# Current technology of fisheries acoustics based on analyzed acoustic data using SonarData's Echoview

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## ABSTRACT

In fisheries acoustics, the scientific echo sounder is the typical instrument for estimating the biomass of aquatic organisms and for studying their ecology. There are key technologies of analysing acoustic data from echo sounders as follows: 1) Fish tracking techniques for counting the number of fish especially in rivers and lakes, and also to provide behavioural characteristics such as fish speed and direction, and their depth distribution. 2) School detection techniques allow fish schools to be detected automatically for obtaining morphological, bathymetric, and energetic characteristics. 3) Acoustic species identification techniques use various characteristics of aquatic organisms, such as the frequency-dependence of their backscatter (dB difference and three-colour techniques), and geometric and energetic characteristics. The use of scientific echo sounders has been expanding. For example, seabed classification techniques place the focus on acoustic characteristics of the seabed to categorize fish habitat and to search for mineral resources. Meanwhile, there is a movement towards the use of new instruments such as mutibeam and scanning sonars for the same purposes as echo sounders. Sonars cover a wider area and provide higher resolution compared to conventional echo sounders, and provide one more dimension to observe schools in various ways. For example, 4D display gives changes of morphology and behaviour of 3D detected schools according to time. Inspection technique (a view of cross section of the school) provides a hint of the internal structure of schools. A combination of 3D schools and 3D sea bottom (generated either from the sonar data set or from electronic charts such as C-map) gives improved overall understanding. Quantitative morphologic and energetic school parameters can be generated and exported to text formats for quantitative study. Echoview has been developed to provide access to the latest technologies. In this paper, representative examples of above techniques are introduced using Echoview.

## INTRODUCTION

Single and split beam echo sounders, multibeam sonars and scanning sonars are essential instruments for fisheries acoustics. The acquisition and analysis of data from echo sounders need to be very reliable to estimate precise abundance of aquatic resources and to study their ecology. Meanwhile, commercial sonars have started to be used for the purpose of scientific survey. The main output for most sonars is the video image (Gerlotto *et al* 1999). This has not been satisfactory for quantitative purposes as the scientist can not determine the effects of the different settings, and calibrating the beams is difficult.

Over the past two decades, the performance and operation of sounders and sonars, and their software package have greatly improved with the rapid development of micro-electronic technology. Increased processing speed and improvement in storage devices together with the development of new software tools has allowed new concepts in the analysis of acoustic data. The huge amount of sonar data collected makes an acquisition and storage procedure indispensable. Once these raw digital data are extracted, it becomes possible to reconstruct the images of fish schools.

Acoustic data analysis technology for stock assessment of aquatic organisms, their behaviours and habitat classification are of increasing importance. The technology can be applied to tools to improve the estimation of biomass, identify among species, and improve target strength estimation. An effective way to explain current technology is to use analysis software. This paper introduces the latest technology of fisheries acoustics using various data from echo sounders and sonars in SonarData's Echoview.

## METHODS

The Echoview acoustic analysis software can read data from many echo sounders including Simrad (EK500, EK60, ES60), Kaijo (KFC3000), Furuno (FQ80), and BioSonics (DT4000/5000/6000). It also supports the HAC exchange format (Simard *et al* 2000) for acoustic data. Multibeam sonars such as the Kongsberg Maritime EM3002 and EM710, Simrad Mesotech SM20/2000, Reson SeaBat 6012, 8101 and 8125 are also supported, along with the Furuno FSV-30R and Kongsberg Mesotech MS1000 scanning sonars. Raw variables (data channels) logged from an echo sounder are displayed conventionally as echograms after applying any required calibration adjustments. It can be run on raw variables from many data files at the one time for rapid data processing. Understanding the concepts of the flow of data through the program is essential for performing advanced analyses (Higginbottom *et al* 2000). Figure 1 shows the data flow from raw data from acoustic instruments to outputs of display and analysis result. Preliminary data analysis such as noise removal, application of a grid, and identification of regions of interest is often necessary and can be easily performed in Echoview.

## RESULTS

### Fish tracking technique

Echoview uses a fish tracking technique called the Alpha-Beta tracking algorithm (Blackman 1986). This algorithm selects single targets as candidates for appending to a track. Once identified as a candidate, a target is assigned a measure which determines the track allocation process. The measure depends on weighted component distances from the predicted location, and the target strength (TS) and time difference to the last target in the track. The allocation process is completed and all tracks are filtered according to the track acceptance criteria. A track is closed once the maximum ping gap is exceeded. Closed tracks are tested against the criteria for both the minimum number single targets and pings.

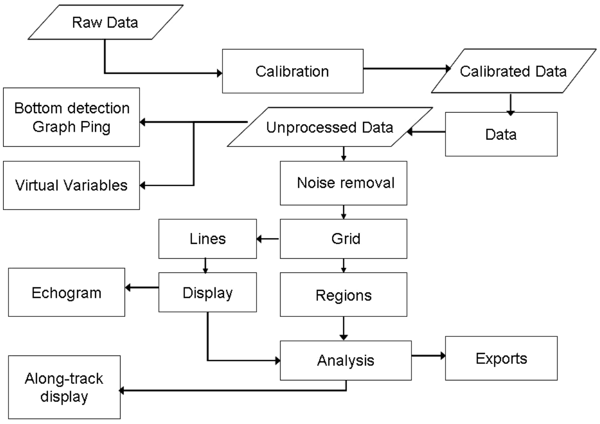


Figure 1. Flow chart of data in Echoview.

Fish tracking can be used for fish counting and behavioural studies (Kieser and Mulligan 1984). Stock assessment of salmon in Alaska is a typical example for using fish counting. To understand behaviours of fish precisely, outputs of this technique such as swimming direction horizontally and vertically, change of distributed depth, swimming speed, and tortuosity are very useful. Figure 2 shows an example study using fish tracking. This technique can be also utilized to obtain TS which is a scale factor to calculate the biomass of aquatic resources. *In situ* TS measurements, TS measurements of free swimming and suspended fish in tanks, and mathematical models are used in order to obtain accurate TS values. The mean TS of tracked fish can be processed to become the representative TS of the species.

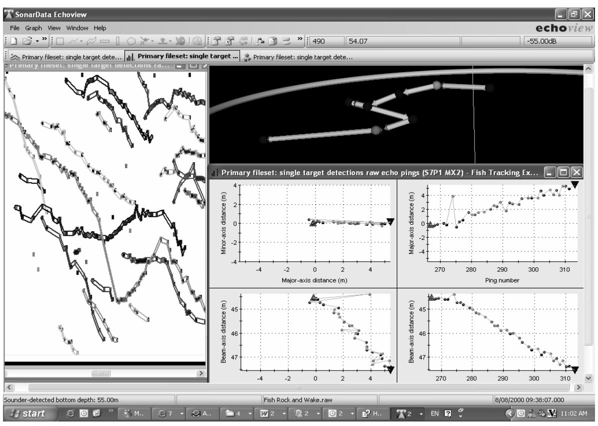

Figure 2. Fish tracking echogram (left), 3D tracked fish (top right), 2D projections graph (bottom right). To find the position and movement of the fish in the beam precisely, 2D graphs (Minor-axis distance vs. major-axis distance, major-axis distance vs. ping number, beam-axis distance vs. major-axis distance, beam-axis distance vs. ping number) are very useful. 3D visualization can provide easier understanding of the change of location of fish.

## School detection technique

In broader terms, school parameters fall into five general categories. The first is positional, for example, longitude, latitude, depth, time of day and season and are related to the position of the school in time and space. The second is morphometic, that is, shape as seen on the echogram e.g. area, length, perimeter, thickness, horizontal and vertical roughness coefficient etc. The third is energetic which is total, mean, maximum acoustic energy reflected and indices of internal school variation. The fourth is environmental, describing the immediate environment of the school, e.g. temperature, salinity, seabed substrate and topography. The fifth is biological, which is the taxonomy of the schools and associated variables e.g. length, weight, age etc (ICES 2000).

Acoustic school detection technique can provide morphological, bathymetric, and energetic characteristics of school that correspond to the first, second and third categories (Barange 1994). Figure 3 shows an example of morphological and bathymetric descriptors of a school. Before applying the school detection technique a minimum threshold should be set in order to exclude the data surrounding the school. Although there are many studies regarding optimisation of the threshold data when detecting schools, the ICES study group on echo trace classification has suggested a threshold for school detection of -60 dB for pelagic schools. Regarding school detection algorithms, school candidates should meet the minimum requirements for length and height. Candidates that meet the relevant criteria can be linked to one another to form a larger candidate. The two linking distances form the vertical and horizontal semi-axes of an ellipse. The ellipse is, in effect, moved around the boundary of a school candidate. If any part of any other school candidate falls within the ellipse, a link is created between the school candidates. Finally, schools are rejected if they are smaller than the specified minimum length and height.

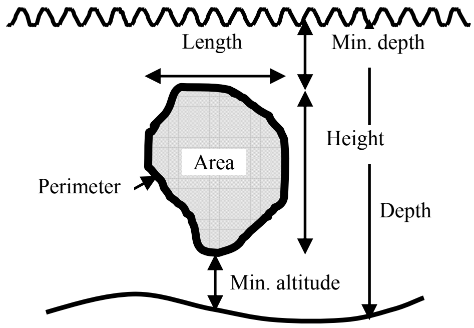


Figure 3. Morphological and bathymetric descriptors of a school.

## Acoustic species identification technique

The process of "scrutinizing" should be done to estimate biomass of target species. This process is to select echoes from targeted organisms and to remove noise and unwanted signal e.g. sea bottom, bubbles. It is not always easy to choose echoes from only targeted species, because multiple species are mixed together, and some species are distributed close to sea bottom etc. To decide echoes from targeted ones accurately, the above school categorisation are often used. To obtain biological information and to confirm species in the echogram, net sample collection is often carried out. However, if acoustic species identification can be used, time and cost for ground-truth sampling will be reduced. Therefore, species classification is important as it may allow direct acoustic stock evaluation, species by species, and school by school. This would be a great improvement on the classical method which produces a global biomass estimate which must be split into its different specific components, for instance by using catch results (Horne 2000).

The following two major techniques for species identification are developed based on the difference in the frequency characteristics of aquatic organism scattering. First, dB difference (or the difference of mean volume backscattering strengths ($\Delta$MVBS) among frequencies) is a typical technique used widely. There was an example study which used two frequencies (38 and 120 kHz) to identify krill and walleye pollock in the Pacific Ocean off Hokkaido, Japan (Figure 4) (Kang *et al* 2002). ΔMVBS was described as

$$\Delta MVBS = MVBS\ (120\ kHz) - MVBS\ (38\ kHz) \quad (1)$$

The ΔMVBS was derived by subtracting the mean volume backscattering strength (MVBS) of 38 kHz from the MVBS of 120 kHz. The second is the three-colour technique. Three colours, which were converted from the representative frequency characteristics among three frequencies, indicate three different species. This method was developed by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) for identifying similarly distributed species (Figure 5) (Kloser *et al* 2002).

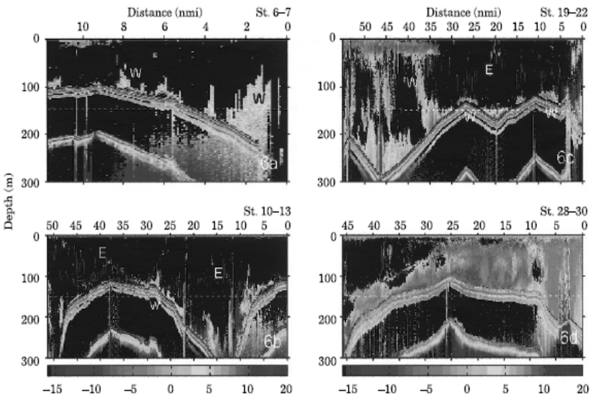


Figure 4. The echograms of ΔMVBS in four areas. Station numbers are shown at the top right on the horizontal axes. The echoes with an uppercase letter ''W'' are attributed to walleye pollock, those with ''E'' to krill. Note that the horizontal scales are different for each echogram.

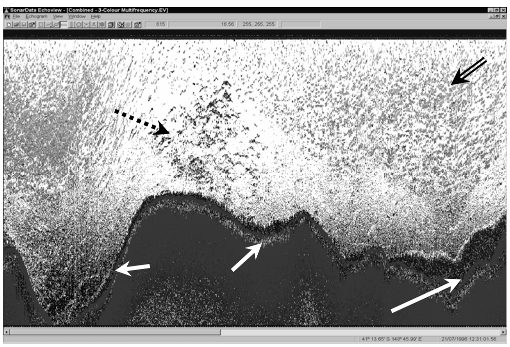

Figure 5. Three colour technique. The dotted-line arrow shows large gas bladder fish (whiptails, morid cods), the two-line arrow shows small swimbladder fish (myctophids) and the white arrows show orange roughy.

### Seabed classification (RoxAnn-like) technique

There are various purposes for classifying the seabed. Fishermen have used changes in appearance of the seafloor echo to identify fish habitat association. Geologists have searched for flares or bubbles from the seafloor to find mineral deposits or other exploitable resources. Safety managers have monitored sediment or obstruction on the seafloor in ports, estuaries and other important navigation channels.

There is a relatively simple way to classify the seabed using a single beam echo sounder (Kloser *et al* 2001). This technique uses the first and second echoes from the sea bottom. The tail of the first seabed echo is increasingly scattered on acoustically rougher surfaces. Integrating a tail portion of the first seabed echo estimates seabed roughness. The total acoustic pressure reflection coefficient is an excellent descriptor of seabed hardness (the second seabed echo reflected up and down twice from the surface is proportional to the 4th power of the acoustic pressure coefficient). Integrating the whole second echo can be used to estimate seabed hardness. Figure 6 shows the display of hardness on the cruise track and echogram as well as a video shot (Jordan *et al* 2002). Figure 7 shows an example of a study indicating seabed fields categorized using first and second echoes from sea bottom in outside of Echoview.

### 4D visualization

Water-column data from multibeam and scanning sonars has been used for visualization and analyses of schools. Sonars cover a wider area and provide higher resolution compared to conventional echo sounders, and provide one more dimension for studies of swimming and avoidance behaviours, schooling behaviours, fish migrations and for mapping and abundance estimation of fish near the surface.

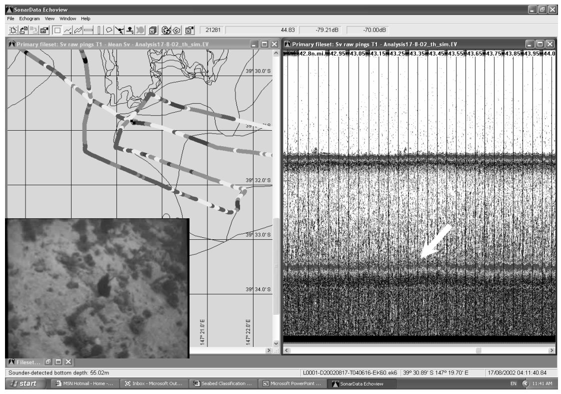

Figure 6. Hardness on the cruise track (left) and an echogram with second echoes shown by the arrow (right). Greyscale shows the intensity of hardness of seabed echoes. Video shot for the comparison with result from the echo sounder is also shown. A dataset collected near Deal Island, the Kent Group of Islands, Bass Strait, Australia.

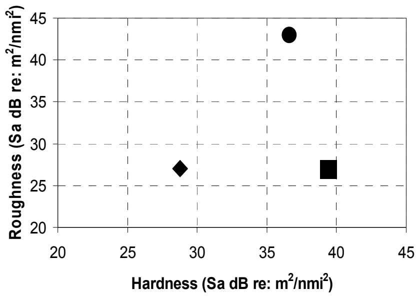


Figure 7. Seabed classification using roughness and hardness coefficients. Circle indicates reef, diamond sand, square sparse sponge. The results were confirmed by underwater video.

There have not been many studies that integrate morphology- and behaviour of 3D schools with time. 4D display can provide the dynamic changes of shapes and movement of 3D schools according to time. Figure 8 shows movement of 3D schools on the 3D sea bottom based on time. This technique supports an accurate view of when and where fish or plankton aggregate. Furthermore, it can be applied to observe how this varies in relation to external parameters, e.g. environmental or hydrographic variables. Then, it should be possible to determine how an aggregation varies in relation to the biology of the stock e.g. age structure or stock state is necessary.

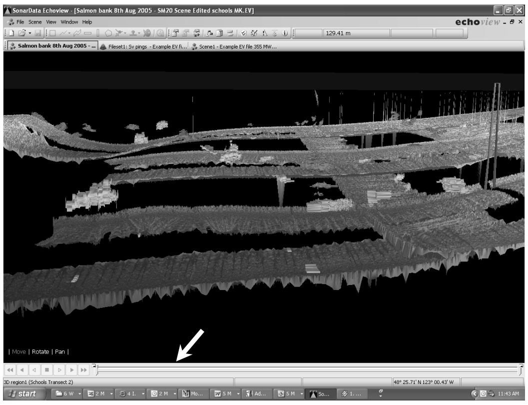

Figure 8. Detected 3D schools in grey on the seabed surface sweated by multibeam sonar (Kongsberg Mesotech SM20). The 3D schools can be controlled by the time scale bar, shown by the arrow.

### Inspection technique

There is little information about internal structure of schools. A scanning sonar, that is Furuno FSV-30R, has various modes such as horizontal (H), vertical (V), slant, and the target-locked which has a pair of pings horizontally and vertically. Those diverse mode data can allow fish school to be observed in various aspects. Using target-locked mode, the intersection between H and V pings is able to see internal structure of a fish school (Figure 9). The data can be exported other software e.g. 3Dview (RMR Systems Limited) to be able to display inner structure of a school.

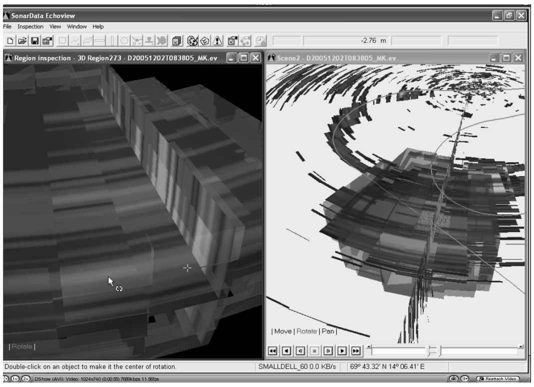

Figure 9. Inspection window (which is the cross section of the school (left)) and extrapolated 3D schools using H and V pings (right).

### Visualization and analysis of 3D schools

To understand better the relationship between schools and seabed and/or to visualize 3D schools on a precisely described sea bottom, 3D schools can be displayed on the sea bottom surface using data from electronic charts (C-map) or the sonar data set being analyzed. When presented and analysed together, these can provide valuable information about the behaviours of the species observed, population dynamics, and surrounding environment. Figure 10 shows a 3D school and its location using sea bottom surface, transparent cruise map with latitude and longitude, the coast map (surface and raster image).

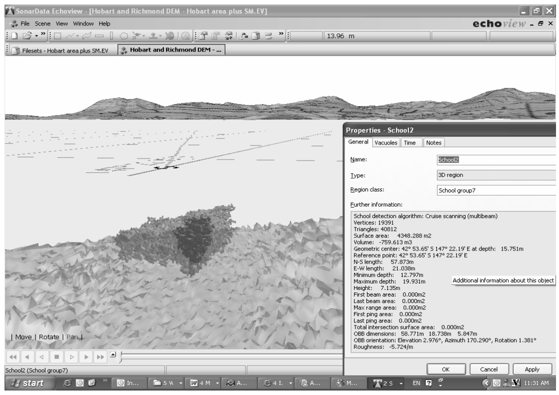

Figure 10. The 3D school has been created using two school detections at different threshold levels. This allows for the visualization of the dense area of the school in the middle (shown quite dark) and peripheral school area (shown lighter). A bottom surface created from the sonar data is also shown. 3D school parameters may also be displayed to the screen.

**Table 1**. Metrics and integration variables of 3D school

| Variable | Unit |
|---|---|
| Surface_area | $m^2$ |
| Length_North South | m |
| Length_East West | m |
| Depth_minimum | m |
| Depth_maximum | m |
| Height | m |
| Volume | $m^3$ |
| Geometric_center_latitude | degrees |
| Geometric_center_longitude | degrees |
| Geometric_center_depth | m |
| OBB_length 1, 2, 3 | m |
| Roughness | $m^{-1}$ |
| Vacuoles | - |
| Total_vacuole_volume | $m^3$ |
| N_sigma_bs | $m^2$ |
| Volume_integration | $m^3$ |
| Sv_mean, min, max | dB re $1m^{-1}$ |
| Mass_center_latitude, longitude, depth | |
| Species_name | - |
| Species_percent | % |
| Species_TS | $m^2$ |
| Species_weight | kg |
| Density_number | $m^{-3}$ |
| Density_weight | kg $m^{-3}$ |
| Fish_number | - |
| Fish_weight | kg |

Quantitative morphologic and energetic school parameters can be generated and exported to text formats for quantitative study (Tang *et al* 2006). Table 1 shows precise morphologic and energetic 3D school information. They can be used for further analysis for quantitative studies. Where, “OBB_length 1, 2, 3” are longest, next longest, and shortest dimension of the object-(school)-aligned bounding box. “Roughness” is the surface_area of the 3D school divided by volume of the 3D school. “Vacuoles” is the number of vacuoles in the school. “Total_vacuole_volume” is the total volume of the vacuoles in the 3D region. “N_sigma_bs” is an analysis variable useful for the purposes of biomass estimation, where N is the number of fish in the school and sigma_bs is expected back scattering cross section of an individual fish in the school. “Volume_integration” is an estimate of the physical volume contained within the school. “Species_name” is name of a species as defined on the school. “Species_percent” is expected proportion of individual members of Species_name to the whole school. “Species_TS” and “Species_weight” are expected TS and expected weight of individual members of the species. "Fish_number" is the number of fish of Species_name in the school. "Fish_weight" is the weight of fish of Species_name in the school. "Density_number" is the volumetric density of fish expressed in fish numbers. "Density_weight" is the volumetric density of fish expressed in mass units.

## DISCUSSION

There are demands for more automated processing for analysing acoustic data, such as noise removal, outlier detection etc. Relatively new instruments of multibeam and scanning sonar, and the development towards measurement of absolute school biomass based on quantification of back scattered echo intensity from schools is to be encouraged. This will be a demanding process which will require measurement of TS on side aspect, modelling of school TS, and methods to determine the aspect angle of fish in schools when recorded *in situ*. It will also require sonars that provide a calibrated output of volume back scattering strength compensated for the gain and filter settings of the sonar (Foote *et al* 2005).

Echoview will move forward with latest technology for implementing single and multi-frequency data analysis. This software make a considerable point of flexible approach to conditioning data from many sources and then combining and transforming the data to achieve a specified result.

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