Review of Northeast Fisheries Science Center, Woods Hole, Massachusetts, Acoustics Research Program to Estimate the Abundance and Biomass of Atlantic Herring in the Gulf of Maine and Georges Bank Regions

by

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for

UM Independent System for Peer Reviews
Rosenstiel School of Marine and Atmospheric Science
4600 Rickenbacker Causeway
Miami, FL 33149-1098
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under

Consulting Agreement # 15828

Executive Summary of Findings and/or Recommendations

The Northeast Fisheries Science Center (NEFSC), Woods Hole, Massachusetts, first implemented a fisheries acoustics research program in 1998 with the objective of estimating the abundance and biomass of Atlantic herring *(Clupea harengu*s) in the Gulf of Maine and Georges Bank regions. NEFSC has completed four acoustic surveys of these regions, one per year, and has carried out analysis work on data from the first three years. Although the survey results have been reviewed through the on-going NEFSC Stock Assessment Review Committee process, NEFSC decided an independent review of the work done to date would be appropriate at this time.

Through conduct of this review, I found that NEFSC has assembled an effective and harmonised fisheries acoustics research program that has made significant progress towards estimating the abundance and biomass of Atlantic herring in the Georges Bank and Gulf of Maine regions. In addition, team members have carried out commendable work in both laboratory and in-situ acoustical target strength research. To sustain the team's momentum, I recommend the group acquire one full-time technical support person. The current practice of hiring a contract person for six months per year does not provide adequate support and is very inefficient because each person hired must be trained.

NEFSC have done a lot of experimenting with survey designs on Georges Bank and now need to decide on one design and use it for a minimum of three to five years.

Estimating herring abundance in the Gulf of Maine will be more problematic than on Georges Bank due to a number of factors. The main one is lack of co-ordination and co-operation among the agencies conducting science and assessment work within the region. Consequently, I recommend NEFSC take the lead role in establishing an inter-agency steering committee with a mandate to provide guidance and procure the resources needed to co-operatively improve the accuracy and precision of Gulf of Maine herring stock assessments.

NEFSC needs to develop protocols for documenting the calibration of acoustic systems and tracking changes and maintenance to the acoustic instrumentation. Also, NEFSC must document correct procedures for handling and fishing the mid-water trawl and for tracking and carrying out trawl maintenance.

NEFSC scientists acknowledge they have been experiencing difficulties ageing herring. Also, the technician chiefly responsible for reading otoliths is likely to retire soon and no full-time person has been hired as a replacement. Consequently a knowledge/skill gap may occur and compound the problem. Therefore I recommend staffing action and a training program be established ASAP for a technician to read herring otoliths. In addition, NEFSC should implement an otholith exchange program (inter-agency and international) to achieve consistency in age reading among participating agencies.

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Background

The Northeast Fisheries Science Center (NEFSC), Woods Hole, Massachusetts, first implemented a fisheries acoustics research program in 1998 with the objective of estimating the abundance and biomass of Atlantic herring *(Clupea harengu*s) in the Gulf of Maine and Georges Bank regions. NEFSC has completed four acoustic surveys of these regions, one per year, and has carried out analysis work on data from the first three years. Although the survey results have been reviewed through the ongoing NEFSC Stock Assessment Review Committee process, NEFSC decided an independent review of the work done to date would be appropriate at this time. Therefore, NEFSC requested the Rosenstiel School of Marine and Atmospheric Science (RSMAS), Miami, FL, to organise and oversee this review. RSMAS, through their UM Independent System for Peer Reviews, contracted consultants to independently carry out a review of the survey design, operational procedures, data processing and analyses, and biomass estimation work undertaken by NEFSC.

Under the terms of the RSMAS contracts, the consultants were required to conduct an onsite site review with NEFSC scientists to cover potential agenda items as defined in the Statement of Work prepared by RSMAS (Appendix I). Also, the consultants were required to prepare and submit reports to RSMAS to provide guidance for improving each item listed in the Statement of Work. These reports were expected to reflect the individual consultant's area of expertise; consequently, no consensus opinion (or report) was to be produced.

Upon selection, I was advised by RSMAS that my knowledge and expertise in fisheries acoustic instrumentation and calibration would complement that of the assessment and survey design reviewers. Consequently, my report places emphasis on instrumentation and calibration. Also, as I have considerable experience in logistics, vessel operations, and resource requirements needed to undertake acoustic surveys, I have provided comments and recommendations in these areas.

Description of Review Activities

Under the terms of the consultant agreement with RSMAS, I was requested to spend several days reading all background documents, attend a three-day meeting with scientists at the NEFSC in Woods Hole, and produce a written report that provides guidance for improving the survey design, operational procedures, data analyses, and biomass estimates for Atlantic herring.

Background documents (Appendix II) were provided by Manoj Shivlani, Senior Research Associate, Division of Marine Biology and Fisheries, RSMAS. The documents arrived via e-mail on 21 November 2001. I studied the documents and assembled and read relevant material from additional sources.

I attended the three-day meeting with scientists at the NEFSC in Woods Hole, on 03 – 05 December 2001. The meeting closely followed the agenda (Appendix III) that was prepared by Dr. Wendy L. Gabriel, Chief Fisheries and Ecosystems Monitoring and Analysis Division, National Marine Fisheries Service.

I produced this report following the format given in ANNEX I: REPORT GENERATION AND PROCEDURAL ITEM (Appendix I). Please note, although I was requested to seek additional information on report generation from web site:
http://www.rsmas.miami.edu/groups/cimas/Report_Standard_Format.html.
This was not possible as I was unable to access the site. Within the limits of my knowledge and expertise, this report provides guidance for improving each item referenced in the Statement of Work (Appendix I).

Summary of Findings

NEFSC has assembled an effective and harmonised fisheries acoustics research program that has made significant progress towards estimating the abundance and biomass of Atlantic herring in the Georges Bank and Gulf of Maine regions. In addition, team members have carried out commendable work in both laboratory and in-situ acoustical target strength research.

Through study of the background information and the material presented in the 3-day meeting I've identified the following areas that need to be addressed to strengthen and enhance the program.

- The group lacks sufficient technical support staff to effectively and consistently acquire and analyse the survey data required to annually estimate the abundance and biomass of Atlantic herring in the Gulf of Maine and Georges Bank regions.

- There is a lack of co-ordination and co-operation among NEFSC and the other agencies conducting science and assessment work on Atlantic herring in the Gulf of Maine.

- Research work conducted by program scientists will be diminished significantly if the group is required to undertake more stock assessment responsibilities without additional technical and scientific staff.

- The program lacks a protocol for documenting the calibration of acoustic systems and tracking changes and maintenance to the acoustic instrumentation.

- The program lacks a protocol describing correct procedures for handling and fishing the mid-water trawl and for tracking and carrying out trawl maintenance.

- NEFSC scientists acknowledge they are experiencing difficulties ageing herring.

Guidance for improving each item in the Statement of Work

1.) Survey Design

General

Survey design was discussed extensively during the 3-day meeting at Woods Hole. During the meeting, NEFSC scientists had the benefit of obtaining information from a leading expert in this field, John Simmonds, Marine Laboratory, Aberdeen, Scotland, plus NEFSC will likely receive additional comments and recommendations through his report.

Georges Bank

NEFSC has conducted acoustic surveys on Georges Bank in each of the past four years. The geographical area surveyed on the northern side of Georges Bank has been similar during the past three years, although slight increases in size occurred in each of the last two years to ensure spawning concentrations were not missed. NEFSC scientists believe the coverage is now sufficient to include all of the spawning stock. In addition, NEFSC have detected no evidence of a migration on/off the bank during the survey period. Consequently, the spatial and temporal aspects of this spawning stock appear to have been defined and these parameters can be used to set the geographical limits and survey timing. Also, NEFSC have detected little evidence of diurnal behaviour; therefore surveying throughout a 24-hour period appears to be an acceptable practice on Georges Bank.

- As noted during the 3-day meeting, the geographical range of the stock may be increasing in relation to its growth. Recommend NEFSC expand the geographical size of the survey as necessary to ensure full coverage of the spawning concentrations. Note this may require additional survey days to maintain the same density of acoustic coverage and biological sampling.

- Recommend NEFSC conduct experiments to test for evidence of a migration on/off the bank during the survey period and for diurnal behaviour.

With respect to selection of a survey design, a systematic zigzag design is not recommended given the occasional requirement to extend transects for full coverage of herring aggregations. Also, a systematic zigzag design is not recommended because the majority of transect lengths exceed five times the transect spacing (MacLennan and Simmonds, 1992). The main decision is whether to use a systematic parallel or random parallel design. Basically, a systematic parallel design can provide better geographic coverage, while a random parallel design significantly decreases the difficulty associated with estimating variance. The pros and cons of both approaches were discussed extensively during the 3-day meeting and NEFSC will likely receive additional guidance from J. Simmonds through his report.

During the 3-day meeting, the reviewers recommended biological sampling be increased to 3 or 4 mid-water trawling sets per day. NEFSC scientists indicated a preference to complete the survey of Georges Bank within one 12-day vessel trip. From logistic and synoptic perspectives a 12-day survey may be highly desirable; but NEFSC will have to balance good survey coverage and sufficient biological sampling against their desire for a 12-day trip.

Gulf of Maine

To date, NEFSC have used a systematic parallel design with close transect spacing to survey four banks (traditional hot spots) within the Gulf of Maine. While this approach is insufficient to estimate the abundance within the entire region, these surveys do provide indices for these areas and the effort required to carry out this work appears to be within the current capacity and capabilities of NEFSC's fisheries acoustics research program.

During discussions on survey design options for the Gulf of Maine, NEFSC scientists stated:

- The region is thought to contain about one-tenth the biomass of Georges Bank.
- There are a greater number of participants in the Gulf of Maine fishery.
- In addition to NEFSC, other agencies are doing mostly uncoordinated science and assessment work.
- The fish exhibit diurnal behaviour.
- The fish inhabit areas with water depths less than 45 meters.

Each of these factors increases the difficulty in designing and conducting a survey. If NEFSC were to assume sole responsibility for surveying and estimating fish abundance for all of the Gulf of Maine, I would recommend NEFSC be given a huge increase in resources (e.g. funds, staff, vessel time, acoustic and fishing technology). A more cost-effective means may be to develop co-operative efforts with other agencies and industry. My recommendations with respect to other agencies are presented in Section 7. Inter-agency co-ordination. An example of what can be achieved through co-operation with industry in undertaking acoustic surveys is described by Melvin et. al. (2000). While this approach does have problems, the survey coverage provided by industry can reduce costs to science institutions and the multi-vessel support provided by industry can be used to address synoptic issues.

2.) Operational Methodology

a.) EK-500

NEFSC scientists appear to be well versed in the capabilities, operation and calibration of the EK500. The following recommendations are offered primarily to improve the continuity of their work.

- Recommend NEFSC develop a protocol to document echosounder components (e.g. modules, circuit boards and transducers) so that changes made to the sounder(s) by service personnel can be tracked – also see Section 2.g. Calibration.

- Recommend NEFSC acquire spare circuit boards (at least spare transceiver cards) or a backup echosounder. Note as the EK500 is no longer produced or sold, it may not be possible to purchase spare components. The best option for obtaining backup support may be to acquire a new EK60 scientific sounder.

- The echograms presented by NEFSC scientists showed an abnormal ringing behaviour in the 12 kHz channel. Recommend the EK500 manufacturer/representative be asked to determine the reason for this behaviour. NEFSC researchers indicated they plan to replace the 12 kHz channel with an 18 kHz split-beam transceiver and transducer. As noted above, the EK500 is no longer produced or sold; so the best option for obtaining an 18 kHz channel may be the purchase of a new EK60 scientific sounder.

- The summary document provided by NEFSC stated the EK500 was configured during surveys to use a mean sound velocity of 1460 m/s. When questioned about the appropriateness of this value, NEFSC scientists were unsure of the actual sound speed setting. Using the oceanographic data (average temperature: 10° C and average salinity: 32 – 35 parts/thousand) provided in the document "Summary of Atlantic Herring Hydroacoustic Research at the Northeast Fisheries Science Center", I calculated the mean sound speed should be approximately 1489 m/s. Ranges to targets and to the ocean floor will be underestimated by approximately 2% if the 1460 m/s value is used. While this is not a large error, it does affect many of the data products produced by the echosounder. Recommend NEFSC scientists analyse the oceanographic data acquired during previous surveys, then compute and use the most appropriate mean sound velocity. Also, note the first 5 parameters in the Sound Profile Menu (Profile Type, Depth Upper, Depth Lower, Velocity Min. and Velocity Max.) affect only how the EK500 displays the sound profile graph, not the actual sound profile used by the sounder to compute bottom depth.

- NEFSC scientists thought the value of the "Minimum Level" parameter in the Bottom Detection Menu controlled the ability of the sounder to detect and track the ocean floor. Actually, the EK500's bottom tracking algorithm functions independently and accepts no control parameters from the operator beyond the definition of the operating range (i.e. the Minimum Depth and Maximum Depth values). After bottom detection, the EK500 decrements the detected depth value by sample step intervals until the received echo level is below the value of the Minimum Level parameter. Recommend the Minimum Level value be set to zero, thereby disabling this feature. This will reduce the processing load on the EK500, which will decrease the number of "ping interval warnings". Also, with the value set to zero, the EK500 is less likely to report incorrect depths when fish are close to the ocean floor – see Section 5.a. Acoustical Noise Filtering.

- NEFSC have not had an opportunity to acquire underwater radiated noise signatures for their vessels. This information would be useful in assessing the probability of the survey vessel disturbing fish populations under study and in explaining differences in data obtained with the current vessels and with a replacement vessel. Therefore, recommend underwater radiated noise signatures be obtained for the current vessel(s).

b.) Omni-directional sonar

To date NEFSC scientists have used the sonar in a qualitative manner during surveys to assist biological sampling (trawling) and during *in-situ* experiments to locate and observe the spatial movement and structure of fish aggregations. This model of sonar is optimised for fishing activity, not scientific work; therefore it has minimal abilities to quantify acoustic signals.

- In addition to the current applications, recommend NEFSC consider using the instrument in a qualitative manner to test for vessel avoidance, especially while surveying the shallow water areas of the Gulf of Maine.

- Omni-directional and multi-beam sonar technology is advancing at a rapid pace and will play an important role in fisheries acoustic research and survey work. Recommend NEFSC scientists follow these advancements closely, especially since they may have an opportunity to procure this technology through the acquisition of a new science vessel.

c.) Pelagic trawling

NEFSC scientists have selected a mid-water trawl that appears to be well suited to the current vessel and to the capture of herring in water depths greater than 45 meters.

- Recommend NEFSC procure the funding needed to repair and maintain their mid-water trawls, determine what organisation or company is going to carry out the maintenance work, and develop a quality control mechanism to ensure trawls are repaired and maintained in a consistent manner.

- Recommend a protocol be developed (e.g. documentation, photos and video) for storing, rigging, handling (on deck and with the net-drum), deploying, retrieving and towing the trawl. Mid-water trawls are much more complex than bottom (ground) trawls. In addition, the mid-water trawl is used infrequently (on only one or two surveys per year). Consequently, a protocol is needed to reacquaint and train fishing officers and crew with proper procedures to ensure the trawl is used effectively and consistently from survey to survey.

- NEFSC scientists stated that the minimum fishing depth for the mid-water trawl was 45 meters. Recommend NEFSC acquire the capability to fish in water depths less than 45 meters. Perhaps this could be achieved by reconfiguring the towing arrangement for the current trawl (e.g. different doors or doors fitted with flotation); maybe a different (smaller) trawl is needed for shallow water sampling. While the minimum sampling depth of 45 meters does not appear to be a problem at the present time for the Georges Bank survey, it could restrict sampling in areas of the Gulf of Maine – see Section 1. Survey Design.

d.) Underwater video

To date NEFSC scientists have used their underwater video capability as a qualitative tool to improve their understanding of the targets observed acoustically. As their in-situ target strength research evolves, NEFSC will need to advance their underwater video technology.

- Recommend NEFSC follow advancements in underwater video technology and procure equipment as required to support their in-situ target strength experiments.

e.) Other sampling

No comments or recommendations.

f.) Data management and processing at sea

NAFC scientists appear to have developed an effective means for managing data at sea.

- Recommend NAFC ensure sufficient data back-ups are performed while at sea and adequate spare computing resources are available to recover from equipment failures.

g.) Calibration

The summary document provided by NEFSC contained a table of calibration data acquired from 1997 – 2001. An examination of the 38 kHz Ts and Sv gain values presented in the table showed a significant shift in these values for the years 1998 – 2000. When asked to explain the shift, NEFSC scientists presented a plausible explanation that the shift was due to the incorrect selection of a calibration sphere during the years in question.

- Recommend a protocol be developed for conduct of calibration measurements; it should include:
  - Documentation of all equipment used, including echosounder components – see Section 2.a. EK500.
  - Collection of oceanographic data (i.e. a CTD cast) coincident with the acoustic measurements.
  - Documentation of location, procedure, data products, results, and comments. As an example, the procedure used by the Hydroacoustics Section, Newfoundland Region Department of Fisheries and Oceans, Canada is given in Appendix IV.

- Recommend an experiment be conducted to increase confidence that selection of the wrong calibration sphere was the cause of the shift for the years 1998 – 2000.

- If confident the cause of the shift was selection of the wrong calibration sphere, recommend correction factors be computed and all applicable survey results be scaled.

3.) In-situ Acoustical Experiments in Support of Hydroacoustics Survey Abundance Estimates

The presentation given by NEFSC scientists demonstrated they have a sound understanding of the problems and pitfalls associated with conducting in-situ target strength work.

To date NEFSC scientists have been limited by the processing power of the EK500 (i.e. maximum detection of 30 targets per ping). The new software tools (Echo Log and Echo View) now available to NEFSC scientists will permit them to overcome the target detection limitations of the EK500; hence, more sophisticated experiments can be undertaken.

- Recommend management make significant efforts to ensure in-situ acoustical experiments are supported.

4.) Laboratory Acoustical Experiments in Support of Hydroacoustics Survey Abundance Estimates

NEFSC scientists are to be commended for work done in this area. With their co-operative research partners, they are presently the leaders in the field of modelling acoustic backscatter by fish.

- Recommend management make significant efforts to ensure this work continues.

5.) Data Processing and Management

a.) Acoustical noise filtering

NEFSC scientists use an off-bottom distance of 0.5 meters to reduce the likelihood of including bottom echoes as fish.

- In Section 2.a. EK500, a recommendation was given to set the Minimum Level in the Bottom Detection to zero. If this recommendation is adopted, the choice of 0.5 meters as an off-bottom distance should be re-examined. Most likely the off-bottom distance will have to be increased slightly to compensate for additional bottom samples. If the Minimum Level is set to zero, recommend NEFSC scientists conduct an investigation to ensure the selection of an optimum off-bottom distance.

- The Sv threshold method (really Sv per meter) applied by NEFSC scientists appears to be valid for this application. Note a depth dependent threshold may be required if surveys are extended to deeper water. For the areas presently surveyed, recommend the threshold criteria be re-examined if a decision is made to have EchoLog collect Sv data (i.e. Sample Sv).

b.) Species partitioning of acoustical data

- To have echo traces classified as herring, NEFSC scientists have evoked a rule that Sv values must be approximately equivalent among all three frequencies. Recommend additional biological sampling with the mid-water trawl and other tools (e.g. IYGPT trawl and/or RMT-8) be used to confirm this classification rule, especially in areas with low fish densities. I acknowledge this will be time consuming and may be difficult to implement due to limited deck space onboard the vessel.

c.) Biological and physical data

The number of mid-water trawl tows conducted per survey appears to be quite low considering the extent of the geographical area surveyed.

- Recommend the number of tows be increased to provide biological samples from more locations within the survey area. Obviously the number of tows has to balanced against acoustical survey coverage and the scientific staff available to process catches. Recommend a minimum of one tow per 12-hour period, with an average of at least three tows per day.

- Recommend tows be distributed throughout the geographical area, even in areas of low fish density.

- Presently about 400 otoliths have been collected per year during the acoustic surveys of the Gulf of Maine and Georges Bank regions. Recommend this number be increased substantially with the objective of improving the accuracy and precision of herring ageing. I recognise this will increase the workload on technical staff both at sea and in the laboratory; but I feel it is essential NEFSC improve the quality of their herring ageing data.

- Recommend transects be surveyed and biological sampling be conducted to avoid correlation between depth and time of day (i.e. ensure work is organised so that not all surveying and sampling of shallow or deep water areas occur at the same time of day).

d.) Data management (archival and accessibility)

- NEFSC scientists are in the process of providing the herring acoustic database to the Data Management Services Branch for them to oversee and maintain. Recommend a means be devised that permits NEFSC scientists to overwrite errors discovered in this database even after it is administered by the Data Management Services Branch.

6.) Data Analyses

a.) Density distributions
b.) Backscatter and individual target strength estimates
c.) Backscatter/length/weight/age relationships
d.) Abundance and biomass estimates
e.) Spatial, temporal and diurnal variability
f.) Population assessment

During the 3-day meeting, NEFSC was advised by reviewer J. Simmonds to use the target strength equation published by Foote (1987) instead of the equation developed by ICES for North Sea herring. Mr. Simmonds stated the Foote equation was based on more accurate and recent data and was more defensible as it had been peer-reviewed and published. I concur and add that the Foote equation is used by Canadian herring assessment scientists (Melvin, 2000); consequently, adoption of a common target strength equation will aid the US-Canadian transboundary meeting on assessment of the Atlantic herring stock complex.

Graphs of age-based estimates presented at the 3-day meeting indicated a discontinuity in ageing likely had occurred between 1999 and 2000. Consequently, NEFSC scientists acknowledged they were experiencing difficulties ageing herring. To alleviate this problem, recommend:

- Biological sampling during acoustic surveys should be increased to 3 or 4 mid-water trawling sets per day and otoliths should be collected from these fishing sets as opposed to the stratified random trawl surveys.

- The number of otoliths used to determine age-based estimates should be increased from 400 to greater than 1000.

- An otholith exchange program (inter-agency and international) should be implemented to achieve consistency in age reading among participants.

As noted in Section 2.g. Calibration, it’s likely correction factors will need to be computed for the scaling of applicable results from the 1999 and 2000 surveys, which will reduce the biomass estimated for these surveys by approximately 40 percent. While the size of these reductions may be somewhat disturbing to stock assessment scientists unfamiliar with the complexities of hydroacoustic technology, surveys and associated analysis processes, it is important to remember that the fisheries acoustics research program at NEFSC is only 4 years old, mistakes do happen, and the required adjustments can be implemented easily. As noted earlier, adoption of a more rigorous protocol will significantly reduce the likelihood of calibration-related errors occurring in the future.

7.) Inter-agency coordination

a.) Gulf of Maine Aquarium

b.) Maine Department of Marine Resources

c.) Island Institute

In addition to NEFSC, other agencies are doing mostly uncoordinated science and assessment work in the Golf on Maine.

- Recommend a steering committee be formed with members from NEFSC and the other three (or interested) agencies. The long-term objective of the steering committee would be to provide the guidance and procure the resources needed to co-operatively improve the accuracy and precision of Gulf of Maine and Georges Bank herring stock assessments. The first objective of the steering committee would be to define terms of reference for a series of inter-agency science workshops. The initial workshops must determine strengths and weaknesses in current work, how agencies can work together, and define common standards for the collection and analysis of data.

Conclusions/Recommendations

NEFSC has assembled an effective acoustics research team that has made significant progress towards estimating the abundance and biomass of Atlantic herring on Georges Bank.

- To sustain the team's momentum, the group must acquire one full-time technical support person. The current practice of hiring a contract person for six months per year does not provide adequate support and is very inefficient because each person hired must be trained.

- NEFSC will need more scientific staff before taking on additional stock assessment responsibilities. Otherwise the present scientific staff will lose opportunities to conduct research work (e.g. in-situ and laboratory acoustical experiments).

NEFSC scientists are looking forward to the arrival of a new fisheries research vessel in 4 – 5 years.

- Recommend resources (funds, staff and equipment) be made available to carry out comparative acoustic studies and surveys between the new and old vessels. Estimate a minimum of six weeks of vessel time will be needed to conduct the comparative work.

NEFSC scientists acknowledged they were experiencing difficulties ageing herring and a discontinuity had probably occurred between 1999 and 2000. Also, the technician chiefly responsible for reading otoliths is likely to retire soon and no full-time person has been hired as a replacement. Consequently a knowledge/skill gap may occur and compound the problem.

- Recommend staffing action and a training program be established ASAP for a technician to read herring otoliths.

- Recommend NEFSC implement an otholith exchange program (inter-agency and international) to achieve consistency in age reading among participating agencies.

As noted earlier, estimating herring abundance in the Gulf of Maine will be more problematic and require inter-agency co-ordination.

- Recommend NEFSC take the lead role in establishing an inter-agency steering committee with a mandate to provide guidance and procure the resources needed to co-operatively improve the accuracy and precision of Gulf of Maine herring stock assessments.

References

Foote, K.G. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am., 82: 981-987.

MacLennan, D.N. and E.J. Simmonds. 1992. Fisheries Acoustics. Chapman Hall, London, England: 336p.

Melvin, G.D., T. Scheidl, F.J. Fife, M.J. Power, K.J. Clarke, R.L. Stephenson, C.L. Waters and S.D. Arsenault. 2000. Summary of 1999 herring acoustic surveys in NAFO Divisions 4WX. DFO Canadian Stock Assessment Secretariat Res. Doc. 2000/066: 40p. Note: cited with permission of lead author and available via web site: http://www.dfo-mpo.gc.ca/CSAS/CSAS/English/Publications/Research_Doc_e.htm

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Appendix I. A Copy of the Statement of Work

STATEMENT OF WORK

Consulting Agreement Between the University of Miami and Christopher Stevens

November 20, 2001

A. General

The Northeast Fisheries Science Center (NEFSC) first implemented a fisheries acoustics research program in 1998 to estimate the abundance and biomass of Atlantic herring in the Gulf of Maine and Georges Bank regions. Although part of the review system in the on-going NEFSC Stock Assessment Review Committee process, the hydroacoustics survey and analysis process is technologically complex and is not familiar to most stock assessment scientists. A dedicated review of the survey design, operational procedures, data analyses, and biomass estimates for Atlantic herring is therefore appropriate, given the newness of the process, the highly specialized procedures involved, and the likelihood of provisions to open access to the fishery for this species to foreign joint ventures in the near future. Such a review would prove very useful for the US-Canadian transboundary assessment meeting, where results, if acceptable, could be incorporated in the assessment of the Atlantic herring stock complex.

The consultant shall conduct a review of the survey design, operational procedures, data processing and analyses, and biomass estimates before the assessments of Atlantic herring using fisheries acoustics can be used for fisheries management advice. The consultant shall conduct an onsite site review with NEFSC scientists to cover potential agenda items for the US-Canadian transboundary assessment meeting. Finally, the consultant shall complete a report that provides guidance for improving each item in the agenda, including:

1.) Survey design

2.) Operational methodology
- a.) EK-500
- b.) Omni-directional sonar
- c.) Pelagic trawling
- d.) Underwater video
- e.) Other sampling
- f.) Data management and processing at sea
- g.) Calibration

3.) In-situ acoustical experiments in support of hydroacoustics survey abundance estimates

4.) Laboratory acoustical experiments in support of hydroacoustics survey abundance estimates

5.) Data processing and management

a.) Acoustical noise filtering
b.) Species partitioning of acoustical data
c.) Biological and physical data
d.) Data management (archival and accessibility)

6.) Data analyses
a.) Density distributions
b.) Backscatter and individual target strength estimates
c.) Backscatter/length/weight/age relationships
d.) Abundance and biomass estimates
e.) Spatial, temporal and diurnal variability
f.) Population assessment

7.) Inter-agency coordination
a.) Gulf of Maine Aquarium
b.) Maine Department of Marine Resources
c.) Island Institute

B. Specific

The consultant's duties shall not exceed a maximum total of 2 weeks- several days to read all background documents, attend a three-day meeting with scientists at the NEFSC in Woods Hole, Massachusetts, and several days to produce a written report of the findings. It is expected that the individual contribution of the consultant shall reflect the consultant's area of expertise; therefore, no consensus opinion (or report) will be accepted. Specific tasks and timings are itemized below:

1. Read and become familiar with the relevant documents provided in advance to the consultant;
2. Discuss potential agenda items with scientists in Woods Hole, MA, over December 3-5, 2001;
3. No later than January 7, 2002, submit a written report of guidelines, findings, analysis, and conclusions. The report should be addressed to the "UM Independent System for Peer Reviews, " and sent to David Die, UM/RSMAS, 4600 Rickenbacker Causeway, Miami, FL 33149 (or via email to ddie@rsmas.miami.edu).

Signed_________________________________ Date_____________

ANNEX I: REPORT GENERATION AND PROCEDURAL ITEMS

1. The report should be prefaced with an executive summary of findings and/or recommendations.

2. The main body of the report should consist of a background, description of review activities, summary of findings, conclusions/recommendations, and references.

3. The report should also include as separate appendices the bibliography of all materials provided and a copy of the statement of work.

Please refer to the following website for additional information on report generation:
http://www.rsmas.miami.edu/groups/cimas/Report_Standard_Format.html

Appendix II. Background Documents

Three background documents were provided (via e-mail) by Manoj Shivlani, Senior Research Associate, Division of Marine Biology and Fisheries, Rosenstiel School of Marine and Atmospheric Science:

- Summary of Atlantic Herring Hydroacoustic Research at the Northeast Fisheries Science Center. Prepared by: W. Michaels, W. Gabriel, M. Jech, W. Overholtz and E. Pratt. November 19, 2001. 84p.

- Report on the Northwest Atlantic Herring Acoustic Workshop, Darling Marine Center, Walpole, Maine, March 13 - 14, 2001. Editor: W. L. Michaels, Conveners: P. Yund and W. L. Michaels. NOAA Techn. Mem. 2002-xx. 30p.

- The start-up script file used with Simrad's EK500 (version 5.3) and BI500 (version 1.9.1996) software for EK500 data logging during the 2000 Atlantic Herring Hydroacoustic Survey and The parameters script file used with Simrad's EK500 (version 5.3) and BI500 (Version 1.9.1996) software for EK500 data logging during the 2000 Atlantic Herring Hydroacoustic Survey. 30p.

Appendix III. Agenda for three-day meeting

Agenda for three-day meeting was held with scientists at the NEFSC in Woods Hole, Massachusetts, on 03 – 05 December 2001, as prepared by Dr. Wendy L. Gabriel, Chief Fisheries and Ecosystems Monitoring and Analysis Division, National Marine Fisheries Service.

Atlantic Herring Hydroacoustics Survey and Analysis Program
Northeast Fisheries Science Center
Center for Independent Experts Review

3 - 5 December 2001
Agenda

3 December 2001

9:00 a.m. Introduction, Overview

9:15 a.m. Operational Methodology
- EK-500 scientific sounder, noise measurements
- EK-500 calibration
- Omni-directional sonar

10:30 Break

10:45 Operational Methodology
- Ground-truthing
- At-sea data processing
- Biological sampling

12:00 Lunch

1:00 Survey designs and coverages (descriptive)

2:00 Data processing and management
- Shipboard data collection
- Shore-side database structure

2:30 Break

2:45 Data processing and management

Post-processing of acoustical data

4:00 Adjourn

4 December 2001

9:00	Data analyses • Spatial distributions • Length-weight, TS-length relationships • Acoustic SA estimation
10:30	Break
10:45	Data analyses • Abundance and biomass estimation • Length and age estimation
12:00	Lunch
1:00	Applications of acoustic estimates in herring assessments
2:00	Acoustic research • In-situ experiments of individual target strength and diurnal variability
2:30	Break
2:45	Acoustic research • Laboratory experiments and modelling • Field testing and experiments using advanced technology
4:00	Adjourn

5 December 2001

9:00	NEFSC Acoustic Research
	Survey design: past and future directions
	Cooperative/collaborative survey and assessment work
	Break
12:00	Lunch
1:00	Additional topics arising during review
	Discussion
	Break
4:00	Adjourn

Appendix IV. Mathcad procedure for assistance with Simrad EK500 calibration measurements

The following is reproduced with permission of C. Stevens, Hydroacoustic Section, Aquatics Division, SOE, DFO, Canada.

Legend for procedure:

- Violet font: text data
- Blue font: procedural steps
- Black font: parameters and values used in calculations

EK500 Calibration Procedure - June 2001

Date: June 24, 2001

Location: Sunnyside, Trinity Bay

Vessel: CCGS TELEOST

System Description: Vessel's 38 kHz transceiver and transducer (adjacent ADCP ram).

1. Measure magnitude of transducer impedance (ohms) for each quadrant:
   CH1: 95.7
   CH2: 118.4
   CH3: 117.2
   CH4: 88.4

2. Enter the Draft value for the transducer:

   Draft := 6.0

3. Acquire and process oceanographic data to determine the temperature and salinity at the transducer face:
   CTD cast # : 3
   Temperature: 5.979
   Salinity: 33.002

4. Perform basic EK Test as per the EK500 Manual, Calibration, Section 2 (Calibration Procedure), p.6, **Checking the internal test oscillator**.

   Internal Test oscillator reading (dB): -53.7

5. Setup EK and a computer for serial communications (record computer name)
   Compaq Ping #2

6. Setup EK and a computer for LAN communications (record computer name)
   Unit #1.

7. Rig, deploy and bring calibration sphere(s) into EK's beam pattern.

8. Use EK to get an estimate of the range from the transducer face to the calibration sphere.

Initial_Range := 30.2
Initial_Depth := Initial_Range + Draft
Initial_Depth = 36.2

9. Using the initial Range and Depth estimates, process oceanographic data to obtain values for the average sound speed and the average absorption coefficient:

CTD cast # : 3

Initial average sound speed: 1448.0

Initial average absorption coefficient: 9.72

10. Adjust EK's sound speed and absorption coefficient values to match those listed above and get a new estimate of the range to the calibration sphere:

New_Range := 30.0

11. Using the new range estimate, reprocess the oceanographic data to obtain new values for the average sound speed and average absorption coefficient:

New average sound speed: 1447.8

New average absorption coefficient: 9.72

12. Adjust EK's sound speed and absorption coefficient values to match those listed above and get an additional estimate of the range to the calibration sphere.

Range := 30.0
Range_Difference := New_Range – Range
Range_Difference = 0

13. If the range difference is large, loop through Steps 11 & 12 until the difference is not greater than 0.1 m.

14. Process the oceanographic data to obtain a sound speed value for the depth of the calibration sphere.

Sphere_Depth := Range + Draft
Sphere_Depth = 36

Temperature: -0.724
Salinity: 32.3
Sound Speed: 1442.6

15. Obtain a TS value for the calibration sphere.

Calibration Sphere information:
Materiel: Copper
Diameter (mm): 60

TS_Sphere := -33.89

16. Center sphere in the beam and set EK parameters as per the EK500 Manual, Calibration, Section 2 (Calibration Procedure), p. 11, **Centering of split beam**.

17. Set EK parameters as per the EK500 Manual, Calibration, Section 2 (Calibration Procedure), p. 15, **TS-measurement**.

18. Enter current value for the EK's TS Transducer Gain parameter:

Old_TS_Transd_Gain := 25.37

19. Enter the measured Target Strength value:

TS_Measured := -33.8

20. Calculate a new value for the TS Transducer Gain parameter and update EK's value:

$$\text{New\_TS\_Transd\_Gain} := \text{Old\_TS\_Transd\_Gain} + \frac{\text{TS\_Measured} - \text{TS\_Sphere}}{2}$$

$$\text{New\_TS\_Transd\_Gain} = 25.415$$

21. Complete the LOBE procedure as per the EK500 Manual, Calibration, Section 3, p.17, THE LOBE CALIBRATION PROGRAM.

LOBE Information:
Computer used: Ping #2
Data file location & name: C:\EK-Lobe\data\our38_TR1

22. If the results from the LOBE procedure are within acceptable limits, allow LOBE to update the EK parameters:

LOBE Information:
Relative Angle [%]: 150
RMS [dB]: 0.15
TS Gain [dB]: 25.67
Athw_Beam [deg]: 6.83
Along_Beam [deg]: 6.96
Athw. Off [deg]: -0.10
Along Off [deg]: -0.11

23. Center sphere and set EK parameters as per the EK500 Manual, Calibration, Section 2 (Calibration Procedure), p. 15, **SA-measurement**.

24. Enter current range to the sphere and the equivalent 2-way beam angle:

$r := 30.6$ $\qquad$ Equ_Beam_Angle:= -20.5

25. For the current range, sphere target strength, and equivalent 2-way beam angle, compute the theoretical SA value:

$$\sigma_{bs} := 10^{\frac{TS\_Sphere}{10}}$$

$$\sigma_{bs} = 4.083\times 10^{-4}$$

(backscattering cross section)

$$\Psi := 10^{\frac{Equ\_Beam\_Angle}{10}}$$

$$\Psi = 8.196\times 10^{-3}$$

(arithmatic form of equivalent 2-way beam angle)

$$SA\_Theory := \frac{4\cdot\pi\cdot\sigma_{bs}\cdot 1852^2}{\Psi\cdot r^2}$$

$$SA\_Theory = 2.293\times 10^3$$

26. Enter current value for the EK's Sv Transducer Gain parameter:

Old_Sv_Transd_Gain := 25.54

27. Enter the measured SA value:

SA := 2290

28. Calculate a new value for the Sv Transducer Gain parameter:

$$New\_Sv\_Transd\_Gain := Old\_Sv\_Transd\_Gain + \frac{10\cdot\log\left(\frac{SA}{SA\_Theory}\right)}{2}$$

$$New\_Sv\_Transd\_Gain = 25.537$$

End