Gulf of Maine Cod 2014 Assessment Update Peer Review
August 28-29, 2014
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Peer Review Report

The New England Fisheries Management Council sponsored a scientific peer review of the 2014 Gulf of Maine Cod Operational Update Assessment. The meeting took place at the Sheraton Harborside Hotel in Portsmouth, New Hampshire on August 28-29, 2014. The Review Panel consisted of seven scientists representing the New England and Mid-Atlantic Fisheries Management Council's Scientific and Statistical Committees. These included Patrick Sullivan (chair), Steve Cadrin, Yong Chen, Chris Legault, Andrew Pershing, Alexei Sharov, and Michael Wilberg. The assessment update was presented by Michael Palmer (NEFSC) with scientific and logistical support provided by Paul Rago (NEFSC) and Jamie Cournane (NEFMC). The Operational Update Assessment Report is presented as a separate document. The Peer Review Report consists of consensus summary findings by the Review Panel of the nine Terms of Reference provided by the Council's Assessment Oversight Panel.

The Review Panel wishes to thank Mr. Palmer for his detailed analysis and thorough presentation of the assessment. The Review Panel also wishes to thank the members of the public who attended the meeting and contributed throughout the process.

Terms of Reference

1. *Update all fishery-dependent data (landings, discards, catch-at-age, etc.) and all fishery-independent data (research survey information) used as inputs in the baseline model or in the last operational assessment. Update SARC 55 analyses of the spatial distribution of fishing effort.*

The Review Panel concludes that this TOR was met. The Panel did not identify any major issues in the fishery-dependent data. Commercial landings showed a declining trend consistent with a reduction in fishing effort. Close correspondence between the commercial landings data and vessel trip reports suggests that the fishery landing data accurately represent removals. Commercial discards showed a declining trend during 2012-2013. The coefficient of variation (CV) for commercial discard estimates was lower than 0.3, which is the target precision. Estimates of recreational catch have declined over time and also have low CVs (0.07 – 0.25). The Panel concluded that the fishery-dependent data used as input in the Operational Assessment had been properly updated. The Panel acknowledged that the TOR specifies that the analysis of the spatial distribution of fishing effort should be updated, but effort was not specifically examined in the assessment report because of the difficulty in defining targeted fishing effort for this fishery. However, the spatial distribution of landings was presented in the report, which is considered by the Panel as an informative proxy for the spatial distribution of fishing effort.

Survey indices remained at low levels from 2011-2014 and had CVs lower than 0.3. Presence/absence of cod in the Northeast Fisheries Science Center (NEFSC) and Massachusetts

Division of Marine Fisheries (MA DMF) surveys were summarized in the assessment report. The Panel concluded that the fishery-independent data used as inputs in the Operational Assessment had been properly updated. The Panel did note two sources of uncertainty in the survey data: insufficient inshore coverage and possible changes in survey selectivity and fish availability resulting from potential changes in the distribution of cod (horizontally and vertically) in response to environmental conditions. Both of these sources of uncertainty should be evaluated in the future and the benefits of this would extend beyond cod. However, indices from Maine-New Hampshire survey were presented at the meeting, and they show similar declining trends as were evident in the other surveys. While changes in distribution have been observed, there are no indications that they are impacting survey indices for this species, but further research is warranted.

2. *Estimate fishing mortality and stock size for the current year, and update estimates of these parameters in previous years, if these have been revised. Compare the results from the two model formulations used at the last benchmark.*

The Review Panel concludes that this TOR was met. The two ASAP model runs, denoted M=0.2 and M-ramp, were updated with fishery and survey data from 2012 and 2013. No changes were made to either model configuration. Terminal year estimates of fishing mortality (F) on fully selected ages for 2013 were 1.33 for M=0.2 and 1.24 for M-ramp. Terminal year estimates of spawning stock biomass (SSB) in 2013 were 2,063 mt for M=0.2 and 2,432 mt for M-ramp. Both models indicate an increase in F and a decrease in SSB since the last assessment at SARC55. The increase in the estimate of F despite declining catch in the fishery is due to the revision of SSB estimates which indicate a more rapid decline than those seen in the catches. The trends in SSB are evidenced by a lack of older-aged fish in the survey indices, commercial landings, and recreational landings as well as lower overall abundance and decreased weight-at-age for the older ages in the population.

3. *Evaluate the diagnostics of the model and the model fit to the data. Identify and quantify data and model uncertainty that can be considered for setting Acceptable Biological Catch limits.*

The Review Panel concludes that this TOR was met. The model diagnostics were consistent with those seen in SARC55. Fits to the different model components, i.e. total catch, catch at age proportions, survey series, and survey proportions at age, were similar to those presented at SARC55. The retrospective pattern for the M=0.2 model was again slightly outside the uncertainty bounds for the terminal year. The SSC may wish to consider the magnitude and direction of this retrospective pattern when providing catch advice based on this model. Based on previous experience, the retrospective diagnostic and any attempts to adjust for it, including specifying alternative assessment models such at the M-ramp model which assumes increasing natural mortality rate, present a challenge for setting catch advice to achieve desired fishing mortality rates. However, both models indicate low stock size and high fishing mortality rates currently, as described in TOR 5.

Estimates of uncertainty in the data were used to weight their relative contribution to the model fit through the use of input coefficients of variation (CV), which were unchanged from SARC55. The CVs indicate the relative precision of the estimated catch (CV of 0.05) with more variable survey estimates (CVs of 0.4-0.6), as in SARC55. Survey information from inshore Maine and New Hampshire were not included in the model because cod from that survey have not yet been aged. Changes in the spatial distribution of cod associated with declining abundance could contribute to changes in survey selectivity. Selectivity patterns in the fishery may have also changed because of changes in stock distribution or changes in fisher behavior, due perhaps in part to recent reductions in minimum size or other regulations. There are currently too few years in the assessment with this new minimum size to allow estimation of a new selectivity block. Projections should consider the uncertainty in this potential shift to younger ages as the current selectivity patterns indicate a lag between the onset of maturity and subsequent availability to the fishery.

The panel also noted that the assumed level of the CV on the recruitment deviations (0.5) in the current assessment could contribute to overestimates of recruitment in recent years and inflate associated short-term projections and the sensitivity of these estimates to that assumption should be examined periodically in that context.

4. If appropriate, update the values of biological reference points (BRPs).

1. The reference point methods approved by SARC55 were updated.
    a. The overfishing reference point ($F_{40\%}$ assuming M=0.2) was estimated with minor changes to the data inputs (maturity, weights, selectivity), but the value of $F_{40\%}$ was the same as that estimated at SARC55 ($F_{40\%}$=0.18).
    b. Long-term projections at F=0.18 and M=0.2 were updated using 1982-2011 recruitment series, producing estimates of rebuilding targets (the SSB_{MSY} proxy) of 47,184 mt (using the ASAP M=0.2 recruitment series) and 69,621 mt (M-ramp recruitment series).
2. The Review Panel revisited debates about reference points specified under the M-ramp model, with two perspectives on the most appropriate approach:
    a. National Standard 1 guidelines suggest that MSY reference points should be based on prevailing conditions (e.g., a M=0.4 regime). The SARC55 rebuilding target associated with the M-ramp recruitment series and M=0.2 (69,621 mt) may be unattainable if the current environmental regime continues (M=0.4).
    b. Conversely, if M has increased, the target F should be maintained or reduced to offset the increase in M.
3. As an exploration, the Panel requested estimates of $F_{40\%}$ and the associated long-term SSB assuming M=0.4 so that the uncertainty and implications can be communicated to the entire SSC for consideration in recommending OFL and ABC. Although this was informative, the panel did not accept these as alternative approaches to reference points.

5. Evaluate stock status with respect to updated status determination criteria.

The Review Panel concludes, based on the information presented in the Operational Assessment that the stock is overfished and overfishing is occurring. This conclusion is robust to both assessment models (M=0.2 and M-ramp) as well as exploratory approaches to the M-ramp reference points.

The findings may be summarized as follows:

1. Based on the M=0.2 assessment, fully-recruited F in 2013 was 1.33 (0.89 - 1.92), which is more than seven times the F_{MSY} proxy (0.18), and 2013 SSB was 2,063 mt (1,561 - 2,774 mt) which is 4% of the SSB_{MSY} proxy (47,184 mt).
2. Based on the M-ramp assessment and the SARC55 approach to reference points, fully-recruited F in 2013 was 1.24 (0.84 - 1.78), which is nearly seven times the F_{MSY} proxy (0.18), and 2013 SSB was 2,432 mt (1,819 - 3,230 mt) which is 3% of the SSB_{MSY} proxy (69,621 mt).
3. Based on the exploratory analyses described above, fully-recruited F in 2013 was well above the F_{MSY} proxy , and 2013 SSB was far below the SSB_{MSY} proxy.

6. Provide a historical retrospective analysis of the performance of the assessment models and associated projections.

The Review Panel concludes that this TOR was met. Retrospective analyses were completed in 2014 assessment update for the two candidate assessment models (M=0.2 and M –ramp) with a 7-year peel (2004-2013 terminal years). As with the assessment presented at SARC55, results indicate a retrospective error in both F and SSB with the tendency for the model to underestimate F and overestimate SSB. However, the magnitude of the retrospective bias differed between the two models, with M=0.2 model showing a greater retrospective pattern. The 7-year Mohn's rho value for SSB and F were 0.53 and -0.33 respectively for M=0.2 model and 0.17 and -0.05 respectively for M-ramp model. The Panel noted that although a strong retrospective pattern exists in M=0.2 model suggests an internal inconsistency between data sources given the assumed constant level of natural mortality, both models should be retained because at present no definitive evidence supporting the assumption of an increase in natural mortality (as depicted in the M-ramp model) has been assembled. It is also noted that despite the differences in the level of retrospective bias, both models result in similar a characterization of the status of the stock (overfished and overfishing occurring).

A historical review of assessment model performance (namely a comparison across model predictions historically used for management advice) indicated that all assessment models had similar general trends of SSB and fishing mortality, but differed in scale. The 2014 assessment update provided the lowest estimates of the SSB time series. There occurred a number of changes in the input data through time that lead to changes in scale of the estimated biomasses, but the 2014 assessment update is believed to assimilate the best available biological and catch information.

Short term predictions based on the assessment presented at SARC55 indicate that terminal year estimates for the M=0.2 and M-ramp models appear to be too optimistic with respect to SSB when compared to the 2014 assessment update results due, in part, to the retrospective bias. Both models originally expected the 1,550 mt ABC to produce a low fishing mortality in 2014 given expected catch, but now revised estimates indicate that overfishing will occur in 2014 with predicted F well above F_{MSY}.

7. *Perform short-term projections, taking into account recent recruitment observations; compare results to rebuilding schedules.*

The Review Panel concludes that this TOR was met. The updated assessment evaluated the stock using two models, M=0.2 and M-ramp, and both were used to make forward projections.

The Operational Assessment Report presented projections that generally used the same recruitment protocol presented at SARC55, however, it adopted a slightly modified protocol for the "hockey stick" approach (Figure 1.45 of the Operational Assessment Report). The previous protocol set the hinge point of the spawner-recruit relationship at the lowest SSB observed. For the update, the hinge point was not modified from that used in SARC55, in recognition of the lower recruitments observed in recent years. Furthermore, the time period used to estimate age 1 recruitment in year t+1 was modified from using the geometric mean of the previous 10 years to using the geometric mean of only the last 5 years in an effort to better characterize recent lower recruitment patterns.

Two methods of projection representing different sets of assumptions were considered for each model. These will be discussed in association with each model in turn.

For the M=0.2 model, one projection was developed from the base model without a retrospective adjustment as was done for SARC55, while the other used the base model with a retrospective adjustment to the 2014 abundance. Both variants use the same reference points: F_{MSY}=0.18, SSB_{MSY}=47,184. Although the report presents evidence that adjusting for the retrospective pattern from the previous assessment would have produced better fits relative to the estimates of current abundance, the panel elected to dismiss this variant as a basis for projections for reasons similar to those expressed at SARC55.

The two M-ramp projections differed in their assumptions about future mortality rates. One configuration (M-ramp M=0.2) assumes that mortality will return to base levels of M=0.2, the other configuration (M-ramp M=0.4) assumes that M will remain at 0.4 throughout the 10 year rebuilding period. Both used reference points based on M=0.2: F_{MSY} = 0.18 and SSB_{MSY} =69,621.

Using 75% F_{MSY}, the three models produce similar catch advice for 2015 (Table 1.37 of the Operational Assessment Report), with catch recommendations ranging from 332 mt (M-ramp

M=0.4) to 460 mt (M-ramp M=0.2). The catch recommendations increase by 2017, although the range expands to 509-1,016 mt.

The most significant difference between the models lies in their implication for stock rebuilding. Under M=0.2 and M-ramp M=0.2 scenarios, rebuilding in the 10 year time horizon is possible, although it requires very low fishing mortality (F=0.06). If higher natural mortality continues as implied by the M-ramp M=0.4 model, then rebuilding in 10 years is not possible, even if catch is set to zero.

Several sources of uncertainty exist in the projections. First, the spawner-recruit relationship does not include depensation (i.e. an Allee effect). If this were to occur, it would lead to even slower stock recovery. The panel also explored the consequences of basing reference points on M=0.4. As discussed above, this leads to lower SSB_{MSY} but higher F_{MSY}. It represents a radical rethinking of the life history and potential productivity of this stock, one that is worthy of consideration in a future benchmark assessment. If the retrospective pattern continues, then these projections will be overly optimistic. This stock assessment is scheduled to be updated next year in 2015, which will provide an opportunity to confirm or revise the projections.

8. *Comment on whether assessment diagnostics—or the availability of new types of assessment input data—indicate that a new assessment approach is warranted (i.e., referral to the research track).*

The Review Panel recognizes that a number of research recommendations have been previously proposed by NEFSC assessment working groups and GARM, SARC and SSC peer reviews. However, the Panel wishes to highlight the following issues because of their relevance to the current review. The Panel also notes that several sources of new information are available that could be considered under research track assessment.

To begin with, the Panel recommends that the criterion for retrospective adjustment should be re-considered in a research track assessment.

Based on SARC53, the SSC identified four topics that warranted further investigation (stock structure, recreational catch estimates, discard mortality, fishery CPUE). The recreational catch, discard and CPUE topics were addressed prior to and during SARC55. With regard to stock structure, several new sources of information are available. A workshop was held on 'Stock Structure of Atlantic Cod in the Gulf of Maine Region' (June 12-14 2012, http://www.gmri.org/mini/index.asp?ID=52&p=149). The Workshop agreed that "*all information from U.S. waters indicates that there are three genetic stocks: 1) Offshore- Eastern Georges Bank (with some connectivity with the Scotian Shelf); 2) Inshore - Northern, Spring-Spawning Complex; and 3) Inshore – Southern, Winter-Spawning Complex*" and "*cod in the eastern Gulf of Maine appear to be distinct from other groups*." Many of the workshop participants felt that there was compelling evidence that the current management units need to be revised. However, the Workshop did not reach any conclusions on what the most appropriate management units might be. Several recent publications have followed up on the research recommended by workshop:

- Pershing AJ, JH Annala, S Eayrs, LA Kerr, J Labaree, J Levin, KE Mills, JA Runge, GD Sherwood, JC Sun & S Tallack-Caporossi. 2013. The Future of Cod in the Gulf of Maine (http://www.gmri.org/resources/resource-archive/future-cod-gulf-maine)
- Cao J, SB Truesdell & Y Chen. 2014. Impacts of stock mixing on the assessment of Atlantic cod in the Gulf of Maine (ICES JMS doi: 10.1093/icesjms/fsu066).
- Zemeckis DR, D Martins, LA Kerr & SX Cadrin. 2014. 'Stock identification of Atlantic cod (Gadus morhua) in US waters: an interdisciplinary approach' (ICES JMS doi: 10.1093/icesjms/fsu032).
- Kerr LA, SX Cadrin & AI Kovach. 2014 'Consequences of a mismatch between biological and management units on our perception of Atlantic cod off New England' (ICES JMS doi: 10.1093/icesjms/fsu113).

The Council has set a priority on examining how stock structure of cod stocks may influence management in the Northeast region. If the Council finds that it is not possible to identify appropriate actions to take concerning differences in stock structure, then the Workshop and subsequent publications have suggested that a research track assessment is warranted in order to consider recent information on cod stock structure off New England for the evaluation of actions such as specifying more appropriate management units.

The Review Panel and members of the public spent considerable time at the meeting discussing the potential that Gulf of Maine cod is responding to a "regime shift" in the environment. In many ways, this view is implicit in the M-ramp model. The Gulf of Maine is near the southern end of the range of cod, and the Gulf of Maine has experienced rapid warming (Mills et al., 2013). Developing a deeper understanding of how environmental factors influence cod would help with the interpretation of alternate model scenarios and management options. Assessment models that specifically incorporate environmental factors such as temperature, prey availability, or the presence or influence of predators could be used to better evaluate the effects of environment on stock dynamics and the assessment.

Additionally, the Review Panel noted that data from the Maine-New Hampshire survey may be available for the next research track assessment if the aging is completed. The aggregate index from this survey indicated a similar decreasing pattern as that shown in the other surveys that are included in the assessment.

Mills, K. E., A. J. Pershing, C. J. Brown, Y. Chen, F. Chiang, D. S. Holland, S. Lehuta, J. A. Nye, J. C. Sun, A. Thomas, and R. A. Wahle. 2013. Fisheries management in a changing climate: lessons from the 2012 ocean heat wave. Oceanography 26:191-195.

9. *Should the baseline model fail when applied in the operational assessment, provide guidance on how stock status might be evaluated. Should an alternative assessment approach not be readily available, provide guidance on the type of scientific and management advice that can be.*

As indicated by the statements made in the previous Terms of Reference for this report, the Review Panel decided to go forward with the two baseline models, the M=0.2 model and the M-ramp model, for providing management advice and guidance on stock status. Please refer to the comments made for the other Terms of Reference for further details.