Coastal Marine Science 29(1): 75–80, 2004

Species diversity and abundance of seagrasses in southwestern Thailand under different influence of river discharge

Masahiro NAKAOKA[1)]*, Yoshiyuki TANAKA[2)] and Masako WATANABE[2)]

[1] *Graduate School of Science and Technology, Chiba University, Inage, Chiba 263–8522, Japan*
**E-mail: nakaoka@faculty.chiba-u.jp*
[2] *Akkeshi Marine Station, Hokkaido University, Akkeshi, Hokkaido 088–1113, Japan*

Received 11 February 2004; Accepted 30 March 2004

Abstract—Seagrass beds are among the most important components in coastal ecosystem, but are susceptible to human-induced changes in terrestrial ecosystem. As a first step to understand the effects of terrestrial input through river discharge on tropical seagrass ecosystems, we carried out quantitative mapping of seagrass beds at Pang-gna and Trang Provinces, southwestern Thailand to examine spatial variation in species composition, species diversity and biomass of seagrasses. Five seagrass beds were chosen as study sites that locate at different distances from the major river mouths, and thus subjected to different impacts of river discharge. These seagrass beds differed greatly in environmental conditions, seagrass diversity and abundance. Seagrass beds located near large river mouths showed higher silt-clay content in the sediments and light attenuation of water, possibly due to transportation of sediment from rivers and its resuspension. A total of nine seagrass species occurred. *Enhalus acoroides* and *Halophila ovalis* occurred in all the stations, whereas distribution of other species were mostly confined to seagrass beds with small or moderate degree of siltation and light attenuation. Seagrass species diversity measured by species richness and Simpson's diversity index was lower in seagrass beds near the river mouth. These findings highlight negative impacts of terrestrial ecosystems through river discharge on seagrass biodiversity and its functioning along the coastal areas of southwestern Thailand.

Key words: seagrass, Thailand, river discharge, spatial comparison, diversity, biomass

Introduction

Seagrass beds, mangrove and coral reefs are major components in coastal ecosystems in tropical areas, supporting high productivity and biodiversity (Fortes 1988, Duarte and Chiscano 1999, Hemminga and Duarte 2000). However, these habitats are declining rapidly due to a variety of human-induced disturbance in tropical regions (Fortes 1988, 1995, Short and Wyllie-Echevarria 1996). For example, deforestation causes massive sediment discharge from terrestrial to coastal areas, resulting in increase in turbidity and light attenuation (Milliman and Meade 1983). Urbanization along the river areas and development of farmland and aquaculture hatcheries causes heavy nutrient loads, leading to serious eutrophication in coastal waters (Short and Wyllie-Echevarria 1996). Seagrass beds are considered to be most susceptible to such effects of terrestrial input because they generally locate soft bottoms near river mouth.

One of the effective approaches to understand the impact of terrestrial input on seagrass ecosystems is to compare status and dynamics of seagrass beds among sites under different influence of river discharge. It is generally predicted that seagrass beds near large rivers with large watershed areas are affected in greater degree by terrestrial-derived matters than those locating far from rivers or along rivers with small watershed areas. Based on this idea, we carried out a large-scale comparisons of seagrass beds in southwestern Thailand subjected to different influence of terrestrial and riverine impacts with concurrent monitoring of physical, biogeochemical and biological processes (Lewmanomont and Supanwanid 2000, Nakaoka and Supanwanid 2000, Kuramoto and Minagawa 2001, Yamamuro et al. 2001).

The aim of the present paper is to examine species composition, species diversity and biomass of the seagrasses as a first step to understand the effects of terrestrial input to seagrass ecosystems. We conducted a series of quantitative census of five seagrass beds at three sites locating at river months with different sizes of watershed areas. The comparisons of seagrass communities and surrounding environments were carried out at two spatial scales: (1) among river-watershed systems (30–300 km scale), and (2) within a river-watershed system (1–10 km scale) to understand appropriate spatial scale at which terrestrial effects operate.

Materials and Methods

The study was carried out at three sites along the Andaman Sea coast of Thailand (southwestern Thailand), where many seagrass beds with rich flora have been described (Chansang and Poovachiranon 1994, Poovachiranon and Chansang 1994, Lewmanomont et al. 1996, Poovachiranon 2000) (Fig. 1). Several major seagrass beds locate at Haad Chao Mai National Park in Trang Province. One seagrass bed (TLB) locates at the mouth of Trang River, one of the largest rivers in southern Thailand. A monitoring station was chosen between Ko Talibong and the mainland where the greatest influence of river discharge is expected. The depth of the station ranges from intertidal to 1 m below mean low water level.

Another research site in Haad Chao Mai National Park locates between Ko Muk and the mainland (LYL) where the largest seagrass bed along the Andaman Sea coast of Thailand exists (ca. 18 km^2; Lewmanomont and Supanwanid 2000, Nakaoka and Supanwanid 2000). This area has no major river systems, and is thus considered to have the least impact of terrestrial and riverine input. See Nakaoka and Supanwanid (2000) for detailed information on this site. Two stations were established for the census. The shallower station (LYL1) located at intertidal site, and the deeper (LYL2) approximately at the mean low water level. These stations were separated by 1 km from each other.

The third research site was located at the mouth of Khura River, northern Pang-gna Province. Khura River is relatively small compared to Trang River, and therefore this area is regarded to have the medium effects of terrestrial input among the three sites. Three isolated seagrass beds were chosen as monitoring stations along the river. Ko Chong (KC) locates at the innermost part, Mai Hang (MH) at the southwestern edge, and Thong Nan Dam (TND) at the northeastern edge of the river mouth. The depth range of the stations was similar: from intertidal to 1 m below mean low tide. The three staions were separated by 1–3 km from each other. Comparisons of the three stations within Khura River site were designed to examine effects of river discharge at the small spatial scale, whereas comparisons among three sites (Khura River, Ko Muk and Ko Talibong) were aimed for examination at large spatial scale.

For environmental factors, silt-clay content in the sediments and light attenuation rate of the water column were measured in May 2001 at all the seagrass beds except for TLB. Triplicate sediment samples were collected at each station using a 25 cm-length plastic corer with a 5 cm internal diameter. After drying at 105°C for more than 24 hours, weight was measured. The silt-clay content was obtained by washing

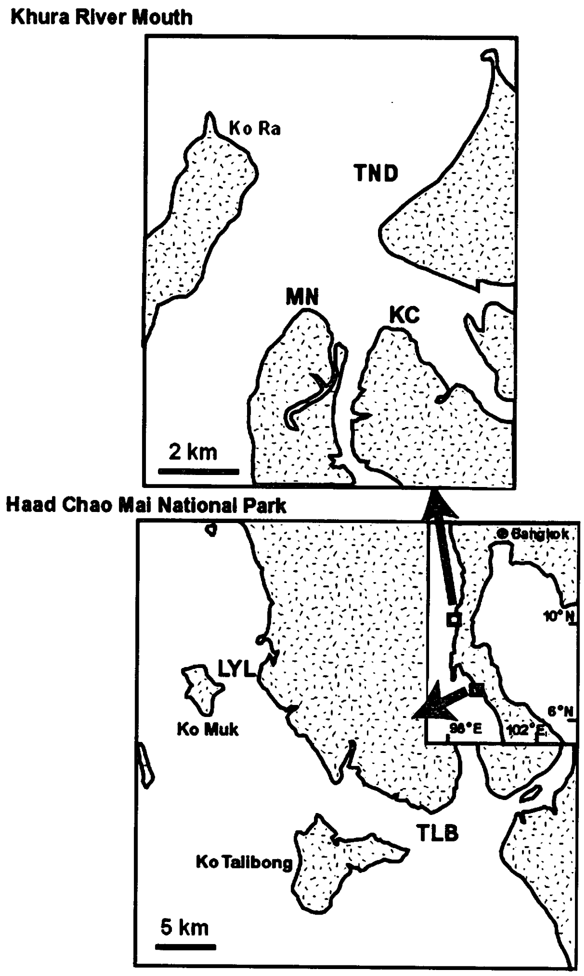

Fig. 1. Study seagrass beds along the Andaman Sea coast of Thailand. Three seagrass beds (KC, MH and TND) locate at the river mouth of Khura River, Pang-gna Province. A seagrass bed at the mouth of Trang River (TLB) and another bed near Ko Muk (LYL) locate Haad Chao Mai National Park, Trang Province.

the sediment carefully with running water through a 63 μm-mesh sieve. The samples were dried again in the same condition and re-weighed. The difference of weights before and after sieving was calculated as the content of silt-clay in the sediment. In each site, light attenuation rate was measured with underwater quantum cosine sensor (Li-Cor 192SA) under stable light condition (clear or overcast). Data of at least five times up-and-down repetitive measurements were averaged to calculate light attenuation rate.

The quantitative census of seagrass species composition, species diversity and biomass at each seagrass bed was carried out during January 16–19, 2001 at Khura River Mouth and during January 26–29, 2001 at Haad Chao Mai National Park. At each station, we established a census plot of 60–100 ha in area. Three to five parallel transects of 100 m in length were first set perpendicular to shoreline at the interval of 25

m. Along each transect, five census points were set at the interval of 25 m. As the result, a grid consisting of 15–25 census points were established at each station (three to five points parallel to the shoreline, times five points along the depth gradient).

At each point, we randomly placed three to five 0.5×0.5 m quadrates haphazardly. Species composition of seagrasses and ranked estimates of aboveground biomass of each seagrass species were recorded for each quadrat by one observer. Biomass estimates were made according to the rapid visual technique to minimize disturbances to seagrass beds and time loss caused by seagrass collection at numerous points (Mellors 1991, Nakaoka and Supanwanid 2000). Seagrass biomass within each quadrat was ranked between 0 and 10 at the intervals of 1. Later, rank of each observer was converted to biomass by the following process. After the census, 10 quadrats of the equal size were placed at a typical position of each station covering the full range of biomass observed during the survey. Seagrass biomass in these quadrats (calibration quadrats) was ranked by all the observers. Aboveground part of seagrasses in each quadrat was then harvested, sorted to each species, dried at 60°C to a constant weight, and measured on an electrical balance to the nearest 0.01 g. Rank estimates were converted to biomass 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) because this equation gives better fits than a linear equation ($Y=aX+b$) (Nakaoka and Supanwanid 2000). Regression coefficient (R^2) of the allometric equation varies between 0.1537 and 0.9998 with an average of 0.7706 and standard deviation of 0.2207. Data on biomass estimates of each seagrass species per quadrat were averaged for each census point.

Diversity of seagrasses in each seagrass bed was represented by two parameters: species richness and Simpson's diversity index D, the latter using the information of relative abundance of ith species p_i based on biomass data ($D=1-\sum_i p_i^2$). Simpson's diversity index was calculated at the two different spatial scales: fine-scale diversity D_α (per each census point within a station, based on seagrass occurrence and coverage per 1.25 m^2 area) and broad-scale diversity D_γ (per each station obtained by using data of all the census points). For Simpson's index, subtraction from D_γ by D_α equals turnover diversity D_β representing differences in species composition and abundance among census points at each station (Lande 1996).

Table 1. Silt-clay content and light attenuation at four seagrass beds (five stations) measured in May 2001.

	Silt-clay content (%)		Light attenuation rate (m^{-1})
	mean	sd	
Khura River			
Ko Chong (KC)	7.1	2.7	0.87
Mai Hang (MH)	9.8	0.8	0.88
Thong Nan Dam (TND)	12.0	3.6	0.97
Ko Muk			
Laem Yong Lam Shallow (LYL1)	4.7	1.4	0.72
Laem Yong Lam Middle (LYL2)	1.4	0.3	0.61

Results

Environmental factors

Silt-clay content varied greatly among four seagrass beds at two sites (Table 1). It was greater at seagrass beds in Khura River than at LYL (Ko Muk). Along Khura River, it was greatest at TND, followed by MH and KC. At LYL, silt-clay content was greater at the shallower station than the deeper (Table 1).

Light attenuation rate showed a similar pattern of variation with that of silt-clay content. It was greater at three stations in Khura River than at two stations in LYL. Within Khura River area, it was higher at TND than KC and MH, with the latter two stations showing the similar value. At LYL, it was greater at the shallower station (Table 1).

Seagrass species composition, diversity and biomass

A total of nine seagrass species were observed at six stations in three sites by the census conducted in January 2001 (Table 2). Species composition and diversity varied greatly among regions and stations. *Enhalus acoroides* and *Halophila ovalis* occurred in all the stations. *Halophila beccarii* was found only at KC. *Thalassia hemprichii* occurred only at the two stations in LYL, but not in Khura River areas. Other species occurred at two to three stations both at Khura River and Haad Chao Mai National Park (LYL and TLB).

Species richness at over an entire station was highest at the deeper Laem Yong Lam (LYL2), followed by MH, TND, shallow LYL (LYL1). It was the lowest at KC and TLB where only three species were found. Average species richness per census point (1.25 m^{-2}) was higher at stations with higher species richness per station (Table 2).

Species diversity at the small spatial scale represented by Simpson's diversity index D_α was highest at LYL2, followed

Table 2. List of species, diversity and biomass of seagrasses at five seagrass beds (six stations) along southwestern coast of Thailand surveyed in January 2001.

Seagrass bed	Occurrence of each seagrass species									Species richness	Mean species richness per census point ($1.25\,m^{-2}$)	Simpson's diversity index			Average segrass biomass ($gDW\,m^{-2}$)	CV (%)
	Ho	*Hb*	*Ea*	*Th*	*Cr*	*Cs*	*Hu*	*Hp*	*Si*			D_α	D_γ	D_β		
Khura River																
Ko Chong (KC)	○	○	○	×	×	×	×	×	×	3	0.9	0.002	0.216	0.218	25.0	186.5
Mai Hang (MH)	○	×	○	×	○	○	○	○	○	7	2.2	0.400	0.223	0.623	30.3	67.9
Thong Nan Dam (TND)	○	×	○	×	×	○	○	○	○	6	1.7	0.079	0.185	0.264	33.6	79.6
Ko Muk																
Laem Yong Lam Shallow (LYL1)	○	×	○	○	○	×	×	×	×	4	1.6	0.126	0.330	0.456	41.1	68.3
Laem Yong Lam Middle (LYL2)	○	×	○	○	○	○	○	○	○	8	3.0	0.458	0.067	0.525	128.9	28.3
Ko Talibong																
Trang River Mouth (TLB)	○	×	○	×	×	×	×	○	×	3	0.9	0.024	0.113	0.136	16.6	149.0

Ho: Halophila ovalis; Hb: Halophila beccarii; Ea: Enhalus acoroides; Th: Thalassia hemprichii; Cr: Cymodocea rotundata; Cs: Cymodocea serrulata; Hu: Halodule uninervis; Hp: Halodule pinifolia; Si: Syringodium isoetifolium.

by MH. It was lowest at KC, followed by TLB. Turnover diversity (D_β) was highest at LYL1 and the lowest at LYL2. The resultant large-scale diversity (D_γ) was highest at MH, followed by the two stations in LYL, TND, KC and TLB (Table 2).

Seagrass biomass and its spatial variation also varied greatly among seagrass beds (Table 2). The average biomass was minimum at TLB ($17\,g$ dry weight m^{-2}), intermediate at the three seagrass beds along River Khura (25–35 g dry weight m^{-2}), and maximum at Laem Yong Lam (40–130 g dry weight m^{-2}). The magnitude of spatial variation in seagrass biomass at each station, represented by the coefficient of variation (CV) among 15–25 census points, was greatest at KC, follwed by TLB, and smallest at LYL2 (Table 2).

Discussion

The present study revealed that species composition, diversity and biomass of seagrasses vary greatly among seagrass beds located under different distances from river mouths. Species diversity, measured both by species richness and Simpson's diversity index, and average biomass of seagrasses were smaller at seagrass beds located near the river mouth (such as TLB and KC) than those remote from rivers (such as LYL). The finding suggests that terrestrial and riverine input can cause negative impacts on seagrass communities.

Silt-clay content and light attenuation rate were larger at seagrass beds along Khura River than those at Laem Yong Lam which has no major river systems. In the former, siltation due to river discharge and decrease of water transparency due to resuspension of sediment are commonly observed, causing large disturbance and low light availability for seagrass survival and growth. For seagrass beds around Ko Talibong where environmental parameters were not taken in our study, Terrados et al. (1998) reported the average silt-clay content of 9.8% (with the range of 0.9–49.7%) and the average light attenuation rate of $0.53\,m^{-1}$ (with the range of 0.13–$1.71\,m^{-1}$). Because our station in Ko Talibong (TLB) located at nearmost position to Trang River mouth, silt-clay content and light attenuation rate in TLB probably exceed those in Khura River and Laem Yong Lam. It is likely lower diversity and biomass at seagrass beds like TLB and KC are related to such poor environmental conditions. Terrados et al. (1998) conducted large-scale comparisons of seagrass beds in the Philippines and Thailand, and revealed that species diversity and biomass of seagrasses were lower in seagrass beds with high siltration, which agrees with the findings of the present study.

Changes in seagrass species diversity and biomass along environmental gradient of silt-clay content and light attenuation were evident through large-scale comparison among three sites (Khura River, Ko Muk and Ko Talibong areas). At small-scale comparison within Khura River system, however, silt-clay contents, light attenuation did not monotonically decrease with the distance from the river mouth. The relationship between environmental factors and seagrasses diversity/abundance was neither obvious among the three seagrass beds in this site although seagrass diversity and biomass were the smallest at KC that located at the innermost parts of the river. Thus, effects of river discharge on seagrass community was detected only at among-regional scale (among sites separated by 30–300 km), but not within-site spatial scale (1–10 km scale). Among three seagrass beds in Khura River, local topography and hydrodynamics at TND was complex as this site is surrounded by well-developed sand dunes. Such confounding factors possibly prevented us to detect direct effects of river discharge on seagrass community at this site.

Concerning occurrence pattern of each seagrass species, *E. acoroides* and *H. ovalis* were observed in all the seagrass beds, whereas distribution of other species were limited to some beds where silt-clay content and light attenuation were small or moderate. *Enhalus acoroides*, the largest seagrass in tropical seagrass flora, can tolerate siltation, sediment burial and the resultant light attenuation in greater degree than other species (Duarte et al. 1997, Bach et al. 1998). Small-sized *H. ovalis* is more vulnerable to sediment disturbance than other species, although it has higher recolonization ability after the disturbance due to its high growth rate (Preen 1995, Duarte et al. 1997, Nakaoka and Aioi 1999). It is considered that such different types of adaptive traits against sediment disturbance enable these two species to survive and grow at seagrass beds subjected to large disturbance due to river discharge. In contract, dominant middle-sized species such as *T. hemprichii* and *C. rotundata* are most susceptible to sediment disturbance and siltation (Duarte et al. 1997, Terrados et al. 1998, Bach et al. 1998, Tanaka 2004). It is notable that *T. hemprichii* was never found in the three beds in Khura River although it inhabits deeper gravel bottom near Ko Ra, ca. 2 km apart from MH and TND (Nakaoka, personal observation). High siltation load due to river discharge and massive resuspension of sediment may prevent colonization of this species in the study site from nearby populations.

Seagrass beds subjected to large riverine impact showed not only low species diversity and low biomass, but also greater spatial variability, as shown by large CV in biomass (Table 2). The spatial variation in these beds is partly due to patchy distribution of seagrasses caused by heavy siltation, resuspension and frequent disturbance near the river mouths, and due to the absence of middle-sized species in these seagrass beds. It is also likely that patchy seagrass beds with low species diversity and seagrass biomass near the river mouth show larger temporal variability (i.e., instability) compared to those with less impacts of river dischage. Long-term monitoring of temporal changes in species diversity and biomass in these seagrass beds will shed light on how and to what degree spatial and temporal variation in seagrass beds is affected by dynamics of terrestrial and riverine ecosystems.

Acknowledgment

We wish to thank K. Lewmanomont, C. Aryuthaka, C. Meksumpun, C. Supanwanid, T. Duangdee and S. Nimsantichareon for invaluable support in various aspects of this research project. We are also grateful to the staff in Ranong Coastal Resource Research Station, Kasetsart University and Marine National Park Education Center, Thailand for field assistance, to K. Aioi, T. Kawai, I. Koike, N. Kouchi, M. Matsumasa, H. Mukai, S. Nojima, T. Suzuki, U. Umezawa and K. Watanabe, for their advices, comments and assistance. This research is supported by a Grant-in-Aid for International Scientific Research Program entitled "Studies on ecosystem function of tropical seagrass beds and their conservation" from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

References

Bach, S. S., Borum, J., Fortes, M. D. and Duarte, C. M. 1998. Species composition and plant performance of mixed seagrass beds along a siltation gradient at Cape Bolinao, The Philippines. Mar. Ecol. Prog. Ser. 174: 247–256.

Chansang, H. and Poovachiranon, S. 1994. The distribution and species composition of seagrass beds along the Andaman Sea coast of Thailand. Phuket Mar. Biol. Cent. Res. Bull. 59: 43–52.

Duarte, C. M., Terrados, J., Agawin, N. S. R., Fortes, M. D., Bach, S. and Kenworthy, W. J. 1997. Response of a mixed Philippine seagrass meadow to experimental burial. Mar. Ecol. Prog. Ser. 147: 285–294.

Duarte, C. M. and Chiscano, C. L., 1999. Seagrass biomass and production: a reassessment. Aquat. Bot. 65, 159–174.

Fortes, M. D. 1995. Seagrasses of East Asia: Environmental and Management Perspectives. RGU/EAS Technical Report Series No. 6. United Nations Environmental Programme, Bangkok.

Fortes, M. D. 1988. Mangrove and seagrass beds of East Asia: habitats under stress. Ambio 17: 207–213.

Hemminga, M. and Duarte, C. M. 2000. Seagrass Ecology. Cambridge University Press, Cambridge.

Kuramoto, T. and Minagawa M. 2001. Characterization of organic matters in a mangrove ecosystem at the southwestern coast of Thailand inferred from stable carbon and nitrogen isotopes. J. Oceanogr. 57: 421–431.

Lande, R. 1996. Statistic and partitioning of species diversity, and similarity among multiple communities. Oikos 76: 5–13.

Lewmanomont, K., Deetae, S. and Shimanobhas, V. 1996. Seagrasses of Thailand. *In* Seagrass Biology: Proceedings of an International Workshop, Rottenest Island, Western Australia, 25–29 January 1996. Kuo, J., Phillips, R. C., Walker, D. I. and Kirkman, H. (eds.), pp. 21–26, Faculty of Science, The University of Western Australia, Nedlands.

Lewmanomont, K. and Supanwanid, C. 2000. Species composition of seagrasses at Haad Chao Mai National Park, Trang Province, Thailand. Kasetsart Univ. Fishery Res. Bull. 22: 1–9.

Mellors, J. E. 1991. An evaluation of a rapid visual technique for estimating seagrass biomass. Aquat. Bot. 42: 67–73.

Milliman, J. D. and Meade, R. H. 1983. World-wide delivery of river sediment to the oceans. J. Geol. 91: 1–21.

Nakaoka, M. and Aioi, K. 1999. Growth of the seagrass *Halophila ovalis* at the dugong trails compared to existing within-patch variation in a Thailand intertidal flat. Mar. Ecol. Prog. Ser. 184: 97–103.

Nakaoka, M. and Supanwanid, C. 2000. Quantitative estimation of the distribution and biomass of seagrass at Haad Chao Mai National Park, Trang Province, Thailand. Kasetsart Univ. Fishery Res. Bull. 22: 10–22.

Poovachiranon, S. 2000. Species composition and their depth distribution of seagrass beds along the Andaman Sea coast of Thailand. Biol. Mar. Medit. 7: 412–416.

Poovachiranon, S. and Chansang, H. 1994. Community structure and biomass of seagrass beds in the Andaman Sea. I. Mangrove-associated seagrass beds. Phuket Mar. Biol. Cent. Res. Bull. 59: 53–64.

Preen, A. 1995. Impacts of dugong foraging on seagrass habitats: observational and experimental evidence for cultivation grazing. Mar. Ecol. Prog. Ser. 124: 201–213.

Short, F. T. and Wyllie-Echeverria, S. 1996. Natural and human-induced disturbance in seagrass. Environ. Conserv. 23: 17–27.

Tanaka, Y. 2004. Effect of physical environment factors on community structure of tropical seagrass meadows. Ph D dissertation. University of Tokyo.

Terrados, J., Duarte, C. M., Fortes, M. D., Borum, J., Agawin, N. S. R., Bach, S., Thampanya, U., Kamp-Nielsen, L., Kenworthy, W. J., Geertz-Hansen, O. and Vermaat, J. 1998. Changes in community structure and biomass of seagrass communities along gradients of siltation in SE Asia. Estur. Coast. Shelf Sci. 46: 757–768.

Yamamuro, M., Umezawa, Y. and Koike, I. 2001. Seasonality in nutrient concentrations and stable isotope ratios of *Halophila ovalis* growing on the intertidal flat of SW Thailand. Limnology 2: 199–206.