"A Cause for Optimism": Identification of threats and resiliency on Pacific Reefs through establishment of a long term reef monitoring network in Fiji: The Fiji Coral Reef Monitoring Network (FCRMN)

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ABSTRACT

The Fiji Coral Reef Monitoring Network (FCRMN), a node of the Global Coral Reef Monitoring Network (GCRMN) includes scientists, tourism operators, and community members. Long term monitoring of reefs across the Fiji Islands for nine years included mass temperature-related coral bleaching events, cyclones, and Crown-of-thorns seastar (COTS) outbreaks.

Survey protocols used variants of Point-Intercept Transects for coral cover, and Belt Transects for indicator fish and invertebrate populations. Percentage hard coral cover was used for regional and time-line comparisons. More detailed protocols allowed comparisons by coral life-form category. Data was compiled through the Coral Reef Initiative for the South Pacific (CRISP).

Coral cover fell dramatically in 2000 – 2002 after two mass bleaching events, plus regional COTS outbreaks, but recovered to pre-bleaching levels by 2005. Cyclones affected localised coral health in shallow waters, but caused no large scale or permanent damage, and in some cases served coral recovery by lowering water temperatures and clearing new substrate for settlement.

Overall, Fiji's reefs appear to be remarkably resilient to sudden catastrophic events, a cause for optimism.

Major "chronic" continual impacts on coral reef health:
- **Eutrophication**
- **Siltation (deforestation / coastal development)**
- **Over fishing**

Occasional or sporadic "acute' impacts on coral health:
- **Temperature-related bleaching**
- **Predation and disease**
- **Cyclones**

Features contributing to coral resilience:
- **Geographically remote from industrialised land masses**
- **Large physical reef diversity**
- **Connectivity of habitats and genetic stocks**
- **Few overtly destructive fishing practices**
- **Network of locally managed marine protected areas**

Keywords

Coral bleaching, Coral resiliency, Long term monitoring.

1. INTRODUCTION

The Fiji branch of the GCRMN started in Fiji in 2000, in response to a country-wide mass coral bleaching event, to coordinate, build and expand on scattered reef monitoring projects. The FCRMN has carried out long term reef monitoring across the Fiji Islands since 1999 (earlier on some sites). This period has covered mass temperature-related coral bleaching mortality (2000 and 2002), cyclones (2001 and 2004), and Crown-of-thorns seastar (COTS) and corallivorous Drupe snail outbreaks (1996 - 2000 and 2005 – 2008). (Zann 1992, Cumming 2002, Lovell 2004, Sykes 2006).

In-water temperature loggers originally in limited areas (Quinn 2004) and later in a country-wide network (Sykes 2006) allowed the FCRMN to relate coral health to water temperature and to ground truth Sea Surface Satellite data (SSTs) (NOAA 2007).

In 2001, Reef Check and GCRMN coordinators led a co-operative project to train survey teams in easily compared techniques, to report on coral reef health across the country.

FCRMN continues as a largely unfunded voluntary contribution network, contributing to GCRMN and Reef Check global reports. Data is gathered and surveys supported by organisations including Scientists, Non-Governmental Organisations, Tourism Operators and Community Members. Most sites are monitored annually, others opportunistically. There are consequent data limitations, but long term patterns repeat in all regions.

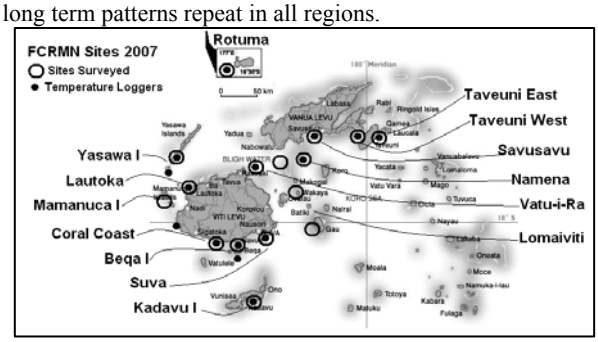

Figure 1. FCRMN long term monitoring and temperature logger sites

2. METHODS

2.1.1 Annual biological surveys

Minimum level carried out by all teams:

- 20m x 5m Belt Transects for indicator fish and invertebrates
- 20m x 40 Point Intercept Transects for basic substrate cover (Reef Check 2007).

Additional surveys where capability exists:

- 20m x 40 Point Intercept Transects for coral cover to Lifeform Categories (English 1997)
- In-water temperature data gathered every 2 hours by Vemco and Hobo submersible water temperature loggers at 5 - 10 m
- Assessment of reef resilience using draft checklist (McCleoud 2007)
- A simplified version of "Reefs at Risk" threat index to assess potential threats to reef health in each region. (Burke 2000, Lovell 2004)

3. RESULTS

3.1 Impacts on coral health

3.1.1 Elevated sea water temperatures

Fiji's coral bleaching threshold temperature has been identified as 29.3°C (NOAA 2007). In 2000, when Fiji's mean daily in-water sea temperature was recorded above 29°C for over 90 consecutive days, a mass bleaching mortality occurred, during which Fiji lost between 40 and 80% of the hard coral across the country. (Cumming 2002).

Apart from this event, limited bleaching was observed in most years, but mass bleaching only took place when there were more than 80 consecutive days of mean water temperature above 29°C. Years with 35 – 60 consecutive days average temp over 29°C resulted in bleaching only in limited areas.

2000: 90 consecutive days over 29°C → Mass bleaching
2002: 90 consecutive days over 29°C → Mass bleaching
2006: 60 consecutive days over 29°C → Limited bleaching
Other years: Less than 40 consecutive days over 29°C → very limited, apparently reversible bleaching with no or low mortality.
2001: Cyclone & heavy rainfall (Fiji Met Service 2008)
→ water temperatures dropped by up to 1.5°C overnight
→ bleaching ceased.

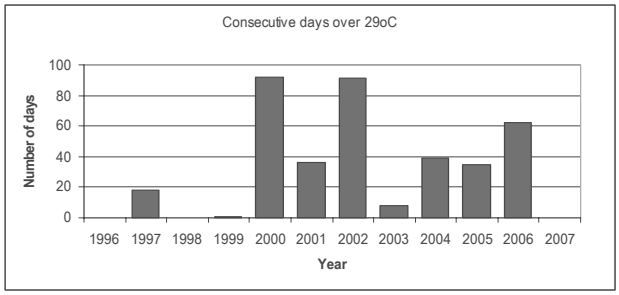

Figure 2. Number of consecutive days with a mean sea water temperature of 29°C or higher, from 1996 to 2007. Data from in-water loggers set in the central Vatu-i-Ra passage, at 5m depth.

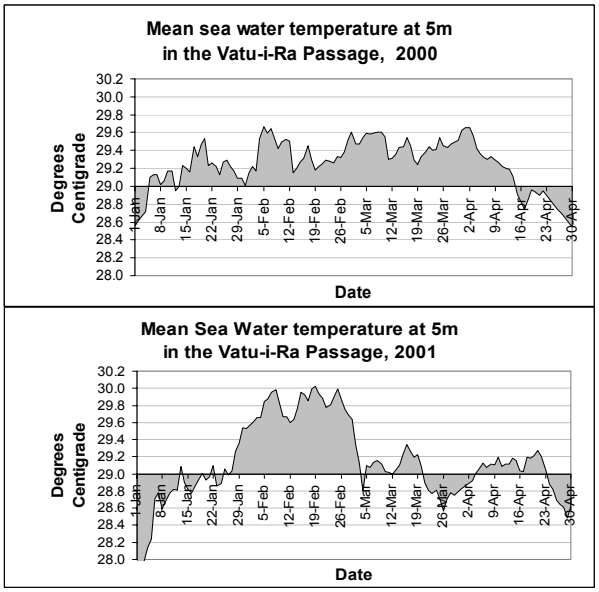

Figure 3. Mean daily water temperature in the Vatu-i-Ra Passage January – April 2000 and 2001. Temperature drop on 5 March corresponds with Cyclone Rita (1-5 March). X axis set at 29°C

3.1.2 Crown-of-thorns seastar (COTS) predation

One region of Fiji suffered a massive COTS outbreak between 2004 and 2008. COTS numbers peaked in 2006, then fell as *Acropora* coral cover diminished. Non-*Acropora* corals were much less affected, and increased once COTS numbers reduced. Some very small *Acropora* colonies appeared by the end of 2008.

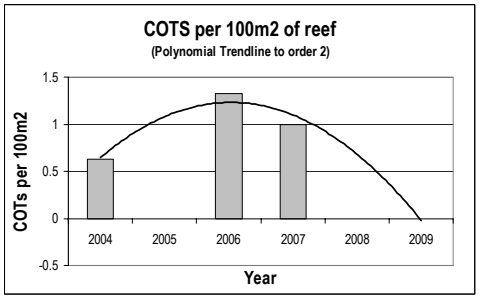

Figure 4. Number of COTS per 100m^2 of reef 2004 - 2008

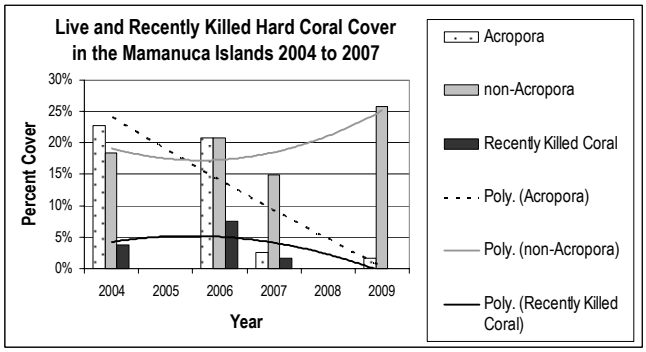

Figure 5. Percent cover of *Acropora*, non-*Acropora*, and recently killed hard coral 2004 – 2008 (Polynomial trendlines to order 2)

3.2 Changes in hard coral cover

Large scale hard coral losses were seen after mass bleachings in 2000 and 2002. In many areas hard coral cover recovered to pre bleaching levels by 2004 or 2005.

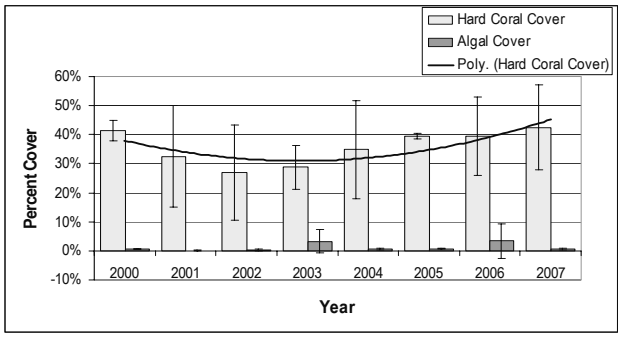

Figure 4. Mean hard coral and algal cover on reefs 10m and deeper, across the Fiji Islands 2000 – 2007

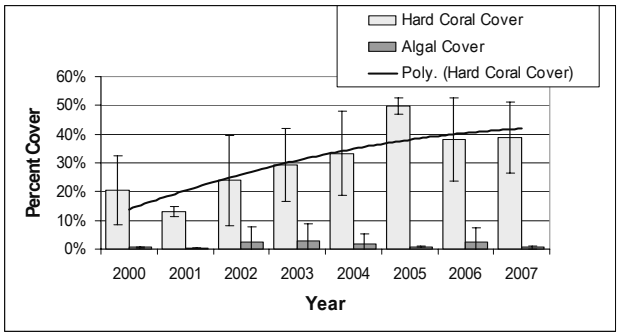

Figure 5. Mean hard coral and algal cover on reefs shallower than 10m, across the Fiji Islands 2000 – 2007

Acropora corals were hardest hit by coral bleaching and other impacts, but recovered to pre-bleaching cover levels within five years. Reefs across the country showed greater life-form diversity of both *Acropora* and non-*Acropora* corals after the mortality than before.

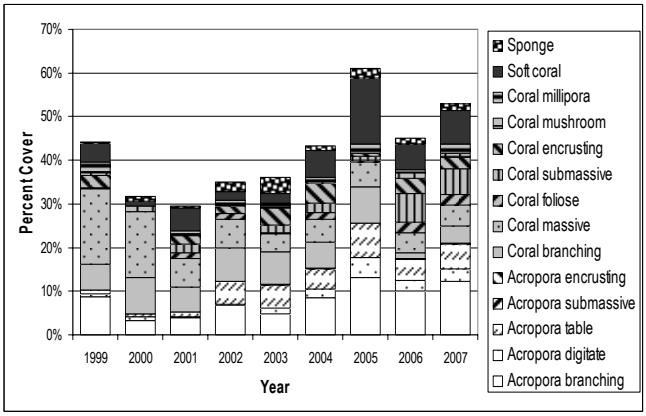

Figure 6. Mean main coral types in life-form categories across the Fiji Islands 1999 – 2007 (all depths)

3.3 Threats and resiliency

3.3.1 Threat Index

A simplified version of "Reefs at Risk (Burke 2000, Lovell 2004), identified over-fishing as the largest risk factor for most of the country, plus sedimentation in near-shore areas.

Reef Area	Integrated Threat Index	Highest risk factor
Taveuni, Somosomo	Low	Pollution (shipping)
Taveuni, Waitabu	Very Low	Sedimentation
Savusavu	Medium	Sedimentation Over-fishing
Namena	Very Low	Sedimentation
Lomaiviti	Low	Over-fishing
Suva	Very High	Pollution, Sedimentation Over-fishing
Kadavu	Medium	Over-fishing
Beqa	Medium	Over-fishing
Coral Coast	High	Sedimentation Over-fishing Destructive Fishing
Momi Bay	Medium	Over-fishing
Mamanucas	Medium	Over-fishing
Lautoka	High	Pollution, Sedimentation Over-fishing
Yasawas	Medium	Over fishing
Vatu-i-Ra	Very Low	Sedimentation Over-fishing Destructive Fishing
Rotuma	Low	Over-fishing

Table 1: Integrated threat index for each reef area (from Burke 2000)

3.3.2 Resiliency

Most of Fiji's reefs scored highly for factors relating coral resiliency to climate change, particularly in the areas of large-scale water movement, water quality, coral health and diversity, survival of previous hot water events, and marine protection.

Above water factors	Below water factors
Upwellings	Fine-scale Water Movement
Large Scale Water Movement	Reef Shading
Reef Shading	Coral Cover
Water Quality	Resistant / Tolerant Corals
Water Cover at Low Tide	Coral Diversity
Hot Water Events	Mixed Size-class Distribution
Temperature Variability	Abundance of Mature Corals
Connectivity	Abundance of Herbivores
Protected from Overfishing	Substrate Stability
Protected from Physical Impacts	Clean Substrate Availability
	Unsedimented Substrate
	Protected from Physical Impacts
	Coral Solidity
	Coral Health

Table 2: List of factors assessed for each reef area's resiliency to climate change (from McCleoud 2007)

4. DISCUSSION

4.1 Main impacts on Fiji's reefs

Over the survey period covered by the FCRMN, two main categories of threat were identified:

- "Acute" or sudden catastrophic events
- "Chronic", long term, gradual but continuing, stressors

"Acute" catastrophic events attracted a great deal of attention, both in Fiji and globally. These included:

- Temperature-related bleaching
- Predation and disease (COTS and Drupe snails)
- Cyclones

These impacts are dramatic and visible, global in nature, and are difficult to address locally.

"Chronic" impacts were not as immediately visible as acute ones, but were identified by the Integrated Threat Index.
These included:

- Siltation (watershed deforestation, coastal development)
- Over fishing (subsistence and commercial)
- Eutrophication & pollution (agriculture, population density)

These impacts are more insidious, less likely to attract attention, and are often over shadowed by "acute" events. They have long term and far-reaching effects, but could be nationally controlled if the will was there and the resources were available

4.2 Recovery from acute catastrophic events

Short term monitoring was able to identify immediate, and usually damaging, results of "acute" impacts on coral health. Longer term monitoring was more effective at showing effects of "chronic" impacts, and illustrating resilience and recovery cycles.

Fiji's reefs showed remarkable ability to resist and recover from several "acute" events during the period of study. Many events which initially had negative impacts on reef health either turned out to be less permanently damaging than expected (bleaching, COTS), or actually had positive long term outcomes (cyclones).

Year(s)	Event	Long term effect
1998 - 2000	Regional COTS and Drupe snail outbreaks	Between 40 and 80% coral mortality across the country, but recovery by 2005, with greater diversity
2000 & 2002	Temperature related mass coral bleaching mortality	
2001 & 2004	Cyclones caused coral breakage in some areas	Re-growth within 2 years, New coral settlement on cleared substrate Reduced water temperature halted bleaching.
2005 - 2008	Regional COTS and Drupe snail outbreaks	COTS reduced by 2008 as coral cover declined. Small coral colonies starting to grow.

Table 3. "Acute" events affecting coral cover between 1998 and 2008, and their long term effects

4.3 Factors contributing to coral resilience

Fiji is a relatively large archipelago, located in a deep ocean, away from major land masses. While it is subject to many stressors, and has suffered from major coral-damaging events, overall recovery has been fast and wide-spread. The following factors appear to play a major part in resiliency to stresses:

- Geographically remote from major industrialised land masses
- Large physical reef diversity
- Large species biodiversity
- Water temperature range across country
- Connectivity of habitats and genetic stocks
- Few overtly destructive large-scale fishing practices
- Network of locally managed marine protected areas

CONCLUSIONS

After over nine years of monitoring, including two mass bleaching and COTS predation events, Fiji's reef system seems remarkably resilient, with rapid coral re-growth. Many reefs returned to pre-bleaching coral cover levels within five years.

While short term monitoring can identify immediate results of stressing events, long term monitoring is essential to accurately represent actual cycles of coral reef health.

Fijian reefs can survive "acute" events as long as they do not occur too often, perhaps not more than every five years. Ongoing "chronic" impacts are probably more of a long term threat and need to be addressed at a national level.

Reefs in remote areas such as Fiji may be vital reservoirs of resilient coral and habitats and therefore should be given priority in protection of global reef health.

Overall, Fiji's reefs appear to be remarkably resilient to acute catastrophic events, a cause for optimism.

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- GCRMN (Global Coral Reef Monitoring Network)
- IMR (Institute of Marine Resources, University of the South Pacific)
- Marine Ecology Consulting, Fiji
- Reef Check

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- Coral Cay Conservation
- Diveaway Fiji
- Fiji Meteorological Service
- Frontier-Fiji
- Georgia Aquarium
- Jean-Michel Cousteau Resort Fiji Islands
- *Laje*Rotuma Initiative
- Lalati Resort
- Marine Ecology Consulting Fiji
- Matava Resort
- Nai'a Cruises
- Nanuya Island Resort
- Reef Safari
- Resort Support Fiji
- Subsurface Fiji
- University of the South Pacific
- Waitabu Marine Park

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