# Utilizing Hydroacoustic Method to Assess Small Pelagic Fish Distribution in Cenderawasih Bay, Indonesia

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## ABSTRACT

Cenderawasih Bay is one of the territorial waters of Indonesia with high fishery potential. In 2022, the Indonesian Goverment revealed that the bay's small pelagic fishery potential reached 135, 140 t, yet the utilization rate remains at only 0.3, indicating underutilization. This shows the necessity of estimating fish distribution in the bay to maximize the use of small pelagic fisheries resources. The hydroacoustic method, known for its extensive survey coverage and minimal environmental impact, can be employed to estimate the distribution of small pelagic fish. Therfore, this research aims to investigate the distribution of acoustic parameters of small pelagic fish using a split beam echosounder, specifically the SIMRAD EY-60, to obtain fish SV value and distribution data. SV (Scattering Volume) values were coverted to TS (Target Strength) values and projected onto a spatial distribution map. The distribution of fish exhibited a varied range of values, with the highest SV value ranging from -59.7 to -57.4 dB and the highest TS values ranging from -59.4 to -46.7 dB. Fish distribution was more concentrated in areas with warmer temperatures and dispersed evenly across different salinity ranges, with a higher concentration of fish detected in areas with elevated chlorophyll levels.

**Keywords:** Acoustic, Environmental parameters, Fisheries resource, Small pelagic fish

## INTRODUCTION

Indonesia has a large fishing ground with rich fishery resources, especially in the Republic of Indonesia Fisheries Management Area (FMA) 717, which includes the waters of Pacific Ocean and Cenderawasih Bay. Fisheries production in the bay was recorded at 48.8 t in 2014, containing around 52 species of fish (Ministry of Maritime Affairs and Fisheries, 2015). The catch at FMA 717 in 2016 showed that 79% of the catch was small pelagic fishes, with the main catch being mackerel scad (*Decapterus macarellus*) (Suman *et al*., 2018). According to data from the Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia (2022), FMA 717 has an estimated fisheries potential of 135,140 t with a utilization rate of 0.3, which is still in the not fully utilized category.

This utilization rate is still low compared to other FMAs, with rates greater than 0.5. In FMA 717, the utilization rate of small pelagic fish is the second lowest after crabs. Small pelagic fish are a group of species inhabiting the upper 200 m of the ocean. They play an important role in food security in developing countries, such as Indonesia, as they are more affordable than other fish (Sekadende *et al*., 2020). Increasing the utilization of pelagic fish potential in FMA 717, particularly in Cenderawasih Bay, can be conducted by understanding the distribution of small pelagic fish inhabiting the area. Management must be improved and monitored properly in order to increase the potential to overcome

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environmental and economic problems in the future (Harlyan *et al*., 2022). The hydroacoustic method can be used to obtain the distribution of fish school, including small pelagic species, with a smaller negative impact on the environment than conventional methods (Allen-Ankins *et al*., 2023).

Hydroacoustic is a method that utilize sound waves propagating through the water medium to observe objects/targets in the water (Simmonds and MacLennan, 2005; Scoulding *et al*., 2023). A target, such as a school of fish, exposed to sound waves, will produce an echo with backscatter value that identifies the target. The backscatter received is divided into backscatter from a single target, known as target strength (TS), and backscatter from groups of targets, known as volume backscattering strength (SV) (Lubis, 2017; Fauziyah *et al*., 2018; Pujiyati *et al*., 2020).

The distribution of small pelagic fish can be determined by environmental conditions such as the abundance of phytoplankton for plankton-feeder pelagic species, as well as temperature and salinity (Rivai *et al*., 2018; Takarina *et al*., 2018; Hatta *et al*., 2019). The water temperature in Indonesia is greatly influenced by tchanges in ocean currents due to the presence of the Asian-Australian Monsoon (AAM) (Wirasatriya *et al*., 2021). Chlorophyll-*a* is an important substance in the photosynthesis process carried out by phytoplankton, the abundance of which can be predicted by its concentration in the water surface (Nurdin *et al*., 2013). Hence, this study aims to investigate the distribution of acoustic parameters-specifically TS and SV-of small pelagic fish, alongside environmental factors such as temperature, salinity, and chlorophyll-*a*, within Cenderawasih Bay to ascertain the correlation with the distribution pattern of these fish.

## MATERIALS AND METHODS

### *Acoustic data collection*

Acoustic data collection (sounding) was carried out in Cenderawasih Bay on 6$^{th}$ to 11$^{th}$ November 2019 using parallel and zigzag data collection trajectories (Figure 1). The sounding track had a length of 670.509 NM (nautical miles), with an area of 7,096.543 NM$^2$ with a Degree

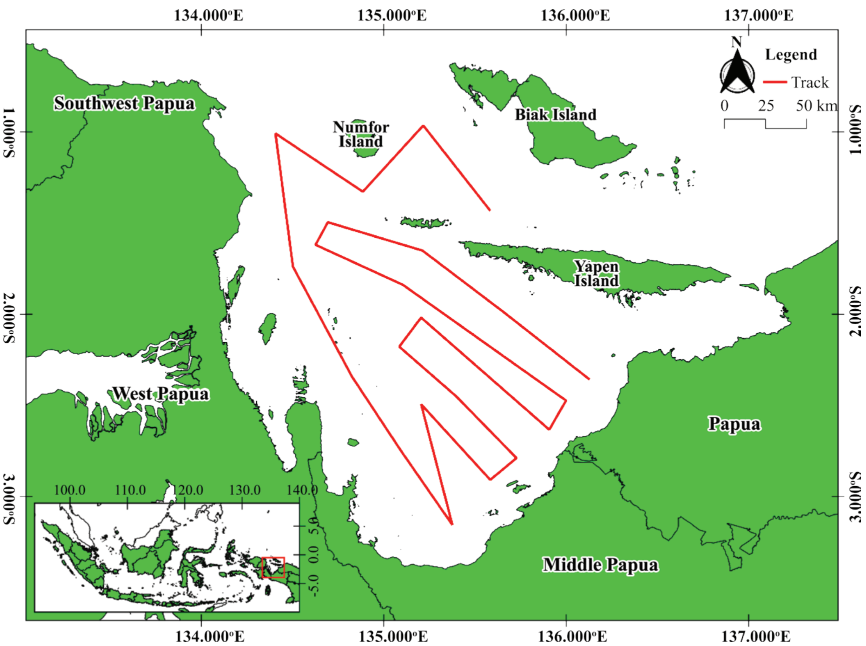


Figure 1. Map of data collection area by using SIMRAD EY-60 in Cenderawasih Bay, Papua in November 2019.

of Coverage (Λ) value of 7.96, meeting survey requirements (≥4) (Aglen, 1983). Sounding was carried out using a SIMRAD EY-60 split-beam echosounder operating at a frequency of 38kHz, designed for deep water surveys, with a continuous pulse duration of 1.024 ms. Environmental parameter data were obtained from the E.U. Copernicus Marine Service Information (CMSI) (2021a and 2021b). The data used included temperature, salinity, and total chlorophyll recorded from 6$^{th}$ to 11$^{th}$ November 2019. The data obtained covered a depth range of 0–100 m, influenced by the distribution of small pelagic fish (White *et al*., 2013). Additional data in the form of bathymetric data were sourced from GEBCO's global gridded bathymetric data sets from 2020.

*Small pelagic fish data collection*

Small pelagic fish data were collected from sounding in Cenderawasih Bay using an Echo View 4.8 dongle, with a threshold ranging from -60 dB to -34 dB and a processing column depth of 2 m to 100 m. The selected threshold range used in this study was the general range of Sound Backscatter values for small pelagic fish (Ma'mun *et al*., 2018; Manik *et al*., 2018). Given this threshold range, the detected fish length should not exceed 30 cm, considering that small pelagic fish typically have a length of less than 30 cm (Ma'mun *et al*., 2018). Depths shallower than 2 m were not processed due to potential noise interference from ship movements and engines. Subsequently, the data were separated using the "detect school" fuction in EchoView 4.8 to distinguish schooling fish in different regions. The minimum length and width criteria for schooling fish were set at 1 m, with a minimum distance of 1 m between schooling groups. The processed data were then converted to include latitude, longitude, SV data, and the number of fish per beam volume for each defined region.

*Data analysis*

TS value were derived from SV data along with the count of individuals in each region, obtained from the converted data. This approach was necessitated by the fact that the Echoview dongle only provided SV values and fish count per beam volume. The relationship between TS and SV values can be elucidated using equations proposed by Simmond and MacLennan (2005) and Pujiyati *et al*. (2007):

$$SV = 10 \log (N \times \sigma_{bs}) \quad \text{(Eq.1)}$$

$$SV = 10 \log N + TS \quad \text{(Eq.2)}$$

Where: SV = Volume Backscattering Strength (dB), N= Numerical amount, $\sigma_{bs}$= Backscattering cross-section, TS = Target Strength (dB).

The TS value is ten times the logarithmic value of the ratio between the sound emitted intensity and the sound reflected intensity by the target at a distance of 1 m (Lubis, 2017). The TS value referred in Eq.2 is the average value of the TS value for all depths at the same coordinate point, which can be obtained using the equation proposed by Simmonds and MacLennan (2005):

$$TS = 10 \log \sigma_{bs} \quad \text{(Eq.3)}$$

$$\sigma_{bs} = 10^{\frac{TS}{10}} \quad \text{(Eq.4)}$$

$$\overline{\sigma_{bs}} = \frac{\sum \sigma_{bs}}{N} \quad \text{(Eq.5)}$$

$$\overline{TS} = 10 \log \overline{\sigma_{bs}} \quad \text{(Eq.6)}$$

Where: $\overline{\sigma_{bs}}$ = Average Backscattering cross-section, $\overline{TS}$ = Average Target Strength (dB)

Eq.2 could be rewritten by substituting Eq.6, assuming that the numerical value is proportional to the number of individual fish per unit volume of the beam:

$$SV = 10 \log \rho + \overline{TS} \quad \text{(Eq.7)}$$

$$\overline{TS} = SV - 10 \log \rho \quad \text{(Eq.8)}$$

Where: ρ = Number of Individuals (ind·m$^{-3}$)

The SV and TS values obtained were merged to create a distribution map using QGIS 3.14, based on their respective value ranges. This map illustrates the distribution of detected fish alongside the horizontal representation of average temperature, salinity, and chlorophyll-*a* in the Cenderawasih Bay.

## RESULTS AND DISCUSSION

*Enviromental parameter data*

The vertical temperature distribution in Cenderawasih Bay (Figure 2a) exhibited a decline in the average water temperature from 29.93 °C to 24.55 °C within the 0–100 m depth range. This decrease is attributed to the diminishing light intensity with depth, resulting in warmer surface waters compared to deeper regions (Sidabutar *et al*., 2019). Notably, this temperature decline indicated the absence of a distinct thermocline layer, marked by an absence of temperature variation exceeding ± 0.1 °C·m$^{-1}$ beyond a certain depth (Irmasyithah *et al*., 2019). Conversely, the average salinity increased from 33.67 ‰ to 35.27 ‰ within the same depth range. This range surpassed the salinity variations observed in other Indonesian seas, such as the Java Sea (30.00–35.00 ‰) and the Banda Sea (33.19–34.98 ‰) (Bahiyah *et al*., 2019; Rugebregt *et al*., 2023). This condition is caused by the geographical properties of this bay, making Cenderawasih Bay resemble a large salt lake with relatively stable environmental conditions (Ministry of Forestry, 2012). The vertical average of total chlorophyll-*a* (Figure 2c) displayed a tendency to decrease with depth. This trend was evident below 35 m, with a subsequent increase at 10 m. The highest chlorophyll-*a* value, indicating plankton biomass-phytoplankton, the primary food source for small pelagic fish-reached 0.38 mg·m$^{-3}$ at a depth of 35 m (Nurdin *et al*., 2013).

*Acoustic parameter data*

The horizontal distribution of both TS and SV values (Figure 3 and Figure 4) exhibited variations in the detection of small pelagic fishes based on their value ranges. Small plagic fishes were detected by using a thershold range primarily designed for fish less than 30 cm in legth. Within the TS value distribution, the lowest occurrence was observed between -59.4 to -46.7 dB (Figure 3a), indicated by fewer fish detected (point symbol) on distribution maps. Notably, TS values between -67.9 to -65.8 dB (Figure 3d) displayed a broader spread across the data collection path. Similarly, the distributions of TS values within the depth ranges of -64 to -59.4 dB (Figure 3b) and -65.8 to -64 dB

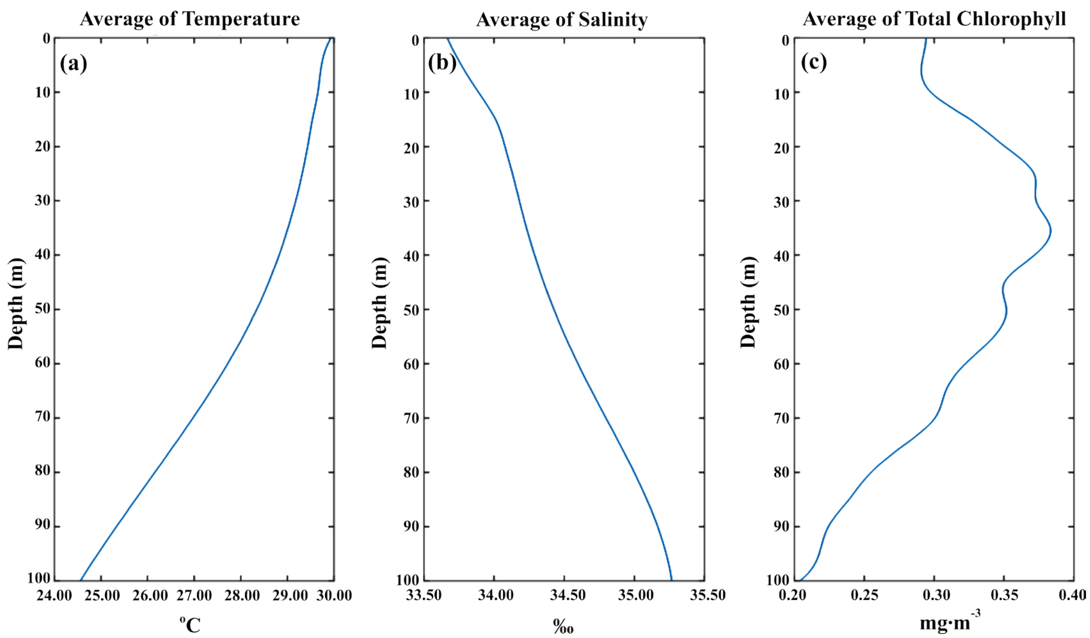


Figure 2. Average vertical distribution of (a) temperature, (b) salinity, and (c) chlorophyll, in Cenderawasih Bay, in November 2019.

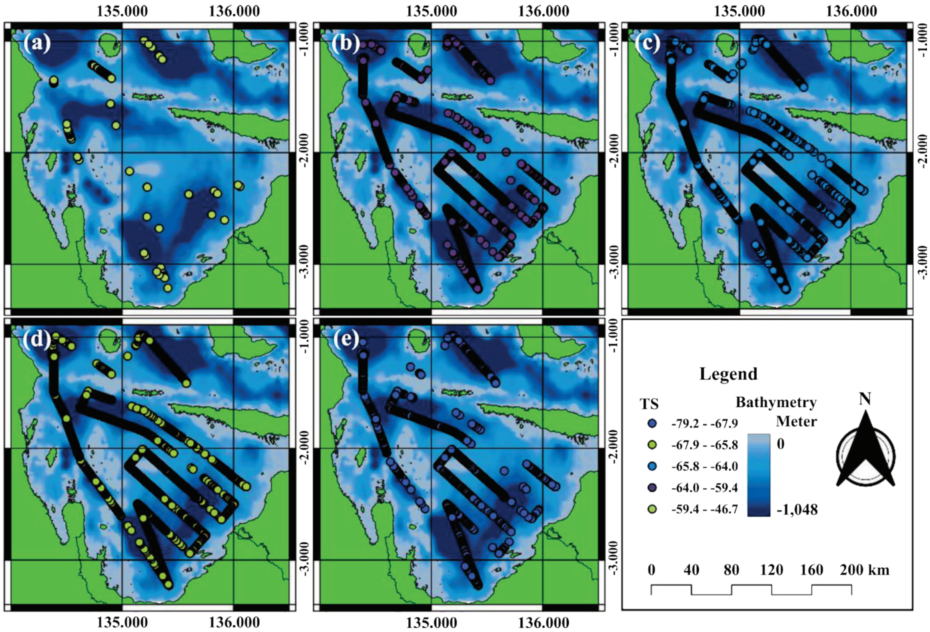


Figure 3. Horizontal distribution of average TS (Target Strength) values within specific ranges: (a) -59.4 to -46.7 dB; (b) -64.0 to -59.4 dB; (c) -65.8 dB to -64.0 dB; (d) -67.9 to -65.8 dB; and (e) -79.2 to -67.9 dB, observed in Cenderawasih Bay, in November 2019.

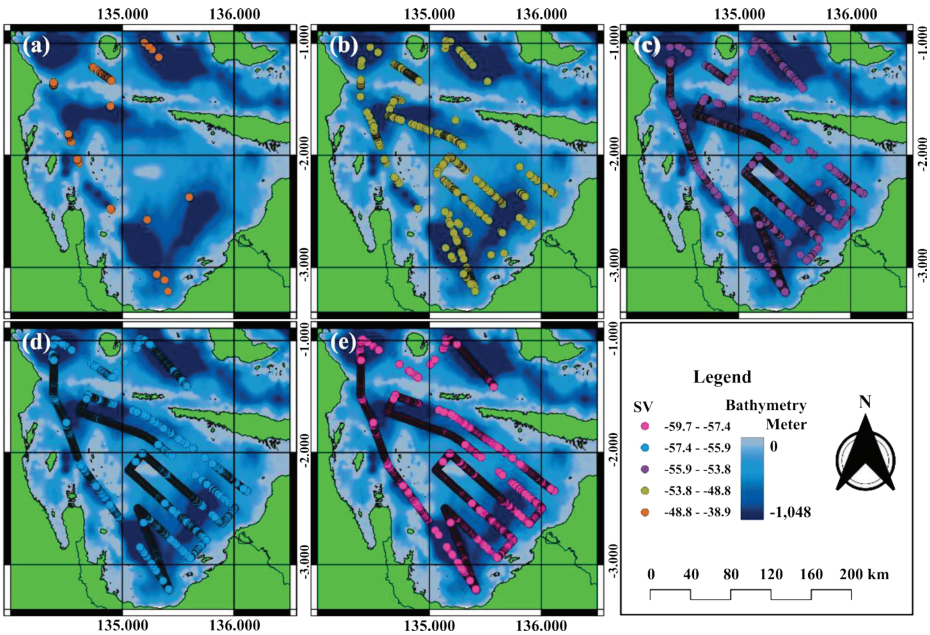


Figure 4. Horizontal distribution of average SV (scattering volume) values across different depth ranges: (a) -48.8 to -38.9 dB; (b) -53.8 to -48.8 dB; (c) -55.9 dB to -53.8 dB; (d) -57.4 to -55.9 dB; and (e) -59.7 to -57.4 dB, observed in Cenderawasih Bay, in November 2019.

(Figure 3c) exhibited comparable patterns along the data collection route. Additionally, within the TS value range of -79.2 dB to -67.9 dB (Figure 3e), a higher concentration was observed in areas with depths exceeding 400 m arcoding to GEBCO's global gridded bathymetric data.

The SV value distribution reveals distinct ranges in Figure 4. The range from -48.8 to -38.9 dB range (Figure 4a) displays the lowest frequency distribution, while the range from -59.7 to -57.4 dB range (Figure 4e) exhibits the most prevalent distribution. Notably, the ranges from -55.9 to -53.8 dB and -57.4 to -55.9 dB (Figures 4c and 4d) showcase similar distributions. Figure 4b, encompassing SV values between -53.8 to -48.8 dB, presents a less concentrated data spread. Examining the horizontal distribution of TS and SV, higher values exhibit limited variability, contrasting with lower values that display wider variability. The TS and SV value distributions suggest a dominance of small pelagic fish within the -79.2 to -59.4 dB TS value range and the -59.7 to -48.8 dB SV value range.

The analysis of fish distribution in Cenderawasih Bay, utilizing average values of environmental factors like temperature, salinity, and chlorophyll (Figure 5), revealed a concentration of fish at multiple specific points. The horizontal temperature distribution reveals a prevailing warmth, typically between 28.23 and 29.41 °C in these waters (Figure 5a) (Nugroho and Muzaki, 2021; Suhermat *et al*., 2021). This is evident from the clustering of numerous dots in regions displaying brighter colors, which indicate a higher abundance of fish at elevated temperatures (Figure 5a). Conversely, the salinity distribution (Figure 5b) demonstrates a broader spread, with higher values observed farther from the bay's interior, typically ranging between 33.83 and 34.38 ‰. Despite this, the fish detected do not exhibit any notable aggregation and appear evenly distributed across areas of both lower and higher salinity. Similar to the salinity pattern, the horizontal distribution of chlorophyll (Figure 5c) exhibits an escalating trend as it extends away from the inner bay, peaking notably around the Biak-Numfor area, typically ranging between 0.42 and 0.50 mg·m$^{-3}$. Correspondingly, the distribution of fish appears to intensify around the Biak-Numfor area, aligning with regions of heightened chlorophyll concentrations. Pearson correlation results (Table 1) showed differences in the number of fish detected with temperature, salinity and total chlorophyll. Salinity and total chlorophyll had the more significant influence on the number of fish detected in the Cenderawasih Bay than temperature.

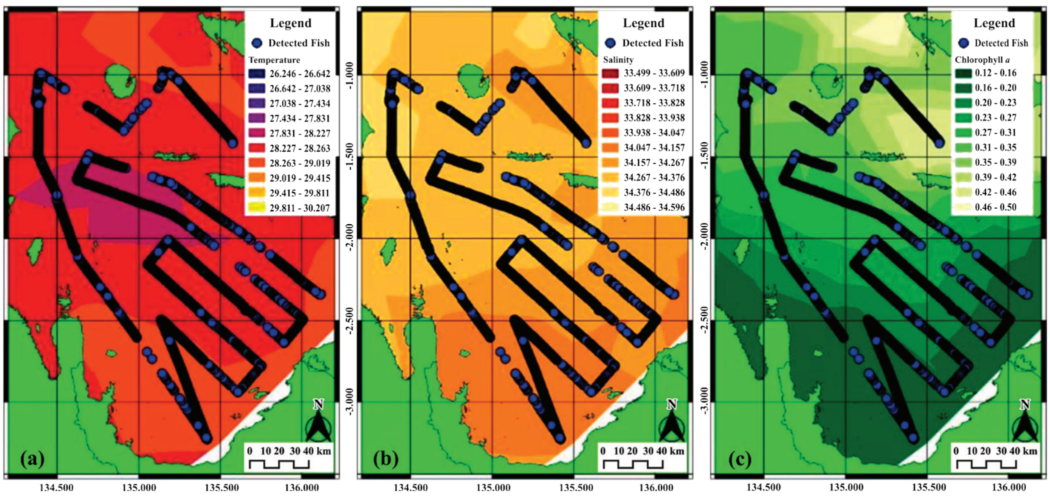


Figure 5. Horizontal distribution of fish relative to average (a) temperature, (b) salinity, and (c) chlorophyll in Cenderawasih Bay, in November 2019.

Table 1. Correlation between fish detected and enviromental parameters (temperature, salinity, and total chlorophyll) in the Cenderawasih Bay, Papua in November 2019

| | Fish Detected | Temperature | Salinity | Total Chlorophyll |
|---|---|---|---|---|
| Fish Detected | 1 | - | - | - |
| Temperature | -0.146889392 | 1 | - | - |
| Salinity | 0.173521763 | -0.965937606 | 1 | - |
| Total Chlorophyll | 0.154240875 | 0.207751968 | -0.095463875 | 1 |

The temperature, salinity, and chlorophyll distribution in Cenderawasih Bay were significantly impacted by powerful currents, specifically the New Guinea Coastal Current and the New Guinea Coastal Under Current. These currents played a pivotal role in transporting water masses from the east to the west within the northern Papua waters (Wattimena *et al*., 2018). The water transported by these currents originates from the warmer and saltier South Pacific Ocean differing in temperature and salinity from the water masses in the North Pacific Ocean (Kolibongso, 2020). Additionally, these currents bear substantial nutrient loads, a pivotal factor affecting the chlorophyll levels within a water body (Abigail *et al*., 2015).

The mackerel scad, a small pelagic fish commonly found in Cenderawasih Bay, typically inhabits depths of 40–200 m in tropical (circumtropical) waters (White *et al*., 2013; Suman *et al*., 2018). This species was most likely the one detected in the survey because it dominated the small fish commodity in FMA 717 (Marine Fisheries Research Institute, 2014).

## CONCLUSION

The detected fish exhibited a wide range of TS (Target Strength) and SV (Volume Backscattering Strength) values, showcasing significant diversity. The SV values peaked between -59.7 to -57.4 dB, while the highest TS values ranged from -59.4 to -46.7 dB. These findings underscore the success of acoustic detection, particularly in identifying fish at low backscatter levels. Analyzing fish distribution in relation to environmental factors revealed a notable correlation with warmer temperatures, indicating a higher concentration of fish in these areas. Furthermore, fish appeared evenly distributed across varying salinity ranges, with numerous detections occurring near regions of elevated chlorophyll concentration. Further research regarding mapping of fishing areas needs to be carried out in order to see the dynamics of changes in fishing areas. Sustainable fisheries policies need to be created and implemented so that increased resource utilization remains limited to catch. This policy aims to ensure that fisheries resources, especially small pelagic fish in these waters, are not overused which could cause a decline in fisheries production in Cenderawasih Bay.

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