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A stability assessment on seasonal variation of seaweed beds in the Trat peninsula of Thailand

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ABSTRACT Species diversity, biomass and distribution pattern of seaweed beds in the Trat peninsula, east coast of Thailand, were investigated in relation to environmental conditions from January to December 2011. The macroalgal samples and environmental factors were collected monthly; covering cool-dry (January-February, November-December), hot-dry (March-April) and rainy (May-October) seasons at four sampling stations; Ao Cho, Ao Lane, Laem Tien and Laem Sok. A total of 26 taxa of marine benthic algae were recorded, of which 16 species of red marine algae were the most diverse group. It was found that *Catenella nipae*, *Gracilaria salicornia*, *Gelidium pusillum*, *Hydropuntia changii*, *Hypnea hamulosa*, *Kyrtutrix maculans*, *Laurencia decumbents*, *Lyngbya majuscula*, *Peyssonnelia rubra* and *Ulva clathrata* were the most abundant throughout the sampling period. The highest number of marine flora species was obtained in March (25 species), whereas the lowest in June (12 species). Algal biomass had a maximum value in April (59.50 g/m^2 dry weight) and minimum value in July (20.14 g/m^2 dry weight).

KEY WORDS Seasonal variation; benthic algae; seaweed beds; Conservation; Trat peninsula.

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INTRODUCTION

The seaweed or marine macrophytic algae, which are a large and diverse group of eukaryotic photosynthetic organisms occurring in marine environment, are one of the major marine fishery resources in Thailand (Edwards et al., 1982). Seaweed beds are a common habitat in coastal inshore communities consisting of large benthic vegetation and distributed widely along coastline of Thailand (Lewmanomont, 1998; Prathep, 2005).

They are highly valuable ecologically and economically and perform a variety of functions within marine coastal ecosystems (Lobban & Harrison, 1994; Stachowicz et al., 2008). Most seaweed beds are served as a vitally important food sources for fish and aquatic invertebrates and provide breeding area for several species of marine animals (Zhang et al., 2008). Additionally, seaweeds are used around the world as food and fertilizers and for the extraction of valuable commercial products (Sambamurty, 2006, Graham et al., 2009).

Trat is one of the provinces located in the east of Thailand, and encloses the upper Gulf of Thailand adjacent to the border between Thailand and Cambodia. Along the coastline of Trat peninsula, there are many different types of coastal ecosystems including estuaries, mangrove areas, sandy shores and mudflats. In addition to coastal environment, there is a considerable amount of nutrient supply variation in the response of wave exposure gradient.

Because of the properties of coastal area features and environmental diversity, Trat peninsula has remarkably diverse marine fishery resource, especially macroalgal flora; wild populations of macroalgae are widely distributed in the intertidal and subtidal zones of Trat peninsula (Pirompug, 1976) and used as human food and for agar extraction (Edwards & Tam, 1984; Chirapart et al., 1992).

Currently, the abundance and diversity of Thai seaweed has been vulnerable to decline because of over-harvesting of natural populations and the ecological deterioration of several inshore and estuary ecosystems (Lewmanomont, 1998).

In Trat costal areas and adjacent waters, the rapid extension and development of fisheries activities by local fishermen and conversion of mangrove areas into shrimp farms and urban areas threaten aquatic organisms (Menasveta, 1997) and this situation has a potentially negative impact on the coastal ecosystem (Doydee, 2005). Accordingly, the change in ecosystem and environmental conditions, mangrove deterioration and costal land-use activities would result in a decrease of macroalgal biodiversity and biomass in Trat peninsula.

The need to promote a scenario of seaweed resource management is therefore important for sustainable conservation and restoration of coastal ecosystem. However, information and knowledge regarding to macroalgal assemblages and their ecology is very limited in this coastal region. In order to provide useful data for a possible preliminary management strategy for conservation of seaweed resources in Trat peninsula we determined seasonal variation in the species diversity, biomass and distribution pattern of macroalgae with reference to some environmental variables for better understanding of the recent situation in algal communities.

MATERIALS AND METHODS

Study area

The study site is located at the coastal area of Trat province, east of Thailand. Four coastal areas of intertidal habitat, which are different in shape and environmental condition, were chosen as research station: Ao Cho (site 1), Ao Lane (site 2) Laem Tien (site 3) and Laem Sok (site 4).

Among the stations, Ao Cho and Ao Lane are semi-exposed areas. Ao Cho is characterized by the formation of sandy beaches alternated with rocky shores and partly surrounded by mangroves, while natural habitat of Ao Lane is composed mainly by mudflat and this area is moderately occupied by indigenous fisheries community.

Laem Tien is a non-exposed area with muddy sand bottom fringed by mangroves, and some parts of this area are heavily exploited for aquaculture and shrimp farms. Additionally, Laem Sok, a fully exposed area with rocky shore habitat, is partially converted for commercial and industrial activities.

Sample collection and laboratory analysis

Species diversity, biomass and distribution

Field sampling was carried out once a month at four stations for a year (from January to December 2011). Benthic marine macroalgae were sampled thoroughly by wading or snorkeling. Complete thalli of live specimens were uprooted by hand or with paint-scraper, placed in plastic bags, labeled by location and date of collection, and transported to laboratory.

Algal samples were rinsed to remove sediment and debris, photographed, preserved as herbarium vouchers, or, on some occasions, preserved in 4% formalin-seawater solution, and deposited at the Algal Bioresources Research Center, Faculty of Fisheries, Kasetsart University. The species identification was based on gross morphology and internal features following Lewmanomont & Ogawa (1995); Huisman (2000) and Litter & Litter (2000; 2003). In order to determine algal biomass and distribution pattern, a quadrat method along a vertical transect line set across the intertidal zone perpendicularly to the coastal line was performed monthly throughout the study period.

Once a month 25 replicates of sampling quadrat (50×50 cm) from research stations were collected for determination of algal biomass. Algal samples from each quadrat were carefully cleaned with freshwater to remove sand, silt, epiphytes and other debris before weighting. Dry weight of algal biomass was obtained by drying the samples in the oven at 105^{o}C for 48 hours (Wong & Phang, 2004).

Environmental parameters

Environmental parameters, including physical and chemical factors, were recorded seasonally at the moment of each sampling. For physical variables, seawater temperature, salinity, pH, turbidity and dissolved oxygen (DO) were measured in the field. Seawater temperature and DO were determined using a salinity compensated dissolved oxygen meter (YSI Model 57).

Salinity was determined by hand refractometer; pH was measured using a pH meter (YSI Model 60) and water transparency was estimated by a turbidimeter (LaMotte Model 2020).Total rainfall of Trat peninsula was obtained from the Meteorological Department of Thailand. For chemical variables, nutrient concentration in the seawater was evaluated.

Water quality was sampled from each study site and fixed in ice chests to examine alkalinity, hardness, ammonia, nitrate, nitrite and phosphate, using the methods of Sasaki & Sawada (1980) and Strickland & Parsons (1972).

Statistical analysis

Data for statistical analysis were tested initially for normality and homogeneity (Zar, 1984). Oneway analysis of variance (ANOVA) was employed to search for any significant difference among month, site and biomass data of each species.

Statistical significance was set at $p<0.05$ and the stability of the estimate reflected by 95% confident intervals. All tests and analyses were performed with SPSS version 12.0 (SPSS, Inc., Chicago, IL).

RESULTS

Species diversity

A total of 26 taxa were identified including 3 species of Cyanobacteria, 3 species of Chlorophyta, 4 species of Phaeophyta and 16 species of Rhodophyta (Tables 1, 2).

The number of species varied during the study period and ranged from 25 (March 2011) to 12 (June 2011). *Catenella nipae*, *Gracilaria salicornia*, *Gelidium pusillum*, *Hydropuntia changii*, *Hypnea hamulosa*, *Kyrtutrix maculans*, *Laurencia decumbents*, *Lyngbya majuscula*, *Peyssonnelia rubra* and *Ulva clathrata* were found throughout the sampling period.

On the other hand, *Brachytrichia quoyi*, *Chaetomorpha crassa*, *Cladophora sp*., *Dictyota dichotoma*, *Hydroclathrus clathratus*, *Padina australis*, *P. sanctae-crucis*, *Acanthophora spicifera*, *Bostrycia tenella*, *Centroceras clavulatum*, *Ceramium flaccidum*, *Erythrotrichia sp*., *Gelidiopsis intricatum*, *Gracilariopsis irregularis*, *Neosiphonia savatieri* and *Palisada papillosa* had only single occurrences in time.

Biomass and distribution pattern of marine benthic algae in each season and site

Total marine macroalgal biomass gradually increased from January to March, reached to the peak in April (hot-dry season) with 59.50 g/m^2 dry weight and dramatically decreased in July (rainy season) with 20.14 g/m^2 dry weight, and then steadily increased from August to December, reaching to the peak again in November (cool-dry season) with 55.46 g/m^2 dry weight. The seasonality of macroalgae biomass at the site was less uniform. During both dry and wet seasons, *Gracilaria salicornia* and *Hydropuntia changii* attained the maximum biomass mean value at 29.51 g/m^2 dry weight and 14.82 g/m^2 dry weight, respectively.

Acanthophora spicifera, *Hydroclathrus clathratus* and *Padina sanctae-crucis* had greatest biomass during the cool-dry season, and less biomass during the wet season. In contrast, *Gracilariopsis irregularis*, *Hypnea hamulosa*, and *Padina australis* exhibited higher biomass during the hot-dry season than in the wet season.

Most seaweed biomass exhibited greatest abundance in Ao Cho e.g. *Gracilaria salicornia*, *Gracilariopsis irreguralis*, *Hypnea hamulosa*, *Hydropuntia changii*, *Palisada papillosa* and *Padina sanctae-crucis*. Some species, e.g. *Acanthophora spicifera*, *Hydroclathrus clathratus*, *Hypnea hamulosa*, *Hydropuntia changii*, *Palisada papillosa* and *Padina australis*, were common in Ao Lane.

The brown algae, *Padina australis* and *P. sanctae-crucis*, however, were common in Laem Tien. Some species, e.g., *Gracilaria salicornia*, *Hypnea hamulosa*, and *Palisada papillosa* were common in Laem Sok. In general, there were no patterns found in biomass of algae among different sites.

Ten species were found throughout the entire study period. These included two species of cyanobacteria, *Kyrtutrix maculans*, *Lyngbya majuscula*, one species of green algae, *Ulva clathrata*, seven species of red algae, *Catenella nipae*, *Gracilaria salicornia*, *Gelidium pusillum*, *Hydropuntia changii*, *Hypnea hamulosa*, *Laurencia decumbents* and *Peyssonnelia rubra*.

	Ao Cho												Ao Lane											
TAXA	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
CYANOBACTERIA																								
Brachytrichia quoyi (Agardh) Bornet et Flahault	+	+	+																					
Kyrtutrix maculans (Gomont) Ume zaki	+	+	+					+	+	+	+	+	+	+	+									+
Lyngbya majuscula (Dillwyn) Harvey	+	+	+	+	+	+	+	+	+			+	+	+	+	+	+	+	+	+	+			+
CHLOROPHYTA																								
Chaetomorpha crassa (C.Agardh) Kützing	+	+	+	+	+						+	+	+	+	+									
Cladophora sp. Kützing	+	+	+	+	+	+				+	+	+	+	+	+									
Ulva clathrata (Roth) C.Agardh	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PHAEOPHYTA																								
Dictyota dichotoma (Hudson) Lamouroux		+	+										+	+	+									
Hydroclathrus clathratus (C.Agardh) M.A.Howe	+	+	+									+				+	+							
Padina australis Hauck													+	+										
Padina sanctae-crucis Børgesen	+	+	+					+	+	+	+	+												
RHODOPHYTA																								
Acanthophora spicifera (M. Vahl) Børgesen													+	+	+	+							+	+
Bostrycia tenella (J.V. Lamouroux) C.Agardh																								
Catenella nipae Zanardini	+	+	+	+	+	+	+	+	+	+	+	+												
Centroceras clavulatum (C.Agardh) Montagne		+	+																					
Ceramium flaccidum (Harvey ex Kützing) Ardissone	+	+									+	+												
Erythrotrichia sp. Areschoug	+	+	+	+	+						+	+	+	+	+	+								
Gelidiopsis intricatum (C.Agardh) Vickers	+	+	+	+	+	+	+	+	+	+														
Gelidium pusillum (Stackhouse) Le Jolis	+	+	+	+	+	+	+	+	+	+	+	+												
Gracilaria salicornia (C.Agardh) E.Y.Dawson	+	+	+	+	+	+	+	+	+	+	+	+												
Gracilariopsis irregularis Abbott													+	+	+	+	+							
Hydropuntia changii (Xia et Abbott)Wynne	+	+	+	+	+	+	+	+					+	+	+	+	+	+	+	+	+	+	+	+
Hypnea hamulosa (Esper) J.V. Lamouroux	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+						+	+
Laurencia decumbents Kützing	+	+	+	+	+	+	+	+	+	+	+	+												+
Neosiphonia savatieri (Hariot) M.S.Kim	+	+	+	+	+						+	+	+	+	+	+	+	+					+	+
Palisada papillosa (C.Agardh) K.W.Nam	+	+	+	+	+	+	+	+	+				+	+	+	+	+	+						
Peyssonnelia rubra (Greville) J.Agardh	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+				+

Table 1. Seasonality of macroalgae at Trat Peninsula January (=1)/December (=12) 2011: Ao Cho and Ao Lane.

	Laem Tien												Laem Sok											
TAXA	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
CYANOBACTERIA																								
Brachytrichia quoyi (Agardh) Bornet et Flahault																								
Kyrtutrix maculans (Gomont) Ume zaki	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Lyngbya majuscula (Dillwyn) Harvey	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+
CHLOROPHYTA																								
Chaetomorpha crassa (C.Agardh) Kützing	+	+	+						+			+		+										+
Cladophora sp. Kützing	+	+	+	+	+	+	+					+						+	+					
Ulva clathrata (Roth) C.Agardh	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PHAEOPHYTA																								
Dictyota dichotoma (Hudson) Lamouroux																								
Hydroclathrus clathratus (C.Agardh) M.A.Howe																								
Padina australis Hauck	+	+	+	+																				
Padina sanctae-crucis Børgesen	+	+	+	+																				
RHODOPHYTA																								
Acanthophora spicifera (M. Vahl) Børgesen																								
Bostrycia tenella (J.V. Lamouroux) C.Agardh																				+	+	+	+	+
Catenella nipae Zanardini																								
Centroceras clavulatum (C.Agardh) Montagne																								
Ceramium flaccidum (Harvey ex Kützing) Ardissone																								
Erythrotrichia sp. Areschoug	+	+	+	+									+	+	+	+							+	+
Gelidiopsis intricatum (C.Agardh) Vickers	+	+	+	+	+	+							+	+	+	+	+							
Gelidium pusillum (Stackhouse) Le Jolis	+	+	+	+	+	+	+						+	+	+	+	+	+	+	+	+	+	+	+
Gracilaria salicornia (C.Agardh) E.Y.Dawson													+	+	+	+	+	+	+	+	+	+	+	+
Gracilariopsis irregularis Abbott																								
Hydropuntia changii (Xia et Abbott)Wynne																								
Hypnea hamulosa (Esper) J.V. Lamouroux	+	+	+	+									+	+	+	+	+	+	+				+	+
Laurencia decumbents Kützing																								
Neosiphonia savatieri (Hariot) M.S.Kim	+	+	+											+	+									
Palisada papillosa (C.Agardh) K.W.Nam													+	+	+	+	+	+						
Peyssonnelia rubra (Greville) J.Agardh	+	+	+	+	+	+	+						+	+	+	+	+	+	+	+	+	+	+	+

Table 2. Seasonality of macroalgae at Trat Peninsula January (=1)/December (=12) 2011: Laem Tien and Laem Sok.

Physical and chemical factors study

There were insignificant variations in water temperature ($p>0.05$) among sites but significant variations in water temperature ($p<0.05$) among months. The water temperature was 27.5-33.5^{o}C during the dry season and 25.5-31.5^{o}C during the rainy season. The range was rather wide and was likely to influence the species diversity, biomass and distribution pattern of seaweed beds. In addition, there were insignificant differences in salinity ($p>0.05$) among sites but significant differences in salinity ($p<0.05$) among months. The salinity during the dry season was 32-37 ‰ and 15-27 ‰ during the rainy season.

Such a rather wide range was likely to influence the marine macroalgae. There were insignificant differences in turbidity ($p>0.05$) among sites but significant variations in turbidity ($p<0.05$) among months. The turbidity was 4.70-346.67 NTU during the dry season and 10.33-983.33 NTU during the rainy season. These differences could influence the species diversity, biomass and distribution pattern of marine algae

ANOVA revealed that there were insignificant variations in PO_4^{3-} ($p>0.05$) and TIN (total inorganic nitrogen: $NH_4^+ + NO_3^- + NO_2^-$) ($p>0.05$) among sites but significant variations in PO_4^{3-} ($p<0.05$) and TIN ($p<0.05$) among months. The phosphate during the dry season was 0.0004-0.0391 mg/l and 0.0030-0.0670 mg/l during the rainy season. And the TIN was 0.0134-0.2642 mg/l during the dry season and 0.0343-0.2800 mg/l during the rainy season. These ranges were rather wide, and were likely to influence the marine macroalgae.

DISCUSSION

Species diversity study

A total of 25 genera and 26 species of marine benthic algae were recorded, of which 16 species of red marine algae (a characteristically abundant and diverse group in the tropics) were the most assorted. Red algae occupy a wide range of irradiance environments, including high-latitude and high-intertidal habitats subjected to long periods of full sunlight (Graham et al., 2009).

Twenty-four percent higher species richness of marine algae was found at our study site compared to the study of Laehyeb (2011), in which only 21 species were reported throughout Trat peninsula; only three field collections were made in that previous study as compared to the four field collections in this study. Thus, the number of visits for field collection as well as the collection efforts could be important for appraising species diversity more accurately. In addition, the differences we observed suggested that there was temporal variation in species diversity of marine algae.

Many marine macroalgae have posed ecological problems in some marine ecosystems, which is probably due to environmental changes linked to decreasing of mangrove forest, sewage discharges, shrimp culture, tourism and factories activities (Doydee, 2005; Thongroy et al., 2007; Laehyeb, 2011). These activities have had serious impact on coastal environments.

Biomass and distribution pattern study

Among all four study areas of Trat peninsula, marine macroalgal biomass and diversity were the highest at Ao Cho during the dry season. This area is semi-exposed, sandy bottom with rocks and partly surrounded by mangroves. This same phenomenon was observed in macroalgae at Sirinart Marine National Park by Prathep (2005) in Thailand. Water motion is one of the most important variables influencing marine macroalgae, because it regulates turbidity, light penetration and nutrient availability (Nishihara & Terada, 2010; Kang et al., 2011).

At Ao Cho, marine macroalgae were exposed to intermediate levels of water motion, which allows the exchange of gases and uptake of nutrients (Lobban & Harrison, 1994; Kang et al., 2011). Ao Lane is a semi-exposed area as same as Ao Cho but is characterized by large mudflats and harbours a lot of fishery communities. This place is very sensitive to environmental changes due to human activity stressing the natural environment, such as sewage discharges of fishery communities, which can cause the decrease of the species diversity and of seaweed abundance. Laem Tien is a wave-sheltered area covered by mangroves with a large muddy sand bottom. Some parts of this place are used for aquaculture.

This site showed the lowest biomass and species diversity. Taking into account that the area is rather sheltered from wave action, marine macroalgae may be exposed to some physiological stress due to limited circulation of nutrients and gas exchange (Prathep & Tantiprapas, 2006; Thongroy et al., 2007).

In addition, this site is subjected to environmental changes because of water pollution from the shrimp farms. Laem Sok is a wave-exposed area with a large rocky shore habitat and many restaurants nearby the harbor. This place shows a high level of water motion, which is likely to affect species diversity and abundance of macroalgae (Prathep, 2005; Kang et al., 2011). In addition, in this area mangrove forests decreased in the last few years (Doydee, 2005; Laehyeb, 2011).

Generally speaking, mangroves are really important since these plants indirectly participate to habitat complexity and diversity of fauna and flora, particularly marine macroalgae (Ashton et al., 2003; Ellison, 2008, Doydee & Buot, 2011).

In fact by trapping nutrients and sediments from river runoffs from the uplands and transporting them to coastal waters (Anongponyoskun & Doydee, 2006; Ellison, 2008; Doydee, 2009) they contribute to improve shoreline stability and water quality. Therefore, the decrease of mangrove forests is certainly another reason affecting negative changes in species diversity and abundance of seaweed.

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