Distribution of fish target strength value in Menjangan Island waters, West Bali National Park

Imam Syahnanda Irawan[1*], *Sri* Pujiyati[2], *Syamsul* Bahri Agus[3], *Steven* Solikin[4]

[1]Marine Science and Technology Study Program, Faculty of Fisheries and Marine Science, Bogor 16680, Indonesia
[2]Department of Marine Science and Technology, Faculty of Fisheries and Marine Science, IPB University, Bogor 16680, Indonesia

Abstract. Research on the target strength (TS) value of fish is generally influenced by various internal and external factors, either from fish or signals. This study aims to identify the composition and analyze the target strength value of fish in four directional zones in the waters of Menjangan Island. The distribution of fish TS values in 4 zones at depths of 1.5 - 5.0 m ranged from -59.8 to -39.5 dB. The presence of fish was validated by dive data, which showed that the composition of fish was dominated by the Pomacentridae family, at approximately 54.5%. Results from the estimation of fish length using Foote's (1987) algorithm, ranged from 4.3 - 44.6 cm. Based on the zone, the North Zone had the highest number of fish detected at 2179 fish, while the West Zone had the lowest number at 1213 fish. The range of the TS values detected was dominated by the range of -61 to -58 dB and the least detected range was -40 to -37 dB. This indicates that the fish individuals detected around the depth near the surface of these waters tend to be small, and few were large, based on the results of the literature study.

1 Introduction

Menjangan Island is a popular tourist destinations within the West Bali National Park. This area has a variety of attractions in the field of tourism, with a stretch of coral reefs and various cultural tourism sites sacred to the Balinese Hindu community. Based on the Minister of Forestry Decree No. 493/Kpts-II/1995, West Bali National Park has a land area of 15587.89 ha and waters of 3.145 ha located at coordinates 8°05′20″S – 8°15′25″E and 114°25′00″S – 114° 56′30″E, and is administered in the territory of two regencies in Bali, namely Buleleng and Jembrana [1]. The water conditions at this location have many underwater caves, such that the habitat is rich in fish diversity, especially fish that live in coral reef ecosystems, and have several points with a sudden vertical decrease in depth (drop off) due to various factors such as geological changes and other underwater formations [2].

*Corresponding author: sripu@apps.ipb.ac.id

The word "fish" in this study refers to the interpretation of fish in general, which is defined as a vertebrate organism that lives in water and is taxonomically included in the phylum Chordata with the characteristics of having gills that are useful for taking dissolved oxygen from water and fins that are used for swimming [3]. The most common fish found in Menjangan Island waters is the reef fish group, where 16 fish families were found and dominated by the Pomacentridae or reef fish family, Chaetodontidae or indicator fish, and Acanthuridae or herbivorous fish [4]. Each type of fish has different physiological mechanisms, based on differences in habitat conditions and the surrounding environment [5].

The hydroacoustic method is an underwater detection method that uses a transducer to generate sound waves or echoes that propagate in a water medium, and then the signal is scattered or reflected back by the object [6]. This technology is highly effective for studying aquatic biota and the environment without causing significant damage or environmental changes [7]. Target strength (TS) is the ability of an object to reflect the sound that hits it [8]. If the TS value is small, then the object is estimated to be small; otherwise if the TS value is large, then the object is estimated to be large [9]. The factors that affect changes in TS values in fish are size, shape, behavior, presence of swim bladder, pulse incidence angle, wavelength, frequency, acoustic impedance, flesh, bones, scales, and fins [10]. This study aims to identify the composition and analyze the target strength value of fish in four directional zones in the waters of Menjangan Island. This research is important to fill the data gap of fish target strength (TS) values in Menjangan Island waters, provide basic information for conservation, and validate acoustic methods for identifying fish composition and distribution.

2 Method

2.1 Data acquisition

The survey was conducted during the Himiteka Expedition VIII by the Marine Science and Technology Student Association of IPB University on Wednesday, August 9th 2023, in the waters of Menjangan Island, West Bali National Park. This activity starts in the morning between 9.00 AM – 3.00 PM (WITA). Fish data acquisition was also carried out using the Underwater Visual Census (UVC) method because it can be used as supporting data to validate the presence of fish up to a depth of 5 m. Bathymetric information was obtained by downloading bathymetry images from the Batimetri Nasional (BATNAS) website page for the eastern part of Java Island and the western part of Bali Island. The selection of this bathymetry data source was based on the fact that this information is only a complement to the visuals on the research map. A map of the research locations is shown in Figure 1.

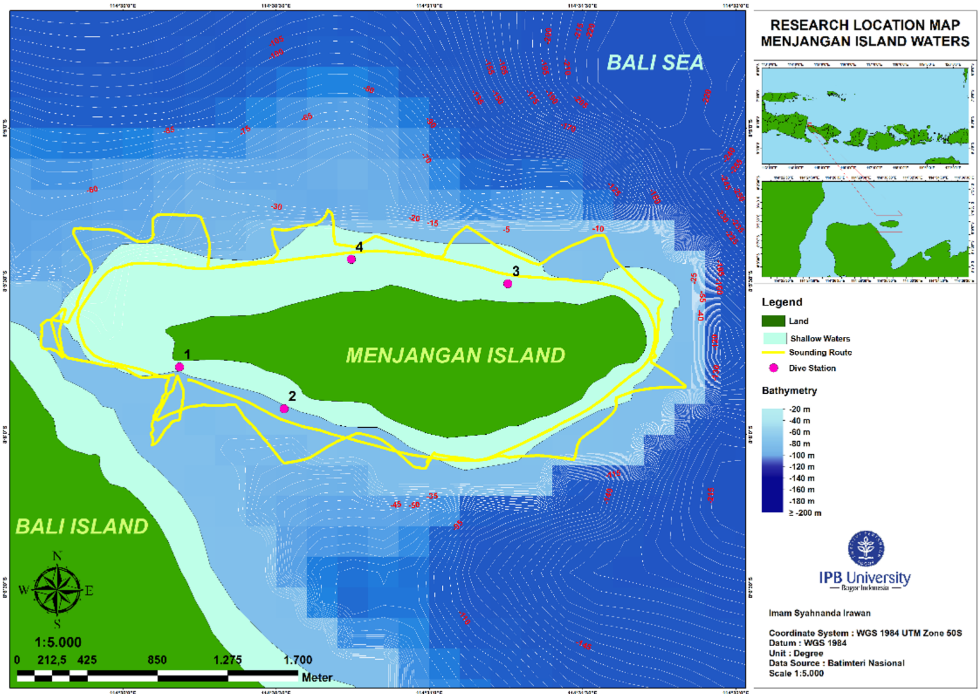

Fig 1. Research location map of Menjangan Island waters

The equipment used in the acoustic data acquisition process in the waters of Menjangan Island, West Bali National Park is the Scientific Echo Sounder Simrad EK15. Simrad EK15 is a single beam hydroacoustic Sound Navigation and Ranging (SONAR) instrument designed with a frequency of 200 kHz and a beam width of 26° for a variety of needs in aquatic environments. The full specifications of the Simrad EK15 are listed in Table 1 [11].

Table 1. Simrad EK15 Specifications (Simrad 2012)

Instrument Specifications	
Operational frequency	200 kHz
Transmission	Simultaneous or sequential ping rate up to 40 s Pulse durations 80 to 1240 μs Data rate 1,6 Mbps
Transceiver Unit	Maximum number in use 15 Output power 45 W IP rating, IP66
Data output formats	Raw data (EK60 format)
Third party post-processing	Echoview and SONAR5
Transducer	Type Single Beam Maximum installation depth 600 meters Beamwidth 26 degrees

The 200 kHz frequency was operated in the shallow area of the Menjangan Island Waters. The output data recorded by the echosounder were the amplitude value with *.raw extension. Echograms of acoustic recording results from Simrad EK15. The raw format was converted into *.uuu format using the SONAR5_pro software dongle borrowed from Syiah Kuala University, Banda Aceh. The supporting equipment used was GPS Garmin 585, diving equipment, and stationery. The GPS has 2 frequencies of 50/200 kHz, a maximum depth of

1500 ft or 457.2 m, and an accuracy level of about 0.2 m [12]. The Simrad EK15 settings related to the beaming activity are shown in Table 2.

Table 2. Simrad EK15 Settings

Instrument Settings	
Sound Speed (m/s)	1537,69
Transducer Gain (dB)	9,200
Transmission Frequency (kHz)	200
Transmit Power (W)	46,080
Beam Width (°)	26°
Pulse Length (ms)	0,320
Ping Interval (m/s)	500
Minimum Threshold (dB)	-100
Time Variable Gain (TVG)	*Target Mix*

The acoustic sounding process was carried out in one round for each of 2 different paths around the waters of Menjangan Island to fulfill the area representation of each observation zone. The transducer was installed under clear weather conditions and calm waves 1 m from the keel, to the right of the center of the ship, because it is assumed that the part of the ship is the most balanced and receives the least disturbance or noise. Tool settings related to the target to be detected or Time Variable Gain (TVG), ping interval, sound speed, gain, temperature, salinity, and depth need to be performed to maximize the tool performance and adjustment to field conditions through environmental parameters.

The fish data acquisition was conducted in four zones (West, South, North, and Northeast). The acquisition process aims to identify the diversity and size of fish in situ in Menjangan Island waters using the Underwater Visual Census (UVC) method. UVC is a method of directly observing fish underwater to determine their diversity, abundance and size. This method was performed by visual observation at a depth of 3 - 5 m for three replicates [13]. The dive direction at stations 1 and 4 moved westward, whereas at stations 2 and 3 it moved eastward. Each of the four stations had a transect length of approximately 50 m with a visibility of 2.5 m right and left of the diver. The observers dive along the transect while observing the fish.

2.2 Data Processing and Analysis

2.2.1 Acoustic Data

Data processing and analysis were conducted at the Laboratory of Acoustics, Instrumentation, and Marine Robotics (AIR) Division, Department of Marine Science and Technology (ITK), IPB University. Acoustic data in the form of echograms were obtained, and further analyzed to obtain information on the detection results of the distribution of target strength values of fish. This data processing and analysis was performed from a depth below the near field line to 5.0 m. The near field zone can be calculated using equations (1) and (2) as follows [14] :

$$\lambda = \frac{c}{f} \quad (1)$$

$$Nf = \frac{L^2}{\lambda} \quad (2)$$

Where Nf is the near field (m), L is the longest area of the transducer surface, λ is the wavelength (m), and c is the speed of sound in water (m/s). The acoustic data from the sounding results had a *.raw format and must first be converted to *uuu format. The conversion process of SONAR5_pro software produces two types of data, one of which is

40log(R) for single target backscatter. 40log(R) represents the single detected target information. The use of 40log(R) is related to how large the physical size of the detected target is, so that it can provide information about the size of the target reflected by the SONAR signal. SONAR signals can experience a decrease in intensity that is proportional to the change in the square of the distance from the target (R).

Data processing was performed using a minimum threshold of -60.0 dB and a maximum of -34.0 dB [15]. Processing and analysis of acoustic data using SONAR5_pro software by dividing the data by 50 pings in every 1 Elementary Sampling Distance Unit (ESDU) at a depth stratum of 1.5 - 5.0 m. The main reason for this is related to data quality. The more data that are divided, the more detailed the information. The number of detected targets was calculated using the SONAR5_pro software system. The information obtained is "Detected No. SED", or the number of single signals detected by the fish. This value is compiled to obtain the number of single fish targets. The TS value was calculated using the following equation [14] :

$$TS = 10log\frac{I_r}{I_i} \qquad (3)$$

Where *TS* is the target intensity in decibels, I_r is the intensity of the transmitted energy, and I_i is the intensity of the energy backscattered from the object. The TS value obtained from equation (1) was used to estimate the length of the fish using the following equation [16] :

$$TS = 20logL - A \qquad (4)$$

Where L is the length of the fish in centimeters and A is the constant TS value for 1 cm of fish length. Basically the "A" value for all types of fish is always different whether the fish has an open swim bladder (physotome), closed (physochlist), even those without a swim bladder (bladderless fish). Fish with an open swim bladder have an "A" value of 71.9, fish with a closed swim bladder have an "A" value of 67.5, fish without a swim bladder have an "A" value of 80, while the "A" value of 68.0 is used to determine the general length of fish that are not known specifically related to species and swim bladder conditions. It should be noted that all of these "A" values are derived from focusing on detecting, measuring and estimating the length of pelagic and demersal fish in situ using various acoustic system operations (single-beam, dual-beam, split-beam) integrated at a frequency of 38 kHz [16].

2.2.2 Fish Data

Fish data processing was carried out by calculating the fish composition to obtain data on the ratio between the number of individuals of each species to the number of individuals of all species in the waters of Menjangan Island. Reef fish composition can be calculated using the following equation [17] :

$$KJ = \frac{ni}{N} \times 100\% \qquad (5)$$

Where *KJ* is the fish species composition in percentage (%), n_i is the number of individuals of each i-th fish species, and *N* is the total number of individuals of all fish species. The results of these calculations were then tabulated in Microsoft Excel to produce the fish family composition data visualized in graphical form. The data obtained are associated with the results of acoustic data processing in the area adjacent to the dive point. The next step was to sort the fish data to determine the type of fish swim bladder. The length of fish obtained in situ is used in equation (2), and is based on validation data and comparison with the results of acoustic data processing.

3 Result and Discussion

3.1 Fish Data

The fish family composition in Menjangan Island at a depth of 3 – 5 m was dominated by reef fishes, where nine fish families were identified. The largest percentage of fish families is the Pomacentridae family at 54.5%, followed by Acanthuridae at 10%, Chaetodontidae at 5.7%, Labridae at 5.6%, Balistidae at 5.4%, Serranidae at 4.2%, Caesionidae at 3.5%, Lutjanidae at 3.5%, Zanclidae at 2.1%, and others at 5.4%. The fish family composition information was used to validate the presence of fish from the acoustic results. A graph of the percentage composition of fish families in Menjangan Island is shown in Figure 2.

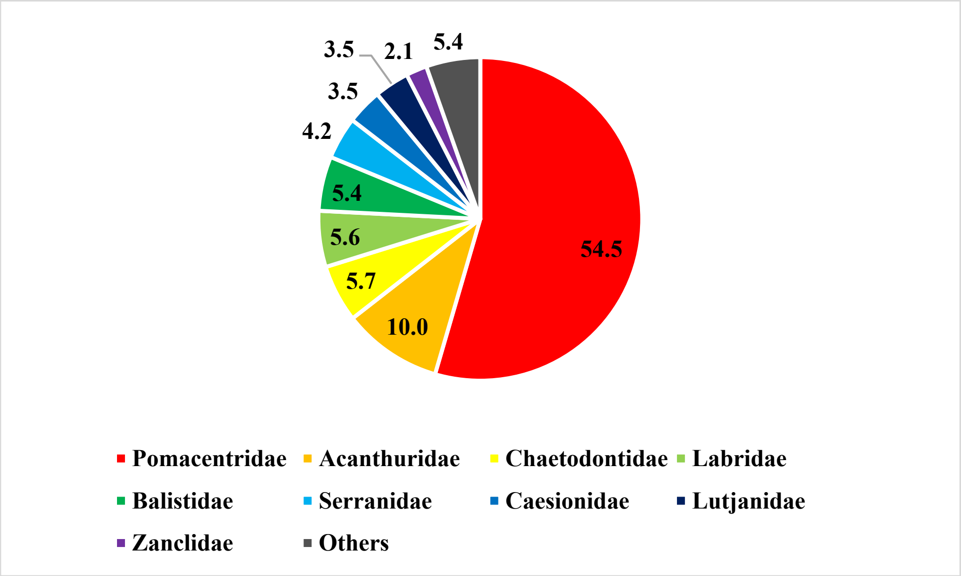

Fig 2. *Chart of fish family composition in Menjangan Island waters*

Fish can be divided into three types based on the shape of their swim bladder. Physostome or open swim bladder, the swim bladder has a connecting channels with the digestive tract, physoclist or closed swim bladder that does not have connecting channels with the digestive tract, and bladderless fish or without swim bladder and is usually a type of deep-sea fish. The swim bladder is an organ that functions to regulate the fish body when floating in water by adjusting the body volume and specific gravity to the depth of the water environment. Another function of the swim bladder is as a space to resonate in producing or receiving sound, so that sound waves can be reflected perfectly because it generally contains air [18]. Taxonomy of fish families distinguished by their swim bladder type are presented in Figure 3 [19].

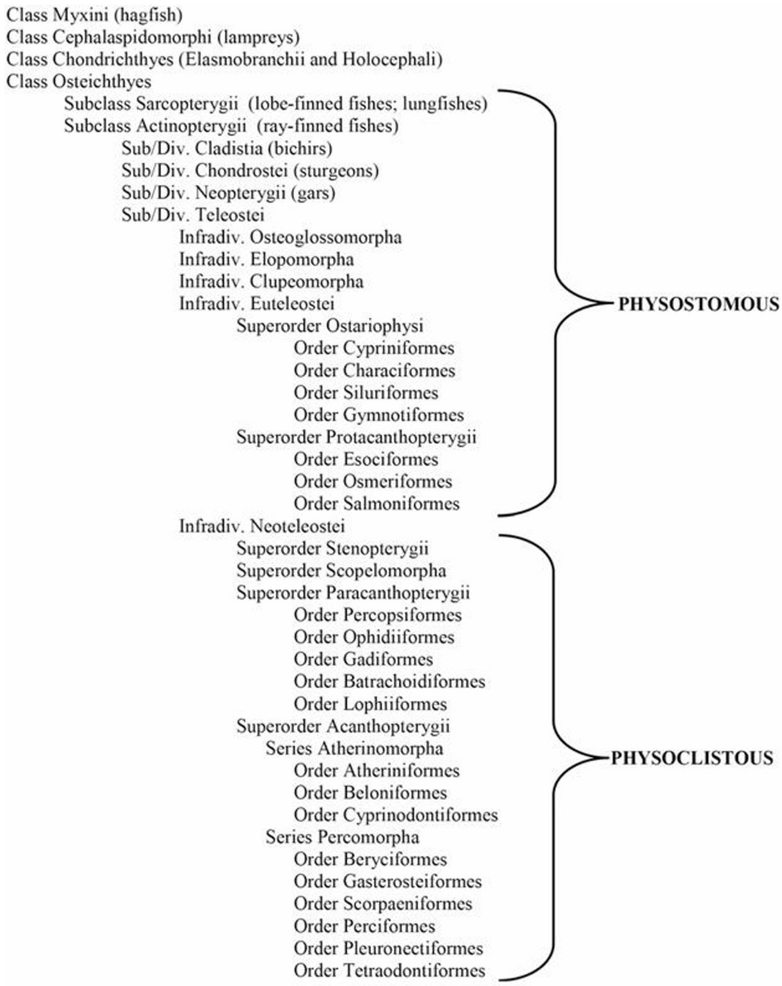

Fig 3. *Fish family taxonomy distinguished based on swimming bladder type*

Based on the identification results of the fish family composition, fish in Menjangan Island Waters can be declared as a group of fish that have closed swim bladder. All fish families belong to the order of true bony fish or Perciformes, which is a group of fish with closed swim bladder (physoclistous).

3.2 Acoustic Data

The distribution of TS (single) values in the depth stratum is from -59.8 to -39.5 dB. The estimated length of fish at this depth is from 4.3 - 44.6 cm and is thought to be dominated by the Pomacentridae or reef fish family. The South Zone consisted of 141 ESDUs, with the highest number of targets detected in the -61.0 to -58.0 dB value range of 899 targets and the least number detected in the -40.0 to -37.0 dB range of 13 targets. The blue line shows the relationship between the two variables in the form of polynomial regression of degree two. The blue dashed line shows the relationship between the two variables in the form of polynomial regression of degree two. This regression model was chosen because it has the highest coefficient of determination (R^2) with a correlation coefficient of r = 0.988 (very strongly correlated). A histogram graph of fish TS values againts the number of detected targets in the South Zone of the 1.5 to 5.0 m depth stratum is shown in Figure 4.

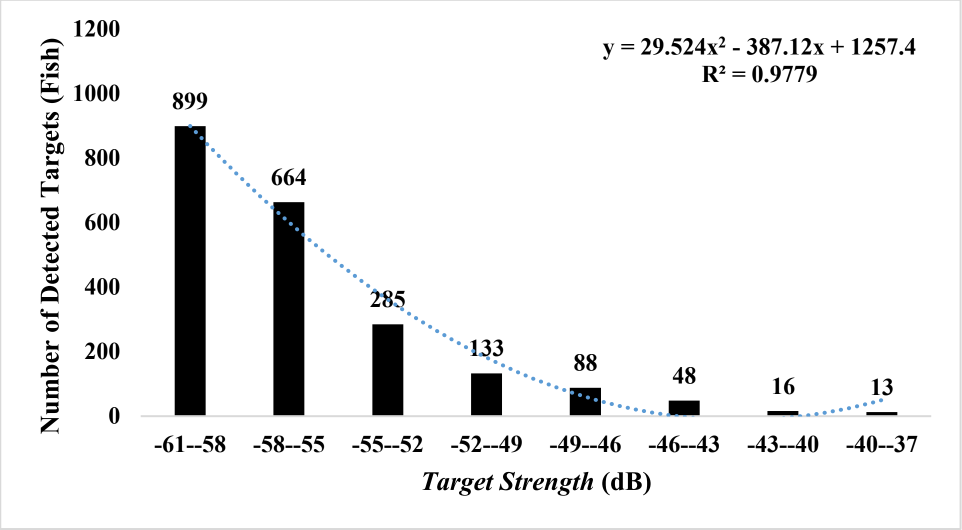

Fig 4. *Histogram of fish TS toward the number of detected targets at the South Zone*

The East Zone consists of 62 ESDUs. The highest number of detected targets was in the range of -61.0 to -58.0 dB values with 485 targets and the least number detected was in the range of -40.0 to -37.0 dB with 29 targets. The blue dashed line shows the relationship between the two variables in the form of a polynomial regression of degree two. This regression model was chosen because it had the highest coefficient of determination (R^2) with a correlation coefficient of r = 0.986 (very strongly correlated). A histogram graph of fish TS values with respect to the number of detected targets in the East Zone of the 1.5 - 5.0 m depth stratum is shown in Figure 5.

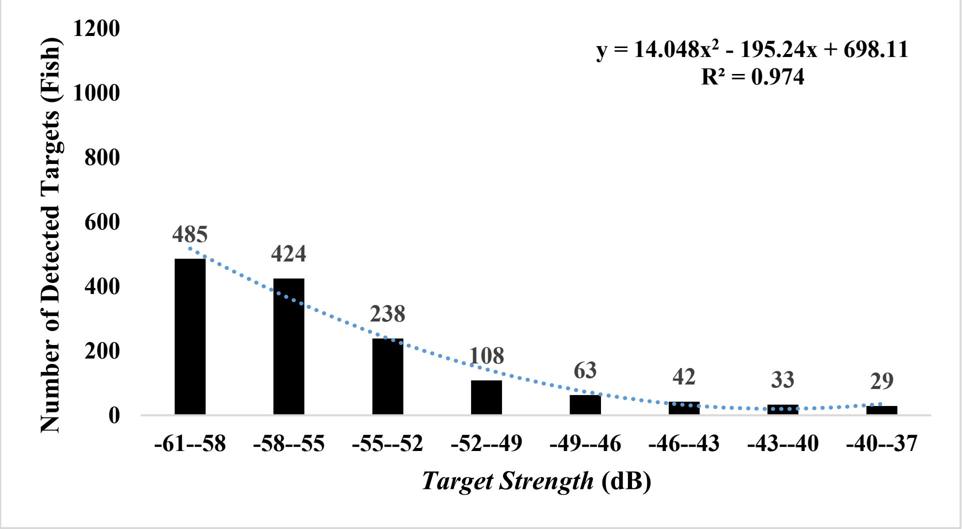

Fig 5. *Histogram of fish TS toward the number of detected targets in the East Zone*

The North Zone consists of 162 ESDUs. The highest number of targets detected was in the range of -61.0 to -58.0 dB values with 1034 targets and the least number detected were in the range of -40.0 to -37.0 dB with 16 targets. The blue dashed line shows the relationship between the two variables in the form of polynomial regression of degree two. This regression model was chosen because it had the highest coefficient of determination (R^2) with a correlation coefficient value of r = 0.983 (very strongly correlated). A histogram graph of fish TS values with respect to the number of detected targets at the North Zone of the 1.5 - 5.0 m depth stratum is shown in Figure 6.

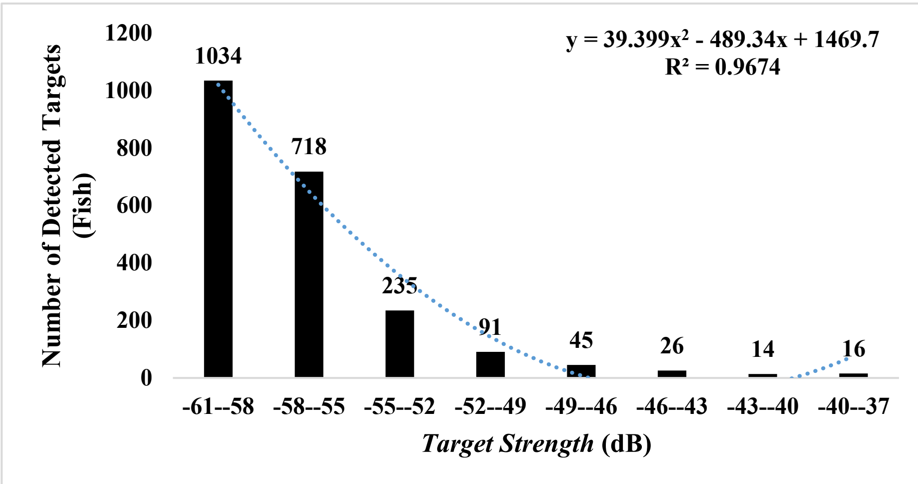

Fig 6. *Histogram of fish TS toward the number of detected targets in the North Zone*

The West Zone of 1.5 to 5.0 m depth consisted of 49 ESDUs and the most number of targets detected was in the range of -61.0 to -58.0 dB values with 453 targets and the least number detected was in the range of -40.0 to -37.0 dB with 13 targets. The blue dashed line shows the relationship between the two variables in the form of a polynomial regression of degree two. This regression model was chosen because it had the highest coefficient of determination (R^2) with a correlation coefficient of r = 0.984 (very strongly correlated). A histogram graph of fish TS with respect to toward the number of detected targets in the West Zone of the 1.5 - 5.0 m depth stratum is shown in Figure 7.

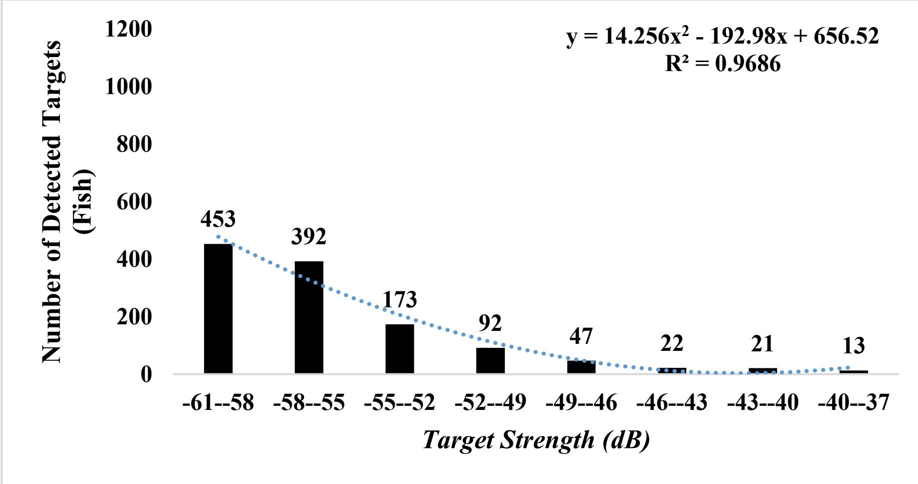

Fig 7. *Histogram of fish TS toward the number of detected targets in the West Zone*

The North Zone had the highest number of detected fish by zone at 2179 individual fish, followed by the South Zone at 2146 individual fish, the East Zone at 1422 individual fish, and the West Zone at 1213. Overall, the successful and dominant TS values detected in the 1.5 - 5.0 m depth stratum were in the range of -61 to -58 dB and the least detected were in the range of -40 to -37 dB. This indicates that this depth stratum is not only inhabited by small fish but also by some that are thought to be larger fish. Some fish species tend to rise to the surface when looking for food, therefore the presence of larger fish at certain depths is thought to be to find food by preying on smaller fish [20]. A graph of the distribution of fish TS values against the number of targets detected in all zones of the Menjangan Island waters in the 1.5 - 5.0 m depth stratum is shown in Figure 8.

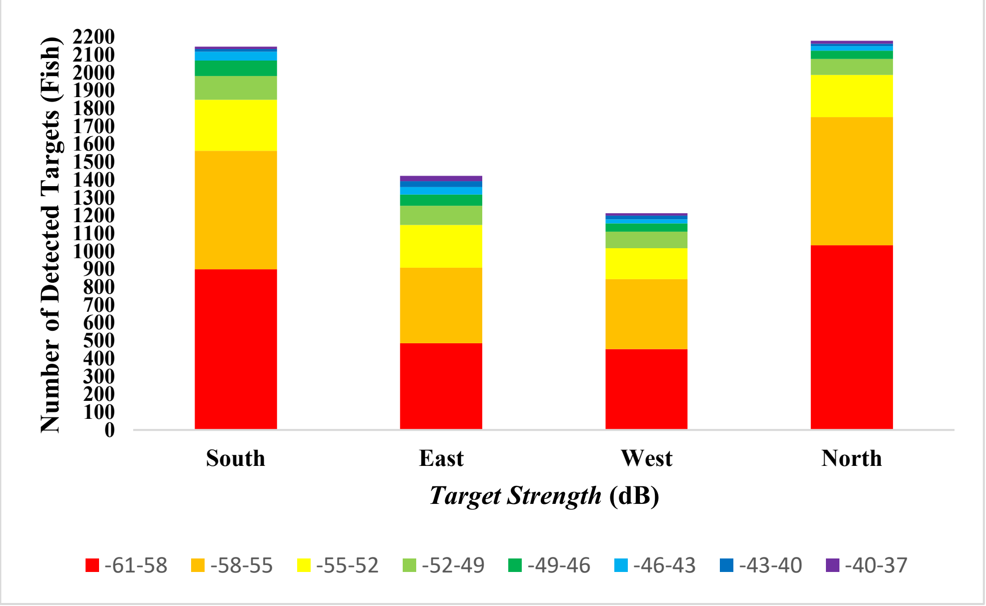

Fig 8. *Graph of distribution of fish TS values toward the number of detected targets in all water zones of Menjangan Island*

Fish length can be estimated by knowing the type of swim bladder, where the longer the fish size, the larger the swim bladder [21]. Physoclist-type fish can regulate buoyancy through a relatively slow gas-diffusion process, which can regulate the flow of gas in and out of the swim bladder. This causes the filling rate of the swim bubble and the resulting partial pressure to vary, to achieve a neutral level of buoyancy at greater depths [18]. The fish size can be distinguished in 3 groups, namely small (-70.0 to 60.0 dB), medium (-59.9 to -50.0 dB), and large (-49.9 to 30.0 dB), so it is known that the composition of individual fish detected in all depth stratum of 1.51 - 5.0 m in Menjangan Island waters belongs to the small to large group of fish [22].

4 Conclusion

Based on the results of processing and analyzing acoustic data of the 1.5 - 5.0 m depth stratum, the distribution of fish TS values is in the range of -59.8 to -39.5 dB. At this study site, the total number of detected targets was 6960 single individual fish, where TS values of -61.0 to -58.0 were the dominant TS value range with 2871 targets detected and TS values of -40 to -37 were the least detected TS value range with 71 targets detected in all zones. The North Zone had the highest number of detected targets by zone with 2179 individual fish, followed by the South Zone with 2146 single individual fish, the East Zone with 1422 single individual fish, and the West Zone with 1213 single individual fish. The estimated length of fish at this depth is from 4.3 - 44.6 cm and is estimated to be dominated by the Pomacentridae or reef fish family. At this depth, it is indicated that it is not only inhabited by small fish but also by large fish based on the results of the estimated length size.

Fish in these waters are not only schooling but also solitary. The main strength of this study is that, it was able to detect, estimate and quantitatively justify the specific number of solitary fish targets in this protected marine area. The main weakness of this research lies in the limited supporting data that can be used to validate the correctness of fish presence, given that fishing activities are strictly prohibited in these waters; therefore, an alternative approach in the form of a literature study was used.

Imam Syahnanda Irawan, as the main contributor expressed his deepest gratitude to the management of West Bali National Park for their cooperation in supporting the success of this research activity. The author's greatest appreciation goes to Mr. Syahrul Purnawan, S.Pi., M.Si as a lecturer at Syiah Kuala University Banda Aceh, Mrs. Sri Ratih Deswati, S.Pi, M.Si as Education Personnel at IPB University, Friansyah as the Chief Executive of Himiteka VIII Expedition who has allowed the author to use the data and all committees who have helped and facilitated the author during the research.

References

1. E. Sulistyadi, Zoo Indonesia, 25(2), pp. 142-159 (2017).
2. R. Hernowo, D. Djumanto, and N. Probosunu, Biota: Jurnal Ilmiah Ilmu-Ilmu Hayati, 18(1), pp. 11-20 (2013).
3. S.S. Fitrah, I. Dewiyanti, and T. Rizwan, Jurnal Ilmiah Kelautan dan Perikanan Unsyiah, 1(1), pp. 66-81 (2016).
4. M.I. Febrianti, F. Purwanti, and A. Hartoko, Jurnal Ilmu dan Teknologi Kelautan Tropis, 10(1), pp. 15-24 (2018).
5. C.K. Bangsa, Sugito, Zuhrawati, D. Razali, A. Nuzul, and Azhar, Jurnal Medika Veterinaria, 9(1), pp. 9-11 (2015).
6. S. Pujiyati, N.M.N. Natih, B. Hamuna, and L. Dimara, Journal of Applied Geospatial Information, 3(2), pp. 240-243 (2019).
7. F.W. Shabangu, J.C. Coetzee, I. Hampton, S.E. Kerwath, W.M. Wet, and A.L. Ochoa, Reflections on the State of Research and Development in the Marine and Maritime Sectors in South Africa, Pretoria: Council for Scientific and Industrial Research (2014).
8. M.Z. Lubis, Oceanography and Fisheries, 3(2), pp. 1- 6 (2017).
9. D.P. Anggraeni, F. Supriyadi, Jurnal Ilmiah Matematika dan Ilmu Pengetahuan Alam, 16(2), pp. 176-184 (2019).
10. M. Farhan, H.M. Manik, and T. Hestirianoto, Jurnal Teknologi Perikanan dan Kelautan, 13(2), pp. 175-186 (2022).
11. Simrad, Multi Purpose Scientific Echo Sounder Simrad EK15, Norway: Kongsberg Maritime (2012).
12. S. Marona, Junaidi, Dalrino, and E. Fernando, Andalas Civil Engineering Conference (2018).
13. I. Manuputty, Jurnal Ilmu Kelautan, 11(1), pp. 1-12 (2006).

https://doi.org/10.1051/bioconf/202516805008

14. E.J. Simmonds, D.N. Maclennan, Fisheries Acoustic: Theory and Practice 2nd ed, Oxford: Blackwell Science Ltd (2005).
15. D. Bakhtiar, Y.A. Ompusunggu, A. Anggoro, and S. Supiyati, *Jurnal Kelautan Tropis*. 27(1), pp. 51-58 (2024).
16. K.G. Foote, J. Acoust. Soc., 82, pp. 981-987 (1987).
17. A.E. Greenberg, Standard Methods for the Examination of Water and Waste water for 4th Edition, Washington (WA): American Public Health Association (1989).
18. A.I. Burhanuddin, Biologi Kelautan, Yogyakarta: Lily Publisher (2019).
19. R.S. Brown, A.H. Colotelo, B.D. Pflugrath, C.A. Boys, L.J. Baumgartner, Z.D. Deng, L.G.M. Silva, C.J. Brauner, M. Mallen-Copper, O. Phonekhampeng, G. Thorncraft, and D. Singhanouvuong, Fisheries, 39(3), pp. 108-122 (2014).
20. N. Aryani, Ikan dan Perubahan Lingkungan, Padang: Bung Hatta University Press (2014).
21. E. Ona, X. Zhao, I. Svellingen, and J.E. Fosseidengen, Proceedings of the Herring, pp. 461-487 (2001).
22. V. Samedy, M. Wach, J. Lobry, J. Selleslagh, M. Pierre, E. Josse, P. Boet, Fisheries Research, 172, 225-233 (2015).