Survey of Guam Benthic Habitats and Coral Health

Results of Surveys Performed 22 May to 26 July 2017

By

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Summary

Coral reefs have been an important resource to marine ecosystems as well as to the residents of many island communities, including Guam. In recent years, these reefs have been faced with many environmental and anthropogenic threats to their existence. Preservation efforts on Guam have been implemented through reef assessment studies and the establishment of a long-term reef monitoring program, but few of these studies are comprehensive and the monitoring program is still in development. This study aims to contribute to the ongoing effort of documenting reef health by providing an alternative methodology for assessment as well as benthic habitat composition for three Guam reef sites. Site information was gathered through transect surveys, light/temperature loggers and reporting of bleaching status. The transect data showed a positive correlation with coral cover percentage and coral species diversity and was also used to create detailed benthic habitat maps of the sites in question which may be used for future studies. Abiotic conditions (light/temperature) experienced inconsistencies in deployment which may have affected the legitimacy of its analysis. Bleaching reports show no significant change during the time of the study (22 May to 26 July 2017).

Table of Contents

List of Figures

List of Tables

Introduction

Coral reefs are of fundamental importance to marine ecosystem health as well as to the welfare of Guam's residents and visitors. Guam's reefs protect its shorelines from coastal erosion, serve as a food source for its people via reef fish, and attract numerous tourists each year, sustaining a thriving tourism market. Despite the significance of these reefs to many communities, they are currently facing several threats to their existence. Reynolds et al. (2014) have observed that since 1998, reefs worldwide have been experiencing high rates of bleaching and mortality, and these events correlate with high measurements of sea surface temperatures. The article states that Guam was considered an exception, but in 2013, the island experienced its first severe bleaching and mortality event. Since then, these events have been observed to be recurring. Other environmental and anthropogenic events are also negatively impacting these vital reefs such as run-off from land, overfishing, crown-of-thorns predation, and recreational misuse (Goldberg et al., 2008).

In an effort to preserve these important organisms, numerous studies have been conducted on the island to assess reef health and resilience (Burdick, 2005, 2012; Burdick et al., 2008; Lujan et al., 2011; Maynard et al., 2017). However, due to lack of resources such as reliable boat availability, many of the more comprehensive assessments have only been conducted in recent years (Lujan et al., 2011) and these thorough reports are mainly compilations of other studies (Burdick et al., 2008). To assist with this issue, the Guam Coral Reef Monitoring Group created a long-term monitoring program in 2006, but it still remains in development (Lujan et al., 2011).

This report aims to provide an alternative, viable methodology for quantitative reef assessment as well as provide survey data for three sites on Guam's coral reefs that can be used for future research. In this study, transect photos were taken of benthic habitats, and a coral assessment software, CPCe (Coral Point Count with excel extensions) was used for the determination of coral cover. The data collected in this survey were mapped using ArcGIS. Inter- and intra-site analyses were also conducted on the dataset provided by this survey. Abiotic conditions (light and temperature) as well as bleaching status of several coral colonies in each site were recorded and included in this document.

Methods

Site Selection

Three sites were selected for this study: Merizo Pier, Tumon Bay, and East Agaña Bay (Figure 1). These sites were chosen because they are easily accessible, some of the safest sites on the island year-round, and each site had a unique aspect worth looking into. Merizo Pier (Figure 2), the southernmost site, was previously recorded as containing only turf algae (Burdick, 2005). From a local perspective, however, Merizo Pier is known to be home to a few coral colonies near the shore. Surveying Merizo Pier would provide new information on a previously documented site. Tumon Bay (Figure 3), the northernmost site, is a marine protected area (MPA). Surveying this site provides useful data to compare against the other two sites which are not MPAs. East Agaña Bay (Figure 4) was also chosen because of its unique geomorphic shape which resembles that of Tumon Bay. Since it is not an MPA but has a similar shape to that of Tumon Bay, which is an MPA, a comparative analysis between the two sites proves to be worthwhile.

Figure 1: Overview photograph of sites chosen (Merizo Pier, Tumon Bay, and East Agaña Bay)

Figure 2: (a) Close-up photograph of Merizo Pier site. (b) Location of light/temperature logger (yellow pin) and transects (in red) for Merizo Pier site.

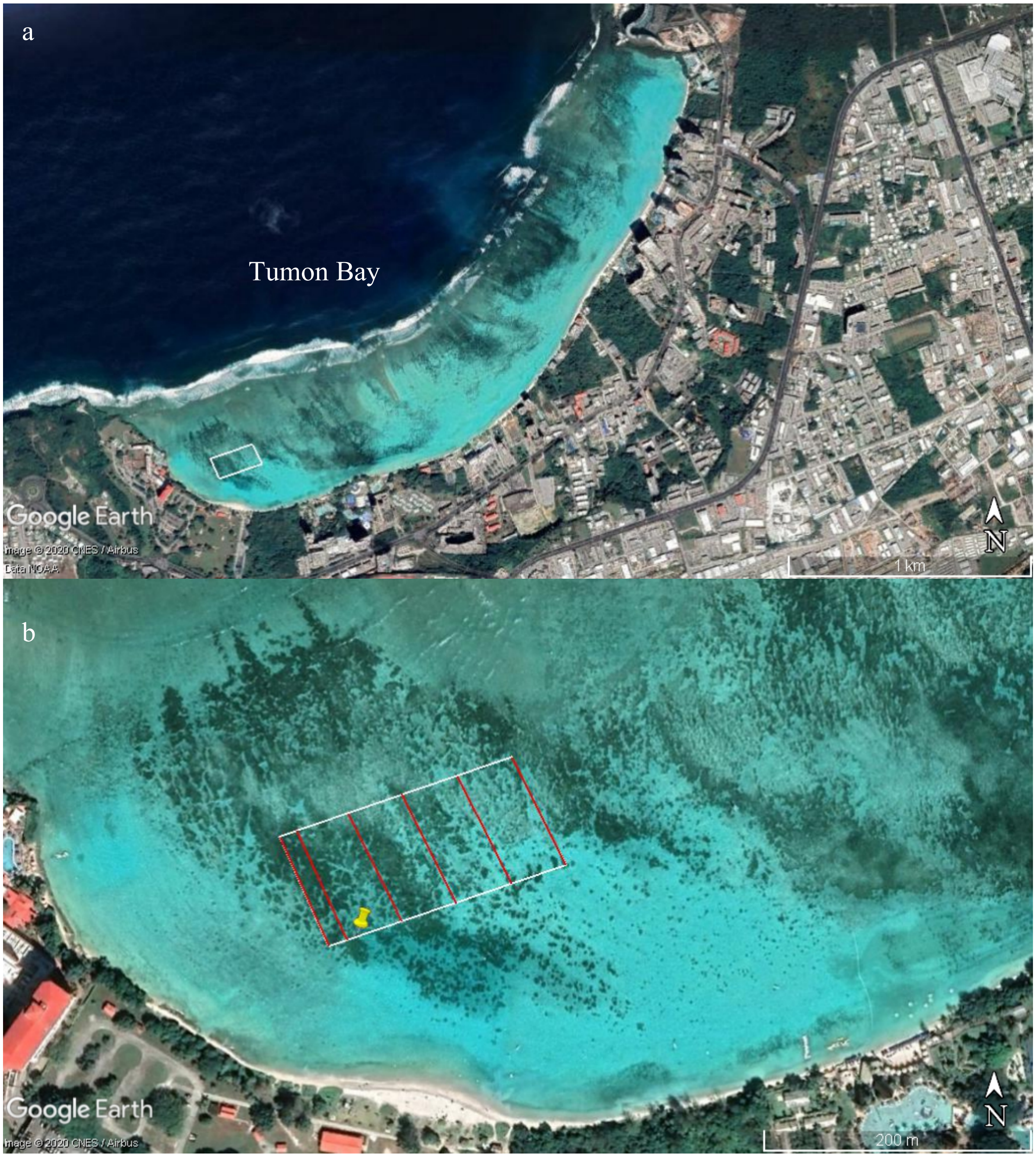


Figure 3: (a) Close-up photograph of Tumon Bay site. (b) Location of light/temperature logger (yellow pin) and transects (in red) for Tumon Bay site.

Figure 4: (a) Close-up photograph of East Agaña Bay site. (b) Location of light/temperature logger (yellow pin) and transects (in red) for East Agaña Bay site.

Transect Surveys

Benthic habitat compositions were recorded through transect surveys with tools shown in Figure 5. Several transects were laid over a small area of interest in each site, mapped out using Google Earth and found using GPS coordinates. Photographs of the habitat were taken every 2.5 m along each transect in Merizo Pier, and every 10 m in East Agaña Bay and Tumon Bay (Figure 6).

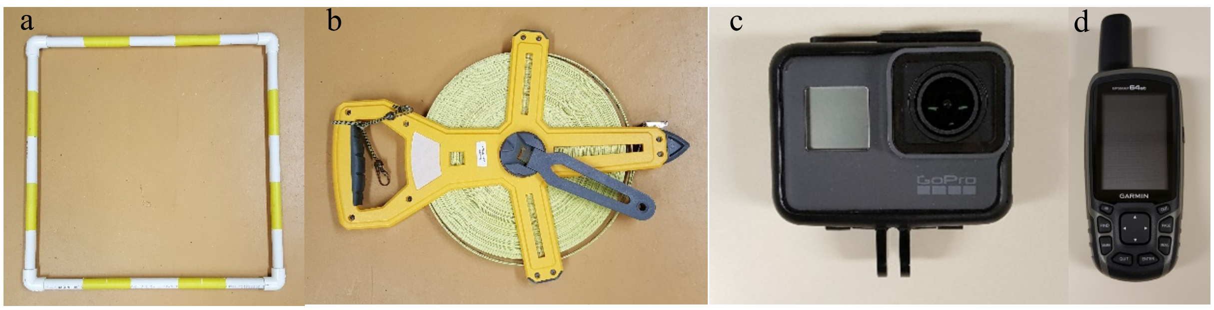


Figure 5: (a) Quadrat (0.5 m x 0.5 m) used for the transect surveys. (b) Transect (100 m) used for surveys. (c) GoPro Hero 5 used to capture images for later analysis. (d) GPS (Garmin GPSMAP 64st) used to find coordinates predetermined using Google Earth.

Figure 6: Alexandra Wen and Vince Fabian conducting transect surveys in Tumon Bay.

Photo Correction

Several transect images in this study experienced disproportional appearances due to the natural fish-eye behavior of the GoPro camera as well as certain settings used that exacerbated the "pincushion" distortion. Vertical and horizontal distortions were also present because of the inability to capture quadrat images properly as a result of shallow water levels from low tide as well as turbulent currents. These images were corrected using Adobe Photoshop Elements 13 (Figure 7).

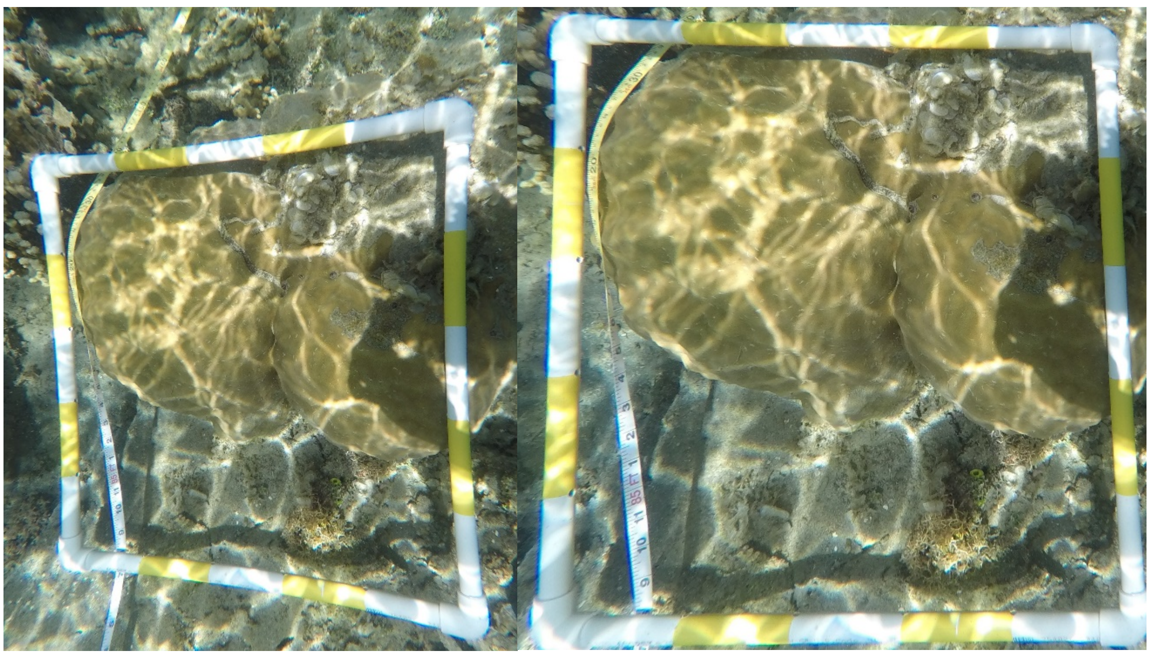


Figure 7: (Left) Image from a transect survey in Merizo Pier exhibiting "pincushion" distortion. (Right) Corrected version of the same image, fixed using Adobe Photoshop Elements 13.

Logger Deployment

Light/temperature loggers (HOBO Pendant) were deployed to record conditions at each site for one month. These loggers were secured near predetermined areas of interest on hard substrates such as rocks or dead coral skeletons (Figure 8).

Figure 8: A light/temperature logger placed in East Agaña Bay.

Coral Monitoring Surveys

Bleaching status of several coral colonies near the deployed loggers at each site was determined using the Coral Health Chart (Figure 9). Their status was recorded at the time of logger deployment and logger retrieval, showing the change over a month's span.

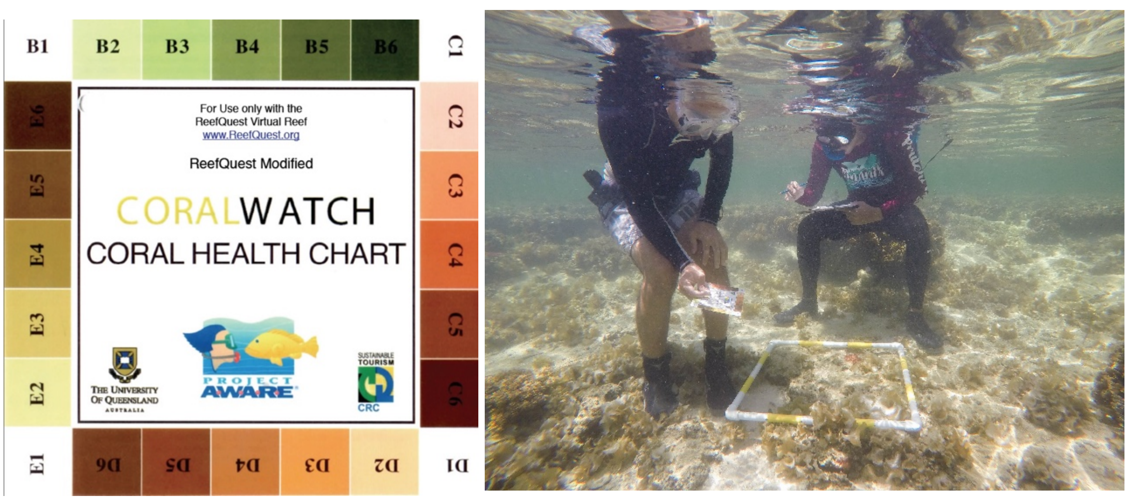


Figure 9: (Left) Coral Health Chart. (Right) Atsushi Fujimura and Vince Fabian comparing a coral colony to the coral health monitoring chart and Vince Fabian recording the color status in East Agaña Bay.

Data Analysis

Photographs captured from the transect surveys were analyzed using CPCe (Coral Point Count with excel extensions) (Kohler and Gill 2006). Classification of habitat composition was based on the same classification system used in Burdick (2005) (Tables 1 and 2). The following screenshots show the steps of the classification procedure (Figures 10a-f).

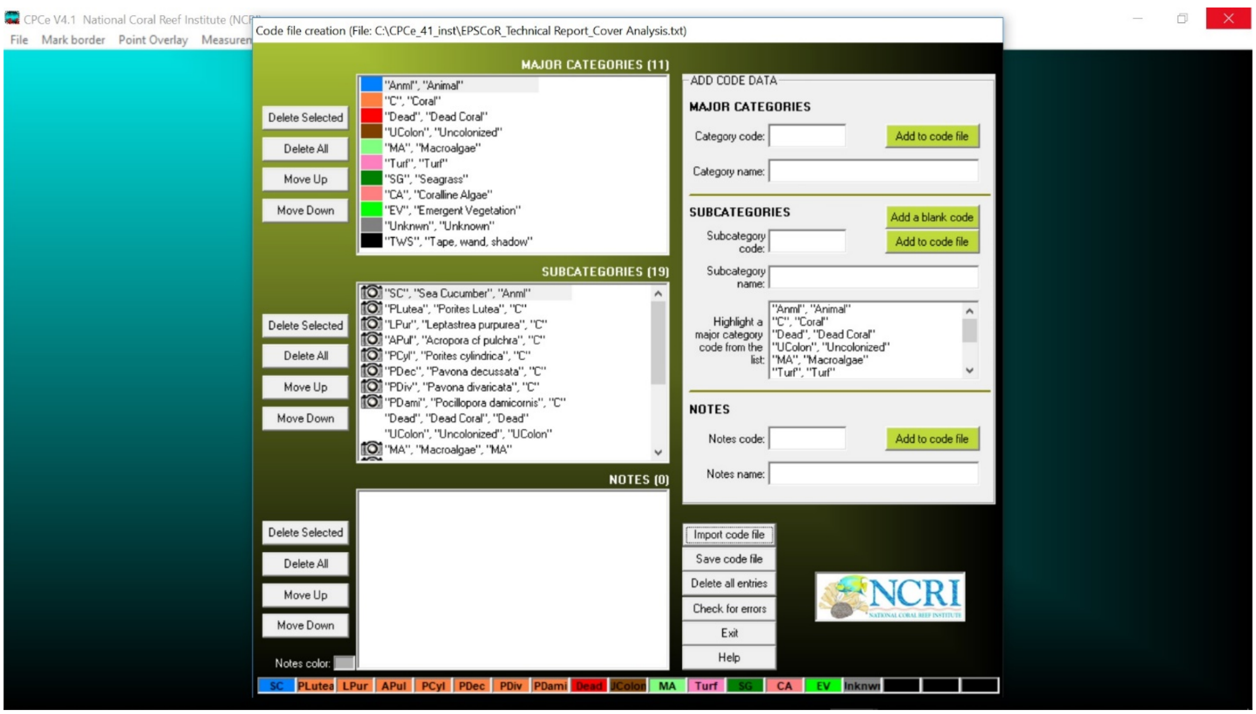
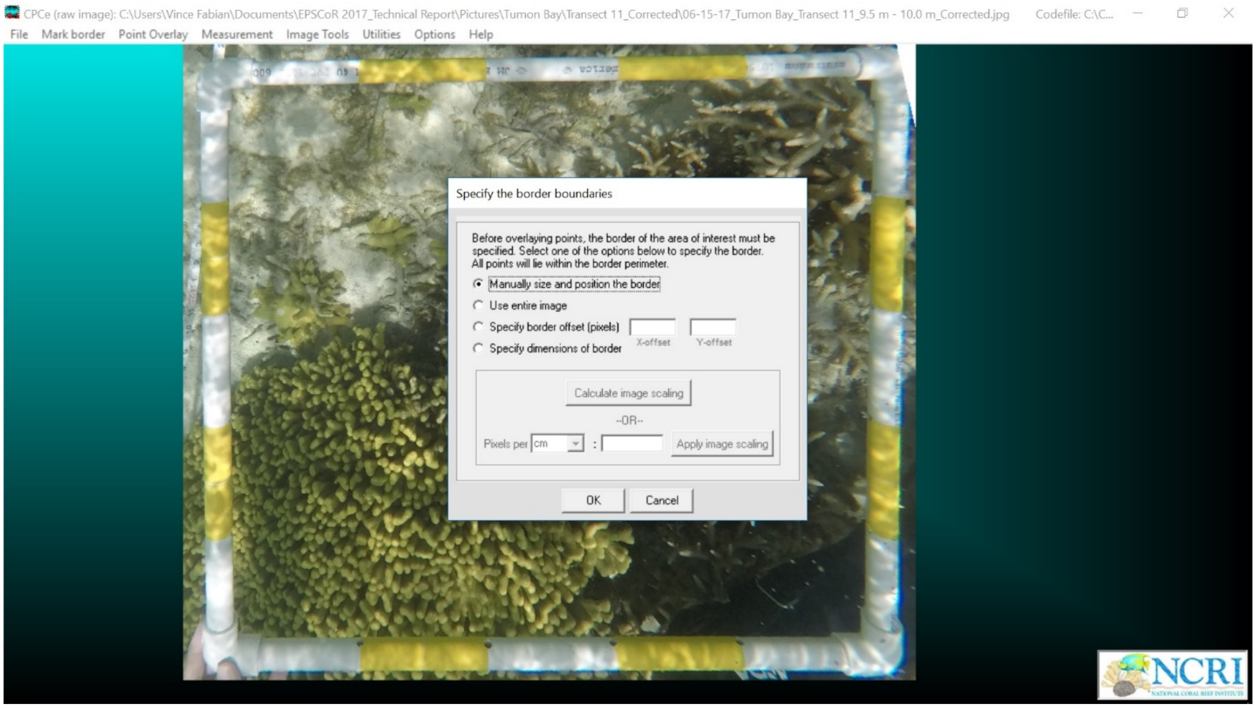
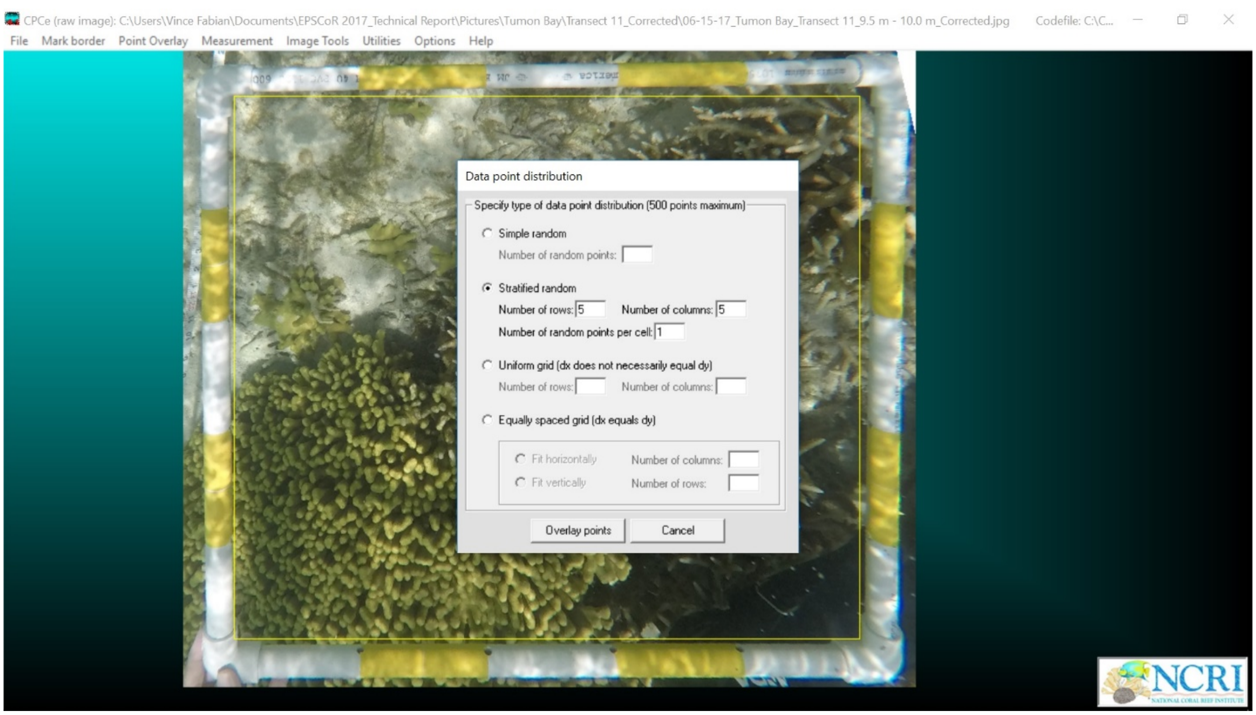


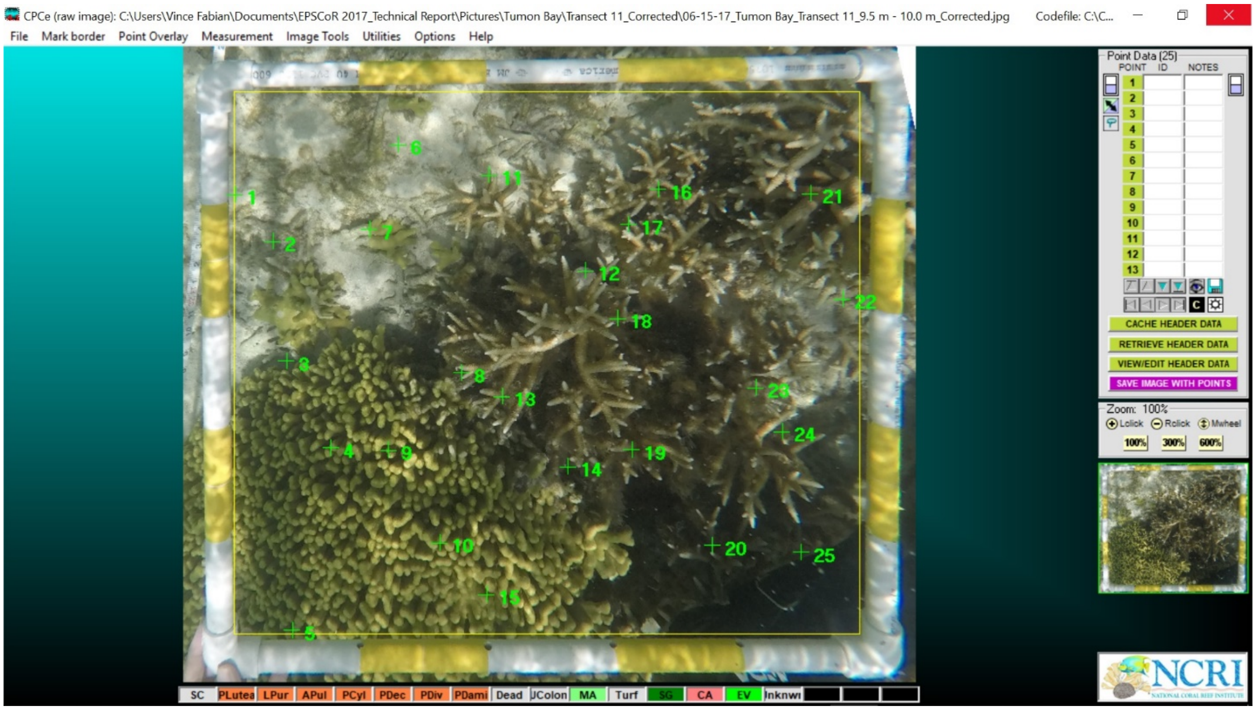
Figure 20: (a) The code file used in CPCe to analyze the transect images captured in this study.



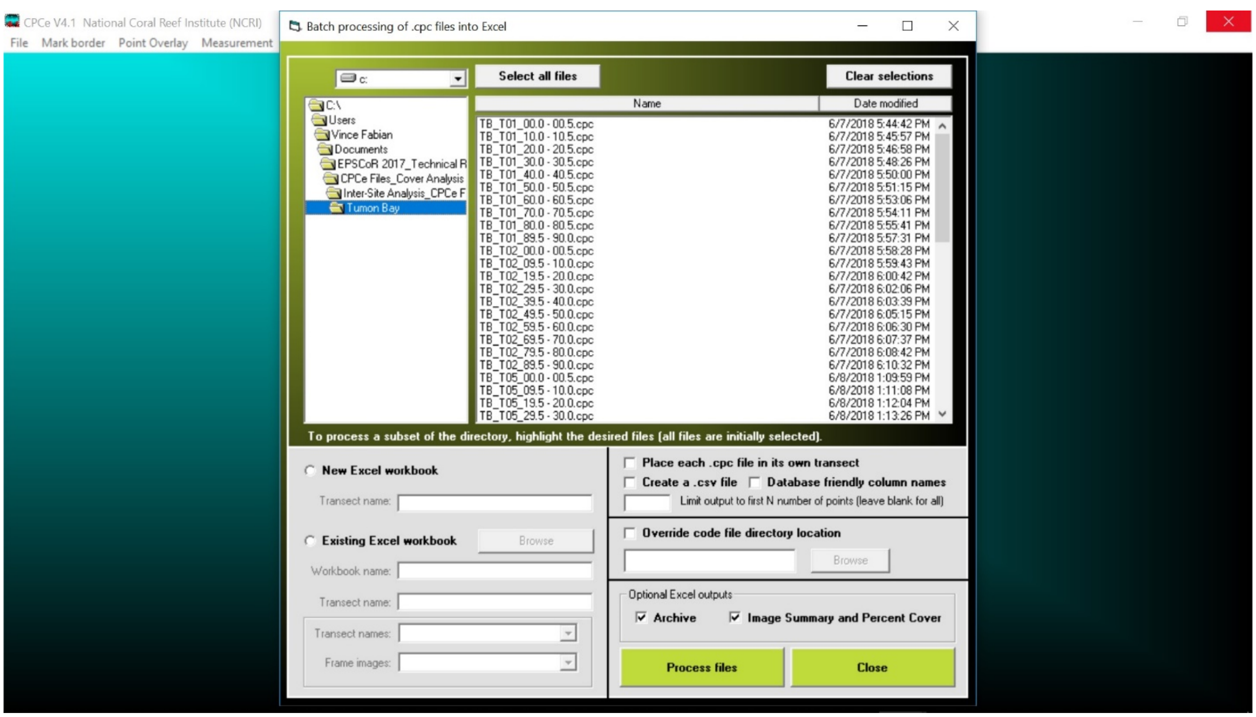
(b) Marking the border for analysis in the image of study.



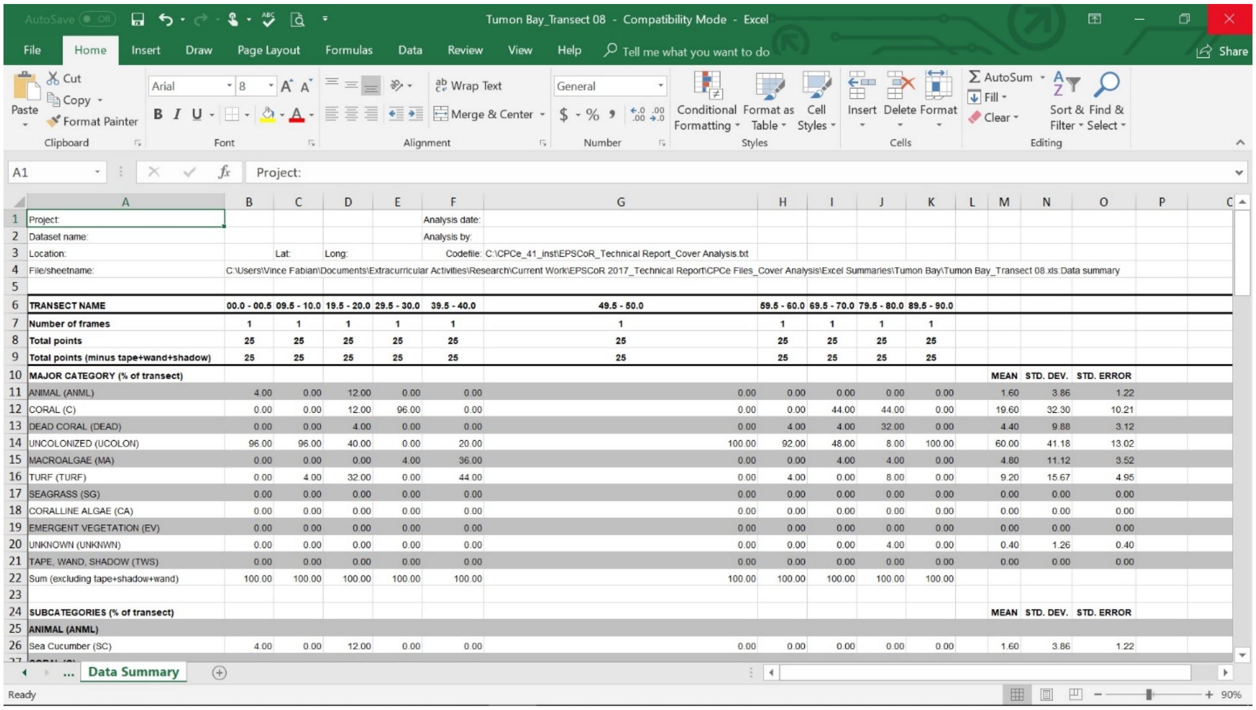
(c) Specifying the data point distribution for image analysis. This study used the stratified random point distribution (five rows and columns with one point in each cell).



(d) Data point distribution after specification.



(e) CPCe files created after analysis which can then be exported into a summarized excel spreadsheet.



	A	B	C	D	E	F	G	H	I	J	K	M	N	O
1	Project:					Analysis date:								
2	Dataset name:					Analysis by:								
3	Location:		Lat:	Long:		Codefile:	C:\CPCe_41_inst\EPSCoR_Technical Report_Cover Analysis.txt							
4	File/sheetname:	C:\Users\Vince Fabian\Documents\Extracurricular Activities\Research\Current Work\EPSCoR 2017_Technical Report\CPCe Files_Cover Analysis\Excel Summaries\Tumon Bay\Tumon Bay_Transect 08.xls:Data summary												
5														
6	**TRANSECT NAME**	**00.0 - 00.5**	**09.5 - 10.0**	**19.5 - 20.0**	**29.5 - 30.0**	**39.5 - 40.0**	**49.5 - 50.0**	**59.5 - 60.0**	**69.5 - 70.0**	**79.5 - 80.0**	**89.5 - 90.0**			
7	**Number of frames**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**			
8	**Total points**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**			
9	**Total points (minus tape+wand+shadow)**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**			
10	**MAJOR CATEGORY (% of transect)**											**MEAN**	**STD. DEV.**	**STD. ERROR**
11	ANIMAL (ANML)	4.00	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	3.86	1.22
12	CORAL (C)	0.00	0.00	12.00	96.00	0.00	0.00	0.00	44.00	44.00	0.00	19.60	32.30	10.21
13	DEAD CORAL (DEAD)	0.00	0.00	4.00	0.00	0.00	0.00	4.00	4.00	32.00	0.00	4.40	9.88	3.12
14	UNCOLONIZED (UCOLON)	96.00	96.00	40.00	0.00	20.00	100.00	92.00	48.00	8.00	100.00	60.00	41.18	13.02
15	MACROALGAE (MA)	0.00	0.00	0.00	4.00	36.00	0.00	0.00	4.00	4.00	0.00	4.80	11.12	3.52
16	TURF (TURF)	0.00	4.00	32.00	0.00	44.00	0.00	4.00	0.00	8.00	0.00	9.20	15.67	4.95
17	SEAGRASS (SG)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	CORALLINE ALGAE (CA)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	EMERGENT VEGETATION (EV)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	UNKNOWN (UNKNWN)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.40	1.26	0.40
21	TAPE, WAND, SHADOW (TWS)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	Sum (excluding tape+shadow+wand)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00			
23														
24	**SUBCATEGORIES (% of transect)**											**MEAN**	**STD. DEV.**	**STD. ERROR**
25	**ANIMAL (ANML)**													
26	Sea Cucumber (SC)	4.00	0.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60	3.86	1.22

(f) The excel summary produced by CPCe from the files analyzed.

Table 1. Classification scheme for geomorphological structure analysis.

Geomorphological Structure Type	
Major Structure	*Detailed Structure*
Coral Reef and Hardbottom	Pavement
	Aggregate Reef
	Spur and Groove
	Rubble
	Aggregated Patch Reef
	Rock/Boulder
	Individual Patch Reef
	Scattered Coral/Rock
Unconsolidated Sediment	Sand
	Mud
Other Delineations	Artificial

Table 2. Classification scheme for biological cover analysis. *Additional category "unknown" refers to portions of the transect image that were unable to be classified due to certain factors (i.e. turbidity, poor image quality, shadow). "Other Life" category was not used in Burdick's classification scheme but was included in this study's analysis due to the consistent presence of other marine life in various images (mainly sea cucumbers).

Biological Cover Type
Coral
Uncolonized
Macroalgae
Turf
Seagrass
Coralline Algae
Emergent Vegetation
Unknown*
Other Life*

Benthic Habitat Mapping

Benthic habitat composition data acquired from the CPCe analysis of the three Guam sites was mapped using ArcMap 10.6, following the same mapping methodology as done by Burdick (2005) (Figure 11). Polygons representing transect sections were drawn onto satellite imagery backgrounds in the software, using GPS coordinates for accurate mapping. These polygons were then categorized according to the transect's respective composition data and assigned symbology representative of each category's characteristics.

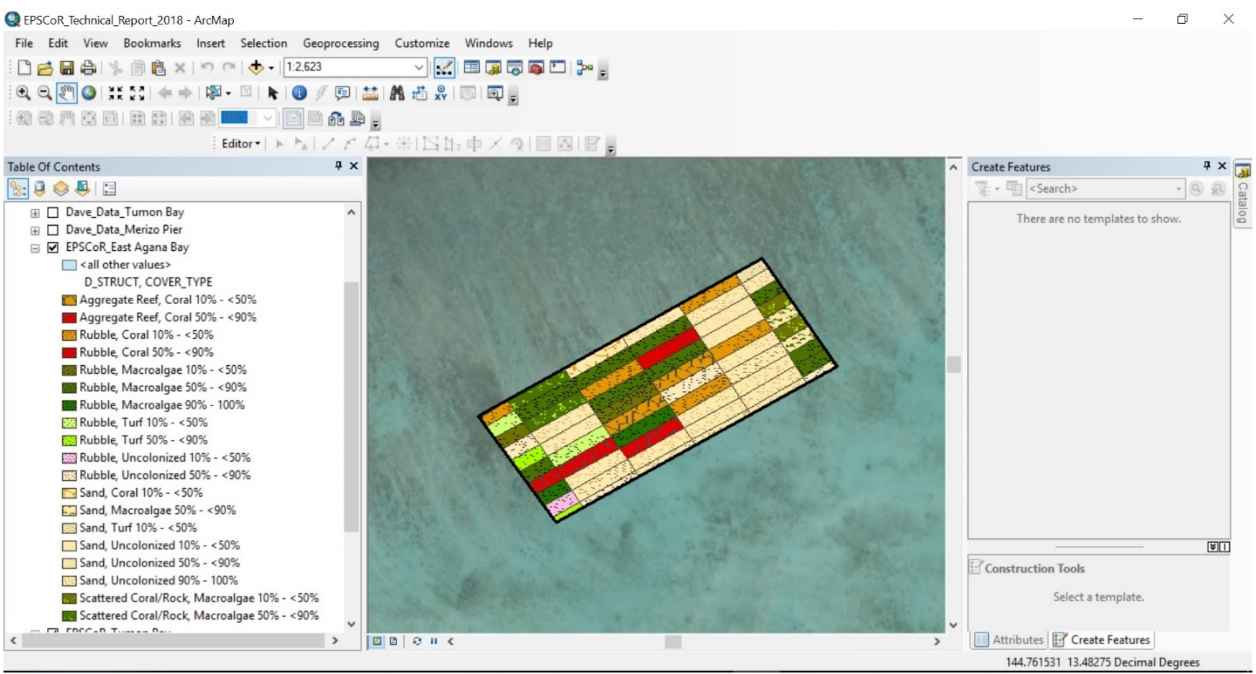


Figure 31: East Agaña Bay site mapped using ArcMap 10.6.

Results and Discussion

Transect Surveys

The percentages for the benthic habitat compositions obtained in the transect surveys show that Tumon Bay has the highest percentage of coral cover (19.73%), East Agaña Bay has the next highest percentage (11.33%) and Merizo Pier has the lowest (2.78%) (Figure 12). Tumon Bay is an MPA, so its marine protection status could indicate why it has a much higher coral cover percentage than the other two areas, which are not MPAs. Further research should be done to further clarify this correlation since no measurable data of MPA efficiency was performed in this study. Merizo Pier's coral cover percentage may be extremely low, but it does indicate that the site contains a few coral colonies that were not previously recorded in Burdick (2005). The presence of this low percentage of coral colonies may indicate a need to assess reef protection in that area since it frequents many human recreational activities such as boat traffic and litter from tourists. Merizo Pier's high algae percentages (45.16% Macroalgae and 32.30% Turf) could also be an indicator that the few colonies present in the area are having trouble competing for space. Looking at the coral species composition at each site, there seems to be a correlation with the amount of coral cover and the amount of coral species found at each site (Figures 12). From lowest to highest coral cover, Merizo Pier's coral colonies comprise mainly of three species, East Agaña Bay with four, and Tumon Bay with five. A closer look at the different conditions at these sites such as the currents in the area and susceptibility to run-off could provide a clearer picture as to why this correlation is present. Results from these surveys, however, cannot be used to generalize the entirety of the three sites since only a small portion of each site was surveyed. Areas of interest were focused on the most "coral-dense" portions judging from satellite imagery, so these percentages could be indicative of the highest possible coral cover percentages for the sites.

Abiotic Conditions

Light and temperature data collected from all three sites show similar patterns throughout the period of deployment (Figure 13). All three sites experience similar dips and peaks in their light and temperature ranges, with a significantly low measurement for both on June 20th which coincides with a thunderstorm occurring. The average temperature was lower for Merizo Pier (30.96°C) than it was for Tumon Bay (32.01°C) or East Agaña Bay (32.30°C). However, this trend could be due to the inconsistency of the logger depth in the water. The lowest temperature seems to coincide with the deepest logger placement and the highest temperature seems to coincide with the shallowest logger placement. Merizo Pier's logger was at a depth of 90 cm, Tumon Bay at 65 cm and East Agaña Bay at 40 cm. It seems that the shallower the logger is, the more light is able to reach the sensor. Warmer water can also be found at shallower depths. This inconsistency may have affected the legitimacy of the light and temperature data collected at the three sites.

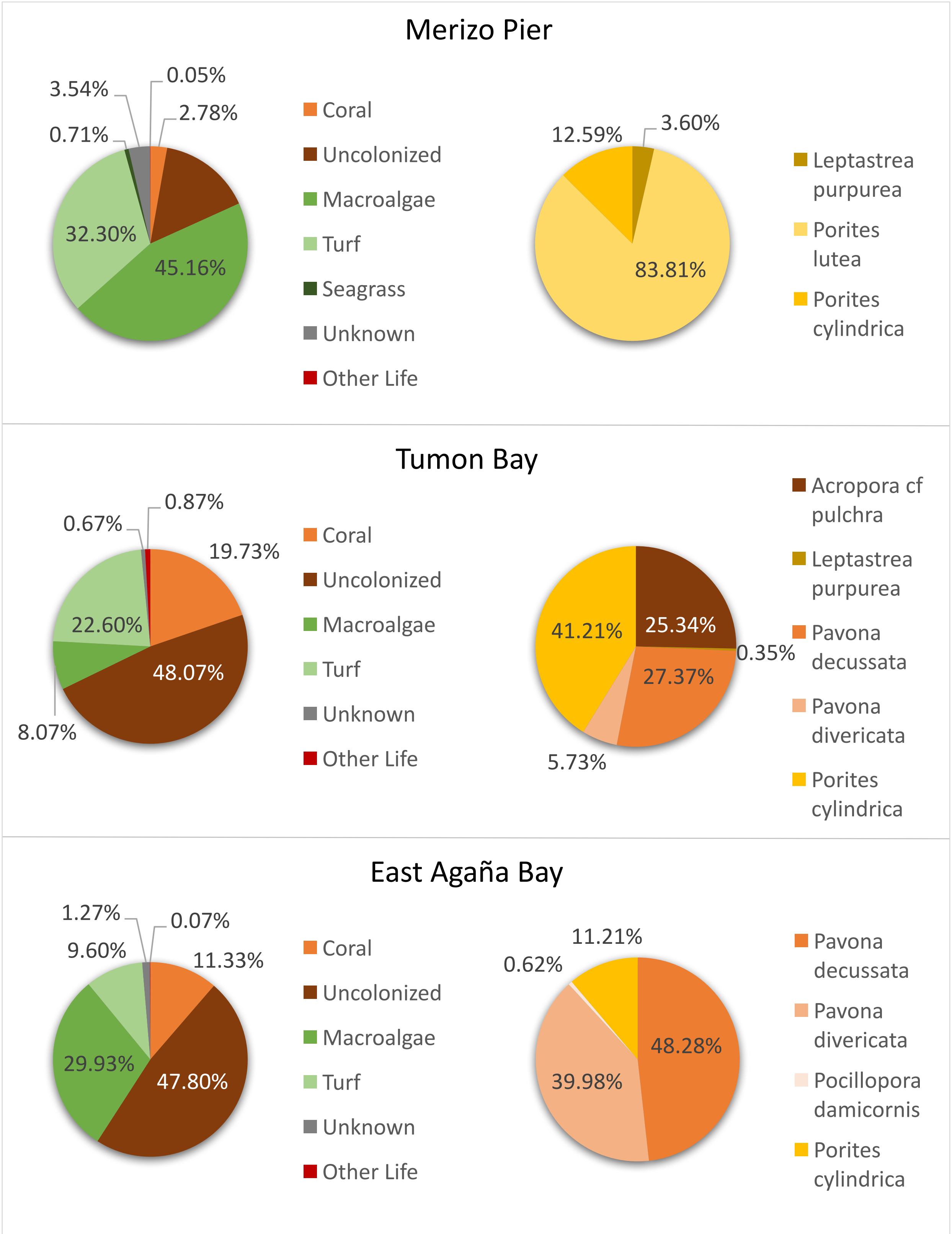


Figure 42: (Left) Benthic habitat composition. (Right) Coral species composition

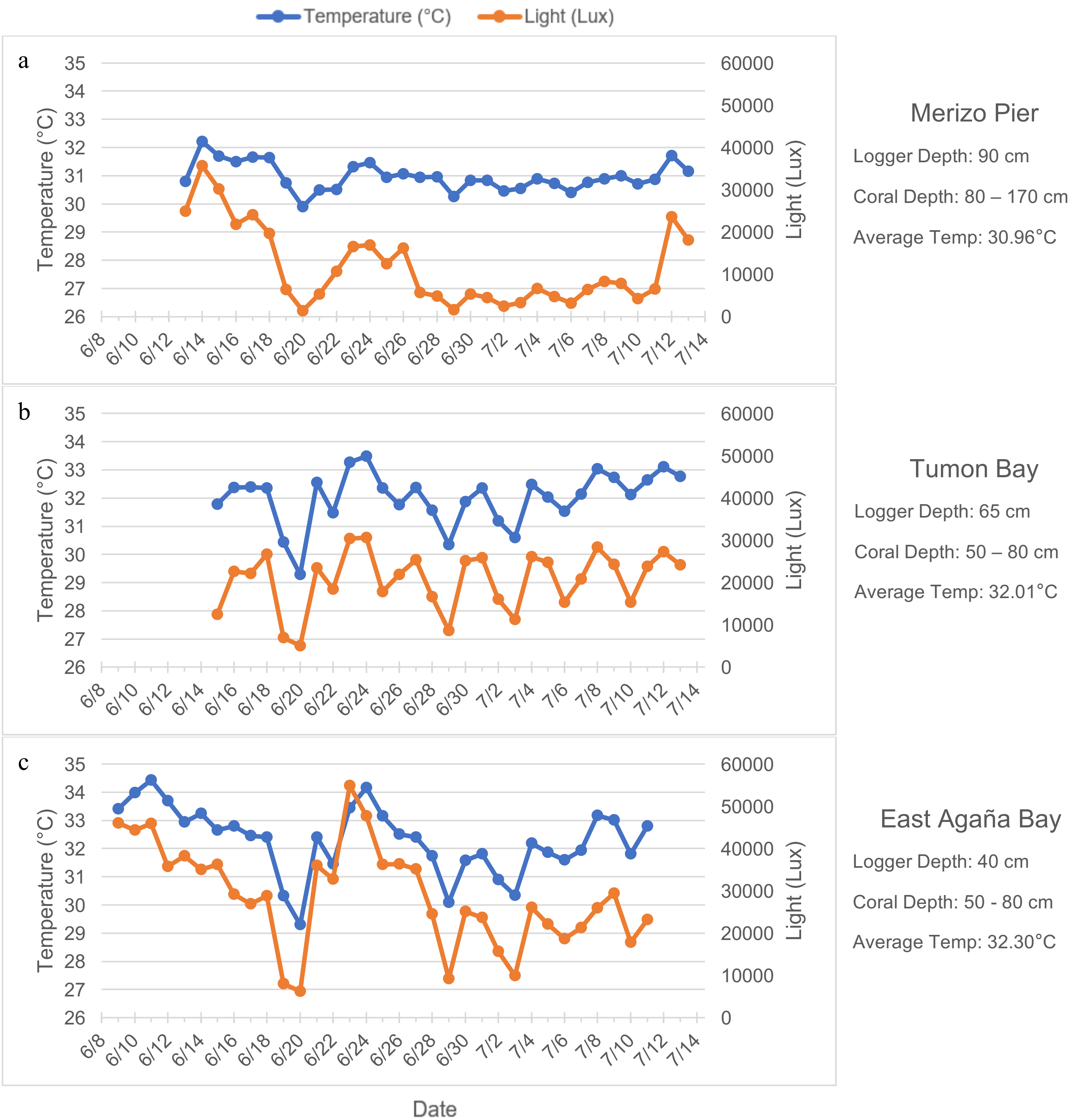


Figure 53: Daily light and temperature data for the sunlit hours (12 hours) of (a) Merizo Pier (b) Tumon Bay (c) East Agaña Bay.

Coral Monitoring Surveys

For the month of study (mid-June – mid-July), coral colonies at all three sites showed little to no change in their bleaching status (Table 3). Many of the coral colonies even showed slightly improved health statuses with the exception of a few colonies experiencing only one health status lower (Merizo Pier Coral 3 & Tumon Bay Coral 4). However, these results do not necessarily conclude that the corals did not bleach this year. These colonies remained healthy during the time of this study which was right before or at the beginning of the expected bleaching season of the year. In fact, Guam reefs experienced a severe bleaching event in 2017 (Raymundo et al., 2019).

Images of each coral colony surveyed can be found in the appendix (Figure 17).

Table 3. The color status of all corals surveyed in study based on the Coral Health Chart (Figure 9). *Coral could not be found again.

Location	Coral	Species	Start Bleaching Status	Finish Bleaching Status
Merizo Pier	1	*Porites lutea*	E2 - E3	E2 - E5
Merizo Pier	2	*Porites lutea*	E2 - E3	E2 - E4
Merizo Pier	3	*Porites lutea*	D3.5	D2.5
Merizo Pier	4	*Porites lutea*	D2 - D2.5	D2.5
Merizo Pier	5	*Porites lutea*	D2 - D2.5	D2.5
Merizo Pier	6	*Porites lutea*	E3	N/A*
Tumon Bay	1	*Porites cylindrica*	E3	E3
Tumon Bay	2	*Acropora cf. pulchra*	D1 - D4	D2 - D3
Tumon Bay	3	*Acropora cf. pulchra*	C1 - C4	D2 - D4
Tumon Bay	4	*Porites cylindrica*	E3 - E5	E3 - E4
Tumon Bay	5	*Acropora cf. pulchra*	C2 - C3	D1 - D6
Tumon Bay	6	*Acropora cf. pulchra*	D1 - D4	D3 - D6
East Agana Bay	1	*Leptastra purpurea*	D3 - D4	D3 - D4
East Agana Bay	2	*Pavona divericata*	E2 - E4	D2.5
East Agana Bay	3	*Pavona divericata*	E2 - E4	D3
East Agana Bay	4	*Pocillopora damicornis*	C2	C2
East Agana Bay	5	*Pocillopora damicornis*	C2	C2
East Agana Bay	6	*Pocillopora damicornis*	D2	D2.5
East Agana Bay	7	*Pocillopora damicornis*	C1 - C3	D3

Map Comparison

Based off the map comparisons between this study and Burdick (2005) (Figures 14 – 16), this study's methodology seems to provide a more detailed breakdown of the benthic habitat composition. However, our maps are not smooth because uninterpolated rectangular cells were used and spatial resolution of our study (2.5-10 m along transect and 5-50 m cross-transect) is coarser than the pan-sharpened multispectral images (1m) used by Burdick (2005). Also, one should note that the habitat composition in these areas may have changed since Burdick's survey.

Limitations

Due to the time span allowed for this study (one month), many limitations arose that prevented it from being as detailed as intended. Three sites were chosen to be surveyed instead of surveying all 35 sites as done in Burdick (2005) and in each site, only a small portion of the whole area was surveyed. Abiotic conditions in each site were also limited to only light and temperature analyses due to lack of other loggers available for use, such as current logger. Bleaching status of corals also do not suggest that coral colonies surveyed did not bleach during the bleaching season. The corals were surveyed for a month immediately prior to the island's expected bleaching season which is why many of the coral colonies surveyed experienced little to no change.

Merizo Pier

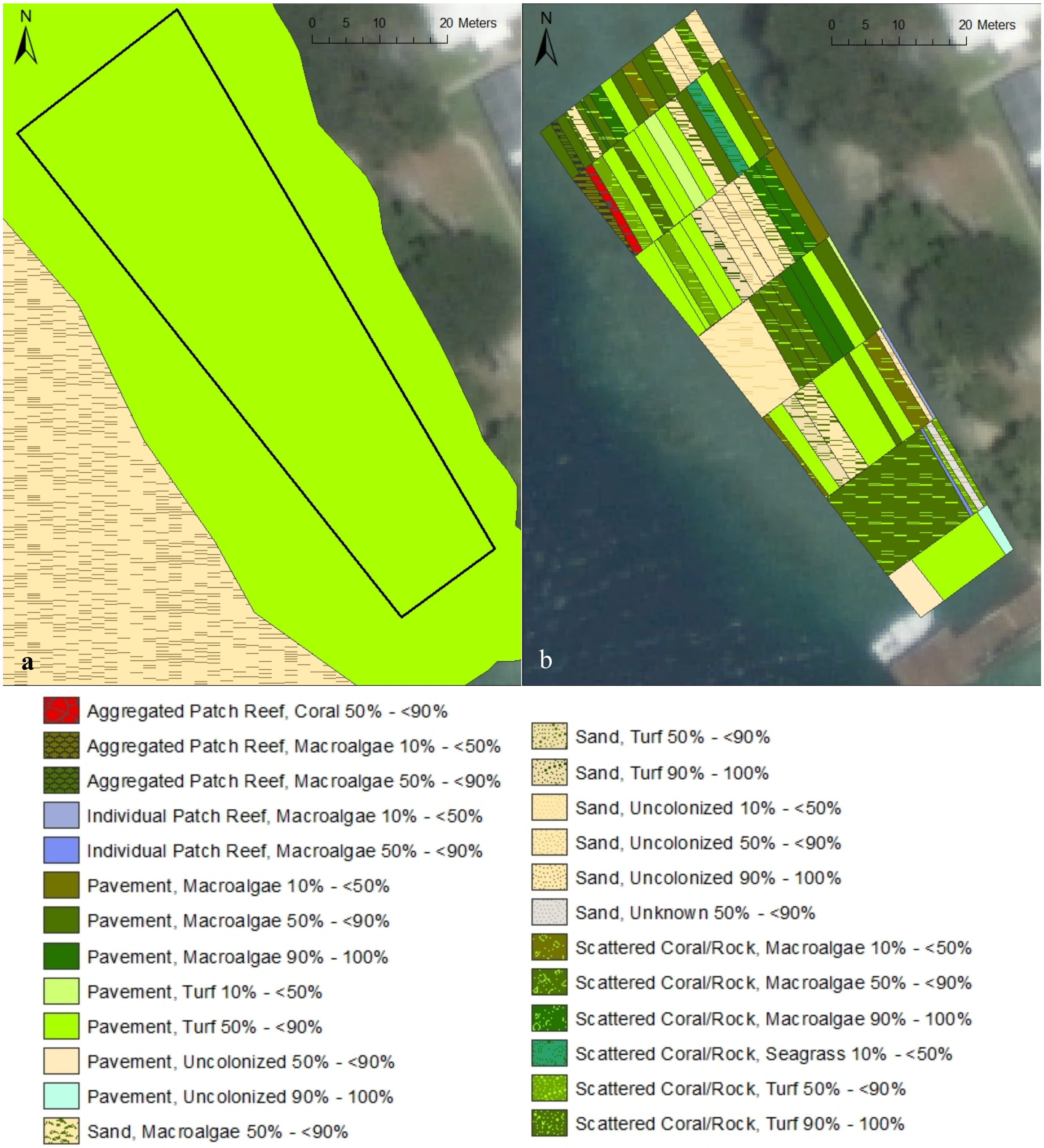


Figure 64: (a) Benthic habitat composition of Merizo Pier from Burdick (2005) with this study's area of interest outlined (in black) for comparison. (b) Benthic habitat composition of Merizo Pier based off transect data acquired in 2017.

Tumon Bay

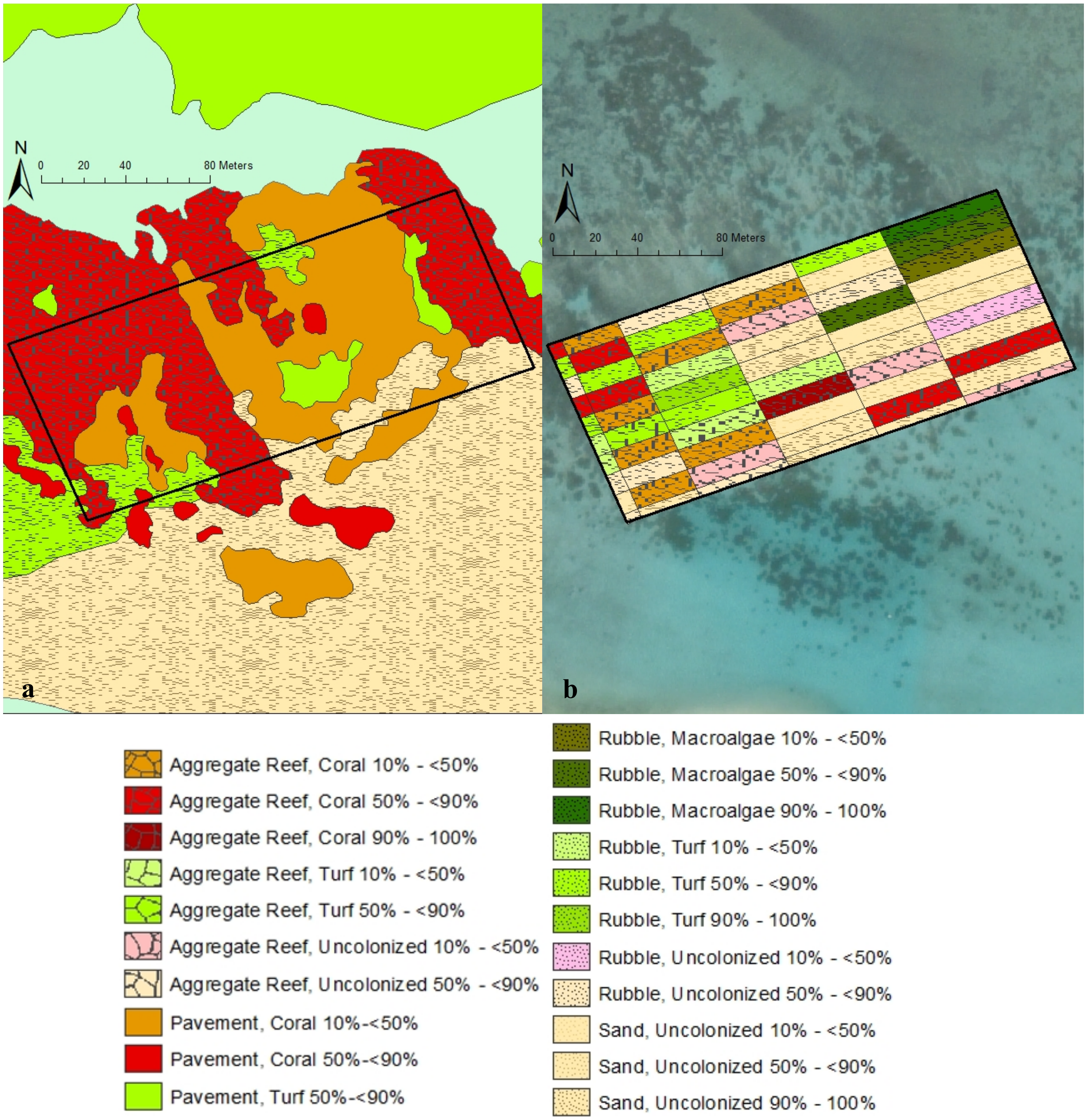


Figure 75: (a) Benthic habitat composition of Tumon Bay from Burdick (2005) with this study's area of interest outlined (in black) for comparison. (b) Benthic habitat composition of Tumon Bay based off transect data acquired in 2017.

East Agana Bay

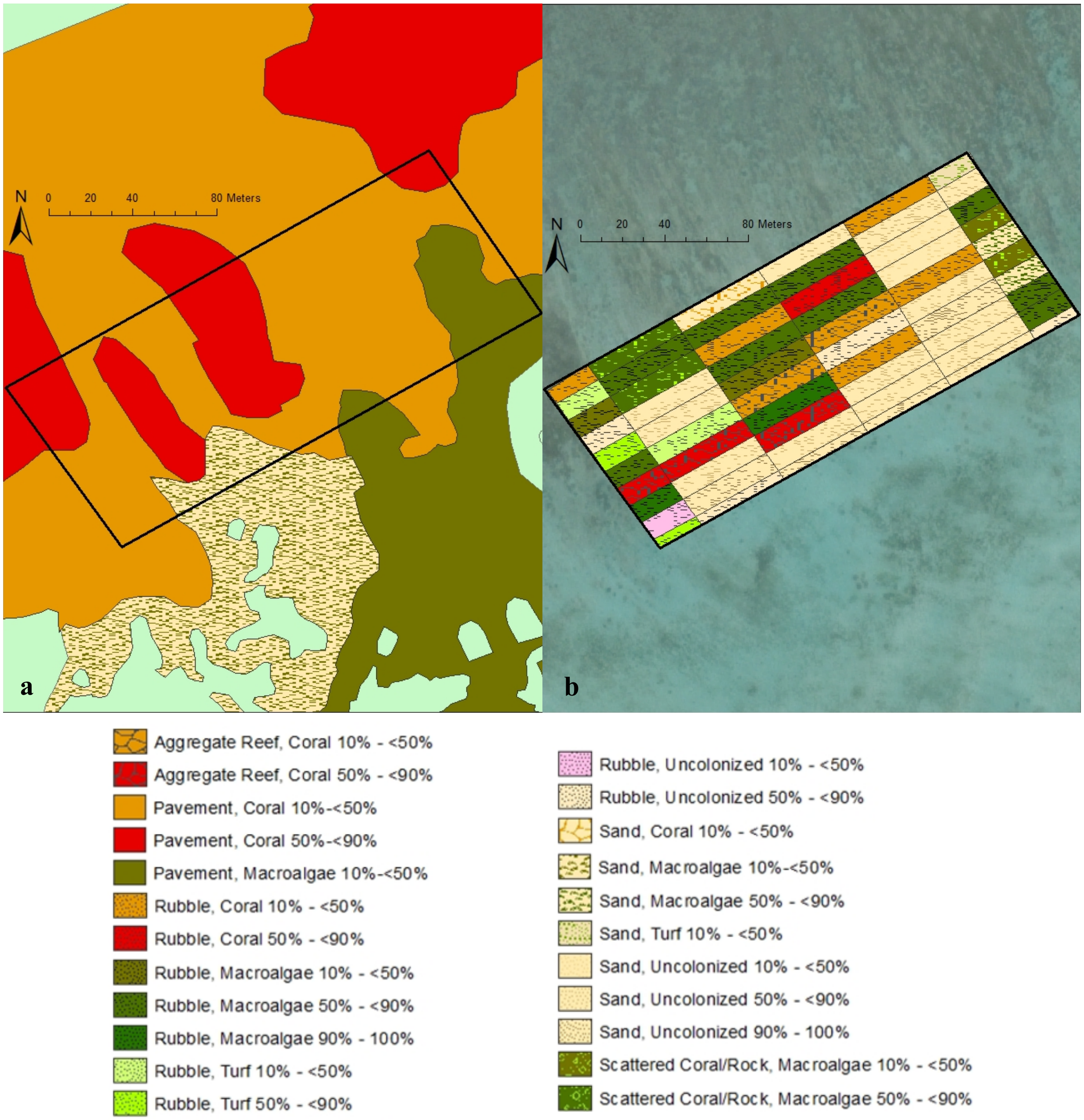


Figure 86: (a) Benthic habitat composition of East Agaña Bay from Burdick (2005) with this study’s area of interest outlined (in black) for comparison. (b) Benthic habitat composition of East Agaña Bay based off transect data acquired in 2017.

Conclusions and Recommendations

Although the data collected from this study is considered small-scale compared to other reef assessments, it does provide information on the sites in question for 2017 which have been otherwise unobserved in that year. The data of coral health and maps of benthic habitat composition in three sites on Guam which may be useful in future research. Despite improper setup of light/temperature loggers at these sites, these errors may inform future surveyors of potential complications they may encounter, and it is recommended to keep loggers at consistent depths with each other and with the colonies under study. Bleaching data provided do not show significant changes in bleaching status during the study's timespan but do show an interesting case as the colonies surveyed imply that corals remained noticeably healthy just prior to the severe bleaching event observed in another study (Raymundo et al., 2019).

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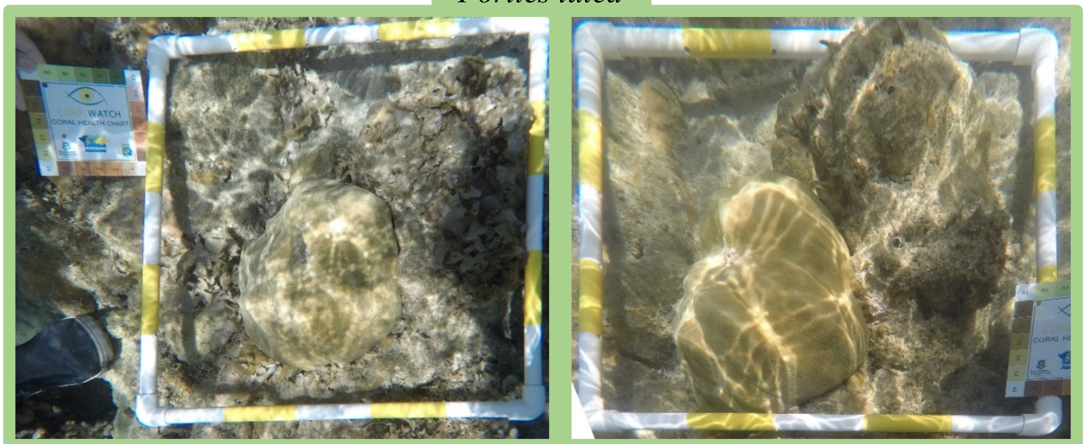
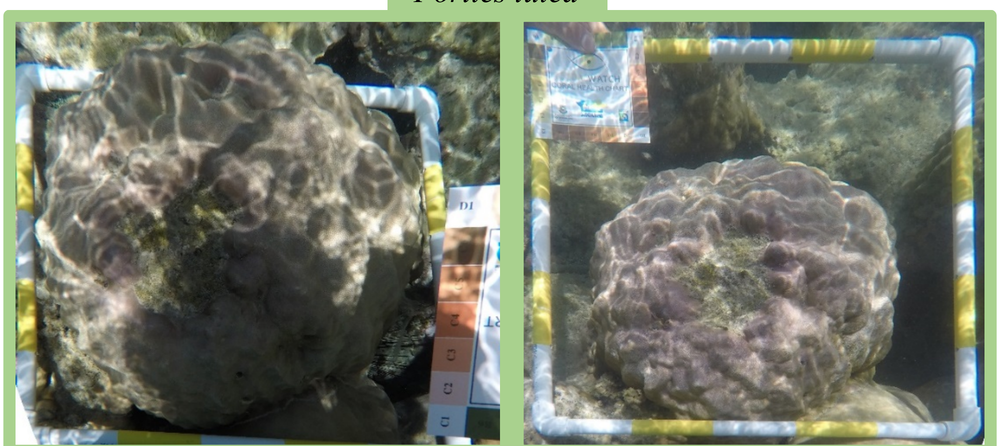
Appendix

Merizo Pier

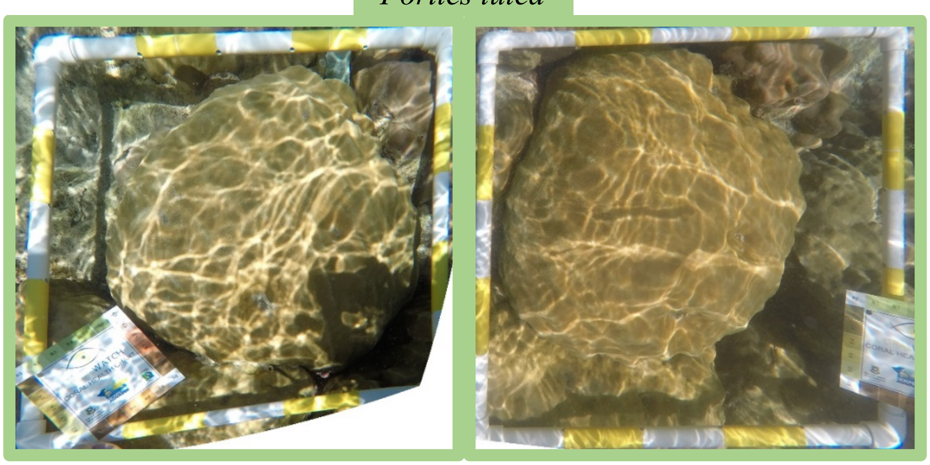
Coral # 1
Porites lutea



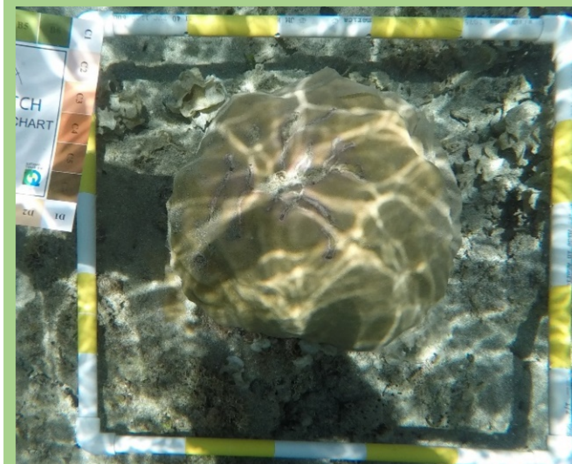
Coral # 2
Porites lutea

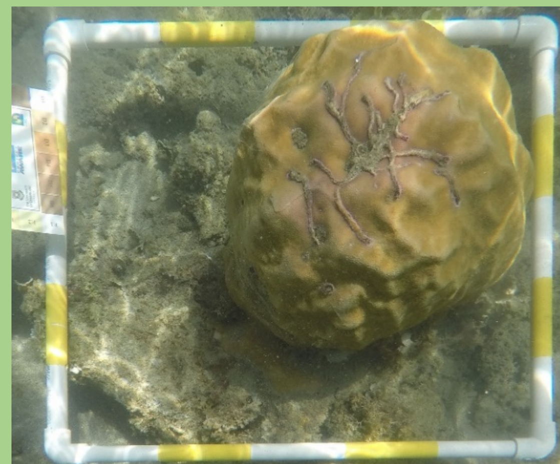


Coral # 3
Porites lutea



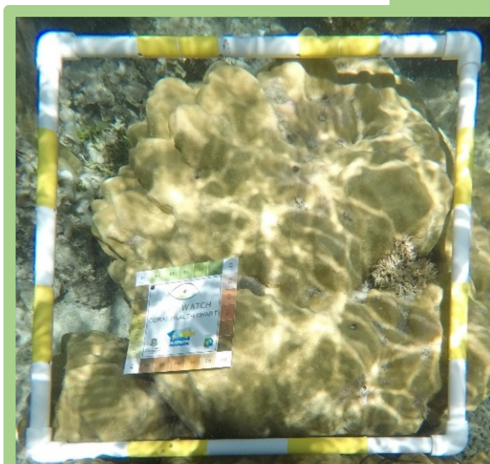
Coral # 4
Porites lutea





Coral # 5
Porites lutea

Coral # 6
Porites lutea

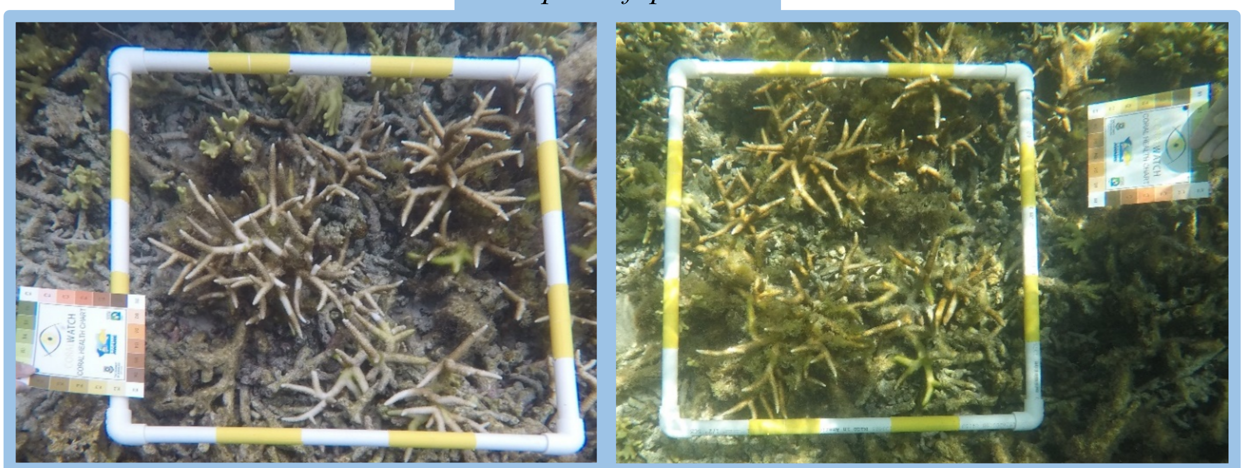


No data: The coral could not be located again

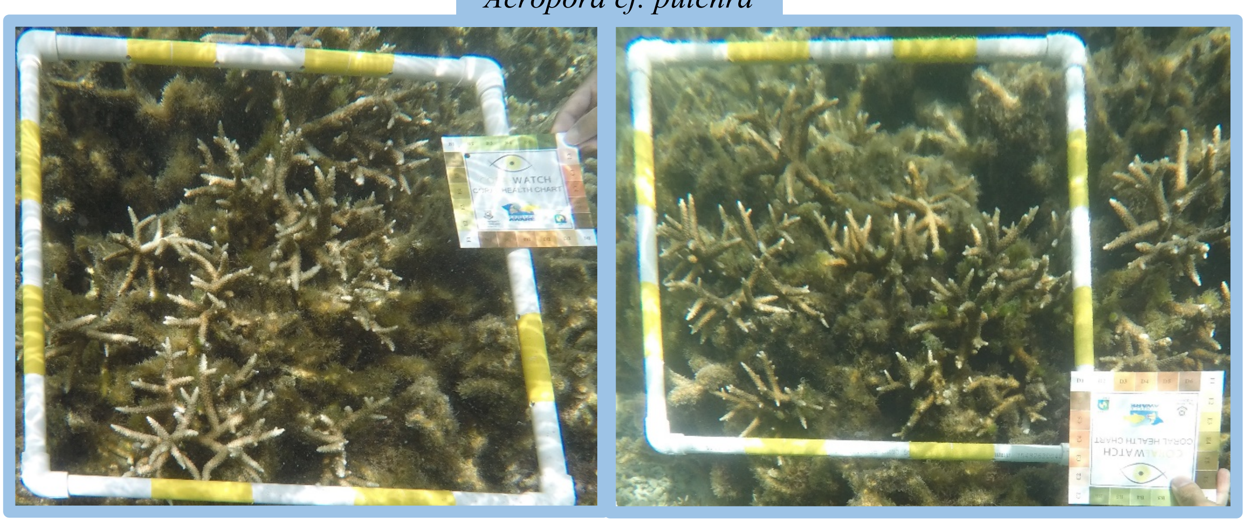
Tumon Bay

Coral # 1
Porites cylindrica

Coral # 2
Acropora cf. pulchra



Coral # 3
Acropora cf. pulchra



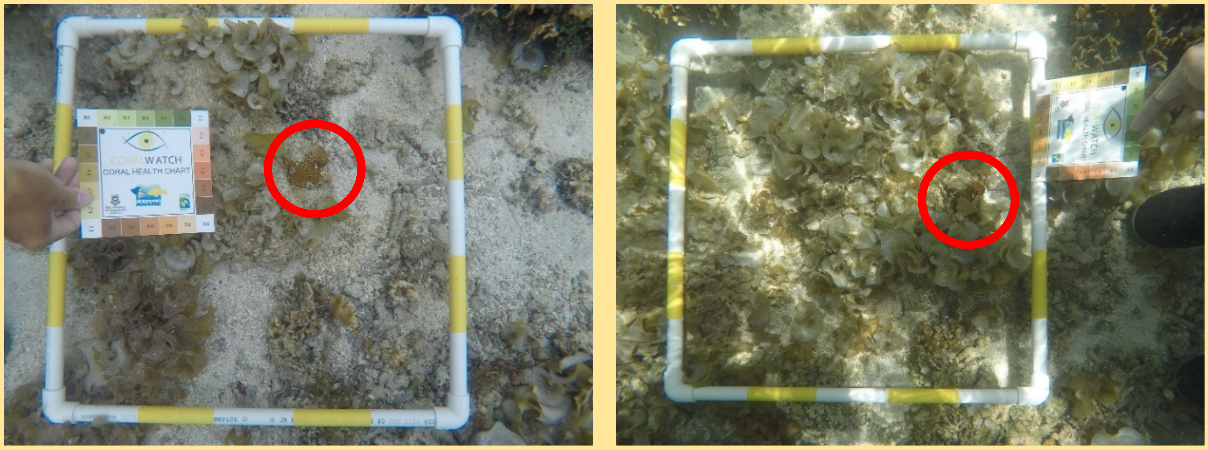
Coral # 4
Porites cylindrica

Coral # 5
Acropora cf. pulchra

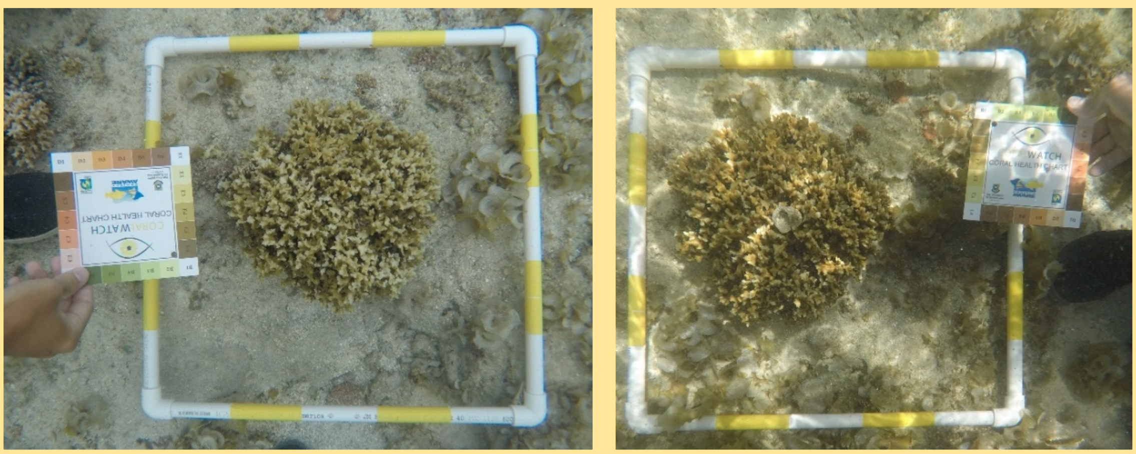
Coral # 6
Acropora cf. pulchra

East Agaña Bay

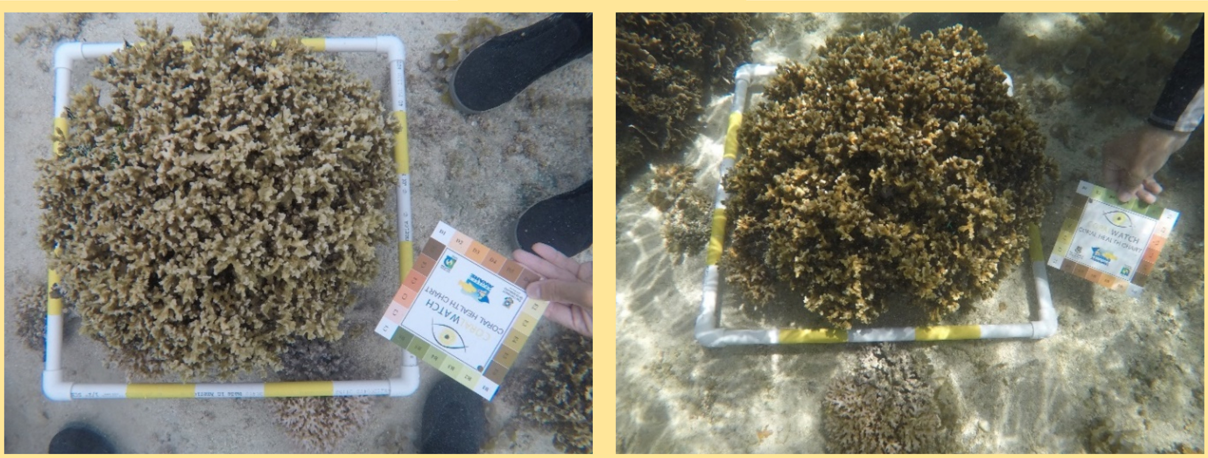
Coral # 1
Leptastrea purpurea



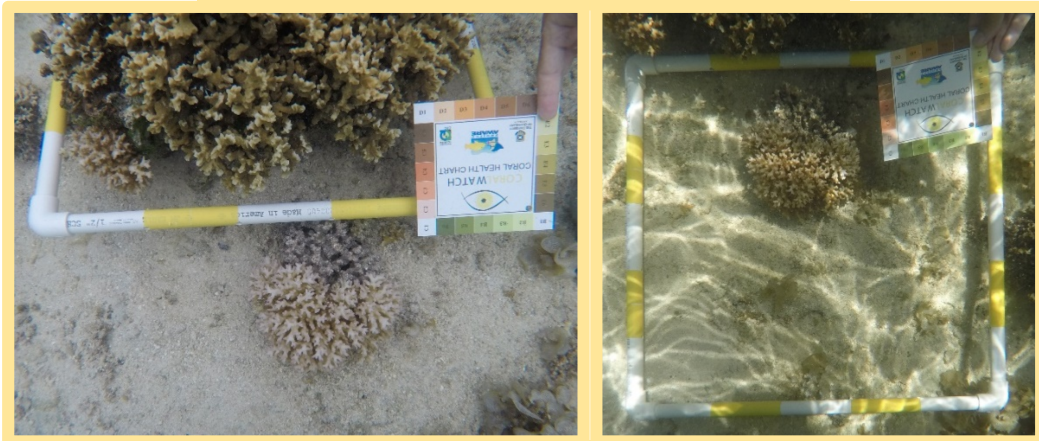
Coral # 2
Pavona divericata



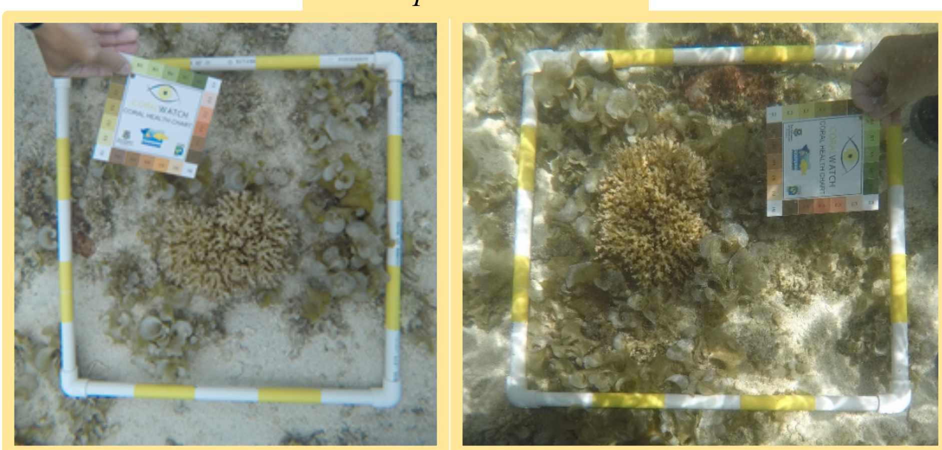
Coral # 3
Pavona divericata



Coral # 4 (Top colony) & 5 (Bottom colony)
Pocillopora damicornis (both)



Coral # 6
Pocillopora damicornis



Coral # 7
Pocillopora damicornis

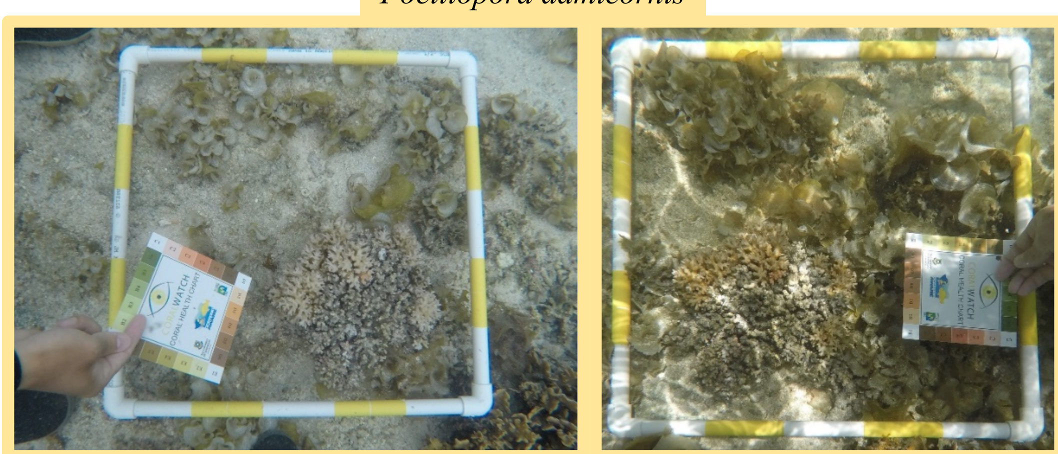


Figure 97: (Left) Beginning survey. (Right) End survey.