“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)

Helen R Sykes¹ and Edward R Lovell²
1) Marine Ecology Consulting, Fiji, 2) University of the South Pacific
1) Helen@marineecologyfiji.com, 2) Lovell_e@usp.ac.fj

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)

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.](image)

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 100m² of reef 2004 - 2008](image)

![Figure 5. Percent cover of Acropora, non-Acropora, and recently killed hard coral 2004 – 2008 (Polynomial trendlines to order 2)](image)
### 3.2 Changes in hard coral cover

Large scale hard coral losses were seen after mass bleaching 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.

### 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.

<table>
<thead>
<tr>
<th>Reef Area</th>
<th>Integrated Threat Index</th>
<th>Highest risk factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taveuni, Somosomo</td>
<td>Low</td>
<td>Pollution (shipping)</td>
</tr>
<tr>
<td>Taveuni, Waitabu</td>
<td>Very Low</td>
<td>Sedimentation</td>
</tr>
<tr>
<td>Savusavu</td>
<td>Medium</td>
<td>Sedimentation, Over-fishing</td>
</tr>
<tr>
<td>Namena</td>
<td>Very Low</td>
<td>Sedimentation</td>
</tr>
<tr>
<td>Lomaiviti</td>
<td>Low</td>
<td>Over-fishing</td>
</tr>
<tr>
<td>Suva</td>
<td>Very High</td>
<td>Pollution, Sedimentation, Over-fishing</td>
</tr>
<tr>
<td>Kadavu</td>
<td>Medium</td>
<td>Over-fishing</td>
</tr>
<tr>
<td>Beqa</td>
<td>Medium</td>
<td>Over-fishing</td>
</tr>
<tr>
<td>Coral Coast</td>
<td>High</td>
<td>Sedimentation, Over-fishing, Destructive Fishing</td>
</tr>
<tr>
<td>Momia Bay</td>
<td>Medium</td>
<td>Over-fishing</td>
</tr>
<tr>
<td>Mamanucas</td>
<td>Medium</td>
<td>Over-fishing</td>
</tr>
<tr>
<td>Lautoka</td>
<td>High</td>
<td>Pollution, Sedimentation, Over-fishing</td>
</tr>
<tr>
<td>Yasawas</td>
<td>Medium</td>
<td>Over-fishing</td>
</tr>
<tr>
<td>Vatu-i-Ra</td>
<td>Very Low</td>
<td>Sedimentation, Over-fishing, Destructive Fishing</td>
</tr>
<tr>
<td>Rotuma</td>
<td>Low</td>
<td>Over-fishing</td>
</tr>
</tbody>
</table>

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.

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

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).

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

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.

5. ACKNOWLEDGMENTS

The FCRMN would not have been formed without the early encouragement and continual support of Dr Ken MacKay. We are also indebted to the GCRMN South West Pacific Node Coordinator Cherie Morris and her team for invaluable data handling support and report editing, and to Chinnamma Reddy for data entry and assistance.

Although the FCRMN is largely unfunded, many organisations have supported individual aspects of the work, including:

- CRISP (Coral Reef Initiative for the South Pacific)
- C-SPOD (Canada-South Pacific Ocean Development)
- GCRMN (Global Coral Reef Monitoring Network)
- IMR (Institute of Marine Resources, University of the South Pacific)
- Marine Ecology Consulting, Fiji
- Reef Check
The following organisations contributed data or provided diving and accommodation support for FCRMN surveys. Without these volunteers there would be no FCRMN.

- Aquasafaris
- Aquatrek / Garden Island Resort
- 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

6. REFERENCES


