SPECIES DIVERSITY AND ABUNDANCE OF RHIZOSTOME SCYPHOZOANS (PHYLUM CNIDARIA) ALONG THE COASTS OF CHON BURI AND PHETCHABURI PROVINCES

Miss Nontivich Tandavanitj

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Marine Science

Department of Marine Science
Faculty of Science
Chulalongkorn University

Academic Year 2001
ISBN 974-03-0833-3

ความหลากหลายของชนิดและความชุกชุมของแมงกะพรุนในกลุ่ม RHIZOSTOMEAE ไฟลัม CNIDARIA บริเวณชายฝั่งจังหวัดชลบุรีและเพชรบุรี

นางสาวนทีวิชญ ตัณฑวณิช

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต

สาขาวิชาวิทยาศาสตร์ทางทะเล ภาควิชาวิทยาศาสตร์ทางทะเล

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By	Miss Nontivich Tandavanitj
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KEY WORD: SPECIES DIVERSITY, ABUNDANCE, RHIZOSTOMEAE, JELLYFISH, THAILAND

NONTIVICH TANDAVANITJ: SPECIES DIVERSITY AND ABUNDANCE OF RHIZOSTOME SCYPHOZOANS (PHYLUM CNIDARIA) ALONG THE COASTS OF CHON BURI AND PHETCHABURI PROVINCES. THESIS ADVISOR: ASSIST. PROF. AJCHARAPORN PIUMSOMBOON, Ph.D., 113 pp. ISBN 974-03-0833-3.

This study focuses mainly on the species diversity, as well as the abundance, of rhizomedusae along the coasts of Chon Buri and Phetchaburi Provinces, where jellyfish fisheries are carried out annually. Samplings were conducted from December 1999 to December 2000 in the Inner Gulf of Thailand. Consequently, 6 species of rhizomedusae were obtained. They are *Cassiopea andromeda* (Forskål, 1775), *Acromitus flagellatus* (Maas, 1903), *Acromitus hardenbergi*, *Catostylus townsendi* Mayer, 1915 and two well-known commercial species, which are *Lobonema smithii* Mayer, 1910 and *Rhopilema hispidum* (Vanhöffen, 1888). *R. hispidum* was predominantly found along the coast of Chon Buri Province while *L. smithii* was found exclusively along the coast of Phetchaburi Province. The results revealed the highest abundance of rhizomedusae in March 2000 (> 23 individuals $\cdot$ 10^4 m^{-3}) and November 2000 (> 302 individuals $\cdot$ 10^4 m^{-3}) for Chon Buri and Phetchaburi, respectively. Among the 6 species obtained, *A. flagellatus*, a relatively small noncommercial species, was the most common species found in both provinces and yielded the highest abundance in term of density (> 300 individuals $\cdot$ 10^4 m^{-3} in November 2000). The environmental factors, which affected the abundance and size structure of rhizomedusae at both provinces, were salinity, water current, and zooplankton concentration in addition to the life history of the medusae themselves.

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Field of Study .... Marine Science .... Advisor's signature ....

Academic Year .... 2001 .... Co-advisor's signature .... -

นนทิวิชญ ตัณฑวณิช: ความหลากหลายของชนิดและความชุกชุมของแมงกะพรุนในกลุ่ม RHIZOSTOME ไฟลัม CNIDARIA บริเวณชายฝั่งจังหวัดชลบุรีและเพชรบุรี (SPECIES DIVERSITY AND ABUNDANCE OF RHIZOSTOME SCYPHOZOANS (PHYLUM CNIDARIA) ALONG THE COASTS OF CHON BURI AND PHETCHABURI PROVINCES) อาจารย์ที่ปรึกษา: ผศ.ดร. อัจฉราภรณ์ เปี่ยมสมบูรณ์, 113 หน้า. ISBN 974-03-0833-3.

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาความหลากหลายของชนิดและปริมาณแมงกะพรุนในกลุ่ม Rhizostomeae บริเวณชายฝั่งจังหวัดชลบุรีและเพชรบุรีซึ่งเป็นแหล่งทำประมงแมงกะพรุนที่สำคัญ ในการเก็บตัวอย่างทุกเดือนเริ่มตั้งแต่เดือนธันวาคม 2542 ถึงเดือนธันวาคม 2543 พบแมงกะพรุนในกลุ่ม Rhizostomeae ทั้งหมด 6 ชนิด แบ่งออกเป็น 2 ประเภท ได้แก่ ประเภทที่นำมาบริโภคได้ คือ *Rhopilema hispidum* (Vanhöffen, 1888) หรือแมงกะพรุนหนัง และ *Lobonema smithii* Mayer, 1910 หรือแมงกะพรุนลอดช่อง และชนิดที่ไม่ถูกนำมาบริโภค คือ *Cassiopea andromeda* (Forskål, 1775), *Acromitus flagellatus* (Maas, 1903), *Acromitus hardenbergi*, และ *Catostylus townsendi* Mayer, 1915 โดยผลการศึกษาพบแมงกะพรุนหนังที่ชลบุรีมากกว่าที่จังหวัดเพชรบุรีและพบแมงกะพรุนลอดช่องเฉพาะที่จังหวัดเพชรบุรีเท่านั้น ตลอดการศึกษาพบปริมาณแมงกะพรุนสูงที่สุดในเดือนมีนาคม 2543 ที่บริเวณชายฝั่งจังหวัดชลบุรี โดยมีปริมาณ > 23 ตัวต่อปริมาตรน้ำ 10^4 ลูกบาศก์เมตรและในเดือนพฤศจิกายน ที่บริเวณชายฝั่งจังหวัดเพชรบุรี โดยมีปริมาณ > 302 ตัวต่อปริมาตรน้ำ 10^4 ลูกบาศก์เมตร *A. flagellatus* เป็นชนิดที่พบในปริมาณมากโดยพบในทั้งสองบริเวณที่เก็บตัวอย่าง โดยมีปริมาณ > 300 ตัวต่อปริมาตรน้ำ 10^4 ลูกบาศก์เมตรในเดือนพฤศจิกายน 2543 นอกเหนือจากการศึกษาในด้านความหลากหลายของชนิดแมงกะพรุนที่พบแล้วยังศึกษาปัจจัยสิ่งแวดล้อมที่ส่งผลต่อปริมาณของแมงกะพรุน พบว่า ปัจจัยสิ่งแวดล้อมที่มีผลต่อปริมาณของแมงกะพรุนคือ ความเค็ม กระแสน้ำ ปริมาณแพลงก์ตอนสัตว์ตลอดถึงวงจรชีวิตของแมงกะพรุนแต่ละชนิด

ภาควิชา วิทยาศาสตร์ทางทะเล ลายมือชื่อนิสิต ....

สาขาวิชา วิทยาศาสตร์ทางทะเล ลายมือชื่ออาจารย์ที่ปรึกษา ....

ปีการศึกษา 2544 ลายมือชื่ออาจารย์ที่ปรึกษาร่วม -

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CHAPTER 1

INTRODUCTION

I. Introduction

Scyphozoans, including rhizomedusae, have been considered an integral component in the marine environment, particularly in terms of trophic levels. Besides serving as important food source for a variety of marine organisms, their predatory behavior is believed to pose a major impact on the zooplankton population and fish stock. The trophic significance of rhizomedusae, nonetheless, is not restricted to the marine environment. Rhizomedusae are subjected for human consumption. In Thailand, particularly in the Gulf, jellyfish fisheries have contributed more than 30 million bahts to the fishery industry annually. The monitoring of this valuable resource is, therefore, necessary for sustainable utilization. At the present, there has not been any certainties concerning the number of species, distribution, seasonality, and related parameters of rhizomedusae in the Gulf of Thailand. Such knowledge specifically species diversity, abundance, monthly variation in species diversity and abundance, reproduction, and governing environmental parameters are necessary to the understanding of the ecology of rhizomedusae. Furthermore, this information can be applied to the fishery management concept as well as the conservation of this particular fishery resource.

Thus, the objectives of this study are to gather information regarding:

1. the species diversity and abundance of rhizostome scyphozoan along the coasts of Chon Buri and Phetchaburi Provinces,
2. the monthly variation in the pattern of occurrence and abundance,
3. the environmental factors affecting the abundance of rhizostome scyphozoans.

II. Classification

Scyphomedusae are organisms belonging to phylum Cnidaria, formerly Coelenterata, and class Scyphozoa. The class Scyphozoa is further divided into four orders. This particular study is focused on the order Rhizostomeae, which is comprised of eight families.

- Phylum Cnidaria
  - Class Hydrozoa
  - Class Scyphozoa
    - Order Stauromedusae
    - Order Coronatae
    - Order Semeostomeae
    - **Order Rhizostomeae**
      - **Family Cassiopeidae**
      - **Family Catostylidae**
      - **Family Cepheidae**
      - **Family Lobonematidae**
      - **Family Lychnorhizidae**
      - **Family Mastigiidae**
      - **Family Rhizostomatidae**
      - **Family Stomolophidae**
  - Class Anthozoa
  - Class Cubozoa

III. General Characteristics of Scyphozoans

Although the medusa form is present in other Cnidarian classes, namely Hydrozoa, Scyphozoa, and Cubozoa, only scyphomedusae and cubomedusae are fundamentally viewed as “true jellyfish”. Unlike the hydromedusae, which are found in both fresh and marine waters, scyphomedusae are exclusively marine. They are often large in size, ranging from 2 to 40 centimeters in diameter. In 1865, however, Agassiz recorded a *Cyanea capillata* in Massachusetts Bay with a diameter of 2.3 meters (Rifkin, 1996). Scyphomedusae are distinguished form hydro- and cubomedusae through the lack of velum or velarium (shelf of tissue extending inward from the margin into the subumbrella space). Instead, the marginal features of scyphozoans consist of lappets, marginal tentacles, and sensory organs called rhopalia, which are located between lappets at the bell margin. There are approximately 200 species of scyphozoans inhabiting pelagic habitats, from surface to deep waters, as well as coastal waters of all oceans, from the Poles to the Tropics. Their large size and the presence of stinging nematocysts have earned them the reputation of danger and nuisance.

The class scyphozoa is subdivided into a total of four orders as follows,

1. Stauromedusae (Figure 1): This particular order is comprised of small permanently and temporarily sessile polypoid medusae, which are attached to the substrate by an aboral adhesive disc on the subumbrella or an aboral stalk (Arai, 1997).

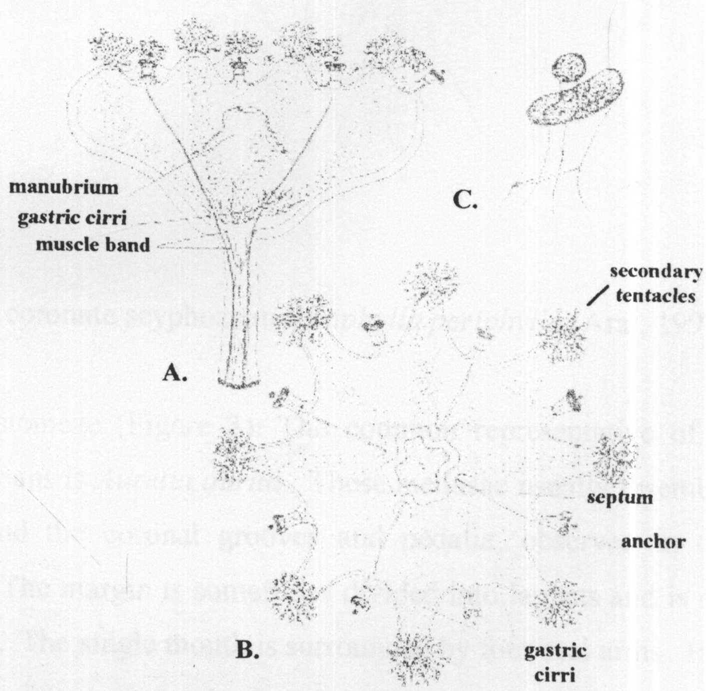


Figure 1. Stauromedusa *Haliclystus salpinx*. (A) Side view; (B) oral view; (C) anchor (Arai, 1997).

2. Coronatae (Figure 2): This order includes the bathypelagic and mesopelagic species possessing deep furrow, or coronal groove, which divides the subumbrella into two distinct regions: the central disc and the peripheral zone where there exist the pedalia (redial thickenings), lappets, and marginal tentacles (Arai, 1997).

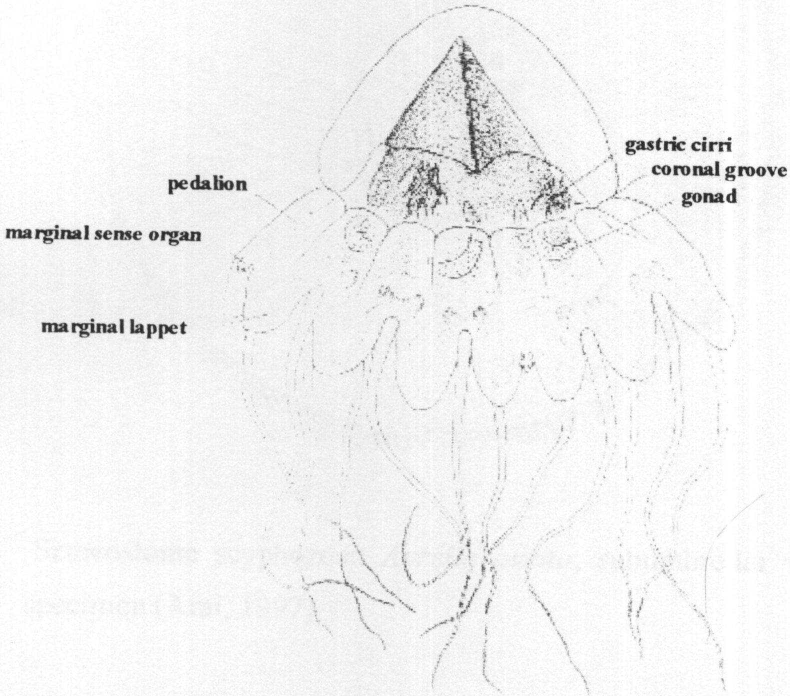


Figure 2. Young coronate scyphozoan *Periphylla periphylla* (Arai, 1997).

3. Semaeostomeae (Figure 3): The common representative of semaeostome scyphozoans is *Aurelia aurita*. These medusae usually resemble a saucer in shape and the coronal grooves and pedalia, observed in coronates, are absent. The margin is sometimes divided into lappets and is equipped with rhopalia. The single mouth is surrounded by four oral arms. Radial pouches or system of canals may be found around the stomach (Arai, 1997).

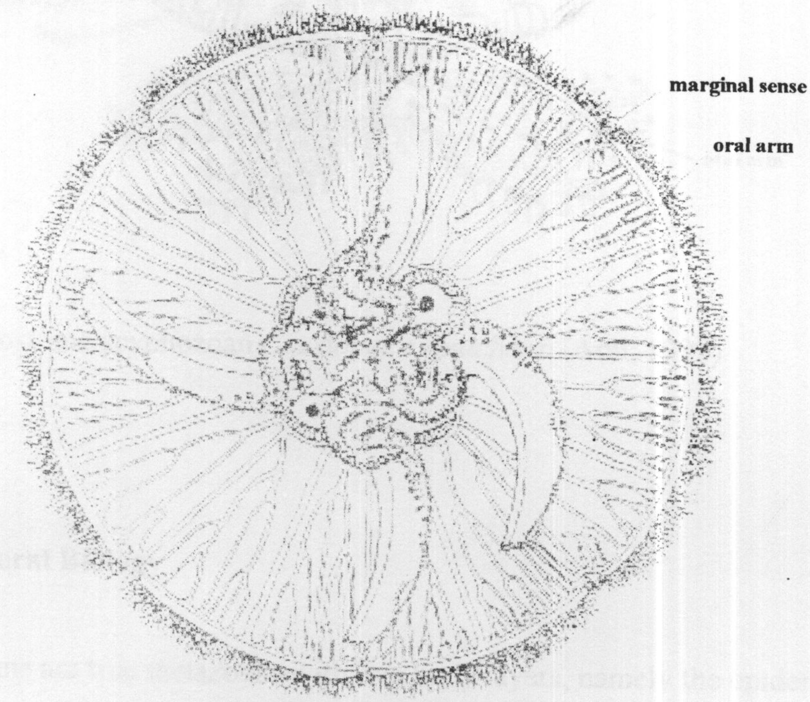


Figure 3. Semeostome scyphozoan *Aurelia aurita*; subumbrellar view of female specimen (Arai, 1997).

4. Rhizostomeae (Figure 4): Several physical characteristics distinguish rhizomedusae from jellyfish in other orders. Rhizostome medusae are recognized by the lack of tentacles along the edge of the bell and the oral arms of the manubrium that is branched, bearing deep folds into which food is passed to the mouth. They are generally found in tropical and subtropical shallow waters, and include both epipelagic and neretic forms. At the present, within order Rhizostomeae, there are 8 families, encompassing a total of 22 species (Arai, 1997). Four of the eight families of rhizomedusae are restricted to the Indo-West-Pacific regions. Few common genera are *Cassiopea, Rhizostoma, Mastigias,* and *Stomolophus* (Barnes, 1987).

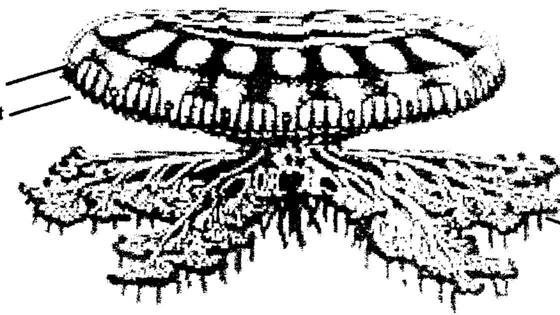


Figure 4. Rhizostome scyphozoan *Cassiopea xamachana* (Arai, 1997).

IV. Biology

A. General Biology

Cnidarians are true metazoans with two body layers, namely the epidermis and gastrodermis, and are entirely aquatic. However, they are mostly found in marine environments. They are radially symmetrical and have only one opening which functions as both the mouth and anus. They possess special stinging cell organelles called cnidae enclosing the thread-like nematocysts, the characteristics of this phylum, which they used for self-defense as well as prey capture. The excretory or respiratory systems are undeveloped and they possess no coelomic cavity.

B. Reproductive Biology and Alternation of Generations

Most scyphozoans are dioecious, having separate sexes. Nonetheless, few species are hermaphrodites. For example, the medusae of *Chrysaora hysocella* are protandrous hermaphrodites as they first produce sperm and then ova. The gonads, arise from the gastrodermis, are situated on the floor of the gastrovascular cavity. In rhizomedusae, the oocytes gradually bulge into the mesoglea of the gonad, while maintaining contact with specialized cells in the epithelium (Figure 5). Sperms, on the other hand, develop in follicles, which are formed by invagination of the epithelium into the mesoglea of the testis (Figure 6). Prior to spawning, accumulation of matured sperms may occur in the subgenital sinus or the oral arms. In *Cassiopea* *andromeda*, spermatozeugmata, or sperm packages with somatic cells in the center surrounded by sperms, are formed (Arai, 1997).

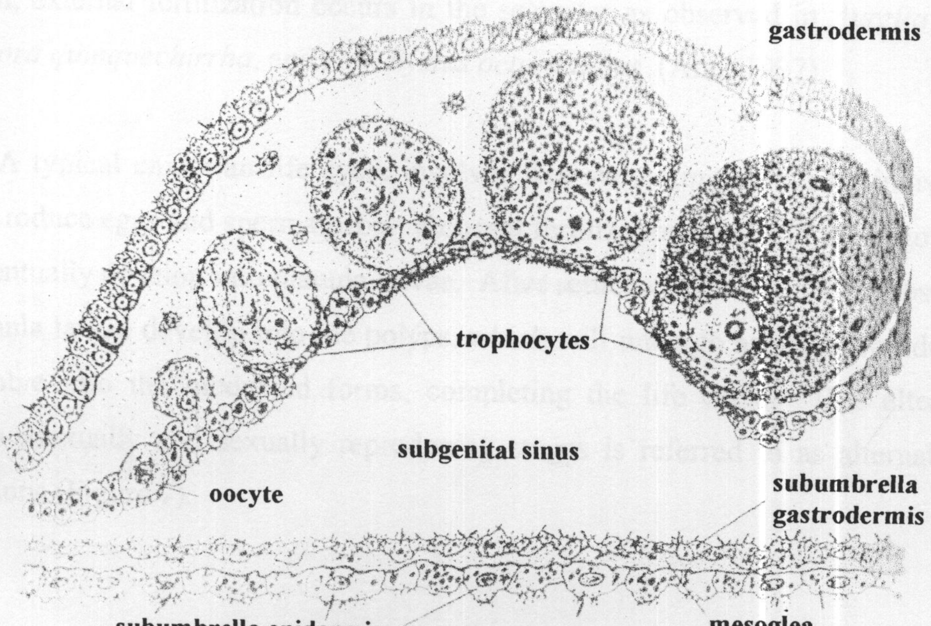


Figure 5. The ovary of *Aurelia aurita* (Arai, 1997).

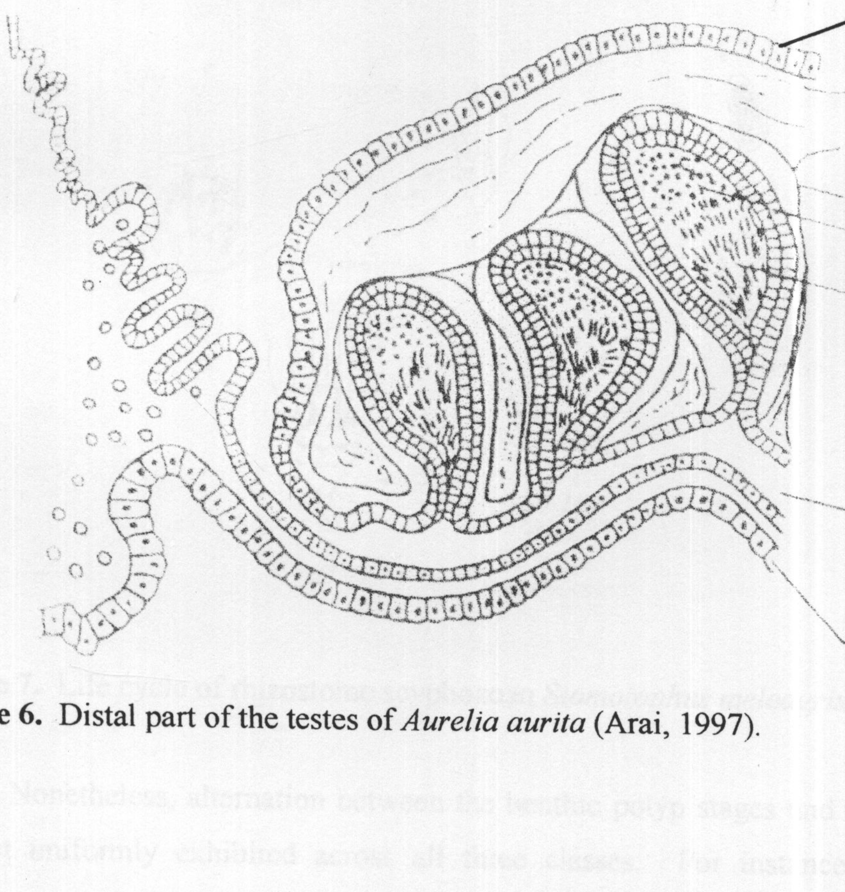


Figure 6. Distal part of the testes of *Aurelia aurita* (Arai, 1997).

Modes of fertilization vary among different species of scyphozoans. Internal fertilization may occur in the gastrovascular cavity of females as observed in *Aurelia aurita* or in the femal gonads, i.e. *Cotylorhiza tuberculata*, or on the oral arms. In addition, external fertilization occurs in the seawater as observed in *Aurelia aurita*, *Chrysaora quinquechirrha*, and *Haliclystus octoradiatus* (Arai, 1997).

A typical cnidarian life cycle involves free-swimming medusoid individuals, which produce eggs and spermatozoa. External fertilization results in the zygotes that will eventually develop into planula larvae. After settlement onto suitable substratum, the planula larvae develop into the polyps, which will undergo asexual reproductions and evolve into the medusoid forms, completing the life cycle. This alternation between asexually and sexually reproducing stages is referred to as alternation of generations (Figure 7).

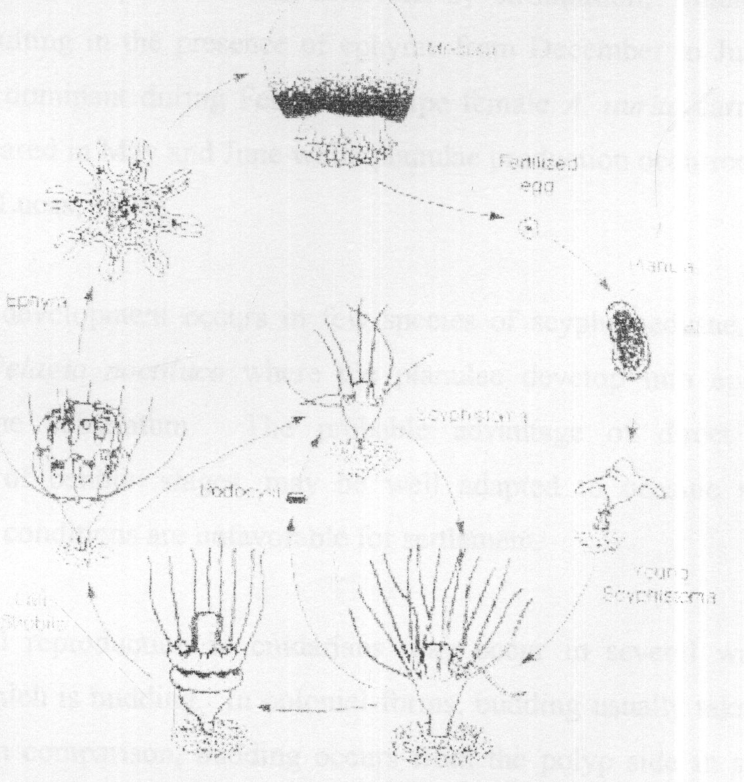


Figure 7. Life cycle of rhizostome scyphozoan *Stomolophus meleagris* (Arai, 1997).

Nonetheless, alternation between the benthic polyp stages and the medusoids are not uniformly exhibited across all three classes. For instance, in the class

Anthozoa (i.e. stony corals and sea anemones), the medusoid stages are entirely nonexistent. In the class Hydrozoa, several species lack either the polyp or medusoid stages. Furthermore, some scyphozoans (i.e. true jellyfish) possess no polyp stages at all.

Alternation of generations is observed in organisms within the class Scyphozoa. In fact, certain species may produce dormant cysts. The life cycle of *Aurelia aurita*, a well-known species of scyphozoan, includes fertilized eggs, planula larvae, scyphistoma, strobila, ephyrae, and subsequent adults. This particular kind of life cycle is typical of scyphozoans. In addition, the scyphistoma may produce further polyps by longitudinal fission, by direct budding, or by formation of stolons, cysts or planuloid buds (Arai, 1997). In Horsea Lake, England, sexual reproduction of *A. aurita* was observed over a 12-month period (from February 1994 to January 1995). Settlement of planulae was followed by strobilation, which started from December resulting in the presence of ephyrae from December to June. However, ephyrae were dominant during February. Ripe female *A. aurita* carrying fertilized eggs first appeared in May and June while planulae production occurred in September to December (Lucas, 1996).

Direct development occurs in few species of scyphomedusae. It had been observed in *Pelagia noctiluca* where the planulae develop into ephyrae without settling on the substratum. The probable advantage of direct development, independence of benthic stages, may be well adapted to oceanic species where environmental conditions are unfavorable for settlement.

Asexual reproduction in cnidarians may occur in several ways, the most common of which is budding. In colonial forms, budding usually takes place along the stolons. In comparison, budding occurs from the polyp side in solitary forms. Several medusae bud directly from the bell margin, manubrium, or tentacular bulbs. In *Cyanea*, the benthic polyp stage usually reproduces asexually via two major methods. One method involves the formation of the podocysts, which are mesoglial tissue enclosed in chitinous sheath. Podocysts eventually excyst and form new polyps. Another alternative to cyst formation is strobilation, which involves transverse fission of the apical portion of the polyp. Strobilation produces ephyrae, which are comparable to early forms of pelagic medusae. Environmental factors, which influence strobilation of polyps, include changing temperature, the extent of illumination, shifts in salinity, and feeding rate. In many instances, the settling planula forms another encysted state called the planulocyst. From their study on the effect of temperature on the benthic stages of *Cyanea* and their seasonal distribution in the Niantic River estuary in Connecticut, Brewer and Feingold (1991) discovered that both planulocysts and podocysts appeared during the warmest time of the years. Their formations appeared to be triggered by increasing temperature. Both types excysted when temperature decreased. Strobilation and liberation of ephyrae subsequently followed excystment. In the Gullmar Fjord, western Sweden, in 1984, strobilation of *Cyanea capillata* occurred in winter and early spring. Ephyrae were first observed towards the end of March and the maximum abundance was observed in June. First sexually matured female was observed in the beginning of September, which was followed by production of planulae. Subsequent settlement of planulae and development of scyphistoma occurred in October. In the laboratory, where predation factor was eliminated, strobilation did not occur until April 1985 and continued until the beginning of July (Gröndahl and Hernroth, 1987).

Alternation of generations provides many advantages as well as disadvantages for cnidarians. In general, the medusae have evolved for the better dispersal of the species (Hardy, 1971). Although some polyps are able to produce planktonic larvae via sexual reproduction, they are usually short-lived. Thus, the ciliated swimming planula, when present, may be more important in selection of favorable environment for the benthic stages than in dispersal (Arai, 1997). Through higher dispersal range, the medusae are able to exploit a wider range of food sources unavailable to the benthic forms. This allows for the sexual reproduction, which usually involves high-energy expenditure. Sexual reproduction of the medusoid forms is also necessary for genetic variability. The benthic stages, on the other hand, may have evolved as a mechanism that aids in survival of temperate and arctic species during period of low planktonic food availability. Several types of cysts may be considered as part of the benthic stage and are formed as protection against unfavorable conditions such as extreme temperature changes. They may also serve as protection against predation as well as seasonal competition for space. Above all, the benthic stages, reproducing asexually, are able to give rise to numerous individuals, which will contribute largely to the recruitment and population continuity of species.

There are few disadvantages to alternation of generations. The benthic polyp stages are constantly prey upon by several benthic invertebrates such as the nudibranchs, which was observed in the Gullmar Fjord, western Sweden (Gröndahl and Hernroth, 1987). The free-floating-medusoid forms are evidently at the risk of being carried away by currents into areas of unsuitable conditions. As mentioned previously, the sexual reproduction of the medusae requires high energy, thus the organisms depend largely on the food concentration in the surrounding medium.

In scyphozoans, the medusoid stage serves similar function as that mentioned earlier, which is to enhance dispersal. Yet, the complex benthic stages are extremely crucial for continuity of population. In the summer, when prey population is often high, encysted stages serve to prevent mortality due to benthic predation. Excystment and strobilation, which occurs during the colder months of the year, could be view as a preparatory phase. As a consequence, ephyrae released during the months of spring are able the exploit the rich resources present in the surrounding water. High food availability would intensify reproductive success due to the fact that sexual reproduction of mature medusae more than likely requires relatively high energy input.

C. Feeding Biology

Scyphomedusae, among all cnidarians, are characterized by the presence of intracellular organelles called cnidae. This particular structure consists of a capsule, which contains coiled thread-like tubule that is discharged when stimulated. All scyphozoan cnidae are termed nematocysts. Nematocysts are cnidae with tubules lacking longitudinal folds or accessory hollow tubules. Equipped with toxins, the functions of cnidae are mainly for prey-capture and defense from predators. Nematocysts are distributed on all parts of the jellyfish including the exumbrella surface, oral and stomach regions, as well as the tentacles. In some species, such as *Cyanea* sp., they are arranged in specific pattern on the tentacles. Since rhizostome scyphozoans lack a central mouth, nematocysts are generally found along the oral arms (Rifkin, 1996).

The majority of scyphozoa medusae are carnivores, although few species, such as the rhizostome *Stomolus meleagris*, are known to exhibit filter-feeding behavior. *Stomolus meleagris* is a rhizostome scyphozoan with globular umbrella, short manubrium, and lacks marginal tentacles. In addition, few may obtain a fraction of their nutritional requirement from symbionts, namely zooxanthellae. For those that are carnivores, two strategies are suggested: medusae can remain still as 'ambush' predators, or swim through the water as 'cruising predators (Arai, 1997). It is further suggested that cruising predators tend to prey upon slower moving prey while ambush predators prey upon faster moving prey. For cruising predators, contact with prey depends largely on the fluid motion, achieved through the swimming motion of the medusa, of the immediate surrounding water. Several scyphozoans, such as *Pelagia noctiluca* (order Semaeostomeae), are known to switch between the ambush and crusing modes depending on the types of preys. In *Aurelia aurita* (order Semaeostomeae), the relationship between bell pulsation, fluid motion, and prey capture is observed. The swimming pattern involved the rhythmic contraction of the bell and the waving motion of the fringing tentacles. This results in water displacement and turbulence, followed by contact with prey (Arai, 1997)

Posteriori to contact with prey, the marginal tentacles contract and prey is transferred towards the mouth. In *Pelagia noctiluca*, it is observed that when prey touches a marginal tentacle, there is an immediate nematocyst discharge, followed by a tentacle contraction after 2-3 seconds (Arai, 1997). Few movements of the oral arms assist in grasping the prey. Through peristaltic and mucous movements, the prey is driven to the oral arm groove, towards the manubrium. An observation of the feeding behavior by Malej (1989) reveals that, in nature, undisturbed *P. noctiluca*, within an aggregated swarm, normally swims with tentacles trailing as long as 1.5 m. During prey capture a tentacle touching a prey contracted quickly while the other tentacles remained extended and fishing. They prey was transferred to the oral arm which bent towards the tentacle. The bell contraction did not cease completely during this prey-handling operation; however, the medusa's speed seemed to be reduced (Malej, 1989). Besides, aggregation for foraging purpose provides few advantages.

Foraging efficiency is enhanced as prey escaping from one medusa becomes more vulnerable to another. Other than reproductive benefits, foraging in groups also promotes predator avoidance and an individual medusa can spend more time feeding.

Fancett and Jenkins (1988), in their study on the predatory impact of scyphomedusae on ichthyoplankton and other zooplankton in Port Phillip Bay, Australia, measured the ıeeding rate of two species of scyphozoan namely *Pseudorhiza haeckeli* and *Cyanea capillata*. *P. haeckeli* is a rhizostome scyphozoan possessing mouth arms which extend further beyond the bell while *C. capillata* is a semaeostome scyphozoan with long marginal tentacles and the oral arms, spread over the surface of the prey, form a thin adhering film (Arai, 1997). In this case, feeding rate was measured in term of clearance rate, which is the volume of water from which all particles are removed over a time interval (Fancett and Jenkins, 1988). The experiment was conducted *in situ* by adding a known prey concentration to a volume of water held in an aquarium. After a period of time, through a filtering process, the number of remaining prey items was counted. A control aquarium was set up with no scyphomedusae. In general, less than 20% of the prey were consumed over a period of 15-45 minutes while prey recovery was 100% for the control. The clearance rate of the two species was independent on prey density and prey concentration. In the field, medusae are rarely observed to have full gut despite high prey abundance. Moreover, it appears to increase with size of the medusae. *P. haeckeli* was observed to have relatively higher clearance rate than *C. capillata*, with no differences in clearance rate among prey taxa. Apparently, it is suggested that this is a result of different feeding modes between the two species. *P. haeckeli* is able to filter more water per unit time. *P. haeckeli* is a rhizostomous scyphomedusan, with a central fleshy mouth bearing many small 'arms' covered with nematocysts (Fancett and Jenkins, 1988). It moves rapidly through water, pumping water downward through the arms. On the other hand, *C. capillata* swims at a relatively lower speed and, with relatively lower clearance rate, revealed differences among clearance rates for copepod taxa. In this case, prey encounter would be the determining factor governing the clearance rate. Since *C. capillata* is a slow swimmer, faster moving prey are likely able to escape, resulting in the different clearance rate for different prey items. Thus, feeding rate of scyphomedusae is affected by two factors: contact rate (resulting in selectivity) and size of both the medusae and the prey. García and Durban (1993) also observed a similar pattern in *Phyllorhiza punctata* in their study on zooplanktivorous predation by large scyphomedusae in Laguna Joyuda. They observed that clearance rates were independent of prey densities and linearly increased with bell diameter.

In Chesapeake Bay, United States, where high biomass of medusae occurs during the months of July and August, copepod's clearance by zooplanktivorous predators resembles the seasonal pattern of gelatinous zooplankton. Clearance rate is relatively low in early to mid-May and peaks in Mid-August (Purcell *et al.*, 1994).

As mentioned earlier, filter-feeding behavior is observed in few species of scyphomedusae i.e. the rhizostome *Stomolophus meleagris*. During his study in the northeastern Gulf of Mexico, Larson (1991) attempts to determine the diet, prey selection, as well as daily ration of this particular species. Belonging to the order Rhizostomae, *S. meleagris* lacks tentacles seen in *P. noctiluca*. Instead, they have lips surrounding the mouth. The mouth has developed into oral arms, which hang from the subumbrella. As the medusa swims, these arms function as filtering sieve for zooplankton. Depending on the species of rhizomedusae, the morphology of the oral arms varies. Despite that fact, all oral arms are formed by enlargement and branching of the original ephyral lips. Branching of the distal portions of the oral arms provides for more filtering surface areas. Preys are captured by the digitata, which are finger-like structures, situated along the margins of the lips and are equipped with nematocysts. Smith (1934 &1936), Thiel (1964), and Larson (1978) observed the feeding mechanism of *S. meleagris* and described that prey were captured by the digitata and were passed into ciliated grooves, which eventually lead to the stomach (Larson, 1991). Commonly, preys are brought into contact with the digitata by means of vortex and turbulence created by the medusa swimming motion. After filtration, the water, that initially fills the subumbrella area during bell expansion, is expelled form the cavity through bell contraction.

V. Locomotion

Larson, in 1991, stated that jellyfish can form near-shore aggregrates, i.e. in bays, inlets, and leeward side of islands, as a result of wave actions or currents. This is useful in ensuring feeding and reproductive success (Rifkin, 1996). Some species may undergo daily vertical migrations, alternating between upward swimming and sinking, oftentimes with expanded tentacles to capture prey items. Many scyphozoans are capable of active as well as passive horizontal movements. Due to the lack of velum and velarium, movement of scyphomedusae relies largely on the circular and radial muscle of the subumbrella. *Mastigias* sp., a rhizomedusa, has been observed to migrate, from one side of a lake to another, employing the sun as taxis cue (Rifkin, 1996).

In general, jellyfish swimming mechanisms involve a series of rhythmic pulsation of the bell margin accompanying by the expulsion of water out of the subumbrella area. The pulsation rate is believed to be related to environmental conditions such as temperature, food, and light concentrations (Rifkin, 1996).

Despite the belief that the polyp stage is a "sessile" stage, the polyps of few scyphozoan species are able to accomplish limited form of locomotion. The scyphistomae of stauromedusae and samaeostomedusae are capable of summersault and gliding movements along the substratum. This particular type of movement involves reversible adhesion of the basal or pedal disc and contraction of the stalk (Arai, 1997).

VI. Ecological Importance and Trophic Relationship

Being opportunistic predators, scyphomedusae utilize a variety of prey items, depending on their availability, corresponding to peak population and seasonality. Zooplankton represents a significant portion of their food source (Table 1). In comparison, although some phytoplankton maybe ingested, it represents only a small and negligible portion. The zooplankton diet of scyphozoan medusae includes fish larvae (and eggs), other medusae, chaetognaths, gastropod mollusks, copepods, nematodes, rotifers, protozoa, arthropod larvae, ctenophores, diatoms, and appendicularians.

Scyphomedusae have continuously been known as fierce predators and play an integral role in the marine food web. Their predation on fish larvae is believed to pose a major impact on the adult population of several commercial fish species.

Pseudorhiza haeckeli, a rhizomedusa, has been observed to have maximum clearance rate of 4.8% per day and 3.8% per day of copepod and fish eggs and larvae, respectively (Fancett and Jenkins, 1988).

Table 1. Prey composition of some field-caught scyphomedusae (Arai, 1997). (*Family Rhizostomeae)

Species	**Prey Size**		
	< 200 μm	**200 μm – 2 mm**	**> 2 mm**
Aurelia aurita	Diatoms, ciliates, tintinnids, rotifers	Veligers, trochophores, barnacle larvae, copepods, cladocera, larvacea	Hydromedusae, eggs, chaetognaths, crustacea, herrings
Cyanea capillata		Copepods, cladocera, larvacea	Hydromedusae, ascidia, ctenophores, fish eggs, fish larvae
Pelagia noctiluca		Copepods, cladocera	Cumacea, amphipods, chaetognaths, euphausiids, mysids, decapods, gastropods, fish eggs, fish larvae
*Pseudorhiza haeckeli**		Copepods, cladocera, larvacea	Decapod larvae, fish eggs, fish larvae
*Stomolophus meleagris**	Tintinnids	Veligers, copepods, larvacea	

Apart from symbiotic relationships, scyphomedusae interact with other organisms in various ways. They are known to be associated with other planktonic organisms including fish, arthropods, nauplii, phyllosoma larvae, and pelagic octopods. Most of these associations involve mutual benefits. The associations between the fish and medusa vary from simple opportunistic relationships, through commensalism, to ectoparasitism and predation (Arai, 1997). Scyphomedusae, despite their notorious reputations, are considered an essential source of nutrition for a wide array of predators i.e. sea turtles, *Mola mola* or sunfish, pelagic coelenterates, parasites, mesopelagic arthropods, shrimps, amphipods, sea anemones, barnacles, birds, fish, and even human.

VII. Important Environmental Parameters

A. Physical Factors

Although it is logical to assume that the distribution and survival of scyphozoa are generally affected by various physical factors, the lack of supporting data suggests that physical factors may also indirectly affect the distribution of these organisms by acting on associated organisms such as their preys. The physical factors, which affect scyphomedusae are:

1. Salinity: Scyphozoans are osmoconformers and euryhaline. They have been shown to change volume with changes in the salinity of the surrounding seawater. Indeed, they are able to tolerate a wide range of salinity. For instance, the medusae, scyphistomae, and planulae of *Rhopilema esculenta* (order Rhizostomeae) can survive in varying salinity of 8, 10, and 12 ppt (psu), respectively (Arai, 1997).

2. Temperature: Temperature has been known to affect several biological functions of most animals including scyphozoans i.e. feeding, swimming, digestion, respiration, cyst formation, strobilation, enzyme activities, and uptake of organic material which, in turn, affect the growth rate. For instance, in *Chrysoara quinquecirrha* (order Semaeostomeae), acclimation in cold temperatures resulted in an increase in glucose-6-phosphate dehydrogenase (Arai, 1997). However, in the Tropics, where the temperature of the seawater fluctuates only within a small range, its effects are not significant to scyphomedusae.

3. Dissolved Oxygen: Concurrent to other factors previously mentioned in this section, scyphozoans can survive in areas of depleted oxygen level as well as in hyperoxia conditions. In some restricted areas, the bottom layers become stagnant and oxygen is depleted. Among the few animals surviving in this layer, with less than 0.5 ml O_2 per liter, are planulae larvae of *Aurelia aurita* (Arai, 1997).

4. Depth: Several environmental factors govern the habitable depth ranges occupied by scyphozoans. Such factors are temperature, light, pressure, prey density, salinity, oxygen gradients, and buoyancy. The exclusion of sulfate ions permits the organisms to achieve identical density with the surrounding waters, thus, vertical migration is allowed. In *Pelagia noctiluca* (order Semaeostomeae) and *Mastigias* sp. (order Rhizostomeae), vertical migration between the surface and the chemocline occur at night (Arai, 1997). This ability is utilized by scyphozoans in exploring new habitats and exploitation of resources.

5. Pollution: Found in coastal waters all over the globe, scyphozoans are subjected to various forms of adverse environmental conditions such as eutrophication induced by nutrients derived from runoffs and domestic sewage, contamination of hydrocarbons such as DDT, and heavy metals such as copper, lead, mercury, and zinc. In many instances, eutrophication resulted in an increase in numbers of scyphozoa. The density of *Cassiopea fondosa* and *Cassiopea xamachana* was observed to be relatively higher in a lagoon where there were tourist activities compared to an undisturbed lagoon. The effects of pollution may differ depending on the life stages. Contamination by heavy metals may cause reduction of strobilation in addition to production of abnormal polyps and ephyrae. In contrast, *Rhizostoma sp.*, a rhizomedusa, has been observed to be able to survive in diesel oil polluted environments (Arai, 1997).

Correspondingly, it is highly possible that these physical factors act on the different life stages of scyphozoans in affecting the distribution or abundance of the adult medusae. As in Brewer and Feingold's study (1991) mentioned in the preceding section, temperature appears to be the governing factor for the development of the benthic stages of *Cyanea sp*. Hindered benthic development would likely lead to poor recruitment into the medusa population.

B. Biological Factors

Besides physical factors, biological factors, particularly food concentration and predators, also play an important role in the survival and abundance of scyphozoans, both the polyps stages and the medusae.

1. Food Concentration: Food concentration is believed to affect the abundance of scyphomedusae both directly and indirectly. During the summer of 1986, zooplankton bloom is believed to be the main reason for the aggregations of the scyphomedusa *Rhizostoma pulmo* in the Lebanese coastal waters. Preceding the aggregations, a blooming episode of phytoplankton is reported followed by an increase in zooplankton biomass, namely Chaetognatha, Appendicularia, Cladocera, and other meroplanktonic larvae (Lakkis, 1991). In the Gullmar Fjord, western Sweden, the maximum abundance of *Cyanea capillata* ephyrae is significantly less in comparison to the abundance of *Aurelia aurita* during 1984-1985 (Gröndahl and Hernroth, 1987). This marked difference is explained by the fact that the scyphistomae of *Aurelia* develop during the period of maximum food availability, encouraging asexual reproduction and release of ephyrae. On the contrary, *Cyanea*'s scyphistomae develop during winter and early spring where there is minimum zooplankton biomass, which affected the production of ephyrae.

   In *Aurelia aurita*, an experiment had shown that food availability governed both the maturation process as well as individual growth. While food scarcity reduces the growth rate, energy is allocated towards reproduction, which occurs at a relatively smaller size than well-fed medusae (Ishii and Båmstedt, 1998). Lucas (1996) observed a similar trend in Horsea Lake, England. Abundance of *Aurelia aurita* was limited by numerically and species-poor mesozooplankton community. However, small-size medusae were able to reach sexual maturity and reproduce. Here, medusae appeared to partition the available food resources into either somatic growth, when food was abundant, or reproduction, when food was scarce.

2. Predation: Another possible explanation for the low abundance of scyphomedusae, for example *Cyanea* sp., is the constant exposure of the scyphistomae to predation by nudibranchs coupling with the low number of planula larvae settling in the area 1985 (Gröndahl and Hernroth, 1987). According to the typical life cycle of scyphozoans, the asexual reproduction of the benthic stages produces high number of offspring. Thus, unsuccessful settlement of the planktonic larvae and predation are logical causes of low abundance of rhizomedusae.

VIII. Economical Importance

Despite the notorious reputation, jellyfish are subjected to fisheries for human consumption. In China, jellyfish are believed to possess medicinal properties that relieve pains associated with urinary bladder infections and cramps. In 1981, the value of scyphozoans exported from Asian countries, including Thailand, was US$ 40 million, or approximately 1,200 million bahts, with the important markets being Japan and China. Most fisheries are for rhizostome medusae: *Rhopilema esculenta, Lobonema smithi, Lobonemoides gracilis, Rhopilema hispidum,* and *Stomolophus meleagris*. Small-scale fisheries are carried out in South Korea, West Japan, and India. In 1981, Omori reported that the main sources of jellyfish are China, Philippines, Thailand, Malaysia, and Indonesia. The potential is mainly in countries with warm coastal waters and populations of rhizostome medusae (Arai, 1987). Usually, medusae are preserved with a mixture of table salt and alum, a collagen-like protein, and dried before they are sold to the market.

In Thailand, fisheries of jellyfish have been conducted for more than 20 years. The species that are commonly harvested are *Rhopilema esculenta, Mastigias* spp., and *Lobonema smithii*. In addition, Boonyanej (1979) reports *Rhopilema hispidum* as a commercial species. Rhizostome jellyfish are found in abundance during March, and also between August and September, along coastal areas of the eastern provinces including Chonburi and Rayong. Along the western coast of the Gulf of Thailand, i.e. Petchaburi, they are found between October to November. Jellyfish are collected 2 to 4 kilometers from shore. Regardless of the virtually low-cost procedure, a fishing boat may earn up to 2,000-3,000 bahts per day. Jellyfish production had decreased drastically in 1993 (Table 2). However, there has been an increase in demand along with opening of new markets in Korea, Taiwan, Malaysia, Singapore, Europe, and America. As a result, export values have been on an increasing trend in the later years (Table 2). Jellyfish fisheries are now spreading to the southern provinces of the Gulf of Thailand and the Andaman Sea, i.e. Phang Nga, Phuket, Krabi, and Pattani (Table 3). Most exported products had already been processed and dried (Sirirattanachai, 1994).

Table 2. Annual jellyfish production from 1992–1996 (Department of Fisheries, 1996).

Year	Value in 1000 Tons	Value in Million Baht
1992	103.2	52.5
1993	15.6	13.8
1994	86.1	68.5
1995	33.7	39.7
1996	30.5	36.3

Table 3. Jellyfish production in the Gulf of Thailand and the Andaman Sea in 1996 (Department of Fisheries, 1996).

	Value in Tons	Value in 1,000 Baht
Gulf of Thailand	17,956	26,479
Andaman Sea	12,540	9,842
Total	30,496	36,321

IX. Rhizostome Scyphozoans in Thai Waters

In Thailand, apart from few commercial species, the information pertaining to the species diversity of scyphomedusae is somewhat scattered. Below is the list of species of rhizomedusae (Table 4), the main focus of this particular study, that are found worldwide (Arai, 1997) and the species that are found in coastal regions of the Thai/Malaysian Peninsula, including Singapore (Cornelius, 1995).

Table 4. List of rhizomedusa species found worldwide and in Thailand (Arai, 1997 and Cornelius, 1995).

Species (Worldwide)		Species found in Thailand
Family Cassiopeidae:	*Cassiopea andromeda*	✓
	Cassiopea frondosa	
	Cassiopea ornata	✓
	Cassiopea xamachana	
Family Catostylidae:	*Catostylus ouwensi*	✓
	Acromitus flagellatus	✓
Family Cepheidae:	*Cephea cephea*	✓
	Cotylorhiza tuberculata	
Family Lobonematidae:	*Lobonema smithii*	✓
	Lobonema gracilis	
Family Lychnorhizidae:	*Pseudorhiza haeckeli*	
Family Mastigiidae:	*Mastigias albipunctatus*	
	Mastigias papua	✓
	Phyllorhiza peronlesueuri	
	Phyllorhiza punctata	✓
Family Rhizostomatidae:	*Rhizostoma pulmo*	
	Rhopilema esculenta	
	Rhopilema hispidum	✓
	Rhopilema nomadica	
	Rhopilema verrilli	
Family Stomolophidae:	*Stomolophus meleagris*	
	Stomolophous nomurai	

Despite their importance in the ecosystem and the fishery economy, most information regarding the species diversity of rhizomedusae are limited to few commercial species such as those mentioned earlier. In consequence, to assess the species diversity, the sole purpose of this research aims at the systematic sampling of rhizomedusa specimens present along the coast of Chon Buri and Phetchaburi Provinces, where there are intensive fisheries for jellyfish. This will serve as representative of the Eastern and Western Gulf of Thailand, respectively. Furthermore, to gain insights on the annual distribution and abundance of different species of rhizomedusae, the physical and biological environmental parameters will be monitored.

CHAPTER 2

MATERIALS AND METHODS

I. Preliminary Survey

Preliminary surveys, by means of questionnaires (Appendix 1), were carried out in Chon Buri, Samut Sakorn, and Phetchaburi Provinces. Target species at these locations are *Rhopilema hispidum* and *Lobonema smithii*. At Chon Buri Province, jellyfish fishery starts from April until October. At Samut Sakorn Province, jellyfish fishery generally starts in April until the end of the year. At Phetchaburi Province, fishery is conducted in July and August depending on the meteorological conditions of each year. The fishing methods used in all three provinces appeared to be dip nets. However, jellyfish are also obtained as by-catch from boats equipped with push nets (Table 5).

Table 5. Summary of interviews carried out in Chon Buri, Samutsakorn, Samutsongkram, and Phetchaburi Provinces.

	Province			
	Chon Buri	**Samutsakorn**	**Samutsongkram**	**Phetchaburi**
Fishing Season	April, June - October	April-December	April, September-December	July-August
Fishing Equipment	Dip nets	Dip nets, push nets	Dip nets, push nets	Dip nets
Fishing Time	Day and night	Day	Day and night	Day and night
Fishing Areas	Sriracha, Laem Chabung	Tachin River's mouth	Maeklong River's mouth	Along the coast, Baan Laem
Target Species	*Lobonema smithii* and *Rhopilema* sp.	*Lobonema smithii* and *Rhopilema* sp.	*Lobonema smithii* and *Rhopilema* sp.	*Lobonema smithii* and *Rhopilema* sp.

Aboard the long-tail boats, fishermen visually locate swarms of jellyfish. Jellyfish are then fished out of the water with the dip nets, with the mesh size of approximately 1 cm, on to the floor of the boat. According to Cornelius (1995), jellyfish sampling is accomplished by means of an angler's landing net, which is suitable for collecting small to medium size specimen. This method, however, is rather insufficient and impractical in the case of systematic sampling.

Subsequent to a preliminary survey, through means of questionnaires and interviews, it was decided that samples would be collected off the coasts of Baan Laem, Phetchaburi and, south of the Bangpakong River's mouth, Chon Buri Provinces. Both locations are situated in the Inner Gulf of Thailand, approximately opposite each other, and jellyfish fishery is common practice.

II. Scyphomedusae Sampling

A. Collection

A fishing boat equipped with a push net (mesh size ≈ 0.5 inch, mouth width ≈ 12 meters), operating at an approximated speed of 3 to 4 km/hr, was chosen for quantitative jellyfish sampling (Figure 8). The sampling procedures are as follows:

Figure 8. Sampling boat equipped with push net.

1. At each location, a total of three sampling lines running parallel to each other, at approximately half a kilometer apart and perpendicular to the shoreline were established. The length of each line was measured by a time unit, which was trawling time of 10 minutes (Figure 9).

2. After each ten-minute trawl, or at the end of each sampling line, the net and its contents were retrieved. All medusae were isolated from the rest of the contents. Medusae obtained from each sampling line were stored separately.

3. Sampling was conducted once a month, during daytime spring tide, for a period of 13 months from December 1999 to December 2000.

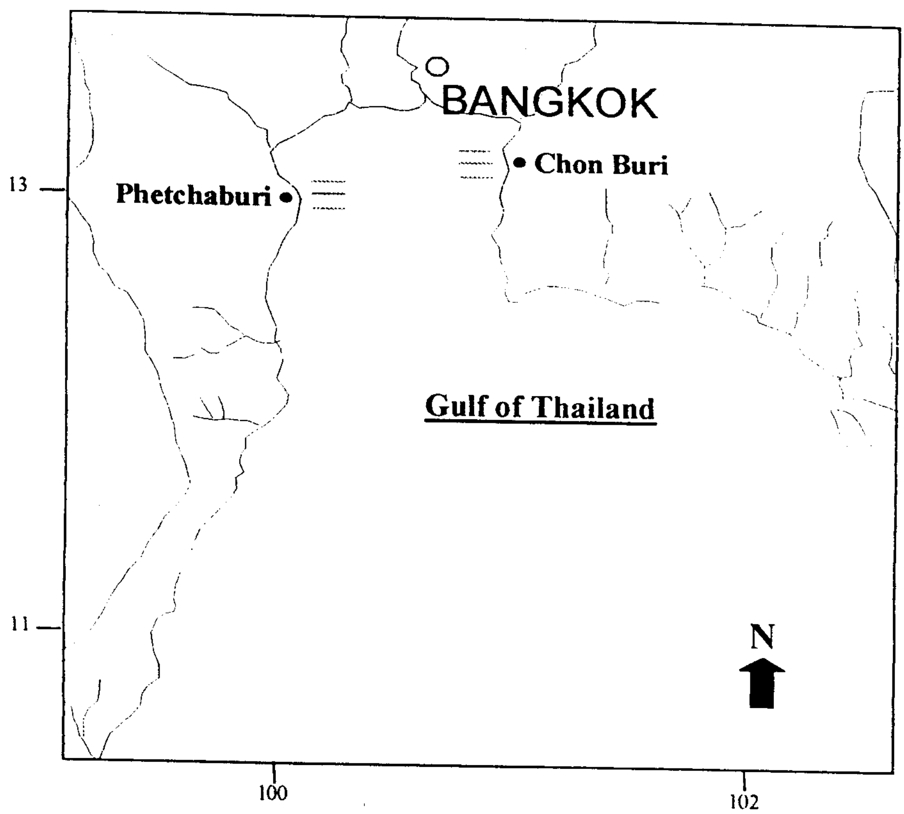


Figure 9. Map of sampling areas.

B. Fixation and Preservation

1. The fixation solution recommended by UNESCO (1976) is 10% formalin (buffered). Borax (Sodium Tetraborate Decahydrate) buffered formalin was prepared as follows:

   30 g. of borax per 1 liter of concentrated formalin

   The buffered solution was diluted by the addition of seawater in a 1:9 ratio (i.e. 10 ml of concentrated formalin to 90 ml of seawater) to yield 10% formalin fixative.

2. After 7 to 10 days, specimens were transferred into a preserving solution. In the case of coelenterates, 70% ethanol is a better alternative compared to formalin (Omori and Ikeda, 1984). To prevent an immediate loss of water, specimens were first transferred to 30% ethanol to be preserved for approximately one week prior to transfer to 70% ethanol.

3. All specimens obtained from the trawls were fixed and transported back to the laboratory. If the amount of specimens obtained was extremely large (> 200 individuals per haul), each specimen was measured for weight and bell diameter. Representatives of the specimens were selected, based on physical resemblance, and fixed prior to transportation to the laboratory.

4. Plastic containers are used for temporary storage of specimens. Long-term storage in polyethylene container causes dissolved complex of paraffin and softening agents to settle as fine, film coating on specimens. This will obscure taxonomically important details necessary for identification purposes. For safety reasons, plastic containers are generally used on board. However, specimens must be transferred to glass containers once they arrive at the laboratory.

C. Identification

All medusae obtained from the field were measured for weight and bell diameter and identified. Identification of specimens is accomplished using existing taxonomical keys i.e. Keys to Thai and Malaysian Cubomedusae and Scyphomedusae (Cornelius, 1995). Although the structures of nematocysts can be used for identification, only external characteristics were used in this study. The physical characteristics that were important to the identification process were shape of bell, exumbrella surface, color patches, presence of terminal filaments or clubs, and mouth arms (Figure 10). Most distinguishing characteristics were recognizable under the naked eyes. However, inconspicuous features, such as the terminal filaments, were best viewed under a stereomicroscope.

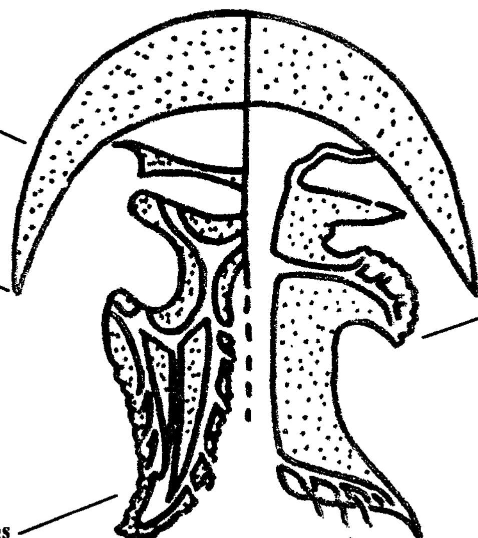


Figure 10. Physical characteristics used in the identification of scyphomedusae (Mianzan and Cornelius, 1999).

D. Abundance

Abundance of rhizomedusae, or number of individuals per 10,000 m^3 of water, was calculated using the following formula:

Trawling distance (m) = Speed x Time

Speed = Speed of the boat (km/h), which was recorded using the GPS
Time = Trawling time (hr)

Thereafter, the volume of water trawled was calculated by:

Volume of water (m^3) = Length x Width x Depth

Length = Trawling distance (m)
Width = Width of push net's mouth (m)
Depth = Depth of water (m)

The average abundance for each month, at each location, was calculated from the abundance obtained from each sampling line. In addition to the average abundance of rhizomedusae, specimens were categorized into various size classes using the measurements of the bell diameter.

E. Gonad Analysis

1. For each species of rhizomedusae obtained from sampling, specimens of varying sizes were selected for gonad analysis.

2. The gonad of each selected specimen was extracted and smeared onto a slide using a scalper. After adding a small amount of water and placing the cover slid on top, the sample was pressed, by lightly tapping on the cover slid, so that it was evenly distributed on the slide.

3. Samples were viewed under the compound microscope and pictures of each sample were taken.

III. Zooplankton Sampling

A. Collection

At the beginning and the end of each ten-minute sampling, vertical zooplankton samplings were conducted using the standard zooplankton sampling net with the mesh size of 330 μm.

B. Fixation and Preservation

Zooplankton samples were immediately fixed in 4% borax buffered formalin solution and transported back to the laboratory.

C. Identification

Each zooplankton sample was counted and identified into major groups, i.e. copepods, fish larvae, amphipods etc., under a stereomicroscope.

D. Abundance

Zooplankton abundance, or number of individuals $\cdot$ 10^2 m^{-3} of water, for each month, at each location, was calculated by means of readings of the flow meter using the following formula,

$$T = \frac{100 \times t}{V}$$

T = Abundance of zooplankton (individuals $\cdot$ 10^2 m^{-3} of water)

t = Actual number of individuals counted from sample

V = Volume of water filtered by zooplankton net (m^3)

V was calculated using the following formula,

$$V = \frac{a \times n}{N}$$

a = Area of mouth of zooplankton net

n = Actual flowmeter reading

N = Flowmeter calibration value

IV. **Physical Parameters** (Figure 11)

1. Few other parameters that were measured include visibility (secchi disk method), depth (using weight tied to a rope), salinity (SCT Meter), temperature (SCT Meter), dissolved oxygen (DO Meter), and pH (pH Meter).

2. Upon collection, on-site records included line number, geographical coordinates of the starting location and terminating location of each sampling line, trawling speed, trawling depth, dimensions of net, and notes on the atmospheric and ocean conditions.

3. All measurements of physical parameters obtained from each month (dissolved oxygen, temperature, and pH) were calculated for average and standard deviation.

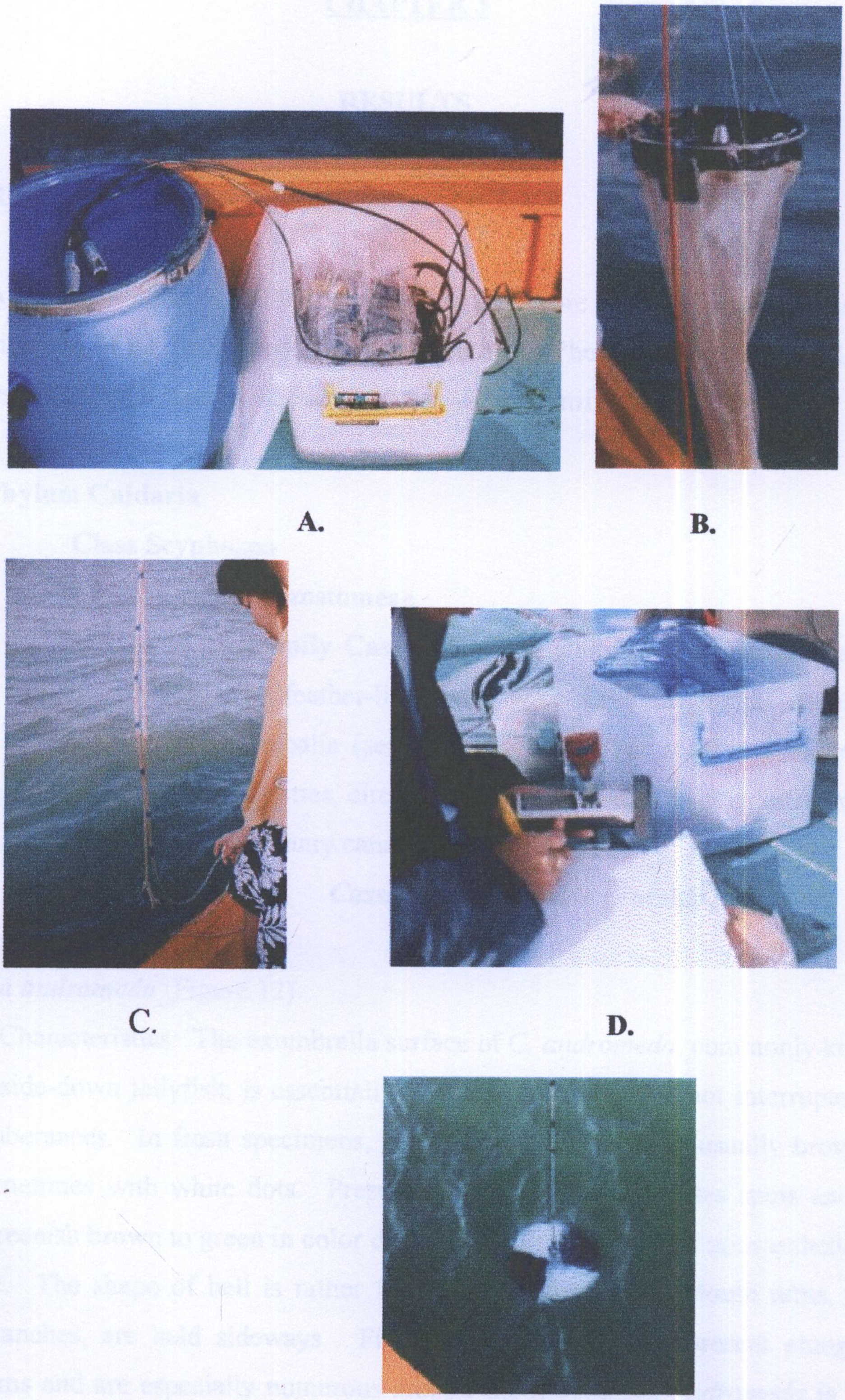


Figure 11. Sampling gears/equipment for physical and biological environmental parameter: (A) SCT Meter and DO Meter; (B) zooplankton net equipped with a flow meter; (C) depth measurement; (D) GPS; and (E) Secchi disc for measurement of transparency.

CHAPTER 3

RESULTS

I. Rhizostome Scyphozoans Diversity

After 13 months of field samplings in near shore water along the coasts of Chonburi, south of the Bangpakong River's mouth and Phetchaburi, near Baan Laem, Provinces, a total of 6 species of rhizomedusae were identified.

Phylum Cnidaria

Class Scyphozoa

Order Rhizostomeae

Family Cassiopeidae: Subumbrella muscles arranged in feather-life arcs, twice as many radial canals as rhopalia (sense organ), with four separated subgenital cavities, circular stomach, arm-disk is octagonal, with 4 primary canals (Cornelius, 1995).

***Cassiopea andromeda* (Forskål, 1775)**

Cassiopea andromeda (Figure 12)

External Characteristics: The exumbrella surface of *C. andromeda*, commonly known as the upside-down jellyfish, is essentially smooth. Its contour is not interrupted by any protuberances. In fresh specimens, the exumbrella surface is usually brown in color, sometimes with white dots. Preserved specimens lack whites spots and are usually greenish brown to green in color depending on the amount of zooxanthellae in the tissue. The shape of bell is rather flat, not hemispherical. Mouth arms, with lateral branches, are held sideways. Filamentous tentacles are present along the mouth arms and are especially numerous around the mouth. *C. andromeda* is very similar to a related species, *Cassiopea ornata*. According to Cornelius (1995), these two species are distinguished from each other by the mouth arms, which appear relatively broader in *C. andromeda*.

Distribution: Chon Buri and Phetchaburi.

Size Range: 1 - 26 cm.

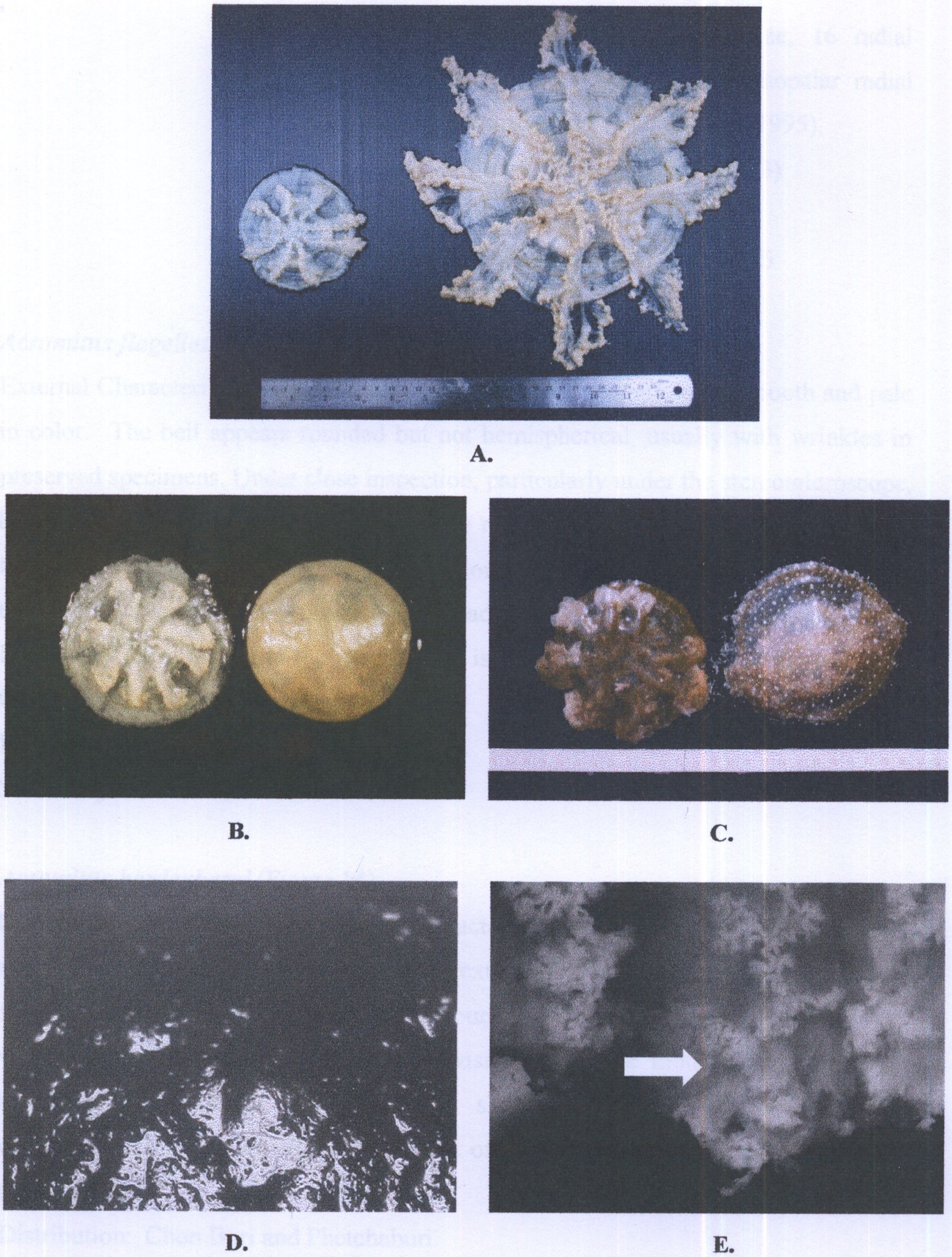


Figure 12. *Cassiopea andromeda*; (A&B) preserved specimens, (C) fresh specimens, (D) smooth bell surface x 6.6, and (E) mouth arms with filaments x 2.2 (arrow).

Family Catostylidae: Without scapulae, 16 radial canals, mouth arms are pyramidal, 8 rhopalar radial canals, 8 interrhopalar canals (Cornelius, 1995).

***Acromitus flagellatus* (Maas, 1903)**

Acromitus hardenbergi

***Catostylus townsendi* Mayer, 1915**

Acromitus flagellatus (Figure 13)

External Characteristics: The exumbrella surface of *A. flagellatus* is smooth and pale in color. The bell appears rounded but not hemispherical, usually with wrinkles in preserved specimens. Under close inspection, particularly under the stereomicroscope, bell surface appears finely granulated. The mouth arms hang down, without lateral branches. Filaments are commonly found along the sides of the mouth arms and near the mouth. The mouth arms, which are broad, tapering distally, have terminal whip-like clubs. The outline of the mouth arms is conical or pyramidal, sometimes with filaments projecting from the contour.

Distribution: Chon Buri and Phetchaburi.

Size Range: 2 – 17 cm.

Acromitus hardenbergi (Figure 14)

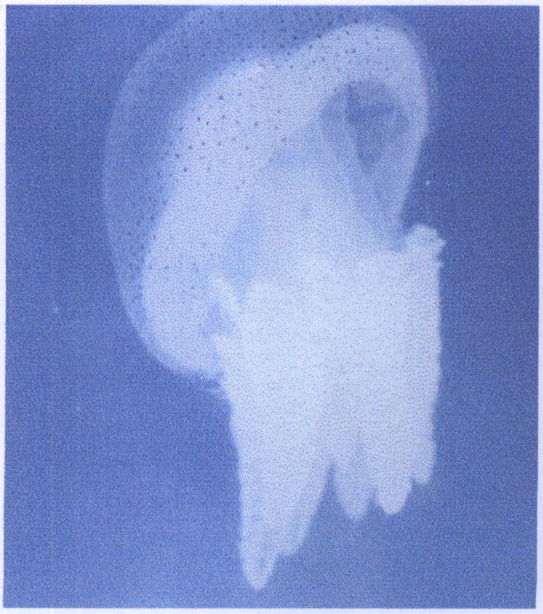
External Characteristics: The external characteristics of *A. hardenbergi* are eminently resembling those of *A. flagellatus*. The exumbrella surface of *A. hardenbergi* is smooth and pale in color. The bell is rounded and the mouth arms hang down, without lateral branches. Filaments are visible along the mouth arms, which are broad, tapering distally, and conical in shape. However, *A. hardenbergi* is distinguished from *A. flagellatus* by its lack of terminal whip-like clubs on the mouth arms.

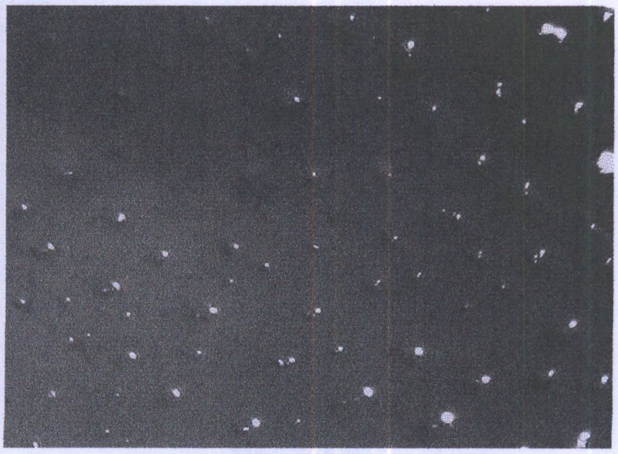
Distribution: Chon Buri and Phetchaburi.

Size Range: 2 – 14 cm.

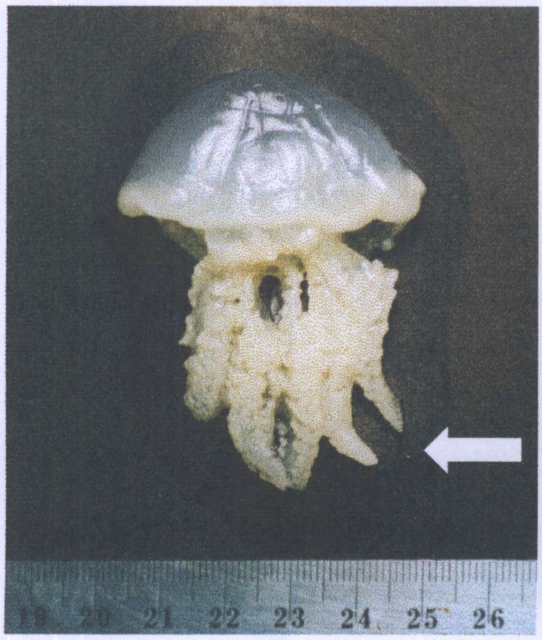
Catostylus townsendi (Figure 15)

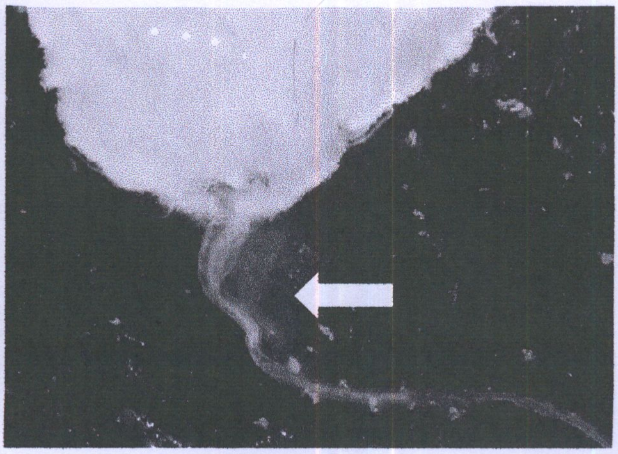
External Characteristics: The exumbrella surface is smooth and creamy white in color. Some specimens have reddish brown or pale brown patches on the exumbrella surface. The shape of the bell is roughly hemispherical. The length of the mouth





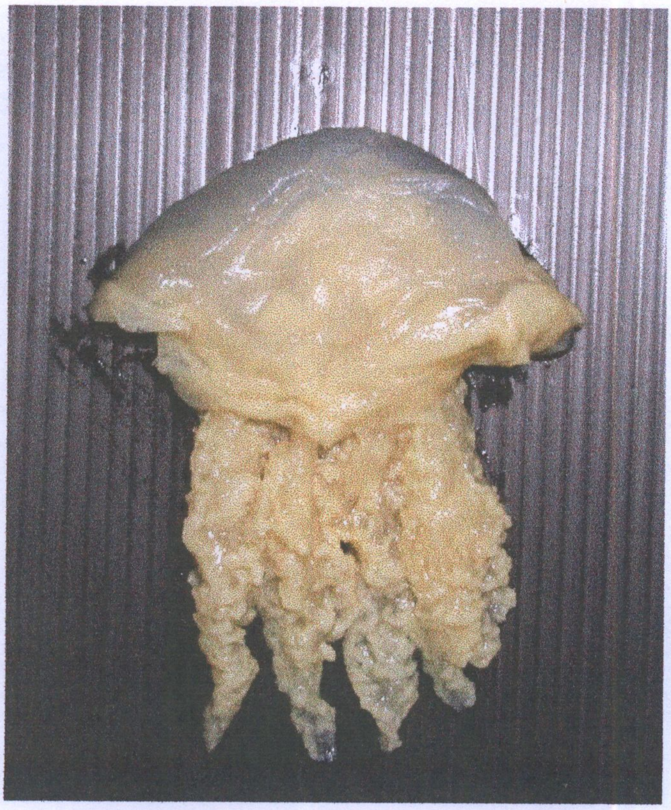
A. **B.**



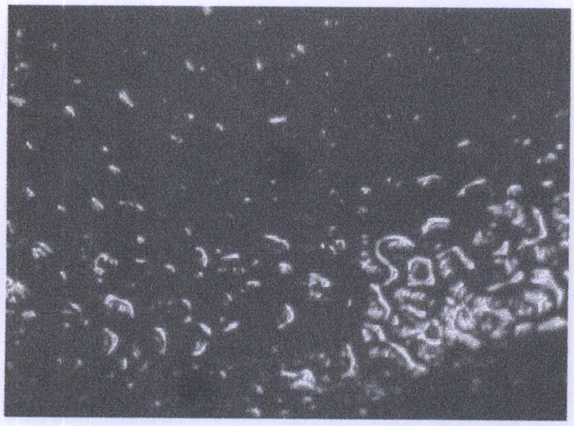


C. **D.**

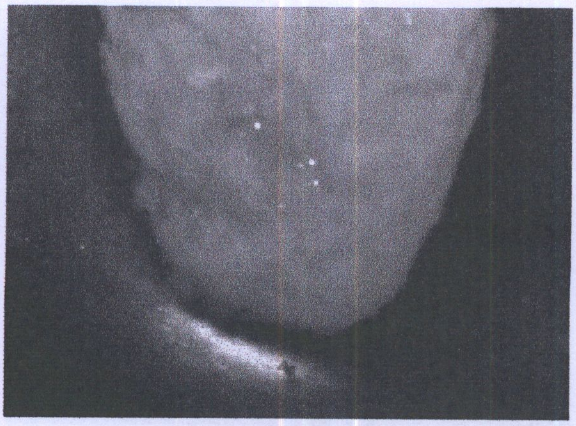
Figure 13. *Acromitus flagellatus*; (A) fresh specimen, (B) smooth bell surface x 6.6, (C) preserved specimen with terminal filaments (arrow), and (D) mouth arm with terminal filament x 2.2 (arrow).



A.

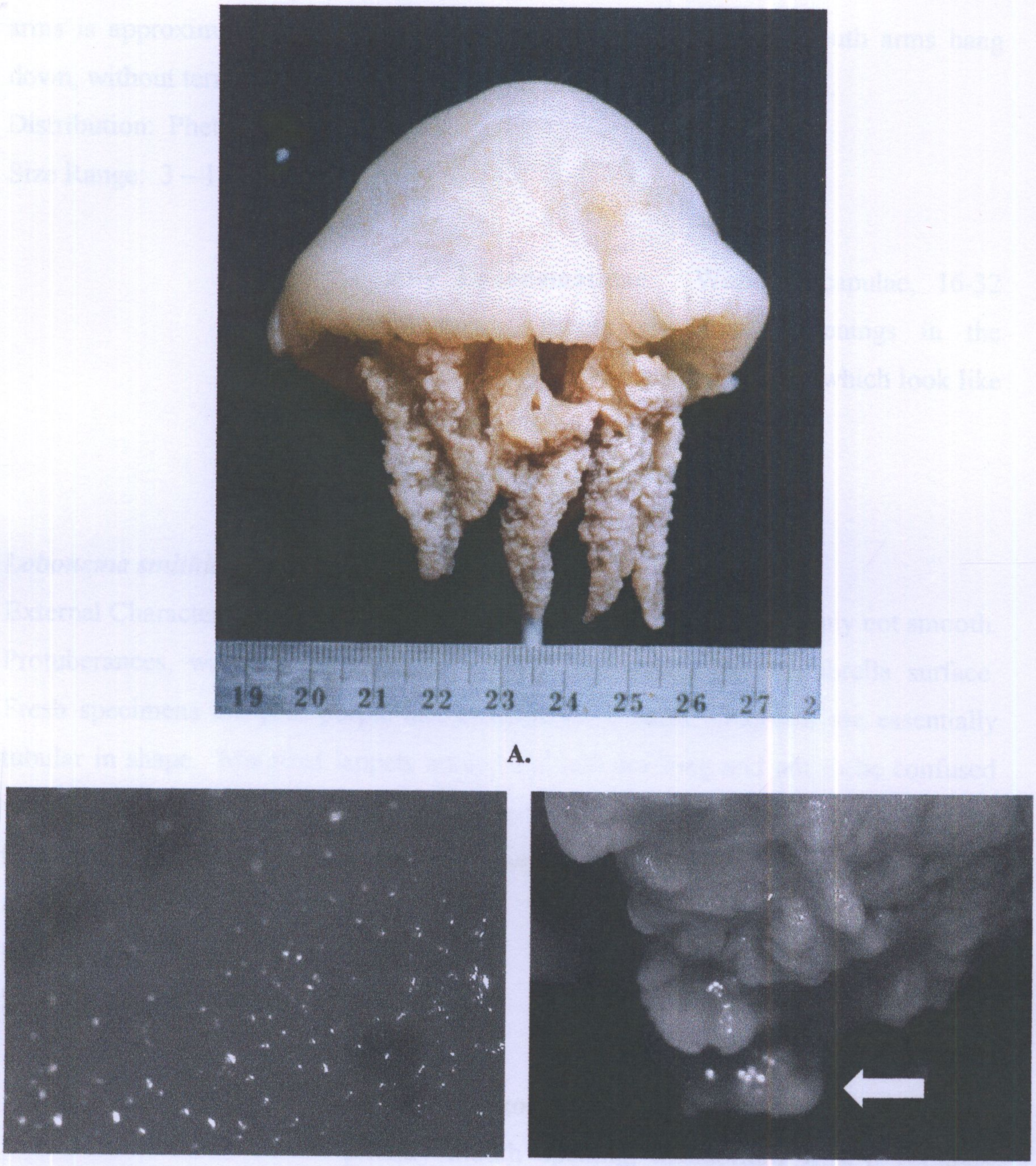


B.



C.

Figure 14. *Acromitus hardenbergi*; (A) preserved specimen, (B) smooth bell surface x 6.6, and (C) mouth arm with no terminal filament x 2.2.



B. C.

Figure 15. *Catostylus townsendi*; (A) preserved specimen, (B) smooth bell surface x 6.6, and (C) mouth arm without terminal filaments x 2.2 (arrow).

arms is approximately equal or shorter than the bell diameter. Mouth arms hang down, without terminal filaments and without filaments along the sides.

Distribution: Phetchaburi.

Size Range: 3 – 12 cm.

Family Lobonematidae: Without scapulae, 16-32 radial canals, mouth arms with openings in the membranes, elongated marginal lappets which look like tentacles (Cornelius, 1995).

***Lobonema smithii* Mayer, 1910**

Lobonema smithii (Figure 16)

External Characteristics: The exumbrella surface of *L. smithii* is certainly not smooth. Protuberances, warts, or papillae, are present throughout the exumbrella surface. Fresh specimens are pale purple and translucent in color. Papillae are essentially tubular in shape. Marginal lappets around the bell are long and not to be confused with marginal tentacles. Bell is round and nearly hemispherical. There are numerous filaments present allover the mouth arms, which lack scapulae that are present in *R. hispidum*. Most specimens are large.

Distribution: Phetchaburi.

Size Range: 24 – 53 cm.

Family Rhizostomatidae: With scapulae, without primary mouth opening, manubrium with a complex canal system, proximal portion of mouth arms are joined, distal portion is 3-winged (Cornelius, 1995).

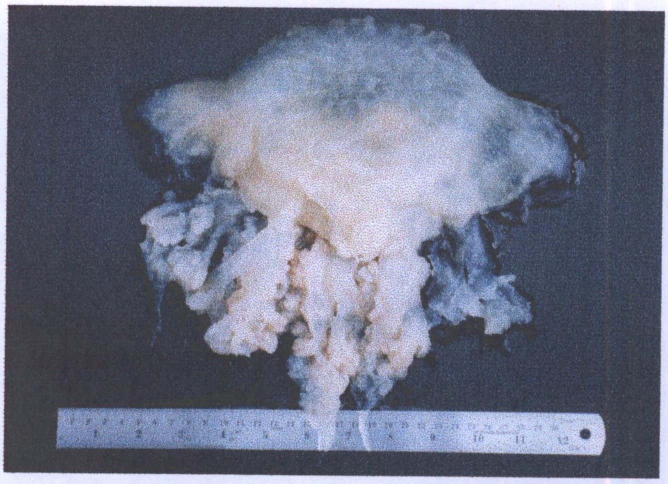
***Rhopilema hispidum* (Vanhöffen, 1888)**

Rhopilema hispidum (Figure 17)

External Characteristics: The exumbrella surface of *R. hispidum*, white in color, is distinctly granulated and rough to touch. Fine granulation is present allover the bell surface. The shape of the fleshy bell is somewhat hemispherical, sometimes with tiny brownish dots. Mouth arms are with scapulae and numerous filaments along the sides. Most specimens found are usually larger than 15 cm in bell diameter.

Distribution: Chon Buri and Phetchaburi.

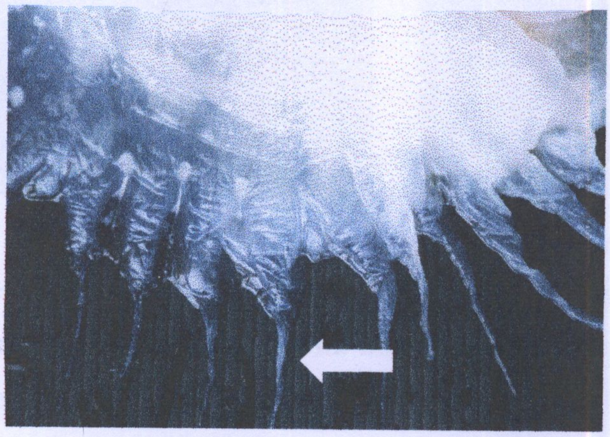
Size Range: 15 – 54 cm.



A.

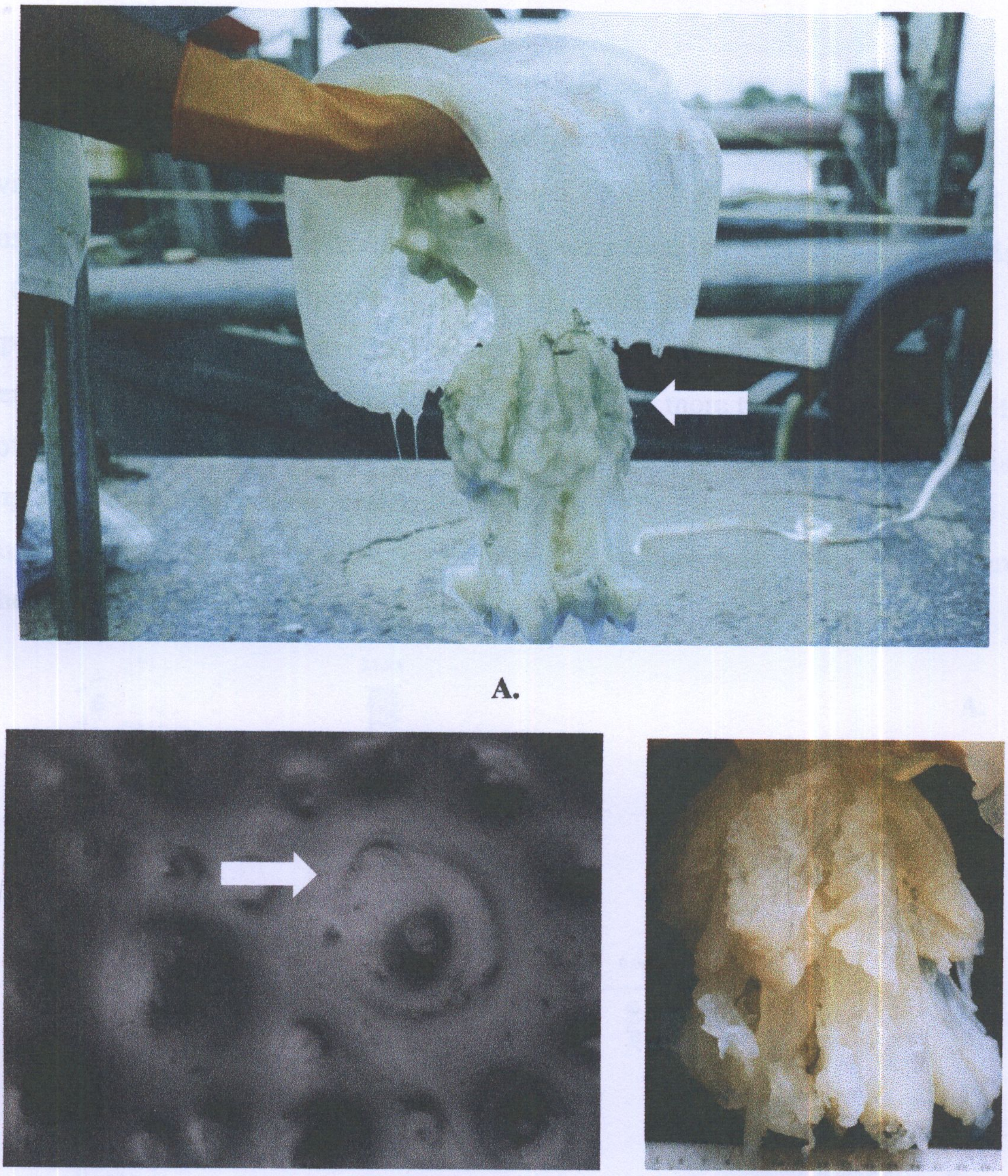
B.

C.



D.

Figure 16. *Lobonema smithii*; (A) preserved specimen, (B) protuberances on bell surface or papillae x 2.2 (arrow), (C) fresh specimen, and (D) marginal lappets (arrow).



A.

B. C.

Figure 17. *Rhopilema hispidum*; (A) fresh specimen with scapulae (arrow), (B) finely granulated bell surface with minute warts x 6.6 (arrow), and (D) scapulae.

II. Abundance of Rhizostome Scyphozoans

At Chon Buri Province, rhizomedusae occurred in highest abundance (> 23 individuals · 10^4 m^{-3}) during the month of March 2000. Relatively smaller number of rhizostome specimens (< 3 individuals · 10^4 m^{-3}) were found in January, February, May, and October 2000. No rhizostome specimens were found in other months. In comparison, the highest abundance at Phetchaburi Province occurred during the month of November 2000 (> 300 individuals · 10^4 m^{-3}). In addition, more than 25 individuals · 10^4 m^{-3} of specimens were obtained in June and October 2000. No rhizomedusae were found during the months of March and September 2000. Interestingly, the abundance of medusae was more than 10 times higher in magnitude at Phetchaburi Province compared to Chon Buri Province (Figure 18A and B).

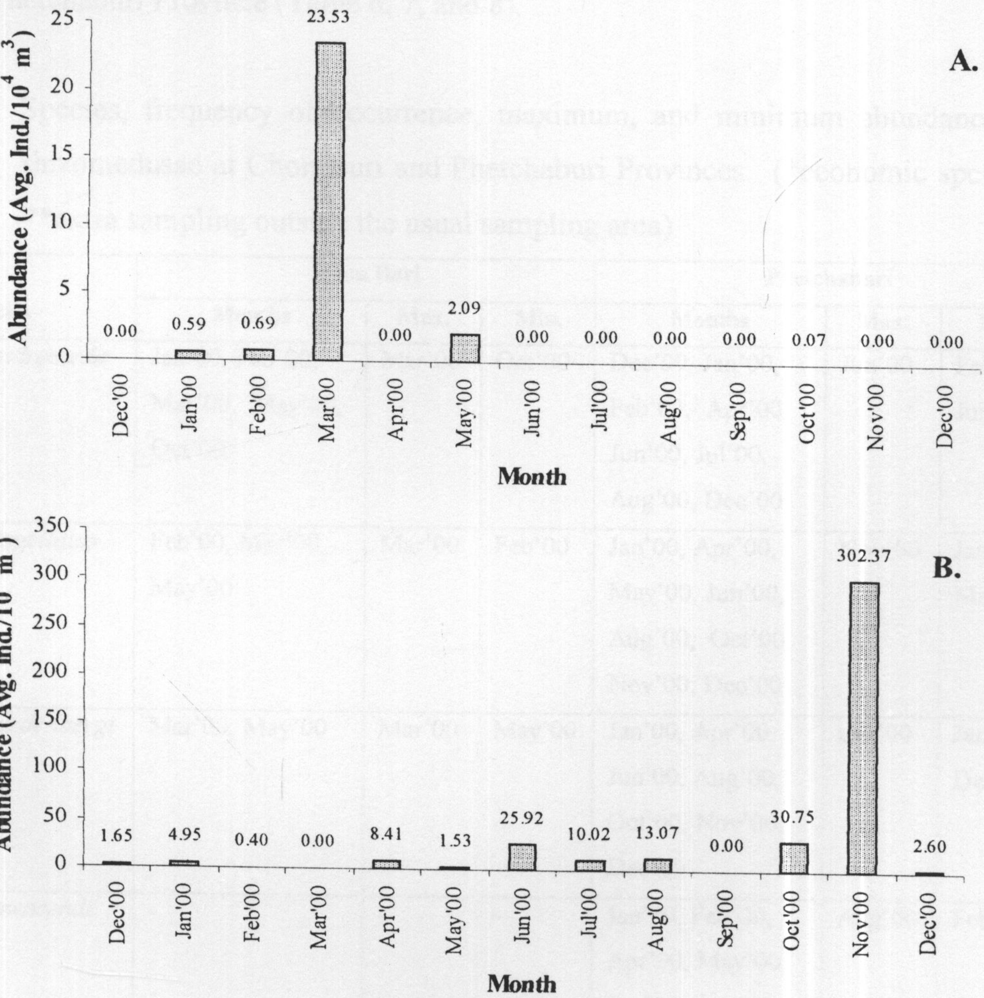


Figure 18. Abundance of rhizomedusae at (A) Chon Buri and (B) Phetchaburi Provinces from December 1999 to December 2000.

During the month of March, with the highest abundance of rhizomedusae observed at Chon Buri Province, the dominant species was *Acromitus flagellatus*, which was also a dominant species at Phetchaburi. Noticeably, at Chon Buri Province, *Cassiopea andromeda* was the most encountered species and was found in 5 months out of the 13-months sampling period. Both *A. flagellatus* and *C. andromeda* was the most encountered species at Phetchaburi Province and were predominantly found in 8 months out of the 13-months sampling period. In term of the number of species found at each sampling area, Phetchaburi Province appeared to have a relatively higher number of species of rhizomedusae, 6 species, in addition to cubomedusae and other scyphomedusae. There were only 3 species, yielded from the Chon Buri Province excluding *Rhopilema hispidum*, which was found outside the usual sampling area. Highest species diversity was observed in March 2000 for Chon Buri Province and June 2000 for Phetchaburi Province (Table 6, 7, and 8).

Table 6. Species, frequency of occurrence, maximum, and minimum abundance of rhizomedusae at Chon Buri and Phetchaburi Provinces. (*economic species, **extra sampling outside the usual sampling area)

Species	Chon Buri			Phetchaburi		
	Months	**Max.**	**Min.**	**Months**	**Max.**	**Min.**
Cassiopea andromeda	Jan'00, Feb'00, Mar'00, May'00, Oct'00	Mar'00	Oct'00	Dec'99, Jan'00, Feb'00, Apr'00, Jun'00, Jul'00, Aug'00, Dec'00	Jun'00	Feb'00, Jul'00
Acromitus flagellatus	Feb'00, Mar'00, May'00	Mar'00	Feb'00	Jan'00, Apr'00, May'00, Jun'00, Aug'00, Oct'00, Nov'00, Dec'00	Nov'00	Jan'00, May'00
Acromitus hardenbergi	Mar'00, May'00	Mar'00	May'00	Jan'00, Apr'00, Jun'00, Aug'00, Oct'00, Nov'00, Dec'00	Oct'00	Jan'00, Dec'00
Catostylus townsendi	-	-	-	Jan'00, Feb'00, Apr'00, May'00, Jun'00, Aug'00	Aug'00	Feb'00
Lobonema smithii *	-	-	-	Jun'00, Jul'00	Jul'00	Jun'00
Rhopilema hispidum *	Aug'00**	-	-	Jul'00	-	-

Table 7. Species and abundance of scyphomedusae obtained from 3 sampling transects at Chon Buri Province from December 1999 to December 2000. (Unit: individuals · 10^4 m^{-3})

Date	Line 1		Line 2		Line 3	
	Species	Abun.	Species	Abun.	Species	Abun.
12-21-99	No jellyfish		No Jellyfish		No jellyfish	
01-22-00	*Cassiopea andromeda*	0.26	*Cassiopea andromeda*	0.88	*Cassiopea andromeda*	0.34
			Unknown	0.29		
02-19-00	*Cassiopea andromeda*	0.58	*Acromitus flagellatus*	0.54	*Cassiopea andromeda*	0.96
03-21-00	*Acromitus flagellatus*	16.15	*Acromitus flagellatus*	29.97	*Acromitus flagellatus*	11.17
	Acromitus hardenbergi	0.84	*Acromitus hardenbergi*	5.66	*Acromitus hardenbergi*	0.29
	Cassiopea andromeda	0.28	*Cassiopea andromeda*	1.13	*Cassiopea andromeda*	2.29
	Unknown	0.56	Unknown	2.26	Other (Cubozoa)	0.57
04-22-00	No jellyfish		No jellyfish		No jellyfish	
05-14-00	*Acromitus flagellatus*	0.23	*Acromitus flagellatus*	1.13	*Acromitus flagellatus*	2.63
	Unknown	0.23			*Acromitus hardenbergi*	0.58
					Cassiopea andromeda	0.29
					Unknown	1.17
06-15-00	No jellyfish		No jellyfish		No jellyfish	
07-15-00	No jellyfish		No jellyfish		No jellyfish	
08-18-00	No jellyfish		No jellyfish		No jellyfish	
09-16-00	No jellyfish		No jellyfish		No jellyfish	
10-17-00	No jellyfish		No jellyfish		*Cassiopea andromeda*	0.20
11-11-00	No jellyfish		No jellyfish		No jellyfish	
12-15-00	No jellyfish		No jellyfish		No jellyfish	

Table 8. Species and abundance of scyphomedusae obtained from 3 sampling transects at Phetchaburi Province from December 1999 to December 2000. (Unit: individuals · 10^4 m^{-3})

Date	Line 1		Line 2		Line 3	
	Species	Abun.	Species	Abun.	Species	Abun.
12-22-99	*Cassiopea andromeda*	0.36	*Cassiopea andromeda*	2.54	*Cassiopea andromeda*	2.04
01-24-00	*Acromitus flagellatus*	0.75	*Acromitus flagellatus*	0.52	*Acromitus flagellatus*	0.62
	Cassiopea andromeda	0.38	*Acromitus hardenbergi*	1.03	*Cassiopea andromeda*	9.26
	Catostylus townsendi	0.75	*Cassiopea andromeda*	1.55	Other (Semeostomeae)	0.62
02-20-00	No jellyfish		*Cassiopea andromeda*	0.61	Other (Semeostomeae)	1.16
			Catostylus townsendi	0.61		
03-22-00	No jellyfish		No jellyfish		Other (Semeostomeae)	0.56

Table 8. (Cont.) Species and abundance of scyphomedusae obtained from 3 sampling transects at Phetchaburi Province from December 1999 to December 2000. (Unit: individuals · 10^4 m^{-3})

Date	Line 1		Line 2		Line 3	
	Species	**Abun.**	**Species**	**Abun.**	**Species**	**Abun.**
04-23-00	*Acromitus flagellatus*	4.09	*Acromitus flagellatus*	0.46	*Acromitus flagellatus*	3.95
	Acromitus hardenbergi	0.68	*Acromitus hardenbergi*	0.92	*Acromitus herdenbergi*	0.49
	Cassiopea andromeda	2.73	*Cassiopea andromeda*	4.14	*Cassiopea andromeda*	0.49
	Catostylus townsendi	1.36	Other (Semeostomeae)	0.92	*Catostylus townsendi*	0.99
	Unknown	2.04	Unknown	0.92	Unknown	1.98
05-15-00	*Acromitus flagellatus*	0.66	*Acromitus flagellatus*	1.96	Other (Cubozoa)	1.89
	Other (Semeostomeae)	2.64	*Catostylus townsendi*	1.31	Other (Semeostomeae)	15.78
	Unknown	0.66	Other (Semeostomeae)	33.33		
06-14-00	*Acromitus flagellatus*	16.84	*Acromitus flagellatus*	16.60	*Acromitus flagellatus*	7.65
	Acromitus hardenbergi	2.11	*Acromitus hardenbergi*	1.28	*Acromitus hardenbergi*	2.04
	Cassiopea andromeda	21.05	*Cassiopea andromeda*	3.40	*Cassiopea andromeda*	3.57
			Catostylus townsendi	0.85	*Catostylus townsendi*	1.02
			Lobonema smithii	0.43	*Lobonema smithii*	0.51
			Other (Cubozoa)	0.43		
			Unknown	0.43		
07-14-00	*Cassiopea andromeda*	0.59	*Lobonema smithii*	9.43	*Lobonema smithii*	13.77
	Lobonema smithii	5.87	*Rhopilema hispidum*	0.41		
	Other (*Aurelia aurita*)	2.93				
08-16-00	*Acromitus flagellatus*	10.53	*Acromitus flagellatus*	3.62	*Acromitus flagellatus*	4.88
	Acromitus hardenbergi	0.88	*Cassiopea andromeda*	1.03	*Acromitus hardenbergi*	0.89
	Cassiopea andromeda	0.88	*Catostylus townsendi*	3.62	*Cassiopea andromeda*	3.10
	Catostylus townsendi	1.75	Unknown	0.52	*Catostylus townsendi*	5.32
	Unknown	1.75			Unknown	0.44
09-17-00	No jellyfish		No jellyfish		No jellyfish	
10-18-00	*Acromitus flagellatus*	5.84	*Acromitus flagellatus*	42.36	*Acromitus flagellatus*	23.26
	Acromitus hardenbergi	3.25	*Acromitus hardenbergi*	4.86	*Acromitus hardenbergi*	8.79
	Unknown	1.30			Unknown	2.58
11-12-00	*Acromitus flagellatus*	139.20	*Acromitus flagellatus*	114.49	*Acromitus flagellatus*	646.65
					Acromitus hardenbergi	4.73
					Unknown	2.03
12-16-00	*Acromitus flagellatus*	1.45	*Acromtius flagellatus*	1.09	*Acromitus flagellatus*	2.68
	Acromitus hardenbergi	0.73	*Cassiopea andromeda*	0.73	*Cassiopea andromeda*	0.38
	Cassiopea andromeda	0.36			Unknown	0.38

The average weight of each species of rhizomedusae obtained from each month, from December 1999 to December 2000 at Chon Buri Province, appeared to be related to the abundance with the exception of *Cassiopea andromeda* (Figure 19). *C. andromeda* was found in highest abundance (> 1 individuals · 10^4 m^{-3}) during March 2000. However, the highest weight of *C. andromeda* (> 106 g) was observed in January 2000 due to the fact that most specimens were relatively larger, with the largest specimen measured 15 cm in diameter, compared to other months (Figure 19A). The highest abundance and weight of both *Acromitus flagellatus* and *Acromitus hardenbergi* were observed in March 2000 (Figure 19B and C).

At Phetchaburi Province, the highest abundance of *C. andromeda* was observed in June 2000 (> 9 individuals · 10^4 m^{-3}). On the contrary, the highest weight observed was in April 2000 (Figure 20A). The abundance and the weight of *A. flagellatus* found at Phetchaburi Province were in correlation with each other. Both the highest abundance (> 300 individuals · 10^4 m^{-3}) and weight (> 75,000 g) was observed in November 2000 (Figure 20B). A similar trend was observed for *Catostylus townsendi*, *Lobonema smithii*, and *Rhopilema hispidum*, where the highest abundance and weight were observed in the same month (Figure 20D, E, and F). The highest abundance of *A. hardenbergi* was observed in October 2000 (> 5 individuals · 10^4 m^{-3}) while the highest weight of rhizomedusae was observed in June 2000 (> 340 g) (Figure 20C).

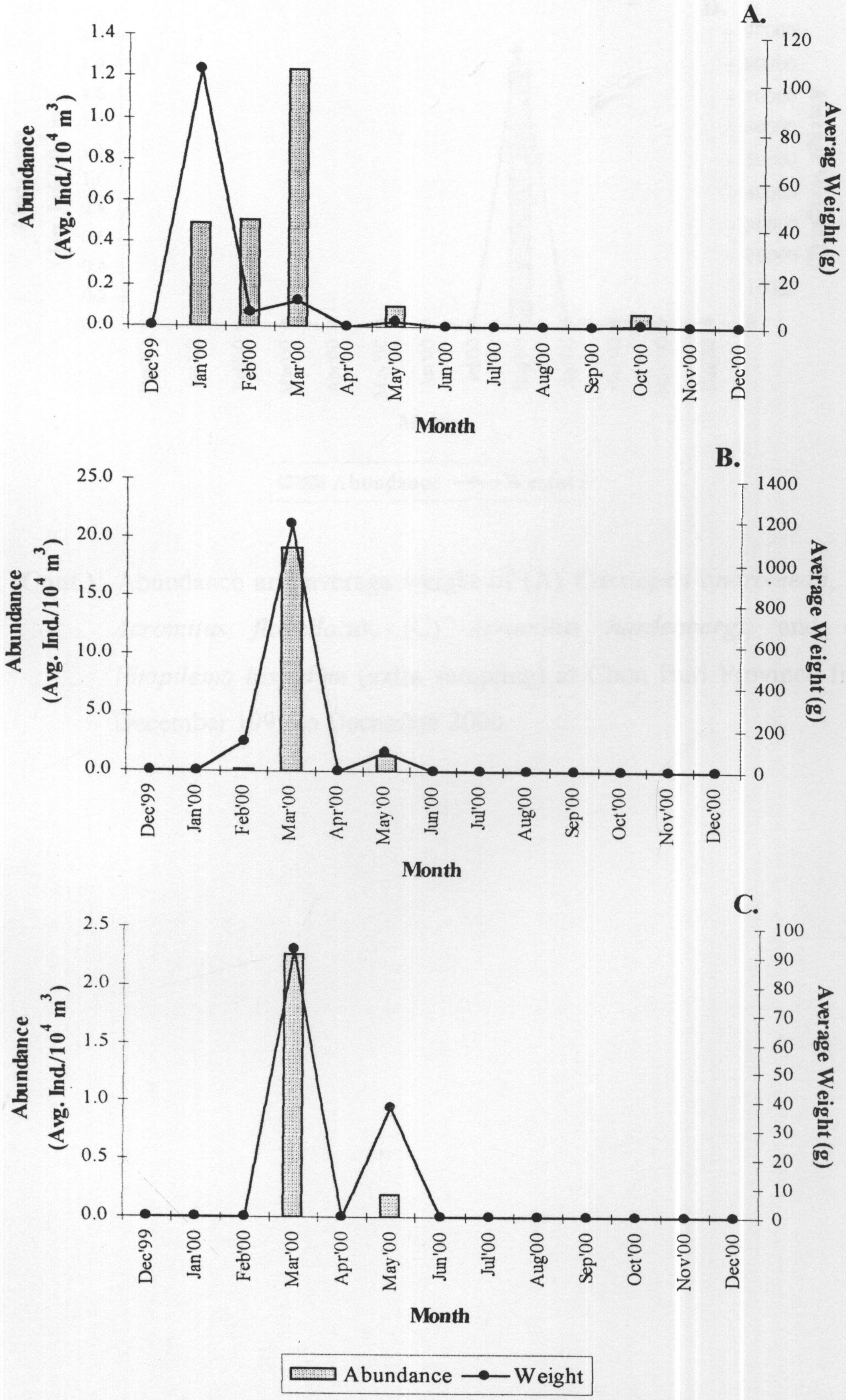


Figure 19. Abundance and average weight of (A) *Cassiopea andromeda*, (B) *Acromitus flagellatus*, (C) *Acromitus hardenbergi*, and (D) *Rhopilema hispidum* (extra sampling) at Chon Buri Province from December 1999 to December 2000.

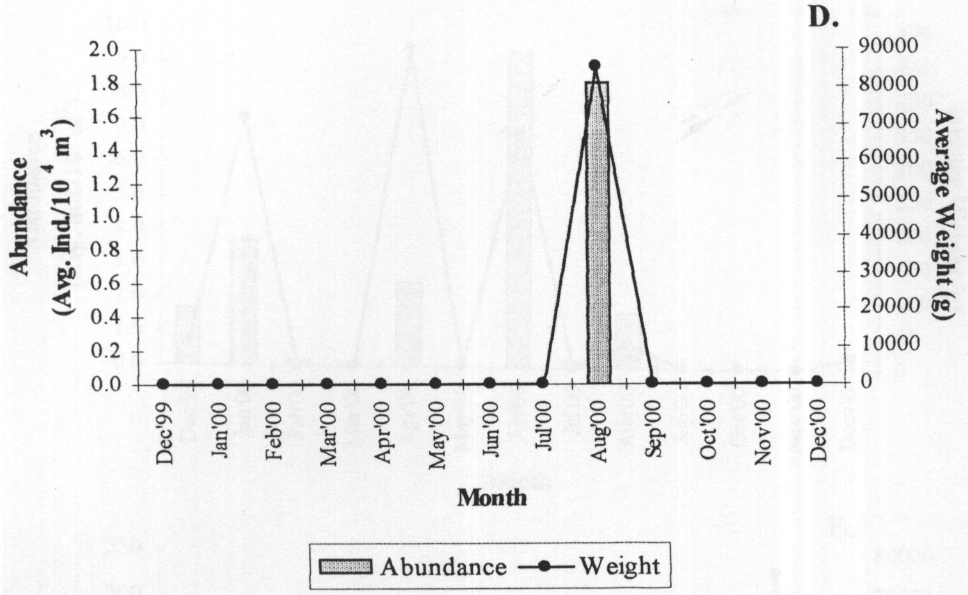


Figure 19. (Cont.) Abundance and average weight of (A) *Cassiopea andromeda*, (B) *Acromitus flagellatus*, (C) *Acromitus hardenbergi*, and (D) *Rhopilema hispidum* (extra sampling) at Chon Buri Province from December 1999 to December 2000.

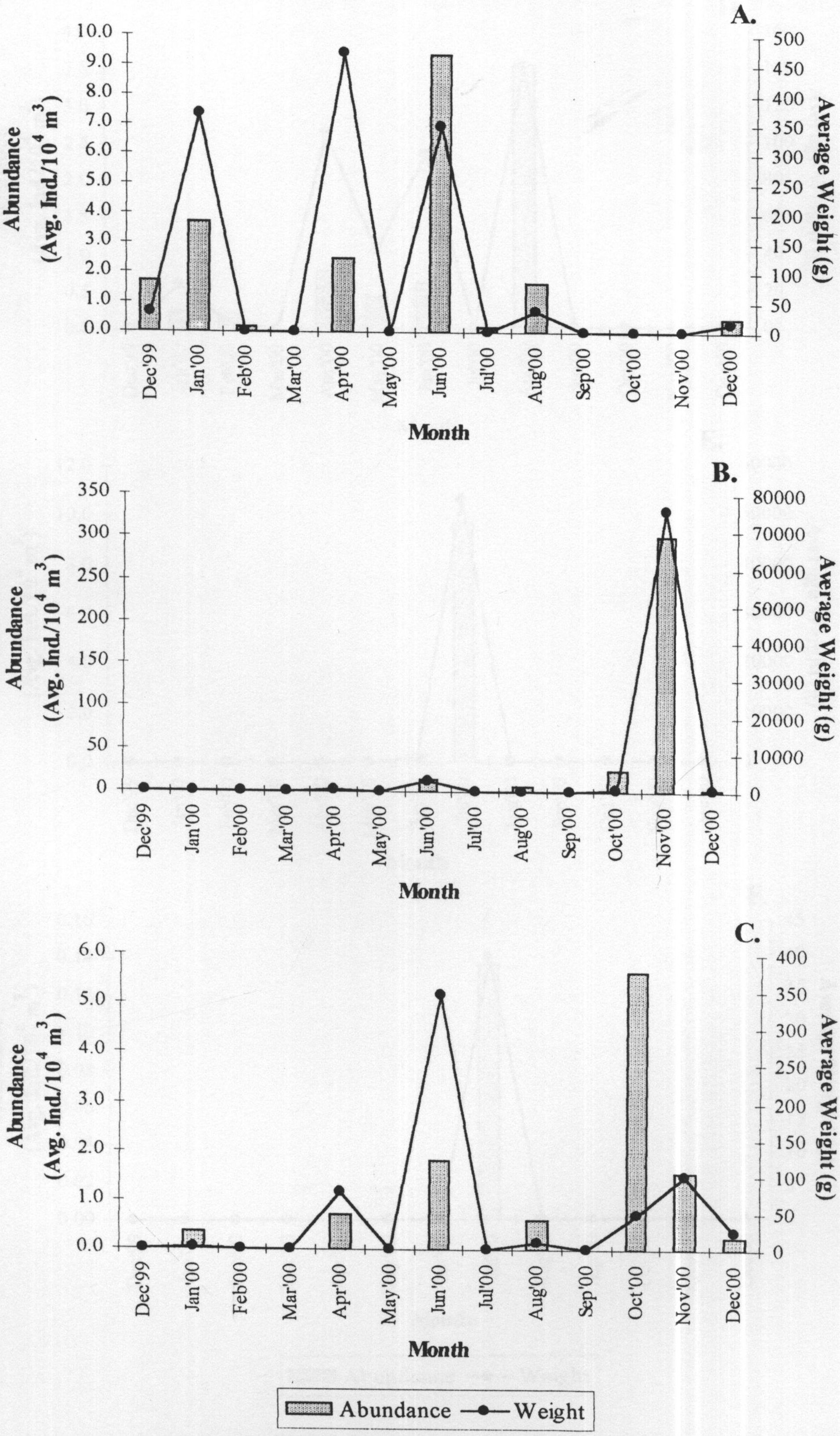


Figure 20. Abundance and average weight of (A) *Cassiopea andromeda*, (B) *Acromitus flagellatus*, (C) *Acromitus hardenbergi*, (D) *Catostylus townsendi*, (E) *Lobonema smithii*, and (F) *Rhopilema hispidum* at Phetchaburi Province from December 1999 to December 2000.

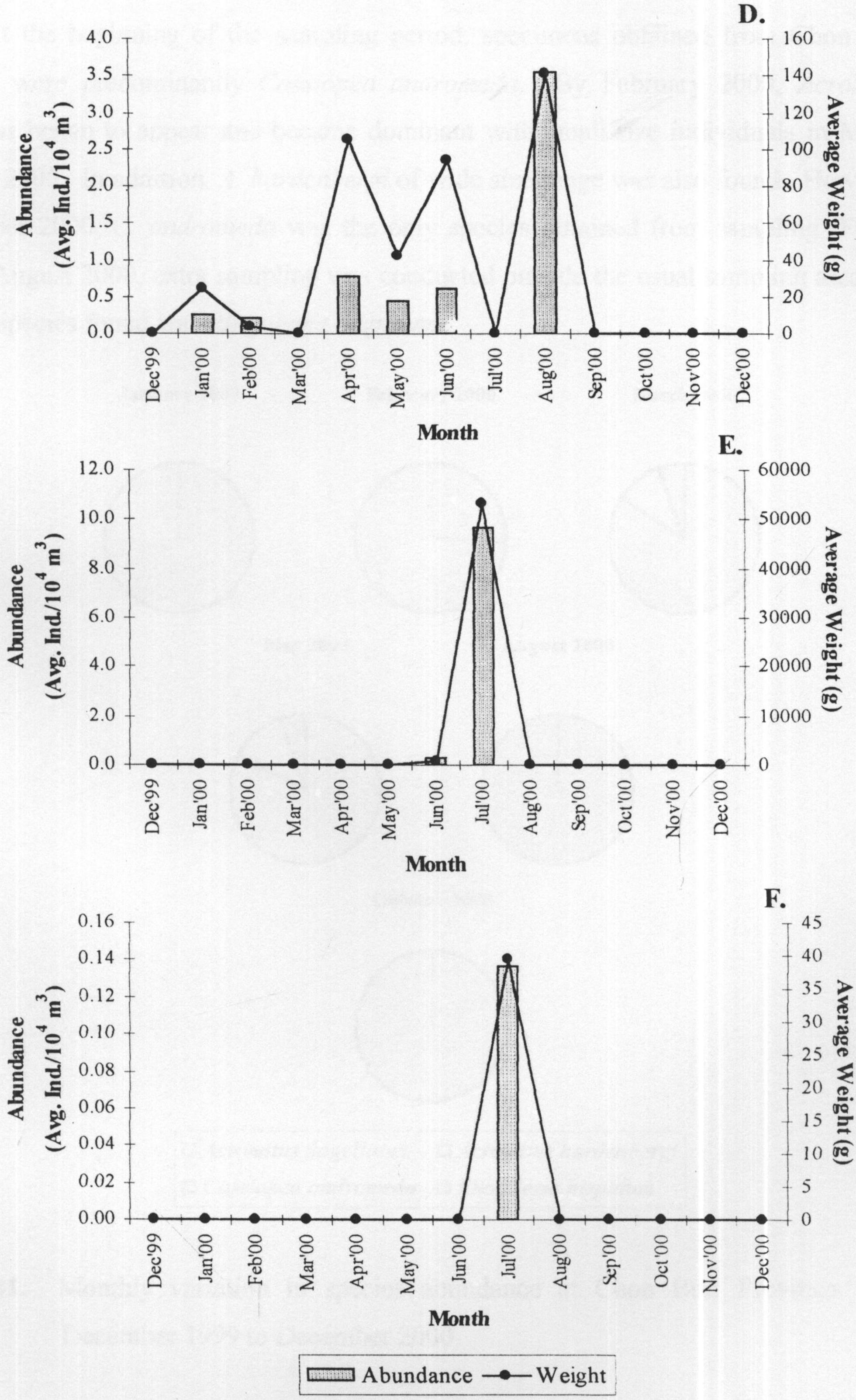


Figure 20. (Cont.) Abundance and average weight of (A) *Cassiopea andromeda*, (B) *Acromitus flagellatus*, (C) *Acromitus hardenbergi*, (D) *Catostylus townsendi*, (E) *Lobonema smithii*, and (F) *Rhopilema hispidum* at Phetchaburi Province from December 1999 to December 2000.

At the beginning of the sampling period, specimens obtained from Chon Buri Province were predominantly *Cassiopea andromeda*. By February 2000, *Acromitus flagellatus* began to appear and became dominant with small-size individuals in March and May 2000. In addition, *A. hardenbergi* of wide size range was also found. However, by October 2000, *C. andromeda* was the only species obtained from sampling (Figure 21). In August 2000, extra sampling was conducted outside the usual sampling area and the only species found was *Rhopilema hispidum*.

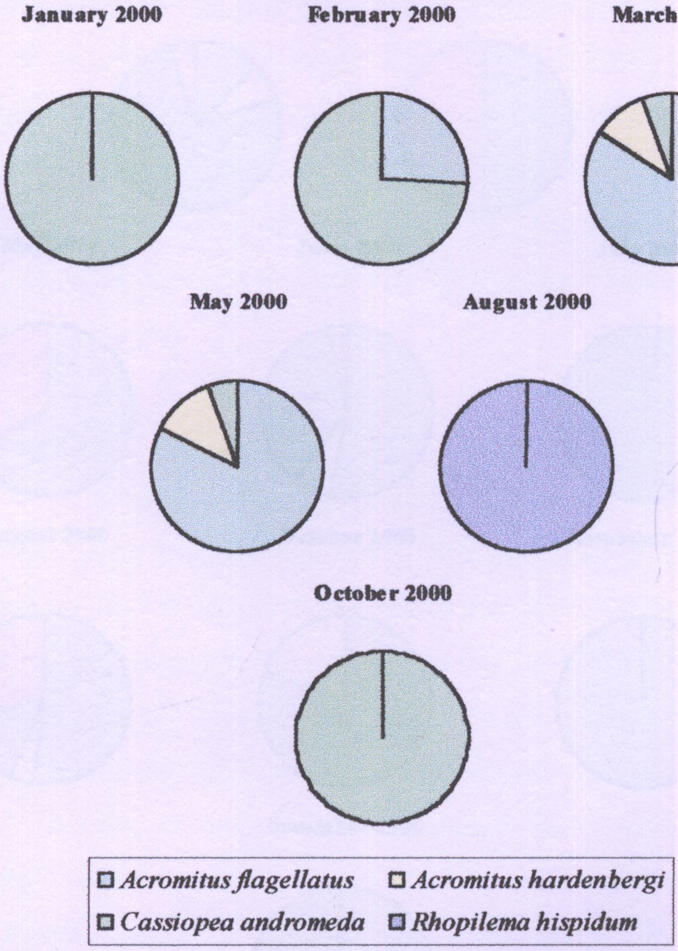


Figure 21. Monthly variation in species abundance at Chon Buri Province from December 1999 to December 2000.

At Phetchaburi Province, in December 1999, the only species obtained from sampling was *Cassiopea andromeda*, which was also the predominating species in January 2000. In addition to *C. andromeda*, *Acromitus flagellatus*, *A. hardenbergi*, and *Catostylus townsendi* were also found in January 2000, but not in February 2000. This is perhaps due to the different reproduction period, which will be discussed in the following section. In February 2000, *C. andromeda* and *C. townsendi* were found in equal abundance. The predominating species in April, May, and June 2000 was *A. flagellatus*. *Lobonema smithii* was first obtained in June 2000 and became the species dominated the jellyfish abundance in July 2000. *Acromitus flagellatus* was the predominating species for the rest of the sampling period; August, October, November, and December 2000 (Figure 22).

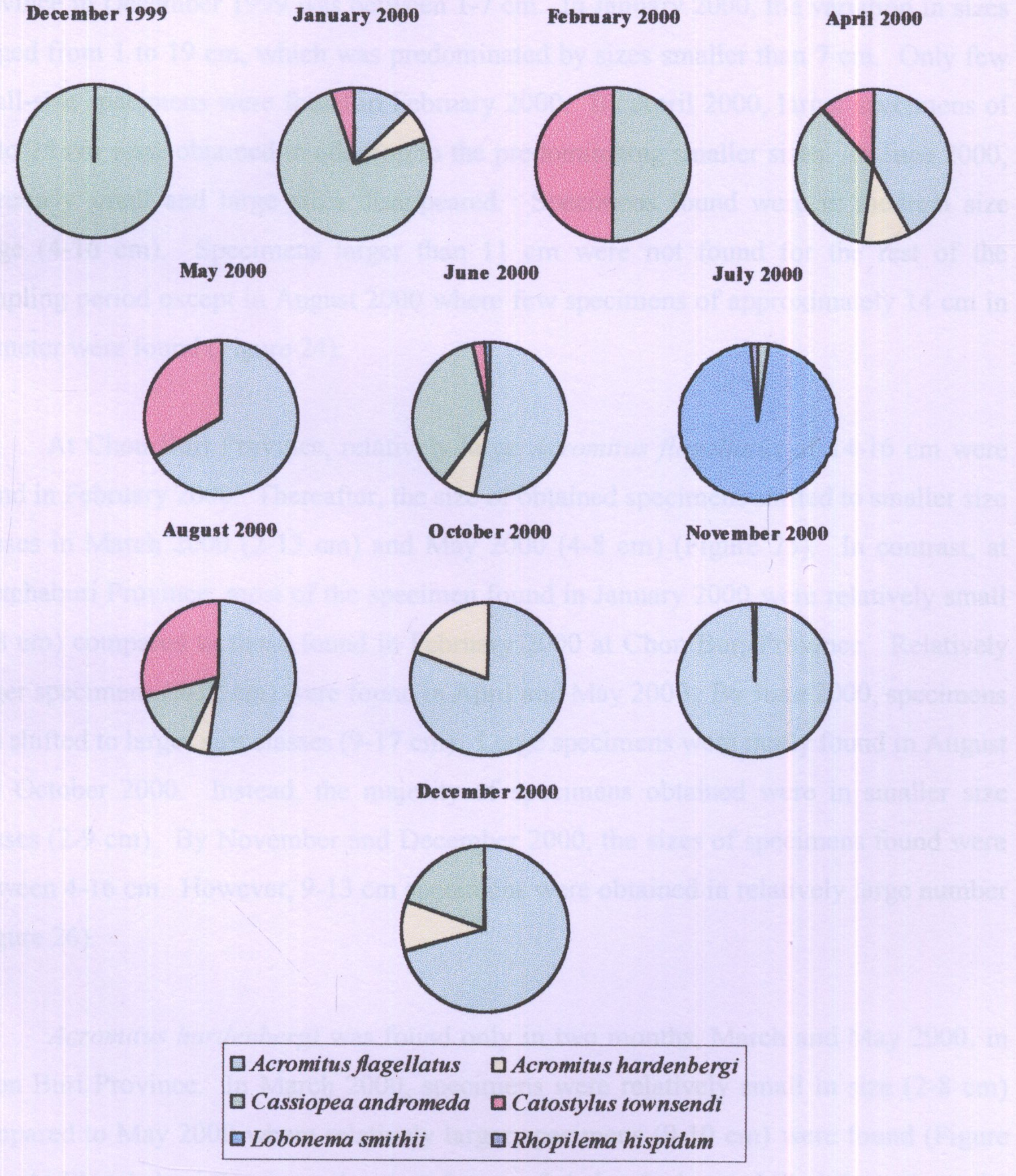


Figure 22. Monthly variation in species abundance at Phetchaburi Province from December 1999 to December 2000.

III. Size Distribution

In January 2000, at Chon Buri Province, *Cassiopea andromeda* specimens obtained were in various sizes ranging from 5 to 15 cm. Large specimens were not found in February 2000. Instead, relatively smaller sizes (1-7 cm) appeared in February and March 2000 (Figure 23). The majority of *C. andromeda* obtained from Phetchaburi Province in December 1999 was between 1-7 cm. In January 2000, the variation in sizes ranged from 1 to 19 cm, which was predominated by sizes smaller than 7 cm. Only few small-size specimens were found in February 2000. By April 2000, larger specimens of up to 25 cm were obtained in addition to the predominating smaller sizes. In June 2000, extremely small and large sizes disappeared. Specimens found were in medium size range (4-16 cm). Specimens larger than 11 cm were not found for the rest of the sampling period except in August 2000 where few specimens of approximately 14 cm in diameter were found (Figure 24).

At Chon Buri Province, relatively large *Acromitus flagellatus* of 14-16 cm were found in February 2000. Thereafter, the size of obtained specimens shifted to smaller size classes in March 2000 (2-13 cm) and May 2000 (4-8 cm) (Figure 25). In contrast, at Phetchaburi Province, most of the specimen found in January 2000 were relatively small (2-8 cm) compared to those found in February 2000 at Chon Buri Province. Relatively larger specimens (5-12 cm) were found in April and May 2000. By June 2000, specimens had shifted to larger size classes (9-17 cm). Large specimens were rarely found in August and October 2000. Instead, the majority of specimens obtained were in smaller size classes (2-9 cm). By November and December 2000, the sizes of specimens found were between 4-16 cm. However, 9-13 cm specimens were obtained in relatively large number (Figure 26).

Acromitus hardenbergi was found only in two months, March and May 2000, in Chon Buri Province. In March 2000, specimens were relatively small in size (2-8 cm) compared to May 2000 where relatively larger specimens (9-10 cm) were found (Figure 27). At Phetchaburi Province, the size classes of *A. hardenbergi* shifted throughout the sampling period. In January 2000, obtained specimens were relatively small (2-4 cm). The size classes increased to 7-11 cm in April and to relatively larger sizes (9-14 cm) in

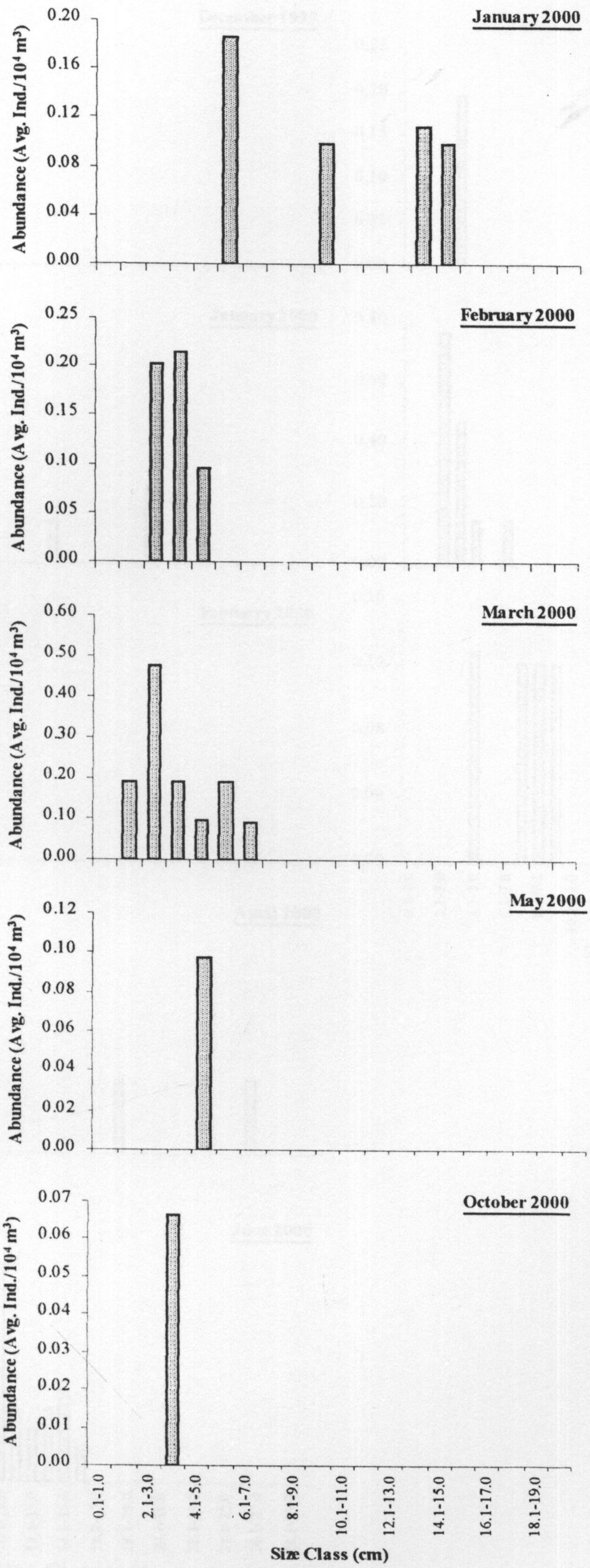


Figure 23. Size class distribution for *Cassiopea andromeda* at Chon Buri Province from December 1999 to December 2000.

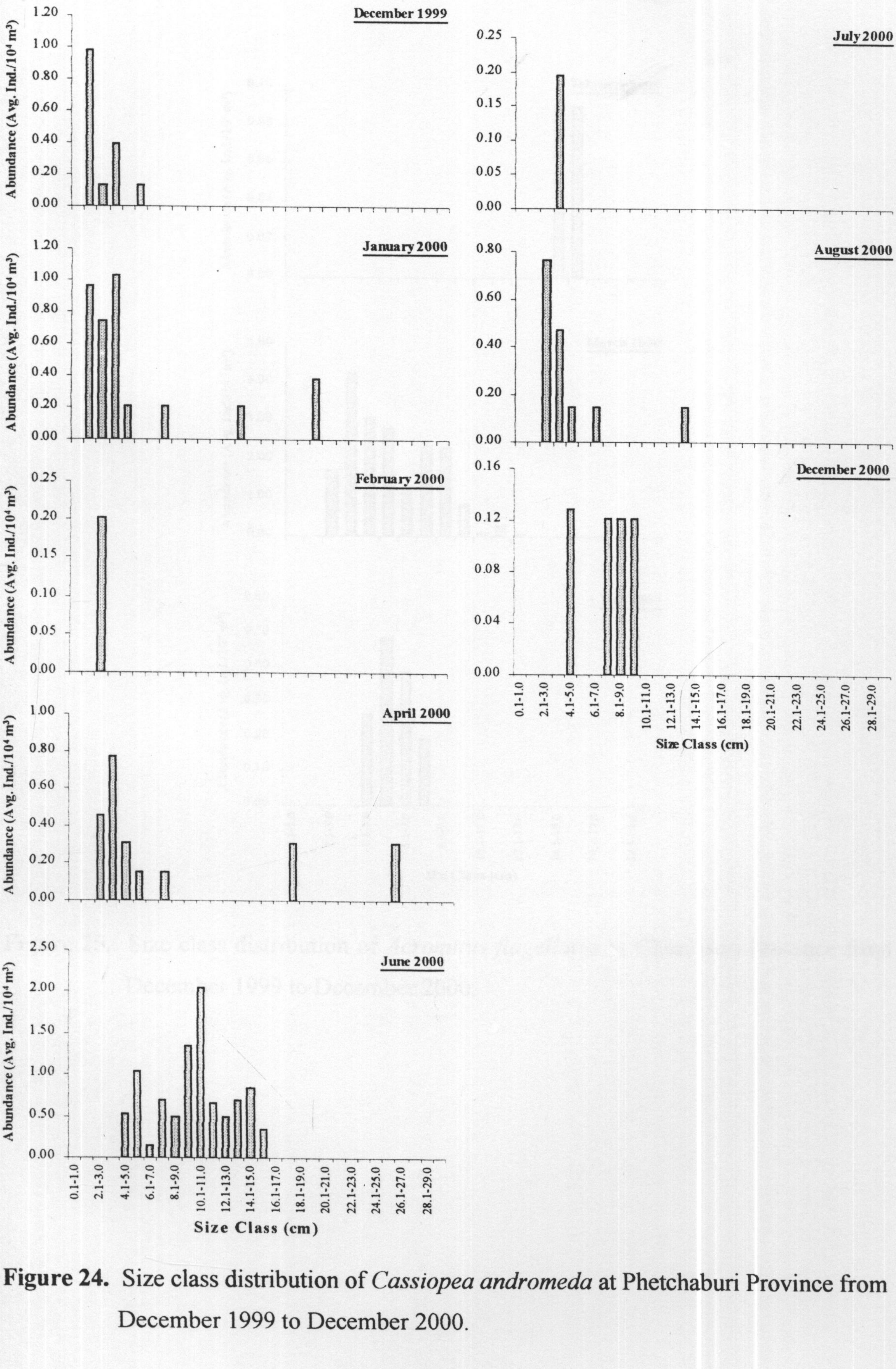


Figure 24. Size class distribution of *Cassiopea andromeda* at Phetchaburi Province from December 1999 to December 2000.

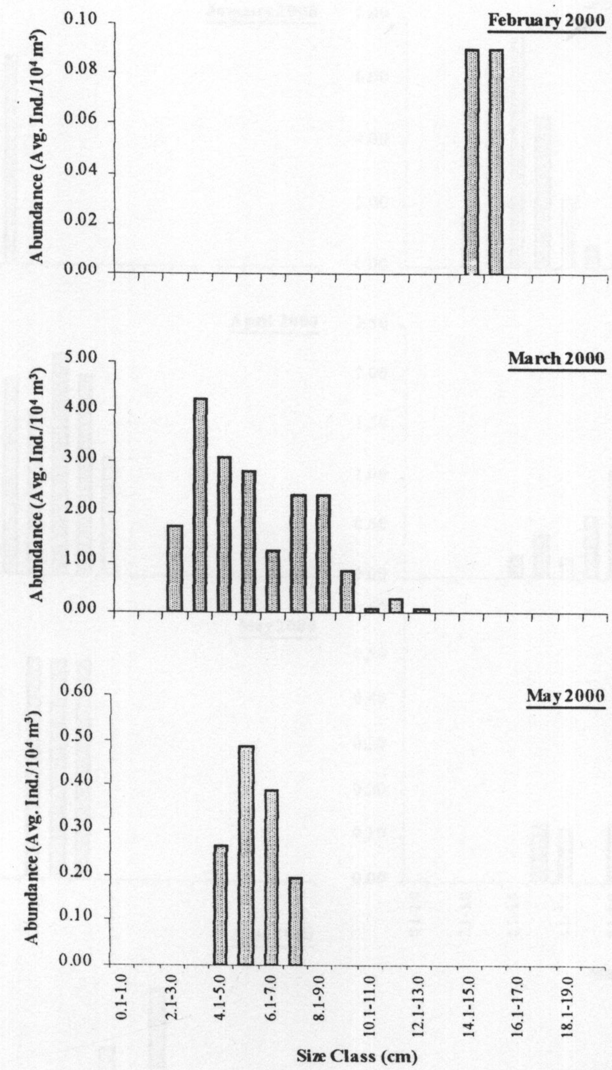


Figure 25. Size class distribution of *Acromitus flagellatus* at Chon Buri Province from December 1999 to December 2000.

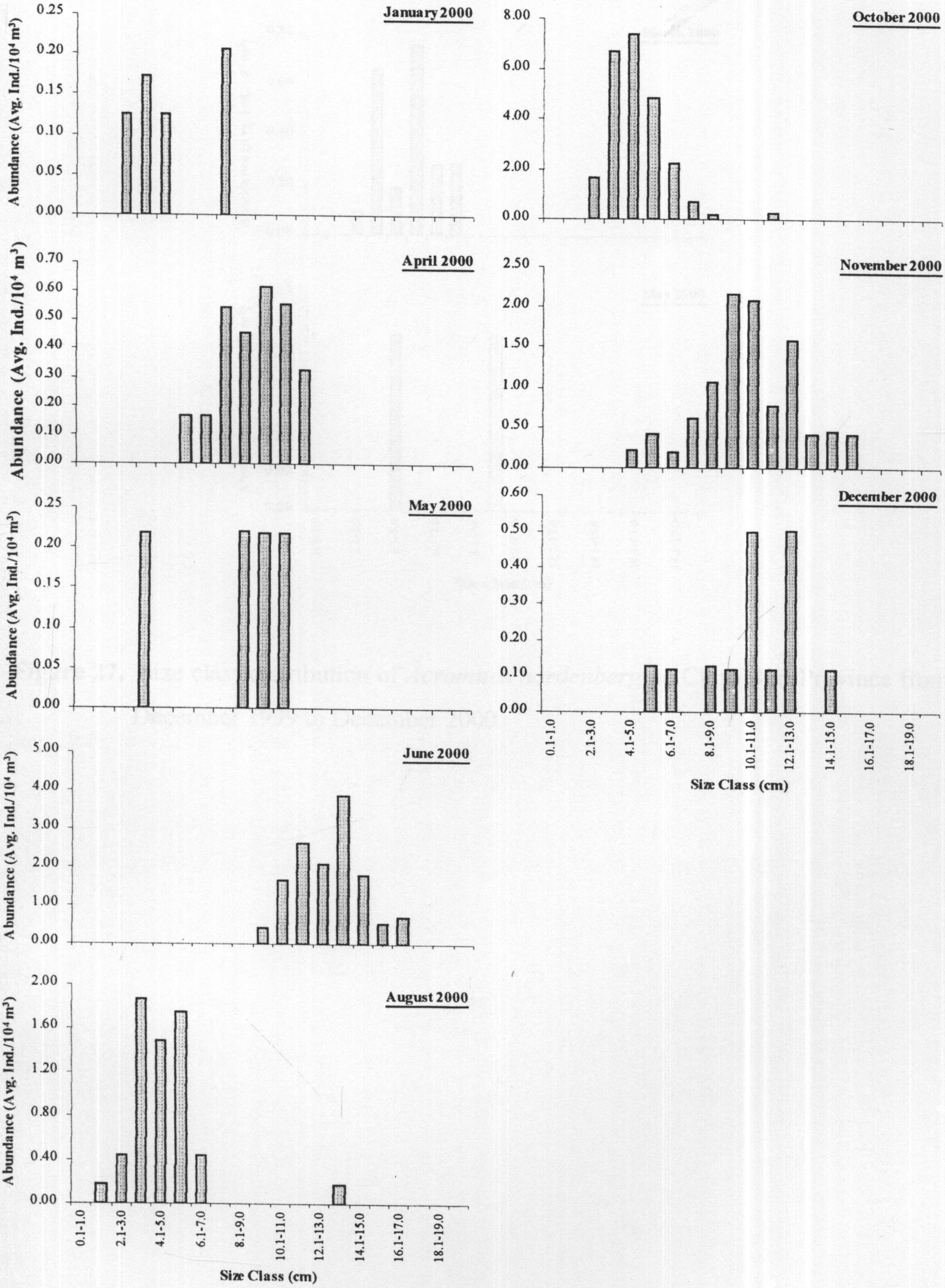


Figure 26. Size class distribution of *Acromitus flagellatus* at Phetchaburi Province from December 1999 to December 2000.

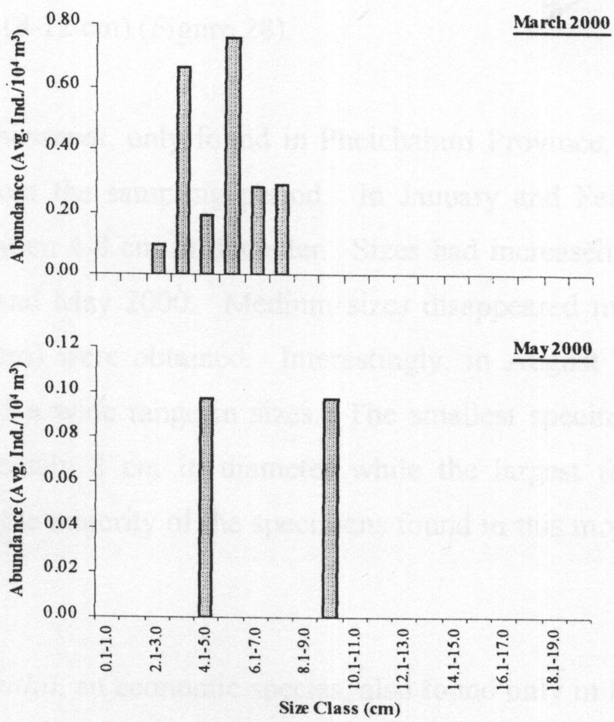


Figure 27. Size class distribution of *Acromitus hardenbergi* at Chon Buri Province from December 1999 to December 2000.

June 2000. Smaller specimens (2-7 cm) were obtained again in August and October 2000. By November and December 2000, there was an increase in diameter of specimens to larger size classes (8-12 cm) (Figure 28).

Catostylus townsendi, only found in Phetchaburi Province, established a shift in size classes throughout the sampling period. In January and February 2000, sizes of specimens were between 4-8 cm in diameter. Sizes had increased to larger size classes (7-12 cm) in April and May 2000. Medium sizes disappeared in June 2000 and only larger sizes (10-12 cm) were obtained. Interestingly, in August 2000, specimens that were found displayed a wide range in sizes. The smallest specimens found in August 2000 were approximately 2 cm in diameter while the largest found were 10 cm in diameter. However, the majority of the specimens found in this mouth were between 4-6 cm (Figure 29).

Lobonema smithii, an economic species, also found only in Phetchaburi Province, were obtained only in June and July 2000. Within these two months, specimens that were found shifted from smaller sizes (24 cm and 32 cm) to relatively larger sizes (28-53 cm) by July 2000, which coincided with jellyfish fishery season. The majority of the specimens found were between 36-45 cm in diameter (Figure 30).

At Chon Buri Province, *Rhopilema hispidum* was not found within the regular sampling area. However, an additional sampling was conducted south of the regular sampling area in August 2000 and specimens were obtained. *R. hispidum* that were obtained from this area ranged from 16.1 cm to 54 cm in diameter. Specimens that were 30 cm in diameter were found in highest abundant while the second most abundant were specimens with bell diameter of 39 cm (Figure 31). At Phetchaburi Province, *R. hispidum* were found only in July 2000 and specimens were 15 cm in diameter (Figure 32).

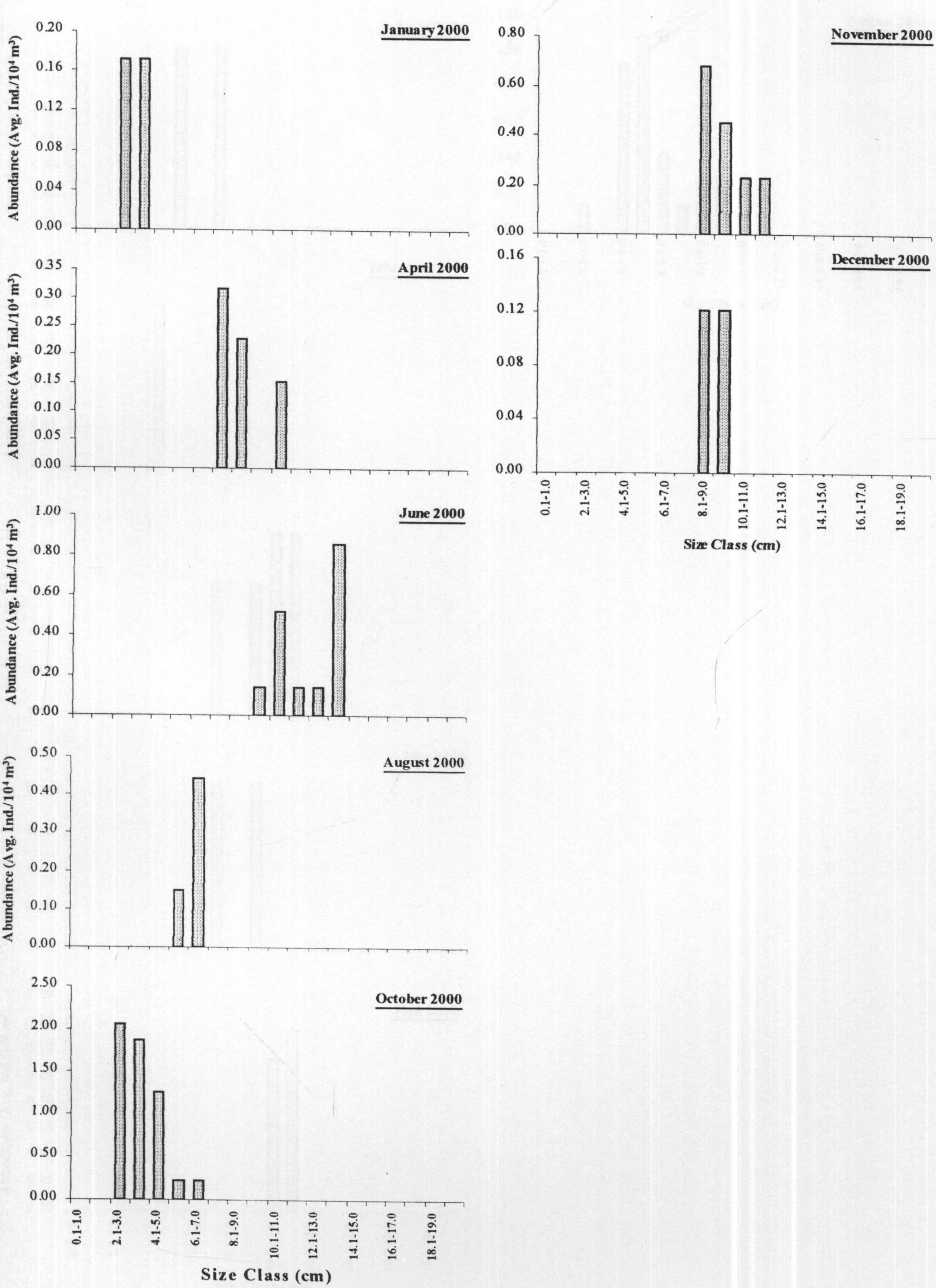


Figure 28. Size class distribution of *Acromitus hardenbergi* at Phetchaburi Province from December 1999 to December 2000.

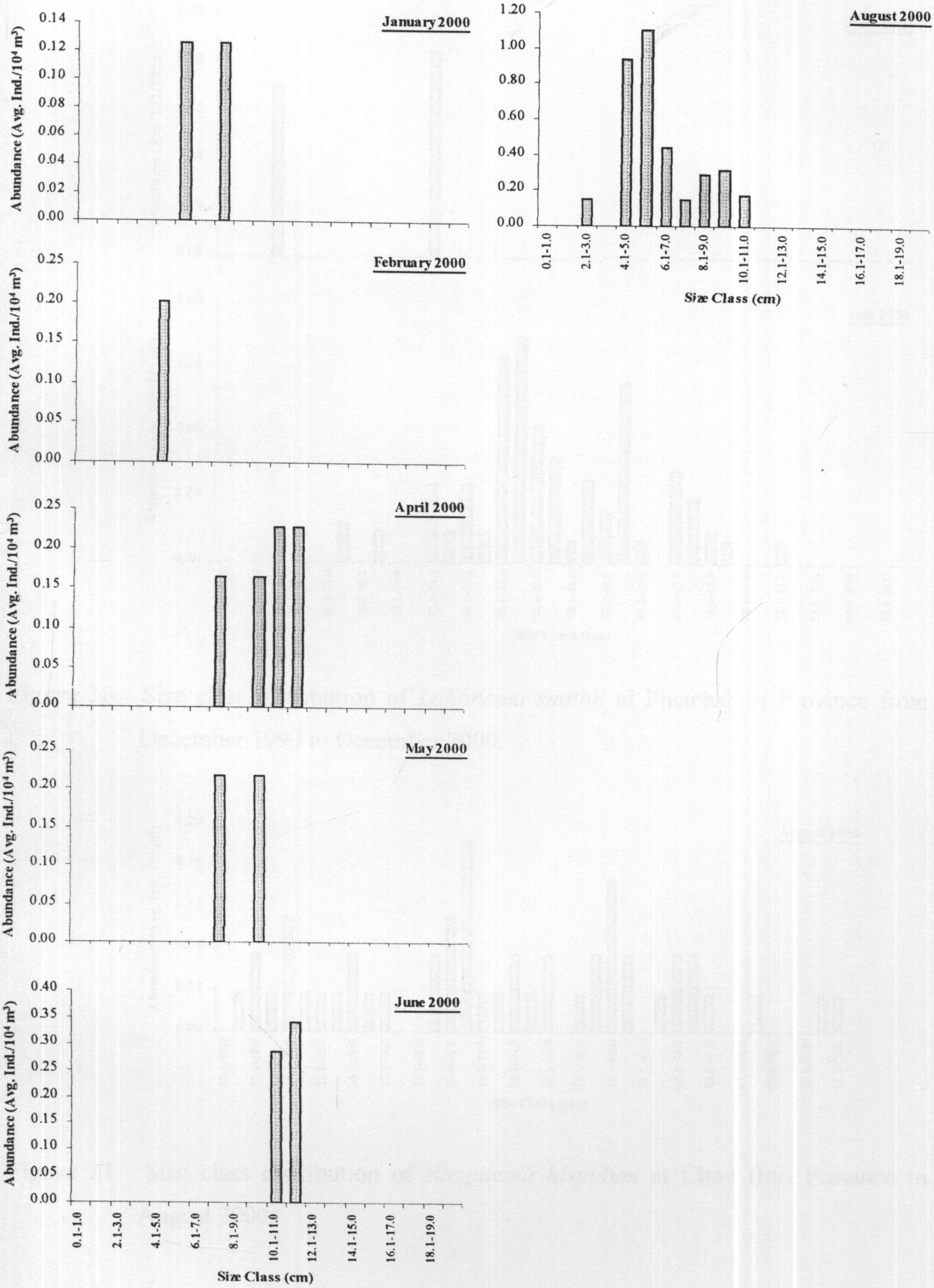


Figure 29. Size class distribution of *Catostylus townsendi* at Phetchaburi Province from December 1999 to December 2000.

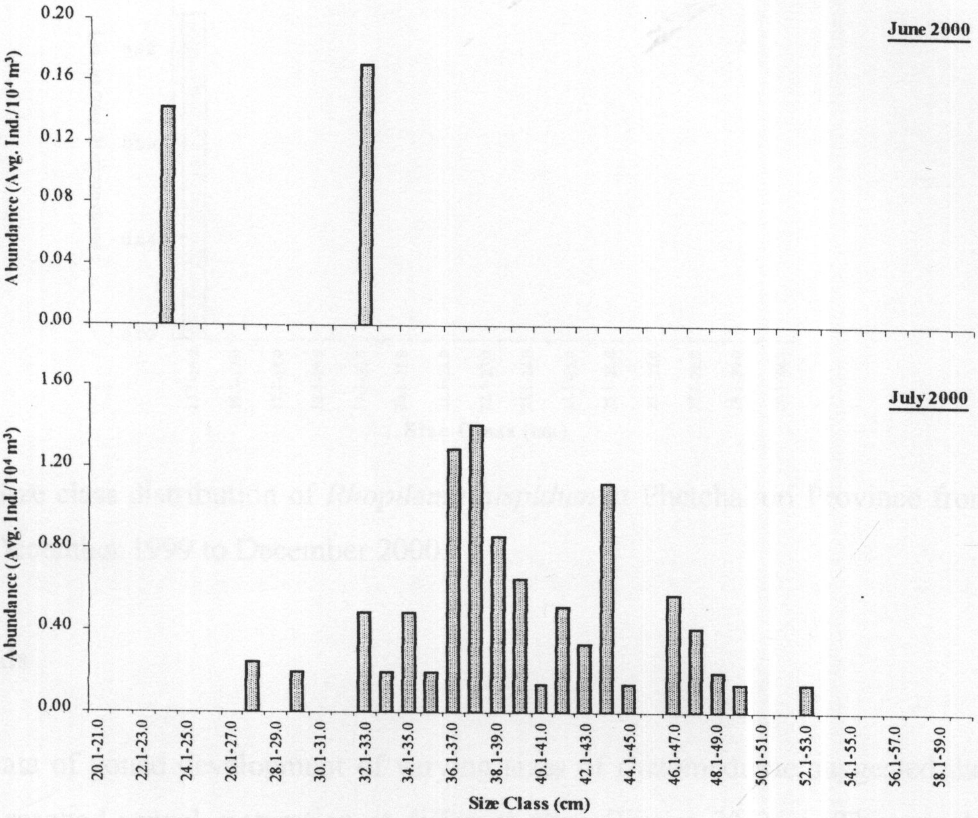


Figure 30. Size class distribution of *Lobonema smithii* at Phetchaburi Province from December 1999 to December 2000.

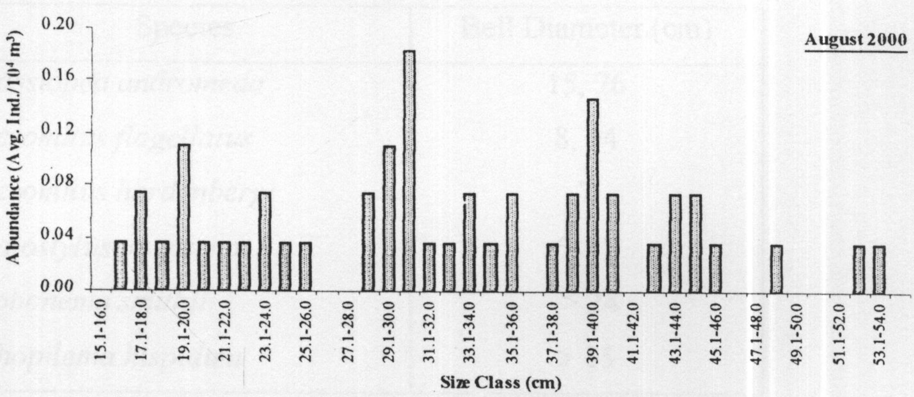


Figure 31. Size class distribution of *Rhopilema hispidum* at Chon Buri Province in August 2000.

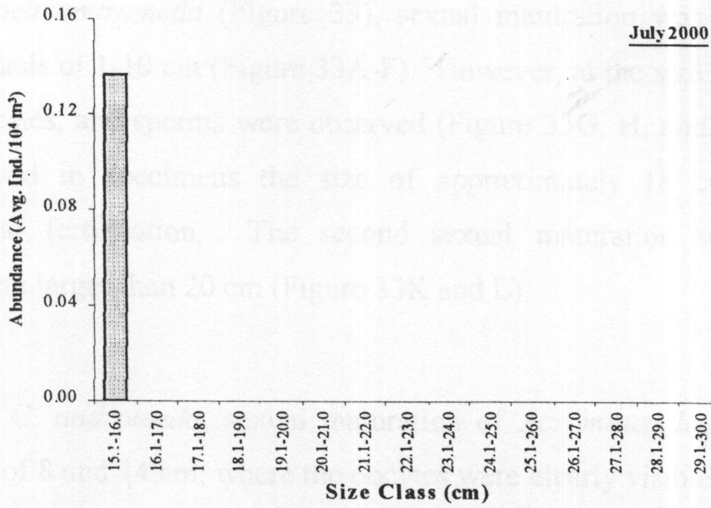


Figure 32. Size class distribution of *Rhopilema hispidum* at Phetchaburi Province from December 1999 to December 2000.

IV. Gonads

The data of gonad development of varying sizes of rhizomedusae suggested that each species reached sexual maturation at different sizes (Figure 31-36). This can be summarized as follows (Table 9):

Table 9. Sexual maturation stages of 6 species of rhizomedusae obtained from this study.

Species	Bell Diameter (cm)
Cassiopea andromeda	15, 26
Acromitus flagellatus	8, 14
Acromitus hardenbergi	7
Catostylus townsendi	6, 12
Lobonema smithii	> 24
Rhopilema hispidum	> 15

In *Cassiopea andromeda* (Figure 33), sexual maturation was not observed in small-size individuals of 1-10 cm (Figure 33A-F). However, at the size of approximately 15 cm, oocytes, testes, and sperms were observed (Figure 33G, H, and I). The blastula stage was observed in specimens the size of approximately 18 cm (Figure 33J), suggesting internal fertilization. The second sexual maturation was observed in specimens that were larger than 20 cm (Figure 33K and L).

Similar to *C. andromeda*, sexual maturation of *Acromitus flagellatus* occurred twice, at the sizes of 8 and 14 cm, where the oocytes were clearly visible (Figure 34E and K). In contrast, the oocytes of *Acromitus hardenbergi* were visible at the size of approximately 7 cm, indicating sexual maturation (Figure 35D).

In *Catostylus townsendi*, first sexual maturation was observed at the size of 6 cm (Figure 36A). Thereafter, the blastula stage was observed indicating that the fertilization occurred internally (Figure 36B, C, and D). The second sexual maturation was observed in samples obtained from specimens larger than 12 cm in diameter (Figure 36E).

Since specimens of *Lobonema smithii* and *Rhopilema hispidum* obtained from the field were large specimens, sexual maturation was observed in the smallest size obtained. In *L. smithii* and *R. hispidum*, oocytes were observed in specimens larger than 24 cm and 15 cm in diameter, respectively (Figure 37 and 38).

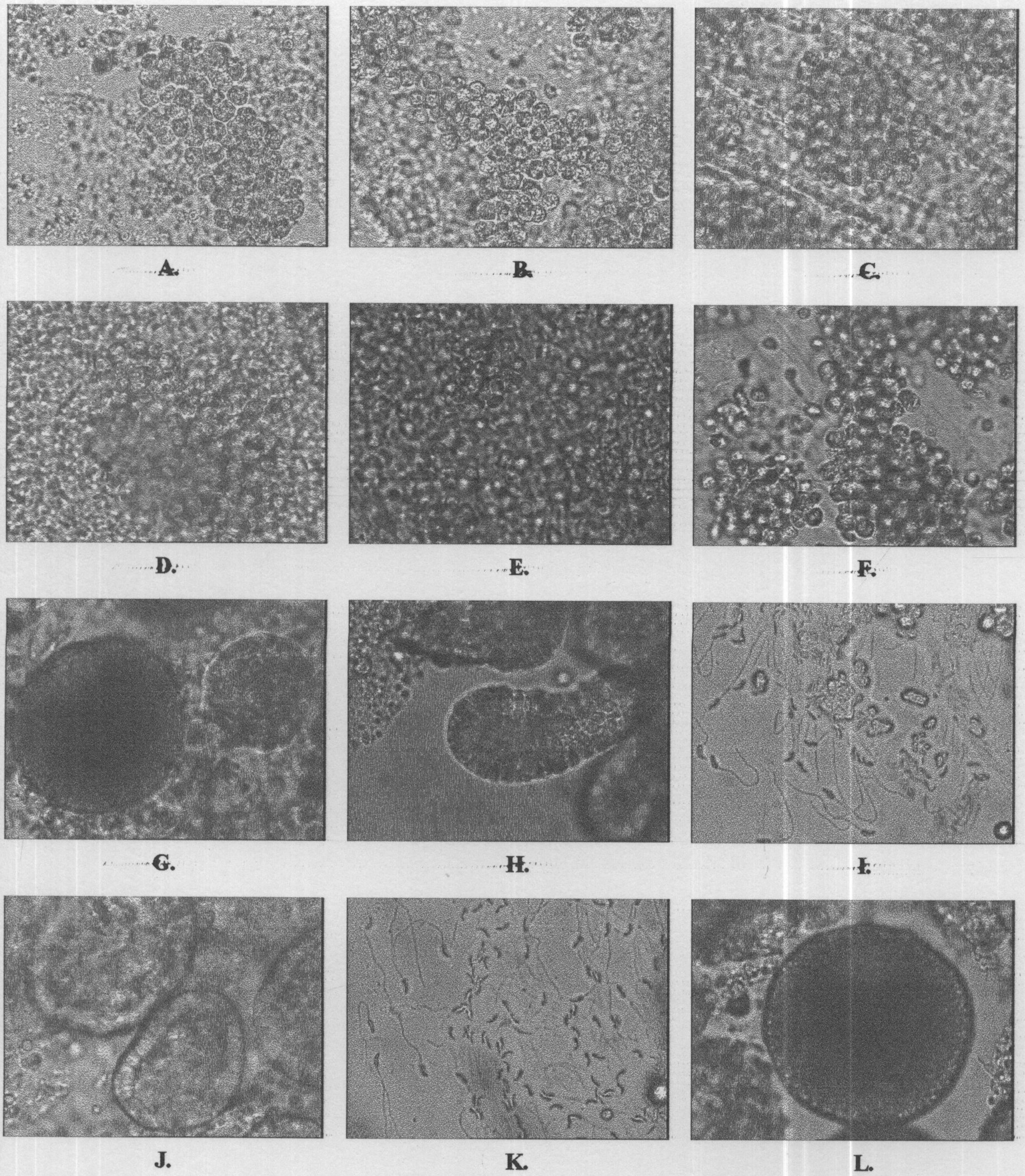


Figure 33. Gonad development of *Cassiopea andromeda*; (A) 1.5 cm, (B) 3 cm, (C) 4 cm, (D) 7 cm, (E) 8.5 cm, (F) 10.5 cm, (G) 15 cm, (H) 15 cm (spermatocytes), (I) 15 cm (sperms), (J) 18 cm, (K) 21 cm (sperms), and (L) 26 cm in diameter.

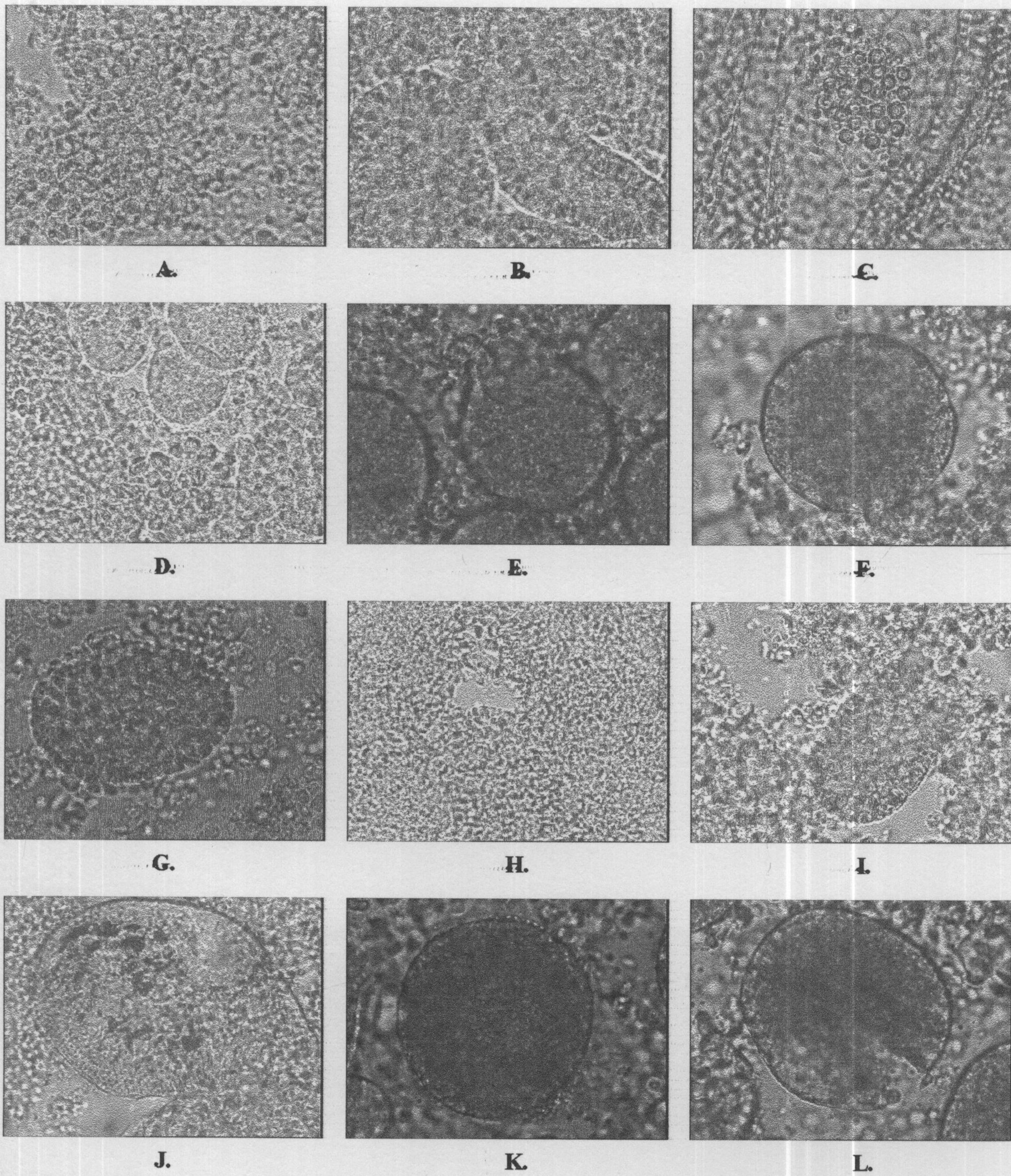


Figure 34. Gonad development of *Acromitus flagellatus*; (A) 2 cm, (B) 3.5 cm, (C) 4.5 cm, (D) 6.5 cm, (E) 8 cm, (F) 9 cm, (G) 9 cm, (H) 10 cm, (I) 10.5 cm, (J) 12.5 cm, (K) 14 cm, and (L) 15.5 cm in diameter.

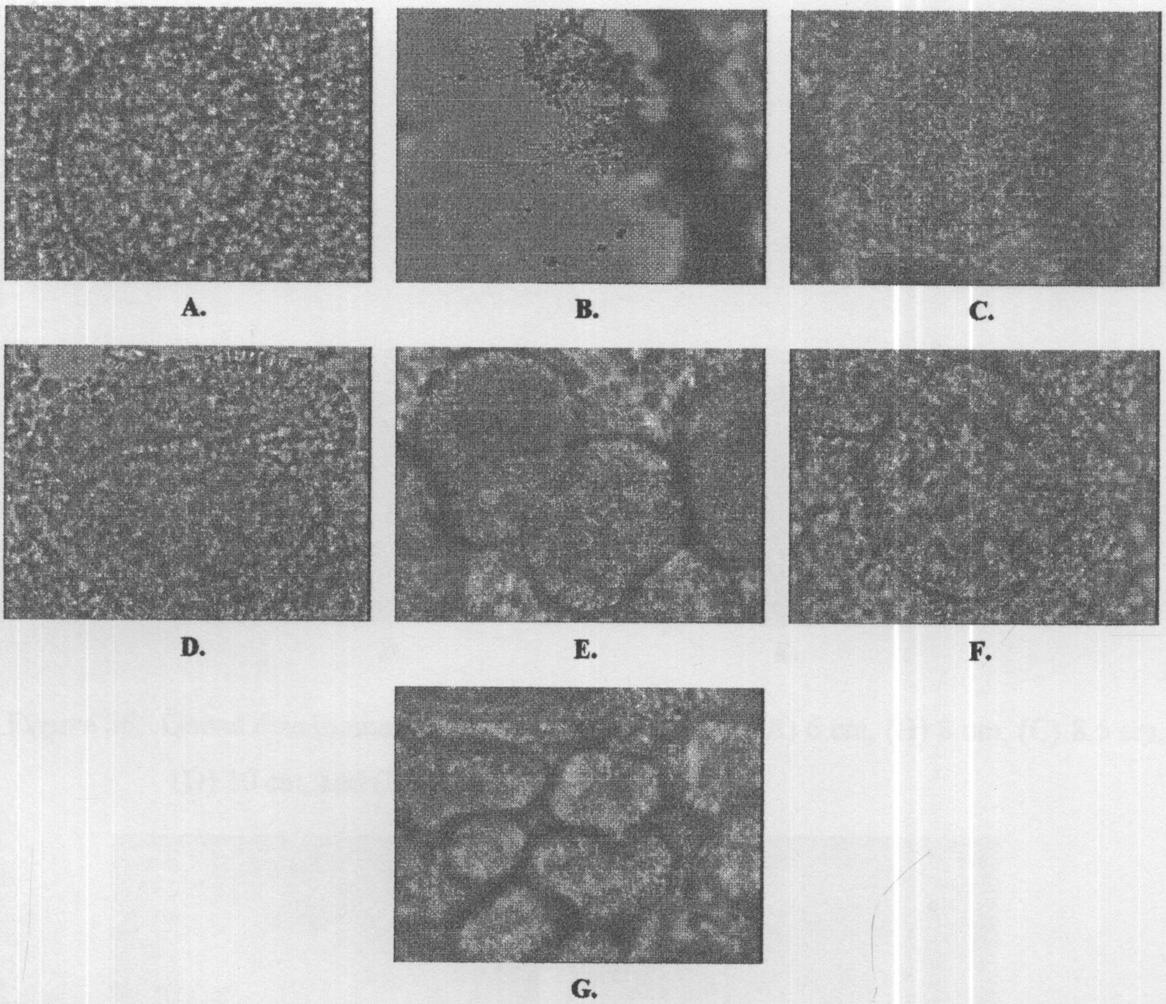
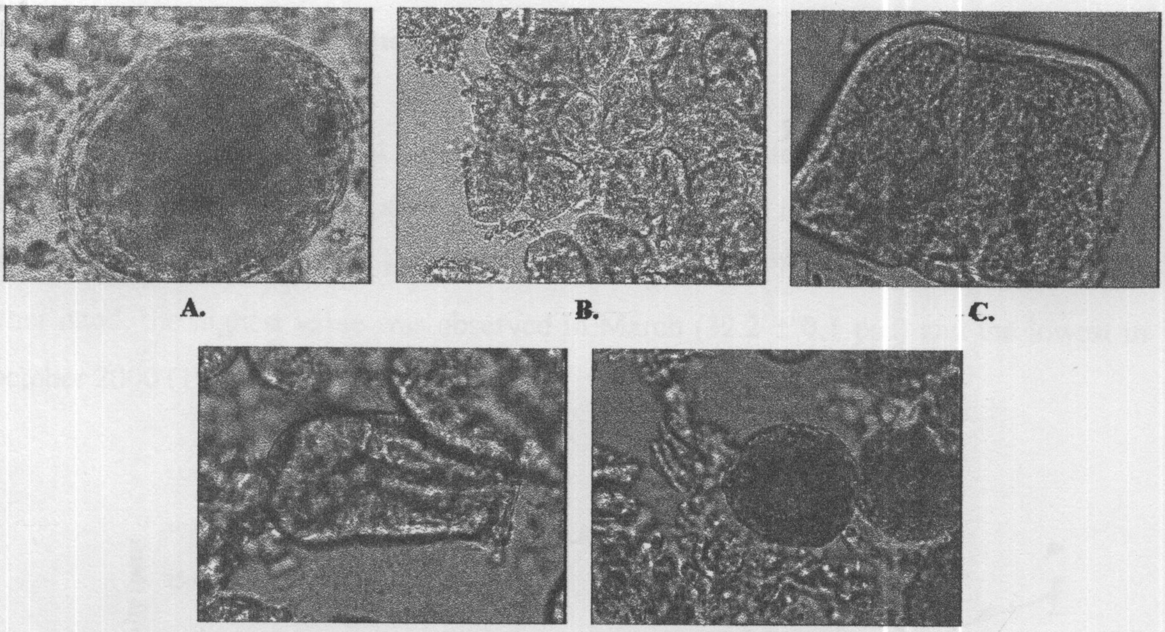


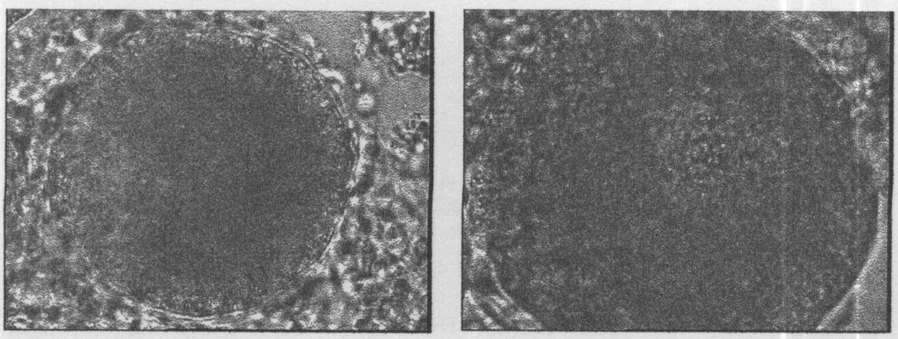
Figure 35. Gonad development of *Acromitus hardenbergi*; (A) 4.5 cm, (B) 6.5 cm (sperms), (C) 6.5 cm, (D) 7.5 cm, (E) 8.5 cm, (F) 10 cm, and (G) 11 cm in diameter.



A. B. C.

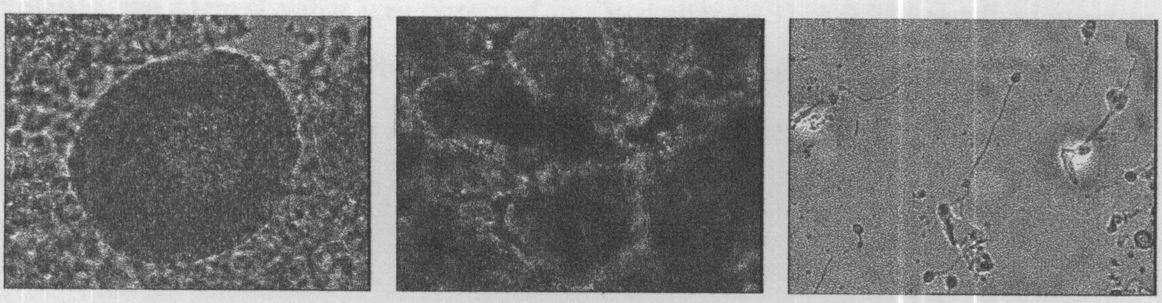
D. E.

Figure 36. Gonad development of *Catostylus townsendi*; (A) 6 cm, (B) 8 cm, (C) 8.5 cm, (D) 10 cm, and (E) 12.5 cm in diameter.



A. B.

Figure 37. Gonad development of *Lobonema smithii*; (A) 24 cm and (B) 33 cm in diameter.



A. B. C.

Figure 38. Gonad development of *Rhopilema hispidum*; (A) 15.5 cm, (B) 37 cm, and (C) 46 cm (sperms) in diameter.

V. Environmental Parameters

The average salinity at Chon Buri Province fluctuated severely through out the sampling period. The highest average salinity was observed in February (31.5 ± 0.1 psu) and the lowest was observed in June (0.3 ± 0.0 psu). At Phetchaburi Province, on the other hand, the highest value was observed in March (32.2 ± 0.1 psu) and the lowest in October 2000 (19.9 ± 0.9 psu) (Figure 39).

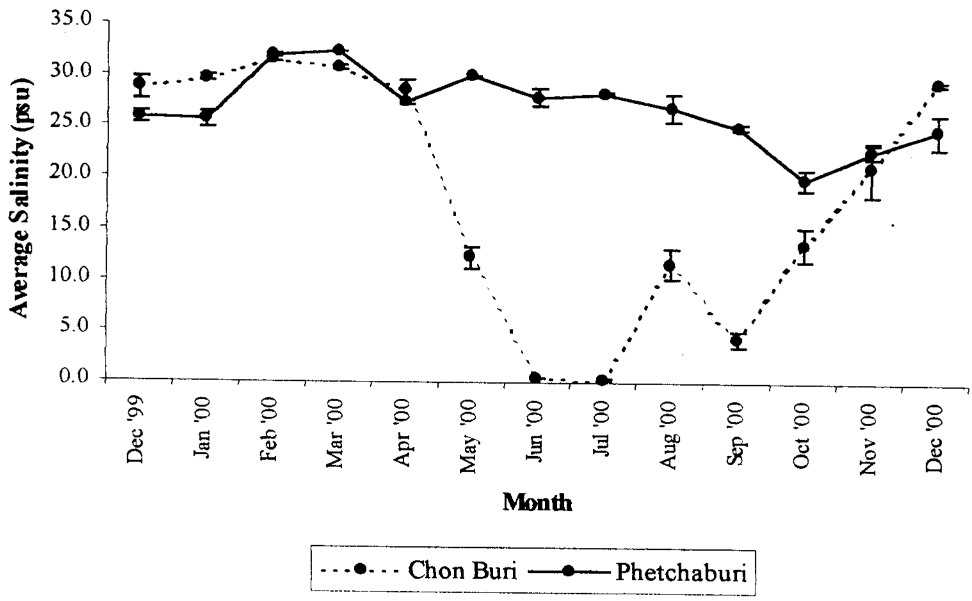


Figure 39. Average salinity at Chon Buri and Phetchaburi Province from December 1999 to December 2000.

The average pH values fluctuated through out the sampling period. At Chon Buri Province, the highest value was observed in December (8.31 ± 0.08) and the lowest in June 2000 (6.96 ± 0.08). At Phetchaburi Province, the highest value was observed in July (8.59 ± 0.08) and the lowest value was observed in December 2000 (7.52 ± 0.09) (Figure 40).

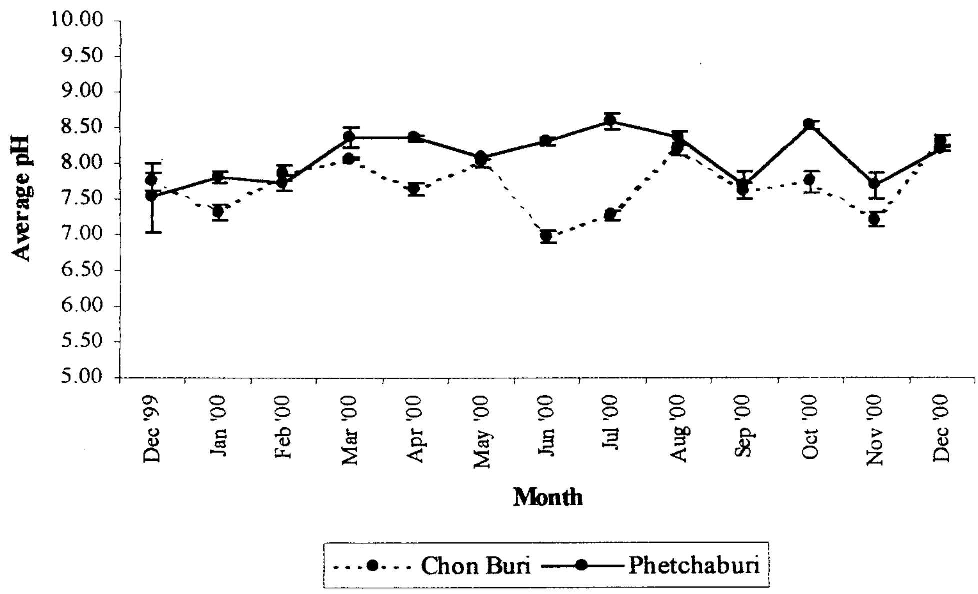


Figure 40. Average pH at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

Evidently, the values for dissolved oxygen concentration varied throughout the sampling period. For both Chon Buri and Phetchaburi Provinces, the lowest values were observed in September. These values are 2.70 ± 0.15 mg/l for Chon Buri Province and 2.62 ± 0.18 mg/l for Phetchaburi Province (Figure 41). Comparatively, average temperature at both locations did not vary much throughout the sampling period. The lowest values were observed in the winter, December 2000, for both locations. The highest values were observed in June for Chon Buri Province (31.6 ± 0.1 °C) and in August for Phetchaburi Province (31.6 ± 0.4 °C) (Figure 42).

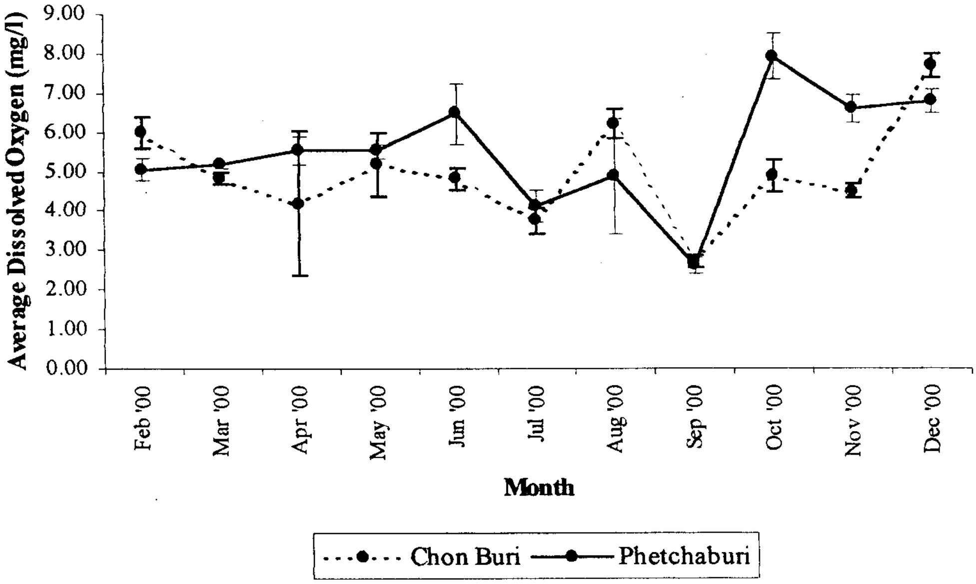


Figure 41. Average dissolved oxygen content at Chon Buri and Phetchaburi Provinces from February 2000 to December 2000.

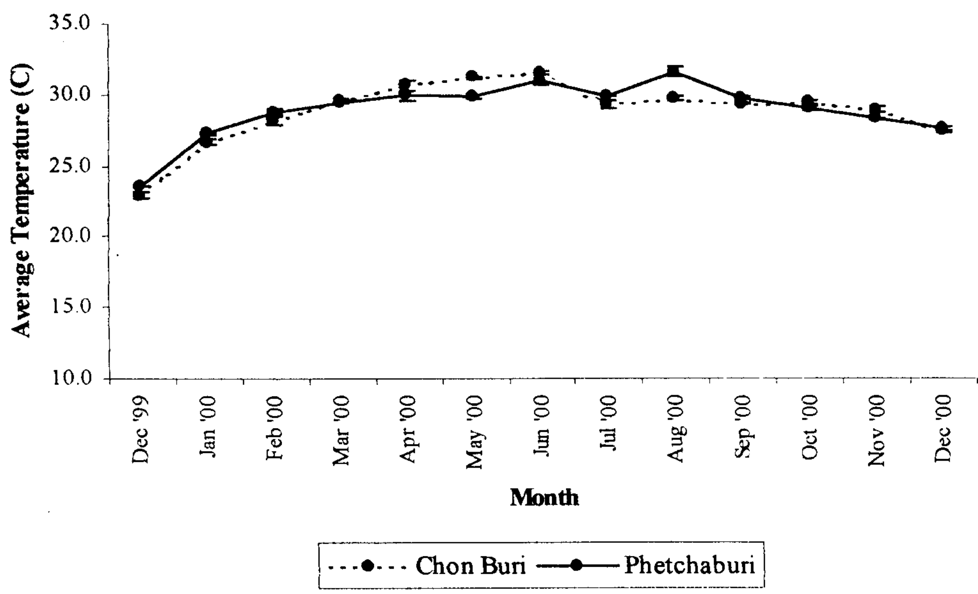


Figure 42. Average temperature at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

At Chon Buri Province, the highest zooplankton concentration occurred during the months of November 2000 (716,569 individuals · 10^2 m^{-3}), where the major fraction of zooplankton were copepods, while the lowest concentration was observed October 2000 (71,703 individuals · 10^2 m^{-3}) (Figure 43A). In comparison, at Phetchaburi Province, the highest concentration was observed during October 2000 (2,734,438 individuals ·10^2 m^{-3}), where the majority of the zooplankton were decapod larvae and copepods. The lowest concentration was observed during September 2000 (80,781 individuals · 10^2 m^{-3}) (Figure 43B).

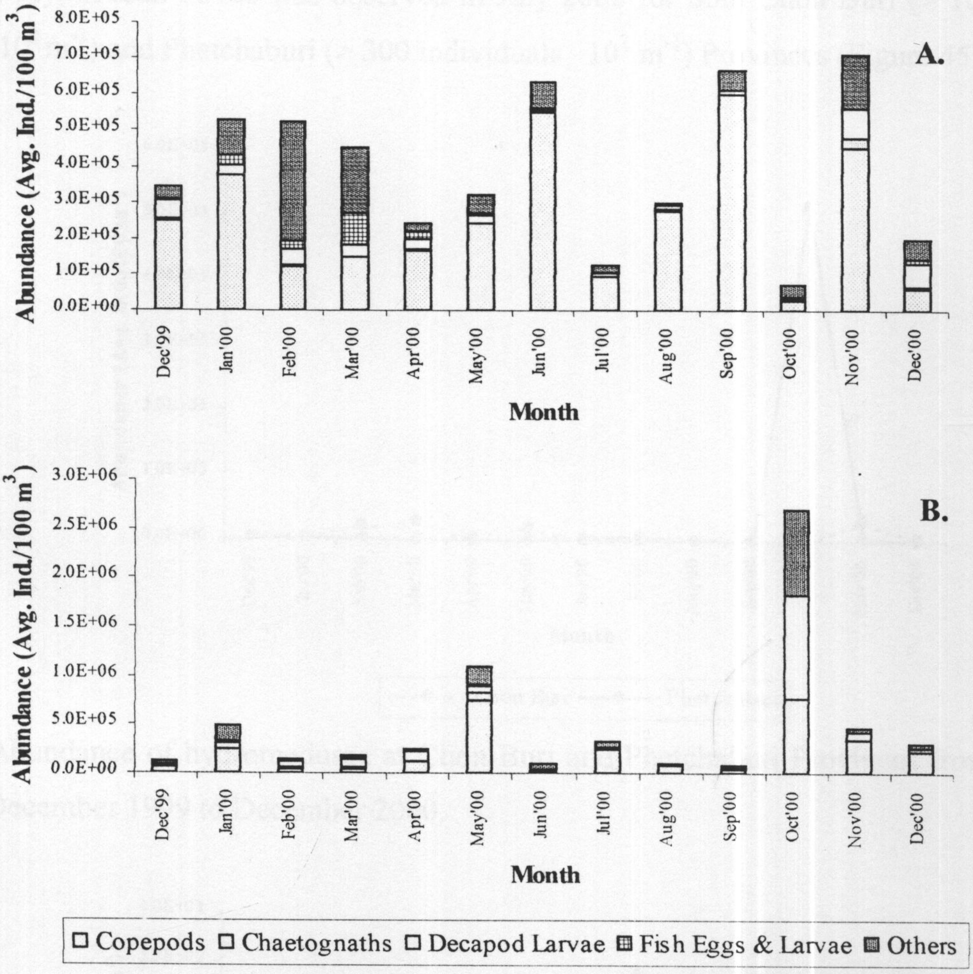


Figure 43. Average zooplankton concentration and composition at (A) Chon Buri and (B) Phetchaburi Provinces from December 1999 to December 2000.

The abundance hydromedusae at Chon Buri Province was highest in November 2000 (> 29,000 individuals · 10^2 m^{-3}) while the highest abundance (> 51,000 individuals · 10^2 m^{-3}) at Phetchaburi Province was observed in October 2000 (Figure 44). The highest abundance of scyphozoan larvae was observed in July 2000 for both Chon Buri (> 100 individuals · 10^2 m^{-3}) and Phetchaburi (> 300 individuals · 10^2 m^{-3}) Provinces (Figure 45).

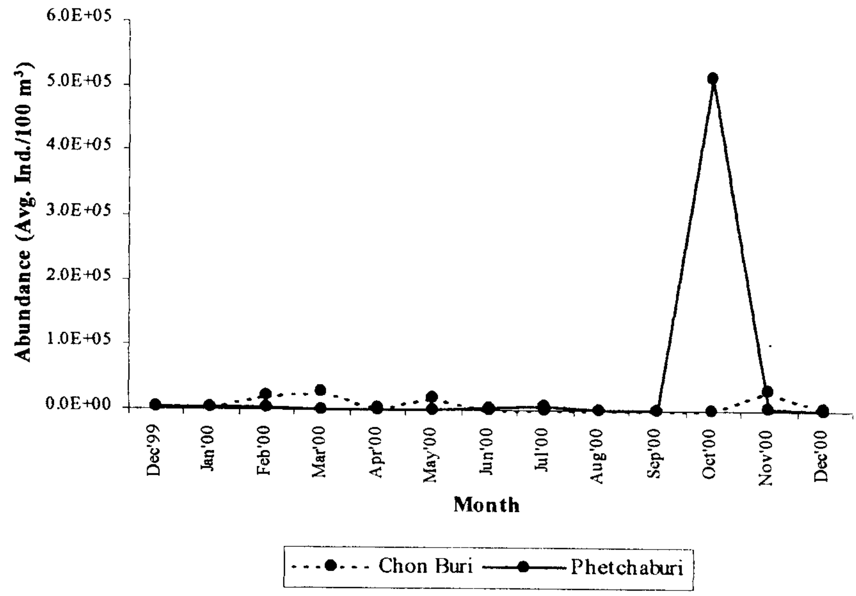


Figure 44. Abundance of hydromedusae at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

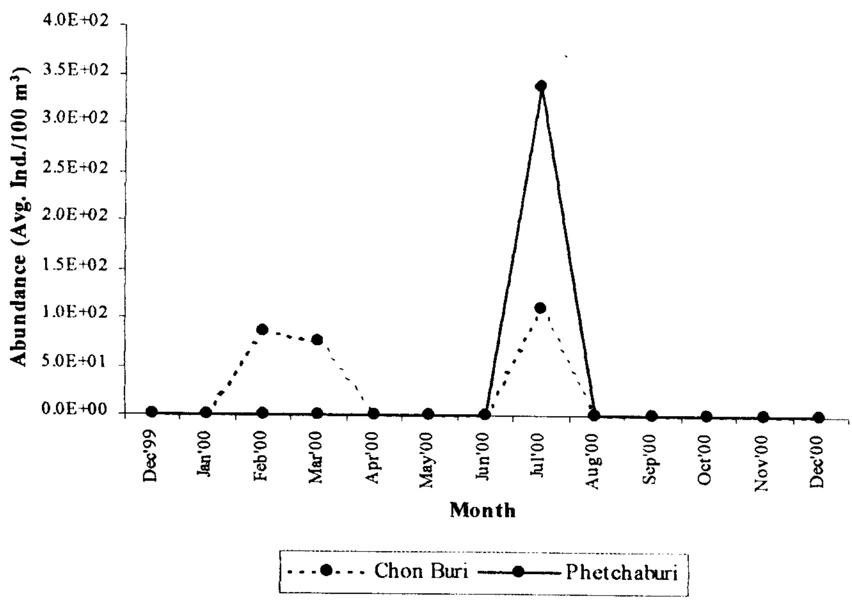


Figure 45. Abundance of scyphozoan larvae at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

The abundance of ctenophores at was highest in November 2000 (> 32,000 individuals · 10^2 m^{-3}) and October 2000 (> 67,000 individuals · 10^2 m^{-3}) at Chon Buri and Phetchaburi, respectively (Figure 46). At Chon Buri Province, the highest abundance of polychaetes was observed in February 2000 (> 9,000 individuals · 10^2 m^{-3}) and in October 2000 (> 23,000 individuals · 10^2 m^{-3}) at Phetchaburi Province (Figure 47).

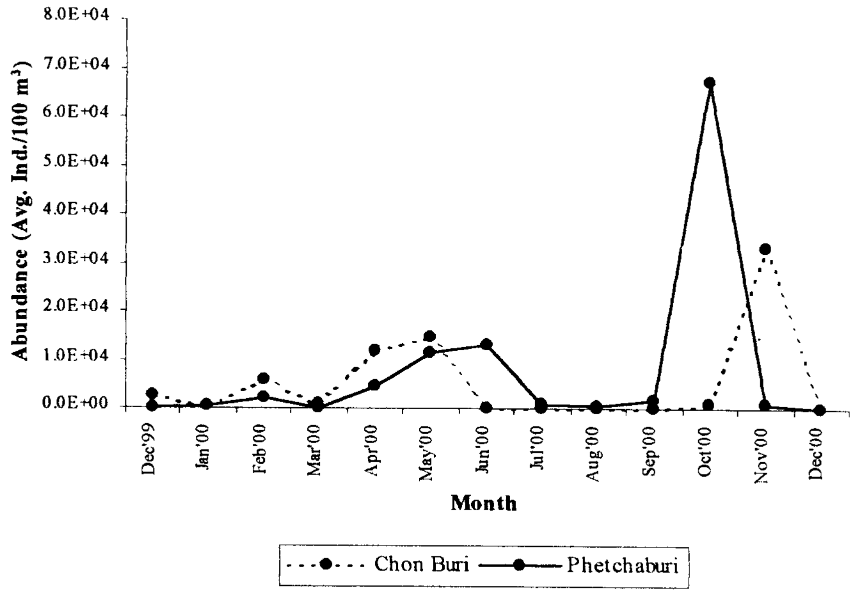


Figure 46. Abundance of ctenophores at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

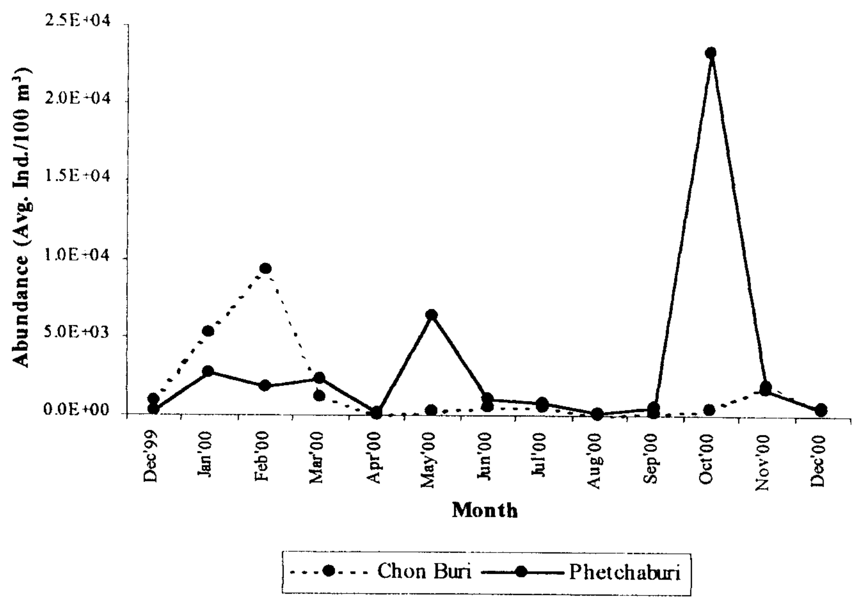


Figure 47. Abundance of polychaetes at ChonBuri and Phetchaburi Provinces from December 1999 to December 2000.

The highest abundance of barnacle larvae was observed in February 2000 (> 250,000 individuals · 10^2 m^{-3}) and October (> 230,000 individuals · 10^2 m^{-3}) for Chon Buri and Phetchaburi, respectively (Figure 48). At Chon Buri Province, the highest abundance of cladocerans was observed in June 2000 (> 27,000 individuals · 10^2 m^{-3}) while, at Phetchaburi Province, it was observed in January 2000 (> 37,000 individuals · 10^2 m^{-3}) (Figure 49).

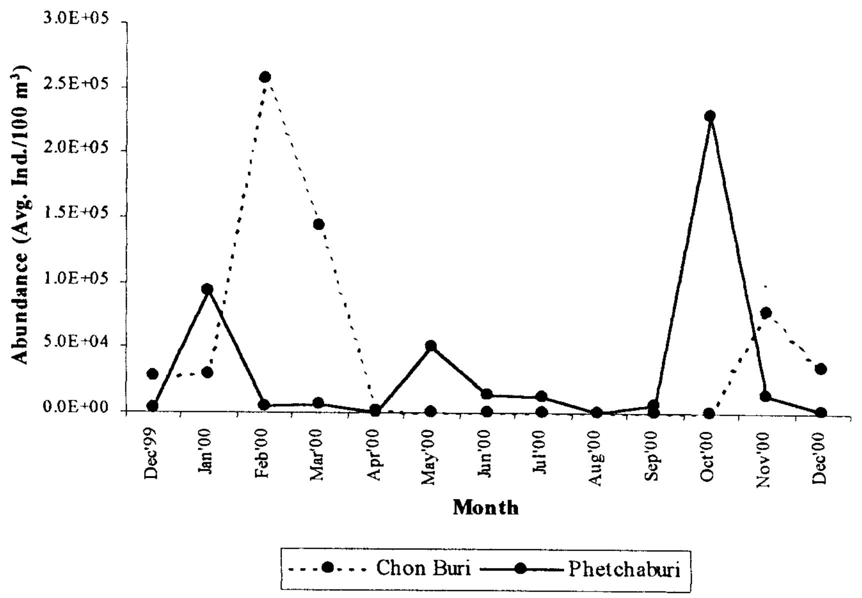


Figure 48. Abundance of barnacle larvae at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

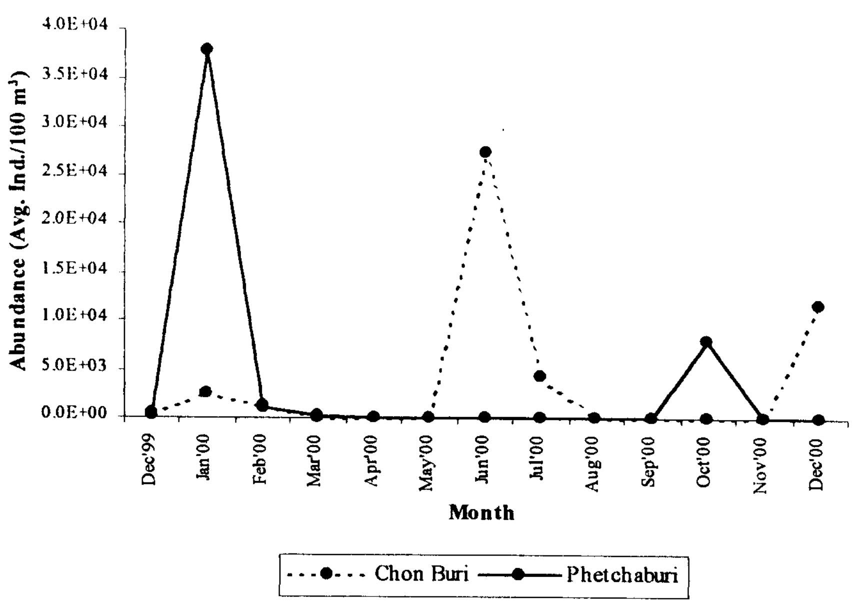


Figure 49. Abundance of cladocerans at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

At Chon Buri Province, the highest abundance (> 11,000 individuals · 10^2 m^{-3}) of amphipods was observed in September 2000. On the other hand, at Phetchaburi Province, the highest abundance (> 6,000 individuals · 10^2 m^{-3}) was observed in December 2000 (Figure 50). The highest abundance of gastropods was observed in February 2000 and May 2000 for Chon Buri (> 12,000 individuals · 10^2 m^{-3}) and Phetchaburi (> 2,800 individuals · 10^2 m^{-3}), respectively (Figure 51).

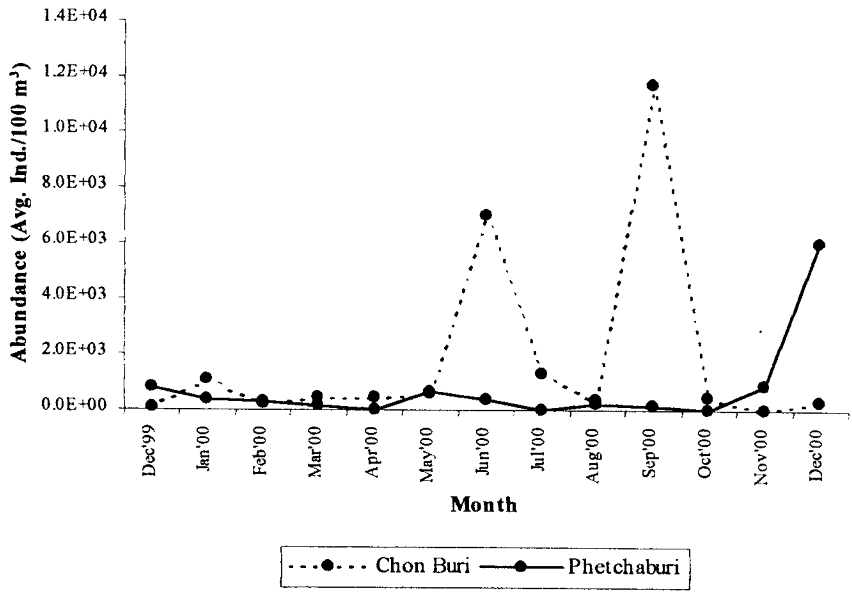


Figure 50. Abundance of amphipods at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

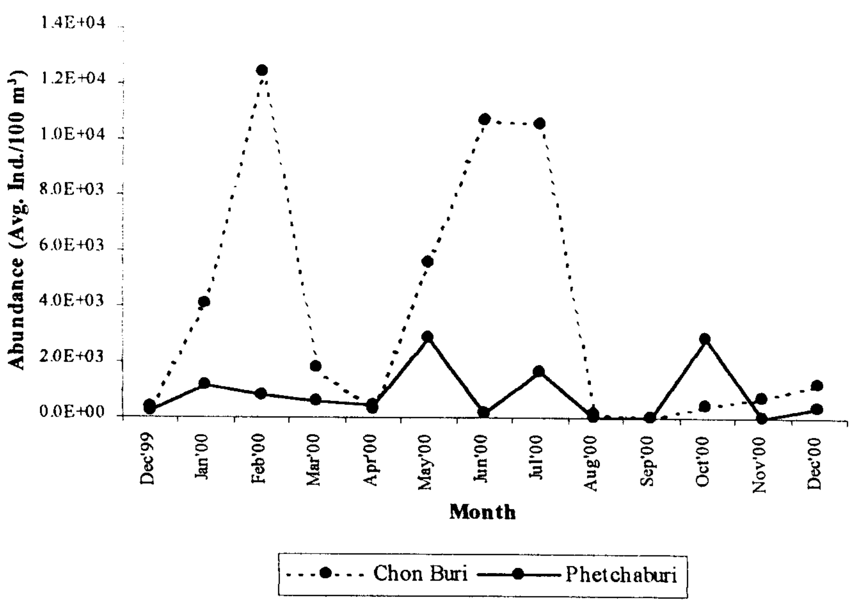


Figure 51. Abundance of gastropods at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

The highest abundance of bivalves was observed in October 2000 (> 25,000 individuals · 10^2 m^{-3}) and November 2000 (> 11,000 individuals · 10^2 m^{-3}) for Chon Buri and Phetchaburi, respectively (Figure 52). For copepods, the highest abundance at Chon Buri Province was observed in September 2000 (> 600,000 individuals · 10^2 m^{-3}) and in October 2000 (> 760,000 individuals · 10^2 m^{-3}) at Phetchaburi Province (Figure 53).

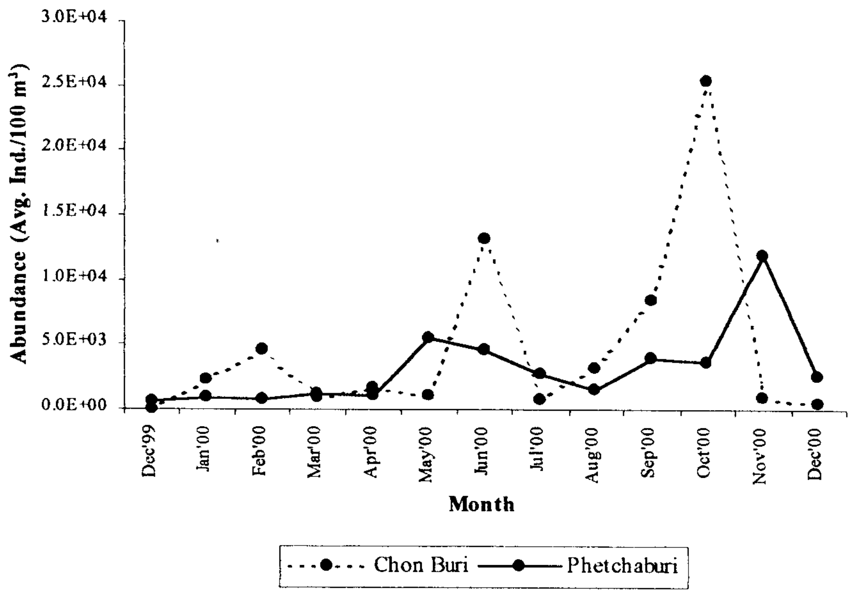


Figure 52. Abundance of bivalves at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

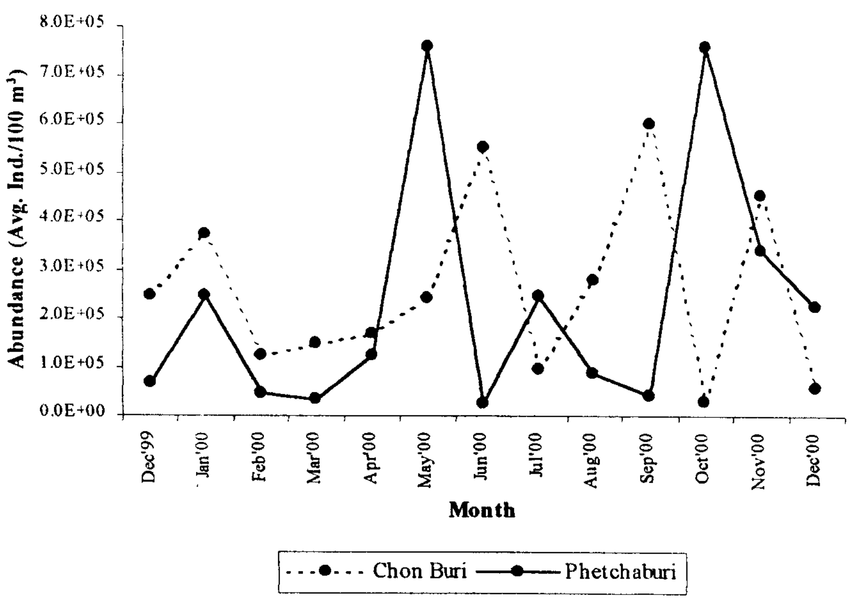


Figure 53. Abundance of copepods at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

The highest abundance of lucifers and lucifer larvae was observed in November 2000 at Chon Buri Province (> 59,000 individuals · 10^2 m^{-3}). At Phetchaburi Province, the highest abundance (> 27,000 individuals · 10^2 m^{-3}) was observed in May 2000 (Figure 54). Similarly, the highest abundance of shrimps and shrimp larvae was observed in November 2000 (> 3,500 individuals · 10^2 m^{-3}) and May 2000 (> 12,000 individuals · 10^2 m^{-3}) for Chon Buri and Phetchaburi, respectively (Figure 55).

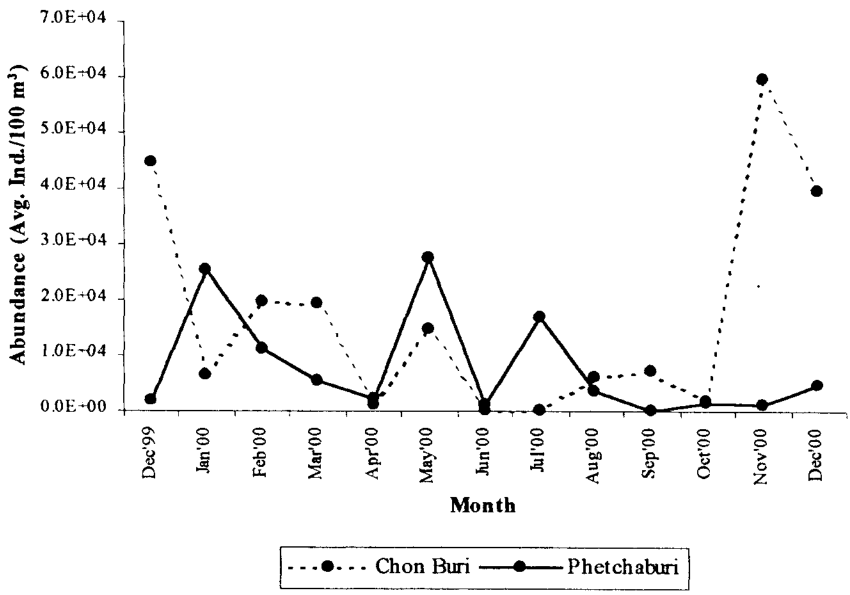


Figure 54. Abundance of lucifers and lucifer larvae at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

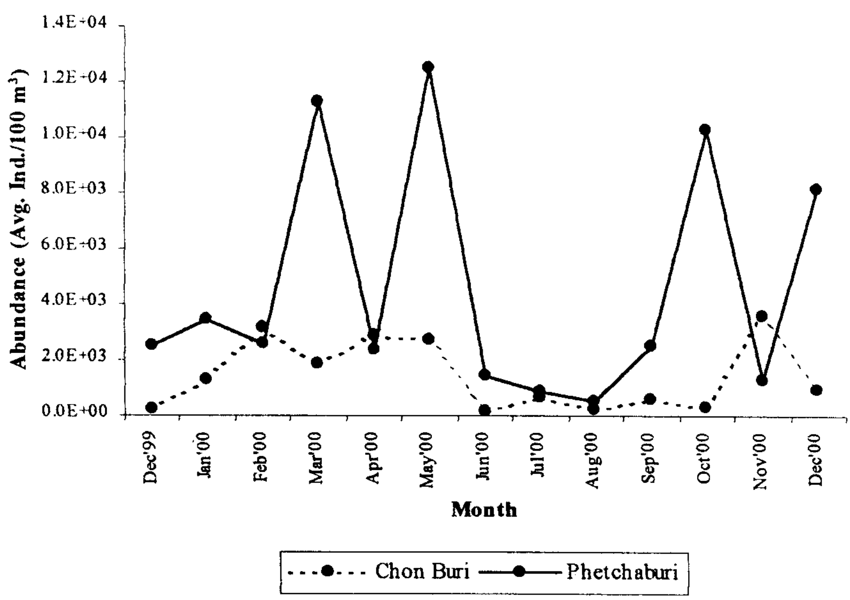


Figure 55. Abundance of shrimps and shrimp larvae at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

In December 2000 and October 2000, the highest abundance of juvenile crabs and crab larvae was observed for Chon Buri (> 27,000 individuals · 10^2 m^{-3}) and Phetchaburi (> 1,000,000 individuals · 10^2 m^{-3}), respectively (Figure 56). The highest abundance of larvaceans was observed in December 1999 (> 14,000 individuals · 10^2 m^{-3}) at Chon Buri and October 2000 (> 28,000 individuals · 10^2 m^{-3}) at Phetchaburi (Figure 57).

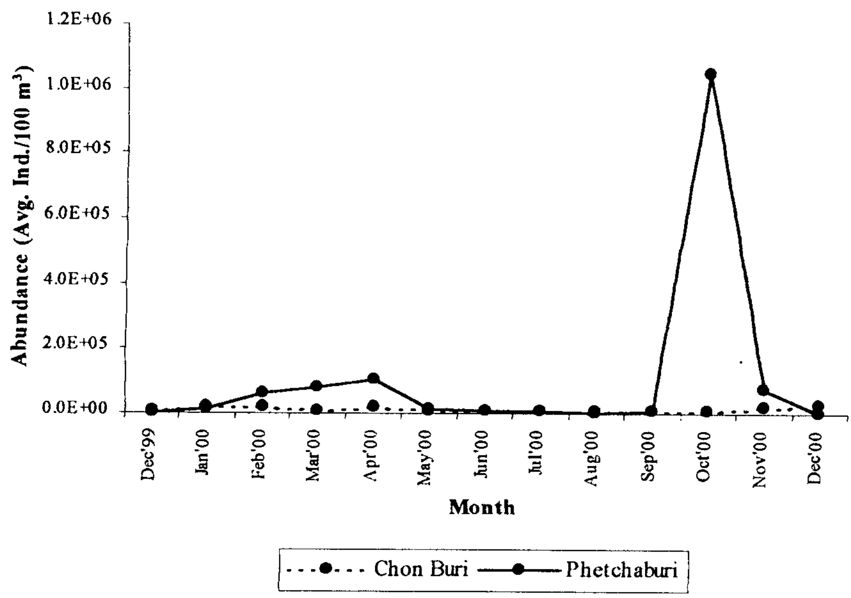


Figure 56. Abundance of juvenile crabs and crabs larvae at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

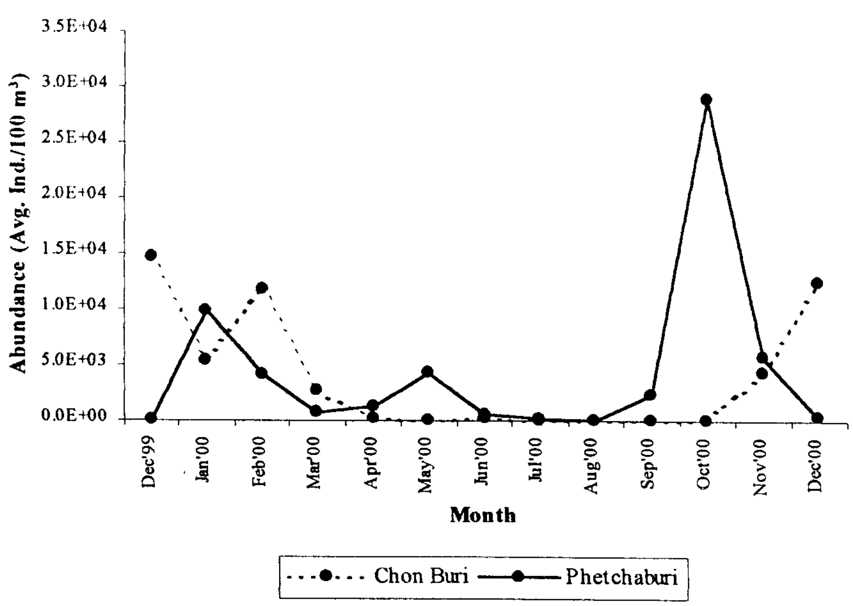


Figure 57. Abundance of larvaceans at Chon Buri and Phetchaburi Provinces from December 1999 and December 2000.

At Chon Buri and Phetchaburi Provinces, the highest abundance of juvenile fish and fish larvae was observed in February 2000 (> 3,500 individuals · 10^2 m^{-3}) and October 2000 (> 2,300 individuals · 10^2 m^{-3}), respectively (Figure 58). The highest abundance of planktonic eggs was observed in March 2000 (> 91,000 individuals · 10^2 m^{-3}) at Chon Buri Province and in May 2000 (> 21,000 individuals · 10^2 m^{-3}) at Phetchaburi Province (Figure 59).

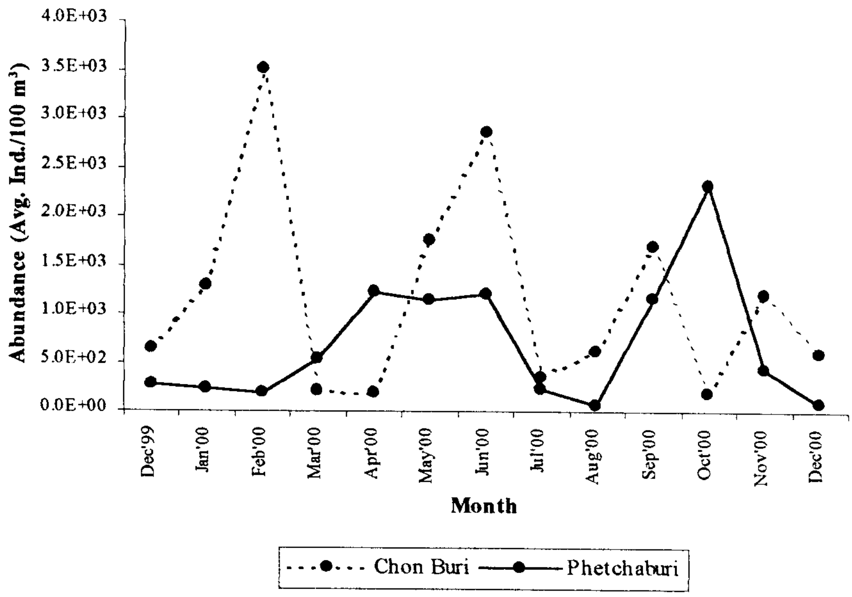


Figure 58. Abundance of juvenile fish and fish larvae at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

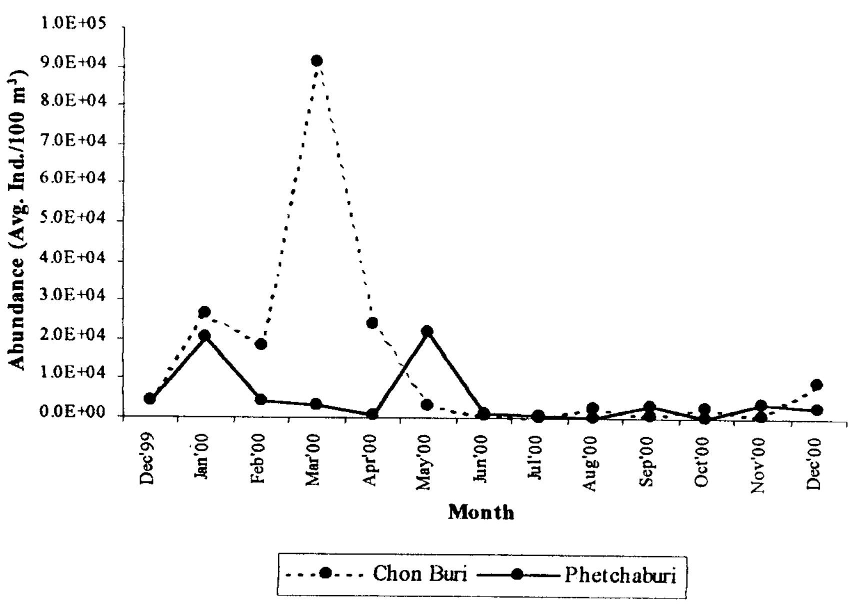


Figure 59. Abundance of planktonic eggs at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

The highest abundance of chaetognaths was observed in November 2000 (> 23,000 individuals · 10^2 m^{-3}) and May 2000 (> 70,000 individuals · 10^2 m^{-3}) for Chon Buri and Phetchaburi, respectively (Figure 60).

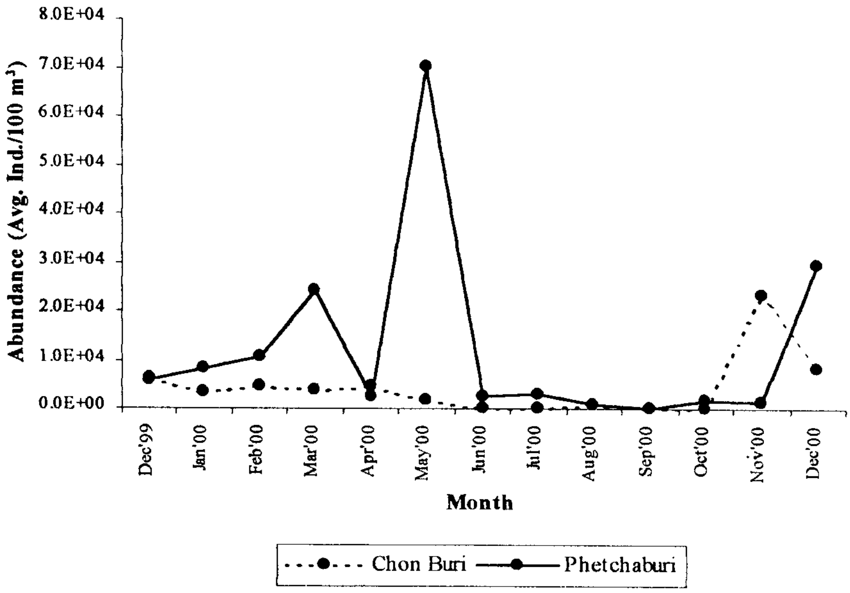


Figure 60. Abundance of chaetognaths at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

CHAPTER 4

DISCUSSION

I. Taxonomy of Rhizomedusae

As mentioned earlier, the taxonomy of rhizomedusae was accomplished using only external physical characteristics, most of which were visible to the naked eyes. Some, however, were best viewed under the stereo microscope. Particularly, the terminal tentacles, which were delicate and easily torn during the sampling process.

Among the 6 species of rhizomedusae that were identified from this study, 3 species were relatively easy to distinguish from the rest. They were *Cassiopea andromeda*, *Rhopilema hispidum*, and *Lobonema smithii*. *C. andromeda* has distinctly flat bell and mouth arms. The color of both the fresh and preserved specimens was also readily recognizable. Fresh *C. andromeda* specimens were reddish brown in color while preserved specimens appeared greenish brown (Figure 12). *R. hispidum* was recognized through the presence of scapulae and the bell surface that was obviously rough to touch (Figure 17). *L. smithii* was distinguished from other species through the presence of papillae allover the bell surface and the elongated marginal lappets, which facilitate locomotion (Figure 16). *Acromitus* spp. was distinguished from *Catostylus* sp. through relatively thinner bell and the presence of filaments along the mouth arms and among mouth (Figure 13 and 15). Identification of *A. flagellatus* and *A. hardenbergi* were relatively complicated (Figure 13 and 14). These two species are distinguished from each other by the presence of terminal filaments at the tip of the mouth arms (Cornelius, 1995). As these terminal filaments, whose primary functions are defense and prey capture, are extremely thin and fragile, all of the five mouth arms must be checked thoroughly. If, in fact, all terminal filaments were lost during sampling, the identity became uncertain. According to Cornelius (1995), the validity of *A. hardenbergi* is yet to be confirmed.

Besides the terminal filaments, other characteristics used to identify rhizomedusae were bell shape and bell surface. According the Cornelius (1995), bell shape can be categorized into flat, round, nearly hemispherical, and hemispherical. However, the fixing and preserving solution tended to extract excess water, thus, distort the shape of the bell in preserved specimens making it rather difficult to distinguish between nearly hemispherical and hemispherical. Likewise, bell surface is categorized into smooth and rough (finely granulated or with protuberances). Bells that were rough, with protuberances, were easily distinguished. In spite of that, bells that appeared smooth to the naked eyes can be finely granulated under the stereo microscope as in the case of *Acromitus flagellatus* and *Acromitus hardenbergi*.

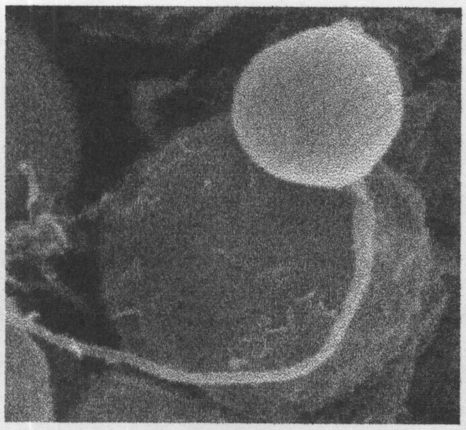
In addition to the external morphologies, Mongkonsangsuree (2002) had revealed that different rhizomedusae have different types of nematocysts, which can be used in the identification process as well (Table 10 and Figure 11).

Table 10. Nematocysts of each species of rhizomedusae (Mongkonsangsuree, 2002).

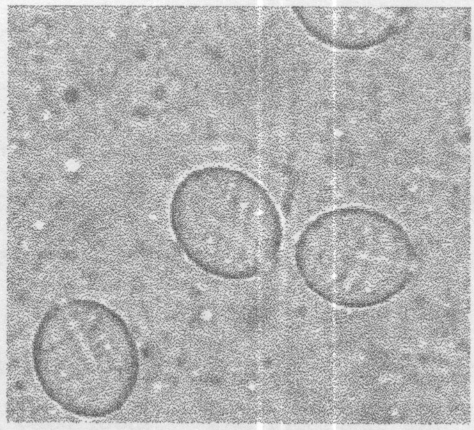
Species	Type of Nematocysts
Cassiopea andromeda	Atrichous Isorhiza (Figure 61A)
Acromitus flagellatus *Acromitus hardenbergi* *Catostylus townsendi* *Lobonema smithii*	Holotrichous Isorhiza (Figure 61B)
Rhopilema hispidum	Heterotrichous Anisorhiza (Figure 61C)

The results from this study can be used to create an artificial key to identification for 6 species of rhizomedusae as follows,

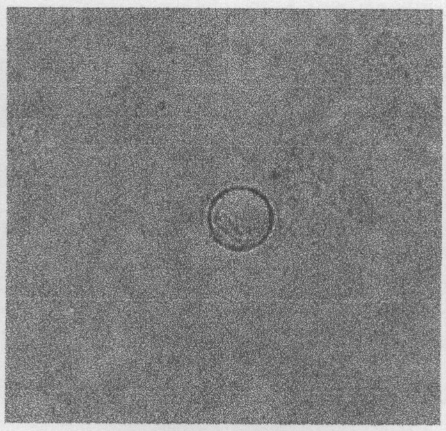
1.	Bell surface is smooth to touch.	2
	Bell surface is rough to touch, with protuberances.	3
2.	Bell is relatively flat, mouth arms are flat and wide.	*Cassiopea andromeda*
	Bell is relatively round, nearly hemispherical.	4
3.	Bell is granulated, with scapulae.	*Rhopilema hispidum*
	Bell is rough, with papillae.	*Lobonema smithii*
4.	Mouth arms without filaments.	*Catostylus townsendi*
	Mouth arms with filaments among the mouth, and along the mouth arms.	5
5.	Mouth arms with terminal filaments.	*Acromitus flagellatus*
	Mouth arms without terminal filaments.	*Acromitus hardenbergi*



A.



B.



C.

Figure 61. Types of nematocysts found in rhizomedusae; (A) Atrichous Isorhiza, (B) Holotrichous Isorhiza, and (C) Heterotrichous Anisorhiza (Mongkonsangsuree, 2002).

II. Species Diversity and Abundance

During the months when rhizomedusae were found in highest abundance, the results revealed that the abundance of rhizomedusae at Phetchaburi Province was more than 10 times higher in magnitude than that of Chon Buri Province (Figure 18). Furthermore, sampling in Chon Buri and Phetchaburi Provinces yielded 4 and 6 species of rhizomedusae, respectively (Table 6). Such differences in abundance, and species diversity, may be best explained through population dynamics, in term of reproductive strategy, coupling with the surface current pattern, food availability, fishing pressure, and environmental factors, such as salinity, in the Gulf of Thailand.

A typical cnidarian life cycle, characterized by alternation of generation, involves free-swimming medusoid individuals, which produce eggs and spermatozoa. Fertilization results in the zygotes that will eventually develop into the planula larvae. After settlement onto the substratum, the planula larvae develop into the polyps, which will undergo asexual reproduction and evolve into the medusoid forms, completing the life cycle. The benthic stages, reproducing asexually, are able to give rise to numerous individuals, which will contribute largely to the recruitment and population continuity of species. Different reproductive success, specifically asexual stages, would probably contribute to the abundance of the medusae at each locale. The medusae, which are planktonic and are carried by surface current, have evolved for the better dispersal of the species (Hardy, 1971). It is highly possible that the parental stocks for Chon Buri and Phetchaburi Provinces originate in different areas, resulting in the variation in species diversity that was observed. The muddy bottom of the Inner Gulf of Thailand is rather unsuitable for the attachment and development of the benthic stages. Thus, the medusae were likely transported from outside into the Inner Gulf by current. In fact, during the month of March, the current flows northward along the western part of the middle Gulf, and eastward at the upper part of the upper Gulf (Buranapratheprat and Bunpapong, 1998). It can be assumed that the young ephyrae were carried by the current and matured when they reached the coastal water off Chon Buri Province, resulting in the high abundance as observed. If this was the case, scyphozoans larvae should be present in the zooplankton samples obtained from the western part of the Gulf, or at Phetchaburi Province, few months prior to the peak of rhizomedusae at Chon Buri Province. However, scyphozoan larvae were first observed at Phetchaburi Province in July 2000 (Figure 45). In the same manner, in November when rhizomedusae were found in highest abundance at Phetchaburi Province, the direction of flow at the most northern part of the Upper Gulf changes from eastward to westward (Buranapratheprat and Bunpapong, 1998). Zooplankton data revealed the presence of scyphozoan larvae at Chon Buri Province in July 2000 (Figure 45). Thus, it is plausible that these larvae were transported to the western part of the Gulf by current as they grew, resulting in the peak of abundance of rhizomedusae observed in November 2000.

Besides the current, a physiochemical factor, which affected the abundance of rhizomedusae, appeared to be salinity. The average salinity at Chon Buri Province fluctuated severely through out the sampling period. The highest average salinity was observed in February (31.5 ± 0.1 psu) and the lowest was observed in June 2000 (0.3 ± 0.0 psu). During the period of low salinity in June and July 2000, either none or less than 5 individuals · 10^4 m^{-3} of scyphomedusae was obtained from sampling (Figure 62A).

At Phetchaburi Province, on the other hand, the highest value of salinity was observed in March (32.2 ± 0.1 psu) and the lowest in October 2000 (19.9 ± 0.9 psu). The fluctuation of salinity did not appear to be related to the abundance of rhizomedusae at Phetchaburi Province (Figure 62B).

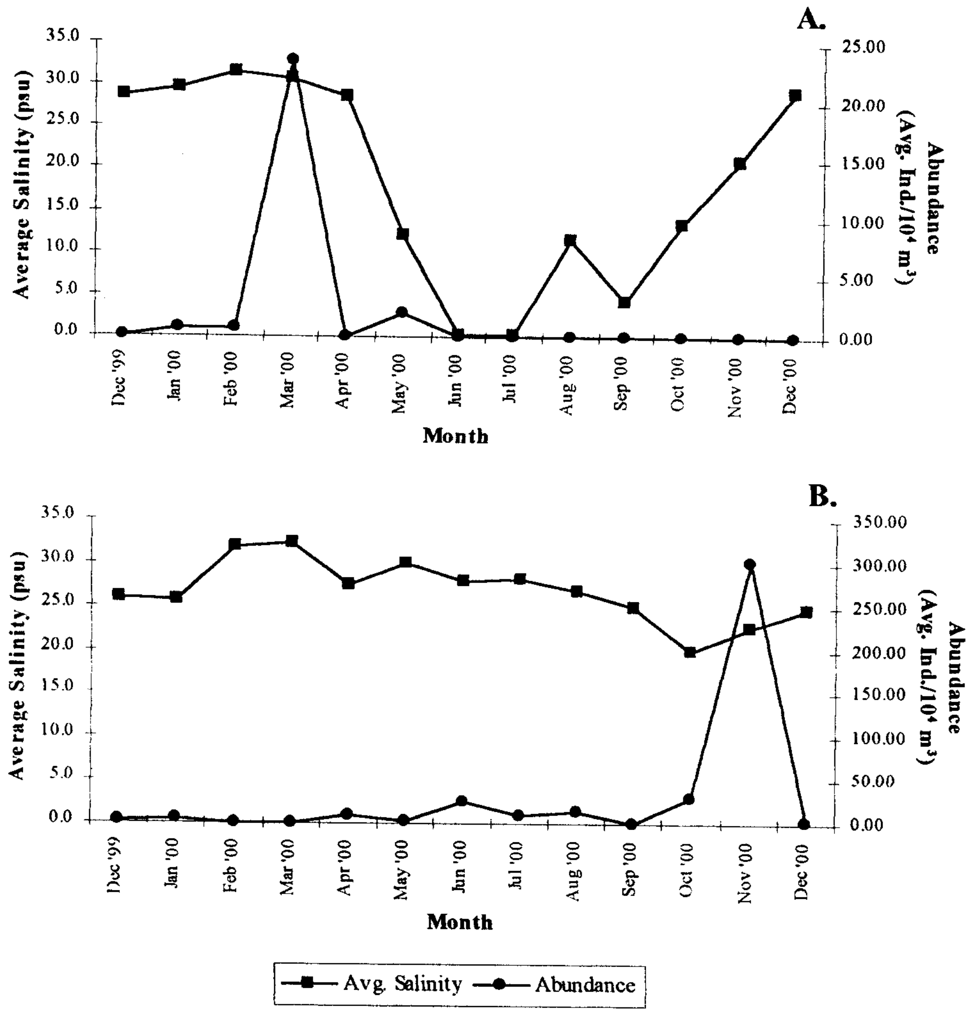


Figure 62. Average salinity and abundance of rhizomedusae at (A) Chon Buri and (B) Phetchaburi Provinces from December 1999 to December 2000.

Scyphozoans are euryhaline, and are able to tolerate a wide range of salinity. The medusae, scyphistomae, and planulae of *Rhopilema esculenta* (order Rhizostomeae) can survive in varying salinity of 8, 10, and 12 ppt, respectively (Arai, 1997). In the study on biomass and size structure of the scyphomedusae *Aurelia aurita* in the northwestern Black Sea, Weisse and Gomoiu (2000) revealed that abundance and biomass of medusae were unrelated to temperature and salinity when salinity exceeded 13 ppt. Biomass was relatively low at coastal stations where salinity dropped to less than 11 ppt. Evidently, the salinity values at Chon Buri Province between June to September 2000 were much lower (near 0 psu) than the tolerable range for rhizostome jellyfish. In 1998, the salinity at the mouth of the Bangpakong River was also 0 ppt (Burapha University, 1998). The freshwater input from the Bangpakong River, situated north of the monthly sampling area, resulted in the low salinity that was observed. In order to confirm this speculation, an extra sampling was carried out further south of the usual sampling area off the coast of Chon Buri Province during August 2000. The average salinity of that particular area was 16.3 ± 0.6 psu. At the end of a tow that lasted for one hour and thirty minutes, a total of 49 specimens (1.80 individuals $\cdot$ 10^4 m^{-3}) of *Rhopilema hispidum*, an economic species, were yielded. Thus, it can be concluded that the extremely low salinity affected the presence, and magnitude of abundance, of rhizostome scyphozoans at Chon Buri Province.

A biological factor, which appeared to be related to the abundance of rhizomedusae at Chon Buri and Phetchaburi Provinces, was zooplankton concentration. During the summer of 1986, in the Lebanese coastal waters, high production rate of phytoplankton resulting in high zooplankton biomass, high temperature, salinity, and water transparency are believed to be factors responsible for aggregations of *Rhizostoma pulmo*. The outburst of zooplankton was characterized by Chaetognatha, Appendicularia, Cladocera, and other meroplanktonic larvae (Lakkis 1991). At Chon Buri Province, the highest zooplankton concentration occurred during the months of November 2000 (716,569 individuals $\cdot$ 10^2 m^{-3}), where the major fraction of zooplankton were copepods, while the lowest concentration was observed October 2000 (71,703 individuals $\cdot$ 10^2 m^{-3}). Preceding the peak of rhizomedusae, in February 2000, the peaks of few zooplankton prey items were observed. They are polychaetes (Figure 47), barnacle larvae (Figure 48), gastropods (Figure 51), larvaceans (Figure 57), and fish larvae (Figure 58). During the month of March 2000, where the peak of rhizomedusae abundance was observed, a large fraction of the zooplankton population was composed of fish eggs and larvae (91,494 individuals · 10^2 m^{-3}). In April 2000, the total concentration of zooplankton had decreased dramatically. In addition, the concentration of fish eggs and larvae had decreased to 23,932 individuals · 10^2 m^{-3} (Figure 43A). This is believed to be a result of the predatory impact by scyphomedusae. Fancett and Jenkins (1988) reported that the impact, in patches, of predation by scyphomedusae, *Cyanea capillata*, reached 2.8% day^{-1} of fish eggs and larvae.

In comparison, at Phetchaburi Province, preceding the peak of the highest rhizomedusae abundance in November 2000, the highest zooplankton concentration was observed during October 2000 (2,734,438 individuals · 10^2 m^{-3}). The majority of the zooplankton was decapod larvae and copepods. In fact, the peak of rhizomedusae at Phetchaburi Province followed the peak of several groups of zooplankton prey items, namely hydromedusae (Figure 44), ctenophores (Figure 46), polychaetes (Figure 47), barnacle larvae (Figure 48), gastropods (Figure 51), copepods (Figure 53), shrimps and larvae (Figure 55), crabs and larvae (Figure 56), larvaceans (Figure 57), and fish larvae (Figure 58). During the month of November 2000, and thereafter to the end of the year, the concentration of copepod and decapod larvae severely decreased (by approximately half in November) (Figure 43B). Once again, it is highly plausible that the decrease in zooplankton concentration was a direct result of the predatory impact of rhizomedusae. Fancett and Jenkins (1988) had revealed that *Cyanea capillata* and *Pseudorhiza haeckeli* can consume the maximum of 1.6% day^{-1} and 4.8% day^{-1} of copepods, respectively.

Although the results of this study demonstrated that salinity and zooplankton concentration are directly related to the abundance of rhizomedusae, it is possible that these factors play important roles in governing the abundance of rhizomedusae indirectly. As mentioned earlier, a typical cnidarian life cycle involved the planktonic stages as well as the benthic polyp stages. These development and survival of these stages are crucial and contribute largely to the survival and abundance of the planktonic stages. In the Gullmar Fjord, western Sweden, it was reported that the scyphistomae of *Aurelia aurita* develop during the period of maximum food availability, encouraging asexual reproduction and release of ephyrae. On the contrary, *Cyanea capillata*'s scyphistomae develop during winter and early spring where there is minimum zooplankton biomass (Gröndahl and Hernroth, 1987). Brewer and Feingold (1991) revealed that, in an experiment, a transfer from low to high temperature induced podocysts (cysts produced by the polyps) formation in *Cyanea capillata* and transfer from high to low temperature led to excystment of podocysts as well as strobilation of polyps to form ephyrae. In the Niantic River estuary, Connecticut, field observations of the benthic stages agreed with laboratory results. In Chesapeake Bay, ephyra and polyp production of *Chrysaora quinquecirrha* was relatively lower at salinity lower than 11 ppt and higher than 25 ppt (Purcell *et al.*, 1999). Moreover, *Cassiopea xamachana*, a tropical jellyfish, has cold-sensitive scyphistomae and temperature-tolerant medusae, which are found year round (Fitt and Costley, 1998). Since this study was conducted in the tropics, where there is very little change in annual temperature, factors that affect the benthic stages, which in turn affect the abundance of rhizomedusae would be salinity, food concentration, and type of substrate available for settlement of planula larvae. As mentioned earlier, the bottom topography of the Inner Gulf is generally muddy, making it unsuitable for the attachment of polyp stages.

III. Size Distribution

The effects of surface current (Figure 63), salinity, food abundance, and reproductive strategy are more apparent when the size distribution of each species of rhizomedusae are analyzed separately.

A. *Cassiopea andromeda*

Cassiopea andromeda was found at both Chon Buri and Phetchaburi Provinces (Table 6). The planula larvae of the up-side-down jellyfish, *Cassiopea xamachana*, in South Florida are known to settle on degraded mangrove leaves, where the development and metamorphosis of the polyp stages take place (Fitt and Costley, 1998). Thus, the surrounding environment of both sampling sites, with mangrove forests along the coasts, would be ideal for settlement and development of *C. andromeda* larvae. It is possible than the life cycle of *C. andromeda* evolves within the mangrove forest. This is demonstrated in the size distribution of *C. andromeda* at each sampling location, where a wide range of size class was observed in the same month.

From the gonad analysis, *C. andromeda* reached sexual maturation at the size of approximately 15 cm in diameter and another maturation period at 26 cm in diameter (Table 9 and Figure 33). At Chon Buri Province, in January 2000, the largest size of *C. andromeda* obtained from sampling was 15 cm, at which sexual maturity was observed.

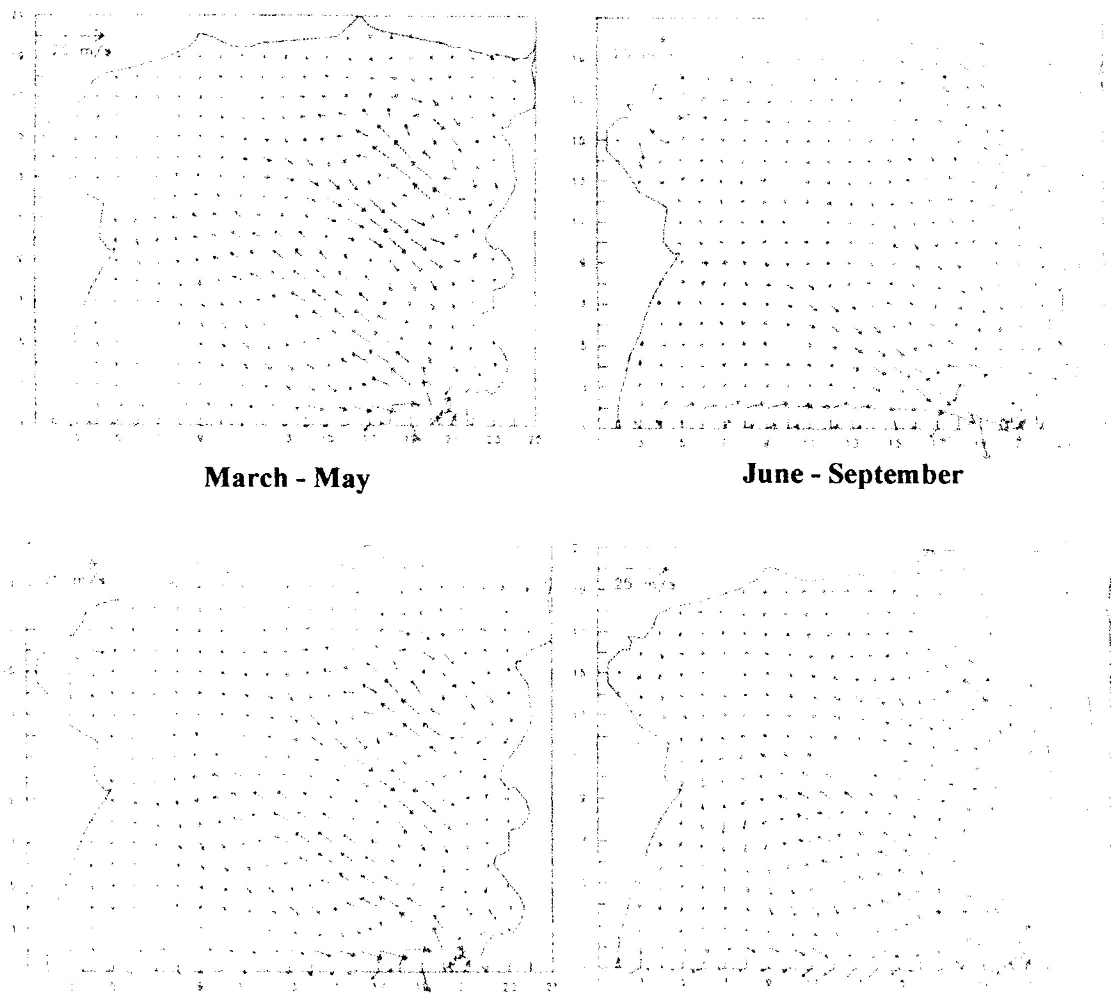


Figure 63. Water circulation in the Upper Gulf of Thailand (Sojisuporn and Putikiatikajorn, 1998).

In February and March 2000, scyphozoan larvae were observed in zooplankton samples (Figure 45) Thereafter, the size distribution of specimens was between 2 cm to 7 cm (Figure 23). At Phetchaburi, in December 1999, the sizes of specimens were smaller than 5 cm. However, in January 2000, specimens larger than 15 cm were obtained. Furthermore, in April 2000, specimens larger than 26 cm were obtained. The reproduction these of sexually matured individuals would likely resulted in the presence of smaller size classes observed throughout the rest of the sampling period (Figure 24). The reproduction of this species at both Chon Buri and Phetchaburi Provinces did not appear to coincide with the peak of abundance of any zooplankton group. This is due to the fact that *C. andromeda* are able to attain nutrients from symbiotic algae, or zooxanthellae residing in their tissues. Thus, zooplankton concentration may not play an important role in governing the reproduction and abundance of this species.

B. *Acromitus flagellatus*

Similar to *C. andromeda*, *Acromitus flagellatus* was also found at both Chon Buri and Phetchaburi Provinces. *A. flagellatus* appeared to reach sexual maturation at approximately 8 cm and at 14 cm (Table 9 and Figure 34). Contrary to *C. andromeda*, monthly surface current played an important role in the abundance of *A. flagellatus* found at each sampling location.

A. flagellatus specimens were first obtained at Phetchaburi Province in January 2000 and the sizes of specimens were smaller than 8 cm (Figure 26). Thereafter, no specimens were found at Phetchaburi until April 2000. However, specimens larger than 14 cm were found at Chon Buri in February 2000. It is possible that specimens were either transported from Phetchaburi to the southern or the eastern part of the Gulf by current. Those that were transported to the eastern part of the Gulf may be trapped within the gyre that occurs between November to February. This resulted in a shift to a larger size class form January 2000 at Phetchaburi to February 2000 at Chon Buri Province. The reproduction of sexually matured individuals at Chon Buri in February 2000 resulted in the smaller size classes observed in March 2000 at Chon Buri.

According to the current pattern, specimens found at Chon Buri in March 2000 were likely transported to Phetchaburi in April 2000. This is evident in the shift of size class from 3-7 cm at Chon Buri to 8-10 cm at Phetchaburi. In addition, reproduction of sexually matured individuals, size > 8 cm, found at Chon Buri in March 2000, as well as populations further south, would result in the small individuals, sizes 4 to 8 cm, found in May 2000 at both locations. It is highly possible that this transportation of specimens back and forth, between the western and eastern sides of the Gulf, occurred throughout the rest of the year. Nonetheless, no specimens were obtained at Chon Buri after May

2000 (Figure 25). It is suspected that the freshwater input from the Bangpakong River during the rainy season, coupling with the strength of the discharge, had transported specimens to a location further south of the sampling area.

After May 2000, at Phetchaburi Province, there was a shift to a larger size class and specimens larger than 14 cm were obtained. It was expected that the reproduction of these sexually matured individuals would likely result in the smaller juveniles in June 2000. However, no specimens were found in June 2000. Nonetheless, the results of zooplankton concentration revealed a high abundance of scyphozoans larvae at Phetchaburi Province in June 2000. In fact, these larvae were smaller than the mesh size of the push net used for sampling. A shift from juveniles, 3-7 cm, to larger individuals, 9-15 cm, was observed for the rest of the sampling period (Figure 26).

C. ***Acromitus hardenbergi***

Although *A. hardenbergi* was found at both sampling locations, they were found only in 2 out of the 13-months sampling period (Table 6). This was also the result of the discharge of the Bangpakong River as mentioned earlier in the case of *A. flagellatus*. However, at Phetchaburi Province, *A. hardenbergi* was found in 7 months (Table 6) and a clear shift in size classes of specimens was observed. There was an alternation between smaller juveniles (< 7 cm) and sexually matured adults that were greater than 7 cm in diameter (Table 9 and Figure 35), which were found in April and June as well as in November and December 2000 (Figure 28).

Interestingly, at Phetchaburi Province, during the months where both *A. flagellatus* and *A. hardenbergi* were found (Table 6), the abundance of *A. hardenbergi* was relatively lower compared to the abundance of *A. flagellatus* (Figure 22). However, the size of both species, within the same month, appeared to be similar (Figure 26 and 28). The explanation for the difference in the abundance of both species is possibly the fact that *A. flagellatus* possess terminal filaments, which are located on the tips of the mouth arms and are not present in *A. hardenbergi*. This structure, whose main function is prey capture, would enable *A. flagellatus* to compete for food better than *A. harderbergi*.

D. *Catostylus townsendi*

Compared to *A. flagellatus* and *A. hardenbergi*, the shift in size class was not as distinct in *C. townsendi* (Figure 29). The analysis of gonads revealed than the sexual maturity of *C. townsendi* occurred at the size of approximately 6 cm and 12 cm (Table 9 and Figure 36). This data, in addition to the size class distribution, implies that sexually matured adults were found in 5 out of 6 months where *C. townsendi* were found at Phetchaburi Province. On the contrary, smaller juveniles were found only in August 2000. Current may be an important factor, which transport the smaller juveniles, found in August 2000 (Figure 29), to the southern part of the Gulf but not eastern part since *C. townsendi* were not found at Chon Buri.

E. *Lobonema smithii*

L. smithii were found only at Phetchaburi Province and specimens were obtained only in June and July 2000 (Table 6). In addition, the smallest size specimens (approximately 15 cm in diameter) obtained were already sexually matured (Table 9 and Figure 37). Since *L. smithii* is an economic species, they were subjected to intense fishery during July 2000. The data of gonad development of this particular species did not imply whether *L. smithii* can reproduce more than once during their life cycle since specimens were obtained in only 2 months out of the 13-months sampling period. Indeed, if they reproduce only once during their life span, fishery prior to or during reproductive periods may result in future decrease of population.

F. *Rhopilema hispidum*

All *R. hispidum* specimens obtained from both Chon Buri and Phetchaburi Provinces had already reached reproductive maturity (Table 9 and Figure 38). Relatively smaller specimens ($\approx$ 15 cm in diameter) were found in July 2000 at Phetchaburi Province and larger specimens (> 15 cm in diameter) were obtained at Chon Buri in August 2000 (Figure 31 and 32). Specimens were possibly transported by current upward along the coasts of Samutsongkram and Samutsakorn Provinces and down along the coast of Chon

Buri Province during these two consecutive months. Similar to *L. smithii*, this particular species is also an economic species and are subjected to intense fishery.

In general, when comparing the sizes of the same species of rhizomedusae found at the two provinces, the size of medusae at Phetchaburi Province appeared to be larger than that of Chon Buri Province. For instance, the largest *Acromitus flagellatus* found were 12.5 cm and 16.8 cm in diameter at Chon Buri and Phetchaburi, respectively. The largest *A. hardenbergi* found were 7.9 cm at Chon Buri and 14.0 cm at Phetchaburi (Table 11).

Table 11. Summary of size distribution of rhizostome species found at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

Species	Chon Buri		Phetchaburi	
	Min.(cm)	**Max.(cm)**	**Min.(cm)**	**Max.(cm)**
Cassiopea andromeda	1.9 (Mar.)	15.0 (Jan.)	1.1 (Jan.)	26.0 (Apr.)
Acromitus flagellatus	2.1 (Mar.)	16.0 (Feb.)	2.0 (Aug.)	16.8 (Jun.)
Acromitus hardenbergi	2.8 (Mar.)	10.0 (May.)	2.5 (Oct.)	14.0 (Jun.)
Catostylus townsendi	-	-	3.0 (Aug.)	12.0 (Jun.)
Lobonema smithii	-	-	24.0 (Jun.)	53.0 (Jul.)
Rhopilema hispidum	16.1 (Aug.)	54.0(Aug.)	15.5 (Jul.)	

There are many factors, which are believed to affect the size distribution of medusae. In Namibia, the size structure of *Chrysoara hysoscella* changed with both depth and distance offshore. Medusae that were found inshore, and at the surface, were significantly smaller than at depths greater than 30 m. These medusae were also smaller than those obtained from surface waters further offshore where bigger and more mature individuals were found (Buecher *et al.*, 2001). In the northwestern Black Sea, Weisse and Gomoiu (2000) observed that there was a difference in the size structure of *Aurelia aurita* at inshore and offshore stations. Relatively smaller sized individuals were found at the inshore stations compared to those found offshore. Since the depths of both sampling areas were considerably shallow, approximately 1-3 m, it can be disregarded as affecting the size structure of rhizomedusae in both locations.

Food concentration and water circulation in the inner Gulf are belived to affect the size structure of medusae at Chon Buri and Phetchaburi Provinces. In *Aurelia aurita*, an experiment had shown that food availability governed both the maturation process as well as individual growth. While food scarcity reduces the growth rate, energy is allocated towards reproduction, which occurs at a relatively smaller size than well-fed medusae (Ishii and Båmstedt, 1998). Lucas (1996) observed a similar trend in Horsea Lake, England. Abundance of *Aurelia aurita* was limited by numerically and species-poor mesozooplankton community. However, small-size medusae were able to reach sexual maturity and reproduce. Here, medusae appeared to partition the available food resources into either somatic growth, when food was abundant, or reproduction, when food was scarce. As mentioned earlier, the general size of rhizomedusae appeared to be relatively larger at Phetchaburi compared to Chon Buri. At the same time, the zooplankton concentration at Phetchaburi was relatively higher in magnitude than at Chon Buri (Figure 43).

There was a peak in several zooplankton groups, preceding the reproductive period of each species of rhizomedusae. Prior to the reproductive period of *A. flagellatus* at Chon Buri Province, which occurred in March, peaks of fish larvae and gastropods were observed in February 2000. Likewise, the November reproductive period of *A. flagellatus* at Phetchaburi Province was preceded by the peaks of chaetognaths, polychaetes, barnacle larvae, hydromedusae, ctenophores, copepods, shrimp larvae, crab larvae, and fish larvae in October 2000. Similar, reproductive period of *A. hardenbergi* at Phetchaburi Province was preceded by the same peaks of zooplankton group. However, rhizomedusae at each location appeared to reach reproductive maturity at approximately the same sizes. Thus, surface current, coupling with life history of each species, was probably responsible for the different in sizes observed at both sampling locations.

CHAPTER 5

CONCLUSIONS

After 13 months of sampling south of the Bangpakong River's mouth, Chon Buri Province, and along the coast of Baan Laem, Phetchaburi Province,

1. A total of 6 species of rhizomedusae (Cnidaria, Scyphozoa) were yielded. They are *Cassiopea andromeda* (Forskål, 1775), *Acromitus flagellatus* (Maas, 1903), *Acromitus hardenbergi*, *Catostylus townsendi* Mayer, 1915, *Lobonema smithii* Mayer, 1910, and *Rhopilema hispidum* (Vanhöffen, 1888).

2. All 6 species of rhizomedusae were found at Phetchaburi Province. In comparison, only 4 species were found at Chon Buri Province. *C. townsendi* and *L. smithii* were not obtained from Chon Buri's samplings.

3. The highest abundance of rhizomedusae occurred during March 2000 and November 2000 at Chon Buri and Phetchaburi, respectively. When the abundance of both locations were compared, the abundance at Phetchaburi Province appeared to be higher in magnitude than the abundance at Chon Buri Province.

4. Factors believed to affect the abundance of rhizomedusae at the two provinces are water current, salinity, food concentration in term of zooplankton concentration, and the life history of each species.

Apart from their important roles as economic species in the jellyfish fishery industry, rhizostome scyphozoans are also considered an integral part of the marine ecosystem. Their predatory behaviors are believed to pose major impacts on the fish stocks of economically important species. In order to establish a better understanding of these complex animals as well conservation for sustainable utilization of this fishery resource, more information regarding the ecology, growth rate, and reproductive biology of rhizomedusae is extremely crucial. The knowledge on growth rate, in addition to the information on the polyps and the benthic stages, will be useful in the understanding of the complex life cycle of these organisms.

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APPENDIX

Appendix 1. Questionnaire used to interview locals fishermen for preliminary survey (in Thai).

ชื่อ-สกุล______________________________

ที่อยู่______________________________

เบอร์โทรศัพท์ที่สามารถติดต่อได้______________________________

ท่านเคยพบเห็นแมงกระพรุนที่ใดบ้าง?

____

ชนิดอะไร?

____

มีพิษหรือไม่?

____

ในฤดู หรือ ช่วงไหนของปี?

____

ส่วนมากท่านพบแมงกระพรุนในช่วงไหนของวัน?

____

อากาศแบบไหน?

____

สภาพท้องทะเลแบบใด?

____

แมงกระพรุนที่ท่านจับได้ จับโดยวิธีใด?

____

หากเป็นอวนลาก ขนาดตาของอวนเท่าไร?

____

ใช้เวลาในการลากกี่ชั่วโมง?

____

ลากที่ความลึกเท่าไร?

____

โดยประมาณแล้วจับได้จำนวนเท่าไร?

____

Appendix 2. Salinity values at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000. (Unit: psu)

Month	Chon Buri								Phetchaburi							
	B1	E1	B2	E2	B3	E3	Avg.	SD	B1	E1	B2	E2	B3	E3	Avg.	SD
December 1999	28.3	29.5	27.8	29.5	27.4	29.8	**28.7**	**1.0**	26.6	26.4	25.7	26.0	25.3	25.4	**25.9**	**0.5**
January 2000	29.2	29.4	29.5	29.7	29.7	30.0	**29.6**	**0.3**	24.7	25.4	25.1	25.8	25.9	27.1	**25.7**	**0.8**
February 2000	31.7	31.5	31.3	31.5	31.4	31.6	**31.5**	**0.1**	32.2	31.9	31.8	31.9	31.6	31.7	**31.9**	**0.2**
March 2000	31.1	30.9	30.8	30.5	30.8	30.5	**30.8**	**0.2**	32.3	32.3	32.2	32.2	32.2	32.2	**32.2**	**0.1**
April 2000	27.1	28.5	28.7	28.3	29.7	29.2	**28.6**	**0.9**	27.2	27.6	27.2	27.5	27.7	27.6	**27.5**	**0.2**
May 2000	11.3	11.2	12.8	14.2	11.7	11.8	**12.2**	**1.1**	29.9	30.0	29.8	30.0	30.0	30.0	**30.0**	**0.1**
June 2000	0.3	0.3	0.3	0.3	0.3	0.3	**0.3**	**0.0**	28.6	29.2	26.8	27.4	27.2	28.1	**27.9**	**0.9**
July 2000	0.2	0.2	0.2	0.2	0.5	0.2	**0.3**	**0.1**	28.3	28.3	28.2	28.2	28.1	28.2	**28.2**	**0.1**
August 2000	9.6	10.4	11.1	12.6	12.1	13.5	**11.6**	**1.5**	29.2	27.2	26.7	26.3	25.3	26.5	**26.9**	**1.3**
September 2000	4.5	5.0	2.9	4.0	4.9	4.2	**4.3**	**0.8**	25.5	25.2	24.9	25.1	24.6	24.6	**25.0**	**0.4**
October 2000	12.4	13.5	10.8	13.7	14.9	15.5	**13.5**	**1.7**	20.4	19.0	19.6	18.7	20.4	21.1	**19.9**	**0.9**
November 2000	20.5	21.9	22.9	19.1	24.2	17.0	**20.9**	**2.6**	21.7	23.0	22.4	23.4	22.5	22.9	**22.7**	**0.6**
December 2000	29.5	29.1	29.5	29.3	29.4	29.4	**29.4**	**0.2**	25.7	26.7	23.5	25.9	22.4	23.6	**24.6**	**1.7**

Appendix 3. pH values at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000.

Month	Chon Buri								Phetchaburi							
	B1	E1	B2	E2	B3	E3	Avg.	SD	B1	E1	B2	E2	B3	E3	Avg.	SD
December 1999	7.91	7.76	7.53	7.75	7.77	7.71	**7.74**	**0.12**	7.47	7.67	7.50	7.54	7.50	7.42	**7.52**	**0.09**
January 2000	7.53	7.28	7.27	7.30	7.20	7.32	**7.32**	**0.11**	7.91	7.70	7.81	7.97	7.70	7.68	**7.80**	**0.12**
February 2000	7.79	7.83	7.93	7.78	7.75	8.07	**7.86**	**0.12**	7.94	7.70	7.57	7.77	7.63		**7.72**	**0.14**
March 2000	8.09	8.07	8.05	8.07	8.04	8.05	**8.06**	**0.02**	8.43	8.35	8.35	8.37	8.34	8.31	**8.36**	**0.04**
April 2000	7.48	7.62	7.72	7.66	7.65	7.66	**7.63**	**0.08**	8.37	8.34	8.37	8.37	8.36	8.30	**8.35**	**0.03**
May 2000	7.92	7.94	8.11	7.99	8.14	8.06	**8.03**	**0.09**	8.02	8.08	8.11	8.04	8.10	8.19	**8.09**	**0.06**
June 2000	6.90	6.91	6.94	6.94	7.12	6.97	**6.96**	**0.08**	8.21	8.16	8.45	8.33	8.38	8.31	**8.31**	**0.11**
July 2000	7.31	7.18	7.28	7.15	7.33	7.34	**7.27**	**0.08**	8.51	8.54	8.58	8.67	8.71	8.53	**8.59**	**0.08**
August 2000	8.07	8.14	8.24	8.19	8.25	8.25	**8.19**	**0.07**	8.00	8.29	8.40	8.44	8.50	8.48	**8.35**	**0.19**
September 2000	7.58	7.62	7.58	7.81	7.50	7.62	**7.62**	**0.10**	7.75	7.68	7.79	7.60	7.66	7.69	**7.70**	**0.07**
October 2000	7.77	7.83	7.44	7.80	7.77	7.82	**7.74**	**0.15**	8.60	8.38	8.46	8.29	8.65	8.78	**8.53**	**0.18**
November 2000	7.09	7.10	7.23	7.24	7.33	7.24	**7.21**	**0.09**	7.63	7.63	7.69	7.70	7.73	7.71	**7.68**	**0.04**
December 2000	8.17	8.30	8.37	8.38	8.34	8.30	**8.31**	**0.08**	8.20	8.26	8.21	8.23	8.15	8.19	**8.21**	**0.04**

Note : B1, B2, B3 = Beginning of sampling line no.1, 2, and 3

E1, E2, E3 = End of sampling line no. 1, 2, and 3

Appendix 4. Dissolved oxygen concentration at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000. (Unit: mg/l)

Month	Chon Buri								Phetchaburi							
	B1	**E1**	**B2**	**E2**	**B3**	**E3**	**Avg.**	**SD**	**B1**	**E1**	**B2**	**E2**	**B3**	**E3**	**Avg.**	**SD**
December 1999																
January 2000																
February 2000	5.87	5.93	5.74	6.20	5.52	6.63	**5.98**	**0.39**	5.56	4.92	5.12	4.82	4.89	4.92	**5.04**	**0.27**
March 2000	4.62	4.85	4.86	4.80	4.78	5.05	**4.83**	**0.14**	5.20	5.12	5.30	5.10	5.11	5.11	**5.16**	**0.08**
April 2000	0.77	5.00	3.40	5.20	5.50	5.30	**4.20**	**1.84**	5.80	5.80	5.50	5.80	5.50	4.90	**5.55**	**0.35**
May 2000	4.70	4.68	5.20	4.47	6.62	5.45	**5.19**	**0.79**	5.55	5.45	5.57	5.48	5.26	5.75	**5.51**	**0.16**
June 2000	4.79	4.64	4.86	4.60	5.35	4.69	**4.82**	**0.28**	5.52	5.45	6.93	6.74	7.33	6.86	**6.47**	**0.79**
July 2000	3.26	3.72	3.57	3.95	4.13	3.88	**3.75**	**0.31**	3.36	4.07	4.44	4.37	4.21	4.35	**4.13**	**0.40**
August 2000	6.47	6.07	6.77	6.06	6.28	5.60	**6.21**	**0.40**	2.40	4.48	4.45	6.00	6.40	5.50	**4.87**	**1.45**
September 2000	2.90	2.71	2.70	2.45	2.77	2.69	**2.70**	**0.15**	2.70	2.46	2.69	2.35	2.86	2.65	**2.62**	**0.18**
October 2000	5.38	4.97	5.24	4.85	4.55	4.35	**4.89**	**0.39**	8.33	7.25	7.71	7.35	8.14	8.73	**7.92**	**0.58**
November 2000	4.25	4.40	4.64	4.46	4.69	4.56	**4.50**	**0.16**	6.74	5.88	6.73	6.53	6.88	6.68	**6.57**	**0.36**
December 2000	7.64	7.67	7.97	8.07	7.62	7.25	**7.70**	**0.29**	7.02	6.41	6.74	6.44	7.04	7.12	**6.80**	**0.31**

Appendix 5. Temperature at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000. (Unit: °C)

Month	Chon Buri								Phetchaburi							
	B1	**E1**	**B2**	**E2**	**B3**	**E3**	**Avg.**	**SD**	**B1**	**E1**	**B2**	**E2**	**B3**	**E3**	**Avg.**	**SD**
December 1999	22.5	23.1	22.8	23.0	22.8	23.2	**22.9**	**0.3**	23.5	23.6	23.5	23.6	23.5	23.6	**23.6**	**0.1**
January 2000	26.5	26.6	26.6	26.8	26.7	26.9	**26.7**	**0.1**	27.1	27.3	27.3	27.2	27.3	27.3	**27.3**	**0.1**
February 2000	27.8	28.7	28.0	28.2	27.9	28.3	**28.2**	**0.3**	28.6	29.1	28.8	28.9	28.6	28.7	**28.8**	**0.2**
March 2000	29.3	29.5	29.6	29.4	29.6	29.7	**29.5**	**0.1**	29.3	29.4	29.5	29.4	29.6	29.6	**29.5**	**0.1**
April 2000	31.0	30.9	30.2	30.8	30.4	30.4	**30.6**	**0.3**	29.6	29.8	29.8	29.7	29.9	30.7	**29.9**	**0.4**
May 2000	31.3	31.3	31.2	31.2	31.2	31.1	**31.2**	**0.1**	29.7	29.8	30.0	29.8	29.8	29.8	**29.8**	**0.1**
June 2000	31.7	31.5	31.5	31.7	31.4	31.5	**31.6**	**0.1**	30.6	30.7	30.8	31.1	31.3	31.4	**31.0**	**0.3**
July 2000	29.0	29.1	29.5	29.1	29.7	29.4	**29.3**	**0.3**	29.9	29.9	29.8	29.9	29.9	29.8	**29.9**	**0.1**
August 2000	30.0	29.7	29.5	29.7	29.6	29.7	**29.7**	**0.2**	30.9	31.4	31.6	31.7	32.0	31.7	**31.6**	**0.4**
September 2000	29.4	29.3	29.3	29.3	29.3	29.4	**29.3**	**0.1**	29.7	29.7	29.7	29.7	29.9	29.7	**29.7**	**0.1**
October 2000	29.3	29.3	29.3	29.4	29.6	29.7	**29.4**	**0.2**	29.1	29.0	28.9	29.0	29.0	29.3	**29.1**	**0.1**
November 2000	29.0	28.8	29.0	28.5	29.2	28.9	**28.9**	**0.2**	28.2	28.3	28.1	28.4	28.1	28.3	**28.2**	**0.1**
December 2000	27.3	27.4	27.5	27.4	27.5	27.5	**27.4**	**0.1**	27.5	27.7	27.5	27.7	27.3	27.5	**27.5**	**0.2**

Appendix 6. Zooplankton concentration at Chon Buri and Phetchaburi Provinces from December 1999 to December 2000. (Unit: individuals · 10^2 m^{-3})

Month: December 1999

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	0	0	0	0	0	128443	798	312	485	0	0
Cnidaria	Hydromedusae	559	0	2078	264	4517	3795	1647	798	935	3394	3055	1364
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	909	0	10390	882	807	1897	0	0	0	0	0	0
Chaetognatha	Chaetognaths	6294	0	14546	1146	7663	6641	17290	1730	1870	5333	6109	2273
Annelida	Polychaetes	699	0	0	88	1613	3320	0	266	935	0	436	0
Arthropoda	Barnacle Larvae	6644	0	47794	4143	71385	36523	9880	133	1558	2909	436	3636
	Ostracods	0	0	2078	176	1855	1423	823	1197	1247	0	0	0
	Cladocerans	490	0	0	0	484	949	823	0	0	0	0	0
	Copepods	173572	0	721060	57126	364427	160321	89745	35389	112523	29092	104730	14546
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	70	0	0	0	81	474	0	798	1247	0	2618	0
	Lucifers & Larvae	39861	0	89353	23714	72353	43638	5763	665	623	0	436	2273
	Shrimps & Larvae	699	0	0	0	161	474	823	2794	4675	2424	2182	2273
	Crabs & Larvae	2587	0	22858	3350	1210	2846	823	798	623	4364	1746	3636
Mollusca	Gastropods	140	0	0	176	1855	0	0	133	312	970	0	0
	Bivalves	0	0	0	0	0	0	1647	798	1247	0	0	0
Urochordata	Larvaceans	2448	0	68573	2733	1452	12332	0	0	0	0	0	0
Chordata	Fish Larvae & Juvenile	70	0	2078	176	1049	474	823	0	312	0	436	0
	Eggs	0	0	10390	4055	7179	1423	12350	0	2182	2909	3491	3636
	Others	0	0	10390	88	0	949	1647	1730	8416	3394	3491	455
	Total	**235042**	**0**	**1001588**	**98119**	**538090**	**277479**	**272529**	**48028**	**139017**	**55274**	**129167**	**34092**

Month: January 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	2046	0	4426	0	6675	9160	1169	902	6749	11902	955
Cnidaria	Hydromedusae	1699	3273	5681	1897	5453	8246	2893	1558	5410	1446	6492	955
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	0	1227	271	0	0	393	0	0	902	482	541	0
Chaetognatha	Chaetognaths	2831	4910	2435	3794	2337	2749	3375	3895	13074	2410	15148	10025
Annelida	Polychaetes	566	6956	1082	11066	1948	9817	482	1948	2254	2410	7574	1432
Arthropoda	Barnacle Larvae	6228	12275	20288	20235	52196	61649	29407	80242	334523	43388	50314	26255
	Ostracods	0	0	0	1265	390	0	1446	0	1353	3857	1082	2387
	Cladocerans	0	2046	541	316	1948	9817	4821	9738	71233	6267	7033	127933
	Copepods	303468	674305	427396	322497	262930	244632	101720	170223	220912	98346	789331	87357
	Isopods	0	409	0	2529	1558	785	0	0	0	1446	541	477
	Amphipods	0	1637	0	2529	2337	0	0	0	0	964	1082	0
	Lucifers & Larvae	2265	13912	1082	11382	1558	9424	7231	21034	18034	9642	79528	17662
	Shrimps & Larvae	1132	1227	812	1897	2337	393	0	1169	4508	2410	10279	2387
	Crabs & Larvae	7360	13912	22181	3794	52196	7461	1446	6622	46887	12052	18935	4774
Mollusca	Gastropods	1132	2864	812	11066	5453	3141	482	1948	2254	0	2164	0
	Bivalves	0	2046	0	4743	3895	3141	0	779	0	964	541	2864
Urochordata	Larvaceans	1132	3682	3517	2213	5843	15707	11088	3116	15779	5785	6492	17185
Chordata	Fish Larvae & Juvenile	566	1227	541	1897	2337	1178	0	390	451	0	0	477
	Eggs	30573	25368	13255	25294	37394	27487	43870	14412	25698	14945	13525	8592
	Others	2265	26187	0	110661	146462	14529	4821	6232	13525	4821	9197	85925
	Total	**361217**	**799510**	**499891**	**543502**	**588574**	**427222**	**222242**	**324475**	**777699**	**218385**	**1031702**	**397641**

Appendix 6. (Cont.)

Month: February 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	439	10254	1680	0	887	0	0	572	718	1645	0
Cnidaria	Hydromedusae	27674	22809	18456	28977	5408	19960	2322	637	1716	718	3290	3153
	Scyphozoan Larvae	0	0	513	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	8139	6141	3589	8819	4867	1774	3870	1910	572	2871	2741	631
Chaetognatha	Chaetognaths	4070	6579	4101	5879	5948	887	20125	7004	11442	2871	13159	8829
Annelida	Polychaetes	9767	12282	9741	17218	2163	4436	6192	3820	0	718	0	0
Arthropoda	Barnacle Larvae	520110	311424	156880	210400	140600	207140	5418	2547	2861	7178	3838	4414
	Ostracous	9767	6579	14355	13439	3785	2218	0	0	0	0	0	0
	Cladocerans	1628	1316	0	0	0	3992	6192	0	0	0	0	0
	Copepods	78953	109656	272745	198641	57322	19960	73534	54757	24601	38759	25769	41620
	Isopods	0	439	513	2940	1082	887	0	0	0	0	0	0
	Amphipods	0	0	513	840	0	0	774	0	572	0	548	0
	Lucifers & Larvae	32558	25440	10254	9659	18927	19960	27092	10187	4005	9331	10417	6306
	Shrimps & Larvae	1221	3509	5127	4620	1082	3105	4644	637	572	2871	2741	3784
	Crabs & Larvae	15465	19738	33837	17218	21090	17742	31736	47117	51491	25839	25769	180986
Mollusca	Gastropods	20349	16229	12304	19318	2704	3548	2322	637	572	718	548	0
	Bivalves	4477	3070	3076	12599	1622	3105	1548	0	0	2153	548	0
Urochordata	Larvaceans	32151	7457	11792	6299	6489	6653	0	1273	1716	718	10417	10090
Chordata	Fish Larvae & Juvenile	4070	3948	3589	5879	0	3548	0	0	572	0	548	0
	Eggs	40697	12282	13330	31077	5948	6210	3096	637	1716	2153	13707	1892
	Others	1221	3070	11279	19318	4326	9758	6192	3184	1144	718	1645	3784
	Total	**812316**	**572406**	**596246**	**614822**	**283364**	**335770**	**195059**	**134347**	**104126**	**98332**	**117332**	**265488**

Month: March 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	0	1254	3424	0	782	1198	666	0	734	2054	1240
Cnidaria	Hydromedusae	46874	17285	20902	12840	17681	42986	0	1332	0	2935	3082	0
	Scyphozoan Larvae	455	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	455	1383	418	1284	589	391	0	0	0	0	0	0
Chaetognatha	Chaetognaths	6371	4840	2508	2140	2358	4299	63515	18642	23320	17609	15408	5372
Annelida	Polychaetes	1820	1383	1254	856	589	782	4794	1997	972	2201	4109	0
Arthropoda	Barnacle Larvae	267136	164895	145480	93732	116696	73467	11984	1332	8259	5870	4109	6199
	Ostracods	455	346	836	3852	2947	391	0	3329	486	2935	1027	0
	Cladocerans	0	0	0	0	0	0	0	666	0	734	0	413
	Copepods	213891	199464	120397	125404	101373	121533	59920	17310	22348	31550	48278	6199
	Isopods	0	0	0	0	589	0	0	0	0	0	0	0
	Amphipods	455	0	418	428	1179	0	0	666	0	0	0	0
	Lucifers & Larvae	28215	15210	28427	7704	12377	23056	9587	5326	5344	2201	3082	5785
	Shrimps & Larvae	1820	1037	836	2568	2358	2345	21571	6658	6316	16142	14381	2479
	Crabs & Larvae	17748	5877	7525	2996	7662	3908	139014	14647	47612	99785	72931	94632
Mollusca	Gastropods	455	691	2508	1284	589	5080	0	0	486	1467	1027	413
	Bivalves	0	1383	1672	1712	589	391	0	3329	0	2935	1027	0
Urochordata	Larvaceans	3186	691	3344	1284	7073	0	3595	0	486	0	0	413
Chordata	Fish Larvae & Juvenile	0	0	836	428	0	0	1198	0	486	734	0	826
	Eggs	135161	151413	57690	66340	94889	42204	1198	0	486	734	16435	413
	Others	910	3457	3762	2996	1768	782	26365	2663	0	0	0	413
	Total	**725409**	**569353**	**400069**	**331271**	**371306**	**322395**	**343940**	**78562**	**116601**	**188564**	**186950**	**124798**

Appendix 6. (Cont.)

Month: April 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	0	3606	0	1055	0	0	4431	795	4381	0	9278
Cnidaria	Hydromedusae	2377	728	1202	3231	3165	2651	0	738	0	876	0	663
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	17825	10193	0	19384	4220	18556	10769	0	2386	7009	5084	1988
Chaetognatha	Chaetognaths	7130	1456	1202	5654	7384	3976	1077	5169	0	5257	2542	0
Annelida	Polychaetes	0	0	0	0	0	0	0	0	0	876	0	0
Arthropoda	Barnacle Larvae	0	728	4809	0	3165	1325	3231	0	0	0	0	0
	Ostracods	0	0	19234	0	1055	3976	0	3692	795	6133	1695	663
	Cladocerans	0	0	0	0	0	0	0	0	0	0	0	0
	Copepods	78428	73533	152670	225342	265842	202789	119536	446023	14315	45559	86435	21207
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	0	0	2404	0	0	0	0	0	0	0	0	0
	Lucifers & Larvae	4159	728	0	0	1055	1325	0	738	2386	4381	5084	0
	Shrimps & Larvae	594	0	3606	3231	3165	6627	1077	2215	2386	1752	4237	2651
	Crabs & Larvae	29114	45139	1202	14538	12659	23858	219689	34707	105769	84108	110162	55005
Mollusca	Gastropods	0	0	0	808	1055	0	0	738	0	0	1695	0
	Bivalves	594	0	6011	0	1055	2651	2154	2215	0	876	847	0
Urochordata	Larvaceans	0	728	0	0	0	0	0	0	0	1752	5932	0
Chordata	Fish Larvae & Juvenile	0	0	0	0	1055	0	2154	0	795	4381	0	0
	Eggs	14260	16017	3606	18577	10549	79525	1077	0	0	0	1695	0
	Others	1188	0	1202	0	1055	1325	0	738	0	0	0	663
	Total	**155668**	**149250**	**200755**	**290764**	**317533**	**348586**	**360763**	**501407**	**129626**	**167340**	**225409**	**92117**

Month: May 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	24857	14755	2423	1122	0	37160	49546	44951	1858	50166	9058
Cnidaria	Hydromedusae	77551	9039	9836	10906	6360	1161	0	0	1798	0	2787	3484
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	9694	18078	8197	32717	13841	4645	6193	2064	5394	13935	30657	9754
Chaetognatha	Chaetognaths	2423	4519	0	2423	0	0	35095	9290	32365	131917	139349	72461
Annelida	Polychaetes	0	0	0	1212	0	0	4129	13419	5394	6503	4180	4877
Arthropoda	Barnacle Larvae	0	0	0	1212	0	0	51611	31999	66528	25083	37624	94061
	Ostracods	2423	753	0	0	0	0	0	46450	0	0	1393	4180
	Cladocerans	0	0	0	0	0	0	0	0	0	0	0	0
	Copepods	145408	763783	278698	140561	29553	91738	187863	1119952	363206	1448300	433375	1005402
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	0	0	0	0	0	3484	0	2064	0	929	0	697
	Lucifers & Larvae	21811	13558	16394	18176	7108	11612	2064	5161	41355	34373	30657	50862
	Shrimps & Larvae	4847	753	8197	2423	0	0	2064	17548	5394	16722	8361	25083
	Crabs & Larvae	16964	3013	9836	4847	1496	2322	12387	8258	7192	1858	12541	41108
Mollusca	Gastropods	26658	6779	0	0	0	0	4129	3097	5394	4645	0	0
	Bivalves	4847	0	1639	0	374	0	2064	20644	3596	1858	2787	2090
Urochordata	Larvaceans	0	0	0	0	0	0	10322	0	3596	0	1393	10451
Chordata	Fish Larvae & Juvenile	0	2260	1639	2423	1870	2322	0	4129	0	2787	0	0
	Eggs	0	6026	1639	3635	4863	1161	8258	4129	10788	21367	15328	70371
	Others	0	6026	1639	0	0	0	4129	12387	19779	4645	2787	349069
	Total	**312626**	**859444**	**352471**	**222958**	**66588**	**118447**	**367468**	**1350136**	**616731**	**1716778**	**773386**	**1753009**

Appendix 6. (Cont.)
Month: June 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	0	0	0	0	0	2372	17695	29447	58925	12387	3097
Cnidaria	Hydromedusae	0	0	0	0	0	0	8302	4424	0	796	0	0
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	0	0	0	0	0	0	42694	34505	1052	796	0	0
Chaetognatha	Chaetognaths	0	0	0	0	0	0	0	885	11569	796	688	0
Annelida	Polychaetes	0	0	899	0	2488	0	3558	1770	0	0	688	0
Arthropoda	Barnacle Larvae	0	0	0	0	0	0	20161	18580	29447	9555	6193	0
	Ostracods	1664	20740	11687	4233	2986	2787	4744	1770	3155	2389	1376	619
	Cladocerans	21630	40184	24274	15522	25879	36231	0	0	0	0	0	0
	Copepods	41597	642949	512444	133352	1669698	314929	17789	35390	10517	40610	28214	3716
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	1664	9074	14384	1411	9953	5574	0	885	1052	0	0	0
	Lucifers & Larvae	0	0	0	0	0	0	3558	0	1052	796	688	0
	Shrimps & Larvae	0	0	0	706	0	0	0	1770	5258	796	688	0
	Crabs & Larvae	832	3889	4495	10583	3981	6503	35578	7078	0	796	9634	619
Mollusca	Gastropods	4160	23333	22476	5645	6967	1858	0	0	0	0	688	0
	Bivalves	1664	40184	22476	2117	4977	7432	8302	4424	5258	3185	4817	1858
Urochordata	Larvaceans	0	0	899	0	0	0	0	0	0	796	2064	0
Chordata	Fish Larvae & Juvenile	0	3889	2697	2117	995	7432	0	885	6310	0	0	0
	Eggs	832	0	0	706	0	0	3558	3539	0	0	0	0
	Others	832	22037	17981	1411	8958	5574	1186	885	2103	0	688	0
	Total	**74874**	**806279**	**634712**	**177802**	**1736885**	**388319**	**151801**	**134483**	**106221**	**120238**	**68814**	**9909**

Month: July 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	0	0	0	0	0	19038	9406	21383	8230	18998	4688
Cnidaria	Hydromedusae	0	0	0	0	0	0	2644	4389	12380	7681	5896	5540
	Scyphozoan Larvae	655	0	0	0	0	0	0	627	0	549	0	852
Ctenophora	Ctenophores	0	0	0	0	0	0	1586	1881	0	0	655	1705
Chaetognatha	Chaetognaths	0	0	0	0	0	0	2115	3762	1125	1097	4586	5114
Annelida	Polychaetes	0	0	0	3304	0	0	0	627	1125	1097	1310	426
Arthropoda	Barnacle Larvae	1310	0	1071	0	0	0	43364	5016	5627	2743	5896	6818
	Ostracods	0	10814	2141	2832	3990	1330	1058	627	3376	3292	6551	1278
	Cladocerans	2620	5089	5353	2832	4988	4655	0	0	0	0	0	0
	Copepods	91716	57251	186275	58523	53868	117046	124274	238900	129426	440022	254838	282531
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	2620	1908	1071	1416	0	665	0	0	0	0	0	0
	Lucifers & Larvae	655	0	0	0	0	0	7932	15049	10129	31822	17033	18750
	Shrimps & Larvae	0	1272	0	472	1995	0	1058	2508	0	0	655	852
	Crabs & Larvae	2620	25445	7494	4720	4988	6650	1058	4389	5627	2743	7861	2983
Mollusca	Gastropods	3931	19720	19270	5664	5985	8645	2644	1254	0	3292	1965	852
	Bivalves	0	636	1071	472	1995	0	529	2508	3376	2743	5896	1705
Urochordata	Larvaceans	0	0	0	0	0	0	0	0	0	0	655	0
Chordata	Fish Larvae & Juvenile	0	0	0	1416	0	665	529	0	0	0	0	852
	Eggs	0	0	0	0	0	0	1586	1254	0	0	0	0
	Others	1310	3817	2141	472	1995	665	3173	627	9004	37857	16378	2557
	Total	**107438**	**125952**	**225885**	**82121**	**79804**	**140323**	**212587**	**292825**	**202580**	**543169**	**349174**	**337503**

Appendix 6. (Cont.)
Month: August 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	0	0	0	0	0	0	2552	4209	593	5434	6096
Cnidaria	Hydromedusae	424	0	0	410	0	0	686	510	0	0	0	1829
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	0	363	0	0	0	0	1372	0	601	593	0	0
Chaetognatha	Chaetognaths	0	725	0	820	2232	1488	686	2042	0	0	0	1219
Annelida	Polychaetes	0	0	0	0	0	0	0	0	601	0	0	0
Arthropoda	Barnacle Larvae	424	0	542	0	744	744	0	0	601	0	418	0
	Ostracods	424	1088	0	410	1860	0	0	0	0	0	418	0
	Cladocerans	0	0	0	0	0	0	0	0	0	0	0	0
	Copepods	368042	488983	68819	455333	143580	146184	35663	76046	190601	160148	5852	37796
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	0	0	271	410	1488	0	0	0	1203	0	0	0
	Lucifers & Larvae	11435	7618	7586	6563	1488	1488	1372	5614	601	11270	836	1219
	Shrimps & Larvae	0	0	0	0	372	744	0	510	601	1779	0	0
	Crabs & Larvae	19482	5078	0	8204	372	1860	4115	510	1203	593	0	610
Mollusca	Gastropods	0	0	0	0	372	372	0	0	0	0	0	0
	Bivalves	1271	5441	271	3692	6323	1860	0	510	7215	593	0	1219
Urochordata	Larvaceans	0	0	0	0	0	0	0	0	0	0	0	0
Chordata	Fish Larvae & Juvenile	2541	363	0	410	0	372	0	0	0	0	418	0
	Eggs	3388	1451	1626	410	3348	3720	0	0	0	0	0	0
	Others	0	0	0	0	0	0	0	510	0	593	0	0
	Total	**407430**	**511111**	**79115**	**476664**	**162179**	**158831**	**43892**	**88806**	**207437**	**176163**	**13377**	**49989**

Month: September 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	0	0	0	0	0	940	5361	5477	5477	15462	1248
Cnidaria	Hydromedusae	0	0	0	0	0	0	705	2011	2054	0	910	0
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	0	0	0	0	0	0	2114	6702	0	0	0	0
Chaetognatha	Chaetognaths	0	0	1158	0	0	0	352	0	0	0	0	0
Annelida	Polychaetes	0	0	579	0	568	0	235	670	0	0	0	2497
Arthropoda	Barnacle Larvae	0	0	0	0	0	0	8223	9382	4792	2738	0	11235
	Ostracods	1540	29089	55563	30449	27854	21037	0	0	0	0	0	3745
	Cladocerans	0	0	0	0	0	0	0	0	0	0	0	0
	Copepods	347596	386387	1135569	860182	561625	308918	11394	65676	30806	23960	50023	74901
	Isopods	513	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	0	14819	579	11764	2274	40968	117	670	0	0	0	0
	Lucifers & Larvae	3081	4940	8103	2076	17053	7197	117	0	0	0	0	0
	Shrimps & Larvae	513	0	579	692	1137	554	352	9382	1369	685	1819	1248
	Crabs & Larvae	3594	4940	2315	8996	3979	2214	587	29487	4792	6846	5457	3745
Mollusca	Gastropods	0	0	0	0	0	0	0	0	0	0	0	0
	Bivalves	0	4940	11576	13148	3411	17162	117	670	1369	2054	4548	14980
Urochordata	Larvaceans	0	0	0	0	0	0	0	2011	6161	2054	2729	1248
Chordata	Fish Larvae & Juvenile	1027	549	579	3460	2842	1661	117	2011	1369	1369	910	1248
	Eggs	1027	2195	579	0	0	0	0	670	2054	0	910	16229
	Others	1027	2744	5788	5536	3979	5536	0	0	0	685	910	2497
	Total	**359918**	**450601**	**1222965**	**936305**	**624722**	**405248**	**25372**	**134704**	**60243**	**45867**	**83675**	**134822**

Appendix 6. (Cont.)

Month: October 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	0	535	539	0	2558	23178	2046	15163	2312	57821	415	4363
Cnidaria	Hydromedusae	0	535	0	0	0	464	230689	88013	143328	1644276	307462	674496
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	520	0	539	1262	512	1391	89514	6263	63188	10841	65144	169279
Chaetognatha	Chaetognaths	0	0	0	631	0	0	0	0	0	0	415	8726
Annelida	Polychaetes	0	0	0	0	2046	464	2558	659	1541	3614	2904	129140
Arthropoda	Barnacle Larvae	1041	535	539	0	1023	464	126342	36260	73205	607117	154353	383058
	Ostracods	520	1604	0	12624	0	0	6650	4285	3082	28910	3734	34903
	Cladocerans	0	0	0	0	0	0	6138	330	1541	18069	7469	13961
	Copepods	17176	54524	8631	71328	9207	6026	306392	206023	416114	1409379	384639	1838505
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	0	2673	0	0	0	0	0	0	0	0	0	0
	Lucifers & Larvae	2082	2138	3236	631	512	2318	3069	330	1541	0	830	2618
	Shrimps & Larvae	0	0	0	1894	0	0	3581	6922	3853	39752	1660	6108
	Crabs & Larvae	3123	6415	1079	5050	1023	2781	107416	480611	137934	5344800	130702	93365
Mollusca	Gastropods	0	0	539	631	1535	0	0	989	771	3614	415	11343
	Bivalves	2602	18709	539	121194	7673	1854	512	330	771	3614	830	15706
Urochordata	Larvaceans	0	0	0	0	0	0	9207	989	16182	0	70538	76786
Chordata	Fish Larvae & Juvenile	0	0	0	631	512	0	1023	330	0	0	415	12216
	Eggs	3643	5880	1618	1262	0	3708	0	0	0	0	0	0
	Others	520	535	0	1262	0	0	1535	1319	2312	10841	830	3490
	Total	**31229**	**94080**	**17261**	**218402**	**26598**	**42647**	**896671**	**848817**	**867674**	**9182648**	**1132754**	**3478063**

Month: November 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	E1	B2	E2	B3	E3	B1	E1	B2	E2	B3	E3
Protozoa	Foraminiferans	756	994	0	0	0	274	4222	482	49516	1712	1121	30299
Cnidaria	Hydromedusae	33657	11931	17286	31799	44783	37807	844	3371	3032	856	0	7313
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	50675	23861	11007	17612	52159	42464	0	963	2021	0	0	2090
Chaetognatha	Chaetognaths	28363	17399	15818	8317	46363	24383	844	963	1011	856	0	4179
Annelida	Polychaetes	3025	1988	652	2691	1581	1918	1689	482	1011	0	2242	4179
Arthropoda	Barnacle Larvae	114964	88983	31147	85125	56900	92874	11822	14447	15158	6849	2242	33433
	Ostracods	1891	497	82	1468	3161	1370	0	0	0	0	0	6269
	Cladocerans	0	0	0	245	0	0	0	0	0	0	0	0
	Copepods	760880	190891	257249	114722	599033	807372	182392	632311	196041	308209	40347	682240
	Isopods	0	0	0	0	0	0	0	0	0	0	0	0
	Amphipods	0	0	0	0	0	0	0	0	1011	0	1121	3134
	Lucifers & Larvae	57482	30324	35061	35713	48471	150680	844	963	0	0	2242	3134
	Shrimps & Larvae	1891	2486	2528	489	1054	12876	0	2408	0	4281	1121	0
	Crabs & Larvae	24959	6960	8235	9295	13171	50683	21955	45268	83873	106161	11208	181791
Mollusca	Gastropods	1135	0	245	978	1054	822	0	0	0	0	0	0
	Bivalves	756	1491	245	1712	527	548	4222	1445	9095	0	3362	53284
Urochordata	Larvaceans	1513	3480	6523	2691	7903	3562	0	6742	1011	12842	1121	12537
Chordata	Fish Larvae & Juvenile	3025	497	978	245	527	1918	0	482	1011	0	1121	0
	Eggs	756	994	734	0	1581	274	4222	2408	5053	2568	3362	5224
	Others	1891	5965	1142	2691	4215	6027	844	482	0	2568	1121	3134
	Total	**1087620**	**388742**	**388931**	**315792**	**882480**	**1235852**	**233901**	**713216**	**368841**	**446904**	**71729**	**1032241**

Appendix 6. (Cont.)
Month: December 2000

Phyla	Taxa	Chon Buri						Phetchaburi					
		B1	**E1**	**B2**	**E2**	**B3**	**E3**	**B1**	**E1**	**B2**	**E2**	**B3**	**E3**
Protozoa	Foraminiferans	452	3397	0	398	0	4208	0	524	485	0	8285	3328
Cnidaria	Hydromedusae	3617	2912	1541	2784	1230	1202	0	2619	0	1290	0	525
	Scyphozoan Larvae	0	0	0	0	0	0	0	0	0	0	0	0
Ctenophora	Ctenophores	0	0	514	0	0	601	0	0	0	0	0	0
Chaetognatha	Chaetognaths	6781	1456	24650	3977	2870	9016	74052	14140	16014	16771	40786	13662
Annelida	Polychaetes	0	971	514	795	0	601	0	0	485	0	1275	175
Arthropoda	Barnacle Larvae	53347	42219	60084	16704	13121	28852	2885	524	1941	0	3186	525
	Ostracods	0	0	0	0	0	2404	0	1571	0	0	0	0
	Cladocerans	18084	19411	514	13522	13531	4208	0	0	0	0	0	0
	Copepods	64649	48042	82680	40168	21322	90762	515481	206341	84922	268343	153585	116473
	Isopods	0	0	0	0	0	0	0	0	0	645	0	0
	Amphipods	904	0	0	398	410	0	1923	30375	0	3225	637	0
	Lucifers & Larvae	58320	62115	26704	26646	13941	49889	10579	2619	5338	2580	3824	3503
	Shrimps & Larvae	904	971	1027	398	1230	1202	10579	12045	3882	4515	15932	2102
	Crabs & Larvae	8138	11647	26191	4772	5740	108794	14426	1571	0	0	1275	876
Mollusca	Gastropods	2260	1456	0	1193	0	2404	962	1047	0	0	0	0
	Bivalves	452	971	514	795	0	0	0	10998	0	1290	3186	0
Urochordata	Larvaceans	1808	9220	12325	7954	15581	28250	0	0	485	1290	0	0
Chordata	Fish Larvae & Juvenile	452	971	514	0	410	1202	0	0	485	0	0	0
	Eggs	4521	8735	16947	6761	10251	7814	1923	3142	2912	1290	637	5079
	Others	452	2912	1027	3182	0	0	962	41897	485	4515	3186	350
	Total	**225141**	**217401**	**255743**	**130447**	**99639**	**341410**	**633773**	**329413**	**117436**	**305756**	**235795**	**146598**

VITAE

Miss Nontivich Tandavanitj was born in Bangkok, Thailand, on December 2, 1972. She had received a Bachelor of Science degree in General Biology from the University of California, San Diego.