



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

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3 1 **Effects of wave exposure and shore level on seagrass abundance and**
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19 6 **Kattika Pattarach, Jatdilok Titioatchasai, Anuchit Darakrai, and Jaruwan Mayakun***
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2
3 **Abstract**
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6 The abundance and distribution of *Thalassia hemprichii* (Ehrenb.) Aschers and
7
8 *Cymodocea rotundata* **Asch. & Schweinf.** based on their different degrees of wave exposure
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10 and shore levels were investigated. *T. hemprichii* was the most dominant seagrass and
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12 occupied large areas from sheltered to exposed shores with the greatest percentage of cover
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14 (46± 4.63%) whereas *C. rotundata* was restricted to the sheltered shore with a 12.22± 4.95%
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16 cover. There were significant differences in abundance of these two species among the
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18 different degrees of wave action, shore sites, and month. Wave action might be the main
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20 influence on the percentage cover and distribution of these two seagrasses. In this study, the
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22 area covers of *T. hemprichii* and *C. rotundata* were around 0.104 km² and 0.096 km²,
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24 respectively.
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29 **Key words:** *Cymodocea*, **intertidal seagrass community**, Seagrass community, *Thalassia*,
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44 Introduction

45 Seagrasses are unique marine flowering plants that have ecologically, physiologically,
46 and morphologically adapted submerged in the sea. They are distributed worldwide with a
47 low taxonomic diversity that includes 12 genera and around 60 species worldwide
48 (Leopardas, Uy, & Nakaoka, 2014); 18 species from the ASEAN region and 18 species in the
49 Philippines (Fortes, 2013), 13 species are found in Thailand (Tuntiprapas, Shimada,
50 Pongparadon, & Prathep, 2015), 9 species in Taiwan and 7 species from Dongsha Island,
51 Taiwan (Lin, Hsieh, & Liu, 2005). Seagrasses provide numerous important ecological
52 services to coastal waters, including nutrient cycling, sediment stabilization, food source for
53 ocean herbivores such as dugongs, sea turtles, and parrotfish (Lee, Huang, Chung, Hsiao, &
54 Lin, 2015), habitats for many animals, organic carbon production and export, carbon
55 sequestration from the atmosphere, nursery grounds for many economical important fishes;
56 finfish and shellfish, and shoreline protection (Duarte, 2002; Lin, Hsieh, & Liu, 2005; Duffy,
57 2006; Short et al., 2014). In addition, seagrass meadows are known as an important global
58 carbon sink (Duarte & Chiscano, 1999; Huang, Hsiao, Lee, Chung, & Lin, 2015) and carbon
59 sequestration. Kennedy et al. (2010) estimated that carbon burial rates in seagrass beds is
60 around 48-112 Tg y⁻¹ and between 41 and 66 gC m⁻² y⁻¹ of the organic carbon originates from
61 seagrass production. The results showed that seagrass beds are important repositories of
62 organic carbon produced in the beds and elsewhere (Kennedy et al., 2010).

63 Unfortunately, seagrass losses have been reported worldwide and these have been
64 accumulating over the past few decades, including both temperate and tropical regions (Orth
65 et al., 2006). Seagrass meadows are being threatened by environmental events and
66 anthropogenic stresses such as climate change, overfishing, coastal development, increased
67 loading of nutrients and sediment (Duarte et al., 1997). Nutrient enrichment and sediment
68 runoff are well-documented causes of seagrass losses in all regions (Duarte et al., 1997;

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3 69 Touchette & Burkholder, 2000; Orth et al., 2006) and it has resulted in large-scale declines of
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5 70 seagrass meadows.

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8 71 **Changes in** seagrass diversity, abundance, and distribution have also been affected by
9
10 72 the physical disturbances such as wave exposure, sediment movement, and desiccation. In the
11
12 73 intertidal seagrass community, wave action can affect seagrass growth and distribution by
13
14 74 causing the deposition and resuspension of sediment particles which can shade the light or
15
16 75 bury the seagrasses and then **cause** mortality (Duarte et al., 1997; Cabaço, Santos, & Duarte,
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18 76 2008), leading to seagrass loss. Additionally, strong wave action may wash up the above
19
20 77 ground part of seagrasses, and alter habitat suitability for seagrass growth (Worcester, 1995;
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22 78 Prathep, 2003). High wave action can prevent the establishment of new shoots. Air and
23
24 79 sunlight exposures at low tide especially during the dry season can also cause desiccation
25
26 80 stress which can limit the distribution of seagrasses (**Lan, Kao, Lin, & Shao, 2005**) and cause
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28 81 the burnt seagrass leaves (Erfteimeijer & Herman, 1994). It has been suggested that changes
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30 82 in cover and species diversity tend to be greater at the wave exposure shore where there is a
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32 83 moderate level of disturbance than in wave sheltered shore (Sousa, 1979).

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37 84 For the extreme physical disturbances such as tsunami, it is expected to affect
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39 85 diversity and abundance of seagrass (Duarte, 2002). Nakaoka, Tanaka, Mukai, Suzuki, and
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41 86 Aryuthaka (2007) evaluated the impact of the 2004 Tsunami that hit the coastal areas along
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43 87 the Andaman Sea coast of Thailand and Indonesia on abundance and biomass of seagrass.
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45 88 They found that the abundance and biomass of seagrass in some areas declined after the
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47 89 tsunami and the impact of tsunami on abundance of seagrass was variable among seagrass
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49 90 beds. However, there are not many studies monitoring the recovery ability of seagrass after
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51 91 the 2004 tsunami in Thailand. These studies would be useful for us to understand the effects
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53 92 of the tsunami disturbance on seagrass community and also the recovery of seagrass
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55 93 community.

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3 94 In Thailand, there are still areas with large areas of seagrass coverage in both the
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5 95 Andaman Sea and the Gulf of Thailand with 9,448 ha and 5,489 ha, respectively.
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7 96 Adulyanukosal and Poovachiranon (2006) reported the status of seagrass beds from both the
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9 97 Andaman coast and the Gulf of Thailand, and showed that around 40% of seagrass beds in
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11 98 the Andaman coast were in a good condition while the seagrass beds in the Gulf of Thailand
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13 99 had been changed by monsoons. Most of the losses of seagrass beds have been caused by
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15 100 high sediment runoff from river mouths and land, fisheries and coastal and industrial
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17 101 development (Adulyanukosal & Poovachiranon, 2006) and tsunami (Nakaoka et al., 2007).
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19 102 However, there have been very few studies on the long term monitoring on the changes in
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21 103 abundance and distribution of seagrasses and even the recovery ability of seagrass after the
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23 104 2004 tsunami reported. Thus, the changes of seagrass communities and all aspects of seagrass
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25 105 biology and ecology are still needed to understand community dynamics and get a long term
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27 106 database and achieve sustainable seagrass management practices. The objectives of the
28
29 107 present study were 1) to determine the abundance and distribution of seagrasses based on the
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31 108 different degrees of wave exposure and shore levels, and 2) to report on any changes in the
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33 109 abundance and distribution of seagrasses since the first report 13 years ago and after the 2004
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35 110 Tsunami.

111 **Materials and methods**

112 The study site was located at the intertidal zone of Koh Pling, Sirinat Marine National
113 Park (8° 05'N, 98° 17'E), Phuket Province, Southern Thailand. The climate of this area is
114 under monsoonal influence. There are two dominant seasons, a wet season dominated by the
115 southwest monsoon (May-October) and a dry season predominated by the northeast monsoon
116 (November to April). This area has a variety of marine habitats such as rocky shores, coral
117 reefs and seagrass beds and a high diversity of marine macroalgae. For the seagrasses study
118 in this area, Prathep in 2003 was the first study, monitoring and investigating the abundance

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3 119 and distribution of seagrasses at three shore levels and three degrees of wave exposure for
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5 120 two seasons: dry and wet seasons. Also, her result was the first dataset before the 2004
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7 121 tsunami event. Two seagrass species; *Thalassia hemprichii* (Ehrenb.) Aschers and
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9 122 *Cymodocea rotundata* Asch. & Schweinf. were reported. *T. hemprichii* was the most
10
11 123 dominant species and found at all study sites while *C. rotundata* was only restricted to the
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13 124 sheltered shore. Sedimentation has been shown as the factor that can affect the seagrass cover
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15 125 and distribution (Prathep, 2003). Recently, *Enhalus acoroides* (L.f) Royle was found in this
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17 126 area (Personal observation).
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21 127 In this study, the study site was divided into three shore areas and three shore levels.
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23 128 The three shore areas were selected based on the different degrees of wave exposure:
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25 129 sheltered, semi-exposed, and exposed shore. The sheltered and the semi-exposed shore were
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27 130 protected by fringing reefs and the exposed shore was influenced by wave action. The water
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29 131 currents of each site were monitored during April and July, 2013. The average water currents
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31 132 at the sheltered, semi-exposed, and exposed shore were $4.36 \pm 1.13 \text{ m s}^{-1}$, $6.92 \pm 0.77 \text{ m s}^{-1}$,
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33 133 $8.82 \pm 0.97 \text{ m s}^{-1}$, respectively and there were significant differences among sites ($P < 0.05$).
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35 134 The three shore levels were; the upper, middle, and lower shore level as described following
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37 135 Prathep (2003; 2005). The line transects of 100 m long were perpendicular to the shoreline;
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39 136 0-40 m was designated as the upper shore level, 41-80 m was the middle shore level, and 81-
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41 137 100 m was lower shore level as described in Prathep (2003; 2005) and Thongroy, Liao, and
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43 138 Prathep (2007). Three quadrats (50 cm x50 cm) were randomly placed along each random
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45 139 line transect at 10 m intervals to estimate the percentage cover of seagrasses. Samplings were
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47 140 collected every three months from April 2013-July 2014.
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53 141 **Statistical analyses**

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3 142 Data had a non-normal distribution after a series of transformations (transformed with
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5 143 Log(x+1) and square root) then a non-parametric test was employed. Friedman's ANOVA
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7 144 test was performed to test for the percentage cover of each species against different degrees
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9 145 of wave action, shore level, and time. All data were analyzed using SPSS version 13.0 for
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11 146 Windows.

147 Results

148 Two species of seagrasses, *Thalassia hemprichii* and *Cymodocea rotundata* were
149 found in this area. *T. hemprichii* was the most dominant seagrass and had the greatest
150 percentage cover with $46 \pm 4.63\%$ at the upper level of semi-exposed shore and occupied a
151 large area from the sheltered to the exposed shores while *C. rotundata* was restricted to the
152 sheltered shore, the highest percentage cover was $12.22 \pm 4.95\%$ (Fig. 1). There were
153 significant differences in the abundance of the two species, *T. hemprichii* and *C. rotundata*,
154 among the different degrees of wave action, shore levels, and time (Friedman test, $\chi^2 = 157.84$
155 and 206.19, respectively, $P < 0.05$; Fig. 1) and the percentage cover of these two seagrasses
156 varied during the year. When considering between seasons, there was no significant
157 difference of the percentage cover for both species between the dry and the wet seasons
158 ($P > 0.05$). The maximum percent cover of *T. hemprichii* was found in both the dry and the
159 wet seasons at the middle of the sheltered zone; $36.56 \pm 8.38\%$ and $38.50 \pm 3.50\%$,
160 respectively. Maximum percent cover of *C. rotundata* was found around $6.83 \pm 3.1\%$ in the
161 dry season at the lower-sheltered zone and around $2.01 \pm 1.1\%$ in the wet season at the upper-
162 sheltered zone. However, the cover of *C. rotundata* from the lower-sheltered zone
163 disappeared in the wet season. When compared to the study reported by Prathep (2003), the
164 area covers of *T. hemprichii* and *C. rotundata* in this recent study were around two and six
165 times greater than they were in 2003; $0.043\text{-}0.069 \text{ km}^2$ and 0.017 km^2 , respectively. The areas

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3 166 covered by these two species in the recent study were around 0.104 km² and 0.096 km²,
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5 167 respectively.

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8 168 **Discussion**

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10 169 In this study site, two species of seagrasses, *T. hemprichii* and *C. rotundata*, were
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12 170 found. *T. hemprichii* was first reported by Changsang and Poovachiranon (1994) and *C.*
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14 171 *rotundata* was reported by Prathep (2003). These species are common along the Andaman
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16 172 Sea coast of Thailand (Changsang & Poovachiranon, 1994). This present study revealed that
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18 173 the temporal changes in the abundance of these two species are variable among the different
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20 174 degrees of wave action and shore levels and the percentage cover of these two seagrasses
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22 175 varied during the year.
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26 176 *T. hemprichii* was the dominant species with the highest abundance and distribution.
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28 177 This species occupied area two times greater than 13 years ago (Prathep, 2003), even though
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30 178 its highest percentage cover was lesser. This might be because *T. hemprichii* was a good
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32 179 competitor with a high growth rate. Tuntiprapas (2010) revealed that this seagrass required
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34 180 around 10-11 days producing a new leaf and leaf elongation rate was around 1.2 cm shoot⁻¹
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36 181 day⁻¹. Tough rhizome could attach well to hard substrate such as dead coral skeletons as well
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38 182 as growing in a soft base down to 15 – 20 cm deep. This species can also grow in fine,
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40 183 medium, coarse, and muddy sand or in dead coral rubble substrates in sheltered habitats or
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42 184 semi-exposed habitats (Changsang & Poovachiranon, 1994; Lewmanomont, Deetae, &
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44 185 Srimanobhas, 1996; Tomascik, Mah, Nontji, & Moosa, 1997). The transplantation
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46 186 experiments of Lan et al. (2005) revealed that *T. hemprichii* prefer growing in lower sediment
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48 187 silt/clay habitat. However, the growth of this species was not affected by sediment and the
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50 188 new leaves became larger in higher silt/clay habitat.
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3 189 Lan et al. (2005) showed that *T. hemprichii* is better adapted to tolerate desiccation
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5 190 and high light irradiance than another seagrass species such as *Halodule uninervis* which
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7 191 dominates in the lower intertidal zone. It might be simply because that the thick leaves of *T.*
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9 192 *hemprichii* might be more resistant to desiccation and wave action in the intertidal zone (Lan
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11 193 et al., 2005). Their results revealed that *T. hemprichii* had a high tolerance time to the
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13 194 combined effect of high light irradiance and air exposure for around 90 min. It might also be
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16 195 well-adapted to the intermediate levels of wave action. These factors may have resulted in it
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18 196 becoming the most common and abundant species in the area. However, any high wave
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20 197 action could be a factor that limits the distribution of this species in the middle and lower
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22 198 shore levels of the wave exposed areas as no plants were found in these zones.

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26 199 For *C. rotundata*, it was restricted to this sheltered area where the substrate was soft
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28 200 with a sand-muddy bottom and there was no strong wave action. The areal cover of this
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30 201 species in this study was 6 times greater than that reported by Prathep (2003). It might be
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32 202 because *C. rotundata* has a long and thin root and can have abundant roots on vertical
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34 203 rhizomes to adapt for stabilizing unsettled sediment. This seagrass prefers a fine to medium
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36 204 sandy sediment and muddy sand area mixed with dead coral fragments in sheltered areas at 1-
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38 205 4 m depth (Chansang & Poovachiranon, 1994; Lewmanomont et al., 1996). In addition, the
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40 206 percentage cover of *C. rotundata* in the dry season was higher than the cover in the wet
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42 207 season. It might be because of a less strong wave action and the presence of more light for
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44 208 photosynthesis. Also, this species can tolerate high temperatures when it expose to the air at
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46 209 the low tide (McMillan, 1984). In a previous study, the cover of *C. rotundata* in the exposed
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48 210 area has been reported (Prathep, 2003) however it had disappeared from the exposed area in
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50 211 this present study. This species might not be able to survive in strong waves. Strong wave
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52 212 action can have direct and indirect effects on seagrass. Increased wave action can erode, tear
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54 213 up plants, or prevent new shoots from establishment. Strong wave also reduce number of
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3 214 seagrass shoots (van Katwijk & Hermus, 2000). Thus, wave action might influence the
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5 215 distribution range of *C. rotundata* in this exposed area.
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8 216 However, the percentage cover showed losses of both seagrasses. Seagrass meadows
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10 217 have been threatened by environmental events and anthropogenic stresses. The major causes
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12 218 have been mentioned in Chansang and Poovachiranon (1994) and Prathep (2003) and both
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14 219 indicated that coastal development such as construction of buildings on hill slopes and fishing
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16 220 activities such as trawlers, push-net fishing, and beach-seining on the seagrass beds have
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18 221 caused their destruction. In addition, the drastic decline in seagrass coverage and biomass
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20 222 caused by tsunami 2004 has been reported by Nakaoka et al. (2007). Their results suggested
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22 223 that tsunami could change the bottom topography and the deposition of sand that buried
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24 224 seagrasses too deep, around 50 cm of sediment and this led to decreases in coverage and
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26 225 biomass of seagrass around those areas. Seagrass loss decreases primary production, carbon
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28 226 sequestration and can threaten such endangered species such as the dugong. Thus, the
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30 227 knowledge and concern over the losses are needed to get a better understanding of the
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32 228 importance of seagrasses are and to produce a sustainable seagrass management and
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34 229 conservation program.
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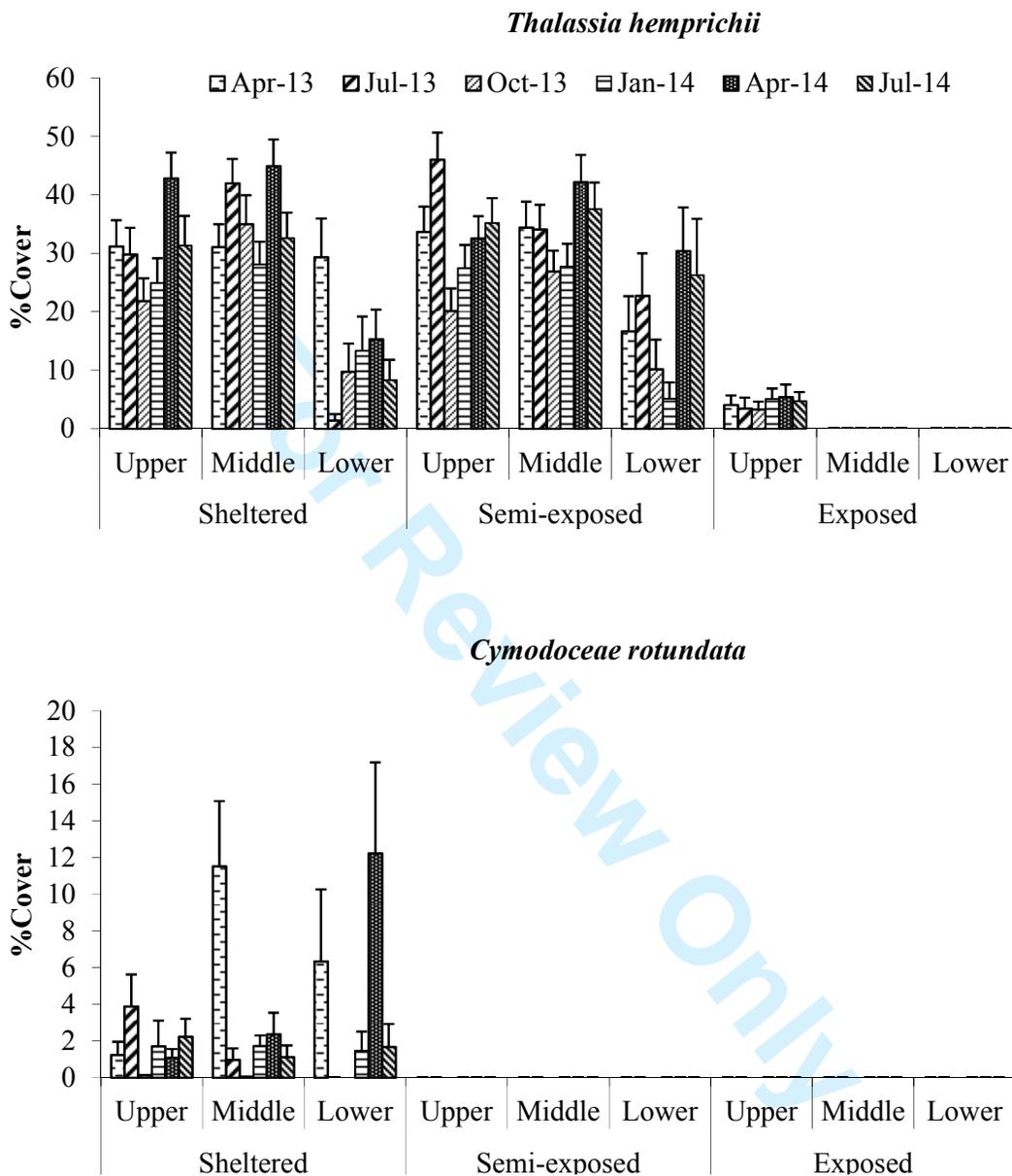


Fig. 1 Distribution of the percentage covers of *Thalassia hemprichii* and *Cymodocea rotundata* (mean±SE) at different sites and shore levels.