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WAVE CHARACTERISTICS IN SABAH WATERS

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF SCIENCE WITH HONOURS

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April 2007

DECLARATION

I affirm that this dissertation is of my own effort, except for the materials referred to as cited in the reference section.

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ABSTRACT

This study aims to identify the wave characteristics in Sabah waters to compare its characteristics at five different waters and to determine the effects of the Northeast monsoon (NEM) and Southwest monsoon (SWM) to the east coast and west coast of Sabah waters. Monthly wave observation data of wave height, wave period and wave power between 1991 to 1998 covering areas waters off Labuan, Kota Kinabalu, Kudat, Sandakan and Tawau was collected from the Meteorological Department. The wave height and wave period were analysed directly from the data provided while wave power was calculated according to the wave power equation. The wave data at different area were analysed through the probability density function (p.d.f) and the cumulative probability density function (c.p.d.f). The range of wave heights in coastal waters surrounding Sabah is found to be between 0.5 m to 2 m. Both wave characteristics in Sandakan and Tawau waters appeared to have similar trend compared to that in Labuan, Kota Kinabalu and Kudat. Higher ranged wave heights and wave power occurred in the west coast of Sabah during the NEM. However, the wave period is almost the same for the east coast and west coast during both monsoonal seasons. The findings of this study will be useful for navigation purpose and coastal zone management activities.

ABSTRAK

Kajian ini bertujuan mengenalpasti ciri-ciri ombak di perairan Sabah, membandingkan ciri-ciri ombak berdasarkan lima kawasan berbeza dan juga untuk menentukan kesan monsun Timur Laut dan monsun Barat Daya kepada kawasan perairan pantai timur dan pantai barat Sabah. Data pemantauan bulanan untuk ketinggian ombak dan kalaan ombak untuk jangka masa 1991 hingga 1998 bagi kawasan perairan Labuan, Kota Kinabalu, Kudat, Sandakan dan Tawau diperolehi daripada Jabatan Meteorologi. Ketinggian ombak dan kalaan ombak dianalisis secara terus daripada data yang disediakan manakala tenaga ombak dikira menurut persamaan tenaga ombak. Data ombak untuk kawasan berbeza dianalisis melalui fungsi ketumpatan kebarangkalian (f.k.k) dan fungsi longgokan ketumpatan kebarangkalian (f.l.k.k). Julat ketinggian ombak di perairan Sabah didapati berada dalam lingkungan 0.5 m hingga 2.0 m. Ciri-ciri ombak di perairan Sandakan dan Tawau adalah hampir serupa dengan ciri-ciri ombak di perairan Labuan, Kota Kinabalu dan Kudat. Semasa monsun Timur Laut, ketinggian ombak dan tenaga ombak di perairan pantai barat Sabah berada pada julat yang lebih tinggi. Walau bagaimanapun, kalaan ombak adalah lebih kurang sama untuk pantai barat dan pantai timur bagi kedua-dua musim monsun. Hasil kajian ini boleh digunakan untuk tujuan pelayaran dan kepelautan serta aktiviti-aktiviti pengurusan pesisiran pantai.

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km	kilometres
m	metres
km^2	kilometre square
Kw	kilowatts
W	watts
s	seconds
kWm^{-1}	kilowatt per metre
ms^{-1}	metre per second
°	degree
′	minute
N	North
E	East

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Sea waves are mostly generated by the action of the wind over water. However, waves are also generated by moving objects such as passing boats and ship (Dean and Dalrymple, 2002). The waves are formed initially by a complex process of resonance and shearing action, in which waves of differing wave height, length and period are produced. Once formed, waves can travel vast distances, spreading in area and reducing in height, but maintaining wavelength and period (Chadwick and Morfett, 1996).

Knowledge of sea waves is necessary for a complete understanding of the sea condition. Sea waves greatly affect all maritime activities. The widespread effects of storm waves on shipping are well known. The wave conditions affect directly the fishing operations. The waves are known to affect also the behaviour and occurrence of pelagic fish (Reddy, 2001). Turbulence associated with sea waves promotes interchange between sea and atmosphere, as well as circulation and distribution of oxygen, heat and other elements within the upper layer of the sea (Moon, 2005). The lasting effects of ocean waves come from their erosion of coastal formations. Wave induced currents are primarily responsible for transportation and deposition of near shore sediments. Thus, waves play the dominant role in determining the configuration of the coastline and associated shoreline feature (Castelle *et al.*, 2006).

1.2 Objectives

The study of wave characteristics in Sabah waters has three main objectives, these objectives include:

1. To identify wave characteristics for waters off Labuan, Kota Kinabalu, Kudat, Sandakan and Tawau.
2. To determine wave characteristics during the Northeast monsoon (NEM) and the Southwest monsoon (SWM).
3. To compare the wave characteristics of waters off east coast and west coast of Sabah.

1.3 Significance of Study

The study of wave characteristics in Sabah is important as it contributes significantly to fisheries activities, navigation, marine habitat management and coastal development and planning. The lack of knowledge on the wind and wave climate in Sabah contributes to a great lost of properties and lives.

1.3.1 Fisheries Activities

The study of wave characteristics in Sabah waters is important for the well-being of the fisheries sector. This sector would need information on the wave characteristics during the NEM and SWM to determine the reasons behind their yield. Wave information will aid in the estimation of when the sea is at its roughest and give out warning signs. This in all will help lower the number of casualties due to rough sea conditions and help save time and resources. The information will aid fishermen in planning whether they should go out to sea. This planning minimizes the resources wasted, for example, the amount of ice and petrol needed per trip.

The wave condition can determine the depth of the mixed layer in the upper layer and thus help determine the most appropriate fishing gear for fishing activity in an area (Reddy, 2001). This will help maximise the number of catch and minimise the resources used for the catch.

1.3.2 Navigation

South China Sea, Sulu Sea and Celebes Sea serve as important navigational routes for Sabah. A large number of vessels pass through the seas surrounding Sabah. The waters of Sabah play an important role in the transportation of fertilisers and agricultural products. Historically, South China Sea is important for the navigational trail of China and India. During times when vessels depended mainly on wind and wave force for navigation, the NEM was used to navigate vessel from China to Melaka and the SWM was used to navigate the vessels to India. Today, the South

China Sea is the world's second busiest international sea lane, and more than half of the world's supertanker traffic passes through the waters that lie among the Spartly Islands (TRACC, 2001).

Results obtained from this study would be important for navigational purposes. Vessels heading to sea would have a clear mind on what to expect during the two monsoonal seasons. Other than that, since this study covers all three seas covering Sabah, vessels would know which part is more turbulent during these times, aiding in the choosing of the best route and appropriate time for their journey. The information will help save life and prevent losses from equipment damage. The preparation done due to informative will also ensure a smooth and successful voyage.

1.3.3 Coastal Construction

As sea level rises, the threat of coastal erosion has become an increasing concern to beachfront developers, property owners and coastal planners. Fluctuations in the volume of sand on a beach affect its ability to serve as a dissipative buffer in protecting valuable property from the attack of high-energy storm waves (Haxel and Holman, 2004). Knowledge of wave characteristics is essential for the planning, design and construction of new ports coastal protection constructions, harbours, and navigational channels (Schneggenburger *et al.*, 2000). Maintenance and continuous operation of existing ports and harbours would also need information on the wave characteristics (Sundar and Ananth, 1988). An understanding of waves is desirable before we can answer many questions related to coastal protection, environmental control and management, and sustainable development (Schneggenburger *et al.*, 2000).

1.3.4 Biological Processes

Wave characteristics play an important role in the biological processes of nature. The sea state directly influences the suspended matter regime. Thus, through waves, the sea condition has an impact on the water quality. Some classes of nutrients and pesticides may be attached to sediments and suspended matter (Schneggenburger *et al.*, 2000). Therefore, wave action plays a role in introducing pesticides and nutrients submerged in sediments to the surrounding waters. Waves proved to play a significant role in distribution of suspended sediment concentrations and bedform activities (Lee *et al.*, 2004). Suspended particulate matter in a water column increases turbidity and reduces the available solar radiation for the photosynthetic activity of phytoplankton (Baretta-Bekker *et al.*, 1998). Thus, the study of wave characteristics aids in the understanding and estimation of the water quality of a sea area.

Large-scale horizontal mixing of sediments on intertidal sandflats by physical factors is most frequently driven by locally generated wind waves, making the relative importance of biological versus physical mixing dependent on wave exposure (Bell *et al.*, 1997). Important factors affecting this relationship include the length of time the intertidal flat is exposed to wave-induced turbulence, the amount of energy expended by the waves on the sediment, and the frequency, which wave-induced mixing occurs. The amount of mixing and erosion of sediment driven by waves will vary with both large and small-spatial changes in hydrodynamics (Hewitt *et al.*, 2003). Catastrophic sedimentation events, depositing centimetres thick layers of fine terrigenous sediments in short time periods, can lead to mass mortality of benthic fauna (Peterson, 1985). Although, in the short-term, mortality is the most dramatic effect, perhaps more important is the potential for broad-scale, longer-term alteration of habitats and subsequent community changes (Ellis *et al.*, 2000). Thus, the information obtained from this study will aid in the understanding of the sedimentation rate of an area and help in determining measures needed to tackle this problem.

Waves also play a significant role in the dispersion and transportation of fish larvae. Thus, this study will aid in the understanding of the distribution and yield of fishes in a certain area and help in the determination of the time period for fish recruitment and reproduction.

1.3.5 Emergency Management Purposes

Modelling and prediction of tropical cyclones has been in the centre of attention for many years because of their potential to cause severe damage to life and property. Apart from high wind speeds and increased mean water levels at landfall, wave heights associated with tropical cyclones pose a major hazard. Accurate modelling of wind waves generated by hurricanes is, therefore, of great importance for emergency management purposes (Tolman and Alves, 2005).

The findings of this study would aid further researches conducted in these areas. It could also reinforce studies conducted before this and help form a better understanding on the wave characteristics of South China Sea, Sulu Sea and Celebes Sea during the NEM and SWM.

1.4 Study Area

Study of wave chracteristics in Sabah is conducted at the seas surrounding Sabah which consist of South China Sea, Sulu Sea and Celebes Sea (Figure 1.1). Monsoonal climate has a strong influence on the three seas. The NEM between November and February, and the SWM between June and September change the surface current circulation patterns of the sea with predictable regularity (Babu *et al.*, 2005). Wind forces are small but constant, while storms and typhoons are confined to the northern and northeastern sectors (Chou and Alino, 1995).

1.4.1 South China Sea

The South China Sea extends 2800 km from the equator to the Tropic of Cancer, and 1800 km from Indochina to the Philippine archipelago. With an area of 3.5×10^6 km^2, it is the largest marginal sea in the world and is a major connection between the Pacific Ocean and the Straits of Malacca and the Indian Ocean (Liu *et al.*, 2002). At the southern edge of the South China Sea, lies the Sunda Shelf, which averages only about 50 m in depth; thus, waters in the aphotic zone cannot enter the South China Sea through the Sunda Shelf (Chen *et al.*, 2006). It is bordered by the continental Asian landmass along its western and northern flanks. A sizeable part of the sea extends into the Gulf of Thailand.

The unique geographical position of the South China Sea and the configuration of surrounding harbour together with the variation in seafloor characteristics have enabled it to contain many different types of marine habitats as well as support a remarkably high diversity of marine species (Chou and Alino, 1995). Two main depth contours exist, the Sunda shelf segment (100 - 200 m) along the southern edge and a portion of the northeast, separated by a deeper central trench (> 5000 m). It is from this deep abyssal plain that the Spratly and Paracel islands and reefs reach towards the surface. There are approximately 200 isolated oceanic islands and reefs among these areas, and they are considered to be within the epicentre of tropical reef biodiversity (TRACC, 2001).

The South China Sea is one of the world's largest seas (TRACC, 2001). It is obviously larger in comparison with the two other seas surrounding Sabah (Sulu Sea and Celebes Sea).

1.4.2 Sulu Sea

The Sulu Sea, extending from 6°N to 12°N and from 117°E to 123°E, is a portion of the western North Pacific (Wang *et al.*, 2006). It is a 'Mediterranean sea' isolated from the surrounding water by a chain of islands: Borneo Island in the southwest, Palawan in the west, Busuanga and Mindoro in the north, Panay, Negros and Mindanao in the east, and the Sulu Archipelago in the southeast. It is a deep basin with an average depth of 4450 m, deepest in the northwest with a broad sloping sea floor in the southeast. The Sulu Sea exchanges surface water with surrounding waters over shallow sills, with the deepest sill connecting to the South China Sea at 420 m through the Mindoro Strait (Wyrtki, 1961). Thus the Sulu Sea is a closed sea for its deep water and a semi-closed sea for its upper layer.

1.4.3 Celebes Sea

The Celebes Sea of the western Pacific Ocean is bordered on the north by the Sulu Archipelago and Sulu Sea and Mindanao Island of the Philipines, on the east by the Sangihe Islands chain, on the south by Sulawesi, and on the west by Borneo. The border between the Celebes and the Sulu Sea is at the Sibutu-Basilan Ridge. Strong ocean currents, deep sea trenches and sea mounts, combined with active volcanic islands, result in complex oceanographic features. The waters of Celebes are influenced by monsoonal changes as the monsoon currents changes its pattern and direction each time the monsoon season changes. The Celebes Sea is connected with the Pacific Ocean only by four narrow passages, and it is separated in the South from the Flores Sea (Wyrtki, 1961).

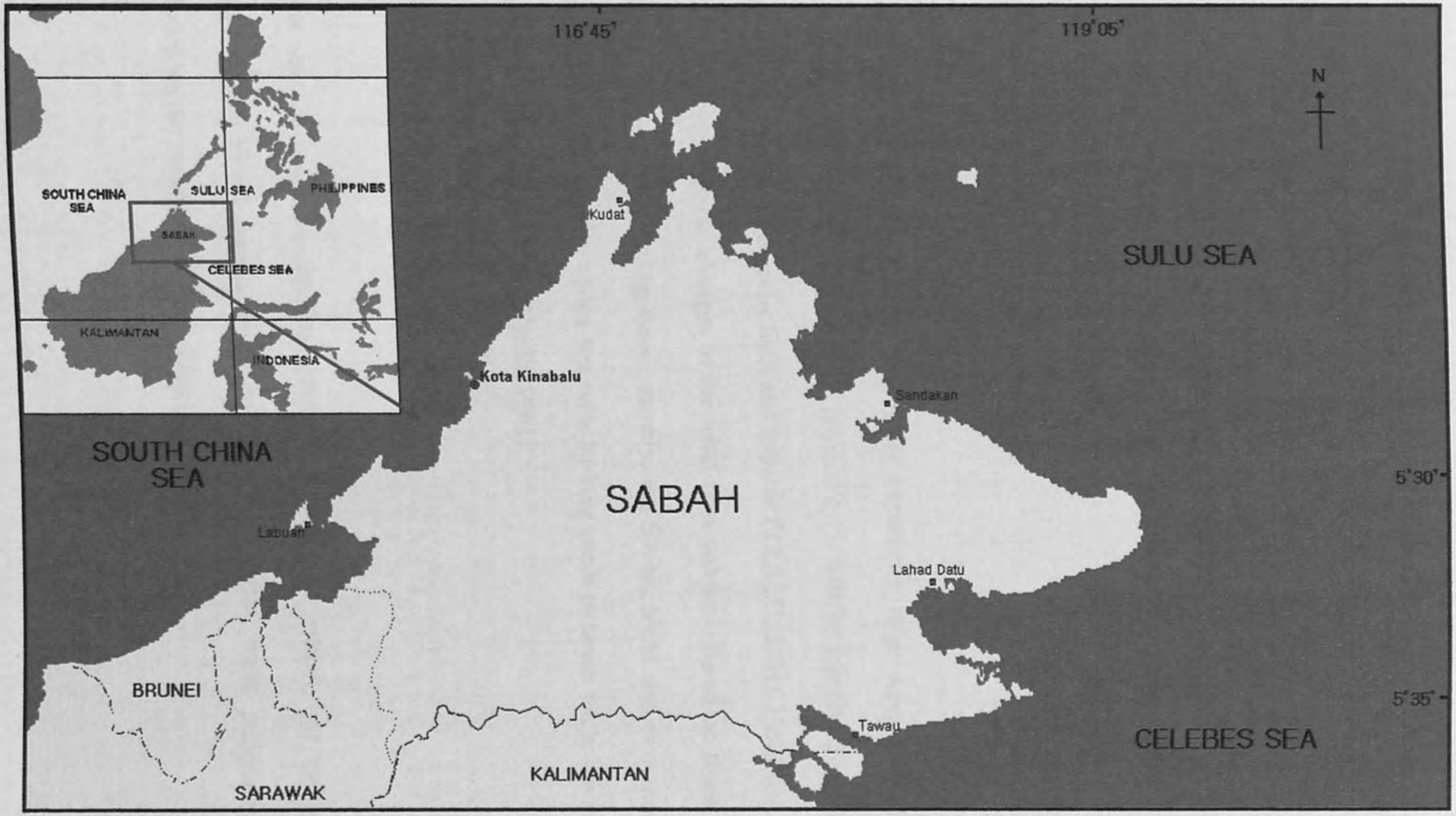

Figure 1.1 Seas surrounding Sabah waters.

Source: Modified from C-Map World for Windows version 3.14, 1996.