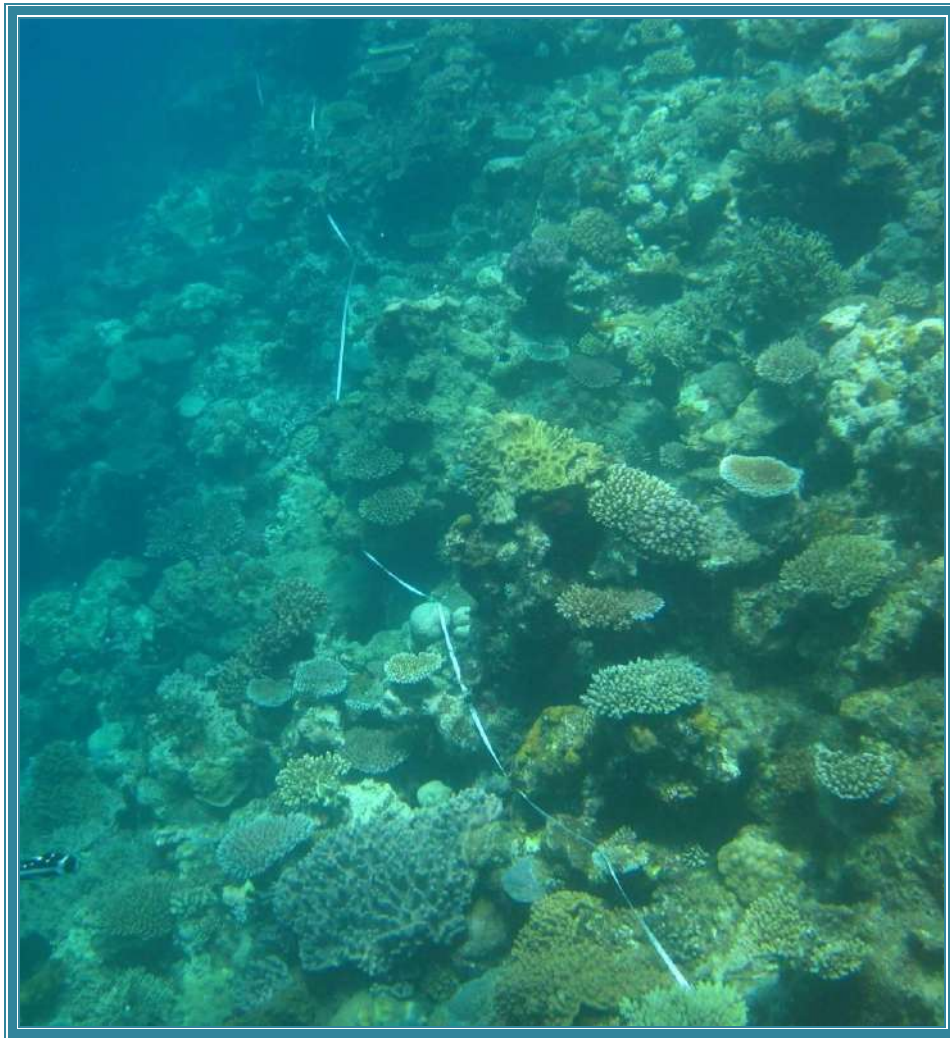


Marine Ecological Benthos Assessment of Shark Reef Marine Reserve

Pacific Harbour, Viti Levu, Fiji

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December 2014



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1.0 Executive Summary:

A marine benthos assessment was carried out over four days between 30 November and 20 December 2015, as part of an ecological description of marine life on the reefs of the Shark Reef Marine Reserve, Viti Levu, Fiji.

Reef profiles and quantitative belt and point intercept transects were used to provide information on marine life populations at four sites representative of the area.

The Shark Reef Marine Reserve is situated on a single reef outcrop, with a flat which partially dries at extreme low tide, and sides which drop steeply to a deep floor at around 28 to 30 metres depth on the front and sides, while the back reef slopes more gradually below 12 metres.

Coral cover is high on the flats and shallow sides, decreasing with depth. Macro-algae and Sponges are found at higher than expected levels on all of the deeper reef slopes, probably reflecting high nutrient levels due to land-based sediments in flood-water run-off from the Navua and Pacific Harbour rivers, which regularly affects the area.

Coral diversity was high at all sites, with many Life-form categories and coral families represented on the Side and Front Sites, but dominated by *Acropora* on the Back Reef. While there are species with low tolerance to bleaching and predation, there are also many with higher tolerance, indicating high resilience to stress factors, particularly below 5m depth, and a strong likelihood that the reefs can quickly recover from crisis events such as siltation, temperature-related bleaching, cyclone breakage and predation.

There is little apparent difference in coral cover or type between the Front Reef adjacent to the Feed Site and the other two Front and Side Reefs.

There is some indication that there may still be low-level handline fishing going on within the reserve.

2.0 Aims of the study:

At four sites within the Shark Reef Marine Reserve, representative of the Front Reef adjacent to the Shark Feed Site, the Front Reef remote from the Shark Feed Site, the Back Reef, and the Side Channel:

- Create a sketch reef profile from surface to 30m depth or more, and characterise and describe the marine habitats along that profile
- Record coral cover to AIMS Life form category, with comments on genus and species where possible, at 4 x 20m long Point Intercept Transects (PIT) at three characteristic habitats at three depths:
 - Reef flats or edge between 2 and 5 m
 - Reef slope between 9 and 12 m
 - Deeper channel floor or reef slope between 20 and 30m
- Provide detailed photographs of habitats and coral types.
- Record GPS points and detailed description of transect start sites.

Provide a report, to include a sketch map or annotated aerial photograph of sites, with marine habitats and areas of sensitive ecology/ conservation significance located.

3.0 Methods:

Depth and water temperature measurements were taken at the start of each survey day. In addition, survey dates, times and weather were recorded. Survey areas were marked with a Garmin hand held GPS. Photographs were taken of each habitat using a Canon Powershot SD1100 IS camera in a dive housing.

3.1 Reef Profiles and Habitat Type

Reef profiles were drawn, and habitat type was mapped, to a depth of 30 metres where feasible, at four areas around the marine reserve, representing two front reef areas adjacent to and remote from the feed site, the side reef and the back reef.

3.2 Benthic Cover

At each of the four sites, sets of four 20m Point Intercept Transects for Benthic Cover were carried out on the reef flats and on the slope at depths of 28m (or 18m where site dictated), 10m and 5m.

Along each 20m Linear Transect, benthic cover was recorded under 40 points at 50cm intervals, to coral and algal Lifeform category and/or family using the categories listed in table 1, as defined by the Australian Institute of Marine Science (AIMS), with notes as to genus and species where possible. Where in-water species identification was not possible, photographs were taken for later examination.

Table 1: Substrate and Lifeform Categories used

Reef Check basic substrate	Australian Institute of Marine Sciences Lifeform categories	Code
Hard Coral	<i>Acropora</i> branching coral	ACB
	<i>Acropora</i> digitate coral	ACD
	<i>Acropora</i> tabular coral	ACT
	<i>Acropora</i> encrusting coral	ACE
	<i>Acropora</i> submassive coral	ACS
	Non- <i>Acropora</i> coral branching	CB
	Non- <i>Acropora</i> coral massive	CM
	Non- <i>Acropora</i> coral encrusting	CE
	Non- <i>Acropora</i> coral foliose	CF
	Non- <i>Acropora</i> coral submassive	CS
	Non- <i>Acropora</i> coral fungoid (mushroom)	CMR
	Non- <i>Acropora</i> coral <i>Millipora</i> (fire)	CME
	Non- <i>Acropora</i> coral <i>Heliopora</i> (blue)	CHE
Soft Coral	Soft coral (eg <i>Sinularia</i> , <i>Sarcophyton</i> , <i>Dendronepthea</i> sp)	SC
Sponge	Sponge	SP
Other	Zoanthid	ZO
	Other biota	OT
Rock	Coralline algae	CA
Macro-Algae	<i>Halimeda</i> algae	HA
	Turf algae	TA
	Macro algae	MA
	Algal assemblage	AA
Recently Killed Coral	Dead coral	DC
Rock	Dead coral + algae	DCA
	Rock (> 15cm in length)	RC
Rubble	Rubble (> 0.5cm but < 15cm in length)	RB
Sand	Sand (< 0.5cm and falls quickly to the bottom if dropped)	SD
Silt	Silt (0.002 – 0.05mm sediments that remain in suspension if disturbed)	SI

All “Hard Coral” species here are classified as *Scleractinian* corals, those fixed, reef building corals which secrete calcium carbonate to form a hard skeleton. For the sake of simplicity during habitat description, *Helipora*, *Millipora* and *Fungiod* corals have been included in this category. Soft corals are similar, but polyps secrete a fleshy or leathery skin instead of a hard skeleton.

Additional information such as coral bleaching, disease and predation was also recorded, both during quantitative surveys and general habitat assessments.

3.3 Key Fish and Macro-Invertebrate population density

A very brief assessment of population density of key fish and invertebrate groups was made along 20m x 5m (100m²) Belt Transects at depths of 28m (18m), 10m and 5m.

These key groupings were based on a standard technique known as Reef Check (www.reefcheck.org), which selects groups for their usefulness to indicate ecosystem health and fishing pressures, and for international comparability.

Three groups of fish with local relevance to the South Pacific were added (indicated with *).

Table 2: Key Fish and Invertebrate groups recorded

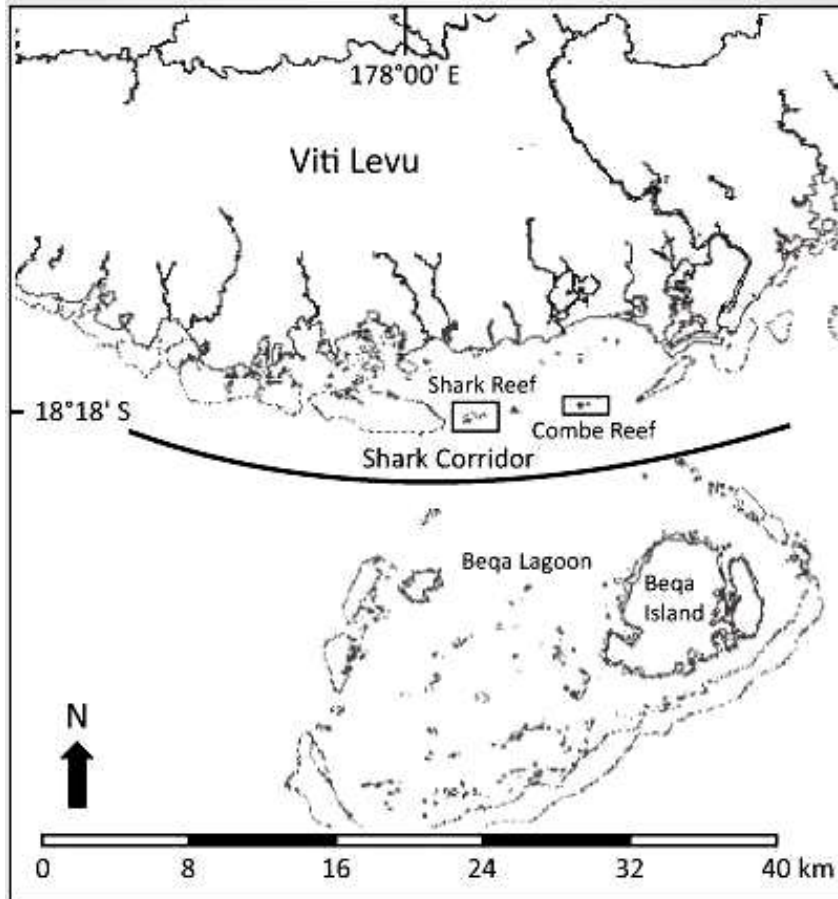
Fish		Macro-Invertebrates	
Common Name	Scientific name	Common Name	Scientific name
Butterflyfish	<i>Chaetodontidae</i>	Giant Clam	<i>Tridacna sp</i>
Sweetlips	<i>Haemulidae</i>	Sea Cucumber	<i>Holothuridae</i>
Snapper	<i>Lutjanidae</i>	Diadema Urchins	<i>Diadema sp</i>
Grouper	<i>Serranidae</i>	Collector Urchin	<i>Triplonaster gratilla</i>
Parrotfish	<i>Scaridae</i>	Pencil Urchin	<i>Heterocentrus mammillatus</i>
Moray Eels	<i>Muranidae</i>	Triton's Trumpet	<i>Charonia tritonis</i>
Humphead Wrasse	<i>Chelinus undulatus</i>	Crown of Thorns Starfish	<i>Acanthaster planci</i>
Bumphead Parrotfish	<i>Bolbometopon muricatum</i>	Banded Coral Shrimp	<i>Stenopus hispidus</i>
Surgeonfish *	<i>Acanthuridae</i>	Spiny Lobster	<i>Palinuridae</i>
Goatfish *	<i>Mullidae</i>		
Jacks/Trevallies *	<i>Carangidae</i>		

These surveys were not the main focus of the survey and were made to assess relative biological richness of each area.

4.0 Maps and Photos:

Shark Reef lies approximately 3.25 Km south of Viti Levu, off Pacific Harbour. The Shark Reef Marine Reserve (SRMR) was legally gazetted in November 2014 (Legal Notice No 41)

Figure 1: Map and Google Earth images showing location of Shark Reef Marine Reserve.



Marine Reserve within Blue Lines:
No fishing or removal of marine organisms

Buffer Zone within Green Lines:
No use of shark-targeted fishing gear.

Figure 2: Google Earth image showing location of survey sites within Shark Reef Marine Reserve.

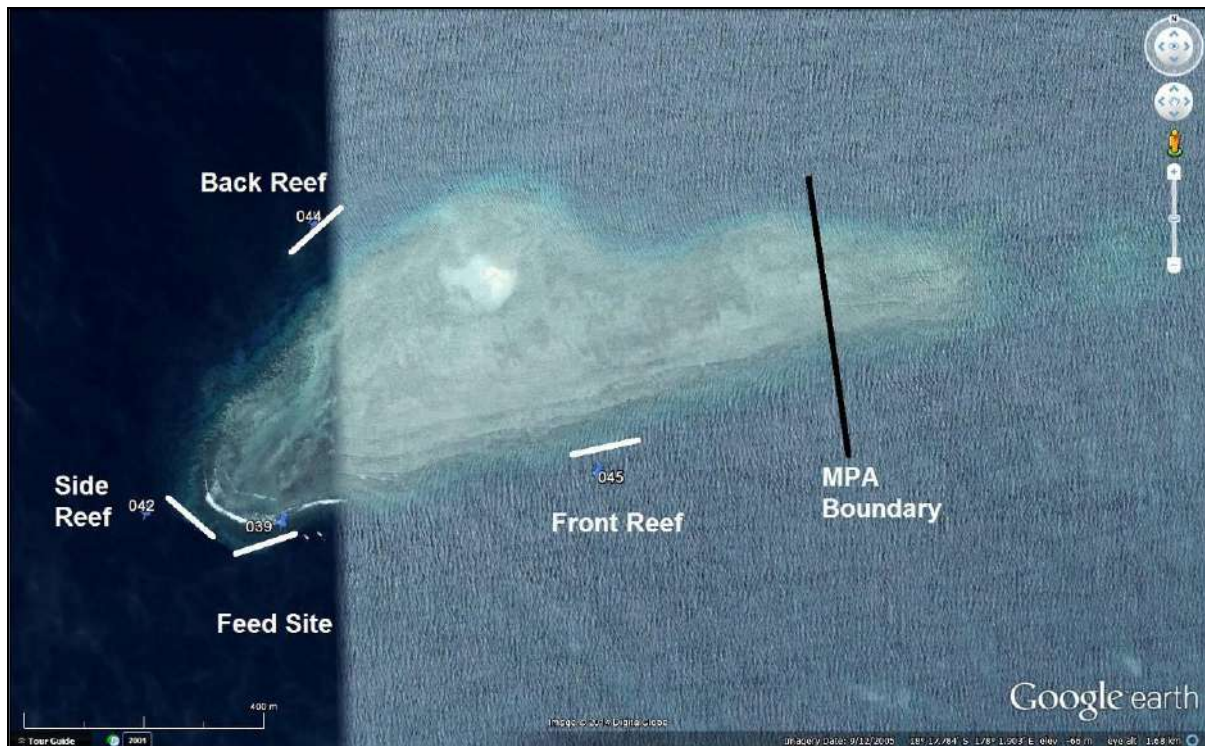


Table 3: Coordinates of survey sites

Degrees South	Degrees West	Survey site
S18 18.051	E178 01.062	Front Reef adjacent to "The Arena" Shark Feed Site
S18 17.930	E178 01.610	MPA Boundary
S18 18.041	E178 00.937	Side Reef
S18 17.778	E178 01.079	Back Reef
S18 18.009	E178 01.352	Front Reef remote from "The Arena" Shark Feed Site

5.0 Results:

5.1 Environmental Conditions

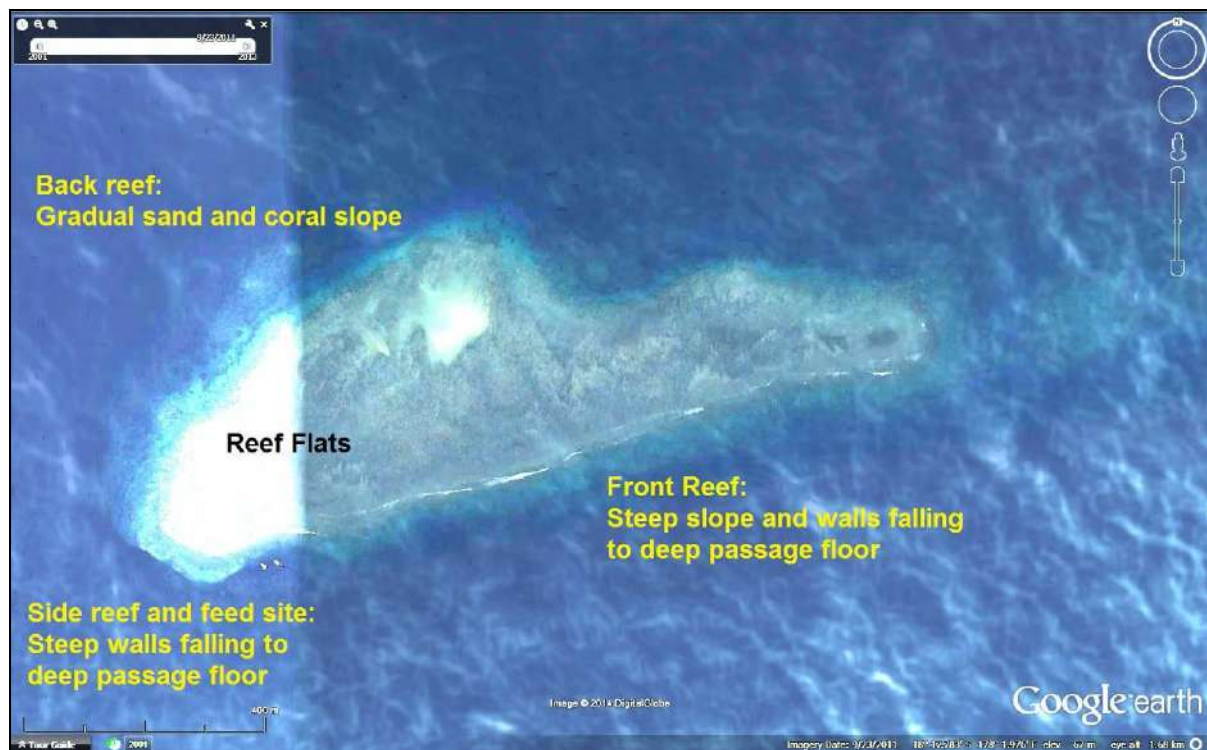
Weather, seawater temperature and horizontal visibility at depth were recorded on every dive.

Table 4: Water temperature and horizontal visibility

Date 2014	Low Tide	High Tide	Times of in-water surveys	Water temp	Cloud Cover (octas)	Sea/wind State	U/W Horizontal Visibility (m)
30 Nov	06.37	13.07	9:40 – 11:35	27°C	1	1	15
14 Dec	05.52	12.20	9:30 – 11:30	28.5°C	0	1	12
17 Dec	08:24	14.46	9:15 – 10:40	28°C	2	1	10
21 Dec	11.32	17.41	9:05 – 10:25	28°C	8	2	8

5.2 Habitats

Figure 3: Google Earth Image of Shark Reef showing main reef habitats

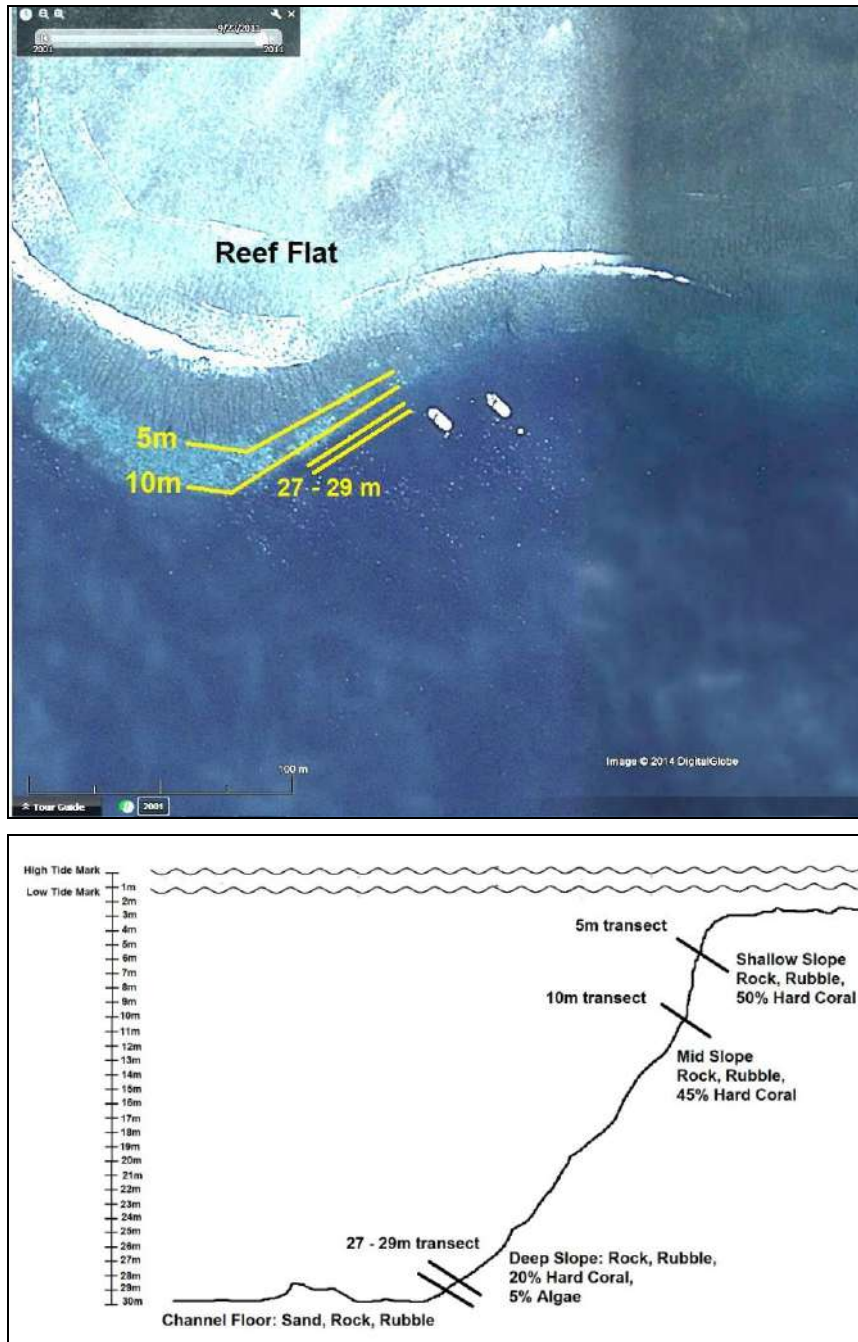


5.3 Reef Character

5.3.1 Front Reef adjacent to Shark Feed Site

Figure 4: Google Earth Image and Reef Profile of Front Reef Adjacent to Feed Site (Arena)

Transects at 27 – 29 m were laid parallel to each other (at 5m distance) rather than consecutively, due to need for safety divers to observe sharks around surveyors.



The reef to the immediate west of the Shark Feed Site (“The Arena”) was a steep slope, dropping to a 30m sand and rubble floor, with coral outcrops further out into the passage.

There was high coral cover, particularly of table and branching corals, on the reef flats and on the slope to about 18m, thereafter the deeper slope was mostly rubble and rock with lower coral cover. Quite high amounts of sponge and macro algae were found below 20 metres.

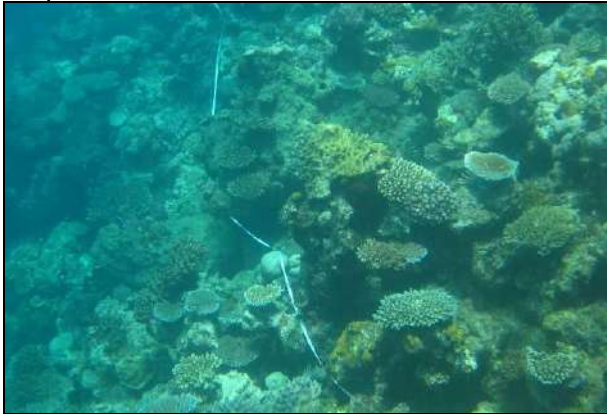
Where the transects turned into the side passage, the slope was more gradual, with many Gorgonian fans, suggesting regular currents in that area.

Figure 5: Photographs of reef character at Front Reef adjacent to Feed Site

Reef Flats



Slope at 5m



Slope at 10m

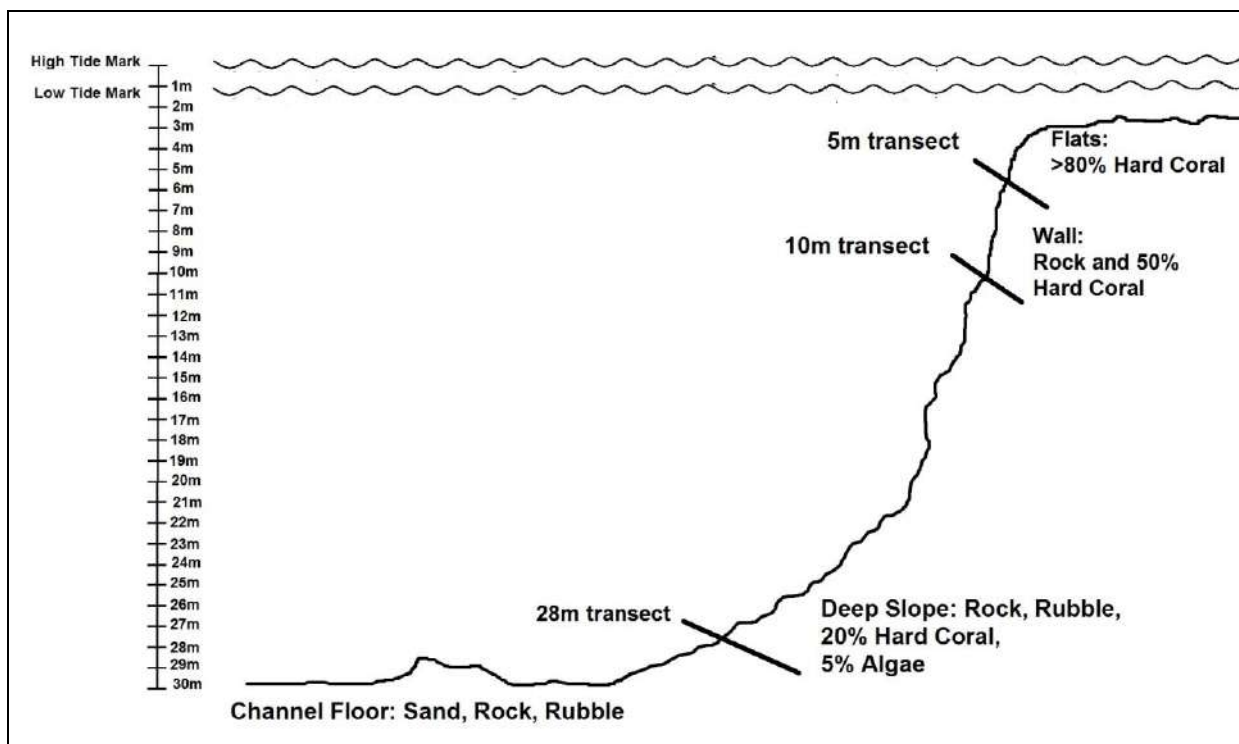
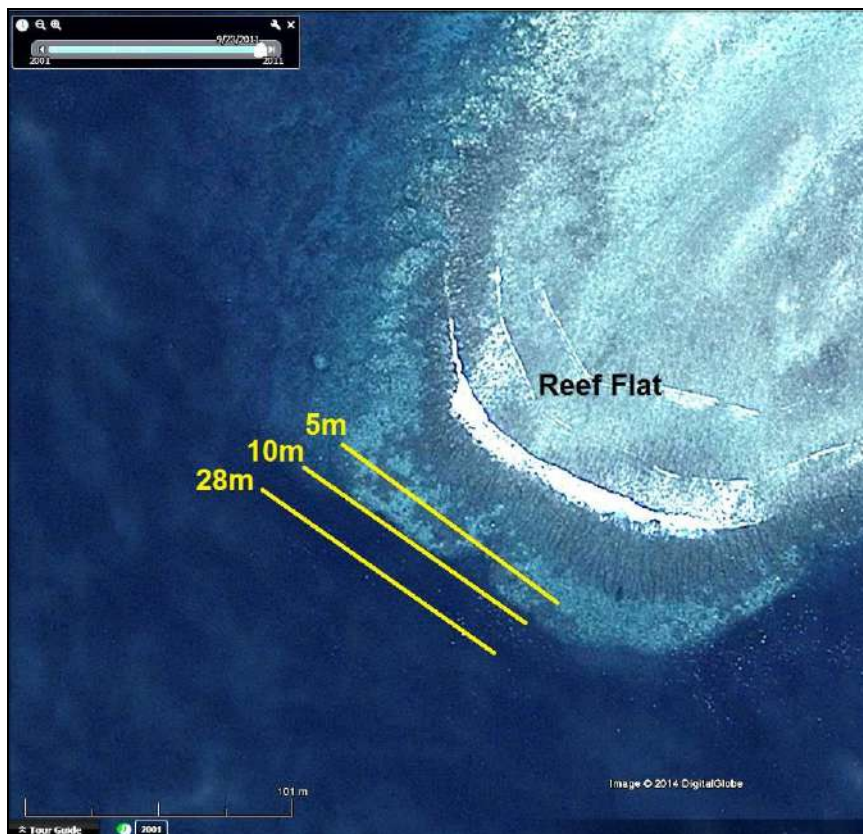


Slope at 28m



5.3.2 Side Reef

Figure 6: Google Earth Image and Reef Profile of Side Reef



The Side Reef was physically very similar to the reef adjacent to the Feed Site, with a steep slope to 20m, becoming more gradual before reaching the floor at 30m.

The reef flats and shallow reef had high hard coral cover, particularly of table and branching corals, the lower slopes being made up of rock, rubble, and lower amounts of hard coral, with a significant amount of sponge and macro algae.

Figure 7: Photographs of reef character at Side Reef

Shallow Slope and Reef Flats



Slope at 5m



Slope at 10m

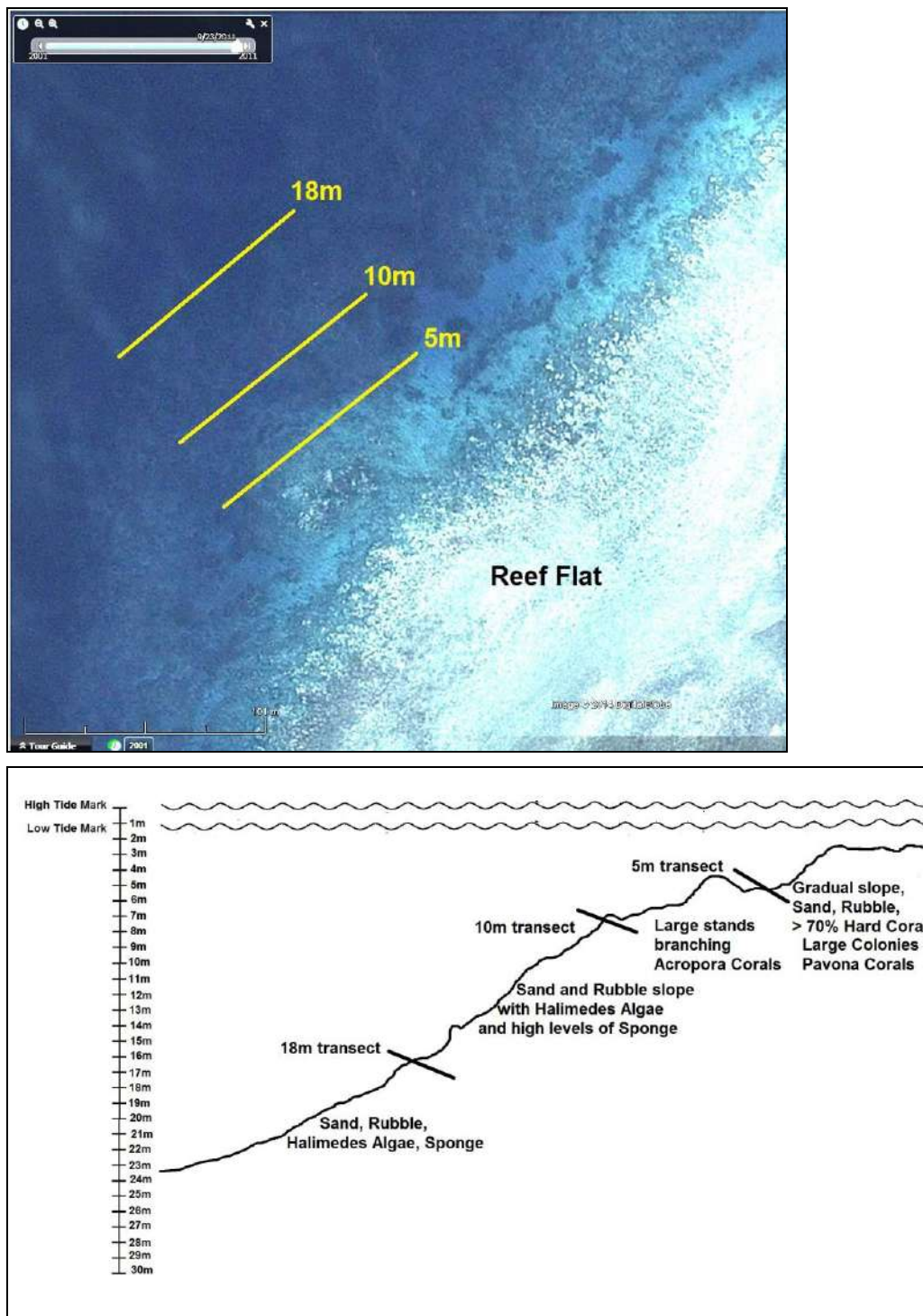


Slope at 28m



5.3.3 Back Reef

Figure 8: Google Earth Image and Reef Profile of Back Reef



The Back Reef had a significantly different character from the other sites, having a long, gradual reef slope dropping to an even more gradually sloping sand and rubble floor below 12m.

The deeper surveys were done at 18m rather than 28m, as below 20m the slope was an homogenous stretch of sand with approximately 20% dead coral rubble, and 5 – 10% sponge and *Halimeda* algae.

The shallow flats and slope were dominated by extremely large stands of table and branching corals, while below 12m there was very little coral at all, but large amounts of sponge, and clumps of *Dictyota* and *Halimeda* algae.

Figure 9: Photographs of reef character at Back Reef

Slope at 5m



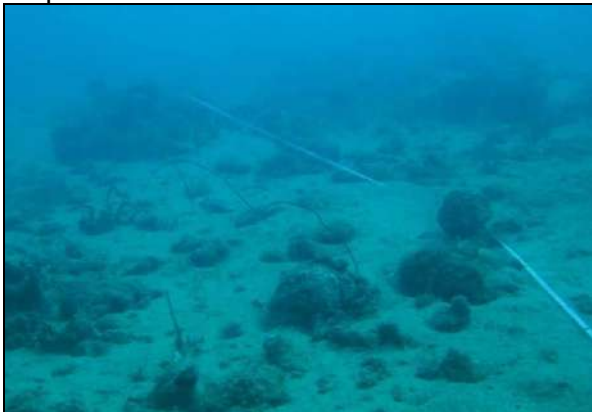
Reef Flats under mooring, 7m



Slope at 10m



Slope at 18m

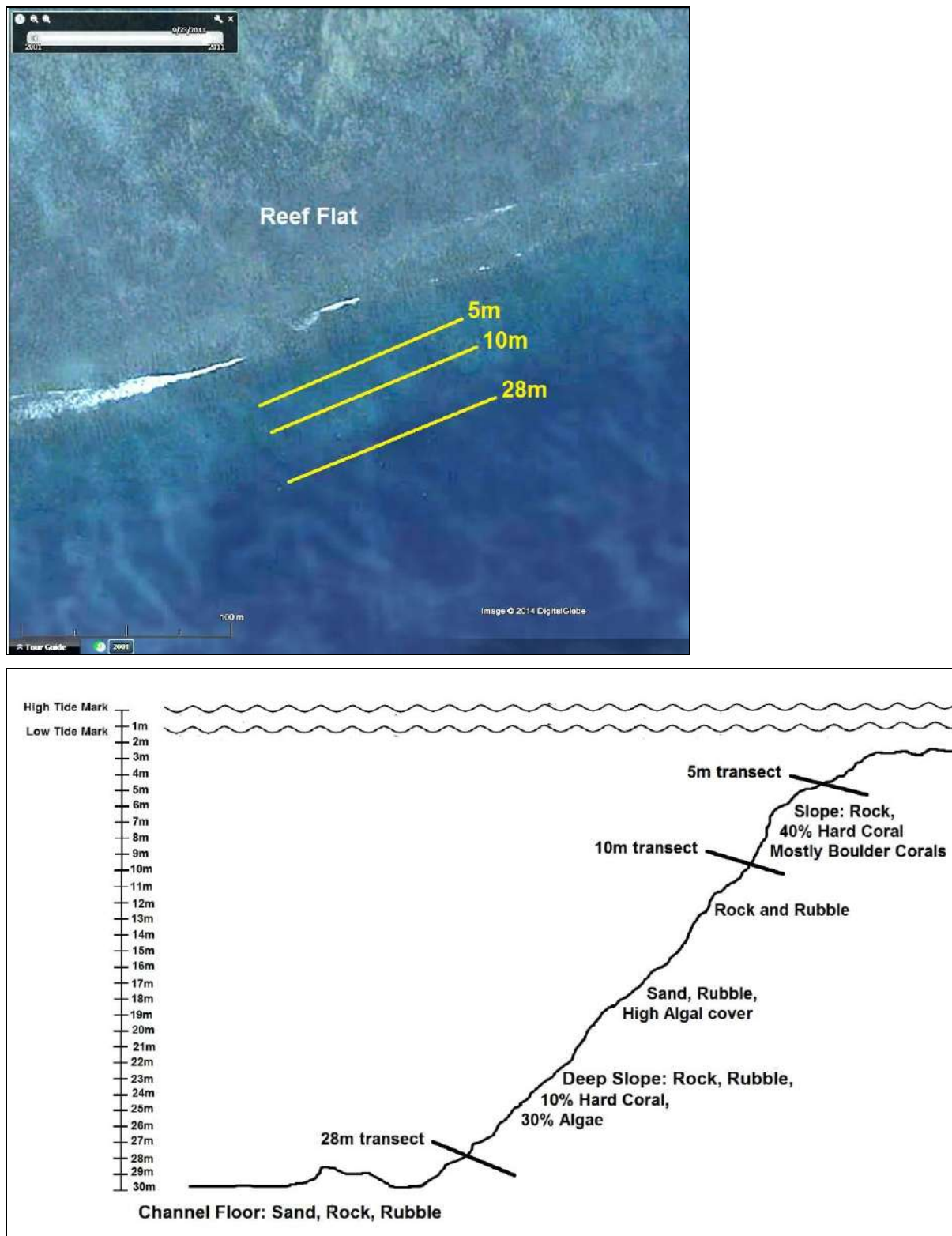


Slope at 28m



5.3.4 Front Reef remote from Shark Feed Site

Figure 10: Google Earth Image and Reef Profile of Front Reef remote from Feed Site



The Front Reef remote from the Feed Site is physically similar to the other Front and Side Reefs, falling over a slightly more gradual slope to a sandy floor at 30m. The area of higher coral cover was above 12m.

The deeper slope had very high amounts of macro algae, but a different type from that seen on the other sites.

Figure 11: Photographs of reef character at Front Reef remote from Feed Site

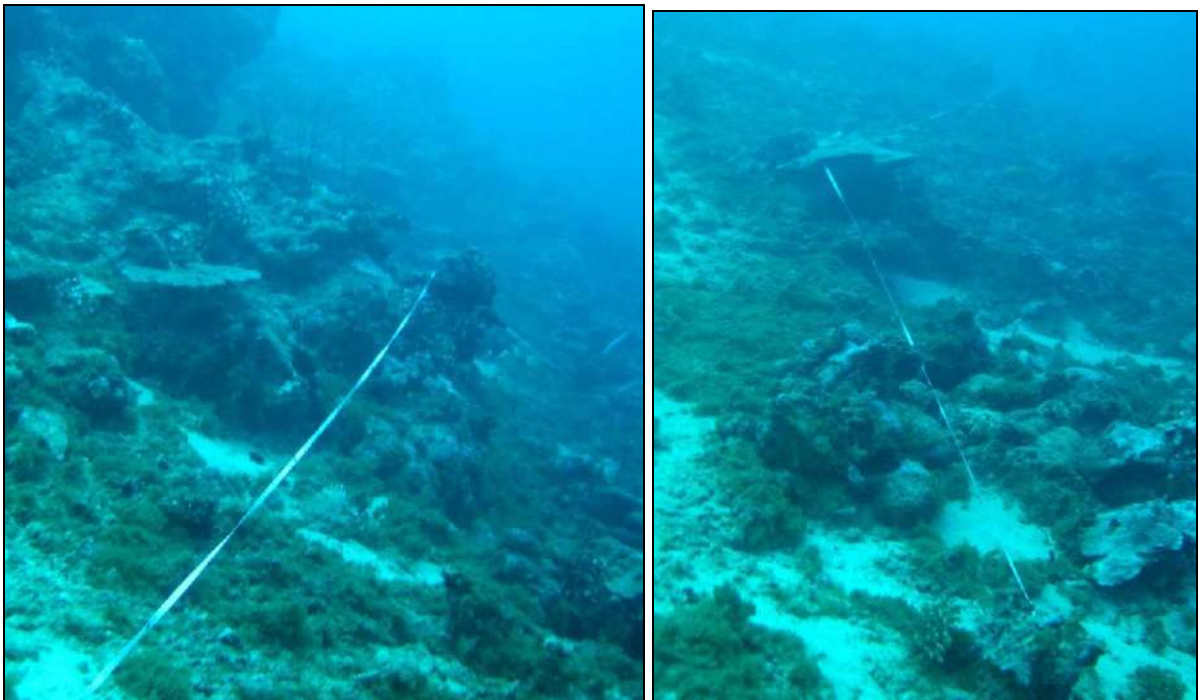
Slope at 5m



Slope at 10m

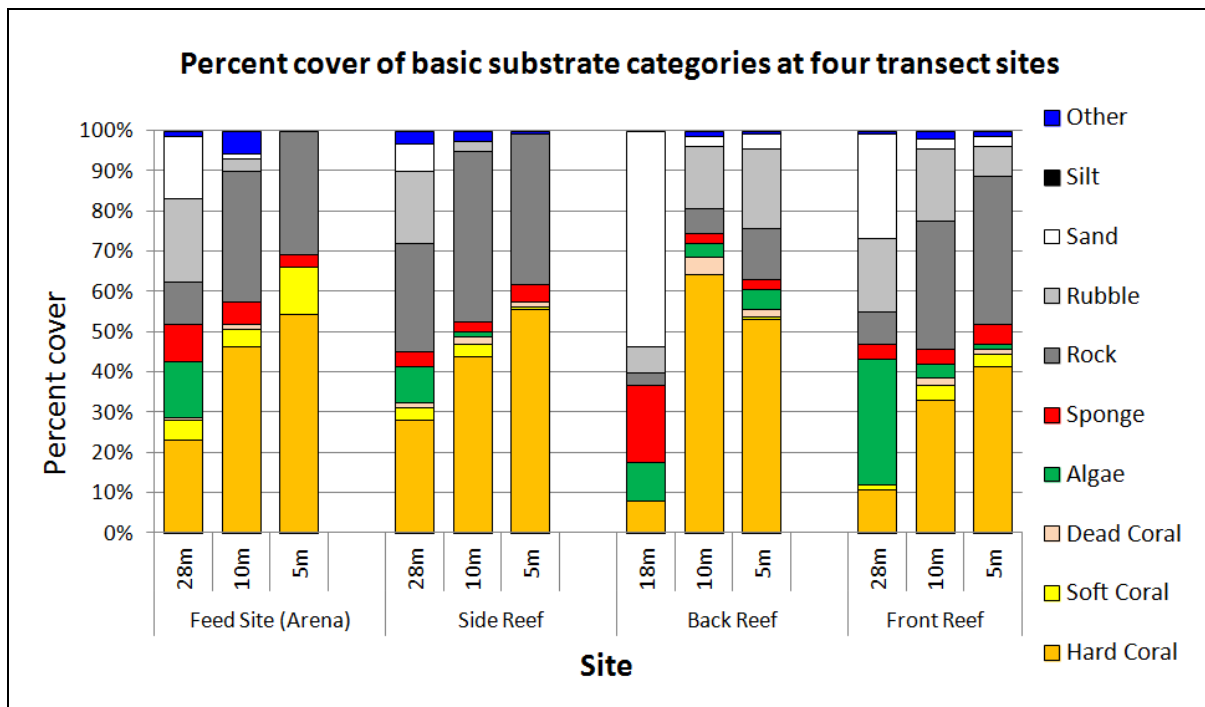


Slope at 28m



5.4 Benthic Substrate Cover:

Figure 12: Bar chart of Coral and other lifeform types at the transect sites



At all sites, coral cover was highest on the shallower transects and lowest on the deepest.

In 2013, average coral cover across Fiji was 46% (Sykes 2013). The reefs above 10m at the Front Reef adjacent to the Feed Site, the Side Reef, and the Back Reef were all at or above the national average coral cover, but the Front Reef remote from the Reef Site fell slightly below that figure.

Soft corals were found in low amounts at all Front and Side Reef sites, but not at all on the Back Reef.

Algal cover was high at all the deeper transect sites (18m – 28m), and extremely so at the Front Reef remote from the Feed Site.

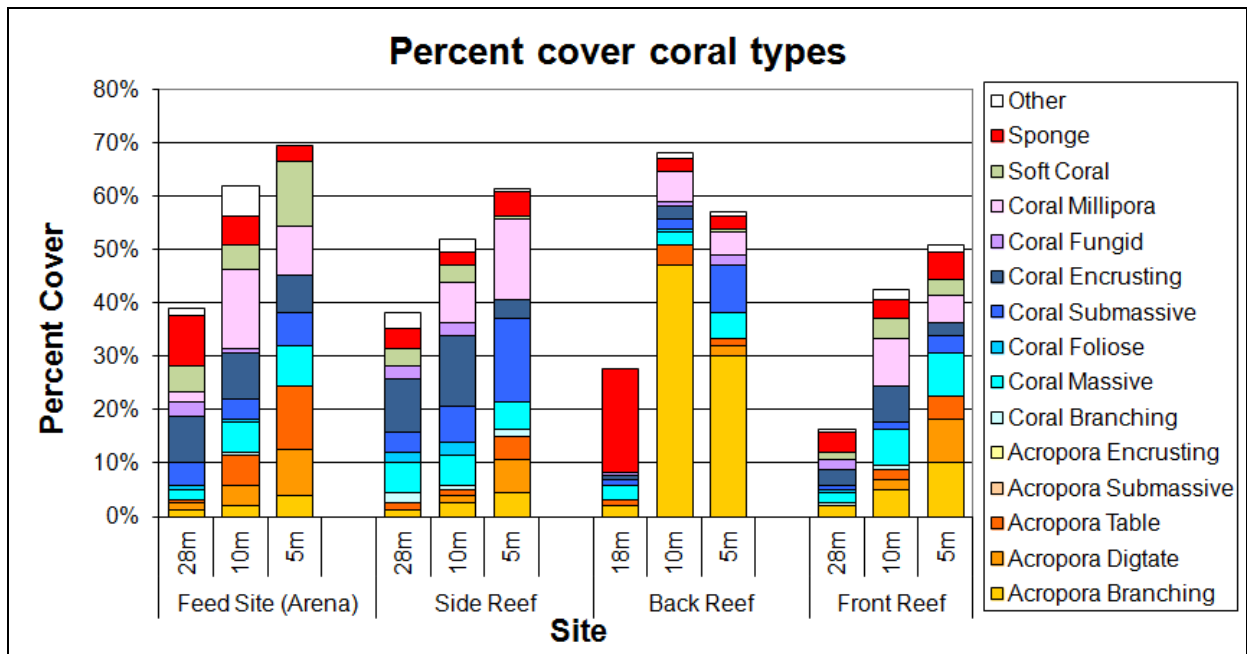
There was quite high amount of sponge at all sites, particularly so at 18m on the Back Reef.

5.5 Coral

5.5.1 Coral Types

Using the Australian Institute of Marine Science (AIMS) Lifeform categories, benthic type was recorded every 50 centimetres along four 20 metre-long line transects at all four sites. Average cover was calculated from four transects at each site.

Figure 13: Bar chart of Coral and other lifeform types at the transect sites



The Back Reef site was different from the other three areas, being dominated by extensive stands of Branching *Acropora*, particularly at 10m, and with large outcrops of Submassive *Pavona clavus* at 5m.

Both of the Front Reef sites and the Side Reef had very diverse types of hard corals, with more *Acropora* Branching, Table and Digitate (Finger) forms on the 5m transects than elsewhere.

Below 5m, hard coral tended to be dominated by Massive (Boulder), Submassive, and Encrusting forms.

Massive (Boulder) corals were dominated by *Porites*, particularly on the Back Reef, but also included large *Diploastrea heliophora*, *Lobophyllia* and Brain coral colonies on the other three sites

Most Submassive corals were *Pocillopora* species, primarily *P. damicornis* and *P. eydouxi*, with a little *Montipora spumosa*, and *Stylophora pistillata*.

There were many species of Encrusting and Foliose (Leafy) corals, notably *Turbinaria mesenterina* and *Galaxea fascicularis*.

Non-*Acropora* Branching corals were mostly *Tubastrea micrantha*, or *Seriatopora* species.

High amounts of *Millipora* (Fire) coral were found at all sites, particularly in the 5 and 10m transects.

Soft corals were mostly of the "Leathery" types, *Sacrophyton* and *Sinularia* sp, but the Front and Side Reef sites also had several small *Dendronephthya* colonies.

The category "Other" represented different things at different sites, mostly *Gorgonian* fans at all sites at 30m, Hydroids on the shallower reefs on the Front and Side Reef sites, and patches of Colonial Tunicates (*Ascidians*) on the Back Reef and at 5m on the Front Reef remote from the Feed Site.

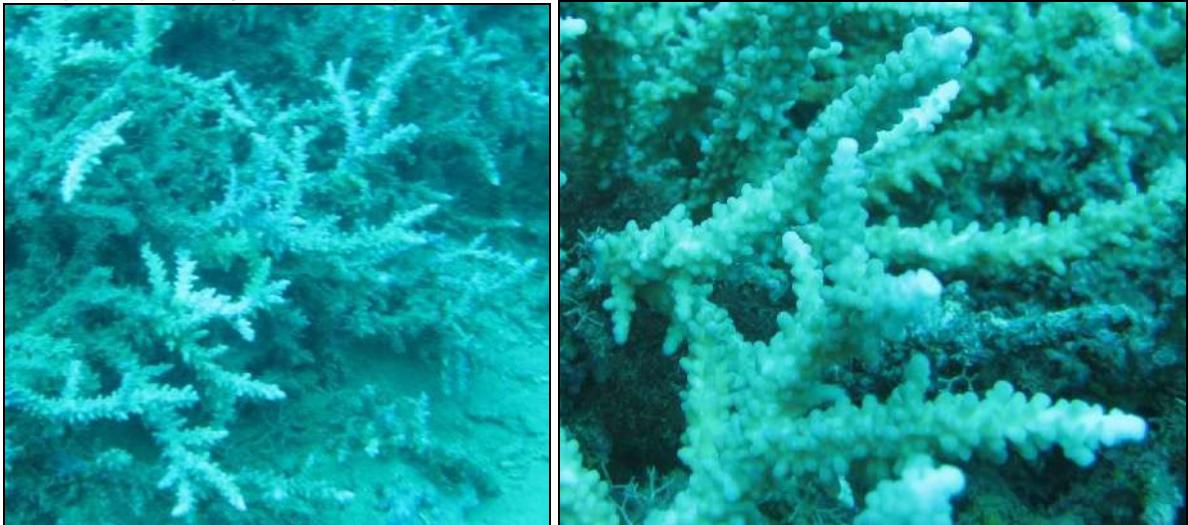
Figure 14: Photographs of some corals seen during surveys

ACB: Acropora Branching

Acropora valenciennesi (Back Reef)



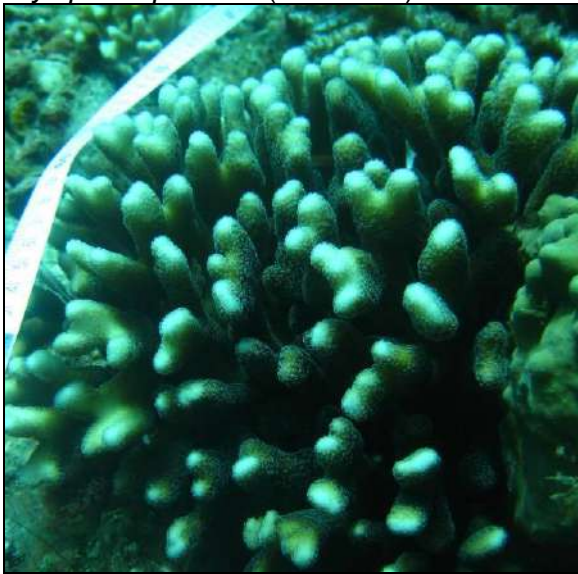
Acropora, possibly *A. tortosa* (Back Reef)



Acropora, probably *A. longicyanthus* (Back Reef)

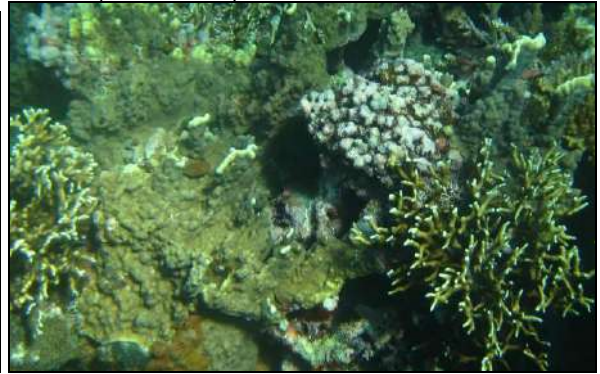


Acropora, possibly *A. exquisita* (Back Reef)*Acropora*, possibly *A. microphthalma*
(Front Reef remote from Feed Site)*Acropora*, possibly *A. florida*
(Front Reef adjacent to Feed Site)**ACT: Acropora Tabulate***Acropora hyacinthus* (Back Reef)*Acropora*, probably *A. cytherea* (Back Reef)*Acropora*, possibly *A. latistella*
(Side Reef)**ACD: Acropora Digitate** (assorted)
(Front Reef adjacent to Feed Site)

CS: Coral Submassive*Stylophora pistillata* (Side Reef)

(Back Reef)

*Pavona clavus* (Back Reef)*Pocillopora verrucosa*
(Front Reef Remote from Feed Site)**CB: Coral Branching** *Seriatopora hystrix*
(Front Reef remote from Feed Site)

CMR: Coral Mushroom (Fungid)*Zoopilus echinatus* (Back Reef)*Herpolitha*, probably *H. limax*
(Front Reef Remote from Feed Site)**CME: Coral Millipora (Fire)**
(Side Reef)Solitary Coral possibly a *Scolymia* sp (Back Reef)

CE: Coral Encrusting

Galaxea fascicularis (Back Reef) *Merulina scabricula* (Front Reef Remote from Feed Site)

**CM: Coral Massive (Boulder)**

Platygyra sinensis (Front Reef Remote from Feed Site)



Diploastrea heliopora (Front Reef Remote from Feed Site)



5.5.2 Coral Health

Most corals seen were in good health, but there was some evidence of coral disease, predation and bleaching in low amounts. Probable White Band disease was seen at all sites.

At the Front Reef adjacent to the Shark Feed Site, and the nearby Side Reef, *Drupe* snail predation was seen. A single Crown of Thorns Starfish *Acanthaster planci* was found at 10m on the Side Reef, but there is no evidence of a current outbreak.

A few scattered pale coral colonies were seen on most sites but there was no mass coral bleaching at the time of survey.

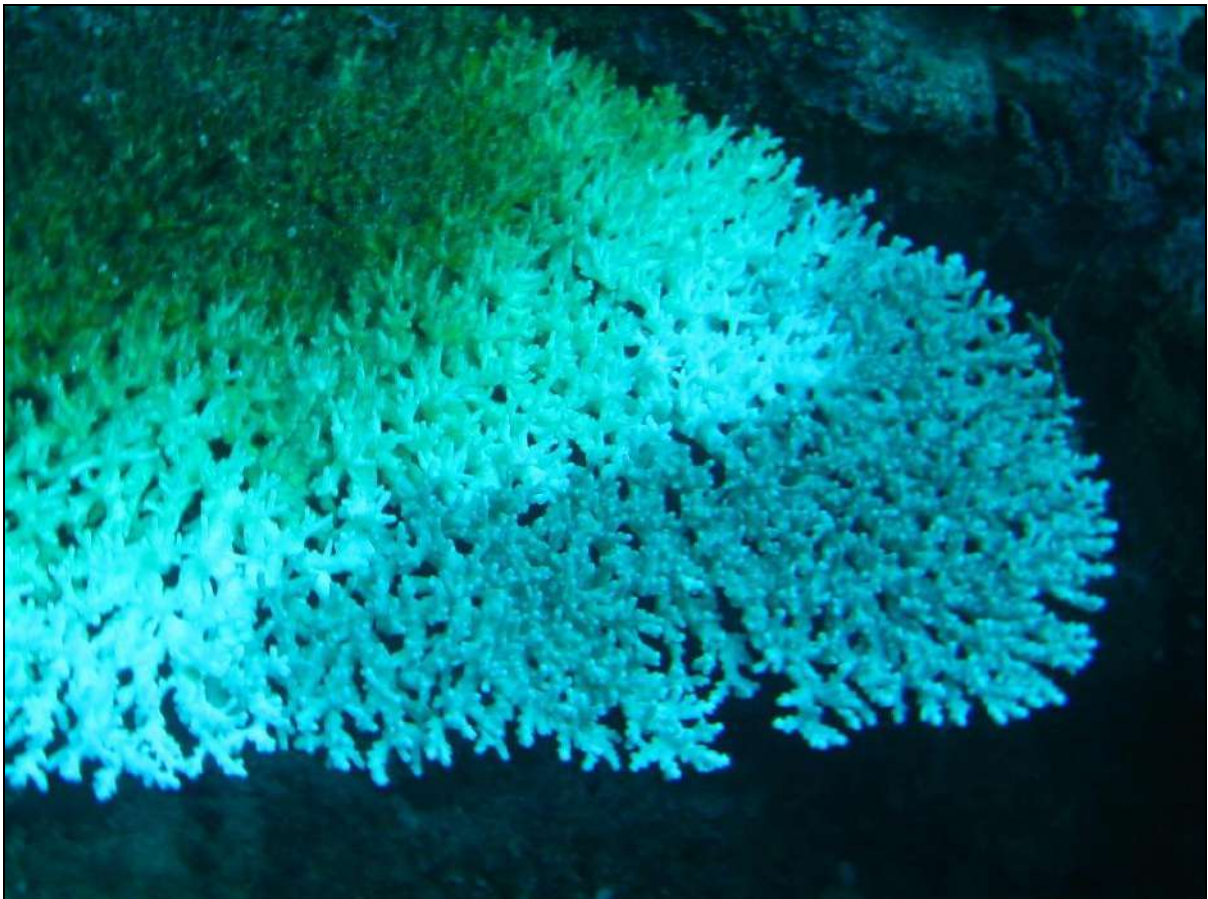
Figure 15: Photographs of Corals impacted by disease and predation

Disease:

White Band Disease or Syndrome on *Acropora* (Back Reef)

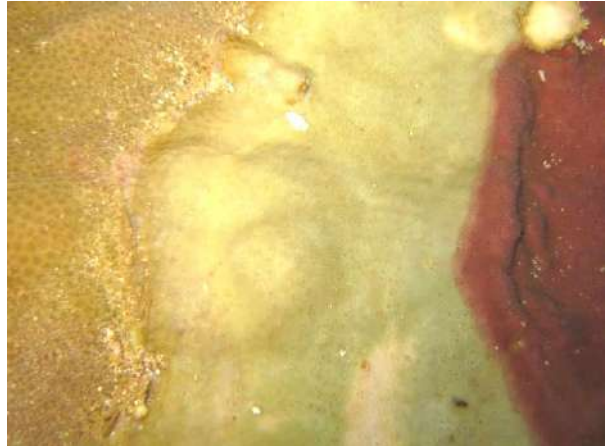


White Band Disease on *Acropora* (Front Reef adjacent to Feed Site)



Overgrowth:

Boulder Coral killed by White Band Disease being overgrown by Encrusting Fire Coral

**Predation:**

Drupe snails on *Acropora* (Back Reef)



Drupe snails (Side Reef)



(Front Reef adjacent to Feed Site)

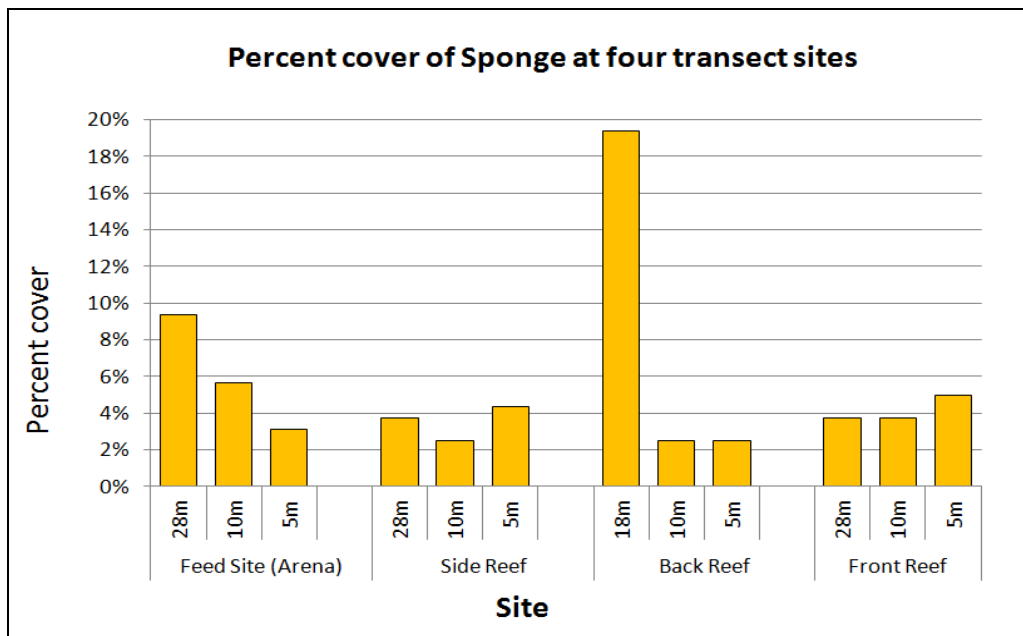


Crown of Thorns *Acanthaster planci* (Side Reef)



5.6 Sponge

Figure 16: Bar chart of Sponge cover at the transect sites



Normal average sponge cover across Fiji reefs is 3% (Sykes 2013) so most of the sites had relatively high amounts of sponge. In particular the deep reefs at the Front Reef adjacent to the Feed Site and the Back Reef had unusually high amounts.

Figure 17: Photographs of some Sponges seen during surveys

White Tube sponge *Aka* sp (Back Reef)

Unidentified sponge (Back Reef)

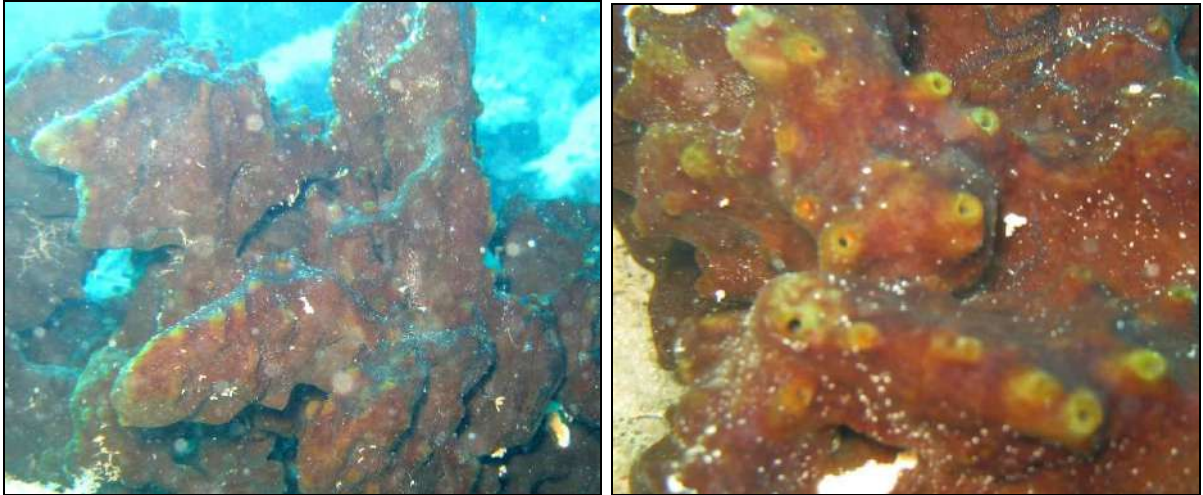


Brown sponge, possibly a *Plakortis* sp
(Front Reef remote from Feed Site)

(Front Reef adjacent to Feed Site)



Brown sponge, probably *Pseudoceratina verongitea* (Back Reef)



Brown and green sponges, probably *Hippospongia* sp (Back Reef)



Green Rope sponge (Back Reef)
possibly a *Clathria* or *Amphimedon* sp

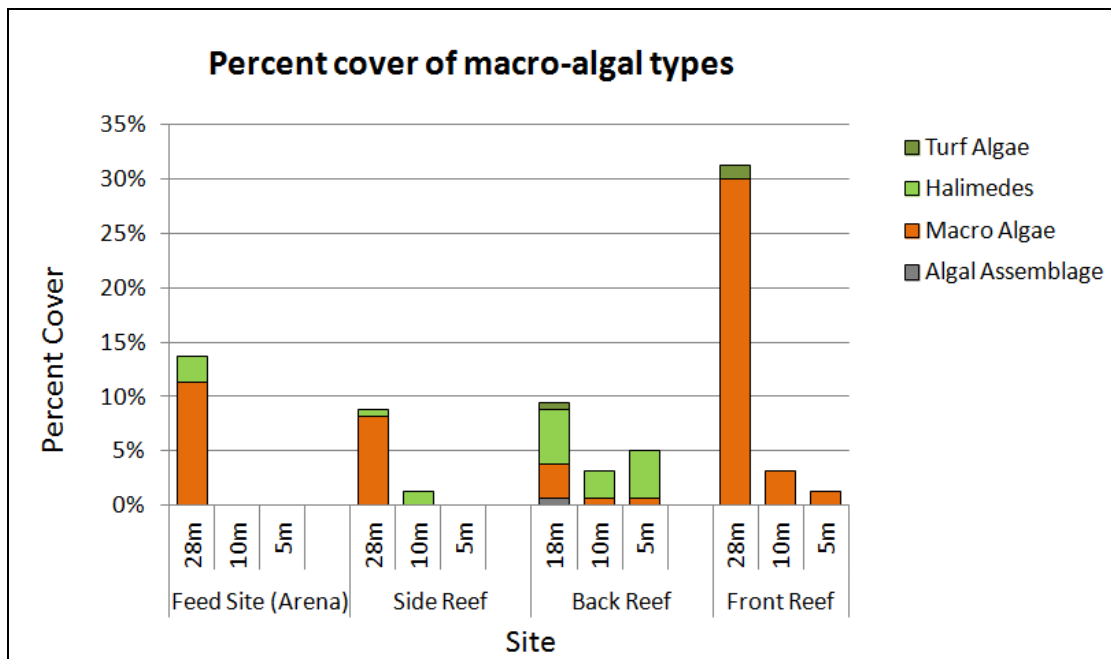


Brown Volcano sponge (Back Reef)
Spirastrella vagabunda



5.7 Macro-Algae

Figure 18: Bar chart of Macro-Algal types at the transect sites



Macro-algae levels on areas above 20m were low, normal for Fijian reefs. The sand slopes on the Back Reef had large patches of the green algae *Halimedes borneensis*, a normal and healthy component of sandy reef areas.

However, the deeper reef areas, particularly below 20m on the Front and Side Reef sites had unusually high amounts of macro-algae, more typical of nutrified reefs, or reefs lacking herbivores.

At the Front Reef adjacent to the Feed Site, and at the Side Reef, this algae was primarily a common brown algae, probably *Dictyota canaliculata*, mixed with the red algae *Galaxaura marginata*, and what is probably an *Amphiroa* species.

At the Front Reef remote from the Feed Site, the dominant algae found in deep piles was a very finely branched green algae, possibly *Cladophora prolifera*, which the author has not found in such large amounts elsewhere in Fiji.

Figure 19: Photos of some Macro Algae seen on transects

Green algae, *Halimedes borneensis* (Back Reef)



Green algae, possibly *Cladophora prolifera* (Front Reef remote from Feed Site)



Red algae, probably *Amphiroa* sp
(Front Reef adjacent to Feed Site)



Red algae, probably *Galaxaura marginata*
(Front Reef adjacent to Feed Site)

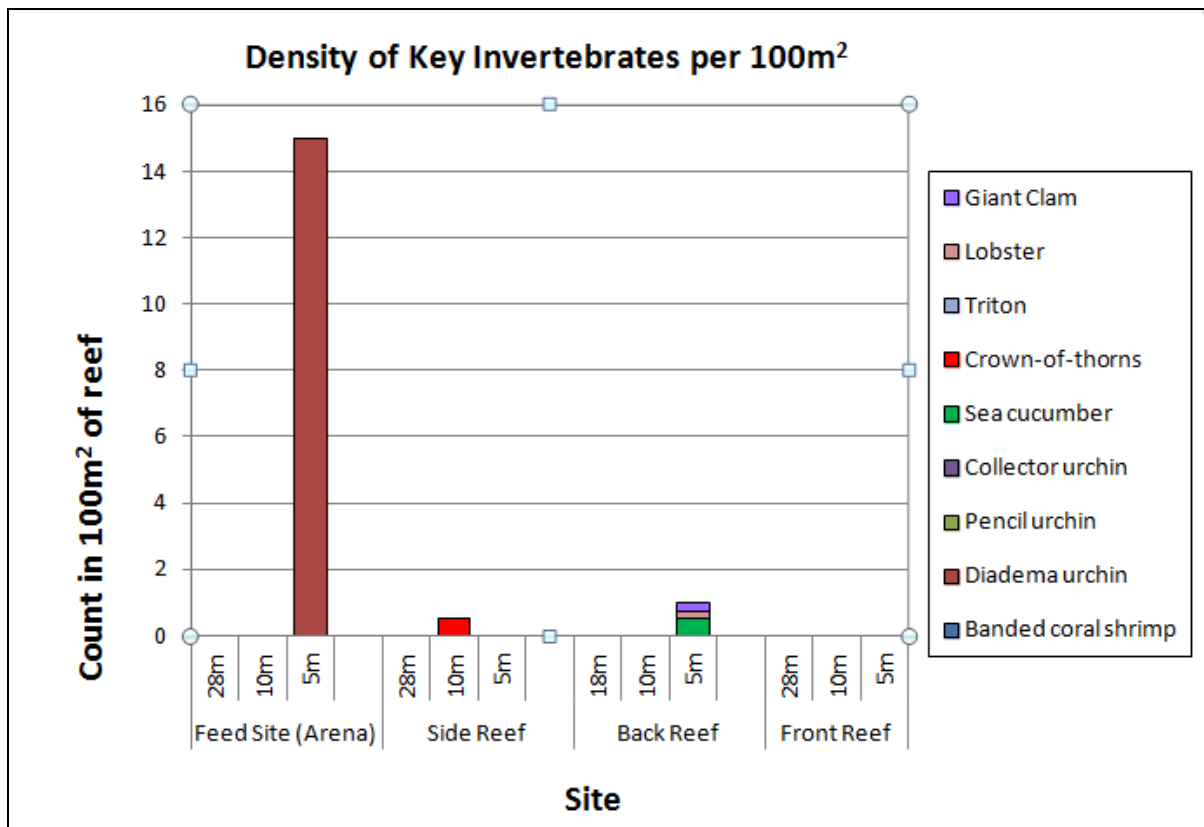


Brown algae, probably *Dictyota canaliculata* (Back Reef)



5.8 Macro-Invertebrates

Figure 20: Bar charts of Macro-Invertebrate types at the transect sites



Very few Macro-Invertebrates were seen during surveys, other than a group of small rock-boring urchins *Echinostrephus aciculatus* at 5m on the Front Reef adjacent to the Feed Site.

One Crown of Thorns Starfish *Acanthaster planci* was found at 10m on the Side Reef but nowhere else, although other divers reported seeing a heavy outbreak on the outer reefs of Yanuca Island.

On the Back Reef, a few more invertebrates of fisheries significance were found at 5m, namely two Pinkfish Sea Cucumbers *Holothuria edulis*, one Lobster and one Giant Clam *Tridacna squamosa*.

Figure 21: Photographs of some Macro-Invertebrates found during surveys

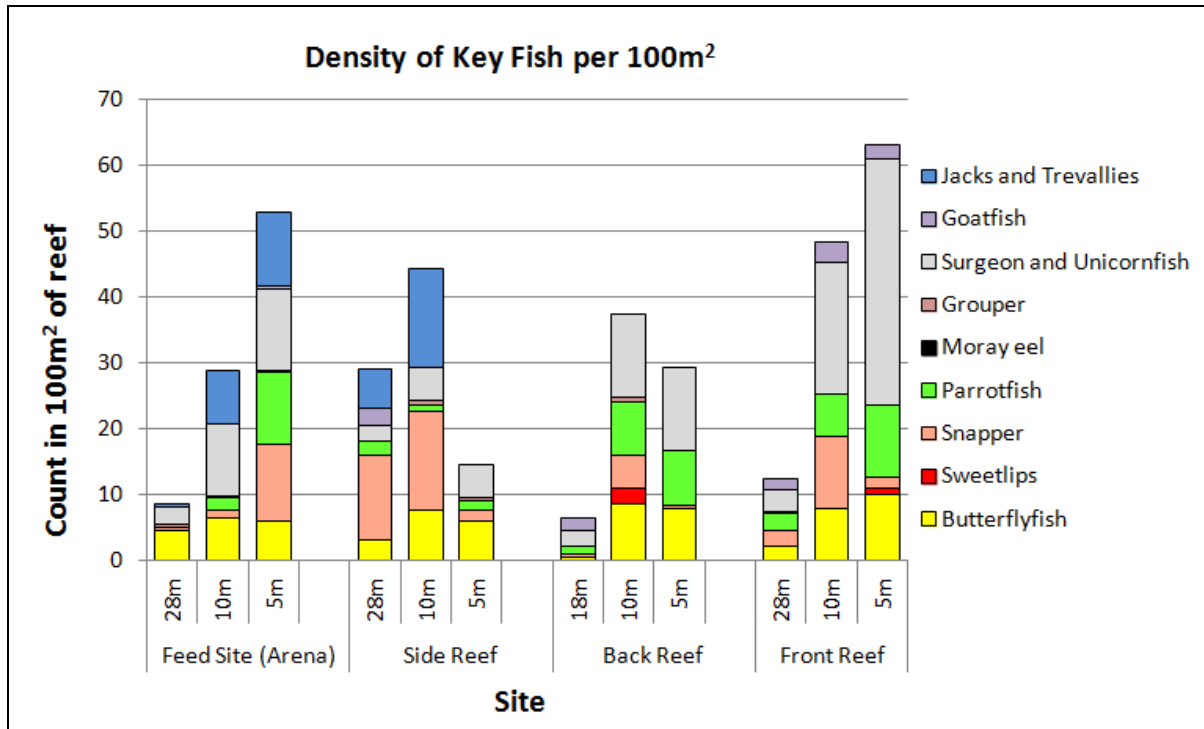
Giant Clam *Tridacna squamosa* and Pinkfish Sea Cucumber *Holothuria edulis* (Back Reef)



5.9 Fish

Key fish selected as indicators of fishing pressures (as listed in the Reef Check method) were recorded over 4 x 100m² belt transects per site. These surveys do not represent all fish seen.

Figure 22: Bar charts of population density of Key Fish at survey sites



Fish populations were reasonably high, with a spread of most of the Key families seen.

Sweetlips (*Haemulidae*) and Grouper (*Serranidae*) were only found in small numbers, except for five Sweetlips at 10m on the Back Reef, but there were many Snappers (*Lutjanidae*) and Surgeonfish (*Acanthuridae*), especially on the shallower areas.

Butterflyfish (*Chaetodontidae*) were seen at all sites, in lower numbers where coral cover was low.

Parrotfish (*Scaridae*) numbers were lower than expected at the Front Reef adjacent to the Feed Site and the Side Reef, except for a very large school (estimated 200+) of Filament Fin Parrotfish *Scarus altipinnis*, reportedly resident at the Feed Site (Beqa Adventure Divers staff). Numbers were higher at the Back Reef and the Front Reef remote from the Feed Site.

Jacks and Trevallies (*Carangidae*) were common on the Front Reef adjacent to the Feed Site, and the nearby Side Reef, but not found on the Back Reef or the Front Reef remote from the Feed

Site. Goatfish (*Mullidae*) were only found in sandy habitats such as the deeper Back Reefs, and sand/rubble bays on the other reefs.

A single ray (*Taeniura lymma*) was seen on the sandy bottom of the Back Reef (off transect).

Figure 23: Photographs of some Fish found during surveys

Bluespotted Ribbontail Ray (Back Reef)

Taeniura lymma



Harlequin Sweetlips (Back Reef)

Plectorhinchus chaetodonoides



School Filament Fin Parrotfish *Scarus altipinnis* (Front Reef adjacent to Feed Site)



Bluefin Trevally *Carangoides ferdau* (Front Reef adjacent to Feed Site)



5.10 Other marine species

Table 5: Other marine species sighted during surveys

	28m	10m	5m
Front Reef adjacent to the Feed Site	Multiple Bull, Grey and White Tip sharks	Multiple White Tip sharks	1 Hawksbill Turtle
Side Reef	1 Grey, 2 Bull sharks		
Back Reef		Colonial Tunicates	
Front Reef remote from Feed Site	3 Bull sharks Elephant Ear Tunicate	1 small Hawksbill Turtle 1 large Green Turtle (1.5m)	

Sharks were seen in higher numbers at the Front Reef adjacent to the Feed Site than elsewhere, but Bull Sharks arrived at the start of each dive at every site except the Back Reef. All sharks left after the first few minutes of each dive and were not seen again.

Turtles were seen on the shallow reefs on both Front Reef Sites, but not on the Side or Back Reefs.

Colonial Tunicates (*Asciadiacea*) were found in small patches on the Back and Front Reefs..

Figure 24 : Photographs of other marine species found at survey sites

Hawksbill Turtle *Eretmochelys imbricate*
(Front Reef adjacent to Feed Site)



Elephant Ear Tunicate (unidentified)
(Front Reef remote from Feed Site)



Colonial Tunicates, possibly a *Eusynstyela* species (Back Reef)



5.11 Fishing gear

Fishing lines were found at all depths at the Front Reef adjacent to the Feed Site, at 10m and 5m on the Side Reef, at 5m on the Back Reef, and not at all at the Front Reef remote from the Feed Site.

These were thin hand-lines, and most had probably been in the water for a few months to a few years, evidenced by algal growth.

Figure 25: Photographs of Fishing Lines found within the Shark Reef Marine Reserve

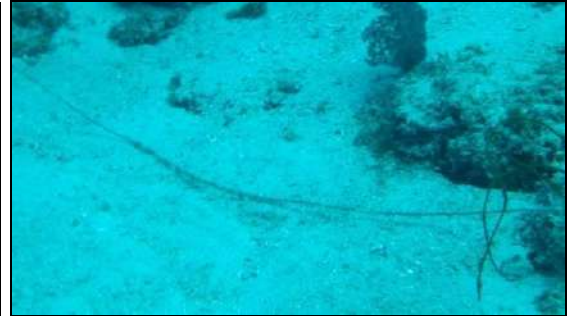
Back Reef



Side Reef



Front Reef adjacent to Feed Site



6.0 Discussion:

6.1 Physical Reef Type

The Shark Reef Marine Reserve is situated on a single reef outcrop, with a flat which partially dries at extreme low tide, and sides which drop steeply to a deep floor at around 28 to 30 metres depth on the front and sides, while the back reef slopes more gradually below 12 metres.

Coral cover is high on the flats and shallow sides, decreasing with depth. Macro-algae and Sponges are found at higher than expected levels on all of the deeper reef slopes, probably reflecting high nutrient levels due to land-based sediments in flood-water run-off from the Navua and Pacific Harbour rivers, which regularly affects the area.

6.2 Coral Cover

Coral cover on the reefs shallower than 12m is high: between 50 and 60% on the Back, Side and Front Reefs adjacent to the Shark Feed Site, and slightly lower (40 – 50%) on the Front Reef remote from the Shark Feed Site. The area appears to have fully recovered from Crown of Thorns Starfish predation and occasional temperature-related coral bleaching within the past 10 years.

Coral diversity was high at all sites, with many Life-form categories and coral families represented on the Side and Front Sites, but dominated by *Acropora* on the Back Reef.

6.3 Coral Types and Stress Resilience

Certain genres of coral are more susceptible to environmental stressors than others. In general, *Acropora* and other fine branching corals grow quickly, but are susceptible to multiple stresses. Massive and other thicker corals grow more slowly, but tend to be more resistant to many potential impacts.

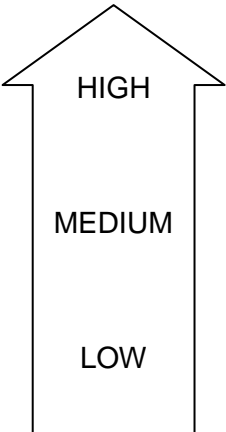
In particular, *Acropora* corals have been shown to be extremely vulnerable to temperature-related bleaching, predation and storm and cyclone damage (Cumming 2001, Lovell 2004, Sykes 2007, Chin 2011).

Where *Acropora* species come to dominate a reef, the reef becomes a good fish habitat, but is vulnerable to sudden crisis events which may kill all the *Acropora* in a short space of time, leaving other species to dominate.

Other coral types such as *Porities* and *Montipora* contain species which are very tolerant to sedimentation and poor water quality (Sykes, personal observations 2005 – 2014).

Diversity of coral species relates to a reef's resilience in the face of environmental stressors. The more species diversity a reef shows, the more likely it is to survive or recover from major crisis events. (Marshall 2006)

Table 6: A generalised hierarchy of coral susceptibility to bleaching (Marshall 2006)

Resistance to bleaching	Growth Form	Coral Family	Examples
	Various	<i>Various</i>	<i>Turbinaria</i> <i>Cyphastrea</i>
	Massive, Boulder	<i>Poritidae</i>	<i>Porites</i> <i>Goniopora</i>
	Massive, Brain	<i>Faviidae</i>	<i>Favia</i> , <i>Favites</i> <i>Leptoria</i> <i>Goniastrea</i> <i>Platygyra</i>
	Branching, Tabulate, Encrusting, Foliose	<i>Acroporidae</i>	<i>Acropora</i> <i>Montipora</i>
	Fine Branching	<i>Pocilloporidae</i>	<i>Seriatophora</i> <i>Stylophora</i> <i>Pocillopora</i>

In the case of the Side and Front Reefs, there is a wide spread of coral types, with high *Acropora* cover on the shallow reefs at 5m and above, mixed with many other species and growth forms. While there are species with low tolerance to bleaching and predation, there are also many with higher tolerance, indicating high resilience to stress factors, particularly below 5m depth, and a strong likelihood that the reefs can quickly recover from crisis events such as siltation, temperature-related bleaching, cyclone breakage and predation.

There is little apparent difference in coral cover or type between the Front Reef adjacent to the Feed Site and the other two Front and Side Reefs.

The Back Reef above 12m is dominated by extremely large stands of branching and table *Acropora*, and submassive *Pavona* corals. The size of these colonies suggests that there have not been any major coral-damaging stresses in this area for several years, but in the event of bleaching, breakage or predation, this area would be more vulnerable than the other sites.

In all areas there are large amounts of *Millipora* (Fire) coral, and in some cases this was observed overgrowing other corals, particularly *Porites* Massive (Boulder) corals. This may be due to opportunistic colonisation of corals which have died due to disease or predation.

6.4 Sponge

Sponges are filter feeders, and often occur in large quantities where water quality is poor and nutrient levels high. Sponge levels on the deeper reefs were much higher than usually seen in Fiji waters, particularly on the gradual slope of the Back Reef.

This reef is in the path of run-off from local rivers during flood events, which frequently results in high water turbidity and sedimentation onto the deeper reef slopes. It is likely that the sponges in this area are indicative of nutrient enrichment from this run-off.

Sponge levels are by far the highest on the Back Reef, where sediments can slowly collect on the shallow slope, and lowest on the Side Reef which is regularly scoured by strong tidal currents.

6.5 Macro-Algae

On the shallow reefs above 12m, Macro-algal levels are generally low, as is usually found on healthy Fijian reefs. However, on the deeper reef slope and floor, algal levels are higher, particularly at the Front Reef remote from the Feed Site, where there were unusually extensive drifts of fine green algae. These high amounts of algae probably reflect elevated nutrification in the same way as the sponges.

6.6 Macro-Invertebrates

Few Key Macro-Invertebrates were seen. Those that were found were on the Back Reef between 10 and 5m deep. This is likely to reflect habitat limitation, but may also be a result of previous over-collection, and numbers may increase as non-fishing regulations are enforced.

6.7 Fish

A reasonable spread of Key Fish were seen at all sites, but those frequently targeted by local fishermen such as Groupers and Sweetlips were in low numbers. Small predators such as Snappers and Jacks/ Trevallies were seen in the sites closest to the Shark Feed Site, but also closest to the strongest currents. Fish numbers were highest on the shallow reefs above 12m, where coral cover was also high.

6.8 Other Marine Species

As expected, sharks were attracted to the entrance of divers at the three sites on the Side and Front Reefs, but quickly dispersed once it became obvious that feeding was not taking place. Turtles are regularly reported at the Front Reef sites, and were seen at both of them during surveys, which may reflect their protection from fishing in the reserve.

Colonial Tunicates can occur in problem amounts in some areas, often overgrowing and killing corals. Only a few patches were seen during surveys, and in these small amounts are not likely to be causing a problem.

6.9 Fishing Gear

Although there has been theoretical protection from fishing at the Feed Site for several years, hand-fishing line such as is normally used by local subsistence fishers was found at three sites: the Front Reef adjacent to the Feed Site, the Side Reef, and the Back Reef. Many of these lines had probably been there less than a year, so it is likely that a small amount of fishing is still on-going.

The fact that the fishing line was found at these three sites, and not at the Front Reef remote from the Feed Site suggest that small subsistence fishing boats may be using the moorings at the Feed Site and the Back Reef.

7.0 Conclusions:

The Shark Reef Marine Reserve is set on a healthy patch reef occasionally affected by run-off from the Navua and Pacific Harbour rivers. Coral cover is high, but deeper reefs show the effects of land-based nutrification in the form of elevated Sponge and Macro-algae levels.

There is no significant difference in reef character between the reefs adjacent to the Feed Site and other physically similar reefs in the area.

The reef has a high diversity of coral forms, and is likely to be resilient to, and have the ability to rapidly recover from, stress and crisis events.

There is some indication that there may be low-level hand-line fishing going on within the reserve.

8.0 Bibliography and References:

Chin, A., Lison De Loma, T., Reyta, K., Planes, S., Gerhardt, K., Clua, E., and Burke, L., Wilkinson, C. (2011).

Status of Coral Reefs of the Pacific and Outlook: 2011.

Publishers Global Coral Reef Monitoring Network. 260 P.

ISBN 0 642 322228 7 © Global Coral Reef Monitoring Network

www.gcrmn.org <http://www.icriforum.org/icri-documents/associated-publications/status-coral-reefs-pacific-and-outlook-2011>

Cumming, R.L., Toscano, M.A., Lovell, E.r., Carlson, B.A., Dulvy, B.A., Hughes, A., Koven, J.F., Quinn, N.J., Sykes, H.R., Taylor, O.J.S., Vaughan, D. (2001)

Mass Coral Bleaching in the Fiji Islands 2000.

Proceedings of the 9th International Coral Reef Symposium, Bali.

Ellison, J.C. (2009)

Wetlands of the Pacific Islands Region

Wetlands Ecol Manage (2009) 17:169-206 DOI 10.1007/s11273-008-9097-3

<http://eprints.utas.edu.au/8299/>

Lovell, E., H. Sykes, M. Deiye, L. Wantiez, C. Garrigue, S. Virly, J. Samuelu, A. Solofa, T. Poulasi, K. Pakoa, A. Sabetian, D. Afzal, A. Hughes and R. Sulu, (2004)

Status of Coral Reefs in the South West Pacific: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands, Tuvalu and Vanuatu.

p: 337-362 . in C. Wilkinson (ed.). Status of coral reefs of the world: 2004. Volume 2. Australian Institute of Marine Science, Townsville, Queensland, Australia. 557 p

Marshall, P. and Schuttenberg, H (2006)

A Reef Manager's Guide to Coral Bleaching

Great Barrier Reef Marine Park Authority

ISBN 1 876945 40 0 www.iucn.org/bookstore

Sykes H and Morris C (2007)

Status of Coral Reefs in the Fiji Islands, 2007

In South-West Pacific Status of Coral Reefs Report 2007

Global Coral Reef Monitoring Network and Coral Reef Initiative for the Pacific

http://www.reefbase.org/resource_center/publication/main.aspx_ref_ID_A0000003032

Sykes, H, 2005 – 2014

More than 50 coral health and environmental impact assessments in Fiji, Kiribati, Solomon Islands, Samoa, Tonga and Vanuatu.

Personal observations.

Veron, J.E.N. (2000)

Corals of the World Volumes 1, 2 & 3

Australian Institute of Marine Science, ISBN 0 642 32236 8; 0 642 32236 6; 0 642 322387 4

Wilkinson, C. (2008).

Status of coral reefs of the world: 2008.

Global Coral Reef Monitoring Network and Reef and Rainforest Research Centre, Townsville, Australia, 296 p.

ISBN 1447-6185 © Global Coral Reef Monitoring Network www.gcrmn.org

Work, T.M. and Aeby, G. S. (2006)

Diseases of American Samoa Coral

American Samoa Department of Marine And Wildlife Resources

9.0 Appendix:

Data from Surveys

Substrate Cover: Basic Reef Check Categories (Average cover over 4x 20m transects)

	Front Reef adjacent to Feed Site				Side Reef		
	28m	10m	5m		28m	10m	5m
Hard Coral	23.13%	46.25%	54.38%		28.13%	43.75%	55.63%
Soft Coral	5.00%	4.38%	11.88%		3.13%	3.13%	0.63%
Dead Coral	0.63%	1.25%	0.00%		1.25%	1.88%	1.25%
Algae	13.75%	0.00%	0.00%		8.75%	1.25%	0.00%
Sponge	9.38%	5.63%	3.13%		3.75%	2.50%	4.38%
Rock	10.63%	32.50%	30.63%		26.88%	42.50%	37.50%
Rubble	20.63%	3.13%	0.00%		18.13%	2.50%	0.00%
Sand	15.63%	1.25%	0.00%		6.88%	0.00%	0.00%
Silt	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%
Other	1.25%	5.63%	0.00%		3.13%	2.50%	0.63%

	Back Reef				Front Reef remote from Feed Site		
	18m	10m	5m		28m	10m	5m
Hard Coral	8.13%	64.38%	53.13%		10.63%	33.13%	41.25%
Soft Coral	0.00%	0.00%	0.63%		1.25%	3.75%	3.13%
Dead Coral	0.00%	4.38%	1.88%		0.00%	1.88%	1.25%
Algae	9.38%	3.13%	5.00%		31.25%	3.13%	1.25%
Sponge	19.38%	2.50%	2.50%		3.75%	3.75%	5.00%
Rock	3.13%	6.25%	12.50%		8.13%	31.88%	36.88%
Rubble	6.25%	15.63%	20.00%		18.13%	18.13%	7.50%
Sand	53.75%	2.50%	3.75%		26.25%	2.50%	2.50%
Silt	0.00%	0.00%	0.00%		0.00%	0.00%	0.00%
Other	0.00%	1.25%	0.63%		0.63%	1.88%	1.25%

Substrate Cover: AIMS Lifeform Categories (Average cover over 4 x 20m transects)

	Front Reef adjacent Feed Site				Side Reef		
	28m	10m	5m		28m	10m	5m
Acropora Branching	1%	2%	4%		1%	3%	4%
Acropora Digitate	1%	4%	9%		0%	1%	6%
Acropora Table	1%	6%	12%		1%	1%	4%
Acropora Submassive	0%	0%	0%		0%	0%	0%
Acropora Encrusting	0%	0%	0%		0%	0%	0%
Coral Branching	0%	1%	0%		2%	1%	1%
Coral Massive	2%	6%	8%		6%	6%	5%
Coral Foliose	1%	1%	0%		2%	3%	0%
Coral Submassive	4%	4%	6%		4%	7%	16%
Coral Encrusting	9%	9%	7%		10%	13%	4%

Coral Fungid	3%	1%	0%		3%	3%	0%
Coral Millipora	2%	15%	9%		0%	8%	15%
Soft Coral	5%	4%	12%		3%	3%	1%
Sponge	9%	6%	3%		4%	3%	4%
Other	1%	6%	0%		3%	3%	1%
Algal Assemblage	0%	0%	0%		0%	0%	0%
Macro Algae	11%	0%	0%		8%	0%	0%
Halimedes	3%	0%	0%		1%	1%	0%
Turf Algae	0%	0%	0%		0%	0%	0%
Coralline Algae	2%	11%	16%		6%	13%	8%
Rock	9%	19%	13%		21%	29%	30%
Rubble	21%	3%	0%		18%	3%	0%
Sand	16%	1%	0%		7%	0%	0%
Dead Coral	1%	1%	0%		1%	2%	1%
Dead Coral with Algae	0%	3%	1%		0%	0%	0%

	Back Reef				Front Reef remote from Feed Site		
	18m	10m	5m		28m	10m	5m
Acropora Branching	2%	47%	30%		2%	5%	10%
Acropora Digitate	0%	0%	2%		0%	2%	8%
Acropora Table	1%	4%	1%		0%	2%	4%
Acropora Submassive	0%	0%	0%		0%	0%	0%
Acropora Encrusting	0%	0%	0%		0%	0%	0%
Coral Branching	0%	0%	0%		1%	1%	0%
Coral Massive	3%	3%	5%		2%	7%	8%
Coral Foliose	0%	1%	0%		1%	0%	0%
Coral Submassive	1%	2%	9%		1%	1%	3%
Coral Encrusting	1%	3%	0%		3%	7%	3%
Coral Fungid	1%	1%	2%		2%	0%	0%
Coral Millipora	0%	6%	4%		0%	9%	5%
Soft Coral	0%	0%	1%		1%	4%	3%
Sponge	19%	3%	3%		4%	4%	5%
Other	0%	1%	1%		1%	2%	1%
Algal Assemblage	1%	0%	0%		0%	0%	0%
Macro Algae	3%	1%	1%		30%	3%	1%
Halimedes	5%	3%	4%		0%	0%	0%
Turf Algae	1%	0%	0%		1%	0%	0%
Coralline Algae	0%	3%	7%		5%	6%	18%
Rock	3%	3%	6%		3%	26%	19%
Rubble	6%	16%	20%		18%	18%	8%
Sand	54%	3%	4%		26%	3%	3%
Dead Coral	0%	4%	2%		0%	2%	1%
Dead Coral with Algae	0%	0%	0%		0%	0%	0%

Key Invertebrates: Reef Check (Average count over 4 x 100m² transects)

	Front Reef adjacent Feed Site				Side Reef		
	28m	10m	5m		28m	10m	5m
Banded coral shrimp	0	0	0		0	0	0
Diadema urchin	0	0	15		0	0	0
Pencil urchin	0	0	0		0	0	0
Collector urchin	0	0	0		0	0	0
Sea cucumber	0	0	0		0	0	0
Crown-of-thorns	0	0	0		0	0.5	0
Triton	0	0	0		0	0	0
Lobster	0	0	0		0	0	0
Giant Clam	0	0	0		0	0	0

	Back Reef				Front Reef remote from Feed Site		
	18m	10m	5m		28m	10m	5m
Banded coral shrimp	0	0	0		0	0	0
Diadema urchin	0	0	0		0	0	0
Pencil urchin	0	0	0		0	0	0
Collector urchin	0	0	0		0	0	0
Sea cucumber	0	0	0.5		0	0	0
Crown-of-thorns	0	0	0		0	0	0
Triton	0	0	0		0	0	0
Lobster	0	0	0.25		0	0	0
Giant Clam	0	0	0.25		0	0	0

Key Fish: Reef Check (Average count over 4 x 100m² transects)

	Front Reef adjacent Feed Site				Side Reef		
	28m	10m	5m		28m	10m	5m
Butterflyfish	4.5	6.5	6.00		3	7.5	6
Sweetlips	0	0	0		0	0	0
Snapper	0.5	1	11.5		13	15	1.5
Humphead wrasse	0	0	0		0	0	0
Bumphead parrot	0	0	0		0	0	0
Parrotfish	0	2	11		2	1	1.5
Moray eel	0	0	0		0	0	0
Grouper < 30 cm	0	0	0		0	0	0
Grouper 30-40 cm	0	0	0		0	0.5	0
Grouper 40-50 cm	1	0	0		0	0.5	0.5
Grouper	0	0	0.5		0	0	0
Grouper >60 cm	0	0.5	0		0	0.5	0.5
Total Grouper	0.5	0.25	0.25		0	0.75	0.5
Surgeon and Unicornfish	2.5	11	12.5		2.5	5	5
Goatfish	0	0	0.5		2.5	0	0
Jacks and Trevallies	0.5	8	11		6	15	0

	Back Reef				Front Reef remote from Feed Site		
	18m	10m	5m		28m	10m	5m
Butterflyfish	0.5	8.5	7.75		2	7.75	10
Sweetlips	0	2.5	0		0	0	1
Snapper	0.5	5	0.5		2.5	11	1.5
Humphead wrasse	0	0	0		0	0	0
Bumphead parrot	0	0	0		0	0	0
Parrotfish	1	8	8.5		2.5	6.5	11
Moray eel	0	0	0		0	0	0
Grouper < 30 cm	0	0.5	2.5		0	0	0
Grouper 30-40 cm	0	1.5	0		0	0	0
Grouper 40-50 cm	0	0	0		0	0	0
Grouper	0	0	0		0	0	0
Grouper >60 cm	0	0	0		0	0	0
Total Grouper	0	0.75	0		0	0	0
Surgeon and Unicornfish	2.5	12.5	12.5		3.5	20	37.5
Goatfish	2	0	0		1.5	3	2
Jacks and Trevallies	0	0	0		0	0	0