Center for Independent Experts (CIE)_Independent Peer Reviewer Report of the Atlantic Cod Research Track Stock Assessment

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Executive Summary

This report provides an independent peer review of the 2023 Atlantic Cod Research Track Stock Assessment. Previous assessments of Atlantic Cod (*Gadus morhua*) were based on two stocks: the Gulf of Maine and Georges Bank. Both assessments suffered from retrospective bias and the Georges Bank assessment was rejected in 2015 and substituted by a data limited approach. The Atlantic Cod Research Track Working Group (WG) adopted, to the extent possible, the stock structure recommended by the Atlantic Cod Stock Structure Working Group. It therefore developed four assessments: i) Western Gulf of Maine (WGOM), ii) Georges Bank (GB), iii) Southern New England (SNE) and iv) Eastern Gulf of Maine (EGOM).

The WGOM and GB assessments were developed from the previous Gulf of Maine and Georges Bank assessments respectively with changes to area boundaries (and therefore commercial and survey data aggregations), inclusion of new surveys where possible and a switch from the Age Structured Assessment Program (ASAP) to the Woods Hole Assessment Model (WHAM) assessment modelling platform. The SNE and EGOM assessments were essentially new and final proposed versions of these assessments also used the WHAM platform. A significant motivation for using WHAM models was the ability to include random effects in recruitment, natural mortality *M* or numbers at age (NAA). Other considerations were the ability to estimate reference points and make projections within the model and platform consistency across the four cod stocks.

The WG also attempted to identify environmental drivers that might influence Atlantic cod stock dynamics. Exploratory modeling was able to establish links between temperature and cod weight at age in WGOM and GB stocks. For the GB region it also identified a distributional shift in cod on GB in spring. Environmental drivers for recruitment can be tested directly in WHAM and this was done for the WGOM stock. For the most part, however, the WG attempted to accommodate ecosystem/climate influences through inclusion of random effects in the models. Further exploration of explicit environmental drivers was limited by time constraints. This area is something that can be returned to in future research tracks.

The scientific and statistical analyses were presented to a review panel between 31 July and 3 August 2023. The analyses and presentations provided by the WG were of a high standard and the WG report thorough. This reviewer accepts the WG's recommended assessments for all four stocks. The WG made recommendations for future research. The Review Panel categorized these into different levels of priority and made some additional recommendations. Both the prioritization and new recommendations were agreed by all panel members. The WG recommended that any backup assessment for providing scientific advice to managers remain an integrated assessment. I agree with this recommendation because stock status appears robust for all stocks and because retaining an integrated assessment allows for its continued development.

Background

Previous stock assessments for Atlantic Cod (*Gadus morhua*) in the Northeast USA were based on two stocks: the Gulf of Maine (most recently updated in 2021) and Georges Bank (age-based

stock assessment rejected in 2015, the 'Ismooth' data limited approach (Legault et al. 2023) was used in 2017, 2019, and 2021). Following growing concerns the two areas were not correctly representing cod stock structure, the Atlantic Cod Stock Structure Working Group (McBride and Smedbol, eds. 2022) performed an extensive review of information available and identified five biological units in the area, including two biological units in the Western Gulf of Maine, the winter and spring spawning components. The Atlantic Cod Research Track Working Group (WG) adopted the stock structure working group's areas but, because of operational difficulties in partitioning biological data, opted to combine the winter and spring spawning components into one assessment unit. The Atlantic Cod Research Track Working Group therefore conducted four assessments: i) Western Gulf of Maine (WGOM), ii) Georges Bank (GB), iii) Southern New England (SNE) and iv) Eastern Gulf of Maine (EGOM). There is a separate assessment unit on Eastern Georges Bank managed jointly by the USA and Canada.

The Research Track Stock Assessment Peer Review Panel met via WebEx on July 31 – August 3, 2023. The Panel was composed of three scientists selected by the Center for Independent Experts (CIE): Noel Cadigan (Independent contractor, Newfoundland and Labrador, Canada), Steven Holmes (National Institute of Water and Atmospheric Research, New Zealand), and Coby Needle (Independent contractor, Scotland). The Panel was chaired by Jean-Jacques Maguire (New England Fishery Management Council).

The WG attempted to convey all the necessary information for the peer review panel to draw conclusions (on whether to accept the work reviewed) in the WG report, but in addition provided 20 working papers that included additional details and background information. The Panel was also given access to the GitHub repository used by the WG for cod modeling. The list of materials provided for review is given in Appendix 1. The Performance Work Statement for CIE reviewers is provided in Appendix 2 and the list of attendees in Appendix 3.

Overall Comments and Comments by ToR

The WG attempted to convey in the WG report all necessary information for the peer review panel to draw conclusions on whether to accept the work reviewed and to a large degree this was successful. The WG report was well organized, which was helped by a logical sequence of ToRs. This, in combination with the presentations on each ToR greatly facilitated the Panel's work. Because there were four assessments ToRs 4, 5, 6 and 8 were presented on a stock-by-stock basis which was a good initiative. All members of the WG were responsive to questions and requests for additional information. That said, I feel the review suffered a little from the sheer volume of information. Specific details varied between stocks and might be detailed in a ToR, or a stock focused document (and cross references were a bit circular at times) sometimes making fact checking when completing reports quite difficult.

All further comments and recommendations are made against each ToR.

TOR 1. Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the relevant sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other TORs. Report how the findings were considered under impacted TORs.

I conclude that this ToR was fully addressed for all WGOM, GB, SNE and EGOM cod stocks.

The literature review on this subject area appeared very comprehensive. Given the strong evidence of recent environmental changes, especially in the Gulf of Maine region, restricting the literature review to papers published after the year 2000 was reasonable. The aim of the sub-group was the inclusion of ecosystem considerations in assessment model assumptions and parameterization if warranted. The approach taken was logical and well presented: science reviews to establish indicators, consideration of which indicators affect which life history traits, rationalization of indicators via consistent criteria (theoretical merit, i.e., the ability of the indicator to inform knowledge of a key process and operational merit, i.e., the ability of the indicator to be created and analyzed in a timely manner), and exploratory modeling to test the strength of linkages.

As part of the first phase the WG elicited fishers' expert knowledge and perspectives at workshops held in February and March 2022. Summaries of the possible influences on cod that were raised during the meeting were made in the main report, two working papers and the presentation given to the Panel. However, with respect to some of the topics raised it was unclear the extent to which these had been followed up. Another member of the Panel also identified several papers on seal predation of cod that were not in the references cited by the WG. Given the large number of potential ecosystem and climate influences that needed consideration I can imagine resource limitations prevented certain lines of investigation being pursued, but hopefully, even if it wasn't possible to follow-up on suggestions in this research track it can be done in future. It would be unfortunate if this good initiative started to be perceived unfavorably by stakeholders (as something of a 'tick box' exercise), reducing the potential for good science-industry cooperation in future.

I was pleased to see the WG recommended "further exploration of density dependent effects and evaluation of the likelihood of spurious relationships identified between ecosystem drivers and aspects of stock dynamics". Generalized additive models (GAMs) can only test for statistically significant correlations between a dependent variable and postulated explanatory covariates and the likelihood that some significant results indicated causation seemed unlikely (e.g., zooplankton abundance as a cause for fish condition at ages where zooplankton would no longer be the prey). The WG identified a potentially very useful tool for teasing out genuine causality (convergent cross mapping or CCM) and I encourage this aspect of work to be continued.

The development of stock size indices by integrating survey data using the Vector Autoregressive Spatio-Temporal (VAST) package was explored but not considered ready for inclusion into the stock assessments. The model has, however, already proven useful in a broader context, e.g., it estimated centers of gravity for three size classes of cod and a working paper clearly illustrated that stock centers of gravity for all size classes were typically well within the spatial bounds of the model and therefore high emigration out of the model spatial domain as the cause of population decline was not supported. Results also highlighted the importance of relatively small areas within the stock areas to the size classes of cod and a general indication of a northward and offshore shift

and contraction in spatial distribution. This last point seems especially important considering concerns about conflicting signals from the Northeast Fisheries Science Center (NEFSC) and Canadian Department of Fisheries (DFO) spring surveys for the GB stock. I recommend further work using VAST with one possibility being a version of the model just concentrated on the GB area. The current model, for practical considerations, used type of survey as the grouping variable for the 'vessel effect' random variable. A model focused on the GB area may be able to reconcile the NEFSC-DFO spring surveys issue. Also, because of the reduced number of surveys relevant to the area, concerns over the change in catchability within the NEFSC survey when the vessel changed from the Albatross to the Bigelow in 2009 could be addressed by supplying vessel to the 'vessel effect' random variable. Finally, a GB focused model would not need to use extrapolated bottom temperature, which was a requirement for inshore strata with the current model.

Under ToR 1, the WG tested for environmental influences on recruitment, growth (condition and weights-at-age) and distribution. Sensitivity runs for the SNE assessment when using the Stock Synthesis platform showed promise for the inclusion of environmental covariates, but time constraints prevented the same explorations using WHAM. As the research track progressed WHAM became the preferred model platform across all four stocks (see ToR 4). In the WHAM models only models for recruitment were explored further as condition and distribution cannot yet be implemented directly. In only one WHAM model, that for WGOM, was it attempted to use environmental data explicitly, as explanatory covariates (three temperature related metrics). For both SNE and EGOM a relatively late switch to WHAM and time constraints were cited as the reason for not considering potential environmental drivers explicitly and, although not stated, this may also have been a factor for the GB assessment. It was clear analysts wish to conduct further investigations of the utility of potential environmental covariates and this is something I support.

For the most part the WG attempted to accommodate ecosystem/climate influences through inclusion of random effects in the models, although these couldn't always be adopted because of model non-convergence or poor diagnostics. It is possible the inclusion of random effects in recruitment and/or *M* and/or numbers at age (ages 2+) may negate the need to identify specific causal links between environmental drivers and a species' dynamics. However, a reliable causal link, if identified, might increase confidence in projections if the covariate can be predicted.

Ecosystem/climate changes were accommodated in reference point calculations and projections by recognizing changes in weight-at-age and maturity-at-age and using the last five years of weight-at-age (WAA) and maturity-at-age (MAA) data for the calculations (although not for SNE and not for EGOM for WAA where the data are too few). Conflicting indicators led to some debate within the review about the time period that best represented possible recruitment for reference point and projection calculations (for the WGOM stock). The WG was fully aware that the correct choice was not always clear cut and had recommended a 'discussion' across species. Russell Brown informed the Panel that a research track focused on projections is likely to take place in the near future and I welcome that development.

TOR 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.

I conclude that this ToR was fully addressed for all WGOM, GB, SNE and EGOM cod stocks.

The assignment of 'miscellaneous' statistical areas to the new stock areas was well handled with a good use of length frequency comparisons. The move to assessing as four stocks has reduced the amount of sampled data for any given stock assessment. Landed weights in the SNE and EGOM areas suggest commercially sampled data from these areas will be very scarce (EGOM has very little or no length sampling from any market category for most of the last decade). Biological sampling is stratified by market categories. It was possible length samples could be missing for a market category from an entire year. When the effect of this was investigated by dropping length samples from a category in each year from WGOM data (where length samples were always available) the WG found on average the result was substantial bias in numbers at age (NAA) and weights at age (WAA). As a panel we agreed with the decision to not estimate NAA and WAA in years with a missing market category.

Given the very low commercial landings currently, recreational catches have become a significant source of fishing mortality in the SNE and EGOM areas (representing well over 80% of catches in SNE in 2019-2021 and up to 40% of removals in EGOM). The explanation for retaining raw length frequencies for the recreational catch rather than using 'expanded length frequency' was well made and the decision accepted. Age samples are not collected for the recreational fisheries. Length data from the recreational catch are converted to ages using age samples from the commercial fisheries and surveys. Given the almost complete lack of commercial samples from the EGOM, ages are being inferred from the surveys. The spatial coverage of the surveys that can be used in the area seems reasonable and all ages of fish are covered, however cohort tracking was weak across all surveys tracking multiple ages, (see also ToR 3).

Recreational catch estimates are provided by the Marine Recreational Information Program (MRIP). The data are collected in two-month periods or 'waves'. Wave one (January-February) is only collected towards the south of the SNE stock area (it is a known period of low fishing activity further north). Data from wave one was not available to the WG but should be incorporated in the SNE assessment when available.

When calculating numbers at age (NAA) and weights at age (WAA) for the recreational catch, for EGOM and WGOM gaps in the age-length key were filled using a multinomial regression. For SNE such gaps were filled using a state-space growth model. The motivation for the state-space model was the lack of age data from commercial or survey data in some years in the SNE area. The resulting growth model seemed a reasonable fit to the data available, but in some years, there was a suggestion the age-length curve would tend towards too low an asymptote, i.e., gave a higher age for a given length than was justified by the data. Using the state-space growth model led to considerably more entries at older ages than using the standard annual ALK, which was interpreted by the WG as the standard ALK 'missing' older ages, but it is not clear to me the problem is not one of the state-space growth model estimating ages that are too high. Another consequence was fewer yearly values for fish at age one from the growth model compared to the standard annual

ALK. It is believed this is because those fish at a length the ALK would assign to age one, the growth model assigned to age two, resulting in more years with no fish at age one estimated to have been caught. What the state-space growth model does allow is to fill in for years where raw age data are missing completely.

In the EGOM area, from previous studies it was estimated lobster trap dead discards accounted for 50% of total removals in 2013, but more recent data on lobster trap discards was not available. All members of the Review Panel considered it essential that a time series of lobster trap discards be available and incorporated into the management track assessment for this stock.

Discard mortality rates are applied to discards from all sources. It was pointed out by another panel member that the rates applied seemed low compared to estimates from studies conducted elsewhere. The comment was primarily related to recreational catch discard mortality. The studies used to inform the WG on the likely rate in the SNE area varied widely in their estimates but as a panel we accepted the WG had done the best possible to reconcile these differences and the rate used (30%) was logically derived. The WG recommended further studies on this subject and given the importance of recreational catch in the SNE area, this was a recommendation to which all panel members agreed.

TOR 3. Present the survey data used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, application of catchability and calibration studies, etc.) and provide a rationale for which data are used. Describe the spatial and temporal distribution of the data. Characterize the uncertainty in these sources of data.

I conclude that this ToR was fully addressed for all WGOM, GB, SNE and EGOM cod stocks.

The WG considered the utility and appropriateness of eleven survey indices, including surveys utilizing different gears (bottom long line and jigging) as well as the familiar bottom trawl surveys. In the main report and presentations, the WG was consistent regarding the exploratory and diagnostic summaries presented and a large amount of material was presented. To conclude on whether the available surveys were able to track cohort strength for the four stocks, panel members more familiar with diagnostics used in ICES assessments requested bivariate scatterplots with fitted linear regressions and associated correlation coefficients, survey catch curves, and time-series of log survey indices by age (with cohort as the *x*-axis). The first two types of figures were produced overnight and presented during the review meeting (commercial data was also included). In my opinion the additional plots did prove useful and should be standard output for future research and management track assessments. However, given the number of surveys accepted for use across four stock assessments there was insufficient time to consider each survey and its applicability to a given assessment in much detail in this review.

The time series analyses presented in WP 9 appeared a little inconclusive, although (with one exception) the analyses suggested fall results for a given survey could not be predicted by spring results from the same survey series. The point was made in that paper's summary that there is

some inconsistency between surveys in what months constitute spring and fall. Standardizing boundaries between seasons would be a good idea.

The inclusion of surveys that do not cover the whole stock area and that do not or only partially overlap does suggest the pursuit of a method for creating a single spatio-temporal survey index based on the contributing surveys. The WG did explore using the Vector Autoregressive Spatio-Temporal (VAST) package (see also ToR 1) and I agreed with the rest of the Panel that this work should be continued. The integration does not necessarily need to be over the full four stock area. If the four-stock hypothesis is correct the method could be applied to the individual stock areas, possibly facilitating work prior to, and inclusion in, a management track assessment. An alternative to the VAST approach would be use of a spatio-temporal GAM (generalized additive model). From the work done under ToR 1 there is clearly expertise in GAM modelling available. Cross comparison of results between methods could act to increase confidence in results.

The results from the Groundfish LPUE project were presented under ToR 3. Only one index was proposed for inclusion in an assessment, that for the recreational LPUE index for the SNE stock (based on 'for hire' vessels). I agreed with the rest of the Panel that it was necessary to include the index because of the lack of other data for this stock and the relative importance of recreational catch compared to commercial catch in this area in recent years. A concern was that the index was based only on positive data (i.e., those recreational fishing events that had led to cod catch) and would not respond appropriately (produce biased estimates) if there were trends in the proportion of zero catches over time. It was agreed with the WG that it should not be attempted to produce a new index including zero returns during the panel review because thought was required over what trips should be eligible for inclusion. It should be possible to produce a revised index including zero catches by the time of the next management track assessment and as a panel we strongly recommended this happen. As a panel we agreed that an LPUE index from a recreational fishery was less likely than a commercial fleet to be affected by hyper-stability. All other LPUE indices were rejected by the WG because of poor diagnostics when included in assessment models. For the WGOM and GB stocks it does not seem a pressing issue as these areas are well served by surveys and sampled commercial data. However, I note that a recreational LPUE index for the EGOM stock was not attempted. The EGOM stock is relatively data poor and recreational catch a significant component of landings. I would encourage future work to investigate the feasibility of a recreational LPUE index for the EGOM stock.

TOR 4. Use appropriate assessment approach to 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(s). Evaluate a suite of model fit diagnostics (e.g., residual patterns, sensitivity analyses, retrospective patterns), and (a) comment on likely causes of problematic issues, and (b), if possible and appropriate, account for those issues when providing scientific advice and evaluate the consequences of any correction(s) applied.

I conclude that this ToR was mostly addressed, i.e., all four proposed assessments are accepted for use in subsequent management track processes. However, I agree with other panel members

there are research recommendations that must be addressed before using the models in management track processes for two of the stocks. I highlight these at the end of subsections for those stocks.

The WG had established a clear set of criteria for model selection that was consistent across stocks, and this was communicated clearly to the Review Panel. It was a recommendation from a recent review in which I participated that presentations on model development explicitly reference the selection criteria used and it was good to see the idea well executed in this research track.

It was noticed that many of the exploratory WHAM model runs seem to have been discarded due to a lack of convergence in the run. I agree with other panel members that this issue should be explored more fully in future. It was suggested, for example, that a resolution could be as simple as resetting parameter bounds if lack of convergence is due to bounds being reached. The WG had explored many different configurations of model and for a couple of stocks the decision to switch to the WHAM platform had come relatively late in the research track process so I can fully understand it would not have been possible to devote large amounts of time to any given run. However, a failure of convergence during this research track should not rule out a given model configuration for the future. This view is reinforced by the realization that for the WGOM stock, and to an extent other stocks, if a new or changed feature of the assessment model had been accepted it was retained in all subsequent investigations. It is possible a model change, e.g., age dependent *M*, that failed to converge or provide good diagnostics given the overall model set up in place, may have performed better given differences in model set up elsewhere.

A major difference between the assessments using the WHAM platform and the preceding ASAP assessments was the introduction of random effects. NAA random effects in particular seem to be an effective way to improve model diagnostics but may also act as a convenient way to mask model misspecification and/or biased data. For the WGOM stock the WG conducted missing catch experiments such that catch data provided to the model were the result of reported catch linearly reduced to 75% or 25% of the original value over the final 20 years. The WG concluded the missing catch led to "generally unaffected" model diagnostics but "increasingly negative process errors with increasing missing catch". The WG cautioned against assuming that NAA process errors indicate changes in natural mortality. In management track and research track assessments going forward it will be important to consider any trends in process errors if random effects are incorporated.

The WHAM platform was chosen in all cases partly for reasons of platform consistency across the four cod stocks. I consider this entirely reasonable given that hopefully it allows expertise to be transferred readily between analysts and developed to a high level across a larger pool of personnel.

Presentations were given on a stock-by-stock basis (covering ToRs 4, 5, 6 and 8) and all were comprehensive and helpful. Comments specific to each stock follow.

Western Gulf of Maine (WGOM)

In addition to a presentation to the Panel the assessment of the WGOM stock was presented through the relevant section in the main report under ToR 4, as well as via WP 17.

The new WGOM stock boundaries differ from the former stock area by excluding statistical areas 511 and 512 (which now form part of the EGOM assessment area) but adding statistical areas 521 and 526 (formally part of the GB assessment area) and fishery data from 541.

Key differences in the former assessment model and the final model presented to the Panel were summarized in the main document (Table 1):

Table 1: WGOM assessment model comparison

	GOM model (NEFSC 2013)	Proposed final WGOM model
Model platform	ASAP	WHAM
Start year	1982	1981
Fleet structure	Single fleet	Two fleet (recreational and commercial)
Fleet selectivity blocks	1982 - 1989, 1990 - 2004, 2005+	1981 - 1989, 1990 - 2011, 2012+
Fleet selectivity function	logistic	Logistic, logistic, age-specific
Age-composition distribution	Multinomial	Dirichlet
Indices of abundance	NEFSC BTS spring, NEFSC BTS fall, MADMF spring	NEFSC BTS spring, NEFSC BTS fall, MADMF spring, MENH spring, MENH fall, IBS spring, BLLS spring, BLLS fall
NEFSC BTS vessel calibration	Calibrated to FSV Albatross units	Uncalibrated (split)
Recruitment	Deviations from mean as fixed effects	Deviations from the mean as random effects
M	M=0.2, M-ramp	M=0.2
NAA random effects	None	All ages

Moving the start year to the first year in which length data was recorded from recreational catch was logical. Equally logical was to split the commercial and recreational fleet data so that possible differences in selectivity can be accommodated. In the event, adoption of separated fleets led to improvement in fleet age-composition residuals and prediction accuracy and no degradation in other criteria, but the change may still have been appropriate even if diagnostics had been equivocal.

Regarding fleet selectivity blocks, the first split (1989-1990) is supported by the fact that legislation changed in 1990 (increases in minimum legal size for both commercial and recreational fleets). It was explained to the Panel that a second split at 2010-2011 is supported because of elimination of trip limits and introduction of annual catch limits in 2010, as well as spawning closures, (the previously used split, 2004-2005, had been chosen primarily based on model diagnostics). Additional catch restrictions were implemented in 2014-2015 which may also have impacted selectivity, possibly resulting in avoidance of older ages (i.e., domed selectivity) for both fleets and four block selectivity was investigated through age-specific selectivity in all four blocks. Ultimately a three-block model was chosen with logistic selectivity in blocks 1 & 2 and age-based selectivity in block 3 (starting in 2012), but a four-block model with logistic selectivity in blocks 1 to 3 and age based in block 4 does not seem to have been considered. One of the Panel recommendations was that a four-block logistic-age based version of the model be tested in future.

The WG had identified nine additional survey indices for possible inclusion in the WGOM assessment in addition to the three used previously. It was justified to not include the age 0 indices (or MADMF fall survey) as diagnostics suggested these indices would effectively be adding noise to the assessment. This still meant inclusion of five additional surveys (see table above). The NEFSC BTS spring, NEFSC BTS fall and MADMF BTS spring surveys were used to test for prediction error because they were included in all model variants considered. Prediction error for these surveys improved when the additional surveys were included and the fits to the aggregate indices of the eight surveys was generally good, with age-composition residuals without problematic patterning.

As a panel we agreed with the decision to split the NEFSC survey indices at the change point in survey vessels (and gear) from the Albatross to the Bigelow in 2009. Calibration estimates used to convert Bigelow survey stratified mean numbers-at-length to Albatross units were based on only 130 tows and highly uncertain at young and older ages. I agree with the WG rationale that the assessment model may provide a more accurate calibration between the two vessels given that it now has 13 years of data to estimate vessel differences. I would suggest the split of this survey in 2009 should be considered in all stock areas.

The WG attempted to estimate a Beverton-Holt stock-recruitment relationship in the model: however, the Beverton-Holt function was estimated to be linear in SSB, which implies an unbounded upper limit on recruitment. The final model estimated recruitment as deviations from the mean but with autocorrelation between years (as a consequence of including 2Dar1 random effects for numbers at age). Environmental effects on recruitment can be directly incorporated into WHAM and the WG tested whether including the ecosystem variables of sea surface temperature (SST), bottom temperature or heatwave index as covariates would improve the assessment model. The covariates tested explained little of the variability in recruitment, in contrast to the run with

estimated Beverton-Holt stock-recruitment relationship. Similar diagnostics (apart from lower self-test convergence rates for the heatwave and SST models) combined with the small variability explained led to the WG choosing the proposed final model configuration without environmental covariates. It might be useful to revisit these tests in future, especially as it was unclear from the presentation and report whether the covariates were only tested individually or also in combination. There is also an argument that if the Beverton-Holt stock-recruitment relationship was able to explain variability in recruitment it could be retained, given SSB is known to be currently far below historical levels. Environmental covariates in combination with the Beverton-Holt stock-recruitment relationship is another avenue for consideration.

The WG attempted to estimate a constant natural mortality *M* across all ages and a time varying *M* via random effects. Estimation of a constant lifetime *M* was possible but all (seven) variants of the model including a time varying *M* failed to converge (see comment at the head of the ToR 4 section about model convergence). Because the estimated age- and time-invariant *M* of 0.21 was very close to the value of 0.2 calculated outside of the model and based on life history traits, the WG decided to retain the fixed *M* model specification on the grounds of parsimony. Given similar model diagnostics between model variants this was perfectly reasonable.

Although attempts to include time varying *M* were unsuccessful, the 'M-ramp' variant of the GOM model (the lifetime *M* was increased linearly from 0.2 to 0.4 between 1989 and 2002 and held at 0.4 after 2002) was not retained. This was primarily because random effects for numbers at age (NAA) were incorporated into the model. These cohort process errors can be considered to account for time-varying *M* and incorporating NAA random errors led to a large improvement in retrospective error (bad retrospective errors had been a motivation for introducing the M-ramp model previously). The type of error assumed was 2Dar1 (autocorrelation across ages and between years) and the autocorrelation across ages is applied to all ages. Another panel member pointed out that recruitment process errors (acting on age 1) would be expected to be considerably different to survival process errors at ages 2-9+. There is no option to unlink ages 1 and 2+ currently within the WHAM package if using 2Dar1 errors but it is hoped this option will become available. If it does become available, it should be explored.

As a panel we concluded that the final WGOM WHAM model was appropriate, and our comments and concerns were relatively minor.

Georges Bank (GB)

In addition to a presentation to the Panel the assessment of the GB stock was presented through the relevant section in the main report under ToR 4, as well as via WP 19.

The new GB stock boundaries differ from the former stock area by excluding statistical areas 521 and 526. The new stock boundaries meant there is no longer recreational catch assigned to the GB stock, so models were fit to commercial data only. Key differences in the former assessment model and the final model presented to the Panel were summarized in the main document (Table 2):

Table 2: GB assessment model comparison

	GB model (NEFSC 2015)	Final GB model
Model platform	ASAP	WHAM
Start year	1978	1978
Fleet structure	Single fleet	Single fleet
Fleet selectivity blocks	1978 - 1993, 1994+	1978 - 1993, 1994+
Fleet selectivity function	logistic	logistic
Age-composition distribution	Multinomial	Dirichlet-Multinomial
Indices of abundance	NEFSC BTS spring, NEFSC BTS fall, DFO spring	NEFSC BTS spring, NEFSC BTS fall, DFO spring
NEFSC BTS vessel calibration	Calibrated to FSV Albatross units	Calibrated to FSV Albatross units
Recruitment	Deviations from mean as fixed effects	Deviations from mean as random effects
M	M=0.2	M=0.29
NAA random effects	None	All ages

Start year (based on the first year of age composition data availability from both US and Canadian commercial fleets) and choice of lifetime *M* based on the studies conducted for this research track were both logical. A decision to model a combined US-Canadian fleet was also reasonable given the comparison of diagnostics between this assumption and a split fleet model. This does mean the selectivity blocks, to reflect changes in US legislation, have selectivity estimates based on data that is partially unaffected by that legislation. Logistic selectivity for trawl fleets is appropriate. It should be used unless there is strong evidence for a more domed shaped selectivity (to avoid introduction of cryptic biomass).

The GB assessment did not split the NEFSC survey indices at the change point in survey vessels (and gear) from the Albatross to the Bigelow in 2009. In agreement with the rest of the Panel I think a version of the assessment with this split should be investigated. The issue may be related to a comment from the public that it would be worth investigating further the relative perceptions in the NEFSC and DFO spring surveys. Prior to about 2010, the DFO index is generally above those for the NEFSC surveys. After 2010, the NEFSC indices are consistently above the DFO index. It was noticed the final model has a residual pattern, with mostly negative residuals for the DFO spring survey indices since 2010, and mostly positive residuals for the NEFSC spring and fall survey indices since 2010. The GB assessment returned the largest Mohn's rho values for SSB and F of the four stocks and a possible cause is the residual patterns identified.

The WG did investigate if differences in sampling timing, location, density, or distributional shifts may account for the difference in trends between the NEFSC and DFO spring surveys. The analysis found that large Georges Bank cod had shifted slightly to the Northeast over the time series in the spring. Attempts to introduce catchability random effects failed (non-convergence). An alternative approach would be to develop a stock size index by integrating survey data using the Vector Autoregressive Spatio-Temporal (VAST) package or spatio-temporal GAMs (see also ToR 1).

As for the other stocks, retrospectives were improved after introduction of random effects. The GB assessment implemented random effects for numbers at age (NAA) which in the GB assessment were assumed independent across all ages and years (iid) as opposed to autocorrelated across ages and years (2Dar1). Under the current version of WHAM this has pros and cons. The variance of the age 1 process errors was estimated separately from the variance of process errors at ages 2-9+ which is appropriate, but the Panel noted that predicted process errors seemed to show autocorrelation. Ideally a 2Dar1 assumption across ages 2-9+, but with random effects at age 1 independent of the effects at ages 2-9+ (because the recruitment random effects are expected to be very different from the survival random effects at older ages), should be investigated, but this would need an update to the WHAM package. The autocorrelation seen in the results may be connected to the residual patterns seen in the fits to survey indices.

Inclusion of a fishery-dependent LPUE index was explored but not used because its inclusion did not result in a converged model. Fishery-independent indices are usually preferable, if available, and the surveys for the GB area are comprehensive. The additional investigations outlined above should take precedence over further work to include the LPUE index.

During the review meeting the Panel requested a sensitivity run to investigate how robust assessment outputs were to the choice of age composition distribution. A comparison between the Dirichlet-Multinomial distribution of the proposed model and a Dirichlet distribution with zeros omitted was prepared overnight (which was impressive) and demonstrated very little difference in diagnostics between the two models.

As a panel we concluded that the final GB WHAM model was appropriate but, because of the model fit issues with respect to the NEFSC and DFO surveys, recommended investigations into splitting the NEFSC survey indices at the change point in survey vessels from the Albatross to the Bigelow at the management track assessment.

Southern New England (SNE)

In addition to a presentation to the Panel the assessment of the SNE stock was presented through the relevant section in the main report under ToR 4, as well as via WP 18.

This was the first time that a specific SNE assessment had been developed, as it was previously considered part of the wider Georges Bank (GB) stock. The SNE cod stock is prosecuted by both commercial and recreational fisheries, with recreational catches larger than commercial catches in

recent years. Age composition sampling in the commercial fleet is limited, with only 7 years covered since 1981, and age sampling does not take place in the recreational fleet (age compositions for the recreational fleet are inferred using ALKs from surveys and available commercial data). Discard mortality rate was set at 30%, which was a compromise between studies which had estimated values of 13% and 47% respectively. As a panel we considered the approach adopted by the WG reasonable but a dedicated study, similar to the one providing the value for the Gulf of Maine region, would be welcome.

Four surveys were relevant to the SNE area. The Northeast Fisheries Science Center (NEFSC) spring and fall surveys cover the area comprehensively, but in several years caught very few (or zero) cod and consequently do not track cohort strength very well. Only the spring survey seems to have been used in the final model without a reason given for the omission of the fall survey. The other surveys, the Rhode Island Department of Environmental Management (RIDEM) spring and fall; Massachusetts Department of Marine Fisheries (MADMF) spring and fall; and the University of Rhode Island Graduate School of Oceanography (GSO), catch primarily age 0 cod and were thus explored as recruitment indices. A joint index was also explored that combined all the age 0 indices into a single index. However, in all cases inclusion of a recruitment index led to poor fits.

Other indices available to this assessment were LPUE indices from the commercial and recreational fleets. All LPUE series considered by the WG started in 1996 but I am unsure why. The commercial LPUE model showed good diagnostics but there was concern biases might be present because of the influence of regulations, so focus was placed on the recreational LPUE. The recreational series was based on for-hire vessels using handline gear with LPUE represented by catch per angler. The LPUE model resulted in 44% deviance explained and diagnostics were good. Model retrospective patterns improved with inclusion of the recreational LPUE and mean absolute scaled error (MASE) scores were lower for the LPUE index than for the NEFSC index. As detailed under ToR 3 the fact the index had only used positive catch data was a concern. Re-estimation of the index with zero hauls included was not possible during the review meeting but seemed possible in the near term. Meanwhile, as a panel we agreed it was better to include the LPUE index than not.

The start year of the model was 1981 (as for WGOM and EGOM) because this is the first year of recreational catch data. Better retrospective patterns and fits to mean length were achieved by separating the commercial and recreational fleets. The two-fleet model also allowed different selectivity to be used for each. The final model run included a Beverton-Holt recruitment assumption, which was well-supported by the data (in contrast to other stocks). The steepness parameter did have to be fixed, however, at a value from the literature.

As occurred in other stock areas the use of the WHAM platform resulted in better retrospective results. It is not clear from the presentation and report whether this was the result of inclusion of random effects. Random effects (iid) on recruitment were included. All other attempts at including random effects seemed to result in the model failing to converge. This was possibly because of the limited data available for this stock. The data limitations also dictated that weights at age and maturity at age were held time invariant. While time invariant, natural mortality M was age based.

As a panel we concluded that the final SNE WHAM model was appropriate but with the proviso that a recreational LPUE series including zero hauls be made available by the time of the first management track assessment. When available, recreational catch from the MRIP wave one period should be incorporated.

Eastern Gulf of Maine (EGOM)

In addition to a presentation to the Panel the assessment of the EGOM stock was presented through the relevant section in the main report under ToR 4, as well as via WP 16.

This was the first time that a specific EGOM assessment had been developed, as it was previously considered part of the wider Gulf of Maine (GOM) stock. The EGOM cod stock is prosecuted by both commercial and recreational fisheries, with recreational catches a significant proportion of total removals in recent years (up to 40%). Age composition sampling in the commercial fleet is limited, with 23 of 41 years missing age data between 1981 and 2021, and age sampling does not take place in the recreational fleet (age compositions for the recreational fleet are inferred using ALKs from surveys and available commercial data). The WG made the point that when all cod in the Gulf of Maine were assessed as a single unit, fishery-dependent sampling was concentrated in the WGOM where the bulk of landings occurred. However, with EGOM assessed independently, it is essential to characterize the catch-at-age of this fishery going forward. All panel members agreed.

Catches in this area have always been modest but since the early 1990s catches have fallen to very low levels with a recorded catch in 2021 of only 1 mt. Relatively speaking, lobster trap discards are likely a major source of removals but estimates of recent discards were not available for the research track process. Dead discards in the lobster trap fishery were estimated to have ranged between 2.5 and 10 mt during 2006-2013, meaning they could potentially represent multiple times the removals from other sources in recent years. The Review Panel was informed new estimates of dead discards are being prepared and we considered the assessment must be updated with these estimates before the management track assessment.

The start year of the model was 1981 (as for WGOM and SNE) because this is the first year of recreational catch data. There has been a consistent level of sampling of the recreational fleet through this period and the WG were confident years of zero catches represented true zeros. Discard mortality rate was set at 16.5%, which is based on a dedicated acoustic telemetry study in the Gulf of Maine. Mortality rates are temperature dependent (a factor considered when deriving a mortality rate for the SNE region). If the Gulf of Maine continues to warm, the discard mortality value will need to be re-considered in a future research track.

Six survey indices were available for the EGOM area. Fits to a recruitment index survey (NEFSC Fall YOY), as well as to the Maine - New Hampshire Inshore Trawl Survey (spring and fall) and Eastern Gulf of Maine Sentinel Survey were reasonable, but fits fell outside the confidence intervals of the NEFSC Bottom Trawl Survey for several years for both the spring and fall surveys. During the meeting it was suggested the model could be run with only the NEFSC Spring and

Autumn surveys to compare with a model run using only the other surveys. It was also proposed that leave-one-survey-out runs could provide useful insights and EGOM would appear an appropriate stock to trial that approach. I also note that there was no mention with this stock of splitting the NEFSC surveys at the changeover from Albatross to Bigelow research vessel.

I accept data limitations required weights at age and (lifetime) *M* to be time invariant. The assessment was able to accommodate time varying maturity at age. Selectivity assumptions and the break in selectivity for the commercial fleet in 1997 were well justified. Runs attempting to incorporate random effects on numbers at age (NAA) did not converge but (ar1) random effects on recruitment were incorporated. As with other stocks, incorporating random effects improved retrospectives, although in the case of EGOM only to a small extent.

This was a stock where time constraints prevented explicit investigation of environmental drivers, but the WG was keen to return to this area in future work. I endorse this, especially as several surveys showed drops in index value after 2010 that the model cannot yet account for.

As a panel we concluded that the final EGOM WHAM model was appropriate but with the proviso that estimates of dead discards from the lobster trap fishery be made available by the time of the first management track assessment. Also, that further work be undertaken to improve fit to survey indices.

TOR 5. Update or redefine status determination criteria (SDC; point estimates or proxies for BMSY, BTHRESHOLD, FMSY and MSY reference points) and provide estimates of those criteria and their uncertainty, along with a description of the sources of uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for reference points. Compare estimates of current stock size and fishing mortality to existing, and any redefined, SDCs.

I conclude that this ToR was fully addressed for all WGOM, GB, SNE and EGOM cod stocks.

In the previous catch-at-age based cod assessments, MSY reference points were based on a spawning potential ratio (SPR) of 40% with a lack of a stock-recruit relationship as motivation for the proxy-based approach. The WG had re-examined support for stock-recruit relationships under the new spatial units but concluded the relationships were not well determined and/or not useful to make projections. This conclusion was well supported for the WGOM and GB stocks because attempts to fit a Beverton-Holt relationship had led to linear stock recruit relationships, i.e., unlimited recruitment at high SSB. For the SNE stock a Beverton-Holt curve could be fitted which from a figure of the fitted curve looked reasonable, but this had only been possible after fixing the steepness parameter because of instability when trying to estimate steepness within the model. For the EGOM there didn't seem to have been an attempt to fit a parametric stock-recruit relationship when using WHAM (only a Beverton-Holt relationship in the preceding ASAP model). WHAM supports a Ricker stock-recruit option, but this didn't seem to be considered for any stock. Another panel member suggested a segmented regression ('hockey stick' regression) could be another consideration. I think this is certainly an area that can be revisited and is included in the panel

recommendations as "further investigations of robust approaches to modeling recruitment in the assessment model".

Choice of selectivity for fisheries were appropriate for all four stocks. The results of work conducted under ToR 1 were considered for determining the appropriate time frame for characterizing growth, maturity, natural mortality, and recruitment in the calculation of reference points. For the WGOM and GB stocks the most recent five years of weight-at-age were used and this was easily justified by the figures for weight-at-age (lack of data required time invariant WAA be used for the SNE and EGOM stocks). In three stocks the most recent five years of maturity-at-age were used, again justified by results presented in the report (data limitations required time invariant maturity for the SNE stock). For all four stocks, a time invariant *M* was used to inform reference point calculation, in part because it was not possible to achieve a converged model using annual process errors in natural mortality *M*.

Again, for all four stocks the WG chose to use the full time series of modeled recruitments to calculate reference points. For the GB, SNE and EGOM stocks this was easily accepted. Results of a changepoint analysis on NEFSC spring survey data indicated a change point in 2010 for the WGOM stock for both recruitment and recruitment rate (R/SSB) but the R/SSB time series from the proposed assessment model suggested variation without trend. The WG chose the full time series of modeled recruitments based on the modelled R/SSB time series and the fact that inclusion in the assessment model of three temperature-based covariates had failed to demonstrate a link between these and recruitment. I could accept this decision given that predictions would include an autocorrelated random effect for recruitment which should restrict recruitments in early prediction years to values similar to those late in the time series of the historic assessment. The WG had also recommended an across species initiative "for defining time windows to characterize prevailing conditions for stocks" which I strongly support. The WG did seem to suggest one reason for their decision was because of a lack of evidence for a change point from the other stock areas. Presentation of results from ToR 1 suggested to me, however, that the Gulf of Maine experiences climate influences unique compared to neighboring waters. An alternative consideration would be to draw recruit per spawner (R/SSB) to estimate biological reference points (and for projections) on the basis that recruits per spawner may implicitly account for environmental influences.

The status determined for each stock was:

WGOM:	Overfished; Overfishing occurring; both with high probability.
GB:	Overfished; Overfishing not occurring; both with high probability.
SNE:	Overfished; Overfishing occurring; both with high probability.
EGOM:	Overfished; Overfishing not occurring; both with high probability.

For all stocks the high confidence with which stock status had been determined suggested changes/investigations recommended by the Panel would not alter perception of stock status.

TOR 6. Define appropriate methods for producing projections; provide justification for assumptions of fishery selectivity, weights at age, maturity, and recruitment; and comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions.

I conclude that this ToR was fully addressed for all WGOM, GB, SNE and EGOM cod stocks.

The WG proposed that the candidate model run for each stock would be used as a basis for short-term projections. Because all candidate models had been developed in the WHAM package this also meant short-term projections could be produced internally within the WHAM framework. Being able to perform projections within WHAM is advantageous as it facilitates maintaining the same assumptions on growth, maturity, natural mortality, selectivity and recruitment between the historic assessment and projections, (although it shouldn't be a basis for choosing a package if another provided a superior historic assessment).

The use of random effects was talked about in the presentations on the four stocks but as a panel we realized it was not always clear in report sections or from presentation material which type of random effect had been used (iid or ar1) or even whether a random effect had been used for a given quantity. In the same way the WG was very clear in the way it presented the criteria for model selection, a consistent and clear statement of projection assumptions, including where random effects are being applied, of what type and the justification for that type of random effect is recommended (this became a panel recommendation).

The assumption to use the full series of recruitment estimates for projections should be re-visited, especially if the nature of the links between temperature (bottom and/or surface) and recruitment become better understood, (as noted under ToR 5). An alternative consideration would be to draw recruit per spawner (R/SSB) for projections (and estimation of biological reference points) on the basis that recruits per spawner may implicitly account for environmental influences.

TOR 7. Review, evaluate, and report on the status of research recommendations from the last assessment peer review, including recommendations provided by the prior assessment working group, peer review panel, and SSC. Identify new recommendations for future research, data collection, and assessment methodology. If any ecosystem influences from TOR 2 could not be considered quantitatively under that or other TORs, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations.

I conclude that this ToR was fully addressed.

The WG produced an excellent summary of all previous research recommendations and whether they had been addressed.

The WG had produced a large number of their own recommendations. At the request of Russell Brown the Panel prioritized these recommendations. We grouped them into:

- Necessary for management track: The assessment to which the recommendation was directed would be unlikely accepted by the Panel members if in a management track review until the recommendation was addressed.
- High priority: Work that may not be possible to complete by the end of the next management track, but which should receive funding priority.
- Medium/long term: Ongoing work that should be pursued as resources allow. If possible, the research could be conducted outside of the management track process but then incorporated when mature.
- Low priority: To an extent these were considered recommendations for actions that would likely be undertaken anyway, e.g., "monitoring the accuracy of projections during future assessments" or that were dependent on other recommendations, e.g., work on the multi-stock feature of WHAM in WGOM can only begin "when sufficient data are available".

Some recommendations were essentially repetitions (one recommendation generic across stocks and another made with reference to a specific stock) and these were linked when performing the ranking. The Panel members discussed the prioritization and were able to quickly come to a consensus. I therefore simply state here that I agree fully with the prioritization as presented in the panel summary report without reproducing the list of recommendations in this report.

I am also in agreement with all panel recommendations and have no further recommendations to add.

As a panel we felt it important that work on integrating survey data using the Vector Autoregressive Spatio-Temporal (VAST) package, or by some other means, be continued. I will add that I believe interpretation and presentation of results is particularly important for this subject area because the techniques used are relatively new (and therefore unfamiliar to most) and quite complex.

TOR 8. Develop a backup assessment approach to providing scientific advice to managers if the proposed assessment approach does not pass peer review or the approved approach is rejected in a future management track assessment.

I conclude that this ToR was fully addressed for all WGOM, GB, SNE and EGOM cod stocks.

For each of the four cod stocks the WG recommended that if the proposed WHAM assessment model was rejected in a future management track assessment that the backup be a simplified WHAM model. There is a clear risk to this approach. The proposed models are obviously considered the optimal configurations of WHAM. If any were rejected within a management track it would imply reverting to (what was considered by the WG at least) a less optimal set-up. For the WGOM and GB stocks I consider the risk of rejection low, but, because of the current data limitations in the areas, this is more of a concern for SNE and EGOM.

The WG based much of their argument on the results from the Index-Based Research Track Working Group (NEFSC 2020, Legault et al. 2023). Certain aspects of the simulation study might have flattered the statistical catch-at-age model, e.g., CVs and effective sample sizes were specified at their true underlying values and all life-history traits were fixed at their correct values. However, the fact remains that data limited methods rely on ad hoc setting of reference points.

What was not mentioned by the WG, but which is a valid consideration, is the fact that if the proposed assessment approach were replaced by an empirical backup, it is necessary to wait for a future research track assessment to reinstate an integrated assessment. As a review panel we agreed we were happy with the general assessment frameworks for all four stocks, the main concerns were to include more data for the EGOM and SNE assessments (and revised estimation of recreational LPUE for SNE). It would seem counterproductive to exclude the possibility of using an integrated assessment even as more comprehensive data became available.

For all stocks the high probability of the determined stock status (ToR 5) increases confidence that changes to the WHAM models would be unlikely to alter perception of stock status.

TOR 9. Apply the findings of the Atlantic Cod Stock Structure Working Group and identify what assessment approaches the available data can support in defining the appropriate scale of Atlantic cod stock assessment. Consider implications for management processes and other practical limitations in the final units and boundaries used for stock assessments.

I conclude that this ToR was fully addressed.

The WG had clearly applied the findings of the Atlantic Cod Stock Structure Working Group. Except for combining the winter and spring spawning components within the Western Gulf of Maine, the biological units identified by the stock structure WG were adopted as assessment units. The main reason for combining the winter and spring spawning components within the Western Gulf of Maine was operational difficulties in partitioning the biological data.

During the review it became clear that data support for the EGOM and SNE assessments was only just sufficient, and all panel members agreed inclusion of dead discard data from the lobster pot fishery in EGOM and re-estimation of the recreational LPUE series including zero catches in SNE were prerequisites for acceptable management track assessments. The WG had identified these data gaps for the SNE and EGOM stocks and made appropriate recommendations to address them. There is also a recommendation, endorsed by the Panel, to determine the magnitude of recreational catch in the MRIP wave one period for addition to the SNE recreational catch data.

References

Legault, C.M., Wiedenmann, J., Deroba, J.J., Fay, G., Miller, T.J., Brooks, E.N., Bell, R.J., Langan, J.A., Cournane, J.M., Jones, A.W., Muffley, B. 2023. Data Rich but Model Resistant: An Evaluation of Data-Limited Methods to Manage Fisheries with Failed Age-based Stock Assessments. Can. J. Fish. Aquat. Sci. 80: 27–42.

McBride RM, and RK Smedbol (Eds.). 2022. An Interdisciplinary Review of Atlantic Cod (Gadus morhua) Stock Structure in the Western North Atlantic Ocean. NOAA Technical Memorandum NMFS-NE-273.

NEFSC. 2020. Report of the Index Based Methods Working Group. https://apps-nefsc.fisheries.noaa.gov/saw/sasi.php

Appendix 1. Materials provided for review

Atlantic Cod WG Report

Working Papers:

WP1 Stakeholder Meeting Summary

WP2 Development of Ecosystem Indicators

WP3 Environmental Influences on Cod

WP4 Stakeholder Meeting 2 Summary

WP5 Rec Discard Mortality

WP6 FDD Exploration

WP7 Cod LPUE

WP8 NEFSC Trawl Survey Expanded Figs

WP9 Survey Time Series Correlations

WP10 Integrated Survey Indices (VAST)

WP11 EGOM Sentinel Index Modification

WP12 Time Varying Cod Maturity

WP13 Time Varying Cod LW

WP14 Estimating Cod M by Stock

WP15 Atlantic Cod Model Selection Procedure

WP16 EGOM Assessment Model ToR 4

WP17 WGOM Assessment Model ToR 4

WP18 SNE Assessment Model ToR 4

WP19 GB Assessment Model ToR 4

WP20 Reference Points

Presentations:

31 July 2023:

Atlantic Cod Research Track Stock Assessment.	Lisa Kerr
ToR 9 - Stock Structure.	Lisa Kerr and Rich McBride
ToR 1 - Ecosystem and Climate Influences.	Scott Large and Jamie Behan
ToR 2 - Fishery Data.	Charles Perretti and Kathy Sosebee

1 August 2023:

Data Processing Methods [additional presentation to address Panel questions].	Lisa Kerr
ToR 3 - Survey Data.	Lisa Kerr and Steve Cadrin
ToR 4,5,6, & 8 – Assessment, reference points, projections, back-up assessment.	Lisa Kerr
Woods Hole Assessment Model	Tim Miller
Western Gulf of Maine Cod (ToRs 4, 5, 6, 8).	Charles Perretti

2 August 2023:

Cohort Tracking Diagnostics and R/SSB by Stock [additional presentation to address Panel questions].	Lisa Kerr
Georges Bank Cod (ToRs 4, 5, 6, 8).	Amanda Hart
Southern New England Cod (ToRs 4, 5, 6, 8).	Alex Hansell, Cole Carrano, Steve Cadrin
EGOM Cod Assessment Model (ToRs 4, 5, 6, 8).	Micah Dean

3 August 2023:

Age composition likelihood comparisons for GB candidate model (19A) [additional presentation to address Panel questions].	Amanda Hart
ToR 7 - Research Recommendations.	Lisa Kerr.

Provided to the Review Panel but not presented:

Standardizing Landings per Unit Effort from Cod Fishery Data.	Lucy McGinnis, Gavin Fay, Alex Hansell, Steve Cadrin

Appendix 2. Performance Work Statement for CIE reviewers for the Atlantic cod research track stock assessments.

Performance Work Statement (PWS)
National Oceanic and Atmospheric Administration (NOAA)
National Marine Fisheries Service (NMFS)
Center for Independent Experts (CIE) Program
External Independent Peer Review
Under Contract #1305M219DNFFK0025

Atlantic Cod Research Track Peer Review
July 31 – August 3, 2023

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[1].

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

[1] https://www.whitehouse.gov/wp-content/uploads/legacy_drupal_files/omb/memoranda/2005/m05-03.pdf

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 the Atlantic cod stocks. The requirements for the peer review follow. This Performance Work Statement (PWS) also includes: **Annex 1**: TORs for the research track, which are the responsibility of the analysts; **Annex 2:** a draft meeting agenda; **Annex 3:** Individual Independent Review Report Requirements; and **Annex 4:** Peer Reviewer Summary Report Requirements.

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. Modifications to the PWS and ToRs cannot be made during the peer review, and any PWS or ToRs modifications prior to the peer review shall be approved by the Contracting Officer's Representative (COR) and the CIE contractor. 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, model diagnostics from various population models, and how catch advice is provided from stock assessment models. In addition, knowledge and experience with simulation analyses is helpful.

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 NMFS 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
- 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. Individual reviewer perspectives should be provided in their individual reports, and any lack of consensus should be clearly described in the panel's summary report.

- Each reviewer shall assist the Peer Review Panel Chair with contributions to the Peer Review Panel's Summary Report.
- Deliver individual Independent Reviewer Reports to NMFS 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:
Review the Report of Atlantic Cod Research Track Working Group.

The Peer Review Panel Chair, with the assistance from the reviewers, will write the Peer Reviewer Summary Report. Each reviewer and the 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 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. Again, the CIE reviewers are not required to reach a consensus. The chair will take the lead in editing and completing this report. The 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.

Place of Performance
The place of performance shall be remote, via WebEx video conferencing.

Period of Performance
The period of performance shall be from the time of award through October 2023. 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.

Schedule	**Milestones and Deliverables**
Within 2 weeks of award	Contractor selects and confirms reviewers
Approximately 2 weeks later	Contractor provides the pre-review documents to the reviewers
July 31 – August 3, 2023	Panel review meeting
Approximately 2 weeks later	Reviewers submit draft peer-review reports to the contractor for quality assurance and review
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
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Michele.Traver@noaa.gov

Annex 1. Generic Research Track Terms of Reference

1. Identify relevant ecosystem and climate influences on the stock. Characterize the uncertainty in the relevant sources of data and their link to stock dynamics. Consider findings, as appropriate, in addressing other TORs. Report how the findings were considered under impacted TORs.
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 used in the assessment (e.g., indices of relative or absolute abundance, recruitment, state surveys, age-length data, application of catchability and calibration studies, etc.) and provide a rationale for which data are used. Describe the spatial and temporal distribution of the data. Characterize the uncertainty in these sources of data.
4. Use appropriate assessment approach to 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(s). Evaluate a suite of model fit diagnostics (e.g., residual patterns, sensitivity analyses, retrospective patterns), and (a) comment on likely causes of problematic issues, and (b), if possible and appropriate, account for those issues when providing scientific advice and evaluate the consequences of any correction(s) applied.
5. Update or redefine status determination criteria (SDC; point estimates or proxies for BMSY, BTHRESHOLD, FMSY and MSY reference points) and provide estimates of those criteria and their uncertainty, along with a description of the sources of uncertainty. If analytic model-based estimates are unavailable, consider recommending alternative measurable proxies for reference points. Compare estimates of current stock size and fishing mortality to existing, and any redefined, SDCs.
6. Define appropriate methods for producing projections; provide justification for assumptions of fishery selectivity, weights at age, maturity, and recruitment; and comment on the reliability of resulting projections considering the effects of uncertainty and sensitivity to projection assumptions.
7. Review, evaluate, and report on the status of research recommendations from the last assessment peer review, including recommendations provided by the prior assessment working group, peer review panel, and SSC. Identify new recommendations for future research, data collection, and assessment methodology. If any ecosystem influences from TOR 2 could not be considered quantitatively under that or other TORs, describe next steps for development, testing, and review of quantitative relationships and how they could best inform assessments. Prioritize research recommendations.
8. Develop a backup assessment approach to providing scientific advice to managers if the proposed assessment approach does not pass peer review or the approved approach is rejected in a future management track assessment.
9. Apply the findings of the Atlantic Cod Stock Structure Working Group and identify what assessment approaches the available data can support in defining the

appropriate scale of Atlantic cod stock assessment. Consider implications for management processes and other practical limitations in the final units and boundaries used for stock assessments.

Research Track TORs:

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.

Annex 2. Draft Review Meeting Agenda
{Final Meeting agenda to be provided at time of award}

Atlantic Cod Track Assessment Peer Review Meeting

July 31 –August 3 , 2023

WebEx link: TBD

DRAFT AGENDA* (v. 4/27/2023)
**All times are approximate, and may be changed at the discretion of the Peer Review Panel chair. The meeting is open to the public; however, during the Report Writing sessions we ask that the public refrain from engaging in discussion with the Peer Review Panel.*
Monday, July 31, 2023

Time	Topic	Presenter(s)	Notes
9 a.m. - 9:30 a.m.	Welcome/Logistics Introductions/Agenda/Conduct of Meeting	Michele Traver, Assessment Process Lead Russ Brown, PopDy Branch Chief Panel Chair	
9:30 a.m. - 10:30 a.m.	TOR #1		
10:30 a.m. - 10:45 a.m.	Break		
10:45 a.m. - 11:45 a.m.	TOR #1 cont.		
11:45 a.m. - 12:15 p.m.	Discussion/Summary	Review Panel	
12:15 p.m. - 12:30 p.m.	Public Comment	Public	
12:30 p.m. - 1:30 p.m.	Lunch		
1:30 p.m. - 3 p.m.	TOR #2		
3 p.m. - 3:15 p.m.	Break		
3:15 p.m. - 4:15 p.m.	TOR #2 cont.		

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		

Tuesday, August 1, 2023

Time	**Topic**	**Presenter(s)**	**Notes**
9 a.m. - 9:15 a.m.	Welcome/Logistics	Michele Traver, Assessment Process Lead Panel Chair	
9:15 a.m. - 10:30 a.m.	TOR #3		
10:30 a.m. - 10:45 a.m.	Break		
10:45 a.m. - 11:45 a.m.	TOR #3 cont.		
11:45 a.m. - 12:15 p.m.	Discussion/Summary	Review Panel	
12:15 p.m. - 12:30 p.m.	Public Comment	Public	
12:30 p.m. - 1:30 p.m.	Lunch		
1:30 p.m. - 3 p.m.	TOR #4		
3 p.m. - 3:15 p.m.	Break		
3:15 p.m. - 4:15 p.m.	TOR #4 cont.		
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, August 2, 2023

Time	**Topic**	**Presenter(s)**	**Notes**
9 a.m. - 9:15 a.m.	Welcome/Logistics	Michele Traver, Assessment Process Lead Panel Chair	
9:15 a.m. - 10:30 a.m.	TOR #5		
10:30 a.m. - 10:45 a.m.	Break		
10:45 a.m. - 11:45 a.m.	TOR #6		
11:45 a.m. - 12:15 p.m.	Discussion/Summary	Review Panel	
12:15 p.m. - 12:30 p.m.	Public Comment	Public	
12:30 p.m. - 1:30 p.m.	Lunch		
1:30 p.m. - 3 p.m.	TOR #7		
3 p.m. - 3:15 p.m.	Break		
3:15 p.m. - 4:15 p.m.	TOR #8-9		
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		

Thursday, August 3, 2023

Time	**Topic**	**Presenter(s)**	**Notes**
9 a.m. - 5 p.m.	Report Writing	Review Panel	

Annex 3. 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.

Annex 4. Peer Reviewer Summary Report Requirements

1. 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. It should also include whether they **accept or reject** the work that they reviewed, with an explanation of their decision (strengths, weaknesses of the analyses, etc.)

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.

2. 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.

3. 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 3. Attendees for July 31 – August 3 Atlantic cod research track peer review meeting.

Atlantic Cod Research Track Peer Review Attendance
July 31 – August 3, 2023

DFO - Department of Fisheries and Oceans (Canada)
GARFO - Greater Atlantic Regional Fisheries Office
GMRI - Gulf of Maine Research Institute
MADMF - Massachusetts Division of Marine Fisheries
MEDMR - Maine Department of Marine Resources
NEFMC - New England Fisheries Management Council
NEFSC - Northeast Fisheries Science Center
SMAST - University of Massachusetts School of Marine Science and Technology
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JJ Maguire - Chair
Steven Holmes - CIE Panel
Noel Cadigan - CIE Panel
Coby Needle - CIE Panel

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

Alex Dunn - NEFSC
Alex Hansell - NEFSC
Alicia Miller - NEFSC
Alison Frey - NEFSC
Amanda Hart - GMRI
Angela Forristall - NEFMC Staff
Andy Jones - NEFSC
Anna Mercer - NEFSC
Brian Linton - NEFSC
Burton Shank - NEFSC
Caira Clark - Nature Conservancy of Canada
Carla Guenther - Maine Center for Coastal Fisheries
Cate O'Keefe - NEFMC Executive Director
Charles Adams - NEFSC
Charles Perretti - NEFSC
Chris Kellogg - NEFMC Deputy Director
Chris Legault - NEFSC
Cole Carrano - SMAST
Dave McElroy - NEFSC
Doug Butterworth - University of Cape Town (South Africa)
Frank Blount - Frances Fleet
Gareth Lawson - Conservation Law Foundation
Gary Nelson - MADMF
Irene Andruschchenko - DFO
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Jackie Odell - Northeast Seafood Coalition
Jamie Behan - GMRI
Jamie Cournane - NEFMC Staff
Jessica Blaylock - NEFSC
John Pappalardo - Cape Cod Hook Fishermen's Association
Jon Deroba - NEFSC
Julie Nieland - NEFSC
Kathy Sosebee - NEFSC
Katie Lankowicz - GMRI
Kelly Whitmore - MADMF
Kiersten Curti - NEFSC
Kristan Blackhart - NEFSC
Libby Etrie - NEFMC Member
Lisa Hendrickson - NEFSC
Lisa Kerr - University of Maine
Liz Brooks - NEFSC
Liz Sullivan - GARFO
Mark Terceiro - NEFSC
Max Grezlik - SMAST
Melanie Barrett - DFO
Melanie Griffin - MADMF
Micah Dean - MADMF
Nicholas Calabrese - SMAST
Paul Nitschke - NEFSC
Rebecca Peters - MEDMR
Rebecca Rademeyer - Independent Consultant (South Africa)
Rich McBride - NEFSC
Rick Bellavance - NEFMC Member
Robin Frede - NEFMC Staff
Robyn Linner - Stony Brook University
Roger Brothers - GMRI
Scott Large - NEFSC
Spencer Talmage - GARFO
Steve Cadrin - SMAST
Susan Wigley - NEFSC
Tara Dolan - MADMF
Tim Barrett - DFO
Tim Miller - NEFSC
Tim O'Donnell - Gloucester Marine Genomics Institute
Toni Chute - NEFSC
Yanjun Wang - DFO