ORIGINAL ARTICLE

Seasonal variations in diversity and abundance of macroalgae at Samui Island, Surat Thani Province, Thailand

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Abstract

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Diversity and abundance of macroalgae at Samui Island, Surat Thani Province, Southern Thailand was investigated during rainy and dry seasons. Five study sites were chosen around the Island on the basis of its high species richness and abundance. Applying a "Visual Census Method", the abundance of macroalgae in terms of percentage cover could be estimated. Thirty-four taxa of marine algae were found from the five sites around the Island: Phra Yai, Sila-ngu, Hua-tanon, Ban Pang-ga and Taling-ngam. A total of thirty-four taxa were identified during this study, comprising 1 Cyanophyta, 9 Chlorophyta, 10 Phaeophyta and 14 Rhodophyta. The brown alga, *Sargassum polycystum*, was widely distributed and found at all sites, while *Padina* and *Acanthophora* were the most abundance species throughout this study. Sila-ngu and Hua-tanon sites had the richest diversity of macroalgae during the dry season; 22 species and 20 species were found respectively. This high diversity might be the result of greater habitat complexity, while only 2 species of

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macroalgae were found on the soft-bottom substrate at Phra Yai. A greater abundance of macroalgae was found during the dry season which might be due to the combination of increasing light intensity and the accumulation of nutrient run off during the rainy season. The algae, therefore, could have greater photosynthesis and grow later in the early part of dry season. Diversity of macroalgae, however, was 35 % less in the last 18 years. This might be the result from increasing tourist activities in Thailand. Thus, marine conservation and management are urgent issues for the island. In addition, further intensive studies on macroalgae are also needed because they have received less attention when compared to other marine organisms such as corals and fishes.

Key words : abundance, diversity, macroalgae, Samui Island

บทคัดย่อ

จารุวรรณ มะยะกูล และ อัญชนา ประเทพ

การเปลี่ยนแปลงตามฤดูกาลของความหลากหลายและปริมาณสาหร่ายทะเลที่เกาะสมุย จังหวัดสุราษฎร์ธานี

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ศึกษาความหลากหลายและปริมาณของสาหร่ายทะเล ณ เกาะสมุย จังหวัดสุราษฎร์ธานี ในระหว่างช่วงฤดูฝนและฤดูร้อน โดยวิธี "Visual Census Method" โดยสุ่มจุดศึกษาที่มีความหลากหลายและปริมาณของสาหร่ายทะเลสูง จำนวน 5 จุด รอบเกาะสมุย คือ วัดพระใหญ่ วัดศิลางู บ้านหัวถนน บ้านพังกา และตลิ่งงาม พบสาหร่ายทะเลทั้งหมด 34 สกุล ซึ่งประกอบด้วย กลุ่มสาหร่ายสีเขียวแกมน้ำเงิน 1 สกุล สาหร่ายสีเขียว 9 สกุล สาหร่ายสีน้ำตาล 10 สกุล และสาหร่ายสีแดง 14 สกุล สาหร่ายที่พบกระจายอยู่ทุกบริเวณที่ทำการศึกษาคือ สาหร่ายสีน้ำตาลชนิด *Sargassum polycystum* ในขณะที่สาหร่ายสีน้ำตาลสกุล *Padina* และสาหร่ายสีแดงสกุล *Acanthophora* มีปริมาณมากที่สุดในการศึกษาครั้งนี้ ส่วนบริเวณที่พบความหลากหลายของสาหร่ายสูงที่สุดคือ วัดศิลางู 22 ชนิด และบ้านหัวถนน 20 ชนิด ทั้งนี้อาจเนื่องมาจากความซับซ้อนและความหลากหลายของพื้นที่ยึดเกาะของทั้ง 2 บริเวณ เมื่อเปรียบเทียบกับพื้นที่บริเวณพระใหญ่ที่เป็นเพียงพื้นโคลนเท่านั้นและพบสาหร่ายเพียง 2 เท่านั้น นอกจากนี้สาหร่ายมีปริมาณและชนิดในช่วงฤดูร้อนมากกว่าในฤดูฝน ทั้งนี้อาจเนื่องมาจากปริมาณแสงที่เพิ่มมากขึ้นและการสะสมสารอาหารที่ถูกชะล้างลงมาระหว่างฤดูฝน ส่งผลให้มีการสังเคราะห์แสงมากขึ้นและเจริญเติบโตได้อย่างรวดเร็วในช่วงต้นฤดูร้อน จากผลการศึกษาในครั้งนี้ เมื่อเปรียบเทียบกับ 18 ปีที่แล้ว พบว่ามีความหลากหลายของสาหร่ายทะเลลดลงถึง 35% ซึ่งอาจเป็นผลกระทบจากการท่องเที่ยวที่เพิ่มขึ้นและสภาพแวดล้อมที่เปลี่ยนไป ดังนั้นการอนุรักษ์และการจัดการทรัพยากรทางทะเลเป็นเรื่องสำคัญที่ควรมีการศึกษาอย่างเร่งด่วน เช่นเดียวกับการศึกษาด้านสาหร่ายทะเลซึ่งในปัจจุบันได้รับความสนใจและมีการศึกษาน้อยมาก เมื่อเปรียบเทียบกับสิ่งมีชีวิตอื่น ๆ เช่น ปะการัง และปลาในแนวปะการัง

หน่วยวิจัยสาหร่ายและหญ้าทะเล ภาควิชาชีววิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยสงขลานครินทร์ อำเภอหาดใหญ่ จังหวัดสงขลา 90112

Seaweeds play a pivotal role as one of the main groups of primary producers in marine ecosystems. Diversity, distribution and abundance of seaweeds are known to be influenced by both physical and biological factors (Lobban and Harrison, 1994; Nybakken, 2001). Grazing pressure, a biological factor, has been regarded as the major factor controlling the structure of macroalgal communities (Anderson and Underwood, 1997; Underwood, 1998). There have been various studies on inter-and intraspecific competition for nutrients and space of macroalgae during the last ten years (McCook, 1997, 1999, 2001; Miller and Hay, 1998; McCook *et al*., 2001; Lirman, 2001), and they are known to determine patterns of macroalgal dominance or exclusion in coral reef ecosystems. Water motion, a physical factor, has been proven to be a key determinant of macroalgal production (Lobban and Harrison, 1994), influencing a number of abiotic and biotic factors that control macroalgal zonation and community structure, including nutrient availability, temperature (Costa *et al*., 2002) and rates of herbivory (Lubchenco, 1978; Kim, 1997; Lotze *et al*., 2000; Belliveau and Paul, 2002). Water motion can also influence the community structure via wave action (Lobban and Harrison, 1994), which influences propagule dispersal, fertilization, settlement and recruitment (Vadas *et al*., 1990; Serrao *et al*., 1996; Costa *et al*., 2001).

The role of algae in the economic life of humans and ecosystems is relatively well known. The use of algae as food, animal fodder, fertilizers, as raw materials in the production of industrial phycocolloids, and as natural feeds for economically important aquaculture species has received much attention in Thailand and in many other countries around the world (Aungtonya and Liao, 2002) such as in Japan, China, and other Asian countries. In recent years, seaweeds have also been considered as potential solar-energy converters, to provide biomass as a source of nutrients and energy for methane-producing bacteria (Lobban and Harrison, 1994). As part of the human diet, seaweeds provide protein, vitamins, and minerals especially iodine from kelp. In addition, commercially important phycocolloids-agars, carrageenans, and alginated-alginates are extracted from red and brown algae. Agars obtained from *Gelidium* are used extensively in microbiology and tissue culture for solidifying growth media, and more recently in electrophoresis gels. The agar from *Gracilaria* is used mainly in foods. Carragenans chiefly from *Eucheuma* and *Chondrus* are widely used as thickeners in dairy products. Alginates, from *Macrocystis* and *Laminaria*, are also used as thickeners in a multitude of products ranging from salad dressing to oil-drilling fluids to the coatings in paper manufacture (Chapman and Chapman, 1980; Waaland, 1981; Lobban and Harrison, 1994). Some 400-500 species of seaweeds are collected for food, fodder, or chemicals, but fewer than 20 species in 11 genera are commercially cultivated (Lobban and Harrison, 1994).

These values of seaweeds are known and have been supported for a series of cultivation studies for example FAO reports (Leipzig, 1996). Basic research on taxonomy and ecology of macroalgae provides important information for further uses of seaweeds; for example in taxonomy and uses of economically important species in South East-Asia (Prud'homme van Reine and Trono, 2001) and a series of taxonomy of economic seaweeds: with reference to some Pacific species (e.g. Abbott, 1994, 1995). However, there are only a few scientific publications on macroaglae from Southeast Asian waters (Ogawa *et al*., 2003), although they are known to be highly valuable both ecologically and economically. The very first report of marine algal flora in Thailand was published in 1866 in "Die Preussische Expedition nach Ost-Asien" (Martens, 1866), followed by "Flora of Koh Chang" (Schmidt, 1900-1916) and "List des algues du siboga" (Weber van Bosse, 1913-1928). Later in the 1970's there were a few studies of marine algae reported e.g. Egerod (1971, 1974, and 1975), Velasquez and Lewmanomont (1975), Lewmanomont (1976, 1978). Recently, there have been a series of taxonomical studies on red algae such as *Gracilaria* in Thailand (Lewmanomont, 1994, 1995; Lewmanomont and Chirapart, 2004). However, only a few investigations have been carried out on seaweeds in recent years and the number of seaweed studies in Thailand has rather declined (Powtongsook, 2000).

To our knowledge, the only two recent recorded studies of macroalgae are 1) cultivation of *Gracilaria* (Chirapart and Lewmanomont, 2004) and 2) additional records of *Gracialria* in Thailand (Lewmanomont and Chirapart, 2004). Therefore, more studies on various aspects of seaweeds are still urgently needed, especially on population or community ecology. Such information could provide a baseline for more complex ecological studies and coastal management in the future, as well as applied aspects of the uses of seaweeds.

Therefore, the purpose of this study is to describe the diversity and abundance of the marine macroalgae at Samui Island, Surat Thani Province, Thailand. The results are believed to be useful as reference sources for the further study of marine flora in Thailand and South East Asian countries.

Materials and Methods

Study sites

The study sites were located at Samui Island, Surat Thani Province, Southern Thailand. This island has many marine habitats such as rocky shores, coral reefs and sandy beaches. Samui Island has one of the richest diversity of macroalgae in Southern Thailand. In addition, seaweeds are important to the local people who collect them during low tide for use as food. There are various species of seaweeds that have been used as vegetables e.g. *Gracialria, Acanthophora, Sargassum, Turbinaria* and *Ulva* (personal observation). However, the macroalgae data of this study site have not been updated; the most recent study of which was conducted almost 18 years ago (Petta,

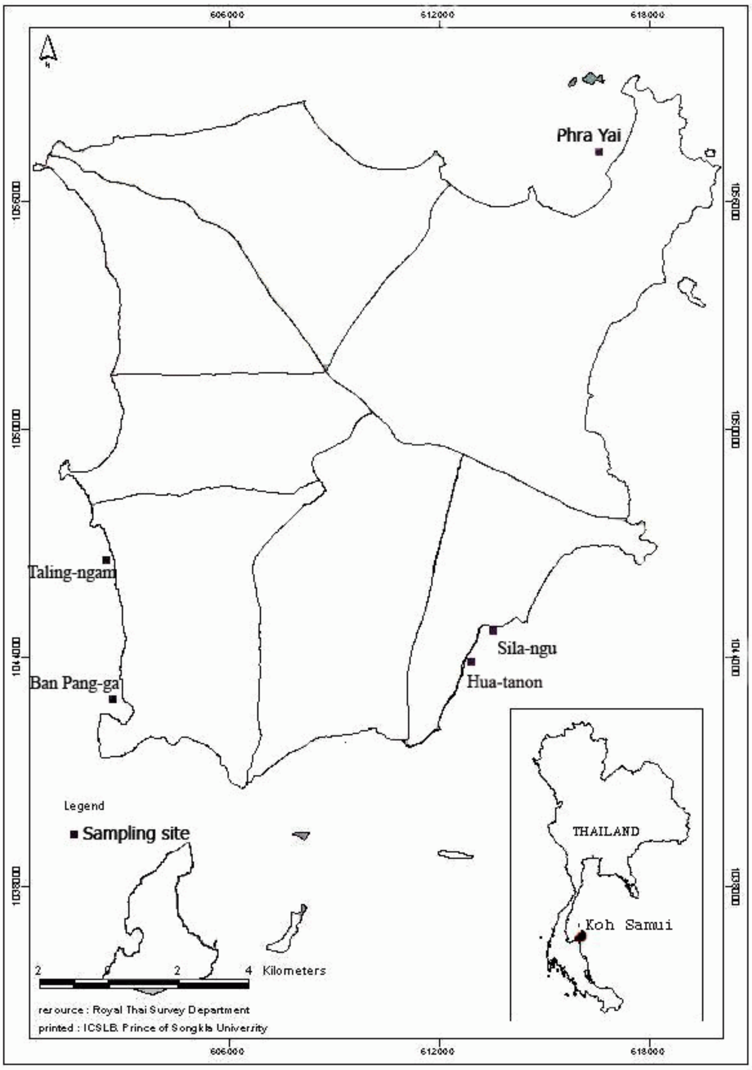

Figure 1. ......

1986; Mesang, 1987).

Lists of sampling stations:

The characteristics of study sites are described by the following

1) Sila-ngu, southeast Samui: shallow reefs and sandy beaches with big rocks and shallow coral reefs.

2) Hua-tanon, southeast Samui: sandy mudflats with coral rubble and rocks. This site is located near commercial harbors and tourist seaside resorts.

3) Ban Pang-ga, southwest Samui: sandy beaches, sand/mudflats.

4) Taling-ngam, southwest Samui: sandy beaches, sandflats.

5) Phra Yai is on a sheltered bay, northern of Samui Island: a sandy mudflat substrate.

Field sampling

Seaweeds were collected and observed at five sampling sites around Samui Island. These sites were chosen on the basis of their diversity of macroalgae and variety of substrate types. They were Phra Yai (47P 0616576, UTM 1058166), Sila-ngu (47P 0613544, UTM 1044467), Hua-tanon (47P 0612739, UTM 1043691), Ban Pang-ga (47P 0603500, UTM 1042606), and Taling-ngam (47P 0602745, UTM 1046506) (Figure 1).

Data were collected during the rainy season (October, 2002 during the south-west monsoon) and the dry season (April, 2003 during the north-east monsoon). Percentage cover of seaweeds was estimated using the "Visual Census Method" (adapted from English *et al*., 1994; Halford and Thompson, 1994). Macroalgae percentage cover can be estimated visually by giving the score 1-5 as follows:

Mean of the percentage cover:

Not found	= -
$\leq$ 3000 cm^2	= 1
3001-6000 cm^2	= 2
6001-9000 cm^2	= 3
9001-12000 cm^2	= 4
> 12000 cm^2	= 5

The study was carried out during low and high tides. Algae collection was conducted by snorkeling at a depth not exceeding 2 metres. The specimens were put in plastic bags and preserved using 4% formaldehyde in seawater. The specimens were taken to a laboratory and identified using various taxonomical identification guides, *e.g.* Common Seaweeds and Seagrasses of Thailand (Lewmanomont and Ogawa, 1995), Seaweeds of Queensland (Cribb,1996), Caribbean Reef Plants (Littler and Littler, 2000), Plant Resources of South-East Asia No 15(1) and Cryptogams: Alga (Prud'homme van Reine and Trono, 2001). All specimens were sorted out after sampling and hand sections were made to identify specimens and then pressed following standard herbarium procedures and deposited at the Prince of Songkla University Herbarium.

Results

Species composition

A total of 34 taxa were identified during this study, comprising 1 Cyanophyta, 9 Chlorophyta, 10 Phaeophyta and 14 Rhodophyta (Table 1). The genera *Caulerpa, Halimeda, Padina, Turbinaria, Gracilaria* and *Laurencia* had the highest number of taxa (three species each). *Sargassum polycystum* had the widest distribution, being able to colonize all sampling stations. In contrast, some species were found only at specific sites, for example, *Caulerpa racemosa, Padina gymnospora* and *P. japonica* occurred only at Ban Pang-ga, while *Ceramium* sp., *Laurencia intricata* and *Gracilaria* sp.1 occurred only at Sila-ngu, and *Jania* sp. was found only at Taling-ngam.

Seasonal variations

There were variations in diversity among sites and seasons (Figure 2). Sila-ngu and Hua-tanon sites had the most diversity of macroagale, 22 species and 20 species respectively during the dry season, while the least diversity was found at Phra Yai; only 1 species which was present during the rainy season. In addition, the richness of

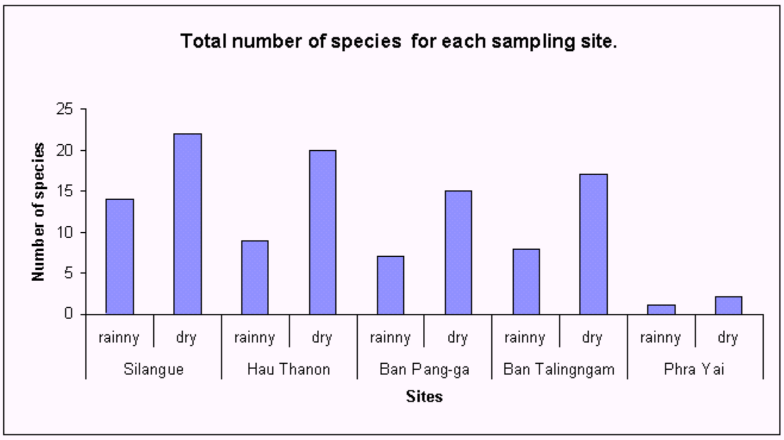

Figure 2. Total number of species for macroalgae cover on sampling sites.

macroaglae was two-three times lesser in the rainy season compared to the dry season (Table 1). There were 9 species that occurred only in the dry season, e.g. *Ceramium* sp., *Gracilaria* sp.1, *G. salicornia, Hypnea* sp., *Bryopsis pennata, Caulerpa racemosa, Halimeda macroloba, Lobophora variegata* and *Turbinaria decurrens*, while *Halimeda tuna, Padina gymnospora* and *P. japonica* occurred only in the rainy season.

Apart from having the widest distribution, *Sargassum polycystum*, also formed the abundant underwater forest at Phra Yai bay. The alga had an average length of 2.5-3.0 metres, and grew close together, with various epiphytes, amphipods, isopods and other small invertebrates associated with their fronds. It also provided substrates to other sessile marine organisms *e.g.* barnacles, and sponges. Another two common species at Samui Island were *Acanthophora spicifera* and *Padina* spp. *A. spicifera* dominated the algal community by occupying large patches and grew together with other algae at the sites, while *Padina* spp. formed their own dense patches.

Discussion

There were variations in diversity and abundance of marine macroalgae between sites and seasons with a total of 34 taxa of marine algae found. The species with the richest diversity found in this study was red algae, which are the majority of seaweeds worldwide. More than 4,000 species are described and are known to have greater diversity in the tropics than in the temperate regions (Lee, 1999). Thus, we are likely to find greater diversity of red algae at the study sites than other groups of algae. We found a 37% lesser diversity of macroalgae as compared to the study of Petta (1986) which was also conducted at Samui Island. There was one site which had been studied both by Petta in 1986 and in this study, there was 35% lesser macroalgae at Bann Phang-ga.

The highest numbers of algal taxa were found at the Sila-ngu and Hua-tanon sites. This might be a result of spatial heterogeneity or habitat complexity of the study sites. The spatial heterogeneity or habitat complexity is an environmental feature generally believed to affect species diversity directly (Dean and Connell, 1987). It is usually assumed that increased habitat complexity produces increased numbers of distinct niches and consequently, allow more species to coexist (e.g., Cody, 1981; Dean and Connell, 1987). Thus, the greatest diversity was found at the more ecologically complex sites at Sila-ngu and Hua-tanon. In contrast, the least diversity was found at Phra Yai, where there was a soft bottom substrate and high turbidity due to strong water circulation stirring up the bottom sediment. The high turbidity is known to cut down the light intensity decreasing

Table 1. Percentage cover of macroalgae during 8-12 October 2002 and 17-21 April 2003 at Samui Island, Surat Thani Province, Thailand.

Algae Taxa	Study site									
	Sila-ngu		Hua tanon		Ban Pangga		Taling Ngam		Phra Yai	
	Oct.	Apr.	Oct.	Apr.	Oct.	Apr.	Oct.	Apr.	Oct.	Apr.
Cyanophyta										
Lyngbya sp.	3	5	4	5	-	-	-	-	-	-
Chlorophyta										
Bryopsis pennata Lamouroux	-	2	-	1	-	-	-	-	-	
Caulerpa racemosa (Forssk.) J. Agardh	-	-	-	-	-	1	-	-	-	-
Caulerpa serrulata (Forssk.) J. Agardh	-	-	2	2	-	2	2	1	-	-
Caulerpa taxifolia (Vahl) C. Agardh	2	-	-	1	-	1	-	-	-	-
Halimeda macroloba Decaisne	-	-	-	3	-	-	-	2	-	-
Halimeda sp.	3	4	4	3	-	4	-	-	-	-
Halimeda tuna (J. Ells & Sol.) J. V. Lamour.	2	-	-	-	-	-	-	-	-	-
Udotea flabellum (J.Ells & Sol.)J.V.Lamour.	3	4	-	-	4	5	-	-	-	-
Rhipidosiphon javensis Montagne	4	4	-	2	-	-	-	1	-	-
Phaeophyta										
Dictyota sp.	-	-	-	2	-	2	-	1	-	-
Padina gymnospora (Kutz.) Sond.	-	-	-	-	5	-	-	-	-	-
Padina japonica Yamada	-	-	-	-	5	-	-	-	-	-
Padina sp.	5	5	4	3	5	4	4	-	-	-
Lobophora variegata (J. V. Lamour.) Womersley	-	1	-	1	-	-	-	-	-	-
Turbinaria decurrens Bory	-	2	-	2	-	1	-	-	-	2
Turbinaria ornata (Turner) J. Agardh	3	-	-	-	-	2	-	2	-	-
Turbinaria conoides (J. Agardh) Kützing	-	2	4	2	4	1	3	1	-	-
Sargassum oligocystum Montagne	-	2	-	-	3	-	4	-	-	-
Sargassum polycystum C. Agardh	5	2	4	1	4	3	-	3	5	4
Rhodophyta										
Actinotrichia sp.	2	2	-	-	-	-	-	1	-	-
Acanthophora spicifera (Vahl) Borgesen	-	5	5	4	-	5	4	5	-	-
Amphiroa fragilissima (Linnaeus)	3	3	-	2	-	-	-	3	-	-
Lamouroux										
Ceramium sp.	-	1	-	-	-	-	-	-	-	-
Gelidiella acerosa (Forssk.) Feldmann & Hamel	2	1	-	1	-	-	-	1	-	-
Gracilaria sp.1	-	1	-	-	-	-	-	-	-	-
Gracilaria sp.2	-	-	2	1	-	-	2	1	-	-
Gracilaria salicornia (C. Agardh) Dawson	-	1	-	1	-	1	-	2	-	-
Hypnea pannosa J. Agardh	-	-	-	-	-	-	3	2	-	-
Hypnea sp.	-	2	-	2	-	2	-	3	-	-
Jania sp.	-	-	-	-	-	-	-	2	-	-
Laurencia papillosa (C. Agardh) Grev.	3	2	-	-	-	3	-	-	-	-
Laurencia intricata Lamouroux	4	3	-	-	-	-	-	-	-	-
Laurencia sp.	-	1	4	3	-	-	5	4	-	-
Total	**14**	**22**	**9**	**20**	**7**	**15**	**8**	**17**	**1**	**2**

Number means the percentage cover

Not found	=	-
≤ 3000 cm^2	=	1
3001-6000 cm^2	=	2
6001-9000 cm^2	=	3
9001-12000 cm^2	=	4
> 12000 cm^2	=	5

photosynthetic ability for photosynthesis in both algae and seagrasses (Dennison, 1987; Larkum *et al*., 1989; McCook, 1999). It is also known to decrease the ability of spore settlements and growth of macroalgae (Neushul *et al*., 1976, Devenny and Volse, 1978).

Slightly increasing abundance of macroalgae during the dry season may be the result of greater light intensity, resulting in increased photosynthesis and growth of macroalgae (Lünning, 1990; Cheshire *et al*., 1996). In addition, nutrients run off during the rainy season might influence growth and abundance of the macroalgae during the early part of the dry season. (Petta, 1986). *Lynbya*, for example, is known to bloom during the dry season and occur in dense patches on the shore of tropical zones (Whitton and Potts, 2000; Thacker *et al*., 2001); and also in this study. However, the abundance of *Sargassum* and *Turbinaria* dropped 2-3 times during the dry season. This might be due to the annual change of *Sargassum*, which is known to snag and leave only the holdfast during the dry season (Prud'homme van Reine and Trono, 2001) Thus, the abundance of *Sargrassum* populations became less at all sites during dry season, while, *Turbinaria* blades fell off leaving only stems on the shores.

The most common algae in this study were *Acanthophora spicifera* and *Padina* spp. *A. spicifera* had greater abundance and occurred with other macroalgae and was widely distributed throughout the algal zone. The high occurrence of *A. spicifera* might be the result of vegetative propagation. Once the fragile *A. spicifera* is broken or snagged, it can attach to other organisms or substrates and forms a new *A. spicifera* plant (Kilar and McLachlan, 1986). Therefore, we found *A. spicifera* widely distributed in the algal zone, with some attached on the *Udotea flabellum* and seagrasses. *Padina* spp. however, formed many dense patches, occurred as *Padina* zone. The ability of spore dispersal of *Padina* might be limited only nearby to the parent cells due to the low water velocity around the study sites. Thus, *Padina* spp. recruited and grew mainly next to the parent's plants, formed *Padina* zonation, which is also known in other common brown algae such as *Sargassum* and *Turbinaria* (Stiger and Payri, 1999). The small range of dispersal in these brown algae could cause the dense recruitment of *Sargassum* spores, which later formed *Sargassum* forest observed at Phra Yai.

Samui Island has been significantly affected by tourism. It is the second most popular destination for foreign tourists due to its richness and diversity of tropical marine life. During the last ten years, the number of tourists traveling to Samui has reached 1.1 million people each year (Kruger, 1996). Such number of tourists could disturb coral reefs, seaweeds, seagrasses and other marine life due to water activities such as boating, scuba diving and waste dumping from hotels and restaurants, as well as the uncontrolled building of tourist facilities on this island. Some constructions at Hau-Tanon and Phra Yai obstructed water circulation at the bay, caused decreasing of macroalgae diversity around the sites (Personal Communication). In addition, the Island has been in acute shortage of freshwater during the dry season in these recent years. Therefore, conservation and management are urgently needed not only for the city expansion but also for the marine resources management.

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