ASPECTS OF BIOLOGY OF HORSESHOE CRABS FROM MENGGATAL RIVER AND NEARBY COASTAL WATER, SABAH

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I hereby declare that this dissertation is the result of my own independent work/investigation, except for quotations, summaries and references, which have been duly acknowledged.

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ABSTRAK

Kajian ke atas belangkas yang telah dijalankan di Sungai Menggatal dan kawasan perairan pesisir berhampiran telah menemui tiga spesies belangkas, iaitu *Carcinoscorpius rotundicauda*, *Tachypleus gigas,* and *Tachypleus tridentatus.* Hasil tangkapan per unit usaha yang rendah (12.4 individu/ha^2) telah dicatatkan di Sungai Menggatal. Nisbah *C. rotundicauda* jantan kepada betina adalah 6.6: 1 mencerminkan ketidakseimbangan populasi dinamik spesis ini di Sungai Menggatal. Spesimen yang dikumpul adalah individu matang berusia antara 10 hingga 15 tahun. Tempoh masa kematangan yang panjang menyebabkan sebarang penyingkiran belangkas matang akan meninggalkan impak yang besar terhadap populasi. Kajian penandaan menunjukkan bahawa *C. rotundicauda* bergerak dalam julat kawasan yang kecil dari tapak pelepasan. Ia juga terdedah kepada kadar penangkap semula yang tinggi terutamanya di kawasan yang mempunyai aktiviti penangkapan ikan yang tinggi. Di Tanjung Aru dan Teluk Likas masing-masing merekodkan 4.8 % dan 23.81 % belangkas yang ditanda telah ditangkap semula dalam tempoh masa 2 bulan. Belangkas didapati lebih menggemari cacing poliket daripada jenis makanan lain menunjukkan keserasian dengan habitat bentik. Berdasarkan penemuan ini, dicadangkan sebab-sebab antropogenik merupakan punca utama penurunan populasi spesis dan ketidakseimbangan nisbah jantina. Oleh demikian, aktiviti manusia seperti memancing, mengorek, menebusguna serta pemusnahan habitat persisir akan memberikan kesan yang buruk terhadap populasi belangkas.

ABSTRACT

A study on horseshoe crab was conducted at Menggatal River and the nearby coastal water found three species, which were *Carcinoscorpius rotundicauda*, *Tachypleus gigas,* and *Tachypleus tridentatus.* Low catch per unit effort (12.4 individual/ha^2) was recorded in Menggatal River. Ratio of *C. rotundicauda* males to female was 6.6: 1 reflects the imbalance population dynamic of the species in Menggatal River. Specimen collected were mature individuals of between 10 to 15 years old. Lengthy maturity period may result in any removal of matured individual to greatly impact the population. A tagging study found *C. rotundicauda* moving within a small range from the initial release site. It was also vulnerable to high rate of recapture especially in areas with high fishing activity. In Tanjung Aru and Teluk Likas, 4.8 % and 23.81 % of the tagged individuals were recaptured within 2 months respectively. Horseshoe crabs were found to prefer polychaetes worms to other food items which agreed to its benthic habitat. Based on these findings, it is suggested that anthropogenic causes were possibly the major reason for the decline in total population of species and imbalance sex ratio. Therefore, human activities such as fishing, dredging, reclamation and loss of coastal habitats would be highly detrimental to the population of horseshoe crabs.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Horseshoe crab is also known as king crab or sea spider and classified under the phylum Arthropoda, subphylum Chericerata, class Merostomata, subclass Xiphosuran, order Xiphosurida, and family Limulidae. They are a living fossil, having evolved from 500 million years ago. The morphology of the horseshoe crab has shown very little change since the latter half of the Paleozoic era, which is the Devonian period, about 350 million years ago (Barthel, 1974). Barthel (1974) also suggested that *Mesolimulus* of the upper Jurassic resembles closely to the modern day horseshoe crab species.

There are four extant species of horseshoe crab in the world, *Limulus polyphemus, Tachypleus gigas, Tachypleus tridentatus,* and *Carcinoscorpius rotundicauda.* One species, *L. polyphemus* is found off the coast of North and South America. Three other species, *T. gigas, T. tridentatus* and *C. rotundicauda* are found in the Southeast Asian seas (Sekiguchi, 1988). They are locally known as Belangkas, Kuncung, Koncos, or Keroncong at different locality within Malaysia.

In Peninsular Malaysia, only two species of horseshoe crab *T. gigas* and *C. rotundicauda* can be found around Perlis, Kedah, Penang, Perak, Selangor, Negeri Sembilan, Pahang, Johor, Terengganu, and Kelantan (Christianus, 2006). However, in Borneo, all three species of the Asian horseshoe crab could be found, namely *T. gigas*, *C. rotundicauda* and *T. tridentatus* (Shuster, 1960, 1982; Sekiguchi, 1988; Christianus, 2006).

1.2 Habitat

Horseshoe crabs thrive well in brackish estuarine water, where mixing of river water and seawater occur, by maintaining a steady osmotic state. Thus, the organisms including horseshoe crab that are found under this condition should be able to avoid or tolerate different forms of stress induced by a variety of abiotic and biotic factors such as extreme temperatures, desiccation, exposure to both salt and freshwater inundation as well as the rapid alteration of the environment due to tidal activity.

Stormer (1955) suggested changes have occurred several times in the habitat of the horseshoe crab, from marine to brackish water or fresh water and from fresh water to marine since the Devonian period and eventually to marine coastal water now, hence assuming that the habits of the ancient horseshoe crab were similar to that of extant species. The horseshoe crab has continued to live in coastal regions since the Mesozoic era and did not evolve to terrestrial life as other eurypterids (Sekiguchi & Yamasaki, 1988). They further explained that the limited in distribution and consistency of the habitat environment has contributed to the relatively small number of species and to the little change in physical appearance of the horseshoe crab.

As detritus and selective benthic feeders, they use the fifth walking legs equipped with gnathobase to push the sand or sediment aside and to crush the food propelled inward by the flabellum. Propelling of this flabellum not only helps the horseshoe crab to capture the food, but also prevent the leftover or sediment from clogging the gill chamber (Sekiguchi, 1988).

1.3 Importance of Horseshoe crab

The eggs of *Limulus polyphemus* form an important component of the diet for migratory shorebirds during their stopover in Delaware Bay (Smith, 2007). Smith (2002) in his study also shows that there is no substitute food item exists in sufficient quantity and quality to meet energetic requirements for migration and reproduction of the birds. Thus the absent or reduced in *Limulus* eggs will lead to ecological problem where the migratory birds' population will drop drastically. This species has also been exploited greatly, for commercial and medical purposes.

Female horseshoe crabs are used as life bait to capture eels and whelks. They are believed to be able to attract eels as they release specific odor or chemicals into the water. Each of these crabs provide baits for one to four eel or whelk pot and can last for three to five tidal cycles depending upon water temperature (Fisher & Fisher, 2000). Alternative bait and trap design has been initiated and applied to reduce the fishery demand for horseshoe crab as it protects horseshoe crab bait from scavengers and prolonged the lifespan of the bait.

The blood of *Limulus polyphemus* contains white blood cells called Limulae Ameboecyte Lysate (LAL) used for detecting endotoxins in the medical field. Since the LAL test was approved by the Food and Drug Administration in 1970s, the exploitation of *L. polyphemus* has intensified. This method is preferred as it takes a shorter time compared to the rabbit test and can detect even trace level of endotoxins as low as to 10^{-10} g. Other than being used in detection for the injectibles and food contamination, the LAL also applied in lipopolysaccharides assay and water quality research.

Horseshoe crab is an ingredient in local delicacies prepared as gulai, kerabu and soup. However, preparing horseshoe crab in an improper manner will leads to poisoning and lethal effect as recorded after consuming *C. rotundicauda*. Studies found that tetrodotoxin or TTX produced by *Vibrio algilinoticus* found in the intestine contributes to the toxic effect of horseshoe crab (Christianus & Saad, 2007).

Female horseshoe crabs are used as bait by the local to capture eel. The carapace of the horseshoe crab found by the locals is taken back home as decorative ornaments. There are some claims saying that the horseshoe crab having medical properties in curing skin problems, asthma, and joints pain such as arthritis. However, there's no scientific evidence to support these claims despite its wide use for medical purpose locally (Christianus & Saad, 2007).

1.4 Conservation effort

The horseshoe crab population in Malaysia is found to be in decline due to overharvesting by the local and destruction of natural spawning ground by coastal development, land reclamation and anthropogenic pollution (Christianus& Saad, 2007).

Conservation on the horseshoe crab can be executed through continual and consistent monitoring horseshoe crab population. The American has established a tagging system for all the captured or studied horseshoe crab that they found. This has largely contributes to the more effective monitoring of the American species. Laws, regulations and quotas have been established for the control of commercial exploitation of horseshoe crab. However, in Malaysia and many other Asian countries, these practices are not yet implemented. Public awareness and education on the importance of horseshoe crab in ecological balance is essential for effective monitoring and conservation effort.

Culturing of horseshoe crab is important in ensuring the continuity of supply for horseshoe crab stock. This method is also known as re-stocking. The management of coastal area need to be intensified as the anthropogenic development in the natural habitat of the horseshoe crab is worsens nowadays (Christianus, 2006). Horseshoe crab sanctuary should be established for better protection of the horseshoe crab habitat in their natural state without intrusion from human being.

1.5 Significance of the study

Studies on the Asian horseshoe crab is still lacking in Malaysia, particularly in Sabah. This study will help to contribute data and general view on the status of horseshoe crab in an area which experiencing rapid development. In wider perspective, this study may contribute to future research on the habitat in Menggatal River as well as a guideline for similar assessment to the horseshoe crab study in other areas.

1.6 Objectives

There are five main objectives to be achieved in this study, which are:

1. To determine the diversity and abundance of horseshoe crab in Menggatal River.
2. To identify the diet of horseshoe crab in Menggatal River.
3. To determine the size and age of the horseshoe crabs in Menggatal River.
4. To study the site specificity of the horseshoe crabs.
5. To study the level of awareness of public on the existence of horseshoe crab.

CHAPTER 2

LITERATURE REVIEW

2.1 Classification

Horseshoe crab is classified under phylum Arthropoda by Siebold and Stannius in 1848 (Yamasaki, 1988). Initially, horseshoe crab was considered to belong to subphylum Crustacea before it was found to be related closely with Scorpionida in subphylum Arachnids in 1881, and finally classified under subphylum Chericerata in 1901 by Heymon (Yamasaki, 1988). Dana (1852) established the class Merostomata, putting organisms with mouth positioned posteriorly between the two coxae of the prosomatic legs in this class.

Horseshoe crab is placed under subclass Xiphosuran, order Xiphosurida and suborder Limulina (Yamasaki, 1988). Leach (1819) put horseshoe crab under superfamily Limuroidea and family Limulidae. All the extant horseshoe crabs are included in family Limulidae. The most important contributors to the modern taxonomy of the horseshoe crab are van der Hoeven and Pocock, who have classified the four extant species.

Pocock (1902) divided the four species of horseshoe crab in family Limulidae into two subfamilies, Limulinae (Leach, 1819) and Tachypleinae (Pocock, 1902). American horseshoe crab, the *Limulus polyphemus* (Linnaeus, 1758) is classified under genus *Limulus* (Muller, 1785) of subfamily Limulinae. For subfamily Tachypleinae, there are two genus, *Tachypleus* (Leach, 1819) consists of *Tachypleus gigas* (Muller, 1785) and *Tachypleus tridentatus* (Leach, 1819); and genus *Carcinoscorpius* (Latreille, 1802) consists of *Carcinoscorpius rotundicauda* (Latreille, 1802).

Horseshoe Crab Image * note the coin used as scale except for *L. polyphemus*				
Family	Limulidae	Limulidae	Limulidae	Limulidae
Sub-family	Limulinae	Tachypleinae	Tachypleinae	Tachypleinae
Genus	*Limulus*	*Tachypleus*	*Tachypleus*	*Carcinoscorpius*
Species	*Limulus polyphemus*	*Tachypleus tridentatus*	*Tachypleus gigas*	*Carcinoscorpius rotundicauda*

Figure 2.1 Classification of horseshoe crab (Pocock, 1902)

The horseshoe crabs are designated into different species according to their physical characteristics:

- *Limulus polyphemus* is a large species, with vaulted or bowl turned over shaped prosomatic carapace; having a circular arch anterior margin; its lateral lobes relatively narrow and its ventro-posterior part densely with bristle; its telson is triangular in cross section, with dorsal keel the apex of the triangle (Muller, 1785; Linnaeus, 1758).

- *Tachypleus gigas* species is a middle-sized species, with gently elevated prosomatic carapace; having anterior margin without notches; has sub-frontal area of venter with a mesal spines moderately projecting posteriorly; its telson is covered with small spines on its ventral margin and is triangular in cross-section with a dorsal keel and a ventral longitudinal groove (Muller, 1785; Leach, 1819).

- *Tachypleus tridentatus* is a large species, with strongly vaulted prosomatic carapace; having sharp mesal spines projected sharp posteriorly at the subfrontal area of the venter; its telson has numerous thorn-like spines on dorsal keel and ventral margin (Leach, 1819).

- *Carcinoscorpius rotundicauda* is a small species, with rather flat prosomatic carapace; having relatively short mesal spine projected posteriorly of the sub-frontal area of venter; has latero-ventral marginal part continuing from ventral sub-frontal area swollen ventrally and without groove formed; its telson is entirely smooth and has a row of dense white hair at the ventral ridges.

2.2 Distribution of horseshoe crab

The American species, *Limulus polyphemus* is distributed from 19°N to 44°N along the east coast of the North America, from Northernmost Maine to the southernmost Mexico. The *L. polyphemus* favours sandy-mud beaches that are protected from surf and tidelands, such as the Delaware Bay of New Jersey and Cape Cod Bay of Massachusetts (Shuster, 1960), imply that low-energy embayment is preferred over high energy one.

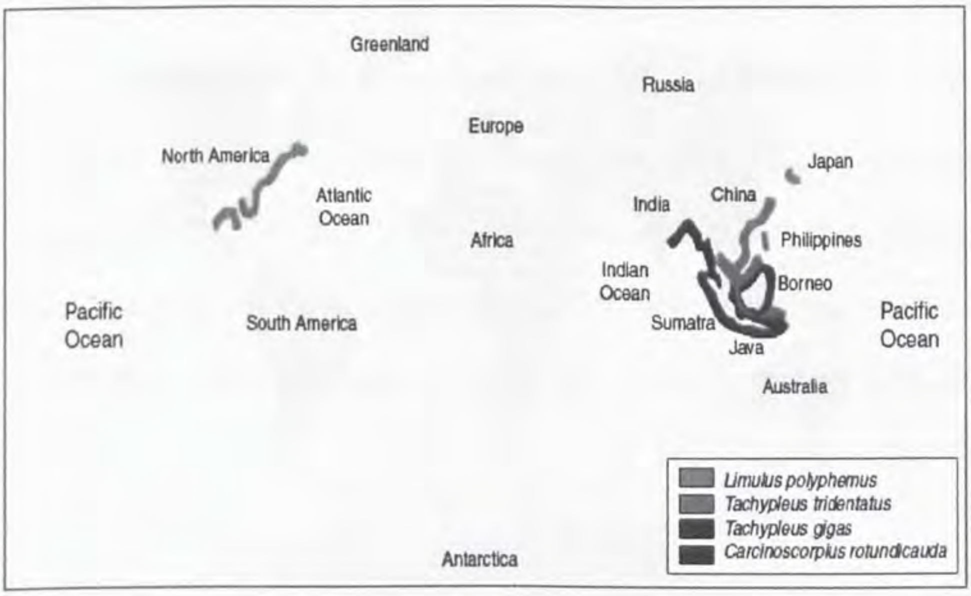

Figure 2.2 Distribution of the four extant horseshoe crabs species (Sekiguchi, 1988)

The distribution of horseshoe crab in the Southeast Asian country has not been well studied by the Asian worker, as work was done mostly by Europeans and Americans until the 1970s (Sekiguchi, 1988a).

Tachypleus tridentatus was found distributed in Inland Sea and Kita-Kyushu of Japan, Hainan Island of China, Nha Trang of Vietnam, islands of West Philippines, and North Borneo of Malaysia (Pocock, 1902; Smedley, 1929, 1931; Waterman 1953, 1958). Further study by Sekiguchi (1988a) shows that this species distribution is same as the one recorded by the above researchers with additional site in northern Sulawesi, eastern Java and the Indian Ocean coast of Sumatra (Indonesia), with higher population found in the northern region and decreasing towards the southern region of Southeast Asia.

Tachypleus gigas was recorded to be distributed in areas ranging from Orissa of India to Torres Strait of Australia, North Borneo of Malaysia, and Northern Vietnam (Pocock, 1902; Annandale, 1909; Smedley, 1929, 1931; Waterman, 1953; Rao and Rao, 1972). Sekiguchi (1988a) shows a greater variety of location where *T. gigas* can be found – in the Bay of Bengal (India), Malay Peninsula and the coast of Saigon, Gulf of Siam (Thailand), south coast of the Indochina Peninsula, and Indonesia.

As for the *Carcinoscorpius rotundicauda*, it was distributed throughout Southern Philippines, Indonesia, Malaysia, Gulf of Siam of Thailand, and Bay of Bengal (India) (Pocock, 1902; Annandale, 1909; Smedley, 1929, 1931; Waterman, 1953; Rao and Rao, 1972). The *T. gigas* and *C. rotundicauda* have generally almost similar distribution or overlap according to Sekiguchi (1988a) and population is high in Chonburi District in Thailand and Sumatra, Indonesia during research conducted.

As a whole, *T. gigas* and *C. rotundicauda* always live sympatrically in Southeast Asia and the distribution ranges of the two species completely overlaps from east to west across the equator whereas *T. tachypleus* distribution extends across the equator (Sekiguchi & Yamasaki, 1988).

2.3 Reproduction and spawning

The male chelae of the first and second walking legs are thickened and form claspers for grasping the right and left margins of the female opisthosoma during pairing for spawning (Yamasaki *et al.*, 1988). *L. polyphemus* males approach the beaches, with the rising high tide waiting for the females arrival and coupling occurs. The males that fail to pair with females will surround a female and released sperm.

The breeding behaviour however is not found in the Asian species. *T. tridentatus* females approached the beach with one male on each back and lay eggs in the hole they dig. According to Yamasaki *et al.* (1988), the males release their sperms in the hole containing the eggs and the couples will proceed to another nest just 15-20 cm away and repeat the whole process for several times before returning to the sea. *T. gigas* pairs have been found spawning in the 70 to 80 cm depth on a shoal, during high tide forming spawning foam. The *C. rotundicauda* goes upstream during high tide and depositing their eggs in the sandy mud layer alongside the river bank (Sekiguchi, 1988). Sekiguchi finding has further confirmed the study by Annadale (1909) which shows that *C. rotundicauda* went upstream at least 90 miles (about 145 km) from the sea in the Hooghii River and was found near the Calcutta.

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