Fish Stock Status Assessment in Alue Naga Waters Using A 200 Khz Single Beam Echosounder

Syahrul Purnawan[1,2], Sofyatuddin Karina[2], Myounghee Kang[3], Henry M. Manik[4]*

[1]Laboratory of Marine Acoustics, Faculty of Marine and Fisheries, Universitas Syiah Kuala
[2]Department of Marine Sciences, Faculty of Marine and Fisheries, Universitas Syiah Kuala
Jl. Teuku Nyak Arief Darussalam, Banda Aceh, Aceh, 23111 Indonesia
[3]Department of Maritime Police and Production System, Gyeongsang National University
501 Jinju-daero, Jinju-si, Gyeongsangnam-do, Republic of Korea
[4]Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, IPB University
Jl. Rasamala, Kampus IPB Darmaga Bogor 16680 Indonesia.
Email: henrymanik@apps.ipb.ac.id

Abstract

Monitoring fish stocks is an important part of sustainable management of fisheries resources. Conducting the current evaluation is very difficult since there are no reliable data on the potential for fisheries in the waters surrounding Banda Aceh city. The hydroacoustic method was used for the first time in the waters of Alue Naga, located north of Banda Aceh, to evaluate the condition of fish stocks. A single beam scientific echosounder with a frequency of 200 kHz was used to collect hydroacoustic data in the area. The collected data was then processed using the Sonar5-Pro software. Cell integration was carried out at an interval of 10 meters vertically with an elementary sampling distance (ESD) of 200 m. While the volume backscattering strength (SV) value tends to be the highest in intermediate layers, the target strength (TS) value was found to be maximum in deeper layer, reaching a maximum value of -49.46 dB at a depth of 51–60 m. Area density value (#.ha^{-1}) was found to be the highest at a depth of 11-20 m, while Biomass (g.ha^{-1}) at a depth of 21-30 m was the highest among other depth layers with a value of 1558 g.ha^{-1}. According to the in-situ catches of Carangoides, Selaroides, Aphareus, Variola, and Priacanthidae, there are a number of potential reef fish resources in the waters of Alue Naga. The findings of this study strongly support the conclusion that the hydroacoustic method effectively provides comprehensive information on the horizontal and vertical distribution of fish in Alue Naga waters.

Keywords: *Banda Aceh, hydroacoustic, Simrad EK-15, sonar5 pro, target strength*

Introduction

Estimating fish stocks is generally using the conventional method, specifically by counting the number of fishes landed from each ship, measuring the catch per unit of effort, and a structured approach based on biological measurements and fish length (Damora *et al*., 2021; Fadli *et al*., 2021). Meanwhile, information on the availability (stock) of fish is very important in the process of managing fishery resources in waters (Hilborn, 2007; Hilborn *et al*., 2020). Hydroacoustics is a well-known method that is very effective and efficient hydrographic survey method, both for exploration purposes and to find specific targets (Manik, 2014; Manik *et al*., 2017).

The most typical use of hydroacoustics in fisheries research is the measurement of fish abundance. The use of hydroacoustics to estimate fish distribution and stock requires information on acoustic volume backscattering strength (SV) or target strength (TS) data for each species (Benoit-Bird and Lawson, 2016; Dawson and Karp Dawson, 1990; Kang *et al*., 2009; Zare *et al*., 2017). Target strength is described as the echo intensity of the fish in decibels (dB) when it is placed on the acoustic axis of the transducer (Manik, 2015). Target strength distributions may be used to assess the size structure of a fish stock (Orduna *et al*., 2021; Wanzenböck *et al*., 2020). To accomplish this, several models illustrating the relationship between fish size and target strength should be used, from multispecies general equations to particular species-specific equations (Love, 1971; Frouzova *et al*., 2005; Lilja *et al*., 2000). The TS value may also be used to estimate the horizontal-vertical distribution, fish size, and fish biomass in the water column (Manik and Nurkomala, 2016; Pujiyati *et al*., 2017; Hidayat *et al*., 2019). Meanwhile, SV is the backscattering strength given by a certain mass in the unit volume, where SV is an important acoustic parameter in estimating fish biomass (Manik, 2013; Manik *et al*., 2017).

Banda Aceh is located at the northern tip of Sumatra Island, with the Indian Ocean, Strait of Malacca, and Andaman Sea surrounding its waters. Although the northern waters of Banda Aceh have a

*) Corresponding author

https://ejournal.undip.ac.id/index.php/ijms
DOI: 10.14710/ik.ijms.28.1.57-68
Received : 07-12-2022
Accepted : 15-02-2023

lot of fishing potential, only around 76 percent of the Maximum Sustainable Yield (MSY) is utilized (DKP Aceh, 2019). The primary catch in this area is pelagic fish i.e. tuna, mackerel, grouper, mackerel, skipjack, and pomfret (Haridhi *et al*., 2018; Jatmiko *et al*., 2020; Damora *et al*., 2021). Even so, many small pelagic fish are also found, such as *Decapterus ruselli*, *Thryssa baelama, Selaroides leptolepis*, *Decapterus macrosoma*, *Amblygaster sirm*, *Stolephorus spp,* and *Formio niger* (Kurnia *et al*., 2016; Aprilla *et al*., 2018).

Most of Banda Aceh's traditional fishermen are in the Alue Naga district. Fishermen in this region use small traditional boats called *thepthep* as their fishing fleet, and most fish are caught in close proximity. However, there is a problem that has to be addressed, the lack of information on the availability and distribution of fish makes it difficult for most traditional fishermen operating in these waters. The data on fish catches is sometimes incomplete, particularly for traditional fishermen who do not land their catch at the main fishing port. As a result, the statistics on the stock of fish in Banda Aceh's waters might be inaccurate. This study determines the distribution of TS value data in the northern waters of Alue Naga by using underwater acoustic techniques. It is feasible to go beyond basic counting of individual fish by using target strength distributions to estimate the area density of the fish biomass. The findings of this study may be used for fish resource management in Banda Aceh City, particularly in the northern waters of Alue Naga, as the effectiveness of fisheries management in the area is contingent on the availability of high-quality data.

Materials and Methods

Field data acquisition was carried out on April 2021 in the waters of Alue Naga, Banda Aceh City. The survey location was 3 nautical miles from the coast and had a transect length of 30 km (Figure 1.). A traditional fishing boat was used during data collection, with the boat's speed set between 3 and 4 knots. The weather was bright and the sea was calm while the data collecting took place, with an average temperature of 27.8°C, rainfall of 0 mm, sunshine duration of 8.7 h, and average wind speed of 2 m.s^{-1} (BMKG, 2023).

A Simrad EK-15 scientific echosounder was used to collect the data, which had a frequency of 200 kHz, a pulse duration of 0.080 ms, and a ping interval of 1000 ms; further information is shown in Table 1. The transducer was attached to the port side of the fishing boat and positioned 1 meter below the water surface. To complete its acoustic data acquisition functionality, the echosounder was paired with a GPS device connected to the CPU to provide position data. Before data collecting began, a careful calibration process was carried out using a 38mm spherical ball. The sphere was lowered to a depth of 8-10 m, and the echo from the sphere was measured. Previously, calibration was also performed in the laboratory.

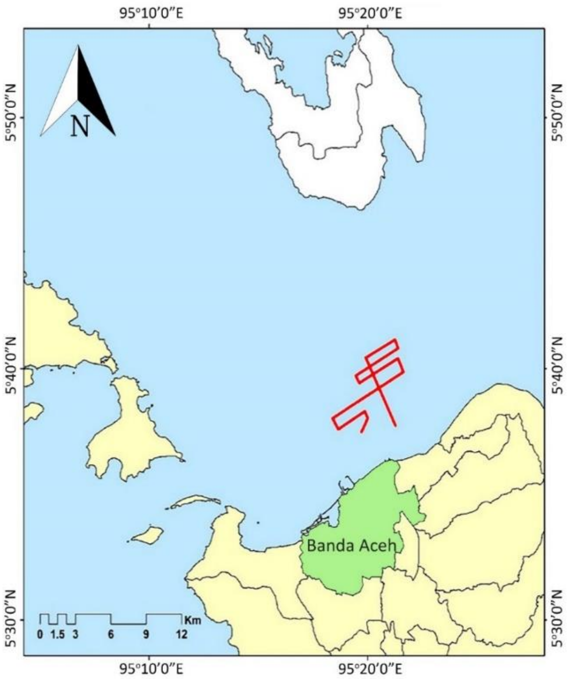

Figure 1. Survey map and acoustic track located in northern of Banda Aceh City

Table 1. Specification of Simrad EK-15

Parameter	Spesification
Transducer Type	Single beam
Frequency	200 kHz
Near Field	0.33 m
Ping Interval	1000 ms
Beam Width	26 deg
Output Power	45 w
Maximum Range	600 m
Pulse Length	0.080 ms
Transducer Gain	14,2 db

Data processing

Data processing was carried out at the Acoustic Laboratory of Universitas Syiah Kuala. Sonar5-Pro Ver. 606.16 was used as post-processing software (Balk and Lindem, 2014; Balk and Lindem, 2000), although it used to require a dongle to convert Simrad *.raw data to *.uuu files (Figure 2.). The integration layer was made for every 10 m of depth ranging from 1 to 60 m, within elementary sampling distance unit each 100 m long. The data were processed by averaging or adding up either vertically or horizontally, for vertical and horizontal analysis, respectively. The Single Echo Detector (SED) function was deployed to identify an echo strength from a single target. SED is a technique for recognizing single fish echoes by reducing overlapping echoes, allowing it to be used in low signal-to-noise ratio situations (Manik and Nurkomala, 2016; Nurkomala, 2016).

Mean target strength (TS) value for every integrated cell was determined based on single echo detections (SED). The threshold for TS was adjusted to -70 dB during the data post-processing. Target strength data were processed at a minimum distance of 1 m from the transducer to eliminate bias in the analysis owing to the near-field effect. Target strength (TS) is an acoustic parameter that measures the echo strength (dB) of the fish when it is located on the axis of the transducer beam. The greatest energy is reflected by fish that are on the acoustic axis (Traynor and Ehrenberg, 1990). Furthermore, the TS value correlates to the transducer's output level (signal excess, SE) in decibels, which is calculated using the equation:

$$SE = SL + G_R + TS + 2B(\theta,\varphi) + G_{TVG} - TL \quad (1)$$

Note: SL= source level (dB); Gr= receiving gain (dB); TS= Target Strength (dB); $B(\theta,\varphi)$= beam-pattern factor; G_{TVG}= time-varied-gain; and TL= Transmission loss (dB). TL is consisting of spreading and absorption loss (eq. 2)

$$TL = 40 \log(R) + 2\alpha R \quad (2)$$

Note: 40 log(R) is spreading loss (dB); $2\alpha R$ is absorption loss (dB); R is range (m).

The strength of the returning sound is determined by fish characteristics such as length-weight. The general relationship between TS value and fish length is explained by the equation:

$$TS = A \log10(L) + B \quad (3)$$

The volume backscattering strength (SV), which is derived through echo-integration, is an equivalent logarithmic measure of the volume backscattering coefficient (*sv*). The volume backscattering coefficient (*sv*) taking into account the σbs, is the backscattering cross-section (m2) of targets in sampling volume V (eq. 4). It has been discovered that SV, particularly for small targets, is a good expression of biomass distributions. Fish density values, or the number of fish per hectare ($\#.ha^{-1}$), were calculated using the SV/TS scaling method, which involves using the volume backscattering strength (SV), and the mean target strength (TS). Fish biomass ($g.ha^{-1}$) itself can be expressed as a stand-alone function of volume backscattering strength (SV), although complex calculations require information from the TS parameter for a particular species combined with other information.

$$sv = \sum \frac{\sigma_{bs}}{V} \quad (4)$$

Note: σ_{bs} is the backscattering cross-section (m^2) of fish; and V (m^3) is the sampling volume containing the targets, scaled to 1 m^3.

Result and Discussion

Target strength distribution

Data extraction is obtained from each cell, where the cell division is determined based on the ESD of 100 m and the layer depth of 10 m. According to the specified ESD limit, the surface area contains the most cells. It was discovered that there were fewer cells in the deeper layers, which may be related to the fact that the water depth varied between locations and caused an uneven distribution of the water column cells. Only 1265 out of all the cells created based on ESD included echo values (#SED) coming from the target. The layer below the surface (11-20m) was found to be the layer with the highest number of cells containing SED, which is 282 cells. Even if there are fewer cells in the deeper layers, they tend to have more SEDs per cell (Figure 3.).

The values in TS per cell (TSc) indicate the magnitude of a reflection each object in the cell is producing. Classes are used to divide the TSc value distribution into 3 dB intervals. Additionally, a depth layer with a 10-m interval is used to integrate the distribution value of the TSc value. A low TS value, for example, equates to a small target, whereas a high TS value, for example, equates to a large target (Simmonds and Maclennan, 2007; Manik, 2009). Layers 1-10 m have a total of 29745 SEDs detected, where the distribution of TS values in this layer is dominated by TS class of -67 dB which reaches up to 56.1%. The highest SED accumulation was found in the 21-30 m layer with a total of 345818, where in this layer the highest frequency was produced by the -64 dB class, which was 25.9%. The distribution pattern changes at different depths, where the higher TS class gets a larger portion in the deeper layers (Figure 4).

The average TS value is calculated by linear integration of TSc values per layer depth. In line with the previous data in Figure 4, where the TS class with a higher value has a higher frequency, it appears that the average TS value tends to rise as depth increases (Figure 5). The highest average TS value is obtained at the 51-60 m layer, but the lowest average TS is at the 11-20 m layer instead of the surface layer.

The horizontal distribution of TS (dB) is obtained by averaging the linear target strength (*ts*) of each cell from the surface layer to the deepest layer, where this process resembles the calculation of the mean volume backscattering strength. The horizontal distribution of the TS values has a maximum value of -45.45 dB. Figure 6 shows the distribution of the mean volume of TS that has been overlaid with the contours of the seabed.

Data sampling with in situ catches was carried out to determine the types of fish in the survey location in order to complete the information on fish resources at the survey location. There were 5 types of fish caught, and then the *in-situ* TS value was measured from the caught fish. Measurements were made by immediately lowering the fish alive to a depth of 3 m using a fishing line given a weight. The distance between the target fish and the ballast is 1 m apart, so that the echo from the ballast and the target can be separated properly. Generally, the fish caught were about 20 cm long and the target strength was around -42 to -44 dB (Table 2.).

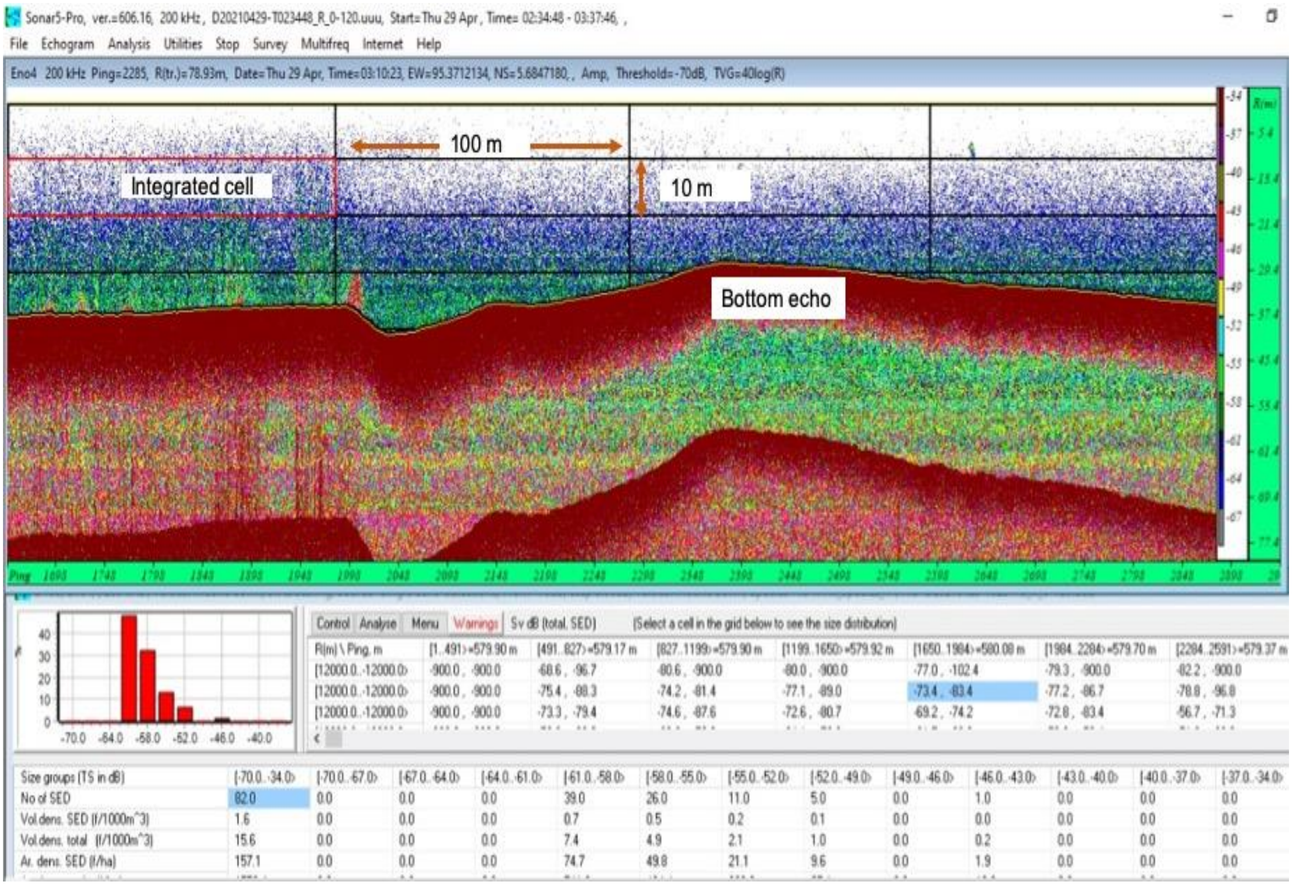

Figure 2. Sonar5-Pro post-processing software interface. The used integrated cell has a horizontal integration of 100m and a depth integration of 10m.

Area density and biomass

The volume backscattering strength (SV) is the key factor in determining the density and biomass of fish in the water (Simmonds and Maclennan, 2007). The average SV value per layer depth is shown in Figure 7, where there are six layers in total. based on the distribution, the highest SV value is at the 21-30 m layer, and there is a tendency for the value to decrease after a depth of 31-40 m. Biomass value is obtained by converting the volume backscattering strength (SV) value into the fish metric value (Simmonds and Maclennan, 2007)

Meanwhile, the density calculation was carried out to obtain information on the distribution of fish in the survey area. The area density was found to be highest in the 11-20 m layer, then decreased in the deeper layers. The biomass value rises from the surface and peaks in the 21-30 m layer but then declines as it goes deeper (Figure 8.). Figure 9 illustrates the horizontal distribution of area density ($\#.ha^{-1}$) and biomass ($g.ha^{-1}$) values based on SED in Alue Naga waters. The average biomass is 3284 $g.ha^{-1}$ with the maximum value reaching 316510 $g.ha^{-1}$, meanwhile the average value of area density is 35427 $fish.ha^{-1}$ with the highest value being 3406570 $fish.ha^{-1}$. The locations at 95.35° E and 5.64°N have the highest biomass and area density.

The average number of SEDs per cell in the inner layer is higher than the surface area, despite the deeper layer having fewer cells. This could indicate that the target appears more dispersed in the surface layer. The surface area's TS value is similarly lower, indicating that the dominating target in this layer is a small one, such as zooplankton or extremely small fish. The sea surface layer is where little biota like these live.

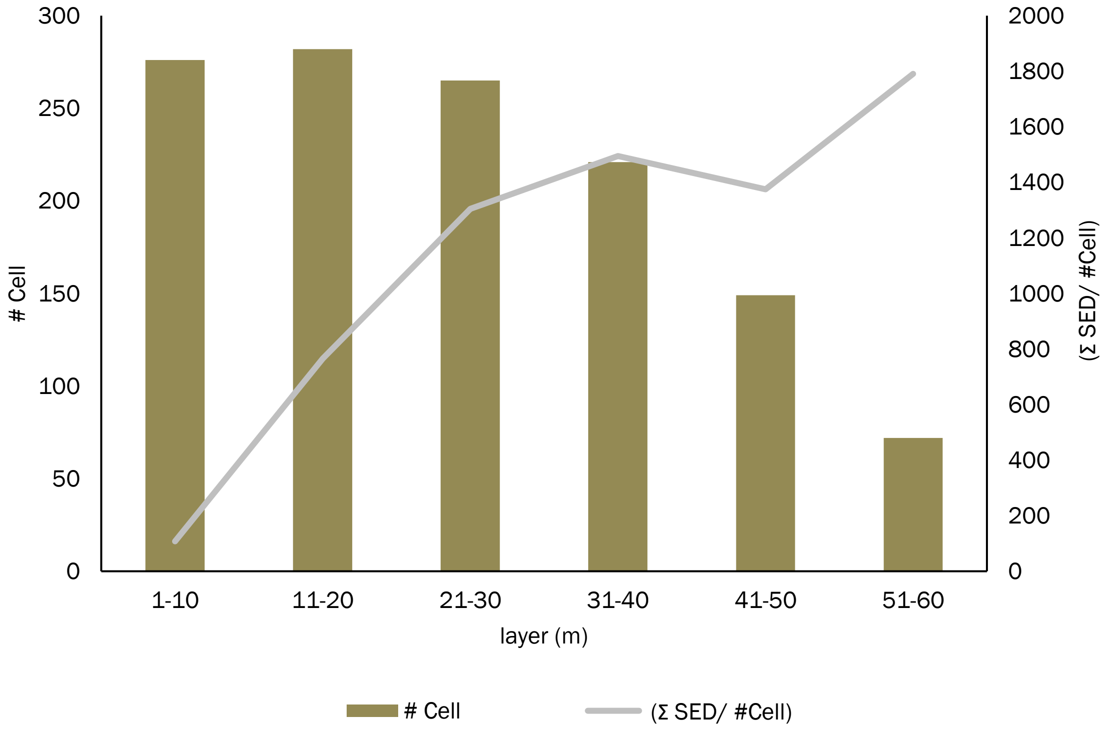

Figure 3. Number of cells containing echo target (SED) and average SED (ΣSED /#cell) for each depth layer

Table 2. Fish caught, length-weight information and TS value

Local Name	Scientific Name	Weight (g)	Length (cm)	TS [dB]
Rambe	*Carangoides caeruleopinnatus*	232	23	-44
Selar	*Selaroides leptolepis*	105	21	-43
Cangah	*Aphareus furca*	115	21	-43
Kerapu Ekor Bulan	*Variola albimarginata*	159	22	-44
Mata Besar	*Priancanthidae*	-	30	-42

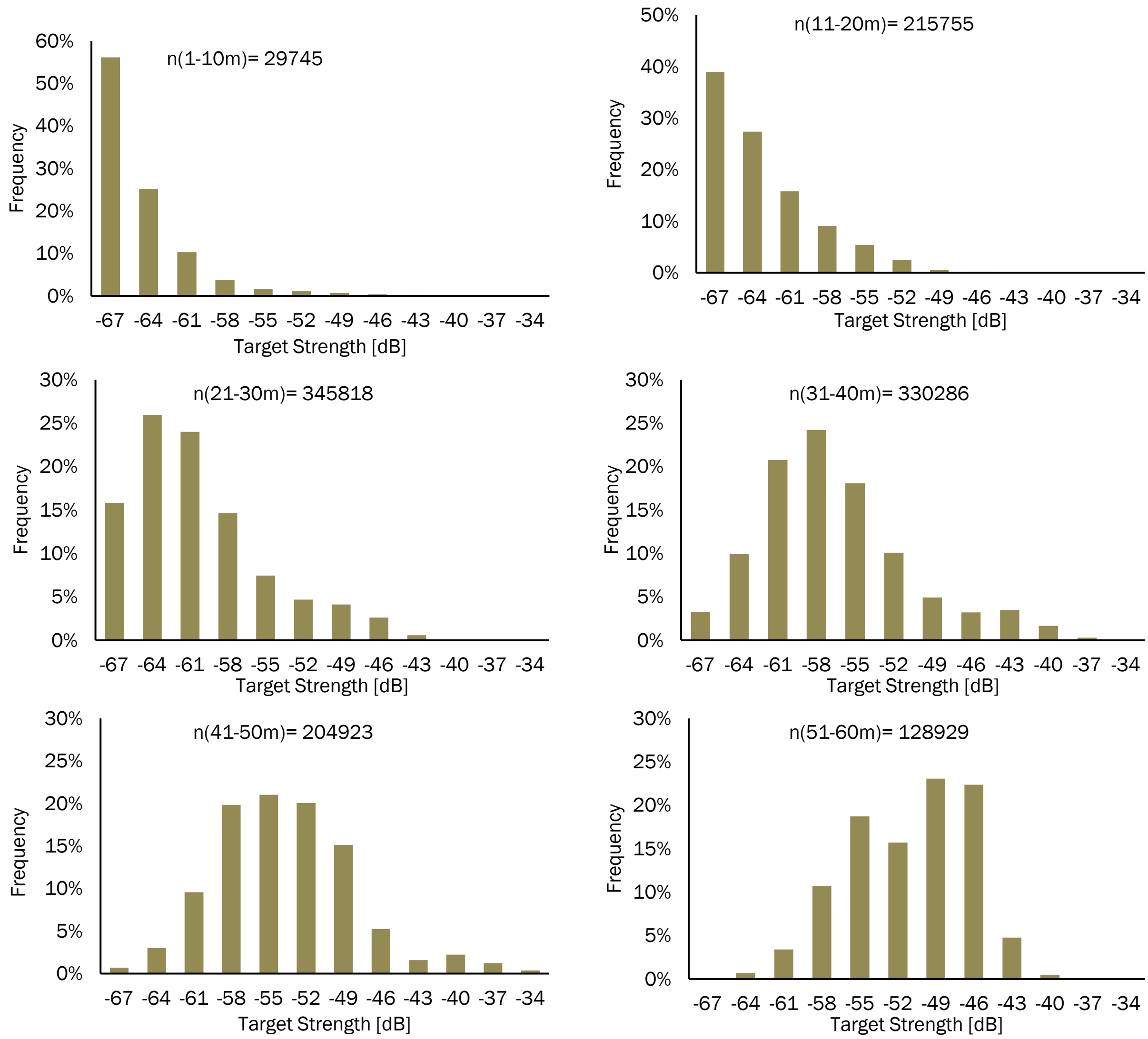

Figure 4. Distribution of the TS class at each depth layer

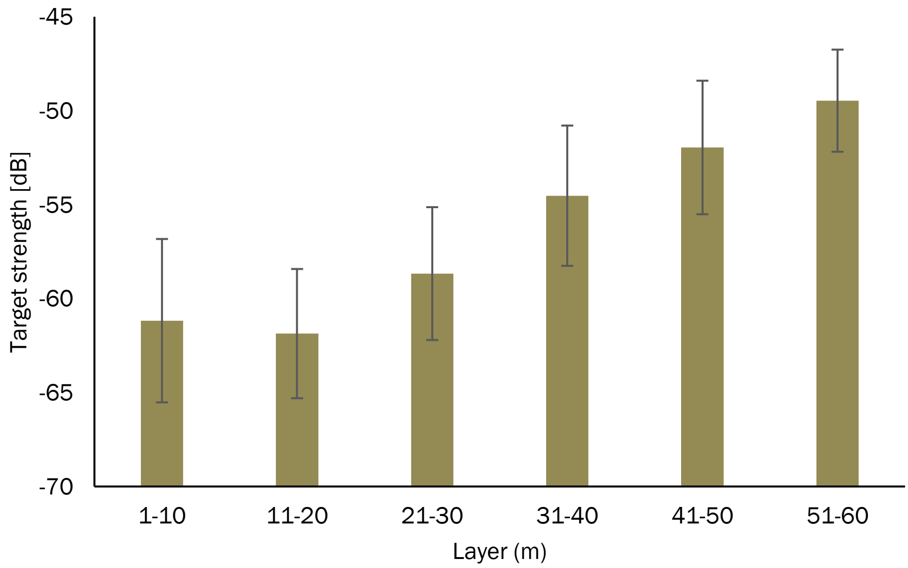

Figure 5. The Average (±SD) TS value per layer

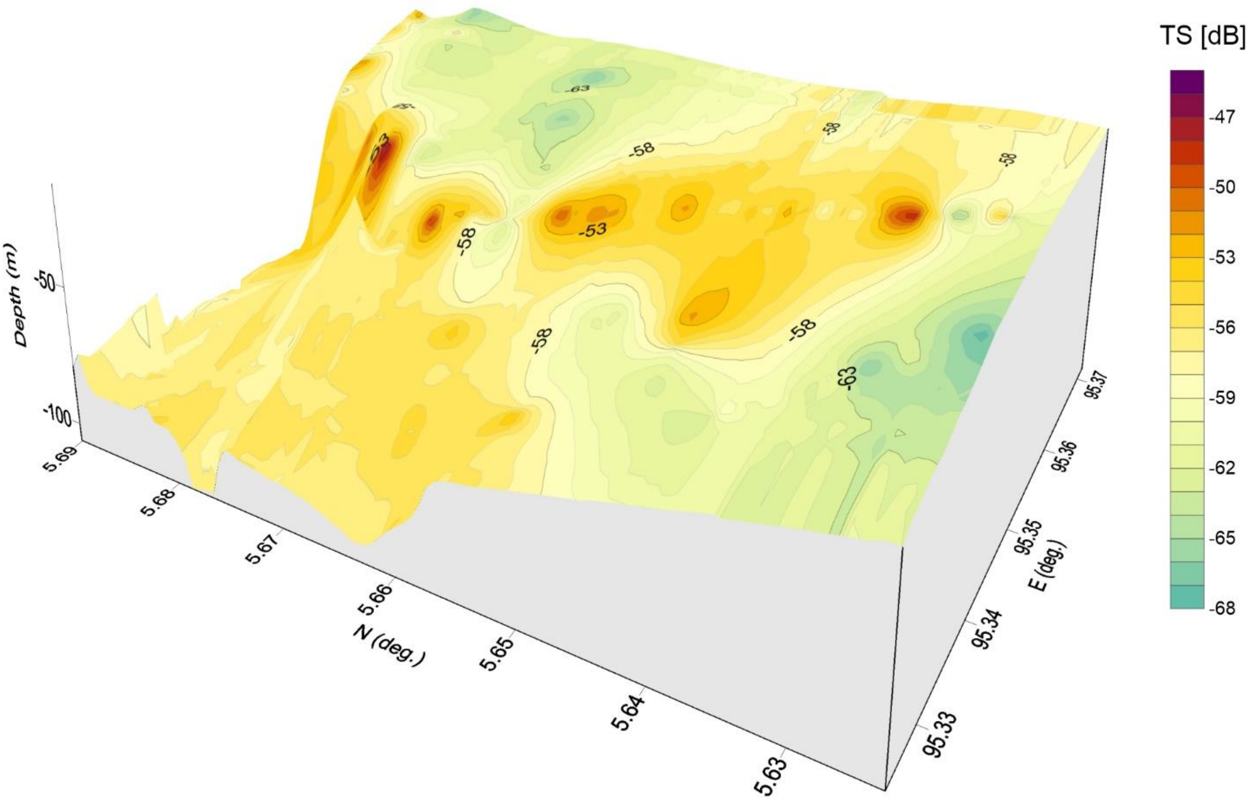

Figure 6. Distribution of the mean TS value of the water column

The frequency distribution of TS values per depth shows a shift in the distribution pattern of TS values at different depths, as shown in Figure 5. In deeper layers, the target frequency with a higher TS value increase, indicating a change in the target size composition. The average TS value per depth (Figure 6.) confirms this, with the surface area having a small mean TS value. Small biota such as zooplankton, ichthyoplankton, and small fish can result in the presence of small targets in the sea surface area (Espinosa-Fuentes *et al*., 2013; Kingsford and Cole, 2022). Larger targets can be found in deeper layers, where they have a better chance of avoiding surface exposure. Light is widely acknowledged as a key factor influencing pelagic fish behavior and dispersion patterns in the water column. Because light is critical to the visual effectiveness and selective foraging of many fish, it is sometimes considered a top-down factor in marine pelagic food web architecture. Biota near the seabed, such as fish associated with the seafloor, can also contribute to the high TS value in the lower layer.

Habitat types are significant not only for understanding fish distribution and ecology at the individual, species, and community levels but also for fish stock assessment and management since they are one of the most critical aspects in distinguishing stock units with regard to exploitation (Britten *et al*., 2021). Demersal fish, like reef fish, are related to the seabed and spend much time near the bottom of the water. Reef fish are biota whose life cycles are linked to coral reef environments, such as foraging for food, breeding, or serving as nurseries. Local fishermen have confirmed that some parts of the Alue Naga waters contain coral reef areas 3 miles from the shore with depths ranging from 20 to 40 m. The catch of reef fish like Carangoides and Priancanthidae (Table 2.) demonstrates that the Alue Naga waters area has a reef fish fishing ground. Local fishermen reinforce this by catching fish with fishing lines rather than fishing rods, which are better for reef fish.

The caught fish had a size range of 20 to 30 cm, a weight of roughly 100 to 200 g, and a target strength value of -42 to -44 dB, according to ground truth data. Similar target strength values for reef fish species have been described in a variety of literature. The distribution of area density (#SED.ha^{-1}) and biomass (g.ha^{-1}) in Alue Naga waters is calculated using the number of echo and TS values in each integrated cell. Figure 9 shows that the surface area (1-10 m) has a low area density, with only around 1975 SED.ha^{-1}. Furthermore, the largest area density was observed at layers 11-20 m (16569 $SED.ha^{-1}$), however area density values started to decrease as depth increased, until only 148 $SED.ha^{-1}$was recorded at layers 51-60 m.

There is a shift between the peak area density and peak biomass values when it is related to the biomass ($g.ha^{-1}$) acquired at each depth layer. The peak biomass is 1558 $g.ha^{-1}$ at a depth of 21-30 m, with lesser biomass in the surface layer and deeper layers. If the number of SEDs and the distribution of TS values are linked, biomass is produced from the relationship between these two parameters, with the maximum number of SEDs (345818 SED) and higher TS values on the near-surface in the 21-30-m layer. Despite having a higher mean TS value, the amount of SED found in the deeper layers has an impact on the biomass produced. The vertical distribution of fish is a difficult concept to grasp because it varies by habitat, fish type, and even season (Alvarez-Filip *et al*., 2011; Gray, 1993). The adaptation of biota to predation patterns is one factor that influences the vertical distribution pattern (Thiriet *et al*., 2022). Larger fish, for example, can be found in deeper water, but their distribution is more concentrated in specific areas. The presence of large TS targets at deep depth layers is thought to be influenced by the presence of coral reef ecosystems, unlike targets with modest TS values on a more equally distributed surface. Cells with a high density were discovered in some cells in the high depth layer, contrasted to a number of other cells with a relatively low-density value or no SED.

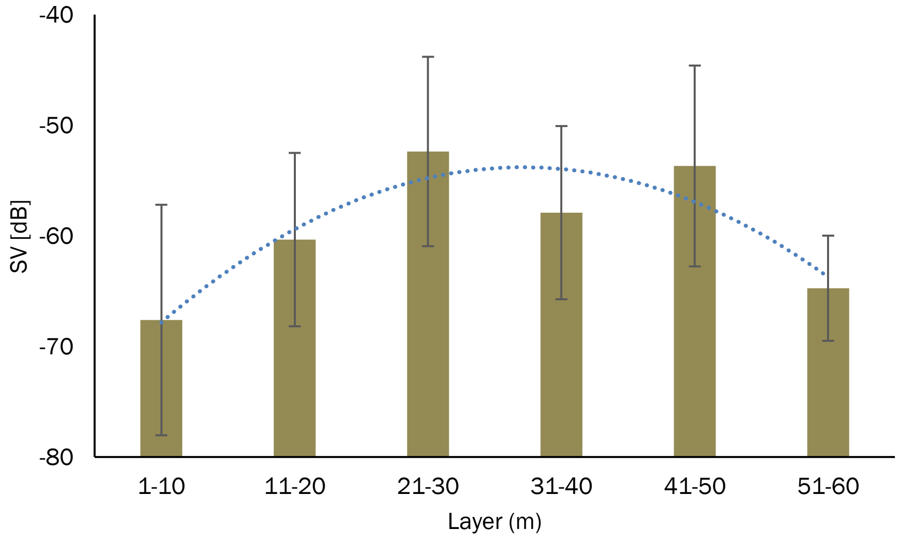

Figure 8. The SV value at each depth layer. The graph demonstrates that the SV value's peak is located at an intermediate depth

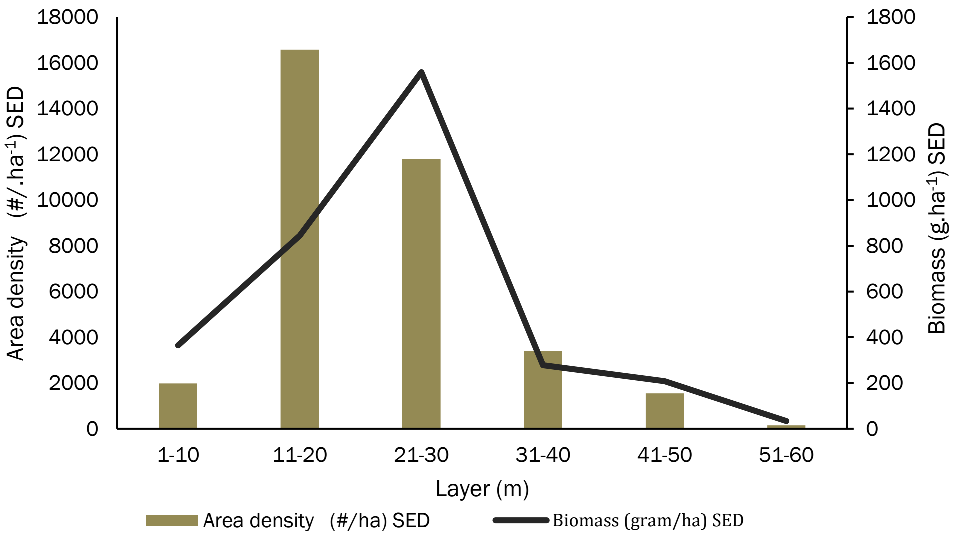

Figure 8. Area density value ($\#.ha^{-1}$) SED and Biomass ($g.ha^{-1}$) SED at each depth layer

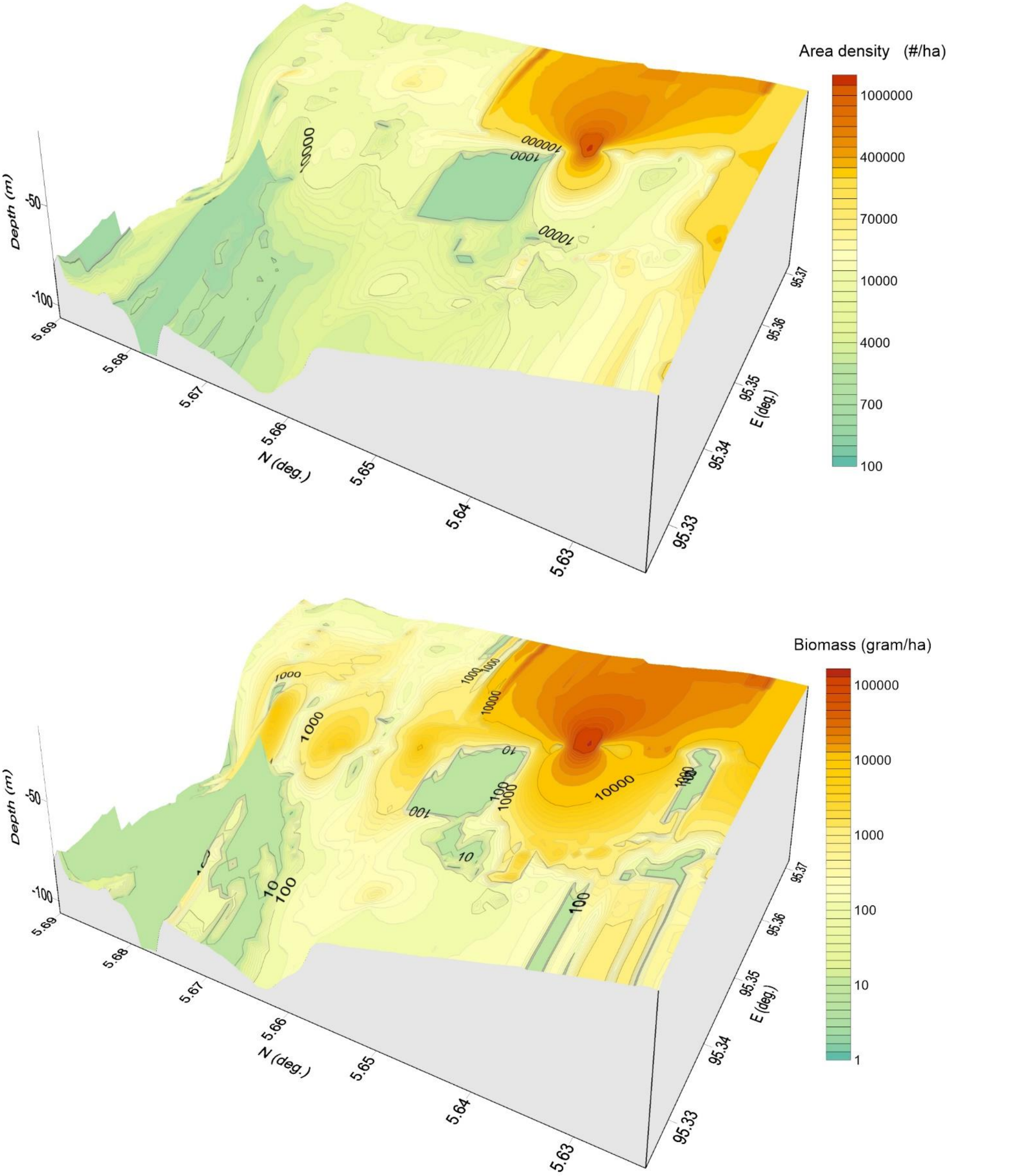

Figure 9. Horizontal distribution of area density (#.ha^{-1}) (top) and biomass (g.ha^{-1}) (bottom) in Alue Naga waters. Each value is displayed by overlaying the bathymetric profile at the survey site.

Uneven distribution may be seen in the horizontal distribution of the TS parameters, area density, and biomass. This inequality distribution may be caused by the tendency of each type of fish to have a specific preference to determine their area to live in (Galaiduk *et al*., 2018; Yusop and Mustapha, 2019). As observed in Figure 10, there is a propensity for some locations to have higher values than other regions. The maximum densities and biomass values are found around 95.35° East and 5.64° North of Alue Naga waters. Based on a quest conducted through on-site interviews with local fisherman, it was discovered that the area had a coral reef ecology, which was further confirmed by sampling the fish that were captured (Table 2.) and finding that they were reef-associated fish (FishBase, 2022). The coral reef area itself is known as a large-scale marine life support area and has a high abundance, biomass, and species richness when compared to other marine areas (Medina *et al*., 2021; Ulfah *et al*., 2021). Figure 10 illustrates how biomass and density distribution overlap, indicating that high biomass appears to be driven more by a relatively high target density.

The horizontal distribution of the mean TS value (Figure 7.) illustrates a distribution that is relevant to the target body size, whereas areas with a higher mean TS value are in line with the presence of targets with larger body sizes (Manik, 2015; Zare *et al*., 2017). It is intriguing to note that the high-TS value sites do not overlap with areas that have high densities and biomass when TS value distribution is taken into account. A relatively high mean TS value is discovered not far from the area of the highest density, despite the fact that they do not overlap. In addition to being influenced by habitat preferences, these location differences may also be influenced by location shifts between predators and prey (Eklöf *et al*., 2020). Furthermore, it is reasonable to say that the horizontal profile in the Alue Naga waters varies depending on where big targets and areas with a lot of biomasses are present.

Conclusion

The hydroacoustic method proved to be effective in providing valuable insights into the vertical and horizontal distribution of fish in Alue Naga waters. Specifically, TS values were found to increase in deeper waters, while SV values were highest at intermediate depths. The vertical distribution of area density values was found to be maximum at a depth of 11 to 20 m, while the maximum biomass was found at a deeper depth of 21 to 30 m with a value of 1558 $g.ha^{-1}$. According to the horizontal distribution in Alue Naga waters, it can be seen that the locations with the highest area density and the highest biomass locations overlap each other.

Acknowledgement

The authors would like to acknowledge Syiah Kuala University for funding this research through the Lektor Research scheme, with contract number: 147/UN11/SPK/PNBP/2022 Date February 11th 2022 (on behalf of Syahrul Purnawan). The authors would like to thank Fajar Permadi, S.Kel, Leni Angraini, S.Kel, Althaf Haqqi, S.Kel who have assisted in field data acquisition and data processing. The author is also grateful to Haekal Azief Haridhi, Ph.D who has provided input in presenting the data and Panglima Laot Ihok Alue Naga who has provided easy permission during field data collection.

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