CHARACTERIZATION OF SONAR DATA FOR DETECTION AND MAPPING OF SUBMERGED SEAGRASS AT MERAMBONG SHOAL, JOHOR

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ABSTRACT: Sonar imaging has been widely used in detecting objects in the deep ocean. Advancement in sonar technology has seen the increased in the spatial resolution of the sensor, hence provide an added advantage for better detectability of objects apart of being an active sensor able to sense the target-of-interest even in less clear coastal water type. In this paper, an approach of sonar image analysis for detecting substrates, particularly seagrass is presented. The sonar image is captured with side-looking, guided with GPS-based navigation, traversing a set scan lines over the study area in Merambong shoals in Straits of Johor, Malaysia. Methods investigated in the sonar image analyses comprised of: sonar image pre-processing where restoration of image due to speckling and geometrical distortions was performed. The main object-based detection for the substrate classes were based on textural analysis, followed by preliminary result of submerged seagrass mapping based on the detailed image interpretation. In such an approach, the sonar backscatter vectors of specific targets (seagrass against the background mud, sand, coral and weeds) could be determined at absolute values within a specific range. Using known sea-truth samples, the sonar-driven map of substrates could be driven. Despite tedious-processing, the results have good agreement with the sea-truths data when assessed (overall accuracy > 85%, kappa statistic> 0.70), thereby concluded as best economical active sensor for substrate detection and mapping.

1. INTRODUCTION

Seascape-level shallow substrates data are extremely valuable for the use of research and management of aquatic systems. Seagrass is an intelligent natural agent to stabilize coastal ecology and economically important to local fishermen (UNEP-WCMC, 2005). The characterization of underwater habitat features at the landscape scale is, however, notably difficult and costly, especially submerged seagrass detection in non-favorable and turbid systems.

Due to the important functions of seagrass, numerous studies have been conducted to map seagrass spatial distribution from satellite, taxonomy, coverage and its biomass. Remote sensing satellite data with different spatial scale and sensor specifications have been used to map seagrass in global coastal water with various accuracy, depends on the technique, complexity of seagrass habitat and satellite image characteristics. However, the challenge is remains for turbid coastal water where the submerged seagrass is hardly exposed and identifiable through optical satellite imagery. Thus, side-scan-sonar (SSS) is an optional close-range remote sensing application that is effectively used to map sea bottom features including seagrass with various density in hazardous aquatic system.

Data quality of satellite image has been degraded by turbidity and depth of the coastal environment as light had been greatly attenuated through atmospheric layers and its propagation through the water column. By using SSS, these limitations can be resolved and enhance the map accuracy solely yielded from satellite image. SSS transmits acoustic signals and receives its reflection before translated to produce two and three dimensional image of sea floor landscape (Teruhisa et al., 2003). This study is to examine the feasibility of SSS data to characterize acoustic information to map the distribution submerged seagrass in turbid and complex coastal environment and its comparability to optical satellite imagery. Texture is the frequency of change and spatial arrangement of pixel values in an image, as a function of spatial scale. A flat image in which all digital numbers (DNs) are equal is said to have a uniform texture. In this case, seagrass occurrence will indicate variation of backscattered signal received by SSS.

2. METHODOLOGY

The study area encompassed Merambong area along the Strait of Johor near the city of Gelang Patah, Johor, where the river flows into Lake Seminole. Merambong shoal is the largest single seagrass bed in Malaysia water data. But, this area now is being actively developed where the prospect of massive development is residential unit. The seagrass bed is characterized by a stable water surface and exposed only during low tide. In many years, detectability of seagrass patches and leaves submerged in this area which has high turbidity had been asked since personnel diving skills or any traditional observation method is still been questioned and limitation, time as well as cumulative cost to map the whole area.

Merambong area is reported to have more than 10 seagrass species with different physical appearance. The substrate comprises of unconsolidated soft sediments, including muddy to shelly sands with occasional hard bottom areas. Besides that, coastal development, including large port area, power plant project, vast development on the opposite site of Singapore and human-made island called ‘Banker Island’ are very close to Merambong shoal. Due to this factor, the receiving signal to SSS is varies and ambiguity of seagrass intermingled with other shallow substrate can be solved through thorough and highly skilled SSS data interpretation and texture analysis. ENVI 4.8 image processing system was used to interpret the data. To visualize the sea bottom features with SSS data accordingly, underwater camera was towed together rightly behind the SSS, yet the video clarity was distracted by turbidity level of water in Merambong area. To add, SSS data from the study area were analyzed using guidance from StarFish 990X software, interpretation skills of the features submerge on seafloor and indication of different range of decibels of different features recorded.

In comparing SSS with seagrass map yielded from medium scale of satellite image, Bottom Reflectance Index (BRI) by Sagawa et al. (2010) is used in turbid tropical coastal water straits to detect and map a spatial distribution of seagrass. Landsat-8 OLI acquired in 2013 was used in order to extract the distribution information of the seagrass coverage. With 30 meter of spatial resolution, 11 spectral bands and 16-bits quantization level (USGS, 2013), it has a capability in estimating the submerged seagrass along the coastal region in tropical areas with acceptable accuracy. For field verification, handheld GPS and diving skills were required to document more than 30 accurate seagrass positions and other sea bottom features. Submerged seagrass in Merambong area located within depth area ranged from 2m to10m within about 1 hour and 15 minutes when traveling at about 1.5 ms^{-1} (3 knots or less than 5 knots).

3. RESULTS AND DISCUSSION

Many sonar images contain regions characterized by variation in brightness rather than any unique value of brightness. Texture refers to the spatial variation of image tone as a function of scale. To be defined as a distinct textural area, the grey levels within the area must be more homogeneous as a unit than areas having a different texture. Texture analysis produce seagrass habitat map that is slightly different from seagrass map produced through satellite data (from high altitude or hundreds kilometers above the Earth surface).

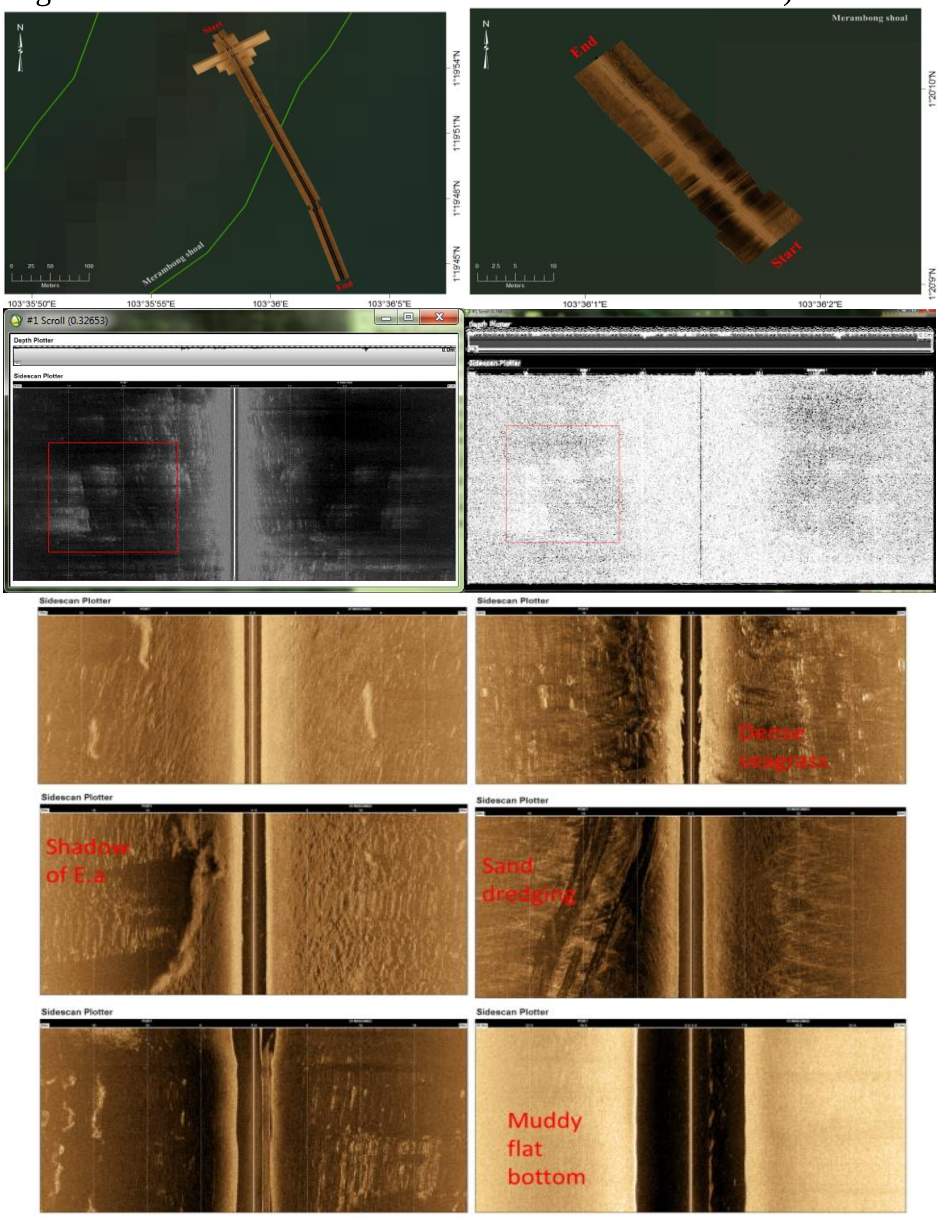

Figure 1. Backscattering figures and texture analysis of SSS data at Merambong area. The brighter line shows the presence of seagrass species while uniform color tone indicates sandy or muddy seafloor.

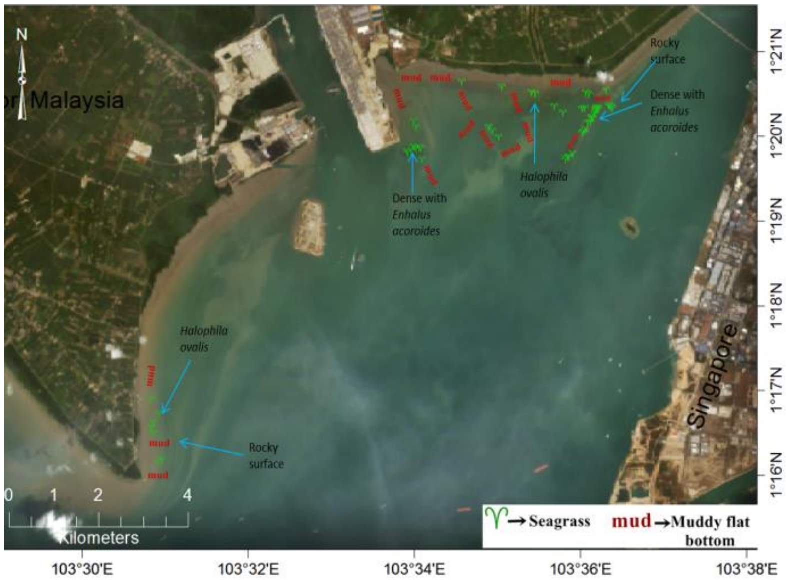

Figure 2. Location of substrate features after SONAR data characterization at Merambong shoal and vicinity

SONAR was towed along the Merambong shoal and recorded data shows variation of decibels range as indication of seagrass coverage or heterogeneity of seagrass species. Seagrass patches vary in size nearby this shoal. Decibels range of seagrass is high, >40 to 77dB, while mud is 20-40dB.

Table 1. Backscaters properties of different benthic features.

Substrate Features	Decibels range	Comment
Mud	20-<40 dB	Smooth flat surace, moderate brightness, dark flat surface shows muddy mingled with sand/loam.
Seagrass	>40-77 dB	*Enhalus acoroides (E.a)* obviously seen, very bright lines, short white line or cluster is non-E.a seagrass,e.g: *H.o, H.s, T.h*
Seaweed	<35-50 dB	Mingle with seagrass, grey-shaped features, low backscatter of echo.
Rocky surface	7-<20 dB	Dark circle/polygons on SSS, rough surface.
Anomalies	Varies, uncertain	Man-made features or activity, e.g: sand dredging or dugong feeding line on seagrass bed

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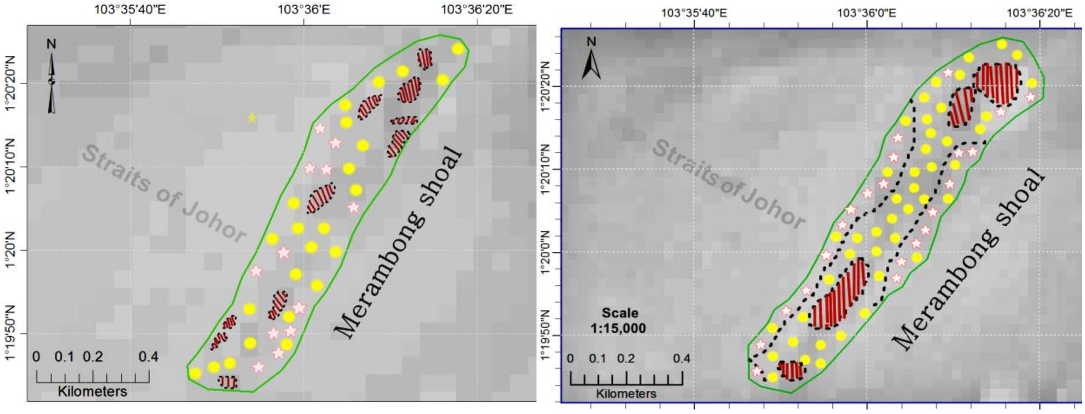

Figure 4. BRI-based seagrass coverage at Merambong shoal with input from sonar data.

In order to conduct side-scan sonar data collection, tidy fieldwork plan was discussed first to avoid challenges from water current, turbidity, depth and diurnal tidal height that can causes ambiguity of seagrass backscatter, in dB unit with backscattering signal from other benthic features. However, SSS data most influenced by depth and seagrass various density. An important, potential limitation of SSS was examined in this study involves the relationship between SSS range, transverse resolution and seagrass backscattering. Target separation or transverse resolution, is the ability to distinguish two objects (seagrass and mud) that parallel to the boat path as separate objects. At a fixed frequency (e.g. 455 kHz), increasing sonar ranges leads to decreasing transverse resolution due to horizontal beam spreading, an effect that is magnified in the far-field or near-edge portions of the sonar image (Toda et al., 2007).

To estimate the error of submerged seagrass detection from SSS data, 50 scattered locations of seagrass along the Strait of Johor were compared with corresponding locations of detected-pixels with seagrass on Landsat-8 OLI using BRI method since BRI is effective to detect submerged seagrass in less clear water (Misbari and Hashim, 2016; Hashim et al., 2014). The relationship between dB of sonar data and pixel with BRI value is indirectly proportional where brighter dB shows darker tone on BRI processed-image, which indicates low BRI value. Therefore, the bottom depth measured by the side-scan system had a precision of 43 out of 50 locations (overall accuracy: >85%; kappa statistic> 0.70) of submerged seagrass, demonstrated that sonar could really help in satellite-based detecting submerged seagrass in complex environment of coastal area which surrounded by low water clarity.

The resulting decline in image resolution can hinder the ability to discriminate and accurately classify features in far-field portions of an image. As a river widens, however, the sonar range must be increased to image the entire river channel when conducting a single-pass survey. Thus, the selection of range setting is a practical issue when planning a sonar survey, with trade-offs between efficiency on single or multiple pass and image resolution. A goal of this study was to define a relationship between the sonar range and the proportion of poorly resolved areas in the sonar images that could be referenced when planning future sonar missions in streams of varying widths.

4. CONCLUSIONS

The detection of submerged seagrass in turbid coastal water can be efficiently done with SSS input which requires good interpretation skills to read the data correctly. The seagrass extend show the declining trend directly has positive correlation with active human activities and rapid coastal development along the coastline. With ample of field data set, the technique is validated. To put it in a nutshell, SSS data is effective to be integrated with BRI-based detection method on satellite data (2-dimension). SSS is a very useful three-dimensional (3-D) apparatus to visualize shallow substrates distribution and monitor the devastating impact of human-induced disturbance along coastal area as well as degraded sea water quality that causes decrement of seagrass biomass at significant loss rate.

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