SAW/SARC 55 Working Group
Report of the Data Meeting
Aquarium Building, S.H. Clark Conference Room, Woods Hole
27 – 31 August 2012

Introduction

Benchmark assessments of the Gulf of Maine (GOM) and Georges Bank (GB) cod stocks are to be reviewed at the SAW/SARC 55 meeting of 3 – 7 December 2012. The Terms of Reference for this review are at http://www.nefsc.noaa.gov/saw/saw55/SAW-SARC-55-FINAL_TORs-2012-05-30-1.pdf. The last benchmark review of the Gulf of Maine cod assessment was conducted at the SARC 53 meeting of 29 Nov – 2 Dec 2011 while that of Georges Bank Cod was conducted at the GARM III meeting in August 2008. In preparation for the December review, the SAW/SARC 55 Working Group (WG) of the NMFS Northeast Fisheries Science Center (NEFSC), Woods Hole, is conducting three meetings:

- Data issues: 27 – 31 August 2012
- Modeling issues: 15 – 19 October 2012
- Modeling and Reference point issues: 29 October – 2 November 2012

The task of the WG is to prepare a draft Assessment Report and Assessment Summary Report for each stock by 16 November 2012. These reports are to address the SAW/SARC 55 TOR, taking into consideration the issues confronting each stock and will be peer reviewed at the December SARC 55.

This Meeting

An array of issues confronts the assessments of Gulf of Maine and Georges Bank cod. These include:

- spatial and temporal processes
- changes in growth, weight and fish condition
- causes of natural mortality
- estimates of discarding and associated mortality
- catch by the commercial and recreational fisheries, and
- characteristics of commercial and surveys indices of abundance

For some issues, separate meetings have already been held. Regarding spatial processes, the NEFSC sponsored a public workshop (12 – 14 June 2012) which was facilitated by the Gulf of Maine Research Institute (http://www.gmri.org/mini/index.asp?ID=52&p=148). The NEFSC also sponsored workshops on the analysis of commercial and recreational landings per unit effort (LPUE) and cod discard mortality (http://www.nefsc.noaa.gov/saw/cod/), the results of which will be considered during SAW 55.

The draft Data Issues meeting agenda is provided in Appendix 1. A number of changes were made to the agenda to meet contingences which arose during the meeting.

A list of background documents and working papers considered during the meeting are provided in Table 1. All papers and analyses conducted during WG meetings are preliminary and have no official status with the agency.

The participant list is provided in Table 2.

The reports by the rapporteurs (L. Alade, J. Blaylock, T. Chute, J. Nieland, M. Traver, S. Wigley, A. Wood) greatly assisted the drafting of this report and were much appreciated.

Gulf of Maine Cod

TOR 1: Estimation of Catch

Working paper (WP) 6 summarizes the analyses undertaken to estimate the catch.

During SAW 53, a small adjustment was made to the commercial landings data in response to the imposition of the 1984 US / Canada Hague Line. Specifically, the line splits three statistical unit areas (464, 465 and 467). Prior to 1985, it is likely that landings in these areas were from the Southwest Nova Scotian cod stock. Since 1985, the US landings reported from these unit areas are assumed to be part of the GOM stock. This is a small adjustment; during 1985 – 93, about 0.4% of the total GOM cod landings came from these unit areas. The WG concurred with this treatment.

Non-dealer transactions are landings that are not reported to primary seafood dealers but are required by law to be recorded in the Vessel Trip Reports (VTR). These landings have represented less than 0.2% of the total dealer landings and have not been included in previous assessments. The WG concurred with this treatment.

An issue in the allocation of within trip landings was considered by the WG (WP 1). Specifically, landings during a trip are assigned to statistical unit area, and thus stock, based upon the reporting of the area of capture in the VTR. Misreporting of unit area has been previously identified as a problem and it was necessary to better understand its magnitude. During WG discussion, it was noted that an analysis by Tom Nies conducted during GARM III suggested that the VTR was primarily recording the first unit area fished rather than the location of all fishing sets. This could not be verified at the meeting. However, a comparison of VTR and VMS (Vessel Monitoring System) records during 2004 – 2011 indicated that this error is small (less than 5% of stock level landings and frequently less than 2%) although was primarily unidirectional (VTR records of GOM cod landings less than VMS-based allocations). The WG concluded that this scale of error would not be consequential to the assessment.

An overview of the trends in commercial landings since the 1800s was considered by the WG. Commercial landings during 1890 – 2000 were in the order of 10.4 kt annually. Alexander at al., 2009) estimated that annual landings during the 1800s were in the order of 50 – 80 kt although this was based upon a number of assumptions. Notwithstanding the issues with these historical data, the WG considered that it was important to consider the historical time series during SAW 55; it indicates that fishing has been underway on GOM cod since prehistoric times. Thus even during 1960 – 70, the stock cannot be considered to have been in a virgin state.

A comprehensive description of the temporal and spatial patterns in commercial landings was considered by the WG. These highlighted the steady contraction of the fishery to statistical unit area 514 in the western Gulf since about the mid-1990s.

The construction of the commercial landings at age was comprehensively described. While samples exist back to 1969, it is only since 1982 that sampling intensity has been sufficient to characterize the age/size composition of the landings. The WG concurred with the construction of the commercial landings at age as presented.

The WG noted that while information on the age composition of the landings is available up to about age 14, it is very sparse past age 9 which leads to issues in data interpretation. This was particularly the case in the 1990s. For instance, the sparse data at old ages leads to non-sensible changes in weights at age (large decreases for some cohorts). Sensitivity analyses conducted during SAW 53 indicated that there were no major differences in the assessments

using either an age 9+ or 11+ age group. While the GARM III had employed an age 11+ group, the WG concurred with the SAW 53 use of an age 9+ group as a starting point for the models' meeting. This issue can be revisited during the models' meetings, if warranted.

The WG noted the considerable analyses undertaken to estimate commercial discards and their age/size composition. Discard rates estimated using the NEFOP (Northeast Fisheries Observer Program) and at-sea monitors (ASM) data were not significantly different (WP 3) and were thus combined. The SBRM (Wigley et al., 2007) d_{cod}/k_{all} ratio was applied in the exploration of a number of sampling stratification schemes to estimate discards since 1989. There were no discard data available for 1982 – 1988 and thus these were hindcast based upon observed discard rates during 1989 – 91 for shrimp trawl and 1989-93 for large mesh otter trawl and large mesh gillnet. The size composition was based upon a comparison of fishery and survey length frequencies during this period. The WG concurred with the estimation of the commercial discards and their age/size composition.

A summary of the findings of the Discard Mortality workshop was considered by the WG. Using a Delphi approach, workshop participants with a wide range of expertise reached consensus on gear – specific estimates of cod discard mortality. The WG agreed that the median estimates of discard mortality (ranging 20 – 80% dependent upon the gear type) be used in both cod assessments.

A comprehensive summary of the recreational landings and age/size composition was considered by the WG. Since SAW 53, a number of adjustments have been made to the estimates of the recreational catch. Data on recreational landings are available from MRFSS since 1981 while both landings and discards are available from MRIP since 2004. For 2004 to the present, MRIP[1] estimates were used in place of the MRFSS data. For 1981 – 2003, a ratio of the summed MRFSS to MRIP landings and discards during 2004 – 2011 was used to update the MRFSS statistics during 1981 – 2003. This method adheres to the recommendation of the MRFSS-MRIP Calibration Working Group. The WG agreed that all years (2004 – 2011) be used in the estimation of this ratio. While the data for 2010 appeared anomalous in one direction, those of 2011 appeared anomalous in the opposite direction. Size composition data on discards are available from MRIP during 2005 – 2011. These were used in a similar manner to that used for the commercial data to hindcast the recreational discard size composition back to 1981. Overall, the WG concurred with the estimation of the recreational catch and its age/size composition as presented.

The WG wished to highlight issues with the availability of the catch data prior to 1982. As background to this discussion, it noted that regulatory changes over the history of the fishery have been extensive (documented in WP 6 back to 1973). This will confound attempts to hindcast the age / size composition of the catch prior to 1982. Notwithstanding this, as noted above, there is a long history of commercial landings data, with official records starting in 1932. Prior to this, estimates of commercial landings have been based upon proration using various assumptions (e.g., F. Serchuk pers. comm., Alexander et al., 2009).

Commercial sampling (length frequency and aging) in sufficient intensity has only been underway since 1982. Sampling prior to this year does not allow characterization of the age/size composition of the landings in any meaningful way.

Commercial discards data are available since 1989. The data back to 1982 was based upon hindcasting of the average magnitude of discarding during 1989 – 1991 or 93 (dependent upon gear) combined with a comparison of survey to commercial size composition to infer the length frequency of discards.

[1] It is worth noting that during 2004 – 2011, reference to MRIP means the application of the MRIP estimation process collected by the MRFSS protocols. Thereafter, reference to MRIP means a change in both hoe the datas were collected as well as a different estimation process from MRFSS.

Recreational landings and discard data have been collected by the MRFSS program since 1981. The MRIP program has collected similar types of data since 2004. The MRFSS data for 1981 – 2003 has been updated based upon the ratio of the MRFSS/MRIP data during 2004 – 2011. There is no recreational data prior to 1981.

Recreational sampling data of the landings but not discards are available from MRFSS and MRIP since 1981. For discards, data are only available from MRIP since 2005. These data were hindcast to 1981 in a similar manner as used for the commercial data. No recreational sampling data are available prior to 1981.

TOR 2: Survey and Commercial Indices of Abundance

Spatial and temporal trends in the Northeast Fisheries Science Center's (NEFSC) annual spring (since 1968) and fall (since 1963) bottom trawl surveys (BTS) were considered by the WG (WP 9). It noted that these surveys sample the areas of the heaviest commercial and recreational fishing activity. It also noted that, consistent with the trends in the fishery, the distribution of cod has become increasingly concentrated in the western GOM since the mid-1990s. There has been a gradual loss of cod from the coastal and central GOM. Consistent with this trend, there has been an increase in the variability of the survey indices. The WG noted that while variability has increased, the survey design-based indices are still unbiased estimates of abundance and biomass.

The SAW 53 data WG had recommended that consideration be given to inclusion of the inshore strata data when switching to the Bigelow survey time series. Sampling in these strata during both spring and fall surveys has been inconsistent or non-existent, dependent upon the stratum. The analysis presented to the WG indicated that inclusion of these inshore strata had minimal influence on the trends in both survey indices. It was thus recommended that these inshore strata be excluded from the SAW 55 analyses.

A number of operational changes have been made to the NEFSC spring and fall surveys during the times series, including a change in vessel (Delaware/Albatross historically and introduction of the Bigelow in 2009), trawl door (during 1984-85) and trawl net (Yankee 36/41 in spring survey). As well, a concern had been raised that differences in day versus night time sampling might be introducing bias into the time series. The analysis (WP 6) presented to the WG indicated that the trends in the calibrated and uncalibrated surveys indices were very similar and with the exception of the fall 2009 abundance index, the effects of the Bigelow calibration were less than the historical door/vessel calibration effects. Further, the survey trends were very similar between day and night and both day and night indices were consistently within the 80% confidence interval (CI) of the combined index with little evidence of systematic bias.

Overall, the WG recommended that the adjusted series of each NEFSC survey time series be used during SAW 55.

The WG noted a recommendation made during SAW 54 to include the ratio of estimated calibration coefficients, constrained by a penalty function of the expected ratio based upon the calibration studies, included in the objective function of the assessment model (Francis, 2012). In some cases (e.g. trawl door change), the time series is too short to adopt this approach. As an alternate approach, the WG recommended that sensitivity analyses be undertaken during the modeling to explore the impact of uncertainty in the calibration coefficients.

The WG considered a GLM model of the survey data, in which the factors considered included cruise (proxy for year), stratum, temperature, depth and time of day (WP 7). This model highlighted the highly contagious and over dispersed nature of the data, which called for use of a negative binomial distribution (one of many explored) in the fitting of the model. The best fit to the data was achieved with a model using cruise, stratum and time of day as factors. Overall, the temporal trends estimated by the model were similar to those of the design-based estimators.

The WG considered that use of the GLM estimates in the assessment model would result in an underestimation of the variability in the survey indices as the GLM is effectively acting as a smoothing function of each time series. It therefore recommended that the design-based survey indices be used in the assessment models. However, it noted that the coefficients of variation (CV) from the GLM could be compared to those generated during the stage two iterative re-weighting process as the latter incorporate both observation and process error, similar to what the GLM produces.

The WG considered a comprehensive analysis of the Massachusetts inshore spring (May) and fall (September) BTS (WP 6). These surveys started in 1978, although aging information is only available since 1982. The abundance indices of these surveys exhibit the same overall trends as the NEFSC surveys, with the spring index being at an all-time low.

The WG considered diagnostics of the Massachusetts spring and fall surveys, specifically one that showed how well the abundance of year-classes was being tracked by each survey. In general, year-class tracking in the spring survey was reasonable for ages one to six but only reasonable for ages zero and one in the fall survey. The WG discussed reasons why this might be the case, including seasonal movements of cod between the inshore and offshore. Based upon this analysis, the WG recommended that the Massachusetts spring, but not fall, survey time series be used in the SAW 55 assessment model of GOM cod.

In constructing the proportions at age in Massachusetts inshore survey, it was noted that a number of length groups in the age/length key (ALK) were missing age information. While there was a modest (20 days) difference of the timing of this and the NEFSC spring survey, an attempt was made to augment the ALK of the inshore survey using aging data collected during the sampling of the inshore strata of the NEFSC survey. The amount of aging material (i.e. otoliths) in both surveys was about the same. After analysis conducted during the WG meeting, it was agreed that such augmentation was not necessary, with the ALK before and after this treatment being very similar. It was therefore recommended that the aging data in the Massachusetts inshore survey not be augmented with the NEFSC ageing data.

The WG considered a comprehensive analysis of the Maine/New Hampshire inshore spring (May) and fall (October) BTS (WP 6). The time series of these surveys is short, starting in 2001 and 2000 for the spring and fall respectively. As well, while aging material has been collected, it has not yet been processed. The WG noted that while abundance and biomass indices was being tracked well on an annual basis, such was not the case between the spring and fall survey in each year, comparable to the pattern seen in the Massachusetts inshore surveys. This prompted discussion on the seasonal north/south movements of cod along the Maine coast. The WG concluded that while this survey may be valuable in the longer term, it is both too short and lacking the aging data to be used in the SAW 55 assessment.

The WG briefly reviewed the historical data available from the survey datasets. For the NEFSC surveys, as noted above, the spring and fall series start in 1968 and 1963 respectively. While length frequency data are available from the beginning of each series, aging data are only available since 1970. For the Massachusetts inshore surveys which start in 1982, aging data are available for the entire time series.

A number of analyses were considered by the WG in an attempt to develop representative indices of GOM cod fishable biomass based on commercial and recreational landings per unit effort (LPUE) (WPs 9, 10 and 11). It noted that the SAW 53 had considered a commercial LPUE index but had ultimately not included it in the final assessment model formulation. The LPUE index which had been used by Mayo et al. (1994) was updated (WP 9). This used year, depth, tonnage class, quarter and statistical unit area as factors in a GLM assuming lognormal error. Trends produced by the analysis tracked spawning biomass (SSB) as estimated during the SAW 53 relatively well up until 2006 after which time LPUE increased much faster than SSB. The reasons for this divergence were discussed at length by the WG. A hypothesis considered by the

WG (WP 4) is that sand lance abundance, which a forage species of cod, has become concentrated in a small region of the western GOM (near Stellwagen Bank). This has resulted in the aggregation of cod in the area and thus elevated commercial catch rates. The incidence of occurrence of sand lance in cod stomachs collected during the spring and fall NEFSC BTS surveys has increased since 2006. These surveys indicate that the Stellwagen Bank area appears to be a forage 'hot spot' for cod feeding on sand lance. As well, the VTR, observer and VMS information from the commercial fishery indicates that fishing effort since the mid-2000s has become concentrated in this area.

The WG discussed at length the processes that may be influencing the cod distribution in the Gulf of Maine. It appears that two related but separate processes may be underway. Over the longer term, there has been a loss of cod from the central and coastal areas of the Gulf with an apparent concentration of cod in the western area. In addition to this, since 2006, there has been a further aggregation of cod within this area into forage hot spots, hypothesized to be driven by sand lance, as noted above. While it is difficult to prove definitely that these processes are responsible for the observed distribution changes, the evidence is suggestive. Notwithstanding the causes of the observed patterns, cod appear now to be aggregated in a small area of the Gulf, which suggests that the catchability (relationship between LPUE and biomass) has changed over the LPUE time series and has likely increased more recently. Over the longer term, there have a number of regulatory changes (e.g. seasonal closures, trip limits, etc) which call into question the utility of commercial LPUE as an index of GOM cod biomass. Similar issues with commercial catch rate indices have been observed elsewhere (e.g. Harley et al., 2001). Based on these concerns, the WG recommended that the commercial LPUE index not be used in the SAW 55 assessment model. This recommendation is consistent with the findings of the recent NEFSC-sponsored LPUE workshop.

An LPUE index was also developed for the recreational fishery (WP 11). A GLM using year, month, area, permit and fishing category as factors was applied to the 1994 – 2011 recreational landings data. A number of error structures were explored with a lognormal model ultimately chosen. Contrary to the commercial fishery, recreational fishing has consistently occurred within a restricted region of the western Gulf. As with the commercial fishery, recreational fishing has been impacted by a series of regulations (e.g. seasonal closures, bag limits, etc). The analysis only included landings and was not able to include the release information which has become an increasing component of the catch. Further, the GLM analysis was only able to include party-charter boats. Overall, given concerns comparable to those of the commercial fishery, the WG recommended that the recreational LPUE index not be included in the GOM cod assessment model.

TOR 3: Stock Structure

A summary of the 12 – 14 June 2012 workshop report (GMRI, 2012) on cod stock structure in the Gulf of Maine area was provided to the WG. The terms of reference were ambitious, consisting of three phases (the first of which was the workshop); there were gaps in attendance (e.g. no Canadian researchers were present). Consensus was reached on a number of concepts related to stock structure, but while many workshop participants felt that there was compelling evidence that the current management units needed to be revised, the workshop did not reach any conclusions on what the most appropriate management units might be.

The workshop did not explicitly address the next steps in the process. The workshop steering committee subsequently recommended that an inclusive but focused working group, involving a small group of Canadian and US scientists, be convened to consider the results of the workshop and address the short-term data and analyses in order to delineate the most appropriate management units.

For the purposes of reporting the results of the workshop at the SAW 55 (thus meeting TOR 3), the WG considered that a concise statement on the progress to date, without getting into the detailed findings of the workshop (which are available in its report) was appropriate. In aid of this, the following text was drafted:

> A work plan on the topic of Atlantic cod stock structure in the Northeast United States/Scotian Shelf region was recommended by the New England Fishery Management Council's Scientific and Statistical Committee. The work plan laid out a three-phase process for re-evaluating, and possibly revising, the spatial basis for assessment and management of Atlantic cod. The first phase was to review data (genetic, life history, tagging, etc.) in order to evaluate the "null hypothesis" of the status quo management units.
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> The NEFSC sponsored a public workshop on cod stock structure, held June 12-14, 2012, facilitated by the Gulf of Maine Research Institute to address Phase I. Invited participants from the fishing and scientific communities presented on a range of topics with opportunities for discussion. The full workshop report is available at http://www.gmri.org/mini/index.asp?ID=52&p=149.
>
> Many of the workshop participants felt that there was compelling evidence that the current management units need to be revised. The Workshop did not reach any conclusions on what the most appropriate management units might be. This will require further data analysis and modeling in order to complete Phase I of the SSC recommended process. The workshop report also identifies gaps in the data and analyses and recommended action to address them.
>
> The Workshop did not explicitly address and propose the next steps in the process. The Steering Committee recommended that an inclusive but focused Working Group meeting be held involving a small group of Canadian and US scientists to consider the results of the Workshop. This Working Group should be provided the short-term data and analyses identified as missing by the Workshop. Using that information, as well as the conclusions from the Workshop, the Working Group should determine the most appropriate representations of biological stock structure to complete Phase I of the process. The results from this Working Group meeting should be evaluated through an independent peer-review process.
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> Since the phased review process of cod stock structure that was recommended by the SSC has not been completed, no changes to stock structure were incorporated into this assessment.

TOR 4: Natural Mortality

Estimates of natural mortality (M) based upon the maximum age, the Gonad-Somatic Index and growth parameter (K) ranged 0.18 – 0.25 compared to 0.2 used in SAW 53 (WP 6). The method of Lorenzen (1996) was used to provide an aged-based estimate of M. This method, which is based upon the relationship between body weight and M across a wide range of species, was used in SAW 54 to provide age-based estimates of M for Southern New England – Mid Atlantic Bight yellowtail flounder. The peer review panel of SAW 54 (O'Boyle, 2012) considered that applying an inter-species relationship to infer within – species dynamics was an

over-interpretation of the method. While M no doubt may be age-specific, the pattern estimated from the Lorenzen method may not be appropriate. Recent work performed by Jon Deroba (NEFSC) and Amy Shueller (SEFSC) (https://afs.confex.com/afs/2012/webprogram/Paper10183.html) indicated that using constant or age varying mortality would have similar impacts on the assessment. The WG thus concluded that the parsimonious approach is for the SAW 55 assessment models to use a single M for all ages.

An analysis of tagging data collected during 2003 – 2005 to jointly estimate natural and fishing mortality was undertaken during GARM III. This analysis was updated for SAW 55 (WP 12). Contrary to the earlier work, this analysis was not length-based. Estimates of M ranged 0.4 – 0.5 for the three areas (Southwest Nova Scotia, GOM and GB) included in the model. It also provided evidence of significant cod movements between GOM and GB as well as Southwest Nova Scotia and GB. While M was relatively high compared to current estimates, F was comparatively low, prompting discussion on whether or not it was representative of the fishery due to local effects.

Concerns were raised with the tagging conducted in the Cape Cod area, which represented over 50% of the date in the database. The tagging had been conducted employing a wide range of expertise with mostly small cod tagged. This in combination with the warm water in the area may have resulted in higher tag induced mortality than assumed in the model. There were additional concerns with the assumed tag reporting rate (100%) for high reward tags. The analysis was rerun assuming an assumed range of high reward tag returns (80 – 100%) and including only 50+ cm cod which would largely exclude the Cape Cod data. This analysis again suggested high M in all three areas.

The WG discussed how best to use these estimates of M in the models' meetings. It was hesitant to conclude that M was in the range of 0.4 – 0.5 and to recommend that these estimates be directly included in the assessment models. Rather, the tagging analysis is another form of modeling that should be considered during the model's meetings. It will be up to the latter to explore model formulations which consider the consistency of tag – based M with competing hypotheses.

Three working papers (WP 8, 18 and 19) considered the predator field of cod in the Gulf of Maine area. WP 18 noted that directed piscivory of cod by other fish was not common, with well less than 200 cod in over 550,000 stomachs observed. Similarly, the evidence for cannibalism is weak with only 20 cod found in over 20,000 stomachs. Studies to date suggest that M due to fish predation is likely low and is focused on juvenile and smaller size groups (Smith and Link, 2010).

WPs 8 and 19, as well as part of 18, considered marine mammals as a potential source of elevated M in the Gulf of Maine area. Four species of seals (Harbor, Grey, Harp and Hooded) are found in New England with Harbor and Grey seals being the most numerous. The Harbor seal population, which was about 38,000 individuals in 2001, has been growing at an annual rate 6.6%. The Grey seal herd has increased from tens of animals in the early 1980s to thousands of animals in the late 2000s. Firm estimates on the size of the current herds are not available. Notwithstanding this, the food habit research suggest that cod mortality due to seals is low.

The WG recommended that summaries of these broader ecosystem processes be include in the draft assessment reports of both GOM and GB cod.

TOR 5: Estimation of Fishing Mortality, Recruitment and Stock Biomass

Work for this term of reference will primarily be undertaken at the next two meetings of the WG. There was, however, some discussion relevant to this TOR during the meeting.

A short presentation on catch curve analysis of survey and fishery indices at age was presented which indicated little evidence of domed selectivity in both the fishery and NMFS surveys. This analysis will also be considered during the next two meetings of the WG.

The WG had discussion on the main issues confronting the GOM cod assessment to inform potential model formulations of the next two meetings of the WG. These include, but not exclusively:

- Observation related
  - Implications for use of NEFSC survey inshore strata & LPUE
  - Fishing fleets to be included in the models
  - Treatment of uncertainty in survey calibration coefficients
  - Flat vs domed survey and fishery selectivity
- Process related
  - Pre – 1982 recruitment
  - Implications for changes in natural mortality

Some of these issues were raised by Diodati and Rothschild (2012). Many of these issues were explored both during and subsequent to SAW 53 while others require further work. For instance, in relation historical recruitment, it may be possible to apply the assessment model-derived catchabilities to the 1970 – 81 NEFSC BTS data to estimate pre-1982 recruitment, in a manner similar to what has been done in Georges Bank yellowtail assessments.

Overall, the WG offered general guidance on the GOM cod assessment models without being overly proscriptive.

TOR 6: Reference Points

Analyses (WP 9) of a number of biological parameters related to the estimation of reference points were considered by the WG.

One issue is the weights at age to use for estimation of spawning stock biomass (SSB). While the spring survey is well timed for calculating spawning weights at age, estimates are not available for every age in every year. Two options were considered by the WG – 1) weights at age based upon the landings and discard sampling information with the method of Rivard to estimate weight at time of spawning and 2) use of a smoothing function applied to the survey data to estimate weights at age for all ages and all years (WP 5). Both methods characterized the general trends in weights at age with pros and cons with each method. The WG recommended that option one be used as this is consistent with previous practice.

In relation to spawning time, genetic and growth research presented to the WG (WP 13) indicated that GOM cod is comprised of northern spring (May/June) and southern winter (December/January) spawning components, with homing of each group to their respective and distinct spawning grounds. This raised the issue as to what date to use for peak spawning. The previous assumed peak was February 1st. The WG recommended that rather than a peak spawning date be defined, the date for the estimation of SSB be based upon the mid-point between the spawning periods, which is 1st April.

A von Bertalanffy growth curve analysis was considered by the WG (WP 6). It showed that, based upon the NEFSC spring and fall survey data, GOM cod grow slower than GB cod and that there were no strong temporal trends. A plot of year-class strength from SAW 53 against the Brody growth coefficient, K, revealed no relationship suggesting that strong year-classes do not appear to be subject to density-dependent growth as has been observed in Georges Bank haddock.

An examination of the length-weight relationship in the NEFSC surveys over time (WP 6) uncovered no discernible trend suggesting that fish condition has not changed over the long term, supporting the conclusions of SAW 53. The application of the length-weight relationship derived from the NEFSC survey data to estimate catch numbers was criticized during SAW 53. The comparison of estimated to recorded fishery sample weights indicated that while there was no temporal trend, the gutted to live weight conversion factor was closer to 1.2 rather than the 1.17 that has been used. Further study of this is required; the WG recommended that the present conversion factor (1.17) continue to be used.

An analysis of the maturity at age data in the NEFSC spring surveys (WP 6) indicated that, notwithstanding the high level of variability in the time series, the average age of 50% maturity (A_{50}) was been relatively stable over the long-term. In the 1970s, the average age of maturity was higher but this was a period of high CVs. The WG recommended that the time series average of the maturity at age be used, as had been the case during SAW 53, as there is no compelling reason for a change.

The length at 50% maturity (L_{50}) exhibited more significant temporal changes than the A_{50}. Further examination at the meeting indicated that these changes appeared to be related to variation of the length frequency data rather than being process related.

TOR 7: Evaluation of Stock Status

Work against this term of reference is to be undertaken at the next two meetings of the WG.

TOR 8: Projections

Work against this term of reference is to be undertaken at the next two meetings of the WG.

TOR 9: Research Recommendations

A report on progress towards the SAW 53 research recommendations was provided to the WG, three of which related to the Maine/New Hampshire inshore survey. While progress has been made on the implementation and analysis of the data collected since the start of this survey in 2000/2001, much still needs to be done. For instance, aging the collected cod otoliths was still considered as a priority.

Overall, the WG considered that discussion on the research recommendations would more usefully pursued after the models' meetings.

Georges Bank Cod

TOR 1: Estimation of Catch

A comprehensive overview of landings trends by country, year, gear and areas was provided to the WG (WP 15). The fishery on Georges Bank has experienced numerous changes over the years, with European distant water fleet exploiting the bank during the 1960s, ICNAF management until 1977, with US and Canadian regulation of their respective areas (5Z-6 and eastern Georges Bank) since October 1984. While landings data have been recorded since 1932, prorated estimates are available back to the 1890s. Fisheries are known to have operated for years and perhaps centuries prior to this. The WG agreed that providing this long-term perspective during SAW 55 will be valuable.

Sampling to characterize the age and size composition of the commercial landings has been adequate to good subsequent to 1987 but was poor before then. The temporal and spatial stratification of the sampling data to construct the landings at age since 1978 was fully described. The WG noted the importance of estimating the landings at age separately for the US and Canada, as both countries exploit distinct areas with different fleets.

Commercial discards were estimated for 1989 – 2011 using the SBRM method (Wigley et al., 2007). Discards (mt) were hindcast to 1978 based on a survey filter method that applies selection ogives to NEFSC survey length frequencies that are prorated to total discards based on the percentage of landings from large mesh gear and the relationship between estimated survey 'kept' and observed kept commercial length frequencies. Characterization of the age/size composition was based on the NEFSC survey age/length/weight data. The hindcasting used only data from the trawl fishery due to low sampling of the other gears. Annual commercial discards at age were estimated by half year and for the eastern and western part of 5Z-6. The WG concurred with the treatment as presented.

Canadian discard information is available for its scallop fishery since 1978 while only since 1997 for the groundfish (mostly longline) fishery. There is a lack of observer data for both the mobile and fixed gear fleets prior to 1997. The WG queried whether or not hindcasting of discards could be conducted for 1978 – 1996 in a similar fashion as done for the US fishery. A request was made to the Transboundary Resource Assessment Committee (TRAC) through the US TRAC co-chair (L. O'Brien) to have this analysis undertaken as part of the spring 2013 benchmark assessment of eastern Georges Bank cod. For the SAW 55, the Canadian discards will be used as presented.

Regarding discard mortality, as with the GOM cod, the WG recommended that the gear-specific estimates from the discard mortality workshop be used during SAW 55.

An analysis of the recreational landings and discard data for 1981 – 2011 was considered by the WG (WP 15). A similar treatment was used as that for GOM cod. Specifically, for 1981 – 2003, MRFSS data were updated using the MRFSS/MRIP ratio (seasonally estimated) for 2004 – 2011. The WG agreed that all years be used in the estimation of this ratio. The size composition of recreational discards during 1981 – 2003 was based the NEFSC survey length frequencies with an annually adjusted length cut point to reflect changes in the regulations. For 1978 – 1980, both the magnitude and size composition of the discards was assumed to be the same as that in 1981. The WG concurred with the treatment of the recreational discard data as presented to the WG.

TOR 2: Survey and Commercial Indices of Abundance

A description of the spatial distribution of the NEFSC spring and fall surveys was considered by the WG (WP 15). The survey indices are based on strata 13 – 25. Historically, cod have been distributed as far south as the coast of New Jersey but have recently not been caught in any quantity in that area. Overall, though, contrary to the situation with GOM cod, there is no evidence of temporal distributional changes in either the spring or fall surveys. While there are significant year effects in the spring and fall survey time series of abundance, overall, the CVs are modest, being less than 20%.

The WG noted that the spring and fall NEFSC surveys commenced in 1968 and 1963 respectively. While length frequency data are available from the beginning of each series, aging data are only available since 1970.

As with the GOM cod, a number of conversion factors have been applied to the spring and fall survey datasets to compensate for changes in vessel, trawl door and net. The WG discussion on how these adjustments should be handled in the GB assessment is provided under TOR 2 for GOM cod. In summary, the WG recommended that the adjusted series of each survey

be used in the SAW 55 assessments but also recommended that sensitivity analyses be undertaken during the modeling to explore the impact of uncertainty in the calibration coefficients.

DFO has been conducting a winter survey on eastern Georges Bank since 1986. Both aging and length frequency data are available for this survey since then. An issue with this survey is that it didn't sample certain areas in 1993, 1994 and 2012. To maintain a consistent time series, the WG recommended that these years be excluded from the SAW 55 assessment.

A GLM analysis of the GB cod NEFSC spring and fall survey data was undertaken in a similar manner as that for GOM cod (WP 7). In this case, a lognormal error model provided a superior fit to the data, compared to the negative binomial. The factors considered in this analysis were the same as those in the GOM cod analysis. Time of day was determined to be a significant factor perhaps due to the presence of some large tows. A negative binomial error model resulted in a superior fit to the fall data. Overall, the model and design – based abundance and biomass trends are very similar. Overall, the conclusions of this analysis are the same as those for GOM cod – the GLM is acting as a time series smoother and thus to best reflect uncertainty in the survey data, the WG recommends use of the design-based indices. As with GOM cod, the coefficients of variation (CV) from the GLM can be compared to those generated during the stage two iterative re-weighting process as the later incorporate both observation and process error, similar to what the GLM produces.

A commercial LPUE index was last used in the 1994 GB cod stock assessment. This index was updated using a comparable GLM analysis with year, statistical area, quarter, tonnage class, and depth as factors (WP 15). A lognormal error model best fit the data. In contrast to the survey time series, LPUE was shown to be increasing since about 2005 while nominal fishing effort has decreased. An issue with this index is that it primarily represents the western part of the stock area since 1985. This was illustrated in a series of quarterly distribution maps of commercial LPUE during 1978-1994 (WP 17a-c) and annual distribution maps of LPUE during 1994-2011 (WP 16). The eastern area contributes about 30% to the overall landings. In addition, there have been significant regulatory changes (e.g. trip limits, closed areas) during the history of the fishery, resulting in large-scale spatial shifts in where the fishery occurs (WP16), all of which detract from the utility of the index as a measure of abundance. Based on these concerns, the WG recommended that the commercial LPUE index not be used in the SAW 55 assessment model. This recommendation is consistent with the findings of the recent NEFSC-sponsored LPUE workshop.

A GLM analysis using year, month, area, permit and fishing category as factors was applied to the 1994 – 2011 recreational landings per unit effort data (WP 11). Of 7730 trips conducted since 1994, 3780 were selected for the analysis. Only party and charter boat permitted vessels were included in the analysis. A number of error structures were explored with a lognormal model ultimately chosen. The index first declined from 1994 to about 2005 after which time it increased significantly. Concerns in data quality at the beginning of the times series were raised by the WG. Specifically, it is possible that pounds rather than counts were initially being recorded which could account for the initial drop in the index. To get a better sense of the trends in the data, the time series for each of the 17 party or charter boats involved in the analysis were plotted. It was evident that a consistent time series of data was available for only about four permits with the contribution of data from the other permits being inconsistent across the times series. Also, recreational fishing activity has occurred almost solely in the western portion of Georges Bank stock area - west of the Great South Channel (WP 16). Given these issues, the WG recommended that the recreational LPUE index not be included in the GB cod assessment model.

TOR 3: Stock Structure

The discussion on stock structure is provided under GOM cod above.

TOR 4: Natural Mortality

Estimates of natural mortality (M) based upon the maximum age ranged 0.2 – 0.4 compared to 0.2 used in GARM III. An estimate of M of 0.3 based on the Lorenzen (1996) method was also presented. As with GOM cod, the main concern raised by the WG is that it is applying an inter-species relationship to infer within – species dynamics. The WG concluded that, for the SAW 55 assessment models on GB cod, a single M for all ages should be employed rather than one that was age-dependent.

The discussion on the tag-based estimates of M is also provided under the TOR 4 for GOM cod. That analysis (WP 12) indicated that during 2003 – 2005, the period covered by the tagging study, the estimate of M for GB cod were 0.56, compared to 0.57 for GOM cod. These estimates are considerably higher than both the GARM III estimate of 0.2 and the more recent estimates of 0.2 – 0.4 based on maximum age and the GSI. The WG discussed the possibility that M has increased in recent years. It was reported that the 2011 TRAC assessment (Wang et al, 2011) of the eastern GB cod resource incorporated an option with M fixed at 0.5 for ages 6+ after 1994 as an attempt to resolve the retrospective pattern present in the assessment. Wang et al. (2011) acknowledged that this assumed change in M could be aliasing "missing" catch, particularly during the regulatory and reporting changes of the mid-1990s. They noted that it could also be aliasing emigration or imperfect designation of the boundaries for this component, though an excess of larger/older fish is not apparent in adjacent cod components.

This discussion led the WG to consider the three working papers (WP 8, 18 and 19) and background document of Smith and link (2010) on potential sources of elevated M due to predation. As noted in the GOM cod discussion on natural mortality, the food habits research suggests that predation of GB cod, either by fish or by seals, is likely not a significant source of natural mortality. WP 18 notes that while the hypothesis that cod M has increased may still be viable, it is likely not due to predation and may be due to changes in growth. As will be seen under TOR 5, there has been a recent decline in GB cod fish size although this has not been observed in GOM cod (see TOR 6 of GOM cod).

In summary, there is little empirical evidence to support an increase in M in recent years. While the retrospective pattern in the eastern GB cod assessment can be somewhat addressed by assuming elevated M, it may be aliasing other processes. The WG was hesitant to conclude that M was in the range of 0.4 – 0.5 and to recommend that these estimates be used in the assessment models. As with GOM cod, the tagging analysis is another form of modeling that should be considered during the model's meetings. It will be up to the latter to explore model formulations which consider the consistency of tag – based M with competing hypotheses based on M in the order of 0.2 – 0.4.

TOR 5: Estimation of Fishing Mortality, Recruitment and Stock Biomass

Work against this term of reference is primarily to be undertaken at the next two meetings of the WG. There was, however, some discussion relevant to this TOR during the meeting.

The last assessment of GB cod, conducted during GARM III, used VPA which assumes that there is negligible error in the catch at age. Adoption of a statistical catch at age (SCAA) approach will allow consideration of the errors in removals along with other sources of uncertainty. The GOM cod assessment underwent a similar migration (from VPA to SCAA) and thus during SAW 53, a 'bridging' analysis was undertaken to illustrate how the results of the

new analytical approach compared to the previous one. This analysis will be an important part of SAW 55 assessment for GB cod.

Contrary to the situation with GOM cod, the GB cod assessment has experienced a severe retrospective pattern, the source(s) of which have yet to be determined. The WG discussed the potential sources of the retrospective pattern. The underlying cause is the loss of recruitment productivity that cannot be explained by either subsequent survey catch rates or fishery removals. The WG discussed possible causes which would explain this process including unreported catch, mis-specification of the survey and / or fishery selectivity at age, and / or unaccounted for increase in natural mortality. Some of these hypotheses have been investigated in previous SAW and TRAC reviews. In preparation for SAW 55, the WG agreed that further exploration of these and other possible causes of the retrospective pattern will be important to the GB cod assessment.

An additional consideration in the GB assessment is that the resource inhabiting the eastern part of Georges Bank is managed and fished as a transboundary management unit with Canada. It will be important to compare and contrast stock trends in this and the larger 5Z-6 area.

TOR 6: Reference Points

Analyses (WP 15) of a number of biological parameters related to the estimation of reference points were considered by the WG.

Regarding growth, since the mid-1990s, there have been declines in cod weight and length at ages three and older in the NEFSC spring and fall surveys. Estimates of L_{inf}, based on a growth curve analysis, also indicate that there has been a decline in growth rate during 2001 – 2011.

An analysis of temporal changes in the length-weight relationship derived from the NEFSC spring survey indicated that condition (weight of cod of 60 – 65 cm) has declined since about 1990. This trend has not observed in the fall survey, prompting WG discussion on whether or not spawning time has changed relative to the timing of the spring survey. While the WG concurred with the condition analysis as presented, it recommended further exploration to confirm the trends, the results of which should be considered during the models 'meetings.

The decline in fish condition raised concerns regarding estimation of the landings numbers as the 1992 – 2007 length-weight relationship is used in the computation of the landings numbers. If condition has changed, this could impact these estimates. However, cod of 15 – 80 cm in length are caught by the fishery so the impact will likely be small. The WG recommended that a sensitivity analysis be undertaken which compares estimated and reported commercial samples weights using a range of length-weight relationships.

Based on the NEFSC spring survey observations, the age of 50% maturity at age (A_{50}) of GB cod declined during the 1970 – 80s and has increased since 1990. A similar pattern was observed with the L_{50}. The GARM III estimated the maturity ogive based upon a five-year moving window. Given the long-term changes in A_{50}, the WG recommended that this practice be continued.

TOR 7: Evaluation of Stock Status

Work against this term of reference is to be undertaken at the next two meetings of the WG.

TOR 8: Projections

Work against this term of reference is to be undertaken at the next two meetings of the WG.

TOR 9: Research Recommendations

As with GOM cod, the WG considered that discussion on the research recommendations would more usefully pursued after the models' meetings.

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Table 1. List of Working Papers and Background Documents considered at the SAW 55 Data Meeting

WP #	Topic	TOR	Stock	Author	Title
1	Commercial Landings	1	Both	Palmer & Wigley	Using positional data from vessel monitoring systems (VMS) to validate the logbook-reported area fished and the stock allocation of commercial fisheries landings, 2004-2011
2	Discards	1	Both	Palmer	A review of factors affecting the mortality of discarded Atlantic cod (Gadus morhua)
3	Discards	1	Both	Wigley, Palmer & Legault	A Comparison of Discard Rates Derived from 2011 At-Sea Monitoring and Observer Trips
4	Commercial LPUE	2	GOM Cod	Richardson, Palmer & Smith	Relationship of forage fish abundance to aggregations of Gulf of Maine Atlantic cod (*Gadus morhua*) and possible implications for catch-per-unit-effort indices.
5	Growth, Weight, Condition	6	Both	Brooks	Evaluating methods to calculate stock weights at age for Gulf of Maine and Georges Bank cod
6	Overview	all	GOM Cod	Palmer	Gulf of Maine Cod presentation
7	Research Surveys	2	Both	Terceiro	Modeling of NEFSC trawl survey indices for Georges Bank Atlantic Cod NEFSC spring trawl survey indices
8	Natural Mortality	4	Both	Waring	NEFSC seal research and issues
9	Commerical LPUE	2	GOM Cod	Palmer	Commercial catch-per-unit-effort (CPUE) indices for Gulf of Maine Atlantic cod (Gadus morhua).
10	Commerical LPUE	2	GOM Cod	Palmer	Spatial dynamics of the Gulf of Maine cod commercial and recreational fisheries and implications for CPUE indices effort
11	Commerical LPUE	2	Both	Wood	Standardized LPUE for Gulf of Maine and George's Bank Cod
12	Natural Mortality	4	Both	Miller	Tag-recover models for GMRI Atlantic cod tagging project
13	Stock Structure	3	GOM Cod	Dean et al	Otolith structure and GOM spawning components
14	Recreational Landings	1	GOM Cod	Dean et al	Recreational discard mortality
15	Overview	all	GB Cod	O'Brien	Georges Bank Cod presentation
16	Commercial LPUE	2	GB Cod	Hendrickson	Commercial and recreational LPUE maps by ten-minute square during 1994 - 2011
17	Commercial LPUE	2	GB Cod	O'Brien	1978 - present LPUE maps
18	Natural Mortality	4	Both	Link	Observations on consumption of GB and GOM cod
19	Natural Mortality	4	Both	Waring	Observations on marine mammals in Gulf of Maine area
Background	Stock Structure	3	Both	GMRI	Final report of the workshop on stock structure of Atlantic Cod in the Gulf of Maine region. June 12 - 14, 2012
Background	Natural Mortality	4	Both	Lorenzen	The relationship between body weight & M in juvenile & adult fish
Background	Research Surveys	2	Both	Miller et al.	Estimation of Albatross IV to Henry Bigelow calibration factors
Background	Research Surveys	2	Both	Brooks et al.	Determining length-based calibration factors for cod, haddock & yellowtail
Background	Natural Mortality	4	Both	Smith & Link	Trophic dynamics of 50 finfish and 2 squid species in northeast region
Background	Natural Mortality	4	Both	Hart & Miller	Analyses of tagging data for evidence of decreased fishing mortality for large Gulf of Maine Cod, Gadus morhua
Background	Reference Points	6	GB Cod	Brodziak & Link	The incredible shrinking Georges Bank haddock (Melanogrammus aeglefinus)
Background	Natural Mortality	4	Both	Link & Burnett	The relationship between stomach contents & maturity state for major northwest Atlantic fishes: new paradigms?

Table 2. List of Participants of the SAW 55 Data Meeting

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Appendix 1.

Draft Agenda*
55th Northeast Regional Stock Assessment Workshop (SAW 55)
Working Group Meeting on Data Issues
27 – 31 August 2012

TIME/DATE	TOPIC
Monday, 27 August	
09:00 – 09:15	Introductory comments (WG Chair)
GOM Cod	
09:15 – 10:30	Research survey indices of abundance
10:30 – 12:00	Cod growth, weight & condition
12:00 – 13:00	Lunch
13:00 – 14:00	Natural mortality
14:00 – 15:00	Commercial landings
15:00 – 16:00	Commercial indices of abundance (LPUE)
16:00 – 17:00	Recreational fishery
Tuesday, 28 August	
09:00 – 10:00	Discard Workshop Results
10:00 – 10:30	Summary on GMRI cod stock structure workshop report
Georges Bank Cod	
10:30 – 12:00	Research survey indices of abundance
12:00 – 13:00	Lunch
13:00 – 15:00	Cod growth, weight and condition
15:00 – 16:00	Natural mortality
16:00 – 17:00	Commercial landings
Wednesday, 29 August	
09:00 – 10:00	Commercial indices of abundance (LPUE)
10:00 – 11:00	Recreational Fishery
11:00 – 12:00	Discards
12:00 – 13:00	Lunch
13:00 – 17:00	Revisit of Monday's discussion
Thursday, 30 August	
09:00 – 12:00	Revisit of Tuesday's discussion
12:00 – 13:00	Lunch
13:00 – 17:00	Revisit of Wednesday's discussion
Friday, 31 August	
09:00 – 12:00	Revisits of all discussions
12:00 – 13:00	Lunch
13:00 – 15:00	Meeting synopsis
15:00	Adjournment

* Times are approximate, and may be changed at discretion of WG chair; breaks will be held in morning and afternoon at discretion of chair; meeting is open to the public