Fisheries and Oceans Canada Pêches et Océans Canada

Canadian Stock Assessment Secretariat
Research Document 98/96

Secrétariat canadien pour l'évaluation des stocks
Document de recherche 98/96

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Hydroacoustic Calibration Techniques used for southern Gulf of St. Lawrence Herring Fishing Vessels - 1997

by A. Clay[1] and R. Claytor[2]

Femto Electronics Ltd.
P.O. Box 690
Lower Sackville, Nova Scotia. B4C 3J1

[2]Department of Fisheries and Oceans
P.O. Box 5030
Moncton, New Brunswick E1C 9B6

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ISSN 1480-4883
Ottawa, 1998
Canada

Abstract

The calibration procedure and results used on small herring inshore (<45') boats to collect acoustic data during surveys and regular herring fishing activity in the southern Gulf of St. Lawrence are compared to calibrations on DFO research vessels used to conduct acoustic research surveys in Atlantic Canada. Calibrations of acoustic equipment on inshore boats provide comparable results to those of research vessels. The ability to collect high quality acoustic data from small inshore vessels is a valuable new tool for stock assessments of inshore coastal water pelagic species such as herring.

Résumé

La procédure et les résultats d'étalonnage appliqués aux petits bateaux côtiers (<45 pi.) de pêche du hareng pour l'obtention de données acoustiques pendant les relevés et la pêche du hareng dans le sud du golfe Saint-Laurent sont comparés aux étalonnages réalisés sur les navires de recherche du MPO utilisés pour les relevés acoustiques de recherche dans le Canada atlantique. Les étalonnages des appareils acoustiques des bateaux côtiers ont donné des résultats semblables à ceux obtenus avec les navires de recherche. La possibilité de recueillir des données acoustiques de haute qualité à partir de petits bateaux côtiers s'avère un nouveau moyen très utile pour l'évaluation des stocks d'espèces pélagiques côtières comme le hareng.

1. Introduction

Acoustic surveying is a non-intrusive method of determining biomass indices and distributions of fish populations. The value of these indices depends significantly on the hardware calibration. Errors in the calibration parameters can have appreciable effects on estimates of biomass indices (Fig. 1).

Hardware calibration is a routine part of any acoustic survey which occurs on research vessels. Recently, acoustic data collected by fishing vessels completing surveys or collecting acoustic data during regular fishing activity have become a more important part of annual herring stock assessments (Claytor et al. 1997; Stephenson et al. 1997; Claytor et al. 1998). Hardware calibration is as important for interpreting data collected by fishing vessels as it is from research vessels. However, because acoustic data collection by these vessels is new, the calibration of these vessels is not routine and results of calibrations have not been previously recorded. This paper reports on calibration methods used on fishing vessels and compares these results to those obtained from research vessels used to conduct acoustic surveys. Our principal question is: Can calibrations of equivalent accuracy and reliability be completed on fishing vessels? This question is important to answer because if the answer is yes, it means that the acoustic data collected by these two types of vessels can be directly compared in stock assessments.

The estimation of biomass indices from acoustic data requires two steps:

1. Determine Target Strength(TS) per kilogram(TS/kg) using fish size distributions
2. Estimate biomass by applying target strength to surveyed acoustic backscattering

The TS/kg relationship is usually extracted from the literature and applied to the calibrated survey backscatter to arrive at a biomass estimate. That is, rather than estimate target strengths for each individual research project on a particular species, a constant relationship between target strength and fish size is used. This means that, providing the backscatter can be accurately determined, the biomass indices will be comparable over time. To optimize the precision of the backscatter estimates it is necessary to do a complete system calibration of the acoustic hardware prior to each survey year.

Changes in calibration values may occur because of environmental effects like temperature or because of hardware effects such as aging in the ceramics of the transducer. These parameters affect the transmit and receive sensitivities (how the transducer converts between electrical energy and acoustic energy) of the transducer. This paper considers only calibration values resulting from hardware variables and the methods described here are the latest techniques used to maximize our ability to obtain accurate calibrations.

2. Methods

All data collection and processing for these calibrations was done using the Femto Hydroacoustic Data Processing System (HDPS). It is the same software and hardware system used for acoustic research surveys and on all the fishing vessels participating in stock assessment projects in the southern Gulf of St. Lawrence.

Two calibrations are done for each installation:

1. Ball calibration
2. Time varied gain (TVG) calibration

The order of these calibrations is of no consequence. The ball calibration is normally done at the beginning of the season but due to weather and vessel scheduling constraints, it may be postponed until a later date during or just after the season. The TVG calibration can be done while the vessel is tied to the wharf and therefore is less constrained by vessel use and weather. All calibrations must be done before any biomass estimates are produced.

To complete a ball calibration, the vessel is moved to an area of calm, clear, representative water having a depth of 20 meters or more. The water column should be clear of biology so there is no target interference. The greater the range of the target from the transducer, the wider the beam and thus a depth of 20 meters or more is preferred. The water must be calm so the that there is no relative motion between the target and the transducer. The water temperature should be representative of the water during the proposed survey period since there is some temperature dependence on the sensitivity of the transducer. Unfortunately, all these conditions can rarely be met simultaneously so it is normally a matter of evaluating the probability of a successful calibration given a series of constraints, including funding, to repeat a failed attempt.

The ball calibration involves a process of logging echoes from a calibrated sphere of known TS suspended directly beneath the transducer and on the acoustic axis or center of the transducer beam. Our system of suspension consists of three extendible rigid aluminum poles with an off-the-shelf fishing reel at one end and an eyelet at the other. The poles are temporarily attached via rope, tape, and/or clamps to the vessel such that the outboard tips are all horizontally equidistant and as far away as practical from the transducer to be calibrated. This positioning is not critical but the closer the installation is to this ideal, the easier it is to position the sphere on the acoustic axis (within ½ meter is typically fine). A typical installation would see one pole in line with and on the opposite side of the vessel as the transducer and two poles on the same side as the transducer. The angle between each pair of poles is approximately 120 degrees. The sphere is enclosed in a custom mesh bag made of monofilament line with the fewest knots possible. Twelve pound monofilament line is used to suspend the sphere from the three fishing reels. Metallic swivels are placed every 10 meters on the monofilament line to act as visual references and to prevent tangling of the lines.

To start the deployment of the sphere, all three lines are brought forward to a point at the bow and on the same side as the two poles. The sphere is then attached to the three lines. The sphere and all knots in the vicinity of the sphere are then saturated in a concentrated mixture of soap and water for about 5 minutes to ensure the rapid release of all trapped air when the sphere is deployed. With no tension on the lines and with the boat steady and no current, the sphere is lowered to a point well below the vessel and directly under the bow. Paying due consideration to the possibility of the sphere hitting the bottom, the lines are released. As the sphere falls, the line is retrieved on the reels to a point where all lines have tension. Once the sphere has descended to depth, the lines are adjusted so that the 10 meter swivel (marker) on each line is at the water line. The sphere should now be visible on the echosounder. If not, the ball must be scanned across the beam by fixing two reels and adjusting the third. Depending on the transducer beam angle and weather conditions, this could be the most time consuming aspect of the calibration, so patience and a methodical approach are required.

With the sphere in the beam, the next task is to move it to the center of the beam. Again, a methodical approach generally achieves best results in the shortest time. There are two methods that we have found most effective:

1. Peak echo voltage
2. Two point 6dB down (1/2 voltage)

The peak echo voltage method is the most typical. With this method each reel is adjusted systematically and in sequence to the point of greatest echo return. The adjustments are continued until there is no increase in echo amplitude with any adjustment. The second method is used when weather conditions make calibration difficult using the first method. It involves scanning for an approximate peak and then looking, on both sides of this peak, to determine where the echo voltage drops to ½ of the peak. The lines are then adjusted to a point ½ way between where these 6dB down amplitudes occur. Again this process is repeated sequentially for all lines until no increase is noted in the average final amplitude. The ball is now on the acoustic axis of the transducer.

With the sphere on the acoustic axis of the transducer, two or more acoustic data files providing over 1000 ball echoes are collected as if the data were from a typical survey. All transmitter, receiver, and digitizer settings must be identical to those that will be used during the acoustic data collection. If more than one configuration setting is to be used during data collection, at least two data files for each configuration must be logged. A file is considered good if it satisfies the following conditions:

1. No significant variation in the echo amplitude from ping to ping
2. No vertical movement of the target for the duration of the file
3. No or few pings with biology in the water column at or above the sphere
4. No interference from other sounders or sonars
5. No interference from such sources as bilge pumping or prop wash

These files are then archived and the field portion of the ball calibration is complete. The calibration can be made more robust by completing additional calibrations at various depths.

The second type of calibration is a time varied gain (TVG) calibration. All echosounders have a TVG stage which applies an increasing gain with time (and therefore range) to account for spherical spreading and absorption. These TVG's are not always accurate and a calibration is required to remove these inaccuracies. Some sounders do not account for absorption which can subtract 14dB(25 times) from a 200KHz signal for every 100 meters of depth. Temperature variations in the ideal TVG reach 3dB(2 times) for a change of 20° Celsius at 200KHz in 100 meters. Losses due to spherical spreading are greatest at short ranges and therefore the amplifiers must change gain most rapidly during the first few meters of the TVG curve (14dB in the first 5 meters vs 24dB in the next 95 meters). Unfortunately, for logistical reasons, 5 meters is where the sphere is often placed during ball calibrations.

The TVG calibration is accomplished by applying a dummy load, which simulates the presence of a transducer, to the transceiver and sending a known continuous wave (CW) signal into the receiver. The CW usually corresponds to the transmitter frequency but the actual voltage of the CW signal is not important as long as the output from the receiver is such that it does not saturate at the longest range (depth) of interest and is well above the noise level at short ranges. The output of the receiver is then recorded as if it were a normal acoustic data collection. Again, the configurations of the transmitter, receiver, and digitizer must be those used during the acoustic data collection. Two data files of 100 pings each from each configuration are collected and archived to complete the TVG calibration.

Having the two calibration files (ball and TVG) in hand, the generation of the calibration factors can now be done. The first step is to compute the gain (A_{TVG}) at range (R) of an ideal TVG curve:

$$A_{TVG} = 20 \operatorname{Log} R + 2 \alpha R$$

given the actual survey conditions. The alpha coefficient (α) is assumed to be constant over depth and computed using the formula developed by Francois and Garrison (1984) which incorporates operating frequency and average water depth, temperature, salinity, and pH. A second curve is computed from the data file logged during the TVG calibration. These two curves are then compared and a correction factor at each 0.1 meters is produced. The mean value of this correction factor is not significant since we are interested only in the variation from the shape of the ideal TVG curve.

After the parameters of the TVG curve are estimated, the data file logged during the ball calibration is processed for target strength(TS) in the same manner as for a TS distribution of fish (less deconvolution since the ball is on the acoustic axis. Deconvolution is a process by which the beam pattern is removed from the TS distribution during routine TS analysis). The error between the known TS of the sphere and the computed TS is then the fixed gain error which is the amount by which each 0.1 meter correction factor must be adjusted. This correction is made, and the TS software is rerun. The new computed TS is compared to the known TS of the sphere. Usually after one correction the corrected and known TS match. When this match occurs, the calibration parameters have been estimated correctly.

The results are retained and used during all subsequent processing to estimate biomass indices.

The results of the calibrations completed in this manner on fishing vessels are compared to calibrations done on DFO research vessels. The research vessels compared are the Teleost and the Creed because we have had experience with calibrations on these vessels. The Teleost is a large research vessel from the Newfoundland region for which significant effort is taken to achieve good acoustic results by using high quality equipment and calibration techniques which typically require up to 5 days to complete. The Creed is a twin hull research vessel used by DFO for the annual Gulf acoustic survey which has excellent historical calibration results. Three comparisons are made among the research and fishing vessels:

1. Echograms of the ball calibration
2. Single ball echo return
3. Ball file TS distribution

3. Results

The echogram from a Teleost ball calibration indicates a water depth of about 18 meters and a relatively constant ball echo, which is enlarged on the right side of the figure (Fig. 2). The ball calibration echogram from the Creed at the Bedford Institute of Oceanography (BIO), Dartmouth, Nova Scotia finger jetty is relatively constant throughout the 300 pings shown (Fig. 3). The 0.1 meter jitter in depth of these two images is caused by lack of tight synchronization between the digitizer and sounder and does not reflect motion of the sphere. This jitter does not affect the interpretation of subsequent biomass indices. The ball calibration echogram from a gillnetter, the Broke Again, at the Pictou, Nova Scotia wharf indicates that, even at the short range of 4 meters, the ball echo is very stable (Fig. 4). The ball calibration for the Broke Again was done in better than average conditions for fishing vessel calibrations because we were able to tie to the wharf to maintain a stable platform.

Ideally, the ball echo return should be a square envelop having a width equal to the pulse duration and an amplitude consistent with the TS of the calibration sphere (Figs. 5, 6, 7). This ideal return is drawn on the figures for reference. The full amplitude has been reached only at the last sample for the Teleost and the Creed yet, for the Broke Again, most of the samples have reached full amplitude (pulse durations are not identical and are noted on the figures). Each figure represents the first echo return from the respective ball calibration files.

The TS distributions for the calibration spheres using the final calibration constants generated by the HDPS for the Teleost, Creed and Broke Again demonstrate similar characteristics (Figs. 8, 9, 10). Of primary interest is the sharpness of the peak, at the higher normalized frequencies, which is indicative of system electronic and mechanical stability. The width of the distribution at low frequencies (less than 30 when normalized) is typically indicative of biology in the water column.

Sometimes, because calibrations of the gillnetters occur at the wharf or in very shallow water there are large amounts of biology in the water column. When this situation occurs relatively long calibrations are necessary in order to get enough good echoes to process. This situation occurred when calibrating the gillnetter S.S. Jeffrey in Alberton, Prince Edward Island (Figs. 11, 12). In a case like this, an hour or more of data may be required to be able to retain enough good echoes to process.

4. Discussion

The figures showing the echograms demonstrate that the calibrations from all three vessels are consistent Each echogram indicates no vertical motion of the target for the duration of the file, a repeatable echo, no significant biology, and no interference.

The individual echo returns demonstrate a potential problem with acoustics hardware which is that of filtering to eliminate noise. The more the signal is filtered, the more rounded are the corners of the pulse. In the case of the target echo from the Teleost and the Creed, the echo only achieves full amplitude at the end of the pulse (Figs. 5,6). Had the pulse not reached full amplitude, the calibration would be in error. Another problem is that the more rounded the echo, the more difficult it is to determine the leading edge of the pulse which is also instrumental in the calibration process. The Broke Again echo (Fig. 7) is more representative of the ideal rectangular echo return of the sphere than those of the Teleost and the Creed (Fig. 5, 6). Aside from the degradation in the precision of the biomass estimates, an echo which has a long rise and decay will tend to smear details and in some cases miss some detail altogether. The TS analysis software of the HDPS uses the peak echo amplitude and not the average when generating the TS distribution. This favors the sounders with filtering (Teleost and Creed) because the filtering is essentially averaging the echo. Also because of this, slight range jitter in the first sample of each ball echo in the Broke Again data places a minor mode at -39.4 dB. Since this peak amplitude method has historically been used, switching to an averaging approach requires some effort to determine the effects on previous data. Future work should include addressing this issue.

Finally, the results of the TS analysis on the calibration sphere should indicate a narrow range of possible values. This range is indicated by the width, at the higher normalized frequencies, of the major mode of the distribution. A range of +- 0.2 dB results in a biomass estimation error of 5% (Fig.1). Often, there may be a large range in the overall TS distribution due to biology in the water column interfering with the echo, but the width of the major mode must always be narrow to be an acceptable calibration. As seen from the comparisons of the TS distributions from the Teleost, Creed, and Broke Again, the Broke Again is certainly comparable to the other two vessels (Figs. 8, 9, 10).

In cases where considerable biology exists during calibration subjective editing of data is necessary to achieve the final calibration data (Fig.11). In these cases, more than one peak may be evident (Fig. 12). The question is then which peak is the clean ball echo. To make this determination, it is necessary to view each target echo as is shown in Figures 5, 6, and 7. Those echoes that do not follow the normal ball shape can be removed. As well, those with obvious biology in the vicinity can be extracted. With careful editing, a single peak will emerge which will be used for the calibration.

In summary, all indications of the calibrations show that the calibration done on the gillnetter, Broke Again, is as good as those done on the DFO research vessels used routinely on acoustic surveys. The quality of these calibration results from a small inshore (<45') vessel indicate that biomass indices derived from acoustic data collected by fishing vessels is comparable to those obtained during research surveys.

The calibrations we describe are only one piece in the estimation of biomass from acoustic data. They allow us to convert acoustic signals to relative abundance indices that can track population trends from one survey to the next, provided that, like any other method, conditions and methodologies are consistent among surveys. Future work is needed to interpret acoustic biomass estimates as absolute. This should include investigating the temperature stability of the transducers, inter-vessel comparisons, and beam pattern determination. Biological interactions that may affect the ability to interpret acoustic biomass estimates as absolute are variability of backscattering in high target concentrations, the relationship between target strength and fish size, and species identification. The ability to obtain reliable acoustic calibrations from research and fishing vessels provides a valuable tool for tracking fish stock trends that was not available even a few years ago. Continued research in the identified areas will strengthen this tool.

5. Acknowledgements

We wish to acknowledge the captains of all the inshore vessels we have worked on during this project. They went out of their way to accommodate our often bizarre requests and without their help and good humor none of this work would have been possible.

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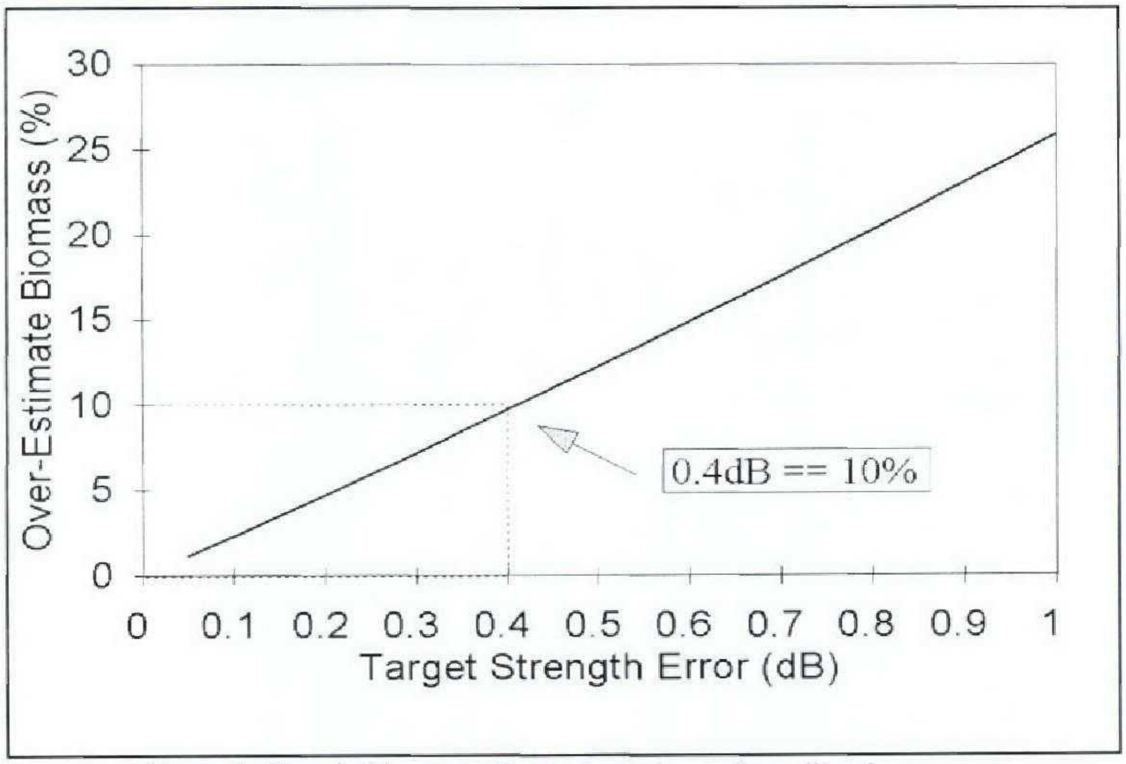

Figure 1. Error in biomass estimate due to imprecise calibration

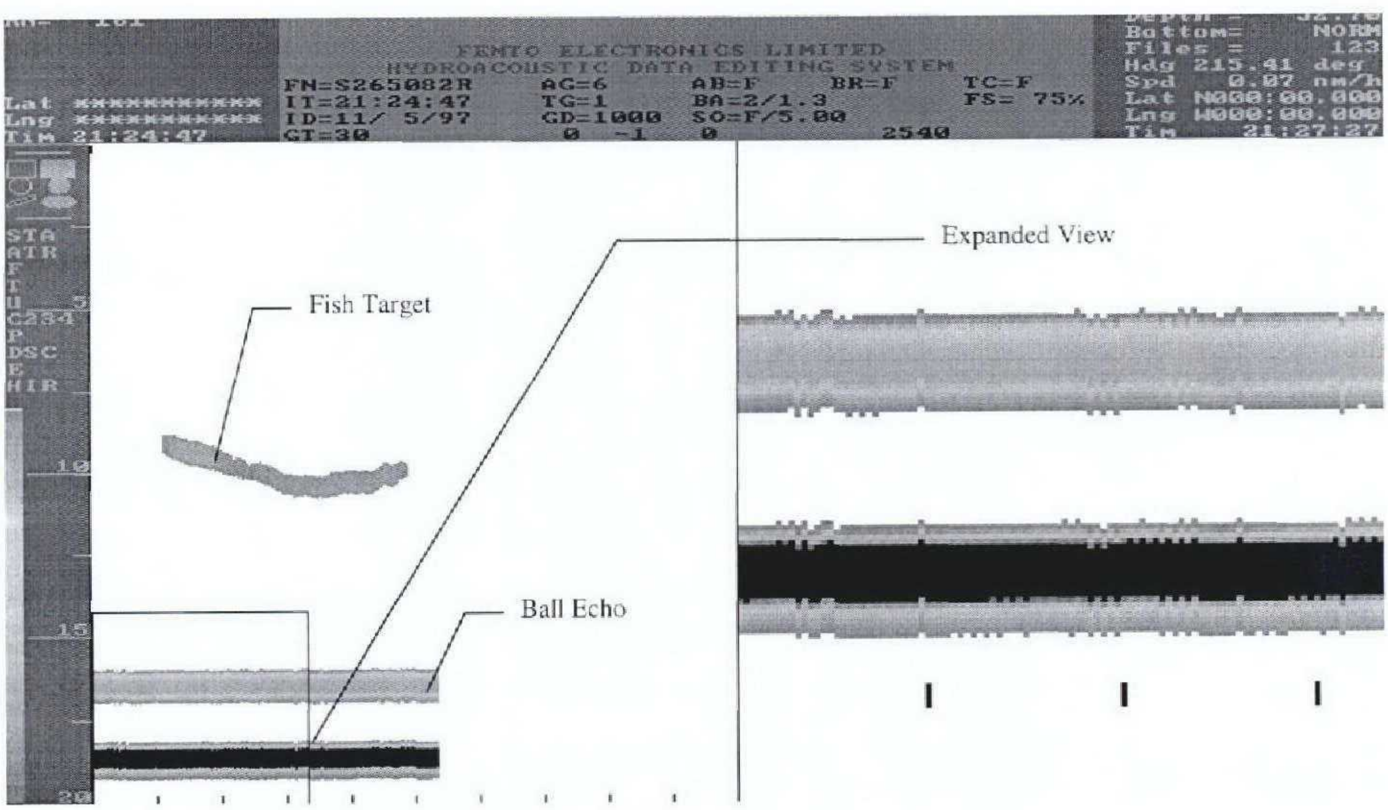

Figure 2. Echogram of Teleost ball calibration (Expanded view on right).

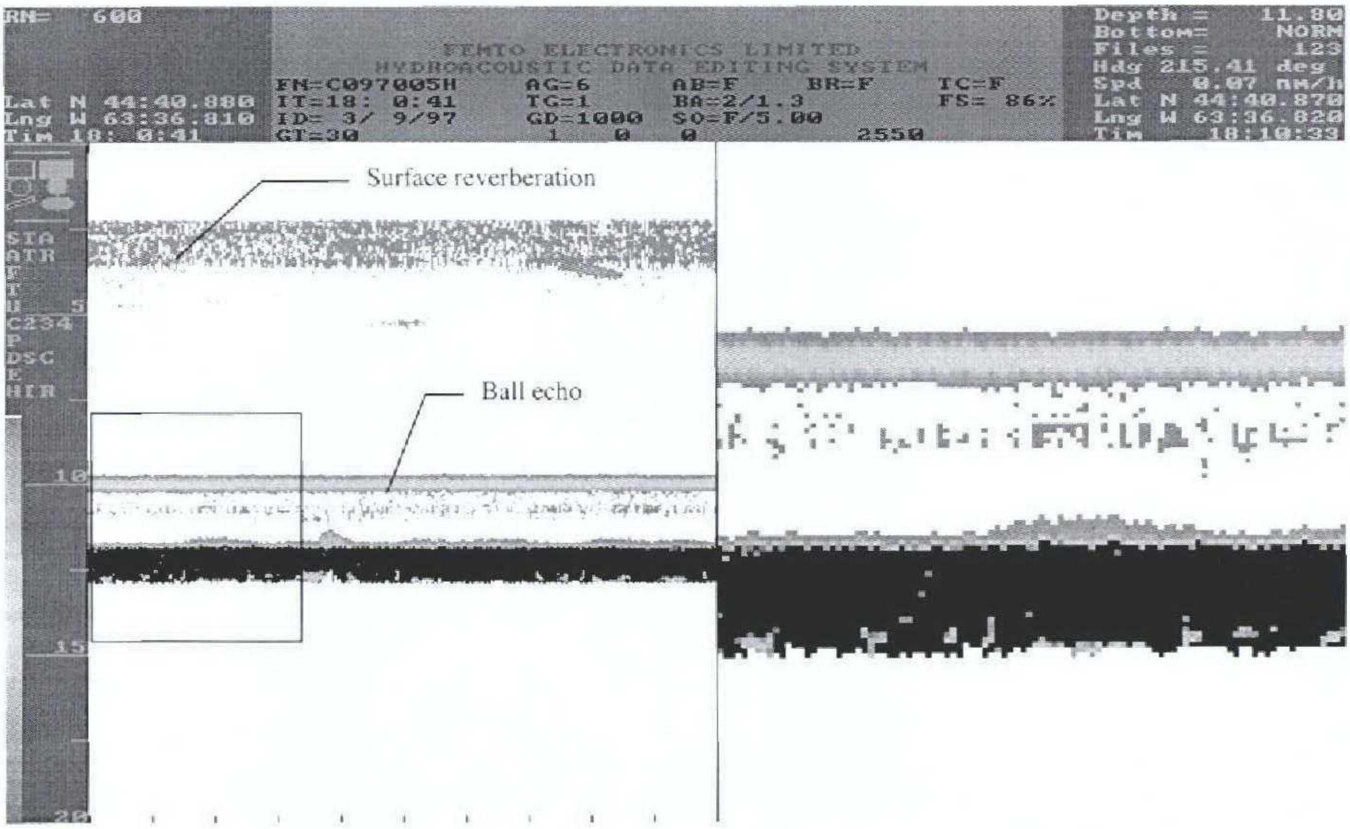

Figure 3. Echogram of Creed ball calibration (Expanded on right).

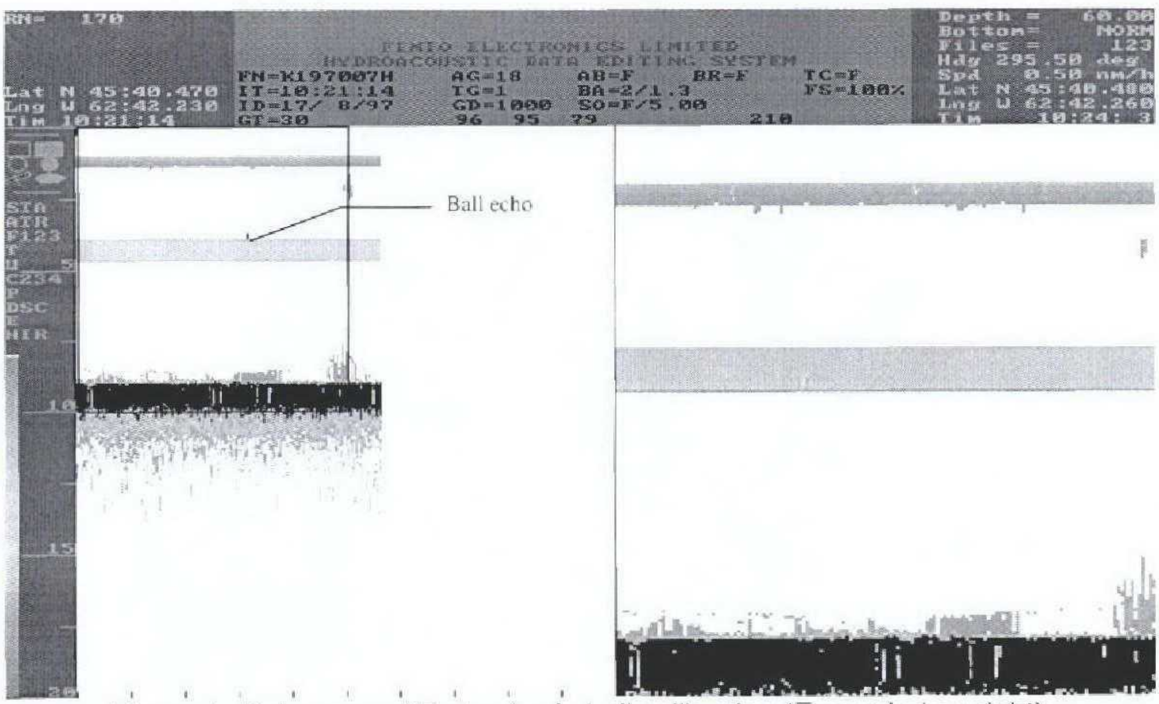

Figure 4. Echogram of Broke Again ball calibration (Expanded on right).

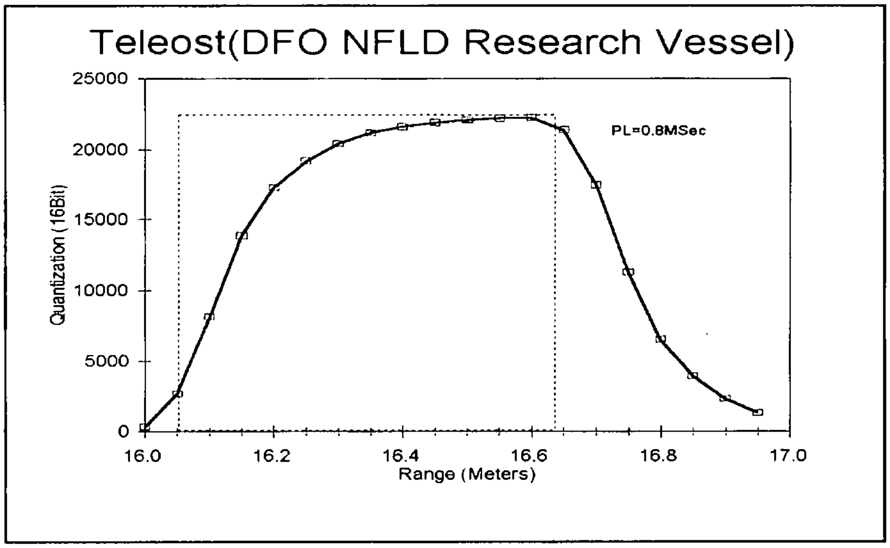

Figure 5. Ball echo from the first ping of the Teleost data file

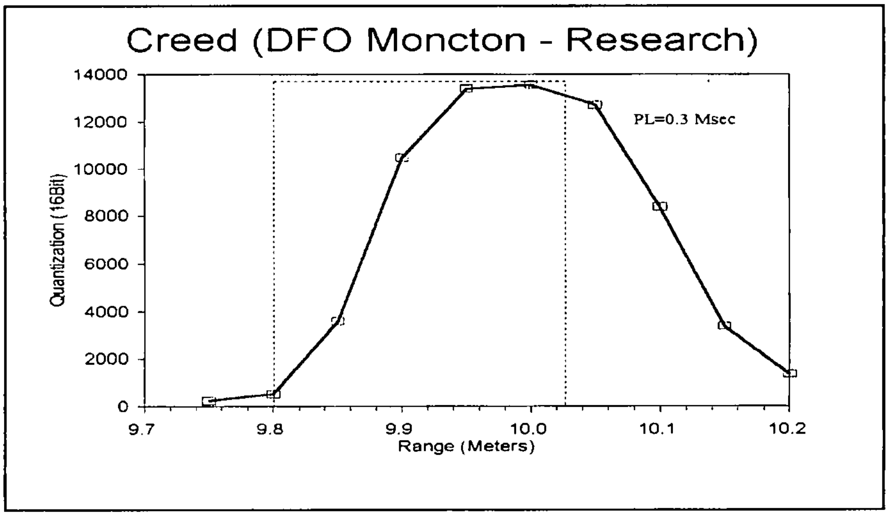

Figure 6. Ball echo from the first ping of the Creed data file

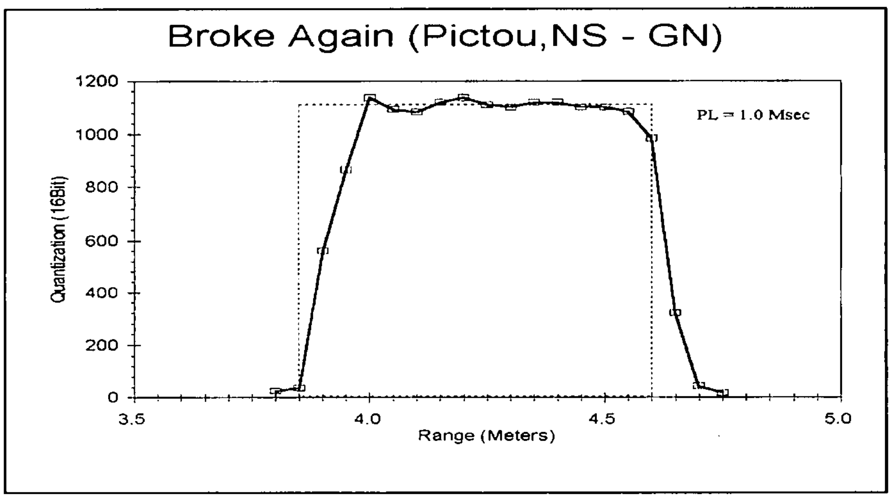

Figure 7. Ball echo from the first ping of the Broke Again data file

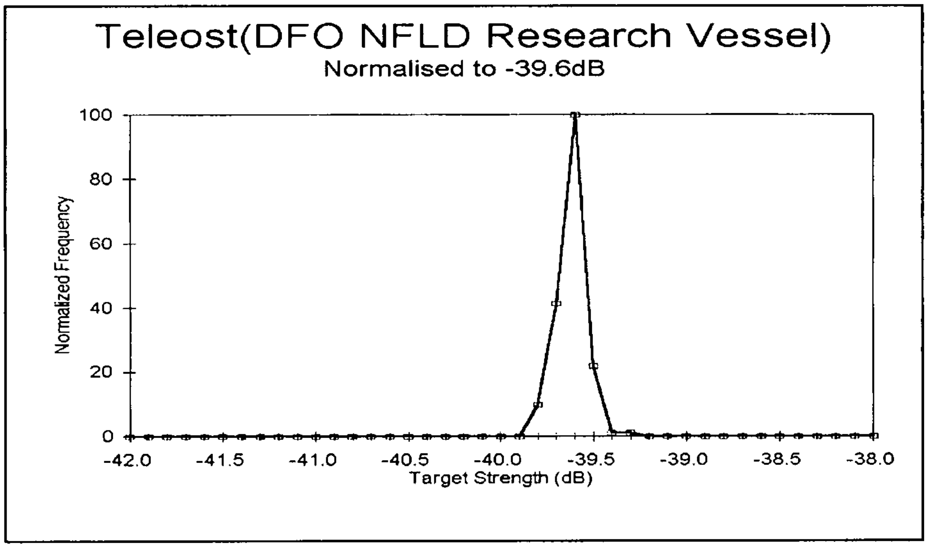

Figure 8. Target strength distribution of calibration sphere for Teleost

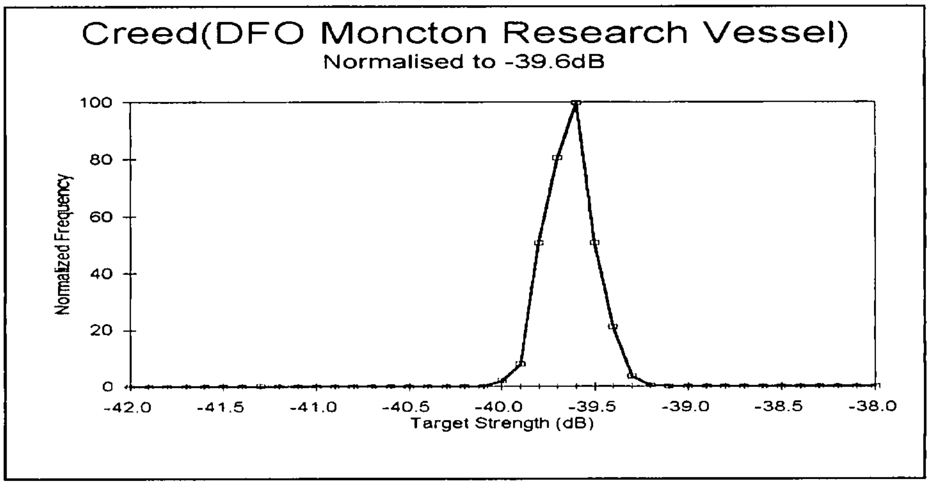

Figure 9. Target strength distribution of calibration sphere for Creed

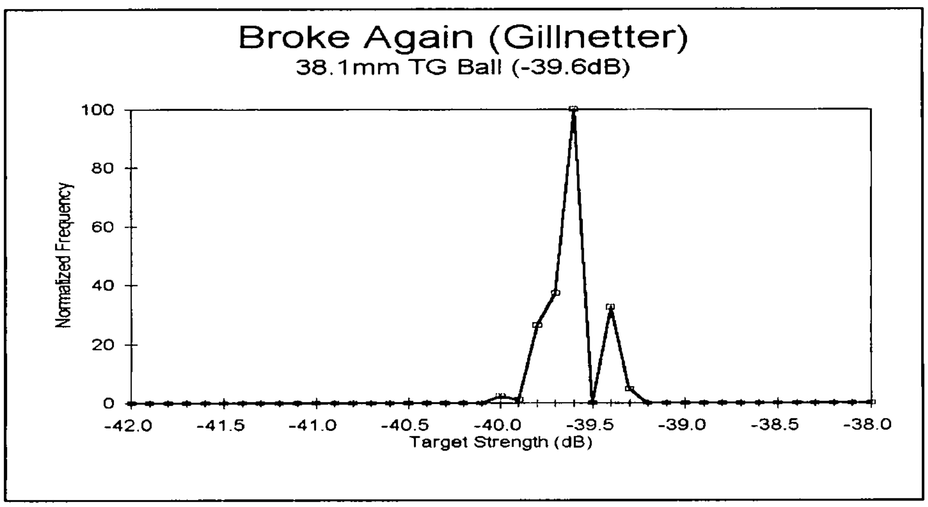

Figure 10. Target strength distribution for the calibration sphere for Broke Again

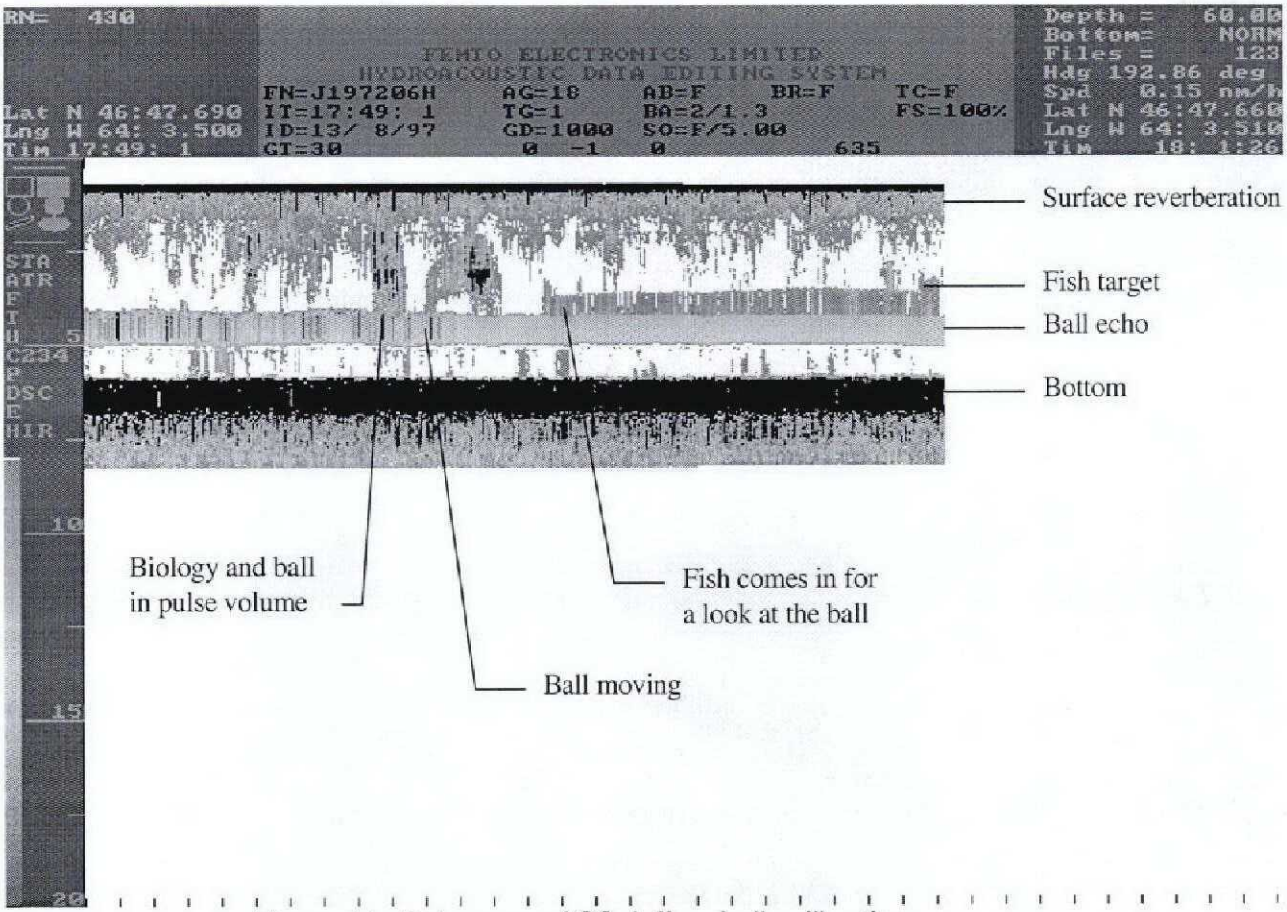

Figure 11. Echogram of SS Jeffrey ball calibration

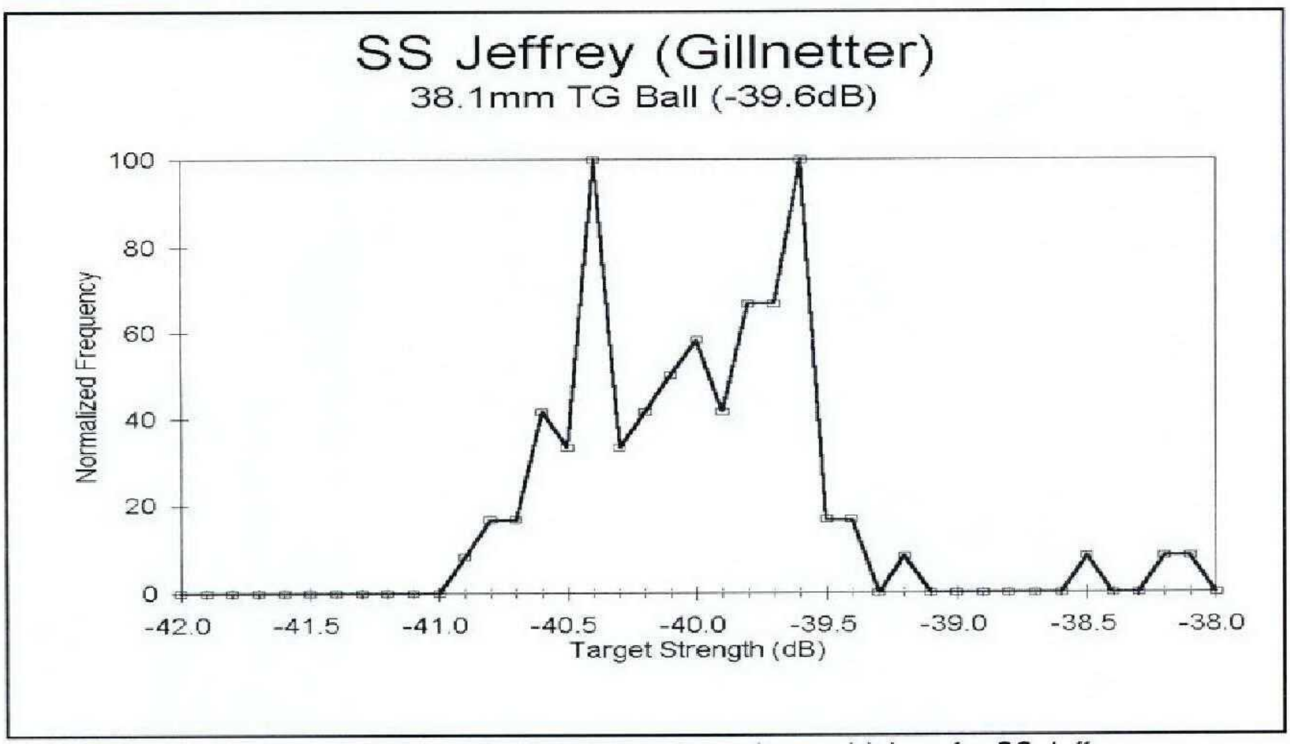

Figure 12. Target strength distribution for calibration sphere + biology for SS Jeffrey