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Proceedings of the Maritime Provinces Regional Advisory Process on the Assessment Framework for 4VWX Herring Stocks

Compte rendu du Processus consultatif régional des provinces Maritimes sur le cadre d'évaluation du hareng de 4VWX

31 October – 1 November 2006
9 – 11 January 2007

31 octobre – 1 novembre 2006
9 – 11 janvier 2007

Robert O'Boyle
Meeting Chair

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April 2007 | **avril 2007**

Canada

FOREWORD

The purpose of these proceedings is to archive the activities and discussions of the meeting, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or misleading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

AVANT-PROPOS

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion, notamment en ce qui concerne les recommandations de recherche et les incertitudes; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s’est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s’il est clairement indiqué qu’elle l’est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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SUMMARY

The Maritimes Regional Advisory Process (RAP) review of the assessment framework for the SW Nova Scotia / Bay of Fundy Management Unit (SWNS/BoF) of the 4VWX stock complex was to be undertaken in three meetings: stock structure and fishery data inputs (31 October – 2 November 2006, St. Andrew's), indices of abundance (9 – 11 January 2007, Dartmouth) and models used to determine stock status, productivity, and harvest implications (26 February – 2 March 2007, St. Andrew's). Due to issues with the input data (i.e., ageing information), the last meeting has been postponed until the winter of 2008. These meetings benefited from the input of Department of Fisheries and Oceans Canada (DFO) and non-DFO scientists, members of the herring industry, DFO managers and provincial representatives. The results of these meetings will be useful to the assessment to be conducted in support of the 2007/08 fishery.

SOMMAIRE

L'examen, par le Processus consultatif régional des Maritimes, du cadre d'évaluation du complexe de stocks de hareng de 4VWX pour l'unité de gestion du secteur sud-ouest de la Nouvelle-Écosse/baie de Fundy devait se dérouler en trois réunions, comme suit : structure des stocks et données d'entrée sur les pêches (31 octobre – 2 novembre 2006, St. Andrews), indices d'abondance (9 – 11 janvier 2007, Dartmouth) et modèles utilisés pour déterminer l'état du stock, la productivité et les effets sur la pêche (26 février – 2 mars 2007, St. Andrews). En raison de problèmes concernant les données d'entrée (données sur l'âge, notamment), la dernière réunion a été reportée à l'hiver 2008. Au cours des deux premières réunions, des scientifiques du ministère des Pêches et des Océans (MPO) et de l'extérieur ont donné leur avis, ainsi que des membres de l'industrie de la pêche du hareng, des gestionnaires du MPO et des représentants provinciaux. Les résultats de ces réunions seront utiles pour l'évaluation qui sera réalisée en prévision de la pêche de 2007-2008.

INTRODUCTION

The 2005 and 2006 assessments (DFO, 2005; DFO, 2006c) of the status of the southwest Nova Scotia / Bay of Fundy Management Unit (SWNS/BoF) of the 4VWX stock complex highlighted the need for an in-depth review of the data and models used to assess progress against these objectives. For instance, the population model (VPA) and acoustic surveys estimates of current biomass differ substantially, which has focused attention on whether or not the acoustic survey biomass estimates should be considered absolute or relative as well as the veracity of the VPA.

Subsequent to the 2006 assessment meeting, a planning committee was struck to develop the terms of reference (Appendix 1) for a comprehensive review of the framework to be used to assess the status of the SWNS/BoF management unit. This group, chaired by R. O'Boyle (Maritimes RAP Coordinator), consisted of the DFO St. Andrew's herring assessment team (G. Melvin, M. Power, K. Clark, J. Fife, J. Porter, and R. Stephenson), the DFO herring resource manager, C. MacDonald, and members of the herring fishing industry (R. Stirling, R. Cochrane, R. Stewart, D. Morrow, D. Larkin, S. D'Eon, and J. Lugar). Based upon the discussions of this group, the process to meet the terms of reference was to be undertaken over three sequential meeting during fall 2006 – winter 2007, scheduled to ensure that modifications identified in a meeting could be incorporated into the preparations and deliberations of the following meeting:

- Stock structure and fishery data inputs: 31 October – 1 November 2006.
- Indices of abundance, including the acoustic survey: 9 – 11 January 2007.
- Models to determine stock status, productivity, and harvest implications of management options: 26 February – 2 March 2007 (postponed until winter 2008).

The current management plan for the 4VWX herring stock complex pursues three conservation objectives:

1. To maintain the reproductive capacity of herring in each management unit through:
    - Persistence of all spawning components in the management unit,
    - Maintenance of biomass of each spawning component above a minimum threshold,
    - Maintenance of a broad age composition for each spawning component, and
    - Maintenance of a long spawning period for each spawning component.
2. To prevent growth overfishing:
    - Continue to strive for fishing mortality at or below $F_{0.1}$.
3. To maintain ecosystem integrity/ ecological relationships (ecosystem balance):
    - Maintain spatial and temporal diversity of spawning, and
    - Maintain herring biomass at moderate to high levels.

During the framework review, it was intended to identify biological indicators associated with each of these objectives. If during the review, biological processes became apparent for which additional objectives might be required, these would be proposed to the Scotia-Fundy Herring Advisory Committee for approval.

During the first meeting, a problem with the herring ageing was reported (documented herein) which required modification of the approach to the subsequent meetings. Resolution of this issue may not occur until early winter 2009. It was agreed after the second meeting to postpone the third modeling meeting until the re-aged material is available.

Throughout the review, recommendations were made to improve the framework in the longer term and recorded in these proceedings for discussion and prioritization in a post-framework joint DFO–industry herring research program planning meeting, anticipated to occur before 31 May 2007.

The lists of participants (Appendix 2), agendas of the two meetings (Appendix 3), and comments by the external reviewers (Appendix 4) are provided below. An update on the re-ageing of the historical herring otoliths by winter 2008/09 is provided in Appendix 5.

These proceedings were adopted by correspondence subsequent to each meeting.

STOCK STRUCTURE AND FISHERY DATA INPUTS
Biological Station, St. Andrew's
31 October – 1 November 2006

The meeting commenced with the Chair, R. O'Boyle welcoming the participants. He particularly noted the presence of M. Dickey-Collas, C. LeBlanc, M. Sinclair, R. Claytor, and G. Poirier, who were the invited external scientific reviewers for the meeting. The context and overall process of the framework review, as outlined in the terms of reference were then presented. Following this, there was a discussion on the objectives of this first meeting of the framework which focused on stock structure and data inputs. The agenda was briefly reviewed with comment on the possibility of working late on the Wednesday to allow completion of the meeting by 10:00 am on Thursday morning, rather than 12:00 pm as planned. This was to allow industry participants from southwest Nova Scotia (SWNS) to catch the noon Digby ferry.

The Chair noted that the draft 2006 assessment research document (Power, et. al., 2006) and Science Advisory Report (DFO, 2006a) had been circulated prior to the meeting, as was a Science Expert Opinion on herring ageing (DFO, 2006b). These were available at the back of the meeting room along with the meeting working papers.

After thanking Paul Boudreau, the Meeting Rapporteur, the presentation of the working papers commenced.

Biological Basis of Management Unit

Stephenson, R.L., et al. 2006. Review of the Biological Basis for the Herring Management Unit. RAP Working Paper 2006/26.

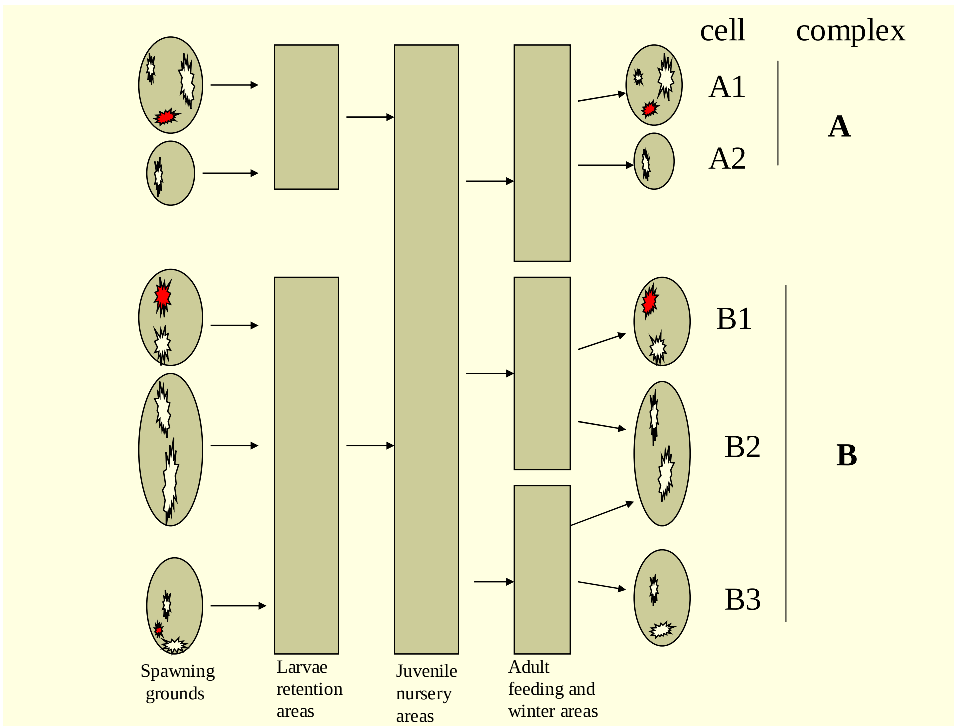
Presentation Highlights

The working paper and presentation reviewed the biological basis for the management unit, based on the following observations/hypotheses or assumptions related to population structure:

- Herring spawn in discrete locations.
- Herring spawning locations are predictable (in both space and time).
- There may be multiple spawning locations and/or times within an area.
- Herring spawn completely, in schools, in events that have been described as waves.
- Most spawning grounds have multiple waves of herring during a spawning season.
- Herring larvae remain aggregated.
- There are predictable patterns of distribution of larvae (larval retention areas).
- There are general patterns of distribution of juveniles and adults, and movement among spawning, overwintering, and summer feeding areas.
- Herring migrate widely.
- Herring return (annually) to spawning grounds they have used previously.
- Herring are presumed to 'home'.
- Herring mix (with those from other spawning areas) at juvenile and non-spawning adult stages.
- Mixing is not uniform – herring remain aggregated or clumped in schools.
- Herring exhibit a high degree of population 'complexity' or 'richness'.

Herring do not comprise a single homogeneous population, but rather a complex population made up of a number of discrete spawning units that may mix at times in the life history, but separate out to spawn. There are major discontinuities in herring distribution at spawning, both in space and time. There is sufficient evidence for repeated use of spawning grounds and indications of homing to suggest that the spawning unit is the appropriate basis for the management unit. There are also discontinuities in distribution of herring larvae. Persistent aggregation (retention) of larvae has been proposed as important for maintaining stock structure.

The conceptual figure of herring stock structure that has emerged in recent years is illustrated in the following figure:



Conceptual Figure of Herring Population Structure

Spawning areas (which may have a number of spatial or temporal spawning areas/waves) are grouped on the basis of geographical or temporal separation into 'cells' (ovals) in which there is at least one persistent, annually predictable spawning event. Spawning 'cells' are grouped into a 'complex' on the basis of the distribution of larvae (larval retention areas). Herring that share a common larval distribution (larval retention area) are considered to be part of the same complex.

Juvenile and non-spawning adult herring mix widely, but separate out to spawn with a high degree of fidelity to the complex, and to the cell. It is recognized that there must be some 'straying' or crossover between spawning grounds (including the establishment of spawning in novel areas), but this is expected to be highest within the cell, lower among cells in a complex, and lowest between complexes. It is noted that herring are slow to occupy vacant spawning grounds.

The underlying biological model put forward in this working paper is essentially the model that is being used at present. New information (tagging, genetics, morphometrics) confirm rather than refute basic assumptions. This model is not unique to this area, but is applicable to herring generally.

Emphasis on the spawning ground as the basis for stock definition and management is appropriate. Preservation of all spawning grounds and of the duration of spawning is also appropriate.

It was recommended that there be a change in the assumption regarding the affinity of NB weir fish. There is clearly a link with 4X spawning areas, and the hypothesis that they are not of SWNS/BoF origin is easily refuted. It was recommended that a fraction of weir landings in the 4X assessment.

Regarding subdivision of 4VWX management units:

- SWNS/BoF spawners supply the quota fishery.
- Coastal (inshore) Nova Scotia spawning grounds are small and not traditionally part of the mobile fishery. While not a homogenous group (taken in small fisheries along the coast), they are conveniently treated as a complex apart from SWNS/BoF.
- Offshore Scotian Shelf Banks. Evidence of spawning makes this a separate group. Spawning grounds need further definition.
- Regarding transboundary (4X/5Y) movement. Tag evidence shows some movement across the Can/USA border. Transboundary movement occurs in overwintering, summer feeding and juvenile stages. The amount of transboundary movement is not easily quantified. Migration and mixing outside of the spawning time means that fish from 4X spawning areas may be in US waters (and therefore available to US fishery) at some times, but the greatest landings and mortality are considered to be in the Canadian fishery. Herring originating from 4WX spawning grounds are adequately managed by Canadian regulation.

Discussion

There was an in-depth discussion on the conceptual model of herring population structure as presented in Figure 19 of the working paper. It was felt that the conceptual model fits well for some herring (e.g., North Sea), but not all herring stocks. After detailed questions, there was overall agreement with the model as presented, but some modification to the linkages between the adult feeding/winter areas and spawning grounds when considering the SWNS/BoF management unit. Specifically, there needs to be diagonal arrows added to join the “adult feeding and winter areas” with the “spawning grounds” depicted on the right of the figure.

There was a discussion on the relationship between herring and grey seal abundance on the spawning grounds with a question from industry whether or not seals could disrupt spawning. A definitive answer could not be given other than observing that seals will go where the food is.

The discussion on inter-stock linkages then focused first on the northeast (Scotian Shelf) and then on the southwest (Gulf of Maine).
Regarding the Scotian Shelf, there was a short discussion on the demarcation line (Figure 10 of working paper) between the nearshore and offshore Scotian Shelf. This was to separate offshore bank herring from those migrating up the coast from southwest Nova Scotia. This then led to a discussion on the overwintering aggregations in Chedabucto Bay and Chebucto Head which have recently not occurred. Overall, it was considered that there is no basis to change the boundaries of the SWNS/BoF spawning component to the northeast. However, it was

recommended that the basis of the boundaries for the offshore spawning components needs to be clearly documented.

Much of the subsequent discussion focused on demarcation of the stock structure to the southwest. The working paper notes, based upon recent tagging information, that there is a clear link of NB weir herring with the 4X spawning grounds; the hypothesis that they are not of SWNS/BoF origin was considered to be easily refuted. Thus, the recommendation was made to include a large fraction of weir landings in the 4X assessment.

The rationale for the current conceptual model linking the NB weir catch to subarea 5 was questioned. Historical tagging in the 1970s showed a high degree of interchange between herring off Grand Manan and coastal Nova Scotia, as well as the western part of the Gulf of Maine, although there was not a strong linkage with Scotts Bay, and SWNS showed some linkage with the Western GoM. It was felt that the amount of interchange of NB weir fish with the Gulf of Maine has always been considered to be high, but of an unknown proportion. Historically it was unknown how much of a contribution of the weir catch was the result of the 4X or 5 fish. The working paper estimated that 17 / (49 + 14 + 17) = 21% of the NB weir tag returns came from the Gulf of Maine (table 12 of working paper). In addition, there is indication of separation from the meristics studies. Gill rake and vertebrate counts showed some difference between Nova Scotia and New Brunswick. Initial morphometrics have supported the hypothesis that there is a small fraction of Canadian fish in the mixing areas. However, it was pointed out that the tagging results were likely biased by a lack of reporting of tags from the US. If one were to adjust for tag misreporting, the percentage of US fish in the NB weir fishery would rise to over 50%. It was pointed out that changes in the US and Canadian fisheries would have an impact on the proportions of these fish in the NB weirs. The increase of US mid-water trawls on Georges Bank was noted. On the other hand, weir and purse seine effort in Canada has declined. This tends to suggest that annual adjustments to the percentage contribution were necessary. However, the European experience in reallocating the contribution of herring from various spawning stocks has not been very successful. It is be more appropriate to assume a stable fraction over an extended period, say the past 10-20 years for this area, taking into account important events such as the collapse and recovery of Georges Bank spawning stock.

On balance, the meeting participants felt that it cannot be assumed that all of the weir catch is either from the US or Canadian. The existing conceptual model is that there is a mix of unknown proportions of subarea 4 and 5 spawners in the NB weirs and that there is no means to identify the exact proportion. The new tagging information that was presented does not support a change in this model. Further analyses of these data were encouraged to better quantify the transboundary movement of herring. The conceptual model as stated in the 2006 Science Advisory Report (SAR) appears to be inconsistent with the existing conceptual model. Thus, it was recommended that a review be undertaken to determine when the current statement was added to the SARs and this statement corrected in the next report.

In summary, it was agreed that the biological definition of the SWNS/BoF herring spawning component was appropriate and there is no need to change it. In addition, it was suggested that a sensitivity analysis be undertaken to evaluate the impact of different assumed proportions of US origin herring in the NB weir catch on the assessment be carried out. This might also be able to evaluate the impact of changes in relative US and Canadian fishing effort over time.

It was noted that advice has been provided separately on the four spawning groups. Is there any reason to change this situation? The only way to manage strictly on a spawning basis is to restrict fishing to the spawning grounds at the time of spawning. This is not practical and exploitation has to be adjusted to protect the smallest stocks within the mixed fishing. This is in essence the management approach that has been taken.

Precision and Bias of Current Ageing Protocols

Melvin, G.D. 2006. Overview of 4WX Herring Ageing and Ages. RAP Working Paper 2006/21.

Fife, F.J. 2006. Herring Otolith Sampling and Ageing Protocol. RAP Working Paper 2006/27.

Presentation Highlights

Consistent and comparable ageing are critical in the application of any aged based assessment model. Unfortunately, discrepancies in the age assigned by competent readers of scales and otoliths are not an uncommon occurrence. This working paper provides an overview of herring otolith ageing at the St. Andrews Biological Station (SABS), established protocols and a summary of the results from several recent (since 2002) otolith exchanges amongst four research laboratories, involving 5 experienced herring readers. In every exchange significant ($P<0.01$) differences in mean age and a bias toward younger or older ages, depending upon the reader, were observed. Several trends in ages between laboratories were found with the SABS primary reader consistently ageing herring younger than the other readers. Of great concern was the lack of agreement between the primary and secondary readers at SABS for ages older than 3-4, and the implications of these differences on the age based assessment model (see Expert Opinion). Intra-reader consistency, or the repeatability of age assignments between readings of the same otolith, was not as severe as the inter-reader assignments, but did occur.

Other information examined included the variability in mean length and length frequency since 2000. No definitive statement could be made on the cause of the observed difference or when the divergence might have started. The data, however, do suggest that there may have been a drift toward younger ages by the primary ager at SABS and some evidence that the availability of fish length during reading may be influencing or biasing the final assigned age, especially for the older ages. The data also suggest that the departure may have begun when the current primary ager became responsible for the herring ageing (1999-2000) especially for the younger ages. Yet, there is a hint in the data for older ages that it may go back as far as 1994/95 when there was another change in readers.

In summary, the report concluded that there are serious inconsistencies and uncertainties in assigned ages both within (between readings) and between readers for herring. And, that these significant inter- and intra-otolith reader differences can and will have an impact on VPA outputs and our interpretation of stock status. The current level of reader difference is such that it places real uncertainty on any age related outputs, especially beyond age 4. New protocols and quality control measures must be established to improve both inter- and intra-reader consistency before fully age based assessment models are employed in the evaluation of the 4WX herring stock. The report recommended:

1) Revised ageing protocols must be established to improve the intra-reader comparability/repeatability and output quality control.

2) A new and enlarged otolith reference collection needs be established to provide a standard for comparison and training of new readers.

3) Repeat reading standards must be developed and achieved annually prior to proceeding with the batch processing of otoliths.

4) Regular otolith exchanges between institutes should be undertaken to monitor the readers for consistency and repeatability in ageing.

The methods used in herring sampling and ageing were reviewed. This included sample design, lab methods, variables collected and microscopic techniques. There was also some information on otolith features used to discern annual rings. Examples were shown of herring otoliths from ages 1-10. A frequency table of pair-wise comparisons of age estimates and accompanying bias plot were given as an example of an intra-reader test.

Discussion

There was discussion on the relative size of intra- versus inter-reader error. There was some suggestion from the ageing exchanges that inter-reader error was higher than intra-reader error. This could provide clues as to the basis of the problem. However, it was pointed out that, against the benchmark of 80% ager agreement, the problem is with both inter- and intra-reader comparisons. This benchmark has only been achieved for herring of age two and younger.

The observation that reference to the length information by the readers was a concern. It was pointed out that the ageing protocol used by DFO Gulf does not include reference to the length information. Subsequent to the meeting, it was reported by M. Dickey-Collas that the herring ageing protocol at his institute in the Netherlands also does not include reference to length information.

There was some discussion on ways to validate the ageing, including the tracking of a large yearclass through the age length keys. It was pointed out that this might be considered in the internal review being undertaken by Steve Campana at BIO.

The earliest date which the problem could have arisen was discussed. This may be related to when primary ageing responsibilities changed. It could also be related to when secondary checks decreased in frequency. It was noted by the St. Andrew’s herring group that there may be records to check the frequency of secondary checks. The problem may also be related to changes in otolith mounting practices, which were instigated as a cost saving measure. These issues will no doubt be investigated during the internal review. It was considered that the problem goes back as far as at least 1999, and perhaps 1995. One means to check when this problem might have started would be by considering the inter-annual change in length span on a cohort by cohort basis.

Some options to address this problem in the models were discussed, including use of historical growth information in the recent ‘error’ period, whatever this is deemed to be and use of a age 3+ group in a delay-difference model, as used in 2003, for Georges Bank herring. Further exploration of these options must await the results of the internal ageing review.

Estimation Procedures of By-Catch of Other Species in the Fishery

Power, M.J. 2006. Review of Species By-catch in the Herring Fisheries from 1991-2006. RAP Working Paper 2006/24.

Presentation Highlights

All available data from the Scotia-Fundy observer program for 1991 to 2006, where herring was the main target species, was summarized. The dominant by-catch species by weight in the catch has not changed from that previously reported with spiny dogfish, and mackerel making up the highest component by weight. The prevalence by number of sets observed is similar to previous reports with spiny dogfish, mackerel, cod and silver hake the most prevalent over the time series. Note that whales and other marine mammals are occasionally captured, but these are released alive and unharmed and their prevalence is very low.

In summary, the by-catch in herring fisheries is very low (about 0.5%) as a proportion of total catch while incidence of species other than herring does occur in relatively low numbers on a regular basis (about 30% of observed sets).

Discussion

It was reiterated that the desire is to develop a view of the overall impact of the herring fishery on the ecosystem, which would require absolute estimates of bycatch and discard by fleet, season and area. The catches presented in the working paper need to be adjusted up to the absolute estimates of discards by the fishery.

There was some discussion on the nature of seemingly high discards of herring in 2000 (Figure 11 of working paper). This may be due to the reporting of herring that was pursed, but then released due to high incidence of dogfish in the net. In the herring fishery, fish are not brought aboard and then discarded, as occurs in others fisheries. The definition of what constitutes 'discard' as used by the observer program needs to be checked. Live released herring would not be defined as discard. Alternatively, this high discard may be due to midwater trawl activity. This needs to be checked.

It was pointed out that there are captures of tuna, porpoise, and other species in the weir fishery. These observations need to be included.

It was agreed that, overall, the level of by-catch in the herring was low (0.5% of total catch by weight) although the incidence of non herring species is about 30%.

Precision and Bias of Current Sampling Protocols

Melvin, G.D., and M.J. Power. 2006. Review of 4WX Herring Biological Sampling and Samples. RAP Working Paper 2006/22.

Presentation Highlights

The current biological and length frequency sample database for Atlantic herring (*Clupea harengus*), collected from the commercial fishery and research surveys in the Atlantic region dates back more than half a century. The digital database represents one of the most extensive in the world (Power and Iles, 2001), but prior to 1973, must be considered work in progress as the data have not been validated.

The working paper provides an overview the biological samples and sampling protocols used in the 4VWX herring stock assessment. Since 1972, a total of 29,666 length frequency samples (4,477,677 measured fish) and 12,761 detailed herring samples that involved measuring 420,414 fish for length, weight, sex, maturity, gonad weight, and reading 393,205 otoliths. The primary source of length frequency data and detailed biological samples are from the herring industry who, under a cooperative program, sample at major fish plants. Additional samples are obtained from groundfish research surveys, commercial fishery observers, spawning ground surveys, and opportunistic ports visits.

In recent years, the number of lake frequency (LF) samples has increased and the number of detailed samples collected and processed has decreased, reflecting the increased dependency on the fishing industry for LF samples and a reduction of technical support for the processing, as well as some rationalization and sampling efficiencies. Annually, more than 140,000 fish are measured and 5,000 analyzed, with 80% of the length frequency and 60% of the detailed samples originating from 4X. Most of the gillnet fisheries tends to be on the fringe of the main fishing areas and many landings go to smaller fish plants which do not participate in the industry sampling program. The percent of the catch by gillnet is also relatively small and the sampling of these fisheries poor.

Geographical and fleet coverage is extensive, but basically opportunistic. The protocol for LF sampling involves the random selection and measurement to the nearest ½cm of approximately 200 fish from a landing. For detailed samples two fish per ½cm interval are retained for sizes greater than 24.5cm and one fish per ½cm less than 24.5cm, labeled and frozen for future analysis from selected LF samples. The standard length measurement for herring is total length. Canadian and US groundfish data must be converted from fork length. A 2% correction is added to frozen samples. Sufficient otoliths are collected during the main months (June through October) of the fishery to meet the 250 minimum, however is some years few otoliths are available for the fringe months and from the coastal gillnet fisheries.

Purse seine and weir length frequency and detailed biological sampling are more than adequate and perhaps excessive. The number of samples per 100t averages between 2 and 3 for weirs and 0.75 to 1.0 for purse seine. Modifications to reduce the numbers of LF samples may be disruptive and are not recommended. However, there is a general absence of LF samples from the gillnet fisheries of SW and coastal Nova Scotia and increased sampling is recommended. Further analysis of the detailed biological sampling is required to determine optimum levels. A disproportionate number of smaller and younger fish collected under the current sampling approach. Consideration should be given to increasing the number of larger fish sampled and to decrease the numbers of small fish collected.

Discussion

The participants were impressed by the volume of sampling that had been undertaken over the years. However, it was noted that there had been no analysis to judge the adequacy of sampling levels, as per the meeting terms of reference. There is a need to identify how much sampling is sufficient for assessment and management purposes. There is a need to establish precision driven targets for length at age and weight at age rather than sampling from a set number of tons of catch. Efficiencies might be possible by changing the focus on different age groups, both spatially and temporally.

It was asked how the observer and dockside sampling information are integrated. It is important that a trip's catch not be sampled and reported twice, by both an observer and by the dockside sampler. It was noted that the observer information is separately entered by that program and staff in the St. Andrew's herring group. There may be efficiencies for the herring group in using the observer database directly.

Overall, it was recommended to maintain the current levels of sampling, but to undertake the investigation of the appropriate levels of sampling. Also, every effort should be made to report the variance around the catch numbers and weight at age.

Construction of Catch at Age

Power, M.J. 2006. Construction of the Catch at Age for 4WX Herring. RAP Working Paper 2006/23.

Presentation Highlights

The catch at age for 4WX herring assessments is constructed using the application 'Catch at Age' (version 10.4); a windows based program for computing catch at age statistics as part of the stock assessment process. Catch at age statistics are calculated from length frequency and age-length key samples expanded to total catch using appropriate monthly length-weight relationships. The data are grouped or combined to produce catch at age statistics by NAFO unit area, gear-type and month.

Age-length keys (ALK's) are combined by month groupings for the 4WX area with a minimum target about 250 fish in each grouping. Shortfalls are identified and may be combined with adjacent months to attain the desired number. The ALKs are also enhanced if required where there are gaps of lengths with no ages.

The Catch at Age program requires input in the form of weight length relationships to weight the sample length data and for the calculation of weight at age. These are grouped by month using all the available length and weight data corresponding to the age length keys.

Individual length frequency samples are weighted using the amount of catch or market weight that the sampled landing represents. The length samples are then grouped by gear, area, and month with the appropriate catch applied to each grouping. It was noted that the recording of market weight for individual samples is a relatively new feature. Prior to 2002, the catch data for individual samples was not recorded for herring and a market weight was calculated using the total sample weight for each length frequency. Using the current weighting with catch weights, samples with more catch weight will now get proportionally more weighting within the overall catch grouping.

There are always cases of landings without length frequency samples for some area, gear, month groupings. These are usually small catches or minor gears at the edges of seasons or areas, and are included with adjacent months or areas when the catches are assigned to the sample groupings. The age statistics are calculated for each area, gear, and month groupings and are then combined to complete a table of age statistics which match the original landings by stock component, gear, and month similar. The final result for the overall stock catch at age is created by adding up the numbers by age for each of the defined stock components. These data are then appended to the historical catch at age and used as basic input into the VPA. The history of the catch at age construction is documented in each of the research documents since

1972. Each of the gear components catch composition has also been reported for each assessment and is available for separate analysis if new groupings are required.

Discussion

There was a discussion on the reliability of the catch data. There were known to be problems in misreporting in the 1980s, through a study undertaken by P. Mace. The catch had been adjusted to account for this. While the annual assessment research documents report these adjustments, it would be useful, as part of the framework review, to consolidate this information in the research document(s) to be produced.

Dockside monitoring was introduced in 1992, and it is considered that the catch information since then is reliable. There were problems with the use of false holds (gizmos) being used in the mid-1990s, but the ubiquity of these was not reported. It was recommended that the St. Andrew's herring team and the fisheries managers discuss and document these devices in the framework research document(s). Overall, though, it was considered that the level of misreporting with this device was low compared to what occurred in the 1980s.

Misreporting by area is not considered an issue, given the logbook coverage of the fleet.

There was a brief discussion on herring killed, but not brought on board the vessel. This might have occurred in previous years, but is not now considered an issue.

It was pointed out that, up until four years ago, the weighting of the samples was done using the sample weights (kg). Since then, the market weights as reported by the trip have been used. It was recommended that a comparison of the use of sample versus market weights be undertaken for the recent time period, for which both sources of information exist, to determine the sensitivity of the sample weighting to this calculation.

It was noted that the catch at age (CAA) construction focuses on developing the CAA by gear, month and unit area. As one of the objectives of the IFMP is the maintenance of the spatial and temporal diversity of spawning, it was recommended that CAA be developed for particular spawning areas (e.g., Scots Bay) to allow tracking of the population dynamics of each of these areas. For instance, are there different year-class strengths being exhibited by these? These trends are obfuscated using the current sampling aggregation procedure to construct the CAA.

How best to combine the age/length keys (ALK) for application to the length frequency samples was then discussed. The procedure, which attempts to apply ALKs to the length frequencies sampled in comparable times and areas sometimes produces gaps in the ages for some length groups. These are filled using subjective decision on the likely age based upon the length frequency information, adjacent ALKs, and so on. It was pointed out that the ALKs likely do not change significantly during the time of the year when growth is slow (e.g., winter – spring). It would be worthwhile investigating aggregating ALKs across seasons to avoid the need for subjective decisions on age gaps. Additional aggregation across gear and area could also be explored, keeping in mind the desire to develop spawning area CAA.

Regarding the sampling itself, collection of otoliths is stratified by length. There may be a need to increase the number of otoliths collected for the larger herring to ensure adequate representation of older fish in the CAA.

The recommendations made above will require extensive explorations of the sampling data base. It was felt however that these explorations should await resolution of the ageing issue as the latter will likely have much greater impact on the CAA than refinements to the CAA construction procedure.

Protocols to Estimate Growth and Size at Maturity

Power, M.J., T.D. Iles, G.D. Melvin, and R.L. Stephenson. 2006. Review of Growth and Size at Maturity in 4WX Herring. RAP Working Paper 2006/25.

Presentation Highlights

This paper reviewed the herring biological sampling database for the Scotia-Fundy area and estimated herring growth and maturity trends from 1970 to 2005. The 4WX herring fishery and research trawl surveys catches have been extensively sampled to describe size, age, maturity and growth with over 300,000 fish in the database.

Examination of the trends in proportion mature shows consistent declining trend in length at maturity since at least 1990, possibly reflecting heavy exploitation. The maturity at length for 2005 4WX herring shows the L50 values at 225mm and 100% mature at about 250mm which are near the lowest recorded for this stock. The mean length and weight at age calculated for the months of August and September show minor fluctuations over time, but there are no consistent changes by age in the most recent period since 1990. The growth increment at age compared with the overall average shows a decrease in the mean increment at age in recent years showing slower growth.

Discussion

It was queried whether or not there was a problem in using fish samples only to develop age and size specific maturity estimates. Fisheries directing on spawning aggregations do not sample the entire population and thus it is not possible to determine what percent of the population is not spawning (outside of the fishing area). It was agreed that to calculate an annual maturity ogive would require sampling of the population and not just the fishery. It might be possible to use bottom trawl survey information to develop unbiased maturity ogives, although survey timing and coverage (the DFO summer survey samples the offshore areas, not inshore in SWNS) is an issue. Also, there is the additional complication of herring moving in three, not two, dimensions. Given these issues, it might be more profitable to establish the spawning ages as three plus and calculate spawning stock numbers and biomass based upon this. This was agreed as a sensible approach rather than pursuing further analysis of maturity ogives based upon the fishery sampling.

It was noted that if further work is pursed on this, that the analysis should be done by sex and then recombined afterwards as is done with other species.

A comment was made that it would be useful to develop an indicator of the percent of first time spawners in the catch. High levels of first time spawners are generally indicative of overexploitation. This was not pursued at the meeting, but would require further exploration.

The algorithms used to calculate the population and fishery weights at age need to be reviewed and documented. For determination of spawning biomass, the population estimates should be used whereas indicators relevant to the fishery require fishery weight at age.

Synopsis of Stock Structure and Data Inputs

The conclusions of the meeting were reviewed and agreed upon by participants on the last morning of the meeting. These included both work required within the time frame of this framework review and recommendations for longer term research. While a number of recommendations and suggestions for further work were made throughout the meeting, those summarized below were considered the priority issues:

Biological Basis of Management Unit

For This Framework

- The underlying biological basis of the management unit was agreed to and there is no need to change the current definition.
- A review of the scientific literature on the SWNS/BoF management unit is required to clarify the historical wording on the association of this component with the catch from the NB weir fishery; based upon this, ensure that associated is reflected in the wording of the 2007 CSAS Science Advisory Report.
- A sensitivity analysis of the impact on the assessment of assumptions of different percentage of NB weir catch associated with the SWNS/BoF management unit needs to be undertaken.

Longer Term Research Needs

- There is a need for better documentation on the biological basis of the offshore banks management units.
- There is a need for more tagging studies to better describe the transboundary movement of herring.
- It was suggested that the autumn larval herring survey be conducted to both describe the spatial distribution of spawning, as well as provide a relative indicator of spawning stock biomass for comparison to survey estimates from the 1970s and 1980s. This will be discussed further at the second framework meeting in January 2007.
- Using updated tagging information, redo the sensitivity analysis of the impact on the assessment of assumptions of different percentage of NB weir catch associated with the SWNS/BoF management unit needs to be undertaken.

Precision and Bias of Current Ageing Protocols

For This Framework

- Regarding the ageing inconsistencies, the following was concluded:
    - Using 80% agreement as a benchmark, there is inconsistent ageing primarily for ages 3 + and this varies by ageing lab.
    - Inter-reader is more problematic than intra-reader.
    - The source of the problem has not been not identified, but may be due to a combination of reader transition and otolith preparation technique.
    - The problem could have started about 1995-2000, but this is uncertain and requires further investigation. Historical changes in the cohort specific length span could be investigated to identify the time of initiation of this problem.
- The age distributions that we have prior to a given date and the subsequent reliable age information for at least ages 1 and 2 (and maybe older) should be used. A plus group might be required.

- The use of a growth model applied to length frequency information for the period affected by the ageing issue should be explored.

<u>Longer Term Research Needs</u>

- The recommendations of the internal ageing review will need to be actioned.

Estimation Procedures of By-catch of Other Species in the Fishery

<u>For This Framework</u>

- It was agreed that the overall level of non-herring bycatch in the herring fishery is low
- The absolute bycatch, in numbers and weight, of all species in the herring fishery needs to be produced. This should include bycatch from all herring fisheries, e.g., weir bycatch of tuna and porpoise.

<u>Longer Term Research Needs</u>

- The appropriate level of sampling needs to be determined. There is a need to increase gillnet sampling effort appropriate levels. The redirection of sampling effort to larger sizes needs to be explored to ensure adequate representation of older fish. There is a need to ensure that these sampling levels are adequate to detect changes in growth.
- Estimates of the variance around the CAA and weights ar age need to be reported in assessments.

Precision and Bias of Current Sampling Protocols

<u>For This Framework</u>

- Overall, the level of sampling was considered very good.
- The current levels of length sampling should be maintained; there is a need to clarify the protocol for data entry of observer information.

<u>Longer Term Research Needs</u>

- None identified.

Construction of Catch at Age

<u>For This Framework</u>

- Overall, refinements in the age-length keys are expected to have small impacts compared to the resolution of the ageing issues.
- Regarding estimates of total catch, the historical adjustments need to be documented as well as use and implications of the baffles (GIZMOS) in 2000.
- An indicator of condition factor (plumpness) over season and years needs to be developed.
- The impact on the CAA of sample versus catch weighting should be explored.

<u>Longer Term Research Needs</u>

- The aggregation of ALKs to avoid assumptions needed to fill gaps in ageing need to be explored, but only after resolution of the ageing issue.

- It was suggested to create ALKs by spawning component due to potential recruitment differences amongst spawning grounds.

Protocols to Estimate Growth and Size at Maturity

For This Framework

- Maturity ogives by year should be developed using sampling of the before-spawning population for length and age maturity indices, and avoid dependence of fisheries sampling.
- The algorithm for calculating population and fisheries weight at ages requires review and documentation.

Longer Term Research Needs

- None identified.

Consequences for Assessment Framework and 2007 Assessment

The meeting then discussed the implications of the meeting on the overall framework. While it is still early in the process and the situation may change based upon the results of the second meeting, it was suggested that two assessment frameworks could be used until the ageing issues are resolved. The first would use growth information from the most recent historical period (for which reliable ageing is felt to exist) to reconstruct the catch at age for the most recent period. The second would apply a growth model for the full historical record. These and other approaches will be discussed leading up to the third, modeling, meeting.

It was suggested that the VPA results (1984–present) from the southern Gulf of St. Lawrence herring assessments could be compared to the results of the September Gulf DFO RV bottom trawl survey to estimate survey catchability coefficients for herring which may be applicable to the DFO summer RV survey catch rates for the offshore banks.

CONCLUDING REMARKS

The Chair reviewed the process to be followed for the remainder of the assessment framework review. It was requested that the draft summary bullets from the meeting be sent to all participants for information.

The Chair then thanked all the participants and closed the meeting.

INDICES OF ABUNDANCE
NAFO Headquarters, Dartmouth
9 – 11 January 2007

After greetings by J. Fischer, the Executive Secretary of NAFO, the meeting commenced with the Chair, R. O'Boyle welcoming the participants. He particularly noted the presence of I. Hampton, J. Wheeler, C. LeBlanc, S. Smith, W. Stobo, W. Overholtz, R. Claytor, G. Poirier, and J.M. Coutu, who were the invited external scientific reviewers for the meeting. The context and overall process of the framework review, as outlined in the terms of reference were then presented. Following this, there was a discussion on the objectives of this second meeting of the framework which focused on indices of abundance. The agenda was then reviewed. It was subsequently agreed to review the spatial and temporal distribution of herring on the spawning grounds prior to the review of acoustic system calibration and target strength.

It was pointed out that copies of the working papers were available at the back of the room, along with the proceedings of the first meeting.

After thanking Paul Boudreau, Mike Power and Kirsten Clark, the Meeting Rapporteurs, the presentation of the working papers commenced.

Acoustic Survey Design

Melvin, G.D., and M.J. Power. 2007. Development of an Acoustic Survey Design for 4WX Spawning Herring Employing Commercial Fishing Vessels. RAP Working Paper 2007/01.

Rapporteurs: P. Boudreau and M. Power

Presentation Highlights

Since 1995, the 4WX herring stock complex has been assessed and managed using data originating from industry based acoustic surveys and fishing excursions of spawning fish. The approach has evolved from an ad hoc process of data collection to a structured survey design following standard protocols. During the early years (1995-1999), the surveys provided valuable information on the abundance of herring on specific spawning grounds, but were considered a minimum spawning stock biomass as they represented an estimate of the fish present in the limited area. Inter-annual trends in abundance were not detectable due to the restricted and variable coverage. Furthermore, synoptic coverage of the stock during non-spawning periods was not feasible due to the broad geographical distribution and uncertainty of mixing with adjacent stocks. To overcome this problem, past catch and biological data from the fishery were used to define spawning ground boundaries and to identify potential survey areas during the spawning season. Survey coverage area was further reduced by isolating the locations which contains more than 90% of reported landings during the spawning period. Thereafter, standard transects were established within the survey area. Utilization of fishery data provided a mechanism to minimize survey effort, to optimize survey coverage and to standardize the survey area for inter-annual comparisons of trends in abundance.

Details were provided on how the extensive fishery catch statistics for the 4WX herring stock complex were integrated with the observed biological characteristics and industry driven survey initiatives to optimize vessel time and standardized survey coverage area for individual spawning grounds. Length and maturity data of herring collected within the survey and surrounding areas were examined to document the distribution of adult (>23cm) and spawning fish. A sensitivity analysis was undertaken to explore the incremental effect of changing the size survey box size by 2 nautical miles from -4 to 4 nm of the original size. Survey transects were designed to be selected at random for each spawning ground, the number dependent upon vessels available. Deviations from the design occurred over the time series were discussed.

Discussion

Survey Area

There was discussion on the survey area coverage in relation to the stock area. It was asked what was the percent of the population sampled by the survey. While a precise answer could not be given, it was felt that it was large, in the order of 90%. Scots, Trinity, and German are the main spawning areas for the stock. This is where most of the roe is caught. There was discussion on spawning elsewhere, e.g., around Grand Manan. However, spawning in this area has not been seen since the time of Huntsman and is thus not now thought to be an important spawning location. It was noted that while the seiners cannot fish in this area, the weirs are very well sampled. It was pointed out that in the Gulf of St. Lawrence, there is good evidence that herring home to their spawning grounds.

There was discussion on backscatter observed at the edge of the survey areas. This could be examined to see if the area boundaries need to be changed.

There was discussion on the use of the percent catch as a metric to judge percent of the population surveyed. However, what is required is knowledge of the fishing effort in addition to the catch, this both inside and outside the survey area and how this has changed over time. The assumption is that the herring are not where the fleet is not. This again raised the discussion on the merits of a sampling design versus census approach to surveying the population. In the case of the former, as is done now, it is assumed that a large, but constant proportion of the spawners are being sampled. A census approach would require surveying a larger area. Some industry participants noted their desire to conduct a census approach industry survey. To undertake a census, better understanding of how spawners are distributed would be required. For instance, does spawning occur at certain depth contours? Where specifically are the spawning beds? There is no information on this. What are the impacts of temperature? It was offered that when there are large numbers of grey seals around Seal Island, the herring appear to move into deeper water. These are all factors for which there is limited understanding, but would impact a census survey.

There was a question of clarification on when the survey commences. The initiation of the survey is determined by observations of spawning fish while fishing. Once the decision is made to survey, this sets the time for the next survey (10-14 days later). It was also clarified that surveying only occurs at night.

Sampling Design within Survey Area

There was discussion on the allocation of sampling within the survey area. It appeared that the sampling plan is different within each area. In Scots Bay, transects are selected at random from a continuous line running along the top end of the survey box and run parallel to the shore with a spacing of about 1.2 nm between transects although the acoustic swath is only meters wide. It was pointed out that this is not strictly speaking a randomized sampling design and would require modification to the formulae used to estimate the variance. It was pointed out that these designs were a compromise to both collect valuable scientific information and maintain industry support.

On German Bank, the transects are evenly spaced with the number of these dependent on the number of fishing vessels available. Thus, the number of transects varies across years. It was pointed out that the 66 20 line is always sampled with evenly spaced transects placed around it. A subset of all the transects is chosen for acoustic recorders. Information on the general distribution of herring in the survey area is recorded on all transects and only acoustic backscatter on a subset of these.

On Trinity, the sampling design is quite different. An adaptive design is used in which the schools are actively searched for and once located sonified by acoustics.

For the Scots Bay and German Bank surveys, it was considered that, notwithstanding the deviation from a strictly random design, that the data be analyzed as if it were from a random design. However, no attempt should be made to post-stratify the data during this analysis.

In the case of Trinity, it is likely that the adaptive approach is providing good estimates of sonified school biomass which could be considered minimal as no extrapolation to non-surveyed areas is undertaken. The bigger issue is that this survey is not comparable to the other two and efforts should be made to ensure that it is.

It was recommended that adaptive designs be explored for all three areas. This might consist of a two-phase process with initial broad sampling followed by fine scale sonification of located schools. At the very least, more use and formal incorporation of the information in the deck sheets should be made to enhance the backscatter estimates.

It was asked how the sampling is conducted in relation to the transects. It is done independently of these with schools sampled after the acoustic survey is over. It is assumed that the sampling is representative of the sonified biomass, but it was not possible to confirm this. It would be useful to present an analysis of how acoustic backscatter has been sampled.

Power, M.J., G.D. Melvin, K.J. Clark, and D. Know. 2007. Spatial and Temporal Distribution of Herring on the Spawning Grounds. RAP Working Paper 2007/03.

Rapporteurs: P. Boudreau and K. Clark

Presentation Highlights by Kirstin Clark

- Tagging experiments were conducted on the spawning grounds of Scots Bay and German Bank to examine the length of time that herring remained on the spawning grounds.
- The results of past tagging studies on German Bank in 1998 and 2001, were shown and the problems with these experiments were explained.
- The number of tags applied to fish in Scots Bay in 2005 and 2006, and on German Bank in 2005, was shown. The tag return rates, dates of returns and the timing of the tagging events in relation to the spawning ground fisheries were presented.
- Some tagged herring were shown to remain on the spawning grounds for at least three weeks after tagging, and in some cases, up to five to six weeks after tagging. As a result, acoustic surveys that are spaced at two week intervals are surveying some of the same fish more than once.

- The residency time of herring on the spawning grounds appeared to be variable, but the tagging in Scots Bay in 2005, shows a gradual decline in tag returns over time indicating migration off the spawning grounds.
- The timing and location of tag returns from areas other than Scots Bay and German Bank was also presented.

Presentation Highlights by Gary Melvin

Observations of Atlantic herring on the spawning grounds by fishers and scientific staff indicate that herring display variable spatial and temporal distribution patterns within and between spawning seasons. We examine the evidence from tagging on the amount of time a herring spend on the spawning grounds before spawning and leaving (i.e., turnover). The results of these estimates were then applied to our acoustic biomass estimates and compared with other scenarios affecting the spawning stock biomass (SSB). Finally, we look at how the distribution of fish in the water column may have changed since the acoustic survey time series began in 1999.

Spawning stock biomass (SSB) on individual spawning grounds, such as Scots Bay and German Bank, have been determined by the addition of acoustic biomass estimates from multiple surveys undertaken during the spawning season. The surveys, conducted at 10-14 day intervals, were assumed to allow sufficient time for herring present at the time of a survey to spawn and depart the spawning grounds before the next survey, thereby minimizing the likelihood of double counting. Inconsistencies with the VPA estimate and recent tagging information suggests that this assumption may not be valid and that double counting has occurred. The four approaches examined and compared to evaluate the potential impact of an increase in the time fish spend on the spawning grounds would have on the total SSB:

1) The current practice of summing all survey biomass estimates which are separated by 10-14 days.

2) The maximum biomass estimate for a single survey as the total SSB.

3) Correction of SSB to reflect the recent observed decaying turnover time for a period of 4 weeks or more.

4) Correction of the SSB to reflect the biomass of stage six/seven fish in the survey area.

The data for analysis points 1) and 2) are essentially self explanatory and available in the annual research documents summarizing the acoustic surveys. The methods used to correct for a decaying retention time and maturity stage further explanation. A regression analysis of days at large and the portion of fish remaining on the spawning ground was undertake with the tagging results for both Scots Bay and German Bank. The regression equations were then used to estimate the biomass of herring still on the spawning grounds from previous surveys at the time of surveying. The number of days between surveys was used to estimate the proportion of fish remaining on the spawning grounds and the biomass was adjusted accordingly. A similar approach was used to adjust the SSB based on the ratio of maturity stage six/seven to all stages for the assumption that only the stage six fish spawn and move on in the 10-14 day window between surveys.

The results of this analysis using the tagging information produced a significant percent reduction in annual spawning biomass in Scots Bay that ranged from 19-38%, with an average of 30% over the last seven years. In a given year, the greatest decreases occurred for the later surveys as a significant proportion of the estimated biomass was found to originate from earlier surveys. A similar comparison was undertaken for German Bank using the tagging results specific to the area. Again, there was a significant decline in the biomass throughout the time series. The mean decrease in abundance ranged from 27.7% in 2000, to 47.9 % in 2001, with a mean of 36.2% from 1999 to 2005.

The estimation of SSB based on the proportion of maturity stages six and seven also shows a substantial decline in the index of abundance for both spawning areas. In Scots Bay, the estimate of biomass was consistent with the tagging adjustment and followed a similar pattern. The results for German Bank showed a similar pattern, but the biomass estimate was generally mid way between the current approach and the tagging adjustment. One possible explanation for the different observation between spawning areas is the low number of tag returns and the limited amount of biological sampling from German Bank. The poor concurrence between the two approaches on German Bank could stem from one or both approaches not representing the dynamics of the spawning ground.

In summary, these analyses indicated that the estimate of spawning biomass is extremely sensitive to how the data are pooled from multiple surveys. The perceived biomass can decline substantially depending upon how the multiple survey estimates are combined. In the case of Scots Bay and German Bank, applying the results of the 2005 tagging study to determine how long and what proportion of herring remain on the spawning ground after tagging, indicates that some fish can remain on the grounds for four weeks or more (five on German Bank), and that the SSB may be much lower than expected using our current approach. In light of this information, caution is warranted when employing the cumulative biomass estimates as absolute in any of the survey areas. Consequently, it is advisable to use the acoustic biomass estimates as a relative index of abundance to tune or calibrate an assessment model then to assume the parameters are correct for estimating absolute biomass. Future enhancements and in-situ studies/data collections may provide sufficient information to confidently estimate absolute biomass, however, at the moment we are simply not there.

Presentation Highlights by Michael Power

Examination of acoustic data was made in response to industry's observation in the 2006 SSR that fish are staying closer to bottom than in the past. Description was given of basic editing methods and problems encountered with editing and determining bottom. Survey data from the German Bank area from 2002 to 2005, was processed by one meter depth layers relative to bottom. The proportion of total backscatter, as well as density and biomass by depth was determined and compared between individual surveys and years for the German Bank area.

The 2005 surveys of German Bank found an average of 90% of total backscatter in the bottom 19 meters and more than 50% in the bottom 5m. The 2004 surveys were reduced to 74% of total backscatter in the bottom 19 meters, while the 2002 and 2003 surveys had only 52% in the bottom 19 meters. The total backscatter in the meter interval closest to bottom was minimal (range of 1 to 5%) and illustrated the difficultly in separating fish from bottom when herring schools are tightly aggregated near bottom.

In summary, it was reported that herring can be separated from bottom in most instances, but are hard to distinguish from bottom in the final meter. The recent observations of herring closer to bottom in 2005, were confirmed (over 90% in bottom 19m). Seasonal trends with fish less closely associated with bottom later in the season were observed.

The reasons for these changes in vertical distribution is unknown and requires further study, as well as continued monitoring of the vertical distribution of herring from the acoustic surveys.

Discussion

The biological process that herring go through before, during and after spawning was discussed and it was evident from this discussion that it is not well understood. A number of assumptions underlie the current acoustic survey plan:

- All herring spawn in one of these three areas.
- Prior to spawning, abundance builds up and then spawning occurs.
- Schools spawn en masse – the act of spawning stimulates spawning in the rest.
- Spent herring leave after spawning.

It was noted that on Georges Bank, herring tend to aggregate for spawning and when spawning is finished, they are gone on masse. Consistent with this, in the Bay of Fundy, it is rare to get spent herring. Industry participants stated that there could be waves of spawners entering and leaving the grounds over much shorter time periods than the gap between the surveys, which would introduce a negative bias.

It was asked how spawning actually occurs. Do they spawn by school? A video of spawning on Georges Bank was mentioned in which herring were seen to form vertical aggregations. It was asked if environmental factors influence spawning. This is possible, but the processes are unknown.

There was discussion on bank-related differences in the spawning process. It appeared that in some areas, stage five stick around longer to develop. Thus, there may be differences by bank. However, it was noted that this might also be due to the survey coverage of the bank. If the coverage is wider over one bank than another, it is possible that processes along the edge of the bank pre and post spawning would be observed in one case and not another.

It was noted that the turnover analysis indicated an average resident time of about 15 days which is longer that the current 10-14 day survey interval, and suggests that double counting is occurring. From the analysis, it appears clear that is a bigger issue in Scots Bay where some portion of the fish are staying around more than 2-3 weeks after spawning. Turnover rates appear higher on German. Some industry participants noted a difference in the type of spawning fish in Scots Bay as opposed to on German Bank, with more of a mixture of maturity stages in the former. They could be staying there longer due to a difference in these maturities. This led to a discussion on knowledge of stage duration. It is assumed that stage six lasts two days, but this might not be accurate. Overall, it was agreed that more work is required on stage duration, especially stage six. It was commented that it is difficult to measure the proportion mature that is surveyed due to small sample size for maturity.

Overall, there is a need to better understand the spawning process and tagging was offered as one means to assist in this. There was a discussion on tagging to better understand herring movements. It was suggested to undertake daily tagging, rather than the weekly studies that have been conducted, to better understand the movements of herring before, during and after spawning.

It was suggested that another use of tagging could be to estimate stock biomass, and the variance in the estimate, through traditional (i.e., Jolly/Seber) mark and recapture methods, restricting the analysis to the week after tagging, and assuming a closed system. Estimates of tag loss and mortality would be needed. The only recent tagging that has been done is a tag loss experiment using a weir which indicated 50% tag loss rates. It was asked if any studies had been done on tagging mortality to which the response was "no". Tag return rates are also an issue. Plants need to be more proactive in returning tags (e.g., only three plants currently returning tags). This might be related to plant operations at each site.

There was an extended discussion on the issue of the 'dead zone' - the area close to the bottom where it is not possible to resolve fish and bottom. It was confirmed that the first meter of data above the bottom is edited out on the assumption that the bottom is in there somewhere. It was asked how much backscatter is edited out, but this could not be answered. It was noted that this source of error is an issue during years when herring appear to be closer to the bottom during the surveys. In 2004 and 2005, this was the case, but is not more recently.

It was agreed that this was an issue that required addressing and that more could be done than just editing out the information. It was recommended to use the density information at the two meter depth interval or some analysis of a range of depths (e.g., linear trend or average) to estimate herring in the dead zone. This procedure would have to be undertaken for all years, but would be most relevant for 2004 and 2005.

It was noted that in future surveys, the size of the dead zone could be investigated through experiments with different pulse lengths

Acoustic System Configuration

Melvin, G.D., A. Clay, and M.J. Power. 2007. System Calibration, Field Studies and Comparisons. RAP Working Paper 2007/04.

Presentation Highlights by Gary Melvin

Many factors are known to affect the conversion of backscattered acoustic energy into an estimate of fish biomass. Measurement of the precision and accuracy of any acoustic system is a major challenge and is affected by physical, electrical and biological characteristics of the system's environment. In this working paper, we provide a summary of the HDPS (Hydroacoustic Data Processing System) acoustic system, methodologies, and operational procedures of our current acoustic program. In addition, we discuss several studies/comparisons undertaken to estimate the precision of the acoustic equipment deployed aboard commercial fishing vessels and the accuracy of biomass estimates given our assumptions are described.

Field Studies:

Over the years, we have undertaken a number of studies and opportunistic comparisons to investigate how the assumptions translate into real world estimates of biomass. Of particular importance, were the studies conducted in herring weirs to acoustically estimate the biomass of a known quantity of confined herring. Other investigations include the comparison of biomass from a school surveyed by two independent vessels and the repeated coverage of a fish school by the same boat using orthogonal transects.

Herring weirs provided an excellent opportunity to undertake experimental work on the fish while they are maintained in their natural environment. Water depth also varies in the weirs by from 12-20 meters or more given the 8-10m tides in the area. Once the fish have entered the weir, they typically mull around in a subsection until they are removed by seining. The fish are removed and weighed in the processing plant providing an estimate of absolute biomass. Using a combination of single and multi-beam sonar technology estimates of fish biomass were made in several weirs during the fall of 1999 and 2000. The HDPS was used to estimate the average number of fish (kg/m^2) under the transducer and the multi-beam system to determine surface area of the fish (m^2). Standard editing and analytical procedures were followed to estimate the mean area backscatter, and then converted to a biomass using the Foote equation to estimate target strength (TS) from the biological samples. The actual difference in tonnage reported removed from the weir ranged from 7.2% to 13.6% of the acoustic estimate, with all estimates to date are greater than the weight landed. Several possible factors could explain the difference; reported weight is a volumetric conversion to tonnes, all fish ensonified may not have been captured during the seining operation and possible variation in the TS equation.

The results of these experiments provided the basis for our assumption that the estimates we were obtaining from our acoustic surveys were within the realm of reality. Thus, it was concluded that the biomass estimate from a single survey was reflective of the fish present on the spawning grounds at the time of the survey. Unfortunately, no consideration was given to TS changes due to gonad development or other behavioural features.

Although no formally inter-vessel comparisons or multiple calibrations were undertaken within a given year, we did take advantage of any opportunity that arose to validate our assumptions. Over the years, a number of situations developed that permitted us to make such comparisons. In a series of surveys involving multi-vessels over several years, estimates of inter-and intra-vessel biomass estimates of the same aggregation(s) were examined to determine the comparability of results. Estimates of biomass varied from 2.0 to 4.7% depending upon the combination of vessels used in the analysis, thus supporting our assumption of between vessel comparability.

Another source of potential error is the editing practices of the specific individuals scrutinizing the data files. Over the years a number of between editor comparisons have been conducted to ensure that consistent and comparable practices are being employed. In every case, we have found that those reviewing the data were following an almost identical protocol and that biomass estimates generated in isolation were within 5% of each other for any given dataset or survey when the same area was employed in the estimates. Some differences have arisen in the subjective interpretation of the survey boundaries. The most recent comparison of two schools of herring (2006) resulted in difference in biomass estimates between editors of 1.0 and 4.9%.

Presentation Highlights by Allen Clay

This presentation focused on the validation of the acoustic systems provided by Femto Electronics which are used to collect and analyze marine acoustic data. The talk concentrated on the acoustic hardware, system calibration, and comparisons with other systems.

The hardware consists of a self-contained digital echosounder, one of several off-the-shelf and custom transducers, a personal computer, and the ships global positioning system (GPS). Although the transducers are normally hull mounted, the system can be temporarily installed on a commercial fishing vessel for only the duration of the fishing season or can be permanently installed. In all cases, activating the system is done solely by turning the power on. Shutting down is done by turning the power off. No other operator intervention is required however there is an operator interface that allows the fisher to use the system as a normal sounder without compromising the data being collected.

A complete system calibration is performed once per year on all systems. These are performed by Allen Clay, according to the availability of the vessel and adequate weather and water conditions. Four separate calibrations are performed to provide the conversion factors used to convert the sounder output data into volume scattering coefficients which are then converted to biomass using an appropriate target strength. The four calibrations are: Time Varied Gain Calibration (TVG), Ball Calibration, Integration Calibration Factor, and Beam Angle Calibration.

The TVG calibration is used to determine the time varied gain applied to the data by the sounder during data collection. This gain must be removed from the data during post-processing so a more accurate TVG based on the survey conditions of temperature, depth, salinity, PH, and sounder frequency can be applied. It was noted in the presentation that nominal values for these parameters are currently being used in the absence of real-time information. This is one area of improvement that should be addressed in the future. The result of the TVG calibration is a series of correction factors to be applied to the data at a vertical resolution of 0.1 meters. The resulting curve of correction factor vs. range from the transducer is called the TVG corrections curve.

The ball calibration is used to supply the fixed gain to the TVG corrections curve. This is done by analyzing the echoes from a calibration sphere of known target strength (TS) placed directly below and on the acoustic axis of the transducer. Positioning the ball is accomplished using a three point suspension system employing three poles positioned in a nominally equilateral triangle centered on the acoustic axis of the transducer. The target is assumed to be in the center of the beam when the echo level is peaked. Typically, 3000 to 4000 echoes are collected from the sphere to ensure enough “good” echoes are available for processing. Good echoes are those remaining after the data is edited to remove those which are corrupted by fish, bubbles, turbulence, seaweed, vessel movement, wake, sounder interference, etc.

The integration calibration factor is the parameter that accounts for the non-square envelop of the echo received from a target. The factor is calculated as the ratio between the area scattering coefficient of an ideally square echo to that received from the calibration ball during the ball calibration.

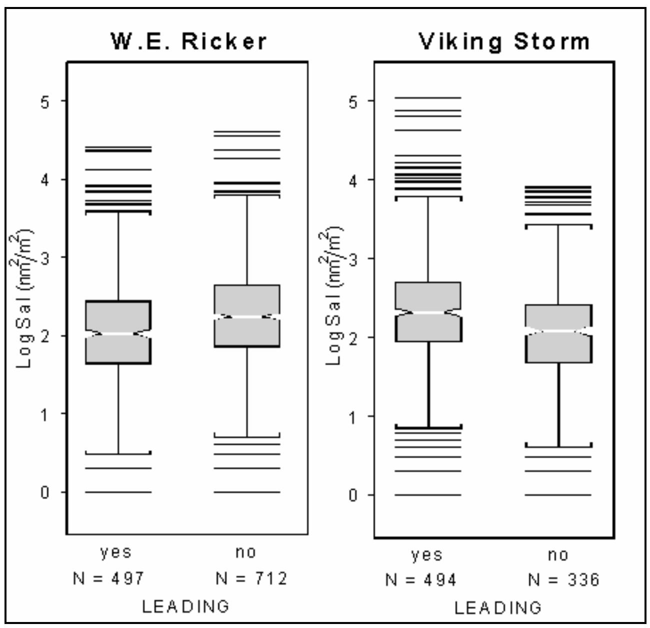
The beam angle calibration is performed to determine the beam angle of the transducer. The beam angle of a transducer will normally not change unless there is some form of physical damage. Currently, this calibration is used solely to evaluate the health of the transducer and is not used to alter the beam angle used in the calculations. To calculate the beam angle, the suspension line on each of the three rods is lengthened and shortened until the ball reaches the edge of the beam indicated by attenuation in the signal return of 6 dB. This provides 6 points on the perimeter of the main lobe of the beam that are then used to get the best fit on an elliptical and a circular beam.

The presentation then showed several examples of methods used to verify the results produced by the HDPS. The results from the original software were compared regularly with those of Dr. Udo Buerkle, DFO St. Andrews, during the development of the Hydroacoustics Data Processing System (HDPS). In the early 1990s, results from trials with the *Tenyo Maru*, a Japanese research vessel, and the *WE Ricker*, a DFO research vessel from Nanaimo, BC, demonstrated satisfactory comparisons among Japanese scientists, DFO scientists, and Femto using systems from Furuno, Biosonics, and HDPS, respectively.

In 2003, DFO Moncton decided to migrate from a Femto analog acoustic system to a Femto digital acoustic system for the annual DFO herring acoustic research cruise. To verify the compatibility between the two systems repeat transects were compared. The overall difference between the two systems of 3% was considered excellent considering that the time delay between the original transect and the repeat transect varied from 40 minutes to 160 minutes.

In 2000, to compare systems of different frequencies, two systems consisting of three frequencies 120KHz, 75KHz, and 40KHz were installed on the fishing vessel *Western Wave* in Portland Maine. The dual frequency 120/40 was a portable system with a towed body and the 75KHz system had a hull-mounted transducer. All three frequencies were logged simultaneously. The results of the average biomass density estimates for the three frequencies of 120, 75, and 40 were 12.0, 13.2, and 13.8kg/m^2 respectively.

In 1999, the fishing vessel *Viking Storm* with a Furuno sounder connected to a Femto J9001 (analog) HDPS, and the research vessel *WE Ricker,* with a Simrad EK500/BI500 c/w a retractable keel transducer performed comparative surveys off the coast of British Columbia. The results summarized in the box and whisker plots indicate good agreement between the two systems.



In 2006, some preliminary target strength work was performed which indicated that target strength for non-spawning herring in the Bay of Fundy may agree with the commonly used Foote equation. Further work on TS is suggested.

Discussion

<u>HDPS (Hydro Acoustic Data Processing System)</u>

The presentation was a good overview of the system. It was asked if there was information on the impact of calibration. The response was that this depends upon a number of factors, but overall calibration is required to ensure that all sub-systems are working appropriately.

There was some discussion on calibration issues with one boat.

Calibration

The TVG formula (40 log R + 2 alpha R) was discussed. Alpha depends upon range, temperature, salinity, PH, and frequency of the sounder. The sources of current information on these parameters was requested. This could be reported in subsequent research documents. It was pointed out that the overall uncertainty increases with depth, but given the relatively shallow depths involved (70m in Bay of Fundy), this should not be a problem.

It was noted that integration calibration has been used since 2002. The data earlier than this has not been modified. It was agreed that the historical data should be modified to ensure a consistent time series.

There was some discussion on the beam angle calibration. This does not change from year to year and is really associated with confirming the health of the transducer.

Overall, it was agreed that the system is working to 5% accuracy.

Hardware / Software Verification

Using the same TS relationships, the comparisons showed that the systems generally compare favorably. It was interesting that the weir experiments on juveniles showed 7.2–13.6% higher biomass than was actually there. Overall though, it was agreed that backscatter was being consistently reproduced with low error (less than 5%).

There was discussion on the editing protocols employed and whether or not a standard ‘reference input data set’ was used. It was recommended that protocols and a reference data set be developed to ensure long-term system maintenance.

Target Strength

Melvin, G.D. 2007. Estimates of Target Strengths for Determining Biomass. RAP Working Paper 2007/02.

Presentation Highlights

Many factors contribute to the echo received at the transducer and small changes in these factors can produce relatively large variations in the TS of the targets and the subsequent computed biomass. In this working paper, we explore the reported variability of several factors known to affect the TS and the potential implications of this variability on our biomass estimates.

Our current method to convert the backscatter to weight (biomass) was developed from the Foote equation with an additional coefficient based on weight/length relationship of herring. This allows the direct conversion of acoustic energy into tonnes/unit area.

$$TS_{Weight} = =20 \text{ Log (length in cm)} – 71.9 - 10 \text{ Log (wt in kg)}$$

Selecting the above equation was based on the following:

1) Previous herring biomass estimates in 4WX used the Foote equation. (Buerkle, 1992).

2) The Foote equation represents the mean TS from a number of herring studies under a variety of conditions.

3) Acoustic surveys in other regions use the Foote equation to estimate biomass, although there was some indication that it may be inappropriate (Leblanc, 1999, McQuinn and Lefebvre, 1999; Wheeler, et al., 1994).

4) The acoustic biomass estimates were found to be very similar in scale and trends with the VPA outputs for 4R herring. If anything they were considered to be under or minimum biomass estimate.

In this report, we investigate the within or between sample variability in mean length and how this variability might affect our estimate of TS and subsequent spawning stock biomass (SSB). Examination of samples by day indicated that in general within any given day the mean length of most samples do not differ significantly from one another, but there are exceptions. Two causes of the difference are: one, several aggregations of herring are observed in the survey box, and the differences in mean length reflect the size of fish in the individual aggregations. Or, the sample(s) were from a school of small juvenile fish often encountered near the boundaries of the spawning box.

For any given survey, there are a number of sampling days and multiple samples/day that could be selected to estimate the mean length of herring within the survey box. To evaluate the variability associated with the selection of samples to estimate the mean length, the effects of using samples from a specific day and from individual samples on the biomass for a selection of surveys were examined. The main objective of the exercise was to obtain an estimate of the observed difference in biomass given the variability in observed mean length between samples. The mean % difference for the nine German Bank surveys ranged from 0.73 to 3.89 with a maximum of 7.8% if samples with a mean length of 24m or less were excluded. Samples containing a majority of fish less than 24cm would not be considered part of the spawning group, and a separate biomass calculation based the distribution of these smaller fish would be undertaken. Inclusion of these samples (i.e., German Bank survey 2 and 3 in 2000) increases the mean % difference to a high of 13.6 and a maximum on a given day to 32.4%.

The same approach was used to investigate the potential error associated with single samples instead of multiple samples from a specific day. The mean % difference ranged from 1.21 to 4.30% with maximum for any survey period of 15.80% excluding the samples with a mean length of 24cm or less. In the worst case scenario, the mean % difference was comparatively small with a mean ranging from 0.86 to 5.8% when the few samples with a mean length of less than 24cm were excluded. However, including theses samples resulted in a significant increase in the mean % (29.1%) difference for a survey with a maximum difference of 51%.

In summary, the current approach of using multiple length frequency samples collected from within the spawning box, be it on one or more days around the survey, to estimate TS will on average account for less than 4% of biomass error and in the worst case less than 8%. Care must be taken to insure that samples containing primarily small, non-spawning fish are not included in the estimate of mean length for TS estimates of the spawning fish. Their presence can substantially increase the mean and maximum percent difference to greater than 13 and 32% respectively, thus biasing the estimate of spawning fish. When only a single sample is available (unusual given our extensive sampling program) the data must be examined closely to ensure it represents the acoustic observations and not a group of fish on the boundaries of the survey box. Use of a single sample of small fish (mean length less than 24cm) can result in errors of 40% or more. Fortunately, multiple length frequency samples (five or more) on a given survey date are more the norm than the unusual. When small fish are observed in the survey, their distribution should be identified and a separate biomass made to remove their inclusion in the estimate of SSB.

Discussion

There was discussion on the different formulae used to calculate target strength (TS) and factors that influence it. In essence, TS is a function of the acoustic reflective properties of organs within a fish, most commonly the swim bladder. Thus, any factor that could cause a change in the cross sectional area of the swim bladder seen by the acoustic transducer would case a change in TS. Length can obviously be an important factor to adjust for and it is using the size frequency samples taken during the survey. It was considered that length differences are likely causing less than four percent error, eight percent as a worst case.

It was emphasized that an estimate of TS is required for an absolute estimate of abundance, and that some estimate of the variability of TS is desirable for relative acoustic estimates. The TS scales the backscatter to the biomass, taking into account the various influential factors. However, There are many factors than can impact TS and precise estimates of TS would be required in order to calculate absolute estimates of biomass. For this reason, it was considered that the current survey time series should be used as a relative, not an absolute, biomass index.

There was discussion on how to improve TS estimates. The most appropriate means is to have these determined as the survey is underway (in-situ). This would require use of split beam technology with the transducer lowered down to within 10m of the school of fish. It was mentioned that the Georges Bank herring acoustic survey uses a compensated towed body, as well as hull mounted system and offers of collaboration with NMFS, Woods Hole, were made. A similar offer was made by I. Hampton from South Africa. The SABS herring team is to follow up on this.

At the end of the discussion on the acoustic survey, there was a general recommendation made to undertake modeling to determine the overall absolute and relative accuracy of the survey and the relative magnitude of the error from the sources discussed at the meeting, including TS, turnover on spawning grounds, calibration, absorption, sampling design, dead zone, survey area and so on. There are also possible dependencies amongst parameters that could be modeled. It was agreed that this would be a worthwhile initiative.

Age – Disaggregated Acoustic Indices

Melvin, G.D., and M.J. Power. 2007. Age Disaggregation of the Acoustic Abundance Indices. RAP Working Paper 2007/06.

Presentation Highlights

The ability to apportion the observed backscatter or biomass from each survey into the age groups has several advantages as an index of abundance and to monitor the spawning dynamics on individual spawning grounds. The apportioning of the backscatter from individual survey requires detailed biological and length frequency data specific to the survey. Utilization of monthly age-length-keys (ALK) for the entire fishery tends to bias the assignment of age for smaller lengths to younger fish when they are not observed in samples collected on the spawning grounds.

The purpose of this report is to utilize the available acoustic and biological data to apportion the total acoustic backscatter into size intervals consistent with the length frequency sampling. Once the backscatter has been apportioned it is then proposed to estimate the number of individual herring per interval and apply an age-length key to obtain an estimate of the herring in each age group for each survey.

Information requirements included:

- The weighted mean area backscatter (Sa) in dB/m^2 for each survey. This is standard output from HDPS.
- Target strength equation.
- Annual survey area of coverage in km^2.
- Length frequency of herring samples.
- Weight/length relationship from herring samples during the survey period.
- Age-Length Key for the spawning period or the individual survey.

The total area backscattering coefficient (SA) was apportioned in to size intervals as follows;

$$Sa_{(interval)} = 10Log_{10}(TS_{(individual)} * LF_{(interval)}/Sum(LF_{interval} * TS_{(individual)})* Sa_{(total)})$$

Where:

$LF_{(interval)}$ = length frequency or number of fish in the interval.
$TS_{(individual)}$ = Target strength of an individual fish in the size interval.
$Sa_{(total)}$ = Weighted area backscatter (dB/m^2) output by HDPS.

The main difference between the age-disaggregated index and the standard reported biomass is the former estimates the number of fish based on each individual size interval summed, whereas the latter uses the overall mean length to estimates the total number of fish observed. Both can easily be converted into biomass based on the length/weight equation.

Currently, there are problems with the ageing of herring and a mechanism has been developed to resolve these issues and to move forward. Once resolved, the approach described in this working paper can be used to investigate the inter-age and intra-age dynamics on individual spawning grounds and to generate an age-disaggregated index of abundance for the acoustic backscatter. The age length key should be developed from samples collected from within the survey box if possible to avoid potential errors in age assignment.

Discussion

It was confirmed that sampling was conducted differently in Scots Bay and on German Bank. In the former survey, sampling is conducted right after the transects are completed whereas on German, the sampling is conducted the day after the transects are completed. It was noted that one sample (250 fish for length frequencies and 50 for biological samples) is collected per boat.

The concern was raised that there might be schools that are not sampled by this protocol. It was recommended that in future assessments the percent schools sampled, as determined from the deck sheets, be documented.

Other Abundance Indices

Power, M.J. 2007. Review of Abundance Indices for southwest Nova Scotia / Bay of Fundy Herring Stock Component. RAP Working Paper 2007/05.

Presentation Highlights

An overview of other indices of abundance for herring besides the acoustic surveys was presented. These include the larval herring survey conducted from 1972 to 1998, and the July bottom trawl survey begun in 1970, and now ongoing.

The larval series while useful to document spawning success and the distribution of various fish larvae, fish egg and invertebrate species is of little predictive utility in the VPA. The larval series was re-examined using an updated SSB which is converged over the larval index period with no change in the view that rejects its use in the VPA.

The July research bottom trawl series was examined and remains with shortcomings which have precluded its use as an abundance indicator for southwest Nova Scotia / Bay of Fundy herring. The series is informative as to the size, maturity, and age of herring with widespread catches in most areas covered. However, the survey does not cover the German Bank and inshore areas of southwest NS due to poor bottom. Herring catch indices in the stock area have been highly variable in recent years and there is a lack of tracking of year-classes in the series.

A historical summary of the indices used in each stock assessment from 1977 to 2005, was also presented. A variety of indices besides the above mentioned larval survey, bottom trawl, and acoustics have been examined over the years. Among others, these include various CPUE series for purse seine, weir and gillnet gear types as well as the Chedabucto Bay overwintering survey.

Discussion

There was discussion on whether or not the Browns Bank strata should be included in the groundfish trawl estimate, to which the answer was yes. It is also necessary to consider the post 1983 information separately as the earlier information was collected using a side trawler.

It was noted that an increase in herring abundance in the NMFS fall survey was observed at about the same time as observed in the DFO summer survey. While it was recognized that the catchability of herring in these surveys is low and potentially bias by trends in availability e.g., herring coming off bottom, it was agreed that an age-based groundfish trawl survey index for the appropriate strata be calculated and evaluated in assessments for its consistency with the other information.

There was discussion on other indicators of abundance. Both DFO Newfoundland and NMFS Woods Hole have undertaken juvenile surveys, the latter for the last five to six years using a bottom trawl in the inshore. It was pointed out that there may be weir sites in the inshore that could provide a juvenile index. Also, there was mention of a salmon study conducted in Passamaquoddy Bay that caught small herring. These are possibilities that were considered worthwhile to pursue in upcoming discussions on the overall herring research program.

Synopsis of Indices of Abundance

Following the presentations, there was a synopsis of the discussions led by the Chair.

There was general recognition that while the current acoustic survey can only provide a relative index of abundance, efforts should continue towards an absolute estimator.

It was requested to add an update to these proceedings on the previously identified ageing problem (see Appendix 5).

Acoustic Survey Area

It was agreed that the main herring spawning areas are being surveyed (Scots Bay, Trinity & German Bank). While there has been spawning around Grand Manan/inshore NB, this is historical and while not documented recently, is likely small in comparison to the other areas.

The survey assumption is that all, or a large percent of the spawners, use these survey areas during spawning. The metric to determine the percent of spawners surveyed is not adequate. A measure of effort is needed to determine relative abundance.

Regarding the acoustic survey area, it was concluded that:

- Areas sampled large, but unknown percent of spawning biomass.
- Trinity estimate considered a minimum.
- The size of each area should not be modified.

It was added that if an adaptive design is adopted, the time series may be impacted. Possibly, the standard area could be used, but for an absolute estimate, exploratory work may be also needed.

Acoustic Survey Timing

Regarding survey timing, the following was concluded:

- Surveys conducted every 10-14 days to avoid double sampling.
- The 2005 and 2006 tagging studies indicate that some proportion of herring remain in survey area three weeks and some longer:
    - Double counting occurs, but extent not well determined.
    - No work has been done to see if the fish have moved on and off the bank between samples.
- Staging fish mixed with spawners on Scots Bay compared to German:
    - Bank dependent processes evident.
- Dynamics uncertain by maturity stage.
- More assumptions needed for use survey as absolute index; therefore use now as relative index.

It was offered that the survey has not looked at whether fish are being missed. The information was considered to see if double counting was occurring. This will be important if we are working towards an absolute. In response it was noted that the design was to determine the retention time (more or less than two weeks). If all of the tags had disappeared, then maybe the 10-14 day repeat sampling might not be appropriate.

Acoustic Survey Sampling Design

During the meeting, the following observations were made regarding the survey design:

- Varies by survey area:
  - Scots Bay: transects chosen randomly from perimeter (continuous line) and run parallel to shore.
  - German Bank: transects evenly spaced dependent on number of vessels available; central transect always sampled.
  - Trinity: searching followed by sonification of located schools; protocol issues.

It was noted that the 2006 index is only for German Bank in 2006. Trinity should not be added as the sampling strategy is significantly different. If the estimates in the Scots and German are unbiased and assumed to have the same catchability, then they can be added together to generate one relative index. The relative size of the survey areas would need to be taken into account in generating this index.

It was noted that on Trinity, there is gear selectivity effect on the sampling as gillnets are used to sample. This could impact on catch at age. It was reiterated that a consistent design should be used in all three areas and an adaptive design should be considered.

For the sampling design, it was concluded:

- In calculating the relative indices, assume a random design was used.
- Do not post-stratify based upon the data.
- Adaptive two-stage designs, using for example sonar data in the first phase, should be considered to improve survey efficiency.
- Estimation formulae for variance inappropriate for design:
  - Modify equations to be consistent with design.

Acoustic Survey Processing

It was agreed that the bottom dead zone is an issue, and that the 1st meter of data on bottom should be processed to differentiate herring from bottom. Dead-zone corrections based on estimates of the dead-zone height and estimates of density immediately above the dead-zone should be considered. It was difficult to determine how much herring was being edited out in recent years. It was noted that in 2004 and 2005 (and maybe into the future), herring were found close to bottom, and this there is a time trend in the survey.

It was asked if the pulse length could be changed to reduce the dead zone. Yes, but this puts lower energy into the water and so the signal to noise ratio deteriorates. The HDPS can go to a 0.1 second pulse length.

Acoustic Survey Calibration

The following was concluded:

- Femto system produces SA similar with acoustic systems elsewhere.
- Backscatter estimates being reproducibly produced amongst systems with low error (less than 5%).
- Sensitive to length composition, but if relatively constant, not a big factor.
- Calibrations appropriate.

While no problem was identified with the centre beam, there may be problems with using different transducers. The wider the beam angle, the more of the bottom that is being ensonified. This is not considered a problem if the calibration is done correctly and if the integration calculation is used, although the effective mean TS does depend to some extent on beamwidth, which would introduce a (probably small) beamwidth dependency into the biomass estimates which is not removed by the calibration. It was suggested to confirm the integration equation

Acoustic SurveyTarget Strength

Regarding the target strength calculation, it was agreed that it is influenced by a number of parameters, some of which have been accounted for (indicated in bold below). The group reached a consensus on the relative impact of these parameters on the survey relative estimate:

Parameter	Impact
Length	**small**
Frequency	**small**
Fish depth	small
Gonad	small
Stomach	small
Tilt angle	**small**

It was noted that relative indices may be influenced by these parameters. For instance, if the fish depth is 30m we will get one estimate of biomass, but if in another year the average fish depth is 40m the biomass estimate will be different, even if there is no change in stock size. One of the plots in the meeting showed 2 dB changes over the depths encountered which implied a 58% change in the acoustic biomass index. The cage study was shown only to demonstrate the possible impact. However, on German's bank, there can be a 10m change in the depth of the fish, but for the effect to be important, it is the average that is important. Generally, for the depth changes that are observed, unless the fish are staying on bottom, there should be a limited impact of depth on the relative index and this can be mitigated (incorporated into the TS equation).

The group reached consensus on the relative impact of the parameters on the survey absolute abundance estimate:

Parameter	Impact
Length	**small**
Frequency	**small**
Fish depth	sm-med
Gonad	prob large
Stomach	small
Tilt angle	large

Overall, it was concluded that the relative survey estimate is less impacted by TS issues than the absolute estimate.

Acoustic Survey Biological Sampling

The following observations were made regarding the survey sampling:

- Sampling not done in direct association with survey:
    - Scots: done right after survey.
        - German: done either night before or after survey.
- The main fishable aggregations are likely sampled, but needs to be verified. Sampling percentage needs to be verified.
- "Fringe" aggregations are less likely to be sampled.

An analysis is required to determine the relationship between the survey and the sampling. Scots and Germans up to 2005, have mostly been sampled on the night of the survey. Only in 2006, was there no sampling on the night of the survey, in either Scots or German. It was suggested that samples from the plants be considered to select the most appropriate samples to associate with the particular survey. Assumptions would be required in 2006 that the same fish are seen two nights in a row.

Regarding sampling, it was concluded:

- Generally good sampling levels, but concern for linkage with survey.
- Undertake sensitivity of assessment to sampling assumptions.
- Length frequencies should be used to bump up the maturity stages.

Acoustic Survey Overall Conclusions

From these discussions, it was concluded that the acoustic survey is an essential part of assessment, but improvements are needed to improve implementation and analysis. More assumptions are needed to use the survey as an absolute estimate indicator of biomass, these relating to the survey area, inter-annual turn-over processes on each area and factors that influence the TS/SA. The relative impact of the latter on the two types of survey indices is:

Variable	Relative	Absolute
Timing/turnover	high	high
Dead zone	medium	medium
TS/Sa	low	high
Survey area	low	medium
Survey design	low	low
Calibration	low	low
Sampling	med. low	med. low

Recommendations for Future

The group discussed recommendations that would lead to future improvements in the herring indicators of abundance. Below are outlined the recommendations for each of the survey aspects considered at the meeting.

Survey Area and Design

- Explore implementation of adaptive acoustic survey design.
- Consider stratification optimization.
- Make Trinity survey consistent with others.

The possibility of using a two phase design should be contemplated. The first pass is to identify and locate the schools followed by a second pass to survey the identified schools. This may be better received by the industry that likes to focus effort where fish are.

Survey Timing (high priority)

- Quantify the duration of maturity stage processes.
- Undertake more tagging and more frequent tagging to estimate turnover rates.
- Consider increasing survey frequency to reflect duration of maturity stages.

It was asked if fish can be returned with tags attached. This may be possible, but there are so many fish with tags that consumers have complained about tags making their way into the processed product. Return rates are lower now that the roe fisheries is less.

It was asked how much sampling would be required to scale the acoustic biomass into less than 23 juvenile, and greater than 23 adults. To do this would require sampling at the same time as the acoustic survey and do the maturity estimation.

The possibility of using acoustic tags should be explored although they may be too big and/or expensive at the moment.

Acoustic Survey Sampling

- Investigate and verify representativeness of sampling for the survey.
- If this is not true:
    - Investigate use of some/special vessel(s) to undertake survey related sampling.

Acoustic Survey Data Processing and Calibration

- Use SA at other depths to estimate SA in 'first meter'.
    - At 2m or at chosen depths (average, linear trend).
- Modify historical data to incorporate integration calibration.
- Develop protocols and 'reference collection' for inter-editing and quality control.
- Document procedure for determining juveniles and adults and review.

The integration calibration can affect results by 20%. This can be done on all historical data, but cost is a challenge. The first series started in 1999, and then the next series started in 2003. How much does the calibration change from year to year for the same boat and system? Can we get information on the changes?

The Dual Venture calibration changed a lot from one year to another.

Acoustic Survey Target Strength

- Undertake weir study for TS of spawning fish.
- Study isolation of single targets using available HPDS data.
- In situ measurement of TS per fish.

It was noted that DFO does not have capacity to undertake in-situ measurement at the moment. There was discussion on how this might be done (e.g., lower the transducer into the water column from a stationary boat close enough to see individual fish, but this did not work in the US system; a compensated towed body with a transducer designed to work at depth has been successful; hull mounted situations also appear to be working), but overall some form of collaboration with US and/or South African colleagues is likely the best future short-term option.

Other Initiatives

- Explore estimation of biomass using 2005 and 2006 tagging data:
  - Improve tag returns from plants.
- Design tagging to estimate biomass:
- Carry out modelling for error and uncertainty in the acoustic survey.

A tag and recapture study could investigate the dynamics of the school tagged, but it might not be possible to establish the residence time if there is immigration and emigration.

Other Indicators

- Desirable to have additional (independent) indicators.
- Larval survey:
  - Has been looked at extensively and unless something else emerges, do not need to pursue.
- 4VWX Groundfish Survey Data:
  - Using appropriate strata (84-95).
  - Consider consistency of time series with others and modeling.
- Investigate use Juvenile Survey:
  - Standard inshore trawl.
  - Gulf did bottom trawl survey.
  - NS and NB weir sampling.
  - Salmon smolt surface gear.

It was agreed that funding is a limitation on any and all future research. The issue is one of prioritization – is the funding available being spent in the best possible manner.

Dead Zone

- Investigate changes in pulse length.
- Investigate use of a video camera to observe herring in dead zone.
- Explore CHS seabed mapping information as a source of bottom depth information.

CONCLUDING REMARKS

The Chair offered that the meeting had been successful in meeting its terms of reference. He then thanked the external reviewers and all participants for their valuable contribution and closed the meeting.

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APPENDICES

Appendix 1. Terms of Reference

Context

The current management plan for the 4VWX herring stock complex pursues three conservation objectives:

1. To maintain the reproductive capacity of herring in each management unit through:
    - Persistence of all spawning components in the management unit.
    - Maintenance of biomass of each spawning component above a minimum threshold.
    - Maintenance of a broad age composition for each spawning component.
    - Maintenance of a long spawning period for each spawning component.
2. To prevent growth overfishing:
    - Continue to strive for fishing mortality at or below $F_{0.1}$.
3. To maintain ecosystem integrity/ ecological relationships (ecosystem balance):
    - Maintain spatial and temporal diversity of spawning.
    - Maintain herring biomass at moderate to high levels.

If during the current review, biological processes become apparent for which additional objectives might be required, these would be proposed to the Scotia-Fundy Herring Advisory Committee for approval.

The 2005 and 2006 assessments of the status of the southwest Nova Scotia / Bay of Fundy Management Unit (SWNS/BoF) of the 4VWX stock complex highlighted the need for an in-depth review of the data and models used to assess progress against these objectives. For instance, the population model (VPA) and acoustic surveys estimates of current biomass differ substantially, which has focused attention on whether or not the acoustic survey biomass estimates should be considered absolute or relative as well as the veracity of the VPA.

This review is to be conducted over three sequential meetings scheduled to ensure that modifications identified in a meeting can be incorporated into the preparations and deliberations of the following meeting. The first meeting (31 October – 1 November 2006) will review the stock structure and fishery data inputs. The second meeting (9 - 11 January 2007) will review indices of abundance, including the acoustic survey. The third meeting (26 February - 2 March 2007) will review the models used to determine stock status, productivity, and harvest implications of various management options. The third meeting will also outline the assessment procedure to follow until the next framework review. The framework will be used for the first time in March/April 2007 in support of the 2006/07 fishery.

Throughout the review, recommendations will be made to improve the framework in the longer term. These will be recorded in the proceedings for later discussion and prioritization in a post-framework joint DFO–industry herring research program planning meeting, anticipated to occur before 31 May 2007.

Objectives

Definition of the Management Unit and Fishery Data Inputs (31 October – 1 November 2006)

- Review information (e.g., tagging, spawning bed distribution, morphometrics, meristics, growth) on the biological basis of the SWNS/BoF management unit in support of subsequent decisions on the management unit definition by FAM and industry, including:
    - Inter-relationships of herring from the SWNS/BoF management unit with herring from the offshore Scotian Shelf Banks, coastal (South Shore, Eastern Shore, and Cape Breton) and southwest NB Migrant Juvenile management units, as well as herring caught in the winter fishery off Cape Cod.
- Review precision and bias of current commercial sampling protocols, including:
    - Sampling protocol to ensure it is not responsible for the low representation of older fish in the catch at age in recent years.
    - Catches and reporting including observer coverage and verification of landing weights.
    - Construction of catch at age including protocols for grouping and weighting of samples and catches.
- Review estimation procedures of by-catch of other species in the fishery.
- Review precision and bias of current ageing protocols, including:
    - Findings of the 2006 Canada/US Ageing Workshop and subsequent otolith exchange.
- Review protocols to estimate growth and size at maturity.

Review of Indices of Abundance (9 – 11 January 2007)

- Review precision and bias of the industry/DFO Science acoustic survey to evaluate most appropriate use of current data and required changes to utilize these data in alternate ways, including :
    - Survey design including survey area, sampling unit (e.g., transect) definition and allocation, and survey sampling timing (both seasonally and on the spawning beds to avoid potential double counting of spawners).
    - Protocols used to estimate post-survey relative indicators of abundance and biomass.
    - Influence of spatial and temporal changes in herring distribution and behaviour on the survey results.
    - Estimation of survey abundance at age using sampling from the survey.
- Document the index of spawning biomass estimated from the historical Bay of Fundy Larval Abundance Survey.
- Review the 4VWX summer bottom trawl survey series and explore options, including age disaggregated indices.
- Consider other sources of abundance indicators that may be available.

Review of Models to Assess Status and Productivity (26 February – 2 March 2007)

- For each conservation objective and sub-objective, determine biological indicators and the biological consequences of different levels of these (i.e., what does 'persistence of all spawning components' mean in real terms?).
- Determine the methodology, exploring a range of models, to estimate the current state of the stock.

- Determine the methodology to characterize stock productivity.
- Determine the methodology to provide short, medium and long-term yield forecasts.
- Provide guidance on the assessment procedure to be used during interim years, recommended timing of subsequent reviews, as well as procedures to verify the on-going efficacy of the framework.

Outputs

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

Participation

DFO Science Maritimes and other regions
DFO Maritimes FAM
Scotia – Fundy Herring Advisory Committee
Provincial representatives
External reviewers

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Appendix 3. Agendas

Stock Structure and Fishery Data Inputs: Biological Station, St. Andrew's, NB.
31 October – 1 November 2006

31 October 2006 – Tuesday

08:30 - 09:00	Welcome and Introduction (Chair)
09:30 - 12:00	Review biological basis of management unit
12:00 – 13:00	Lunch
13:00 – 17:00	Review precision and bias of current ageing protocols

1 November 2006 - Wednesday

08:30 – 12:00	Review precision and bias of current sampling protocols
12:00 – 13:00	Lunch
13:00 - 15:00	Review estimation procedures of by-catch of other species in the fishery
15:00 - 17:00	Review protocols to estimate growth and size at maturity

2 November 2006 - Thursday

08:30 – 12:00	Review of meeting conclusions
12:00	Adjournment

Indices of Abundance: NAFO Headquarters, Dartmouth, NS.
9 – 11 January 2007

<u>9 January 2007 - Tuesday</u>

09:00 – 09:30 Introduction & Welcomes (O'Boyle)

09:30 – 17:00 Review precision and bias of industry/DFO Science acoustic survey

09:30 – 10:00 Overview presentation (Melvin)

Break

10:15 – 12:00 Acoustic Survey Design (Melvin and Power)

Working Paper: An Acoustic Survey Design for 4WX Spawning Herring empLoying Commercial Fishing Vessels.

Lunch

13:00 – 15:00 Review of acoustic hardware, calibration procedures and processing protocols (Melvin, Clay and Power)

Working Paper: System Calibration and Field Studies.

Break

15:15 – 17:00 Variability in Target Strength (TS) estimates (Melvin)

Working Paper: Estimating Target Strength for Determining Biomass. (Melvin)

<u>10 January 2007 - Wednesday</u>

09:00 – 10:15 Spatial and temporal changes in herring distribution and behaviour on the survey results (i.e., turnover and closeness to bottom). (Power, Melvin, Clark)

Working Paper: Spatial and Temporal Distribution of Herring on the Spawning Grounds.

Break

10:30 – 12:00 Age disaggregated acoustic indices of abundance (Melvin and Power)

Working Paper: Age Disaggregation of the Acoustic Abundance Indices.

Lunch

13:00 – 15:00 Review precision and bias of other available indices. (Melvin & Power).

Working Paper: Non-acoustic indices of abundance. (Power)

Break

15:15 – 17:00 Continuation of review of other indices

11 January 2007 - Thursday

09:00 - 10:15 Meeting Synopsis

Break

10:30 - 12:00 Meeting Synopsis

12:00 Adjournment

Appendix 4. External Review Comments

Stock Structure and Fishery Data Inputs: Biological Station, St. Andrew's, NB.
31 October – 1 November 2006

Mark Dickey-Collas, IMARES, The Netherlands

On the Process

The process appeared reasonable and strong; the idea of developing an assessment framework, with a review every half decade, made a lot of sense to me. The atmosphere of the framework review was very constructive and cordial. It appeared that there was a strong degree of shared understanding between all those in the process. I personally felt that no member of the review was thought to be outside the process. The meeting was good humoured and well chaired. I was interested to note that there was no participation by members of other interested parties (e.g., conservation and ecological lobby groups).

There was a slight impression that the submitted working documents were hurriedly put together, and I thought that they contained rather too much description and not enough analysis. In the future, authors should consider carefully whether their working documents address the full terms of reference for each section of the review.

On the Science

I made comments on the science throughout the review. However, I wish to raise two of those subjects again: ageing and stability. The review considered many aspects of the input data into the assessment (catch sampling, raising procedures, by-catch, management units), but the most important aspect is the ageing of herring. It is clear that without a reliable catch at age matrix, the current stock assessment methods are inappropriate. Resolving this issue must be a priority, and I am aware that a workshop is planned to address this problem. Both the reasons for the differences in estimates of age and the correction of the data (if required) must be addressed. I was not convinced that length did not play a larger role in the allocation of an age to a herring, than the structure of the otolith.

Stability in populations: I was a little worried about the assumed stability in the dynamics of the populations of herring in 4VWX (whether in growth, behaviour or natural mortality). My experience of North East Atlantic herring, is that characteristics of the populations are often more variable than assumed and that differences can occur between both years and cohorts. Whether such differences can affect sustainable fishing or precautionary management can be tested through simulations of management measures. This approach is cheaper than trying to monitor all of the dynamics of a population through sampling or surveys.

I was impressed by the degree of cooperation between scientists and the industry, and I commend both the shared tagging studies and the length sampling by the industry. These are very progressive.

Be wary of applying fixed or annually varying "proportions of herring origin" to the catch. This is a minefield that we entered in the North East Atlantic, and are now paying the price. Find modelling solutions, which express the uncertainty better, and carry out more sensitivity analyses to your assumptions.

Consideration for the Review Parts II and III

Surveys- initial reading of the assessment document lead me to worry about the assumed relationship between survey estimates and actual biomass being 1:1. The framework review part II must clearly state why the catchability is assumed to be 1 and why the assumed relationship is linear.

Assessment models- I was worried that in recent years the catch was dominated by younger, smaller fish, which were the age groups that performed badly in the assessment model (see residuals at age). The survey also does not cover these younger fish very well. This needs further exploration and explanation, which I presume will take place in Part III of the review.

Indices of abundance: NAFO Headquarters, Dartmouth, NS.
9 – 11 January 2007

<u>**I. Hampton, Fisheries Resource Surveys cc., Cape Town, South Africa**</u>

General

I was impressed by both the spirit and the scope of the review process. It is clearly a valuable exercise, especially since it is repeated at regular intervals and involves a wide spectrum of outside opinion in the form of external reviewers.

The extent to which the industry is involved in the review process, and in many vital aspects of the data generation is also impressive. Their contribution in terms of vessels in the collection of the acoustic data, in particular, is extraordinarily large by any standard, and has clearly been vital in the absence of a local research vessel for acoustic surveys. The exceptional degree of collaboration between the scientists and industry in the survey programme was evident throughout the meeting, and I am sure has been an important ingredient in the extremely large amount of data which has been collected over the years.

Regarding the acoustic programme, the calibration of so many commercial vessels with such a diverse range of non-scientific echo-sounders and over such a long time period is a major achievement in itself, which clearly owes much to the professionalism and long involvement of Femto Electronics in the Programme. I was also impressed by the way in which advantage had been taken of the limited opportunities for inter-calibrating equipment and testing the methodology (e.g., the assumed target strength relationship for herring). In all, exceptionally good use seems to have been made of equipment not intended for scientific work, resulting in a particularly cost-effective study within the limitations of the funding and other resources.

On the negative side, I found the shortage of statutory funding for the research programme particularly unfortunate considering the value of the herring fishery, and the reputation Canada has for excellence in the field of fisheries research. It is surprising to see such an able and obviously dedicated group of scientists hamstrung in many areas for funding which would be taken for granted in many less developed countries. The fact that the acoustic group does not possess a scientific echo-sounder and has to rely almost totally on industry vessels for both survey and experimental work illustrates the point.

In the following, I have picked out a few specific areas where I believe substantial progress could be made in the survey programme at relatively modest cost.

Specific suggestions

Turnover rate

It was abundantly clear that uncertainty regarding the turnover rate (alternatively, average residence time) of herring on the spawning ground is a major source of uncertainty in the acoustic surveys. This applies to both absolute estimates and, because of the fact that turnover rate is likely to vary substantially from year to year, to relative estimates as well. Studies for reducing the uncertainty, such as further, more intensive tagging work (as recommended by the Meeting) and, perhaps time studies in which a spawning aggregation is sampled and surveyed repeatedly over a period of a number of days, are clearly important. While definitive estimates of turnover rate could not be expected for many years (if ever), in the short term these studies may at least be able to narrow limits on the current estimates enough to be useful in models of the overall error in the survey estimates.

Target strength

By global standards, the support through comparison experiments for the herring target strength/length relationship in use (the so-called Foote expression) is relatively good, although as recognised by the Meeting, there are outstanding questions regarding the effect of gonad state and depth on target strength which are relevant to both absolute and relative estimates. The goal here should be to measure target strength of spawning herring *in situ* under the conditions of the survey if at all possible. This will require getting a split-beam transducer as close as possible to a spawning aggregation without disturbing the fish, and probably, some means of enhancing conventional single-target recognition methods. Options include the simultaneous use of a co-axial single beam high-frequency transducer operating on a very short pulse to screen out multiples through comparison of range at the two frequencies, various phase-based methods and the tracking of single targets through the beam. The target strength measurements would probably have to be made at one of the standard split-beam frequencies (e.g., 38, 70 or 120 kHz) and if necessary converted to other frequencies by comparison of the backscatter from spawning aggregations at this frequency with that at the other frequencies.

Mark/recapture estimates of biomass

To illustrate how this method might be useful, the Table below gives estimates of biomass (B) of herring in Scots Bay in 2005 and 2006, calculated from the number of marked and recaptured fish through the equation:

$$B = N_t W_c / n ,$$

where N_t is the number of fish tagged, and n the number of them recovered from a catch of weight Wc. Emigration/immigration and tag loss through mortality or shedding is assumed to be zero. The data were taken from Tables 1-3 and 1-4 of RAP Working Paper 2007/03 (revised), and were restricted to recoveries within a few days of tagging, and to the latter part of the spawning season, when recovery rates were high.

Area/year	Tag date	N_t	Recovery	W_c (t)	n	B (t)
Scots Bay 2005	15 August	1 662	17 August	282	59	7 943
	24 August	1 400	26 August	200	20	14 000
Scots Bay 2006	20 August	1 074	22 August	297	14	22 784
			23 August	239	38	6 754
			24 August	220	15	15 752

The biomass estimates in both years have a measure of consistency, and it is interesting that the mean for 2005 (10 971 t) is of the same order as the estimate from the acoustic survey on 21 August, (6 333 t, from Table 2.1.7 of RAP Paper 2007/03) which was roughly midway between the tagging events. Correction for tag mortality would probably bring the estimates closer.

What is puzzling is the fact that the tag recovery rates in the earlier part of the season in both years (and to an extent in the 2006 German Bank tagging as well – see Table 1-14 op. cit.) are very much lower than in the latter part of the season. The reason for this would have to be much better understood before the tag recovery rate at any stage of the season could be taken as a measure of biomass.

Error modeling

I suspect that in any model of error in the acoustic surveys, the uncertainties due to uncertainty in turnover rate/residence time, possible error in the target strength expression, and (possibly) sampling variance will far outweigh any of the other potential sources of error, whether absolute or relative. Hopefully the experiments on turnover rate would enable the uncertainty in this parameter to be reduced and better quantified, while the estimation of error in the estimates should be an important goal in any *in situ* target strength experiments. Sampling variance (which was not quoted in any of the papers in the Meeting, but which is presumably estimated as a matter of course) can be estimated formally, so inclusion of this source of error in the model should pose no particular problems if the survey design is sound.

Even if the error model inputs are very uncertain, even somewhat arbitrary, the model should be useful for research planning in that it should show where effort is most needed to reduce the overall error, and in some cases, how much improvement might be expected for a given level of effort, which would be useful in a cost-benefit analysis. Use of the model to set actual error bounds on estimates would have to be done with greater circumspection.

Appendix 5. DFO Science Update on Resolution of Herring Ageing Issue

At the second herring framework RAP on abundance indices, an update on the re-ageing issue that was raised in the first meeting was requested.

Steve Campana, an internationally recognized fish ageing expert who works at BIO, was requested by the DFO Director of Maritimes Science, M. Sinclair, to meet with the SABS herring team and. with them, investigate the possible causes of the problem and outline a program to resolve it. He determined that a key problem was the lack of verified herring ages, something that no lab (Canada or US) on the east coast can claim to have, and he has designed a radio carbon project to provide these. Early indications are that resolution of the herring ageing problem is tractable and as a result, the necessary work on herring age validation has commenced. This work will not be complete until 31 March 2008, at which time the re-ageing of the historical otoliths (about 40,000) can commence. The re-ageing could take a number of months and, including updating of the databases, the newly aged material would only be available for consideration in the assessment in winter 2008/09.

The intent of the third meeting of the framework review was to undertake an in-depth examination of the models and procedures used to determine stock status, productivity, and harvest implications of various management options. This will not be possible without the updated ageing data. Thus, the third meeting would have to restrict consideration to age aggregated models, which would be used in the interim until the new ageing is available in winter 2008/09, at which time a fourth herring framework meeting would need to be convened. A number of international experts have been invited to the third meeting which have considerable modeling expertise, but would be better employed once the new age material is available.

Therefore, it is appropriate and more efficient to postpone the third herring framework RAP until the re-aged material is available in winter 2008/09. This way, the full suite of models and approaches that are available can be considered rather than restricting discussion to a sub-optimal subset.

In discussion with the SABS herring team, at the herring assessment meeting to be conducted during 17 - 19 April 2007, the necessary analyses to provide advice for the 2006/07 fishery, taking into account the ageing inconsistencies, will be undertaken. Specifically, the 2006 assessment formulation (based upon Virtual Population Analysis) will be updated with data from the fishery and surveys and the sensitivity of harvest advice to different assumptions of ageing precision and bias explored. Thus, the April 2007 herring assessment meeting will be a more complete examination of the assessment model and data than had been planned before uncovering the ageing errors.