SEABED SEDIMENT CLASSIFICATION OF SIDE SCAN SONAR DATA USING HISTOGRAM APPROACH

NUR AINA BINTI MOHD AZLAN JAMAL

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DEDICATION

To the people who always enlightened me with academic knowledge and gave me constant guidance and incalculable advice whenever I needed it the most.

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ABSTRACT

Side scan sonar (SSS) delivered an advantage for sediment classification studies. In particular, the availability of backscatter intensity offers an alternative method to study seafloor hardness and softness. Numerous seabed mapping processes used many kinds of classification techniques can produce sediment maps from backscatter images, ranging from simple clustering to machine learning approaches. This study aims to perform a pixel grouping method for backscatter images from SSS using the histogram generated from the backscatter intensities. The aim will be achieved through three (3) objectives; to classify the seabed characteristic using histogram classification, to produce a sediment map through a histogram classification created and, lastly to test the model's validity using ground-truthing data ground-truthing data such as sediment distribution and coral video transect. Acoustic data from the SSS data acquired in Labuan Marine Park was used in this study. The 900 kHz side scan data was processed and corrected using SonarWiz 7 software. The data were then categorised the pixel intensities based on the histogram shape. A few data classify techniques were tested to produce classification maps using equal intervals, quantile methods, natural breaks, and, geometrical intervals. Classification maps derived from these methods were then validated with ground truth samples collected using underwater videos and sediment grabs to assess their accuracies via qualitative assessment. The result shows that geometrical interval was the only method that relatively complemented the ground truth data and works reasonably well. Therefore, this can be a good tool in designing management programs for the marine park to know the general view of the sediment distribution in that area. It creates a simple and straightforward but statistically robust objective of general overview based on geophysical data provided.

ABSTRAK

Sonar imbas sisi memberikan kelebihan di dalam kajian klasifikasi sedimen. Khususnya, ketersediaan keamatan taburan balik menawarkan kaedah alternatif untuk mengkaji cir-ciri yang terdapat di dasar laut. Terdapat perlbagai proses pemetaan dasar laut dalam penghasilan peta taburan sedimen dengan menggunakan pelbagai jenis teknik pengelasan berdasarakan imej mozek hamburan balik Daripada pengelasan atau pengelompokan mudah kepada pendekatan pengelasan peta berasaskan pembelajaran mesin. Kajian ini bertujuan untuk melaksanakan kaedah penyusunan data yang mudah bagi imej mozek hamburan balik daripada SSS menggunakan histogram yang dihasilkan daripada keamatan data hamburan balik. Matlamat tersebut akan dicapai melalui tiga (3) objektif; untuk mengelaskan ciri dasar laut menggunakan klasifikasi histogram daripada perisian ArcGIS, untuk menghasilkan peta sedimen melalui klasifikasi histogram yang dibuat dan akhir sekali untuk menguji kesahihaan model menggunakan data pembenaran tanah data pembenaran tanah seperti taburan sedimen data transek foto bawah air. Data akustik yang diperolehi dari dasar Taman Laut Labuan telah daripada sonar imbas sisi telah digunakan, di dalam kajian ini. Data imbasan sisi 900 kHz diproses dan diperbetulkan menggunakan perisian SonarWiz 7. Data kemudiannya dikelaskan dalam histogram untuk mengkategorikan keamatan piksel berdasarkan bentuk histogram dipilih. Beberapa teknik pengelasan data telah diuji untuk menghasilkan peta pengelasan menggunakan selang yang sama, kaedah kuantil, selang semula jadi dan selang geometri. Peta klasifikasi yang diperoleh daripada kaedah ini kemudiannya disahkan ketepatannya melalui penilaian kualitatif. Dengan menggunakan sampel kebenaran tanah yang dikumpul dari video bawah air dan sampel sedimen yang telah ambil serta diproses. Keputusan menunjukkan bahawa selang geometri adalah satu-satunya kaedah yang secara relatifnya sepadan dengan data kebenaran tanah dan berfungsi dengan baik. Oleh itu, klasifikasi ini boleh menjadi alat yang baik dalam mereka bentuk program pengurusan untuk taman laut untuk mengetahui pandangan umum taburan sedimen di kawasan itu. Ia mewujudkan objektif gambaran umum yang ringkas dan mudah tetapi kukuh secara statistik berdasarkan data geofizik yang disediakan.

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LIST OF ABBREVIATIONS

2D	-	Two-Dimensional
3D	-	Three-Dimensional
GIS	-	Geographical Information System
AUV	-	Autonomous Underwater Vehicle
CILAS	-	A laser diffraction systems equipment
CPCe	-	Coral Point Count with Excel extension
CV	-	Cross-validation
CVT	-	Coral Video Transect
DGNSS	-	differential global navigation satellite system
FCM	-	Fuzzy C-Means
IUCN	-	International Union for Conservation of Nature's
LMP	-	Labuan Marine Park
LVQ	-	Learning Vector Quantisation
MBES	-	Multibeam Echo Sounder
MHz	-	Megahertz
MPA	-	Marine Protected Area
NOAA	-	National Oceanic and Atmospheric Administration
ROC	-	Receiving Operating Curve
SBES	-	Single beam Echo Sounder
SHM	-	Support Histogram Machin
SSS	-	Side Scan Sonar
SVM	-	Support Vector Machine
TPU	-	Transceiver Processing Unit
UAC	-	Underwater Acoustic Communication
UASN	-	Underwater Acoustic Sensor Network
UAV	-	Unmanned aerial vehicle
UNESCO	-	United Nations Educational, Scientific and Cultural Organization
USGS	-	United States Geological Survey.
XTF	-	eXtended Triton Format

LIST OF SYMBOLS

Φ	-	Phi
cm	-	centimetre
kHz	-	kilohertz
km	-	kilometre
m	-	meter
μm	-	micrometre

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Seafloor classification is essential for ship safety, especially when the ship wants to stop by throwing anchors in the middle of the sea (Garlan et al., 2018). It is also essential for the environment to monitor benthic habitat impacts, sediment transport, dredging material, and offshore waste (Khomsin et al., 2021). Not to mention utility construction, for example, installing gas and oil pipelines, electricity and optics cables, telecommunications, and platform structure. Since the marine environment is being pressured by human activities that cause severe damage to the seafloor ecosystem and lower the benthic biodiversity, it is predicted that fisheries resources will collapse beyond the point of recovery (Worm et al., 2006). Therefore, immediate mitigation action is needed to reduce impacts on the ocean's environment. Furthermore, to ensure such a situation, there is a need to document baseline information about it on an ecosystem level for long-time monitoring and estimate the geographic quantity of crucial habitat. However, our knowledge of such baseline information is lacking due to sampling difficulties, which reduce our ability to obtain such data caused by conventional, in-situ sampling techniques and seafloor survey methods (Van Rein et al., 2009; Wright and Heyman, 2008).

In addition, only a few habitats have been classified and are usually done at a basic level, which provides insufficient scientific data (Prada et al., 2008). Besides that, large mapping areas of the seabed using underwater field surveys can be very costly and time-consuming. Therefore, alternative methods such as acoustic remote sensing technologies have been developed due to their enormous potential to generate high-resolution maps where a comprehensive habitat composition and spatial distribution could be obtained at multiple scales. These spatial distribution studies can be a way to present the characteristic of seabed habitat in a gradational manner by

providing a realistic representation of how seabed communities are structured (Brown et al., 2011).

The rising human exploitation of the oceans has brought to a demand for accurate seafloor information, i.e., maps—the information required for both the seafloor topography and the distribution of the seafloor composition. The problem is the unavailability of nautical charts, which contain necessary and complete seabed characteristic information or seabed classifications maps that are complete and accurate. Spatial maps are critical to understanding the complex ecosystem dynamics and relationship of biota and habitats. Several studies have been conducted using acoustic technologies to generate reliable benthic habitat maps using side scan sonar. This acoustic sensor is commonly employed in shipwrecks exploration, elaborating nautical charts, and seabed imaging globally (Fish and Carr, 1990). However, side scan sonar imagery application for tropical habitat classification is still limited (Franklin et al., 2003). Nevertheless, this technology does not limit the capabilities of the side scan sonar in describing benthic features, covers, and zones in the marine ecosystem and providing critical marine resource assessments today. It is possible to map benthic features at a fine-scale since it can cover a large area of the seafloor and delineate them into geological and geomorphological regions to aid the distribution of the biological system and identify artefact components (Kostylev et al., 2001; Singh et al., 2000; Todd et al., 1999).

1.2 Problem Statements

The Labuan Marine Park is surrounded by Malaysia's most fascinating islands, rich with corals and fish species. Reef Check Malaysia (2020) reported that this marine park is in the fair category based on the percentage of live coral cover. Although reefs were reported healthy, they face tremendous environmental pressure, especially the tourism industry growing rapidly. The increasing human recreational activities adversely impacted the marine ecosystem, thus threatening the survival and resilience of coral reefs and their sedimentation. This may result in a coral dominance shift to a macroalgae-dominated system (Liew et al., 2001). Unfortunately, the long-term data

such as the extent and degradation rate of seabed morphology and coral cover in the whole Labuan Marine Park area has not been established clearly.

Only a few studies use acoustic technology to provide an accurate visual representation of benthic habitat for that area, i.e., a study was done by Mustapha et al. (2015) on an assessment of marine habitat mapping where the assessment aims to identify the substrate and type of biotic present at the area. They used a seafloor classification and marine habitat based on NOAA's biogeography scheme. Determine the spectral characteristics of corals and associated habitats and map its spatial distribution using Seabed classification and marine habitat was based on NOAA's biogeography. Another study is by Samsudin et al. (2013), where they aim to produce a full coverage bathymetry dataset with the accommodation of backscatter data through Fledermaus Geocoder Toolkit (FMGT). This study discusses how the result could aid in enhancing the final output of the backscatter mosaic and be adequately used in habitat mapping and classification modules.

Consequently, while reviewing the studies in this area, that mainly about seafloor morphology classification, there is a lack of detailed presenting on the marine environment for spatial management in Malaysia, specifically the whole Labuan Marine Park, limiting conventional seabed surveys. Part of the reasons include the lack of appropriate field data for ground truth validation and insufficient systemic evaluation of high spatial imagery. Hence, this has led to the prevailing decision-making in many countries, including Malaysia, which can cause separation of environmental factors from the policy, planning, and management levels (Toda et al., 2007).

1.3 Research Question

There are several research questions as outlined below:

(a) What type of classification will be used for this study?

(b) Can a simple data arrangement process such as histogram classification produce a sediment map?

(c) Does the model's validity correspond to the ground truthing data?

1.4 Aim and Objectives of the Study

This study aims to perform a pixel grouping method for backscatter images from side scan sonar data using the histogram generated from the backscatter intensities. Thus, the aim will be achieved through following objectives:

(a) To classify the seabed characteristic using histogram classification.

(b) To produce a sediment map through a histogram classification created.

(c) To validate the classification using ground truthing data such as sediment distribution and coral video transect.

1.5 Scope of Study

This study involves underwater mapping utilising side scan sonar and underwater verification covering one nautical mile radius surrounding the islands. This study aims to use a simple data arrangement method that can be applied for side scan sonar data using the histogram generated from the sonar's backscatter intensities to represent the seafloor. The concept is to test whether this simple data arrangement process could produce similar classes to a sediment classification map with the

reference of Che Hasan (2016). The classification will be verified and supported through the ground truth data that have been collected and processed before. Information and results from a previous study on seafloor morphology conducted by Mustajap (2015), Ismail et al. (2018), and Abd Mutalib (2018) will be used as references to verify and validate the accuracy of the seafloor classification of the study area.

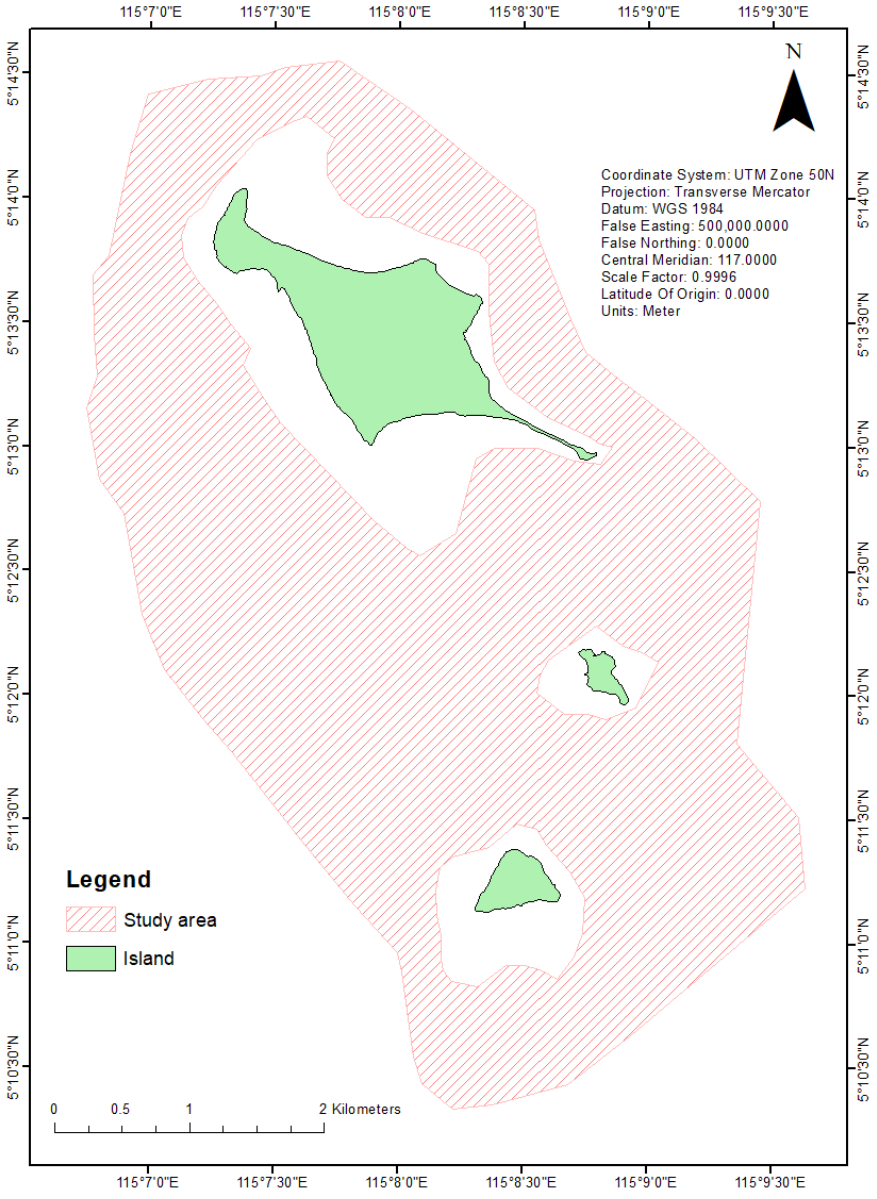

Figure 1.1 Study area correspond to side scan sonar mapping that covering one nautical mile radius surrounding the islands of Labuan Marine Park.

1.6 Significance of The Study

Updated seafloor information is needed to effectively manage the marine park area and conserve since the seabed changed throughout the years. The previous map was not comprehensive enough to provide spatial details and also was outdated. The primary purpose of this study is to suggest a practice in using straightforward techniques in identifying the seabed characteristic in shallow reef areas through a side scan sonar imagery interpretation to produce their seabed classification. It is one of the efforts to better understand and comprehend the marine ecosystem through scientific data collection on seabed characteristics' status and distribution. This study is necessary for providing overview information for conservation and ecosystem-based management to aid in future development projects such as prior environmental impact assessment reports and marine spatial planning. The availability of side scan sonar imagery backscatter intensity offers alternative methods to study seafloor hardness and softness. As for the seabed mapping process, there are a lot of classification techniques that can be used to produce sediment maps from side scan imagery from simple clustering approaches.

1.7 Organisation of the Project Report

The structure of this report as follows:

(a) Chapter 1: This chapter emphasises the background of the study, problem statement, research questions, research goal and objectives, the scope of the study.

(b) Chapter 2: This chapter concentrates on a compilation literature review about general concepts definition and issues related to the sonar data and classification methods for the seafloor derived from sonar’s backscatter imagery and the relevant variables of the derivatives layer for the classification method.

(c) Chapter 3: This chapter explains the data processing and analysis methodologies. The description of the type of processing used and the procedures taken to conduct the study comprises quantifying the relationship and variables classification.

(d) Chapter 4: This chapter shows the results of the classification method used. The results will show the differentiation of coral reefs and sediments, and verified with the ground truth data. This chapter will discuss the findings from the analysis and classification method used.

(e) Chapter 5: This chapter describes the final findings from the research and suggestion for further research.

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