Shark Reef Marine Reserve (SRMR)
Benthic Biodiversity Assessments, Serua, Viti Levu, Fiji

Helen Sykes , Marine Ecology Consulting,
September 2022

All photos by Helen Sykes except where credited

Photo Credit: Tom Vierus

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Contents

Introduction

Shark Reef Marine Reserve (SRMR) is a section of patch reef approximately 3 Km from the southern shore of Viti Levu in the Fiji Islands. In 2014 it was declared a statutory marine reserve under the Fisheries Act of 1942 (Cap 158) with the specific objective of protecting shark populations in the area.

Shark feeding for the purpose of creating an attraction for tourist SCUBA divers and researchers has been carried out at one specific site on the reef front since 1999, although at a reduced level during Covid-19-related closures in 2020 and 2021.

The reef flat partially dries at extreme low tide, then drops 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. Baseline rapid assessment surveys of several sites around the SRMR were conducted at three depths in November and December 2014.

In April – June 2022, three of these sites were selected and monitored at two depths for comparison with the 2014 study, plus an additional three sites at two depths at Combe Reef (CR), a nearby patch reef approximately 5 Km from SRMR, which is not under any fishing protection, for comparison.

Detailed surveys at these sites were carried out to be used to measure differences between protected and unprotected reefs in future monitoring of reef health, key animal populations, and fish biomass and diversity.

FIGURE 1: GOOGLE EARTH IMAGE SHOWING POSITION OF SRMR AND CR SITES

Survey Teams

As part of these surveys, training in reef survey techniques was carried out for personnel from the Fiji Ministry of Fisheries, the University of the South Pacific, the dive operator Beqa Adventure Divers, and a voluntourism company Projects Abroad.

Rapid Assessments (RA) were carried out by the newly trained team, with supervision from the trainer, to allow for surveys by less specialised survey teams in future monitoring if specialist team members are unavailable.

Extended Surveys (ES) were carried out by specialist team members to provide more detailed information than could be drawn from the Rapid Assessment, and to allow comparison with other global projects.

TABLE 1: SURVEY TEAM MEMBERS 2022

Rapid Assessment (RA) team			
Name		**Affiliation**	**Role**
Helen Sykes	HS	Marine Ecology Consulting	Trainer/ supervisor
Stuart Gow	SG	Marine Ecology Consulting	Reef Check
Janice Taga	JT	USP – Post graduate student	Reef Check
Shivam Jalam	SJ	Ministry of Fisheries Officer	Reef Check
Viliame Salabogi	VS	Ministry of Fisheries Officer	Reef Check
Natasha Marosi	NM	Beqa Adventure Divers	Reef Check
Sydney Shier	SS	Beqa Adventure Divers	Reef Check
Irene Lily	IL	Projects Abroad	Reef Check
Extended Survey (ES) team			
Name		**Affiliation**	**Role**
Helen Sykes	HS	Marine Ecology Consulting	Fish Abundance and Biomass
Amanda Ford	AF	University of the South Pacific - Lecturer	Substrate cover and genera
Sangeeta Mangubhai	SM	Talanoa Consulting (ex WCS Fiji Director)	Coral bleaching
Mike Neumann	MN	Beqa Adventure Divers	Photography and videography
Tom Vierus	TV	Environmental photo journalist	Photography and videography

TABLE 2: SURVEY DATES AND TEAMS 2022

Date	**Site**	**Depth**	**Team**
Training			
2 April 2022	Beqa Adventure Divers	Classroom training	HS, NM, VS, TV. JT, SS, IL
3 April 2022	Combe Back Reef	In water training	HS, JT, SS, NM, TV
In water surveys			
24 April 2022	SRMR Back Reef	10m & 5m	HS, NM, SJ, SM, AF, TV
1 May 2022	SRMR Feed Site	10m & 5m	HS, NM, SJ, SM, AF, TV
8 May 2022	Combe Back Reef	10m & 5m	HS, NM, SJ, JT, AF, TV
29 May 2022	Combe Reef Front 1	10m & 5m	HS, SM, AF
5 June 2022	SRMR Remote Combe Reef Front 2	10m 10m	HS, JT, AF
19 June 2022	SRMR Remote Combe Reef Front 2	5m 5m	HS, SG, AF

Methodology

Sites

Three sites each on the Shark Reef Marine Reserve and on Combe Reef were surveyed at 5m and 10m: one on each site along the back reef slope, and two at each site on the front reef slope.

Reef profiles were drawn, with habitat types, to a depth of 20 metres where feasible, to ensure sites were as physically comparable as possible, and to inform future monitoring.

At SRMR Front Reef 1 was the shark feed site dived on an almost daily basis, while the other two sites were not normally dived. Front Reef 2 was physically similar to Front Reef 1, but remote from the feed site.

At CR the Back Reef and Front Reef 1 sites were sometimes used as dive sites by two operators, whereas Front Reef 2 was less often dived. However, the entire reef is open for fishing and a local boat with spear fishing snorkel divers was seen in the area during surveys.

Shark Reef Marine Reserve sites 2014 and 2022

Combe Reef sites 2022

FIGURE 2: GOOGLE EARTH IMAGES OF SURVEY SITES USED FOR 2022 COMPARISON

Rapid Assessments

Substrate cover and populations of key fish and invertebrates

At each of the sites / depths, along sets of four replicate 20m long Point Intercept Transects, benthic cover was recorded at 40 points spaced at 50cm intervals to standard Reef Check categories (www.reefcheck.org)

TABLE 3: REEF CHECK BENTHIC SUBSTRATE CATEGORIES

Category	Code	Definition
Hard Coral	HC	Live hard coral (including bleached)
Soft Coral	SC	Live soft coral and zoanthids
Recently Killed Coral	RKC	Died within 12 months – corallites still visible
Sponge	SP	All sponges (not tunicates)
Nutrient Indicator Algae	NIA	Algae over 3 cm tall.
Other	OT	Any other living animals not listed above.
Rock	RC	Any hard substrate including eroded dead coral
Rubble	RB	Loose pieces of rock smaller than 15 cm
Sand	SD	Particles smaller than 0.5 cm (fall quickly to floor)
Silt	SI	Mud layer more than 1 mm deep,

Along the same transects, four replicate 20 x 5m (100m^2) Belt Transects were recorded for key fish and macro invertebrate populations.

Organisms selected were based on standard Reef Check, for their usefulness to indicate ecosystem health and fishing pressures, and for international comparability. Other groups of fish with local relevance to the South Pacific were added (indicated with *), plus herbivores which may be related to fishing pressures or benthic resilience at SRMR (marked with #).

TABLE 4: KEY FISH AND INVERTEBRATE GROUPS USED IN RAPID ASSESSMENT

Fish	
Common Name	***Scientific name***
Butterflyfish	*Chaetodontidae spp*
Sweetlips	*Haemullidae spp*
Snapper	*Lutjanidae spp*
Grouper	*Serranidae spp*
Parrotfish	*Scaridae spp*
Moray Eels	*Muranidae spp*
Surgeon/ Unicornfish *	*Acanthuridae spp*
Goatfish *	*Mullidae spp*
Jacks/Trevallies *	*Carangidae spp*
Rabbitfish #	*Siganidae spp*
Pygmy Angelfish #	*Centropyge spp*
Humphead Wrasse	*Chelinus undulatus*
Bumphead Parrotfish	*Bolbometopon muricatum*
Giant Trevally #	*Caranx ignobilis*

Macro-Invertebrates	
Common Name	***Scientific name***
Giant Clam	*Tridacna spp*
Sea Cucumber	*Holothuridae spp*
Diadema Urchins	*Diadema spp*
Spiny Lobster	*Palinuridae spp*
Individual species of interest	
Triton's Trumpet	*Charonia tritonis*
Crown of Thorns Star	*Acanthaster planci*
Banded Coral Shrimp	*Stenopus hispidus*
Collector Urchin	*Tripnuestes gratilla*

Extended Surveys

Reef Profiles, Coral Genera, Fish Abundance and Biomass

At each of the sites / depths, along sets of three replicate 50m long Point Intercept Transects, benthic cover was recorded at 100 points spaced at 50cm intervals, to Lifeform categories plus corals to genera and bleaching level.

TABLE 5: SUBSTRATE LIFEFORM CATEGORIES USED

Australian Institute of Marine Sciences (English et al) Lifeform categories	**Code**
Acropora branching coral	ACB
Acropora digitate coral	ACD
Acropora tabular coral	ACT
Acropora encrusting coral	ACE
Acropora submassive coral	ACS
Acropora corymbose	ACC
Non-*Acropora* coral branching	CB
Non-*Acropora* coral massive	CM
Non-*Acropora* coral encrusting	CE
Non-*Acropora* coral foliose	CF
Non-*Acropora* coral submassive	CS
Non-*Acropora* corymbose	CC
Non-*Acropora* coral fungoid (mushroom)	CMR
Non-*Acropora* coral *Millepora* (fire)	CME
Soft coral (eg *Sinularia, Sarcophyton, Dendronepthea* sp)	SC
Sponge	SP
Zoanthid	ZO
Other biota	OT
Coralline algae (3D structure)	CA
Coralline algae (crustose / encrusting)	CA
Halimeda algae	HA
Turf algae	TA
Macro algae	MA
Algal assemblage	AA
Microbial mats – cyanobacter etc	MC
Dead coral	DC
Dead coral + fleshy algae	DA
Rock (> 15cm in length)	RC
Rubble (> 0.5cm but < 15cm in length)	RB
Sand (< 0.5cm and falls quickly to the bottom if dropped	SD
Silt (0.002 – 0.05mm sediments remain in suspension)	SI

At each of the sites / depths, sets of three replicate 50m long x 5m wide (250m^2) from reef base to 5m above, Belt Transects were recorded, taking 15 – 20 minutes per 50m line. Fish seen within the following fish families were recorded to species level, within 5 cm size "bins": 2-5, 6-10, 11-15, 16-20, 21-25, 26-30, 31-35, 36-40, and >40 (size estimate >40cm recorded).

TABLE 6: FISH FAMILIES RECORDED FOR ABUNDANCE AND BIOMASS

Common Name	*Scientific name*
Surgeonfish and Unicornfish	*Acanthuridae*
Triggerfish	*Balistidae*
Fusiliers	*Caesionidae*
Jacks and Trevallies	*Carangidae*
Butterflyfish	*Chaetodontidae*
Porcupinefish	*Diodontidae*
Spadefish aka Batfish	*Ephippidae*
Sweetlips	*Haemulidae*
Chubs and Rudderfish	*Kyphosidae*
Wrasses	*Labridae*
Emperors	*Lethrinidae*
Snappers	*Lutjanidae*
Filefish	*Monacanthidae*
Goatfish	*Mullidae*
Breams	*Nemipteridae*
Sandperch	*Pinguipedidae*
Angelfish	*Pomacanthidae*
Bigeyes	*Priacanthidae*
Parrotfish	*Scaridae*
Groupers (not Anthias & Soapfish)	*Serranidae*
Mackerel & Tuna	*Scombridae*
Rabbitfish	*Siganidae*
Barracuda	*Sphyraenidae*
Lizardfish	*Synodontidae*
Puffers	*Tetraodontidae*
Moorish idol	*Zanclidae*
Sharks**	*All families*

** Sharks were noted but not included in biomass data, as a single shark would skew the data from all other fish

Observations were entered into Data Mermaid database, https://www.datamermaid.org/ which uses a standardised formula for biomass calculation: The relationship between length (L) and weight (W) expressed as W=aL^{b}\!\, using length and weight values for each species taken from standard values listed on FIshbase. https://www.fishbase.se/

Water Temperature

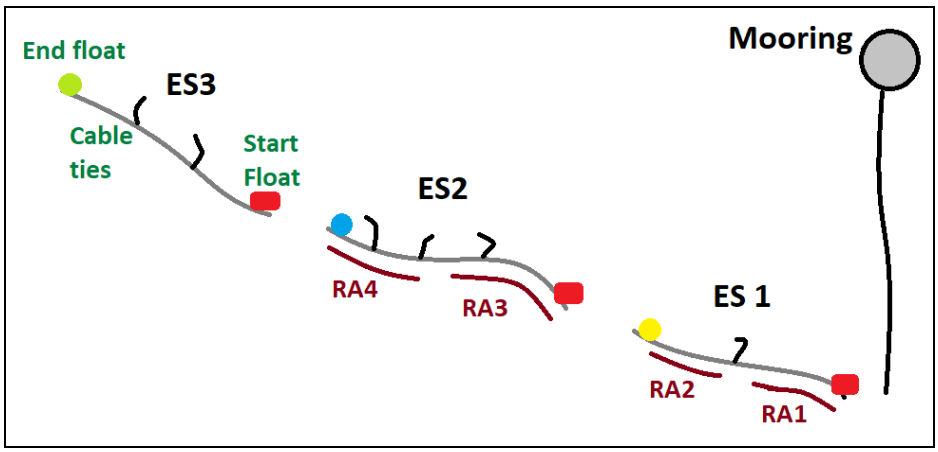
Water temperature was recorded every 2 hours, using a Hobo U22-001 logger[1] attached to the SRMR Front 1 mooring at 10m deep.

[1] https://www.onsetcomp.com/products/data-loggers/u22-001/

Marking permanent transects

To ensure that future monitoring could be carried out in the same area, transect lines were started, wherever possible, at moorings, and then marked along the three 50m transect lines with fishing floats. The 20m Rapid Assessment (RA) lines were surveyed in the same areas as the 50m Extended Surveys (ES), with RA lines 1 and 2 running along the first ES line, and RA 20m lines 3 and 4 running along the second ES line. 5m gaps were left between each line.

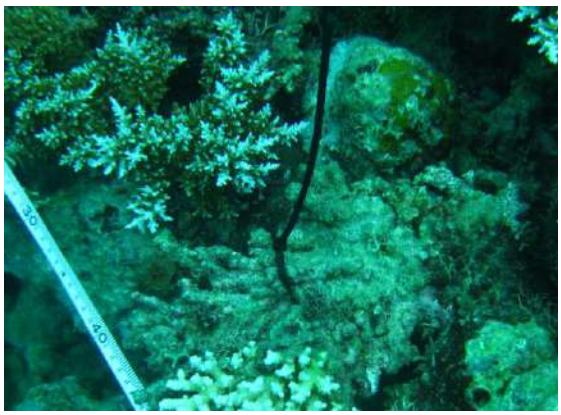
ES start points were marked with a red cylindrical fishing float, and end points with a disc-shaped rubber float of various colours. Along the route, black cable ties without floats were fastened at irregular intervals where the line could otherwise diverge.



Start float

End float

Cable tie route marker



Surveryors on transect line

FIGURE 3: SKETCH AND PHOTOGRAPHS OF TRANSECT LINE MARKERS

Reef profiles and transect positions

SRMR Front 1 – Shark Feed Site

Start Point coordinates: -18.300706° 178.018117°

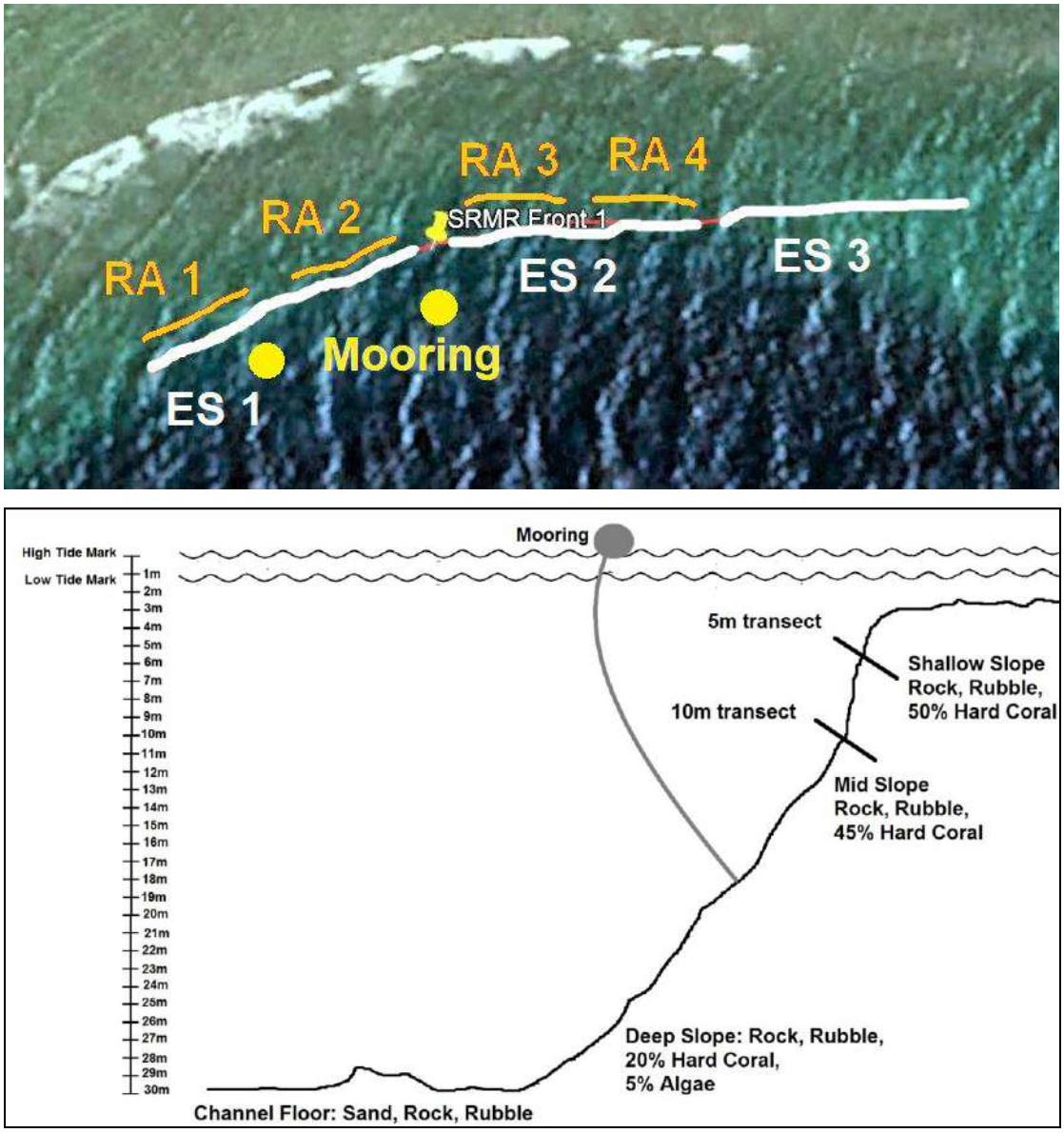


FIGURE 4: SRMR FRONT 1 SITE DESCRIPTION

Drop in point is first mooring .

Swim towards reef and start lines ES 1 and RA 1 and 2 heading west, with reef slope on right., passing second mooring.

Return to start point, and set lines ES 2 and 3, and RA 3 and 4 to east, with reef slope on left.

All ES transects are marked with floats and cable ties.

Safety diver is necessary to ensure divers are not distracted by sharks.

SRMR Front 2 – Remote from Shark Feed Site

Start Point coordinates: -18.299979° 178.022274°

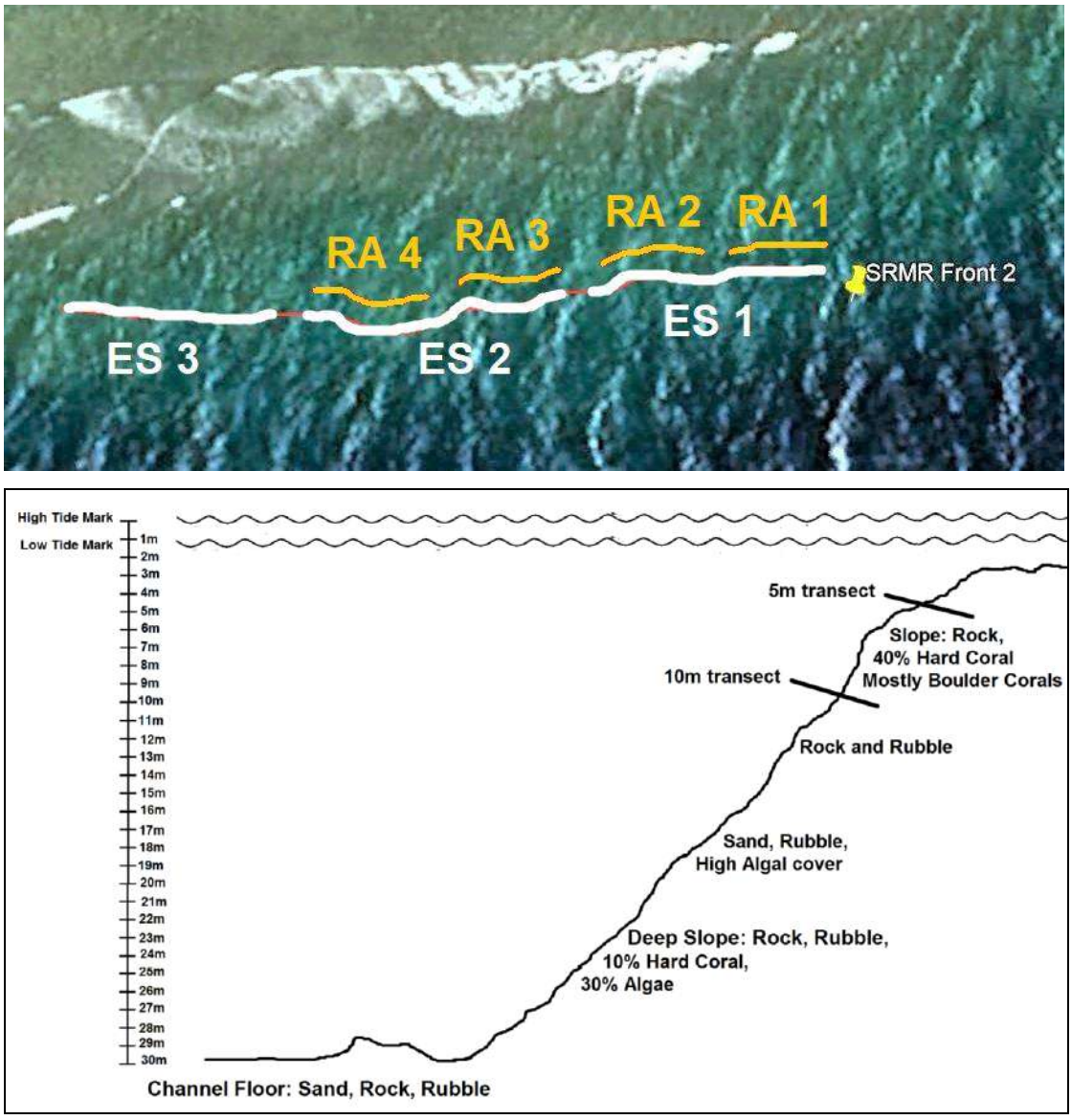


FIGURE 5: SRMR FRONT 2 SITE DESCRIPTION

As there are no moorings in this area, lines start opposite a landmark: the landward edge of the sandbank on top of the reef.

Site can be badly affected by surge – 5m transects are not always possible on choppy days.

These transect lines were not marked, as start and end points cannot be guaranteed to be exactly the same every time.

The direction of survey lines will depend on current – always start by swimming initially INTO the current.

In 2022, surveys were carried out with the reef slope on the right.

SRMR Back Reef

Start Point coordinates: -18.298028° 178.017442°

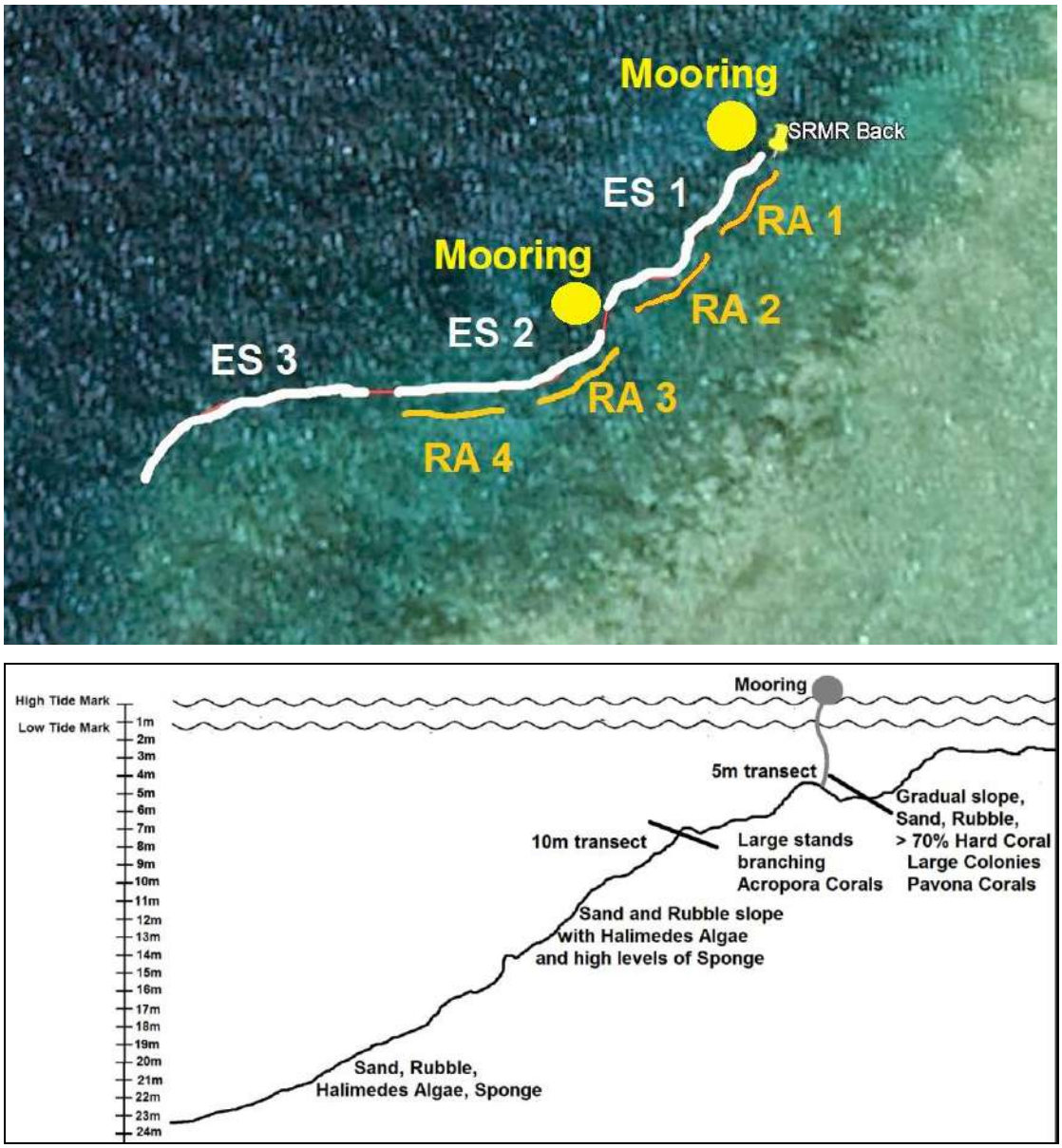


FIGURE 6: SRMR BACK REEF SITE DESCRIPTION

Drop in point is first mooring. 5m line starts at base of mooring. For 10m lines swim directly down from mooring to reach desired depth.

All lines run west with the reef slope on the left.

There is a second mooring at the end of ES 1/ RA 2.

The line changes direction sharply on the 10m end of ES 2/ RA 4.

All ES transects are marked with floats and cable ties.

Good buoyancy control is essential, as this site has very large stands of extremely delicate corals.

CR Front 1

Start Point coordinates: -18.293779° 178.077840°

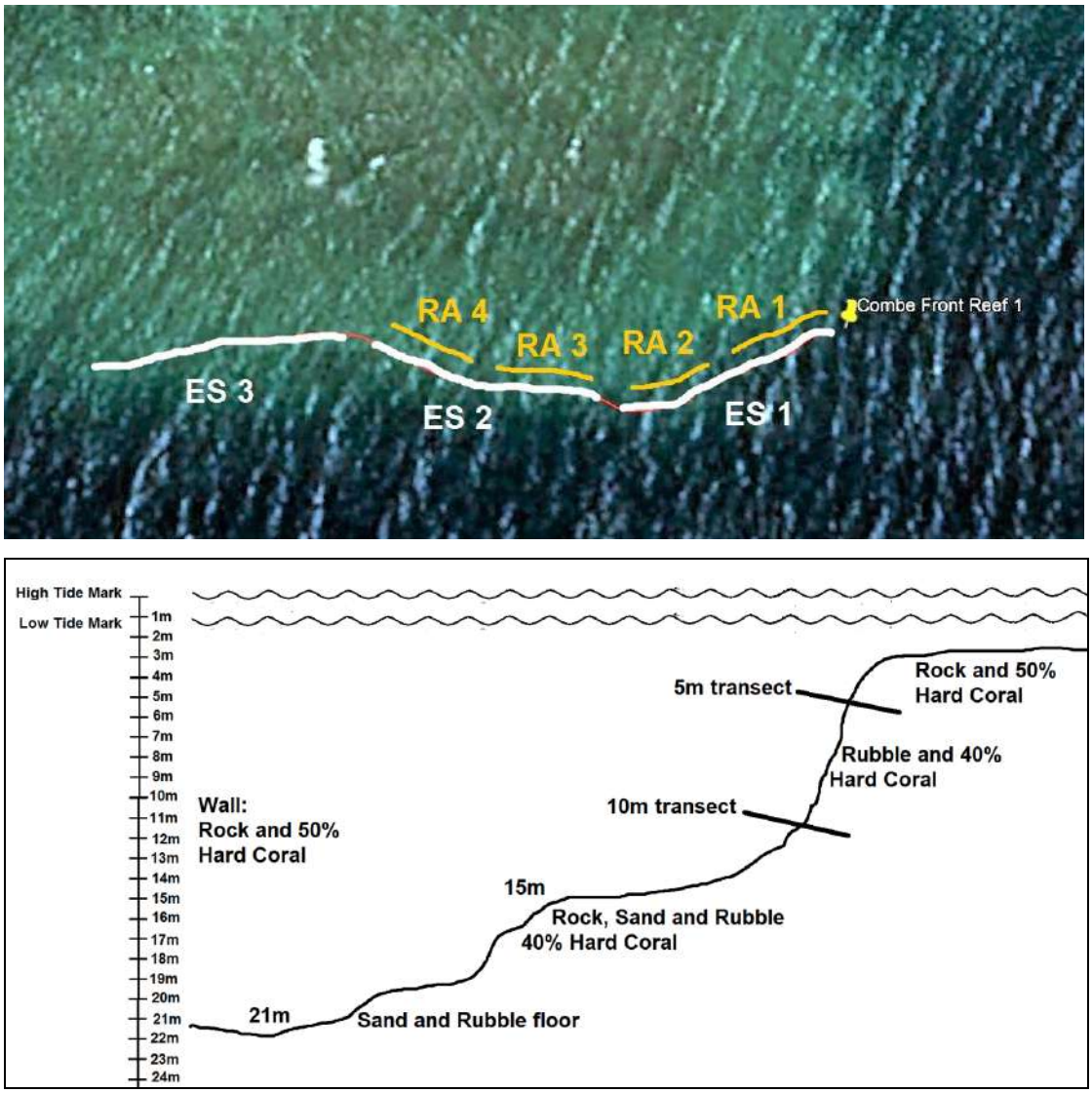


FIGURE 7: CR FRONT 1 SITE DESCRIPTION

As there are no moorings in this area, lines start opposite a landmark: the western edge of the shallow "bay" in the centre of the reef front (see Figure 2).

From the drop in point, lines run west, with the reef slope on the right.

These transect lines were not marked, as start and end points cannot be guaranteed to be exactly the same every time.

CR Front 2

Start Point coordinates: -18.293375° 178.078933°

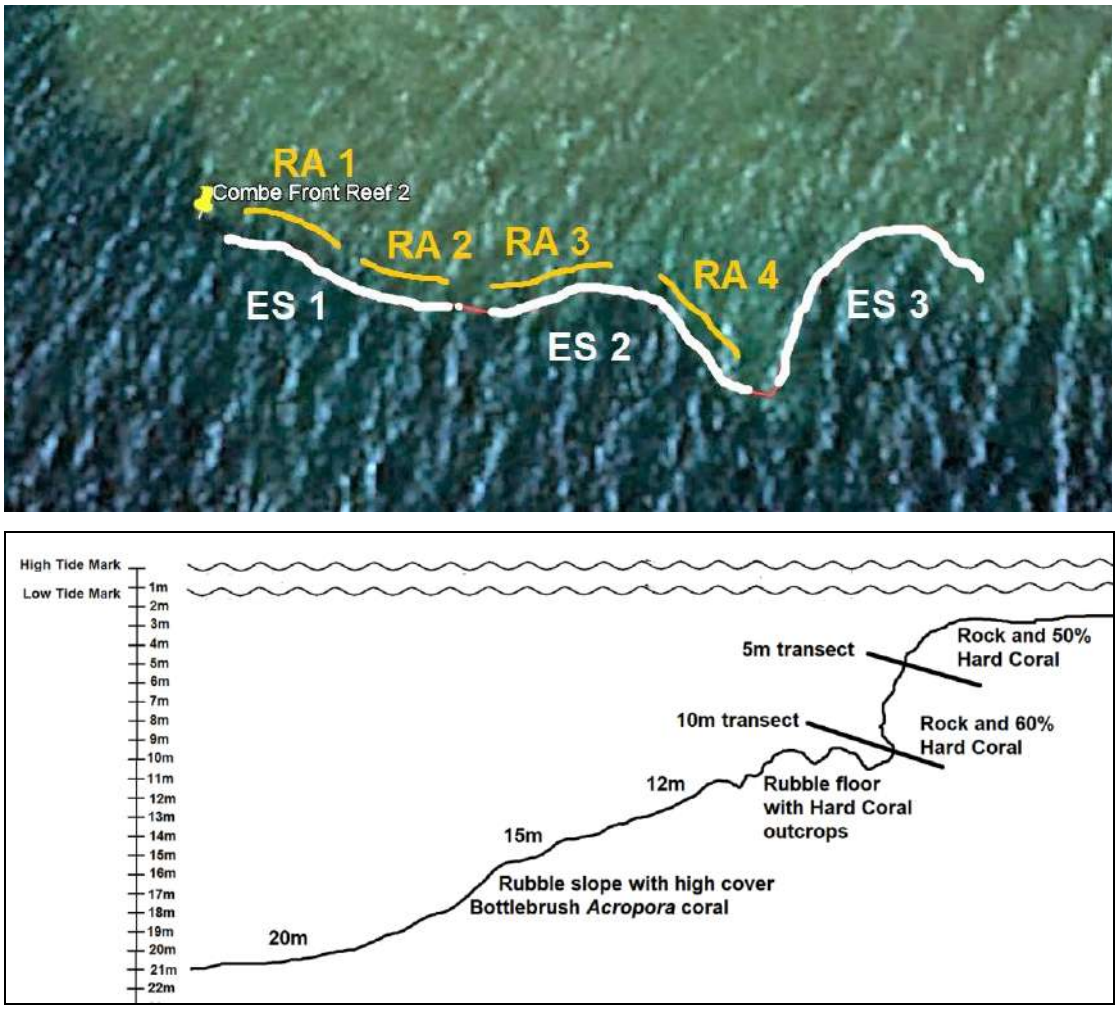


FIGURE 8: CR FRONT 2 SITE DESCRIPTION

As there are no moorings in this area, lines start opposite a landmark: the eastern edge of the shallow "bay" in the centre of the reef front (see Figure 2).

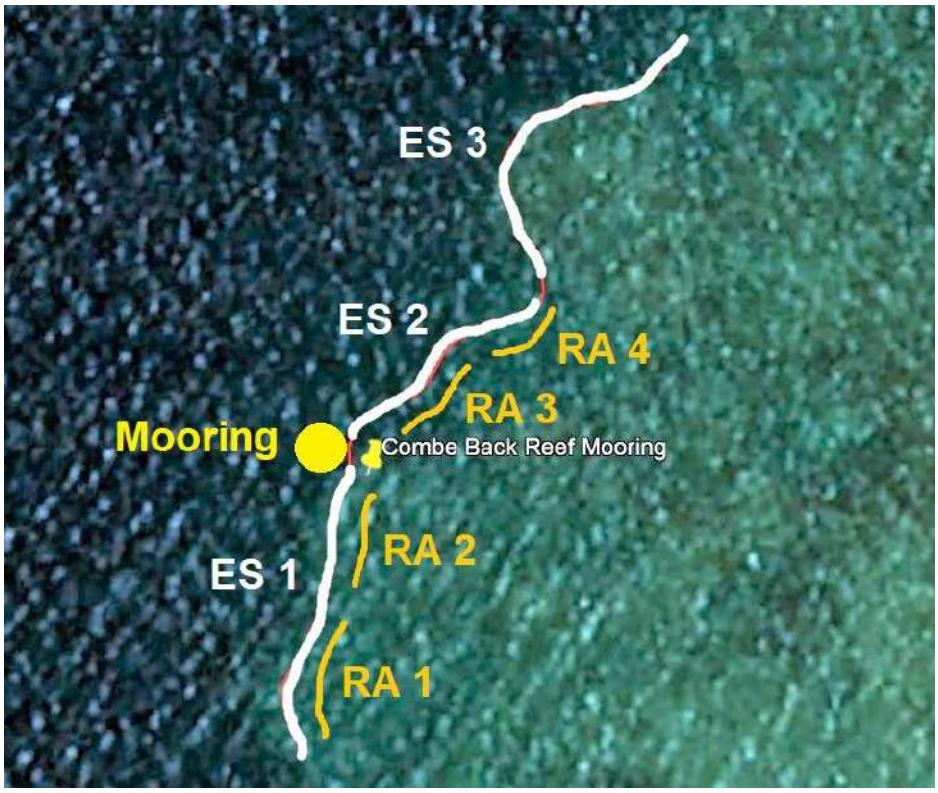
From the drop in point, lines run east, with the reef slope on the left.

At 10m the transect line runs along a few areas of wall – line should stay out of overhangs and instead stay on bommies with live coral.

These transect lines were not marked, as start and end points cannot be guaranteed to be exactly the same every time.

CR Back Reef

Start Point coordinates: -18.293217° 178.075395°



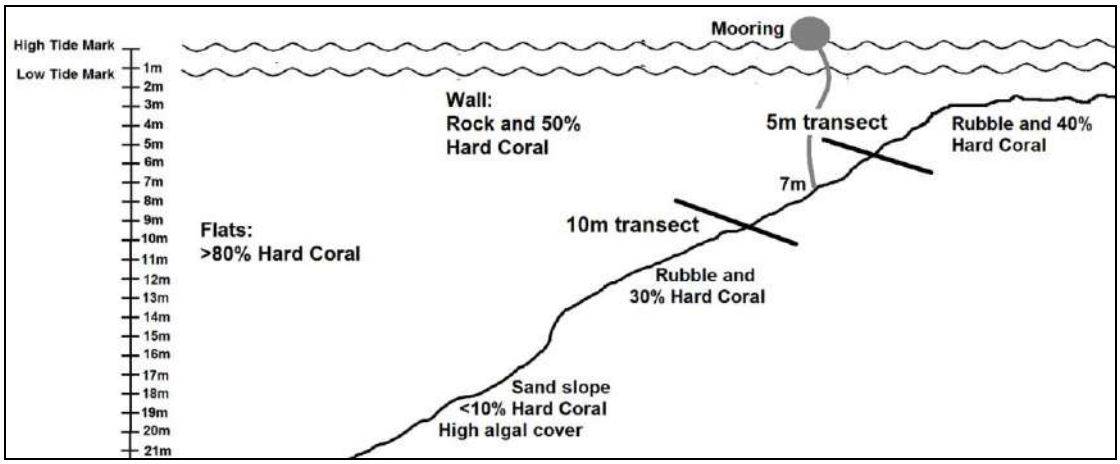


FIGURE 9: CR BACK REEF SITE DESCRIPTION

Drop in point is mooring. 10m transect starts under mooring base, 5m transect start above it.

From the mooring, lines ES 1 and RA 1 and 2 run south, with the reef slope on left .

Return to start point, and set lines ES 2 and 3, and RA 3 and 4 to north, with reef slope on right.

All ES transects are marked with floats and cable ties.

Water Quality

As part of a larger study carried out in 2019[2], basic surface water quality parameters were measured at the backs of both SRMR and Combe Reef, as well as at more remote sites within the Beqa Lagoon, after a period of heavy rainfall when land-based influences would have been maximised. Both reefs are within 10 Km of the sediment-laden outlets of the Deuba and Navua rivers.

At 3m below the surface, turbidity was quite high, measured as horizontal underwater visibility of 8m at SRMR and 12m at Combe Reef. General coliform bacterial levels were estimated via a presence/ absence field test as moderate at SRMR and high at Combe Reef. In other surveys these estimations have been seen to correlate to quantitative counts of faecal coliform levels of <100 bacteria/ 100ml and >100 bacteria/ 100ml respectively.

TABLE 7: RESULTS OF WATER QUALITY TESTING IN SERUA AND BEQA LAGOON APRIL/ MAY 2019

Shaded boxes = atypical results

Area	**East Beqa**		**West Beqa Lagoon**						
Site	**Suli-yaga**	**Suli-yaga**	**Naya-motu**	**Kau-viti**	**Bird Island**	**Kauviti Back**	**Frigate's Pass outer**	**Frigate's Pass side**	**Naya-motu back**
Temp °C	30	30	28	29	27	29.5	28	29	30
Horizontal visibility m	12	12	20	12	10	10	20	25	10
salinity PPT hydrometer	36	36	**32**	**33**	**32**	**33**	**33**	**33**	**32**
pH	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4	8.4
Bacteria levels	Low		Low		Low				Low

Area	**East Beqa Lagoon**		**Pacific Harbour**			
Site	**Suliyaga Inner sand slope**	**Suliyaga Outer slope**	**Combe Reef**	**Serua Reef**	**SRMR**	**Nasoro-waca**
Temp °C	28.5	28.5	26.5	28	27	26.5
Horizontal visibility m	**5**	12	12	**8**	**8**	**5**
salinity PPT hydrometer	**30.5**	**30.5**	37	35	**32.5**	**32**
pH	8.4	8.4	8.8	8.8	8.4	8.4
Bacteria levels			**High**	**High**	**Moderate**	**High**

Comparison with results from Beqa Lagoon sites showed that after heavy rainfall, water clarity and salinity were lower closer to the Viti Levu coast than further out in the Beqa Lagoon, but poor visibility and lowered salinity extended out as far as Storm Island. Sites further away from the main coast were the least affected.

There were few signs of nutrient enrichment, but the area closest to the river outlets, including SRMR and Combe Reef, did have slightly elevated levels of Nitrate (testing at USP IAS laboratory). This, coupled with the higher levels of Coliform bacteria, suggest that the Deuba and Navua rivers are washing water contaminated by sewage into the marine environment and as far out as the north-eastern reefs of Beqa Lagoon.

[2] Helen R Sykes, Marine Ecology Consulting, June 2019
Assessment of Marine Resources for Aquarium Fish (Fiji) Ltd. Pacific Harbour, Fiji

Section 1:
Rapid Assessment of Marine Life in SRMR 2014 vs 2022

Photo Credit: Tom Vierus

A suite of surveys carried out in 2014 at three sites and two depths within the SRMR, was compared with surveys of the same areas in 2022 to examine the impacts and effects of stress events on reef health and populations over an eight-year period. Stress events included a category 5 cyclone (Winston, February 2016), periods of elevated temperatures (El Nino, 2014 – 2016) and possible over-fishing due to loss of income in the local communities (Covid-19-related closures 2020 – 2021). A strong wave event after this survey period affected coral cover on the SRMR Front Reef 1 site. To account for this, a video was taken and surveyed as a second level baseline.

Methods:

- Four replicate 20 x 5m (100m^2) belt transects for key fish and macro-invertebrates
- Four replicate 20m x 40-point Intercept transects for substrate to lifeform categories

FIGURE 10: USP POST-GRADUATE STUDENT JANICE TAGA CARRYING OUT RAPID ASSESSMENT SURVEY

Results -Substrate Cover

Basic substrate types

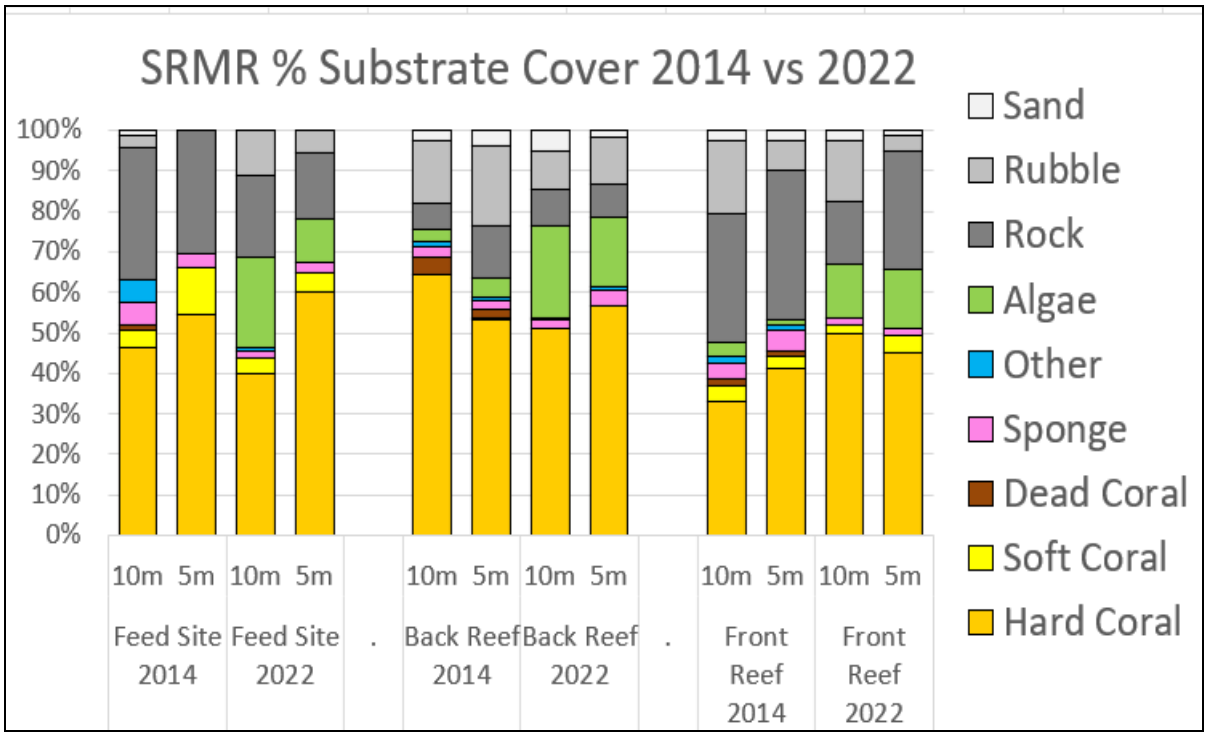


FIGURE 11: BAR CHART SHOWING PERCENT COVER OF BASIC SUBSTRATE TYPES ON SRMR 2014 VS 2022

Overall, substrate types changed very little from 2014 to 2022

On the SRMR Front Reef 1, at the feed site, live hard coral (orange) remained between 40 and 60% cover, with higher cover always on the shallower section (5m).

On the SRMR Back Reef. coral cover was very high, between 51 and 63%, with a slight drop from 2014 to 2022 at 10m and a slight rise from 2014 and 2022 at 5m, but was not majorly changed over the eight year period.

On the SRMR Front Reef 2, remote from the feed site, coral cover was lower than the other sites over both survey periods, although the coral cover at 10m was slightly higher in 2022 than seen in 2014.

The main difference on all sites between was an apparent increase in algal cover (green) by 2022. There are three possible explanations for this:

- If there had been a large amount of coral death, algae may be covering the dead coral substrate
- Microbial mats (cyanobacteria), included in the overall algae category, may have increased by 2022.
- As there were different observers recording substrate cover in 2022 than in 2014, the observers may have been recording some algal categories differently.

Percent Substrate Cover: Coral Lifeforms

Coral Lifeforms are expressed as a percentage of all living coral recorded at each site.

- *Acropora* corals in shades of orange
- non-*Acropora* corals in shades of blue
- *Millepora* (Fire) coral in red
- Soft corals in yellow
- Sponge in green
- Other (mainly gorgonians, ascidians, hydroids) in white

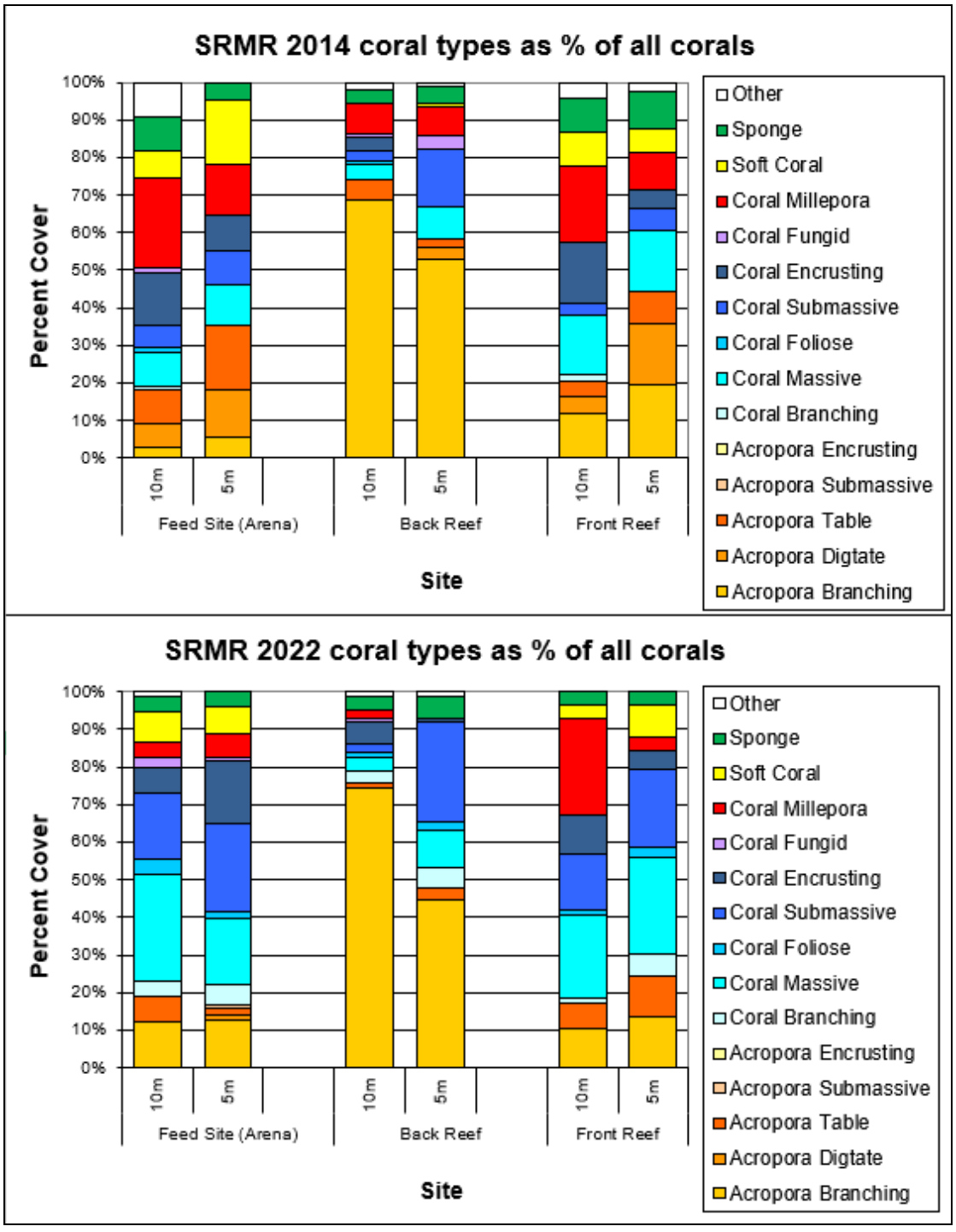


FIGURE 12: BAR CHARTS SHOWING PERCENT OF CORAL LIFEFORMS ON SRMR 2014 VS 2022

In both survey periods, the SRMR Back Reef was dominated by much higher levels of *Acropora* corals than either of the Front Reef sites, mostly due to very large stands of two main types of branching and bottlebrush corals flourishing in the sheltered sandy slope of the back reef. Many of these were bleached or partially bleached at the time of survey.

In the Front Reef sites, at both site 1 the shark feed site and at site 2, the site remote from the feed sites, and in both survey years, *Acropora* coral cover was higher at 10m deep, whilst the 5m transects had higher levels of non-*Acropora* massive (predominantly *Porites* and *Goniastrea*), submassive (predominantly *Pocillopora*) and encrusting corals. *Millepora* fire coral and soft corals were also seen on the front reefs more than on the back.

Acropora coral had declined on the front reef site, and in place higher levels of *Porites* and *Goniastrea* massive and *Pocillopora* submassive corals were seen, some bleached or recovering from bleaching. This may be due to impacts of coral bleaching, *Acanthaster planci* crown of thorns starfish outbreaks or breakage from storm and cyclone wave action, all of which tend to affect *Acropora* more than other corals.

Bleached and unbleached branching and bottlebrush *Acropora* on SRMR Back Reef

Partially bleached massive *Goniastrea* and submassive *Pocillopora* on SRMR Front Reef

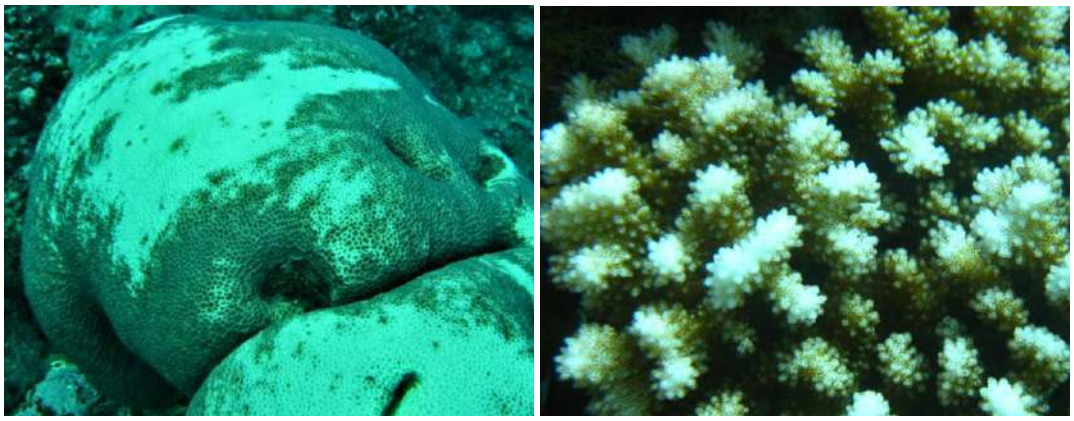


FIGURE 13: PHOTOGRAPHS OF CORALS ON THE SRMR REEFS

Reef Damage in July 2022

In July 2022, after surveys had been completed, a strong wave event damaged the SRMR Front Reef 1 site. Video footage of the reef at 10m depth was taken for a Rapid Assessment of the extent of the damage, which was perceived to be high.

320 seconds of high resolution video was taken at 10m depth on SRMR Front Reef 1 along approximately 100m of reef on the path of the 10m deep Rapid Assessment lines 1, 2, 3 & 4. For analysis the video was paused every 10 seconds to allow substrate types to be recorded under 5 random points marked on a covering screen, a total of 160 points, as recorded on the in-water Rapid Assessment Reef Check survey in May 2022.

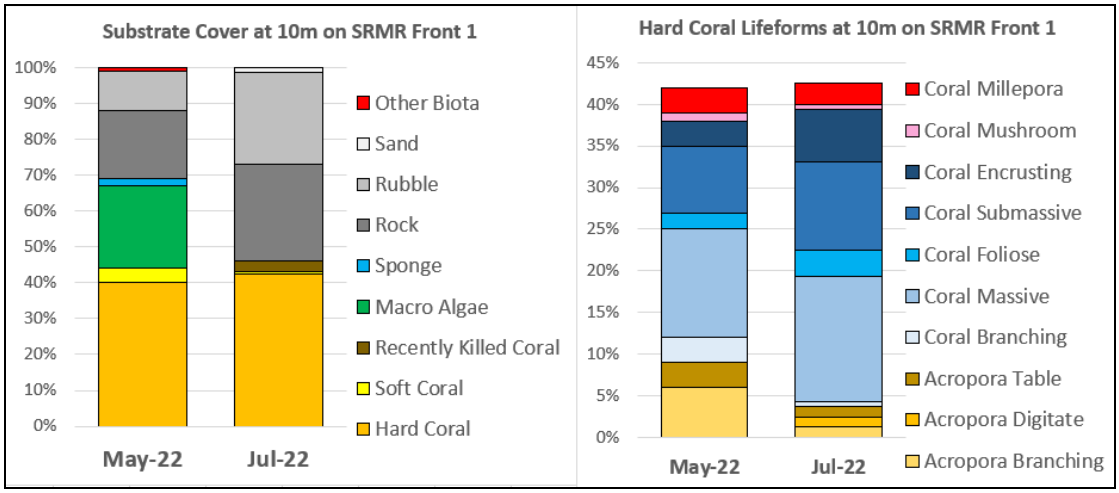


FIGURE 14: BAR CHARTS OF PERCENT COVER OF SUBSTRATE TYPES ON SRMR MAY AND JUNE 2022

Surprisingly, and even in the face of visibly broken coral on the video, the percentage of coral cover barely changed between May 2022 (40% hard coral and 4% soft coral), before the high wave event, and July 2022 (45% hard coral and 1% soft coral) after the event. Of the hard coral seen, there was an obvious decrease in *Acropora* corals, but an apparent increase in massive, submassive and encrusting corals such as *Porites*, *Pocillopora* and *Montipora*.

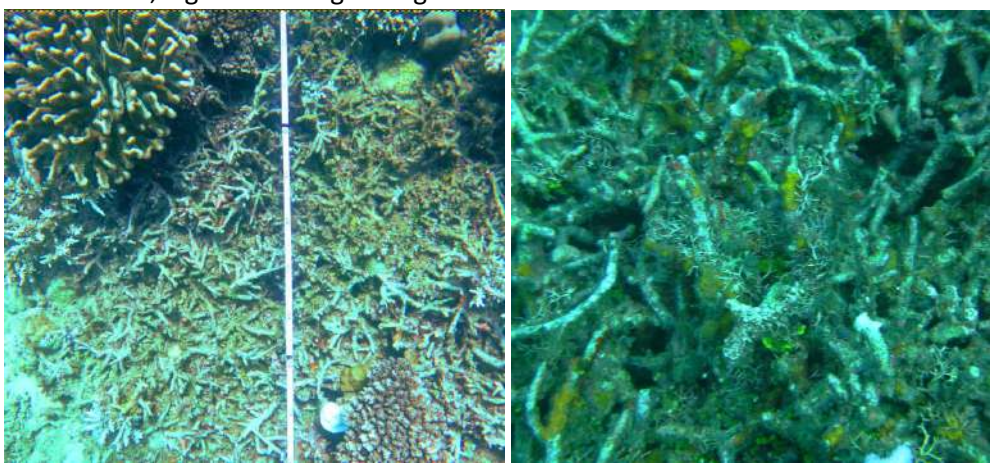
It is not surprising that *Acropora* cover decreased, as these corals are largely fragile, and susceptible to breakage. The apparent increase in other corals cannot be due to coral growth over a two to three month period but is likely to be due to exposure of underlying coral after overgrowing corals have been broken and removed. It also was not possible to tell the state of health of these corals from video footage, and only subsequent surveys will demonstrate whether these corals survived or not.

The most obvious change was the drop in algal cover, which made up 23% of substrate cover in May whilst none was recorded in July. While there may be an element of observer error, as it was not easy to determine whether all rubble was clean or covered with algal turfs from the video, it is presumed that the wave event scoured the rock and rubble substrate clean of algal mats, an assumption supported by the observations of the videographer.

Overall, while the event demonstrably damaged the reef, it is likely that the remaining corals will find substrate clean of algae to expand onto, and that new *Acropora* will quickly re-establish itself. Coral cover is predicted to remain fairly stable, although coral types may be altered for a while.

General reef appearance before (first photo) and after (second photo) the wave event

Intact corals, algal turf overgrowing rock and rubble substrate before the wave event



Broken *Pocillopora eydouxi*, scoured rock and rubble from video taken after the wave event

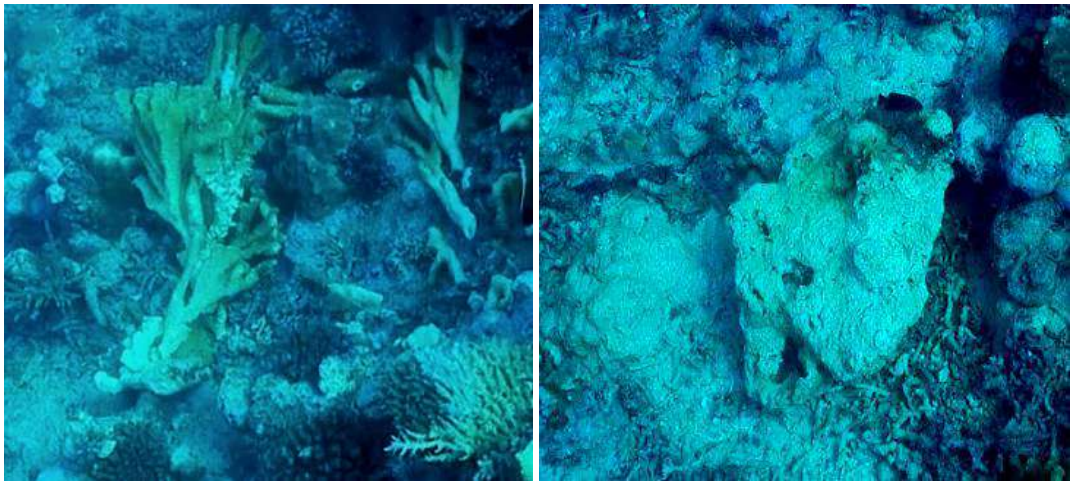


FIGURE 15: PHOTOGRAPHS OF CORAL AND SUBSTRATE BEFORE AND AFTER THE WAVE EVENT OF JULY 2022

Results -Fish and Invertebrate Populations

Key Fish Population Density

Key fish are selected as indicators of fishing pressures or of reef type and health. Counts are expressed as count /100m^2 of reef surface (average of four 20m x 5m belts).

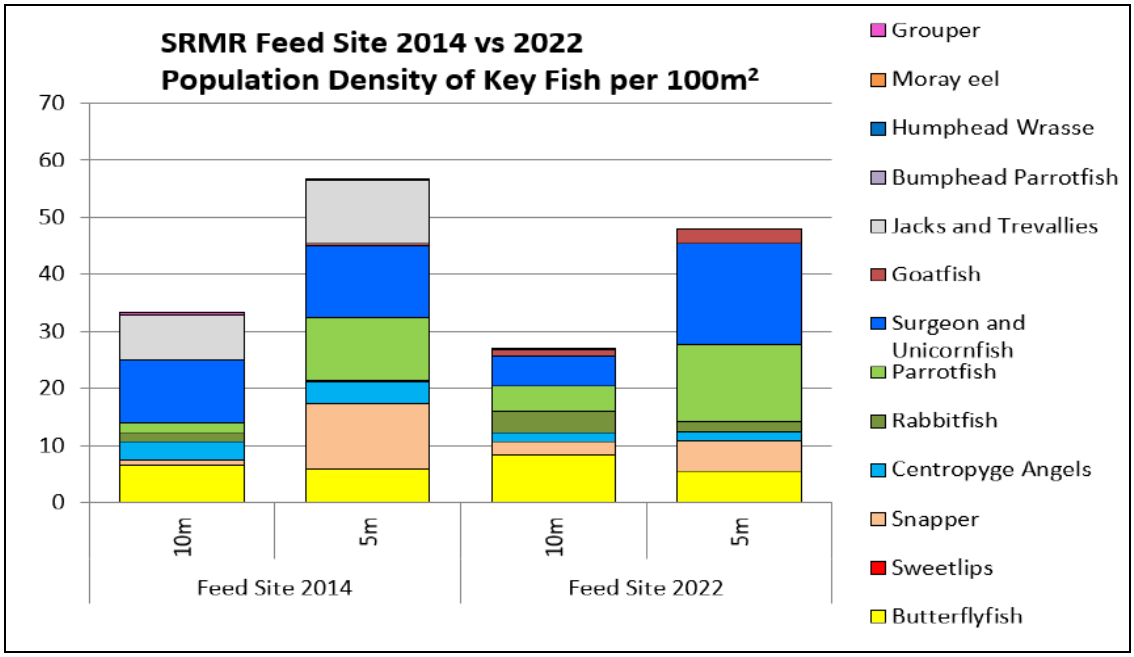


FIGURE 16: BAR CHART OF POPULATION DENSITY OF KEY FISH AT SRMR FRONT REEF 1 SHARK FEED SITE

At SRMR Front Reef 1, the feed site, there was little change between most fish groups from 2014 to 2022, although there were more fish at 5m than at 10m during both periods. The main change seen was the absence of Jacks and Trevallies *(Carangidae)* at both depths since 2014, and a decrease in numbers of Snappers *(Lutjanidae)* at 5m. In both survey periods there were no or very low number of Groupers *(Serranidae)* and Sweetlips *(Haemullidae),* fish favoured by spearfishers.

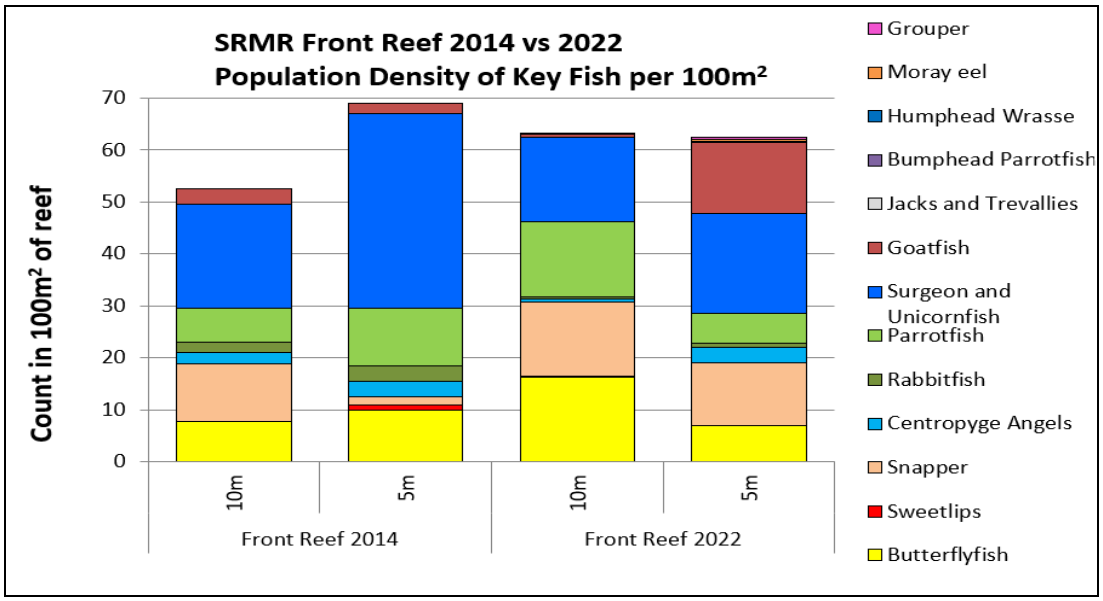


FIGURE 17: BAR CHART OF POPULATION DENSITY OF KEY FISH AT SRMR FRONT REEF 2 REMOTE SITE

At SRMR Front Reef 2, remote from the Feed Site, fish numbers were the highest recorded during both survey periods, with schools of Snappers *(Lutjanidae)* and large numbers of Parrotfish *(Scaridae)* and Surgeon/ Unicornfish *(Acanthuridae).* In 2022 schools of Goatfish *(Mullidae)* were present at 5m, but not at 10m or in 2014.

Fish numbers were much higher at the Remote Site (50 – 70 fish per 100m^2 of reef) than at the Feed Site (25 – 55) at both depths and both survey periods.

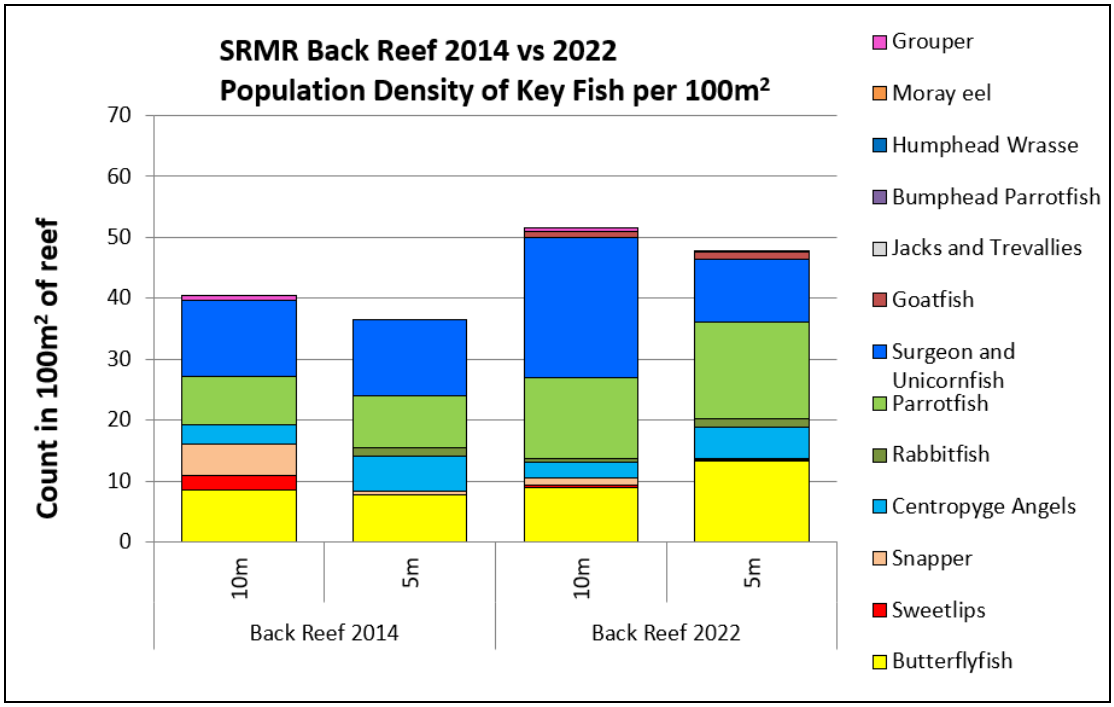


FIGURE 18: BAR CHART OF POPULATION DENSITY OF KEY FISH AT SRMR BACK REEF

At the SRMR Back Reef, overall fish numbers were similar to the Feed Site, but made up of more Surgeonfish *(Acathuridae)* and Parrotfish *(Scaridae)* than Snappers *(Lutjanidae).*

There was little difference between the survey periods, apart from the decrease in Sweetlips *(Haemullidae)* and Snappers *(Lutjanidae)* at 10m.

Indicator Fish Population Density

- ***Indicators of reef type****:*
  Butterflyfish *(Chaetodontidae)* – corallivores and omnivores, related to coral cover, *Centropyge* Dwarf Angelfish *(Pomanthidae)* and Rabbitfish *(Siganidae)* – herbivores and omnivores, related to algal cover.
- ***Food Fish – fish often gathered for subsistence food or sale.***
  Surgeon/Unicornfish *(Acanthuridae),*Parrotfish *(Scaridae)* and Snappers *(Lutjanidae).*
- ***Targeted Fish – fish often targeted by spearfishers for sale or subsistence food.***
  Groupers *(Serranidae),* Jacks/ Trevallies *(Carangidae)* and Sweetlips *(Haemullidae).*

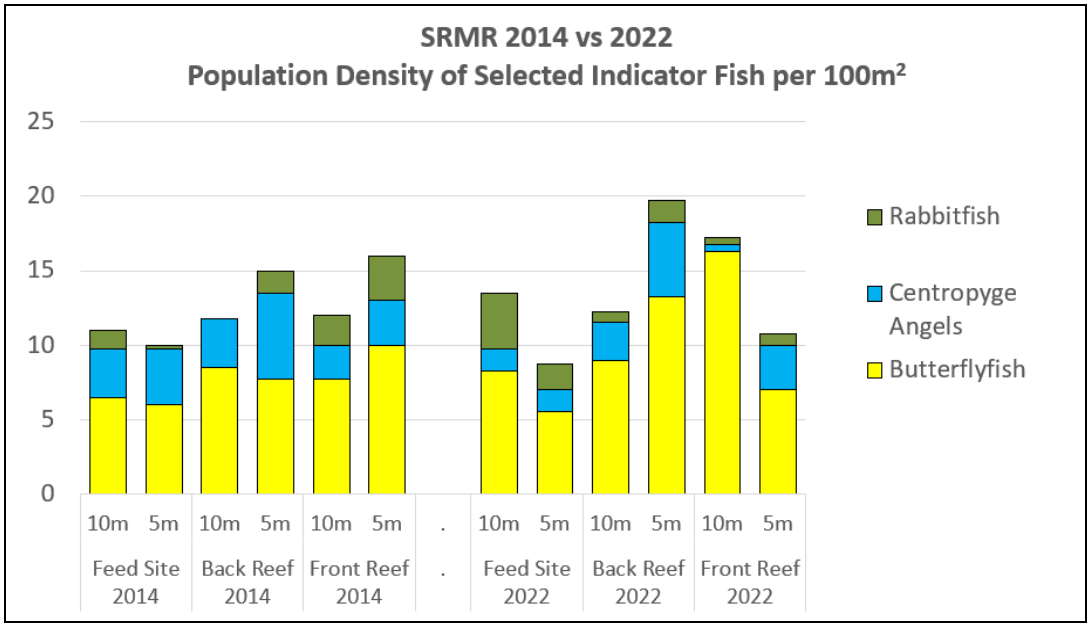


FIGURE 19: BAR CHART OF POPULATION DENSITY OF FISH INDICATORS OF REEF TYPE

Overall, **Indicators of reef type** numbers were not majorly changed between 2014 and 2022.

Butterflyfish numbers were slightly higher at 5m on the Back Reef and at 10m on the Front Reef than seen in 2014, or at other depths and sites. Dwarf Angelfish and Rabbitfish were seen in similar numbers at most sites, depths and periods.

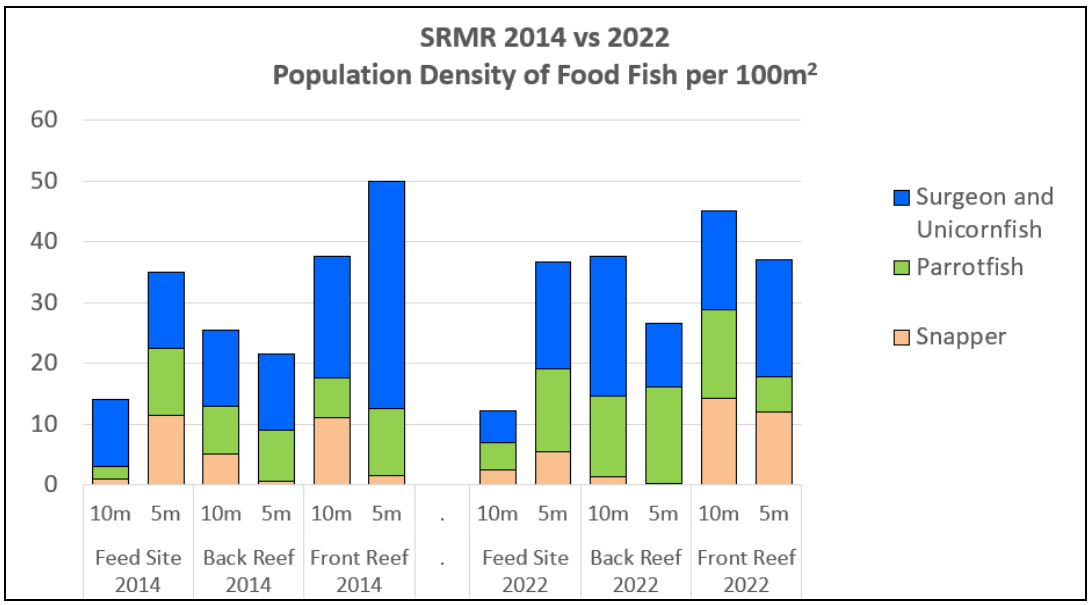


FIGURE 20: BAR CHART OF POPULATION DENSITY OF FISH INDICATORS OF FISH TAKEN FOR SUBSISTENCE

Food Fish were found in similar densities at most sites and periods. In both surveys there were far fewer of these fish seen at 10m at the Feed Site than at other areas.

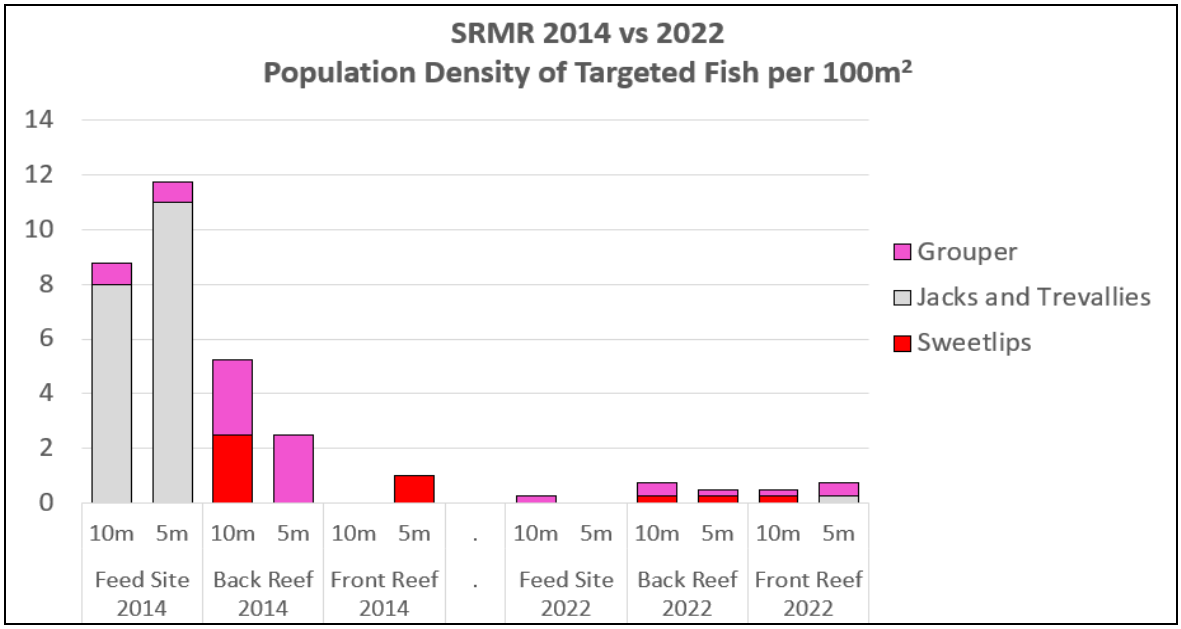


FIGURE 21: BAR CHART OF POPULATION DENSITY OF FISH INDICATORS OF TARGETED FISHING

Targeted Fish, although always seen in much lower numbers than other fish, fell in 2022 from the 2014 numbers.

The greatest difference was in the absence of Jacks/ Trevallies from the Feed Site, which may be related to fishing or to a reduction in shark feeding activities in 2020 – 2021.

Sweetlips and Groupers were always found in very low numbers but were reduced in 2022 from 2014 densities, particularly from the Back Reef.

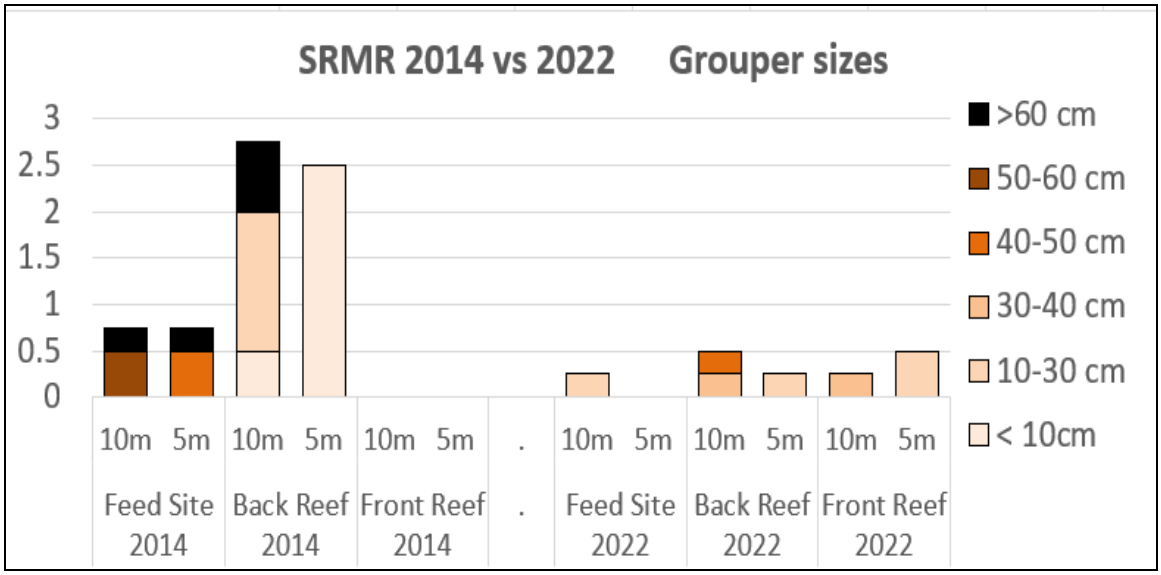


FIGURE 22: BAR CHART OF GROUPER SIZES

The Groupers recorded in 2022 were much smaller than those seen in 2014.

Key Macro-Invertebrate Population Density

Key macro-invertebrates are selected as indicators of specific criteria, some relating to fishing pressures, others to reef type and health. Counts of these key invertebrates are expressed as counts per 100m^2 of reef surface (20m x 5m belts).

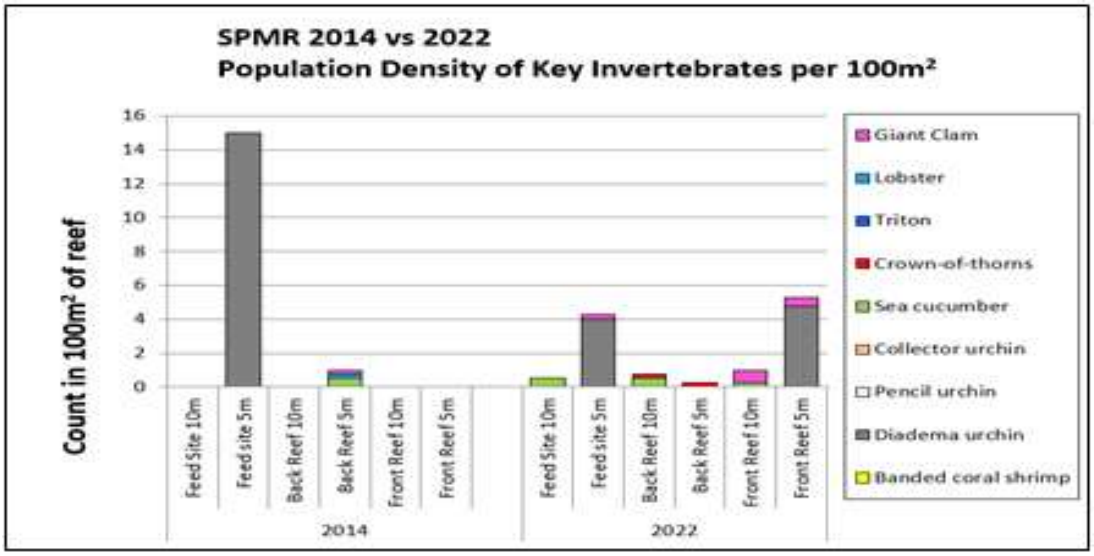


FIGURE 23: BAR CHART OF POPULATION DENSITY OF KEY MACRO-INVERTEBRATES

By far the most common macro-invertebrate recorded were small *Echinothrix diadema* sea urchins, frequently found in large groups deep in small holes in the reef substrate.

Other invertebrates were found in population densities of less than one per 100m^2 of reef, as shown in the following graph with the sea urchins removed.

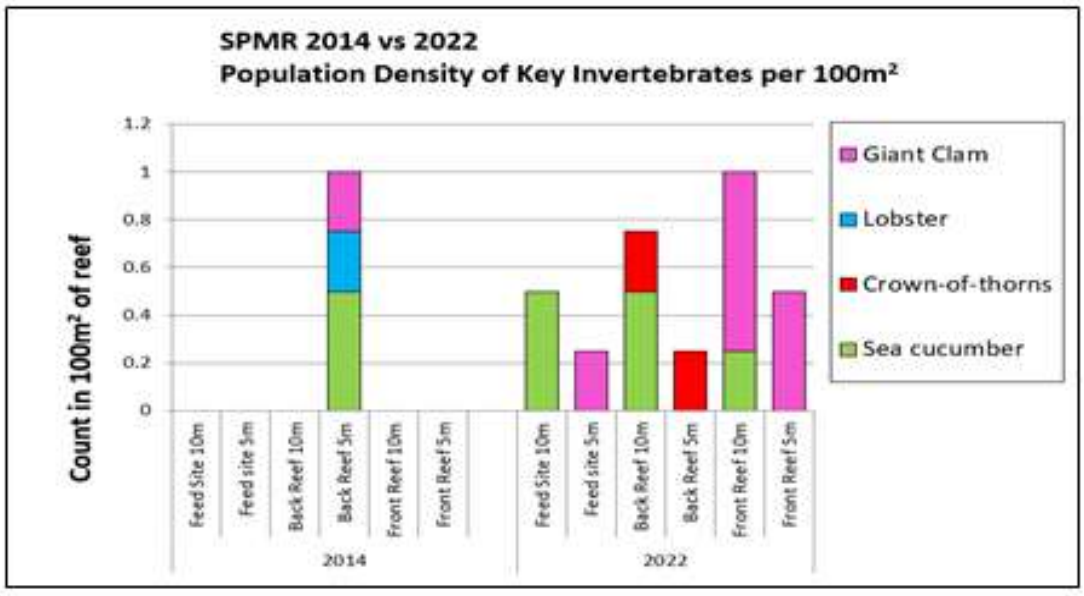


FIGURE 24: BAR CHART OF POPULATION DENSITY OF KEY MACRO-INVERTEBRATES WITHOUT SEA URCHINS

A few sea cucumbers and giant clams were found, as well as a few *Acanthaster planci* crown of thorns coral predatory starfish on the back reef in 2022.

Although more invertebrates were found in 2022 than in 2014, at these low numbers this is not considered a significant change.

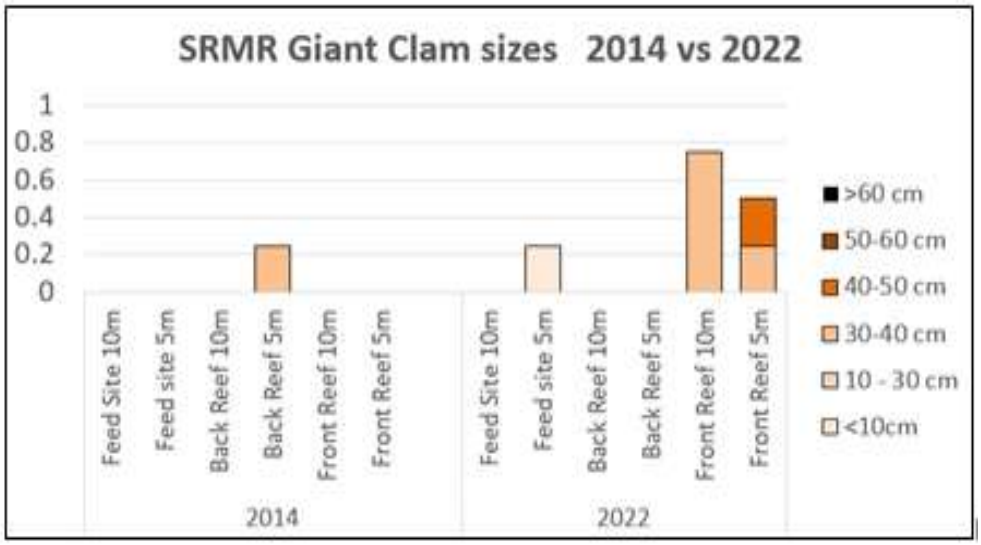


FIGURE 25: BAR CHART OF GIANT CLAM SIZES

Of the few *Tridachna* spp giant clams that were recorded, the one seen in 2014 was 30 – 40 cm long (longest axis of mantle), whilst the ones seen in 2022 ranged from very small, under 10cm, to mature sizes 30 – 50cm. Although the numbers were low, the range of sizes suggests that there is the basis for a healthy population.

Discussion of Rapid Assessments of SRMR 2014 – 2022

Overall, the Rapid Assessment survey showed considerable similarities of reef character and populations at SRMR in 2014 and 2022, a period of eight years which covered multiple stress events. As an example, surveys before and after a strong coral-damaging wave event in June 2022 showed that stressors may change coral type without affecting overall coral cover. This demonstrates the high resilience and recovery potential of many reefs in Fiji, and the stable character of SRMR in particular

It would appear that this reef is well able to withstand and/ or recover quickly from natural pressures and impacts, although the increase in algal cover in 2022, if actual and not observer error, may indicate an increase in nutrient flow from the nearby watershed of Viti Levu, (as shown in the Introduction, Water Quality). As this was reported from all areas of SRMR it is not likely to be a result of adding natural fish off-cuts as used in shark feeding to the environment. Algal cover on SRMR was reduced by the wave event in June 2022, leaving clean substrate that could allow for elevated coral settlement after spawning occurs in October and November. This could be further reduced if algal grazers such as sea cucumber numbers were increased.

One of the factors of concern over this period was the potential impact of illegal fishing through the years 2020 - 2021 when many protected areas suffered from poaching due to lack of other income during the Covid-19 global pandemic.

Although combined key indicator fish numbers did not appear to decrease, there was an obvious reduction in the type of fish which are largely targeted for sale, probably at markets or along the roadside, such as trevallies/ jacks and larger groupers, strongly indicative that poaching has occurred.

Further comments on fish abundance and biomass can be found in Section 2.

Section 2
Extended Surveys of Marine Life in SRMR vs Combe Reef

Photo credit: Natasha Marosi

A suite of surveys was carried out in 2022 at three sites and two depths within the SRMR and compared with surveys carried out within the same time period at three sites and two depths at Combe Reef, an area with no protection from fishing, approximately 5 Km from SRMR (see Section 1, Figure 1).

Methods:

For the Extended Survey, data was gathered from three 50m belts at each site and depth:

- Three replicate 50m x 100-point Intercept transects for substrate cover to lifeform categories and coral genera**
- Colony counts in 1m^2 quadrats for coral bleaching and coral genera (two sites only)
- Three replicate 50 x 5m (250m^2) belt transects for fish abundance and size class, identified to species level

** For comparison with substrate cover from the Rapid Assessment in Section 1, data from four 20m lines was extracted from ES lines 1 and 2.

Photo Credit: Tom Vierus

FIGURE 26: DR AMANDA FORD AND DR SANGEETA MANGUBHAI CARRYING OUT EXTENDED SURVEYS

FIGURE 27: NATASHA MAROSI OF BEQA ADVENTURE DIVERS RECORDING INDICATOR FISH

Results – Substrate cover and diversity

Percent Substrate Cover

Averages of four x 20m lines extracted from ES lines 1 and 2

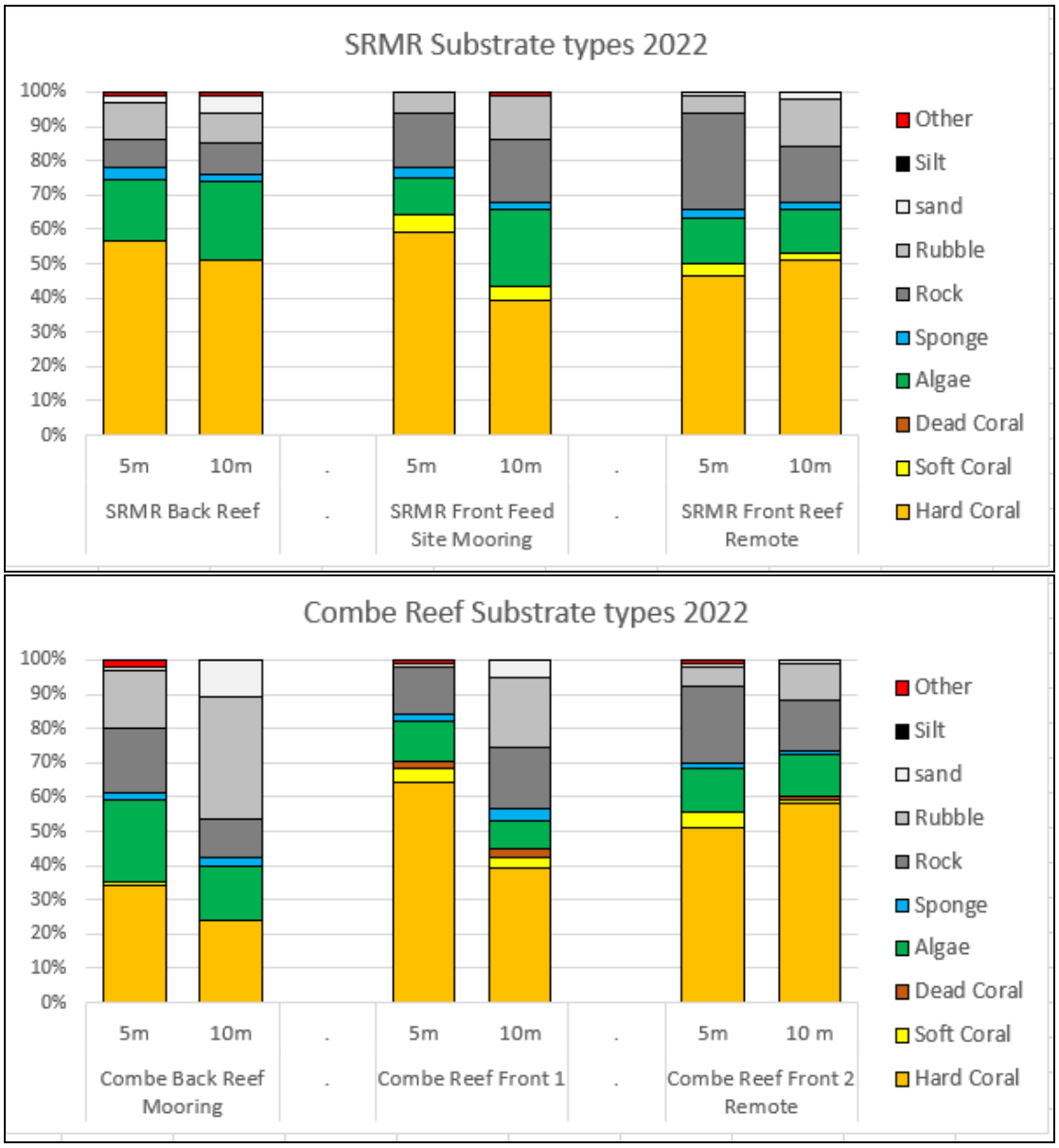


FIGURE 28: BAR CHART OF PERCENT COVER OF BASIC SUBSTRATE TYPES ON SRMR AND CR 2022

On both SRMR and Combe Reef the Front Reef sites were physically comparable, with coral cover between 40% and 65% and algal cover between 8% and 23%. On both reefs the Front 1 sites had higher coral cover at 5m than at 10m, while the Front 2 reefs were very similar at both depths.

There was more difference in reef character between the back reefs, with SRMR having coral cover of 51% and 57% at 5m and 10m respectively, but Combe Reef having only 34% and 24% respectively. Although this means that the two back reef sites are not the best for paired comparison, exploration of the rest of the Combe back reef yielded only sand and rubble slopes with extremely low amounts of coral cover, so it remains the best site to be found.

Percent Coral Lifeform cover

Averages of four x 20m lines extracted from ES lines 1 and 2
Coral Lifeforms are expressed as a percentage of all living coral recorded at each site.

- *Acropora* corals in shades of orange and yellow
- non-*Acropora* corals in shades of blue and green
- *Millepora* (Fire) coral in red
- soft corals in purple

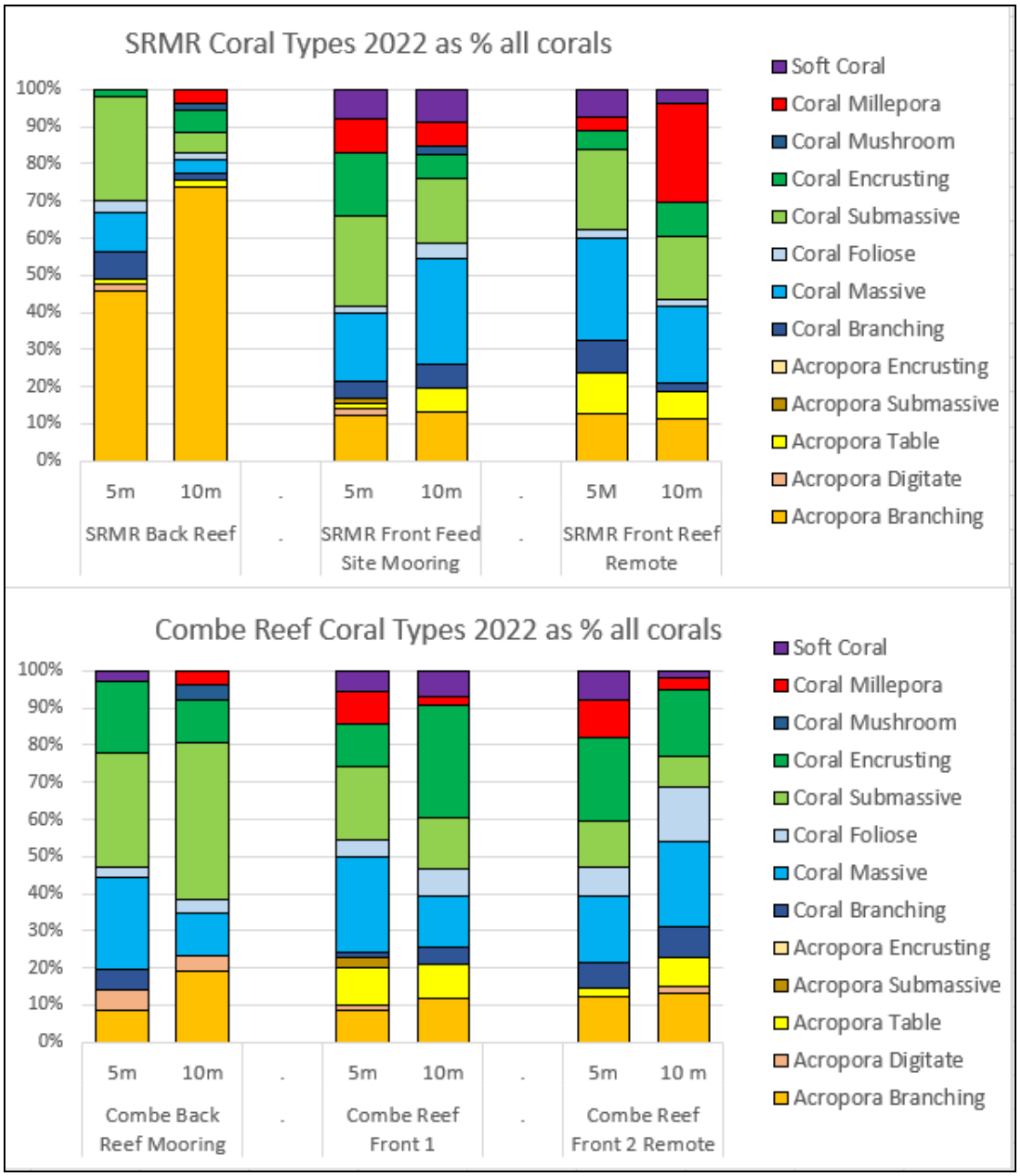


FIGURE 29: BAR CHARTS OF PERCENT OF CORAL LIFEFORMS ON SRMR AND CR 2022

The back reefs of SRMR and Combe Reef were, as discussed, very different in coral character from each other, whilst the front reef sites were quite similar in lifeform make up.

On the front reefs *Acropora* corals made up between 10% and 20% of all hard coral recorded, and other non-*Acropora* hard corals, predominantly massive, submassive and encrusting forms such as *Porites*, *Pocillopora* and *Montipora,* made up between 50% and 70%.

Millepora (fire) coral was more common on the front reefs than on the back, and in most cases made up a higher proportion of hard corals at 5m than at 10m, with the exception of the 10m transects on SRMR Front 2, where around 25% of all hard corals were *Millepora*.

The greatest difference seen was the SRMR back reef where between 50% and 70% of all corals recorded were *Acropora*, a very sensitive and unusual habitat for the area.

Branching and "bottlebrush" *Acropora* corals

Photo credit: Tom Vierus

FIGURE 30: PHOTOGRAPHS OF LARGE STANDS OF *ACROPORA* CORALS AT THE SRMR BACK REEF

Coral Genera on each Reef

Over all three sites and two depths combined, a total of 1,800 substrate points were recorded on each reef, SRMR and CR, along the 50m ES transect lines (300 points per three-line transect x six transects per reef)

Of these, living coral made up 55% of SRMR points and 48% of CR., with a total of 43 hard coral genera recorded; an average of 21 genera on SRMR and 23 genera on Combe Reef.

Acropora coral was the most common genus on both reefs, although it made up a higher percentage of SRMR coral (32%) versus 17% of CR corals, due to the exceptionally high *Acropora* cover on the SRMR back reef. Otherwise, the coral genera make-up of the two reefs was very similar.

Pocillopora was found at similar levels on both reefs; 12% of SRMR and 14% of CR, as were massive forms of *Porites* with 13% of SRMR and 11% of CR, and identical levels of *Porites rus*, 6% on both reefs. Soft corals also made up identical amounts of each reef, 4%.

Large *Diploastrea* massive corals, encrusting or submassive *Montipora* and branching *Stylophora* were more common on CR than on SRMR, with *Diploastrea* making up 9% and 3%, Montipora 12% and 6%, and *Stylophora* 3% and 1%, respectively.

Coral genera seen in smaller numbers are recorded in the data table in the Appendix.

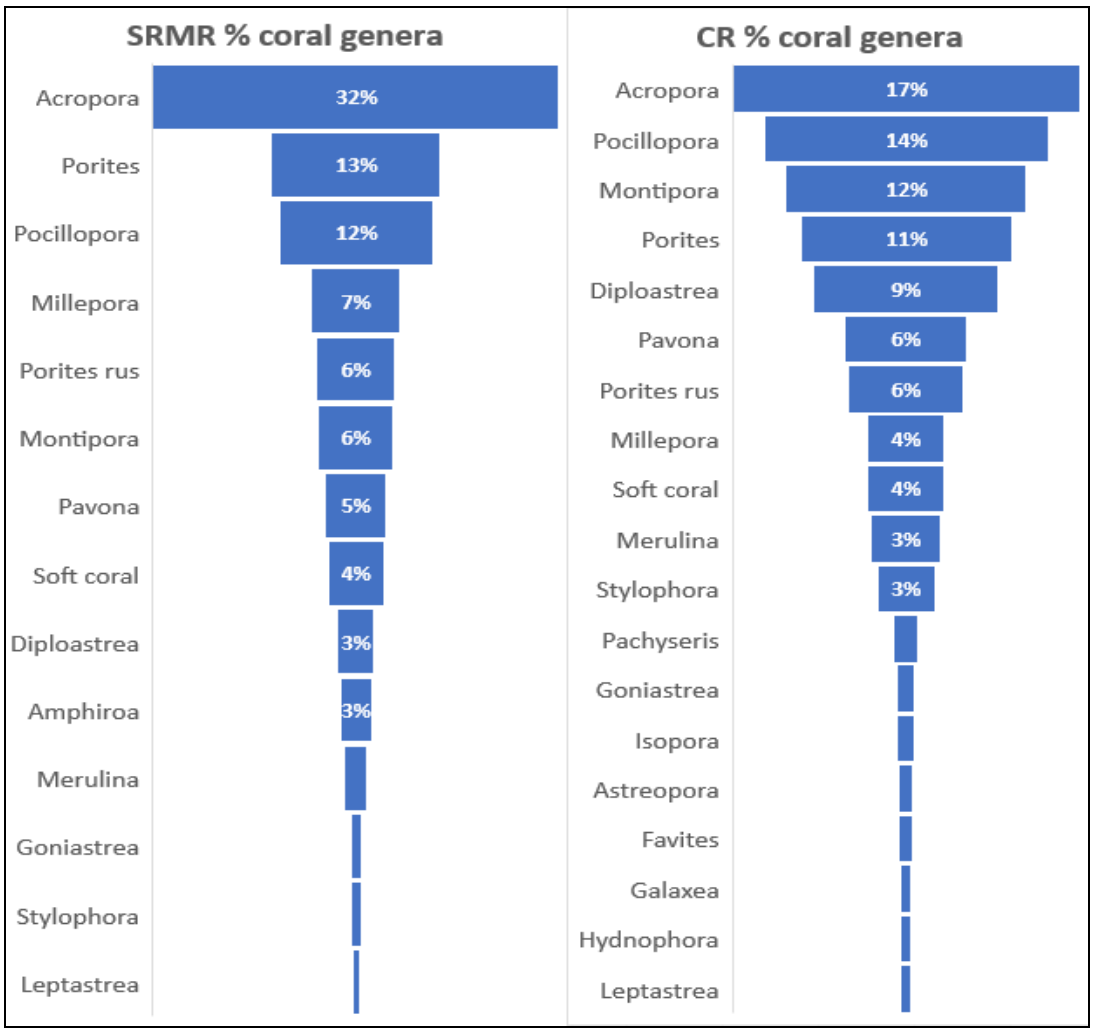


FIGURE 31: FUNNEL CHARTS OF COMMONNESS OF CORAL GENERA ON SRMR AND CR 2022

Percent Substrate Cover Algae and other Biota

Averages of four x 20m lines extracted from ES lines 1 and 2

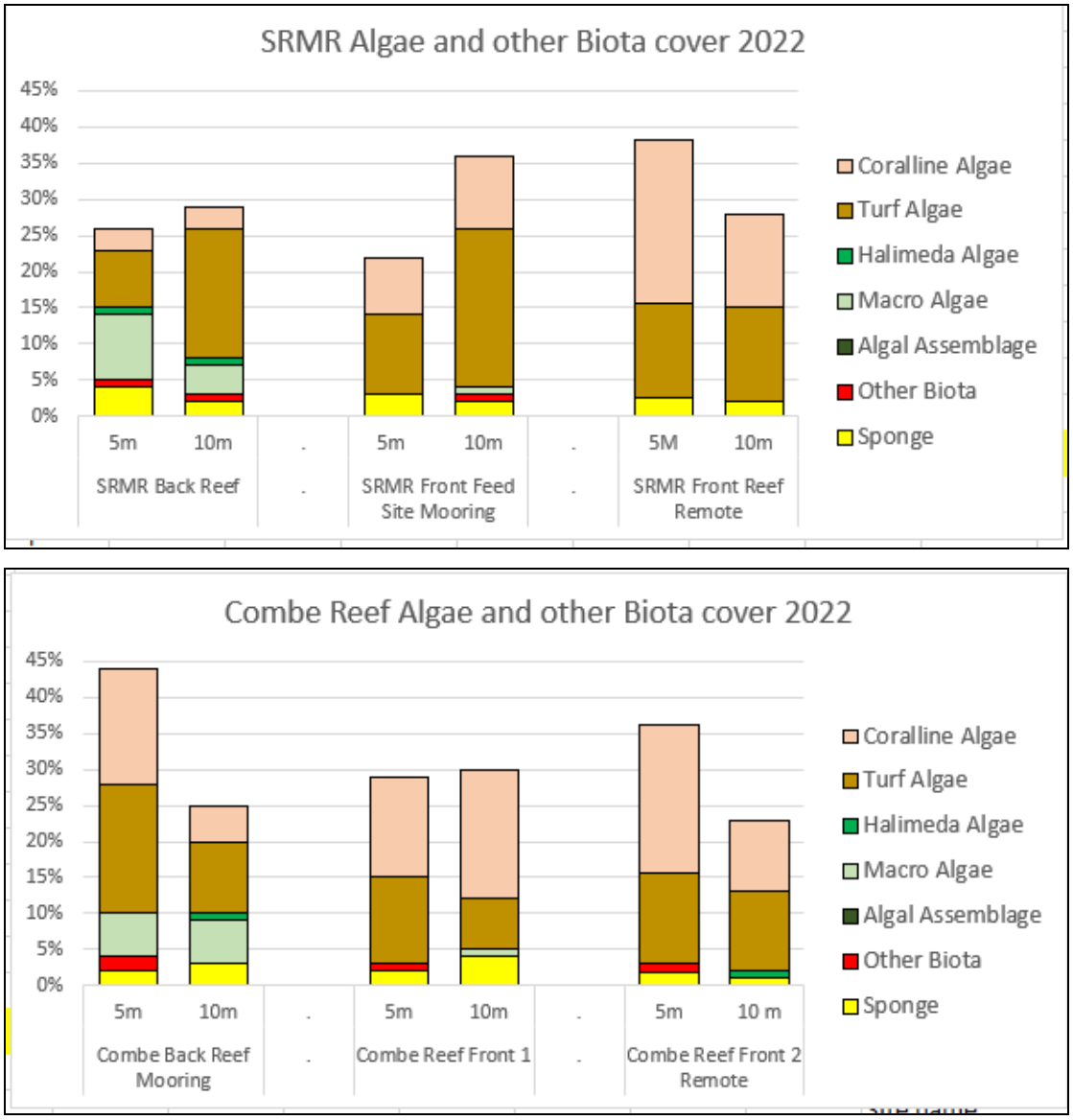


FIGURE 32: BAR CHARTS OF PERCENT COVER OF ALGAE AND OTHER BIOTA ON SRMR AND CR 2022

Total algal cover was similar on both reefs, although slightly higher at 5m on Combe Back Reef than other transects. The back of both reefs had higher macro-algal cover than the front reefs. Sponge cover was low (less than 5%) on all transects, as was *Halimeda* algae.

Turf algae, including mats of red filamentous cyanobacteria, was quite high in all areas (7% to 22%) but particularly so at 10m on SRMR Back and Front 1 sites. As discussed in Section 1, a great deal of this algae was removed during a high wave event in July 2022, after these surveys were completed, creating new bare substrate available for new coral settlement.

Coral Bleaching in April 2022

The bleaching level of coral colonies was recorded in 1m^2 Quadrats at 2 sites at the end of April/ start of May when the water temperatures were dropping from an extended period of warm water with average daily water temperatures at 10m deep of 29 to 30°C[3]

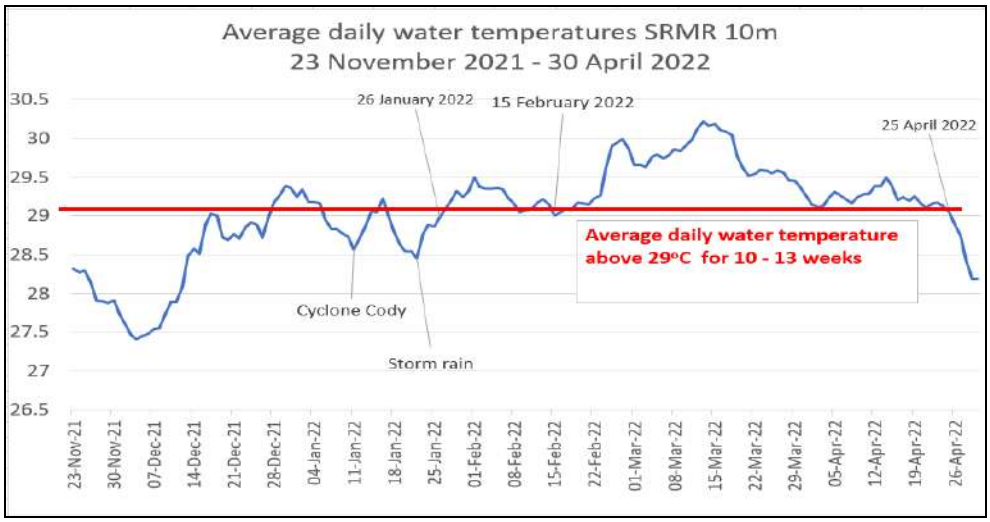


FIGURE 33: GRAPH OF AVERAGE DAILY WATER TEMPERATURES AT SRMR 23 NOV 2021 TO 25 APRIL 2022

In Fiji, previous mass mortality from coral bleaching has been seen when daily average water temperatures have been consistently over 29°C for more than 6 – 8 weeks[4].

Partial to full bleaching was seen on all sites and depths during this survey period, but dead coral cover was low. SRMR was more affected on the back reef, where *Acropora* corals made up a higher percentage of coral cover, than on the front reef. Although no detailed data was collected from Combe Reef due to personnel limitations, general observations and photographs suggested that bleaching levels were similar at both reefs.

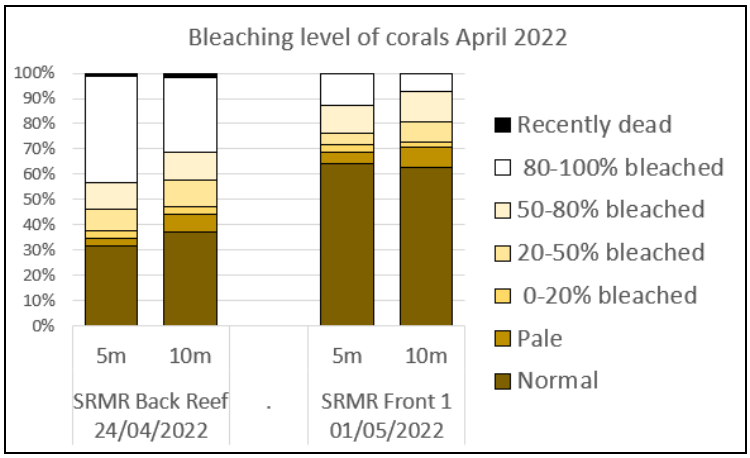


FIGURE 34: BAR CHART OF BLEACHING LEVELS AT SRMR IN APRIL/ MAY 2022

[3] Data from Hobo U22 logger, recording every 2 hours, Fiji Coral Reef Monitoring network.

[4] Cumming, R.L., Toscano, M.A., Lovell, E.R., Carlson, B.A., Dulvy, B.A., Hughes, A., Koven, J.F., Quinn, N.J., Sykes, H.R., Taylor, O.J.S., Vaughan, D. Mass Coral Bleaching in the Fiji Islands 2000. Proceedings of the 9th International Coral Reef Symposium, Bali.

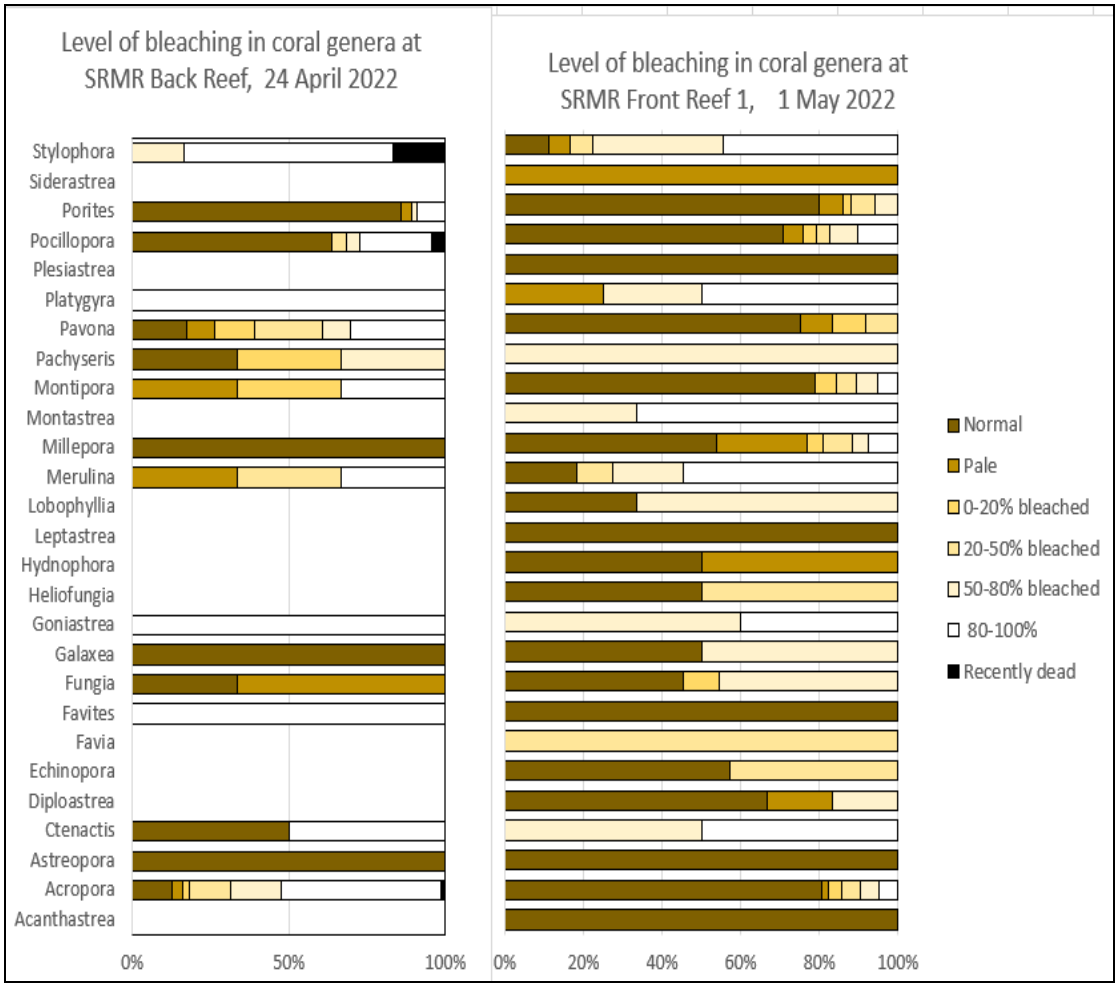


FIGURE 35: BAR CHART OF CORAL BLEACHING LEVEL IN CORAL GENERA ON SRMR APRIL/ MAY 2022

The SRMR back reef had fewer genera than the front reef, dominated by *Acropora, Pocillopora* and *Pavona*. This was probably related to the difference in habitat and in poorer cooling by water circulation, which strong wave action brings to the front reef. Genera that had not bleached or been little affected by bleaching by the end of April included *Porites, Plesiastrea, Leptastrea, Astreopora and Acanthastrea*. Of these five genera, the last four were only found in very small numbers, and so cannot be considered representative.

Bleaching affected most coral genera, with the most extensive bleaching seen in *Stylophora, Platygyra*, *Merulina, Favites,* and *Ctenactis* (mushroom corals) and, on the back reef, *Acropora*.

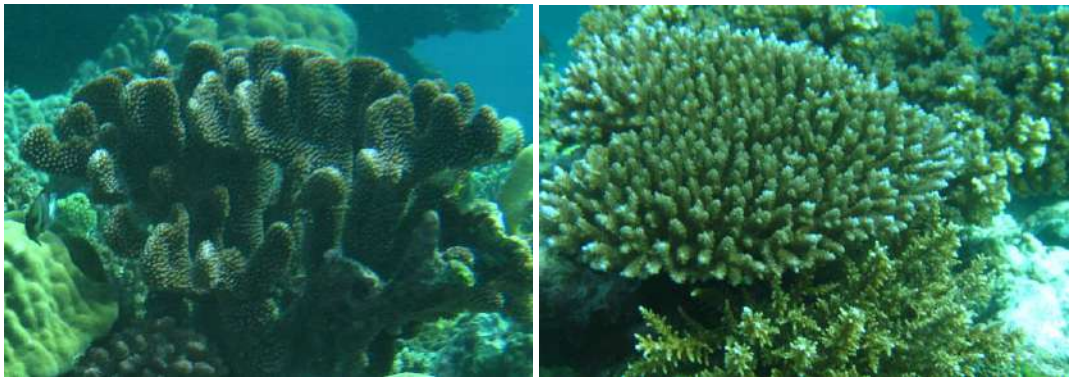
Corals that bleached more on the back reef than on the front reef included *Platygyra, Montipora, Goniastrea, Favites* and *Acropora.*

A few corals on all sites exhibited bright or fluorescent colours. Recent research[5] suggests that these may be due to corals evolving pigments to protect them from bleaching once zooxanthellae algae have been lost.

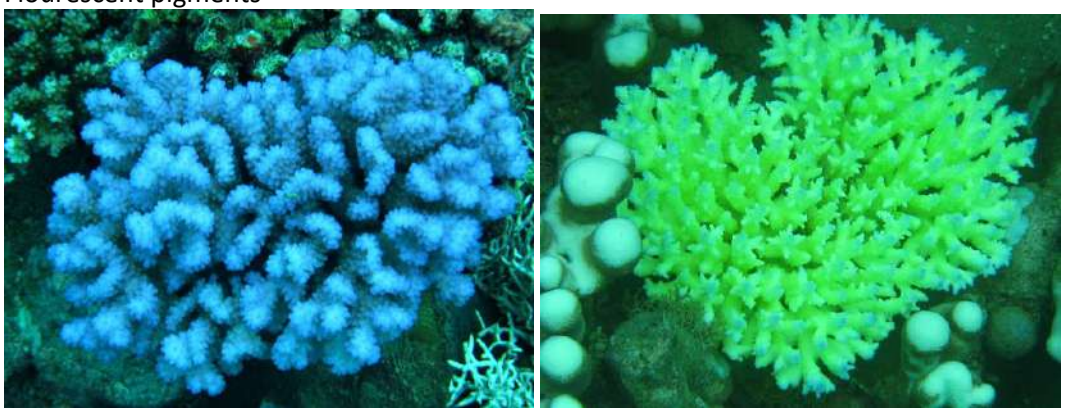
[5]Bollati et al., 2020, Optical Feedback Loop Involving Dinoflagellate Symbiont and Scleractinian Host Drives Colorful Coral Bleaching
Current Biology 30, 1–13 July 6, 2020 Crown Copyright ª 2020 Elsevier Inc
https://doi.org/10.1016/j.cub.2020.04.055

FIGURE 36: PHOTOGRAPHS OF TYPICAL BLEACHING EXTENT ON COMBE REEF FRONT MAY 2022

Unbleached coral colonies



Flourescent pigments



Partial or patchy bleaching

Fully bleached colonies

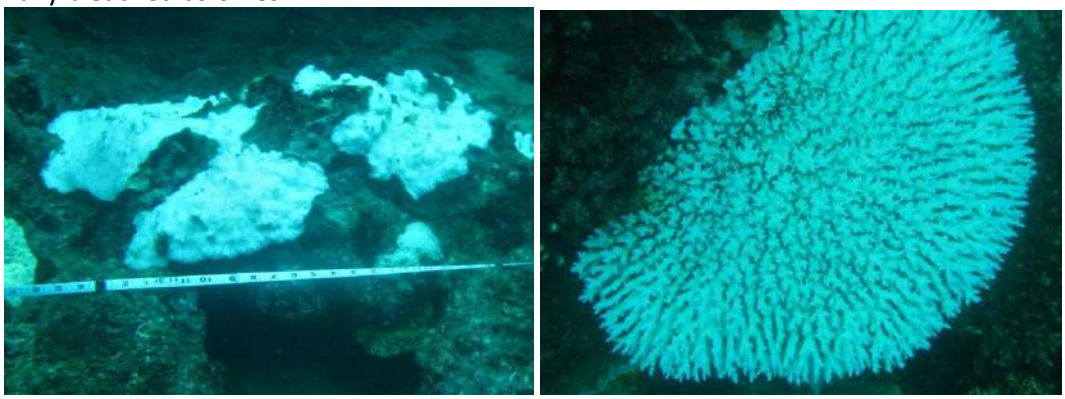
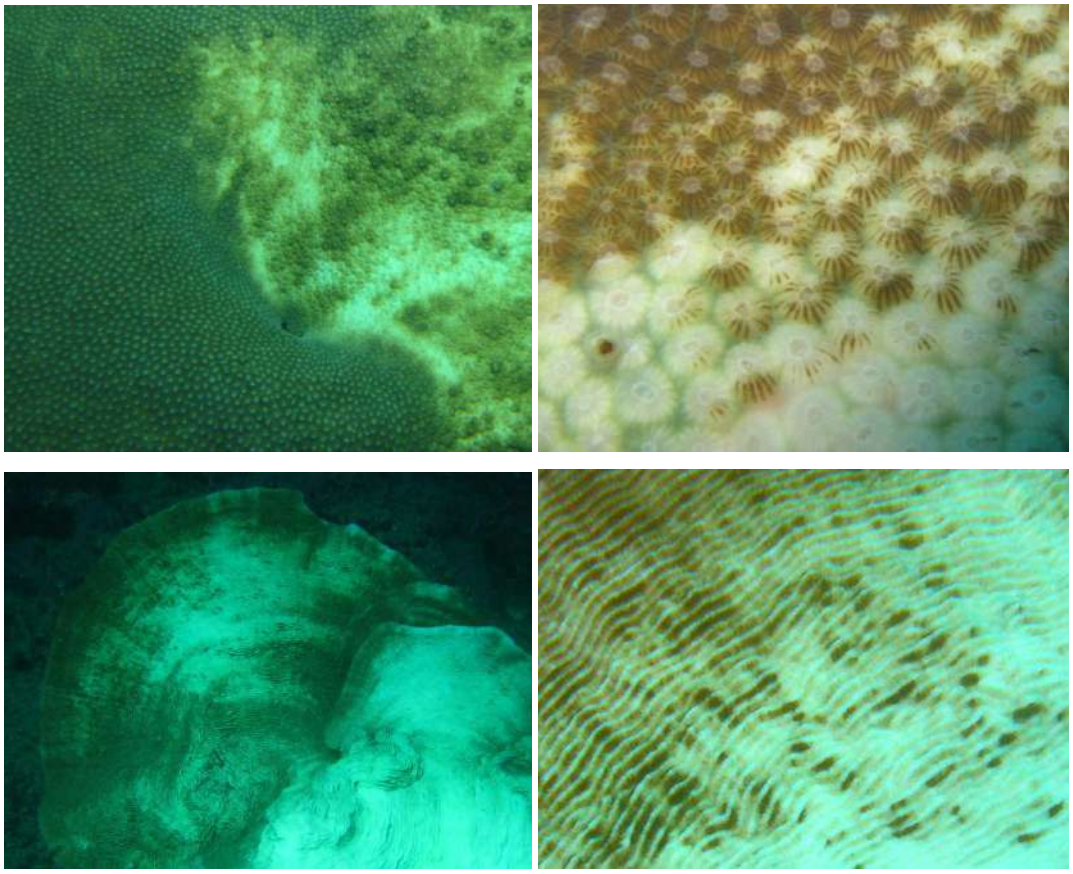
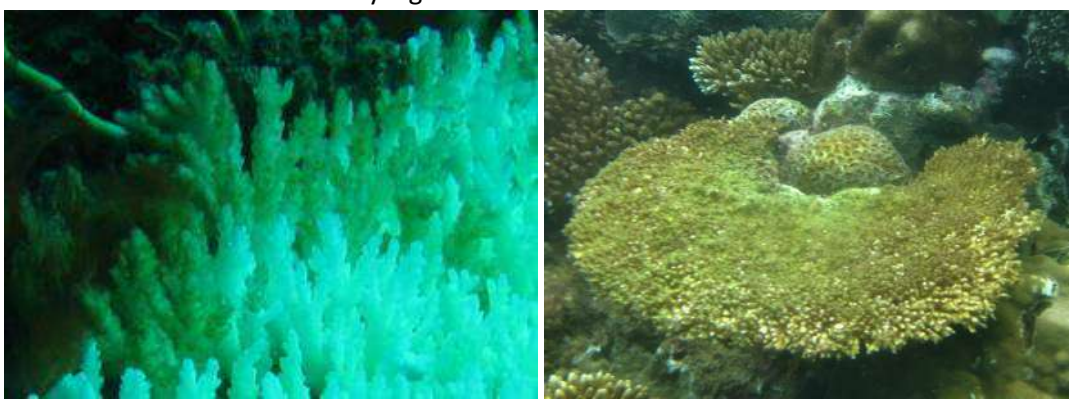


FIGURE 37: PHOTOGRAPHS OF CORAL BLEACHING LEVELS ON COMBE REEF FRONT MAY 2022

Recovery from bleaching - recolonisation of corals by zooxanthellae



Coral death and colonisation by algal turfs



Coral death and colonisation by red filamentous cyanobacteria

FIGURE 38: PHOTOGRAPHS OF POST BLEACHING CORALS ON COMBE REEF FRONT JUNE 2022

Results – Fish abundance, biomass and diversity

Fish Species

A total of 169 targeted fish species were counted over the combined reef systems. Diversity (no. of species) on each reef was virtually the same, with 140 species recorded on Combe reef and 147 on SRMR.

TABLE 8: FISH FAMILIES RECORDED FOR ABUNDANCE AND BIOMASS

Common Name	*Scientific name*
Surgeonfish and Unicornfish	*Acanthuridae*
Triggerfish	*Balistidae*
Fusiliers	*Caesionidae*
Jacks and Trevallies	*Carangidae*
Butterflyfish	*Chaetodonotidae*
Porcupinefish	*Diodontidae*
Spadefish aka Batfish	*Ephippidae*
Sweetlips	*Haemulidae*
Chubs and Rudderfish	*Kyphosidae*
Wrasses	*Labridae*
Emperors	*Lethrinidae*
Snappers	*Lutjanidae*
Filefish	*Monacanthidae*
Goatfish	*Mullidae*
Breams	*Nemipteridae*
Sandperch	*Pinguipedidae*
Angelfish	*Pomacanthidae*
Bigeyes	*Priacathidae*
Parrotfish	*Scaridae*
Groupers (not Anthias & Soapfish)	*Serranidae*
Mackerel & Tuna	*Scombridae*
Rabbitfish	*Siganidae*
Barracuda	*Sphyraenidae*
Lizardfish	*Synodontidae*
Puffers	*Tetraodontidae*
Moorish idol	*Zanclidae*

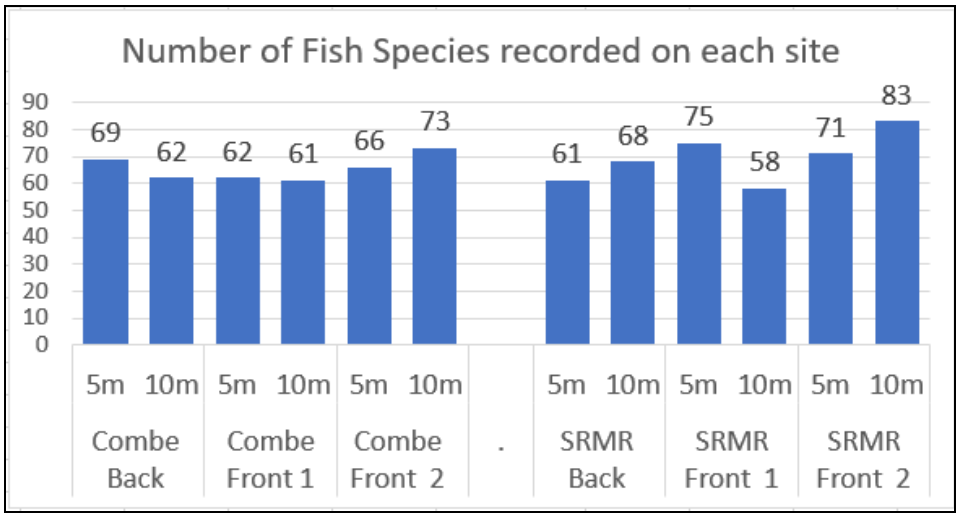


FIGURE 39: BAR CHART OF NUMBER OF FISH SPECIES RECORDED ON EACH SITE

Sites had similar numbers of fish species in the targeted groups, varying from 56 species on SRMR Front 1 at 10m, to 83 species at SRMR Front 2 at 10m.

Fish Abundance

Average number of fish recorded over three 250m^2 ES belts per site excluding non-recorded species such as sharks, *Pomacentridae* (Damselfish) small *Serranidae* (Anthias), *Blenniidae* (Blennies), *Gobiidae* (Gobies) etc.

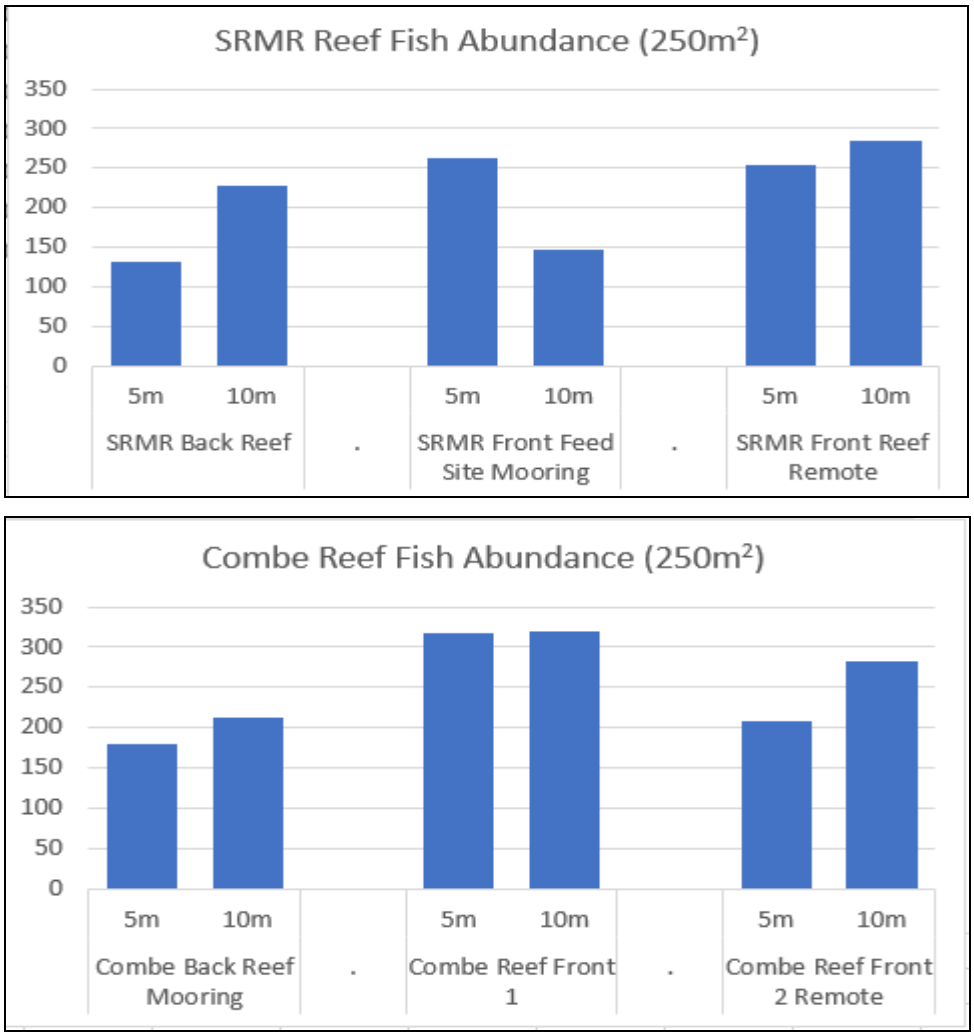


FIGURE 40: BAR CHARTS OF FISH ABUNDANCE AT SRMR AND CR 2022

Overall, fish were more abundant on the front reef sites than the back reefs, with the highest numbers of fish seen at both depths on Combe Reef front site 1, largely due to the presence of schools of *Caesionidae*, fusiliers.

FIGURE 41: PHOTOGRAPH OF SCHOOL OF FUSILIERS AT COMBE REEF FRONT 1

Fish Biomass

Average biomass (expressed as kilograms of fish per hectare or reef) of fish recorded over three 250m^2 ES belts per site excluding non-recorded species such as sharks, *Pomacentridae* (Damselfish) small *Serranidae* (Anthias), *Blenniidae* (Blennies), *Gobiidae* (Gobies) etc.

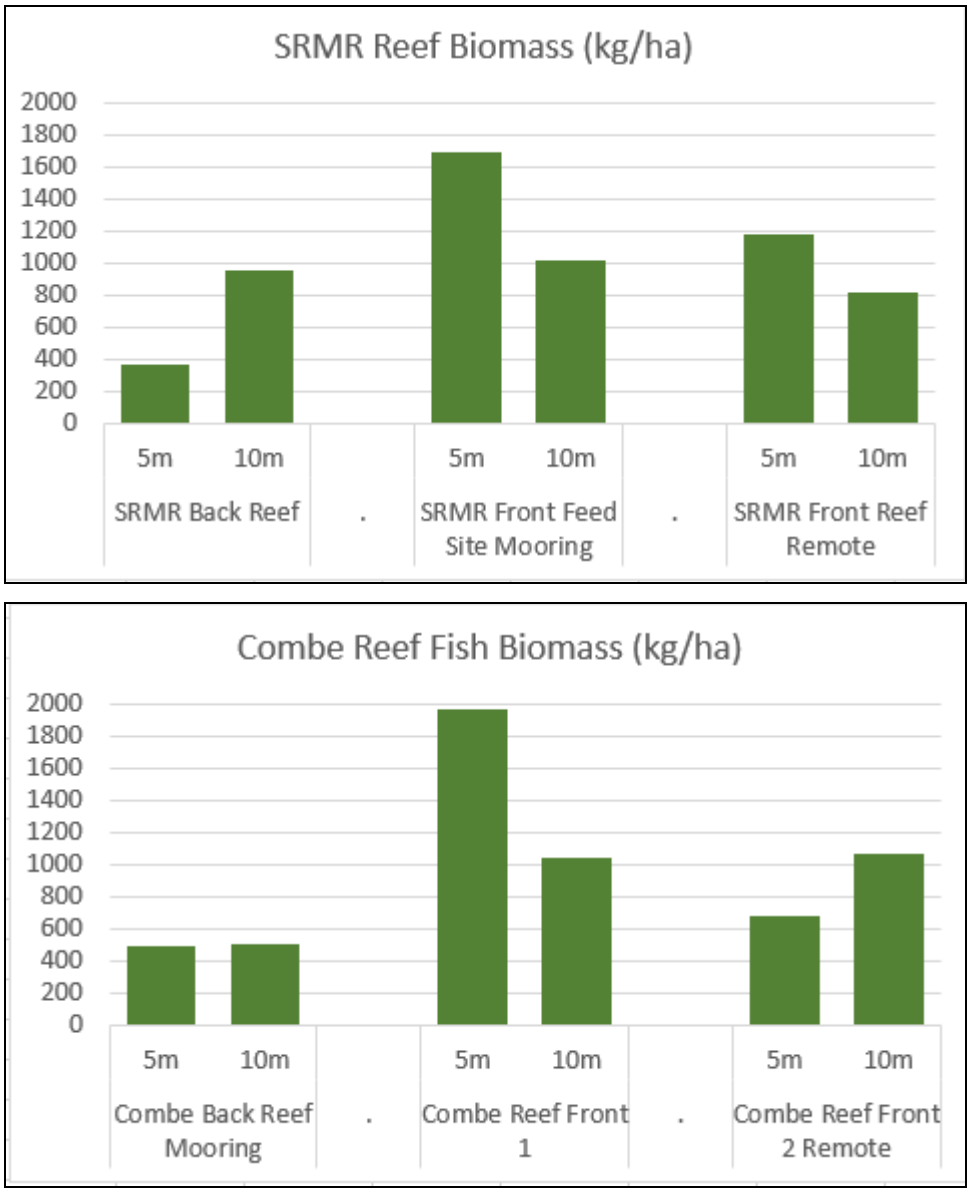


FIGURE 42: BAR CHARTS OF FISH BIOMASS AT SRMR AND CR 2022

Biomass is calculated according to the abundance and size (length) of each fish species recorded. Different fish have different body shapes, and so biomass varies between species.

A high biomass may represent many small fish, a few larger fish, or a mixture of both.

As with abundance, biomass was greater on the front reef sites than on the back reefs, with the highest levels (over 1,600 Kg/ Ha) seen on SRMR and Combe Reef Fronts 1 at 5m deep.

The lowest biomass seen (under 500 Kg/ Ha) was at Combe Back Reef, and at 5m on the SRMR Back Reef.

Fish Biomass / Abundance

Average biomass divided by average abundance of fish recorded over three 250m^2 ES belts per site excluding non-recorded species such as sharks, *Pomacentridae* (Damselfish) small *Serranidae* (Anthias), *Blenniidae* (Blennies), *Gobiidae* (Gobies) etc.

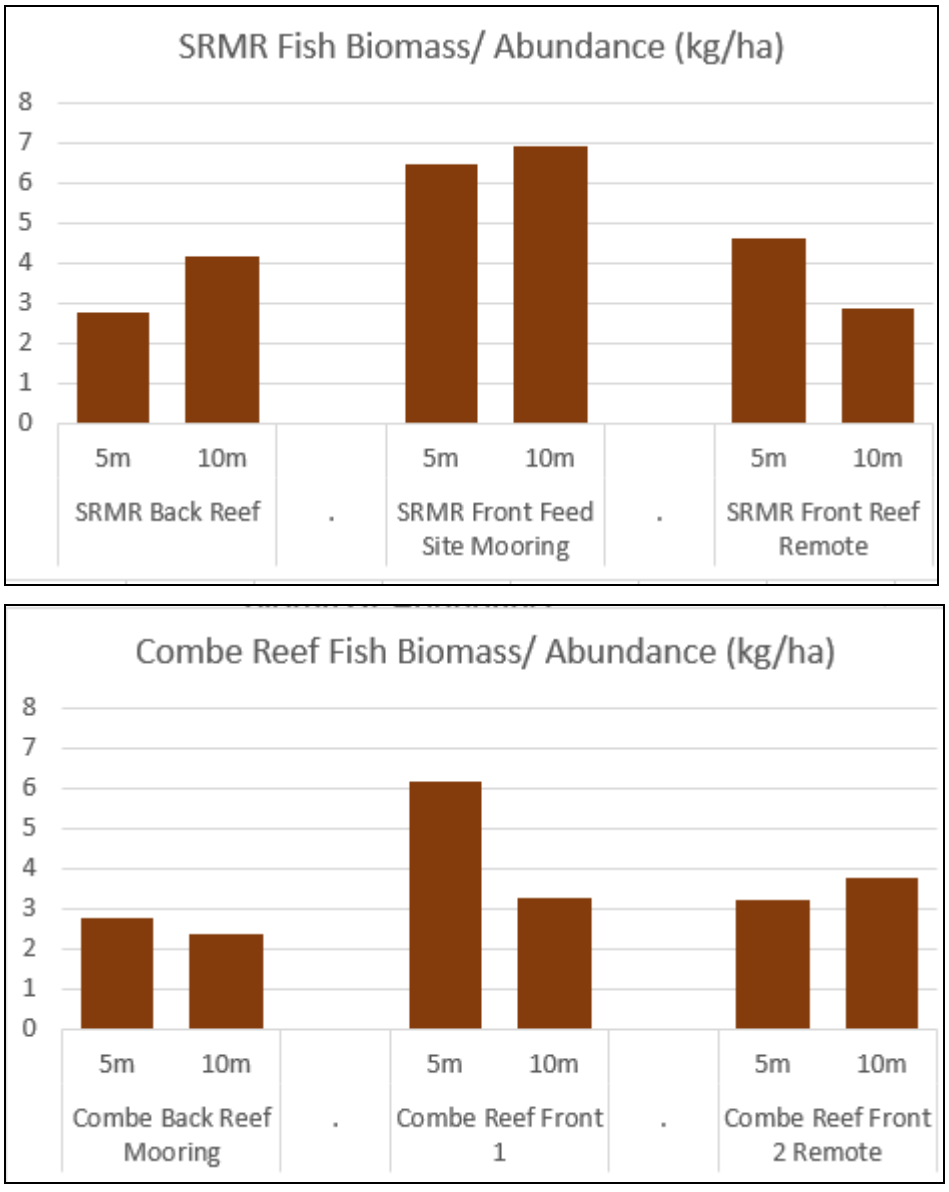


FIGURE 43: BAR CHART OF AVERAGE FISH BIOMASS / ABUNDANCE AT SRMR AND CR 2022

Dividing Biomass by Abundance gives a characteristic description of a representative fish size at each site.

Using this calculation, a representative fish would seem to be, on average, larger at both depths of SRMR Front 1, and at 5m deep on Combe Reef site 1, and generally smaller on Combe Reef than on SRMR.

Variation in Fish Abundance and Biomass at SRMR Front 1

The previous graphs show the averages of three replicate lines at each site and depth. There was some diversity between individual 50m lines, frequently related to reef topography, as fish tended to cluster around bommies and crevices in the reef slope.

Some lines had moderate fish numbers, but low biomass, indicative of smaller fish in the area, others had only moderate abundance but higher biomass, indicative of larger fish in that section.

On Combe Reef there was no apparent pattern to the variation between individual lines at each site or depth.

FIGURE 44: BAR CHART OF FISH ABUNDANCE & BIOMASS ALONG INDIVIDUAL LINES ON COMBE REEF 2022

On SRMR there was no apparent pattern of variation along the Back Reef or Front Reef 1 replicate lines, but at SRMR 1, the shark feed site, there an obvious pattern of increasing fish abundance and biomass on lines further from the actual feeding area (marked with arrows on the bar charts below), at both depths 5m and 10m.

- Line 1 runs west from the first mooring and past the second mooring, encompassing a 50m long stretch of shallow reef above the area where shark feeding takes place.
- Line 2 runs east from the first mooring and ends 50m away from the feeding area.
- Line 3 runs east of line 2, so covers an area 50 – 100m away from the feeding area.

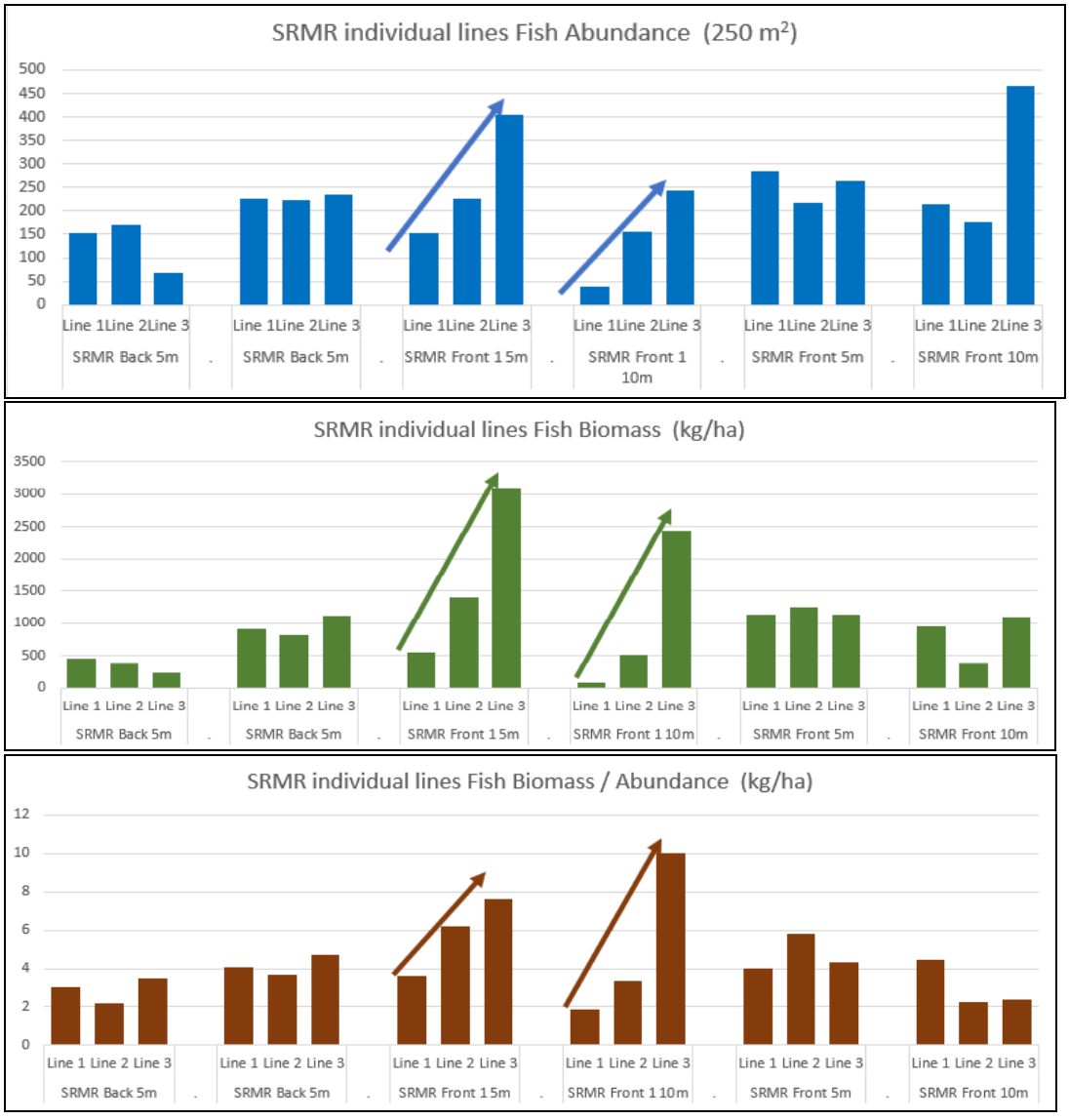


FIGURE 45: BAR CHART OF FISH ABUNDANCE & BIOMASS ALONG INDIVIDUAL LINES ON SRMR 2022

Both fish abundance and biomass were much greater along Line 3 of the SRMR Front Reef 1 sites, at both depths, than at any other site, but along Line 1 at 10m, the closest section to the actual feeding area, where many bull sharks *Carcharhinus leucas* were seen during the survey, there were far fewer other fish.

It is possible that while fish are attracted to the general area where natural fish off-cuts used in shark feeding are frequently added, they avoid the actual site frequented by the sharks when divers are in the water.

Abundance and Biomass of Fish Families

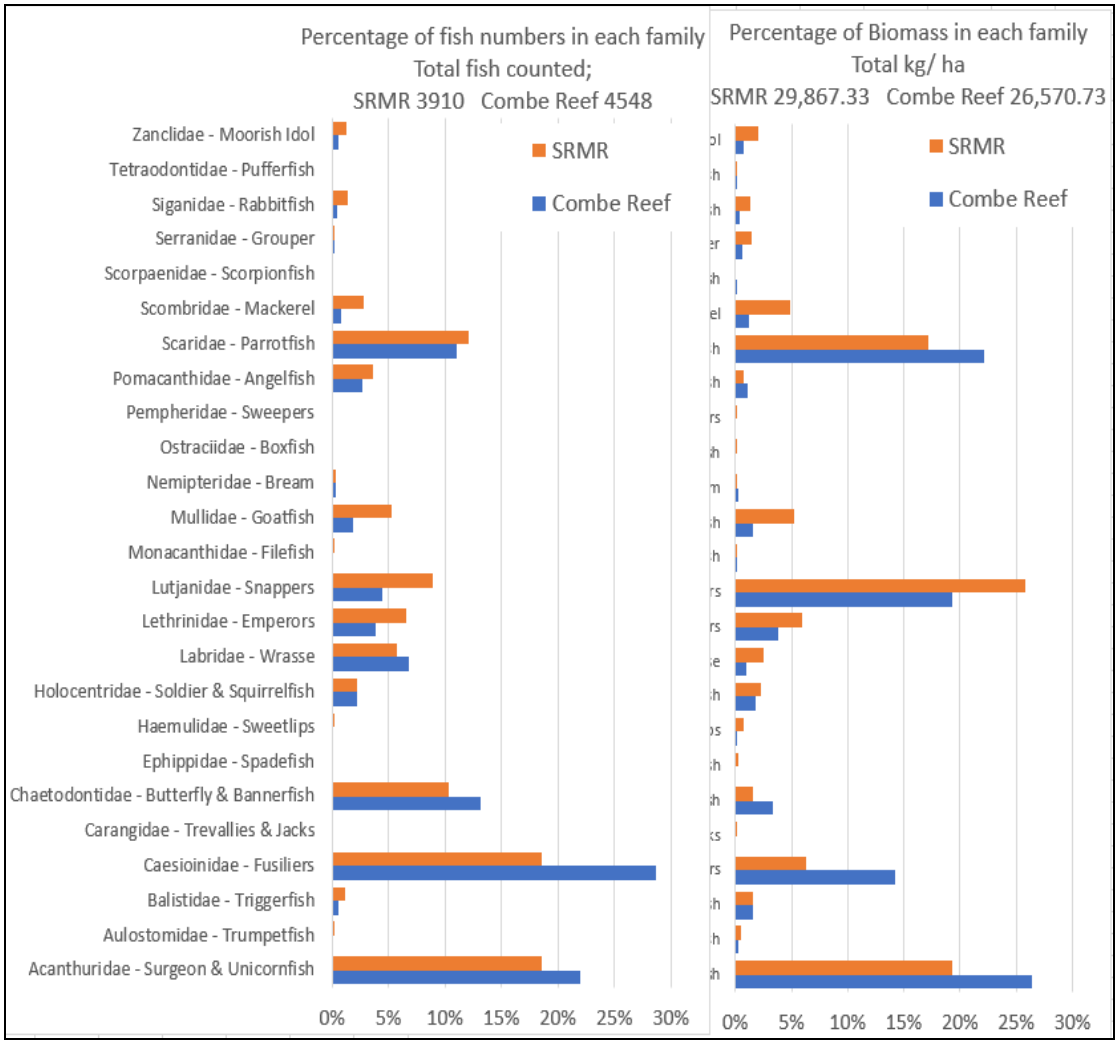


FIGURE 46: BAR CHARTS OF FISH FAMILY PERCENT ABUNDANCE AND BIOMASS AT SRMR AND CR 2022

On both reefs the most abundant fish families were *Acanthuridae* (Surgeon and Unicornfish), *Caesioinidae* (Fusiliers), *Chaetodontidae* (Butterfly and Bannerfish) and, to a lesser effect, *Scaridae* (Parrotfish). Sharks were seen on many dives, but not included in either abundance or biomass, as they would skew the data away from other fish populations.

The higher biomass on SRMR was largely due to *Lutjanidae* (Snappers) and larger *Scaridae* (Parrotfish), as well as small numbers of *Serranidae* (Groupers) and *Haemullidae* (Sweetlips).

TABLE 9: SUMMARY OF FISH DIVERSITY, ABUNDANCE AND BIOMASS ON BOTH REEFS

Reef	Total no. of fish species	Total fish abundance	Total fish biomass (Kg/Ha)	Representative fish biomass (Kg/Ha) [6]
SRMR	147	3,910	29,867.33	7.64
Combe Reef	140	4,548	26,570.73	5.82

Although there was a higher abundance of fish seen on Combe Reef, there was greater biomass on SRMR, and a larger fish size overall. Species diversity was essentially the same.

[6] Biomass divided by Abundance

Mixed school of Ringtail Surgeonfish *Acanthurus blochii* and Swarthy Parrotfish *Scarus niger*

Photo Credit: Natasha Marosi

Yellowfin Goatfish *Mulloidichthys vanicolensis*

Photo Credit: Natasha Marosi

FIGURE 47: PHOTOGRAPHS OF TYPICAL FISH ON SRMR FRONT MAY 2022

Discussion of Extended Surveys SRMR vs CR 2022

These extended surveys were the first comparison of three areas in the protected SRMR with three unprotected sites on Combe Reef, and were the first detailed baseline study of Combe Reef.

Although the topography of the front reefs was dissimilar (see Section 1, Reef profiles and transect positions), with the Combe Reef walls meeting the slope at shallower depths, the front reef sites were all comparable in relation to algal and coral cover, lifeform and genera.

The back reefs were less comparable, as the sheltered SRMR back reef was a remarkable habitat dominated by very large and delicate *Acropora* corals, whilst the more exposed Combe back reef was more impacted by strong current and wave action. However as there was no better area found, this area stands as the Combe back reef comparison site.

Surveys were carried out during the bleaching event of April/ May 2022, and although this had not been planned for in the overall survey methodology, additional personnel were able to carry out detailed bleaching surveys on two SRMR sites. General observations and photography on the other sites suggested that bleaching levels were very similar on both reefs.

By June 2022 some corals were in recovery state, with zooxanthellae recolonising the coral tissues, but others had died and were becoming covered in algal turfs. The high variety of coral genera, and the survival or regrowth of many corals through multiple past stress events, points to high resilience of these reefs. In particular, corals that survive the 10 – 13 weeks of elevated water temperatures seen in 2022 (see Figure 33) may be developing increased tolerance to higher temperatures, compared to the extensive mortality seen after 8 weeks of elevated temperatures in 2000. Subsequent coral cover monitoring is required to determine the recovery rate of these reefs.

Fish surveys showed a remarkably similar number of species and individual fish on both reefs. Fewer species and fewer individual fish were recorded on the back reef sites than on the front of both reefs.

Fish biomass (weight as related to length) was similar on each reef, with the lowest biomass on the backs of both reefs. Overall SRMR had a higher number of larger fish than Combe Reef, but in general terms fish abundance and biomass were within similar ranges.

An interesting pattern of increasing fish abundance and biomass correlating with distance from the shark feeding area was noted at SRMR Front 1. Some bull sharks *Carcharhinus leucas* did approach the team during surveys on the 10m deep transect, and smaller shark species were seen at 5m (mostly Blacktip and Whitetip reef sharks, *Carcharhinus melanopterus* and *Triaenodon obesus* respectively). Most sharks seen were on ES Line 1 of each transect, a few on ES Line 2 and none on ES Line 3. This correlation suggests that while fish may be attracted to the general area of the shark feed, they may avoid the actual sharks unless feeding activities are taking place. It would take further observation to establish this.

Overall, both Combe Reefs and SRMR appear to be in a state of moderate to good health, with comparable coral and fish populations, and are suitable sites for long term monitoring to record the impacts of, and recovery from, reef stressing events such as land-based pollution, climate change, fishing and cyclones.

Future work

The Shark Reef Marine Reserve (SRMR) is a long-standing and legalised statutory reserve, protected from fishing, with a focus on shark-feeding tourism.

Reef monitoring on SRMR over the past eight years has shown that coral and key indicator invertebrate and fish populations have not changed significantly over that period, despite coral bleaching, cyclones, and land-based pollution.

However, illicit fishing during the Covid-19 related closure period of 2020 and 2021, when there was no tourism income for the community, has resulted in the loss of larger fish from the reef. This is supported by video evidence[7] from another shark feeding site in the vicinity, which appears to show a similar disappearance of large snapper *Lutjanidae* and trevally *Carangidae* species.

Pairing three areas of the SRMR protected area with three areas on the nearby Combe Reef allowed a comparison to be drawn between a no-take protected area and an open fishing ground. It is postulated that protection from fishing would create a greater biomass of fish, including larger number of herbivores, which should reduce algal cover and allow for faster recolonisation and regrowth of corals after any coral stressing event.

The reduction in numbers and size of certain key fish groups on SRMR may be due to illicit fishing in 2020 – 2021, but there is hope of a swift recovery now that tourism has restarted, providing income to the community, and hopefully reducing the level of poaching.

The coral bleaching event of April / May 2022, and a strong wave event in July 2022 has resulted in some coral bleaching, breakage and death, but many corals showed signs of recovery and regrowth.

Follow up monitoring is proposed toward the end of 2022, and annually thereafter, to establish the following:

- Water temperature on SRMR over an extended period through deployment of further in-water temperature loggers
- Impacts of bleaching in April/ May 2022, and any future events, and implications of the resilience of coral genera affected
- Impacts of storm breakage in July 2022, and of future storms and cyclones, and speed and level of regrowth of coral genera
- Levels of increased herbivores (invertebrate and vertebrate) within a protected area vs an unprotected reef.
- Levels of fish abundance and biomass within a protected area vs an unprotected reef.
- Effects of increased herbivory on algal cover within a protected area vs an unprotected reef.
- Effects of increased herbivory on coral cover within a protected area vs an unprotected reef.

[7] https://www.facebook.com/groups/177007715686284/posts/5462393337147669/

Appendix:
Data from Surveys

Rapid Assessment (Lifeform) Substrate

Average of 4 x 20m lines

Survey Date 2022	08-May		29-May		29-Jun	05-Jun	24-Apr		01-May		July	29-Jun	05-Jun
Site	Combe Back Reef		Combe Reef Front 1		Combe Reef Front 2		SRMR Back Reef		SRMR Front Reef 1			SRMR Front Reef 2	
											Video		
Depth	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	10m	5m	10m
Acropora Branching	3%	5%	6%	5%	7%	8%	26%	39%	8%	6%	1%	6%	6%
Acropora Digitate	2%	1%	1%	0%	0%	1%	1%	0%	1%	0%	1%	0%	0%
Acropora Table	0%	0%	7%	4%	1%	5%	1%	1%	1%	3%	1%	6%	4%
Acropora Submassive	0%	0%	2%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
Acropora Encrusting	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Coral Branching	2%	0%	1%	2%	4%	5%	4%	1%	3%	3%	1%	4%	1%
Coral Massive	9%	3%	18%	6%	10%	14%	6%	2%	12%	13%	15%	14%	11%
Coral Foliose	1%	1%	3%	3%	4%	9%	2%	1%	1%	2%	3%	1%	1%
Coral Submassive	11%	11%	14%	6%	7%	5%	16%	3%	16%	8%	11%	11%	9%
Coral Encrusting	7%	3%	8%	13%	13%	11%	1%	3%	11%	3%	6%	3%	5%
Coral Mushroom	0%	1%	0%	0%	0%	0%	0%	1%	0%	1%	1%	0%	0%
Coral Millepora	0%	1%	6%	1%	6%	2%	0%	2%	6%	3%	3%	2%	14%
Soft Coral	1%	0%	4%	3%	4%	1%	0%	0%	5%	4%	1%	4%	2%
Sponge	2%	3%	2%	4%	2%	1%	4%	2%	3%	2%	0%	3%	2%
Other Biota	2%	0%	1%	0%	1%	0%	1%	1%	0%	1%	0%	0%	0%
Algal Assemblage	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Macro Algae	6%	6%	0%	1%	0%	0%	9%	4%	0%	1%	0%	0%	0%
Halimeda Algae	0%	1%	0%	0%	0%	1%	1%	1%	0%	0%	0%	0%	0%
Turf Algae	18%	10%	12%	7%	13%	11%	8%	18%	11%	22%	0%	13%	13%
Coralline Algae	16%	5%	14%	18%	21%	10%	3%	3%	8%	10%	0%	23%	13%
Rock	1%	3%	0%	0%	0%	3%	4%	4%	6%	9%	27%	0%	3%
Rubble	17%	36%	0%	21%	6%	11%	11%	9%	6%	13%	26%	5%	14%
Sand	1%	11%	1%	5%	1%	1%	2%	5%	0%	0%	1%	1%	2%
Silt	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Dead Coral	0%	0%	2%	3%	0%	1%	0%	0%	0%	0%	3%	0%	0%
Dead Coral & Algae	2%	3%	0%	0%	2%	3%	1%	3%	3%	0%	0%	6%	1%

Rapid Assessment (Reef Check) Substrate Averages of 4 x 20m lines

Survey Date 2022	08-May		29-May		29-Jun	05-Jun	24-Apr		01-May		July	29-Jun	05-Jun
Site	Combe Back Reef		Combe Reef Front 1		Combe Reef Front 2		SRMR Back Reef		SRMR Front Reef 1			SRMR Front Reef 2	
											VIDEO		
Depth	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	10m	5m	10m
Hard Coral	34%	24%	65%	40%	51%	59%	57%	51%	60%	40%	43%	46%	51%
Soft Coral	1%	0%	4%	3%	4%	1%	0%	0%	5%	4%	1%	4%	2%
Dead Coral	0%	0%	2%	3%	0%	1%	0%	0%	0%	0%	3%	0%	0%
Algae	24%	16%	12%	8%	13%	12%	18%	23%	11%	23%	0%	13%	13%
Sponge	2%	3%	2%	4%	2%	1%	4%	2%	3%	2%	0%	3%	2%
Rock	19%	11%	14%	18%	23%	15%	8%	9%	16%	19%	27%	28%	16%
Rubble	17%	36%	0%	21%	6%	11%	11%	9%	6%	13%	26%	5%	14%
sand	1%	11%	1%	5%	1%	1%	2%	5%	0%	0%	1%	1%	2%
Silt	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	2%	0%	1%	0%	1%	0%	1%	1%	0%	1%	0%	0%	0%

Rapid Assessment Invertebrates Average numbers from 4 x 100m2 Belts

Survey Date 2022	08-May		29-May		29-Jun	05-Jun	24-Apr		01-May		29-Jun	05-Jun
Site	Combe Back Reef		Combe Reef Front 1		Combe Reef Front 2		SRMR Back Reef		SRMR Front Reef 1		SRMR Front Reef 2	
Depth	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m
Banded coral shrimp	0	0	0	0	0	0	0	0	0	0	0	0
Diadema urchin	22.75	2.5	25.5	2.5	15.5	0	0	0	4	0	4.75	0
Pencil urchin	0	0	0	0	0	0	0	0	0	0	0	0
Collector urchin	0	0	0	0	0	0	0	0	0	0	0	0
Sea cucumber	1.75	2	0	0.25	0	0.5	0	0.5	0	0.5	0	0.25
Crown-of-thorns	0	0	0	0	0	0	0	0	0	0	0	0
Triton	0	0	0	0	0	0	0	0	0	0	0	0
Lobster	0	0	0	0	0	0	0	0	0	0	0	0
Giant Clams	0	0	0.25	0	0.25	0.25	0	0	0.25	0	0.5	0.75
Giant clam size (cm)												
<10 cm	0	0	0	0	0	0	0	0	0.25	0	0	0
10-20 cm	0	0	0	0	0.25	0	0	0	0	0	0	0
20-30 cm	0	0	0	0	0	0.25	0	0	0	0	0.25	0.75
30-40 cm	0	0	0.25	0	0	0	0	0	0	0	0.25	0
40-50 cm	0	0	0	0	0	0	0	0	0	0	0	0
>50 cm	0	0	0	0	0	0	0	0	0	0	0	0

List of coral genera per site

Points per genera in six combined 100-point 50m ES lines per site

(both depths combined – 600 points per site)

Genus	CR Back	CR Front 1	CR Front 2	SRMR Back	SRMR Front 1	SRMR Front 2
Acropora	38	55	57	209	45	65
Amphiroa	1			25		
Astrea		1	2		1	2
Astreopora		3	3		1	2
Coscinaraea		1				1
Cyphastrea		1	3			
Dendrophyllia						1
Diploastrea	9	40	31	2	15	12
Dipsastrea			1			
Echinopora		2			3	
Favia					1	
Favites	1	4	1		1	1
Fungia	2	2		1	1	
Galaxea	1	1	3			
Gardineroseris						2
Goniastrea	1	7			4	4
Gorgonian	2			1	1	
Herpolitha	1					
Hydnophora		5			3	
Isopora		7			1	
Leptastrea	1	2	2	1	4	1
Leptoria		1			1	
Leptoseris	1	3				
Lobophora	2					
Merulina	6	10	14	2	10	5
Millepora	2	18	13	4	27	39
Montipora	21	33	50	3	28	28
Mycedium	1					
Oxypora		1	1		2	1
Pachyseris		3	8	2		
Palythoa tuberculosa					2	2
Pavona	18	16	19	36	5	7
Platygyra		2	2			
Plesiastrea					3	
Pocillopora	45	47	31	22	49	49
Pocilloporidae				1		
Porites	20	28	43	22	49	62
Porites rus	10	23	17	17	31	13
Psammocora					1	
Psammocoridae	1					
Soft coral	6	15	12		23	21
Stylaster			1			
Stylophora	8	4	13	1	5	2
***Turbinaria*-coral**			4	2	2	
Zoopilus				1		

List of bleaching level of coral genera

Colony counts in 1 m² quadrats at two sites: SRMR Front Reef 1 and SRMR Back Reef, both depths combined

SRMR Front Reef 1, 1 May 202							
Genus	**Normal**	**Pale**	**0-20% bleached**	**20-50% bleached**	**50-80% bleached**	**80-100% bleached**	**Recently dead**
Acanthastrea	5	0	0	0	0	0	0
Acropora	50	1	2	3	3	3	0
Astreopora	1	0	0	0	0	0	0
Ctenactis	0	0	0	0	1	1	0
Diploastrea	4	1	0	0	1	0	0
Echinopora	4	0	0	3	0	0	0
Favia	0	0	0	1	0	0	0
Favites	4	0	0	0	0	0	0
Fungia	5	0	1	0	5	0	0
Galaxea	1	0	0	0	1	0	0
Goniastrea	0	0	0	0	3	2	0
Heliofungia	1	0	0	1	0	0	0
Hydnophora	1	1	0	0	0	0	0
Leptastrea	2	0	0	0	0	0	0
Lobophyllia	1	0	0	0	2	0	0
Merulina	2	0	0	1	2	6	0
Millepora	14	6	1	2	1	2	0
Montastrea	0	0	0	0	1	2	0
Montipora	15	0	1	1	1	1	0
Pachyseris	0	0	0	0	2	0	0
Pavona	9	1	1	1	0	0	0
Platygyra	0	1	0	0	1	2	0
Plesiastrea	1	0	0	0	0	0	0
Pocillopora	41	3	2	2	4	6	0
Porites	40	3	1	3	3	0	0
Siderastrea	0	1	0	0	0	0	0
Stylophora	2	1	0	1	6	8	0
Grand Total	**203**	**19**	**9**	**19**	**37**	**33**	**0**

SRMR Back Reef, 24 April 2022							
Genus	Normal	Pale	0-20% bleached	20-50% bleached	50-80% bleached	80-100% bleached	Recently dead
Acanthastrea							
Acropora	18	5	3	19	23	73	2
Astreopora	1	0	0	0	0	0	0
Ctenactis	1	0	0	0	0	1	0
Diploastrea							
Echinopora							
Favia							
Favites	0	0	0	0	0	2	0
Fungia	1	2	0	0	0	0	0
Galaxea	1	0	0	0	0	0	0
Goniastrea	0	0	0	0	0	1	0
Heliofungia							
Hydnophora							
Leptastrea							
Lobophyllia							
Merulina	0	1	0	1	0	1	0
Millepora	3	0	0	0	0	0	0
Montastrea							
Montipora	0	1	1	0	0	1	0
Pachyseris	1	0	1	0	1	0	0
Pavona	4	2	3	5	2	7	0
Platygyra	0	0	0	0	0	1	0
Plesiastrea							
Pocillopora	14	0	0	1	1	5	1
Porites	48	2	0	0	1	5	0
Siderastrea							
Stylophora	0	0	0	0	1	4	1
Grand Total	**92**	**13**	**8**	**26**	**29**	**101**	**4**

Rapid Assessment Indicator Fish

Average number in 100m² Belts

Survey Date 2022	08-May		29-May		29-Jun	05-Jun	24-Apr		01-May		29-Jun	05-Jun
Site	Combe Back Reef		Combe Reef Front 1		Combe Reef Front 2		SRMR Back Reef		SRMR Front Reef 1		SRMR Front Reef2	
Depth	5m	10m	5m	10m	5m	10 m	5m	10m	5m	10m	5m	10m
Butterflyfish	8.5	9.75	15	16.25	17.25	17.75	13.25	9	5.5	8.25	7	16.25
Sweetlips	0	0	0	0	0	0	0.25	0.25	0	0	0	0.25
Snapper	0	0	18.75	13	0.5	1.75	0.25	1.25	5.5	2.5	12	14.25
Centropyge Angels	0.75	7	1	1.75	2	2.75	5	2.5	1.5	1.5	3	0.5
Rabbitfish	2	1.25	0	0	0	0.5	1.5	0.75	1.75	3.75	0.75	0.5
Parrotfish	13	15.75	10.5	8.25	11.5	12.25	15.75	13.25	13.5	4.5	5.75	14.5
Surgeon & Unicornfish	17.5	30.25	32.5	11.25	17.25	40.25	10.5	23	17.75	5.25	19.25	16.25
Goatfish	1.5	1.75	0.75	1.25	0.25	1	1	1	2.5	1	13.75	0.5
Jacks & Trevallies	0	0	0	0	0	0	0	0	0	0	0.25	0
Bumphead Parrotfish	0	0	0	0	0	0	0	0	0	0	0	0
Humphead Wrasse	0	0	0	0	0	0	0	0	0	0	0	0
Moray eel	0	0	0	0	0	0	0	0	0	0	0.25	0
Grouper	0	1	0.25	0	0.5	0.25	0.25	0.5	0	0.25	0.5	0.25
Grouper sizes (cm):												
< 30 cm	0	0.5	0	0	0	0.25	0.25	0	0	0.25	0.5	0
30-40 cm	0	0.25	0.25	0	0.5	0	0	0.25	0	0	0	0.25
40-50 cm	0	0.25	0	0	0	0	0	0.25	0	0	0	0
50-60 cm	0	0	0	0	0	0	0	0	0	0	0	0
>60 cm	0	0	0	0	0	0	0	0	0	0	0	0

Total Fish Biomass

Average Kg/ Ha number in 250m² Belts

Survey Date 2022	08-May		29-May		29-Jun	05-Jun	24-Apr		01-May		29-Jun	05-Jun
Site	Combe Back Reef		Combe Reef Front 1		Combe Reef Front 2		SRMR Back Reef		SRMR Front Reef 1		SRMR Front Reef 2	
Depth	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m	5m	10m
Total Biomass	492	502	1,962	1,039	673	1,062	360	949	1,685	1,011	1,177	817
Total Abundance	179	212	318	319	209	281	131	228	262	146	255	285
Biomass/ Abundance	2.76	2.37	6.18	3.26	3.22	3.78	2.75	4.16	6.44	6.92	4.62	2.87

List of Fish species per site and depth

Total number of fish recorded over 6 combined 250m^2 ES belts per site (both depths combined, 4,500m^2), excluding non-recorded species such as sharks, *Pomacentridae* (Damselfish) small *Serranidae* (Anthias), *Blenniidae* (Blennies), *Gobiidae* (Gobies) etc.

Counts of fish species recorded on Combe Reef

Combe Reef	Back		Front 1		Front 2	
	5m	10m	5m	10m	5m	10m
Total Species count	69	61	61	63	66	72
Acanthuridae - Surgeon & Unicornfish						
Acanthurus auranticavus						
Acanthurus lineatus	4		35		60	
Acanthurus mata				20		
Acanthurus nigricauda	3	15		11	4	5
Acanthurus nigrofuscus				5		
Acanthurus olivaceus						
Acanthurus pyroferus		2			1	3
Acanthurus thompsoni						
Ctenochaetus binotatus	44	100	35	35	2	38
Ctenochaetus striatus	12	1	25	19	70	39
Naso brevirostris			24			10
Naso hexacanthus				50		50
Naso lituratus	7	4	2		7	13
Naso vlamingii			50			
Zebrasoma flavescens				2		
Zebrasoma scopas	25	66	20	18	26	32
Zebrasoma veliferum					3	
Aulostomidae -Trumpetfish						
Aulostomus chinensis		1	1			2
Balistidae - Triggerfish						
Balistapus undulatus	7	5	1	5	2	1
Balistoides viridescens	1				1	2
Melichthys vidua						
Sufflamen bursa						
Caesioinidae - Fusiliers						
Caesio caerulaurea	36		150	100	95	30
Caesio teres	10	25	20			160
Pterocaesio marri	10					
Pterocaesio pisang		30	110	200	30	100
Pterocaesio tile						
Pterocaesio trilineata			100	70	30	
Carangidae - Trevallies						
Carangoides ferdau						
Chaetodontidae - Butterfly and Bannerfish						

Chaetodon auriga	1					2
Chaetodon baronessa	8	11	14	2	6	26
Chaetodon bennetti					6	
Chaetodon citrinellus			4		7	
Chaetodon ephippium	2	3	2		8	
Chaetodon flavirostris					1	
Chaetodon kleinii	1	4	8	5	6	18
Chaetodon lineolatus				1		
Chaetodon lunula	1					
Chaetodon lunulatus	7	12	23	21	31	21
Chaetodon melannotus					4	
Chaetodon mertensii		2		4		3
Chaetodon ornatissimus						
Chaetodon pelewensis	4	10	25	13	6	26
Chaetodon plebeius						2
Chaetodon rafflesii	2			4	5	
Chaetodon reticulatus			4			
Chaetodon trifascialis			3	2	1	
Chaetodon ulietensis	3	5		2	19	2
Chaetodon unimaculatus			2	1	9	2
Chaetodon vagabundus	6	10		1	5	2
Forcipiger flavissimus	5				4	2
Hemitaurichthys polylepis						5
Heniochus acuminatus	3	2				
Heniochus chrysostomus		1	13	21	3	
Heniochus diphreutes						25
Heniochus monoceros						1
Heniochus singularius	1	1	2		1	2
Heniochus varius	8	4	14	8	8	12
Ephippidae - Spadefish						
Platax orbicularis						
Haemulidae - Soldier & Squirrelfish						
Plectorhinchus vittatus	1					
Holocentridae	26	5	39	24	7	1
Myripristis kuntee	19	3	33	23	2	1
Myripristis violacea	2	1	3			
Myripristis vittata	1		1			
Neoniphon sammara	1		1		4	
Sargocentron caudimaculatum		1	1		1	
Sargocentron melanospilos	3			1		
Sargocentron spiniferum						
Labridae - Wrasse						
Anampses meleagrides						1

Anampses neoguinaicus	2	1	1			
Anampses twistii	1	1				2
Bodianus axillaris	2	1	1	1	3	6
Bodianus loxozonus		1				
Bodianus mesothorax				2		
Cheilinus chlorourus		1		1		
Cheilinus fasciatus		2				
Cheilinus oxycephalus			1			
Cheilinus trilobatus						1
Cirrhilabrus punctatus	5	92		100		
Coris aygula	1					
Coris gaimard		3				
Epibulus insidiator	1			2	3	1
Gomphosus varius	2	8	3			3
Halichoeres argus						
Halichoeres hortulanus	2	1		1	1	
Halichoeres marginatus	1					
Halichoeres prosopeion		1				
Halichoeres richmondi						
Hemigymnus fasciatus	4	3				4
Hemigymnus melapterus						1
Labrichthys unilineatus		2	1	1	2	
Labroides bicolor					1	1
Labroides dimidiatus		3	1		1	
Oxycheilinus digramma		2		3	1	2
Stethojulis bandanensis	1					
Thalassoma hardwicke	3		1		2	
Thalassoma lunare		1				
Thalassoma lutescens			2			1
Lethrinidae - Emperors						
Gnathodentex aureolineatus	110					
Lethrinus erythracanthus						
Lethrinus obsoletus						
Monotaxis grandoculis						3
Monotaxis heterodon	10	8	13	5	7	21
Lutjanidae - Snappers						
Aphareus furca						
Aprion virescens						
Lutjanus bohar			1			
Lutjanus ehrenbergii						
Lutjanus fulviflamma						
Lutjanus fulvus				1		
Lutjanus gibbus			23	50		17
Lutjanus monostigma			16			

Lutjanus semicinctus		1		2	1	2
Macolor macularis				13		
Macolor niger	1		69	3	2	
Monocanthidae - Filefish						
Aluterus scriptus	1		1	1		3
Amanses scopas			1			
Oxymonacanthus longirostris	1			1		3
Mullidae - Goatfish						
Mulloidichthys flavolineatus	40					
Mulloidichthys vanicolensis						
Parupeneus barberinus	1			2		
Parupeneus crassilabris	3				4	
Parupeneus cyclostomus				2	2	2
Parupeneus multifasciatus	6	9	2	6	2	
Parupeneus pleurostigma						2
Nemipteridae - Bream						
Scolopsis bilineata	1	4		6	2	3
Ostraciidae						
Ostracion cubicus						
Pempheridae - Sweepers						
Pempheris oualensis						
Pomacanthidae - Angelfish						
Apolemichthys trimaculatus						2
Centropyge bicolor	3	24		9	8	14
Centropyge bispinosa	3	14	1	3	2	4
Centropyge flavissima	1		3	2	3	5
Genicanthus melanospilos						
Pomacanthus semicirculatus						
Pygoplites diacanthus	3	6	1	4	4	4
Scaridae - Parrotfish						
Calotomus carolinus		3				
Cetoscarus ocellatus	1					
Chlorurus bleekeri		9		11	4	22
Chlorurus japanensis					1	
Chlorurus microrhinos			39	6		
Chlorurus sordidus	20	26	20	17	37	28
Scarus altipinnis			5			
Scarus chameleon	4		2			1
Scarus dimidiatus						
Scarus frenatus	2				12	1
Scarus ghobban					1	
Scarus globiceps						
Scarus niger	13	1	2	1	9	16
Scarus oviceps						

Scarus rubroviolaceus						2
Scarus schlegeli	33	65		26	11	8
Scarus spinus	9	8	4		20	2
Scombridae - Mackerel						
Rastrelliger kanagurta			8	25		5
Scorpaenidae - Scorpion & Lionfish						
Pterois radiata			1			
Serranidae - Groupers						
Anyperodon leucogrammicus		1				
Cephalopholis argus						
Cephalopholis urodeta			1	1	1	1
Epinephelus howlandi					1	
Epinephelus merra						1
Epinephelus polyphekadion				1		
Variola albimarginata		1				
Variola louti		2				
Siganidae - Rabbitfish						
Siganus argenteus	2					
Siganus doliatus	3	6				2
Siganus punctatus	1	1				
Siganus uspi					2	2
Tetraodontidae - Pufferfish						
Arothron nigropunctatus			1			2
Zanclidae - Moorish Idol						
Zanclus cornutus	2	4	3	3	7	9

Counts of fish species recorded on SRMR

SRMR	Back		Front 1		Front 2	
	5m	10m	5m	10m	5m	10m
Total Species count	60	68	74	56	69	83
Acanthuridae - Surgeon & Unicornfish						
Acanthurus auranticavus						5
Acanthurus lineatus						
Acanthurus mata		25				
Acanthurus nigricauda		7	2			4
Acanthurus nigrofuscus						
Acanthurus olivaceus					3	
Acanthurus pyroferus	2	4	2	1		
Acanthurus thompsoni			1			
Ctenochaetus binotatus	11	30	4	3	2	36
Ctenochaetus striatus	13	28	19	10	100	40
Naso brevirostris				11	56	
Naso hexacanthus		35	10		6	13
Naso lituratus	2	5	18	8	16	5
Naso vlamingii						5
Zebrasoma flavescens						
Zebrasoma scopas	19	43	14	33	15	46
Zebrasoma veliferum			8	4	2	
Aulostomidae -Trumpetfish						
Aulostomus chinensis	1	2		1	3	1
Balistidae - Triggerfish						
Balistapus undulatus	9	5	4	10	2	3
Balistoides viridescens				3	1	
Melichthys vidua			4	1	1	
Sufflamen bursa						2
Caesioinidae - Fusiliers						
Caesio caerulaurea		150	35		70	70
Caesio teres			10	20	1	52
Pterocaesio marri		70				
Pterocaesio pisang			20			100
Pterocaesio tile			30			
Pterocaesio trilineata			50			50
Carangidae - Trevallies						
Carangoides ferdau					1	
Chaetodontidae - Butterfly and Bannerfish						
Chaetodon auriga						
Chaetodon baronessa	12	18		2	12	3
Chaetodon bennetti				3	4	5
Chaetodon citrinellus	2					

Chaetodon ephippium	8					2
Chaetodon flavirostris						2
Chaetodon kleinii		1	3	12	2	36
Chaetodon lineolatus						
Chaetodon lunula			4			2
Chaetodon lunulatus	28	11	2	11	7	20
Chaetodon melannotus						
Chaetodon mertensii		4		4	3	2
Chaetodon ornatissimus			6			
Chaetodon pelewensis	6	10	6	9	13	11
Chaetodon plebeius	1	2				2
Chaetodon rafflesii			6	2	4	1
Chaetodon reticulatus			2			
Chaetodon trifascialis			3		5	
Chaetodon ulietensis	1	3				
Chaetodon unimaculatus	1	5	6		1	3
Chaetodon vagabundus			1	2		2
Forcipiger flavissimus	5	2	1		4	
Hemitaurichthys polylepis						2
Heniochus acuminatus				1		
Heniochus chrysostomus			4	3	1	2
Heniochus diphreutes						
Heniochus monoceros						2
Heniochus singularius	1	3		3		2
Heniochus varius	2	3	2	1	11	8
Ephippidae - Spadefish						
Platax orbicularis		1				
Haemulidae - Soldier & Squirrelfish						
Plectorhinchus vittatus	3	1			3	1
Holocentridae	50	1	32	1	2	1
Myripristis kuntee	6		23	1		1
Myripristis violacea	7	1	8			
Myripristis vittata					1	
Neoniphon sammara	37					
Sargocentron caudimaculatum					1	
Sargocentron melanospilos						
Sargocentron spiniferum			1			
Labridae - Wrasse						
Anampses meleagrides						
Anampses neoguinaicus	4	1	2		2	2
Anampses twistii		1				
Bodianus axillaris		1	1		5	2
Bodianus loxozonus			2			1

Bodianus mesothorax	1			1		
Cheilinus chlorourus		1	1			
Cheilinus fasciatus	4	2				
Cheilinus oxycephalus						
Cheilinus trilobatus					7	
Cirrhilabrus punctatus	30	10		25		10
Coris aygula			2			1
Coris gaimard						
Epibulus insidiator	6	3	2			2
Gomphosus varius	5		5		3	1
Halichoeres argus		1				
Halichoeres hortulanus			2			3
Halichoeres marginatus						
Halichoeres prosopeion		1				
Halichoeres richmondi		1		2		
Hemigymnus fasciatus	2		3	6	3	8
Hemigymnus melapterus		3				
Labrichthys unilineatus	2	15		2	3	
Labroides bicolor			1		1	
Labroides dimidiatus		2	2		1	
Oxycheilinus digramma				1		3
Stethojulis bandanensis						
Thalassoma hardwicke	2		2		3	
Thalassoma lunare		1				
Thalassoma lutescens			1		1	2
Lethrinidae - Emperors						
Gnathodentex aureolineatus			100		75	
Lethrinus erythracanthus			1			
Lethrinus obsoletus						2
Monotaxis grandoculis	2	1				
Monotaxis heterodon		1	17	3	21	35
Lutjanidae - Snappers						
Aphareus furca		1				
Aprion virescens						1
Lutjanus bohar			12	15	4	1
Lutjanus ehrenbergii					1	1
Lutjanus fulviflamma					2	
Lutjanus fulvus	1		6			
Lutjanus gibbus			61	84	80	45
Lutjanus monostigma		4				
Lutjanus semicinctus		3	1			
Macolor macularis		6		1		
Macolor niger		2			2	13
Monocanthidae - Filefish						

Aluterus scriptus	5	1				1
Amanses scopas	3	1				1
Oxymonacanthus longirostris	2					
Mullidae - Goatfish						
Mulloidichthys flavolineatus						
Mulloidichthys vanicolensis			65		80	
Parupeneus barberinus		2				
Parupeneus crassilabris			3		3	
Parupeneus cyclostomus	2		3	2		2
Parupeneus multifasciatus	6	3	10	5	15	4
Parupeneus pleurostigma						2
Nemipteridae - Bream						
Scolopsis bilineata		7	1			4
Ostraciidae						1
Ostracion cubicus						1
Pempheridae- Sweepers						
Pempheris oualensis	3					
Pomacanthidae - Angelfish						
Apolemichthys trimaculatus						
Centropyge bicolor	19	8	1	16		7
Centropyge bispinosa	6	4	7	7	5	7
Centropyge flavissima	2		4		13	2
Genicanthus melanospilos				7		4
Pomacanthus semicirculatus				1		
Pygoplites diacanthus	3	6	2	3	6	2
Scaridae - Parrotfish						
Calotomus carolinus						
Cetoscarus ocellatus	3		4			2
Chlorurus bleekeri		2				7
Chlorurus japanensis			3			1
Chlorurus microrhinos			22		4	
Chlorurus sordidus	29	63	18	25	15	25
Scarus altipinnis			1			
Scarus chameleon	3	6	9	5		4
Scarus dimidiatus	9	7				1
Scarus frenatus					1	1
Scarus ghobban	4	5		1		4
Scarus globiceps					1	
Scarus niger	13	4	8	6	7	15

Scarus oviceps					16	
Scarus rubroviolaceus						
Scarus schlegeli	14	25	4	5	11	34
Scarus spinus	2		7	3	4	10
Scombridae - Mackerel						
Rastrelliger kanagurta			60	25	5	20
Scorpaenidae - Scorpion & Lionfish						
Pterois radiata						
Serranidae - Groupers						
Anyperodon leucogrammicus						
Cephalopholis argus	1					
Cephalopholis urodeta		1		1	3	
Epinephelus howlandi						
Epinephelus merra	1					
Epinephelus polyphekadion				1		
Variola albimarginata						
Variola louti						1
Siganidae - Rabbitfish						
Siganus argenteus	2	1		10	1	2
Siganus doliatus		2	9	7	2	
Siganus punctatus	2			2	2	
Siganus uspi	12					
Tetraodontidae - Pufferfish						
Arothron nigropunctatus	1	1			1	1
Zanclidae - Moorish Idol						
Zanclus cornutus	14	7	11	7	5	7

List of all fish species recorded on Combe Reef and SRMR (169 spp total)

Total Species count	Combe	SRMR
Acanthuridae - Surgeon & Unicornfish		
Acanthurus auranticavus		X
Acanthurus lineatus	X	
Acanthurus mata	X	X
Acanthurus nigricauda	X	X
Acanthurus nigrofuscus	X	
Acanthurus olivaceus		X
Acanthurus pyroferus	X	X
Acanthurus thompsoni		X
Ctenochaetus binotatus	X	X
Ctenochaetus striatus	X	X
Naso brevirostris	X	X
Naso hexacanthus	X	X
Naso lituratus	X	X
Naso vlamingii	X	X
Zebrasoma flavescens	X	
Zebrasoma scopas	X	X
Zebrasoma veliferum	X	X
Aulostomidae -Trumpetfish		
Aulostomus chinensis	X	X
Balistidae - Triggerfish		
Balistapus undulatus	X	X
Balistoides viridescens	X	X
Melichthys vidua		X
Sufflamen bursa		X
Caesioinidae - Fusiliers		
Caesio caerulaurea	X	X
Caesio teres	X	X
Pterocaesio marri	X	X
Pterocaesio pisang	X	X
Pterocaesio tile		X
Pterocaesio trilineata	X	X
Carangidae - Trevallies		
Carangoides ferdau		X
Chaetodontidae - Butterfly and Bannerfish		
Chaetodon auriga	X	
Chaetodon baronessa	X	X
Chaetodon bennetti	X	X
Chaetodon citrinellus	X	X
Chaetodon ephippium	X	X
Chaetodon flavirostris	X	X
Chaetodon kleinii	X	X
Chaetodon lineolatus	X	
Chaetodon lunula	X	X
Chaetodon lunulatus	X	X
Chaetodon melannotus	X	
Chaetodon mertensii	X	X
Chaetodon ornatissimus		X
Chaetodon pelewensis	X	X
Chaetodon plebeius	X	X
Chaetodon rafflesii	X	X
Chaetodon reticulatus	X	X
Chaetodon trifascialis	X	X
Chaetodon ulietensis	X	X
Chaetodon unimaculatus	X	X
Chaetodon vagabundus	X	X
Forcipiger flavissimus	X	X
Hemitaurichthys polylepis	X	X
Heniochus acuminatus	X	X
Heniochus chrysostomus	X	X
Heniochus diphreutes	X	
Heniochus monoceros	X	X
Heniochus singularius	X	X
Heniochus varius	X	X
Ephippidae - Spadefish		
Platax orbicularis		X
Haemulidae - Soldier & Squirrelfish		
Plectorhinchus vittatus	X	X
Holocentridae	X	X
Myripristis kuntee	X	X
Myripristis violacea	X	X
Myripristis vittata	X	X
Neoniphon sammara	X	X
Sargocentron caudimaculatum	X	X
Sargocentron melanospilos	X	
Sargocentron spiniferum		X
Labridae - Wrasse		
Anampses meleagrides	X	
Anampses neoguinaicus	X	X
Anampses twistii	X	X

Bodianus axillaris	X	X
Bodianus loxozonus	X	X
Bodianus mesothorax	X	X
Cheilinus chlorourus	X	X
Cheilinus fasciatus	X	X
Cheilinus oxycephalus	X	
Cheilinus trilobatus	X	X
Cirrhilabrus punctatus	X	X
Coris aygula	X	X
Coris gaimard	X	
Epibulus insidiator	X	X
Gomphosus varius	X	X
Halichoeres argus		X
Halichoeres hortulanus	X	X
Halichoeres marginatus	X	
Halichoeres prosopeion	X	X
Halichoeres richmondi		X
Hemigymnus fasciatus	X	X
Hemigymnus melapterus	X	X
Labrichthys unilineatus	X	X
Labroides bicolor	X	X
Labroides dimidiatus	X	X
Oxycheilinus digramma	X	X
Stethojulis bandanensis	X	
Thalassoma hardwicke	X	X
Thalassoma lunare	X	X
Thalassoma lutescens	X	X
Lethrinidae - Emperors		
Gnathodentex aureolineatus	X	X
Lethrinus erythracanthus		X
Lethrinus obsoletus		X
Monotaxis grandoculis	X	X
Monotaxis heterodon	X	X
Lutjanidae - Snappers		
Aphareus furca		X
Aprion virescens		X
Lutjanus bohar	X	X
Lutjanus ehrenbergii		X
Lutjanus fulviflamma		X
Lutjanus fulvus	X	X
Lutjanus gibbus	X	X
Lutjanus monostigma	X	X
Lutjanus semicinctus	X	X
Macolor macularis	X	X

Macolor niger	X	X
Monacanthidae	X	X
Aluterus scriptus	X	
Amanses scopas	X	X
Oxymonacanthus longirostris		X
Mullidae - Goatfish		
Mulloidichthys flavolineatus	X	
Mulloidichthys vanicolensis		X
Parupeneus barberinus	X	X
Parupeneus crassilabris	X	X
Parupeneus cyclostomus	X	X
Parupeneus multifasciatus	X	X
Parupeneus pleurostigma	X	X
Nemipteridae - Bream		
Scolopsis bilineata	X	X
Ostraciidae		X
Ostracion cubicus		X
Pempheridae - Sweepers		
Pempheris oualensis		X
Pomacanthidae - Angelfish		
Apolemichthys trimaculatus	X	
Centropyge bicolor	X	X
Centropyge bispinosa	X	X
Centropyge flavissima	X	X
Genicanthus melanospilos		X
Pomacanthus semicirculatus		X
Pygoplites diacanthus	X	X
Scaridae - Parrotfish		
Calotomus carolinus	X	
Cetoscarus ocellatus	X	X
Chlorurus bleekeri	X	X
Chlorurus japanensis	X	X
Chlorurus microrhinos	X	X
Chlorurus sordidus	X	X
Scarus altipinnis	X	X
Scarus chameleon	X	X
Scarus dimidiatus		X
Scarus frenatus	X	X
Scarus ghobban	X	X
Scarus globiceps		X
Scarus niger	X	X
Scarus oviceps		X
Scarus rubroviolaceus	X	
Scarus schlegeli	X	X

Scarus spinus	*X*	*X*
Scombridae - Mackerel		
Rastrelliger kanagurta	*X*	*X*
Scorpaenidae - Scorpion & Lionfish		
Pterois radiata	*X*	
Serranidae - Groupers		
Anyperodon leucogrammicus	*X*	
Cephalopholis argus		*X*
Cephalopholis urodeta	*X*	*X*
Epinephelus howlandi	*X*	
Epinephelus merra	*X*	*X*
Epinephelus polyphekadion	*X*	*X*
Variola albimarginata	*X*	
Variola louti	*X*	*X*
Siganidae - Rabbitfish		
Siganus argenteus	*X*	*X*
Siganus doliatus	*X*	*X*
Siganus punctatus	*X*	*X*
Siganus uspi	*X*	*X*
Tetraodontidae - Pufferfish		
Arothron nigropunctatus	*X*	*X*
Zanclidae - Moorish Idol		
Zanclus cornutus	*X*	*X*