Journal of Fisheries and Aquaculture Development

Review Article

Split Beam Echo Sounder (Acoustic Systems) to Determine Abundance of Fish in Marine Fisheries

Muhammad Zainuddin Lubis[*], **Wenang Anurogo, Hanah Khoirunnisa**

Department of Informatics Engineering, Geomatics Engineering Batam Polytechnic, Batam Kepulauan Riau 29461. Indonesia.

*Corresponding author: Muhammad Zainuddin Lubis, Department of Informatics Engineering, Geomatics Engineering Batam Polytechnic, Batam Kepulauan Riau 29461. Indonesia E-mail: zainuddinlubis@polibatam.ac.id

Abstract

Acoustic waves are transmitted into the subsurface ocean will experience scattering (scattering) caused by marine organisms; material distributed in the ocean, the structure is not homogeneous in seawater, as well as reflections from the surface and the seabed. Estimation of fish stocks in the waters wide as in Indonesia have a lot of them are using the acoustic method. Acoustic method has high speed in predicting the size of fish stocks so as to allow acquiring data in real time, accurate and high speed so as to contribute fairly high for the provision of data and information of fishery resources. Split beam echo sounder comprises two aspects, and a transducer. First aspect is the high-resolution color display for displaying echogram at some observations and also serves as a controller in the operation of the echo sounder. The second aspect is transceiver consisting of transmitter and receiver. Echo sunder divided bim first inserted into the ES 3800 by SIMRAD beginning of the 1980s and in 1985 was introduced to fishermen in Japan as a tool for catching up. Split beam transducer is divided into four quadrants. Factors that contribute affect the value of Target Strength (TS) fish Strength target can generally be influenced by three factors: a target factor itself, environmental factors, and factors acoustic instrument. Factors include the size of the target, the anatomy of fish, swim bladder, and the behavior of orientation.

Introduction

Acoustic waves are transmitted into the subsurface ocean will experience scattering (scattering) caused by marine organisms; material distributed in the ocean, the structure is not homogeneous in seawater, as well as reflections from the surface and the seabed. Part of the initial acoustic energy on an object and is reflected back to the source called backscattering [1].

According in [2], a good fisheries resource management must control the number of catches in conjunction with the number of stocks that can be exploited. It required an estimate of the number of fish stocks at the time and acoustic survey techniques can be used to estimate the abundance of fish at a time and under certain conditions. The use of echo sounder and echo integrator for the purposes of exploration of fishery resources today is growing rapidly.

Hardware echo integrator aims to get the echo signal integration. The accuracy of this method is very high so it can be applied as estimate the abundance of fish in the waters [2]. According in [3], hydro acoustic method with detection backscatter value of mangrove crab [4] using crushproof fish finder pcff-80 hydro acoustic instrument. According in [5] hydro acoustic method is an underwater detection method that uses acoustic devices, among others: echo sounder, fish finder, sonar, and Acoustic Doppler Current Profiler (ADCP).
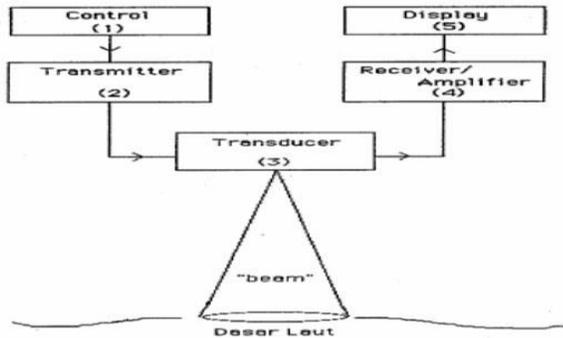
Figure1. Working mode of hydro acoustic tool [5].

According in [6] a good fisheries resource management must control the number of catches in conjunction with the number of stocks that can be exploited. It required an estimate of the number of fish stocks at the time and acoustic survey techniques can be used to estimate the abundance of fish at a time and under certain conditions.

The use of echo sounder and echo integrator for the purposes of exploration of fishery resources today are growing rapidly. Hardware echo integrator aims to get the echo signal integration. The accuracy of this method is very high so it can be applied as an estimate abundance of fish in the waters [2].

Estimation of fish stocks in the waters wide as in Indonesia have a lot of them are using the acoustic method. Acoustic method has high speed in predicting the size of fish stocks so as to allow acquiring data in real time, accurate and high speed so as to contribute fairly high for the provision of data and information of fishery resources [6].

The second aspect is transceiver consisting of transmitter and receiver. Echo sunder divided bim first inserted into the ES 3800 by SIMRAD beginning of the 1980s and in 1985 was introduced to fishermen in Japan as a tool for catching up. Split beam transducer is divided into four quadrants [7] in which the transmitting wave conducted by the merger of four full beam. The signal reflected by the target is received by each quadrant and reassembled to form a full beam. Gilihat of direction on the ship split beam is divided into four (4) ie Fore, Aft, Port and Starboard. While in principle Split Beam is divided into four quadrants that FP.FS.AP and AS.
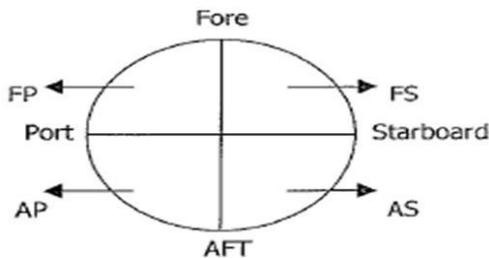

Figure 2. Split beam transducer, Source in [6].
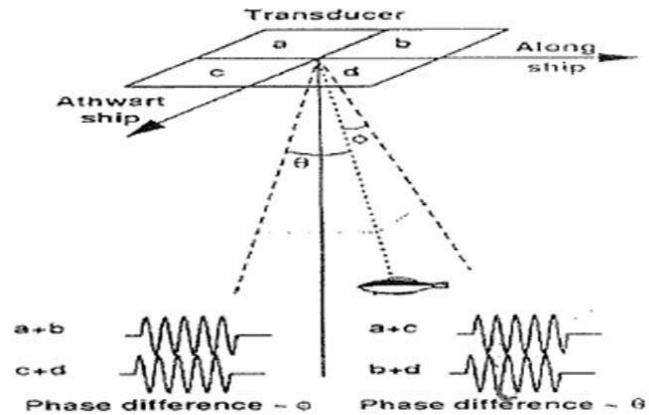

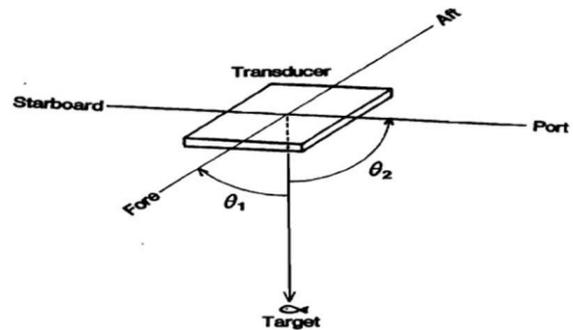**Figure3.** Figure 3 Split beam shape and a Full beam Transducer, Source: in [6].

Figure 4. Geometry targets in Split Beam transducer. Towards the target defined by the $\theta 1$ and $\theta 2$ angle, Source in [6].

Split beam echo sounder has the function of Time Varied Gain (TVG) in acoustic data acquisition system serves as reliever TVG attenuation (Amplifier) whether caused by geometrical spreading and absorbs noise as it propagates into the water. There are two types of functions, namely TVG function that works to echo a single fish called TVG 40 log R and a function for a group of fish that TVG 20 log R.
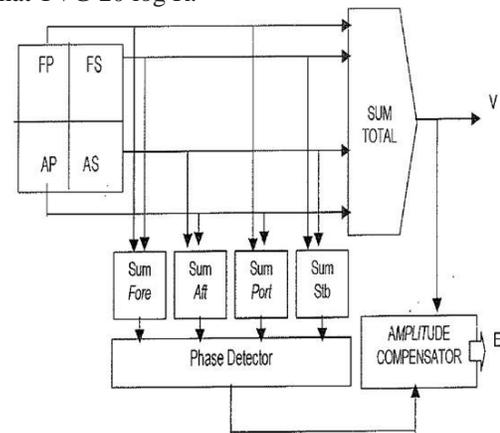

Figure 5. Block diagram of the receiver split beam echo sounder, Source in [8].
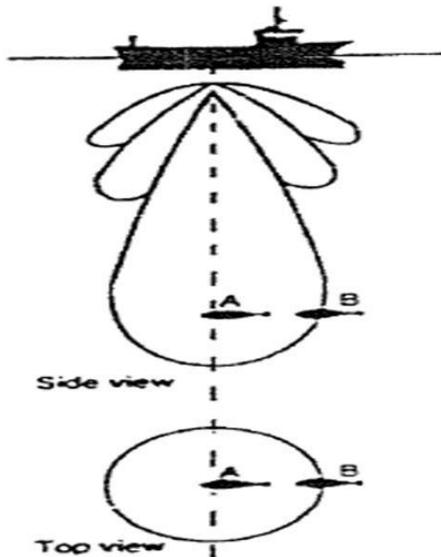
Figure.6 The working principle of Split Beam on Detecting fish echo sounder, Souce in [8].

In (Figure 6) by Simrad, fish axis A located right above the maximum transducer gain, while fish B is located at the end (edge) transducer beam where the gain is lower. A fish echo thus more likely to result stronger than the backscatter echo in fish B. Although both of these fish are at the same depth and the same size. To determine the size of the fish from the echo strength alone is not enough, however, knowledge about the pattern beam transducer and the fish in the beam position is very important to correct transducer gain strength and determining the target value of real fish.
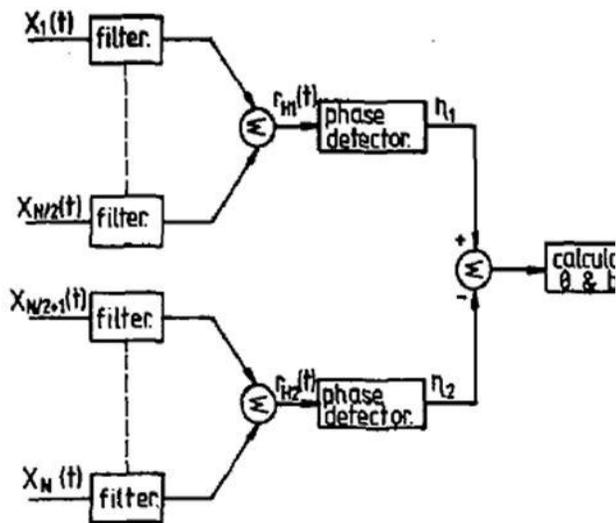

Figure 7. Split Beam Processor to obtain estimates of the incidence angle and the beam pattern factor, Souce in [9].
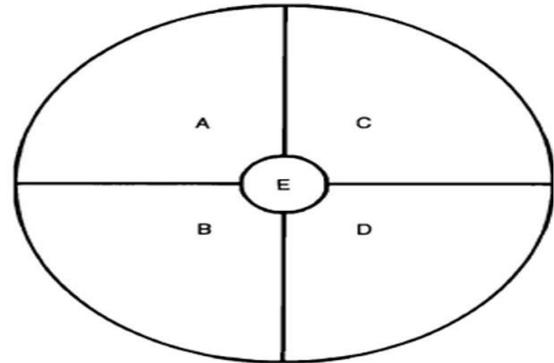

Figure 8. Diagram of a dual beam transducer / split beam, showing the location of the various segments described in the text and the shape of each beam used in the split reception beam or dual beam, Source in [10].

An estimate obtained approximate angle of incidence and factors beam pattern in the acoustic signals can be obtained by using a processor of the split beam which has a signal source X leads to Phase detection and will produce energy or power by means of calculating the results of input and will generate output waveform display in figure 8.

Table1. Beam descriptions, TVG, Used, and signal in split beam echo sounder

Beam descriptions	TVG	Used	Signal
A+C	40 log R +2 α R	Split-beam phase measurements	10 kHz
B+D	40 log R +2 α R	Split-beam phase measurements	10 kHz
A+B	40 log R +2 α R	Split-beam phase measurements	10 kHz
C+D	40 log R +2 α R	Split-beam phase measurements	10 kHz
E	40 log R +2 α R	Amplitude Dual Beam, Split Beam	Detected
A + B + C + D +E	40 log R +2 α R	Integration echo	Detected

Target strength (TS) is the ability of the target to reflect a sound about it. Based domain is used, the target strength is defined into two, namely in the form of Target Strength Intensity (TSi) and Energy Target Strength (TSE). Target Strength (TS) can be defined as the quotient between the values of the intensity of the noise coming about the target and multiplied by the number of ten (10) in [11] is:

$$TSi = 10 \log Ir/Ii \qquad (1)$$
$$TSe = 10 \log Er/Ei \qquad (2)$$

Information:

TSi: Intensity target of strength
Ii: Intensity of sound on targets
Ir: Reflected sound intensity targets
TSE: Energy Target Strength
Ei: Energy sound on targets
Er: Energy reflection sound at a distance of 1 meter from the target

According in [11]stated that the Target Strength (TS) is a measure decibel sound that is returned by the target as measured on a standard distance of 1 meter from the acoustic center of the target is located, relative to the intensity of sound that hit the target. A simple model to estimate the back scattering cross section based on the size of fish referred by [6]:

$$\sigma_{bs} = b_0\, L^2 \quad (3)$$
$$TS = 20\, Log\, L + b_0 \quad (4)$$

Then according in [12] introduced the equation which connects the backscattering cross section (σ_{bs}), fish length (L) and wavelength (λ) by the following equation: $\sigma_{bs} / \lambda = a(L/\lambda)^{\beta}$ (dB) where A and B are constants that depend on the anatomy, fish size and wavelength. Equation (4) can be converted into a logarithmic form becomes:

$$TS = a\, Log\,(L) + b\, Log\,(f) + b_0 \quad (5)$$

Information

TS = Target strength (TS)
F= Sound frequency
A, b= Constant

Then obtained the possibility of the average best performing measurements on the measurement of the target strength of the dorsal aspect:

$$TS_D = 19, 1\, log\,(L) - 0, 9\,(f) - 62 \quad (6)$$

But according in [13] explains more about the similarities that show no difference in the comparison of results of different frequencies. Furthermore, the equation [9] to formulate relationships TS (Target Strength) to the length of the fish, namely:

$$TS = 20\, Log\,(L) - 68 \;(dB) \quad (7)$$

Conversions strength target value into a length (L) for pelagic fish used equation TS = 20 log L-73.97 [13]. Relations targets strength and OBS (backscattering cross-section, m2) is calculated based in [6] with equation:

$$TS = 10\, log\, óbs \quad (8)$$

Equation for densities ikan (ñA, ind. /nmi^2) is:

$$ñA = sA / óbs \quad (9)$$

Fish length (L) associated with óbsis:

$$óbs = aL^b \quad (10)$$

Associated of target strength and L is:

$$TS = 20\, log\, L + A \quad (11)$$

Where:

A = the value of the target strength to 1 cm long fish (normalized target of strength)

Conversions strength target value into a length (L) for pelagic fish used equation: TS = 20 log L-73.97 [13]. According in [14] the relationship length (L) and weight (W) of a species of fish that is:

$$W = aL^b \quad (12)$$

In addition [13] has a long and weighs equation to convert length into weight alleged allegations are as follows:

$$Wt = a\left\{\sum_1^{i1} .ni(Li + \ddot{A}L/2)^{b+1} - (Li - \ddot{A}L/2)^{b+1}\right\}/\{(b+1)\ddot{A}L\}\} \quad (13)$$

Information

Wt: Total weight (g)
Al: Class interval length (cm)
Li: The midpoint of the long-th grade (cm)
Ni: Number of individuals in the i-th grade
a,b: Constants for certain species

Factors that contribute affect the value of Target Strength (TS) fish Strength target can generally be influenced by three factors: a target factor itself, environmental factors, and factors acoustic instrument. Factors include the size of the target, the anatomy of fish, swim bladder, and the behavior of orientation [15]. Factors such targets are:

Size of fish

There is a relationship between the sizes of the fish with a value of TS, but the relationship varies greatly depending on the species. Generally for fish species, the larger the fish the greater its value TS. This is especially true for the region of the graph geometrical relationship between the size of the target and TS, for the region, resonance, resonance region and the transition region, the tendency of the relationship is not valid [11]. Anatomy such as the head, body, tail and fins have a different sound reflections. Likewise, stomach, intestine, liver, bones, flesh and gills have a specific gravity = (ρ) and the speed of sound = (c) different so acoustically will have the ability to reflect a different sound.

Swim bladder of fish

Acoustically fish and marine organisms are divided into two major groups, namely blader fish (have a swim bladder). Fish that have a swim bladder generally do not have the right maximum

TS on the dorsal aspect, while fish that do not have a swim bladder with a maximum value of TS is generally right on the dorsal aspect. TS value of fish that have a swim bladder [16]. With deformed-cylinder model (DCM) with Approximation of> 5 and the value of Tilt Angle was not until (<40°) according to [17]. Results from the resultant corner of a fish that has swim bladder that is:
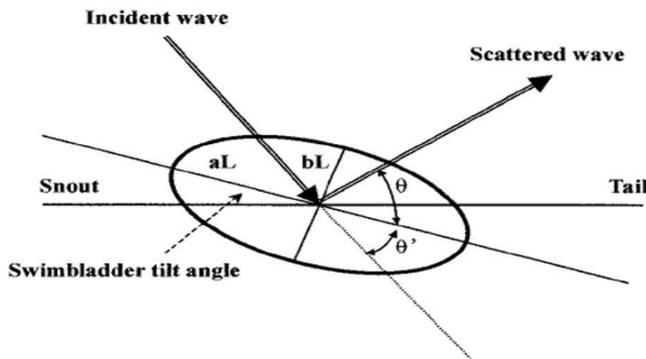

Figure 9. Swim bladder Geometry for Soft spheroid models, Source in to [17, 18].

Behavior / Orientation Fish

Results of a previous study conducted by [19, 20] states that the value of Target Strength (TS) is determined by the orientation of the fish, especially the slope of the body to a line connecting between the head and tail. Fish orientation will include tilting, yawing and rolling along. Yawing no effect because generally spherical transducer position so that the fish does not cause changes in the angle when viewed from the transducer, for Rolling no real effect because the fish have a swim bladder due partly reflected energy is derived from the swim bladder did not come from the dorsal aspect. Tilting lead to a change in angle position transducer is good for fish that have a swim bladder or not [8].

Instrumental factor

The small big factor value Beam pattern depending on the extent of the transducer will be greater the beam angle of the transducer, and vice versa. Large beam angle changes cause TS great value, separately it is better to use a relatively narrow beam.

Acoustic reflections of fish and plankton that are returned in the form of echo is detected by the receiver has an appeal. Estimation of biomass can be seen from how much force the target and how to interpret it. TS plankton is numbers that indicate the size of the echo. The larger the value, the greater echo energy is returned to the receiver by the target. Unit of measure Standard International (SI) for the TS expressed in decibels (dB). The decibel is a logarithmic form of a comparison or ratio of the two intensities due to the values involved can be very large or very small. According in [21] TS formulated as backscattering cross-section of the

target which returns a signal and is expressed in the equation:

$$TS = 10 \log (\sigma / 4\pi) \qquad (14)$$

Then the value of TS theoretical spherical object is:

$$TS = 10 \log a^2/4 \qquad (15)$$

Where σ = Target strength individual or backscattering cross-section (σ bs) with TS according in [21, 22] with equation:

$$TS = 10 \log \sigma BS \qquad (16)$$

Volume Backscattering Strength (SV)

Volume Backscattering Strength (SV) is defined as the ratio between the intensity reflected by a group of single targets (target located at a water volume of certain diinsonifikasi instantaneously measured at a distance of 1 m from target with the intensity of sound that hit the target. Definition Volume Backscattering Strength (SV) has the same meaning as the target strength for a single target, while Volume Backs catering strength (SV) for a group of fish.

Each individual targets is the source of the reflected sound wave, so that the output of the integration will be proportional to the quantity of fish in the group. Echo integration methods used to measure Volume Backscattering Strength (SV) based on the measurement of the total power backscattered on the transducer [8].

Volume Backscattering Strength (SV) is the ratio between the intensity reflected by single group targets where the target is located at a water volume [23]. This is similar to the definition of TS where TS value is the result of the detection of a single organism, while SV is the value for mendetaksi organism groups in [24] states SV is defined into the equation:

$$SV = 10 \log (Is \, i/ I) \qquad (17)$$

Information

Is: Intensity scattering volume measured 1 m from the center of the acoustic waves.

Ii: Scattering intensity emitted

Fish Density (Abundance Fish)

To date research on fish stock estimates done by cruise track using a SIMRAD EK 60 Scientific split beam echo sounder system with a frequency of 70 kHz and acoustic data acquisition is performed continuously during the day and night during the period boat cruise at speeds ranging between 7-8 knots. Trails include a data acquisition area of an area that allows the analysis of spatially made with zig-zag shape according to in [25, 26] with the length of each transect approximately 12 NMI of bounds islands outwards. Density values for fish processing performed on Ms. Excel. The treatment may be carried out after the integration process SV and

TS. Density is generated by using the formula [27].

$$SV \ (dB) = 10 \log (N \ \tau bs) = 10 \log N + TS \quad (18)$$

Assuming the numerical density is proportional to the density of individuals, and then the equation (1) can be rewritten as follows:

$$SV \ (dB) = 10 \log \rho + A \quad (19)$$

Where

SV: Volume strength (dB)

ρ : Abundance / density of organisms (Ind / m^3)

A: Target average strength (dB)

References

1. Maisonhaute E, Prado C, White PC, Compton RG (2002) Surface acoustic cavitation understood via nanosecond electrochemistry. Part III: Shear stress in ultrasonic cleaning. Ultrasonics sonochemistry 9: 297-303.

2. Benoit-Bird KJ, Au ww (2001) Target strength measurements of Hawaiian mesopelagic boundary community animals. The Journal of the Acoustical Society of America 110: 812-819.

3. Lubis MZ, Pujiyati S (2016) Detection Backscatter Value of Mangrove Crab (Scylla Sp.) Using Crushproof Fish finder Pcff-80 Hydro acoustic Instrument. J Biosens Bioelectron 7: 2.

4. Pujiyati S (2008) Pendekatan Metode Hidroakustik untuk Analisis Keterkaitan antara Tipe Subsrat Dasar Perairan dengan Komunitas Ikan Demersal. Disertasi. Sekolah Pasca Sarjana. Institut Pertanian Bogor.

5. Pujiyati S, Hestirianoto T, Wulandari PD, Lubis MZ (2016) Fish Stock Estimation by Using the Hydro acoustic Survey Method in Sikka Regency Waters, Indonesia. J Fisheries Livest Prod 4: 2.

6. MacLennan DN, dan Simmonds EJ (1992) Fisheries Acoustic. Chapman and Hall. London.

7. Foote KG (1987) Introduction to the Use of Sonar System for Estimating Fish Biomass. FAO. Fisheries Technical Paper No 199 Revision 1.

8. Arnaya IN (1991) Akustik Kelautan II. Proyek Peningkatan Perguruan Tinggi. Institut Pertanian Bogor. Bogor.

9. Ehrenberg E John (1979) A Comparative Analysis of In Situ Methods for Directly Measuring the Acoustic Target Strength of Individual Fish IEEE journal of oceanic engineering 10.1109/JOE.1979.1145434.

10. Foote KG, Traynor JJ (1988) Comparison of walleye pollock target strength estimates determined from in situ measurements and calculations based on swim bladder form. J.Acoust.Soc.Am 83.

11. Maclennan DN, Fernandes PG, Dalen J (2002) A consistent approach to definitions and symbols in fisheries acoustics. ICES Journal of Marine Science: Journal du Conseil 59: 365-369.

12. Love RH (1997) Target Strength of an individual Fish at any aspect. J.Acoust. Soc. Am 62: 1397-1403.

13. Natsir M, Sadhotomo B, Wudianto (2005) Pendugaan biomassa ikan pelagis di perairan Teluk Tomini dengan metode akustik bim terbagi. Jurnal Penelitian Perikanan Indonesia 11: 101-107.

14. Effendie MI (2002) Biologi Perikanan. Yayasan Pustaka Nusatama 163.

15. Priatna A Wijopriono (2011) Estimasi stok sumber daya ikan dengan metode hidroakustik Di perairan kabupaten bengkalis. J. Lit. Perikan. Ind 17: 1.

16. Manik HM, Furusawa M, Amakasu K (2006) Measurement of sea bottom surface backscattering strength by quantitative echo sounder. Fisheries Science 72: 503-512.

17. Yasuma H, Sawada K, Ohshima T, Miyashita K, Aoki I (2003) Target strength of mesopelagic lanternfishes (family Myctophidae) based on swim bladder morphology. ICES Journal of Marine Science 60: 584-591.

18. Jørgensen R (2003) the effects of swim bladder size, condition and gonads on the acoustic target strength of mature capelin. ICES Journal of Marine Science: Journal du Conseil 60: 1056-1062.

19. Henderson MJ, Horne JK, Towler RH (2008) the influence of beam position and swimming direction on fish target strength. ICES Journal of Marine Science: Journal du Conseil 65: 226-237.

20. Fässler SM, Gorska N, Ona E, Fernandes PG (2008) Differences in swim bladder volume between Baltic and Norwegian spring-spawning herring: Consequences for mean target strength. Fisheries Research 92: 314-321.

21. Lurton X (2002) an Introduction to Underwater Acoustic. Principles and Applications. Praxis Publishing Ltd. Chincester UK.

22. DeCino RD, Willette TM (2014) Blackwell Science. Susitna drainage lakes pelagic fish estimates, using split-beam hydro acoustic and midwinter trawl sampling techniques, Alaska Department of Fish and Game, Fishery Data Series 14- 47.

23. Xie J, dan Jones ISF (2009) A Sounding Scattering Layer in a Freshwater Reservoir. Marine Study Center University of Sydney. Australia.

24. Kaartvedt S, Staby A, Aksnes DL (2012) efficient trawl avoidance by mesopelagic fishes causes large underestimation of their biomass. Marine Ecology Progress Series 456: 1-6.

25. Diez MJ, Cabreira AG, Madirolas A, Lovrich GA (2016) Hydro acoustical evidence of the expansion of pelagic swarms of Munida gregaria (Decapoda, Munididae) in the Beagle Channel and the Argentine Patagonian Shelf, and its relationship with habitat features. Journal of Sea Research 114: 1-12.

26. Jurvelius J, Marjomäki TJ, Peltonen H, Degtev A, Bergstrand E, et al. (2016) Fish density and target strength distribution of single fish echoes in varying light conditions with single and split beam echo sounding and trawling. Hydrobiology 1-12.

27. Lubis MZ, Anurogo W (2016) Fish stock estimation in Sikka Regency Waters, Indonesia using Single Beam Echo sounder (CruzPro fish finder PcFF-80) with hydro acoustic survey method. Aceh Journal of Animal Science 1: 2.