Kiribati Trip Report

Fieldwork April – May 2018

Simon Donner, Heather Summers, Sara Cannon
Department of Geography
University of British Columbia
Vancouver, British Columbia, Canada

THE UNIVERSITY OF BRITISH COLUMBIA

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Introduction

This report presents the initial findings of field research conducted by our team (Simon Donner, Heather Summers, and Sara Cannon) from April 12 to May 4, 2018. In partnership with the Fisheries Division of the Ministry of Fisheries and Marine Resource Development (MFMRD), we conducted SCUBA-based surveys at 16 outer reef sites in Tarawa Atoll and Abaiang Atoll. The underwater data collection included benthic surveys, coral size measurements, photomosaics (to reconstruct reef complexity), photosynthetic rates, and water temperatures. We also collected surface water samples at each site which were exported to the United States for water quality analysis by our colleague Diane Thompson (formerly of Boston University, now the University of Arizona). These results are still pending.

These surveys were follow-up to previous research conducted by Simon Donner with MFMRD, who began participating in coral reef benthic monitoring in Kiribati via the Kiribati Adaptation Project in 2007. For more information about previous research and access to relevant reports, publications, and presentations, please visit http://simondonner.com/kiribati-research/. Future publications produced from this research will also be made available at that site.

Acknowledgements

This research was only possible because of an ongoing partnership with the Fisheries Division of the Ministry of Fisheries and Marine Resource Development (MFMRD). We thank the Director of Fisheries (Coastal Fisheries Division) Tooreka Teemari and OIC Karibanang Tamuera for approving of the research, facilitating our research permit, and giving the Research Unit time to dedicate to this work. Max Peter, Erietera Aram, and Toaea Beiateuea of the Research Unit were valuable partners on all of the research activities and worked many long days at sea and on land to ensure that the data could be collected and analysed. We could not have done the research without their hard work and professionalism.

In addition, we would also like to thank the Mayor of Abaiang Ianetama Kaitiitaake, Tebui Tererei from Fisheries in Abaiang, as well as Kaboua John for approving our work in Abaiang and helping to facilitate our visit. Nabuti Mwemwenikarawa of the PIPA Trust and Eretia Monite of the Ministry of Education also provided valuable support by organizing a cross-ministry workshop and hosting us in North Tarawa so that we could complete the coastal data collection. Finally, Ariera Tekaata and the staff of Kiribati Sea Co. Ltd. coordinated our safe transport to and from the dive sites on the boat “Christine,” and waited patiently as we conducted our work.

Description of Study Sites

Surveys were conducted at eight outer reef sites in South Tarawa, two sites in North Tarawa, and six sites in Abaiang (Figure 1).

The sites were chosen based on previous surveys conducted by Donner together with the Fisheries Division of MFMRD in 2016. For this research, we also added new sites off Bonriki in South Tarawa (TRW16) and near Nuotea at the northwest part of Abaiang (ABG05, ABG06). These additional sites will allow us to examine reefs with different levels of exposure to the prevailing winds and currents.

Water samples were collected at all of the sites and at five stops on the drive between Betio and Abaiang.

Coastal measurements were recorded for all Tarawa sites except TRW07, which is distant from land.

***Figure 1**. Map of study sites.*

Benthic Cover

Benthic composition data can provide important information about species abundance and diversity, and insights into the ability of coral reefs to resist or recover from disturbances. The severity of ecosystem degradation is spatially heterogeneous, with previous research from the Donner lab showing sites in Tarawa and Abaiang undergoing changes in biodiversity and species abundance.

For this study, benthic composition data was collected by taking quadrat photos taken at 50 cm intervals along a 50-m transect tape, for a total of approximately 100 photos per site. The quadrat photos were processed in the lab using Coral Point Count with Excel Extensions Research Software (CPCe Software). For the 100 photos, CPCe Software overlays 20 random points per photo and the benthos related to each point was manually identified to the genus level for coral (with the exception of *Porites rus*) and macroalgae, and to functional groups for sponges, soft coral, algal turf, crustose coralline algae, and cyanobacteria (Figure 2).

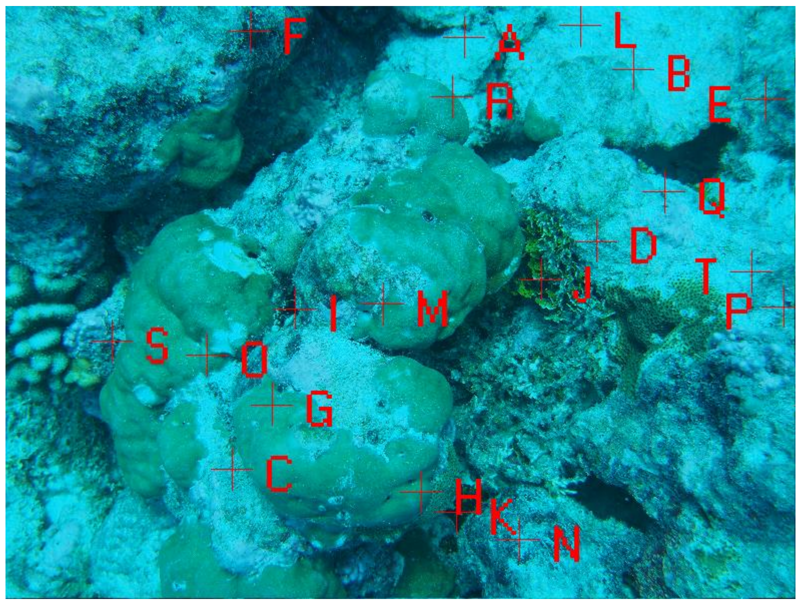

***Figure 2**. Sample image being processed in CPCe software, with 20 random points marked as letters.*

Algal turf was the most common benthic composition, ranging from 22% to 54% across all sites (Figure 3a, next page). *Halimeda* spp. was the most common of the observed macroalgae, ranging from 0% to 26% across all sites. Reefs in North Tarawa and Abaiang had significantly more *Halimeda* spp. (p-value <0.0001), which is a common indicator of a healthy reef with low disturbance. By contrast, sites in South Tarawa had significantly more cyanobacteria (p-value <0.001), which is likely due to higher human disturbance and high nutrient input.

To distinguish differences in benthic composition for major coral taxa between sites and atolls, the percent benthic cover data was grouped into the most ecologically important and prevalent reef-building taxa: *Acropora*, *Heliopora*, *Pocillopora*, *Favids*, massive *Porites*, and *Porites rus* (Figure 3b, next page). The analysis revealed differences in the typical coral community compositions between sites in South Tarawa and sites in North Tarawa and Abaiang. *Porites rus* was significantly (p-value <0.0001) more common at sites in South Tarawa, with a median of 91%, likely due to the capacity for *Porites rus* to thrive in areas with high nutrient input. Given

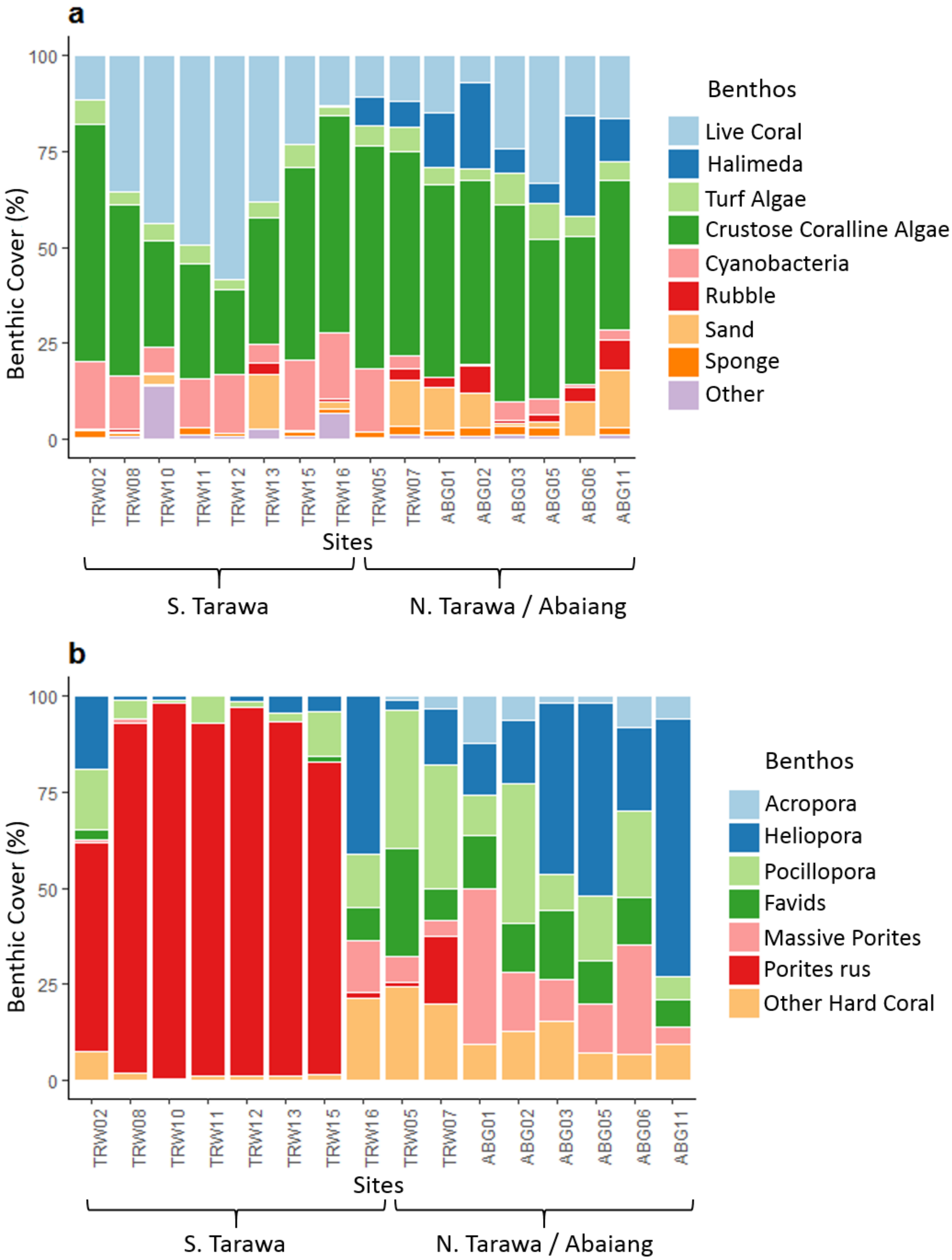

***Figure 3**. Benthic cover of (a) key benthic categories and (b) live coral at each study site.*

the competition from “weedy” species such as *Porites rus*, there were no sites in South Tarawa with *Acropora* spp. and few with massive *Porites* and *Favids*. By contrast, sites in North Tarawa and Abaiang were dominated by *Heliopora* (p-value < 0.05), *Favids* (p-value < 0.0001), massive *Porites*, and *Acropora* (Figure 3b), indicating these sites were less disturbed than those of South Tarawa.

Next steps will include determining whether there is a significant difference in the benthic composition reported in 2018 with previous survey data. In addition, the benthic cover data will be used to create estimates of carbonate production for major reef-building corals between sites and atolls. Decreases in coral cover will inevitably reduce habitat complexity and calcium carbonate production and therefore these changes negatively affect the ability of coral reefs to provide shoreline protection.

Photomosaics and Structural Complexity

The structural complexity of coral reefs is directly related to reef health, biodiversity, and surface roughness. For example, coral reefs with lower structural complexity grow more slowly and are less effective at dissipating wave energy. Consequently, reefs with lower structural complexity may afford shorelines less protection from rising seas. Previous studies conducted in Kiribati have found that sites around South Tarawa have low biodiversity of reef-building corals due to a shift towards “weedy,” temperature-tolerant species such as *Porites rus*. Reefs comprised of *Porites rus* offer very little structural complexity compared to reefs comprised of large, three-dimensional coral colonies formed by *Acropora*, *Heliopora*, and *Pocillopora*, which create large frictional forces important for wave attenuation.

To measure structural complexity of reefs, overlapping, high-resolution underwater images were taken at different angles over a 10 x 10 m grid at each site (Figure 4a). Within each 100 m^2 plot, approximately 1500 to 3000 individual images were captured using the pattern in Figure 4b and then separate images were combined using structure-from-motion software (Agisoft PhotoScan) to create detailed three-dimensional models of the benthos (Figure 5, next page).

Most of the sites have “spur and groove” structures, which are formed by a series of parallel, linear coral ridges (spurs) separated by channels of sediment or rubble (grooves). The finger-like shapes are commonly found on the windward sides of exposed coral reefs and play an important role in wave

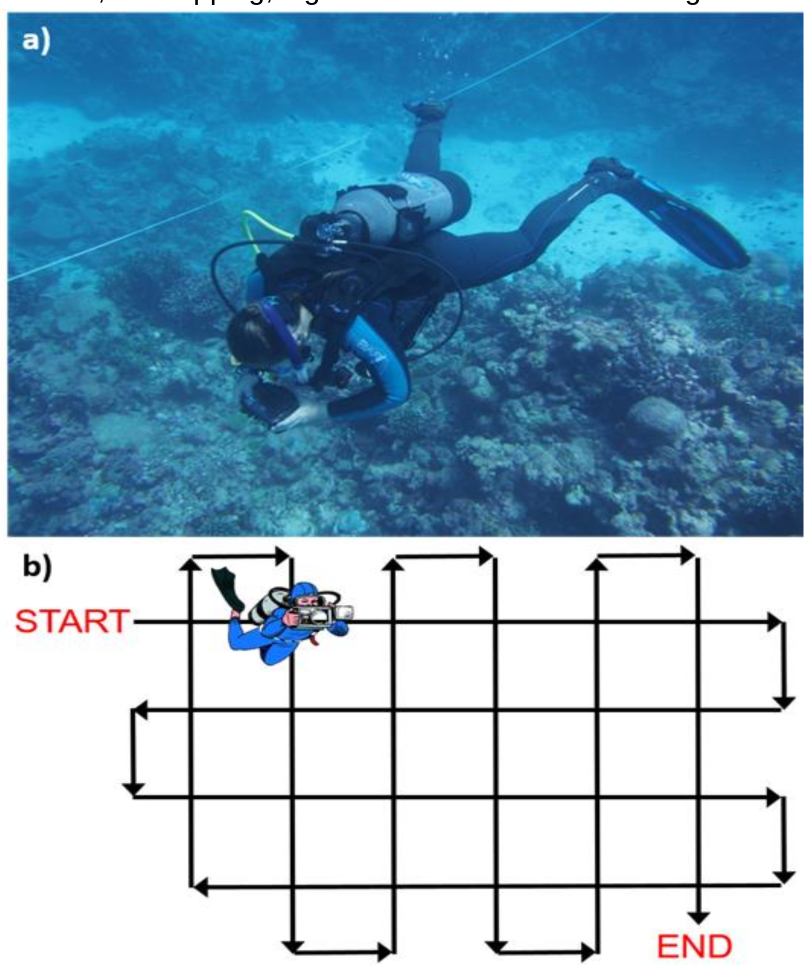

Figure 4. *(a) Heather Summers acquires an image for generating a photomosaic, (b) the diver operating the camera follows this pattern over the plot, keeping the height and orientation of the camera above the substrate consistent.*

attenuation at the reef crest. Preliminary observations of the three-dimensional models indicate that sites in South Tarawa have spurs with less structurally complex coral compared to sites in North Tarawa and Abaiang. Coral reefs in South Tarawa have a lower biodiversity and a high abundance of coral species such as *Porites rus*, which are less structurally complex, compared to other common reef-building corals (Figure 5a). By contrast, the sites in North Tarawa and Abaiang support a higher diversity of structurally complex reef-building corals and therefore have a higher overall structural complexity (Figure 5b). Further analysis is being done to quantify structural complexity metrics using spatial analysis tools in ArcGIS.

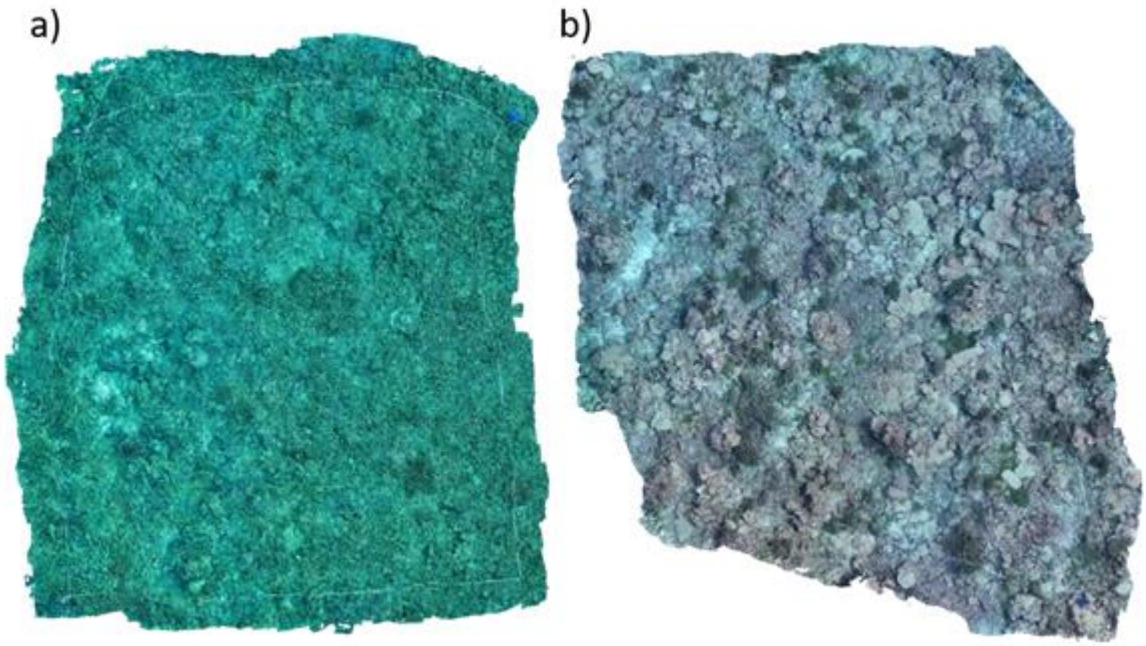

***Figure 5**. Three-dimensional models of the benthos at (a) TRW12 (South Tarawa) and (b) ABG03 (Abaiang).*

Coastal Analysis

In addition to reef structural complexity, the shape and surface "roughness" of the reef flat affects the wave energy that reaches the shoreline. Wider reef flats with a lower water depth can dissipate more wave energy, compared to narrower reef flats with a higher water depth, such that adjacent shorelines experience less erosion. Reef flats dominated by boulders or coral – higher surface roughness or friction – also dissipate more wave energy than reef flats dominated by smooth, flat rock and algal turf.

The reef flats around South Tarawa are predominantly smooth rock with 75% to 100% seagrass or algal turf (Figure 6a), implying low friction and possibly greater shoreline erosion. By contrast, the reef flat analyzed in North Tarawa (TRW05) was predominantly (80%) dead, un-eroded coral or boulders greater than 30 cm (Figure 6b), implying higher friction and possible lower shoreline erosion (Table 1, next page). The lack of large boulders on the South Tarawa reef flats is likely related to past removal of boulders for construction of sea walls and other infrastructure.

As the sea level increases, reef flat surface roughness and width will become increasingly important in wave attenuation. Site TRW02 is predicted to experience the greatest negative impact from shoreline erosion and flooding due to a comparatively low reef flat surface roughness and narrow width.

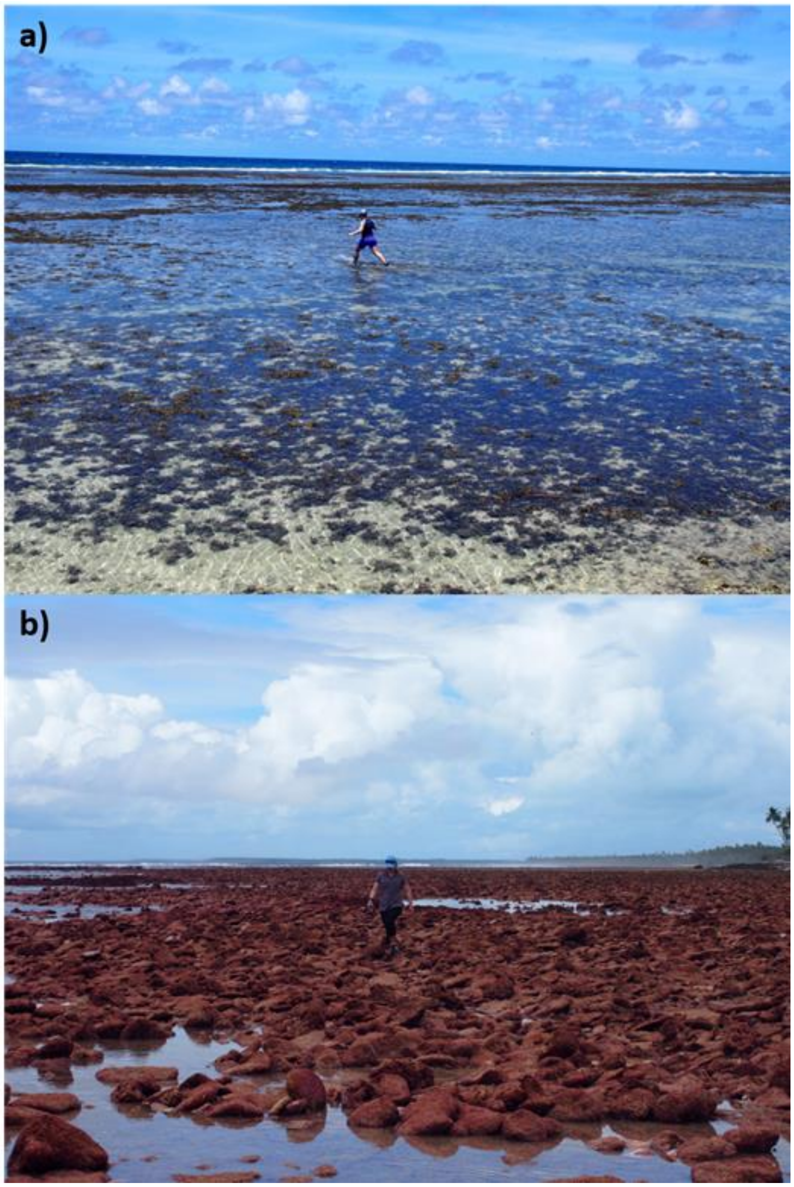

***Figure 6**. Reef flats in (a) South Tarawa and (b) North Tarawa.*

Using the reef flat morphology metrics outlined in Table 1 as well as the slope of the wave-breaking zone recorded during the photomosaics, we will be developing a model to quantify wave energy reaching the shorelines at each site.

Table 1. Reef flat morphology for sites around Tarawa.

Site	Reef Flat Roughness	Water Depth at High Tide (m)	Reef Flat Width (m)
TRW02	Smooth rock with 50% algal turf and 10% boulders	1.40	161
TRW08	Smooth rock with 70% to 80% algal turf and 20% to 30% boulders	1.75	211
TRW10	Smooth rock with 75% to 100% algal turf	2.13	221
TRW11	Smooth rock with 85% algal turf and 15% boulders	1.82	208
TRW12	Smooth rock with 70% algal turf and <10% boulders	1.40	499
TRW13	Smooth rock with 20% algal turf and 80% sand	1.78	649
TRW15	Smooth rock with 75% to 100% algal turf	1.75	210
TRW16	Smooth rock with 75% to 100% algal turf	2.0	381
TRW05	Smooth rock with 80% boulders covered in coralline algae and red algal turf and 10% sand	1.8	205

Coral Size Distributions

Coral size distributions can provide important information about coral recruitment, the effect of disturbances, and the recovery from disturbances. For example, there was a bleaching event in early 2010 and an outbreak of the predatory Crown-of-Thorn starfish (COTs) in 2013 and 2014 that affected the coral communities of Tarawa and Abaiang. Since we have been collecting coral size measurements at several sites since 2012, we can compare the distribution of coral size at each site over time to evaluate the effect of the COTs outbreak and the long-term recovery from bleaching.

To record the coral size, we swam along a 50-m transect tape at 10 m to 12 m depth at each site. We recorded the length of all corals that fell at least partly within 25 cm of either side of the transect tape. Each coral is identified to the genus level.

Table 2. Size-frequency statistics for corals, measured in centimeters.

Atoll	Category	Number	Mean Size (cm)	Standard Deviation (cm)	Standard Error (cm)
Abaiang and North Tarawa	All	2993	10.32	10.33	0.19
	Acropora	44	12.91	6.16	0.93
	Favids	1138	8.25	4.60	0.14
	Heliopora	551	13.50	16.65	0.71
	Montipora	135	12.93	6.95	0.60
	Pocillopora	552	10.18	11.36	0.48
	Porites (massive)	573	10.71	11.36	0.47
	Porites rus	-	-	-	-
South Tarawa	All	1562	20.80	41.97	1.06
	Acropora	14	12.29	7.21	1.93
	Favids	144	8.84	4.40	0.37
	Heliopora	287	10.22	9.83	0.58
	Montipora	15	16.00	8.07	2.08
	Pocillopora	190	16.11	13.31	0.97
	Porites (massive)	32	19.13	17.96	3.18
	Porites rus	880	27.50	54.14	1.83

In general, we found more of each genera of coral in Abaiang and North Tarawa than in South Tarawa (Table 2, previous page). For example, we recorded 573 massive *Porites* at the 8 sites in Abaiang and North Tarawa and only 32 at the 8 sites in South Tarawa. The sites in South Tarawa tend to be dominated by the encrusting coral species *Porites rus,* which grows commonly in areas with high disturbance. No *Porites rus* was present at the Abaiang or North Tarawa sites.

Pocillopora, *Acropora*, and *Heliopora* are branching corals that contribute to reef structural complexity. We measured only 14 *Acropora* colonies in South Tarawa and they were all rather small (less than 25 cm) (Figure 7). *Heliopora* in South Tarawa was somewhat common, although colonies in South Tarawa were smaller than those found in Abaiang and North Tarawa. *Pocillopora* was also common in all study sites, although they had a larger mean size in South Tarawa.

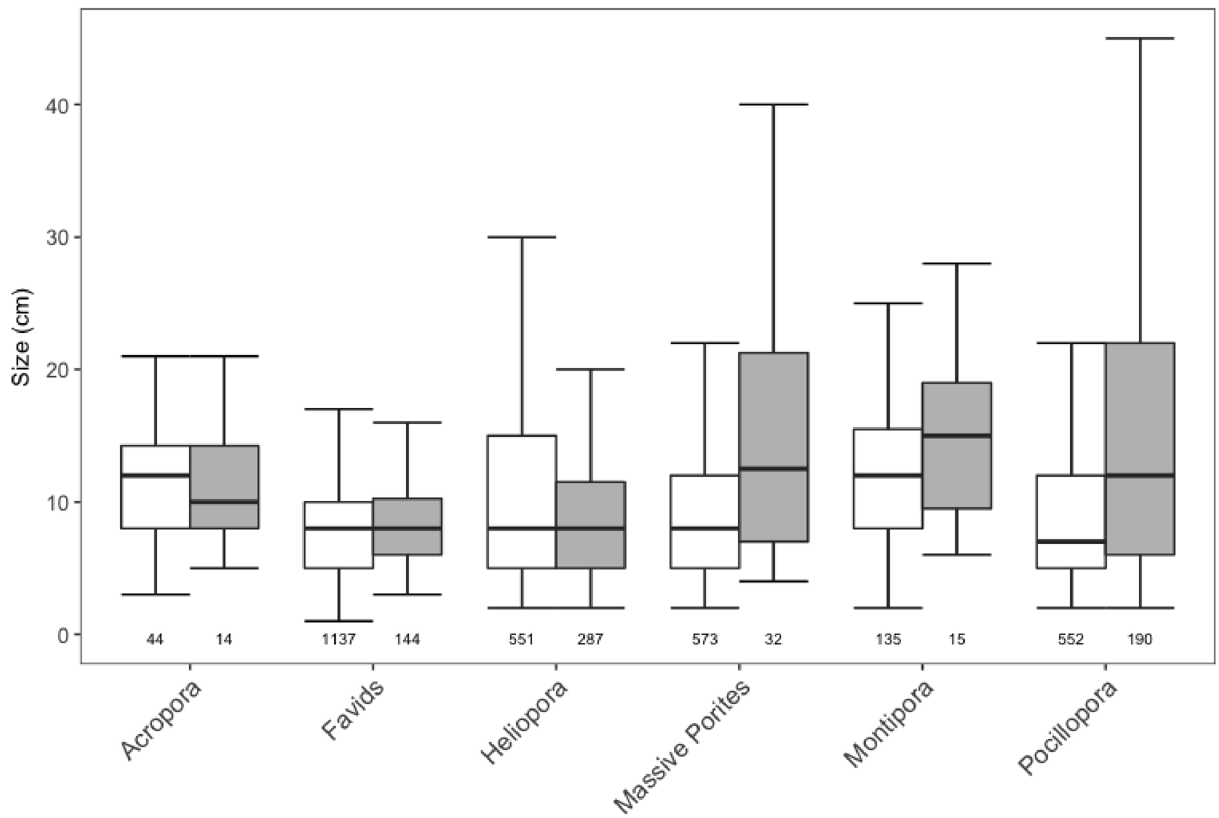

Figure 7. *Quartile plots of coral size frequency for Abaiang and North Tarawa (white bars) and South Tarawa (grey bars). The number of observations is listed at the bottom.*

Photosynthetic Activity

For the first time in Kiribati, we used an instrument called a pulse amplitude modulated (PAM) fluorometer to help estimate productivity (how much the corals are photosynthesizing) at different sites around Abaiang and Tarawa. We collected 5 small samples (<2 cm) from 5 different individual corals of each of the 5 most common coral genera at each of our sites (for a total of 125 coral samples per site). Figure 8a shows Sara Cannon collecting a sample of *Heliopora*. These samples were stored in a dark cooler full of ambient seawater and brought back to land for testing.

The PAM fluorometer shoots a bright light at the coral sample, which causes a chain reaction in the zooxanthellae's photosynthetic adapters. The zooxanthellae give off fluorescence as a by-product of this reaction. The fluorometer measures the amount of fluorescence and uses it to calculate photosynthetic rates, giving us an idea of the individual coral sample's productivity.

Figure 8b demonstrates how we used the PAM fluorometer to measure photosynthetic rates of coral samples. Note that the actual measurements were done in a dark room; this image is just a demonstration of the method.

We are using the results to examine whether the corals at some sites are more productive than others. For example, we can compare the fluorescence (in mV) of four coral genera commonly found at sites across atolls (Figure 9, next page).

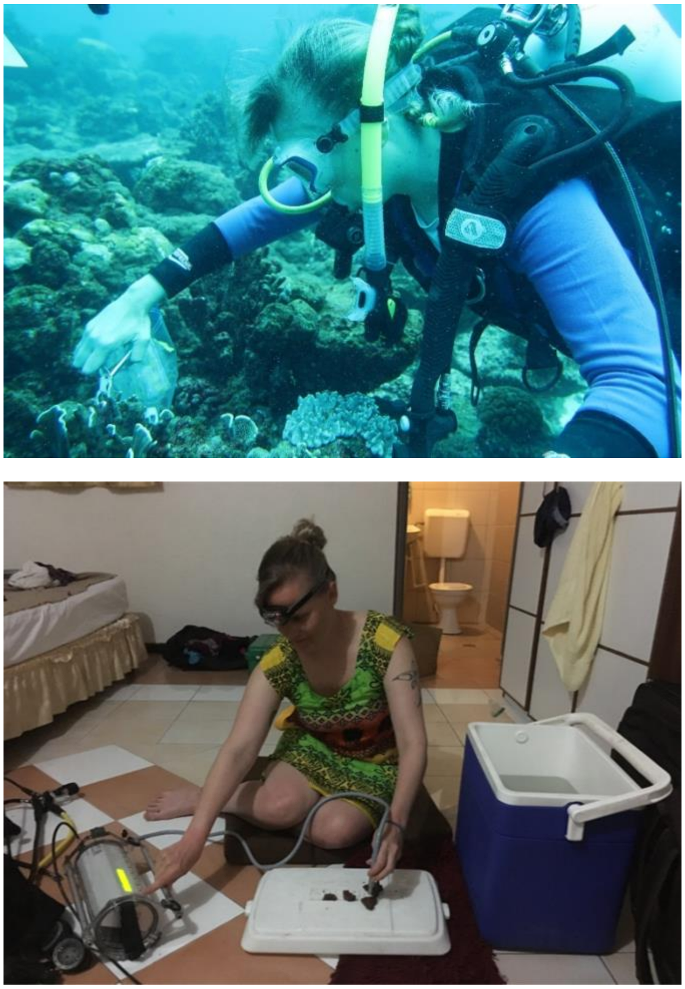

Figure 8. *(a) Collecting samples underwater, and (b) demonstrating the PAM fluorometer work.*

These data show that the fast-growing coral genera, *Acropora*, *Heliopora*, and *Pocillopora*, all appear to have higher fluorescence (or greater productivity) in South Tarawa compared to Abaiang and North Tarawa. However, massive *Porites*, which are slow-growing corals, had much lower fluorescence (lower productivity) in South Tarawa as compared to North Tarawa and Abaiang. We need to do more research to see what could be causing these differences in photosynthetic rates, but it is possible that greater turbidity in the water means that the faster-growing corals need to work harder at photosynthesizing in order to grow and survive.

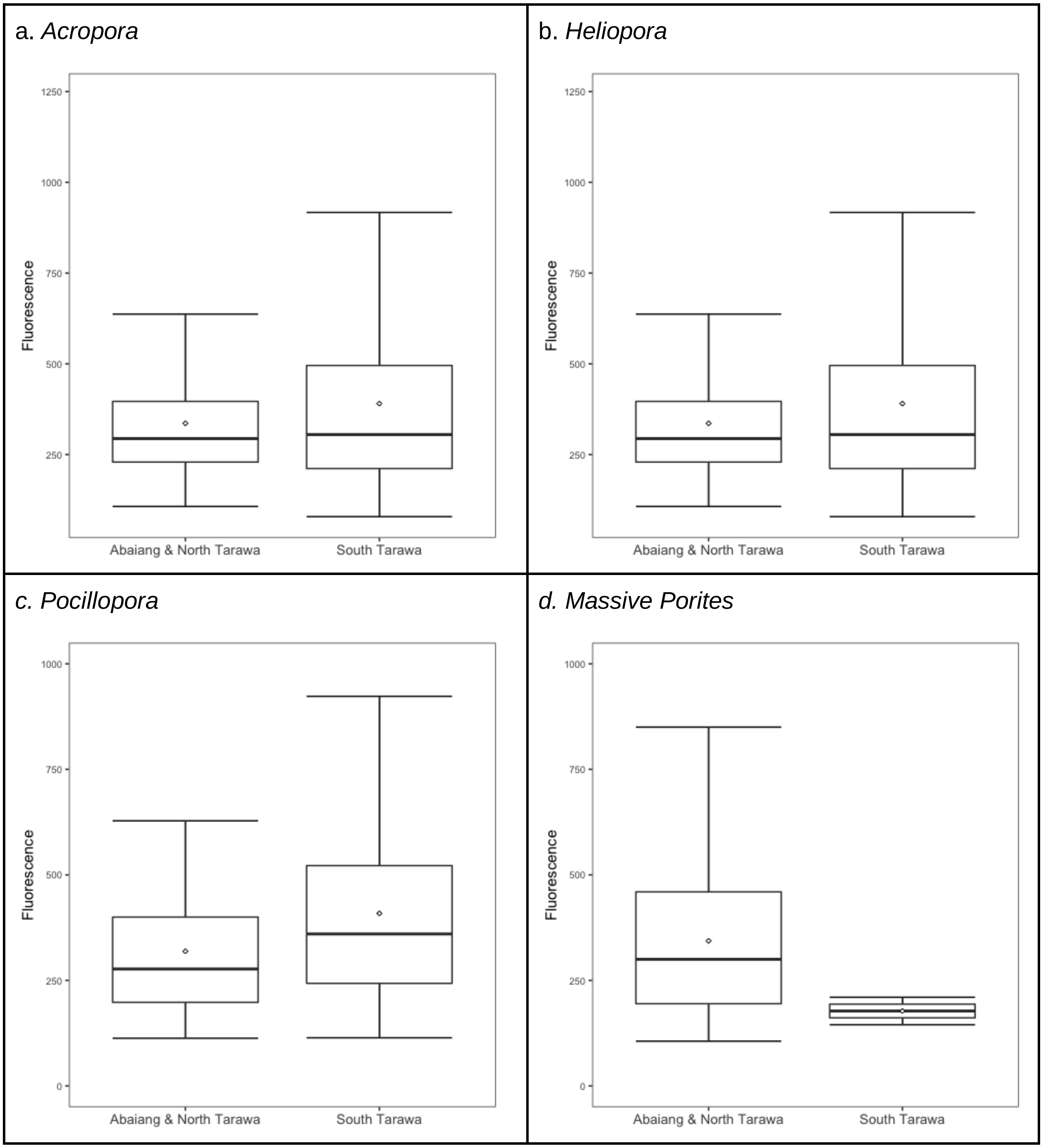

Figure 9*. Quartile plots of fluorescence (mV) measurements for samples of four common coral taxa, grouped by atoll (n=40 in each plot). Data is preliminary.*

Sea Surface Temperature

Starting in 2014, Simon Donner worked with the MFMRD Research Unit to install small HOBO u22 loggers to record sea surface temperatures (SSTs) at sites in Tarawa and Abaiang. These loggers have sufficient memory and battery power to record hourly data for four years. Given the risk of loss due to waves or theft, and the difficultly of locating loggers, our goal is to download the data and replace or redeploy the loggers every two years, if possible. Figure 10 shows what a logger looks like before being deployed in the water (a) and after two years of being attached to the reef (b).

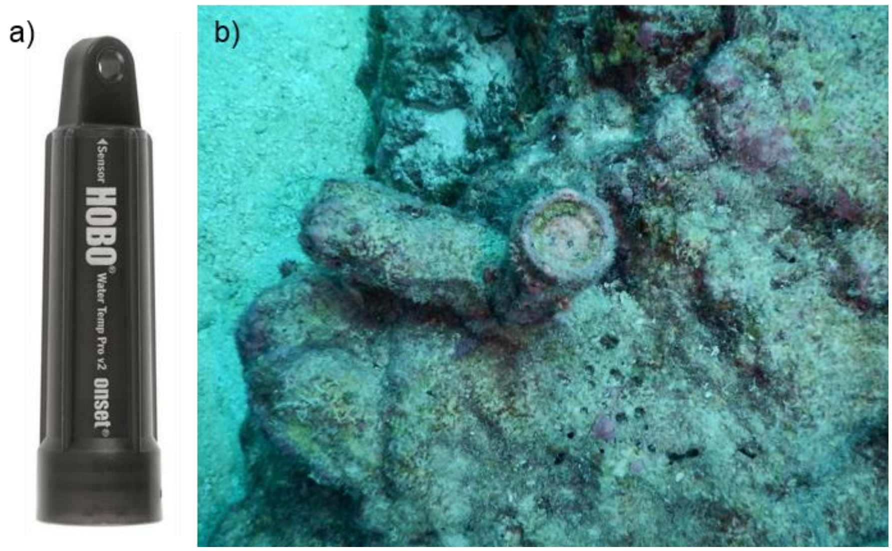

Figure 10. *(a) new logger, and (b) logger after two years in the water.*

In 2016, loggers were successfully recovered from TRW13 (Betio), TRW07 (Buariki, Figure 10b), ABG01 (Manra Island), and ABG03 (Tebontebike) and all replaced or redeployed. On the 2018 trip, we were only able to locate loggers at TRW13 (Betio) and ABG03 (Tebontebike). The data was downloaded and the loggers were redeployed.

The available data (Figure 11, next page) shows subtle differences in SST mean and variability between sites. The two Abaiang sites experience a smaller overall range of SST (2.8°C at ABG03, 3.8°C at ABG01) than the North Tarawa site (4.7°C at TRW07) and the Betio site (5.3°C at TRW13). The SST was similar at all four sites from logger deployment in May 2014 until January 2016, after which TRW13 (Betio), TRW07 (Buariki), and ABG01 (Manra), experienced marked cooling of ~2°C and an increase in variability. This cooling is related to the El Niño dynamics from 2014 through 2016, which brought warm waters to much of the region.

During El Niño events, the trade winds and westward flowing South Equatorial Current that affects Tarawa and Abaiang slows or reverses directions, pushing warmer western Pacific waters towards Kiribati and further east. However, the effect of El Niño on SST in the different Kiribati island chains depends on timing and strength of the event. In 2014 and early 2015, a weak event developed that led to elevated SST throughout Tarawa and Abaiang: the loggers show SST at or above 30°C at all sites from May 2014 through June 2015. In July of 2015, a strong El Niño developed that eventually pushed the warm waters further east toward the

Phoenix Islands, the Line Islands, and the Galapagos. The decrease in SST after January 2016 was likely caused by winds and currents pushing the centre of warmth east of the Gilbert Islands and promoting upwelling of cooler waters.

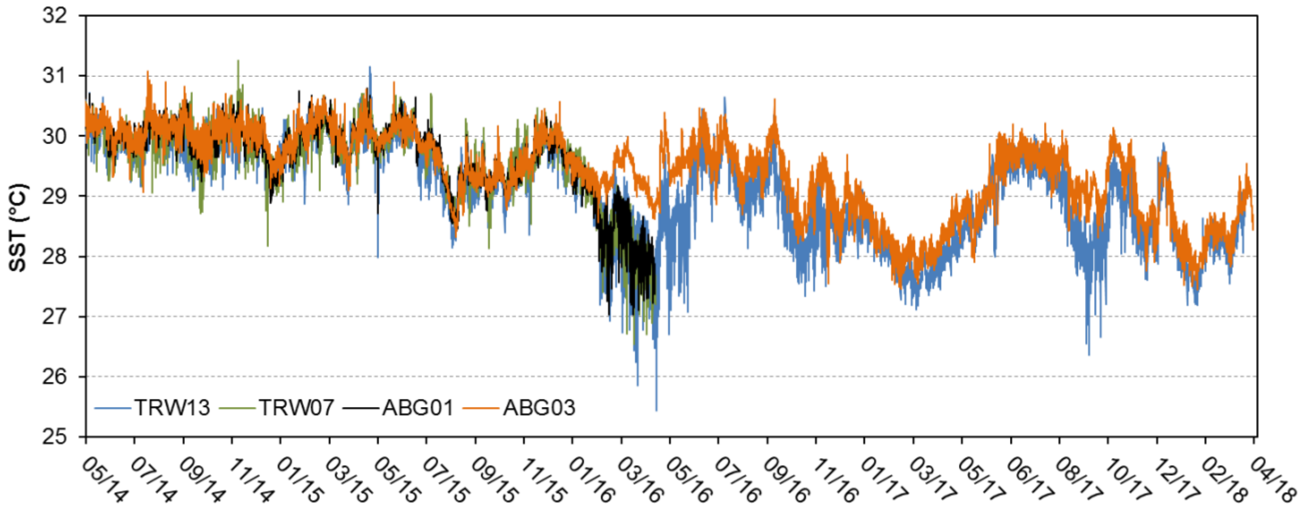

Figure 11. *Available SST observations from Betio (TRW13), Buariki (TRW07), Manra (ABG01), and Tabontebike (ABG03) from May, 2014 through April, 2018.*

The first three sites experienced high frequency periods of cool temperatures from January to May 2015, at times reaching below 26°C. The site ABG03 (Tebontebike), however, did not. The southern side of Abaiang has different exposure to the prevailing currents and may not experience the same upwelling of cooler waters associated with changes in El Niño dynamics. This would suggest that the coral reefs there may be more vulnerable to some El Niño events.

To investigate these temperature patterns further, we have deployed new loggers at TRW02 (Teaoraereke) and TRW16 (Bonriki). We also deployed more precise RBR TDR0160 temperature loggers at TRW03 (Betio) and TRW16 (Bonriki) in hopes of later examining differences in low frequency (year to year) and also high frequency (seconds to minutes) variability in temperatures at leeward and windward sites.

Next Steps

This report presents preliminary findings from field data collected in April and May, 2018. Over the next year, we will be conducting more detailed analyses including, i) examining the changes in benthic cover and coral size since previous surveys (in 2016 and before), ii) evaluating the relationship between human disturbance (possibly including water quality) and the coral and algal community, and iii) quantifying the structural complexity at each site from the photomosaics and evaluating its influence on wave attenuation. We will also continue to assist Max Peter and the research team with analyses of data collecting during their monitoring activities. Any products of this further analysis will be shared via e-mail with our Kiribati partners and also made available at http://simondonner.com/kiribati-research/.

With the permission of MFMRD and MELAD, we hope to return by April 2020 at the latest to conduct further surveys and continue assisting the research team and others with their work. The next trip will hopefully involve surveys in Butaritari and other outer atolls, in addition to re-visiting the sites in Abaiang and Tarawa that are described in this report.

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Simon, Heather, and Sara

Appendix A: Site List

A list of the coordinates of the field sites surveyed as a part of this research is provided at right.

The survey of ABG14L was informal and not included in the results presented above.

Site	Name	Latitude	Longitude
TRW02	Teaoraereke	1.3332	173.0217
TRW05	Naa	1.6325	172.9673
TRW07	Buariki / NW reef	1.6178	172.9336
TRW08	Bikenibeu (east of hospital)	1.3581	173.1446
TRW10	Causeway	1.3302	172.9634
TRW11	Eita / LDS School	1.3570	173.0790
TRW12	Bairiki-Nanikai causeway	1.3246	172.9951
TRW13	Betio	1.3463	172.9241
TRW15	Ambo	1.3506	173.0466
TRW16	Past airport / Bonriki	1.3911	173.1507
ABG01	Manra	1.8577	172.8796
ABG02	Western reef	1.8820	172.8180
ABG03	Tebontike	1.7143	172.9865
ABG05	Calm north reef	1.9209	172.8040
ABG06	NW point	1.8972	172.7772
ABG11	Teirio point	1.8033	172.9088
ABG14L	Ribono (lagoon)	1.7576	172.9720

Appendix B: Abaiang MPA Demarcation

We assisted in marking the boundaries of the proposed Abaiang lagoon MPA and developed the following map for Fisheries.