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Remote Sensing of Seagrass and Seabed using Acoustic Technology in Bintan Seawater, Indonesia

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ABSTRACT

Seagrass were flowering plants that grow entirely under the sea. Seagrass were a significant element in coastal habitats such as Bintan waters because it acts as a protective beach. Seagrasses have the capacity to stabilize the bottom waters of sediments and were able to generate sediments that can fertilize the waters. Seagrass can be a reference in coastal area to improve the stability of the coastal environment. Seagrass beds are useful for a protected area for tiny organisms, a spawning location for aquatic biota, and a location for juvenile and larval enlargement. Distribution of seagrass abundance are essential to understand because they can define coastal regions whether they are harmed or not. Seagrass surveillance techniques were still using divers with restricted coverage of the study region. For this reason, an acoustic method was used through this research to detect seagrass and the habitats that it occupied. It can be concluded that the acoustic method can measure sound intensity or acoustic backscatter from seagrass and their habitat. The height of the seagrass can be evaluated depending on the acoustic reflection value of the seagrass. There were 3 seagrass groups based on percent closure in the research place, which were tiny to none of the seagrass groups, unusual seagrass groups, and many seagrass groups. Seagrass was mostly found in good sedimentary habitats. The increase in the quantity of manually calculated seagrass biomass was accompanied by a rise in the value of acoustic backscattering intensity. The overall accuracy of the seagrass species using the acoustic technique is 87%.

Keywords: Backscatter, biomass, hydroacoustics, seagrass

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INTRODUCTION

Seagrass is an important component in coastal habitat because it acts as a protector of beach. Seagrasses have the ability to stabilize basic water sediments and are able to produce sediments that are able to fertilize the waters. Seagrass can be a reference in strategic management of coastal areas to improve the stability of the coastal environment. Seagrass beds are a protected area for small organisms, a place for spawning aquatic biota, and a place for juvenile and larval enlargement. Distribution maps and abundance of seagrasses are important to know because they can indicate if coastal areas are damaged or not (Anderson et al., 2008).

Seagrass is an important component of nearshore ecosystems that supports many estuarine species, including a number of commercial fisheries (Ardizzone et al., 2006). The distribution of seagrasses is controlled by light availability, and also by several physical, geological and geochemical factors in the environment near the coast (Belzunce et al., 2005). Many habitat requirements for seagrass beds can be disrupted by human activities, and loss of seagrass habitats is often associated with anthropogenic causes (Bozzano et al., 1998). Damage to seagrass beds throughout the world has caused many government agencies and environmental groups to develop monitoring programs for this important coastal resource (Brouwer, 2008; Buia et al., 1992).

One innovation that is generally utilized as a device in evaluation and mapping of seagrasses is acoustic technology. The application of acoustic technology begins with its ability to detect fish, zooplankton, benthos and depth of water. With the development of information technology and material science, acoustic instruments can be used to detect oil and gas (Sidiq et al., 2019). Underwater acoustic methods for seabed mapping have been extensively developed over the past few decades. In particular, the development of bathymetry has enabled the creation of detailed maps of seabed topography and acoustic backscatter data; this data has been used to predict the type of sediment and habitat (Carbo & Molero, 1997). Several studies have compared backscatter responses to watershed types (examples of sampling, video images from the seabed) to assess the ability of different acoustic technologies to classify sea floor types (Di Maida et al., 2011; Duarte, 1987; Komatsu, 2007). Backscatter intensity is carried out through sound measurement to detect sediment and energy from sediments back to the transmitter with acoustic reflection and scattering. This has been shown to be related to the nature of sediments (Komatsu, 2007; Komatsu et al., 2003). The backscatter intensity of the muddy seabed has been shown to be inversely proportional to sediment porosity, percent sludge content and clay content percent.

Seagrass beds in Bintan for commercial species of penaeid shrimp and fish are significant nursery habitat. Seagrass is a major food for dugongs, dugongs (Miller) and green turtles, *Chelonia mydas* (Linnaeus) (Lefebvre et al., 2009) and acts as an absorber of nutrients and sediments. Seagrasses play a significant role in preserving sediment stability and water clarity in coastal regions, linked to marine ecology, environmental, and also climate factors in the study area. Seagrass meadow is a significant economically and environmentally sound source. Management uses information on seagrass structure, abundance and distribution for seagrass protection areas.

It is therefore important to know accurate information about seagrass habitats (distribution, abundance and species composition), to determine the sampling design applied in surveys of seagrass habitats. Surveys that rely on diving-based operations are usually difficult to do in murky waters and over large areas. Dive based surveys also increase the safety risk of divers where there are attacks from dangerous marine animals. So that it needs a reliable remote sensing technique to observe seagrasses that will help reduce this risk and increase the intensity and resolution of the data collected.

Current remote sensing techniques (satellite imagery and aerial photography) are useful for mapping seagrass beds of dense habitat in clear waters in temperate climates, but in the tropics, they are inadequate to detect seagrasses with low biomass or turbid water. Recent advances in acoustic techniques for surveying benthic habitats indicate new possibilities for application in surveys of seagrass beds in the tropics. In this research an initial evaluation of acoustic techniques for surveying Bintan's tropical seagrass habitat and comparing this technique with diving-based survey methods will be used.

The acoustic or sonar method is an important tool in fisheries studies, mapping the types of seabed, underwater vegetation, sediments and sub-lower sediment types. Acoustic instruments are also used under water to look for sinking ships, airplanes and falling pipelines. The advantage of using acoustic waves is being able to propagate through visual media or other media to extract information in the marine environment. Acoustic signals are less absorbing than optic to turbidity or depth. Data collected at higher spatial resolutions and large areas can be surveyed quickly compared to diving-based surveys.

Management based on Marine Ecosystems

The acoustic scattering of seagrasses is poorly understood compared to rocks and sediments. Several studies have analyzed the acoustic response of different seagrass species to understand the mechanism of underlying physical scattering. Laboratory experiments have shown the speed of sound in resonators filled with plants to depend on plant biomass and tissue characteristics, which vary for different seagrass species (Maceina & Shireman, 1980; McCarthy & Sabol, 2000). The acoustic response of seagrass is also influenced by photosynthetic activity, which produces free gas bubbles in plant sand in the water column (Minami et al., 2010; Miner, 1993; Orlowski, 2009).

Aim

The aims of this research were:

1. to determine the feasibility of mapping tropical seagrass beds using an acoustic method.
2. to assess the efficacy of seagrass biomass acoustic methods.
3. to find out how acoustic survey techniques are effective in describing the kinds of seabed sediments.
4. to assess the efficiency of the mapping of tropical seagrass habitats using acoustic methods.

The expected results from the study were identification and classification of seagrass genera based on acoustic backscattering values. Another result is looking at the correlation of the seabed type based on the reflection coefficient value with seagrass habitat.

MATERIALS AND METHODS

In April-June 2018, surveys were performed at sea (Figure 1). Acoustic methods were surveyed in each region, followed by diving. The Garmin GPS was used for recording the position of each acoustic data point and for seagrasses and sediments sampling place. Positioning is a key element for the identification and mapping of seagrass. Acoustic data were used to analyze biomass and sediment information.

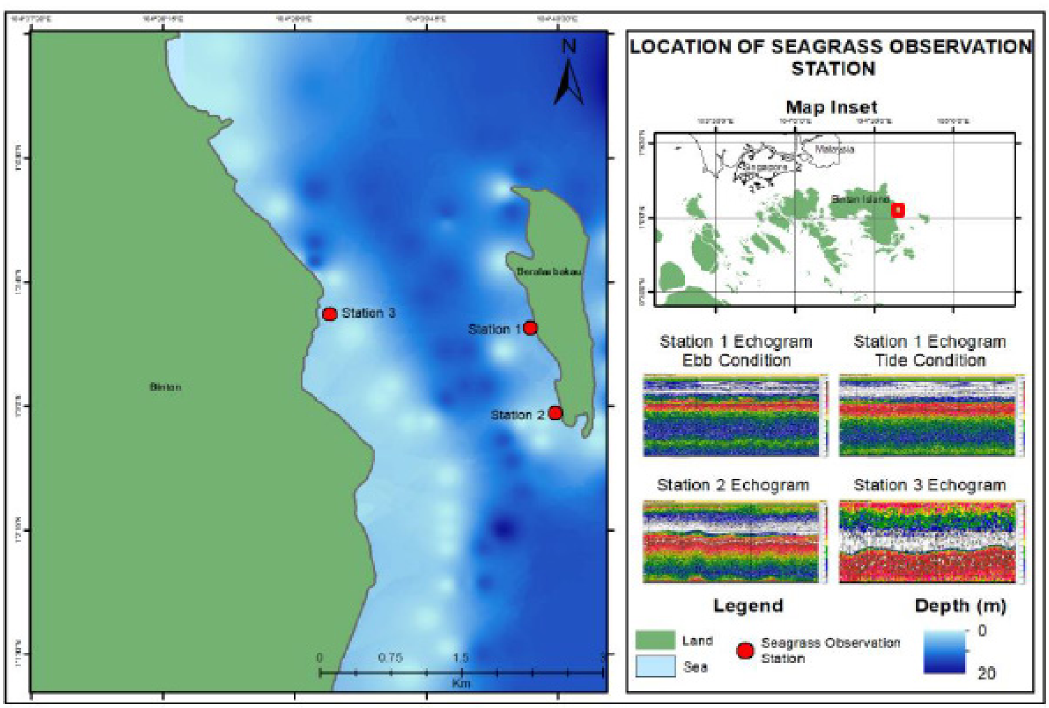

Figure 1. Research Location for Detection and Quantification of Seagrasses

This study gave an assessment of the acoustic methods used in the Bintan Island waters to map tropical seagrass habitats. Underwater acoustic method and visual estimation were used to detect seagrasses using diver. Underwater acoustic technology used in this research was Simrad EK15 single-beam echosounders. The acoustic transducer transmits one single vertical beam towards the seagrass and seafloor for determining the water depth. Acoustic data stored as a raw files integrated with GPS data with NMEA format. A part of the incident wave is backscattered in all directions and another part penetrates to the seabed. This backscattered energy is received by the transducer echosounder and used for depth and echo strength measurements. For this study the transducer was installed in a fixed position below the ship (Figure 2).

Dive-based surveys were conducted to check the parameters of seagrass beds on a good or wide spatial scale. Although this method is labor intensive, it provides qualitative and quantitative data. Qualitative information can be in the presence / absence, percent cover and / or composition of species. Quantitative data can include measurements of density or biomass, composition of species, growth characteristics of seagrass beds and depth distribution in certain locations. This survey method requires extensive field resources (labor and time) and involves increasing the risk of safety of divers where dangerous marine animals occur. Coupled with intensive dive seagrass data, acoustic remote sensing data can be used to map the distribution of seagrass communities with high densities over large areas.

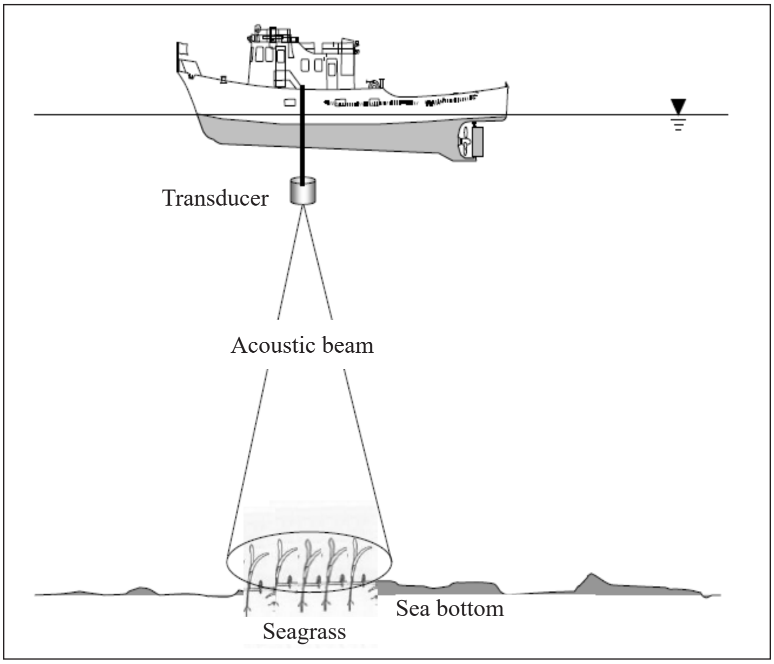

Figure 2. Equipment used in acoustic survey of seagrass

Calculation of Seagrass Biomass

Acoustic signal and images were produced by Matlab software. Quantification of acoustic signals were used to survey the biomass of seagrasses in each of the three locations. Acoustic echo received by the transducer is influenced by the density of seagrass.

Measurement of seagrass biomass, composition of seagrass species and sediment characteristics were calculated at each site surveyed. Divers recorded estimates of the amount of biomass of seagrasses. Seagrass species were identified according to previous research (Pasqualini et al., 2000). For seagrass data collection, seawater depth (bathymetry) and acoustic backscatter were the common data used. The positioning of seagrass is a vital component for vegetation mapping.

Measurement of Sediment Properties

The type of sediment is measured along the transect using a backscatter technique. Acoustic data and sediment sampling were collected simultaneously. Sediment samples were obtained from the survey area using a standard van veen grab. The grain size analysis was measured by sieving each sample through a series of standard nets. Percentage composition of dry weight was determined for each grain size category: gravel (> 2000 μm), coarse sand (> 500 μm), sand (> 250 μm), fine sand (> 63 pmm) and mud (<63 μm). The average size of the sediment grain for each sediment sample was calculated from the sediment composition data and each grain size class.

Calibration of Underwater Acoustic Instrumentation

The calibration of the acoustic instrument was conducted to measure the standard Target Strength value using a ball sphere with a frequency of 200 kHz. The target strength calibration results would be verified by theoretical acoustic sphere ball measurements. Calibration value would determine the level of accuracy of the instruments used such as the factor transmitting and receiving transducer, the speed of sound propagating in the water column and the noise factor. The configuration system for underwater acoustic instruments used was given in Figure 3.

Acoustic Data Collection and Processing in Bintan Waters

Research tools used include underwater acoustic instruments, sphere balls for calibration, underwater cameras, diving equipment, sediment samplers, global positioning systems (GPS), computer devices (Figure 4) and research vessels. Sea wave conditions when collecting data as shown were calm.

The installation and setup of the acoustic sensor (transducer) was placed on the left side of the ship and is lowered 1 meter below sea level (Figure 5) with a water depth of about 20 m.

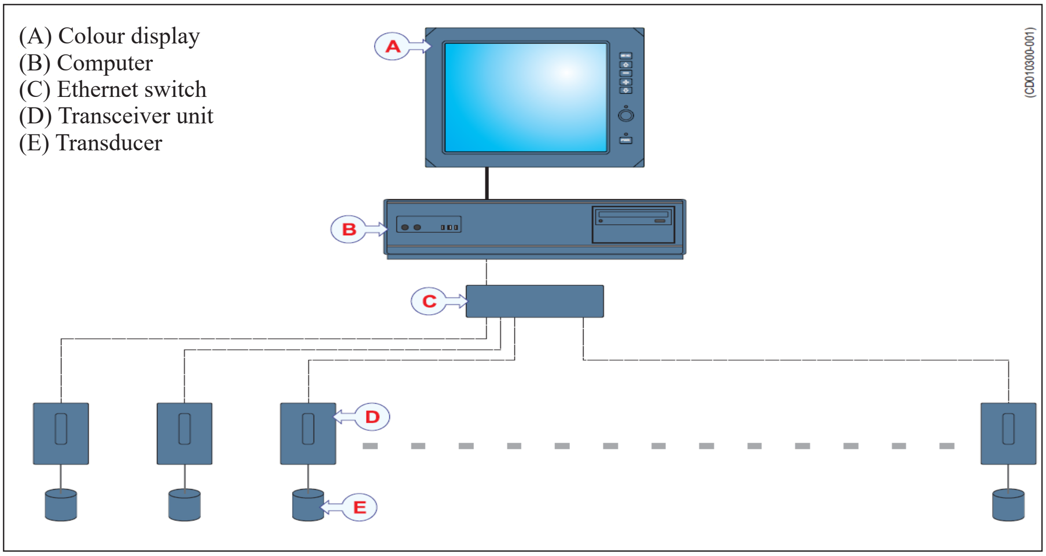

Figure 3. Configuration system of underwater acoustics instrument (Simrad manual)

Figure 4. Research vessel used during acoustic survey

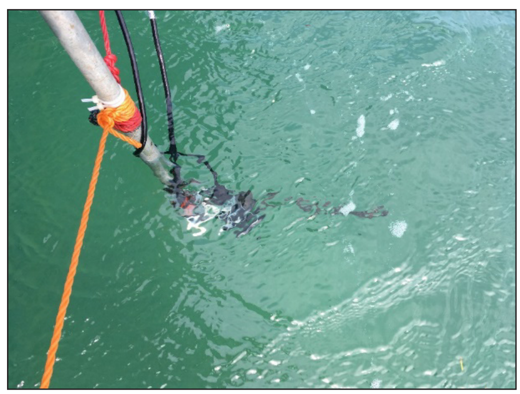

Figure 5. Installation and set-up of underwater transducer

RESULTS

Seagrass Acoustic Instrument

The detection results of the seagrass acoustic instrument are shown in Figures 6, 7, 8 and 9. The value of the acoustic backscattering volume (SV) of seagrass at station 1 at low tide was -47.45 to -39.45 dB and the bottom SV was -25.26 to -12.74 dB (Figure 6). The average height of seagrass acoustically was 57 cm. At station 1 when the tide was obtained, the seagrass SV value was -47.45 to -39.45 dB while the watershed SV was -25.26 to -12.74 dB with an acoustic average seagrass height of 57 cm (Figure 7). At station 2 the seagrass SV values were -52.45 to -42.83 dB and the watershed SV values were -30.50 to -16.59 dB with an acoustic average seagrass height of 40.3 cm (Figure 8). At station 3 the seagrass

SV value was -49.27 to -35.73 dB and the SV of the water base was -31.62 to -23.47 dB with the average height of seagrass acoustically was 27.7 cm (Figure 9).

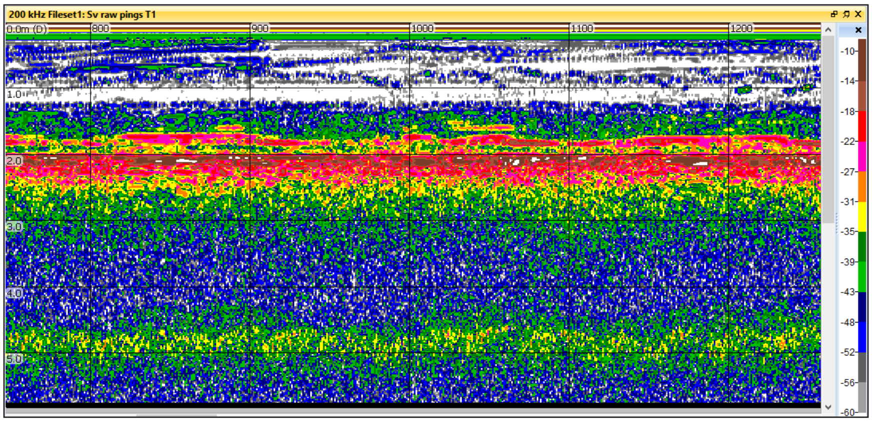

Figure 6. Seagrass detection during low tide using acoustics

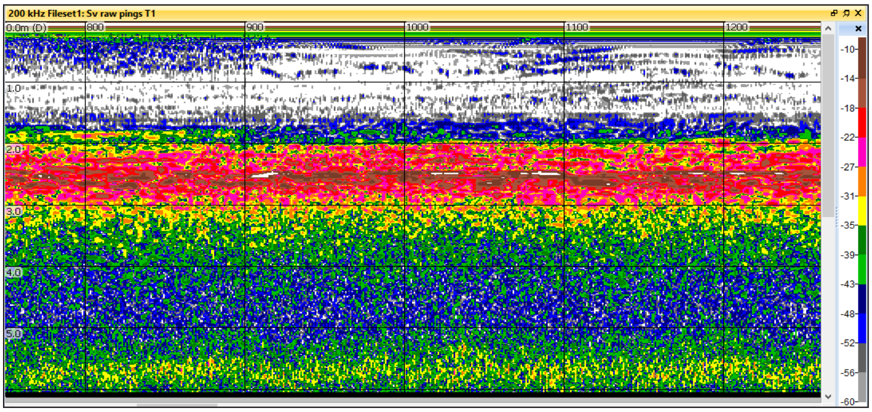

Figure 7. Detection of seagrass during high tide

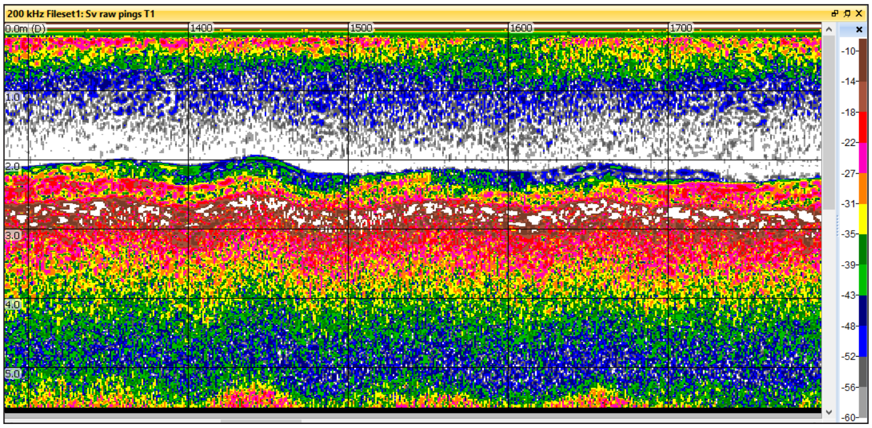

Figure 8. Seagrass detection in calm sea condition at station 2

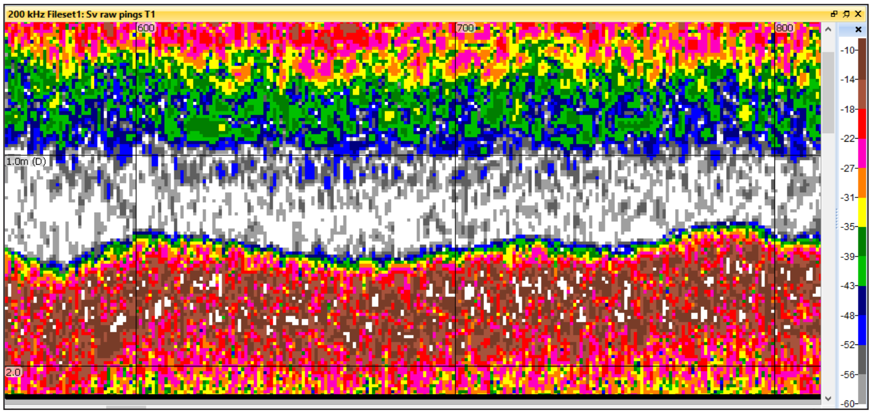

Figure 9. Seagrass detection in calm sea condition at station 3

Acquisition of Sediment samples in Bintan seawaters is shown in Figure 10.

Figure 10. Sediments at Bintan seawaters

Seagrass Data Collection

Ground truth survey is vital for object identification and classification. Measurement of seagrass biomass using the transect method is shown in Figure 11. Seagrass classification was used for extracting information from acoustic images (echogram). Seagrass belongs to four families known as Posidoniaceae, Zosteraceae, Cymodoceaceae, and Hydrocharitaceae.

Classification of stations based on the presence of seagrass can be divided into 3 categories including locations with dense seagrass numbers, scattered seagrasses, and little seagrasses until there are no seagrasses (Figure 12).

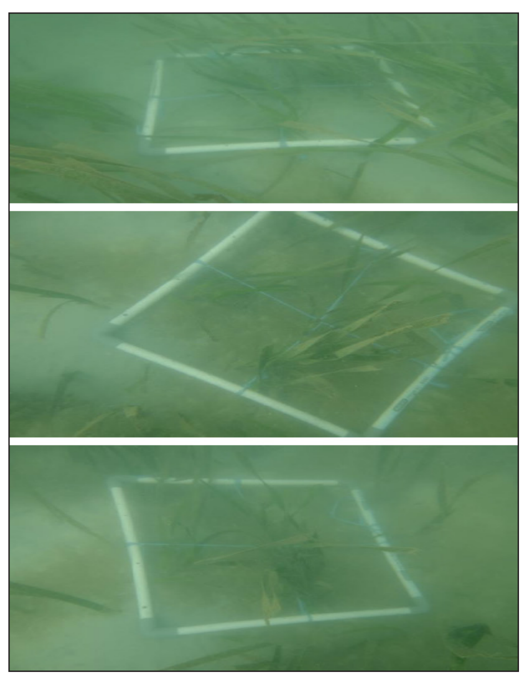

Figure 11. Measurement of seagrass biomass using the transect method.

(a) (b) (c)

Figure 12. Examples of underwater images of video camera belonging to three categories of relative abundance of seagrass: (a) dense seagrass; (b) sparse seagrass; and (c) little to no seagrass.

Table 1 represents 3 categories of relative abundance of seagrasses based on underwater and underwater acoustic videos. Table 2 is a sea floor map matrix error based on the criteria of 95% confidence level and depth range. Table 3 is a comparison of data obtained from biological samples and acoustic data.

Table 1
Three categories of relative abundance of seagrass

Underwater Photo			Acoustic Data (Beam Depth)		
Categories	95 % Confidence Level		Depth Range (m)		Mean Bottom Depth (m)
	Mean	S.D	Mean	S.D	
Dense seagrass	1.62	0.31	3.15	0.41	3.2
Sparse seagrass	0.57	0.16	2.28	0.18	2.9
Little to no seagrass	0.14	0.12	0.15	0.14	3.11

Table 2 shows error matrix of seagrass map of 95% CL and depth range. Overall accuracy of depth range (0.83) was slightly higher than of 95% CL (0.80).

Table 2
Error matrix for seagrass map

		Reference Data			User Accuracy
		Dense	Sparse	No	
(A) 95 % Confidence Level					
Classified	Dense	8	1	0	0.89
	Sparse	5	1	0	0.6
	Little to No	4	0	15	0.8
Producer accuracy		0.65	0.7	0.9	Overall accuracy 0.87
(B) Depth Range					
Classified	Dense	6	1	1	0.89
	Sparse	2	1	0	0.6
	Little to No	4	0	16	0.8
Producer accuracy		0.75	0.6	0.93	Overall accuracy 0.85

Table 3
Comparison of data derived from biological samples and acoustic

	Station 1	Station 2	Station 3
Sampling area (m^2)	0.25	0.25	0.25
Biomass (kg/0.25 m^2)	2.25	1.18	2.4
Mean SV (dB)	-28.9	-35.8	-33.3
Mean TS (dB)	-52.1	-54.2	-53.1
Mean Height, biological sample (m)	0.3	0.4-0.5	0.3-0.5

From Table 3, the relationship between data from biological sampling and the results of detection of acoustic instruments was obtained. These results indicate that the SV value was related to seagrass biomass. The higher the value of seagrass biomass was followed by an increase in the value of acoustic volume backscattering strength (SV). The average height of seagrass conducted manually by divers showed that acoustic measurements were not much different from manual measurements.

Comparison of the classification of underwater videos and acoustic classifications for seagrass densities was given by criterion 1 a bit until there were no seagrasses, rare seagrasses, and abundant seagrasses (Figure 13).

Results of acoustic detection to determine the percentage of seagrass closure are provided to all stations shown in Figure 14. These findings show distinct percentage closures for all stations. Figure 15 shows the quantification of the outcomes of recording seagrass identification to calculate seagrass acoustic backscattering strength using scientific or quantitative fish finder. The findings of sediment assessment based on grain size of the Bintan waters are shown in Figure 16.

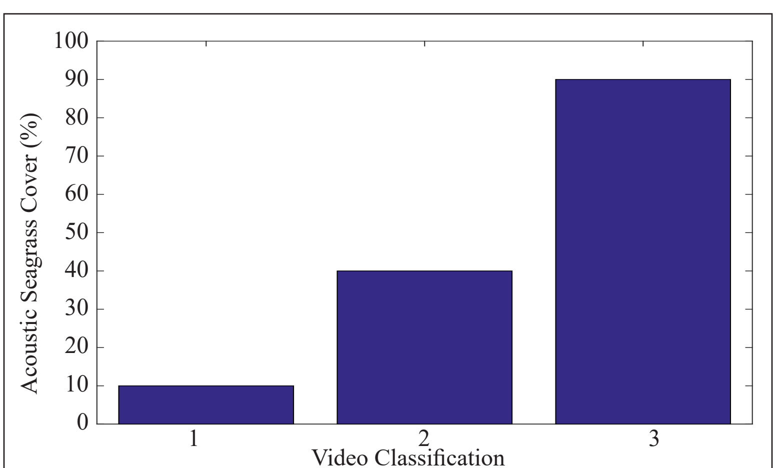

Figure 13. Comparison of acoustic and video classification for different densities of seagrass (1, little to no seagrass; 2 sparse; 3 dense)

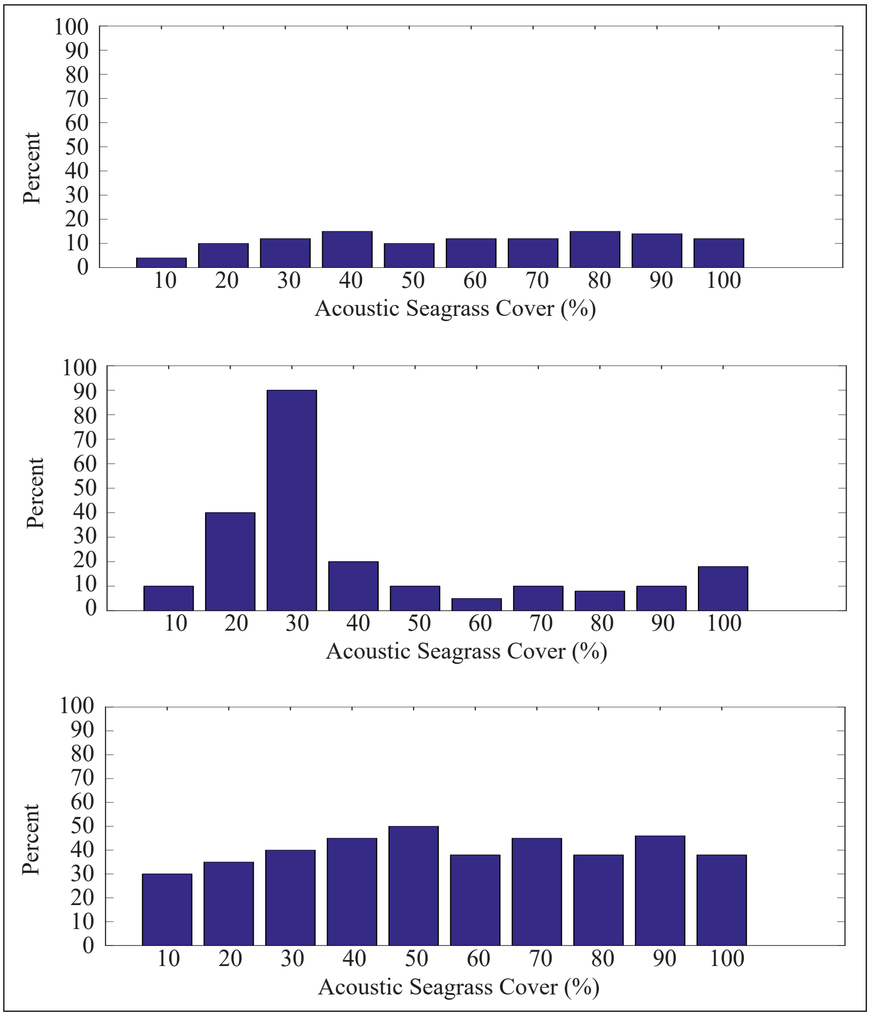

Figure 14. Seagrass percent cover using acoustic method

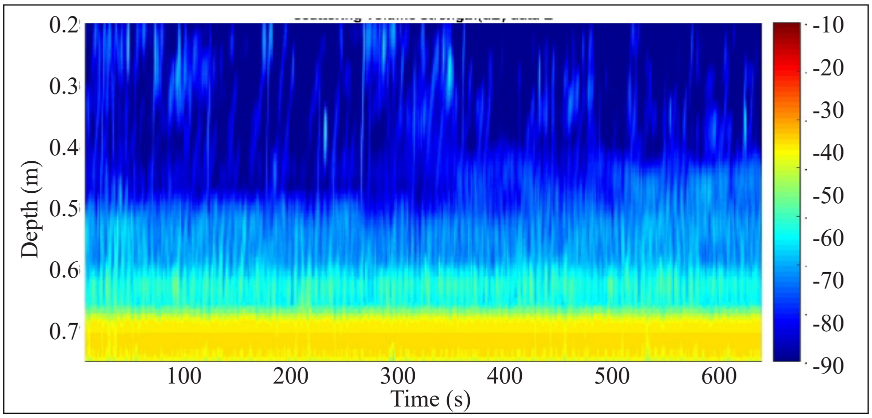

Figure 15. Acoustic backscattering (SV) of seagrass

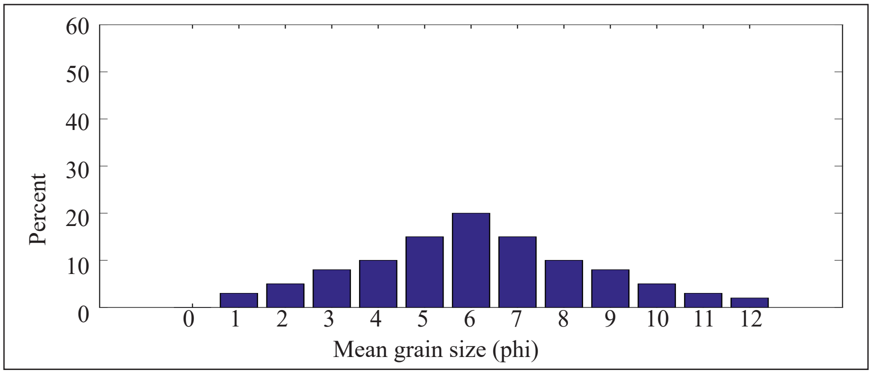

Figure 16. Sediment grain size distribution

Table 4 shows the location and size of the grain size of sediments in Bintan waters and Figure 17 shows the relationship of seagrass biomass with fine-sized sediments.

Table 4
Location and grain size parameters for samples collected at Bintan seawaters

Station	Gravel	Sand	Silt	Clay	Mean (phi)	Mean (mm)	Variance	Skewness	Kurtosis
1	0	95.8	2.8	1.4	2.7	0.15	1.37	3.25	18.75
2	0	92.5	5.2	1.3	2.65	0.16	1.28	3.35	16.6
3	0	96.5	2.3	1.2	2.33	0.2	1.07	3.53	23.5
4	0	99	1	0	2.04	0.24	0.58	0.24	3.93
5	0	100	0	0	0.86	0.55	1.95	-0.15	2.99
6	17.5	82.5	0	0	0.88	0.54	1.95	-1.25	3.34
7	13.3	86.7	0	0	1.12	0.46	1.64	-1.57	4.77
8	40	60	0	0	-0.34	1.27	2.35	-0.23	1.45
9	62.4	37.6	0	0	-1.35	2.58	2.18	0.44	1.53
10	62.3	37.3	0.7	0	-0.91	1.88	2.05	0.11	1.54

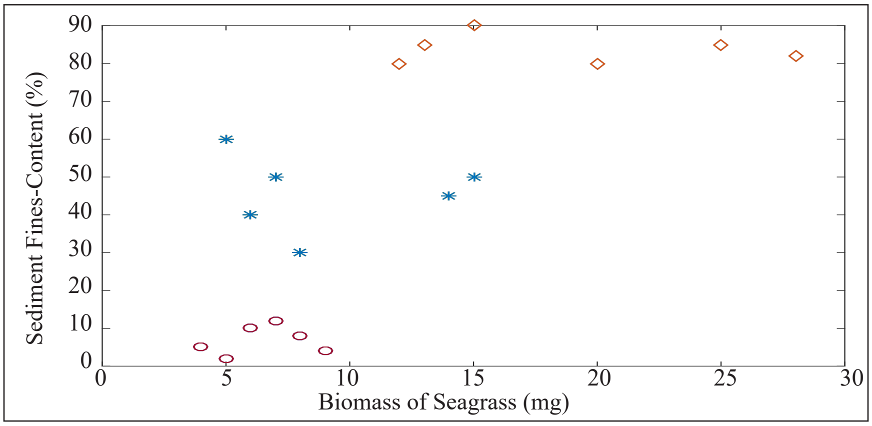

Figure 17. The relationship between sediment-fines content and seagrass biomass

Figure 18 was the acoustic backscattering from the seabed where clay had a small backscatter compared to sand or rough rock. This was caused by the acoustic impedance of coarse sand is higher than very fine sand. The other reason is the grain size of very find sand was lower than coarse sand. Reverberation level from mud (silt and clay) had smaller value compared to other sediments (Figure 19).

Figure 20 is the intensity value of the acoustic reflection of the water column and seagrass bottom. Basic seagrass waters range from -35.0 dB to -20.0 dB.

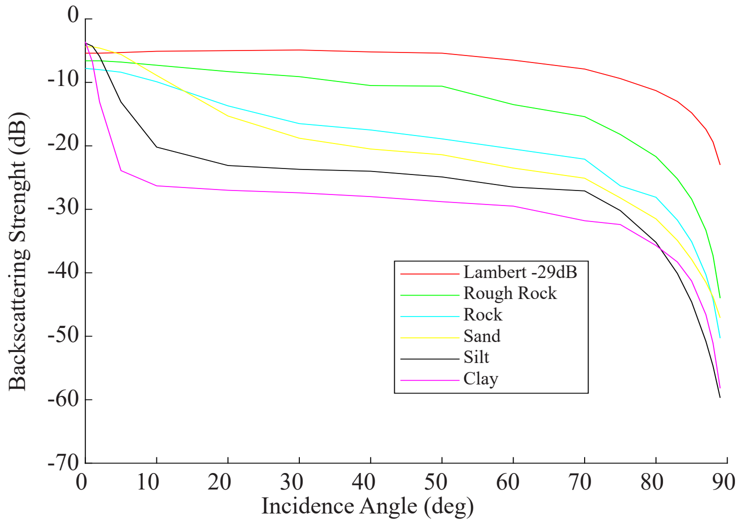

Figure 18. Acoustic backscattering strength of sea bottom

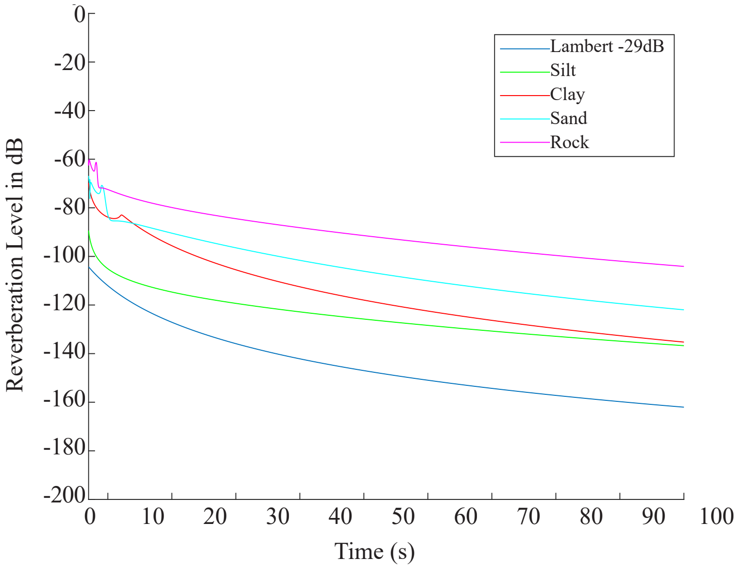

Figure 19. Reverberation level of sea bottom

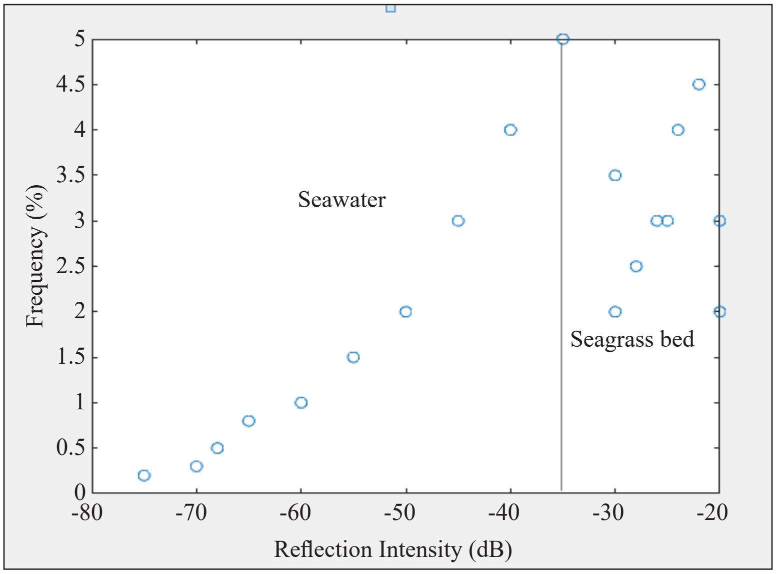

Figure 20. Acoustic reflection intensity of Seagrass bed

DISCUSSION

The coastal area of Bintan waters has high potential natural resource. Seagrass meadow is one of a chain of coastal ecosystems that greatly determines the sustainability of the marine ecosystem. Some functions of seagrass beds include protecting mangrove ecosystems and land from the influence of ocean waves. Another thing is that seagrass beds have a function of protecting coral reefs on the seabed and can inhibit pollution from the land so as to maintain the quality of sea water.

Seagrass beds on the east coast of Bintan Island have an area of more than 2500 ha with high species diversity, where 10 species of seagrass are found in 12 species in Indonesian waters. Seagrass beds in Bintan waters need to be protected because of the presence of rare animals such as dugong and turtles which can be a special income in the tourism sector.

From the results of the study, we found 6 types of seagrass such as *Cymodocea rotundata* (CR), *C. serrulata* (CS), *Enhalus acoroides* (EA), *Thalassia hemprichii* (TH), *Thalassodendron ciliatum* (TC), and *Syringodium isoetifolium* (SI).

This study shows that acoustic remote sensing was able to detect seagrass height and to measure backscatter of seagrass. The value of acoustic backscatter indicated the species of seagrass. This area of study also corresponds with dense seagrass, sparse seagrass, and little to no seagrass. These characteristics were classified with depth range and 95 % Confidence Level (CL). We found depth range measurement was influenced by the length of seagrass. Therefore, for seagrass mapping the method of depth range and 95 % CL were practical need.

This study also shows acoustic backscatter (SV) correlated with seagrass biomass. The higher of SV indicated the higher concentration of seagrass biomass. Each individual species of seagrass had a specific value of Target Strength (TS). By this TS value the discrimination of seagrass species was possible. It was supported using underwater image produced by acoustic instrument.

This work found a novel approach to distinguish bottom sediment characterized by grain size using acoustic remote sensing. The sediment type in this area consisted of clay, silt, sand, and gravel. Our method had shown the ability of acoustic frequency used of 200 kHz to distinguish seagrass species and sediment type in shallow water. Biomass of seagrass was distributed in sediment fine. The backscattering of seabed was influenced by sea bottom type, frequency of acoustic instrument, orientation of transducer, and reverberation level.

We found seagrass percent covered by acoustic method was nearly equal with conventional method. The proportion of substrate by seagrass was used for accurate assessment of biomass density. Therefore, this acoustic method was indispensable method for rapid assessment of seagrass distribution.

High plant density results in higher echo amplitude and other seafloor factors. Using scuba divers, the acoustic detection accuracy was computed as 87 %. Backscatter of seagrass depends on the leaf canopy, echosounder frequency and sea bottom substrate. The frequency of transducer affects the received echo level in decibel. These results are in agreement with the other researchers (De Falco et al., 2000; Parnum, 2007; Parnum et al., 2004; Kenny et al., 2003).

Acoustic technology is capable of detecting seagrass and basic aquatic habitats that inhabit it. It was proven that hydroacoustic method could survey large areas within short time (Short et al., 2010). The acoustic signal from vegetations and sediment differentiate underwater meadows (Bostrom et al., 2006). Seawater turbidity and light are the major environmental factors that control seagrass distribution (Phinn et al., 2008). In this area, we found a very large plant with long leaves and poor resistance to perturbation (Green et al., 2003). The seagrass beds play key role in ecological ecosystem and fish habitat (Moyer et al., 2005). The important role of seagrass in the marine environment and as bioindicator, to assess the distribution, biomass, and species (Descamp et al., 2005). The ability of acoustic method was obtained by measuring the value of acoustic backscattering from detected objects. This was caused by the difference value of acoustic impedance between seawater and seagrass (Wilson and Dunton, 2009). Single beam acoustic system has been used for discriminating bottom type (Manik et al., 2006; Serpetti et al., 2011, Manik, 2012). Seagrass produces a strong backscatter just above the seabed (Sabol et al., 2002). In this study, seagrass have a complex structure including small patches that change from higher density areas to lower density ones over short distances (Tseng, 2009).

Overall, we found the acoustic remote sensing was potentially a valuable technology for detection, quantification, and characterization of seagrass.

CONCLUSION

From the results of the study it can be concluded that the acoustic method can measure sound intensity or acoustic backscatter from seagrass and its surrounding habitat. Seagrass height can be measured based on the acoustic reflection value of seagrass. In the study location there were 3 seagrass groups based on percent closure, which were small to none of seagrass groups, rare seagrass groups, and many seagrass groups. Seagrass is mostly in fine sedimentary habitats. The increase in the amount of seagrass biomass calculated manually is followed by an increase in the value of acoustic backscattering strength. Identification of seagrass species using the acoustic method has an overall accuracy of 87%.

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