TEMPORAL CHANGES IN MACROBENTHOS COMMUNITIES ON SANDY SHORES OF RAYONG PROVINCE

WASANA PHANNATAEWEE

A THESIS PRESENTED TO RAMKHAMHAENG UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE
(BIOLOGY)
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การเปลี่ยนแปลงตามเวลาของกลุ่มสิ่งมีชีวิตหน้าดินขนาดใหญ่บริเวณหาดทรายของจังหวัดระยอง

วาสนา พรรณเทวี

วิทยานิพนธ์เสนอต่อมหาวิทยาลัยรามคำแหง
เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญา
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Thesis Title	Temporal Changes in Macrobenthos Communities on Sandy Shores of Rayong Province
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ABSTRACT

Thesis Title : Temporal Changes in Macrobenthos Communities on Sandy Shores of Rayong Province

Student's Name : Miss Wasana Phannataewee

Degree Sought : Master of Science

Major : Biology

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Advisory Committee :

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Temporal changes in macrobenthos communities on four intertidal sandy shores with different environmental conditions, i.e., Paknamprasae, Haad Maepim, Haad Maerampueng and Haad Takuan were examined during December 1998–July 2000. The present study focused on community structure of macrobenthos including population density, species composition and diversity and seasonal variation. Mutivariate analyses by using Principle Components Analysis (PCA) revealed that species composition of Haad Paknamprasae was remarkably different from the others. Community structure of macrobenthos varied with exposure to wave action, freshwater, industrial and tourism activities. Variations in the distribution and abundance of macrobenthos and other environmental factors existed at different temporal and spatial scales. Temporal changes in population density were partly correlated with recruitment patterns. The macrobenthos frequently found at Haad Paknamprasae were the polychaete, *Glycera* sp. and *Nothria* sp., the bivalve, *Tellina* sp., the gastropod, *Umbonium vestiarium* and the crab, *Dotilla wichmannic.* For Haad Maepim and Haad Maeramphueng, the polychate, *Glycera* sp., the bivalve, *Donax incarnatus*, and the sand dollar, *Echinodiscus* sp. were frequently found but the crab, *D. wichmannic* were also found frequently at Haad Maepim. The polychaete, *Glycera* sp. and the bivalve, *Donax cuneatus* were found frequently at Haad Takuan. The present study provides comprehensive data of sandy shores for coastal resource managenent.

บทคัดย่อ

ชื่อเรื่องวิทยานิพนธ์ : การเปลี่ยนแปลงตามเวลาของกลุ่มสิ่งมีชีวิตหน้าดินขนาดใหญ่บริเวณหาดทรายของจังหวัดระยอง

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3. รองศาสตราจารย์สุภาวดี จุลละศร

ศึกษาการเปลี่ยนแปลงตามเวลาของสัตว์ทะเลหน้าดินขนาดใหญ่บริเวณเขตน้ำขึ้น-น้ำลงของหาดทราย ที่มีปัจจัยสิ่งแวดล้อมแตกต่างกัน 4 แห่ง ได้แก่ หาดปากน้ำประแสร์ หาดแม่พิมพ์ หาดแม่รำพึง และหาดตะกวน ตั้งแต่เดือนธันวาคม 2541 ถึง เดือนกรกฎาคม 2543 โดยมุ่งเน้นศึกษาโครงสร้างของประชาคมสัตว์ทะเลหน้าดินขนาดใหญ่ ซึ่งได้แก่ ความหนาแน่นของประชากร องค์ประกอบของชนิด ความหลากหลายของชนิด และความแปรปรวนตามฤดูกาล จากการวิเคราะห์ด้วย Principle Components Analysis (PCA) พบว่าองค์ประกอบของชนิดสัตว์ทะเลหน้าดินของหาดปากน้ำประแสร์มีความแตกต่างจากบริเวณอื่นอย่างเด่นชัด โครงสร้างของประชาคมสัตว์ทะเลหน้าดินขนาดใหญ่แปรผันตาม แรงกระทำของคลื่น อิทธิพลจากน้ำจืด ผลกระทบจากอุตสาหกรรม และกิจกรรมการท่องเที่ยว การแพร่กระจายและความชุกชุมของกลุ่มสัตว์ทะเลหน้าดินขนาดใหญ่มีความแปรปรวนมากตามเวลาและสถานที่ ซึ่งความแปรปรวนตามเวลาของประชากรส่วนหนึ่งเป็นผลมาจากการทดแทนประชากรของสัตว์ทะเลหน้าดิน สัตว์ทะเลหน้าดินชนิดที่พบบ่อยบริเวณ หาดปากน้ำประแสร์ คือ ไส้เดือนทะเล *Glycera*

sp., *Nothria* sp., *Scoloplos* sp. หอยสองฝา *Tellina* sp. หอยหลอด *Solen* sp. หอยทับทิม *Umbonium vestiarium* และปูทหาร *Dotilla wichmannic* สัตว์ทะเลหน้าดินที่พบบ่อยบริเวณหาดแม่พิมพ์และหาดแม่รำพึง คือ ไส้เดือนทะเล *Glycera* sp. หอยเสียบ *Donax incarnatus* และเหรียญทะเล *Echinodiscus* sp. แต่จะพบ ปูทหาร *D. wichmannic* ในบริเวณหาดแม่พิมพ์ด้วย สำหรับบริเวณหาดตะกวนสัตว์ทะเลหน้าดินที่พบบ่อย คือ ไส้เดือนทะเล *Glycera* sp. และหอยเสียบชนิด *Donax cuneatus*. ในรายงานการศึกษานี้มีข้อมูลจำนวนมากเกี่ยวกับหาดทรายซึ่งสามารถนำไปใช้เพื่อการจัดการทรัพยากรชายฝั่งทะเล

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Wasana Phannataewee

TABLE OF CONTENTS

Chapter | Page

LIST OF TABLES

Table	Page

Table Page

LIST OF FIGURES

Figure Page

Figure Page

Figure | Page

Figure Page

Figure Page

Figure | Page

CHAPTER 1

INTRODUCTION

Sandy beaches are devoid of any biological structures and their morphology and dynamics can be defined in terms of three interacting factors: wave energy, tide and sand particle size (McLachlan 2001, 742). The diversity and abundance of their intertidal macrobenthic communities are controlled by waves, tide and sediment types and then consideration of biological and biogeographic issues (McLachlan et al. 1995, 148).

On exposed beaches, long shore movement rates of macrofauna could potentially be affected by a number of behavior, ecological and physical factors, such as intertidal height, and seasonal episodic changes in wave and swash. Global patterns of macrofauna biodiversity on sandy beaches are tightly coupled to physical features of the beach environment and can be reliably on the basis of beach type (Dugan and McLachlan 1999, 121). Exposed sandy beaches support intertidal macrobenthos well adaptation to the physical rigorous of the dynamic environment (McLachlan et al. 1995, 148). Animals require special adaptation to live in an environment where the substrate is physical unstable in the sense that sand grain are continually moved by turbulent water (Lalli and Parson 1997, 206).

Sandy beaches suffer pollution from a number of sources, including sewage from industrial effluent, oil spill and many polluting materials (Brown and McLachland 1990, 227). The mobile species change their behavior in such a way as to avoid polluted areas. The permanent sandy beach infauna of polychaete worms and bivalves must sit out the pollution. Many of them can shut down their activities temporarily but they are not capable of leaving the area (Brown 1976, 197).

The macrobenthos is the most conspicuous component of the biota on most sandy beaches and comprises benthic forms too large to move between the sand grains (Brown and McLachlan 1990, 121). The distribution and diversity of macroenthos of sandy beaches is largely determined by physical factors, primary wave action and particale size of the sand, which in turn fix the morphodynamic state and slope of the beach and surf zone (Brown and McLachlan 1990, 143). The intertidal macrobenthos of ocean sandy beach is usually dominated by crustaceans, molluscs, and polychaetes with other groups, such as insects, nemertean worms, echinoderms, anemones, and fishes, being of minor importance or restricted to the extreme upper or lower fringes (McLachlan 2001, 744). Sandy beaches are open ecosystem in which food chains receive most their energy input from either the land or sea. The benthic food chain is also linked to the pelagic production (Alongi 1998, 15). For example the polychaete, *Laeonereis acuta* were found at the sand flat and it seems to constitute an important food resource for many crustaceans, fishes and birds (Omena and Amaral 2000, 429).

More than 70% of the world' s coast are sandy. The larger mobile infauna of soft sediment shores, particularly exposed sandy beaches, are generally poorly studied and perceived as difficult subjects for ecological experiments (Dugan and McLachlan 1999, 122). Relative to others shore types beaches have been rather neglected by ecologist (McLachlan 2001, 742). Very little is known about the long term consequences of natural or human induced disturbances on the structure and dynamics of sandy beaches population (Defeo and de Alava 1995, 73). Tropical sandy beaches, like those elsewhere, are the most widely utilized intertidal habitat for tourism and recreation, and experience major anthropogenic modifications (Dexter 1996, 26). These shoreline habitats are seriously threatened by human disturbance and pollution, which is a great need for further documentation of the biota of these poorly studied systems. (Dexter 1996, 26). Sandy beach organisms must be included in any comprehensive program of environmental monitoring (Souel & Kleppel 1988, 199). The ecology of sandy beaches is being subject of study of several authors in the last decades and it happens strongly after the international Symposium "Sandy Beaches as Ecosystems" realised in 1983 in South Africa (Barros 2001, 351).

Objectives

The major objectives of this study are as follows:

1. To study on species composition of macrobenthos on sandy beach in the eastern Gulf of Thailand.
2. To monitor on temporal changes in macrobenthos communities.
3. To analyse important environmental impacts on macrobenthos community.
4. To provide basic information for coastal management.

Hypothesis

Temporal changes in macrobenthos communities on sandy shores of Rayong Province are environmental bioindicators of sandy beach instability.

Scope of Research

This research concentrate on temporal changes in macrobenthos communities on sandy shores of Rayong Province, environment factors controlling structures of macrobenthos communities and using macrobenthos indicators as an early warning of pollution or degradation in sandy beach ecosystem.

CHAPTER 2

LITERATURE REVIEW

Beach Types

Beach (or shore) is the zone from mean low water line to the inner edge of the landward limit of effective wave action; normally to the foot of coastal cliff or to the line of permanent vegetation. A beach includes foreshore and backshore, the former lying between the low and high water marks where wave uprush and backwash, and the latter extending from the high water shoreline to the landward limit of wave during the most severe storms (Silvester and Hsu 1993, 111). Sand on beaches consist of tiny grains of quartz, which are weathered from granite or other igneous rock by mechanical or chemical means. It is composed of silicon (Si) and oxygen (O) bounded chemically to form silica (SiO_2). A sand is generally of glassy appearance but can contain other minerals to give it distinct coloration (Silvester and Hsu 1993, 112). Mclachlan (1980, 137-138; 2001, 742-743) described sandy beach types, ocean beaches are defined by the interaction of the wave energy they experience, they were tidal regimes, and the nature of the sand available for sorting and transport by the tide and wave. In a microtidal regime, where beaches wave dominated, three beach states can be recognized: reflective, intermediate, and dissipative. The reflective beach, characterized by a steep face and absence of a surf zone, occurs under a combination of coarse sand, which occurs under these conditions, causes all sediment to be stored on the subaerial beach face; the reflective beach thus represents the accretionary extreme in beach states. Waves surge up the beach face, where they may break before being reflected back to sea (Figure 1).

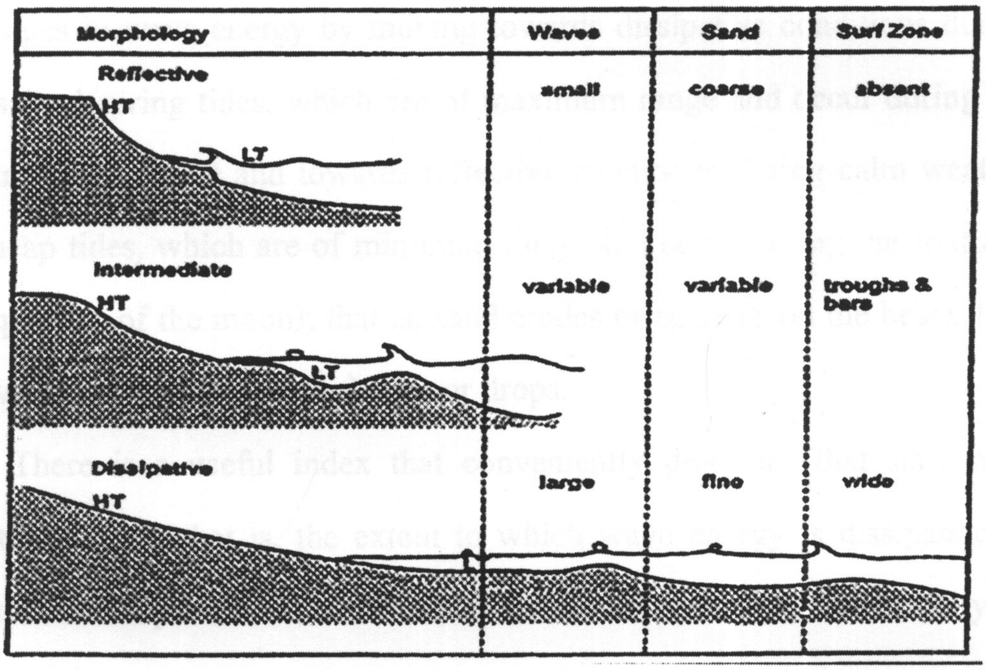

Figure 1 Three Morphodynamic States of Microtidal Beaches (HT=high tide, LT=low tide).

Dissipative beaches, in contrast, are a product of large waves moving over fine sand. This results in a flat beach face and wide surf zone. Waves break far out and dissipate their energy while traversing the surf zone as bores before expiring as swash on the beach face. Dissipative beach, with their sand spread out over extensive surf zones, thus represent the erosional extreme in beach states. Between these two extremes, intermediate beaches are distinguished by the presence of surf zones that are smaller than in the dissipative situation and generally 20-100 m wide. The intermediate surf zone characteristically has well-developed bars (sandbanks) and channels with rip current (Figure 1).

Beaches are not locked into a single morphodynamic state and respond to changes in wave energy by moving towards dissipative conditions during storms (and spring tides, which are of maximum range and occur during the new and full moons) and towards reflective conditions during calm weather (and neap tides, which are of minimum range and occur during the first and third quarters of the moon); that is, sand erodes or accretes on the beach face as wave height (and tide range) rises or drops.

There is a useful index that conveniently describes that state of a microtidal beach, that is, the extent to which wave energy is dissipatate or reflected. Dean' parameter, also known as the dimensionless fall velocity, is given by:

Omega = wave energy / sand fall velocity

where wave energy is given by modal breaker height (cm) divided by modal wave period (seconds) and sand fall velocity is the sinking rate (cm per second) of the mean sand particle size on the beach . Values for omega that are < 2 generally indicate reflective beaches and values > 5 indicate dissipative beaches. Under large tidal regimes (mean spring range > 4 m) beaches are generally tide dominated, whereas in intermediate situations (tide range 2-4 m) they are mix and either waves or tides can dominate. A useful index of the relative importance of waves and tides is the relative tide range (RTR) which is given by the mean spring tide range divided by the modal breaker height. By combining the dimensionless fall velocity and RTR, a two-dimensional model of beach states can be produce (Figure 2).

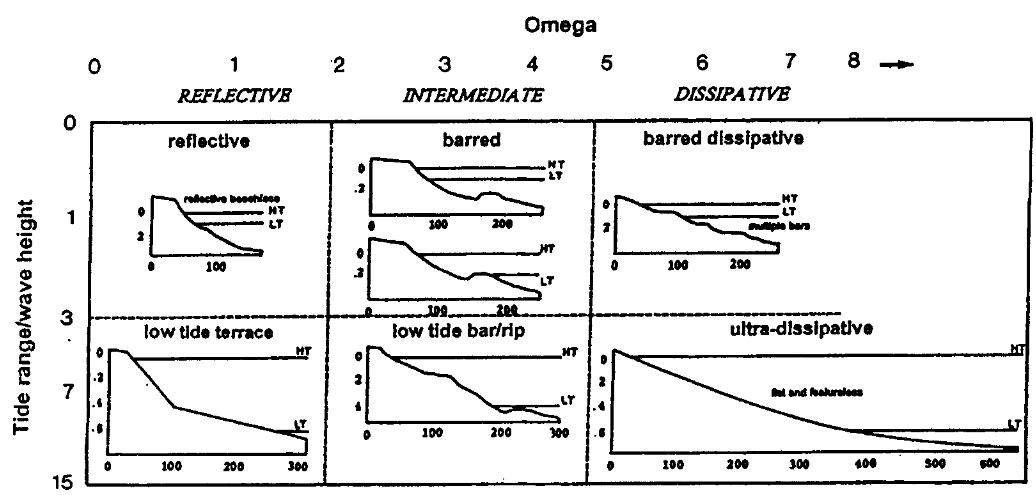

Figure 2 Two-Dimensional Modal of Beach States (McLachlan, 2001). Distance are in Meters.

Seasonal Variation

Zonation on sandy beach is also dynamic and variable; as the tide rise, many population change their position on the shore; or enter the water column (Lalli and Parson 1997, 206). Seasonal variations in the zonation patterns could be related to seasonal variations in water temperature (Brazeiro and Defeo 1996, 534).

Macrofauna assemblage is subjected to greater stress from physical factors (Fred and Roberts 1980, 506). Salinity, slope and beach/swash width were the main environmental variable in inducing change in the habitat of the macrobenthic community as a result of the gradient generated by the freshwater discharge (Lercari and Defeo 2003, 1170).

This could suggest that also at Zouara the juvenile of *Tylos europaeus* might be tied to specific organic matter freshly deposited along the drift line. In this way they could maintain under stable wave action and in the absence of large tidal excursion, the same zonation pattern in the two seasons. It can be hypothesizes that large-size individuals, mainly composed of males and breeding of females avoided area with unsuitable sand characteristics, such as, site where high sand salinity (Colombini et al. 2002, 1008).

The increase in abundance and biomass were associated with changes in the sediment environmental. The seawall construction seem to have influence the sedimentary environment of the sand flat which, in turn, appears to have effected the benthic community assemblage. The hydrodynamic processes, which determine sedimentary properties, play an important role in structuring the sand benthic community (Ahn and Choi 1998, 814-816).

It was not only population abundance that differed along the shore, but also the population structure, which a physical rather than a biology explanation (Donn 1987, 221). *Donax serra* has the ability to control its emergence from the sediment and weather it moves upshore or downshore and perhaps the amount of this movement. The bivalves can be moved laterally due to wave action alongshore currents. Infauna distribution patterns on sandy beaches are scale dependent (Giménez and Yannicelli 2000, 122). Relative position of seaward zone vary within the magnitude of wave action (Rakocinski et al. 1993, 98).

The *Donax serra* are carried in a clockwise direction around the bay (Donn 1987, 222). In *Emerita brasilensis* and *Excirolana armata*, the shape of the patches was ellipsoidal oriented obliquely to the longshore axis of the back with the shortest axis parallel to the direction of the upswash movement (Giménez and Yannicelli 2000, 120)

McLachlan (1996, 215) explained the reasons for change in community structure, including loss of species such as sand mussels, following tailing disposal could be (1) increasing sand particle size limiting body size, borrowing rates and other functions in a variaty of species; (2) smothering by rapid accumulation of tailings; (3) clogging of gills and other structures by the mud plumes associated and concomitant changes in swash climate.

Trevallion et al. (1970, 276-277) reported the main fauna division summarised as follows:

1. An upper zone which is characterized by the Talitridae and Ocypodidae. Within this zone, also there may be found individuals of some *Donax* species.

2. A middle zone characterized normally by an isopod of the family Cirolanidae, and by one or more spionid polychaete. Certain bivalve species may be found in the lower part of this zone.

3. A lower zone which is less well characterised by resident species

burrowing prawns such as *Callianassa* sp., and stomatopod cruatrsceans like *Lysiosquilla* sp., which inhabit semi-permanent burrows, also appear commonly in this zone as do gastropod of the genus *Terebra*.

The beach level located at the dry zone, drift line and uppermost beach level of the retention zone were characterized by *Orchestoidea tuberculata* and *Emerita braziliensis* those beach level which included most of the retention zone were most occupied by *Excirolana hirsuticauda* and *Euzonus heterocirrus* and the resurgence and swash zone were typically occupied by *Emerita analoga* (Jaramillo 2000, 14).

Across shore variation seems to occur commonly in assembleges of sandy beach macrofauna. Assemblage of sandy beach macrofauna varied among zone across the beach and similar pattern of zonation occurred along the entire beach. (James and Fairweather 1996, 83-101).

The abundance of individual taxa varied at several spatial scales both along and across shore. Across shore difference were detected among levels (James and Fairweather 1996, 102). Seasonal change in both phenological and environmental influences may elicit dynamic zonation pattern (Rakkocinski et al. 1993, 97). The distribution within each zone was mainly due to a preference for specific microhabitat characteristics and food source (Colombini et al. 2002, 1010).

The different species may be physically separated in their vertical distribution because their response to the changing physical characteristics of the beach during the tidal cycle differ (Ansell et al. 1972, 330). Distribution of sandy beach macrofauna that are daily tidal migrant and those that occur at lower tidal levels might be influenced more by long shore currents and such animal may exhibit movement rate (Dugan and McLachlan 1999, 121). Variation in the tidal level must be considered as a crucial descriptor of the intertidal gradient, acting as a spatially asynchronous key factor in the form and intensive of the patchy distribution and in the relative position of the fauna across the beach (Brazeiro and Defeo 1996, 543). Species distribution at times overlapped or swapped adjacent zones. Variability in species spatial distribution increased from reflective beach to dissipative beaches, suggesting that latter would harbor the most variable communities regarding spatial distribution. Slope was the main factor controlling in zonation pattern (Gimnez and Yannicelli 1997, 205). The intertidal distribution of crabs differed between beach, at the dissipative beach they were primary located at the swash zone, while at the reflective beach they were mostly located at the low tide level and shallow subtidal (Jaramillo et al. 2000a, 113). Seasonal variability could be related to seasonal variation in water temperature, which lower temperature would be the reason for the seasonal migration of the species toward their lower levels of distribution (Brazeiro and Defeo 1996, 534). Temporal change in species distribution may be a consequence of difference in morphological adaptation of organism to move and bury in the sandy beach environment (Degraer et al. 1999, 750).

The decrease of the density and biomass in the high intertidal zone may be explained the heavy storm, which affected the sediment in the uppermost stations (slightly increasing the coarseness) and the freezing temperature, cover the high intertidal zone with ice, prior to the winter sampling campaign.

In the low intertidal zone, no impact of the storm on the sedimentology and because of the more frequent submergence of the low intertidal zone, temperatures on and in the sandy sediments were buffered by the more temperature water (minimum 2°C). On the other hand, even with high mortality rate during winter, the low intertidal species association can retain similar densities and biomass due to a possible continuous influx of animal from the subtidal into the low intertidal zone. The high intertidal species association lacks this habitat continuity with a source of immigrants: strong disturbances may deplete these populations (Degraer et al. 1999, 750)

In general, change in species distribution as a consequence of change of swash zone position could occur by different mechanisms. (Giménez and Yanniclli 1997, 206). Variation in community structure have been related to seasonal changes in physical factors which the fauna experience (Dexter 1984, 667). The number of species was lowest at the most exposed site and increased with decreasing exposure, crustacea dominated the more exposed sites and polychaete become more abundant with increasing protection (Dexter 1984, 671).

Wu (1998, 46) explained the patterns in the distribution of infauna across the intertidal zone as follows:

1. The changes in the environment across the intertidal give rise to a set of conditions, which differentially favour the survival of different taxa.

2. Some taxa are highly mobile and migrate across the intertidal zone moving between stations as the tide move in and out. This mobility of taxa

will therefore result in a varying picture of the composition of these communities depending upon the state of the tide at the time of sampling.

Relationship between Macrobenthos and Beach Morphodynamics

Jaramillo et al. (2001, 324-342) analyzed the seasonal relationships between community structure and beach types at eight sites distributed from the northern coast of Chile (18-20 °S) to that of southern Chile (40-42°S). The study showed that the community structure of the intertidal macroinfauna of Chilean sandy beaches locate along a latitudinal gradient of about 3000 km does not change linearly with changes in beach morphodynamics Highest abundance and biomass of the macroinfauna were found at intermediate beaches located near area of persistents (upwelling water enhanceing primary productivity) are also important in the community structure of the sandy beach macroinfauna.

Dean's parameter was the best predictor for species richness (Jaramillo and McLachlan 1993, 620). Sampling sites with intermediate values of Dean's parameter (low intermediate beach states) usually had the highest abundance and biomass values (Jaramillo 2001, 340). Species richness and macroinfauna abundances were higher at site and lower at the reflective beach, show that beach types are not always good predictors of community attributes on exposed sandy beaches (Jaramillo et al. 2000b). The isopod *Exirolana hirsuticauda* tended to be larger in size in beach with steeper profiles (more reflective condition) (Jaramillo and McLachlan 1993, 621). Crabs from the dissipative beach reached large sizes than those at the reflective beach (Jaramillo et al. 2000a, 113).

Grain Size

Mean grain size was the best predictor for the spatial variability of abundance biomass of macroinfauna (Jaramillo and McLachlan 1993, 620). The grain size distributions are the location of the largest sand particle at the bar plunge point of the breaker location and a decrease in the grain size both toward deeper water and shoreward across the surf and the swash zone with the finest material in the offshore part of the profile (Medina et al. 1994, 202). Dugan et al. (2000a, 243) suggested that none of the hippoid species investigated would be exclude on the basis of grain size alone in that range of sediment.

Distribution and abundance of species were strongly influenced by tidal level. Densities changed during the year but no seasonal changes in interidal zonation patterns. Changes in density were correlated with the reproductive activities of the abundance species (Dexter 1984, 663).

Sound is a major cue in determining whether these clams jump out of the sand to swash-ride. Loud sounds from large waves stimulate the clams to jump, and an endogenous rhythm of responsiveness modulates the jumping behavior and is thus a proximate cause of the characteristic tidal migration of these clams (*Donax variabilis*). A large fraction of clams is responsive at high than at low tide (Ellers 1995a, 135;1995b, 128-137).

Human Disturbances

Disturbance, human activities, may strongly influence the structure of macrobenthos communities inhabiting exposed sandy beach (Dugan et al. 2000b, 343). Defeo and de Alava (1995, 73-82) suggested that two different sources of human impact appeared to produce the distribution patterns of the wedge clam population observed in the field: (1) The fishing activity exerted on the sympatric bivalve (2) Fishing effort exerted of *Mesodesma mactroides* was the lowest and was less reliable predictor of wedge clam recruitment abundance, the salinity variation cause by the canel. The relative importance of the harshness of the physical environment could out weigh the effect of human exploitation (Defeo and de Alava 1995, 80).

A total density was slightly lower in the exploitation areas than in unexploited sites, but within these areas no relationship existed between the density of the benthos and the density of people searching. The species richness analysis indicated that the exploited area had a somewhat lower species richness than the unexploited area. This was mainly caused by non abundant species that were not taken by the local population (Boer and Prins 2002, 234).

It is possible to hypothesize that any engineering structure installed in the back shore of sandy beaches would have more effect on small pocket beaches, as in the case of the beach at Los Molinos. It would be expected that change in sediment size and hence in beach face slope would primarily happen during such condition; i. e., rise in sea level would lead to beach erosion since the construction of the seawall took about 3 m of the upper beach levels. There is little literature on the effects of engineering structure upon macroinfaunal sand beach communities. Upward movement and digging deeper may then help to cope with changing beach condition (Jaramillo 2002, 527-528).

The heterogeneous sediment, the organic matter content, and salinity were important for distribution of the mollusk community. Moreover, the distributions of some species could be related to variations in tide level and availability of food (Arruda and Amaral 2003, 299).

Barros (2001b, 401-403) Staked that human activity on beaches appears to affect ghost crabs in some way. Exactly how is not yet understood. Construction of roads and buildings immediately above the dunes results in modification of the exchange and the supply of sand in the beach/dune system, and potentially can interfere with the movements of many animals, such as ghost crabs. Therefore, it is recommended that counting number of ghost crabs be included in ecological or morphological sand dunes surveys, because dune modification will affect part of the habitat of these animals. Different human impacts like erosion prevent works (e. g. beach nourishment, groynes, sand dune restoration) and recreational activities (e. g. trampling, fishing, off-road vehicles) must be considered for sandy beach ecosystems (Barros et al. 2001, 362). Beach bulldozing caused reduction of densities of *Emerita* in the intertidal zone and ghost crabs on the high shore by 35-37 % and 55-65 %, respectively (Peterson et al. 2000, 375).

Defeo and Rueda (2002, 1224) summarized that; (1) geostatistics provided key information on spatial organization and for abundance estimation, and, thus, it is suggested as a powerful tool for further application in studies of sandy beach macroinfauna. (2) Environmentally driven sampling strategies are prone to distorting reality concerning the nature of spatial structure, thereby provide biased abundance estimates and, thus should be avoided in sandy beach population studies.

Movement Mechanisms

Burrowing in soft-bodied animals, such as polychaete worms, burrowing anemones, bivalves and gastropods, is essentially similar. There is an initial penetration phase followed by burrowing proper. Penetration is usually made by repeat small movements. Large movements would end up displacing most animals away from the sediment because their weight is low in water. In worms such as *Arenicola*, repeated probing movement the proboscis are made, each movement applying very little force (Figure 3). This scarping action pushes sediment aside and the head becomes drawn into the initial burrow. The pharynx is then everted, enhancing the probing of the proboscis. Subsequently, waves of contraction of the body wall dilate the mouth and evert the proboscis against the sediment. Anchorage is achieved by the worm sticking to the sediment using its chaetae and by flange-like ridges on the front segment which become erect and press against the sediment. After about 20 seconds, sufficient penetration has been achieved for the burrowing cycling to start. In bivalves, initial penetration is achieved by rapid probing of the foot. Once the animal is firmly lodged in the sediment, burrowing proper occurs through a series of powerful digging movements. In bivalves, the penetration anchor is formed when the shell presses against the substratum when the adductor muscle is relaxed (Figure 3). The foot then extends downwards. The siphon close next, and following contraction of the adductor muscles, water is forced out either side of the foot causing a short-lived liquefaction of the sand. The increase in internal haemocoelic pressure by the contraction of the adductor muscle expands the far end of the foot to form a terminal anchor which press against and dilate the sediment. The anterior and retractor muscle contract, pulling the shell in to the sediment (Raffaelli and Hawkins 1996, 159-162).

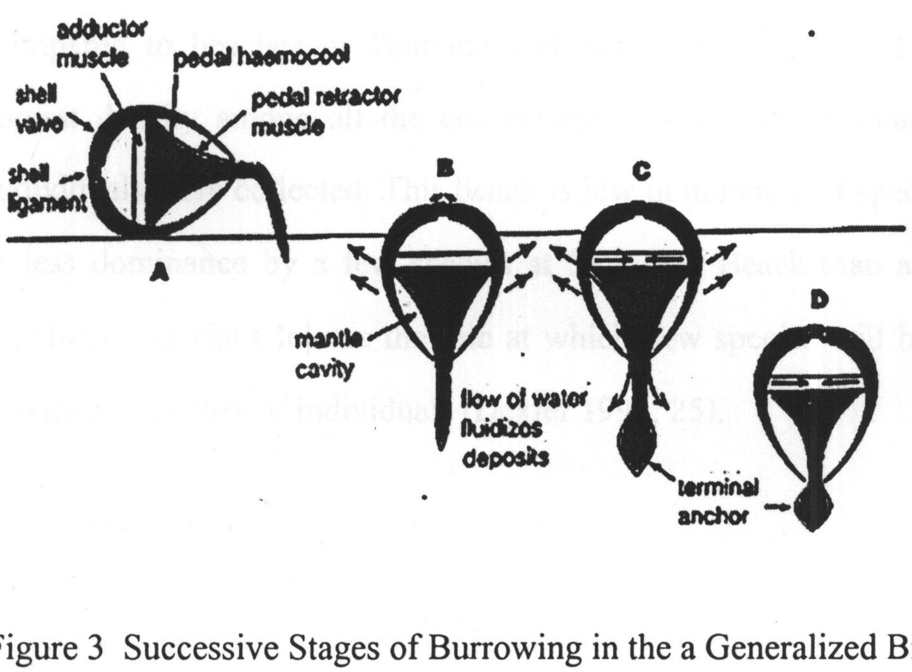

Figure 3 Successive Stages of Burrowing in the a Generalized Bivalve. Based on Newell (1979) from Truema (1975).

Dexter (1996, 2-23) investigated the community structure of several beaches (13 beaches), to identify the macroscopic invertebrate living in the intertidal sand and to document densities, zonation, and seasonality. Beaches along the open northwest coast of Phuket Island are subjected to the greater wave action, median grain size ranges from medium to very coarse sand, and fauna diversity and density are low. Although infauna densities may increase during the dry season, when wave action is reduced, the sediment grain size remains high (Dexter 1996, 23) All study sites experience changes in physical conditions seasonally with higher wave action and rainfall during the southwest monsoon season. Change in fauna composition and community structure coincide with such change, and overall the total number of species is increased by such seasonality. When comparison between more intensively sampled tropical and temperature beaches. The data suggested that a major difference in species richness among the tropical beaches of Panama compared to beaches in Thailand and Singapore Shimmey beach had the lowest density among all the comparison beaches, but similar numbers of individuals were collected. This beach is low in numbers of species, but there is less dominance by a few species at Shimmey Beach than at Naos. High dominance at Naos lowers the rate at which new species will be added with increasing number of individuals (Dexter 1996, 25).

Trophic Relationships

In spite of the fact that the species from intertidal sandy beaches do not present any commercial value, they are links of a complex trophic network with other subtidal species that are important fisheries resources for region fisherman (Barros et al. 2001, 362). The beach itself produced little direct nutritional support for the macrobenthos (Ansell et al. 1972a, 60). The food chain of intertidal sands begin in organisms from other environments and end in the predacious animals not normally resident in the intertidal zone (Brown 1964, 38). *Emerita* and *Donax* are importance food source on high energy beaches. *Emerita* and *Donax* as the major link between plankton and detritus, which they eat, and large animals on the beach (including some subtidal fauna). And, the entire populations of *Emerita* and *Donax* become available to subtidal predators when they move from the wash zone to deeper water in mid summer and in the fall. (Leber 1982, 95).

Adaptation

Exposed sandy beaches are composed of unconsolidated sediments subject to constant movement by waves and represent a challenging and physically unstable habitat for intertidal organisms (Dugan et al. 2000a, 229). Body size and means of locomotion (such as swash-riding) were important parameters to which organisms were able to live on beaches as the swash "climate" harsher (Ellers 1995c, 146). Predation may be more intense on dissipative beaches and large size may provide a refuge from predation. Burial time usually increase with size, large clams will experience longer exposure to predators when exhumed by the waves. Bivalves from reflect beaches to be uniformly small, medium to fast burrowing, wedge-shaped and of high density, whereas those from more dissipative beaches vary widely in all these characteristics (McLachland et al. 1995, 158-159) McLachland et al. (1995, 159) suggested that high density and wedge shape are primarily adaptations to aid stability and control to animal moving in the swash on the beach face. Morphology, temperature and sand particle size all influence burrowing rate in bivalves, streamline shape and thin shells without ornamentation aiding rapid burying. Burrowing behavior is an important adaptation for molluscs (McLachland et al. 1995, 157). Species which are rapid burrowers may be able to successfully inhabit a wider range of beach morphodynamic types than species which burrow slowly (Dugan et al. 2000a, 231). Huz et al. (2002, 92) suggested that sediment sensibility of *Donax trunculus* varies with its life cycle. Burrowing time of *Donax trunculus* increased with increasing shell length in all the grades of sand tested. The coarser granulometries had a negative effect on burrowing rating. Difference in burrowing time in the various sands indicate that Donax *trunculus* is a substrate sensitive organism. Huz et al. (2002, 92) observed differences in burrowing time in response to sediments of the various size classes. Shorter burrowing times of individual smaller than 25 mm were obtain in medium and coarse sand, whereas shorter burrowing times of individuals larger than 25 mm were measure in fine and medium sands. Differences in burrowing time of the difference size classes in graded sand were significant in the smallest (5-15 mm) and biggest (35-45 mm) individuals, whereas no significant differences were observed in the intermediate size classes.

The metabolic activity of *Donax trunculus* was relatively constant in the control granulometry. The coarser granulometries exerted a clearly negative effect on both metabolic activity and growth rate. This effect was greater on growth than on metabolic activity (Huz et al. 2002, 92). At the most unstable zone, adaptation together with the protection offered by the tube (Ong and Krishnan 1995, 31).

CHAPTER 3

MATERIALS AND METHODS

Study Sites

Four sandy beaches of Rayong Province were selected as they represented different environmental factors (Figure 4-8). Haad Paknamprasae located near the Prasae River,the beach was affected by freshwater. Haad Maepim located 2 km west of Laem Maepim. Haad Maeramphueng, the most popular beach for tourists, was affected from tourism activities. Haad Takaun located near Maptapud Industrial Estate, was affected from Indrustrial area.

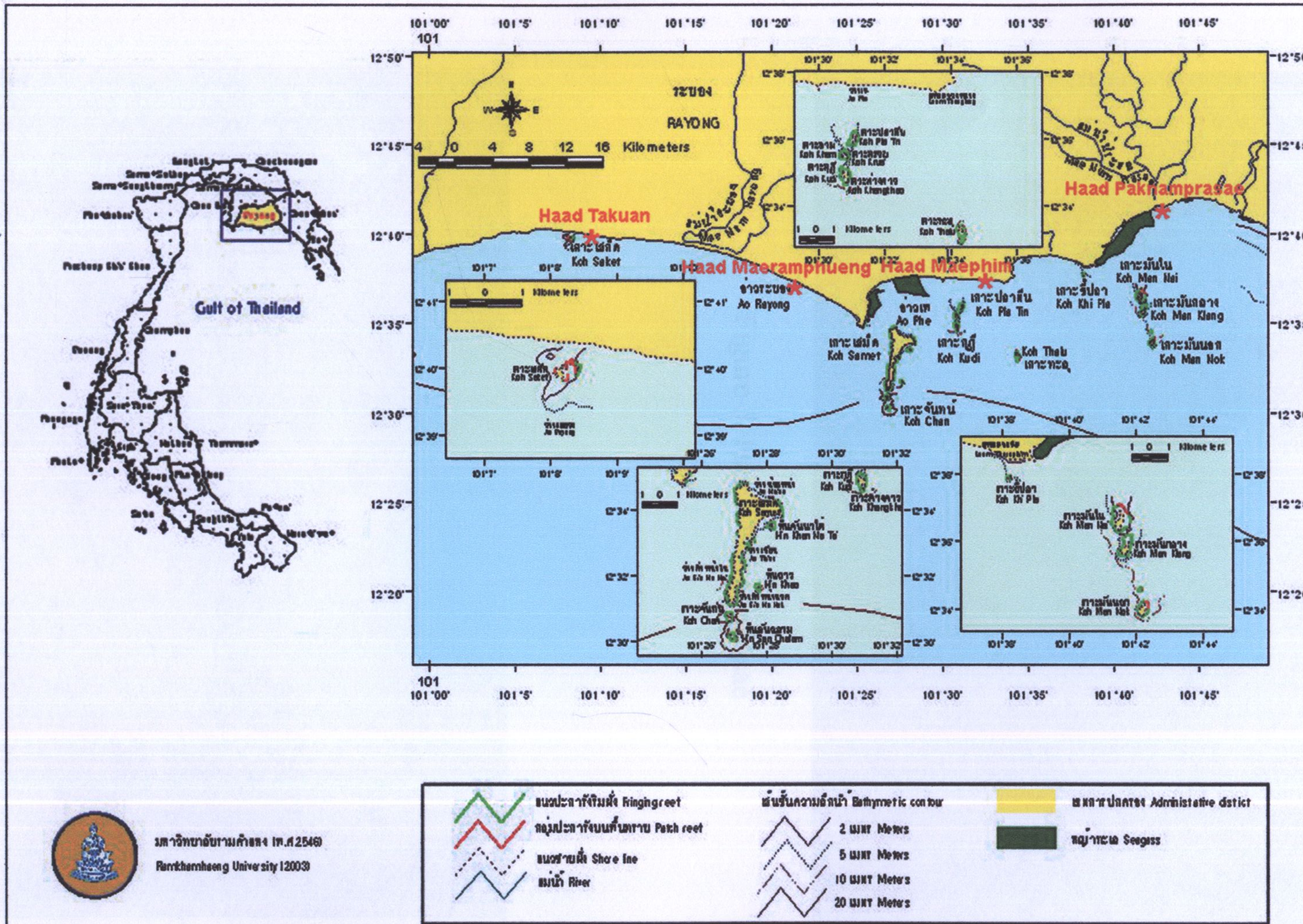

Figure 4 Four Sandy Beaches of Rayong Province

Figure 5 Haad Paknamprasae

Figure 6 Haad Maephim

Figure 7 Haad Maeramphueng

Figure 8 Haad Takuan

Field Works

Field studies were conduct bimonthly from December 1998 to July 2000. Macrobenthos were collection were made at lowest tide. The intertidal zone along the transect was divided into equal horizon. The transect were established perpendicular to the shoreline. A 0.1 m^2 quadrat was sampled to a depth of 30 cm in the sand at each station (Figure 9). Samples for macrobenthos were passed through a 0.5 mm. Sieve, hand-picked from the sieved material, separated into taxonomical groups and quantified (Figure 10-11). Preservation in 5% formalin in sea water and transfered to 70 % alcohol in laboratory were done.

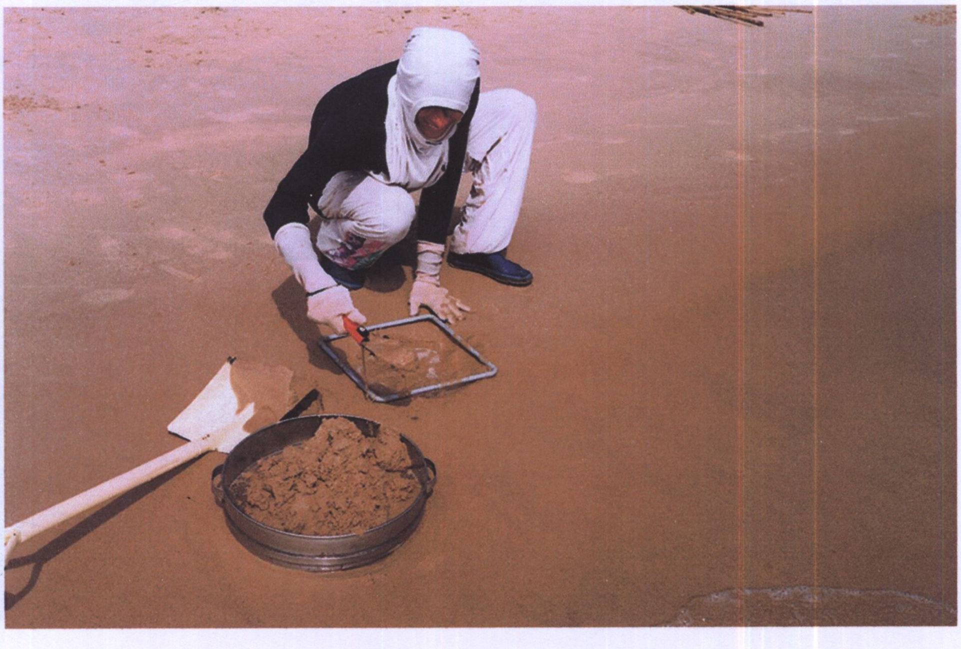

Figure 9 Macrobenthos Collection were During the Low Tide

Figure 10 Collection of Macrobenthos by Sieve

Figure 11 *Donax* sp. Collected From the Sieve

Physical Parameters Measurement

Water temperature were measured in the adjacent sea-water on each beach by using a mercury thermometer.

Salinity of the sea-water was measured to the nearest 0.51 by using a Reichest salinity refractometer.

Sediment collection for grain size analyses (100 grams dry-weight) and organic matter content analyses (20 grams dry-weight).

Beach profile were measured along the transect by using the Emery's profiling technique (1961) (Figure 12-13).

Laboratory Works

Organic Matter Content

Organic matter content was determined with the ash-free dry weight technique.: Sediment samples were oven dried at 105°C for 24 h. weighted 20 g and then burned at 550°C for 5 h, and finally weighed again to determine total organic matter:

$$\text{Total organic Content} = \frac{\text{Decrease in sample weight} \times 100}{\text{Oven} - \text{dry sample weight}}$$

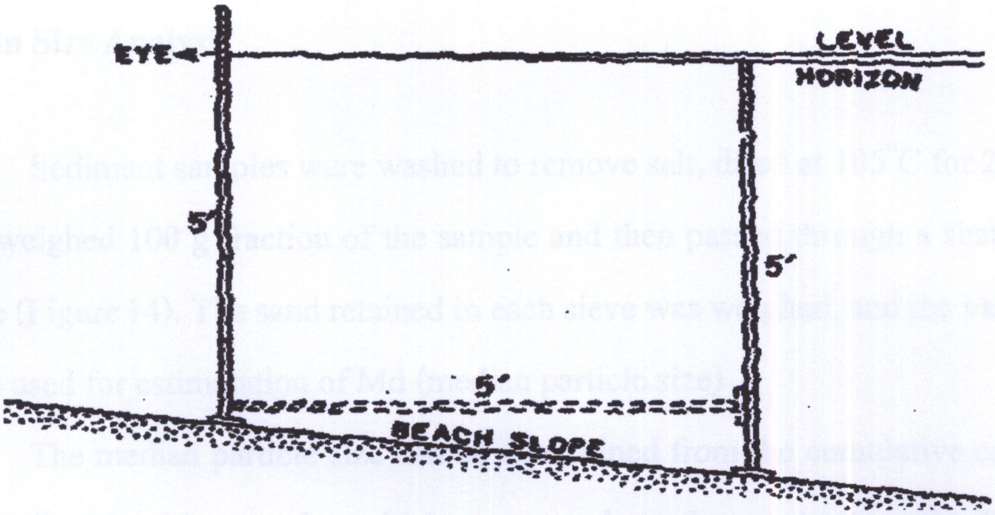

Figure 12 Sketch of Equipment-Two Wooden Rods 5 ft Long and Mark off in Feet and Tenth of Feet-Use for Measuring Profiles of Beaches

Sources: Emery, K. O. 1961. A simple method of measuring beach profiles. **Limnology and Oceanography** 6: 90-93.

Figure 13 Measuring Profiles of Beaches

Grain Size Analysis

Sediment samples were washed to remove salt, dried at 105°C for 24 h. and weighed 100 g fraction of the sample and then passed through a shaking sieve (Figure 14). The sand retained in each sieve was weighed, and the values were used for estimatation of Md (median particle size)

The median particle size can be determined from the cumulative curve by reading the micron value which corresponds to the point where the 50 % line crosses the cumulative curve.

Macrobenthos Procedures

Macrobenthos Identification

Community parameter are data analysed from the samples at a higher taxonomic level such as family or phyla, rather than to species.

Macrobenthos were removed, identified to species if possible and counted (Figure 15). Counts were reported as total densities (number of ind/0.1 m^2). Polycheates were identified to the lowest taxonomic level as possible, as it was the dominant faunal group, and counts were similarly reported as species densities.

Figure 14 The Shaking Sieve for Grain Size Analysis

Figure 15 Sample of Macrobenthos for Species Identification

Size–Frequency Distribution

The anter–posterior lengths (shell length) of all *Tellina* sp. and *Donax incarnatus* were measured to the nearest 1 mm with vernier calipers. The data were used for size-frequency distribution analyses.

Statistical Analysis

Multivariate analyses by using Principal Component Analysis (PCA) for grouping in macrobenthos communities were applied. Transformation of raw data before computing the ordination was also carried out. The data transformation was done by using Log transformation, Log (1+X) (Zar 1999).

Statistical treatments of the data included determination of species diversity (H') by Shanaon–Wiener index and species eveness (J')

One-way ANOVA procedures tested for differences in density of macrobenthos between beaches, and for difference on median grain size on each beach were analyzed.

Two-way ANOVA procedures tested for pH, mean organic matter, salinity, temperature of sea water, species diversity index of macrobenthos, evenness index of macrobenthos and density of macrobenthos on each beach were also carried out.

t-test procedures tested for differencet in shell length of bivalves were applied in certain cases.

Regression procedures tested for relationship between species diversity index of macrobenthos and environmental factors were carried out.

CHAPTER 4

RESULTS

Environmental Factors

Temperature:

The sea water temperature varied between 27 °C to 36 °C. The sea water temperature was high in April 2000 (36°c), at Haad Paknamprasae. The variations of sea water temperatures were shown in Figure 16. They were significantly different both space and time ($P < 0.05$).

pH:

pH of sea water varied from 6.9 to 8.4 (Figure 17). pH showed little variation during the study period ($P < 0.05$). They were not significantly different between beaches ($P > 0.05$).

Salinity:

Salinity of sea water was found between 11 ‰ to 35 ‰ (Figure 18). At Haad Paknamprasae, in May 1999 and September 1999, salinities were lower than those of other months (only 17‰ and 11 ‰, respectively) and lower than thosed of the other beaches because the former is located near the Prasae River. The salinity of sea water at Haad Maephim and Haad Maeramphueng were similar ($P > 0.05$). The salinity of sea water of Haad Takuan, in September 1999 was lower than those of other months, (16 ‰). The salinity was significantly different between beaches and significantly different in seasons (Two-way ANOVA, $P < 0.05$).

Organic Matter Content

The mean organic matter content was found between 0.30% to 3.43% (Figure 19). The mean organic matter content was highest at all beaches in December 1998 and 1999. Lower organic matter contents were found in July 1999 and 2000. The organic matter contents were significantly different among beaches and months (Two-way ANOVA, $P < 0.01$).

Figure 16 Temperature Variation on Sandy Shores of Rayong Province, Haad Paknamprasae, Haad Maephim, Haad Maeramphueng, and Haad Takuan

Figure 17 pH Variation of Sea Water on Sandy Shores of Rayong Province, Haad Paknamprasae, Haad Maephim, Haad Maeramphueng, and Haad Takuan

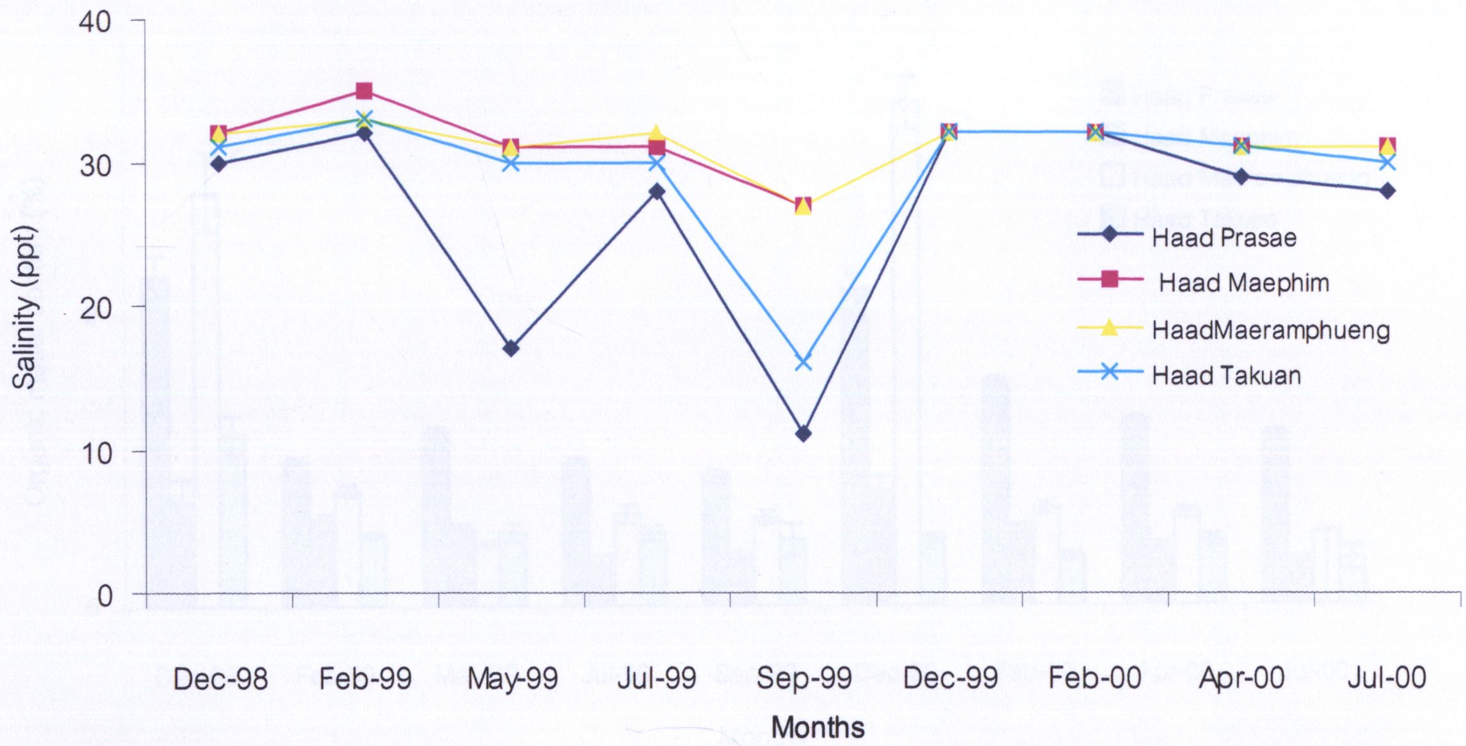

Figure 18 Salinity Variation on Sandy Shores of Rayong Province, Haad Paknamprasae, Haad Maephim, Haad Maeramphueng, and Haad Takuan

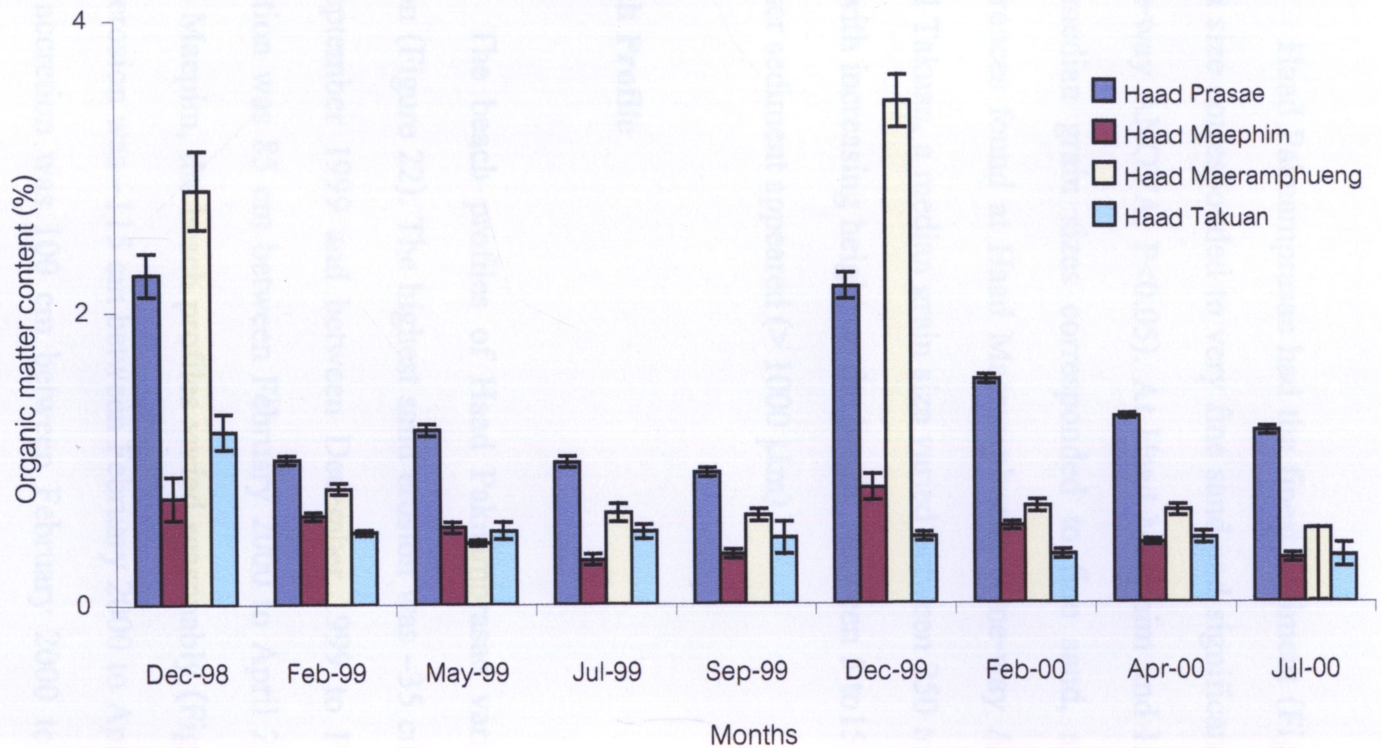

Figure 19 Temporal Variation of Mean Organic Matter Content (mean±S. E.) on Sandy Shores of Rayong Province, Haad Paknamprasae, Haad Maephim, Haad Maeramphueng, and Haad Takuan.

Grain Size

Haad Paknamprasae had the finest sediment (Figure 20). The median grain size corresponded to very fine sand and significantly seasonal different (One-way ANOVA, $P<0.05$). At Haad Maephim and Haad Maeramphueng, the median grain sizes corresponded to fine sand, significantly seasonal differences found at Haad Maeramphueng (One-way ANOVA, $P<0.05$). At Haad Takuan, a median grain size varied between 250 to > 1000 μm (Figure 21) with increasing height on the beach. Between 5 to15 m (from drift line) a coarser sediment appeared (> 1000 μm).

Beach Profile

The beach profiles of Haad Paknamprasae varied slightly between season (Figure 22). The highest sand erosion was –35 cm between July 1999 to September 1999 and between December 1999 to February 2000. Sand accretion was 85 cm between February 2000 to April 2000 (Figure 23). On Haad Maepim, the beach profiles varied seasonably (Figure 24). The highest sand erosion was –115 cm between February 2000 to April 2000. The highest sand accretion was 100 cm between February 2000 to April 2000. At the middle beach (15-50 m from the drift line) the highest sand particle transport was found (Figure 25). Haad Mearamphueng was a stable profile (Figure 26). The highest sand erosion was –70 cm between February 1999 to May 1999.

The highest sand accretion was 65 cm between May 1999 to July 1999 (Figure 27). Haad Takuan beach was the highest temporal changes in beach profile (Figure 28). The highest sand erosion was –165 cm between April 2000 to July 2000. The highest sand accretion was 120 cm between February 2000 to April 2000. At the upper beach (5-20 m from drift line), the highest sand particle transport was found (Figure 29).

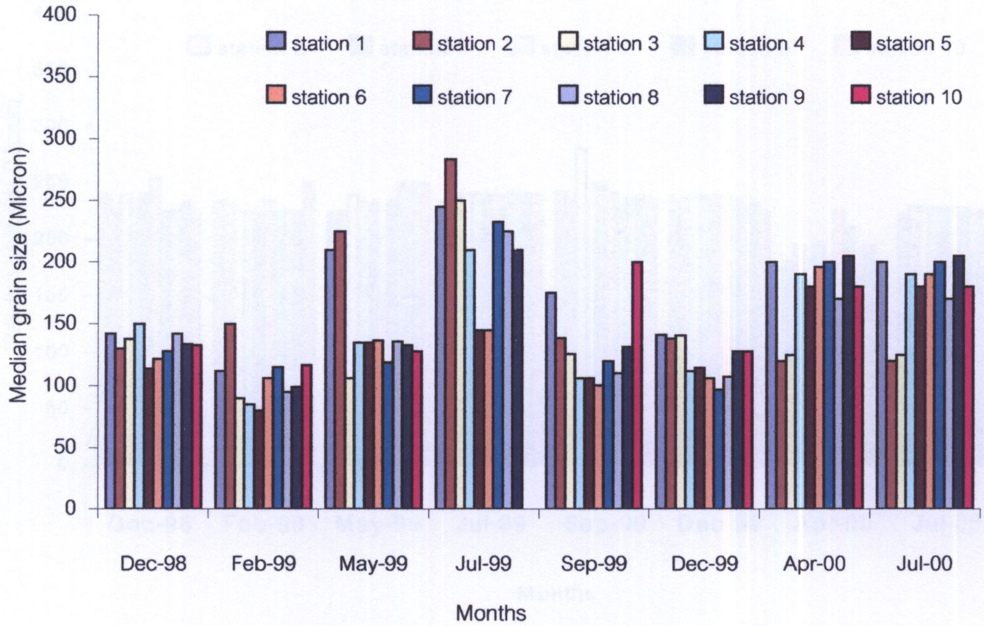

Figure 20 Median Grain Size on Haad Paknamprasae

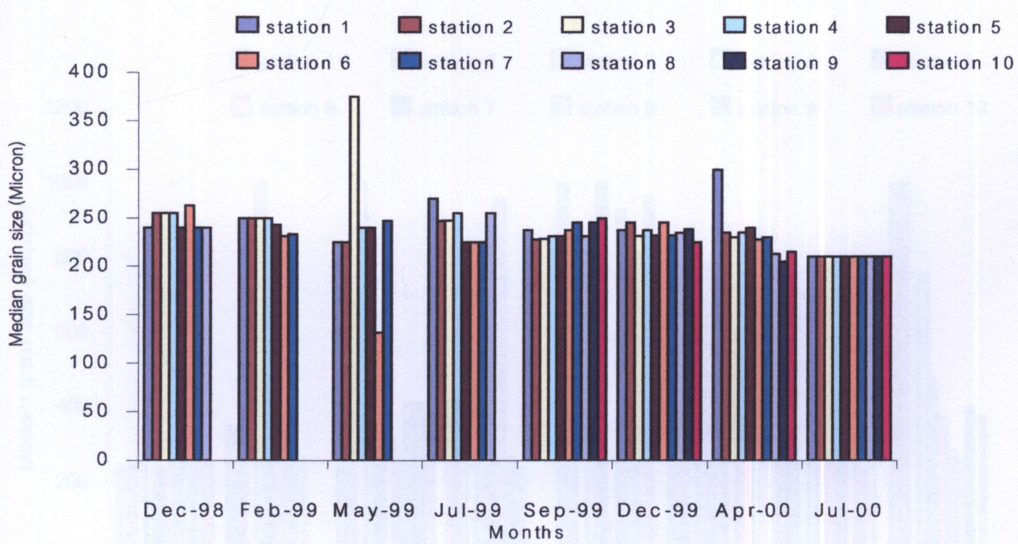

Figure 21 Median Grain Size on Haad Maephim

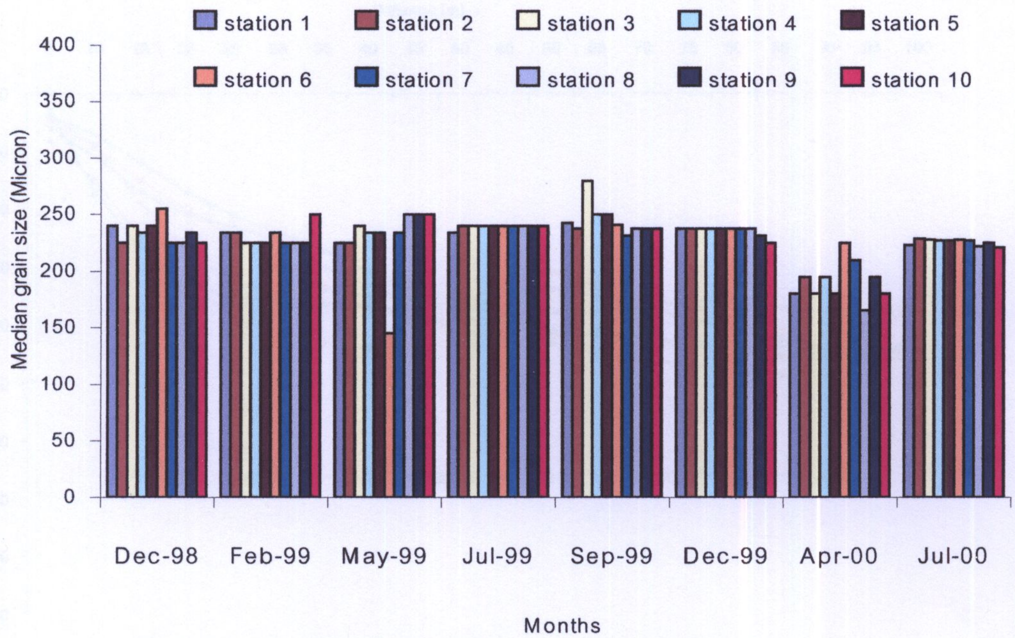

Figure 22 Median Grain Size on Haad Maeramphueng

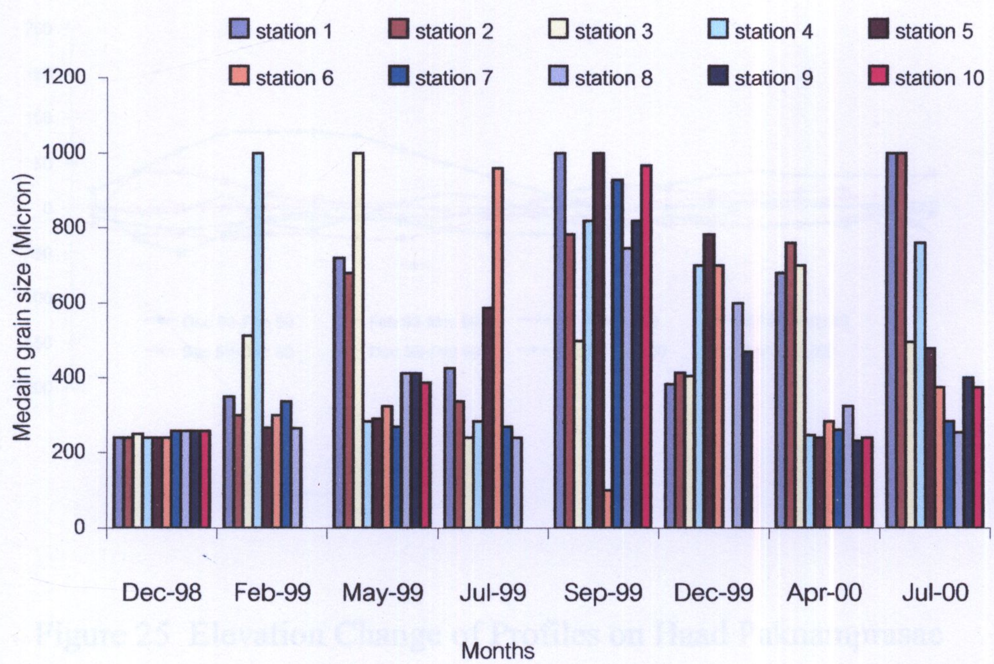

Figure 23 Median Grain Size on Haad Takuan

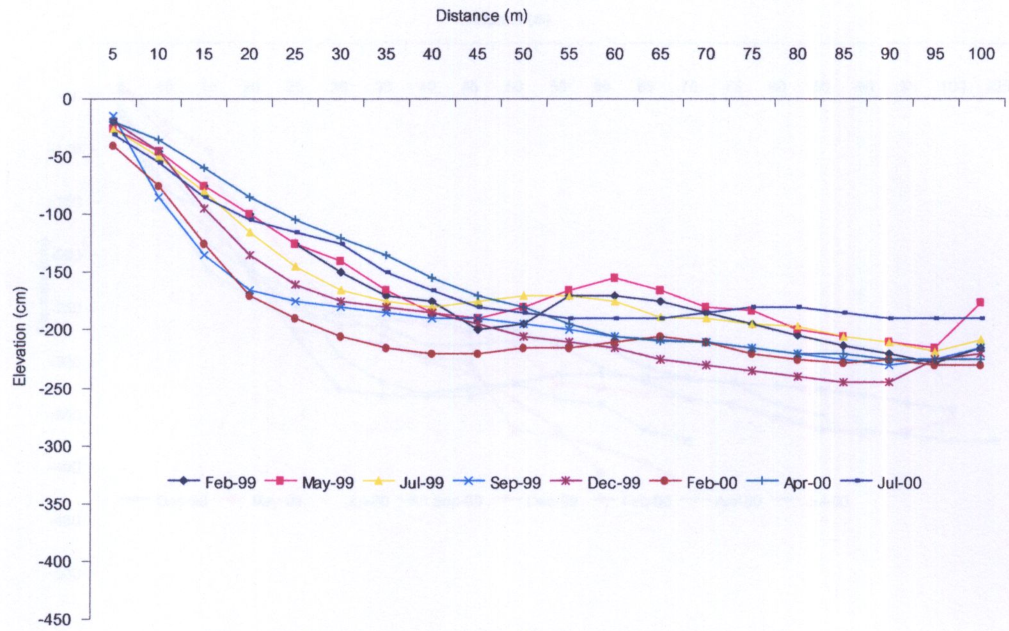

Figure 24 Beach Profiles of Haad Paknamprasae

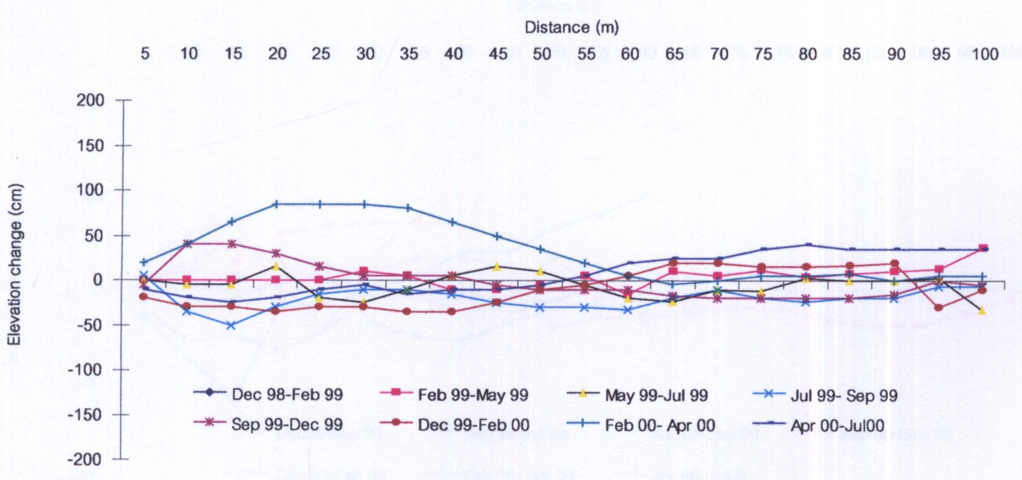

Figure 25 Elevation Change of Profiles on Haad Paknamprasae

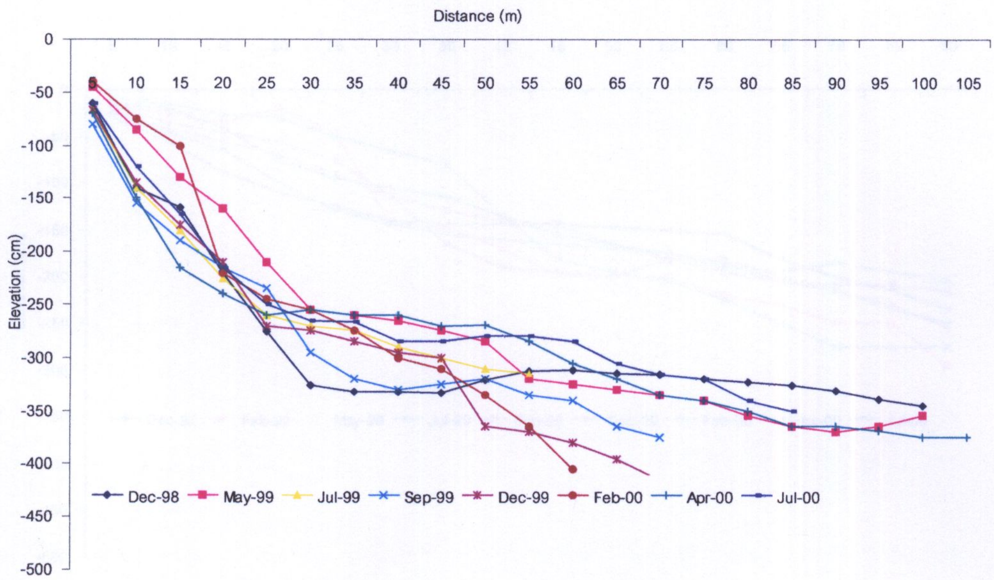

Figure 26 Beach Profiles of Haad Maephim

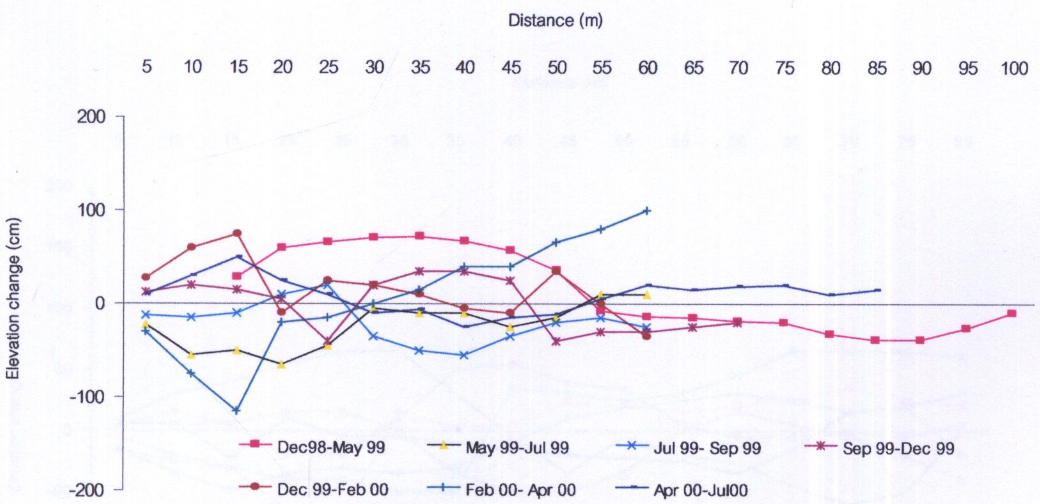

Figure 27 Elevation Change of Profiles on Haad Maephim

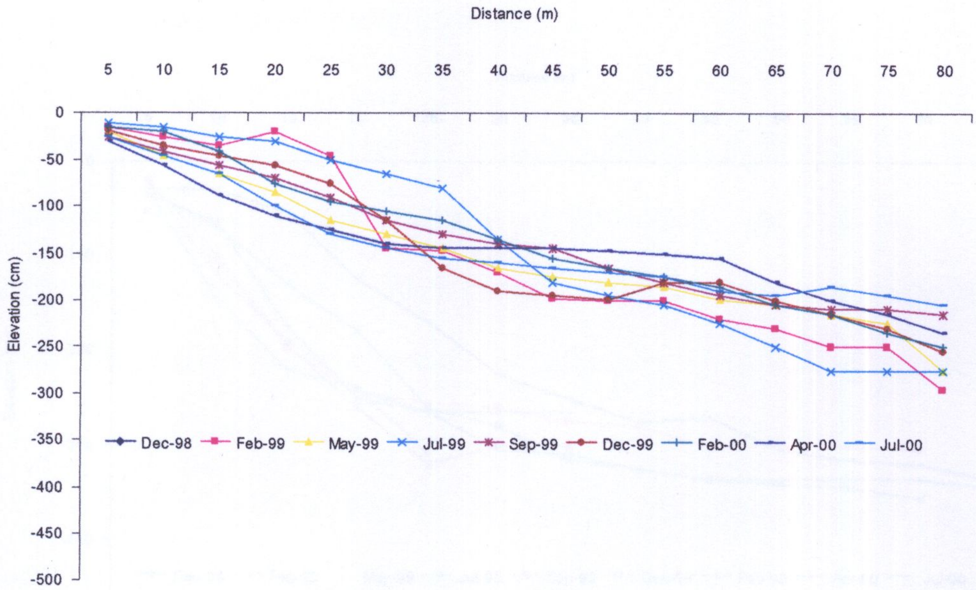

Figure 28 Beach Profiles of Haad Maeramphueng

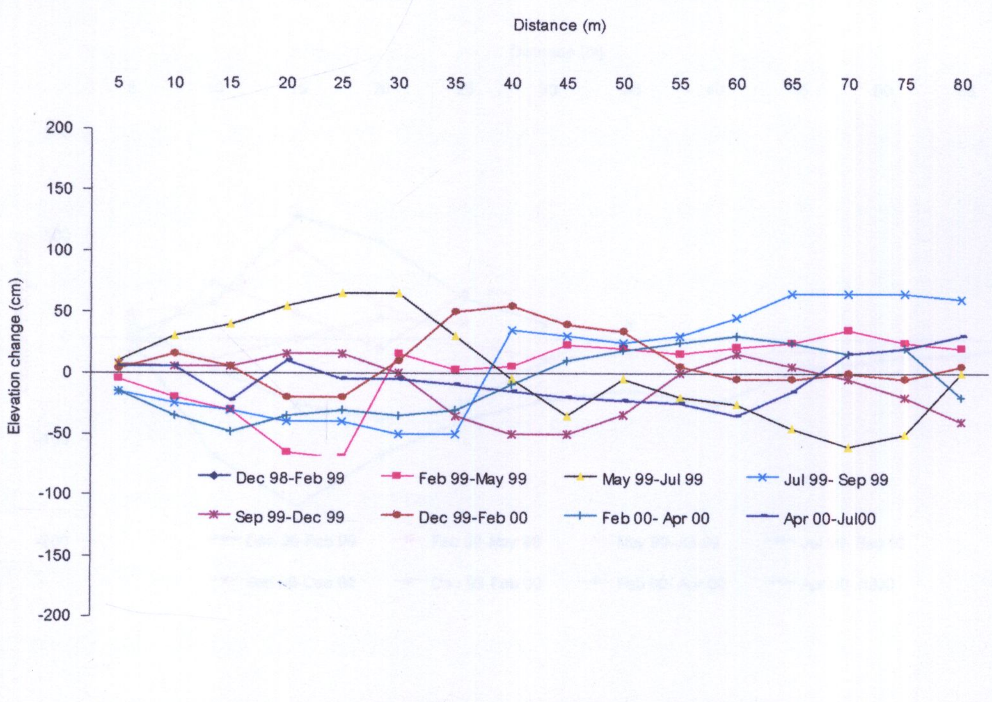

Figure 29 Elevation Change of Profiles on Haad Maeramphueng

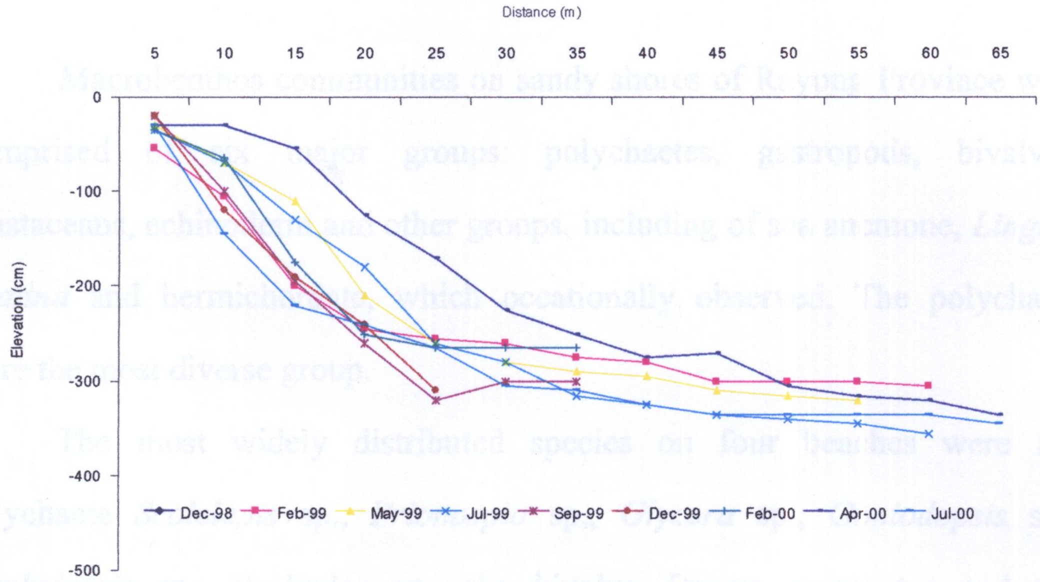

Figure 30 Beach Profiles of Haad Takuan

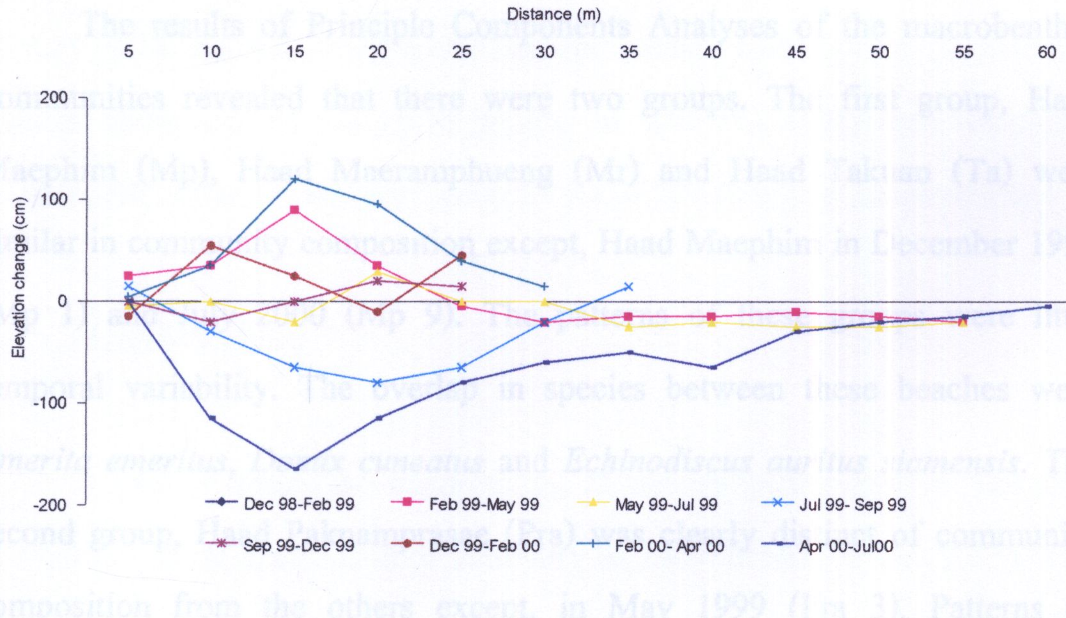

Figure 31 Elevation Change of Profiles on Haad Takuan

Species Composition of Macrobenthos

Macrobenthos communities on sandy shores of Rayong Province were comprised of six major groups: polychaetes, gastropods, bivalves, crustaceans, echinoderm and other groups, including of sea anemone, *Lingula anatina* and hermichordate, which occationally observed. The polychates were the most diverse group.

The most widely distributed species on four beaches were the polychaete *Scolelepis* sp., *Prionospio* sp., *Glycera* sp., *Goniodopsis* sp., *Lumbrineris* sp., *Scoloplos* sp., the bivalve *Donax incarnatus* and the gastropod *Antillophos* sp. The total diversity index (H') of macrobenthos community at Haad Paknamprasae was highest (2.478) followed by Haad Maeramphueng (2.155), Haad Takuan (2.059) and Haad Maephim (0.936).

The results of Principle Components Analyses of the macrobenthos communities revealed that there were two groups. The first group, Haad Maephim (Mp), Haad Maeramphueng (Mr) and Haad Takuan (Ta) were similar in community composition except, Haad Maephim in December 1998 (Mp 1) and July 2000 (Mp 9). The patterns of these groups were little temporal variability. The overlap in species between these beaches were *Emerita emeritus*, *Donax cuneatus* and *Echinodiscus auritus siamensis*. The second group, Haad Paknamprasae (Pra) was clearly distinct of community composition from the others except, in May 1999 (Pra 3). Patterns of community composition on Haad Paknamprasae were distinct temporal variability (Figure 32). The differences between two groups were caused by many species of the polychaetes.

Haad Paknamprasae:

A total of individuals representing 50 species were collected. The total diversity index of macrobenthos community on Haad Paknamprasae was 2.478. The species composition of macrobenthos are shown in Table 1. The macrobenthos were numerically dominated by the bivalves *Tellina* sp. (Figure 33) with an abundance of 3.84±1.28 ind./0.1m^2 (36.64%), the polychaete *Scoloplos* sp. (Figure 34) with an abundance of 1.44±0.51 ind./0.1 m^2 (13.80%), the gastropod *Umbonium vestiarium* (Figure 35) with an abundance of 0.97±0.50 ind./0.1 m^2 (9.30%), the razor clam *Solen* sp. with an abundance of 0.89±0.34 ind./0.1 m^2 (7.82%) and the soldier crab *Dotilla wichmannic* with an abundance of 0.81±0.24 ind./0.1 m^2 (7.75%). Other taxa were only occasionally observed and accounted for 24.67 % of the total macrobenthos.

Haad Maephim:

A total of individuals representing 15 species were collected. The total diversity index of macrobenthos comunity on Haad Maephim was 0.936. The species composition of macrobenthos are shown in Table 2. The macrobenthos were numerically dominated by the bivalve *Donax incarnatus* with an abundance of 4.14±1.99 ind./0.1 m^2 (78.14%), sand dollar

Echinodiscus sp. with an abundance of 0.36±0.14 ind./0.1 m^2 (6.84%), the soldier crab *Dotilla wichmannic* with an abundance of 0.35±0.14 ind./0.1 m^2 (6.77%) and the polychaete *Glycera* sp. with and abundance of 0.12±0.03 ind./0.1 m^2 (2.23%). Other taxa were only occasionally observed and accounted for 6 % of the total macrobenthos.

Haad Maeramphueng:

A total of individuals representing 19 species were collected. The total diversity index of macrobenthos comunity on Haad Maeramphueng was 2.155 The species composition of macrobenthos are shown in Table 3. The macrobenthos were numerically dominated by the bivalve *Donax incarnatus* (Figure 36) with an abundance of 0.8±0.3 ind./0.1 m^2 (31.72%), the polychaete *Scoloplos* sp.with an abundance of 0.4±0.2 ind./0.1 m^2 (16.01%), *Umbonium vestiarium* with an abundance of 0.26±0.18 ind./0.1 m^2 (10.42%) the soldier crab *Dotilla wichmannic* (Figure 40) with an abundance of 0.19±0.08 ind./0.1 m^2 (7.78%) and the sand dollar *Echinodicus* sp. (Figure 37) with an abundance of 0.18±0.06 ind./0.1 m^2 (7.05%). Other taxa were only occasionally observed and accounted for 27.01 % of the total macrobenthos.

Haad Takuan:

A total of individuals representing 30 species were collected. The total diversity index of macrobenthos comunity on Haad Takuan was 2.05. The species composition of macrobenthos are shown in Table 4. The most abundant species were the bivalve *Donax cuneatus* (Figure 38) with an abundance of 0.48±0.33 ind./0.1 m^2 (36.11%), *Donax incarnatus* with an abundance of 0.31±0.29 ind./0.1 m^2 (23.33%) and the polychaete *Glycera* sp. (Figure 39) with an abundance of 0.14±0.05 ind./0.1 m^2 (10.55%). Other taxa were only occasionally observed and accounted for 30 % of the total macrobenthos.

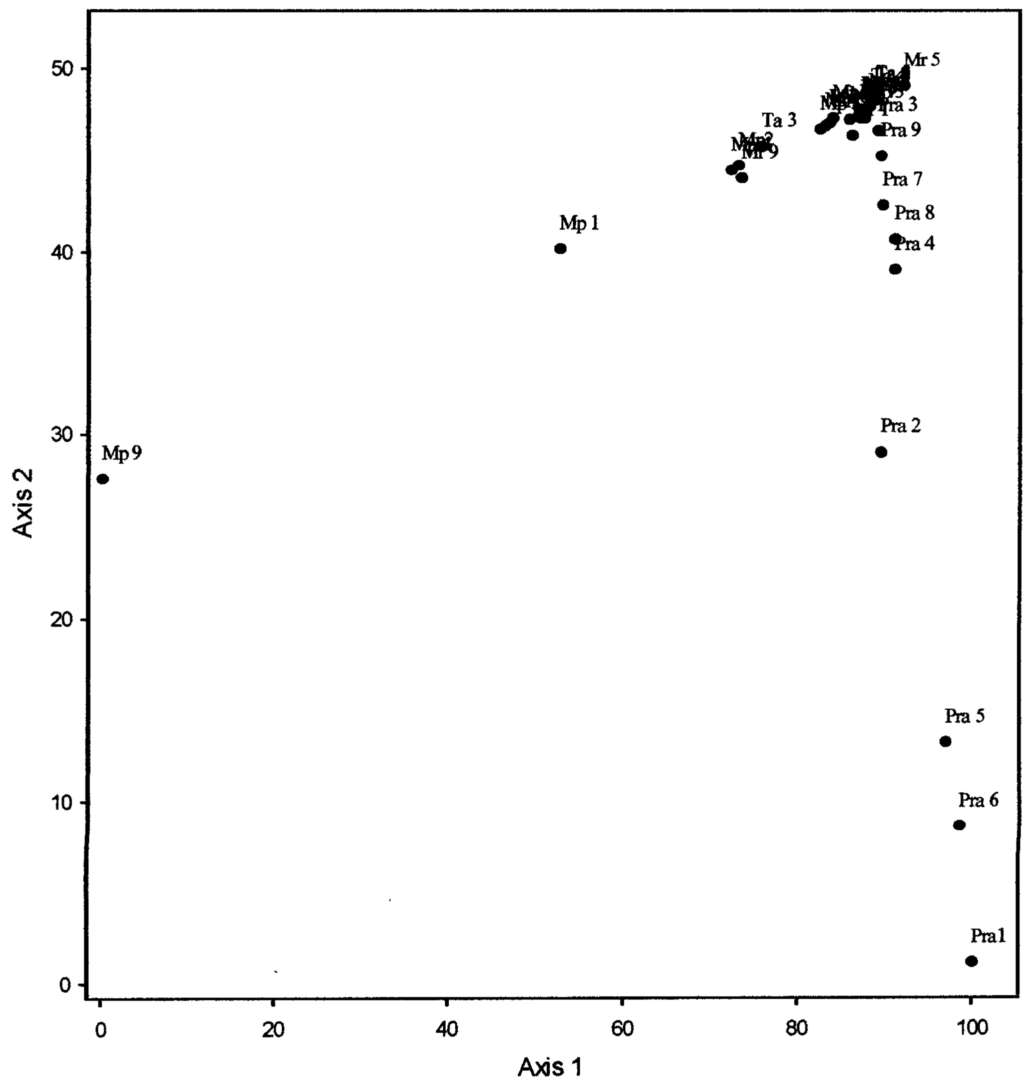

Figure 32 The Principle Components Analysis Community Composition of Macrobenthos (Pra = Haad Paknamprasae, Mp = Haad Maephim, Mr =Haad Maeramphueng, Ta = Haad Takuan)

Figure 33 The Bivalve (*Tellina* sp.), a Dominant Species Found at Haad Paknamprasae

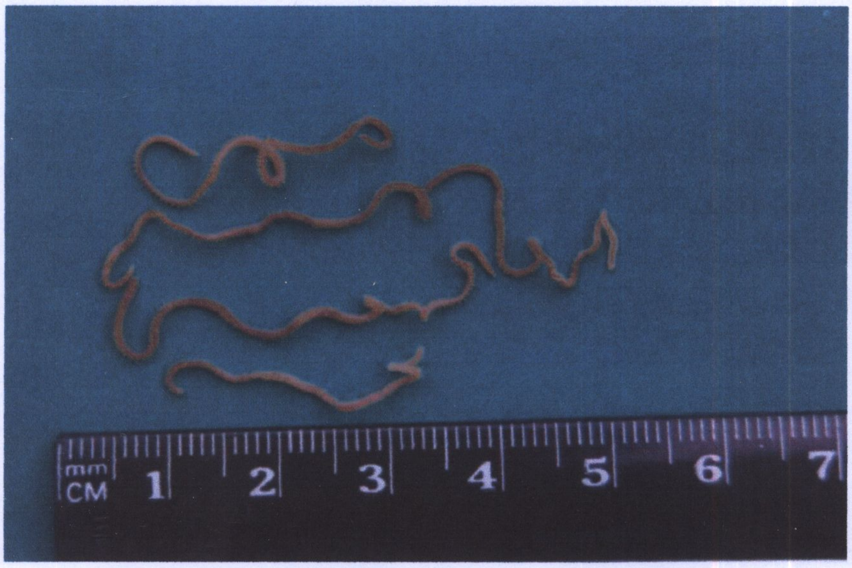

Figure 34 The Polychaete, *Scoloplos* sp., a Dominant Species Found at Haad Paknamprasae

Figure 35 The Gastropod *Umbonium vestiarium*, a Dominant Species Found at Haad Paknamprasae

Figure 36 The Bivalve *Solen* sp., a Dominant Species Found at Haad Paknamprasae

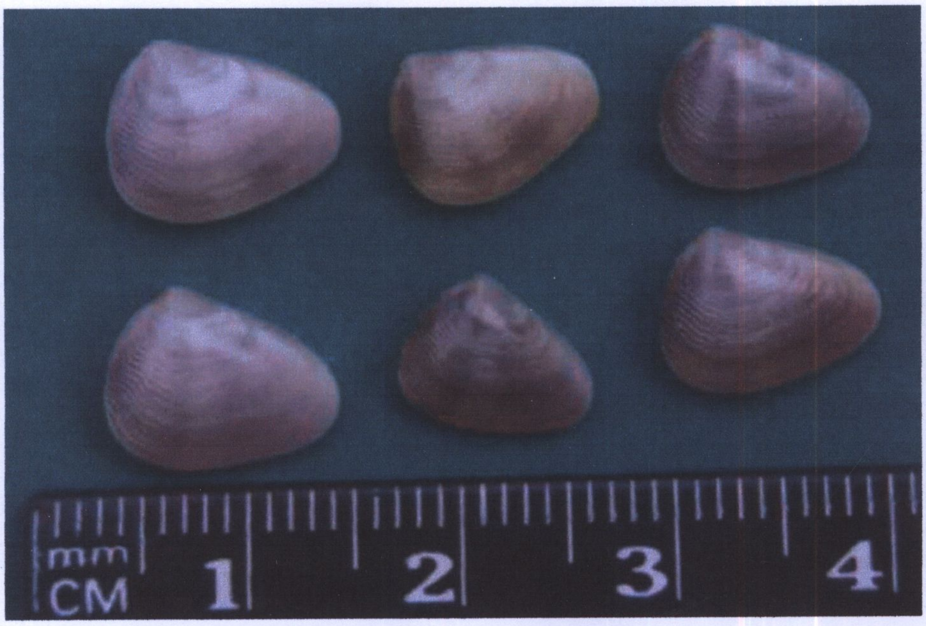

Figure 37 The Bivalve (*Donax incarnatus*), a Dominant Species Found at Haad Maephim and Haad Maeranphueng

Figure 38 Sand Dollar *Echinodiscus* sp., a Dominant Species Found at Haad Maephim and Haad Maeranphueng

Figure 39 The Bivalve *Donax cuneatus*, a Dominant Species Found at Haad Takuan

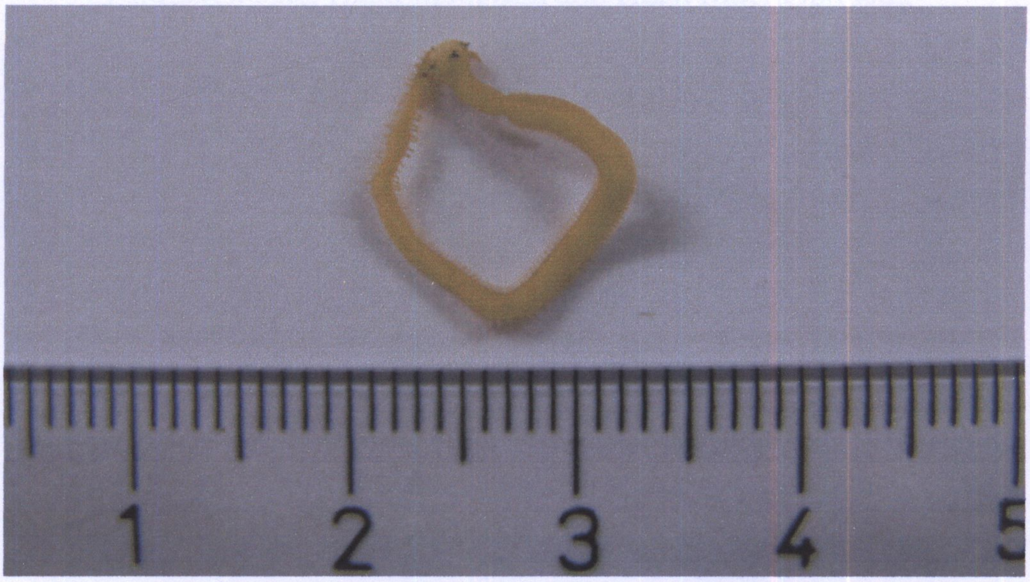

Figure 40 The Polychaete (*Glycera* sp.), a Dominant Species Found at Haad Takuan

Figure 41 Soldier Crab *Dotilla wichmannic* Dominant Species Found at Haad Paknamprasae, Haad Maephim and Haad Maeranphueng

Table 1 Composition of the Macrobenthos in Number of Individuals and Percentage at Haad Paknamprasae

Phylum	Class	Family	Species	Abundance	% Abundance
Cnidaria	Anthozoa		Unidentified anemone	1	0.04
Brachiopod	Brachiopoda		*Lingula anatina*	7	0.29
Annelida	Polychaeta	Maldanidae	*Asychis* sp.	5	0.2
			Maldanidae sp.1	7	0.29
		Spionidea	*Dispio* sp.	0	0
			Scolelepis sp.	7	0.29
			Prionospio sp.	1	0.04
		Cirratulidae	*Chaetozone* sp.	4	0.16
			Cirratulus sp.	1	0.04
		Glyceridae	*Glycera* sp.	76	3.09
		Gonionidae	*Goniodopsis* sp.	5	0.2
		Oweniidae	*Myrioglobula* sp.	5	0.2
			Owenia sp.	56	2.28
		Capitellidae	*Heteromastus* sp.	10	0.41
			Leiochrus sp.	3	0.12
			Notomastus sp.	18	0.73
			Rashgua sp.	15	0.61
		Lumbrineridae	Lumbrineridae	13	0.53
			Lumbrineris	2	0.08
		Magelonidae	*Magelona* sp.	1	0.04
		Nephtyidae	*Neptys* sp.	2	0.08

Table 1 (continued)

Phylum	**Class**	**Family**	**Species**	**Abundance**	**% Abundance**
		Nereidae	*Nereis* sp.	1	0.04
			Perinereis sp.	65	2.65
		Onuphidae	*Nothria* sp.	45	1.83
			Diopatra sp.	9	0.37
			Onuphis sp.	56	2.28
		Opheliidae	Ophelina sp.	2	0.08
		Eunicidae	*Marphysa* sp.	2	0.08
		Pectinariidae	*Pectinaria* sp.	4	0.16
		Chaetopteridae	*Phyllochaetopterus* sp.	3	0.12
		Orbiniidae	*Scoloplos* sp.	390	15.88
			Orbinia sp.	48	1.95
		Amphinomidae	*Eurythoe* sp.	0	0
		Apitobranchidae	_	1	0.04
		Ampharetidae	_	1	0.04
		Flabellgelidae	_	3	0.12
		Polynoidae	_	1	0.04
		Sagalionidae	_	1	0.04
		Trichobranchidae	_	3	0.12
		Sternaspidae	_	1	0.04
		Terebellidae	_	44	1.79

Table 1 (continued)

Phylum	**Class**	**Family**	**Species**	**Abundance**	**% Abundance**
Hemichordata			Unidentified Hemichordate	6	0.24
Mollusca	Gastropoda	Trochidae	*Umbonium vestiarium*	263	10.71
		Buccinidae	*Antillophos* sp.	1	0.04
		Naticidae	*Eunaticina* sp.	10	0.41
	Bivalvia	Donacidae	*Donax cunaetus*	0	0
			Donax incarnatus	65	2.65
		Tellinidae	*Tellina* sp.	717	29.19
			Tellina sp. 2	1	0.04
		Solenidae	*Solen* sp.	221	9
		Lucinidae	Lucinidae	0	0
		Corbulidae	Corbulidae	0	0
		Veneridae	_	0	0
			Dosinia sp.	0	0
		Isognomonidae	*Perna* sp.	0	0
		Somilidae	*Semele* sp.	0	0
		Psammobiidae	*Gari* sp.	0	0
		Mactridae	*Mactra* sp.	0	0
		Limidae	*Lima* sp.	0	0
Arthropoda	Malacostraca		Amphipod	34	1.38
	Crustacea	Paguridae	_	6	0.24
		Hippidae	*Emerita emeritus*	0	0
		Ocypodidae	*Dotilla whichmannic*	206	8.39
Echinodermata	Echinoidae	Laganidae	*Echinodiscus* sp.	0	0
	Stelleroidea		*Macrophiothrix sp.*	7	0.29
Total				**2456**	**100**

Table 2 Composition of the Macrobenthos in Number of Individuals and Percentage at Haad Maephim

Phylum	Class	Family	Species	Abundance	% Abundance
Cnidaria	Anthozoa		Unidentified anemone	0	0
Brachiopod	Brachiopoda		*Lingula* anatina.	0	0
Annelida	Polychaeta	Maldanidae	*Asychis* sp.	0	0
			Maldanidae sp.1	0	0
		Spionidea	*Dispio* sp.	1	0.08
			Scolelepis sp.	8	0.61
			Prionospio sp.	3	0.23
		Cirratulidae	*Chaetozone* sp.	0	0
			Cirratulus sp.	0	0
		Glyceridae	*Glycera* sp.	32	2.44
		Gonionidae	*Goniodopsis* sp.	3	0.23
		Oweniidae	*Myrioglobula* sp.	0	0
			Owenia sp.	0	0
		Capitellidae	*Heteromastus* sp.	0	0
			Leiochrus sp.	0	0
			Notomastus sp.	0	0
			Rashgua sp.	0	0
		Lumbrineridae	Lumbrineridae	0	0
			Lumbrineris sp.	3	0.23
		Magelonidae	*Magelona* sp.	0	0
		Nephtyidae	*Neptys* sp.	0	0

Table 2 (continued)

Phylum	Class	Family	Species	Abundance	% Abundance
		Nereidae	*Nereis* sp.	0	0
			Perinereis sp.	0	0
		Onuphidae	*Nothria* sp.	0	0
			Diopatra sp.	0	0
			Onuphis sp.	0	0
		Opheliidae	*Ophelina* sp.	1	0.08
		Eunicidae	*Marphysa* sp.	0	0
		Pectinariidae	*Pectinaria* sp.	0	0
		Chaetopteridae	*Phyllochaetopterus* sp.	0	0
		Orbiniidae	*Scoloplos* sp.	2	0.15
			Orbinia sp.	0	0
		Amphinomidae	*Eurythoe* sp.	0	0
		Apitobranchidae	_	0	0
		Ampharetidae	_	0	0
		Flabellgelidae	_	0	0
		Polynoidae	_	0	0
		Sagalionidae	_	0	0
		Trichobranchidae	_	0	0
		Sternaspidae	_	0	0
		Terebellidae	_	0	0

Table 2 (continued)

Phylum	Class	Family	Species	Abundance	% Abundance
Hemichordata			Hemichordate	0	0
Mollusca	Gastropoda	Trochidae	*Umbonium vestiarium*	8	0.61
		Buccinidae	*Antillophos* sp.	1	0.08
	Bivalvia		*Eunaticina*sp.	0	0
		Donacidae	*Donax incarnatus*	1019	77.67
			Donax cuneatus	35	2.67
		Tellinidae	*Tellina* sp.	0	0
			Tellina sp. 2	0	0
		Solenidae	*Solen* sp.	0	0
		Lucinidae	_	0	0
		Corbulidae	_	0	0
		Veneridae	_	0	0
			Dosinia sp.	0	0
		Isognomonidae	*Perna* sp.	0	0
		Somilidae	*Semele* sp.	0	0
		Psammobiidae	*Gari* sp.	0	0
		Mactridae	*Mactra* sp.	0	0
		Limidae	*Lima* sp.	0	0
Arthropoda	Malacostraca		Amphipod	0	0
	Crustacea	Paguridae	_	0	0
		Hippidae	*Emerita emeritus*	17	1.3
		Ocypodidae	*Dotilla* sp.	81	6.17
Echinodermata	Echinoidae	Laganidae	*Echinodiscus* sp.	98	7.47
	Ophiuroidea		*Macrophiothrix sp.*	0	0
Total				**1312**	**100**

Table 3 Composition of the Macrobenthos in Number of Individuals and Percentage at Haad Maeramphueng

Phylum	Class	Family	Species	Abundance	% Abundance
Cnidaeia	Anthozoa		Unidentified anemone	0	0
Brachiopod	Brachiopoda		*Lingula* sp.	0	0
Annelida	Polychaeta	Maldanidae	*Asychis* sp.	0	0
			Maldanidae sp.1	0	0
		Spionidea	*Dispio* sp.	0	0
			Scolelepis sp.	22	3.36
			Prionospio sp.	1	0.15
		Cirratulidae	*Chaetozone* sp.	0	0
			Cirratulus sp.	0	0
		Glyceridae	*Glycera* sp.	29	4.43
		Gonionidae	*Goniodopsis* sp.	18	2.75
		Oweniidae	*Myrioglobula* sp.	0	0
			Owenia sp.	0	0
		Capitellidae	*Heteromastus* sp.	0	0
			Leiochrus sp.	0	0
			Notomastus sp.	0	0
			Rashgua sp.	0	0
		Lumbrineridae	Lumbrineridae	1	0.15
			*Lumbrineris*sp.	5	0.76
		Magelonidae	*Magelona* sp.	0	0
		Nephtyidae	*Neptys* sp.	0	0

Table 3 (continued)

Phylum	Class	Family	Species	Abundance	% Abundance
		Nereidae	*Nereis* sp.	0	0
			Perineris sp.	0	0
		Onuphidae	*Nothria* sp.	0	0
			Diopatra sp.	0	0
			Onuphis sp.	0	0
		Opheliidae	*Ophelina* sp.	17	2.6
		Eunicidae	*Marphysa* sp.	0	0
		Pectinariidae	*Pectinaria* sp.	0	0
		Chaetopteridae	*Phyllochaetopterus* sp.	0	0
		Orbiniidae	*Scoloplos* sp.	119	18.17
			Orbinia sp.	1	0.15
		Amphinomidae	*Eurythoe* sp.	1	0.15
		Apitobranchidae	_	0	0
		Ampharetidae	_	0	0
		Flabellgelidae	_	0	0
		Polynoidae	_	0	0
		Sagalionidae	_	1	0.15
		Trichobranchidae	_	0	0
		Sternaspidae	_	0	0
		Terebellidae	_	0	0

Table 3 (continued)

Phylum	**Class**	**Family**	**Species**	**Abundance**	**% Abundance**
Hemichordata			Hemichordate	0	0
Mollusca	Gastropoda	Trochidae	*Umbonium vestiarium*	71	10.84
		Buccinidae	*Antillophos* sp.	4	0.61
		Naticidae	*Eunaticina* sp.	0	0
	Bivalvia	Donacidae	*Donax incarnatus*	206	31.45
			Donax cuneatus	18	2.75
		Tellinidae	*Tellina* sp.	0	0
			Tellina sp. 2	0	0
		Solenidae	*Solen* sp.	0	0
		Lucinidae	_	0	0
		Corbulidae	_	0	0
		Veneridae	_	0	0
			Dosinia sp.	0	0
		Isognomonidae	*Perna* sp.	0	0
		Somilidae	*Semele* sp.	0	0
		Psammobiidae	*Gari* sp.	0	0
		Mactridae	*Mactra* sp.	0	0
		Limidae	*Lima* sp.	0	0
Arthropoda	Malacostraca		Amphipod	0	0
	Crustacea	Paguridae		2	0.31
		Hippidae	*Emerita emeritus*	38	5.8
		Ocypodidae	*Dotilla* sp.	53	8.09
Echinodermata	Echinoidae	Laganidae	*Echinodiscus*sp.	48	7.33
	Stelleroidea		*Macrophiothrix* sp.	0	0
Total				**655**	**100**

Table 4 Composition of the Macrobenthos in Number of Individuals and Percentage at Haad Takuan

Phylum	Class	Family	Species	Abundance	% Abundance
Cnidaria	Anthozoa		Unidentified anemone	0	0
Brachiopod	Brachiopoda		*Lingula* sp.	0	0
Annelida	Polychaeta	Maldanidae	*Asychis* sp.	0	0
			Maldanidae sp.1	0	0
		Spionidea	*Dispio* sp.	9	2.62
			Scolelepis sp.	10	2.91
			Prionospio sp.	3	0.87
		Cirratulidae	*Chaetozone* sp.	0	0
			Cirratulus sp.	0	0
		Glyceridae	*Glycera* sp.	29	8.43
		Gonionidae	*Goniodopsis* sp.	1	0.29
		Oweniidae	*Myrioglobula* sp.	0	0
			Owenia sp.	1	0.29
		Capitellidae	*Heteromastus* sp.	0	0
			Leiochrus sp.	0	0
			Notomastus sp.	2	0.58
			Rashgua sp.	0	0
		Lumbrineridae	Lumbrineridae	0	0
			Lumbrineris	2	0.58
		Magelonidae	*Magelona* sp.	0	0
		Nephtyidae	*Neptys* sp.	0	0

Table 4 (continued)

Phylum	Class	Family	Species	Abundance	% Abundance
		Nereidae	*Nereis* sp.	0	0
			Perineris sp.	0	0
		Onuphidae	*Nothria* sp.	0	0
			Diopatra sp.	0	0
			Onuphis sp.	1	0.29
		Opheliidae	*Ophelina* sp.	0	0
		Eunicidae	*Marphysa* sp.	2	0.58
		Pectinariidae	*Pectinaria* sp.	0	0
		Chaetopteridae	*Phyllochaetopterus* sp.	0	0
		Orbiniidae	*Scoloplos* sp.	3	0.87
			Orbinia sp.	1	0.29
		Amphinomidae	*Eurythoe* sp.	0	0
		Apitobranchidae	*Apitobranchiae* sp.	0	0
		Ampharetidae	_	0	0
		Flabellgelidae	_	0	0
		Polynoidae	_	0	0
		Sagalionidae	_	0	0
		Trichobranchidae	_	0	0
		Sternaspidae	_	0	0
		Terebellidae	_	0	0

Table 4 (continued)

Phylum	**Class**	**Family**	**Species**	**Abundance**	**% Abundance**
Hemichordata			Hemichordate	1	0.29
Mollusca	Gastropoda	Trochidae	*Umbonium vestiarium*	0	0
		Buccinidae	*Antillophos* sp.	29	8.43
	Bivalvia		*Eunaticina sp.*	0	0
		Donacidae	*Donax cunaetus*	130	37.79
			Donax incarnatus	84	24.42
		Tellinidae	*Tellina* sp.	0	0
			Tellina sp. 2	0	0
		Solenidae	*Solen* sp.	2	0.58
		Lucinidae	_	3	0.87
		Corbulidae	_	1	0.29
		Veneridae	_	1	0.29
			Dosinia sp.	2	0.58
		Isognomonidae	*Perna* sp.	7	2.03
		Somilidae	*Semele* sp.	1	0.29
		Psammobiidae	*Gari* sp.	1	0.29
		Mactridae	*Mactra* sp.	1	0.29
		Limidae	*Lima* sp.	2	0.58
Arthropoda	Malacostraca		Amphipod	0	0
	Crustacea	Paguridae	_	8	2.33
		Hippidae	*Emerita emeritus*	5	1.45
		Ocypodidae	*Dotilla* sp.	0	0
Echinodermata	Echinoidae	Laganidae	*Echinodiscus* sp.	2	0.58
	Ophiuroidea		*Macrophiothrix* sp.	0	0
Total				**344**	**100**

Community Composition Changes

The species diversity indices (H') of four sandy shores of Rayong Province were much variation between sampling periods (Figure 42) and significantly different (Two-way ANOVA, $P<0.05$). The evenness indices (J') of macrobenthos varied between sampling periods (Figure 43) and significantly different (Two-way ANOVA, $P<0.05$). The changes in communities and species diversity indices were caused by change in density of individuals and number of species. The density changes were found in numerically dominant species. The mean density of macrobenthos was significantly different (One-way ANOVA, $P<0.05$) between beaches (Figure 48).

Haad Paknamprasae

The ordination of community composition by using Principle Components Analysis (PCA) (Figure 44) showed closer communities between May 1999 (Pra 3), February 2000 (Pra 7) and April 2000 (Pra 8), and greater separation between other months. The variances on axis 1 and axis 2 were 43.826 % and 25.286%, respectively. There were obviously seasonal changes in community composition and density. The greatest in terms of density on macrobenthos was found in December 1999. The numerically dominant species was the bivalve *Tellina* sp. (7.8+1.48 ind./0.1m^2). The species diversity index (H') of this month was 2.159. The evenness indices showed similar density of macrobenthos between species, except in December 1998 and February 1999. The greatest in terms of diversity of macrobenthos was found in February 2000. The species diversity index (H') and the evenness (J') were 2.750 and 0.825, respectively. The numerically dominant species was the top shell *Umbonium vestiarium* (1.67+0.98 ind./0.1m^2).

The dominant species was the bivalve *Tellina* sp. in almost months, replaced by the soldier crab *Dotilla whichmannic* in May 1999, the top shell *Umbonium vestiarium* in December 1999, the polychaete *Scoloplos* sp. in April 2000 and July 2000. The densities of macrobenthos were significantly different between species (Two-way ANOVA, $P<0.05$).

Polychaete was the diverse group. The highest abundance was found in *Scoloplos* sp. in July 2000 (4.93+0.96 ind./0.1m^2), followed by *Glycera* sp. The highest abundance was found in December 1999 (1.06+0.36 ind./0.1m^2) and *Perineris* sp. (2.13+0.47 ind./0.1m^2). The other taxa groups were low abundance. The highest abundance of gastropod was represented by *Umbonium vestiarium.* The highest abundance was found in December 1999 (4.7+0.97 ind./0.1m^2) and followed by February 2000 (1.67+0.98 ind./0.1m^2). The other taxa of gastropoda were similar in abundance. The highest abundance of bivalves was found in *Tellina* sp. in December 1998 with an abundance 10.63+3.46 ind./0.1m,^{2} followed by September 1999 (7.33+1.69 ind./0.1m^2) and December 1999 (7.8+1.48 ind./0.1m^2). The highest abundance of crustacean was represented by the soldier crab *Dotilla wichmannic*. The highest abundance of *Dotilla wichmannic* was found in December 1998

(2.2+0.78 ind./0.1m^2). Other taxa in the group were similar in abundance. The variation in density of macrobenthos are shown in Figure 49-59.

Haad Maephim:

The ordination of community composition showed greater variation on macrobenthos community (Figure 45). The variances on axis 1 and axis 2 were 80.005 % and 11.637%, respectively. The number of species varied between 4-8 species, and varied in species diversity indices, especially in December 1998 and May 1999 were lower (0.620 and 0.967, respectively). The greatest in terms of density of macrobenthos was found in July 2000. The obviously increasing of density was caused by the bivalve *Donax incarnatus* (18.87+16.67 ind./0.1m^2). The species diversity index (H') of this month was 1.167 and the relative abundance of species was highly diferrent. The evenness indices showed highly different in density between species, except in April 2000(0.822). Total numerical densities were greatest in July 2000, with increased densites of *Donax incarnatus* (18.87+16.67 ind./0.1m^2). The most frequency abundance species were the polychaete *Glycera* sp., the top shell, *Umbonium vestiarium*, *Donax cuneatus*, the soldier crab *Dotilla wichmannic*, *Echinodiscus* sp. Other taxa were occationally observed.

The dominant species was *Donax incartus* found in almost sampling months and replaced by the soldier crab *Dotilla whichmannic* in May 1999 and *Echinodiscus* sp. in February 2000. The densities of macrobenthos were significantly different between species (Two-way ANOVA, $P<0.05$).

The polychaete *Glycera* sp. was the highest abundant species. The highest abundances were found in December 1999 (0.17+0.03 ind./0.1m^2) and July 2000 (0.17+0.06 ind./0.1m^2). The gastropod were found only two species, *Umbonium vestiarium* and *Antillophos* sp. This group was low in abundance. The highest abundance of bivalves was represented by *Donax incarnatus*. The highest abundance was found in July 2000 (18.86+16.67 ind./0.1m^2). Mean individual size of this species was smallest in this month. The highest abundance of soldier crab *Dotilla wichmannic* was found in July 2000. (1.2+0.47 ind./0.1m^2). The echinoderm was represented by *Echinodiscus* sp. with the highest abundance in February 1999 (1.5+0.49 ind./0.1m^2). The variations in density of macrobenthos are shown in Figure 60-65.

Haad Maeramphueng

The ordination of community composition showed greater variation of macrobenthos community (Figure 46). The variances on axis 1 and axis 2 were 43.224 % and 28.617%, respectively. The greatest in terms of density of macrobenthos was found in July 2000. The increasing of density was caused by the bivalve *Donax incarnatus* (3.27+1.81 ind./0.1m^2). The species diversity index (H') of this month was 1.851. The most frequency abundant species were the polychaete *Glycera* sp. and *Donax incarnatus*. The dominant species was the top shell,*Umbonium vestiarium* in December 1998 and July 1999, replaced by *Donax incarnatus* in February 1999, May 1999, September 1999, and July 2000. In December 1999, the dominant species was the polychaete *Glycera* sp. In February 2000 and April 2000, the dominant species was the polychaete *Scoloplos* sp. The densities of macrobenthos were significantly different between species (Two-way ANOVA, $P<0.05$).

The polychaete *Scoloplos* sp. was the highest abundance in this group. The highest abundance was found in July 2000 (1.87+0.13 ind./0.1m^2). The other taxa were low abundance. The gastropod *Umbonium vestiatium* was the highest abundance in gastropod group. The highest abundance was found in December 1998 (1.7+0.63 ind./0.1m^2). The highest abundance in this bivalve group was *Donax incarnatus*. The highest abundances were in July 2000 (3.27+1.81 ind./0.1m^2) and February 1999 (1.2+0.45 ind./0.1m^2). The other bivalve taxa were only *Donax cuneatus*. The abundance of this species was similar in almost months. Two species of crustacean were low abundance and only occasionally observed. The echinoderm group was found only *Echinodiscus* sp.,which was low abundance population and similar in abundance almost months. The variations in density of macrobenthos are shown in Figure 66-71.

Haad Takuan:

The ordination of community composition showed closer similarity on macrobenthos community except in May 1999 (Ta3), December 1999 (Ta6), and April 2000 (Ta8) (Figure 47). The variances on axis 1 and axis 2 were 86.880 % and 5.346%, respectively. The greatest in terms of density on macrobenthos was found in May 1999, The increasing of density was caused by the bivalve *Donax cuneatus* (3.13+2.02ind./0.1m^2). The species diversity index (H') of this month was 1.128. The evenness indices showed similar density of macrobenthos between species. The most frequency abundances were the polychaete *Glycera* sp. and *Donax cuneatus*. The dominant species was *Donax cuneatus* almost months, except in September 1999 and July 2000, replaced by the polychaete *Scolelepis* sp. The densities of macrobenthos were significantly different between species (Two-way ANOVA, $P<0.05$).

The polychaete *Glycera* sp. was the highest abundance in polychaete group. The highest abundance was found in April 2000 (0.43+0.13 ind./0.1m^2). Bivalves of Haad Takuan were higher diverse than other beaches but were low in density. *Donax cuneatus* was the highest abundance in this group. The highest abundance was found in May 1999 with an abundance of 3.13+ 2.02 ind./0.1m^2. The abundances of other taxa were low abundance. The variations in density of macrobenthos are shown in Figure 72-75.

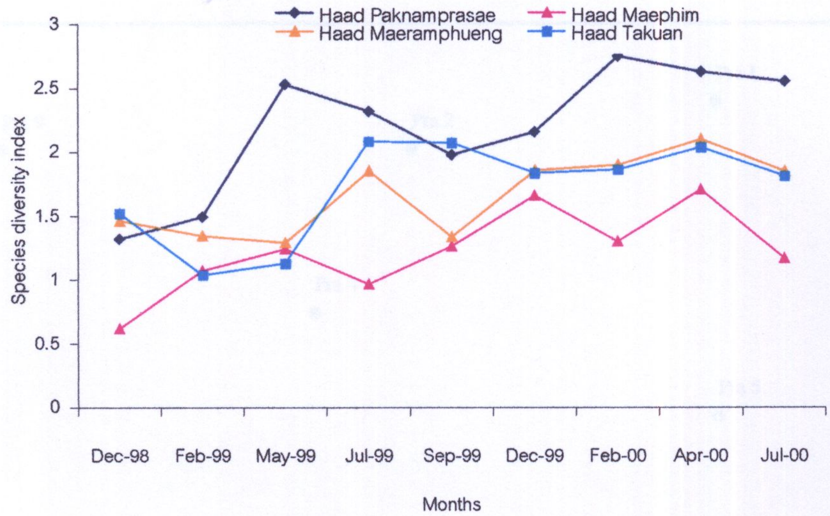

Figure 42 Seasonal Variability of Species Diversity Indices on Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

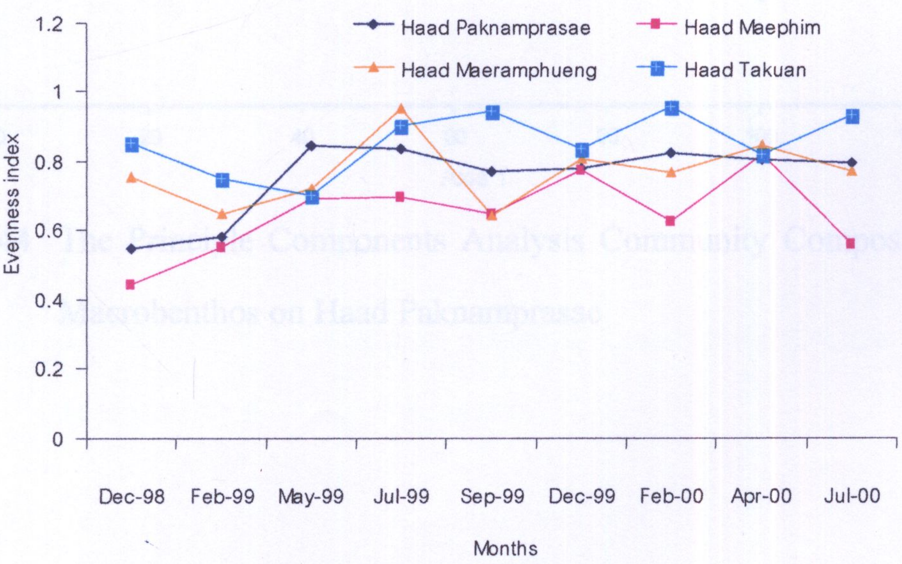

Figure 43 Seasonal variability of Evenness Index on Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

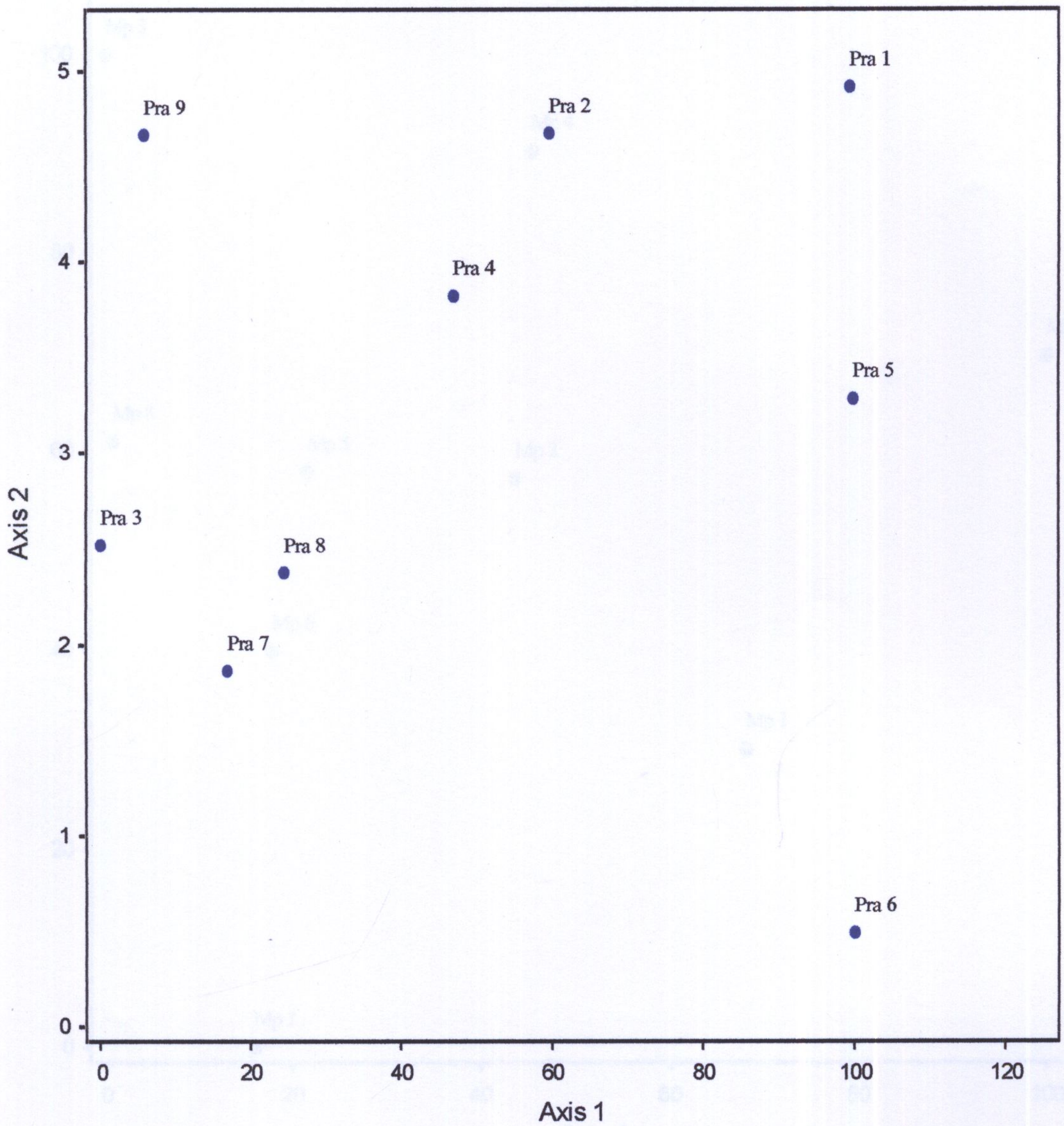

Figure 44 The Principle Components Analysis Community Composition of Macrobenthos on Haad Paknamprasae

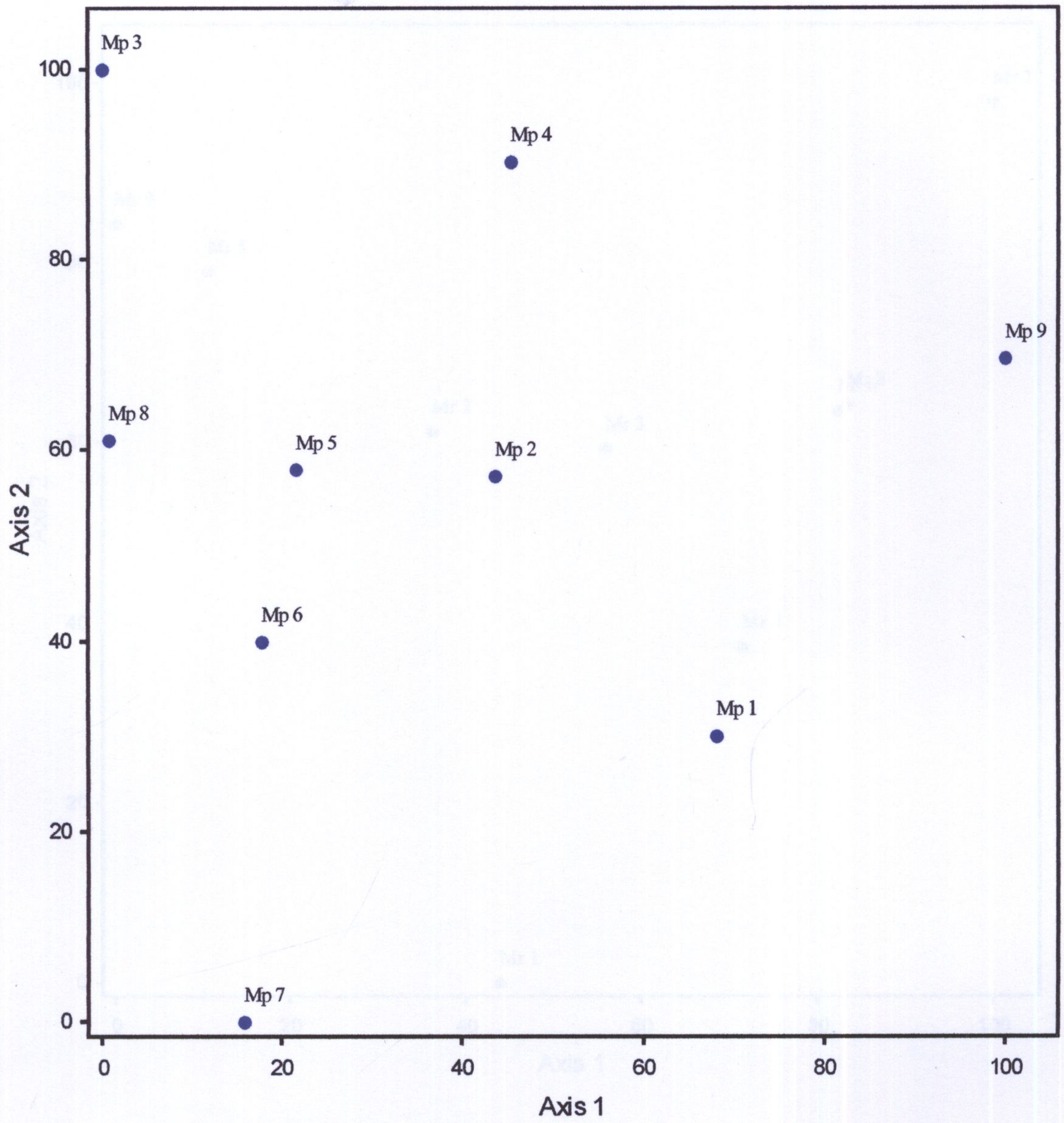

Figure 45 The Principle Components Analysis Community Composition of Macrobenthos on Haad Maephim

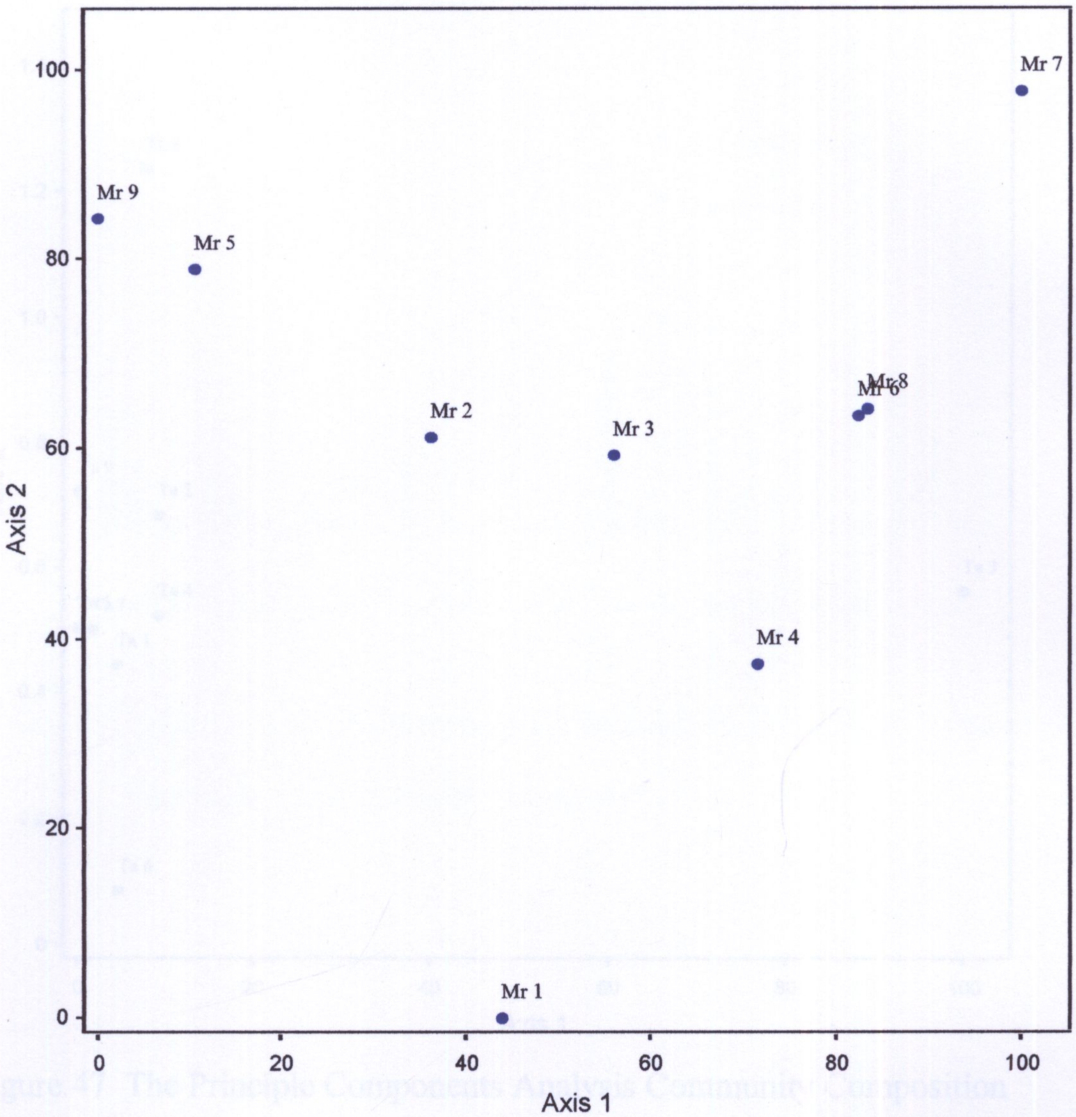

Figure 46 The Principle Components Analysis Community Composition of Macrobenthos on Haad Maeramphueng

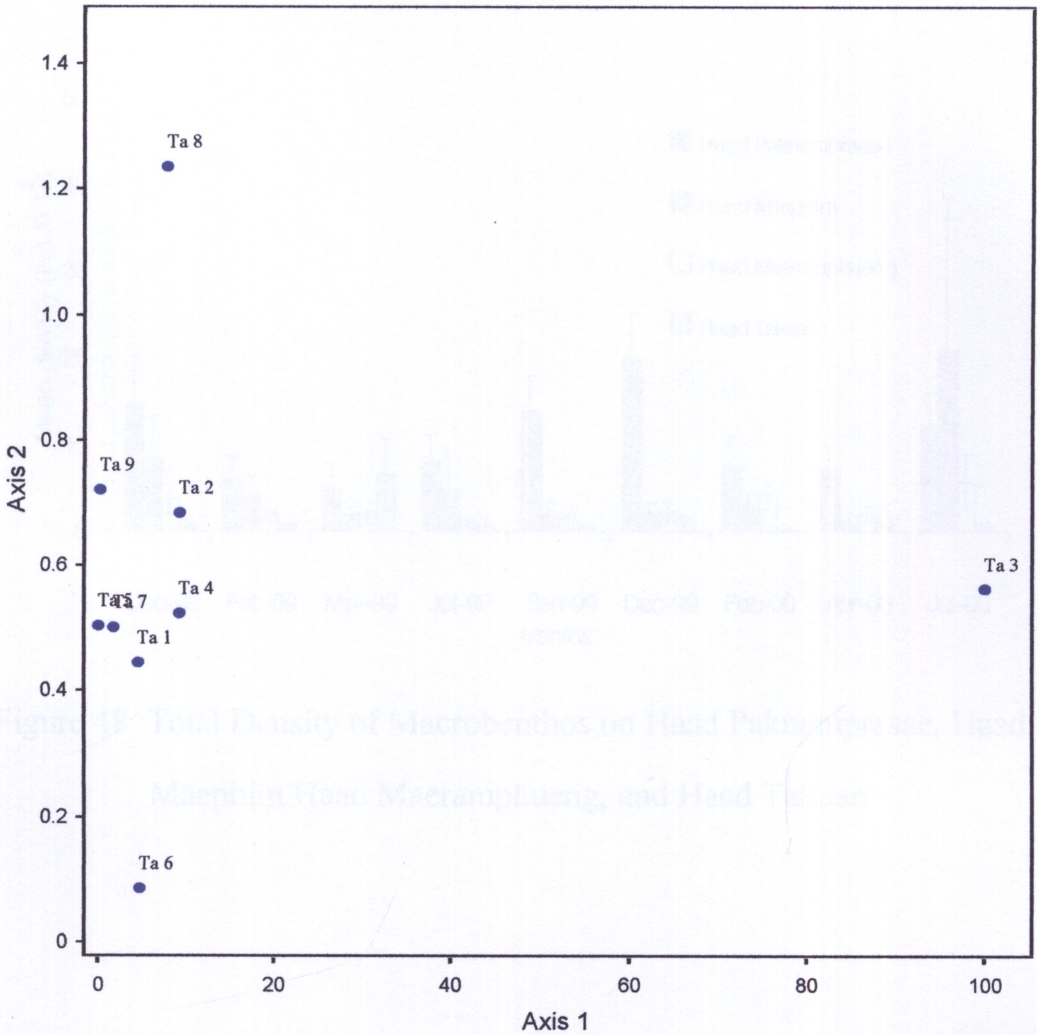

Figure 47 The Principle Components Analysis Community Composition of Macrobenthos on Haad Takuan

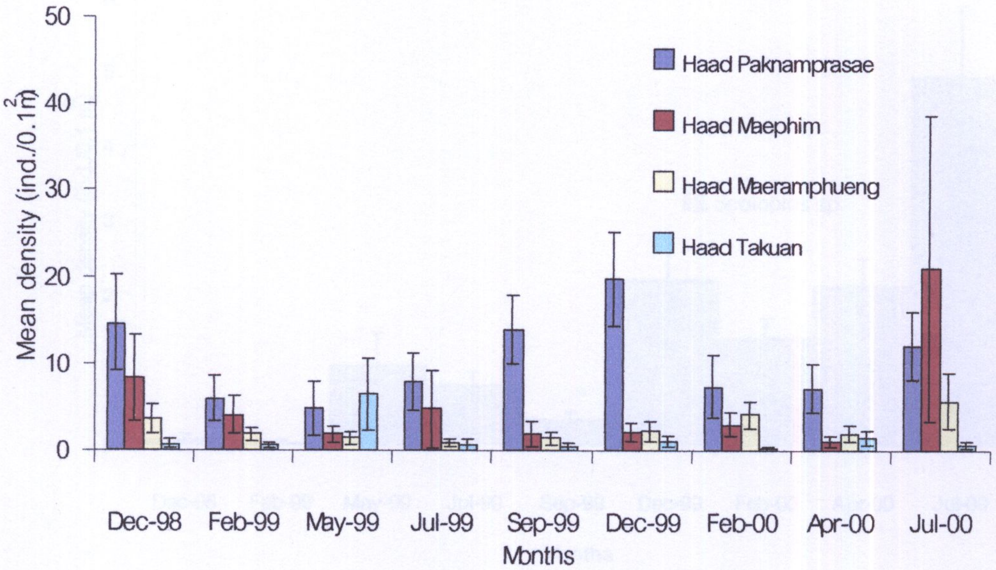

Figure 48 Total Density of Macrobenthos on Haad Paknamprasae, Haad Maephim Haad Maeramphueng, and Haad Takuan

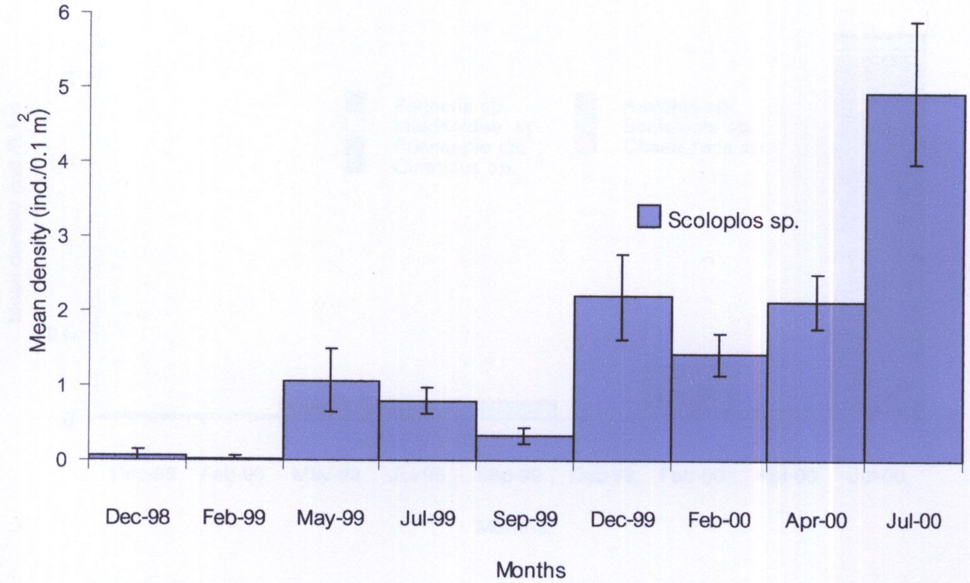

Figure 49 Seasonal Variability in the Abundance of the Polychaete *Scoloplos* sp. on Haad Paknamprasae

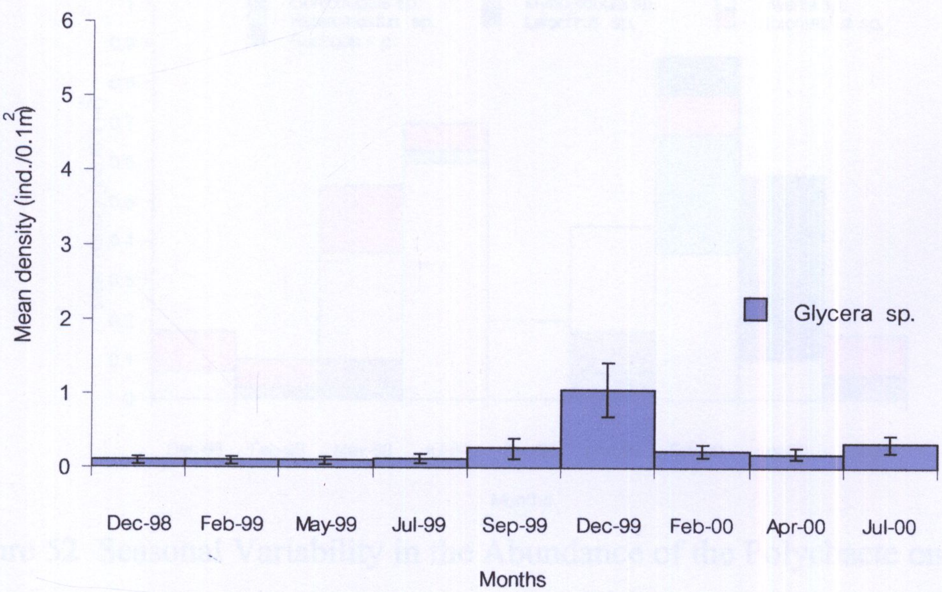

Figure 50 Seasonal Variability in the Abundance of the Polychaete *Glycera* sp. on Haad Paknamprasae

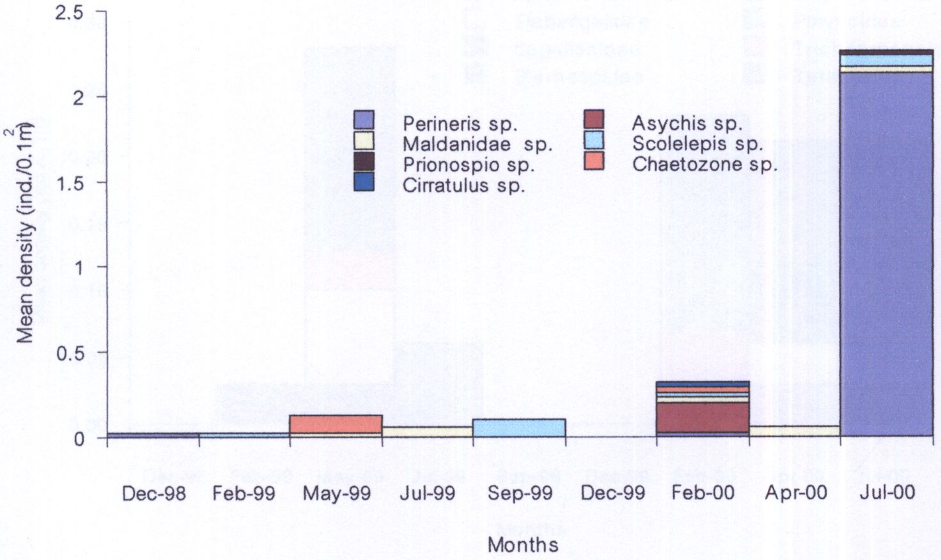

Figure 51 Seasonal Variability in the Abundance of Polychaete on Haad Paknamprasae

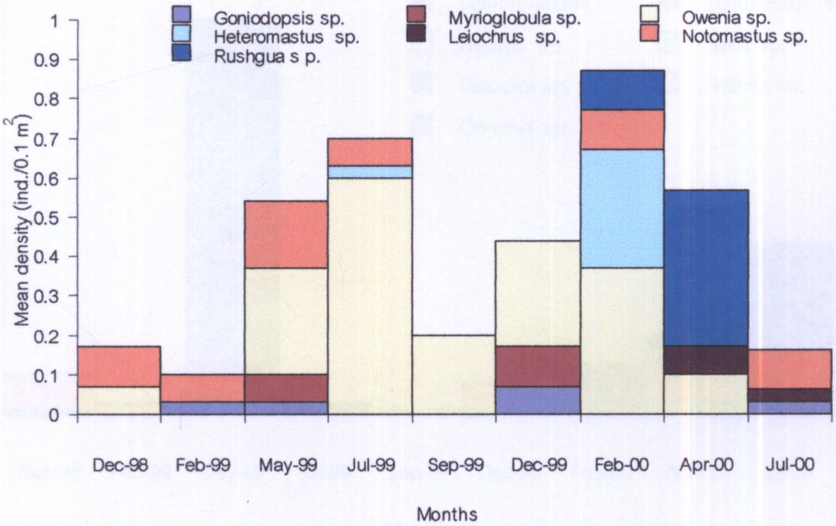

Figure 52 Seasonal Variability in the Abundance of the Polychaete on Haad Paknamprasae

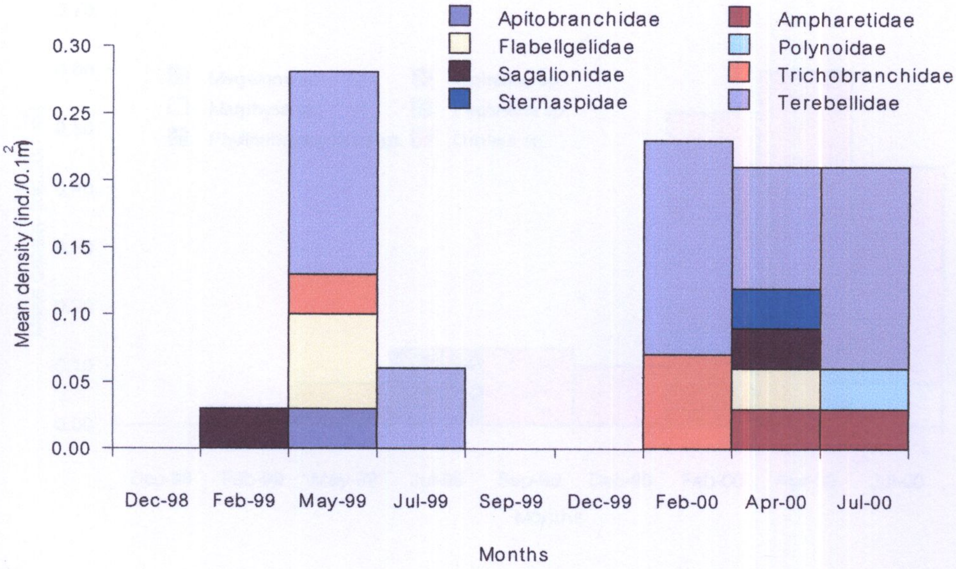

Figure 53 Seasonal Variability in the Abundance of Polychaete Taxa on Haad Paknamprasae

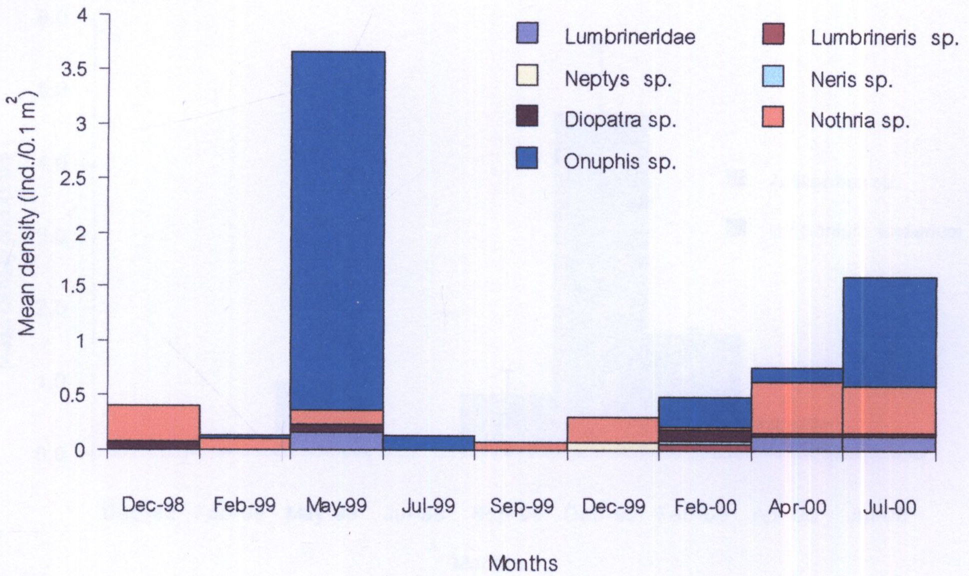

Figure 54 Seasonal Variability in the Abundance of Polychaete on Haad Paknamprasae

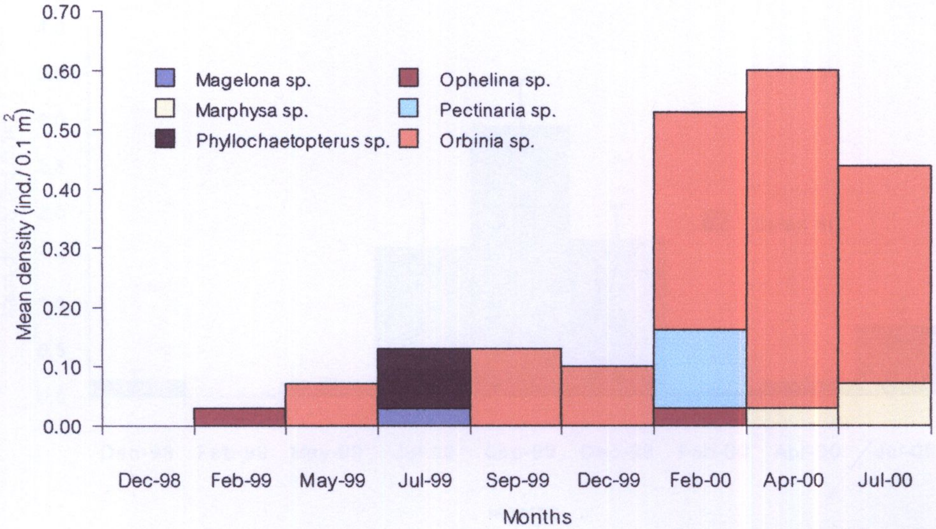

Figure 55 Seasonal Variability in the Abundance of Polychaete on Haad Paknamprasae

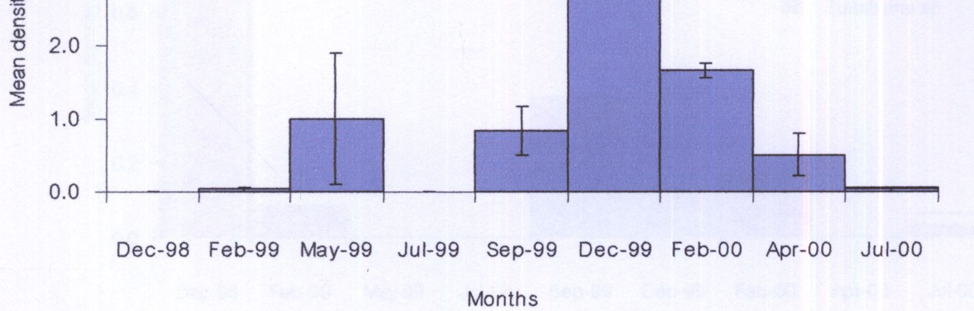

Figure 56 Seasonal Variability in the Abundance of *Umbonium vestiarium* and *Antillophos* sp.on Haad Paknamprasae

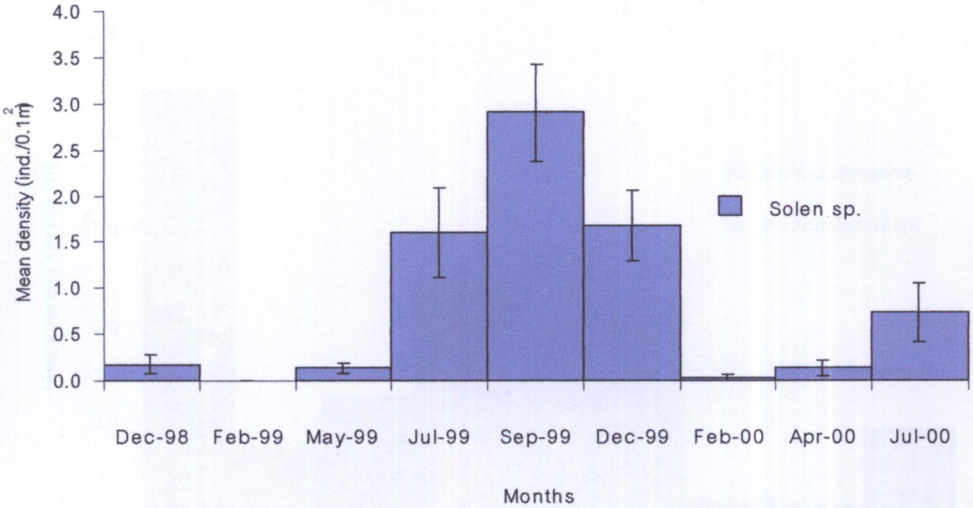

Figure 57 Seasonal Variability in the Abundance of Razor Clam *Solen* sp. on Haad Pakknamprasae (mean density ± S. E.)

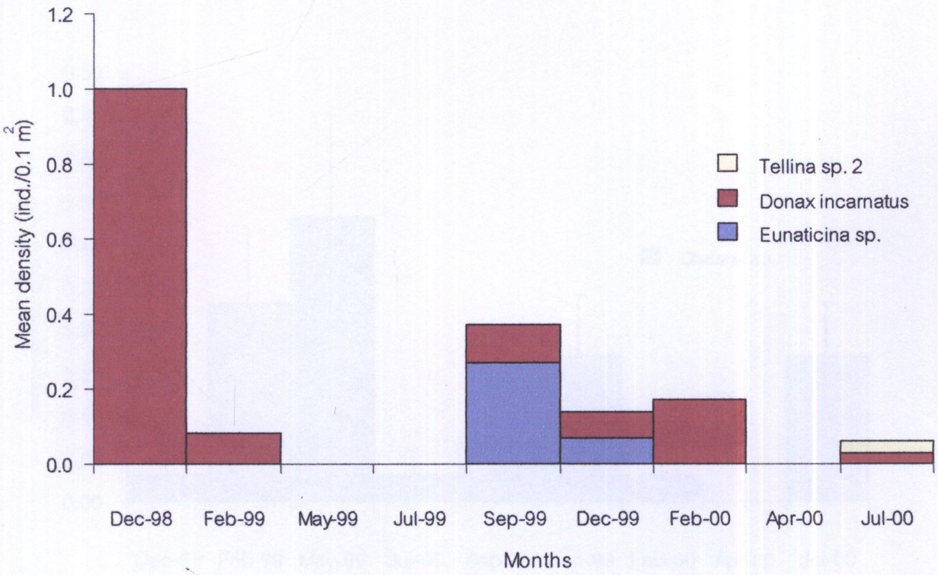

Figure 58 Seasonal Variability in the Abundance of *Tellina* sp.2 *Donax incarnatus*, *Enaticina* sp. on Haad Paknamprasae

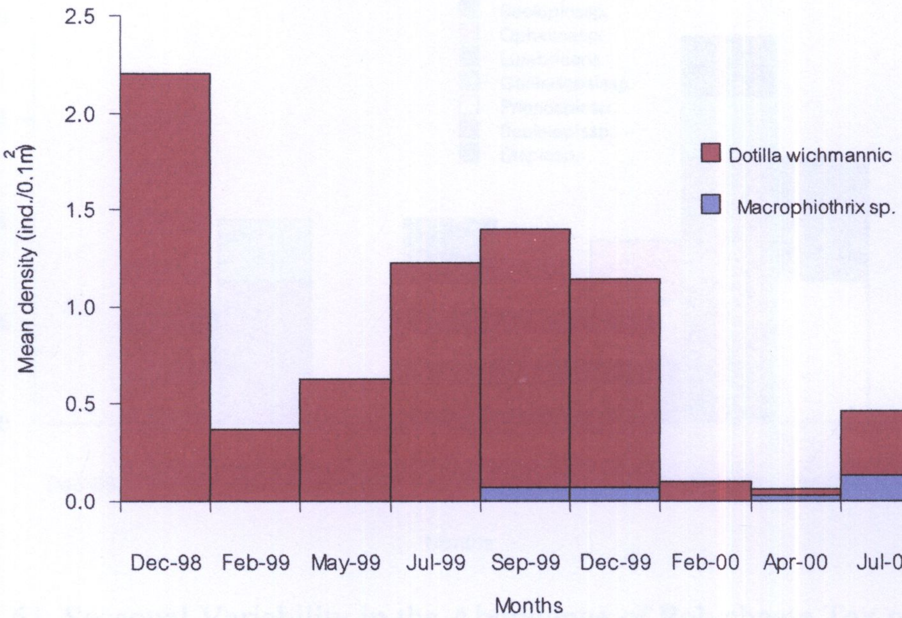

Figure 59 Seasonal Variability in the Abundance of *Dotilla* sp. and *Macrophiothrix* sp. on Haad Paknamprasae

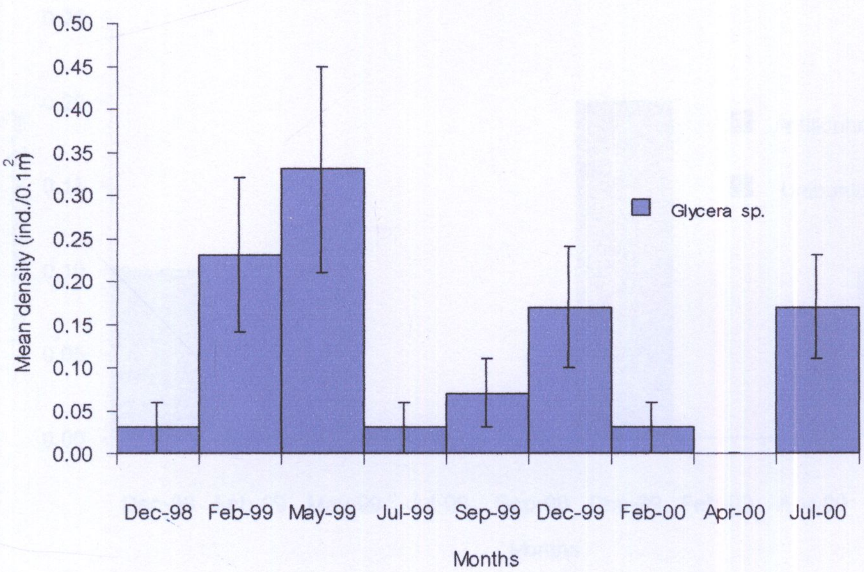

Figure 60 Seasonal Variability in the Abundance of Polychaete *glycera* sp. on Haad Maephim

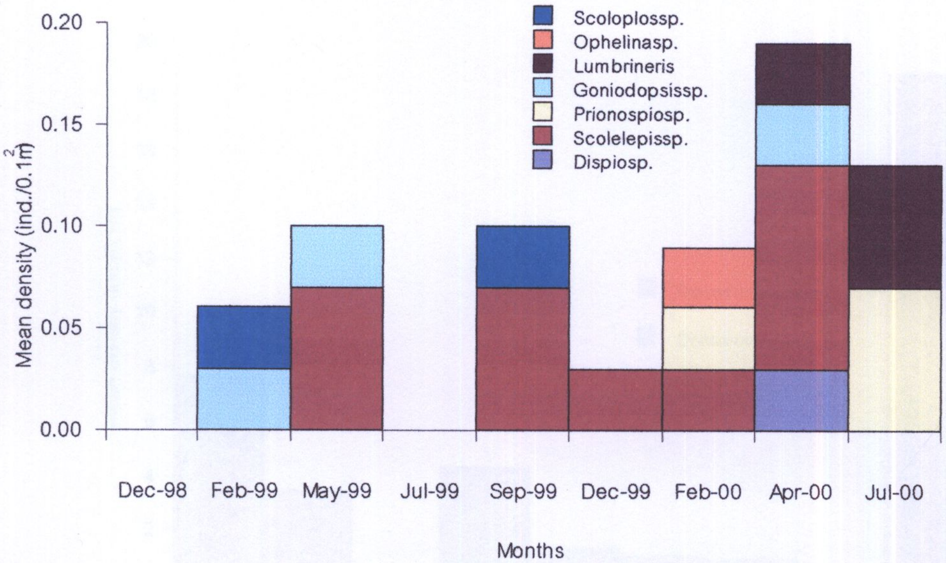

Figure 61 Seasonal Variability in the Abundance of Polychaete Tax on Haad Maephim

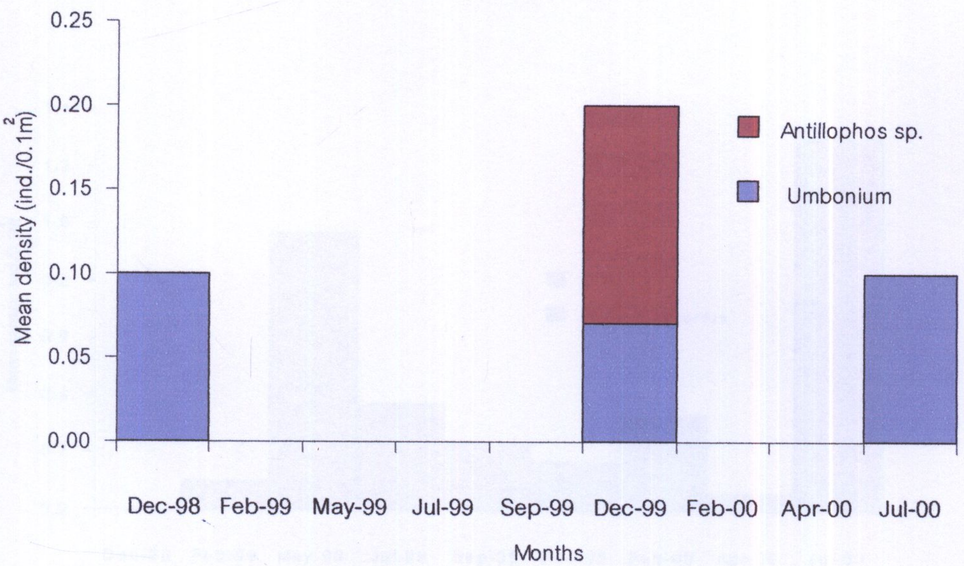

Figure 62 Seasonal Variability in the Abundance of *Antillophos* sp.and *Umbonium vestiarium* on Haad Maephim.

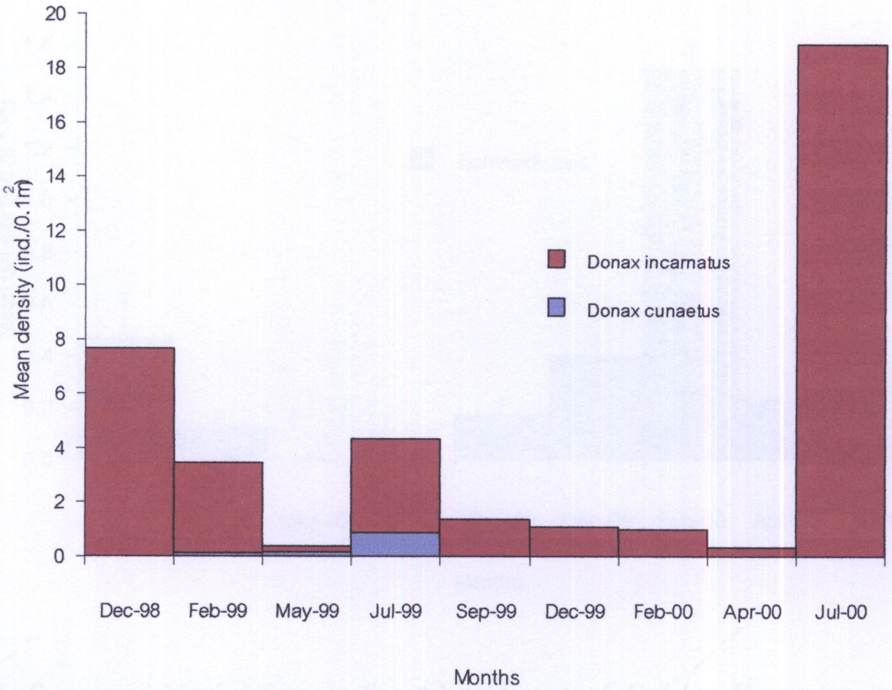

Figure 63 Seasonal Variability in the Abundance of Cuneatus Donax, *Donax cuneatus* and *Donax incarnatus* on Haad Maephim

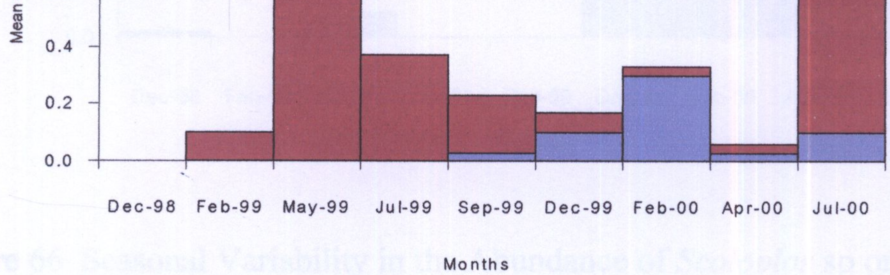

Figure 64 Seasonal Variability in the Abundance of *Dotilla* sp.and *Emerita emeritus* on Haad Maephim.

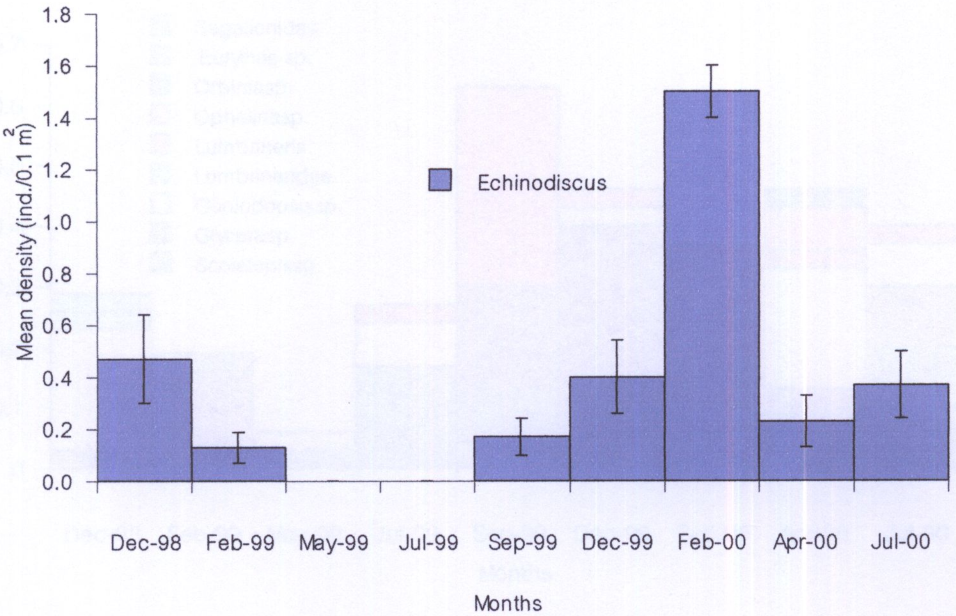

Figure 65 Seasonal Variability in the Abundance of *Echinodiscus* sp. on Haad Maephim

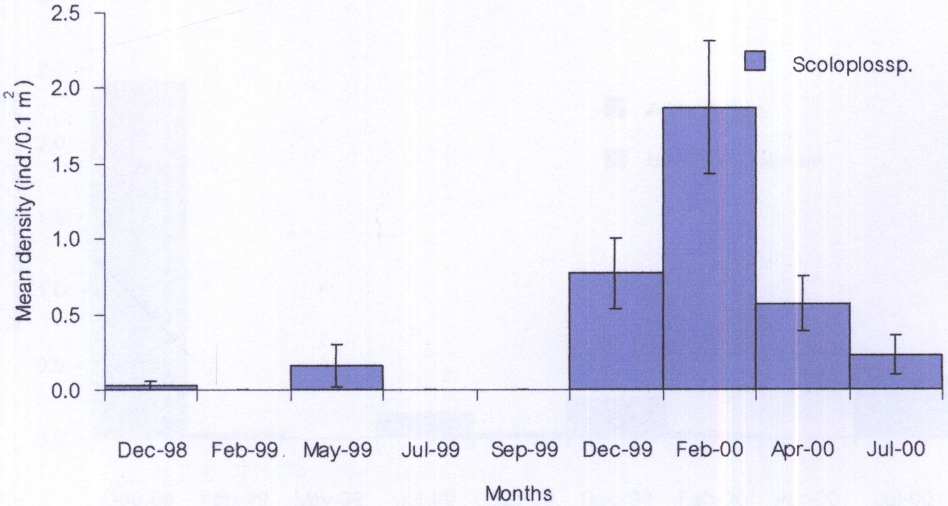

Figure 66 Seasonal Variability in the Abundance of *Scoloplos* sp on Haad Maeramphueng

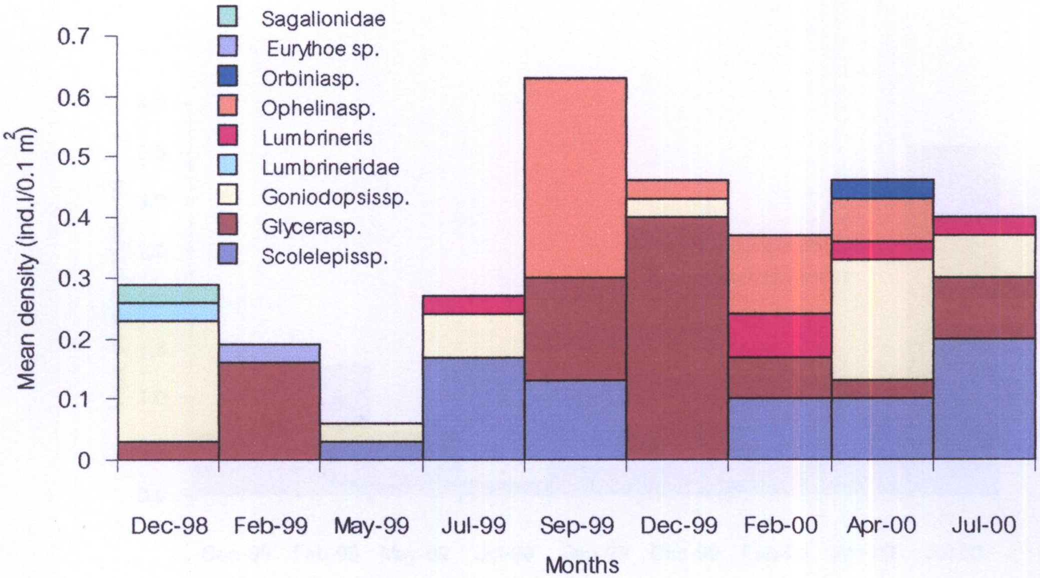

Figure 67 Seasonal Variability in the Abundance of Polychaete on Maeramphueng

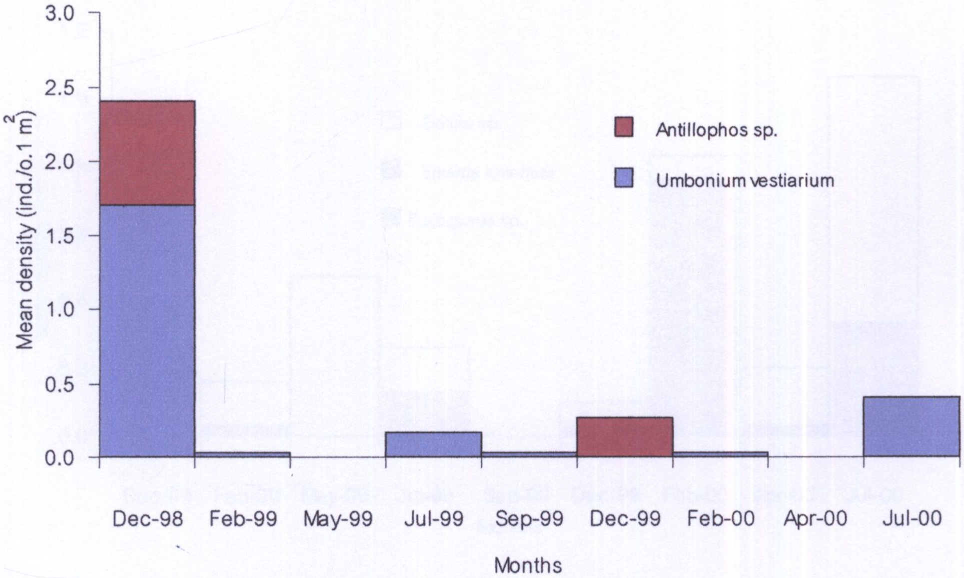

Figure 68 Seasonal Variability in the Abundance of Gastropod on Haad Maeramphueng

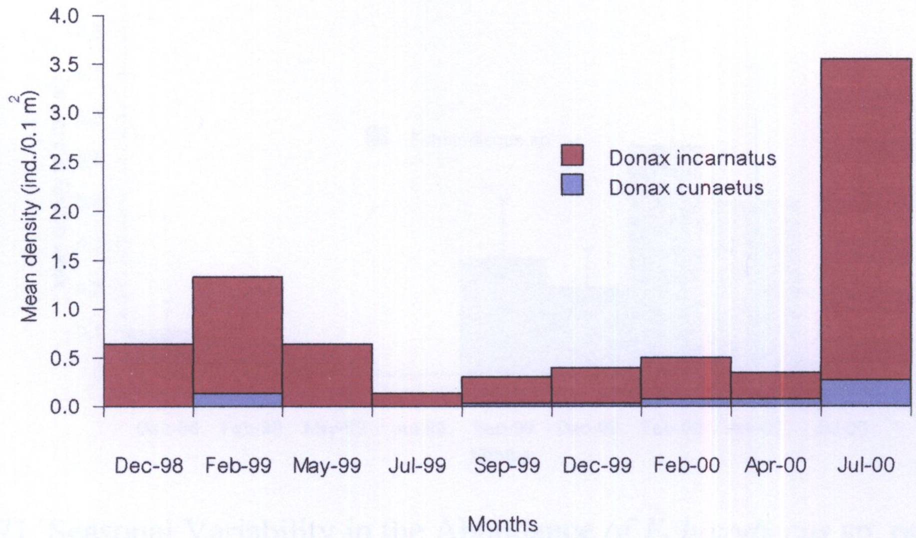

Figure 69 Seasonal Variability in the Abundance of *Donax* spp. On Haad Maeramphueng

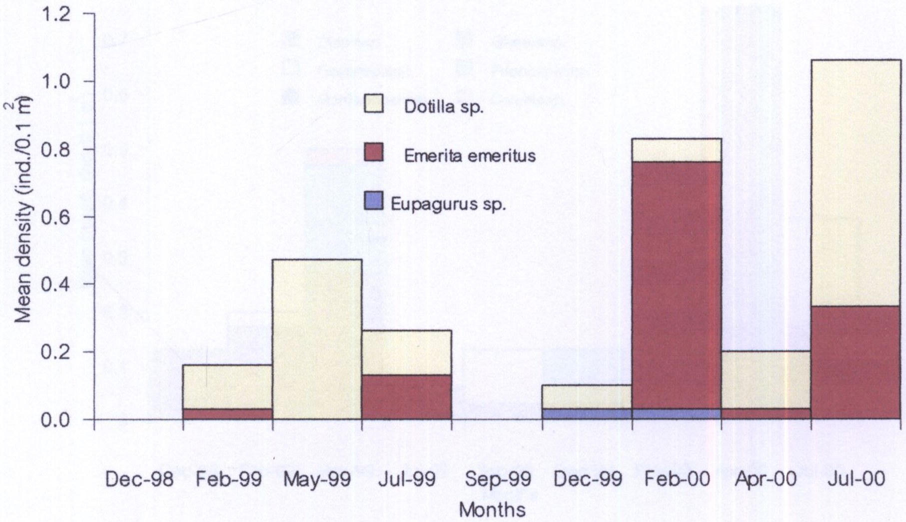

Figure 70 Seasonal Variability in the Abundance of *Dotilla* sp., *Emerita emeritus* and *Eupagurua* sp. on Haad Maeramphueng

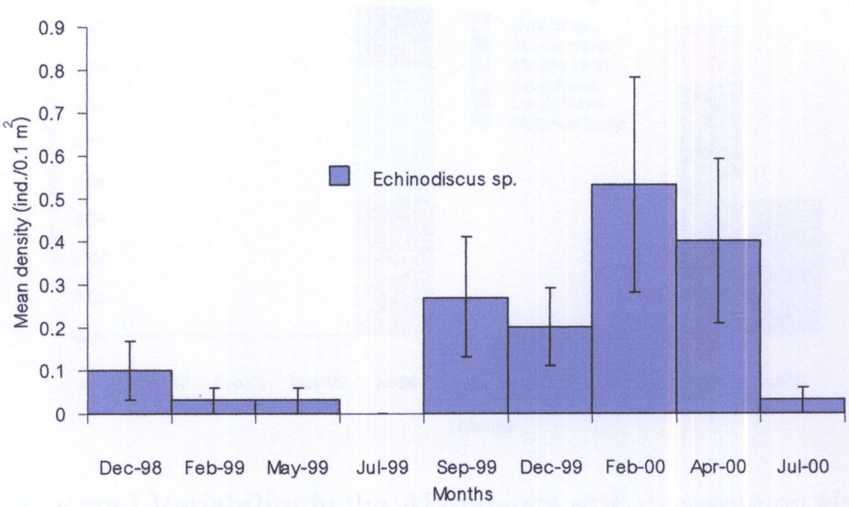

Figure 71 Seasonal Variability in the Abundance of *Echinodiscus* sp. on Haad Maeramphueng

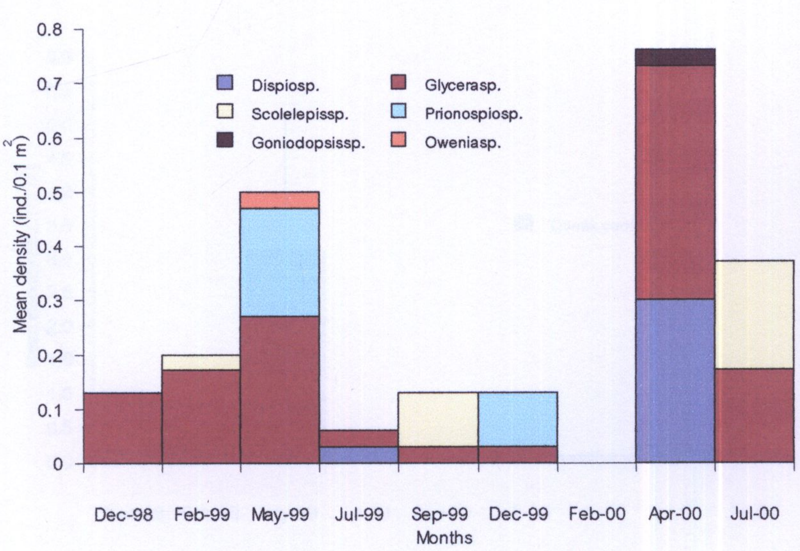

Figure 72 Seasonal Variability in the Abundance of Polychaete on Haad Takuan

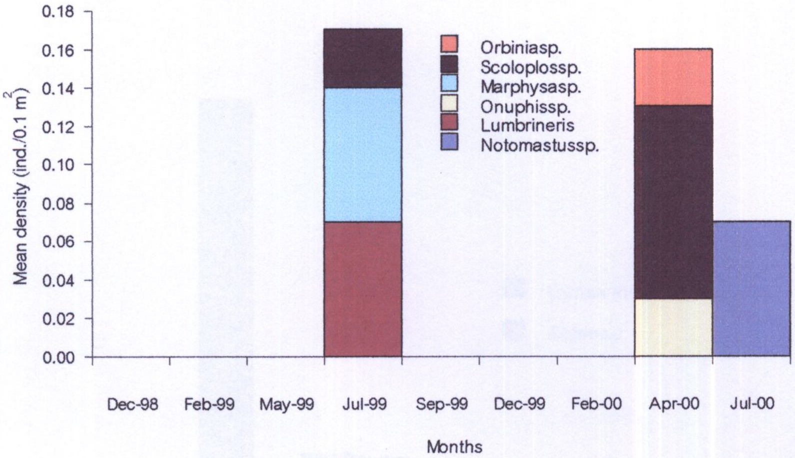

Figure 73 Seasonal Variability in the Abundance of Polychaete on Haad Takuan

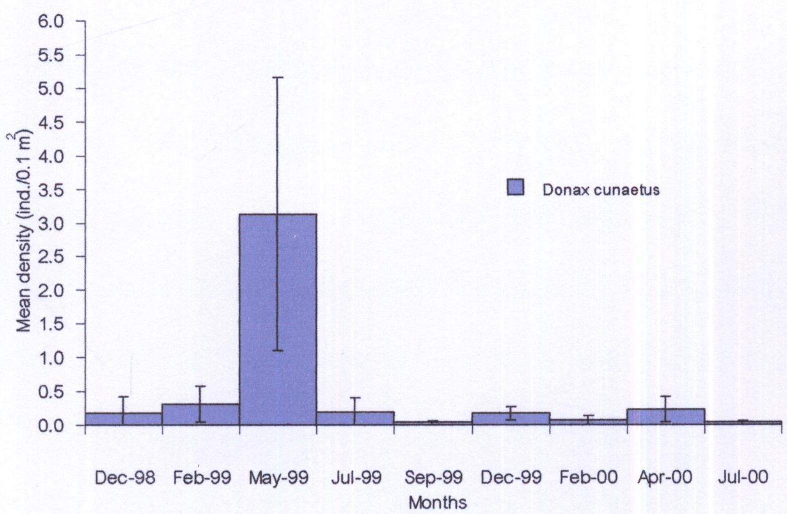

Figure 74 Seasonal Variability in the Abundance of *Donax cunaetus* on Haad Takuan

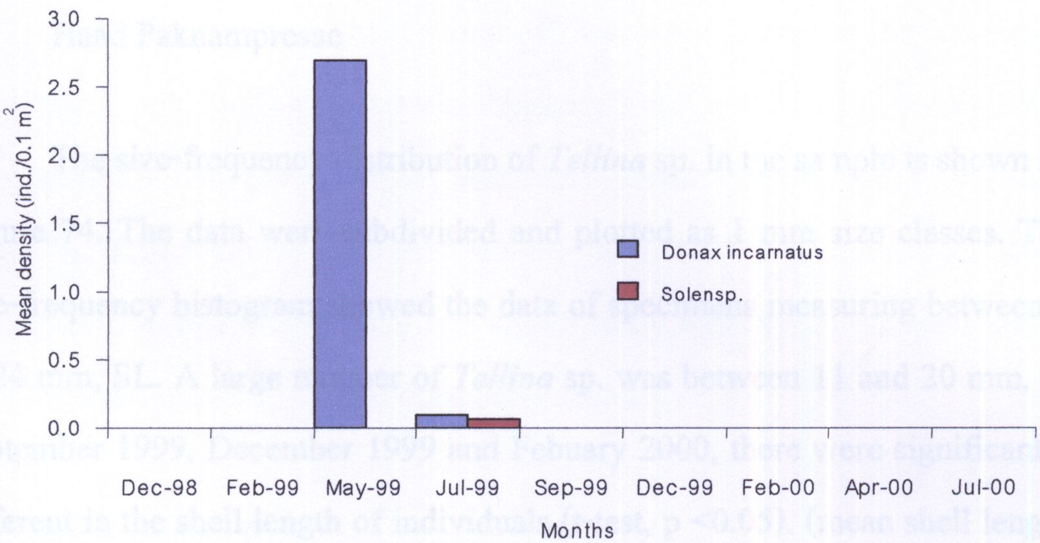

Figure 73 Seasonal Variability in the Abundance of *Donax incarnatus* and *Solen* sp. on Haad Takuan

Size-Frequency Distribution

Haad Paknampresae

The size-frequency distribution of *Tellina* sp. in the sample is shown in Figure 74. The data were subdivided and plotted as 1 mm size classes. The size-frequency histogram showed the data of specimens measuring between 6 to 24 mm, SL. A large number of *Tellina* sp. was between 11 and 20 mm. In September 1999, December 1999 and Febuary 2000, there were significantly different in the shell length of individuals (t-test, $p < 0.05$). (mean shell length 13.89 ± 0.27, 14.21 ± 0.21 mm, and 13.31 ± 0.66 mm, respectively).

Haad Maephim

The size-frequency distribution of *Donax incarnatus* in the samples is shown in Figure 75. The histogram showed the data of specimen measuring between 2 mm to 24 mm, SL. In July 1999 and July 2000, the population consisted of small individuals (mean shell length 6.25 ± 0.13 and 4.42 ± 0.05 mm). The large numbers were between 3-9 mm and 2-8 mm, respectively (92% and 97% of the total abundance in these months). In these months there were significantly different in the shell length of individuals (t-test, $p < 0.05$).

Haad Maeramphueng

The size-frequency distribution of *Donax incarnatus* in the samples is shown in Figure 76. The sizes varied between 3 mm and 21 mm. In July 2000, the population consisted of small individuals (mean shell length 8.76 $\pm$ 0.32 mm). The large numbers were between 4-6 mm (68.37% of total abundance in this month). In this month there was significantly different in the shell length of individuals (t-test, $p < 0.05$) from other months.

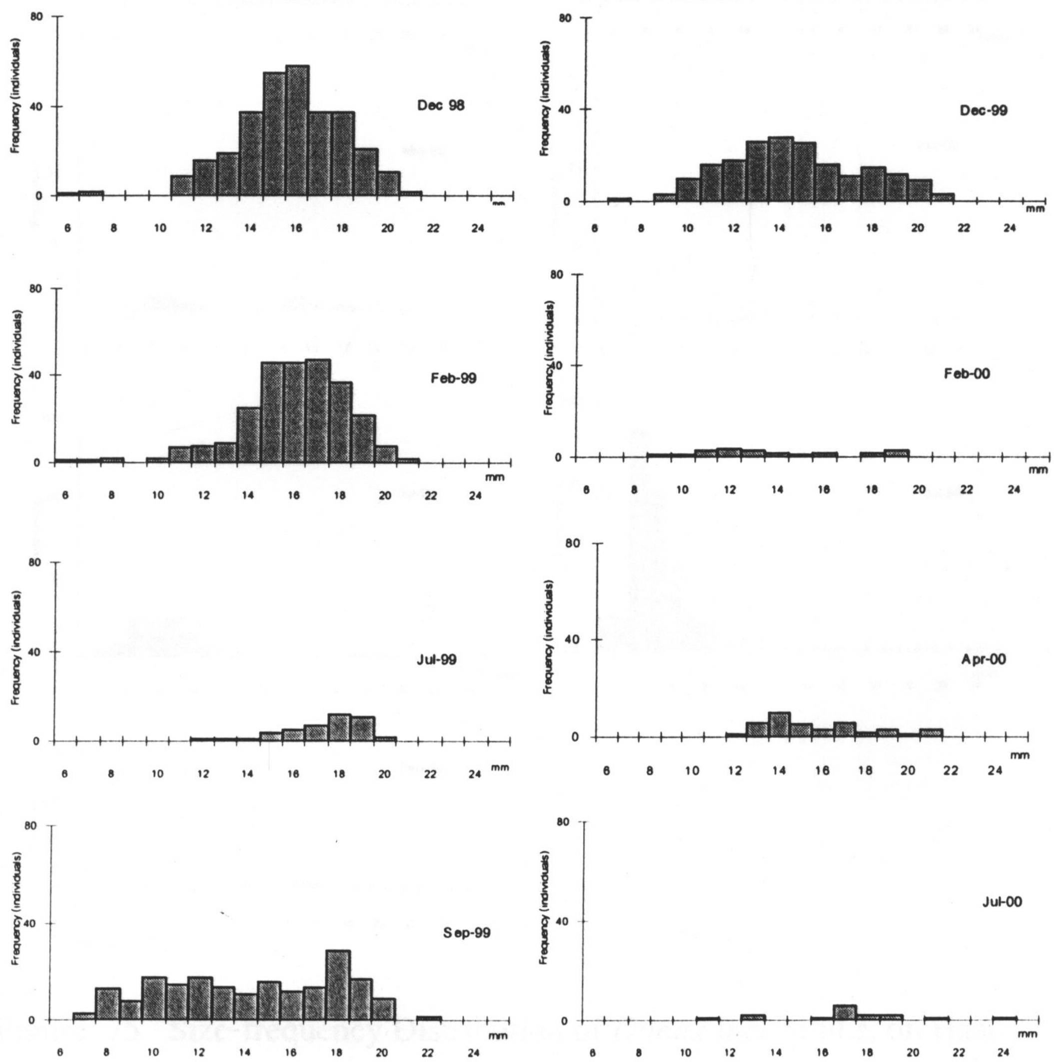

Figure 74 Size-frequency Distribution of *Tellina* sp., on Haad Paknamprasae, Rayong Province. (shell length, mm)

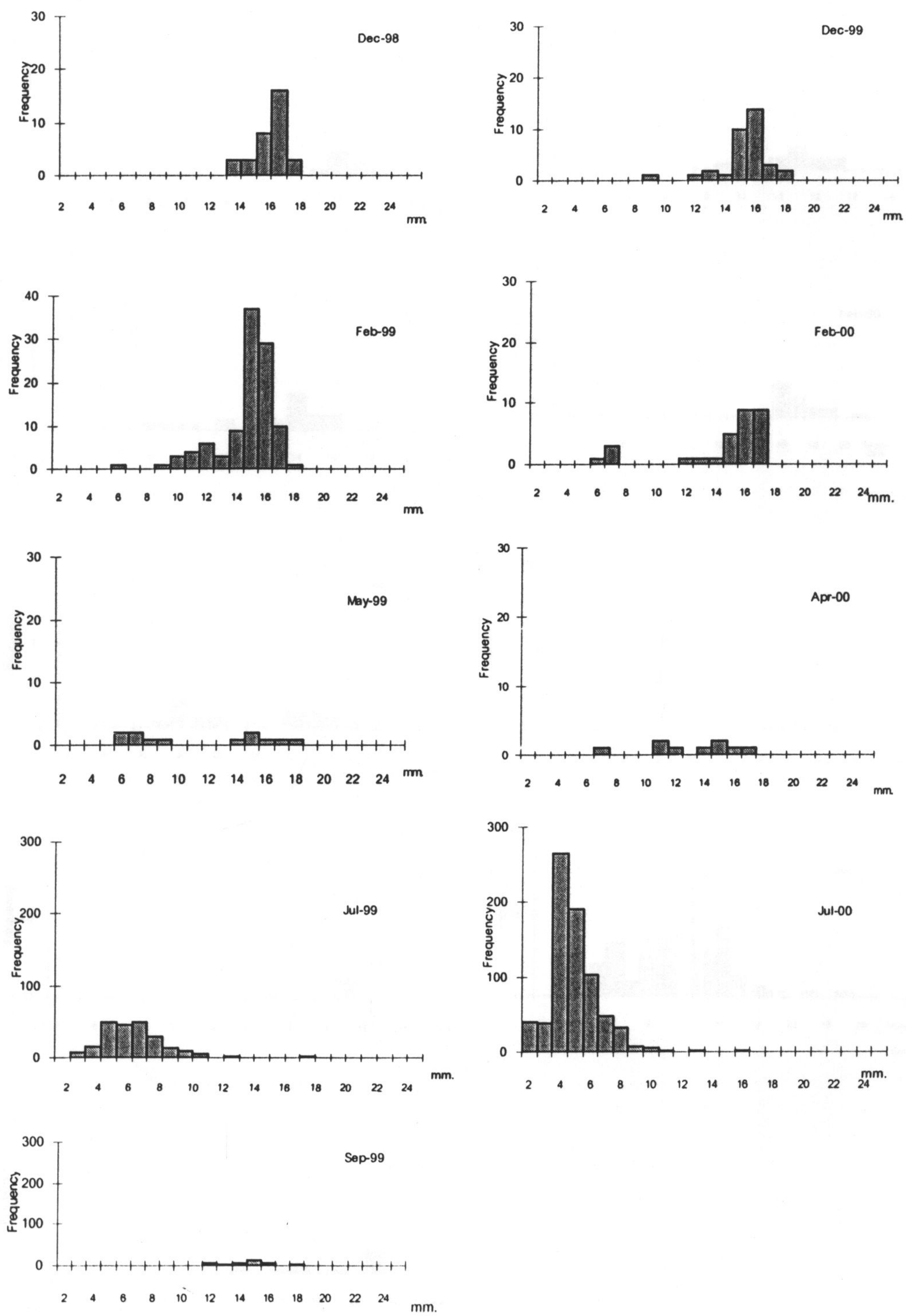

Figure 75 Size-frequency Distribution of *Donax incarnatus*, on Haad Maephim, Rayong Province (shell length, mm)

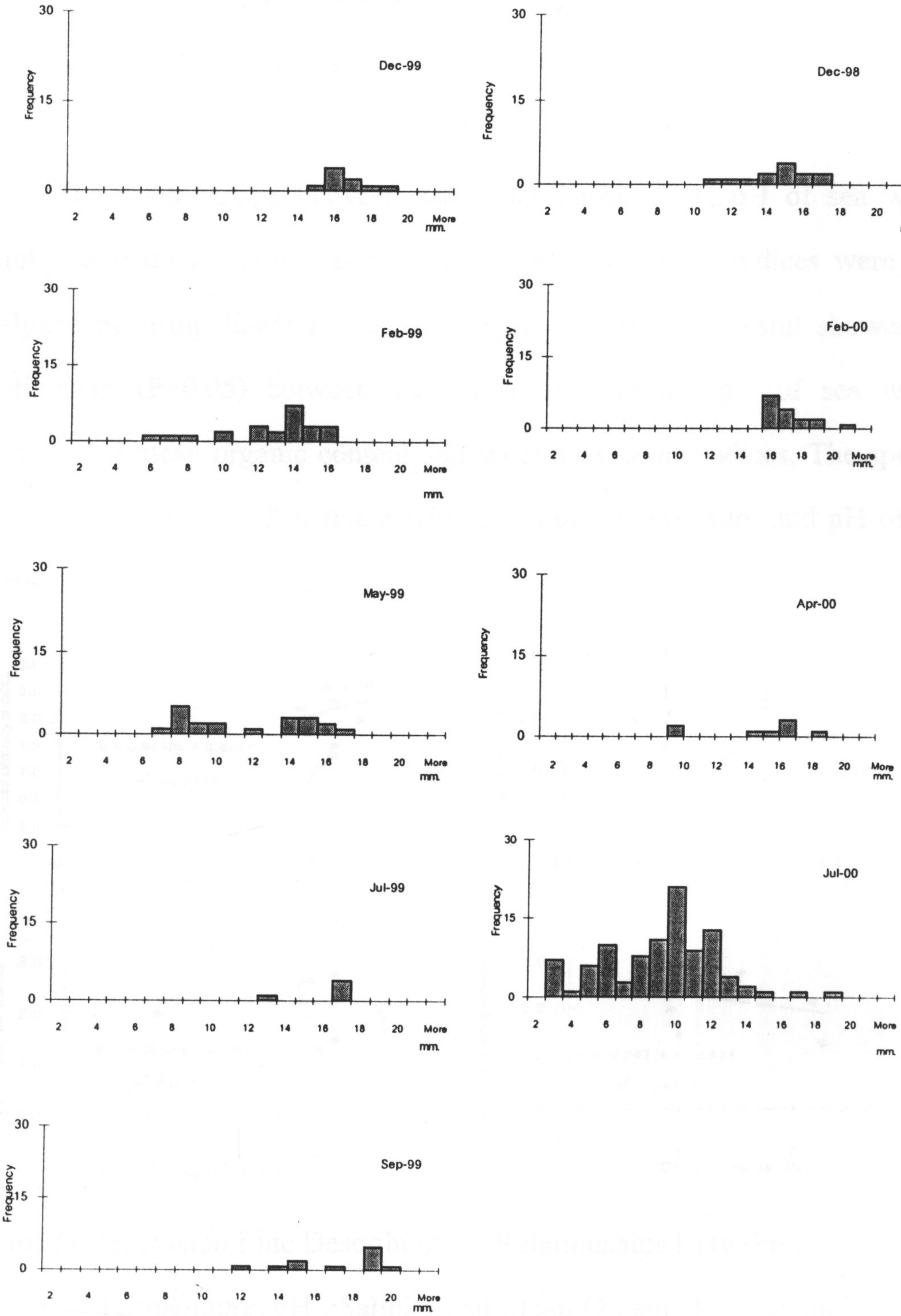

Figure 76 Size-frequency Distribution of *Donax incarnatus*, on Haad Maeramphueng, Rayong Province (shell length, mm)

Relationships between Environmental Factors and Species Diversity indices

The relationships between sea water temperature, pH of sea water, salinity, and mean organic content and species diversity indices were also analyzed by using linear regression (Figure 77-80). The result showed no relationship (P>0.05) between sea water temperature, pH of sea water, salinity, and mean organic content and species diversity indices. The species diversity indices tended to relate with sea water temperature and pH of sea water .

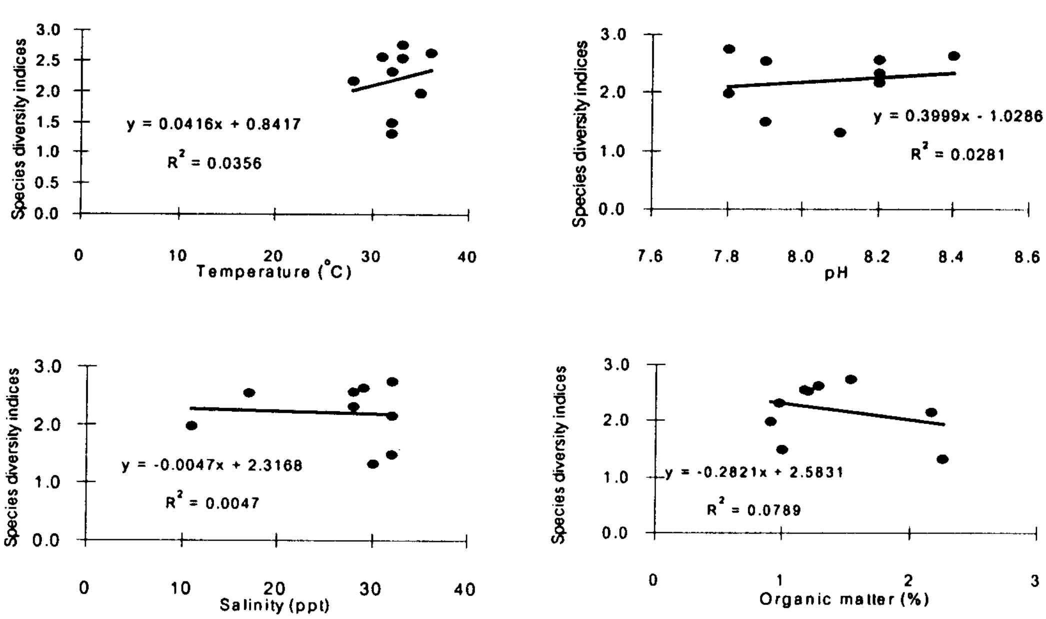

Figure 77 Regression Line Describing the Relationships Between Sea Water Temperature, pH , Salinity and Mean Organic Content and Species Diversity Indices at Haad Paknamprasae

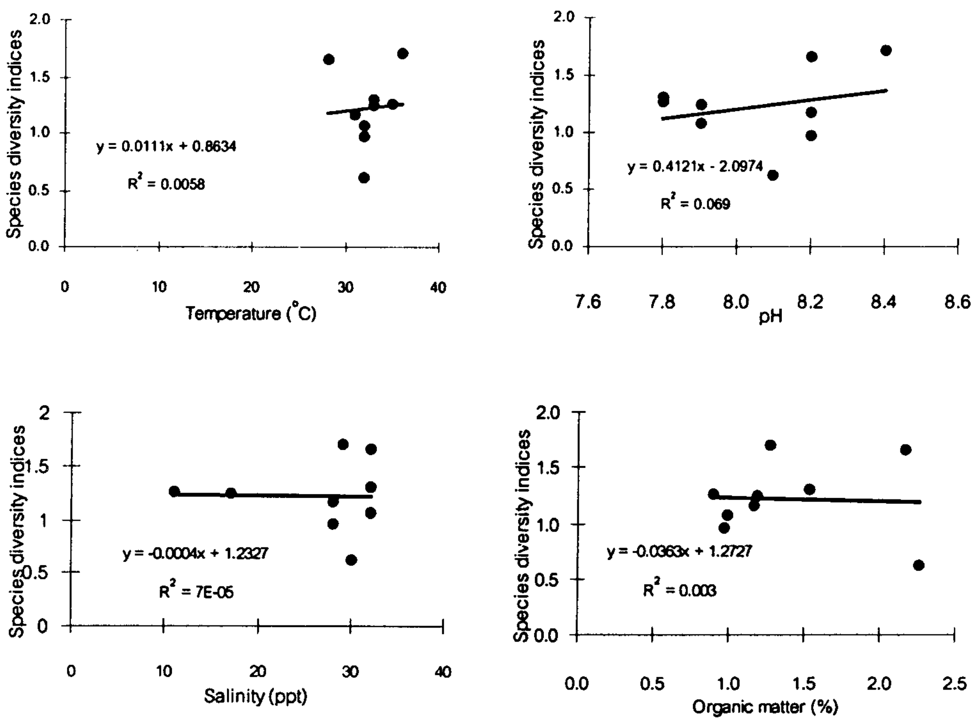

Figure 78 Regression Line Describing the Relationships Between Sea Water Temperature, pH, Salinity and Mean Organic Content and Species Diversity Indices at Haad Maephim

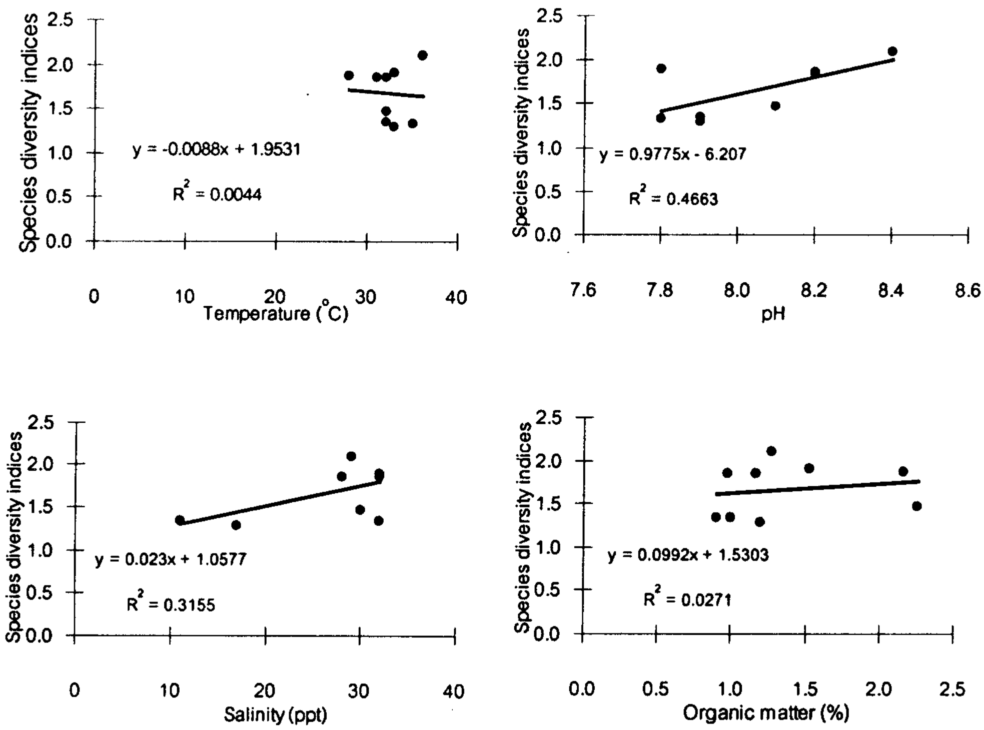

Figure 79 Regression Line Describing the Relationships Between Sea Water Temperature, pH, Salinity and Mean Organic Content and Species Diversity Indices at Haad Maeramphueng

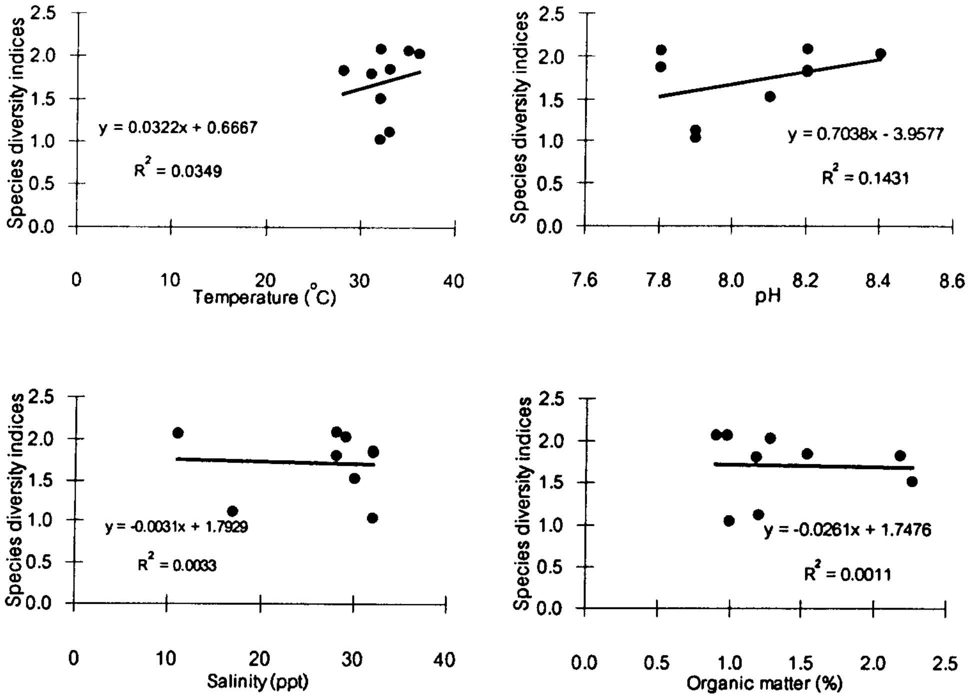

Figure 80 Regression Line Describing the Relationships Between Sea Water Temperature, pH, Salinity and Mean Organic Content and Species Diversity Indices at Haad Takuan

CHAPTER 5

DISSCUSTION

Temporal Changes

The abundance of macrobenthos on sandy shores of Rayong province was seasonally variation. In the case of bivalve *Donax incarnatus* on Haad Maephim and Haad Maeramphueng, the higher numbers were found in July 2000, mainly due to the new generation (small individauls size). The increase in population was attributed to recruitment of certain species. Ong and Krishman (1995, 24) showed the sharp increase in mulluscan population after June 1988, with attribution to recruitement of *Umbonium vestiarium* and the number apparently reduced during the monsoon months. Major increase in density of *Spio pacifica* was due to the recruitment of juveniles to population. The abundance peaks are usually related to the reproduction events (Bone and Klein 2000, 283). Annual recruitment of species increased their population densities (Bamber 1993, 103). The high numerical density in the midlittoral association is a result of the vast number of the small gastropod *Hydrococcus graniformis* and *Batillariella estuarina* (Well and Roberts 1980, 506). Bone and Klein (2000, 285) suggested that macroinfauna density peaks may be synchronized with organic-rich sediment. Richards et al. (1999, 174) concluded that predation, especially by *Carcinus* can significantly reduce bivalve densities and may act as a causal mechanism for both the spatial and temporal variability in intertidal bivalves. An abundance food source may allow for increased survivorship and hence a large population size (Donn 1987, 221). The variation in food source may explain the difference in growth rate, individual size, and life span (Omena and Amaral 2000, 428).

In case of the bivalve, *Tellina* sp. on Haad Paknamprasae, which were absent in May 1999, but rediscovered in July 1999 explained that population of *Tellina* sp. in May 1999 was less than 0.5 mm. The greatest decrease attributed to recruitment failure and with its small size, may be under sample by a 0.5 mm (Bamber 1993, 105-106). The numerical difference was due to the succession of the different phase of the species life cycle (Colombini et al. 2002, 1005). Bamber (1994, 40) concluded that the major factor structuring the littoral benthic community has been the appearance of the predator. Quijón and Jaramillo (1993, 665) suggested that the absence of adult individuals (Juvenile might have been there but went through the 500 μm sieve) in the sediment can be accounted for by predation.

Change in community composition of marobenthos on sandy shores of Rayong province can be explained by the diversity and density. The changes in number of taxa were primarily related to species that were not common or abundance.(Jaramillo et al. 2001, 341). The increase density of *S. pacifica* was responsible for the decline in diversity and species evenness (Dexter 1984, 668-669).

Dominant Species

In this study (Rayong Province) *Tellina* sp. was numerically dominated on Haad Paknamprasae. *Donax incarnatus* was numerically dominated on Haad Maephim and Haad Maeramphueng. *Donax cuneatus* was numerically dominated on Haad Takuan. Comparing with Dexter (1996, 6-18) studied at Phuket Island, the dominant species were the polychaete, *Armandia leptocirris* on Nai Yang sand flat, the bivalve *Donax faba* on Patong Beach, the harpacticoid copepod *Canuella* n. sp. on Kuta Beach, and spionid polychaete *Scolelepis* n. sp.1 on Nai Harn Beach. Barros et al. (2001a, 359) showed that the polycheate *Scolelepis sqaumata* was the numerically dominant in six beaches near Guaratuba Bay, South Brazil. Polychaetes *Scolelepis squamata* was dominated in terms of density on the beaches of De Panne, Belgium (Degraer et al. 1999, 747). At Kyeonggi Bay, Korea, the sand flat benthic communities were dominated by the filter-feeding bivalves, *Mactra veneriformis* and *Solen strictus*, the capitellid polychaete *Mediomastus* sp., the paraonid polychaete *Aricidea* sp. and the gastropod *Reticunassa festiva* (Ahn and Choi 1998, 811). *Emerita analoga* and the isopod *Excirolana hirsuticauda* were dominated at the beaches of Los Molinos, Bahía Corral, south central Chile (Jaramillo et al. 2002, 528). The air-breathing crustaceans *Talorchestia quadrispinosa* and *Tylos granulatus* were recorded at Namibian coast (McLachlan 1996, 209). In the Atlantic coast or Uruguay, benthic communities were numerically dominated by the ciroranid isopod *Excirolana armata* , the polychaete *Scolelepis guacha*, and *Emerita armata* (Lercari and

Defeo 2003, 116). At the ultra-dissipative beach of De Panne, Belgium, the polychaete *Scoloplos squamata* dominated in terms of density (Degraer et al. 1999, 747). The macrofauna on Penang Island, Malasia was dominated by crutsracean; *Excirolana oreintatalis*, *Ocypod ceratophthalmus*, and mollusc; *Donax faba*, *Umbonium vestiarium*, *Tylosochri* (Jones 1979, 680).

Macrobenthos Community

The study on macrobenthos on sandy shores of Rayong Province revealed that there were six major groups. These comprised of polychaetes, gastropods, bivalves, crustaceans, echinoderms and other groups, comprising of sea anemone, brachiopod and hemichordate. Comparing with the study of the macrobenthos community on sandy beaches of the eastern Thailand, studied by Kullathan (2002, 97) found 5 major groups, comprising of bivalves, gastropods, crustaceans, polychaetes and echinoderms, with a total of 73 species. On Phuket Island, Dexter (1996, 7) found that nemerteans, sipunculids, polychaetes, bivalves, gastropods, crustaeans, and ohiuroidea recruited on the beaches. Dexter (1984, 663-672) studied on variability in the community structure at south-eastern New South Wales. From the four intertidal sandy beaches represented 85 species, with 3 major groups comprising of polychaetes, crustaceans, bivalves. Brazeiro and Defeo (1996, 525) studied on sandy beach macroinfauna at Barra del Chuy beach, on the eastern coast of Uruguay. The results showed that there were 23 taxa with 5 major groups, comprising of crustaceans, insects, gastropods, bivalves and polychaetes. Ong and Krishnan (1995, 30) studied at Telong Aling, Penang, they found 47 species of macrobenthos, with 6 major groups comprising of bivalves, gastropods, polychaetes, echinoderms, crustraceans and other groups, including of *Aspidosiphon* sp. and *Sipunculus nudus*. Shelton and Robertson (1981, 836) studied on community structures of intertidal macrofauna at two surf-zone Texus sandy beaches. A total of 50 species was collected with 8 major groups including of turbellarians, nemerteans, polychaetes, oligochaetes, gastropods, bivalves, crustaceans and echinoderms. The major groups in South Brazil were reported to be polychaetes, crustaceans, molluscs and other groups (Barros 2001, 354).

Relationship between Macrobenthos and Environmental Factors

Temperature

Seasonal variation of seawater temperatures at the study sites seemed to affect sandy beach macrobenthos. The intertidal polychaete *Diopatra cuprea* showed thermal sensitivity rates, but the metabolic rates did not acclimate at the two temperatures (5^{o}C and 20^{o}C) (Mangum 1972, 113). Increased oxygen consumption of purple shore crab *Hemigrapsus nudus* resulting from an independent of acute or acclimate temperature was reported (Hulbert et al. 1976, 221).

Brey (1995, 90-91) compared two environmental conditions with different temperature, then the first strategy would result in more or less constant reproductive output, but at the coast of having less energy available for other metabolic demands at lower temperature. The second strategy would result in more or less constant share of gonad metabolism in total metabolism. Thermal was affected on cellular level: action potential generation, organelle level: mitochondrial respiration, membrane level: alteration in bilayer static order, biochemical synthesis: protein synthesis and the heat shock response, protein level:enyme thermal stability (Somero 2002, 782-786). From a case study, *Bathyporeia. gulliamsoniana* distributed south to the Mediterranean, showed no correlation with temperature (Bamber 1993, 106). Ansell et al. (1972b, 316) indicated that *E. holthuisi*, living in area with a sea water temperature approaching 30°C for most of the year, showed no temperature compensation in rate of growth.

Salinity

The salinity at Rayong sandy beach is generally 11‰-35‰. The species diversity index was decreased at low salinity. The fauna at Nai Yang was higher density during the dry season, suggested that fauna was limited by reducing salinities during the wet season (Dexter 1996, 24). The clam can not maintain normal metabolic activity in salinities lower than 15 ‰ when the clams are exposed for a long time (Kim et al. 2001, 160-161). Increased oxygen consumption of purple shore crab *Hemigrapsus nudus* resulting from an acute decrease in salinity appeared to be immediate (Hulbert et al. 1976, 221). At Cochin beach there was a less diverse, the restriction results partly from the seasonally much reduced salinity (Ansell et al. 1972, 59).

Organic Matter

Factors extrinsic to the community, mainly related to the input of pulses of external organic materials ("food" e. g. dissolved organic matter) (Bone and Klein 2000, 284.). Large amounts of potential food for deposit-feeder organisms are showed by the higher amount of organic matter in sediment (Quijón and Jaramillo 1993, 665). The higher density of organism along the Pacific beaches would provide a greater food source for *E. braziliensis*. Organic debris within the sand was a source of food for deposit feeders (Dexter 1979, 554). Organic matter contents of the present study indicated the importance for macrobenthos nutrition.

Regression analyses between species diversity variation and temperature, salinity and mean organic content showed no significant relationship within each beach.

Beach Characteristics and Sand Transportation

The beach characteristics of four sandy shores of Rayong Province, Haad Paknamprasae, Haad Maephim, Haad Maeraphueng, and Haad Takuan were different. Higher density and species diversity of macrobenthos on Haad Paknamprasae was related with flatter and stable beach profiles. Variability of beaches profiles are attributed to seasons. Higher sand transports were found between February to July. The density of macrobenthos was decreased in higher sand transport month. Jaramillo et al. (2001, 340) suggested that morphodynamic beach stages were not always a straight predictor of the community structure of the sandy beach macroinfauna. This is similar to the conclusion of Jaramillo et al. (2000b). The highest species richness and macroinfauna abundances occurred at the dissipative beach (highest Dean' parameter), while the lowest value for that community attributes were found at the reflective site with the lowest Dean's parameter. (Jaramillo et al. 2001). The four study sites in Rayong Province clearly explained how beach characteristics can play a role on macrobenthos communities.

The present study clearly showed that there were certain erosion rates in Rayong Province. Ong and Krishnan (1995, 27) pointed out that *Umbonium* disappeared due to partly redistribution by erosion and partly to death from reduction in salinity caused by unimpeded runoff after removal of the vegetation. Macrobenthos was clearly effected by the local sediment instability, showing the lowest values of abundance and species (Netto et al. 1999, 301). Potential effects of beach erosion on benthic macrofauna are poorly known (Barros et al. 2001, 352).

Sediment Characteristics

The differences of sand particle size between beaches were found. Haad Maephim and Haad Maeramphueng were similar in sediment charteristics, fine sand. The sediment characteristic of Haad Paknamprasae were very fine sand and Haad Takuan, coarser sand. The sediment characteristic has a limited role in the community structure of the intertidal macroinfauna (Quijón and Jaramillo 1993, 662). The frequency distribution showed that in 67 % of 36 beaches, *E. braziliensis* was found inhabiting fine sands (i. e. 0.125-0.250 mm), whereas in only four of the 54 beaches , all pertaining to Uruguayan data, it inhabited coarse sand (0.5-1 mm) (Defeo et al. 1997, 457). Several groups of macrobenthos observed in Rayong Province showed relationship with sediment characteristics.

Bioindicator

The soldier crab *Dotilla wichmanni* on sandy shores of Rayong Province was a useful bioindicator for anthropogenic impacts on exposed sandy beaches. Barros (2001, 403) concluded that urban beaches had significantly lower numbers of burrow of *Ocypode cordimana* than did non-urban beaches thus, the number of burrows is likely to be a useful indicator for anthropogenic impacts on exposed sandy beaches.

Population Structure

The basic information on population structure of mole crab on an intertidal habitat could be included in a plan of the future research programme leading to commercial exploitation of this nutritionally rich resource on sustainable basis (Ingole et al. 1998, 19). Moreover the commercially harvested clams such as *Donax incarnatus* on Haad Maephim and Haad Maeramphueng should be monitored in a long term in order to know trends of population dynamics for appropriate coastal resource management.

The major environmental factors on macrobenthos of Rayong Province were beach characteristics, sand particle size, sand transportation, salinity of sea water and anthropogenic impacts, i.e. tourist activities. The effects of these factors resulted in difference of macrobenthos community between beaches. Haad Maephim and Haad Maeramphueng were in the same environmental factors, except high tourist activities on Haad Maeramphueng. It caused low population density on macrobenthos, for the cases of populations of *Donax incarnatus* and the soldier crab, *Dotilla wichmannic.*

APPENDIX

Results of ANOVA Analyzed and Principle Components Analysis

Table 5 Results of Two Factor ANOVA on pH of Haad Paknamprasae, Haad Maephim, Haad Maephim and Haad Takuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Months)	3.5289	8	0.441	12.841	0.0000	2.3551
Columns (Beaches)	0.1831	3	0.061	1.7763	0.1786	3.0088
Error	0.8244	24	0.0343			
Total	4.5364	35				

Table 6 Results of Two Factor ANOVA on Mean Organic Matter of Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and Haad Takuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Months)	7.3396	8	0.9174	3.8876	0.0045	2.355
Columns (Beaches)	5.451	3	1.817	7.6991	0.0008	3.0087
Error	5.6639	24	0.2359			
Total	18.4545	35				

Table 7 Results of Two Factor ANOVA on Salinity of Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Months)	487.5556	8	60.9444	6.4593	0.0002	2.3551
Columns (Beaches)	134.3056	3	44.7685	4.7449	0.0098	3.0088
Error	226.4444	24	9.4352			
Total	848.3056	35				

Table 8 Results of Two Factor ANOVA on Temperature of Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Months)	121	8	15.125	22.2245	0.0000	2.3551
Columns (Beaches)	18.9167	3	6.3056	9.2653	0.0003	3.0088
Error	16.3333	24	0.6806			
Total	156.25	35				

Table 9 Results of Single Factor ANOVA on Median Grain Size of Haad Paknamprasae

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	88230.23	7	12604.3184	14.0459	0.0000	2.1415
Within Groups	63712.84	71	897.3639			
Total	151943.1	78				

Table 10 Results of Single Factor ANOVA on Median Grain Size of Haad Maephim

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	9131.86	7	1304.551	1.9973	0.0697	2.1613
Within Groups	40495.34	62	653.1506			
Total	49627.2	69				

Table 11 Results of Single Factor ANOVA on Median Grain Size of on Haad Maeramphueng

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19155.7	7	2736.529	13.3721	0.0000	2.139657
Within Groups	14734.41	72	204.6446			
Total	33890.12	79				

Table 12 Results of Single Factor ANOVA on Median Grain Size of HaadTakuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1581079	7	225868.5	4.4467	0.0004	2.1497
Within Groups	3403206	67	50794.12			
Total	4984285	74				

Table 13 Results of Two Factor ANOVA on Species Diversity Index of Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Months)	3.0427	8	0.3803	4.7941	0.0013	2.3551
Columns (Beaches)	4.2497	3	1.4166	17.8556	0.0000	3.0088
Error	1.9040	24	0.0793			
Total	9.1964	35				

Table 14 Results of Two Factor ANOVA on Evenness Index of Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Months)	0.1718	8	0.0215	3.0141	0.0172	2.3551
Columns (Beaches)	0.1974	3	0.0658	9.2358	0.0003	3.0088
Error	0.1710	24	0.0071			
Total	0.5401	35				

Table 15 Results of Two Factor ANOVA on Density of Macrobenthos on Haad Paknamprasae

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Taxa)	158.6278	51	3.1103	7.1627	0.0000	1.3786
Columns (Months)	3.70569	8	0.4632	1.0667	0.3855	1.9611
Error	177.1705	408	0.4342			
Total	339.504	467				

Table 16 Results of Two Factor ANOVA on Density of Macrobenthos on Haad Maephim

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Taxa)	140.4147	14	10.0296	4.1488	0.0000	1.78105
Columns (Months)	20.8849	8	2.6106	1.0799	0.3824	2.02209 1
Error	270.7551	112	2.4175			
Total	432.0547	134				

Table 17 Results of Two Factor ANOVA on Density of Macrobenthos on Haad Maeramphueng

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Taxa)	6.0414	18	0.3356	3.4144	0.0000	1.6759
Columns (Months)	1.0591	8	0.1324	1.3468	0.2252	2.0033
Error	14.1550	144	0.0983			
Total	21.2555	170				

Table 18 Results of Two Factor ANOVA on Density of Macrobenthos on HaadTakuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Taxa)	2.7027	29	0.0932	1.5418	0.0436	1.5165
Columns (Months)	0.9696	8	0.1212	2.0050	0.0467	1.9785
Error	14.0233	232	0.0604			
Total	17.6956	269				

Table 19 Results of Single Factor ANOVA on Density of Macrobenthos Between Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups (Beaches)	435.4958	3	145.1653	8.3047	0.0003	2.9011
Within Groups (Beaches)	559.3551	32	17.4798			
Total	994.8509	35				

Table 20 Results of Principle Components Analysis Between Haad Paknamprasae, Haad Maephim, Haad Maeramphueng and HaadTakuan

Sampling	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Pra1	3.38317	8.94406	2.46674	-.07203	-.98348	-.25263
Pra 2	1.19806	2.84252	1.06224	-.06805	-.60372	.08501
Pra3	1.13439	.99122	-1.08455	.22351	.00802	-.22783
Pra 4	1.50131	-.66707	.01152	.77471	1.44117	-.75898
Pra 5	2.72984	6.30223	.53870	.32877	1.42720	.13537
Pra 6	3.07308	7.29254	-3.38131	-.50773	-.09720	.56918
Pra 7	1.21207	.10333	-1.72101	.00899	-.35226	-.19744
Pra 8	1.49915	-.30456	-1.06466	.32038	-.43640	-1.35155
Pra 9	1.18338	.68581	.21017	.62079	1.38821	.34913
Mp 1	-6.42020	-.40967	.01149	.16448	-.18851	.18435
Mp 2	-2.20090	.57015	.17705	.00980	-.07327	.12650
Mp 3	.80246	1.14363	.37879	.08575	.10971	.08447
Mp 4	-2.35137	.51835	.28744	-.62002	.17918	-.08307
Mp 5	-.25830	1.01390	.24895	.14669	-.10088	.16187
Mp 6	-.03550	1.07952	.18729	.12358	-.15282	.23415
Mp 7	.03495	1.14178	.26326	.26034	-.30212	.12436
Mp 8	.73877	1.23817	.30865	.16256	-.08828	.18214
Mp 9	-17.31314	-3.16858	-.18371	.40872	.02446	-.04030

Table 20 (continued)

Sampling	**Axis 1**	**Axis 2**	**Axis 3**	**Axis 4**	**Axis 5**	**Axis 6**
Mr 1	.50212	.93838	-1.09726	-.25021	-.24510	1.12211
Mr 2	-.12989	1.04939	.23308	-.01529	-.05433	.17851
Mr 3	.42748	1.12059	.22634	.19368	-.05589	.04255
Mr 4	.91763	1.27487	.16021	.08278	-.10639	.28076
Mr 5	1.74463	1.51379	.26591	.06927	-.13216	.22664
Mr 6	.70881	1.19799	-.17142	.17869	-.20646	-.35212
Mr 7	.68485	1.12993	-.73038	.39264	-.43764	-1.32887
Mr 8	.78918	1.23291	-.00285	.18101	-.19101	-.26483
Mr 9	-2.12426	.41248	-.16436	-.05083	.02159	.03074
Ta 1	1.03530	1.35654	.29983	-.06711	-.07030	.18242
Ta 2	1.03410	1.35316	.28688	-.19373	-.02512	.14210
Ta 3	-1.63381	.79907	.39209	-2.75021	.73285	-.66116
Ta 4	.94162	1.32076	.26962	-.07720	-.00718	.14560
Ta 5	1.03775	1.35202	.28768	.05990	-.10347	.21794
Ta 6	1.03631	1.35694	.27812	-.07500	-.08388	.19907
Ta 7	1.03725	1.35103	.28254	.01875	-.09235	.20802
Ta 8	1.04036	1.33789	.19548	-.12182	-.04643	.08345
Ta 9	1.03933	1.34762	.27142	.05339	-.09574	.22235

Table 21 Results of Principle Components Analysis on Haad Paknamprasae,

Sampling	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Pra 1	.51012	.37897	-.20515	-.03567	-.06220	-.18269
Pra 2	.09620	.32684	-.29966	.01600	-.00877	.18086
Pra 3	-.52324	-.14390	-.01113	-.11119	-.20535	-.04951
Pra 4	-.03518	.14028	.33272	-.37419	.05778	.01177
Pra 5	.51432	.02419	.21707	.05042	-.00343	.10385
Pra 6	.51726	-.58806	.06943	.14128	-.01518	-.02945
Pra 7	-.34689	-.28728	-.16581	-.00860	-.07514	.05616
Pra 8	-.26948	-.17585	-.18982	-.03914	.28579	-.05432
Pra 9	-.46311	.32481	.25236	.36110	.02650	-.03664

Table 22 Results of Principle Components Analysis on Haad Maephim

Sampling	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Mp 1	.40351	-.13204	-.08042	-.04573	.04863	.01354
Mp 2	.10727	.00555	-.10007	-.05431	-.03737	-.03007
Mp 3	-.42062	.21972	.10378	.00548	.00662	.00296
Mp 4	.12747	.17105	-.14789	.12765	.00261	.00554
Mp 5	-.16070	.00856	-.02038	-.06434	.01111	-.01258
Mp 6	-.20675	-.08192	-.02269	-.04021	-.04927	.03361
Mp 7	-.22957	-.28247	.07391	.10853	-.00213	-.01152
Mp 8	-.41136	.02454	.03205	-.03818	.03136	-.00145
Mp 9	.79075	.06701	.16171	.00110	-.01157	-.00002

Table 23 Results of Principle Components Analysis on Haad Maeramphueng

Sampling	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Mr 1	-.06548	-.38805	.19713	.03051	-.00452	.00866
Mr 2	-.11625	.00333	-.11840	.02088	.01707	-.05174
Mr 3	.01416	-.00934	-.13371	-.08861	.03455	.02934
Mr 4	.11746	-.14992	-.14034	-.07692	-.07653	-.04543
Mr 5	-.28593	.11687	-.05003	.16841	-.05980	.01322
Mr 6	.18983	.01790	-.00682	.08587	.12882	-.02238
Mr 7	.30566	.23580	.18607	-.00593	-.05394	-.02955
Mr 8	.19643	.02241	-.05222	.00111	-.01768	.09300
Mr 9	-.35588	.15100	.11831	-.13534	.03204	.00488

Table 24 Results of Principle Components Analysis on Haad Takuan

Sampling	Axis 1	Axis 2	Axis 3	Axis 4	Axis 5	Axis 6
Ta 1	-.09074	-.03046	.03885	-.02850	-.06838	-.00240
Ta 2	-.05039	.02164	-.00579	-.02095	.00903	.05300
Ta 3	.70991	-.00500	.00768	.00636	-.00012	-.00135
Ta 4	-.05025	-.01358	.01917	-.04832	.03067	-.02458
Ta 5	-.12783	-.01737	.04528	-.00528	.01229	-.01059
Ta 6	-.08807	-.10917	-.10348	.03570	-.00227	-.00293
Ta 7	-.11314	-.01826	.00566	-.02260	.02497	.00322
Ta 8	-.06273	.14243	-.07616	-.00121	-.01115	-.01400
Ta 9	-.12676	.02978	.06878	.08480	.00495	-.00038

Table 25 Variance Extracted, First 10 Axes of Sandy Shores of Rayong Province

AXIS	Eigenvalue	% of Variance	Cum.% of Var.	Broken-stick Eigenvalue
1	412.561	58.277	58.277	51.211
2	226.827	32.041	90.318	40.485
3	27.552	3.892	94.210	35.122
4	10.203	1.441	95.651	31.547
5	8.861	1.252	96.903	28.865
6	7.307	1.032	97.935	26.720
7	5.323	.752	98.687	24.932
8	3.317	.469	99.156	23.400
9	2.181	.308	99.464	22.059
10	1.040	.147	99.611	20.867

Table 26 Variance Extracted, First 10 Axes of Haad Paknamprasae

AXIS	Eigenvalue	% of Variance	Cum.% of Var.	Broken-stick Eigenvalue
1	1.484	43.827	43.827	.300
2	.856	25.286	69.112	.234
3	.422	12.459	81.571	.200
4	.308	9.108	90.679	.178
5	.138	4.067	94.746	.162
6	.088	2.592	97.339	.148
7	.054	1.589	98.927	.137
8	.036	1.073	100.000	.128
9	.000	.000	100.000	.120
10	.000	.000	100.000	.112

Table 27 Variance Extracted, First 10 Axes of Haad Maephim

AXIS	**Eigenvalue**	**% of Variance**	**Cum.% of Var.**	**Broken-stick Eigenvalue**
1	1.283	80.005	80.005	.355
2	.187	11.637	91.642	.248
3	.083	5.156	96.798	.194
4	.040	2.516	99.314	.159
5	.007	.467	99.781	.132
6	.003	.159	99.939	.111
7	.001	.039	99.978	.093
8	.000	.022	100.000	.078
9	.000	.000	100.000	.064
10	.000	.000	100.000	.052

Table 28 Variance Extracted, First 10 Axes of Haad Maeramphueng

AXIS	Eigenvalue	% of Variance	Cum.% of Var.	Broken-stick Eigenvalue
1	.408	43.224	43.224	.183
2	.266	28.167	71.391	.131
3	.144	15.283	86.674	.105
4	.069	7.329	94.003	.087
5	.032	3.365	97.368	.074
6	.016	1.683	99.051	.064
7	.005	.566	99.618	.055
8	.004	.382	100.000	.047
9	.000	.000	100.000	.041
10	.000	.000	100.000	.035

Table 29 Variance Extracted, First 10 Axes of Haad Takuan

AXIS	Eigenvalue	% of Variance	Cum.% of Var.	Broken-stick Eigenvalue
1	.574	86.880	86.880	.086
2	.035	5.346	92.226	.065
3	.025	3.827	96.053	.054
4	.013	1.911	97.964	.047
5	.007	1.003	98.967	.041
6	.004	.567	99.534	.037
7	.002	.361	99.895	.034
8	.001	.105	100.000	.031
9	.000	.000	100.000	.028
10	.000	.000	100.000	.026

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