Center for Independent Experts (CIE) Independent Peer Review of SEDAR 69 Atlantic Menhaden Single Species and Ecological Reference Points

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Individual Peer Review Report prepared for the Center for Independent Experts by

Dr. Daniel Howell, Institute of Marine Research, Norway

daniel.howell@hi.no

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Executive summary

The SEDAR 69 review was aimed at both reviewing the single species assessment and to propose methods to adjust the fishery in the event of recovery plans being implemented for key predator species in the region. The current situation is that the Atlantic menhaden stock is in a healthy state, while several commercially or recreationally important predators (e.g., striped bass) are in a depleted state. The review covered a combination of a single species assessment and potential ecosystem inputs into operational management for the forage fish stock Atlantic menhaden. The work presented focused on coupling a Statistical Catch At Age (SCAA) model (the "BAM" model) with an Ecopath with Ecosim (EwE) model to propose a method of giving advice, which is precautionary and based on the best available single species assessment, while allowing for considerations of the importance of menhaden as a food source for important predator species.

The proposed methodology represents a viable method of moving towards a more ecosystem-based management of fish stocks in general and the Atlantic menhaden stock in particular. The methodology involves producing stock status, reference points and quota from a single-species assessment model, and then using an ecosystem model to revise the target F without exceeding the precautionary limit reference point from the single species model. This overall system is a sound method of incorporating ecosystem considerations into current management while retaining the level of precision and precautionarity of the single species assessment. This is currently at the forefront of the state of the art in ecosystem-based management, and represents a viable step towards full ecosystem based management in the region. As well as giving catch advice, the combined model setup also allows for managers and other stakeholders to explore the tradeoffs inherent in multispecies management in the region.

The actual review meeting contained a large number of models, one single species assessment model and five different models (and variants of models) on the ecosystem side. This gave a wide-ranging perspective, which was helpful for the review, but posed a considerable workload for the meeting. In several places there was less investigation of specific details than would have been conducted in a conventional single species review. This is likely a necessary feature of a more wide-ranging review incorporating ecosystem aspects, which was considered appropriate given the mature nature of the stock assessment model. All the documents for review were thorough, clear, and available in advance, which was essential to such a large review. In the event of a future new assessment model, or an assessment model with major problems (such as a strong retrospective pattern), then a separate single species model review prior to the ecosystem review might be preferable.

The "BAM" SCAA assessment model was reviewed as continuing to provide a sound basis for advice for the Atlantic menhaden stocks. Changes to the model, especially in the estimation of M, have led to significant changes in the assessed biomass, but the stock status relative to reference points and the advised fishing level have not been impacted to the same degree. The key recommendation for improvement of the model is to work to obtain fisheries-independent data on the larger fish in the northern part of the region. This would address the main weakness of the model tuning at present. A secondary point is that the convergence of the BAM model needs to be checked (via a so-called jitter analysis) each time it is run.

Two different EwE models were presented, one “full” model, and a simplified model focusing only on the key species interacting with Atlantic menhaden. The rationale for the simplified model was to have a manageable level of complexity and a model which could more easily be updated on a regular basis in order to support ongoing management. This was accepted by the review panel, and the model in general was considered appropriate for examining the impact on predators of changes in the menhaden stock. In contrast to the mature BAM model, the EwE models have had less of a development and review process, and the simplified model in particular should continue to be developed. Focus should be given to the diet data and modelling - in other areas the EwE models draw directly on expertise, data and results from the single species models. The main concern around the use of the EwE model in a management context was the “ecotrophic efficiency” (“EE”) parameters in the model. These govern the strength of the predation interactions and are rather poorly constrained. This was addressed through sensitivity tests showing that the model results were robust to a plausible range of EE values at stock sizes similar to current stock status, although further research here would be beneficial. Reference points from EwE may not be directly transferable to single species models, and the methodology proposed does not require this. Rather, the relative change from the current fishing to a desired fishing level is calculated within EwE, and that relative change is then applied to the target fishing level calculated from the single species assessment. In this case, the change would be a possible reduction in catch in order to support predator recovery. The assessment model then calculates the advice quota arising from the revised target fishing level. The overall conclusion of the review panel was that provided the changes in stock and fishing level were not too extreme, and provided the revised fishing level does not exceed the initial level proposed by the assessment model, then this is a precautionary and viable method of giving ecosystem advice. Furthermore, the combination of models allows for the evaluation of combined management actions on the different stocks. The results from the EwE showed that, for example, the key driver for recovery of striped bass would be a reduction in F on striped bass directly, but also that if this was done then a moderate reduction in F on menhaden would be needed to support full recovery.

In addition, several production models, and one statistical multispecies model were presented. The multispecies model in particular represents a valuable tool for examining multispecies interactions. However, none of these models directly model the bottom effects required for the management questions around predator stock recovery. It is therefore recommended that development continue on the multispecies model, but that the EwE is the appropriate tool for use in operational management. This report focuses mainly on the BAM and reduced EwE models.

Background

The SEDAR 69 Atlantic Menhaden Single Species and ERP Review Panel (hereafter referred to the “Panel”) was convened on November 4th – 8th, 2019 in Charleston, SC. The goal of the review was to evaluate the proposed single species stock assessment model for Atlantic menhaden, and to further evaluate the proposed methodology for extending the reference points for this species to include ecosystem considerations. The single species part of the review included detailed analysis of proposed changes to the existing Statistical Catch At Age (SCAA) model (Beaufort Assessment Model, or “BAM”) and the resulting reference points, especially in light of proposed changes in methods to estimate fecundity and M. This stock is managed with target and threshold precautionary reference points, and therefore no analysis was presented on fishing or biomass MSY estimates. The Ecosystem Reference Points (ERP) part of the review covered evaluating the proposed method for modifying the single species reference points to account for ecosystem interactions (specifically on impacts of menhaden as a food source for predators).

Review Panel

The Panel consisted of Dr. Michael Jones (Chair), and Center of Independent Expert reviewers Dr. Kenneth Frank, Dr. Laurence Kell, and Dr. Daniel Howell. In addition, Dr. Sarah Gaichas was a member of the review panel, although not a CIE reviewer. Dr. Michael Jones is Professor Emeritus at the Quantitative Fisheries Center at Michigan State University. Dr. Kenneth Frank is a Research Scientist at Fisheries and Oceans Canada. Dr. Laurence Kell is a Visiting Professor in Fisheries and Management at Imperial College London. Dr. Daniel Howell is a Research Professor at the Institute of Marine Research, Norway. Dr. Sarah Gaichas is a Research Fisheries Biologist at NOAA.

As Chair of the Panel, Dr. Jones facilitated the meeting and made sure that all the terms of reference were reviewed by the Panel. He also led the preparation of the Peer Review Panel Summary Report. Drs. Sarah Gaichas, Daniel Howell, Kenneth Frank, and Laurence Kell served as independent and impartial reviewers. The CIE reviewers each completed independent peer review reports in accordance with the requirements specified in the Statement of Work and terms of reference (Appendix A), in adherence with the required formatting and content guidelines; reviewers were not required to reach a consensus. CIE Reviewers submitted Individual Peer Review Reports and contributed to the Peer Review Panel Summary Report.

Review Activities

During the review, SEDAR tasked the Panel with two objectives: 1) review the proposed single species assessment model and Reference Points for Atlantic menhaden, and 2) review the proposed methodology for extending the reference points to include ecosystem considerations and produce Ecosystem Reference Points (ERP). Note that the review did not cover evaluating specific proposed ERP values, only the methodology by which such reference points could be derived. Detailed terms of reference were provided for both the single species and the ERP review, and are presented in Appendix A.

Prior to the in-person meeting, the Panel was provided written materials to review describing the single species model and the proposed multispecies and ecosystem models considered during the review. These were also presented at a web meeting to familiarize the review panel with the material prior to the meeting. During the in-person meeting the technical team provided presentations of the biological and ecosystem context of the fisheries, the different single and multispecies models, and details of sensitivity and uncertainty evaluations conducted (see meeting agenda, Appendix B).

The review was a public meeting that had several designated times on the agenda for public comment and was open for participation through webinar. All written materials and presentations were made available at the Egnyte Connect website: (https://asmfc.egnyte.com/fl/TYQPnUIr1k#folder-link/Atlantic%20Menhaden%202019).

Introduction

The review covered both the single species assessment (and related reference points) and the proposal to extend the methodology for estimating reference points to include the impact of menhaden abundance on the predators. These were presented as separate ToRs for each topic, and this review will follow that structure. It should be noted, however, that the two sides are not in any way independent. The ecosystem modelling depended in part on outputs from the single species assessment, and could thus not be run in a standalone manner. Furthermore, the proposed Ecopath with Ecosim (EwE) model cannot directly generate ERPs or quotas that would be consistent with the assessment. Rather, EwE results are expressed in terms of ratios, and then applied to modify the values from the single species assessments. It is therefore important to bear in mind that the single species and ecosystem modelling form a coherent whole and need to be considered as such. It should also be noted that the single species work is rather more mature than the ecosystem modelling. The single species model has already passed several reviews. In contrast, the ecosystem modelling work is proposing new methodology which has not previously been evaluated, and which is ahead of the field in ecosystem fisheries management in a global context. It is therefore likely that both the model, and the process for using it, will be refined as more experience is gained.

Although many regions and jurisdictions have a goal to move towards some variety of Ecosystem Management, actual progress has been relatively slow. The approach presented is essentially a single species assessment producing reference point and quota advice, and then using ecosystem modelling to refine that advice. A similar overall approach is being investigated in the Irish Sea under the ICES WKIRISH process, where the aim is to use ecosystem modelling to vary F_{target} within previously defined (single species based) precautionary ranges of F_{MSY}. This approach holds considerable promise as it avoids the worry around precautionarity, which is one of the key concerns of using ecosystem models directly in the advice-giving process. In the menhaden example, the ecosystem information is used to adjust the single-species advice. Since this will be a downwards revision of the advice arising from the single species model, the revision will not cross the precautionary reference point.

The presence of both the single species and the ecosystem models in a single review resulted in a large workload for the review panel. As a consequence of this breadth, there were occasions where depth suffered and there was insufficient time to fully investigate all of the details of the single species model. Specific examples are given under the relevant ToRs below. To a large extent, this is an inevitable consequence of the linked nature of the single species and ecosystem modelling. It is desirable that these be reviewed together, and as result the workload is inevitably high. On the single species side, this was mitigated by the use of a mature assessment model where the review was mostly concerned with evaluating changes in data and model since the last review. On the ecosystem side the work was new, and four different models were presented in the process of deciding on which were appropriate for use in management. It is therefore likely that in the future the ecosystem side of the review may become more streamlined. Based on this, I would conclude that the linked, single species plus ecosystem, nature of the review was appropriate given the maturity of the single species assessment. All the documentation was available prior to the meeting, which allowed time to read the large documents. The use of a web meeting prior to the physical meeting also contributed to the success of the review, by making it clear which parts of the overall review documents were being focused on by the team. I would not consider that there would have been sufficient time if a new single species assessment model (or a radical change of an existing model) was under consideration. In such a case it would be better to hold a review of the single species, and then a subsequent evaluation of the selected model configuration and the ecosystem work.

Specific comments on each ToR

Terms of Reference for the Atlantic Menhaden Single-Species Peer Review

1. *Evaluate the thoroughness of data collection and the presentation and treatment of fishery-dependent and fishery-independent data in the assessment, including the following but not limited to:*
    a. *Presentation of data source variance (e.g., standard errors).*
    b. *Justification for inclusion or elimination of available data sources,*
    c. *Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, ageing accuracy, sample size),*
    d. *Calculation and/or standardization of abundance indices.*

There was extensive documentation provided, which was available in advance of the meeting together with web presentations of the work conducted. This was critical given the large amount of information reviewed in the short time of the meeting. In general, the data was well presented, with weaknesses well highlighted. Given the limited time available, some parts of the analysis could be not be evaluated in depth. One example would be the method for combining aggregate abundance indices from disparate individual surveys. However, the method used is a standard approach in other US stocks, and the overall method has therefore been through previous review. The justification for excluding data (the two candidate CPUE indices) from the single species model was clearly presented and well justified. Estimation of variance is always difficult, but the panel considered that the estimation was appropriate.

The assessment uses both fishery-dependent and fishery-independent data. The fisheries dependent data used exclude any CPUE index. Two indices were developed and presented to the review, but both were shown to be poorly suited to tracking the overall biomass of the menhaden stock and were therefore not included in the model tuning. The review panel concurred with this judgement. The fisheries independent data were used as combined indices. The methods used to combine these indices follow other stocks in the US (Conn 2018) and were previously used and reviewed for menhaden at SEDAR 40, and the details of this were not examined during this review. Of 49 indices screened, 16 were used in the tuning (combined into a number of composite indices). None of the surveys were dedicated menhaden surveys and many are poorly suited (due to gear or spatial/temporal coverage) to sampling menhaden. Survey data are mostly only available in the form of length data, which limits the ability to conduct cohort coherence studies in the datasets. The model used a Young Of Year (YOY) survey, and it was demonstrated that this did have some predictive power for the subsequent stock development. Given the fragmented and non-targeted nature of the survey data, it is important that the scientists work to demonstrate the consistency between the combined surveys, to examine alternative methods of combining surveys (e.g., the Vector-Autoregressive Spatio-Temporal, VAST methodology) and, importantly, to continue to monitor the survey for any changes in consistency.

The main concern about the fisheries-independent data is the lack of data on the larger fish, especially in the north of the region. A key recommendation from the review panel is to collect more data on this portion of the stock both via surveys and better sampling of the bait fishery, but it may be possible to get more tuning information on the larger fish by re-evaluating the individual series used in the combined indices, focusing on the larger size categories. In general, since the menhaden is considered to represent an important fish stock (both commercially and ecologically), it would be highly desirable to have more focus on the menhaden in survey design and ideally a dedicated menhaden survey.

2. *Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, including but not limited to:*
    a. *Evaluate the choice and justification of the preferred model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?*
    b. *If multiple models were considered, evaluate the analysts' explanation of any differences in results.*
    c. *Evaluate model parameterization and specification (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, plus group treatment).*

The single species Statistical Catch At Age (SCAA) model (the "BAM" model) has previously been reviewed and is currently used for assessing this stock, and the review panel agreed that this is still an appropriate assessment model for the Atlantic menhaden. The model results were well presented, fitting in with global best practice (bubble plots of misfits, error bars where possible and so on in addition to the standard model outputs of population size, F and catches). These were considered sufficient to evaluate the model performance.

The main concern with the BAM model not covered in ToR 2.c (below) was with the optimization of the solution. Some evidence was presented and investigated further during the meeting that there were occasions where the optimizer failed to converge to the appropriate solution. While recognizing that absolute convergence to the global optimum cannot be guaranteed, it is critical that a jitter analysis be used to increase confidence in the final optimized solution. Such an analysis is necessary and sufficient to address the concerns, and that the optimizer (with a jitter analysis) was suitable to support the stock assessment.

A second concern was over the lack of data on the large fish, which is problematic for a SCAA. Collecting better data on the larger fish is discussed further in section 8, where it is identified as the most pressing data collection recommendation for this stock.

No additional models were presented for single species stock assessment. Several of the ecosystem models (the two production models) could potentially be used as assessment models. However, in addition to limitations concerning production models in general, the models presented rely on poor quality CPUE indices and were therefore not considered suitable for assessment.

The assessment model was previously evaluated in SEDAR 40, and in many respects the work presented at that review continues to be appropriate. This section therefore focusses on the changes since SEDAR 40. The most important changes are the likelihood methodology, M and fecundity.

The rationale for the change in fecundity was clearly presented and the panel agreed that the new methodology better represented the biology of the spawning of the menhaden and was therefore a better reflection of reality than the previous approach. Although the change in fecundity changes the overall biomass of the modelled stocks, it has little impact on the management advice, as reference points are also increased and the advised catch is similar.

The change in M had a larger impact on the model results. The new methodology was directly based on data. The panel noted that the data used were from the 1960s, but accepted that the conditions to repeat the experiment (processing plants spread out along the coast) no longer existed. Comparing the M-at-age estimates with other similar fish gave a “sanity check” on the values and led the SAS to conclude the higher estimates were not unreasonable for this species. Noting that estimating M is notoriously difficult in stock assessments, the panel therefore accepted this revised methodology as providing the best available estimates of M. As a side point, the panel noted that with the higher M there are relatively few modelled fish in the plus group, and there are therefore not any plus-group related issues with this assessment.

Time varying blocks of selectivity were chosen, and the justification was clearly explained and appeared valid. There is a possibility that the choice of blocks could be simplified slightly, but the panel concluded that the current scheme represents a viable basis for advice. The choice of two blocks for q in the YoY survey was clearly explained and shown to be justified.

The choice of selectivity form (logistic rather than dome shaped) for the NAD index was highlighted as an area of concern. The misfit data suggested that a dome-shaped selectivity performed better for that survey, However, this would leave the model with no asymptotic selectivity tuning dataset. This would be concerning as the model would then have no direct data constraint on the modeled number of larger fish. The panel concluded that, although sub-optimal, the logistic selection for the NAD was the appropriate choice at present, but recommended a re-evaluation of the available data aimed at identifying an index series that provided better coverage of the larger fish, and in the longer term gave a recommendation to survey these larger fish directly.

Related to the issue of large fish, there was a trend in the length-weight relationship for the larger fish. It was unclear if this represented a biological change or a change in the sampling. This issue is best addressed by improved sampling of the larger fish.

A modified (Dirichlet) likelihood scheme was used for optimization in this assessment and that change in methodology for computing the likelihoods had an impact on the final solution. The new likelihood weighting scheme was considered appropriate by the panel, although time constraints prevented a more in-depth analysis of the weighting scheme. In addition to the effects of the weighting scheme, the change in methodology for computing likelihoods produced an appreciable change in the model solution. In principle, the new scheme is an improvement, as the Dirichlet is designed to be self-weighting and to perform better with correlated data. The Dirichlet was also presented as being increasingly used in other US fisheries assessments. There was not time to address this further at the review, and the panel therefore recommends that the technical team compare the changes they obtained for menhaden with changes in other stocks where this change in likelihood calculation has occurred.

As noted under ToR 3b, the retrospective analysis highlighted a potential for the model optimizer to finish on a non-optimal solution. Further work identified that a jitter analysis could help to identify the overall solution and highlight cases where the optimizer had performed poorly. The recommendation here is that the model (including the optimizer) is fit for purpose, provided that a jitter analysis is conducted to increase confidence that the model has converged on the global solution.

In summary, this is clearly a mature assessment model, and while noting that further research to improve the model is warranted (see ToR 8), the panel concluded that this represents a suitable and viable basis for giving advice for this stock.

3. *Evaluate the diagnostic analyses performed, including but not limited to:*
    a. *Sensitivity analyses to determine model stability and potential consequences of major model assumptions*
    b. *Retrospective analysis*

Sensitivity analyses were presented on the impacts of including or excluding surveys, both as a “leave one out” analysis and with surveys excluded in combination. This mostly showed little sensitivity to the choice of tuning series, which might be expected given the relative lack of signal in the different surveys. The exception was the NAD survey, where leaving this out had large impacts on the model results. This is because this is the one series with a logistic selectivity function, and hence the only dataset providing direct data on the fraction of the stock in the large size categories. The sensitivity runs did serve to highlight this feature of model tuning, and further sensitivity runs that involved giving the NAD a dome shaped selectivity confirmed that the selectivity was the driving factor here, rather than the inclusion or exclusion of the NAD data. This is discussed further under ToR 2c.

Further sensitivity tests on the choice of M showed that the absolute model estimates were sensitive to the choice of M, as would be expected, but that the trends and status determination were robust to the different M values examined.

A sensitivity test on the method used to compute misfit scores for the likelihood components was presented, and demonstrated quite a large change in modelled population. A recommendation for research would be to identify other stocks where similar changes have been made in the likelihood methodology, and compare the changes encountered here with those obtained in other assessments.

There is an issue over the level of detail to be provided on the outcomes of the sensitivity runs in future reviews. It is suggested that the diagnostics in the current report be retained, but that in addition a full suite of diagnostics (including the parameter estimates and likelihood components) be made available online for examination prior to and during the review.

In general, there was a reasonable range of modeling assumptions and dataset choices examined in the sensitivity tests, and these served their purpose in identifying issues around model stability that would need to be monitored during further use of the assessment model.

A retrospective analysis was presented for the BAM model, and showed little systematic pattern. The analysis did highlight an instability, where the 2014 retrospective was markedly different from the 2013 and 2015 values. In this context, the retrospective runs were useful for validating that such an outlier is not occurring in the terminal year of the assessment.

Given the issue with fitting highlighted under ToR 2, above, it is important that the convergence of the retrospective runs also be validated using a jitter analysis to avoid potential issues of reaching erroneous conclusions on the basis of unconverged solutions.

4. *Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.*

Two methods were used to assess the parameter uncertainty. The first focused on uncertainty on natural mortality and fecundity (Monte Carlo Bootstrap, MCB). These parameters are set externally to the model, and both have changed since the previous SEDAR 40 review. A second Monte Carlo Markov Chain (MCMC) analysis was used to evaluate the uncertainty in the estimated model parameters. The results indicated that model outputs were sensitive to changes in the life history (M and fecundity) parameters, as would be expected. The model was less sensitive to the uncertainty in estimated parameters (the MCMC analysis).

The use of the two different methodologies to investigate the two uncertainties was appropriate, and gave useful insight into the robustness of the model outputs to both changes in life history and the uncertainties in the estimation of model parameters. Although absolute estimates were found be sensitive to some choices, the stock status determination was robust to the uncertainties evaluated.

5. *If a minority report has been filed, review minority opinion and any associated analyses. If possible, make recommendation on current or future use of alternative assessment approach presented in minority report.*

There was no minority report.

6. *Recommend best estimates of stock biomass, abundance, and exploitation from the assessment for use in management, if possible, or specify alternative estimation methods.*

The Base Run of the BAM model presented in the Single Species report gives estimates of biomass, abundance and exploitation that represent the best available estimates and are suitable for use in management.

7. *Evaluate the choice of reference points and the methods used to estimate them. Recommend stock status determination from the assessment, or, if appropriate, specify alternative methods/measures.*

The key reference points presented were target and threshold fishing mortality, and a precautionary reproductive reference point. No F_{MSY} reference point was presented.

Current target and threshold fishing mortality reference points are based on the mean and maximum fishing mortality rates respectively for ages 2 to 4 during the period 1960-2012. Reference points for reproductive output are the fecundity (number of maturing or ripe eggs) estimates associated with the fishing mortality target and threshold estimated from the BAM. Calculations were based upon the estimated selection pattern of landings across all fleets and areas, and the assumed time invariant M-at-age and 1:1 sex ratio. Uncertainty in the derived reference point was estimated by two approaches, namely a parametric Monte Carlo bootstrap (MCB) procedure in which the input values of M and fecundity were resampled (MCB) and a MCMC analysis to estimate parameter uncertainty.

The methodology is sound, and the choice of the 1960-2012 period, where fishing had not caused stock collapse (even though the fishery was without management constraints) gives a good reference for fishing levels that the stock can potentially sustain. The decision not to base reference points on F_{MSY} calculations for this species was well presented and is valid.

The reference points are currently single species. This reviewer would conclude that this is currently the most appropriate option, even under ecosystem management. While the ultimate aim is to have full Ecological Reference Points (ERPs), it is not clear that these could currently be derived in a precautionary manner. The proposed method of adjusting the target fishing level within the single-species precautionary reference points is an important step towards ecosystem-based management, bringing in elements of ecosystem reality while retaining the precautionarity within the current system.

An evaluation of methods used for projections of future stock status was not explicitly included in the ToR; however, a main reason for conducting stock assessments and estimating reference points is to inform the determination of future total allowable catches (TACs). The capacity of the stock assessment model to forecast the future state of the resource is therefore important. Due to the assumed high level of natural mortality, future stock biomass is largely driven by year-class strength and hence recruitment. There does not, however, appear to be a stock recruitment relationship and recruitment has been relatively stable, with no signs of recruitment failure events. Variability in recruitment is relatively low (with a CV of 30%).

One concern around the stock forecast is that there is a relatively long lag between the last year in the assessment and the years for which TACs are being set, i.e., the last year in the current assessment is 2017 which will be projected for reported landings in 2018 and preliminary estimates for 2019. The TAC will then be set for 2020 to 2022. Given the high level of natural mortality, the stock in 2020 through 2022 is likely to be dominated by year-classes not estimated by the current assessment. Therefore, an evaluation of prediction skill is important. This could be done using a retrospective analysis, where the stock is projected forwards from different end years and compared with historical outcomes. This lag also highlights the importance of not reducing the frequency of the assessments. It should be noted that the relatively low variability of the recruitment provides some reassurance on the performance of the stock forecasts. However, in the event that the recruitments were to become more variable, then consideration should be given to whether it is possible to reduce the lag (for instance, through more frequent update assessments).

8. *Review the research, data collection, and assessment methodology recommendations provided by the TC and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.*

The key recommendation on the data side is clearly for a thorough exploration of options for adding a survey or fishery dependent dataset that more representatively samples the larger, older fish in the population. One option might be expansion of sampling from the bait fishery. This would address the main gap in the current tuning data.

Collection of age data for the existing fishery independent surveys is also considered a priority and has been recommended in the past (SEDAR 40). The TC's recommendations for the development of a coast-wide fishery-independent index of abundance-at-age would also be useful, given that none of the existing fishery-independent surveys are specifically directed towards menhaden.

One potential recommendation would be to conduct a Management Strategy Evaluation. A MSE would certainly be valuable for evaluating the robustness to uncertainty of reference points and control rules informed by the single species assessment. Another potential benefit would be to evaluate the benefits of improved data collection and biological sampling. However, there are "devils in the details": decisions about how to structure the MSE will require careful thought to avoid progress on management being impeded by a process that could take several years and require a large commitment of resources. Therefore, the recommendation is that an MSE be considered, rather than a definitive finding that such an exercise should be undertaken. Finally, if an MSE is to be undertaken, it would make sense that it be framed in the context of Ecosystem Reference Points rather than single species management.

With respect to research recommendations regarding assessment methods, while the Automatic Differentiation optimizer in ADMB is fast and therefore efficient, it is vulnerable to false convergence problems. It is therefore important that the performance of the optimization be examined carefully before presenting model solutions. There were instances with the single species BAM model (see ToR 2) where diagnostics suggested an optimization failure. The panel therefore strongly recommends that a so-called jitter analysis be performed on any model solution. This involves running a large number of optimizations, each one with slightly different starting parameters, to increase confidence that the final solution represents the global optimum solution. Given the occasional optimization issues seen at the review, it would be inappropriate to give advice based on output from this model which had not been subjected to such a test.

9. *Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.*

The team working on the models recommended continuing the timing of benchmark assessments and updates for the single species assessment, with an update in 3 years and the next benchmark in 6 years, and this seems appropriate. The single species assessment model is "mature" and does not appear to require any substantial modifications that would warrant a benchmark sooner than 2025. Given the relatively short lifespan of Atlantic menhaden, and the unpredictability of future recruitment trends, it does not seem appropriate to extend the time between benchmarks beyond 6 years. Even if recommendations from this review regarding fishery independent assessment of larger, older, menhaden are successfully addressed soon, it will take several years for a new index time series to be highly informative in the assessment model.

However, given that with movement towards ecosystem-based reference points for Atlantic menhaden and consequently linkages between management strategies for several species of ASMFC concern, there will be large benefits in the future for synchronization of assessment updates and benchmarks among the key species in the models that inform ecosystem-based reference points. This may have implications for the timing of future Atlantic menhaden assessment updates.

10. *Prepare a peer review panel terms of reference and advisory report summarizing the panel's evaluation of the stock assessment and addressing each peer review term of reference. Develop a list of tasks to be completed following the workshop. Complete and submit the report within 4 weeks of workshop conclusion.*

This report has been prepared and submitted.

Terms of Reference for Atlantic Menhaden Ecological Reference Points Peer Review

Before addressing the specific ToRs, it should be noted that a number of different models were presented: two versions of production models, two versions of EwE models (NWACS-FULL and NWACS-MICE), and one statistical multispecies model. The recommendation of the team working on the models (endorsed by this reviewer and the review panel) is to use the

EwE with a restricted set of species in providing advice. This review will therefore focus on this version of the EwE model, although the other models will also be discussed as appropriate.

1. *Evaluate the justification for the inclusion, elimination, or modification of data from the Atlantic menhaden single-species benchmark assessment.*

The key difference in data between the single species and ecosystem models was the use of CPUE indices. Although both candidate CPUE indices were rejected for the single species model, the surplus production models required such an index for tuning. The technical group therefore were forced to choose between the two candidate indices (even though both were considered sub-optimal), and the justifications for rejecting the local version was appropriate and well justified.

Additional tuning information was required by the EwE. It is important that the EwE model corresponds as closely as possible to the BAM outputs in order to be of use in advice giving. The use of the BAM outputs as inputs (alongside direct data for the EWE-MICE model) to the EwE is therefore appropriate here.

2. *Evaluate the thoroughness of data collection and the presentation and treatment of additional fishery-dependent and fishery-independent data sets in the assessment, including but not limited to:*
    a. *Presentation of data source variance (e.g., standard errors).*
    b. *Justification for inclusion or elimination of available data sources,*
    c. *Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, aging accuracy, sample size),*
    d. *Calculation and/or standardization of abundance indices.*

The data collection, presentation and treatment of additional fishery-dependent and fishery-independent data sets across all five presented ERP models were thorough and appropriate. There was a large extent of data collation and treatment represented in the report. That said, with five models at different levels of complexity, including representations of multispecies and full food web dynamics, there are always data gaps to be filled or alternative treatments of data that might be considered. It should also be noted that there was little time available for a thorough analysis of so many models during the review.

Overall, the strategy of using input datasets (fishery independent indices, total catch, and both fishery dependent and independent age and length data) directly from previously vetted and approved stock assessments for modeled predator species makes sense. This streamlines the process for multispecies and ecosystem modeling greatly by relying on existing processes to review input data. The review panel did not need to review already vetted assessment inputs again for this process, and trusts that previous review processes evaluated variance in data sources, calculation and/or standardization of indices, and considered data strengths and weaknesses. However, none of the data sources for ERP models were shown with standard errors or other depictions of variance. In future reporting, it would be helpful to include a presentation of the variance even if the data were previously vetted to ensure that future review panels can address specific requests such as ToR 2a.

Taking each data set as already evaluated and tested, the primary concern is whether the process for inclusion/elimination of available predator stock assessment input data sources was appropriate, and if the process applied all considerations above to data sources that had not been previously reviewed (i.e., diet data, dogfish inputs for the VADER model, and additional EwE inputs).

Note that stock assessment model outputs (F, SSB, recruitment, or other model-estimated quantities) were not considered to be "data" in this context even if they were inputs to the ERP models, and these were to be previously reviewed information.

Selecting stock assessment fishery independent indices

The selection of the subset of input data for the VADER and the simplified EwE-MICE model was conducted by asking the expert teams for the individual stocks to identify the three most influential indices for each stock. This aims at keeping the amount of data required manageable, while focusing on the key information. This draws on the expertise for each stock, and is a reasonable approach, although some flexibility in the number of datasets per stock might be beneficial. The exception to this is spiny dogfish, and therefore this is a species that should receive more attention in the next revision of the model.

Diet data

In general, the diet data have been compiled from a number of sub-optimal datasets ("snapshot" data, short time series, restricted range or low catches of Atlantic menhaden). This is, unfortunately, typical for diet data, and the combination of sources represents a good basis for the diet modelling. In addition to using all the data sources (NEAMAP and ChesMMAP as well as NEFSC), it would be worth investigating other methodologies, such as genetic barcoding.

Ecopath biomass inputs

While stock assessment model outputs are not "data", assessment model-estimated biomass is used as an input to the Ecopath portion of both EwE models. This is a reasonable approach to Ecopath modelling in general but is especially appropriate here given that the EwE results are intended to modify the target F arising from the stock assessment model. One advantage of the EwE-MICE model compared to the full EwE was the use of index data (similar to the VADER model) rather than assessment model output. The use of stock assessment output in the initial mass balance sets up the scale of the food web model while the dynamic predator prey interactions are estimated from the combination of index trends across all species/groups in the EwE MICE model. This approach "lets the data speak" to some extent in estimating key dynamic predator-prey parameters used for ERP development.

Environmental data (discussed but not implemented at present)

At present, the work covers trophic interactions (both food supply to predators and mortality induced on prey), but not the environmental side of ecosystem model. This is a reasonable focus given the objectives of the work.

There is potential to include environmental drivers in the models. For example, the VADER model has the capacity to include a temperature time series affecting consumption rates. Rather than speculate here, it should be noted that data on temperature and oceanic conditions exists which could be used in modelling, but also that care needs to be taken to avoid taking correlations with environmental conditions and putting these into models as mechanistic drivers.

3. *Evaluate the methods and models used to estimate Atlantic menhaden population parameters (e.g., F, biomass, abundance) that take into account Atlantic menhaden's role as a forage fish, including but not limited to:*
    a. *Evaluate the choice and justification of the recommended model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?*
    b. *If multiple models were considered, evaluate the analysts' explanation of any differences in results.*
    c. *Evaluate model parameterization and specification as appropriate for each model (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, choice of ecological factors).*

The key point here is to note that the ERP modelling was not primarily concerned with producing absolute estimates of F, biomass or abundance for use in advice giving. By using the methodology of having the ecosystem model scale the desired target F, but using the BAM model to compute actual reference points, target F, and quota advice, many of the difficulties in comparing absolute values between models are avoided. It is of course still important that trends are realistic, and that the relative abundance of different species within a given model are well modelled. Although the models covered different aspects of the ecosystem, the overall trends for Atlantic menhaden were similar between the modelling approaches. Where tests on the start year were conducted for the surplus production models, the results proved rather sensitive to this choice. A full sensitivity analysis on the impact of the choice of start year would be valuable for all the models.

The ERP report presented five models to estimate menhaden population parameters that account for menhaden's role as forage. The models ranged in structural complexity from a simple surplus production model with time-varying menhaden production (SPM-TVr) to a full food web model for the Northwest Atlantic continental shelf (NWACS-FULL, an EwE model). Intermediate models included a surplus production model that explicitly accounted for menhaden removals due to predation (Steele-Henderson), a multispecies statistical catch at age model with menhaden and 5 other species (VADER), and a scaled down food web model focused on menhaden and a subset of key predator and prey species (NWACS-MICE, an EwE model).

As noted above, the recommendation from both the expert team and the review panel was to use a combination of the BAM model and the NWACS-MICE model to estimate Atlantic menhaden population parameters that take into account Atlantic menhaden's role as a forage fish.

The ERP working group provided strong justification for choosing the BAM and NWACS-MICE models based on their ability to provide information relevant to ecosystem management objectives specified in a 2015 stakeholder workshop as well as their technical merits. Objectives and performance metrics from the 2015 workshop related to sustaining menhaden to provide for menhaden fisheries and predators, to provide fishery stability, and to minimize risk due to changing environmental conditions. While all presented models could address sustainability for menhaden fisheries, only VADER, NWACS-MICE and NWACS-FULL could address menhaden predators or their fisheries (and no models are currently set up to address changing environmental conditions). Further, only the NWACS models directly model menhaden effects on predators as well as predator impacts on prey, and the NWACS-FULL model was difficult to update within required management time frames. This review thus agreed with the conclusion that NWACS-MICE is best able to address the full suite of management objectives when combined with BAM, which best captured menhaden population dynamics.

The ERP report retained analysis of all models and compared results across them (including BAM) in section 15. This clear summary, with the pros and cons of each model listed in this section, was critical given the limited time for review. All models showed generally similar recent trends and scale in comparable outputs (Age 1+ biomass, exploitation rate). This approach increases confidence that input data rather than model structure are largely driving model results and argues for continuing to maintain a suite of supporting models with a range of complexity (if only for sanity checking the main results). Differences between the results were mainly attributable to structural assumptions: for example, surplus production/biomass dynamics models are not designed to track short term biomass changes that arise from inter-annual recruitment variability. Further useful comparisons explaining differences between the NWACS-MICE and FULL models were made in the report and in presentations during the meeting.

NWACS-MICE (selected model)

The overall specification of NWACS-MICE is reasonable and well suited to the aim of modifying the target F level from the BAM model. The key concerns are the low level of the menhaden mortality captured by the model predators, and the potential sensitivity of the results to poorly constrained parameters.

There are two components to the model specification: the static (Ecopath) model and the dynamic (Ecosim) model. The static model initializes the dynamic model, which is then calibrated using sum of squares fits to time series of biomass and catch for multiple species.

The NWACS-MICE static (Ecopath) model parameterization used information from regional databases and stock assessments as available; this is appropriate and is discussed in detail under ERP ToR 2. In particular, the decision to use biomass accumulation terms does not force the food web model to start in equilibrium. Some parameters were used directly or aggregated from the NWACS-FULL (such as diet imports for predators); therefore, these models should continue to be reviewed and updated together. The main issue noted with the static model parameterization related to low estimates of EE for menhaden age groups resulting from B and P/B inputs from the BAM for menhaden combined with diet and other inputs for predators, even when considering that only a subset of predators were included in the model. This was addressed in a sensitivity run (see ToR 5). Further simulation testing, similar to that performed for other ERP models, could be useful for the NWACS-MICE model in the future.

Production models

These were the simplest models presented and did not model food supply effects on the predators. Furthermore, they were reliant on the use of a CPUE index which was rejected for use in stock assessment. However, they do have the potential to provide a "sanity check" on the more complex modelling and the two variants open the possibility for more investigations. The model with time varying r could be used to evaluate correlations between r and predator metrics, and could potentially contribute to a powerful predictive analysis to evaluate time series of menhaden r and effects on striped bass. The Steele-Hendersen model could potentially evaluate total consumption by having a combined "total predation" predator. The models were rather sensitive to the choice of start year. If the model is to continue being developed then a full sensitivity analysis of the choice of start year should be conducted. As noted above, this would be useful for all the models, but it would be most important for the production models.

VADER statistical catch at age (supporting model)

The VADER model provides more detail than the surplus production models, and is able to directly estimate F and other management-relevant quantities directly from data (which the EwE models are unable to do). Because the model is structurally different from the EwE approach, using both models together provides information on structural uncertainty.

Several assumptions were made in the model formulation which should be explored through sensitivity testing: the assumption of constant ecosystem carrying capacity but variable other food versus the more common assumption of fixed other food is one which should be tested, and the interactions between this other food and the residual mortality (M0) for each species should be explored. To avoid problems with optimization, a jitter analysis similar to that applied to BAM is critical here, and the team should try using direct length-based predator prey dynamics (rather than conversion from length to age to weight).

NWACS-FULL (supporting model)

This model covers a wider range of predators than the EwE-MICE model (NWACS-MICE). Given that the proportion of mortality in menhaden caused by the predators in the EwE-MICE model was rather low, this wider perspective would be valuable. However, there are clear practical difficulties of regularly updating the full EwE model in an advice-giving context, and therefore this full model is more suited to use as a research tool than in supporting advice directly. It would be useful in future iterations to apply the same parameter estimation techniques as used for NWACS-MICE (see above), which alleviate some concerns that arise from EwE software constraints. In addition, alternative specifications that fit NWACS-FULL to index time series instead of assessments would be useful for comparison with NWACS-MICE. Further exploration of incorporating habitat drivers into NWACS-FULL would also be useful to address the management objectives to minimize risks due to shifting environmental drivers.

4. *Evaluate the methods used to estimate reference points and total allowable catch.*

The methodology presented here represents major progress since SEDAR 40 in 2014, and is at the cutting edge of taking ecosystem information directly into advice. The approach restricts the use of the EwE to rescaling the target F computed in the BAM, and leaving stock status determination, reference point calculation and the translation of F into quota advice within the BAM. Provided that the final quota advice remains within the precautionary limits from the single species model, this combination continues to exploit the strengths of single species stock assessments while allowing for ecosystem inputs from the EwE model.

The models presented provide a transparent approach that allows the trade-offs between menhaden and their predators to be evaluated within a multispecies context. The combination of NWACS-MICE and BAM can be used to develop a scientific management framework to both set precautionary single species TACs and evaluate their impact on predator species. The approach illustrated in the ERP report seems appropriate and is ready for presentation to managers to initiate discussions about trade-offs among potentially competing fishery objectives and for use in making moderate changes to the target fishing mortality and hence quotas.

The one caveat concerns the poorly known Ecotrophic Efficiency values in the EwE models. The sensitivity analysis presented at the review showed that the results were robust to a plausible range of uncertainty in the EE values provided that fishing mortalities did not deviate too far from the historical levels. Further sensitivity testing is required to identify how large changes of fishing mortality can be well modelled by this system.

5. *Evaluate the diagnostic analyses performed as appropriate to each model, including but not limited to:*
    d. *Sensitivity analyses to determine model stability and potential consequences of major model assumptions*
    e. *Retrospective analysis*

The different classes of models evaluated here have different structures, and therefore used different sensitivity tests. Because the NWACS-MICE model is the one currently proposed for use in management, this section focusses on that model. However, the other models are summarized first.

For the CPUE models, a sensitivity to the choice of two potential CPUE indices (RCPUE and PRFC) was conducted and indicated significant differences in trend between 1970 and 1990, although a much closer agreement since 1990. The rationale presented to use the RCPUE as the base case and the PRFC as the sensitivity was clearly presented and appropriate.

Sensitivity tests for the production models also included a brief analysis of the impact of the start date of the model; this is addressed under the retrospective analysis below.

For the VADER model the sensitivity run comparing the model with and without trophic interactions produced counter-intuitive results. This could point to problems with the proportion of total mortality (Z) allocated to predation, and a research recommendation is to investigate this through a more detailed sensitivity analysis. The modelled sensitivity to alternate tuning indices and prey composition was also presented.

A sensitivity test should also be conducted of the choice to fix overall food biomass (other food plus modelled prey) against the alternate hypothesis of fixing other food and allowing total biomass to vary.

In general, the suite of sensitivity tests performed on the VADER model and the two surplus production models is adequate at this time, given that these are not being currently proposed for direct use in management. Should the VADER model be used to inform management in the future, the additional sensitivity tests noted above would be recommended.

For the NWACS-MICE and NWACS-FULL models, a suite of sensitivity runs were conducted with alternative dynamic (Ecosim) parameterizations using iterative vulnerability estimation as described above under ToR 3. The NWACS-FULL sensitivities explored model behavior with and without vulnerability caps, with and without manual adjustments to selected parameters, and with observed and increased diet proportions of menhaden for predators (in the static Ecopath model). The NWACS-MICE sensitivities explored similar parameterizations to NWACS-FULL as well as the effect of EwE-estimated “primary production anomalies.” A final sensitivity examined impacts of fitting to recruitment deviations as well as increasing the prey-switching exponent.

The range of sensitivity runs was useful and informative. Exploration of sensitivity to Ecosim dynamic parameters is especially valuable because model results tend to be highly sensitive to these parameter settings. In general, sensitivity runs for the NWACS-FULL suggested that manual tuning of parameters was necessary to balance model fits to biomass with reasonable stock-recruitment dynamics. For the NWACS-MICE (fitting to indices rather than stock assessment outputs), sensitivity runs demonstrated that vulnerability-caps reduced or eliminated model instabilities in projections, which is desirable.

One additional sensitivity test was performed for the NWACS-MICE model during the meeting, at the request of the review panel. This investigated the sensitivity of the results to increases in predation mortality for menhaden. The ecotrophic efficiency (EE) parameter represents the fraction of species production that is used within the ecosystem, so a low EE suggests that the model is not accounting for much mortality (or other loss from the system) explicitly. For forage species, food web models usually account for a substantial proportion of production as predation mortality, with EE often approaching 1. In general, the predation mortality on menhaden estimated within the model was quite low, and the proportion caused by any given predator even lower (for 0 group menhaden around 4% of overall mortality came from striped bass, while for age 1+ menhaden predation this value was around 1%). Given the available data, it is difficult to say if this is correct or not, but it does give rise to a situation where small changes in the absolute value might have significant impacts on model outputs.

A single sensitivity run was conducted, which indicated that increasing the EE to a higher (but reasonable) value by increasing predator diet proportions of menhaden increased the slope of the curve relating B/B_{target} for striped bass to F in menhaden (Figure 148 in the ERP report). This resulted in very little change in the results for small changes around the current menhaden F. However, the distance between B_{target} and $B_{threshold}$ decreased as the slope increased, indicating that the results from larger changes in menhaden F could be sensitive to the choice of EE parameters.

This sensitivity test indicated that the overall NWACS-MICE result was robust to both reasonable increases in predator consumption of menhaden from those currently observed in food habits data and to small changes from current management. There should therefore be a further suite of sensitivity tests to examine how robust the results are for greater deviations from current management. The results of the sensitivity tests on all the key outputs for management (ERP Report, Figures 144-148) should be investigated.

These tests should cover:

- A more thorough investigation of reasonable bounds on predation mortality to evaluate the effect of low observed predation mortality on low EE.
- Runs with menhaden B and P/B at different values (using bounds from BAM sensitivity runs), to evaluate the effect of high production on low EE.
- Runs including a range of values for other predators in the ecosystem (current runs looked at only status quo F, while one could use target, threshold, or specified F based on catch limits on the books for future years).
- Investigation of the possibility to capture more of the menhaden mortality with a minor increase in the number of modelled predators.
- More testing of the sensitivity of the ERP results to static (Ecopath) model input parameters (B, P/B, Q/B) for predators of menhaden and other key groups.

As noted earlier (ToR 4), notwithstanding this request for further analysis of the range over which the NWACS-MICE model can be considered robust with the caveat that the model is most suitable for examining small changes from status quo fisheries and stock sizes, it is therefore concluded that the NWACS-MICE model is suitable for use in exploring trade-offs in a management context.

Retrospective analysis

Retrospective analysis is most relevant in the multispecies SCAA model VADER, and a retrospective analysis was presented for this model. The retrospective was short, only a three-year peel. This was limited by the three-year block used for averaging the prey preferences over a three-year period. This would not prevent a longer peel, but one would expect a discontinuity every three years as the peel extended to a different three-year block of diet preferences. Within the three-year period, the model was stable.

Some retrospective analyses were also conducted for the production models. Here removal of up to four years of data from the end of the time series had little effect on model performance. This is as expected since there is little contrast in the CPUE data at the end of the time series. In contrast, the outputs of the surplus production models were strongly influenced by the start time of the model. Again, this is not surprising given that the greatest contrast is in the early years. A research recommendation would be to conduct a retrospective-style analysis at the start of the surplus production models to identify which years had the greatest impact on model performance.

6. *Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.*

For the ERP models, less formal attention was given to characterizing uncertainty in estimated parameters. In a sense, the consideration of multiple models constitutes an approach to accounting for structural (model) uncertainty. The model comparisons presented in the ERP report generally suggested qualitative alignment among comparable simulations across models, particularly when the models were adjusted for scaling differences in relevant parameters. Such an alignment might be expected given the commonality of underlying data sources, but is reassuring nonetheless.

Other, regional time series were investigated, and produced different model outcomes – this is likely evidence of the unsuitability of a local index for informing a regional model.

Other aspects of uncertainty were addressed in sensitivity analyses and are discussed elsewhere in this report. Overall, the level of uncertainty analysis is appropriate for this stage of ERP model development and application. Future development should focus on the models being proposed for advice – in particular, there is clear scope for evaluating the impact of uncertainties around the parameterization of the EwE-MICE model.

7. *If a minority report has been filed, review minority opinion and any associated analyses. If possible, make recommendation on current or future use of alternative assessment approach presented in minority report*.

No minority report was filed.

8. *Recommend best estimates of stock biomass, abundance, exploitation, and stock status of Atlantic menhaden from the assessment for use in management, if possible, or specify alternative estimation methods.*

The proposed method of using the stock biomass, abundance, exploitation and stock status estimates from the base run of the BAM model for use in management, with the EwE-MICE results potentially used to rescale the target fishing level, should be adopted. Details are under the single species ToRs.

9. *Review the research, data collection, and assessment methodology recommendations provided by the TC and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.*

The report included a number of recommendations for future research, data collection, modelling and management, for both the short and long term. These included expanding collection of diet and condition data to include non-finfish predators and data-poor prey species, to conduct management-strategy evaluation (MSE) to identify harvest strategies that will meet ecosystem management objectives, and to continue the development of the EwE models (NWACS-MICE and NWACS-FULL) and VADER models.

All these recommendations are appropriate and a number of additional specific recommendations for research on the ERP models and assessment methods to inform these models are presented earlier in this report in the context of other ToRs.

As noted under ToR 8 for the single species review, a MSE process could be beneficial for this stock, but it should be stressed that it will be important to plan any potential MSE process carefully, to avoid progress on management being impeded by a process that could take several years and require a large commitment of resources.

10. *Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.*

It is likely that the update schedule for the ecosystem model will match that of the single species model, which is more fully discussed above. Given that the EwE model is reliant on outputs from the single species model, the next ecosystem review should not occur later than alongside or shortly after the next single species review.

11. *Prepare a peer review panel terms of reference and advisory report summarizing the panel's evaluation of the stock assessment and addressing each peer review term of reference. Develop a list of tasks to be completed following the workshop. Complete and submit the report within 4 weeks of workshop conclusion.*

This review has been prepared and submitted to SEDAR.

APPENDIX A: Bibliography of materials provided for review

SEDAR 69

Atlantic Menhaden Document List

Document #	Title	Author
SEDAR 69 – SAR1	Assessment of Atlantic Menhaden Single Species Benchmark Report	To be prepared by SEDAR 69
SEDAR 69 – SAR2	Assessment of Atlantic Menhaden Ecological Reference Point Report	To be prepared by SEDAR 69
	ASMFC Instructions for Reviewers	
Supplementary Materials		
SEDAR 69 – RD01	SEDAR 40 Stock Assessment Report Atlantic Menhaden	SEDAR 2015
SEDAR69 – RD02	Hierarchical analysis of multiple noisy abundance Indices	P. Conn 2010
SEDAR 69 – RD03	Estimation of movement and mortality of Atlantic menhaden during 1966–1969 using a Bayesian multi-state mark-recovery model	Liljestrand et.al. 2019
SEDAR 69 – RD04	Trends in Relative Abundance and Early Life Survival of Atlantic Menhaden during 1977–2013 from Long-Term Ichthyoplankton Programs	Simpson et.al. 2016
SEDAR 69 – RD05	Multi-state dead recovery mark-recovery model performance for estimating movement and mortality rates	Liljestrand et. al. 2019
SEDAR 69 – RD06	A MULTISPECIES STATISTICAL CATCH-ATAGE (MSSCAA) MODEL FOR A MIDATLANTIC SPECIES COMPLEX	McNamee, 2018
SEDAR 69 – RD07	Evaluating the performance of a multispecies statistical catch-at-age model	Curti, 2013
SEDAR 69 – RD08	Parameter estimation in Stock Assessment Modelling: Caveats with Gradient-based algorithms	Subbey, 2018
SEDAR 69 – RD09	Reconciling single-species TACs in the North Sea demersal fisheries using the Fcube mixed-fisheries advice framework	Ulrich et.al. 2011
SEDAR 69 – RD10	Working Group on Mixed Fisheries Advice (WGMIXFISH-ADVICE)	ICES Advisory Committee, 2016
SEDAR 69 – RD11	Evaluation of Current and Alternative Harvest Control Rules for Blue Whiting Management using Hindcasting	Kell and Levontin, 2019
SEDAR 69 – RD12	Public comment Forum Submissions	SEDAR, 2019

SEDAR 69 – RD13	Cookbook for Using Model Diagnostics in Integrated Stock Assessments	Carvalho, 2019

APPENDIX B: Personal Work Statement

Performance Work Statement (PWS) for Kenneth T. Frank

Center for Independent Experts (CIE) Program

External Independent Peer Review

SEDAR 69 Atlantic Menhaden Assessment Review

Background

The National Marine Fisheries Service (NMFS) is mandated by the Magnuson-Stevens Fishery Conservation and Management Act, Endangered Species Act, and Marine Mammal Protection Act to conserve, protect, and manage our nation's marine living resources based upon the best scientific information available (BSIA). NMFS science products, including scientific advice, are often controversial and may require timely scientific peer reviews that are strictly independent of all outside influences. A formal external process for independent expert reviews of the agency's scientific products and programs ensures their credibility. Therefore, external scientific peer reviews have been and continue to be essential to strengthening scientific quality assurance for fishery conservation and management actions.

Scientific peer review is defined as the organized review process where one or more qualified experts review scientific information to ensure quality and credibility. These expert(s) must conduct their peer review impartially, objectively, and without conflicts of interest. Each reviewer must also be independent from the development of the science, without influence from any position that the agency or constituent groups may have. Furthermore, the Office of Management and Budget (OMB), authorized by the Information Quality Act, requires all federal agencies to conduct peer reviews of highly influential and controversial science before dissemination, and that peer reviewers must be deemed qualified based on the OMB Peer Review Bulletin standards. http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf). Further information on the CIE program may be obtained from www.ciereviews.org.

Scope

The SouthEast Data, Assessment, and Review (SEDAR) is the cooperative process by which stock assessment projects are conducted in NMFS' Southeast Region. SEDAR was initiated to improve planning and coordination of stock assessment activities and to improve the quality and reliability of assessments.

SEDAR 69 will be a CIE assessment review conducted for ASMFC Atlantic menhaden. The review workshop provides an independent peer review of SEDAR stock assessments. The term review is applied broadly, as the review panel may request additional analyses, error corrections and sensitivity runs of the assessment models provided by the assessment panel. The review panel is ultimately responsible for ensuring that the best possible assessment is provided through the SEDAR process. The stocks assessed through SEDAR 69 are within the jurisdiction of the Atlantic States Marine Fisheries Commission and the states of Florida, Georgia, South Carolina, North Carolina, Virginia, Maryland, Delaware, Pennsylvania, New Jersey, New York, Connecticut, Rhode Island, Massachusetts, New Hampshire, and Maine.

The specified format and contents of the individual peer review reports are found in Annex 1. The Terms of Reference (TORs) of the peer review are listed in Annex 2. Lastly, the tentative agenda of the panel review meeting is attached in Annex 3.

Requirements

NMFS requires three (3) reviewers to conduct an impartial and independent peer review in accordance with the Performance Work Statement (PWS), OMB guidelines, and the TORs below. The reviewers shall have a working knowledge in stock assessment, statistics, fisheries science, and marine biology sufficient to complete the primary task of providing peer-review advice in compliance with the workshop Terms of Reference fisheries stock assessment. It would be preferable for CIE reviewers to have expertise in forage fish population dynamics, Statistical Catch-at-Age modeling, Multispecies/Ecosystem Models with a focus on Multispecies Statistical Catch-at-Age models and Ecopath with Ecosim models, menhaden/forage fish life history and ecology, and/or management strategy evaluations/decisional frameworks.

Tasks for Reviewers

1) Two weeks before the peer review, the NMFS Project Contacts will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contacts will consult with the contractor on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the PWS scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

2) Attend and participate in the panel review meeting. The meeting will consist of presentations by NOAA and other scientists, stock assessment authors and others to facilitate the review, to answer any questions from the reviewers, and to provide any additional information required by the reviewers.

3) After the review meeting, reviewers shall conduct an independent peer review report in accordance with the requirements specified in this PWS, OMB guidelines, and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus.

4) Each reviewer should assist the Chair of the meeting with contributions to the summary report.

5) Deliver their reports to the Government according to the specified milestones dates.

Foreign National Security Clearance

When reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for reviewers who are non-US citizens. For this reason, the reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website: http://deemedexports.noaa.gov/ and http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-nationalregistration-system.html. The contractor is required to use all appropriate methods to safeguard Personally Identifiable Information (PII).

Place of Performance

The place of performance shall be at the contractor's facilities, and in Charleston, SC.

Period of Performance

The period of performance shall be from the time of award through January 2020. Each CIE reviewer's duties shall not exceed 14 days to complete all required tasks.

Schedule of Milestones and Deliverables: The contractor shall complete the tasks and deliverables in accordance with the following schedule.

Within two weeks of award	Contractor selects and confirms reviewers
2 weeks prior to the panel review	Contractor provides the pre-review documents to the reviewers
November 4-8, 2019	Panel review meeting
Approximately 3 week later	Contractor receives draft reports
Within 2 weeks of receiving draft reports	Contractor submits final reports to the Government

Applicable Performance Standards

The acceptance of the contract deliverables shall be based on three performance standards: (1) The reports shall be completed in accordance with the required formatting and content; (2) The reports shall address each TOR as specified; and (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel

All travel expenses shall be reimbursable in accordance with Federal Travel Regulations (http://www.gsa.gov/portal/content/104790). International travel is authorized for this contract. Travel is not to exceed $10,000.

Restricted or Limited Use of Data

The contractors may be required to sign and adhere to a non-disclosure agreement.

Project Contacts:

Larry Massey – NMFS Project Contact
150 Du Rhu Drive, Mobile, AL 36608
(386) 561-7080
larry.massey@noaa.gov

Kathleen Howington - SEDAR Coordinator
Science and Statistics Program
South Atlantic Fishery Management Council
4055 Faber Place Drive, Suite 201
North Charleston, SC 29405
Kathleen.howington@safmc.net

Annex 1: Peer Review Report Requirements

1. The report must be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The report must contain a background section, description of the individual reviewers' roles in the review activities, summary of findings for each TOR in which the weaknesses and strengths are described, and conclusions and recommendations in accordance with the TORs.

a. Reviewers must describe in their own words the review activities completed during the panel review meeting, including a brief summary of findings, of the science, conclusions, and recommendations.

b. Reviewers should discuss their independent views on each TOR even if these were consistent with those of other panelists, but especially where there were divergent views.

c. Reviewers should elaborate on any points raised in the summary report that they believe might require further clarification.

d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

e. The report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report.

The report shall represent the peer review of each TOR, and shall not simply repeat the contents of the summary report.

3. The report shall include the following appendices:

Appendix 1: Bibliography of materials provided for review

Appendix 2: A copy of this Performance Work Statement

Appendix 3: Panel membership or other pertinent information from the panel review meeting.

Annex 2. Terms of reference.

TERMS OF REFERENCE

For the 2019 ASMFC Atlantic Menhaden Single-Species Benchmark Peer Review and
2019 ASFMC Atlantic Menhaden Ecological Reference Points Benchmark Peer Review

Terms of Reference for the Atlantic Menhaden Single-Species Peer Review

11. Evaluate the thoroughness of data collection and the presentation and treatment of fishery-dependent and fishery-independent data in the assessment, including the following but not limited to:
    a. Presentation of data source variance (e.g., standard errors).
    b. Justification for inclusion or elimination of available data sources,
    c. Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, aging accuracy, sample size),
    d. Calculation and/or standardization of abundance indices.

12. Evaluate the methods and models used to estimate population parameters (e.g., F, biomass, abundance) and biological reference points, including but not limited to:
    a. Evaluate the choice and justification of the preferred model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?
    b. If multiple models were considered, evaluate the analysts' explanation of any differences in results.
    c. Evaluate model parameterization and specification (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, plus group treatment).

13. Evaluate the diagnostic analyses performed, including but not limited to:
    a. Sensitivity analyses to determine model stability and potential consequences of major model assumptions
    b. Retrospective analysis

14. Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.

15. If a minority report has been filed, review minority opinion and any associated analyses. If possible, make recommendation on current or future use of alternative assessment approach presented in minority report.

16. Recommend best estimates of stock biomass, abundance, and exploitation from the assessment for use in management, if possible, or specify alternative estimation methods.

17. Evaluate the choice of reference points and the methods used to estimate them. Recommend stock status determination from the assessment, or, if appropriate, specify alternative methods/measures.

18. Review the research, data collection, and assessment methodology recommendations provided by the TC and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.

19. Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.

20. Prepare a peer review panel terms of reference and advisory report summarizing the panel's evaluation of the stock assessment and addressing each peer review term of reference. Develop a list of tasks to be completed following the workshop. Complete and submit the report within 4 weeks of workshop conclusion.

Terms of Reference for Atlantic Menhaden Ecological Reference Points Peer Review

12. Evaluate the justification for the inclusion, elimination, or modification of data from the Atlantic menhaden single-species benchmark assessment.

13. Evaluate the thoroughness of data collection and the presentation and treatment of additional fishery-dependent and fishery-independent data sets in the assessment, including but not limited to:
    a. Presentation of data source variance (e.g., standard errors).
    b. Justification for inclusion or elimination of available data sources,
    c. Consideration of data strengths and weaknesses (e.g., temporal and spatial scale, gear selectivities, aging accuracy, sample size),
    d. Calculation and/or standardization of abundance indices.

14. Evaluate the methods and models used to estimate Atlantic menhaden population parameters (e.g., F, biomass, abundance) that take into account Atlantic menhaden's role as a forage fish, including but not limited to:
    f. Evaluate the choice and justification of the recommended model(s). Was the most appropriate model (or model averaging approach) chosen given available data and life history of the species?
    g. If multiple models were considered, evaluate the analysts' explanation of any differences in results.
    h. Evaluate model parameterization and specification as appropriate for each model (e.g., choice of CVs, effective sample sizes, likelihood weighting schemes, calculation/specification of M, stock-recruitment relationship, choice of time-varying parameters, choice of ecological factors).

15. Evaluate the methods used to estimate reference points and total allowable catch.

16. Evaluate the diagnostic analyses performed as appropriate to each model, including but not limited to:
    i. Sensitivity analyses to determine model stability and potential consequences of major model assumptions
    j. Retrospective analysis

17. Evaluate the methods used to characterize uncertainty in estimated parameters. Ensure that the implications of uncertainty in technical conclusions are clearly stated.
18. If a minority report has been filed, review minority opinion and any associated analyses. If possible, make recommendation on current or future use of alternative assessment approach presented in minority report.

19. Recommend best estimates of stock biomass, abundance, exploitation, and stock status of Atlantic menhaden from the assessment for use in management, if possible, or specify alternative estimation methods.

20. Review the research, data collection, and assessment methodology recommendations provided by the TC and make any additional recommendations warranted. Clearly prioritize the activities needed to inform and maintain the current assessment, and provide recommendations to improve the reliability of future assessments.

21. Recommend timing of the next benchmark assessment and updates, if necessary, relative to the life history and current management of the species.

22. Prepare a peer review panel terms of reference and advisory report summarizing the panel's evaluation of the stock assessment and addressing each peer review term of reference. Develop a list of tasks to be completed following the workshop. Complete and submit the report within 4 weeks of workshop conclusion.

APPENDIX C: Agenda

Agenda (Draft 10.18.19)
SEDAR 69 Atlantic Menhaden & Ecological Reference Points
Review Workshop
Charleston, South Carolina
November 4-8, 2019
Monday
9:00 a.m. Convene
9:00 a.m. – 9:20 a.m. Introductions and Opening Remarks Coordinator/Chair
- *Agenda Review, TOR, Task Assignments*

9:20 a.m. – 11:00 a.m. Assessment Presentations: Atlantic menhaden
- *Assessment History Kristen Anstead*
- *Life History*
- *Regulatory History Max Appelman*
- *Commercial Reduction Fishery Ray Mroch*
- *Commercial Bait and Recreational Fisheries Kristen Anstead*
- *Indices of Abundance*

11:00 a.m. – 11:15 a.m. Break
11:15 a.m. – 12:15 p.m. Continue Assessment Presentations
- *Assessment Model and Results Amy Schueller*

12:15 p.m. – 1:30 p.m. Lunch Break
1:30 p.m. – 3:30 p.m. Continue Assessment Presentations
- *Reference Points and Stock Status Amy Schueller*
- *Projection Methodology*
- *Research and Modeling Recommendations Kristen Anstead*

3:30 p.m. – 3:45 p.m. Break
3:45 p.m. – 4:45 p.m. Panel Discussion Chair
- *Begin discussion with SAS*
- *Identify additional analyses, sensitivities, corrections*

4:45 p.m. – 5:15 p.m. Panel Comments Chair
- *Initial panel comments on assessment*

5:15 p.m. – 5:45 p.m. Day 1 Summary & assignments to analytical team Chair
5:45 p.m. – 6:00 p.m. Public Comment
Monday Goals**:** Initial single-species assessment presentations completed, sensitivity and base model discussion begun, additional analyses requested

2

Tuesday

8:30 a.m. – 9:00 a.m. Review additional single-species analyses *Amy Schueller*

9:00 a.m. – 10:30 a.m. Ecological Reference Points Assessment

-Ecological Modeling Objectives Matt Cieri

-Modeling History

-Predator & Prey Choices

-*Multispecies Data Katie Drew*

10:30 a.m. – 10:45 a.m. Break

10:45 a.m. – 11:45 a.m. Ecosystem Modeling Presentations

Multispecies Surplus Production Models Katie Drew

11:45 a.m. – 12:15 p.m. Panel Discussion Chair

- *Discussion on surplus production models*

- Identify additional analyses to be requested

12:15 p.m. – 1:30 p.m. Lunch Break

1:30 p.m. – 2:30 p.m. Ecosystem Modeling Presentations Continued

Multispecies Statistical Catch-at-Age Model Jason McNamee

2:30 p.m. – 3:15 p.m. Panel Discussion Chair

-Discussion of MSSCAA model

-Identify additional analyses to be requested

3:15 p.m. – 3:30 p.m. Break

3:30 p.m. – 4:30 p.m. Ecosystem Modeling Presentations Continued

Ecopath with Ecosim Models Dave Chagaris

4:30 p.m. – 5:15 p.m. Panel Discussion Chair

-Discussion of EwE models

-Identify additional analyses to be requested

5:15 p.m. – 5:45 p.m. Day 2 Summary & assignments to analytical team Chair

5:45 p.m. – 6:00 p.m. Public Comment

Tuesday Goals**:** Initial ecosystem model presentations completed, sensitivity and base model discussion begun, additional analyses requested

3

Wednesday

8:30 a.m. – 10:30 a.m. Ecological Reference Points Presentation

- Review & Synthesis of Results Matt Cieri &

- Management & reference points recommendations Dave Chagaris

10:30 a.m. – 11:00 a.m. Break

11:00 a.m. – 12:00 p.m. Panel Discussion Chair

- *Ecological reference points & management*

- Identify additional analyses to be requested

12:00 p.m. – 1:30 p.m. Lunch Break

1:30 p.m. – 3:30 p.m. Continue Panel Discussion Chair

- *Ecological reference points & management*

- Identify additional analyses to be requested

3:30 p.m. – 4:00 p.m. Break

4:00 p.m. – 5:00 p.m. Review additional ecosystem modeling analyses *TBD*

5:00 p.m. – 5:45 pm. Day 3 Summary & assignments to analytical team Chair

5:45 p.m. – 6:00 p.m. Public Comment

Wednesday Goals**:** Initial review and discussion of reference points and management recommendations

Thursday

8:30 a.m. – 10:30 a.m. Panel Discussion Chair

- Final menhaden analyses & projections reviewed

10:30 a.m. – 11:00 a.m. Break

11:00 a.m. – 12:00 p.m. Panel Discussion Chair

-Single-species discussions continues

12:00 p.m. – 1:30 p.m. Lunch Break

1:30 p.m. – 3:30 p.m. Panel Discussion Chair

- Final ecosystem analyses reviewed

3:30 p.m. – 4:00 p.m. Break

4:00 p.m. – 5:45 p.m. Panel Discussion Chair

- Ecological reference points assessment

5:45 p.m. – 6:00 p.m. Public Comment

4

Friday

8:30 a.m. – 10:30 a.m. Panel Discussion/Panel Work Session Chair

- Continue deliberations

- Recommendations and comments

10:30 a.m. – 11:00 a.m. Break

11:00 a.m. – 12:30 p.m. Panel Discussion or Work Session Chair

- Review Reports

12:30 p.m. – 1:00 p.m. Public Comment

1:00 p.m. ADJOURN

Appendix D: Panel Membership

The review panel consisted of Dr. Michael Jones (Chair), and Council of Independent Expert reviewers Dr. Kenneth T. Frank (author of this report), Dr. Laurence Kell, and Dr. Daniel Howell. In addition, Dr. Sarah Gaichas was a member of the review panel, although not a CIE reviewer. Dr. Michael Jones is Professor Emeritus at the Quantitative Fisheries Center at Michigan State university. Dr. Kenneth Frank is Research Scientist at Fisheries and Oceans Canada. Dr. Laurence Kell is Visiting Professor in Fisheries and Management at Imperial College London. Dr Daniel Howell is Research Professor at IMR, Norway. Dr. Sarah Gaichas is Research Fisheries Biologist at NOAA.

Workshop Participants

SEDAR 69
Atlantic Menhaden
Single Species & Ecological Reference Points Review Workshop Participants

APPOINTEE	FUNCTION	AFFILIATION/LOCATION
Review Panel		
Mike Jones	Review Panel Chair	ASFMC Appointee
Sarah Gaiches	Reviewer	ASMFC Appointee
Kenneth Frank	Reviewer	CIE
Daniel Howell	Reviewer	CIE
Laurence Kell	Reviewer	CIE
Analytical Representatives		
Amy Schueller	Single Species Lead Analyst & Chair	SEFSC – Beaufort, NC
Jason McNamee	ERP Lead Analyst	RI DEM – Jamestown, RI
Matt Cieri	ERP Work Group Chair	ME DMR – Boothbay, ME
Katie Drew	Assessment Team	ASMFC – Arlington, VA
Kristen Anstead	Assessment Team	ASMFC – Arlington, VA
Dave Chagaris	ERP Work Group	UF – Gainesville, FL
Ray Mroch	Assessment team	SEFSC- Beaufort, NC
Staff		
Max Appelman	Atlantic Menhaden Coordinator/Rapporteur	ASMFC – Arlington, VA
Sarah Murray	ERP Coordinator/Rapporteur	ASMFC – Arlington, VA
Pat Campfield	ASMFC Contact	ASMFC – Arlington VA
Ciera Graham	Admin	SAFMC
Kathleen Howington	Coordinator	SEDAR
Observers		
Bob Beale	Observer	ASFMC
Julie Neer	Observer	SEDAR
Joseph Ballenger	Observer	SCDNR
Peter Himcheck	Observer	Omega Protien
Genny Nesslage	Observer	UMCES
Chris Dollar	Observer	TRCP
Howard Townsend	Observer	NOAA Fisheries
Jeff Kaelin	Observer	Lunds Fisheries

Acronyms

ASMFC – Atlantic States Marine Fisheries Commission
CIE – Center for Independent Experts
ERP – Ecological Reference Points
ME DMR – Maine Department of Marine Resources
RI DEM – Rhode Island Department of Environmental Management
SEDAR – Southeast Data, Assessment, and Review
SEFSC – Southeast Fisheries Science Center, NMFS
UF – University of Florida
SAFMC – South Atlantic Fishery Management Council
UMCES – University of Maryland Center for Environmental Science
TRCP – Theodore Roosevelt Conservation Partnership