

Small-scale variations in the effects of coral bleaching in Rodrigues

E. R. Hardman¹, J. Thoma², N. S. Stampfli³, M. S. Desiré¹, S. Perrine¹

- 1) Shoals Rodrigues, Pointe Monier, Rodrigues, Mauritius
- 2) School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, UK
- 3) Department of Environmental Sciences, Swiss Federal Institute of Technology Zurich, Switzerland

Abstract. Rodrigues was one of the few reef locations in the Western Indian Ocean to escape the mass coral bleaching event of 1997 – 1998, however shallow reef sites have suffered from bleaching events in 2002, 2005 and 2007. In all 3 years, there were small-scale spatial variations in the severity of bleaching and associated mortality. Temperature data indicate small-scale variations in sea temperature around the lagoon and current data suggest that bleaching tended to occur in areas with the lowest current speeds. Recovery of sites from bleaching also showed small-scale spatial variations. Inshore sites, displayed limited recovery to the bleaching events and sites are dominated by turf algae (>60 %) with low live coral cover (<15 %), whereas live coral cover has increased at a site further offshore. This variation in recovery is likely to be due to the proximity to land and increased human impacts. This suggests that if coral bleaching events continue to occur on a regular basis then these inshore reefs could become overgrown by algae and their structural complexity eroded. Rodrigues is a small, isolated island with a limited coral larval supply and such a scenario would leave the island vulnerable to coastal flooding and storm damage.

Key words: coral bleaching, mortality, recovery, sea surface temperature, Indian Ocean

Introduction

Rodrigues is a semi-autonomous island forming part of the Republic of Mauritius, located 560 km north east of the main island in the western Indian Ocean. The island is surrounded by 90 km of fringing coral reef, which creates a shallow lagoon of 240 km². One hundred and sixty species of coral have been recorded in Rodrigues (Fenner et al. 2004) and the fore reefs have high live coral cover (30 – 50 %) at 6 – 12 m depth (Shoals Rodrigues unpublished data).

The coral reefs of Mauritius and Rodrigues were some of the few reef areas in the Indian Ocean to escape the mass coral bleaching event of 1997 - 1998 (Turner et al. 2000). However, unusually warm and calm conditions occurred during February 2002 resulting in coral bleaching, particularly at sites in the north and west of Rodrigues (Hardman et al. 2004). Surveys showed that although the bleaching was not widespread, it was severe where it did occur, resulting in mortality of up to 75 % of corals at some sites. Further coral bleaching occurred in 2005. Bleaching was again most severe in the north and west of the island, where up to 50 % of coral bleached, although mortality was not so severe as in 2002 (Hardman et al. in press).

This study investigates whether further coral bleaching occurred during 2007, following another

period of warm, calm weather in January of that year. It also examines spatial variations in the recent coral bleaching events and subsequent recovery of affected sites.

Methods

Coral bleaching

Rapid assessment surveys were carried out at 26 sites around the island during June and July 2007 (Fig. 1). Sites were identified on the reef flat, reef slope and on the patch reefs within the lagoon.

Surveys were carried out using snorkelling techniques by a team of 2 - 3 personnel. Surveys on the reef flat were carried out at high tide so that surveyors could swim into the lagoon over the reef front and thus assess bleaching on the reef slope down to a depth of 5 – 6 m. Surveyors swam across the reef area for two minutes and then stopped and recorded the occurrence of bleaching within an area of approximately 5m x 5m. This was repeated to give a total of 20 observations per site. During each observation for each coral genus observed, the abundance of the genus and the percentage of colonies of that genus that was recently dead (still standing, but covered in a thin layer of turf algae), bleached (pale to completely bleached) and healthy was recorded on a 6-point semi-quantitative scale (0 = 0 %; 1 = 1 – 10 %, 2 = 11 – 30 %, 3 = 31 – 50 %, 4 =

51 – 75 % and 5 = 76 – 100 %) (Turner et al. 1999). The bleaching values for each genus were then averaged and multiplied by the abundance score for that genus to give a bleaching score for each coral genus observed. These values were then averaged to produce a mean bleaching value for each site.



Figure 1: The 26 survey sites around the island of Rodrigues.

National Oceanic and Atmospheric Administration (NOAA) Sea Surface Temperature (SST) Hotspot charts and meteorological data (temperature, SST and sunshine hours) obtained from the Mauritius Meteorological Services were studied to identify annual large-scale variations in environmental conditions. Smaller scale spatial variations were investigated using data collected by Shoals Rodrigues. Continuous temperature loggers were placed on the reef flat at 3 sites in the north of Rodrigues (Totor, Grand Bassin and Ile aux Fous) between March 2006 and December 2007 and recorded SST every hour. Data on current speeds around the lagoon, collected using drogue buoys in 2002, were also analysed.

Recovery from bleaching

Additional detailed surveys were undertaken at three sites, which had been worst affected by the 2002 and 2005 bleaching events: Totor, Passe Armand and Ile aux Fous. All surveys were undertaken on the reef flat at depths of approximately 1 m. Three 20 m transect lines were laid parallel to the reef edge and separated by a distance of 10 m. Benthic community was assessed along each of the transects using the line intercept transect method (English et al. 1994). The abundance of coral recruits (colonies <10 cm in diameter) was also assessed by counting all of the colonies within thirty 0.25 m² quadrats randomly placed along the transects. These data were compared with similar surveys undertaken in 2003 (Hardman 2004) and 2006 (Stampfli 2006) to assess recovery over time.

Results

Coral bleaching

Recent coral mortality was observed on one patch reef in the southern lagoon (SW Lagoon 5). At this site, 100% of branching and tabular *Acropora* spp. were dead and had been recently colonised by turf algae. Live coral cover was <1 % and consisted of small encrusting and massive coral colonies (*Goniastrea* sp. and *Cyphastrea* sp.) as well as *Fungia* spp. Nearby patch reefs (<1 km away) were not affected by this bleaching and no other coral bleaching was observed. Indeed, at 95% of the sites surveyed during 2007, 76 – 100 % of coral colonies were healthy and showed no sign of bleaching or recent mortality.

NOAA SST charts indicate that Hotspots values were 1.0 °C above the climatological maximum from 16th until 26th March 2002; >1.0 for a 1-month period from 26th February until 26th March 2005 and were >0.5 from 26th January until 20th February 2007 (NOAA/NESDIS/OSDPD 2008). Meteorological data indicate that maximum sea temperatures >30 °C were recorded in February 2002, March 2005 and January 2007 (Fig 2). Maximum air temperatures were above the long-term mean (1971 - 2000) during January - March 2002 and 2005 and during January 2007; hours of sunshine were above the long-term mean during February 2002, January 2005 and January 2007 and wind speeds were below the long-term mean during January and February 2002, March 2005 and February and March 2007.

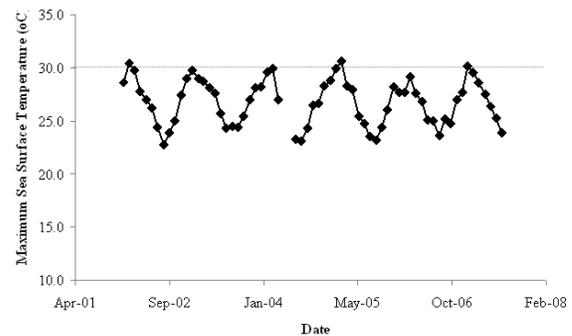


Figure 2: Sea surface temperature (SST) data for the Rodrigues lagoon from January 2002 – July 2007. Data provided by the Mauritius Meteorological Services.

Data from the continuous temperature loggers suggest that there are small-scale variations in SST around the lagoon and mean SST was significantly higher at Passe Cabri than at Grand Bassin and Ile aux Fous (1-way ANOVA, $p < 0.001$). Current speeds ranged from 0.48 m. s⁻¹ in the southern lagoon to <0.1m. s⁻¹ in the Port Mathurin Bay area and were significantly higher in the southern lagoon (mean: 0.27 m. s⁻¹) compared to the northern lagoon (mean: 0.18 m. s⁻¹) (T-Test, $p < 0.05$).

Recovery from bleaching

In 2007, the sites at Totor and Passe Armand were dominated by turf algae (>60 %) with low live coral cover (<15 %). In contrast, Ile aux Fous had a live coral cover of 21% and was dominated by coralline algae (49 %). The abundance of coral recruits varied from 2.0 ind. m⁻² at Totor to 13.2 ind. m⁻² at Ile aux Fous.

Passe Armand and Totor showed no change in live coral cover over time (Fig 3). The percentage cover of turf algae increased from 57 % in 2003 to 68 % in 2007 at Passe Armand and from 34 % in 2006 to 65 % in 2007 at Totor. At Ile aux Fous, live coral cover increased from 14 % in 2003 to 21 % in 2007; rubble fell from 35 % in 2003 to 0 % in 2007 and coralline algae increased from <1 % to 49 %.

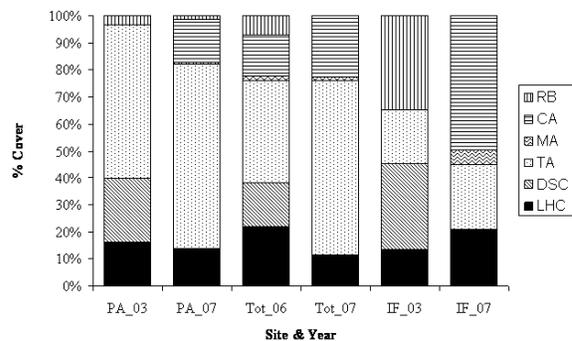


Figure 3: The percentage cover of 6 benthic categories at Passe Armand (PA), Totor (Tot) and Ile aux Fous (IF) during 2003, 2006 and 2007 assessed using the line intercept transect method.

Discussion

Coral bleaching

The data from 2002, 2005 and 2007 highlight small-scale variations in coral bleaching around Rodrigues. In both 2002 and 2005, sites in the north and west of the island were most severely affected. In 2002, 50 – 100 % of branching and tabular *Acropora* spp. died at 5 sites in the north of the island, whereas sites in the south and east were either healthy (no bleaching) or suffered from partial bleaching on the upper surfaces of branching colonies only (Hardman et al. 2004). In 2005, >50 % of coral colonies bleached at 10 sites in the north and west of the island and coral mortality occurred at 1 site, whereas bleaching in the south and east was mild and patchy (Hardman et al. in press). This study found that coral bleaching had occurred on just 1 patch reef in the southern lagoon, whereas sites <1 km away did not suffer from bleaching-related mortality. Coral bleaching was most widespread during 2005, but subsequent mortality was greater during 2002. In all cases, coral bleaching occurred at depths of <2 m and branching and tabular *Acropora* spp. were most severely affected. Previous studies have also shown that this genus is the most

susceptible to coral bleaching and subsequent mortality (e.g. Brown and Suharsono 1990; Edwards et al. 2001; McClanahan 2004).

Data from NOAA and the Mauritius Meteorological Services suggest that conditions were conducive to coral bleaching during 2002, 2005 and 2007. SST data indicates that 30°C may be the threshold for coral bleaching in Rodrigues, as this was recorded during February 2002, March 2005 and January 2007, but not in years when bleaching did not occur. This is higher than the threshold of 27.5°C recorded in Mauritius (McClanahan et al. 2005), highlighting geographical variations in bleaching response. During February 2002, high air and sea temperatures, high hours of sunshine and low wind speeds all combined to promote heating of shallow water and increased solar penetration and thus explains the more severe bleaching observed during 2002. Although temperatures were high, sunshine hours were below average during March 2002 and wind speeds were above average during January 2007. Furthermore, in 2007, temperatures fell below average in February and March and February had very low cloud cover accounting for the limited bleaching that was observed during that year. This indicates that a combination of climatic factors, not just high temperature, is required for widespread coral bleaching to occur (e.g. Brown and Suharsono 1990).

Data from Shoals Rodrigues indicates small-scale variations in environmental conditions within the lagoon. SST varied significantly at sites 3 – 5 km apart and was found to be highest at the most inshore, sheltered site of Totor and lowest at the more exposed site of Grand Bassin. Totor was one of the worst affected sites in 2005 where 31 – 50 % of coral colonies bleached (Hardman et al. in press) whereas, although bleaching occurred at Grand Bassin in both 2002 and 2005, it was less severe (Hardman et al. 2004; in press). Current speeds were lower in the north of the lagoon than the south, suggesting that the decreased water flow may have increased the severity of coral bleaching at sites in the north and west of the island during 2002 and 2005. Environmental stress to corals has been shown to be reduced with high water flow whereas in areas of decreased water flow, oxygen accumulates within the coral tissues, resulting in oxidative stress and an increased severity of bleaching (Finelli et al. 2006). In contrast, McClanahan et al. (2005) show that in Mauritius, coral bleaching was positively associated with high water flow, with the most severe bleaching occurring on windward sites with the highest current speeds. They suggest that corals living in stable, less environmentally stressed environments such as these are more susceptible to bleaching increases. This may explain the bleaching in 2007, which occurred on the

southern patch reef only, a site with the highest current speeds, which had not exhibited bleaching in previous years.

Recovery from bleaching

Recovery from the bleaching events also showed small-scale variations with sites <5 km apart demonstrating different responses. Totor and Passe Armand have shown limited recovery 2 and 5 years respectively after suffering from bleaching-induced mortality and sites were dominated by turf algae with low live coral cover. In contrast, Ile aux Fous showed an increase in live coral cover, a high cover of coralline algae and the highest abundance of new coral recruits, indicating more successful recovery. Totor and Passe Armand are inshore sites (500m offshore), situated within the sheltered Port Mathurin Bay. These sites are subjected to high sedimentation, especially following periods of heavy rainfall (Hardman 2004), increased nutrient input (Shoals Rodrigues unpublished data) and human impacts such as trampling damage from octopus fishers.

The variation in recovery rates is therefore likely to be as a result of these additional human impacts. Lambo and Ormond (2006) also suggest that in Kenya, coral bleaching, sedimentation and fishing pressure have combined to result in further declines in live coral cover following the 1997/1998 coral bleaching event. Totor also has a high abundance of the bioeroding sea urchin, *Echinometra mathaei* (Hardman et al. in press) and bioerosion rates may counteract up to 150 % of the total calcification at this site. This high level of bioerosion suggests that if reefs continue to be affected by coral bleaching then there may be a loss of the coastal protection function of the reef.

Although Rodrigues escaped the mass bleaching event of 1997/1998, coral bleaching events have occurred in 2002, 2005 and 2007 causing locally severe mortality. It has been predicted that coral bleaching events will occur annually by 2030 - 2050 (Hoegh-Guldberg 1999) and Sheppard (2003) estimates that reefs in the Indian Ocean will be affected every five years by 2010 - 2025, becoming ecologically extinct within the next 20 - 40 years. If coral bleaching events continue to occur on such a frequent basis, then this will affect the integrity of the reef structure causing breaks in the reef's protective barrier, leaving these areas vulnerable to wave action and resulting in increased coastal flooding and storm damage with loss of coastal habitats and significant damage to coastal properties.

Rodrigues is a very isolated island, which receives a limited larval supply, suggesting that the reefs rely on larval retention and self-seeding for population recovery. Although McClanahan et al.

(2005) suggest that the lack of bleaching in 1997/1998 and the local climatic conditions mean that reefs in this region may be more resilient to temperate anomalies, the limited larval supply inhibits recovery, making reefs more susceptible to climate change-driven reef degradation (Graham et al. 2006). These inshore reefs, already affected by human impacts, are therefore at risk of suffering a phase-shift to an algal dominated community with the associated loss of structural complexity. Rodrigues is highly reliant on its coral reef resources for food, employment and coastal protection and a loss of reef structure could have very serious consequences for the future of this small island.

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