In situ TS measurement of Mackerel Scad (*Decapterus macarellus*), Leopard Coral Trout (*Plectropomus leopardus*), and Largehead Hairtail (*Trichiurus lepturus*)

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Abstract. Acoustic target strength (TS) measurements were performed on one small pelagic fishes, and two demersal fishes, which are very important for Indonesia fisheries, namely: mackerel scad (*Decapterus macarellus*), coral trout (*Plectropomus leopardus*), and largehead hairtail (*Trichiurus sp.*). The TS data analysis is performed numerically using the best-fit technique to establish the relationship between length, fish orientation, and TS. The TS-length relationship was obtained as follow: for mackerel scad, TS = 20log - 84.38; for coral trout, TS = 20log - 76.68, and for large headhairtail, TS = 20log -91.88.

1. Introduction

The existence of small pelagic fish in Indonesian waters is very diverse and abundance continues to change due to migration and environmental changes. The calculation of potential existence of fish has been done by the Ministry of Marine Affairs and Fisheries in the last several years. Various efforts have been made by conducting surveys of fish stocks using acoustic technology and catch sampling as well as recording of fishermen catch data at ports throughout Indonesia [1]. The results of the axis analytical measurements are strongly influenced by the accuracy of measured values of fish target strength (TS). Therefore it is necessary to accurately measure the target strength value (TS) of small pelagic fish for verification of the results of an axis survey for fish stock estimation [2]. Fisheries management in the territorial waters of Indonesia, especially in coastal areas need to be done. One of the first actions to begin is to know precisely the stock or abundance of fish in fishing ground [3]. This can be done by utilizing acoustic technology to obtain the value of abundance, fish biomass based on the reflected sound of the object/target (fish). Before making the determination of fish abundance and biomass must be known exactly the actual value of the target strength of the target fish. This is especially important because target strength is the main parameter for determining fish density, abundance and biomass in acoustic technology applications [4]. The results of this study are expected to be useful to assist decision makers for the management of fishing so as to have a controlled stock, which in the long term will help in the preservation of coastal fisheries communities.
2. Methods

2.1. Time and location
In situ TS measurement was performed from the floating lift net [Figure 1], in Pelabuhan Ratu Bay waters during November 2016. The live fish was placed inside of the cage, while for dead fish was tethered using monofilament line.

![Figure 1. Floating rides (lift net) vehicle as a place to do research.](image)

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 sample 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 [4]. Measurement 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 and strong current conditions, so 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.

| 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
In the previous TS measurements, a test was conducted to examine the differences in TS values between live fish and dead fresh fish for the same fish samples. The result of the TS measurements after paired t test on the 5 fish were obtained conclusion that the measurement value of TS for the fish (Megalaspis cordyla) living and dead conditions is equal to zero. Thus, TS measurements for living
conditions and fresh dead conditions have no significant difference. The results obtained are the basis for TS measurement testing for other small pelagic fish species conducted on dead-fresh fish samples. Measurements of fish were measured done using tethered techniques, where each fish was located and hung on a monofilament strings net [5]. Each individual fish is scanned with an acoustic system, with the transducer placed over a hanging fish sample, so the target (fish) is in the beam acoustic beam area. 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.

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 distributed within a certain range, but generally distributed normally and have a certain modus value [6].

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 [5] TS is a backscattering cross section (obs) of the returned target signal, and the relationship between TS and obs is expressed as $\text{TS} = 10 \log (\text{obs})$. Then the average TS is $\text{TS} = 10 \log (\text{obs})$. 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 analyze the empirical relationship between the two so that TS-length formulation is formed. The empirical relationship between TS and L refers to $\text{TS} = 20 \log (L) + A$, where A is the target strength value for 1 cm of normalized strength depending on the species of fish species [4]. Based on the equation, then to get TS-length formulation we 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 $\text{TS} = a \log L + b$ is formed, then the partial test is the significance of variable L to TS, with the hypothesis: $H_0 = \text{L variable has no significant effect on TS}$; $H_1 = \text{L variable has significant effect on TS}$.Regression equation obtained, then compared with equation [4] that is $\text{TS} = 20 \log L + A$, 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 $\text{TS} = 20 \log L + C$ [7].Measurements of TS values for dead fresh fish conditions in this study used Mackerel Scad (*Decapterus macarellus*), Leopard Coral Trout (*Plectropomus leopardus*), and Largehead Hairtail (*Trichiurus lepturus*).

3. Results

3.1 Target Strength value
The measurement result with 200 kHz acoustic frequency of the 17 samples Mackerel Scad (*Decapterus macarellus*) showed that the TS value was distributed from -66 s/d -42dB. Each fish size has a different modus class value. The value of the TS Mackerel Scad modus class tends to increase with the larger size (table 2). A number of Mackerel Scad measured for their TS values, scattered from size 20.0-33.5 cm FL, with an average number of samples measuring 300 times for each fish. Measurement results showed that,TS values ranging from -61.14 ± 1.7 dB to -46.06 ± 1.7 dB. The average value of TS Mackerel Scad in the 20.0-33.5 cm FL size is -55.63 ± 1.7 dB (table 7). The results of measurements of Mackerel Scad with acoustic frequency have the same diversity values.
The TS value from 6 samples Leopard Coral Trout (*Plectropomus leopardus*) was distributed from -56.04 s/d -40.67 dB. Each size of fish has a different modus class value. The value of the TS Leopard Coral Trout modus class tends to increase with the larger size (table 2). A number of Leopard Coral Trout measured their TS values, scattered from size 21 – 28 cm TL. The average value of TS Leopard Coral Trout in the 21 – 28 cm TL size is -49.63 dB (table 2), and average TS value from 5 samples of Largehead Hainraill (*Trichiurus lepturus*) is -56.73 dB distributed from -59.02 s/d – 40.67 dB with scattered from size 43 – 50 cm TL. Both the results of measurements of Coral Trout and Largehead Hairtail with acoustic frequency have the same diversity values.

### 3.2 Formula TS-Length Fish

Based on the results of measuring activities of Target Strength (TS) from three fishes (Mackerel Scad, Leopard Coral Trout, and Largehead Hairtail) 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 is, 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 below 30, so the normality test did become necessary [8].

The analysis of fish length relationship three fishes 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. In sequence number of samples fish measured Mackerel Scad, Leopard Coral Trout, and Largehead Hairtail is 17, 6 and 5 piece of samples.

Based on the results of treatment of data to meet the assumptions required in the regression analysis, then after the exploration of data, from 17 fish samples measured TS value there were values of deviants (outliers). The normality test (figure 3-5. left) showed that plot results in residual values are in the vicinity of the normality line or approximately on the diagonal line, so the residual normality assumption is fulfilled. Homoskedasticity test (figure 3-5. right) to see the homogeneity of variance, showed fitted values vs. residual values randomly distributed, meaning that the residual variation is constant, so that residual homoskedasticity assumption is fulfilled. So the data of measurement result is feasible for regression analysis.

**Table 2.** Structure of size and value of fish TS Mackerel Scad (*Decapterus macarellus*), Leopard Coral Trout (*Plectropomus leopardus*), and Largehead Hairtail (*Trichiurus lepturus*).

| No. DeadFish | TL (cm) | FL (cm) | W (g) | Swimblader (cm) | TS rata-rata (dB) |
|--------------|---------|---------|-------|-----------------|------------------|
| MS1          | 24.5    | 22.5    | 147.3 | 7               | -52.11           |
| MS2          | 31.5    | 28.5    | 305   | 10              | -58.21           |
| MS3          | 26      | 24      | 120   | 7.5             | -61.02           |
| MS4          | 37      | 33.5    | 440   | 15              | -58.2            |
| MS5          | 28.2    | 25.8    | 225   | 7               | -61.14           |
| MS6          | 27.2    | 24.8    | 180   | 6.5             | -55.1            |
| MS7          | 24.5    | 23      | 123   | 8               | -55.78           |
| MS8          | 28      | 25.8    | 193.7 | 8               | -58.22           |
| No. Dead Fish | TL (cm) | FL (cm) | W (g) | Swimblader (cm) | TS rata-rata (dB) |
|---------------|---------|---------|-------|-----------------|------------------|
| MS9           | 24.7    | 22.9    | 164   | 7               | -55.15           |
| MS10          | 28.5    | 26      | 146   | 8               | -59.08           |
| MS11          | 25.4    | 23.6    | 176   | 7               | -46.06           |
| MS12          | 25.5    | 23.5    | 155   | 6               | -49.37           |
| MS13          | 24.5    | 22      | 170   | 6               | -58.26           |
| MS14          | 24.7    | 22.5    | 123   | not visible     | -52.36           |
| MS15          | 27      | 24      | 173   | 10              | -52.11           |
| MS16          | 21.5    | 20      | 103   | 5               | -58.33           |
| MS17          | 28      | 23.5    | 178   | 7               | -55.27           |
| LC1           | 25.5    | 25.5    | 220   | 5.5             | -51.12           |
| LC2           | 21      | 21      | 138   | 5               | -51.52           |
| LC3           | 23      | 23      | 264   | 6               | -40.67           |
| LC4           | 28      | 28      | 407   | 6.5             | -46.51           |
| LC5           | 22      | 22      | 209   | 5.4             | -51.91           |
| LC6           | 21.9    | 21.9    | 187   | 5               | -56.04           |
| LH1           | 80.5    | 80.5    | 170   | -               | -54.69           |
| LH2           | 49      | 49      | 115   | -               | -59.02           |
| LH3           | 43      | 43      | 59    | -               | -58.07           |
| LH4           | 60      | 60      | 180   | -               | -55.12           |
| LH5           | 55      | 55      | 124   | -               | -56.76           |

Figure 3. Normality plot (left) and Interdependent between error (right) for value TS Mackerel Scad fish (Decapterus macarellus).

Figure 4. Normality plot (left) and Interdependent between error (right) for value TS Leopard Coral Trout (Plectropomus leopardus).
Figure 5. Normality plot (left) and Interdependent between error (right) for value TS Largehead Hairtail (*Trichiurus lepturus*).

After normality and homoscedasticity tests for three small pelagic fish, both tests were performed to look at the homogeneity of the data, whether the data were spreading randomly so that the residual homoskedasticity assumptions were met. So the data of the measurement result is feasible for the regression analysis for the three fish species.

Figure 6. Relationship value TS (y) Mackerel Scad fish (*Decapterus macarellus*) as log function FL (x).

Figure 7. Relationship value TS (y) Coral Trout (*Plectropomus leopardus*) as log function FL (x).

Figure 8. Relationship value TS (y) Largehead Hairtail (*Trichiurus sp.*) as log function FL(x).
The regression equation for TS-length Mackerel Scad fish (Decapterus macarellus) fish formulation is $TS = -23.85 \log (FL) - 22.59$ with coefficient of determination ($R^2 = 8.3\%$) and $R^2$ (adj) = 2.2\% (figure 6). The regression equation for TS-length Leopard Coral Trout fish formulation is $TS = 40.34 \log (FL) - 104.9$ with coefficient of determination ($R^2 = 12.9\%$) and $R^2$ (adj) = 0 \% (figure 7), and the regression equation for TS-length Largehead Hairtail fish formulation is $TS = 15.52 \log (FL) - 83.88$ with coefficient of determination ($R^2 = 73.8\%$) and $R^2$ (adj) = 65.1 \% (figure 8).

3.3. Formula TS-Length
Mackerel Scad (Decapterus macarellus)
If the relation of the length of the fish to the TS value of each individual is based on the formula

$$TS = 20 \log (FL) + C$$

(1)

then the following calculation applies:

Equation

\[
\begin{align*}
    y & = -23.85x - 22.59 \\
    \text{if} & \\
    \text{then} & \\
    TS & = 20 \log (FL) + C \\
    20 \log (FL) + C & = -23.85 \log (FL) - 22.59 \\
    C & = -23.85 \log (FL) - 22.59 - 20 \log (FL) \\
    C & = -43.85 \log (FL) - 22.59
\end{align*}
\]

By entering the values of FL in the range of fish measured Mackerel Scad, then obtained variation of value $C$ (table 5). The average $C$ value for fish Mackerel Scad with size 20.00 – 33.5 cm FL is $C = -84.38$. Foote equation for fish Mackerel Scad (Decapterus macarellus) obtained is $TS = 20 \log (FL) - 84.38$.

| FL  | 19  | 19.5 | 20  | 20.5 | 21  | 21.5 | 22  | 22.5 | 23  | 23.5 | 24  |
|-----|-----|------|-----|------|-----|------|-----|------|-----|------|-----|
| C   | -78.66 | -79.16 | -79.64 | -80.11 | -80.57 | -81.02 | -81.46 | -81.88 | -82.30 | -82.71 | -83.11 |
|     | 24.5 | 25   | 25.5 | 26   | 26.5 | 27   | 27.5 | 28   | 28.5 | 29   | 29.5 | 30   |
|     | -83.50 | -83.89 | -84.27 | -84.64 | -85.00 | -85.36 | -85.70 | -86.05 | -86.38 | -86.72 | -87.04 | -87.36 |
|     | 30.5 | 31   | 31.5 | 32   | 32.5 | 33   |
|     | -87.68 | -87.99 | -88.29 | -88.59 | -88.89 | -89.18 |

Final Foote Equation for Mackerel Scad fish: $TS = 20 \log - 84.38$

If we repeat the procedure above for two other fish it will get the value of $C = 20.34 \log (FL) - 104.90$ for Leopard Coral Trout (Plectropomus leopardus) and $C = -4.48 \log (TL) - 83.88$ for Largehead Hairtail fish (Trichiurus lepturus), then entering the values of TL in the range of fish measured Coral Trout fish (21 – 28 cm TL) we get final foote equation Coral Trout fish: $TS = 20 \log (TL) - 76.68$. Same for Largehead Hairtail fish (43-50 cm TL), final foote equation: $TS = 20 \log (TL) - 91.88$.

4. Conclusion
1. In case of Torpedo Scad fish (Megalaspis cordyla), TS measurements for living condition and fresh dead condition treatments have no significant difference using T Paired test.
2. 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.

3. The empirical relationship in the form of The TS-length relationship was obtained as follow: for mackerel scad, TS = 20log-84.38; for coral trout, TS = 20Log-76.68, and for large headhairtail, TS = 20Log-91.88.

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