DIVERSITY AND DISTRIBUTION OF CHAETOGNATHS OF DIFFERENT MARINE ENVIRONMENTS ALONG THE STRAITS OF MALACCA

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By

HEIDI JANE DE GUZMAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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Dedication

This work is dedicated to my beloved parents, Jovito de Guzman and Helen de Guzman for their endless love and support. To my siblings, Clarence Christopher, Christy Claire, and Rachel Jolen for their understanding and encouragement.

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

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Chairperson: Professor Fatimah Md. Yusoff, PhD

Institute : Institute of Bioscience

Two different study sites were selected along the coastal areas of the Straits of Malacca for the determination of the biodiversity and distribution of chaetognaths in polluted and pristine environments. These are the coastal waters off an industrial area, Kuala Juru (between 05°19.91'N, 100°23.75'E and 05°19.68'N, 100°22.95'E) and coastal waters off mangrove forest, Kuala Gula (between 04°55.19'N, 100°27.84'E and 04°55.01'N, 100°27.76'E. Zooplankton and water samples from the coastal waters off Kuala Juru and coastal waters off Kuala Gula were collected monthly from August 2007 to July 2008. Samples for biodiversity study were collected by vertical tows (from the deepest depth at every station) from three randomly selected stations in each ecosystem using conical shaped (with mouth opening size of 0.30 m and 1.00 m length) plankton net with 100 µm mesh with an acrylic plastic cod end. Samples for biomass and taxonomic analyses were

preserved in buffered formalin at 5% concentration. Chaeotognaths enumeration and identification were done under dissecting microscope. Biomass of the chaetognaths was determined using different standard techniques (wet, dry weight and ash free dry weight for total chaetognaths). A total of 11 species of chaetognaths from seven genera were identified from Kuala Gula samples, compared to nine species and four genera from Kuala Juru. The most abundant species in Kuala Gula was *S. regularis* (162.48 ind./m^3). Similarly, this species accounted the highest density in Kuala Juru (55.11 ind./m^3) .The mean Shannon Index (*H'*) value for Kuala Gula and Kuala Juru were 2.3 and 2.1, respectively. The species richness (d) were d=2.6 for Kuala Gula and d=2.3 for Kuala Juru. Cluster analyses and multi-dimensional scaling analyses revealed two characteristics of chaetognath populations in the coastal areas. The coastal waters off a mangrove reserve was characterized by high-density and high species diversity, whereas the coastal waters off a polluted industrial area was characterized by a relatively low-density and low species diversity. Samples from three different ecosystems were analyzed for the determination of the distribution of chaetognaths from other coastal ecosystems along the Straits of Malacca.

These three sampling locations were located in the coastal waters off a shrimp aquaculture farm (SAF), (between 03°15.11'N 101°17.79'E and 03°16.42'N 101°14.96'E); fish cage mariculture area (CMA); (between 03°00.67'N 101°16.27'E and 02°59.77'N 101°16.7'E), and seagrass area (SGA), (01°20.045'N 103°35.99'E and 01°19.78'N 103°05.67'E). Cluster and

multi-dimensional scale analysis revealed three characteristics of chaetognaths communities from the three coastal ecosystems. The mean Shannon Index (*H'*) value for SAF overall was 1.9, 1.7 for CMA, and 1.6 for SGA, with d (Margalef's species richness) values of 2.0, 1.6, and 1.4 respectively. The coastal waters SAF was characterized by high-density values and high species diversity, CMA was characterized by a low-density values and low species diversity and similarly, the SGA was characterized by a low-density values and low species richness.

In addition to different density and biodiversity between the polluted and unpolluted areas, individual chaetognath also showed some fouling on the body surface. Chaetognaths from the pristine environment showed the most fouling by organisms on the body surface compared to those from nonpolluted area. The highest percentage of biofouling invasion was aquatic fungus from the Kingdom Chromista (73.68%), followed by parasitic fungus (18.42%), and the least was bacteria (7.90%). Bacterial colonization (10.0%) was only observed in deformed chaetognaths collected from the polluted coastal waters off the industrial area. Although there was a high percentages of periphytic invasion on chaetognaths body collected from both sites, significantly higher ($p<0.05$) percentage of more destructive periphytes in the chaetognaths were found in Kuala Juru than in Kuala Gula.

This study illustrated that chaetognaths distribution was influenced by geographical locations and the species characteristics of the environment.

Aidanosagitta neglecta was found to be the most dominant chaetognath species which was able to tolerate variable environmental conditions. In addition, significantly ($p<0.05$) higher percentage of biofouling on chaetognath occurred in pristine environment.

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

DIVERSITI DAN TABURAN CHAETOGNATH DALAM PERSEKITARAN MARIN YANG BERBEZA DI SEPANJANG SELAT MELAKA

oleh

HEIDI JANE DE GUZMAN

April 2011

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Dua kawasan kajian yang berbeza telah dipilih di sepanjang perairan Selat Melaka untuk menentukan kepelbagaian dan taburan chaetognath di kawasan perairan tercemar dan kawasan tidak tercemar. Kawasan-kawasan ini adalah kawasan perairan tercemar berdekatan zon perindustrian, Kuala Juru (di antara 05°19.91'N, 100°23.75'E dan 05°19.68'N, 100°22.95'E) dan kawasan hutan simpan paya bakau, Kuala Gula (di antara 04°55.19'N, 100°27.84'E dan 04°55.01'N, 100°27.76'E 01^{0}20.045'N 103^{0}35.99'E dan 01^{0}19.78'N 103^{0}05.67'E). Persampelan air dan chaetognath telah dijalankan di Kuala Juru dan Kuala Gula bermula dari Ogos 2007 sehingga Julai 2008. Sampel bagi analisis kepelbagaian (tiga replikat) telah diambil secara tundaan menegak (pada kedalaman terdalam di setiap stesen persampelan) di tiga stesen yang telah dipilih secara rawak dari setiap ekosistem dengan menggunakan jaring plankton (saiz jaringan 100 µm) yang terdapat kod plastik akrilik di hujungnya. Bagi analisis biomas dan taksonomi, sampel

diawet menggunakan formalin berkepekatan 5% yang telah dicampur bersama penampan. Enumerasi dan identifikasi chaetognath dijalankan di bawah mikroskop pembedahan. Biomass bagi chaetognath ditentukan melalui tiga kaedah piawai (berat basah, berat kering dan berat kering tanpa abu). Sebanyak 11 spesies chaetognath dan tujuh genus telah dikenalpasti dari sampel Kuala Gula, berbanding dengan sembilan spesies dan empat genus dari Kuala Juru. Nilai Shannon Indeks (*H'*) untuk Kuala Gula dan Kuala Gula adalah masing-masing sebanyak 2.3 dan 2.1. Spesis yang mencatatkan kepadatan tertinggi di Kuala Gula ialah *S. regularis* (162.48 ind./m^3). Spesis ini juga mencatatkan kepadatan yang tertinggi di Kuala Juru (55.11 ind./m^3). Sementara itu, kekayaan spesies (d) adalah d=2.6 bagi Kuala Gula dan d=2.3 bagi Kuala Juru. Melalui analisis kluster dan skala multidimensi, didapati komuniti chaetognath mempamerkan dua sifat yang nyata daripada dua ekosistem yang dipilih sepanjang perairan Selat Melaka. Hutan simpan paya bakau dikategorikan sebagai kawasan yang mempunyai nilai kepadatan, kepelbagaian species, dan kekayaan spesies yang tinggi. Walau bagaimanapun, hutan paya bakau berdekatan zon perindustrian mempunyai nilai kepadatan, kepelbagaian spesies, and kekayaan spesies yang agak rendah jika dibandingkan dengan hutan simpan paya bakau.

Sampel dari tiga ekosistem sepanjang Selat Melaka dianalisis bagi menentukan taburan chaetognath dari ekosistem yang berbeza. Stesen-stesen ini adalah kawasan perairan ladang penternakan udang, (SAF), (antara 03°15.11'N 101°17.79'E dan 03°16.42'N 101°14.96'E); kawasan

penternakan ikan dalam sangkar (CMA), (antara 03°00.67'N 101°16.27'E dan 02°59.77'N 101°16.7'E); dan kawasan rumpai laut (SGA), (antara 01°20.045'N 103°35.99'E dan 01°19.78'N 103°05.67'E). Analisis kluster dan analisis skala multi-dimensi menunjukkan tiga sifat komuniti chaetognath dari ketiga-tiga ekosistem ini.. Min Indeks Shannon (H') untuk SAF adalah 1.9, 1.7 untuk CMA, dan 1.6 untuk SGA, dan nilai d (kekayaan spesies Margalef) adalah 2.0, 1.6, dan 1.4 masing-masing. SAF mempunyai nilai kepadatan dan kepelbagaian spesis chaetognath yang tinggi, CMA mempunyai nilai kepadatan dan kepelbagaian spesis chaetognath yang rendah, dan begitu juga dengan SGA, mempunyai nilai kepadatan dan kepelbagaian spesis chaetognath yang rendah, dan begitu juga dengan SGA.

Sebagai tambahan kepada kepadatan dan kepelbagaian antara kawasan perairan tercemar dan kawasan tidak tercemar, permukaan badan individu chaetognath juga menunjukkan kehadiran organisma penempel. Chaetognaths dari kawasan hutan simpan paya bakau menunjukkan kehadiran organisma penempel yang lebih tinggi berbanding kawasan yang tidak tercemar. Peratus tertinggi organisma penempel adalah fungus akuatik dari Alam Chromista (58.3%), diikuti fungus parasitik (18.42%), manakala peratus terendah adalah bakteria (7.90%). Koloni bakteria (10.0%) hanya didapati pada chaetognath yang abnormal yang disampel dari perairan tercemar berdekatan zon perindustrian. Walaupun terdapat peratusan yang tinggi bagi organisma penempel pada chaetognath yang disampel dari kedua-dua stesen, peratus organisma penempel yang lebih tinggi ($p<0.05$)

dikenalpasti pada chaetognath yang disampel dari Kuala Juru berbanding Kuala Gula.

Kajian ini menunjukkan bahawa taburan chaetognath dipengaruhi oleh lokasi dan sifat persekitaran tertentu. *Aidanosagitta neglecta* ialah spesies yang menunjukkan kepadatan chaetognaths tertinggi yang dapat menyesuaikan diri dalam persekitaran yang pelbagai. Sebagai tambahan, kehadiran organisma penumpang adalah lebih tinggi ($p<0.05$) pada permukaan badan chaetognaths dari kawasan perairan tidak tercemar.

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CHAPTER I

INTRODUCTION

Background of the Study

The phylum Chaetognatha is one of the most abundant zooplankton groups in the marine environment. Chaetognaths comprised more than 100 species, which are distributed in 22 genera (Bieri, 1991). Although chaetognaths are small in size, they play a vital role as one of the main sources of food for marine communities. In addition, chaetognaths may strongly influence their prey population dynamics under conditions of low productivity but continuous predation impact on copepods (Kimmerer, 1984). Crustaceans, hydromedusae, barnacle nauplii, cladoceran, fish larvae, and other chaetognaths also contribute to the chaetognaths diet periodically (Lebour, 1923; Rakusa-Suszcewski 1967; Kuhlmann, 1977; Pearre 1982; Oresland, 1987). The life span, generation time of chaetognaths, and their distribution in the oceans are affected by the abundance of prey, but this relationship remained unclear (Fulmer and Bollen, 2005).

Chaetognaths are often rank second after copepods in abundance and their biomass had been estimated as 10-30 % of that of copepods in the world ocean (Bone et al., 1991). As a voracious and selective predator to smaller

zooplankton, chaetognaths are of great significance in transferring of energy from copepods to higher trophic levels in the marine ecosystems, as they also become prey themselves to other chaetognaths and larger zooplankton (Bieri, 1959; Alvarino, 1965; Pierrot-Bultts and Nair, 1991; Terazaki, 2001). The prey selection is dependent on the maturity stages of chaetognaths and differed between species (Reeve and Walter, 1972a; Pearre, 1980; Duro and Saiz, 2000; Saito and Kiorboe, 2001).

The distribution of chaetognaths can be used to ascertain the variations of hydrographic characteristics of marine environments (Alvarino, 1964) and the results have been frequently discussed in recent studies. Pierce (1953) found out that chaetognaths population was low in area with reduced salinity, whereas certain species favored colder and inshore waters. Moreover, Bumpus and Pierce (1953) clarified that during intrusion conditions, *Sagitta enflata* showed higher density in surface waters compared to above bottom layer, and was in contrast to *Sagitta helenae*. In addition, the abundance of several species of chaetognaths is a useful indicator of water masses distribution as well as to determine the water movement (Rakuza-Suszczewski, 1967; Bieri, 1959). The oceanic circulation causes mixing between different water masses which in turn creates a species boundary, and uniquely isolated chaetognaths species from each other (Bieri, 1959). As a result, chaetognaths distribution and species composition may vary from coastal to offshore waters.

Despite chaetognath's importance to the marine environment, studies of their taxonomy, biology, as well as species composition are uncommon in comparison to other marine invertebrates (Brodeur, 1999). In addition, their unique and astonishing morphological characteristics to adapt to harsh environmental stressors puzzled taxonomists for years. Nair et al. (1992) reported that change in morphological features of zooplankton collected from polluted waters is uncommon. They found out that *Sagitta bedoti* developed a bulky collarette, and this might act as a protective sheath to withstand the polluted environment of Bombay coast. And to date, the status of chaetognaths taxonomy and systematics are still on debate. The taxonomy of chaetognaths remained essentially the same as that published by Ritter-Zahony (1911a), and followed by Tokioka (1965a), who expanded the classification of this phylum. Tokioka (1965b) used his own technique of classification to study the phylogenetic relationships within this group of invertebrates, and named six new genera, which included *Zonosagitta*, *Parasagitta*, *Mesosagitta*, *Flacisagitta*, *Solidosagitta*, and *Caecosagitta*.

Quantitative data regarding the species composition and abundance of chaetognaths along the Straits of Malacca, however, appears to be non-existent. In fact, the study of distribution of chaetognaths in Malaysia was done only by Pathansali et. al (1960), who identified several species near Penang Island. Only a few papers were published regarding the species composition of chaetognaths in South East Asia region compared to

numerous extensive works in other parts of the world ocean. Studies on chaetognaths distribution were reported by Noblezada and Campos (2008) in the northern Bicol Shelf, Philippines and Johnson et al. (2006) in the Celebes and Sulu Seas. Other previous work was also reported in the Andaman Sea, Thailand (Nair et al., 2008). In this paper, they reported two new chaetognath's species that were endemic to the coral ecosystems.

Although chaetognaths are very abundant in the world ocean, studies on their biology are rarely described. This may be due to the difficulty to tow undamaged chaetognaths and maintained them in the laboratory for accurate growth and reproduction rate measurements. Besides that, the study on diseases of chaetognaths has received lack attention from most biologists. It is often overlooked in studies of population dynamics because of the almost unknown information of the effects of microbial colonization on the reproduction and mortality of chaetognaths.

This study provides quantitative and qualitative information on the distribution and species composition of chaetognaths thriving along the Straits of Malacca. Analysis of spatial and temporal distribution of chaetognaths according to sexual maturity stage is a relatively little-studied aspect (Conway and Williams, 1986), since most of the work currently available in the literature deals only with species, making no reference to the different

maturity stages (Russell, 1927, 1931; Hesthagen, 1973; Palma, 1985). Specifically, the study was undertaken with the following objectives:

1. To determine the biodiversity and biomass of chaetognaths in different coastal ecosystems along the Straits of Malacca, which include species composition and densities and distribution in relation to the biological and physical environments, and
2. To determine the occurrences of different biofouling organisms on chaetognaths in two mangrove ecosystems with different hydrological characteristics.

Based on the above objectives, the following null hypothesis were tested:

1. Ho1: There were no significant differences in chaetognaths distribution and species composition from different ecosystems throughout the year.
2. Ho2: There were no significant differences in chaetognaths species diversity, abundance, and biomass from different ecosystems throughout the year.
3. Ho3: Biofouling of Chaetognaths is higher in polluted area compared to natural ecosystem.

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