisions. The SAW proposed that an alternative model formulation, which penalizes the magnitude of recent year-classes, also be used for projections to demonstrate the effect if these year-classes are overestimated in the base model. Given the magnitude of recent recruitment is the largest source of uncertainty in the assessment this is a reasonable approach to bracket this uncertainty.

An investigation of the potential impact of “spillover” of Georges Bank (GB) haddock to the GoM stock was explored using the SCAA model. This model was first fitted to the same data as the ASAP model, and when run with similar assumptions to the ASAP base model gave similar results. The SCAA model was then used to explore alternative hypotheses of movement between GB and GoM, including both permanent and temporary movement assumptions. The runs assumed that movement from GB to GoM occurs at a constant rate when GB biomass is above a fixed critical level, with all ages 2 and older (sensitivities for ages 1++ and 3++) moving at that rate. Results supported movement from GB to GoM, but at low rates (<0.8%). The stock reconstructions with the movement hypotheses were similar to those for the isolated stock hypothesis. The SARC 59 Panel felt this was an interesting and useful approach for investigating the potential effect of "spillover" of haddock from GB to GoM, though they felt that results were not definitive. That is, only a single movement parameter was estimated (appropriately, given the limited data to support movement estimates), and if there is movement from GB to GoM the process is likely much more complex than that modeled.

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.

This ToR was met.

The existing stock status definitions and biological reference points were estimated in the last assessment which used a VPA model. Overfishing was occurring if fishing mortality was above F_{MSY} = F40% = 0.46, the stock was considered overfished if SSB was less than 2452mt, i.e. less than half SSB_{MSY} = 4,904 mt.

The reference points were updated with the new stock assessment results. Stochastic projections at F40% were used to determine new recommended biomass-related reference points (proxies for both SSB_{MSY} and MSY). The projection methodology used to determine SSB_{MSY} and MSY proxies was identical to those used for short-term projections. Under the updated reference points, the overfishing definition remains the same (F>0.46), but the overfished threshold is lower at 2054 mt.

The review panel was not convinced that the use of a proxy for F_{MSY} was appropriate and asked for more details on why an analytic estimate of F_{MSY} would not be preferable (or at least estimated). The reasons for this became clear following a demonstration of the estimated yield-per-recruit (YPR) and stock-recruit (SR) curves for Gulf of Maine haddock. The YPR curve does not reach an obvious asymptote, but instead continues to rise steadily as fishing mortality is increased. This implies that a realistic value of F_{MAX} cannot be estimated. Similarly, SR curves do not fit the estimated stock-recruit data well – the scatterplot of points is extremely noisy and there does not seem to be an obvious causal relationship between parental SSB and subsequent recruitment. The combination of these two poor relationships means that F_{MSY} and the corresponding MSY and B_{MSY} values would be highly uncertain, and therefore it is indeed preferable to use proxies.

The panel also asked how the catch is divided up between the four catch components in short-term forecasts. The response was that the subdivision is made at a later stage by the management bodies, and that it is not part of the scientific SAW/SARC assessment process

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).

This ToR was met.

The Gulf of Maine haddock stock was not overfished and overfishing was not occurring in 2013. Spawning stock biomass (SSB) in 2013 is estimated to be 4,153 mt which is 101% of the SSB_{MSY} proxy (4,108 mt). The 2013 fully selected fishing mortality is estimated to be 0.39 which is below the F_{MSY} proxy (0.46).

The stock status appeared to be good on the basis of both existing and updated BRP estimates, with several large recent year-classes and relatively low fishing mortality contributing to forecasted rises in SSB. Technically, the Gulf of Maine haddock stock is not overfished and overfishing is not occurring in 2013.

The selectivity ogive used in calculating reference points does not reach 1.0 until age 8. This implies that the fully recruited fishing mortality applies only to a few ages and the fishing mortality on mature fish is probably not as high considering that 100% maturity is reached at age 4. It might be useful to have a measure of exploitation rate, e.g. catch divided by exploitable biomass, which would be more stable and more indicative of the exploitation on the mature part of the population.

Considering the management approach, it was the view of the review panel that the assessment process is conducted too infrequently for GoM haddock. Any haddock stock is liable to undergo highly episodic recruitment events, with large year-classes appearing unexpectedly at irregular intervals, and fixed multi-annual TACs can quickly become inappropriate following one of these events. The Review Panel suggested that consideration be given to the approach used for salmon in some ICES areas: here a 3-5 year stock projection is made in which the abundance indices are also projected. The update procedure then consists of comparing the realized (observed) indices with the projected indices for each year, and revision action is only taken if the observations lie outwith a prespecified confidence bound about the projections. This could serve to keep management relevant whilst not overburdening the advisory system with unnecessary work.

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.

This ToR was met.

Two projections were provided in the original presentation; the first based on the proposed final population model, the second based on an assumption that constrained the size of the 2012 year-class. Both models were run under two assumptions about the intermediate year, firstly with a continuation of recent fishing mortality (the *status quo* F option), and secondly assuming that the 2014 removals would be 500 mt. There were also supplementary runs carried out that included an assumption of low mixing between the Gulf of Maine and Georges Bank stocks, but as these made no significant difference to the outcome they were not considered further.

Further runs were requested during the meeting following the presentation of data from the 2014 Spring NEFSC survey, which concurs with suggestions that the 2012 and 2013 year-classes are both large. The new runs also accounted for the differences in selectivity between the commercial and recreational fisheries – as expected, the results from the final joint-selectivity run were approximately scaled averages of the two fishery-specific runs.

The conclusions from all of these runs were very similar – SSB stayed well above any reasonable estimate of SSB_{MSY}, and the confidence intervals of projected catch from different runs overlapped significantly. In particular, the assumptions about the size of the 2012 year-class (constrained or not) made little difference to SSB projections because of the age of maturity for this stock (most fish don't mature until ages 3 or 4) and the relatively slow growth in recent years.

All the runs provided seemed plausible to the review panel. The constraint on the 2012 year-class may appear *ad hoc*, but past experience of retrospective bias with this stock suggests that unconsidered acceptance of recent year-class strength estimates may be unwise. On the other hand, the retrospective bias has all but disappeared most recently, so a constraint may be unwarranted. The panel would need to know more about the progress through 2014 of the fishery to conclude whether an F(status quo) or constrained catch approach would be more appropriate. Finally, although the runs assuming all-commercial or all-recreational selection patterns can be averaged to produce the final joint-selection run, it may be appropriate in future to model these two fisheries separately in the forecast, as this would give a better indication of their relative impacts on the stock.

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

The review panel requested the spring 2014 survey results, and these were collated and provided: the indications are that both the 2012 and 2013 year-classes are high.

Projections were provided as described above (ToR 7c). Given the large incoming year-classes, the stock's vulnerability to becoming overfished appeared to be extremely low under any plausible range of settings for the projections.

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.

This ToR was met.

- The review panel considers that the use of a fixed TAC for three years following a benchmark assessment is problematic: a fixed TAC for an episodic recruiting stock like haddock is always likely to increase the risk of over- or under-exploitation. The review panel suggested that consideration be given to the approach used for salmon in some ICES advice: there a 3-5 year projection is made in which the abundance indices are also projected. The update procedure then consists of comparing the realized (observed) indices with the projected indices for each year, and revision action is only taken if the observations lie outwith a pre-specified confidence bound about the projections.
- The Gulf of Maine haddock stock is currently considered to be distinct from the Georges Bank haddock stock (and indeed the Scotian Shelf stock), although survey distribution maps indicate a relatively continuous extent of haddock across area boundaries. Existing data indicate a low mixing between the GoM and GB stocks, but further biological data collection and analyses would be required to reach firm conclusions and to quantify the rate of mixing. If the issue of stock mixing with the Georges Bank stock remains an issue, the review panel suggests that approaches such as directed tagging studies, egg dispersal modeling, genetic differentiation determination or otolith microchemistry analysis would be needed to quantify mixing, and hence determine stock identity.
- The review panel recommends that a trial programme of age-reading from the recreational fishery be carried out to determine if the recreational ALKs are different from the bottom trawl survey ALKs or not.
- To address concerns about the consistency of survey index time series following significant changes in vessel, net and door configurations, the review panel suggest that it would be appropriate to develop priors on net, door and vessel effects for the model estimation.

3. Review of Atlantic Sea Scallops

3.1 Synopsis of Panel Review

The SARC Panel agreed with the SAW 59 WG's conclusion that the Atlantic sea scallop stock is neither overfished nor was it experiencing overfishing in 2013.

The assessment used biomass and abundance estimates from a scallop survey which has been conducted every year since 1979 on Georges Bank and the Mid-Atlantic Bight using a scallop dredge and a random-stratified design, as well as indexes from a towed digital still camera survey (Habcam) and one from a video drop camera survey (SMAST) using a systematic grid design was also included in the stock assessment for Georges Bank and the Mid-Atlantic. The Habcam data was used for the first time in the assessment. The review panel suggested using relative catchability parameters in future model parameterization to reflect that the survey indices are not truly independent as they are currently treated.

Stock reconstructions were conducted using a statistical length-based model (CASA) that has been used for US scallop assessments since 2007. Separate analyses were conducted for the open and closed areas of Georges Bank (GB) and for the Mid-Atlantic Bight (MAB), and results combined to assess the entire stock. The SARC 59 panel concluded that the methods used to reconstruct the scallop resource and estimate fishing mortality, recruitment, and stock biomass are sound and provide a scientifically credible basis for developing fishery management advice. The Panel felt that uncertainty in the assessment was underestimated and identified approaches to improve this and other areas of the analyses.

During 2013, the sea scallop stock was not overfished and overfishing was not occurring. Past assessments have overestimated biomass, in particular when strong recruitment year classes have entered the population, and may continue to do so. The estimated fishing mortality rate during 2013 was F=0.32. Based on the new recommended overfishing threshold reference point FMSY=0.48, overfishing was not occurring in 2013. Past assessments have underestimated fishing mortality and may continue to do so.

3.2 Evaluation of Terms of Reference for Atlantic Sea Scallop

B. Atlantic Sea Scallop

1. Estimate removals from all sources including landings, discards, incidental mortality, and natural mortality. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these assumptions and sources of data. If possible using sensitivity analyses, consider the potential effects that changes in fishing gear, fishing behavior, and management may have on the assumptions.

This ToR was met.

Landings were calculated for each year and by main fishing ground and gear type and landings from the two biggest fishing regions, Georges Bank and Mid-Atlantic, were included in the stock assessment. Catches from other areas were minor in comparison to catches from the two main regions. Landings from areas that have primarily remained closed to fishing in Georges Bank as well as areas open to fishing were available. For the period since 1994 this information was based on vessel trip reports and dealer reports. Prior to 1994 such information was collected during port interviews. Information on the size composition of catches was also available from dealer reports and information collected from observers. Estimates of discards (mt meats) were derived for seven fleets using Northeast Fishery Observer Program (NEFOP) and Northeast Fishery Science Center (NEFSC) commercial landings (i.e., dealer) data for the 1989 to 2013 time period. Discard estimates were also derived for scallop dredge fleets at a finer stratification using NEFOP and Vessel Trip Report (VTR) data for the 1994 to 2013 time period. Discards estimates were not included in the stock assessment because it was assumed that a) they were low in comparison to landings and b) the mortality of discarded scallops was low. Incidental mortality due to dredging was considered highly uncertain but a formula to describe incidental mortality was constructed for the stock assessment model.

The magnitude of incidental and discard mortality remains a source of uncertainty, as does possibly variable natural mortality by age and over time.

Changes in the size frequency of landed scallops have been interpreted as changes in the selectivity of the fleet over the years. However, those changes could just reflect a change in the size-structure of the population as it recovers.

Data on growth at length collected in surveys during recent periods have highlighted that the range of growth at a given length was greater than that found using a sample from periods when fishing pressure was higher. The assumption used in the report was that growth of scallops was different during those two periods and hence, a different growth curve was constructed to describe growth at different time periods. However, it was not clear whether the change in observed growth at size was because fast growers were removed from the population at times of high fishing pressure so, they were not appropriately represented in the survey samples, and not because of a change in the growth patterns. The panel recommended that this assumption be explored further in future stock assessments.

There were further indications that growth might differ among key fishing grounds; the panel noted that because of such biological characteristics, this stock lends itself to spatial management. The Panel recommends that a table with all the management changes over the years in the past 15-20 years be included in the next assessment.

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

This ToR was met

The assessment used biomass and abundance estimates from a scallop survey which has been conducted every year since 1979 on Georges Bank and the Mid-Atlantic Bight using a scallop dredge and a random-stratified design. The efficiency of the dredge was calculated both for sand and gravel/cobble habitat using a Habcam towed camera system. Estimates of the dredge selectivity were also available. Certain strata were excluded from the survey to reflect the limited availability of scallops in those areas (marginal scallop habitat) and reduce the uncertainty in mean estimates of abundance from such areas; the survey estimates were then inflated so that the survey results were representative of all strata (those surveyed and those excluded). It was not clear how much the overall survey uncertainty increased due to that inflation. This approach might also mean that certain areas with variable scallop abundance over time might not be adequately represented in the survey.

Abundance indexes from a towed digital still camera survey (Habcam) and one from a video drop camera survey (SMAST) using a systematic grid design was also included in the stock assessment for Georges Bank and the Mid-Atlantic. The Habcam data was used for the first time in the assessment.

Length composition data were also produced for each survey; the decline in abundance of young scallops (recruitment) that the length composition shows is not consistent with the assumption used in the stock assessment that natural mortality is density independent and has the same value for all size groups. Future work to consider whether mortality is size or density dependent and use such effects, if the work is conclusive, in future stock assessments is recommended.

The measurement errors in the length composition indices from the HABCAM and SMAST surveys were adjusted using information on length composition from the dredge survey. All survey indices were assumed to be independent of each other and represent absolute abundance. Concerns were raised about the accuracy of such an assumption and model results with bigger CVs for the surveys were presented during the review to consider whether assessments result were sensitive. The results of the stock assessment with higher survey CVs were similar to the original results. The review panel accepted the original results but suggested using relative catchability parameters in future model parameterization to reflect that the survey indices are not truly independent as they are currently treated.

The assessment document does not provide adequate detail in describing the SMAST camera survey. For example, descriptions of the areas surveyed and the method used to convert camera abundance to absolute abundance would be useful to judge the value of this survey in the assessment.

3. Investigate the role of environmental and ecological factors in determining recruitment success. If possible, integrate the results into the stock assessment.

This ToR has been met.

The analysis considered the effects of two factors, phytoplankton availability and predator (sea star, *Astropecten americanus*) spatio-temporal distribution, on scallop recruitment success in the mid-Atlantic. Both factors appeared to be relevant and could potentially affect recruitment and some progress was made to describe the link between recruitment and each of those factors, but results were considered preliminary. Therefore, the results of this analysis were not included in the stock assessment. The work presented responded well to the term of reference for the mid-Atlantic but the panel noted that although the link between the spring bloom and recruitment could be real, other factors could affect survival at age 1 and 2 and deteriorate the relationship. The impact of environmental and ecological factors on recruitment predictions was not considered for Georges Bank so extension of the analysis to consider whether recruitment in that area is also linked to such effects would be useful.

4. Estimate annual fishing mortality, recruitment and stock biomass for the time series, and estimate their uncertainty. Report these elements for both the combined resource and by sub-region. Include a historical retrospective analysis to allow a comparison with previous assessment results and previous projections.

This ToR was met.

Stock reconstructions were conducted using a statistical length-based model (CASA) that has been used for US scallop assessments since 2007. Separate analyses were conducted for the open and closed areas of Georges Bank (GB) and for the Mid-Atlantic Bight (MAB), and results combined to assess the entire stock. CASA models growth using transition matrices estimated from shell ring increment data, and discard and incidental mortality can be modeled explicitly. The models are fitted to abundance estimates from a relatively long time-series of dredge survey data (1979-2013), a video camera survey (SMAST), a digital still camera survey (HABCAM), and a NEFSC bottom trawl survey (MAB only).

The SARC 59 panel concluded that the methods used to reconstruct the scallop resource and estimate fishing mortality, recruitment, and stock biomass are sound and provide a scientifically credible basis for developing fishery management advice. The Panel felt that uncertainty in the assessment was underestimated and identified approaches to improve this and other areas of the analyses.

The HABCAM digital still camera survey theoretically provides an estimate of absolute abundance (for scallops of 40mm shell height and greater), and the assumption that “catchability” (q) for this survey has a mean of 1 is probably reasonable (we ignore the actual scaling of the data and the model q in this discussion). However, the assumed CV on this survey q (0.1) likely underestimates its true uncertainty, given adjustments made to the data for areas not surveyed and difficulty in identifying dead shells in the video images.

The dredge survey and SMAST camera surveys do not provide estimates of absolute abundance (for the 40mm+ scallops), however the data are adjusted to account for scallops not observed in the surveys and then treated as if they were absolute abundance in the model (i.e. assumption that the *q* mean is 1). For the dredge survey, the data adjustments are based on capture efficiency estimates from experimental work comparing dredge and HABCAM observations. Thus, the model *q*'s for HABCAM and the dredge survey are not independent. An approach that is more consistent with how the data was collected and reflects the lack of independence between the HABCAM and dredge survey *q*'s would be to use the unadjusted dredge survey observations in the model with a prior for the ratio of the dredge *q* to the HABCAM *q*. The prior for that ratio would be based on the efficiency estimates from the HABCAM/dredge comparisons.

The SMAST camera survey does not fully "observe" smaller-sized scallops, and comparison data using "small" and "large" cameras were used to estimate size-selectivity for the SMAST survey. The actual SMAST observations are adjusted using this size-selectivity to estimate total (40mm+ scallops) abundance for use in the CASA model. A more appropriate approach would be to use the "small" versus "large" camera comparison data directly in CASA to estimate the SMAST size-selectivity and fit to the actual SMAST observations. This would appropriately account for the uncertainty in the fraction of the population sampled by the SMAST survey.

For all three assessment regions at least two of the point estimates for the survey *q*'s are at the extremes of their priors. The treatment of the survey time series (dredge survey, HABCAM and SMAST) as independent estimates of absolute abundance will result in uncertainty being underestimated and stock biomass being potentially biased.

Certain aspects of the data suggest that juvenile scallop mortality may be density-dependent, with higher natural mortality on large year-classes. Survey abundance increases dramatically when a large year-class recruits but over the following 1 to 2 years declines much quicker than expected from a constant natural mortality assumption. The model cannot fit the large increases in survey abundance, and retrospective patterns occur when large year classes recruit. A formulation of the CASA model that included a juvenile density dependent mortality assumption was fitted to the GB open and GB closed data. This formulation improved the fits to the survey data, and resulted in greater consistency between the point estimates for survey q's (i.e. modes of the posteriors) and their priors. Due to insufficient time to fully explore the density dependent mortality models, they were presented only as exploratory runs. The SARC 59 Panel considers this work promising and suggests that evaluation of the density dependent juvenile mortality assumption should be continued.

The implementation of CASA used for the scallop assessment applies incidental/discard mortality to all sizes, assuming that incidental/discard mortality is roughly 2.5 times larger on small non-commercial sizes. This model assumption should be changed and the model fitted to the discard length frequency data. However, the SARC 59 Panel did not feel that any strong bias would result from this incorrect assumption because discards have tended to be a relatively small component of the catch.

The rationale provided in the assessment document for using a length-based model rather than an age-based model is that for some shells the annual growth rings for younger ages are not visible. Given that age-based models tend to be much more informative about year-class strengths and mortality rates it would be helpful if the document provided more narrative to justify the use of a length-based model.

Two aspects of the stock assessment suggest that the CASA models may be overestimating recent stock abundance: 1) there are relatively strong retrospective patterns for all 3 regions, with stock biomass tending to decrease as additional years of data are added, and 2) there is a lack of fit to recent survey trends, with surveys suggesting the total stock abundance has decreased over the last 3 years while the assessment models suggest abundance has remained at an historic high. These patterns may be related to incorrect model specification of juvenile natural mortality.

This stock is a good candidate for an explicitly spatial assessment model. Although Hart et al (2013) concluded that the use of separate assessments for closed and open areas in Georges Bank provides more quantitatively robust stock estimates, the approach is still problematic because a) there is larval transport between the closed areas, b) the closed areas are not contiguous, and c) closures are not constant through time (so selectivity differences are blurred). Therefore the usual assessment model assumption of a discrete closed population does not necessarily hold.

During the meeting, the review panel noted that the text on the Von Bertalanffy growth parameters states that the L_{inf} and K values were drawn from "independent normal distributions". Generally these parameters would be highly correlated, so the panel asked whether what is actually meant is that the parameters are drawn from bivariate Normal distributions that are independent from draw to draw? It would be odd if the covariance between Linf and K were not taken into account. In response, the stock assessors noted that:

"*A distinction needs to be made between the estimation covariance, and the covariance among individuals in the population - it is the latter than we are simulating.*

The estimation covariance is always negative since growth at a given L(inf) and K is similar to growth at a slightly smaller L(inf) and larger K, so the uncertainty in the estimates of the parameters is strongly negatively correlated. This is very different than the true variability in L(inf) and K among individuals in the population. If one simulates a population where L(inf) and K are uncorrelated, the estimates in L(inf) and K will still be strongly negatively correlated for the reason discussed above. Thus, the fact that the estimation covariances are negative is not evidence that these parameters are negatively correlated among individuals in the population.

If one looks at environmental correlates within each of the three model regions (depth and latitude), these either affect only L(inf) or the covariate affects both L(inf) and K in the same direction (see Hart and Chute ICESJMS 2009), suggesting that these parameters are either independent or positively correlated. On the other hand, fishing pressure reduces L(inf) and increases K, suggesting a negative correlation, but even here, it is much weaker than the sampling correlation. Given the ambiguity in this situation, we chose to model the variability within the population of the two parameters as being independent.

We have checked the matrices generated in this way with using the shell increments directly, and they are reasonably similar."

The SARC Review Panel accepted this explanation of the approach taken.

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

This ToR has been met.

The existing stock status definitions and biological reference points were estimated in SARC 50. Overfishing was occurring if fishing mortality was above F_{MSY} = 0.38, the stock was considered overfished if SSB was less than 62 670 mt of meat

The reference points were updated with the new stock assessment results. Under the updated reference points, overfishing occurs when F is above F_{MSY} = 0.48, and the overfished threshold is lower at 48 240 mt of meat.

A Stochastic Yield Model was used to estimate reference points taking into account uncertainty in key processes such as recruitment and natural mortality. This model also used a stock recruitment relationship to calculate recruitment which is different from the approach used in CASA. The model combined per-recruit analysis with stock-recruitment relationship to estimate maximum sustainable yield (MSY) and the associated biomass and fishing mortality reference points B_{MSY} and F_{MSY}. The Panel agreed that both the choice of the model and incorporation of mortality from discards in the calculations was appropriate.

The process followed made good use of all relevant information and provided an appropriate way to capture and reflect uncertainty. However, as mentioned for previous ToRs, the use of a single value of natural mortality for all size classes might not be the most appropriate way to simulate natural mortality, so this was identified as an area in which improvement could be made. Also, the stock-recruitment relationships were calculated assuming that recruitment from each area (Georges Bank, mid- Atlantic) remains in that area (no transfer of larvae to other areas, etc). It was not clear why/whether this assumption was correct or if there was uncertainty about that assumption. Also, values of fishing mortality were not allowed to exceed 1 and that led to some convergence issues (estimates of fishing mortality were hitting the upper boundary). Use of a higher upper limit on F was recommended to avoid skewed distribution when presenting the results.

The review panel also requested to see the BRP for each of the two areas separately: F_{MSY} estimates for Georges Bank (0.30) and for the Mid Atlantic Bight (0.74) differ greatly. The review panel is concerned that applying the combined estimate (0.48) to the whole stock uniformly could imply that Georges Bank could be fished harder than biologically advisable and the Mid Atlantic Bight might be fished more lightly than biologically advisable.

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

a. Update the existing model 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).

This ToR was met.

During 2013, the sea scallop stock was not overfished and overfishing was not occurring. Estimated biomass (40+ mm SH) was 132.561 thousand mt meats. Using the new recommended reference points, biomass was well above the $B_{TARGET}=B_{MSY}= 96.48$ thousand mt meats, and the $B_{THRESHOLD}=½B_{MSY}=48.24$ thousand mt meats. The probability that the stock was overfished in 2013 is near zero based on the recommended reference points. Compared with reference points from the previous assessment (NEFSC 2010), biomass during 2013 was also above the $B_{TARGET}=B_{MSY}= 125.358$ thousand mt meats, and the $B_{THRESHOLD}=½B_{MSY}=62.679$ thousand mt meats. Past assessments have overestimated biomass, in particular when strong recruitment year classes have entered the population, and may continue to do so.

The estimated fishing mortality rate during 2013 was F=0.32. Based on the new recommended overfishing threshold reference point F_{MSY}=0.48, overfishing was not occurring in 2013. The probability that overfishing occurred during 2013 was about 13% based on the recommended reference points. Overfishing was also not occurring using the reference point from the previous assessment, F_{MSY}=0.38. Past assessments have underestimated fishing mortality and may continue to do so.

Subsequent to the SARC 59 meeting, the review panel had an exchange with the assessment team on the retrospective pattern in fishing mortality for the whole stock.

Comparing the new fully recruited F from the Catch and Status Table to the old F_{MSY}, overfishing occurred during 2005-2012 but not in 2013. The assessment team believes that this comparison is not meaningful because of the different assumptions about M. The review panel disagrees: increasing M in the assessment would be expected to decrease the estimated F if the model works on estimating total mortality. Comparing the new fully recruited F estimates for 2005-2013 to the new higher F_{MSY} estimate using the higher M, overfishing occurred in 2009, but not in any other year.

The definition of stock status was given for the whole stock (Georges Bank and mid-Atlantic) and the stock was considered not to be overfished with overfishing not occurring. This conclusion was reached based both on existing and updated reference points.

The F_{MSY} for Georges Bank is below the F_{MSY} for the whole area; the Panel considered spatially disaggregated information to be important since it indicated that there might be a risk of Georges Bank being overexploited if a uniform fishing effort is applied across the whole area for management purposes. There was discussion with the assessment scientists about the effect a combined F might have on the stock.

7. Evaluate the realism of stock and catch projections and compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level).

This ToR was met

a. Provide numerical annual projections (through 2016). 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).

Some projections were conducted using the SAMS (Scallop Area Management Simulator), and a different model was run for each sub-area within Georges Bank closed or open, and mid-Atlantic areas to reflect the different fishing mortality patterns in each sub-area. An important difference between this model and the one used for calculating the reference points was that this model uses area specific biological information (e.g growth at length); the Panel considered this parameterization to be appropriate and recommended that where possible area-specific parameter values be used in all models (CASA, SYM, SAMS). Recruitment was modeled stochastically, assumed to be log-normal in each subarea and also a stationary process, (no stock-recruitment relationship assumed). An example simulation, based on expected management during 2014-2016, predicts gradual increases in biomass and landings. The assessment group informed the Panel that projections to help manage the fishery were carried out by the Scallop Plan Development Team while evaluating potential management measures, so a broader range of scenarios would be covered then. The Panel was content with that explanation.

b. Comment on the realism of the projections. Consider the major uncertainties in the assessment as well as sensitivity of the projections to various assumptions.

The projection model captures key sources of uncertainty such as uncertainty in natural mortality and growth values well. The fact that it does not allow for density dependent juvenile mortality might lead to projections that are somewhat optimistic; that might be counter- balanced by the fact that the mean, variance and covariance of the recruitment in a subarea was set to be equal to that observed in the historical time-series between 1979-2013, so, big changes in recruitment from what already observed were less probable. The assessment scientists were aware of that shortcoming and had already indicated that they would try to incorporate density dependence into future stock assessments. The Panel supported that decision and also supported the use of a stock recruitment function.

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

Based on a small number of projections presented at the meeting, the stock does not appear to be at risk of overexploitation. However, given the possibility that projection results might be optimistic, the outcomes of the projection were considered cautiously.

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 Panel noted progress made so far to address research recommendations from the previous assessment (SARC-50) and supported new work recommendations to better coordinate surveys undertaken by various survey programs and develop a better understanding of the effects of environmental factors on recruitment success. In addition to new recommendations that the assessment team had put forward, the Panel felt that additional work on retrospective analysis of spatial projections would be useful to evaluate the reliability of the model.

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5. Appendices

Appendix 1: 59th SAW/SARC Stock Assessment Terms of Reference (file vers.: 1/17/2014)

A. 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.

B. Sea scallop

1. Estimate removals from all sources including landings, discards, incidental mortality, and natural mortality. Describe the spatial and temporal distribution of landings, discards, and fishing effort. Characterize the uncertainty in these assumptions and sources of data. If possible using sensitivity analyses, consider the potential effects that changes in fishing gear, fishing behavior, and management may have on the assumptions.

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

3. Investigate the role of environmental and ecological factors in determining recruitment success. If possible, integrate the results into the stock assessment.

4. Estimate annual fishing mortality, recruitment and stock biomass for the time series, and estimate their uncertainty. Report these elements for both the combined resource and by sub-region. 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. Comment on the scientific adequacy of existing BRPs and the "new" (i.e., updated, redefined, or alternative) BRPs.

6. Evaluate stock status with respect to the existing model (from previous peer reviewed accepted assessment) and with respect to a new model or model formulation developed for this peer review.
    a. Update the existing model 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. Evaluate the realism of stock and catch projections and compute the statistical distribution (e.g., probability density function) of the OFL (overfishing level).
    a. Provide numerical annual projections (through 2016). Each projection should estimate and report annual probabilities of exceeding threshold BRPs for F, and probabilities of falling below threshold BRPs for biomass. Use a sensitivity analysis approach in which a range of assumptions about the most important uncertainties in the assessment are considered (e.g., terminal year abundance, variability in recruitment).
    b. Comment on the realism of the projections. 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.