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Commercial fishing vessels, automatic acoustic logging systems and 3D data visualization

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Over the past five years we have investigated and used commercial fishing vessels and their associated acoustic hardware as platforms for acoustic surveying and data collection. During this period we developed an automated acoustic logging system that will simultaneously record data from the ship's existing sounder, sonar, and navigation systems. The system was designed to be self contained and easy to activate. Once calibrated, the vessel's vertical echo sounder can be used for quantitative fish biomass estimates in a manner similar to a scientific echo sounder. Sonar data are collected in the form of digital images with a navigation file header. Post processing, editing, and visualization tools were developed to scale the sonar images according to range setting and tilt angle. Thereafter, both the sounder and sonar data are combined into a 3D visualization package for presentation, observation, and school area estimates. Industry based acoustic surveys of herring spawning grounds have been used to estimate spawning stock biomass and for near real-time decisions regarding harvest levels in NAFO Statistical Division 4WX since 1997. Currently, there are eight systems deployed on commercial purse seiners within the region. For the past four years data from structured surveys and fishing excursions have played a key role in the assessment of herring spawning stock biomass. While the application of the technology has been driven by a stock assessment mandate, its potential use is more far reaching. The spatial nature the data means that detailed and quantitative studies of fish behaviour, vessel avoidance, fish distribution, and target area can be undertaken from commercial fishing vessels with the addition of minimal equipment. However, quantification of sonar images is restricted to area/volume estimates as no digital amplitude data are available from the commercial fishing units.

Keywords: Atlantic herring, fishing vessels, hydroacoustics, surveying, stock assessment, visualization.

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Introduction

Prior to 1995 the Scotia-Fundy Atlantic herring stock (NAFO Statistical Division 4WX) was assessed and managed as a single stock complex with a global "total allowable catch" (TAC). It was however recognized that within the TAC, individual major and minor spawning components could be adversely affected by concentrating fishing effort on a single spawning area, especially during periods of low abundance (Figure 1). Past occurrences, such as the collapse of the Trinity Ledge spawning component, the decline in 1992 and 1993 of catches on German Bank and the rapid decrease in catches from the Little Hope area, have clearly demonstrated the potential negative effects of such activity (Stephenson *et al.*, 1996). In 1994 the herring industry expressed concern about absence of fish from traditional fishing grounds, poor fat content, and the level of effort being exerted by the roe fishery on individual spawning components. The 1995 stock assessment affirmed their concern and indicated a significant decline in stock abundance (Stephenson *et al.*, 1995). The quota was

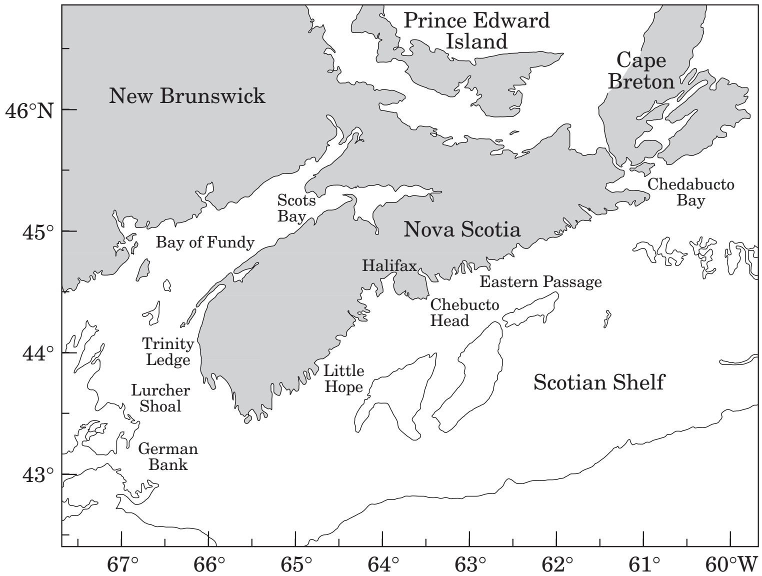

Figure 1. Map of the Bay of Fundy, southwest Nova Scotia, and the Scotian Shelf identifying the location of the herring fishery grounds and major and minor spawning components. Coastal spawning has been reported in the past along most of the southern and eastern shores of Nova Scotia.

subsequently reduced from the 151 500 t in 1994 to 80 000 t in 1995 and 57 000 t in 1996 (Stephenson *et al.*, 1996).

To provide a second level of protection within the global TAC, the Canadian Department of Fisheries and Oceans (DFO), in conjunction the herring fishing industry initiated a "survey, assess, then fish" protocol for the key spawning grounds (Stephenson *et al.*, 1999). Target catches were based on historical landings for the main spawning components within the stock (Melvin *et al.*, 2001). The basic principle of the protocol was that sufficient quantities of fish had to be observed or documented on individual grounds during the spawning season to warrant fishing. The initial process involved industry based subjective in-season surveys of spawning aggregations using the existing acoustic hardware aboard commercial herring seiners (i.e. vertical echo-sounders and sonars), captains experience, and scientific staff to estimate biomass from visual observations of distribution and density. Upon completion of a survey all participants summarized their observations, the sample data (i.e. fish size and roe hardness) were reviewed and a consensus biomass reported to the management committee. However, it soon became apparent that a more objective and quantitative approach was required if in-season surveys were to be used in the stock assessment process.

Commercial herring seiner captains, like most pelagic fishers, rely extensively on acoustic hardware and software to locate fish schools, estimate quantities, and to set their gear for optimal catches. These professionals have developed the ability to extract information necessary for a successful fishing set (i.e. species, school size, movement, and position in the water column) from onboard acoustic systems. On several occasions experienced captains have been observed cutting a small quantity of fish from a large school to meet their specific requirements (i.e. market or hold capacity). Unfortunately, their observations and conclusions could not be quantified without a method to document actual sonar and echo-sounder data.

In recognition of the subjective nature of the biomass estimates from fishing observations and in-season surveys, a project was initiated to develop an automated recording system which would simultaneously log a ships echo-sounder, sonar, and GPS digital telegrams from existing commercial hardware. The main objective of the project was to develop a system, which would allow fishing captains to accurately record the acoustic information they use to estimate fish biomass without the major expense of purchasing new hardware. In addition, the system had to be simple to operate, and reliable to allow for unattended data collection. The ship's echo-sounder was also calibrated in accordance with standard protocol for single beam system's so that quantitative biomass estimates could be obtained (Foote *et al.*, 1987; MacLennan and Simmonds, 1992).

The program to develop an automated logging system and the tools for 3D visualization/quantification of acoustic data began in 1995 and enlisted the efforts of DFO, the herring fishing industry, Femto Electronics, and the University of New Brunswick. A number of subsequent programs evolved under this initiative. This report concentrates on the adaptation of the automated

Table 1. Summary of acoustic hardware aboard the two commercial herring seiners used to test and deploy the automated logging system.

Vessel name	Type	Model	Frequency (kHz)	Beam angle
"Margaret Elizabeth"	Sounder	Simrad EC–210	50	14°
	Sonar	Furuno CH-16	150	6.5°
"Island Pride II"	Sounder	SeaTex HE711	50	18°
	Sonar	Wesmar SS265	160	7°

logging system to existing acoustic hardware aboard commercial fishing vessels, our current applications and our progress to date in the area of data quantification and 3D visualization of data collected from commercial fishing vessels. Details of the progress on the 3D visualization and quantification of multi-beam sonar data are presented in Mayer *et al*. (2001).

System description

The original logging system was comprised of two separate computing facilities. The first consisted of a personal computer (PC) connected to a Femto J9001 Digitizer and interfaced with the ship's echo-sounder and global positioning system (GPS). The echo-sounder's key pulse was used to synchronize the collection of analog output data. Annual time varied gain (TVG) and sphere calibrations were performed according to accepted standards (Clay and Claytor, 1998). The second PC interfaced to the vessel's GPS and was equipped with an image capture card connected to the ship's sonar. All hardware was plugged into a single power bar. Pushing the on button initiated the automated logging routines in both computers. The only prerequisite for operation was that the ship's acoustic gear be activated prior to starting the automated logging system. Only the central processing unit (CPU) and digitizer remained on-board during normal fishing operations. Downloading of data required a monitor, keyboard, and backup tape drive.

The automated acoustic logging unit was designed to be flexible and adaptable to most commercial sounders and sonars. To date the system has been connected to six different sounders and seven sonars, however sonars must have a video output or option for a video output to be utilized by the system. During the past five years a number of modifications have been made to both the hardware and the software. Of significance is the conversion of the logging module from DOS to Windows operating system, the reduction to a single computer for data collection and the installation of exchangeable hard drives. In addition, whenever possible a FEMTO DE9320 Digital Echosounder connected to the ship's transducer was used to replace the onboard equipment. Currently, there are six systems deployed amongst the 4WX herring fleet. The original two systems, installed aboard the MV "Margaret Elizabeth" and the MV "Island Pride", which use the early technology (i.e. two computers) and software are still fully operational after six years. Four new units were purchased by the Pelagic Research Council (an industry group formed to promote collaborative research) and deployed in 1998; three fixed (i.e. utilizing a hull mounted transducer on a commercial fishing vessel) and one portable. The latter is a completely independent unit, contained in a towed body, which can be deployed from almost any size vessel capable of lifting 250 kg.

The information presented in this report is data collected by the two original logging systems, although any of the systems would produce the same types of output. Details of each ship's acoustic hardware are provided in Table 1. It should also be noted that the testing and operation of these systems was voluntary and that vessels did not receive any financial benefits. The cost of installation, additional hardware, and calibration was, however, covered by the project.

Software

Over the course of the program several versions (Ver 5.6–Ver 5.8) of the HDPS software (Hydroacoustic Data Processing Software, Femto Electronics Ltd) have been used for logging, editing and echo integration. All versions are backward compatible with a standardized output format. Several modifications were also made to the HDPS to incorporate the sonar logging module. These include a standard set of input parameters within a configuration file that allows sequential incrementation of image data files over several days, variable capture rate for sonar images, logging directories and summary algorithms. During normal operation the screen capture rate is set for intervals of 180 seconds and saved in Targa format (tga). The interval can be reduced to a minimum of 16 seconds when greater detail is required. All data are digitally stored and geo-referenced in a file header. Sonar editing and 2/3D visualization is achieved using the HDPS output format and in-house computer software.

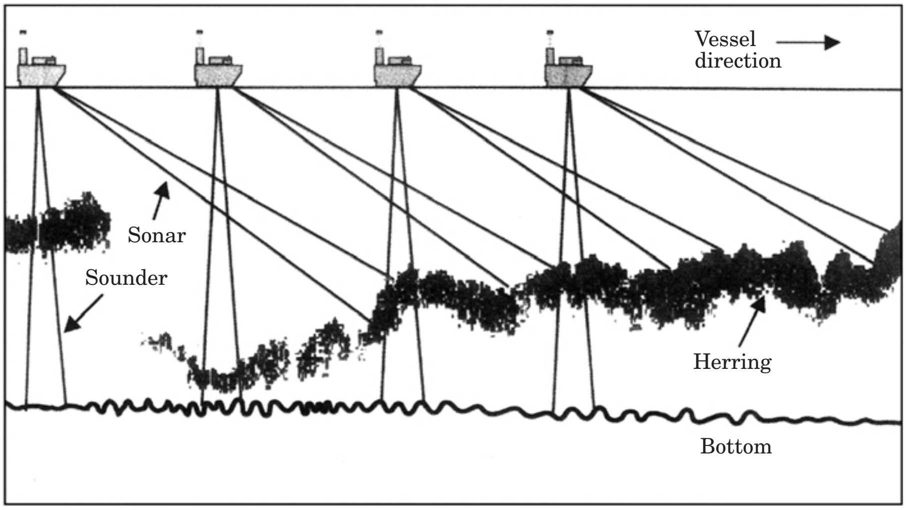

Figure 2. Schematic of echo-sounder and sonar ensonifying a school of herring at four time intervals as the vessel moves over the fish. The ping rate of the sounder is typically set at 1^{-1} and the sonar image captured at 180-s intervals.

Once activated, the computer automatically initiates the sounder and sonar logging modules of HDPS. Figure 2 shows a schematic of how the data are collected relative to the vessel. Echo-sounder logging is continuous at a ping rate of 1^{-1} while sonar information is digitized at a preset time interval which can be reduced to a point where successive images overlap. An example of data collected by the system is displayed in Figure 3 and includes a standard echogram and two images collected by the MV "Margaret Elizabeth" on 23 January 2000 off Chebucto Head, Nova Scotia.

Data are typically downloaded from the vessel's computer to a backup tape or to removable hard drive, then burned to CD for long term storage. Editing and initial biomass estimates are undertaken by individuals familiar with characteristic herring echograms using HDPS for removal of the bottom and non-fish echoes (i.e. noise) from standard echograms. Echo-integration is then performed within HDPS to compute a single distance weighted mean area backscatter (S_a) for each transect. Each transect is then weighted to arrive at a single distance weighted mean S_a for the survey area. The fish target strength is estimate from industry length frequency samples and the Foote equation (Foote, 1987). Thereafter, a biomass estimate can be obtained using standard acoustic survey protocol (Melvin *et al.*, 2000).

To incorporate the sonar data each "tga" file must be edited to remove non-fish returns such as bottom if the tilt angle and range is sufficient to ensonify bottom, interference from other sonars of similar frequency, and/or wake from another vessel. The initial step involves positioning each image on the screen and manually in-putting information regarding the sonar range setting and tilt angle from the first image file in the sequence. These values are then set, as the default and new input is required for changes only. The S_a values from the integrated echogram file and water depth are automatically extracted from the appropriate files and added to the existing header of each image file (Figure 4). The semi-automated process within HDPS requires approximately ten to 15 minutes to revise 100 sonar files. Once processing is complete the non-fish targets can be removed from each sonar file using either the editing tools provided with HDPS (a somewhat cumbersome process) or the user friendly image editing package developed at UNB (TargaEditor). Both approaches provide identical output files for 2- and 3D visualization of the data.

Visualization

The ability of HDPS to capture, in digital format, the amplitude profile from the vessel's echo-sounder, sonar images and GPS data was critical to the 2- and 3D visualization of information collected by commercial fishing vessels. It also paves the way for detailed studies of fish behaviour, vessel avoidance, fish distribution relative to the survey vessel, targets unavailable to traditional vertical echo-sounders, fish mapping and horizontal area of targets. To meet the program objectives, a versatile visualization package (TargaEditor) was developed to display and edit sonar images in 2D, to generate 3D displays of sonar images and echogram traces, to combine the two data sets in 3D space and to provide area (m^2) estimates of fish schools (Figures 5

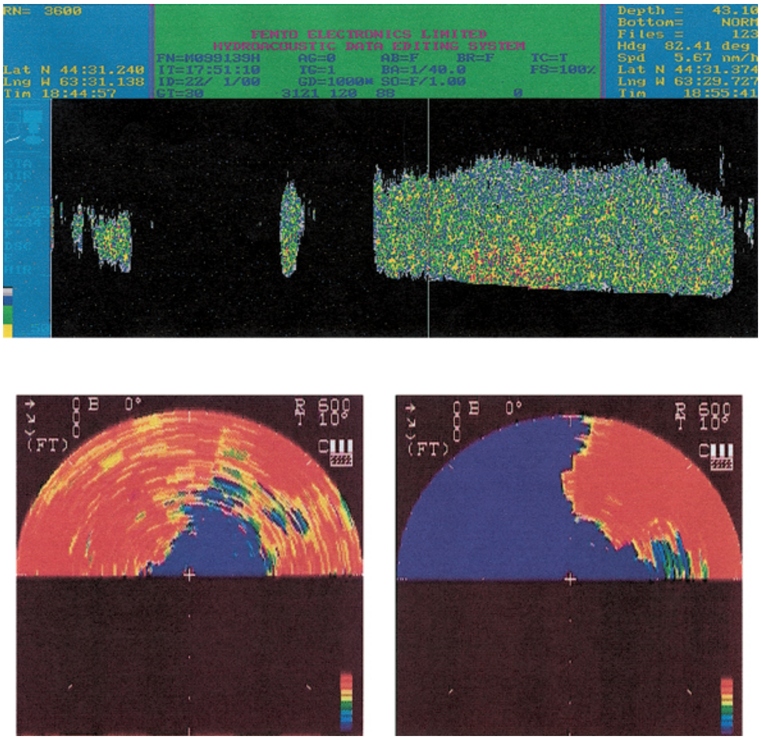

Figure 3. Ten minute echogram (600 pings) and two sonar images collected by the "Margaret Elizabeth" on 23 January 2000 from an over-wintering aggregation of herring off Chebucto Head, Novia Scotia. Note the echogram has had the bottom removed for integration while the sonar images are unaltered.

and 6). The software will accept several different types of sonar output including HDPS, Simrad EK500 scientific echo-sounder and the Simrad MS 900 sector scanning sonar. Future versions of the software will include the ICES recommended data exchange format HAC (Simard *et al*., 1997) and the new Simrad EK 60 echo-sounder when available.

The Windows 95/98 and NT version of TargaEditor contains dropdown menus and a tool bar to display 2D and 3D data and to access editing functions for sonar images. Figure 6 shows the main window of the software with menu and toolbar options. In this case a single echogram file (3600 pings) from 23 January is presented in 3D within the viewing window. Because the data are in 3D the vessel track can be examined from any viewpoint. In addition, activating the feedback box and the area operation functions allows one to draw, in 3D space, a polygon or series of polygons for which the area is calculated. No echogram editing occurs in the TargaEditor. Data are read directly from output files of compatible storage formats common to several commercial acoustic editing packages. Several on-screen image editing tools are available including global removal of a specific colour and deletion of a polygon or rectangular section of the image. The objective of the exercise is to produce an image with only the fish or other targets of interest remaining (Figure 4). A feedback box provides information specific to the image being edited. While the editing is a bit time consuming, only those images that actually contain targets need to be edited in detail.

Once a sonar image has been edited, the image must be converted to 3D before any quantitative estimates of school area can be made. Thereafter, the image is added to the transect list (Figure 5) to be incorporated into the vessel track. Figure 6 shows the combined vessel track and the sonar images in 3D space. The polygon function can then be used to draw and calculate target area (m^2). Output data are provided via the feedback box. In this example the time interval for screen capture is three minutes (180 s), thus the gap between successive images. By increasing the rate of capture it is possible to overlap sonar images and to identify the extent of the school or schools within the swath of the sonar (typically 200–400 m). It is also possible to examine both the horizontal and vertical perspective of the survey area to determine if the fish schools are continuous or segmented. Currently, the software does not have 3D contouring or kriging. Future versions are likely to contain an option for volumetric estimates of density gradients within fish aggregations.

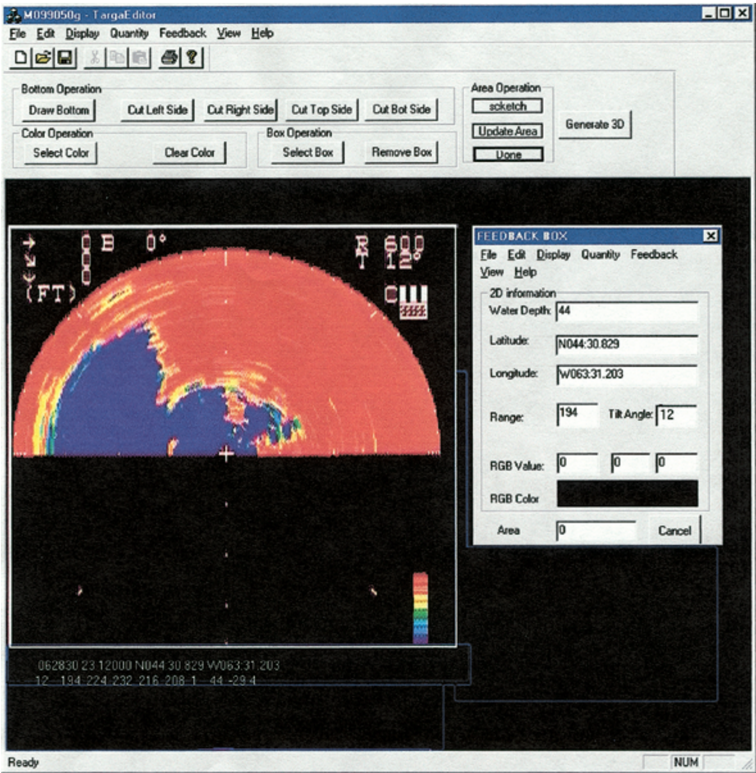

Figure 4. Example of a single unedited sonar file and feedback box displayed in the TargetEditor. The numerical text beneath the image is the file header information which includes date, latitude, longitude, tilt angle, range setting, image position (used for scaling), water depth, and S_a value directly beneath the vessel.

Implementation and applications

The first automated acoustic logging system was deployed on the MV "Island Pride II" between 15 September and 15 October 1996 for testing and evaluation of operational capabilities. Instructions where given to the vessel's captain to engage the system whenever they felt sufficient quantities of fish were observed to warrant recording. On 1 November, a second system was installed aboard a vessel, the MV "Margaret Elizabeth", with a different acoustic hardware configuration (Table 2). Aside from a few software glitches encountered during the testing, both logging systems have been found to reliable. Several thousand hours of data have been logged during the past five years.

Data collected by the automated acoustic recording systems falls into three broad categories; standard fishing operations, structured industry surveys and integrated surveys. Figure 7 provides an example of survey tracks for each data category. The upper panel illustrates a typical vessel track of a seiner once it has located a school(s) suitable for setting. Recordings from fishing operations, which do not follow any standardized survey design, have been primarily used to test the system's reliability and have typically been activated during the search phase of the night's fishing. However, if sufficient coverage of the search area is available an estimate of observed biomass can be obtained. Analysis of these data involves the integration of that portion of the vessel track considered to be representative of the school(s), estimation of coverage area (rectangular or polygon) from sonar images and the extrapolation of integrated fish densities.

Structured industry surveys typically involve several vessels in a two phase design (i.e. search then survey) using randomly selected transects within a defined area (Melvin *et al.*, 2000). These surveys are usually conducted on spawning aggregations of herring and the survey coordinated by an experienced staff member. However, there have been several occasions when a vessel with logging equipment has encountered a large aggregation of fish, established transects through the aggregation and undertaken a survey on their own initiative. The first independent survey occurred on the night of 9 October 1997, when the Island Pride documented 194 100 t ± 32 500 t of herring in 14.95 km^2 (Melvin *et. al.*, 1998).

Integrated surveys or surveys which involve both scientific and commercial fishing vessels have an

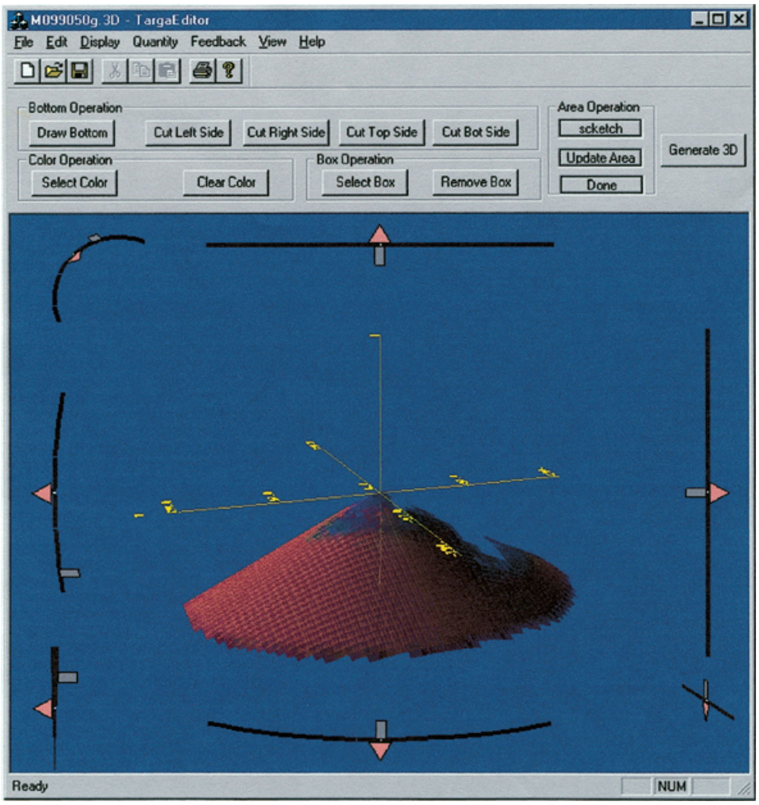

Figure 5. The 3D view of the sonar image presented in Figure 4. Note that shading has been used to highlight the left side of the image.

advantage when working among the active fishing fleet. On the night of 18 September 1997 the first cooperative survey was undertaken using the Canadian RV "Teleost" and the two commercial purse seiners equipped with automated logging systems (Figure 7). The survey area was divided into two compartments; the active fishing area and the boundary waters. The total coverage was 85.74 km^2, 69.06 km^2 by the RV "Teleost" and 16.68 km^2 by commercial vessels. The importance of the integrated survey was that it demonstrated research and commercial vessels can complement each other to provide an overall estimate of fish biomass in the area. The heaviest concentration of fish occurred where the fleet was fishing and was not accessible for surveying by the research vessel due to the vessel's size and clearance restrictions. The research vessel was useful in confirming the absence of significant schools in the larger area not surveyed by the commercial vessels.

Survey timing of spawning aggregations was also found to be critical to the observed biomass on the spawning grounds. An extensive survey (1026 km^2) undertaken 21 and 22 September 1997 from Lurcher to Southern German Bank observed 33 078 t $\pm$ 6065 t in 1028 km^2. Less than two weeks later an industry survey documented approximately 215 000 t in 10.29 km^2 on German Bank (Melvin *et al.*, 1998). The ability to undertake a survey when the fish are present is critical for accurate estimates of biomass (Stephenson *et al.*, 1999). In Canada, research vessel scheduling does not allow the flexibility to react on short notice. This can only be achieved through industry based surveys.

Since the development of the automated acoustic logging system, industry based surveys have become a key factor in assessing the status of the 4WX herring stock and the partitioning of fishing effort among the main spawning areas. Details of how the program developed, current applications, and the incorporation of data from commercial fishing vessels into the Regional Assessment Process (RAP) are presented in Melvin *et al.* (2000).

Discussion

Estimates of fish biomass using hydroacoustics have been undertaken since the late 1960s and have, by convention, relied upon single beam, downward looking, single and multi-frequency echo-sounders (Craig and Forbes, 1969; Forbes and Nakken, 1972). Improvements during the 1980s in acoustic hardware,

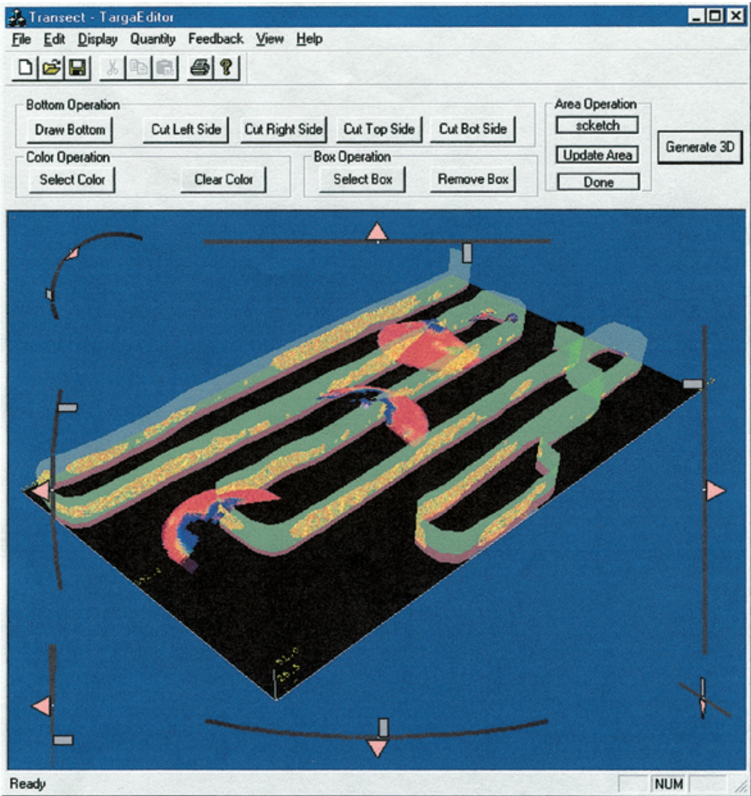

Figure 6. Combined 3D display of vessel track and selected sonar images from a commercial fishing vessel survey undertaken on 23 January 2000. Selection of "Area Operation" menu will allow a polygon to be drawn around school(s) for area (m^2) determination. The vessel track and fish distribution are from a single HDPS data file, looking southwest to northeast. Dimensions of the rectangular box are 1105 by 1889 m.

standardized calibration procedures, multi-frequency applications and new models of scattering properties improved reliability and increased the accuracy of measurements (Brandt, 1996; Foote *et al*., 1986). Recent advancements in computer technology and digital data storage have also led to enhanced data display and analytical tools. Today, quantitative acoustic surveys are used throughout the world to assess fish stocks,

Table 2. Summary of recording nights from fishing excursion and structured surveys in 1998 and 1999. The difference between logging nights and analysed nights is largely due to the systems being left on while the vessel was in port over a weekend or the absence of navigation data resulting from the GPS being disconnected or turned off.

	1997	1998	1999
Fishing excursions:			
Logging nights	11	92	184
Analysed nights	11	84	143
Structured surveys:			
Acoustic surveys	3	8	29

however, they are still constrained by the available research vessel time and the difficult task of collecting a representative sample (i.e. groundtruthing) of the acoustic targets.

Traditionally, acoustic surveys have involved the use of one or more research vessels equipped with a downward looking echo-sounder following a series of transects (usually randomly or systematically selected) within a predefined stratum. A good review of the technology, survey design and applications is provided in MacLennan and Simmonds (1992) and more recently in the proceedings of the ICES International Symposium on Fisheries and Plankton Acoustics (Simmonds and MacLennan, 1996). The data from these surveys, once edited to remove unwanted targets or noise, are integrated to determine the mean area backscatter along the transect and within the survey area. Target strength estimates, based on length frequency data, are then applied to determine fish density and extrapolated to the survey area. Biomass estimates are, however, based solely upon observations beneath the vessel.

For any survey, acoustic coverage area is statistically enhanced over traditional survey approaches (i.e. trawl

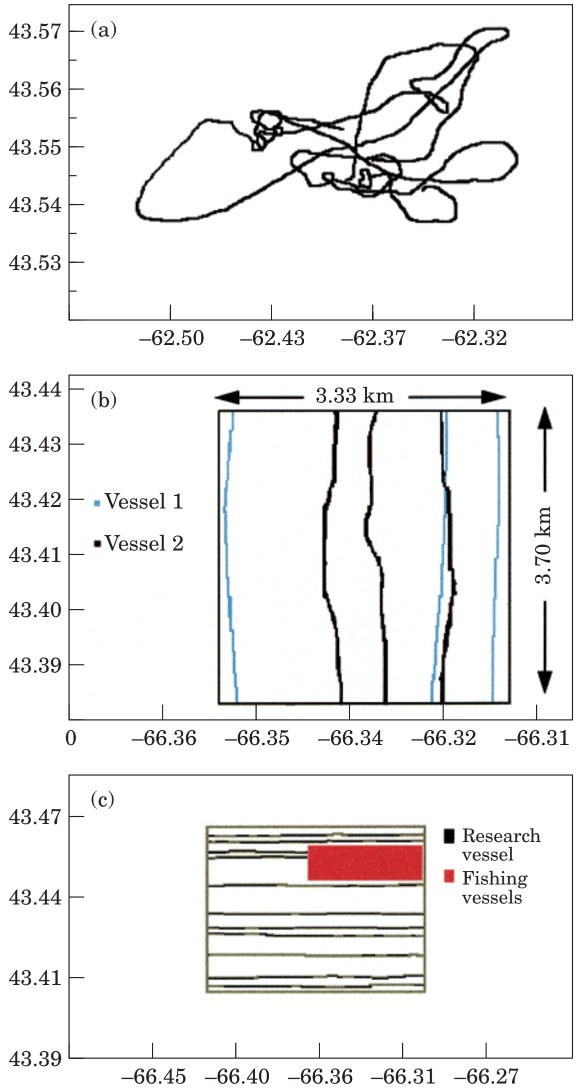

Figure 7. Summary of the vessel tracks for (a) a typical fishing track once an aggregation of fish is observed, (b) an industry based survey using two vessels, and (c) a combined industry/ research survey.

surveys), but it is still relatively small when compared with the overall survey area. Aglen (1994) in his review of sources of error in acoustic estimates of fish abundance points out two potentially serious sources of error in estimating biomass; along-track dead zones and vessel avoidance. Dead zones are those areas within the water column where fish are undetectable and typically occur near the surface and bottom. When fish are close to the bottom or appear to extend into the bottom, it is difficult to separate the two. In shallow water the bottom dead zone will average about 0.5 m, yet in deep slope water the zone may exceed 10 m. At the other extreme many pelagic fish species demonstrate diurnal vertical migrations where they move from the bottom to disperse in the surface waters. In many cases, especially for larger vessels with deep drafts, the fish can occupy the water above hull depth and are thus unavailable to traditional acoustic gear. Without some mechanism, such as sonar for looking upward or off the vessel track, the investigator has no information on whether or not fish are being excluded from the survey.

Vessel avoidance may be another serious source of error if only a downward looking sounder is employed for echo integration and biomass estimates, especially if the target species is distributed near the surface. The reaction of fish to an approaching vessel depends upon a multitude of factors. Several authors have documented the behavioral response of fish under varying conditions and situations. Soria *et al*. (1996) report the avoidance patterns of small sardines (*Sardina pilchardus*) and anchovies (*Engraulis encrasicolus*) in relation to school size, structure and position in the water column. The authors clearly demonstrated a vertical compression associated with horizontal movement to an approaching vessel and the effects on biomass estimates, but within a limited range. Diner and Masse (1987) have shown a range dependent and vessel speed related response as well as seasonal and diurnal differences for the sardine, *Sardina pilchardus,* while Misund and Aglen (1992) found a relationship between avoidance swimming speeds and sound-propagation conditions. For herring, horizontal avoidance of vessels have been reported by Mohr (1971), Misund and Aglen (1992), Misund *et al.* (1996), and Engas *et al.* (1995).

Regardless of the triggering mechanism or the reaction of fish to stimuli, the fact that vessel avoidance can and does occur has a major impact on any acoustic estimate of biomass. Without reliable information on what is occurring around the vessel the investigator has no indication that the survey actually reflects the abundance of fish. The principal author of this paper has personally witnessed events with herring where the fish covered several square nautical mile in the surface waters (Simrad SR240 sonar), but were undetectable by the hull mounted EK 500 (Browns Bank, September 1998). If the sonar had not been available, no fish would have been documented within the survey area. In all cases this occurred after dark during the summer feeding period.

In today's high tech world, most fishing vessels are equipped with navigation equipment (GPS/DGPS), an echo-sounder and many purse seiners have one or more sonars. The fishers utilize the acoustic hardware to locate, to determine the distribution (vertical and horizontal) and to estimate quantities of fish prior to setting their gear. The quality of the equipment varies from extremely poor to state-of-the-art. However, assuming that the electronics are relatively stable and that the echo-sounder can be calibrated, these vessels can become valuable survey platforms which operate within

the fishery throughout the season. For pelagic fish species, sonar information, both sector scanning and omni-directional, is critical to the observer's perception of where the fish are located relative to the vessel, the size of fish schools, and their behaviour. In many cases the sounder would reveal few or no fish directly beneath the vessel, yet large schools of herring can be observed at distances of 200–1000 m on either side of the search track. While the commercial fishing sonars are not quantifiable at the moment, using conventional acoustic assessment methodology, they do provide important information on the distribution of fish, the number of schools, and the horizontal area relative to the survey track.

The development of an automated sounder/sonar logging system for deployment aboard commercial fishing vessels was a critical step in the inclusion of industry based acoustic biomass estimates into the stock assessment process and provides a direct mechanism for fisher's input to the process (Melvin *et al.*, 1998; Stephenson *et al.*, 1998). The advantages of using commercial fishing vessels are numerous. Vessels equipped with an automated logging system are on the water almost nightly and available to survey throughout the entire fishing season. Large multi-function research vessels generally require booking several months in advance for a survey and available time is restrictive. In addition, captains familiar with acoustic survey protocol can set-up a survey whenever they see something they would like to document. This means that information once considered anecdotal about the vast amounts of fish they observed just before or after the research survey can now be quantified. Groundtruthing of species composition and size is also relatively easy. This is particularly true for purse seiners which, due to the small mesh size of the seine, collect a representative sample of the fish present. By working in conjunction with the fleet, samples can be obtained from the survey vessel (assuming they fish after a survey) or other vessels fishing in the area. Commercial and research vessels can also complement each other during a scheduled survey with the commercial vessel operating amongst the fleet (likely where most of the fish are located) and the research vessel covering the boundary areas.

For the 4WX herring stock, the automated logging system has provided a mechanism to undertake surveys of individual spawning components within the stock complex on very short notice. The commercial fleet typically conducts surveys as herring move on to the major spawning grounds. Timing of the survey(s) is determined from industry reports and biological factors (i.e. gonad development stage). Data analysis is usually completed within 48 hours of the survey and the harvest levels on spawning grounds based on near real-time data. In the event that another wave of spawning fish arrives on the grounds the survey is repeated and a new biomass estimate for the stock component determined (Melvin *et al.*, 1999). Because harvest levels are based on observed biomass, the approach has added a second level of protection for the key spawning components and minimizes the possibility of over-fishing within the global TAC.

The automated logging system also provides a means to undertake research to address specific questions on fish behavior and vessel avoidance. Past studies have employed expensive sonars (Simrad SR 240 and SF 950), prohibitive to most institutes, aboard research vessels to examine these questions (Misund, 1997; Misund *et al.*, 1996; Pitcher *et al.*, 1996; Freon *et al.*, 1996). Arrangements can be made with fishing vessels to either charter the vessel or negotiate terms to undertake a specific study. The key feature of the system is that it is adaptable and that all data are stored in digital format and geo-referenced, making it possible develop specific application software. It also pre-empts the tedious task of digitizing video images (Gerlotto *et al.*, 1994). Visualization software has also been developed to display and to quantify the sonar data in terms of school area in conjunction with traditional sounder data.

Future considerations

The system described in this report has limitations imposed by the hardware used to collect the data. The ability to estimate area backscatter from the commercial systems ultimately depends upon the quality of the echo-sounder and the stability of its electronics. Although commercial fishing sonars are multi-beam systems, very little quantitative information regarding the amplitude profile of individual beams or the volume backscatter can be extracted from the images. In 1998 Simrad released the SM2000 multi-beam sonar. The relatively inexpensive sonar is capable of providing raw (pre-beamformed) or beamformed data for each of its 128 beams at rates up to 20 pings s^{-1} within the range setting of its 180° coverage. This represents complete water column and bottom coverage from individual beams stored in a digital format (Mayer *et al.*, 1998, 2001). The system can be employed to investigate many of the concerns associated changing target strength off the vertical axes, vessel avoidance, school dynamics, and provides sufficient data for comprehensive bottom mapping. Another system, which uses sideways looking transducers to address the concern of off-track coverage, is currently under development by Femto Electronics Ltd.

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