11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008
Session number 18

Rapid recovery from bleaching events - Fiji Coral Reef Monitoring Network Assessment of hard coral cover from 1999-2007

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Abstract. Long-term biological monitoring of coral reef sites across the Fiji Islands was carried out over a nine year period which included mass coral bleaching events. Sites were fringing reef slopes close to shore, or patch reefs facing deeper water, and surveys were carried out between 5 and 20m depth. Data was contributed by many organisations, including scientists, tourism operators, non-governmental organisations and community members. All surveys utilised point intercept transects from which the percentage of hard coral cover was applied for regional comparisons over-time. Benthic data was generally recorded as coral life-form categories. High sea surface temperatures (SST) in 2000 and 2002 led to large-scale coral bleaching events with hard coral mortality of 40 – 80%. In both cases, temperatures remained above the long-term summer average (28.3°C) for over 3 months. Though variable, substantial recovery to pre-bleaching levels was seen within 5 years in many areas. Fiji's reefs show great diversity, and are spread over a large geographical area. Though mass bleaching events were expansive, they did not affect the entire country's reef systems at one time. Some areas and habitats appear to have elements conducive to minimising the effects of bleaching. This allowed for the repopulating of affected areas more swiftly than may occur in reefs that are more isolated. A high level of resiliency of the Fiji reef system as a whole is indicated and is a cause for optimism.

Key words: coral reef monitoring, coral bleaching, resilience, Fijian coral reefs

Introduction

Coral reefs have been characterized as degrading worldwide (Indo Pacific (Wilkinson 2008); SE Asia (Burke et al. 2002); Caribbean (Gardner et al. 2003)). While many areas with high human population density are greatly affected by human-related impacts, in more remote areas climate change is a more immediate issue, and coral bleaching events are amongst the main factors contributing to wide scale degradation. Coral bleaching events are the main factor contributing to the wide scale degradation, having impacted coral reefs globally. However, some coral reef regions have experienced rapid recovery after major bleaching events, and such is the case in Fiji (Lovell & Sykes 2004, Sykes 2007).

Relative resilience to the widespread mortality of coral reefs during a coral bleaching event is variable. In Fiji, the rapid recolonization of affected reefs may be due largely to the size and physical complexity of the archipelago. The Fijian archipelago spans 18,500km^2 and comprises high and low islands with all reef types including one of the world's longest barrier reef (South and Skelton 2000, Vuki et al. 2000). It is a mid-ocean archipelago surrounded by deep water and washed by oceanic currents.

This paper represents a summary of annual reports submitted by the Fiji Coral Reef Monitoring Network (FCRMN) as part of its contribution to the Global Coral Reef Monitoring Network (GCRMN) and Reef Check. Data was collated from a number of organizations which include scientists, tourism operators, non-governmental organisations and community members. The programme is coordinated by the authors and the Institute of Marine Resources. It is currently supported by the University of the South Pacific and the Coral Reef Initiative in the South Pacific (CRISP).

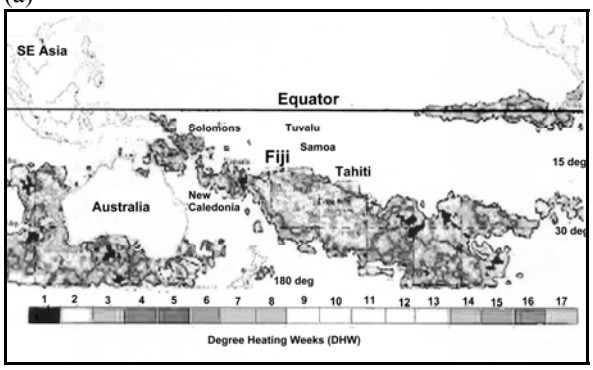
This paper summarizes the results of nine years of biological monitoring, using the Reef Check and FCRMN Point Intercept Transect (PIT) methodologies.

Background

Fiji SSTs range annually between 24°C and 28°C, with a bleaching threshold at 29.2°C (National Oceanic and Atmospheric Agency (NOAA) NESDIS satellite information).

High SSTs in 2000 and 2002 led to large scale coral bleaching events with hard coral mortality of 40-80% in depths <5m. In both cases, the temperature remained above the long-term mean and the bleaching threshold for 3 months with a band of warm water extending from the Solomon Islands to the southeast, either partially or completely covering the archipelago (Cummings et al. 2001, 2002; Lovell and Sykes 2004).

(a)



(b)

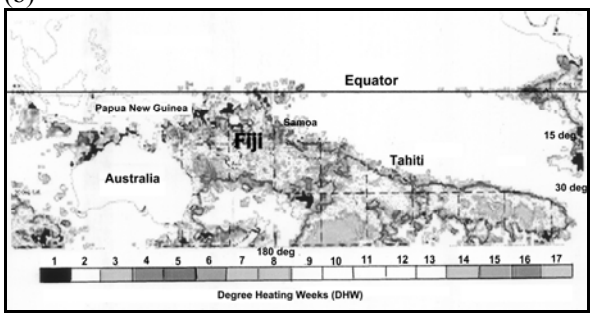


Figure 1. Chart of Degree Heat Weeks (DHW) accumulated in April, 2000 (a) and in 2002 (b) in the South Pacific. Light shading indicates 8-10 DHW's, darker shading inside of the light shading indicates 10-14 DHW's. See NOAA website: http://psbsgil.nesdis.noaa.gov:8080/PSB/EPS/SST/dhw_retro.html. National Oceanic and Atmospheric Agency (NOAA) NESDIS satellite information.

Methodology

Benthic data was assessed using point intercept transects, with the benthic attributes recorded as coral life-form categories or species. In all cases, the information was gathered over a period of years, although the most detailed and longest term data came from two areas, Suva and the central Vatu-i-Ra Passage. In-situ temperature loggers were placed in sites where biological surveys were made.

Results

In-situ temperature loggers showed a North-South sea water temperature variation of 1.5^{o}C across the archipelago (Figure 4).

For depths of 10m and deeper (<20m), benthic assessment showed a consistent trend of declining hard coral cover after the 2000 and 2002 mass coral

a)

b)

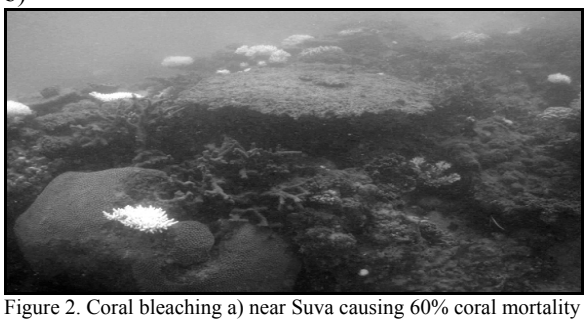


Figure 2. Coral bleaching a) near Suva causing 60% coral mortality in 2000 and b) at a reef near Vatu-i-Ra Passage.

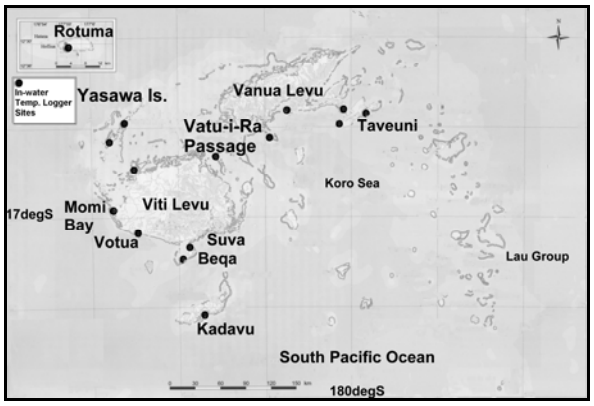


Figure 3. Chart of the Fiji archipelago showing the survey and temperature recording sites. Adapted from Spalding, Ravilious and Green (2001).

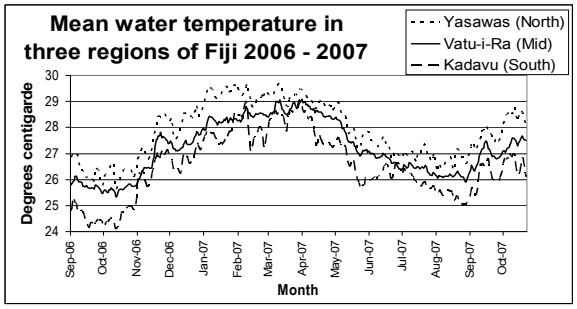
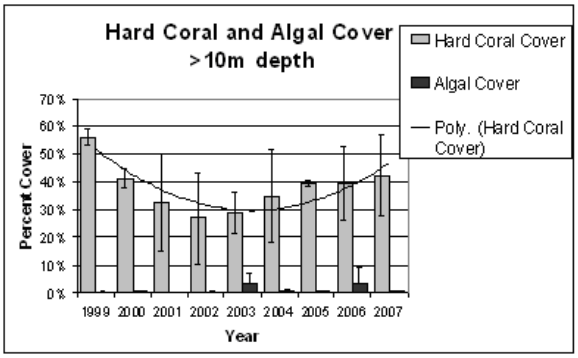


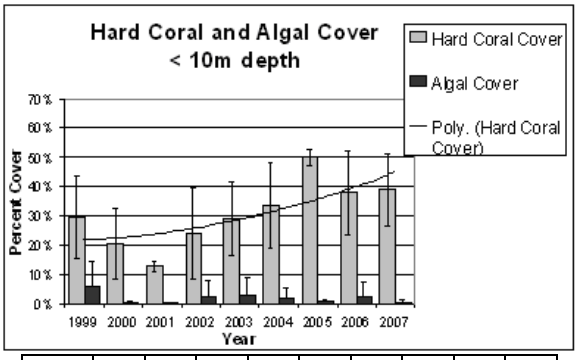
Figure 4. Graph of mean sea water temperatures at depths of 5 - 10m at three sites across the Fijian Archipelago (Vemco Mini-loggers set at 2 hour intervals).

bleaching events. An increase in coral cover was evident by 2003, and by 2007 was approaching the 1999 level (Figure 5). For depths less than 10m, by 2005, the degree of coral cover exceeded the coral coverage assessed in 1999 (Figure 6). As was characteristic of all reefs, algal cover remained low except in areas where anthropogenic effects, such as nutrient pollution and overfishing, have occurred (Mosley and Aalsberberg 2003).



Year	99	00	01	02	03	04	05	06	07
N	2	2	3	6	5	10	2	16	15

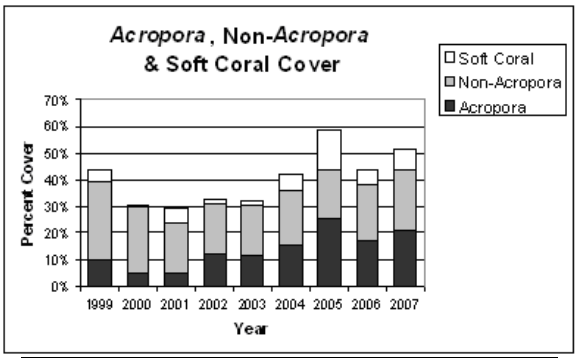
Figure 5. Mean hard coral and algal cover on reefs deeper than 10 m, across the Fiji Islands 1999 – 2007. Error bars show standard deviation with polynomial trend lines, Order 2.



Year	99	00	01	02	03	04	05	06	07
n	3	3	2	12	15	15	5	17	17

Figure 6. Mean hard coral and algal cover on reefs shallower than 10 m across the Fiji Islands 1999 – 2007. Error bars show standard deviation with polynomial trend lines, Order 2.

Figure 7 shows the breakdown of coral types into *Acropora* or non-*Acropora* and soft coral over the 9 years of assessment. The bleaching phenomenon in 2000, 2002, and subsequent crown of thorns seastar predation and cyclone damage had greater impacts on *Acropora* corals than on non-Acropora and soft corals. Differences in trends between Figures 5-6 and Figure 7 are due to the combination of data from all depths in Figure 6.



Year	99	00	01	02	03	04	05	06	07
n	5	4	5	8	10	15	3	26	25

Figure 7. Mean hard coral cover across the Fiji Islands 1999 – 2007, showing separation into coral types (Acropora, non-Acropora and soft coral) combining all depths.

Figure 8. summarises the effects of coral bleaching at one site from 1999 – 2007. There was 60% live coral coverage in the Vatu-i-Ra passage in 1999. In 2000, 42% had died or were bleached. In subsequent years, partial bleaching occurred but the general level of coral coverage increased.

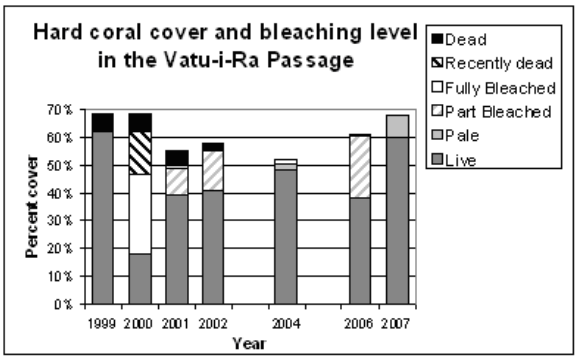


Figure 8. Hard coral cover and extent of bleaching at time of survey in the Vatu-i-Ra Passage (Mount Mutiny) 1999 – 2007. No surveys were carried out in 2003 and 2005.

In Figures 9 and 10, coral types using lifeform categories (English et al. 1997) are shown for the years 1999 – 2007, for a single site and as the Fiji-wide mean. In both cases, *Acropora* coral forms were more severely affected by bleaching than non-*Acropora*, but had recovered to pre-bleaching levels by 2005. Post bleaching reefs showed a higher diversity of coral lifeforms than pre-bleaching.

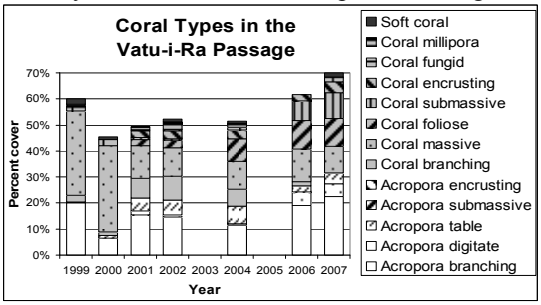
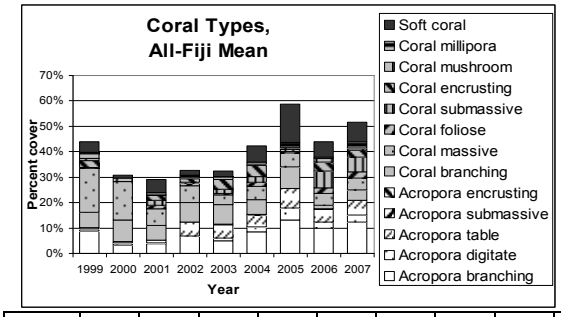


Figure 9. Mean main coral types in life-form categories at the Vatu-i-Ra Passage site 1999 – 2007. No surveys were carried out in 2003 and 2005.



Year	99	00	01	02	03	04	05	06	07
n	5	4	5	8	10	15	3	26	25

Figure 10. Mean main coral types in life-form categories for all sites in Fiji during the period of 1999 – 2007.

Discussion

In 2000 and 2002, Fiji's coral reefs experienced extensive bleaching mortality, with a total loss of between 40 and 80% of hard coral across the archipelago. The worst affected corals were largely from the *Acropora* family, which in some areas were completely obliterated.

For a two to three year period after the 2000 bleaching, many reefs were dominated by non-*Acropora* corals, predominantly *Pocillopora*, *Porites* and *Montipora* species, but *Acropora* corals reappeared after a very short hiatus, and by 2004 equalled or exceeded pre-bleaching levels.

By 2007, coral cover was substantial on most reefs, recovering to a national average of 45%, with up to 80% live hard coral cover in some regions. In many areas recovered with hard coral cover and lifeform diversity in 2007 was higher than pre-2000 bleaching levels.

In many cases reefs which recovered quickly were down-current of unaffected areas, and so were probably connected to sources of new coral spawn. Recovery in some areas appeared to be accelerated by a cyclonic event which cleared many reefs of dead algae-coved rubble, creating new coral settlement habitat. Where recovery was slow, probable causes include physical remoteness or algae domination preventing coral settlement.

While the coral bleaching events were extensive they did not affect the entire country's reef systems at one time, and though variable, substantial recovery to pre-bleaching levels was seen within 5 years, in many areas indicating a high level of resiliency to bleaching events. Several factors are thought to be integral to this resiliency.

Fiji's reefs show great physical and species diversity and are spread over a large geographical area. Reservoirs of unaffected coral were always to be found somewhere in the archipelago.

While Fiji's sea water temperatures have reached or exceeded the bleaching threshold in most summers of the last 10 years, there is a sea water temperature range of 1.5^{o}C over the archipelago. This range provides areas where corals exist in lower temperature water, and appear to have escaped the mass bleachings.

In addition Fiji is remote from highly populated landmasses and large scale industrial pollution sources. There are threats to near-shore reefs from agricultural pollution, coastal development, and over-fishing, but there are extensive reefs areas unaffected by these.

As a result of combinations of these factors, corals have managed to survive the mass bleaching mortality events of 2000 and 2002 in habitats which appear to be conducive to minimizing the effects of bleaching. This allowed for the repopulating of affected areas more swiftly than may occur in more isolated reefs.

Conclusions

After 9 years of monitoring including the 2000 & 2002 bleaching events, Fiji's reef system experienced rapid coral re-growth in many areas.

Over the country, many reefs returned to pre-bleaching coral cover levels in approximately 5 years. Fiji corals can survive catastrophic events as long as they do not occur too often. A high degree of resiliency of the Fiji reef system as a whole is indicated, and is a cause for optimism.

There may be a case for special attention to preservation of remote yet connected reef systems such as Fiji to provide reservoirs of resilient corals in the face of the continuing global downturn in coral reef health.

Acknowledgements

Appreciation for the Global Coral Reef Monitoring Network (GCRMN) and Reef Check for initiating a co-operative project to train a network of survey teams who could report on coral reef health across the country. Many thanks to the Fiji Coral Reef Monitoring Network participants whose data is summarized in this report. Coordination for the project was provided by the Institute of Marine Resources at the University of the South Pacific and Resort Support, Fiji. The Coral Reef Initiative in the South Pacific (CRISP) provided funding for this project.

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