Empirical acoustic TS - Length relationship for Torpedo Scad (*Megalaspis cordyla*)

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Abstract. One of the main challenge in fish stock assessment with acoustic method is how to improve the accuracy of the estimated acoustic target strength (TS) of the fish under investigation. Various factors contribute to the bias in acoustic TS, namely the high diversity of fish species, body shape, orientation and size. It is therefore necessary to have a database of acoustics TS of fish on a particular species, size (length), and orientation as a reference to be used in grouping and in estimating the overall TS-length relationship of the species. In this paper we reported the result of in situ TS measurements of Torpedo Scad (*Megalaspis cordyla*). The TS data analysis is performed numerically through the best-fit technique to establish the relationship between length, object orientation, and TS. The TS-length relationship obtained for Torpedo Scad (*Megalaspis cordyla*) is $TS = 20 \log (FL) - 53.68$. This relationship could be used to eliminate bias in the fish stock assessment by acoustic method.

1. Introduction

In order to achieve sustainable fisheries management, where exploitation rates are balanced with the rate of recovery and growth of fish resources, adequate information is needed on the condition or status of fish stock resources. In addition, one of the main information that needs to be known in determining of fisheries management that is realistic, measurable and can be evaluated objectively the initial description of the condition of fish stocks to serve as the starting point of reference. The effectiveness of management actions that have been and will be taken can be determined with a high level of trust. The status of fish resources can be known through a study of fish stocks. There are various methods of assessing fish stocks that are developing today. One of them is the acoustic method, which has evolved since 50 years ago [1]. The main challenge in assessing fish stocks with acoustic surveys is how to improve the accuracy of the results. One of the factors of bias is the high diversity of fish species, both shape and size [2]. It is therefore necessary to have a database of acoustic values (target strength, TS) of fish on a particular type and size, as a reference used in grouping and estimating the length of the species [3].

Acoustical method is one of the standard method stock assessment, in addition to other methods such as from the catch of fish. Currently, the accuracy of fish stock estimation with acoustic method is still not satisfactory due to the high diversity of fish species, both shape and size. While very little target strength (TS) measurements from individuals of various dominant commercial fish species [4]. It is therefore necessary to measure the physical parameters of fish (length, weight, orientation) with acoustic parameters (TS, target strength).

The result of the measurement of the target value of each individual/fish species on each particular size (FL) structure will be a reference to verify the acoustic data of fish size (dB) to length (cm), in order to reduce the bias in further analysis towards estimation biomass and stock potential of Fish Resources based on hydro-acoustic method [5]. The objective that is expected to be achieved through
this research is the increasing accuracy of estimation fish stock assessment using acoustic method. Activities in the study of TS Characteristics (Target Strength) and TS-Length Formulation on Fish Key Indicators for Increasing Fishery Stock Estimation Accuracy, including calculating TS values of some dominant commercial fish species. Formulating empirical relationships between acoustic parameters and physical parameters. The formulation of the relationship between TS Acoustic values and the length or weight of fish for some commercial fish is important.

Formulation of the relationship between TS Acoustic value and length or weight of fish for some commercial fish is important for increasing accuracy of fish stock estimation for sustainable fisheries management [4]. The research results are used as input for the formulation of fishery management policy in the form of model as one component in estimation calculation fish stock. The more valid and measurable management steps required for sustainable and optimal fisheries management.

2. Methods

2.1. Time and study area
Acoustic measurements were conducted in Palabuhan Ratu Bay, with floating lift net (Figure 1), in two trips, namely August and November 2016.

Figure 1. Floating rides (lift net) vehicle as a place to do research with the transducer placed above the cage.

2.2. Tools and materials
The tools and materials used in this study include: Scientific Echosounder Simrad EK 80-200 kHz transducer split beam, sphere ball (target standard) type tungsten carbide (WC) 38.1 mm diameter, cage where live fish are measured by their TS value and confinement of live fish sampling before measured, measuring instruments (meter), digital scales and CTD SBE 19 plus to measure temperature and salinity.

Before performing the TS measurement activity of each individual fish with an acoustic system, the acoustic instrument is first calibrated [6]. Measurement of profiles of temperature and salinity of waters to obtain the speed of sound value is done with CTD SBE 19 plus. Limited scope of the lift net the maximum sphere ball can only be placed at a depth of 4.5 m from the surface of the transducer. The parameter setting used in calibration is in table 1, and is used at the time of acquisition of TS value of each individual fish.
Table 1. Setting of acoustic parameters.

| Parameter     | Value   |
|---------------|---------|
| Frequency     | 200 KHz |
| Pulse Duration| 0.512 ms|
| Power transmit| 150 watt|
| Sound speed   | 1542 m/s|
| Absorption    | 82.9 dB/Km|
| SV threshold  | -60 dB  |
| TS threshold  | -60 dB  |

2.3. Measurement of TS value
TS measurements were performed on each individual species of fish collected under living conditions at various lengths. For a fish that cannot be sustained alive then it is measured in a fresh die condition. Each individual live fish is placed inside the cage, then the individual fish is scanned with an acoustic system, with the transducer placed above the cage, so the target (fish) is in the beam acoustic beam area [2]. The echosounder parameter settings used at the time of acquisition must correspond to the setting of parameters at calibration time (table 1). The measurements of each individual fish are declared successful, until a normal distribution of TS values is generated.

Figure 2. Measurement of TS fish values a) cage method (confinement) for live fish; b) tethered method for dead fish.

2.4. Data analysis
Acoustic data is processed using SONAR5-pro software, extraction results are target strength values (TS) in decibels (dB). The number of TS values per fish individual measured by acoustics consists of many variations of TS values that spread within a certain range, but generally spread normally and have a certain modus value.

2.4.1. The target strength value (TS) of each individual fish. The amount of data used to obtain the average TS value of one individual fish is the TS data in the range of ± 3dB from the middle peak value of its modus mode. According to [2] TS is a backscattering cross section (σbs) of the returned target signal, the relationship between TS and σbs is expressed as TS = 10 log (σbs). Then the average TS is TS = 10 Log (σbs). The mean TS score is assumed to be the TS value of each individual fish, and is used in the regression analysis to obtain TS-length formulations on similar species.
2.4.2. Empirical relationship of TS values with length of fish. A series of coupled data between length (L) and average TS for the same species is used to analyse the empirical relationship between the two so that TS-length formulation is formed. The empirical relationship between TS and L refers to $TS = 20 \log (L) + A$, where $A$ is the target strength value for 1 cm of normalized strength depending on the species of fish species [6]. Based on the equation, then to get TS-length formulation only use linear regression analysis between independent variable L and dependent variable TS. Previously a series of L and TS data of each individual in the same species tested the normality of the data as a condition of regression analysis. After the regression equation $TS = a \log L + b$ is formed, then the partial test is the significance of variable L to TS, with the hypothesis: $H_0 = L$ variable has no significant effect on TS; $H_1 = L$ variable has significant effect on TS. Regression equation obtained, then compared with equation [6] that is $TS = 20 \log L + A$, so will be obtained equation to get value of $A$ on certain species. If $A$ has been obtained, then by entering the L value of each measured individual fish, it will get the average value of $A$ or call $C$. So the TS-length formulation is $TS = 20 \log L + C$ [7].

3. Results and discussion

3.1. Target strength values

A total of 100 live fish species Torpedo Scad fish (Megalaspis cordyla), which successfully collected at night successfully measured the TS value in living conditions only as many as 35 pieces of samples. Result of measurement with 200 kHz acoustic frequency of 35 fish of Torpedo Scad, its TS value is distributed starting from $-61.67 \pm 1.6$ dB up to $-49.22 \pm 1.5$ dB. Each fish size has a different modus class value. The value of the TS taught fish class modus tends to increase with the larger size (table 2). A number of fish are measured TS value, spread from the size 18.8-22.0 cm FL, with the average number of samples measuring 300 times for each fish, the average value of TS fish Torpedo Scad at size 18.8 - 22.0 cm FL is $-58.04$ dB (table 2).

| No. | Fish | TL (cm) | FL (cm) | W (g) | Swimblader (cm) | Average TS | Deviation Standard |
|-----|------|---------|---------|-------|-----------------|------------|-------------------|
| 1   | 22.0 | 20.1    | 103.8   | 5.0   | 5.0             | -58.13     | 1.6               |
| 2   | 22.1 | 20.6    | 104.6   | 5.0   | 5.0             | -58.28     | 1.7               |
| 3   | 20.2 | 19.0    | 94.5    | 5.0   | 5.0             | -58.64     | 1.5               |
| 4   | 21.3 | 20.0    | 98.0    | 6.8   | 6.8             | -60.94     | 1.8               |
| 5   | 20.9 | 19.6    | 100.2   | 5.0   | 5.0             | -55.15     | 1.7               |
| 6   | 21.1 | 19.8    | 101.3   | 4.5   | 4.5             | -58.27     | 1.7               |
| 7   | 20.5 | 19.4    | 92.2    | 4.1   | 4.1             | -58.57     | 1.7               |
| 8   | 20.9 | 19.5    | 101.2   | 4.5   | 4.5             | -57.99     | 1.7               |
| 9   | 21.9 | 19.7    | 105.5   | 4.5   | 4.5             | -58.20     | 1.7               |
| 10  | 21.9 | 20.4    | 94.2    | 4.2   | 4.2             | -58.20     | 1.6               |
| 11  | 21.3 | 20.9    | 108.0   | 5.0   | 5.0             | -55.32     | 1.7               |
| 12  | 21.5 | 19.6    | 96.6    | 5.0   | 5.0             | -55.85     | 1.5               |
| 13  | 21.6 | 19.6    | 96.2    | 5.0   | 5.0             | -57.99     | 1.7               |
| 14  | 21.8 | 18.9    | 83.1    | 5.0   | 5.0             | -58.11     | 1.7               |
| 15  | 21.5 | 19.6    | 103.4   | 4.5   | 4.5             | -58.04     | 1.7               |
| 16  | 20.5 | 18.8    | 92.9    | 4.5   | 4.5             | -58.08     | 1.6               |
3.2. Formula TS-Length Fish Torpedo Scad (Megalaspis cordyla)

The analysis of fish length relationship (FL) Torpedo Scad (Megalaspis cordyla) to TS value from each individual to get the empirical value in the form of $TS = 20 \log (FL) + C$ was done based on the measurement data presented in table 2. Number of samples fish measured Torpedo Scad is 35 piece of samples.

![Figure 3. Relationship value TS (y) fish Torpedo Scad as log function FL (x).](image)

| No. | TL (cm) | FL (cm) | W (g) | Swimblader (cm) | Average TS | Deviation Standard |
|-----|---------|---------|-------|-----------------|------------|--------------------|
| 17  | 21.4    | 19.8    | 96.3  | 5.5             | -55.34     | 1.7                |
| 18  | 21.2    | 20.0    | 101.6 | 5.5             | -58.09     | 1.7                |
| 19  | 20.8    | 18.9    | 88.9  | 4.0             | -58.12     | 1.6                |
| 20  | 21.2    | 19.3    | 93.5  | 6.0             | -58.01     | 1.7                |
| 21  | 21.3    | 20.3    | 108.6 | 5.5             | -55.23     | 1.7                |
| 22  | 22.2    | 20.6    | 94.6  | 5.0             | -49.22     | 1.5                |
| 23  | 20.8    | 19.3    | 96.6  | 5.0             | -58.09     | 1.7                |
| 24  | 23.8    | 20.9    | 102.2 | 5.5             | -58.00     | 1.7                |
| 25  | 23.8    | 21.7    | 101.3 | 5.0             | -61.67     | 1.6                |
| 26  | 21.9    | 20.4    | 86.3  | 5.0             | -58.39     | 1.7                |
| 27  | 21.7    | 19.6    | 93.1  | 5.0             | -58.35     | 1.5                |
| 28  | 22.6    | 20.4    | 105.3 | 5.5             | -58.58     | 1.6                |
| 29  | 21.9    | 20.0    | 97.5  | 4.5             | -60.91     | 1.7                |
| 30  | 21.2    | 19.8    | 96.4  | 6.0             | -60.88     | 1.6                |
| 31  | 21.4    | 20.0    | 92.2  | 5.5             | -58.29     | 1.7                |
| 32  | 23.3    | 22.0    | 91.1  | 5.5             | -58.33     | 1.6                |
| 33  | 21.1    | 19.2    | 86.7  | 5.5             | -58.11     | 1.6                |
| 34  | 21.2    | 19.3    | 87.6  | 5.0             | -60.99     | 1.6                |
| 35  | 21.8    | 19.9    | 106.6 | 5.0             | -60.91     | 1.7                |
Table 3 shows the result of the regression analysis for the significance of the independent variable (x) Log FL to average TS value. The result of t-test at 95% confidence level indicates that the length size (FL) has no significant effect on the TS value, where the absolute t-count (0.34) < t-table, also insignificant (P-value (0.737) > 0.05). Regression equation model based on research data is not significant meaning, linear regression model does not meet the criteria of linearity. The regression equation for TS-length fish formulation TS = 8.35 Log (FL) - 68.9 with coefficient of determination (R² = 0.30%) and R² (adj) = 0% (figure 4).

Table 3. Independent variable coefficient (x) is the length of fish (FL) in the regression equation.

| Variable | Coefficient | SE Coef | T    | p    | VIF |
|----------|-------------|---------|------|------|-----|
| Constant | -68.9       | 32.2    | -2.14| 0.040|     |
| FL       | 8.35        | 24.81   | 0.34 | 0.738| 1.00|

The result of F-test or ANOVA (table 4) shows the value of F-count (0.11) < F-table (1; 34; 0.05) (4.13), then reject H₀ which means linear model between fork length (FL) with its TS value is insignificant. Test the suitability of models in the ANOVA table shows that the significance (p-value = 0.000) < α = 0.05, then reject H₀. The independent variable that is long (FL) Torpedo Scad fish effect simultaneously to the dependent variable (TS value), so regression model is feasible to be used.

Table 4. ANOVA table for TS-length Torpedo Scad (Megalaspis cordyla) regression equation.

| Source    | Degree of freedom | SS    | Mean Square | F value | P value |
|-----------|-------------------|-------|-------------|---------|---------|
| Regression| 1                 | 0.584 | 0.58412     | 0.11    | 0.000   |
| Error     | 33                | 169.267 | 5.12931   |         |         |
| Total     | 34                | 169.51 |             |         |         |

If the relation of the length of the fish to the TS value of each individual is based on the formula TS = 20 Log (FL) + C, then the following calculation applies:

The equation y = 8.35x-68.89

If TS = 20 log (FL) + C, then

20 log (FL) + C = 8.35log (FL) - 68.89

C = 8.35log (FL) - 68.89 - 20 log (FL)

By entering the values of FL in the range of fish measured Torpedo Scad, then obtained variation of value C (table 5). The average C value for fish Torpedo Scad with size 18.0 - 22.5 cm FL is C = -53.68. Foote equation for fish Torpedo Scad (Megalaspis cordyla) obtained is TS = 20 Log (FL) - 53.68.

Table 5. C value of FL value per length of fish Torpedo Scad (Megalaspis cordyla).

| FL (cm) | 18 | 18.5 | 19 | 19.5 | 20 | 20.5 | 21 | 21.5 | 22 | 22.5 |
|---------|----|------|----|------|----|------|----|------|----|------|
| C (dB)  | -54.27 | -54.1 | -53.99 | -53.86 | -53.73 | -53.61 | -53.49 | -53.37 | -53.25 | -53.14 |

3.3. TS measurement torpedo scad samples in the dead fresh condition

Paired T Test were conducted on fish samples to see if there were differences in TS values resulting from two different treatments. Paired T Test is also used as a comparative test or difference if the data scale of the two variables is quantitative (interval or ratio) [8]. The treatment performed in this research is the calculation of TS fish Torpedo Scad for the conditions in living conditions and the condition of fish in a dead fresh (table 6.). The measuring time range between the treatment of live and dead fish ranges from 2 hours to 9 hours after the measurement of the initial condition (life). Within
the span of time, it is expected that fish morphology and elasticity of fish meat is not much different from the initial condition (life).

**Table 6. Measurement of TS fish with Torpedo Scad two different treatments.**

| Variables         | Torpedo Scad A | Torpedo Scad B | Torpedo Scad C | Torpedo Scad D | Torpedo Scad E |
|-------------------|----------------|----------------|----------------|----------------|----------------|
| TL (cm)           | 22.2           | 21.3           | 20.2           | 23.3           | 23.8           |
| FL (cm)           | 20.6           | 20.9           | 19             | 22             | 20.9           |
| Log FL            | 1.313867       | 1.320146       | 1.313867       | 1.3424         | 1.3201         |
| W (g)             | 94.6           | 108            | 94.5           | 91.1           | 102.2          |
| L Swimblader (cm) | 5              | 5              | 5              | 5.5            | 5              |
| TSavg (dead)      | -58.75         | -57.98         | -57.31         | -53.15         | -57.85         |
| TSavg (live)      | -49.22         | -55.32         | -58.64         | -58.33         | -58            |
| Δ t               | 2:56:00        | 5:57:00        | 8:31:00        | 1:48:00        | 3:50:00        |

Δ t = time lapse difference in fish for living conditions and dead fresh condition (within hours)

The hypothesis of this case can be written:

H₀: μ₁ = μ₀
H₁: μ₁ ≠ μ₀

α = 0.05

H₁ means that the actual difference of the two averages is not equal to zero.

**Table 7. Paired T test for fish TS Torpedo Scad Live and Dead Fresh conditions.**

|        | N  | Mean  | StDev | SE Mean |
|--------|----|-------|-------|---------|
| TS Live| 5  | -55.90| 3.965 | 1.77    |
| TS dead fresh | 5 | -57.01| 2.22  | 0.99    |
| Perbedaan | 5 | 1.1   | 5.49  | 2.45    |

95% CI for mean difference: (-5.71, 7.92)

T-Test of mean difference = 0 (vs ≠ 0):

T-Value = 0.45  P-Value = 0.676

The p-value of the paired t-test above is 0.676, which is greater than 0.05. Thus, the statistical conclusion we take is THRIVE H₀. This means that the TS measurement values for fish Torpedo Scad living and dead fresh conditions equal to zero. Thus, TS measurements for living conditions and fresh dead conditions have no significant difference.

**4. Discussion**

4.1. *Empirical relationship of TS value with length of fish*

Based on the results of measuring activities of Target Strength (TS) values for Torpedo Scad fish (*Megalaspis cordyla*) it is possible to perform a simple statistical TS-length analysis. The Central Limit Theorem says that the more observations (in this case the experimental sample unit) the data is getting closer to the normal distribution. The general rule, if the experimental unit is more than or equal to 30 then the data is considered to follow the normal distribution. In this study the experimental unit was 35 (above 30), so the normality test did not become necessary.

Based on table 2, regression equation for TS-length fish formulation is $TS = 8.35 \log(FL) - 68.9$ with coefficient of determination ($R^2 = 0.30\%$) and $R^2$ (adj) = 0% (figure 3). The t-test result at the 95% confidence level (table 3) shows that the length (FL) does not significantly affect the TS value. The regression equation model based on the research data is not significant, the linear regression model does not meet the linearity criteria so that this equation cannot be used for prediction or
forecasting. Test the suitability of models in the ANOVA table (table 4.) shows that the significance ($P_{\text{value}} = 0.000 < \alpha = 0.05$), then reject $H_0$. The independent variable that is long (FL) fish Torpedo Scad effect simultaneously to the dependent variable that is TS value, so regression model is feasible to be used.

If the relation of the length of the fish to the TS value of each individual is based on the formula $TS = 20 \log(FL) + C$, then $20 \log(FL) + C = 8.35 \log(FL) - 68.89$. So $C = -11.65 \log(FL) - 68.89$. By entering the values of FL in the range of fish measured Torpedo Scad, the variation of the value of $C$ (table 5) is obtained. Thus, the average $C$ value for Torpedo Scad fish with size 18.0 - 22.5 cm FL is $C = -53.68$. So we get the equation Foote for Torpedo Scad fish ($Megalaspis cordyla$) is $TS = 20 \log(FL) - 53.68$.

4.2. Paired T Test Measurement TS Torpedo Scad fish
Paired T Test is performed on fish samples to see if there are any differences in TS values resulting from two different treatments. The treatment conducted in this research is the calculation of TS Torpedo Scad fish for living conditions and the condition of fish in a dead fresh (table 6.). The $p$-value of the paired $t_{\text{diff}}$ is 0.676, which is greater than 0.05 ($\alpha$). Thus, the statistical conclusion we take is THRIVE $H_0$. This means that the TS measurement values for Torpedo scad fish living and dead fresh conditions equal to zero. Thus, TS measurements for living conditions and fresh dead conditions have no significant difference. The condition of the morphology of fish samples measured at live and dead fresh is not much different is very influential on the paired t test results.

5. Conclusion
The measurements of TS values of each individual fish in the same species in this study have shown evidence and reinforce the hypothesis that TS values are a function of the length of the fish. TS value has a linear relationship with the length of the fish, the larger the size of the fish the TS value is greater. The empirical relationship in the form of TS-length for Torpedo Scad fish ($Megalaspis cordyla$) is $TS = 20 \log L - 53.68$. TS measurements for living conditions and fresh dead conditions have no significant difference.

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