Environmental Drivers of Plankton Backscattering Strength (SV) in Tunda Island's Marine Ecosystem, Banten

Farras Taqy Alya Nuswantari[1], Sri Pujiyati[1*], Steven Solikin[1],
Totok Hestirianoto[1] and Muhammad Hisyam[2]

ABSTRACT

Plankton play a crucial role in pelagic ecosystems, serving as a primary food source in marine food webs and influencing nutrient cycling. Hydroacoustic methods are effective for detecting targets such as plankton by generating backscatter values, which indicate their distribution. This approach provides insights into their horizontal and vertical distribution. This research aimed to map and analyze the spatial and temporal distribution of plankton volume backscattering strength (SV) values using hydroacoustic methods, and to examine the relationship between these SV values and environmental parameters in the waters around Tunda Island, Banten. Data collection included oceanographic measurements: temperature, salinity, DO, pH, currents and water clarity, as well as acoustic data. Oceanographic data were gathered from 16 sampling points at the water surface around Tunda Island. The relationship between oceanographic parameters and acoustic data was analyzed using Principal Component Analysis (PCA). The study found that temperatures around Tunda Island ranged from 28 to 30.2 °C, salinity from 30.3 to 33.5‰, pH from 8.1 to 8.4, DO from 6.39 to 7.67 mg·L^{-1}, water clarity from 9.57 to 34.36%, and currents from 0.13 to 0.69 m·s^{-1}. The SV for horizontal plankton distribution ranged from -82.04 to -76.06 dB, while vertical distribution ranged from -82.04 to -75.07 dB. PCA analysis showed that the relationship between plankton distribution and aquatic parameters accounted for 57.2% of the cumulative variance, with each parameter making either a positive or negative contribution. This research provides baseline data on plankton abundance and environmental conditions in Tunda Island's waters, highlighting the use of hydroacoustic methods for detecting fine-scale distribution patterns in relation to ecological variables. The findings contribute valuable insights into plankton ecology in areas impacted by anthropogenic activity, supporting future ecological monitoring, fisheries management, and resource conservation efforts.

Keywords: Environmental parameter, Hydroacoustics, Plankton, Tunda Island

INTRODUCTION

Plankton, which are categorized into zooplankton and phytoplankton, play a crucial role in pelagic ecosystems by transferring organic materials from primary producers to higher trophic levels (Le Borgne *et al*., 2011; Azani *et al*., 2021). The patterns in plankton distribution serve as useful indicators for identifying fishing areas and assessing changes in water conditions (Pangestu, 2022). Plankton migrate spatially and temporally to find waters with optimal conditions based on the suitability of temperature, salinity, oxygen and nutrients (Pangestu, 2022).

Hydroacoustics enables the detection of targets such as fish, larvae, and plankton in both the water column and at the bottom by measuring

[1]Department of Marine Science dan Technology, Faculty of Fisheries dan Marine Science, IPB University, Bogor, Indonesia
[2]Department of Marine Science, Faculty of Mathematic dan Natural Science, Cenderawasih University, Jayapura, Indonesia
[*]Corresponding author. E-mail address: sripu@apps.ipb.ac.id
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backscatter values, which indicate the distribution of these targets (Pujiyati *et al*., 2022). This technology, often termed active acoustics, is widely used to detect fish and plankton and to observe their behavior (Bergeon *et al*., 2013). The method produces volume backscattering strength (SV) values, which help describe the size and distribution of plankton patches in both horizontal and vertical planes (Pujiyati *et al*., 2022).

The waters around Tunda Island are rich in marine biodiversity, supported by coral reef, seagrass, and mangrove ecosystems, along with productive fisheries areas (Prameswara and Suryawan, 2019). These ecosystems present significant potential for sustainable development and optimization efforts.

The aims of this research are to map and analyze the spatial and temporal distribution of plankton volume backscattering strength (SV) values using hydroacoustic methods, as well as to examine the relationship between these SV values and environmental parameters in the waters surrounding Tunda Island, Banten.

MATERIALS AND METHODS

This research was conducted from August to November 2022, involving data processing and analysis at the Marine Acoustics, Instrumentation and Robotics Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, Bogor Agricultural Institute. Data acquisition took place on August 10–11, 2022, in the waters around Tunda Island, Banten, during the Himiteka VII Expedition. The study included 16 station points, with four points located in each of the northern, eastern, southern, and western parts of the island. Data collection in the southern part of the island was conducted on August 10, 2022, and continued in the western, northern and eastern parts on August 11, 2022. The research location is shown in Figure 1.

The equipment used for data acquisition included a SIMRAD EK15 Single Beam Echosounder, a laptop, a Garmin GPS, an Oregon GPS, a fishing boat, a current meter, a refractometer, a Van Dorn water sampler, an HI98107 water pH meter, and a DO meter. Data processing was performed using

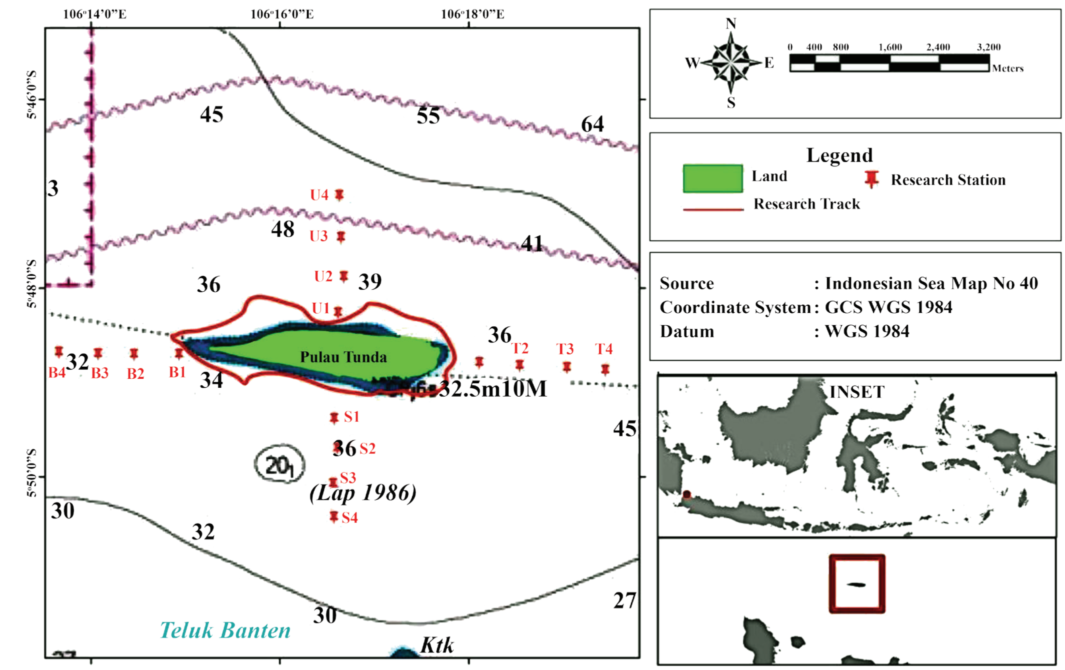


Figure 1. Research location in Tunda Island, Banten.

EchoView 4.8 software for acoustic data processing and Microsoft Excel for data analysis.

The materials used in this research consisted of raw acoustic sounding acquisition data in *.raw file format, including both tracking and stationary data from the 16 station points. Physical parameters of the aquatic environment, such as temperature, pH, salinity, current speed, DO, and water clarity, were also collected from samples taken at the 16 stations around Tunda Island.

Data collection consists of oceanographic and acoustic measurements. Water temperature and pH were measured at the surface by immersing the HI 98107 pH meter into the water column. Water salinity was measured using a refractometer on samples collected at a 5 m depth with a Van Dorn water sampler at each station. Current speed was recorded using a current meter, which was lowered to a depth of 3–5 m at each station and measured for a duration of 5 min. Water brightness data were obtained by lowering a Secchi disk to a specific depth to determine water clarity. Dissolved oxygen (DO) levels were measured from water samples collected at a 5 m depth using a DO meter.

The SIMRAD EK15 Single Beam Echosounder was operated continuously at a vessel speed of approximately 4–5 knots along the research track around the island to acquire tracking data and determine the spatial distribution of plankton SV. Stationary data were collected by performing stationary sounding for five minutes when the vessel stopped at each of the 16 station points, producing temporal distributions of plankton SV.

The calibrated data were processed with a threshold range of -100 dB to -70 dB. The Elementary Sampling Distance Unit (ESDU) was set to 50 pings. Data processing was integrated with depth strata divisions, spaced at 5 m intervals from the surface to the bottom. The subsequent steps included digitizing and obtaining the SV value for each integrated grid cell. Volume Backscattering Strength (SV) was calculated as the ratio of intensity reflected by a collection of single targets, using the equations from Simmonds and MacLennan (2005):

$$SV = 10 \log sv \tag{1}$$

$$sv = 10^{\left(\frac{SV}{10}\right)} \tag{2}$$

$$\overline{sv} = \frac{\sum sv}{n} \tag{3}$$

$$\overline{SV} = 10 \log \overline{sv} \tag{4}$$

where SV is the Volume Backscattering Strength, sv is the Volume Backscattering Strength coefficient, and n = number of data points.

Principal Component Analysis (PCA) is a descriptive statistical method used to present graphical representations that maximize the information within a data matrix (Supranto, 2010). The data matrix in this research comprised rows representing the points or coordinates of the research locations, and columns representing quantitative variables that reflect the physico-chemical characteristics of the waters. Since the data had differing units of measurement and variance, normalization was performed by centering and scaling the data. This step was necessary to account for the different units of measurement across parameters, enabling accurate interpretation of relationships within the data and reducing bias (Mansor *et al*., 2020). The normalization equation used in this research is shown in Equation (5).

$$Zi = \frac{xi\text{-}min(x)}{max(x)\text{-}min(x)} \tag{5}$$

where: $x = x_1, x_2, x_3, \ldots x_n$, and z_i are normalized data.

This analysis method divides the parameter correlation matrix into several components, so that it could organize the diversity of these components from the largest to the primary component axis (Martina and Rajawane, 2019). The PCA method is represented by Equation (6) below:

$$PCi = a_{1i}\, x_1 + a_{2i}\, x_2 + \ldots + a_{ni}\, x_n \tag{6}$$

where:
PCi = i^{th} principle component
$x_1, x_2, \ldots, x_n$ = i^{th} independent variable
$a_{1i}, a_{2i}, \ldots, a_{ni}$ = independent variable coefficients in PCA

The purpose of using the PCA method was to reduce the dimensionality of correlated data by extracting essential information from the dataset and representing it as a new set of orthogonal variables called principal components (Supranto, 2010). This approach displayed the similarity patterns of observations and variables as points on a map, allowing for easier and more representative interpretation by simplifying the various factors and variables in the data structure. In this research, PCA was employed to categorize acoustic and aquatic environmental parameters into distinct, acoustically homogeneous classes based on statistical methods, as well as to examine the relationships between environmental parameters and acoustic data across different stations.

Data processing using PCA began with gathering various numerical data variables and organizing them into the desired parameters. In this research, data were divided according to the parameters relevant to each station. The next step involved standardizing each data value to ensure that all variables contributed equally to the formation of the principal components. Finally, the reduced data was visualized with a biplot graph showing the two main component axes and a score plot graph illustrating the proximity of data points based on each parameter or component.

RESULTS AND DISCUSSION

Environmental parameters

The surface temperature values in the waters around Tunda Island, shown in Figure 2a, range from 28 to 30.2 °C, which falls within the optimal range for plankton growth (Herawati *et al*., 2021). Surface temperature is a key physical factor that influences the life cycle of aquatic organisms, including plankton (van der Molen and Pätsch, 2022). Higher environmental temperatures increase plankton metabolism, leading to greater feeding activity and, consequently, a higher demand for oxygen.

The pH of a body of water influences plankton life by affecting physiological processes and enzyme reactions in various tissues. Figure 2b shows that surface acidity (pH) levels in Tunda Island waters range from 8.1–8.4, which falls within the optimum range for plankton growth [e.g., 7–8.5, Nindarwi *et al*. (2021)].

Dissolved oxygen (DO) levels also serve as an indicator of water quality, with lower levels indicating higher pollution. Figure 2c shows DO levels in the research area, ranging from 6.39 to 7.67 $mg \cdot L^{-1}$. According to Nindarwi *et al*. (2021), waters with DO values above 5 $mg \cdot L^{-1}$ are favorable for plankton life cycles, indicating that DO levels in Tunda Island waters are optimal for supporting aquatic biota.

The brightness measurements at the research site, converted into percentages and shown in Figure 2d, range from 9.57 to 34.36%. Brightness is a key factor for photosynthesis, indicates the depth to which light penetrates in the water column (Herawati *et al*., 2021). Higher brightness levels suggest a favorable environment for the growth of photosynthetic organisms (Herawati *et al*., 2021). Moreover, Figure 2e shows that salinity value in Tunda Island waters range from 30.3 to 33.5‰, which is within the ideal range for plankton growth [e.g., 30–35‰, Nyabakken (1992)].

Current speed values shown in Tunda Island waters (Figure 2f) range from 0.13 $m \cdot s^{-1}$ to 0.69 $m \cdot s^{-1}$. Figure 3 shows the bathymetric conditions around Tunda Island, classifying it as a shallow-water area with depths ranging from 0.5 to 52.2 m. The 3D bathymetry (Figure 3b) reveals a significant slope on the seabed, likely due to varying inclinations of seabed cliffs. According to research by Febrianto *et al*. (2015), the seabed slope in Tunda Island waters ranges from 0 to 56.134 degrees.

Horizontal spatial distribution of plankton SV values

The horizontal spatial distribution of plankton SV values is analyzed to identify differences in plankton distribution at the surface level. Figure 4 displays the spatial distribution of plankton SV values at depth of 2–5 m, with SV values ranging from -82.04 to -76.06 dB. The SV range of -86.50 dB to -62.64 dB represents plankton organisms detected

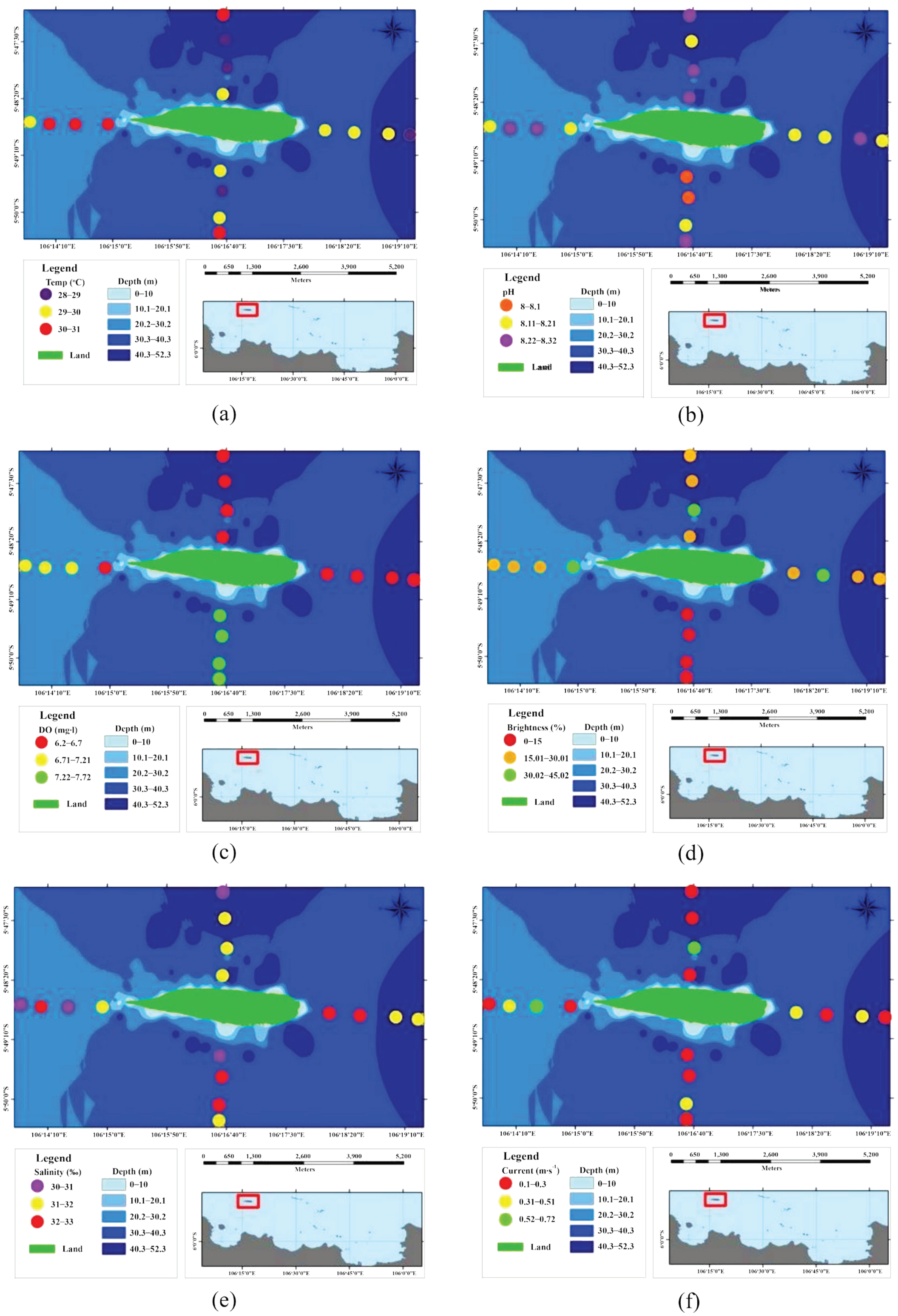
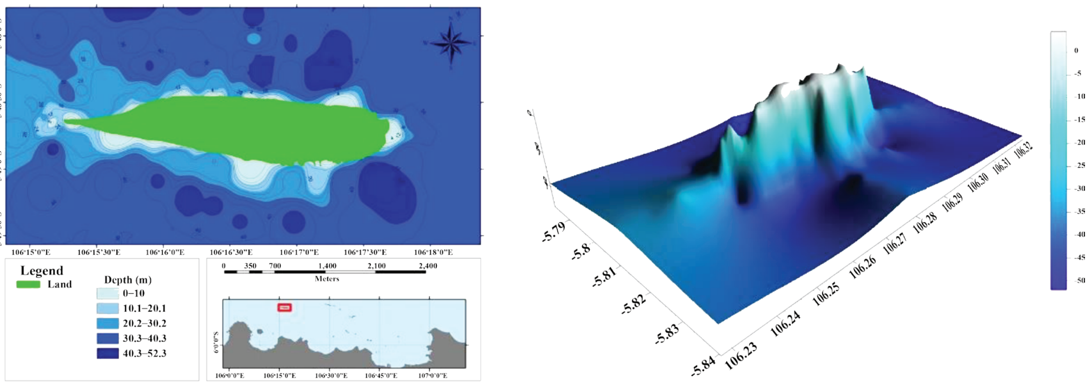


Figure 2. Distribution of environmental parameters in the waters of Tunda Island, Banten: (a) Temperature, (b) pH, (c) Dissolved Oxygen, (d) Brightness, (e) Salinity, and (f) Current.

by acoustic instruments within a depth range of 5–200 m (Maclennan *et al*., 2002). At the research location, the horizontal distribution of SV values ranges from -82.04 to -76.06 dB, with a median of -78.69 dB based on 473 data points collected from acoustic soundings around Tunda Island.

The analysis of plankton SV values is divided into three categories, as illustrated by color legend in Figure 4, which indicates the relative strength of the acoustic signals reflected by plankton target. The first category, with the highest SV range of -78 to -75 dB, is represented by large green circles in Figure 4. The second category, with a medium range of -81.01 to -78.01 dB, is symbolized with medium-sized yellow circles. The third category, indicating lower SV values from -84.02 to -81.02 dB, is depicted with small red circles.



(a) (b)

Figure 3. Bathymetry of Tunda Island displayed in: (a) 2D, and (b) 3D.

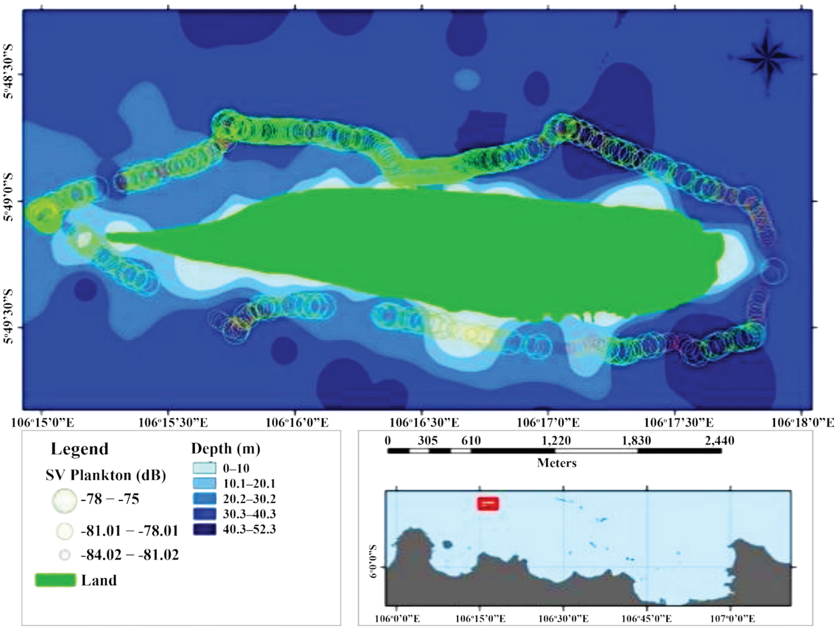


Figure 4. Spatial distribution of plankton SV values around Tunda Island.

The results indicate that areas with the highest SV values, represented in green in Figure 4, are predominantly in the northern waters, with average depth ranging from 20 to 40 m, showing substantial variation in the vertical distribution of plankton. Conversely, regions with lower SV values, shown in red, are located in the eastern and southern waters, where brightness levels are comparatively low. Brightness is a critical factor for plankton, as it directly affects photosynthesis through light penetration (Herawati *et al*., 2021). The western waters exhibit moderate SV values, denoted with yellow (-81.01 to -78.01 dB), suggesting an area abundant in plankton and frequented by fishers for cultivation, highlighting its ecological fertility.

The southern waters exhibit a widespread yellow color along the acoustic track, with SV values ranging from -81.01 dB to -78.01 dB, likely due to environmental factors. This area borders Banten Bay and is influenced by Jakarta Bay, as well as significant anthropogenic waste from barge traffic. These observations suggest that human activity and external factors heavily impact the water conditions. One indicator of water fertility is the distribution of plankton. Figure 4 shows a dominance of green circles which indicate an abundant horizontal surface distribution of plankton, with values between -78.00 dB and -75.00 dB.

Vertical distribution of plankton SV values

Figure 5 presents the vertical distribution of SV values in Tunda Island waters, with distinct SV values at varying depth. At 5 m depth, SV values range from -82.04 to -76.07 dB, with a peak at -76.07 dB across 473 data points. Plankton SV at 10 m shows a range of -79.51 dB to -75.14 dB. A depth of 15 m in Tunda Island waters shows a distribution of plankton SV values of -78.80 dB to -75.09 dB, with similar patterns at subsequent depths down to 50 m, albeit with decreasing data points due to the area's bathymetric limitations. Vertical migration patterns, influenced by sunlight intensity and temperature, lead plankton to concentrate at depths of 10 to 30 m as the day progresses (Macdonald *et al*., 2014). This migration is driven by the plankton's need to avoid excessive surface light while optimizing nutrient access. The distribution of plankton within the water column varies with depth, as plankton often group together in patches influenced by environmental conditions. Figure 5 illustrates variations in plankton presence across different depth layers, likely due to the changing intensity of sunlight as it penetrates the waters column. Sunlight entering the water undergoes reflection, absorption, and attenuation, resulting in varying light intensities with depth (Sudarsono *et al*., 2024). According to Figure 5, at depths of 2–5 m, plankton SV values are more widely distributed than at other depths, with the lowest minimum and maximum SV values. This may be due to high sunlight intensity during data collection, as excessive light can damage phytooxidative enzymes in phytoplankton, leading to mortality in less resilient species (Sriwijayanti *et al*., 2019).

At depths between 10 and 30 m, the amount of data indicating plankton presence declines with increasing depth, likely reflecting the bathymetric variations of the research area. A similar pattern is observed between 35 and 50 m, where the data show a decrease in plankton presence as average water depth rarely exceeds 30 m, with few areas reaching beyond 35 m. Plankton SV values from 10 to 25 m increase with depth before decreasing again at 30 m. Between 35 and 50 m, SV values tend to be more homogeneous. Minimum SV values from 10 to 30 m also decrease with depth, as plankton migrate vertically to avoid high surface temperatures and light intensity, becoming more distributed between 10 and 30 m during peak sunlight hours. This phenomenon aligns with findings by Macdonald *et al*. (2014), who observed that plankton ascend to the surface in the cooler morning hours but avoid intense light by migrating deeper during the day.

At depths from 35 to 50 m, minimum SV values increase slightly, possibly due to widespread plankton distribution at these depths. The decrease in plankton SV values with depth reflects the bathymetric conditions of Tunda Island waters, where depths vary and not all areas reach 35 to 50 m. Plankton distribution at each depth is influenced by the vertical mixing of water masses, a process that can enhance water column fertility by bringing nutrients from deeper layers to the surface (Pujiyati *et al*., 2022).

An analysis of the relationship between SV and environmental parameters in Figure 6 shows that factor 1 accounts for 30.3% of the variance, and factor 2 accounts for 26.9% together explaining 57.2% of the variance. Ma'mun *et al*. (2013) stated that the proximity of lines between variables indicates a strong relationship. Figure 6 reveals that the plankton SV value line and the depth line in quadrant IV have a close Euclidean angle with the brightness parameter line in quadrant I, indicating a direct relationship between depth, brightness, and plankton SV values. This aligns with observed changes in plankton SV values with depth, as plankton migrate in response to environmental conditions, particularly light availability within the water column.

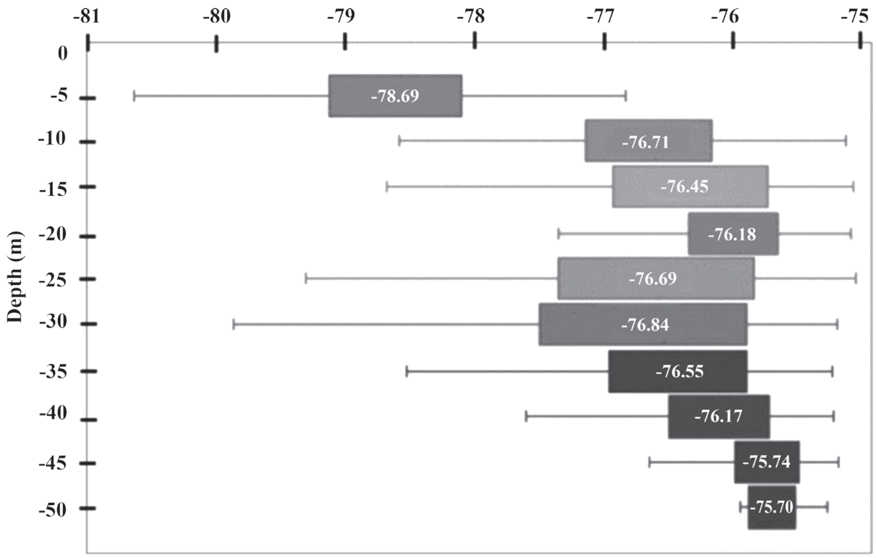
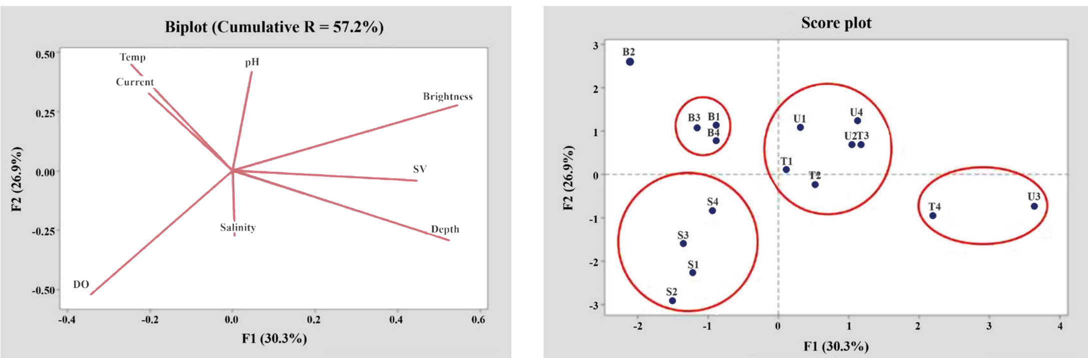


Figure 5. Vertical distribution of plankton SV values in Tunda Island.



(a) (b)

Figure 6. Principal Component Analysis (PCA) results: (a) Biplot showing the relationships among environmental parameters (e.g., brightness, depth, DO, etc.) and plankton backscattering strength (SV); (b) Score plot highlighting the grouping of sampling locations based on similarities in environmental factors and SV values.

CONCLUSIONS

The environmental conditions in the waters around Tunda Island are favorable for plankton growth, as indicated by SV values in the horizontal distribution ranging from -82.04 dB to -76.06 dB, and in the vertically distribution from -82.04 dB to -75.07 dB. Plankton distribution in Tunda Island waters is influenced by various water parameters, as evidenced by axis 1 (F1) and axis 2 (F2) in the analysis, which together explain 57.2% of the cumulative variance, reflecting both positive and negative contributions from each parameter.

Further research is recommended to explore the spatial and temporal distribution of plankton across different seasons or months for a deeper understanding of plankton dynamics. Additionally, *in situ* plankton data collection is needed to assess plankton abundance, which can be integrated with acoustic data for comparative analysis.

LITERATURE CITED

Azani, N., M.A. Ghaffar, H. Suhaimi, M.H. Azra, M.M. Hassan, L.H. Jung and N.W. Rasdi. 2021. The impacts of climate change on plankton as live food: A review. **IOP Conference Series: Earth and Environmental Science** 869(012005): 1–9. DOI: 10.1088/1755-1315/869/1/012005.

Bergeon, J.P., N. Koueta and J. Massé. 2013. 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. **Fisheries Research** 143(2013): 184–190. DOI: 10.1016/j.fishres.2013.02.006.

Dedi, N.P. Zamani and T. Arifin. 2016. The relationship between environmental parameters and coral health disorders in Island Tunda, Banten. **Jurnal Kelautan Nasional** 11(2): 105–118. DOI: 10.15578/jkn.v11i2.6112. (in Indonesian)

Edwards, K.F., M.K. Thomas, C.A. Klausmeier and E. Litchman. 2016. Phytoplankton growth and the interaction of light and temperature: A synthesis at the species and community level. **Limnology and Oceanography** 61(4): 1232–1244. DOI: 10.1002/lno.10282.

Febrianto, T., T. Hestirianoto and S.B. Agus. 2015. Bathymetry mapping in the shallow waters of Tunda Island, Serang, Banten uses singlebeam echosounder. **Jurnal Teknologi Perikanan dan Kelautan** 6(2): 139–147. DOI: 10.24319/jtpk.6.139-147. (in Indonesian)

Herawati, E.Y., A. Darmawan, R. Valina and R.I. Khasanah. 2021. Abundance of phytoplankton and physical chemical parameters as indicators of water fertility in Lekok Coast, Pasuruan Regency, East Java Province, Indonesia. **IOP Conference Series: Earth and Environmental Science** 934: 012060. DOI: 10.1088/1755-1315/934/1/012060.

Le Borgne, R., V. Allain, R.J. Matear, S.P. Griffiths, A.D. McKinnon, A.J. Richardson and J.W. Young. 2011. **Vulnerability of open ocean food webs in the tropical Pacific to climate change.** In: Vulnerability of Fisheries and Aquaculture in the Tropical Pacific to Climate Change (eds. J. Bell, J.E. Johnson and A.J. Hobday), pp. 189–250. Secretary of the Pacific Community, Noumea, France.

Ma'mun, A., H.M. Manik and T. Hestirianoto. 2013. Design algorithm and the application on acoustic single beam for detection lower water. **Jurnal Teknologi Perikanan dan Kelautan** 4(2): 173–183. DOI: 10.24319/jtpk.4.173-183. (in Indonesian)

Macdonald, R.G., D.G. Bowers, D. McKee, G.W. Graham and W.A.M. Nimmo-Smith. 2014. Vertical migration maintains phytoplankton position in a tidal channel with residual flow. **Marine Ecology Progress Series** 509: 113–126. DOI: 10.3354/meps10872.

Maclennan, D.N., P.G. Fernandes and J. Dalen. 2002. A consistent approach to definitions and symbols in fisheries acoustics. **ICES Journal of Marine Science: Journal du Conseil** 59(2): 365–369. DOI: 10.1006/jmsc.2001.1158.

Mansor, A.A., S. Shamsul, S. Abdullah, N.C. Dom, N.N.L. Napi, Ahmed and M. Ismail. 2020. Identification of Indoor Air Quality (IAQ) sources in libraries through Principal Component Analysis (PCA). **IOP Conference Series: Materials Science and Engineering** 1144: 012055. DOI: 10.1088/1757-899X/1144/1/012055.

Martina, A. and M. Radjawane. 2019. Data analysis on sea water quality data in Jakarta Bay using Principal Components Analysis (PCA) method during transitional monsoon 2012. **IOP Conference Series: Earth and Environmental Science** 339: 012023. DOI: 10.1088/1755-1315/339/1/012023.

Nindarwi, D.D., S.H. Samara and M.B. Santanumurti. 2021. Nitrate and phosphate dynamics of phytoplankton abundance in Kanceng River, Sepuluh, Bangkalan, East Java, Indonesia. **IOP Conference Series: Earth and Environmental Science** 679: 012063. DOI: 10.1088/1755-1315/679/1/012063.

Nyabakken, J.W. 1992. **An Ecological Approach.** Gramedia, Jakarta, Indonesia. 459 pp.

Pangestu, C.H. 2022. **Plankton Backscatter Values in Java Sea Waters Using Acoustic Instruments Simrad Me70.** Undergraduate Thesis, IPB University, Bogor, Indonesia. 45 pp. (in Indonesian)

Prameswara, B. and I.B. Suryawan. 2019. Development of the marine tourism potential of Tunda Island, sub-district tirtayasa, Serang Regency, Province Banten. **Jurnal Destinasi Pariwisata** 7(1): 180–187. DOI: 10.24843/JDEPAR.2019.v07.i01.p27. (in Indonesian)

Pujiyati, S., B. Haimunna, Rohilah, M. Hisyam, E. Srimariana and I.N.M. Natih. 2022. Distributions of environmental parameters and Plankton's volume backscattering strength at Yos Sudarso Bay, Jayapura, Indonesia. **Egyptian Journal of Aquatic Research** 48(2022): 37–44. DOI: 10.1016/j.ejar.2021.08.001.

Simmonds, E.J. and D.N. Maclennan. 2005. **Fisheris Acoustic: Theory and Practice.** Blackwell Publishing, Oxford, UK. 429 pp. DOI: 10.1002/9780470995303.

Sriwijayanti, L.A., Djumanto, R.Y. Setiawan, M.R. Firdaus, N. Fitriya and H.Y. Sugeha. 2019. Community structure of phytoplankton in the surface and thermocline layers of Sangihe and Talaud waters, Indonesia. **Bonorowo Wetlands** 9(2): 57–64. DOI: 10.13057/bonorowo/w90201.

Sudarsono, Ratnawati, Budiwati and A. Latifa. 2024. Spatio-temporal comparison of planktonic environmental balance in artificial basin at Bantul District Yogyakarta. **Berita Biologi** 23(1): 1–25. DOI: 10.55981/beritabiologi.2024.390. (in Indonesian)

Supranto, J. 2010. **Analysis Multivariate: Meaning and Interpretation.** Rineka Cipta, Jakarta, Indonesia. 359 pp. (in Indonesian)

Van der Molen, J. and J. Pätsch. 2022. An overview of Atlantic forcing of the North Sea with focus on oceanography and biogeochemistry. **Journal of Sea Research** 189(102281): 1–7. DOI: 10.1016/j.seares.2022.102281.