

## Original Article

## Effects of wave exposure and shore level on seagrass abundance and distribution in the intertidal community

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**Abstract**

The abundance and distribution of *Thalassia hemprichii* (Ehrenb.) Aschers and *Cymodocea rotundata* Asch. & Schweinf. based on their different degrees of wave exposure and shore levels were investigated. *T. hemprichii* was the most dominant seagrass and occupied large areas from sheltered to exposed shores with the greatest percentage of cover ( $46\pm 4.63\%$ ) whereas *C. rotundata* was restricted to the sheltered shore with a  $12.22\pm 4.95\%$  cover. There were significant differences in abundance of these two species among the different degrees of wave action, shore sites, and month. Wave action might be the main influence on the percentage cover and distribution of these two seagrasses. In this study, the area covers of *T. hemprichii* and *C. rotundata* were around  $0.104\text{ km}^2$  and  $0.096\text{ km}^2$ , respectively.

**Keywords:** *Cymodocea*, intertidal seagrass community, seagrass community, *Thalassia*, wave action

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**1. Introduction**

Seagrasses are unique marine flowering plants submerged in the sea that have ecologically, physiologically, and morphologically adapted. They are distributed worldwide with a low taxonomic diversity that includes 12 genera and around 60 species worldwide (Leopardas, Uy, & Nakaoka, 2014). Eighteen species are in the ASEAN region and 18 species are in the Philippines (Fortes, 2013) while 13 species are found in Thailand (Tuntiprapas, Shimada, Pongparadon, & Prathep, 2015), 9 species in Taiwan, and 7 species are from Dongsha Island, Taiwan (Lin, Hsieh, & Liu, 2005). Seagrasses provide numerous important ecological services to coastal waters, including nutrient cycling, sediment stabilization, food source for ocean herbivores such as dugongs, sea turtles, and parrotfish (Lee, Huang, Chung, Hsiao, & Lin, 2015). Furthermore, seagrasses provide habitats for many animals, organic carbon production and export, carbon sequestration from the atmosphere, as well as nursery grounds for many economical important fishes, such as finfish and shellfish, and seagrasses

provide shoreline protection (Duarte, 2002; Lin, Hsieh, & Liu, 2005; Duffy, 2006; Short *et al.*, 2014). In addition, seagrass meadows are known as important global carbon sinks (Duarte & Chiscano, 1999; Huang, Hsiao, Lee, Chung, & Lin., 2015) and for carbon sequestration. Kennedy *et al.* (2010) estimated that carbon burial rates in seagrass beds are around  $48\text{--}112\text{ Tg y}^{-1}$  and between  $41\text{ and }66\text{ gC m}^{-2}\text{ y}^{-1}$  of the organic carbon originates from seagrass production. The results showed that seagrass beds are important repositories of organic carbon produced in the beds and elsewhere (Kennedy *et al.*, 2010).

Unfortunately, seagrass losses have been reported worldwide and these have been accumulating over the past few decades, including both temperate and tropical regions (Orth *et al.*, 2006). Seagrass meadows are being threatened by environmental events and anthropogenic stresses such as climate change, overfishing, coastal development, and increased loading of nutrients and sediment (Duarte *et al.*, 1997). Nutrient enrichment and sediment runoff are well-documented causes of seagrass losses in all regions (Duarte *et al.*, 1997; Touchette & Burkholder, 2000; Orth *et al.*, 2006) and it has resulted in large-scale declines of seagrass meadows.

Changes in seagrass diversity, abundance, and distribution have also been affected by the physical disturbances such as wave exposure, sediment movement, and desiccation.

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In the intertidal seagrass community, wave action can affect seagrass growth and distribution by causing the deposition and resuspension of sediment particles which can shade the light or bury the seagrasses and then cause mortality (Duarte *et al.*, 1997; Cabaço, Santos, & Duarte, 2008), leading to seagrass loss. Additionally, strong wave action may wash up the above ground part of seagrasses and alter habitat suitability for seagrass growth (Worcester, 1995; Prathep, 2003). High wave action can also prevent the establishment of new shoots. Air and sunlight exposures at low tide especially during the dry season can also cause desiccation stress which can limit the distribution of seagrasses (Lan, Kao, Lin, & Shao, 2005) and cause burnt seagrass leaves (Erfemeijer & Herman, 1994). It has been suggested that changes in cover and species diversity tend to be greater at the wave exposure shore where there is a moderate level of disturbance than in wave sheltered shore (Sousa, 1979).

In extreme physical disturbances such as a tsunami, it is expected to affect diversity and abundance of seagrass (Duarte, 2002). Nakaoka, Tanaka, Mukai, Suzuki, and Aruythaka (2007) evaluated the impact on the abundance and biomass of seagrass from the 2004 tsunami that hit the coastal areas along the Andaman Sea coast of Thailand and Indonesia. They found that the abundance and biomass of seagrass in some areas declined after the tsunami and the impact of the tsunami on the abundance of seagrass was variable among seagrass beds. However, not many studies have monitored the recovery ability of seagrass after the 2004 tsunami in Thailand. These studies would be useful for us to understand the effects of the tsunami disturbance on the seagrass community and also recovery of the seagrass community.

In Thailand, there are still large areas of seagrass coverage in both the Andaman Sea and the Gulf of Thailand with 9,448 ha and 5,489 ha, respectively. Adulyanukosal and Poovachiranon (2006) reported the status of seagrass beds from both the Andaman coast and the Gulf of Thailand and showed that around 40% of seagrass beds in the Andaman coast were in a good condition while the seagrass beds in the Gulf of Thailand had changed by monsoons. Most of the losses of seagrass beds were caused by high sediment runoff from river mouths and land, fisheries, coastal and industrial development (Adulyanukosal & Poovachiranon, 2006), and by the tsunami (Nakaoka *et al.*, 2007). However, very few studies have reported on the long term monitoring of the changes in abundance and distribution of seagrasses or even the recovery ability of seagrass after the 2004 tsunami. Thus, knowledge on the changes of seagrass communities and all aspects of seagrass biology and ecology is still needed to understand the community dynamics to get a long term database and achieve sustainable seagrass management practices. The objectives of the present study were to determine the abundance and distribution of seagrasses based on different degrees of wave exposure and shore levels and to report on any changes in the abundance and distribution of seagrasses since the first report 13 years ago and after the 2004 tsunami.

## 2. Materials and Methods

The study site was located at the intertidal zone of Koh Pling, Sirinat Marine National Park (8° 05'N, 98° 17'E), Phuket Province in southern Thailand. The climate of this area is under monsoonal influence. There are two dominant

seasons. The wet season is dominated by the southwest monsoon (May-October) and the dry season is predominated by the northeast monsoon (November to April). This area has a variety of marine habitats such as rocky shores, coral reefs, seagrass beds, and a high diversity of marine macroalgae. A study by Prathep (2003) in this area was the first to monitor and investigate the abundance and distribution of seagrasses at three shore levels and three degrees of wave exposure for the dry and wet seasons. Also, her results were the first dataset before the 2004 tsunami event. Two seagrass species were reported; *Thalassia hemprichii* (Ehrenb.) Aschers and *Cymodocea rotundata* Asch. & Schweinf.. *T. hemprichii* was the most dominant species and found at all study sites while *C. rotundata* was restricted only to the sheltered shore. Sedimentation was shown to be a factor that can affect seagrass cover and distribution (Prathep, 2003). By personal observation, *Enhalus acoroides* (L.f) Royle was recently found in this area.

In this study, the study site was divided into three shore areas and three shore levels. The three shore areas were selected based on different degrees of wave exposure: sheltered, semi-exposed, and exposed shore. The sheltered and the semi-exposed shores were protected by fringing reefs and the exposed shore was influenced by wave action. The water currents at each site were monitored during April and July of 2013. The average water currents at the sheltered, semi-exposed, and exposed shore were  $4.36 \pm 1.13 \text{ m s}^{-1}$ ,  $6.92 \pm 0.77 \text{ m s}^{-1}$ ,  $8.82 \pm 0.97 \text{ m s}^{-1}$ , respectively, and there were significant differences among the sites ( $P < 0.05$ ). The three shore levels were the upper, middle, and lower shore level as described following Prathep (2003, 2005). The line transects of 100 m long were perpendicular to the shoreline. The upper shore level was designated as 0-40 m while 41-80 m was the middle shore level and 81-100 m was the lower shore level as described in Prathep (2003; 2005) and Thongroy, Liao, and Prathep (2007). Three quadrants (50x50 cm) were randomly placed along each random line transect at 10 m intervals to estimate the percentage cover of seagrasses. Samplings were collected every three months from April 2013 to July 2014.

## 2.1 Statistical analyses

Since the data had a non-normal distribution after a series of transformations (transformed with  $\text{Log}(x+1)$  and square root), a non-parametric test was employed. Friedman's ANOVA test was performed to test for the percentage cover of each species against different degrees of wave action, shore level, and time. All data were analyzed using SPSS version 13.0 for Windows.

## 3. Results

*Thalassia hemprichii* and *Cymodocea rotundata* were the two species of seagrass found in this area. *T. hemprichii* was the most dominant seagrass and had the greatest percentage cover with  $46 \pm 4.63\%$  at the upper level of semi-exposed shore and occupied a large area from the sheltered to the exposed shores while *C. rotundata* was restricted to the sheltered shore with the highest percentage cover of  $12.22 \pm 4.95\%$  (Figure 1). There were significant differences in the abundance of *T. hemprichii* and *C. rotundata* that depended on the different degrees of wave action, shore levels, and time

(Friedman test,  $\chi^2=157.84$ , and 206.19, respectively) ( $P<0.05$ ) (Figure 1) and the percentage cover of these two seagrasses varied during the year. When the seasons were considered, there were no significant differences in the percentages of cover for either species between the dry and wet seasons ( $P>0.05$ ). The maximum percent cover of *T. hemprichii* was found in both the dry season ( $36.56\pm 8.38\%$ ) and wet season ( $38.50\pm 3.50\%$ ) at the middle of the sheltered zone. Maximum percent cover of *C. rotundata* was found at around  $6.83\pm 3.1\%$  in the dry season at the lower-sheltered zone and at around  $2.01\pm 1.1\%$  in the wet season at the upper-sheltered zone. However, the cover of *C. rotundata* from the lower-sheltered zone disappeared in the wet season. When compared to the study reported by Prathep (2003), the area covers of *T. hemprichii* and *C. rotundata* in this recent study were around two and six times greater than in 2003 which were  $0.043\text{-}0.069\text{ km}^2$  and  $0.017\text{ km}^2$ , respectively. The areas covered by these two species in the recent study were around  $0.104\text{ km}^2$  and  $0.096\text{ km}^2$ , respectively.

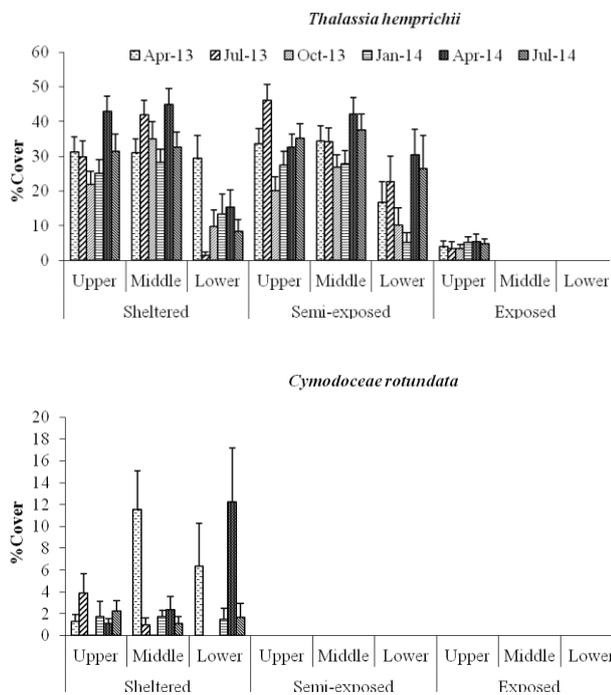


Figure 1. Distribution of the percentage covers of *Thalassia hemprichii* and *Cymodocea rotundata* (mean $\pm$ SE) at different sites and shore levels.

**4. Discussion**

In this study site, two species of seagrasses, *T. hemprichii* and *C. rotundata*, were found. *T. hemprichii* was first reported by Changsang and Poovachiranon (1994) and *C. rotundata* was reported by Prathep (2003). These species are common along the Andaman Sea coast of Thailand (Changsang & Poovachiranon, 1994). This present study revealed that the temporal changes in the abundance of these two species varied among the different degrees of wave action and

shore levels and the percentage cover of these two seagrasses varied during the year.

*T. hemprichii* was the dominant species with the highest abundance and distribution. This species occupied an area that was two times greater than 13 years ago (Prathep, 2003), even though its highest percentage cover was lower. This might be because *T. hemprichii* was a good competitor with a high growth rate. Tuntiprapas (2010) revealed that this seagrass required 10-11 days to produce a new leaf and the leaf elongation rate was  $1.2\text{ cm shoot}^{-1}\text{ day}^{-1}$ . Tough rhizome could attach well to the hard substrate such as dead coral skeletons as well as growing in a soft base down to 15-20 cm deep. This species can also grow in fine, medium, coarse, and muddy sand or in dead coral rubble substrates in sheltered habitats or semi-exposed habitats (Chansang & Poovachiranon, 1994; Lewmanomont, Deetae, & Srimanobhas, 1996; Tomascik, Mah, Nontji, & Moosa, 1997). The transplantation experiments of Lan *et al.* (2005) revealed that *T. hemprichii* prefer growing in a lower sediment silt/clay habitat. However, the growth of this species was not affected by sediment and the new leaves became larger in higher silt/clay habitat.

Lan *et al.* (2005) showed that *T. hemprichii* is better adapted to tolerate desiccation and high light irradiance than another seagrass species such as *Halodule uninervis* which dominates in the lower intertidal zone. It might be simply because that the thick leaves of *T. hemprichii* might be more resistant to desiccation and wave action in the intertidal zone (Lan *et al.*, 2005). Their results revealed that *T. hemprichii* had a high tolerance time to the combined effect of high light irradiance and air exposure for around 90 min. It might also be well-adapted to the intermediate levels of wave action. These factors may have resulted in it becoming the most common and abundant species in the area. However, any high wave action could be a factor that limits the distribution of this species in the middle and lower shore levels of the wave exposed areas as no plants were found in these zones.

*C. rotundata* was restricted to this sheltered area where the substrate was soft with a sand-muddy bottom and there was no strong wave action. The areal cover of this species in this study was 6 times greater than reported by Prathep (2003). It might be because *C. rotundata* has a long and thin root and can have abundant roots on vertical rhizomes to adapt for stabilization in unsettled sediment. This seagrass prefers a fine to medium sandy sediment and muddy sand area mixed with dead coral fragments in sheltered areas at 1-4 m depth (Chansang & Poovachiranon, 1994; Lewmanomont *et al.*, 1996). In addition, the percentage cover of *C. rotundata* in the dry season was higher than the cover in the wet season. It might be because of a weaker wave action and the presence of more light for photosynthesis. Also, this species can tolerate high temperatures when exposed to the air at the low tide (McMillan, 1984). In a previous study, the cover of *C. rotundata* in the exposed area was reported (Prathep, 2003); however, it had disappeared from the exposed area in this present study. This species might not be able to survive in strong waves. Strong wave action can have direct and indirect effects on seagrass. Increased wave action can erode, tear up plants, or prevent new shoots from establishment. Strong waves also reduce the number of seagrass shoots (van Katwijk & Hermus, 2000). Thus, wave action might influence the distribution range of *C. rotundata* in this exposed area.

However, the percentage cover showed losses of both seagrasses. Seagrass meadows have been threatened by environmental events and anthropogenic stresses. The major causes were mentioned in Chansang and Poovachiranon (1994) and Prathep (2003) and both indicated that coastal development such as construction of buildings on hill slopes and fishing activities such as trawlers, push-net fishing, and beach-seining on the seagrass beds have caused their destruction. In addition, the drastic decline in seagrass coverage and biomass caused by the tsunami in 2004 has been reported by Nakaoka *et al.* (2007). The results suggested that the tsunami could change the bottom topography and the deposition of sand that buried seagrasses too deep to around 50 cm of sediment and this led to decreases in coverage and biomass of seagrass around those areas. Seagrass loss decreases primary production and carbon sequestration, and can threaten such endangered species such as the dugong. Thus, knowledge and concern over the losses are needed to get a better understanding of the importance of seagrasses to produce a sustainable seagrass management and conservation program.

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