SEXUAL REPRODUCTION OF A SOFT CORAL, CLADIELLA TUBEROSA TIXIER-DURIVAULT (CNIDARIA : ANTHOZOA : ALCYONACEA), IN CORAL COMMUNITIES IN THE INNER AND THE EASTERN GULF OF THAILAND

PARNHATHAI NOBCHINWONG

A THESIS PRESENTED TO RAMKHAMHAENG UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE
(BIOLOGY)
2001

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73/1 ถนนพระรามที่ 6 เขตราชเทวี
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การสืบพันธุ์แบบอาศัยเพศของปะการังอ่อน *Cladiella tuberosa* Tixier-Durivault บริเวณกลุ่มปะการังอ่าวไทยตอนในและอ่าวไทยฝั่งตะวันออก

ปานหทัย นพชินวงศ์

วิทยานิพนธ์เสนอต่อมหาวิทยาลัยรามคำแหง
เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญา
วิทยาศาสตรมหาบัณฑิต (ชีววิทยา)
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ABSTRACT

Thesis Title : Sexual Reproduction of a Soft Coral, *Cladiella tuberosa* Tixier-Durivault (Cnidaria: Anthozoa: Alcyonacea), in Coral Communities in the Inner and the Eastern Gulf of Thailand
Student's Name : Miss Parnhathai Nobchinwong
Degree Sought : Master of Science
Major : Biology
Academic Year : 2001
Advisory Committee :

1. Dr. Thamasak Yeemin Chairperson
2. Asst. Prof. Dr. Sutat Subinprasert
3. Assoc. Prof. Dr. Pongpan Kongtong
4. Assoc. Prof. Supawadee Chullasorn

The alcyonacean is a very important member of coral communities in the Gulf of Thailand. Sexual reproduction of a soft coral, *Cladiella tuberosa* Tixier-Durivault, was studied in coral communities of Khang Khao Island, Chonburi Province, in the Inner Gulf of Thailand and Samet Island, Rayong Province, in the Eastern Gulf of Thailand during September 1998 – September 2000. Monthly sampling of tagged colonies and microtechnique analysis of histological samples in the laboratory were carried out. *C. tuberosa* was a

Thesis Title	Sexual Reproduction of a Soft Coral, *Cladiella tuberosa* Tixier-Durivault (Cnidaria: Anthozoa: Alcyonacea), in Coral Communities in the Inner and the Eastern Gulf of Thailand	
Student's Name	Miss Parnhathai Nobchinwong Department of Biology, Faculty of Science	
Advisory Committee	Dr. Thamasak Yeemin	Chairperson
	Asst. Prof. Dr. Sutat Subinprasert	

Ramkhamhaeng University approved this thesis as a partial fulfillment of the requirement for the degree of Master of Science (Biology)

.... Dean of Graduate School

(Assoc. Prof. Dr. Suraphol Rajbhandaraks)

Examination Committee

..........................Thamasak Yeemin.......................... Chairperson

(Dr. Thamasak Yeemin)

.... Member

(Asst. Prof. Dr. Sutat Subinprasert)

.... Member

(Assoc. Prof. Dr. Pongpan Kongtong)

.... Member

(Assoc. Prof. Supawadee Chullasorn)

gonochoric species, whose male and female colonies were separated. Several developmental stages of oocytes were found in each sampling period. Mature oocytes of *C. tuberosa* were 500-625 μm in diameter. Fecundity greatly varied in each polyp. Spermatocytes began to develop near the spawning period. Which occurred in July – September. Severe coral bleaching phenomenon in the Gulf of Thailand during April-May 1998, the interrupted gametogenesis of *C. tuberosa* for several months. Moreover, partial mortality of several colonies was obviously recorded. Recovery patterns of gonadal development of the soft corals from the two study sites were outstandingly different due to certain environmental factors, such as turbidity, sedimentation rate and population structures.

บทคัดย่อ

ชื่อเรื่องวิทยานิพนธ์ : การสืบพันธุ์แบบอาศัยเพศของปะการังอ่อน *Cladiella tuberosa* Tixier-Durivault ในชุมชนปะการังอ่าวไทยตอนในและอ่าวไทยฝั่งตะวันออก
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1. ดร.ธรรมศักดิ์ ยีมิน ประธานกรรมการ
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3. รองศาสตราจารย์ ดร.พงศ์พันธุ์ กองทอง
4. รองศาสตราจารย์สุภาวดี จุลละศร

ปะการังอ่อนเป็นองค์ประกอบที่มีความสำคัญของบริเวณกลุ่มปะการังในอ่าวไทย การศึกษาการสืบพันธุ์แบบอาศัยเพศของปะการังอ่อน *Cladiella tuberosa* Texier-Durivault ในบริเวณกลุ่มปะการังของเกาะค้างคาว จังหวัดชลบุรี ซึ่งอยู่ในบริเวณอ่าวไทยตอนใน และที่เกาะเสม็ด จังหวัดระยอง ในบริเวณอ่าวไทยฝั่งตะวันออก ในช่วงเดือนกันยายน 2541 ถึงเดือนกันยายน 2543 โดยทำการเก็บตัวอย่างโคโลนีที่ทำเครื่องหมายไว้ทุกเดือนและทำการวิเคราะห์เนื้อเยื่อด้วยระเบียบวิธีทางไมโครเทคนิคในห้องปฏิบัติการ จากการศึกษาพบว่าโคโลนีปะการังอ่อน *C. tuberosa* มีการแยกเพศเป็นโคโลนีเพศผู้และโคโลนีเพศเมีย การศึกษาตัวอย่างที่เก็บมาในแต่ละครั้งพบว่าเซลล์ไข่จะมีการพัฒนาหลายระยะในโพลิปเดียวกัน เซลล์ไข่ที่พัฒนาเต็มที่จะมีขนาด 500-625 μm ความดกของไข่ในแต่ละโพลิปมีความแปรปรวนมาก เซลล์สืบพันธุ์เพศผู้จะเริ่มพัฒนา

ใกล้ช่วงที่มีการปล่อยเซลล์สืบพันธุ์ ในช่วงเดือนกรกฎาคมถึงเดือนตุลาคม ปรากฏการณ์ปะการังฟอกขาวอย่างรุนแรงที่เกิดขึ้นในอ่าวไทยช่วงเดือนเมษายน ถึงเดือนพฤษภาคม 2541 ส่งผลให้การสร้างเซลล์สืบพันธุ์ของปะการังอ่อน *C. tuberosa* หยุดชะงักเป็นเวลาหลายเดือน นอกจากนี้ยังสังเกตเห็นการตายเป็นบางส่วนของโคโลนีปะการังอ่อนอย่างชัดเจน รูปแบบการฟื้นตัวในการสร้างเซลล์สืบพันธุ์ของปะการังอ่อนจากทั้งสองบริเวณมีความแตกต่างกันอย่างชัดเจน เนื่องจากปัจจัยสิ่งแวดล้อมที่แตกต่างกัน เช่น ความขุ่น อัตราการตกตะกอน และโครงสร้างประชากร

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Parnhathai Nobchinwong

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CHAPTER 1

INTRODUCTION

Coral reefs are one of the most complex communities in the tropical ocean (Connell 1978, 1302-1319). The major components are scleractinain or hard corals and soft corals (e.g. Yamazato et al. 1981, 671). The soft corals of order Alcyonacea, especially their representatives of the family Alcyoniidae, are the major reef-dwelling and one widespread throughout the tropical Indo-Pacific region (Benayahu and Loya 1981, 514; Dinesen 1983, 229). In some areas, soft corals are even more abundant than hard corals, particularly in the area where the stony corals have been destroyed or devastated by certain limiting factors. In some occasions, the soft corals may cause a negative effect on stony coral growth and survirorship (Maida et al. 1995, 303-311). Sexual and asexual reproduction led their ways to easily occupy the spaces in coral communities.

Accordingly, the chemical substances isolated from soft corals can play a major role in pharmaceutical sciences (Yamada et al. 1997, 363-396; Rashid et al. 2000, 531). However, natural products were extracted from the tissue of soft corals, directly collected from the sea. Hence reproductive biology of soft coral is the first consideration for its ecology and cultivation. In Thailand, only a preliminary investigation on soft corals just began over the past decade but very little information was reported (i.e. Ukkrit Satapoomin and Sudara 1988, 27-31).

The fundamental data about sexual reproduction such as gametogenesis, the timing of spawning, fertilization, fecundity, development and recruitment of planulae are the essential information for management of living resources and rehabilitation in coral communities at present and in the future.

In the Gulf of Thailand, A soft coral, *Cladiella tuberosa* Tixier-Durivault, is a dominant species in the shallow zone of coral communities at 3-5 m in depth. This study intends to provide data on reproductive biology of a soft coral, *C. tuberosa* at Khang Khao Island and Samet Island, in the Inner and the Eastern Gulf of Thailand respectively. The study focuses on gametogenesis, fecundity, reproductive patterns, population density, distribution patterns and environmental factors that effected reproductive pattern of *C. tuberosa.*

Objectives

The major objectives of this study are as follows:

1. To study reproductive patterns of a soft coral, *C. tuberosa* in the coral communities in the Inner and the Eastern Gulf of Thailand.
2. To investigate the onset and releasing times of *C. tuberosa.*
3. To determine fecundity of *C. tuberosa* and its influencial effect, of major environmental factors.
4. To provide fundamental data for possible application on management of living resources in coral communities.

Hypothesis

A soft coral, *Cladiella tuberosa* Tixier – Durivault , is a gonochoric species, having separated male and female colonies. They release gametes into the water column all year round.

Scope of Research

This research concentrates on reproduction of a soft coral, *C. tuberosa* in the coral communities of the Inner and the Eastern Gulf of Thailand. Additionally, distribution patterns and certain ecological aspects of *C. tuberosa* are also studied in details in order to provide primarily biological data for future sustainable usage and management.

CHAPTER 2

LITERATURE REVIEW

Researches on soft corals (Cnidaria: Octocorallia) have been reported from all around the world, e.g. from the Red Sea, Papua New Guinea, Central Great Barrier Reef, Taiwan, the Gulf of Mexico, and the Caribbean Sea (Fishelson 1970, 106; Tursch and Tursch 1982, 321; Dinesen 1983, 229; Benayahu and Loya 1985, 255; Yang 1985, 273; Nelson et al. 1988, 791; Fabricius 1997, 159; Sânchez 1999, 215). Soft corals are important members of sessile marine invertebrates in tropical and temperate waters. They are the second most common benthos component in coral reefs of the Indo-Pacific and the Red Sea, in which their abundance can be higher than that of hard corals (Benayahu and Loya 1981, 514; Dinesen 1983, 229).

Competition for space among marine organisms has been reported by other previous studies, particularly between stony corals and soft corals (La Barre and Coll 1982, 119; Lasker et al. 1983, 173; Sammarco 1985, 199; Sammarco et al. 1983, 173; Aceret et al. 1995, 317; Maida et al. 1995, 303; Atrigenio and Aliño 1996, 179). The interaction was characterized by extensive deposition of undifferentiated aragonite by the scleractinian in the vicinity of the soft coral. Additionally, they release toxic compounds (diterpenes), which cause tissue necrosis and death in nearby scleractinian corals (Sammarco 1985, 199; Sammarco et al. 1983, 173).

Although metabolite compounds of the soft corals show toxic to the nearby stony corals, they display antimicrobial, antimalarial, antiviral, anticancer, HIV-inhibitory activity, etc. (Kanit Suwanborirux 1998, L-4; Kelman et al. 1998, 87; Chai et al. 2000, 843-844; Duh et al. 2000, 884-885; Rashid et al. 2000, 531-533). The Genus *Cladiella* such as *C. sphaeroides*, *C. kashmani*, and *C. tuberosa* have chemical substances, that are toxic to brine shrimps (Nisit Pisuithananta 1995, 1; Yamada et al. 1997, 393; Gray et al. 2000, 1551).

Major studies of soft corals are their reproductive biological aspects. There are several reports of soft corals in diverse regions, namely Australia, Israel, Japan, the Philippines, South Africa, and the USA (Yamazato et al. 1981, 671; Benayahu and Loya 1983, 353; Farrant 1986, 381; Bermas et al. 1992, 443; Kruger et al. 1998, 423). For many years, the sexual reproduction of octocorals was best known for only the boreal alcyonacean *Alcyonium digitatum* (Hartnoll 1975, cited by Benayahu et al. 1990, 323). Goldberg and Hamilton (1974, cited by Benayahu 1990, 323) stated that the sexual cycle, larval morphology and development of most octocorals demonstrated a remarkable similarities. Nevertheless, data accumulated in recent years suggested a variety of reproductive features among alcyonaceans. Benayahu et al. (1990, 324-327) summarized modes of reproduction of soft corals, i.e. brooding, external surface brooding, and broadcasting. The majority from the Alcyoniidae are gonochoric broadcast spawners like other octocorallians such as gorgonians (Brazeau and Lasker 1989, 1; Coma et al. 1995, 175) whereas the hermaphroditic brooders from the Xeniidae are rare.

The alcyonacean coral, *Lobophytum crassum* Marenzeller was studied in Okinawa by Yamazato et al. (1981, 671). It was a dioecious species. Gonads were borne on all mesenteries of a polyp except a pair of dorsal directives. The gonads reached mature size in May and June and the breeding took place in June.

In the Red Sea, several reports about reproduction of alcyonacean octocorals were recognized. *Parerythropodium fulvum fulvum* (Forskål, 1775) was an encrusting soft coral. It was also a dioecious species. Oocytes and sperm sacs are found even in very young colonies. Young oocytes appeared annually in August and reached their maximal diameter within 10-11 months. Sperm sacs started to develop later and mature after 7-9 months. Spawning occurred at dusk and was fully synchronized by lunar periodicity. Fertilization took place inside the polyp cavities (Benayahu and Loya 1983, 353). In 1984, Benayahu and Loya investigated the Red Sea soft coral *Xenia macrospiculata,* Gohar 1940 (Benayahu and Loya 1984, 32). They found that the population of *X. macrospiculata* started to reproduce at a markedly early age of two years and the percentage of sexually mature colonies increased along with coral size. In addition, the shallow and the deep *Sarcophyton glaucum* populations were examined (Benayahu and Loya 1986, 32). Sexual reproduction of the alcyonacean octocoral, *S. glaucum* was studied for a period of about four years. *S. glaucum* was a dioecious with gonads borne in the autozooids. Sex ratio of males and females in the *S. gluacum* was 1:1. Three to four years later, Benayahu et al. (1989, 203; 1990, 263) studied the soft coral *Heteroxenia fuscescens.* They observed polyp dimorphism and functional, sequential hermaphroditism and development of planulae within a mesogleal coat in the *H. fuscescens*. Mature eggs filled most of the gastrovascular cavity and fertilized eggs were very often observed in its basal part. Gametogenesis began at a remarkably early age. Gonads of *Dendronephthya hemprichi* at all developmental stages were found throughout the year by Dahan and Benayahu (1997b, 573-579).

Dinesen (1985, 89) observed life histories of the xeniid soft coral, *Efflatounaria* in central Great Barrier Reef. He found that *Efflatounaria* sp. was dioecious. Releasing of eggs occurred in early summer and was not fully synchronous but was largely epidemic. This soft coral propagated vegetatively by means of stolons which gave rise to daughter colonies. Egg releasing pattern of *Efflatounaria* was the same as *Capnella gaboensis*, i. e. not synchronous (Farrant 1986, 381).

Overlapping of soft coral spawning in the Philippines was studied by Bermas et al. (1992, 443). Cordes et al. (2001, 491) found that the deep-sea octocoral *Anthomastus ritteri* exhibited continuous reproduction, because, the mature gonads were presented all year-round. This pattern may represent overlapping seasonal cycles of oogenesis similar to that found by Kruger et al. (1998, 423)in the tropical alcyonacean, *Anthelia glauca.*

Chemically mediated attraction between the gametes has recently been reported for the soft coral (Coll et al. 1995, 137-143; Slattery et al. 1999, 75-84); besides fertilization success and reproductive output has depended on body size, population density, gamete dilution (Lasker and Stewart 1992, 476; Lasker et al. 1996, 45). Moreover, environmental factors were also affected reproductive biology and growth rate of soft corals (Riegl 1995, 517; Michalek-Wagner and Willis 2001a, 231; 2001b, 240).

Daughter colonies of soft corals from asexual reproduction augmented by means of fragmentation, fission, and autotomy in small-sized fragments (Lasker 1984, 261; 1988, 763). An autotomy event of azooxanthellat octocoral, *Dendronephthya hemprichi* was completed within only 2 days (Dahan and Benayahu 1997a, 5).

Larvae of the soft coral, *Alcyonium siderium*, usually settles and metamorphoses on vertical rock surfaces near the parent colony (Sebens 1983, 286). Larvae of *H. fuscescens* abled to metamorphose immediately upon release and tended to settle adjacent to the parent colonies as well (Ben-David Zaslow and Benayahu 1996, 55). Whereas the larvae of *L. crassum* took time sixteen days to settle and develop into polyps (Uehara 1987, 185). No significant differences existed for the competence or longevity of the zooxanthellate and azooxanthellate planulae of several species of soft corals (Ben-David-Zaslow and Benayahu 1998, 235).

CHAPTER 3

MATERIALS AND METHODS

Historical Background of the Materials

Taxa and description of *Cladiella tuberosa* Tixier – Durivault.

Kingdom : Animal
  Phylum : Coelenterata (Cnidaria)
    Class : Anthozoa (Actinozoa)
      Subclass : Alcyonaria (Octocorallia)
        Order : Alcyonacea
          Family : Alcyoniidae
            Genus : *Cladiella*
              Species : *tuberosa*

Characteristics of the Order Alcyonacea Lamouroux, 1812

1. There is a calcareous skeleton of spicules which may or may not become aggregated to form a continuous mass.
2. The coenenchyma is typically canaliferous, sclerite filled.
3. The colony is usually massive and flexible.
4. Lower part of polyp fuses to fleshly mass from which only oral are protruded, not axial.

The colonies of the Family Alcyoniidae are more or less fleshy colonies, membranous or massive, bush–like or tree–like, in the last cases with a barren basal part, the stalk, and a distal part bearing anthocodiae, the polyparium. Sclerite small (usually less than 1 mm long, but in some genera considerably more), mostly spindle–shaped but occasionally with club. Polyps monomorphic or dimorphic, retractile (Bayer 1995, 620)

Characteristic of the Genus *Cladiella* (Dai 1989, 66; Fabricius and Alderslade 2001, 84)

1. Colonies have monomorphic polyps.
2. Colonies are thick, massive, upper surface plicate of lobates: sclerites with complex warts.
3. All sclerites are very small and colourless.
4. Predominant sclerites are stout, thorny or spinose double stars (Figure 1-3); lobes of upper surface of colonies usually short and rounded.

Colonies of the soft coral, *Cladiella tuberosa*, are generally white, gray or pale brown when protracted (Figure 4). The rapid retraction of polyps upon disturbance results in a characteristic instantaneous color change from brown to white. The colony is flat and covering dead stony corals or rocks (Figure 5-6).

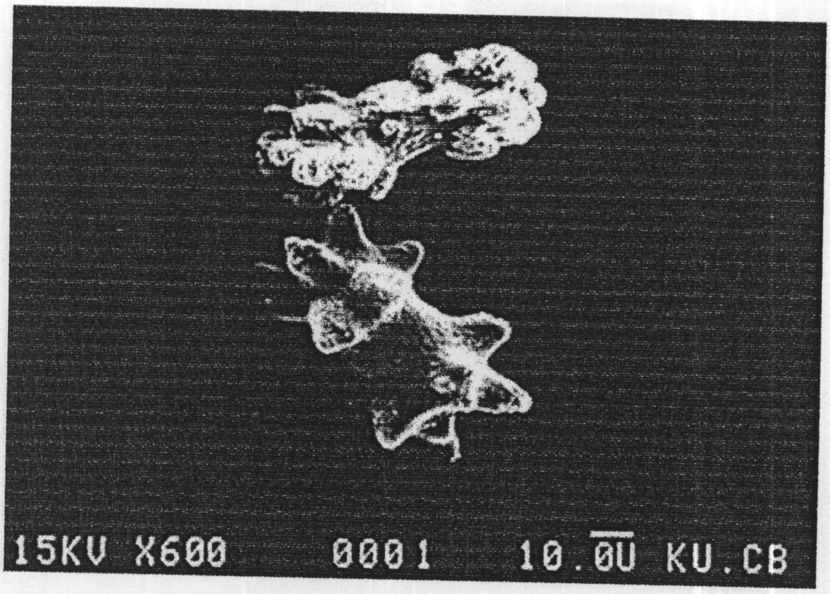

Figure 1 Sclerites from Cortex of Lobes of *C. tuberosa* Tixier – Durivault

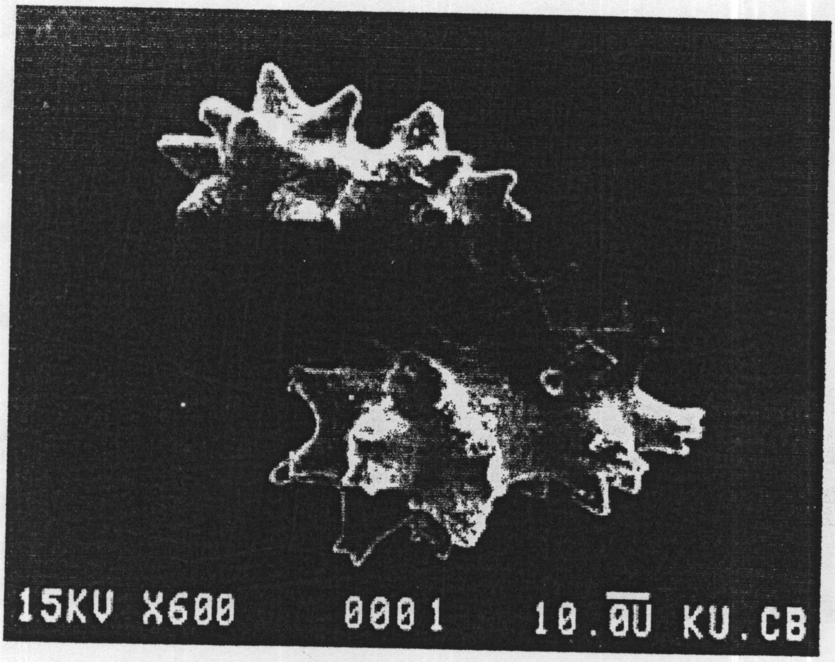

Figure 2 *C. tuberosa*: Sclerites from Interior of the Basal Stalk

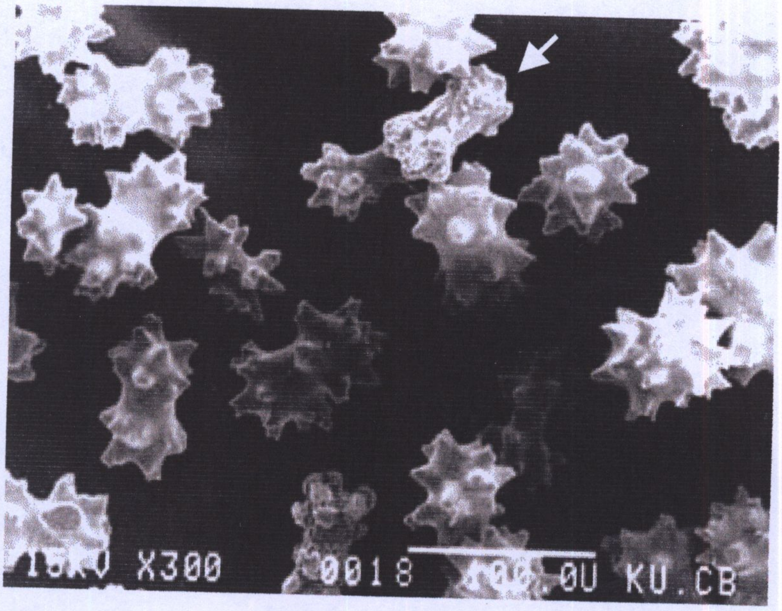

Figure 3 *C. tuberosa* : Sclerites from Cortex of Lobes (Arrow) and Interior of the Basal Stalk

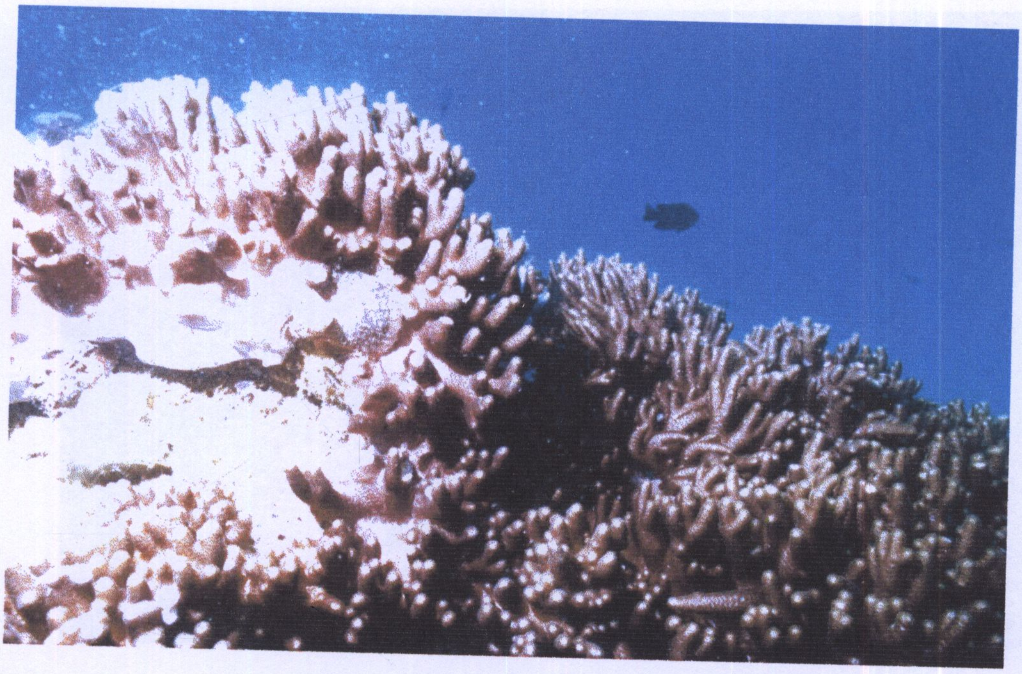

Figure 4 Brownish Retracted Colonies of the Soft Coral, *C. tuberosa*

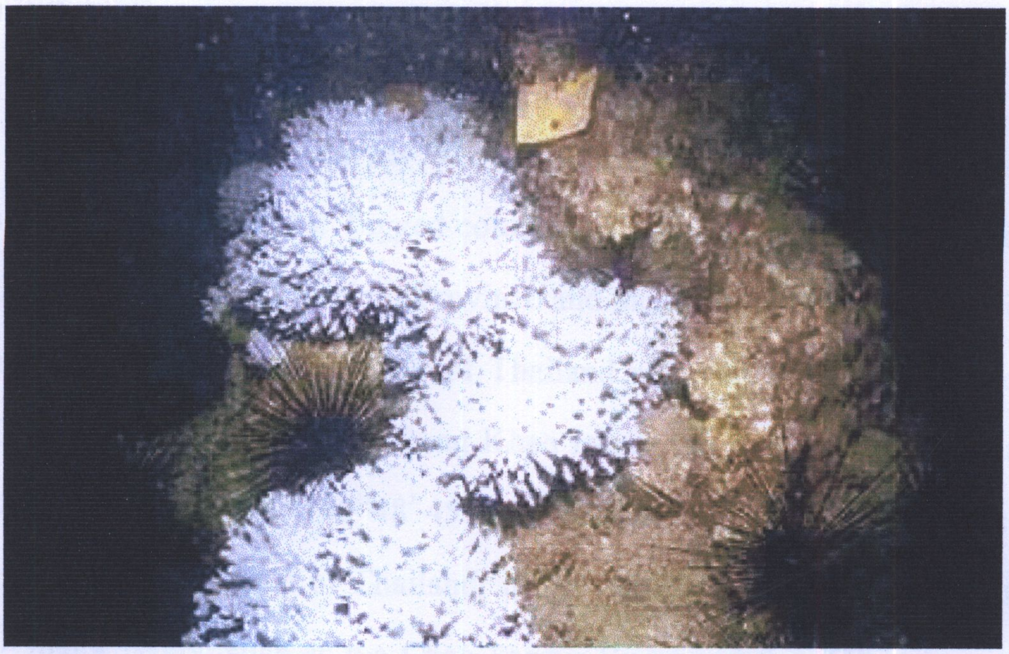

Figure 5 Colonies of *C. tuberosa* on Dead Coral

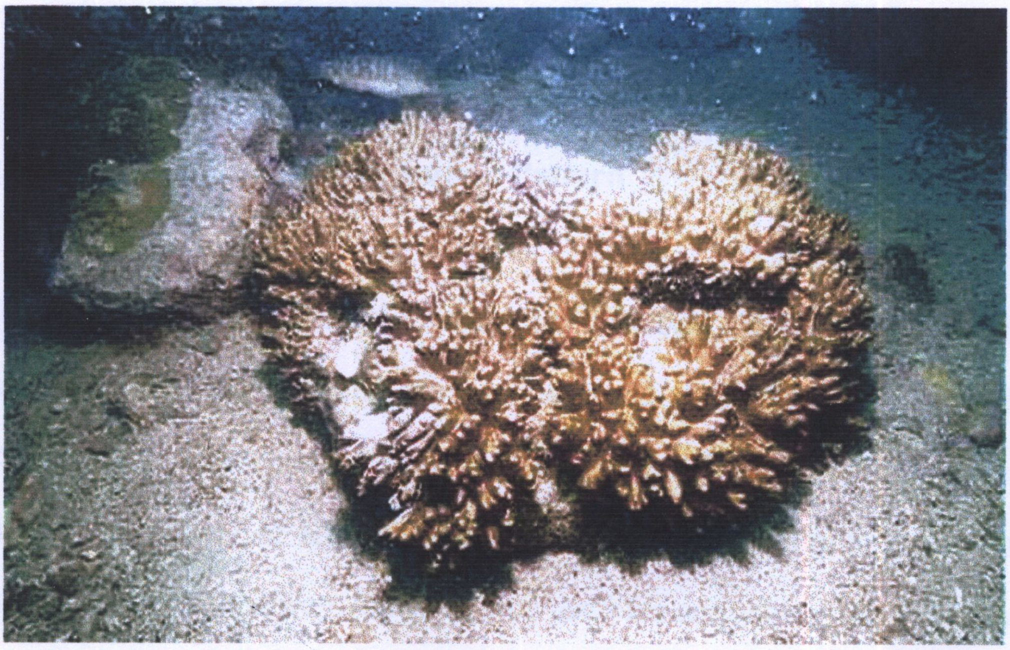

Figure 6 Colonies of *C. tuberosa* on the Rock

Study Sites

The preliminary survey was carried out to select the appropriate study sites by SCUBA divers. Tagged colonies of *C. tuberosa* were collected from Khang Khao Island, Chonburi Province and Samet Island, Rayong Province in the Inner and the Eastern Gulf of Thailand respectively, during September, 1998 to September, 2000. Khang Khao Island (latitude 13°06′24″ N to 13° 07′0″ N and longitude 100°48′ 45″ E to 100°49′ 0″ E; Figure 7) locates in the upper part of the Gulf of Thailand, influenced by runoff and sediment from the major rivers, such as the Chao Phraya River and the Bangpakong River. These factors resulted in low salinity and high turbidity than Samet Island, in the Eastern Gulf of Thailand (at latitude 12°34′7″ N and longitude 101°28′ 22″ E, Figure 8).

Population Density and Distribution Pattern

Population densities of *C. tuberosa* on coral communities of Khang Khao Island and Samet Island were investigated. The number of individuals of *C. tuberosa* was counted from thirty 1-m^2 quadrats randomly placed at station A, C, and D of Khang Khao Island and at Aow Look Yoan, Samet Island (Figure 9). Two-way ANOVA was used for analyzing mean population densities of *C. tuberosa* between Khang Khao Island and Samet Island. A standardized Morisita's Index of Dispersion (*Ip*) was used to ascertain the spatial distribution (Krebs 1999, 216-217).

Environmental Factors

Temperature

Surface Seawater Temperature (SST) of Khang Khao Island and Samet Island were detected during September 1998 – September 2000 by using a digital underwater thermometer.

Salinity

Salinity of seawater of Khang Khao Island and Samet Island were examined during September 1998 – September 2000 by using a digital underwater refractometer.

Gametogenesis

Histological Study

In order to examine the sequences of gamete development, histological sections of tagged colonies were prepared. Small pieces of *C. tuberosa* were collected from at least ten tagged colonies (Figure 10) at approximately monthly intervals between September, 1998 and September, 2000, from Khang Khao Island and Samet Island. The samples were fixed immediately in 10% formalin – seawater, decalcified in a 1: 1 solution of 10% acetic acid and 10% formalin (Yeemin 1988, 5-6). The tissue were washed for 24 hours in running water to remove formalin, then dehydrated through a graded series of ethanol: 70%, 80%, 90%, 95%, absolute 1, absolute 2 for 30 minutes, respectively. The samples were transferred to ethanol – xylene (1: 1), xylene1, xylene 2, for 30 minutes respectively, then passed to be impregnated in warm xylene – paraffin (1: 1), pure paraffin 1, pure paraffin 2 and finally embedded in pure paraffin in plastic blocks (Figure 11). The samples were cut into serial sections (10 µm thick, Figure 12), and stained with hematoxylin and eosin. Both transverse and longitudinal sections were then examined with a light microscope for reproductive structures.

Gamete Development and Fecundity

All *C. tuberosa* samples were preserved in 70% ethanol before observation. In order to determine fecundity of gametes by counting and measuring the diameter of all eggs and sperm sacs in 15 polyps using a binocular dissecting microscope fitted with an eyepiece micrometer. Polyps were chosen randomly. Oocytes diameters were converted to volumes (assuming gametes were sphearical). The average value of number of polyps per cm was used for the calculation of fecundity of each station. Fecundity of oocytes and sperm sacs was statistically analyzed by Two-way ANOVA (Zar 1999, 231).

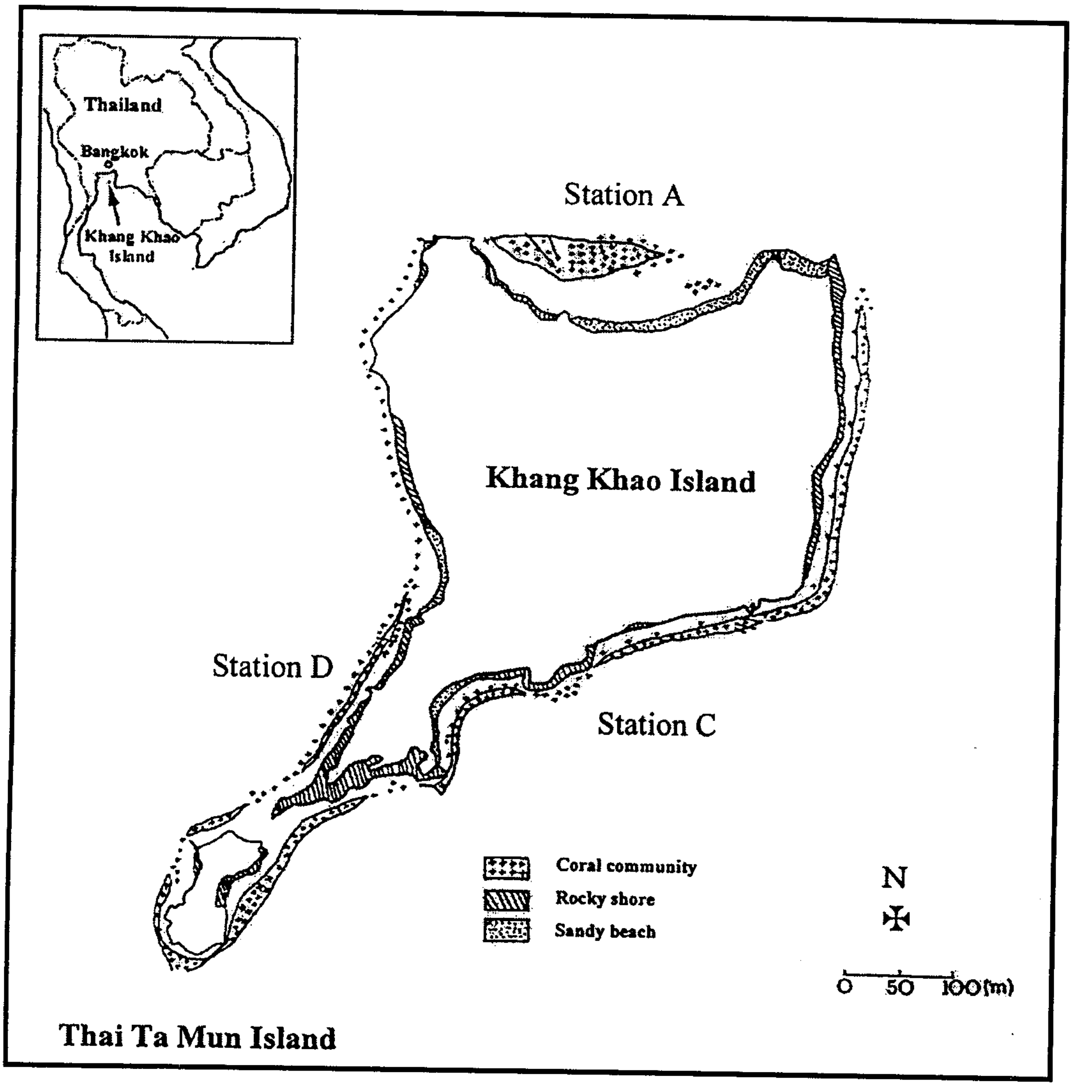

Figure 7 Map of the Study Sites at Khang Khao Island

Source: Yamazato, K., and T. Yeemin. 1986. Preliminary study on the inter- and intra-specific interaction among corals of Khang Khao Island, the Sichang Island, Gulf of Thailand. **Galaxea** 5: 163-174.

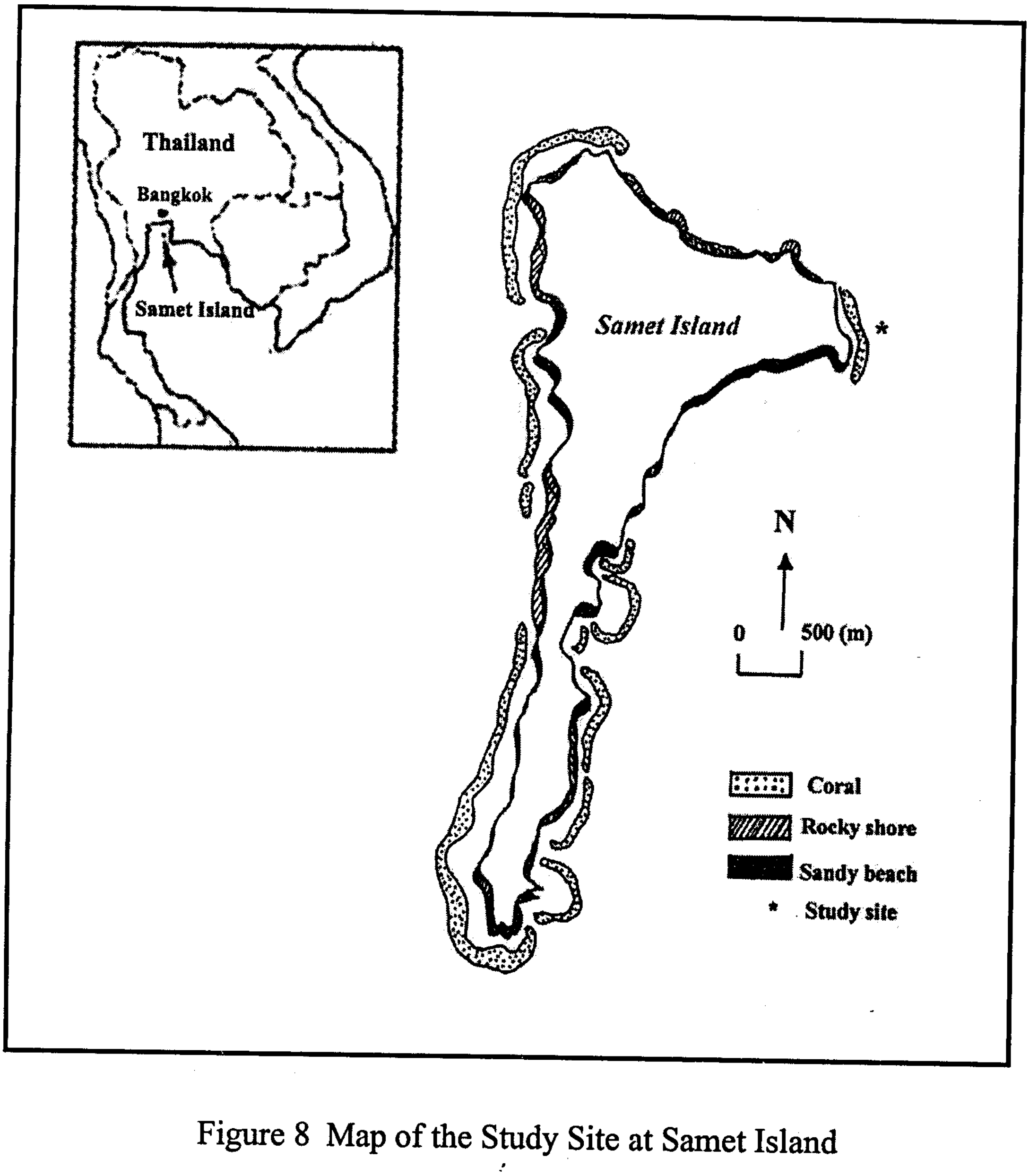

Figure 8 Map of the Study Site at Samet Island

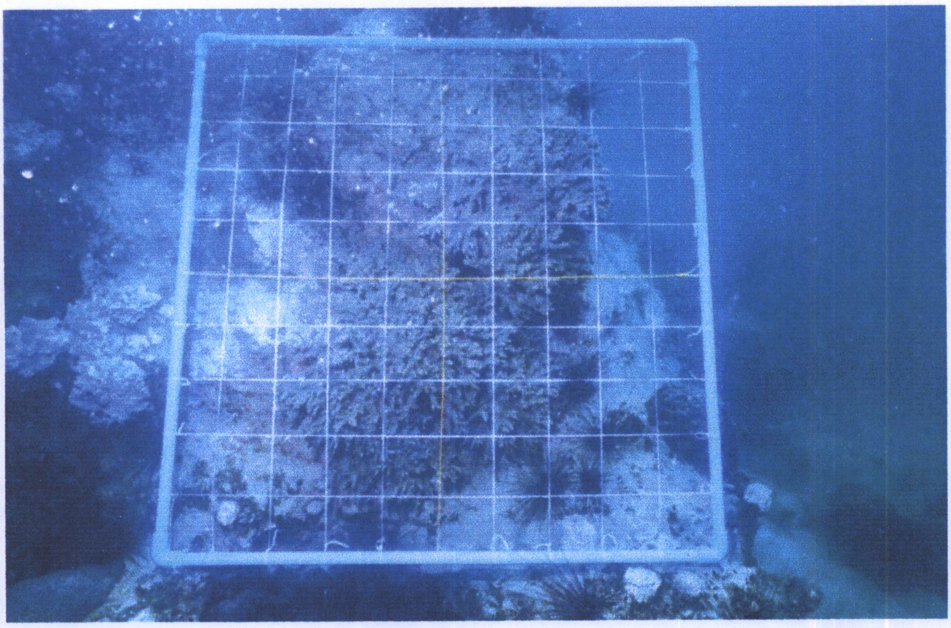

Figure 9 Random Quadrat Used to Examine Distribution Patterns of *C. tuberosa* at All Study Sites

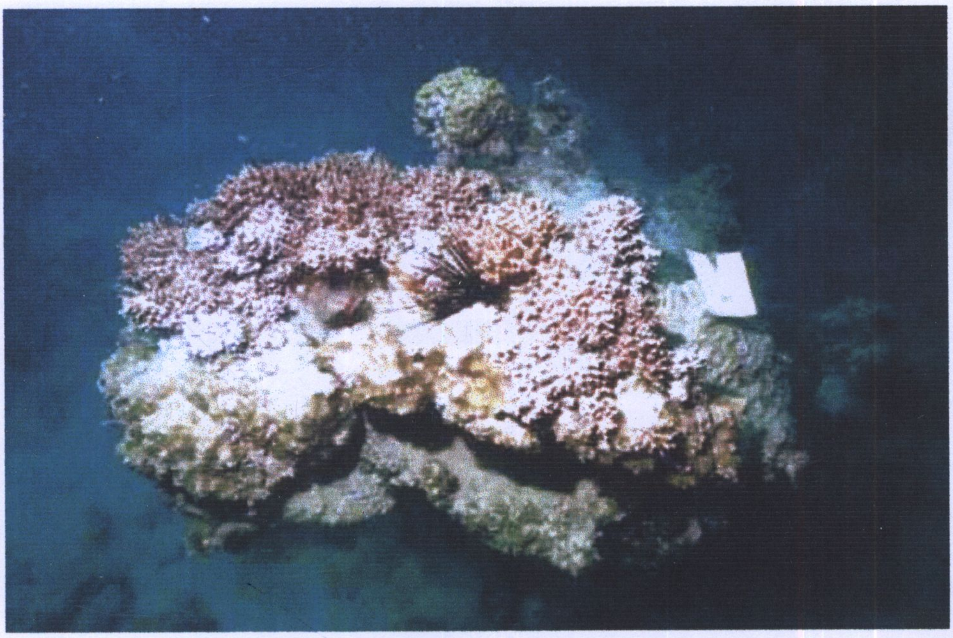

Figure 10 Tagged Colonies of *C. tuberosa* for Gametogenic Investigation

Figure 11 The Embedded Samples of *C. tuberosa* in Pure Paraffin before Serial Sections

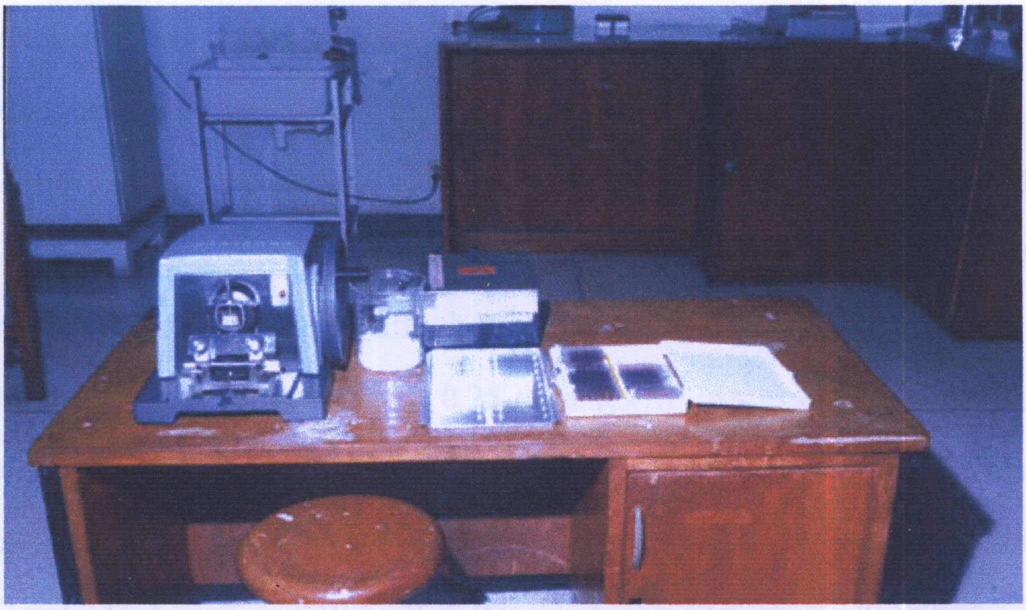

Figure 12 Gametogenesis Examination of *C. tuberosa* by Standard Microtechnique in the Laboratory

CHAPTER 4

RESULTS

Population Density and Distribution Patterns

Cladiella tuberosa Tixier-Durivault were observed in shallow water at 3-5 m in depth. *C. tuberosa* attached mostly on four types of substrate, i.e., hard corals (mostly on *Porites lutea*), rock, dead corals and other marine benthic organisms e.g., encrusting sponges (Figure 14-17) and zoanthids. *C. tuberosa* at Khang Khao Island seemed to grow on hard corals better than dead corals, rock and marine benthic organisms respectively, whereas those at Samet Island seemed to grow on dead corals better than hard corals, rock and marine benthic organisms respectively. Mean population densities of *C. tuberosa* on hard corals, dead corals, rock and marine benthos at Khang Khao Island were 6.5 ± 0.65 (mean ± SE), 5 ± 0.41, 3.25 ± 0.63 and 1.5 ± 0.87 colonies/m^2, respectively. While those at Samet Island were 0.5 ± 0.29, 1.25 ± 0.25, 0.25 ± 0.25 and 0.25 ± 0.25 colonies/m^2, respectively as shown in Figure 13. According to the statistical analysis, mean population densities of *C. tuberosa* at Khang Khoa Island and Samet Island were highly statistical different (Two-way ANOVA, $P < 0.001$). Mean population densities of *C. tuberosa* on the four substrates were significantly different (Two-way ANOVA, $P < 0.001$).

Dispersion patterns of *C. tuberosa* at Khang Khao Island were clumped (Standardized Morisita index, *Ip* > 0.5; Figure 18), while those at Samet Island were random distribution (*Ip* < 0.5; Figure19).

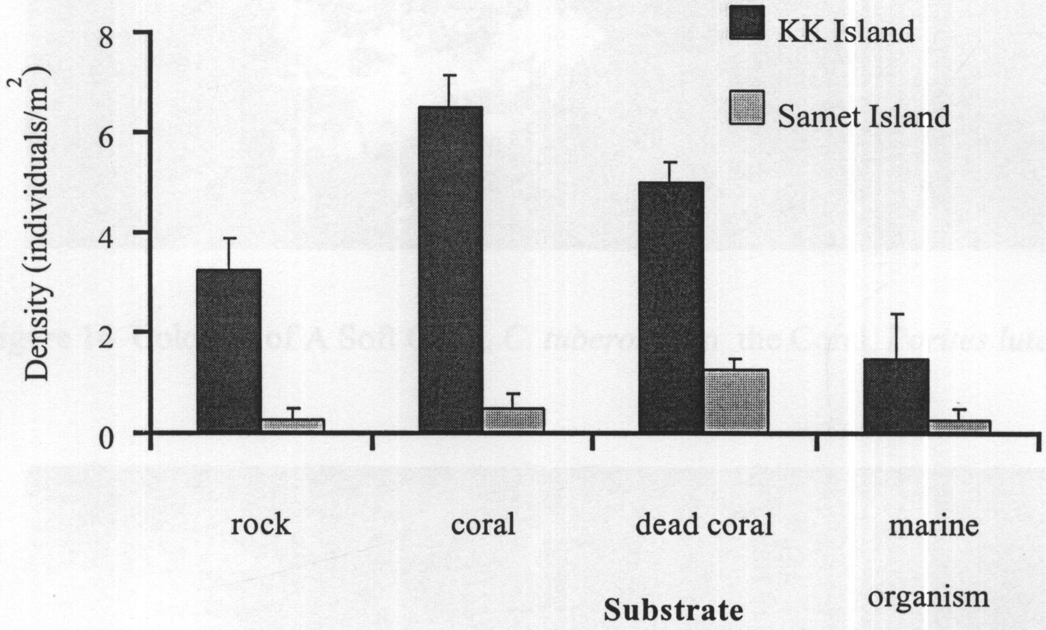

Figure 13 Mean Population Densities of *C. tuberosa* on Different Types of Substrates at Khang Khao Island (KK Island) and Samet Island

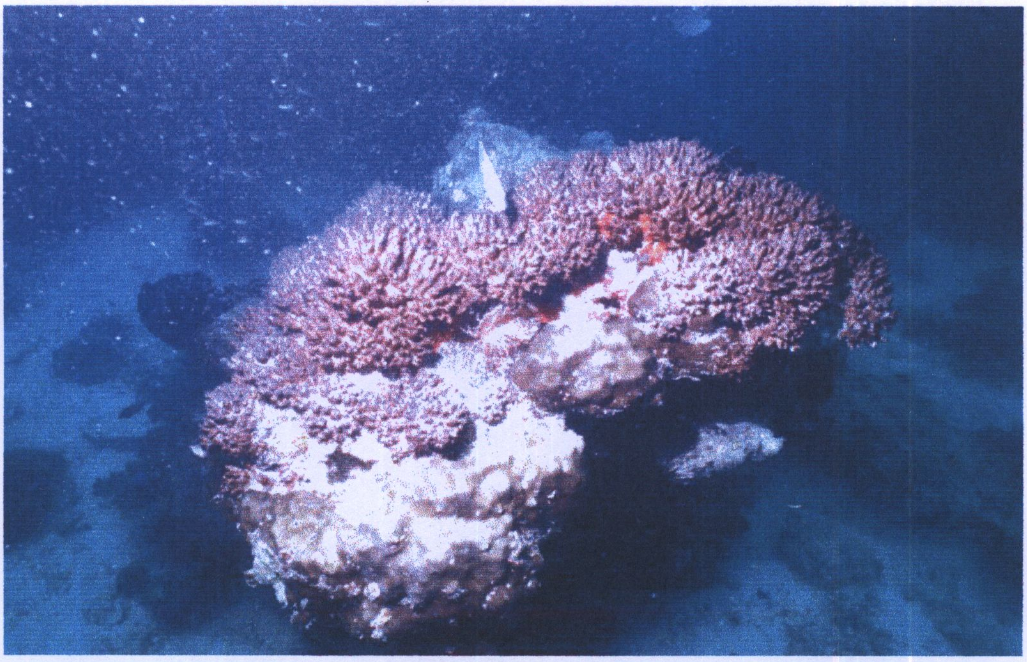

Figure 14 Colonies of A Soft Coral, *C. tuberosa*, on the Coral, *Porites lutea*

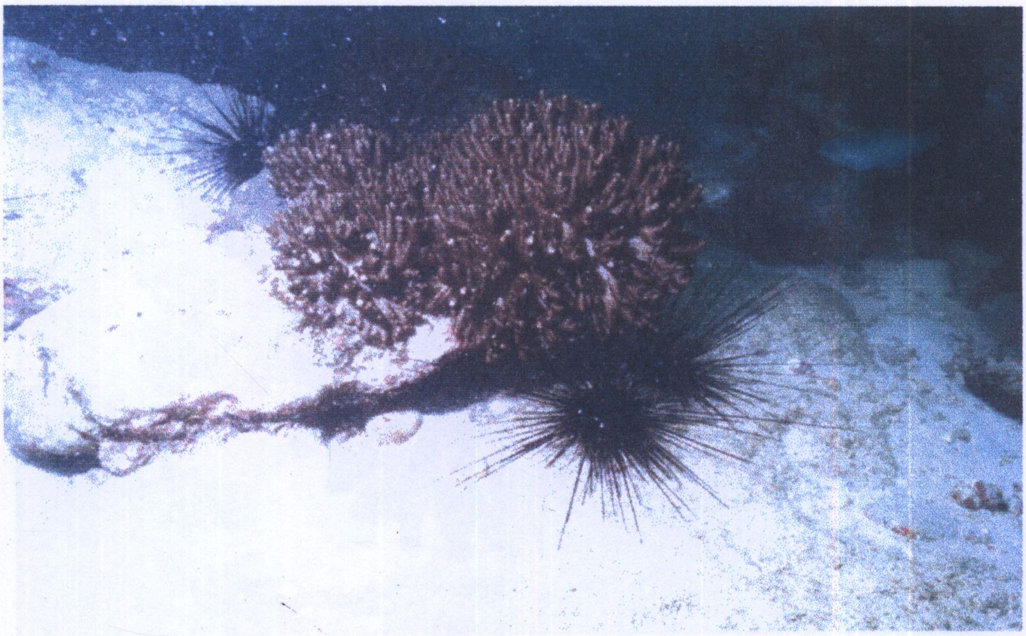

Figure 15 Colonies of *C. tuberosa* Growing on Rock

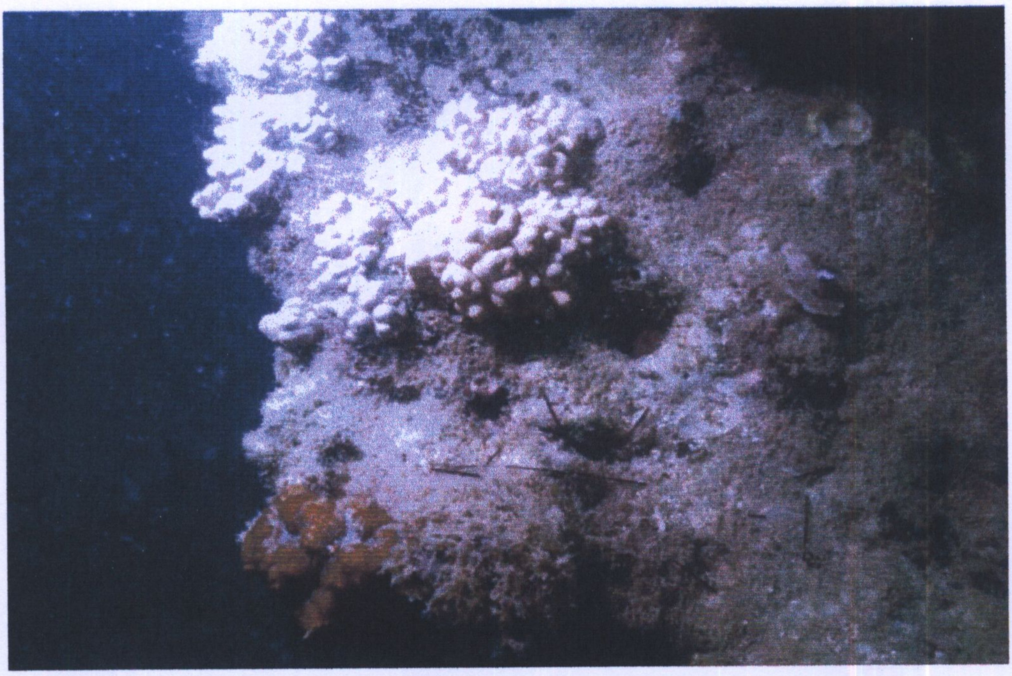

Figure 16 A soft Coral, *C. tuberosa* Growing on Dead Coral

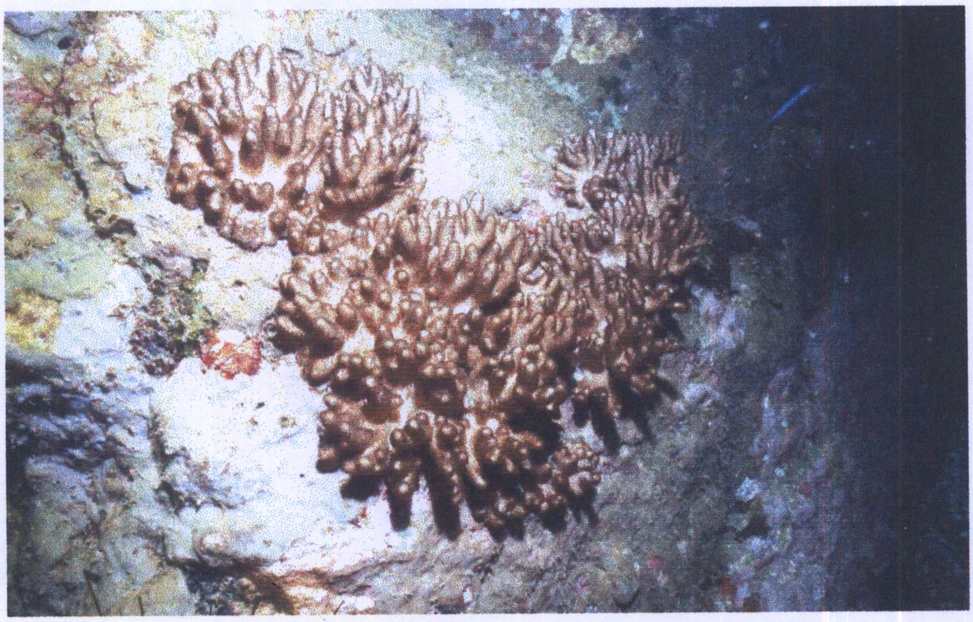

Figure 17 Colonies of A soft Coral, *C. tuberosa* on An Encrusting Sponge

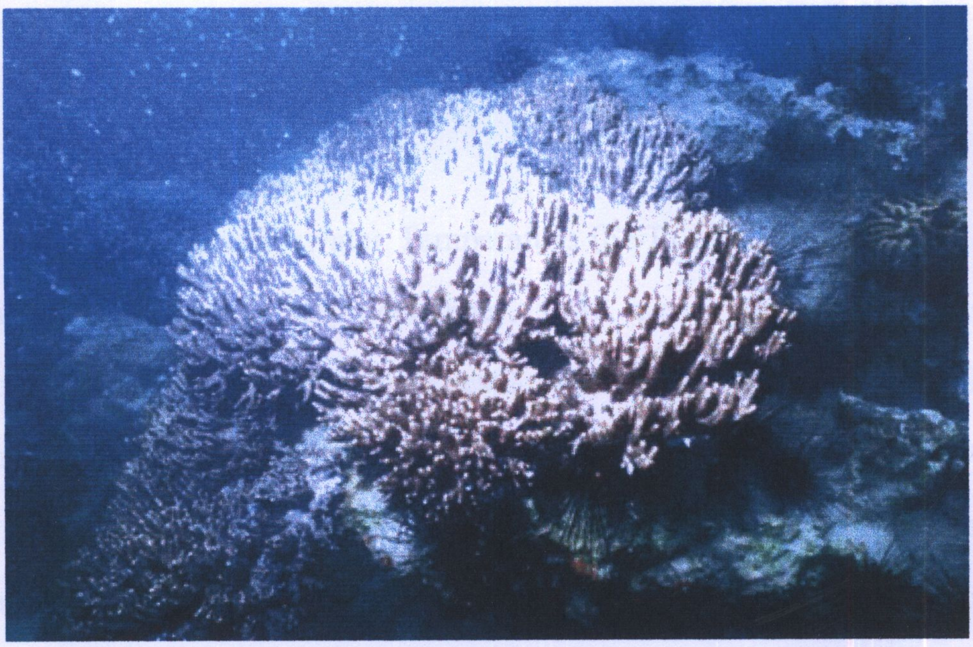

Figure 18 Clumped Distribution of *C. tuberosa* at Khang Khao Island

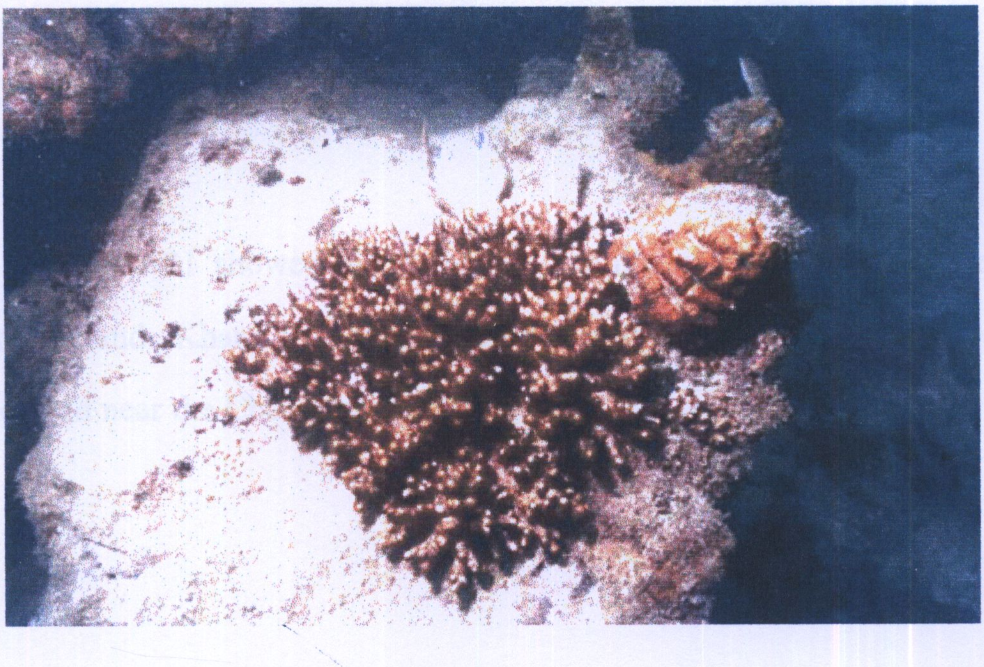

Figure 19 Random Distribution Pattern of *C. tuberosa* at Samet Island

Environmental Factors

Temperature

The Surface Seawater Temperature (SST) of Khang Khao Island and Samet Island during May-September, 1998 were higher than those after January, 1999 (Figure 20). These result caused the first severe coral bleaching phenomenon, affected by anomalous high temperature, in the Gulf of Thailand corresponding with the data of the NOAA (National Oceanic and Atmospheric Administration) (Figure 22). The soft coral, *C. tuberosa*, was affected by the bleaching phenomenon as well as some other marine invertebrates i.e., corals, sea anemones, sponges etc., (Figure 23). Moreover, the rest of gametogenesis was occurred by the abnormal increasing SST as follow the next parts.

Salinity

Figure 21 showed the maximum salinity of Khang Khao Island and Samet Island. Khang Khao Island had less salinity than Samet Island because it located near the Chao Phraya River mouth.

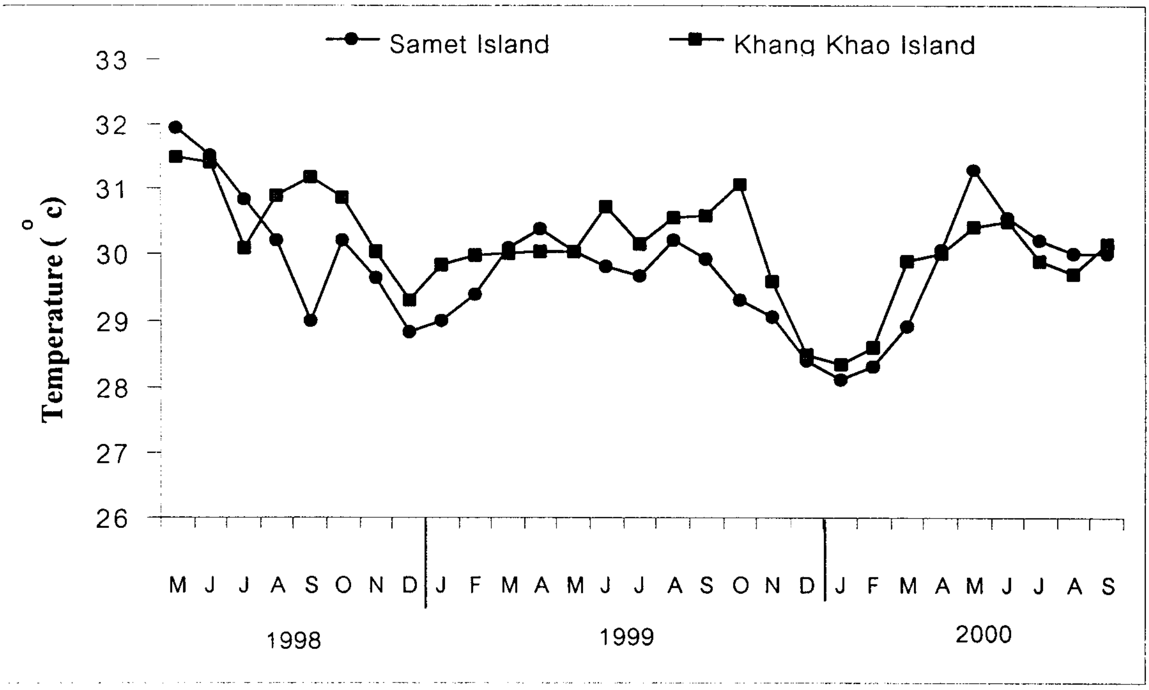

Figure 20 Maximum Temperature Between the Two Study Sites

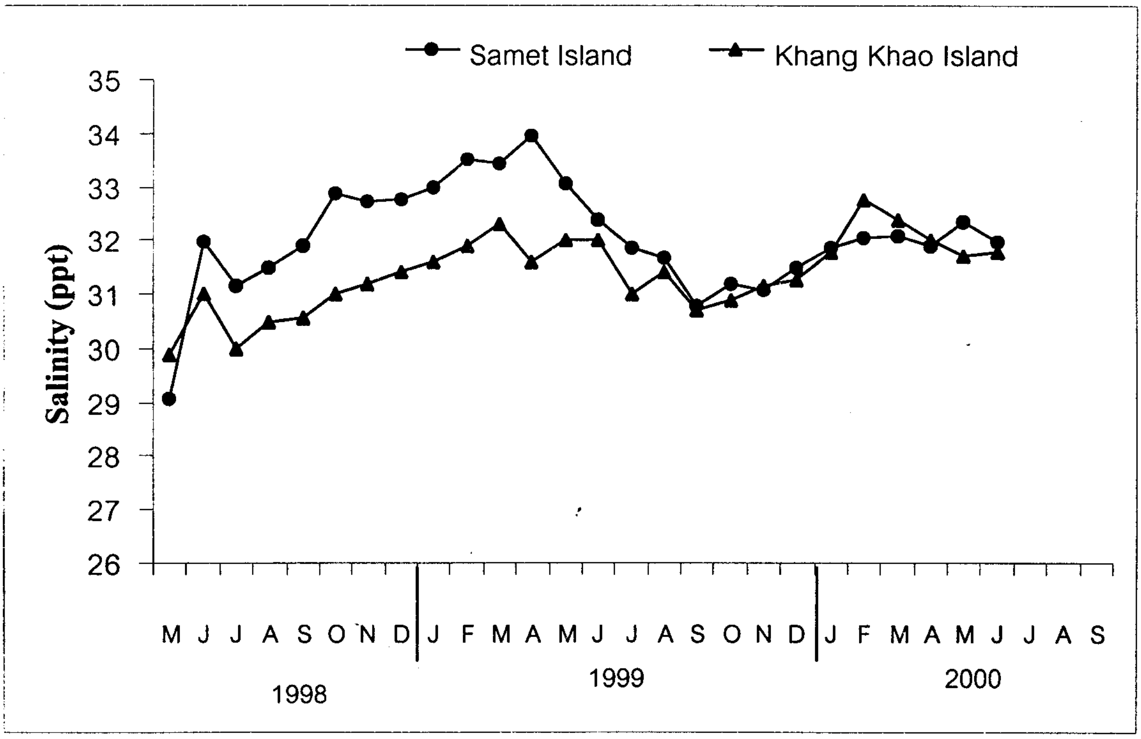

Figure 21 Maximum Salinity Between the Two Study Sites

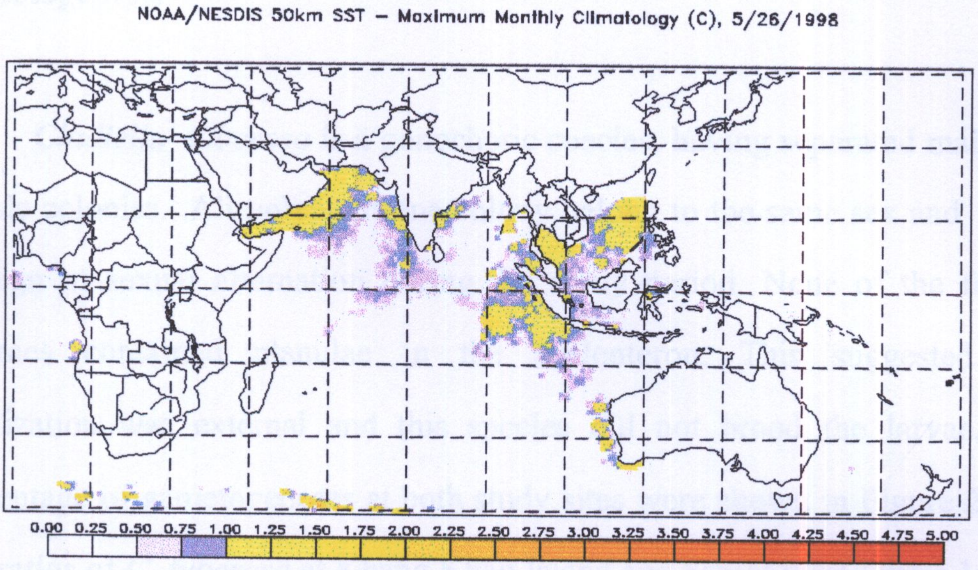

Figure 22 Report of Sea Surface Temperature in May 1998 from NOAA (A Color Table is the Degree of Temperature (°C) that Exceed the Maximum Monthly Climatology in Each Region)

Figure 23 Affected Sea Anemone During the Coral Bleaching Phenomenon in 1998

Gametogenesis

Cladiella tuberosa is a gonochoric species, having separated male and female colonies. All polyps of one colony belong to the same sex and show no sign of sexual alternation during the study period. None of the female colonies contained planulae in the coelenteron. This suggested that fertilization was external and this species did not brood the larvae. The percentage of gametogeneses at both study sites were shown in Figure 24-25. Sex ratios of *C. tuberosa* at Khang Khao Island and Samet Island were 1: 1 ($\chi^2 = 0.44$; $\chi^2 = 0.18$, $P < 0.05$, DF = 1, respectively). Colonies of different sex were identified in the field by cutting a polyp and observing the color of the gonads (pale-brown or gray in females, and white, transparent in males) (Figure 26-27). The colonial color changed from pale-brown, gray and white to yellow when they were preserved in 10% formalin or 70% alcohol (Figure 28).

Oocyte Development

Oocytes were developed year round along the mesenteries within the polyp cavities. Primodial oocytes appeared in clusters (Figure 29), covered by a common layer of endodermal cell. The small oocytes, less than 150 μm in diameter, were transparent. The oocytes had visible nuclei and nucleoli and were surrounded by a follicular layer. As they became larger, the oocytes gradually lost their transparency and became opaque. The clusters of primodial oocytes appeared at the upper most part of the autozooid (Figure 30). Oocytes were located at the rimmed polyps of the colony. In some cases they were found at the base. Different stages of oocytes were found within a polyp (Figure 35). Oocytes were classified in four stages, namely, stage I, stage II, stage III and stage IV.

Stage I oocytes had little ooplasm but large nuclei, with diameters ranging from 25-150 μm and mean diameter was 103 ± 34.54 μm (mean ± SD, n = 586).

Stage II oocytes had the mean diameter increaseing to 217 ± 33.7 μm (n = 654) due to the accumulation of ooplasm. Nuclei were centralized and contained one conspicuous nucleolus (Figure 31).

The onset of vitellogenesis and the migration of nucleus to the periphery of the oocyte were characteristic of Stage III oocytes (Figure 36). The yolk droplets were small, giving the ooplasm a fine granular appearance. The mean diameter of Stage III increased to 316 ± 24.9 μm (n = 193).

Stage IV oocytes were characterised by an indented nucleus, a pronounced purple follicular layer and azooxanthellae ooplasm filled with large yolk droplets that were a mottled pink and white when stained. Mature oocytes had a mean diameter of 567 ± 118 μm, n = 227 (Figure 32-34). The follicular layer thickened throughout oocyte development and remained azooxanthellate at all stage (Figure 36-38).

Oogenic Cycle and Fecundity

In 1998, coral communities in the Gulf of Thailand had affected by the coral bleaching phenomenon during April 1998 to September 1998. Our marine benthic organisms such as sponges, sea anemones, hard corals and soft corals shared disastrous effects too. The hazardous result focused on gametogenic cessation of the soft coral. Trouble recovering procaine came a Samet Island, when oogenesis of *C. tuberosa* began to produce again in December. Small oocytes (50 µm) were almost found in some polyps and the average number of oocytes was 8.67 ± 9.79 oocytes/polyp (mean ± SD). *C. tuberosa* at Khang Khao Island showed no sign of recovering throughout the year.

Sign of gametogenetic recovery at Khang Khao Island began on January, 1999, started from oogenesis which were noticeable in most colonies in March. The most abundant gonads were 50-100 µm in diameter, constituting 40-70% of the measured gonad, while the other size groups were presented in low frequencies (Figure 39). A few tiny oocytes group filled in some polyps. Mean fecundity was 6.73±3.97 oocytes/polyp (Figure 43). While thos of Samet Island was 22 ± 8 oocytes/polyp and the most abundant oocytes were 100-150 µm in diameter (Figure 41). Maximum oocytic sizes of *C. tuberosa* at Khang Khao Island and Samet Island were 250 µm and 225 µm in diameters, respectively. However oocytes were continuously developed to enlarge size in July. Oocytes were found at all stages in each polyps and maximum oocyte size at Khang Khao and Samet Island were 475 µm and 500 μm in diameters, respectively. Maximum mature oocytes, detected in September, which island was 625 μm. *C. tuberosa* from Khang Khao Island spawned in September because the histological studies of the samples in October had not mature ooctyes in the polyps. But in November, some colonies and some polyps of *C. tuberosa* at Khang Khao Island had few mature oocytes (5.6±3.9 oocytes/polyp). The maximum oocyte diameter was 650 μm (Figure 44).

In January 2000, some female colonies at Khang Khao Island, not at Samet Island, produced all stages of oocytes (200-500 μm, Figure 40). Spawning tended to occur in this month. Immature oocytes began to develop in March. Enlarged eggs were detected in June, and the most abundant oocytes were 200-300 μm in diameter (Figure 40). Mature ooctyes were spawned in late September of that year. Maximum diameter of oocytes was 750 μm. Whereas the majorities of oocytes diameters of *C. tuberosa* at Samet Island were 100-150 μm, 150-200 μm and 400-450 μm in February, April and July, respectively (Figure 42). Maximum oocytes diameters are shown in Figure 44.

According to the statistical analysis, fecundity of oocytes of Khang Khao Island and Samet Island during September of 1999 and 2000 were not statistically different (Two-way ANOVA, $P>0.05$). However the monthly differences in fecundities at Khang Khao Island and Samet Island were highly significant (Two-way ANOVA, $P<0.001$). Fecundity of oocytes in each polyp of female colonies did not differ at the same location (Island) but it was highly varied between the two islands (Two-way ANOVA, $P<0.001$). For egg volume per surface area, *C. tuberosa* at Khang Khao Island had higher value than those at Samet Island (Table 1).

Table 1 Fecundity, Egg Diameter and Egg Volume before the Spawning Time

Location	Eggs/polyp			Polyps/	Eggs/	Egg diameter (μm)			Egg volume/
	$\bar{X}$	SD	range	cm^2	cm^2	$\bar{X}$	SD	range	cm^2 (ml)
Khang Khao Island	7.75	6.84	1-15	109.85	851.3	636.4	77.64	425-800	114.342
Samet Island	8.47	5.58	1-17	97.5	825.8	496	9	450-500	52.603

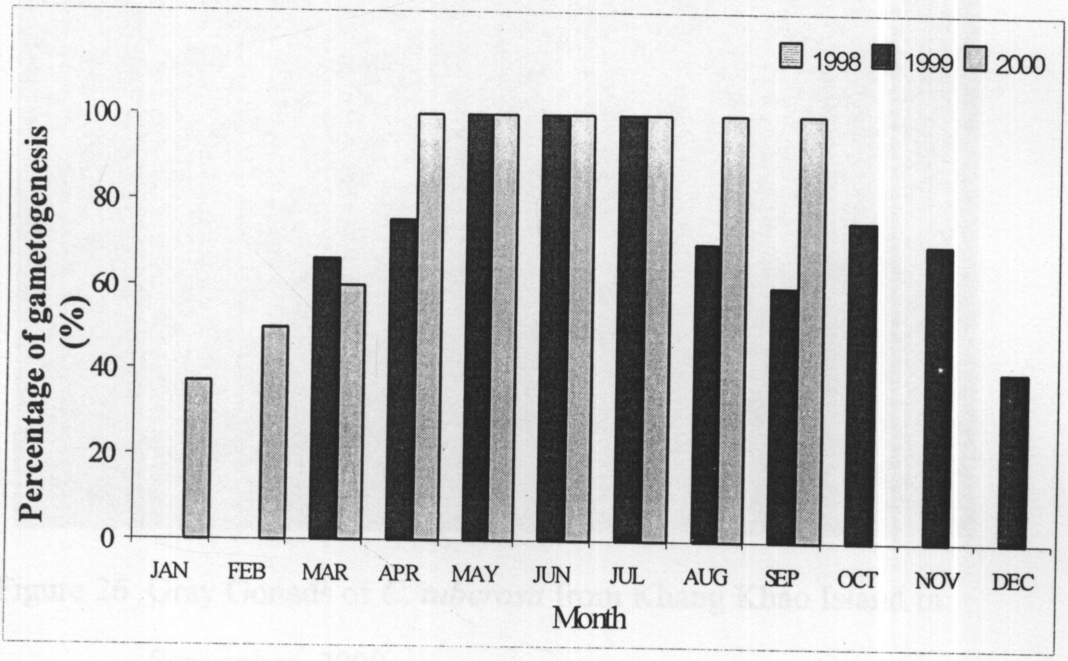

Figure 24 Percentage of Gametogenesis at Khang Khao Island

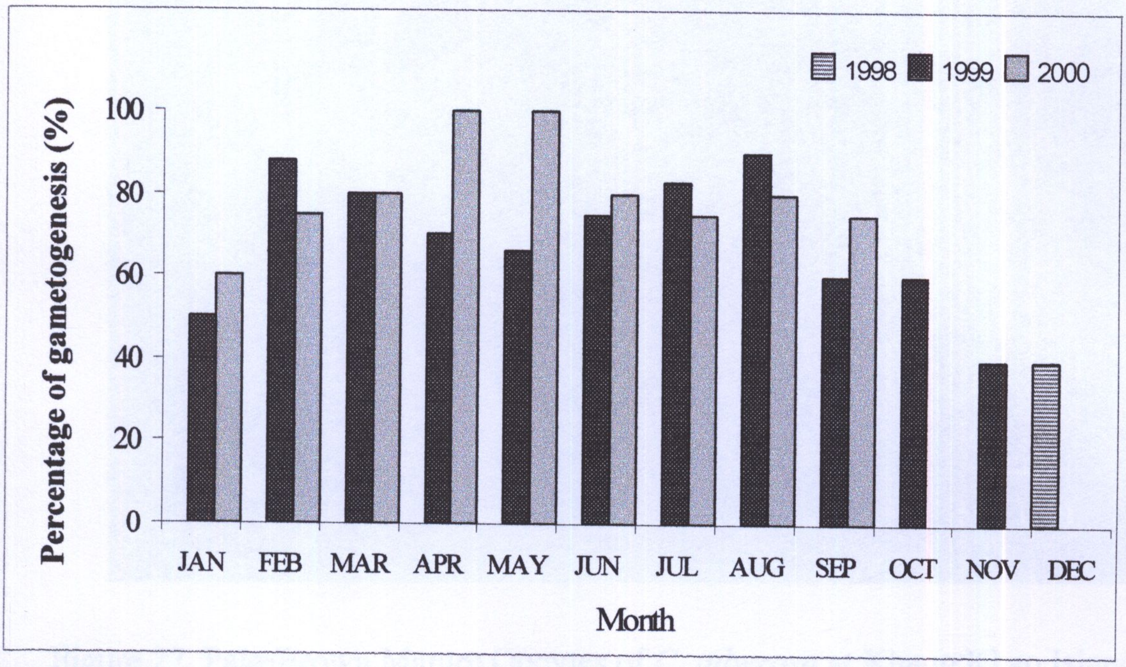

Figure 25 Percentage of Gametogenesis at Samet Island

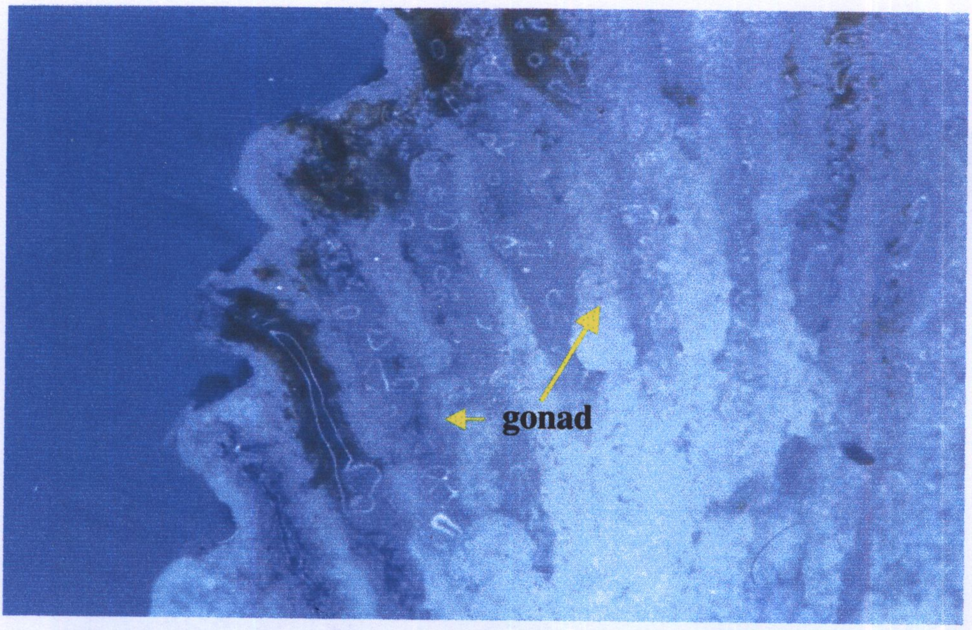

Figure 26 Gray Gonads of *C. tuberosa* from Khang Khao Island in September, 2000

Figure 27 Pale-Brown Mature Oocytes of *C. tuberosa* at Khang Khao Island in September, 2000.

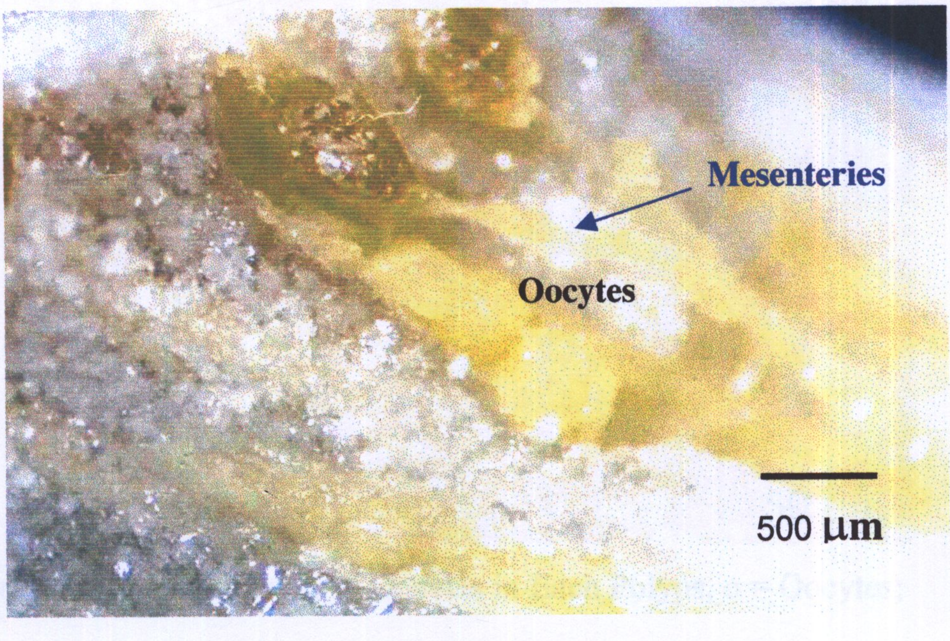

Figure 28 Gonatic Color Alterntion of *C. tuberosa*

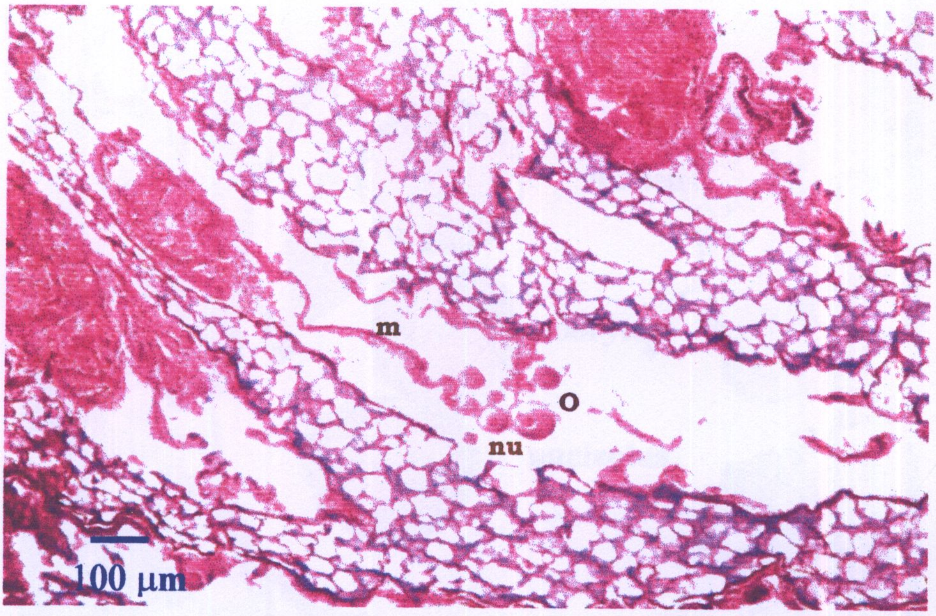

Figure 29 Immature Oocytes of *C. tuberosa*, (Hematoxylin and Eosin Stian)

m = Mesentery; o = Oocytes; nu = Nucleus

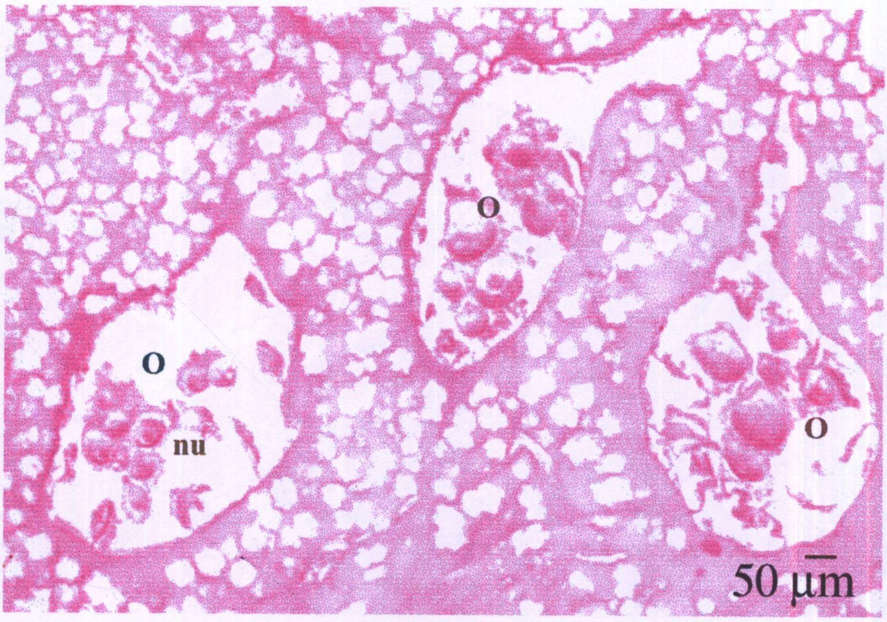

Figure 30 Various Number of Oocytes in Each Polyps, o = Oocytes;

nu = Nucleus

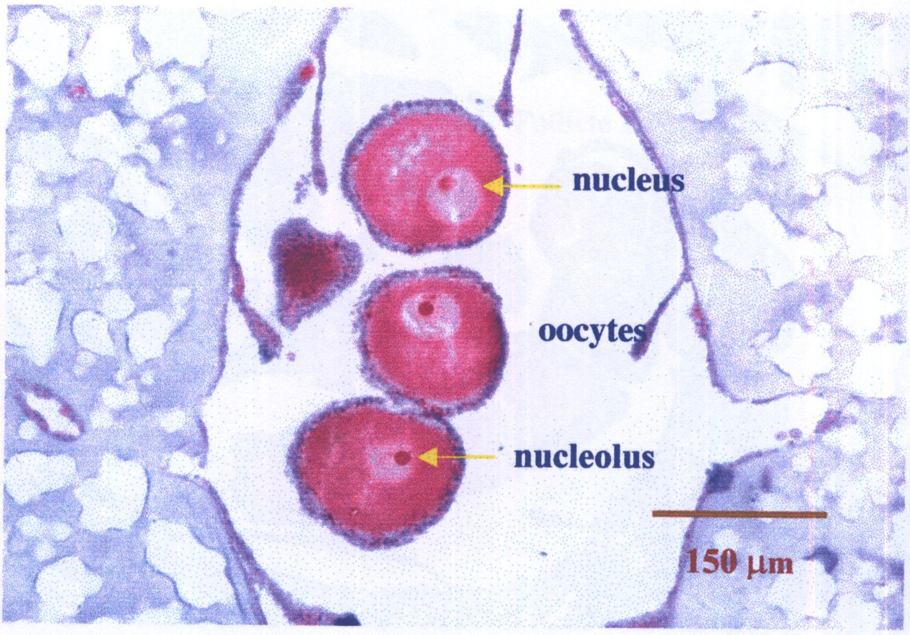

Figure 31 Nucleolus and Nucleus in the Primary Oocytes

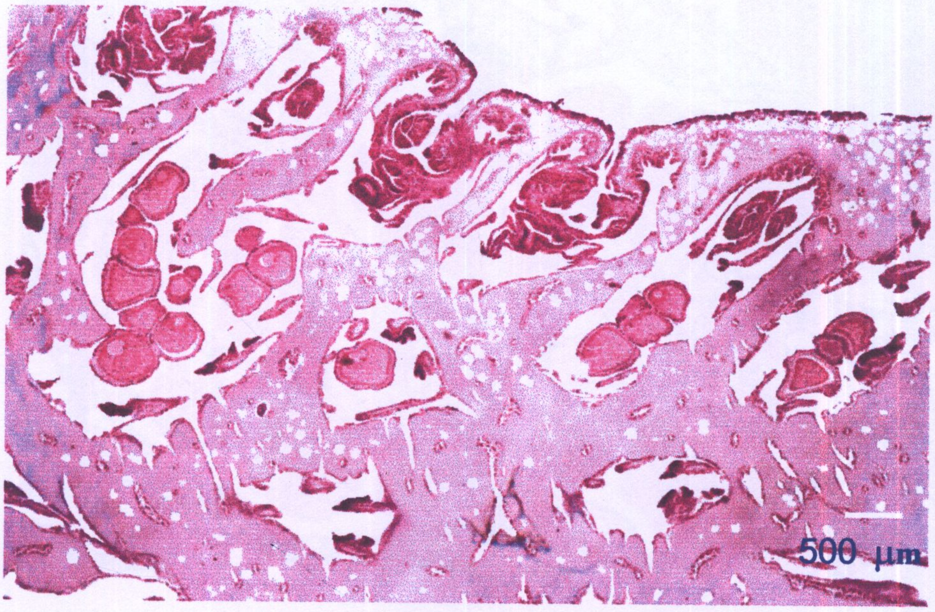

Figure 32 Mature Oocytes observed from Samet Island in July, 2000

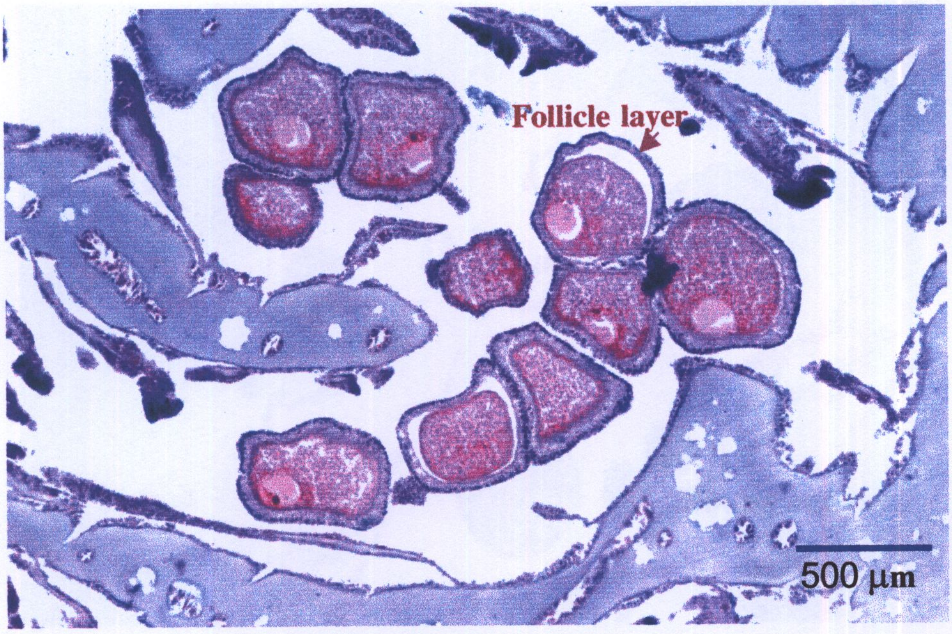

Figure 33 Mature Oocytes of *C. tuberosa* at Samet Island before the Spawning Time

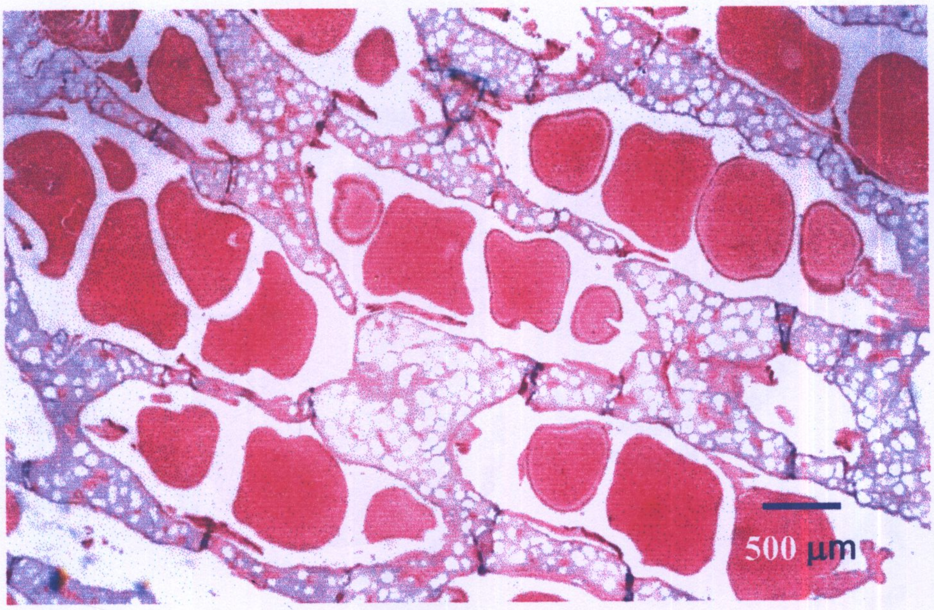

Figure 34 Mature Oocytes Found in All Polyps before the Spawning Peroid

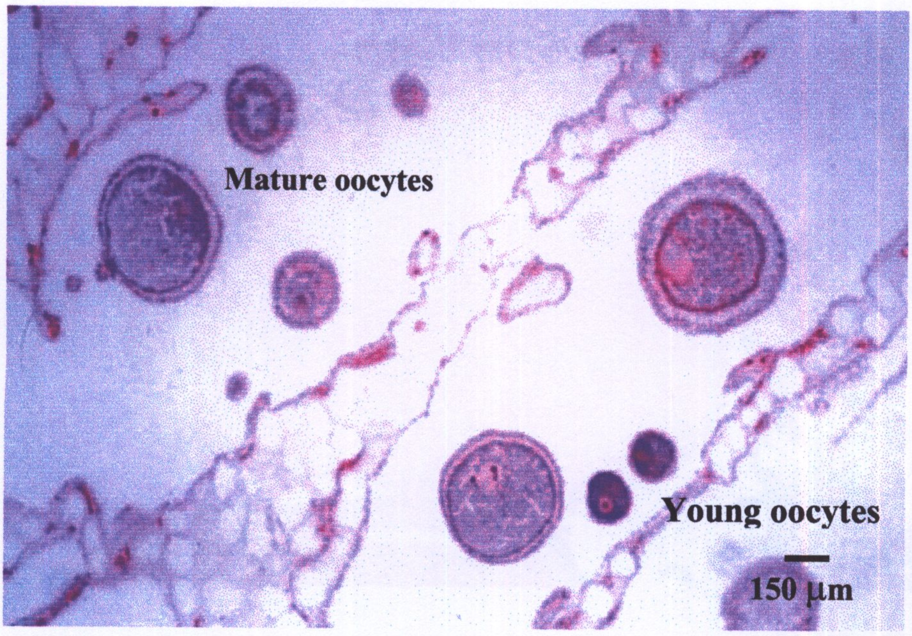

Figure 35 Young and Mature Oocytes of *C. tuberosa* from Khang Khao Island Found at the Spawning Time

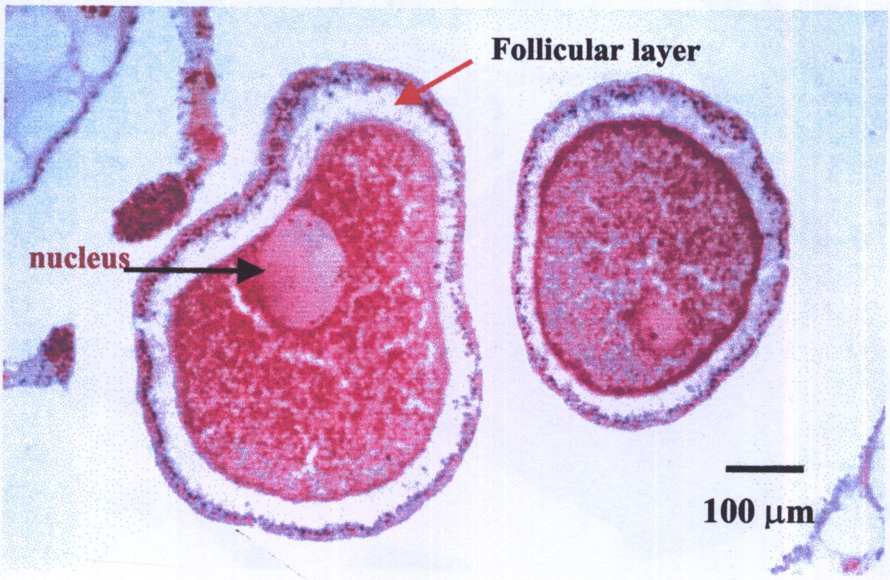

Figure 36 The III Stage Oocytes of *C. tuberosa* at Khang Khao Island

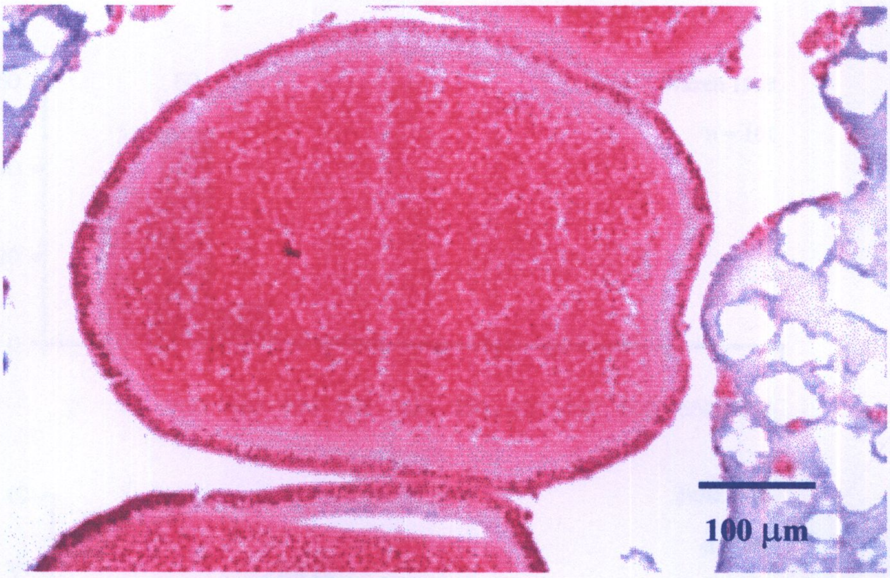

Figure 37 Mature Oocyte of *C. tuberosa* without Zooxanthellae

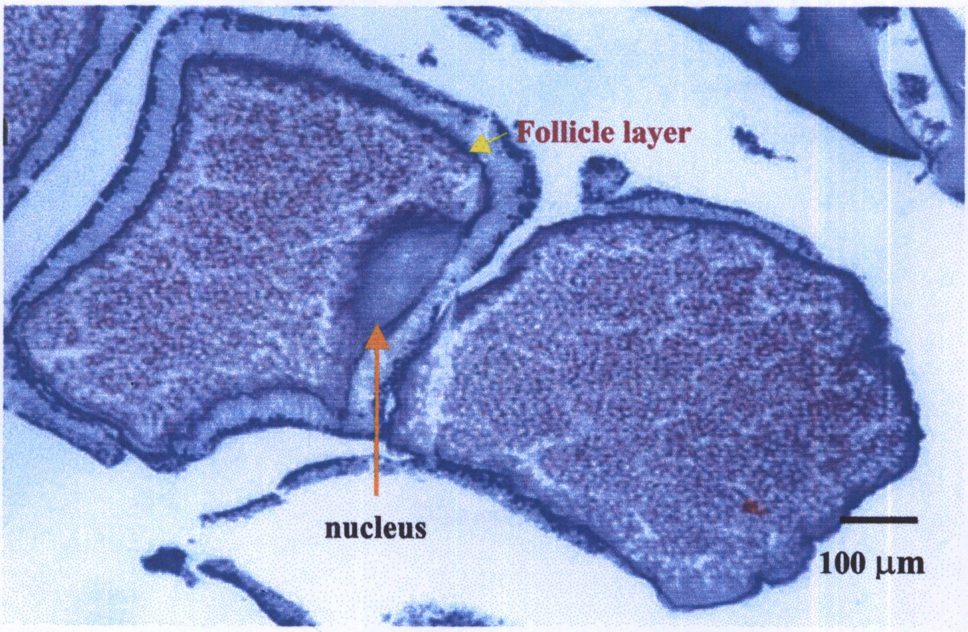

Figure 38 Mature Oocytes of *C. tuberosa* at Samet Island in July, 2000

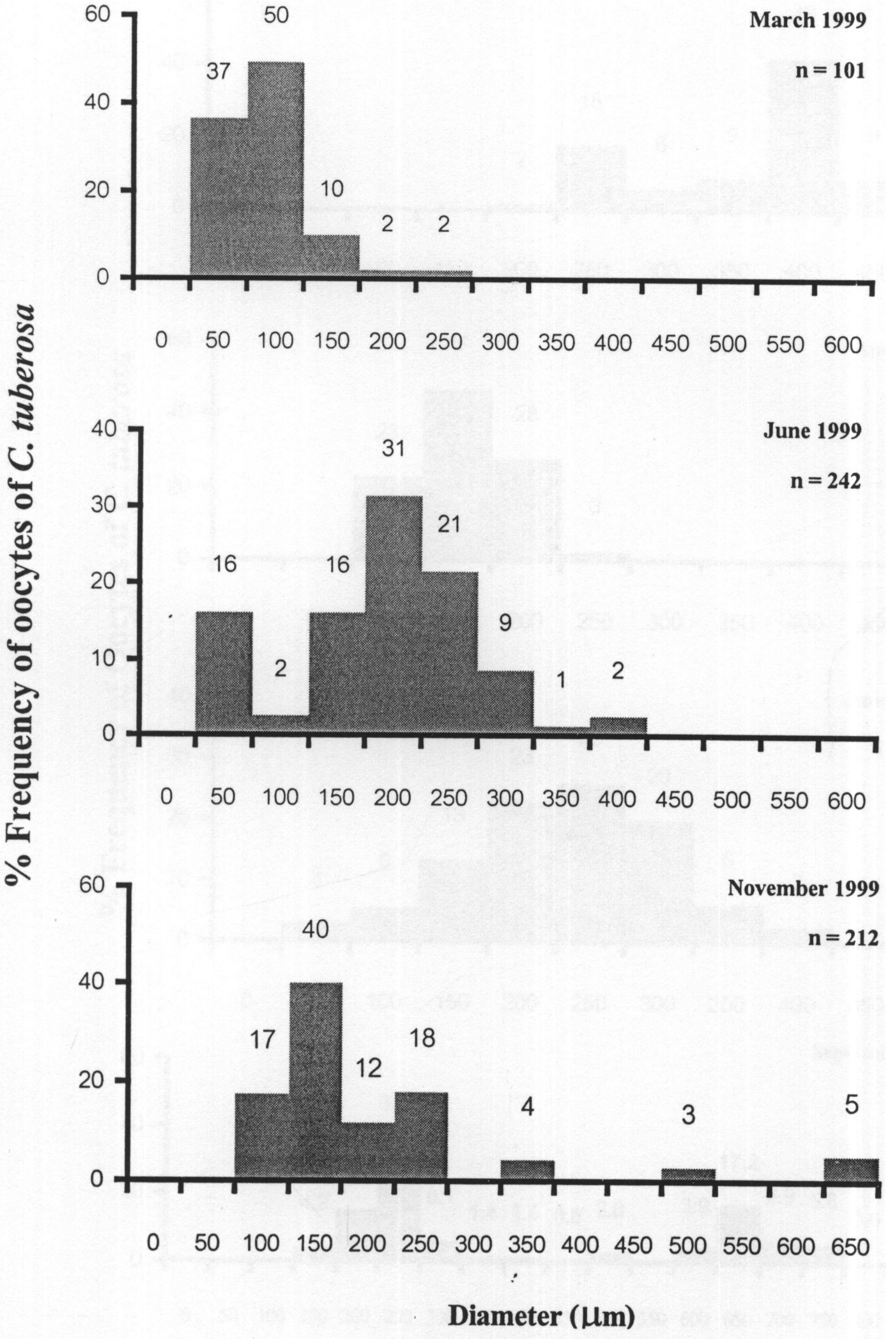

Figure 39 Percent Frequency of Oocytes of *C. tuberosa* at Khang Khao Island in 1999

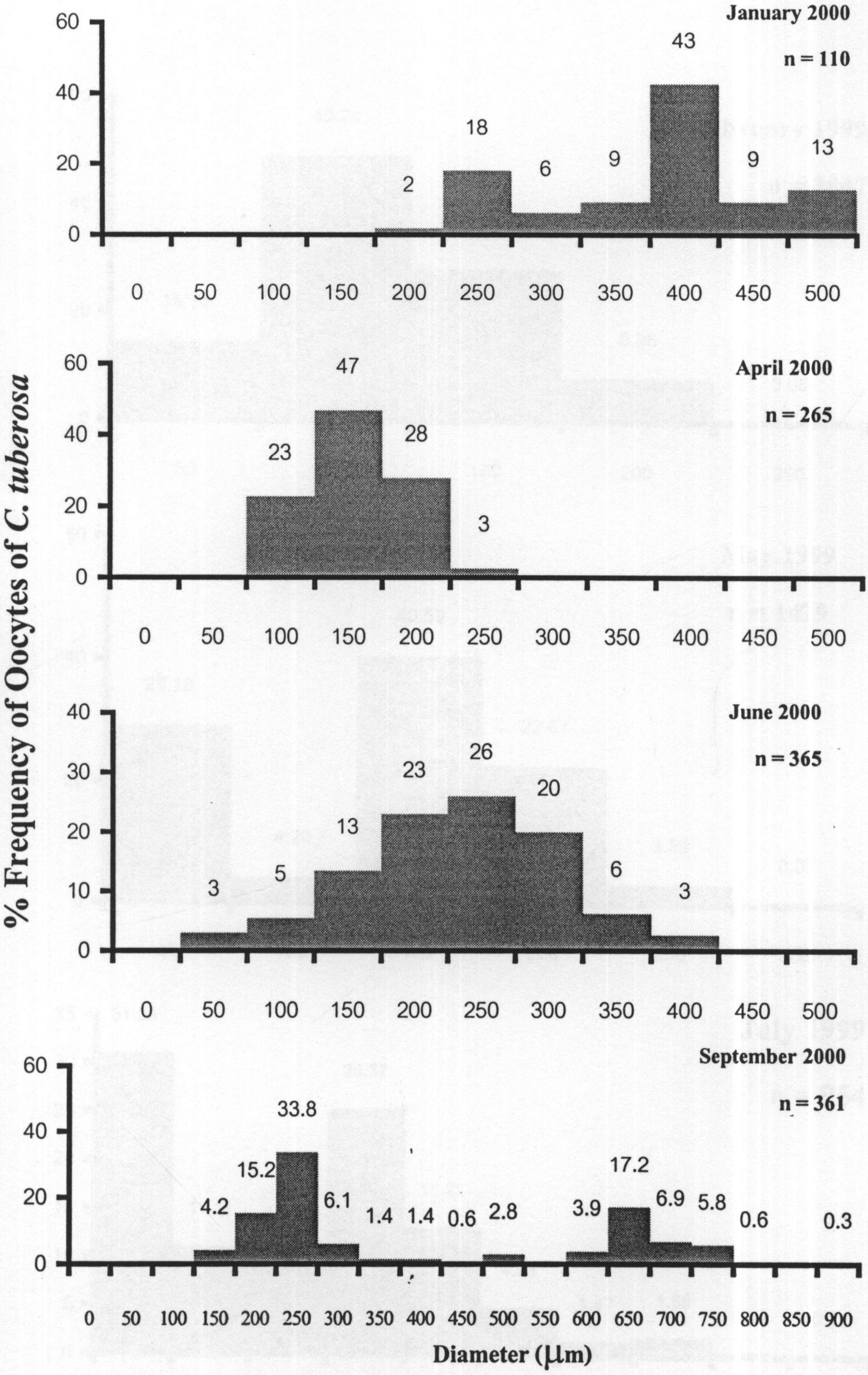

Figure 40 Percent Frequency of Oocytes of *C. tuberosa* at Khang Khao Island in 2000

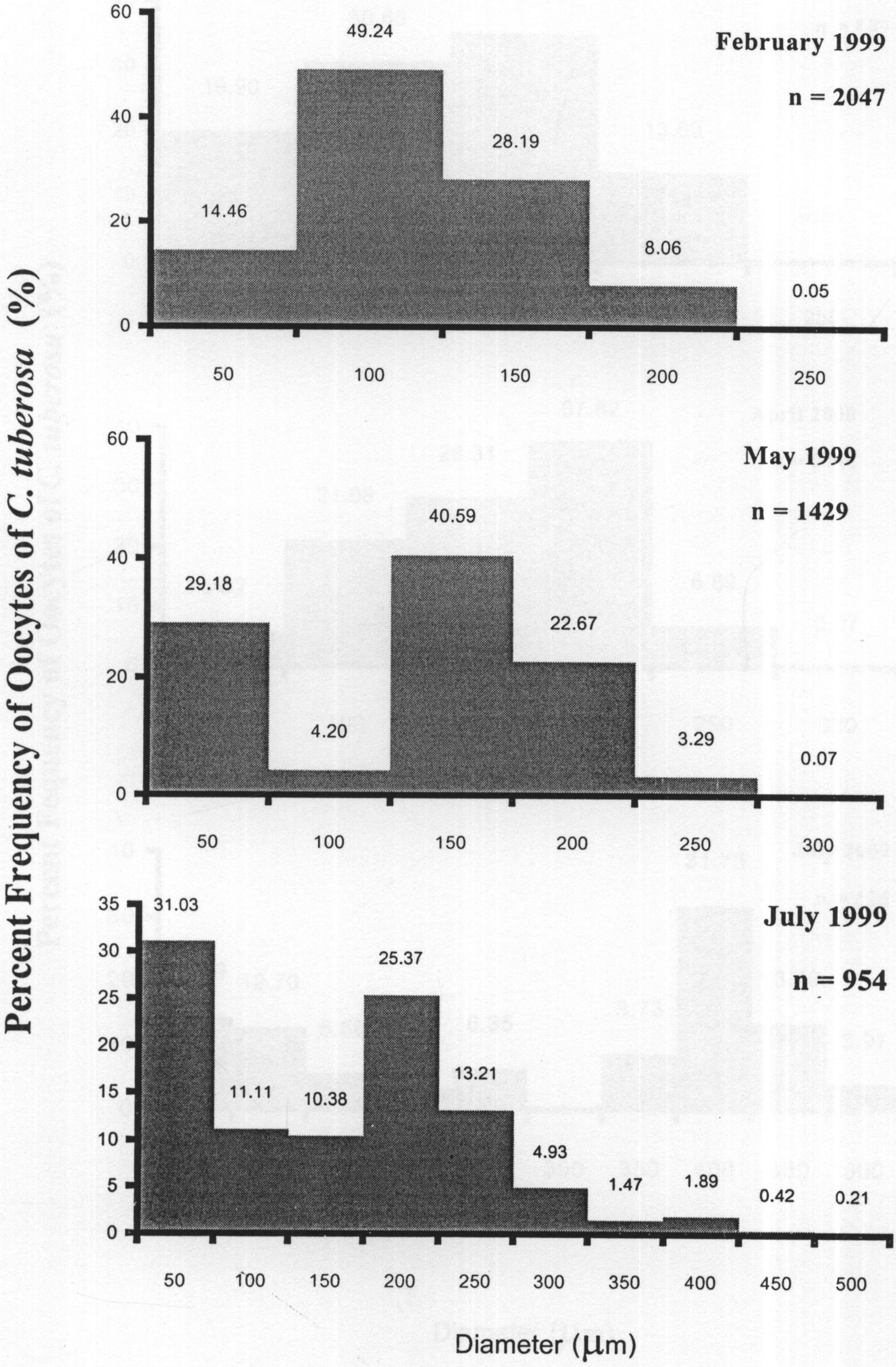

Figure 41 Percent Frequency of Oocytes of *C. tuberosa* at Samet Island in 1999

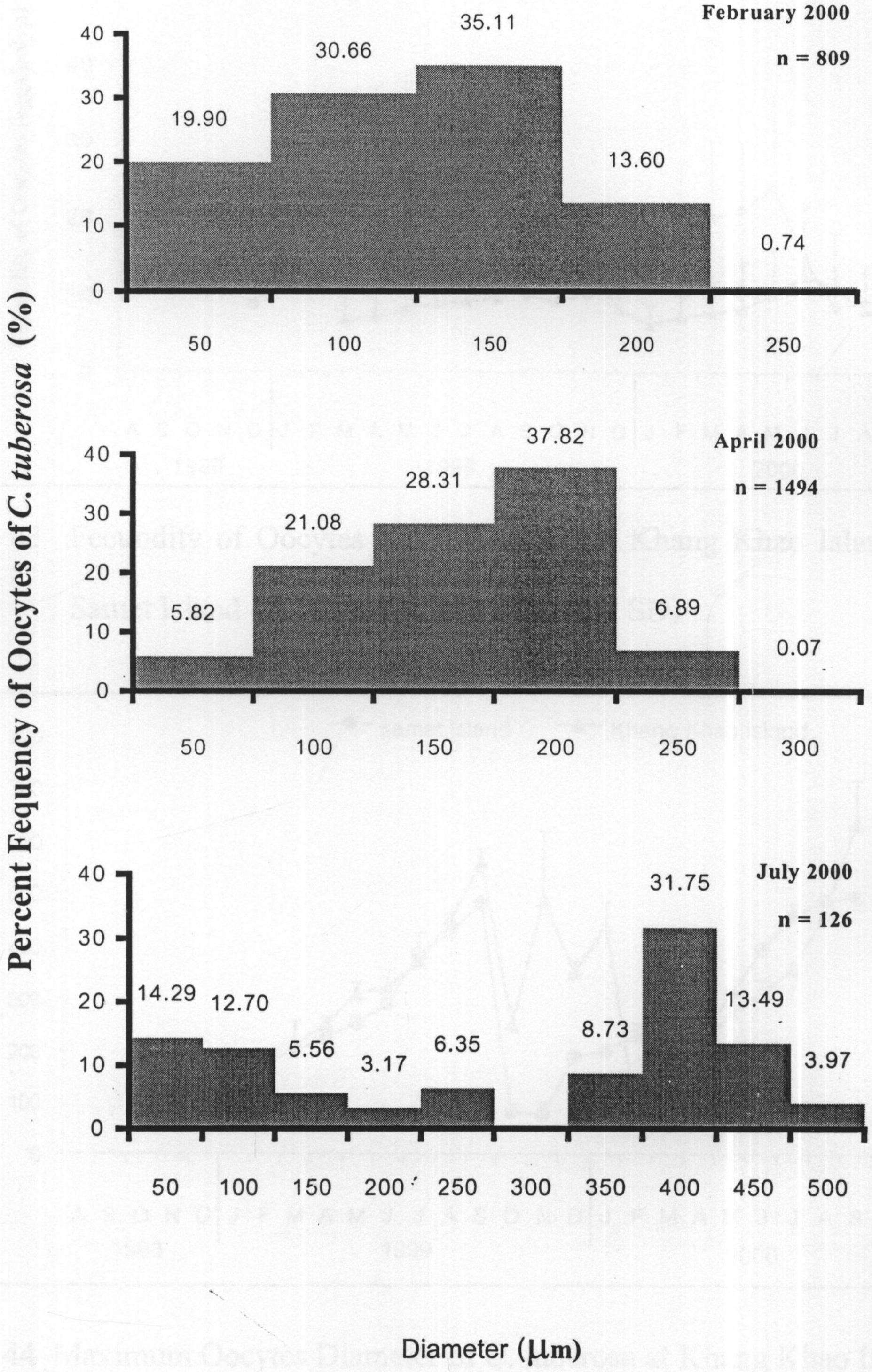

Figure 42 Percent Frequency of Oocytes of *C. tuberosa* at Samet Island in 2000

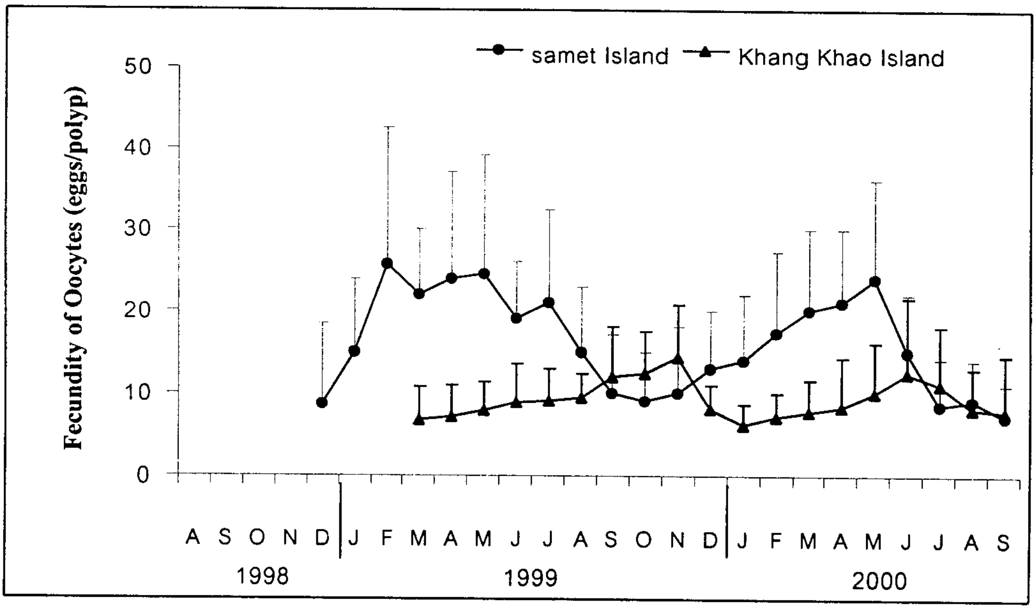

Figure 43 Fecundity of Oocytes of *C. tuberosa* at Khang Khao Island and Samet Island during 1998-2000 (mean ± SD)

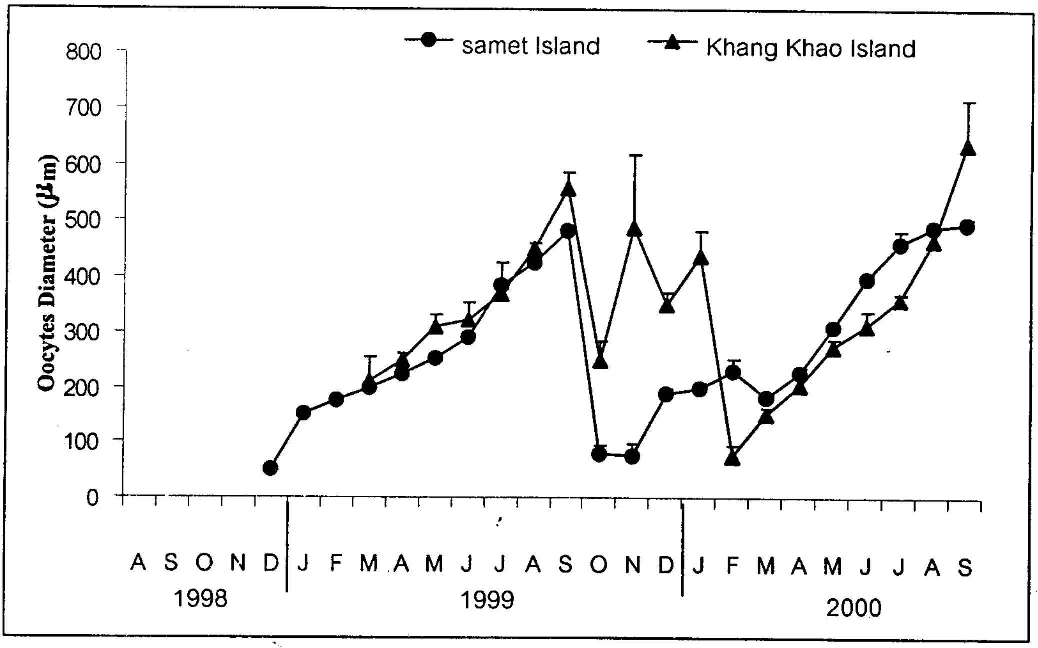

Figure 44 Maximum Oocytes Diameter of C. tuberosa at Khang Khao Island and Samet Island (mean ± SD)

Sperm Sac Development

Three spermatogenic stages were usually found in a single polyp, stage I and II with stage III or IV (Figure 50). Spermatogonia, 60.13±21.13 μm in diameter (mean±SD, n=200) had conspicuous nuclei, but the cytoplasm was not well defined (Figure 45). The primodial sperm sacs attached the wall by means of peduncle (Figure 46).

Stage II, sperm sacs had distinctive boundaries and contained spermatocytes with large nuclei. The mean diameter of the Stage II sperm sacs was 151.9±22.41 μm (mean±SD, n=200).

Stage III, sperm sacs contained spermatids which were more numerous but smaller in size than the spermatocytes. The spermatids nuclei were small and having conspicuously dark purple stain (Figure 48, 51). A lumen formed in each Stage III sperm sacs was just before the transformation of spermatids into spermatozoa, with the spermatids arranged on the periphery of the spermary. The mean diameter of Stage III spermaries was 329±32.07 μm (mean±SD, n=200).

Stage IV, sperm sacs (470±92.94 μm in diameter) contained mature spermatozoas that were about half size of the spermatids (Figure 47). Tails of spermatozoas were usually visible and having pink stain (Figure 54). The sperms arranged into clusters inside the spermaries and oriented themselves by protruding their heads outward (Figure 49, 52). In sections, mature sperm was no longer packed tightly against sperm sacs wall but had dispersed throughout the sperm sac (Figure 53). The membrane surrounding spermaries was greatly reduced in mature specimens, and in some cases it had ruptured releasing the sperm into the polyp cavity.

Spermatogenic Cycle

During April to September, 1998 the coral communities in the Inner Gulf of Thailand had effects from coral bleaching phenomenon. The main effect of this phenomenon was spermatogenesis cessation. *Cladiella tuberosa* at Khang Khao Island entirely stopped spermatogenesis throughout the year but at Samet Island, sperm sac of *C. tuberosa* began to produce again in December, 1998. Small sperm sacs (50-75 µm in diameter) almost found in some polyps and average density of sperm sacs was 11.57 ± 4.13 sperm sacs/polyp (mean ± SD).

The unaffected sperm sacs in some polyps of the soft coral resumed function on the early month of 1999, starting from the development of sperm sacs which were observed in March. Each colony showed variable number of sperm sacs. Measurements of the sperm sacs sizes were selected from those whose colonies produced maximum number of sperm sacs per colony. The average size of sperm sac of *C. tuberosa* at Khang Khao Island was 50 µm in diameter while those at Samet Island were 100 µm in diameter (Figure 55, 57). The primary stage of sperm sacs was found throughout the sampling period. Various stages of sperm sacs were observed in a single colony. Variation in sperm sac sizes at any time was due to the presence of several spermatogenic stages. The sperm sacs increased their size to mature in June, 1999 but had a few number. The maximum sperm sac of *C. tuberosa* was shown in Figure 61. Spawning time was in September 1999 since the number of mature sperm sacs was rare in October, 1999. However, *C. tuberosa* at Khang Khao Island had mature sperm sacs in November 1999. This event showed asynchronous spawning in the population.

In February 2000, *C.tuberosa* at Samet Island displayed asynchronous spawning, similar to *C. tuberosa* at Khang Khao Island, in November 1999, because they had several big sperm sacs (Figure 58, 60). However *C. tuberosa* at Khang Khao Island had not mature sperm sacs (Figure 56). Diameters of mature sperm sacs at Samet Island were larger than those at Khang Khao Island.

According to the statistical analysis, numbers of sperm sacs at Samet Island and Khang Khao Island during 1999-2000 were not statistically different (Two-way ANOVA, $P>0.05$). The difference of monthly number of sperm sacs between Khang Khao Island and Samet Island was highly significant (Two-way ANOVA, $P<0.001$; Figure 59).

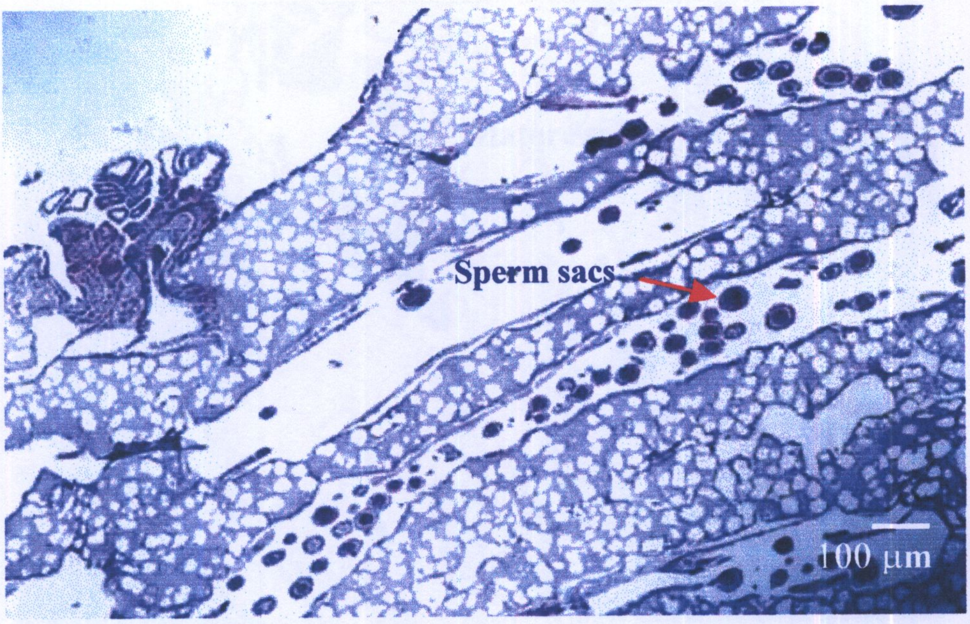

Figure 45 The Primary Stage of Sperm Sacs Found in July, 2000

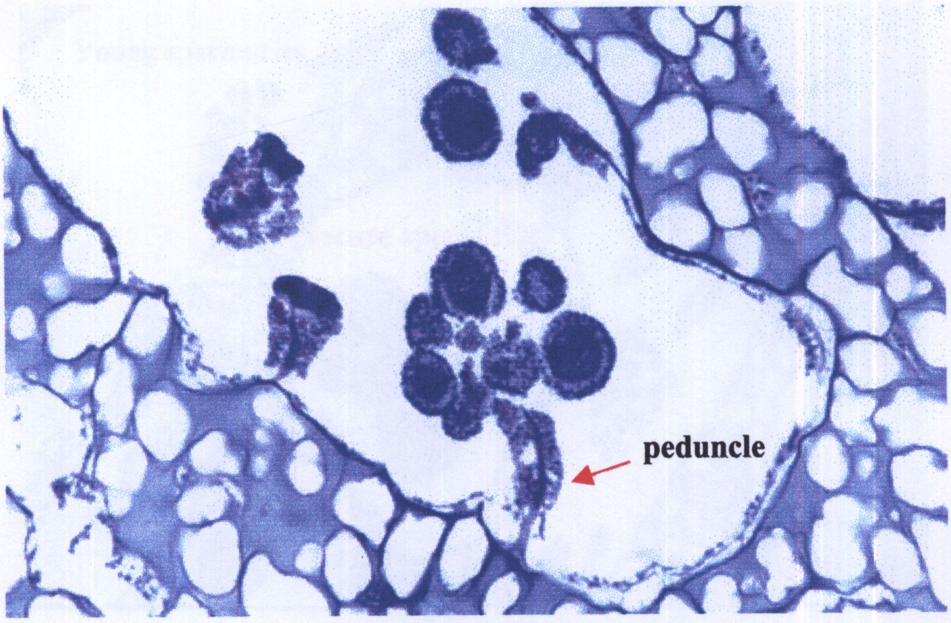

Figure 46 The Primodial Sperm Sacs Attached to the Cavity by the Peduncle

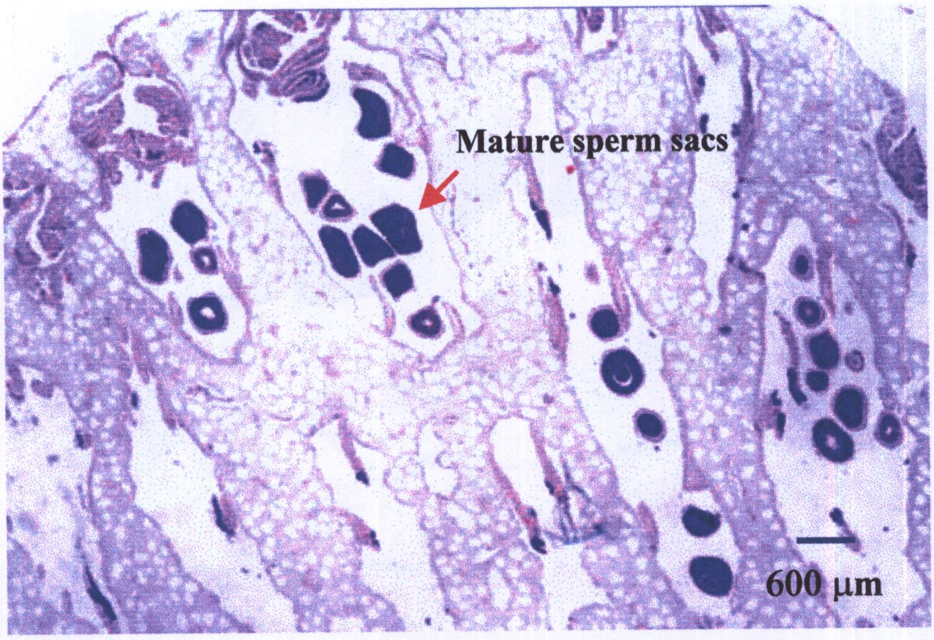

Figure 47 Numerous Sperm Sacs of *C. tuberosa* in Each Polyp

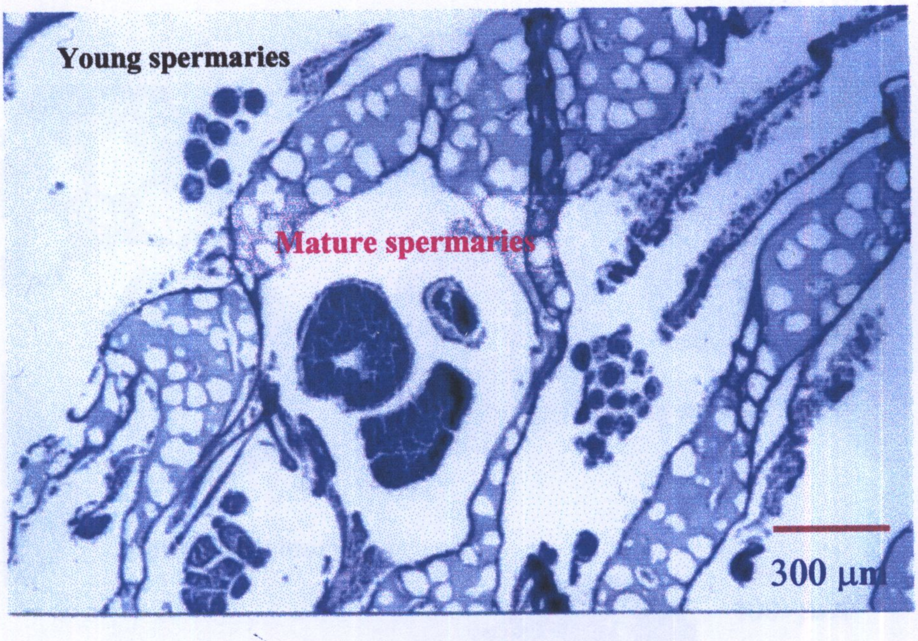

Figure 48 Different Stages of Sperm Sacs in the Same Colony

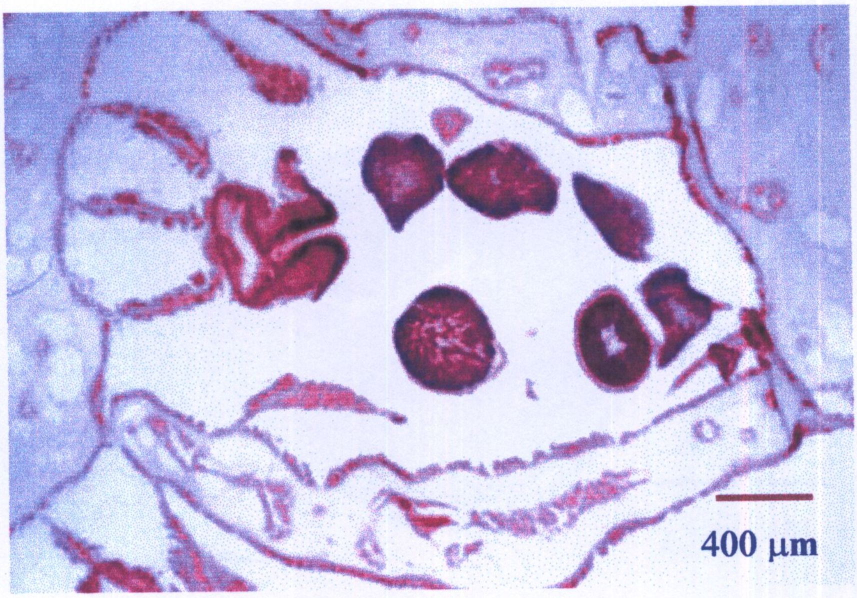

Figure 49 Mature Sperm Sacs of *C. tuberosa* in September, 2000

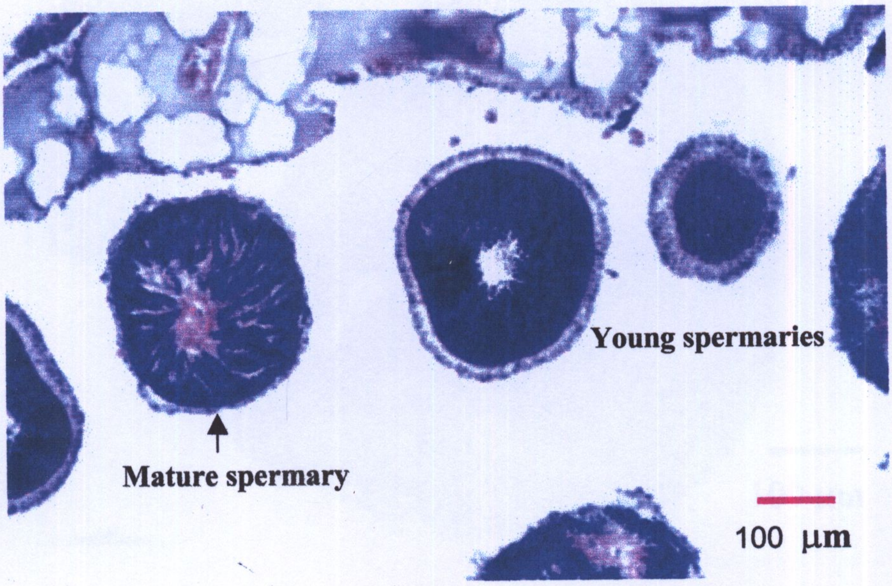

Figure 50 Various Stages of Sperm Sacs Found in the Polyp of *C. tuberos*

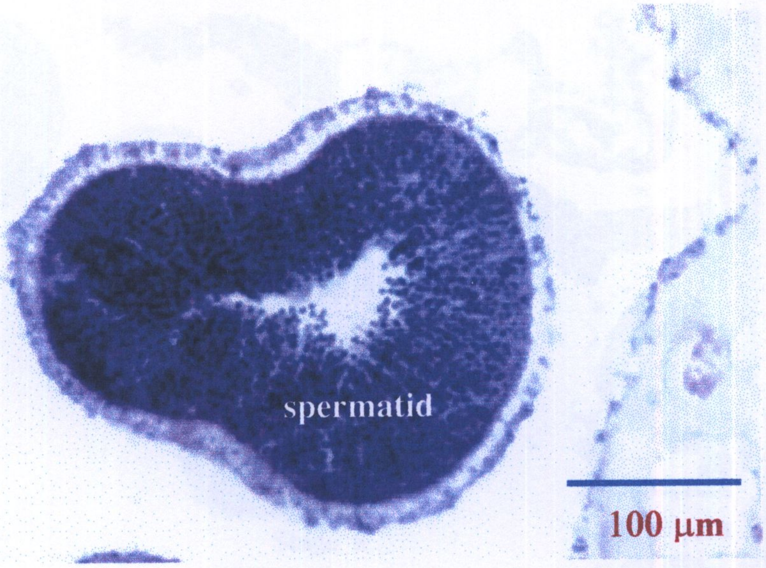

Figure 51 The Spermatid Inside the III Sperm Sac of *C. tuberosa*

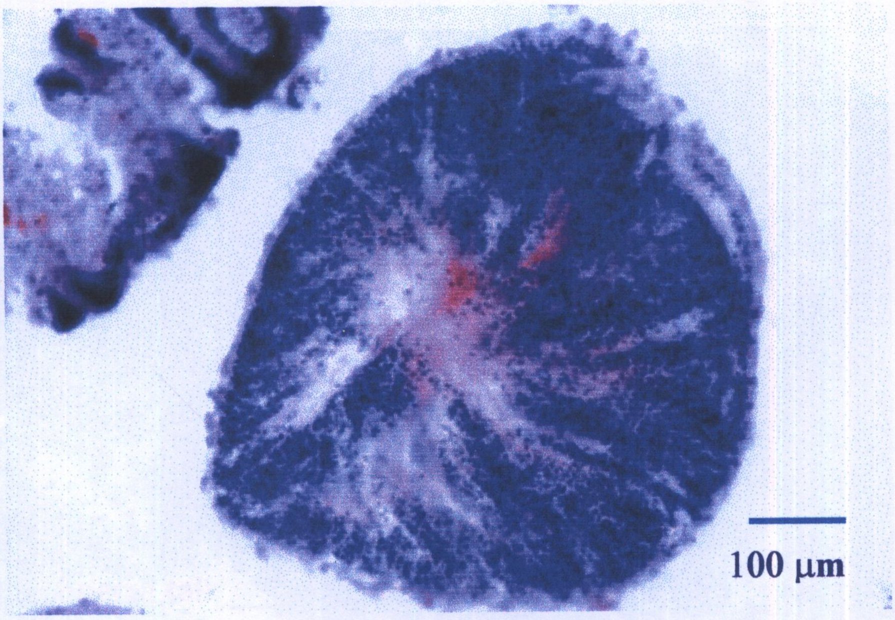

Figure 52 The Mature Stage of Sperm Sac of *C. tuberosa*

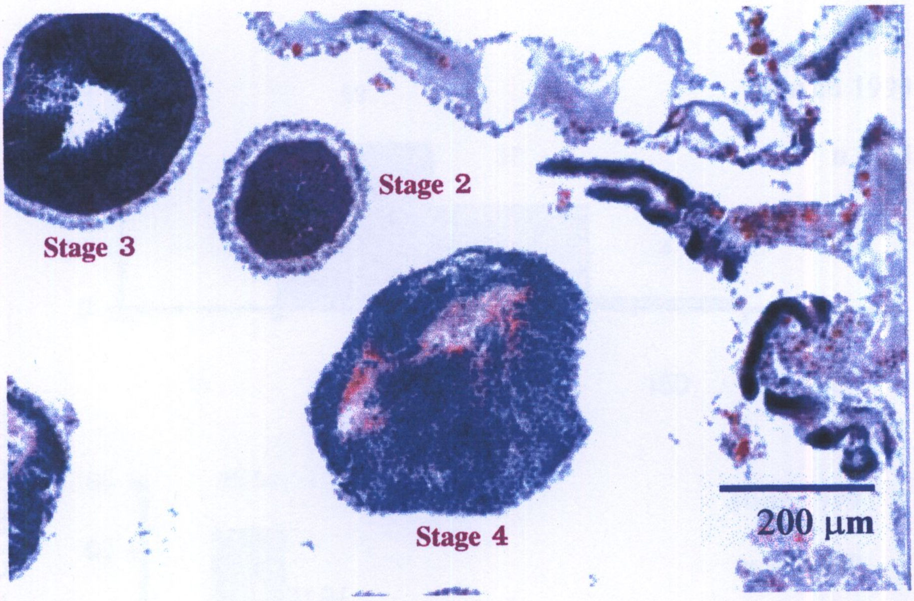

Figure 53 Various Stages of Sperm Sacs in A Polyp of *C. tuberosa* before the Spawning Period

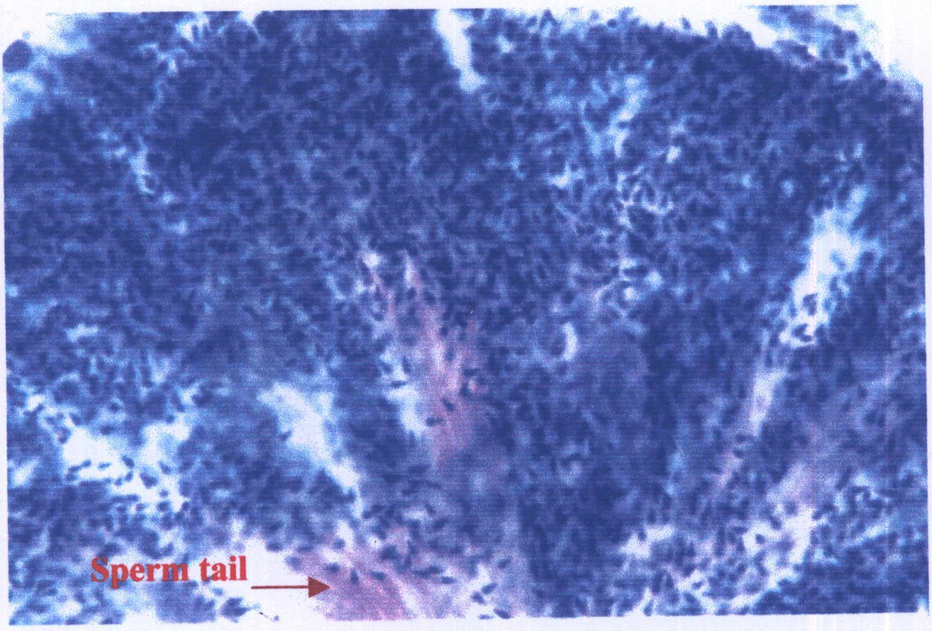

Figure 54 Sperm Tails in Mature Sperm Sacs under the Microscope (x1000)

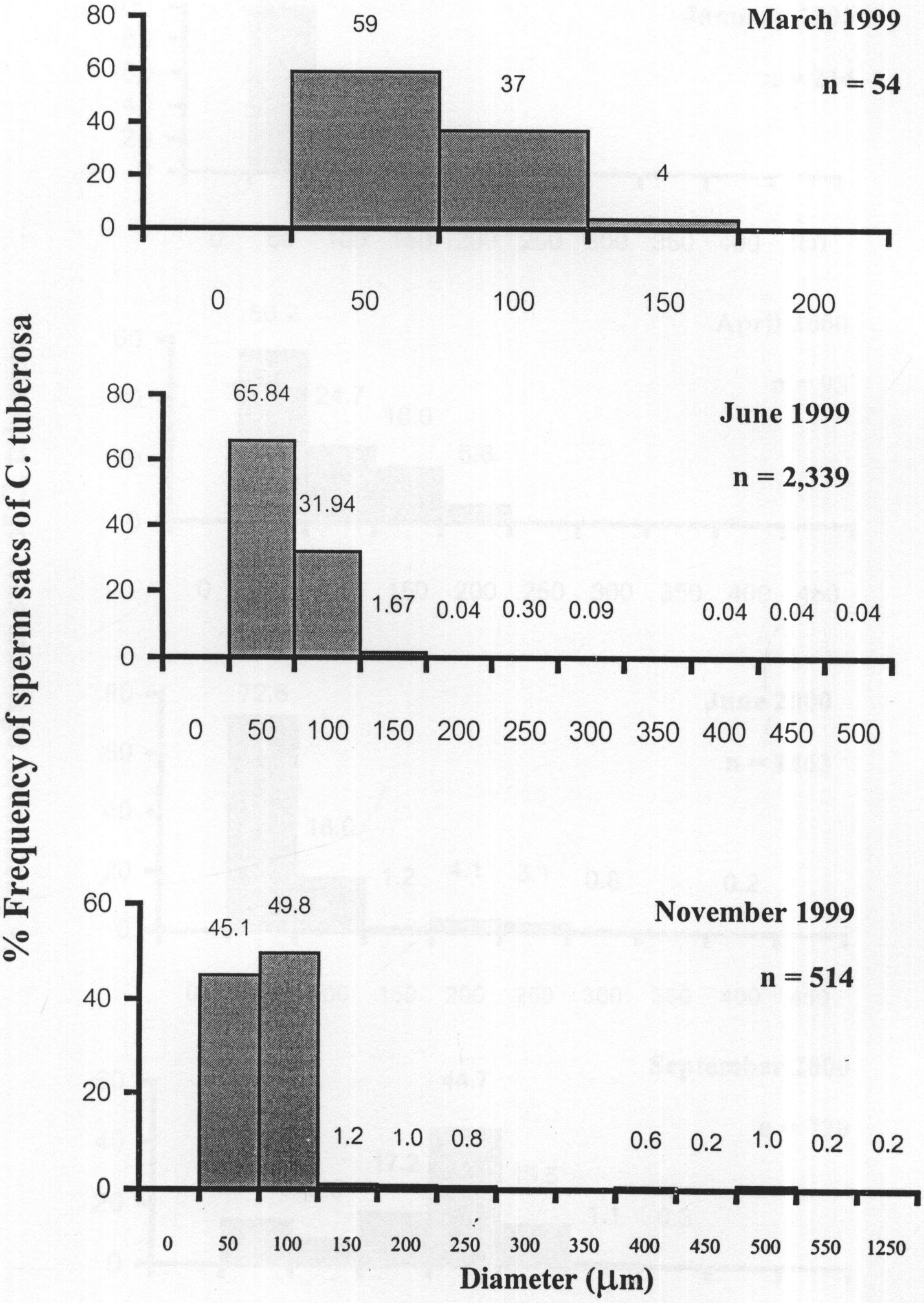

Figure 55 Percent Frequency of Sperm Sacs of *C. tuberosa* at Khang Khao Island in 1999.

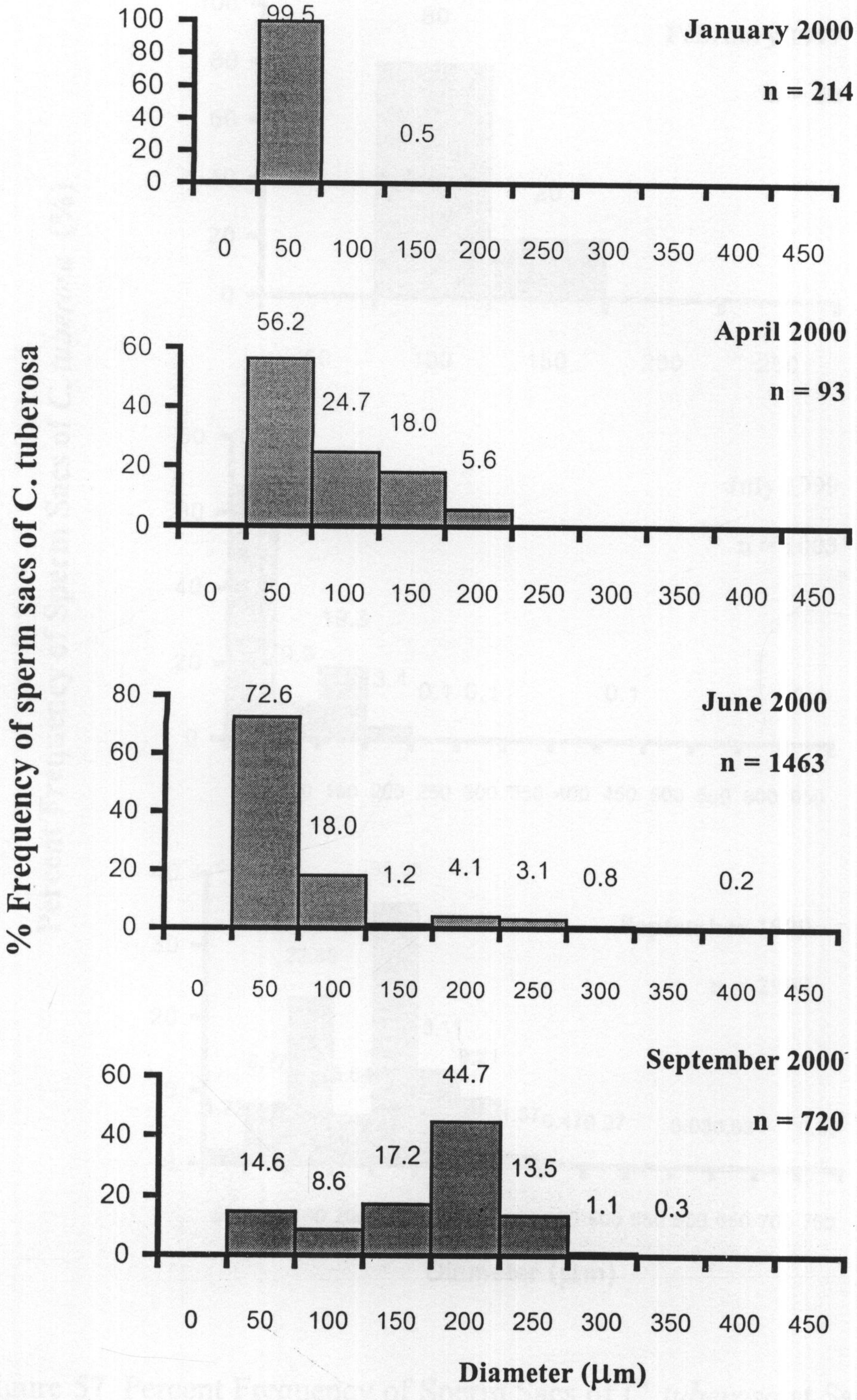

Figure 56 Percent Frequency of Sperm Sacs of *C. tuberosa* at Khang Khao Island in 2000.

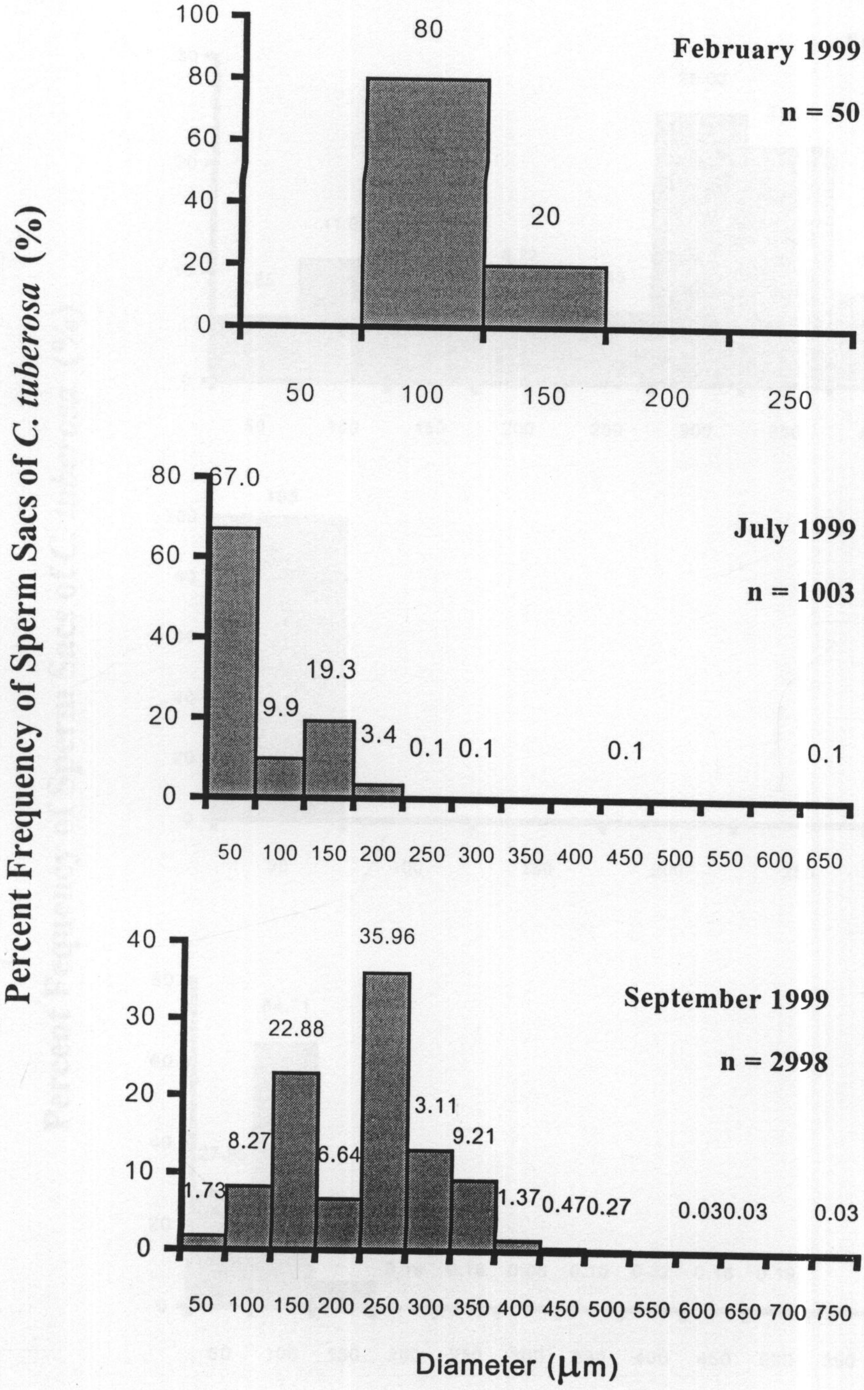

Figure 57 Percent Frequency of Sperm Sacs of *C. tuberosa* at Samet Island in 1999

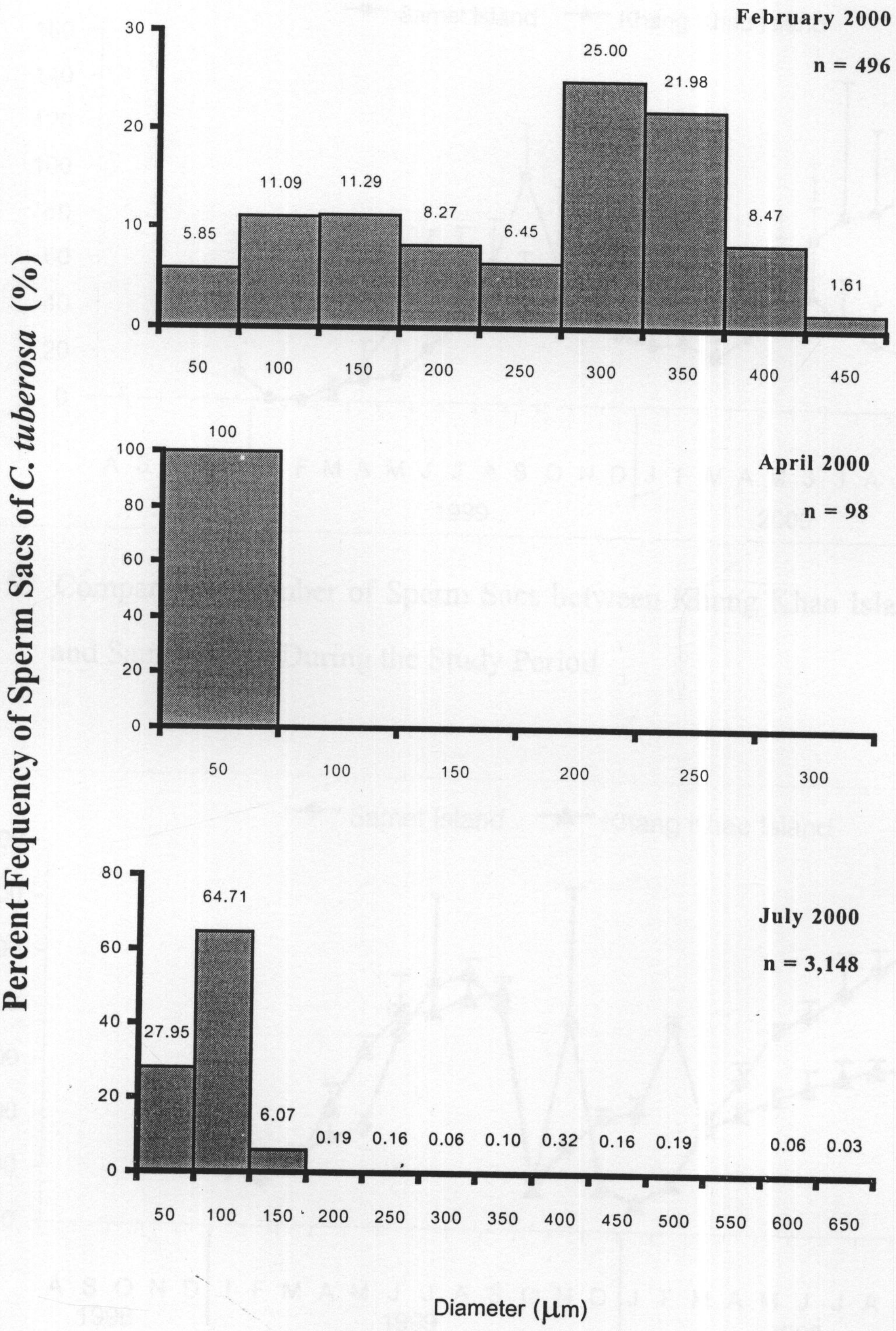

Figure 58 Percent Frequency of Sperm Sacs of *C. tuberosa* at Samet Island in 2000.

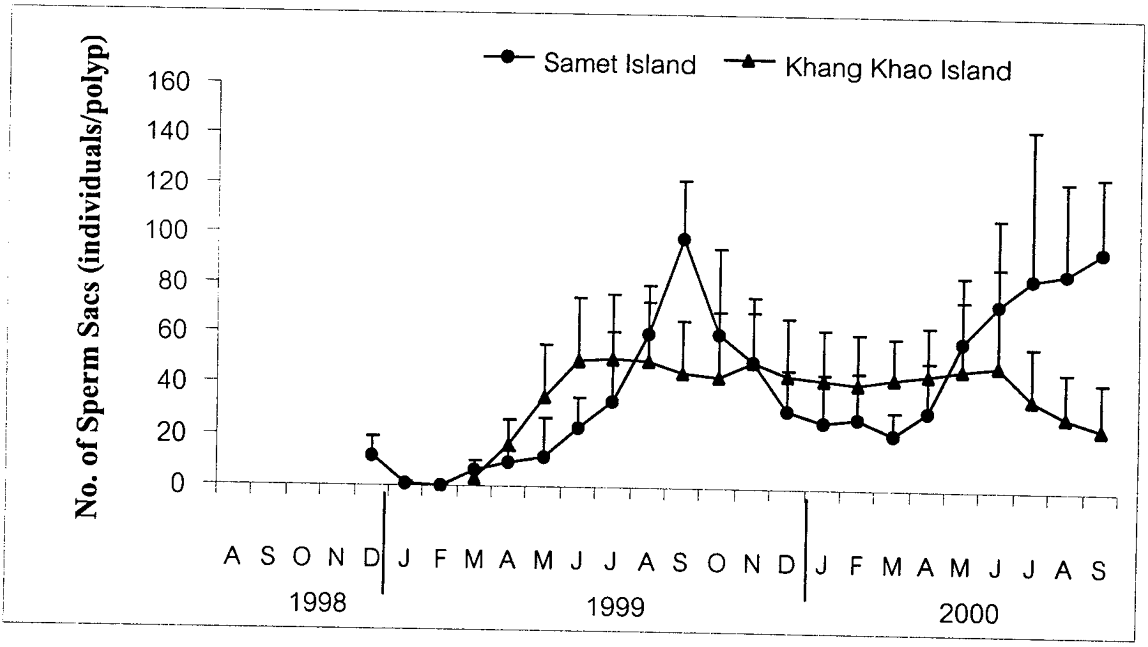

Figure 59 Comparative Number of Sperm Sacs between Khang Khao Island and Samet Island During the Study Period

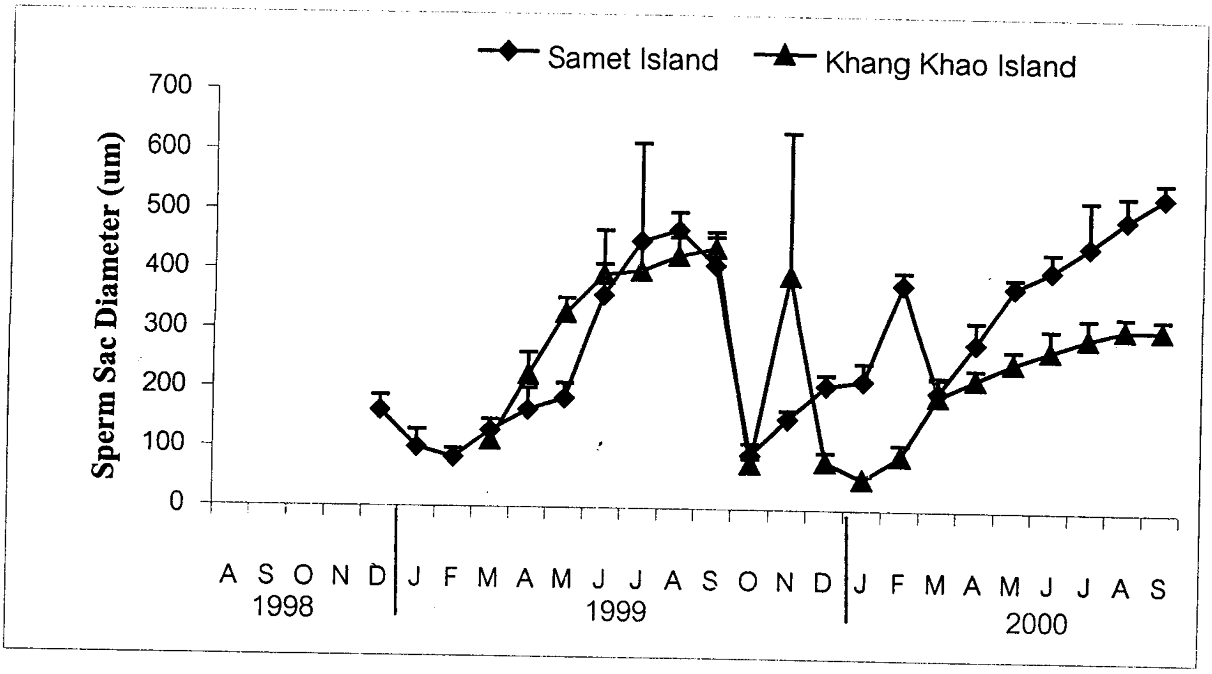

Figure 60 Maximum Sperm Sac Diameters of *C. tuberosa* at Khang Khao Island and Samet Island (mean ± SD)

Asexual Reproduction

A soft coral, *C. tuberosa*, had asexual reproduction by means of fission or protraction apart of colony to the next area (observations in the field) when it grew over the substrates. Some juvenile colonies of *C. tuberosa*, at Khang Khao Island, grew by this fashion (Figure 61). They took a period of time to cover the substrates in coral communities in the Gulf of Thailand as shown in Figure 62.

Mortality

After the first severe coral bleaching phenomenon in the Gulf of Thailand during April-August 1998, some colonies of *C. tuberosa* were grazed by the predators, mainly the sea urchin, *Diadema setosum*. *C. tuberosa* which were obviously observed at Samet Island (Figures 63-64). The mortality rates were approximately 50% of the whole colonies.

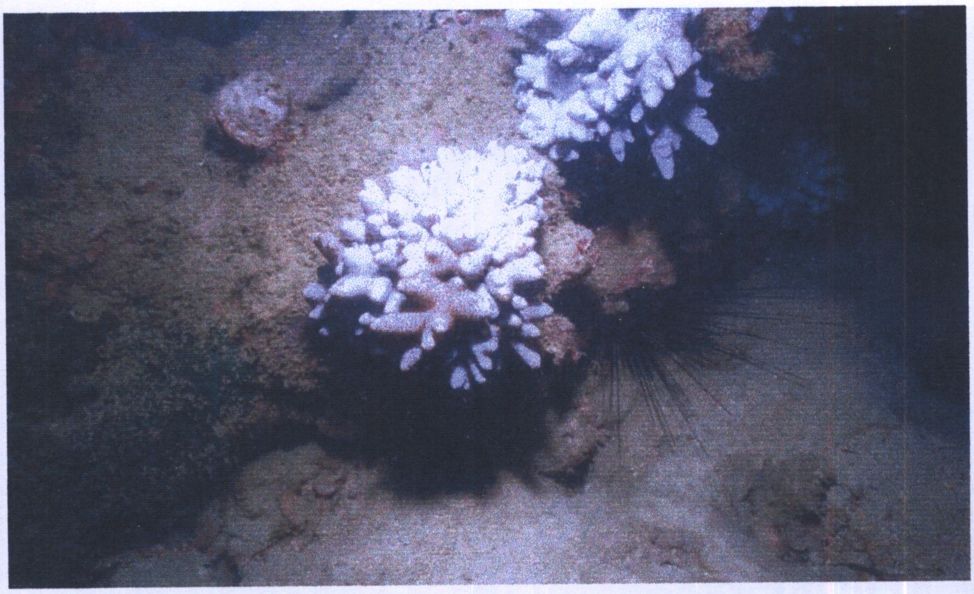

Figure 61 Juvenile Colonies of *C. tuberosa* at Khang Khao Island

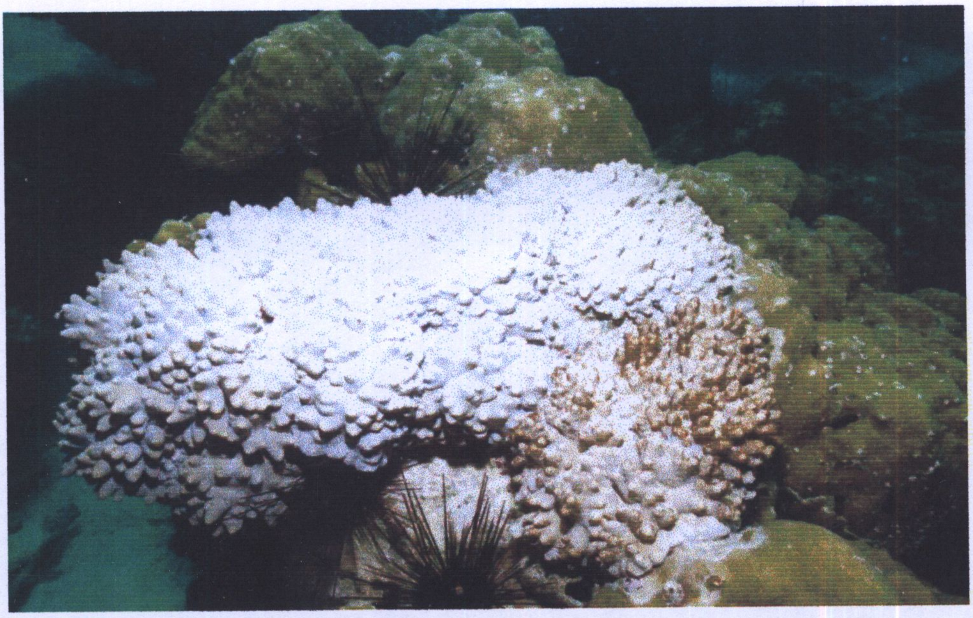

Figure 62 Adult Colonies of *C. tuberosa* among coral Communities in the Gulf of Thailand

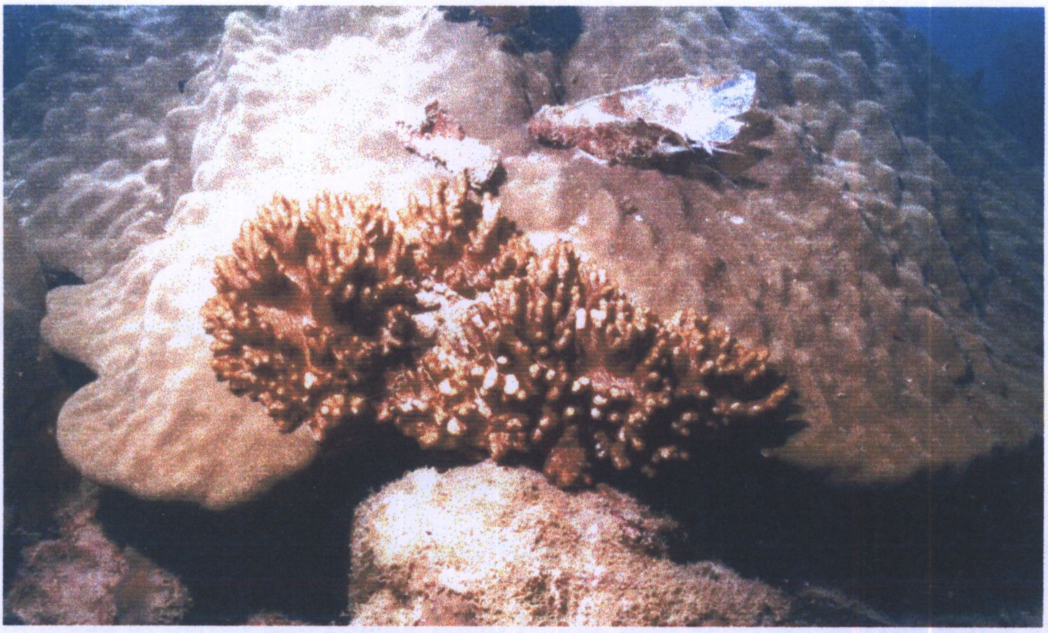

Figure 63 *C. tuberosa* on Coral, *P. lutea*, at Samet Island During February, 2000

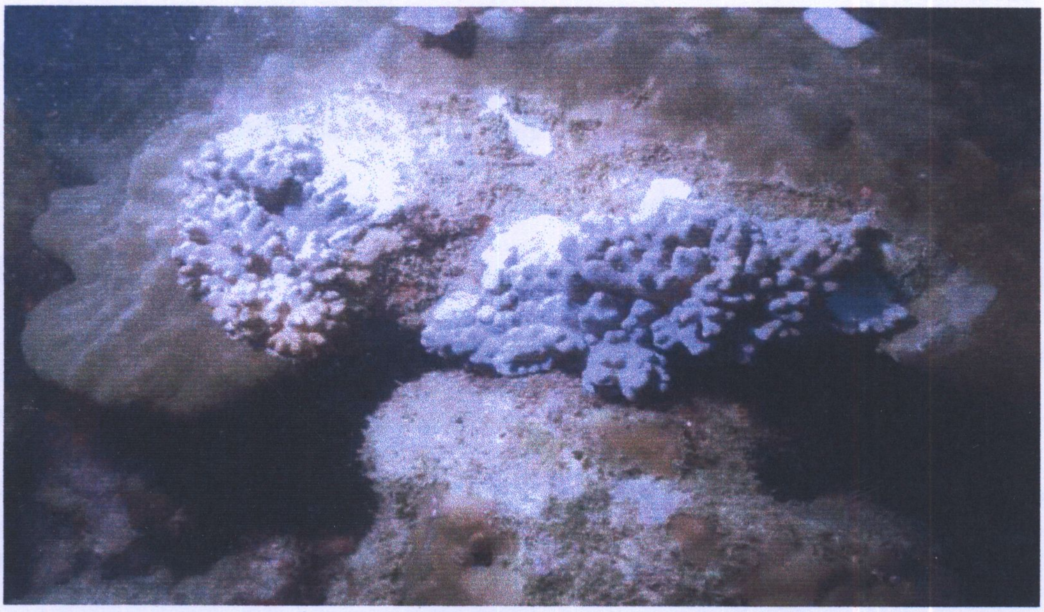

Figure 64 The Same Colony of *C. tuberosa* in July, 2000, Showing the effect of Grazing Activities by A Sea Urchin, *Diadema setosum*

CHAPTER 5

DISCUSSIONS

Population Density and Distribution Pattern

In general, soft corals in the Gulf of Thailand can be found from 1-15 m in depth (Ukrit Satapoomin and Sudara 1988,27). The soft corals, *Cladiella tuberosa* at Samet and Khang Khao Island, also grow in shallow water at 3-5 m depth. They were found on dead coral heads or on stone in reef flats similar to other distribution patterns of soft corals, such as *Cespitularia*, *Sinularia* and *Sacophyton* in other regions (e.g. Fishelson 1970, 106). Fabricius and Alderslade (2001, 84) documented encrusting colonies of *Cladiella* which were found as individuals or clones of a small number of evenly sized colonies. This distribution pattern corresponds with *C. tuberosa* at Khang Khao Island (clumped distribution) and at Samet Island (random distribution).

However population density of the soft coral at different locations is significantly distinguishable because the study area at Samet Island has less suitable substrata. An important limiting factor of octocoral distribution is the abundance of hard substrata suitable for planula settlement (Kinzie 1973, cited by Nelson et al. 1988,794; Benayahu 1985, 255). Moreover other factors which influence the distribution patterns of octocorals are temperature, salinity, light availability and water movement (Dinesen 1983, 229; Yang

1985, 273; Sánchez 1999, 215). Benayahu (1985, 255) informed that competitive interactions with other benthic reef-organisms play an important role in the distribution of the Red Sea soft corals.

The independence of branch growth and size may reflect the diversion of energy away from growth toward reproduction (Brazeau and Lasker 1992, 269)

Reproductive Mode

C. tuberosa is a gonochoric, separated male and female colonies, and broadcasting spawner. This agrees with previously reports on reproduction of most octocorals (Chai and Crawford 1973, 7; Benayahu et al. 1990, 324-325), actiniarians (Wedi and Dunn 1983, 458; Lin et al. 2001, 254), and scleractinians (Kramarsky-Winter and Loya 1998, 175). Sex ratio of *C. tuberosa* is 1: 1 similar to some precedent documents (Table 2).

Gamete Development

Gonads of all stages of *C. tuberosa* were found throughout the year. Small-sized oocytes and sperm sacs, 50-100 µm in diameter, are highly abundant. These features result from continuous gametogenesis (Dahan and Benayehu 1997, 573). Sperm sacs are rapidly developed from small-sized to mature size within a few months (Figure 55-58). Previous studies on both soft and stony corals indicated a shorter spermatogenic cycle than oogenic cycle

Table 2 Mode of Reproduction, Fertilization, Sex Ratio, Maximum Oocytes Diameter, and Number of Mature Eggs per Polyp in the Different Octocorals Studied Todate. (G: Gonochoric, H: Hermaphrodite, S: Spawner, B: Brooder, SB: Surface Brooder, -: Indicated that Information Was Not Supplied by the Authors and * : Indicated that Information Was Derived From Occasional Measurements)

Species	Sex	Mode	Sex ratio	Maximum Oocytes Diameter (μm)	No. of Eggs per Polyp	Source
Cladiella tuberosa	G	S	1 : 1	400-800	9.11	**This study**
**C. pachyclados (Klunzinger)*	G	S	-	450	-	Pratt 1903
Dendronephthya hemprichi	G	S	3 : 2	500	-	Dahan and Benayahu 1997
Lobophytum crassum	G	S	-	603.3	79.83	Yamazato et al. 1981
Sarcophyton glaucum	G	S	1 : 1	500-650	25-35	Benayahu and Loya 1986
Paramuricea clavata	G	S	1 : 1	400-500	?	Coma et al 1995
Anthelia glauca	G	B	1 : 1	787	69	Kruger et al. 1998
Anthomatus ritteri	G	B	-	400-600	5.3	Cordes et al. 2001
Xenia macrospiculata	G	B	~1 : 2	500	-	Benayahu and Loya 1984
Heliopora coerulea	G	B	4.25 : 1	>800	~2	Babcock 1990
Parerythropodium fulvum fulvum	G	SB	1 : 1	500-700	18-24	Benayahu and Loya 1983
Heteroxenia fuscescens	H	B	-	700-800	-	Benayahu et al. 1989; Achituv and Benayahu, 1990

(Yamazato et al. 1981, 671; Benayahu et al. 1990, 323; Coma et al. 1995, 173; Thamasak Yeemin 1999).

Temperature and Reproductive Activity

The onset of oogenesis, and the consequent incerase in mean oocyte diameter, coincided with an increase in both monthly mean sea temperature and daylength (e.g. Parker et al. 1997, 130). Many earlier reports have suggested about effects of temperature on marine invertebrates reproduction (Cochran and Engelmann 1975, 400; Qiu and Qian 1999, 129; Garrido and Barber 2001, 447).

Effects of Bleaching Phenomenon on Reproductive Pattern

The severe coral bleaching in early 1998 was the first reported in the Gulf of Thailand. However these events have been taken place in the West Coast of Thailand in the past (Brown et al. 1994a, 209; 1994b, 230; 1996, 151; Martin et al. 1996, 235). Mass coral bleaching phenomena were reported in the world wide (Goreau and Macfarlane 1990, 211; Glynn 1993, 1; Hoegh-Guldberg and Salvat 1995, 181; Baird and Marchall 1998, 376; Fabricius 1999, 54; Yamazato 1999, 83). During the detrimental event, zooxanthellae affected by the elevated surface seawater temperature (SST), solar radiation, both of elevated SST and high solar radiation (Brown 1997). They resulted in decreasing of healthy zooxanthellae – loss of their pigment and cell shrinkage – and dysfunction in their host cells (Gates et al. 1992; Brown et al. 1995; Kuroki and Van Woesik 1999). Thus, corals and algae symbiotic animals have weakening, bleached, and died (Ukrit Satapoomin 1993; Thamasak Yeemin 1998; Fabricius 1999; Westmacott et al. 2000). Bleached colonies of *C. tuberosa* did not develop gonads and hence showed no gametogenesis during the reproduction season as the same patterns as a soft coral, *Lobophytum compactum*, hard corals, *Acropora hyacinthus*, *Montastrea annularis*, *Oculina patagonica*, and a sponge, *Petrosia* sp. (Szmant and Gassman 1990, 217; Thamasak Yeemin 2000; Saiprateep Asa 2000; Fine et al. 2001, 1202; Michalek-Wagner and Willis 2001a, 231; 2001b, 240).

Bleached corals were not able to complete gametogenesis during the reproduction season following the bleaching event, whereas recovered corals were able to follow a normal gametogenic cycle. Moreover difference of gametogenic recovering between the two study sites depended on population structure, energy allocation and environmental factors such as turbidity, sedimentation and degree of bleaching.

Asexual Reproduction

An important mode of asexual reproduction of *C. tuberosa* is by colony fission (Fabricius and Alderslade 2001, 84). However, new colonies derived from fragmentation in *Parerythropodium fulvum fulvum* were obviously observed (Benayahu 1982, cited by Benayahu and Loya 1983, 353).

Fragmentation occurs in a wide variety of taxa but has been most thoroughly documented in the hard coral (Highsmith 1982, 207; Highsmith et al. 1980, 322). Fragmentation of soft corals has been described for *Sinularia* and soft corals that subjected to intense predation (Tursch and Tursch 1982, 321). Moreover several gorgonian species have been previously studied (Wlaker and Bull 1983, 137; Lasker 1984, 268; 1990, 1578). The first evidence for autotomy of numerous small-sized fragment from a single soft-bodied octocoral by the root-like process such as those of the families Alcyoniidae or Nephtheidae were presented by Dahan and Benayahu (1997, 5). Lasker (1988, 763) documented the incidence and rate of vegetative propagation among coral reef alcyonaceans on the Great Barrier Reef. Among clonal forms, the ability of a colony to regenerate itself from a small fragment of the colony provides not only a mean of enhancing colony survival but also a mean of propagating and dispersing the clone.

Mortality

Although determination of causes of partial colony mortality is not directly addressed in this study, the following important factor is identified from photographs. The biological disturbance, by a sea urchin, *Diadema setosum*, bulldozing and grazing is the major cue of partial mortality of *C. tuberosa*. As has been reported in other studies of marine clonal organisms (Garrabou 1999, 193). Small colonies, area <100 mm^2 suffered whole colony mortality more frequency than did large colonies, simply because the latter, being bigger, could stand the biomass losses or escape from whole mortality better than the former, whatever the cause of biomass loss (Jackson 1979, cited by Garrabou 1999, 193). Thus, for instance, bulldozing by the sea urchin *Diadema setosum* could lead to dislodgment of small colonies and not affect large colonies at all. Sebens (1983, 263) demonstrated, for *Alcyonium siderium*, that small colonies settled near the larger ones have a higher survivorship due to the effective protection of large colonies against the sea urchin's bulldozing or direct predation.

Scope for Future Studies

At present, using genetics as a famous tool for estimating modes of marine species reproduction and dispersal. Because sexual and asexual reproductions of soft corals are not only the factors that affecting their distribution and abundance but for identification and systematics studies also.

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VITA

Ms. Parnhathai Nobchinwong was born on July 11, 1973 in Bangkok. She finished her primary and high school education from Anubarn Sam Sen School in 1986 and Santiraj Vittayalai School in 1991, respectively. She studied biological science in the same year. She graduated with Bachelor Degree of Science (Biology) from Department of Biology, Faculty of Science, Ramkhamhaeng University in 1995. After that she studied for a Master Degree in Biology at the same institute. Her research outputs are presented in the International Conferences and the lists are shown as follow:

Parnhathai Nopchinwong, and T. Yeemin. 1999. Reproduction of a soft coral, *Cladiella* sp., in the Gulf of Thailand. In **Asia-Pacific congress on the biology of the environment**, 54. Singapore: The Singapore Institute of Biology.

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