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PLANKTON DISTRIBUTION ANALYSIS WITH UNDERWATER ACOUSTIC REMOTE SENSING

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Abstract. Hydroacoustic methods are rapidly growing as a key technique in marine ecology, particularly for efficient and non-invasive monitoring of plankton and fish. This technology utilises sound waves to detect, measure and map the distribution of marine biota by analysing the backscatter strength (Sv). This study used a SIMRAD EK-60 echosounder and a Seabird SBE37 CTD to analyse the relationship between plankton distribution and environmental parameters, such as temperature, salinity and conductivity. Results show that plankton are more abundant in the surface layer with high temperature and low to moderate salinity, while conditions at depth limit their biological activity. This research contributes to the sustainable management of marine resources through an integrated hydroacoustic approach.

1 Introduction

Hydroacoustic methods have developed rapidly as one of the main techniques in marine ecology, especially for monitoring marine resources such as plankton and fish. This technology uses sound waves to detect, measure, and map the distribution and abundance of marine life efficiently and non-invasively [1]. Hydrography with hydroacoustic can be determinate an exploration of marine resource exploration and specialized target searches [2, 3, 4]. Indonesia, the potential of this technology is increasingly important considering the role of plankton as a primary producer that supports the ecology ecosystem chain, especially in euphotic zones where photosynthesis can take place [5].

The distribution of plankton is not only affected by physical factors such as light, temperature, and salinity, but can also be observed directly through acoustic analysis. These environmental parameters are key in understanding the dynamics of plankton and fish populations. Hydroacoustic technology allows mapping the distribution of plankton spatially, both horizontally and vertically, by utilizing Backscattering Strength (Sv) Analysis which shows the value of plankton sound reflection in the range of -82 dB to -75 dB [6].

Previous studies have shown the effectiveness of hydroacoustic methods in marine ecology. For example, the studies of [7] and [1] proved the ability of this technology to accurately detect the distribution of plankton and fish. Research conducted in the waters of the Banggai Sea by [8] provides clear evidence that the distribution of fish stocks and plankton can be mapped well using the backscattering coefficient area.

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Although previous studies have shown the success of hydroacoustic methods in detecting plankton distribution, there have not been many studies that have deeply examined the relationship between plankton distribution and environmental parameters such as temperature and salinity through hydroacoustic approaches. The study also seeks to integrate in-situ data and acoustic analysis to provide more comprehensive insights. This study aims to analyze the distribution of plankton using hydroacoustic technology and correlate it with environmental conditions at the research site. With this approach, it is hoped that research can make an important contribution to better management of marine resources, especially in the context of the sustainability of marine ecosystems.

2 Material and Methods

The material used of this study was bathymetry data obtained from measurements using SIMRAD EK-60 from cruise ship. Specifically, the SIMRAD EK-60 used is a Singlebeam Echosounder with a frequency of 38 kHz, capable of conducting measurements up to a depth of 15,000m. The specifications of the tool need to be known as an effort to get the agreed precision, here are the specifications of SIMRAD EK-60.

The specifications of the tool need to be known as an effort to get the desired product, here are the specifications of SIMRAD EK-60 in Table 1

Table 1. EK-60 Transceiver

Frequency	*12, 18, **38**, 70, 120, 200, 400, 710 kHz*
High pressure transducers	***38**, 120, 200 kHz*
Ping rate	*Up to 40 s-*
Range	*0 to 15000 m*
Data output	*Raw or processed data to user defined file*

In addition, to get environmental conditions in the form of CTD, use CTD Seabird SBE37 SMP. The specifications of *the Seabird SBE 37 SMP CTD* device used are presented in the following Table 2.

Table 2. Specifications CTD Seabird SBE 37 SMP

Conductivity	*0 to 7 S/m (0 to 70 mS/cm)*
Temperature	*-5 to 45 °C*
Optional Pressure	*20 / 100 / 350 / 600 / 1000 / 2000 / 3500 / 7000 (meters of deployment depth capability)*
Acquisition Time	*1.9 - 2.9 sec/sample (see manual)*
Memory Capacity	*530,000 samples CTD*

The methode used with this study using Software EchoView^{TM} Ver.4.0. EchoView^{TM} allows the identification of plankton masses based on the intensity of the acoustic signals reflected by organisms in the water column. Once the plankton is identified, the acoustic return value (*Backscatter*) is integrated to calculate the estimation of plankton biomass, which can be used for ecological analysis and fisheries management quantitatively [9]. The study addresses two primary questions:

1. examines the potentional underwater remote sensing feature which is utilized to determine the abundance of plankton.
2. Explore the relationship between the Sv (dB) values observed in the water column and the environmental conditions

3 Result And Discussing

3.1 The Potentional Underwater Remote Sensing Feature that Utilized to Determine the Abundance of Plankton.

The propagation of sound in underwater environments is influenced by the physical characteristics of the medium. The presence of dynamic sound speed profiles in marine environments introduces an element of uncertainty, which complicates the prediction of propagation characteristics [10], hydroacoustic is the main technique used for underwater remote sensing. Underwater remote sensing Various types of survey tools, such as echosounders, sonars, and other acoustic devices, are used to detect strong, intermittent traces of surreal reflections that are used to detect seabed features and others. During the underwater remote sensing analysis, here are some details analyzed:

3.1.1 Volume Backscattering Strength ($\overline{Sv}$)

$\overline{Sv}$ It is the ratio between the intensity reflected by a *single target* group describes $\overline{Sv}$ *a schooling* or swarm of species, the value is the ratio of the intensity of the sound reflected by many simultaneously amplified targets and measured at one meter from the target to the intensity of the sound that hits the target [1]. In addition, $\overline{Sv}$*Target Strength (TS)* is a value in decibels that indicates the strength of the sound bounce from the target measured at a standard distance of 1-meter from the center of the acoustic target, compared to the intensity of the sound received by the target [11].

In $\overline{Sv}$ Analysis According to [1], $\overline{Sv}$ the following equation is used to describe the value of plankton and provide a summary of the vertical distribution of plankton $\overline{Sv}$:

$$sv = 10^{\left(\frac{Sv}{10}\right)} \quad (1)$$
$$\overline{sv} = \sum \; (sv.n)/n\text{total} \quad (2)$$
$$\overline{Sv} = 10\log\left(\overline{sv}\right) \quad (3)$$

Where:
$sv =$ Linear form of Sv
$\overline{sv} =$ Average sv
$n = The\ number\ of\ individual\ targets$
$\overline{Sv} = The\ average\ of\ Sv$

3.1.2 Target Strength (TS)

The backscatter value that hits the target object is understood as target strength. Target strength (TS) is the ability of an object to reflect sound waves that hit it [8]. The TS value can indicate the size of the detected object; for example, if the TS value is small, the target is small in size, and if the TS value is large, the target is large in size. The TS value of fish can vary due to several factors, one of which includes the wave frequency [1].

3.1.3 Plankton

To carry out photosynthesis, plankton absorb light energy and carbon dioxide (CO2). Because they are the initial binder of solar energy, plankton is very important for marine autonomous ecosystems [12]. Phytoplankton are foods that zooplankton eat to grow. Phytoplankton and zooplankton are important components of the aquatic food chain that determine the number of fish present. An oceanographic biological parameter that can be used to determine the fertility level of aquatic is plankton abundance. There may be algae growth in the waters if the number of phytoplankton increases [11].

3.2 The relationship between the Sv (dB) values observed in the water column and the environmental conditions

3.2.1 Results of environmental conditions on CTD data

The physic-chemical conditions of marine waters, such as salinity, temperature, and conductivity, play an important role in determining the distribution of marine organisms, including plankton. Plankton, especially phytoplankton, are a key component in marine ecosystems because they act as primary producers that support the food chain. Variations in environmental parameters such as depth, temperature, and salinity will affect the abundance and distribution of plankton in different layers of seawater. To understand this relationship, analysis of graphs showing changes in salinity, temperature, and conductivity to depth is necessary. The following is an explanation of each of the graphs displayed, as well as their relationship with the distribution of plankton in the study area.

3.2.2 Salinity VS Depth

The results of CTD measurements showed the relationship between the salinity (salinity) of seawater in the PSU (Practical Salinity Unit) and the depth (m). The deeper the seawater, the salinity tends to increase. The salinity range varies from about 34.5 PSUs at the surface to more than 36 PSUs at depth. Plankton is greatly affected by changes in salinity. Lower salinity on the surface may favor the presence of phytoplankton that require optimal and stable conditions for photosynthesis.

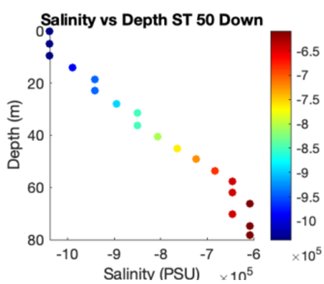

Figure 1. Salinity VS Depth

3.2.3 Temperature VS Depth

The CTD temperature measurement results describe the relationship between seawater temperature (°C) and depth (m). The temperature decreases as the depth increases. At the surface, the temperature reaches more than 25°C, while at depth, the temperature drops close to 5°C. Temperature plays a key role in the distribution of plankton. On the surface, high temperatures favor phytoplankton growth because light and nutrients are more available. While at depth, low temperatures limit the metabolic activity of planktonic organisms.

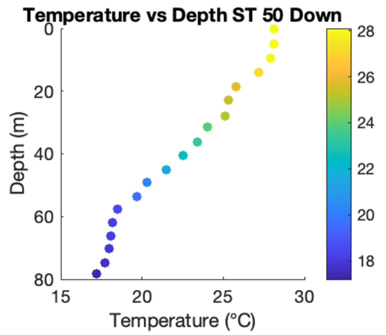

Figure 2. Temperature VS Depth

3.2.4 Conductivity vs Depth

In the CTD results on the data of seawater conductivity (in mS/cm) to depth (m). Conductivity increases with depth, closely related to salinity changes. The conductivity range is around 4.5–6.5 mS/cm. Conductivity is directly related to salinity. Higher salinity at depth creates a less supportive environment for some plankton, especially phytoplankton, which generally dominate in the surface layer.

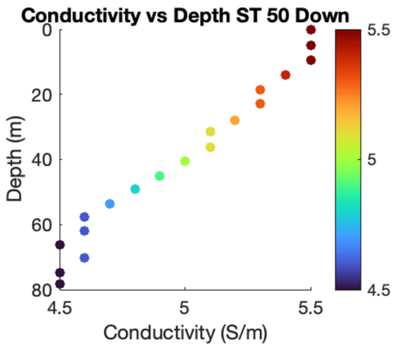

Figure 3. conductivity VS Depth

The graphs shown above show the relationship between salinity, temperature, and conductivity with seawater depth. On the salinity vs depth graph, salinity increases as the depth increases, with salinity values lower at the surface and higher in the seabed layer. The temperature vs depth graph shows a significant downward trend in temperature with increasing depth, where the surface temperature reaches more than 25°C, while at depth it drops to close to 5°C. Whereas on the conductivity vs depth graph, conductivity tends to increase with depth, following a pattern like salinity because the two are interrelated.

These three parameters have a close relationship with the distribution of plankton in marine waters. At sea level, higher temperatures, relatively low to moderate salinity, and abundant sunlight create an ideal environment for phytoplankton to photosynthesize. These conditions favour the growth and abundance of plankton in the surface layers, which form the basis of the marine food chain. In contrast, at deeper depths, increased salinity and conductivity and low temperatures tend to limit the biological activity and metabolism of plankton. Thus, plankton, especially phytoplankton, tend to be more abundant in the ocean surface layer, where the physic-chemical conditions of seawater support optimal biological productivity.

3.3 Relationship between Sv Value and environmental conditions from CTD measurements

Bathymetry research which often uses acoustic parameters, such as Sv (volume backscattering strength) values, to identify and analyze the presence and distribution of marine life in the water column. The Sv value reflects the level of reflection of sound waves from organisms in the water, such as plankton, small fish, or other particles. The higher the Sv value, the more likely it is that there is a concentration of organisms at a certain depth. This graph presents the relationship between the Sv value and the depth of the water, which can provide an overview of the vertical distribution of marine life in the aquatic ecosystem. In this study, the value of the Sv result is found as shown in the graph in the following figure 4.

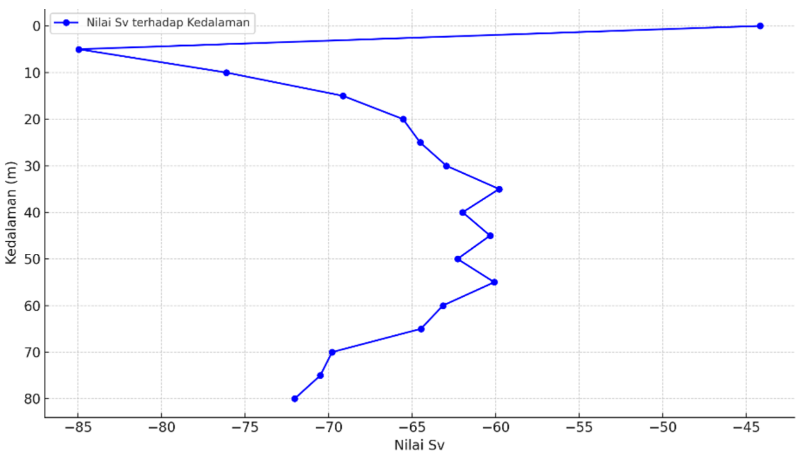

Figure 4. Graph of Sv Value to depth

This graph above illustrates the value of Sv to the depth of the water, starting from the surface (0 m) to about 80 m. In the surface layer up to a depth of 20 m, the value of Sv tends to increase around -45 dB to -80 at a depth of 0 to 5 meters from the surface, which indicates the possibility of high biota density which indicates low sound wave reflection and the possibility of biota density starting to decrease as the depth increases. At a depth of 20–50 m, the graph shows a fluctuating pattern, with the Sv value increasing to about -62.5 dB. This pattern indicates the presence of a concentration of organisms or plankton in this layer, which may be caused by favourable environmental conditions, such as the availability of light, nutrients, and optimal temperatures for marine life.

At a depth of 50–80 m, the Sv value again decreases close to -75 dB, indicating that the density or presence of organisms begins to decrease in the deeper layers. This decline can be

caused by factors such as a lack of light for the process of photosynthesis, a decrease in temperature, or a decrease in nutrients needed by plankton and other organisms.
The results of this study are like [6] showing that the vertical distribution of plankton throughout the waters has a return scattering strength (Sv) value ranging from -82 dB to -75 dB. The distribution of plankton decreases as the depth increases, and environmental parameters such as temperature and salinity play a significant role in the survival of plankton in the area.

4 Conclusion

The vertical distribution of plankton in the water column is influenced by environmental parameters such as temperature, salinity, and conductivity. The Sv (Volume Backscattering Strength) values reveal variations in marine life density across depths, with the highest plankton density observed in the surface layer (0–20 m), where Sv values range from -45 dB to -80 dB, supported by warm temperatures, low salinity, and abundant sunlight that optimally facilitate photosynthesis. At depths of 20–50 m, Sv values fluctuate, peaking at -62.5 dB, indicating uneven plankton concentrations due to variations in nutrient distribution, light penetration, and temperature. Below 50 m, Sv values decrease to -75 dB, reflecting reduced plankton density due to less favourable conditions, such as low temperatures, limited light, and scarce nutrients. Temperature is a key factor, with high surface temperatures promoting plankton metabolic activity and abundance, while low temperatures at greater depths hinder biological processes. Increasing salinity and conductivity with depth further create an unfavourable environment for phytoplankton, typically dominant in the surface layer. This study aligns with [6], who reported similar Sv value patterns (-82 dB to -75 dB) and emphasized the significant role of temperature and salinity in shaping plankton distribution. Overall, plankton density decreases with depth, with the surface layer showing the highest productivity, while deeper layers exhibit reduced biota density due to limitations in light, temperature, and nutrients. The objective hydroacoustic for exploration ocean ecology and target strength will be tight with this method [2] on other hand with different target strength can be identification schooling and length of pelagic fish also give us a reference about the ecological insitu [13].

References

1. J. Simmonds, D. MacLennan, Fisheries acoustics: Theory and practice, 2nd edn. (Fisheries Acoustics: Theory and Practice, 2007), pp. 1–252. https://doi.org/10.1002/9780470995303
2. C. Feuillade, Superspheroidal modeling of resonance scattering from elongated air bubbles and fish swim bladders, J. Acoust. Soc. Am. 131(1), 146–155 (2012). https://doi.org/10.1121/1.3658440
3. A.N. Hasanah, N. Rukminasari, F.G. Sitepu, Perbandingan kelimpahan dan struktur komunitas zooplankton di Pulau Kodingareng dan Lanyukang, Kota Makassar, Torani J. Fish. Mar. Sci. 24(1) (2014). https://doi.org/10.35911/torani.v24i1.113
4. H.M. Manik, Seabed identification and characterization using sonar, Adv. Acoust. Vib. 2012(2) (2012). https://doi.org/10.1155/2012/532458
5. Nontji, Plankton Laut (LIPI Press, Indonesia, 2008).
6. S. Pujiyati, B. Hamuna, R. Hisyam, M. Srimariana, I.N.M. Natih, Distributions of environmental parameters and plankton's volume backscattering strength at Yos

Sudarso Bay, Jayapura, Indonesia, Egypt. J. Aquat. Res. 48(1), 37–44 (2022). https://doi.org/10.1016/j.ejar.2021.08.001
7. J.P. Bergeron, N. Koueta, J. Massé, Interannual fluctuations in spring pelagic ecosystem productivity in the Bay of Biscay (Northeast Atlantic) measured by mesozooplankton aspartate transcarbamylase activity and relationships with anchovy population dynamics, Fish. Res. 143, 184–190 (2013). https://doi.org/10.1016/J.FISHRES.2013.02.006
8. M.Z. Lubis, Acoustic Systems (Split Beam Echo Sounder) to Determine Abundance of Fish in Marine Fisheries, Oceanogr. Fish. Open Access J. 3(2) (2017). https://doi.org/10.19080/ofoaj.2017.03.555607
9. Y. Ladroit, P.C. Escobar-Flores, A.C.G. Schimel, R.L. O'Driscoll, ESP3: An open-source software for the quantitative processing of hydro-acoustic data, SoftwareX 12, 100581 (2020). https://doi.org/10.1016/J.SOFTX.2020.100581
10. X. Huo, P. Zhang, Z. Feng, Study of underwater sound propagation and attenuation characteristics at the Yangjiang offshore wind farm, Ecol. Inform. 84, 102919 (2024). https://doi.org/10.1016/j.ecoinf.2024.102919
11. H. Manik, I. Nurkomala, Pengukuran target strength dan stok ikan di perairan Pulau Pari menggunakan metode single echo detector, Mar. Fish. Technol. Manag. 7, 69–81 (2016). https://doi.org/10.29244/jmf.7.1.69-81
12. F.M. Suseno, Biologi Laut: Suatu Pendekatan Ekologis (James W. Nybakken) (2001). https://books.google.com/
13. A. Achmadi, T. Hestirianoto, H.M. Manik, Detection of pelagic fish schooling using hydroacoustic methods in Palu Bay, Central Sulawesi, J. Teknol. Perikanan Kelautan 5(2), 129–137 (2015). https://doi.org/10.24319/jtpk.5.129-137