The relation between volume backscattering strength (SV) and density of *Enhalus acoroides* at Wangi-Wangi Island, Wakatobi Regency

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Abstract: Seagrass is a fundamental vegetation that can optimize the function of coastal areas, to obtain information about the survival of seagrass. Thus an effective and efficient seagrass monitoring method is required. Seagrass density measurements can be performed using in-situ observation and hydroacoustic methods. The purpose of this study was to analyze the oceanographic parameters, SV values, and their correlation with the density and height of *E. acoroides*, as well as oceanographic parameters at Wangi-Wangi Island, Wakatobi Regency. Stationary data were acquired at five stations through acoustic clustering and in-situ diving. The density values at each station were 32 ind/m^2, 33 ind/m^2, 29 ind/m^2, 35 ind/m^2 and 37 ind/m^2. The range of SV values for *Enhalus acoroides* was (-50,19) – (-37,41) dB. The average SV values at each station were -40,76 dB, -40,63 dB, -41,10 dB, -40,48 dB, and -40,46 dB. Logarithmic regression analysis of density against SV values showed a strong relationship R = 0,96. PCA with a cumulative percentage of 92,7% from the biplot correlated most closely with the SV values of densities and seagrass heights. The project's implications and contributions include advancing seagrass monitoring techniques using acoustic methods for improved oceanographic parameter analysis.

1 Introduction

Seagrass, a flowering plant (Angiospermae), anchors itself with rhizomes, leaves, and roots [3], and reproduce through pollination and shoot growth [2]. Its roots and rhizomes stabilize coastlines against wave action, thriving in sandy, muddy, and sometimes rocky substrates, where root penetration varies [14]. Ecologically, seagrass serves as nursery, feeding, and spawning grounds [17], which are crucial for coastal functions and human well-being [10], an interact with abiotic (substrate, water) and biotic (flora, fauna) components (Supriyadi et al., 2018). From the intertidal to subtidal zones, seagrass thrives in submerged high-salinity waters [3].

Indonesia boasts 15 seagrass species, including seven : *Cymodocea rotundata*, *Halodule uninervis*, *Thalassodendron ciliatum*, *Syringodium isoetifolium*, *Thalassia hemprichii*,

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Enhalus acoroides, and *Halophila ovalis*. *Enhalus acoroides*, including *Enhalus acoroides*, are documented on Wangi-Wangi Island, Wakatobi Regency [6]. *Enhalus acoroides*, distributed uniformly in intertidal and shallow waters on sandy/muddy substrates, is the focus off SV analysis in this study, across various research stations.

Hydroacoustics is a method for monitoring and mapping the seabed, assessing the substrate, and underwater vegetation using echo signals [14]. This technology categorizes survey data and this; widely applied to in study fish and plankton distributions. Hydroacoustic devices can detect underwater objects by transmitting sound waves from a transducer through a water column. The reflected waves were converted to electrical signals, recorded, amplified, and displayed. The backscattering strength (SV), which indicate the intensity of the reflected signals, is crucial. Instruments such as the Simrad EK-15 echo sounder used here are efficient and offer high accuracy in delineating water body characteristics based on SV values.

Wangi-Wangi Island, part of the Wakatobi Archipelago in Southeast Sulawesi Province, has healthy seagrass potential due to minimal industrial activity and eco-friendly fishing practices. Most Wakatobi research focuses on coral reefs, but seagrass and coral reefs play crucial roles in coastal ecosystems. Despite extensive seagrass beds, little in-situ and hydroacoustic research has been conducted. Thus, further research analyzing seagrass in this area is of great interest.

This study aimed to analyze oceanographic parameters, the volume backscattering strength (SV) values of *Enhalus acoroides* seagrass, and the relationship between SV values and the density and height of *Enhalus acoroides* seagrass.

2 Materials and Methods

This study was conducted on May 3rd, 2023. The research location was Pulau Wangi, Wakatobi Regency, Southeast Sulawesi Province (Figure 1). This is a coastal area with seagrass vegetation at a depth of 2.9 meters. Five stationary stations were used for the research, including in-situ seagrass data acquisition and acoustic, oceanographic, and substrate data.

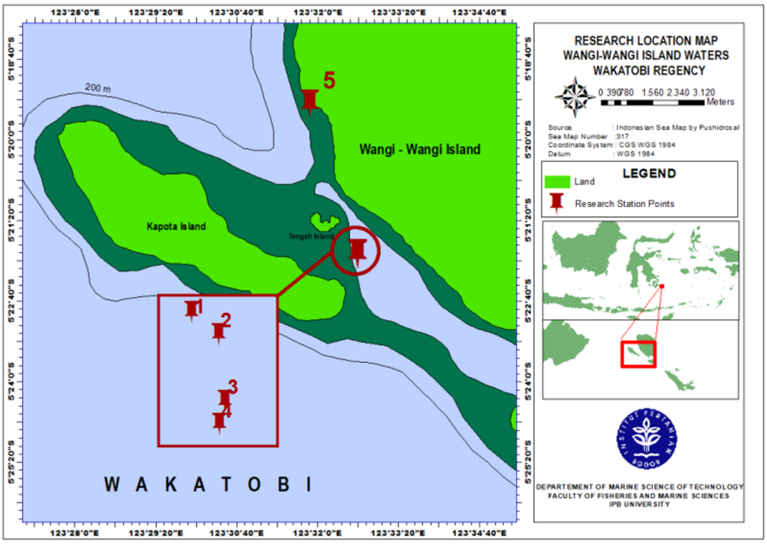


Fig. 1. Research Location Data Acquisition at Wangi – Wangi Island Waters

The equipment used for data acquisition wass aSimrad EK-15 instrument, Garmin Montana GPS, laptop, boat, refractometer, water quality checker, 1x1 m transect, PVC Pipe Frame, Underwater Camera, diving equipment, buoy and weights, fabric meter, underwater recording device, plastic clips, and labels. The software used for data processing included Echoview 4.0, Ms Office, and other necessary software packages.

2.1 Data Acquisition and Processing Procedure

The process begins with the acquisition and processing of oceanographic parameters data, in-situ *Enhalus acoroides* seagrass, and the processing of acoustic data.

2.1.1 Oceanographic Parameters Data

Oceanographic data were obtained from recordings using a refractometer and water quality checker. The oceanographic data includes temperature, salinity, and pH, which are used to help calculate and display the visualizations of the results we have obtained, and facilitate the analysis of oceanographic data in Wangi-Wangi Island, Wakatobi Regency.

2.1.2 In-Situ Enhalus Acoroides Seagrass

In situ data collection involves identifying seagrass types and measuring density, and height using 1x1 m random transects at each station. Density was determined by counting seagrass stands within the transect, whereas height was measured from the rhizome to the leaf tip. Substrate information was directly observed in each transect/station and documented using an underwater mobile phone camera. Visual observations were used to validate the acoustic data obtained later. Diving transects at observation stations precede acoustic data collection [11]. The variables included substrate type, seagrass density (ind/m²), and average height (m). Seagrass density is the number of individuals per unit area, calculated using Equation (1) as follows [9] :

$$D = \frac{N}{A} \quad (1)$$

Explanation :
D = species density (stands/1m²)
N = total number of species stands (individuals)
A = sampled area (m²)

The average height of theseagrass was calculated using at sampling method with a sample size of 10. The average seagrass height was calculated the following formula:

$$\underline{Ti} = \frac{\Sigma Ti}{n} \quad (2)$$

Explanation :
$\underline{Ti}$ = Average height of seagrass obtained from the number of samples (m)
ΣT = Total seagrass height obtained from number of samples (m)
n= Number of seagrass samples (individuals)

2.1.3 Acoustic of Seagrass

Acoustic data were obtained by directing the transducer at each seagrass and substrate target at frequency of 200 kHz. The transducer was placed on a frame composed of PVC pipes with a diameter of 0.75 inches. The transducer was positioned perpendicular to the target (90°), and recordings were made for 5 min The 5-minute seagrass data collection was deemed sufficient because it showed the presence of detected seagrass. This was supported by the condition of the waters during the sounding, which tended to be calm so that. The noise in the data is very small, so the seagrass can be detected well. resulting in the acoustic data in (. raw) format. These data were processed using the Echoview Demo software with a threshold of -70 to -35 dB to detect *Enhalus acoroides* seagrass based on previous research references, producing seagrass SV values. The volume backscattering strength (SV) value can be explained as the ratio of the intensities reflected by a group of single targets. SV can describe a group of targets in a water column. Data processing to obtain the SV value using Echoview 4.0 software can be performed using the following equation [11]:

$$SV = 10 \; log \; log \; Sv \quad (3)$$

$$Sv = 10^{\left(\frac{SV}{10}\right)} \quad (4)$$

$$\underline{Sv} = \frac{\Sigma Sv}{n} \quad (5)$$

$$\underline{SV} = 10 \log \underline{Sv} \quad (6)$$

Explanation :
SV = Volume Backscattering Strength
Sv = Volume Backscattering Strength linier
n = Number of data

2.2 Data Analysis Procedure

2.2.1 The Relation Between Volume Backscattering Strength (SV) and the Density Value of Enhalus acoroides Seagrass Using Logarithmic Regression Analysis

The relationship between SV and the density value of *Enhalus acoroides* seagrass, using logarithmic regression analysis, expresses the functional relationship of the predetermined variables in mathematical form. The logarithmic regression analysis useds two variables The first variable is the independent variable, which is the density value, while the dependent variable is the SV value of *the Enhalus acoroides* seagras*s*. The relationship between the two variables is visualized in the form of a graph. This graph produces a regression coefficient (R^2) that indicates the percentage of correlation between two variables. The strength of the correlation between these variables can be determined by examining the correlation coefficient (R) values in Table 1.

Table 1 Coefficient Correlation Value (R) [6]

R Value	Correlation
R ≥ 0,00 - < 0,20	Very low
R ≥ 0,20 - < 0,40	Low
R ≥ 0,40 - < 0,70	Moderate
R ≥ 0,70 - < 0,90	Strong
R ≥ 0,90 - ≤ 1,00	Very Strong

2.2.2 The Relation Between Volume Backscattering Strength (SV), Density, Height of Enhalus acoroides Seagrass, and Oceanographic Parameters using Principal Component Analysis (PCA)

The SV values, density, and height of *Enhalus acoroides* seagrass, along with oceanographic parameters, were analyzed using Principal Component Analysis (PCA). PCA is a statistical method that highlights variations in variables or parameters and; extracts the most significant information from at dataset (Rahimah et al., 2020). Due to differing measurement units, data normalization (0 to 1 range) is crucial for precise relationship interpretation and for reducing bias in forming principal components [8]. The principal components were derived using the cumulative variance proportion, eigenvalues from covariance/correlation matrices, and scree plots illustrating the variance/eigenvalues across components. The reduced data were visualized using a biplot graph showing the two principal component axes.

3 Results and Discussion

3.1 Oceanographic Parameters Data

Oceanographic data measurements were obtained during high-tide conditions (Table 2). Sea surface temperatures ranged from 31.30 to 33.50 °C, which is optimal for *Enhalus acoroides* seagrass growth (28.00 - 34.00 °C). The salinity was stable at 34.00 ppt across all stations, with *Enhalus acoroides* showing good tolerance. pH levels ranged from 6.80 to 6.84, within the normal range (6.81 - 8.06) supporting seagrass and organism growth. Weather conditions varied: clear skies at stations 1, 4, and 5 and; light rain at stations 2 and 3.

Table 2 Resullt of Acquisition oceanographic parameters

Parameters	Station				
	1	2	3	4	5
Temperature (˚C)	33,50	33,50	33,50	31,30	31,30
Salinity (ppt)	34,00	34,00	34,00	34,00	34,00
pH	6,84	6,84	6,84	6,80	6,80

3.2 In Situ Data of Seagrass

The seagrass community found diversity on Wangi-Wangi Island, including seven species: *Cymodocea rotundata, Halodule uninervis, Thalassodendron ciliatum, Syringodium isoetifolium, Thalassia hemprichii, Enhalus acoroides, and Halophila ovalis* [6]. This study focuses on *Enhalus acoroides* because of its dominance, high density, and uniform distribution across all transects (Table 3). Unlike the others, *Cymodocea rotundata* and I have a low density and short seagrass height (0-0.015m), resulting in overlapping SV values with seabed SV, precluding further analysis.

Table 3 Species of Seagrass Found at Each Observation Station

Spesies	**Station**				
	1	2	3	4	5
Enhalus acoroides	✓	✓	✓	✓	✓
Cymodocea rotundata	-	✓	✓	-	✓
Thallasia hemprichii	✓	-	✓	✓	-

Explained:

✓ = founding at the research location

- = Unfounded at research location

The study was conducted Wangi-Wangi Island, and with data are ummarized in (Table 4). The observation stations showed varying densities of dense seagrasses Visual observations indicate homogeneous seabed conditions. Substrate information was directly observed in each transect/station and documented using an underwater mobile phone camera. The Results from the substrate with fine sand, sandy mud, and sandy substrates, average a depth of 2.9 meters across the five stationary stations..

Table 4 Result of Acquisition data of *Enhalus acoroides* with diving

Station/Transect	**Density** (ind/m²)	**Average High (m)**	**Type of Substrat**
1	32	0,79	fine sand
2	33	0,91	sandy mud
3	29	1,19	sandy mud
4	35	0,81	sandy mud
5	37	1,23	sand

Enhalus acoroides seagrass is a large species with leaf lengths exceeding 1 meter [11] (Figure 2). This aligns with the diving data in Table 7, showing the seagrass dense green color of seagrass and its ability to adapt to various substrates such as mud, sand, and coral sand submerged in water. Therefore, they were found across all stations [6]. Seagrass density analysis revealed values ranging from 29 inds/m^2 to 37 inds/m² across transects 1-5. Station 5 had the highest density, whereas station 3 had the lowest density. Differences in density are attributed to natural factors, such as topography and substrate variations at each station, which influence seagrass adaptation patterns. Density is also influenced by seasonal changes, wave energy, substrate organic content, and other environmental factors (Short & Coles, 2001). Average seagrass height measurements ranged from 0.79 to 1.23 meters from rhizome to leaf tip in the study area..

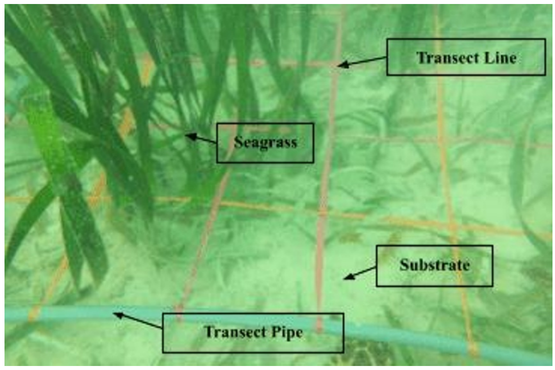


Fig. 2. *Enhalus acoroides* founding at research location

The type of seabed substrate is crucial for understanding the growth and distribution of seagrasses. According to [14], suitable substrate conditions are a primary factor influencing seagrass development and growth and are characterized by adequate sediment content. Thinner seabed substrates can destabilize seagrass, whereas thicker substrates support more vigorous growth.

3.3 Acoustic Instrument Calibration (Simrad EK-15)

An acoustic instrument calibration was conducted to measure the standard Target Strength (TS) using a 35 mm diameter tungsten sphere at a frequency of 200 kHz. The calibration TS results were verified against the theoretical TS measurements of the sphere. This calibration value determines the accuracy of the instrument, considering factors such as the sound propagation speed, transmitter and receiver transducers, and noise levels. The acoustic calibration results are show in Figure 3.

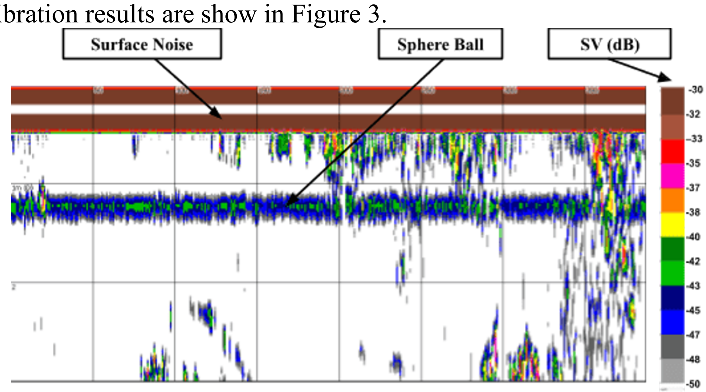


Fig. 3. Calibration Simrad Ek-15 with Sphare ball

Calibration of the acoustic instruments was performed using a 35 mm tungsten sphere at 200 kHz. The measured standard TS value was -43.94 dB, while the theoretical TS for the Simrad EK-15 is -45.96 dB (Elson et al. 2022). This results in a 2.013 dB correction factor for the volume backscattering strength (SV) of *Enhalus acoroides* seagrass. Calibration with the Echoview software showed an absorption coefficient of 8.8789 x 10^-3 dB/m and a sound speed of 1544.38 m/s

3.4 Seagrass Acoustic Data

Hydroacoustic technology enables the retrieval of information from the water column to the seabed, including organism migration, seabed structure, plankton, and underwater vegetation, such as seagrass (Ma'mun et al., 2013). The Simrad EK-15 displays the survey results in the *. raw format, which weare then processed using the Echoview 4.0 Demo software to generate echogram displays.

3.4.1 Echogram

An echogram, derived from echosounder recordings; visually depicts the time, echo strength, and echo return times [4]. The x-axis shows the ping count, while the y-axis represents the water depth (m), measured 1 m below the transducer from the water surface. Each ping's interpretation of the echogram displays the volume backscattering strength (SV) in decibels (dB). Figure 4 illustrates the echogram of the eagrass, where color variations indicate different dB ranges corresponding to the detected objects. Depths detected on the echogram extend to 1.8m, with false echoes attributed to noise from surface reflections caused by waves

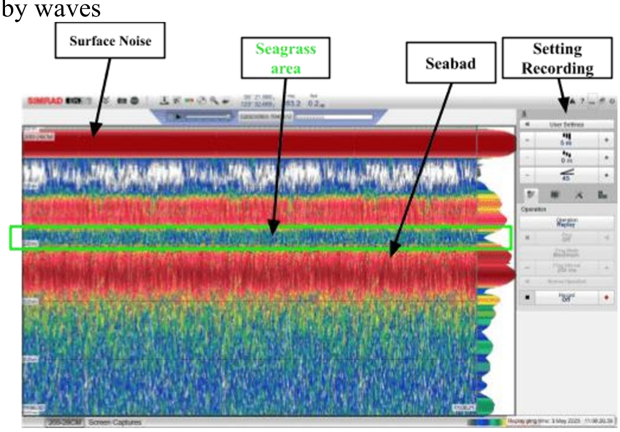


Fig. 4. Echogram result acqusition acoustic data

3.4.2 SV Value of Enhalus acoroides

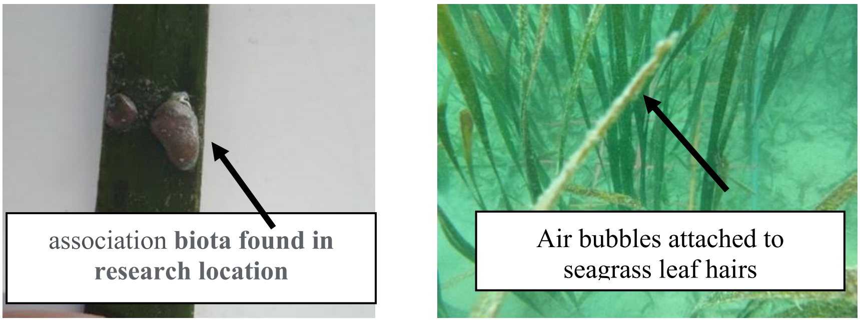
The processed acoustic survey data for seagrass spanned 5 min. The SV values represent the backscattering strength obtained from the echoes reflected by objects; sourced from the transducer. The SV values for *Enhalus acoroides* seagrass at each station are compared in Table 5.

Table 5 Comparison of Statistical Parameters of Volume Backscattering Strength (SV) for *Enhalus acoroides* Across All Stations

Parameters	Station				
	1	**2**	**3**	**4**	**5**
ESDU	41	45	35	46	32
SV Minimum (dB)	-50,19	-43,94	-47,57	-44,75	-44,40
SV Maximum (dB)	-37,71	-38,63	-37,60	-38	-37,41
$\underline{SV}$ (dB)	-40,76	-40,63	-41,10	-40,48	-40,46
Standard Deviation	0,94	0,79	0,99	1,56	1,34

Observations of the volume backscattering strength (SV) for *Enhalus acoroides* seagrass compared across the five stations revealed distinct variations. The lowest minimum SV value, -50.19 dB, occurred at Station 1, indicative of softer seagrass morphology owing to flexible and soft leaves adapted to fine sand substrate conditions at this station. This aligns with Ole's [13] findings that the substrate type significantly affects seagrass root penetration. Conversely, the highest maximum SV value, -37.41 dB, was observed at Station 5, which was attributed to both the morphology and harder sand substrate, challenging seagrass root penetration and supporting diverse attached biota on seagrass leaves (Figure 5a).

Stations 2, 3, and 4 share a similar muddy sand substrate yet exhibit varied SV values: Station 2 ranges from -47.57 to -38.63 dB ($S\overline{V}$ = -40.63 dB), Station 3 from -47.57 to -37.60 dB ($S\overline{V}$ = -41.10 dB), and Station 4 from -44.75 to -38 dB ($S\overline{V}$ = -40.48 dB). These differences may stem from seagrass morphology, particularly leaf color and texture, with Stations 2 and 3 showing younger, smoother leaves, resulting in lower SV compared to Station 4. Overall, a comparison of SV values across all stations in Table 4 reveals notable standard deviation differences: station 1 ± 0.94, station 2 ± 0.79, station 3 ± 0.99, station 4 ± 1.56, and station 5 ± 1.34. Station 2 demonstrateds relatively accurate data acquisition with a low standard deviation, indicating good measurement precision [13].



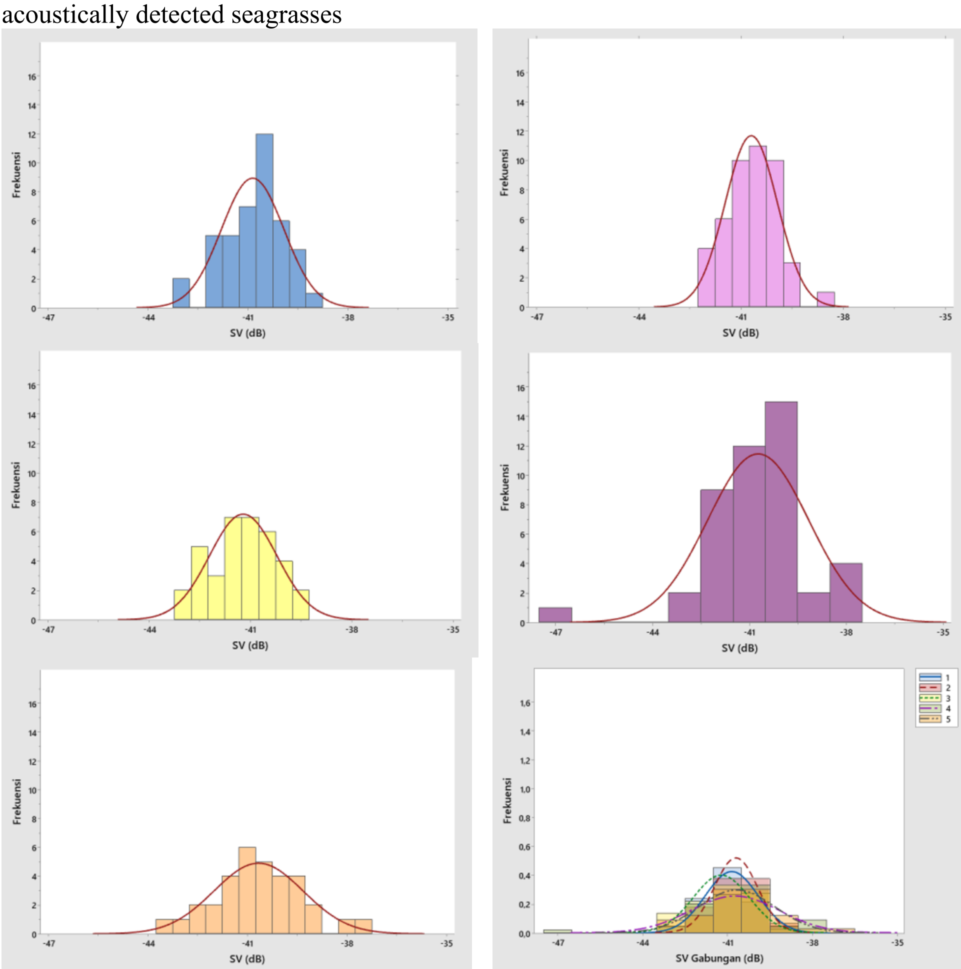
(a) (b)

Fig. 5. Associated biota (a) and air bubbles (b) attached to the hair/nodes of seagrass leaves

Additionally, current flow plays a crucial role, with nutrient-rich currents likely to enhance seagrass fertility. Stations 1 to 4, located in closed current areas, may experience suboptimal nutrient intake compared to Station 5, benefiting from open currents and nutrient accumulation from nearby docks. Thus, Station 5 exhibiteds higher SV values, reflecting superior seagrass growth fertility. Air bubbles, which are ideal reflectors, notably impact hydroacoustic recordings near the surface, potentially introducing noise, including bubbles adhering to fine *Enhalus acoroides* seagrass hairs (Figure 5b), further amplifying SV values [15].

3.4.3 Frequency Distribution of Enhalus acoroides

The frequency of occurrence of *Enhalus acoroides* seagrass data (Figures 6, 7, 8 9, 10 and 11) revealed significant variations across the study stations. Station 1 (Figure 6) exhibits a rising frequency distribution, peaking at 12 occurrences at -40 dB, with data ranging from -43.10 to -38.84 dB and showing slight variability. Station 2 (Figure 7) displays a sharply peaked frequency distribution, with the highest frequency at 11 occurrences at -40 dB, spanning -42.25 to -38.70 dB with minimal variability. Station 3 (Figure 8) shows a moderate distribution with a peak frequency of seven occurrences at -41 dB, ranging from -43.08 to -39.48 dB with even occurrence trends. Station 4 (Figure 9) presents a rising frequency distribution, peaking at 15 occurrences at -40 dB, spanning -42.82 to -37.55 dB with scattered and varied occurrences. Station 5 (Figure 10) has a broader distribution shape compared to other stations, with the highest frequency of 6 occurrences at -40 dB, ranging from -43.41 to -37.32 dB, showing a flat, even, and highly variable occurrence trend. Figure 11 combines these frequency distributions, indicating diverse occurrences despite sharing the same SV scale range, reflecting the variability in the presence of acoustically detected seagrasses



3.5 The Relation Between SV Values, Density of Enhalus acoroides, and Other Parameters

Based on the obtained data, further analysis was conducted to examine the relationship between SV values and seagrass density, as well as between SV values and other parameters.

3.5.1 The Relation Between SV and Density Values of Enhalus acoroides Using Logarithmic Regression Analysis

It looks like you are summarizing the results of a logarithmic regression analysis in your study, focusing on the relationship between seagrass density and the average backscattering strength (SV) of *Enhalus acoroides* seagrass. The table (Table 6) illustrates that lower seagrass density corresponds to lower average SV values, as depicted in Figure 12. The analysis reveals a positive correlation (symbolized by σ) between SV values and seagrass density. The logarithmic regression equation derived is $\overline{(SV)} = 2.7445\ln(\sigma) - 50.289$, with a regression coefficient (R2) of 0.9407, indicating that 94% of SV variability is explained by seagrass density, while 6% is influenced by other factors. The correlation coefficient (R) of 0.96 falls within the range of $R \geq 0.90 - \leq 1.00$, signifying a very strong/high relationship between seagrass density and $\overline{(SV)}$ values. This strong relationship suggests that higher seagrass density results in higher acoustic echo amplitudes. In-situ data acquisition by scuba divers ensures a 94% accuracy in acoustic detection. The backscattering of seagrass depends on leaf canopy and echo sounder frequency, consistent with findings by [7], highlighting the frequency influence on received echo levels in decibels.

Table 6 Result of volume backscattering strength (SV) value and density of seagrass

Transect/Stasion	$\underline{SV}$ (dB)	Density (Ind/m²)
1	-40,76	32
2	-40,63	33
3	-41,10	29
4	-40,48	35
5	-40,46	37

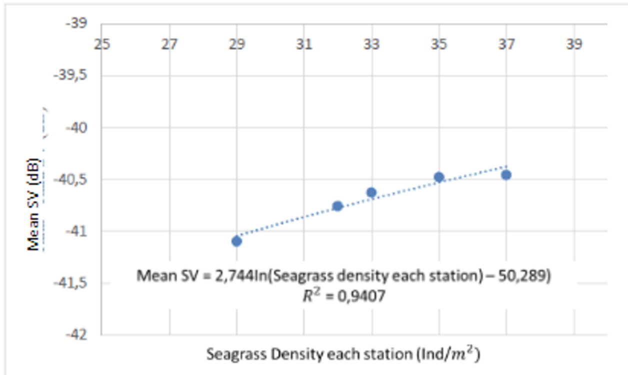


Fig. 12. Logarithmic regression of seagrass SV at all stations with density

3.5.2 The Relation Between Volume Backscattering Strength (SV), Density, Height of Enhalus acoroides Seagrass, and Oceanographic Parameters using Principal Component Analysis (PCA)

PCA analysis included SV, density, and height of *Enhalus acoroides* seagrass, along with oceanographic parameters (temperature, salinity, and pH). Two main components, F1 and F2 (eigenvalues > 1), collectively explained 92.7% of the variance, meeting the PCA criterion for reducing components while retaining data variability (Supranto, 2010). The biplot (Figure 13) shows the SV, density, height, and oceanographic parameters on the F1 and F2 axes. Factor 1 (69% variance) was positively correlated with temperature, salinity, and pH; Factor 2 (23.7% variance) was positively correlated with SV and density, and negatively correlated with seagrass height. Positive and negative correlations we are shown by line proximity, illustrating variable associations (Ma'mun et al., 2019)

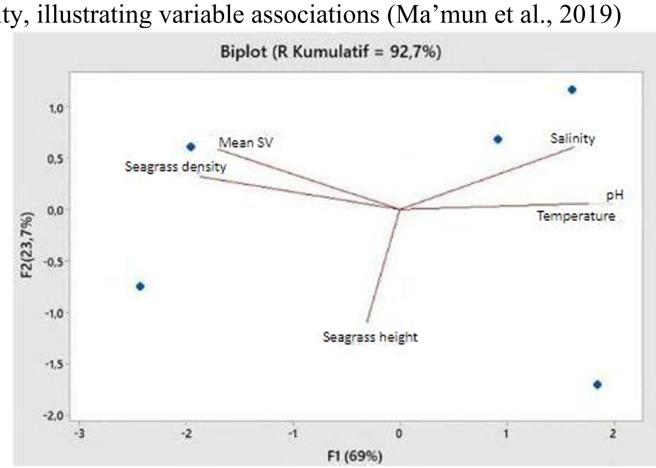


Fig. 13. Biplot of PCA analysis results of seagrass SV values at each station with seagrass density and height values, as well as oceanographic parameters on axis (F1) and axis 2 (F2).

The PCA analysis across five stations (S1-S5) on Wangi-Wangi Island (Figure 14) revealeds correlations among variables, as shown in Figure . The figure illustrates the grouping of stations into zones characterized by different variable relationships. Stations S4 and S5 correlated with SV, density, and seagrass height. Stations S1, S2, and S3 correlated with salinity, temperature, and pH. Clear correlations were observed, particularly between SV and density values, evident in the station zoning. For instance, S4 and S5 show similar

SV (-40.48 dB and -40.46 dB, respectively) and density (35 ind/m² and 37 ind/m²), indicating proximity between these and SV values, resulting in a more dispersed zone in the figure. This analysis highlights positive and negative correlations among SV, density, seagrass height, and oceanographic parameters, demonstrating the varied environmental influences on *Enhalus acoroides* seagrass growth on sand, mud, and coral sand substrates [6]. Similarly, S1 and S2 exhibit close values, S1 at SV -40.76 dB and density of 32 ind/m², and S2 at SV -40.63 dB and density of 33 ind/m². In contrast, S3 exhibited a lower density.

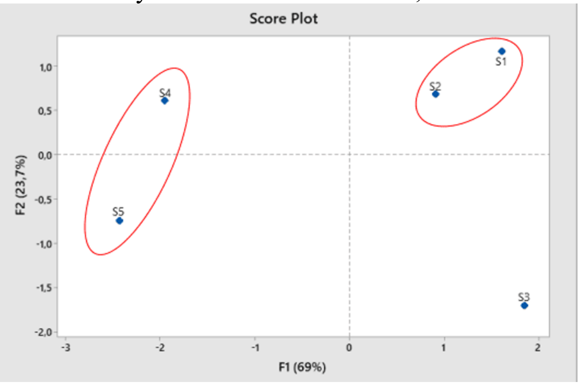


Fig. 14. Score Result of PCA Analys on five stasiun in Wangi – Wangi Island, Wakatobi Regency

4. Conclusion

The conclusion of this study indicates that the oceanographic parameters in Pulau Wangi – Wangi and Wakatobi Regency are suitable for the growth of *Enhalus acoroides* seagrass. The temperature ranges from approximately 31.30 to 33.50 °C, salinity is around 34.00 ppt, and pH levels range from 6.80 to 6.84. The SV values of seagrass detected at all research stations range from -50.19 dB to -37.41 dB, with seagrass density ranging from 29 ind/m2 to 37 ind/m2, and an average seagrass height of 0.79 to 1.23 m. Logarithmic regression analysis demonstrateds a strong positive correlation (R2 = 0.96) between SV and seagrass density. Principal Component Analysis (PCA) confirmeds the dominance of seagrass density and height over SV, with Axis 1 (F1) and axis 2 (F2) explaining 92.7% of the variability. The correlation matrix indicates the positive and negative contributions to the variability.

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