Summary Report of the Georges Bank and eastern Georges Bank Haddock Research Track Stock Assessment Peer Review

March 28 through March 31, 2022
Northeast Fisheries Science Center, Woods Hole Massachusetts

Report prepared by Panel Members:
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Introduction

The last assessment (NEFSC 2019) of the Georges Bank (GB) haddock (*Melanogrammus aeglefinus*) stock was a Level-2 operational update of the 2017 Virtual Population Analysis (VPA; NEFSC 2017). The last benchmark for this stock was in 2008 (Brooks et al. 2008). Based on the assessment in 2017, the stock was not overfished, and overfishing was not occurring. The 2019 assessment updated commercial fishery catch data, research survey indices of abundance, as well as weights and maturity at age. The analytical VPA model and reference points were fit to the updated data through 2018. Stock projections were provided through 2022.

The eastern Georges Bank (EGB) haddock assessment (also a VPA) was updated in 2019 but was not accepted because of a large retrospective pattern (TRAC 2019). Subsequent assessments have been empirical (TRAC 2021) and catch advice has been provided based on previous conditions and indicators of stock condition.

Since 2020 the two stocks have been the focus of a research track stock assessment effort designed to improve the quality of the assessments and address their retrospective patterns. A Working Group (WG) was created with staff from NOAA Fisheries, academia, and Fisheries and Oceans Canada (DFO). This 12 person WG (Chaired by Brian Linton, NEFSC) met from September 2020 through February 2022 to prepare updated assessment advice for three stocks of haddock – Gulf of Maine, Georges Bank, and eastern Georges Bank. Terms of Reference for the WG are provided in Appendix 1.

The WG's products have been reviewed by the Georges Bank and eastern Georges Bank Haddock Research Track Stock Assessment Peer Review Panel who met via WebEx from March 28 through March 31, 2022 (see agenda in Appendix 2). The Panel was composed of three scientists selected by the Center for Independent Experts (CIE): Anders Nielsen (Technical

University of Denmark), Kevin Stokes (Stokes.Net.NZ Ltd), and Joseph Powers (NOAA retired). The Panel was co-chaired by Rob Kronlund (Interface Fisheries Consulting, Ltd.) and Richard Merrick (member of the New England Fisheries Management Council Scientific and Statistical Committee).

The Panel was assisted by Michele Traver (Chair, NEFSC's Stock Assessment Workshop Process Lead) and Russ Brown (Chief, NEFSC Population Dynamics Branch). Documentation was prepared by the Haddock Working Group, and presentations were made by Steve Cadrin (University of Massachusetts), DFO staff and contractors (Monica Finley, Yanjun Wang, and Tom Carruthers), as well as NOAA Fisheries staff (Liz Brooks, Kevin Friedland, and Brian Linton (all NEFSC)). Other WG members contributed to the discussions on various topics. Chuck Adams, Alex Hansell, Tony Wood, Toni Chute, Jason Boucher, Abby Tyrell, Alicia Miller, and Sarah Salois (all from the NEFSC) acted as rapporteurs throughout the meeting (see Appendix 4 for materials provided and Appendix 5 for meeting attendees).

Two weeks prior to the meeting, assessment documents were made available to the Panel through https://apps-nefsc.fisheries.noaa.gov/saw/sasi/sasi_report_options.php, as well as a GitHub repository for the EGB modeling. Prior to the meeting, members of the Panel met with Michele Traver and Russell Brown to review and discuss the meeting agenda, reporting requirements, meeting logistics and the overall process.

The meeting opened on the morning of Monday March 28, with welcoming remarks and comments on the agenda by Russ Brown, Michele Traver, and the Panel co-chairs. The meeting agenda is provided as Appendix 2. The first three and a half days of the meeting focused on presentations and discussion of the 12 Terms of Reference (TOR) for the 2022 research track assessment. Day 4 concluded with a Panel discussion of the 12 TORs, with that discussion providing the primary input to this document, the Panel's Summary Report. The Panel co-hairs compiled and edited this Panel Summary Report with assistance (by correspondence) from the CIE Panelists, before submission of the report to the NEFSC. Additionally, each of the CIE Panelists will submit their separate reviewer's reports to the Center for Independent Experts.

The scientific and statistical analyses conducted by the WG were extremely thorough and of high quality. Their very clear reports and presentations made the Panel's job much easier.

The Panel agreed that all 12 TORs had been met, and that the WG's approaches to estimating biological reference points (BRPs) and making projections for both stocks were well reasoned; they should form a reasonable basis for providing harvest advice for the GB and EGB management units when data are updated.

There was one Panel concern that should be mentioned. The EGB response to TORs 6 and 11 had neither been fully reviewed nor agreed upon by the WG prior to their presentation to the Panel. As such, the Panel's review here is simply that of the specific analyst's work and not of the WG's findings. This is awkward and the Panel recommends that this be avoided in future Research Track Stock Assessments, particularly for trans-boundary stocks. The lack of the consensus by the WG on TORs 4 and 12 was also noted, but it was recognized the full WG had at least had the opportunity to review and discuss the results of the work on the TOR. As such, it

is different from presenting work which the WG has not reviewed.

The Panel's overarching evaluation of the WG's response to the 12 TORs is provided below and concludes with a summary of key recommendations.

Evaluation of the Terms of Reference for Georges Bank and Eastern Georges Bank Haddock

1. *Review existing research efforts, data, and habitat information in the Gulf of Maine and Georges Bank, identify any findings relevant to influences of ecosystem conditions on haddock, and consider those findings, as appropriate, in addressing other TORs. For processes that the working group deems important and promising that are not currently feasible to consider quantitatively, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments.*

The Panel agreed that this TOR has been met for both GB and EGB haddock.

The WG effectively reviewed the existing research that formed the basis for the TOR and probably has gone as far as it can, given the current state of knowledge about the haddock's habitat relationships on Georges Bank.

The Panel was somewhat concerned that the research on species distribution models based on machine learning methodologies (Friedland et al. 2020) may be describing haddock distribution rather than habitat relationships. None-the-less this research has the promise of supporting development of a mechanistic model to improve the understanding of the habitat relationships with possible application to stock assessment. At the least, the Random Forest model seems like a useful tool to help define which variables may be important to understanding the underlying mechanisms that define haddock habitat.

The analysis of the spatial distribution of haddock on GB using a Poisson-link delta model also holds promise for improving management of the stock. Elucidation of stock movements northwards and to some extent eastward into Strata 29 and 30, perhaps in association with warming bottom temperatures, led to the inclusion of data observed from these strata into the EGB assessment model. This analysis also points out the need to consider stock structure as a dynamic rather than fixed feature of the management process (a conclusion supported in the discussion of TOR 12).

Overall, it was relatively clear that this research could ultimately be considered within the Woods Hole Assessment Model [WHAM] framework (Stock and Miller 2021) to determine if management outcomes are improved. There was particular interest in using this research to consider varying natural mortality, *M*, based on habitat use.

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

The Panel agreed that this TOR has been met for both GB and EGB haddock.

Both the US and Canada have implemented procedures sufficient for commercial catch and discard estimation. The Panel **commended** the Canadian approach to reducing discards, including the use of at-sea observers with average coverage of ~37% of the landed catch in recent years.

The changes to estimating the length-weight relationship used to calculate catch-at-age was a topic of some discussion. This issue was identified as a source of uncertainty for both the US and Canadian data. The Panel agreed that at this time the issue is more important for Canadian catch-at-age because Canadian catches are a significant portion of total catch. The Panel concluded that both groups had developed reasonable approaches to dealing with the change in the length-weight relationship over time.

The Panel **recommended** the WG proposal to update the gutted fish to whole fish conversion factors for the US and Canadian catch data, noting that conversion factors may depend on the form of the product (e.g., gutted versus gutted and gilled).

Finally, the Panel **commended** the WG for compiling a thorough list of uncertainties in the estimation of catches, and NOAA/DFO are encouraged to develop ways to reduce these uncertainties.

3. *Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty in these sources of data.*

The Panel agreed that this TOR has been met for both GB and EGB haddock.

The Panel supported the WG's decision not to split the NOAA survey time series and was reassured that the surveys showed consistent trends between DFO and NOAA based on their matching cohort tracking. The calibration work to update survey indices for changes in NOAA vessels and gear was well done. The Panel concluded the survey time series would provide robust data to support the assessment modeling.

The Panel also acknowledged that the WG provided clear evidence of temporal variability in maturity, weights at age, lengths at age, and natural mortality (M). As such, these biological parameters could benefit from further research and the Panel suggested considering hypotheses that included age-dependent changes in M. However, work on the stock assessment models could continue without this research being concluded.

4. *Estimate annual fishing mortality, recruitment, and stock biomass (both total and spawning stock) for the time-series and estimate their uncertainty. Compare the time series of these estimates with those from the previously accepted assessment model and evaluate the strength and direction of any retrospective pattern(s) in both the current and the previously accepted model. Enumerate possible sources of the retrospective patterns and characterize plausibility, if possible.*

The Panel agreed, **with reservations**[1], that this TOR has been met for both GB and EGB haddock.

The Panel **commended** the WG for very thorough analyses and excellent presentations. The step wise approach to transition the VPA modeling frameworks to the proposed new model platform under WHAM was **commended**. None-the-less the Panel has several concerns about the evaluation and applicability of the models as described below.

Georges Bank haddock

This TOR was addressed by first updating the current VPA model with new data to the extent possible, and then examining the impact of new data treatments on the scale of abundance and the measure of retrospective pattern (Mohn's rho). Next, a bridge was built between the VPA and a statistical catch at age model (Age Structured Assessment Program [ASAP], Legault and Restrepo 1998). This bridge provided a transition to the proposed state-space framework base model implemented using WHAM. Model structure, diagnostics, fleet selectivity blocking, and post-hoc weighting adjustments were examined for ASAP fits. A full exploration of model configuration and model building was pursued in arriving at the proposed base model implemented in WHAM with generally positive results.

The Panel **commended** the analyst for the thorough model search and well-argued path of modelling choices. They were generally comfortable with this model as a basis for assessing GB as a whole and for moving forward to the Management Track.

Despite the generally good performance on the model, the Panel was concerned that the conditional simulation test showed that the model appeared to have a substantial bias (of about 30-40%) on both SSB and *F* estimated time series compared to the true SSB and fishing mortality (*F*) from which the observations were simulated (Fig. B134 in the GB report). This was likely to have been an error in the simulation code as opposed to a problem in the estimation model, because the model comparisons (Fig. B135 in GB report) show no indication of a bias of that magnitude. The conditional simulation approach can be expected to give some "smoothing bias", but not a consistent bias of this magnitude. The Panel provided a short-term **recommendation** that the pattern of simulation bias be resolved prior to application of the model

[1] The reservations related to the possible simulation bias in the GB model, and the potential difficulty in applying two separate assessment models to what appears to be one stock, while acknowledging that the EGB model has not been applied to GB and there are management implications for a single assessment approach that have not been evaluated.

for Management Track advice. This could be achieved by (a) diagnosing whether the simulation code required revision, or (b) adjusting the model specification to reduce the bias.

Eastern Georges Bank haddock

Like the GB model, development of a new EGB model began with exploration of a bridge from the earlier VPA model (which had failed due to a strong retrospective bias) to a WHAM framework model. Four broad categories of models ranging from a conventional catch-at-age model to a state-space model were considered in the search for a base model. The selected base model was similar in many respects to the GB model. It built on much of the groundwork established by the GB model with two major and several minor exceptions. First, it was developed based solely on the stock and fishery monitoring data and characteristics of haddock surveyed in the EGB area. Secondly, M for the EGB base model was fixed at 0.2 for years preceding 2010 as in the GB model but was estimated as an age-invariant fixed effect parameter for the last 10 years (2010-2019) of the reconstruction. This choice was made because (a) analyses by the WG suggested a hypothesis that M has increased significantly in the past decade in the EGB unit, and (b) model performance relative to survey index trends improved substantially relative to alternative formulations.

The Panel again **commended** the quality of the model search and the logical presentation of results. Implementation of this WHAM-based EGB assessment model produced results with good model consistency (e.g., small retrospective patterns), and generally good diagnostics (generally good behavior of model residuals and good simulation self-testing performance). Model sensitives were explored and generally supported the choice of model. There were issues of asynchrony in the model predictions of peak years for the survey indices (NFMS fall and DFO spring), low model estimates of selectivity for younger age classes, and residual errors in survey age composition that should be investigated. However, these issues do not preclude consideration of the model for management application.

The Panel was, however, concerned about the utility of the model outside of the current decade as recent strong year classes exit the biomass (i.e., when density dependent effects are reduced and no longer reduce survival, length-at-age, weight-at-age). Also, the relevance of the model to the full GB stock was unclear, as it was developed based only on characteristics of the haddock surveyed in the EGB management area and was not applied to the entire GB management area. The Panel's ability to understand and assess the applicability of the EGB model would have been greatly enhanced if the model had been fit to the full GB dataset.

Overall

The two models are both largely complete and the Panel **recommended** they be used for providing management advice over the short term. They do, however, represent two different hypotheses about stock and fishery dynamics for the Georges Bank haddock population, with the EGB model using a subset of the data available for the entirety of Georges Bank. As a result, the Panel was unable to directly compare the performance of the models or whether they could be applied without producing conflicting advice. The Panel provided a long-term **recommendation** that NOAA and DFO develop a merged or nested haddock assessment model, potentially

implemented using the WHAM framework. Such an approach would be consistent with the conclusion of TOR 12 that "the current distribution and connectivity of haddock across the Bank suggest that haddock on Georges Bank (eastern Georges Bank and western Georges Bank) is a single stock." The Panel, however, is cognizant that management performance and implementation considerations would need to be carefully evaluated when pursuing a single model.

Next, it could be especially helpful to derive a cross-consistent approach to GB/EGB assessment ("convergence" of modelling approaches) if natural mortality is changing over time. Data availability and models fits from EGB indicate that M can be estimated with higher confidence than often seen in assessment models due the unique recent recruitment circumstances for haddock. For the EGB model, the parameterization of M=0.2 prior to 2010 and estimated for the 2010-2019 period is a parsimonious choice that performs well at this time but is sensitive to the period chosen for estimation. A state-space model where M is parametrized as a stochastic process (possibly linked to density of cohort size) should be investigated as long-term research **recommendation**. The objective would be to determine if a model could be formulated that performed similarly to the EGB base model in terms of retrospective and residual patterns. It would be appropriate to evaluate such a model for both the GB and EGB management units. This approach then would provide a consistency cross-check on both models, as the EGB data are largely a subset of the data input to the GB assessment and shows similar trends. This approach would also facilitate nesting the EGB model within the GB model to allow both to be evaluated for management performance.

5. *Update or redefine status determination criteria (Status Determination Criteria, point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and Maximum Sustainable Yield [MSY]) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for Biological Reference Points (BRPs).*

The Panel agrees that this TOR has been met for GB haddock. Note that this TOR was not a requirement for EGB haddock.

The analyst proposed to continue to use $F_{40\%SPR}$ as the proxy to F_{MSY}, based on the full time series for recruitment, with 5-year averages for selectivity, weight-at-age, and SSB. Because of the well documented poor performance of BRPs beyond 3 years for the GB assessment, the expectation is that these will be updated every 2nd year as part of Level 2 management track assessments.

The Panel supported all these decisions. The only significant discussion here related to how this research track assessment would be transitioned to the management track, a topic which is still under discussion at NOAA.

6. *Define the methodology for performing short-term projections of catch and biomass under alternative harvest scenarios, including the assumptions of fishery selectivity, weights at age, maturity, and recruitment.*

The Panel agrees that this TOR has been met for both GB and EGB haddock, though this TOR was generally most relevant to the GB assessment process.

The GB analyst proposed to use WHAM for the projections and specifically to propagate the numbers-at-age consistently with the assumed (stochastic) process model. Two-year averaging was deemed appropriate for numbers-at-age and weight-at-age, with 5 year averaging for selectivity. Again, because of the poor performance of projections beyond 3 years, the expectation is that these averages will be updated every 2nd year as part of management track assessments. Note, however, that those projections are typically made for 4 years including the bridge year.

The Panel supported the approach for GB projections and supported the use of WHAM to perform the projections.

For the EGB projections, the analyst converted the EGB base model implemented in WHAM to an operating model within the OpenMSE framework (https://openmse.com; Hordyk et al. 2022) to develop closed-loop simulations. The state dynamics of the two models were demonstrated to be identical. The primary purpose of this step was to allow investigation of reference points (TOR 11 for EGB only), projection of various management options (TOR 6), and evaluation of "Plan B" options (TOR 8). For TOR 6 two operating models were configured for investigating short-term projections. Both operating models assume the estimation of *M* from 2010 to 2019 ("step up" of the M_{est} base model). However, for simulated future data one of the models reverts to the historical M=0.2 ("low M") while the other maintains the recent estimated *M* for all projection years ("high M", MLE of 0.473).

Ultimately, projections and risk evaluation based on the "low M" scenario were conditionally identified for consideration, while acknowledging the possibility of a future scenario with higher *M*. This conclusion was reached given the higher *M* produced estimates of projected SSB lower than any historical SSB, i.e., stock levels outside of historical precedent. The Panel noted that if decreasing *M* is a function of density dependence it is not clear how long it would take for the density dependence effect to diminish. In this regard, the analyst suggested that the final selection of an *M* projection scenario for the upcoming TRAC assessment could be based on inspection of two years of additional biological and survey data. The Panel supported the proposed projection methodology proposed for EGB.

7. *Review, evaluate and report on the status of the Stock Assessment Review Committee (SARC) and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.*

The Panel agreed that this TOR has been met for both GB and EGB haddock.

This was a very thorough response to the various research recommendations generated as part of previous assessments and peer review. The WG's response to the TOR would, however, have benefited from additional detail to facilitate prioritization of recommendations that have not yet been fulfilled.

8. *Develop a "Plan B" for use if the accepted assessment model fails in the future.*

The Panel agreed that this TOR has been met for both GB and EGB haddock, although it was largely meant for consideration with the GB assessment.

For GB haddock, the analyst proposed the use of Plan B Smooth, an index-based method utilizing Loess smoothing of survey data to produce a multiplier to be applied to prior year's catch or quota data. The recommendation was to use only the NMFS spring and fall survey data (as the DFO survey was incomplete for the GB management unit) over the past 33 years of surveys with a loess span parameter of 0.27.

The Panel was somewhat perplexed about the conditions that would lead to a peer reviewed analytic assessment being replaced with an index-based model, particularly for a data-rich stock like GB haddock. After discussion of these concerns, the Panel seemed comfortable with the understanding that a "Plan B" is intended as a precautionary measure for the future. Still, the Panel **recommended** NOAA establish clear guidance for conditions that would lead to the failure of a peer reviewed analytic model. For example, the proposal for Plan B Smooth recommended adjustments relative to previous quotas rather than catches which would have been established using analytic assessments. The Panel provided **no recommendation** here. With this exception, the Panel supported the Plan B Smooth approach to providing alternative advice for GB haddock.

For EGB haddock, the analyst proposed a single biomass index developed by averaging the NMFS spring, NMFS fall and DFO spring biomass surveys. This index was used to inform three index-based management procedures (MPs): Plan B smooth ('PBS') and a constant index ratio approach (e.g., 'I2'). An alternative set of age-structured indices was developed to inform a new age composition index ('ACI') to determine whether improved performance could be obtained using age-structured information. Ultimately, the I2 approach appeared to provide outcomes most consistent with SSB of the $F_{40\%SPR}$ level based on closed-loop simulation evaluation.

The Panel accepted this approach for EGB haddock.

9. *Review and present any research related to recruitment processes (e.g., spawning and larval transport, and retention), and potential hypotheses for large recruitment events.*

The Panel agreed that this TOR has been met for both GB and EGB haddock.

Both the presentations and underlying research were well done and represented steps forward in understanding haddock stock recruitment. Conversely, the findings also made it clear how difficult it will be to quantify recruitment, particularly with respect to predicting large recruitment events.

10. *Review and present any research related to density-dependent growth*.

The Panel agreed that this TOR has been met for EGB.

No directed work to model density-dependent growth on GB was conducted, however discussion can be found in earlier TORs for dealing with the observed trends in size and weight, and how best to deal with those trends in reference points and short-term projections.

With respect to EGB, the data and analyses presented for review strongly suggest density dependent effects on haddock growth. The Panel noted that consistent results were obtained regardless of whether the analysis was based on the long-term or short-term time series, the latter limited by available phytoplankton bloom statistics. It was noted that the growth variability increased in years with large cohorts (e.g., 2003, 2010, 2013). This observation supported a hypothesis that increased occupancy of suboptimal habitat at higher population densities may result in more variation in growth and perhaps increased mortality.

The analysis highlighted the important challenge of accurately quantifying gear selectivity when there are rapid changes and increased variability in fish size. The Panel pointed this out because of the importance of selectivity and weight/length-at-age to the TOR 6 projections.

11. *For eastern Georges Bank, provide advice to TMGC on appropriate reference points.*

The Panel agreed that this TOR has been met for EGB, though the TOR was very vague as to the expected outcome.

The EGB analyst used this TOR to explore alternative approaches to reference points that could be considered by the TMGC, particularly because reference points provide the foundation for stock projections and implementation of a "Plan B" approach should the assessment model fail. The analyst applied a retrospective forecasting approach within the OpenMSE framework using an operating model derived from the EGB WHAM model (see TOR 6 discussion). Retrospective forecasting of reference points required simulation of historical simulated conditions. Two operating models were investigated, one where reference points were calculated assuming there is no step up in M in the last 10 years ("low M") and another where the estimated M (MLE 0.473) was assumed for the last 10 years ("high M"). A range of alternative $F_{40\%SPR}$ management procedures were tested over the recent past in which relatively large changes in $F_{40\%SPR}$ have occurred due to changes in weight-at-age and fishery selectivity.

The current $F_{ref} = 0.26$ which was derived in 2002 is well below the values of $F_{40\%SPR}$ investigated in the retrospective analysis. It was proposed to adopt a $F_{40\% SPR}$ (current mean value of 0.488) updated every 4 years and calculated as the mean over the last 10 years ('U4M10'). This choice implies trade-offs among biomass level, catches, and catch variability that represent a management choice.

The Panel noted that the closed-loop simulation approach led to management procedures (including control rules). Each management procedure implies trade-offs in performance that could be considered by the TMGC with respect to objectives related to reference points and status determination (whereas the GB analysis under TOR6 would provide BRPs and SDCs).

12. *Review data related to stock structure of haddock on Georges Bank (including eastern Georges Bank management area) and implications for assessments conducted on the whole bank and on subareas of the bank.*

The Panel agreed that this TOR has been met for GB and EGB.

The Panel **commended** the well prepared and presented the materials on GB/EGB stock structure. Adding the hyperstability analysis to the review provided significant improvement to understanding the consequences of different stock structures.

The WG focused on evaluating stock structure relative to the assumptions of stock assessment (e.g., reproductive isolation, demographic independence, homogeneous vital rates, no immigration/emigration). They concluded that neither a GB nor EGB management units met all stock assumptions perfectly; each had pros/cons with respect to meeting the assumptions.

The Panel acknowledged that defining stock structure is complicated given the dynamic distribution of haddock over time but **recommended** the WG's conclusion that "the current distribution and connectivity of haddock across the Bank suggest that haddock on Georges Bank (eastern Georges Bank and western Georges Bank) is a single stock." Also, the Panel agreed with the conclusion that "despite some evidence of geographic variation and partial isolation, haddock in the Great South Channel cannot be considered a separate stock." There were weak connections noted between Georges Bank and other areas or stocks (e.g., Gulf of Maine and Scotian Shelf) although results discussed in earlier TORs suggested that future conditions may change these conclusions (e.g., stock response to climate drivers).

The hyperstability analysis was used to examine the hypothesis that the EGB assessment may suffer from hyperstability by failing to capture range expansion westwards in years of high abundance and assuming expansion into WGB originates from EGB. Estimates of the hyperstability parameter, β, suggested hyperstability in the observations from the NMFS spring and DFO spring surveys, but not in the NMFS fall survey. However, estimates of β derived from the predicted survey observations did not suggest hyperstability. Furthermore, evaluation of estimated selectivity and survey age residuals also did not suggest strong evidence of emigration from EGB into WGB.

The Panel also **suggested** that stock structure and assessments should focus on a biological stock, and stock management should be dealt with somewhat separately but within the context of the biological stock. In this regard, the choice of an assessment model could be considered as one consideration to inform the choice of management approach. For example, one approach to identifying Canadian and US harvests (a TRAC/TMGC issue) for a single biological stock would be to use the assessment model within closed-loop simulations (a Management Strategy Evaluation) focused on the maintenance of comparable fishing mortalities in each management unit.

Another **suggestion** of how to assess an EGB management unit within a larger GB management unit would be to expand the work being done with state space assessment modeling of "linked" stocks. More development of this idea will be available in the CIE Panelist's reports.

Further discussion of how to jointly assess this single stock is provided under TOR 4.

Panel Recommendations

Overall, the Panel thought the Georges Bank and eastern Georges Bank haddock assessments, and the new research track review process were well done. The Panel provided several recommendations which we summarize here.

With respect to the GB and EGB assessments, the Panel provided:

- A recommendation that the two models be used for providing management advice only over the short term. This is coupled with a long-term recommendation that NOAA and DFO develop a merged or nested haddock assessment model, potentially implemented using the WHAM framework.

- A general recommendation supporting the WG's conclusion that "the current distribution and connectivity of haddock across the Bank suggest that haddock on Georges Bank (eastern Georges Bank and western Georges Bank) is a single stock."

- A short-term recommendation that the pattern of simulation bias in the GB assessment model be resolved prior to application of the model for Management Track advice.

- A long-term research recommendation for investigation of a state-space model where *M* is parametrized as a stochastic process (possibly linked to density of cohort size).

- A general recommendation for updates of the gutted fish to whole fish conversion factors for the US and Canadian catch data, noting that conversion factors may depend on the form of the product (e.g., gutted versus gutted and gilled).

With respect to the research track process itself, the Panel recommends that:

- All materials presented in a WG supported Research Track assessments be thoroughly reviewed by the WG prior to submission and presentation to the Panel, such that clear statements can be made that the WG did or did not reach consensus on their recommendations. In cases where consensus is not reached, the reasons should be documented.

- NOAA establish clear guidance for the conditions that would lead to the failure of a peer reviewed analytic model.

Appendix 1 - Terms of Reference for Research Track Georges Bank and eastern Georges Bank Haddock Stock Assessments

1. Review existing research efforts, data, and habitat information in the Gulf of Maine and Georges Bank, identify any findings relevant to influences of ecosystem conditions on haddock, and consider those findings, as appropriate, in addressing other TORs. For processes that the working group deems important and promising that are not currently feasible to consider quantitatively, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments.

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

3. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty in these sources of data.

4. Estimate annual fishing mortality, recruitment and stock biomass (both total and spawning stock) for the time series and estimate their uncertainty. Compare the time series of these estimates with those from the previously accepted assessment model and evaluate the strength and direction of any retrospective pattern(s) in both the current and the previously accepted model. Enumerate possible sources of the retrospective patterns and characterize plausibility, if possible.

5. Update or redefine status determination criteria (SDC point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs.

6. Define the methodology for performing short-term projections of catch and biomass under alternative harvest scenarios, including the assumptions of fishery selectivity, weights at age, maturity, and recruitment.

7. Review, evaluate and report on the status of the Stock Assessment Review Committee (SARC) and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

8. Develop a “Plan B” for use if the accepted assessment model fails in the future.

9. Review and present any research related to recruitment processes (e.g., spawning and larval transport, and retention), and potential hypotheses for large recruitment events.

10. Review and present any research related to density-dependent growth.

Additional GB/EGB TOR

11. For Eastern Georges Bank, provide advice to TMGC on appropriate reference points.

12. Review data related to stock structure of haddock on Georges Bank (including Eastern Georges Bank management area) and implications for assessments conducted on the whole bank and on subareas of the bank.

Appendix 2 – Initial Agenda for Georges Bank and eastern Georges Bank Haddock Research Track Assessment Peer Review meeting, March 28 through March 31, 2022

Monday, March 28, 2022

Time	Topic	Presenter(s)	Notes
11 a.m. - 11:15 a.m.	Welcome/Logistics Introductions/Agenda/Conduct of Meeting	Michele Traver, Assessment Process Lead Russ Brown, PopDy Branch Chief Richard Merrick and Rob Kronlund, Panel Co-Chairs	
11:15 a.m. - 12:45 p.m.	Term of Reference (TOR) #2	Liz Brooks Monica Finley	GB Catch data (US/Can) EGB Catch data (US/Can)
12:45 p.m. - 1:15 p.m.	Discussion/Summary	Review Panel	
1:15 p.m. - 1:45 p.m.	Break		
1:45 p.m. - 3:45 p.m.	TOR #3	Liz Brooks Monica Finley	GB Surveys EGB Surveys
3:45 p.m. - 4 p.m.	Break		
4 p.m. - 4:30 p.m.	Discussion/Summary	Review Panel	
4:30 p.m. - 4:45 p.m.	Public Comment	Public	
4:45 p.m.	Adjourn		

Tuesday, March 29, 2022

Time	Topic	Presenter(s)	Notes
11 a.m. - 11:05 a.m.	Welcome/Logistics	Michele Traver, Assessment Process Lead Richard Merrick and Rob Kronlund, Panel Co-Chairs	
11:05 a.m. - 1 p.m.	TORs #1 and #9	Kevin Friedland Yanjun Wang Liz Brooks	Ecosystem and Recruitment Processes
1 p.m. - 1:30 p.m.	Discussion/Summary	Review Panel	
1:30 p.m. - 2 p.m.	Break		

Time	Topic	Presenter(s)	Notes
2 p.m. - 4 p.m.	TORs #10 and #12	Yanjun Wang Steve Cadrin Brian Linton	Density-Dependent Growth and Stock Structure
4 p.m. - 4:15 p.m.	Break		
4:15 p.m. - 4:45 p.m.	Discussion/Summary	Review Panel	
4:45 p.m. - 5 p.m.	Public Comment	Public	
5 p.m.	Adjourn		

Wednesday, March 30, 2022

Time	Topic	Presenter(s)	Notes
11 a.m. - 11:05 a.m.	Welcome/Logistics	Michele Traver, Assessment Process Lead Richard Merrick and Rob Kronlund, Panel Co-Chairs	
11:05 a.m. - 1 p.m.	TOR #4	Liz Brooks Tom Carruthers Brian Linton	Mortality, Recruitment and Biomass Estimates GB Models EGB Models WG Opinion Survey
1 p.m. - 1:30 p.m.	Break		
1:30 p.m. - 4 p.m.	TOR #4 cont.	Liz Brooks Tom Carruthers Brian Linton	Mortality, Recruitment and Biomass Estimates GB Models EGB Models WG Opinion Survey
4 p.m. - 4:15 p.m.	Break		
4:15 p.m. - 4:30 p.m.	Discussion/Summary	Review Panel	
4:30 p.m. - 4:45 p.m.	Public Comment	Public	
4:45 p.m.	Adjourn		

Thursday, March 31, 2022

Time	**Topic**	**Presenter(s)**	**Notes**
11 a.m. - 11:05 a.m.	Welcome/Logistics	Michele Traver, Assessment Process Lead Richard Merrick and Rob Kronlund, Panel Co-Chairs	
11:05 a.m. - 1 p.m.	TORs #5, #11 and #6	Liz Brooks Tom Carruthers	BRPs EGB Reference Points Projections
1 p.m. - 1:30 p.m.	Break		
1:30 p.m. - 3:30 p.m.	TORs # 8 and #7	Liz Brooks Tom Carruthers Brian Linton	Alternative Assessment Approach Research Recommendations
3:30 p.m. - 4 p.m.	Discussion/Summary	Review Panel	
4 p.m. - 4:15 p.m.	Public Comment	Public	
4:15 p.m. - 4:30 p.m.	Break		
4:30 p.m. - 5:30 p.m.	Panel Wrap-up and report discussion	Review Panel	
5:30 p.m.	Adjourn		

Appendix 3 - Performance Work Statement (PWS) - Center for Independent Experts (CIE) Program – Georges Bank and Eastern Georges Bank Haddock Research Track Peer 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[2]. Further information on the Center for Independent Experts (CIE) program may be obtained from www.ciereviews.org.

Scope

The Research Track Peer Review meeting is a formal, multiple-day meeting of stock assessment experts who serve as a panel to peer-review tabled stock assessments and models. The research track peer review is the cornerstone of the Northeast Region Coordinating Council stock assessment process, which includes assessment development, and report preparation (which is done by Working Groups or Atlantic States Marine Fisheries Commission (ASMFC) technical committees), assessment peer review (by the peer review panel), public presentations, and document publication. The results of this peer review will be incorporated into future management track assessments, which serve as the basis for developing fishery management recommendations.

The purpose of this meeting will be to provide an external peer review of Eastern Georges Bank and Georges Bank and haddock stocks. The requirements for the peer review follow. This Performance Work Statement (PWS) also includes: **Appendix 1**: TORs for the research track, which are the responsibility of the analysts; **Appendix 2:** a draft meeting agenda; **Appendix 3:** Individual Independent Review Report Requirements; and **Appendix 4:** Peer Reviewer Summary Report Requirements.

[2] http://www.cio.noaa.gov/services_programs/pdfs/OMB_Peer_Review_Bulletin_m05-03.pdf

Requirements
NMFS requires three reviewers under this contract (i.e. subject to CIE standards for reviewers) to participate in the panel review. The chair, who is in addition to the three reviewers, will be provided by either the New England or Mid-Atlantic Fishery Management Council's Science and Statistical Committee; although the chair will be participating in this review, the chair's participation (i.e., labor and travel) is not covered by this contract.

Each reviewer will write an individual review report in accordance with the PWS, OMB Guidelines, and the TORs below. All TORs must be addressed in each reviewer's report. The reviewers shall have working knowledge and recent experience in the use and application of index-based, age-based, and state-space stock assessment models, including familiarity with retrospective patterns and how catch advice is provided from stock assessment models. In addition, knowledge and experience with simulation analyses is required.

Tasks for Reviewers

- Review the background materials and reports prior to the review meeting
    - Two weeks before the peer review, the Assessment Process Lead will electronically disseminate all necessary background information and reports to the CIE reviewers for the peer review.
- 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 provide any additional information required by the reviewers, and to answer any questions from reviewers
- Reviewers shall conduct an independent peer review in accordance with the requirements specified in this PWS and TORs, in adherence with the required formatting and content guidelines; reviewers are not required to reach a consensus.
- Each reviewer shall assist the Peer Review Panel (co)Chair with contributions to the Peer Reviewer Summary Report
- Deliver individual Independent Reviewer Reports to the Government according to the specified milestone dates
- This report should explain whether each research track Term of Reference was or was not completed successfully during the peer review meeting, using the criteria specified below in the "Tasks for Peer Review Panel."
- If any existing Biological Reference Points (BRP) or their proxies are considered inappropriate, the Independent Report should include recommendations and justification for suitable alternatives. If such alternatives cannot be identified, then the report should indicate that the existing BRPs are the best available at this time.
- During the meeting, additional questions that were not in the Terms of Reference but that are directly related to the assessments and research topics may be raised. Comments on these questions should be included in a separate section at the end of the Independent Report produced by each reviewer.
- The Independent Report can also be used to provide greater detail than the Peer Reviewer Summary Report on specific stock assessment Terms of Reference or on additional questions raised during the meeting.

Tasks for Review panel

- During the peer review meeting, the panel is to determine whether each research track Term of Reference (TOR) was or was not completed successfully. To make this determination, panelists should consider whether the work provides a scientifically credible basis for developing fishery management advice. Criteria to consider include: whether the data were adequate and used properly, the analyses and models were carried out correctly, and the conclusions are correct/reasonable. If alternative assessment models and model assumptions are presented, evaluate their strengths and weaknesses and then recommend which, if any, scientific approach should be adopted. Where possible, the Peer Review Panel chair shall identify or facilitate agreement among the reviewers for each research track TOR.
- If the panel rejects any of the current BRP or BRP proxies (for B_{MSY} and F_{MSY} and MSY), the panel should explain why those particular BRPs or proxies are not suitable, and the panel should recommend suitable alternatives. If such alternatives cannot be identified, then the panel should indicate that the existing BRPs or BRP proxies are the best available at this time.
- Each reviewer shall complete the tasks in accordance with the PWS and Schedule of Milestones and Deliverables below.

Tasks for Peer Review Panel chair and reviewers combined:

The Peer Review Panel (co)Chair, with the assistance from the reviewers, will write the Peer Reviewer Summary Report. Each reviewer and the (co)chair will discuss whether they hold similar views on each research track Term of Reference and whether their opinions can be summarized into a single conclusion for all or only for some of the Terms of Reference of the peer review meeting. For terms where a similar view can be reached, the Peer Reviewer Summary Report will contain a summary of such opinions.

The (co)chair's objective during this Peer Reviewer Summary Report development process will be to identify or facilitate the finding of an agreement rather than forcing the panel to reach an agreement. The (co)chair will take the lead in editing and completing this report. The (co)chair may express their opinion on each research track Term of Reference, either as part of the group opinion, or as a separate minority opinion. The Peer Reviewer Summary Report will not be submitted, reviewed, or approved by the Contractor.

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, country of birth, country of citizenship, country of permanent residence, country of current residence, dual citizenship (yes, no), passport number, country of passport, travel dates.) to the NEFSC Assessment Process Lead 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-national-

registration-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 held remotely, via WebEx video conferencing.

Period of Performance - The period of performance shall be from the time of award through April 14, 2022. Each 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 2 weeks of award	Contractor selects and confirms reviewers
Approximately 2 weeks later	Contractor provides the pre-review documents to the reviewers
March 28-31, 2022	Panel review meeting
Approximately 2 weeks later	Contractor receives draft reports
Within 2 weeks of receiving draft reports	Contractor submits final reports to the Government

* The Peer Reviewer Summary Report will not be submitted to, reviewed, or approved by the Contractor.

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 (3) The reports shall be delivered as specified in the schedule of milestones and deliverables.

Travel - No travel is necessary, as this meeting is being held remotely.

Restricted or Limited Use of Data -The contractors may be required to sign and adhere to a non-disclosure agreement.

NMFS Project Contact
Michele Traver, NEFSC Assessment Process Lead
Northeast Fisheries Science Center
166 Water Street, Woods Hole, MA 02543
Michele.Traver@noaa.gov

Haddock Research Track Terms of Reference

1. Review existing research efforts, data, and habitat information in the Gulf of Maine and Georges Bank, identify any findings relevant to influences of ecosystem conditions on haddock, and consider those findings, as appropriate, in addressing other TORs. For processes that the working group deems important and promising that are not currently feasible to consider quantitatively, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments.

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

3. Present the survey data being used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, etc.). Characterize the uncertainty in these sources of data.

4. Estimate annual fishing mortality, recruitment, and stock biomass (both total and spawning stock) for the time series and estimate their uncertainty. Compare the time series of these estimates with those from the previously accepted assessment model and evaluate the strength and direction of any retrospective pattern(s) in both the current and the previously accepted model. Enumerate possible sources of the retrospective patterns and characterize plausibility, if possible.

5. Update or redefine status determination criteria (SDC point estimates or proxies for B_{MSY}, $B_{THRESHOLD}$, F_{MSY} and MSY) and provide estimates of their uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for BRPs.

6. Define the methodology for performing short-term projections of catch and biomass under alternative harvest scenarios, including the assumptions of fishery selectivity, weights at age, maturity, and recruitment.

7. Review, evaluate and report on the status of the Stock Assessment Review Committee (SARC) and Working Group research recommendations listed in most recent SARC reviewed assessment and review panel reports. Identify new research recommendations.

8. Develop a “Plan B” for use if the accepted assessment model fails in the future.

9. Review and present any research related to recruitment processes (e.g., spawning and larval transport, and retention), and potential hypotheses for large recruitment events.

10. Review and present any research related to density-dependent growth.

Additional GB/EGB TOR

11. For Eastern Georges Bank, provide advice to TMGC on appropriate reference points.

12. Review data related to stock structure of haddock on Georges Bank (including Eastern Georges Bank management area) and implications for assessments conducted on the whole bank and on subareas of the bank.

General Clarification of Terms that may be used in the Research Track Terms of Reference

Guidance to Peer Review Panels about "Number of Models to include in the Peer Reviewer Report":

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

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

> *Acceptable biological catch (ABC)* is a level of a stock or stock complex's annual catch that accounts for the scientific uncertainty in the estimate of Overfishing Limit (OFL) and any other scientific uncertainty…" *(p. 3208) [In other words, OFL ≥ ABC.]*
>
> *ABC for overfished stocks.* For overfished stocks and stock complexes, a rebuilding ABC must be set to reflect the annual catch that is consistent with the schedule of fishing mortality rates in the rebuilding plan. *(p. 3209)*
>
> NMFS expects that in most cases ABC will be reduced from OFL to reduce the probability that overfishing might occur in a year. (p. 3180)
>
> ABC refers to a level of ''catch'' that is ''acceptable'' given the ''biological'' characteristics of the stock or stock complex. As such, Optimal Yield (OY) does not equate with ABC. The specification of OY is required to consider a variety of factors, including social and economic factors, and the protection of marine ecosystems, which are not part of the ABC concept. (p. 3189)

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

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

Participation among members of a Research Track Working Group:

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

Individual Independent Peer Reviewer Report Requirements

1. The independent Peer Reviewer report shall be prefaced with an Executive Summary providing a concise summary of whether they accept or reject the work that they reviewed, with an explanation of their decision (strengths, weaknesses of the analyses, etc.).

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. The independent report shall be an independent peer review and shall not simply repeat the contents of the Peer Reviewer Summary Report.

    a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including a concise summary of whether they accept or reject the work that they reviewed, and explain their decisions (strengths, weaknesses of the analyses, etc.), 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 Peer Reviewer Summary Report that they believe might require further clarification.

    d. The report may include recommendations on how to improve future assessments.

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.

4. Peer Reviewer Summary Report Requirements

    a. The main body of the report shall consist of an introduction prepared by the Research Track Peer Review Panel chair that will include the background and a review of activities and comments on the appropriateness of the process in reaching the goals of the peer review meeting. Following the introduction, for each assessment /research topic reviewed, the report should address whether or not each Term of Reference of the Research Track Working Group was completed successfully. For each Term of Reference, the Peer Reviewer Summary Report should state why that Term of Reference was or was not completed successfully.

    To make this determination, the peer review panel chair and reviewers should consider whether or not the work provides a scientifically credible basis for developing fishery management advice. If the reviewers and peer review panel chair do not reach an agreement on a Term of Reference, the report should explain why. It is permissible to express majority as well as minority opinions.

The report may include recommendations on how to improve future assessments.

b. If any existing Biological Reference Points (BRPs) or BRP proxies are considered inappropriate, include recommendations and justification for alternatives. If such alternatives cannot be identified, then indicate that the existing BRPs or BRP proxies are the best available at this time.

c. The report shall also include the bibliography of all materials provided during the peer review meeting, and relevant papers cited in the Peer Reviewer Summary Report, along with a copy of the CIE Performance Work Statement.

The report shall also include as a separate appendix the assessment Terms of Reference used for the peer review meeting, including any changes to the Terms of Reference or specific topics/issues directly related to the assessments and requiring Panel advice.

Appendix 4 - Materials provided or referenced during the Georges Bank and eastern Georges Bank Haddock Research Track Stock Assessment Peer Review meeting

Brooks, E.N, M.L. Traver, S.J. Sutherland, L. Van Eeckhaute, and L. Col. 2008. In. Northeast Fisheries Science Center. 2008. Assessment of 19 Northeast Groundfish Stocks through 2007: Report of the 3rd Groundfish Assessment Review Meeting (GARM III), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 4-8, 2008. US Dep Commer, NOAA Fisheries, Northeast Fish Sci Cent Ref Doc. 08-15; 884 p + xvii. http://www.nefsc.noaa.gov/publications/crd/crd0815/

Friedland, K.D., J.A. Langan, S.I. Large, R.L. Selden, J.S. Link, R.A Watson, and J.S. Collie. 2020. Changes in higher trophic level productivity, diversity and niche space in a rapidly warming continental shelf ecosystem. Science of the Total Environment 704: 135270.

Hordyk, A.R., Q. Huynh, and T.R. Carruthers. 2022. *OpenMSE R Package* (1.0.0) [Computer software]. Blue Matter Science. https://cran.r-project.org/package=openMSE.

Legault, C.M. and V.R. Restrepo. 1998. A flexible forward age-structured assessment program. ICCAT. Col. Vol. Sci. Pap. 49: 246–253.

NEFSC (Northeast Fisheries Science Center). 2017. Operational Assessment of 19 Northeast Groundfish Stocks, Updated Through 2016. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 17-17; 259p. doi: 10.7289/V5/RD-NEFSC-17-17.

NEFSC (Northeast Fisheries Science Center). 2019. Georges Bank haddock 2019 assessment update report. Unpubl. Rpt. 10 pp. nefsc.fisheries.noaa.gov/saw/sasi/sasi_report_options.php

NEFSC (Northeast Fisheries Science Center). In Review. Final Report of the Haddock Research Track Assessment Working Group. Unpubl. Rpt. 65 pp. https://apps-nefsc.fisheries.noaa.gov/saw/sasi/sasi_report_options.php

Stock, B.C., and T. J. Miller. 2021. The Woods Hole Assessment Model (WHAM): A general state-space assessment framework that incorporates time- and age-varying processes via random effects and links to environmental covariates. Fisheries Research 240, 105967. https://doi.org/10.1016/j.fishres.2021.105967

TRAC (Transboundary Resources Assessment Committee). 2019. Eastern Georges Bank haddock [5Zjm; 551,552,561,562]. TRAC Status Report 2019/01.

TRAC (Transboundary Resources Assessment Committee). 2021. Eastern Georges Bank haddock [5Zjm; 551,552,561,562]. TRAC Status Report 2021/01.

Appendix 5 - Meeting attendees at the Georges Bank and eastern Georges Bank Haddock Research Track Stock Assessment Peer Review meeting

NEFSC - Northeast Fisheries Science Center
GARFO - Greater Atlantic Regional Fisheries Office
NEFMC - New England Fisheries Management Council
DFO - Department of Fisheries and Oceans (Canada)
SMAST - University of Massachusetts School of Marine Science and Technology
MAMFI - Massachusetts Marine Fisheries Institute
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Richard Merrick - US Co-Chair
Allen (Rob) Kronlund - Canadian Co-Chair
Joe Powers - CIE Panel
Anders Nielsen - CIE Panel
Kevin Stokes - CIE Panel

Russ Brown - NEFSC, Population Dynamics Branch Chief
Michele Traver - NEFSC, Assessment Process Lead

Abigail Tyrell - NEFSC
Alain d'Entremont - Scotia Harvest Inc., TMGC Canadian co-chair
Alex Hansell - NEFSC
Alicia Miller - NEFSC
Angela Forristall - NEFMC Staff
Anthony Wood - NEFSC
Brian Linton - NEFSC
Cate O'Keefe - Fisheries Applications Consulting Team
Catriona Regnier-McKellar - DFO
Charles Adams - NEFSC
Charles Perretti - NEFSC
Irene Andrushchenko - DFO
Jamie Cournane - NEFMC Staff
Jason Boucher - NEFSC
Kathryn Cooper-MacDonald - DFO
Kathy Sosebee - NEFSC
Kevin Friedland - NEFSC
Kris Vascotto - Atlantic Groundfish Council, Executive Director
Larry Alade - NEFSC
Libby Etrie - NEFMC Member
Liz Brooks - NEFSC
Liz Sullivan - GARFO
Lottie Bennett - DFO
Mark Terceiro - NEFSC
Melanie Griffin - MAMFI
Michelle Greenlaw - DFO
Mike Simpkins - NEFSC
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Monica Finley - DFO
Paul Nitschke - NEFSC
Robin Frede - NEFMC Staff
Sarah Salois - NEFSC
Scott Large - NEFSC
Steve Cadrin - SMAST
Tara McIntyre - DFO
Tara Trinko Lake - NEFSC
Tim Miller - NEFSC
Tom Carruthers - Blue Matter Science, consultant for DFO
Tom Nies - NEFMC, Executive Director
Toni Chute - NEFSC
Yanjun Wang - DFO