

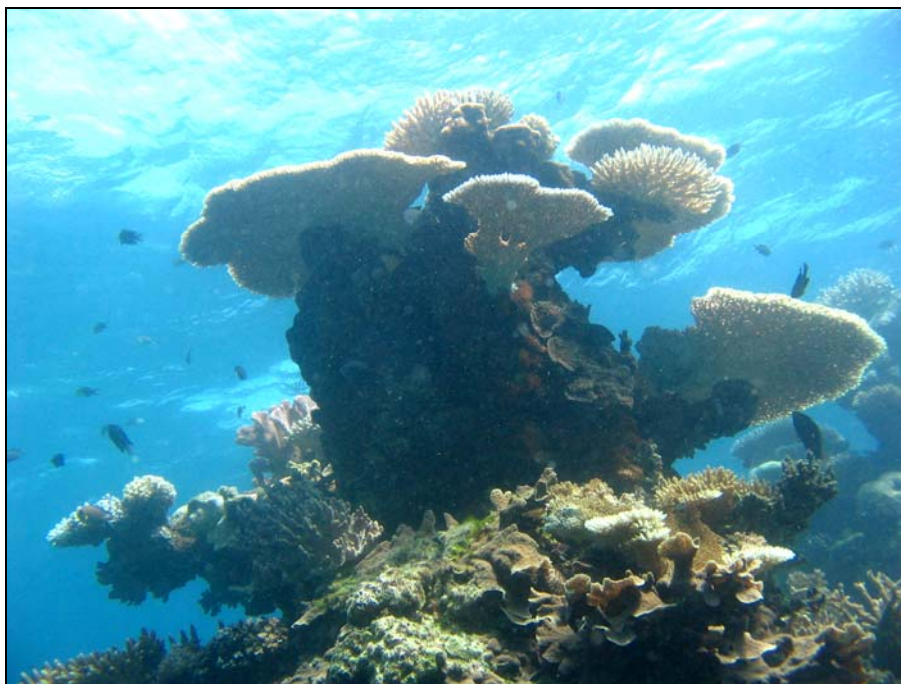
# STATUS OF CORAL REEFS IN THE FIJI ISLANDS, 2006



Fiji Coral Reef Monitoring Network



## Part 1: Reef Health across the Fiji Islands



# CRISP



Coral Reef Initiative for the South Pacific  
Initiative Corail pour le Pacifique Sud

marine ecology consulting

**Helen R Sykes**  
Marine Ecology Consulting  
Resort Support  
**May 2007**

**RESORT**  
Support

**PART 1**

<b>Section 1) Introduction</b>	<b>5</b>
• Acknowledgements and Contributors 2005 and 2006	6
• Survey Sites	7
• Methods	8
<b>Section 2) Reef health in Fiji, 2006</b>	<b>9</b>
<b>Section 3) Progressive reef health since 1999</b>	<b>15</b>
<b>Section 4) Bleaching and water temperature since 1997</b>	<b>20</b>
<b>Section 5) Discussion and references</b>	<b>23</b>

---

**PART 2**

<b>Section 6) Regional details</b>	<b>25</b>
a) Coral Coast, Viti Levu	25
b) Savusavu, Vanua Levu	27
c) Suva Harbour, Viti Levu	31
d) Taveuni, West - Somosomo Straits	35
e) Taveuni, East - Waitabu	39
f) Yasawa Islands	41
g) Namena	45
h) Gau, Passage	46
i) Gau, Fringing Reef	48
j) Kadavu, South	49
k) Kadavu – Astrolabe Reef	52
l) Vatu-i-Ra Passage - Deeper sites	53
m) Vatu-i-Ra Passage - Shallow site	58
n) Rotuma	60
o) Mamanuca Islands	63

**Figures:** **Page #**

---

**PART 1**

**Section 1) Introduction:**

Figure 1.1: Map showing survey sites and temperature loggers, Dec 2006	7
Figure 1.2: Table of regular sites surveyed in 2005 and/or 2006	7
Figure 1.3: Key to codes used in graphs	8

**Section 2) Reef Health in Fiji, 2006**

Figure 2.1: Coral Cover: Sites across Fiji in 2006: Reefs deeper than 6m	10
Figure 2.2: Coral Cover: Sites across Fiji in 2006: Reefs 6m and shallower	11
Figure 2.3: Indicator Fish populations: Sites across Fiji in 2006	12
Figure 2.4: Indicator Macro-Invertebrates: Sites across Fiji in 2006	13
Figure 2.5: <i>Diadema</i> Sea Urchin populations: Sites across Fiji in 2006	14

**Section 3) Progressive Reef health since 1999**

Figure 3.1: Bar Charts showing Hard Coral & Algal Cover in Fiji 1999 – 2006	15
Figure 3.2: Bar Chart showing overall Coral types in Fiji 1999 – 2006	16
Figure 3.3: Bar Chart showing overall Algal types in Fiji 1999 – 2006	17
Figure 3.4: Bar Chart showing abundance of Indicator Fish in Fiji, 2002 – 2006	18
Figure 3.5: Bar Chart showing abundance of Invertebrates in Fiji, 2002 – 2006	19
Figure 3.6: Bar Chart showing abundance of <i>Diadema</i> in Fiji, 2002 - 2006	19

**Section 4) Bleaching and water temperature since 1997**

Figure 4.1: Graphs of water temperatures 1999 – mid 2006	20
Figure 4.2: Graph of number of days with high water temps 1997 – 2006	21
Figure 4.3: Graph of consecutive days with high water temps 1997 – 2006	21
Figure 4.4: Graph of extent of bleaching in Vatu-i-Ra 2000 – 2006	21
Figure 4.5: Weather conditions 1999 – 2006	22
Figure 4.6: Graphs of environmental conditions & bleaching 1999 – 2006	22

**PART 2**

**Section 6) Regional details:**

**a) Coral Coast**

Figure a.1: Graph showing Hard Coral and Algal Cover, 2002 – 2006	25
Figure a.2: Graph showing number of Indicator Fish, 2002 – 2006	25
Figure a.3: Graph showing number of Indicator Invertebrates, 2002 – 2006	26
Figure a.4: Graph showing number of <i>Diadema</i> urchins, 2002 – 2006	26

**b) Savusavu**

Figure b.1: Graphs showing Hard Coral and Algal Cover, 2002 – 2006	27
Figure b.2: Photographs of Coral in 2006.	27
Figure b.3: Graphs showing number of Indicator Fish, 2002 – 2006	28
Figure b.4: Graph showing number of Indicator Invertebrates, 2002 – 2006	29
Figure b.5: Graph showing number of <i>Diadema</i> urchins, 2002 – 2006	30

**c) Suva Harbour – Fish Patch only**

Figure c.1: Graph showing Hard Coral and Algal Cover, 2002 – 2006	31
Figure c.2: Graph showing number of Indicator Fish, 2002 – 2006	32
Figure c.3: Graph showing number of Indicator Invertebrates, 2002 – 2006	33
Figure c.4: Graph showing number of <i>Diadema</i> urchins, 2002 – 2006	34

<b>Figures, cont'd</b>	<b>Page #</b>
<b>d) Taveuni, West - Somosomo Straits</b>	
Figure d.1: Graphs showing Hard Coral and Algal Cover, 2002 – 2006	35
Figure d.2: Photographs of Coral in 2006.	36
Figure d.3: Graph showing number of Indicator Fish, 2002 – 2006	37
Figure d.4: Graph showing number of Indicator Invertebrates, 2002 – 2006	38
Figure d.5: Graph showing number of <i>Diadema</i> urchins, 2002 – 2006	38
<b>e) Taveuni, East – Waitabu</b>	
Figure e.1: Graph showing Hard Coral and Algal Cover, 1998 – 2006	39
Figure e.2: Photographs of Corals 2005 and 2006.	40
<b>f) Yasawa Islands</b>	
Figure f.1: Graph showing Hard Coral and Algal Cover, 2002 – 2006	41
Figure f.2: Photographs showing Corals at 10m and 5m in 2006	41
Figure f.3: Graph showing number of Indicator Fish, 2002 – 2006	42
Figure f.4: Graph showing number of Indicator Invertebrates, 2002 – 2006	43
Figure f.5: Graph showing number of <i>Diadema</i> urchins, 2002 – 2006	44
<b>g) Namena</b>	
Figure g.1: Graph showing Hard Coral and Algal Cover, 2002 – 2006	45
Figure g.2: Photographs of Corals 2004 and 2006	45
<b>h) Gau, Passage - Anthias Avenue</b>	
Figure h.1: Graphs showing Hard Coral and Algal Cover, 2002 – 2006	46
Figure h.2: Photographs of Corals, 2004 and 2006	47
<b>i) Gau, Fringing Reef</b>	
Figure i.3: Graph showing Hard Coral and Algal Cover, 2006	48
Figure i.4: Graph showing number of Indicator Fish and Invertebrates, 2006	48
<b>j) Kadavu, South</b>	
Figure j.1: Graph showing Hard Coral and Algal Cover, 2002 – 2006	49
Figure j.2: Photographs of Corals, 2005 and 2006	50
Figure j.3: Graph showing number of Indicator Fish, 2002 – 2006	51
Figure j.4: Graph showing number of Indicator Invertebrates, 2002 – 2006	51
<b>k) Kadavu – Astrolabe Reef</b>	
Figure k.1: Graph showing Hard Coral and Algal Cover, 2006	52
Figure k.2: Graph showing number of Indicator Fish and Invertebrates, 2006	52
<b>l) Vatu-i-Ra Passage –Deeper Sites</b>	
Figure l.1: Graph showing Hard Coral and Algal Cover, 1999 – 2006	53
Figure l.2: Graphs showing Coral types, deeper sites, 1999 – 2006	54
Figure l.3: Photographs of Corals at E6, 2004 and 2006	55
Figure l.4: Photographs of Corals at Mount Mutiny, 2004, 2006	56
<b>m) Vatu-i-Ra Passage – Shallow site</b>	
Figure m.1: Graphs showing Coral types, shallow site, 1999 – 2006	58
Figure m.2: Photographs of Corals, 2004 and 2006	59
<b>n) Rotuma (Laje Rotuma)</b>	
Figure n.1: Graph showing Hard Coral and Algal Cover, 2003 – 2006	60
Figure n.2: Graphs showing Coral types, 2003 – 2006	61
Figure n.3: Graph showing number of Indicator Fish, 2006	62
Figure n.4: Graph showing number of Indicator Invertebrates, 2006	62
<b>o) Mamanucas</b>	
Figure o.1: Graph showing Hard Coral and Algal Cover, 2006	63
Figure o.2: Graph showing number of Indicator Fish and Invertebrates, 2006	63
Figure o.3: Photographs of Corals and predation, in 2006	64

## **Section 1) Introduction:**

In 2000, the Fiji Islands was at the northern edge of a large pool of unusually warm water, and suffered extensive hard coral death due to coral bleaching. A paper composed of a collection of studies from across the Fiji islands, linking this coral death to elevated sea temperatures at the time, was published (*Cummings et al 2000*). The difficulty of gathering data from very different sources, and which had been recorded using many different methods, established the need for standardised and regular surveys of representative sites across the Fijian archipelago, in order to measure long-term changes affecting the entire country.

With this in mind, a Fiji branch of the Global Coral Reef Monitoring Network (GCRMN), the Fiji Coral Reef Monitoring Network (FCRMN), was formed, as part of the GCRMN South-West Pacific node. The FCRMN established 12 survey sites across Fiji, placed temperature loggers on some of them, and published a report focusing on the recovery of Fiji's reefs between 2000 and 2004. (*Lovell and Sykes, 2004*)

This report follows up those sites which have been surveyed since that report, and presents the results of surveys carried out in 2005 and 2006. Some sites have not been followed up, and others have been established. More temperature loggers have been set out.

### **Constraints**

In the first three years of this project, since 2001, financial support was made available to cover the costs of establishing and monitoring the selected sites, in order to provide the basis of long-term studies of progressive reef health across the country, and to contribute information to the GCRMN network.

Funding has since been made available for placing of temperature loggers, coordination of data, and for the writing of this report, but there has been no direct funding for reef monitoring, and consequently it has not been possible to re-visit all sites first established. Without financial support for the costs of field surveys it has become apparent that the aim of long-term monitoring will fail.

Despite stated willingness to form a data-reporting network, few NGOs or educational organisations have actually been able to submit reef health data when requested. This is an apparent difficulty over data analysis and publication priority.

The majority of the data used in this report has been collected by teams led in person by the FCRMN co-coordinator, Helen Sykes, with the support of tourism dive operators and aquarium collection companies, who have contributed dive support and sometimes personal assistance. The other main long-term contributor has been the marine biologist at Jean-Michel Cousteau Resort in Savusavu, to whom we are very grateful.

In 2006 data was sent in by occasional contributors Coral Cay Conservation, Frontier Fiji, and Laje Rotuma, and it is hoped that some of these organisations will be able to continue to contribute in the future.

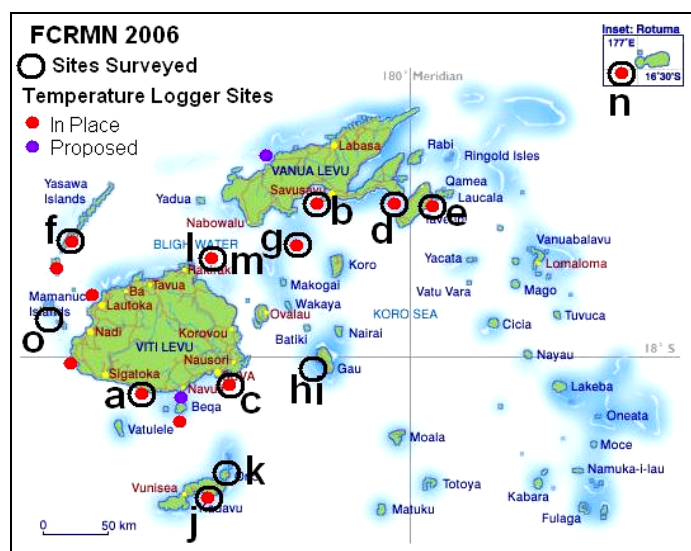
## Acknowledgements and Contributors 2005 and 2006

<b>Data entering and processing</b>	Simita Singh, <b>Marine Ecology Consulting</b> aquastellar1@yahoo.com	
<b>Report</b>	Helen Sykes, <b>Marine Ecology Consulting</b> Helen@marineecologyfiji.com	
<b>Data Contributors</b>		
Kadavu Astrolabe 2006	Simon Harding PhD, Marine Science Co-ordinator <b>Coral Cay Conservation Ltd.</b> 1st Floor Block 1, Elizabeth House, 39 York Road, London, SE1 7NJ, UK Tel: +44 (0)870 750 0668 Fax: +44 (0)870 750 0667 sh@coralcay.org www.coralcay.org	
Savusavu 2002 - 2006	Mike Greenfelder, Johnny Singh, Marine Biologists; <b>Jean-Michel Cousteau Resort Fiji Islands,</b> fiji4fun@connect.com.fj biologist@fijiresort.com gahooley@hotmail.com	
Gau Somosomo and Vadravadra 2006	Lesley Brown, Marine Research Coordinator <b>Frontier-Fiji</b> The Society for Environmental Exploration / Frontier 50 - 52 Rivington Street, London EC2A 3QP, UK frontierfiji@yahoo.ac.uk www.frontier.ac.uk	
Rotuma 2006	Teri Tuxson. Monifa Fiu, Sydney Malo <b>LajeRotuma Initiative</b> P.O. Box 10816 Laucala Beach Estate, Suva, Fiji Tel: (679) 922 8422 ttuxson@yahoo.com monifa_fiu@yahoo.com malo_s@usp.ac.fj www.rotuma.net/os/lajerotuma.htm	
Suva Harbour Fish Patch 2006	Yashika Nand, <b>University of the South Pacific</b> yashika_nand@yahoo.com.au	
Weather information 1999 – 2006: cyclones, annual rainfall and sunshine hours.	Simon McGree, Principal Scientific Officer Praveena Patel, Relieving Scientific Officer Climate Services Division <b>Fiji Meteorological Service</b> Ph: +679 6724 888 Ext. 5039 Fax: +679 6736 047 Url: www.met.gov.fj	
All other data	Helen Sykes, Director Chinnamma Reddy, Field Scientist <b>Marine Ecology Consulting, Resort Support</b> PO Box 2558, Government Buildings, Suva, Fiji Islands Tel: (679) 336 3625 Helen@marineecologyfiji.com www.marineecologyfiji.com www.resortsupportfiji.com	
<b>Diving support</b>		
Coral Coast	<b>Diveaway / Hideaway Resort,</b> <b>Aquasafari</b>	www.diveaway-fiji.com www.aquasafarifiji.com
Mamanucas	<b>Subsurface / Musket Cove Resort</b>	www.fijidiving.com
Yasawas	<b>Nanuya Island Resort</b>	www.nanuyafiji.com
Vatu-i-Ra, Namena, Lomai Viti – Gau	<b>Nai'a cruises</b>	www.naia.com.fj
Taveuni – Ss Straits	<b>Aquatrek / Garden Island Resort</b>	www.aquatrek.com
Taveuni – East	<b>Waitabu Marine Park</b>	www.boumafiji.com
Kadavu – South	<b>Matava Resort</b>	www.matava.com
<b>Financial Support</b>		
Survey expenses	<b>Marine Ecology Consulting / Resort Support</b>	
Report Production	<b>Coral Reef Initiative for the South Pacific (CRISP)</b>	

## Survey Sites

The network of survey sites was expanded in 2006, to cover as many different regions of the Fiji Islands as possible.

**Figure 1.1: Map showing survey sites and temperature loggers as of Dec 2006**



**Figure 1.2: Table of regular sites surveyed in 2005 and/or 2006**

Site #	Region	Site name	Partners
a	Coral Coast	Cowrie Crawl, Tukituki	Resort Support, Aquasafaris, Diveaway
b	Savusavu	Jetty, Golden Nuggets, Light House, Mystery	J-M Cousteau Fiji Islands Resort
c	Suva	Fish Patch	University of the South Pacific / SMS
d	Somosomo Straits	Great White Wall, Rainbow Reef	Resort Support, Garden Island Resort
e	East Taveuni	Waitabu MPA Cut	Resort Support, Waitabu Marine Park
f	Yasawa Is	Whisky Reef, Wonderland	Resort Support, West Side Watersports, Nanuya Island Resort
g	Namena	Two Thumbs Up Arch	Resort Support, Nai'a Cruises
h	Gau Island	Anthias Avenue	Resort Support, Nai'a Cruises
i	Gau Island	Vadravadra	Frontier Fiji
j	Kadavu	Eagle Rock, Vesi Bay	Resort Support, Matava Resort
k	Kadavu	Astrolabe Reef	Coral Cay Conservation
l	Vatu-i-Ra Pg	E6, Mount Mutiny	Resort Support, Nai'a Cruises
m	Vatu-i-Ra Pg	Humann Nature	Resort Support, Nai'a Cruises
n	Rotuma		Laje Rotuma
o	Mamanuca Is	Sunflower Reef	Resort Support, Subsurface / Musket Cove

Sites featured in earlier surveys but not surveyed in 2005 or 2006, are not included in this report, but can be found in the 2004 status report. These are listed below.

When surveys are carried out on these sites, they will be included in future reports.

- Lautoka, Coral Farm (Walt Smith International)
- Momi Bay (Biological Consultants)
- Suva – Fish Patch 5m, Dennis Patch 5m, Muiavuso 1m, Nukuboca 1m (USP)
- Beqa – Kavukavu Reef (Aquarium Fish Fiji, Bruce Carlson)

A new survey and temperature logger site in Beqa lagoon, near Storm Island, was added in January 2007. This data will be added in the 2007 report.

## Methods

*Note: This methodology was used in all surveys conducted by Helen Sykes, and the tourism network. Where other methods have been used by data contributors, the results have been manipulated to provide comparable data.*

**Point Intercept Transects** were used to record coral health and substrate cover, with 40 points being recorded along each of four 20-metre transects at each site.

At all sites, data was collected to a minimum of “Reef Check” standards, a method most suitable where non-specialist recorders may be collecting data, such as at tourism dive operations.

At sites where surveys were carried out by more scientifically qualified personnel, coral and substrate cover was recorded to the “Lifeform” categories suggested in the AIMS Survey Manual (*English et al. 1997*)

Analysis of all data in “Reef Check” categories was used to provide a simple and reliable indicator of live coral and algal cover at each site, compared with different regions of Fiji, and with previous years.

Analysis of data in more complete “Lifeform” categories was used to examine changing dominance of coral types at relevant sites.

**Belt transects** were used to record numbers of key invertebrates and fish. Again, four 20-metre transects were recorded at each site, 5 metres wide for invertebrates, and 5m wide by 5m high for fish. Species selected were also a minimum of “Reef Check” on all sites, expanded to include other locally relevant species as required.

**Site selection** was made by choosing a site representative of each reef area as a whole. In most cases, these were tourism dive sites, pre-selected by the dive operative most familiar with the area. This makes it simple to return to the site year after year, as most such sites are marked with permanent moorings, and their location is well known to local boat drivers. Surveys were carried out at two depths where possible, one depth where reef topography was limited. Surveys were separated into *Shallow* (5 metres and above) and *Deep* (below 6 metres).

**Figure 1.3: Key to codes used in graphs**

General categories		Acropora live coral forms		Algae types	
HC	Live Hard Coral	ACB	Acropora - Branching	AA	Algal Assemblage
SC	Live Soft Coral	ACD	Acropora – Digitate	MA	Macro Algae
SP	Sponge	ACT	Acropora – Table	HA	Halimedes
OT	Other Biota	ACS	Acropora - Submassive	TA	Turf Algae
MA	Macro Algae	ACE	Acropora - Encrusting	CA	Coralline Algae
RB	Rubble	<b>Non-Acropora live coral forms</b>			
RC	Rock	CB	Coral Branching		
SD	Sand	CM	Coral Massive (Boulder)		
		CF	Coral Foliose		
		CS	Coral Submassive		
		CE	Coral Encrusting		
		CMR	Coral Mushroom		
		CME	Coral Millipora (Fire)		



## **Section 2) Reef health in Fiji, 2006**

(See following graphs)

Coral health across the Fiji Islands was generally good on reefs deeper than 6 metres, with many areas recovered to or above pre-2000 bleaching levels (see following section on reef health since 1999).

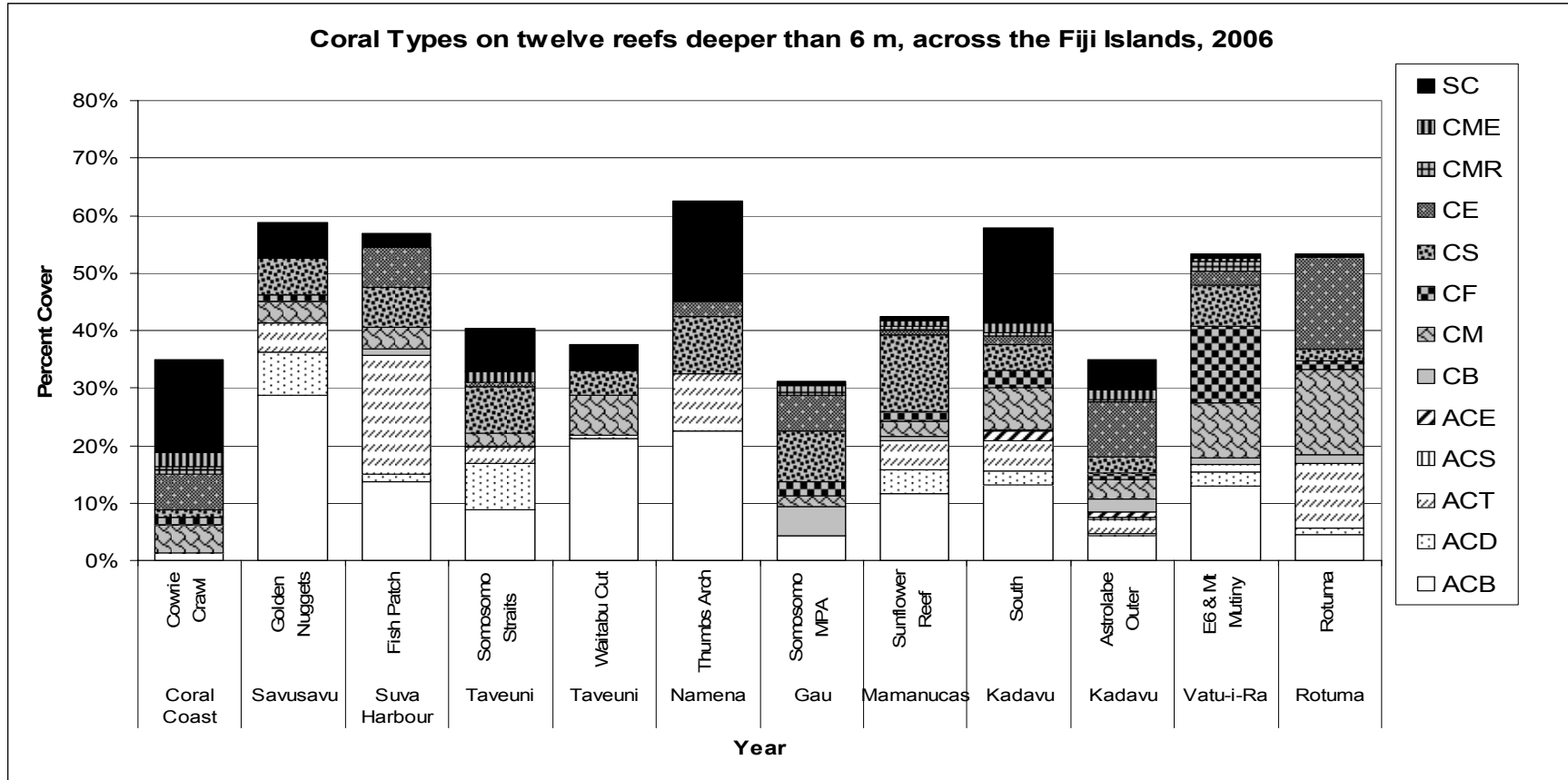
40% coral cover appears to be an average level for many reefs, with those with more than 50% considered to have high coral cover.

In general, the highest coral cover was found in Savusavu, Suva Harbour, Namena, South Kadavu, the Vatu-i-Ra passage, and Rotuma; and the lowest coral cover on the Coral Coast of Viti Levu, and Gau Island in Lomai Viti.

*Acropora* coral species (primarily branching, finger and table corals, most heavily affected by coral bleaching) have recovered especially well and once again make up a high proportion of many coral populations, particularly in Savusavu, Suva Harbour and Namena. The Coral Coast of Viti Levu, Kadavu Astrolabe Reef, and the nearshore reef in Gau have fewer *Acropora* corals, and are dominated more by submassive, encrusting, and soft corals.

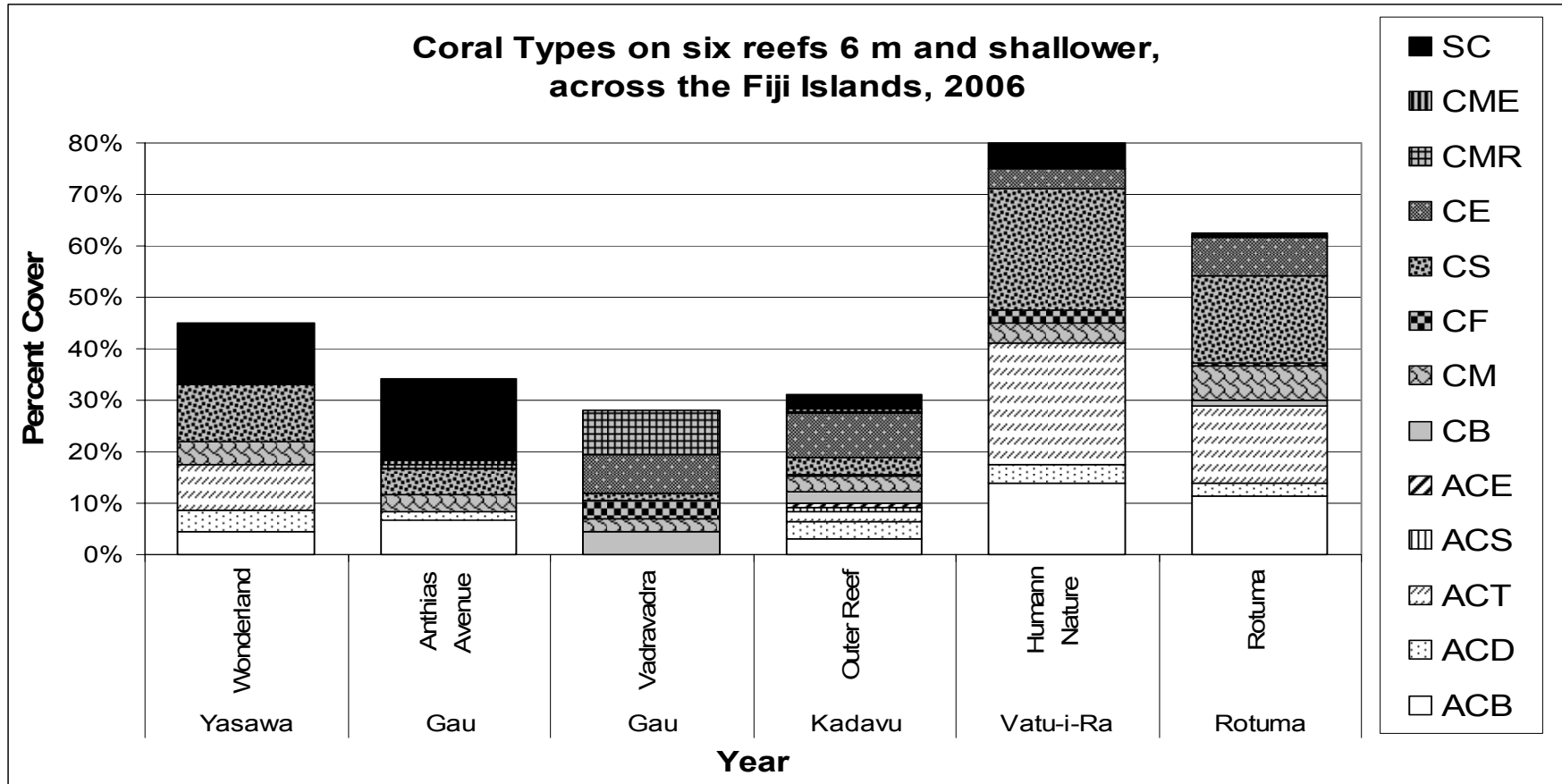
In comparison, coral health on shallower reefs was generally lower, except in Rotuma and the Vatu-i-Ra passage, where very high coral cover (80%) was recorded. The shallower reefs in the Yasawas, Gau and Kadavu had lower levels of *Acropora* corals than the deeper reefs, and more submassive, encrusting and soft corals. Fewer shallow surveys were carried out, as in many areas of Fiji, shallow reefs are subject to too much surge and wave action for safety.

**Figure 2.1. Coral Cover: Sites across Fiji in 2006: Reefs deeper than 6m**



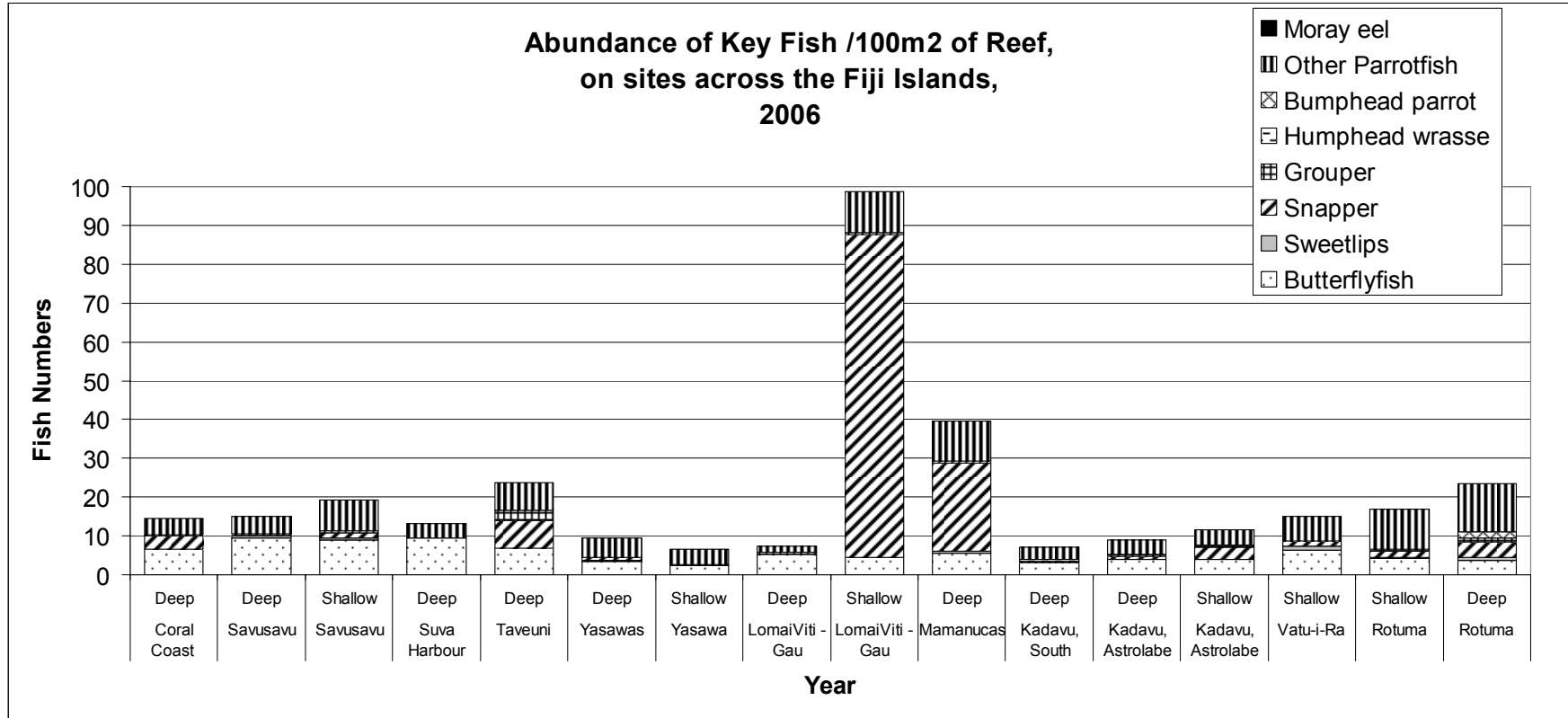
Coral types vary widely across the country. On reefs deeper than 6 metres, *Acropora* species (white background) can be seen to be lowest on the Coral Coast, Gau and the Kadavu Astrolabe reef, and particularly high in Savusavu, Suva Harbour and Namena. Soft corals (black) representing both the “Leather” corals such as *Sarcophyton* and *Sinularia*, and the “Glass” or “Broccoli” coloured soft corals, such as *Dendronepthea*, are highest on the Coral Coast, Taveuni, Namena and Kadavu.

Figure 2.2. Coral Cover: Sites across Fiji in 2006: Reefs 6m and shallower



Fewer shallow sites were surveyed than deeper ones. On reefs shallower than 6 metres, *Acropora* cover was highest in the Vatu-i-Ra passage, and low to non-existent in Gau. Soft corals were most numerous in the Yasawa Islands and Gau, but these were primarily the “Leather” corals, not the *Dendronepthea* species usually seen on deeper reefs.

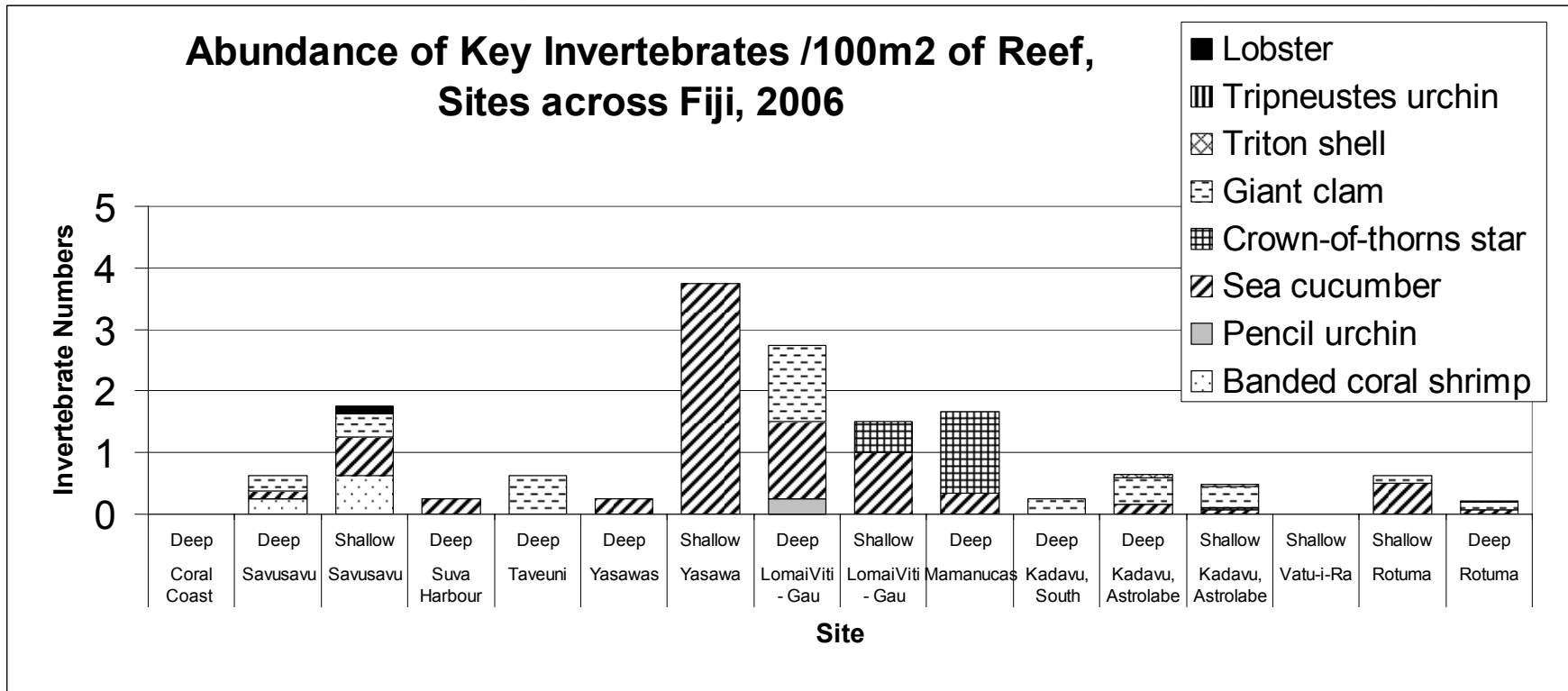
**Figure 2.3. Indicator Fish populations: Sites across Fiji in 2006: all depths**



Most reefs across Fiji had an average of 10 – 20 indicator fish per 100m<sup>2</sup>, with the exception of the shallow reef in a Marine Protected Area in Gau, and one site in the Mamanucas, where schools of Snappers elevated the numbers. For the most part, Butterflyfish were the most numerous of the fish families counted, followed by Parrotfish and Snapper. Overall numbers of larger food fish such as Grouper and Sweetlips were low across the country. Bumphead Parrotfish were only seen during surveys in Rotuma and Kadavu, although they were seen at other times in the Yasawa Islands. Humphead Wrasse were not seen during any surveys, but are commonly seen in large numbers in Taveuni.

**Figure 2.4. Indicator Macro-Invertebrate populations: Sites across Fiji in 2006: all depths**

Note: *Diadema* urchins are excluded from this graph for reasons of scale. They are represented in their own graph on the following page.



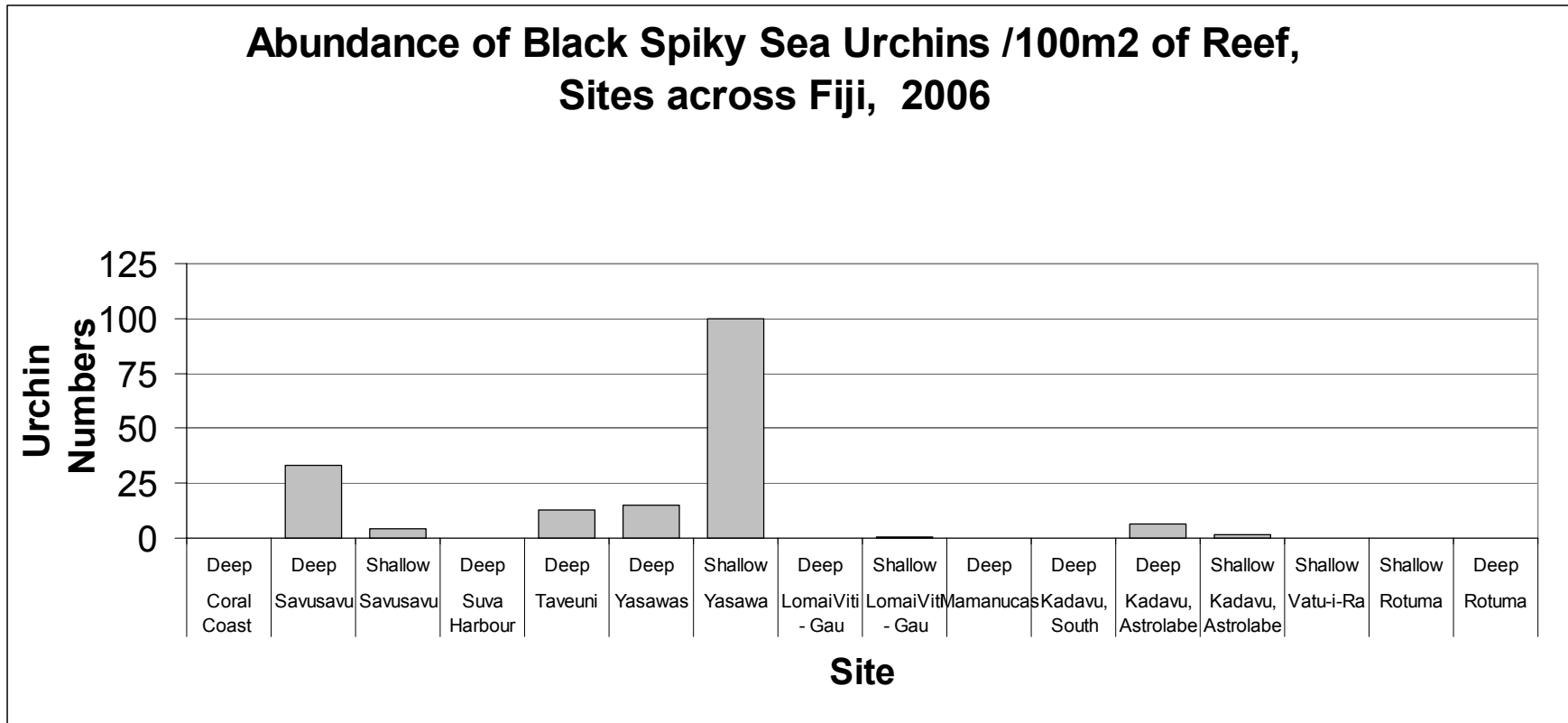
Macro-Invertebrate numbers are generally low across the country.

Large numbers of Sea Cucumbers were recorded in the Yasawa Islands and Gau, and *Tridachna* Giant Clams were found in the highest numbers in Savusavu, Gau and Taveuni.

*Acanthaster* Crown-of Thorns Stars (COTS) were found on shallow reefs in Gau, and deep reefs in the Mamanuca Islands. Large numbers of COTS have been seen in the Mamanuca Island reefs in both 2005 and 2006.

**Figure 2.5. *Diadema* Sea Urchin populations: Sites across Fiji in 2006: all depths**

Note: these urchins include all true *Diadema* urchin species, plus the smaller black spiky rock-boring urchin *Echinostrepehlus aciculatus*



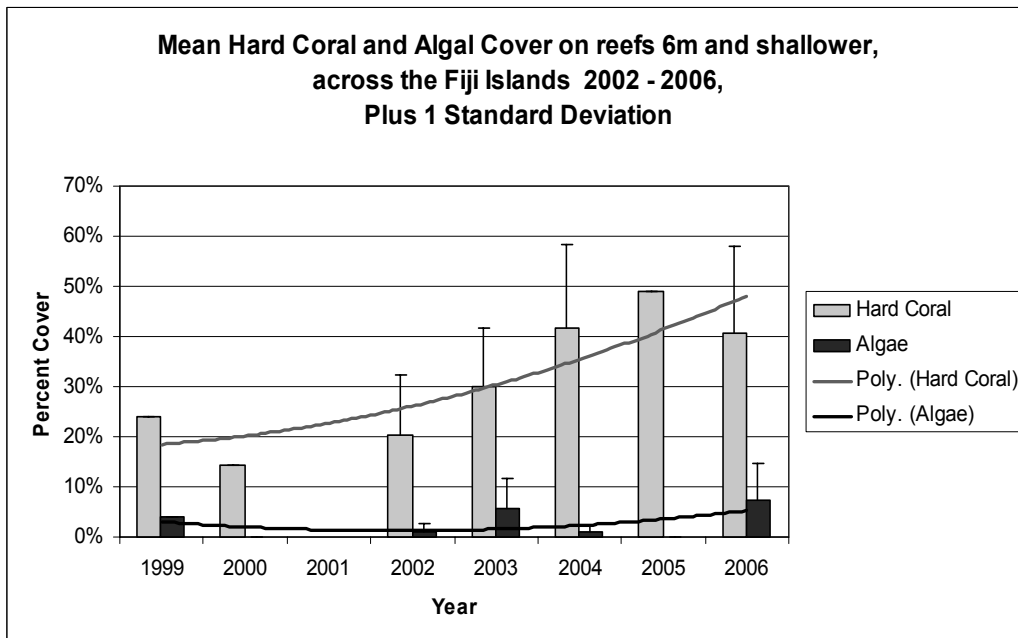
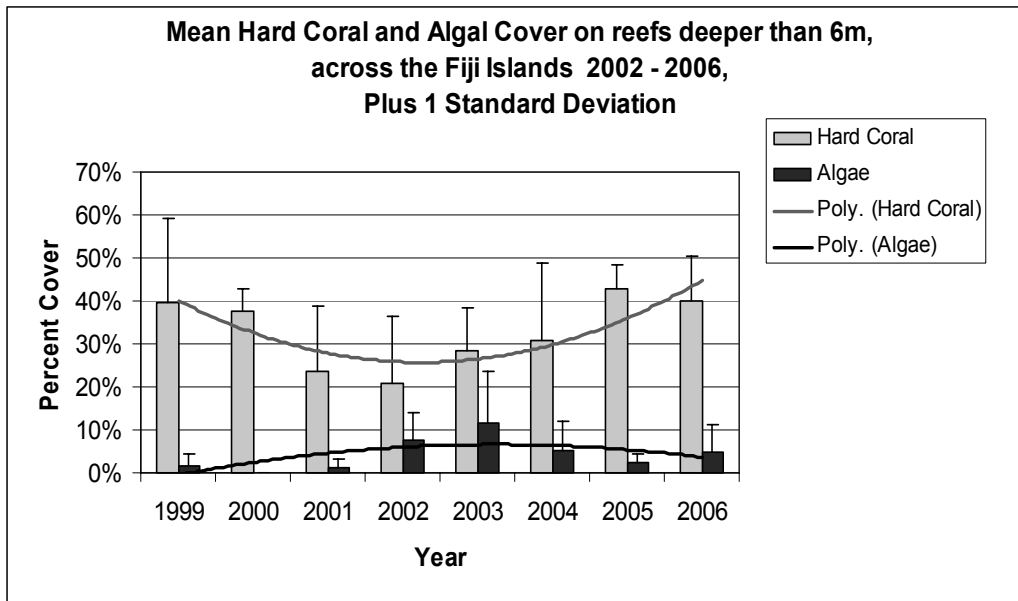
Black Spiky Sea Urchins were by far the commonest macro-Invertebrates counted, especially the smaller rock-boring urchin *Echinostrepehlus aciculatus*, which is often found in large colonies in rocky reef substrate. In particular these urchins were seen in large numbers in the Yasawas and Savusavu. Elevated numbers of these may relate to over-fishing of certain predatory species such as Triggerfish.

### Section 3) Progressive reef health since 1999

Fiji-wide coral and algal cover means were calculated by combining data from all regions. Variation is high, as indicated by the Standard Deviation bars, reflecting the variation between regions of Fiji as seen in the previous section. Details of trends over time in each region are given in Section 6) "Regional details".

**Figure 3.1: Bar Charts showing overall Hard Coral and Algal Cover in the Fiji Islands 1999 – 2006**

- No shallow surveys were conducted in 2001.
- 2005 figures are represented by only a few sites, as little data was gathered that year due to logistical constraints. Fiji-wide coral cover from that year appears artificially high due to consequent site bias.
- Lines show general trends (Polynomial Trendlines)

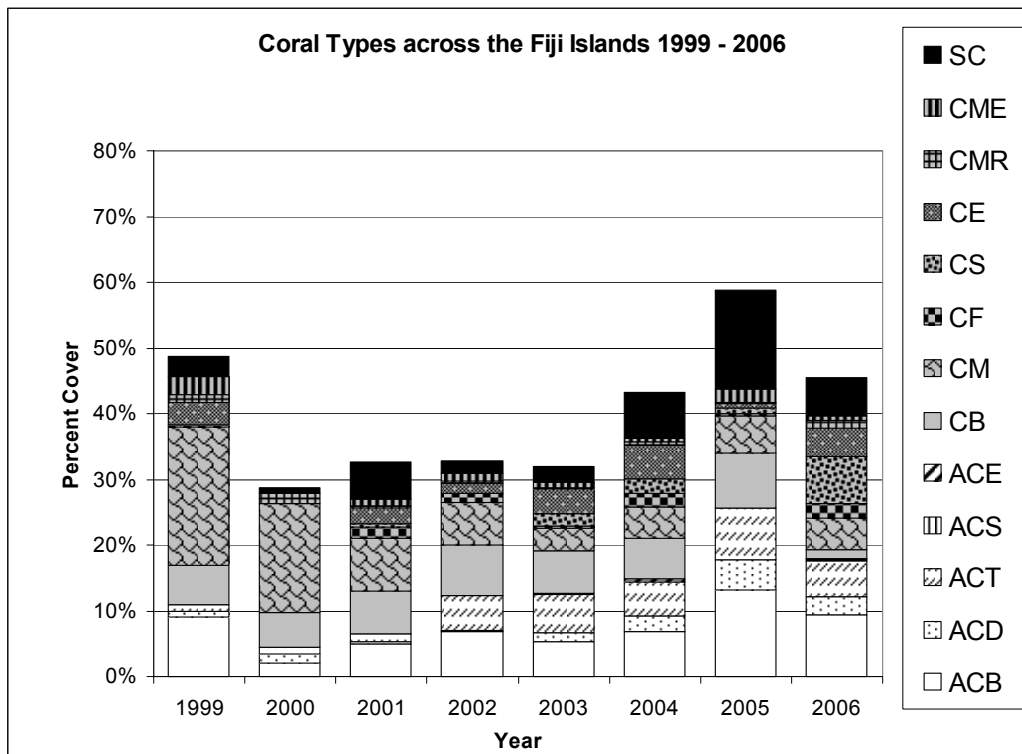


There was a decline in hard coral cover after the mass coral bleaching of 2000, falling to the lowest point in 2001 / 2002. Since that time, coral cover has been gradually increasing, and reached pre-bleaching levels in 2005, plateauing off at an overall Fiji mean of 40% coral cover on both shallow and deep reefs. This is presumed to represent normal coral cover in the region.

Algal Cover, while remaining generally low, rose in the years when live hard coral was in decline, and has fallen again as coral cover increases. This is considered to be due to algal colonisation of dead coral skeletons following bleaching events.

These patterns are most evident on the deeper reefs, but can also be seen on the shallower sites.

**Figure 3.2: Bar Chart showing overall coral types in the Fiji Islands 1999 - 2006**



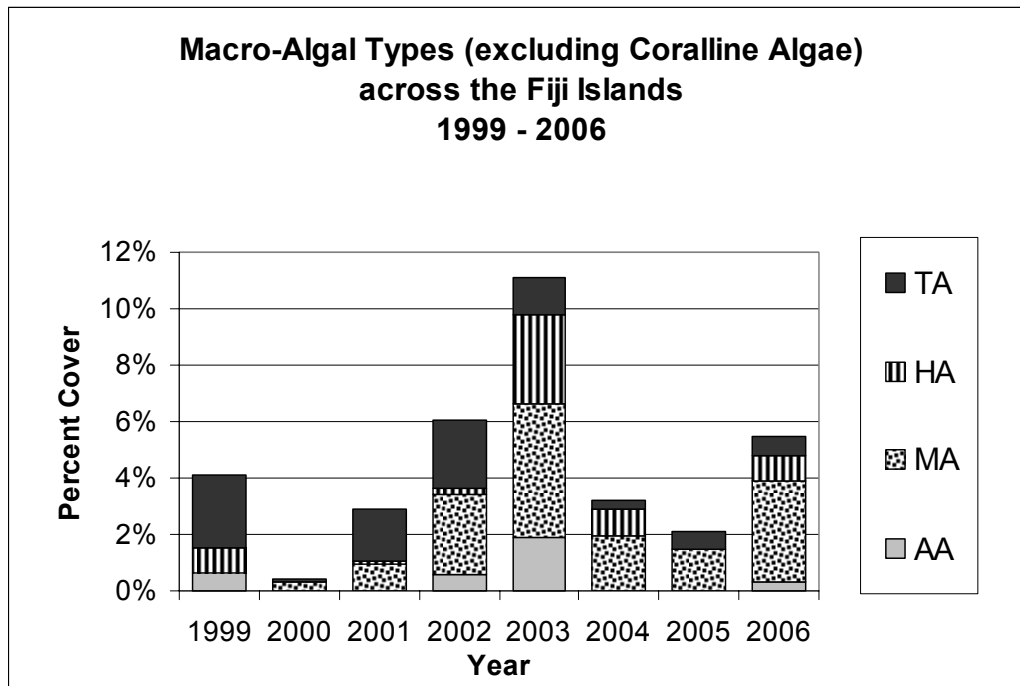
*Acropora* coral species were most affected by the bleaching of 2000, with less than 6% *Acropora* coral cover surviving by 2001. However, recovery has been remarkably swift, and in many areas *Acropora* corals are now back to or higher than pre-bleaching levels. In particular Finger (Digitate) and Table *Acropora* coral forms appear to be flourishing. In some places, branching *Acropora* corals were seen to grow 15 cm in one year.

In contrast, the non-*Acropora* coral forms were much less affected by the bleaching, with the only change being an apparent drop in Boulder (Massive) coral forms. In-water experience suggests that this is probably due to *Acropora* coral growth above Boulder corals, rather than death of these species.

(Addition of Soft Corals to this graph means that overall percentage cover is higher than that shown in the Hard Coral graphs on the previous page.)



**Figure 3.3: Bar Chart showing overall Algal types in the Fiji Islands 1999 - 2006**



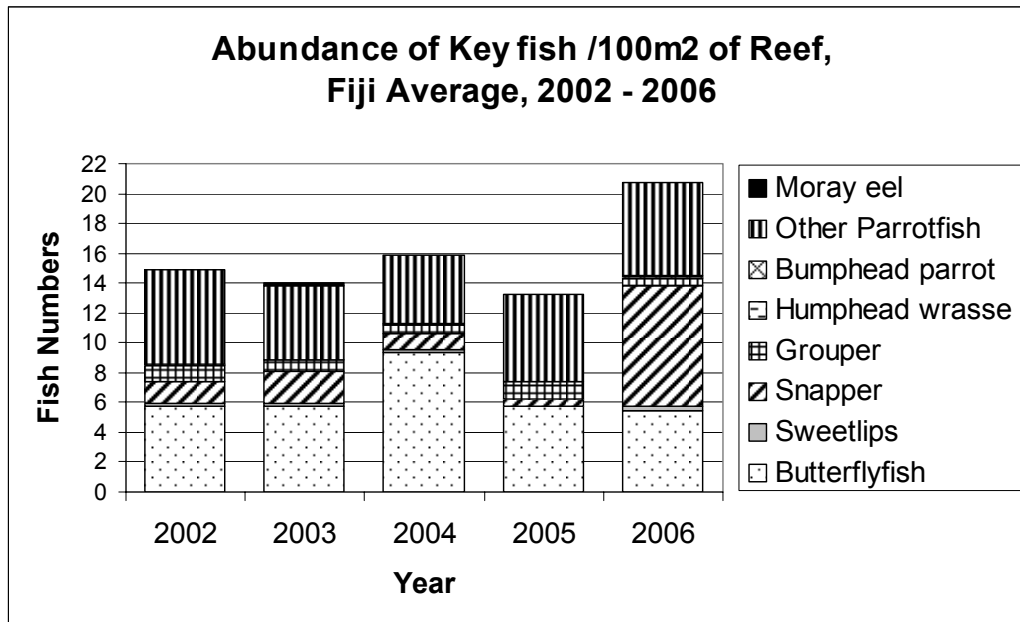
Some alga, such as *Halimedes* (HA), are considered normal inhabitants of the reef and do not reflect adverse changes. Other Macro-Algae (MA and AA) may be the result of over-fishing of grazing fish and invertebrates, or indicators of nutrient enrichment such as from improper sewage treatment or agricultural fertiliser run off.

Turf algae such as Filamentous Blue-green algae, are often associated with nutrient pollution or coral death.

There was an increase in all types of algae observed in 2002 and 2003, which may be due to the coral death from the 2000 and 2002 coral bleachings, providing an increased amount of substrate for algal growth. This is followed by a drop in algal cover as coral health improves in 2004, 2005 and 2006.

No other patterns are seen.

**Figure 3.4: Bar Chart showing abundance of key Indicator Fish in the Fiji Islands, 2002 - 2006**



Allowing for site variations, indicator fish populations appear to have remained very consistent over the years. Inclusion of new sites with resident schools of Snappers led to elevated Snapper numbers in 2006.

There does not appear to be any wide-spread alteration in fish populations relating to the coral health changes seen over the past 5 years, although it should be noted that pre-bleaching population levels are not available.

Of the fish groups counted, numbers of important food fish such as Groupers *Serranidae*, Sweetlips *Haemulidae*, large Snappers *Lutjanidae*, and the particularly endangered species Humphead Wrasse *Cheilinus undulatus* and Bumphead Parrotfish *Bolbometopon muricatum* are low on Fijian reefs, and have been for at least the past 5 years. Consistently, most indicator fish seen are Butterflyfish *Chaetodontidae* and Parrotfish, and smaller Snapper *Lutjanidae* species.

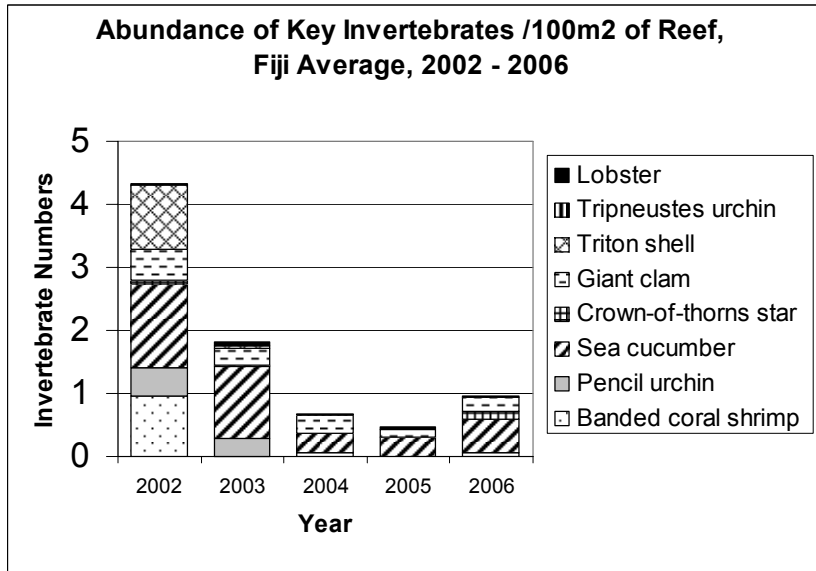
This probably reflects high pressures from subsistence and small-scale commercial fishing affecting most reefs in the Fiji Islands. In particular, coastal fringing reefs near local communities rarely have high populations of the larger food fish species.

Humphead Wrasse *Cheilinus undulatus* is severely endangered, and trade in this species has been forbidden under the Convention on International Trade in Endangered Species (CITES).

Bumphead Parrotfish *Bolbometopon muricatum* are facing a local extinction (extirpation) in the Fiji Islands, and sites where schools of these fish are still seen should be considered prime candidates for protection from fishing, if the Fiji populations are to be saved.

**Figure 3.5: Bar Chart showing abundance of key indicator Invertebrates in the Fiji Islands, 2002 - 2006**

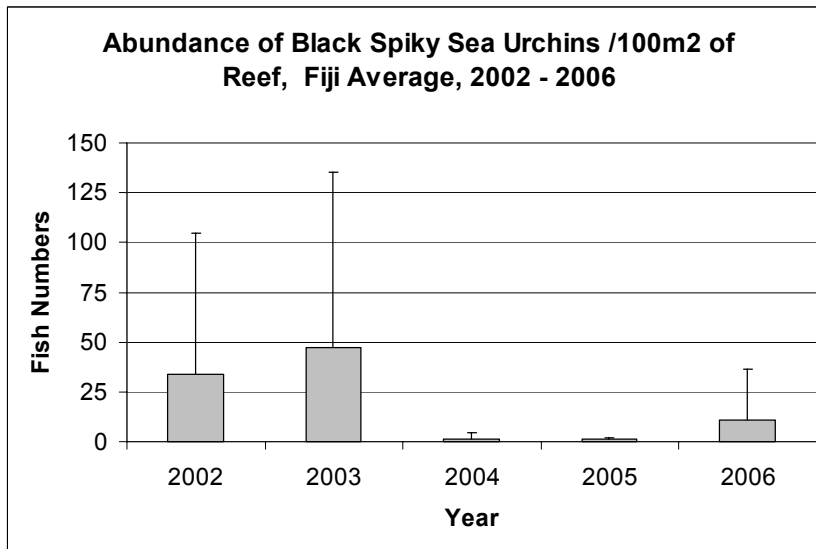
Note: *Diadema* Urchins are excluded from this graph for reason of scale.



There is an apparent drop in invertebrate numbers since 2002, but it should be noted that the 2002 data included banded Coral Shrimp and Tritons Trumpet shell which were seen on a single site.

Overall numbers of the commoner Macro Invertebrates such as Sea Cucumbers and Giant Clams were low, and not seen to alter greatly over time.

**Figure 3.6: Bar Chart showing abundance of *Diadema* Sea Urchins in the Fiji Islands, 2002 - 2006**



Note: Includes *Diadema* species, plus *Echinostrephus aciculatus*.

*Diadema* urchins appear to have declined since 2003.

However, the large variation between sites (as shown by the Standard Deviation bars) suggests that this may be due more to site variation than to a definitive population trend. Refer to details of each region (Section 6) for more information.

In general, Macro-Invertebrates are not seen in large enough numbers on Fiji's reefs to provide a reliable indicator of population trends on the broad scale. They may be more important local indicators, and as such, the regional graphs in Section 6) may be more informative.

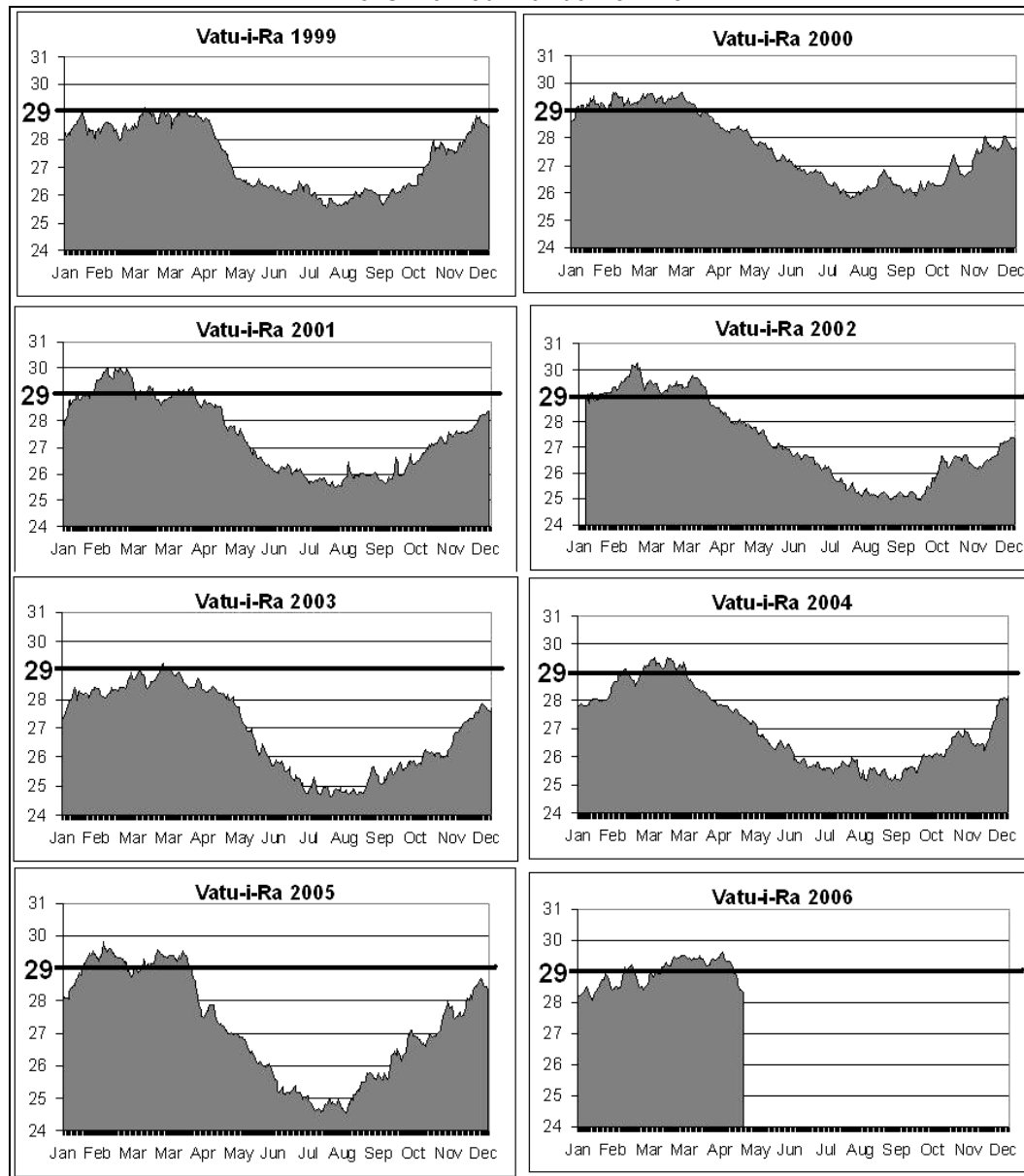
## **Section 4) Bleaching and water temperature since 1997**

Since 1996, in-water temperature loggers have been in place in some areas of Fiji. Originally placed by Norm Quinn and Peter Newell, with the support of Nai'a Cruises, the logger network has been expanded in past years by the FCRMN.

Long-term data is available from the pinnacle known as Mount Mutiny, in the Vatu-i-Ra passage, which has also been a coral survey site since 1999. Loggers are placed between 5 and 7m depth, on a steep wall facing the deep ocean.

- Data from 1996 – 2004 Norm Quinn / Nai'a Cruises
- Data from 2004 – 2006 FCRMN

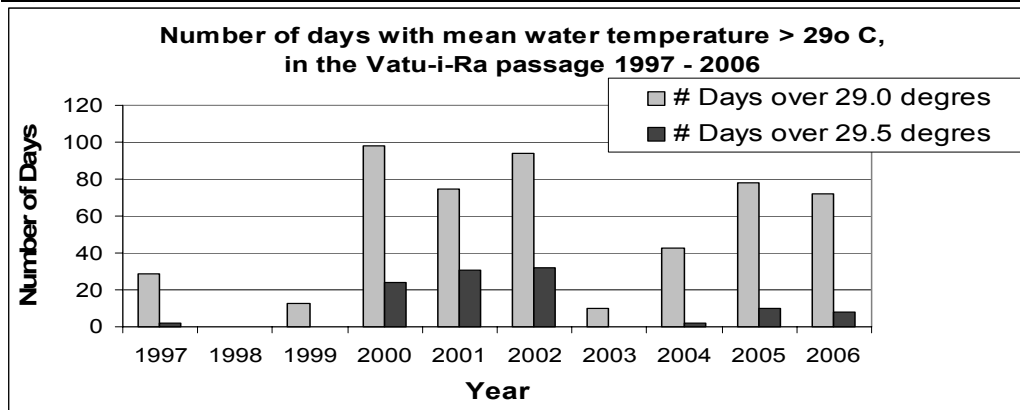
**Figure 4.1: Graphs of water temperatures, Vatu-i-Ra Passage 1999 – mid 2006**  
*29°C marked with darker line*



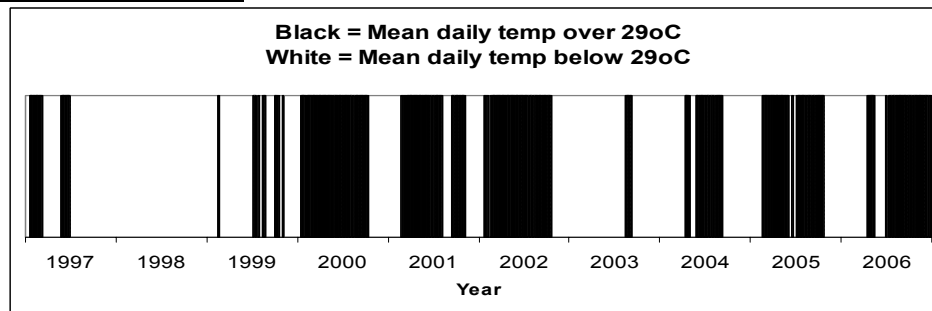
This Vatu-i-Ra temperature data was subsequently analysed to provide daily means, the number of days in each year where mean water temperature was over 29.0°C and 29.5°C, and times of long periods of consecutive high temperatures.

All data from the Vatu-i-Ra Passage:

**Figure 4.2: Graph of number of days with high water temperatures 1997 - 2006**



**Figure 4.3: Graph of consecutive days between Jan and May with high water temperatures 1997 - 2006**

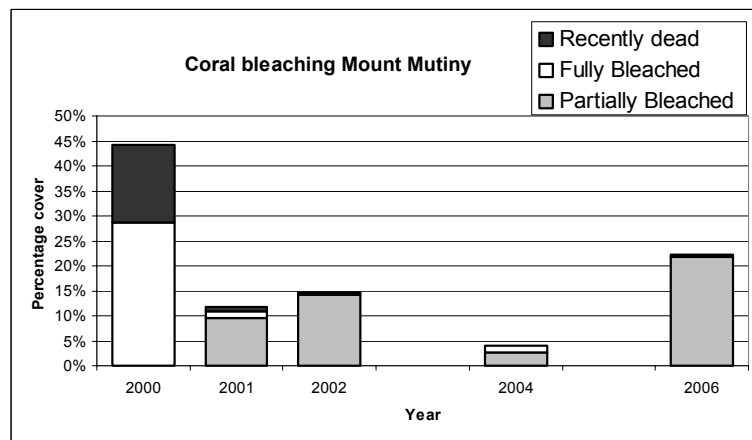


**Figure 4.4: Graph of extent of bleaching in the Vatu-i-Ra Passage 2000 - 2006**

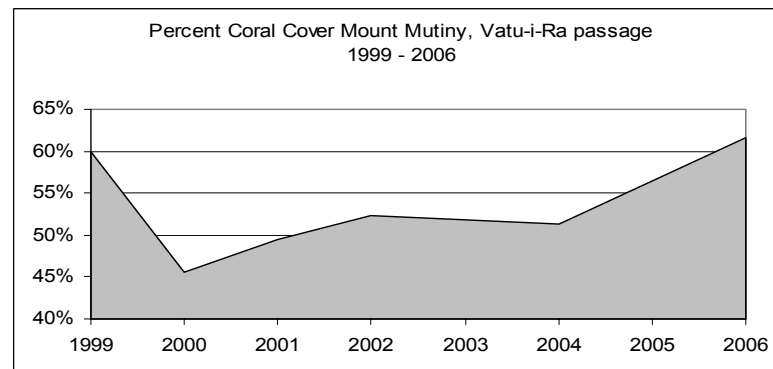
*Note- No surveys were carried out in 2003 or 2005, but no significant bleaching was reported by dive operator in those years.*

Mass coral bleaching was reported across Fiji in 2000, and smaller, more localised events in 2002 and 2006.

On this site, partial bleaching was observed in most years, but large-scale full bleaching was only seen in 2000.



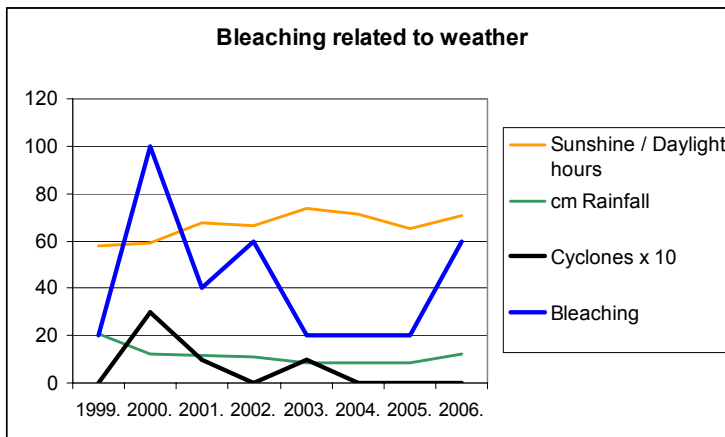
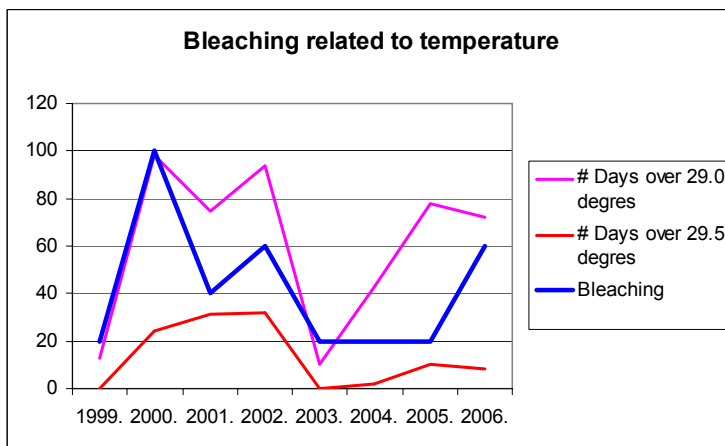
Large scale coral death followed the extensive bleaching of 2000, but percent coral cover at this site was back to 1999 levels by 2006.



**Figure 4.5: Weather conditions 1999 - 2006**

Year	1999	2000	2001	2002	2003	2004	2005	2006
Cyclones	None	3	1	None	1	None, but coral damaging storm	None	None
Cyclone focus		Mamanucas, Viti Levu, Kadavu	Viti Levu, Kadavu, Lau		Vanua Levu, Taveuni	Vatu-i-Ra passage		
Mm Rainfall (Lautoka) Jan - April	2061	1229	1160	1124	857	825	881	1198
Hours Sunshine (Lautoka) Jan - April	692	711	815	797	881	858	785	851
Summary	No Cyclones High rainfall Low sunshine Water cool	3 Cyclones Moderate rainfall Moderate sunshine Long consecutive periods hot water	1 Cyclone Moderate rainfall High sunshine	No Cyclones Moderate rainfall Moderate sunshine Long consecutive periods hot water	1 Cyclone Low rainfall High sunshine Water cool	No Cyclones, but coral damaging storms Low rainfall Moderate sunshine High sunshine	No Cyclones Low rainfall Moderate sunshine	No Cyclones Moderate rainfall High sunshine
Bleaching Scale 1-100	UNKNOWN	HIGH (100)	LOW (40)	MODERATE (60)	UNKNOWN	VERY LOW (20)	UNKNOWN	MODERATE (60)

**Figure 4.6: Graphs relating environmental conditions to bleaching 1999 - 2006**



*Note, Extent of Bleaching and some weather factors are represented on arbitrary scales, rather than actual values, to enable graphing.*

Bleaching appears to coincide with elevated water temperatures over long consecutive periods. It is likely that some partial bleaching occurs most years, but only progresses to a mass event when temperatures remain elevated to 29 – 29.5°C for longer than 8 – 12 weeks.

Weather conditions, including number of cyclones per year, annual rainfall, and sunshine hours, did not appear to relate directly to bleaching intensity.

## **Section 5) Discussion and References**

### **The present state of Fiji's reefs**

Fiji is a large archipelago with a great variety of reef types, in various states of health. By examining a network of sites spread across the country, it has been possible to examine both regional status and overall trends.

The bleaching event of 2000 provided an interesting starting point, in that coral health was affected across the country with 40 – 80% loss of hard coral. This provided a basal low point, from which it has been possible to record rates and levels of coral recovery.

Where recovery was slow, reefs were found to be either physically remote from areas of healthy coral, and so from sources of new coral spawn, or badly affected by algal overgrowths which may have prevented coral settlement. Certain areas that escaped major bleaching have been seen to regularly have lower water temperatures than the rest of the country.

Coral bleaching is not the only stressor on Fiji's reefs, which are also regularly affected by cyclones and large storms, as well as more localised factors such as over-fishing, nutrification, algal overgrowth and coral predation from *Acanthaster planci* Crown of Thorns Star and coral-eating snails such as *Drupella*.

Coral regeneration after damaging storms has usually been rapid, and these are not considered a great threat to long-term reef health. More serious factors threatening long-term coral health are over-fishing, nutrification from farming and increasing populations (both resident and tourist), and algal overgrowths as a result of both of these.

Coral predation appears to occur at regular intervals, but does not usually affect the entire country at the same time. Currently the Mamanuca Islands are suffering an outbreak of Crown-of-Thorns Stars, now in its second year. This last happened in that area in 1996/1997, bearing out the 8-10 year cycle suggested in Australia. *Drupella* snails are also frequently found, but do not appear to have large-scale adverse effects unless they occur in the wake of another coral damaging event when they tend to concentrate on the few surviving corals.

The main finding from these six years of monitoring since the 2000 bleaching is that, on the whole, Fiji's reef system is remarkably resilient, with remarkably rapid coral re-growth in many areas. Over the country, many reefs returned to pre-bleaching coral cover levels in less than 6 years.

This appears to suggest that corals in Fiji can survive quite catastrophic events as long as they do not occur too often, perhaps not more than every 6 years, and this is a cause for optimism.

However, human-generated impacts such as over-fishing and careless development have the potential to seriously harm localised coral health in the long term, and should be controlled.

## **The future**

FCRMN has now placed an extensive network of temperature loggers on many of the regularly surveyed sites, to collect long-term information about temperature variations in the different areas of Fiji. This data, coupled with regular survey information on reef health, will enable the network to identify areas at particular risk from, and areas of likely resilience to, future bleaching events.

Continuing survey work will provide information as to whether the reefs suffer regular setbacks which maintain them at or around the pre-bleaching level of health, or whether they will continue to improve and exceed those levels. Assessing speed of recovery will enable researchers to measure the likelihood of reef survival in the face of future events.

Over-fishing is a major stress on many of Fiji's reefs, and removal of grazing fish and invertebrates is a probable factor in much of the algal issues seen in many areas. Identification of areas with good fish and invertebrate populations is an important step to suggesting sites for protection and conservation. In particular, reefs that house endangered species could be suggested for the formation of no-take Marine Protected Areas.

It has also become obvious from these studies that there is a need for continuity of long term monitoring if patterns are to be made visible. Six years of monitoring has shown recovery from a single bleaching event, and some consequences of storm damage, but it will probably take ten to fifteen years of data collection to make regular cycles apparent. Short-term projects allow snapshots of reef health, but without long-term support, these are only disconnected data spots. The value of long-term monitoring of regularly visited sites has become apparent, but cannot be carried out unless resources are committed well into the future.

## **References**

Cumming, R.L., Toscano, M.A., Lovell, E.R., Carlson, B.A., Dulvy, B.A., Hughes, A., Koven, J.F., Quinn, N.J., Sykes, H.R., Taylor, O.J.S., Vaughan, D.

"Mass Coral Bleaching in the Fiji Islands 2000".

Proceedings of the 9<sup>th</sup> International Coral Reef Symposium, Bali.

English, S., Wilkinson, C., and Baker, V.

"Survey Manual for Tropical Marine Resources" Second Edition

Australian Institute of Marine Resources 1997 ISBN 0 642 25953 4

Lovell, E.R., and Sykes, H.R.

"Status of Coral Reefs in the Fiji Islands, 2004"

In press, Institute of Marine Resources, University of the South Pacific