IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 14, Issue 5 Ser. II (May 2020), PP 53-61
www.iosrjournals.org

Analysis of Reef Fish Target Strength through Ex-Situ Measurement Using Acoustic Methods

Deddy Bakhtiar[1*], Indra Jaya[2], Henry M. Manik[2],
Hawis H. Madduppa[2], Try Febrianto[3]

[1]*Post Graduate School of the Marine Technology IPB University Bogor,Indonesia*
2Departement of Marine Science and Technology, Faculty of Fisheries and Marine Science IPB University Bogor,Indonesia
[3]*Faculty of Fisheries and Marine Science University of Maritime Raja Ali Haji Tanjungpinang, Indonesia.*

Abstract: *The application of the acoustic method has been a common method to estimate the pelagic fish density. However, it has not been widely used in estimating the abundance of reef fish. Having high diversity, reef fish are difficult to be estimated using acoustic which it is needed to know the acoustical characteristic of each reef fish. This research was aimed at analyzing the backscattering characteristics of dominant fish composing of Abudefduf saxatilis, Chaetodon trifasciatus, Ctenochaetus striatus, Halichoeres hortulanus, and Scolopsis lineatus in Tikus Island, Bengkulu Province, and analyzing the relationship between the fish length and target strength (TS) values using two different frequencies (38 kHz and 200 kHz). The tethered method was used to measure TS value through ex-situ measurement. Simrad EY-60 (38 kHz) and Simrad EK-15 (200 kHz) were used in this research. Acoustical data were analyzed using Echoview 8 and statistical data were analyzed using Minitab. The results show that the averages of TS in all frequencies are not significantly different to all reef fish. The relationship between standard length and the average of TS are significant. The model relationship between TS and standard length points out a significant relation at all frequencies. Nonetheless, the discrepancy of the relationship between TS and square of fish length is found.*

Keywords: *backscattering, standard length, multispecies,tethered method, b20*

Date of Submission: 13-05-2020 Date of Acceptance: 25-05-2020

I. Introduction

One of the resources in the coral reef ecosystem is the existence of various fish species. Reef fish contribute as the highest biodiversity in this ecosystem (Allen and Werner 2002). The diversity of reef fish in Kepulauan Seribu consists of 216 species in 29 families (Madduppa *et al.* 2014), in Maratua Island, East Kalimantan composes of 159 species in 30 families (Madduppa *et al.* 2012) and in Enggano Island, Bengkulu is about 191 species in 24 families (Adrim 2007).

Information regarding the abundance and density of reef fish are highly needed in managing the coral reef ecosystem (McClanahan *et al*. 2016). Estimating the reef fish is commonly conducted using a method of *in situ* surveys which one of them is a visual underwater census by scuba diving (Caldwell *et al*. 2016), however, this technique possesses limitedness on depth, visibility, and time (Costa *et al*. 2014). The other limits of this technique are to count a lot of fish in huge aggregating groups (Campanella and Taylor 2016), and not all fish species appears in the daytime as well as the response of fish to avoid from the divers (Caldwell *et al*. 2016).

Estimating the fish abundance using acoustic method currently has been conducted a lot (Manik 2013) which is commonly applied for various pelagic fish in both ocean and freshwater (Simmonds and MacLennan 2005). However, applying this method to the coral reef ecosystem is still under development (Taylor and Ebert 2012), and is not widely used (Costa *et al.* 2014) due to the high diversity of reef fish and incapability in identifying the fish species (Kracker *et al.* 2011; Taylor and Ebert 2012; Campanella and Taylor 2016).

The acoustic estimation techniques need the 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 estimating the fish resource acoustically (Ona 2003; Kang *et al*. 2009). In the coral reef ecosystem, in general, the reef fish configure an aggregation of various species which is very difficult to be conducted the discrimination of acoustic target in this mix aggregation (Gauthier and Horne 2004). The echo energy coming from reef fish is a combination of varied species and sizes, therefore the total acoustic backscattering is the number of echo energy originating from sundry species containing in the aggregation (Korneliussen 2018). Furthermore, the TS varies greatly among individuals of fish, and even in the same species and sizes (Chen *et al.* 2012). Hence, information regarding the characteristics of acoustic target strength (TS) of each detected fish is needed (MacLennan 1990).

Studies relating to TS on fish had been widely conducted mainly on pelagic fish on ex-situ (Kang *et al*. 2009; Sawada *et al*. 2009) and *in-situ* (Ryan *et al*. 2009; O'Driscoll *et al*. 2013; Dunford *et al*. 2015). While the reef fish is still limited and merely tend to be conducted on the target species of consumption fish like groupers (Zhang *et al*. 2013) white-spotted spinefoot (*Siganus canaliculatus*), black porgy (*Acanthopagrus schlegelii*), and creek red bream (*Lutjanus argentimaculatus*) (Chen *et al*. 2012). Further, Manik (2013) carried out a measuring TS of some fish such as pearly monocle bream, rabbitfish, longfin grouper, spotted coral grouper, and parrotfish in the waters of Pramuka Island. Moreover, in the waters of Tikus Island, Bengkulu City, the reef fish are not only dominated by target fish, but the major fish also from family *Pomacentridae* and indicator fish from family *Chaetodontidae* (Bakhtiar *et al*. 2012), and mostly the dominant fish have not well recognized yet their acoustic characteristics.

This research was aimed at analyzing the target strength of five dominant reef fish species in Tikus Island waters composing of *Abudefduf saxatilis*, *Chaetodon trifasciatus*, *Ctenochaetus striatus*, *Halichoeres hortulanus*, and *Scolopsis lineatus*; and analyzing the relationship of the length reef fish of each species on TS using two different frequencies (38 kHz and 200 kHz).

II. Materials and Methods

This research was conducted in the waters of Tikus Island, Bengkulu City. The measuring times were carried out in two different periods namely in July and September 2017. The main tools used in this research were scientific echosounder Simrad EY-60 with a frequency of 38 kHz and Simrad EK-15 with a frequency of 200 kHz. Five fish species dominantly in the waters of Tikus Island such as *Abudefduf saxatilis*, *Chaetodon trifasciatus*, *Ctenochaetus striatus*, *Halichoeres hortulanus*, and *Scolopsis lineatus*, were utilized in this research. Before measuring and sounding the sampled fish, the set acoustic tools were calibrated prior. Calibrating these echosounders used the standard target method (Foote *et al*. 1987) by placing the tungsten carbide sphere ball (a 38.1-mm diameter and 200 kHz frequency) and copper phere ball (60 mm diameter and 38 kHz frequency) on the acoustic angles of these transducers. Measuring the targets was taken in 12-m depth with the temperature and salinity of the waters were in the ranges of 30-31^{o}C and 32-35$^{o}/_{oo}$, respectively.

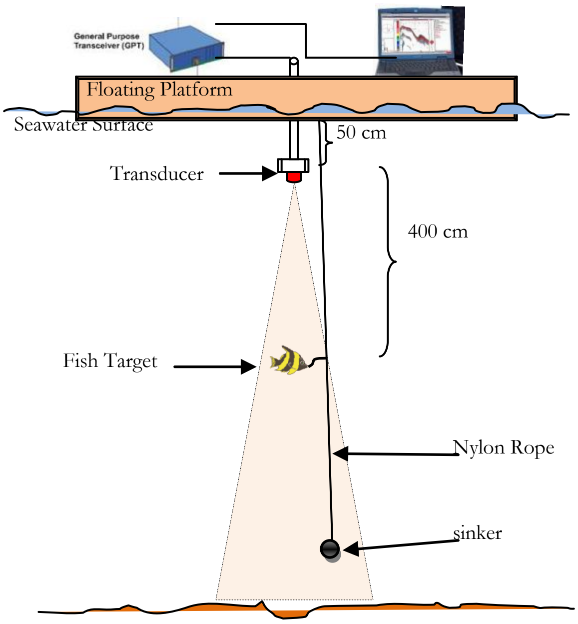

Figure 1. The design of data acquisition

Both the CPU (computer) and the receiver (GPT) were laid on the floating platform during data acquisition and the transducer was set on the water column in a range of 50 – 100 cm depth. The gathered TS Data were the acoustic data taken through *ex-situ* used a tethered method. The nylon rope had been tied a sinker and dropped down in 8-m depth from the seawater surface, and then the target fish was hanged on the between the ballast and seawater surface (4-m depth) beneath the transducer that was able to be defined (Figure 1).

The measured TS on the fish were only their dorsal aspects. Recording the fish data were taken for 5 minutes for each reef fish species. Each fish that was going be sounded was released from its hook to measure its standard length (SL). The TS data were processed using two software namely ER 60 (Kongsberg Maritime) and Echoview 8.0 (Myriax Soft. Pty. Ltd. 2016).

Backscattering analysis

The TS values of each reef fish species were changed into a linear form becoming backscattering cross-section (σ_{bs}) and then the average value of backscattering cross-section ($<\sigma_{bs}>$) was counted using the following steps.

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

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

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

Where σ_{bsi} is a backscattering cross section for fish-i; TSi is a target strength for fish-I, and; $<\sigma_{bs}>$ is the average of backscattering cross-section for each fish species as well as <TS> is the target strength average of each fish species. Furthermore, to count the difference of TS averages in varied frequencies, a comparative test (t-test) proceeded.

Analysis of the relationship between TS and Fish Standard Length

The simple linear regression analysis would generate a linear relationship model between TS as the dependent variable and the fish standard length (SL) as the independent variable. This linear relationship model used in this research followed the equation of Love (1971) as follows.

$\sigma = aL^b$, in the logarithm form, becoming:

$$TS = b \log L_{SL} + a \quad [dB] \quad (4)$$

Where σ is the acoustic backscattering, L is the length of the target, L_{SL} is the fish standard length, and both a and b are intercept and slope of the regression equation. The regression model gained from the equation above (4) was tested further using variance analysis (F-test).

Being a comparison, the equation of Love (1977) was used stating that σ is proportional on L^2 ($\sigma = aL^2$) where the value of b is equal to 20 (b20) that is in this research becoming a logarithm form as follows.

$$TS_{b20} = 20 \log L_{SL} + a \quad [dB] \quad (5)$$

III. Results and Discussions

1. Target Strength Distribution

The results of measuring TS on five reef fish species utilized two echo sounders Simrad EY-60 with 38 kHz frequency and Simrad EK-15 with 200 kHz frequency are presented in Table 1. The highest and the lowest TS average values on 38 kHz frequency occur on fish *Ctenochaetus striatus* and fish *Halichoeres hortulanus*, respectively. Furthermore, on 200 kHz frequency, the fish *Ctenochaetus striatus* possesses the highest TS average value and the lowest one is *Abudefduf saxatilis*.

The fluctuation of TS average values on each reef fish species as seen Table 1 signifies that the standard-length difference of each reef fish species causes a different of TS average values. The beam of an acoustic wave carrying out vertically is going to touch the dorsal part of the fish in which the backscattering of the fish also merely depends on the fish body area that can reflect the acoustic wave, not on the body volume (Frouzova *et al*. 2005). The backscattering value called as TS is highly depended on the fish morphological parameters which is one of them is the fish length (Hazen and Horne 2003; Gauthier and Horne 2004). The same perspective also has been expressed by Frouzova *et al*. (2005), the total fish length contributes significantly on the TS and becoming a main predictor of TS.

Table 1 also exhibits that the difference of TS average value happens among some fish species even though those fish have similar body sizes such as *Abudefduf saxatilis* with TS average of -54.52 dB and *Chaetodon trifasciatus* with TS average of -51.75 dB possessing 2.77 dB difference on both fish measured on 38 kHz frequency. Furthermore, on the 200 kHz frequency, both fish also have the difference of TS average value as many as 3.51 dB although these fish own the comparable standard-length ranges. This difference of TS average value is presumed due to other sources of variabilities besides the fish length that defines the fish TS. Zare *et al*. (2017) express that the TS average can vary as many as 4 dB for fish with the same sizes indicating another factor besides the fish size contributes substantially on the TS variability on fish. Hazen and Horne (2003) reveal that the hidden factors where the influence of a certain factor (like the tilt angle of fish swimming) is not able to be separated from the other factors' influences such as either fish length or swim. Likewise, Henderson *et al*. (2007) express that the fish swimming direction can contribute highly on TS regarding acoustic beam angle. The TS is highly varied among individuals of fish is caused by the differences in internal morphology and body orientation on the transmitted beams (Chen *et al.* 2012).

Table 1 The comparison of reef fish target strengths on the 38 kHz and 200 kHz frequencies

Fish Species	Frequency (kHz)	Range of standard length (cm)	Target Strength (dB)			p-value (t-test)
			Minimum	Maximum	Average	
Abudefduf saxatilis	38	8.5 – 11.5	-56.38	-52.72	-54.52	0.426^{ns}
	200	5 - 9	-55.37	-52.97	-54.17	
Chaetodon trifasciatus	38	8 – 9.5	-53.53	-49.86	-51.75	0.449^{ns}
	200	5 - 10	-54.55	-48.16	-50.66	
Ctenochaetus striatus	38	12 – 22.5	-50.74	-47.06	-47.98	0.979^{ns}
	200	10 - 16	-49.98	-44.55	-47.74	
Halichoeres hortulanus	38	4 – 10.5	-58.10	-54.46	-56.04	0.004*
	200	11 - 19	-53.47	-49.78	-51.19	
Scolopsis lineatus	38	9 – 15.5	-54.13	-46.28	-49.14	0.096^{ns}
	200	7.5 - 15	-53.87	-49.97	-51.90	
Gabungan (*Multispesies*)	38	4 – 22.5	-58.1	-46.28	-52.09	0.420^{ns}
	200	5 - 19	-55.37	-44.55	-51.52	

where: *: significantly different on 0.05 ($p<0.05$); ns: not significantly different on 0.05 ($p>0.05$)

The results of the comparative test (t-test) on the TS average of reef fish using the two different frequencies point out that among those five tested fish species. Four of those fish species possess the p-values which are higher than 0.05 ($p>0.05$) indicating not significantly different of TS average on both frequencies 38 kHz and 200 kHz (Table 1), and the rest, fish *Halichoeres hortulanus* has the p-value of 0.04 ($p<0.05$) undergoing a significantly different of TS value on both frequencies. This difference is surmised due to a difference of fish lengths used on both frequencies. Further, the combination of TS averages for all reef fish species (multispecies) denotes an insignificant difference with p-value is 0.42 ($p>0.05$). Hence, this research proves that the frequency factor does not contribute significantly on TS averages of reef fish. This result is different with statements which have been well known so far that the different frequencies affect the TS (Foote 1985; Holliday and Pieper 1995; Horne and Clay 1998; Hazen and Horne 2003). However, Gauthier and Horne (2004) find the contrasting results that ΔTS of fish capelin *Mallotus villosus*) and Pacific herring (*Clupea pallasii*) are significantly different on the frequency pair of 200-12 kHz, and not significant distinct on the frequency pair of 120-38 kHz, as well as the backscatter model prediction for both fish with a very similar length on all frequencies.

2. The Relationship between Target Strength and Fish Standard-Length

The relationship between TS and standard length (SL) of reef fish as seen in Table 2 points out a real relationship statistically ($p<0.05$) on almost all fish species for both frequencies (38 kHz and 200 kHz) except *Chaetodon trifasciatus* and *Halichoeres hortulanus* on frequency of 38 kHz and *Ctenochaetus striatus* on frequency of 200 kHz. The unreal regression model statistically ($p>0.05$) is due to the fish used as samples are in a small amount that is not enough to detect a real relationship, therefore, the generated regression model is not able to be used to predict the fish biomass. Furthermore, the combination of all fish represents a real relationship between TS and fish standard-length for both frequencies. Hence, this relationship can become a basis in estimating the fish biomass in the coral reef waters. Boswell *et al.* (2008) express selecting the equation of TS-fish length relationship generates substantial impacts in estimating the individual parameters and contributing to fish biomass estimation.

Table 2 denotes that the generated regression equation model has a slope (b) in a range of 5.45 to 41.62. This result signifies that the generated relationship model is not suitable with the empirical equation of Love (1977) for an individual of fish, the TS of dorsal aspect increases increase proportionally with the fish length quadrate. Similarly, Simmonds and MacLennan (2005) that σ_{bs} is proportional to L^2, and TS is equal to 20 log L plus the constant number.

Table 2 The values of b (slope), variance analysis and determinant coefficient of TS for the reef fish standard-length on the 38 kHz and 200kHz frequencies.

Fish Species	Frequency (kHz)	b	R^2	p-value (Anova)
Abudefduf saxatilis	38	17.30	0.49	0.023*
	200	5.45	0.55	0.021*
Chaetodon trifasciatus	38	41.62	0.69	0.167^{ns}
	200	15.80	0.65	0.008*
Ctenochaetus striatus	38	9.01	0.66	0.050*
	200	19.07	0.56	0.053^{ns}
Halichoeres hortulanus	38	7.18	0.84	0.082^{ns}
	200	12.77	0.87	0.0001*
Scolopsis lineatus	38	27.09	0.84	0.001*
	200	9.64	0.87	0.0001*
Gabungan (Multi spesies)	38	18.44	0.72	0.0001*
	200	10.50	0.46	0.0001*

Annotation: *: a real relationship statistically ($p < 0.05$); ns: unreal relationship statistically ($p > 0.05$)

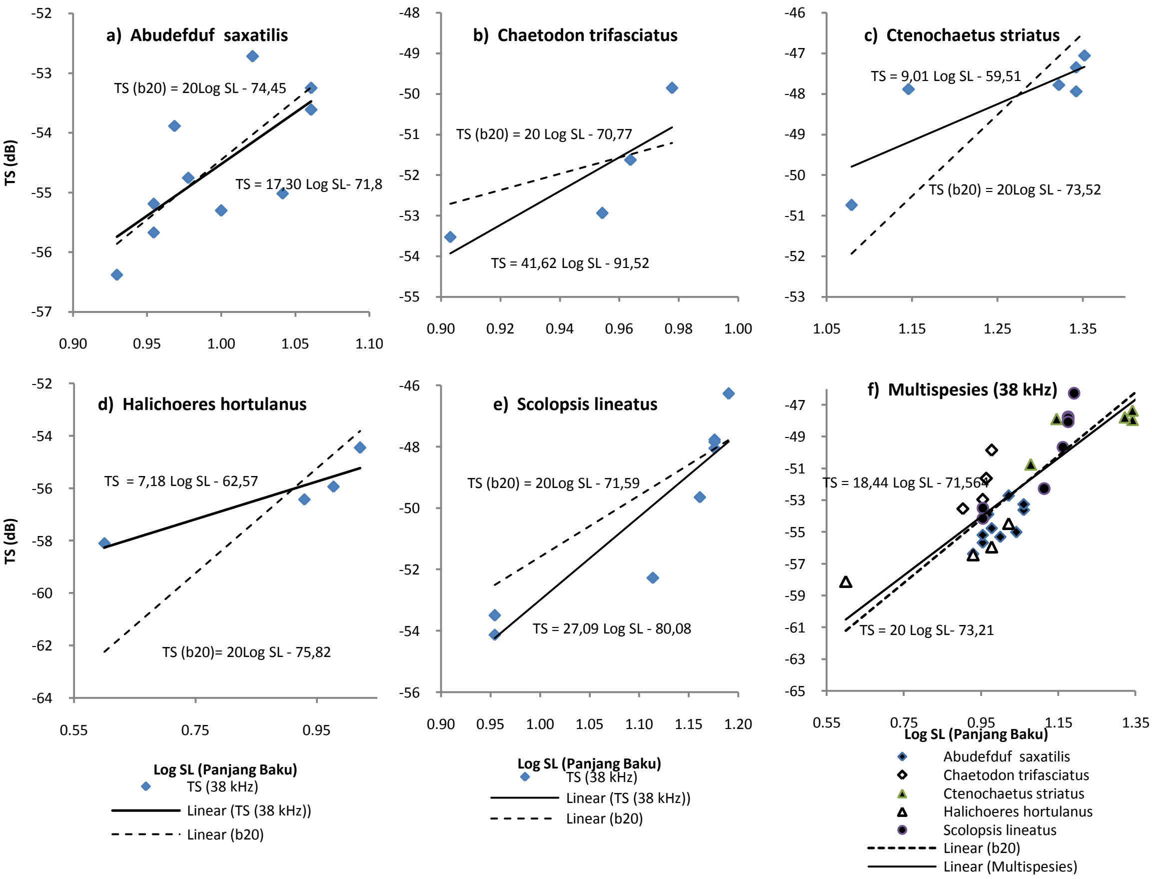

Figure 2. The regression line of relationship between TS average and standard-length of reef fish on the 38 kHz frequency comparing to the regression model of b20.

However, McClatchie *et al*. (1996) express that most of the fish species are not suitable with the quadratic fish length on TS and the averages of slope for most fish species are in the range of 15 to 25. Furthermore, 20 of 26 fish species possess slope less than 20 indicating that the slope is not proper with the relationship of 20 log L. In addition, Foote (1987) reports the broader range (5.1–29.7) for fish gadoid (*Gadus morhua*), herring (*Clupea harengus*), redfish (*Sebastes marinus*), and greater silver smelt (*Argentina silus*).

Figure 2 exhibits that the regression model of the relationship between TS values and standard-length of reef fish on the 38 kHz frequency gathered from field measurement is not fitted with the regression model determining the slope as high as 20 (b20) except in the fish *Abudefduf saxatilis* which reaches the slope-20 where their regression lines are almost coincide. The similar result also is presented in combining all fish (multispecies) which is nearly suitable with the model b20.

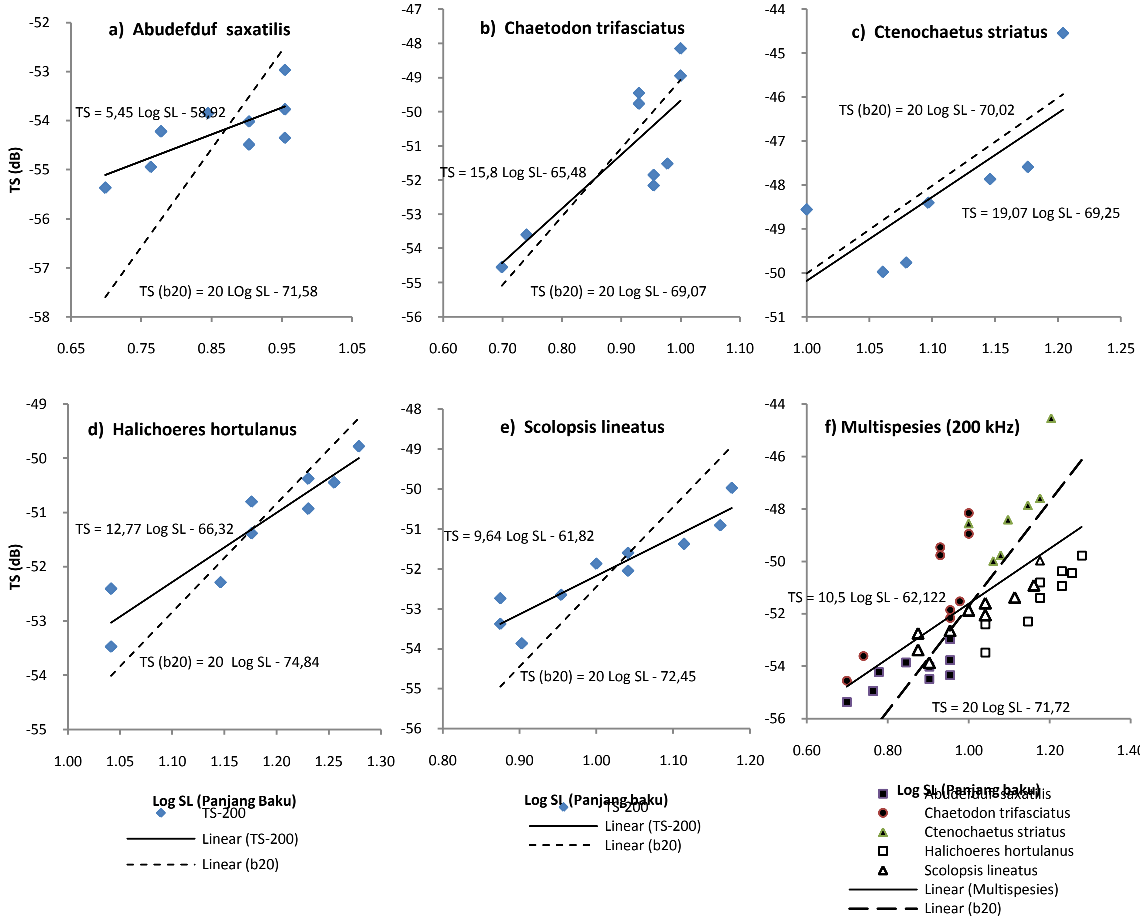

Figure 3. The regression line of relationship between TS average and standard-length of reef fish on the 200 kHz frequency comparing to the regression model of b20.

Figure 3 denotes the similar results on the 38 kHz frequency where the regression model of b20 is not proper to the field measurement results except for fish *Ctenochaetus striatus* that nears to the slope 20. However, the combination of all fish (multispecies) on the 200 kHz frequency demonstrates an improperness to the model b20.

Based on Figure 2 and 3, it can be inferred that the regression model of the relationship between TS and fish length with a provision of the slope as high as 20 (20 Log L) is not able to be used for reef fish. Frouzova *et al*. (2005) compared commonly results of various authors, species effect only contributes 0.2 and 0.6% of total variabilities and the fish species role in the variability of TS could be lower when the morphological difference is not clear from a certain species group. Additionally, McClatchie *et al*. (2003) point out that many deviations of the 20 log L relationship will be found if more data gathered regarding the relationship between <TS> and L for broader various species. Furthermore, if the ranges of fish length that will be surveyed are narrow, the equation function of TS = 20 log L + b20 can be applied reasonably in estimating the fish biomass. This assumption might be different if the sizes are varied in the population that will be surveyed.

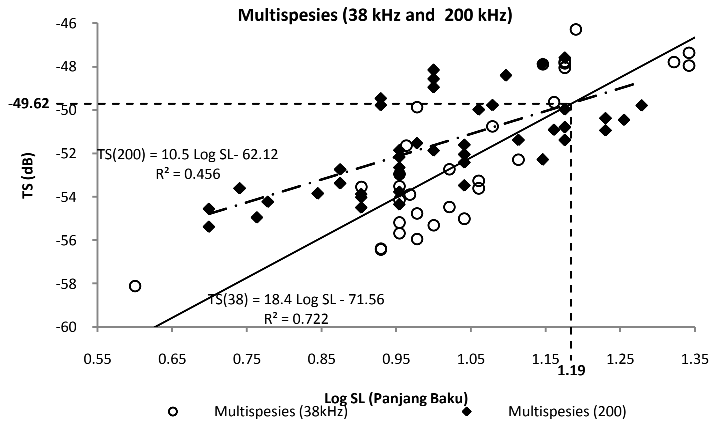

Figure 4 The comparison of the relationship regression model between TS average and standard-length of reef fish combination (multispecies) on the 38 kHz and 200 kHz frequencies.

Figure 4 signifies the regression model of TS average and standard-length of reef fish combination (multispecies) that were measured on both different frequencies namely 38 kHz and 200 kHz, respectively. This regression equation model can be a reference based on the consideration of coral reef waters condition and a high reef fish diversity that is not able to distinguish possibly the fish species for gaining the TS-L relationship. The comparable condition also has been proposed by Frouzova *et al.* (2005) that in an impossible circumstance to segregate the fish species in the certain waters which is a mix of various fish species, therefore the common equation can be used to represent the relationship between TS-L of all species. The relationship equations of TS-L from the recent research with the 38 kHz and 200 kHz frequencies are $TS_{(38kHz)} = 18.4 \text{ Log SL} - 71.56$ (R^2 = 0.72), and $TS_{(200kHz)} = 10.5 \text{ Log SL} - 62.12$ (R^2 = 0.46), respectively.

The regression equation of the relationship between TS average and standard-length of fish (Log SL) for both frequencies meets at an intercept where the Log SL value as high as 1.19 (15.49 cm) and the TS average is -49.62 dB. For fish that is smaller than 15.49 cm in length, its TS average is higher on 200 kHz frequency than the 38 kHz frequency. Reciprocally, when the fish standard-length which is lengthier than 15.59 cm, its TS average on the 38 kHz frequency is higher than the 200 kHz frequency. Gauthier and Horne (2004) explain that in a fish mix aggregation possessing the same length of distribution, the TS difference might not enable to segregate the species. However, the frequency can affect the number of fish backscattering (Foote, 1985; Holliday and Pieper, 1995). As proposing by Boyra *et al.* (2018), from a single target measurement, TS of tuna *in situ* on 38 kHz frequency is lower than 5 dB, and 5.5 dB for both frequencies, 120 kHz and 200 kHz. The difference of TS average on both frequencies in this research is presumed due to the differences of tissues and spine density on the different fish lengths. Moreover, Boyra *et al.* (2018) express that the meat acoustic property contributes to the main distinctiveness between skipjack and mackerel, and then followed by the backbone properties. Conversely, the variations of shape and orientating angle distribution are relatively small contributions to the TS differences. Korneliussen and Ona (2004), the backscattering of the fish spine is lower than the fish meat on the 38 kHz frequency, however, it becomes dominant on the 120 kHz and 200 kHz frequencies.

IV. Conclusion

The distribution of reef fish target strength averages is different in each fish species depends on the range of standard length. The average values of target strength for the 38 kHz and 200 kHz frequencies do not contribute significantly on all reef fish.

The standard-length of reef fish delivers the significant relationships on the target strength average value change on all reef fish species and the combination of those species (multispecies) neither the 38 kHz nor 200 kHz frequencies. The relationship model of TS on the reef fish standard-length signifies an incompatibility of TS relationship on fish quadratic length with the regression slope that is not equal to 20.

The TS average of reef fish combination on the 200 kHz frequency is higher than the 30 kHz one especially for fish that is shorter than 15.49 cm length. However, for fish which is lengthier than 15.49 cm length, its TS average on the 38 kHz frequency is higher than the 200 kHz one.

Acknowledgements

This research was financed by the Directorate of Research and Community Service, General Directorate of Research Empowerment and Development at the Ministry of Research and Higher Education on budgeting 2017. Thanks to this ministry that had sponsored this research..

References

[1] Allen GR, Werner TB. 2002. Coral reef fish assessment in the 'coral triangle' of Southeastern Asia. *Environ Biol Fish.* 65:209–214.

[2] Madduppa HH, Zamani NP, Subhan B, Aktani U, Ferse1 SCA. 2014. Feeding behavior and diet of the eight-banded butterflyfish *Chaetodon octofasciatus* in the Thousand Islands, Indonesia. *Environ Biol Fish.* 97. DOI 10.1007/s10641-014-0225-z.

[3] Madduppa HH, Agus SB, Farhan AR, Suhendra D, Subhan B.2012. Fish Biodiversity in Coral Reefs and Lagoon at The Maratua Island, East Kalimantan. *BIODIVERSITAS*, 13 (3): 145-150

[4] Adrim M. 2007. Reef Fish Communities in the Waters of Enggano Island, Bengkulu Province. *Oseanologi dan Limnologi di Indonesia*, 33: 139 – 158. [In Indonesian].

[5] McClanahan TR, Maina JM, Graham NAJ, Jones KR. 2016. Modeling Reef Fish Biomass, Recovery Potential, and Management Priorities in the Western Indian Ocean. *PLoS ONE* 11(5): e0154585. doi:10.1371/journal.pone.0154585

[6] Caldwell ZR, Zgliczynski BJ, Williams GJ, Sandin SA. 2016. Reef Fish Survey Techniques: Assessing the Potential for Standardizing Methodologies. *PLoS ONE* 11(4): e0153066. doi:10.1371/journal.pone.0153066

[7] Costa B, Taylor JC, Kracker L, Battista T, Pittman S. 2014. Mapping Reef Fish and the Seascape: Using Acoustics and Spatial Modeling to Guide Coastal Management. *PLoS ONE 9(1):* e85555. doi:10.1371/journal.pone.0085555

[8] Campanella F, Taylor JC. 2016. Investigating acoustic diversity of fish aggregations in coral reef ecosystems from multifrequency fishery sonar surveys . *Fish Res*. 181(2016):63–76

[9] Manik HM. 2013. Deteksi Ikan Karang Menggunakan Teknologi Echosounder. Di dalam: Hidayat TT, Syamsuddin S, Sudrajat A, Simson, Nainggolan C, Raharjo P, Sipahutar YH, editor. SEMINAR NASIONAL PERIKANAN INDONESIA 2013; 2013 November 21-22, Jakarta (ID): P3M STP. Jilid 1: 19-24

[10] Simmonds EJ, and MacLennan DN. 2005. Fisheries Acoustics, Theory and Practice. Blackwell Publishing, Oxford, 437pp.

[11] Taylor JC, and Ebert E.2012. Mapping coral reef fish schools and aggregations with high-frequency multibeam and split-beam sonars. Proc. Mtgs. Acoust. 17, 070041; doi: 10.1121/1.4772586.

[12] Kracker LM, Taylor JC, Ebert EF, Battista TA, and Menza C. 2011. Integration of fisheries acoustics surveys and bathymetric mapping to characterize midwater-seafloor habitats of US Virgin Islands and Puerto Rico (2008–2010). NOAA Technical Memorandum NOS NCCOS 130. 44 pp.

[13] Dawson, JJ, Karp WA. 1990. In situ measures of target strength variablelity of individual fish. *Rapp. P.-V. Reun. Cons. Int. Explor. Mer*. 189:264-273.

[14] Benoit-Bird KJ, Whitlow WLA, Christopher DK, Christopher T. 2003. Acoustic backscattering by deepwater fish measured in situ from a manned submersible. Deep-Sea Research I, 50: 221–229

[15] Zare P, Kasatkina SM, Shibaev SV, Fazli H. 2017. In situ acoustic target strength of anchovy kilka (*Clupeonella engrauliformis*) in the Caspian Sea (Iran). *Fish Res*. 186 : 311–318

[16] Ona E. 2003. An expanded target-strength relationship for herring. *ICES J Mar Sci*. 60:493–499.

[17] Kang D, Cho S, Lee C, Myoung JG, Na J. 2009. Ex situ target-strength measurements of Japanese anchovy (*Engraulis japonicus*) in the coastal Northwest Pacific. *ICES J Mar Sci*. 66:1219–1224.

[18] Gauthier S, Horne JK. 2004. Potential acoustic discrimination within boreal fish assemblages. *ICES J Mar Sci*. 61:836-845

[19] Korneliussen, RJ. (Ed.). 2018. Acoustic target classification. ICES Cooperative Research Report No. 344. 104 pp. http://doi.org/10.17895/ices.pub.4567

[20] Chen G, Li Y, Chen P, Zhang J, Fang L, Li N. 2012. Measurement of single-fish target strength in the South China Sea. *Chinese J Ocean Limn.* 30(4):554-562

[21] MacLennan DN. 1990. Acoustical measurement of fish abundance. J Acoust Soc Am, 87: 1–15.

[22] Sawada K, Takahashi H, Abe K, Ichii T, Watanabe K, Takao Y. 2009. Target-strength, length, and tilt-angle measurements of Pacific saury (*Cololabis saira*) and Japanese anchovy (*Engraulis japonicus*) using an acoustic-optical system. *ICES J Mar Sci*. 66:1212–1218.

[23] Ryan TE, Kloser RJ, Macaulay G.J. 2009. Measurement and visual verification of fish target strength using an acoustic-optical system attached to a trawlnet. *ICES J Mar Sci*. 66, 1238–1244.

[24] O'Driscoll RL, Oeffner J, Dunford AJ. 2013. In situ target strength estimates of optically verified southern blue whiting (*Micromesistius australis*). *ICES J Mar Sci*. 70: 431–439.

[25] Dunford AJ, O'Driscoll RL, Oeffner J. 2015. Improvements in estimating an acoustic target strength–length relationship for hoki (*Macruronus novaezeladiae*). *Fish Res.* 162:12–19

[26] Zhang J, Chen PM, Chen GB, Fang LC, dan Tang Y. 2013. Acoustic target strength measurement of banded grouper (*Epinephelus awoara (*Temming & Schlegel, 1842*)*) and threadsial filefish (*Stephanolepis cirrhifer (*Temming & Schlegel, 1850*)*) in the South China Sea. *J App Ichthyol*. 29(6):1453-1455.

[27] Bakhtiar D, Djamali A, Arifin Z, Sarwono T. 2012. The Community Structure of Reef Fish in the waters of Tikus Island, Bengkulu City. This manuscript is in: Bakti D, Rosmayati, Putri LAP, Handarini R, Latifah S, Tafsin M, Razali, Sabrina T, Hanum H, Julianti E, Ginting J, Irmansyah T, Fauzi, editor. *Peningkatan Presisi Menuju Pertanian Berkelanjutan. Seminar Nasional dan Rapat Tahunan Bidang Ilmu-ilmu Pertanian BKS-PTN Wilayah Barat Tahun 2012*; 2012 April 3-5; Medan (ID): USU Pr. Volume 2:764-772 [In Indonesian].

[28] Foote, KG, Knudsen HP, Vestnes GD, MacLennan N, Simmonds EJ, 1987. Calibration of acoustic instruments for fish density estimation: a practical guide. *ICES Coop. Res. Rep.* 144, 1–69

[29] Love RH. 1971. Dorsal-aspect target strength of an individual fish. *J Acoust Soc Am*. 49(3): 816–823.

[30] Love RH. 1977. Target strength of an individual fish at any aspect. *J.Acoust. Soc. Am*. 62 :1397-1403

[31] Frouzova J, Kubecka J, Balk H, Frouz J. 2005. Target strength of some Europeanfish species and its dependence on fish body parameters. *Fish Res*. 75, 86–96.

[32] Hazen EL, Horne JK. 2003. A method for evaluating the effects of biological factors on fish target strength. *ICES J Mar Sci*. 60:555–562

[33] Henderson MJ, Horne JK, Towler RH. 2007. The influence of beam position and swimming direction on fish target strength. *ICES J Mar Sci*. 65:226–237

[34] Foote, KG. 1985. Rather-high-frequency sound scattering by swimbladdered fish. *J Acoust Soc Am*, 78: 688–700.

[35] Holliday DV, Pieper RE. 1995. Bioacoustical oceanography at high frequencies. *ICES J Mar Sci*. 52:279–296.
[36] Horne JK, Clay C. 1998. Sonar systems and aquatic organisms: matching equipment and model parameters. *Can J Fish Aquat Sci*. 55:1296–1307.
[37] Boswell, K.M., Kaller MD, Cowan JH Jr, Wilson CA. 2008. Evaluation of target strength–fish length equation choices for estimating estuarine fish biomass. *Hydrobiologia*. 610:113–123
[38] McClatchie S, Alsop J, Coombs RF. 1996. A re-evaluation of relationships between fish size, acoustic frequency, and target strength. *ICES J Mar Sci.* 53:780–791.
[39] Foote, KG. 1987. Fish target strengths for use in echo integrator surveys. *J Acoust Soc Am*, 82(3): 981–987
[40] McClatchie S, Macaulay GJ, Coombs RF. 2003. A requiem for the use of 20 log10 Length for acoustic target strength with special reference to deep-sea fishes. *ICES J Mar Sci*. 60:419–428
[41] Boyra G, Moreno G, Sobradillo B, Pe´rez-Arjona I, Sancristobal I, and Demer DA. 2018. Target strength of skipjack tuna (*Katsuwanus pelamis*) associated with fish aggregating devices (FADs). *ICES J. Mar Sci*. doi:10.1093/icesjms/fsy041.
[42] Korneliussen, RJ, and Ona E. 2004. Verified acoustic identification of Atlantic mackerel. *ICES CM2004/R:20, 14p.*

Deddy Bakhtiar. et. al. "Analysis of Reef Fish Target Strength through Ex-Situ Measurement Using Acoustic Methods." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 14(5), (2020): pp 53-61.