Measurement of Acoustic Reflection of Tuna Fish Using Echosounder Instrument

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Abstrak

Indonesia merupakan salah satu negara yang memiliki potensi perikanan tuna yang besar. Pendugaan populasi ikan tuna selama ini menggunakan statistik perikanan. Pendekatan statistik memiliki keterbatasan antara lain membutuhkan waktu yang lama, akurasi yang diragukan dan luas cakupan perairan yang sempit. Untuk itu perlu diupayakan metode baru yang memberikan informasi yang akurat, komprehensif, mutakhir dan berkelanjutan tentang ikan tuna. Salah satu metode mutakhir yang dapat mengetahui kondisi ikan tuna adalah metode akustik. Penerapan teknologi akustik memiliki kelebihan antara lain mudah dalam pengoperasian instrumen, akurasi dan presisi yang tinggi, dapat melakukan pemantauan dan kuantifikasi stok ikan secara kontinu, in situ dan real time dalam pemrosesan serta analisis data. Untuk aplikasi metode akustik tersebut maka penelitian dasar untuk menghitung sifat refleksi akustik atau dikenal dengan Target Strength (TS) dari ikan tuna dilakukan menggunakan echo sounder. Hasil yang diperoleh adalah hubungan nilai TS terhadap panjang ikan dan volume gelembung renang terhadap ikan tuna mata biru (Thunnus obesus) dan tuna sirip kuning (T. albacares). Target Strength (TS) ikan tuna mata biru lebih besar 3 dB dari ikan tuna sirip kuning pada ukuran yang sama. Hasil ini berhubungan dengan perbedaan volume gelembung renang dari kedua spesies tersebut. Hubungan antara TS dan volume gelembung renang ikan tuna dibahas dalam hasil penelitian ini. Implikasi hasil riset ini adalah tersedianya data dasar penelitian akustik terhadap ikan tuna di Indonesia.

***Kata kunci** : ikan tuna, target strength (TS), split beam echo sounder*

Abstract

Indonesia has a big potency of tuna fisheries. Unfortunately, a quantification method for tuna fish resources is not understood well. Usually, the estimation of tuna fish population using statistic method. This method has a limitation such as time consuming, less accuration and small area covered. For this reason, a novel method was used to give the high accuration, comprehensiveness, modern technology and real time monitoring of tuna fisheries. One of the modern method to detect and quantify tuna is underwater acoustics. The application of acoustic method has many advantages such as easy to operate the instrument, high accuration and precision, continuously monitoring and quantification, real time data processing and analysis. For this purpose, a research programme was carried out in order to study the acoustic wave reflection or target strength (TS) of tuna fish using an echo sounder (QES). The relationships between TS to fork length (FL) and swimbladder volume, for bigeye tuna (Thunnus obesus) and yellowfin tuna (T. albacares) are investigated. The TS of bigeye tuna was about 3 dB higher than yellowfin tuna when comparing species at the same size. The result can be correlated to the swimbladder volume difference between species. The relationship between TS and swimbladder volume was quantified for both species. The implication of this research is the avalaibility of tuna fish database using underwater acoustic technique.

***Key words** : tuna fish, target strength, split beam echo sounder*

Introduction

Information of acoustic reflection from target or target strength (TS) is of prime importance for underwater acoustic work such as stock assessment and behavior studies (Manik *et al*., 2006). The target strength is defined by the intensities of the incident and the backscattered waves. In principle it is possible to compute the target strength of fish body which contribute to the echo, notably the swimblader (Foote, 1980; Blaxter & Batty, 1990). The scattering of sound by fish is too complicated for useful target strength values to be derived from theoretical model. For practical purposes, it is necessasry to measure the target strength by experiment. Target strength value depends on internal physiology of fish, swimbladder, fish behaviour and orientation of the body with respect to the transmitted beam (Foote, 1987; Furusawa, 1988). Those recent

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Table 1. Measurement of Target-strength value for bigeye tuna (Thunnus obesus) and yellowfin (Thunnus albacares)

Species	Fork length (cm)	Weight (kg)	Average TS (dB)	Swimbladder Volume (cm^3)
T. obesus	50	3	-32.1	110
T. obesus	55	5	-31.4	230
T. obesus	60	7	-30.1	310
T. obesus	70	10	-28.9	580
T. obesus	80	20	-26.5	890
T. obesus	110	30	-24.6	1102
T. obesus	120	40	-23.3	1519
T. obesus	130	50	-21.2	1817
T. obesus	135	55	-20.3	2110
T. obesus	140	60	-19.8	2350
T. albacares	55	3	-34.1	55
T. albacares	60	4	-34.6	60
T. albacares	70	6	-33.6	72
T. albacares	75	9	-34.0	89
T. albacares	90	14	-33.2	149
T. albacares	95	15	-31.2	198
T. albacares	105	20	-31.0	217
T. albacares	108	25	-30.4	254
T. albacares	110	28	-29.7	265
T. albacares	120	30	-26.3	389

investigations have conducted a tuna fish TS measurement at 38 kHz. The split beam hydroacoustic method was applied to tuna which were vertically distributed over a large range of depths. The results of this method can be compiled to obtain a first range of TS for bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*T. albacares*) of juvenile and adult sizes (Table 1).

The swimbladder is responsible for 90–95% of the acoustic backscattering energy (Foote, 1980). Therefore, the study of the relationships between TS and the swimbladder volume can improve our knowledge of tuna physiology and swimbladder volume compensation. Here, we reported preliminary relationships between TS and both fish length and swimbladder volume.

The objectives of this study are to quantify of tuna fish target strength using quantitative echo sounder and relate target strength with fish length and swimbladder volume.

Materials and Method

Hydroacoustic experiment was supported by the Incentif Program of Ministry of Research and Technology Republic of Indonesia. The acoustic calibration measurements were conducted in the Ocean Acoustic Laboratory Department of Marine Science and Technology Faculty of Fisheries and Marine Science Bogor Agricultural University. The underwater transducer calibration for checking acoustic apparatus were performed in a 1.5-m-deep by 3.7-m-long and 2.4-m-wide tank filled with filtered seawater. An underwater transducer was mounted in the tank facing horizontally.

The ocean observations were made during surveys on board the Research Vessel (12 m long). The hydroacoustic instrument used during these experiments is a Simrad system (Simrad, 1993). Experiments were carried out in the Pelabuhan Ratu bays on June 2007. For the ocean experiment, the signal was received through an underwater transducer fitted on a Vfin, then decoded and stored by electronic receiver/ decoder on board. Tuna fish were caught on board by longline fishing units and the fork length was measured by using a measuring apparatus to the nearest 50 cm. Tuna fish weight was also measured and the result is shown in Table 1.

Underwater acoustic data were collected by using a split beam echo sounder with operating frequency of 38 kHz, beam angle of 6.9° and pulse duration of 0.6 ms employed in seawater column up to 500 m in depth. The split beam acoustic transmission on-axis and off-axis calibration was done by using the standard procedure (Manik, 2006).

The Matlab program was constructed to extract single targets selected by the echo sounder. The target strength (TS) used in this paper are logarithmic expression of the result of backscattering cross section (σ_{bs}) measured *in situ*, by using formula TS = 10 log (σ_{bs}). Target strength values were quantified on single fish echo of fish tuna. The measurement tuna species are bigeye tuna and yellowfin tuna. Number of species for bigeye tuna and yellowfin tuna was 10 samples for each species.

Result and Discussion

The fish fork length and weight were measured for tuna fish which were hauled aboard deck vessel without causing injury, and the obtained TS values are presented in Table 1.

Estimation of Swimblader Volume of Tuna

Tuna specimens were used to determine the relationships between swimbladder volume (SBV) *versus* fork length (FL) for tuna fish which were caught by longline fishing gears in seawater off Pelabuhan Ratu. Freshly caught fishes fork length were measured to the nearest centimetre unit. The swimbladder volume was measured for 10 yellowfin tuna and 10 bigeye tuna fishes. The inflated swimbladder were excised carefully from the abdominal cavity and then it was frozen. A small incision was made on the anterior part of the frozen swimbladder, then it was filled with seawater until it burst. The volume of water was measured to the nearest 10 ml unit. The results of measured swimbladder volume are shown in Table 1.

The relationships between fork length and swimbladder volume for bigeye and yellowfin tuna are shown in Figure 1. It is clearly indicated that the swimbladder volume is significantly greater for bigeye than for yellowfin tuna. The variation of target strength with tuna fork length (cm) for bigeye and yellowfin tuna are shown in Figure 2 and indicates its best fit regression function.

Relationships of Target-strength and Fish Length

The proposed relationships of tuna fish TS *versus* fish fork length are only preliminary, because of the small number of observations (Table 1). There are also influence of the stochastic nature of target-strength and the possible error in estimating the fish length which were not hauled abroad. It is commonly assumed that TS depends on fish size according to the relationship: TS = a log FL+ b, where a and b are constants for a species and (in) a given frequency and FL is fork length (cm). Therefore, in this experiment the following relationships were obtained (Figure 2.) which were applied for 60–120 cm yellowfin and 50–140 cm bigeye tuna fishes:

Bigeye tuna : TS = 21,02 Log (FL) - 77,67

Yellowfin tuna : TS = 19,80 Log (FL) - 68,82

In case of *in situ* target strength measurements, the constant value of a is generally close to 20 (MacLennan & Simmonds, 1992). Indeed, the acoustic cross section $(\sigma = 4\pi \,.10^{(TS/10)})$ is proportional to the horizontal section of the organs which contributes to the echo. This area should be proportional to the square of fish length (FL^2) and that the TS is defined by 20 log FL + b. However, in case of tuna fish, the TS values increase more faster as the size increase.

In this experiment, bigeye tuna has TS higher by 3 dB approximately than that of yellowfin tuna of the same size. This difference is very significant given the similarity of the two species both in terms of their fish shape and the density of their flesh.

Relationships of Target-strength to swimbladder volume

For a given length bigeye tuna has a swimbladder that is longer than that of yellowfin tuna (Freeze & Vanselous, 1985). The difference of swimbladder length can explain the observed difference in the relationship of TS and fish length for the species. However, if we represent TS according to the volume of swimbladder, we observe instead a single trajectory for each species (Figure 3), since TS increases logarithmically with the swimbladder volume (SBV, in ml).

Thus the difference between species is not observed if the swimbladder volume is taken into ac-

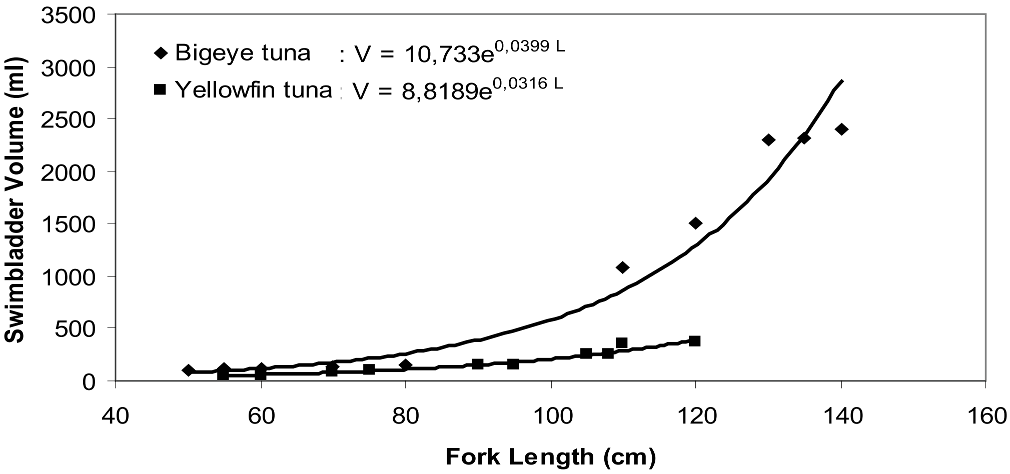

Figure 1. Relationships between fork length and swimbladder volume for bigeye and yellowfin tuna. The fitted lines are the regression function.

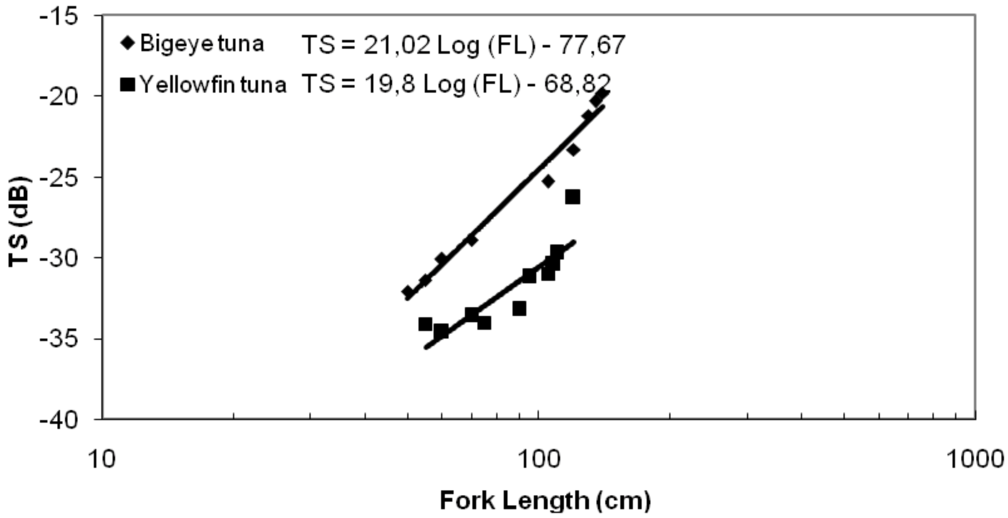

Figure 2. Variation of target strength with tuna fork length (cm) for bigeye and yellowfin tuna. Solid line is the best fit equation TS = a log FL + b of experimental data.

count. This following equations are based on our experimental observations, they are:

Bigeye : TS = 0,0036 (SBV) - 30,16

Yellowfin : TS = 0,0209 (SBV) - 35,59

This relationship applies for swimbladder volumes ranging between 50 and 2400 cm^3. Yellowfin and bigeye tuna have a closed swimbladder with a gas gland and resorption area for gas secretion/resorption from the blood to and from the swimbladder (Misund, 1997). Misund showed that the swimbladder of the bigeye tuna was not fully compressed, even at great depths. Therefore, tuna (at least bigeye tuna) have the ability to adjust the volume of their swimbladders better than might be supposed from the literature for other physoclists. Misund stated that the variations of TS with depth are weak, which suggests that there must be some compensation of gas volume with changing depth. More than the volume itself, though, it is the cross-section which contributes to TS (MacLennan and Simmonds, 1992). The swimbladder is able to to compress uniformly in volume because the muscle and bone will maintain the shape of the upper surface area. Therefore, the swimbladder may never be adapted precisely to depth at a given time. The future research should take more account of the surface area of the swimbladder normal to the insonification of acoustic wave.

Even the small number of fish measured *in situ* condition, it is still proved empirically the validation of

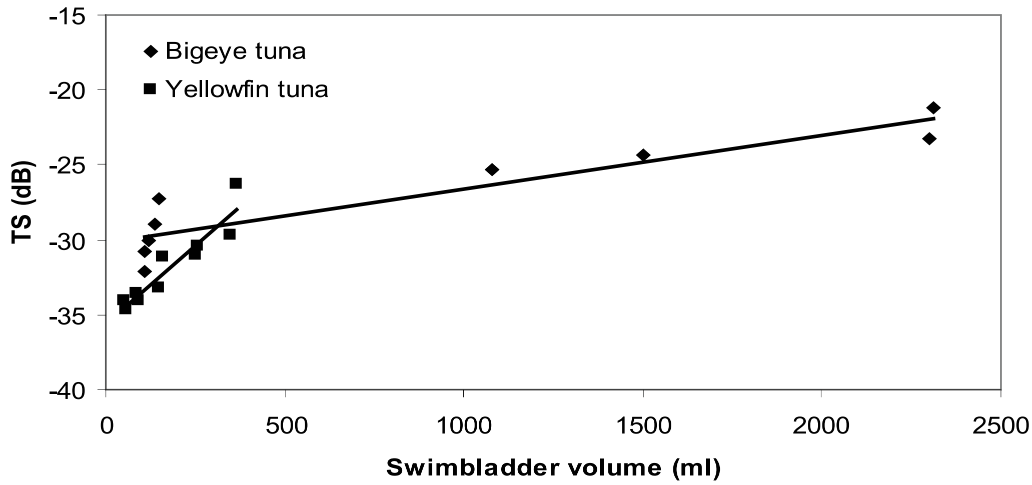

Figure. 3. Variation of target strength with tuna swimbladder volume (ml) for bigeye and yellowfin tuna

TS measurements for the estimation of fish size. Figure 3 also confirms our assumption that tuna fish are very effective in controlling the volume of their swimbladders. This is due to the swimbladder which is always containing gas to maintain fish swimming depth, and the surface area of swimbladder determined the insonification for sound reflectivity (Mukai and Iida, 1996). The swimbladder played the dominant role for backscattered energy by fish. However, it was difficult to measure the rate of gas secretion into the swimbladder at the time of measurements.

Conclusion

Measurement of tuna fish target strength depends on fish length and swimbladder volume. A bigeye tuna has target strength higher by approximately 3 dB than that of a yellow fin tuna of the same size. These results also confirm tuna fish are very effective in controlling the volume of their swimbladders.

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