Fish Assemblages and Benthic Communities in the Manell-Geus Watershed, Cocos Lagoon, and Achang Reef Flat Marine Preserve

Data Report

K. McCoy[1], T. Kindinger[1], I. Williams[2]

[1] Joint Institute for Marine and Atmospheric Research
University of Hawai`i at Manoa
1000 Pope Road
Honolulu, HI 96822

[2] Pacific Islands Fisheries Science Center
National Marine Fisheries Service
NOAA Inouye Regional Center
1845 Wasp Boulevard, Building 176
Honolulu, HI 96818

INTRODUCTION

In 2014, the National Oceanic and Atmospheric Administration (NOAA) established the Manell-Geus watershed as a Habitat Focus Area (HFA), as part of the Habitat Blueprint, with a range of biological and social objectives. One of those objectives is to improve the health of fish habitat in the HFA. This effort is focused on nearshore coral reef habitats in the Achang Reef Flat Marine Preserve (MP) and Cocos Lagoon and the surrounding forereef (hereafter referred to as Cocos) (Figure 1). The project uses integrated monitoring for key indicators, including fish abundance, fish diversity, coral cover and coral diversity, to inform the HFA's adaptive management process.

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Figure 1. Manell-Geus Habitat Focus Area. The Manell-Geus Habitat Focus Area is located at the southern tip of Guam and includes Cocos Lagoon and the Achang Reef Flat Marine Preserve. Photo: NOAA PIRO/Office of Habitat Conservation.

NOAA's Pacific Islands Fisheries Science Center's (PIFSC) Ecosystem Sciences Division (ESD) and Pacific Islands Regional Office (PIRO) staff conducted baseline surveys of coral reef fishes and benthos in the HFA in 2014. As the full baseline survey effort could not be regularly repeated due to budget and staffing constraints, NOAA PIRO worked with the University of Guam Marine Lab (UOGML) to establish two long-term monitoring sites at a subset of the sampled HFA area. One was within the Achang MP, and the other, Cocos, was located outside of the MP along the eastern side of Cocos Lagoon. NOAA PIRO and UOGML repeated some of those surveys in 2018 using the same survey methods. This report summarizes biological data gathered by those surveys, and, where possible, assesses the degree of change in a number of biological indicators.

Overall, the area was characterized by low coral cover and high macroalgal cover, with no significant change detected in the benthos from 2014 to 2018. Similarly, the fish assemblage showed no significant changes from 2014 to 2018, both inside and outside of the Achang MP.

BACKGROUND AND METHODS

The Manell-Geus watershed is located on the southern end of Guam (Figures 1 and 2). In 2014, the watershed and the adjacent waters were designated as a Habitat Focus Area under the NOAA Habitat Blueprint program. The Manell-Geus HFA is one of ten HFAs located around the country (and U.S. Pacific Territories). These managed sites are intended to improve habitat conditions to support fisheries, coastal management, and marine life. The Manell-Geus HFA work described here expands upon the initial watershed management efforts that began in 2010.

A portion of the reef habitat in the Manell-Geus watershed falls within the Achang MP, which was established in 1997 and enforced starting in 2001. Fishing within the Achang MP remains highly restricted, with limited cultural take of a small number of species allowed only under a special permit issued by the Guam Department of Agriculture; development, construction, drilling, and trenching are highly regulated within the preserve. The Achang MP was designated by the multi-partner Guam Coral Reef Monitoring Group as one of seven high-priority reef areas targeted for long-term monitoring by the Guam Long-term Monitoring Program (GLTMP). The GLTMP monitors the reef fish and benthic communities associated with a section of forereef slope within the Achang MP, as well as those associated with a similarly sized portion of forereef slope at a nearby non-preserve site (Cocos), with the aim of evaluating the effectiveness of the preserve in restoring reef fish communities and assessing the responses of marine communities to changes in water quality (Burdick et al. 2019).

In 2014, NOAA PIFSC and NOAA PIRO scientists conducted baseline surveys of coral reef fishes and benthos at 58 sites in the HFA, along forereef and lagoon habitats between 1 – 30 meters depth, and established the two long-term monitoring areas, Achang MP and Cocos, within the HFA (Figure 2). The Cocos reef area was chosen as a comparison site because of its proximity and similar habitat to Achang MP, but fishing is allowed at this site.

PIRO scientists resurveyed the Achang MP in 2018 using the same methods. A mixed sampling design was used for the 2018 surveys; this approach involved resurveys of some sites established in 2014, along with surveys at new, randomly located sites within the target survey areas (Figure 2). Site metadata is provided in Appendix A, Tables A1–A3.

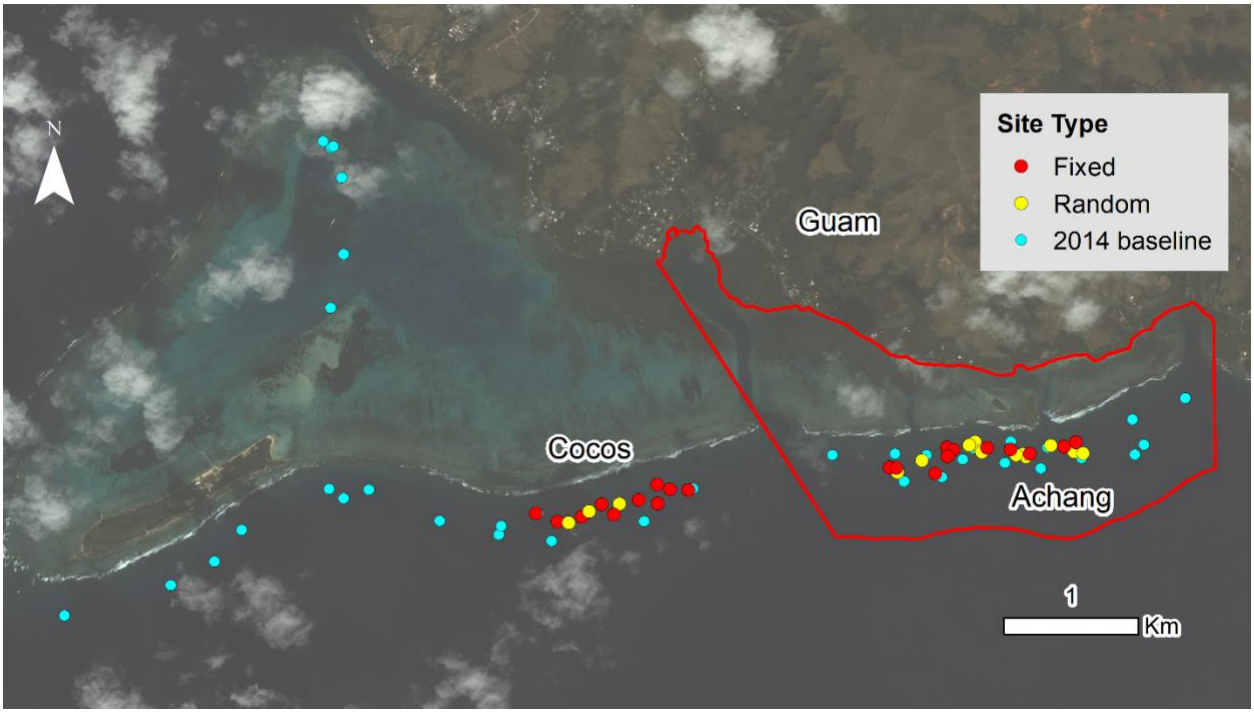

Figure 2. Survey site locations in the Manell-Geus Habitat Focus Area in Guam. The Achang Marine Preserve is outlined in red, and survey sites are indicated by points.

Methods followed standard NOAA Rapid Assessment and Monitoring Program (RAMP) protocols comprising fish "stationary point count" surveys, coupled with benthic-photographic transects completed at each site (Ayotte et al. 2011). In brief, a pair of divers assessed the reef fish assemblage by identifying, counting, and sizing all fishes within cylindrical survey areas with a 7.5-meter radius. Two main observation types are summarized here: instantaneous (I) observations were of fishes seen at the time of the species count following the 5-minute list of species; non-instantaneous (N) observations were fish that were identified in the 5-minute period, but were not present at the time of counting that species. After each respective fish survey, divers took photographs of the benthic substrate at 1-meter intervals along a 30-meter transect in the center of the survey area. All sites surveyed were completed between 1- and 30-meter depth contours.

Coral reef fish biomass per site was estimated using species, abundance, and size information, along with standard length-to-weight conversion parameters used by NOAA PIFSC. Biomass was summarized at family and consumer group levels for most analyses.

Benthic photographs were analyzed using the automated CoralNet machine learning platform.[1] The NOAA PIFSC CoralNet robot was trained using benthic photoquadrat images from the Mariana region, which had previously been collected, annotated, and analyzed by PIFSC scientists. Recent analyses demonstrated that trained CoralNet systems were capable of generating cover data over broad benthic functional groups (e.g., "hard coral") that were highly

[1] https://coralnet.ucsd.edu/.

consistent with results generated from human analysts and manual image annotation (Williams et al. 2019). Data generated by CoralNet was used to estimate percent cover of the primary functional groups (hard coral, macroalgae, crustose coralline algae (CCA), encrusting macroalgae (EMA), sediment, and turf) algae at site level.

When benthic photographs were not available, diver-based visual estimates of hard coral cover were used as a proxy, which were recorded immediately upon completion of in situ fish surveys. These hard coral estimates are shown to be comparable to estimates from photo-quadrat surveys, although estimates of other functional groups were not as comparable (McCoy et al. 2015).

Baseline summary data are shown for all survey sites: total fish biomass, key fish families, and total hard coral cover. Comparison statistics were only generated for a subset of sites: (i) differences in coral reef benthos between Achang MP and Cocos in 2014; (ii) changes in benthic cover at Achang MP between 2014 and 2018; and (iii) changes in fish assemblage metrics at Achang MP between 2014 and 2018. Other potential comparisons were not made due to low sampling replication. Assessments of differences between Cocos and Achang reefs were made only using sites surveyed at the same depth strata, between 6 and 18 meters (sites in Figure 3). Assessments of changes in time were only focused on resampled sites– i.e., fixed sites that were sampled in both 2014 and 2018. Statistical comparisons were based on estimates of the 95% confidence interval of the difference between locations (Achang vs. Cocos) or time periods. When those confidence intervals do not overlap zero, it is taken as statistically significant evidence of change or difference.

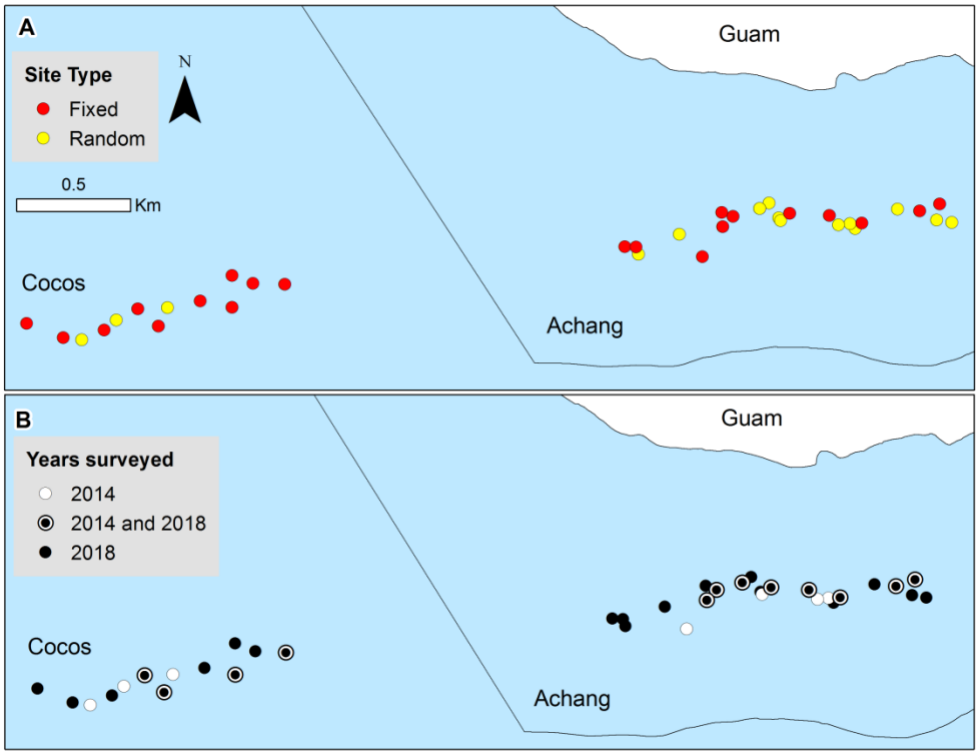

Figure 3. Long-term monitoring survey site locations. Sub-sampled areas of the Habitat Focus Area in the unprotected Cocos reef and the Achang MP. Panel A shows sites by survey type, fixed or random. Panel B shows years that sites were surveyed: 2014, 2018 or both years.

RESULTS

1. BENTHIC COVER

A. 2014 Overview

For comparison purposes, we used visually estimated benthic data for 2014 instead of photoquads, as we did not have photoquad data for all sites. Hard coral cover ranged from 1% to 55% and was highest at one site within the lagoon (Figure 4). The mean coral cover was 7.0% ± 7.5 (mean ± SD). Hard coral cover is the only metric displayed, as this category was shown to have the highest level of agreement between diver visual estimates and benthic photo-quadrat analyses (McCoy et al., 2015).

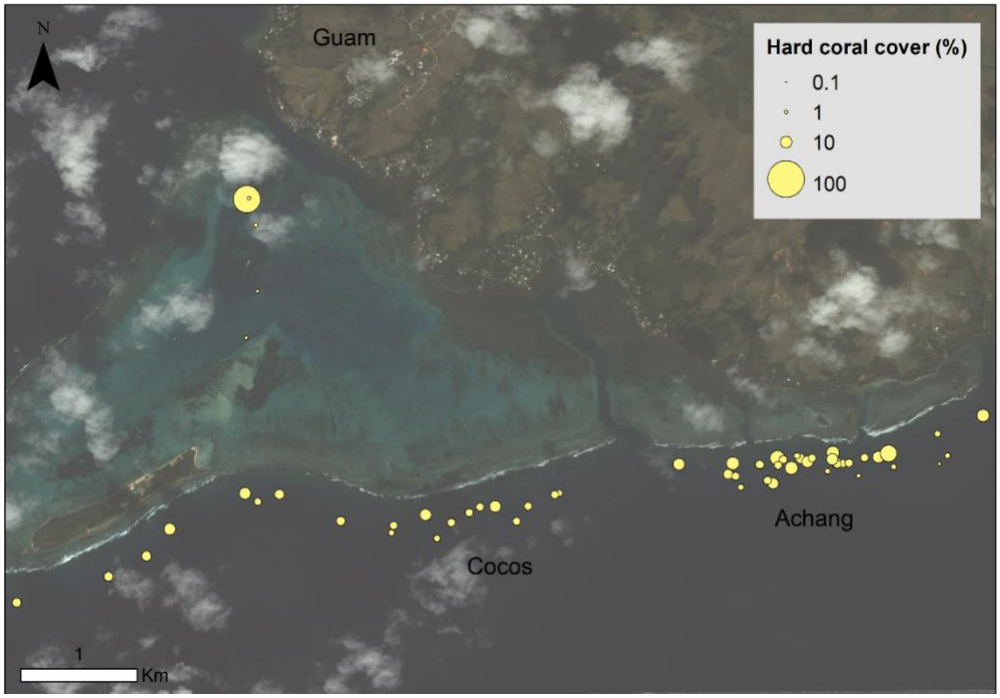

Figure 4. Hard coral cover. Each bubble represents a survey site. Bubble size symbolizes the percentage of hard coral cover.

B. 2014 vs 2018 Subsample – Achang and Cocos

Coral cover was low at all sites in the two sub-sampled comparison areas in both 2014 and 2018; the highest coral cover recorded at any site was 8.1%, with the mean across all surveys of 4% ± 2% (mean ± SD, Figure 5). All survey sites at Achang MP and Cocos were dominated by turf algae in both years, with estimates above 80% in all but three surveys (Figure 5). It is important to note that while the CoralNet algorithm classified most of the benthic cover as turf algae, a category which can include nearly invisible microturfing algae, close visual examination of a subset of photo transect images revealed that the majority of substrate was covered by a sediment-laden algal matrix comprised of a mix of filamentous turfing algae, thinly branched coralline algae (e.g., *Amphiroa fragilissima* and *Jania* spp.), recumbent macrophytes (e.g., *Caulerpa racemosa* var. *lamourouxii*), as well as a significant amount of cyanobacteria (D. Burdick, pers comm). Macroalgae was not abundant at any sites (<6%), and averaged <2% across all surveys. Crustose coralline algae (CCA) cover was >10% at two sites in Cocos in 2018, but was otherwise mostly low, averaging approximately 3% (Figure 5).

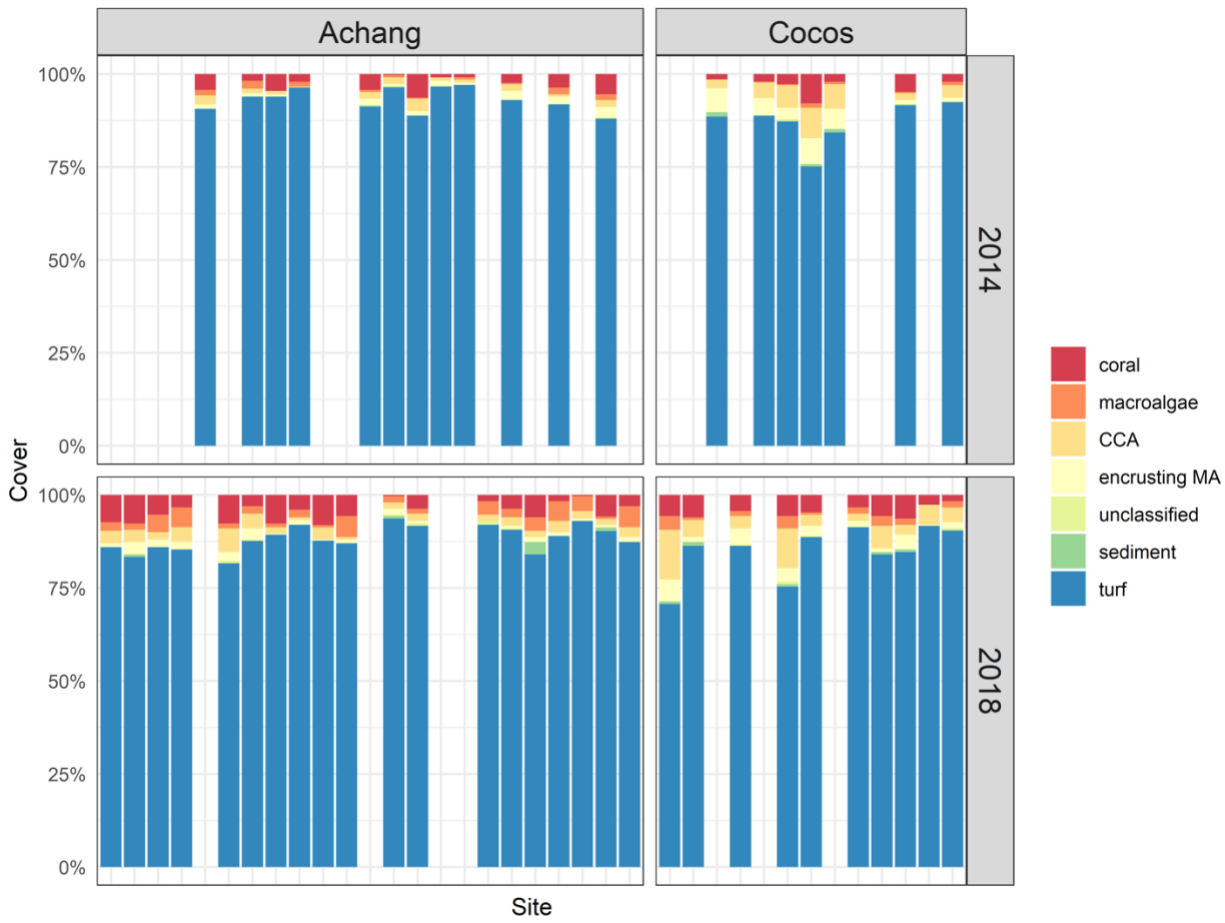

Figure 5. Benthic cover by site, Achang MP and Cocos, and year, 2014 and 2018. Types of benthic cover included hard coral, macroalgae, crustose coralline algae (CCA), encrusting macroalgae (MA), unclassified, sediment, and turf algae. Sites are ordered from west to east (longitudinally; left to right). Sites that align in position between 2014 and 2018 were repeat sites.

Comparisons in 2014 benthic cover between Achang MP and Cocos are shown in Table 1. There were no differences in coral cover, with mean cover at approximately 3% for both locations. However, Cocos sites had significantly more cover of CCA and encrusting macroalgae, even though the absolute scale of difference between locations was relatively low (e.g., CCA cover at Achang MP in 2014 was 1.5 ± 0.9%, compared to 4.6 ± 2.4% at Cocos sites). Turf algae was the dominant cover at both sites. This is consistent with findings from an earlier report, which showed similarly low coral cover in Achang MP in 2014 of 5 ± 4% (Burdick et al., 2019). That report also cited high cyanobacteria cover (49 ± 13%), which was most likely included in the "turf" category in our present analysis.

Table 1. Comparison of benthic cover at Achang MP and Cocos based on all 2014 surveys. Data are illustrated as mean and standard deviation (SD) of percent cover by major functional categories. The difference in cover between Achang and Cocos is expressed as a mean difference and 95% confidence interval (CI). A 95% CI not overlapping zero is equivalent to a p-value < 0.05 in a t-test. Significant differences are highlighted in bold. Number of sites (n) are listed for each area.

	Achang MP Mean ± SD	n	Cocos Mean ± SD	n	Achang-Cocos Diff	(95% CI)
Coral	3.1% ± 1.9%	12	3.3% ± 2.3%	7	-0.2%	(-2.4%, 1.9%)
Macroalgae	0.9% ± 0.7%	12	0.5% ± 0.4%	7	0.4%	(-0.2%, 0.9%)
CCA	1.5% ± 0.9%	12	4.6% ± 2.4%	7	**-3.2%**	**(-5.1%, -1.2%)**
Encrusting macro	1.3% ± 0.9%	12	4.2% ± 2.4%	7	**-2.8%**	**(-4.8%, -0.9%)**
Sediment	0.1% ± 0.1%	12	0.4% ± 0.5%	7	-0.4%	(-0.7%, 0.0%)
Turf algae	93.1% ± 3.1%	12	86.9% ± 5.8%	7	**6.3%**	**(1.3%, 11.3%)**

BENTHIC TRENDS

Eight of the Achang MP sites that were photographically surveyed in 2014 were resurveyed in 2018, with results shown in Table 2 and Figure 5. Coral cover remained low between 2014 and 2018 (3.3 ± 2.0% to 3.7 ± 2.3%, respectively). There were no statistically significant differences for any benthic cover categories at the eight resurveyed Achang MP sites between 2014 and 2018.

Table 2. Trends in benthic cover (%) at resurveyed sites in Achang MP (n = 8). Data are illustrated as mean and standard deviation per year. The difference in cover between 2014 and 2018 is expressed as mean change and 95% confidence interval (CI). 95% CIs in all cases overlap zero, indicating that no changes are statistically significant. This result is equivalent to non-significant results in a paired t-test.

	2014 Mean ± SD	2018 Mean ± SD	Mean Change	(95% CI)
Coral	3.3% ± 2.0%	3.7% ± 2.3%	0.4%	(-1.2%, 2.0%)
Macroalgae	1.0% ± 0.8%	2.0% ± 1.4%	1.1%	(0.0%, 2.2%)
CCA	1.5% ± 1.0%	2.1% ± 1.0%	0.6%	(-0.5%, 1.8%)
Encrusting Macro	1.3% ± 1.0%	1.2% ± 0.9%	-0.2%	(-1.5%, 1.1%)
Sediment	0.1% ± 0.1%	0.2% ± 0.4%	0.1%	(-0.1%, 0.3%)
Turf Algae	92.8% ± 3.1	90.5% ± 1.9%	-2.2%	(-5.0%, 0.5%)

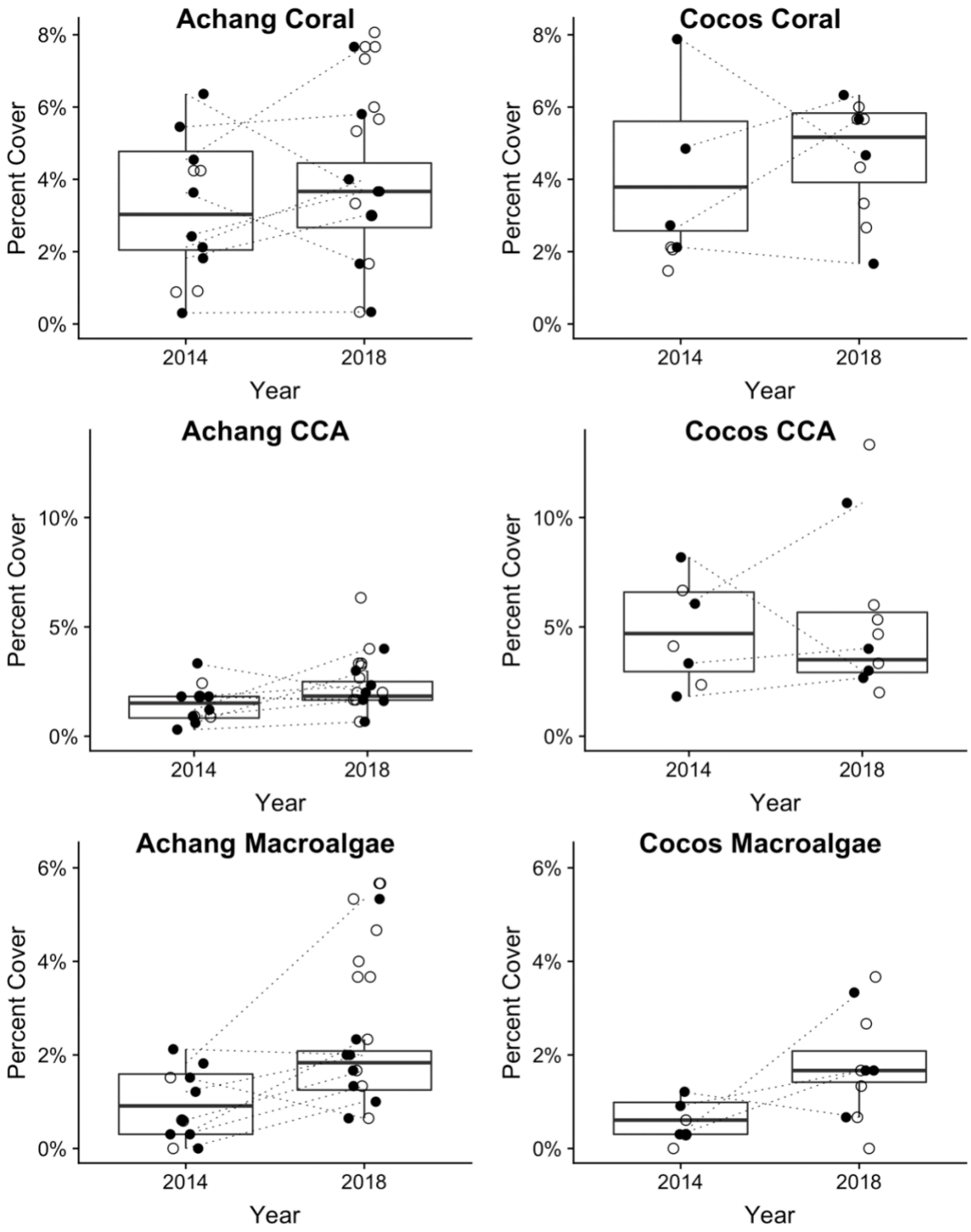

Figure 6. Percent cover of key benthic groups by location and year. Box plots depict median and middle 50% quantiles of cover at resurveyed sites (i.e., sites surveyed in both 2014 and 2018). Filled circles represent cover at resurveyed sites, and open circles represent randomly located sites surveyed in either 2014 or 2018. Dotted lines link 2014 and 2018 data at resurveyed sites.

For completeness, we provide results from all sites combined (i.e. both resurveyed and random sites) in Table 3 and Figure 6. As previously noted, comparisons of trends at resurveyed (fixed) sites are likely more representative of real change at Achang. Results incorporating the random sites as well as fixed sites showed broadly similar patterns to those at fixed sites only (Table 2), but with slightly more change in percent cover between time periods, including marginally significant increases in both macroalgae and CCA cover. The slight difference between resurveyed sites and random sites is illustrated in Figure 6, e.g., several random sites (open circles) surveyed in 2018 have relatively high macroalgal cover.

Table 3. Trends in coral cover at all sites in Achang MP surveyed in either 2014 or 2018. These include both the resurveyed and random sites at each time period. Data are illustrated as mean and standard deviation per year. The difference in cover between 2014 and 2018 is expressed as mean difference and 95% confidence interval (CI). 95% CIs not overlapping zero indicate significant differences equivalent to a p-value < 0.05 in a t-test and are highlighted in bold.

	2014 (n = 12) Mean ± SD	2018 (n = 19) Mean ± SD		Difference	(95% CI)
Coral	3.1% ± 1.9%	4.5% ± 2.5%		1.4%	(-0.2%, 3.1%)
Macroalgae	0.9% ± 0.7%	2.9% ± 1.8%		2.0%	**(1.1%, 2.9%)**
CCA	1.5% ± 0.9%	2.5% ± 1.3%		1.0%	**(0.2%, 1.8%)**
Encrusting macro	1.3% ± 0.9%	1.3% ± 0.9%		0.0%	(-0.7%, 0.6%)
Sediment	0.1% ± 0.1%	0.3% ± 0.8%		0.2%	(-0.2%, 0.6%)
Turf Algae	93.1% ± 3.1%	88.3% ± 3.4%		-4.8%	**(-7.3%, -2.4%)**

2. FISH ASSEMBLAGES

C. 2014 Overview

Total fish biomass at the site level ranged from 5 to 140 g m^{-2}, with a median value of 20 g m^{-2} (Figure 7). The highest biomass value (140 g m^{-2}) for the forereef site in the Cocos area was due to the presence of large moray eel (*Gymnothorax* sp.), and the second highest value (133 g m^{-2}) was a lagoon site with a large mixed assemblage school of breams and squirrelfishes.

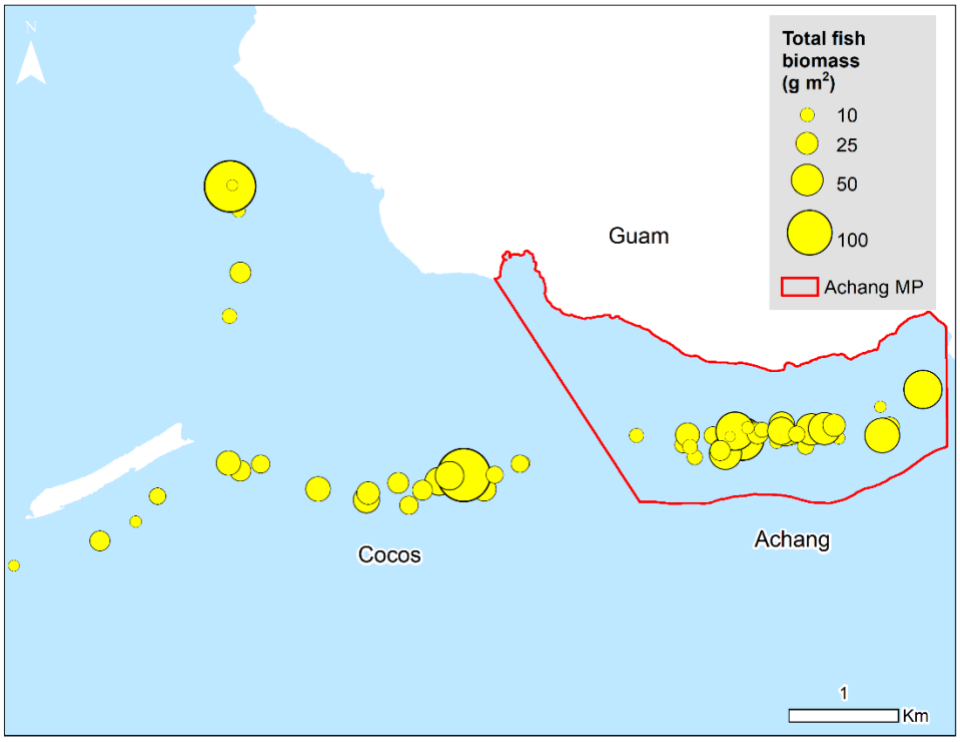

Figure 7. Total fish biomass by site. All sites were surveyed in 2014. Bubble marks depict individual survey sites. Bubble size represents total fish biomass.

Primary and secondary consumers made up the majority of the biomass, with a few sites having high biomass for piscivores (Figure 8). The fish communities at the sites within the lagoon (upper left portion of the maps) were notably different from the forereef sites, with low piscivore biomass and high secondary consumer biomass.

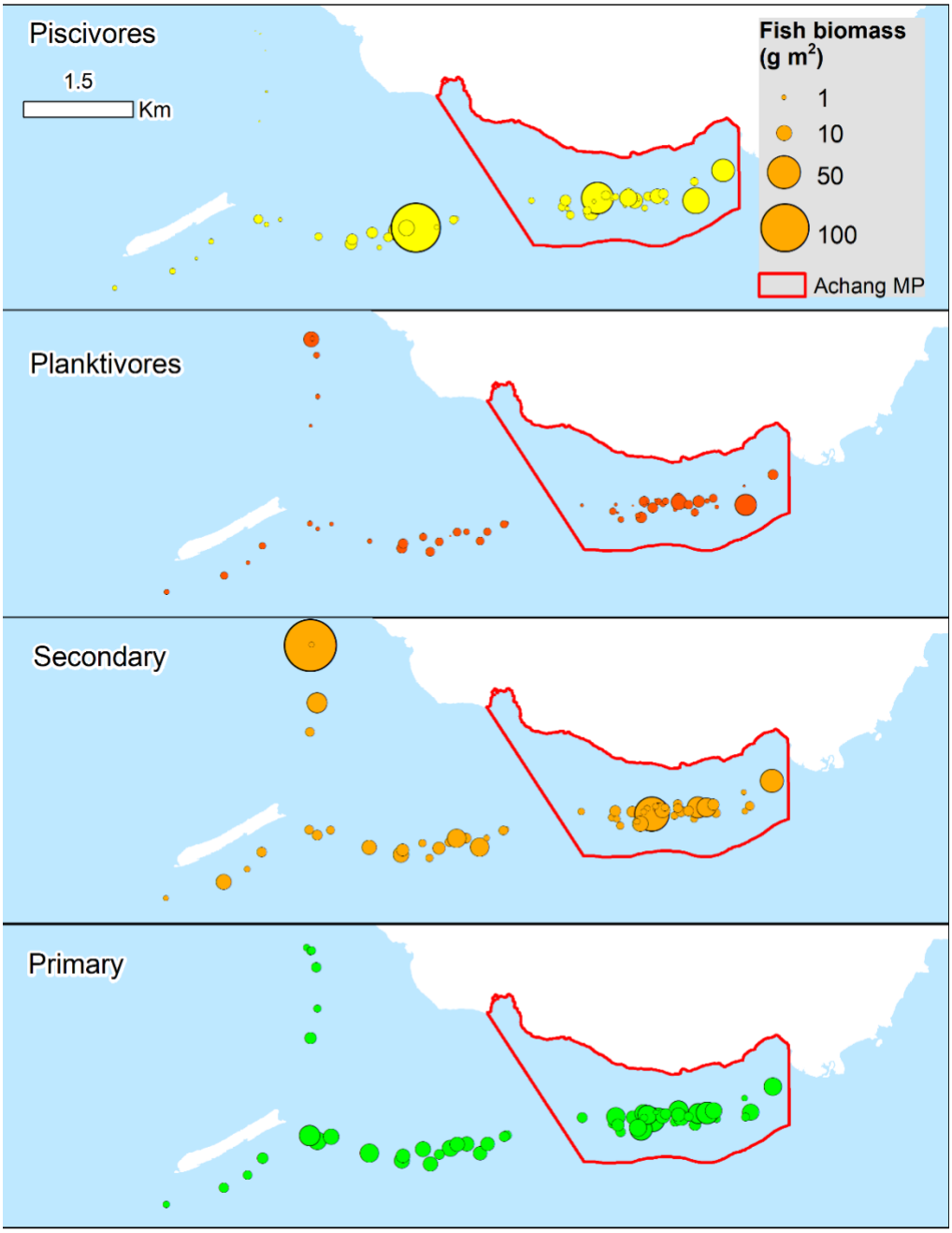

Figure 8. Total fish biomass by site. All sites were surveyed in 2014. Bubble marks depict individual survey sites. Bubble size represents the fish biomass by consumer group. Secondary = secondary consumers (omnivores and invertivores), primary = primary consumers (herbivores).

D. 2014 vs 2018 Subsample – Achang and Cocos

Fish biomass at Achang in 2014 and 2018 are shown in Figures 4 and 5, and summarized differences in biomass between years are shown in Table 4. As fish are mobile, there is much less value in focusing on permanent resampled sites than there is for benthic cover. As such, the results depicted below generally considers all sites surveyed in each of the two sampling periods (2014 and 2018; 20 sites surveyed in each period).

Table 4. Trends in fish biomass at Achang survey sites. Data illustrate mean and standard deviation of biomass in g m^{-2}. Differences in biomass between 2014 and 2018 are expressed as mean differences and 95% confidence intervals (CIs). A 95% CI not overlapping zero indicates a significant difference equivalent to a p-value < 0.05 in a t-test. No categories changed significantly between time periods.

	2014 (n = 20) Mean ± SD	2018 (n = 20) Mean ± SD	Mean Change	Low CI High CI
All Fish	21.4 ± 20.7	19.8 ± 13.9	-1.7	(-12.9, 9.6)
Piscivore	4.4 ± 5.8	5.1 ± 5.7	0.7	(-3, 4.4)
Planktivore	2 ± 2	2.9 ± 4.3	1	(-1.2, 3.1)
Herbivore/Detritivore	8.1 ± 6.7	7.3 ± 5.6	-0.9	(-4.8, 3.1)
Secondary	6.9 ± 11.9	4.5 ± 3.2	-2.4	(-8, 3.1)
Surgeonfish	4.1 ± 3.6	3.4 ± 2.8	-0.7	(-2.8, 1.3)
Parrotfish	3.3 ± 4.7	3.2 ± 3.5	-0.1	(-2.8, 2.6)
Wrasse	1.7 ± 1.2	1.2 ± 1.1	-0.4	(-1.2, 0.3)
Damselfish	0.7 ± 0.4	1.6 ± 3.9	0.9	(-0.9, 2.7)
Sharks	2.5 ± 5.5	3.9 ± 5.4	1.3	(-2.2, 4.8)
Snapper	2.9 ± 8.1	0.9 ± 2.2	-2	(-5.8, 1.8)
Emperors	0.6 ± 1.4	0.2 ± 0.7	-0.4	(-1.1, 0.3)
Jacks	0.7 ± 0.8	1.1 ± 1	0.4	(-0.2, 0.9)
Grouper	21.4 ± 20.7	19.8 ± 13.9	-1.7	(-12.9, 9.6)

Overall, there were no clear indications of a change in Achang fish assemblages between 2014 and 2018 (Figures 9 and 10, Table 4). For example, while total fish biomass was 21.4 ± 20.7 g m^{-2} (mean + SD) in 2014 and 19.8 ± 13.9 g m^{-2} in 2018, the difference between these values was not statistically significant. Although there was slight fluctuation in mean values between time periods at the trophic and family levels, none were statistically significant.

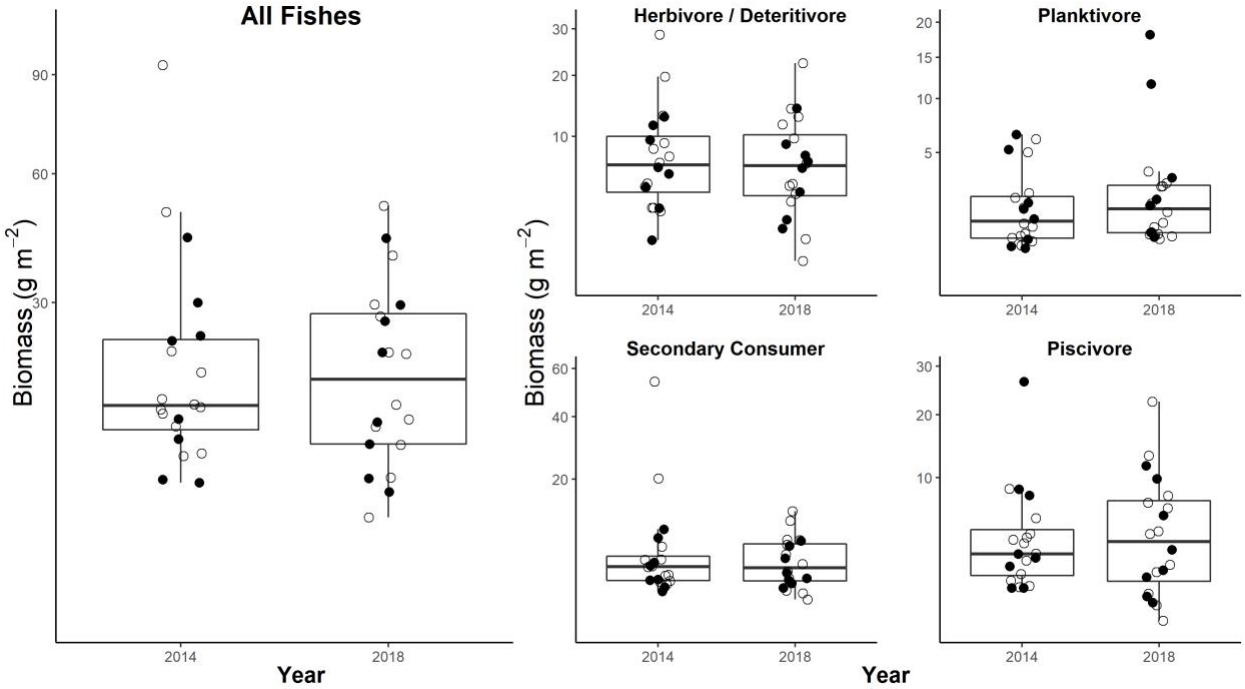

Figure 9. Achang fish biomass trends for all species combined and by consumer group. Herbivores and detritivores are characterized by parrotfish and surgeonfish, but comprise a variety of other genera. Secondary consumers consist largely of invertivores, corallivores and omnivores, including most wrasses, hawkfish, squirrelfish, goatfish, butterflyfish, along with other sub-trophic groups. Box plots depict median and middle 50% quantiles of biomass at all surveyed sites. Filled circles represent resurveyed sites, while open circles represent randomly located sites surveyed in either 2014 or 2018. Note that y-axes are shown on a square-root scale, so that visualization is not dominated by a few high biomass sites.

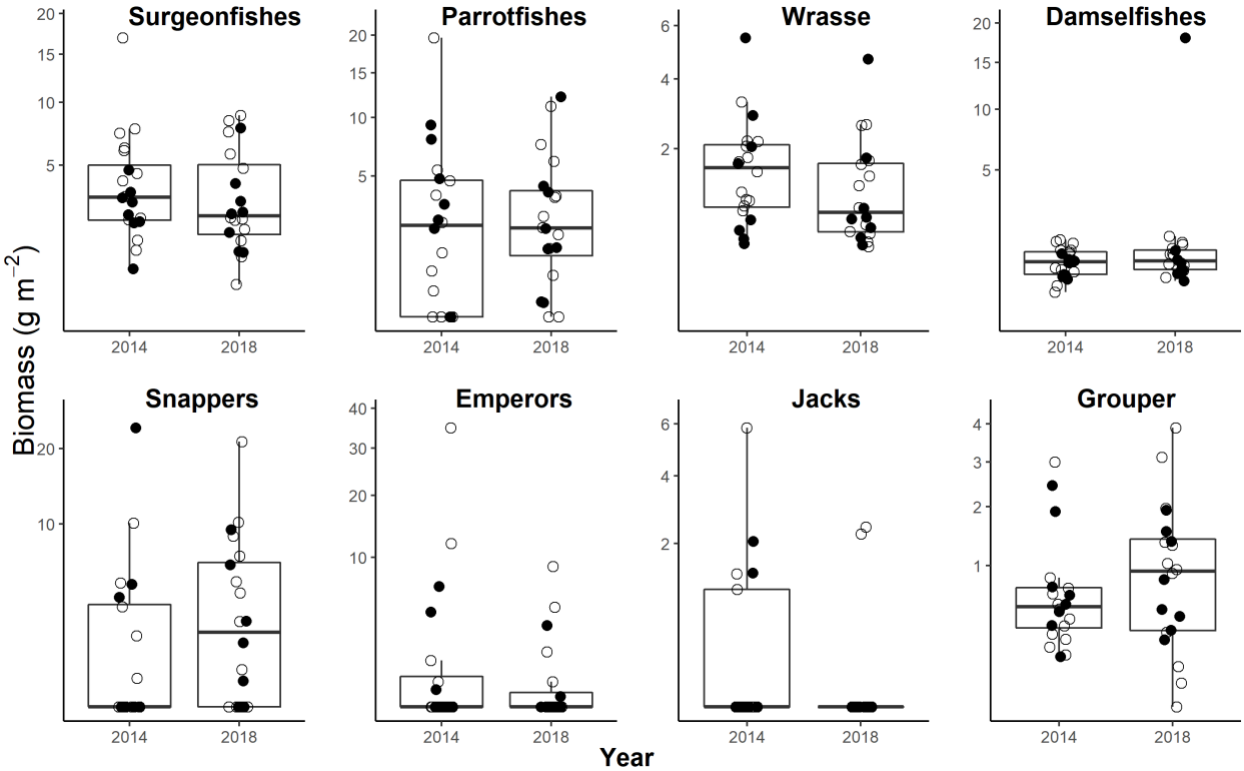

Figure 10. Achang MP fish biomass trends by family. Box plots depict median and middle 50% quantiles of biomass at all surveyed sites. Filled circles represent resurveyed sites, and open circles represent randomly located sites surveyed in either 2014 or 2018. Note that y-axis is shown on a square-root scale.

CONCLUSIONS

Overall, benthic community composition was similar between Achang MP and Cocos, with no detectable changes for either area between 2014 and 2018. Reef ecosystems at both Achang and Cocos appear to be in relatively poor condition, with benthic habitats largely dominated by turf cover, and low coral cover (averaging approximately 3% at both areas). The site in the lagoon with 55% coral cover and high fish biomass would merit additional, future monitoring to see if desirable conditions persist.

Guam was subjected to a minor bleaching event in 2016, and a severe event in 2017 (Raymundo et al. 2019). However, results presented in this report provide little evidence of meaningful changes to benthic or reef fish communities at the Achang MP between 2014 and 2018, with no significant changes to coral cover at fixed sites, and no significant changes to fish assemblages between survey years, possibly due to the pre-existing poor reef condition. The absence of detectable changes to benthic communities in response to recent coral bleaching events is consistent with results obtained for other sites monitored by the GLTMP.

Continued monitoring of these reef areas by the Government of Guam, with the support of federal partners such as PIFSC, would provide data critical to evaluating the effectiveness of the

Achang MP in restoring reef fish communities, and the effectiveness of watershed restoration projects in improving nearshore water quality and the condition of benthic communities.

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APPENDIX

TABLE A1. ACHANG SITES

				Photoquadrats		Fish surveys	
SITE	CRED SITE	LATITUDE	LONGITUDE	2014	2018	2014	2018
GUA-01159	GUA-01159	13.2403157	144.698952			X	
ACH-00022		13.240226	144.698955		X		X
ACH-00026		13.240215	144.699399		X		X
ACH-00017		13.2399235	144.699495		X		X
GUA-01166	GUA-01166	13.2401496	144.699531			X	
GUA-01193	GUA-01193	13.2393047	144.69993			X	
ACH-00019		13.240723	144.701112		X		X
ACH-00008	GUA-01306	13.239838	144.702016	X		X	
ACH-00030		13.241581	144.702784		X		X
ACH-00004	GUA-01302	13.241011	144.702824	X	X	X	X
ACH-00002	GUA-01301	13.241427	144.703228	X	X	X	X
GUA-01156	GUA-01156	13.2408006	144.703854			X	
ACH-00015	GUA-01310	13.24173	144.70428	X	X	X	X
GUA-01171	GUA-01171	13.2415042	144.704575			X	
ACH-00021		13.2419542	144.704657		X		X
ACH-00023		13.2413646	144.705039		X		X
ACH-00005		13.241258	144.705105	X		X	
ACH-00006	GUA-01304	13.241546	144.705465	X	X	X	X
ACH-00014	GUA-01309	13.241459	144.70703	X	X	X	X
GUA-01160	GUA-01160	13.2411999	144.707359			X	
ACH-00013	GUA-01308	13.241084	144.707392	X		X	
ACH-00007	GUA-01305	13.241134	144.707843	X		X	
ACH-00025		13.2409495	144.708047		X		X
ACH-00016	GUA-01311	13.241166	144.708309	X	X	X	X
ACH-00027		13.240764	144.709094				X
GUA-01182	GUA-01182	13.2415806	144.709506			X	
ACH-00029		13.241705	144.709722		X		X
ACH-00010	GUA-01307	13.241642	144.710595	X	X	X	X
ACH-00031		13.2412809	144.711273		X		X
ACH-00018	GUA-01312	13.24192	144.711387	X	X	X	X
GUA-01167	GUA-01167	13.2408778	144.711776			X	
ACH-00033		13.241186	144.711868		X		X

TABLE A2. COCOS SITES

				Photoquadrats		Fish surveys	
SITE	CRED SITE	LATITUDE	LONGITUDE	2014	2018	2014	2018
GUA-01225	GUA-01225	13.2303711	144.643855			X	
GUA-01249	GUA-01249	13.2324008	144.650956			X	
GUA-01247	GUA-01247	13.2339889	144.653893			X	
GUA-01278	GUA-01278	13.2360705	144.655706			X	
COC-00024		13.237198	144.675342		X		
COC-00022		13.236643	144.676796		X		
COC-00002	GUA-01314	13.23656	144.67752	X		X	
COC-00023	GUA-01314	13.23656	144.67752	X		X	
COC-00020		13.236943	144.678405		X		
COC-00001	GUA-01313	13.23733	144.67889	X		X	
COC-00021	GUA-01313	13.23733	144.67889	X		X	
COC-00016	GUA-01318	13.237778	144.679736	X	X	X	
COC-00018	GUA-01319	13.237095	144.680545	X	X	X	
COC-00003	GUA-01315	13.23782	144.68091	X		X	
COC-00025	GUA-01315	13.23782	144.68091	X		X	
COC-00012		13.23809	144.682204		X		
COC-00008		13.239094	144.683452		X		
COC-00010	GUA-01317	13.237832	144.68346	X	X	X	
COC-00004		13.238783	144.684285		X		
COC-00006	GUA-01316	13.23874	144.685532	X	X	X	
GUA-01239	GUA-01239	13.2388542	144.685846			X	

TABLE A3. SITE SUMMARY DATA

				Trophic level biomass g m $^{-2}$				Family biomass g m^{-2}									
SITE	YEAR	FIXED	Reef Zone	Piscivore	Planktivore	Primary	Secondary	Acanthuridae	Carangidae	Carcharhinidae	Labridae	Lethrinidae	Lutjanidae	Pomacentridae	Scaridae	Serranidae	Total Fish
GUA-00761	2014		Lagoon	0.29	0.48	6.37	3.74	3.28	0	0	0.10	0.46	0.39	0.61	2.45	0.29	10.88
GUA-00768	2014		Lagoon	0.01	10.58	3.05	119.37	1.15	0	0	0.86	9.82	1.52	7.66	1.61	0.01	133.01
GUA-00769	2014		Lagoon	0.14	1.61	4.62	2.67	1.11	0	0	1.43	0.54	0	1.57	3.23	0.11	9.04
GUA-00775	2014		Lagoon	0.06	0.37	2.51	2.24	0.54	0	0	0.48	0.88	0	1.02	0.55	0	5.18
GUA-00780	2014		Lagoon	0.33	1.20	2.66	17.73	1.70	0	0	0.82	0.87	0	0.60	0.60	0	21.93
GUA-00782	2014		Lagoon	0.05	1.02	3.49	1.35	0.56	0	0	0.64	0.18	0	1.20	2.36	0	5.91
GUA-01145	2014		Forereef	1.81	1.72	12.70	3.86	5.01	0	0	1.80	1.33	1.09	0.51	6.29	0.77	20.09
GUA-01146	2014		Forereef	1.18	0.75	4.43	2.43	2.44	0	0	1.05	0.16	0.28	0.58	1.02	0.77	8.80
GUA-01147	2014		Forereef	1.96	2.51	6.92	2.36	2.15	0	0	1.47	0	0.81	1.00	3.80	1.09	13.75
GUA-01148	2014		Forereef	10.99	5.60	24.04	11.33	7.63	0	0	5.43	2.56	0.90	3.17	14.59	7.65	51.97
GUA-01151	2014		Forereef	34.78	20.65	3.56	1.64	1.51	35.06	0	0.79	0	0	0.49	1.49	1.62	60.64
GUA-01156	2014		Forereef	5.39	5.03	28.64	54.13	7.68	0	0	1.48	34.85	10.11	1.32	19.59	0.48	93.20
GUA-01159	2014		Forereef	3.68	2.37	4.32	2.58	3.15	0	0	0.79	0	4.60	0.47	0.53	0.52	12.96
GUA-01160	2014		Forereef	0.78	0.50	2.40	4.31	1.28	0	0	0.87	0	0	1.26	0	0.18	7.99
GUA-01166	2014		Forereef	1.05	0.41	7.44	1.98	6.02	0	0	1.10	0	0	0.51	0.17	0.64	10.88
GUA-01167	2014		Forereef	0.84	0.72	2.62	3.56	2.11	0	0	1.70	0.95	0	0.14	0	0.33	7.73
GUA-01171	2014		Forereef	3.23	2.14	8.34	4.36	4.46	0	0	2.06	0	0	1.37	3.72	0.71	18.07
GUA-01179	2014		Forereef	26.06	4.92	16.09	25.28	3.85	0	21.65	5.24	4.26	1.27	3.34	10.94	2.47	72.34
GUA-01182	2014		Forereef	4.01	6.08	19.78	20.13	16.90	0	0	0.95	11.97	3.00	1.02	2.24	3.00	49.98
GUA-01183	2014		Forereef	3.45	0.27	1.83	1.24	1.78	0	0	0.37	0	0	0.29	0	3.45	6.79

				Trophic level biomass g m $^{-2}$				Family biomass g m^{-2}									
SITE	YEAR	FIXED	Reef Zone	Piscivore	Planktivore	Primary	Secondary	Acanthuridae	Carangidae	Carcharhinidae	Labridae	Lethrinidae	Lutjanidae	Pomacentridae	Scaridae	Serranidae	Total Fish
GUA-01185	2014		Forereef	0.11	0.20	9.57	5.62	9.03	0	0	3.47	0	0	0.49	0.24	0	15.50
GUA-01191	2014		Forereef	5.95	0.51	16.47	5.55	12.71	3.21	0	1.93	0	2.00	1.17	2.83	0.38	28.47
GUA-01193	2014		Forereef	3.51	1.66	4.61	2.66	4.01	1.04	0	2.18	0	1.50	1.03	0	0.14	12.44
GUA-01197	2014		Forereef	2.16	0.47	5.48	2.16	3.07	0	0	0.73	0	0	1.36	1.54	0.61	10.27
GUA-01202	2014		Forereef	2.93	4.93	15.67	7.12	6.23	0	0	1.33	3.22	3.25	1.70	7.74	0.20	30.65
GUA-01203	2014		Forereef	6.60	4.02	18.05	3.77	7.05	4.89	0	1.02	0	3.71	3.56	8.31	0	32.44
GUA-01204	2014		Forereef	1.26	3.77	10.20	2.51	4.83	0	0	1.58	0.46	0.84	0.77	5.92	0.82	17.74
GUA-01206	2014		Forereef	1.08	0.75	15.46	4.95	1.58	0	0	2.22	0	0.80	0.78	11.99	0.52	22.25
GUA-01217	2014		Forereef	7.08	4.61	10.85	11.21	3.84	0	0	1.58	5.99	9.98	1.55	6.26	0.22	33.76
GUA-01225	2014		Forereef	1.04	1.51	2.46	1.46	2.89	0	0	0.54	0	0	0.47	0	0.70	6.48
GUA-01239	2014		Forereef	1.39	0.74	4.32	1.59	1.60	0	0	1.40	0	0	0.54	2.47	0.45	8.04
GUA-01247	2014		Forereef	0.65	0.86	3.95	1.62	2.35	0	0	0.47	0	0	0.89	0.44	0.28	7.08
GUA-01249	2014		Forereef	2.17	2.71	4.62	10.35	1.73	0	0	2.81	0	0	2.37	2.30	1.76	19.84
GUA-01255	2014		Forereef	3.10	1.18	17.21	9.63	5.00	0	0	2.03	0	1.79	1.16	12.06	0.65	31.12
GUA-01256	2014		Forereef	6.17	4.22	9.12	6.99	7.11	0	0	1.02	3.69	8.32	1.57	1.31	0.35	26.51
GUA-01274	2014		Forereef	4.36	1.44	20.95	3.54	4.55	0	0	1.01	0	1.39	1.35	15.48	2.83	30.29
GUA-01277	2014		Forereef	0.86	0.72	12.63	2.99	2.71	0	0	0.49	0	0	0.78	3.78	0.79	17.21
GUA-01278	2014		Forereef	1.54	2.12	5.82	4.00	1.73	0	0	1.85	0	0	2.12	3.00	0.97	13.48
GUA-01301	2014	X	Forereef	52.52	0.61	18.62	1.60	8.98	2.07	0	0.67	0	46.63	0.64	9.61	3.82	73.35
GUA-01302	2014	X	Forereef	0.78	0.63	2.85	1.57	2.44	0	0	0.83	0	0	0.60	0	0.22	5.82
GUA-01303	2014		Forereef	0.99	1.58	10.58	10.10	8.68	0	0	2.08	0	0	1.64	1.27	0.84	23.25
GUA-01304	2014	X	Forereef	2.27	2.20	5.59	2.42	1.17	0	0	3.62	0	0	1.40	3.91	0.39	12.48

				Trophic level biomass g m $^{-2}$				Family biomass g m^{-2}									
SITE	YEAR	FIXED	Reef Zone	Piscivore	Planktivore	Primary	Secondary	Acanthuridae	Carangidae	Carcharhinidae	Labridae	Lethrinidae	Lutjanidae	Pomacentridae	Scaridae	Serranidae	Total Fish
GUA-01305	2014		Forereef	12.46	1.87	3.58	2.48	3.12	7.55	0	5.89	0	0	1.67	0	0.50	20.40
GUA-01306	2014	X	Forereef	3.49	1.01	14.40	1.87	12.14	2.65	0	1.04	0	0	0.91	1.63	0.28	20.78
GUA-01307	2014	X	Forereef	10.86	0.95	22.90	16.30	4.18	0	0	10.30	8.09	3.26	1.26	18.56	0.84	51.01
GUA-01308	2014		Forereef	4.52	1.08	11.83	4.93	1.35	2	0	3.83	0.56	0.48	0.40	9.33	0.35	22.37
GUA-01309	2014	X	Forereef	15.11	10.43	9.23	3.52	2.11	0	0	1.81	13.01	9.02	1.63	6.39	0.80	38.29
GUA-01310	2014		Forereef	4.22	0.57	1.34	1.70	0.95	4.11	0	0.67	0	0	0.54	0	0.10	7.83
GUA-01311	2014	X	Forereef	0.72	3.69	4.06	5.05	3.92	0	0	0.64	0	0	0.68	0	0.45	13.51
GUA-01312	2014	X	Forereef	4.55	3.06	12.90	5.98	4.41	0	0	1.93	0	0	1.04	7.83	4.55	26.48
GUA-01313	2014		Forereef	22.72	0.20	13.55	3.81	5.34	0	0	3.67	0.37	20.53	0.37	7.26	0.87	40.28
GUA-01314	2014		Forereef	4.43	3.19	5.10	6.89	2.05	0	0	2.12	0	2.04	1.00	2.32	0.55	19.61
GUA-01315	2014		Forereef	124.17	1.70	10.13	4.70	6.16	0	0	1.47	0	10.40	1.65	3.12	0.40	140.70
GUA-01316	2014	X	Forereef	3.68	2.58	5.22	3.88	3.54	0	0	2.92	0	0	2.54	1.05	3.19	15.36
GUA-01317	2014	X	Forereef	1.18	2.66	9.24	1.68	1.33	0	0	1.33	0	0	1.97	6.86	0.62	14.75
GUA-01318	2014	X	Forereef	12.37	2.98	10.45	15.26	4.11	0	0	5.01	0.29	7.94	0.56	5.80	0.82	41.05
GUA-01319	2014	X	Forereef	6.24	2.58	10.96	2.40	5.52	0	0	1.86	0	5.84	1.19	4.23	0.31	22.18
GUA-01329	2014		Forereef	0.75	3.30	9.51	15.46	2.96	0	0	0.76	9.12	0.68	0.72	5.63	0.75	29.02