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Salt marsh and seagrass communities of Bakkhali Estuary, Cox's Bazar, Bangladesh☆

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Abstract

The species identification, distribution pattern, density and biomass of salt marsh and seagrass plants with some of the ecological parameters were studied in the Bakkhali river estuary, Cox's Bazar, Bangladesh during the first half of 2006. Two salt marsh species (*Spartina* sp. and *Imperata cylindrica*) and one seagrass species (*Halophila beccarii*) were identified during this investigation, providing the first reports of *Spartina* sp. and *H. beccarii* in coastal Bangladesh. Seagrass *H. beccarii* was found in an accreted area and co-existing with salt marsh, and scattered sparsely in the salt marsh habitat and macroalgae *Ulva intestinalis*. Flowering and fruiting were recorded from the seagrass *H. beccarri* during January and February. No flowers and fruits were observed for the salt marsh *Spartina* sp. during the study period. Results showed that the shoot density of *Spartina* ranged from 400 to 2875 shoots m^{-2} with the highest total biomass (165.80 g dry weight (DW) m^{-2}) in March. Shoot density of *H. beccarii* ranged from 2716 to 14320 shoots m^{-2} in this estuarine coastal environment. The total biomass of seagrass was higher (17.56 g DW m^{-2}) in March compared to the other months. The highest *H. beccarii* above ground (AG) biomass and below ground (BG) biomass were 9.59 g DW m^{-2} and 9.42 g DW m^{-2}, respectively. These parameters are comparable with those generally observed for the salt marsh and seagrass species in the other places of the world.

Keywords: seagrass; *Halophila beccarii*; salt marsh; *Spartina* sp; biomass; Bangladesh

1. Introduction

Salt marshes are comprised of intertidal rooted vegetation periodically inundated by tidal waters, while seagrasses are extremely widespread underwater flowering plants which occur in coastal and estuarine waters worldwide (Day et al., 1989; Kirkman, 1990; Green and Short, 2003). Salt marsh and seagrass meadows physically filter suspended sediments from the water, help to reduce wave and current energy, and stabilize bottom sediments of the coastal area (Short and Short, 1984). Seagrass and salt marsh habitats are among the most productive ecosystems in the world in terms of the quantity of vegetation produced annually per unit area (Thayer et al., 1977; Day et al., 1989). The high primary production rates of both salt marsh and seagrass are closely linked to the high production rates of associated fisheries (Frasco and Good, 1982; Fortes, 1989). Some herbivores feed on salt marsh and seagrass directly, and a substantial fraction of plant carbon enters into the coastal and estuarine food web through the microbial process of litter and particulate organic detritus (Brouns, 1985a,b; Newell, 2001).

While well studied in some parts of the world, in Bangladesh there is very little scientific information on seagrass (Islam and Aziz, 1980; Islam, 1997) and salt marsh (*Imperata cylindrica*; Das and Siddiqi, 1985; Huq, 1986), and their related ecosystems. Therefore, this study was conducted with the following objectives: (a) to identify the number of species of salt marsh

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and seagrass occurring in the vicinity of the Bakkhali river estuary in Bangladesh; (b) to determine the shoot density and biomass as well as ecological status of the existing salt marsh and seagrass meadows.

2. Materials and methods

The study area was situated in the vicinity of the Bakkhali river estuary, Cox's Bazar (20° 85′ 40″–20° 46′ 92″ N and 91° 96′ 60″–92° 34′ 37″ E; Fig. 1) which has a maritime climate, and the temperatures are buffered by the nearby ocean (Khan and Karim, 1982). The maximum air temperature attained in summer ranges from 31.1–33.3 °C and minimum in winter ranges from 24.8–29.8 °C in the estuarine environment of Bangladesh (Mahmood et al., 1978; Mahmood, 1986). Drought conditions prevail during the winter months, i.e. November–February and rainfall is confined to the monsoon period. Normally, 80–90% of the annual rainfall occurs during the monsoon months of June–September. This study was conducted during the period of January to June 2006. Sampling was done monthly at the spring low tide. The Bakkhali estuary is an important river estuary with a harbor and important local fishery. The estuary is approximately 0.5 km wide and >10 m deep at its mid point. The tide in the coastal and estuarine area of Bakkhali is semi-diurnal with two high and two low periods as per day and maximum amplitude of 3 m at spring tide (Mahmood, 1986).

2.1. Salt marsh and seagrass parameters

2.1.1. Species identification

Fresh samples of salt marsh and seagrass were collected in plastic bags containing sea water and kept in an ice box. All samples were brought back to the Laboratory of Estuarine, Coastal and Aquaculture Research (LECAR) in the Institute of Marine Sciences and Fisheries (IMSF), University of Chittagong. Salt marsh and seagrass species identification were based on reference keys by Chapman (1977) and den Hartog (1970), respectively. All specimens were stored as herbarium sheets in the museum of the Institute of Marine Sciences and Fisheries for future reference.

2.1.2. Shoot density

Shoot density of salt marsh was estimated randomly by using a 20 × 20 cm quadrat in the intertidal and accreted area at the estuary in a permanent plot of 50 × 50 m. At least five quadrat samples were collected randomly from the sampling areas every month. For seagrass, the 20 × 20 cm quadrat was placed in the accreted area where seagrass grows only in association with salt marsh and macroalgae. Shoot density

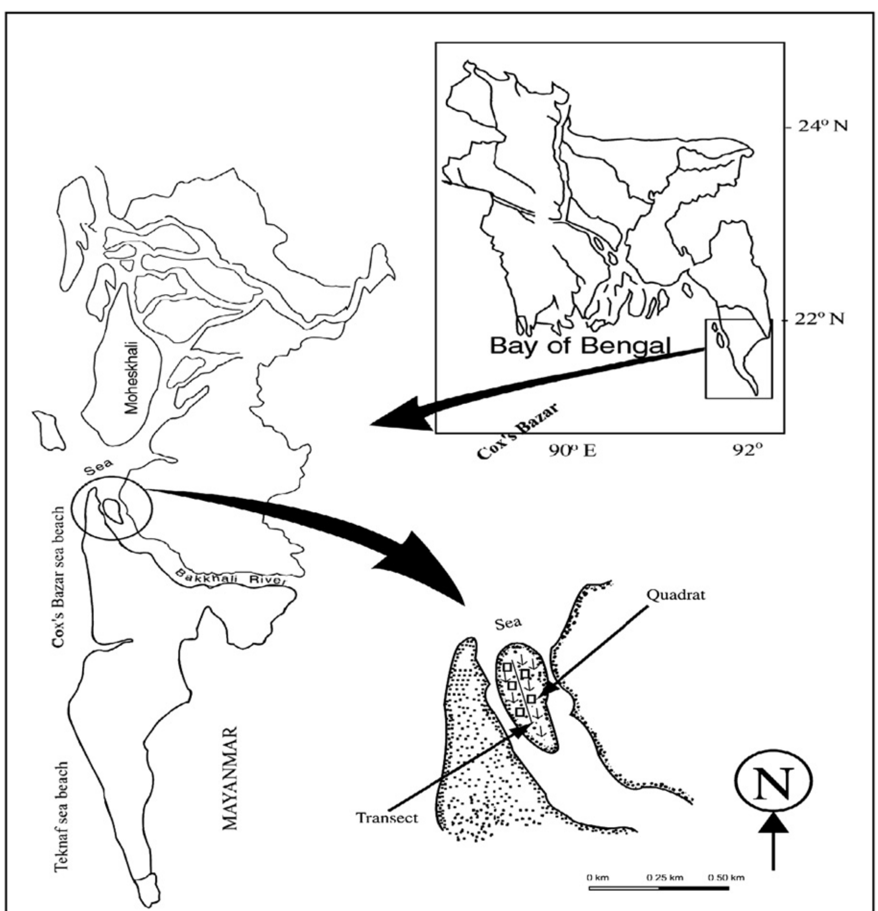

Fig. 1. Study area in the Bakkhali river estuary, Cox's Bazar, showing the location of the sampling area.

of seagrass was sampled along a 50 m transect, with five quadrats sampled each month (Fig. 1) following the procedure described by English et al. (1994) and Brower and Zar (1984). The quadrats were placed randomly along the transect. All plants inside the quadrats were collected in plastic bags carefully and brought back to the LECAR for future analysis. The samples were washed and counted manually in the laboratory. The data obtained were converted to shoots m^{-2}.

2.1.3. Salt marsh and seagrass biomass

Salt marsh and seagrass plants collected for density measures were rinsed briefly under running tap water. Leaves and sheaths for AG biomass were separated from roots and rhizomes for BG biomass. Epiphytes and algal communities were removed carefully from the plants by scraping with a knife (Kemp et al., 1987). Plant material was then dried at 75 °C for 48 h to obtain dry weight (DW) following the procedure described by Schubauer and Hopkinson (1984) and Norhadi (1993). The data obtained from this study were expressed as g DW m^{-2}.

2.2. Ecological parameters

2.2.1. Collection and analysis of soils

As an ecological study of the salt marsh and seagrass, water parameters such as temperature, transparency and salinity were measured *in situ* by mercury thermometer, Secchi disk (30 cm in diameter) and refractometer (0–100‰, OSK, Japan), respectively. Soil pH was detected *in situ* using a soil pH meter (soil tester, Takemura Electrical Works Ltd). Soil samples were collected using a mud corer, placed in plastic bags and labeled. After collection, all samples were brought back to the laboratory within 2–4 h for analysis. In the laboratory, the samples were dried at 100 °C for 24 h and powdered, sieved through a 0.5 mm stainless steel sieve and kept in a desiccator until further analysis. All determinations were in triplicate and the mean value was used to obtain representation of each parameter. The texture of the soil was analyzed following the procedure described by Bouyoucos (1962), soil organic matter by Boyd (1995) and soil carbon by Nelson and Sommers (1982).

3. Results

3.1. Species identification and distribution

Two species of salt marsh belonging to two families and one species of seagrass were recorded from the Bakkhali estuary study area. The salt marsh plants found were *Spartina* sp. (Family: Poaceae) and *Imperata cylindrica* (Family: Gramineae), and the seagrass was *Halophila beccarii* Ascherson (Family: Hydrocharitaceae). The salt marsh *Spartina* sp. and seagrass *H. beccarii* were both new records for Bangladesh (Plates 1 and 2) and other salt marsh *Imperata cylindrica* have been reported previously from the coastal areas of Bangladesh (Huq, 1986).

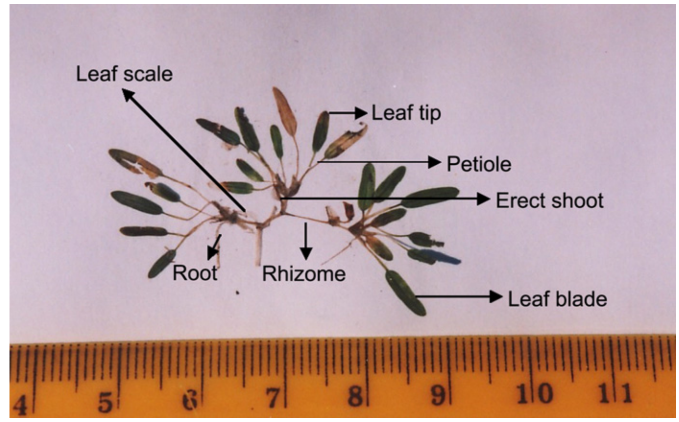

Plate 1. *Halophila beccarii* Ascherson of the Bakkhali river estuary, Cox's Bazar, Bangladesh.

The salt marsh *Spartina* was found as monospecific pure stand within the intertidal area but was also found in a 4-species association with the seagrass *Halophila beccarii*, patches of mangroves (*Avicennia alba*, *Avicennia marina* and *Acanthus ilicifolius*) and the macroalgae *Ulva intestinalis* in clay substrates. The salt marsh also grows in a 3-species association with mangroves and macroalgae, or with seagrass and macroalgae, as well as in a 2-species association with seagrass. Another species of salt marsh *Imperata cylindrica* was found growing patchily along the sheltered coast with the mangroves *A. ilicifolius* and the sea blite *Saudea* sp. in this estuarine environment. The seagrass *H. beccarii* was found growing scattered sparsely in accreted land of this estuarine

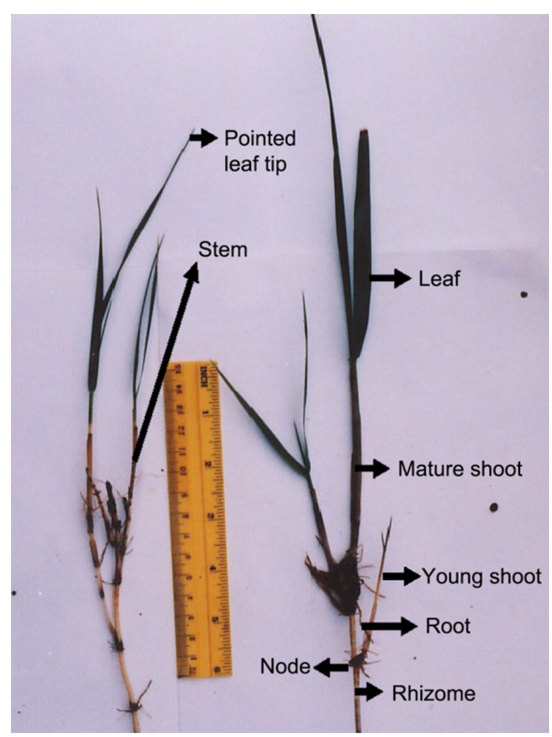

Plate 2. *Spartina* sp. from the Bakkhali river estuary, Cox's Bazar, Bangladesh.

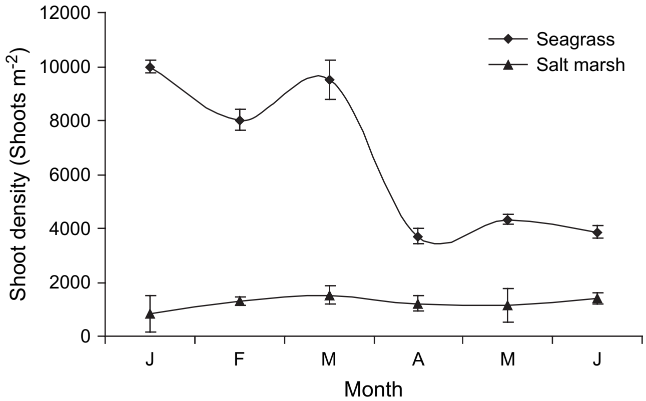

Fig. 2. Monthly variation of shoot density (shoots m^{-2}) of salt marsh and seagrass in the Bakkhali river estuary.

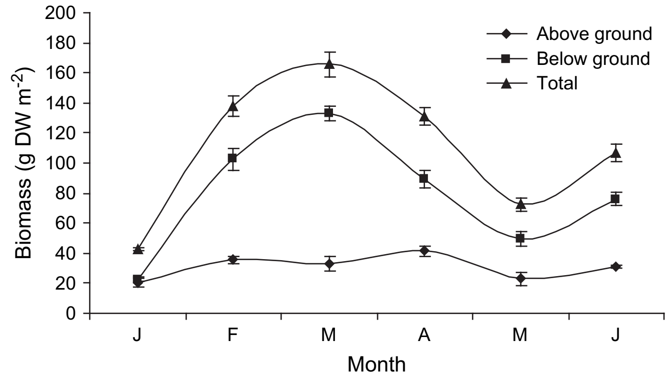

Fig. 3. Mean monthly biomass (g DW m^{-2}) of salt marsh *Spartina* sp. in the Bakkhali river estuary.

area. Seagrass was not recorded in the muddy mangrove area, but a 3-species association with *Spartina* sp. and *Ulva intestinalis* was noted. Flowering and fruiting of *H. beccarii* were recorded during January and February. Seagrass *H. beccarii* bears male and female flowers on the erect shoot of the same plants. However, flowers and fruits were not observed for salt marsh *Spartina* sp. and *I. cylindrica* during the study period.

3.2. Shoot density and biomass

Shoot density showed a monthly fluctuation for both salt marsh and seagrass. The ranges of shoot density of *Spartina* sp. and *Halophila beccarii* were 400–2875 shoots m^{-2} and 2716–14320 shoots m^{-2}, respectively. The shoot density of salt marsh *Spartina* sp. recorded higher (1522 shoots m^{-2}) in March. The mean value of shoot density for seagrass *H. beccarii* was 6570.65 shoots m^{-2}, peaking in the dry months (January–March) and decreasing in the wet months (April–June; Fig. 2). The average total biomass of shoots varied between 42.65 and 165.80 g DW m^{-2} for salt marsh *Spartina* and 4.43–17.56 g DW m^{-2} (from January to June), for seagrass *H. beccarii*. The below ground biomass (78.82 g DW m^{-2}, including rhizome and root biomass) of *Spartina* sp. was generally higher than the above ground biomass (30.65 g DW m^{-2}) during the study period. Biomass values showed some seasonal variation and the maximum average biomass values for both species were recorded in the dry months followed by a decline in the wet months (Figs. 3 and 4). Moreover, the AG and BG parts of the salt marsh and seagrass showed the lowest biomass toward the wet months. Regarding the total biomass of seagrass *H. beccarii* the above ground plants (6.85 g DW m^{-2}) were higher than the below ground plants (5.07 g DW m^{-2}) during the 6-month study period.

4. Discussion

The salt marshes grow in a wide range of habitats from coarse sand to sandy clay and muddy bottoms in the intertidal area. The coastal and estuarine area of Bakkhali is inhabited by a relatively simple coastal band of salt marsh creating brackish water tidal marshes with complex distribution patterns of vegetation. Altogether there are few genera (5) of salt marsh in the coastal and estuarine area of Bangladesh, four (*Imperata cylindrica*, *Eriochloa procera*, *Myriostachya wightiana* and *Phragmites karka*) of which grow in the South Asian and South East Asian subtropical and tropical coasts (Das and Siddiqi, 1985). The salt marsh *Spartina* spp. are concentrated in different geographical regions, i.e., Central American coasts (Caribbean-Eastern-Pacific), South American coasts, North American coasts and also harboring in the Western Indo-Pacific coasts (Hitchcock, 1951; Alderson and Sharp, 1994).

The present study deals with the first quantitative data on distribution and biomass of salt marsh and seagrass in the Bakkhali river estuary, sampled over a period of 6 months. The shorter period of study does not allow firm conclusions and quantitative distribution patterns, and results from future research may slightly differ from the present findings and views.

Seagrass plants are rather simple ecological structures containing one seagrass species, in contrast to the adjacent estuarine or coral reef with their overwhelming biodiversity (Abu Hena, unpublished data). It is a fact that the relatively simple community structure of seagrass beds, dominant and frequently occurring, are good candidates for quantitative

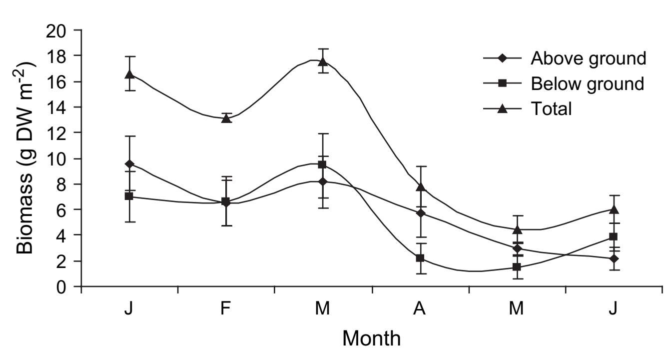

Fig. 4. Mean monthly biomass (g DW m^{-2}) of seagrass *H. beccarii* in the Bakkhali river estuary.

ecological study. Out of 5 seagrass species available in the coastal waters of Bangladesh (Islam and Aziz, 1980; Islam, 1997; Abu Hena, 2007) only one species of seagrass has been found to date in the coast of Cox's Bazar, Bangladesh, inhabiting sandy (86.07%) and clay (12.72%) substrate occasionally interrupted by silt. Similarly, seagrass *Halophila beccarii* was found growing in the intertidal brackish water in a river mudflat and mangrove system in Malaysia (Zakaria et al., 1998, 1999), river mouth and mangrove mudflats in Singapore (den Hartog, 1970), estuaries and marine environment in India (Ramamurthy, 1981) (Table 1).

The seagrass *Halophila beccarii* from the Bakkhali river estuary bearing male and female flowers on the erect shoot of the same plants. A similar type of seagrass *H. beccarii* was found in the tropical coast inhabiting with mangroves (Zakaria et al., 1999). The flowering and fruiting of *H. beccarii* was present for January and February in the present study. Several studies reported the flowering and fruiting of *H. beccarii* to be periodic and seasonal. It occurred during February, March, April, June and August (den Hartog, 1970; Menez et al., 1983; Parthasarathy et al., 1991) and during October when water salinity was low at 5.38 in the mangrove area of Goa, India (Jagtap and Untawale, 1981). Continuous flowering and fruiting throughout the year were observed for *H. beccarii* in Kemaman, Malaysia (Zakaria et al., 1999), *Halophila decipiens* in Panama (McMillan and Soong, 1989) and *Halophila johnsonii* in Florida (Jewett-Smith et al., 1997). However, the present flowering and fruiting of seagrass *H. beccarii* occurs during the dry months at 16–35 water salinity, 21–29.5 °C water temperature, 30–55 cm transparency, 6.0–6.6 soil pH, 1.58–3.34% soil organic matter and 0.83–1.76% soil organic carbon in the Bakkhali estuarine and coastal area of Bangladesh.

Shoot density is a parameter of community structure, which is often used as an indication of standing stock (Jacobs, 1984). Shoot density of both species was comparable with values recorded elsewhere (Schubauer and Hopkinson, 1984; Parthasarathy et al., 1991; Zakaria, 2001) (Table 2). Studies revealed that the variation in shoot density depends on species but also on ecological circumstances (Agostini et al., 2003). Covering of the above ground plants and below ground parts of the salt marsh seems a reliable indicator for total biomass or standing crop. The biomass of salt marsh *Spartina* sp. exhibited monthly patterns, i.e., higher in the dry months and lower in the wet months. The seasonal patterns and the biomass values were reported for *Spartina alterniflora* and *Spartina cynosuroides* in other riverine and estuarine areas elsewhere (Hopkinson et al., 1978; Gallagher et al., 1980). The level of biomass was lower to those previously reported by Weiss et al. (1979), Sanckez et al. (2001) and Schubauer and Hopkinson (1984) in the coastal area of USA (Table 3).

The level of biomass of any seagrass species is directly related to the important role they play in the ecosystem (Costanza et al., 1997). The biomass values of seagrass *Halophila beccarii* in the Bakkhali estuary were comparable to that found by other authors at various geographical locations (Parthasarathy et al., 1991; Zakaria, 2001) (Table 3). Norhadi (1993) stated that the seagrass beds, particularly in the muddy habitat bordering mangroves, were found to produce more biomass. On the other hand, Agostini et al. (2003) revealed that the differences in biomass of seagrass *Cymodocea nodosa* depend on the age and functionality of the tissue. Furthermore, the changes in seagrass shoot density may be influenced by changes in biomass (Vermaat and Verhagen, 1996). Consequently biomass and shoot density are interdependent for aquatic macrophytes like seagrass (Olesen and Sand-Jensen, 1994). Abu Hena et al. (2004) and Backman and Barilotti (1976) found a linear relationship between biomass and shoot density for seagrass *Thalassia hemprichii* and *Zostera marina* respectively elsewhere. Studies by Zakaria (2001) stated that no single factor is responsible for the relationship between biomass and shoot density. In

Table 1
Location and habitat descriptions of *H. beccarii*

Location	Habitat description	Reference
Malaysia	Mudflat and also among the roots of mangrove species, i.e. *Avecennia alba*, *Bruguiera cylindrica* and *Kandelia candel*	Zakaria et al. (1998, 1999)
Singapore	Sandbank in centre of shallow broad waterway of mangrove, exposed at low water tide	den Hartog (1970)
India	Coastal and estuarine environment	Ramamurthy (1981)
Bangladesh	Estuarine intertidal zone and river bank with salt marsh *Spartina* sp., macroalgae *Ulva intestinalis*	This study

Table 2
Comparison of shoot density of seagrass and salt marsh species

Location	Shoot density (shoots m^{-2})	Reference
Seagrass		
India	3632–6152	Parthasarathy et al. (1991)
Malaysia	583.3–10305.56	Zakaria, 2001
Bangladesh	2716–14320	This study
Salt marsh		
Atlantic and Gulf coast, USA	1215–2000	Weiss et al. (1979)
Georgia, USA	733–1234	Schubauer and Hopkinson (1984)
North-west Spain	300–1944	Sanckez et al. (2001)
Bangladesh	400–2875	This study

Table 3
Comparison of AG and BG biomass of sea grass and salt marsh species with other studies in the region

Location	AG biomass (g DW m^{-2})	BG biomass (g DW m^{-2})	Reference
Seagrass			
India	4.3–19.8	1.9–8.6	Parthasarathy et al. (1991)
Malaysia	0.54–45.32	0.39–31.47	Zakaria, 2001
Bangladesh	2.18–9.59	1.45–9.42	This study
Salt marsh			
Bangladesh	15.67–50.24	21.13–148.76	This study
Georgia, USA	175–733	310–315	Schubauer and Hopkinson (1984)

the Philippines, the shoot density, growth, biomass and frequency of occurrence of tropical seagrasses was found to be directly associated with water parameters (Fortes, 1989). It is likely that several environmental and physical factors, i.e., soil organic matter, water quality, activities of domestic animal and coastal communities probably are important in controlling the shoot density and biomass of coastal and estuarine macrophytes. However, the human interruption and grazing effect of domestic cattle cannot be overlooked, and probably influence the distribution, growth and biomass production of these macrophytes especially taller salt marsh *Spartina* sp. compared to creeping seagrass *H. beccarii*.

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References

Abu Hena, M.K., 2007. Seagrass *Halodule pinifolia*, *H. uninervis* and *Halophila beccarii*. In: Rahaman, M.M. (Ed.), Encyclopedia of Flora and Fauna of Bangladesh. Asiatic Society of Bangladesh, Dhaka.

Abu Hena, M.K., Misri, K., Japar Sidik, B., Hishamuddin, O., Hidir, H., 2004. A preliminary study of the biological aspects of an intertidal seagrass *Thalassia hemprichii* (Ehrenberg) Ascherson in Port Dickson, Malaysia. Pakistan Journal of Biological Science 7 (10), 1801–1807.

Agostini, S., Pergent, G., Marchand, B., 2003. Growth and primary production of *Cymodocea nodosa* in a coastal lagoon. Aquatic Botany 76 (3), 185–265.

Alderson, J., Sharp, W.C., 1994. Grass varieties in the United States. Agriculture Handbook No. 170, USDA. SCS, Washington, DC.

Backman, T.W., Barilotti, D.C., 1976. Irradiance reduction: effects on standing crops of the eelgrass *Zostera marina* in a coastal lagoon. Marine Biology 34, 33–40.

Bouyoucos, G.J., 1962. Hydrometer method improving for making particle size analysis of soils. Agronomy Journal 54, 464–465.

Boyd, C.E., 1995. Bottom Soils, Sediment and Pond Aquaculture. Chapman and Hall, New York, USA, 348 pp.

Brouns, J.J.W.M., 1985a. A preliminary study of seagrass *Thalassodendron ciliatum* (Forsssk.) den Hartog from eastern Indonesia, biological results from the Snellius II expedition. Aquatic Botany 23, 249–260.

Brouns, J.J.W.M., 1985b. Aspects of the production and biomass of four seagrass species (Cymodoceoidae) from Papua New Guinea. Aquatic Botany 23, 149–175.

Brower, J.E., Zar, J.H., 1984. Field and Laboratory Methods for General Ecology. Wm. C. Brown Publishers, USA, 226 pp.

Chapman, V.J., 1977. Wet Coastal Ecosystems. Ecosystems of the World. I. Elsevier, Amsterdam, 428 pp.

Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., Limburg, K., Naeem, S., O'Neill, R.V., Paruelo, J., Raskin, R.G., Sutton, P., van der Belt, M., 1997. The value of the world's ecosystem services and natural capital. Nature 387, 253–260.

Das, S., Siddiqi, N.A., 1985. The Mangrove and Mangrove Forests of Bangladesh, Bangladesh Forest Research Institute/FAO, 142 pp.

Day, J.W.J., Hall, C.A.S., Kemp, W.M., Yanez-Arancibia, A., 1989. Estuarine Ecology. John Wiley and Sons, pp. 558.

English, S., Wilkison, C., Baker, C., 1994. Survey Manual for Tropical Marine Resources. ASEAN-Australia Marine Science Project: Living Marine Resources. ASEAN-Australia Marine Science, AIDAB. Australian Institute of Marine Science Publishers, Townsville, Australia, 368 pp.

Fortes, M.D., 1989. Seagrass: a Resource Unknown in the ASEAN region. ICLARM Education Series 5. Philippines, Manila, 46 pp.

Frasco, B.A., Good, R.E., 1982. Decomposition dynamics of *Spartina alterniflora* and *Spartina patens* in a New Jersey salt marsh. American Journal of Botany 69 (3), 402–406.

Gallagher, J.L., Reimold, R., Linthurst, R., Pfeiffer, W., 1980. Aerial production, mortality, and mineral accumulation-export dynamics in *Spartina alterniflora* and *Juncus roemerianus* plant stands in a Georgia salt marsh. Ecology 61, 303–312.

Green, E.P., Short, F.T., 2003. World Atlas of Seagrasses. University of California Press, Berkeley, CA, 324 pp.

den Hartog, C., 1970. Seagrass of the World. Elsevier/North-Holland, Amsterdam.

Hitchcock, A.S., 1951. Manual of the Grasses of the United States. USDA, Washington, DC.

Hopkinson, C.S., Gosselink, J.G., Parrondo, R.T., 1978. Aboveground production of seven marsh plant species in coastal Louisiana. Ecology 61, 1091–1098.

Huq, A.M., 1986. Plants Names of Bangladesh (Native and Scientific). Bangladesh National Herbarium (BARC), Dhaka, 228 pp.

Islam, A.K.M., 1997. A new record of a seagrass (*Halophila decipens* Ostenfeld) for Bangladesh. Bangladesh Journal of Plant Taxonomy 4 (1), 93–97.

Islam, A.K.M.N., Aziz, A., 1980. A marine angiosperm from St. Martin's Island, Bangladesh-*Halodule uninervis* (Forsskal) Ascherson. Bangladesh Journal of Botany 9 (2), 177–178.

Jacobs, R.P.W.M., 1984. Biomass potential of eelgrass (*Zostera marina* L.). Critical Review of Plant Science 2, 48–80.

Jagtap, T.C., Untawale, A.G., 1981. Ecology of seagrass bed of *Halophila beccarii* Aschers. in Mandovi estuary, Goa. Indian Journal of Marine Science 10, 402–404.

Jewett-Smith, J., McMillan, C., Kenworthy, W.J., Bird, K., 1997. Flowering and genetic band patterns of *Halophila johnsonii* and co specific. Aquatic Botany 59, 323–331.

Kemp, W.M., Murray, L., Borum, J., Sand-Jensen, K., 1987. Diel growth in eelgrass *Zostera marina*. Marine Ecology Progress Series 41, 79–86.

Khan, M.S., Karim, A., 1982. Utilization of deltatic zone. In: Fredericks, M.J. (Ed.), Man, land and sea: coastal resource use and management in Asia and the fisheries sector in mangrove environment. Journal of Malaysian Economic Association 13, 40–50.

Kirkman, H., 1990. Seagrass distribution and mapping. In: Phillips, R.C., McRoy, C.P. (Eds.), Seagrass Research Methods. UNESCO, France, pp. 19–25.

Mahmood, N., 1986. Effects of shrimp farming and other impacts on mangroves of Bangladesh. Proceedings of the Workshop of Strategies for the Management of Fisheries and Aquaculture in Mangrove Ecosystems. Thailand, Bangkok, FAO Fisheries Report No. 370, pp. 46–66.

Mahmood, N., Khan, Y.S.A., Ahmed, M.K., 1978. Hydrology of the Karnafully estuary with special reference to prawn and other larvae of economic importance. Final Report. University Grants Commission, Research Program, 33 pp.

McMillan, C., Soong, K., 1989. An annual cycle of flowering, fruiting and seed reserve for *Halophila decipiens* Ostenfeld (Hydrocharitaceae) in Panama. Aquatic Botany 34, 375–379.

Menez, E.G., Phillips, R.C., Calumpong, H.P., 1983. Seagrasses from Philippines, Smithsonian Contribution to the Marine Sciences No. 21. Smithsonian International Press, Washington, DC, 40 pp.

Nelson, D.W., Sommers, L.E., 1982. Total carbon, organic carbon and organic matter. In: Page, A.L. (Ed.), Methods of Soil Analysis, Part W, Chemical and Microbiological Properties. American Society of Agronomy, Inc. Soil Science Society of America, Inc., Madison, WI, pp. 539–579.

Newell, S.Y., 2001. Multiyear patterns of fungal biomass dynamics and productivity within naturally decaying smooth cord grass shoots. Limnology and Oceanography 46 (3), 573–583.

Norhadi, I., 1993. Preliminary study of the seagrass flora of Sabah, Malaysia. Pertanika Journal of Tropical Agriculture Science 16, 111–118.

Olesen, B., Sand-Jensen, K., 1994. Biomass-density patterns in the temperate seagrass *Zostera marina*. Marine Ecological Progress Series 109, 283–291.

Parthasarathy, N., Ravikumar, K., Ganesan, R., Ramamurthy, K., 1991. Distribution of seagrasses along the coast of Tamil Nadu, Southern India. Aquatic Botany 40, 145–153.

Ramamurthy, K., 1981. Observation on the vegetation of South Arcot District, Tamil Nadu. Bulletin Botanical Survey India 23, 107–109.

Sanckez, J.M., Sanleon, D.G., Izco, J., 2001. Primary colonisation of mudflat estuaries by *Spartina maritima* (Curtis) Fernald in Northwest Spain: vegetation and sedimentation accretion. Aquatic Botany 69, 15–25.

Schubauer, J.P., Hopkinson, C.S., 1984. Above and belowground emergent macrophytes production and turnover in a coastal marsh ecosystem, Georgia. Limnological Oceanography 29 (5), 1052–1065.

Short, F.T., Short, C.A., 1984. The seagrass filter: purification of coastal water. In: Kennedy, V.S. (Ed.), The Estuary as a Filter. Academic Press, pp. 395–413.

Thayer, G.W., Engel, D.W., La Croix, M.W., 1977. Seasonal distribution and changes in the nutritive quality of living, dead and detrital fractions of *Zostera marina* L. Journal of Experimental Marine Biology and Ecology 30, 109–127.

Vermaat, J.E., Verhagen, F.C.A., 1996. Seasonal variation in the intertidal seagrass *Zostera noltii* Hornem: coupling demographic and physiological patterns. Aquatic Botany 52, 259–281.

Weiss, T.E., White, D.A., Thien, L.B., 1979. Seasonal dynamics of salt marsh plant associations in Louisiana. Contribution in Marine Science 22, 41–52.

Zakaria, M.H., 2001. Ecology and biology of seagrass *Halophila beccarii* Aschers. in Peninsular, Malaysia. PhD thesis. University of Putra, Malaysia, 360 pp.

Zakaria, M.H., Japar Sidik, B., Hishamuddin, O., 1998. Rumput laut *Halophila beccarii* Ascherson. Fisheries Journal Garing 7 (2), 19–25.

Zakaria, M.H., Japar Sidik, B., Hishamuddin, O., 1999. Flowering, fruiting and seedling of *Halophila beccarii* Ascherson (Hydrocharitaceae) from Malaysia. Aquatic Botany 65, 199–207.