ECOLOY OF *PALYTHOA CAESIA* (ANTHOZOA: ZOANTHIDEa) IN TURBID ENVIRONMENT

NAPALAI JUNTARUK

A THESIS PRESENTED TO RAMKHAMHAENG UNIVERSITY
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE
(BIOLOGY)
2003

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โครงการพัฒนาองค์ความรู้และศึกษานโยบายการจัดการทรัพยากรชีวภาพในประเทศไทย

c/o ศูนย์พันธุวิศวกรรมและเทคโนโลยีชีวภาพแห่งชาติ

อาคารสำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ

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นิเวศวิทยาของพรมทะเล *Palythoa ceasia* (Anthozoa: Zoanthidea)
ในสภาพแวดล้อมที่มีความขุ่น

นภาลัย จันทรักษ์

วิทยานิพนธ์เสนอต่อมหาวิทยาลัยรามคำแหง
เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญา
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Thesis Title	Ecology of *Palythoa ceasia* (Anthozoa : Zoanthidea) in Turbid Environment	
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ABSTRACT

Thesis Title : Ecology of *Palythoa ceasia* (Anthozoa : Zoanthidea) in Turbid Environment

Student's Name : Miss Napalai Juntaruk

Degree Sought : Master of Science

Major : Biology

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Advisory Committee :

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Ecology of *Palythoa ceasia* (Anthozoa : Zoanthidea) in turbid environment at Khang Khao Island, Chonburi Province was studied during June 2000 – February 2002. *P. ceasia* plays a major role as a dominant competitor with sessile reef organisms. It can overgrowth other sessile reef invertebrates because of its rapid growth and propagation by both sexual and asexual reproductions. *P. ceasia* can assimilate sediment on colony surface and in its mesoglea. This study concentrated on distribution patterns, reproductive ecology, growth and mortality rates, sediment assimilation and competition ability of *P. caesia*. The results showed that mean growth rate sediment

assimilation and competition ability of *P. caesia* was 1.45 cm./mo. While mean mortality rate was 25.08% per year. Change of coverage during June 2000 - February 2002 was + 0.41% per year. *P. ceasia* was a hermaphrodite. Average of sedimentation on *P. ceasia* colony surface in deep stations was 3,442.85 $\pm$ 2,173.60 mg./m.^{2} while that of shallow stations was 2,931.81 $\pm$ 2,787.49 mg./m.^{2}. Average of assimilated sediment in deep stations was 15,881.60 $\pm$ 5,837.43 mg./m.^{2} but that of shallow stations was 14,564.62 $\pm$ 6,777.38 mg./m.^{2} Average sediment found in mesoglea was 71.85% of tissue dry weight. Average of sedimentation rates in the filed measured by using sediment traps with 1.5 cm. and 5 cm. in diameters in deep stations were 58.91 $\pm$ 16.41 (mean $\pm$ SE.) and 113.22 $\pm$ 21.01 (mean $\pm$ SE.) mg./cm.^{2}/day, respectively, while those in shallow stations were 58.35 $\pm$ 13.91 (mean $\pm$ SE.) and 80.85 $\pm$ 18.91 (mean $\pm$ SE.) mg./cm.^{2}/day, respectively. Sedimentation rates measured by using sediment plates were very low compared to sediment traps. The present research highlighted the importance of *P. caesia* in coral community changes in the Gulf of Thailand.

บทคัดย่อ

ชื่อเรื่องวิทยานิพนธ์ : นิเวศวิทยาของพรมทะเล *Palythoa ceasia* (Anthozoa : Zoanthidea) ในสภาพแวดล้อมที่มีความขุ่น

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3. ผู้ช่วยศาสตราจารย์ ดร.สุทัศน์ สุบินประเสริฐ

การศึกษานิเวศวิทยาของพรมทะเล *Palythoa ceasia* บริเวณเกาะค้างคาว จังหวัดชลบุรี ซึ่งเป็นบริเวณที่มีความขุ่นสูง โดยทำการศึกษาตั้งแต่เดือนมิถุนายน 2543 – กุมภาพันธ์ 2545 พรมทะเลมีบทบาทสำคัญในความสัมพันธ์แบบแก่งแย่งในแนวปะการัง ซึ่งสามารถเจริญเติบโตขึ้นคลุมทับสิ่งมีชีวิตอื่นได้ดี เนื่องจากเจริญเติบโตได้อย่างรวดเร็ว และสามารถสืบพันธุ์ได้ทั้งแบบอาศัยเพศและไม่อาศัยเพศ พรมทะเลมีความสามารถในการกักเก็บตะกอนบนผิวของโคโลนีและในชั้น mesoglea การศึกษานี้มุ่งเน้นศึกษารูปแบบการแพร่กระจาย นิเวศวิทยาการสืบพันธุ์ อัตราการเจริญเติบโต อัตราการตาย ความสามารถในการกักเก็บตะกอน และการแก่งแย่ง ผลการศึกษาพบว่า *P. ceasia* มีอัตราการเจริญเติบโตเฉลี่ย 1.45 ซม./เดือน อัตราการตายเฉลี่ย 25.08% ต่อปี การเปลี่ยนแปลงพื้นที่การปกคลุมตั้งแต่เดือนมิถุนายน 2543 – กุมภาพันธ์ 2545 เพิ่มขึ้น 0.41% ต่อปี *P. ceasia* เป็นกะเทย (hermaphrodite) การศึกษาปริมาณตะกอนที่พบบนผิว

ของ *P. ceasia* บริเวณที่ลึกเฉลี่ย 3,442.85 ± 2,173.60 มก./ต.ร.ม. ที่ตื้นเฉลี่ย 2,931.81 ± 2,787.49 มก./ตร.ม. ปริมาณตะกอนที่สะสมในเนื้อเยื่อบริเวณที่ลึกเฉลี่ย 15,881.60 ± 5,837.43 มก./ตร.ม. ที่ตื้นเฉลี่ย 14,564.62 ± 6,777.38 มก./ตร.ม. ปริมาณตะกอนที่สะสมในเนื้อเยื่อเฉลี่ยร้อยละ 71.85 ของน้ำหนักแห้ง การศึกษาอัตราการตกตะกอนในธรรมชาติจากกับดักตะกอน ขนาดเส้นผ่าศูนย์กลาง 1.5 ซม. บริเวณที่ลึกเฉลี่ย 58.91 ± 9.43 (mean ± SE.) มก./ตร.ซม./วัน บริเวณที่ตื้นเฉลี่ย 58.35 ± 13.91 (mean ± SE.) มก./ตร.ซม./วัน อัตราการตกตะกอนเฉลี่ยจากกับดักตะกอนขนาดเส้นผ่าศูนย์กลาง 5 ซม. บริเวณที่ลึกเฉลี่ย 113.22 ± 21.01 (mean ± SE.) มก./ตร.ซม./วัน บริเวณที่ตื้นเฉลี่ย 80.85 ± 18.91 (mean ± SE.) มก./ตร.ซม./วัน อัตราการตกตะกอนที่ได้จากกับดักตะกอนแบบจานมีปริมาณน้อยมากเมื่อเทียบกับอัตราการตกตะกอนที่ได้จากกับดักตะกอนทั้งสองขนาด ผลการศึกษานี้ชี้ให้เห็นถึงความสำคัญของพรมทะเล *P. caesia* ที่มีต่อการเปลี่ยนแปลงของกลุ่มสิ่งมีชีวิตในแนวปะการังของอ่าวไทย

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Napalai Juntaruk

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ABBREVIATIONS

μm	=	micrometer
ANOVA	=	analysis of variance
cm	=	centimeter
et al.	=	*et alii*; and others
i.e.	=	*id est* (that is)
ml	=	milliliter
mm	=	millimeter
SCUBA	=	Self-contained underwater breathing apparatus
SE	=	Standard error
sp.	=	Species

CHAPTER 1

INTRODUCTION

Coral reefs are the highest biodiversity in the ocean (Allen and Steen, 1999, 9) and have an important role for marine ecosystem. They are more complex of plants, animals and bacteria that make them be a major marine resource. (Burnett et al. 1994, 153-159; Burnett et al. 1997, 55-6767; Berntson et al. 1999, 423) Hard coral, soft coral and zoanthid are components widespread throughout the tropical Indo-Pacific region (Chulabhorn Research Institute and Thai Royal Navy 1998, 34; Tanner 1994, 793-809; 390-397; 2000, 514-519)

A zoanthid, *Palythoa,* is a dominant competitor of other reef sessile organisms (Suckhnek and Green 1981, 679; Karlson 1988a, 31; Hill 1998, 13). *Palythoa* can rapidly grow over reef sessile invertebrates and produce a highly marine toxin as palytoxin (PTX). Palytoxin has an effect on ion-channel, may kill an animal and make a bare space of reef. (Gleibs et al. 1995, 1531; Leech and Habener 1998, 1066-1072; Gleibs and Mebs 1999, 1525; Wu et al. 2003, 55) In addition to competitive ability *Palythoa* can entomb sediment to their mesoglea. (Haywick and Muller 1997, 39) At the present a little information about biology of *Palythoa* such as of classification, ecology, reproductive biology and sediment retention is available.

Palythoa caesia (Cnidaria: Anthozoa: Zoanthidea) is a dominant species in the Gulf of Thailand and Indo-Pacific region (Chulabhorn Research Institute and Thai Royal Navy 1998, 34) Therefore, their interactions with reef sessile organisms are neces-sary to study in details. Ecological data of *P. caesia* are very important for reef management in the future.

Objectives

The major objectives of this study are as follows:

1. To study distribution pattern of *P. caesia* and its competitive ability with other reef sessile organisms.

2. To study growth rate, mortality rate and reproductive ecology of *P. caesia.*

3. To study sediment assimilated ability of *P. caesia* and to apply the finding as fundamental data for coral reef management.

Hypothesis

A zoanthid, *Palythoa caesia,* can grow in high turbid environment and can entomb sediment in its mesoglea. It play an important role for coral reef development.

Scope of Research

The present study concentrated on ecology of *Palythoa caesia* (Anthozoa: Zoanthidea) in high turbid environment at Khang Khao Island, Chonburi Province.

CHAPTER 2

LITERATURE REVIEW

Kingdom	: Animal
Class	: Anthozoa
Subclass	: Zoantharia
Order	: Zoanthidea
Family	: Zoanthidae
Genus	: *Palythoa*
Species	: *caesia*

Diagnostic feature of *Palythoa caesia* (Burnett et al. 1997, 57-65)

A zoanthid, *Palythoa* (Anthozoa :Zoanthidea) (Allen and Steen 1999, 9; Burnett et al. 1994, 153-159; Burnett et al. 1997, 55-67; Berntson et al. 1999, 423) is a widespread distribution throughout The Gulf of Thailand and the Indo-Pacific. It plays a major role on competition with reef sessile invertebrates (Karlson 1980, 894-898; Suckhnek and Green 1981, 679; Bastidas and Bone 1996, 543).

Morphology of Class Anthozoa

Members of Anthozoa are polypoid but larger and more complex than polyps in other classes. They have a flattened oral disc bearing tentacles and a slitlike mouth leading to a laterally flattened stomodaeum. (Figure 1) Mesenteries, intucked gastrodermis with mesoglea between, divide up the gastrovascular cavities. The edges of the mesenteries are trilobed filaments. The outer filaments carry cilia and the central one carries cnidocytes and cells that secrete enzyme. The mesoglea is thick, fibrous and cellular (Barnes et al. 1988, 63-70) that contains bits of debris and reef elements to support the polyps (Borneman 1998, 3).

Genetics of Class Anthozoa

Taxonomic reviews of class Anthozoa have historically been confounded by high level of morphological variation in family zoanthidea (Burnett et al. 1997, 55). Morphology of *Palythoa* spp. and *Parazoanthus* spp. are shown in Table 1 (Berntson et al. 1999, 423-427) *Palythoa* has 3 forms but from they are no different between fixed gene or clear differences in gene frequent-cies among them based on genetic analysis (Burnett et al. 1997, 55-68). By using 18s rDNA sequences to study a relationship within the class Anthozoa, the order Actiniaria, Zoanthidea, Scleractinia, Antipatharia and Ceriantharia, as well as the subclass Octocorallia, constitute monophyletic taxa and order

Antipatharia as a sista group of order Zoanthidea (Berntson et al. 1999, 417-433).

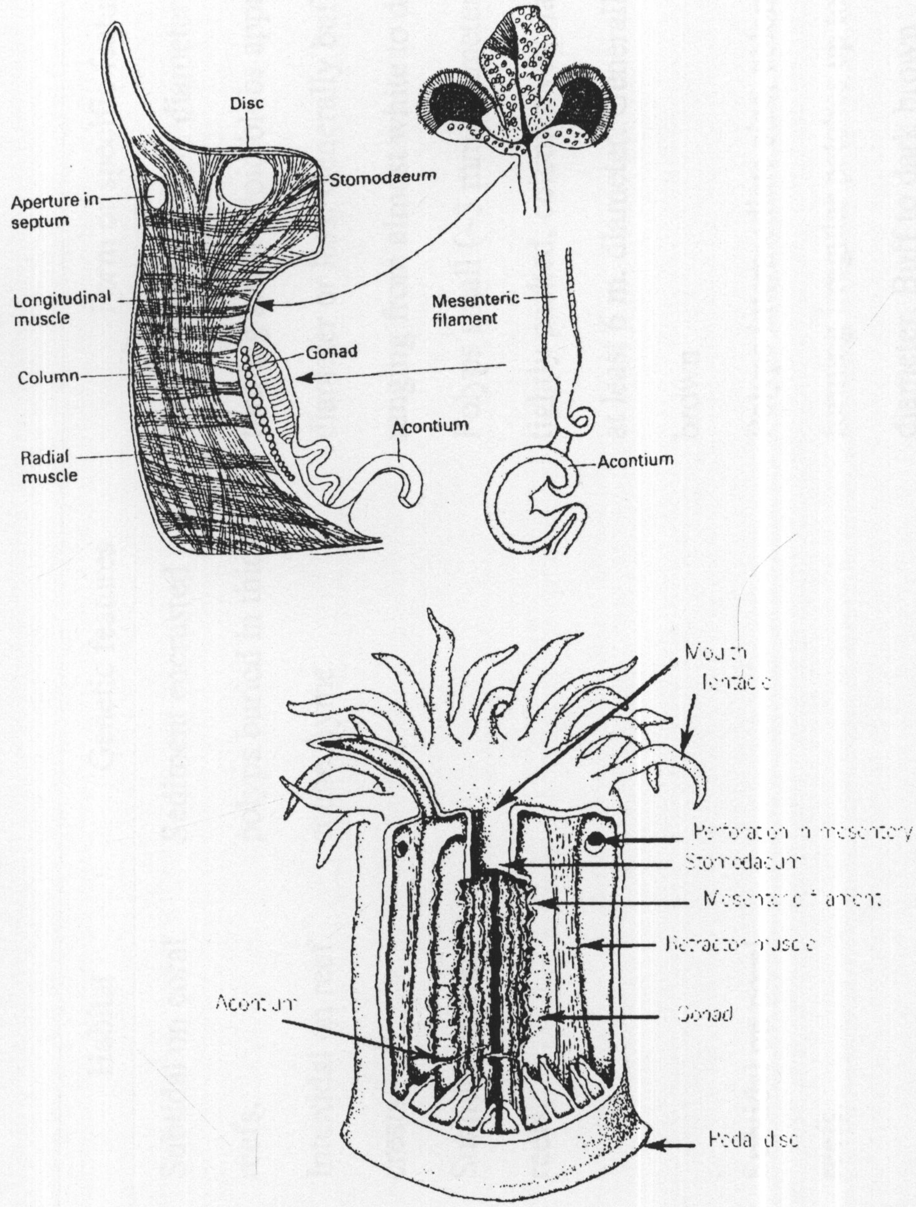


Figure 1 The organelle of Anthozoa

Source: Barnes, R. S. K., P. Calow, P. J. W. Olive, and D. W. Golding. 1988. Phylum Cnidaria (hydras, jellyfish, anemones, corals). In **The Invertebrates**. London Blackwell Scientific Press, pp. 55-70.

Table 1 Diagnostic features for morphological grouping of Zoanthidae and one species of *Parazoanthid*

Morphological group	Habitat	Genetic features	Form or specific features
Palythoa caesia	Subtidal on coral reefs. Intertidal on reef crests	Sediment encrusted polyps buried in thick coenechyme	Polyps large (~8 mm. diameter), colonies forming small ovoid blobs approx. 10 cm diameter or less. Generally buff coloured, ranging from almost white to dark brown
Palythoa form 2	Subtidal on coral reefs.		Polyps small (~3 mm. diameter) and tightly packed, colonies very large, up to at least 6 m. diameter. Generally light brown
Palythoa form 3	Subtidal on coral reefs.		Polyps intermediate size, colonies forming irregular patches up to 50 cm diameter. Buff to dark brown

Table 1 (continued)

Morphological group	Habitat	Genetic features	Form or specific features
Protopalythoa mutuki	Intertidal, reef flats and rocky shores	Sediment encrusted polyps joined only at the base.	Intertidal. Polyps large, oral disk usually dark green with white mouth. Very heavily encrusted with large sand grains
Protopalythoa form 2	Subtidal on coral reefs.		Subtidal. Polyps relatively small unless growing out form under shade. Oral disk brown or green, frequently patterned.
Sphenopus marsupialis	Sandy or muddy substrata, seagrass beds.	Large, solitary polyps free living in sand. Small polyps may be attached to stones or sea grass fronds.	Polyps earthy grey.

Table 1 (continued)

Morphological group	Habitat	Genetic features	Form or specific features
Zoanthus coppingeri	Intertidal, reef flats and rocky shores	Polyps small, not sediment encrusted.	Forming extensive colonal patches, especially on unstable substrata (coral rubble) and the coral *Montipora digitata*. Colour bright and highly variable, generally red, orange, yellow or green
Zoanthus form 2	Intertidal, reef flats and rocky shores		Disk with light coloured pattern on dark green or brown background. Associated with *Protopalythoa mutuki*
Zoanthus form 3	Subtidal on coral reefs		Sutidal. Colonies usually small but occasionally extensive. Disk bright green, tentacles brown

Table 1 (continued)

Morphological group	Habitat	Genetic features	Form or specific features
Zoanthus vietnamensis	Intertidal on reef crests		Colonies thinly encrusting, polyps completely buried in coenechyme. Forming extensive rubbery mats. Powder blue or blue/green.
Parazoanthus dichroicus	Subtidal on coral reefs	Polyps small, encrusted with fine sediment. Often have yellow or orange tentacles.	Growing on hydroids. Polyps small, beige, with distinct capitular ridges. Tentacles yellow or orange.

Source: Burnett, W. J., J. A. H. Benzie, J. A. Beardmore, and J. S. Ryland. 1997. Zoanthids (Anthozoa, Hexacorallia) form the Great Barrier Reef and Torres Strait Australia: Systematic, Evolution and key to species. ***Coral Reefs*** 16:57.

Reproduction

Reproduction of the zoanthids can be both sexual and asexual reproductions (Yamazato et al. 1973, 275; Campbell 1974, 133; Cooke 1976, 281; Fadlallah et al. 1984, 80; Martindale and Henry 1998, 672; Borneman and Lowrie 2001, 903). Asexual reproduction of *Palythoa* by using longitudinal budding from stolon (Cooke 1976, 283; Karlson 1988b., 1219; Borneman 1998,3) or fragmentation (Acosta et al. 2001, 363; Borneman and Lowrie 2001, 903) were reported. Acosta et al. (2001, 363-378) examined asexual reproduction of zoanthids and found that zoanthid built a new colonies from fragments. He used *Palythoa caribaeorum* as a model and proposed a way to produce a fragment by two methods.

1. *Biotic fragmentation* (tissue isolated due to biologically causesed lesions); in this case, primary due to disease causing partial colony mortality in the colony (Figure 2 A. – C.).

2. *Physical fragmentation* (colonies broken into several pieces by storm, current or tide) (Figure 2 D. – E.)

Both methods are incidental fragmentation, not actively directed by the parent colony. A significant positive linear relationship was found between colony area and degree to partial mortality. In general fragmentation in zoanthids plays an important role in asexual reproduction and competition with reef sessile organisms.

In addition to propagation of *P. caesia* by both sexual and asexual modes (Ryland and Babcock 1991, 119). The colonies cannot be identified their sex. Zoanthid gametes developed in mesentery (Borneman 1998, 3). The eggs and spermaris were different (Cooke 1976, 283). Examples of asexual reproduction were reported in zoanthids.

Yamazato et al. (1973, 276-283) studied reproductive ecology of *Palythoa tuberculosa* in Okinawa, Japan and recognized 3 types of colonies.

Type 1 Functional protogynous hermaphrodites in which the individual polyps change their reproductive phases from functional female to functional hermaphrodite, and then the function male.

Type 2 Consecutive protogynous hermaphrodites in which polyps change from non-functional female to functional male without an intervening period of hermaphroditism.

Type 3 Male colonies, which have only male polyps along with sterile ones.

The above conclusion explains why male colonies are found more frequently than female colonies.

Cooke (1976, 281-288) studied reproductive biology of zoanthids, *Zoanthus pacificus* and *Palythoa vestitus,* at Kaneoh Bay, Hawaii and found that the eggs and sperm were very similar in both species. Although fertile polyps for zoanthids were observed throughout the year they did not reveal a seasonal cycle. Gonad developed during summer months and undeveloped in winter months. Both zoanthids had high rates of asexual reproduction by budding new colony near the original colony.

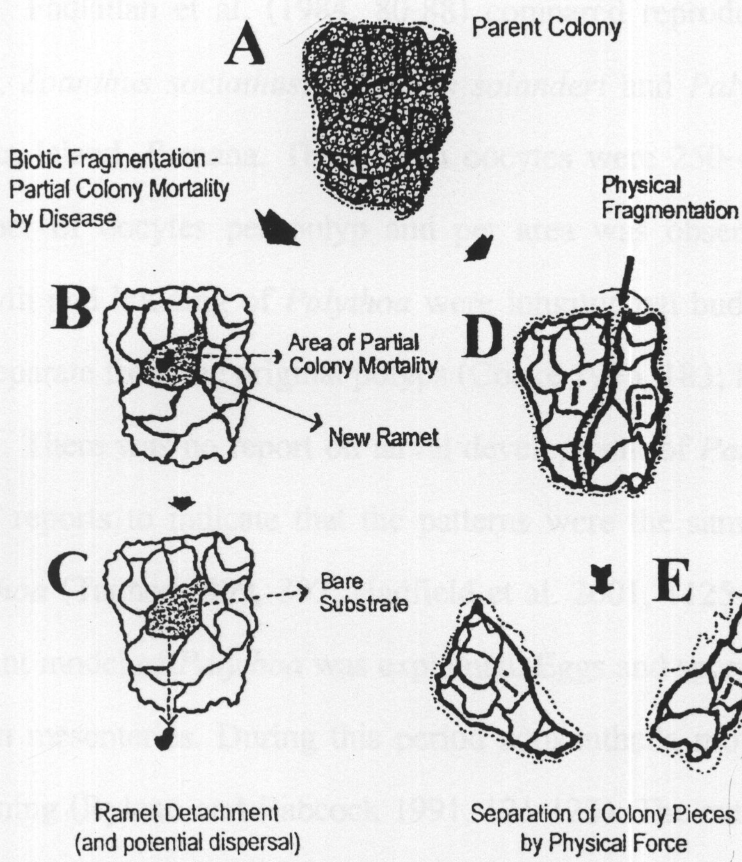


Figure 2 *Palythoa* schematic illustration of asexual reproduction by Fragmentation

Note : Fragmentation processes proceed from partial colony (top figure) tick arrow represent principle partway (A) partial colony, (B) biotic fragmentation (C) detachment o the ramet (D) physical fragmentation by substrate instability. (j' and j" are separate from partial colony as two boulders acting as substratum separate; storm activity might initiate this (C) ramet dispersal usually effected by current, slop of the bottom etc.

Source: Acosta, A., P. W. Sammarco, and L. F. Duarte. 2001. Asexual Reproduction in a zoanthid by fragmentation: the role of exogenous factors. **Bull. Mar. Sci.** 68: 369.

Fadlallah et al. (1984, 80-88) compared reproduction of three zoanthids, *Zoanthus sociathus, Zoanthus solanderi* and *Palythoa caribaecum,* in Galeta Island, Pamana. Their mean oocytes were 250-450 µm. The highest number of oocytes per polyp and per area was observed in *Z. sociathus.* Growth and budding of *Palythoa* were longitudinal budding from stolon but not separate from the original polyps (Cooke 1976, 183; Borneman 1998, 3).

There was no report on larval development of *Palythoa* but there were some reports to indicate that the patterns were the same as those of *Protopalythoa* (Tanner 1999, 397; Hadfield et al. 2001, 1125-1129). Larval development model of *Palythoa* was explained. Eggs and spermaries were developped in mesenteries. During this period zooxanthella moved into eggs before spawning (Ryland and Babcock 1991, 121-123). The externally fertilized egg of *Palythoa* was developed by radial cleavage to produce a hollow blastula. Gastrula formation took place by a mechanism to invaginate and proceed by a flattening of the blastula followed by progressive concave/convex deformation. After that the mouth and mesenteries began to form in the larva prior (Barnes et al. 1988, 68). Then after two weeks the larvae developed to the stage of zoanthella, and were able to settle after 17 to 18 days (Babcock and Ryland 1990, 239-236). The tentacles were formed later (Barnes et al. 1988, 68).

Growth rate

Animals usually grow in relation to their ages. But numbers in order Zoanthidea are different due to food risky, environmental disturbances and competition with other reef sessile organisms (Sebens 1977, 397-408; Karlson 1988a., 31) and strong wave (Koehl 1977, 437). Tanner (1997, 793-810; 1999, 390-397; 2000, 514-519) studied effect of density on the zoanthid by using *Palythoa caesia* in the Great Barrier Reef as a model. The model showed major differences in fission and fusion rates with density, with fission decreasing and fusion increasing as density increased. The growth rate of large colonies decreased substantially as density increased, although small colonies were unaffected. Mortality, on the other hand, was independent of density. Recruitment rates peaked at intermediate densities, but low overall. While density accounted for less than 10% of the variation in the demographic rates measured, it explained 62% of the variation in changes in cover within a given aggregation. Change in cover was greasted (30% in two years) for quadrats with 23-33% cover, and became negative for quadrats with over 80% cover. The highest density quadrats (90% cover) experienced an 18% decrease in cover over two years. When the data on colony level dynamics for each density were integrated into population dynamic models, he found a steady decrease in population growth rates with density, a long with an increase in the proportion of individuals in the largest size class. However, the proportional contribution of each size class to future generations (reproduction value) did not change whit density. These results suggest that the equilibrium cover in the model was 84% and was reached in ≈ 40 years. To determine which density-dependent transitions were involved in population regulation, the strength of density dependence was varied in each independently. This sensitively analysis showed that only changes in probabilities of large colonies remaining large and producing medium colonies, were regulating. These results suggest that regulation is primarily acting on fission of large colonies to produce intermediate-size colonies, in combination with size specific growth rate. Fission rates decrease greatly with density, resulting in a greater proportion of large colonies at high densities and large colonies grow more slowly than small. Overall, this behavior was very similar to that of colonal plants which have a phalanx type life history. Although colony density change to produce intermediate-size depend on colonies size not species or population density.

Competition

Besides reproduction and growth ability, competition is the important point to make *Palythoa* widespread in many localities. Suckhnek and Green (1981, 619-684) found that *Palythoa* can overgrowth many reef sessile organisms such as *Acropora* spp., *Porites* spp., *Favia fragum*, *Millepora* spp., *Zoanthus solanderi*, *Haliclona* sp. and other unidentified sponges. Overgrowth in *Palythoa* can be divided in to 5 types:

1. ***Lateral aggression without physical contact***, there exists a margin of dead tissues in front of the advancing *Palythoa* colony and it is assumed

that some from of allelochmical interaction is likely occurring (it possible that the *Palythoa* colony had previously advanced, smothering the coral polyps, then retracted, leaving a margin of bare space before advancing again) (Figure 3A).

2. *Lateral aggression with physical contact*, the interaction may involve some tentacular action on the part of *Palythoa* or an actual smothering of subordinate species (Figure 3B).

3. *Overtopping without physical contact*, subordinates with zooxanthaellae would be shaded out of existence: it is likely that heterotrophic feeding would be severely impeded in is case as well No allelechemical or tentacular effect need be invoked. hear (Figure 3C).

4. *Overtopping with physical contact*, smothering would again prevail, eventually killing the subordinate. (Rapid growth rate would be necessary to over take the other species (Figure 3D).

5. *Point settlement*, settlement *Palythoa* directly onto a living organism (Figure 3E).

Karlson (1980, 894-898) reported that *Palythoa* was aggressive cnidarian overgrowing *Zoanthus, P. porites, Agaricia, Siderastrea* and *Acropora* as well as *Millepora* at an average rate of 1.3 cm/year (range = 0.3-3.5 cm/year). Bastidas and Bone (1996, 543-555) studied competition between two zoanthids *Palythoa caribaeoum* and *Zoanthus sociatus* in Isla Raton Cuerto Cabello, Venezuella, and found that *P. carivaeom* was strong competition compare to *Z. sociatus*. *P. carivaeom* did a greater the initial cover and growth rates were highly variable, ranging from 0.08 ± 0.02 to 0.12 ± 0.06 cm^2

border/month and *Z. sociatus* raging from 0.05 ± 0.15 to 0.14 ± 0.51 cm^2 border/month. Hill (1998, 513-521) reported the spatial arrangement and genetic composition of populations of the zoanthid *Parazoanthus parasiticus* on sponge *Callyspongia vaginalis*. The pattern of dispersion of *P. parasiticus* on the *C. vagimalis* was randomly for four of six populations. Two populations exhibited overdispersion. Polyps density decreased towards the growing edge of *C. vaginalis*, and approximately 12% of polyps were in process budding. Electrophoretic variability at five enzyme loci indicated that population of *P. parasiticus,* cell collected from there species sponges, can consisted of genetically identical individuals. Heterozygosis at several loci indicated an absent of meiotic segregation, and therefore colonal reproducetion. *P. parasiticus* population may be initiated. One is that a single sexually derived planktonic larva settles on a sponge, and through asexually reproducetion colonizes all of the available surface area. Another possible is that a single genotype out completes a number of colonizers, and takes over the sponge surface through asexual reproduction. Finally, multiple colonization of same genotype may occur with subsequent asexual reproduction.

Environmental effect on Anthozoan behavior

Reef sessile organisms incur at various scales resulting from biotic and abiotic causes. (Wessling et al. 1999, 11-15) Sedimentation is cited as one of the

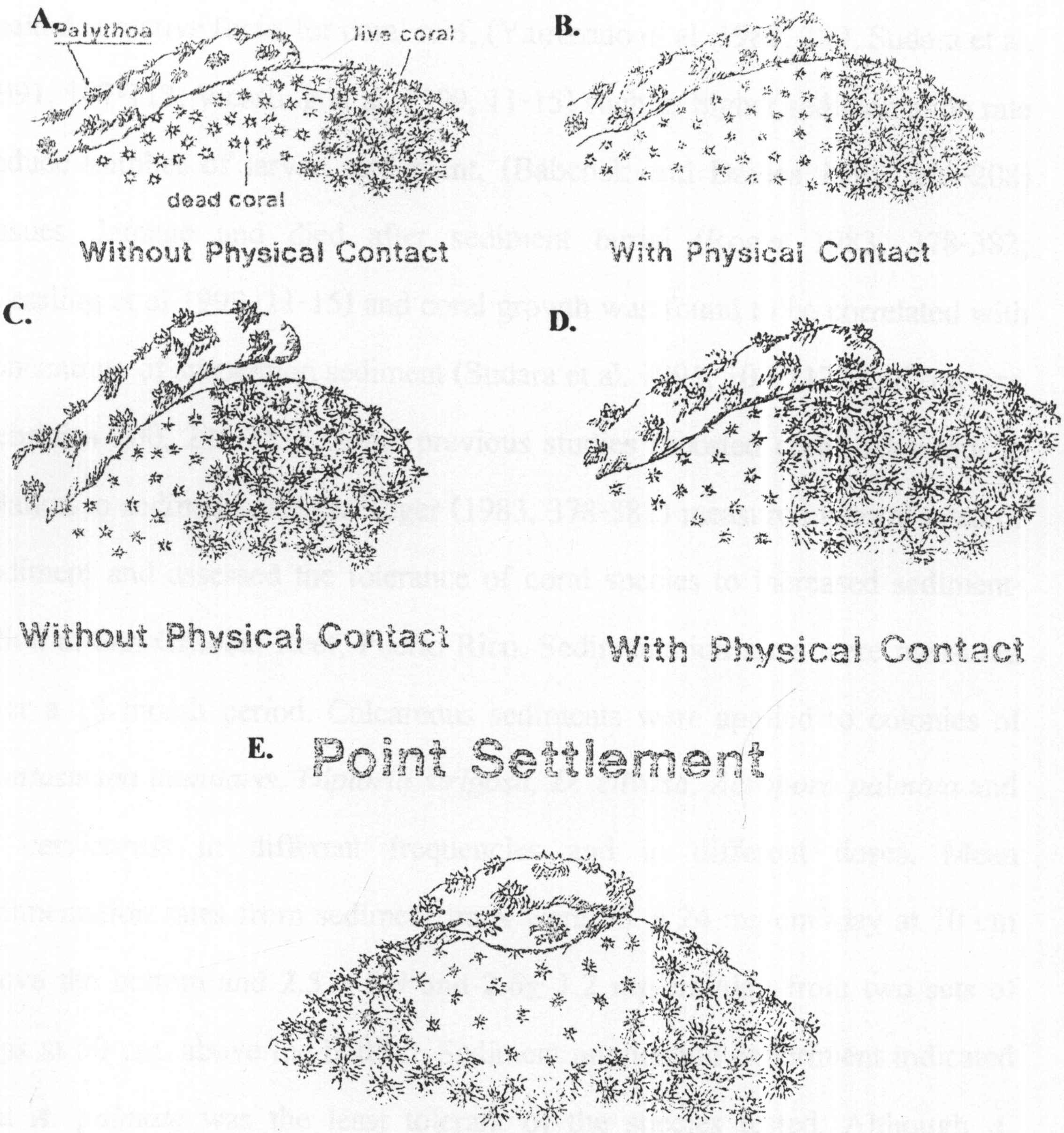


Figure 3 Type of overgrowth interactions *Palythoa* by growing over subordinate species

Source: Suckhnek, T. H., and D. J. Green. 1981. Interspecific competition between *Palythoa caribaeorum* and other sessile invertebrates on St. Croix Reefs, U.S. Virgin Island. In **Prog. 4th. Int. Coral Reef Symp.** Vol. 2. Manila:. University of Philippines, 682.

main destructive focus for coral reef, (Yamazato et al. 1987, 289; Sudara et al. 1991, 107-112; Wessling et al. 1999, 11-15) such as higher sedimentation rate reduce number of larvae settlement, (Babcock and Davies 1991, 205-208) tissues damage and died after sediment burial (Roger 1983, 378-382; Wessling et al 1999, 11-15) and coral growth was found to be correlated with concentrate of suspention sediment (Sudara et al. 1991, 107-112; Anthony and Febricius 200, 221-253). Some previous studies reported coral behaviour in relation to sediment effects. Roger (1983, 378-382) measured natural rates of sediment and assessed the tolerance of coral species to increased sediment-tation at San Critobal Reef, Puerto Rico. Sedimentation rates were measured over a 18 month period. Calcareous sediments were applied to colonies of *Montastraea annularis, Diploria strigosa, D. clivosa, Acropora palmata* and *A. cervicornis* in different frequencies and in different doses. Mean sedimentation rates from sediment traps were 96 $\pm$ 24 mg/cm^2/day at 10 cm above the bottom and 2.5 $\pm$ 0.9 and 2.6$\pm$ 1.2 mg/cm^2/day from two sets of traps at 50 cm. above the bottom. Sediment application experiment indicated that *A. palmate* was the least tolerant of the species tested. Although *A. cervicornis* and *D. stigosa* colonies were not significantly affected, single applications of 800 mg/cm^2 to *M. annularis* colonies and of 200 mg/cm^2 to *A. palmata* colonies caused death of underlying coral tissue. Algae colonized portions of these corals. Sudara et al. (1991, 107-112) did comparison of growth of *Porites lutea* colonies at various sites around Khang Khao Island, on the Inner Gulf of Thiland. Growth studies of *P.lutea* revealed that horizontal growth was slower than vertical growth. Vertical growth of *P. lutea* in the northern part of the island was faster during the period December to June when sedimentation was low levels of suspended solids were also higher during the period December to June. In the southern part of the island, coral growth was not as good during December to June as it was during July to December. Babcock and Davies (1991, 205-208) reported the effects of varying rates of sedimentation (0.5 to 325 mg/cm^2/day) on settlement rates of *Acropora millepora* larvae were examined experimentally, in aquaria. Settlement and juvenile orientation onto conditioned cut coral plates were recorded after two days. Higher sedimentation rates reduced the number of settled larvae were not significantly affected by sedimentary regime. While total settlement was unaffected by under the conditioned experimental conditions, it likely to be reduced under field conditions, since accumulation of sediment on upward facing surfaces will greatly reduce the overall amount of suitable substratum available.

In *Palythoa,* Haywick and Mueller (1997, 36-46) reported that they incorporate sediment into their tissues as they growth. The amount of sediment assimilated is significant, averaging almost 45% of wet tissue weight. *Palythoa* assimilate all available minerals on the reef. There also no preference in terms of skeletal composition: coral grit, coralline red algae, *Halimeda* and other allochems are all equally assimilated into *Palythoa* tissues. The only preference is generally $\leq$ 125 μm in size, far finer than ambient sediment found adjacent to *Palythoa* colonies (predominantly > 500 μm) Acosta (2001, 119-120) suggested other sediment defense mechanisms of *Palythoa* on São Paulo coast, Brazil. During the winter, after period of storms and continuous stress due to turbidity and an extremely high sedimentation rate, 19.7% of the total colonies monitored (*n* = 578) exhibited a thin layer of mucus covering all or part of the colony. Colonies remained retracted, with polyps close and feeding. Some of colonies stayed in this condition for weeks or even months into the winter, appearing dead. A reduction in height of the contracted polyps in the whole colony was evident during this stage, suggesting tissue resorption. Weeks later, the colony released this mucus layer, which was sometimes covered by algae and sediment grains, then opened their polyps and started to feed again. A shiny color on the surface characterized the colonies that finished this period of what might be termed diapause or dormancy. No colonies that experienced this stage died.

In addition to *Palythoa* mucus was composted by marine toxin call Palytoxin or PTX (Kimura et al. 1972, 611-617; Tosteson et al. 1995, 799-807; Gleibs et al. 1995, 1531-1537; Carte 1996, 271; Leech and Habener 1998, 1066-1072; Gleibs and Mebs 1999, 1521-1527; Acosta 2001, 125; Wu et al. 2003, 55). Plytoxin is considered to be one of the most compound, exhibition extreme in mammals (Tosteson et al. 1995,799-806; Gleibs et al. 1995, 1531-1537; Gleibs and Mebs 1999, 1521-1527) PTX was increased the cationic permeability of cell membranes and inhibits the (Na^+, K^+)-activated ATPase, effects that are completely reversed by ouabain. (Mebs 1998, 1519-1522; Rhodes et al. 2002, 631-636; Wu et al. 2003, 55-62) Palytoxin effect uses as an anti-perdition defense of *Palythoa*. (Hill 1998, 513)

CHAPTER 3

MATERIAL AND METHODS

Historical background of the Materials

Taxa and Background of *Palythoa caesia*

Kingdom	: Animal
Class	: Anthozoa
Subclass	: Zoantharia
Order	: Zoanthidea
Family	: Zoanthidae
Genus	: *Palythoa*
Species	: *caesia*

Diagnostic feature of *Palythoa caesia* (Burnett et al. 1997, 57-65)

Habitat	: Subtidal on coral reef. Intertridal on reef crests.
Generic featured	: sediment encrusted polyps buried in thick conenchyme.
From feature	: Polyps large (~ 8 mm diameter), colonies forming small ovoid blobs approx. 10 cm. diameter or less. Generally buff colored, ranging from almost white to dark brown.

Key to Great Barrier Reef and Torres Strait

1. **A** Polyps sand encrusted__________________________________**2**

   B Polyps not sand encrusted_______________________________**6**

2. **A** Polyps solitary. Found living on sublittoral sandy substrata, not coral reefs. Polyps very robust, rounded or slightly pointed at the base. Small specimens may be attached to small stones or sea grass blades by thin stalk________________________________ *Sphenopus marsupialis*

   B Polyps colonial, on coral reefs and rocky shores_______________**3**

3. **A** Polyps completely immersed in a thick coenenchyme when eloseed. Colonies may be small (~3-10 cm) and ovoid coenenchyme with large polyps, or very large with small, densely packed polyps ____________
   ____ *Palythoa caesia*

   B Polyps free standing, conected only at base __________________ **4**

4. **A** Intertidal. Disk green or brown, often with contrasting light colored mouth and hypostome. Polyps cylindrical when closed, with scapus and capitulum of equal diameter. Scapus may appear transversely wrinkled ______________________________ *Protopalythoa mutuki*

   B At extreme low water and subtidal ________________________ **5**

5. **A** Polyps fully open in shade. Disk uniform brown, mottled whit and brown/green, or brown with white radial lines. Often semi-closed in direct sunlight, with triangular appearance. Polyps trumpet shaped when closed ______________________________ *Protopalythoa* sp. **2**

Polyps white or sandy colored, partially buried in coral rock________

______________________________________ *Protopalythoa* sp. **3**

6. **A** Polyps large (to 70 mm), joined at base. Colonies usually with only a few polyps. Body wall with large tubercules usually arranged in longitudinal series. Intertidal and sublittoral ____ *Isaurus tuberculatus*

   B Polyps small (rarely over 20 mm), without tubercles or immersed in a thick coenenchyme ______________________________ **7**

7. **A** Polyps joined at base by stolones. Intertidal or sublittoral. Color highly variable, bright green, red, orange, yellow or brown. Oral disk uniform or platented, tentacles often strongly contrasting color disk___

   ______________________________________ *Zoanthus coppingeri*

   B. Polyps immersed in thick coenenchyme. Intertidal on exposed reef crests. Colonies forming extensive rubbery mats. Colonies strikingly coloured, powder blue or green ____________ *Zoanthus vietnamensis*

Study sites

P. caesia specimens and sedimentation rates were investigated at Khang Khao Island, inner part of The Gulf of Thailand, 13° 06′ 45¨ N, 100° 48′ 52¨ E. The Island is approximately 60 and 40 kilometers from Chow Phraya and Bangpogong river-mounts, respectively, so the area was effected by the sediment runoff during rainy season. (Ruengsawang 1999, 9) In the present study three stations of Khang Khao Island were selected for field study. All stations are influenced by the difference of monsoons, station A is on the north coast of the island which is directly effected by Northeast monsoon during October to February. Station C is on a east coast of the island which is effected by Southwest monsoon during May to September and Southeast monsoon or Southeast trade during February to April. Station D is on the west coast of the island which is also effected by Southwest monsoon. The station descriptions are as follows: (Figure 4)

Station A divided into 2 zones as;

As The shallow zone

Ad The deep zone

Station C divided into 2 zones as;

Cs The shallow zone

Cd The deep zone

Station D divided into 2 zones as;

Ds The shallow zone

Dd The deep zone

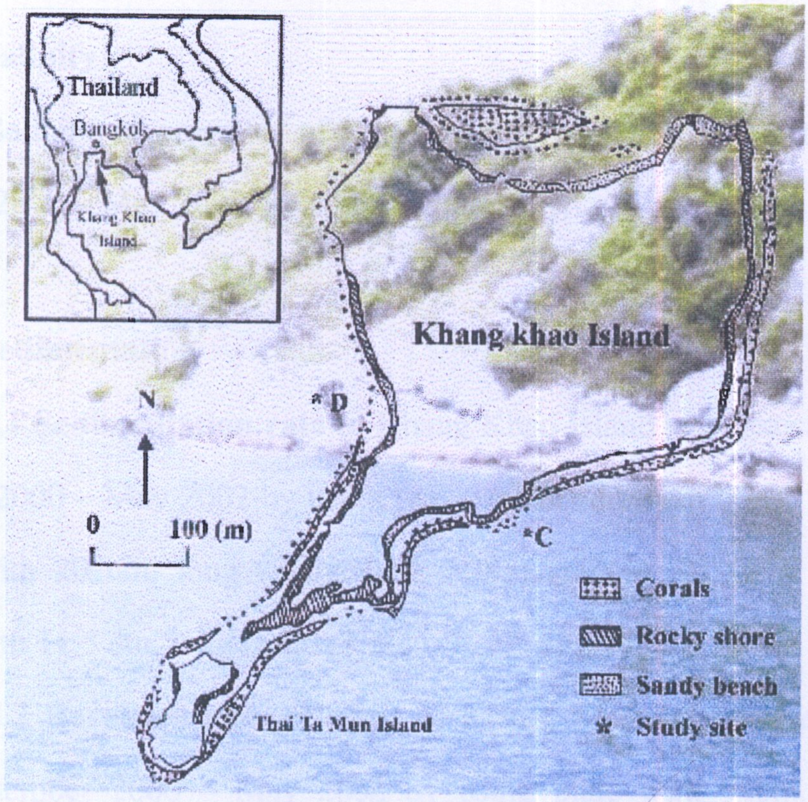


Figure 4 Map of the study area

Field Experiments

Measurement of the environmental factors

1. Temperature

Surface seawater temperature (SST) of Khang Khao Island was detected during September 2000 – May 2002 by using a digital underwater thermometer.

2. Salinity

Salinity of seawater of Khang Khao Island was detected during September 2000 – May 2002 by using a salinometer.

3. Sedimentation

3.1 Sedimentation rate of Khang Khao Island was detected during September 2000 – May 2002 by using two sizes of sediment traps, 1) 1.5 cm. diameter with 20 cm. long (Suthanaruk 1983) (Figure 5B.) and 2) 5 cm. diameter with 11.5 cm. long (English et al. 1997, 59) (Figure 5A.).

3.2 Resuspension sediment of Khang Khao Island was detected during September 2000 – May 2002 by using plate with 9 cm. diameter (Figure 5C.).

4. *P. caesia* specimen

From September 2000 – May 2002, three colonies per station were marked and measured continuously by using underwater photography to detect growth and mortality rates. Nine *P. caesia* colonies from 3 stations (Cs, Ds and Dd) were randomly collected by a sharp knife and fixed in 10% formalin: seawater to detect gamete development and sediment in the tissues. For *P. caesia* interactions, three belts transects and 1 m^2 quadrates, (Aerts and Soest 1997, 126-128) were applied randomly along the reef bed. Four categories of interactions were defined.

1) Aggregation without physical contact

2) Aggregation with physical contact

3) Overtopping

4) Point settlement (Suckhnek and Green 1981, 679-684)

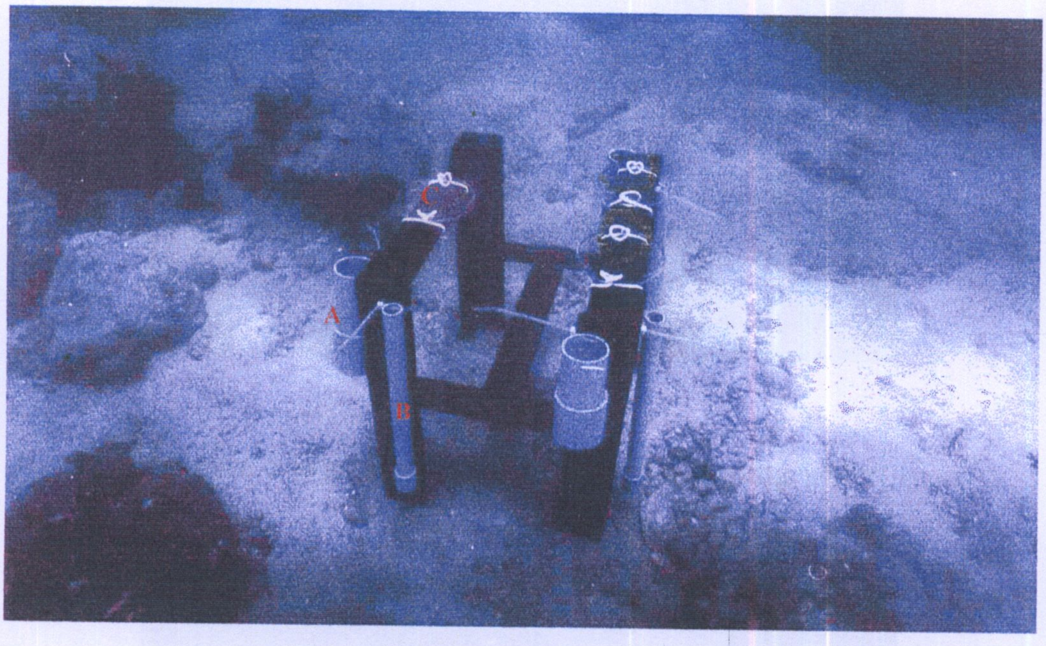


Figure 5 Study of sedimentation and resuspension rate by three types of sediment traps

Note : A. sedimentation trap 5 cm. diameter B. sedimentation trap 1.5 cm. diameter and C. sediment plate.

Laboratory works

1. Sediment trap

To estimate the sediment dry weigh, dry and clean beakers were pre-weighed and running numbers (Figure 6).

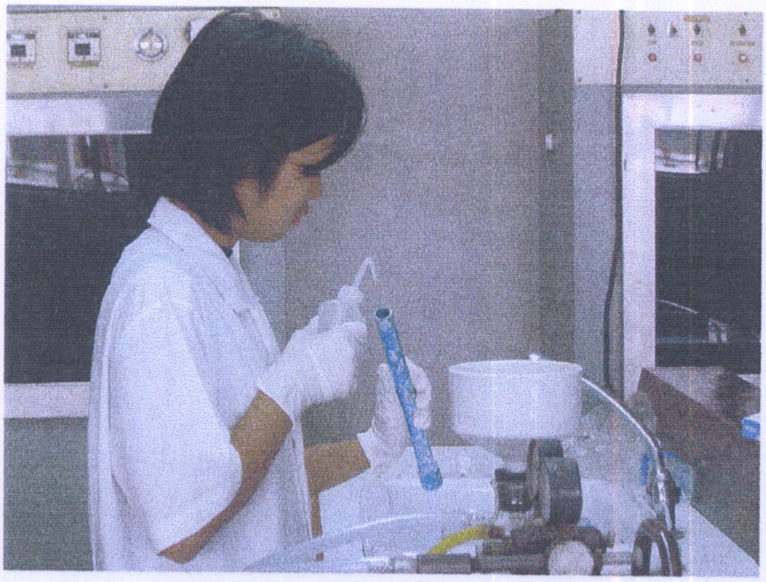


Figure 6 Washing sediment traps by running water

Figure 7 Place beaker in room temperature

Figure 8 Dry sediment from a sediment trap at 105°C, 24 hour

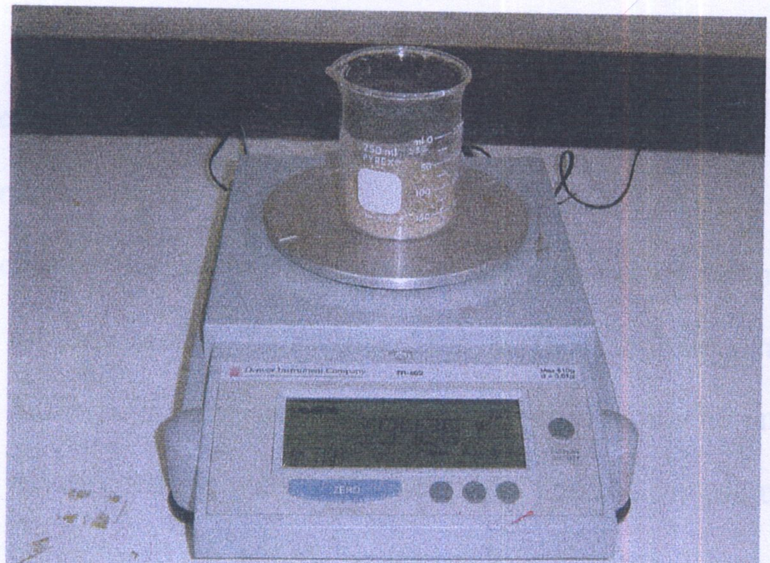


Figure 9 Weighing

Figure 10 Dry sample burn in muffle furnace at 550°C, 5 hours to remove organic matter

2. *P. caesia* colonies

Surface sediment

P. caesia specimens were note surface area before remove surface sediment by running water. To estimate the surface sediment rate, I pre-weight a dry filter paper and poured the water with sediment on the filter paper. Then I determined the weight of filter paper and the sample oven dry at 105°C for 24 hours (until the sample no longer lose weight). Tongs were used for removing the filter paper with sample from the oven and placed it on a desiccator containing silicagel and allowed the sample and filter paper to cool at room temperature and weighed (Figure 11).

Surface sediment of *P. caesia* colony was

Filter paper with sediment weigh - Filter paper weigh = Sediment weigh

Figure 11 Sediment from *P. caesia* surface on a filter paper

3. Entomb sediment

A piece of 2 x 3 cm. from each *P. caesia* sample was cut with a sharp dissection knife then dried at 105°C, 24 hours or until the sample no longer lose weigh before weighed (DW). Sample placed in crucibles and weighed (CW) before ash in muffle furnace at 550°C, 6 hours to investigate lose organic weigh. Tongs were used for removing the crucible from muffle furnace and place in a dedicator contain silica gels, and allowed the sample and crucible cool at room temperature and weighed (IW).

Sediment from sediment traps were remove to beaker respectively by running water and made the sediment traps labeled on this. Place beaker in room temperature for sediment were settling for 3-4 days. (Figure 7) Poor slowly top water (no sediment) dry at 105°C, 24 hour or until the sample no longer lose weight. (Figure 8) Tongs were used for removing the beaker from the oven and placed it on a desiccator containing silicagel and allowed the sample and beaker to cool at room temperature and weighed.

Then 10 mg from each samples were pick to running crucibles (crucibles were pre-weight before add the sample) respectively. After that I place the crucible in a muffle furnace at 550°C for 5 hours to destroy the organic matter. (if black charcoal deposit are still visible, then continues ashing) The temperature did not exceed 550°C because the $CaCO_3$ would be converted to CaO_2, thus resulting in a biased ash sample free dry weight. Finally the furnace has been allowed to cool for several hours. I removed the curable containing the ashed samples and cooled them at room temperature in a desiccator and then weight (Wa).

Organic mater of sediment

10 – Wa = Organic matter

Organic and inorganic weigh of *P. caesia.*

CW – DW = Inorganic weigh (IW)

DW – IW = Organic weigh

Histological Study

In order to examine gamete development, histological sections of marked colonies were prepared 1-2 polyps of *P. caesia* were separated by a sharp dissection knife. After desilified in 20% hydrofluoric acid for 24 hours and decalcified in a solution compared equals parts of formalin and saturation formic acid made up 1:9 with water (Ryland and Babcock, 1991, 118). The tissues were washed in running water to remove formalin then dehydrated through a graded series of ethanol: 70%, 80%, 90%, 95% and absolute 1, absolute 2 for 30 minutes, respectively. The samples were transferred to ethanol – xylene (1:1), xylene 1, 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 block. The samples were cut into serial section, (10μm thick) and stained with hematoxylin and eosin. Both transverse and longitudinal sections were then examined with a light microscope for reproductive structures.

CHAPTER 4
RESULTS

Environmental Factors

Salinity

The present study recorded salinity at Sichang Island, Chonburi Province from February 2000 – December 2001 as follows:

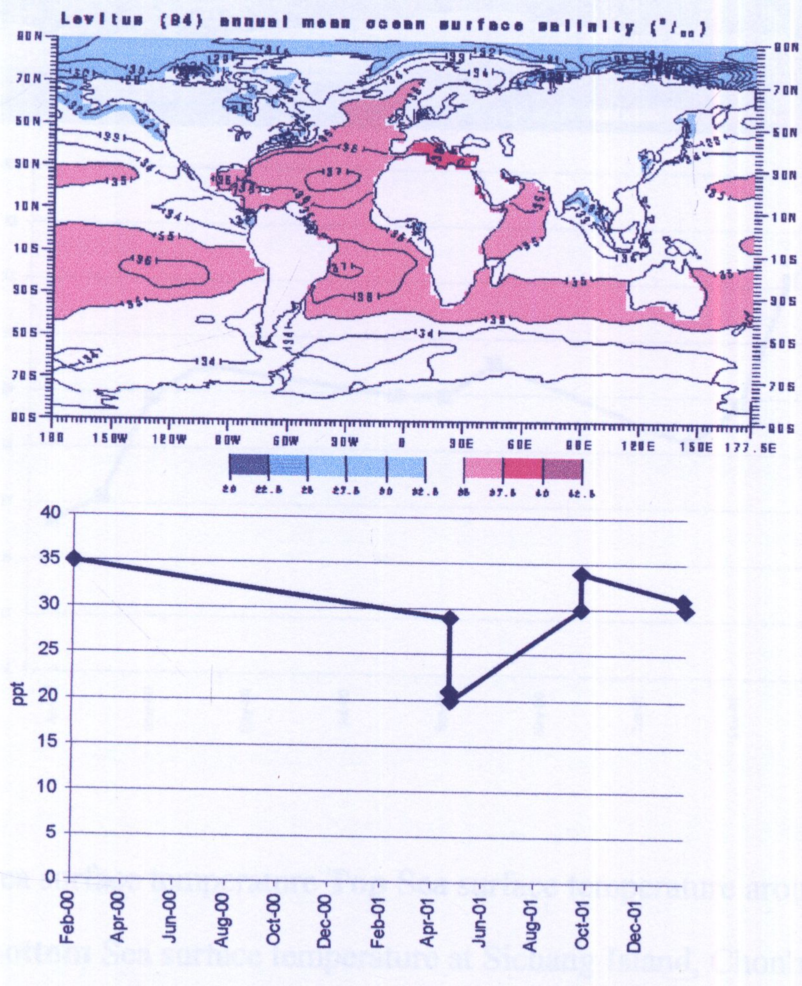


Figure 12 Salinity **Top** Salinity around The World **bottom** salinity during February 2000 – December 2001 at Sichang, Chonburi Province

Sea Surface Temperature

The data of sea surface temperature at Sichang Island, Chonburi Province during January 2000- May 2001 are showed as follows:

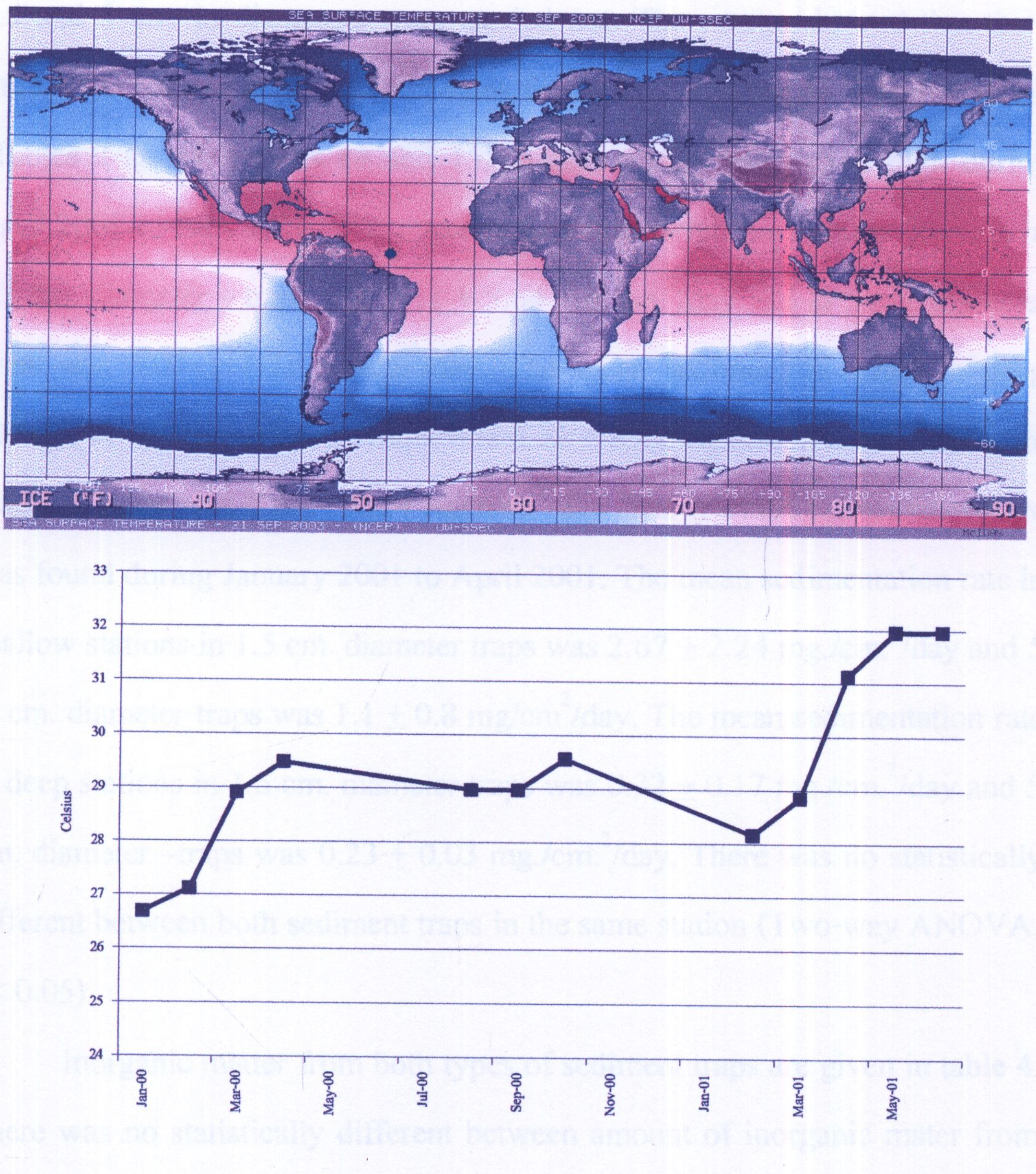


Figure 13 Sea surface temperature **Top** Sea surface temperature around the word **bottom** Sea surface temperature at Sichang Island, Chonburi Province during January 2000- May 2001

Source : Geo-Information and Space Technology Development Agency

Sedimentation rates and Resuspension of bottom sediment

Studies of sedimentation rates by applying two sizes of sediment traps, 1.5 and 5 cm. in diameters were carried out. The results showed that there were higher mean sedimentation rates in shallow stations than deep stations (Tables 2 and 3 Figures 14 and 15). Sedimentation rates were high during April 2001 to July 2001. The mean sedimentation rate in shallow stations in 1.5 cm. diameter – traps was 7.11 $\pm$ 5.64 mg./cm.^{2}/day and in 5 cm. diameter traps was 5.07 $\pm$ 1.71 mg/cm^2/day. The mean sedimentation rate in deep stations in 1.5 cm. diameter traps was 5.92 $\pm$ 8.41 mg./cm.^{2}/day and in 5 cm. diameter traps was 2.67 $\pm$ 2.24 mg./cm.^{2}/day. The lowest sedimentation rate was found during January 2001 to April 2001. The mean sedimentation rate in shallow stations in 1.5 cm. diameter traps was 2.67 $\pm$ 2.24 mg./cm.^{2}/day and 5 in cm. diameter-traps was 1.1 $\pm$ 0.8 mg/cm^2/day. The mean sedimentation rate in deep stations in 1.5 cm. diameter traps was 0.32 $\pm$ 0.17 mg./cm.^{2}/day and 5 cm. diameter –traps was 0.23 $\pm$ 0.03 mg./cm.^{2}/day. There was no statistically different between both sediment traps in the same station (Two-way ANOVA, $P< 0.05$)

Inorganic matter from both types of sediment traps are given in table 4. There was no statistically different between amount of inorganic mater from both traps. Sedimentation rates and inorganic matter had a relationship with mortality rate of *P. caesia*. If sedimentation rate was increased, mortality rate of *P. caesia* was increased as well.

Resuspension of bottom sediment was studied by using sediment plates during April 2001 to May 2002. The results are showed in Table 6 and Figure 16. The results revealed that there were high resuspension of bottom sediment rates in shallow stations than deep stations. The highest resuspension of bottom sediment rate was found in October 2001. The mean resuspension of bottom sediment rate was 545 1.91 $\pm$ 1.33 mg./cm.^{2}/day and the lowest resuspension of bottom sediment rate found in September 2001. The mean resuspension of bottom sediment rate was 0.52 $\pm$ 0.52 mg./cm.^{2}/day. There was statically different between sedimentation rates by sediment traps and resuspension of bottom sediment by sediment plates in the same station (Two-way ANOVA, $P<0.05$).

Table 2 Sedimentation rates in sediment traps 1.5 cm. diameter (mg./cm.^{2}/day.)

		SHALLOW STATIONS						DEEP STATIONS					
		Jul/00-Sep/00	Sep/00-Jan/01	Jan/01-Apr/01	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-May02	Jul/00-Sep/00	Sep/00-Jan/01	Jan/01-Apr/01	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-May02
A	mean	1.454	0.937	0.367	5.268	2.162	1.086	3.590	0.449	0.225	10.470	0.703	0.405
	SD	0.137	0.172	0.107	2.849	0.716	0.424	3.590	0.185	0.063	12.221	0.291	0.100
C	mean	2.795	0.269	0.386	8.518	11.545	6.288	1.544	0.287	0.000	1.544	1.893	2.772
	SD	0.125	0.009	0.113	5.434	2.418	2.999	0.313	0.067	0.000	0.313	0.853	1.871
D	mean	4.512	0.292	0.237	6.996	2.162	0.000	2.269	0.333	0.470	4.248	0.931	1.172
	SD	1.957	0.030	0.033	7.662	0.696	0.000	0.561	0.154	0.197	3.111	0.322	0.508

Table 3 Sedimentation rates in sediment traps 5 cm. diameter (mg./cm.^{2}/day.)

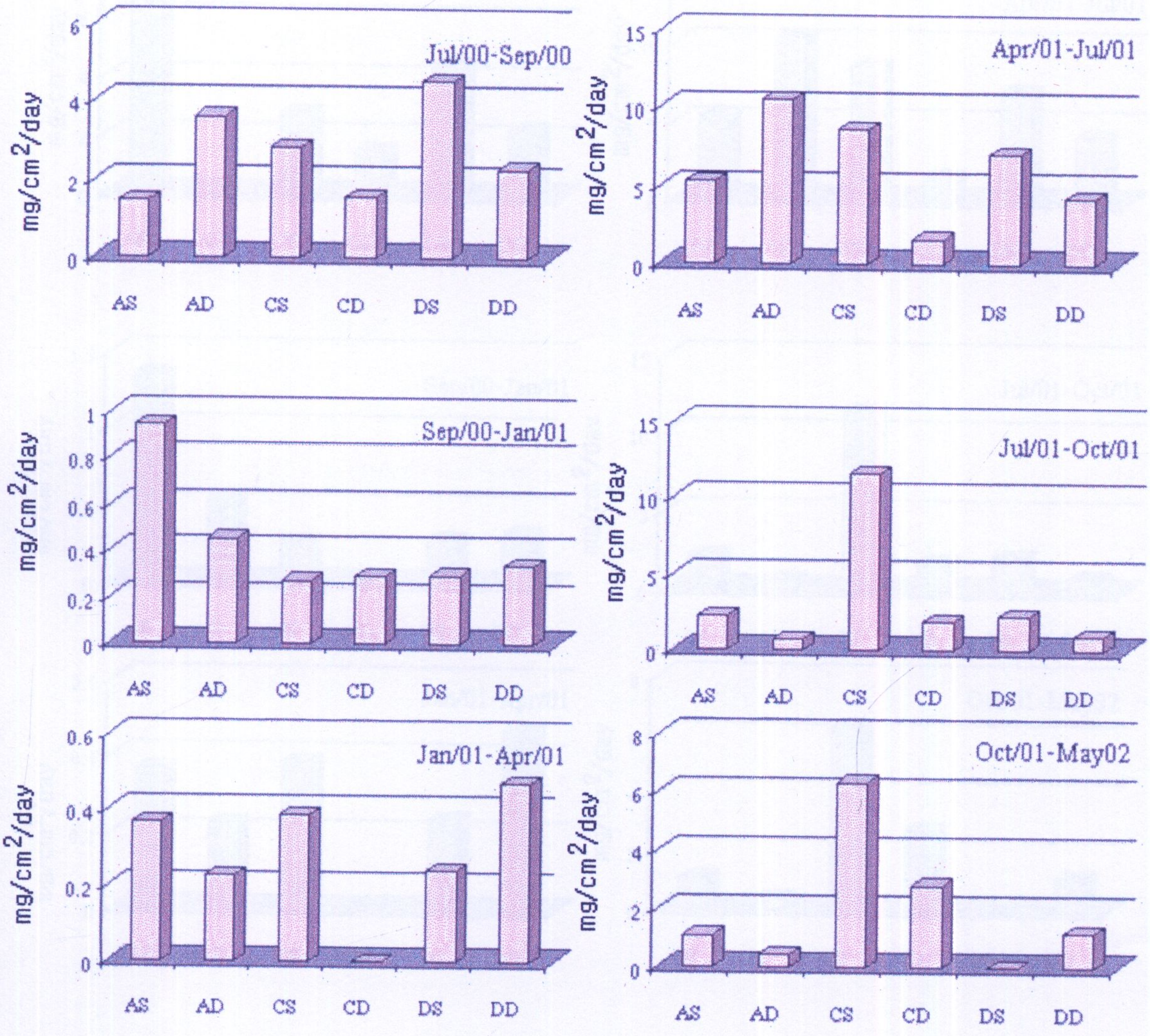
		SHALLOW STATIONS						DEEP STATIONS					
		Jul/00-Sep/00	Sep/00-Jan/01	Jan/01-Apr/01	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-May02	Jul/00-Sep/00	Sep/00-Jan/01	Jan/01-Apr/01	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-May02
A	Mean	6.728	1.349	0.100	1.063	0.287	0.000	0.239	0.539	0.127	1.158	0.428	0.875
	SD	1.087	0.094	0.000	0.451	0.237	0.000	0.058	0.165	0.033	0.496	0.263	0.815
C	Mean	5.574	0.270	1.591	2.587	0.251	2.769	0.000	0.000	0.000	1.686	1.476	1.404
	SD	1.150	0.042	0.133	1.449	0.133	1.041	0.000	0.000	0.000	2.009	1.457	0.978
D	Mean	4.487	0.130	0.160	1.975	0.672	1.804	5.337	0.660	1.230	4.047	0.999	1.717
	SD	1.336	0.000	0.000	2.172	0.300	1.765	0.985	0.000	0.000	2.121	0.234	1.783

Table 4 Mean amount of inorganic mater from sediment traps (g./ash)

		SHALLOW STATIONS						DEEP STATIONS					
		Jul/00-Sep/00	Sep/00-Jan/01	Jan/01-Apr/01	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-May02	Jul/00-Sep/00	Sep/00-Jan/01	Jan/01-Apr/01	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-May02
A	Mean	0.950	0.869	0.765	1.000	0.949	0.813	0.840	0.911	0.846	0.987	0.953	0.887
	S.D.	0.030	0.169	0.258	0.000	0.074	0.317	0.131	0.907	0.070	0.041	0.139	0.160
C	Mean	0.932	0.907	0.908	1.000	0.991	0.816	0.900	0.895	0.000	1.000	0.978	0.953
	S.D.	0.004	0.039	0.057	0.000	0.028	0.273	0.067	0.007	0.000	0.000	0.045	0.044
D	Mean	0.948	0.717	0.850	1.000	1.000	0.945	0.948	0.907	0.888	1.000	0.953	0.957
	S.D.	0.020	0.481	0.026	0.000	0.000	0.012	0.018	0.081	0.093	0.000	0.103	0.012

Table 5 Mean amount of organic matter from sediment traps (g./DW.)

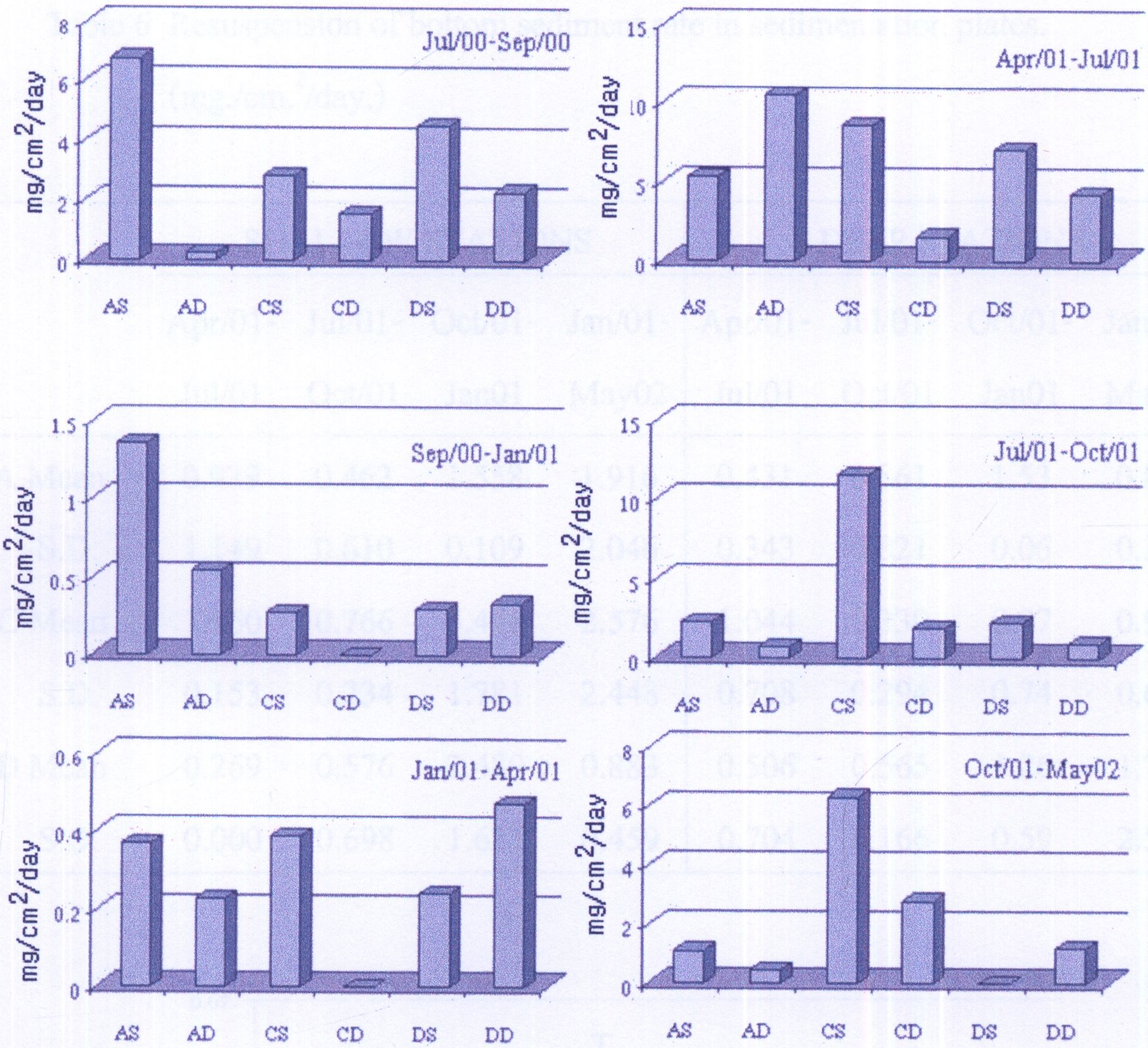
		SHALLOW STATIONS						DEEP STATIONS					
		Jul/00- Sep/00	Sep/00- Jan/00	Jan/00- Apr/01	Apr/01- Jul/01	Jul/01- Oct/01	Oct/01- May02	Jul/00- Sep/00	Sep/00- Jan/00	Jan/00- Apr/01	Apr/01- Jul/01	Jul/01- Oct/01	Oct/01- May02
A	Mean	0.050	0.131	0.235	0.000	0.073	0.187	0.170	0.089	0.186	0.000	0.094	0.113
	S.D.	0.030	0.169	0.258	0.000	0.080	0.317	0.170	0.028	0.035	0.000	0.191	0.160
C	Mean	0.070	0.093	0.092	0.000	0.090	0.184	0.100	0.105	0.000	0.000	0.062	0.047
	S.D.	0.004	0.039	0.057	0.000	0.000	0.273	0.067	0.007	0.000	0.000	0.058	0.044
D	Mean	0.052	0.283	0.150	0.000	0.000	0.055	0.056	0.093	0.134	0.000	0.079	0.043
	S.D.	0.019	0.481	0.026	0.000	0.000	0.012	0.014	0.099	0.084	0.000	0.125	0.020



AS Station A Shallow CS Station C Shallow DS Station D Shallow

AD Station A Deep CD Station C Deep DD Station D Deep

Figure 14 Sedimentation rates from sedimentation traps, 1.5 cm. diameter



AS Station A Shallow   CS Station C Shallow   DS Station D Shallow

AD Station A Deep   CD Station C Deep   DD Station D Deep

Figure 15 Sedimentation rates from sedimentation traps, 5 cm. diameter

Table 6 Resuspension of bottom sediment rate in sedimentation plates.
(mg./cm.^{2}/day.)

	SHALLOW STATIONS				DEEP STATIONS			
	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-Jan01	Jan/01-May02	Apr/01-Jul/01	Jul/01-Oct/01	Oct/01-Jan01	Jan/01-May02
A Mean	0.929	0.462	1.558	1.916	0.431	0.861	1.53	0.886
S.D.	1.149	0.610	0.109	2.046	0.343	0.821	0.06	0.398
C Mean	1.160	0.766	3.448	2.576	1.044	0.330	0.87	0.963
S.D.	0.153	0.234	1.781	2.448	0.708	0.294	0.74	0.633
D Mean	0.269	0.576	2.489	0.883	0.506	0.565	1.26	1.734
S.D.	0.000	0.698	1.627	0.459	0.704	0.166	0.59	2.550

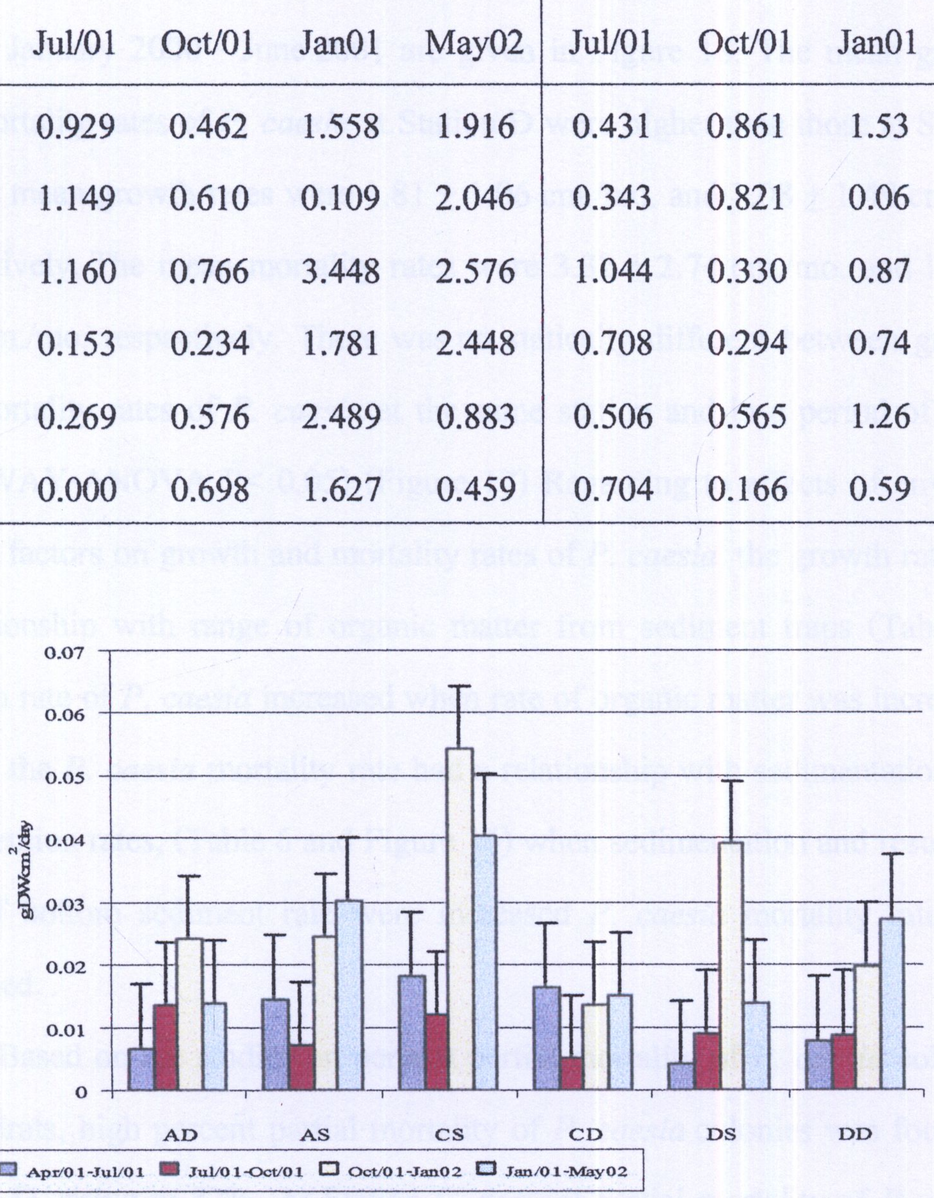


Figure 16 Resuspension of bottom sediment rates from sedimentation plates

Growth and Mortality rates, Change of colonies size and Percent partial Mortality of *P. caesia*

Growth and mortality rates of *P. caesia* from underwater photographs during January 2000 - June 2001 are given in Figure 18. The mean growth and mortality rates of *P. caesia* at Station D were higher than those at Station C. The mean growth rates were 1.81 $\pm$ 1.06 cm./mo. and 1.08 $\pm$ 1.49 cm./mo respectively. The mean mortality rates were 3.32 $\pm$ 2.74 cm./mo. and 1.61 $\pm$ 1.52 cm./mo, respectively. There was no statically different between growth and mortality rates of *P. caesia* at the same station and in a period of time. (ONEWAY-ANOVA $P< 0.05$) (Figure 17) Regarding to effects of environmental factors on growth and mortality rates of *P. caesia,* the growth rate had a relationship with range of organic matter from sediment traps (Table 5). Growth rate of *P. caesia* increased when rate of organic matter was increased. Due to the *P. caesia* mortality rate had a relationship with sedimentation and resuspention rates, (Table 6 and Figure 16) when sedimentation and resuspension of bottom sediment rate were increased *P. caesia* mortality rate was increased.

Based on the studies on percent partial mortality of *P. caesia* colonies in quadrats, high percent partial mortality of *P. caesia* colonies was found at Station D, rising to 82%. At Station C, percent partial mortality of *P. caesia* colonies was only 25%. This result was agreeable with mortality rate of *P. caesia* studied by using underwater photographs.

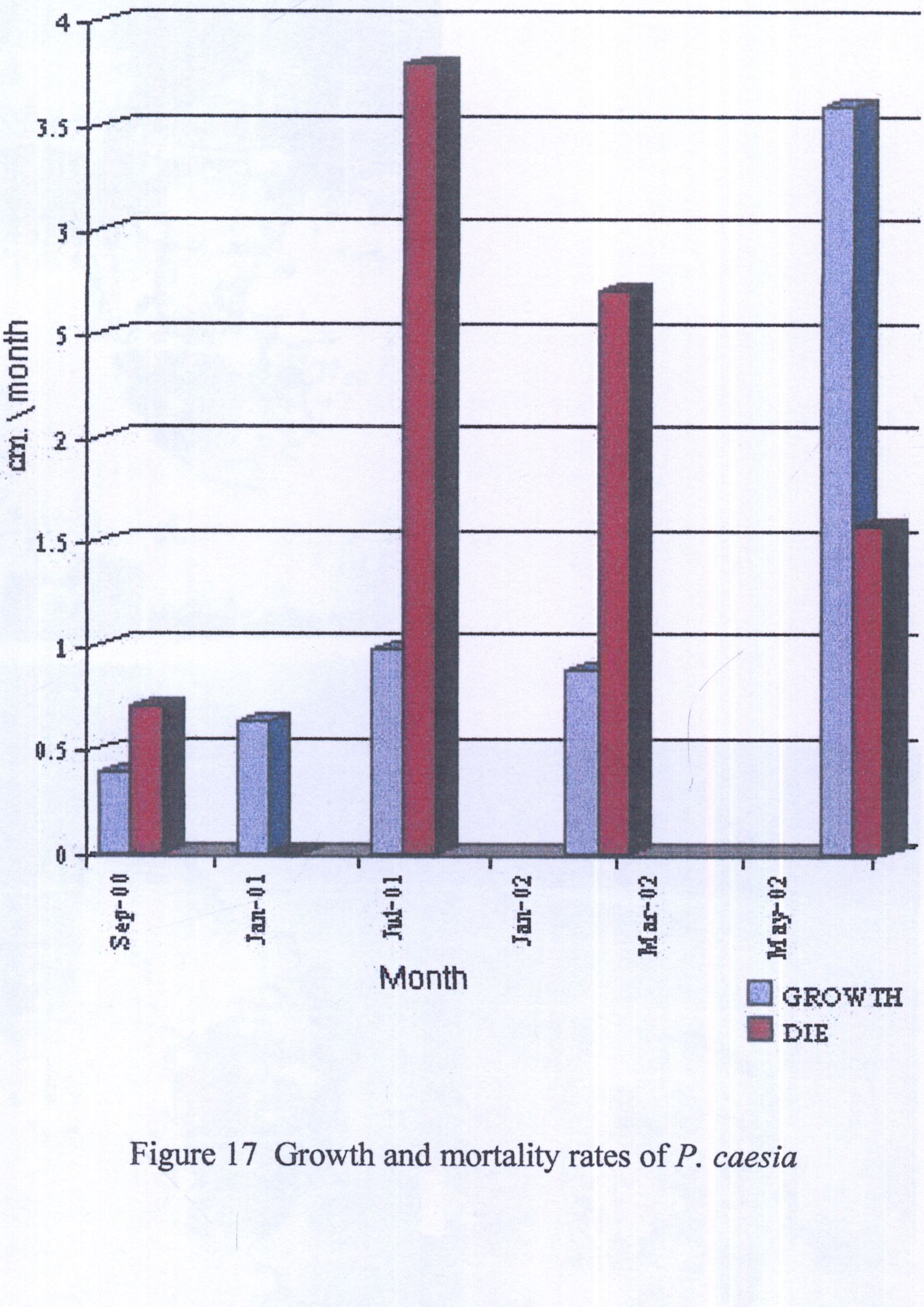


Figure 17 Growth and mortality rates of *P. caesia*

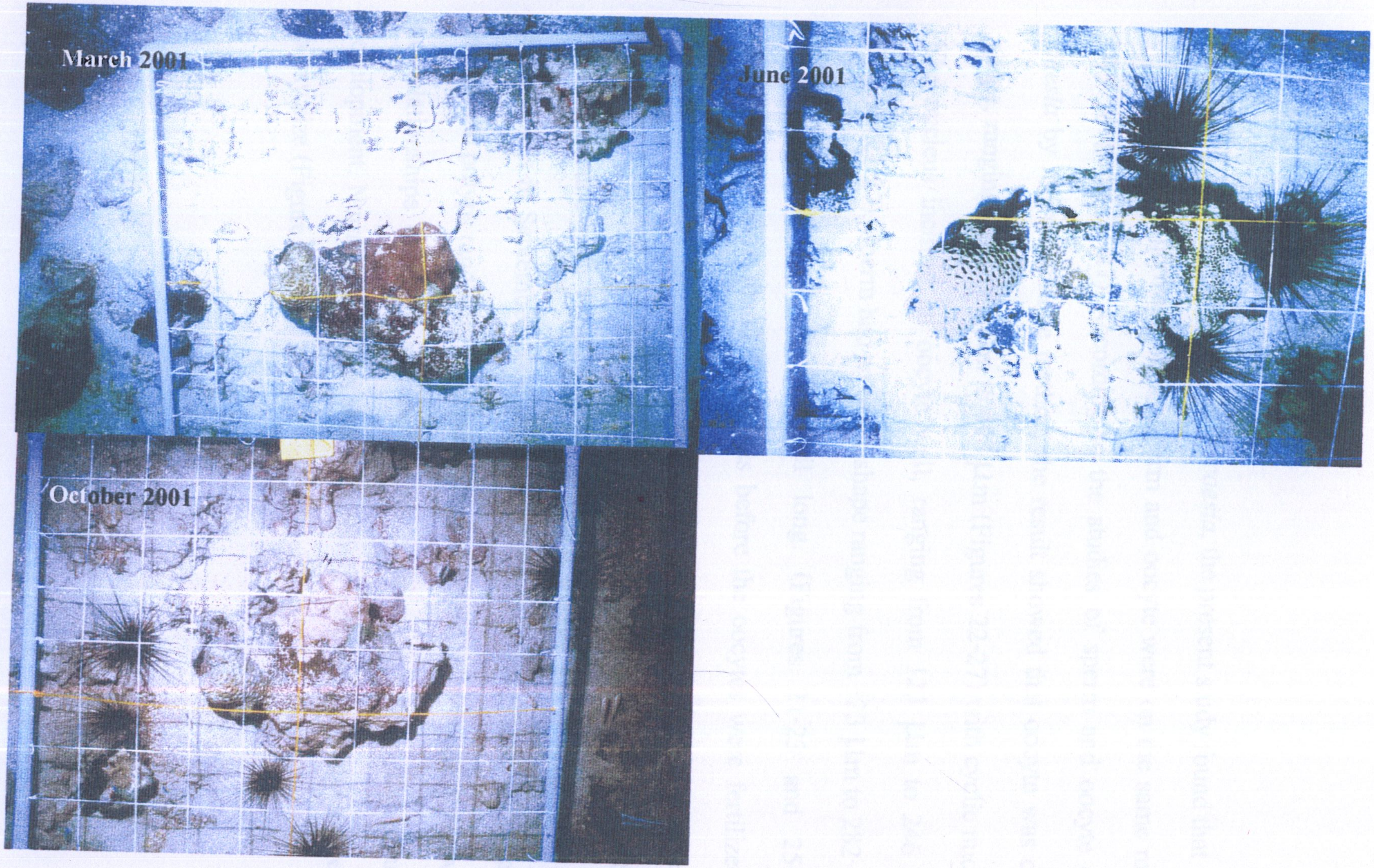


Figure 18 Growth rate, mortality rates and changes in colony sizes in the filed study

Sexual reproduction of *P. caesia*

For sexual reproduction of *P. caesia,* the present study found that *P. caesia* was a hermaphrodite. Sperm and oocyte were on the same mesentery. (Figures 21-27) According to the studies of sperm and oocyte of *P. caesia* by microtechnique method, the result showed that oocyte was cyclic shape, ranging from 246 μm to 498 μm (Figures 22-27) with cyclic nucleus. The nucleus inclined an oocyte wall, ranging from 123 μm to 246 μm. (Figures 21-27). Sperm had an ovoid shape ranging from 123 μm to 282 μm with 794 μm to 2,706 μm tail long. (Figures 21-23 and 25-26). Zooxanthellae were found in oocytes before the oocytes were fertilized in water column because the larvae in their tissues were not found. (Figure 24) *P. caesia* produced gonads throughout the year. Although during the study period. I found high percentage of fertilized polyps per colony from the observations in September 2000 – January 2001, 94.31% (Figure 19). Based on the 650 polyps randomly detected under compound microscope, there were no relationships of polyp size and polyp position in colony and gamete development. Number of polyps showed strongly relationship with change of colony size (Figure 20).

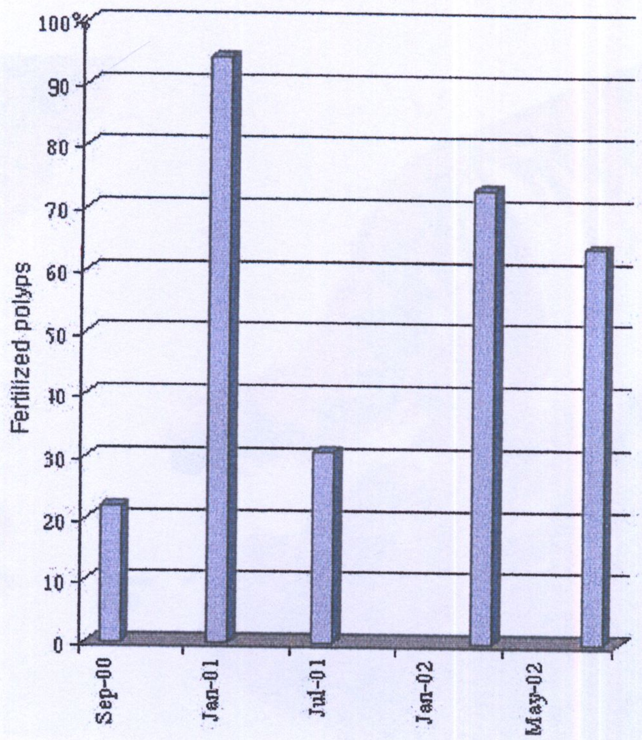


Figure 19 Percentage of fertilized polyps from each sampling periods

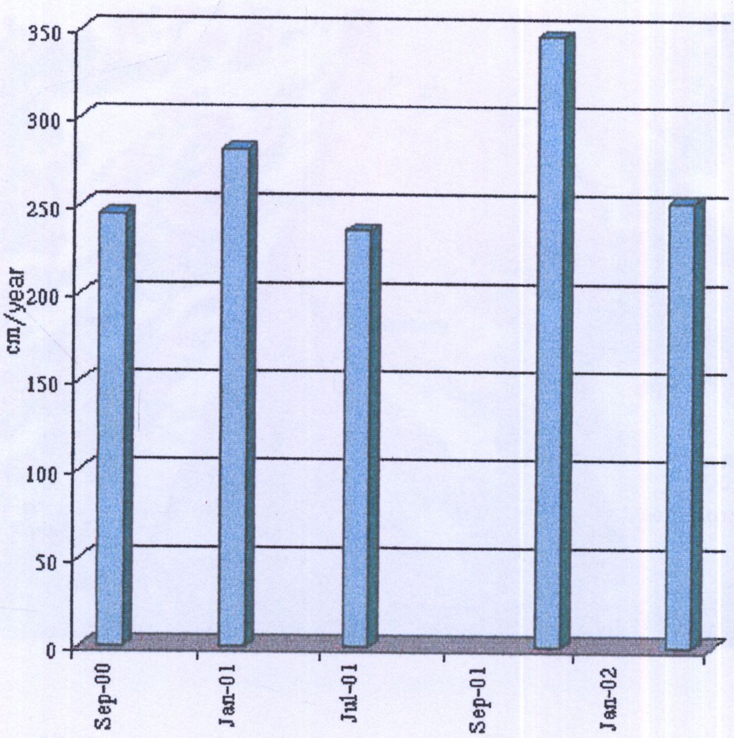


Figure 20 Change of colonies size in *P. caesia*

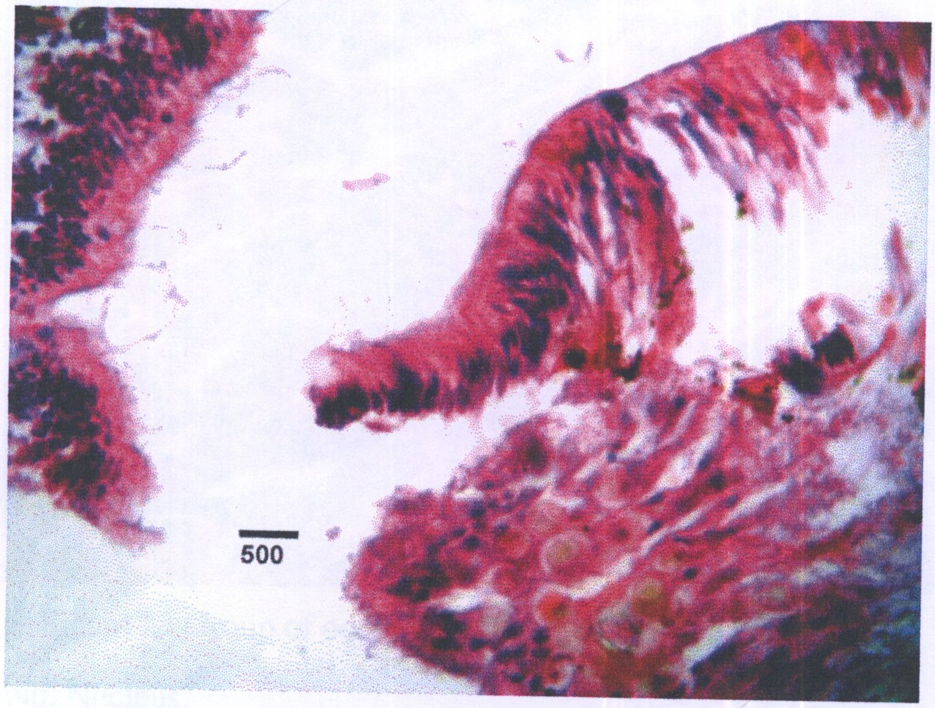


Figure 21 Oocyte and Spermatozoa on the same gonad

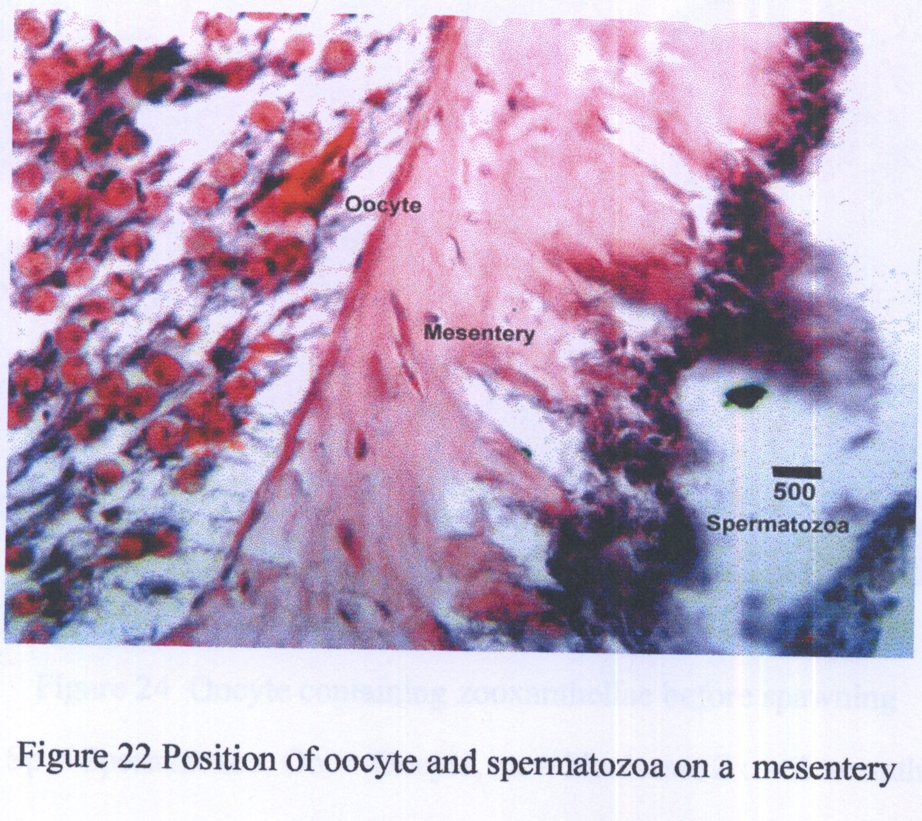


Figure 22 Position of oocyte and spermatozoa on a mesentery

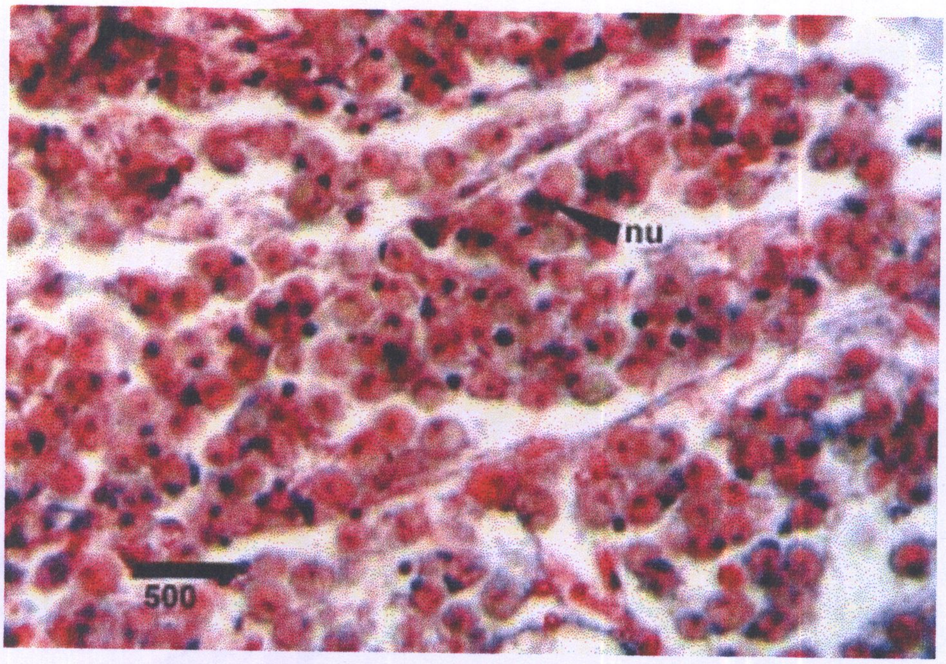


Figure 23 Group of oocytes in gonad and nucleus in oocytes

Note: Nu. Nucleus.

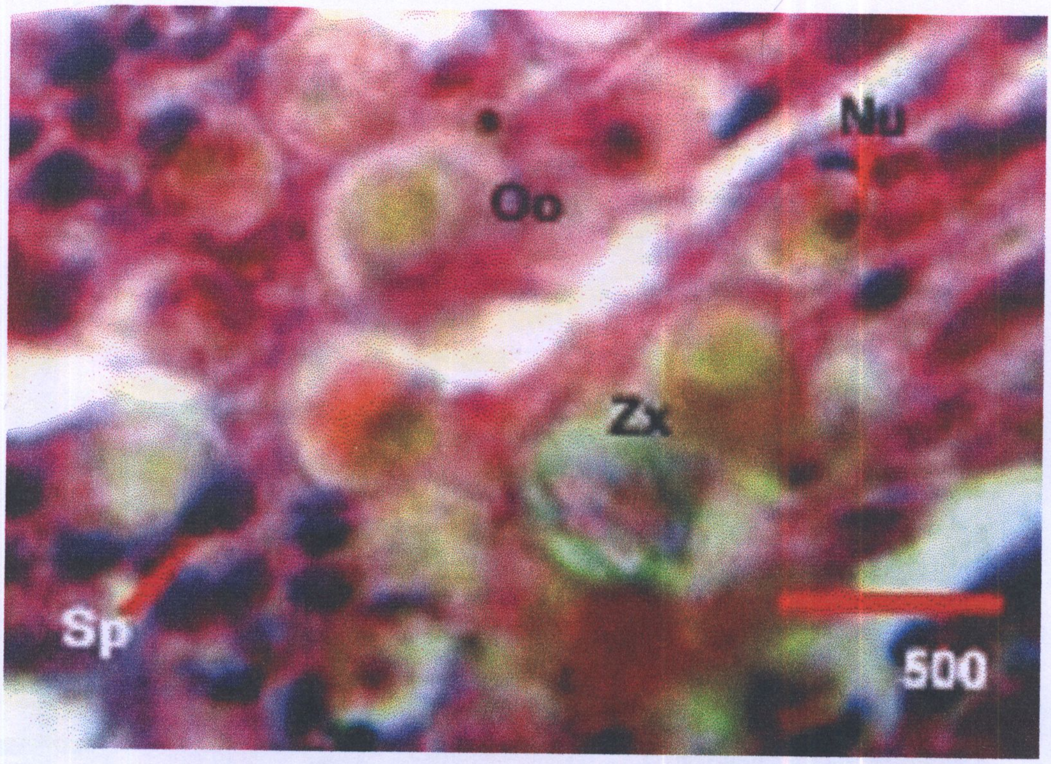


Figure 24 Oocyte containing zooxanthellae before spawning

Note : Sp = Spermatozoa, Oo. = Oocyte, nu = Nuclease, Zx = Zooxanthella

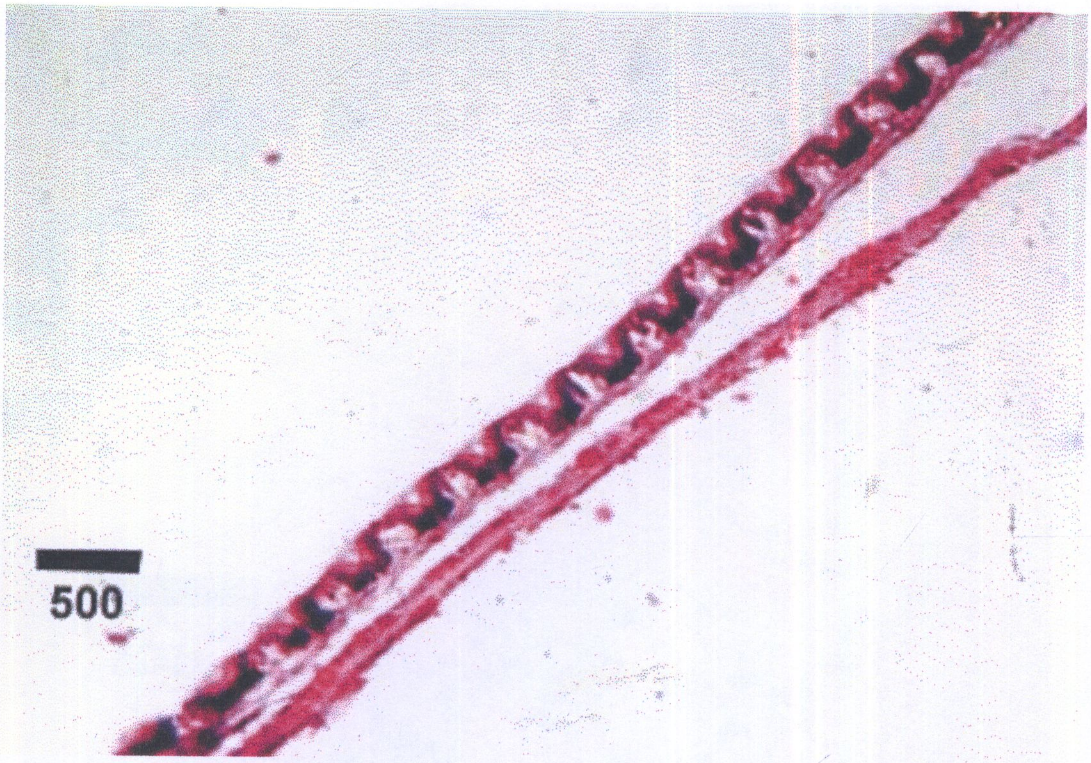


Figure 25 Sperm in a histological section

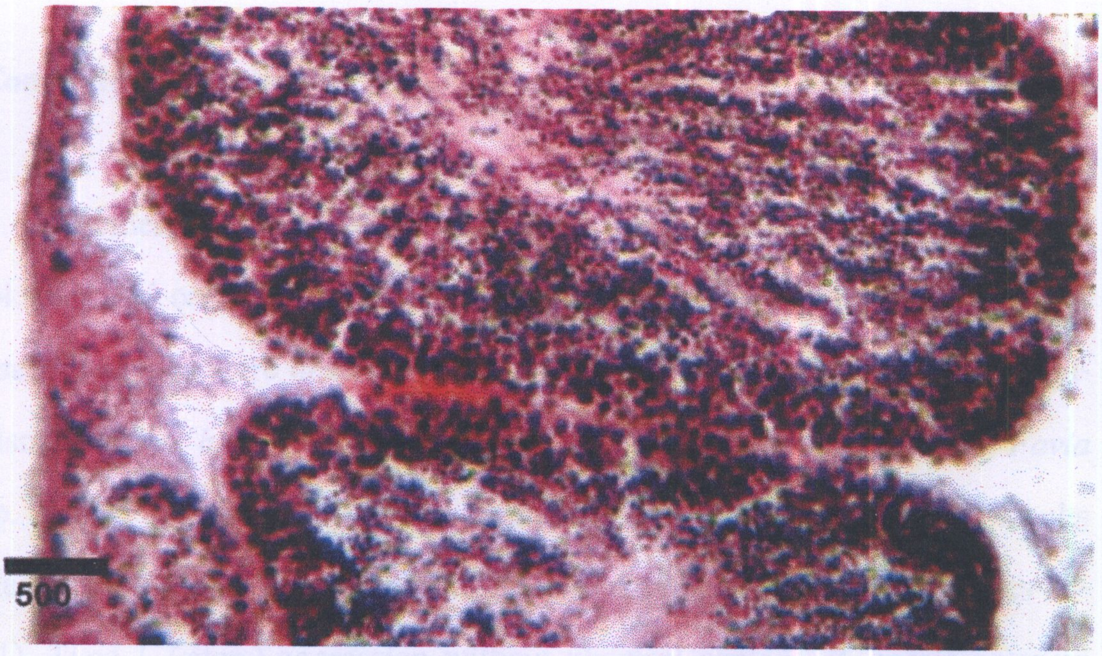


Figure 26 Mature spermatocyte found in a sample

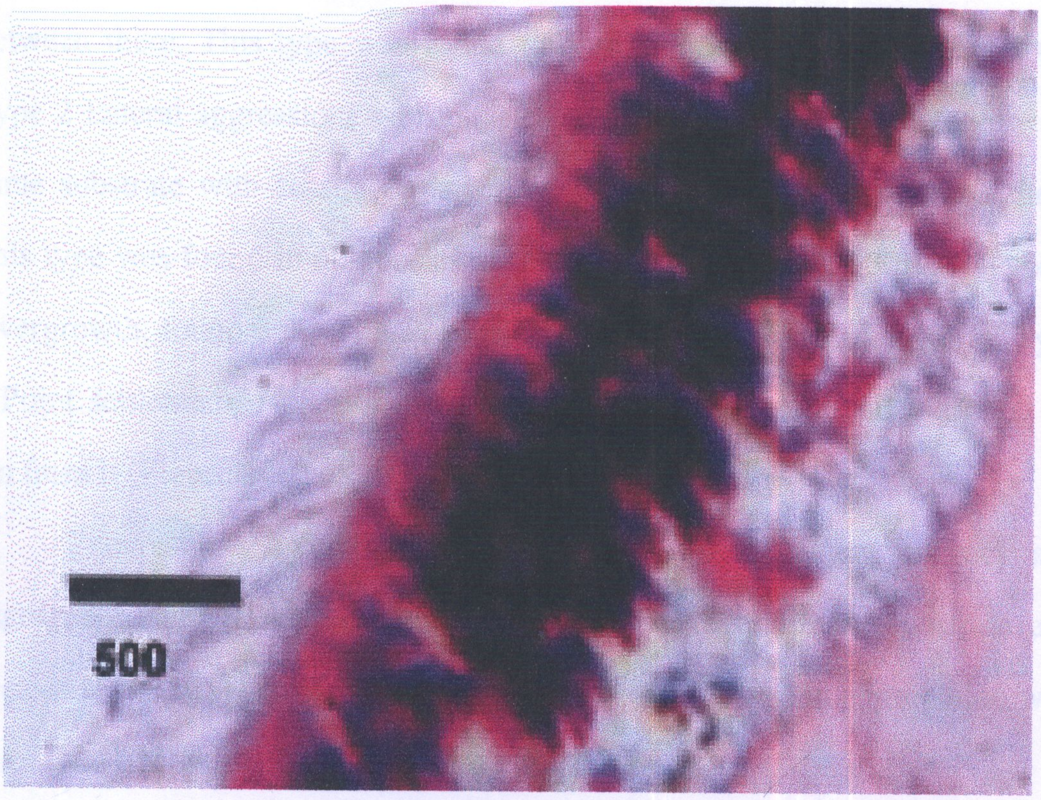


Figure 27 Spermatozoa and sperm tail in a histological section

Competition of *P. caesia*

Settlement of *P. caesia* was found on four types of substrates, rock 64.9%, dead coral 18.9%, sand with rubber 10.8% and living coral 5.4% *P. caesia* colonies were observed in competition with 6 species of sessile organisms, *Porites lutea* 46.4%, *Symphyllia* sp. 3.6%, *Zoanthid* sp. 3.6%, *Favia* sp. 3.6&, *Palythoa* sp. 3.6% and *Haliclona* cf. *delicatula* 39.2%. The results clearly showed that there were four types of aggregations (Table 7 Figures 28-31). Type 1 Lateral aggression without physical contact. *P. caesia* colonies grew on the same substrate with sessile organisms but no tissues in contact between them. This type was found only with *Porites lutea*. (Figure 30A). Type 2 Lateral aggressions with physical contact, *P. caesia* colonies grew on same substrate with sessile organisms and tissues in contact between them. This type was found in all species at the study sites. (Figures 30B-C) Type 3 Overgrowth, found only with *Porites lutea* and *Haliclona* cf. *delicatula*. Type 4 Point settlement, *P. caesia* grew without neighbor reef sessiles around 50 cm from it (Figure 31C).

The result showed high level of *P. caesia* settlement on rock and aggregation with *Porites lutea* because they were dominant substrate and species in the study suites. In certain cases, *P. caesia* was in aggregation with more than one types per colony.

Distribution Patterns of *P. caesia*

Studies on distribution patterns of *P. caesia* by using at stations A, C and D revealed that the highest population density of *P. caesia* was at station D was percent cover 5.76%. The distribution pattern of *P. caesia* at station D was randomly distributed at depths 2.8 m to 3.6 m, 2 m to 20 m from the shoreline of Khang Khao Island (Figure 32). At station C, percent cover was 5.58%, and the distribution pattern of *P. caesia* was also randomly distributed at depths 2 m to 5 m, 13 m to 23 m from the shoreline of the island (Figure 33). *P. caesia* was also found at station A but the population density was relatively low.

Table 7 Percent of aggregation of *P. caesia* with other species.

	contact	without contact	overgrowth	%total interaction
Porites lutea	62.23	15.38	15.38	46.42
Symphyllia sp.	100			3.57
Zoanthid sp.	100			3.57
Favia sp.	100			3.57
Palythoa sp.	100			3.57
Haliclona cf. *delicatula*	27.27		72.72	39.28
				100

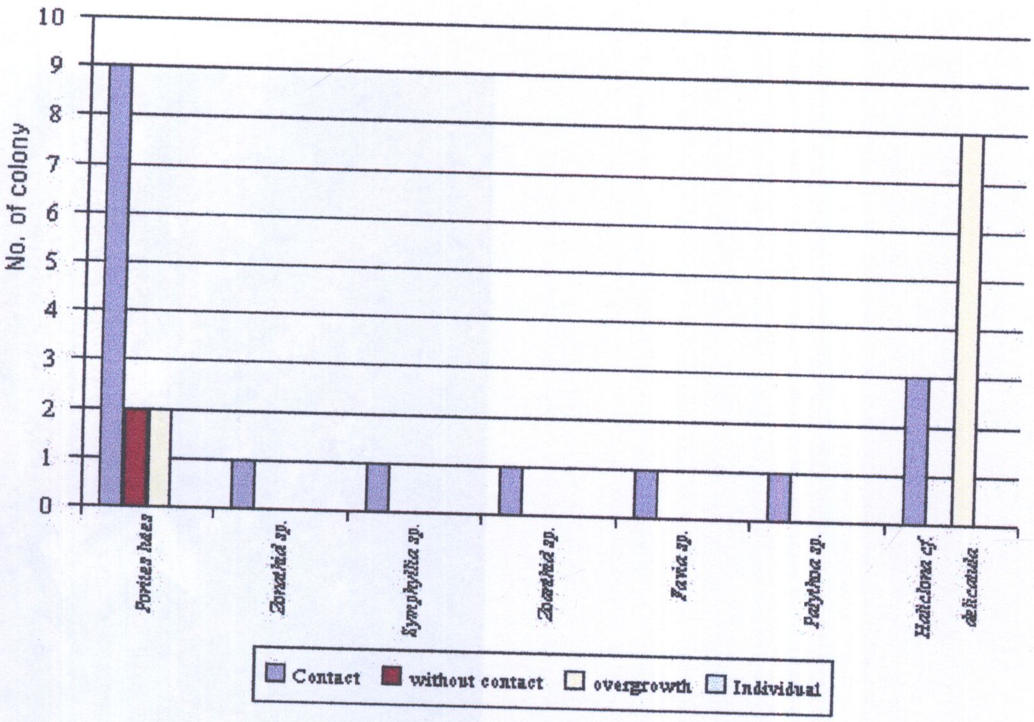


Figure 28 Number of sessile colonies in aggression with *P. caesia*

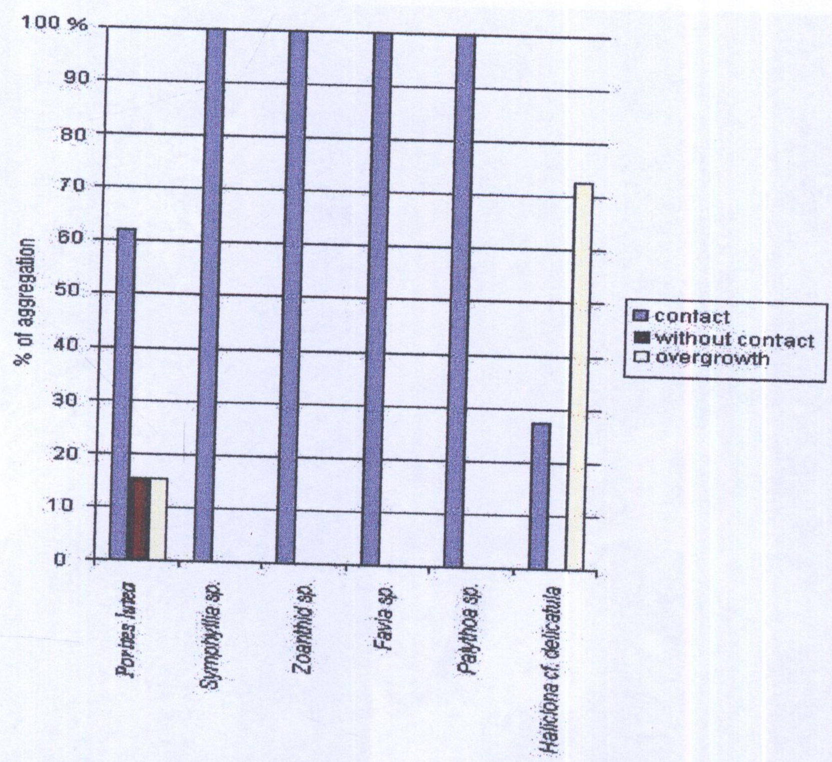


Figure 29 Percent of aggregation of *P. caesia* with other reef organisms

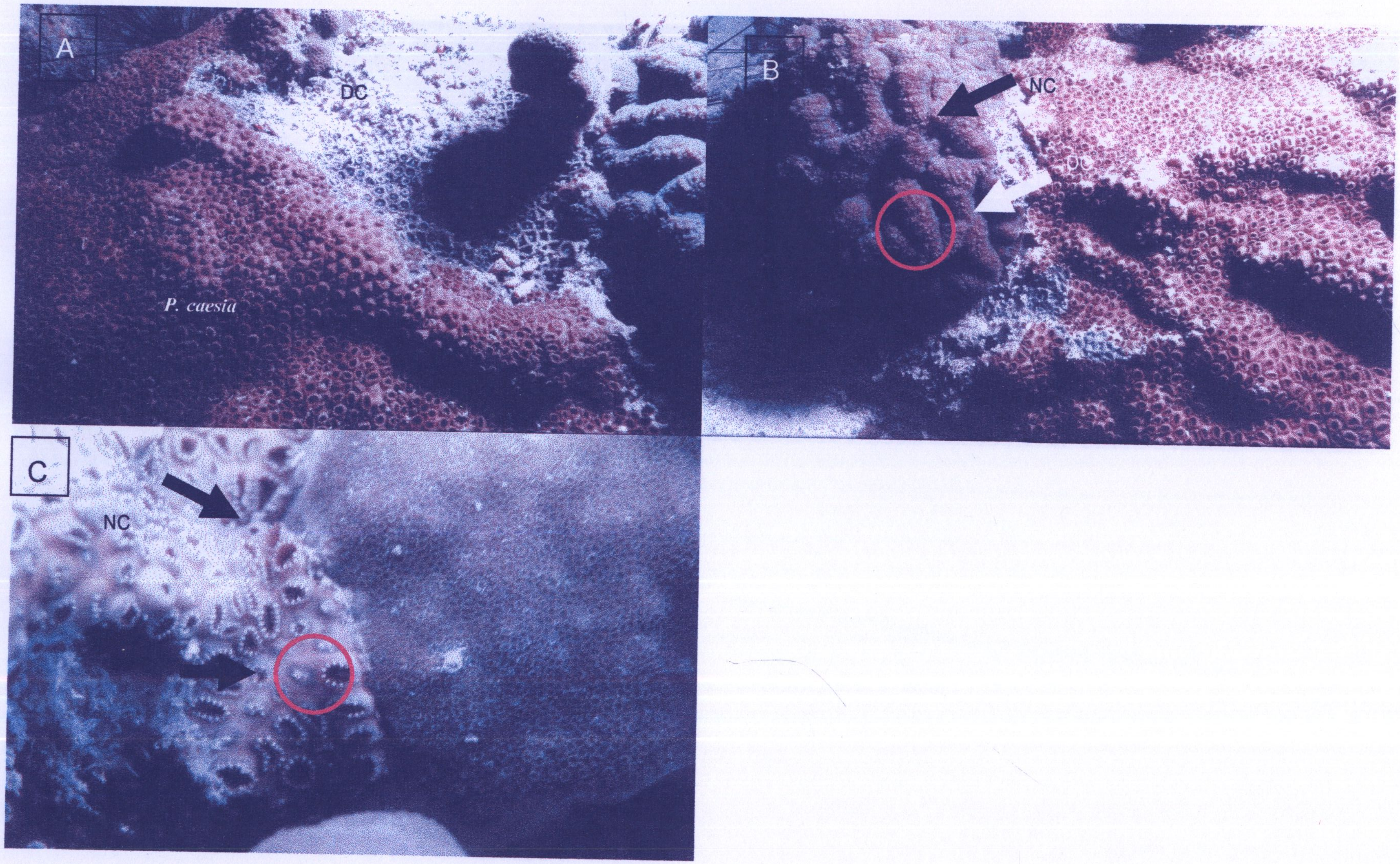


Figure 30 A. *P. caesia* tissues grew on dead coral without contact B.-C. (C) *P. caesia* damaged some areas of other species

Note : (NC) with living coral

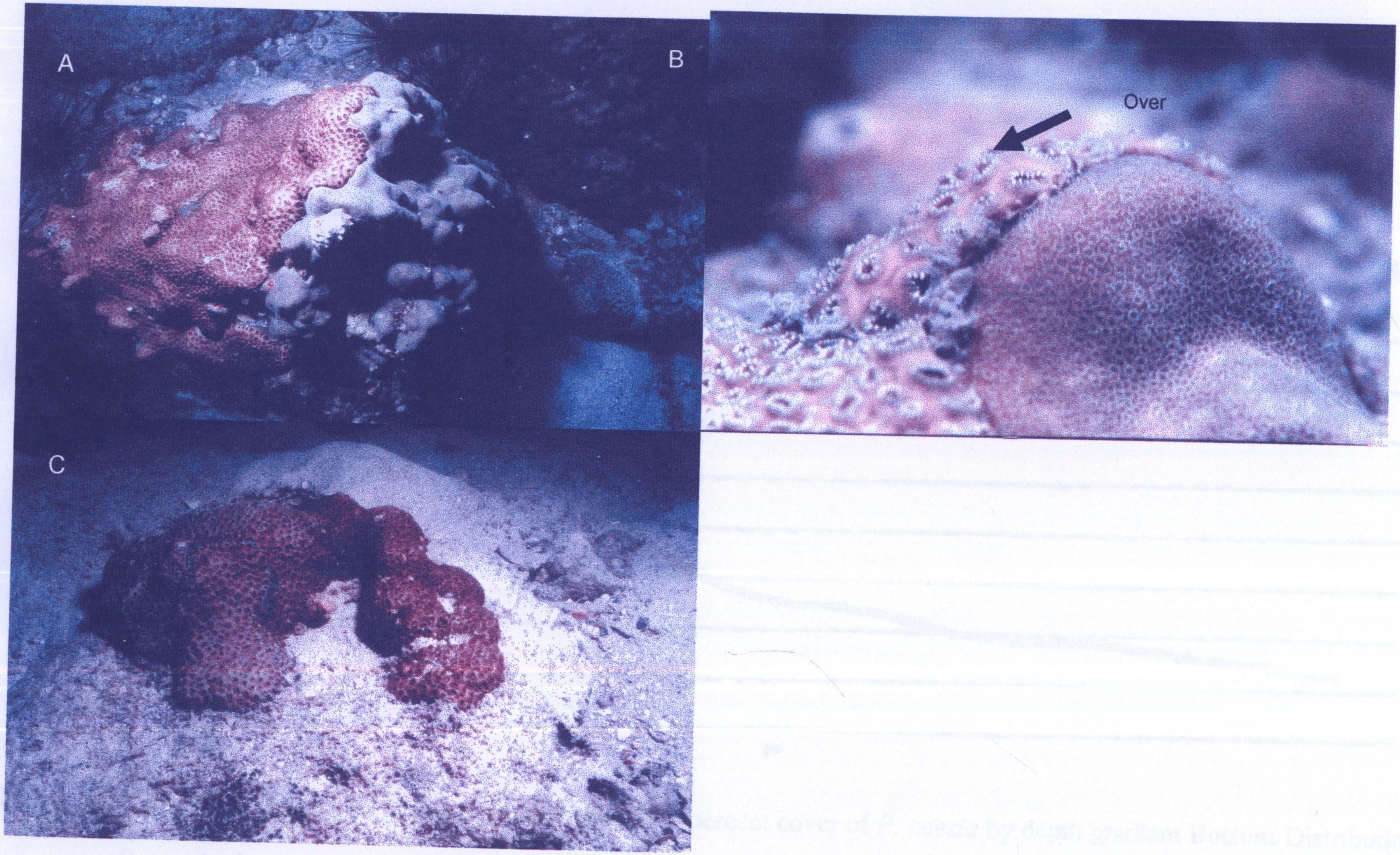


Figure 31 A. –B. *P. caesia* tissues overgrew on living coral. C. *P. caesia* colony settlement on rock without neighbor coral

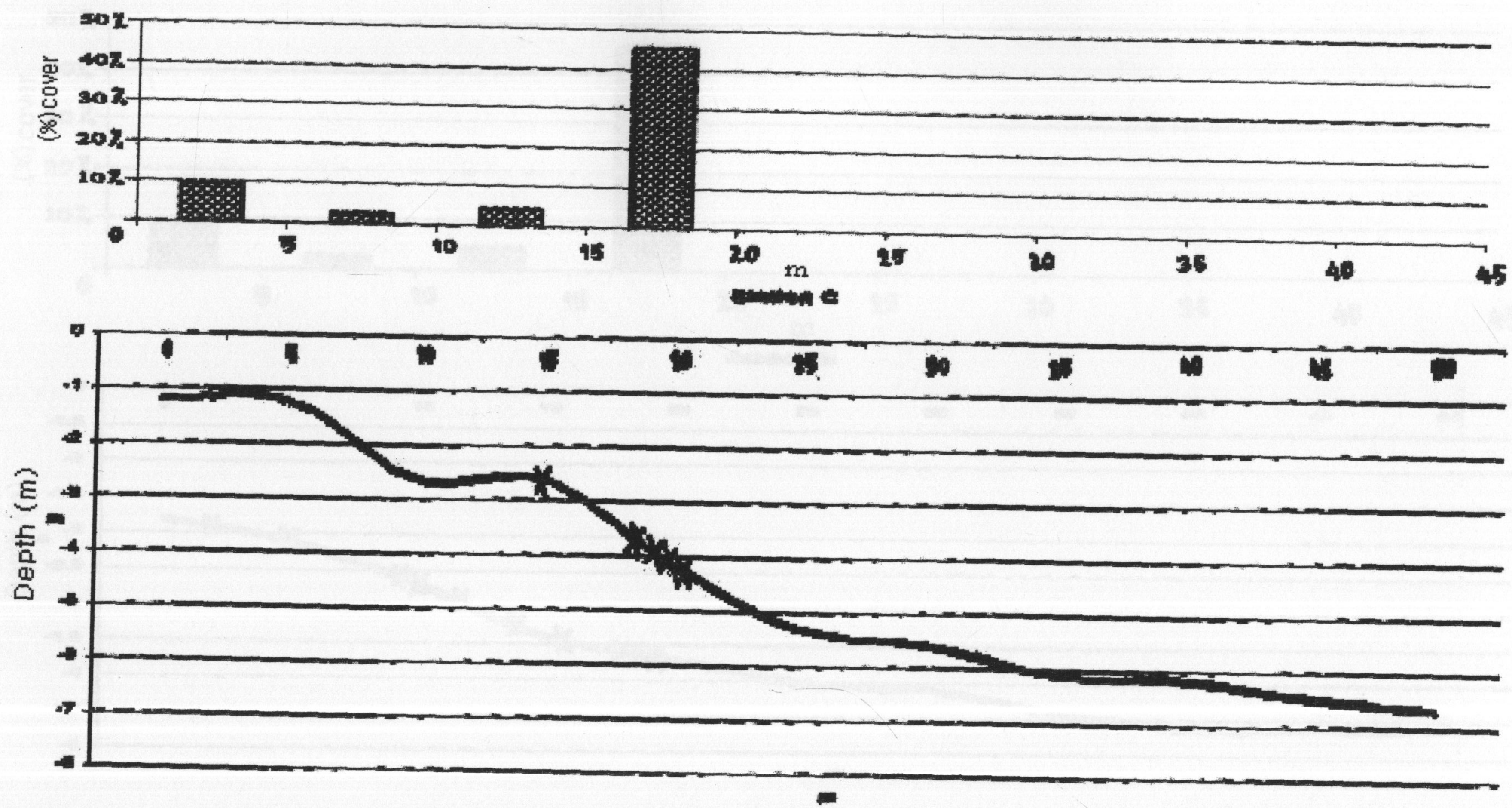


Figure 32 Distribution patterns of *P. caesia* on station C **Top** percent cover of *P. caesia* by depth gradient **Bottom** Distribution of *P. caesia* along the line transect from Khang Khao Island

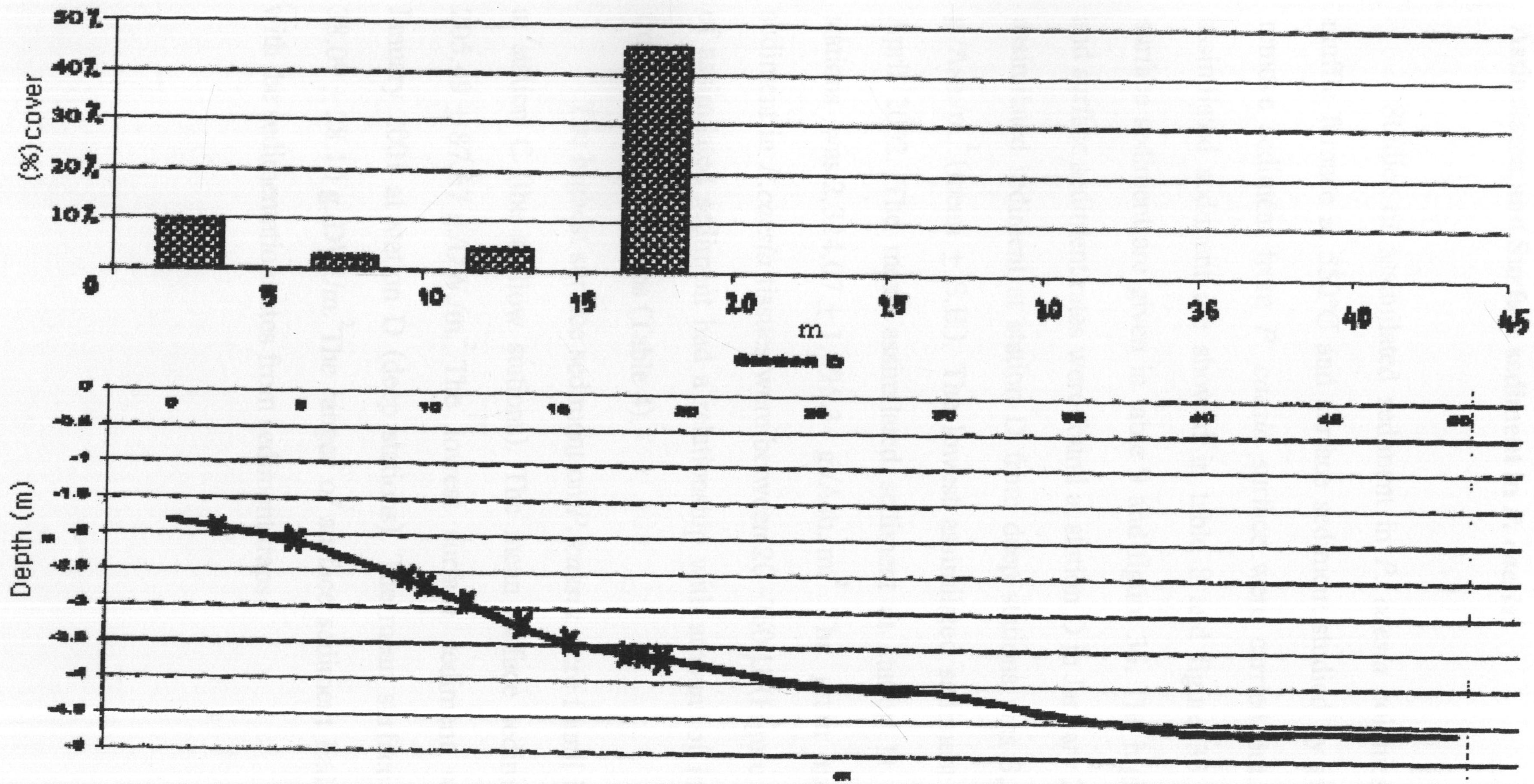


Figure 33 Distribution patterns of *P. caesia* on station D **Top** percent cover of *P. caesia* by depth gradient **Bottom** Distribution of *P. caesia* along the line transect from Khang Khao Island

Assimilated and Surface sediment in *P. caesia*.

Studies of assimilated sediment in *P. caesia* colonies by burning in muffle furnace at 550°C and surface sediment studied by running water to remove sediment from *P. caesia* surface were carried out. The results of assimilated sediment are showed in table 8 and figure 35. The results of surface sediment are given in table 9 and figure 36. The highest assimilated and surface sediment rates were found at station D in January 2001. The mean assimilated sediment at station D from deep stations was 3,364.8 $\pm$ 806.86 g./Ash./m.^{2} (mean $\pm$ S.E.). The lowest assimilated sediment were found in April 2002. The mean assimilated sediment at station D in the shallow stations was 2,324.07 $\pm$ 1,095.34 g./Ash./m.^{2} The grain sizes of entomb sediment in *P.caesia* tissues were between 20 -760 μ (Figure 34). The range of assimilated sediment had a relationship with amount of inorganic matter from the sediment traps (Table 4).

The highest surface sediment on *P. caesia* were found in August 2000 at station C (the shallow stations). The mean surface sediment rates were 205.49 $\pm$ 87.67 g./DW./m.^{2} The lowest surface sediment were found in January 2001 at station D (deep stations). The mean surface sediment was 38.09 $\pm$ 28.10 g./DW./m.^{2}The ranges of surface sediment had a relationship with the sedimentation rates from sediment traps.

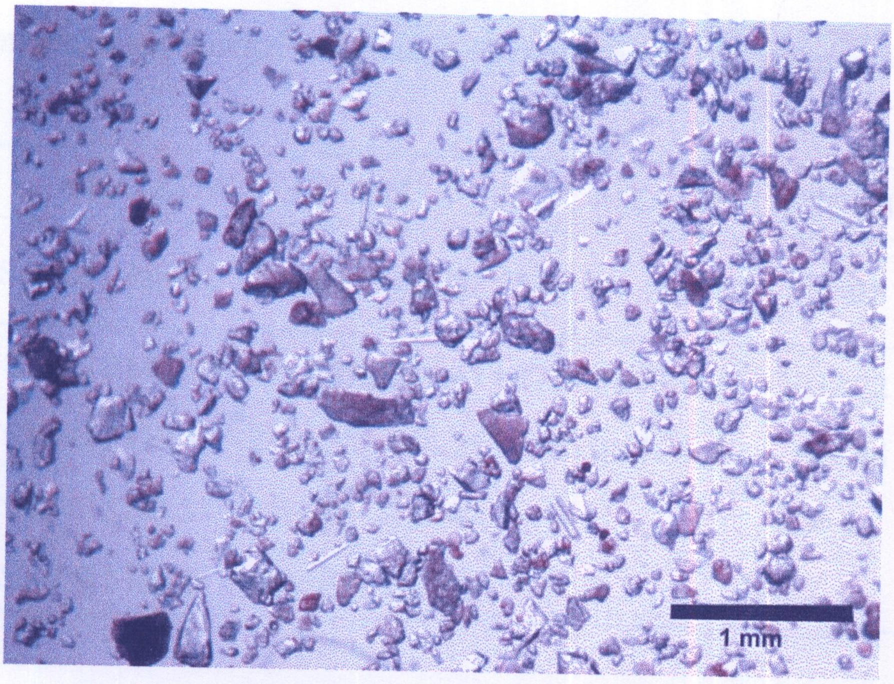
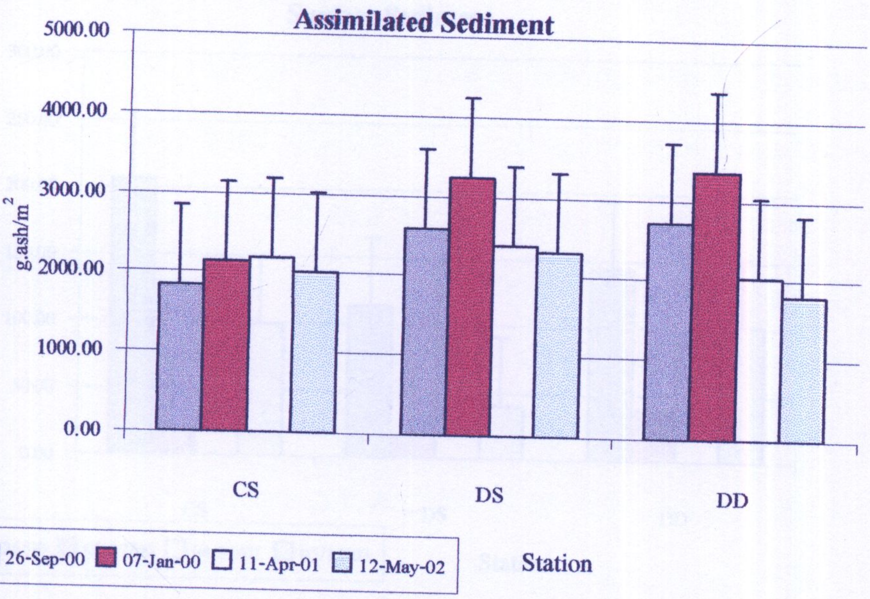


Figure 34 Entomb sediment found in *P. caesia* tissues

Table 8 Amount of assimilated sediment in *P. caesia* tissues (g./Ash./m.^{2})

	SHALLOW STATIONS				DEEP STATIONS			
	Sep-00	Jan-01	Apr-01	May-02	Sep-00	Jan-00	Apr-01	May-02
C Mean	1834.57	2146.30	2192.59	2016.67	2714.81	3364.81	2032.72	1804.17
S.D.	529.41	3139.39	2322.25	754.25	566.05	4192.60	542.44	257.62
D Mean	2582.72	3247.53	2396.83	2324.07	-	-	-	-
S.D.	1533.09	2666.26	1095.35	633.72	-	-	-	-



CS station C at shallow DS station D at shallow

DD station D at deep

Figure 35 Amount of assimilated sediment in *P. caesia* tissues

Table 9 Amount of surface sediment on *P. caesia* colony (g./DW./m.^{2})

	SHALLOW STATIONS				DEEP STATIONS			
	Sep-00	Jan-00	Apr-01	May-02	Sep-00	Jan-00	Apr-01	May-02
C Mean	205.49	21.10	31.62	99.22	143.88	38.09	90.22	101.55
S.D.	87.67	7.87	22.15	75.18	34.25	28.10	0.84	13.24
D Mean	113.44	17.69	147.24	41.04	-	-	-	-
S.D.	33.08	10.94	94.14	3.58	-	-	-	-

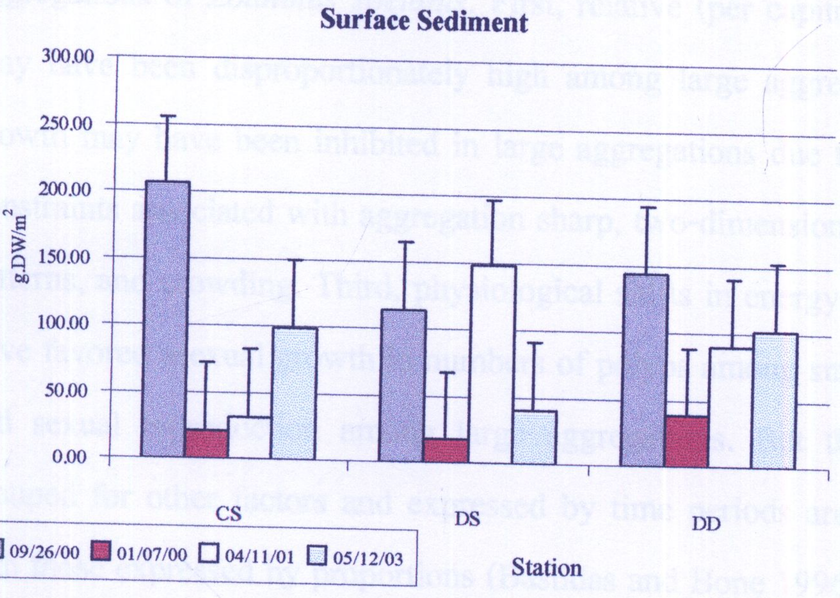


Figure 36 Amount of surface sediment on *P. caesia* colony

CHATER 5

DISCUSSION

Growth and Mortality rates

The results of growth and mortality rates of *P. caesia* at Khang Khao Island, Chonburi Province was 1.45 cm/month and 2.46 cm/mo, respectively. Karlson (1988b, 1225) explanations for high relative growth rates of small aggregations of *Zoanthus sociatus*. First, relative (per capita) mortality rates may have been disproportionately high among large aggregations. Second, growth may have been inhibited in large aggregations due to morphological constraints associated with aggregation sharp, two-dimensional clonal growth patterns, and crowding. Third, physiological shifts in energy allocations may have favored asexual growth in numbers of polyps among small aggregations and sexual reproduction among large aggregations. But the growth rates grouped for other factors and expressed by time periods are slightly higher than those expressed by proportions (Bastidas and Bone 1996, 550). There is evidence that growth form and rates can vary directly in response to limited food and space (Karlson 1988b, 1229). The results showed that growth rate of *P. caesia* had a relationship with range of organic matter from sediment traps. Anthony and Fabricius (2000, 221-253) have supported the idea of sediment as a food source. They showed that suspended sediment had a lower food value than zooplankton or phytoplankton. It constituted an often more abundant component of the session in aquatic environment. It may be the predominant food source for suspension feeders, especially in turbid nearshore habitats.

Mortality rate of *P. caesia* has an effect from high sedimentation rate. This result can be answed by sedimentation rate of sediment traps. The result is agreeable with the study of Wesseling et al. (1999, 11-18) and Roger (1983, 378-382) as noted in the literature review. The other causes of mortality and partial mortality are from predator or diseases (Gleibset et al. 1995, 1531; Meb 1998, 1521; Gleibs and Mebs 1999, 1521; Acosta 2001, 131). The diseased colony is perceptible one or some polyps surrounding polyps appeared swollen bumpy morphology. The disease did not appear to produce excessive mucus as a sediment defense mechanism, when compared to healthy colony (Acosta. 2001, 117). The diseases can cause a partial mortality of *Palythoa* colony and resulting in separation to fragments (Acosta et al. 2001, 369).

Change of *P. caesia* colony size

The present study showed that there was no effect from growth and mortality rates in change of *P. caesia* colony size. Colony sizes marked in the pilot study were reported to show the difference in change of colony sizes. The results showed that large colony changed to small colonies than large colonies in the same station, such as fission in medium and large colonies of *P. caesia* on Australia's Great Barrier Reef (Tanner 1999, 390; Tanner 2000, 514). Why large colonies try to shrinkage to small colonies, Acosta (2001, 976) explained that *Palythoa* was likely to exhibit fragmentation, reducing potentially high levels of colony mortality and costs associated with reproduction. This point may answer the question of why large colonies change in small colonies.

Reproduction

P. caesia has two reproductive modes, hermaphrodite and sterile with spawning (Ryland and Babcock 1991, 117-123; Soong et al. 1999, 338). *P. caesia* produced gonads throughout the year and highly percent of fertilized polyps per colony were observed in cool month periods. Reduce in percent of fertilized polyps per colony were observed during rainy season, may be explained by salinity reduction in this season, probably making gametogenesis difficult (Cooke 1976, 283; Fadlallah et al. 1984, 87-88). Recently, *Sphenopus marsupialis* is known as brooded (Soong et al. 1999, 340). This agrees with previously reports of zoanthids (Kimura et al. 1972, 621; Yamazato et al. 1973, 275; Cooke 1976, 281; Fadlallah et al. 1984, 80; Ryland and Babcock 1991, 229). Gonads of all stages of *P. caesia* were found throughout the year. Some previous studies reported on reproduction modes and reproduction cycles of Zoanthids that are showed in table 9 (Kimura et al. 1972, 621; Yamazato et al. 1973, 275; Cooke 1976, 281; Fadlallah et al 1984, Sex allocation was examined by Yamazato et al. (1973, 275-283) Fertile *Palythoa tuberculosa* polyps were mostly male but fertile *Zoanthus pulchellus* polyps studied by Karlson (1981, 699-704) were mostly hermaphrodite as in *Protopalythoa* sp. (Ryland and Babcock 1991, 117-123) and *Palythoa caesia* (this study).

Table 10 Mode of reproduction, sex, oocyte and sperm diameter and reproduction cycle in the different zoanthid studied to date. (F : Female, M : Male, H : Hermaphrodite, St : Sterile, S : Spawner, B : Broadcaster -:Indicated that information was not supplied by the authors and * : Indicated that information was derived occasional measurements.)

Species	Sex	Mode	Maximum Oocytes Diameter (μm)	Maximum Sperm Diameter (μm)	Reproductio n cycle	Source
Palythoa tuberculosa	F, M, H, St	S	300 – 500	170- 300	August – November, October - December	Kimura and Yamazato. 1972; Yamazato. 1973
Palythoa vestitus *Zoanthus pacificus*	F, M, H, St	S	75 - 280	50 – 390	Throughout the year	Cooke. 1976

Table 10 (Continued)

Species	Sex	Mode	Maximum Oocytes Diameter (μm)	Maximum Sperm Diameter (μm)	Reproduction cycle	Source
Zoanthus solanderi	F, H, St	S	134.8 – 239.5	-	Throughout the year	Fadlallah et al. 1984
Zoanthus sociatus	H, St	S	64.4 – 201.0	-		
Palythoa caribaeorum	F, M, H, St	S	134 - 429	-		
Protopalythoa sp.	F, H, St	S	1.5 – 8.8 mm	250	July - December	Ryland and Babcock. 1990
Sphenopus marsupialis	F, H, M	S, B	180 - 200	-	Throughout the year	Soong et al. 1999
Palythoa caesia	H, St	S	246 - 498	123 - 282	Throughout the year	***This study**

Population density and Distribution pattern

In general, zoanthids were found in shallow water (Karlson 1980, 895; Suckhnek and Green 1981, 680; Burnett et al. 1994, 154; Bastidas and Bone 1996, 544). At Khang Khao Island, *P. caesia* was found from 2 to 5 m. in depth and grew on four types of substrates, rock, dead coral, sand with rubber and living coral as similar to certain reports studied on distribution of zoanthids elsewhere (Fadlallah et al. 1984, 82; Burnett et al. 1997, 58; Acosta et al. 2001, 365). In addition to distribution pattern, there are several factors, such as storm damage, disturbance by sea urchin *Diadema antillarum* and algae can control distribution patterns of zoanthids. They are usually susceptible to storm damage that has an effect to mode of nutrition as noted in the literature review. The zoanthids well attached to occupied substrates (Karlson 1983, 128) or bare substrates (Bastides and Bone 1996, 543). Distribution of zoanthids can be as defension strategies in competition for space (Suchanek and Green.1981, 679; Bastides and Bone 1996, 550). Zoanthids had a slow growth rate when were in competition with other species by decreasing in percent cover mainly due to mortality caused by invasion of marcroalgae (Bastides and Bone 1996, 547).

The population density of *P. caesia* was reviewed in literature review elsewhere. The results from this study do support in certain points.

Competition

Zoanthid was a dominant competitor with reef sessile organisms. Studies of competition of *P. caesia* at Khang Khao Island, Chonburi Province, revealed that three groups of sessile organisms are in contact with *Palythoa.* It can overgrowth scleratinian corals, other zoanthids and sponges. Some previous reports also showed subordinate species which was overgrowth by rapid growth of Zoanthidea. Karlson (1980, 896) reported seven groups of sessile organisms showing overgrowth, *Zoanthus*, Actiniaria, Zoanthidea, sclerati-nian corals, Gorganacea, Corallimorpharia corals and Hydrocorallina. Suchanek and Green (1981, 681) reported four groups of sessile organisms showing interactions with *Palythoa caribaeorum*, scleratinian corals, Hydro-zoan corals, zoanthid and sponges.

It seems clear that in a relatively short time, *Palythoa* should be able to cover even more area on the reef than it does. Only two species are know to have the ability to overgrow *Palythoa*, the encrusting gorgonian *Erythro-podium caribaeoum* (Karlson 1980, 895) in Jamaica an encrusting colonial tunicate *Trididemnum solidum* (Suchanek and Green 1981, 683) in Panama. What, then, limit growth and/or abundant of *Palythoa* Suchanek and Green (1981, 683) explains by two reasons. First, the genus *Palythoa* is charac-terized by having encrustations in the body wall discouraging predation. Secondly, the presence of palytoxin may question of space. Although the competition strategy need more study.

Assimilated and surface sediment in *P. caesia* tissues

The mean assimilated sediment *P. caesia* tissues at Khang Khao Island was 2,844.92 g/ash/m^2 or 71.87% of dry tissues weight. The grain sizes in their tissues were between 20-760 μ. From the assimilated sediment investigated by Haywick and Mueller (1997, 39-46) the amount of assimilated sediment in *P. caribaeorum* and *P. mammilosa* at Florida Key, USA. Were 45% of wet tissues weight. The grain sizes were between < 63-250 μm. The strong vary of assimilated sediment between *P. caesia* and *Palythoa* spp. tissues be able to explained by the differentce of tick mesoglea of *P. caesia* and high sedimentation rates at Khang Khao Island.

Surface sediment on *P. caesia* colony had a relationship with sediment-tation rate from sediment traps. This result is agreeable with Haywick and Mueller (1997, 36-46) and Acosta (2001, 119-120) The sediment defend mechanism as note in literature review. The importance of *P. caesia* in coral community changes in the Gulf of Thailand.

APPENDIX

Table 11 Two factor of ANOVA on Growth and Mortality rates of *P. caesia*

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Month)	81.873	16	5.1171	2.257	0.006	1.7231
Columns (Station)	95.516	8	11.94	5.266	0.000010	2.0115
Error	290.21	128	2.2673			
Total	467.6	152				

Table 12 Two factor of ANOVA on 5 cm. diameter sediment traps and sediment plates

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Station)	22.5946	5	4.518919	0.829879	0.534025	2.382826
Columns (Traps)	193.0124	11	17.54658	3.222351	0.001923	1.967546
Error	299.49	55	5.445273			
Total	515.097	71				

Table 13 Two factor of ANOVA on 1.5 cm. diameter sediment traps and sediment plates

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Station)	230,535.6	1	230,535.6	34.09253	0.004289	7.70865
Columns (Traps)	27,054.18	4	6,763.544	1.00022	0.499917	6.388234
Error	27,048.22	4	6,762.055			
Total	284,638	9				

Table 14 Two factor of ANOVA on surface sediment from *P. caesia* and resuspension of bottom sediment

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Sediment rates)	304,325,466.40	2	1,521,627,33.20	1.002355	0.499412	19.00003
Columns (Station)	27,908,818,993.19	1	27,908,818,993.19	183.8462	0.005395	18.51276
Error	303,610,451.3	2	151,805,225.67			
Total	28,516,754,911	5				

Table 15 Two factor of ANOVA on 1.5 cm. diameter and 5 cm. diameter sediment trap

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Month)	22.5946	5	4.518919	0.829879	0.534025	2.382826
Columns (Station)	193.0124	11	17.54658	3.222351	0.001923	1.967546
Error	299.49	55	5.445273			
Total	515.097	71				

Table 16 Two factor of ANOVA on 1.5 cm. diameter sediment trap and sediment plate

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Traps)	27,054.18	4	6,763.544	1.00022	0.499917	6.388234
Columns (Station)	230,535.6	1	230,535.6	34.09253	0.004289	7.70865
Error	27,048.22	4	6,762.055			
Total	284638	9				

Table 17 Two factor of ANOVA on 5 cm. diameter sediment trap and sediment plate

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows (Traps)	429.5302	4	107.3825	0.993714	0.502365	6.388234
Columns (Station)	1,607.206	1	1,607.206	14.87303	0.018201	7.70865
Error	432.2473	4	108.0618			
Total	2,468.984	9				

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