UNIVERSITI PUTRA MALAYSIA

A STUDY ON DIVERSITY AND DENSITY OF MARINE DINOFLAGELLATES IN THE STRAITS OF MALACCA

AZURA ALIM

FSAS 2001 11

A STUDY ON DIVERSITY AND DENSITY OF MARINE DINOFLAGELLATES IN THE STRAITS OF MALACCA

By

AZURA ALIM

Thesis Submitted in Fulfilment of the Requirements for the Degree of Master Science in the Faculty of Science and Environmental Studies Universiti Putra Malaysia

March 2001

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

A STUDY ON DIVERSITY AND DENSITY OF MARINE DINOFLAGELLATES IN THE STRAITS OF MALACCA

By

AZURA ALIM

March 2001

Chairman : Drs. Idris Abd. Ghani

Faculty : Science and Environmental Studies

The objective of this study is to update and compare the species composition, distribution and abundance of dinoflagellate in the Straits of Malacca. The samples were collected during the JICA-MASDEC Straits of Malacca Expedition on board R/V K. K. Mersuji from November 23 to December 2, 1998 (northeast monsoon season) and March 25 to April 4, 1999 (pre southwest monsoon season) by using "Van Dorm" water sampler. A total of 78 dinoflagellate species from 21 genus, 13 families, and six orders under Division Pyrrophyta were observed and identified. During the northeast monsoon, Peridiniales was the dominant order accounting for 87.87% of the total dinoflagellate density, followed by Dinophysiales (5.49%), Prorocentrales (2.98%), Noctilucales (1.85%), Pyrocystales (1.45%) and Gymnodiniales (0.36%). Peridiniales also constitute of an important group during the pre southwest monsoon with an average 71.84% of the total dinoflagellate density, followed by Gymnodiniales (20.51%), Dinophysiales (4.80%), Pyrocystales (1.40%), Prorocentrales (0.89%) and Noctilucales (0.57%). In terms of numbers, the total density of dinoflagellates

varied from 2.64 cells/l at Station 24 to 2.93×10^3 cells/l at Station 13 and 18.02 cells/l at Station 19 to 6.24×10^2 cells/l at Station 14 during the northeast monsoon season and the pre southwest monsoon season respectively. The middle zone of the Malacca Straits showed the highest density of dinoflagellate compared to the northern and southern zone for both monsoon seasons. During the northeast monsoon, the density of dinoflagellate in the offshore stations was higher than in the inshore stations. In contrast, the inshore stations of the Straits showed the highest density of dinoflagellate compared to the offshore stations during the pre southwest monsoon. *Ceratium furca* was the most dominant species in the Straits of Malacca during the northeast monsoon (maximum cell density reached 2.87×10^3 cells/l at Station 13) and dominated dinoflagellate assemblages almost at all stations. *Gymnodinium simplex, Protoperidinium ovum* and *Ceratium furca* were the three most dominant species in the Straits of Malacca during the pre southwest monsoon. ANOVA showed a significant difference ($F = 21.05, p < 0.05$ and $F = 11.66, p < 0.05$) in species diversity and species evenness between the northeast monsoon and the pre southwest monsoon. However, there was no significant difference ($F = 2.34, p > 0.05$) in species richness between the northeast monsoon and the pre southwest monsoon.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai keperluan untuk ijazah Master Sains

KAJIAN KE ATAS DIVERSITI DAN DENSITI DINOFLAGELAT MARIN DI SELAT MELAKA

Oleh

AZURA ALIM

Mac 2001

Pengerusi : Drs. Idris Abd. Ghani

Fakulti : Sains dan Pengajian Alam Sekitar

Objektif kajian adalah untuk mengemas kini dan membuat perbandingan komposisi spesis, taburan serta kepadatan dinoflagelat di Selat Melaka. Sampel fitoplankton dikumpulkan semasa Ekspedisi Selat Melaka JICA-MASDEC menggunakan kapal R/V K. K. Mersuji dari 23 hb. November hingga 2 hb. Disember, 1998 (monsun timur laut) dan dari 25 hb. Mac hingga 4 hb. April, 1999 (monsun pra barat daya) dengan menggunakan alat pensampelan air "Van Dorm". Sebanyak 78 spesis dinoflagelat daripada 21 genus, 13 famili dan enam order daripada Divisi Pyrrophyta telah dikenalpasti. Semasa monsun timur laut, Peridiniales merupakan order dominan dengan 87.87% daripada jumlah densiti keseluruhan dinoflagelat, diikuti oleh Dinophysiales (5.49%), Prorocentrales (2.98%), Noctilucales (1.85%), Pyrocystales (1.45%) dan Gymnodiniales (0.36%). Peridiniales juga merupakan kumpulan penting semasa monsun pra barat daya dengan purata 71.84% daripada jumlah keseluruhan densiti dinoflagelat, diikuti oleh Gymnodiniales (20.51%), Dinophysiales (4.80%), Pyrocystales (1.40%), Prorocentrales (0.89%) dan Noctilucales (0.57%). Dari segi bilangan,

jumlah keseluruhan densiti dinoflagelat dari 2.64 sel/l pada stesen 24 hingga 2.93 $\times 10^3$ sel/l pada stesen 13 dan 18.02 sel/l hingga 6.24 $\times 10^2$ sel/l pada stesen 14 semasa monsun timur laut dan monsun barat daya. Zon tengah Selat Melaka menunjukkan densiti dinoflagelat yang lebih tinggi jika dibandingkan dengan zon utara dan zon selatan pada kedua-dua monsun. Semasa monsun timur laut, densiti dinoflagelat lebih tinggi di stesen yang terletak jauh dari pantai berbanding stesen yang terletak berhampiran dengan pantai. Berbeza dengan monsun pra barat daya di mana densiti dinoflagelat lebih tinggi di stesen yang terletak berhampiran pantai berbanding dengan stesen jauh dari pantai. *Ceratium furca* adalah spesis dominan di Selat Melaka semasa monsun timur laut (densiti maksimum yang dicapai sebanyak 2.87 $\times 10^3$ sel/l pada stesen 13) dan mendominasi kumpulan dinoflagelat hampir semua stesen. *Gymnodinium simplex, Protoperidinium ovum* dan *Ceratium furca* adalah tiga jenis spesis dominan di Selat Melaka semasa monsun pra barat daya. ANOVA menunjukkan perbezaan bererti ($F = 21.05$, $p < 0.05$ dan $F = 11.66$, $p < 0.05$) bagi diversiti spesis dan kesamarataan spesis antara monsun timur laut dan monsun pra barat daya. Walau bagaimanapun, tiada perbezaan bererti ($F = 2.34$, $p > 0.05$) bagi kekayaan spesis antara monsun timur laut dan monsun barat daya.

ACKNOWLEDGEMENTS

In the name of ALLAH the most merciful and honorable.

I would like to express my appreciation to all those who help to contribute to this research. I thank ALLAH for everything. I sincerely wish to express my gratitude to my advisor Drs. Idris Abdul Ghani for his full support, guidance, understanding and encouragement throughout the cause of this research.

I would like to express my sincere thanks to Dr. Hishamuddin Omar and Dr. Misri Kusnan, for serving as my advisory committee, and providing their expertise and other words of wisdom. Also, I am greatly indebted to them for their critical review of the manuscript of my thesis.

A special thanks must go out to Dr. Hishamuddin for his expert guidance and spent countless hours trying to help me understand the concept of ecology. I thank everyone who has been part of the Aquatic Laboratory.

Finally, I dedicate this work to my lovely son Muhammad Al-Hadi, my beloved husband Mohd. Harees Masian who have encouraged me to continue my study and provided financial support so that I may pursue my study without any difficulties and a special thank must go out to my parents for believing in me and always being there.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

GLOSARY

Antapex	bottom end of the dinoflagellate cell.
Apex	top end of the dinoflagellate cell.
Apical pore	distinctive pore-like structure, present on top of some dinoflagellates cell.
Areola	the regularly repeated circular depressions in the cellulose wall of dinoflagellates.
Armored	dinoflagellate cells with a thick cellulose wall (theca) composed of rigid plates.
Bioluminescent	the emission of visible light by living organisms, such as the fireflies on the land and the dinoflagellates in the sea.
Chain	a group of micro-organisms which are connected in a linear arrangement.
Chlorophyll a	the green colouring substance found in all photosynthetic algae and higher plants.
Cyst	a thick-walled stage in the life-history of a dinoflagellate, also called resting spore. The cyst wall is often made up of resistant *sporopollenin* and may be ornamented with spines. Cysts are often produced at the onset of adverse conditions, and when conditions are suitable, they may germinated to seed new plankton blooms.
Diarrhetic shellfish poisoning	human illness caused by eating shellfish contaminated with certain dinoflagellate toxins (e.g. from *Dinophysis acuminata*).
Dinoflagellates	single-celled golden-brown algae, characteristically having a large nucleus with clearly visible chromosomes, and with two flagella, protruding from the girdle groove and the sulcus groove, respectively.
Epitheca	the upper half of the dinoflagellate cell.
Flagellum	Whip-like extensions of the cells of certain micro-organisms. Mainly used for locomotion.

Girdle groove	the horizontal groove which encircles the dinoflagellate cell and which contains the transverse flagellum.
Horn	extension of the cellulose plates of a dinoflagellate cell.
Hypotheca	the lower half of the dinoflagellate cell.
List	extension of the cellulose plates of dinoflagellate cells, usually around the girdle groove.
Micron	one thousandth of millimeter (μm).
Naked	Plankton cells bounded by a membranous covering only. These organisms are very easily damaged beyond recognition.
Neurotoxins	toxins that disrupt the normal functioning of the human nervous system.
Paralytic shellfish poisoning	human illness caused by eating shellfish which are contaminated with certain dinoflagellate toxins (e.g. *Gymnodinium catenatum* or *Pyrodinium bahamense*). In extreme cases this can lead to death through respiratory paralysis.
Plankton bloom	Prolific growth of plankton algae.
Red tide	dens concentrations of plankton organisms (mostly dinoflagellates) that can colour the sea red or brown.
Scanning electron microscope	a type of electron microscope in which a beam of electrons scans the outer surface of objects previously coated with a thin layer of gold or platinum.
Spine	solid projection on the surface of the dinoflagellate cell wall.
Sulcus	the vertical groove on the dinoflagellate cell, extending onto epitheca and hypotheca, which guides the longitudinal flagellum.
Symbiosis	the living together of two species of organisms with mutual advantages for both.
Theca	the complete cell covering of the dinoflagellate cell.

CHAPTER I

INTRODUCTION

Dinoflagellate is the second most abundant phytoplankton group followed by diatoms. The name 'dinos' comes from the Greek word meaning 'whirling' as this type of movement is characteristic of these organisms. Dinoflagellates is a unique organisms because it posses two flagella or whiplike appendages that help them to move up or down in the water column. They are a diverse group, comprising approximately 115-131 genera (Sournia, 1986; Sournia *et al.,* 1991), 2,000 living species and 2,000 fossil species have been described (Fukuyo & Taylor, 1989). Dinoflagellates are mostly unicellular and range from 2 to 2,000 μm in diameter (Hallegraef, 1988).

The dinoflagellates are very abundant throughout the world. These organisms are important members of the phytoplankton in both fresh and marine waters, although a much greater variety of this form is found in marine relatives. They are found in all latitudes from the Artic and Antartic sea to the tropics. In warm water, dinoflagellates are usually large and occurred in various forms. Lee (1989) reported that dinoflagellate are more important in the warmer waters than in colder polar waters. Many dinoflagellates also occur in marginal habitats. According to Smetacek *et al.* (1991) some are confined to near-shore or neritic waters due to the richness of nutrient and lower salinity than the open sea.

Dinoflagellates are important food source for `marine microzooplankton, including fish larvae of which the production is essential to marine fishery (Zheng *et al.,* 1989). Their blooms are good source of carbon to the marine food web (White, 1984). The organisms making up this group are very diverse in nature, ranging from coral reef symbionts to free-living oceanic phytoplankton. The best known associations are the "zooxanthellae" (*Symbiodinium* spp.) found in corals, clams, radiolarians, acantharians and foraminiferans. In addition, there are some parasitic and saprophytic species (Zheng *et al.*, 1989).

Dinoflagellate are probably best known as a principal cause of red tides and paralytic shellfish poisoning (PSP). "Red tide" is the name given to the phenomenon of red discoloration of marine and estuarine waters caused by a bloom of phytoplankton, particularly dinoflagellates. The water becomes noticeably coloured when concentrations reach to about 200,000-500,000 cell/l, and as the bloom develops, concentrations may exceed 10^8 cell/l (Lalli and Parsons, 1993). The colour of water can range from blood red to orange or brown in daylight and is often visible as phosphorescence at night (Carey, 1983). These are features of coastal waters and more frequent in the tropics and subtropics than temperate seas. Some species have attracted attention because of their beautiful bioluminescent properties or their role in producing either toxic or non-toxic blooms (Hallegraeff, 1993).

The present study deals with dinoflagellate in the Straits of Malacca. The Straits of Malacca is one of the longest straits in the world and the busiest straits in the ASEAN country. This straits is important for shipping and transportation, natural resources, tourism, climatic and life support system of the littoral states and the world. Some 600 ships use it daily with more than 90% of these vessels destined for Japan, Taiwan, Korea, Singapore and Hong Kong (Ibrahim and Noro, 1999).

The increase of economic activities in the region also resulted in an upsurge of traffic in the Straits. The intensified world wide traffic may be responsible for the spread of harmful phytoplankton species between regions and continents (Hallegraef, 1993). Hallegraeff and Bolch (1992) confirmed the presence of *Gymnodinum catenatum* cysts in four ballast water samples entering Australian ports from both Korea and Japan. The organism is now also occurred in Sebatu, Melaka (Ann and Normawaty, 1996; Ann *et al.,* 2000).

Research Objectives

The primary purpose of the present study is to update the species composition, distribution and abundance of dinoflagellate in the Straits of Malacca. The second objective is to compare the species composition, distribution and abundance of dinoflagellates in the Straits during the northeast monsoon season and the pre southwest monsoon season. JICA-MASDEC Straits of Malacca Expedition provides opportunity to do comprehensive study on dinoflagellate in the Straits.

CHAPTER II

LITERATURE REVIEW

Classification

The dinoflagellates are members of Kingdom Protista under the phylum or division Pyrrophyta or Dinophyta (Dinophycophyta) in botanical systems and the order Dinoflagellida or Dinoflagellata in zoological systems. Until recently, the group was generally divided into two classes or subdivisions, which were essentially based on the position of the flagellar insertion. Some of the names for the classes used by various authors;

Adiniferidea	Diniferidea	Lebour, 1925
Adina	Diniferina	Levine *et al.*, 1980
Desmokontae	Dinophyceae	Schiller, 1933, 1937
Desmokontae	Dinokontae	Fritsch, 1935
Desmophyceae	Dinophyceae	Leoblich, 1970

In 1973 Dodge and Bibby showed that there was no basic ultrastructural distinction between the two groups and proposed that they should be amalgamated, therefore Parke and Dixon (1976) and Dodge (1982), used only one class, Dinophyceae. Following this scheme Leoblich (1976) introduced a new class, Syndiniophyceae, for the genera of intracellular parasitic dinoflagellates. Based on Chrétionnot-Dinet *et al.* (1993) dinoflagellates were classified into one class only, namely Dinophyceae, with 14 orders and 42 families.

Morphological Characteristics

Dinoflagellates are single-celled organisms that have two distinctive flagella during the least part of their life cycle and a special type of nucleus known as dinokaryon. The cells is divided by a transverse girdle groove into two parts, an upper (epitheca) and a lower (hypotheca) region. Within the groove lies the flattened, ribbon-like, transverse flagellum which encircles the cell. This may be situated centrally, apically or posteriorly. The smooth longitudinal flagellum extends to the base of the cell within a longitudinal furrow (sulcus). The transverse flagellum causes the rotational motion of the cell, while the longitudinal flagellum propels the cell forward.

Dinoflagellates, like diatoms, can exhibit extensive morphological variations with spines, horns and wings, especially in tropical species. These morphological extensions are thought to aid flotation, protect against grazing by small zooplankton, and enhance nutrient uptake through increased surface area and rotational movements.

Dinoflagellates are described as armored or unarmored, according to the type of cell covering (theca or amphiesma), which always consists of several layers of membranes. The thecate or armored group has a number of cellulosic plates which are thecal plates, or simply theca as a whole. Many thecal plates tightly assembled to form a firm, strong peripheral skeleton. The number, shape and arrangement of these plates form a distinctive geometry or topology known as 'plate tabulation', which is the main means for classification and they are a most important taxonomic criterion (Taylor, 1980).

The number, arrangement and thickness of the thecal plates can vary considerably. They may also be ornamented with pores, depressions, spines, ridges and reticulations (Vesk *et al,* 1990). Scanning electron microscopy has revealed that ornamentation of the thecal plates and fine structure of the apical pore, present on the top of many cells are also useful diagnostic characters (Hallegraeff, 1988). The other, athecate, unarmored, or naked group lacks of the plates.

Taxonomy of Dinoflagellates

Athecate species are identified principally by the size and shape of their cells, i.e. cell outline, position of girdle and sulcus groove, girdle displacement. In the thecate group, genera are classified according to plate pattern, which is decided by the arrangement of thecal plates. Species in each genus are identified by the size and shape of the cell, similarly taxonomy of athecate forms. Therefore, for critical taxonomy of thecate forms, staining or dissociation of thecal plates to recognize their tabulation is necessary in addition to observation of cell shape (Fukuyo and Taylor, 1989).

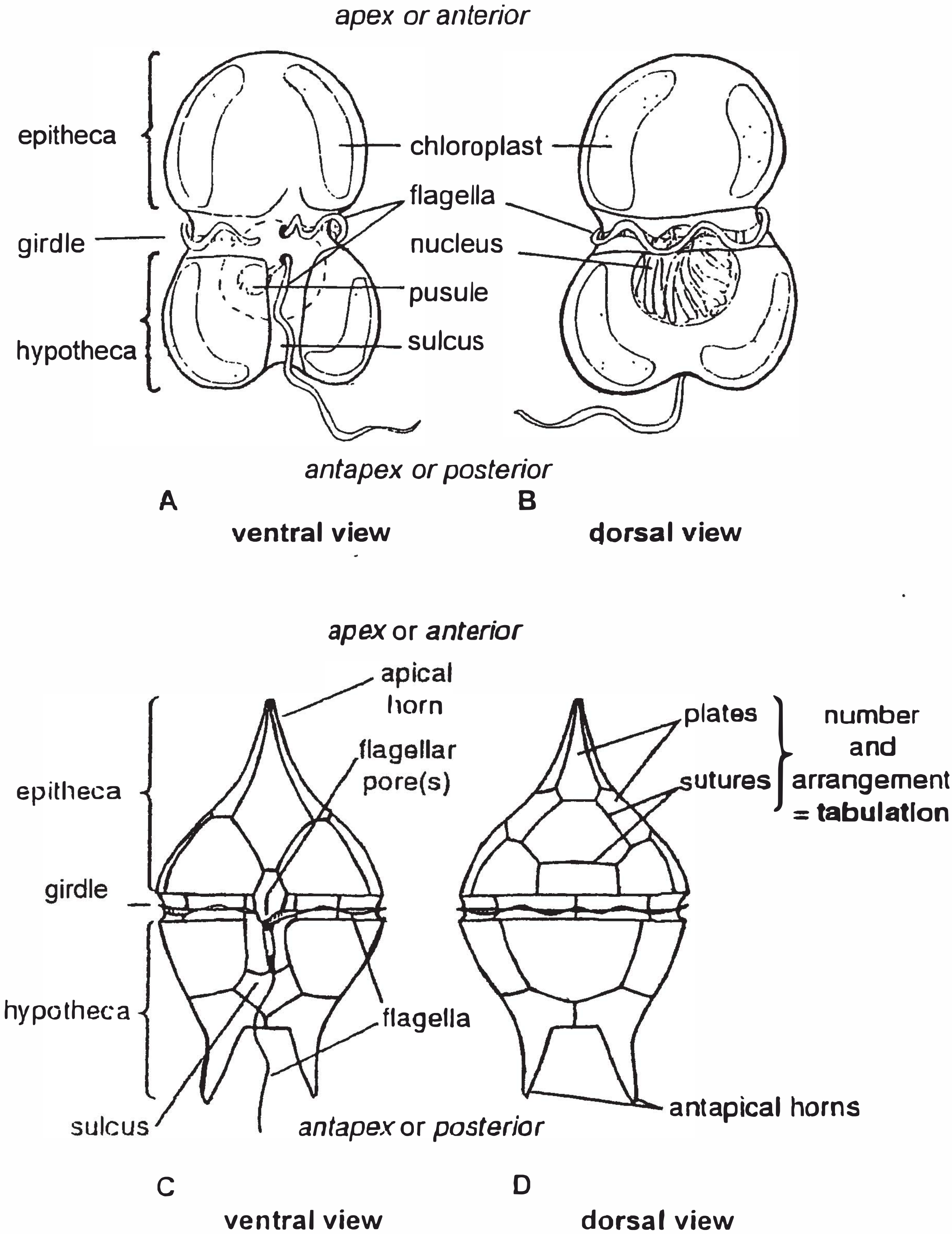

Figure 1: (A, B) Basic anatomy of gymnodinoid dinoflagellate, redrawn from Dodge (1982). (C, D) Basic anatomy of peridinoid dinoflagellate. Modified after Evitt, 1985.