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# St. Andrews' acoustic system* of data collection and processing

by

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*System in this context is assumed to mean method, organization, considered principles of procedure (the Concise Oxford Dictionary 1958)

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## Abstract

The aim of the St. Andrews acoustic system is to provide reliable and accurate estimates of fish abundance as input to the stock assessment process. The system and its advantages in relation to other systems are described and some survey results are compared to total stock estimates.



## Résumé

Le but du système acoustique de St. Andrews est de fournir des estimations fiables et exactes sur l'abondance du poisson dans le cadre de l'évaluation des stocks. On décrit le système et ses avantages par rapport à d'autres systémes, et ou compare certains résultats d'enquête aux estimations des stocks totaux.

The Draft Terms of Reference of the CAFSAC Acoustic Workshop (Halifax Feb. 5-6, 1985) include three items (2a,b,c) related to providing a technical summary, a rigorous evaluation and progress report, and a prognosis and timetable for success of the leading acoustic systems in Atlantic Canada. The following addresses items 2a, b and c of the Draft Terms of Reference in relation to the acoustic system developed at St. Andrews, N.B.

Item 2(a)

Technical summary of the basic differences and possible technical advantages of these systems as they exist, in relation to their use in providing information relevant to fishery management.

## The hardware system

Acoustic data collection at St. Andrews is done with hardware developed at the Marine Ecology Laboratory. It is a 50 kHz system consisting of an Ametek-Straza transducer, Simrad EK50 echo sounder, MEL demodulator, Intel micro-processor and Pertek tape drive. This system differs from the MEL system in current use in that it uses a single channel of data from a single beam of the transducer. Single beam systems are electronically less complex than dual beam systems and are used for the estimation of fish abundance by both echo counting and by echo integration. The disadvantage of single beam systems is that the target strength parameter necessary for estimation on abundance must be determined by other methods (Johannesson and Mitson 1983).

Dual beam methods can be used for the estimation of fish abundance only by echo counting. The principal advantage of the dual beam method is that target strengths can be determined from the echo data. The disadvantage is that the method applies only in situations where the fish are dispersed so that individual fish are resolved as single echos by the acoustic system. Dual beam systems may prove useful for determination of target strengths of individual fish in and around the edges of fish aggregations that are generally too dense for echo counting. When these target strengths can be regarded as good estimators of the target strength of the whole aggregation, they can be used to estimate abundance by echo integration.

## The software system

The main features of the St. Andrews' software system are:

- it is an integration procedure;

- it calculates mean area scattering and related statistics within fish patches rather than along segments of cruise track;

- it utilizes an editing process that allows separation of fish echos from unwanted signals;

- it calculates geographic position and length of acoustic transects in fish patches.

The output of the software is digital data files and printouts that contain the average scattering and variance in each fish patch, a frequency distribution of the scattering levels in the patch and the geographic position and length of the acoustic transect in the patch.

The advantages of the features are discussed individually.

Echo Integration

Echo integration is the most widely used method for acoustic estimation of fish abundance. It can be used on a wide range of fish densities from sparsely distributed single fish to densely packed schooling fish. The upper limit of fish aggregation density for integration depends primarily on the acoustic frequency, the sound scattering-absorption characteristics of the fish and the vertical extent of the fish aggregation. These factors vary and an upper limit is not well defined (Lytle and Maxwell 1983). Most fish aggregation densities encountered during surveys however, seem to be below the limit and echo integration for fish abundance estimation is used all over the world (Nakhen and Venema 1983).

Echo counting on the other hand can be used to determine fish abundance only when the fish are far enough apart for the acoustic system to resolve echos from individual fish. Such distributions occur in some species at some times but it is more common for fish to be distributed so that some fish are resolved as single targets while others are detected as multiple targets. In these situations, only echo integration can produce reliable estimates of fish abundance.

It would be possible to estimate abundance by counting the singly resolved targets and integrating the multiple targets. This, however, would be a needlessly complex process to produce results that would more easily be obtained from integration alone. In addition, the procedure would require discrimination between what are single targets and what are multiple targets in the acoustic data. Because of the complex nature of sound reflection by fish, this separation is problematical and procedures that have been developed (Robinson 1981; Dickie et al. 1983) can not be considered reliable.

Average scattering

The conventional way to calculate acoustic abundance is to calculate the average volume scattering coefficient, or area scattering coefficient, for segments of cruise track or transects and to multiply by an expansion factor that is proportional to the volume, or area, of water represented by the track segments or transects. When fish are distributed throughout the survey area, this method probably results in reasonable estimates of the mean but, depending on the shape of the scattering distribution, there may be doubts about the associated variance.

Herring are typically not distributed throughout the area of possible occurrence. To locate the small areas where they are concentrated, it is necessary to survey large areas that will be found to be completely or almost completely devoid of fish. Within the small areas of concentration, the herring are often aggregated in one or several large schools that may contain all or almost all of the total stock within well defined school boundaries (Jakobsson 1983; Shotton and Randall 1982; Buerkle 1985). In such distributions, estimates of stock abundance must be based on abundance of fish within the schools.

The St. Andrews' method estimates acoustic abundance within schools as the product of the average area scattering coefficient within the school and the area occupied by the school. Both the scattering and the area of schools are estimated from replicate transects across the schools in different directions. Error estimates for the scattering can be calculated, error estimates for school areas remain a problem.

## Editing process

All acoustic survey data need editing of some sort. There are unwanted signals from sources such as surface noise, boat wakes, plankton and undesired fish species. In addition, there are often difficulties in separating fish signals from bottom signals. In herring schools the echos are sometimes strong enough to trigger the bottom pulse of the echo sounder. If the threshold at which the bottom pulse is generated is raised, some of the bottom echos will be too weak to trigger the pulse. That means there is a choice, either miss integrating some fish signal, or integrate some bottom signal. Either choice will bias the results.

One way to solve these problems is to edit the echo sounder charts and integrate only what is identified as desirable on the sounder charts. The procedure is simple and fast. During the survey the sounder chart is marked with time marks, synchronized on the second, with the digital acoustic record times. Editing of the charts is done on a digitizing tablet where the times at time marks and the depth scale of the sounder are entered. Fish patches are identified by moving a pointer to describe a 'box' around the desired signals. The box parameters, that is the times and depths of the four corners of the boxes containing the desired fish signals, are recorded in a digital data file. This file allows the processing software to process only the data in the boxes.

Bottom detection problems can also be handled by this process. By setting the bottom pulse threshold, during the survey, so that the pulse is never triggered by the fish, it may sometimes also not be triggered by the bottom signal. This results in sounder chart records where the bottom is not consistently marked by the white line, but can be easily traced through the missing bottom pulses. Integration of the bottom signal that is digitized and recorded in the echos with a missing bottom pulse is prevented by shaping the edit boxes so that their bottom edges follow the bottom contour.

The advantages of this editing process are that it saves CPU time in processing by allowing processing only in the boxes, and that it is based on visual examination and considered judgement. The process may be regarded as subjective but it is superior to mathematical procedures because such procedures cannot distinguish fish echos from those of noise or bottom as well as experienced operators of acoustic systems can.

The disadvantage of the process is the inaccuracy of depth registration on the sounder chart due to pulse length and bottom echo rise time. This is not considered a serious problem with herring where the vast majority of the fish are more than a metre off bottom. If the method was to be used for groundfish, the problem could be minimized by a precision graphics recorder.

Geographic data

All acoustic survey data can be related to fish stock abundance only through geographic position and area. The usual way of doing this is by log records of time and position of the survey vessel. When the acoustic data are to be averaged over transects it is a simple matter to keep track of the required time and position of each transect. When the acoustic data are to be averaged in fish patches it is more difficult or impossible to accurately record the time and position every time a patch of fish appears or disappears under the transducer. The St. Andrews' software therefore does this automatically; it requires only a log of time and position of the survey vessel. This is kept at 15 min intervals and is synchronized with the time marks on the sounder charts. A digital data file produced from the log records is used by the processing software to calculate the geographic position and length of the acoustic transect in each fish patch identified in the editing process. The output of the software can be plotted directly by computer. This greatly facilitates visualizing the distribution of fish patches and the formulation of analysis procedures.

Item 2(b)

A rigorous evaluation and progress report on the state or stage of development of these systems and their underlying assumptions.

The present St. Andrews' system of acoustic data collection and processing was developed specifically for herring and is based on observed fish distributions and acoustic availabilities. The method takes into account that herring are not distributed throughout the geographic range of occurrence; a large area is surveyed to locate the small areas of fish concentration. The method takes into account that acoustic availability of herring varies seasonally, diurnally and by the hour; replicate transects are run in the areas of fish concentration.

Development of the system in terms of methods for data collection and processing is complete and it is being used in surveys. Results obtained in 1984 indicate that abundance of herring in large schools can be estimated and when the whole stock is aggregated in one or several large aggregations, stock abundance can be estimated. Three sources of error in this estimate are: error in the estimate of average school scattering, error in the estimate of school area, and error in the estimate of school target strength. The error in the scattering is small and can be estimated. The error in school area is larger and methods for its estimation have not been developed. By far, the greatest uncertainty is associated with the target strength. Until in-situ methods are developed and verified, the magnitude of this error is a matter of conjecture.

When the stock or part of the stock is distributed in many smaller schools rather than a few large ones, the area of each individual school can not be determined and not all the schools are detected along the cruise tracks. For these situations, new methods to quantify stock abundance must be developed.

Item 2(c)

Prognosis and timetable for the probable success of the systems to accomplish specific aims for fisheries science in providing advice to management.

The aim of the St. Andrews' system is to provide reliable and accurate estimates of fish abundance as input to the assessment processes. A quantitative estimate of winter herring was produced for 1984. No doubt this estimate will play a role in the next round of stock assessment talks.

Success, however, cannot be measured simply by estimates made. It is the reliability and the accuracy of the estimates that determine success.

Reliability means the production of estimates on a regular basis, and it depends on two factors that cannot be controlled. First, the herring surveys are made in winter and are extremely dependent on weather. It has happened that the weather did not cooperate during the allotted boat time and no results were obtained. Second, the herring are highly mobile and variable in distribution and accessibility. It has happened that they were not found or not properly accessible during the allotted boat time. Lots of boat time, or flexible boat time, could solve these problems and make reliable estimates possible.

Accuracy means how close the estimates of abundance are to the true abundance. The February 1984 herring acoustic survey indicates a biomass of about 550 000 t of mostly 2+ fish aggregated in Chedabucto Bay. The total stock estimates of 2+ fish calculated from commercial catch statistics in May 1984 and May 1985 were about 320 000 t and 464 000 t, respectively. The acoustic estimate in only two patches of fish only a few miles apart exceeds the total stock estimate by about 86 000 t. Although the total stock estimates tend to err on the conservative side, the difference indicates that the accuracy of the estimates, particularly that of the acoustic esitmate, needs to be verified.

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