South African Journal of Botany 2001 67 420–425
Printed in South Africa — All rights reserved

SOUTH AFRICAN JOURNAL OF BOTANY
ISSN 0254-6299

Minireview

Seagrass research in the eastern Africa region: emphasis on diversity, ecology and ecophysiology

SO Bandeira[1]* and M Björk[2]

[1] *Department of Biological Sciences, Eduardo Mondlane University, PO Box 257, Maputo, Mozambique*
[2] *Botany Department, Stockholm University, 10691, Stockholm, Sweden*
* *Corresponding author, e-mail: sband@zebra.uem.mz*

Received 7 April 2001, accepted in revised form 8 June 2001

This paper presents a brief review of seagrass research in the eastern African region, including Somalia, Kenya, Tanzania, Mozambique, eastern South Africa, Seychelles, Comoros, Madagascar, Reunion and Mauritius. Only about 60 references have been published from this region since the 1930's, covering mainly seagrass diversity and ecology, and only about 30 of these have been published during the last 10 years in international journals. These covered mainly ecology, ecophysiology and anatomy/histochemistry. Considering this and the fact that eastern Africa with its 12 species is a region of high diversity of seagrasses, seagrass research in the region appears to be in its infancy. Apart from the need for continued survey and mapping activities, future research has to focus on the significance of seagrass beds in the region, their role in the coastal ecosystem and how they are affected by various anthropogenic changes.

Introduction

Seagrasses comprise a small taxonomic group of marine angiosperms with only about 50 species, which have a world wide distribution and have adapted to a life in seawater by the development of a specific morphology with an anchorage system made up of rhizomes and roots, air lacunae to supply roots with oxygen, flowers with hydrophilous pollination and, in some species, vivipary (Den Hartog 1970, Larkum *et al.* 1989, Elmqvist and Cox 1996). They have the ability to take up nutrients by both roots and leaves (Stapel *et al.* 1996, Pedersen *et al.* 1997, Hemminga 1998), and are mostly clonal plants with shoots (vertical rhizomes) arising from horizontal rhizomes below the ground. Most species have more or less flat linear leaves with parallel veins, except *Halophila* spp., with petiolate leaves, and *Syringodium isoetifolium* (Aschers.) Dandy, with terete leaves. Many of the intertidal seagrass species generally have short stems, while plants growing subtidally may reach considerable lengths. The tallest seagrass species encountered in the East African region is *Thalassodendron ciliatum*, which can measure up to 126cm in length. This was observed from a collection in Inhassoro (21°32'S, 35°12'E), southern Mozambique. *Enhalus acoroides* can also attain considerable length and was observed having up to 100cm length in this region. The smallest ones are the three species of the genus *Halophila*, the species *H. minor* normally only reaching less than 2cm height above bottom.

Seagrasses play an important role in shallow-water ecosystems of both tropical and temperate zones. They have a high productivity, and the rate can be compared to that of crop plants (Dring 1982, Larkum *et al.* 1989). The seagrass beds increase the biodiversity of plants, animals, fungi etc. in the areas where they occur (e.g. Oshima *et al.* 1999, Rindi *et al.* 1999), act as a shelter for juvenile animals and as nursery and foraging areas for many species (e.g. Harlin 1980, Larkum *et al.* 1989). In addition, they trap nutrients (Gacia *et al.* 1999) and promote their recycling, as seagrass decomposition is quite high (Newell *et al.* 1984, Ochieng and Erftemeijer 1999). Seagrass meadows may also act both as sinks and sources for particles (e.g. Gacia *et al.* 1999, Koch 1999). Some of these particles, containing different nutrients, play an important role in seagrass growth dynamics and nutrient budgets. The importance of seagrass beds for littoral nutrient budgets is complex, as a number of models try to explain (e.g. Pergent *et al.* 1994, Erftemeijer and Middelburg 1995, Pergent *et al.* 1997, Oshima *et al.* 1999). In Kenya, Ochieng and Erftemeijer (1999) estimated that around 82 tonnes of dry weight of beach cast material (dispersed in about 10km of coastline) belonged to seagrasses, most of it (c. 62 tonnes) were leaves of *T. ciliatum*. Senescent and detached leaves of *T. ciliatum* are also common in coastal areas and sand dunes, increasing the nutrient content of these nutrient poor marginal areas. De Boer

(2000) estimated that the seagrasses such as *Halodule wrightii* Aschers. and *Zostera capensis* Setchell were the main nutrient source in the southern bay at Inhaca Island contributing altogether with 490, 30 and 2 tones of C, N and P, respectively.

Economically, seagrasses can be utilised for paper production, green manure, flour (seeds of *Zostera marina* L. in Mexico) and fodder. *Thalassia hemprichii* is used in salads in the Philippines (Cordero 1981). Seeds of *Enhalus acoroides* are eaten raw or boiled in the Philippines (Montano *et al.* 1999) and reported to be used as food in periods of food scarcity in Kenya (Cox 1991). Seagrasses are also used in traditional medicine in India (Parthasarathy *et al.* 1991). Overall economic value of seagrasses can be divided in use value (e.g. direct/indirect uses and/or benefits to humans), and existence value (abstract values not necessarily related to human benefits or use). These values are good indicators of the ecological and economical losses when seagrass habitats are destroyed (Thorhaug 1990, Costanza *et al.* 1997, NSW Fisheries 1997). In money terms, this overall seagrass value has been estimated by Costanza *et al.* (1997) to 19 004USD ha^{-1} year^{-1}.

The present study presents a review of seagrass research performed in the eastern African region. Emphasis is given to studies on seagrass diversity and ecology. We have based the review on research work from the region and it covers published research in the eastern African countries including the island states located in the western Indian ocean viz: Somalia, Kenya, Tanzania, Mozambique, eastern South Africa, Seychelles, Comoro, Madagascar, Reunion and Mauritius.

History of seagrass research in the western Indian Ocean

Around 60 published references (see bibliography in reference list) on seagrasses have been published in the region covering the following main fields of research: Taxonomy and distribution (e.g. Isaac 1968, Bandeira 1997a, Spalding and Phillips 1998), ecology (e.g. Hemminga *et al.* 1994, Duarte et al. 1996, Ochieng and Erftermeijer 1999), ecophysiology (e.g. Björk *et al.* 1997, 1999, Beer and Björk 2000), anatomy and histochemistry (e.g. Barnabas 1982, 1983, 1991, 1994), flowering and pollination (e.g. McMillan 1980, Cox 1991) and feeding preferences (Mariani and Alcoverro 1999). Pioneering publications on seagrasses in the region are the ones by Moss (1937), Cohen (1939), Chasse (1962), Isaac (1968) which all covered mainly taxonomical descriptions of seagrasses in Kenya, Madagascar and Mozambique. The dominant part of seagrass research from the region covered the field of ecology (Figure 1). Work from the period 1991–2000 indicates that most recent research on seagrasses was performed in Kenya, Tanzania, Mozambique and South Africa (Figure 2). Examples of important references per country are given in Table 1.

Diversity of seagrasses in eastern Africa

Twelve seagrass species occur in the eastern African region, grouped in three families: Hydrocharytaceae with the species *Enhalus acoroides* (L.f.) Royle, *Halophila minor* (Zoll.) den Hartog, *H. ovalis* (R. Br.) Hook. *f.*, *H. stipulacea* (Forsk.) Aschers. and *Thalassia hemprichii* (Ehrenberg) Asherson; Zosteraceae with *Zostera capensis* Setchell and Cymodoceaeae with *Cymodocea rotundata* Ehrenb. et Hempr. ex Aschers., *C. serrulata* (R. Br.) Aschers. et Magnus, *Halodule uninervis* (Forsk.) Aschers. in Bossier, *H. wrightii* Ascherson, *Syringodium isoetifolium* (Ascherson) Dandy and *Thalassodendron ciliatum* (Forsk.) den Hartog. These 12 species comprise about a fifth of the worlds total seagrass species. This is quite diverse if compared with some other seagrass areas such as the Mediterranean Sea with four species and eight species in the Caribbean Sea with the Gulf of Mexico and Florida. However, Western

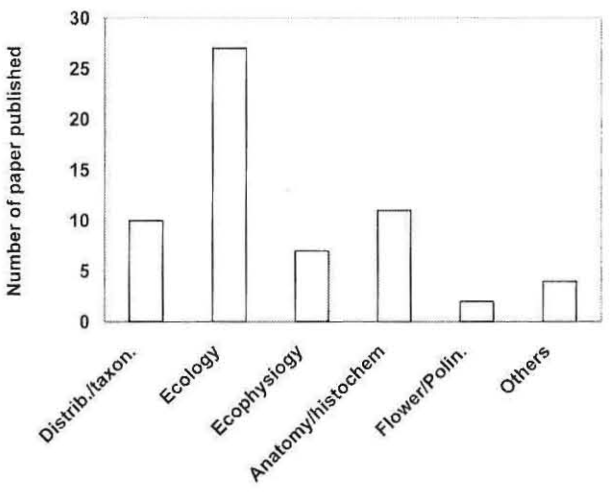

Figure 1: Number of papers per subject groups published in the eastern African region

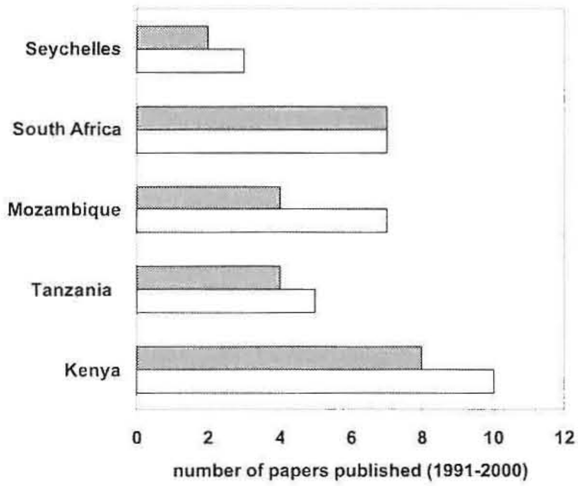

Figure 2: Number of publications per country in the period 1991–2000 (grid bars indicate publications in international journals)

Table 1: Examples of important seagrass references given per country

Country:	Reference
Kenya	Isaac 1968
	McMillan 1980
	Cox 1991
	Coppejans *et al.* 1992
	Hemminga *et al.* 1995
	Wakibya 1995
	Duarte *et al.* 1996
	Uku *et al.* 1996
	Ochieng and Erftemeijer 1999
Tanzania	Semesi 1988
	Björk *et al.* 1997, 1999
	Beer and Björk 2000
	Schwarz *et al.* 2000
	Leliaert *et al.* 2001
Mozambique	Moss 1937
	Cohen 1939
	Macnae 1969
	Johnson *et al.* 1993
	Bandeira 1997b
	De Boer 2000
South Africa	Barnabas 1982, 1983, 1988, 1991, 1994
	Barnabas and Kasavan 1983
	Barnabas and Arnott 1987
	Barnabas *et al.* 1977, 1980
	Iyer and Barnabas 1993
	Adams and Talbot 1992
Seychelles	Pärnik *et al.* 1992
	Titlyanov *et al.* 1995
Comoros	UNEP 1997
Madagascar	e.g. Pichon1964

Australia has more than twice as many, 26 species (Den Hartog 1970, Kuo and McComb 1989). Occurrence of *Enhalus acoroides, Halophila stipulacea* and *Halophila minor* is mainly reported from northern Mozambique to Tanzania and Kenya, whereas *Zostera capensis* is most common in southern Mozambique (e.g. Maputo bay) (Isaac 1968, Bandeira 2000). Mixed seagrass beds are common in the region, often with a high diversity. Eight seagrass species occur in the small southern bay of Inhaca Island, Mozambique (Bandeira 2000), and 11 out of the 12 species reported from the region have been found in one seagrass bed in Zanzibar, with only *Zostera capensis* lacking (Bandeira, Björk and Beer, unpublished)

T. ciliatum in Kenya is called 'Mikuku' in Swahili (Cox 1991), in Tanzania seagrasses and seaweeds are generally called 'Mwani' in Kiswahili (Bandeira 1997b) and at Inhaca Island they are called 'Tanhi' in Xironga. *Zostera capensis* occurs mostly in southern Mozambique and South Africa where monospecific stands may occur. *Halophila minor* and *Enhalus acoroides* are common in Tanzania and Kenya and areas of northern Mozambique.

Seagrasses disperse by the lateral growth of the rhizomes and several species have only rarely been seen flowering. Out of the 12 species occurring in the region, flowering have been observed in *Cymodocea serrulata, Enhalus acoroides, Halodule uninervis, Halophila minor, H. ovalis, H. stipulacea, Syringodium isoetifolium, Thalassodendron ciliatum* and *Thalassia hemprichii* (Isaac 1968, McMillan 1980). Frequent flowering occurs in a few species such as *Halophila ovalis, Syringodium isoetifolium, Thalassia hemprichii* and *Thalassodendron ciliatum.*

Seagrass ecology and ecophysiology

The ecological seagrass research in the region has mainly covered aspects of distribution, structure and productivity (e.g. Duarte 1996, Bandeira 1997b), tolerance to salinity (e.g. Adams and Bate 1994a), seagrass associated with seaweeds (e.g. Coppejans *et al.* 1992), and seagrass epiphytes (Semesi 1988, Leliaert *et al.* 2001, Uku and Björk in this volume).

Leaf growth rate in *Thalassodendron ciliatum* has been reported to vary between 7.5 to 9.5g DW m^{-2} day^{-1}, and the total biomass of this species could reach 862g DW m^{-2} in sandy habitats (Bandeira 2000). Research on nutrients, covered mainly the study of C, N and P concentrations in *Thalassodendron ciliatum* (e.g. Hemminga *et al.* 1995), nutrient resorption from elder to younger leaves of species such as *T. ciliatum* (e.g. Stapel and Hemminga 1997, Bandeira 2000) and nutrient fluxes between mangroves and seagrasses (De Boer 2000). Hemminga *et al.* (1994) also studied carbon fluxes from mangrove forest to seagrass *T. ciliatum* and coral reefs. This issue also publishes a paper on nutrient concentrations and resorption on *Thalassia hemprichii* in Mozambique (see paper by Martins and Bandeira).

Ecophysiological research in the region has compared photosynthetic performances of different seagrasses (e.g. Johnson *et al.* 1993, Björk *et al.* 1997, 1999, Beer and Björk 2000, Schwarz *et al.* 2000) using oxygen and carbon measurements as well as PAM fluorometry. Björk *et al.* (1997) proposed that eight seagrass species in Zanzibar were all limited by the inorganic carbon availability in the natural seawater and could not reach maximal photosynthetic rates. Schwarz *et al.* (2000) conducted a similar study, with *in situ* measurements on seagrasses in Zanzibar and found contrary to Björk *et al.* (1997), that subtidal populations, were not carbon limited, thus highlighting the need for *in situ* measurements for a better understanding of inorganic carbon limitation in seagrasses. Measurements of photosynthetic performances from other countries in the region are scarce, but the adaptation level seem to be comparable in different parts, the saturating irradiance for *T. cilatum* from Inhaca (Johnson *et al.* 1993) was quite similar to what could be measured in shallow-growing plants of the same species in Seychelles (Titlyanov *et al.* 1995). In a study on desiccation tolerance on intertidal and upper sub tidal species, Björk *et al.* (1999) reported that the species growing in the highest intertidal did not appear to be more resistant to desiccation stress than other more submerged species. It was instead suggested that other factors, such as avoidance of dehydration, plays an important role in the zonation pattern of seagrasses exposed to high tidal variations

Other research on seagrasses in the region

Barnabas and co-workers performed anatomical and histochemical research on seagrasses from South Africa (Barnabas 1982, 1983, 1988, 1991, 1994, Barnabas and Arnott 1987, Barnabas and Kasavan 1983, Barnabas *et al.* 1977, 1980) This research covered mainly leaf and root structure and its relation to functional aspects in a number of seagrass species e.g. *Halodule uninervis, Thalassodendron ciliatum, Zostera capensis.*

Mariani and Alcoverro (2000) pioneered in studying fish feeding-preference of seagrasses in Kenya. This study concluded that fish grazing had less preference for long-lived species such as *Enhalus acoroides* and *Thalassodendron ciliatum*, in contrast with higher preference for short-lived species such as *Cymodocea rotundata* and *Syringodium isoetifolium.*

A study on genetic diversity in *Thalassodendon ciliatum* from southern Mozambique was recently carried out using random amplified polymorphic DNA (RAPD) (Bandeira and Nilsson, in press). A high genetic diversity was observed in this species.

Future needs in seagrass research in the region

Research on seagrasses in eastern Africa is still in its infancy. Thus basic research such as studies on distribution, structure and growth dynamics are still greatly needed. However, there is an even greater lack of studies on ecological valuation, impact assessment, studies on pollution effects and linkages to other habitats. In our view, one of the most important challenges for researchers will be to assess the ecological and social importance of seagrass beds in the region, especially those potentially threatened by human activities. Erftemeier *et al.* (see this volume) pointed out five broad research themes for marine botanical work in the eastern Africa region: Pollution, river discharges, habitat degradation and recovery, climate changes, mariculture and natural products. It is our suggestion that future seagrass research in this region follow the same themes and that a strong emphasis is put on supplying the required knowledge and monitoring data for proper management of seagrass habitats in the future.

Acknowledgements — The authors would like to thank Janine Adams, Rachel Rabesandratana and Said Ahamada for providing additional bibliometric data. Erik Söderbäck, Marcus C Öhman and Maricela de la Torre Castro are thanked for constructive comments on the manuscript. SAREC is acknowledged for economical assistance.

References

Bibliography published in the eastern African region (includes also references not cited)

Adams JB, Talbot MMB (1992) The influence of river impoundment on the estuarine seagrass *Zostera capensis* Setchell. Botanica Marina **35**: 69–75

Adams JB, Bate GC (1994) The ecological implications of tolerance to salinity by *Ruppia cirrhosa* (Petagna) Grande and *Zostera capensis* Setchell. Botanica Marina **37**: 449–456

Adams JB, Bate GC (1994) The tolerance to desiccation of the submerged macrophytes *Ruppia cirrhosa* Petagna (Grande) and *Zostera capensis* Setchell. Journal of Experimental Marine Biology and Ecology **183**: 53–62

Bandeira SO (1995) Marine botanical communities in southern Mozambique: sea grasses and seaweed diversity and conservation. Ambio **24**: 506–509

Bandeira SO (1996) Leaf area index (LAI), Grazing and population structure of the seagrass *Thalassodendron ciliatum* at Inhaca Island, Mozambique. In: Björk M, Semesi AK, Pedersén M, Bergman B (eds) Current Trends in Marine Botanical Research in the East African Region. Sida/SAREC, Uppsala, pp 303–314. ISBN 91-630-4907-4

Bandeira SO, António CM (1996) The intertidal distribution of seagrasses and seaweeds at Mecúfi Bay, northern Mozambique. In: Kuo J, Phillips RC, Walker DI, Kirkman H (eds) Seagrass Biology: Proceedings of an International Workshop, Western Australian Museum, Perth, pp 15–20

Bandeira SO (1997a) Seagrasses. In: Richmond MD (ed.) A Guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands. Sida/Department for Research Cooperation, SAREC, Stockholm, pp 64–67. ISBN 91-630-4594-x

Bandeira SO (1997b) Dynamics, biomass and total rhizome length of the seagrass *Thalassodendron ciliatum* at Inhaca Island, Mozambique. Plant Ecology **130**: 133–141

Bandeira SO (in press) Leaf production rates of *Thalassodendron ciliatum* from rocky and sandy habitats. (in press, Aquatic Botany)

Bandeira SO, Nilsson PG (in press) Genetic population structure of the seagrass *Thalassodendron ciliatum* in southern Mozambique. (in press, Marine Biology)

Barnabas AD (1982) Fine structure of the leaf epidermis of *Thalassodendron ciliatum* (Forsk.) den Hartog. Aquatic Botany **12**: 41–55

Barnabas AD (1983) Composition and fine structural features of longitudinal veins in leaves of *Thalassodendron ciliatum.* South African Journal of Botany **2**: 317–325

Barnabas AD (1988) Apoplastic tracer studies in the leaves of a seagrass. 1. Pathway through epidermal and mesophyll tissues. Aquatic Botany **32**: 63–77

Barnabas AD (1991) *Thalassodendron ciliatum* (Forsk.) den Hartog: Root structure and histochemistry in relation to apoplastic transport. Aquatic Botany **40**: 129–143

Barnabas AD (1994) Apoplastic and symplastic pathways in leaves and roots of the seagrass *Halodule uninervis* (Forsk.) Aschers. Aquatic Botany **47**: 155–174

Barnabas AD, Arnott HJ (1987) *Zostera capensis* Setchell: Root structure in relation to function. Aquatic Botany **27**: 309–322

Barnabas AD, Kasavan S (1983) Structural features of the leaf epidermis of *Halodule uninervis.* South African Journal of Botany **2**: 311–316

Barnabas AD, Butler V, Steinke TD (1977) *Zostera capensis* Setchell I. Observations on the fine structure of the leaf epidermis. Zeitschrift fuer Pflanzenphysiologie **85**: 417–427

Barnabas AD, Butler V, Steinke TD (1980) *Zostera capensis* Setchell II. Fine structure of the cavities in the wall of leaf blade epidermal cells. Zeitschrift fuer Pflanzenphysiologie **99**: 95–103

Beer S, Björk M (2000) Measuring rates of photosynthesis of two tropical seagrasses by pulse amplitude modulated (PAM) fluorometry. Aquatic Botany **66**: 69–76

Björk M, Weil A. Semesi S, Beer S (1997) Photosynthetic utilisation of inorganic carbon by seagrasses from Zanzibar, East Africa. Marine Biology **129**: 363–366

Björk M, Uku J, Weil A, Beer S (1999) Photosynthetic tolerances to desiccation of tropical intertidal seagrasses. Marine Ecology Progress Series **191**: 121–126

De Boer WF (2000) Biomass dynamics of seagrasses and the role of mangroves and seagrass vegetation as different nutrient sources for an intertidal ecosystem. Aquatic Botany **66**: 225–239

Chasse C (1962) Remarques sur la morphologie et la bionomie des herbiersde Monocotylédones marines tropicales de la Province de Tuléar (République Malgache). Annals Malgaches **1**: 237–248

Cohen E (1939) The marine angiosperms of Inhaca Island. South African Journal of Science **36**: 246–256

Coppejans E, Beeckman H, De Wit M (1992) The seagrass and associated macroalgal vegetation of Gazi Bay (Kenya). Hydrobiologia **247**: 59–75

Cox PA (1991) Hydrophilous pollination of a dioecious seagrass *Thalassodendron ciliatum* (Cymodoceaeceae) in Kenya. Biotropica **23**: 159–165

Dolgushina IV, Maksimova OV, Saenko GN (1995) Marine vegetation of the Seychelles Islands and bioconcentration of trace elements. Okeanologiya. Moscow **35**: 246–251 (in Russian with English abstract)

Duarte CM, Hemminga MA, Marbà N (1996) Growth and population dynamics of *Thalassodendron ciliatum* in a Kenyan back-reef lagoon. Aquatic Botany **55**: 1–11

Gravier N (1970) Etude des Hydraires épiphytes des Phanérogames marines de la région de Tuléar (Sud-Ouest de Madagascazr). Recueil des Travaux de la Station Marine d'Endoume **10**: 111–161

Hemminga MA, Slim FJ, Kazungu J, Ganssen GM, Nieuwenhuize J, Kruyt NM (1994) Carbon outwelling from a mangrove forest with adjacent seagrass beds and coral reefs (Gazi Bay, Kenya). Marine Ecology Progress Series **106**: 291–301

Hemminga MA, Gwada P, Slim FJ, De Koeyer P, Kazungu J (1995) Leaf production and nutrient contents of the seagrass *Thalassodendron ciliatum* in the proximity of a mangrove forest (Gazi Bay, Kenya). Aquatic Botany **50**: 159–170

Hemminga MA, Marbà N, Stapel J (1999) Leaf nutrient resorption, leaf lifespan and retention of nutrients in seagrass systems. Aquatic Botany **65**: 141–158

Isaac FM (1968) Marine botany of the Kenya coast. 4. Angiosperms. Journal of the East African Natural History Society **27**: 29–47

Iyer V, Barnabas AD (1993) Effects of varying salinity on leaves of Zostera capensis Setchell. 1. Ultrastructural changes. Aquatic Botany **46**: 141–153

Johnson JM, Choinski JS Jr, Heyes JA, Bandeira SO (1993) Factors affecting photosynthesis in the Mozambican seagrasses *Cymodocea serrulata* and *Thalassodendron ciliatum*. Photosynthetica **28**: 307–312

Johnstone R (1995) Community production and nutrient fluxes in seagrass beds (Unguja, Island, Tanzania) In: Hemminga MA (ed.) Interlinkages between eastern-African coastal ecosystems. Netherlands Institute of Ecology, Centre for Estuarine and Coastal Ecology, Yerseke, pp 88–93

Kalk M (1959) A general ecological survey of some shores in northern Moçambique. Revista de Biologia **2**: 1–24

Kalk M (1995) A Natural History of Inhaca Island Mozambique. Witwatersrand University Press, Johannesburg, pp 395

Ledoyer M (1968) Les Caridae de la frondaison des herbiers de Phanérogames de la région de Tuléar (République Malgache). Etudes systématique et écologique. Annals University Madagascar **6**: 63–121

Ledoyer M (1969) Amphipodes Gammariens du sédiment des herbiers de Phanérogames marines et des dunes hydrauliques du Grand Récif de Tuléar (Madagascar). Etudes Systématique et écologique. Recueil des Travaux de la Station Marine d'Endoume **9**: 183–191

Ledoyer M (1970) Mysidacés des herbiers de Phanérogames marines de Tuléar (Madagascar). Etudes systématique et écologique. Recueil des Travaux de la Station Marine d'Endoume **10**: 223–227

Leliaert F, Vanreusel W, De Clerck O, Coppejans E (2001) Epiphytes on the seagrasses of Zanzibar Island (Tanzania), Floristic and Ecological Aspects. Belgian Journal of Botany **134**: 3–20

Macnae W (1969) Sea grasses. In: Macnae W, Kalk M (eds) A Natural History of Inhaca Island, Mozambique. Witwatersrand University Press, Johannesburg, pp 28–30

Macnae W, Kalk M (1962) The fauna and flora of sand flats at Inhaca Island, Mozambique. Journal of Animal Ecology **31**: 93–128

Macnae W, Kalk M (1969) A Natural History of Inhaca Island, Mozambique. Witwatersrand University Press, Johannesburg, pp 163

Mariani S, Alcoverro T (1999) A multiple-choice feeding-preference experiment utilising seagrasses with a natural population of herbivorous fishes. Marine Ecology Progress Series **189**: 295–299

Mcmillan C (1980) Flowering under controlled conditions by *Cymodocea serrulata, Halophila stipulacea, Syringodium isoetifolium, Zostera capensis* and *Thalassia hemprichii* from Kenya. Aquatic Botany **8**: 323–336

Mcmillan C (1986) Sulfated flavonoids and leaf morphology in the *Halophila ovalis – Halophila minor* complex (Hydrocharitaceae) of the Indo-Pacific Ocean. Aquatic Botany **25**: 63–72

Moss M (1937) A preliminary account of the 'seagrasses' of Delagoa bay. South African Journal of Science **33**: 234–345

Munday J, Forbes PL (1979) A preliminary checklist of the flora of Inhaca Island, Moçambique: based on the collection of A.O.D. Mogg. Journal of South African Botany **45**: 1–10

Ochieng CA, Erftemeijer PLA (1999) Accumulation of seagrass beach cast along the Kenyan coast: a quantitative assessment. Aquatic Botany **65**: 221–238

Pichon M (1964) Aperçu préliminaire des peuplements sur sables et sables vaseux libres ou couverts par les herbiers de Phanérogames marines de la région de Nossi-Bé. Cah. ORSTOM, Paris (Océanogr.) **2**: 5–15

Pärnik T, Bil K, Kolmakov P, Titlyanov E (1992) Photosynthesis of the seagrass *Thalassodendron ciliatum*: leaf anatomy and carbon metabolism. Photosynthetica **26**: 213–223

Schwarz AM, Björk M, Buluda T, Mtolera M, Beer S (2000) Photosynthetic utilisation of carbon and light by two tropical seagrass species as measured in situ. Marine Biology **137**: 755–761

Semesi AK (1988) Seasonal changes of macro-epiphytes on the seagrass *Thalassodendron ciliatum* (Forskk) den Hartog at Oyster Bay, Dar es Salaam,Tanzania. In: Mainoya JR (ed.) Proceedings of a Workshop on Ecology and Bioproductivity of Marine Coastal Waters of Eastern Africa. Dar es Salaam, Tanzania, 18–20 January 1988. Published by the Faculty of Science, University of Dar es Salaam, pp 51–58

Simpson D (1989) Flora of Tropical East Africa. Hydrocharitaceae. Royal Botanic Gardens, Kew, pp 29

Spalding MD, Phillips R (1999) Mangroves and Seagrasses of the Indian Ocean. CD-ROM. Swedish International Development Agency (SIDA)

Stapel J, Hemminga MA (1997) Nutrient resorption from seagrass leaves. Marine Biology **128**: 197–206

Titlyanov E, Cherbadgy I, Kolmakov P (1995) Daily variations of primary production and dependence of photosynthesis on irradiance in seaweeds and seagrass *Thalassodendron ciliatum* of the Seychelles Islands. Photosynthetica **31**: 101–115

Uku JN, Martens EE, Mavuti KM (1996) An ecological assessment of littoral seagrass communities in Diani and Galu coastal beaches, Kenya. In: Björk M, Semesi AK, Pedersén M, Bergman B (eds) Current Trends in Marine Botanical Research in the East African Region, SIDA, pp 280–302. ISBN 91-630-4596-X

UNEP (1997) Coastal profile of Grande Comoros Island, EAF5/UNEP/FAO project report

Wakibya JG (1995) The potential human-induced impacts on the Kenyan seagrasses. UNESCO Report in Marine Sciences **66**: 176–187

Wortmann J, Hearne JW, Adams JB (1997) A mathematical model of an estuarine seagrass. Ecological Modelling **98**: 137–149

Other cited references (not dealing with regional seagrasses)

Aioi K, Komatsu T, Morita K (1998) The world's longest seagrass, *Zostera caulescens* from northeastern Japan. Aquatic Botany **61**: 87–93

Chamberlain YM, Norris RE (1994) *Pneophyllum amplexifrons* (Harvey) comb. nov., a mastophoroid crustose coralline red algal epiphyte from Natal, South Africa. Phycologia **33**: 8–18

Cordero PA Jr (1981) Some seagrasses from the Philippines. Publications of the Seto Marine Biological Station **26**: 319–325

Costanza R, d'Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, Van den Belt M (1997) The value of the world's ecosystem services and natural capital. Nature **387**: 253–260

Dring MJ (1982) The Biology of Marine Plants. Cambridge University Press, Cambridge, pp 199

Elmqvist T, Cox PA (1996) The evolution of vivipary in flowering plants. Oikos **77**: 3–9

Erftemeijer PLA, Middelburg JJ (1995) Mass balance constraints on nutrient cycling in tropical seagrass beds. Aquatic Botany **50**: 21–36

Gacia E, Granata TC, Duarte CM (1999a) An approach to measurement of particle flux and sediment retention within seagrass (*Posidonia oceanica*) meadows. Aquatic Botany **65**: 225–268

Harlin MM (1980) Seagrass epiphytes. In: Phillips RC, McRoy CP (eds) Handbook of Seagrass Biology: an Ecosystem Perspective. Garland STPM Press, New York, pp 117–151

Den Hartog C (1970) The Seagrasses of the World. North-Holland Publishing Company, Amsterdam, pp 275

Hemminga MA (1998) The root/rhizome system of seagrasses: an asset and a burden. Journal of Sea Research **39**: 183–196

Koch EW (1999) Sediment resuspension in a shallow *Thalassia testudinum* Banks ex König bed. Aquatic Botany **65**: 269–280

Larkum AWD, McComb AJ, Shepherd SA (eds) (1989) Biology of Seagrasses, a Treatise on the Biology of Seagrasses with Special Reference to the Australian Region. Elsevier, Amsterdam, pp 841

McMillan C (1980) Flowering under controlled conditions by *Cymodocea serrulata, Halophila stipulacea, Syringodium isoetifolium, Zostera capensis* and *Thalassia hemprichii* from Kenya. Aquatic Botany **8**: 323–336

Newell SY, Fell JW, Statzell-Tallman A, Miller C, Cefalu R (1984) Carbon and nitrogen dynamics in decomposing leaves of three coastal marine vascular plants of the subtropics. Aquatic Botany **19**: 183–192

NSW Fisheries (1997) Fish Habitat Protection Plan No. 2: Seagrasses. NSW Fisheries, Sydney, Australia, pp 8

Oshima Y, Kishi MJ, Sugimoto T (1999) Evaluation of the nutrient budget in a seagrass bed. Ecological Modeling **115**: 19–33

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

Pergent G, Romero J, Pergent-Martini C, Mateo MA, Boudouresque CF (1994) Primary production, stocks and fluxes in the Mediterranean seagrass *Posidonia oceanica*. Marine Ecology Progress Series **106**: 139–146

Pergent G, Rico-Raimondino V, Pergent-Martini C (1997) Fate of primary production in *Posidonia oceanica* meadows in the Mediterranean. Aquatic Botany **59**: 307–321

Rindi F, Maltagliati F, Rossi F, Acunto S, Cinelli F (1999) Algal flora associated with a *Halophila stipulacea* (Forsskål) Ascherson (Hydrocharitaceae, Helobiae) stand in the western Mediterranean. Oceanologia Acta **22**: 421–429

Stapel J, Aarts TL, Van Duynhoven BHM, De Groot JD, Van den Hoogen PHW, Hemminga MA (1996) Nutrient uptake by leaves and roots of the seagrass *Thalassia hemprichii* in the Spermonde Archipelago, Indonesia. Marine Ecology Progress Series **134**: 195–206

Thorhaug A (1990) Restoration of mangroves and seagrasses — economic benefits for fisheries and mariculture. In: Berger JJ (ed.) Environmental Restoration. Science and Strategies for Restoring the Earth, Island Press, Washington DC, pp 265–281

Edited by M Björk and RN Pienaar