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Proceedings of a Maritimes Science Advisory Process to Develop a New Assessment Framework for Georges Bank Scallop

18-20 February 2009

Bedford Institute of Oceanography
Dartmouth, Nova Scotia

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Meeting Chair

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October 2009

Compte rendu d'une réunion du Processus de consultation scientifique portant sur l'élaboration d'un nouveau cadre d'évaluation du pétoncle du banc Georges

Les 18 au 20 février 2009

Institut océanographique de Bedford
Dartmouth (Nouvelle-Écosse)

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings include research recommendations, uncertainties, and the rationale for decisions made by the meeting. Proceedings also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Avant-propos

Le présent compte rendu a pour but de documenter les principales activités et discussions qui ont eu lieu au cours de la réunion. Il contient des recommandations sur les recherches à effectuer, traite des incertitudes et expose les motifs ayant mené à la prise de décisions pendant la réunion. En outre, il fait état de données, d'analyses ou d'interprétations passées en revue et rejetées pour des raisons scientifiques, en donnant la raison du rejet. Bien que les interprétations et les opinions contenus dans le présent rapport puissent être inexacts ou propres à induire en erreur, ils sont quand même reproduits aussi fidèlement que possible afin de refléter les échanges tenus au cours de la réunion. Ainsi, aucune partie de ce rapport ne doit être considéré en tant que reflet des conclusions de la réunion, à moins d'indication précise en ce sens. De plus, un examen ultérieur de la question pourrait entraîner des changements aux conclusions, notamment si l'information supplémentaire pertinente, non disponible au moment de la réunion, est fournie par la suite. Finalement, dans les rares cas où des opinions divergentes sont exprimées officiellement, celles-ci sont également consignées dans les annexes du compte rendu.

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SUMMARY

A Maritimes Science Advisory Process to develop a new assessment framework for Georges Bank scallop was held during 18-20 February 2009 at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia. Participants included Department of Fisheries and Oceans (DFO) Science Branch and Resource Management Division, the scallop fishing industry, and invited reviewers. The assessment framework developed at this meeting will be used to conduct the Georges Bank scallop assessment in the future, including changes to the scallop survey design and use of a new population model.

SOMMAIRE

Une réunion s’est tenue à l’Institut océanographique de Bedford, à Dartmouth (N. É.), du 18 au 20 février 2009 dans le cadre du Processus de consultation scientifique de la Région des Maritimes afin d’élaborer un nouveau cadre d’évaluation du pétoncle du banc Georges. Y participaient des représentants de la Direction des sciences et de la Division de la gestion des ressources du ministère des Pêches et des Océans (MPO) ainsi que de l’industrie de la pêche du pétoncle et des examinateurs invités. Le cadre d’évaluation issu de cette réunion sera appliqué aux futures évaluations du stock de pétoncle du banc Georges, y compris pour ce qui est des changements au plan de relevé sur le pétoncle et de l’utilisation d’un nouveau modèle de population.

INTRODUCTION

The Chair of the meeting, T. Worcester, welcomed everyone and thanked them for coming to this Science Advisory Process to develop a new assessment framework for Georges Bank scallop. Participants introduced themselves (Appendix 1), and then the Chair introduced the invited external reviewers: Carolina Minte Vera from the Universidade Estadual de Maringá in Brazil, Deborah Hart from the US National Marine Fisheries Service (NMFS) in Woods Hole, and Monique Niles from the Gulf Region.

Ms. Worcester explained the purpose of the meeting over the next couple of days, which was to provide a thorough scientific review of the information presented in the two working papers, with the intent of using this information and the expertise in the room to propose a new assessment framework for George Bank Scallop. Participants were encouraged to participate actively in the discussion. The accepted assessment framework is described in the proceedings of the meeting (this document) and two research documents.

The Terms of Reference for the meeting were then reviewed, and several modifications were made to the context (revised version provided in Appendix 2). The objectives of the meeting were reviewed:

Review Survey Index of Abundance:
- Reconstruct original catch-rate strata boundaries to facilitate an evaluation of the efficiency of the survey design.
- Propose and evaluate alternate survey stratification design(s).

Review of Model(s) to Assess Status and Productivity:
- Determine the methodology to estimate the current state of the stock, including methods for estimating stock size and fishing mortality.
- Determine the methodology to characterize stock productivity including reference points.
- Determine forecasting methodology for providing advice on harvest levels.
- Provide guidance on next steps, including research recommendations.

The Agenda (Appendix 3) was reviewed, and nothing further was added. It was noted that the final day would be held in the Hayes Boardroom.

ASSESSMENT FRAMEWORK

Working Paper: Jonsen, I.D., A. Glass, B. Hubley, and J. Sameoto. 2009. Georges Bank 'a' Scallop Framework Assessment: Data Inputs and Population Models. CSA Working Paper 2009/01.

Presentation: Scallop Biology
Presenter: J. Sameoto
Rapporteurs: S. Smith and T. Worcester

Presentation Highlights

Sea scallops (*Placopecten magellanicus*) are distributed from Cape Hatteras to Labrador. A brief description of the life cycle and habitat preferences (e.g., depth range 10–100 m, gravel substrates) was provided. Mortality is high during larval stage. Predation decreases with shell height. Juveniles and adults are preyed on by sea stars, crustaceans, and numerous fish species. Scallops can use an escape response to help avoid predation. Growth is highly variable and is dependent on local environmental conditions. Growth rates for sea scallops on Georges Bank are amongst the highest relative to other areas of the species' distribution.

Discussion

The difficulty in ageing scallops was discussed, including the difficulty in distinguishing the first several rings (years) and 'shock' rings.

D. Hart from the US NMFS described the ageing approach that is being used for scallops from the US portion of Georges Bank. Rather than trying to determine absolute ages, which can be difficult to do for scallops, they are estimating growth increments. This approach can also be useful with accompanying tagging information. Analysis of sea scallops in the Mid-Atlantic indicates that there was at least 1 year where growth was visibly different than other years. This suggests there may be changes in growth rates over time. While recent growth rate estimates are different from estimates determined in earlier years (1960s and 1970s), it is not clear whether this is a result of different methodologies or real changes over time. Data from a few hundred scallop shells from the Canadian portion of Georges Bank that were collected by American researchers have been provided to the Canadian Georges Bank scallop assessment team.

It was noted that the US ageing approach has been tested in Scallop Fishing Area (SFA) 29 with good success, and this appears to be a promising approach for other areas. This approach can be used to estimate von Bertalanffy growth parameters, which are used for the population model. Preliminary analysis of scallops provided by the US suggests an asymptotic shell height of 133.7, which is somewhat lower than expected. However, these scallops may have come from relatively deeper water.

Scallops were collected on Georges Bank 'a' back to about 2000, but shells collected by DFO or the scallop industry in the 1980s and 1990s have been discarded. Scallop shells were collected by NMFS back to the 1980s, however, and Canadian scallops may be available from this collection. If so, both potential spatial and temporal changes in growth rate could be investigated.

Presentation: The Georges Bank Scallop Fishery
Presenter: A. Glass
Rapporteurs: S. Smith and T. Worcester

Presentation Highlights

The history of the fishery was briefly described, including the following events:

1973 – Georges Bank fishery transformed into a limited entry fishery.
1977 – Declaration of the 200-mile fishing zone.
1984 – International Court of Justice (ICJ) established an international boundary.
1986 – Enterprise Allocation program began, and inshore and offshore fleets separated.
1995 – 100% dockside monitoring initiated.
1998 – Industry funded port sampling program; Vessel Monitoring System (VMS) implemented; separation of Georges Bank into zones 'a' and 'b'.
2002 – Use of factory freezer trawlers begins.

2005 – Industry implemented voluntary seed box closure to protect high densities of juvenile scallops and improve yields.

In 2009, the regulatory measures in place for this fishery include: an annually set total allowable catch (TAC), meat count of 33 meats per 500 g, 100% dockside monitoring by a dockside observer, VMS, and port sampling. There are also 3 voluntary juvenile scallop closures. There are currently 2 types of vessels used: 11 wetfish vessels and 6 factory freezer trawlers.

Questions

It was recommended that a description of gear changes over time and a map of voluntary fisheries closures be provided in the working paper.

Questions were asked about the voluntary closures, including how long they are typically closed for. The response was that the duration of the closures is determined by the fishing industry. They are surveyed each year, and then Industry decides whether or not to open them. The first voluntary closure in 2005 was closed for 2 years. Closures that were implemented by Industry in 2008 were modified, but remain closed in 2009 (i.e., have been closed for 1 year so far). Research in the US has shown that better yield-per-recruit can be obtained from closures that remain in place for at least 3 years. Scallops appear to grow faster in closed areas (asymptotic shell height was higher). It was suggested that areas of good scallop growth get fished harder than marginal areas; thus, scallops with good growth potential are harvested quickly before reaching their full potential. A closure allows these scallops to grow. Research has also shown that growth inside and outside closures is almost the same until about 90 mm, at which point the growth curves diverge. If this was an effect of fishing disturbance, one might expect to see a similar impact on young and old scallops alike. A brief comparison was made between Canadian and American scallop closures, in terms of location, rationale, and implementation.

Presentation: <u>Data Inputs</u>
Presenter: I. Jonsen
Rapporteurs: S. Smith and T. Worcester

Presentation Highlights

Both fishery dependent and fishery independent data were described.

Fishing logbooks report prorated catch, effort, and location each day fished. Information on catch is available from 1955 to present (excluding 1960), but this does not include US or inshore fleets. The current time series begins in 1981, with US and inshore fleet landings from Georges Bank included. Catch rates are expressed as kilograms per hour meter to provide a consistent measure of effort from both the wetfish and factory freezer vessels. It was noted that once the width of the gear is accounted for, there appears to be no difference in catch rates between these 2 vessel types.

A map of fishing effort from 1955–2007 indicated that distribution of effort has changed over time. For example, the northern edge of Georges Bank started to be more heavily exploited in 1961. In 2007, there was practically no fishing effort in the southern portion of Georges Bank.

Commercial catch rates were presented from 1955-2007. After 1981, removals from other fleets (US and inshore) were accounted for. The graph of commercial catch rates indicates a ramping up of effort initially followed by a decline.

Port sampling was described, and results show that the fishery has been targeting larger scallops through time.

VMS data is used mostly as a monitoring tool; however, it can be used to get an indication of spatial effort allocation. Vessels are polled hourly. In 2007, effort was heavily focused on the area of the previous voluntary closure. Currently, information from VMS is underutilized in the assessment of the fishery.

The survey data time series starts in 1981, and it includes a variety of different vessels (*RV E.E. Prince* up to 1993, *FV Cape Keltic* 1994-2006, *FV E.E. Pierce* 2007-2008, *FV Tenacity* 2008-present). No comparative towing information is available, but survey vessels have used the same gear, the same skipper and crew. Under the current survey stratification scheme, new strata are developed every year, but the same strata definitions are used each year. It is possible to track cohorts in the survey, which is desirable.

Discussion

It was clarified that there is no longer any at-sea sampling during the fishery but that some hydration samples (to obtain meat weight to shell height relationship and GSI [Gonadosomatic index] series) are collected from the survey.

The catch rate time series starting in 1981 does account for Canadian vessels fishing on the US side of the ICJ line, but this information is not used in the Canadian Georges Bank assessment.

Clarification was sought on the historical survey stratification**.** The survey was restratified each year based on commercial catch rates form the previous 9 months. However, stations were added in other areas (e.g., in areas with low catch rates) as deemed appropriate. Survey tows of 10 minutes were standardized to 800 m.

While 2008 data on recruitment was not provided, it was noted that preliminary analysis indicates a large peak of recruits.

Potential uses for VMS data were explored. At present, this information is used on an ad hoc basis to address specific questions that may be asked about fishing patterns of certain vessels, as well as for fleet monitoring purposes. VMS could be used as a covariate, as a measure of fishing pressure/effort.

One issue with the VMS data is that polling is once per hour, whereas actual fishing is occurring at finer resolution. Other countries have polling every half hour, so they are able to more directly relate catch to the VMS records as a measure of effort. However, increasing the VMS polling rate is very expensive. It was suggested that perhaps a subset of vessels could implement a higher VMS reporting rates to determine whether it is useful. It was noted that VMS allows vessel locations to be known in real-time, but this is not needed for research purposes. For research, DFO could obtain the ship's VMS log, which would have more frequent locations, without any extra expense to the Industry.

Another issue is that it can be difficult to determine vessel activity from VMS data, i.e., whether a vessel is fishing in circles, moving slowly, or is engaged in processing. It should be noted that 70% of the effort in the fishery is from freezer vessels, which have different patterns of activity than wetfish vessels. These different activities may be difficult to distinguish through analysis of VMS information. Currently, DFO is working on rules to determine which data points to keep and which ones to throw out.

VMS is being investigated by the assessment team as another variable that could be incorporated into the model. At present, VMS data is being investigated as a ranked measure – not a quantitative measure. The intent is to determine whether using VMS information is helpful.

Use of fishing logbooks was also discussed. In the fishing logbooks, only 1 position per day was recorded until 2007. Now, a location and estimates of catch and effort are provided from every watch. Since fishing effort is generally aggregated, it was suggested that 1 position might have provided an adequate representation of the distribution of effort. However, provision of 4 positions per day from 2007 onwards will be beneficial for future analysis.

A concern was raised that the commercial fleet is only going to target commercial size scallops, and juvenile scallops may be missed entirely. Two year old recruits are reliably caught with a 38 mm lined dredge, but 1 year olds are only commonly caught during years of high abundance.

Working Paper: Hubley, B., S.J. Smith, I.D. Jonsen, and J. Sameoto. 2009. Georges Bank 'a' Scallop Framework Assessment: Survey Design. CSA Working Paper 2009/07.

Presentation: Survey Design
Presenter: B. Hubley
Rapporteurs: J. Sameoto and T. Worcester

Presentation Highlights

The most important input to the population model is the survey index (number of scallops per tow). This is one of two sources of trend information and the only source of recruitment data. Survey stratification can increase precision through allocation and stratification.

The previous survey was stratified using annual catch rate. New strata (very high, high, medium, low, very low catch rate measured as kg per crew hour meter) were constructed every year using fishery data from the 9 months prior to the survey (i.e., October – June). This design is subject to variability in the fishery, i.e., coverage. This design also makes it hard to create a time series for an individual stratum.

Other types of designs include:

- Simple random sampling (SRS) - baseline, no info, high variance.
- Stratified random sampling using a direct measure of abundance as a stratifying variable, i.e.,
    - annual catch rate (ACR)
    - historical catch rate (HCR)
    - historical survey index (HSI)

  or using other variables that affect scallop abundance (growth, disturbance, and substrate) as a stratifying variable.

A comparison of these different designs was presented in terms of their estimated mean (survey index), and precision of the estimate (standard error and relative error). The relative efficiency or percent gain in precision and potential gain in precision (if allocation was optimal) was also compared to a baseline design SRS or ACR). Used kg/hm units used for consistency across years and fleets.

Comparison of Baseline (SRS) with Original Annual Catch Rate (ACR) Stratification

It was difficult to reconstruct the original survey design, as the areas and boundaries of each of the original strata were not retained. The original strata boundaries were only available from a map published in the 2000 research document for the 1999 survey, and a comparison was made between these and the reconstructed boundaries for that year. While the patterns were similar, catch rates were lower in the reconstructed design. Derived isopleths using catch only (per one minute (Lat.) square) captured the difference between the reconstructed and the original design. Catch rate calculations between the original and the reconstructed versions used the same data, but did not result in the same magnitudes in the resulting contours. A strata comparison of the original versus the reconstructed was conducted, but they did not match; the reconstructed strata were consistently underestimated. When compared to SRS, realized relative efficiencies for ACR were largely negative and potential relative efficiency was not high. In summary, the ACR tested was not an exact replicate of the original. The mean was similar, but the error was slightly greater than SRS. Negative efficiency relative to SRS was due to allocation. Modest potential efficiency gains were seen. Overall performance was poor. A previous study found similar results (Smith and Robert 1998).

Comparison of Baseline (SRS+ACR) with Stratification Based on Historical Catch Rate (HCR)

Catch and effort data from the commercial fishery were used from 1981 to 2007. A mean kg/hm over 1 min (Lat.) grid was applied using a jackknife estimate. Strata boundaries do not change from year to year. The number of strata were determined by comparing the gain in precision versus the number of strata. An increasing precision is observed initially, but it levels off after 5 strata. Contours of the historic catch rate were presented using a 5 strata design. Higher catch rates were seen in the northern portion, with modest catch rates in the south. In comparison with SRS, the means and errors were similar. Both realized and potential relative efficiencies were largely positive, indicating a gain in precision over the SRS and ACR approaches. Gains were greater in the more recent period. The stratification using only data prior to the year it is being evaluated was also run, and gains in precision were still found to be present.

Comparison of Baseline (SRS+ACR) with Stratification Based on Historical Survey Index (HSI)

In this approach, data were used from the August survey from 1981-2007. The mean number of scallops (all sizes) per standard tow (1950 m2) over 1 min (Lat.) grid was applied using a jackknife estimate. Strata boundaries do not change from year to year. The number of strata (similar to HCR design) was determined to be 4. The contours of 4 strata based on HSI (#/tow) were presented. Similar abundance patterns were seen, but not as much difference between north and south. This matches better with substrate type, and it was compared to the Kostylev map (Kostylev et al. 2005) that is based on backscatter. Mean and error were found to be lower and substantial improvement were made in potential and realized efficiency over the ACR and SRS approaches. There were only 2 years where gains were not seen. Gains held even when using data from previous years. This approach was considered to be the best of the 3 (except 2007/2001).

Consideration of Other Variables to Use in Stratification

Use of 'Scope for Growth' and 'Disturbance' layers were also explored, and they were found to have some exploratory power. It was suggested that the sediment map from backscatter (Kostylev et al. 2005), combined with the survey index, might be a good basis for a design.

<u>Summary</u>

Stratification based on HSI has the most explanatory power. HCR has the most explanatory power when HSI is removed.

Discussion

Clarification was sought on the use of the jackknife estimator. The jackknife estimator works by calculating total catch/total effort with one observation removed and then takes the average of all possible calculations. It was suggested that this approach is able to produce confidence intervals. Catch rate is a ratio estimator. Ratio estimators tend to be biased, but the jackknife estimate takes care of the bias.

It was clarified that Georges Bank 'b' was not included in the survey design analysis.

It was clarified that in Figure 9 of the working paper, the maximum is not really 23. Rather, this strata includes all catch rates greater than 13. It was suggested that the scale could be used to reflect the fraction of area in each strata.

Possible reasons for the difficulty in reconstructing the original survey boundaries from year to year were discussed. If the magnitudes are ignored, similar boundaries could be produced. DFO does not have the original contours for every year and, therefore, it is not possible to know if the boundaries have been accurately reconstructed. It was asked whether this could be an artifact of converting from crew hour meters (crhm) to hour meters (hm); however, the same reconstructed boundaries were shown in both units (kg/hm and kg/crhm). It is not clear why the same results can not be generated. A different contouring approach (different software) did a good job of capturing the pattern, so it is not likely to be a contouring issue. The means can not be compared because DFO does not have the area of each stratum. It was suggested that an image analysis of the 1999 map that is available could be used to estimate the area for one year.

Lack of efficiency in the current survey design was also discussed, including the very low efficiency estimated for 2 years due to allocation issues. The low efficiency could be because there were not enough tows allocated to the strata with the highest variance. Originally more tows were allocated in the higher catch rate strata. High catch rate strata were least variable with respect to density. Lower catch rates were more variable but they had fewer sets allocated. The stations were not allocated effectively. Stratification gains were only modest even with an ideal allocation. There were only a few years when stratification was appropriate. The original rationale for this allocation approach was discussed. Caddy (1979) wrote a paper on survey design. One of his arguments was that it is important to fish where the fish were. One might expect that the variance would be higher in high density areas, but it does not always work out this way.

It was noted that a previous effort to analyze the Georges Bank scallop survey yielded similar results, including similar difficulties in reconstructing the 3 years that were attempted and similar observations of the limited gains in efficiency using this survey design (Smith and Robert 1998).

It was suggested that two graphs might be useful, one showing crew hour meters versus hour meters. It was noted that the only factor difference would be the crew size. It was also suggested that a catch versus catch rate graph would be useful. If catch versus catch rate is linear, that would explain the pattern a bit. Later on in the discussion it was determined that these would not be necessary since this survey approach was not being recommended.

It was suggested that a new survey stratification design could separate northern and southern strata. The experience from the US is that there is spatial coherence is scallop abundance from year to year. What is going on in the north may not correspond with what is going on in the south. This would double the number of strata. However, the lowest strata might not be worth doing (just look at the moderate catch rate ones).

Fishing patterns and restrictions have changed. It was suggested that the last ten years would be quite different; however, there do seem to be similar patterns.

It was noted that the historical survey index is of abundance instead of biomass. There are differences in growth rates between the northern and southern parts of Georges Bank. More scallops have been removed from the northern area, so one might expect to see a depletion effect reflected in abundance. Where the gravel is in the south, it is too deep for scallops. This is another reason why separate strata for the north and south might be useful.

Depth as an explanatory variable was discussed. It was noted that the ‘Scope for Growth’ index does capture depth to some extent. Also, it was noted that the depth gradient is quite shallow on Georges Bank.

The definition of ‘Disturbance’ was discussed. In this presentation, ‘Disturbance’ referred to natural disturbance of the sea floor (e.g., by currents, sediment movement). It was suggested that disturbance might be more influential on small scallop survival. According to this indicator, there is a disturbed area in the centre of Georges Bank. Retention of small scallops is also influenced by the oceanographic gyre.

It was suggested that both biomass and abundance indices should be evaluated. It was noted that weight of scallops is not being determined during the survey; rather, samples are used to generate the biomass. The survey is picking up small scallops that are not being fished. These may be aggregated, which may generate even more difference between abundance indices and biomass indices. Both approaches should be investigated.

DFO Science in the Maritimes Region has some experience with using bottom type and depth to develop survey stratification. This experience has shown that there can be a strong relationship between scallop densities and bottom type at the start of the fishery but less later on in the fishery. It is unclear whether this relationship gets better again if there is new settlement. There is benthic classification information available for Georges Bank, and better information will be available soon. When this new information becomes available, the assessment team will evaluate it. There was some uncertainty as to whether using information on bottom type would provide a more a more efficient stratification design than the historical survey index. It was suggested that using bottom type information (or other proxies) would be a useful approach where an abundance index did not already exist. An abundance index is expected to integrate influences of bottom type and fishing patterns.

The benefits of switching to a random stratified survey design based on the historical abundance index were discussed. There would be immediate gains in efficiency achieved by moving to the HSI. However, benefits are enhanced by using the variances in subsequent work, i.e., are carried forward in the population model, as the abundance trend (mean) is not much different with the new strata.

How new information will be used when it becomes available was discussed. It was suggested that it would be possible to change the allocation within stratum while still keeping the same boundaries.

Concerns from Industry were raised about the survey coverage given a new survey design (i.e., fewer stations in areas of high density and more in areas of low density). Under the new survey design, survey coverage will be more constant. If the industry is in one area, this means that the biomass is likely concentrated in that area. This will show up in the survey.

Whether changing the survey design and the assessment approach at the same time would be a problem was discussed. It was agreed that current approach is effectively to have a new survey design every year. There will be efficiency gains with the new proposed design, and greater consistency into the future. It is also useful to stratify based on the variable that is being estimated.

In the past, large scallops were of primary interest. A question was raised as to whether the new approach would provide any greater understanding of abundance and distribution of juveniles scallops. It was noted that survey coverage is across the whole bank. It would be possible to evaluate different size classes to see if there was any difference in patterns or trends. The survey will never provide a good estimated of very small scallops, but it does provide information on scallops 50 mm and up. This provides another year of information before recruitment to the fishery.

Now that Georges ‘b’ is a separate management area, it has probably been under sampled. There should be separate strata for Georges Bank ‘b’, but it can easily be stratified by the historical survey index. It is beneficial to have a separate abundance index for this area.

The conclusion of this discussion was that there are significant benefits to be obtained from switching from the old survey design based on annual catch rates to a survey design based on the historical survey index. Separation of northern and southern strata was suggested, as was comparison of the biomass versus abundance index. While information on substrate type has the potential to provide additional efficiencies in survey stratification, this information is not currently available. When it does become available, it will be investigated to determine if any additional gains in efficiency warrant further incorporation of this information into the survey design. However, efforts should be made to minimize alterations in strata boundaries in the future as fixed strata boundaries would better enable analysis of temporal trends in individual stratum. Rather than being used to change strata boundaries, new information could be used to influence allocation of stations within a stratum.

Working Paper: Jonsen, I.D., A. Glass, B. Hubley, and J. Sameoto. 2009. Georges Bank ‘a’ Scallop Framework Assessment: Data Inputs and Population Models. CSA Working Paper 2009/01.

Presentation: Data Inputs to the Population Model
Presenter: I. Jonsen
Rapporteurs: B. Hubley and T. Worcester

Presentation Highlights

Biomass dynamic models use an accounting process where the currency is biomass. New adult biomass = surviving adult biomass + recruit biomass. The surviving biomass = biomass + growth – deaths – catch + recruitment. Assumptions are made that increments in weight at age are linear; all scallops greater than size at recruitment to fishery are fully vulnerable to gear – knife-edge selectivity; and all scallops greater than size at recruitment to fishery have the same natural mortality. Characteristics of the model are that it is size-based (size classes) and forward projecting.

Growth parameters for the model are derived from the hydration data from survey tows (approximately 1 sample per 10 minute square). Meat, gonad, and total weight are measured, as are shell heights. These are used to convert from shell height to meat weight, and also for the gonado-somatic index. A linear mixed effects model is used to estimate the shell height – meat weight relationship. If one fits this to the hydration data, it fits very well. There is not a great deal of variability from year to year in shell height to mean weight. There are a few years when the deviations are greater. Random effects are also incorporated within years.

Ageing data that are used to parameterize the model are from Brown et al. (1972; L_{inf} = 145.5, k = 0.38). Other ageing information is available from Hart (pers. comm.; L_{inf} = 133.7, k = 0.45). While this information is more recent (scallops collected from 2001 to 2007), it may be from slightly deeper water. A number of other ageing estimates for Georges Bank were evaluated, but there were not large differences among all estimates.

Weight at age was generated by fitting a mixed effects model with hydration data. Growth parameters were used to give a range of shell heights at age as input to the shell height – meat weight relationship (assuming fixed effects parameters). Weight at age (t-1) was then plotted against weight at age (t). This is a Ford-Walford plot.

Average meat weight was determined using average weights from hydration data. These were weighted by the number of scallops in each 5 mm bin ≥95 mm in the survey. The change in size at recruitment to the fishery needs to be accounted for. A conversion factor from the hydration data is used to convert meat weights to shell heights. Average meat weight appears to have increased in 3 phases, from ≥75, ≥85 to ≥95 mm. Previously, it was assumed to be constant at ≥95 mm. If one allows size at recruitment to change, an increase in average meat weight over time would be seen. When the survey samples are compared with commercial samples from August and average commercial samples (over whole fishing season), it is a pretty good match. Small younger scallop stock tends to grow faster than older larger stock. This is a property of the model. It is how age structure is accounted for without knowing it explicitly. The growth potential in the stock has declined over time. Initially, the fishery fished a younger population. Then it went through a period of stock rebuilding. Now the fishery is fishing an older, slower growing population.

Natural mortality was set to a constant M=0.1. This is consistent with previous models (Robert et al. 1994).

Commercial and recruit biomass were plotted against year. The survey biomass is not used as the population biomass – this is the index. Like a swept area calculation, it is assumed that scallop rakes have a 100% efficiency.

The model is also fit to the commercial catch rate index. There has been no standardization for potential changes in fishing power over time.

Discussion

It was clarified that no fixed stations are used in the Georges Bank scallop survey. However, fixed stations are used in a different survey series (the May survey).

It was noted that the zero age (t_0) was set to zero shell height in the presentation, but this should be corrected in the working paper. It should not be zero.

Given that there is no hydration data from 1981, it was unclear why there were data points from this time in average meat weight graph. It was clarified that parameters from the mixed effects model were used to estimate it. Port sampling data is available throughout this time.

The possible reason(s) for the change in the size at recruitment was uncertain. It was suggested that regulatory measures had an effect since the timing of changes in the size at recruitment match well with major changes in management of the fishery.

It was clarified that in order to standardize for fishing power, information on vessel sizes and/or equipment would be needed. It was suggested that this might not be worth doing.

It was noted that the proposed model is not size based, but it is size aggregated.

It was felt that the assumptions going into the model were probably good enough and seemed pretty reasonable. They are standard assumptions to use for this type of model. The assumption that concerned the assessment team the most was the assumption of knife edge selectivity. The assessment team is not 100% comfortable with this, but it is something that can be refined over time. It would be possible to build a selectivity curve/function into the model. Sensitivity analysis had been done, but the model did not seem to be that sensitive to this assumption. Break points in the fishery were not investigated. A ‘95% rule’ was used that gave a 3-phase pattern that matched with known changes in the management of the fishery; however, it may be useful to use something firmer.

Concern was expressed that all the hydration data have been collected at same time of year when one would expect meat and gonad weights to vary with season, as well as with the point in the reproductive cycle that samples are taken. Shucking efficiency may also differ between the survey and the fishery. This issue has been investigated in the US; meat weights were compared from the fishery and the survey. Meat weights tended to be a bit smaller in the fishery (going fastest, may not get it all), but the greater difference was in the season. The Canadian survey is done during the summer. A large portion of the fishery occurs before the survey. The fishery is conducted year round, but the majority of it is conducted before the survey. However, this will vary from year to year. There is hydration data available that was collected from fishing vessels, but it was not collected consistently from year to year and it stopped in 2005/2006. This data was reviewed, but it indicated either that there was not a large seasonal effect or that sampling was inadequate to detect such an effect. If enough of the fishery is being conducted during the summer, scallop meats may be larger in July/June compared to August. This may compensate for what is going on at other times, i.e., it may cancel out. There is a conversion factor available for the commercial meats to the survey meats (to take into account the small adductor muscle that is usually lost during processing). The conversion addresses much of this issue.

It was noted that a sensitivity analysis was done on the effect of different growth parameters on the model. The model was re-fit using each of the parameter sets estimated for Georges Bank. The net effect was a plus or minus 12% change in average biomass compared to the default fit using the Brown et al. (1972) parameters, which was not considered to be a large difference. The biomass pattern was the same in all cases, and the different growth parameters just shifted the biomass up or down. It was suggested that the biology of scallops appeared to be determined somewhat by location (i.e., is spatially explicit), and the extent that this could be incorporated into the model would be appreciated.

The Brown et al. (1972) von Bertalanffy parameters have traditionally been used. These seem to be in the middle of the range, though more recent information is available (Thouzeau et al. 1991).

In the Bay of Fundy scallop assessment, an effort was made to try to fit natural mortality to the scallop clapper data after a big mortality event in the Bay of Fundy. A question was asked about whether this type of mortality event was observed on Georges Bank or whether clapper data had been investigated in this way. The response was that this issue has not been looked at in detail. There is not a lot of variability in the clapper data, so there might not be enough information to make it a worthwhile investigation.

It was noted that the model assumes fishing mortality is evenly distributed, which it is not. This could have an effect on the model. The bias - variance tradeoff was discussed. When the data is partitioned into smaller areas, there is not much data for each area. However, it is understood that the scallop population is not acting like a dynamic pool model. It was suggested that it may be useful to report effort with respect to smaller areas. It was also suggested that the estimate of fishing mortality is probably biased low, which could complicate yield based estimates. However, unless advice is being provided on a different spatial resolution, it was not clear how information at a finer level of detail would be used.

Some concern was expressed about the effects of the voluntary closed areas on the assessment. Opening of these areas may lead to dense fishing activity within a small area, which would make the assumption of an even distribution of fishing effort over the management unit less appropriate. It was suggested that this type of effort distribution may become more prevalent through time. Clarification was sought on the size of the voluntary closed areas. It was noted that these areas have been about 100 km^2 so far. No efforts have been made to estimate the proportion of the scallops contained within these area.

The fact that there appeared to be little annual variation in shell height to meat weight was commented upon, though there were a few years where there was quite a lot of variation but only in a few places and not across the whole area. It was noted that this is consistent with the US side of Georges Bank. Spawning appears to be more consistent in this area. There is some spring spawning, but not like in the Mid-Atlantic. It was suggested that the fishery is not going to let scallops get to L_{inf}, so ages 4-5 may be more important.

Some concern was expressed about the curvature in the weight at age figure. It was noted that a similar analysis was done for Browns Bank where there is contemporary ageing, and the plot looked much more linear. There also seemed to be a tendency of increased meat weight with age, which could be due to the people doing the ageing, a fishery effect, or another effect. It was suggested that this was most likely a fishery effect. Some discussion then ensued about the ageing process and whether the agers had changed over time. There have been 4 agers in that time period, with the most recent change in 2005. It was suggested that a depth co-variate could be used to see if there was a trend in the weight at age with depth. It was suggested that the shell height frequency from the survey could be shown using vertical bars or a bubble plot (e.g., 1 cm, 2 cm shell height over time). Recruitment could then potentially be identified. It was noted that the dynamics of younger scallops are not being modeled. This was recognized as a bit of a limit in these models.

The catch rate index was discussed. It was suggested that catch rates are elevated when the seed box is opened and are artificially depressed in the two years previous. Rather than take it out, it was suggested that it could be done proportionally by area. It was clarified that only one 'phase' is used in the CPUE (catch per unit effort) index, and it was unclear whether dividing the index into separate phases would be worthwhile. Different q's would have to be fit, and some overlap would be required. Three separate q's were fit for the survey index. It was noted that changes in management can have an effect on catch rates. The commercial catch rate on Georges Bank appears to be higher than previously. One possible reason is that as fishing effort has gone down, the amount of fishing in marginal areas has decreased. This is why even when the effect of the seed boxes is removed, there are still changes in catch rates.

Whether or not the catch rate index should be used in the model was discussed. Scientists were not totally comfortable with using the catch rate index, as CPUE tends to be used only when there is nothing else available. The survey is very good in this case. However, the model fits to the CPUE index better than the survey index. The CPUE smoothes through the peaks in 1986 and 1992. Relative to other fisheries, the Georges Bank scallop CPUE was felt to be capturing good information. From an Industry perspective, there was some hesitancy in dropping the CPUE index entirely as it does represent what Industry sees. The CPUE index is not used in the inshore scallop assessment because it has been redundant, i.e., it shows the same pattern as the survey. The only reason to use it seems to be because there are a few 'flyers' in the survey data. The other information not being carried forward in the model is the uncertainty in the survey estimates. In the future, the coefficients of variation (CVs) could be included in the model. Using this approach, the seemingly unusual peaks in the survey may be dampened out. Another possibility would be to do a commercial catch rate index for the northern edge of Georges Bank only, as this would be a more consistently fished area. This index would still capture the major portion of the biomass, and the benefits of smoothing would be kept. Alternatively, both a northern commercial index and a southern commercial index could be developed. There may be years when there would be no data for the southern index. It was agreed that this could be revisited later in the meeting.

Presentation: Delay-Difference Model
Presenter: I. Jonsen
Rapporteur: T. Worcester

Presentation Highlights

The proposed Delay-Difference model is a structurally simple model. State space models allow accounting for process error and observation error separately. By separating these out, the hope is to get less biased parameter estimates from the model. A Bayesian State Space approach was applied since errors are not normally distributed, and Markov Chain Monte Carlo sampling was used. Priors were used for the catchability terms (q), scaling term (K), and 4 precision terms (σ^{-2}). Growth parameters and natural mortality (0.1) were fixed.

Biomass estimates from the model were presented (both in terms of fully-recruited biomass and recruit biomass), and model diagnostics were reviewed. In general, this formulation fits the indices well, though CPUE is high in the last year (concentration on the north). The model also fit well to the recruit index. In general, there is a slightly better fit to the CPUE index prior to 2000, and a better fit to the fully recruited survey index after 2000. The model is sensitive to the priors on the precision terms. Changing from the informative priors on precisions, used in the default implementation, to less informative priors (vague Gamma or Uniform) leads to a worse fit to the survey index and a better fit to the CPUE index.

The sensitivity of biomass estimates to the von Bertalanffy parameters was investigated. The largest was +12% and the lowest was -11%. This does not change the patterns of biomass, just the magnitudes (similar to just changing the intercept in a regression). Variability in biomass estimates with different growth parameters is acceptable. The default growth parameters may be a bit conservative as most of the deviations are positive. The most recent growth parameters from D. Hart yield only a 5% difference in the biomass estimates.

Retrospective pattern was presented, as was a 'prospective' analysis. No strong bias is seen in the prospective. The predictive ability of the model was reviewed. Prediction versus estimates were found to be pretty close when nothing is going on. As biomass increases, the predictions lag behind. As it declines, the predictions tend to overestimate biomass. The model appears to underestimate increases and overestimate declines in biomass, which is consistent with most other models. This should be kept in mind when providing advice based on the model.

The Delay-Difference model was compared to the Schaefer Surplus Production model. The Surplus Production model recaptures the pattern well, which is surprising. It just consistently underestimates biomass relative to the Delay-Difference model. The Delay-Difference model was also compared to the incumbent Virtual Population Analysis (VPA) model. A divergence could be observed from 1995, with different peaks. The pattern in biomass estimates from the VPA model is not consistent with the survey index. The same growth parameters are used. The biggest problem is cohort slicing. Past biomass trends from VPA models were looked at. A strong retrospective patterns in the VPA-estimated biomasses can be observed depending on how many years of data are available. This is not a desirable characteristic.

Discussion

Uncertainty in the survey or CPUE indices is not currently being carried through into the model at present, but this can be done in near future.

Fishing vessels that go into the seedbox tend to stay there. DFO has the tools to exclude those events. Whether fishing is occurring inside or outside the seedbox is less important than the impact of exclusive fishing on the northern edge.

Time varying growth information from Georges Bank is not currently incorporated into the model. Growth information is based on published information, but this is a research priority.

It appears as though there is a one year delay in the predictive ability of the model. This is another way of showing process error, and it is a very common pattern.

The Schaefer Surplus Production Model was used, but there are three ways to do this. Clarification was requested on which approach was used. The response was that the State Space approach was used without the growth parameter or recruitment. It was surprising that the Schaefer Surplus Production Model performed as well as it did.

Clarification on the number of q's that were used was sought. Three q's were used for the survey, and one was used for commercial catch. Only two are used in the VPA.

The 3 phases in the survey catchabilities were discussed. It was suggested that larger scallops have been targeted in the later years, while only smaller scallop were available in high densities in early years. It was noted that the model uses the same catchability for adults and recruits. It was unclear why the survey was less efficient during the earlier period (about 25%). Scallops may have been smaller, but they survey should have been able to catch them with the liner.

Depending on the size distribution, the efficiency may change; this is occurring in the inshore survey, but this survey uses very different gear. Dredge may fill up faster with high densities (saturation). Note that 0.4 seems pretty high for the survey gear. This would be a reasonable value in flat sandy environment. Commercial gear efficiency is considered to be 0.6 in the Mid-Atlantic. Looking at paired photos with dredged tows, the catchability in this area is quite high. It looks like it is 10-20% lower on a place like Georges Bank. It was noted that a change from 0.4 to 0.3 changes the biomass by 30%. This is something to watch.

An informative prior may help. Survey catchabilities are being investigated in the US. They had a commercial vessel following the survey vessel for 2007 and 2008 (about 250 tows). The commercial vessel was equipped with a camera system that takes several pictures per second to create a long strip of images. About 150 paired comparisons with a survey tow were done with 3 passes at each site. Photos show how many scallops are in the path. This is then compared to dredge catches. This is a direct way of comparing survey catches to what is on the bottom, and it provides an estimate of the q's. The estimate for the Mid-Atlantic was 0.41, but it would be expected to be lower on Georges Bank. The hope is to look at Georges Bank next year. The mode here is at 0.35, which might be a bit high, but is within the confidence range. The uniform prior might be biasing it. One might argue to use a beta. Some information is available to inform this. The dredge efficiency is between 0.2 to 0.5 with a mean of 0.32. The suggestion was made to try running it that way to see if it makes a difference.

Process errors looked surprisingly similar to each other, which was thought to be a function of the informative prior that was used. It was suggested that the distribution appeared more normal than gamma, but gamma can look normal depending on the shape. A question was asked about why similar process priors and observation priors were used. The response was that process error is about the same as observation error.

It was suggested that there appeared to be auto-correlation in the residuals, which is significant but not serious. It was noted that it is a time series model anyway. This same issue came up in the Bay of Fundy scallop assessment. It has a similar length time series, but the auto-correlation was tested and it did not turn out to be significant. This can be checked for Georges Bank scallop to see if there is any strong pattern.

It was suggested that the reason for assessing sensitivity with uniform priors on precision terms is that there is no such thing as an uninformative gamma. The suggestion was to use uniform priors to let the data speak. They can become more informative once the new survey design is used. The response was that it was not likely to occur this year, but the next assessment could incorporate annual CVs into the assessment model rather than the priors. CVs can be put on the survey index points to show that the model fit is still in the realm of possibility. It was noted that there are two components of error, one fixed and one, the annual CVs. It was agreed that further discussion would be required after review of the survey stratification.

It was suggested that there is no good likelihood solution for this type of model. A particle filter implementation could be used.

Of the model formations that the assessment team has looked at, the default run was still preferred. There was no desire to have the model fitting more closely to the CPUE index because this discounts the more rigorously standardized survey index (i.e., the better quality index).

Some discussion ensured on whether there a better way of coming up with a model selection procedure. Use of deviance information criterion (DIC) as model selection criteria was suggested. However, the feeling was that it might not be useful as it tends to give spurious results. The preference was to look at what model implementation fits the data best using a suite of diagnostics and not rely heavily on model selection statistics.

It was noted that the CPUE index is tracking different things at different times. To address this issue, suggestions were made to break it with different q's or into different areas (south/north). Two options for use of CPUE are 1) north only and 2) north and south separated. It was suggested that both analysis could be presented at the next assessment. Criteria to choose between these options could also be provided. There was some further discussion on how to use the southern indices if there was no fishing that year, i.e., as a missing observation from that year. It was recognized that the south is a minor portion of the fishery and may not need to be included. Biomass in the south might just not be densely aggregated. The influence of the seed boxes is more complicated as they are more ephemeral.

It was also noted that multiple time q's can help with the retrospective pattern, as it gives the model flexibility. However, q's for the last 2 periods were very similar, and the retrospective happens in the last phase. Some surprising sensitivities were seen. For example, if the first point is removed, a retrospective pattern occurs. The first point is important because it is how the model is initiated. It is possible to look at what happens to K, the scaling parameter, when years are removed. It is K that scales the biomass estimates. However, it was noted that the pattern it is following is essentially the same. It was felt that there was not that big a discrepancy and no apparent bias in the retrospective.

Someone asked how knowledge of the model issues would influence the provision of advice. The response was that a statement could be included in the advice saying that the prediction is likely to be an overestimate or underestimate. Some experience working with the model would be required before the magnitude of the over or under estimate could be discussed.

Other variables that are not being taken into account were discussed. For example, discard mortality (likely to discard less than 90 mm, these are subject to discard mortality) and indirect fishing mortality (gear damage to scallops that are not caught) are not addressed. There was an effort to incorporate these factors into the US assessment. They assume 15% of F for incidental damage due to gear (Caddy 1979). This might help in the declining part of the cycle. It was noted that the Caddy study has been misinterpreted in many ways, but he did see 15-20% of scallops on the bottom that were damaged. It was clarified that he saw fewer than this but included extra mortality. That bottom was probably harder and caused more damage that one would get on Georges Bank. A study on the Mid-Atlantic saw virtually nothing (Murawski and Serchuck 1989). Damage on Georges Bank would be expected to be somewhere in the middle. Further investigation of this topic was suggested as a research recommendation, as it might account for the pattern observed. It could be done with the model.

Two size bins were suggested: one for fast growing scallops and one for slow growing scallops. This pattern was observed with a large year-class that recruited to the fishery 6 months ahead of what was expected. Growth shot up. It was not seen in the first 2 years, but it was later on. Shell height increased as did meat weight. The same pattern was observed on Georges Bank. The 1998 year-class recruited in 2001 instead of in 2002 as expected, and there was spreading of the year-class. However, there was felt to be no easy way to take this into account with the model. Reasons for the pattern were discussed, including possible density dependence above 40,000 that may cause crowding or may be because they are old. If the 6 year olds are removed, one gets a better fit. With this approach, all the inference about natural mortality goes away. Defensible and applicable ageing would also help to address this issue.

Problems with the VPA were discussed. It was suggested that the biggest problem with using VPA is cohort slicing. In addition, there is no time change flexibility in the VPA. Divergence matches with the three different phases in the fishery. The VPA has been stiff and slow to react to abrupt changes in biomass. The Delay-Difference model reacts more rapidly. A VPA model where there is no explicit ageing is problematic. VPA runs in previous years track the peak, but this is problematic if the population model gives different results depending on many years of data are used. This would be considered a strong retrospective effect.

Presentation: Reflections on the Georges Bank Population Model (no working paper)
Presenter: B. Mohn
Rapporteur: T. Worcester

Presentation Highlights

For Georges Bank scallop, it is important to know what is the status of the resource and where should it be. The more models are available to evaluate these, the better. If there is lots of data, it is preferable to analyze it in many different ways. The proposed model has one structure to account for processes. Models like smoothness. Given that the survey data is rough and the CPUE is smooth, it is not surprising that the model fits better to the CPUE. CPUE has much more information but it is hard to deal with. There is not a clear relationship between CPUE and abundance. In good times and in bad times they follow a similar trend. In the middle, they seem to be independent. The CPUE should not be incorporated into the model until one understands what it is saying. There is some information in the size structure that it would be a shame to throw away. Using VPA, one can say something about the size/age structure. For example, the fishery seems to focus on certain sized scallops. Another process that is important is the stock-recruit relationship. Analysis shows that scallops can reproduce at smaller sizes. Natural mortality is also important. A random walk analysis indicated that natural mortality may be increasing. In closing, it is important to ask the questions: “Have enough models been considered, are they different enough, where do they agree or disagree, if so, why, and have they captured key processes?”

Discussion

It was suggested that the Canadian portion of Georges Bank scallop is not a stock, and it would be necessary to combine it with the US stock to get a meaningful stock-recruit relationship. While scallops are not a migrating species, their larvae do move. It was noted that a stock-recruitment relationship is not often observed in scallops, and some concerns were expressed about seeing it in the VPA. It was suggested that it was not as important to have a recruitment curve. Rather, the value of doing the VPA was in having all the information available from the data on paper to investigate. The message is that it will be important to collect ageing information, whether it is integrated into a population model or not.

Whether or not natural mortality may be increasing was discussed. Natural mortality may be size dependent, and it may be higher on older animals. Perhaps scallops lose their swimming ability when they are large. As the average age of scallops increases, the natural mortality of the population may be increasing. In closed areas, the natural mortality was very low for young animals. There tends to be a younger population of scallops in the Bay of Fundy, and, in recent years (2005 to present), natural mortality has been in the range of 0.05-0.12. If the old individuals are excluded, natural mortality may be more consistent. A question was asked about whether natural mortality could be connected to the average weight (i.e., recast in terms of average weight). It was agreed that might be worthwhile to look at. If natural mortality is increasing, the population may not be in as good shape as expected. Later in the meeting,

R. Mohn showed a plot that integrated the average weight of the population. He plotted average weight per year by the M per year. This gave a slow, gentle curve, which indicated that big scallops have higher natural mortality. It would appear that natural mortality is increasing over time, but it is just increasing with size.

It was suggested that the model fits might be improved if other sources of error were explored. It was noted that processes such as settlement success and oceanographic processes are not being accounted for.

Presentation: Catch at Size Analysis (CASA) Population Model (no working paper)
Presenter: D. Hart
Rapporteur: T. Worcester

Presentation Highlights

The CASA model is what is used for the US scallop stocks. It is a statistical catch at size model that is similar to ASAP (catch at age model), except it has no ages. It is all based on size and loosely based on Sullivan et al. (1990). A stochastic growth matrix can be estimated based on shell increment data. CVs are included for both surveys (i.e., the DFO and NMFS surveys). The DFO survey is more detailed and has smaller CVs. Shell increment data was obtained from Canadian samples. Some shells might be from the Georges Bank ‘b’ area. The same shell-height meat weight was used. The key to the CASA model is the growth matrix, which is populated by shell increment data. It lets the data speak for itself (i.e., not assuming von Bertalanffy). Multiplying the population by the matrix gives the population next year. This type of matrix is very natural for scallops because of the potential for using growth increments. Results from this model were a bit different from the Delay-Difference results, i.e., it does not jump at peak abundance, but biomass is quite similar (within errors). Recruitment and fishing mortality were estimated, but it is not clear whether the high fishing mortality at the beginning is real. It is more probably that the starting conditions were not quite right, as the model takes a few years to adjust. Results show a fishing mortality that is just a little below the assessment model results. There is no requirement to assume knife-edge recruitment, rather it uses 3 time periods and gets more gradual size selectivity. The model was fit to the survey data. Since it is log transformed, it tends to discount high values. Higher numbers of scallops were seen in 2000, but more biomass is seen now since they are heavier. The stock recruitment relationship is flat through the time series. It has never been really recruitment limited. This presentation did not include recent information, which may show a bimodal pattern. If the US information is included, a slightly different pattern is seen. There were times when most of the spawning biomass was on the Canadian side. The fishing mortality from CASA may not be directly comparable with the Delay-Difference model, but they are similar within error. There were some differences between number versus biomass trends. The benefit of comparing the different approaches was that it indicated that they were both saying something similar. It was noted that the Delay-Difference model has a Bayesian component that the CASA model does not have.

Discussion

Clarification was sought on recruitment. In this case, recruitment comes in at about 5 sizes (20-60 mm) with a Beta distribution. It assumes pulsed recruitment. It does not estimate the shape of the distribution, just the size.

It was clarified that M was assumed to be 0.1 in this model as well, but growth was not assumed to be the same. Growth was somewhat lower.

The same catchabilities were used throughout the survey time series. The only thing that was split was selectivity.

Stock recruit is consistent with what is seen in other scallop stocks.

This is tuning to the survey data, but it has its own internal model. When fishing mortality is low, it assumes there are larger animals out there. This is within the precision of both models.

Someone asked what was going on with commercial catch at size. The response was that the model was certainly tuning to that.

It was suggested that habitat suitability may be working against the stock-recruit relationship.

Presentation: US Ageing Approach (no working paper)
Presenter: D. Hart
Rapporteur: T. Worcester

Presentation Highlights

Some shells are virtually unreadable. Sometimes the northern edge area is pretty bad with this. Problems include false annuli, ring regions, unclear rings, deformed shells, etc. Ten percent (10 %) of shells cannot be aged. Krantz et al. (1984) did stable isotope analysis on 2 shells from the Mid-Atlantic, one suggested that 2 rings per year were laid down; however, the presenter disagreed with this finding. She tracked growth of large cohorts at selected locations in closed areas by repeatedly surveying the locations, and then compared the observed growth to that predicted and also did isotopes. Four repeat locations were investigated. Scallops in the Mid-Atlantic appear not to grow that big, but they do appear to be laying down annual growth rings. The matrix does not predict recruitment. At Elephant Trunk, almost no growth was observed in 2005/2006, then they grew again in 2007. The CASA model is assuming that growth is predicted by the growth matrix. There is a marker on the shell that shows slow growth. This has not been seen on Georges Bank yet, but an ageing program would help to pick it up. These results call into question the notion that 2 rings are laid down per year. Isotope analysis shows that it is difficult to determine where the first year ring is. Rings are read at the temperature maximum (GB). The temperature maximum is also where spawning occurs. This approach is not the gold standard either, as there are still lots of issues. For example, one has to be careful where one drills. However, it suggests that rings are laid down annually at, or slightly before, the temperature maximum. 1-year rings may not be seen because scallops are not spawning until 2 years. For older shells, early rings are not distinguishable. Absolute ages may be impossible to determine, but yearly growth increments are visible. Mean L_{inf}=143.9 and K=0.427 for Georges Bank. Depth has an effect on growth. Fishing appears to have an effect on growth. Where they start diverging is at about 90 mm, which is when the fishing occurs. Three hypothesis are: 1) fishing causes damage, 2) fishing causes false rings on shells, and 3) selective removal of large faster growing scallops. Only the final hypothesis is thought to be consistent with the data. Density has at most a slight effect on growth, and is more apparent in the Mid-Atlantic. Density affects growth only in fished areas. This is consistent with what has been said about removals of faster growing animals by the fishery, i.e., fishing density dependence. Analysis of growth increment data needs to take into account variability in growth (random effects). Growth is well estimated by shell increment data and mixed-effects models.

Discussion

Data is available that shows changes in meat weight at the same time. There are periods when scallop are not growing much, i.e., are not picking up weight or height. They may grow in spurts.

There were approximately 100 samples taken per shell, which is why not many shells are done. It is quite expensive.

Two papers have been submitted on this work – one to the Canadian Journal of Fisheries and Aquatic Science and one to the ICES Journal. It is also included as a discussion in the last assessment, but that does not include the co-variates.

The routines have been provided to the Canadian scallop assessment team, and it has been applied in SFA 29. It is accessible.

It was suggested that it is good to keep collecting scallops in the closed areas. Someone asked how long a closed area needs to remain closed to see these differences. The response was that it is hard to tell. The US closed areas have been closed since 1994. One would have to get shells big enough beyond commercial size to remove selective removal. Two years is not enough to see this effect, but it might start to be seen after 3-4 years.

Working Paper: Jonsen, I.D., A. Glass, B. Hubley, and J. Sameoto. 2009. Georges Bank 'a' Scallop Framework Assessment: Data Inputs and Population Models. CSA Working Paper 2009/01.

Presentation: Providing Advice Using the Delay-Difference Model
Presenter: I. Jonsen
Rapporteur: T. Worcester

Presentation Highlights

Change in biomass from 1 year to the next was plotted against exploitation rate. Results suggest an exploitation rate of 0.25, but the trend is not significantly different from 0. The history of fishing mortality starting at about 0.4-0.5, then went to a lower level. Biomass was divided into 2 time periods based on this change in the fishery. The early portion showed an exploitation rate of 0.32 associated with no change in biomass. Now there is an exploitation rate of 0.17 associated with no change in biomass. This is linked to total mortality and growth potential. There are 2 phases in the fishery with different exploitation rates relating to no change in biomass. With the Delay-Difference model, there is a component called growth potential that changes with average scallop size in the stock. If the stock is smaller and younger, it will grow faster than if it is older and larger. So, one can plot the growth potential against exploitation. The replacement line is the exploitation rate that gives no change in biomass as a function of growth potential discounted for natural mortality. If exploitation is below that replacement line, than one would expect biomass to increase through growth and recruitment. If exploitation is above the line, then removals are higher than biomass gains due to growth and there would only be a biomass increase when recruitment compensates for this, otherwise biomass would decline. Increases in biomass are seen, but these are all associated with times when there was good recruitment. There is no single reference level. Rather, it will depend on growth potential and recruitment, not a threshold or reference limit.

Discussion

It was clarified that total mortality is not assumed to have remained constant. It is considered to be roughly the average fishing mortality over that period. It was also clarified that, from 1996 and onward, recruits includes scallops from 75 mm to just under 85 mm.

Someone asked whether the 2008 point was real data. The response was that it is the real average weight in the stock, but the exploitation rate is for no change in biomass based on the projected biomass for the next year.

It was noted that there is uncertainty around the replacement line, which reflects uncertainty in growth rate parameters and natural mortality.

It was clarified that the probability of biomass decline (third column in decision table) includes all error – both process error and observation error.

It was agreed that the newer decision table would be included in the Research Document.

It was suggested that when there is lower fishing mortality, there is a lower zero replacement. An alternative suggestion was that because scallops are resilient, they can still grow even when you fish them hard.

One can think about scallops as an investment fund. Decisions can be made when to withdraw (fish scallops) and when to invest (do not fish scallops) based on the interest rate (growth potential) and how much return to put back into the investment (recruitment).

It was suggested that if exploitation rate is a useful reference but sustainability is possible at a variety of levels, the reference point would depend on the desired state of the stock. It was clarified that it may not be possible to control what the stock will look like, but management decisions should reflect the current state of the stock.

Concern was expressed that average weight is not perfect for predicting next year's growth. It tends to be biased low due to Jensen's inequality. If there is a big year-class coming in with lots of young animals but some older animals, it might be biased. It was agreed that this is possible, but the curvature in the replacement line during current phase in the fishery is small, suggesting the bias is small.

It was suggested that the decision table be organized to show the results by percent change in biomass. However, Industry likes to see it by catch so that the implications of the different harvest scenarios are clear. This was done and was presented in the next slide.

Industry might want to fish harder when conditions are good, and fish less when recruitment is low. If recruitment was not strong one year, but there's good recruitment coming in, this may influence the management decision. It may not be desirable to have zero biomass change from year to year. It would be desirable to be able to describe the ecosystem implications of various management options.

The approach proposed represents a management framework – not a set of decision rules.

What the table does not provide is advice for the next two years. Context would be provided in the text that describes the table. There is lots of information that needs to guide the decision, including whether it is desirable to increase or decrease the current scallop abundance.

Experience has been gained in using this type of approach in the inshore. All of the necessary information for a management decision is included in the Science Advisory Report.

It was suggested that feasibility of defining an F reference point or a B reference point be explored. B_{msy} has not be established to date; however, a production analysis may also a useful thing to do. There may be a region where biomass is compromised. If the stock-recruit relationship is flat, F_{msy} is F_{max}. This tends to be about 0.24 on the US side of Georges Bank. It presumes historic conditions. There has not been much success at defining it in the past, but it was agreed that it would be something to try. It was noted that the production function depends on recruitment, environment, etc. If F_{msy} can be calculated, it may be informative to management.

Alternative management approaches based on F_{max} were mentioned including that F not exceed $F_{msy.}$ and various conditions under which F would be allowed to exceed $F_{msy.}$ It was noted that there had been growth overfishing in the 1980s, and exploitation had been significantly over 0.2. The appropriate F depends on the current status of the stock, condition in previous years, incoming recruitment, and level of risk tolerance. The decision rule in the US is that F_{max} can not be exceeded unless the fishing mortality in a previous year was below it, i.e., it is possible to borrow from next year. For the Canadian fishery, the last 10 years could be considered that investment period. Some suggested that the fishery could exceed F_{max} as long as there was a process to re-evaluate conditions once the 'investment' has been removed. F_{max} would correspond to an exploitation of about 0.2. If this was the 1980s, this might be considered to be pushing too hard, but at present there is the ability to compensate.

It was suggested that work needs to be done on explaining what it is possible to achieve with this fishery. Using the proposed approach, it will be possible to describe the current state of the scallop population, describe what is undesirable, and begin to discuss the goal or target. Another possible indicator is biomass per recruit -- how much is being produced at F_{max} times some measure of recruitment (median now, but there are arguments for using the mean). As with other yield per recruit reference points, it could be calculated. At present, the Georges Bank Scallop stock is probably above it. This does provide some sense of the increase and decrease of biomass.

It was suggested that there is a problem with assuming constant recruitment. There is expected to be some level of background recruitment and then some exceptional years. It is important to have some expectation of what recruitment is over the long-term. It was clarified that constant recruitment is not being assumed, rather assumptions are made about some long-term level of recruitment. The scallops are integrating across year-classes. It was noted that yield-per recruit curves are shallow, thus very sensitive. It was agreed that a zero change in biomass strategy might not be optimal for this fishery. Further discussion is warranted on the strengths and weaknesses of different indicators. Production analysis may provide guidance on levels below which the stock is not wanted to fall, as well as some insights into what the current state is. There are model-based ways to look at it too (B_{msy}, F_{msy} equilibrium concepts). It would be important to suggest a 'made-for-scallop' approach to reference points, rather than being forced down the default path when it doesn't work well for scallops (or other invertebrates). The development of indicators should be done as longer-term work. A management process will determine what risk level is appropriate. It was also suggested that this type of discussion has to be done within the context of the Integrated Fisheries Management Plan.

SUMMARY AND CONCLUSIONS

Survey Design

There are significant benefits to be obtained from switching from the old survey design based on annual catch rates to a survey design based on the historical survey index. Separation of northern and southern strata was suggested, as was comparison of the biomass versus abundance index. While information on substrate type has the potential to provide additional efficiencies in survey stratification, this information is not currently available. When it does become available, it will be investigated to determine if any additional gains in efficiency warrant further incorporation of this information into the survey design. However, efforts should be made to minimize alterations in strata boundaries in the future as fixed strata boundaries would better enable analysis of temporal trends in individual stratum. Rather than being used to change strata boundaries, new information could be used to influence allocation of stations within a stratum.

Model

The Delay-Difference model presented provides a reasonable fit to the survey and CPUE indices. Biomass estimates from this model seem realistic and are consistent with estimates from two other models (CASA and ADAPT VPA). The estimation and prediction diagnostics show that the proposed model is reasonably robust, and it shows no strong estimation biases. In general, the proposed model appears to perform reasonably well.

Compared to other models, the proposed Delay-Difference model has some distinct advantages over the previous ADAPT VPA model formulation. It helps to avoid cohort slicing problem, it does not require ongoing ageing information, it does not show the same retrospective pattern (more consistent advice over time), it was better able to track peaks in scallop abundance (though some discussion in timing of peaks in biomass versus abundance), and it responds more quickly to changes in biomass. The Schaefer surplus production model, while fitting surprisingly well, did underestimated biomass. However, the proposed model does tend to underestimate biomass during periods of fast population increase and overestimate biomass during periods of fast population decline. It is a reasonably simple model (which can be a good thing). It does not make use of information available on age structure (tracking of cohorts over time), and may not account for all processes (such as stock-recruit relationships, though it is not clear this exists for Georges Bank scallops, changes in natural mortality, etc.). However, the model could be modified to account for a stock-recruit relationship and variable natural mortality if warranted.

Suggestions of additional modifications that could be made to improve the model included: refinement of the input parameters (better growth parameters); addition of more informative priors (e.g., catchabilities); use of uniform priors, coefficients of variation (next year, or at least plot them on the graph this year), and two components of error (one fixed and one variable – influenced by survey design); and separation of the CPUE index into northern and southern indices. It was agreed that the following analyses, and a comparison of their diagnostic results, would be brought forward at the next assessment:

1) Survey + CPUE (default).
2) Survey + Northern and Southern separate indices.
3) Survey.
4) Survey + Northern alone.

It was suggested that a production analysis could also be conducted.

RESEARCH RECOMMENDATIONS

Longer-term research recommendations include: investigation of discard mortality, incidental mortality, changes in natural mortality, and growth. Use of CASA model should be investigated further for comparative purposes. It was noted that the CASA model does not require recent ageing information (using the incremental growth ring ageing approach) as the original version used von Bertalanffy parameters.

NEXT STEPS

- Presentations made at the meeting would be circulated to participants.

- A comparison of abundance trends from all model formulations (from assessment team and reviewers) would be included in the final proceedings. Proceedings would be sent out as soon after the meeting as possible, and 2-3 weeks will be provided for comment.

- The research document would include some of the extra graphs that were presented in the meeting but that were not included in the working paper, and it would incorporate suggestions from the meeting.

- The next Georges Bank scallop assessment would be conducted sometime in April 2009. Supporting documentation would be the research documents from this meeting. The results of the assessment would be described in a draft Science Advisory Report, which would be made available to participants before the 2009 scallop assessment. A companion document including the results of 4 separate fits to combinations of survey and CPUE indices (as described above) would be provided ahead of time.

- The survey was scheduled for May 2009.

- The new survey stratification was expected to be used in the August survey. Additional work on the stratification was to be reviewed before it was implemented in the survey (especially the north/south spilt). It could be presented at the assessment or at some other time before August 2009.

ACKNOWLEDGEMENTS

The scallop assessment team was thanked for their hard work, the external reviewers for their helpful comments and suggestions, and the rest of the participants for participating in the meeting. It was agreed that this had been a very fruitful meeting.

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APPENDICES

Appendix 1. List of Participants

Assessment Framework for Georges Bank Scallop
Maritimes Region Science Advisory Process

Bedford Institute of Oceanography (BIO)
Dartmouth, Nova Scotia

18-20 February 2009

PARTICIPANTS LIST

Name	Affiliation
Curtis, Alexandra	Ecology Action Centre
Despres, Noel	Comeau's Sea Foods Limited
Glass, Amy	DFO Maritimes Science
Hart, Dvora	NOAA, NMFS
Hubley, Brad	DFO Maritimes Science
Hurley, Peter	DFO Maritimes Science
Jonsen, Ian	DFO Maritimes Science
Knickle, David	Adams & Knickle Limited
Lundy, Mark	DFO Maritimes Science
Mite-Vera, Carolina	Universidade Estadual de Maringa / NUPELIA
Mohn, Robert	DFO Maritimes Science
Mosher, Jim	Clearwater Seafoods
Niles, Monique	DFO Gulf Science
Penney, Christine	Clearwater Seafoods
Robert, Ginette	Seafood Producers Assn of NS (SPANS)
Sameoto, Jessica	DFO Maritimes Science
Smith, Stephen	DFO Maritimes Science
Stevens, Greg	DFO Resource Management
Worcester, Tana (Chair)	DFO Maritimes Science

Appendix 2. Terms of Reference

Assessment Framework for Georges Bank Scallop
Maritimes Region Science Advisory Process

Bedford Institute of Oceanography (BIO)
Dartmouth, Nova Scotia

18-20 February 2009

TERMS OF REFERENCE

Context

Georges Bank is one of the main sea scallop stocks fished by the offshore scallop fleet. Since 1986, the offshore scallop fleet has fished Georges Bank year round under an Enterprise Allocation management regime. The long-term objectives of the offshore scallop fishery are biological sustainability and economic viability. The following three management objectives are applicable for the Georges Bank scallop fishery:[1]

- to ensure the conservation of the resource;
- to the degree possible, stabilize landings over time; and,
- to provide increased economic benefits for crews, vessel owners, shore workers and the people of Canada.

To this end, the scallop fishery is managed under the Enterprise Allocation system, which incorporates company quotas, the establishment of fishing areas (including closure of 'seed boxes') and seasons, and meat count limits. Catches are monitored through an industry-funded dockside-monitoring program and vessels are required to carry vessel monitoring systems. The industry also participates in and funds the research vessel surveys, collects data through a port sampling program and conducts sea-bed mapping.

The research vessel survey has used a commercial catch rate-stratified sampling design with allocation proportional to the areas of five catch rate strata. The original strata boundaries were not recorded and, therefore, need to be reconstructed. This reconstruction will allow a full assessment of the efficiency of the catch rate-stratified design with a view to developing improved survey designs in the future.

Stock assessments have been conducted since 1986 using a Sequential Population Analysis (SPA) to estimate population abundance and biomass based on research vessel survey indices, commercial CPUEs and age composition in the stock. The SPA is an age-based model but no current ageing data exists for the Georges Bank stock; implementation of the SPA has relied on old growth rates for Georges Bank published in 1972 (Brown et al. 1972). For a variety of reasons, including poor fit to the 2008 data and projections that were not consistent with the understanding of the resource, the 2008 Georges Bank assessment (DFO 2008) did not use the SPA to assess resource status and provide management advice for 2009. Due to the absence of current ageing data and other issues with the current assessment approach, a new assessment approach is being pursued.

[1] These objectives are a slight modification from those found in the Enterprise Allocation document approved by DFO in 1989 and carried forward in subsequent Integrated Fishery Management Plans.

Objectives

Review Survey Index of Abundance

- Reconstruct original catch-rate strata boundaries to facilitate an evaluation of the efficiency of the survey design
- Propose and evaluate alternate survey stratification design(s)

Review of Model(s) to Assess Status and Productivity

- Determine the methodology to estimate the current state of the stock, including methods for estimating stock size and fishing mortality.
- Determine the methodology to characterize stock productivity including reference points.
- Determine forecasting methodology for providing advice on harvest levels.
- Provide guidance on next steps, including research recommendations.

Outputs

CSAS Science Advisory Report outlining the assessment framework
CSAS Proceedings of the discussion of meetings
CSAS Research Documents

Participation

External experts
DFO Maritimes Science
DFO Maritimes FAM
Fishing industry
Aboriginal communities / organizations
Nova Scotia Provincial representatives

References

Brown, B.E., M. Parrack, and D.D. Flescher. 1972. Review of the current status of the scallop fishery in ICNAF division 5Z. Int. Comm. Northw. Atl. Fish. (ICNAF) Res. Doc. 72/113: 1-13.

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Appendix 3. Agenda

Assessment Framework for Georges Bank Scallop
Maritimes Region Science Advisory Process

George Needler II Boardroom, Bedford Institute of Oceanography (BIO)
Dartmouth, Nova Scotia

18-20 February 2009

DRAFT AGENDA

18 February 2009 – Wednesday

9:00-9:15	Welcome and Introduction
9:15-9:45	Scallop biology/History of Georges Bank fishery
9:45-10:15	Overview of Data Inputs
10:15-10:30	Break
10:30-11:30	Survey Design
11:30-12:00	Discussion
12:00-13:00	Lunch
13:00-14:30	Data Inputs to Population Model
14:30-14:45	Break
14:45-16:30	Discussion

19 February 2009 – Thursday

9:00-9:15	Review of Previous Day
9:15-10:15	Population Models - Background
10:15-10:30	Break
10:30-11:30	Population Models – Results I
11:30-12:00	Discussion
12:00-13:00	Lunch
13:00-14:30	Population Models – Results II (Hart & Mohn)

14:30-14:45 Break

14:45-16:30 Discussion

20 February 2009 – Friday (Hayes Boardroom)

9:00-9:15 Review of Previous Day

9:15-10:15 Follow-up results and/or further discussion

10:15-10:30 Break

10:30-12:00 Next steps

12:00 Meeting Adjourned