REEF CHECK DESCRIPTION
OF THE 2000 MASS CORAL BEACHING EVENT
IN FIJI WITH REFERENCE TO THE SOUTH PACIFIC

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1.0 Introduction

This paper is a description of the coral bleaching event in Fiji, which occurred in February/March 2000. It draws on a variety of sources of information which include the satellite information from the NOAA/ERDIS satellite, aerial surveillance during the event, *in situ* temperature information, reports from members of the Fiji Dive Operators Association (FDOA), researchers at the University of the South Pacific (USP) and World Wide Fund for Nature and Foundation for the People of the South Pacific, who have coral reef related projects.

The dive operator's observations and modified Reef Check assessments are used to provide a broad understanding of the event in Fiji. To compliment this, a program of progressive Reef Checks was used to assess the bleaching phenomenon at various stages.

2.0 Methods

Surveys were conducted by using the Reef Check protocol modified in its benthic assessment as the line intercept transect (LIT) technique with the information taking account of the bleaching and subsequent mortality. Variations in the Reef Check method entailed the shortening of the length that was surveyed and using a more detailed assessment of the benthic transect. Different areas were surveyed in this manner to quantify the percentage cover of bleached coral cover and assess the maturity of the coral bleaching event.

The standard Reef Check method was used at RatTail Passage, the Fijian Hotel and Cousteau Resorts. This involved assessment of the 100m transect for fish, mobile invertebrates and benthic cover according to the Reef Check methods. As the objective of the assessment was to create an overview of the bleaching event, the extent of the survey was determined by both the presence of the bleaching and assessment of a wider range of habitats. The logistical support was, at times, limiting.

Following is the convention used to record the coral bleaching (adapted from Cumming et al. in review) used in the transect assessment.

1. Not bleached or normal coloration had only the species or generic designation.

2. Fully bleached referred to the whole colonies being white or pastel-colored and is designated Bl.

3. Dead referred to new algal turf on the skeleton to a state where the algae was dense and co-existed with other encrusting organisms. D was the designation that the coral had died from the bleaching event.

4. Partially bleached referred to the colony either exhibiting both bleaching (Bl), a normal state (N) or dead state (D).

5. A bleached colony re-establishing its zooxanthellae or recovering were designated RE .

The information recorded in the first portion of the table is in terms of the percentage of the transect length. When considering the states resulting from the bleaching, the percentages are those of the total coral cover and not the entire transect length.

3.0 The Bleaching Event

3.1 Background

Coral bleaching is a global phenomenon. It's frequency, scale and severity seems to be increasing. There have been 60 bleaching events between 1979 and 1990 (Glynn 1993). Few were reported before that period. The worst bleaching event on record affected the Indian Ocean, south and Southeast Asia and Australia in 1998. The South Pacific has recently experienced a major bleaching event.

Coral bleaching is a descriptive term applied to the influence of higher sea temperatures on a variety of coral reef organisms, which include sea anemones, giant clams as well as corals. What they all have in common is the presence of symbiotic algae, the zooxanthellae. In the presence of prolonged, unusually high sea temperatures, physiological problems occur and they are expelled from the host organisms. The resulting appearance of coral or other organisms is a white appearance cue to the removal of the brown colored algae, which give coral its color and masking the natural color of the animal host and may appear commonly pink, blue or yellow.

Figure 1. Variation in the appearance of bleached coral.

(Figure not available in electronic format)

Coral bleaching in Fiji, until recently, has not been recorded though anecdotal village accounts report an event in the early 1950's. This is supported by the long-term weather records of the Hadley Climate Prediction Center, MetOffice, United Kingdom, which shows an apparent peak of warm water at that time. An unsubstantiated account of the bleaching of *Acropora* was recorded in 1988 (Beckman (pers. comm.) in Williams and Bunkley-Williams, 1990). Coral bleaching of *Pocillopora damicornis* and *Seriatopora hystrix* was observed in Bau Waters in the April of 1998. Recently, coral bleaching was first observed in the late summer of 1998/1999 in both Suva Harbor, Bau Waters and to a lesser extent on Cakaulevu Reef north of Labasa. This was minimal by comparison to the year 2000 event but did include the bleaching of such prone genera as *Seriatopora*, *Stylophora*, *Acropora* and, unusually, *Platygyra*.

Currently in February 2001, these corals are bleaching at Muaivuso nnear Suva and bleaching has been reported a Yadua Tabu (Taylo, peers comm.) and Kadavu (Mitchell, pers comm.). From a temperature standpoint, both the 2000 and 2001 event were noted by National Oceanographic and Atmospheric Administration (NOAA) through their NESDIS satellite, which was monitoring hot water anomalies (Toscano et al. (in prep.)), with the bleaching substantiated by observers here in Fiji at the end of February and early March in 2000 and minor bleaching in February 2001. In 2000, the event developed quickly through March, reaching its peak in April. Some coral were beginning to die at that stage and the waters were beginning to cool. The presence of the elevated temperatures as monitored by NOAA (http;//www.psbsgil.nesdis.noaa.gov) showed progressive warming around the island group with some areas experiencing particularly high temperatures. This differential warming was reflected in the extent of the bleaching on the coral benthos.

3.2 South Pacific Context

The major bleaching event in Fiji coincided with prolonged temperatures sometimes in excess of 30^0C. Similar bleaching extended across the South Pacific from Papua New Guinea (PNG) to Easter Island in the east. Satellite surveillance of sea surface temperatures (SST) revealed a band of progressively elevating temperatures initiating in PNG and extending down through the Solomon Islands. This area first experienced warming as early September. Waters around Fiji began to warm in the third week of Dec. 1999. NOAA's SST maps showed waters around Fiji and Tonga, alternately, warming and cooling locally around these island groups into the first week of January 2000. Water temperature continued to increase around north PNG, Solomon Is, south of Fiji and around Tonga. Southeast of this area, patchy elevation of temperature occurred.

By February 1, the trend continued to now include Vanuatu and northeast New Caledonia. Waters of Tonga, Cook Is., Tubai (Austral) Is. and Easter I. began to warm . By the middle of the month, this band of warm water intensified to $+1.0\text{-}1.25^0$C above the maximum monthly mean (MMM), and extended across the South Pacific to Easter I. The MMM is a figure reflecting the average longterm temperature over which incident temperatures are considered elevated. Water temperatures continued to increase. By February 29, the warm water extended to Australia in the northwest and broadened as a continuous band to the southeast to include the Tubai Is. Temperature elevation progressed, characterized by discrete areas of hotter areas occurring within this broad band. By the middle of March, the trans-Pacific zone of higher temperature began to break up. Particularly hot areas to the southwest of New Ireland in PNG and the Solomon's and a large warm water mass south of Fiji, over Tonga, Cook Is. and the Tubai I remained. A separate warm water mass covered Easter I. It is at this time, the first reports of coral bleaching were being made from across the South Pacific.

For southern Viti Levu I. in Fiji, this was determined to be during the week surrounding March 1. Slight bleaching was seen during a Reef Check survey on February 27 but by the first week of March widespread bleaching had occurred. It is thought that the same time-frame applied to the other affected areas of Fiji. Interestingly, the satellite record of SST's north of Vanua Levu indicated much cooler waters. An aerial survey of this area revealed far less bleaching (<5%). By April 15, the warm water mass was dissipating. It had retracted to the Kimbe Bay area and Bouganville in PNG and the Solomon Is. SST's in Vanuatu had returned to normal. The warm water around Fiji was slightly elevated and extended across Tonga to the Cook Is. SST's had returned to normal in both the Tubai Is. and Easter I.

Figure 2. Bleaching in Tonga
(Figure not available in electronic format)

3.2.1 Degree Heating Weeks

Figure 1 shows the state of the event in April as a summary of the elevated water temperatures. The color scale is referred to as Degree Heating Weeks (DHW) and refers to the amount of time the temperature had remained 1^0C higher than the MMM are often expressed as a value within a three month period. 6-10 DHW's are sufficient to have wide scale bleaching. The areas in Kimbe Bay and the southwest side of the Solomon I. showed 3-6 DHW's as did Vanuatu. Those areas south of Viti Levu in Fiji, Tonga and the Cook Is. showed 13-15 DHW in some areas but generally less than 10. Easter I. where 90% of the corals had bleached showed 4-6 DHW. South Pacific countries such as Kiribati, Tuvalu and the Samoas experienced no coral bleaching. Appendix 2 details the development of the elevated temperatures within the South Pacific and areas in Fiji.

Coral bleaching, though correlated with elevated water temperatures is influenced by light, and as a result occurs differentially in the reef environment with corals at depth and in inshore areas being less affected in terms of the amount of bleaching and mortality. Hard coral death was highest in areas characterized by the clearest water such as the forereef environments. This reef zone is typically dominated by table-like *Acropora* assemblage. Mortality of hard coral in these areas may reach 80%.

The unusual occurrence of warm water appears to be the result of a weather phenomenon and is subsequently influenced by oceanic and local currents (Wilkinson et al 1999; Skirving et al. 2001). In the case of the weather, it is characterized by calmness with the prevailing trade winds remaining light. When coinciding with the zenith of the sun on its seasonal transit, warming of the sea surface occurs. Surprisingly, this layer of warm water may extend to a depth of 30m. Bleaching occurs but is less frequent than that which is experienced in the shallow water. Bleaching seems to be moderated by the presence of high currents in location like reef passages. Inshore, more turbid, waters experience less bleaching. The key to this latter observation is the reduced penetration of light and its affect on the algal photosynthetic processes within the host animal. In the presence of high temperatures and light, toxic photosynthetic products such as oxygen radicals poison the animal. Many corals survive the harmful affect of light being moderated and protected by pigments within the animal. Some species of corals don't bleach at all.

In Fiji, there appears to be good survivorship of corals on many reefs. Where there has been high mortality, the presence of relatively unaffected areas at depth and inshore assures a source of recruitment to these areas. The fish and associated invertebrates do not appear to be affected by the event though more rigorous observations may determine a change in the species composition. Coral specific symbionts and predators must vary with the abundance of their hosts. For many it seems, there the habitat relief is all that matters whether it be living coral or algal covered skeletons.

Figure 3. National Oceanic and Atmospheric Administration (NOAA) Degree Heating Weeks (DHW's) Chart of the South Pacific for the last 12 weeks prior to 4/25/2000. The coloured areas show varying numbers of heating weeks accumulation along the west Australian coast and a band extending across the South Pacific. (NOAA website URL: http://www.psbsgil. nesdis.noaa.gov: 8080/PSB/EPS/ SST/dhw_retro.html).

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Figure 4. Map showing the locations of the coral bleaching assessment in Fiji.

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3.3 Assessment

The earliest assessment of the coral bleaching event was initially through a survey conducted by the Reef Check program at the Fijian Resort at Cuvu Reef February 25, 2000. Subsequently, an aerial survey was conducted of the bleaching, particularly with respect to the northern part of Fiji. It was of interest to see if this differential influence was manifest in the degree of coral bleaching.

Subsequently, field visits were conducted to determine the *in situ* effect of the bleaching. These occurred on the Great Sea Reef north of Labasa, Vanua Levu I. On the south side of the island, surveys were conducted by some members of the Fiji Dive Operators Association (see appendix 1) and at the Jean-Michel Cousteau resort. Similar surveys were conducted near Suva, particularly at Rat Tail passage. The Fiji Dive Operators were interviewed on the extent of the bleaching in their area. Summary accounts were made of other surveys conducted throughout Fiji at various stages during the event.

3.4 Aerial flight

An aerial flight was conducted at 11AM on April 21, 2000 to assess the extent of the bleaching from the Suva area to the Cakaulevu Reef, the extensive barrier reef to the north of the main Fiji islands. The NOAA hotspot charts indicated that the area of the highest temperature elevation was the southeast corner of Viti Levu extending both to the southeast and north to southern Vanua Levu. On the northern side of Vanua Levu the temperatures were very reduced, approaching normal. The objective of the flight was to assess whether the bleaching was less. This proved to be the case with severe bleaching indicated in the Suva area and Bau Waters but very reduced on the northern barrier reef.

With clear weather conditions and a low tide, the extent of the bleaching was easily observable. It was pronounced on the fore-reef areas of the barrier reefs which extending from Rat Tail Passage to Naisali Pt, on the southeast corner. Similar observations were made in flying over Bau Waters and heading along the barrier reefs adjacent Ovalau I. It was very clear upon crossing Vanua Levu, that bleaching was far less with little bleaching being discerned on the Cakaulevu barrier reef.

Figure 5. Aerial photos of the contrasting areas of coral bleaching. Nukubuco Reef (above) exhibits substantial bleaching as is evident on the margins of the spur and groove system. By contrast, the area, north of Vanua Levu had only minor bleaching (below).

(Figure not available in electronic format)

Figure 6. Aerial flight path conducted to determine the degree of bleaching from southern Viti Levu to the north of Vanua Levu, Fiji

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4.0 Survey Sites

The suvey of the coral bleaching event in Fiji was based on a sample of three localities which were representative of three regions of increasing latitude. The northern site is where the coral bleaching was minimal. The mid-region was southern Vanua Levu. The third area was southern Viti Levu. These latter areas shared habitats that represented examples of severe, moderate and minimal influence. With in the later two localities contrasting habitats of reef front, inshore reef and reef at depth.

4.1 Northern Vanua Levu Survey

In order to confirm the observations of the aerial survey, site surveys were carried out in the reef areas north of Labasa. These areas were relatively isolated from the waters to the south of the Vanua Levu. The degree and duration of the elevated temperatures in this area was substantially less than the areas south of the main islands. Only a minor amount of bleaching was observed. The surveys involved five habitats. Following are the survey results.

4.1.1 Site 1: Vorovoro I., Southern Side

The first site is the inshore area located on the southern side of Vorovoro Island opposite the Qawa River. It is characterised by soft sediments and general inshore conditions. No bleaching was observed in this area of low diversity and coral cover. The Reef Check survey of fish and mobile invertebrates reflected the low diversity and was characterised by didemnid sea urchins whose herbivorus, detrital feeding diet makes them common in areas of reef rock which is covered by a thin algal layer.

Vorovoro I. Southern Side

	Taxa	N	Total Intercept (cm)	Mean	Std. Dev.	Max.	Min.	Percent Cover
Coral	Porites sp. Massive	2	2300	460	356	1000	0.0	21.90%
	Psammocora sp.	1	800	800	0	800	800	7.62%
Substrate	Rock	1	4800	2400	400	2800	2000	45.71%
	Sand	1	2600	870	602	1700	300	24.76%
			Total 97.8m					Total 100%

Fish	Butterfly Fish	Sweetlip (Haemulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbometopon sp.)*	Lobster
	0	0	0	0	0	0	0
Invert-ebrates	**Banded Coral shrimp *Stenopus hispidus***	**Diadema urchins**	**Pencil urchins (*Hetero-Centrotus mammilatus)***	**Sea cucumber (edible only)**	**Crown-of – thorns star (*Acanth-aster)***	**Giant clam (Tridacna sp.)**	**Triton shell (*Charonia tritonis)***
	0	8	0	1	0	0	0

4.1.2 Site 2: Barrier Reef North of Labasa: Northeast corner of channel

This site is located on the northeast seaward edge of the main channel, which enters through the Cakaulevu Barrier reef. This area was characterised by moderate wave action. It was Acropora dominated, particularly tabulate or plate-like species, and should have been affected by the coral bleaching if it had occurred. The dominant species in the area was *Acropora hyacinthus* and *A. humulis*. Living coral cover was moderate at 59.25%. There was no sign of bleaching in this area. .Due to the wave action there were few invertebrates seen. The most abundant recorded fish were Chaetodons and snappers (*Lujanus kasmira*). Several parrotfish and surgeonfish were seen.

Barrier Reef North of Labasa: Northeast corner of channel

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover
Coral	Acropora aculeus	1	10	10	0	10	10	0.50%
	Acropora sp.	2	70	35.0	5.0	40.0	30.0	3.50%
	Acropora humilis	7	155.0	22.1	13.1	50.0	10.0	7.75%
	Acropora hyacinthus	12	695.0	57.9	25.6	100.0	20.0	34.75%
	Acropora monticulosa	1	20.0	20.0	0.0	20.0	20.0	1.00%
	Acropora nasuta	1	10.0	10.0	0.0	10.0	10.0	0.50%
	Acropora sarmentosa	2	60.0	30.0	20.0	50.0	10.0	3.00%
	Acropora secale	1	30.0	30.0	0.0	30.0	30.0	1.50%
	Hydnophora exesa	1	45.0	45.0	0.0	45.0	45.0	2.25%
	Pocillopora eydouxi	3	70.0	23.3	12.5	40.0	10.0	3.50%
	Pocillopora verrucosa	1	20.0	20.0	0.0	20.0	20.0	1.00%
								Total 59.25%
Algae	Coralline algae	6	465.0	77.5	44.1	170.0	30.0	23.25%
Substrate	Rubble	1	20.0	20.0	0.0	20.0	20.0	1.00%
	Old dead coral	1	50.0	50.0	0.0	50.0	50.0	2.50%
	Sand	3	280.0	280	0.0	280	280	14.00%
			Total 20m					Total 17.50%
								Total 100%

Fish	Butterfly Fish	Sweetlip (Haemulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo-metopon sp.)*	Lobster
	4	0	0	1	0	0	0
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*
	0	2	0	0	0	0	0

4.1.3 Site 3: Inner Cakaulevu barrier Reef areas North of Labasa

This table is the combination of three transects on different sites inside of the barrier reef. These areas are Gunasara Reef (3a) and two sites on the back reef are of the Cakaulevu Reef (3b,c).

Inner Cakaulevu barrier Reef areas North of Labasa

	Taxa	N	Total Intercept	Mean	Std. Dev.	Max.	Min.	Percent Cover
Coral	Acropora humilis	2	40.0	20.0	10.0	30.0	10.0	0.80%
	Acropora hyacinthus	3	70.0	23.3	12.5	40.0	10.0	1.40%
	Acropora intermedia	2	55.0	27.5	12.5	40.0	15.0	1.10%
	Acropora millepora	2	60.0	30.0	10.0	40.0	20.0	1.20%
	Acropora muricata	1	40.0	40.0	0.0	40.0	40.0	0.80%
	Acropora nasuta	3	70.0	23.3	12.5	40.0	10.0	1.40%
	Acropora sp.	4	160.0	40.0	10.0	50.0	30.0	3.20%
	Diploastrea heliopora	1	130.0	130.0	0.0	130.0	130.0	2.60%
	Favites pentagona	1	20.0	20.0	0.0	20.0	20.0	0.40%
	Fungia sp.	1	10.0	10.0	0.0	10.0	10.0	0.20%
	Goniastrea sp.	2	20.0	10.0	0.0	10.0	10.0	0.40%
	Goniastrea reniformis	1	20.0	20.0	0.0	20.0	20.0	0.40%
	Porites cyclindrica	1	90.0	90.0	0.0	90.0	90.0	1.80%
	Porites sp. (massive)	7	160.0	22.9	10.3	40.0	10.0	3.20%
	Porites rus	3	265.0	88.3	42.9	140.0	35.0	5.30%
	Pocillopora verrucosa	1	25.0	25.0	0.0	25.0	25.0	0.50%
	Seriatapora hystrix	2	50.0	25.0	5.0	30.0	20.0	1.00%
Algae	Coralline algae	8	685.0	85.6	68.4	215.0	20.0	16.70%
Other	soft coral	10	680.0	68.0	50.8	190.0	10.0	13.60%
	Sinularia sp.	1	10.0	10.0	0.0	10.0	10.0	0.20%
	Tunicates	1	20.0	20.0	0.0	20.0	20.0	0.40%
Substrate	new dead coral	1	20.0	20.0	0.0	20.0	20.0	0.40%
	old dead coral	3	265.0	88.3	37.0	140.0	55.0	5.30%
	Rock	17	1155.0	67.9	52.5	220.0	10.0	23.10%
	Sand	6	880.0	146.7	59.1	240.0	70.0	17.60%
			Total 50m					Total 100%

Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbometopon sp.)*	Lobster
	9	0	8	1	0	0	0
Invert-ebrates	**Banded Coral shrimp *Stenopus hispidus***	**Diadema Urchins**	**Pencil urchins (*Hetero-centrotus mammilatus)***	**Sea cucumber (edible only)**	**Crown-of – thorns star (*Acanth-aster)***	**Giant clam (Tridacna sp.)**	**Triton shell (*Charonia tritonis)***
	0	5	0	1	1	6	0

4.1.4 Site 4: Cakaulevu Reef near Kia I.

This area is located to the west of Kia I. on the Cakaulevu Barrier Reef. It is a submerged reef on the outer barrier reef. Its location to the west of Kia I. provides protection from the prevailing northeast swells though is exposed to oceanic swells from the northeast. Bleaching was not recorded on the transects but some colonies of *A. robusta* were seen (5 per 20min swim) that appeared as though they were bleached by the light nature of their tips but are now nearly re-established with zooxanthellae. *A. hyacinthus* appeared formerly bleached but now re-established. A colony of newly dead *A. robusta* was seen. A large colony of *Platygyra daedalea* (50cm. Dia.) was obviously bleached but has been largely recolonized by the zooxanthellae. Dead spots were present.

Cakaulevu Reef near Kia I.

	Taxa	N	Total Intercept	Mean	Std. Dev.	Max.	Min.	Percent Cover
Coral	Acropora humilis	7	190.0	27.1	36.2	115.0	5.0	9.50%
	Acropora hyacinthus	8	275.0	34.4	21.7	75.0	10.0	13.75%
	Acropora monticulosa	3	50.0	16.7	9.4	30.0	10.0	2.50%
	Acropora robust	7	205.0	29.3	12.7	50.0	10.0	10.25%
	Acropora valida	1	20.0	20.0	0.0	20.0	20.0	1.00%
	Goniastrea sp.	1	10.0	10.0	0.0	10.0	10.0	0.50%
	Montastrea curta	1	10.0	10.0	0.0	10.0	10.0	0.50%
	Pocillopora eydouxi	3	65.0	21.7	6.2	30.0	15.0	3.25%
	Porites sp. (massive)	1	10.0	10.0	0.0	10.0	10.0	0.50%
	Pocillopora verrucosa	1	10.0	10.0	0.0	10.0	10.0	0.50%
	Turbinaria sp.	1	10.0	10.0	0.0	10.0	10.0	0.50%
								42.75%
Algae	Coralline algae	12	600.0	50.0	27.6	120.0	20.0	30.00%
Substrate	Rock	11	655.0	49.5	37.8	140.0	10.0	27.25%
			Total 20m					100.00%

Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbometopon sp.)*	Lobster
	5	0	8	1	0	0	0
Invert-ebrates	**Banded Coral shrimp *Stenopus hispidus***	**Diadema Urchins**	**Pencil urchins (*Hetero-centrotus mammilatus)***	**Sea cucumber (edible only)**	**Crown-of –thorns star (*Acanth-aster)***	**Giant clam (Tridacna sp.)**	**Triton shell (*Charonia tritonis)***
	0	8	0	1	0	1	0

This is an area of high luxuriance with a living coral cover of 42.75%. The species diversity of coral is high. Despite the fishing pressure from the local village, the fishes are abundant with *Chaetodons* and snapper (*Lutjanus kasmira)* recorded.

(Figure not available in electronic format)

Figure 8. Photographs of the area north of Labasa showing little coral bleaching.

4.2 Southern Vanua Levu

The reef areas surveyed were adjacent to the Jean Michel Cousteau Resort, on both the windward and proctected side of Point Reef. This area is 10 km east of Savusavu. The area was intially surveyed by the participants of the Fiji Dive Operators Association Reef Check training program (April 19, 2000). This was at a site known as Big Blue. This site and several others were subsequently sampled through a survey conducted by the Jean Michel Cousteau Resort (June 29-31, 2000).

This area south of Vanua Levu has been greatly affected by the bleaching and subsequent death. Where as few corals showed signs of bleaching to the north of the island, the southern area was dramatically affected. This was particularly manifest on the windward reefs in the shallower waters.

Figure 9. Aerial photo of Point Reef extending from Vanua Levu and forming the southeast margin of Savusavu Bay. The Big Blue Dive site is located on the southern side near Lesiaceva Point.

(Figure not available in electronic format)

4.2.1 Site 1 Jean-Michel Cousteau Resort: Big Blue Dive Site: 3m reef slope: Site 1
July 5, 2000

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover	% of coral bleached	% Dead	% Normal
Coral	Acropora humilis D	1	60.0	60.0	0.0	60.0	60.0	5.17%		9.30%	
	Acropora hyacinthus D	1	20.0	20.0	0.0	20.0	20.0	1.72%		3.10%	
	Acropora nasuta	1	20.0	20.0	0.0	20.0	20.0	1.72%			3.10%
	Acropora robust D	1	40.0	40.0	0.0	40.0	40.0	3.45%		6.20%	
	Acropora sp. D	4	140.0	35.0	5.0	40.0	30.0	12.07%		21.71%	
	Galaxea fasicularis	2	30.0	15.0	5.0	20.0	10.0	2.59%			4.65%
	Goniastrea reniformis B/R	1	10.0	10.0	0.0	10.0	10.0	0.86%	1.55%		
	Lobophyllia corymbosa	2	40.0	20.0	10.0	30.0	10.0	3.45%			6.20%
	Platygyra sp. R	1	20.0	20.0	0.0	20.0	20.0	1.72%	3.10%		
	Pocillopora damicornis D	1	30.0	30.0	0.0	30.0	30.0	2.59%		4.65%	
	Pocillopora damicornis	1	25.0	25.0	0.0	25.0	25.0	2.16%			3.88%
	Pocillopora eydouxi D	2	80.0	40.0	0.0	40.0	40.0	6.90%		12.40%	
	Pocillopora eydouxi	2	80.0	40.0	20.0	60.0	20.0	6.90%			12.40%
	Pocillopora verrucosa D	1	50.0	50.0	0.0	50.0	50.0	4.31%		7.75%	
			645					55.60%	4.65%	65.12%	30.23%
Other	Soft coral	1	10.0	10.0	0.0	10.0	10.0	0.86%			
Algae	Coralline algae	2	75.0	37.5	17.5	55.0	20.0	6.47%			
Substrate	Rock	1	30.0	30.0	0.0	30.0	30.0	2.59%			
	Rubble	3	180.0	60.0	37.4	100.0	10.0	15.52%			
	Old dead coral	3	220.0	73.3	33.0	120.0	50.0	18.97%			
								Total 37.07%			
			Total 11m					Total 100%			

Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster
	3	1	4	0	0	0	0
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*
	0	2	0	1	0	0	0

This area is one of a steep reef front in which the coral cover is high at 56%. Of the living cover the newly dead coral as the result of the bleaching was 65% and the unaffected or re-established coral 30%. The only remaining bleached coral was 5% of living coverage.

4.2.2 Jean-Michel Cousteau Resort: Big Blue Dive Site: 6m reef slope: Site 3

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover	%of newly dead	%Normal
Coral	Acropora clathrata D	1	240.0	240.0	0.0	240.0	240.0	10.34%	14.63%	
	Acropora hyacinthus D	3	280.0	93.3	57.9	170.0	30.0	12.07%	17.07%	
	Acropora intermedia D	2	370.0	185.0	45.0	230.0	140.0	15.95%	22.56%	
	Acropora muricata D	3	290.0	96.7	66.5	190.0	40.0	12.50%	17.68%	
	Acropora muricata	1	90.0	90.0	0.0	90.0	90.0	3.88%		5.49%
	Acropora nasuta D	1	60.0	60.0	0.0	60.0	60.0	2.59%	3.66%	
	Echinopora lamellosa	2	90.0	45.0	35.0	80.0	10.0	3.88%		5.49%
	Galaxea fascicularis	1	10.0	10.0	0.0	10.0	10.0	0.43%		0.61%
	Pocillopora damicornis D	1	110	110	0	110	110	4.79%	6.71%	
	Pocillopora damicornis	1	20.0	20.0	0.0	20.0	20.0	0.86%		1.22%
	Pocillopora eydouxi	3	80.0	26.7	12.5	40.0	10.0	3.45%		4.88%
		Total	1640.0				Total	70.75%	82.32%	17.68%

Other	Soft coral	1	10.0	10.0	0.0	10.0	10.0	0.43%
Algae	Halimeda	1	70.0	70.0	0.0	70.0	70.0	3.02%
Substrate	Old dead coral	1	100.0	100.0	0.0	100.0	100.0	4.31%
	Rock	1	40.0	40.0	0.0	40.0	40.0	1.72%
	Rubble	5	460.0	92.0	64.0	210.0	40.0	19.83%
			Total 23.20m					Total 100%

Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster
	4	1	4	1	0	0	0
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of –thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*
	0	0	0	0	0	0	0

4.2.3 Jean-Michel Cousteau Resort: Big Blue Dive Site: Deep Site 30m: Transect 1: June 28, 2000

Taxa		N	Total Intercept	Mean	Std. Dev.	Max.	Min.	Percent Cover	% bleached	%Newly dead
Hard Coral	Echinophyllia aspera	4	110	60	5	60.0	50.0	9.17%		
	Echinopora lamellosa	3	125	65	14.6	65.0	65.0	10.42%		

	Echinopora lamellosa D	1	35	35	0	35.0	35.0	2.92%		2.80%
	Fungia N/B	1	10	10	0	10.0	10.0	0.83%	0.80%	
	Fungia sp.	1	140	10	16.7	10.0	10.0	11.67%		
	HC*	5	110	20	19.4	20.0	20.0	9.17%		
	HC B	1	20	20	0	20.0	20.0	1.67%	1.60%	
	Herpetolitha limax	1	30	10	5	10.0	10.0	2.50%		
	Zoopilus echinatus	2	45	25	2.5	25.0	25.0	3.75%		
	Montipora D	1	90	90	0	90.0	90.0	7.50%		7.20%
		20	7.15m				Total	59.58%	2.40%	10%
Other	Soft coral	2	145	15	6.1	475.0	79.2	12.08%		
	Sponge	1	25	25	0	25.0	25.0	2.08%		
								14.17%		
Algae	Coralline algae		70	50	15	50.0	50.0	5.83%		
	Macro algae and rubble		165	330	0	165.0	165.0	13.75%		
								19.58%		
Substrate	Old dead coral		35	35	0	35.0	35.0	2.92%		
	Rubble		55	20	7.5	185.0	185.0	4.58%		
			Total 1210					7.50%		
								Total 100%		

*HC refers to hard coral. This data was collected by Holly Lohuis, Jean-Michel Cousteu Resort

4.2.4 Jean-Michel Cousteau Resort: Big Blue Dive Site: Deep Site 30m: Transect 2: June 30, 2000

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover	% bleached
Coral	Echinophyllia aspera	3	65.0	45.0	12.0	25.0	10.0	4.68%	

	Echinopora lammelosa	3	285.0	47.5	14.6	65.0	20.0	20.75%	
	Fungia partial bleached	1	10.0	10.0	0.0	10.0	10.0	0.83%	0.72%
	Fungia sp.	6	140.0	23.3	16.7	60.0	10.0	11.67%	
	HC	5	110.0	22.0	19.4	60.0	10.0	9.17%	
	HC B	1	20.0	20.0	0.0	20.0	20.0	1.67%	1.44%
	Herpetolitha limax	2	30.0	15.0	5.0	20.0	10.0	2.50%	
	Montipora D	1	90.0	90.0	0.0	90.0	90.0	7.50%	
	Zoopilus echinatus	2	45.0	22.5	2.5	25.0	20	3.75%	
		24	7.95m					62.51%	2.16%
Other	Soft coral	6	145.0	24.2	6.1	30.0	15.0	12.08%	
	Sponge	1	25.0	25.0	0.0	25.0	25.0	2.08%	
								14.17%	
Algae	Coralline algae	2	70.0	35.0	15.0	50.0	20.0	3.75%	
	Macro algae and rubble	1	330.0	330.0	0.0	330.0	330.0	24.16%	
								27.91%	
Substrate	Old dead coral	1	35.0	35.0	0.0	35.0	35.0	2.92%	
	Rubble	2	55.0	27.5	7.5	35.0	20.0	4.58%	
			Total 13.90m					7.50%	
							Total	100.00%	

Only two colonies were bleached and the rest was normal with one newly dead.

4.3 Rat Tail and Suva Passage Reefs

Rat Tail Passage is located near Suva on the southern side of Viti Levu. It is a narrow passage through the barrier reef, which is 1km offshore. The sample area is located on the west side of the passage. It includes the intertidal reef flat and passage reef slope. The inshore area is a fringing reef located seaward of Muaivuso Village.

The sampling period occurred in May, June and July.

4.3.1 Rat Tail Passage Reef flat May 23, 2000: Site 1

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover	Of the Coral Cover % Bleach	%50 Bleach	% dead	% Normal
Coral	A humilis B	1	10.0	10.0	0.0	10.0	10.0	0.50%	0.84%			
	A humilis D	1	20.0	20.0	0.0	20.0	20.0	1.00%			1.67%	
	Acropora anthocercis D/B 50/50	1	30.0	30.0	0.0	30.0	30.0	1.50%		2.51%		
	Acropora cytherea	2	85.0	42.5	27.5	70.0	15.0	4.25%				7.11%
	Acropora diversa	1	15.0	15.0	0.0	15.0	15.0	0.75%				1.26%
	Acropora diversa B	2	45.0	22.5	2.5	25.0	20.0	2.25%	3.77%			
	Acropora diversa D	1	60.0	60.0	0.0	60.0	60.0	3.00%			5.02%	
	Acropora diversa %50B/D	1	30.0	30.0	0.0	30.0	30.0	1.50%		2.51%		
	Acropora humilis	1	10.0	10.0	0.0	10.0	10.0	0.50%				0.84%
	Acropora humilis B	4	100.0	25.0	8.7	40.0	20.0	5.00%	8.37%			
	Acropora humilis D	3	90.0	30.0	14.1	50.0	20.0	4.50%			7.53%	
	Acropora hyacinthus	2	40.0	20.0	0.0	20.0	20.0	2.00%				3.35%
	Acropora hyacinthus D	6	180.0	30.0	14.1	60.0	20.0	9.00%			15.06%	
	Acropora muricata D	2	50.0	25.0	5.0	30.0	20.0	2.50%			4.18%	
	Acropora nana B	1	10.0	10.0	0.0	10.0	10.0	0.50%	0.84%			
	Acropora nasuta 50%D/B	1	30.0	30.0	0.0	30.0	30.0	1.50%		2.51%		
	Acropora nasuta B	2	40.0	20.0	0.0	20.0	20.0	2.00%	3.35%			
	Acropora nasuta D	1	30.0	30.0	0.0	30.0	30.0	1.50%			2.51%	
	Acropora specifera B	1	10.0	10.0	0.0	10.0	10.0	0.50%	0.84%			
	Acropora sp. B	3	50.0	16.7	4.7	20.0	10.0	2.50%	4.18%			
	Acropora sp. D	4	120.0	30.0	12.2	50.0	20.0	6.00%			10.04%	
	Acropora subulata	1	10.0	10.0	0.0	10.0	10.0	0.50%	0.84%			
	Gardineroseris planulata %50B/D	1	10.0	10.0	0.0	10.0	10.0	0.50%		0.84%		
	Montipora sp. B	2	90.0	45.0	5.0	50.0	40.0	4.50%	7.53%			
	Pocillopora damicornis %50D/B	1	10.0	10.0	0.0	10.0	10.0	0.50%		0.84%		

	Pocillopora eydouxi B	1	20.0	20.0	0.0	20.0	20.0	1.00%	1.67%			
		38	1195.0						32.22%	9.21%	46.03%	12.55%
Substrate	Rock	20	765.0	38.3	25.8	110.0	10.0	38.25%				
	Old dead coral	1	40.0	40.0	0.0	40.0	40.0	2.00%				
								40.25%				

Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster
	8	0	5	0	0	0	0
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*
	0	0	0	0	0	0	0

Figure 10. Views of coral bleaching at Rat Tail Passage May 23, 2000 (Figure not available in electronic format)

Figure 11 Aerial views of Suva and RatTail passages.

(Figure not available in electronic format)

4.2.2 Rat Tail Reef Flat June 11, 2000: Site 2

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover	% bleach	% Part Bleach	% Newly Dead	% Normal
Coral	Acropora clathrata D	1	20.0	20.0	0.0	20.0	20.0	1.00%			1.23%	
	Acropora cytherea D	2	50.0	25.0	5.0	30.0	20.0	2.50%			3.09%	
	Acropora cytherea %50N/D	1	20.0	20.0	0.0	20.0	20.0	1.00%		1.23%		
	Acropora divaricata N	2	30.0	15.0	5.0	20.0	10.0	1.50%				1.85%
	Acropora humilis	1	10.0	10.0	0.0	10.0	10.0	0.50%				0.62%
	Acropora humilis D	1	30.0	30.0	0.0	30.0	30.0	1.50%			1.85%	
	Acropora hyacinthus N	8	210.0	26.3	12.4	45.0	10.0	10.50%				12.96%
	Acropora hyacinthus D	7	170.0	24.3	5.6	30.0	15.0	8.50%			10.49%	
	Acropora intermedia	1	20.0	20.0	0.0	20.0	20.0	1.00%				1.23%
	Acropora monticulosa N	1	20.0	20.0	0.0	20.0	20.0	1.00%				1.23%
	Acropora nasuta D	9	300.0	33.3	18.7	60.0	10.0	15.00%			18.52%	
	Acropora robust N/D	1	60.0	60.0	0.0	60.0	60.0	3.00%		3.70%		
	Acropora robust N	5	125.0	25.0	11.8	45.0	10.0	6.25%				7.72%
	Acropora robust D	1	30.0	30.0	0.0	30.0	30.0	1.50%			1.85%	
	Acropora secale N	2	15.0	7.5	2.5	10.0	5.0	0.75%				0.93%
	Acropora selago D	1	10.0	10.0	0.0	10.0	10.0	0.50%			0.62%	
	Acropora spicifera D	1	40.0	40.0	0.0	40.0	40.0	2.00%			2.47%	
	Acropora sp. N	4	70.0	17.5	13.0	40.0	10.0	3.50%				4.32%
	Acropora sp. N/D	1	10.0	10.0	0.0	10.0	10.0	0.50%			0.62%	
	Acropora valida N	3	25.0	8.3	2.4	10.0	5.0	1.25%				1.54%
	Favites russeli	1	30.0	30.0	0.0	30.0	30.0	1.50%				1.85%
	Goniastrea reniformis	1	30.0	30.0	0.0	30.0	30.0	1.50%				1.85%
	Goniastrea sp. B	1	10.0	10.0	0.0	10.0	10.0	0.50%		0.62%		
	Hard coral %50D/N	1	50.0	50.0	0.0	50.0	50.0	2.50%			3.09%	
	Montastrea curta %50B/N	3	100.0	33.3	18.9	60.0	20.0	5.00%			6.17%	
	Montipora sp.	1	15.0	15.0	0.0	15.0	15.0	0.75%				0.93%

	Pavona varians	1	5.0	5.0	0.0	5.0	5.0	0.25%				0.31%
	Platygyra 3/4 B	1	10.0	10.0	0.0	10.0	10.0	0.50%			0.62%	
	Platygyra sp.	1	5.0	5.0	0.0	5.0	5.0	0.25%				0.31%
	Pocillopora eydouxi N	1	45.0	45.0	0.0	45.0	45.0	2.25%				2.78%
	Pocillopora verrucosa D	2	50.0	25.0	5.0	30.0	20.0	2.50%			3.09%	
	Porites lutea	1	5.0	5.0	0.0	5.0	5.0	0.25%				0.31%
		68	16.2m					Totals	0.0	5.56%	53.70%	40.74%
Algae	Coralline algae	1	10.0	10.0	0.0	10.0	10.0	0.50%				
Other	Remains of soft coral	1	50.0	50.0	0.0	50.0	50.0	2.50%			3.09%	
	Zoanthid N	1	40.0	40.0	0.0	40.0	40.0	2.00%				2.47%
								Totals			3.09%	2.47%
Substrate	Rock	10	310.0	31.0	11.6	50.0	10.0	15.50%				
			Total 20m					Total 100%				

Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster
	8	0	4	0	0	0	0
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*
	0	0	0	0	0	0	0

4.2.3 Suva Pass July 8, 2000: Site 3

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover	% Bleach	%part bleached /normal	% Dead	%Normal
Hard Coral												
	Acropora corymbose	1	10.0	10.0	0.0	10.0	10.0	0.20%				0.51%
	Acropora corymbose D	2	90.0	45.0	25.0	70.0	20.0	1.80%			4.63%	
	Acropora monticulosa	3	70.0	23.3	9.4	30.0	10.0	1.40%				3.60%
	Acropora nana	1	30.0	30.0	0.0	30.0	30.0	0.60%				1.54%
	Acropora nana D	2	30.0	15.0	5.0	30.0	10.0	0.60%			1.54%	
	Acropora sp.	10	205.0	20.5	52.6	50.0	10.0	4.10%				10.54%
	Acropora sp. D	5	290.0	19.3	19.3	50.0	10.0	4.80%			14.91%	
	Astreopora sp.	1	10.0	5.5	4.2	10.0	1.0	0.20%				0.51%
	Echinopora lamellosa	2	65.0	32.5	22.9	40.0	25.0	1.30%				3.34%
	Favid	1	40.0	40.0	18.4	40.0	40.0	0.80%				2.06%
	Galaxea astreata	1	10.0	10.0	4.2	10.0	10.0	0.20%				0.51%
	Goniastrea reniformis	1	10.0	10.0	4.2	10.0	10.0	0.20%				0.51%
	Hydnophora exesa	3	40.0	13.3	12.9	20.0	10.0	0.80%				2.06%
	Merulina ampliata	1	10.0	13.3	4.2	10.0	10.0	0.20%				0.51%
	Montastrea sp.	2	60.0	30.0	10.0	60.0	20.0	1.20%				3.08%
	Montipora N/B 40/60	1	70.0	70.0	0.0	70.0	70.0	1.40%		3.60%		3.60%
	Montipora sp.	3	160.0	53.3	53.1	80.0	10.0	3.20%				8.23%
	Pavona minuta	1	30.0	30.0	13.7	30.0	30.0	0.60%				1.54%
	Pavona varians	1	40.0	40.0	18.4	40.0	40.0	0.80%				2.06%
	Platygyra sinensis	3	50.0	25.0	19.7	40.0	40.0	1.00%				2.57%
	Pocillopora damicornis	4	125.0	31.3	39.4	125.0	20.0	2.50%				6.43%
	Pocillopora damicornis	1	10.0	10.0	0.0	10.0	10.0	0.18%			0.51%	
	Pocillopora eydouxi	2	130.0	65.0	55.0	120.0	10.0	2.60%				6.68%
	Pocillopora eydouxi D	1	30.0	30.0	0.0	30.0	30.0	0.60%			1.54%	
	Pocillopora verrucosa D	3	110.0	36.7	35.4	40.0	30.0	2.20%			5.66%	
	Porites cylindrica	1	80.0	80.0	37.2	80.0	80.0	1.60%				4.11%

	Porites massive	6	120.0	20.0	20.0	30.0	10.0	2.40%				6.17%
	Porites massive D	1	20.0	20.0	0.0	20.0	20.0	0.40%			1.03%	
		67	1945.0					34.00%	0.00%	3.60%	28.79%	70.18%
Other												
	Soft coral D	2	50.0	25.0	17.3	30.0	20.0	1.00%				
Algae												
	Coralline algae	3	520.0	173.3	206.6	390.0	60.0	10.40%				
Substrate												
	Rock	30	2730.0	91.0	462.7	220.0	20.0	54.60%				
			Total 52 m					Total 100%				

Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster
	2	1	5	1	0	0	0
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*
	0	4	0	0	0	0	0

4.2.4 Rat Tail Reef Flat July 29, 2000: Site 4

	Taxa	N	Total Intercept	Mean	Std.	Max.	Min.	Percent Cover	% Bleach	%part bleach /normal	%part bleach /dead	% Dead	%Normal
Coral	Acropora clathrata	2	75.0	37.5	12.5	50.0	25.0	3.61%					4.95%
	Acropora cuneata	1	10.0	10.0	0.0	10.0	10.0	0.48%					0.66%
	Acropora cytherea	1	10.0	10.0	0.0	10.0	10.0	0.48%					0.66%
	Acropora digitifera	1	20.0	20.0	0.0	20.0	20.0	0.96%					1.32%
	Acropora humilis	3	60.0	20.0	8.2	30.0	10.0	2.89%					3.96%
	Acropora hyacinthus	1	50.0	50.0	0.0	50.0	50.0	2.41%					3.30%
	Acropora hyacinthus D	5	180.0	36.0	10.2	50.0	20.0	8.67%				11.88%	
	Acropora intermedia	5	130.0	26.0	15.9	50.0	10.0	6.27%					8.58%
	Acropora muricata	1	20.0	20.0	0.0	20.0	20.0	0.96%					1.32%
	Acropora nasuta	1	40.0	40.0	0.0	40.0	40.0	1.93%					2.64%
	Acropora nasuta D	3	100.0	33.3	12.5	50.0	20.0	4.82%				6.60%	
	Acropora robusta	6	175.0	29.2	11.0	50.0	20.0	8.43%					11.55%
	Acropora secale D	3	75.0	25.0	8.2	35.0	15.0	3.61%				4.95%	
	Acropora sp.	2	30.0	15.0	5.0	20.0	10.0	1.45%					1.98%
	Acropora sp. D	4	140.0	35.0	20.6	70.0	20.0	6.75%				9.24%	
	Acropora sp. N/D 50/50	1	10.0	10.0	0.0	10.0	10.0	0.48%			0.66%		
	Acropora subulata	1	60.0	60.0	0.0	60.0	60.0	2.89%					3.96%
	Acropora valida	4	90.0	22.5	8.3	30.0	10.0	4.34%					5.94%
	Acropora valida N/D 50/50	1	40.0	40.0	0.0	40.0	40.0	1.93%			2.64%		
	Montipora sp.	3	50.0	16.7	4.7	20.0	10.0	2.41%					3.30%
	Pocillopora damicornis N/B 90/10	1	35	35	0	35	35	1.69%		2.31%			
	Pocillopora verrucosa	1	20	20	0	20	20	0.96%					1.32%
	Pocillopora verrucosa D	1	30	30	0	30	30	1.45%				1.98%	
	Porites sp.	5	65.0	13.0	6.0	20.0	5.0	3.13%					4.29%
		62	15.0 m					73.01%	0.00%	2.31%	3.30%	34.65%	59.74%
Algae	Coralline algae	11	625.0	56.8	45.6	145.0	10.0	30.12%					

Substrate Rock	2	70.0	35.0	5.0	40.0	30.0	3.37%
	Total 22 m					Total 100%	

5.0 Reef Check Transects Conducted at the Fiji Dive Operators (FDOA) Workshop

April 19, 2000, the Fiji Dive Operators president Curly Carswell of EcoDivers, Savusavu convened a Reef Check training workshop. This was to be the first of three which would encompass all of the dive operations in Fiji. Unfortuantely the coup of May 19 destroyed tourism in the country and put any further plans for the subsequent training periods on hold.

Following are the results of the workshop. Though 100m transects were run by each of the six companies, the first two 20m segments were used as training and the last two were combined with partnered groups. The results are presented. The individual transects ar contained in the appendix 9.5.

5.1 Combined Transects to equal the 4 x 20m										
Eco Divers/ Susies Dive Center: Depth 10m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	53	0	0	0	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-Centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	8	0	9	0	0	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently DeadCoral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	74	60.8	25	7	0	5	6	19	5	

Vuna Divers and Namale Dive Resort: Depth 10-13m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	14	0	0	2	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-Centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	8	0	2	0	1	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently Dead Coral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	84	25	18	21	0	0	7	3	1	
Aqua-Trek Garden I./ Namena I. Resort: Depth 3m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	18	0	2	0	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-Centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	0	0	0	0	0	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently Dead Coral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	78	66	60	0	0	13	0	0	0	

Figure 12 Training session at the Fiji Dive Operators workshop (left).   Reef Check diver swims (right) over severly bleached coral area at the Big Blue Dive Site.

(Figure not available in electronic format)

Figure 13. Diver conducting a Reef Check survey of the coral bleaching (left). Divers returning from survey (right).

Figure not available in electronic format)

5.2 Interview of the Fiji Dive Operators Association members.

The Fiji Dive Operators Association are an important part of the Fiji Coral Reef Monitoring Network. This is part of the Global Coral Reef Monitoring Network (GCRMN), of which, we are one of the member countries in the Pacific Node.

Questions were asked of the dive operators to assess their perceptions of the effect of the bleaching event on the coral reefs that they dive and on their business. The following questions were posed.

How much coral bleaching occurred in your area? Anemones and soft corals?

What areas/habitats were most effected? Inshore? Offshore? Passages? Depth?

Has there been good recovery? What about the fish and other reef inhabitants?

Is there any residual bleaching?

Given the political situation, has there been a substantial impact on your business?

Have certain areas been taken off your dive list?

Do you have any monitoring progam in place to take account of the changing situation?

Do you think the reefs are recovering?

Is there bleaching again this year?

Have you been seeing any Crown-of-Thorns?

5.3 Summary Assessment

Observations by members of the Fiji Dive Operators Association provide a summary of events of the bleaching episode from the perspective of the dive industry. The coral bleaching event was as much a surprise to the dive operators as to the scientific community. Though in a global context, the diving community was well aware of the effects of the bleaching on other dive locations such as the Republic of Palau and the Maldive Islands, in the Indian Ocean, experienced severe bleaching in 1998 (Wilkinson et al. 1998).

With the advent of the bleaching, many of the divers thought that the reef was improving in its health with the corals exhibiting brighter colors. Many of them were unaware, even with substantial whitening of the corals that the reef was now subject to a major coral bleaching event. With the realization of the event, many in the industry felt that any discussion should be confined to the local industry and generally suppressed for fear of adversely influencing dive tourism. It was known from the 1994 bleaching event in Tahiti that there had been a dramatic downturn in the dive tourism resulting from the perception that there was widespread coral death and therefore general coral reef degradation. Reporting of coral bleaching in Fiji by the international press resulted in a hesitation by some to participate fully in the monitoring of the event. The Fiji Dive Operators Association president Curly Carswell had a more pro-active approach with the holding of a Reef Check training program for representatives from various resorts to utilize Reef Check in the surveying of the reef generally and particularly with regard to the bleaching. Unfortunately, the attempted coup of May 19th and the bloody military insurrection (October 2000) created political instability, though greatly improved, continues to the present. The resulting loss of tourism due to the turmoil was devastating to the industry, minimising any influence the perception of coral bleaching might have had. Losses in clientele due to the bleaching event were variously estimated to be 5-15%, though dive tourism became non-existant at the height of the conflict the numbers continue to be depressed by 50% or more.

The coral mortality on the reefs was extreme in some areas with 80% of the coral cover dying. This was balanced by low mortality in areas at greater depth (>20m) and those areas inshore which were dominated by species more resistant to coral bleaching such as *Porites* and *Montipora.* Fishlife remained abundant despite the dead coral skeletons that were rapidly colonized by algae. A full explanation of the phenomenon of the bleaching event presented to the dive tourists provided an interesting focus. Though some of the dive sites had been abandoned during the bleaching and post-bleaching period, by the following November most of the dive sites were being utilised again.

During the period from late October, it was evident that the water temperatures were increasing in a manner similar to the previous year. Indications of early bleaching (bright colour or paling) were being reported from several areas throughout Fiji, most notably Kadavu (January 2001) and Yadua Tabu (January 14). By February 14, *Seriatopora, Stylophora* and *Pocillopora damicornis* were all bleached in the Suva area as were some branching *Acroporas (approx. 50%)* such as *A. muricata* and *A. intermedia* and *Platygyra sinensis.* From the westside of Viti Levu, corals that were being maricultured by Walt Smith International became bleached and began dying. In the wild context in both areas, the small corals, which were developing from the 1999 spawning period, were growing normally seemingly unaffected by the current elevated temperatures. Likewise, the larger corals, which had survived the 2000 bleaching event, were not bleached. Spawning was not reported for the October-November period 2000. *Acropora* samples taken near Suva revealed no eggs with limited sperm present. The film crew aboard the live aboard dive yacht *Nai'a* were unable to observe the mass spawning of October, November or December.

Other phenomenon noted was the degradation of the standing skeletal framework of the recently dead coral. The finer architecture of the corallites had become less evident, with the colonies becoming much smoother and represented by only the main skeletal structure. As well, the algal cover that was characteristic of the newly dead colonies now (February 2001) was very much less. The skeleton had become much more brittle, being heavily infested and weakened by sponges, algae and other boring organisms.

With the path of cyclone Paula (March 3-4) traveling south of Fiji, heavy swell removed much of the superficial algae with the reported appearance of the coral being scrubbed. Much of the coral was broken off and washed into the adjacent deeper areas or inshore.

Interestingly, a number of Dive Operators observed some specimens of the large sea anemone *Heteractis sp.* remained bleached from the 2000 event as did some specimens of the largest massive hard corals *Diploastrea heliopora.* Most of this latter species had re-established its zooxanthellae or had died, usually in patches, on the larger colony. The crown-of-thorns starfish, *Acanthaster planci*, was not reported as abundant, though it had been reported with localised elevated numbers prior to the bleaching.

There was general concurrence among the dive operators that, despite the large amount of coral death, the reef was progressing well in the re-establishment of its coral cover.

6.0 Results

Survey of a selection of reefs north of Labasa, Vanua Levu confirmed that there was only minor coral bleaching. The reefs were representative of platform reefs within and including the barrier reefs. Percentage cover on these reefs extended from inshore where it was only 10% coral cover involving two species of coral to the offshore area of approximately 60% comprised of 17 species of coral. Bleaching was estimated at less than 1%.

On southern Vanua Levu, bleaching was severe. Sampling here was at a single site on an exposed reef front. The maximum coral cover was 70.8% previous living cover with 82.3% death from bleaching at 6m depth. 17.7% remained unaffected by the bleaching. The shallow area (3m) had less mortality, with 65.1% death. Bleaching at 30m depth was relatively minimal at 4.8%. This sample was taken at the end of June/ early July so many of the coral that were bleached in early March had died.

At Rat Tail Passage on southern Viti Levu near Suva, coral bleaching was similar to southern Vanua Levu. As of May 23, 2000, 41% of the coral remained bleached or partially bleached and 46% had died. 12.6% remained unaffected by the bleaching. By June 11, 5.6% remained partially bleached with 53.7% having died. The normal coral had re-established itself to 40.7%. By July 29 Suva Pass, which is similar in nature, had 28.8% mortality and 70.2% living coral indicating substantial survival. On July 29 at Rat Tail Passage, 34.5% had died and 59.7% had recovered.

Observed trends included the survival of small colonies which are now developing despite another year of elevated temperatures in 2001. Such corals as *Acropora crateriformis*, *Echinopora lamellosa, Turbinaria reniformis,* and *Pocillopora eydouxyi* appeared to be resistant to bleaching. Those most liable to bleaching were *Platygyra sinensis, Pocillopora damicornis, P verrucosa, Acropora muricata, A. intermedia, Diploastrea heliopora, and Porites spp.* The percentage of bleaching was less at both depth and in inshore habitats though these communities varied considerably in species dominance from the shallow water species assemblage.

During February, and early March bleaching had begun again with temperatures elevated in a broad area around the Fiji Islands. In the hardest hit areas in 2000, little bleaching has been observed.

7.0 Discussion

7.1 The Nature of the Bleaching Event

The coral bleaching event occurred unexpectedly, though could have been predicted in the short term by the NOAA SST satellite record and in the longer term by an understanding of the influence that the ENSO cycles play in the probability of the bleaching periods. A retrospective record of bleaching may be inferred from past SST (Hadley Center Data, Edwards pers.comm.).

In the year 2000, seawater temperatures were above the expected summertime maximum of 28.3^{o}C for about 5.5 months, above 29^{o}C for 3.5 months and peaking at 30-30.5^{o}C between early March and early April. Mass bleaching occurred throughout Fiji, except in the far north where seawater temperature was not elevated according to NOAA satellite-derived SST, though bleaching was more extensive than predicted by satellite SST in some northernwestern areas such as the Yasawa Islands. Averaged over all sites, 60% of scleractinian corals were partially or fully bleached or had died from bleaching by the time of surveying. Estimates ranged between 0% and 100% (Cumming et al, in review).

7.2 Localised influences

It is widely understood that prolonged elevated temperatures in the presence of sunlight gives rise to the bleaching phenomenon. Variation within species to the prolonged effects of temperature raise questions as to the uniform nature of the response. What is curious are the secondary factors that influence the nature and extent of the bleaching. Inconsistencies are thought to be the result of the influence of secondary variables. The combination of light (cloudiness, UVR), genetics, period of exposure, water flow, oxygen and other (secondary) variables with temperature anomalies over reefs should hold the key to explaining the variation seen between corals and across reefs. (CHAMP Corallist, Hoegh-Guldberg, Aug. 2000). As an example, differential survival of corals in the Seychelles was attributed to different water flow regimes, residence time and localised upwelling (Bradshaw et al, 2000).

Figure 14. Variation exhibitied in the responses of coral to bleaching: A) is between colonies B) within mono-specific stand C) within colony

(*Figure not available in electronic format)*

During the 1998 bleaching event in Palau and in Fiji in 2000, corals in very shallow water survived much better than those just a few feet deeper. Presumably corals on these these shallow water reefs are adapted to extreme heat and sun due to exposure during low spring tides, and therefore better able to survive a warm water anomaly. There are four reef environments where corals have a better chance of survival during a warm water anomaly:

1. Reefs that are exposed at low spring tide
2. Reefs close to shore especially near rivers
3. Reefs with strong water flow during changing tides
4. Reefs below about 30 meters depth

(Carlson, CHAMP Corallist, Aug. 2000)

7.2.1 Temperature

The difference in species composition of inshore vs. offshore communities provide most of the basis for the explanation for differential coral bleaching on a local scale. Factors such as the variation in larger scale fluctations in temperature may play an important role in the amelioration of prolonged high temperatures. The range of temperature fluctuations that is characteristic of inshore areas make the coral more tolerant to the temperature extremes and, by extension, less affected by the a larger range of fluctuations. The first is adaption to a stressful environment in which they are conditioned to large range of temperatures. This has proved very true for the hard corals but is not the case of the fleshy soft coral, Sarcophyton, which was subject to wide spread bleaching in the intertidal areas.

In Mayotte Is., North Mozambique Channel is an example with a huge bleaching event occurring in 1998 spring (end of summer season) where most of 90 percent of the shallow coral of the barrier reefs died. Those corals that survived the best are from the muddy environments in bays, on fringing reef fronts and patches, even in the harbour. Corals living in oceanic cooler waters of the barrier reef belt (170 km long) are less adapted to tolerate hot waters and high level of light. In a population of corals (same species) living in neritic coastal waters, in inner areas of the lagoon, appear to be genetically more adapted to tolerate : high temperature, turbid waters after rainfalls, even falls of salinity. Today in Mayotte, probably the recovery of coral on the mid-lagoon patch reefs (recruitement) is due to larvae coming from these coastal coral populations. This is one of the main reasons to protect these "special" reefs in muddy environments from all the effects of coastal works (marinas, dredgings, infilling of littoral areas for roads, etc. (B. A. Thomassin, CHAMP Corallist, Aug., 2000).

Prolonged temperature exposure is the key component in causing bleaching. The rapiditiy of temperature fluctuations, this doesn't seem to impart much stress. Summer temperatures in Oman, for example, fluctuated daily up to 8 deg. C with maxima up to 33 deg. C and had no apparent effect on an abundant coverage of 26 species of corals (Coles,1997); Quinn and Johnson (1997)). Temperature fluctuations near upper thermal limits were observed with no negative effects on corals near the Kahe Point thermal outfall in Hawaii (Coles,1975). Bleaching threshold(s) in the Gulf apparently are a function of dose-duration. Extreme temperatures are experienced by the Gulf's "tough" corals almost every year, yet bleaching occurs only when exposure duration lasts beyond a certain threshold. The 1996 and 1998 episodes suggest such a mechanism, with a delayed response. Gulf corals are exceptionally tough. Almost every year, between November and December, seawater temperature drops 10-12^0 C in less than two weeks, with corals showing no ill effects. (Y. Fadlalla, CHAMP Corallist, Sept.2000)

It is interesting that the inshore site of Muaivuso fringing reef had such limited coral death with many of the coral species, which suffered high mortality on the exposed faces, being only partially affected. By an large the Portites/ Montipora assemblage was little affected.

7.2.2 Shading

During the 1998 mass coral bleaching event, on the inshore reefs of the GBR, a relatively lower rate of bleached corals in control plots where macroalgal (mainly Sargassum) canopy were left intact (dense and ~ 1 m high) compared to plots where the canopy had been experimentally removed. The preliminary result can be seen on http://www.gbrmpa.gov.au/corp_site/info_services/publications/reef_research/issue2_98/2seaweeds.html (Jamal, CHAMP Corallist, Aug., 2000).

Coral s at depth are thought to excape bleaching due to attenuated light through deeper water may be slighly cooler. Inshore turbid conditions reduce light, which may contribut to the deduction of bleaching and mortality.

7.2.3 Current flow

Flow probably has some effect through the removal of some of the feedback effects of the high oxygen tensions that occur during the daylight hours. If the increased production of active oxygen after thermal stress (Hoegh-Guldberg 1999), then flow might have an ameliorating effect through the decreased boundary layer thickness and hence oxygen tensions close to coral surfaces.

Survival near rivers might be related to the decreased light stress due to the higher turbidity of rivers (Hoegh-Guldberg, CHAMP Corallist, Aug 2000). Van Woesik (in review) attributes the increased survival of massive and sub-massive corals relative to branched corals to the differential effects of passive diffusion. This relationship is attributed to the increased survival of small colonies. Flowing water would reduce risk of small-scale hotspots (measured up to 90'F) and reduce UV penetration. Diffusion rates increase in strong water flow, which offers protection during bleaching. Superoxides forming during warm water events, maybe dispersed more efficinetly in flowing water.

Water motion is greatly underrated. Reef calcification is strongly linked to water motion, which is attributed to a trade-off in terms of saturation state with good flushing, the non-advective, non-symbiotic calcifiers (which includes endoliths down to the bacterial level) can get the CO2 out of their boundary layers faster. Algal symbiosis compensates to a substantial degree. With no motion and especially with high light, excess oxygen becomes a problem by day, oxygen depletion by night (B. Buddemeier, CHAMP Corallist, Aug, 2000)

7.2.4 Oxygen depletion

Dissolved oxygen (DO) depletion may be the cause of some coral bleaching and mortality. Bleaching and mortality of Acropora and Montipora spp. Has been attributed to oxygen depletion in the Houtman Abrolhos Islands, Western Australia. The deep sites (10 to 30m) depressions in the reef had DO concentrations below 1 mg/L in some instances. Transplanted Acropora branches bleached and died within a week at DO's of 2 to 4 mg. Controls suffered no (visible) ill effects. Water temperature was only 24 deg C though (D.Blakeway, CHAMP Corallist, Aug 2000).

Oxygen may be involved (either as an promoter of the photoinhibitory production and build-up of active oxygen within the zooxanthellae as a secondary variable). We know that thermal stress collapses oxygen production and increases respiration (Coles and Jokiel 1977; Hoegh-Guldberg and Smith - J. Exp. Mar. Biol. Ecol. 1989; 129:279-303 and others). If the photosynthetic production of oxygen is down and respiration is up (and probably, bacterial consumption up due to decaying tissue), then oxygen at night over reefs under low flow (especially on reefs where corals dominate) would be expected to decrease, perhaps to critical levels. While not a primary factor, it may actually be an important determinant of mortality (Hoegh-Guldberg, CHAMP corallist, Aug. 2000).

Is it possible that the zooxanethellae, existing inside the coral polyp tissue starts competing with the coral polyp for oxygen at night, when dissolved oxygen levels are low? During periods of low mixing and natural aeration of surface waters, the oxygen level may drop below a threshold and the coral polyp is in a state of competing for oxygen with the zooxanethellae (Causey, CHAMP Corallist, 2000).

7.2.5 Weather

The exceptional warming of sea surface temperatures resulted from a combination of increased insolation from the sun traversing its seasonal path to the Tropic of Capricorn and back. With its zenith passing over the latitude resulted in an apparent prolonged period of heating. This happens twice with in a short period of tiem as the the suns azimuth passes directly over the group in January-February and then again in March and April as it returns northward.

This in combination with calm weather caused by the January to April was dominated by lingering low pressure trough systems and the South Pacific Convergance Zone (SPCZ) remaining more southerly. This gave rise to conditions particularly characterised by reduced wind speeds and variable direction. Normally, summer months are characterized by low winds as the high pressure systems are usually lower. With the band of cloud sitting over any area would also retain heat which also leads to sea surface warming. Most of the effect on Fiji's weather was due to displacement of South Pacific Convergence Zone. Normally, summer months are characterized by low winds as the high pressure systems are usually lower.

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9.0 Appendix

9.1 Fiji Dive Operator Network: Register of Dive Operators

OPERATOR	ADDRESS	PHONE	FAX	EMAIL
LIVE-ABOARD DIVE VESSELS				
Nai'a Cruises	PO Box 332, Pacific Harbour	450382; 450733 hm; 907791	450566	Naia@is.com.fj
Fiji Aggressor		361382	362930	Aggressorfiji@is.com.fj
Mollie Dean	Lot 25 Wailada, Lami	361171; 998801	362930	Sere@is.com.fj
MAMANUCA AND YASAWA GROUPS				
Aqua-Trek Mana Island		669309		Aquatrek@is.com.fj
Aqua-Trek Matamanoa Is. Dive Shop		660511		
Castaway Island		661233	665753	Dive@castawayfiji.com.fj
Subsurface Fiji		666738	665753	Subsurface@is.com.fj
Yasawa Lodge		722266	724456	Yaswawa@is.com.fj
Plantation Divers		669333	669200	Plantation@is.com.fj
VITI LEVU ISLAND				
NORTH				
Ra Divers	Lot 2 Sekoula Est. Nananu-i-Ra	694511; 694900	694611; 694899	Radivers@is.com.fj
Crystal Divers		694747	694747	Crystaldivers@is.com.fj
EAST				
Ovalau				
Toberua Is. Resort	PO Box 567, Suva	472777	472888	Toberua@is.com.fj
WEST				
Inner Space	Adventures Lot 33 Wasawasa Rd.	723833		
South Pacific Adventure Divers	Colonial Plaza Namaka PO Box 10207 Nadi Airport	724246; 720673 998384; 998387		spaddivefiji@is.com.fj
Total Water Ltd	Votualevu Rd Namaka	725523		
West Side Water Sports	34 Thomson Corners, Lautoka	661462		

Aqua-Trek; Ocean Sport; Adventure Fiji	PO Box 10215 Nadi Airport 465 Queens Rd	Nadi 702413/703305 Fax 702412	702412	
Scuba Bula	Momi Bay	706100; 92016	706094	Seashell@is.com.fj
Dive Tropex		703944; 703954	703955	Divetropex@is.com.fj
South Pacific Adventure Divers		724246	720719	Spaddivefiji@is.com.fj
Dive Sonasali		706011; 706225	706092	Aaron@sonaisali.com
Westside Watersports		661462	661462	Westside@is.com.fj
SOUTH				
Aqua-Trek Beqa	Queens Rd Pac. Hbr	450324		
Atlantis Divers Co. Ltd.	57 Kennedy Ave, Nadi	702704		
Coral Coast Scuba Ventures	Shangri-la Fijian Resort	520155		
SCUBAhire Ltd. Beqa Divers	75 Marine Drive, Lami	361088, 361241	361047	Divefiji@is.com.fj
Mikes Divers Fiji	Votua Vlg. PO Box 136, Korolevu, Fiji	530222		Info@dive-fiji.com
Dive Connection (Fiji) Ltd.	PO Box 14869 Suva 16 River Drv. Pac Hbr.	450541 920541	450439	Diveconn@is.com.fj
Aqua –Trek Fiji Diving	Seashell Cove Surf and Dive Resort, Momi Bay	706100		
Warwick Divers Pro Dive	Coral Coast Korolevu	530199		
Waidroka Bay Resort	Coral Coast Dba	304605		
Dive Center (Fiji) Ltd.	4 Matua St. Walu Bay, Suva	300599; 311614; 303832; 998809		
BEQA I.				
Marlin Bay Resort	Beqa I	304042		
VATULELE ISLAND				
Vatulele Island	29326-1055	Island	(2) 9665	Theboss@vatulele.com

	Sydney Australia	550300 Nadi 720300	7833 Sydney Australia Island 520062 Nadi 720062	
KADAVU				
Dive Kadavu, Matava resort	PO Box 8 Vunisea, Kadavu	311780	303860	Divekadavu@is.com.fj
TAVEUNI, MATAGI, LAUCALA, KAIMBU				
Aqua-Trek Taveuni	Garden Island Resort Waiyevo Taveuni	880544	880288	Glennor@aquatrek.com
Aquaventure Taveuni	Postal agency Matei, Taveuni, Fiji Islands	880381		Aquaventure@is.com.fj
Dive Taveuni Resort	Matei, Taveuni	880441; 880445		Divetaveuni@is.com.fj
Fiji Forbes Laucala Island		880077	880099	
Matagi I. Resort		880260	880274	Christene@matangiisland
Susies Dive Center	Navaca Plantation	880125		Susies@is.com.fj
Swiss (Fiji) Dive Center Ltd.	Matei, Taveuni	880586		Sfd@is.com.fj
Vuna Reef Divers	Navaca Plantation	880125		Susies@is.com.fj
VANUA LEVU				
SOUTH				
Eco Divers	Copra Shed Marina	850122 850345 993511	850344	Ecodivers@is.com.fj
Jean-Michel Cousteau Fiji Islands Resort	Private Mail Bag Savusavu: Lesiaceva Pt. Ssv	850188; 850174; 850157;	850340	Fiji4fun@is.com.fj
Moody’s Namenalala Resort		880544		Moodysnamena@is.com.fj
Namale Resort	Namale Savusavu	850435	850400	Namale@is.com.fj
Action Divers			850750	

9.2 Bleaching Time Line for the Fiji 2000 Bleaching event

Date	Location	Observations	Fiji locations and regional sites.	NESDIS Hotspot (degrees above max. monthly mean 28.3^0C)	DHW	Temp. ^0C In situ (n) refers to the degree over the max monthly mean SST of 28.3)	
						Location	Temp. ^0C
Dec. 14, 1999	Regional	No elevated temperatures around Fiji though some appearing (x-^0C) around Solomon I. and north PNG. Also, .25-.50 South of Samoa and Nth of Fiji.	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	(.50-.75; (.75-1.0: 20%)) (.50-.75; .75-1.0: 50%)) 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25		Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 28.03 27.98 27.98 27.6
Dec. 18	Regional	No hotspot to the southwest but temp is elevating to the south east (.25-.50^0C) and south of the Samoa's and over Tonga	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	(.50-.75; .75-1.0) 50% .75-1.0 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25		Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 28.75 (.45) 28.52 (.22) 28.64 (.34) 27.54

Dec. 21	Regional	**Consider this the date of the beginning of the hotwater event based on the hotspot charts.** Hotspot beginning to form southwest of Fiji (.75-1.00^{0}C). It includes the areas of the Yasawa Is. Water beginning to warm around Tonga. A trend of warm water is generally occurring on the southwest sides of the various island groups (New Ireland, Solomon Is., Vanuatu and Fiji).	Bismarck Sea, **P. N. G.**: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	.50-.75 (.75-1.0) 50% .75-1.0 .25-.50 .75-1.0 0-.25 0-.25 0-.25 .50-.75 0-.25 0-.25 0-.25 0-.25		Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 28.95 (.65) 28.98 28.61 27.95
Dec. 25	Regional	Hot spot forming particularly near Savusavu. Warmer water in the Solomon's now concentrated around Bougainville, PNG. Elevated temperatures SE of Viti Levu.	Bismarck Sea, **P. N. G.**: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: SE Viti Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	.50-.75 .50--.75 (.75-1.0) .50-.75 .75-1.0 .75-1.0 1.0-1.2 1.25-1.50 5-.75 .75-1.0 Tongatapu .50-.75 Over remainder .0-.25 0-.25 0-.25 0-.25		Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 29.10 (.8) 28.68 (.38) 28.75 (.45) 28.23

Jan 8, 2000	Regional	Area around the Solomon's and northeast PNG getting much hotter. Fiji continues to warm at (XX) with hot water extending to the east over Tonga: Tongatapu I. (75-1.0 (30%).	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	.75-1.0; 1.0-1.25 (15%) 1.0-1.25 .50-.75 .50-.75 .75-1.0 .50-.75 0-.25 .50-.75 .50-.75; .(75-1.0 (30%)) 0-.25 (Tongatapu I.) 0-.25 0-.25 1.75-2.00		Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 29.20 (.9) 28.60 (.3) 28.97 (.67) 28.98 (.68)
						Taveuni I. Offshore	 29.45 (1.12)
Jan 9						Taveuni I. Inshore	 29.53 (1.23)
Jan. 14	End of Savusavu airport	**Beginning of the DHW event for the Taveuni I./ MtMutiny area (Southern Vanua Levu)** Fiji Dive Operator Association president Curly remembered bleaching beginning. First report of possible bleaching				Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 29.40 (1.1) 29.32 (1.02) 29.22 (.92) 29.00 (.7)

Jan. 18	Regional	Water under Fiji and to the southwest of the Solomon's/NE PNG continue warm. .5-.75 Nth Viti Levu. South of Viti Levu hots water 1.25-1.50 forming. A 1.25-1.75 patch is forming at 20^0S or near southern Tonga (Tongatapu I.). Most of Tonga is 0.5-0.75 The hottest water is on the SW but substantial on the other side so need to check weather.	Bismarck Sea, **P. N. G.**: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: North Viti Levu SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	.50-.75; .75-1.0(50%) 1.25-1.50 .75-1.0 .5-.75 .75-1.00 .75-1.00 0-.25 (Must be an rtifact) 0-.25 " 1.25-1.75 Tongatapu .75-1.0 Ha'apai; Vava'u 0-.25 .5-.75 0-.25 1-1.5		Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 29.68 (1.38) 29.55 (1.24) 29.32 (1.02) 29.09 (.79)
Jan. 30		**Beginning of the DHW event for the Suva area based on the logger data.** The evident trend is that Taveuni I. is heating first followed by Mt. Mutiny and then (two weeks later) Suva. The levels equalise the first week of February but vary with the north generally hotter.				Fish Patch, Suva	29.33 (1.03)

Feb. 1	Regional	Elevated around Fiji and temp increasing. Area near Yadua Tabu And North Vanua Levu where flight was and rated at .75-1.0.	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	(.50-.75; .75-1.0)50% .75-1.0: 1.0-1.25 (20%) .50-.75 .25-.50 1.00-1.25 .75-1.0 .50-.75 1-1.5 Tongatapu .75-1.0 Ha'apai; Vava'u .50--.75 .50-.75 .75-1.0 1.0-1.75		Taveuni I. Inshore Offshore Mt. Mutiny Fish Patch, Suva	 30.45 (2.15) 30.00 (1.7) 29.36 (1.06) 29.51 (1.21)
Feb. 15,	Regional	Band of hot water extends from the NE PNG to Fiji and across the Pacific to SA. 1.25-1.75 around Viti Levu having extended through Vatu-I-Ra Passage Spotty yellow 1-1.25 to the southeast of Fiji	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: Vatu-I-Ra Passage South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **North** **Tubuai:** **Easter I:** **Western Australia:**	1.0-1.25 .75-1.0: 1.0-1.25 (20%) .75-1 1.25-1.75 1.25-1.75 1.25-1.75 1.25-1.75 .50--.75 1.25-1.75 Tongatapu .75-1.0 Ha'apai; Vava'u 1.0-1.25 Rarotonga 0-.5.0 1.0-1.50 1.0-1.25 1.0-1.5 2.75-3.0 (Cape Leeuwin)		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.33 (1.03) 29.57 (1.27) 29.20 (.88) 29.38 (1.04)

Feb. 20	Entrance to the Suva Harbour entrance	Bleaching event first noticed Surfing observations				Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.45 (1.03) 29.40 (1.1) 29.18 (.88) 29.34 (1.04)
Feb. 27	Fijian Resort	Reef Check observed possible bleaching in a couple of colonies No widespread bleaching				Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.75 (1.45) 29.80 (1.50) 29.32 (1.02) 29.57 (1.27)
Feb. 29	Regional	Band of hot water begins to cool on SA side but is as above but doesn't cover the north of Vanua Levu. The Yasawa and west of Viti Levu hot as is the body of water to the southwest of the island groups but not New Caledonia. Water through Vatu-I-Ra passage?? To March 11.	Bismarck Sea, **P. N. G.**: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	1.0-1.25 1.0-1.25 1.0-1.25;.75-1.0 Yasawa 1.0-1.25 1.0-1.25 1.0-1.25 .25-.50 1.25-1.75 1.25-1.75 Rarotonga .5-.75 Cent/North 1.20-1.75 1.0-1.5 1.0-1.5 2.25 (10%)		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.78 (1.48) 29.65 (1.35) 29.51 (1.21) 29.43 (1.13)
March 3						Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 30.13 (1.83) 30.50 (2.2) 29.47 (1.17) 29.67 (1.37)

March 11	Regional	Band of hot water begins to contract but still hot below Fiji and to the southeast. Samoa’s not affected.	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu I.: South/cent. Vanua Levu I: North of Vanua Levu I: **Kingdom of Tonga:** **Cook Is.:** **Tubuai Is.:** **Easter I.:** **Western Australia:**	1.0-1.25 .75-1.0/1.0-1.25 75-1.0 1.0-1.25 1.0-1.75 .50-.75 .50-.75 1.25-1.75 .5-.75/.75-1.0 .75-1.25 .75-1.0/1.0-1.25 1.75-2.0		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.63 (1.33) 29.68 (1.38) 29.30 (1.0) 29.64 (1.34)
March 12	Frigate Pass	Bleaching well underway with large colonies of Acropora bleached. This must have begun a week earlier (March 5, or two weeks Feb 27)					
March 28	Regional	Cooling evident in the NE PNG/Solomon’s but still hot below Fiji and Tonga but cooling to the far southeast. Cook I. on the edge of 1.25-1.50 but probably on .75-1.00	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji**: W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is.:** **Tubuai Is.:** **Easter I.:** **Western Australia:**	.25-50(40%); .50-.75 (40%); .75-1.00 (20%) .25-.50 75-1.0 1.0-1.50 1.0-1.50 1.0-1.50 .25-.50 1.25-1.75 Tongatapu .75-1.00 Ha’apai .50-.75 Vava’u .75-1.0 1.0-1.25 .25-.50/.50-.75 1.0-1.50/1.75		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.9 (1.6) 29.85 (1.55) 29.47 (1.17) 29.98 (1.68)

April 2	Suva Passage Rat Tail Savusavu	Extensive bleaching				Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 30.05 (1.75) 30.33 (2.03) 29.65 (1.35) 30.10 (1.8)
April 13		**End of the DHW event for the Suva area (10.5 wks)**				Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.60 (1.3) 29.45 (1.15) 29.19 (.89) 29.35 (1.05)
April 15	Regional	Waters cooling around Fiji but still elevated south of the islands and Tonga. Hot water contracting north to New Ireland PNG and southwest Solomon's.	Bismarck Sea, **P. N. G.**: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is.:** **Tubuai Is.:** **Easter I.:** **Western Australia:**	1.0-1.25 .75-1.0 .5-.75 .5-.75 .75-1.0 .75-1.0 .25-.50 1.25-1.50 Tongatapu .75-1.0 Ha'apai .50-.75 Vava'u .50-.75/.75-1.0 0-.25 0-.25 1.0-2.00		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.48 (1.18) 29.43 (1.13) 28.91 (.61) 29.23 (.93)
April 19		Flight around Suva and north to the Great Sea Reef					

April 25		**End of DHW period for the Taveuni area based on the insitu temperature data. (14.5 weeks)**				Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.35 (1.05) 29.52 (1.22) 29.65 (1.35) April 23 28.81 (.51)
April 27						Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.28 (0.98) 29.1 (0.80) ------
May 2	Regional	Waters cooling around Fiji but still elevated south of the islands and Tonga. Hot water contracting north to New Ireland PNG and southwest Solomon's.	Bismarck Sea, **P. N. G.**: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent.Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	.75-1.0 0-.25; .25-.50; .75-1.0 0-.25; .25-.50; 0-.75 .75-1.0 .25-.50 0-.25 1.25-1.50 Tongatapu .25-.50 Ha'apai and Vava'u 0-.25 0-.25 0-.25 .75-1.0/1.0-1.25		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 29.00 (.7) 29.95 (1.65) -- 27.6
May 6		**End of hotwater event based on the HotSpot charts (19.5 weeks)**	Only .25-.50 NW of Fiji and .0-.25 in Tonga				
May 9							

May 16	Regional	Waters from Fiji to NE PNG very much cooler. Normal temperatures from the southwest to southeast of Fiji. Temperatures slightly elevated to the north of the island group.	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: Kadavu: South/cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	.25-.50/.50-.75 0-.25; .25-.50 0-.25; .25-.50; 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25; .25-.50; 1.0-1.25		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 28.6 (.3) 28.6 (.3) -- 28.23
June 3	Regional	No elevated temperatures near Fiji. Slight elevation bight of New Britain (Bismarck Sea)	Bismarck Sea, **P. N. G**.: Cent./SW **Solomon Is**: **Fiji:** W/NW Viti Levu I.: SW Viti Levu I.: Beqa I.: : Kadavu I.: South/ cent. Vanua Levu: N. Vanua Levu: **Kingdom of Tonga:** **Cook Is:** **Tubuai:** **Easter I:** **Western Australia:**	.25-.50;.50-.75 0-.25; .25-.50 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25 0-.25; 1.0-1.25		Taveuni I. Inshore Offshore Mt. Mutiny Fish patch, Suva	 28.2 28.03 -- 27.10 (5/31/00)

Temperature data is from a University of the South Pacific project conducted by Dr. N. Quinn and Prof. P. Newell.

9.3 Locations of Field Surveys

Location	**Latitude**	**Longitude**
KINGDOM OF TONGA		
Ha'atafu Beach, Tongatapu	21^0 04' 14.2" S. Lat.	175^0 20' 04" W. Long.
FIJI ISLANDS		
Reef area north of Labasa, Vanua Levu		
Vonovono I., Nagasaudra Bay	16^0 28' 37.7" S. Lat.	179^0 18'31.4" E. Long.
Vuata Reef, back barrier reef	16^0 19' 44.9" S. Lat.	179^0 18'08.7" E. Long.
Vuata Reef, northwest corner, adjacent Mali Channel	16^0 17' 42.5" S. Lat.	179^0 16' 40.3" E. Long.
Cakalevu Reef, Mali channel side of barrier reef: Site 1	16^0 17' 24.8" S. Lat.	179^0 15' 28.4" E. Long.
Cakalevu Reef , Mali channel side of barrier reef: Site 2	16^0 16' 54.4" S. Lat.	179^0 14' 44.8" E. Long.
Cakalevu Reef, ½ way along the barrier reef on the lee west margin	16^0 16' 06.3" S. Lat.	179^0 08' 00.5" E. Long.
Cakalevu Reef, barrier reef west of Kia I.	16^0 14' 25.5" S. Lat.	179^0 02' 06.3" E. Long.
Reef Area south of Vanua Levu		
Jean Michel Cousteau Resort: Big Blue Dive location	16^0 50' 01.8" S. Lat.	179^0 16' 53.0" E. Long.
Jean Michel Cousteau Resort: Fingers Dive site	16^0 49' 57.4" S. Lat.	179^0 17' 56.0" E. Long.
Jean Michel Cousteau Resort: Mystery Reef site	16^0 50' 01.8" S. Lat.	179^0 16' 53.0" E. Long.
Jean Michel Cousteau Resort: Lighthouse	16^0 49' 52.7" S. Lat.	179^0 15' 53.6" E. Long.
South of Viti Levu		
Fish Patch	18^0 08' 35" S. Lat.	178^0 23' 50" E. Long. Approx.
Suva Lighthouse	18^0 08' 29.6" S. Lat.	178^0 23' 39.5" E. Long.
Rat Tail Passage	18^0 08' 37.7" S. Lat.	178^0 22' 56.1" E. Long.

9.4 A Weather Bureau summary of weather patterns exemplifies this (Gosai pers. comm.):

January

For the first three days, a trough of low pressure moved across the group from the north and became slow moving south of Kadavu. It brought rain over most parts of Fiji, with heavier falls concentrated around the Northern Lau Group and Vanua Levu. On the 4^{th}, a tropical depression (06F) developed along this trough and slowly drifted to the southeast. The depression weakened on the 6^{th} and became stagnant around Ono-i-Lau.

From the 12th to the 15th, two westward moving troughs drifted over Vanua Levu and Rotuma, bringing heavy rain to those areas. The troughs became slow-moving between Rotuma and Vanua Levu but continued to intensify.

Two cyclones occurred which gave rise to calm weather on either side of the passage of the weather freedom. The southeast trade winds became dominant over Fiji for the last week of the month.

For Rotuma, with the South Pacific Convergence Zone (SPCZ) oscillating in the vicinity of the Island.

February

The first week of the month was dominated by moist southeast trades affecting the Group.
On the 4th, the South Pacific Convergence Zone (SPCZ) merged with a stationary front to the southwest of Fiji. It slowly drifted northeast towards the Group and became stationary just south of the Group from the 6th to the 9th. This caused occasional rain over most parts of the Group with heavier falls occurring mainly during the afternoon and evening.

The trough to the southwest gradually weakened on the 10th but another trough located to the northeast began drifting towards the Group. It became stationary over the Group on the 11th. A weak low pressure system developed from this trough over Fiji on the 13th. It moved slowly southwest over the next 24 hours.

From the 15th to the 18th another weak ridge developed over the Group with prevailing easterly trades settling in. A trough moved in from the north to lie over the Group on the 19th, which later moved to the southwest on the 20th. Associated cloud and rain bands affected the Group during this two days.

As this trough moved southwest another ridge began advancing towards Fiji from the southeast on the 21st. Once again easterly trades became the dominant weather factor up until the end of the month. Meanwhile on the 24th a tropical depression was identified within Fiji's area of responsibility near 23°S 134°W. On 25th, it was named Kim. Kim initially moved westwards but later turned southwest towards New Zealand's area of responsibility.

March

The month began with a weak, slow moving trough of low pressure lying over the Group. The South Pacific Convergence Zone (SPCZ) lay fairly disorganised to the north of the Group. Areas around Western Viti Levu and Northern Vanua Levu received significant showers during the afternoon on the 1st. From midday on the 2nd, the trough underwent rapid intensification particularly in the area to the west of Viti Levu.

The trough weakened significantly by the 3rd. A general southeast wind-flow had set in by then, which continued for the next five days. This wind-flow was occasionally interrupted by northeast flow, especially between the 5th and 7th. A weak tropical depression had been developing to the east of the Lau Group since the 2nd and drifting slowly towards Fiji. The trough affecting Fiji weakened on the 7th, but the SPCZ to the north became quite active resulting in a northwest wind-flow over the Group. The SPCZ was initially slow moving, but from midday on the 8th it started to drift slowly southwards and by the 9th it had established itself over Fiji. Widespread rain was experienced with heavy falls and thunderstorms between the 9th and 12th. By the 13th, the SPCZ had drifted to the southwest of Viti Levu, allowing a weak ridge to develop over Fiji. This ridge directed a northeast wind-flow over the Group, with resultant showers especially during the afternoon and evening.

Another trough developed to the northwest of Fiji during the 15th and gradually extended over the country. This trough remained over the Group during the 15th and 18th. The trough later drifted slowly to the southwest of Viti Levu. Between 19th and 26th, a series of troughs lay in the vicinity of Fiji, causing moist conditions and resultant afternoon or evening showers. The wind-flow had been predominantly from between northeast and northwest. On the night of 26th, an approaching cold front to the south of Fiji combined with a trough from the northwest, resulting in intense convective activity over the Group. By midnight on the 27th, the system began to disintegrate, with the cold front subsequently moving off to the southeast of Fiji while the northwest portion of the trough slowly drifted southwest.

Rotuma was mostly under the influence of an east to northeast wind-flow during the month. Weak easterly troughs passed by causing brief showers, at times heavy, over the Island.

April

The month began with an active slow moving trough of low pressure lying over Fiji. This trough remained over the country for the first half of the month with moist northerly winds. Series of low pressure systems developed along the trough near Fiji between the 3rd and the 16th. One of these lows formed into a tropical depression over the Northern Lau Group on the 13th and later developed into Tropical Cyclone 'Neil' on the 16th. TC Neil was a very short-lived cyclone, which rapidly moved southwards and was downgraded to a depression within 24 hours The depression subsequently moved out of Fiji's vicinity on the 18th with the trough over the country weakening and moving towards the east. The cyclone caused marginal gale force winds over Kadavu Group and in the seas south of Kadavu and Southern Lau and strong winds over most parts of the country. On the 20th a high pressure system developed to the southeast of the country and pushed a ridge over the group causing a much awaited improvement in the weather. This ridge remained over the country for the next 36 hours bringing in slightly stable weather conditions to some parts.

On the 22nd, a frontal system moved over the group from the southwest producing a brief period of rain over most parts of the country. The front slipped to the southeast and a ridge moved over the group from the southeast, which remained over the country until the next front approached our shore from the southwest on the 26th. This front moved across the country and remained slow moving to the northeast of Fiji. A ridge of high pressure followed this front and remained the dominant feature affecting our weather for the next 24 hours. The front to the northeast joined with a trough to the north and re-intensified before moving south, back over Fiji, causing significant rain over most parts of the country till the end of the month.

Fine weather conditions dominated over Rotuma for most of the month, as the South Pacific Convergence Zone (SPCZ) lay well to the south of the Island. There were only brief occasions of showers mostly due to intrusion of moist air from the east to northeast.

May

May was largely characterised by the wet season type of weather pattern, but a gradual transformation to the dry season pattern occurred as the month ended.

For the first four days, an active trough of low pressure dominated the weather across the country. A low pressure system developed along the trough over the Lomaiviti Group on the 1st, which drifted northwestward initially and curved southwest between 2nd and 3rd. This trough continued to drift south-westwards but moved back over the group on the 4th, again causing heavy rain over parts of Fiji. By the 5th, the trough moved further northwards, giving way to a weak ridge of high pressure that brought some fine intervals over most parts of the country. Over the week from 6th to 12th, a moist easterly wind flow prevailed over the country. This produced more fine conditions except for the afternoon showers about the interior and western parts of the main islands and trade showers about the eastern areas of the country. On the 13th, another trough of low pressure developed to the west of Fiji and gradually moved across the country to lie to the east by later on the 14th. This trough brought rain to most areas with some heavy falls about the Yasawa and Mamanuca area. However, as a moist east to northeast wind flow still prevailed, showers continued over some parts of the country especially during the afternoon and evening. On the 19th, another weak ridge of high pressure developed over the country from the southeast to bring in fine conditions, apart from trade showers about the eastern parts of the larger islands. But the glory of fine weather did not long last as an active trough of low pressure developed to the west of Fiji and gradually moved across the Group between the 24th and 25th, causing heavy rain over most places. This resulted in flash flooding over Rakiraki with reports of water approximately 2m above the road level. As this trough moved eastwards another ridge began to build towards the group from the south on the 27th, directing fairly cool and dry airflow over the country. This ridge remained as the dominant weather feature over the country until the end of the month.

For Rotuma, the SPCZ remained within close proximity of the Island during most of the month, resulting in close to average rainfall.

9.5 Reef Check results of the Fiji Dive Operators Workshop

Eco- Divers: Depth 10m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	0	7	0	0	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	8	0	1	0	0	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently DeadCoral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	45	82.2	18	7	0	2	3	5	1	
Susies Dive Center: Depth 10m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	46	0	0	0	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	0	0	6	0	0	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently DeadCoral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	29	27.5	7	0	0	3	3	14	4	

Namale Resort: Depth 13m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	13	0	0	2	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	0	0	2	0	1	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently DeadCoral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	59	20.4%	4	16	0	2	7	3	0	
Vuna Divers Depth 3m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	4	0	0	0	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	0	0	1	0	0	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently DeadCoral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	25	44	17	16	0	0	0	0	1	
Aqua-Trek Garden Is. Resort: Depth 3m										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse	Bumphead parrotfish	Lobster			

					(Cheilinus undulatus)	(*Bulbo metopon sp.)*				
	6	0	2	0	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	0	0	0	0	0	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently DeadCoral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	40	35	27	0	0	11	0	0	0	
Namena I. Divers										
Fish	Butterfly Fish	Sweetlip (Haeulidae)	Snapper (Lujanidae)	Grouper >30cm	Humphead Wrasse (Cheilinus undulatus)	Bumphead parrotfish (*Bulbo metopon sp.)*	Lobster			
	12	0	0	0	0	0	0			
Invert-ebrates	Banded Coral shrimp *Stenopus hispidus*	Diadema Urchins	Pencil urchins (*Hetero-centrotus mammilatus)*	Sea cucumber (edible only)	Crown-of – thorns star (*Acanth-aster)*	Giant clam (Tridacna sp.)	Triton shell (*Charonia tritonis)*			
	0	0	0	0	0	0	0			
Benthic Survey	Coral Inter-sections	% bleached	Recently DeadCoral	Soft Coral	Fleshy Seaweed	Sponge	Sand	Rubble	Rock	
Inter-sections	38	100	33	0	0	0	0	9	0	

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