Field Report

GLOBAL REEF EXPEDITION: Rangiroa, French Polynesia

8/03/13-23/03/13

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Front cover: Aerial view of Rangiroa atoll. Photo by Andrew Bruckner.

Back Cover: Fore reef location off the northeast end of Rangiroa with unusually high cover of living coral. At 10-20 m the reef was dominated by *Porties lobata*, foliaceous *Montipora* and other taxa. Photo by Andrew Bruckner.

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Executive Summary

Between March 8, 2013 – March 23, 2013, the Khaled bin Sultan Living Oceans Foundation conducted a research mission to Rangiroa Atoll, French Polynesia as part of the Global Reef Expedition. The research focused on coral reefs surrounding Moorea and Rangiroa. The project was conducted in partnership with the University of Queensland, with involvement of scientists from Le Centre de Recherches Insulaires et Observatoire de l'Environnement de Polynésie Française (CRIOBE), University of Maine, Nova Southeastern University, University of the Azores, University of the Philippines, Wildlife Marine, and West Palm Beach Television (WPBT) Public Broadcasting System (PBS). The objectives of the mission were to: 1) identify and characterize shallow marine habitats and develop habitat and bathymetric maps: 2) evaluate the composition, structure and health of coral reefs using a standardized assessment protocol; 3) evaluate threats affecting coral and fish populations, the extent of degradation, patterns of recovery from hurricanes and other acute disturbances, and overall resilience to these stressors; 4) quantify the loss of coral skeleton since the 1998 bleaching event and patterns of recovery within the lagoon; 5) quantify the abundance and grazing intensity of herbivorous reef fish; and 5) assess the status of shark populations.

Groundtruthing: A total of 2113 sq km of WorldView 2 satellite imagery was acquired. To characterize shallow marine habitats, 137 videos (drop cameras) and 703,224 depth soundings were taken across Rangiroa Atoll, covering a distance of 320 km.

Coral Reef Assessments: Detailed coral assessments, including 181 Fish transects, 336 benthic surveys, 90 coral assessments and phototransects were completed in 34 locations around Rangiroa atoll, from 5-30 m depth. This included an assessment of 11,617 corals.

Coral Reef Research:

- Sediment samples were collected from the lagoon and fore reef around Rangiroa (n=69) and the fore reef of Moorea (n=3).
- Stationary video cameras (10/dive) were deployed in 4 sites around Rangiroa to characterize patterns of herbivory.
- Shark populations were assessed along ten 400m belt transects in Rangiroa. A total of 16 sharks were identified. Reef shark abundances were variable, although densities of all reef shark species were highest in the reef passes. Here the whitetip reef shark was numerically dominant, followed by the grey reef shark then the blacktip reef shark. The silvertip shark is not commonly sighted on coral reefs. However three individuals were sighted in the Avatoru Pass, at a level of abundance equivalent to that of grey reef sharks.
- Coral recruits were assessed in four locations on the fore reef and one lagoonal site. Recruits were dominated by Pocilloporids, but also included *Acropora* spp, *Montipora* spp. and *Porites* spp. Recruit densities varied from 8 to 39.2 recruits per m^2.
- A total of 114 colonies of massive *Porites* were surveyed at Tivaru in March 2013 to evaluate changes that occurred since the 1998 bleaching event. The colonies (0.6m to 7.1m in diameter) had 71.0% live tissue, and less than 1% recently dead, exposed skeleton, as compared to 32.5% live tissue and 24.6% recently dead in 1998. This study demonstrated unprecedented post-bleaching recovery of large massive corals even after severe mortality.

Summary of General Findings

Moorea. These reefs were devastated by a severe outbreak of COTS from 2004-2008, then the dead corals were broken up and removed by Hurricane Oli in 2010. After the hurricane, cover on the shallow reef was about 0.5%. During the present surveys, shallow reef (5 m) had a moderate cover (5-10%) of small *Pocillopora, A. hyacinthus, Porites*, branching *Montipora, Psammocora*, and other species, most of which were relatively small (2-12 cm in diameter) and relatively young (2-3 years old). Much of the reef slope and deeper reef communities consisted of rubble fields, barren turf-algal covered substrates, and areas with larger massive coral skeletons (*Porites lobata*) in growth position. The only larger living colonies that appear to have been avoided by COTS were occasional *Porites rus* colonies and *Pocillopora eydouxi*, but cover was generally 0-5%. The largest, old *Porites* colonies were massive, and more flattened in deep water, generally 60-200 cm diameter and up to 100 cm tall. Most were completely dead, although 20-30% had small surviving remnants (up to 15 on some colonies) that appeared as small knobs and mounds elevated above the surrounding skeleton. On the sides and bases, a few of the remnants were resheeting, instead of growing upward. The skeletons supported from 1-2 up to dozens of recruits of other species. Recruits were also observed on the substrate, but these were far fewer in number except in shallow water (0-7 m). Recruits recorded on Porites colonies at20-30 m depth included *Pocillopora, P. varians, Acanthastrea, Leptastrea, Cyphastrea, Montipora*, and *Acropora*. Many of these were small crusts 3-10 cm diameter; *Pocillopora* consisted of two size classes, 1-3 cm and 8-12 cm cohorts. There was very little macroalgae on this reef, except for small patches of *Lobophora* and crusts of pessyonelid algae.

Rangiroa

General fore reef condition

Coral reefs varied considerably in cover of live corals, species composition, amount of macroalgae, extent of dead corals and amount of rubble depending on exposure and depth. Fore reefs on the north coast, especially near the two channels, had lower cover, higher amounts of rubble and more dead, coralline algae encrusted skeletons than reefs on the west, south and northeast coasts. These reefs also had very high cover (20-50%) of *Halimeda* on deeper reef slopes, some of which formed mats 20-30 cm thick. North coast reefs also had considerable amounts of recent partial mortality on *Pocillopora* and *Acropora* attributed to *Drupella* predation and white syndrome. A number of reefs on the west coast have unusually large boulders on the reef flat and continuing down the reef slope that were deposited during a past Tsunami. Some of the reefs on the northwest end have a lot of rubble, considerable amounts of a green sponge overgrowing coral and large patches of *Millepora*. South coast reefs are fairly low-relief with moderate to high cover of corals in shallow water (40-60%). Most coral consists of low-lying branching pocilloporids and acroporids and encrusting corals, with larger plates of *Montipora, Porites* and other species on deeper parts of the reef. The deeper reef also has large patches of *Halimeda* and some large areas of *Caulerpa*. Very low numbers of crown of thorns sea stars were identified; recent mortality was also associated with *Culcita* (starfish) predation.

Coral recruitment

At 10 m depth coral recruits were dominated by *Pocillopora*, but also included *Acropora* spp., *Montipora* spp. and *Porites* spp. Recruit densities varied from 8 to 39.2 recruits per m^2. Such densities are broadly similar to elsewhere in the Pacific, but are significantly higher than that reported in Moorea (7.9 recruits per m^2) a decade earlier (Penin *et al.* 2007). In some areas where there was considerable amounts of dead *Pocillopora* in growth position, very high numbers of Montipora recruits were seen within the branches.

Algal composition and cover

In shallow water (0-10 m depth) crustose coralline algae (CCA) cover was high at outer reef sites, but lower in the lagoon (at Motu Nui), where turf algal cover was dominant on hard substrates. Deeper reefs vary considerably. Some have little macroalgae, while others are dominated by *Halimeda* and/or *Caulerpa*.

Lagoonal reef condition

Lagoonal reefs near the passes had high abundances of *Porites lobata* colonies in shallow water (2-5 m depth), although many had large patches of old mortality and these were colonized by small branching pocilloporids and other species. In the central parts of the lagoon, small patch reefs were identified with dense thickets of branching acroporids in shallow water, some *Porites*, and other species, but coral cover rapidly declined below 5 m. Many of these patch reefs had steep slopes that were mostly sand and rubble with very low coral cover. One lagoonal reef had a very high diversity of *Acropora* and unusually large thickets of this coral. Most was in good shape, although an outbreak of *Drupella* was noted, with 10-20% of the colonies showing recent mortality. Crown of thorns seastars were rare but present on several lagoonal reefs. A shallow (< 10 m deep) lagoonal patch reef at the northwestern end of Rangiroa (Tivaru) was dominated by unusually large (up to 10 m diameter) massive *Porites lobata* colonies. These are reported to have experienced catastrophic tissue loss during the 1998 bleaching event. These demonstrated a remarkable resistance to stress, and a remarkable capacity for recovery. These colonies showed signs of considerable resheeting and very little recent mortality.

Fig. 1 Typical shallow fore reef community on the west side of Rangiroa.

Research Completed

1. Habitat mapping and groundtruthing

Using multispectral satellite imagery obtained from Digital Globe WorldView 2 satellite, high resolution bathymetric maps and habitat maps are being created for shallow coral communities. Groundtruthing efforts necessary to develop these maps focused on aerial surveys of each island's coastline and adjacent shallow marine habitat, continuous bathymetry measures, drop camera analysis, characterization of sediment and hard substrates and habitat features using two acoustic sub-bottom profiling equipment (Stratabox and Hydrobox) and fine scale photo-transect surveys.

Satellite imagery

A total of 2113sq km of WorldView 2 (8 band) satellite imagery was acquired for this project (Table 2). The satellite images had a spatial resolution of 2-m by 2-m (i.e., each pixel covers a 4-m^2 area) enabling real-time navigate in the field to locate features of interest and to avoid dangerous features (e.g., emergent reefs). In order to navigate, the team used the scenes in conjunction with a differential GPS device (dGPS). The imagery is being used in conjunction with ground truth data to create bathymetric and benthic habitat maps.

Benthic Video

An underwater video camera attached to a cable, called a drop-cam, was used to gather video on the benthic composition at each survey site. At each point, the drop-cam was held from the survey boat enabling it to 'fly' along the sea floor as it records video for 15 to 60 seconds. During this time, the laptop operator watched the video in real-time and guided the drop-camp operator to raise or lower the camera. In this manner, we were able to prevent damage to marine life. The video was recorded on a ruggedized laptop, and the geographic position, time, date, boat heading, and boat speed were burned into the video. Drop-cam deployment was limited to depths above 40 m due to the limited length of the tether cable (50 m). The acquired videos are being used to create the benthic habitat maps by providing the necessary information for the development of a habitat classification scheme and training of classification models. A minimum of 30 drop-cam videos were gathered per day.

Acoustic depth soundings

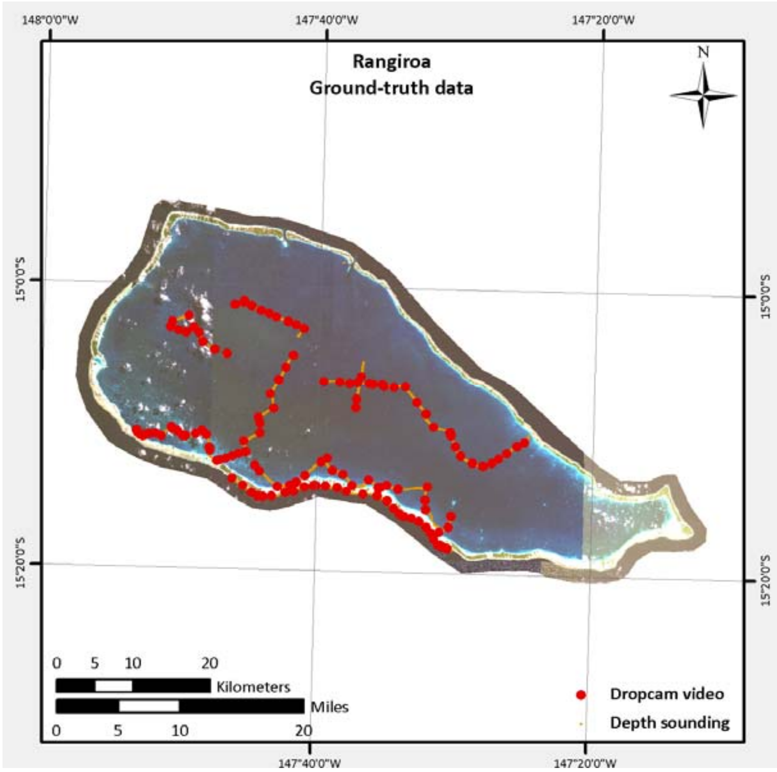
Depth soundings were gathered along transects between survey sites using Hydrobox, a single-beam acoustic transducer, developed by Syqwest. The instrument emits 3 pings per second. Depths were estimated based on the time the return-pulse's reaches the sounder's head. Geopositional data were simultaneously acquired by the dGPS unit. The estimated depth values and their geographic location were recorded in the ruggedized laptop. The soundings were used to train a water-depth derivation model, which is based on the spectral attenuation of light in the water column. The final topographic map will have the same spatial resolution as the satellite imagery. An average of 100,000 acoustic depth soundings was gathered during a full work day.

Acoustic sub-bottom

Profiles of the seafloor's sub-bottom were also gathered along transects using the Stratabox acoustic sounder, also developed by Syqwest. Similar to the bathymetric soundings, the sub-bottom profile emits an acoustic ping which reflects off the seafloor. However, the pulse has a lower frequency (3.5 Khz) enabling it to penetrate the seafloor. The instrument provides observations on striatal geometry beneath the seafloor along the transect lines, allowing estimates of Holocene reef-growth and sediment accumulation to be made. Geopositional data for each ping was simultaneously acquired by dGPS unit; it was recorded in the SEGY file. Profiles were run shore-perpendicular to capture the geometry of the bank flanks and span a depth range of 300 m to 5 m. Total transect length varies with the slope's angle; steeper slopes resulted in shorter transect lines.

Atoll	Site	Mapping area (sq km)	No. dropcams	No. depth soundings	Track length (km)
Rangiroa	Rangiroa	**2113**	**137**	**703224**	**320**

Table 1. Summary of groundtruthing datasets: total area of satellite imagery acquired number of deployments of the drop camera, number of depth soundings and total distance covered by the groundtruthing team.



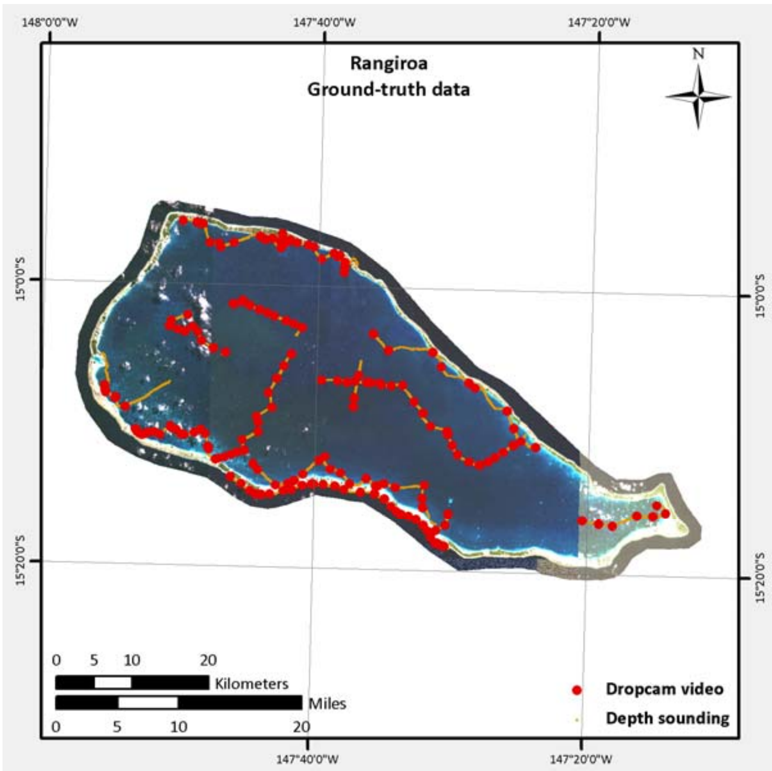


Fig. 2. Track of the groundtruthing team and locations of drop camera deployments in Rangiroa. Groundtruthing undertaken during February 2013 (top) and during November 2012 and February 2013 (bottom).

2. General Approach of SCUBA assessments:

Fish Assessments

For fish, abundance and size structure was collected for over 200 species of fishes (Appendix 1), targeting species that have a major functional role on reefs or are major fisheries targets. Reef fishes were assessed along 4 m X 30 m belt transects. A T square marked in 5 cm increments was used to gauge fish size. A minimum of 6 transects were conducted by each "fish" diver per site. A roving survey was also completed to assess the total diversity and relative abundance (rare, common, and abundant) of reef fishes at each site.

Benthic cover

Cover of major functional groups (corals identified to genus, sponges, other invertebrates, and six groups of algae including macroalgae, crustose coralline algae, erect coralline algae, fine turfs, turf algae with sediment and cyanobacteria) and substrate type (hardground, sand, mud, rubble, recently dead coral, bleached coral, live coral) were assessed along 10 m transects using either recorded observations and/or photographic assessments. Recorded observations involve a point intercept method, whereas the organism and substrate was identified every 10 cm along a 10 m transects (total 100 points/transect), with a minimum of six transects examined per location. When possible surveys were done at 30, 25, 20, 15, 10 and 5 m depth

Photographic assessment

A 10 m long transect tape was extended along depth contours at 30, 20, 15, 10 and 5 m depth. Continuous digital still photographs were taken from of the reef substrate from a height of approximately 0.6-0.75 meters above the substrate, using a one meter bar divided into 5 cm increments placed perpendicular to the transect tape as a scale bar. Approximately 20 photographs were taken per transect to allow for overlap between adjacent images with two photo transects (each 10 m in length) per depth. Images were downloaded onto a computer, and benthic community composition, coral cover and cover of other organisms and substrate type, and to determine the size (planar surface area) of corals were analyzed using Coral Point Count (CPCE) software developed by the National Coral Reef Institute (NCRI). Cover was determined by recording the benthic attribute located directly below random points (30-50 points per photograph). Planar surface area was measured by tracing the outline of individual corals.

Coral assessments

A combination of quantitative methods, including belt transects, point intercept transects, radial plots and quadrats were used to assess corals, fish and other benthic organisms. Five measures were recorded for corals: 1) benthic cover (point intercept, see above); 2) coral diversity and abundance (by genus, except certain common species); 3) coral size class distributions; 4) recruitment; and 5) coral condition. Additional information was collected on causes of recent mortality, including signs of coral disease and predation. Assessment of corals smaller than 4 cm was done using a minimum of five 0.25 m^2 quadrats per transect, with each quadrat located at fixed, predetermined intervals (e.g. 2, 4, 6, 8, 10 m), alternating between right and left side of the transect. Recruits were identified in both point intercept surveys and belt transects. Recruits were divided into two categories: corals up to 2 cm diameter and larger corals, 2-3.9 cm diameter.

Coral population structure and condition was assessed within belt transects (each 10 m x 1), with a minimum of two transects done per depth. Each coral, 4 cm or larger was identified (to genus at minimum) and its growth form was recorded. Visual estimates of tissue loss were recorded for each colony over 4 cm in diameter using a 1 m bar marked in 1 cm increments for scale. If the coral exhibited tissue loss, estimates of the amount of remaining tissue, percent that recently died and percent that died long ago were made based on the entire colony surface. Tissue loss was categorized as recent mortality (occurring within the last 1-5 days), transitional mortality (filamentous green algae and diatom colonization, 6-30 days) and old mortality (>30 days).

For each coral with partial or whole colony mortality, the cause of mortality is identified if possible. The diagnosis included an assessment of the type of disease, extent of bleaching, predation, competition, overgrowth or other cause of mortality. Each coral was first carefully examined to identify cryptic predators. Lesions were initially diagnosed into four categories: recent tissue loss, skeletal damage, color change, and unusual growth patterns; an individual colony could have multiple characteristics (e.g. color change and recent tissue loss). The location (apical, basal, and medial) and pattern of tissue loss (linear, annular, focal, multifocal, and coalescing) was recorded and when possible a field name was assigned. If an outbreak of coral disease was documented, sampling of the affected corals was undertaken to further characterize the disease (see below).

Motile invertebrates

Large motile invertebrates (urchins, octopus, lobster, large crabs, large gastropods, sea cucumbers) were identified and counted along coral belt transects and benthic point intercept surveys. In addition, one or two divers conducted timed swims at different depths to document the species diversity and abundance of sea cucumbers at each site assessed. This assessment included a documentation of the type of habitat occupied by these organisms.

Islands	Number of dive sites	Benthic transects	Fish transects	Coral transects	# corals	Phototransects
Rangiroa	34	324	173	82	11,139	178
Moorea	4	12	8	8	478	37

Table 2. Summary of the coral reef assessments. The total number of benthic, fish and coral transects and number of corals assessed around Rangiroa and Moorea are shown.

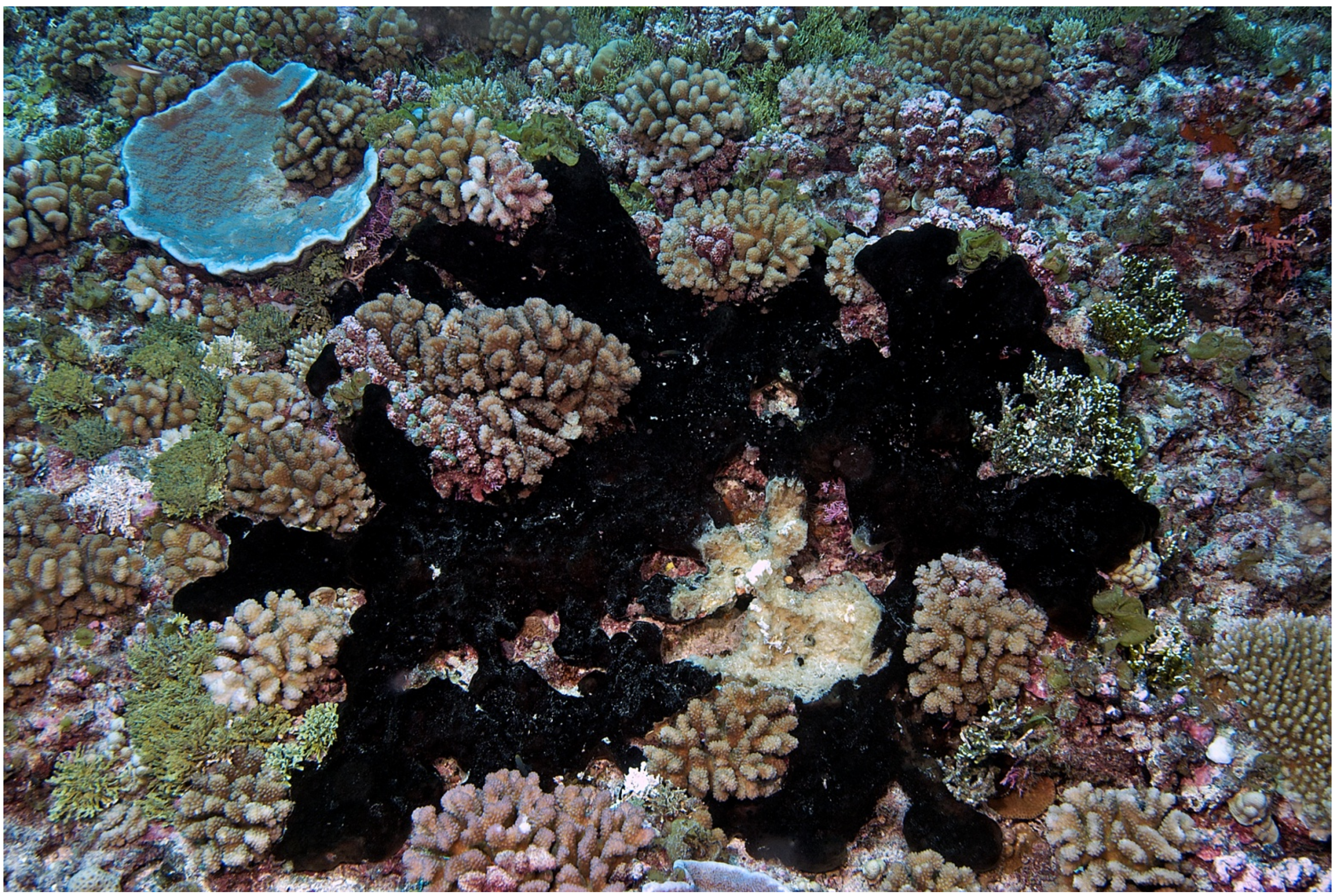


Fig. 3. In several fore reef locations an encrusting sponge was carpeting much of the substrate and overgrowing corals. Many reefs also had high cover of erect coralline algae (*Halimeda*).

Table 3. Coordinates of survey locations, site name, exposure and reef type.

Date	Lat	Long	site name	exposure	reef type
9-Mar-13	-15.1270	-147.9418	MMRA-01	leeward	fore reef
9-Mar-13	-15.0886	-147.9428	MMRA-02	leeward	fore reef
9-Mar-13	-14.9792	-147.6160	MMRA-03	leeward	fore reef
10-Mar-13	-15.1656	-147.9089	MMRA-04	leeward	fore reef
10-Mar-13	-15.0561	-147.9392	MMRA-05	leeward	fore reef
10-Mar-13	-15.0113	-147.9093	MMRA-06	leeward	fore reef
11-Mar-13	-14.9762	-147.8772	MMRA-07	leeward	fore reef
11-Mar-13	-14.9151	-147.8344	MMRA-08	leeward	fore reef
11-Mar-13	-14.9555	-147.6449	MMRA-09	leeward	fore reef
12-Mar-13	-15.2359	-147.6532	MMRA-10	leeward	fore reef
12-Mar-13	-15.2556	-147.5754	MMRA-11	leeward	fore reef
12-Mar-13	-15.2362	-147.7561	MMRA-12	leeward	fore reef
13-Mar-13	-14.9481	-147.6703	MMRA-13	leeward	fore reef
13-Mar-13	-14.9898	-147.5970	MMRA-14	windward	fore reef
13-Mar-13	-14.9695	-147.6272	MMRA-15	leeward	fore reef
14-Mar-13	-14.9295	-147.7640	MMRA-16	windward	fore reef
14-Mar-13	-14.9826	-147.6346	MMRA-17	lagoonal	patch reef
15-Mar-13	-15.0137	-147.5730	MMRA-18	windward	fore reef
15-Mar-13	-14.9721	-147.6221	MMRA-19	windward	fore reef
16-Mar-13	-15.0048	-147.5792	MMRA-20	windward	fore reef
16-Mar-13	-15.0262	-147.5650	MMRA-21	windward	fore reef
17-Mar-13	-15.0015	-147.8808	MMRA-22	lagoonal	patch reef
17-Mar-13	-14.9344	-147.7090	MMRA-23	windward	channel
18-Mar-13	-14.9333	-147.7095	MMRA-23b	windward	channel
17-Mar-13	-14.9615	-147.6318	MMRA-24	windward	fore reef
18-Mar-13	-15.0467	-147.5406	MMRA-25	windward	fore reef
18-Mar-13	-14.9417	-147.6896	MMRA-26	windward	fore reef
19-Mar-13	-15.1447	-147.4247	MMRA-27	windward	fore reef
19-Mar-13	-15.1040	-147.4769	MMRA-28	windward	fore reef
19-Mar-13	-14.9200	-147.8015	MMRA-29	windward	fore reef
20-Mar-13	-14.9684	-147.6247	MMRA-30	windward	fore reef
20-Mar-13	-15.2364	-147.2797	MMRA-31	windward	fore reef
21-Mar-13	-17.4828	-149.9020	MMMO-32	stormward	fore reef
21-Mar-13	-17.4848	-149.8672	MMMO-33	stormward	fore reef
22-Mar-13	-17.4986	-149.9278	MMMO-34	stormward	fore reef

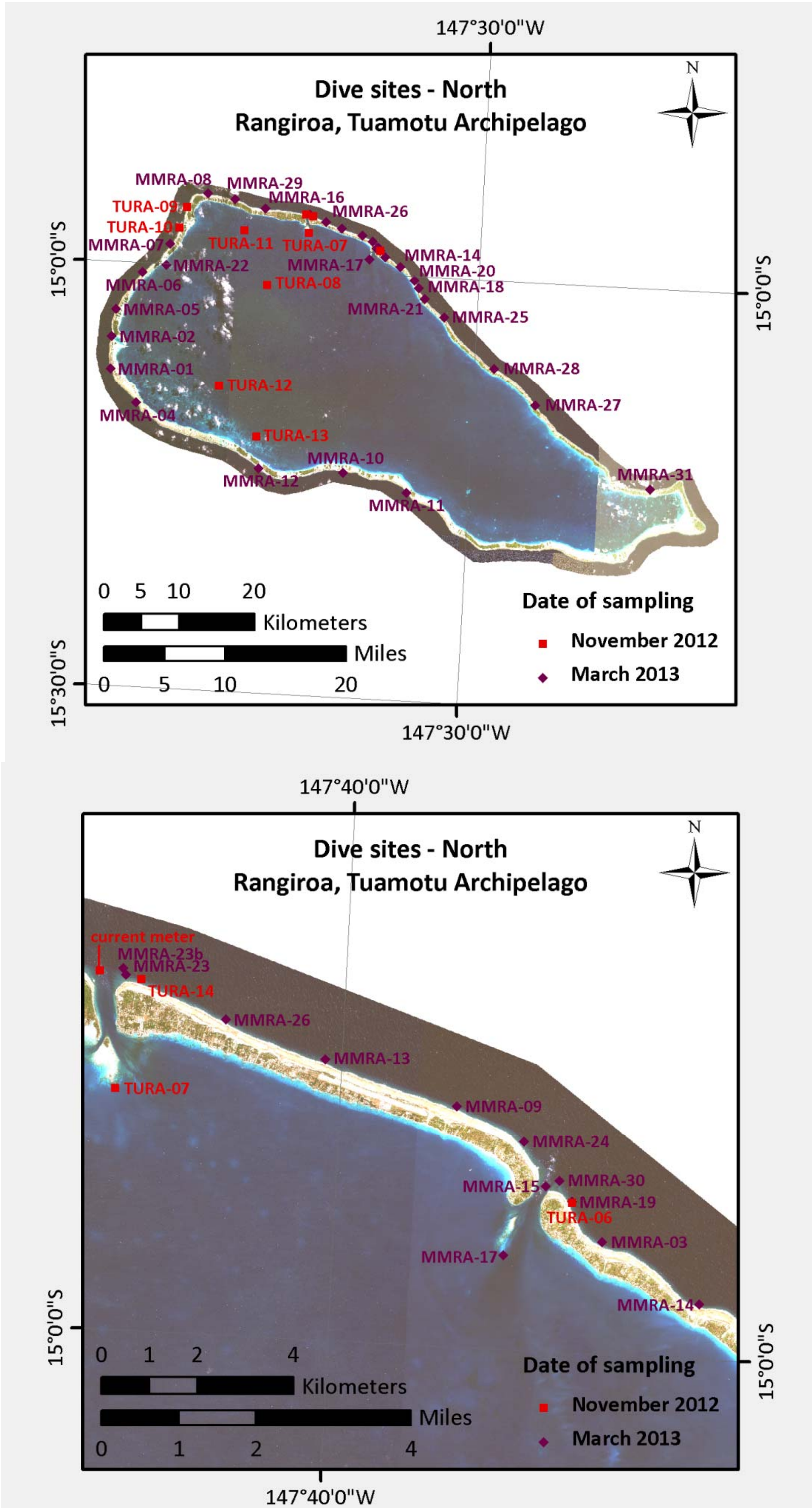


Fig. 4. Location of coral reefs examined around Rangiroa in Nov. 2012 (red) and March 2013 (purple) using SCUBA.

3. Coral reef research

Herbivory:

Field surveys of grazing intensity

Grazing intensity was quantified using stationary video cameras in a total of six sites distributed across Rangiroa. Ten high-definition video cameras (GoPro Hero2) fixed to 3-pound dive weights were installed at each site and programmed to record continuously for two hours in the afternoon (13:00 - 16:00), when herbivory is known to be highest. Cameras were placed at least 10 m apart from any other and mounted on relatively high places of the substratum ensuring a well-lit areas dominated by grazable surfaces could be filmed. Filming resolution was adjusted to capture at least a $1m^2$ field of view and the exact boundaries of this area were marked by briefly showing a gridded $1m^2$ quadrat to each camera at the beginning of each recording. The 10-cm segments of the grid would serve as a size reference to estimate total fish length (TL) during video analyses. Cameras were left filming for a minimum of 70 minutes in the absence of divers.

Site	Dive	Date
Site 1 – (Rangiroa forereef)	Second	15 March
Site 2 – (Rangiroa forereef)	Second	16 March
Site 3 – (Moto nuhi)	Second	19 March
Site 4 – (Moto nuhi)	Second	20 March
Site 5 – (Tiahura)	Second	21 March
Site 6 – (Tiahura)	Second	22 March

Table 4. Locations of GoPro camera deployments

Footage processing

To minimize the time invested in data extraction while surveying a representative portion of the footage, each video will be subdivided in consecutive 3-minute intervals. Data will be extracted from 8 × 3-min intervals per camera (i.e. 40% of footage). To facilitate the detection of feeding events videos will be played in real time in 23-inch computer screens. Prior to data extraction the quadrats and grids filmed by each camera will be traced on an acetate sheet. Data will be extracted while observing the footage through the corresponding grid overlaid on the computer screen. The surveyor will focus on detecting feeding visits of surgeonfish, parrotfishes, and rabbitfish which sustain the grazing process on Pacific reefs. A feeding visit is defined here as the entry of an individual fish into the camera's field of view to take bites on the substratum enclosed within the quadrat boundaries. A visit terminates when the individual exited the quadrat boundaries to feed outside the quadrat while consistently moving away from it, or to exit the camera's field of view. For each feeding visit surveyors will record a) the time of entry and time of exit, b) the species (and life phase for parrotfishes), c) the estimated total length (TL), and c) the number of bites taken per visit. The TL of each visiting fish will be estimated using the grid's segments as a reference.

Fig. 5. A GO-Pro video camera deployed on a shallow lagoonal reef in Rangiroa.

Shark surveys:

Shark populations and large pelagic species were characterized in shallow fore reef (<10 m) and reef crest environments to get a better sense on the population structure and the role of apex predators in coral reef ecosystems. Ten reef crest surveys were conducted on the northern and eastern sides of the Rangiroa atoll, consisting of six transects conducted on the outer reef crest, and four transects in reef passes. Surveys involved swimming 400 m belt transects in 20 minutes on SCUBA, counting all sharks seen within 10 m of the line of travel. Lengths of survey transects were periodically verified with LOF boat staff and handheld GPS units. All dives were also recorded using a stereo camera rig, to allow later analysis of shark movements and sizes if required.

A total of 16 sharks were sighted from four species. All sharks were from the family. Carcharhinidae, and included the blacktip reef shark (*Carcharhinus melanopterus*), the grey reef shark (*C. amblyrhynchos*), the silvertip shark (*C. albimarginatus*) and the whitetip reef shark (*Triaenodon obesus*). A fifth species, the blackfin shark, (*C. limbatus*), was also sighted.

Transect	Date	Time	Location	Depth	Viz (m)
1	15.03.2013	10:47	NE Reef front (SE of Tiputa pass)	12-14 m	30
2	15.03.2013	14:28	NE Reef front (SE of Tiputa pass)	12-14 m	30
3	16.03.2013	8:28	NE Reef front (SE of Tiputa pass)	16 m	25
4	16.03.2013	14:47	NE Reef front (SE of Tiputa pass)	16-18 m	30
5	17.03.2013	7:56	Avatoru pass, East side	18-20 m	30
6	17.03.2013	16:36	NE Reef front (650 m NW of Tiputa pass)	12-15 m	20
7	18.03.2013	8:00	Avatoru pass, East side	12-18 m	30
8	19.03.2013	9:40	Tiputa pass, east side	12-30 m	30
9	20.03.2013	10:19	Tiputa pass, east side	15-25 m	30
10	20.03.2013	15:02	Far east Rangiroa	6-15 m	30

Table 5. Summary of transects completed to assess apex predators

Fig. 6. Camera unit used to document apex predators.

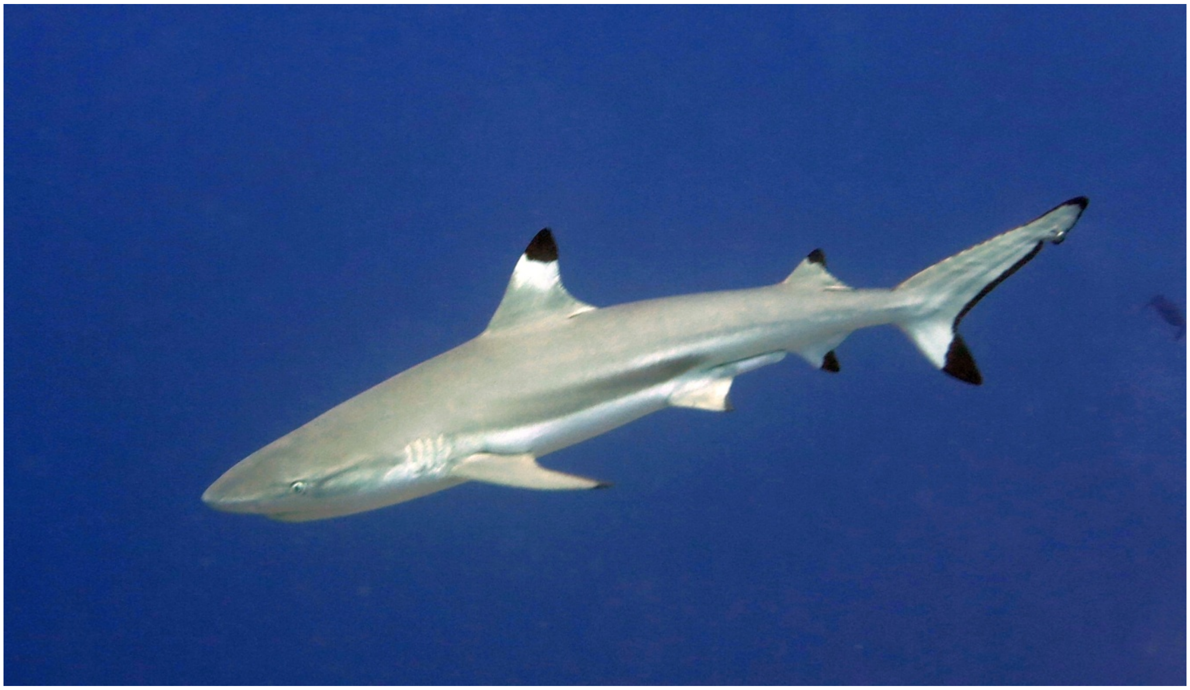


Fig. 7. Blacktip reef shark seen in the pass at the northwest end of RangiroaSediment collection:

Sediment samples were collected using two different methods. The first method used SCUBA and concentrates on the sloped outer flanks of the reef, whilst the second employs a grab sampler to investigate the sediment composition inside the reef lagoon. At each sample station, approximately 100 ml of sediment was shoveled by hand into a 125 ml plastic bottle. Stations were selected so that no benthic life is disturbed or injured. Digital pictures of underwater landscapes surrounding the sampling site were also gathered to provide a visual record of the station. Up to ten samples were collected per day.

In the lagoons, sediment is collected using a Petite Ponar® Grabber. The grabber was attached to an electronic winch wound with 50m of braided polyester line. The winch was mounted on the gunnel of the small ground-truthing boat. The grabber was slowly deployed over the side of the boat until it settles on the seafloor, causing the winch line to slacken and the grab to shut. The sample was then winched back to the surface. Once the grab is retrieved, it was lifted into the boat and the sediment collected. At each deployment of the grabber, 100 ml of sediment was shoveled by hand into a 125 ml plastic bottle. A maximum of five samples were taken per day using this method.

In the laboratory, the samples were rinsed with a weak bleach solution (30% bleach and 70% tap water) and allowed to set for several days. This process halts biological activity and preserves the sediments. The samples were dried in an oven at low heat (50°-70°c) for 24 hours, and then analyzed using a Camsizer® instrument to determine the size and shape of sediment grains. The data are being used to create sediment maps akin to the benthic habitat maps.

Island	Number of samples
Rangiroa	69
Moorea	3
Total	

Table 6. Total number of sediment samples.

Coral recovery following the 1998 bleaching event:

Tivaru

Our partners from University of Queensland evaluated changes in reef community assemblages since the 1998 bleaching event at Tivaru In 1998, seven 5 x 5 m quadrats were surveyed within randomly chosen locations at Tivaru. Within this area, 91 randomly placed 1 m^2 quadrats were sampled to assess benthic cover. *Porites* substrates were categorized as either (i) living tissue, (ii) 'recently dead skeleton' (corallite structure visible, usually colonized by filamentous algae), or (iii) 'old dead' (corallite structure absent, grazing scars of herbivores often visible). In addition, five belt transects of approximately 6 m width and 20 m length were laid between white tarpalins that were georeferenced. Each *Porites* colony along each transect was designated as 'live coral' if ≥80% of the tissue was 100 living; recently-dead if ≤19% (though typically 5%) of the tissue was living and the remainder was recently-dead; partially-dead if the extent of living tissue fell between 20-79%; and old dead if the colony simply comprised eroded substrate.

In 2013, two parallel transects of 30m length and separated by 30m were laid haphazardly across the center of the site. A total of 63 quadrats (0.25m^2) were placed on *Porites* colonies adjacent to transects, and benthic cover estimated for each colony. *Porites* substrates were categorized as either (i) living tissue, (ii) 'recently dead skeleton' (corallite structure visible, usually colonized by filamentous algae), or (iii) 'old dead' (corallite structure absent, grazing scars of herbivores often visible). In addition, the longest of the five belt transects laid in 1998 was resurveyed.

In addition, the condition of the substrate, crustose coralline algae, patterns of coral recruitment and condition of juvenile and adult corals at five sites at Rangiroa [four outer sites on the north coast and a site within the lagoon atoll pass, (Motu Nui)] to determine for coral recruit densities and benthic cover. Data were assessed along 10 m transects. Both recruits and benthic cover was recorded using a 25 x 25cm^2 quadrat measured at 0, 2.5, 5, 7.5 and 10m.

Recruitment and benthic community structure

Coral recruits were dominated by Pocilloporids, but also included *Acropora* spp., *Montipora* and *Porites* spp. Crustose coralline algae (CCA) cover was high at all outer-reef sites, but lower at Motu Nui, where turf algal cover was dominant in non-coral substrates. Macroalgal cover was low across all sites (<10%).

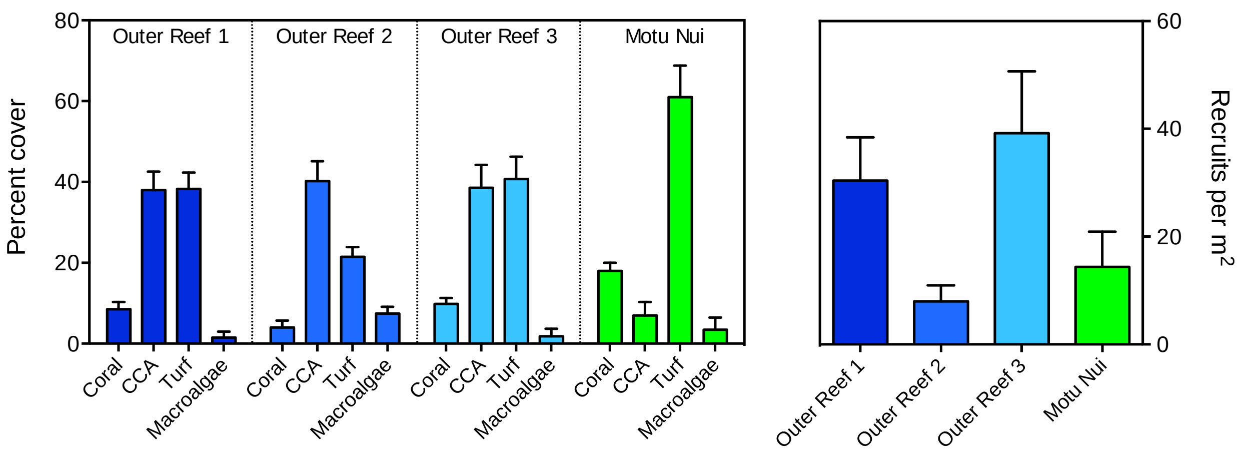


Fig. 8. Percent cover of coral, crustose coralline algae (CCA), turf algae and macroalgae (left) and numbers of recruits (right) observed by the UQ team at three outer sites and one lagoonal site.

Oceanographic measurements:
At each survey location a temperature and salinity profile was acquired using a CastAway CTD. This instrument records a GPS position with a 10 m accuracy, derived salinity (resolution of 0.01), and temperature (resolution 0.01 C) along a depth profile (pressure with a resolution of 0.01 dBar). An assessment of current speeds and direction (Fig. 9) was also made using a Recording Doppler Current Profiler (RDCP). This instrument also recorded depth, tide, surface referred profile columns, surface current measurement, conductivity (salinity), turbidity, oxygen, temperature and wave height. Data were collected for a four day period at a site on the north coast, approximately 200 m from the pass.

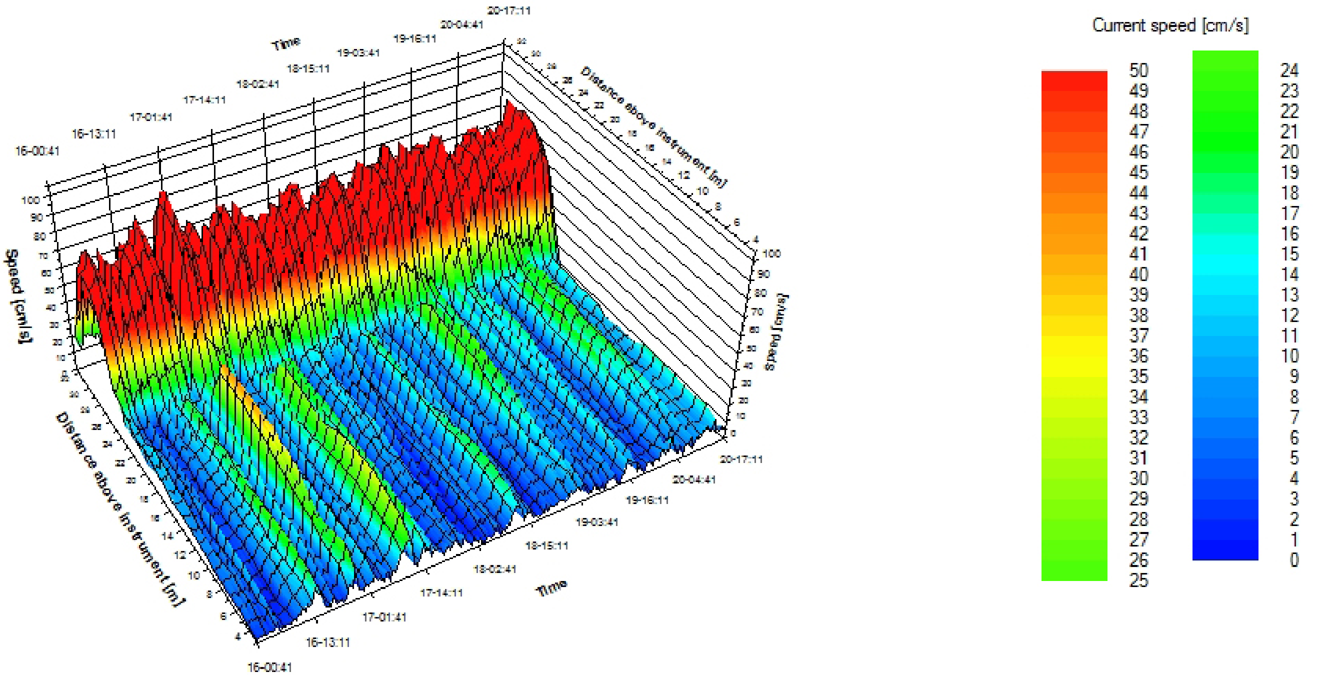


Fig. 9. Current data (horizontal speed) in the channel at Rangiroa over a five day period. The currents were up to 80 cm/second in the top 3-5 m depth, and drop off in deeper water.

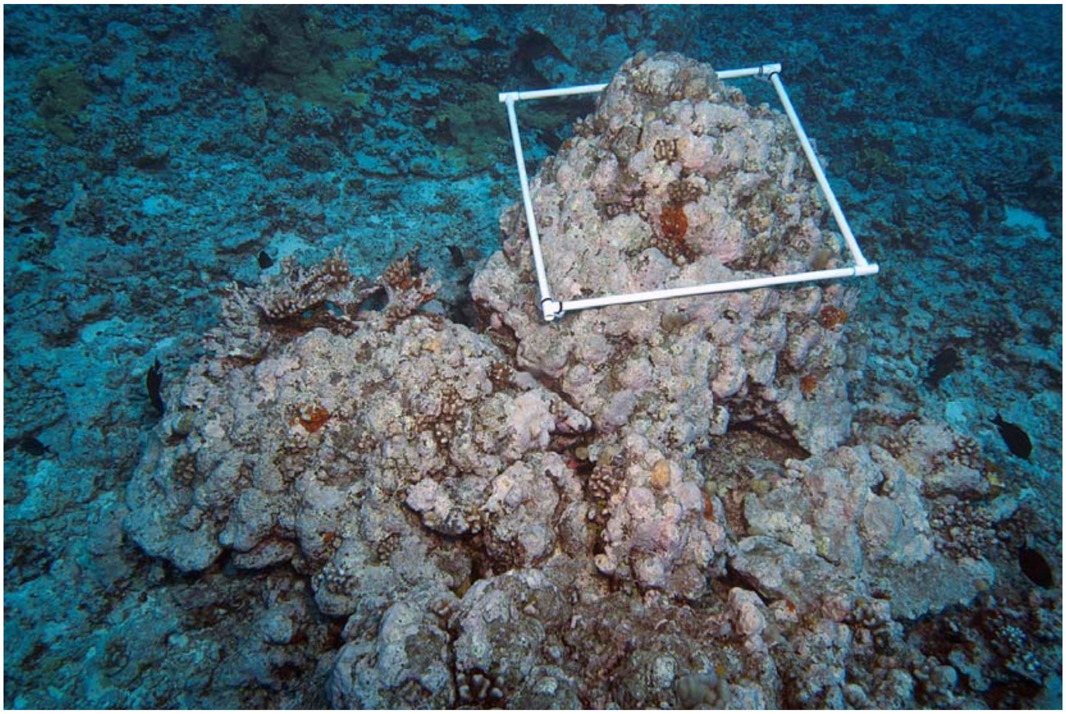


Fig. 10. A large dead *Porites lobata* colony at 20 m depth in Moorea. The coral was consumed by crown of thorns seastars. A high number of pocilloporid corals and other species have colonized the dead skeleton. The quadrat is 1m^2.

Appendix 1. Participants

Name	Institution	Function
Phil Renaud	Khaled bin Sultan Living Oceans Foundation	Executive Director
Andy Bruckner	Khaled bin Sultan Living Oceans Foundation	Chief Scientist
Brian Beck	Khaled bin Sultan Living Oceans Foundation	Coral Reef Ecologist
Badi Samaniego	University of the Philippines, Living Oceans Foundation Fellow	Fish surveyor
Sonia Bejarano	University of Queensland, Living Oceans Foundation Fellow	Fish herbivory
Jeremy Kerr	Nova Southeastern University, Living Oceans Foundation Fellow	Groundtruthing / habitat mapping
Peter Mumby	University of Queensland	UQ Lead Scientist
Bob Steneck	University of Maine	Benthic ecology
Sam Purkis	Nova Southeastern University National Coral Reef Institute	NCRI Lead Scientist
Alex Dempsey	Nova Southeastern University National Coral Reef Institute	Benthic surveyor
Jim Evans	Schools Without Walls, Washington D.C	C.R.E.W. teacher
Maggie Nugues	Le Centre de Recherches Insulaires et Observatoire de l'Environnement de Polynésie Française (CRIOBE)	Benthic surveyor
Gaelle Quere	University of Queensland	Benthic surveyor
Jeremy Sofonia	University of Queensland	Groundtruthing
Marine Couraudon-Reale	Independent contractor	Benthic surveyor
Kate Fraser	Independent contractor	Fish surveyor
Yves-Marie Bozec	University of Queensland	Marine ecology
Jez Roff	University of Queensland	Coral recruitment
Will Robbins	Wildlife Marine	Shark biology
John Ruthven	Independent contractor	Film producer
Doug Allan	Independent contractor	Cameraman
Ken Marks	AGRRA	Photo transects
Nick Cautin	Dive Safety Officer	Diving operations
Sean Hickey	West Palm Beach Television (WPBT) PBS "Changing Seas"	Cameraman
Alexa Elliot	West Palm Beach Television PBS "Changing Seas"	Film producer