Ocean & Coastal Management 114 (2015) 32–41

Contents lists available at ScienceDirect

Ocean & Coastal Management

journal homepage: www.elsevier.com/locate/ocecoaman

Spatial variability in habitat structure and heterogenic coral reef fish assemblages inside a small-scale marine reserve after a coral mass mortality event

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ARTICLE INFO

Article history:
Received 3 November 2014
Received in revised form
30 May 2015
Accepted 5 June 2015
Available online xxx

Keywords:
Marine protected areas
Coral reef
Habitat quality
Fish community
Management
Seychelles

ABSTRACT

Coral reefs at the inner granitic islands in the Seychelles were heavily affected by the worldwide bleaching event in 1998, which led to subsequent coral mortality and widespread phase shifts to macroalgae dominated reefs. In this study, five sites within a small, but well enforced marine reserve at Cousin Island, were investigate using various methods to explore differences in coral habitat quality, coral recruitment, fish assemblages, key invertebrate grazers, and rugosity. The objective of the study was to collect a broad set of scientific data, which could be useful to describe linkage between coral reef and fish assemblages after a large-scale disturbance, as well as for future management decisions regarding marine resources, in terms of MPA protection and recovery abilities. The results showed high spatial variation in coral coverage between sites (from 1.5% to 43.2%), which were higher than previously reported, as well as high variation in dispersal of coral recruits. Furthermore, there were large heterogenic differences in fish densities and composition, which were directly linked to coral habitat quality, e.g. total fish abundance was 15 times higher on sites with high coral coverage in comparison to sites with low coral cover. In summary, this study demonstrates that coral reef habitat and fish assemblage may display high spatial variability and heterogenic differences after large-scale disturbances and suggests that potential recovery from coral mass mortality may occur in a non-linear and patchy procedure, which in turn may depend on underlying stocastical processes that affect coral recruitment and survivorship.

1. Introduction

Degradation, fragmentation, and loss of habitats have been suggested as some of the most critical threats to global terrestrial and marine biodiversity (Musick, 1999; Bellwood et al., 2004; Carpenter et al., 2008; Graham et al., 2011). During the last couple of decades coral reef habitats, which have the highest biodiversity of all marine ecosystems (Birkeland, 1997), have declined at an alarming rate due to a combination of both anthropogenic and natural disturbances (Bruno and Selig, 2007; Gamfeldt et al., 2014). Threats to coral reef habitats and associated fish communities include: over-exploitation (Myers and Worm, 2003; Berkes et al., 2006; Knowlton and Jackson, 2008), decreases in water quality (Wooldridge, 2009), outbreaks of crown-of-thorns starfish (*Acanthaster planci*) (Wilson et al., 2008; De'ath et al., 2012), sedimentation, (Fabricius, 2005; Halpern et al., 2013), and more recently severe large-scale effects from climate change (reviewed by Pratchett et al., 2011; Hoegh-Guldberg, 2012; Wernberg et al., 2012; Hughes et al., 2013).

While the coral reefs in the Seychelles have been considered to be one of the least affected areas by local anthropogenic disturbances in the Western Indian Ocean (Cinner et al., 2009; Burke et al., 2011), the coral reefs at the inner granitic islands at the Seychelles were one of the most severely affected areas by the worldwide 1998 bleaching event (Wilkinson, 2004), with up to 95% coral mortality (Bigot et al., 2000; Graham et al., 2006; Wilson et al., 2012). The coral bleaching event in 1998 occurred as a result of the interaction of the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD), which led to global increased sea surface

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http://dx.doi.org/10.1016/j.ocecoaman.2015.06.003
0964-5691/

temperatures and large-scale coral bleaching, which was followed by coral mass mortality and widespread phase shifts to macroalgae dominated reefs (Goreau et al., 2000; Spalding and Jarvis, 2002; Graham et al., 2006), defined as an extensive decrease in coral cover coinciding with substantial increases in some alternative benthic organism, which have persisted for more than five years (Norström et al., 2009).

Before 1998, coral coverage at the inner granitic islands at the Seychelles was reported to reach in average 28% and surveys conducted within the marine reserve at Cousin Island described the coral reefs within the MPA to be in good condition, with high percentage of coral cover (Wilson et al., 2012) and high levels of fish biomass (Jennings et al., 1996). However, the coral reefs around Mahe and Praslin suffered extensive damage and mortality from the 1998 bleaching event and mean coral cover within the reserve at Cousin Island decreased with 95–99% coverage (Wilson et al., 2012) and covered only approximately 1% of the benthic substrate in to 2005 (Ledlie et al., 2007).

The aims of this study was to investigate spatial variability in coral reef habitat and fish community, as well as examine ecological linkages between habitat quality and coral reef fish assemblages within a small well-protected MPA. Scientific information regarding recovery rates of coral reefs and associated fish assemblages in small marine reserves may have important implications for both the local fishery, as well as for continuing support and coastal management decisions (Halpern and Warner, 2002; Roberts et al., 2003; McClanahan et al., 2006).

Five sites were selected for extensive surveys within the marine reserve at Cousin Island and by using various methods investigate differences in: (1) biotic and abiotic benthic substrate, (2) rugosity, (3) coral recruitment, (4) fish density and functional groups, and (5) key invertebrate grazers.

2. Material and methods

2.1. Study area

The study was carried out inside the no-take MPA around Cousin Island in the Seychelles. Cousin Island is a part of the inner granitic archipelago of the Seychelles and was declared a nature reserve by the government of the Seychelles in 1968 (Jennings, 1998). The area received further legal protection in 1975 and became a 'Special reserve' when the surrounding water, from 400 m from the high tide water mark in all directions around the island covering in total approximately 1.2 km^2 was protected (Francis et al., 2002), which makes it one of the longest established no-take marine reserves in the Western Indian Ocean (McClanahan et al., 2009). The MPA is well enforced (Jennings et al., 1996) by local wardens and the science officer, who lives permanently on the island, and during the turtle season all beaches are frequently patrolled.

The marine area around Cousin Island is characterised by fringing carbonate reef, granite reefs, patch reefs, and extensive areas of sand and *Sargassum* sp., a late succession algae species (McClanahan, 1997). The coral reefs around Cousin Island are affected by large seasonal variation due to the regional monsoon weather system, and the sandy area is repeatedly shifting between the eastern and northern beaches, which during certain times can result in low visibility. All of the reefs within the MPA are located fairly shallow (<20 m).

Five different sites around Cousin Island were surveyed for this study (Fig. 1). Site 1: carbonate reef mainly dominated by a combination of macroalgae and turf algae, but with patches of high coral cover; Site 2: carbonate reef dominated by turf algae and underlying substrate of stable coral rubble, which is being recolonised by coral recruits; Site 3: granitic and carbonate reef mainly dominated by algae and patches of corals; Site 4: carbonate reef flat dominated by high coverage of turf algae and with low structural complexity; Site 5: carbonate reef slope dominated by corals (Fig. 2a, b).

12 and 15 sub-locations were randomly selected for surveying at each site (15 sub-locations at Site 1, 2, and 3; and 12 sub-locations and Site 4 and 5). All sites were located within the 400 m zone where all fishing activities and all other extraction of marine organism are completely prohibited.

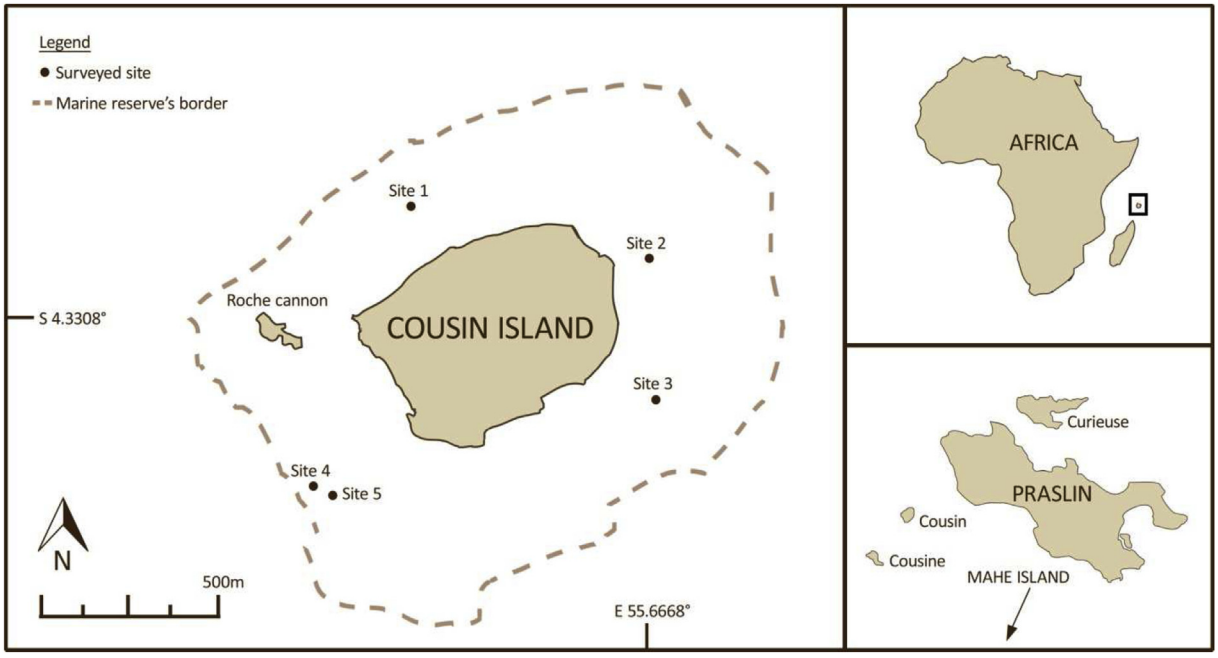

Fig. 1. Map of Cousin Island Special Reserve with the five surveyed sites marked out. Dashed line indicate border of the marine protected area.