QUANTITATIVE ESTIMATION OF THE DISTRIBUTION AND BIOMASS OF SEAGRASSES AT HAAD CHAO MAI NATIONAL PARK, TRANG PROVINCE, THAILAND

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ABSTRACT

A seagrass bed at Haad Chao Mai National Park, Trang Province, is one of the largest seagrass beds with the highest species diversity in Thailand. To elucidate distribution and abundance of seagrasses over the entire bed, we carried out a large-scale quantitative census at subtidal and intertidal bottoms covering ca. 18 km^2 area. On December 1999, a total of 69 stations were set at subtidal and lower intertidal area, and 183 stations along 10 transect lines at upper intertidal area. At each station, coverage of each seagrass species was recorded and aboveground biomass was estimated by the rapid visual technique developed by Mellers (1991). A total of 8 species (*Enhalus acoroides, Halophila ovalis, Thalassia hemprichii, Cymodocea rotundata, C. serrulata, Halodule uninervis, H. pinifolia* and *Syringodium isoetifolium*) were recorded by the census. At subtidal and lower intertidal areas, biomass was highest at shallow stations (<2 m) along the coastlines, while seagrass was rarely observed at the deeper stations and at some shallow stations on sand dunes developed at a river mouth. *E. acoroides* was the most abundant species, followed by *H. ovalis* and *T. hemprichii*. Six seagrass species were found at the upper intertidal area. *H. ovalis* and *T. hemprichii* were dominant, and they formed monospecific patches at sand dunes and tide pools, respectively. Average aboveground biomass was 1.5 times higher at the intertidal area (15.37 gDW m^{-2}) than the subtidal (10.64 gDW m^{-2}). Therefore, the contribution of intertidal seagrass meadow to total standing stock of the study site (23%) was higher than expected from the proportion of area it occupied (17 %). Distribution, species composition and biomass of the seagrass bed are affected by at least 2 factors; water depth (possibly related to light availability) and physical disturbance such as sand movement.

INTRODUCTION

Seagrasses in SE Asia are characterized by their wide occurrence in coastal areas (Fortes, 1995), mixed vegetation with high species diversity (Fortes, 1988a-b; Phillips & Meñez, 1988; Tomasko et al., 1993) and high productivity (Vermaat et al., 1995; Agawin et al., 1996). They provide habitats and food for a variety of associated animals including large herbivores such as dugong and sea turtles. Intensive studies have been carried out to examine factors affecting seagrass community structures and dynamics in some areas such as the Philippines (Vermaat et al., 1995; Duarte et al., 1997; Terrados et al., 1998) and Indonesia (Nienhuis et al., 1989; Erftemeijer & Herman, 1994). However, quantitative information on seagrass biomass and productivity is still unavailable in most of the SE Asian coastal waters.

During the last decade, species composition and distribution of seagrasses have been studied and described along Thailand coasts (Chansang & Poovachiranon, 1994; Poovachiranon & Chansang, 1994; Lewmanomont et al., 1996). At Haad Chao Mai National Park, Trang Province in the Andaman Sea, extensive seagrass meadows develop both intertidal and subtidal soft bottoms where species diversity of seagrasses is highest among major seagrass beds in Thailand (9 species; Lewmanomont et al., 1996; Lewmanomont & Supanwanid, 2000). This area is also known as an important feeding ground for dugongs that are considered to be declining drastically in recent years (Adulyanukosol et al., 1997). The distribution of seagrasses was previously reported non-quantitatively for some parts of the intertidal flats (Meesawat et al., 1999; Purintavaragul et al., 1999), but not for the entire seagrass bed including subtidal bottoms.

To provide a first step for understanding community structure, dynamics and productivity of the seagrass bed of Haad Chao Mai National Park, we carried out a large-scale quantitative census of seagrass distribution and abundance covering an entire part of the seagrass bed (ca 18 km^2). In the present paper, we report spatial variation in species composition and biomass of seagrasses within the study area, mainly focusing on the differences between intertidal and subtidal areas, and discuss possible factors affecting the observed variation in seagrass community structure and abundance.

MATERIALS AND METHODS

Study site

Haad Chao Mai National Park locates southwestern coast of Thailand, facing the Andaman Sea (Fig. 1). Two major seagrass beds develop within the park: (1) at the mouth of Trang River and around Ko Talibong, and (2) at the narrow strait between Ko Muk and the mainland (Laem Yong Lam and Khao Bae Na). In the present study, we carried out quantitative census covering whole area of the seagrass bed between Ko Muk and the mainland (Fig. 2). The tidal range in the area varied between 0.7 m (neap tide) and 2.8 m (spring tide). At spring ebb, two intertidal flats extend westward about 700-1200 m from the shoreline of Laem Yong Lam and Khao Bae Na, whereas intertidal area on the side of Ko Muk is smaller (<400 m). The maximum depth at the subtidal bottom is 4.3 m at LLW (the lowest low water) (Fig. 2). Environmental conditions of the area, e.g., water temperature, salinity, nutrient concentrations of waters and sediments were monitored concurrently with this study and reported elsewhere (Umezawa et al. 1999).

Quantitative census of seagrass distribution and biomass

We determined stations for quantitative census of the seagrass bed by two different methods, depending on how to access each point (either by boat or on foot). The census on subtidal area and the lower part of intertidal areas (referred to as "grid survey", which covered areas deeper than -1 m at LLW) was carried out on December 14-15, 1998. Prior to the census, we set a grid of 500 x 500 m square unit covering the whole area between Ko Muk and the mainland (ca. 12.75 km^2; Fig. 2). A total of 69 stations were then determined at intersections of each grid. We visited each position by a boat with an aid of GPS.

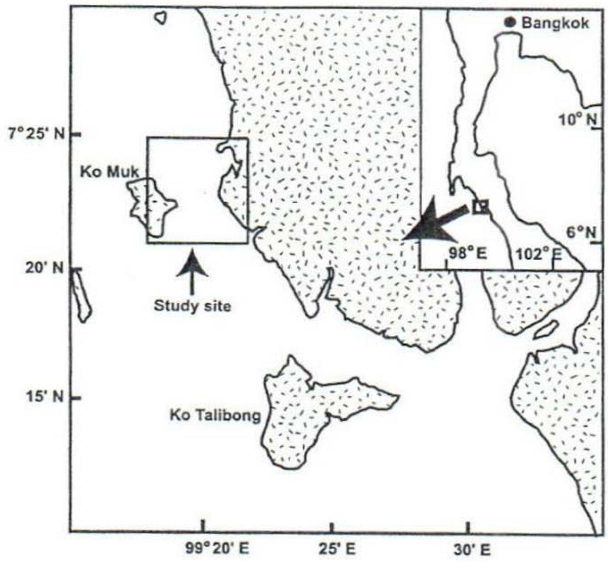

Fig. 1. Location of the study site at Haad Chao Mai National Park, in Trang Province, Thailand.

The survey on upper part of intertidal areas (referred to as "line survey", covering areas shallower than -1 m deep at LLW) was conducted during December 3-18, 1998. A total of 10 transect lines were established at the two intertidal flat on the mainland side; 8 at Laem Yong Lam, and 2 at Khao Bae Na (Fig. 2). Each line was set perpendicular to the shoreline and separated by 200 m from adjacent lines. Within each line, census points were determined from the uppermost coastline to the lowest end (ca. -1 m at LLW) at intervals of 20 m. Each line contained 9 to 37 stations, which were visited by observers on foot during exposed period at low tide.

Three 0.5 x 0.5 m quadrates were haphazardly located (except for Lines D, F and G where 2 quadrats were placed) at each station. Species composition of seagrasses, percentage coverage of each species, and ranked estimates of aboveground biomass were recorded for each quadrat by one of 6 observers. Biomass estimates were made according to the rapid visual technique by Mellors (1991). Seagrass biomass within each quadrat was ranked between 0 and 5 at the intervals of 0.1. Later, 10 quadrats of the equal size were placed so as to cover the full range of biomass observed during the survey, and ranked by each of 6 observers. Aboveground part of seagrasses in each quadrat was then harvested, dried at 60°C to a constant weight, and measured on an electrical balance to the nearest 0.01g. Rank estimates for aboveground biomass were calibrated by calculating a regression equation between actual aboveground biomass of seagrass and ranks for each observer. The data were fitted by an allometric equation ($Y = aX^b$ where Y is aboveground biomass, X is rank, a and b are regression coefficients) instead of a linear equation ($Y = aX + b$) because the former gave better fits (R^2 = 0.66-0.95) than the latter (R^2 = 0.34-0.71) for data of each observer.

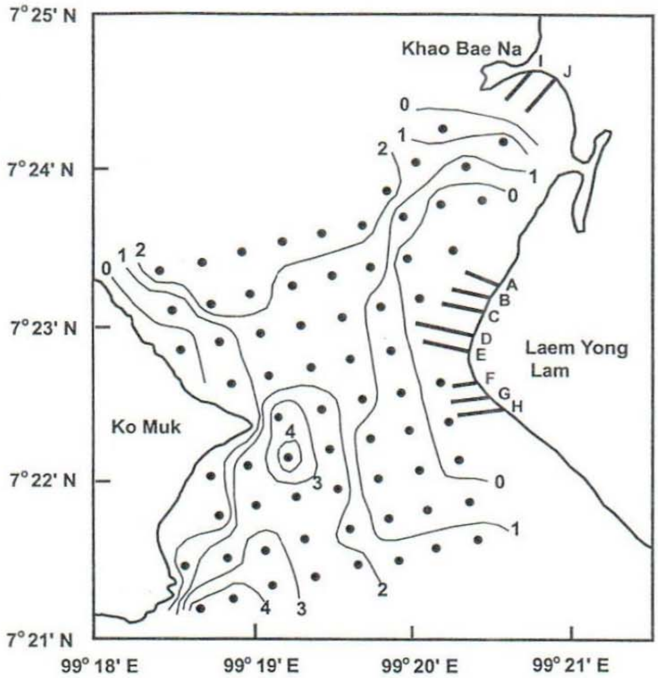

Fig. 2. A map showing census stations of the grid survey conducted at subtidal and lower intertidal areas (solid circles) and the transect lines of the line survey conducted at upper intertidal areas (Lines A-J). Contour lines indicate the depth (in meter) at lowest low water.

Data analyses

Data on biomass estimates and percentage coverage of each seagrass species per quadrat were averaged for each station. The stations were classified into 3 habitats according to the depth: (1) subtidal (deeper than 0 m at LLW); (2) lower intertidal (between -1 and 0 m at LLW); and (3) upper intertidal (shallower than -1 m at LLW). Among 69 stations of the grid survey, 60 points belonged to the subtidal and remaining 9 to the lower intertidal, whereas all the stations in the line survey were upper intertidal. To estimates total biomass over the entire study area, we assumed that vegetation at any point of the area is represented by that at its nearest station; i.e., each station in the grid survey represents vegetation at 500 x 500 m square, and that in the line survey at 20 m (vertical to shoreline) x 200 m (horizontal to shoreline) area. The estimates of total aboveground biomass and average aboveground biomass per square meter were calculated and compared within/among habitats.

RESULTS

Species composition and biomass of seagrasses

Subtidal and lower intertidal area

A total of 7 seagrass species (*Enhalus acoroides, Halophila ovalis, Thalassia hemprichii, Cymodocea rotundata, C. serrulata, Halodule uninervis* and *Syringodium isoetifolium*) were found by the grid survey conducted at subtidal and lower intertidal parts of the seagrass bed. Aboveground biomass of seagrasses estimated by the rapid visual technique varied greatly (between 0 and 61.8 gDW m^{-2}) among stations (Fig. 3a). Stations with high seagrass biomass located at shallow depth along the coastlines of Ko Muk and Laem Yong Lam. On the other hand, no seagrasses were observed at stations established at south-central part, northwestern part, and northeastern parts of the survey area (Fig. 3). The stations in the former 2 parts were generally deeper than 2 m (at LLW), and those in the latter located on a shallow sand dune formed at a river mouth between Khao Bae Na and Laem Yong Lam.

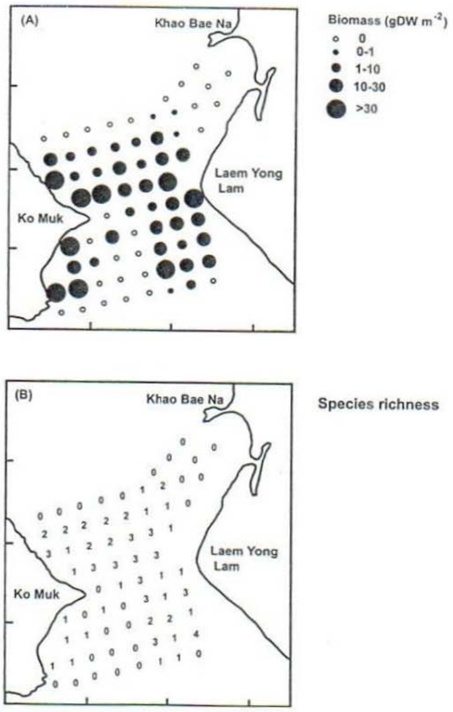

Fig. 3. Aboveground biomass (A) and species richness (B) of seagrasses at subtidal and lower intertidal areas monitored by the grid survey.

Species richness (measured by the number of seagrass species present per 0.5 m^2 area) ranged between 1 and 4 at stations with seagrasses. Mixed stands (where more than 2 species coexist) were generally found at north of the narrowest part of the strait, and at southwestern part of the study area (Fig. 3b).

Among 7 seagrass species, *Enhalus acoroides* was most abundant and found in 29 out of 69 stations with the depth range of –0.6 to 4.2 m. It mostly occurred at shallow bottom (between -0.5 and 2 m deep) along northern and southern coasts of Ko Muk, and southern coast of Laem Yong Lam (Fig. 4a). Especially, this species forms a monospecific stand along the southern coast of Ko Muk (Fig. 3b and Fig. 4a). *Halophila ovalis* was the second dominant species, occurring at 24 stations (depth range of –0.8 to 2.5 m). Main distribution area of this species was central to northern parts of the strait (Fig. 4b). The distribution of the third dominant species, *Thalassia hemprichii* (occurring 18 stations; depth range of –1.0 to 2.3 m) mostly overlapped with *H. ovalis*, although its relative abundance tended to be higher at the lower intertidal area of Laem Yong Lam (Fig. 4c).

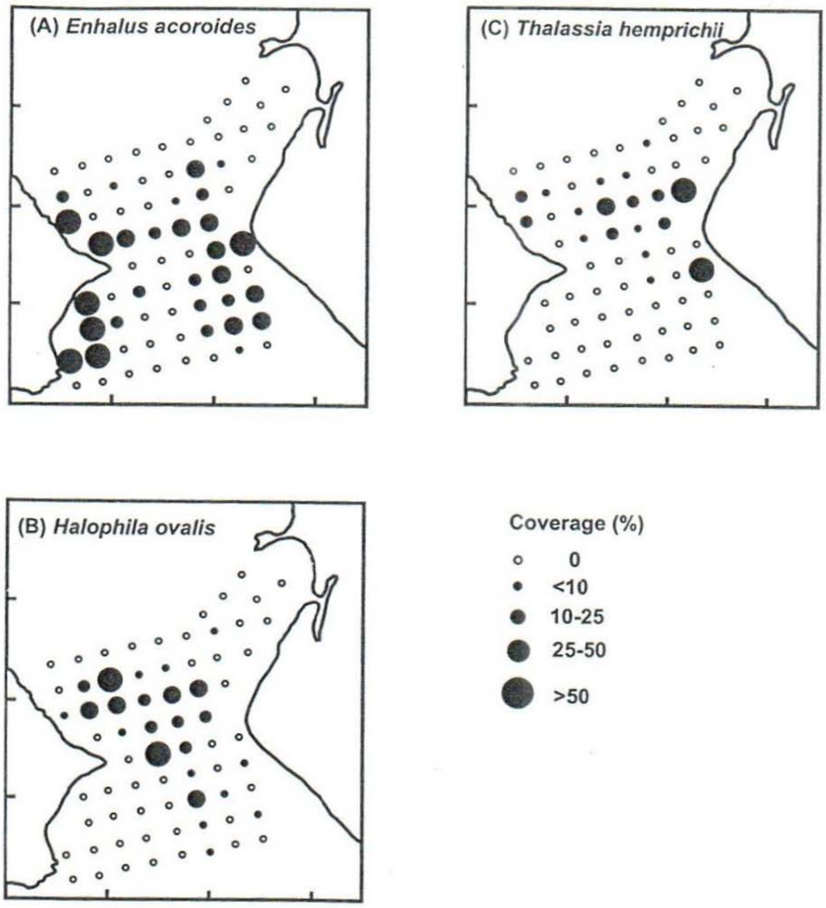

Fig. 4. Percent coverage of 3 dominant seagrass species at subtidal and lower intertidal areas: *Enhalus acoroides* (A), *Halophila ovalis* (B) and *Thalassia hemprichii* (C).

Other 4 species had very limited distribution. *Cymodocea serrulata* was found at 3 stations of subtidal area, *C. rotundata* at 1 station of the intertidal, *Halodule uninervis* at 2 stations of the subtidal, and *Syringodium isoetifolium* at 1 station of the intertidal.

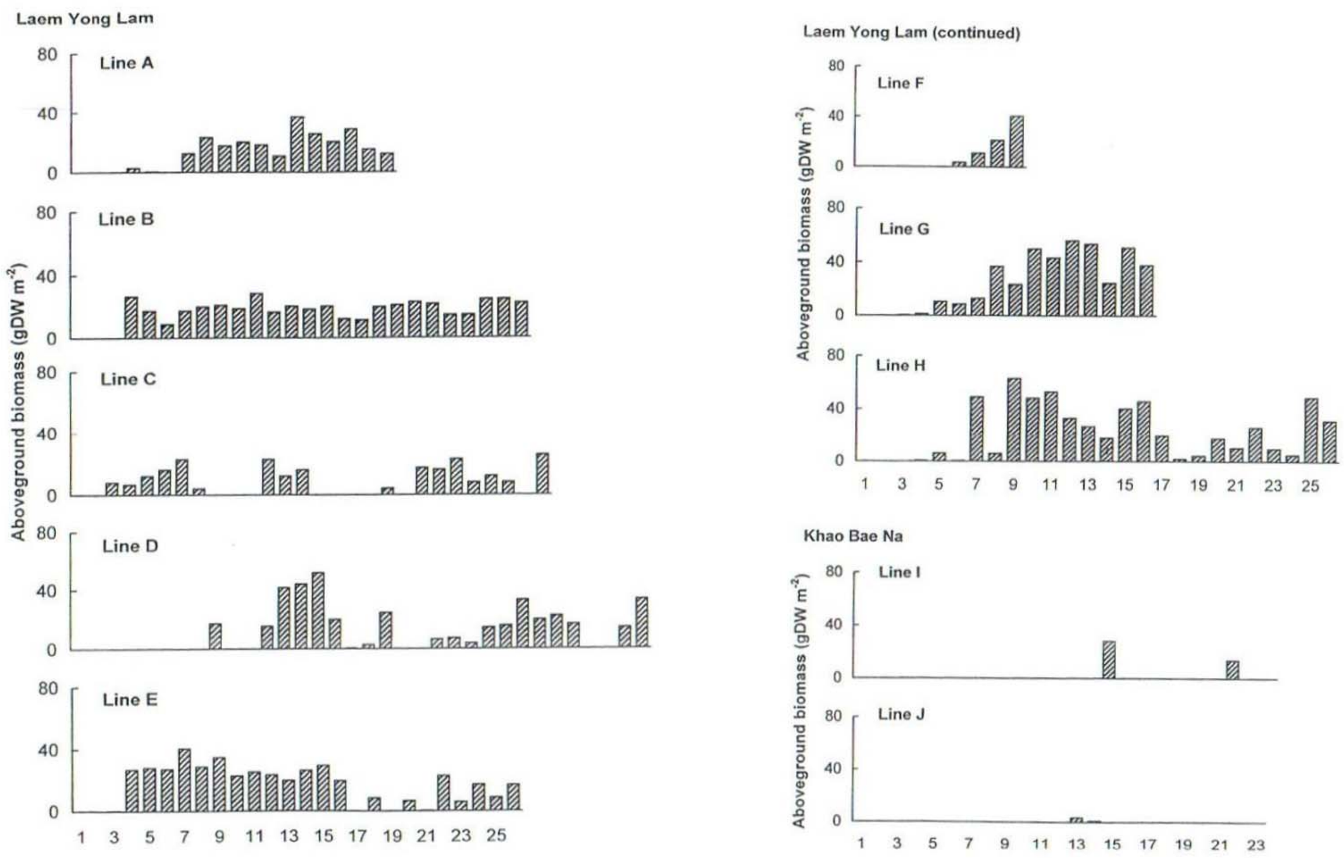

Fig. 5. Estimated aboveground biomass of seagrasses at upper intertidal area. Stations in each line (established at 20 m intervals) are arranged from shoreward (left) to seaward (right) direction.

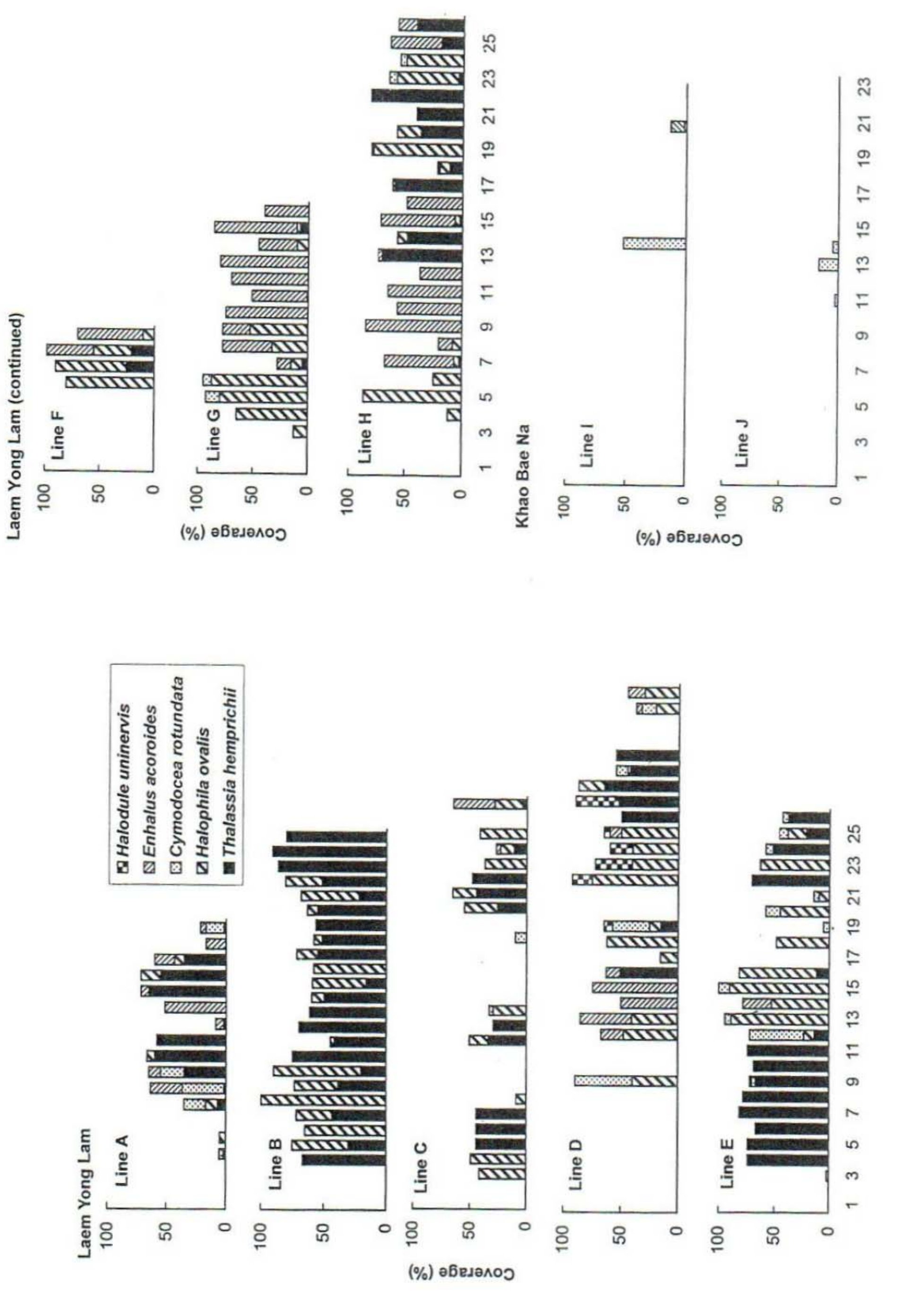

Fig. 6. Percent coverage of each seagrass species at upper intertidal area. See Fig. 5 for the arrangement of stations.

Upper intertidal area

Two intertidal flats of the study area have complex topography, containing sand dunes and tide pools of various size. Accordingly, tidal level did not decrease monotonously along the transect lines established perpendicular to the shoreline.

Both biomass estimates and percentage coverage of seagrasses did not show apparent trends along each transect line (Figs. 5, 6). In some lines, seagrasses vegetation was continuous throughout the census area (e.g., Lines B, G and H), whereas in other lines, vegetation was sometimes interrupted by sand dunes (e.g., Lines C and D). Comparisons of 2 intertidal flats revealed that seagrasses were more abundant at Lam Yong Lum (Lines A-H) than Khao Bae Na (Lines I and J).

A total of 6 seagrass species were found at the upper intertidal area by the line survey (*Enhalus acoroides, Halophila ovalis, Thalassia hemprichii, Cymodocea rotundata, Halodule uninervis, and H. pinifolia*). At Laem Yong Lam, *H. ovalis* (found at 89 out of 183 stations) and *T. hemprichii* (80 stations) dominated over other species in most stations (Fig. 6). Each species formed monospecific patches, *T. hemprichii* in tide pools and *H. ovalis* at more exposed dunes. These 2 species co-occur only at stations that contain both tide pools and dunes. *E. acoroides* (44 stations) and *C. rotundata* (30 stations) occurred in more patchy manner, abundant in some lines (e.g., Lines G and H for *E. acoroides*, and Lines D and E for *C. rotundata*) but totally absent or very rare in other lines (e.g., Lines B and E for *E. acoroides* and Lines B and H for *C. rotundata*; Fig. 6). *H. uninervis* was found only at 7 stations at Lines G and H, while *H. pinifolia* was not found at Laem Yong Lam.

The distribution of seagrass species was very limited and patchy, and their coverage was small at Khao Bae Na (Fig. 6; Lines I and J). *Cymodocea rotundata* was found at 4 out of 47 stations, and *Halophila ovalis*, *Enhalus acoroides* and *Halodule pinifolia* only at 1 station.

Comparisons between subtidal and intertidal areas

Total area of subtidal bottom monitored in the present study was about 5 times larger than intertidal areas (Table 1). Estimated mean aboveground biomass per square meter was the highest at lower intertidal area, followed by upper intertidal and subtidal areas (Table 1). On an average, it was 1.5 times higher at the intertidal than the subtidal. Total aboveground biomass, calculated using above 2 parameters was ca. 3 times greater at the subtidal than the intertidal (Table 1).

DISCUSSION

The present study has revealed large-scale distribution patterns of seagrasses over an entire area (18 km^2) of the seagrass bed between Ko Muk and the mainland. Although seagrasses extended continuously over intertidal and subtidal bottoms of the study area, they were mostly absent at stations deeper than 2 m at LLW (Fig. 3). It is widely accepted that light availability determines depth limits of seagrass distribution (Duarte, 1991; Vermaat et al., 1997). In Thailand seagrass beds, Chansang & Poovachiranon (1994) found that distribution of seagrasses in major seagrass beds along the Andaman Sea coast is limited to the depth of 5 m (at MHW), and considered that turbidity of water is a limiting factor because secchi depth was similar to the maximum depth of seagrasses. The average depth of deeper boundary of seagrass distribution (2 m at LLW) in our study site agrees closely with their findings (taking into account the tidal range of 3 m). Although spatial variation in light intensity was not measured in the present study, turbidity of water was greater between Ko Muk and the mainland than at offshore of Ko Muk (Umezawa et al., 1999). It is therefore likely that light condition at the deeper sites between Ko Muk and the mainland was too poor for seagrasses to expand their distribution.

Table 1. Summary of abundance and species richness of a seagrass bed between Ko Muk and Laem Yong Lam

Habitat		Census type	Number of stations	Area covered (km^2)	Mean abovegroud biomass (gDW/m^2)	Total aboveground biomass ($x 10^3$ kg)	Number of seagrass species
Subtidal		Grid	60	15.00	10.6	159.6	5
Intertidal	(total)			3.17	15.4	48.7	7
	(lower)	Grid	9	2.25	16.6	37.2	5
	(upper)	Line	230	0.92	12.5	11.5	6

At intertidal and shallow subtidal area, seagrasses did not occur where sand dune developed (Figs. 3 and 5). It is frequently observed that sediment dynamics, such as erosion and deposition of sand and silt, greatly affects seagrass distribution, abundance and productivity (Marbà & Duarte, 1995; Duarte et al., 1997; Vermaat et al., 1997; Terrados et al., 1998). Terrados et al. (1998) studied several seagrass communities in the Philippines and Thailand including a seagrass meadow around Ko Talibong, another seagrass bed in Haad Chao Mai National Park (see Fig. 1), and found that seagrasses were absent or, even if exist, species diversity was low in heavy silted sites. Compared to the seagrass bed at Ko Talibong, the present study site was less affected by the siltation because there was no major river input. However, sand movement caused by southwest and northeast monsoon has been known to be intense. At an intertidal flat of Khao Bae Na, a large *Halophila ovalis* bed that was observed in March 1998 (Mukai et al., 1999; Nakaoka & Aioi, 1999) had almost totally disappeared by December 1998 due to sand deposition during the monsoon season (B. Bendell, personal communication), while seagrasses at subtidal bottom seemed to be less affected (Nakaoka, personal observation). Therefore, movement of sand seems to have great impact on seagrass distribution at shallower parts of the seagrass bed.

Among 8 seagrass species found in the census, *Enhalus acoroides* was most dominant at subtidal and lower intertidal bottom, whereas *Halophila ovalis* and *Thalassia hemprichii* dominated at upper intertidal area (Figs. 4 and 6). Among them, *E. acoroides* and *H. ovalis* have been reported to have high coverage in almost all seagrass beds along the Andaman coast of Thailand (Chansang & Poovachiranon, 1994; Poovachiranon & Chansang, 1994). In other countries of the tropical Indo-West Pacific of other areas, *T. hemprichii* and *E. acoroides* are generally dominant in mixed seagrass beds (Brouns, 1987; Hattori et al., 1985; Hattori, 1987; Nienhuis et al., 1989; Erftemeijer & Herman, 1994; Vermaat et al., 1995; Terrados et al., 1998), while other species such as *Cymodocea serrulata* and *Syringodium isoetifolium* become dominant in some areas (Brouns, 1987; Tomasko et al., 1993). In the present study, only *E. acoroides* was found at stations deeper than 3 m (at the deepest of 4.2 m). This species is known to form dense meadows at deepest parts of seagrass beds along Thailand coast (Poovachiranon & Chansang, 1994), and also to be most tolerant to physical disturbance such as sediment loading (Duarte et al., 1997). These characteristics may account for the observed dominance of *E. acoroides* in the turbid, subtidal bottoms.

For intertidal communities, the distribution of 2 dominant species, *Halophila ovalis* and *Thalassia hemprichii* rarely overlapped, and they separately inhabit dunes and tide pools, respectively. In mixed seagrass meadows, *H. ovalis* is regarded as a pioneer species that has ability to colonize unvegetated bottoms rapidly (Preen, 1995; Nakaoka & Aioi ,1999), while *T. hemprichii* is slower growing but competitively-superior species (Brouns, 1987; Vermaat et al., 1995). Also, *T. hemprichii* is more vulnerable to physical disturbance and stress such as sediment burial and desiccation (Erftemeijer & Herman, 1994; Duarte et al., 1997). Such differences in response to environmental factors and stresses, as well as the differences in competitive ability may explain their separate occurrence in the intertidal flat.

Aboveground biomass per unit area was higher at the intertidal area than the subtidal, resulting in smaller difference between 2 habitats in total standing stock of seagrasses than that in area each habitat occupied (Table 1). Furthermore, productivity of seagrasses per unit area is also expected to be higher at the intertidal than the subtidal because seagrass meadow in the former mostly consisted of more productive *Halophila ovalis* and *Thalassia hemprichii*, whereas that in the latter of less productive *Enhalus acoroides*. Koike et al. (1999) revealed that relative growth rate (expressed by production/biomass ratio) was higher in *H. ovalis* and *T. hemprichii* than *E. acoroides* in the study site. Similar results were obtained from mixed beds in other localities (Hattori et al., 1985; Brouns, 1987; Erftemeijer & Herman, 1994; Vermaat et al., 1995). Therefore, contribution of intertidal seagrasses to total primary productivity of the entire seagrass bed is much higher than those expected from the relative portion of area.

One of the advantage of the rapid visual technique for estimating seagrass biomass is its time efficiency (Mellors, 1991). In our study, we used 2 full days (approximately 15 hours) by a boat (by 6 persons) for the grid survey (69 stations) including times for biomass calibration, and only 5 hours on foot (by 2 persons) for the line survey (183 stations). Therefore, this methodology is effective when it is required to asses large areas within limited time, as in the present study.

In conclusion, the present study has shown that distribution, species composition and biomass of the seagrass bed at Haad Chao Mai National Park are possibly affected by at least two factors; water depth (possibly related to light availability) and physical disturbance such as sand movement, and that seagrasses in intertidal area have significant contribution to total biomass and productivity despite its relatively small area within the entire seagrass bed. Further studies examining processes and factors causing the differences in seagrass community structures and dynamics between intertidal and subtidal habitats are necessary for understanding roles and functions of the seagrass bed in coastal ecosystems, and for evaluating its importance for seagrass-associated organisms including important species for fisheries and endangered species such as the dugong.

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