Coastal Marine Science 35(1): 157–168, 2012

Historical review of seagrass research in Malaysia before 2001

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Received 24 November 2010; accepted 18 May 2011

Abstract — This historical review of the seagrass research in Malaysia before 2001 includes the results of the effort for nearly one hundred years in the country. As an inventory of seagrasses and their diversity, total 14 seagrass species (belonging 8 genera from 3 families) have been recognized. Although seagrass biomass data are not much, an example of data set including several species at one locality is shown and compared to those of Indonesia. The other information on the 80 seagrass locations highlighting habitats and species composition, the associated fauna and flora, the utilization seagrasses and seagrass beds, etc. is summarized and tabulated.

Key words: ecology, historical review, Malaysia, seagrass, taxonomy

Introduction

Seagrasses together with seaweeds and phytoplankton form the important primary producers of a shallow marine environment e.g. mangroves, coral reef ecosystem, inter-tidal areas, lagoons, rocky shores. Seagrasses are flowering plants (monocotyledonous Angiosperms), rooted in sediments on the sea bottom, with shoots appearing above substrate. They have different vegetative and reproductive structures. The vegetative shoots comprise of erect stem bearing leaves or blades and are the most obvious component of the plants above the sediment. These range in shape from thin strips to oval structures and may be grouped into shoots with the older leaves on the outside. The leaves grow from the base, with the tips eroding as they age. Shoots are usually surrounded at the base by a fibrous sheath. Below the sediment, there are rhizomes and roots. Rhizomes are underground horizontal stems that connect the different bundles of leaves on shoots. The plants can propagate by sending out rhizomes, which give rise to new shoots and to more rhizomes. Seagrasses' reproductive structures are flowers, fruits and seeds. A single seed can give rise to a large area of clonal shoots connected by a network of rhizomes beneath the sediments. The roots are generally thin and extend from the rhizome through the substrate. In Malaysia, along its 4800 km coastline, stretching along the Malay Peninsula, Sabah and Sarawak bounding much of the southern part of the South China Sea are environments with rocky shores, mangroves, lagoons, coral reefs, inter-tidal shores, sub-tidal areas which form habitats for seagrasses (Japar Sidik 1994, Japar Sidik et al. 1995a) and seaweeds (Johnson 1967, Sivalingam 1977, Crane 1981, Phang 1985, Japar Sidik et al. 1997a, Phang 1998, Japar Sidik and Muta Harah 1996). Seaweeds also colonized mangrove mudflats, pneumataphores and tree trunks (Sarala and Sasekumar 1994). Seagrasses and seaweeds occurred in similar habitats, but they grow in patches to dense extensive coastal beds or meadows in coastal areas between mangroves and corals, from low tide level to the coral reef fringe and sub-tidal areas between the corals and the semi-open sea (Japar Sidik et al. 1995a). Both contribute to the productivity and biodiversity of the habitats just as tropical rain forests, mangroves and coral reefs. This paper summarizes the information available before 2001 with respect to seagrass research covering aspects on inventory, species composition, geographical distribution, ecological information and uses of the resources in Malaysia. In the lists given in this document, there is no attempt to review the taxonomic identification and we maintained those as reported by the respective authors given in the reference section. This review is categorized into (a) inventory on seagrass and diversity, (b) seagrass location, habitat characteristics and species distribution, (c) seagrass species and biomass, (d) seagrass associated fauna and flora, and (e) uses of seagrass and utilization of seagrass areas.

Inventory on seagrass and diversity

The record of the seagrasses *Enhalus acoroides* and *Halophila ovalis* in the shallow bays in coastal areas of Peninsular Malaysia dated back to 1907 in Ridley (Materials for a flora of the Malay Peninsula Part 1, pp. 5–6, 1907; Ridley 1924), followed by the publications of Burkill (1935), Henderson (1954), Holttum (1954) and Keng (1969). These

were seagrass plants' descriptions and habitat lists of 6 species: *E. acoroides* (then referred to as *E. Koenigii* by Holttum 1954), *H. ovalis*, *H. ovata*, *Diplanthera uninervis* (Sinclair 1956), *Thalassia hemprichii* and *Ruppia maritima*. Occurrence of *Halodule uninervis* from Pulau Pangkor and Pulau Tinggi were given by den Hartog (1964). In addition den Hartog (1970) reported 8 seagrass species at various places in Peninsular Malaysia comprising *E. acoroides*, *Cymodocea rotundata*, *C. serrulata*, *H. beccarii*, *H. minor* (a synonym for *H. ovata*), *H. ovalis*, *H. spinulosa*, *T. hemprichii*. However den Hartog (1970) did not include the previous record for *Halodule uninervis* (den Hartog 1964), and *Ruppia maritima* was not considered as a seagrass. Sasekumar et al. (1989) reported *E. acoroides*, *H. ovalis*, *H. spinulosa* and *Syringodium isoetiofolium* (new record for Peninsular Malaysia) occurred in Sungai Pulai estuary, Johore. Adjacent to the Sungai Pulai estuary, Japar Sidik et al. (1996) recorded another 6 species of seagrass: *H. minor*, *C. rotundata*, *C. serrulata*, *Halodule pinifolia*, *H. uninervis* and *T. hemprichii,* thus making the estuary as having diverse seagrasses. Mohd. Rajuddin (1992) recorded 5 species comprising *E. acoroides*, *C. serrulata*, *H. ovalis*, *Halodule pinifolia* and *H. uninervis* from Langkawi, Kuala Setiu and Pulau Sibu. *Halophila decipiens* was described by Japar Sidik et al. (1995b, 1997a respectively) as a new record in the west and east coasts of Peninsular Malaysia. In addition, *Halodule pinifolia* was also recorded in a number of places in Peninsular Malaysia by Japar Sidik et al. (1999a). The occurrence of perennial *Halophila beccarii* in Terengganu (Muta Harah et al. 1999) and annual *H. beccarii* in Kelantan (Muta Harah et al. 2000) was added to the record from Johore by den Hartog (1970). A summary of the inventory of seagrasses from 1907 to 2000 in Malaysia is given in Table 1.

Early records on the distribution of the *Enhalus acoroides* (at Labuan, Sandakan), *Halophila ovalis* (at Lahad Datu, Darvel Bay and Pulau Sibuan) and *Thalassia hemprichii* (at Labuan) in Sabah (then known as North Borneo) were reported by den Hartog (1970). Literature search indicate that a study has been made on the resources of west Sabah by Chua and Mathias (1978) which covers marine resources (fishes, invertebrates, seaweeds, corals and mangroves) but no mentioning in that publication on seagrass resources. A study by Norhadi (1993a) showed that the west and south-eastern coasts of Sabah harbour 8 species consisting of *E. acoroides*, *Cymodocea rotundata*, *C. serrulata*, *H. ovalis*, *Halodule pinifolia*, *H. uninervis*, *T. hemprichii* and *Syringodium isoetifolium*. Additional records of *Halophila decipiens* and *H. spinulosa*, both for the Taman Tunku Abdul

Table 1. Seagrass species in Peninsular Malaysia (Wc: west coast, Ec: east coast, S: southern) and in East Malaysia (SWc: Sabah East coast, SNc: Sabah north coast, SSE: Sabah south eastern, S: Sarawak).

	Family and Species	Peninsular Malaysia			East Malaysia			
		Wc	Ec	S	SWc	SNc	SSE	S
	Hydrocharitaceae							
1.	*Enhalus acoroides* (*L.f.*) Royle	●[2,3,5,8,9,13]	●[11,13]	●[10,13,15]	●[9,12]	●[12]	●[9,12]	
2.	*Thalassia hemprichii* (Ehrenb.) Aschers.	●[13]	●[13]	●[8,9,13,15]	●[9,12]	●[12]	●[12]	
3.	*Halophila beccarii* Aschers.		●[13,20,21]	●[9]				●[1,9]
4.	*Halophila decipiens* Ostenfeld	●[14,13]	●[16]		●[17]			●[22]
5.	*Halophila minor* (Zoll.) den Hartog (*H. ovata* Gaud.)	●[13]	●[16]	●[4,9,13,15]	●[12]	●[13]	●[12]	
6.	*Halophila ovalis* (R. Br.) Hook. F.	●[9,11,13]	●[2,11,13]	●[4,10,13,15]	●[12,13]	●[12,13]	●[12,13]	
7.	*Halophila spinulosa* Aschers.			●[9,10,13,15]	●[19]			
	Cymodoceaceae							
8.	*Cymodocea rotundata* Ehrenb. & Hempr. Ex Aschers.	●[9,13]	●[13]	●[13,15]	●[12,13]	●[12,13]	●[12]	
9.	*Cymodocea serrulata* (R. Br.) Aschers. & Magnus	●[13]	●[11,13]	●[9,13,15]	●[12]	●[12]	●[13]	
10.	*Halodule pinifolia* (Miki) den Hartog	●[11,13,18]	●[11,13,16,18]	●[13,15,18]	●[12,18]	●[12]	●[12]	
11.	*Halodule uninervis* (Forssk.) Aschers. (*Diplenthera uninervis* Aschers.)	●[7,11,13,18]	●[7,11,18]	●[13,15,18]	●[12,18]	●[12,18]	●[12,18]	
12.	*Syringodium isoetifolium* (Aschers.) Dandy		●[9,13]	●[10,13,15]	●[13]	●[12]	●[13]	
13.	*Thalassodendron ciliatum* (Forssk.) den Hartog				●[22]			
	Ruppiaceae							
14.	*Ruppia maritima* L. (*Ruppia rostellata* Koch ex Reichenbach)	●[2,3,8]						
	Total Species Number		**13**		**12**		**2**	

Sources: [1] Beccari (1904), [2] Ridley (1907, 1924), [3] Burkill (1935), [4] Henderson (1954), [5] Holttum (1954), [6] Sinclair (1956), [7] den Hartog (1964), [8] Keng (1969), [9] den Hartog (1970), [10] Sasekumar et al. (1989), [11] Mohd. Rajuddin (1992), [12] Norhadi (1993a), [13] Japar Sidik et al. (1995a), [14] Japar Sidik et al. (1995b), [15] J apar Sidik et al. (1996), [16] Japar Sidik et al. (1997a), [17] Japar Sidik et al. (1997b), [18] Japar Sidik et al. (1999a), [19] Japar Sidik et al. (1999b), [20] Muta Harah et al. (1999), [21] Muta Harah et al. (2000), [22] Phang (2000).

Rahman Park, were made by Japar Sidik et al. (1997b) and Japar Sidik et al. (1999b) respectively. The presence of *Thalassodendron ciliatum* at Tanjung Kiatan was reported by Phang (2000).

In Sarawak, other than record of herbarium specimen, there is little known on the distribution and species composition of seagrass resources. *Halophila beccarii* was reported to be collected by Beccari in Sungei Bintulu (Beccari 1904, den Hartog 1970) and *Halophila decipiens* at Pulau (Island) Talang Talang, Semantan (Phang 2000).

Other inventory records on seagrass are herbarium specimens by various collectors deposited at the herbaria of Royal Botanic Gardens, Kew (England), British Natural History Museum (England), Universitatis Florentinae-Instituto Botanico (Italy), Rijksherbarium, Leyden (the Netherlands), Herbarium of the Botanic Gardens (Singapore), University of Malaya and Faculty of Agriculture and Food Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus (Table 2). Based on the available records then, there are 14 species belonging to 8 genera from 3 families (Table 1) of seagrasses sparsely distributed over wide areas covering the west, east coasts and southern part of Peninsular Malaysia, Sabah and Sarawak of East Malaysia.

Seagrass location, habitat characteristics and species distribution

In Peninsular Malaysia, *Enhalus acoroides* and *Halophila ovalis* were common all around the coast on muddy shores and areas exposed at low tide (Ridley 1924, Burkill 1935, Henderson 1954, Holttum 1954). Seagrass communities (either monospecific or multi-species) are commonly associated with shallow inter-tidal water bodies (Norhadi 1993a, Japar Sidik et al. 1995a), semi-enclosed lagoons (Muta Harah et al. 1999, 2000), mangroves, coral reef flats (Japar Sidik 1994, Japar Sidik et al. 1995a, 1997b, 1999a, b) and also shoals in sub-tidal zones (Japar Sidik et al. 1996). The inter-tidal seagrass communities is not entirely submersed, but inundated twice daily with the rise of the tides. Compilation on 80 seagrass locations (surveyed from 1992–2000) throughout the Peninsular and East Malaysia, habitats, species composition and references to the data are from the authors' (Japar Sidik and Muta Harah) collection and the supporting data from other sources as listed in Tables 3–6. Norhadi (1993a) described seagrass habitats that were already degraded by human activities in Sabah, East Malaysia. Since the early reports, which indicated extensive seagrass beds, much of the habitats (e.g. the west coast of Peninsular Malaysia, East Malaysia, Sabah) have been utilized or deteriorated to a greater extent due to coastal development. Such phenomena would explain their present patchy distribution along the Malaysian coastline. They spread from isolated patches to coverage of several hectares. Information on the total area, extent or size of seagrass beds in Malaysia is lacking although there are reports stating that seagrass beds of Sungai Pulai estuary vary in size from 120 m to 1 km in length and 50 m to 120 m in width (Japar Sidik et al. 1996). In Sabah, seagrass beds occur in patches ranging in size from 10 m to 150 m in diameter (Norhadi 1993b). In Sarawak, records of the presence of seagrasses were those of *Halophila beccarii*, collected in Sungai Bintulu (Beccari 1904) and *H. decipiens* at P. Talang Talang, Semantan (Phang 2000).

Seagrass species and biomass

Subjects on seagrass species and biomass are the least studied in Malaysia. A study of *Enhalus acoroides* at the inter-tidal mudflat in Sungai Pulai by Ethirmannasingam et al. (1996) found that the ratio of AG (above ground biomass): BG (below ground biomass) was 1 : 5.5. The higher BG biomass was an adaptive strategy to the soft and motile mud substrate and prevented the plant from being swept away by water current.

Adjacent to the study site investigated by Ethirmannasingam et al. (1996) at Merambong and Tg. Adang shoals, Japar Sidik et al. (1996) conducted a study on biomasses (AG, BG and total) and distribution for *Enhalus acoroides*, *Thalassia hemprichii*, *Halophila minor*, *H. ovalis*, *H. spinulosa, Cymodocea serrulata*, *Halodule uninervis* and *Syringodium isoetifolium*. The larger species, *E. acoroides,* contribute to the highest mean total biomass (T) ranging from 176.4–276.1 DW m^{-2}, about 82.9–84.0% of which was contributed by the BG components. These values are much lower than those reported in similar mixed seagrass habitats: 468.5 g DW m^{-2} in Sabah, East Malaysia (Norhadi 1993a), 416 g DW m^{-2} in Flores Sea, Indonesia (Nienhuis et al. 1989) and 467.9–500.4 DW m^{-2} in Banten Bay, West Java, Indonesia (Kiswara 1992). Although the mean T are observed to be lower, the AG : BG ratio of 1 : 5.73–1 : 6.01 is higher than 1 : 2.13–1 : 3.93 ratio as reported by Kiswara (1992) and well below 1 : 12.5 ratio reported by Norhadi (1993a). *T. hemprichii*, *C. serrulata*, *H. uninervis* and *S. isoetifolium* have T of 46.8–73.5 DW m^{-2}, 25.2–27.6 DW m^{-2}, 8.3–15.2 DW m^{-2} and 19.2–43.9 DW m^{-2} respectively. These species have a higher BG biomass when compared to AG biomass, with the ratio of 1 : 4.02–1 : 4.07, 1 : 3.50–1 : 4.09, 1 : 2.08–1 : 2.45 and 1 : 1.61–1 : 2.37 respectively. The biomasses and BG : AG ratio are lower when compared to *E. acoroides*. This trend is similar to other tropical mixed seagrass areas (Nienhuis et al. 1989, Kiswara 1992, Norhadi 1993a) and the results of the study are within the ranges established for these areas. The smaller species, *Halophila minor*, *H. ovalis* and *H. spinulosa,* have a comparatively low T, with the lower BG than the AG, indicating that the majority of the biomass lies in the AG (shoot). This trend is reverse as obtained for the other larger species, e.g. *E. acoroides*, *T. hemprichii*, *C. serrulata*, *H. uninervis* and *S. isoetifolium*. *Enhalus acoroides*,

Table 2. Seagrasses in Peninsular Malaysia based on herbarium specimens and collectors.

Family and Species	Types of substrate	Locality	Collected Date	Collector and Herbarium
1. Hydrocharitaceae				
Enhalus acoroides	Sand covered corals	Port Dickson, N. Sembilan	13-01-1954	Van Steenis (L, BM)
	Sandy-muddy	Batu Empat Port Dickson, Negeri Sembilan	06-1992	Japar Sidik and Muta Harah (UPMKB)
	Sandy-muddy	Batu Tujuh Port Dickson, Negeri Sembilan	06-1992	Japar Sidik and Muta Harah (UPMKB)
	Sand covered coral	Cape Rachado, Port Dickson, N: Sembilan	16-05-1987	Phang (UM)
	Sandy-muddy mangrove	Sungai Pulai, Johore	10-06-1989	Sasekumar (UM)
	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-199x	Japar Sidik and Muta Harah (UPMKB)
	At low-water mark	Labuan, W. Persektuan	—	Unknown (K)
	—	Allark Rock Sandakan, Sabah	08-08-1959	W. Meyer (L, K)
Halophila beccarii	Sandy, slightly muddy river bed	Sungai Tebrau, Johore	13-06-1965	J. Sinclair (L, SING)
		Jalan Scudai, Johore	27-06-1965	J. Sinclair (L, SING)
	Mouth of Bintulu river	Bintulu, Sarawak	—	O. Beccari (L, FI, BO, K, BM, C, P)
	Muddy and sandy mangrove mudflats	Kemaman, Terengganu	19-07-1994	Japar Sidik and Muta Harah (UPMKB)
Halophila decipiens (New record)	Shallow turbid water, in sandy-muddy bottom	Batu Tujuh, Port Dickson, Negeri Sembilan	26-06-1994	Japar Sidik and Muta Harah (UPMKB)
Halophila ovalis	On sand banks	P. Langkawi, Kedah	23-11-1934	H.R. Henderson (K, BO, SING)
	In clear, sandy landlocked bay extending to a depth of 5 m	Pasir Bogak, P. Pangkor, Perak	10-07-1955	H.M. Burkill (SING)
	Sandy-Muddy	Batu Tujuh, Port Dickson, Negeri Sembilan	06-1992	Japar Sidik and Muta Harah (UPMKB)
	In mangrove channel	Kuala Berih, West Johor	16-01-1966	H.M. Burkill (L, SING)
	Shallow bay	Strait Kuah, P. Langkawi	03-1982	Stone and Mahmud Sider (UM)
	Sandy	Teluk Kemang, Port Dickson, Negeri Sembilan	08-03-1989	Phang (UM)
	Sandy-muddy mangrove	Sungai Pulai, Johore	10-06-1989	Sasekumar (UM)
	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
	Sandy-muddy in 3 m water	Pulau Sibu, Johore	27-07-1994	Japar Sidik and Muta Harah (UPMKB)
	On coral island	Lahad Datu, Pulau Sibuan	—	W. Meyer (L)
		Darrel Bay, Sabah		
Halophila ovata	Sandy-muddy area	Tanjung Rhu, P. Langkawi	09-02-1986	Phang (UM)
Halophila minor	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
	In sandy-muddy mangrove area	Gong Batu, Terengganu	07-1992	Japar Sidik and Muta Harah (UPMKB)

Table 2. (Continued).

Family and Species	Types of substrate	Locality	Collected Date	Collector and Herbarium
Halophila minor	In sandy-muddy river bank	Merchang, Terengganu	12-1993	Japar Sidik and Muta Harah (UPMKB)
Halophila spinulosa	Sandy-muddy mangrove	Sungai Pulai, Johore	10-06-1989	Sasekumar (UM)
	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
	Sandy-muddy in 3 m water	Pulau Sibu, Johore	27-07-1994	Japar Sidik and Muta Harah (UPMKB)
Thalassia hemprichii	Sandy-muddy	Batu Empat, Port Dickson, Negeri Sembilan	06-1992	Japar Sidik and Muta Harah (UPMKB)
	Sandy-covered coral	Batu Tujuh, Port Dickson, Negeri Sembilan	06-1992	Japar Sidik and Muta Harah (UPMKB)
	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
	Sandy-muddy in 3 m water	Pulau Sibu, Johore	27-07-1994	Japar Sidik and Muta Harah (UPMKB)
	On muddy sand near low-water mark	Labuan, W. Persektuan	—	Motley (K)
Thalassia sp.	Sandy, rocky area	Pantai Dickson, Port Dickson, N. Sembilan	10-10-1988	Phang (UM)
	—	Pulau Tinggi, Johore	19-06-1915	Burkill (SING)
2. Cymodoceaceae				
Cymodocea rotundata	On sand-covered coral	Port Dickson, N. Sembilan	13-01-1954	Van Steenis (L)
	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
C. serrulata (normal/short stemmed)	In still water at 1 m depth	Johore	15-03-1866	Beccari (FL, L)
	Sandy-covered coral	Batu Tujuh, Port Dickson, Negeri Sembilan	06-1992	Japar Sidik and Muta Harah (UPMKB)
C. serrulata (long stemmed)	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
Halodule pinifolia	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
	In sandy-muddy mangrove area	Gong Batu, Terengganu	07-1992	Japar Sidik and Muta Harah (UPMKB)
	In sandy-muddy river bank	Merchang Terengganu	12-1993	Japar Sidik (UPMKB)
Halodule uninervis (Narrow-leaved)	In sandy-muddy bottom exposed during low spring tide	Merambong Shoal, Tebrau Strait, Johore	10-12-1992	Japar Sidik and Muta Harah (UPMKB)
	In sandy-muddy mangrove area	Gong Batu, Terengganu	07-1992	Japar Sidik and Muta Harah (UPMKB)
	In sandy-muddy river bank	Merchang, Terengganu	12-1993	Japar Sidik and Muta Harah (UPMKB)
Halodule uninervis (Wide-leaved)	Sandy-muddy in 3 m water	Pulau Sibu, Johore	27-07-1994	Japar Sidik and Muta Harah (UPMKB)

Table 2. (Continued).

Family and Species	Types of substrate	Locality	Collected Date	Collector and Herbarium
Halodule uninervis (Wide-leaved)	In coral sand in 3–4 m water	Pulau Layang-Layang, Off Sabah waters	12-06-1994	Japar Sidik and Muta Harah (UPMKB)
Syringodium isoetifolium (New record)	Sandy-muddy mangrove	Sungai Pulai, Johore	10-06-1989	Sasekumar (UM)
	Sandy-muddy in 3 m water	Pulau Sibu, Johore	27-07-1994	Japar Sidik and Muta Harah (UPMKB)
3. Potamogetonaceae				
Ruppia rostellata (*Ruppia maritima*)	Coastal brackish	Prai, Province of Wellesley, Penang	—	Burkill (BM)

BM British Museum (Natural History) London, England
BO Herbarium Bogoriense, Bogor, Indonesia
C Botanisk Museum and Herbarium, Copenhagen, Denmark
FI Herbarium Universitatis Florentinae, Istituto Botanico, Firenze, Italy
K Herbarium of the Royal Botanic Gardens, Kew, Richmond, England
L Rijksherbarium, Leyden, the Netherlands
P Museum National d'histoire naturelle, Laboratoire de Phanerogamie, Paris, France
UM University of Malaya, Kuala Lumpur
UPMKB Universiti Putra Malaysia Bintulu Sarawak Campus, Bintulu, Sarawak
SING Singapore Botanic Garden, Singapore

the largest species, has the majority of the biomass in the rhizome and root system which is buried in the substrate. This species has the most developed BG system compared to other seagrasses. Similar trend have been established for the same species by Kiswara (1992) and Norhadi (1993a).

Seagrass associated fauna and flora

Though small in number of species, seagrasses may grow dense and form an extensive meadow e.g. in Sungai Pulai estuary area (Sasekumar et al. 1989, Japar Sidik et al. 1996). Their physical settings account for the high diversity of interactive community within and from outside, and ensure survival of vertebrates, fishes (Table 3, Sasekumar et al. 1989, Mohd. Rajuddin 1992, Arshad et al. 1994), invertebrates e.g. crustaceans (prawns and crabs, Table 4), Molluscs (bivalves, gastropods, Table 5) and echinoderms (starfishes, sea cucumbers, Table 6, Sasekumar et al. 1989, Arshad et al. 1994). Many economically important fish, shellfish, and crustaceans are being harvested from seagrass meadows (Sasekumar et al. 1989, Mohd. Rajuddin 1992). It is noticed that most of the fish in seagrass areas (based on catches landed) belonged to the small-sized fishes. Dollar (1991) suggested that the small sized fishes often prefer seagrass habitats as they can easily seek protection and are able to evade predators. This would agree with the prime function of seagrass bed as nursery and feeding area for many fishes and invertebrates. Besides vertebrates and invertebrates, seaweeds are abundant in seagrass areas. Seaweeds such as *Caulerpa lentillifera*, *Halimeda tuna*, *Chaetomorpha* sp., *Dictyota dichotoma*, *Gracilaria salicornia*, *Amphiroa fragillisima* and *Acanthophora spicifera* were found in the same area of seagrass bed of Sungai Pulai (Sasekumar et al. 1989). Japar Sidik et al. (1996) recorded at least 24 species of macroalgae. They are the important components of the seagrass communities of Merambong and Tg. Adang and to a lesser extent of the Tg. Kupang shoals. Truly rhizophytic algae such as *Avrainvillea*, *Caulerpa*, *Stypopodium* are common to abundant in seagrass beds since all favor sandy or muddy substrate (Brouns and Heijs 1991). The absence of significant hard substrate in the seagrass beds has led some macroalgae to utilize the available substrate presence in the shoals. *Bryopsis plumosa*, *Ceramium affine*, *Chaetomorpha spiralis*, *Cladophora spatentiramea*, *C. fascicularis*, *C. fuliginosa*, *Dictyota dichtoma*, *Hypnea cervicornis*, *Gracilaria coronopifolia*, *G. fisherii* and *G. salicornia* are attached to seagrasses while *Enteromorpha calthrata* and *Gracilaria textorii* attached to mollusc shells or polycheate tubes. Drift macroalgae such as *Acanthophora spicifera*, *Amphiroa rigida*, *A. fragilissima*, *Hypnea esperi* and *Ulva* spp. are loose-lying amongst the seagrasses and may continue their growth.

Many marine and estuarine organisms utilize seagrasses for food. Seagrasses are a primary food for large species, such as dugongs and green turtles. *Dugong dugon* (status: vulnerable, VU A1cd) and *Chelonia mydas* (green turtle, status: endangered, EN A1bd) feed on seagrasses. Dugongs are common in the 50's and later became rare because they were hunted for meat and hide (Holttum 1954). Presently, dugongs are found in areas with abundant seagrasses such as P. Sibu, P. Tengah, P. Besar and P. Tinggi on the east coast and around Tanjung Adang-Merambong shoals of Sungai Pulai, Johore (Japar Sidik and Muta Harah 1996). Tweedie and Harrison

Table 3. List of fish from five seagrass beds. SP: Sungai Pulai, TE: Teluk Ewa, KS: Kuala Setiu, PS: Pulau Sibu and MS: Merambong shoal.

Fauna/Families	Species	[1]SP	[2]TE	[2]KS	[2]PS	[3]MS
Anguillidae	*Anguilla nebulosa nebulos*	+				+
Ambassidae	*Ambassis commersoni*	+				+
	Ambassis gymnocephalus					+
	Ambassis urotaenia	+				
Antennariidae	*Antennarius pinniceps*	+				
Apogonidae	*Apogon amboinesis*			+		
	Apogon endekataenia	+				
	Apogon notatus			+		
	Apogon thermalis	+				
	Apogon guadrifasciatus					+
	Apogon sp.	+	+		+	
Ariidae	*Arius sagor*	+				+
	Arius venosus	+				
Balistidae	*Alutera monoceros*					+
	Abalistes stellaris					+
	Pervagor tomentosus	+				
Batrachoidida	*Batrachus grunniens*	+				
Belonidae	*Tylosurus strongylurus*					
Carangidae	*Caranx sexfasciatus*					+
	Megalaspis cordyla	+				
	Scomberoides lysan					+
	Selaroides leptolepis					+
Chaetodontidae	*Parachaetodon ocellatus*	+				
Chirocentridae	*Chirocentrus dorab*	+				
Clupeidae	*Anodonstoma chacunda*	+				+
	Ilisha megaloptera	+				
	Ilisha melastoma	+				
	Nematalosa nasus	+				
	Sardinella melanura	+				+
Cynoglossidae	*Cynoglossus macrolepidotus*	+				
	Cynoglossus macrostoma	+				
	Cynoglossus lingus					+
Dorosomatidae	*Anodontostoma chacunda*					+
Drepanidae	*Platax teira*					+
Eleotridae	*Eleotridae* sp.	+				
Engraulidae	*Setipinna taty*					+
	Stolephorus indicus					+
Gerreidae	*Gerres abbreviatus*	+	+	+		+
	Gerres filamentosus					+
	Gerres oyena			+		
Gobiidae	*Acentrogobius* sp. 1	+				
	Acenrogobius sp.	+				
	Glossogobius giuris	+				
	Gobiidae sp. A	+				
	Gobiidae sp. D	+				
	Gobiidae sp. E	+				
	Gobiidae sp. F	+				
Hemiramphidae	*Hemiramphus far*					+
Labridae	*Choerodon anchorago*	+				
	Thalassoma lutescens	+				
	Gnathanodon speciosus	+				
Lagocephalidae	*Gastrophysus lunaris*	+				
	Gastrophysus scleratus	+				
Latidae	*Lates calcarifer*	+				
Leiognathidae	*Gazza minuta*					+
	Leiognathus brevirostris	+				+
	Leiognathus eguulus	+				+

Table 3. (Continued).

Fauna/Families	Species	[1]SP	[2]TE	[2]KS	[2]PS	[3]MS
Leiognathidae	*Leiognathus splendens*	+				+
	Leiognathus sp.			+		
	Secutor insidiator	+				
Lethrinidae	*Lethrinus lentjan*					+
	Lethrinus nebulosus	+		+		
Lutjanidae	*Lutjanus argentimaculatus*					+
	Lutjanus chrysotaenia	+				
	Lutjanus russelli		+	+		+
	Lutjanus vitta					+
	Psammoperca waigiensis					+
Monodactylidae	*Monodactylus argenteus*					+
Muglidae	*Liza melanoptera*	+				
	Valamugil seheli					+
Nemipteridae	*Nemipterus japonicus*					+
Periophthalmidae	*Periopthalmodon schlosseri*	+				
Platacidae	*Platax teira*	+				
Platycephalidae	*Platycephalus crocodilus*	+				
	Platycephalus indicus	+				+
	Platycephalus macracanthus	+				
	Platycephalus serratus	+				
	Paltycephalus tuberculatus	+				
Plotosidae	*Plotosus canius*	+				
	Plotosus lineatus					+
Polynemidae	*Polynemus sextarius*	+				+
Pomadasyidae	*Pomadasys argenteus*					+
	Pomadasys hasta	+				+
	Pomadasys maculatus					+
Pristigastridae	*Ilisha elongata*					+
Scatophagidae	*Scatophagus argus*	+				+
Scianidae	*Chrysochir aureus*					+
	Dendrophysa russelli	+				
	Johnius coitor	+				
	Johnius soldadu	+				
	Kathala axillaris	+				
	Otolithes ruber					+
Scombridae	*Rastrelliger kanagurta*	+				
Scorpaenidae	*Scorpaenodes guamensis*	+				
Serranidae	*Epinephelus malabaricus*			+		
	Epinephelus suillus			+		
	Epinephelus sp.		+		+	
Siganidae	*Siganus canaliculatus*			+		+
	Siganus guttatus			+	+	
	Siganus javus				+	+
	Siganus sp.				+	
Sillaginidae	*Sillago sihama*	+				+
Soleidae	*Solea ovata*	+				
Sphyraenidae	*Sphyraena jello*					+
Stromateidae	*Pampus argenteus*					+
Syngnathidae	*Hippocampus kuda*	+				+
	Hippocampus sp. 1	+				
	Hippocampus sp. 2	+				
	Hippocampus sp.	+				
	Syngnathoides biaculeatus	+				
Synodontidae	*Saurida tumbil*					+
Tetraodontidae	*Arothron immaculatus*	+				
	Chelanodon patoca					+
	Ostracion tuberculatum					+
	Tetarodon fluviatilis			+		

Table 3. (Continued).

Fauna/Families	Species	[1]SP	[2]TE	[2]KS	[2]PS	[3]MS
Tetraodontidae	*Tetraodon* sp.			+	+	
Theraponidae	*Therapon jarbua*					+
	Therapon puta	+				
	Therapon guadrilineatus	+				
	Therapon sp.			+	+	
Tricanthidae	*Pseudotriacanthus strigilifer*					+
	Tricanthus biaculeatus	+				
Trichiuridae	*Lepturacanthus savala*					+
	Trichiurus savala	+				
Trygonidae	*Dasyatis uarnak*					+
	Dasyatis zugei					+

Source: [1] Sasekumar et al. (1989), [2] Mohd Rajuddin (1992), [3] Arshad et al. (1994).

Table 4. List of crustaceans (prawns and crabs) from two seagrass beds, Sungai Pulai and Merambong shoal.

Fauna/Families	Species	[1]Sungai Pulai	[3]Merambong shoal
Prawns			
Alpheidae	*Alpheus* sp.	+	
Paslaemonidae	*Macrobrachium* sp.	+	
Penaeidea	*Penaeus indicus*	+	
	Penaeus merguiensis	+	+
	Penaeus monodon	+	
	Penaeus semisculcatus	+	
	Parapeneopsis sp.		+
	Metapeneopsis barbeensis		+
	Metapenaeus sp.		+
Sergestidae	*Lucifer* sp.		+
	Acetes sp.		+
Crabs			
Dorippidae	*Dorippa* sp.	+	
Grapsidae	*Hemigrapsus* sp.	+	+
Parthenopsidae	*Parthenope longimanicus*	+	+
Portunidae	*Portunus pelagicus*	+	+
	Scylla serrata	+	+
	Thalamita sp.	+	+
Calappidae	*Matuta* sp.		+
Order			
Stomatopoda	*Oratosguilla* sp.		
Xiphosura	*Carcinoscorpius rotundicauda*		

Source: [1] Sasekumar et al. (1989), [3] Arshad et al. (1994).

(1954) described *Dugong dugon* as herbivores which feed on seaweeds. Based on a report by Aikanathan and Wong (1994) the coastlines of the 5 islands also have abundant seaweeds. *Enhalus acoroides* has been mentioned to be the main food for *Dugong dugon* (Burkill, 1935). However, from other reports elsewhere (Lanyon et al. 1989, Supanwanid 1996), *Dugong dugon* is known to feed on various types of seagrasses, *E. acoroides*, *Halophila ovalis*, *H. spinulosa*, *Cymodocea serrulata*, *Halodule pinifolia*, *H. uninervis* and *Syringodium isoetifolium*. According to Burkill (1935), in Peninsula Malaysia, Dugongs are accidentally caught by fisherman's net. Tweedie and Harrison (1954) reported that Dugongs were common before, but in the 50's they have become rare because they have been persecuted for its meat and hide. In Peninsular Malaysia, perhaps there is no intentional hunting of Dugongs. However, the decreasing of Dugongs may be due to accidental fishing such as small-mesh seines as in the case of Pulau Sibu.

In Sabah, sighting reports and interviews on fishermen and local villagers have indicated that dugongs are encountered occasionally in Tunku Abdul Rahman Marine Park (Jaaman 2000). Other areas with possibly viable populations are the shallow coastal waters from Semporna, Kudat, Kota Kinabalu, Sepangar Bay, Sabah (Jaaman et al. 1997, Jaaman

Table 5. List of molluscs from Sungai Pulai-Merambong shoal seagrass beds.

Class	Species	[1]Sungai Pulai	[3]Merambong shoal
Gastropoda	*Cerithidea* sp.	+	
	Lambis lambis	+	
	Strombus isabella		+
Bivalvia	*Barbatia* sp.		+
	Circe spp.		+
	Donax sp.		+
	Dosinia sp.		+
	Gafrarium sp.		+
	Macoma sp.		+
	Meretrix sp.	+	
	Modiolus sp.		+
	Musculus sp.		+
	Perna viridis		+
	Polymesoda proxima	+	
	Solen spp.		+
	Tapes sp.		+
	Tellina sp.		+
Cephalopoda	*Loligo edulis*	+	
	Sepia esculenta	+	+

Source: [1] Sasekumar et al. (1989), [3] Arshad et al. (1994).

Table 6. List of echinoderms from Sungai Pulai-Merambong shoal seagrass beds.

Family	Species	[1]Sungai Pulai	[3]Merambong shoal
Asteroidea	*Archaster* sp.	+	
	Asrtopecten sp.		+
	Protoreaster nodusus	+	
Ophiuroidea	*Macrophiothrix* sp.		+
Holothuroidea	*Phyllophorus* sp.		+
	Pentacta quadrangularis		+
	Mensamaria intercedens		+

Source: [1]Sasekumar et al. (1989), [3]Arshad et al. (1994).

1999) to Lawas, Sarawak. Green turtles are abundant at Cagar Hutang, P. Redang, Peninsular Malaysia (Japar Sidik et al. 1997a) and in P. Selingan and P. Bakungan Kecil, Sabah (personal observation). These areas are the nesting ground of turtles and the presence of seagrass meadows in the vicinity may serve as feeding grounds.

Uses of seagrass and utilization of seagrass areas

The uses of seagrasses were described by Burkill (1935). He reported Ridley (1924) recorded leaves of *Enhalus acoroides* as one of the chief foods of the dugong, *Dugong dugon*, which was then common in Malaysia. Later the dugong became rare because it was hunted for meat and hide (Tweedie and Harrison 1954). *Enhalus acoroides* fruits are edible (Burkill 1935) and the coastal communities of Sungai Pulai, Johore, still collect them for consumption (Japar Sidik et al. 1995a). In addition the softer parts of *E. acoroides* form fibers that were made into fishing nets (Burkill 1935). *Ruppia maritima* plants were used in fish ponds to aid in the aeration of the water, and the milk fish (*Chanos* spp.) feeds on it. This functional role has not been observed in Peninsular Malaysia, and is probably based on the observations made in the fishponds of Java, Indonesia (Burkill 1935).

Other forms of utilization include using seagrass areas for cage farming of fishes (*Lates calcarifer* and *Epinephelus sexfasciatus*) which started in 1991 or farming of oyster (*Saccostrea cacullata*) from 1998 (Japar Sidik et al. 1999a). Seagrass areas at Pengkalan Nangka, Kelantan, Paka shoal, Terengganu, and Tanjung Adang shoal, Johore, are used as collection and gleaning sites for food including fishes, gastropods (*Lambis lambis*, *Strombus canarium*), bivalves (*Gafrarium* sp., *Meretrix* sp., *Modiolus* sp.) and echinoderms (sea cucumber e.g. *Pentacta quadrangularis*, *Mensamaria intercedens*).

The Malaysian coastal zone is being subjected to a high degree of resource exploitation as well as pollution (Abdul Aziz 1989). Seagrass beds grow in shallow, coastal zone waters and this renders them susceptible to unplanned and unmanaged urban and industrial development. Losses of seagrass communities in the coastal areas of Malaysia by natural causes or human activities generally pass unnoticed or unrecorded. Sourcing for sand on the east coast is a common activity for landfill and shoreline stabilization projects. Dredging was carried out in the *Halophila beccarii* and *Halodule pinifolia* beds of Pengkalan Nangka, Paka shoal and Telaga Simpul. This dredging has lead to increased sedimentation, smothering of seagrasses and bed removal. More bed removal will eventually occur if dredging is to be continued to supply the increasing demand for sand.

Acknowledgements

We wish to thank Vice-Cancellor, Universiti Putra Malaysia, for encouragement and facilities. Our thanks are extended to the The Ministry of Science, Technology and Environment Malaysia for funding provided under the 'Intensification in Priorities Research Areas 6, 7 and 8 (1996–2001)' programme and some financial and travel supports from the Multilateral Core University Program "Coastal Marine Science" of the Japan Society for the Promotion of Science (JSPS).

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