



รายงานวิจัยฉบับสมบูรณ์

โครงการความหลากหลาย ความหนาแน่น และการแพร่กระจายของ
สาหร่ายทะเลที่เปลี่ยนแปลงตามสภาพภูมิศาสตร์ และฤดูกาล
ในจังหวัดสงขลา

โดย

ผศ.ดร.อัญชนา ประเทพ

14 กรกฎาคม 2547

สัญญาเลขที่ TRG4580041

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ผศ.ดร.อัญชณา ประเทพ
หน่วยวิจัยสาหร่ายและหญ้าทะเล
ศูนย์ความหลากหลายทางชีวภาพแห่งคาบสมุทรไทย
ภาควิชาชีววิทยา คณะวิทยาศาสตร์
มหาวิทยาลัยสงขลานครินทร์
หาดใหญ่ สงขลา

สนับสนุนโดยสำนักกองทุนสนับสนุนการวิจัย
(ความเห็นในรายงานฉบับนี้เป็นของผู้วิจัย สกว. ไม่จำเป็นต้องเห็นด้วยเสมอไป)

กิตติกรรมประกาศ

ผู้วิจัยขอกราบขอบพระคุณอาจารย์ที่ปรึกษาโครงการ ศ.ดร. กาญจนภาณุ ลิ้มโนมนต์ ผู้บุกเบิกงานวิจัยสาหร่ายทะเลในประเทศไทย ผู้ให้ความรู้ ข้อเสนอแนะ และคำปรึกษาแก่ผู้วิจัยทั้งใน ด้านงานวิจัยสาหร่ายทะเลและการเรียนการสอน รวมไปถึงความกรุณาในส่วนอื่น ๆ ดร.สรวิต เผ่าทอง ศุข ให้กำลังใจและเป็นแรงผลักดันในการทำงานวิจัย รวมไปถึงสมาชิกชมรมสาหร่ายและแพลงก์ตอน แห่งประเทศไทยทุกท่าน

ขอขอบคุณสมาชิกหน่วยวิจัยสาหร่ายและหญ้าทะเลทุกคน ที่ช่วยกันสร้างและทำงานวิจัยด้วย ดีเสมอมา มีทั้งเสียงหัวเราะ และร้องไห้ สมหวังและผิดหวังปะปนกันไป

ขอขอบคุณภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยสงขลานครินทร์ คอยสนับสนุน ในการทำงานวิจัย โดยเฉพาะอย่างยิ่ง รศ.ดร.จุฑามาส ศตสุข และ รศ.ดร.สุนทร โสติพิพันธ์ ผู้คอย ให้คำแนะนำในชีวิตการทำงานที่ดีมาโดยตลอด

ขอขอบคุณ สำนักงานกองทุนสนับสนุนการวิจัย (สกว) สำหรับทุนส่งเสริมนักวิจัยรุ่นใหม่ ประจำปี 2545 TRG4580041 สำหรับการวิจัยในครั้งนี้ ซึ่งเป็นฐานที่สำคัญในการสร้างและพัฒนางาน วิจัย การเรียนการสอน และเกิดเป็นหน่วยวิจัยสาหร่ายและหญ้าทะเลขึ้นมาได้

อัญชนา ประเทพ

บทคัดย่อ

รหัสโครงการ: TRG4580041

ชื่อโครงการ: โครงการความหลากหลาย ความหนาแน่น และการแพร่กระจายของสาหร่ายทะเลที่เปลี่ยนแปลงตามสภาพภูมิศาสตร์ และฤดูกาล ในจังหวัดสงขลา

ชื่อนักวิจัย: ผศ.ดร.อัญชนา ประเทพ หน่วยวิจัยสาหร่ายและหญ้าทะเล

ศูนย์ความหลากหลายทางชีวภาพแห่งคาบสมุทรไทย

ภาควิชาชีววิทยา คณะวิทยาศาสตร์

มหาวิทยาลัยสงขลานครินทร์

E-mail address: anchana.p@psu.ac.th, a_prathep@hotmail.com

ระยะเวลาโครงการ: 2 ปี

สาหร่ายทะเลขนาดใหญ่มีความสำคัญทั้งทางนิเวศวิทยาและเศรษฐกิจ เป็นองค์ประกอบที่สำคัญของระบบนิเวศทางทะเลทั่วโลก สาหร่ายทะเลถูกจัดเป็นผู้ผลิตเบื้องต้น เป็นแหล่งหลบภัย และเป็นที่อยู่อาศัยสำหรับสัตว์น้ำวัยอ่อน และเป็นอาหารให้กับสัตว์น้ำนานาชนิด วัตถุประสงค์ของงานวิจัยคือเพื่อ 1) ศึกษาความหลากหลายทางชีวภาพ ความหนาแน่นและการแพร่กระจายของสาหร่ายทะเลในบริเวณจังหวัดสงขลา และ 2) เพื่อศึกษาความผันแปรของสาหร่ายชนิดเด่นคือ *Gelidium pusillum*, *Porphyra vietnamensis* และ *Caulerpa racemosa* ต่อฤดูกาลและสถานที่ รวมถึงการศึกษานิเวศประชากรของสาหร่ายดังกล่าว ทำการศึกษาด้วยวิธีพื้นฐานเช่น การวาง line transect และการสุ่มเก็บ และประเมินตัวอย่างด้วย quadrat ในหลายพื้นที่ การศึกษาเรื่องนิเวศประชากรของสาหร่าย *P. vietnamensis* มีการติดตามศึกษาประชากรสาหร่ายทะเลมานานมากกว่า 2 ปี เพื่อให้ทราบถึงการรูปแบบการเปลี่ยนแปลงของประชากรตามฤดูกาลที่ต่าง ๆ กัน ในขณะที่การศึกษสาหร่าย *G. pusillum* มีการติดตามผลการเปลี่ยนแปลงของประชากรและการสร้างส่วนสืบพันธุ์อย่างใกล้ชิดทุก ๆ เดือน ผลของแรงกระทำของคลื่นลม สารอาหารและปัจจัยทางเคมีกายภาพ ได้ถูกศึกษาเพื่อหาความสัมพันธ์และผลกระทบต่อการประชากรสาหร่ายทะเล ผลการศึกษาพบว่ามีความผันแปรทางชีววิทยาของสาหร่ายทะเลเช่น พื้นที่ปกคลุม ความยาว น้ำหนัก และอวัยวะสร้างเซลล์สืบพันธุ์ของสาหร่ายทั้ง 3 ชนิด และพบว่าแรงกระทำจากคลื่นมีผลกระทบต่อการสาหร่ายทะเล ซึ่งเป็นปัจจัยที่สำคัญในการกำหนดประชากร และการแพร่กระจายของสาหร่ายทะเล การศึกษาต่อไปควรมุ่งเน้นไปที่สาหร่ายวัน *Gracilaria fisherii* ซึ่งมีคุณค่าทางเศรษฐกิจและเคยพบหนาแน่นในทะเลสาบสงขลา แต่ปัจจุบันพื้นที่ได้ถูกรบกวนอย่างมากทำให้ประชากรของสาหร่ายวันลดลงอย่างมาก

คำหลัก: ความหลากหลายทางชีวภาพ, นิเวศวิทยา, สาหร่ายทะเลขนาดใหญ่, สงขลา, ประเทศไทย

Abstract

Project Code: TRG4580041

Project Title: Spatial and temporal variations in diversity, abundance and distribution of macroalgae in Songkla province, Thailand

Investigator: Assistance Professor Dr. Anchana Pratthep, Seaweed and Seagrass Research Unit, Centre of Excellence in Biodiversity of Peninsular Thailand, Department of Biology, Faculty of Science, Prince of Songkla University

E-mail address: anchana.p@psu.ac.th, a_pratthep@hotmail.com

Project period: 2 years

Seaweeds are an ecologically and economically important component of marine ecosystem worldwide: primary producer, shelter, nursery ground and food sources for many marine organisms. The main focus of this project is 1) to investigate diversity, abundance and distribution of macroalgae in Songkhla Province and 2) to investigate spatial and temporal variations and examine population of dominance species: *Gelidium pusillum*, *Porphyra vietnamensis* and *Caulerpa racemosa*. Basic field studies such as line transect and quadrat samplings were employed to monitor the population dynamics of seaweeds and various sites. This research was carried out over 2 years in some seaweed population to replicate the seasonal patterns such as *Porphyra vietnamensis*; while *Gelidium pusillum* was monitored monthly to closely investigate the population and reproductive cycles of the alga. The effects of wave action, nutrients and other chemical-physical parameters were also investigated to examine their effects on the algae population. There were variations of biological characters such as percentage cover, length, weight, reproductive organs of these 3 algae throughout the study; they also were affected greatly by wave motion which is known to be an important parameter to determine population and distribution of macroalgae. Further investigation on *Gracilaria fisherii*, another economically important and dominant alga in Songkhla would be very useful, since Songkhla lake is now badly disturbed and the *Gracilaria fisherii* population has been greatly declined.

Keywords: Biodiversity, Ecology, Macroalgae, Songkhla, Thailand

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Introduction

Seaweeds are an ecologically and economically important component of marine ecosystem worldwide: primary producer, shelter, nursery ground and food sources for many marine organisms. They are used around the world as human foods, fertilizers, and the extraction of valuable products such as industrial gums and chemicals (agars, carageenans and alginates. Recent research has pointed to new opportunities, particularly in the field of medicine, associated with bioactive properties of molecules extracted from seaweeds (e.g. Ali et al., 2002). Indeed, they are an interesting organism for study and research.

Marine organisms including seaweeds have greatest diversity in the tropics, particularly in South-East Asia and the South Pacific, the Indian Ocean and the Caribbean Sea (Norse, 1993). A hundred and twenty species of common seaweeds were reported in Thailand (Lewmanomont and Ogawa, 1995), however more are expected and to be discovered. Recent study has showed that 10 new species of macroalgae are new to Thai water, only at Phuket province alone (Thongroy et al., 2007). Seaweed study in Thailand was rather decline (Powthongsook, 2000), until recently Seaweed and Seagrass Research Unit, Centre for Biodiversity of Peninsular Thailand has put together a few research and publications on seaweed biodiversity and ecology in Thailand (Prathep 2003; Prathep, 2005; Mayakun and Prathep, 2005; Prathep et al., 2006; Prathep and Tantiprapas, 2006; Prathep et al., 2007; Thongroy et al., 2007; Prathep et al., 2008). However, there are still a lot of research questions to be answered both in biology, ecology and cultivation.

Because of seaweeds' habitat and biology, seaweed can be used as a *model* organism to study various ecological theories both in the intertidal and subtidal habitats e.g. competition (space, light and nutrients), herbivore defensive mechanisms and prey-predation.(e.g. Creed et al., 1998; Prathep, 2002.; Prathep et al., 2003)

The main focus of this project is 1) to study diversity, abundance and distribution of macroalgae in Songkhla Province, Thailand, 2) to investigate spatial and temporal variations in population of dominance species: *Gelidium pusillum*, *Porphyra vietnamensis* and *Caulerpa racemosa* and 3) to examine population ecology using *G. pusillum*, *P. vietnamensis* and *C. racemosa* as model organisms.

Materials and Methods

1) Seaweed Diversity study

Site survey was done during August 2002, a long tail boat was used to survey and access all the possible seaweed habitats in Songkhla province, Thailand (Figure 1).

Observation on abundance and distribution of macroalgae has been done; skin and scuba diving techniques were used to collect and observe all the macroalgae found in the sites.

There were 2 sites chosen to study in detail due to seaweeds abundance and richness:

- 1) Saun Song Tha-le (Intertidal habitat, with *G. pusillum* and *P. vietnamensis* abundance) and
- 2) Ko Kham (Subtidal habitat, with *C. racemosa* abundance).

To study spatial and temporal variations of population of *G. pusillum*, *P. vietnamensis* and *C. racemosa*, various biological characters such as percentage cover, frond density, length, width and biomass of these seaweeds were monitored in the field at various sampling sites. Line transects and quadrats samplings were employed to study population and distribution of *G. pusillum*, *P. vietnamensis* during low tide. Scuba divers and quadrats samplings were employed to collect and measure samples on the study of *C. racemosa* population.

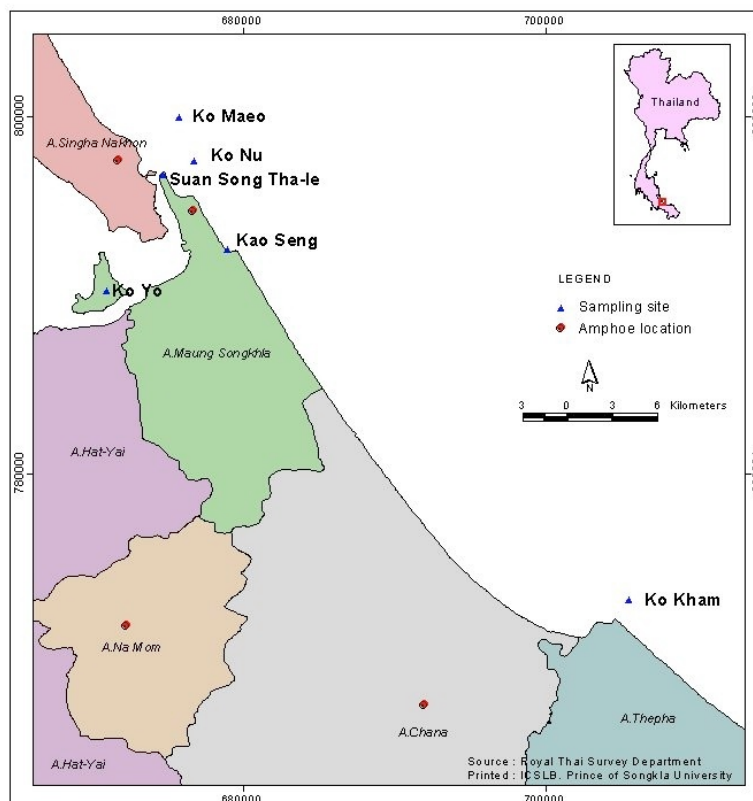


Figure 1 Field collection and study sites in Songkhla province

2) *Gelidium pusillum* population study

Preliminary observations revealed that *G. pusillum* is a dominant red alga on many intertidal shores in Southern Thailand. In Songkhla province, at Suan Song Tha Le (7°13'N, 100°34'W), a high abundance of *G. pusillum* was found over a 1 km long artificial rocky wall. Plants are directly exposed to the wave motion which is especially high during the monsoon season (October-March). Sheltered area plants do not directly face the ocean and therefore are less exposed to waves.

Each month between July 2003 and June 2004, three hundred plants were sampled from ten 50 cm X 50 cm quadrats on both the sheltered and exposed areas of the rocky wall. Fifteen plants from each quadrat were measured for length and examined for reproductive status. Razor blade cross sections were stained using 1% aniline blue and examined for spermatangia, cystocarps and tetrasporic sori (Fredriksen et al., 1994).

Temperature and rainfall were monitored to test for whether there was any correlation with percentage cover, length of thalli, percentage of reproductive fronds and number of different reproductive phases. Nutrients were not considered for this study because the site is on the open mouth of the Songkhla Lake basin. High concentrations of nutrients from urban runoff as well as from agriculture and aquaculture around the basin (Panapitukkul et al., 2005; Chevakidagarn, 2006) are well-known.

Two way ANOVA was employed to test the differences in percentage cover, length of thalli, life phase and numbers of each reproductive phase among sites and seasons using STATISTICA, version 5.0. When necessary, data were transformed to meet the assumptions of the parametric test. Multiple comparisons were made following Zar (1984) when there were significant differences between treatments. Statistical results are presented based on the transformed analyses, but for clarity, graphical output was based on the untransformed means. Spearman Rank correlation was employed to assess the relationship between temperature and rainfall on percentage cover, length, percentage of reproductive fronds, life phase and number of each reproductive phase

3) *Porphyra vietnamensis* population study

P. vietnamensis grows on rocks in the upper littoral zone exposed to strong wave action. It seems to grow best fully exposed, moistened by the spray of the waves. The gametophyte blade of *P. vietnamensis*, appears in the months of November to February during the monsoon season. During this period water temperature decreases from 27-30°C to 24-27°C, salinity from 31-33‰ to 18-26‰ sometimes to 11‰. The light period in Songkhla during October to February is close to 12 hours, about 2-18 minutes shorter than the rest of the

year. Photoperiod, therefore, does not vary much for the whole year in Songkhla province, Thailand (Lewmanomont and Chitpoolkusal, 1993). The sporophyte of *P. vietnamensis* appears on shells in the months of March to October during the dry season (Lewmanomont and Ogawa, 1978).

Suansongthalay (7°13'48"N, 100°34'48"E) and Kaoseng (7°10'57"N, 100°37'22"E), Songkhla province, Southern Thailand were selected for this study due to the abundance of *P. vietnamensis* during the November to March period, which is a rainy season in the Gulf of Thailand. The temperature and salinity ranges dropped from 28-31 °C and 8.17-30 ‰ respectively. At Kaoseng, the site is exposed, facing toward the ocean and has a splash zone while at Suansongthalay, the site is sheltered by an artificial wind break. The water velocity was measured at high tide in May, using MINI Current Meter model SD-6000 (Sensordata, Norway).

The *P. vietnamensis* populations were monitored for 2 years from December 2002 to February 2004. Fifty gametophyte thalli were collected randomly from both sites on 15 December 2002, 5 February 2003, 22 November 2003, 17 January and 29 February 2004. A total of five hundred thalli were gently removed and preserved in 4% seawater formalin for measurement in the laboratory. Length (mm) width (mm) and dry weight (mg) of each thallus were measured using the electronic caliper PD-151 (Pro'sKit, Taiwan) and electronic balance JP-3000 W (Chyo, Japan), respectively.

Physical parameters such as salinity and temperature were recorded at each site. Phosphates and nitrates were provided by NICA (National Institute of Coastal Aquaculture), Songkhla. Wind speed and direction data were provided by Thai Meteorological Department.

Analysis of variance (ANOVA) was employed to test the effect of sites and times of collection on length, width and dry weight of *Porphyra*, PO₄, NO₃, seawater temperature and salinity. If necessary, data were transformed to meet the assumptions of the parametric test. Multiple comparisons were made following Zar (1984). Statistical results were presented based on the transformed analyses, but for clarity graphical output was based on the untransformed means. SPSS Version 15.0 was used for all analyses.

4) *Caulerpa racemosa* population study

The population of *C. racemosa* studied are from the shallow subtidal reefs, 1-2 meters depth, at Koh Kham, Songkhla province, Southern Thailand (6° 71'N, 100° 20'E). The main oceananographic characteristics and the dynamics of the coral reef community of Koh Kham were reported in EIA study on gas separation and piping in Songkhla province (Prince of Songkla University, 2000), but macroalgae populations were not studied. Koh Kham is located on the Gulf of Thailand, nearly 2 kilometers from the coast, with little human activity in proximity to the study sites. Preliminary studies on diversity, distribution and abundance of macroalgae in

Songkhla province, Thailand, were carried out during August 2002, which showed high abundance and many big thick meadows of *C. racemosa* at the site. *C. racemosa* grows together with corals and other algae on sandy, sea shells and rocky substrates near the coral reef flat.

To study the effect of wave motion on the population and morphological plasticity, *C. racemosa* was observed at two sites: on exposed and sheltered sites. The exposed site was on the northern coast of the Koh Kham, which directly opens to the sea. The sheltered site was on the western coast of Koh Kham, where lies parallel to the shore. Also, coral forms were used as biological indicators to measure the degrees of wave exposure. On the exposed site, the higher percentage cover of massive coral such as *Platygyra* sp., *Porites lutea* Milne-Edwards and Haime, 1860 and *Goniastrea pectinata* (Ehrenberg, 1834) were dominant, while foliose coral such as *Turbinaria peltata* (Esper, 1794) had greater percentage cover on the sheltered site.

Percentage cover, frond density, mat thickness and biomass (dry weight) of *C. racemosa* were determined at 3 months intervals from November 2002 to November 2003. Samples were monitored and recorded 4 times within the wet and dry seasons in Southern Thailand. The wet season is predominated by the SW monsoon and a dry season predominated by NE monsoon. Snorkeling and SCUBA techniques were used for data and sampling collection. The wet season study was conducted during 16-17 November 2002 and 19-20 July 2003, and the dry season study during 15-16 February 2003 and 19-20 April 2003. Additional observations of *C. racemosa* population were made on 18 August 2003, 15 November 2003, 13 December 2003 and 27 August 2004. On each sampling dates, five 50 cm X 50 cm quadrats were utilized to randomly sample macroalgal communities at each site. Percentage cover and substrates of macroalgae were estimated visually and recorded at both sites. To investigate frond density, twenty-four 5 cm X 5 cm quadrats were sampled randomly at each site, a thin wooden rod was inserted into the *C. racemosa* mat to measure the mat thickness of the *C. racemosa* meadows at each site with a total of 25 replications. To study *C. racemosa* morphology and biomass, five 50 cm X 50 cm quadrats were randomly sampled at each site across the *C. racemosa* bed. All algal specimens were collected by scraping and then placed into plastic bags. They were placed in dark and cool conditions, immediately brought back to the laboratory and processed. *C. racemosa* thalli were washed; epiphytes and other benthic organisms were removed. Fronds were closely observed and dried at 60°C to constant weight. A few samples were preserved and voucher specimens were deposited at PSU herbarium, Thailand.

Two-way ANOVA was employed to test percentage cover, frond density, mat thickness and biomass against different sites and seasons. Multiple comparisons were tested when there

were significant differences between treatments, following Zar (1984). Cochran's C- test was used before each analysis, to test whether variances were homogeneous and data transformations were applied when necessary. Friedman's ANOVA was employed where homogeneity of the data set was not achieved after transformations. Tukey multiple comparison was employed to test the differences between sites and seasons. Statistical results were presented based on the transformed analyses, but for clarity graphical output was based on the untransformed means.

Results

1) Macroalgae Diversity

All four divisions of macroalgae have been found at various sites around Songkla Province (Table 1), with more than 32 species so far recorded. However, there might have some more seaweeds yet to be found and identified. Some of abundance species are chosen to study more in detail due to their interesting biology and ecology: *Caulerpa racemosa*, *Gelidium pusillum* and *Porphyra vietnamensis*. In addition, there are a few economically important species found e.g. *Gracilaria fisherii*, *Porphyra vietnamensis*, *Gelidium pusillum* and *Caulerpa* spp. These are important baseline data, which can be used for further study in aquaculture, water treatment and biotechnology.

Table 1. Some seaweed species found at various sites of Songkhla province, Thailand.

Sites	Seaweeds found
Ko Meao	<i>Acanthophora</i> sp., <i>Amphiroa</i> spp., <i>Bryopsis</i> spp., <i>Ceramium</i> sp., <i>Dictyota</i> spp.*, <i>Gelidiella</i> sp., <i>Levellia jungermannioides</i> , <i>Lobophora</i> sp., <i>Padina</i> spp.*, <i>Polysiphonia</i> spp., <i>Sargassum</i> spp*.
Ko Kham	<i>Amphiroa</i> sp. <i>Bryopsis</i> spp., <i>Caulerpa racemosa</i> **, <i>Caulerpa</i> spp., <i>Cheatomorpha</i> sp.*, <i>Chlorodesmis</i> sp., <i>Dictyopteris</i> sp., <i>Dictyota</i> spp., <i>Lobophora</i> sp., <i>Lynbya</i> sp., <i>Padina</i> spp.*, <i>Porphyra vietnamensis</i> **, <i>Valonias</i> sp.
Koa Seang	<i>Centoceras</i> sp., <i>Cladophora</i> spp.*, <i>Cheatomorpha</i> sp.*, <i>Enteromorpha</i> sp., <i>Gelidium</i> sp., <i>Gracilaria</i> sp., <i>Polysiphonia</i> spp. <i>Porphyra vietnamensis</i> *
Suan Song Tha- le	<i>Cladophora</i> spp.*, <i>Enteromorpha</i> sp., <i>Gelidium</i> sp.***, <i>Lynbya</i> sp., <i>Porphyra vietnamensis</i> **, <i>Rhizodinium</i> sp., <i>Struvea</i> sp.,
Ko Yo	<i>Gracilaria fisherii</i> *, <i>Enteromorpha</i> sp.

* Abundance species found; percentage cover more than 12,500 cm².

** Abundance species found; they have been studied more in detail due to their interesting biology and ecology.

2) *Gelidium pusillum* population study

There were variations in length of *G. pusillum* among sites and time of year ($F=15.30$, $P < 0.05$). Specimens from the sheltered shore were taller than those on the exposed shore (Fig. 2a). The average longest thalli was $1.04 \pm .03$ cm (mean \pm S.E.) on the sheltered shore during July 2003. On the exposed shore the average shortest plant was $0.6 \pm .01$ cm during May 2004 ($F=7.52$, $P<0.05$). Many bleached tips in late April and beginning of May were observed.

There were variations in percentage cover of *G. pusillum* both among sites and time of year ($F=5.02$, $P < 0.05$). The highest percentage cover was 82.8 ± 2.3 (Mean \pm S.E.) during July 2003 on the exposed area (Fig. 2b). Significant greater percentage cover of *G. pusillum* was

found on the exposed area throughout the study ($F=99.86$, $P < 0.001$). The lowest percentage cover was 39.7 ± 6.06 in October on the exposed shore; and the lowest percentage cover of the sheltered shore was 7.8 ± 2.49 in June 2004, after the bleaching phenomenon observed.

Seasonal variation in percentage of reproduction was striking. Plants reproduced throughout the year, except for November and December 2003, the beginning of the rainy season (Fig. 3a). Both tetraspores and carpospores were observed, but spermatangia were never found in this study. There was greater percentage of tetrasporophytic plants in this population. For example, more than 33% of tetrasporophytic plants were found in July 2003 and February 2004. But also only a few cystocarpic plants were found.

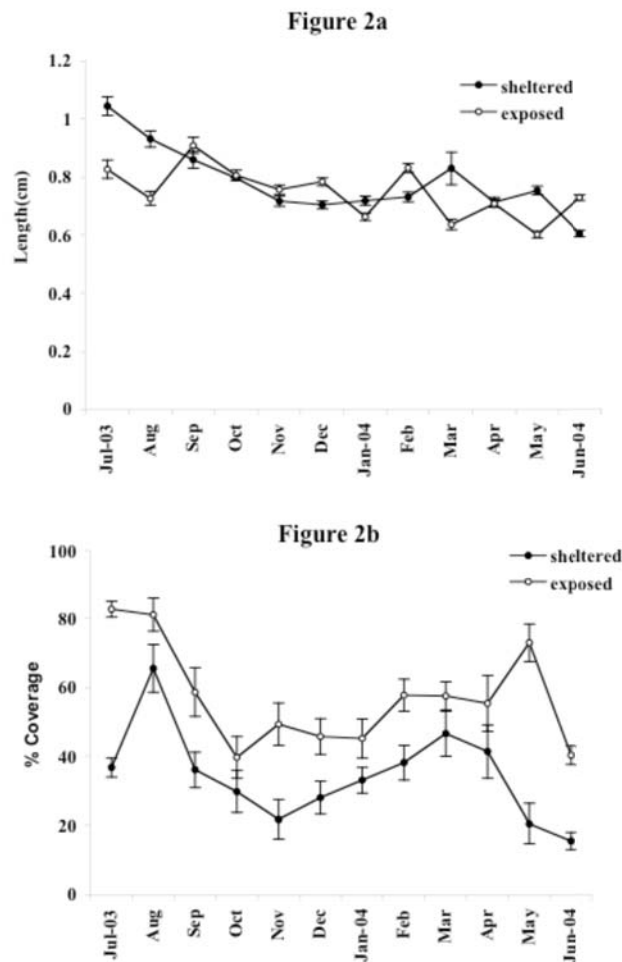


Figure 2 *Gelidium pusillum* population. Effects of wave exposure on length (2a) and % coverage (2b) throughout the year

There were variations in number of tetrasporic sori of *G. pusillum* among sites and seasons ($F=4.49$, $P < 0.001$). In general the thalli produced great numbers of tetraspores. The highest number of tetrasporic sori was 31.91 ± 6.01 sori /frond in January 2004, however, as mentioned above, there were no reproductive fronds in November and December 2003, (Fig. 3b). There were variations of number of cystocarpic specimens among sites and seasons ($F=22.97$, $P < 0.001$). The highest number was $3.52 \pm .089$ cystocarps/ frond in April 2004 at the exposed shore site (Fig. 3c). This suggests that there were male gametophytes in the previous months.

Percentage cover and length of *G. pusillum* were significantly influenced by temperature and rainfall, but there were no strong correlations with either parameter (Table 2). Increased temperature decreased the frond length and some bleaching was observed. The bleached fronds later died off and washed away during the rainy season. After that, of course, the percentage coverage declined.

Reproduction and the number of reproductive structures were significantly influenced by temperature and rainfall (Table 2). High temperature not only stressed reproduction but also caused the plants to die off. However, an increase in temperature was correlated with a fewer cystocarpic fronds (Fig. 4). Rainfall, caused a decrease in salinity to <10 psu during the rainy season. This low salinity is also correlated with low reproduction as expressed in percentage of reproductive fronds (Fig. 5). No reproductive fronds were observed during the mid-rainy season in November-December 2003.

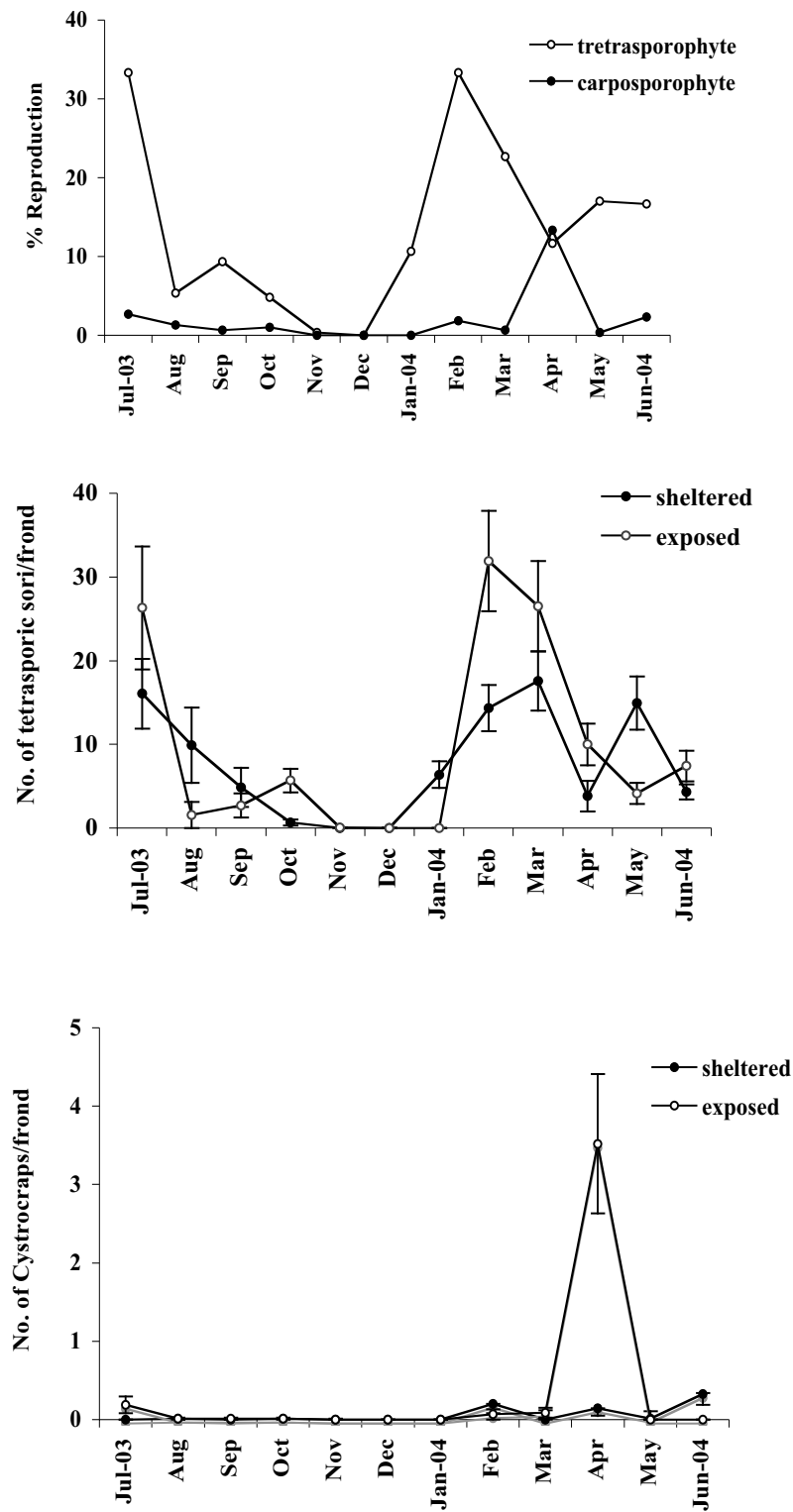
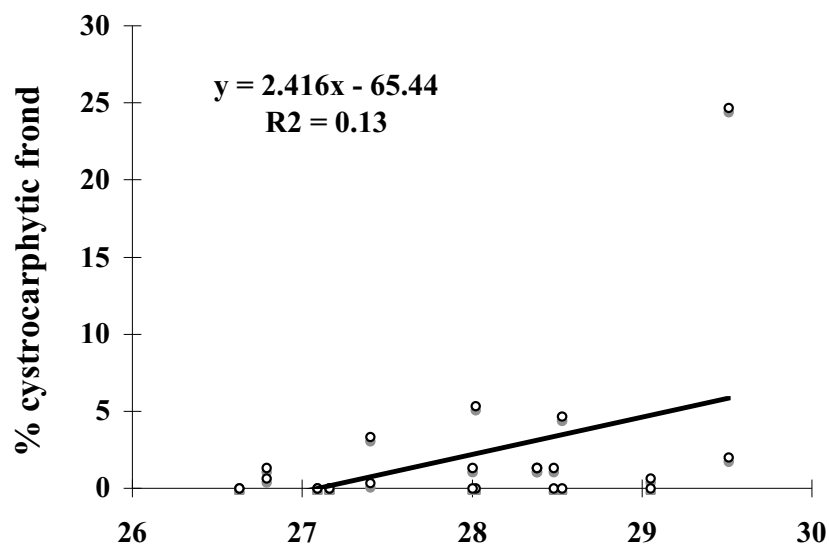


Figure 3 *Gelidium pusillum* population. Effects of wave exposure on % reproduction (3a), No. of tetrasporic sori/ frond (3b) and No. of cystocarps/ frond 3c) throughout the year

Table 2. Summarize of length, percentage cover, percentage of reproductive fronds and number of reproductive organs of *G. pulchellum* at the sheltered and exposed areas; and its relations to temperature and rainfall during July 2003-June 2004 at Songkhla province, Thailand.

		Sheltered area	Exposed area	Temperature (°C)		Rainfall (mm)	
	N	Mean ± S.E.	Mean ± S.E.	R^2	P	R^2	P
Length	1800	0.759±0.007	0.736±0.005	0.18	0.52	0.001	0.85
% Cover	150	35.14±1.65	63.01±1.87	0.07	0.22	0.1	0.131
% Reproductive fronds	12	15.66±3.22	15.88±4.81	0.22	0.13	0.49	<0.01
% Tetrasporic frond	12	14.61±3.01	12.92±4.04	0.08	0.18	0.36	<0.001
% Cystocarpic frond	12	1.05±0.44	2.97±2.01	0.18	< 0.05	0.05	0.31
No. of tetrasporic sori/ frond	1800	7.38±0.06	9.62±0.96	0.07	0.23	0.27	<0.001
No. of cystocarps/frond	1800	0.06±0.02	0.36±0.08	0.16	0.05	0.03	0.38



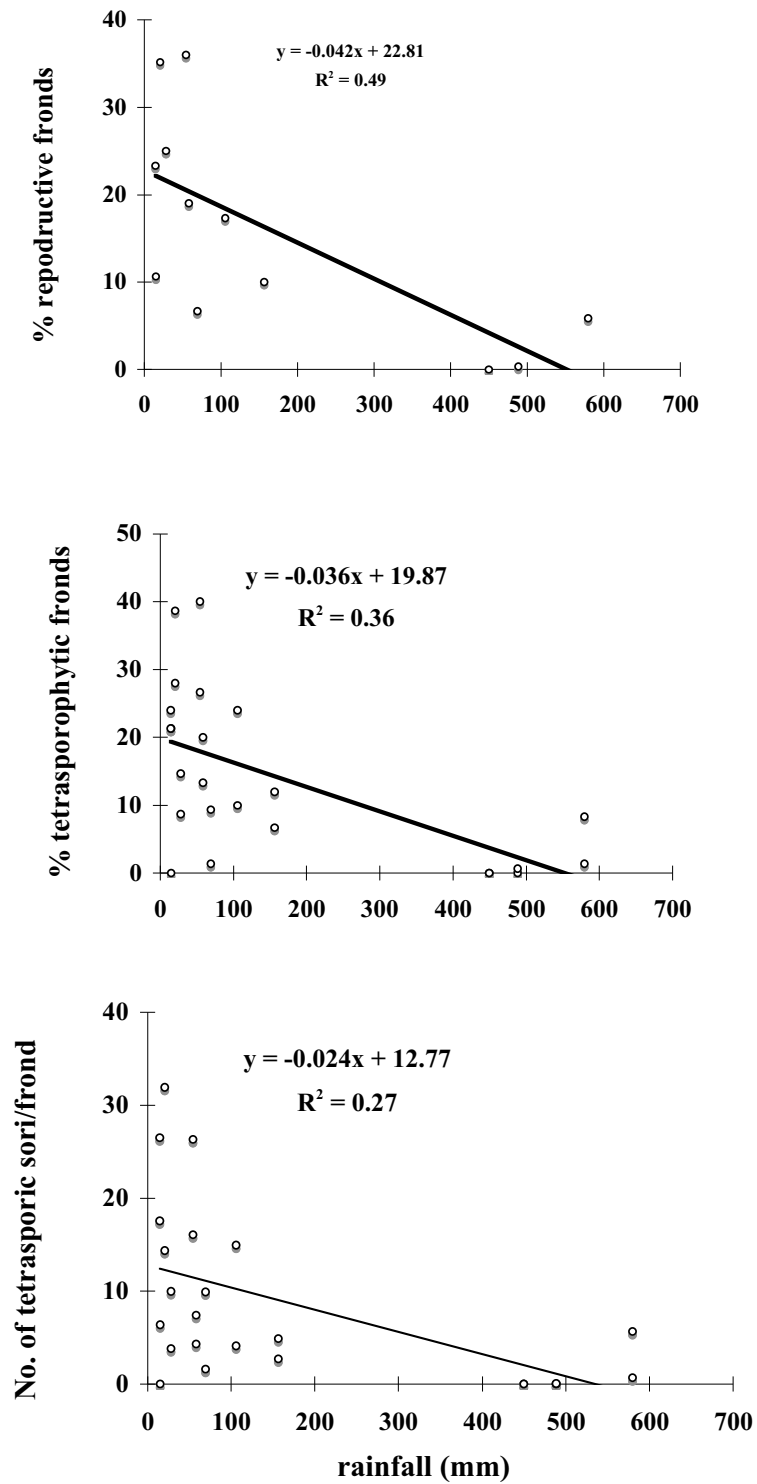


Figure 5 Significant correlation between temperature and % cystocarpic frond and No. of cystocarps/ frond of *Gelidium pusillum*

3) *Porphyra vietnamensis* population study

There were no significant differences in water temperature, salinity, nitrates and phosphates between the two sites ($P>0.05$). The average water temperature, salinity, nitrates and phosphates at both sites were 29.83 ± 0.33 °C, 26.71 ± 2.11 ‰, 0.0668 ± 0.0107 mg/l, and 0.0145 ± 0.0022 mg/l, respectively. Linear regressions of all parameters showed that there was no relationship between these factors on length, width, and dry weight of *P. vietnamensis* (Table 3). However, the average water motion at the exposed shore was higher than at the sheltered shore. Water splashing was also greater. The water velocity at Kaoseng was 3 times greater than at Suansongtalay, 0.106 ± 0.016 ms⁻¹ and 0.034 ± 0.007 ms⁻¹, respectively. In addition, greater wave motion and water velocity are expected during the monsoon season and is on average 3.98 knots, compared to only 1.98 knots in dry season.

Table 3. Summarize of length, width, and dry weight of *Porphyra vietnamensis* Tanaka et Pham-Hoang Ho at the sheltered and exposed areas; and its relations to temperature, salinity, wind speed, nitrate, and phosphate during December 2002 – February 2004 at Songkhla province, Thailand.

	N	Sheltered area	Exposed area	P	Temperature (°C)		Salinity (ppt)		Nitrate (mg/l)		Phosphate (mg/l)	
		Mean±SE	Mean±SE		R ²	P	R ²	P	R ²	P	R ²	P
Length (cm)	320	39.55±2.19	29.12±1.42	0.00	0.217	0.174	0.372	0.061	0.004	0.862	0.007	0.815
Width (cm)	150	5.8±0.34	9.9±0.78	0.00	0.125	0.316	0.129	0.308	0.001	0.918	0.016	0.729
Dry weight (mg)	320	17.4±1.4	24.4±2.8	0.00	0.043	0.566	0.005	0.85	0.022	0.682	0.508	0.021

Growth and Shape of *P. vietnamensis*

Length (mm), width (mm) and dry weight (mg) of *P. vietnamensis* varied between sites ($p<0.05$) (Table 3, 4). The largest fronds at 37.5 ± 2.1 mg were found in February 2003 at the sheltered shore and 37.3 ± 3.9 mg in January 2004 at the exposed shore, while the lowest was found in November 2003, at 3.2 ± 0.4 mg at sheltered site (Table 4). In February 2004, *Porphyra* thalli were not found at Suansongtalay, the sheltered area (Table 4).

Table 4. Summarize of length, width, and dry weight of *Porphyra vietnamensis* Tanaka et Pham-Hoang Ho at the sheltered and exposed areas during December 2002 – February 2004 at Songkhla province, Thailand.

	N	Sheltered area					Exposed area				
		Mean±SE					Mean±SE				
		Dec-02	Feb-03	Nov-03	Jan-04	Feb-04	Dec-02	Feb-03	Nov-03	Jan-04	Feb-04
Length (mm)	320	60.54 +3.86	44.88 +1.89	62.57 +3.06	30.30 +2.16	x	30.32 +1.38	27.94 +0.89	26.23 +1.52	32.08 +1.47	29.04 +1.81
Width (mm)	150	-	-	4.92 +0.26	24.1 +1.46	x	-	-	12.74 +0.85	20.48 +2.04	16.33 +0.99
Dry weight (mg)	320	17.8 +1.6	37.5 +2.1	3.2 +0.4	28.5 +2.8	x	23.6 +2.2	26.6 +2.6	13.9 +1.5	37.3 +3.9	20.6 +3.8

* - : no data; x: not found *P. vietnamensis*

The shape of *P. vietnamensis* varied between sites and among the times of sampling. The thalli at exposed site, were shorter and wider than at the sheltered site. At both sites the blades were narrow and thin during the early sampling period (November and December), and wider and thicker at late sampling period (January and February) (Fig. 6).

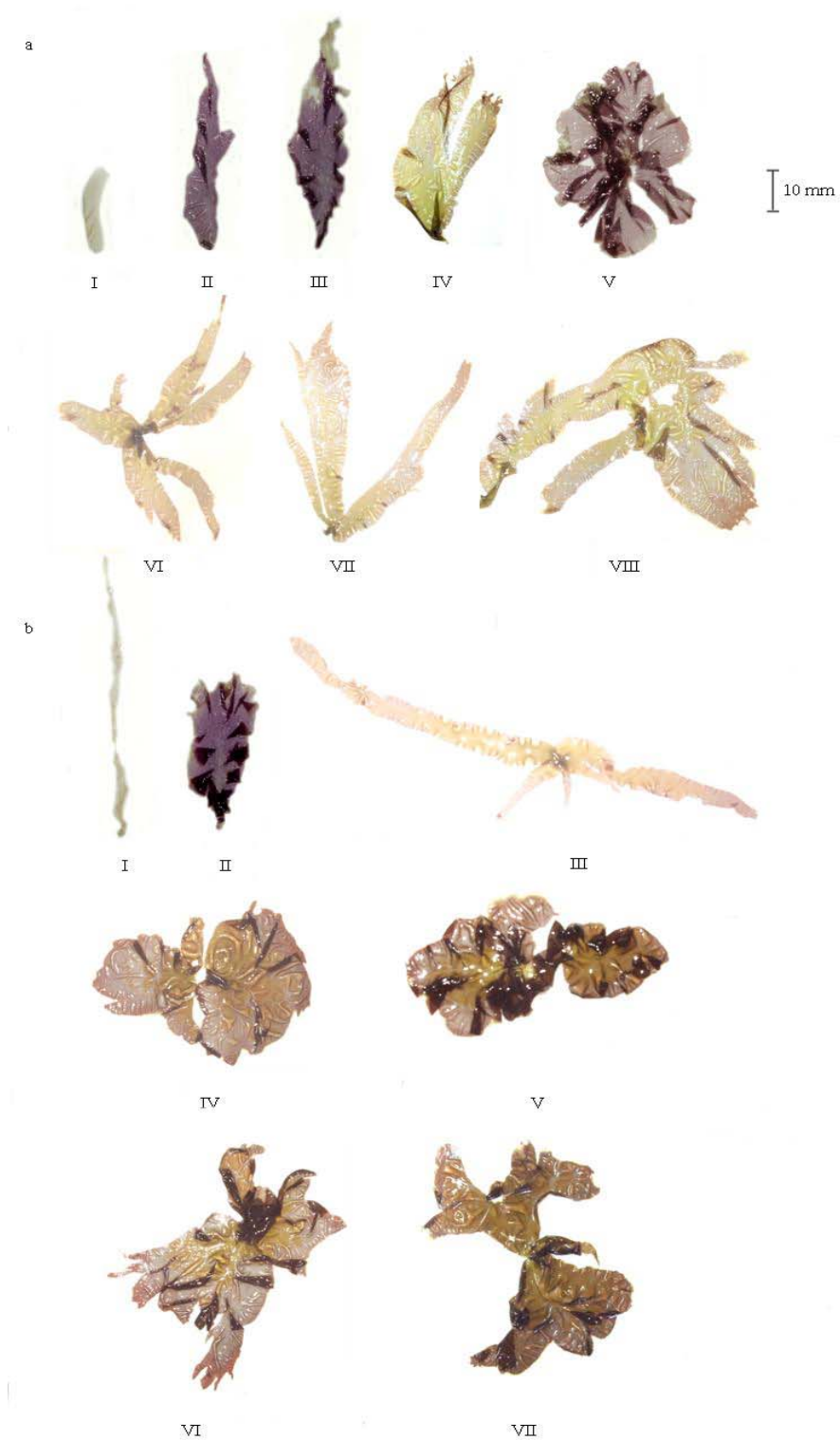


Figure 6 Blade shape of *Porphyra vietnamensis* Tanaka et Pham-Hoang Ho at November 2003 – December 2006 at exposed and sheltered area. Site a: Kaoseng (exposed area), site b: Suansongtalay (sheltered area), I=Dec 02, II=Feb 03, III=Nov 03, IV=Jan 04, V-VIII= Jan 07.

4) *Caulerpa racemosa* populations study

Percentage cover, frond density, biomass and mat thickness of *C. racemosa* varied among sites and seasons. Slightly greater percentage cover of *C. racemosa* occurred on the sheltered site compared to the exposed site, with significant differences among months ($\chi^2 = 27.11$; $df = 7$, $N = 5$, $P < 0.001$; Fig. 7A). *C. racemosa* was very abundant at the site, the maximum percentage cover of *C. racemosa* was found on the sheltered shore during late rainy season and early wet season, around 80% of percentage cover at both sites. Subsequently, in the dry season the percentage cover of *C. racemosa* dropped to 50% when some unhealthy, yellowish fronds were observed. Surprisingly, disappearance of *C. racemosa* occurred in July, 2003. Also, there was no recovery or recruitment of *C. racemosa* population upon revisiting the site in August 2003, November 2003 and December 2003 and August 2004.

Similar patterns were found in *C. racemosa* frond density. There was slightly greater frond density on the sheltered than on the exposed sites, with significant differences among months ($\chi^2 = 107.71$; $df = 7$, $N = 24$, $P < 0.001$; Fig. 7B). *C. racemosa* patches contained very dense greenish fronds. The maximum densest fronds were found at the sheltered site during late rainy season and at the early wet season, 1.75 fronds/cm² in November 2002 and 1.85 fronds/cm² in February 2003 respectively. It was worthwhile to note that there were some *C. racemosa* patches washed up on the shore both on the sheltered and exposed sites. Frond density dropped by 50% in dry season with more *C. racemosa* patches were washed up along the shores; and disappearance of *C. racemosa* was later recorded.

In contrast, *C. racemosa* biomass was significantly greater during the dry seasons. Three hundred percent higher biomass was present in the dry season (April 2003), as compared to the wet season (November 2002) ($F_{(3,14)} = 21.44$, $P < 0.0001$; Fig. 7C), but there was no significant difference between different exposures ($F_{(1,14)} = 1.10$, $P = 0.31$). Due to the very strong wave action, *C. racemosa* stand could not be collected on the exposed site, thus no data was presented for the February, 2003 sampling event.

Similar patterns were found for the mat thickness of *C. racemosa*. There were significant differences in mat thickness among months ($F_{(1,24)} = 271.96$, $P < 0.01$; Fig. 7D). The thickness of *C. racemosa* mat was increased almost 300% in the early dry season compared to those in the wet season, however they became thinner in the middle of the dry season and no differences were found among sites ($F_{(1,192)} = 0.20$, $P = 0.65$).

In addition, close observation on *C. racemosa* fronds showed no differences in frond morphology among sites and seasons. Similar shapes and size of ramuli were found at both

sites. Also, *C. racemosa* fronds underneath the canopy were observed to be bigger and greener than those on the upper part of the patches during February and April 2003.

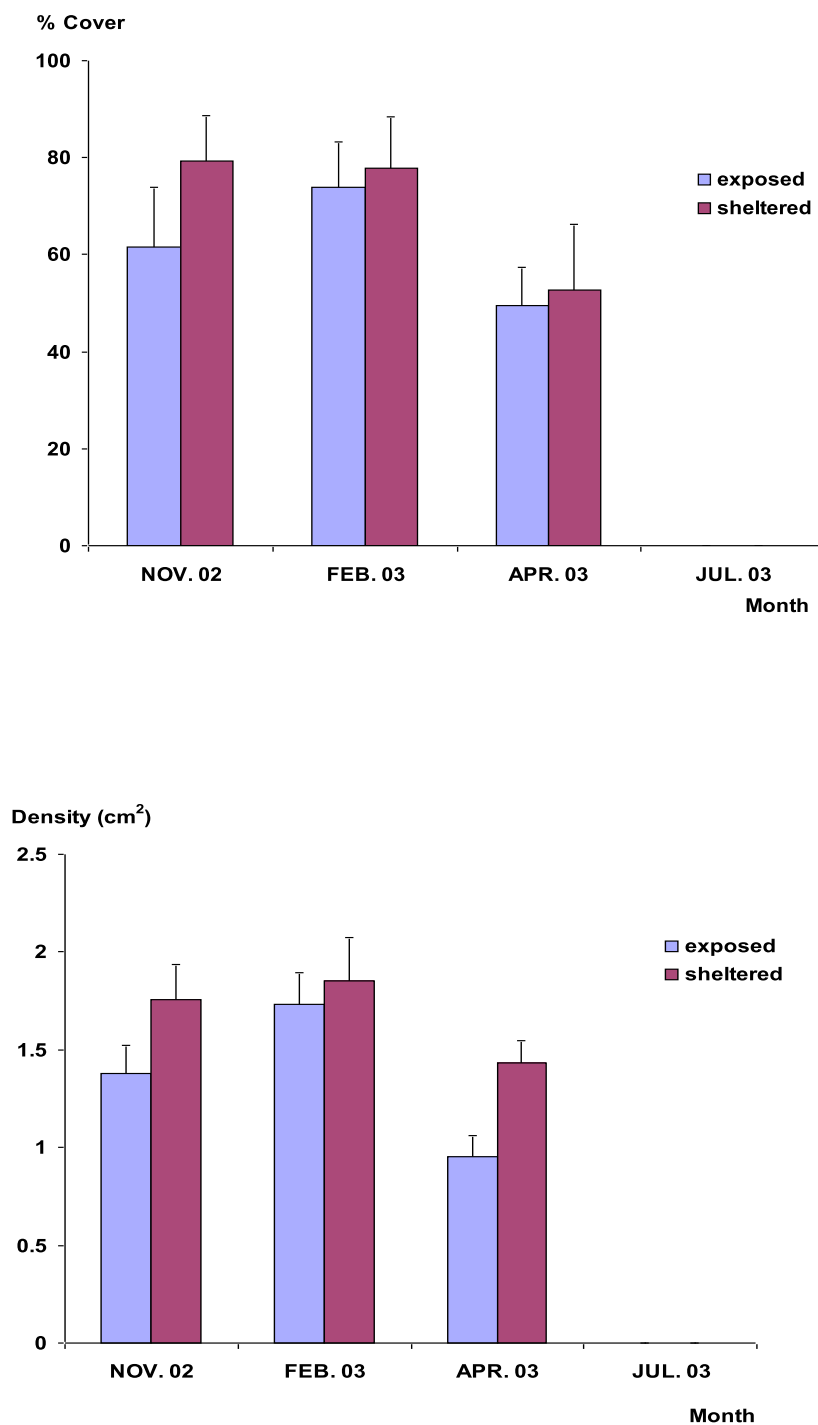


Figure 7 Population characteristics *Caulerpa racemosa* varied among sites and seasons; Figure 7a: percentage cover, Figure 7b: frond density

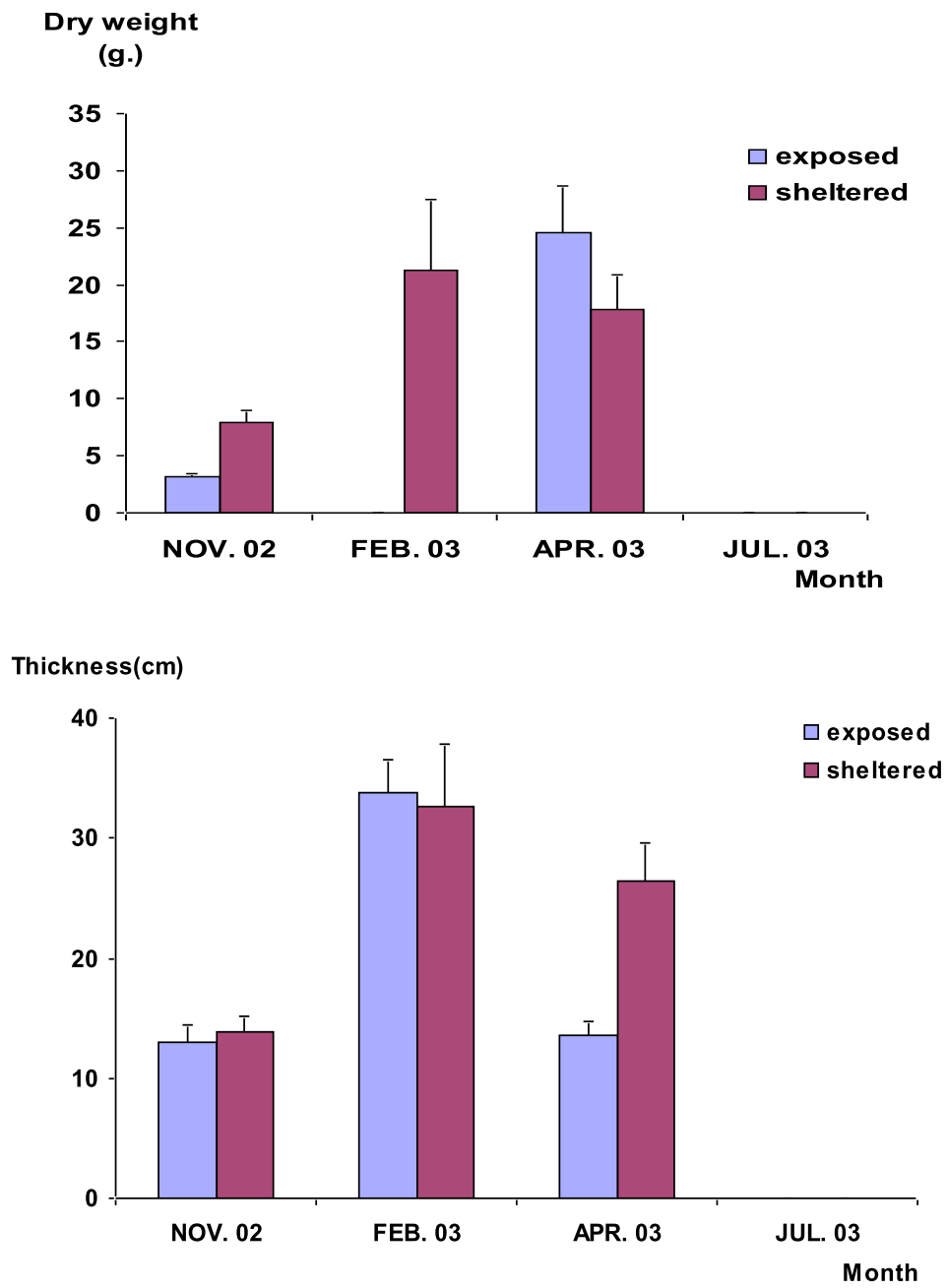


Figure 7 (Cont.) Population characteristics *Caulerpa racemosa* varied among sites and seasons; Figure 7c: biomass and Figure 7d: mat thickness

Discussion

This study has revealed macroalgae diversity at Songkhla province; and provide the seaweed biodiversity and ecology in Thailand. This study is among a few study done on macroalgae research in Thailand. This study has been focused on both economically and ecologically important species: *Gelidium pusillum*, *Porphyra vietnamensis* and *Caulerpa racemosa*.

1) *Gelidium pusillum* population study

The presence of a greater number of tetrasporophytic fronds than cystocarpic fronds, and only a few male or female gametophytic fronds was common in *G. pusillum*. This conforms to the reports for the family Gelidaceae (Akatsuka 1986; Santelices 1988; Serviere-Zaragoza and Scrosati, 2002). However in the closely related order, Gigartinales, gametophytes are the dominant life phase (DeWreede and Green, 1990; Hommersand et al., 1993; Scrosati et al., 1994). In this study the number of cystocarps was influenced by wave exposure. The cystocarps observed were on thalli from the exposed area just after the rainy season, a situation that might be caused by the greater water motion which could increase the success of fertilization by enhancing the ability of the nonmotile spermatia to encounter the trichogyne of the carpogonium.

Plants reproduced throughout the year, a condition which, together with the vegetative reproduction, accounts for the great percentage cover of this species in the study sites. The dense stand of algal-forming turf can persist under high stress along the intertidal shore (Hay, 1981; Guiry and Womersley, 1993). Since fronds could grow into 2 directions both as creeping axes and as uprights, the former withstands the high wave motion and provides a base for the shorter upright axes such as were found in the wave-exposed area. Although, this species is known as a perennial plant, the upright fronds bleached during summer months, when the apical tips became weak, the fronds became shorter and died, decreasing the coverage of the plants two months shortly after. This is similar to the pattern of many other turf forming red algae (Beach and Smith, 1996; Scrosati and DeWreede, 1998).

The onset of tetraspore and carpospore production did not reflect a physiological trade-off between resource allocation to vegetative growth and allocation to reproduction as suggested by Harper and Ogden (1970). *G. pusillum* reproduced spores throughout the year, except in November and December, without any decline of length, density or die off. Although known to be perennial, reproduction was not reduced as hypothesized (Bell 1984a) by the idea that plants reduce allocation to individual growth or general maintenance (Bell 1984b; Obeso

2002) in favor of reproductive cell formation or vice versa. It is possible that resources at the site exceed the requirements. Nutrient levels were high throughout the year. The highest was found during the rainy season, NO₃-1 was 0.12 mg/l and PO₄-3 was 0.024 mg/l.

The rainfall, which decreased the salinity, might be expected to inhibit reproduction. Although increased temperature caused bleaching and later die off, the decline of reproduction might be due to lower salinity, which was < 10 psu at the site during the rainy season. The salinity stress lower than 15 psu was reported to reduce growth rate to almost 5 times in some *Gelidium* spp. (Oliger and Santelices, 1981). This is known to cause a decrease in productivity and reproduction in many red algae and now in *G. pusillum* as well.

There were no shifts of life phase between seasons and sites in *G. pusillum* as has been observed in *Mazzaella* spp. (Mudge and Scrosati, 2003; Scrosati and Mudge, 2004). A predominance of tetrasporophytes is a common feature in *Gelidium* (Montalva and Santelices 1981; Carter 1985, Akatsuka 1986; Macler and West 1987; Santelices 1990; Melo and Neushul 1993; Sosa et al. 1993). Carmona and Santos (2006) have recently tested the advantages of tetrasporophytes over the gametophytes in *G. sesquipedale* through their ecophysiological performance. They found that there were no significant differences either in the photosynthesis rate, nitrogen uptake, nitrate reductase activity, or biochemical composition of phases, but there was an advantage in vegetative recruitment and spore production. The dominance of tetrasporophytes of *G. sesquipedale* cannot be explained but it does reflect the nature of the success of this turf-forming alga throughout the world.

The G:T ratio of *G. pusillum* in our study was 1:14; the G:T ratio in *Gelidium* may be as high as 1:20. Abbott (1980) suggested that this might be because of the failure in the viability of tetraspores, which are the sources of gametophytes and/or the enhanced capability of carpospores to produce tetrasporophytes. Although, we found some mature red tetraspores and carpospores in our study, newly recruited plants were rarely observed. After release spores could be washed away or trapped within the turf, which form new thalli within the patch. Further investigation of spore settlement, recruitment and development both in laboratory and field would allow us to have a better understanding of the population structure and its maintenance in what appears to be a unique red algal species.

2) *Porphyra vietnamensis* population study

Porphyra vietnamensis s gametophyte thalli were present on rocks at Kaoseng and Suansongtalay in the months of November to February, the rainy, coolest time of the year, as also reported by Lewmanomont and Ogawa (1978) and Ruangchuay and Notoya (2007). The smallest fronds of *P. vietnamensis* were found in November which is the first period of its development while the largest were found in the later period, January and February. During

March to October, the conchocelis stage, the sporophyte, was found on the underside of shells. Temperature and salinity are known to be the major environmental factors inducing conchospore release of *P. vietnamensis* in Songkhla Province (Lewmanomont and Chittpoolkusol, 1993). Oyster shells and barnacles were collected from both sites; and the filamentous conchocelis phase was observed and then gametophytes later.

Heteromorphic life cycle of *Porphyra* is unique and complex. The gametophyte and sporophyte phases of *P. vietnamensis* develop at different times of the year. The different phenotypes have advantages by being able to inhabit different ecological niches which, besides other factors, may have different grazing pressures (Taylor and Hay, 1984; Thornber, 2006). Many species have complex life histories as for example, the brown algae, *Lessonia nigrescens*, *Macrocystis pyrifera*, and *Ecklonia radiata*; the brown crust *Ralfsia californica*; and the green alga *Acrosiphonia* spp (Dethier, 1981; Martinez and Santelices, 1998; Sussmann and DeWreede, 2001; Nelson and Schwarz, 2005). The heteromorphic life cycle of *P. vietnamensis* is useful in promoting cultivation because the conchocelis phase can be kept conveniently in small spaces as stock before putting it out into the larger scale cultivation of the marketable gametophyte.

Porphyra thalli at Suansongtalay, the more sheltered and less water-splashed area, disappeared earlier than at Kaoseng. The water splashing decreases desiccation, which increases in late February. In this study the higher temperature in February during 2004 could have caused greater desiccation and die off of gametophyte. Desiccation is known to limit the distribution and life span of many intertidal organisms including seaweeds (Tomanek and Helmuth, 2002)

The shape of *P. vietnamensis* differed at the two sites. The shorter and wider blades were found in exposed area, while the narrower and thinner blades were found at sheltered area. The adaptation of *Porphyra* might give an advantage for survival in the wave-swept rocky intertidal zone. This pattern is found in many marine algae such as *Chondrus crispus*, *Codium fragile*, *Mastocarpus papillatus*, and *Turbinaria ornata* (Kitzes and Denny, 2005; Boller and Carrington, 2006; D'Amours and Scheibling, 2007; Prathep et. al, 2007). However, the size of seaweed is influenced by other physiological and ecological factors, i.e. reproduction, photosynthesis, nutrient uptake and competition. Large macroalgae have more competitive and reproductive advantages than small macroalgae (Dudgeon and Johnson, 1992; Gaylord et al., 1994; Blanchette et al., 2002; D'Amours and Scheibling, 2007). Thus, variation in morphology could be a trade-off between the dislodgement of blade and these factors. Our study shows that wave action plays an important role in establishing the phenotype of *Porphyra* populations.

In 1978, Lewmanomont and Ogawa reported that *Porphyra* in Thailand was harvested and sold on a small scale at US\$6 to 15 kg⁻¹, depending on the quality. An attempt to cultivate *Porphyra* at Kaoseng; was made in 1978. However, it was not successful due to the high water velocity. We suggest that *P. vietnamensis* cultivation should be promoted in Thailand, Vietnam, South East Asia and South Asia, since the life cycle, biology and ecology of *P. vietnamensis* are now better understood. In addition, there are many techniques and technologies which have been used in the cultivation of *P. yezoensis*, *P. haitanensis* and *P. tenera* with great success in East Asia (Ayano et al., 1998; Han, 2006; Cultured Aquatic Species Information Programme, 2007; Monterey Bay Aquarium Research Institute, 2007).

3) *Caulerpa racemosa* population study

Many studies have shown that there is significant morphological plasticity of *C. racemosa* due to various physical factors such as temperature, light, salinity and wave motions (Calvert, 1976; Ohba et al., 1992; Carruthers et al., 1993; Gacia et al., 1996; Verlaque et al., 2000; de Senerpont Domis et al., 2003). Surprisingly, this study showed no differences in percentage cover, frond density, mat thickness, biomass and frond morphology of *C. racemosa* between exposed and sheltered sites. The large meadows of *C. racemosa*, dense compact stolons and fronds are similar to those known to form turf-forming communities in coral reef habitats. The turf-forming algae are known to be an adaptation against herbivory and desiccation (Hay, 1981) and against excessive irradiance which may cause bleaching in many algae (Hay, 1986; Beach and Smith, 1996 a, b). It is also known to reduce water velocities over the individual fronds (Hurd and Stevens, 1997). Thus, there might have been very little influence in such physical factors over *C. racemosa* turfs at both sites, hence similar patterns of *C. racemosa* population were found.

Temporal variations in percentage cover, frond density, mat thickness and biomass were found in the big thick mats of *C. racemosa*, that once covered areas of more than 1,625 m². Populations sharply declined by 50% in April, the middle of dry season. Also, *C. racemosa* fronds underneath the canopy were observed to be bigger and greener than those on the upper part of the patches. Greater exposure to high light could cause bleaching and die off in some other marine algae (Beach and Smith 1997; Scrosati and DeWreede, 1998). Thus, greater exposure to high light in February and April of *C. racemosa* may have caused yellowish unhealthy fronds and later died-off.

Although, seawater temperature of tropical sea is relatively constant (Scrosati, 2001), *C. racemosa* population inhabited at the shallow subtidal with only 1-2 meters depth and may be influenced by an increase of in seawater temperature and greater irradiance in the dry season when the tide was out. The long term monitoring data set of 12 years showed that February

has the minimum rainfall and April was the month with the warmest air temperature at over 30 °C (Prince of Songkla University, 2000), such condition during dry season may have caused the 50% dropped of *C. racemosa* population as shown in the results. The decline of *C. racemosa* populations reported here, therefore, may be a result of a combination of an increased seawater temperature and greater irradiance.

Surprisingly, the *C. racemosa* population disappeared in July 2003 at the beginning of wet season. Although, there was already a record of population dropping in previous sampling, it seemed unlikely to result in the disappearance of such massive populations of *C. racemosa* unless biomass removal was alternatively the result of a typhoon or an endemic pathogen. However, there was no any catastrophic tropical weather event reported during this period. Incidentally, no changes in other marine algae and fauna were noticed at the site. In addition, *Caulerpa* spp. are known to contain secondary compounds such as caulerpin, caulerpicin and caulerpenyne, which are known to deter fishes and other potential marine predators (Hatta, 2001). These toxins help to maintain and make *Caulerpa* population stable and are very successful in favorable conditions in the Mediterranean Sea (Meinesz et al., 1995; Ceccherelli and Cinelli, 1999). Our observations did not indicate the presence of grazing activity.

Some studies have shown population *Caulerpa* decline and died-off after releasing gametes both in the field (Clifton, 1997; Clifton and Clifton, 1999) and in laboratory (Panayotidis and Zuljevic, 2001; de Senerpont Domis et al., 2003). In the field, *C. racemosa* was found releasing their gametes in the early morning after sunrise, however which environmental or biological factors triggering the onset of the sexual reproduction remain unknown (Clifton, 1997). When the conditions become favorable for sexual reproduction, fronds became fertile within 12 hours and it would take only short period of time for gametes releasing. As a result, *Caulerpa* population may disappear in a very short period of time; as short as 3 hours depending on wave motion and currents (Clifton and Clifton, 1999).

The disappearance of such an expansive population of *C. racemosa* in the same period of time is suggestive of sexual reproduction and resulting decline of the population in this study. *Caulerpa* have been classified as a clonal organism (Collado-Vides, 2002) due to their siphonous fronds connection, thus the population may be influenced by the effects of an environmental conditions throughout the clonal mat (de Kroon and Schieving, 1990). They also could have the same set of genetic materials as they could reproduce and increase their population size by asexual reproduction or fragmentation, which already has reported to have resulted in successful population increases in the Mediterranean sea (Panayotidis and Zuljevic, 2001). Therefore, the populations of *Caulerpa* at Koh Kham likely originated from the same parents cell with similar ages, resulting in simultaneous fertility, gamete release, and die-off during the same period of time.

Recruitment and recovering of new population of *C. racemosa* should be found within a few months after sexual reproduction (Clifton and Clifton, 1999). However, after revisiting at the study sites several times for over a year after the disappearance of *C. racemosa*, there has been no recruitment and recovery of *C. racemosa* population. There were only a few patches of small *C. racemosa* observed in the rock cracks or coral crevices. The unsuccessful recruitment of sexually produced gametes of *C. racemosa* in the early rainy season, may have been a result of greater wave motion, as increasing wave motion would dilute gametes and decrease fertilization success (Gordon and Brawley, 2004). The vegetative reproduction and fragmentation, therefore, might be an adaptation of this tropical green alga to maintain its population.

This study was the first to report population dynamics and the disappearance of *C. racemosa* in the tropical shallow subtidal reef in Southeast Asia and Thailand. The incidence of sexual reproduction in this invasive species is still poorly known, thus further studies on what triggers the onset of sexual reproduction would be very useful. Also, this information would be very useful for understanding the population dynamics of this genus of highly invasive macroalgae.

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Output

1. ผลงานตีพิมพ์ในวารสารทางวิชาการนานาชาติ (ระบุชื่อผู้แต่ง ชื่อเรื่อง ชื่อวารสาร ปี เล่มที่ เลขที่ และหน้า)

1.1 Prathep A., Lewmanomont K., Chottithammo A. and Tantiprapaj, P. Population Dynamics of *Caulerpa racemosa* (Forsskl) J. Agardh., a siphonous green alga, in Shallow Subtidal Reefs, Koh Kham, Songkhla Province, Thailand. 2006. Proceedings of 10th International Coral Reefs Symposium: 1870-1876. (ภาคผนวก 1)

1.2 มีการจัดทำ manuscripts 2 เรื่อง และได้ส่งไปวารสาร Journal of Applied Phycology และ Aquatic Botany ตามเอกสารที่แนบมาด้วย (ภาคผนวก 2 และ 3)

2. การนำงานวิจัยไปใช้ประโยชน์

2.1 เชิงสาธารณะ (มีเครือข่ายความร่วมมือ/สร้างกระแสความสนใจในวงกว้าง) เกิดเป็นเครือข่ายความสนใจศึกษาวิจัยสาหร่ายทะเลทั้งในระดับประเทศ และต่างประเทศ ในระดับประเทศเป็นหน่วยวิจัยศึกษาสาหร่ายทะเลในภาคใต้ที่เข้มแข็ง เป็นส่วนหนึ่งของชมรมสาหร่ายและแพลงก์ตอนแห่งประเทศไทย มีการนำเสนอผลงานในที่ประชุมต่าง ๆ ทั้งภายในชมรมสาหร่ายและแพลงก์ตอน และยังมีการนำเสนอผลงานการวิจัยในที่ประชุมทางวิชาการที่เกี่ยวข้องเช่น BRT ในระดับนานาชาติมีเครือข่ายความร่วมมือกับประเทศญี่ปุ่น และประเทศในเอเชียตะวันออกเฉียงใต้ ได้รับเชิญจาก Professor Jeong Ha Kim ของประเทศเกาหลีใต้เพื่อไปนำเสนอผลการศึกษาที่ได้จากโครงการนี้ ได้รับทุนจาก HP Foundation, USA เพื่อให้ไปร่วมเข้าประชุมและนำเสนอผลงานที่ได้จากโครงการ และเป็นฐานในการพัฒนาเครือข่ายความร่วมมืออื่น ๆ อีกมากมาย

2.2 เชิงวิชาการ (มีการพัฒนาการเรียนการสอน/สร้างนักวิจัยใหม่) ผลการศึกษาและองค์ความรู้ที่ได้ถูกนำมาใช้เป็นตัวอย่างในการเรียนการสอน และเป็นฐานในการศึกษาวิจัยต่อมา มีการพัฒนาเป็นหน่วยวิจัยสาหร่ายและหญ้าทะเลขึ้น และในปัจจุบันมีนักศึกษาระดับปริญญาโทที่พัฒนาต่อยอดวิทยุวิจัยจากโครงการนี้อยู่ 1 คน และผลการศึกษาที่ได้จากโครงการนี้ยังเป็นฐานองค์ความรู้ให้กับนักศึกษาระดับบัณฑิตศึกษาที่ทำงานวิจัยเกี่ยวกับสาหร่ายทะเล ซึ่งได้สำเร็จการศึกษาไปแล้วรวม 3 คน และยังเป็นฐานสร้างความสนใจให้กับนักศึกษาเพื่อศึกษาและวิจัยต่อในระดับสูงอีกด้วย

3. อื่น ๆ (เช่น ผลงานตีพิมพ์ในวารสารวิชาการในประเทศ การเสนอผลงานในที่ประชุมวิชาการ หนังสือ การจดสิทธิบัตร)

3.1 Diversity, abundance and distribution of macroalgae in Songkhla province, Thailand: What do we have so far? Oral presentation: "The first National Algal and Plankton Symposium" 20th -21st March 2003. Kasetsart University, Bangkok, Thailand.

3.2 Diversity, abundance and distribution of macroalgae in Songkhla province, Thailand. Poster presentation: "TRF conference" 9th -11th January 2004. Kanjanaburi, Thailand

3.3 Diversity, abundance and distribution of macroalgae in Songkhla province, Thailand.

Oral Presentaion: "The first International Symposium on Marine Biodiversity and Conservation Ecology" 16th -23rd February 2004 Department of Biology, Chungnam National University, South Korea.

3.3 Diversity, abundance and distribution of macroalgae in Songkhla Province, Thailand.

Poster Presentation: " 10th International Coral Reef Symposium" 28th June – 2nd July 2004. Okinawa, Japan

3.4 Diversity, abundance and distribution of macroalgae in Songkhla province, Thailand.

Oral presentation: "TRF conference" 14th -16th January 2005. Kanjanaburi, Thailand

3.5 *Porphyra* Ecology from Songkla Province, Thailand. Invited Speaker in " *Porphyra* : An Economic Macroalga, a potential culture species in Thailand". The Second National Conference on Algae and Plankton, Thailand. 23rd -25th March 2005. Holiday Inn Garden, ChiangMai, Thailand.

3.6 Seasonal Variations in Precentage Cover, Frond Length and Reproductive Cycles of *Gelidium* sp. at Suan Song ThaLe, Songkhla Province, Thailand. Oral Presentation. 23th -25th March 2005. Holiday Inn Garden, ChiangMai, Thailand.

Appendix 1

Population Dynamics of *Caulerpa racemosa*, a siphonous green alga, in Shallow Subtidal Reefs, Koh Kham, Songkhla Province, Thailand

Anchana PRATHEP¹, Kanjanapaj LEWMANOMONT², Atchara CHOTITHAMMO³ and Piyalarp TANTIPRAPAJ⁴

^{1,3}Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand.

²Department of Fishery Biology, Faculty of Fisheries, Kasetsart University, Chatuchak, Bangkok, 10900, Thailand.

⁴Marine Ecology Unit, Phuket Marine Biological Station, Ao Makam, Phuket, 83000, Thailand.

¹Corresponding Author: anchana.p@psu.ac.th

Phone: 66-1-542697; Fax: 66-74-212917

Abstract Population dynamics of *Caulerpa racemosa*, a siphonous green alga, were investigated in shallow subtidal reefs in, Koh Kham, Songkhla Province, Thailand. Percentage cover, frond density, mat thickness, biomass and frond morphology were monitored and observed both in the wet and dry seasons between November 2002-December 2003. The study was carried out both on sheltered and exposed sites to study the effects of wave motion on population dynamics and on *Caulerpa* morphological plasticity. The results showed that there were no significant differences in percentage cover, frond density, mat thickness, biomass and fronds morphology of *C. racemosa* among sites, but there were differences between seasons. Population decreased by 50% during April 2003, the hottest month of the year, when temperature and irradiance were highest, particularly in the shallow subtidal zone habitat. This could, therefore, influence the physiological ecology and population abundance of *C. racemosa*. In addition, some fronds were found unhealthy and turned into yellowish color thalli. Surprisingly, the population of these big meadows of *C. racemosa* which covered the area of more than 1,625 m² disappeared in July 2003 and never recovered or recruited. This study reports and discusses the disappearance of *C. racemosa* populations in the tropical waters, which elsewhere are dominant, very successful and classified as an invasive species.

Key words *Caulerpa racemosa*, population, coral reef, macroalgae, sexual reproduction

Introduction

Macroalgae are known to play very important ecological roles in coral reefs community. Since they are primary producers they provide food sources, shelter and nursery grounds for marine organisms. Recently, many reefs have degraded and undergone a phase-shift in which the abundance of corals declined, and abundance of macroalgae increased. This has caused lower biodiversity and tourism appeal (Done, 1992; Hughes, 1994; McCook, 1999). Many studies have investigated this algal phase-shift involving the replacement of corals with macroalgal communities (e.g. Littler & Littler 1984, Done, 1992, Hughes, 1994; Genin et al., 1995; Lapointe, 1997). However, there are fewer studies of coral reef macroalgae at the population level that provide a specific understanding of macroalgal community population dynamics and management of coral reefs.

The distribution and abundance of macroalgae are known to be influenced by various physical and biological factors such as seawater temperature (Scrosati, 2001), nutrient levels (Lapointe et al., 2004) and sedimentation (Airoldi et al., 1996; Airoldi, 1998). Fishes and sea urchin are known to regulate the macroalgae population within the reefs (Hay and Taylor, 1985; Hughes et al., 1987). Various biological competitions between coral and algae are well studied and known to influence the outcome of reef community (see review: McCook et al., 2001). Although, the Indo-Pacific region is known to have a high rich diversity of coral reefs, very little is known of coral reef macroalgal population dynamics in the tropical region of Thailand or South East Asia.