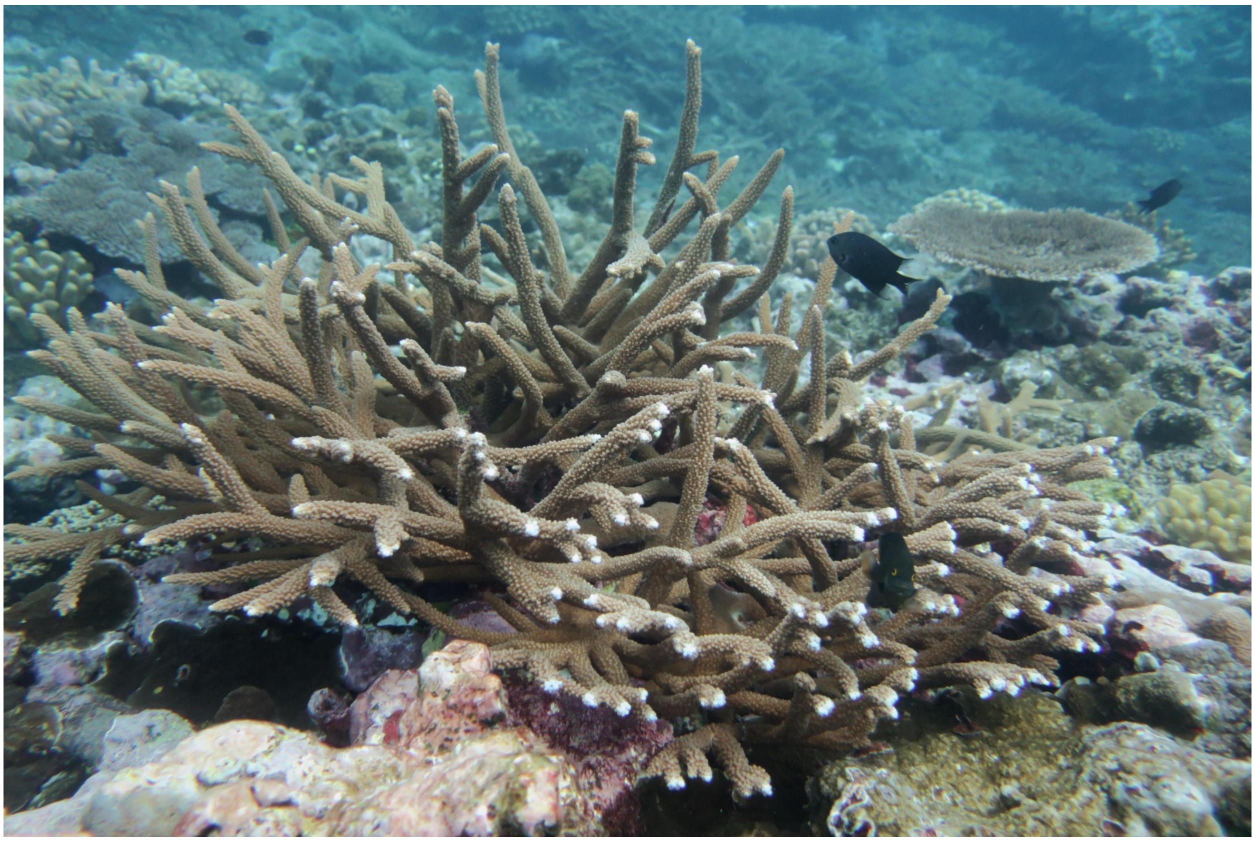
U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Pacific Islands Fisheries Science Center

Ecosystem Sciences Division

Data Report

Status and Trends Assessment of Benthic Coral Reef Communities in Vatia Bay, American Samoa, 2015–2020



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PIFSC Data Report DR-20-020. Issued 25 November 2020.
https://doi.org/10.25923/r7dd-wg50

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Photo caption: Colony of *Acropora intermedia* along the Vatia Bay outer northern mid-depth forereef.
Photo credit: NOAA PIFSC Ecosystem Sciences Division/Bernardo Vargas-Ángel

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Executive Summary

This report provides a summary of key findings for work completed in 2015 and 2020 to assess the status and trends of the benthic coral reef communities in Vatia Bay, American Samoa. Collectively, these data offer a contrast between the 2015 baseline assessment and the subsequent 2020 status survey, and examine how benthic and coral community response variables differed across factors of year (2015 and 2020) and reef stratum (mid-depth north, mid-depth south, shallow north, and shallow south). We deliberately focused our analyses exclusively at detecting measurable change but not attribution. A forthcoming analysis of the Vatia reef biological monitoring data set will attempt to couple the measurable physical and biological gradients to better discriminate and ascribe change over space and time. This work plans to incorporate all available environmental and driver data for Vatia Bay.

Salient findings of this study include:

1. There was a significant 17% increase in coral cover between 2015 and 2020, concomitant with a 5% reduction in fleshy macroalgae and a 19% reduction in turf algae. Percent cover of other benthic functional groups including coralline algae, encrusting macroalgae, and *Halimeda* did not change between survey years.
2. The temporal increase in coral cover varied by colony morphology: 8% for branching, 6% for encrusting, 2.5% for table, and 1.5% for massive corals. Cover of *Acropora* increased five-fold from 1.5% to 7.8% and *Porites* two-fold from 8.5% to 18.4%.
3. No significant differences in adult or juvenile colony densities were detected between survey years.
4. The coral colony size frequency distribution shifted to larger coral colony sizes in 2020 compared to 2015. Mean adult colony size significantly increased over time from 15.4 cm to 25.6 cm.

Conclusions of this study:

Temporal increases in coral cover between 2015 and 2020 were mainly driven by colony growth rather than the addition of new colonies via recruitment or fragmentation/fission. The considerable, measurable improvement of the Vatia reef over the last five year indicates elevated capacity to regenerate, a key element of resilience to attendant human impacts in a changing climate. We believe Vatia reef deserves dedicated attention from local managers and community members.

Objective and Purpose

Herein we provide an assessment of the status and trends for coral reef benthic structure and coral community demographics at Vatia Bay (Territorial priority watershed), based on work conducted in 2015 and 2020 by the Ecosystem Sciences Division (ESD) of NOAA's Pacific Islands Fisheries Science Center (PIFSC). This work was funded by the NOAA Coral Reef Conservation Program (CRCP) through two internal projects: "*Eutrophication Impacts on Coral Ecosystem Health in Vatia, American Samoa*" awarded to David Whitall (NOAA National Center for Coastal and Ocean Science); and "*Status and Trends Assessment for Land-based Sources of Pollution Impacts on Benthic Reef Communities in Faga'alu Bay and Vatia Bay, American Samoa*" awarded to the PIFSC Ecosystem Sciences Division (ESD).

There have been local concerns about the impacts of land-based sources of pollution and water quality on the coral reef ecosystems of Vatia Bay (NOAA CRCP 2012). To that end, the projects above were conceptualized and developed in consultation with the federal and local marine resource management agencies including the NOAA Coral Reef Conservation Program, the American Samoa Department of Marine and Wildlife Resources (DMWR), the American Samoa Coral Reef Advisory Group (CRAG), and the NOAA American Samoa Pacific Islands Regional Office. They were aimed at developing a spatially comprehensive coral reef monitoring framework for Vatia Bay, to complement ongoing local monitoring and management efforts to reduce LBSP in priority watersheds; supporting CRCP Jurisdictional and National Objectives.

With a baseline assessment conducted in October–November 2015 and a subsequent status survey completed in January 2020, herein we examine whether the Vatia reef has undergone measurable benthic changes since the baseline assessment. More specifically, we aimed to address the following overarching questions:

1. Did benthic cover of the most abundant functional groups (crustose coralline algae, hard coral, fleshy macroalgae, encrusting macroalgae, *Halimeda*, sediment, and turf algae) change?
2. Did scleractinian coral cover change?
3. Did the coral community composition—i.e., density of adult and juvenile colonies—change?
4. Did coral colony size and the size frequency distribution change?

Methods

Following Winston et al. (2019), biological surveys used a modified stratified random sampling design to assess the survey domain which encompassed the hard-bottom reef habitat from 0 to 18 m in depth. Based on the geomorphology of the reef, the stratification scheme combined two depth categories (shallow: 0–6 m and mid-depth: 6–18 m) and two cardinal positions (north and south) into four distinct strata: i.e., mid-depth north, mid-depth south, shallow north, and shallow south, hereafter MN, MS, SN, SS (Fig. 1).

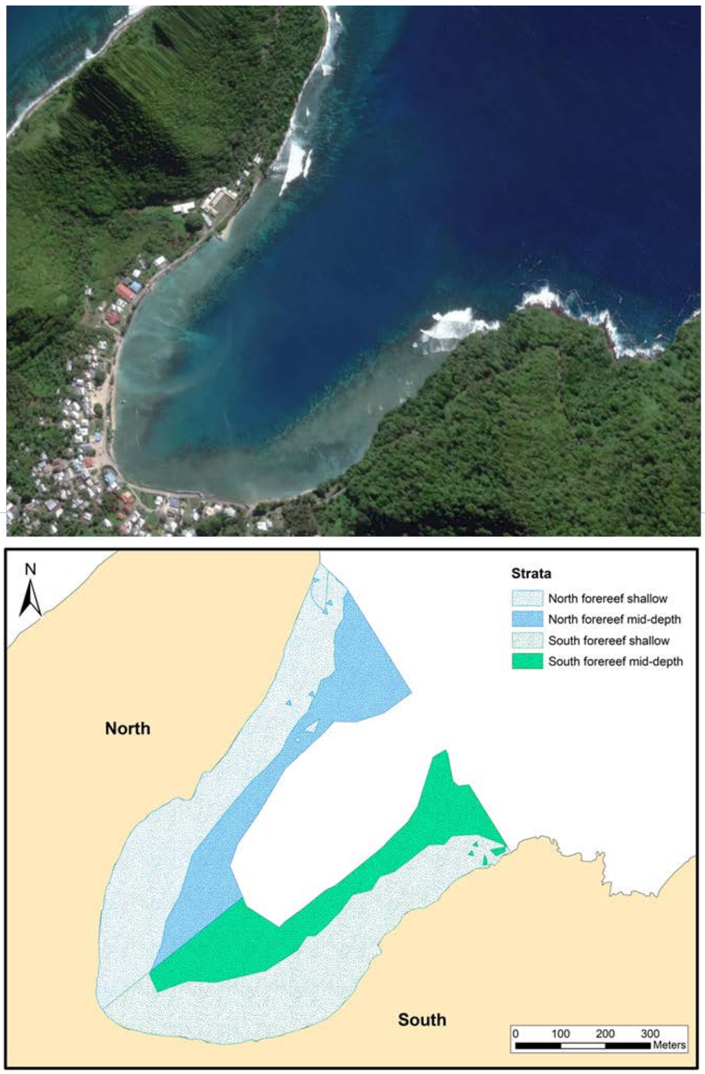

Figure 1. Satellite imagery and spatial coverage of the survey strata in Vatia Bay.

A digital map of the survey domain was overlaid with a 30 m × 30 m grid designating potential survey sites in all four strata. Sampling effort was allocated relative to strata area and survey sites were randomly selected within each stratum (Table 1, Appendix 1). Benthic surveys were conducted at two time points:

October–November 2015 and January 2020. Non-parametric permutation multivariate analysis of variance (PERMANOVA) techniques together with univariate one-way ANOVA and Kruskal-Wallis and post-hoc Dunn's tests (Bonferroni adjustment) were implemented to evaluate how response variables of (1) benthic functional group cover, (2) coral colony morphology cover (i.e., branching, encrusting, foliose, massive, and table), (3) coral taxa cover, (4) adult coral colony density, and (5) juvenile coral colony density, varied across factors of year (i.e., 2015 and 2020) and stratum (i.e., MN, MS, SN, SS). Only coral taxa that occurred in at least 10% of sites surveyed were included in the coral cover and colony density analyses (Table 2). In addition, kernel density estimation (KDE) analyses were implemented to assess differences in mean colony size frequency distribution (SFD) among the survey years. All analyses were run in R (R Core Team 2013) using the *vegan* package 2.5-1v multivariate analyses (Oksanen et al. 2018). See Appendices 2–3 for the in-water survey protocol specifics, extraction of benthic cover data, statistical analyses details, and the complete list of coral taxa captured in the benthic cover and population surveys. Contextual maps illustrating the site-level benthic cover and coral population data are presented in Appendices 4–6.

Table 1. Number of surveys sites conducted in Vatia Bay, American Samoa, between 2015 and 2020. Survey strata: mid-depth north (MN), mid-depth south (MS), shallow north (SN), and shallow south (SS).

	Strata				
YEAR	**MN**	**MS**	**SN**	**SS**	**Total**
2015	5	4	4	5	18
2020	7	6	5	6	24
Total	12	10	9	11	42

Table 2. List of coral taxa with corresponding abbreviations included in the coral cover and colony density analyses. Only taxa that occurred in at least 10% of sites were included in the multivariate PERMANOVA, univariate ANOVA and Kruskal-Wallis, and KDE analyses. *denotes taxa included in the coral cover analyses only.

ACSP: *Acropora**	GONS: *Goniastrea**
ALSP: *Alveopora*	ISSP: *Isopora*
ASSP: *Astreopora*	LEPT: *Leptastrea**
CYPS*: Cyphastrea*	MOSP: *Montipora**
ECHP: *Echinopora*	PAVS: *Pavona**
FASP : *Favia*	POCS*: Pocillopora**
FUSP: *Fungia**	POSP: *Porites**
GASP: *Galaxea*	PSSP: *Psammocora**

Vatia Reef: 2015–2010 Status and Trends

Benthic cover

PERMANOVA analyses indicated that the benthic assemblage varied significantly between years and strata, yet no interaction between factors (Figure 2; Table 3). Cover of hard corals, turf algae, macroalgae, and crustose coralline algae (CCA) determined the difference between years and contributed more than 75% of the variability between years (SIMPER).

- Mean (± SE) coral cover significantly increased by 17% (2015: 25.0% ± 3.2; 2020: 42.1% ± 3.6; ANOVA, $p = 0.001$), with the most notable increases along the north reef (Figure 3).
- Macroalgae cover significantly decreased by 5% between survey years (Kruskal-Wallis, $H = 7.2$, $p = 0.007$) and turf algae by 19% (ANOVA, $p = 0.001$) (Figure 2). The decrease in observed turf algae cover appeared evident in all survey strata; macroalgae cover reductions were more pronounced in the north strata (Figure 3).
- Encrusting macroalgae showed a notable temporal increase along a portion of the mid-depth north stratum (Figure 3, Appendix 4). However, lower levels elsewhere throughout the bay likely determined the absence of differences between survey years.
- Cover of coralline algae, encrusting macroalgae, *Halimeda*, and sediment did not differ significantly between years (Figure 3).
- Although the PERMANOVA analyses indicated significant cover differences among strata (Table 3), a description of these differences could not be statistically discerned using pairwise comparisons ($p > 0.07$).

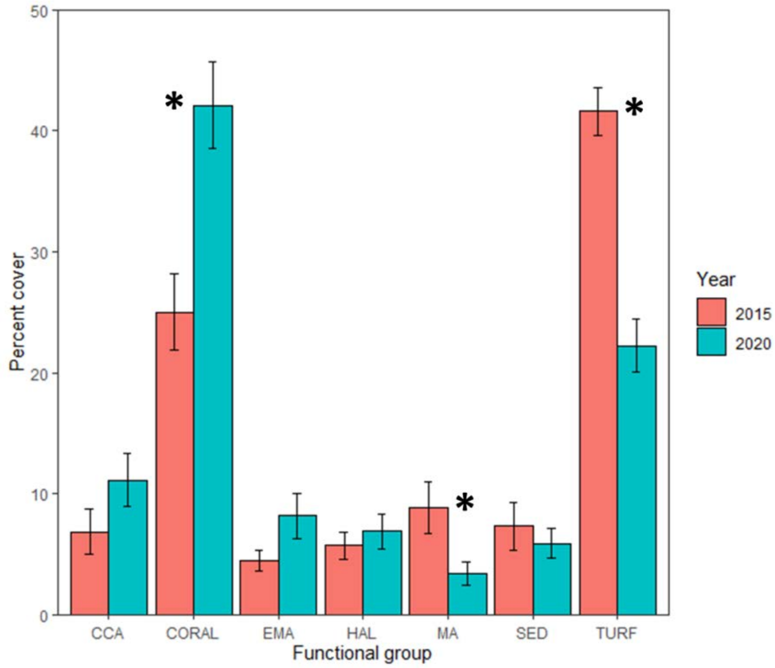

Figure 2. Temporal comparison (2015–2020) of mean percent cover (± SE) by benthic functional group. CCA: crustose coralline algae; CORAL: hard coral; EMA: encrusting macroalgae; HAL: *Halimeda*; MA: fleshy macroalgae; SED: sediment; and TURF: turf algae.

Table 3. PERMANOVA results table for benthic cover of most abundant functional groups of coralline algae, hard coral, encrusting macroalgae, fleshy macroalgae, *Halimeda*, sediment, and turf algae. df: degrees of freedom; SS: sum of squares; MS: mean sum of squares; Pseudo-F: value by permutation; P(perm): p-value based on permutations.

	df	SS	MS	Pseudo-F	P(perm)
YEAR	1	0.719	0.719	13.055	**<0.001**
STRATUM	3	0.581	0.193	3.518	**0.003**
YEAR*STRATUM	3	0.106	0.035	0.646	0.735
Residuals	34	1.872	0.055		

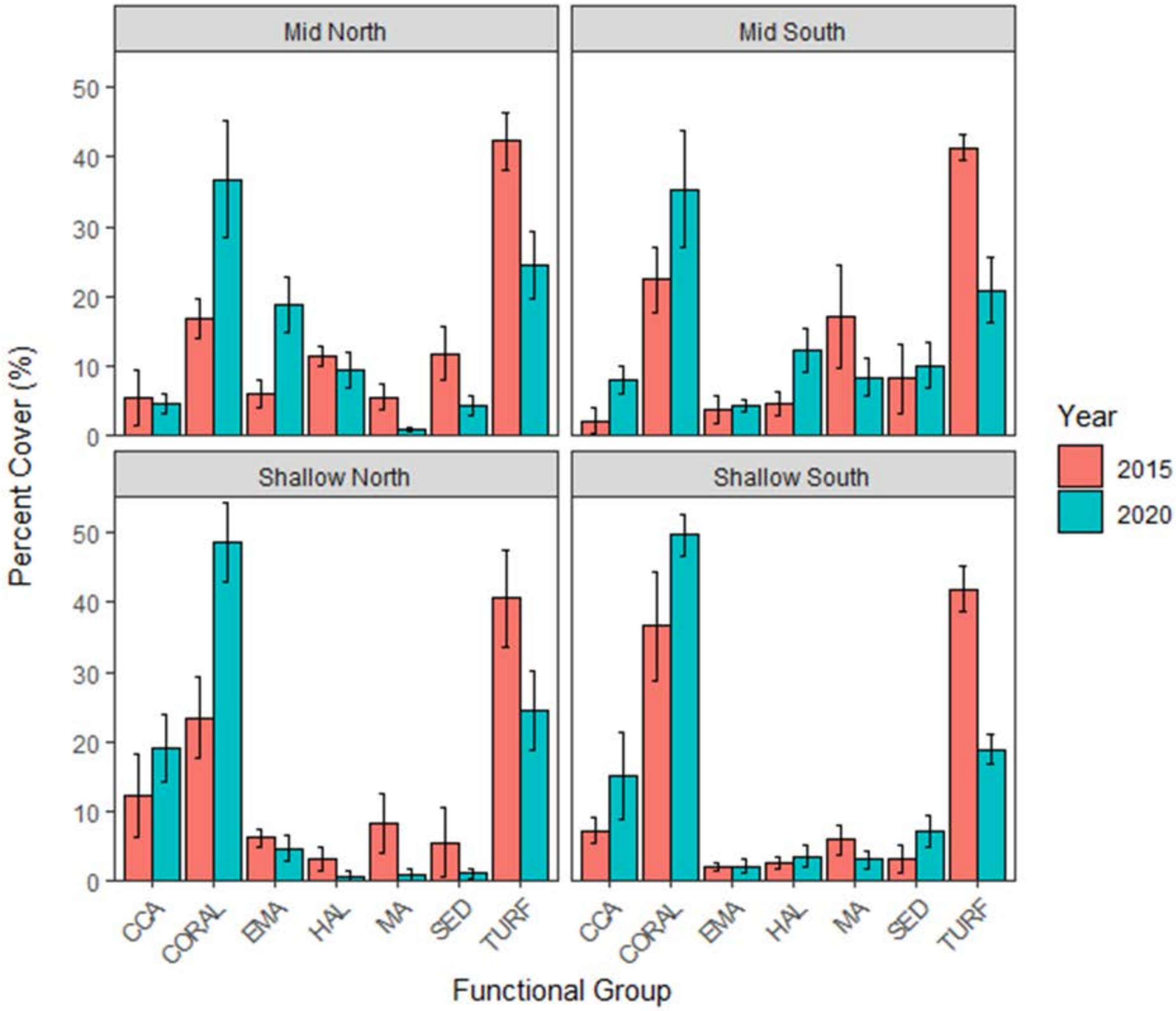

Figure 3. Stratum level comparison of mean cover (± SE) by benthic functional group between 2015 and 2020. CCA: crustose coralline algae; CORAL: hard coral; EMA: encrusting macroalgae; HAL: *Halimeda*; MA: fleshy macroalgae; SED: sediment; and TURF: turf algae

Coral cover

Colony morphology

- Differences in coral cover based on morphology were significant between years and strata, but no significant interaction effect between factors (PERMANOVA Table 4a, Figure 4). Temporal changes by coral morphology occurred as follows:
    - Branching: A two-fold cover increase from 5.3% ± 1.6 in 2015 to 13.5% ± 2.1 in 2020 (Kruskal-Wallis, H = 8.7, p = 0.003).
    - Encrusting: An increase from 9.9% ± 2.1 in 2015 to 16.1% ± 2.0 in 2020 (Kruskal-Wallis, H = 5.5, p = 0.02).

- Table: An increase from 0.4% ± 1.9 in 2015 to 2.9% ± 0.9 in 2020 (Kruskal-Wallis, H = 6.5, p = 0.01).
- Massive: An increase from 1.6% ± 0.9 in 2015 to 3.2% ± 1.2 in 2020 (Kruskal-Wallis, H = 4.9, p = 0.03).
- Foliose: No significant difference between survey years.

Spatial variation in coral colony morphology across strata for both years combined occurred as follows:

- Branching: Cover was greater on the shallow south stratum (15.9% ± 3.0) compared to the mid-depth south stratum (5.4% ± 2.6) (Kruskal-Wallis, H = 9.8, p = 0.02, Dunn's test p = 0.01).
- Massive: Cover was greater on the mid-depth south stratum (6.1% ± 1.7) compared to both the shallow (0.1% ± 0.1) and mid-depth (0.9% ± 0.6) strata on the north reef (Kruskal-Wallis, H = 15.5, p = 0.001, Dunn's test p = 0.007, p < 0.001; Figure 5).
- Foliose: Cover was greater on the mid-depth north stratum (6.1% ± 1.9) compared to the shallow south (0.7% ± 0.2) (Kruskal-Wallis, H = 8.6, p = 0.03, Dunn's test p = 0.01).
- Table and encrusting: No significant cover differences among survey strata (Figure. 5).

Table 4. PERMANOVA results table for (a) coral cover by growth morphology (branching, encrusting, foliose, massive, and table) and (b) coral cover by taxa; df: degrees of freedom; SS: sum of squares; MS: mean sum of squares; Pseudo-F: F value by permutation; P(perm): p-value based on permutations. See Table 2 for a list of coral taxa included in the analysis.

(a) Coral cover: colony morphology					
	df	SS	MS	Pseudo-F	P(perm)
YEAR	1	0.515	0.515	3.630	**0.006**
STRATUM	3	1.398	0.466	3.284	**<0.001**
YEAR*STRATUM	3	0.355	0.118	0.834	0.610
Residuals	34	4.826	0.141		
(b) Coral cover: genera					
YEAR	1	0.552	0.552	3.142	**0.029**
STRATUM	3	0.987	0.329	1.870	0.067
YEAR*STRATUM	3	0.182	0.060	0.346	0.970
Residuals	34	5.981	0.175		

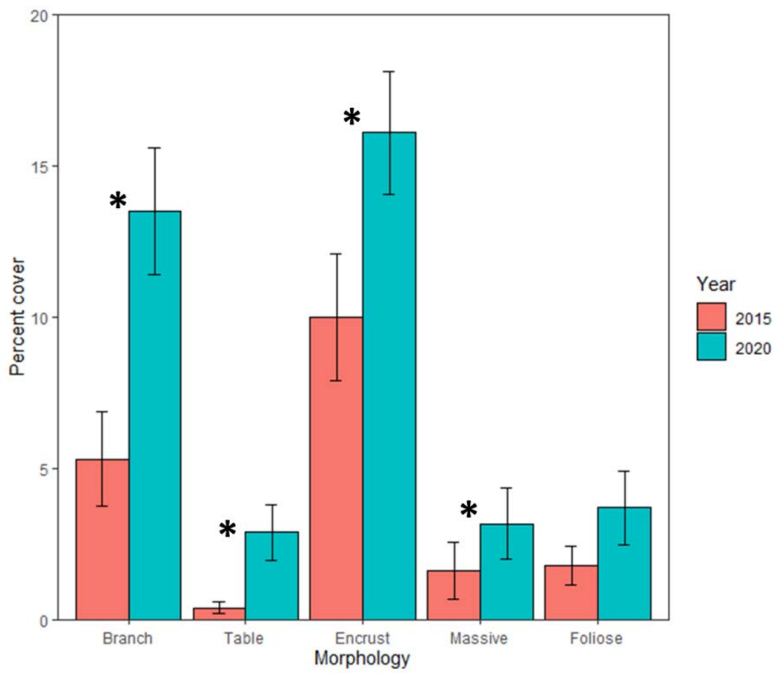

Figure 4. Temporal comparison (2015–2020) of mean percent cover (± SE) by coral colony growth morphology for Vatia Reef. Asterisk above the bars indicates significant differences between years within a growth morphology group (Kruskal-Wallis, p < 0.05).

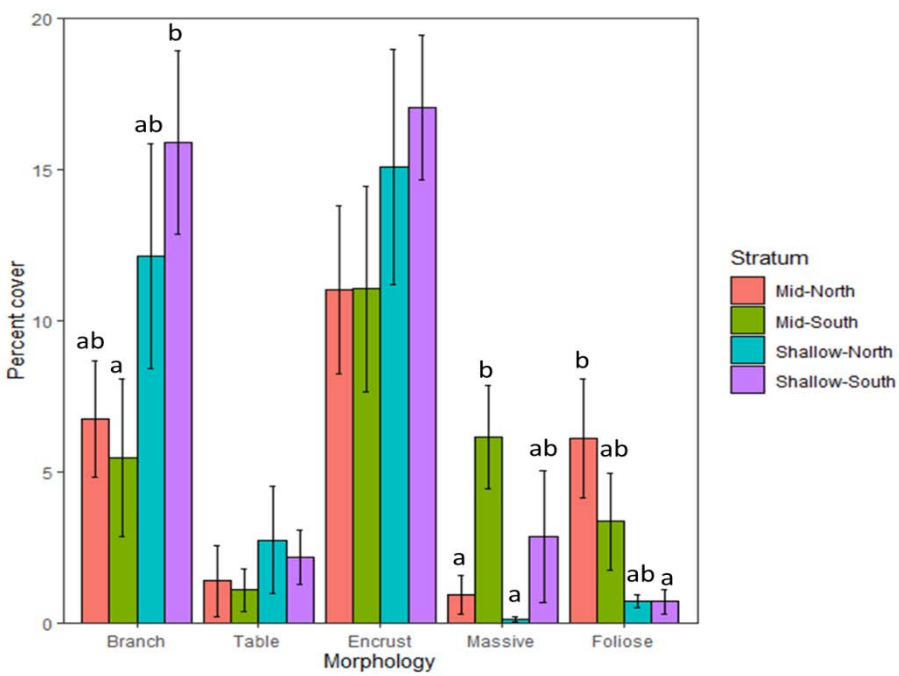

Figure 5. Mean percent cover (± SE) by coral colony growth morphology contrasted between survey strata at Vatia Reef. Letter groups above the bars indicate significant differences among strata within a growth morphology group, where shared letters indicate no significant differences between years within a growth morphology group, and differing letters indicate significant differences (Dunn's test, p, 0.05). If no letters are present for a functional group, the Kruskal-Wallis test was not significant.

Coral genera

- Over the study period, *Acropora*, *Montipora*, and *Porites* together represented 30% of the benthic cover.
- The genus level PERMANOVA indicted cover varied significantly between survey years (Table 4b, Figure 6). Temporal coral cover differences were driven by:
    - A five-fold increase in average cover of *Acropora* (1.5% ± 0.5 in 2015 to 7.8% ± 2.2 in 2020; Kruskal-Wallis, H = 4.7, p = 0.03).
    - A two-fold increase in average cover of *Porites* (8.5% ± 0.7 in 2015 to 18.4 % ± 2.9 in 2020; Kruskal-Wallis, H = 5.1, p = 0.02).
    - A four-fold increase in average cover of *Pocillopora* (0.3% ± 0.1 in 2015 to 1.3 % ± 0.3 in 2020; Kruskal-Wallis, H = 4.1, p = 0.04).
    - A nearly 18-fold increase in average cover was detected for *Psammocora* (0.06% ± 0.04 in 2015 to 0.9 % ± 0.5 in 2020; Kruskal-Wallis, H = 5.8, p = 0.01).

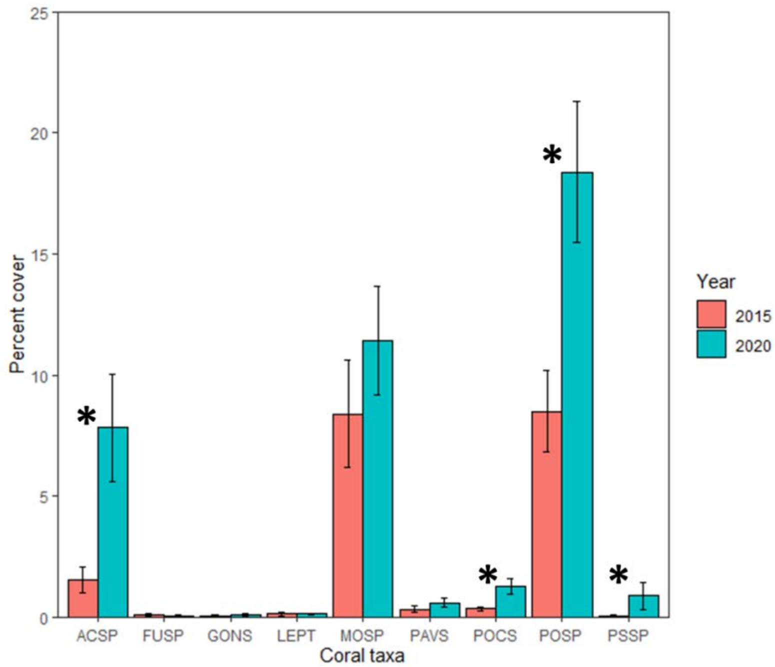

Figure 6. Temporal comparison (2015–2020) of mean percent cover (± SE) by coral genus for Vatia reef (see Table 2 for coral taxa abbreviations). Asterisk above the bars indicates significant differences between years within each taxon.

Adult and juvenile colony densities

- Average adult and juvenile coral colony densities across genera and strata did not differ significantly between survey years (adults: ANOVA, $p = 0.99$; juveniles: Kruskal-Wallis $H = 2.3$, $p = 0.13$; Figure 7)

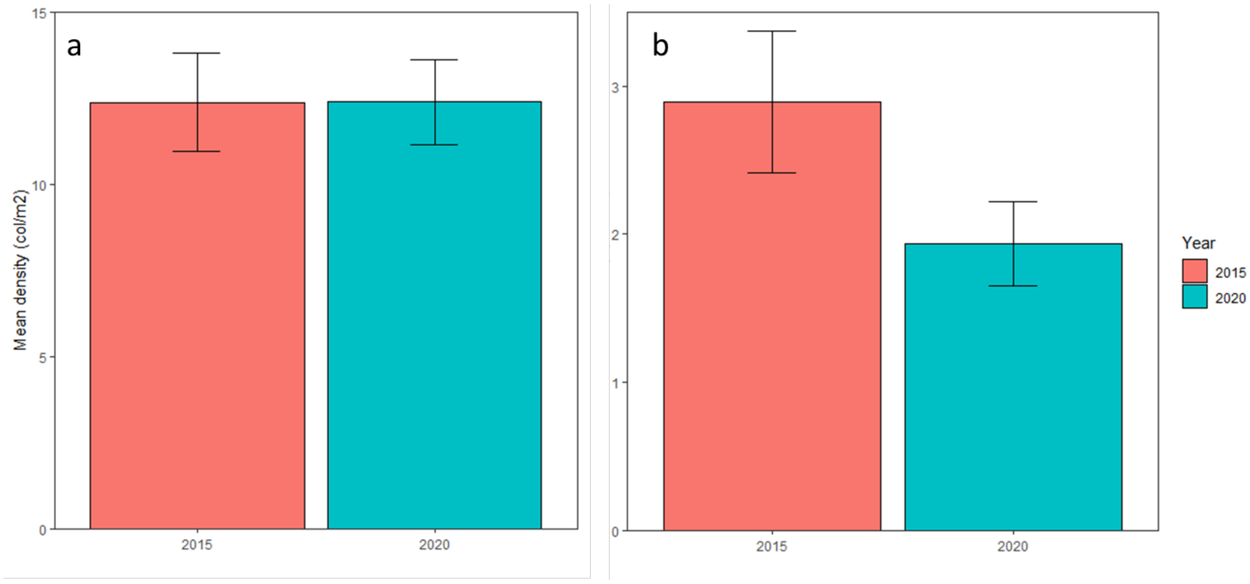

Figure 7. Temporal comparison (2015–2020) of mean total adult (a) and juvenile (b) coral colony density (col/m² ± SE) for Vatia reef.

- Despite the significant temporal cover increases, adult densities of *Acropora*, *Porites* and *Pocillopora* did not differ significantly between survey years (Kruskal-Wallis, $p > 0.2$; Figure 8a)
- Although juvenile densities of *Porites* dropped more than two-fold between survey years, juvenile density did not statistically differ between survey years (Kruskal-Wallis $H = 2.3$, $p = 0.13$; Figure 8b)

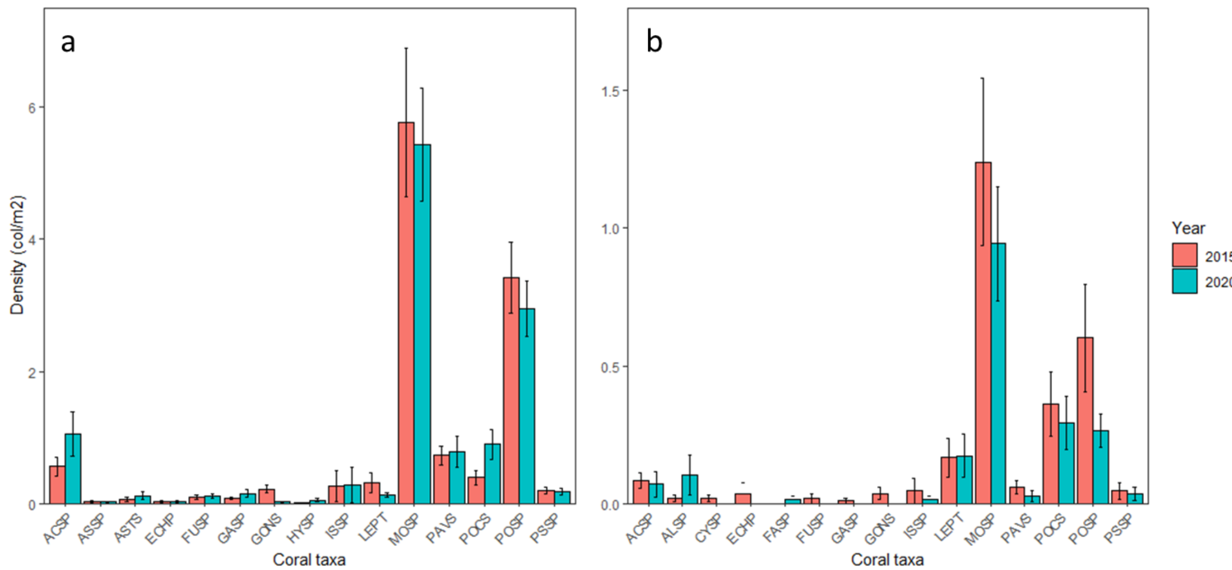

Figure 8. Temporal comparison (2015–2020) of mean adult (a) and juvenile (b) coral colony densities (col/m² ± SE) by genus across strata at Vatia reef. Note the differences in the taxonomic composition for adults and juveniles (see Table 2 for coral taxa abbreviations).

Mean maximum adult coral colony size

- The mean size of adult coral colonies (i.e., ≥5 cm in greatest diameter) significantly increased between survey years, from 15.2 cm ± 0.7 in 2015 to 24.1 cm ± 2.1 in 2020 (ANOVA, $p < 0.001$; Figure 9)
- Of the 16 coral genera analyzed, *Leptastrea* and *Psammocora* were the only taxa that displayed a decrease in observed mean colony size (Table 5). All other coral taxa showed net colony size increases ranging from 3.4% in *Isopora* to 119% in *Goniastrea*.

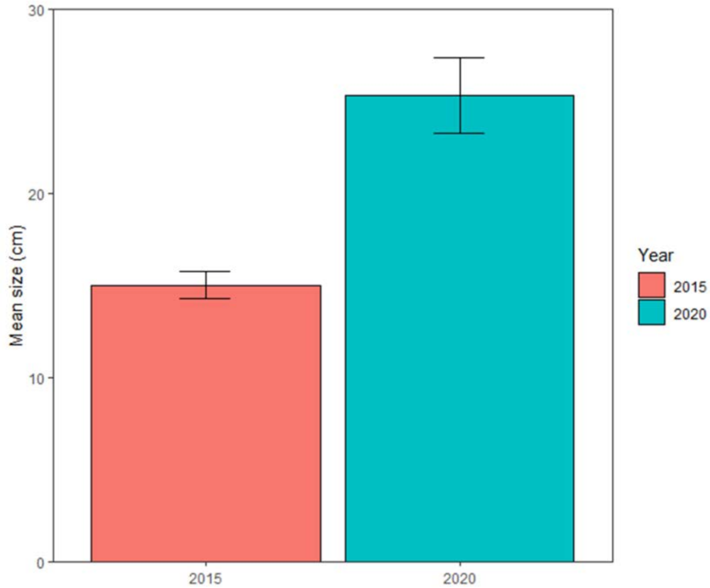

Figure 9. Temporal comparison (2015–2020) of mean adult coral colony size (± SE) for Vatia reef.

Table 5. Temporal comparison (2015–2020) of mean maximum adult coral colony size (cm) and size percent increase between survey years per genus.

Taxon	Mean colony length 2015	Mean colony length 2020	Percent increase
Goniastrea	13	28.5	118.8
Echinopora	14.1	30	111.4
Acropora	22.7	45.2	99.3
Porites	21.7	37.9	74.8
Galaxea	8	12.7	58.7
Astrea	8.6	13.7	58.57
Montipora	15.2	22.5	48.1
Hydnophora	31	43.6	40.7
Pavona	16.4	21.3	30.1
Fungia	11.4	14.7	28.8
Astreopora	11.3	13.7	21.3
Pocillopora	13.5	14.3	6.1
Isopora	14.7	15.2	3.3
Psammocora	11.8	11.4	−2.8
Leptastrea	14.8	12.7	−13.8
Alveopora	5.5	Absent	N/A

Coral colony size frequency distribution

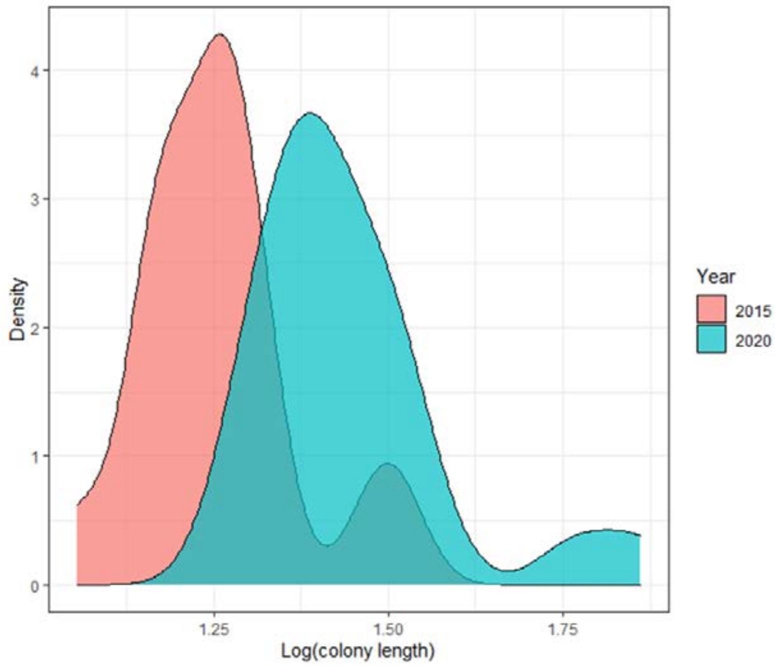

Figure 10. Temporal comparison (2015–2020) schematic of adult colony size probability density function for all coral genera combined at Vatia reef.

- The size frequency analysis on raw data for all coral taxa combined showed a significant shift to larger colony sizes (i.e., shift in curve position) in 2020 compared to 2015 (kernel density analyses on non-standardized data, $p < 0.001$; Figure 10).
- The corresponding analysis with the standardized data set (transformed and aligned) produced a non-significant result ($p > 0.05$) indicating that colony densities within size classes did not change over time (i.e., no changes in the shape of the colony size distribution). The change in position of the distribution along the x-axis indicates that colonies moved into larger size classes (i.e., growth) over the five-year period.
- These finding corroborate that coral cover temporal increases were driven by the widespread colony growth rather than the addition of new colonies via sexual or asexual recruitment.

Acknowledgements

This work was supported by the NOAA Coral Reef Conservation Program. Financial, institutional, and logistic support was also provided by NOAA Pacific Islands Fisheries Science Center's Ecosystem Sciences Division, the American Samoa Department of Marine and Wildlife Resources, the American Samoa Coral Reef Advisory Group, and the National Park of American Samoa. Special thanks are due to J Morioka and M Oshiro for assistance with mission planning, logistics, and service contract preparation. Thanks are also due to M Winston, G Coward, and M Lamirand for assistance with survey execution, graph formatting, data exploration, and benthic image analysis. The authors also want to thank M Winston, J Smith, J Samson, and the anonymous reviewers whose comments greatly improved this manuscript. The manuscript contents are solely the opinion of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government. There is no conflict of interest between co-authors.

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Appendix 1

Survey Site location

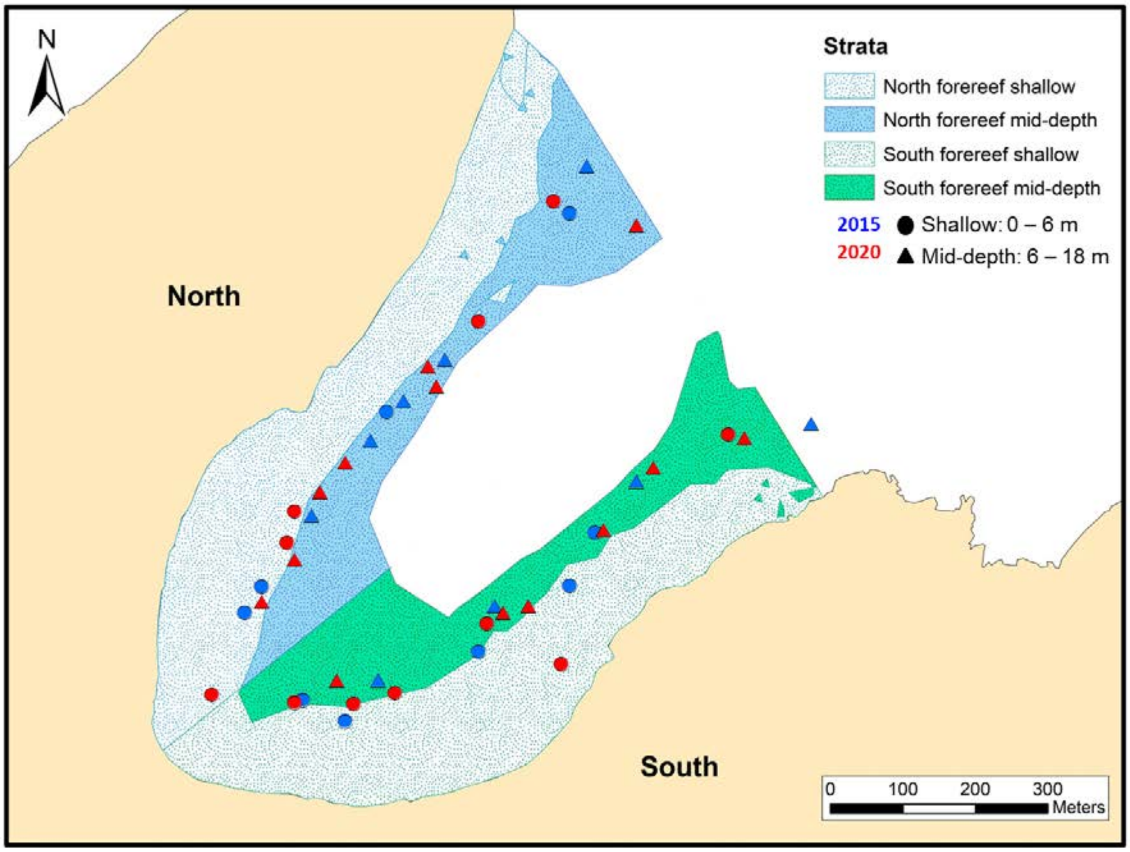

Figure A1. 1. Depth and spatial distribution of survey sites in Vatia Bay, 2015 and 2020.

Appendix 2

Methods

A2.1 Benthic cover and coral community composition and size

Belt-transects were the focal point of the biological surveys. Coral community composition was assessed within individual 1.0 m × 2.5 m segments located at the 0–2.5 m, 5.0–7.5 m, 10–12.5 m, 15–17.5 m marks along each transect; bottom-time permitting, covering a total area ranging 7.5–10 m^2 per transect. Over time, protocols were adjusted to increase efficiency without compromising representativeness such that two 18 m transects were implemented per site in 2015 and one 18 m transect in 2020. Within segments, all adult coral colonies (≥5 cm maximum diameter) whose center fell within 0.5 m on either side of the transect line were identified to the genus-level and measured for size (maximum diameter to nearest cm). Juvenile coral colonies (<5 cm), distinguished by the presence of a distinct tissue and skeletal boundary (not a remnant of a larger colony), were surveyed within three 1.0 m × 1.0 m segments at the 0–1.0 m, 5.0–6.0 m, and 10.0–11.0 m mark of each transect (covering 3 m^2 per transect). Juvenile colonies were identified to genus and measured for size (maximum diameter to nearest 5 mm).

For the estimation of benthic cover, still photographs were collected using the photoquadrat method at predetermined points along the transect line with a high-resolution digital camera mounted on a pole (Winston et al. 2019). In 2015, photographs were taken every meter from the 1-m to the 15-m mark on each of the two transects per site (n = 30) and in 2020, every meter from the 1-m to the 30-m mark along an extended belt-transect line (n = 30). Photoquadrats were analyzed implementing the computer software CoralNet (Beijbom et al. 2015). Benthic cover of each photograph was assessed by randomly overlaying ten points on each image (total of 300 points per site) and identifying the benthic elements underneath each point following the 'Tier3b' genus/functional classification scheme outlined in Lozada-Misa et al. (2017). For example, hard corals were differentiated by genus and morphology (e.g., *Acropora* branching, *Acropora* table, *Montipora* encrusting, *Favia*, *Porites* massive), and macroalgae were identified to the genus level (e.g., *Halimeda*, *Peyssonnelia*, *Lobophora*). The list of coral taxa identified in the benthic cover image analyses and coral population surveys is presented in Appendix 3.

A2.2 Statistical analysis

Non-parametric permutation analytical techniques were implemented to evaluate differences in benthic and coral community composition across year and strata (Table 1). We calculated Bray-Curtis dissimilarity matrices on the untransformed percent cover data for the most abundant benthic functional groups (i.e., coral, crustose coralline algae (CCA), encrusting macroalgae, *Halimeda*, fleshy macroalgae, sediments, and turf algae), coral colony morphology groups (i.e., branching, encrusting, foliose, massive, and table), and all coral genera that occurred in at least 10% of sites (Table 2). Subsequent two-factor, permutation multivariate analyses of variance (PERMANOVA) were performed (9,999 permutations) to test how response variables of (1) benthic functional group cover, (2) coral colony morphology cover, (3) coral taxa cover, varied across factors of year (i.e., 2015 and 2020) and stratum (i.e., mid-depth north, mid-depth south, shallow north, and shallow south). PERMANOVAs were run using Type II sum of squares, and factors were evaluated to meet the assumption of homogeneity of dispersion using the betadisper function. Pair-wise comparisons were run for each significant factor identified from PERMANOVA outputs, and a similarity percentage analysis (SIMPER) was computed to identify which functional or taxonomic group(s) accounted for the differences observed between factor levels. Univariate Kruskal-Wallis and post-hoc Dunn’s tests (implementing the Bonferroni multiple-comparisons correction) were performed to identify which benthic cover functional groups and coral taxa differed significantly among factor levels. Additional Kruskal-Wallis and ANOVA tests were performed to identify differences in adult and juvenile coral colony densities and mean adult coral colony size among survey years. A kernel density estimation (KDE) analysis was implemented to assess differences in mean adult colony size frequency distributions (SFD) among the survey years (following Langlois et al. 2012). KDE analyses were conducted on raw and standardized colony sizes (for all colonies >5 cm in length) to assess whether the SFD shifted in shape (e.g., frequency of size classes) and/or position (e.g., growth). All analyses were run in R (R Core Team 2013) using the *vegan* package 2.5-1v multivariate analyses (Oksanen et al. 2018).

Appendix 3

Table A3 1. Coral genera and corresponding abbreviation recorded within the benthic image analyses and the coral community surveys.

Genus	Genus code	Genus	Genus code
Acropora	ACSP	*Hydnophora*	HYSP
Alveopora	ALSP	*Isopora*	ISSP
Astreopora	ASSP	*Leptastrea*	LEPT
Astrea	ASTP	*Leptoria*	LEPS
Coscinaraea	COSP	*Leptoseris*	LESP
Cycloseris	CYPS	*Lobophyllia*	LOBS
Cyphastrea	CYSP	*Merulina*	MESP
Echinophyllia	ECHL	*Montipora*	MOSP
Echinopora	ECHP	*Pachyseris*	PACS
Euphyllia	EUSP	*Pavona*	PAVS
Favia	FASP	*Platygyra*	PLSP
Favites	FAVS	*Pocillopora*	POCS
Fungia	FUSP	*Porites*	POSP
Galaxea	GASP	*Psammocora*	PSSP
Goniastrea	GONS	*Phymastrea*	PHSP
Halomitra	HASP	*Seriatopora*	SEPS
Herpolita	HERS	*Stylophora*	STYS

Appendix 4

2015–2020 site-level benthic cover

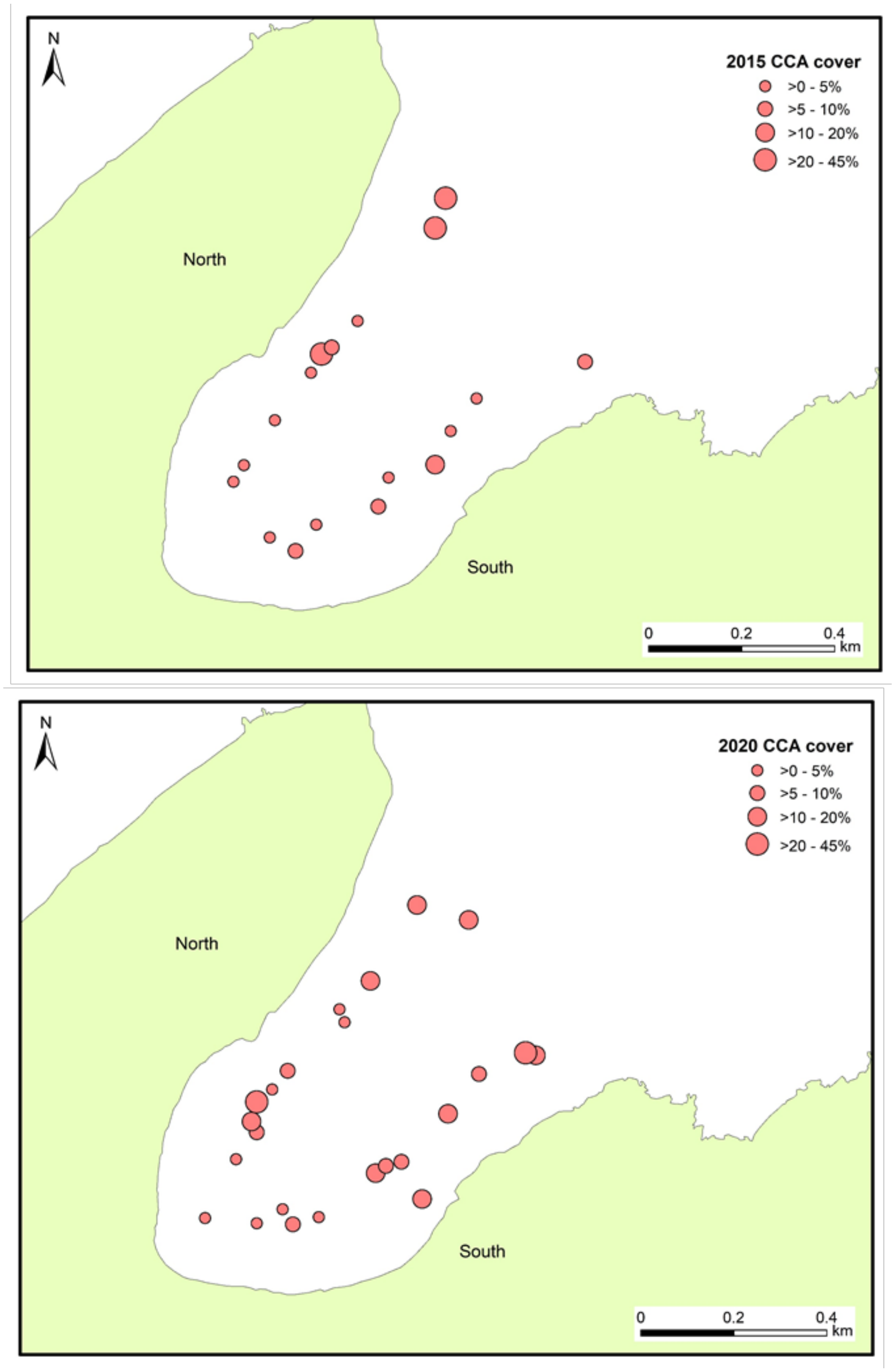

Figure A4. 1. . Crustose coralline algae (CCA) percent cover; upper panel: 2015; lower panel: 2020.

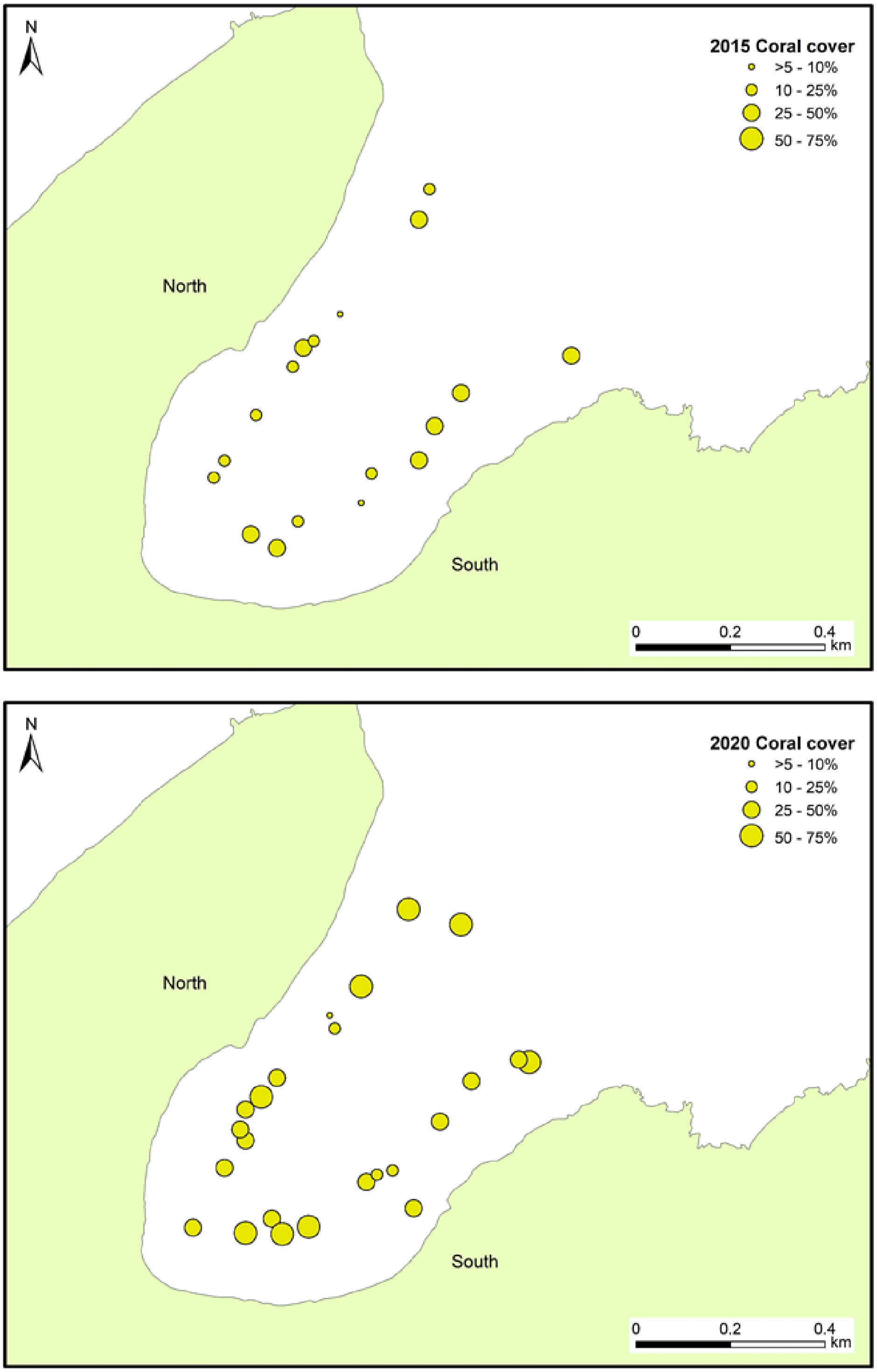

Figure A4. 2. Coral percent cover; upper panel: 2015; lower panel: 2020.

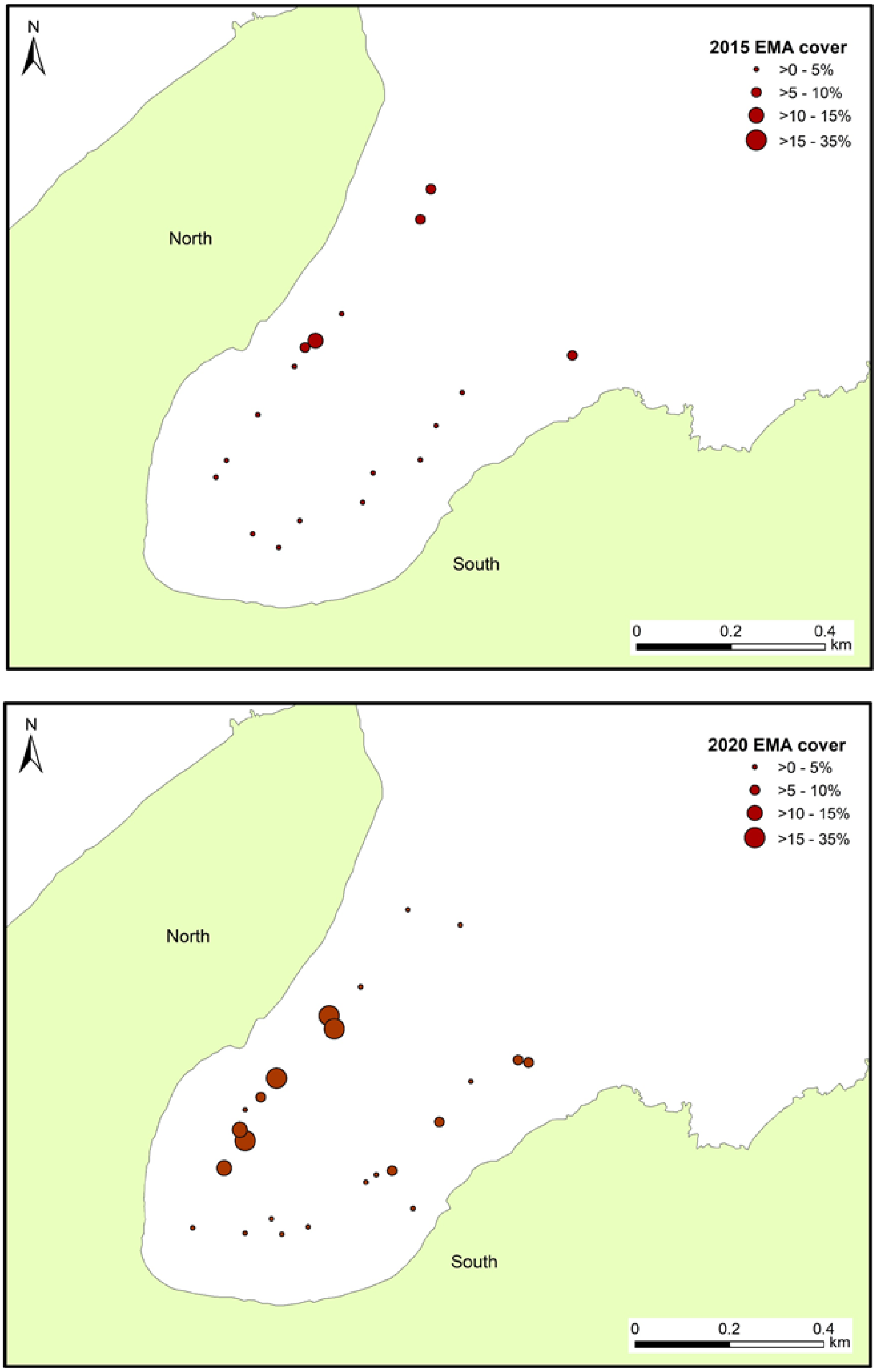

Figure A4. 3. Encrusting macroalgae percent cover; upper panel: 2015; lower panel: 2020.

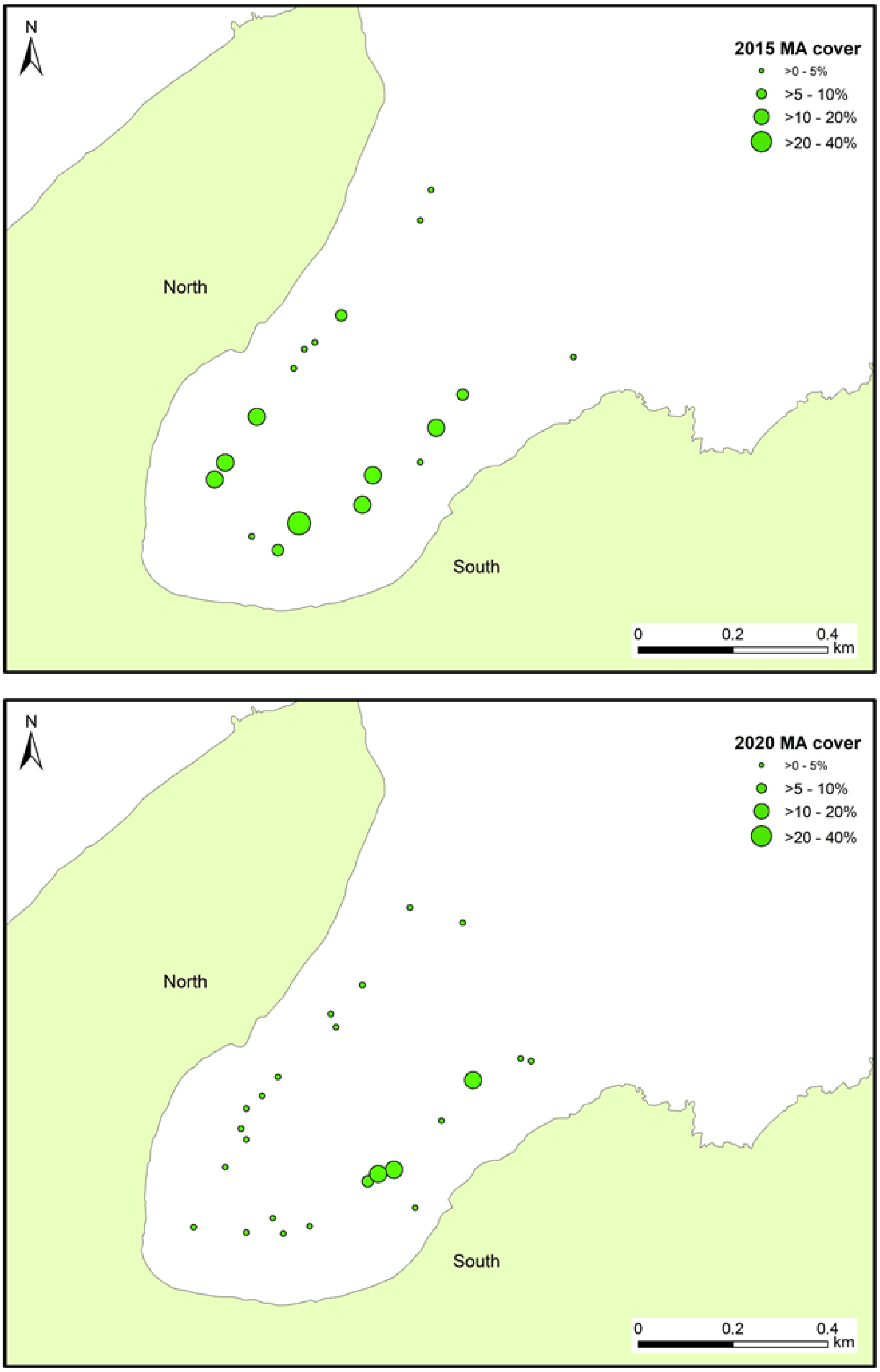

Figure A4. 4. Fleshy upright macroalgae; upper panel: 2015; lower panel: 2020.

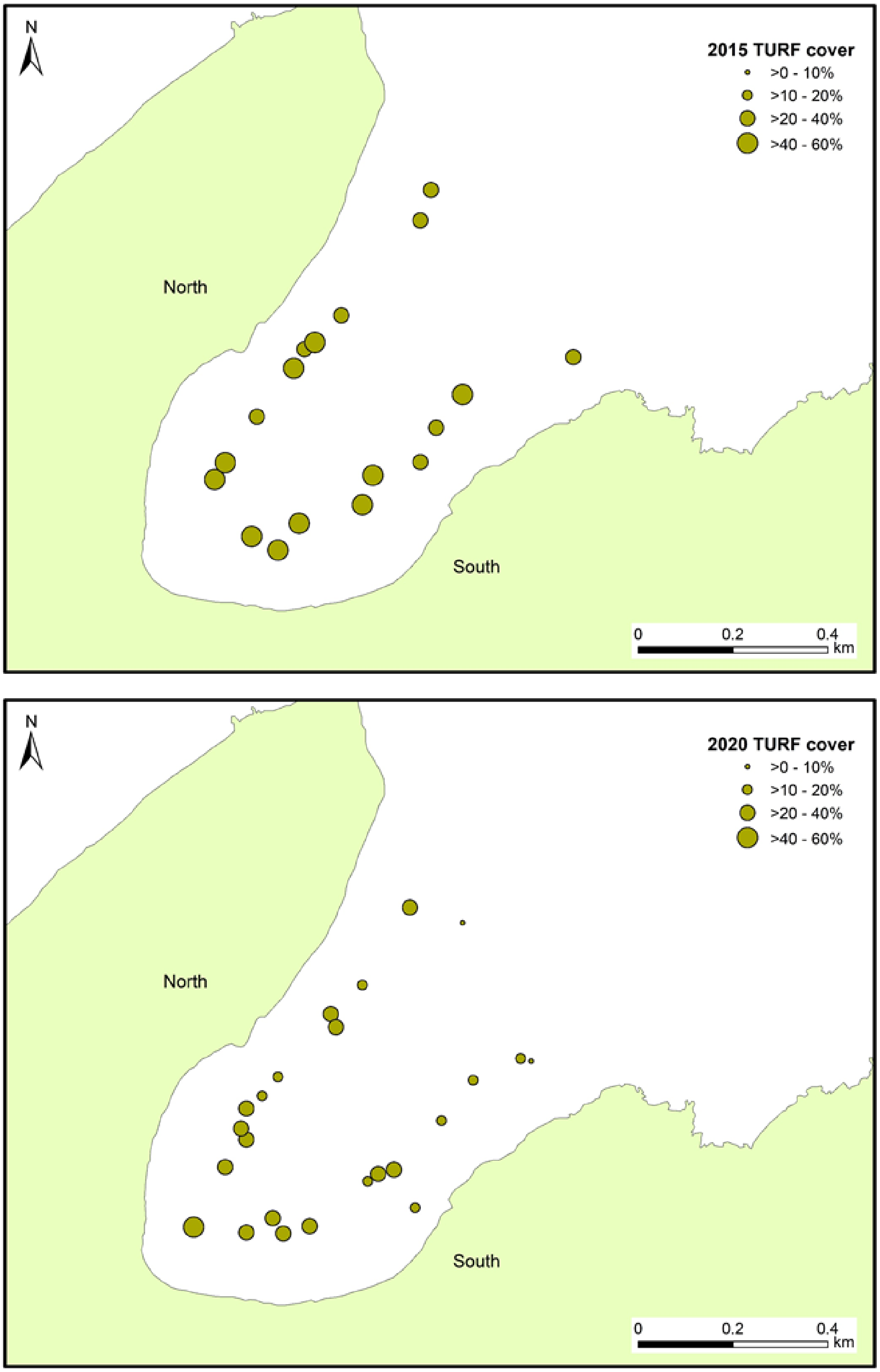

Figure A4. 5. Turf algae percent cover; upper panel: 2015; lower panel: 2020.

Appendix 5

2015–2020 site-level coral percent cover

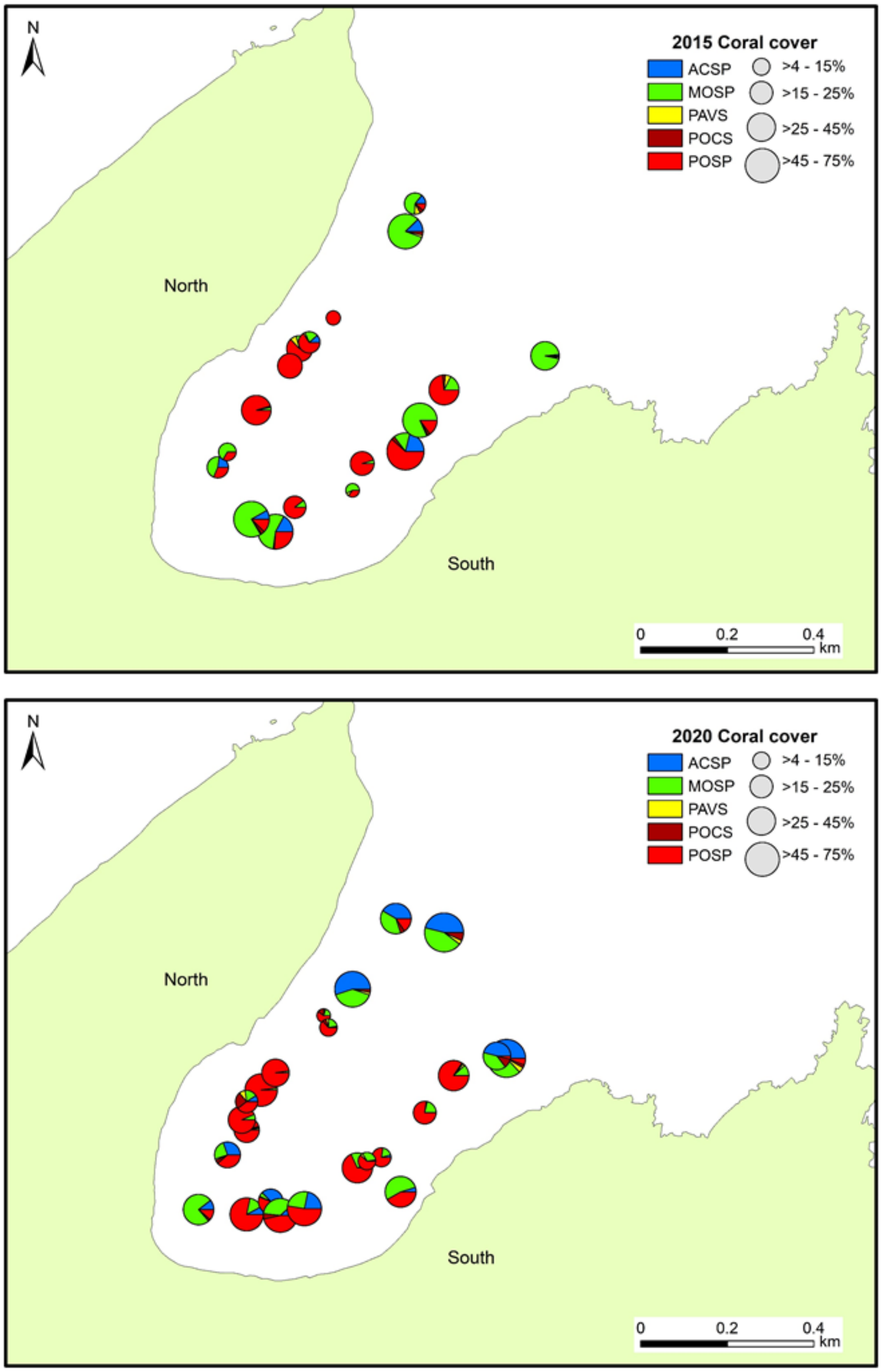

Figure A5. 1. . Coral percent cover of the five most abundant coral genera at Vatia reef. Upper panel: 2015; lower panel: 2020. Site level total coral cover is represented by bubble size.

Appendix 6

Site-level coral colony densities

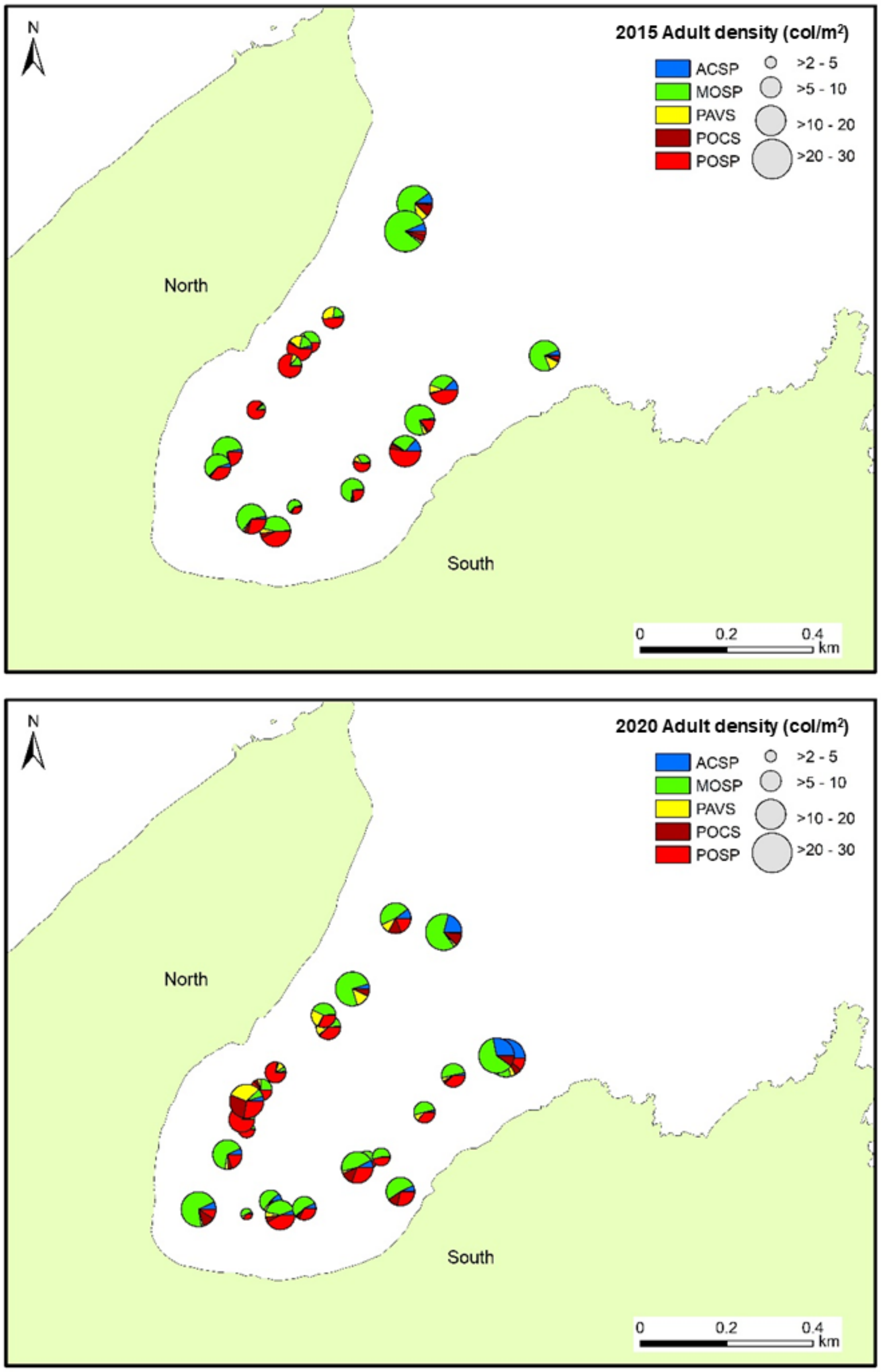

Figure A6. 1. . Adult coral colony density (colonies/m2) of the five most abundant coral genera at Vatia reef. Upper panel: 2015; lower panel: 2020. Site level total adult coral colony densities are represented by bubble size.

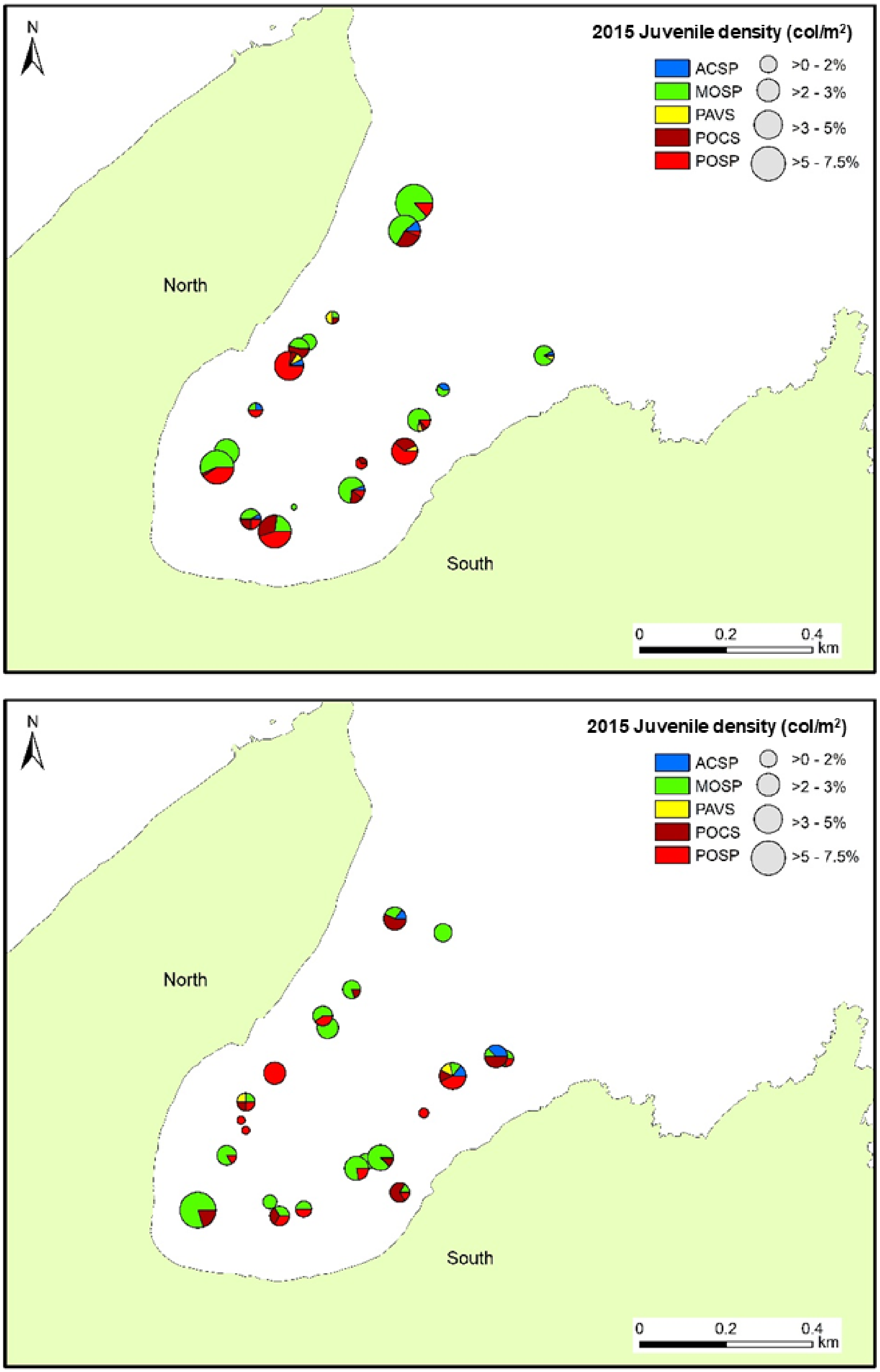

Figure A6. 2. **. Juvenile coral colony density (colonies/m2) of the five most abundant coral genera at Vatia reef. Upper panel: 2015; lower panel: 2020. Site level total juvenile coral colony densities are represented by bubble size.**