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Habitat preference for seaweed farming – A case study from Zanzibar, Tanzania

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ABSTRACT

Global marine seaweed aquaculture is growing rapidly. In Zanzibar, Tanzania, seaweed farming, primarily conducted by women, is the main coastal aquaculture activity. Many types of aquaculture are linked to a specific ecosystem (e.g. shrimp-mangrove), and understanding if such a coupling exists for seaweed farming important for further development. A prerequisite to understand if farming affects coastal habitats is the need to know where, and on which habitat, the farms are located. In this study, we investigated the habitat preferences of seaweed farmers by interviews, field observations and satellite imagery analysis. We found that the majority of the farms were distributed in a narrow "corridor" (380–600 m from shore) along the coast where water depth ($\bar{x} = 2\ m$) and tidal regime (±2 m) allow for a suitable environment for both the algae and the farmers. Within this corridor, thus defined by depth, the water is deep enough for the algae not to be overexposed to sunlight but also sufficiently shallow for the women to access and work on the farms at low tide. The farmers accordingly expressed depth as the major limiting factor when choosing the site for their farms, and the preferred habitat type was seagrass beds. Most farms (92%) were partly located on seagrass meadows, but also other habitats, such as sand. The total area of the studied seaweed farms was 65.6 ha, with 39% of this being seagrass meadow, which is significantly more than the seagrass cover in the farming corridor. The farms also covered 43% sand; however, the interviews indicate that a substantial part of the sandy areas was, in fact, also recently covered by seagrasses.

Our findings are relevant for improved management, conservation, and marine spatial planning, as we show where and on which habitats seaweed farms are preferably located. This information can be used to further investigate the ecological impact on the habitats and their associated fauna and in order to provide more effective management actions. Furthermore, this is much-needed baseline information for investigating the increased production of seaweed, i.e. if the habitat has any effect on the algae growth.

1. Introduction

The coastal shallow sea, with its open and easy access, attracts and allows for several human activities, including marine aquaculture. The multiple uses create competition for space, and the situation can be complicated if activities are unregulated (Nordlund et al., 2014). Marine aquaculture is growing rapidly, both globally and in coastal East Africa (FAO, 2010–2017). Unregulated development of aquaculture can support unsustainable practices and the exploitation of natural resources beyond their capacity (Subasinghe et al., 2009). On the positive side, marine aquaculture creates jobs, food, and an alternative to fishing and gathering of seafood and algae, and thus potentially relieves pressure on wild stocks. During the last few decades, the expansion of some aquaculture systems has developed a spatial link to certain ecosystems. One example is the destruction of mangroves due to the creation of shrimp farms, where research has shown that this single form of aquaculture is the major cause of mangrove deforestation globally (Valiela et al., 2001; Hamilton, 2013). Other examples of linkages between aquaculture and coastal ecosystems are sea cage aquaculture and coral reefs in South East Asia, and the salmon farming and fjords in Norway and Chile (Hedberg et al., 2015). In a study from Chwaka Bay in Zanzibar, Tanzania, de la Torre-Castro and Rönnbäck (2004) described a link between seagrass meadows and seaweed farms, where the farmers actively chose seagrass meadows as the habitat for their farms. Seagrasses are marine flowering plants forming large meadows in nearshore environments, and provide many ecosystem services, and are thus an important habitat in the seascape (Nordlund et al., 2016). Other habitats in the nearshore seascape around Zanzibar

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Fig. 1. A large field of seaweed farms in Zanzibar, Tanzania. The farms are situated on patchy seagrass meadows. Photo: Lina Mtwana Nordlund.

are mangrove, sand, mud, rock, algae and coral.

Seaweed farming is conducted at various intensities globally (Zemke-White and Smith, 2006; Tano, 2016). In Zanzibar, Tanzania, seaweed farming is the main well developed coastal aquaculture (Lange and Jiddawi, 2009) (Fig. 1), and was introduced from the Philippines in 1989 (Rönnbäck et al., 2002; Halling et al., 2013; Msuya et al., 2014). Today, Zanzibar is the main producer of seaweed in East Africa, principally producing two species of red algae *Euchema denticulatum* and *Kappaphycus alvarezii.* There is no formal regulation of seaweed farming (de la Torre-Castro, 2012; this study) except for exporting agreements (Lange and Jiddawi, 2009). Seaweed is farmed with the simple off-bottom method (called “tie-tie”), whereby several small pieces of algae are tied to a rope stretched between two fixed wooden sticks (Bryceson, 2002). In general, it is women that are engaged in seaweed farming in Zanzibar (de la Torre-Castro, 2012; Tobisson, 2013). These women work on their farms during spring low tides, and they work on other activities during neap tides (Tobisson, 2013). Seaweed farming is widely practised and it is estimated to employ more than 23 000 farmers in Zanzibar alone (Unguja and Pemba) (Zanzibar Fisheries Policy, 2013). Major constraints of the cultivation of red algae in Zanzibar and the Western Indian Ocean region are “ice-ice” disease and epiphytes, which are likely due to climate and environmental change (Msuya et al., 2014).

In general, seaweed farming is considered to be a less destructive form of aquaculture, where the major concerns have been related to the spreading of non-native species or species haplotypes, local effects on benthic infauna, fish biomass, and seagrass biomass and seagrass growth rates (Eklöf et al., 2005, 2006a, 2006b; Tano et al., 2015). Seaweed farms have also been reported to be dangerous for dugongs, as they get tangled up in the farming ropes and drown, but also by limiting their feeding range (Poonian and Lopez, 2016). The location of the farm may affect the level of environmental impact as well as the effect on other resource users' incomes. For example, the spread of the invasive haplotypes of *Euchema denticulatum* that are now dominating the *Euchema* strain on Zanzibar may potentially be facilitated by the placement of seaweed farms (Halling et al., 2013; Tano et al., 2015). Another example is the study by Eklöf et al. (2006a), who investigated fish biomass in both sand and seagrass habitats, with and without seaweed farms, and found higher fish biomass in the farms located on sand habitats compared to bare sand without farms, but lower fish biomass in farms located in seagrass beds compared to seagrass areas without farms.

Further investigations of how farms affect the bottom substrate and habitat and its associated species should be undertaken in order to increase our knowledge of the ecological impact of seaweed farming. In order to develop and improve the management of seaweed farming, a better understanding of where and on which habitat seaweed farms are located, the farmers' preferences of habitat and why, and the methods to use to investigate this, is needed. This type of baseline information would, for example, be useful for investigating the ecological impact on the habitat and their associated species. Such information would also be useful for more effective management and governance, including tools such as Marine Spatial Planning. Furthermore, to investigate if it is possible to increase the production of seaweed, the effect of bottom substrate and habitat on the growth of the seaweed should be examined, and a prerequisite for such an investigation is to understand where and on which habitat seaweed farms are, or could be, located. Thus, there is need to understand potential locations for the seaweed farms and the bottom substrate and habitats available in these locations and the preferences of the bottom substrate and habitats among the farmers.

The overall aim of this study was to investigate farmers' preferences of habitat for their seaweed farms and the location of the farms in the seascape in Zanzibar, Tanzania. This was conducted by: (1) interviewing 121 seaweed farmers on their preferred farming habitat, and (2) by visual interpretation and analysis of seaweed farm locations in eight major coastal communities using high spatial resolution satellite images. The results from the interviews, field observations, and the satellite image analysis were then compared and discussed. Furthermore, we discuss the ecological and management implications of habitat preferences of seaweed farming.

2. Method

The methods used in this study were field observations and interviews with seaweed farmers around Zanzibar (Unguja Island) and satellite image analysis, from which we performed habitat mapping, seaweed farm mapping, and suitable “farming corridor” mapping. By combining farmers' perspectives about farming substrates with high-resolution mapping we aimed to obtain information about the causes and consequences of the placement of seaweed farms.

2.1. Study area

This study was conducted in Zanzibar (Unguja Island) in Tanzania (Fig. 2). The Zanzibar coast is influenced by large tidal fluctuations and harbours a rich seascape with large areas of coral reefs, mangroves, seagrass meadows, sandflats and algal beds. The tides are semi-diurnal, with a tidal range varying from over 4 meters during spring tide to around 1 meter during neap tide (Tanzania Port Authority). The eastern coast is lined with barrier reefs, protecting the shallow vegetated bottoms as well as the seaweed farms and other human activities from wave action. Coastal ecosystem services stand at 30% of Zanzibar's GDP, where tourism is the major contributor, followed by fishing and seaweed farming (Lange and Jiddawi, 2009). Seaweed farming is conducted all around the coast but the major farming areas are found on the east coast and in the southern bays.

2.2. Interviews

The focus group interviews with seaweed farmers were conducted in eight sites in Zanzibar between July and September 2015 (Fig. 2). The study sites were selected so as to cover areas around the island, with