NOAA Technical Memorandum NMFS-NE-166

Report on the Third Northwest Atlantic Herring Acoustic Workshop, University of Maine Darling Marine Center, Walpole, Maine, March 13-14, 2001

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northeast Region
Northeast Fisheries Science Center
Woods Hole, Massachusetts

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Report on the Third Northwest Atlantic Herring Acoustic Workshop, University of Maine Darling Marine Center, Walpole, Maine, March 13-14, 2001

William L. Michaels[1,3], Editor and Coconvenor, and Philip Yund[2,4], Coconvenor

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December 2001

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Species Names: The NEFSC Editorial Office's policy on the use of species names in all technical communications is generally to follow the American Fisheries Society's lists of scientific and common names for fishes (*i.e.*, Robins *et al.* 1991[a]), mollusks (*i.e.*, Turgeon *et al.* 1998[b]), and decapod crustaceans (*i.e.*, Williams *et al.* 1989[c]), and to follow the Society for Marine Mammalogy's guidance on scientific and common names for marine mammals (*i.e.*, Rice 1998[d]). Exceptions to this policy occur when there are subsequent compelling revisions in the classifications of species, resulting in changes in the names of species (*e.g.*, Cooper and Chapleau 1998[e], McEachran and Dunn 1998[f]).

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[a]Robins, C.R. (chair); Bailey, R.M.; Bond, C.E.; Brooker, J.R.; Lachner, E.A.; Lea, R.N.; Scott, W.B. 1991. Common and scientific names of fishes from the United States and Canada. 5th ed. *Amer. Fish. Soc. Spec. Publ.* 20; 183 p.

[b]Turgeon, D.D. (chair); Quinn, J.F., Jr.; Bogan, A.E.; Coan, E.V.; Hochberg, F.G.; Lyons, W.G.; Mikkelsen, P.M.; Neves, R.J.; Roper, C.F.E.; Rosenberg, G.; Roth, B.; Scheltema, A.; Thompson, F.G.; Vecchione, M.; Williams, J.D. 1998. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. 2nd ed. *Amer. Fish. Soc. Spec. Publ.* 26; 526 p.

[c]Williams, A.B. (chair); Abele, L.G.; Felder, D.L.; Hobbs, H.H., Jr.; Manning, R.B.; McLaughlin, P.A.; Pérez Farfante, I. 1989. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. *Amer. Fish. Soc. Spec. Publ.* 17; 77 p.

[d]Rice, D.W. 1998. Marine mammals of the world: systematics and distribution. *Soc. Mar. Mammal. Spec. Publ.* 4; 231 p.

[e]Cooper, J.A.; Chapleau, F. 1998. Monophyly and interrelationships of the family Pleuronectidae (Pleuronectiformes), with a revised classification. *Fish. Bull. (U.S.)* 96:686-726.

[f]McEachran, J.D.; Dunn, K.A. 1998. Phylogenetic analysis of skates, a morphologically conservative clade of elasmobranchs (Chondrichthyes: Rajidae). *Copeia* 1998(2):271-290.

[g]ISO [International Organization for Standardization]. 1981. ISO standards handbook 3: statistical methods. 2nd ed. Geneva, Switzerland: ISO; 449 p.

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Acronyms

DFO = (Canada) Department of Fisheries and Oceans
GMA = Gulf of Maine Aquarium
HDPS = (Femto Electronics, Ltd.'s) Hydroacoustics Data Processing System
KRM = Kirchoff ray-mode model
MDMR = Maine Department of Marine Resources
NEFSC = (National Marine Fisheries Service's) Northeast Fisheries Science Center
TRAC = (United States - Canada) Transboundary Resources Assessment Committee
TS = target strength
UM = University of Maine
VPA = virtual population analysis

BACKGROUND

Early cooperative efforts by U.S. and Soviet scientists to survey Atlantic herring (*Clupea harengus*) by using hydroacoustics ("acoutics") in the Northwest Atlantic began in the late 1960s. These research efforts were abandoned by the early 1970s due to the severe decline of Atlantic herring stocks on Georges Bank from overfishing, and to the limitations of analog acoustic instrumentation. The use of fisheries acoustics for research in U.S. waters of the Northwest Atlantic did not resume for about two decades, while scientists in government, academia, and industry working in other regions continued to advance fisheries acoustics. The development during the last decade of scientific quality echosounders with digital output and accurate calibration procedures has resulted in the international acceptance of fisheries acoustics as a valuable tool for surveying and assessing pelagic fish populations.

A number of independent research efforts by Canadian and U.S. scientists implemented fisheries acoustics to survey and estimate the biomass of Atlantic herring in various regions of the Northwest Atlantic during the last decade. Some of these scientists from the National Marine Fisheries Service's Northeast Fisheries Science Center (NEFSC), Canadian Department of Fisheries and Oceans (DFO), Maine Department of Marine Resources (MDMR), and Gulf of Maine Aquarium/University of Maine (GMA/UM) met in Woods Hole, Massachusetts, in 1998 to discuss their acoustic research on Atlantic herring in the Gulf of Maine, Scotian Shelf, and Georges Bank regions. That meeting was the first in a series of Northwest Atlantic Herring Acoustic Workshops. During the first workshop, scientists provided an overview of their field operations and postprocessing procedures. Fisheries acoustic research by the NEFSC included Simrad EK500, omnidirectional sonar, midwater trawling, and underwater video operations in the Georges Bank and Gulf of Maine regions. Scientists from the DFO's St. Andrews Biological Station described their operations with Femto echosounders, sidescan sonar, trawling, and seining from commercial and research vessels on the Scotian Shelf and Georges Bank. The DFO had also begun collaborative efforts with the University of New Brunswick to develop calibration and postprocessing procedures for the recently developed Simrad SM2000 multibeam system. The MDMR presented data based on the use of a Simrad EY500 aboard charter vessels to survey Atlantic herring in coastal waters and nearshore banks in the Gulf of Maine. The GMA/UM initiated a project to implement automated acoustic data loggers aboard commercial Atlantic herring vessels. An overview was also provided on Simrad BI500, SonarData, and Femto postprocessing software. The need to coordinate field operations, compare procedures and results, and develop cooperative Atlantic herring acoustic research in the Northwest Atlantic was recognized at the first workshop.

The second Northwest Atlantic Herring Acoustic Workshop occurred at UM's Darling Marine Center in Walpole, Maine, during January 18-19, 2000. Overviews were provided by NEFSC, DFO, MDMR, and GMA/UM scientists of their 1998 and 1999 research, and these scientists compared preliminary biomass estimates. The results from an intervessel comparison between the F/V *Mary Ellen* and FR/V *Delaware II* were also presented. Scientists discussed the importance of accurate calibrations. Approaches for deriving Atlantic herring abundance and biomass estimates by using acoustic data were discussed and recommended. Representatives from the Atlantic herring fishing industry attended the first day to provide suggestions for improving survey operations. This workshop concluded with the planning and coordination of 2000 field operations.

The Third Northwest Atlantic Herring Acoustic Workshop was held at the Darling Marine Center during March 13-14, 2001. The workshop focused on specific topics identified during the second workshop that had the largest effect on the estimates and variances of the acoustic measurements. The participation was also expanded to include additional Canadian scientists who had analytical expertise in estimating the abundance of Atlantic herring by using acoustic data from various regions in the Northwest Atlantic. The goals of this workshop were to evaluate ongoing research in, identify research requirements of, and improve cooperative operational and scientific efforts in, fisheries acoustics to obtain more accurate, cost-effective, and timely population estimates and variances for Atlantic herring assessment. This document summarizes the presentations and discussions of the workshop.

SUMMARY OF PRESENTATIONS AND DISCUSSIONS

Automated Acoustic Data Logging aboard Commercial Vessels

Philip Yund
Darling Marine Center
University of Maine
Walpole, Maine, USA

Presentation

The Gulf of Maine Aquarium's fisheries acoustic project has collected acoustic data in both fishery-dependent (*i.e.*, normal fishing operations) and fishery-independent (*i.e.*, systematic transects) modes for 2 yr. Results from this year's (*i.e.*, 2000) fishery-independent survey of prespawning aggregations in the coastal waters of the Gulf of Maine suggested a total spawning biomass of approximately 300,000 metric tons. A possible spawning aggregation on Jeffreys Ledge in early November was not surveyed due to scheduling conflicts.

In the fishery-dependent portion of the project, 2 yr of data (*i.e.*, 1999 and 2000) from the F/V *Providian* showed consistently greater biomass on Georges Bank than from coastal or nearshore bank waters (*e.g.*, Jeffreys, Platts, and Fippennies Ledge) in the Gulf of Maine (Figure 1). This pattern was consistent with other acoustic results, and stock assessments suggested that the Georges Bank component of the stock is approximately an order-of-magnitude more abundant than the nearshore Gulf of Maine stock.

Discussion

There is considerable U.S. interest for increasing the use of commercial vessels to survey fish stocks, and of the automated acoustic data logging system as a tool that can be readily implemented. Good progress has been made during the last 3 yr in the Gulf of Maine and Georges Bank region with the collection and processing of acoustic data from commercial Atlantic herring vessels. Biomass estimates from these data seem reasonable. The next step is to implement the use of the acoustic estimates into the Atlantic herring management process. The Canadians have used acoustic data from commercial vessels more extensively and provide many lessons.

Environmental Influences on the Density Distribution of Atlantic Herring

Philip Yund
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University of Maine
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Presentation

We recently started to compare acoustic data to satellite and CTD (conductivity, temperature, and depth) data on surface temperature and chlorophyll density to assess possible oceanographic predictors of Atlantic herring distributions. Preliminary analyses (of two strata on Schoodic Ridge) suggest that Atlantic herring appear to be distributed along frontal boundaries between water masses. Possible correlations with water depth and other variables will be explored in future analyses.

Discussion

Atlantic herring are temperature sensitive, and their density distributions can vary between years due to fluctuations in this variable. Environmental influences are an important concern when determining the time and location

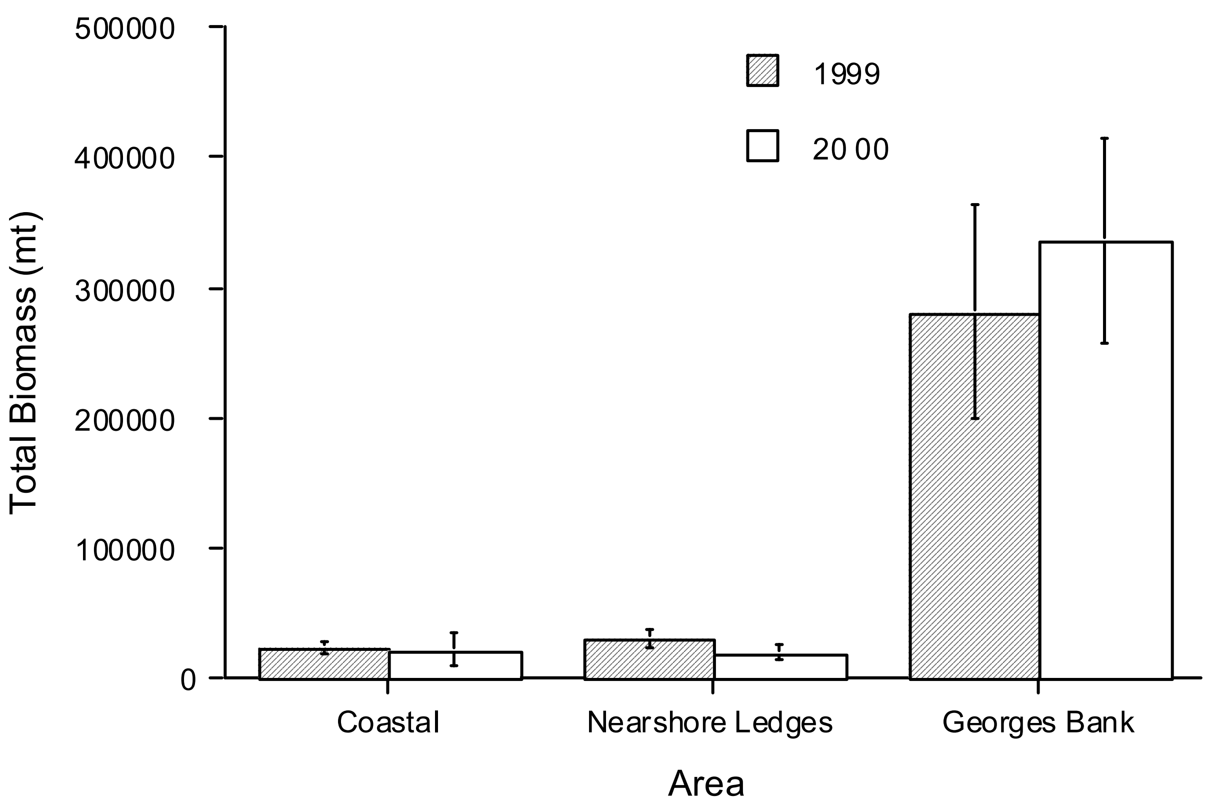

Figure 1. Spatial pattern of relative Atlantic herring abundance from fishery-dependent acoustic data collected by the F/V *Providian*. Range estimate bars represent one standard deviation.

of an acoustic survey. Questions were asked as to whether Atlantic herring feed during spawning; the NEFSC has observed Atlantic herring feeding during the spawning period. A critical requirement of fisheries acoustic research in support of management was recognized in that interannual biomass indices should reflect trends in abundance rather than environmental anomalies.

Fisheries-Independent Estimates from Acoustic Survey Data

William J. Overholtz
Northeast Fisheries Science Center
National Marine Fisheries Service
Woods Hole, Massachusetts, USA

Presentation

Results from the autumn 2000 NEFSC Atlantic herring hydroacoustic surveys were presented. Three different survey designs -- systematic evenly-spaced parallel (Figure 2), stratified random parallel (Figure 3), and systematic zigzag (Figure 4), were employed to survey the spawning concentrations of Atlantic herring in the northern Georges Bank region during September and October 2000. Results suggest that Atlantic herring were abundant over the region, especially in the Cultivator Shoals area. The general impression was that the entire spawning stock was probably covered during each of the three surveys. Survey estimates indicate that the spawning biomass in the region is probably large.

Two surveys, each utilizing a smaller set of transects (*i.e.*, seven), were conducted over a several day period in early October. These surveys were designed to obtain information on the comparability of biomass estimates from two replicates covering the same area. Biomass estimates from these two surveys were similar, indicating that results are reproducible, and that calibrations are reliable.

Future uses for the acoustics data were presented. These uses included directly estimating abundance and biomass, tuning age-structured models, and calibrating several types of biomass models, including surplus production and delay-difference models.

Discussion

The NEFSC biomass estimates from acoustic surveys are similar to the estimates from virtual population analysis, and the estimates within and among acoustic survey designs are similar. The DFO applies the target strength (TS)-length regression in a different manner than the NEFSC; however, both approaches should produce the same result. A review of these procedures and estimates will be conducted this year by the University of Miami's Center for Independent Experts. Ongoing research is focused on evaluating survey design and estimation using classical statistics and geostatistical procedures.

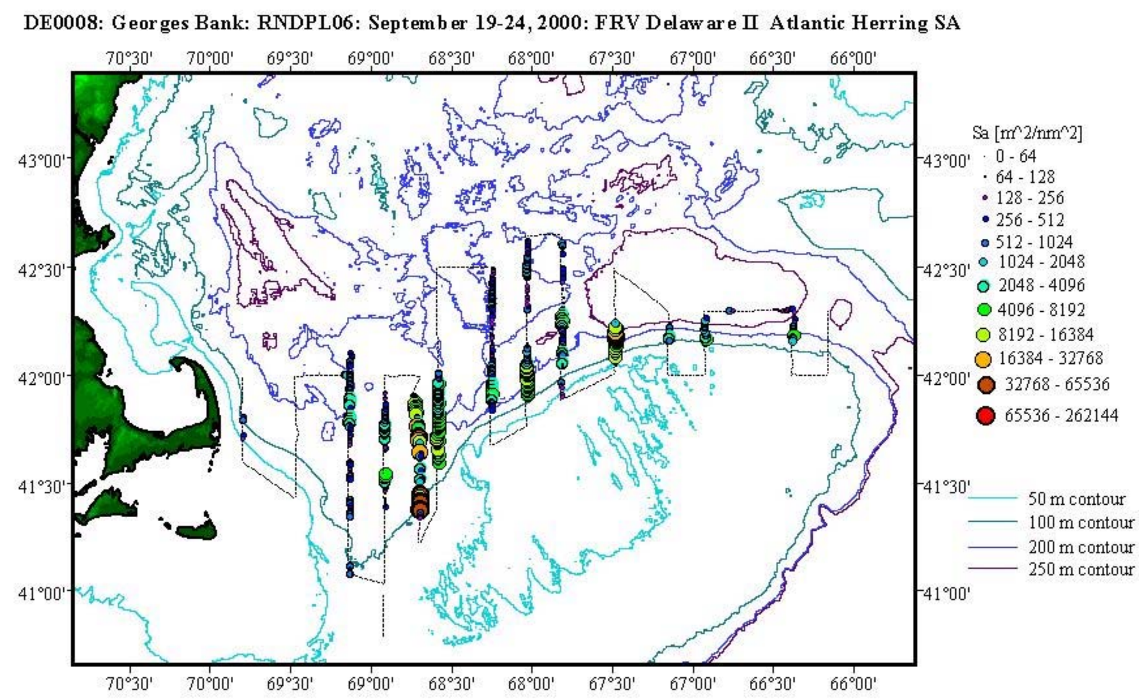

Figure 2. Stratified random parallel transects with acoustic estimates for Atlantic herring.

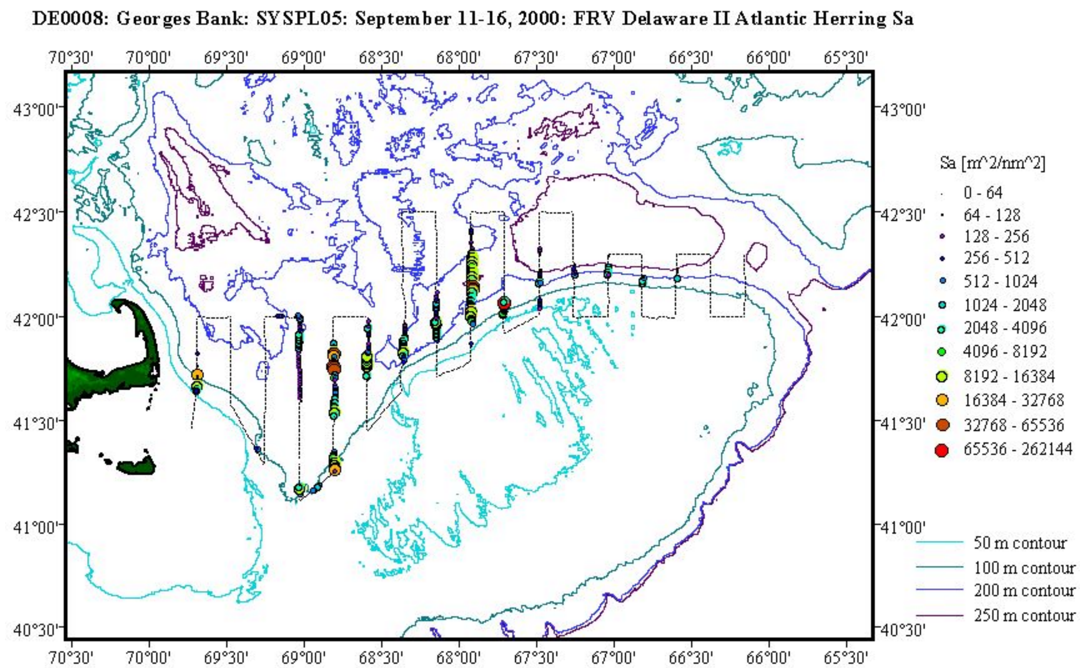

Figure 3. Systematic evenly-spaced parallel transects with acoustic estimates for Atlantic herring.

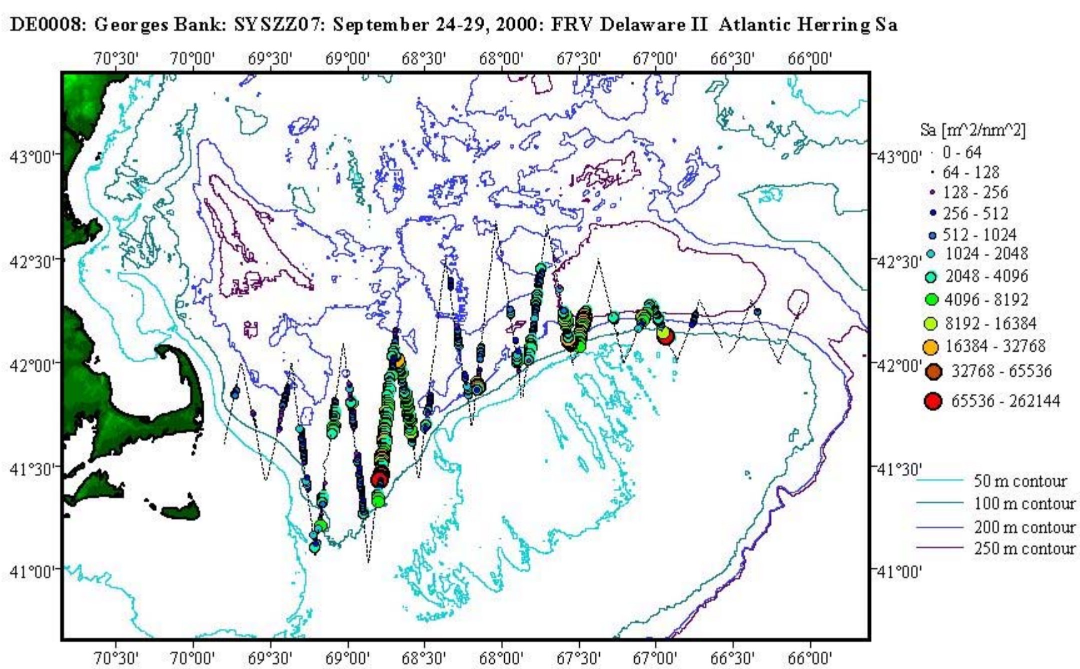

Figure 4. Systematic zig-zag transects with acoustic estimates for Atlantic herring.

In-situ Acoustic Measurements for Northwest Atlantic Herring

William L. Michaels
Northeast Fisheries Science Center
National Marine Fisheries Service
Woods Hole, Massachusetts, USA

Presentation

Acoustic surveys have been conducted during the last 4 yr to estimate Atlantic herring biomass in the Gulf of Maine and Georges Bank regions. During these cruises, individual TS measurements for Atlantic herring have been collected to determine an appropriate TS-length equation. This relationship is important because it directly affects the abundance and biomass estimates when scaling the areal backscatter indices.

An in-situ TS experiment on Atlantic herring was conducted on Fippennies Ledge in the Gulf of Maine during August 1997. Acoustic data were collected using a Simrad EK500 echosounder operating three hull-mounted transducers (*i.e.*, 12-kHz single beam, and 38- and 120-kHz split beams). High-speed midwater rope trawl and Methot trawling operations were conducted to determine fish and macrozooplankton composition, while underwater static video provided direct observations of the acoustic targets (Figure 5). The biological composition contributing to the acoustic data was almost entirely Atlantic herring, euphausiids (*Meganyctiphanes norvegica*), and ctenophores. The EK500 data were processed using the BI500 postprocessing software. The compensated TSs, target depths, and offset angles from the 38- and 120-kHz data were used to remove potential false individual targets from slant range and angle discrepancies. This multifrequency filter removed on average about 98-99% of the TS measurements to reduce the multiple targets associated with tightly aggregated fish such as Atlantic herring. The filter removed multiple targets, resulting in lower TS distributions; however, the mean TS for Atlantic herring in the Gulf of Maine region remained relatively high in comparison to the literature (Figures 6 and 7). Further analyses are needed separate the high TS values that were most likely from larger fish (*e.g.*, Atlantic cod and haddock) and sharks that occurred in the study area.

Atlantic herring TS measurements during the day were also significantly higher than during the night and twilight periods. The EK500 omnidirectional sonar, midwater trawling, and underwater video sampling operations indicated that Atlantic herring exhibited vertical migration patterns from near bottom during the day into the water column at night. Future efforts will be devoted to determining the TS-length relationship for Atlantic herring in the Northwest Atlantic, and variability in TS distributions due to the species' diel behavioral patterns, orientation, enlarged gonads, or morphology.

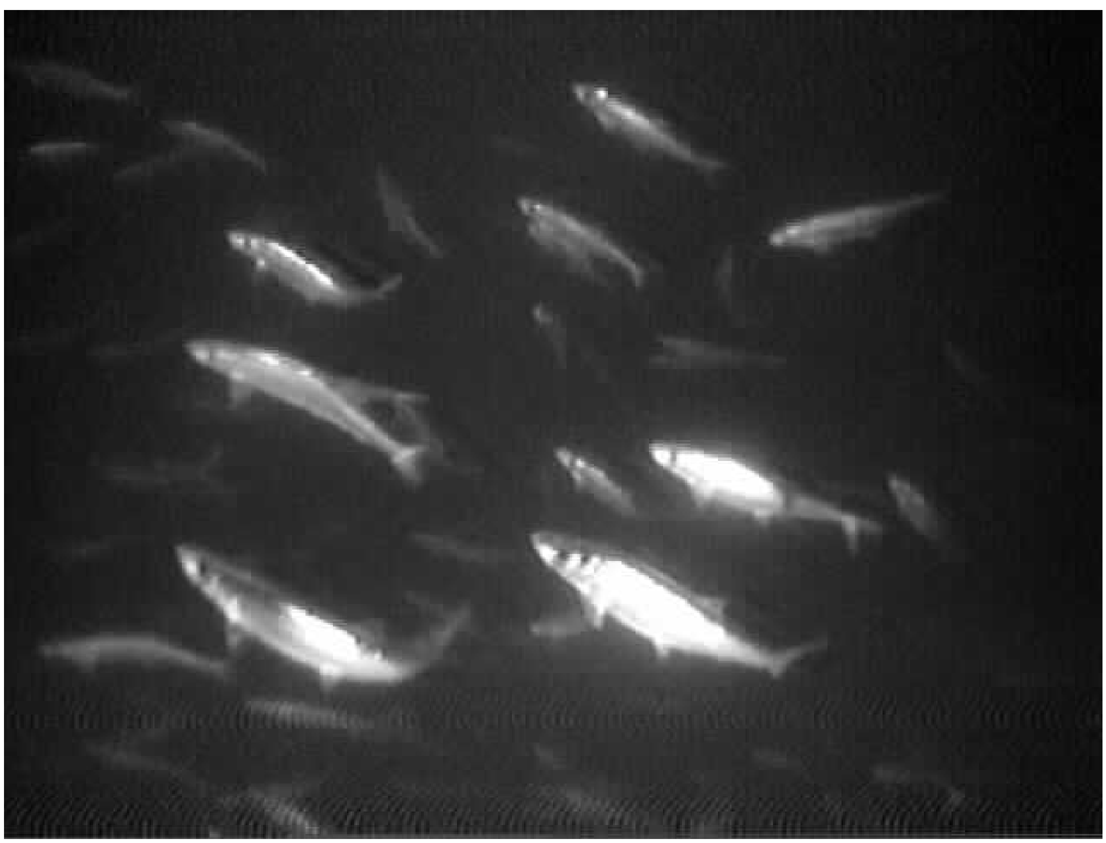

Figure 5. Atlantic herring observed by underwater static video in the Gulf of Maine during the 1997 in-situ target strength experiment.

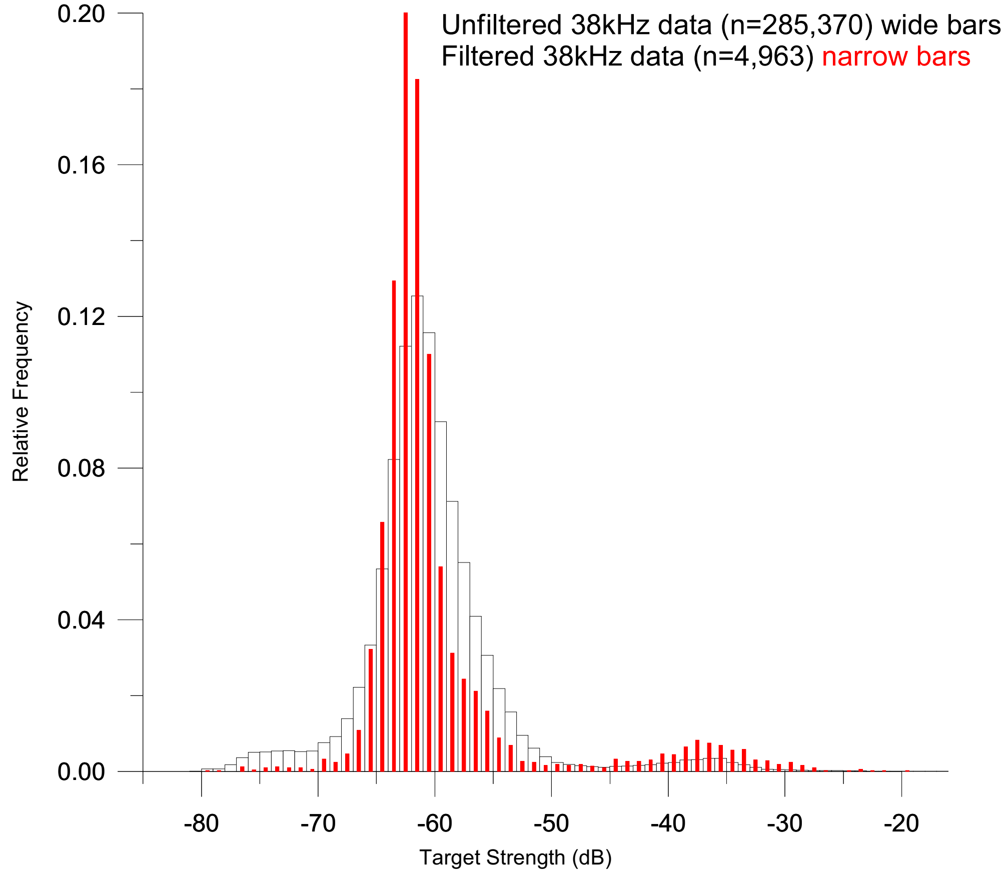

Figure 6. Individual target strength measurements for Atlantic herring at 38 kHz from the Gulf of Maine during August 1997.

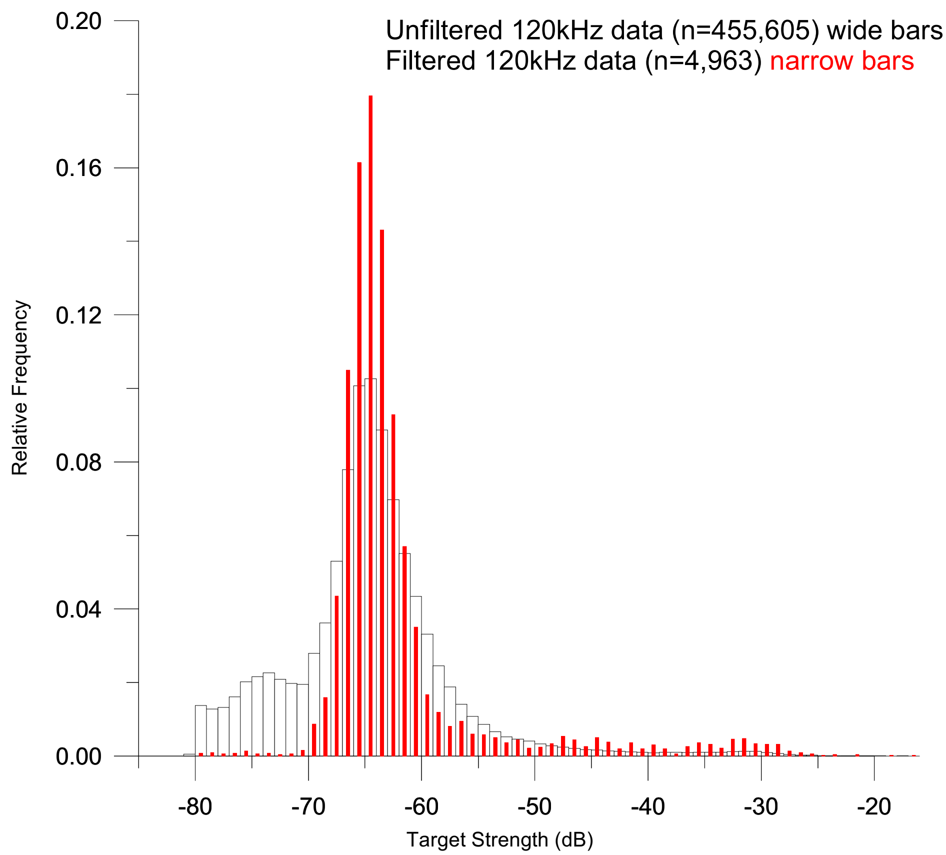

Figure 7. Individual target strength measurements for Atlantic herring at 120 kHz from the Gulf of Maine during August 1997.

Discussion

These high TS measurements for Atlantic herring are similar to observations from an earlier experiment conducted by John Wheeler and George Rose. Workshop participants presently use Foote's equation (except for DFO in St. John's, Newfoundland), but all agree that a new TS-length equation should be developed for Atlantic herring in the Northwest Atlantic. The higher 38-kHz TS measurements observed by the NEFSC suggested that Foote's intercept of -71.9 dB might be increased to possibly -69 dB, resulting in a decrease of the present biomass estimates by half, although further analyses are needed. High TS values for Atlantic herring from a pen experiment by the DFO in St. John's, Newfoundland, have resulted in the use of an intercept of -66 dB for 120 kHz.

Ex-situ (laboratory) Experiments to Refine Acoustic Measurements

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Woods Hole, Massachusetts, USA

Presentation

Fish are complicated scatterers of sound due to the presence or absence of a swimbladder, the shape of the body and/or swimbladder, their behavior, and life history changes in anatomy. Anatomical attributes coupled with organism behavior complicate predictions of fish length from acoustic echoes, and influence the precision and accuracy of abundance or biomass estimates from acoustic data. Combining theoretical acoustic models with in-situ and laboratory measurements will help to explain variability in acoustic backscatter, provide relationships between length and acoustic measures, increase the precision and accuracy of acoustic estimates, and improve target recognition and discrimination among acoustic targets. The Fisheries Acoustics Research Group at NEFSC has been working toward integrating acoustic models with in-situ and laboratory measurements to improve our biomass estimates of pelagic fish stocks in the Gulf of Maine and Georges Bank regions.

Procedures to obtain digital representations of a fish's body and swimbladder, predicted backscatter using a Kirchhoff ray-mode model (KRM), and comparisons of predicted and laboratory measurements were presented at this workshop. The KRM model uses the fish's body and swimbladder morphometry to predict echo amplitudes as a function of fish length, acoustic frequency, and angle of insonification. Radiographs in the dorsal and lateral planes (Figure 8) are used to construct digital images of a fish's body and swimbladder. The KRM model approximates the swimbladder and fish body shapes as finite cylinders and then estimates acoustic backscatter as a function of acoustic frequency or fish aspect. The KRM model predicts a nonmonotonic and nonlinear relationship between reduced backscattering amplitude and fish length or acoustic frequency. In collaboration with scientists at the Woods Hole Oceanographic Institution, measurements on live alewife (*Alosa pseudoharengus*) were obtained in two planes (dorsal/ventral and lateral) of fish aspect angle (Figure 9). Comparisons of model predictions and laboratory measurements suggest that the KRM model predictions are reliable and robust over a wide range of fish aspect angles. We have expanded the KRM model to predict backscattering amplitude for 360^0 of tilt and roll to produce a three-dimensional

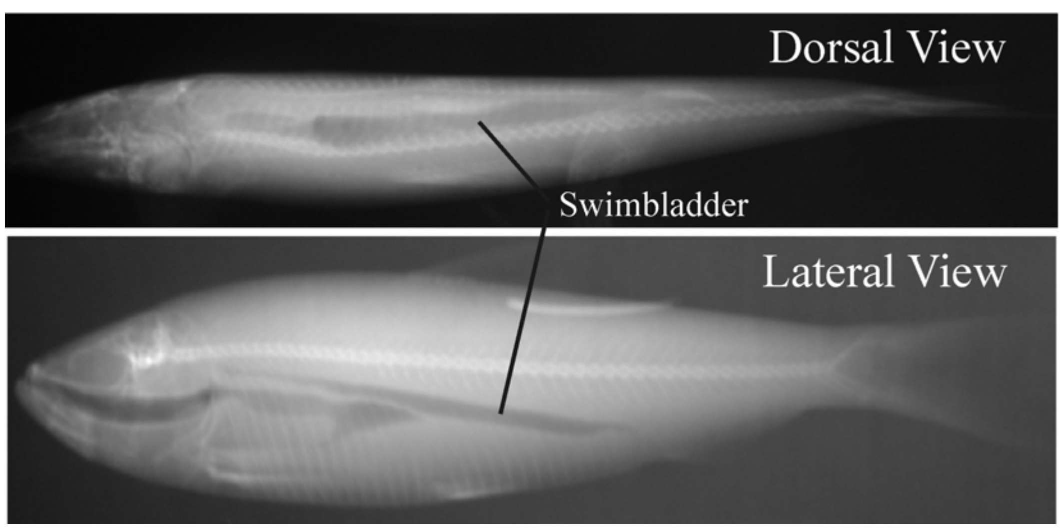

Figure 8. Lateral and dorsal radiographs of an alewife. The swimbladder appears as a dark object relative to the skeletal structure. Note the angle of the dorsal surface of the swimbladder relative to the sagittal axis (essentially the vertebral column) of the fish in the lateral view.

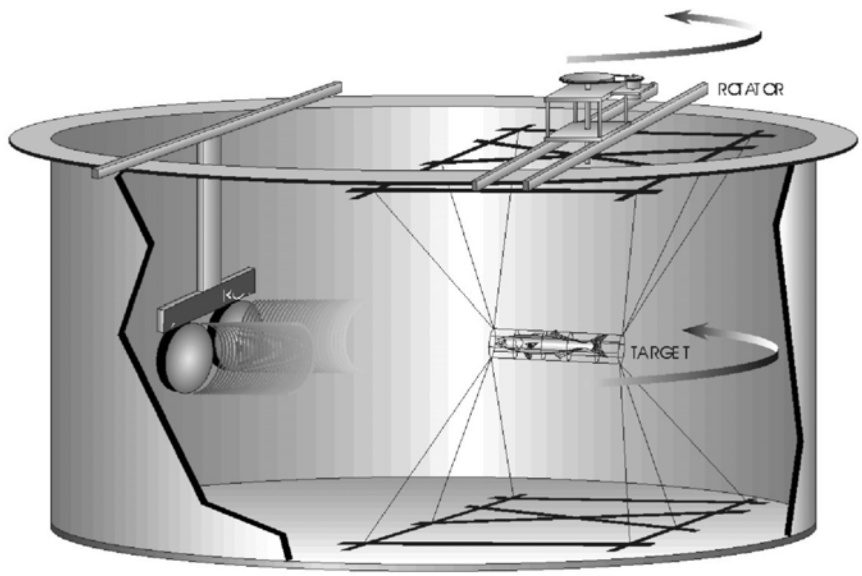

Figure 9. Graphic depiction of our laboratory experiments shows a live fish restrained in a mesh tube, which was rotated at 1^0 increments while insonified with a broadband (35-95 kHz) signal. Fish rotation was computer controlled and synchronized to the transmitted acoustic pulses. Acoustic signals were digitally captured and analyzed for echo amplitudes and pulse compression techniques over a spectrum of frequencies and fish lengths. These types of laboratory measurements provide a foundation for improving acoustic models to quantify variability in acoustic biomass and fish length estimates.

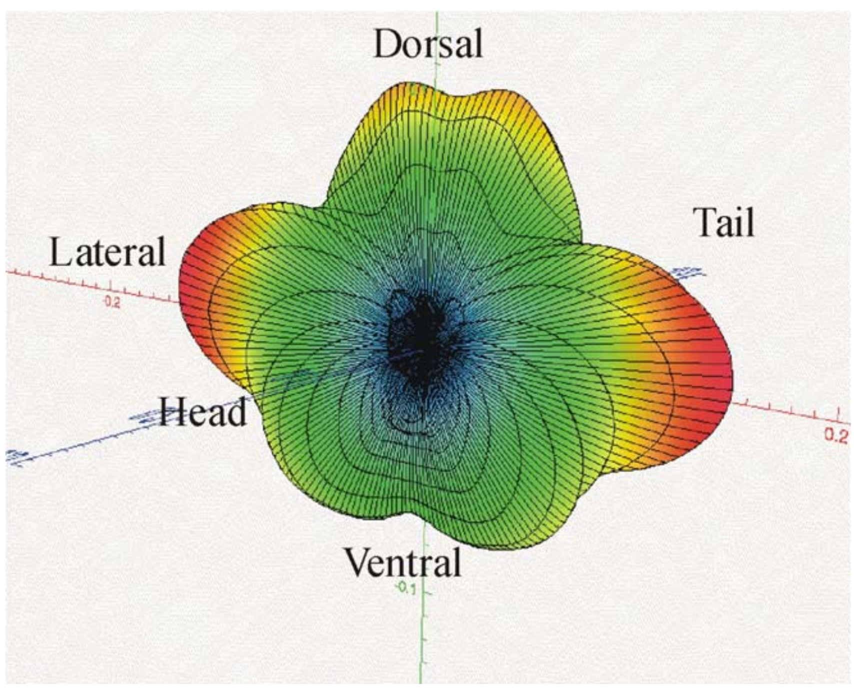

Figure 10. Acoustic backscatter ambit of a 256-mm alewife at 38 kHz. Distance from the center of the axes represents backscatter amplitude. Backscattering amplitude is color coded with highest amplitude as red and lowest amplitude as blue. Insonifying angle resolution is 2^0 in the tilt plane (head-tail) and 2^0 in the roll plane (dorsal-lateral-ventral). The ambit graphically depicts predicted echo amplitude over all degrees of fish orientation. Echo amplitudes are greatly reduced at head-on and tail-on aspects. Maximum amplitudes are at lateral incidences. Maximum dorsal amplitude occurs when the swimbladder is parallel to the incident wave front, which tilts the fish approximately 12^0 head down.

backscattering surface (backscattering ambit, Figure 10). The three-dimensional backscattering surface allows visualization and quantification of the effects of behavior on echo amplitudes and prediction of acoustic backscatter measurements obtained by SONAR or multibeam technology.

Discussion

The laboratory measurements presented on alewife, which has a similar morphology to that of the Atlantic herring, provide a detailed understanding of the species' acoustic ambit which can help to explain the variability observed with in-situ measurements. It was recommended that similar laboratory measurements on Atlantic herring are needed to validate ongoing field investigations to derive a TS-length relationship for Atlantic herring in the Northwest Atlantic. It was also emphasized that the multifrequency measurements from the laboratory will also provide important parameters that allow intercalibration between existing Atlantic herring acoustic surveys that implement different frequencies for estimating abundance.

The Role of Fisheries Acoustics in Support of the Atlantic Herring Industry

Jeff Kaelin
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Winterport, Maine, USA

Presentation

Prior to joining Stinson Seafood, Inc., as Governmental Affairs Coordinator in April 2000, Mr. Kaelin was employed at the Executive Director of the Maine Sardine Council from March 1986 until the council was dissolved on March 31, 2000. The Maine Sardine Council was an industry-funded governmental entity of the State of Maine, established in 1951, that supported research on the Atlantic herring fishery and product quality control of benefit to the Maine sardine industry and the State of Maine.

For many years, Maine's sardine industry, which utilizes Atlantic herring for its products, has supported cooperative fisheries research projects to help estimate the abundance of Atlantic herring available for its operations. During the late 1970s, for example, the Maine Sardine Council and the MDMR cooperated in the tagging of juvenile and adult Atlantic herring along the Maine coast to help understand the migration of Atlantic herring from coastal Maine spawning grounds. The information gathered from this work serves as the basis for many of the assumptions of Atlantic herring spawning stock behavior contained in the federal Atlantic Herring Fishery Management Plan, approved by the Secretary of Commerce in December 2000.

In recent years, the Maine sardine industry has supported investigations into the use of acoustic technology to better estimate Atlantic herring abundance in the Gulf of Maine and Georges Bank region, and to assist in establishing sustainable harvest levels for the resource. Industry supported an acoustic Atlantic herring survey conducted by Dr. Richard Nash and Dr. David Stevenson of the MDMR around 1989. In 1995, the industry supported efforts by Dr. Stevenson to attempt to use acoustics to survey Atlantic herring abundance in the vicinity of Jeffreys Ledge, using a combination of state and federal funds. In 1997, working in cooperation with the GMA and the NEFSC, the industry helped to identify the need to establish a world class acoustic survey capability at the NEFSC, and supported the use of acoustic technology on commercial vessels so that surveys could be carried out where NEFSC vessels cannot operate due to shallow water depths.

During Fiscal Years 1998, 1999, and 2000, the Maine sardine industry, with the assistance of the Maine Congressional Delegation, was successful in having $800,000 added to the NEFSC budget to establish its acoustic survey program. A portion of these funds has been utilized to continue the development of the commercial-vessel survey component. For Fiscal Year 2003 (*i.e.*, October 1, 2002, through September 30, 2003), Stinson Seafood and the GMA are again asking Congress to increase the NEFSC acoustic survey budget, from $200,000 to $500,000, to ensure the continued development of the region's ability to survey Atlantic herring spawning stock abundance at a time when acoustic surveys have begun to be used to determine the abundance of other pelagic species such as Atlantic mackerel and squids.

Discussion

Good progress has been made with implementing fisheries acoustics for estimating Atlantic herring populations in the region. The acoustic estimates are needed to help managers make important Atlantic herring management decisions. Fishers have reported large aggregations of Atlantic herring on northern Georges Bank during the fall (similar to the NEFSC results), and the acoustic estimates will help in assessing the size of the offshore resource.

Cooperative Fisheries Acoustic Research in the Gulf of Maine

Donald Perkins
Gulf of Maine Aquarium Development Corporation
Portland, Maine, USA

Presentation

The fisheries acoustic research on Atlantic herring in the Gulf of Maine region during recent years provides an excellent example of cooperative efforts between government agencies and industry. The Gulf of Maine Aquarium Development Corporation's web site (*http://www.FishResearch.org/*) was introduced as a tool for increasing cooperative opportunities between scientists and commercial fishers. There is considerable interest from industry and funding agencies to foster cooperative research such as the ongoing Atlantic herring acoustic research.

Discussion

Funding and collaborative research opportunities were discussed.

Atlantic Herring Assessment and Management in the Gulf of Maine

David A. Libby
Maine Department of Marine Resources
West Boothbay, Maine, USA

Presentation

Atlantic herring assessment and management in the Gulf of Maine were summarized. Atlantic herring catches were presented for management areas by month for 1998-2000. Graphical presentations of catches were compiled by 10-min square on a bimonthly basis from August through December 1998-2000 to correspond with inshore and offshore acoustic surveys. Preparations are being made for a collaborative United States - Canada Transboundary Resources Assessment Committee (TRAC) assessment meeting on Atlantic herring in 2002.

Discussion

Commercial catch data which corresponds in time and space with Atlantic herring acoustic survey data can improve the partitioning of acoustic data by species. There was discussion regarding the spawning tolerance used to manage fishing on spawning components in the Gulf of Maine. Alternative management strategies used in other areas were also discussed. There was also discussion of the plans to incorporate and review the acoustic estimates of Atlantic herring biomass at the TRAC meeting scheduled for 2003.

Length-Stratified Target Strength Calculations for Biomass Estimates

Claude Leblanc
Gulf Fisheries Center
Department of Fisheries and Oceans
Moncton, New Brunswick, Canada

Presentation

The Southern Gulf of St. Lawrence annual acoustic survey is held at the end of September on Atlantic herring feeding aggregations in inshore areas between 20- and 60-m depths. All major acoustic backscattering detected during survey operations was verified using a midwater trawl for species compositions and length-frequency distributions of Atlantic herring schools. To apply the length-frequency distribution in calculating a mean TS, the following procedure is used. From the detailed biological samples collected per trawl sets, a length-weight regression is calculated to obtain slope and intercept values for the relation: $W = aL^b$. We then use Foote's formula to calculate a TS for every length in the frequency distribution, with the second part of the equation giving us a TS value per kilogram:

$$TS = (20 \cdot \log_{10} L_{cm} - 71.9) - (10 \cdot \log_{10} \cdot W_{kg})$$

We then linearize the TS values per length by using:

$$TS_{linearized} = 10^{(TS/10)}$$

This linearized value of the TS is then multiplied by the number of fish measured for each length in the length-frequency distribution. We next sum the products of this multiplication for all lengths, and divide the sum by the total number of fish in the length-frequency sample. This value is a weighted-mean, linearized TS for the entire length-frequency sample. Finally, we take the antilog value of this weighted-mean, linearized TS to give us a weighted-mean TS in decibels per kilogram.

Discussion

The calculations presented above are the procedures used by the GMA/UM and DFO participants in which an average value of -35.5 dB/kg was used. The NEFSC scientists presently derive the biomass estimates in a slightly different manner, which should produce the same results. The NEFSC approach is to obtain a mean length from a series of transects which is converted to TS using Foote's equation. The individual TS is used to derive the cross-sectional backscatter coefficient of an individual Atlantic herring which is used to divide the mean areal backscatter (Sa) estimates to obtain the number of fish. This estimate is converted to biomass by multiplying it by the mean weight per fish derived from the length-to-weight conversion from the survey. The NEFSC scientists will check both approaches to ensure there are no discrepancies in their biomass estimates.

A Method for Beam-Width Calibration

Allen Clay
Femto Electronics, Ltd.
Sackville, Nova Scotia , Canada

Presentation

Allen Clay from Femto Electronics spoke on recent developments in the firm's Hydroacoustics Data Processing System (HDPS). The beam-angle calibration initiative within the HDPS is primarily intended to improve the confidence in a transducer manufacturer's beam-angle specification, an important parameter in the acoustic integration process. It has also been used to determine the health of all transducer elements, as well as for reviewing the position and amplitude of side lobes. On one occasion, it was instrumental in determining which of two possible transducers was installed on an Atlantic herring seiner. The developed software predicts the beam pattern based on slight ball movements as a result of changes in the line lengths of each of the three suspension lines (Figure 11). The software also accounts for the stretching and shrinkage in the monofilament line as the ball is moved. Upon completion of the procedure, the software predicts the error associated with the estimate of biomass should the manufacturer's specification be chosen over the actual values.

Discussion

It was recognized that most transducer calibrations conducted in the field rely on the manufacturer's beam-angle specification. Although there are calibration programs (*i.e.*, Simrad Lobe program) that derive beam offset parameters, these values are not truly independent from the manufacturer's specifications.

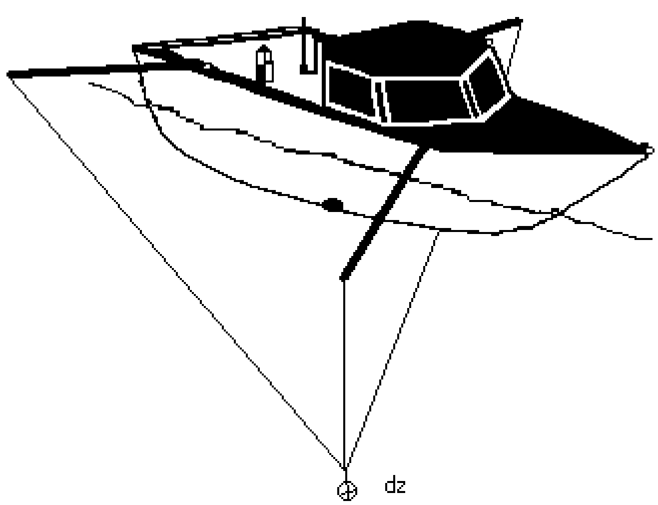

Figure 11. Schematic of the standard calibration procedure using a calibration sphere suspended by three monofilament lines.

Size Discrimination Using a Dual-Frequency System

Allen Clay
Femto Electronics, Ltd.
Sackville, Nova Scotia , Canada

Presentation

The new Femto DE9320 Dual Frequency Digital Echosounder with the 40/120/9.2 Dual Concentric Transducer was presented as a new initiative for addressing areas of interest in the Atlantic herring fishing community. Femto plans to exploit this technology to assist in such concerns as mean target size within a school, mean maturity stage, and Atlantic herring behavioral separation. In the long term, Femto also hopes to provide a tool for bottom typing studies. Preliminary study indicates that the TS of an Atlantic herring of length L obtained by using a frequency F may follow a relationship described by:

$$TS = 10 \cdot \text{Log}\,[B \cdot L^2 \cdot \text{Trig}\,(C \cdot L \cdot F)]$$

where B and C are constants and Trig is a trigonometric function to be determined. In reviewing the modeling studies done by Mike Jech of the NEFSC and presented at the workshop, there are indications that this trigonometric function may exhibit multiple maxima over the commercial size range of Atlantic herring. Although it is not anticipated that this work will quickly lead to a quantitative measure of mean target size since many other factors will influence variability in the signal, it is felt that we will be moving closer to a solution, and that in the meantime, the technology may help fishers in their efforts to target fish of a size needed for a particular market.

Discussion

The advantages with two identical 3-dB beam patterns of different frequencies from a single transducer were discussed (Figure 12). This development will provide improved target classification, and does not have the disadvantage of the varying beam patterns associated with broadband systems.

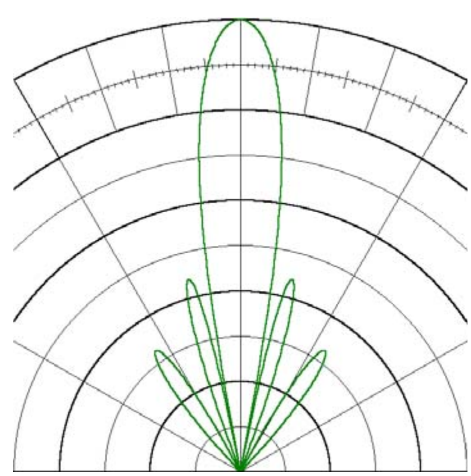

Figure 12. Longitudinal beam pattern of dual concentric transducer.

Recent Multibeam Developments for Fisheries Acoustics

Gary Melvin (presented by Michael Jech)
St. Andrews Biological Station
Department of Fisheries and Oceans
St. Andrews, New Brunswick, Canada

Presentation

An overview on the history and recent developments in the application of multibeam sonar technology to fisheries research was presented. Collaborative efforts between scientists from the University of New Brunswick, DFO's St. Andrews Biological Station, and the University of New Hampshire have made good progress in the development of calibration procedures and postprocessing software for the Simrad SM2000 Multibeam System. The SM2000 is presently the only multibeam system available that collects backscatter data from the water column for fisheries acoustic research. Development of the calibration procedures and postprocessing software is a critical prerequisite before SM2000 survey operations can be routinely implemented.

Extensive progress was made over the past year on calibrating the sonar in order that signal returns from the system can be quantified. The first calibration coefficients obtained from an experiment in February 2001 are presently being incorporated into the display software for computation of volume backscatter. Advances have also been made in the 3D visualization of multibeam data. At present, it is possible to display up to 60 pings on the screen in real time. This provides 3D form to objects as the vessel passes over the bottom. A function is available within the software to count echoes when individual targets are observed in the data. The first attempt to implement multibeam sonar on survey operations for estimating Atlantic herring biomass is scheduled for 2001.

Discussion

Implementation of the SM2000 Multibeam System for fisheries acoustic surveys has been proposed in the Northwest Atlantic by a number of agencies and funding programs. SM2000 installation has also been proposed on new NOAA research vessels. Ongoing research and development with SM2000 calibration and postprocessing software are critical requirements before the SM2000 can be routinely used during survey operations.

Spatial Statistical Approaches for Fisheries Acoustics

Patrick J. Sullivan
Department of Natural Resources
Cornell University
Ithaca, New York, USA

Presentation

Mean biomass estimates and variances were compared from three survey designs (incorporating stratified random parallel, systematic evenly-spaced parallel, and systematic zig-zag transects) on northern Georges Bank during fall 2000 (Figure 13). There appeared to be insignificant differences between the estimates, suggesting that biomass estimates from fisheries acoustic operations were robust. A geostatistical estimator (*e.g.*, kriging) provided a similar mean with reduced variance (Figure 13).

Spatial and Temporal Analysis of Fisheries Acoustic Data from Commercial Vessel Operations

Ross Claytor
Bedford Institute of Oceanography
Dartmouth, Nova Scotia, Canada

Presentation

A method for measuring the spatial and temporal distribution of fish school densities and their exploitation rates using fishery-collected acoustic data and Voronoi - natural neighborhood analysis was described. An Atlantic herring purse seiner fishing on nonspawning feeding aggregations, and an Atlantic herring gillnetter fishing on smaller, highly dense spawning aggregations, in the southern Gulf of St. Lawrence, Canada, collected acoustic data for this study during their regular fishing activity. The declining-catch-per-unit-of-effort estimator, which was associated with the gillnet fishing and which was used to assess this stock, reached asymptotic values at lower-than-expected levels, and was not useful for tracking daily trends in school density.

Gillnet and purse seine catch per distance searched during fishing operations was linearly related to school density, and likely is a suitable abundance index for stock

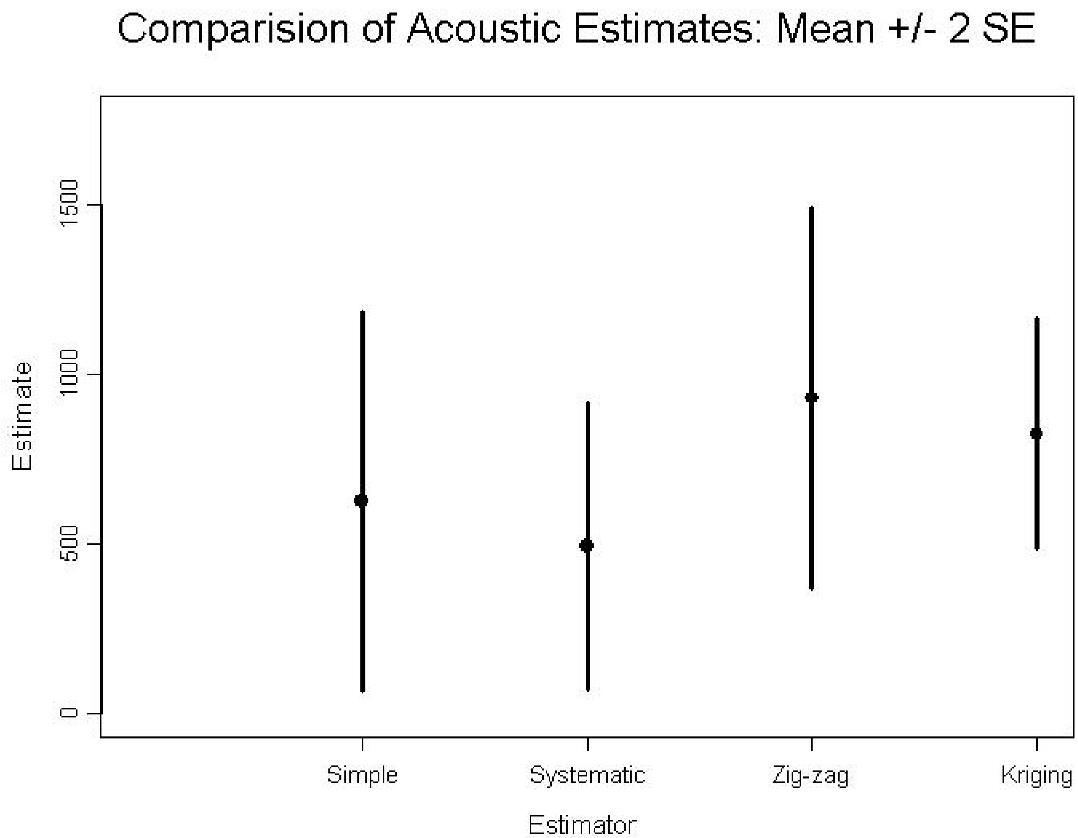

Figure 13. Mean areal backscattering estimates, plus or minus two standard deviations (95% confidence interval), for Atlantic herring from three survey designs (*i.e.*, stratified random parallel, systematic evenly-spaced parallel, and systematic zig-zag transects) and from a geostatistical estimator (*i.e.*, kriging of zig-zag transects).

assessment estimates. An individual boat which collected data in this manner was found to represent trends in the entire fleet. There was a threshold density below which exploitation rates remained low. This threshold provides managers with a method for identifying high exploitation rates and preventing overfishing.

A simulation model calibrated with data from the Pictou 1997 inshore gillnet fishery compared the properties of abundance indices derived from fishery acoustic data to those derived from survey indices. The indices were examined over five fish distribution types, ranging from a single spike to a uniform flat distribution, four conditions of fishing and fish movement, and 16 stock sizes for each of these distribution and conditions. These acoustic data are suitable for deriving abundance indices provided the searching covers the entire population.

Fishery acoustic abundance indices provide a basis for adopting a decision-rule management paradigm, and for allowing the metapopulation structure of Atlantic herring to become the basic management unit for this species. These results represent an important alternative to the current $F_{0.1}$ management paradigm for Atlantic herring populations, and offer an opportunity to develop a more transparent and responsive management system for the long-term viability of Atlantic herring fisheries.

Discussion

Discussions focused on the advantages of estimating exploitation rate from acoustic data collected from commercial vessels. Catch per search distance is considered more sensitive to changes in biomass than catch per net, and less sensitive to varying catch efficiencies among vessels.

Survey Design for Atlantic Herring Acoustic Surveys in the Newfoundland Region

John P. Wheeler
Northwest Atlantic Fisheries Center
Department of Fisheries and Oceans
St. John's, Newfoundland, Canada

Presentation

Acoustic surveys have been conducted on an annual basis since the early 1980s as part of the research program to assess Atlantic herring stocks in the Newfoundland Region. Currently, four coastal stocks are surveyed acoustically on an alternate year basis to estimate stock biomass. Surveys are conducted either during the late fall or overwintering period, depending upon stock area.

In all surveys, the survey area is defined as the area from the coastline to the 120-m depth contour. The 120-m depth contour was selected as the outer boundary as it has been shown that most Atlantic herring are distributed within this depth range during the survey period. The survey areas are divided into strata based upon geographical features and Atlantic herring distribution patterns. Acoustic sampling intensity (*i.e.*, total transect length) is allocated to these strata on a proportional basis based upon Atlantic herring distributional patterns observed in the commercial fishery and previous acoustic surveys.

The survey design within strata has evolved during the time series. Originally, zigzag transects were used; subsequently, random parallel and systematic transects were used. Currently, a multistart systematic design is employed (Figure 14). Each stratum is subdivided into blocks with an equal number of parallel transects per block. Placement of transects is randomly selected in the first block of a stratum, but is defined by this placement in the remaining blocks.

As transects can be of varying lengths within blocks, weighted mean densities are calculated for each stratum and extrapolated to the stratum area to estimate fish biomass. Strata estimates are summed to calculate a total biomass estimate for the survey area.

The multistart systematic design, currently employed, is deemed to be advantageous as it allows for the distribution of acoustic sampling intensity over the survey area in a semisystematic manner, while retaining the ability to calculate a survey-based variance estimate.

Discussion

There was discussion regarding the survey design. Strata were oriented perpendicular to the coastal baseline. This design strategy has the advantage of randomness and even spacing of the transects. This design was decided upon after a working group reviewed the advantages and disadvantages of various designs used in fisheries acoustic surveys. Further insight was also provided on how cruise sampling was allocated among stratum based on densities from previous cruises. The remaining discussion involved concern about whether Foote's equation was appropriate for Atlantic herring in the Northwest Atlantic. The DFO in Newfoundland used a different TS-length equation with an intercept at –66 dB (for 120 kHz) derived from an earlier TS experiment, and this seems to support the high TS measurements observed by the NEFSC.

CLOSING DISCUSSIONS

Data Management and Availability

Closing discussions began with a summary of NEFSC data management and availability. Efforts are underway to archive these data in the NEFSC Oracle database which can be readily accessed by assessment scientists. The NEFSC Atlantic herring acoustic information (*i.e.*,cruise reports, acoustic estimates, and station/catch/biological data from

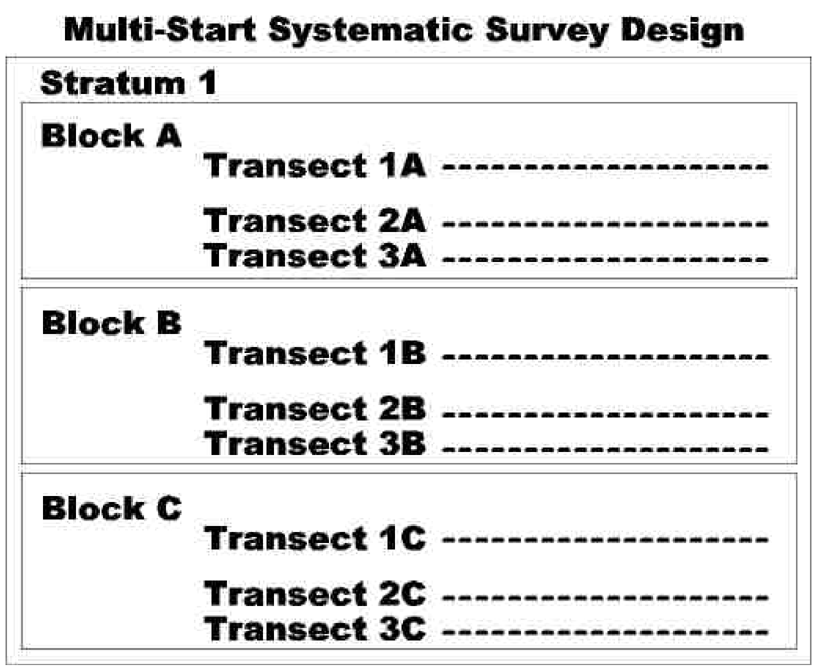

Figure 14. Schematic diagram of multistart systematic survey design where transect placement in block A is randomly chosen, but placement of transects in blocks B and C is determined by placement in block A.

midwater trawl operation) from the 1998-2000 fall surveys were distributed to workshop participates. There was discussion about the advantage of minimal thresholding. Relational data management using Oracle is agreed to be a good approach which can be readily incorporated into new tools (*e.g.*, trawl/acoustical visualization software).

Some participants from DFO and MDMR/GMA manage their acoustic data using Femto's HDPS data structure. The HDPS archives raw data. The NEFSC does not archive raw data. The NEFSC data are logged to the BI500 postprocessor which derives estimates with 2-sec, 0.5-m depth bins, and 0.5-nmi resolution. Data to this resolution are equivalent to about 2 gigabytes per 12-day cruise (*i.e.*, about 4,000 nmi).

In regard to the TS data, it was recommended that the raw data be collected from the EK500 serial port rather than using only binned measurements from the BI500. It was agreed that raw data will be collected on future NEFSC acoustic surveys on selected transects where single-species TS data can be obtained.

The MDMR provided commercial Atlantic herring catch data that can be overlaid with the 1998-2000 Atlantic herring acoustic surveys. Concern was addressed regarding accessibility and confidentiality of commercial catch data. Implementation of VMS vessel tracking in the Gulf of Maine this year will provide more accurate information of commercial operations in real time. Canadian scientists have found VMS tracking not only useful for research and management, but the commercial fishers also have readily accepted vessel tracking as a valuable tool. The commercial vessels knew where other vessels were fishing anyway, and they would prefer to work cooperatively.

Acoustic Estimates and Variances

The discussion began with two questions: what level of accuracy is needed for estimates and variances from Atlantic herring acoustic surveys, and how will the estimates be used? Most participants are presently using the estimates to tune virtual population analysis (VPA) estimates, while Gary Melvin is presently the only participant who is using acoustic estimates as a direct biomass estimate. Gary Melvin is dealing with relatively low F values, while VPA seems to work better with high F values. The goal of the NEFSC is to use the acoustic estimates as both an indirect (*i.e.*, tuning VPA) and direct (*i.e.*, biomass estimate to anchor population models) approach for assessment of Atlantic herring.

Point estimates with confidence intervals are required. Low variance of about 25% is desirable. Geostatistics and bootstrapping appear to be useful approaches for approximating variance. Discrepancies between observed TS measurements and Foote's equation for the Northwest Atlantic herring are a major concern that can significantly affect the biomass estimates; therefore, TS needs further investigation. Design and timing of the survey are another critical element. For example, annual acoustic surveys for Atlantic herring in the Gulf of St. Lawrence began in 1985; however, a meaningful time series did not begin until 1994. This is because distributional shifts of Atlantic herring made for difficult timing and placement of the surveys. Timing and placement of the Atlantic herring acoustic survey on northern Georges Bank do not appear to be a problem given the high biomass, however surveying the nearshore banks and coastal waters of the Gulf of Maine is a problem which needs to be addressed to attain the goal of annual biomass estimates.

RECOMMENDATIONS FOR ONGOING RESEARCH AND THE NEXT WORKSHOP

Agenda suggestions for the next Northwest Atlantic Herring Acoustic Workshop include: 1) sources of error in biomass estimates, 2) TS-length relationship for Atlantic herring, 3) geostatistics, 4) survey design, 5) shallow-water acoustics, and 6) new acoustic technologies. It was recommended that the next workshop be held at the St. Andrews Biological Station in New Brunswick during spring or early summer 2002.

APPENDIX A

Agenda of the Third Northwest Atlantic Herring Acoustic Workshop, University of Maine Darling Marine Center, Walpole, Maine, March 13-14, 2001

March 13

09:00 General Scientific Goals of the Workshop
09:05 Automated Acoustic Data Logging aboard Commercial Vessels (P. Yund)
09:35 Environmental Influences on the Density Distribution of Atlantic Herring (P. Yund)
09:50 Fisheries-Independent Estimates from Acoustic Survey Data (W. Overholtz)
10:15 Break
10:20 Verifying in-situ Acoustic Measurements for Atlantic Herring (W. Michaels)
11:05 Ex-situ (laboratory) Experiments to Refine Acoustic Measurements (M. Jech)
11:50 The Role of Fisheries Acoustics in Support of the Atlantic Herring Industry (J. Kaelin)
12:10 Lunch
13:00 Cooperative Fisheries Acoustic Research in the Gulf of Maine (D. Perkins)
13:20 Atlantic Herring Assessment and Management in the Gulf of Maine (D. Libby)
13:30 Length Stratified Acoustic Estimates (C. Leblanc)
14:45 Break
15:00 A Method for Beam-Width Calibration (A. Clay)
15:50 Size Discrimination Using a Dual Frequency System (A. Clay)
16:20 Recent Multibeam Developments for Fisheries Acoustics (M. Jech for G. Melvin)

March 14

08:00 Spatial Statistical Approaches for Fisheries Acoustics (P. Sullivan)
09:15 Spatial and Temporal Analysis of Fisheries Acoustic Data from Commercial Vessel Operations (R. Claytor)
10:00 Survey Design for Atlantic Herring Acoustic Surveys in the Newfoundland Region (J. Wheeler)
11:00 Break
11:10 Discussion on Acoustic Data Management
11:25 Closing Discussions of Workshop, Ongoing Research, and Next Year's Agenda
12:00 Lunch
13:00 Closing Discussions on Estimates and Variance from Atlantic Herring Acoustic Surveys

APPENDIX B

List of Participants for the Third Northwest Atlantic Herring Acoustic Workshop, University of Maine Darling Marine Center, Walpole, Maine, March 13-14, 2001

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Publishing in *NOAA Technical Memorandum NMFS-NE*

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This series represents a secondary level of scientific publishing in the National Marine Fisheries Service (NMFS). For all issues, the series employs thorough internal scientific review, but not necessarily external scientific review. For most issues, the series employs rigorous technical and copy editing. Manuscripts that may warrant a primary level of scientific publishing should be initially submitted to one of NMFS's primary series (*i.e., Fishery Bulletin, NOAA Technical Report NMFS,* or *Marine Fisheries Review*).

Identical, or fundamentally identical, manuscripts should not be concurrently submitted to this and any other publication series. Manuscripts which have been rejected by any primary series strictly because of geographic or temporal limitations may be submitted to this series.

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The ethics of scientific research and scientific publishing are a serious matter. All manuscripts submitted to this series are expected to adhere -- at a minimum -- to the ethical guidelines contained in Chapter 1 ("Ethical Conduct in Authorship and Publication") of the *CBE Style Manual*, fifth edition (Chicago, IL: Council of Biology Editors). Copies of the manual are available at virtually all scientific libraries.

Manuscript Preparation

Organization: Manuscripts must have an abstract, table of contents, and -- if applicable -- lists of tables, figures, and acronyms. As much as possible, use traditional scientific manuscript organization for sections: "Introduction," "Study Area," "Methods & Materials," "Results," "Discussion" and/or "Conclusions," "Acknowledgments," and "References Cited."

Style: All NEFSC publication and report series are obligated to conform to the style contained in the most recent edition of the *United States Government Printing Office Style Manual*. That style manual is silent on many aspects of scientific manuscripts. NEFSC publication and report series rely more on the *CBE Style Manual,* fifth edition.

For in-text citations, use the name-date system. A special effort should be made to ensure that the list of cited works contains all necessary bibliographic information. For abbreviating serial titles in such lists, use the most recent edition of the *BIOSIS Serial Sources* (Philadelphia, PA: Biosciences Information Service). Personal communications must include date of contact and full name and mailing address of source.

For spelling of scientific and common names of fishes, mollusks, and decapod crustaceans from the United States and Canada, use *Special Publications* No. 20 (fishes), 26 (mollusks), and 17 (decapod crustaceans) of the American Fisheries Society (Bethesda, MD). For spelling of scientific and common names of marine mammals, use *Special Publication* No. 4 of the Society for Marine Mammalogy (Lawrence, KS). For spelling in general, use the most recent edition of *Webster's Third New International Dictionary of the English Language Unabridged* (Springfield, MA: G.&C. Merriam).

Typing text, tables, and figure captions: Text, tables, and figure captions must be converted to the NOAA-wide standard of WordPerfect. In general, keep text simple (*e.g.*, don't switch fonts and type sizes, don't use hard returns within paragraphs, don't indent except to begin paragraphs). Also, don't use the WordPerfect automatic footnoting function; all notes should be indicated in the text by simple numerical superscripts, and listed together in an "Endnotes" section prior to the "References Cited" section. Especially, don't use the WordPerfect graphics function for embedding tables and figures in text.

Tables may be prepared either with WordPerfect text or with the WordPerfect table formatting function. If text is used, then data should be assigned to columns by using all tabs or all spaces, but not a combination of the two.

Each figure should be supplied both on paper and on disk, unless there is no digital file of a given figure. Except under extraordinary circumstances, color will not be used in illustrations.

Manuscript Submission

Authors must submit one paper copy of the double-spaced manuscript, one disk copy, and original figures (if applicable). NEFSC authors must include a completely signed-off "NEFSC Manuscript/Abstract/Webpage Review Form." Non-NEFSC authors who are not federal employees will be required to sign a "Release of Copyright" form.

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Publications and Reports of the Northeast Fisheries Science Center

The mission of NOAA's National Marine Fisheries Service (NMFS) is "stewardship of living marine resources for the benefit of the nation through their science-based conservation and management and promotion of the health of their environment." As the research arm of the NMFS's Northeast Region, the Northeast Fisheries Science Center (NEFSC) supports the NMFS mission by "planning, developing, and managing multidisciplinary programs of basic and applied research to: 1) better understand the living marine resources (including marine mammals) of the Northwest Atlantic, and the environmental quality essential for their existence and continued productivity; and 2) describe and provide to management, industry, and the public, options for the utilization and conservation of living marine resources and maintenance of environmental quality which are consistent with national and regional goals and needs, and with international commitments." Results of NEFSC research are largely reported in primary scientific media (*e.g.*, anonymously-peer-reviewed scientific journals). However, to assist itself in providing data, information, and advice to its constituents, the NEFSC occasionally releases its results in its own media. Those media are in four categories:

NOAA Technical Memorandum NMFS-NE -- This series is issued irregularly. The series typically includes: data reports of long-term or large-area studies; synthesis reports for major resources or habitats; analytical reports of environmental conditions or phenomena; annual reports of assessment or monitoring programs; manuals describing unprecedented field and lab techniques; literature surveys of major resource or habitat topics; proceedings and collected papers of scientific meetings; and indexed and/or annotated bibliographies. All issues receive internal scientific review and most issues receive technical and copy editing.

Northeast Fisheries Science Center Reference Document -- This series is issued irregularly. The series typically includes: data reports on field and lab observations or experiments; progress reports on continuing experiments, monitoring, and assessments; manuals describing routine surveying and sampling programs; background papers for, and summary reports of, scientific meetings; and simple bibliographies. Issues receive internal scientific review, but no technical or copy editing.

Fishermen's Report -- This information report is a quick-turnaround report on the distribution and relative abundance of commercial fisheries resources as derived from each of the NEFSC's periodic research vessel surveys of the Northeast's continental shelf. There is no scientific review, nor any technical or copy editing, of this report.

The Shark Tagger -- This newsletter is an annual summary of tagging and recapture data on large pelagic sharks as derived from the NMFS's Cooperative Shark Tagging Program; it also presents information on the biology (movement, growth, reproduction, etc.) of these sharks as subsequently derived from the tagging and recapture data. There is internal scientific review, but no technical or copy editing, of this newsletter.

OBTAINING A COPY: To obtain a copy of a *NOAA Technical Memorandum NMFS-NE* or a *Northeast Fisheries Science Center Reference Document*, or to subscribe to the *Fishermen's Report* or the *The Shark Tagger*, either contact the NEFSC Editorial Office (166 Water St., Woods Hole, MA 02543-1026; 508-495-2228) or consult the NEFSC webpage on "Reports and Publications" (*http://www.nefsc.noaa.gov/nefsc/publications/*).

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