Available online at www.sciencedirect.com
SCIENCE DIRECT®

Estuarine, Coastal and Shelf Science 63 (2005) 385–396

ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ECSS

Differences in macrofaunal and seagrass assemblages in seagrass beds with and without seaweed farms

J.S. Eklöf[a,*], M. de la Torre Castro[a], L. Adelsköld[a], N.S. Jiddawi[b], N. Kautsky[a]

[a]*Department of Systems Ecology, Stockholm University, S-106 91 Stockholm, Sweden*
[b]*Institute of Marine Science, Dar Es Salaam University, P.O. Box 668, Zanzibar, Tanzania*

Received 1 January 2004; accepted 23 November 2004

Abstract

Since it was introduced to Zanzibar (Tanzania), seaweed farming has significantly contributed to local, socio-economic development. However, several investigations have shown impacts on the coastal environment near where the farms are located. As many seaweed farms are located on seagrass beds, there is a risk that seaweed farming could affect seagrass beds, and thereby disturb important ecosystem functions and the flow of ecological goods and services. This study compares characteristics of macrophytes (focusing on seagrasses), benthic macrofauna and sediment in seagrass beds, with and without seaweed farms, and a sand bank without vegetation in Chwaka Bay, Zanzibar. The results showed that seagrass beds underneath seaweed farms generally had less seagrass and macroalgae, finer sediment, lower sediment organic matter content and a reduced abundance and biomass of macrofauna, than seagrass beds without seaweed farms. Further, the macrofaunal community structure in seaweed farms showed more similarities to that on the sand bank than in the unfarmed seagrass beds. Most of the dissimilarity was attributable to *Lucinidae* (suspension-feeding bivalves), which were almost absent in the seaweed farms, resulting in the large difference in biomass between the seaweed farms and the unfarmed seagrass beds. When interpreted together with information from farmers, the observed pattern is believed to be caused by the seaweed farming activities. This indicates that more research is needed to establish the effects of seaweed farming on seagrass beds, and that more attention should be given to the location of farms and the choice of farming methods.

Keywords: seaweed farming; seagrass bed; macrofauna; sediment; aquaculture; *Eucheuma denticulatum*; Zanzibar; East Africa

1. Introduction

Open-water seaweed farming was introduced to Unguja Island (Zanzibar, Tanzania) around 1990 and mainly two species of red algae, *Eucheuma denticulatum* (formerly *E. spinosum*) and *Kappaphycus alvarezii* (formerly *E. cottonii*), are grown and harvested for extraction of hydrocolloid carrageenans (Petterson-Löfquist, 1995). Unlike other, more destructive and resource-inefficient aquaculture methods (e.g. semi-intensive shrimp and salmon farming), seaweed farming does not require any inputs of fertilisers or pesticides, and is considered not to alter the physical environment in any major way (Johnstone and Ólafsson, 1995; Bryceson, 2002). Further, living standards have increased in many villages following the introduction of seaweed farming (Msuya, 1993; Petterson-Löfquist, 1995; Jiddawi and Ngazy, 2000) This has lead to a common perception that seaweed farming is a highly sustainable aquaculture practice (e.g. Saleh, 1998;

* Corresponding author.
E-mail address: johane@ecology.su.se (J.S. Eklöf).

0272-7714/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.ecss.2004.11.014

McKnight Foundation, 2002). However, several studies have shown that seaweed farming affects components of ecosystems in which such farms are located, e.g. meiobenthos (Ólafsson et al., 1995), benthic microbial production (Johnstone and Ólafsson, 1995), fish assemblages (Bergman et al., 2001), epifauna and macrophytes (Msuya, unpublished data; Semesi, 2002), and the water column around the algae (Collén et al., 1995). These findings indicate that more research on the subject is needed (e.g. Ólafsson et al., 1995; Bryceson, 2002; Zemke-White, in press).

In Zanzibar, the seaweed farms are located in shallow lagoons, and the dominant farming-method is the "fixed off-bottom" or "tie-tie" method, where fronds of the algae are tied to ropes stretched between wooden sticks fixed to the bottom, and harvested every 2–4 weeks during low water spring tides (Petterson-Löfquist, 1995). Seaweed farms are often sited on bottoms with seagrass, and farmers often regard the presence of seagrass as being a good indicator of a suitable environment (de la Torre Castro and Rönnbäck, 2004).

Seagrass bed ecosystems have for a long time been more or less neglected in coastal zone management but, due to the growing consensus about their importance (e.g. Duarte, 2000; Gullström et al., 2002), this is currently changing. Seagrass beds are important contributors to primary production in global oceans (Duarte and Chiscano, 1999), their canopy acts as a hydrodynamic barrier in near shore areas (Koch, 1996) and their roots and rhizomes stabilise bottom sediments (Fonseca, 1989).

Perhaps most important, seagrass beds provide habitats for other organisms. A large number of studies have shown that seagrass beds host more diverse and abundant animal communities than unvegetated areas, both in the temperate (e.g. Pihl, 1986; Boström and Bonsdorff, 1997) and tropical zones (e.g. Coles et al., 1993; Arrivillaga and Balz, 1999). The major factors attributed to this pattern are refuge from predation (Hindell et al., 2000; Salita et al., 2003) and the presence of food (Connolly, 1994; Bologna and Heck, 1999). Many of the animals residing in seagrass beds (e.g. fish and macroinvertebrates) are directly utilised by humans, and are thus of economic importance (de Boer and Longamane, 1996; Lynne et al., 2000; Jackson et al., 2001).

Because of their importance to society, seagrass/algal beds have been estimated to generate gross financial benefits amounting to US$19 000 ha^{-1} $year^{-1}$, this being the third highest value of the 16 biomes investigated (Costanza et al., 1997). In addition, there is growing concern about the worldwide decline of seagrass beds (e.g. Fortes, 1988; Short and Wyllie-Echeverria, 1996; Hall et al., 1999; Duarte, 2002). Since seaweed farming has been shown to impact components of the ecosystems in which such farms are placed there is a risk that seaweed farming could also affect seagrass beds and the associated communities, thereby disturbing important ecosystem functions.

The aim of this study was to investigate seagrass beds with seaweed farms in relation to unfarmed seagrass beds in the seagrass-dominated Chwaka Bay. This was done by comparing seagrass beds with and without seaweed farms and one unvegetated sand bank, using characteristics of three important components of seagrass bed ecosystems – the macrophytes (seagrass and macroalgae), sediment and benthic macrofauna. Because habitat provision is one of the most important functions attributed to seagrass beds, the relationship between macrofauna and environmental variables was also investigated.

The differences between seaweed farms and unfarmed seagrass beds are discussed in terms of the effects of seaweed farming, the implications this might have on ecosystem function, and suggestions regarding future research and management of seaweed farming.

2. Material and methods

2.1. Study area

The study was conducted in Chwaka Bay, an intertidal lagoon located on the east coast of Unguja Island, Zanzibar (6°13–25′ S and 39°37–58′ E; Fig. 1). Its mean water depth is 3.2 m, and the area of the bay covered with water fluctuates between 50 km^2 at high-water spring tide and 20 km^2 at low-water spring tide (Cederlöf et al., 1995). The centre part of the bay is dominated by tidal flats and channels, covered with mixed and monotypic stands of seagrasses and seaweeds. The dominant seagrass species are *Thalassia hemprichii, Cymodocea serrulata, Cymodocea rotundata,*

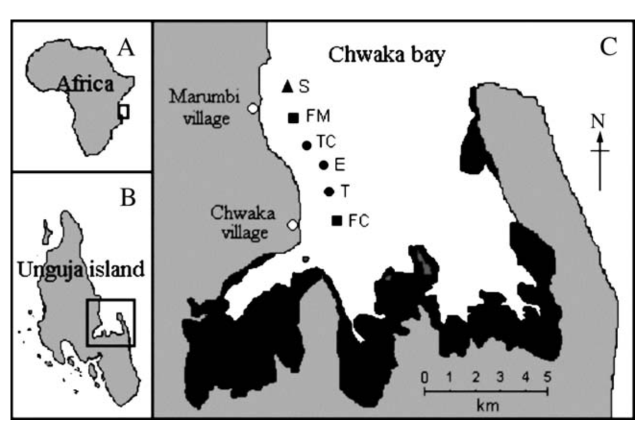

Fig. 1. Map of (A) Africa, (B) Unguja Island (Zanzibar) and (C) Chwaka Bay with the six sampling sites. ■, seaweed farm; ●, seagrass bed; ▲, sand bank. Black areas represent mangroves.