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Acoustic Characteristics of Several Fish Species of Jenggalu River Estuary Through Controlled Measurements in Bengkulu City

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A B S T R A C T

Estuary waters are important habitats as spawning and nursery areas for various species of fish so it is necessary to monitor the fish resources in them. The purpose of this study is to analyze the target strength values of various estuary fish species from the Jenggalu River estuary through controlled measurements and formulate the relationship of target strength to total fish length. The controlled acoustic method uses a Simrad EK-15 echosounder with a frequency of 200 kHz. Measurements were taken in the pond using the tethered method, where the dead test fish was hung horizontally on the frame and then the acoustic signal was emitted vertically from above. The samples used were 13 species of fish with a total of 62 fish. The results obtained the average value of target strength has a range of values ranging from -68.86 to -54.80 dB. The relationship between the target strength value and the total length of the fish shows a very strong relationship with the correlation coefficient (r) value ranging from 0.86 – 0.96 and the coefficient of determination shows more than 74% of the TS value is influenced by the size of the fish length. The resulting equation model of the relationship between TS and total length size showed that TS values on the dorsal aspect increased in proportion to the square of fish length.

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INTRODUCTION

Bengkulu City is one of the cities that has coastal waters directly facing the Indian Ocean. Apart from having a marine area, Bengkulu City also has public waters that flow and empties into the Indian Ocean on the west coast of Bengkulu Province, namely the Jenggalu River (Herawati et al., 2021).

The Jenggalu Estuary is utilized by local residents as an economic asset, one of which is a tourist attraction, and there are common activities carried out by residents as a place to catch fish. This shows that the waters of the Jenggalu Estuary have potential fishery resources that are the livelihood of the local community (Purba et al., 2021).

The Jenggalu estuary ecosystem has a very large role in supporting the lives of people in the Jenggalu estuary area. Various catches obtained by fishermen in the Jenggalu river flow are crab crabs, shrimp, various types of fish, and lokan, which function as a food source for the community. The estuary area has an ecological function as a nursery ground and feeding ground for various types of fish and shrimp.

According to Purba et al. (2021), an estuary is a part of the river that connects the river with the sea. This will affect the characteristics of the water masses in these waters, especially in terms of population, distribution, and abundance of fishery resources. Jenggalu estuary can be a good habitat for shallow-water biota and fish.

Seeing the strategic role of the estuary as one of the waters that has the potential to have fishery resources, there certainly needs to be information collected about these fish resources. One of the most effective and efficient methods to obtain information about fish resources in a water column is the hydroacoustic method. The implementation of hydroacoustic technology itself has been widely utilized in estimating the abundance and distribution of fish in freshwater and marine waters (Simmonds and MacLennan, 2005).

Pujiyati et al. (2020) stated that one of the factors that is very important to know in assessing and estimating the stock of fish resources hydroacoustically is knowing the target strength value. The same opinion was also expressed by Zare et al. (2017), where in acoustic estimation, each target species requires target strength data. There are several factors that can affect the value of the target strength of an object (for example, a fish), such as fish length, body shape, and behavior (Jaya and Aulya, 2019; Bakhtiar et al., 2021; Apdillah et al., 2021).
Acoustic characteristics of fish in relation to fish biological parameters, especially fish length, need to be known for all types of fish so that they can be used as a reference in estimating fish stocks acoustically. Research on the measurement of target strength in a controlled manner has been carried out by Bakhtiar et al. (2020a), where this measurement was carried out on the object of bentong mackerel (Selar boops), then on coral reef fish (Bakhtiar et al., 2020b), gulama fish in the Musi river estuary (Supriyadi et al., 2021), and grouper fish (Febrianto et al., 2023). The characteristics of fish in the estuary are not widely known; therefore, it is necessary to study the acoustic characteristics of various types of fish in the estuary, especially in the Jenggalu estuary, Bengkulu City.

This study aims to analyze the value of target strength (acoustic backscatter) of various types of estuary fish from the Jenggalu river estuary through controlled measurements and formulate the relationship of target strength to total fish length.

THEORETICAL REVIEW

One aspect that needs to be considered in sustainable fisheries management is the bioecological aspect related to the sustainability of stocks or biomass so that utilization does not exceed its carrying capacity (Charles 2001). Stock status analysis is important to be carried out continuously for sustainable fisheries, because fishery resources are dynamic due to changes in mortality (Carruthers et al. 2012). Romakkaniemi (2015) explains that stock assessment is an estimate of the size of the fish population as a management function to estimate the amount of fishing that does not exceed the maximum sustainable yield (MSY). Efforts to determine appropriate management options must be based on research results, especially studies of potential and utilization rates (Suman et al. 2016). According to MacLennan (1990), an estimate of fish stocks is needed and acoustic survey techniques can be used to estimate fish abundance at certain times and conditions.

Hydroacoustics is a technique used as a tool for marine fish density estimation research (Fabi and Sala 2002; Neilson et al. 2003; Axenrot et al. 2004;. Greenstreet et al. 2010). Acoustic estimation techniques require acoustic backscatter or target strength (TS) data for each target species (Dawson and Karp 1990; Benoit-Bird et al. 2003; Zare et al. 2017). TS is an important parameter in acoustic resource estimation (Ona 2003; Kang et al., 2009).

There are many methods used to study the backscatter characteristics of fish as targets, including: (i) theoretical models (Clay and Horne 1994); (ii) ex situ measurements of dead or anesthetized fish or live hooked fish (Iida et al. 1998; Frouzova et al. 2005; Kang et al. 2009; Frouzova et al. 2011; Kang et al. 2014; Manik 2015); ex situ measurements in cages (cage method) (Brooking and Rudstam 2009; Rodriguez-Sanchez et al. 2015a; Rodriguez-Sanchez et al. 2015b); and (iii) in situ measurements of free-swimming fish in their natural habitat (McClatchie and Coombs 2005; Ryan et al. 2009; Sawada et al. 2009; O'Driscoll et al. 2013; Dunford et al. 2015).

Ex situ acoustic backscatter measurements are conducted to determine the influence of several biological and physical parameters of fish on acoustic backscatter values which cannot be known through in situ measurements (Bakhtiar et al., 2020a). Ex situ measurements are also used to study the acoustic backscattering pattern of a group of fish with different densities placed in a container or cage (Bakhtiar et al., 2019). This research was conducted to see the backscattering patterns of several types of estuary fish individually and can be used as a basis for getting the right model in estimating fish abundance in an estuary ecosystem.

METHODOLOGY

This research was conducted in October 2022, when fish sampling was carried out in Muara Jenggalu. While the measurement of fish acoustic data in a controlled way is carried out in the LPW Melati 12 Pinang Mas pond, Bentiring Permai Village, Bengkulu City. The research location map can be seen in Figure 1.

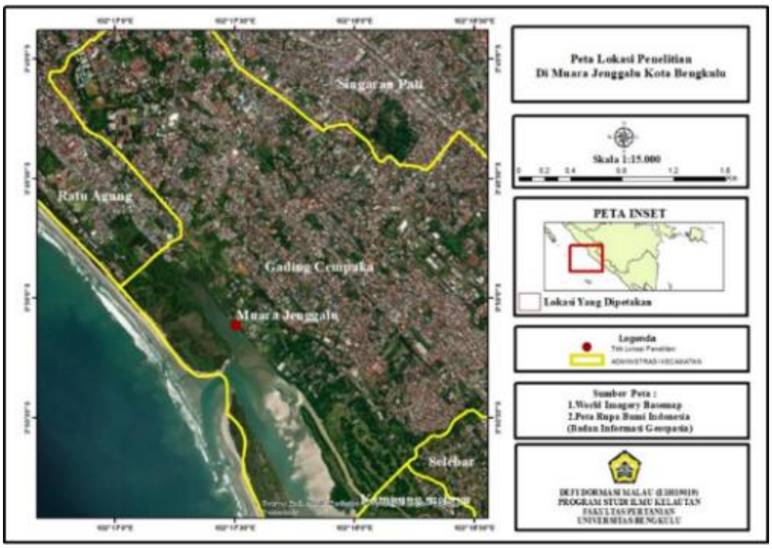


Figure1. Map of the Research Site at the Jenggalu estuary

The tools used in the study were a Simrad EK15 echosounder with a frequency of 200 kHz, a laptop, a ruler, a camera, a round tarpaulin pond (3 meters in diameter), a tethered frame, echoview 8.0 software, net and sondong (fishing gear), a Cool Box, arcmap 10.8 software, and Minitab software.

Fish samples caught with nets and skeins were put in a cool box and then taken to the pond, where ex-situ and controlled measurements were made. The measurement of fish samples in this study was carried out by measuring the total length of the fish. Measurements were made by measuring from the tip of the head to the tip of the tail using a ruler.

Acoustic measurements were taken using a Simrad EK-15 echosounder with a frequency of 200 kHz. Before taking acoustic data, calibration of the hydroacoustic device was carried out using a standard target in the form of a ball of tungsten carbide with a diameter of 38.1 mm (Foote et al., 1987). After calibration, acoustic measurements were made to obtain target strength data for each fish species. This single-fish target strength measurement uses the tethered method. Fish samples are hung using nylon rope; the transducer is 30 cm from the water surface, and the transducer is 40 cm from the top frame of the fish hanging device. The design of the tethered method for fish measurement can be seen in Figure 2.

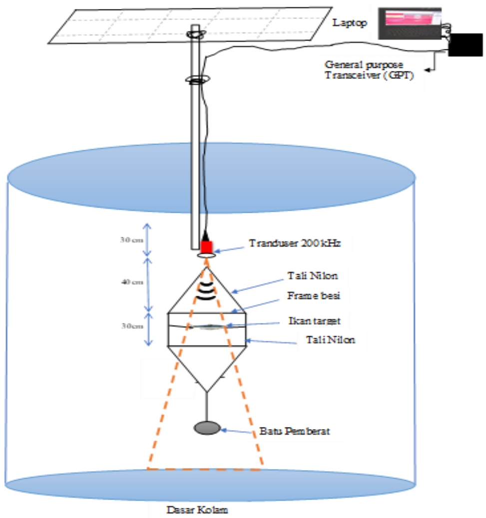


Figure 2. Design of Tethered Method Fish Measurement in Ponds

Acoustic data was obtained from the Simrad EK15 instrument in the form of raw data (an echogram). The raw data obtained is then analyzed using Echoview 8 software to obtain the target strength value of each ping. The target strength value obtained for each ping will be calculated using the following equation (Bakhtiar et al., 2020b):

$$\sigma_{bsi} = 10^{(TSi/10)} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

$$< \sigma_{bs} > = (\textstyle\sum_{i=1}^{n} \sigma_{bsi})/n \quad \ldots\ldots\ldots\ldots\ldots (2)$$

$$<TS> = 10 \log <\sigma_{bs}> \text{ (dB)} \quad \ldots\ldots\ldots (3)$$

Description:

σ_{bsi} : backscattering cross section value for the i-th ping

TSi : target strength value for the i-th ping

$<\sigma_{bs}>$: average backscattering cross section for each fish species and

<TS> : average target strength for each fish species.

n : number of pings

To determine the relationship between target strength and fish length using linear regression analysis. The linear relationship model itself is used by using the Love equation (1969, 1971) as follows:

$$\sigma = aL^{b} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

in logarithmic form, becomes:

$$TS = b \log + TL\ a\ [dB] \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Description:

σ : acoustic backscattering

TL : total length of fish

a : intercept of the regression equation and

b : the slope of the regression equation..

RESULTS

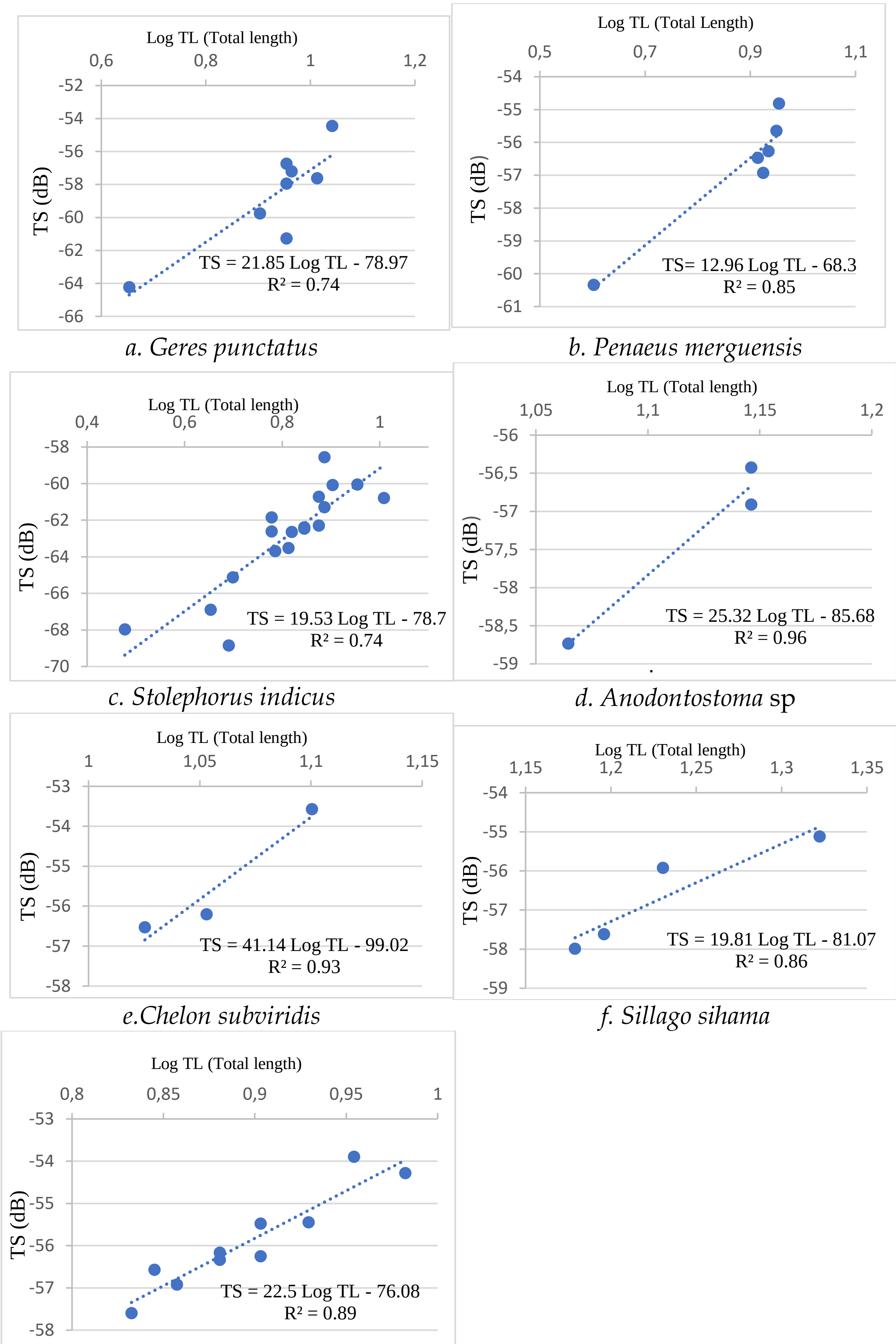
Samples in the study were obtained directly from the catch of fishermen who caught various types of marine biota in the Muara Jenggalu area and also from their own catch. The number of research samples obtained was 62. The types of fish caught in the Jenggalu estuary were 13 species, and the number of individuals (fish) of each species can be seen in Table 1.

Table 1. Target Strength Value of Fish Caught in Jenggalu estuary

Species of Fish	Number of Fish	Total Length Range (cm)	*Target Strength* Range (dB)	TS Mean (dB)
Torquigener pallimaculatus	1	3.7	-62.49	-62.49
Channa sp.	2	3-3.9	(-64.73) - (-64.66)	-64.70
Scatophagus argus	1	1.6	-68.86	-68.86
Geres punctatus	6	4 - 9	(-60.33) - (-54.81)	-56.58
Penaeus merguensis	8	4.5 - 11	(-64.23) - (-54.45)	-57.85
Stolephorus indicus	20	4.5 - 8	(-68.83) - (-58.54)	-62.16
Pseudorhombus malayanus	1	10	-55.31	-55.31
Terapon jarbua	2	9.6	(-58.65) - (-55.85)	-57.03
Anodontostoma sp.	3	11.6 - 14	(-58.73) - (-56.42)	-57.24
Chelon subviridis	3	10.6 - 12.6	(-56.52) - (-53.57)	-54.80
Sillago sihama	4	15.1 - 21	(-57.98) - (-55.11)	-56.49
Aurigequula longispina	10	6.8 - 9.6	(-57.59) - (-53.89)	-55.75
Anguilla sp.	1	2	-66.82	-66.82

The average target strength value of each fish species measured has different values based on the total length size ranging from 1.6–21 cm and also based on the number of samples of each fish species as described in Table 1. The average target strength value of fish caught in the Jenggalu Estuary has a range of values ranging from -68.86 to -54.80 dB. The highest average value of target strength is owned by *Chelon subviridis* fish, and the lowest target strength value is owned by *Catophagus argus* fish.

Target strength (TS) is the ability of an object or target to reflect sound waves. There are several factors that can affect target strength, one of which is fish body length. Figure 3 shows a data distribution plot illustrating the relationship of TS to the total length of fish from the 7 fish species measured, while the other 6 fish species were not analyzed for a linear relationship due to insufficient sample size.



a. *Geres punctatus* b. *Penaeus merguensis*

c. *Stolephorus indicus* d. *Anodontostoma* sp

e. *Chelon subviridis* f. *Sillago sihama*

g. *Aurigequula longispina*

Figure 3. Relationship between Target Strength (TS) and total length (TL) of fishes caught in Jenggalu estuary

Figure 3 shows that the empirical equation model from the regression analysis of the relationship between TS and the total length of the fish produced has a slope (b) generally ranging from 12.96 to 25.32, except for the mullet (*Chelon subviridis)* at 41.14. This shows that the model equation of the relationship between TS and total length size is close to the empirical equation of Love (1977), which states that for an individual fish, TS on the dorsal aspect increases proportionally to the square of the fish length.

Table 2: Empirical equations for the relationship between TS and total length of estuary fishes and their coefficients of determination and correlation coefficients.

Type of Fish	Number of Fish (ind)	R^2	r
Geres punctatus	6	0.85	0.92
Penaeus merguensis	8	0.74	0,86
Stolephorus indicus	20	0.74	0,86
Anodontostoma sp.	3	0.96	0,98
Chelon subviridis	3	0.93	0,96
Sillago sihama	4	0.86	0.93
Aurigequula longispina	10	0.89	0.94

Table 3. Interpretation of Correlation Coefficient

No	Interval Correlation coefficient (r)	Level of Relationship
1	0,00-0,199	Very low
2	0,20-0,399	Low
3	0,40-0,599	Medium
4	0,60-0,799	Strong
5	0,80-1,000	Very strong

Source: Anwar (2009)

Based on the results of the correlation analysis, it shows that the target strength values of all fish species are positively related to the total length of fish, as indicated by the correlation coefficient (r) value ranging from 0.86 to 0.96 (Table 2). The correlation coefficient value, according to Anwar (2009), shows a very strong level of relationship (Table 3). The coefficient of determination (R^2) of the 7 species of estuary fish (Table 2) shows a large value ranging from 0.74 to 0.96, which means that more than 74% of the TS value is influenced by the length of the fish body and the remainder is influenced by other factors derived from internal and external factors.

DISCUSSION

The total length of fish caught in the Jenggalu Estuary ranged from 1.6-21 cm. The results of acoustic measurements obtained the average value of target strength in the range between -68.86 to -54.80 dB, this value is classified into small to medium fish groups. Based on the opinion of Manik (2013), that the classification of fish size can be divided into three groups, namely small (-70 to -61 dB), medium (-60 to -49 dB), and large (-48 to -34 dB). The large number of small fish caught indicates that the Jenggalu estuary area is a spawning ground, nursery ground, and feeding ground for marine fish. Redjeki (2014) suggests that the estuary area is a spawning and nursery ground area, so that the fish caught are more in the size of fingerlings and juveniles.

The difference in length size of each fish species causes differences in the average value of TS. The difference in the length of the fish resulted in different areas affected by acoustic wave transmission. Acoustic waves transmitted vertically will hit the dorsal part of the fish so that backscatter is also more dependent on the area of the fish body that can reflect acoustic waves rather than on body volume (Frouzova et al. 2005). The value of acoustic backscatter referred to as target strength (TS) is highly dependent on the morphological parameters of the fish, one of which is the length of the fish (Hazen and Horne 2003; Gauthier and Horne 2004). The same thing was stated by Frouzova et al. (2005) that total fish length contributes significantly to TS and is the main predictor of TS.

Table 1 shows the difference in the average value of TS between several types of fish even though they have almost the same total length. As in white shrimp (Penaeus merguensis) with an average TS of -57.85 dB and anchovy (Stolephorus indicus) with an average TS of -62.16 dB there is a difference of 4.31 dB measured at a frequency of 200 kHz. The difference in the average value of TS is thought to be due to other sources of variability besides the length of the fish that determine TS. Zare et al. (2017) suggested that mean TS can differ by as much as 4 dB for fish of the same size, indicating that there are factors other than size that contribute substantially to TS variability in fish. Hazen and Horne (2003) suggested that there are hidden factors where the effect of one factor (such as fish swimming angle) cannot be separated from the effect of factors such as swimming bubble length or shape. Similarly, Henderson et al. (2007) suggested that fish swimming direction can have a major influence on TS in relation to acoustic beam angle. TS varies widely among individual fish due to differences in internal morphology and body orientation to the transmitted beam (Chen et al. 2012).

The coefficient of determination (R^2) of the 7 species of estuary fish (Table 2) shows a large value ranging from 0.74 to 0.96, which means that more than 74% of the TS value is influenced by the length of the fish and the rest is influenced by other factors derived from internal and external factors. As stated by Boyra et al. (2018), the acoustic properties of meat accounted for the main difference between skipjack and mackerel, followed by backbone properties. In contrast, shape variation and orientation angle distribution have relatively little effect on TS differences. Korneliussen and Ona (2004) found that backscatter from the backbone is weaker than meat at 38 kHz, but backscatter from the spine dominates at 120 and 200 kHz.

Figure 3 shows the regression equation of the mean TS values of several fish species in relation to the total length of the fish. This regression equation model can be used as a reference in determining the size of acoustically detected fish for stock estimation purposes. Boswell et al. (2008) suggested that the selection of the equation for the fish TS-length relationship has a substantial impact on the estimation of individual parameters and consequently on the estimation of fish biomass. The resulting relationship between TS and total fish length (TL) had a slope (b) generally ranging from 12.96 to 25.32, except for mullet at 41.14 (Figure 3). This suggests that the resulting model equation for the TS-TL relationship is not entirely consistent with Love's (1977) empirical equation that for an individual fish, the dorsal aspect of the TS increases in proportion to the square of the fish length. Similarly, Simmonds and MacLennan (2005) show that σ_{bs} is proportional to L^2, and TS is equal to 20 log L plus a constant value.

CONCLUSIONS AND RECOMMENDATIONS

There were 13 species of estuary fish from the Jenggalu Estuary that were successfully measured for acoustic characteristics, with a total length ranging from 1.6 to 21 cm. The results of controlled acoustic measurements obtained an average target strength value in the range of -68.86 to -54.80 dB. Based on the average target strength values obtained, the fish caught in the Jenggalu Estuary belong to the small to medium fish group (juveniles).

The relationship between the target strength value and the total length of fish carried out on 7 types of fish shows that the target strength value is very strongly positively related to the total length of fish, with a correlation coefficient (r) value ranging from 0.86 to 0.96. This is also supported by the coefficient of determination, which shows that more than 74% of the TS value is influenced by the size of the fish. The results of the linear regression analysis produced an empirical equation of the relationship between TS and total fish length. This regression equation model can be used as a reference in determining the size of acoustically detected fish for stock estimation purposes. This model equation is in close agreement with the empirical equation of Love (1977), where the target strength on the dorsal aspect increases proportionally to the square of the length of the fish.

FURTHER STUDY

The limitations of this study are the small number of fish samples and the small size of the fish due to limited fishing gear for sampling. Therefore, further research needs to be carried out with a larger number of samples and a larger fish size. Aspects of fish orientation towards the direction of acoustic wave propagation also need to be considered in addition to the presence of swimbladder and fish flesh density in measuring acoustic backscatter from fish.

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