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Coral reef resilience to climate change in Guam in 2016

Jeffrey Maynard*, Steven M. Johnson*, David R. Burdick*, Andrew Jarrett, Jordan Gault, Jacques Idechong, Roxanna M. Miller, Gareth J. Williams, Scott F. Heron, Laurie Raymundo

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Executive Summary

Coral reef resilience to climate change in Guam in 2016

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Introduction – Coral reef resilience is the capacity of a reef to resist or recover from degradation and maintain provision of ecosystem goods and services. Resilience-based management (RBM) has been developed to overcome the challenges of supporting ecosystem resilience in this era of rapid change. RBM involves the application of resilience theory and tools to deliver ecosystem-based management outcomes into the future. RBM of coral reefs can include assessing spatial variation in resilience potential and then targeting and tailoring appropriate actions to preserve or restore the resilience of reefs. Resilience assessments involve measuring or assessing resilience indicators (e.g., coral disease, coral recruitment and herbivorous fish biomass) and producing an aggregate score that expresses resilience potential for all sites as relative to the site with the highest (assessed) resilience potential.

The Marine Fisheries Management Plan of Guam explains that understanding the resilience of reef fisheries and the coral reefs upon which they depend is needed for future assessments of yield. This project was designed to meet this need.

Objectives – Obj. 1. Benthic Cover – Assess the percentage cover of major benthic groups, including corals, macroalgae, coralline algae, and 'other' (i.e., turf algae and unconsolidated substrate).

Obj. 2. Relative Resilience – Assess the relative resilience potential of coral reefs at two depths and compare resilience potential among survey sites.

Obj. 3. Resilience Drivers – Determine the drivers of differences in resilience potential between sites.

Results – *Obj. 1* - Coral cover was higher on average in the shallow (25%) survey areas than the deep areas (19%). Differences between the shallow and deep survey sites in coral cover are driven by differences in macroalgae cover as coralline algae (12% shallow and 10% deep) and other cover (41% both depths) are very similar between the depths. Average macroalgae cover was 22% in the shallow and 30% in the deep.

Obj. 2 – For the shallow sites, normalized resilience scores ranged from 0.62 to 1.00. Three sites were assessed as having high resilience, five medium-high, nine medium-low, and two low. The three sites with high relative resilience are Tagua Point, Ague Point, and Pugua Patch Reef; these sites are in northern Guam. The two sites with low relative resilience are Ga'an Point and Fouha Bay, which are in southwestern Guam. There is a strong pattern that the relative resilience classes for survey sites are higher in the northern half of Guam and lower in the southern half and this was true for both depths (see figure below). For both depths and with very few exceptions, scores were medium-high or high for resilience indicators in northern Guam and medium-low or low in southern Guam.

For the deep sites, normalized resilience scores ranged from 0.64 to 1.00. Five sites were assessed as having high resilience, five medium-high, seven medium-low, and three low. The five sites with high relative resilience are Pugua Patch Reef, Ague Point, Luminao Reef, Tagua Point, and Tumon Bay; these sites are in northern Guam. The three sites with low relative resilience are Fouha Bay, Facpi Point and Cocos Barrier Reef-E, which are in southern Guam.

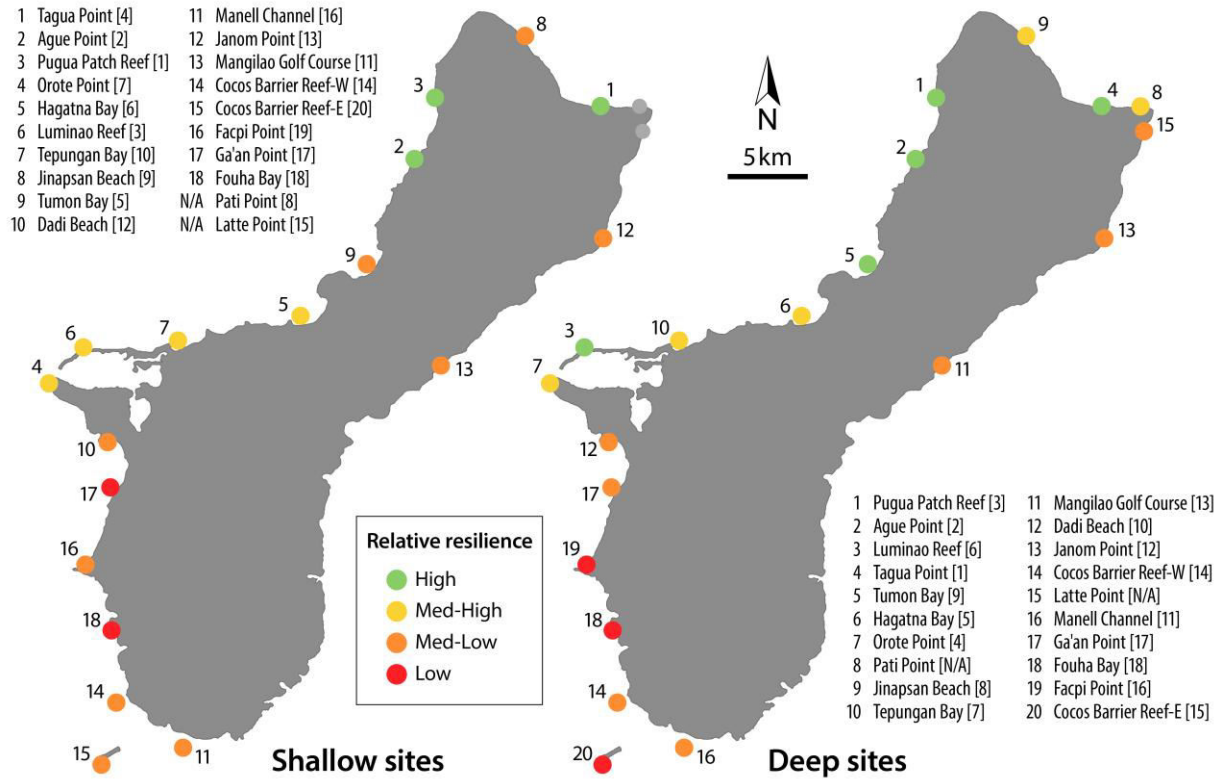

Figure – Spatial variation in relative resilience for both depths. Sites are ranked from highest to lowest relative resilience.

Obj. 3 - Across the shallow reef sites of Guam, higher resilience potential correlated most strongly with high coral cover and high coral recruitment and low resilience potential sites were negatively correlated with these same two indicators. Across the deep reef sites of Guam, higher resilience potential correlated most strongly with high coral recruitment, low macroalgae, high herbivore biomass and high coral cover.

Next Steps - Continued resilience monitoring can help managers identify the reefs that recover the fastest from recent bleaching events in Guam; these may be conservation priority areas. Combining the results of the Guam study with the CNMI study can help provide the groundwork for a regional planning and response. The data and results will be built into a Pacific-wide assessment of coral reef fisheries vulnerability to climate change being led by members of this project team from 2017-2019.

Site summaries – This report concludes with Site Summaries. These are 1-page summaries for each survey site that present the site name origin, and, for each site depth: coordinates, photographs, resilience ranks, resilience indicator scores, benthic community pie charts, and coral and fish species lists.

Acknowledgments - Financial support for this applied research was provided by a grant from the NOAA National Marine Fisheries Service Saltonstall-Kennedy Program. Resources were also provided in support of the fieldwork and project staff from the University of Guam Marine Laboratory. The contents of this report are solely the opinions of the authors and do not constitute a statement of policy, decision, or position on behalf of NOAA or the U.S. Government.

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Introduction

Coral reef resilience is the capacity of a reef to resist or recover from degradation and maintain provision of ecosystem goods and services (Mumby et al. 2007). Resilience-based management (RBM) has been developed to overcome the challenges of supporting ecosystem resilience in this era of rapid change (Bestelmeyer and Briske 2012). RBM involves the application of resilience theory and tools to deliver ecosystem-based management outcomes into the future (Chapin et al. 2009). RBM of coral reefs can include assessing spatial variation in resilience potential and then targeting and tailoring appropriate actions to preserve or restore the resilience of reefs. Such assessments have been strongly recommended by coral reef ecology experts and leading conservation organizations (Maynard et al. 2015; Anthony et al. 2015; McClanahan et al. 2012; Graham et al. 2013). The assessments involve measuring or assessing resilience indicators (e.g. coral disease, coral recruitment and herbivorous fish biomass) and producing an aggregate score that expresses resilience potential for all sites as relative to the site with the highest (assessed) resilience potential (see Maynard et al. 2015 for guidance). Examples are just emerging of assessments of resilience potential that explicitly guide managers in making targeted decisions (Maynard et al., 2015; Weeks & Jupiter, 2013).

The resilience assessment presented here for Guam builds on similar work undertaken in CNMI in collaboration with natural resource managers based in Saipan (Maynard et al. 2015). The CNMI assessment was the first field-based implementation of the framework recommended within *A Guide to Assessing Coral Reef Resilience for Decision Support* (Maynard et al. 2017).

Studies conducted in the late 1990's in Guam showed declines in rates of coral replenishment over the preceding decades and made the case these declines were due to both sedimentation and herbivore overfishing (Birkeland 1997). Those studies are reviewed on page 74 of the Marianas Fishery Management Plan (MFMP). Sedimentation and herbivore overfishing, which can inhibit ecosystem recovery, pose even greater threats to Guam's reefs today given recent coral bleaching events have resulted in substantial coral mortality (Reynolds et al. 2014). In addition to the compromised recovery capacity of Guam's reef systems, the recovery period following the major bleaching event in 2013 was brief, with additional bleaching-associated mortality occurring again in 2014 and 2016. The alarming trend of annual or near-annual bleaching events continues. At time of writing of this report, members of this team were again surveying the reefs in Guam as another severe bleaching event affected the island's reefs between July and October, 2017, with preliminary results suggesting coral mortality rates will be similar to those observed in 2013. The MFMP of Guam makes the case that understanding the resilience of reef fisheries and the coral reefs upon which they depend will be critically important in future assessments of yield. This project will result in managers and fishing community members better understanding spatial variation in the relative resilience of herbivorous fish communities and coral reefs in Guam.

Study Objectives

Obj. 1. Benthic Cover – Assess the percentage cover of major benthic groups, including corals, macroalgae, coralline algae, and 'other' (i.e., turf algae and unconsolidated substrate).

Obj. 2. Relative Resilience – Assess the relative resilience potential of coral reefs at two depths and compare resilience potential among survey sites.

Obj. 3. Resilience Drivers – Determine the primary drivers of differences in resilience potential between sites.

Methods

Field surveys were conducted at shallow (5 m) and deep (12 m) sites at 20 survey areas in the reef slope habitat of Guam from July – September of 2016. The sites surveyed by our 5-diver team represent the vast majority of the ecological and physical conditions around Guam. Some easterly sites we had hoped to include were not surveyed due to weather and logistical restrictions. Methods used to meet the three study objectives are described below.

Obj. 1. Benthic Cover – Benthic cover data was collected using a line-point intercept (LPI) methodology. Each site consists of three replicated 30 m transects. Data points were collected at 0.5 m intervals along the length of each transect. The observer would identify the benthos directly under the transect to the highest taxonomic resolution possible. Point data was then aggregated into the following categories: corals, macroalgae, coralline algae and other substrate (e.g., sand, turf algae or bare rock).

Obj. 2. Relative Resilience – The resilience indicators included were coral cover, coral diversity, coral recruitment, bleaching resistance, macroalgae cover, herbivorous fish biomass, and temperature variability. These indicators were selected from among those reviewed for perceived importance and scientific evidence within McClanahan et al. (2012) and six of these seven (exception: coral cover) were used within a similar resilience assessment conducted in CNMI (Maynard et al. 2015). Methods for assessment or measurement of each of the resilience indicators are described in Table 1.

The resilience assessment compared within rather than among depths; i.e., data for the two depths were not aggregated and shallow was not compared to deep or vice versa. Once data were collected and compiled for each indicator, values for each variable were normalized to a uni-directional scale of 0-1 by dividing by the maximum value for the variable among all 20 sites (i.e. this was done for each depth). To ensure that high scores always infer higher relative resilience, normalized scores were inverted for macroalgae cover. All indicators were equally weighted.

Resilience scores were calculated by averaging the normalized indicator scores for each site and then those site averages were normalized. This expresses resilience of all sites as relative to the site with the highest score. The final resilience scores range from 0-1 and represent decimal percentages of the site with the highest score (1.00). Relative classifications for resilience scores are as follows: high (final scores that are greater than 1 standard deviation (sd) above average), medium-high (<avg+1sd and >avg), medium-low (<avg and >avg-1sd), and low (<avg-1sd).

Resilience rankings and relative classifications, as well as scores for each resilience indicator and relative classifications for these, are all shown within tables and maps in the Results.

Obj. 3. Resilience Drivers – Understanding which variables most influence differences in resilience potential is another valuable product of resilience assessments. This is because the indicators most influencing rankings are: 1) the most important to include in monitoring programs, and 2) may reveal the types of management actions that would benefit the greatest number of sites. Indicators with the greatest variability most drive differences in the resilience rankings. We plotted the average $\pm$ 1 standard deviation and maximum and minimum values for the final resilience scores and for the normalized values for the resilience indicators for both depths. We compare the range of values among the indicators for each depth and identify which indicators have highest and lowest range and variability.

We also used a canonical analysis of principal coordinates (CAP) (Anderson and Willis 2003) to examine which indicators were driving differences in resilience potential across the four relative classifications (low, med-low, med-high, and high) at each depth. The CAP was based on a Euclidean distance matrix. Variables that might be responsible for group differences are investigated by calculating the multiple correlations of canonical ordination axes with the original indicator variables (Anderson 2008).

Table 1. Field survey methods for resilience indicators.

Variable name (unit)	Methods
Coral cover (%)	Average percent of points classified as coral on three 30-m point-intercept transects where points were classified at 50-cm intervals.
Coral diversity (unitless)	The inverse of Simpson's index of diversity, which measures the probability that two species taken at random from the dataset are the same species. The resulting values range from 0-1, with higher values equating to higher diversity. The formula for Simpson's index is: D = ((sum of n(n-1))/N(N-1)), where n = total number of organisms of a particular species, and N = total number of organisms of all species observed.
Coral recruitment (#/m^2)	Average density of corals with a geometric mean < 5 cm from 12 replicate .25 m^2 quadrats; species that fissure and fragment frequently were excluded from this analysis.
Bleaching resistance (%)	Percent of the coral community made up of species considered to be resistant (rating $\leq$ 3 in Table A1)
Macroalgae cover (%)	Average percent of points classified as macroalgae (> 1 cm in height) on three 30-m point-intercept transects where points were classified at 50-cm intervals.
Herbivorous fish biomass (g/m^2)	Six replicate stationary point counts (SPC) were conducted. Observers counted all fishes that occurred in a 7.5-m radius cylinder. All fishes were identified to species and their total length estimated (TL). Biomass values were calculated using standard

Variable name (unit)	Methods
	length-weight regressions. Coefficients were sourced from FishBase and NOAA's Coral Reef Ecosystem Program (Weijerman et al. 2013). Species were classified as herbivores based on NOAA CREP functional group classifications.
Temperature variability	Standard deviation of the warm season (3 months centered on the warmest month – 1985-2016) temperatures (from Heron et al. 2016).

Results

Obj. 1. Benthic Cover

Coral cover was higher on average in the shallow (25%) survey areas than the deep (19%, this difference is not significant). Differences between the shallow and deep survey sites in coral cover are driven by differences in macroalgae cover as coralline algae (12% shallow and 10% deep) and other cover (41% both depths) are very similar between the depths. Spatial patterns in coral and macoralgae cover around Guam are shown in Figures 2 and 6 within the resilience indicator summaries section below. Average macroalgae cover was 22% in the shallow and 30% in the deep. The three shallow sites with the highest average coral cover were Ague Point (43%), Pugua Patch Reef (34%), and Hagatna Bay (33%). The three deep sites with the highest average coral cover were Hagatna Bay (52%), Tumon Bay (44%), and Ague Point (34%). The three shallow sites with the highest average macroalgae cover were Fouha Bay (51%), Ga'an Point (50%), and Facpi Point (32%). The three deep sites with the highest average macroalgae cover were Facpi Point (61%), Cocos Barrier Reef-E (51%) and Fouha Bay (47%).

Table 1. Percent cover of four major benthic groups for the shallow (left) and deep (right) survey sites. Sites are listed in alphabetical order. Data were collected using the line-intercept methodology, with three 30-m transects surveyed at each site.

	Shallow				Deep			
	Coral	Macroalgae	Coralline Algae	Other	Coral	Macroalgae	Coralline Algae	Other
Ague Point	43	13	7	37	34	11	8	47
Cocos Barrier Reef-E	26	18	11	45	13	51	7	29
Cocos Barrier Reef-W	12	24	13	51	8	39	5	48
Dadi Beach	23	21	8	48	11	28	33	28
Facpi Point	19	32	7	42	11	61	4	24
Fouha Bay	6	51	6	37	13	47	9	31
Ga'an Point	16	50	7	27	12	37	6	45
Hagatna Bay	33	12	25	30	52	16	14	18
Janom Point	19	25	8	48	13	41	3	43
Jinapsan Beach	32	26	7	35	18	21	1	60
Latte Point	NA	NA	NA	NA	12	24	12	52
Luminao Reef	27	8	16	49	21	11	21	47
Manell Channel	19	26	5	50	14	42	11	33
Mangilao Golf Course	32	11	12	45	24	34	8	34
Orote Point	29	8	14	49	14	21	4	61
Pati Point	NA	NA	NA	NA	20	16	13	51
Pugua Patch Reef	34	14	21	31	22	16	11	51
Tagua Point	28	16	9	47	16	31	3	50
Tepungan Bay	27	16	21	36	17	37	7	39
Tumon Bay	23	22	20	35	44	19	11	26

Obj. 2. Relative Resilience

Shallow – Normalized resilience scores ranged from 0.62 to 1.00. Three sites were assessed as having high resilience, four medium-high, nine medium-low, and two low. The three sites with high relative resilience are Tagua Point, Ague Point, and Pugua Patch Reef; these sites are in northern Guam. The two sites with low relative resilience are Ga'an Point and Fouha Bay, which are in southwestern Guam. There is a strong pattern that the relative resilience classes for survey sites are higher in the northern half of Guam and lower in the southern half. For both depths and with very few exceptions, scores were medium-high or high for resilience indicators in northern Guam and medium-low or low in southern Guam. Raw and normalized resilience scores, as well as normalized scores for all resilience indicators are presented within Table 2. Spatial patterns in relative resilience are shown for both depths in Figure 1.

Table 2. Resilience scores and relative classes for the shallow survey sites. Sites have been ordered from highest to lowest resilience score for this depth; deep rankings are shown in square [ ] brackets next to the shallow rankings. Relative classifications are as follows: high [green] (final scores that are greater than 1 standard deviation (sd) above average), medium-high [yellow] (<avg+1sd and >avg), medium-low [orange] (<avg and >avg-1sd), and low [red] (<avg-1sd). Indicator codes are as follows: CC – coral cover, CR – coral recruitment, CD – coral diversity, BR – bleaching resistance, MA – macroalgae cover, HB – herbivore biomass, TV – temperature variability.

Local Name	Shallow Rank [Deep]	Resilience score	Raw resilience score	CC	CR	CD	BR	MA	HB	TV
Tagua Point	1 [4]	1.00	0.77	0.65	0.40	0.92	0.67	0.91	1.00	0.85
Ague Point	2 [2]	0.99	0.76	1.00	0.67	0.96	0.80	0.94	0.07	0.89
Pugua Patch Reef	3 [1]	0.96	0.74	0.79	0.66	1.00	0.78	0.93	0.08	0.93
Orote Point	4 [7]	0.94	0.73	0.66	0.75	0.93	0.75	1.00	0.15	0.83
Hagatna Bay	5 [6]	0.93	0.72	0.78	0.43	0.92	0.89	0.96	0.18	0.89
Luminao Reef	6 [3]	0.91	0.71	0.62	1.00	0.72	0.66	0.99	0.08	0.86
Tepungan Bay	7 [10]	0.88	0.68	0.64	0.28	0.96	0.92	0.91	0.17	0.87
Jinapsan Beach	8 [9]	0.84	0.65	0.75	0.48	0.97	0.43	0.81	0.08	1.00
Tumon Bay	9 [5]	0.84	0.64	0.55	0.44	0.92	0.69	0.85	0.12	0.95
Dadi Beach	10 [12]	0.82	0.63	0.53	0.42	0.77	1.00	0.86	0.08	0.77
Manell Channel	11 [16]	0.81	0.63	0.45	0.41	0.98	0.91	0.80	0.07	0.77
Janom Point	12 [13]	0.80	0.61	0.45	0.53	0.91	0.63	0.81	0.05	0.91
Mangilao Golf Course	13 [11]	0.78	0.60	0.74	0.12	0.95	0.48	0.97	0.08	0.88
Cocos Barrier Reef-W	14 [14]	0.78	0.60	0.30	0.41	0.95	0.83	0.83	0.07	0.84
Cocos Barrier Reef-E	15 [20]	0.78	0.60	0.60	0.19	0.99	0.67	0.89	0.07	0.78
Facpi Point	16 [19]	0.77	0.59	0.44	0.30	0.94	0.88	0.73	0.04	0.82
Ga'an Point	17 [17]	0.72	0.56	0.36	0.23	0.95	0.96	0.54	0.08	0.77
Fouha Bay	18 [18]	0.62	0.48	0.14	0.13	0.74	0.94	0.54	0.04	0.82

Deep – Normalized resilience scores ranged from 0.64 to 1.00. Five sites were assessed as having high resilience, five medium-high, seven medium-low, and three low. The five sites with high relative resilience are Pugua Patch Reef, Ague Point, Luminao Reef, Tagua Point, and Tumon Bay; all of these sites are in northern Guam. The three sites with low relative resilience are Fouha Bay, Facpi Point and Cocos Barrier Reef-E, all of which are in southern Guam. As was the case for the shallow reef sites, there is a strong pattern that the relative resilience classes for deep survey sites are higher in the northern half of Guam and lower in the southern half. Raw and normalized resilience scores, as well as normalized scores for all resilience indicators are presented within Table 3. Spatial patterns in relative resilience are shown for both depths in Figure 1.

Table 3. Resilience scores and relative classes for the deep survey sites. Sites have been ordered from highest to lowest resilience score for this depth; shallow rankings are shown in square [ ] brackets next to the deep rankings. Relative classifications are as follows: high [green] (final scores that are greater than 1 standard deviation (sd) above average), medium-high [yellow] (<avg+1sd and >avg), medium-low [orange] (<avg and >avg-1sd), and low [red] (<avg-1sd). Indicator codes are as follows: CC – coral cover, CR – coral recruitment, CD – coral diversity, BR – bleaching resistance, MA – macroalgae cover, HB – herbivore biomass, TV – temperature variability.

Local Name	Deep Rank [Shallow]	Resilience score	Raw resilience score	CC	CR	CD	BR	MA	HB	TV
Pugua Patch Reef	1 [3]	1.00	0.78	0.43	1.00	0.95	0.89	0.94	0.32	0.93
Ague Point	2 [2]	0.95	0.74	0.66	0.62	0.96	0.84	1.00	0.20	0.89
Luminao Reef	3 [6]	0.93	0.73	0.41	0.41	0.98	0.91	1.00	0.54	0.86
Tagua Point	4 [1]	0.93	0.72	0.30	0.42	0.95	0.76	0.78	1.00	0.85
Tumon Bay	5 [9]	0.93	0.72	0.86	0.51	0.68	0.97	0.91	0.18	0.95
Hagatna Bay	6 [5]	0.88	0.69	1.00	0.47	0.39	1.00	0.94	0.10	0.89
Orote Point	7 [4]	0.86	0.67	0.27	0.64	0.88	0.85	0.89	0.36	0.83
Pati Point	8 [NA]	0.84	0.66	0.38	0.41	0.98	0.69	0.94	0.33	0.85
Jinapsan Beach	9 [8]	0.82	0.64	0.34	0.40	0.95	0.75	0.89	0.18	1.00
Tepungan Bay	10 [7]	0.81	0.63	0.33	0.37	0.98	0.91	0.71	0.27	0.87
Mangilao Golf Course	11 [13]	0.79	0.62	0.46	0.21	0.99	0.79	0.74	0.24	0.88
Dadi Beach	12 [10]	0.76	0.60	0.20	0.61	0.94	0.68	0.81	0.16	0.77
Janom Point	13 [12]	0.76	0.60	0.26	0.63	0.97	0.68	0.66	0.06	0.91
Cocos Barrier Reef-W	14 [14]	0.74	0.58	0.15	0.54	0.92	0.79	0.69	0.14	0.84
Latte Point	15 [NA]	0.74	0.58	0.23	0.34	0.96	0.59	0.86	0.21	0.85
Manell Channel	16 [11]	0.74	0.57	0.28	0.30	1.00	0.70	0.66	0.31	0.77
Ga'an Point	17 [17]	0.72	0.56	0.24	0.31	0.89	0.94	0.71	0.09	0.77
Fouha Bay	18 [18]	0.67	0.53	0.25	0.15	0.96	0.87	0.60	0.04	0.82
Facpi Point	19 [16]	0.66	0.52	0.20	0.19	0.97	0.88	0.44	0.13	0.82
Cocos Barrier Reef-E	20 [15]	0.64	0.50	0.26	0.32	0.92	0.53	0.56	0.12	0.78

Spatial patterns for the resilience indicators are presented within Figures 2-8. With very few exceptions, values for the resilience indicators were higher in northern Guam than southern and especially southwestern Guam.

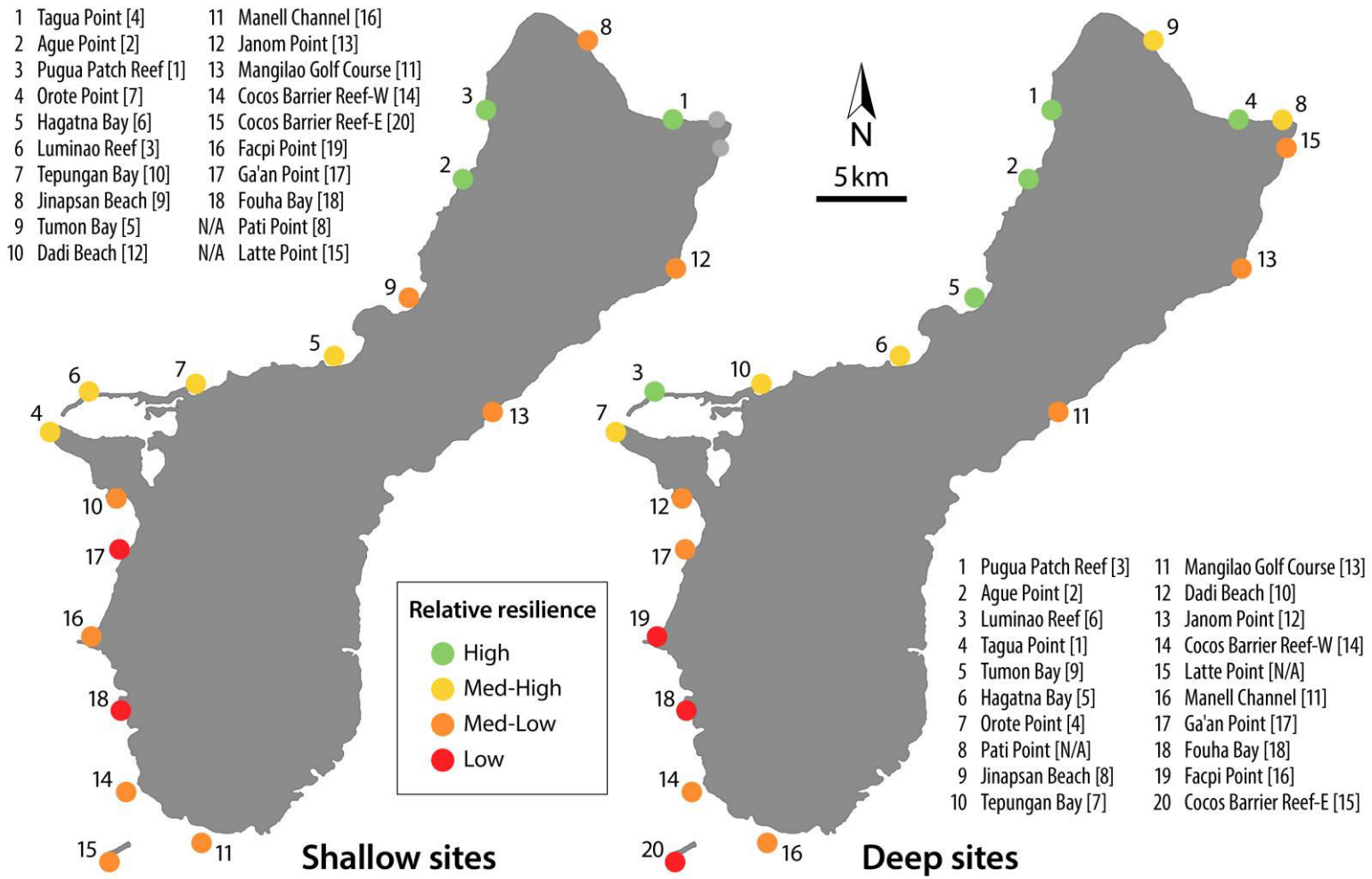

Figure 1. Relative resilience of coral reefs in Guam. Sites are ordered from highest to lowest ranking for the shallow in the top left and deep in the bottom right. Raw and normalized resilience scores are shown for each site within Tables 1 and 2. Relative resilience is an aggregate score for 7 resilience indicators: coral cover, coral recruitment, coral diversity, bleaching resistance, macroalgae cover, herbivore biomass, and temperature variability. Spatial patterns are shown for each resilience indicator within Figures 2-8, in the upcoming pages.

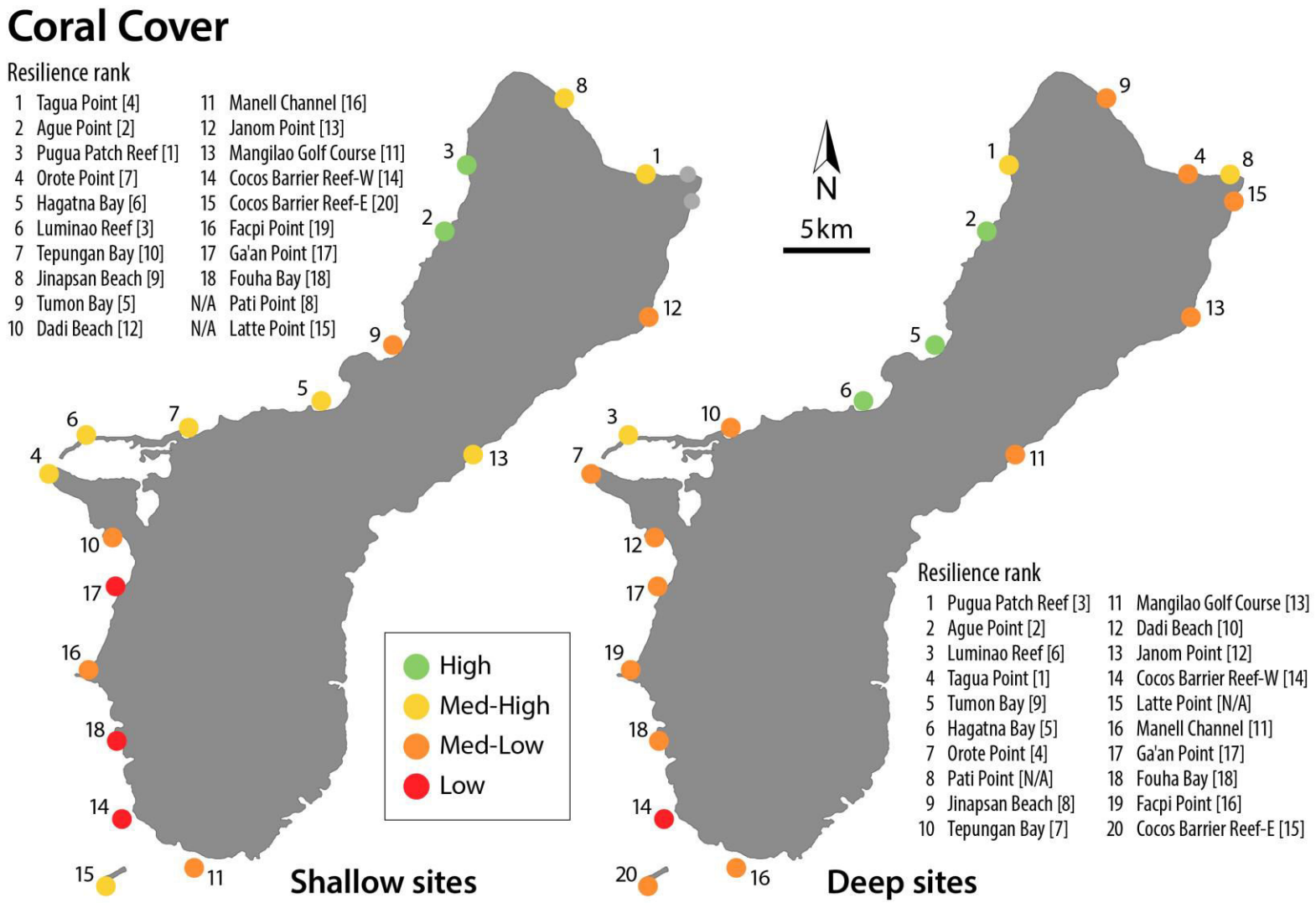

Figure 2. Relative classifications for coral cover. Normalized values for this and the other indicators are presented with Tables 1 and 2. On the shallow side, resilience rankings for deep are in [ ] brackets, and on the deep side, resilience rankings for shallow are in [ ] brackets. This also applies to Figures 3-8.

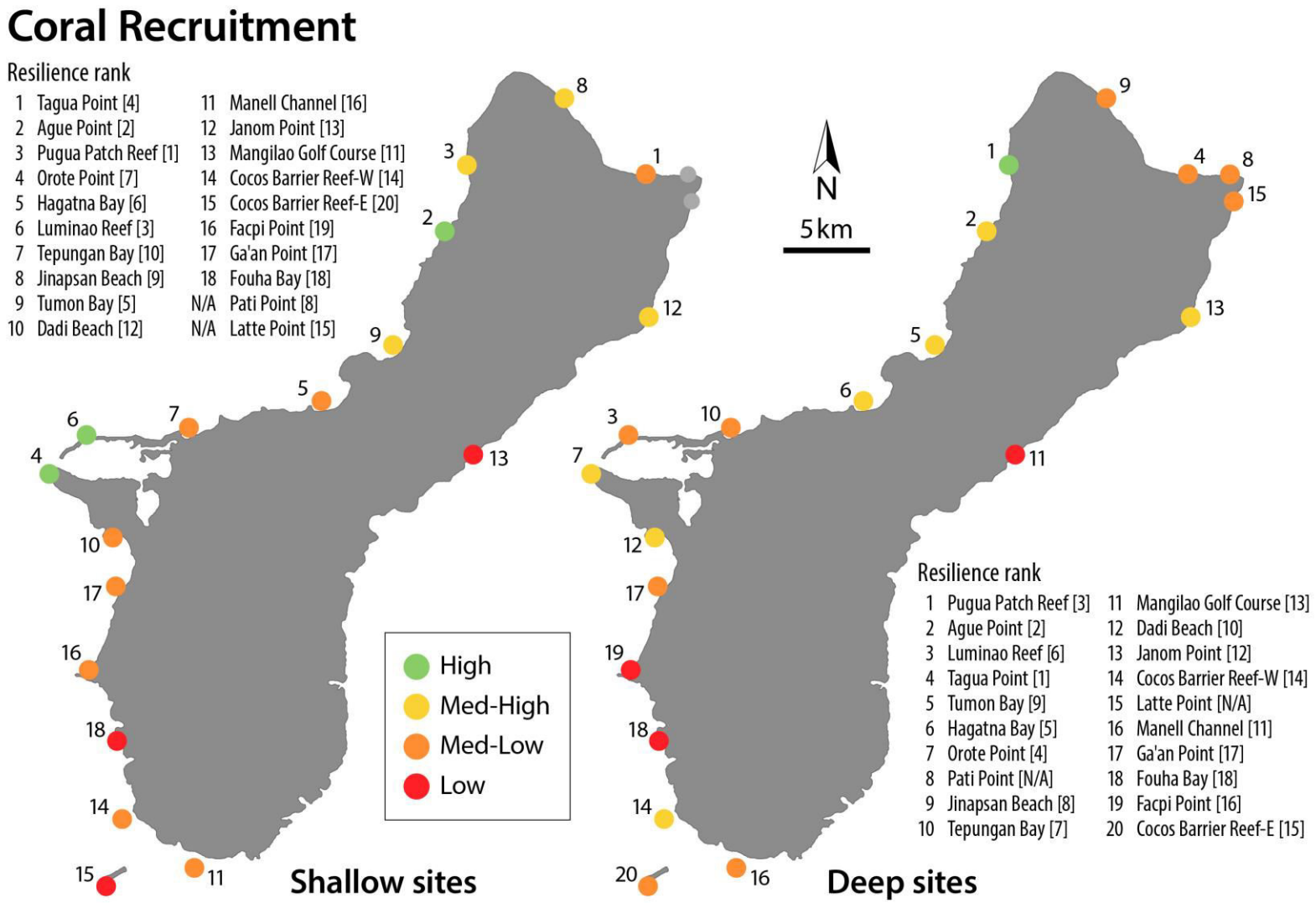

Figure 3. Relative classifications for coral recruitment. Normalized values for this and the other indicators are presented with Tables 1 and 2.

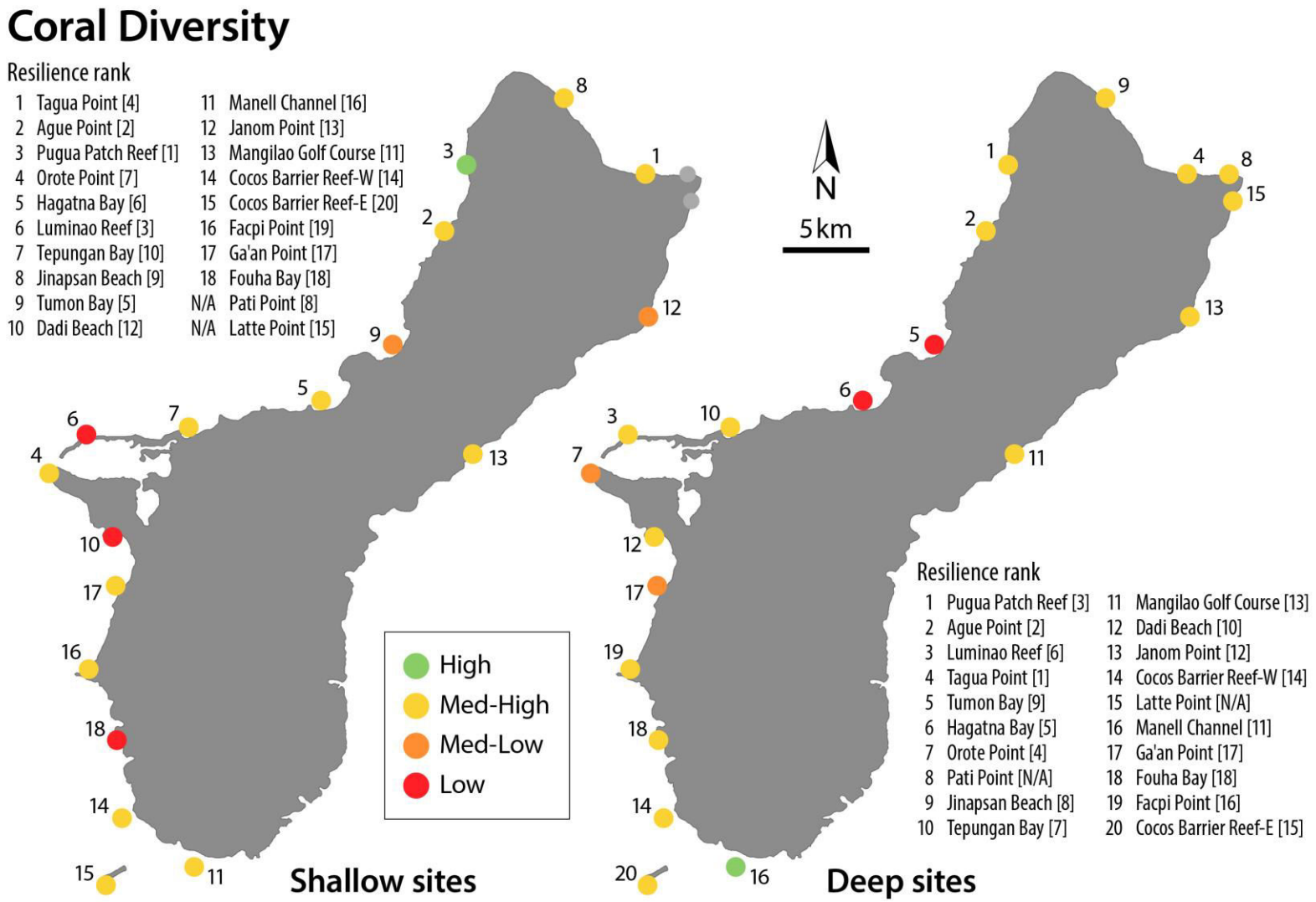

Figure 4. Relative classifications for coral diversity. Normalized values for this and the other indicators are presented with Tables 1 and 2.

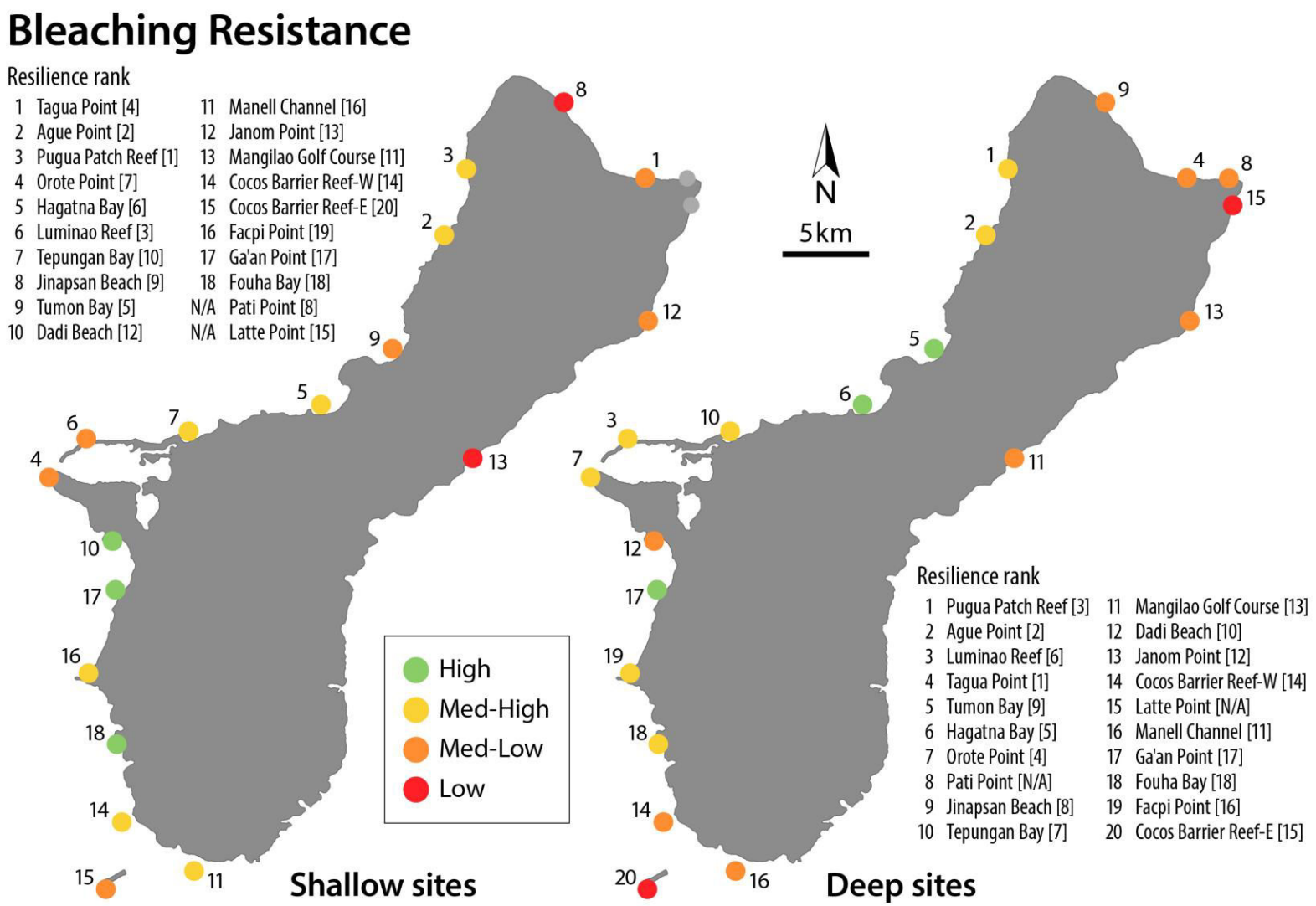

Figure 5. Relative classifications for bleaching resistance. Normalized values for this and the other indicators are presented with Tables 1 and 2.

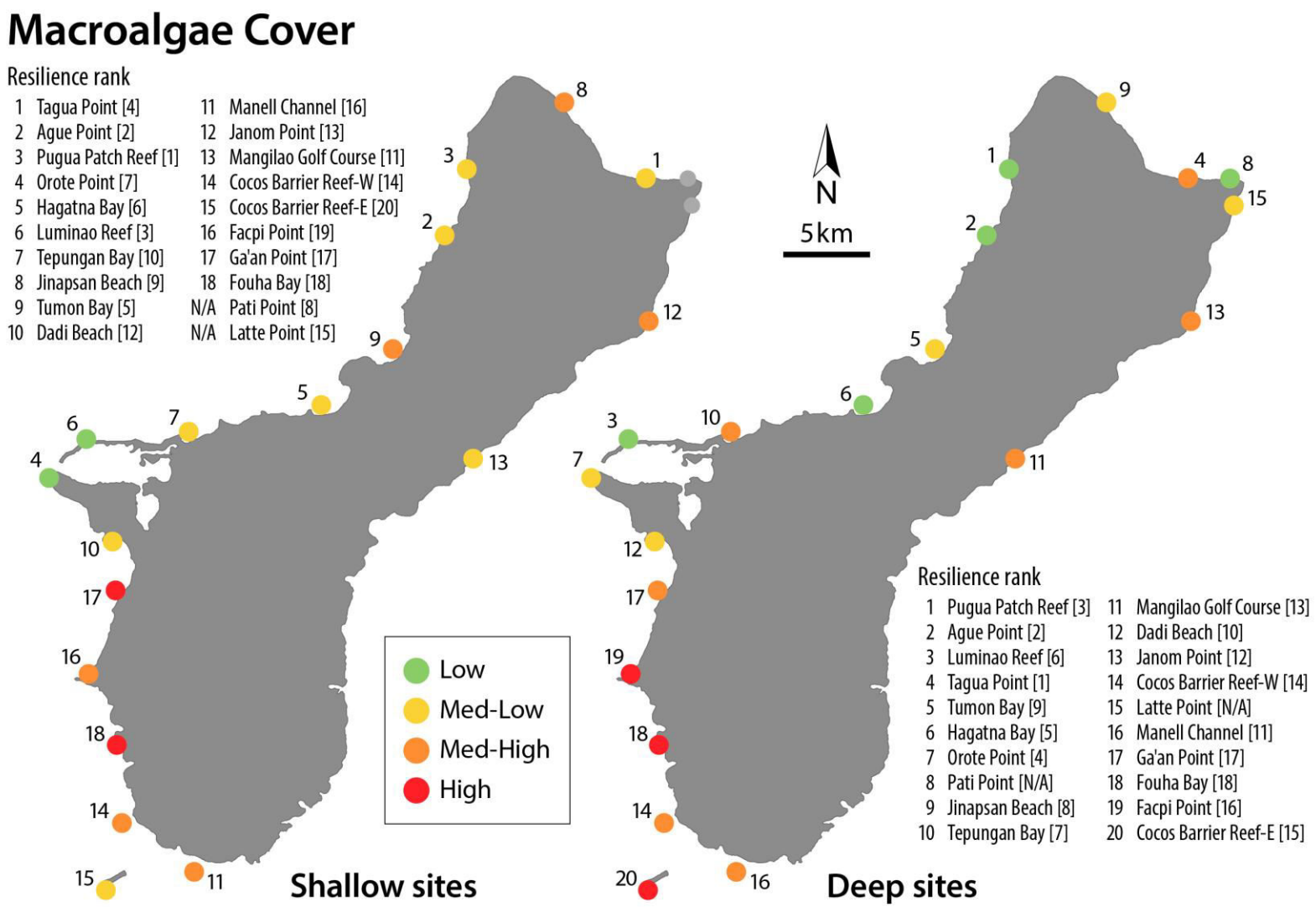

Figure 6. Relative classifications for macroalgae cover. Normalized values for this and the other indicators are presented with Tables 1 and 2.

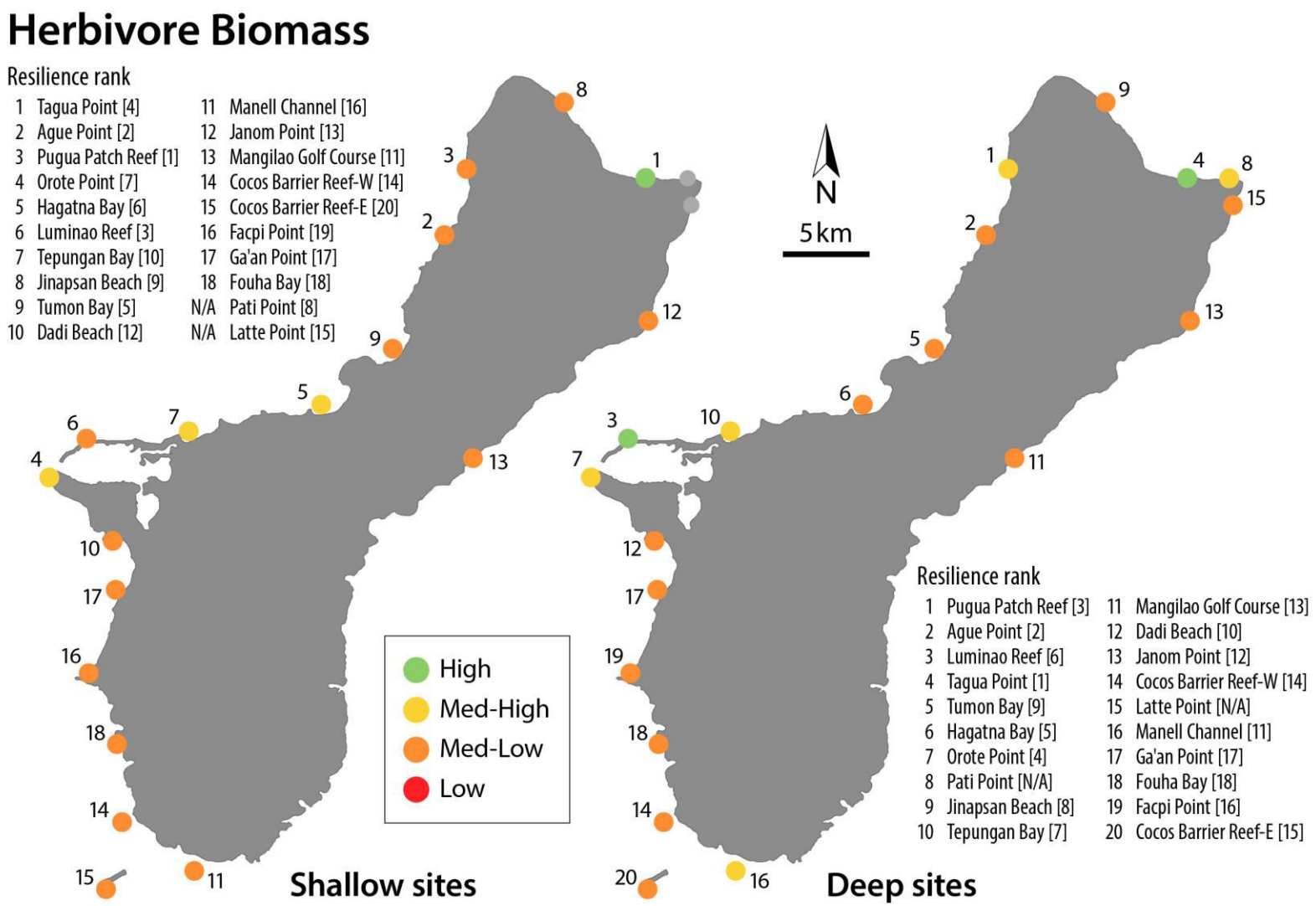

Figure 7. Relative classifications for herbivore biomass. Normalized values for this and the other indicators are presented with Tables 1 and 2.

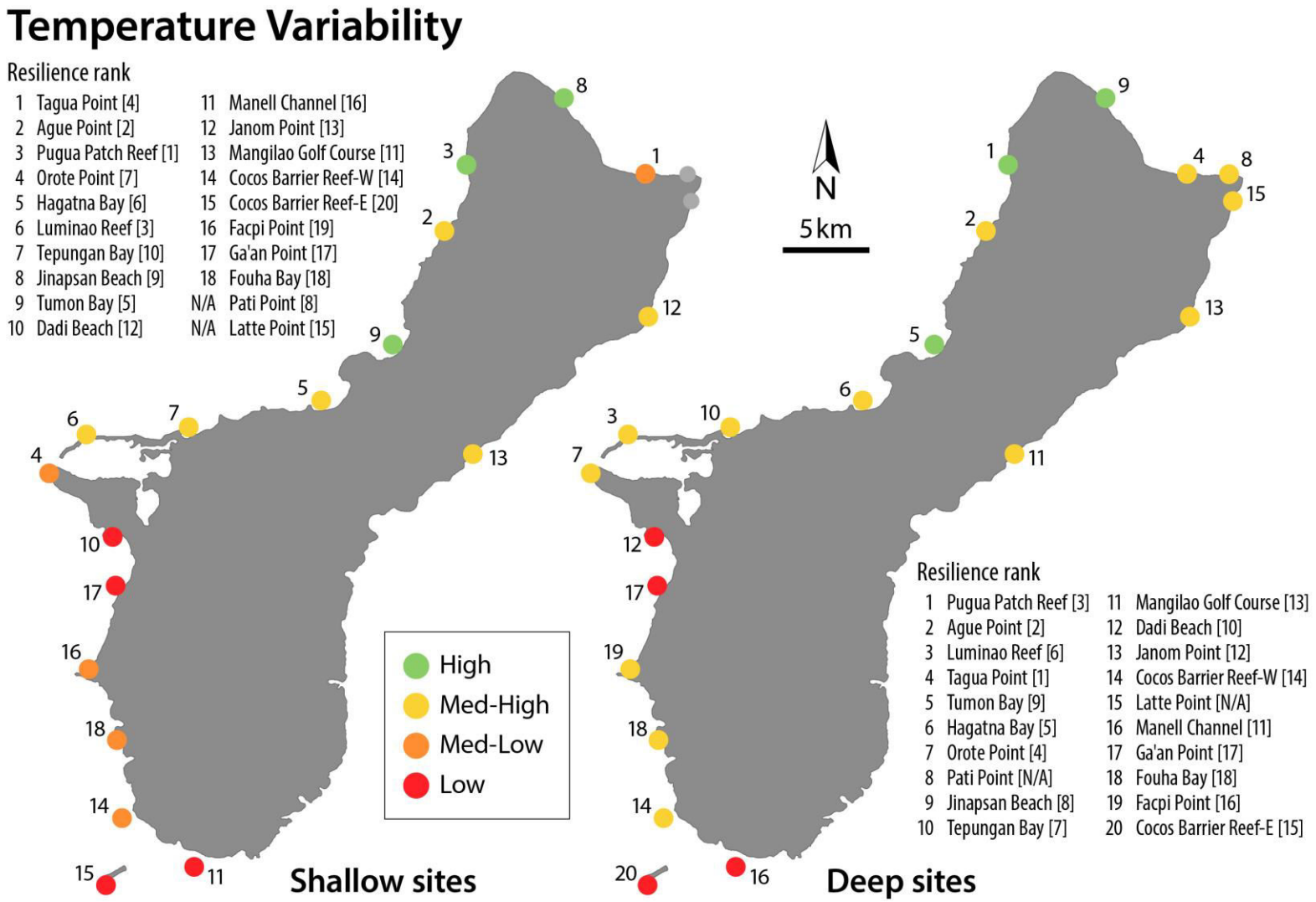

Figure 8. Relative classifications for temperature variability. Normalized values for this and the other indicators are presented with Tables 1 and 2.

Obj. 3. Resilience Drivers

It was possible that high resilience sites could have this classification as a result of having high scores for different indicators and low resilience sites could have low scores for different indicators. We examined whether high scores for some indicators are consistently associated with high resilience (and low scores for some indicators with low resilience) using a CAP analysis.

Across the shallow reef sites of Guam, higher resilience potential correlated most strongly with high coral cover and high coral recruitment (along CAP axis 1), and high herbivore biomass at a single high resilience site (Tagua Point) along CAP axis 2 (Fig. 9). In contrast, low resilience potential sites were negatively correlated with these same three indicators, but were positively associated with increased bleaching resistance (along CAP axis 1) (Fig. 9).

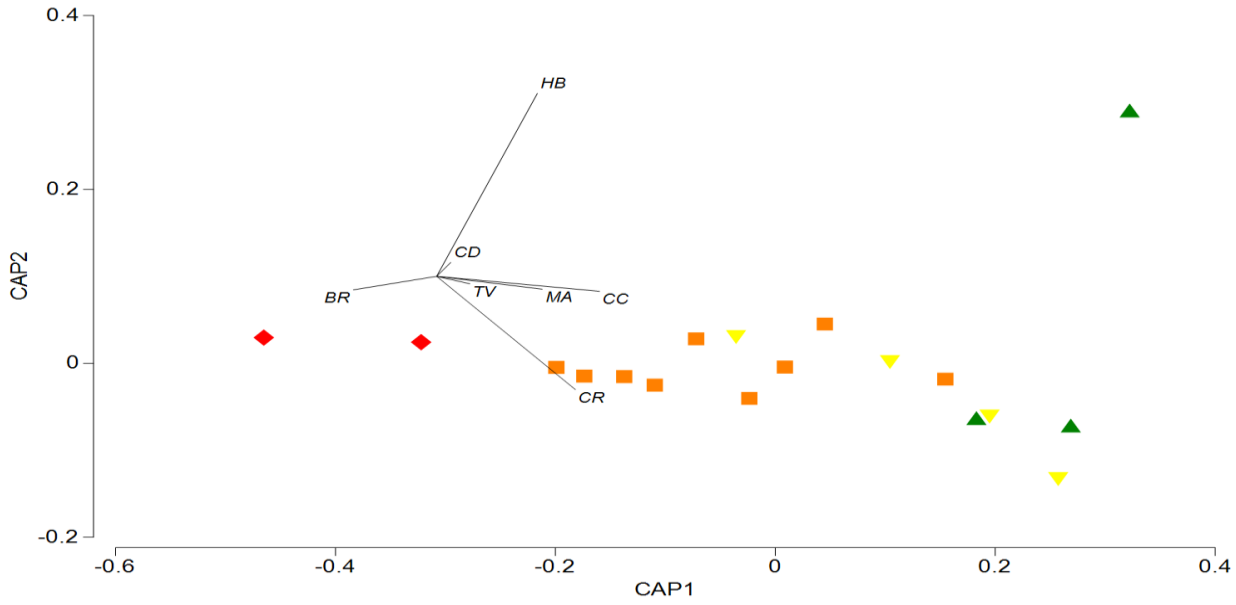

Figure 9. Canonical analysis of principal coordinates showing the relative contribution of the seven resilience indicators (overlaid as vectors) to the overall resilience (High – *green*, Medium-High – *yellow*, Medium-Low – *orange*, Low – *red*) of shallow reef sites at Guam. CC, coral cover; CR, coral recruitment; CD, coral diversity; BR, bleaching resistance; MA, macroalgae cover; HB, herbivore biomass; TV, temperature variability. Squared canonical correlation value (δ^2) of the first and second ordination axes equal 0.778 and 0.122, respectively.

Across the deep reef sites of Guam, higher resilience potential correlated most strongly with high coral recruitment and low macroalgae cover along CAP axis 1 and with higher herbivore biomass and coral cover along CAP axis 2 (Fig. 2). Coral diversity was also positively associated with higher resilience potential along CAP axis 2 and is driving the higher relative resilience at Tagua Point (Fig. 10).

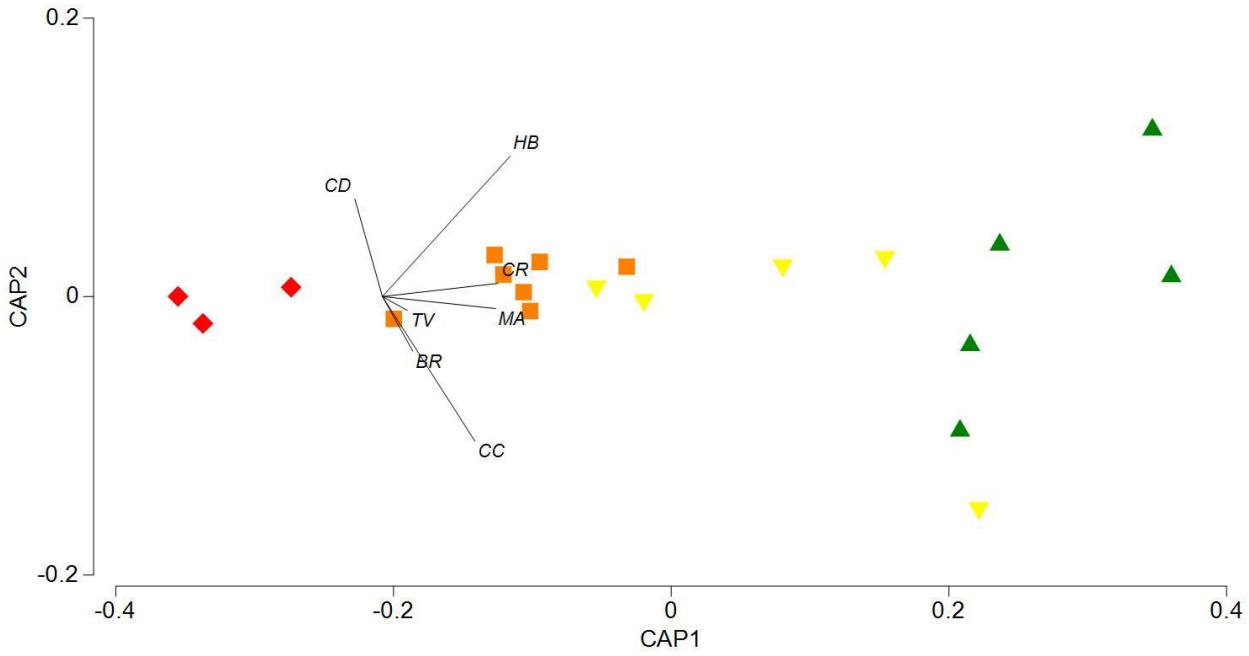

Figure 10. Canonical analysis of principal coordinates showing the relative contribution of the seven resilience indicators (overlaid as vectors) to the overall resilience (High – *green*, Medium-High – *yellow*, Medium-Low – *orange*, Low – *red*) of deep reef sites at Guam. CC, coral cover; CR, coral recruitment; CD, coral diversity; BR, bleaching resistance; MA, macroalgae cover; HB, herbivore biomass – sum of the grazers, reef builders and browsers; TV, temperature variability. Squared canonical correlation value (δ^2) of the first and second ordination axes equal 0.895 and 0.054, respectively.

Next Steps

The following list includes timely research projects and communication and reporting activities that can build on the research and work presented within this report.

- Reef resilience work can be integrated with ongoing bleaching response planning. Data from the resilience study can help guide managers to the places that are most likely to bleach in the future based upon exposure. At time of report publication, such work was underway. Members of this project team led bleaching response surveys in Guam in October of 2017 to document impacts from recurrent bleaching (reefs in Guam also bleached in 2014 and 2016).

- Continued resilience monitoring can help managers identify the reefs that recover the fastest. These reefs would be likely candidates for stronger management actions (e.g., protected area, gear restrictions) that support continued resilience.

- Results from the resilience assessment can help managers target and tailor management actions. A varied management approach across sites can also help manage the various social needs of the island community.

- Combining the results of the Guam study with the CNMI study can help provide the groundwork for a regional planning and response strategy. While the two jurisdictions face different social, economic, and political futures, they both have to deal with climate change. Pooling resources and taking an archipelago-wide approach to management and planning can only give coral reefs in the Marianas a better chance of coping with climate change.

- The results of subsequent assessments of condition and resiliency at the survey sites can be used to assess the predictive power of this first assessment. Such studies could lead to revisions of the assessment methods used and the guidance we have provided to others (Maynard et al. 2017) that want to replicate or adapt our approach.

- The data and results will be built into a Pacific-wide assessment of coral reef fisheries vulnerability to climate change being led by members of this project team from 2017-2019.

- The resilience assessment data and data collected during ongoing (at time of writing) bleaching characterization/post-bleaching recovery assessments can inform studies on population genetics and connectivity. Results of such studies could add important context to the existing resilience and bleaching data, informing both future assessment methods and management activities.

Outreach

Near this project's conclusion, our team led a workshop in Guam to share the resilience assessment results and describe state-of-art information on projected climate change impacts to the reefs of Guam. About 40 people attended including coral reef and fisheries managers, scientists, educators, policy specialists and managers with the Guam EPA, fishers, staff from conservation organizations and public service non-profits, and students. Two quotes from attendees appear below, with a photo of the workshop group.

"This team has developed so much good information on climate impacts and resilience that I can use to inform how I focus my team's efforts." –Jim Richardson (Director of the National Parks Service for Guam and CNMI).

"We now have a far better understanding of how to talk about climate change and explain expected climate change impacts on coastal ecosystems in Guam." - Joe Quinata (Humatak Foundation)

Workshop attendees, Guam 2017.

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Appendix 1 – Bleaching susceptibility ratings for coral species

Table A1. Most common morphology, bleaching susceptibility rating, and known habitats for all coral species observed during the 2016 surveys. Bleaching susceptibility ratings range from 1-5 (from least to most susceptible). Susceptibility ratings are based on the team's personal observations during past bleaching events in Guam and CNMI as well as from a literature review. Habitat classifications are as follows, and refer to the types of habitat(s) the species is known to occur in CNMI: Lf = loose framework reef, P = patch reef, Rf = reef flat, SG = spur and groove reef. Lists of coral species observed at each of the 20 survey sites are within the Site Summary Guide – See Appendix 2).

CORAL SPECIES	GROWTH MORPHOLOGY	BLEACHING SUSCEPTIBILITY	HABITAT
Acanthastrea brevis	Encrusting	2	P, Sg
Acanthastrea echinata	Encrusting	2	Lf, P, Rf, Sg
Acanthastrea hillae	Encrusting	2	P, Sg
Acanthastrea c.f. *regularis*	Encrusting	2	Lf
Acropora abrotanoides	Arborescent	3	Lf, P, Sg
Acropora aspera	Staghorn	5	P, Rf
Acropora azurea	Digitate/corymbose	4	Lf, Sg
Acropora cerealis	Digitate/corymbose	4	Lf, Sg
Acropora cophydactyla	Digitate/corymbose	3	Lf
Acropora cuneata	Arborescent	2	P
Acropora digitifera	Digitate/corymbose	3	Lf, P, Sg
Acropora gemmifera	Digitate/corymbose	3	Lf, Sg
Acropora granulosa	Digitate/corymbose	3	Lf, Sg
Acropora humilis	Digitate/corymbose	3	Lf, Sg
Acropora juv.	Branching	3	Lf, P, Sg
Acropora latistella	Digitate/corymbose	4	Lf, P, Sg
Acropora monticulosa	Arborescent	3	Lf, Rf, Sg
Acropora muricata	Staghorn	5	P
Acropora nana	Digitate/corymbose	5	Sg
Acropora nasuta	Digitate/corymbose	5	Lf, Sg
Acropora pulchra	Staghorn	5	Rf
Acropora robusta	Arborescent	4	Lf, Sg
Acropora secale	Digitate/corymbose	3	Lf, P, Sg
Acropora surculosa	Digitate/corymbose	3	Lf, P, Sg
Acropora c.f. *striata*	Digitate/corymbose	4	Sg
Acropora tenuis	Digitate/corymbose	5	Lf, P, Rf, Sg
Acropora teres	Staghorn	5	P, Rf
Acropora vaughani	Digitate/corymbose	4	Lf, Rf, Sg
Acropora verweyi	Digitate/corymbose	4	Lf, P, Sg

CORAL SPECIES	GROWTH MORPHOLOGY	BLEACHING SUSCEPTIBILITY	HABITAT
Alveopora fenestrata	Massive	3	Lf
Astreopora gracilis	Massive	4	Lf
Astreopora listeri	Massive	4	Lf, P, Sg
Astreopora myriophthalma	Massive	4	Lf, P, Sg
Astreopora randalli	Massive	4	Lf, Sg
Cyphastrea agassizi	Massive	3	Lf, Sg
Cyphastrea chalcidicum	Massive	3	Lf, P, Sg
Cyphastrea c.f. *japonica*	Massive	3	Sg
Cyphastrea ocellina	Massive	3	Lf, Sg
Cyphastrea seraila	Massive	3	Lf, Sg
Diploastrea heliopora	Massive	1	Lf
Echinophyllia aspera	Encrusting	2	P
Echinopora lamellosa	Plate	2	Lf, P, Sg
Favia danae	Massive	3	Lf, R
Favia favus	Massive	3	Lf, P, Sg
Favia helianthoides	Massive	3	Lf, Sg
Favia mathaii	Massive	3	Lf, P, Sg
Favia pallida	Massive	3	Lf, Sg
Favia rotumana	Massive	3	P
Favia speciosa	Massive	3	Lf, P, Sg
Favia stelligera	Massive	4	Lf, Sg
Favites abdita	Massive	2	Lf, P, Sg
Favites flexuosa	Massive	2	Lf, P
Favites russelli	Massive	1	Lf, P, Rf, Sg
Fungia sp.	Free-living	2	Lf
Fungia fungites	Free-living	2	Lf
Fungia paumotensis	Free-living	2	Lf
Fungia repanda	Free-living	2	Lf
Fungia scutaria	Free-living	2	Lf, P, Sg
Galaxea fascicularis	Encrusting	3	Lf, P, Sg
Gardineroseris planulata	Massive	3	Lf, Sg
Goniastrea aspera	Massive	4	P
Goniastrea edwardsi	Massive	4	Lf, P, Rf, Sg
Goniastrea pectinata	Massive	3	Lf, P, Sg
Goniastrea retiformis	Massive	4	Lf, P, Rf, Sg
Goniopora djiboutiensis	Massive	1	Lf
Goniopora fruticosa	Encrusting	1	Lf, Sg
Goniopora minor	Massive	1	P
Heliopora coerula	Branching	1	Lf, P, Rf
Hydnophora microconos	Massive	4	Lf, P, Rf, Sg
Isopora palifera	Arborescent	2	Lf, P, Sg
Leptastrea bottae	Encrusting	2	Lf, P, Sg

CORAL SPECIES	GROWTH MORPHOLOGY	BLEACHING SUSCEPTIBILITY	HABITAT
Leptastrea purpurea	Encrusting	2	Lf, P, Sg
Leptastrea transversa	Encrusting	2	Lf, Sg
Leptoria phrygia	Massive	3	Lf, P, Rf, Sg
Lobophyllia corymbosa	Massive	3	Lf, Sg
Lobophyllia hemprichii	Massive	3	Sg
Millepora dichotoma	Branching	1	Sg
Millepora platyphylla	Massive	1	Lf
Millepora tuberosa	Encrusting	1	Lf, P, Sg
Montastrea curta	Massive	3	Lf, P, Sg
Montastrea valenciennesi	Massive	3	Lf, Sg
Montipora sp.	Encrusting	4	Lf, P, Rf, Sg
Montipora aequituberculata	Encrusting	4	Lf, Sg
Montipora caliculata	Encrusting	4	Lf, P, Sg
Montipora danae	Encrusting	4	P, Sg
Montipora efflorescens	Encrusting	4	Lf, P, Sg
Montipora floweri	Encrusting	4	Lf, Sg
Montipora foveolata	Encrusting	4	Lf, Sg
Montipora grisea	Encrusting	4	Lf, Sg
Montipora hoffmeisteri	Encrusting	4	Sg
Montipora lobulata	Encrusting	4	P
Montipora monasteriata	Encrusting	4	Lf, P, Sg
Montipora nodosa	Encrusting	4	Lf, P, Rf, Sg
Montipora tuberculosa	Encrusting	4	Lf, P, Sg
Montipora verrilli	Encrusting	4	P, Sg
Montipora verrucosa	Encrusting	4	Lf, Sg
Oulophyllia crispa	Massive	3	Lf, Sg
Pavona cactus	Foliose	3	P
Pavona divaricata	Foliose	3	Lf, P, Rf, Sg
Pavona duerdini	Massive	4	Lf, P, Sg
Pavona explanulata	Cryptic	3	Lf
Pavona frondifera	Cryptic	3	Lf
Pavona maldiviensis	Cryptic	3	Lf, Sg
Pavona minuta	Encrusting	3	Lf
Pavona varians	Encrusting	1	Lf, P, Sg
Pavona venosa	Encrusting	2	Lf, Sg
Platygyra daedalea	Massive	3	P, Sg
Platygyra pini	Massive	3	Lf, P, Sg
Plesiastrea versipora	Massive	1	Lf, Sg
Pocillopora sp.	Digitate/corymbose	4	Lf, P, Sg
Pocillopora ankeli	Digitate/corymbose	4	Lf, Sg
Pocillopora damicornis	Digitate/corymbose	2	Lf, P, Rf, Sg

CORAL SPECIES	GROWTH MORPHOLOGY	BLEACHING SUSCEPTIBILITY	HABITAT
Pocillopora danae	Digitate/corymbose	3	Lf, Sg
Pocillopora elegans	Digitate/corymbose	4	Lf, P, Sg
Pocillopora eydouxi	Digitate/corymbose	4	Sg
Pocillopora meandrina	Digitate/corymbose	4	Lf, Sg
Pocillopora verrucosa	Digitate/corymbose	4	Lf, Sg
Pocillopora woodjonesi	Digitate/corymbose	4	Sg
Porites sp.	Massive	1	Lf, P, Rf, Sg
Porites annae	Massive	2	Lf
Porites australiensis	Massive	1	Lf, Sg
Porites cylindrica	Branching	2	Lf, Rf, Sg
Porites deformis	Columnar	2	Lf
Porites densa	Massive	1	Lf
Porites lichen	Encrusting	1	Lf, P, Sg
Porites lobata	Massive	1	Lf, P, Sg
Porites lutea	Massive	1	Lf, P, Rf, Sg
Porites "massive" (lobata/lutea/australiensis)	Massive	1	Lf, P, Rf, Sg
Porites rus	Columnar	1	Lf, P, Sg
Porites vaughani	Encrusting	1	Lf, P, Sg
Psammocora sp.	Encrusting	1	Lf, P, Rf, Sg
Psammocora digitata	Columnar	2	Lf, Rf
Psammocora haimeana	Cryptic	1	Lf, Sg
Psammocora nierstrazi	Encrusting	1	Lf, P, Sg
Psammocora stellata	Cryptic	1	Rf
Scolymia australis	Encrusting	1	P
Stylocoeniella armata	Encrusting	1	Lf, P, Rf, Sg
Stylocoeniella guentheri	Encrusting	1	Lf
Stylophora mordax	Branching	5	Lf, P, Rf, Sg
Turbinaria reniformis	Plate	3	Lf, Sg
Turbinaria stellulata	Encrusting	2	Lf, Sg

Appendix 2 - Site Summary Guide

The first one-page summary is shown in the graphic below. Each part of the summary is enclosed within a box that has a letter label. Descriptions are provided below for each of these parts of the summary, next to the relevant letter label. The 20 one-page summaries are in the upcoming pages.

A – Site name and resilience rankings for the shallow and deep reef areas.

B – Site name origin and map showing the location of the survey site in Guam.

C – Representative site photos for each depth with site coordinates.

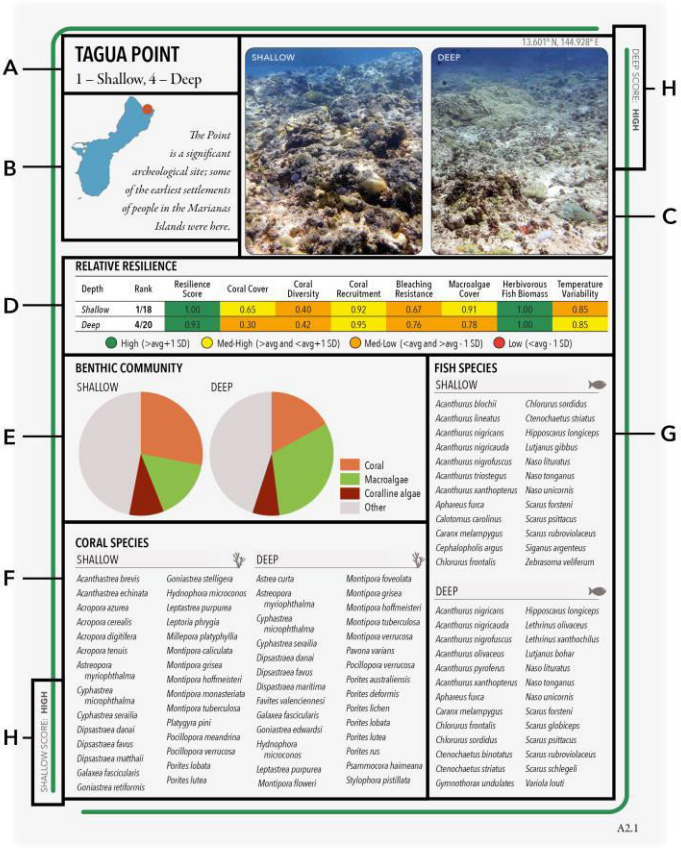
D – Resilience and resilience indicator scores with colors signifying relative classes.

E – Benthic community pie charts showing percent cover of the four major benthic groups for the shallow and deep reef areas. 'Other' refers mostly to turfing algae and, to a lesser degree, unconsolidated substrate.

F – Lists of coral species observed.

G – Lists of fish species observed

H – Relative class for the resilience scores for the shallow (left and top) and deep (right and bottom) reef areas.

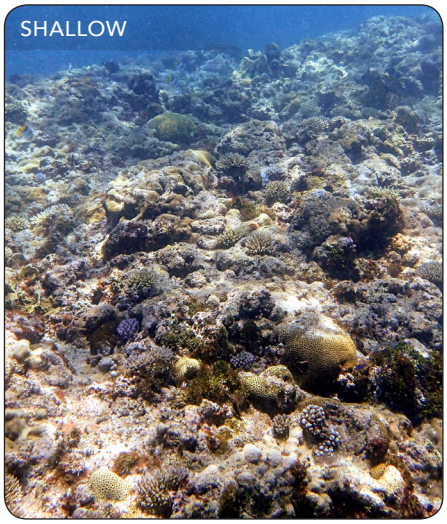


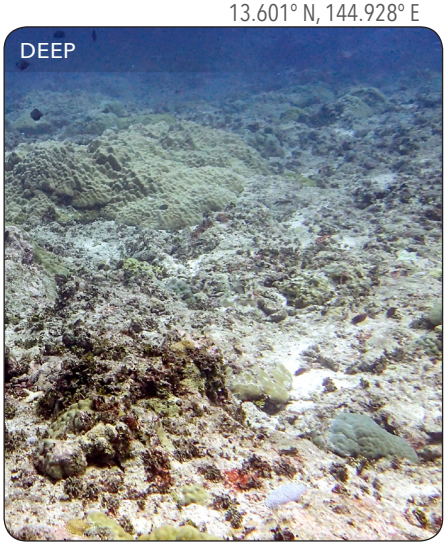
TAGUA POINT

13.601° N, 144.928° E

1 – Shallow, 4 – Deep

The Point is a significant archeological site; some of the earliest settlements of people in the Marianas Islands were here.





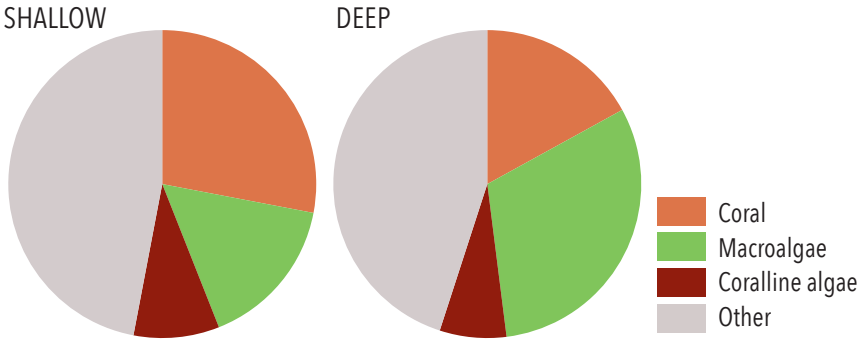
DEEP SCORE: **HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**1/18**	1.00	0.65	0.40	0.92	0.67	0.91	1.00	0.85
Deep	**4/20**	0.93	0.30	0.42	0.95	0.76	0.78	1.00	0.85

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus blochii
Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus triostegus
Acanthurus xanthopterus
Aphareus furca
Calotomus carolinus
Caranx melampygus
Cephalopholis argus
Chlorurus frontalis
Chlorurus sordidus
Ctenochaetus striatus
Hipposcarus longiceps
Lutjanus gibbus
Naso lituratus
Naso tonganus
Naso unicornis
Scarus forsteni
Scarus psittacus
Scarus rubroviolaceus
Siganus argenteus
Zebrasoma veliferum

DEEP

Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus pyroferus
Acanthurus xanthopterus
Aphareus furca
Caranx melampygus
Chlorurus frontalis
Chlorurus sordidus
Ctenochaetus binotatus
Ctenochaetus striatus
Gymnothorax undulates
Hipposcarus longiceps
Lethrinus olivaceus
Lethrinus xanthochilus
Lutjanus bohar
Naso lituratus
Naso tonganus
Naso unicornis
Scarus forsteni
Scarus globiceps
Scarus psittacus
Scarus rubroviolaceus
Scarus schlegeli
Variola louti

CORAL SPECIES

SHALLOW

Acanthastrea brevis
Acanthastrea echinata
Acropora azurea
Acropora cerealis
Acropora digitifera
Acropora tenuis
Astreopora myriophthalma
Cyphastrea microphthalma
Cyphastrea serailia
Dipsastraea danai
Dipsastraea favus
Dipsastraea matthaii
Galaxea fascicularis
Goniastrea retiformis
Goniastrea stelligera
Hydnophora microconos
Leptastrea purpurea
Leptoria phrygia
Millepora platyphyllia
Montipora caliculata
Montipora grisea
Montipora hoffmeisteri
Montipora monasteriata
Montipora tuberculosa
Platygyra pini
Pocillopora meandrina
Pocillopora verrucosa
Porites lobata
Porites lutea

DEEP

Astrea curta
Astreopora myriophthalma
Cyphastrea microphthalma
Cyphastrea serailia
Dipsastraea danai
Dipsastraea favus
Dispastraea maritima
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Hydnophora microconos
Leptastrea purpurea
Montipora floweri
Montipora foveolata
Montipora grisea
Montipora hoffmeisteri
Montipora tuberculosa
Montipora verrucosa
Pavona varians
Pocillopora verrucosa
Porites australiensis
Porites deformis
Porites lichen
Porites lobata
Porites lutea
Porites rus
Psammocora haimeana
Stylophora pistillata

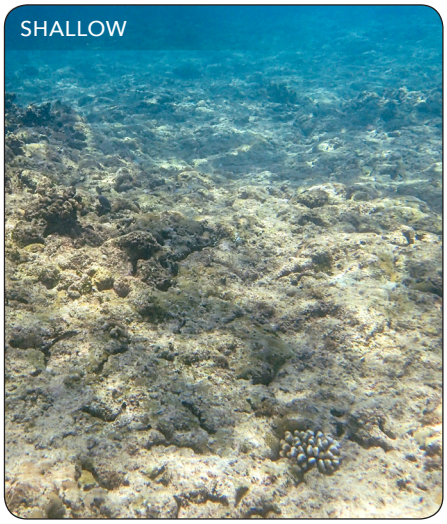
SHALLOW SCORE: **HIGH**

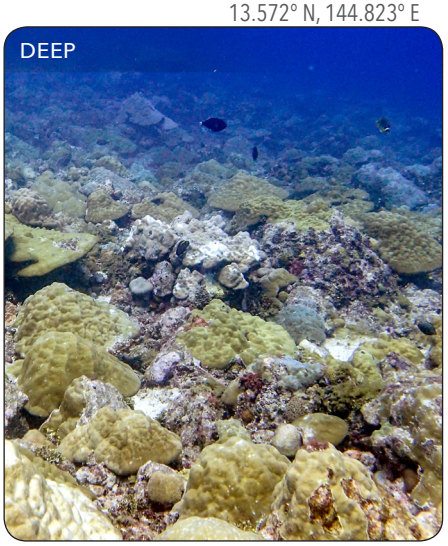
13.572° N, 144.823° E

AGUE POINT

2 – Shallow, 2 – Deep

Ague Cove, located near the Point, is a popular hiking and swimming destination as the cove creates a natural swimming pool.





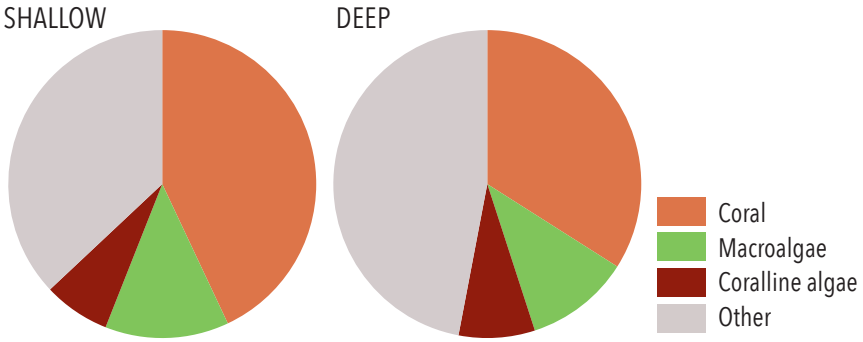
DEEP SCORE: **HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**2/18**	0.99	1.00	0.67	0.96	0.80	0.94	0.07	0.89
Deep	**2/20**	0.95	0.66	0.62	0.96	0.84	1.00	0.20	0.89

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus pyroferus
Aphareus furca
Chlorurus sordidus
Ctenochaetus binotatus
Ctenochaetus striatus
Naso lituratus
Naso unicornis
Scarus psittacus

CORAL SPECIES

SHALLOW

Acanthastrea echinata
Acropora abrotenoides
Acropora digitifera
Acropora globiceps
Acropora surculosa
Acropora verweyi
Astrea curta
Cyphastrea chalcidicum
C. microphthalma
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites colemani
Favites valenciennesi
Galaxea fascicularis
Goniastrea retiformis
Hydnophora microconos
Leptastrea purpurea
Leptoria phrygia
Millepora dichotoma
Millepora platyphyllia
Montipora c.f. studeri
Montipora caliculata
Montipora grisea
Montipora hoffmeisteri
Montipora monasteriata
Montipora nodosa
Montipora tuberculosa
Pavona c.f. meandrina
Pavona chriquiensis
Pavona varians
Pocillopora meandrina
Pocillopora verrucosa
Porites australiensis
Porites horizontalata
Porites lutea

DEEP

Acanthastrea brevis
Astreopora listeria
Astreopora myriophthalma
Astreopora ocellata
Cyphastrea serailia
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Leptastrea purpurea
Montipora caliculata
Montipora tuberculosa
Montipora verrucosa
Paragoniastrea russelli
Pavona duerdeni
Pavona varians
Platygyra pini
Pocillopora damicornis
Pocillopora verrucosa
Porites australiensis
Porites lichen
Porites lobate
Porites lutea
Porites rus
Psammocora haimeana
Stylocoeniella armata

DEEP

Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus pyroferus
Aphareus furca
Chlorurus sordidus
Ctenochaetus binotatus
Ctenochaetus striatus
Gymnosarda unicolor
Naso lituratus
Naso vlamingii
Scarus globiceps
Scarus psittacus
Scarus schlegeli

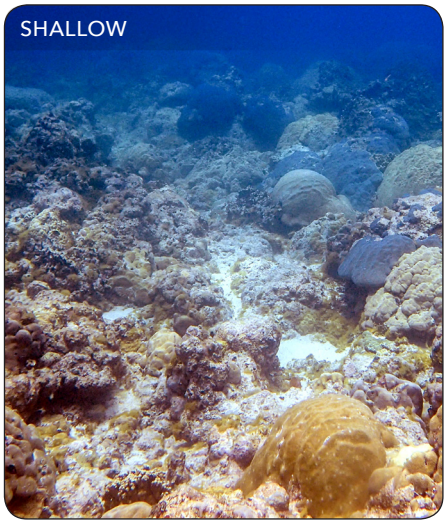
SHALLOW SCORE: **HIGH**

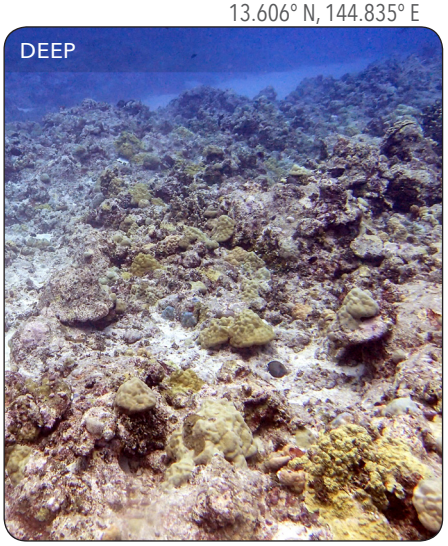
13.606° N, 144.835° E

PUGUA PATCH REEF

3 – Shallow, 1 – Deep

Also known as Double Reef, this is a pair of two patch reefs, which house some of the highest biodiversity seen during these surveys.





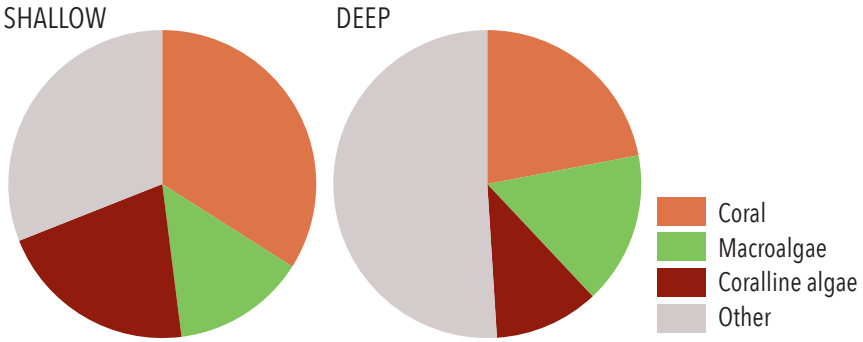
DEEP SCORE: **HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**3/18**	0.96	0.79	0.66	1.00	0.78	0.93	0.08	0.93
Deep	**1/20**	1.00	0.43	1.00	0.95	0.89	0.94	0.32	0.93

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus psittacus

CORAL SPECIES

SHALLOW

Acanthastrea brevis
Acanthastrea echinata
Acropora digitifera
Cyphastrea chalcidicum
C. microphthalma
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida,
Dipsastraea speciosa
Favites colemani
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Goniastrea retiformis
Goniastrea stelligera
Leptoria phrygia
Leptoseris mycetoseroides
Montipora hoffmeisteri
Montipora tuberculosa
Montipora venosa
Paragoniastrea russelli
Pavona chriquiensis
Pavona clavus
Pavona duerdeni
Pavona varians
Platygyra pini
Pocillopora verrucosa
Porites australiensis
Porites deformis
Porites lichen
Porites lobata
Porites lutea
Porites rus
Porites vaughani
Psammocora contigua
Psammocora nierstrazi
Stylocoeniella armata

DEEP

Acropora globiceps
Astreopora gracilis
Astreopora myriophthalma
Astreopora randalli
Cyphastrea chalcidicum
Cyphastrea microphthalma
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea stelligera
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Goniastrea pectinata
Leptastrea purpurea
Leptastrea transversa
Montipora hoffmeisteri
Montipora venosa
Paragoniastrea russelli
Pavona c.f. meandrina
Pavona varians
Porites australiensis
Porites lichen
Porites lobata
Porites lutea
Porites rus
Psammocora haimeana
Psammocora nierstrazi
Stylocoeniella armata

DEEP

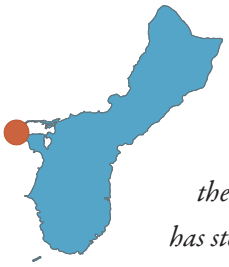
Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Cephalopholis argus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus forsteni
Scarus globiceps
Scarus psittacus
Scarus schlegeli
Zebrasoma flavescens

SHALLOW SCORE: **HIGH**

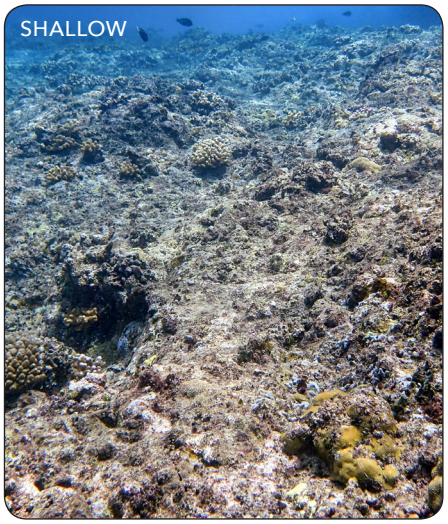
13.446° N, 144.618° E

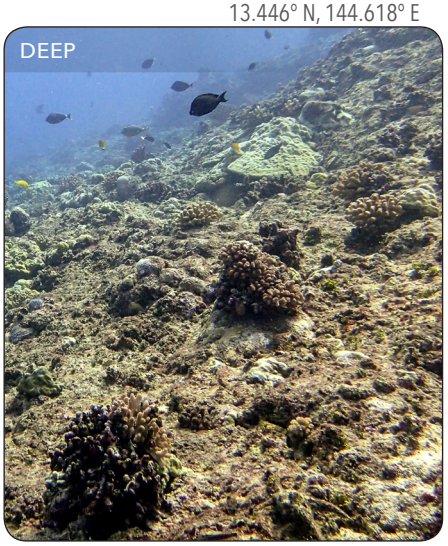
OROTE POINT

4 – Shallow, 7 – Deep



Surrounding Apra Harbor, the Orote Peninsula has steep drop-offs that plunge from shallow reefs to 50 m depths.





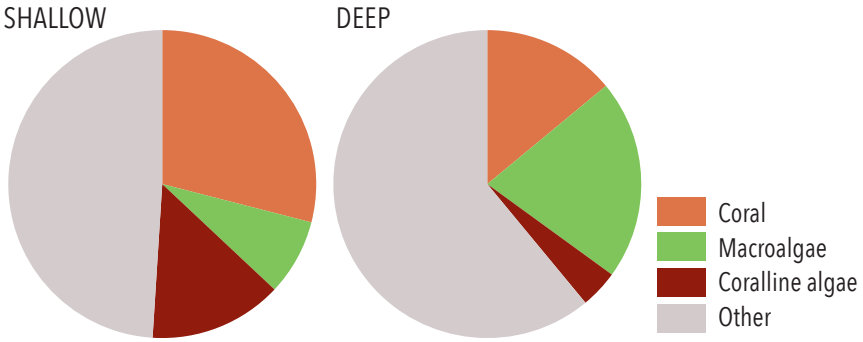
DEEP SCORE: **MED-HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**4/18**	0.94	0.66	0.75	0.93	0.75	1.00	0.15	0.83
Deep	**7/20**	0.86	0.27	0.64	0.88	0.85	0.89	0.36	0.83

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus triostegus
Aphareus furca
Chlorurus sordidus
Ctenochaetus striatus
Monotaxis grandoculis
Naso lituratus
Naso vlamingii
Scarus psittacus
Scarus schlegeli
Zebrasoma flavescens
Zebrasoma veliferum

CORAL SPECIES

SHALLOW

Acanthastrea brevis
Acropora palmerae
Acropora surculosa
Astrea curta
Cyphastrea microphthalma
Dipsastraea matthaii
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Goniastrea stelligera
Hydnophora microconos
Leptastrea purpurea
Leptoria phrygia
Montipora efflorescens
Montipora grisea
Montipora hoffmeisteri
Montipora tuberculosa
Pavona varians
Platygyra pini
Pocillopora ankeli
Pocillopora elegans
Pocillopora eydouxi
Pocillopora verrucosa
Porites lobata
Porites lutea
Psammocora haimeana

DEEP

Acanthastrea brevis
Acropora gemmifera
Acropora globiceps
Astreopora listeri
Astreopora myriophthalma
Astreopora ocellata
Cyphastrea serailia
Dipsastraea helianthoides
Dipsastraea maritima
Dipsastraea matthaii
Favites colemani
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Leptastrea purpurea
Montipora grisea
Montipora nodosa
Montipora verrucosa
Pavona meandrina
Pavona varians
Pocillopora verrucosa
Porites australiensis
Porites lutea
Psammoccora haimeana
Scapophyllia cylindrica

DEEP

Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus triostegus
Aphareus furca
Calotomus carolinus
Caranx melampygus
Chlorurus sordidus
Ctenochaetus striatus
Monotaxis grandoculis
Naso brevirostris
Naso lituratus
Naso unicornis
Naso vlamingii
Scarus forsteni
Scarus psittacus
Scarus schlegeli
Zebrasoma flavescens

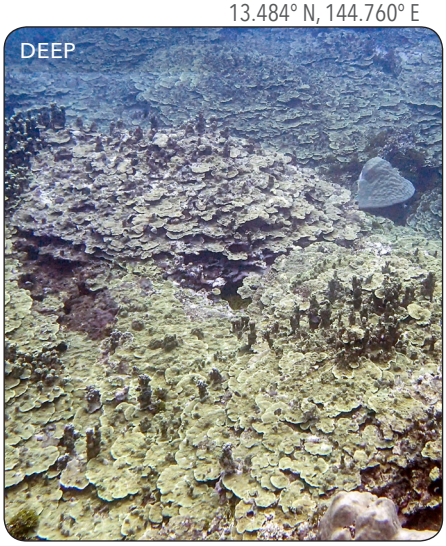
SHALLOW SCORE: **MED-HIGH**

HAGÅTÑA BAY

13.484° N, 144.760° E

5 – Shallow, 6 – Deep

The capital of Guam, Hagåtña is derived from the Chamorro word ***haga,*** *which means blood and is thought to represent the bloodlines of the families that established the village.*



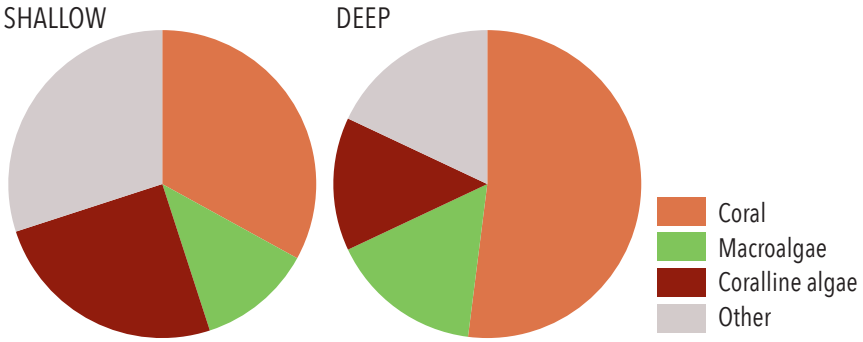
DEEP SCORE: **MED-HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**5/18**	0.93	0.78	0.43	0.92	0.89	0.96	0.18	0.89
Deep	**6/20**	0.88	1.00	0.47	0.39	1.00	0.94	0.10	0.89

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Carangoides ferdau
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Naso unicornis
Scarus psittacus
Scomberoides lysan

CORAL SPECIES

SHALLOW

Acanthastrea echinata
Astrea curta
Astreopora myriophthalma
Dipsastraea favus
Dipsastraea maritima
Dipsastraea pallida
Favites colemani
Favites valenciennesi
Galaxea fascicularis
Goniastrea retiformis
Goniastrea stelligera
Hydnophora microconos
Leptastrea purpurea
Leptoria phrygia
Millepora platyphyllia
Montipora aequituberculata
Montipora caliculata
Montipora danae
Montipora efflorescens
Montipora tuberculosa
Montipora venosa
Pavona clavus
Pavona varians
Pocillopora damicornis
Porites deformis
Porites lutea
Porites rus
Stylocoeniella armata

DEEP

Galaxea fascicularis
Pocillopora verrucosa
Porites monticulosa
Porites rus
Porites vaughani
Psammocora profundacella

DEEP

Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Lutjanus fulvus
Monotaxis grandoculis
Naso lituratus
Naso unicornis
Scarus psittacus
Zebrasoma flavescens

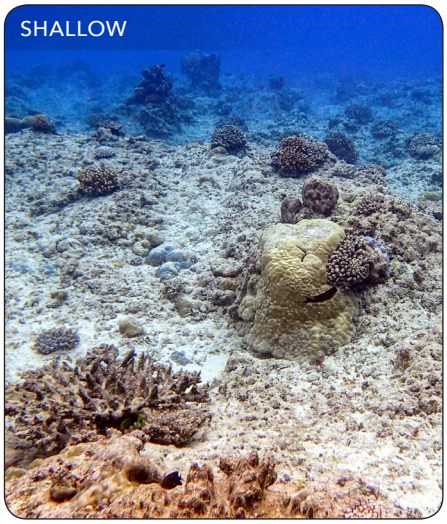
SHALLOW SCORE: **MED-HIGH**

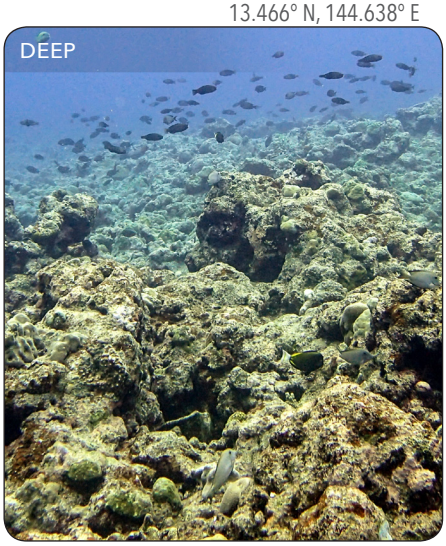
13.466° N, 144.638° E

LUMINAO REEF

6 – Shallow, 3 – Deep

Enclosing Apra Harbor, Luminao Reef has the Glass Breakwater built atop it. ***Luminao*** *is Chamorro for earthquake, named for the sound the waves make while breaking.*





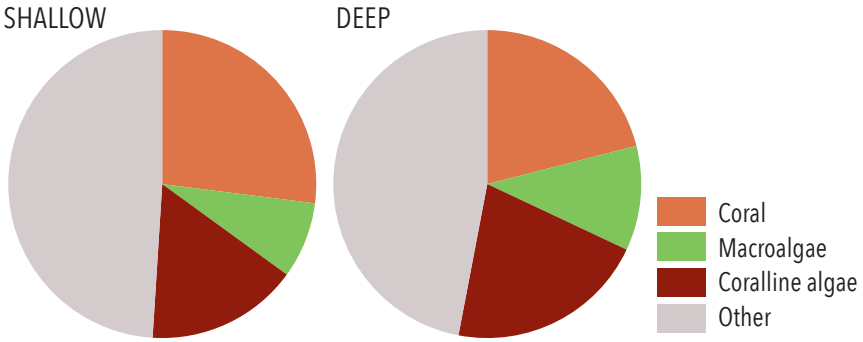
DEEP SCORE: **HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**6/18**	0.91	0.62	1.00	0.72	0.66	0.99	0.08	0.86
Deep	**3/20**	0.93	0.41	0.41	0.98	0.91	1.00	0.54	0.86

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigrofuscus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus psittacus
Zebrasoma veliferum

CORAL SPECIES

SHALLOW

Acanthastrea echinata
Acropora surculosa
Astrea curta
Cyphastrea microphthalma
Favia stelligera
Galaxea fascicularis
Goniastrea retiformis
Hydnophora microconos
Leptastrea purpurea
Leptoria phrygia
Montipora foveolata
Montipora grisea
Montipora tuberculosa
Montipora verrucosa
Pavona varians
Platygyra pini
Pocillopora elegans
Porites australiensis
Porites lobata

DEEP

Astreopora myriophthalma
Coscinaraea columna
Cycloseris vaughani
Cyphastrea chalcidicum
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Goniastrea retiformis
Goniastrea stelligera
Herpolitha weberi
Leptastrea purpurea
Leptoria phrygia
Lobophyllia hemprichii
Montipora tuberculosa
Paragoniastrea russelli
Pavona clavus
Pavona varians
Porites australiensis
Porites lobata
Porites lutea
Porites rus
Porites vaughani
Psammocora haimeana
Psammocora nierstrazi
Stylocoeniella armata

DEEP

Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus olivaceus
Aphareus furca
Calotomus carolinus
Cetoscarus bicolor
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Lutjanus fulvus
Naso lituratus
Naso vlamingii
Scarus globiceps
Scarus psittacus
Scarus schlegeli
Zebrasoma flavescens

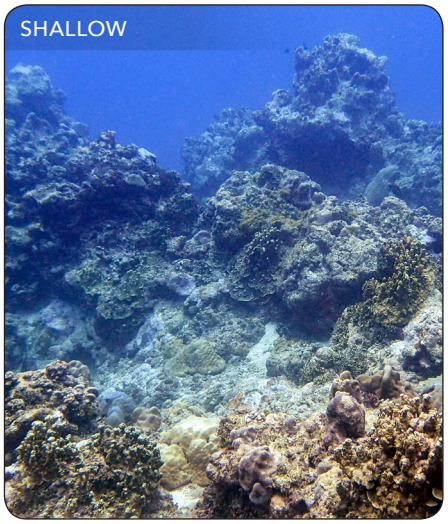
SHALLOW SCORE: **MED-HIGH**

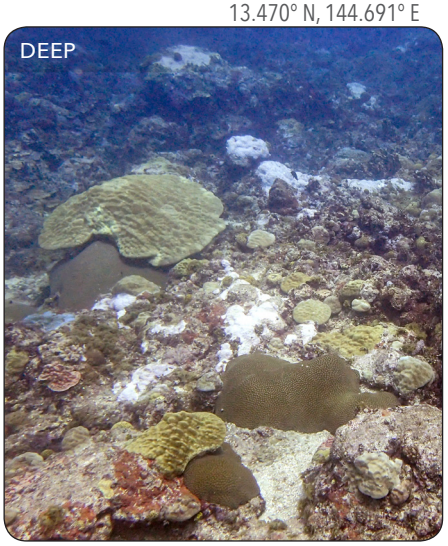
13.470° N, 144.691° E

TEPUNGAN BAY

7 – Shallow, 10 – Deep

Also known as Piti Bay, this is one of Guam's marine protected areas and the location of The Fish Eye Observatory.



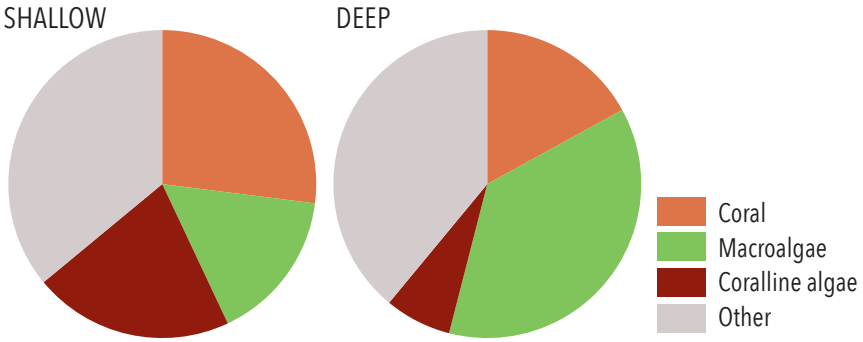


RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**7/18**	0.88	0.64	0.28	0.96	0.92	0.91	0.17	0.87
Deep	**10/20**	0.81	0.33	0.37	0.98	0.91	0.71	0.27	0.87

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Calotomus carolinus
Caranx melampygus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Kyphosus cinerascens
Lutjanus fulvus
Macolor macularis
Monotaxis grandoculis
Naso lituratus
Naso unicornis
Scarus altipinnis
Scarus forsteni
Scarus globiceps
Scarus psittacus
Scarus schlegeli
Zebrasoma veliferum

CORAL SPECIES

SHALLOW

Acanthastrea brevis
Acanthastrea echinata
Acropora abrotenoides
Acropora surculosa
Astreopora listeria
Astreopora myriophthalma
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites valenciennesi
Galaxea fascicularis
Goniastrea retiformis
Goniastrea stelligera
Leptastrea purpurea
Leptoria phrygia
Lobophyllia corymbosa
Pavona chriquiensis
Pavona varians
Platygyra pini
Pocillopora coniculus
Pocillopora damicornis
Pocillopora verrucosa
Porites australiensis
Porites horizontalata
Porites lobata
Porites lutea
Psammocora nierstrazi
Stylocoeniella armata

DEEP

Acropora globiceps
Cyphastrea microphthalma
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites colemani
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Goniastrea pectinata
Goniastrea stelligera
Leptastrea purpurea
Lobactis scutaria
Paragoniastrea russelli
Pavona chriquiensis
Pavona varians
Pocillopora coniculus
Pocillopora verrucosa
Porites australiensis
Porites lobata
Porites lutea
Porites rus
Psammocora haimeana
Stylocoeniella armata

DEEP

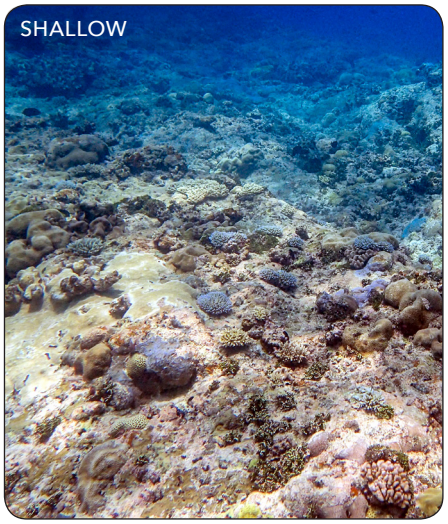
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus pyroferus
Aphareus furca
Calotomus carolinus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Hipposcarus longiceps
Lutjanus bohar
Macolor macularis
Monotaxis grandoculis
Naso lituratus
Plectropomus laevis
Scarus altipinnis
Scarus fuscocaudalis
Scarus psittacus
Scarus schlegeli
Zebrasoma flavescens
Zebrasoma scopas

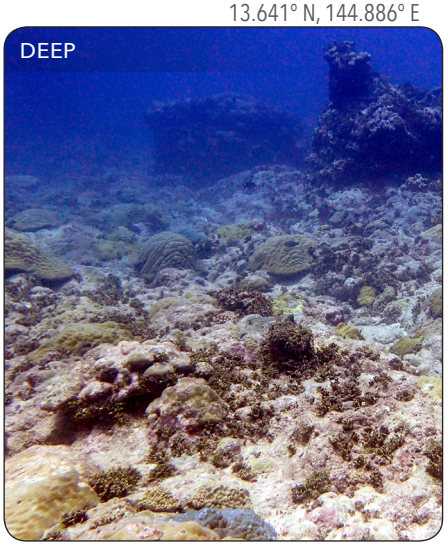
13.641° N, 144.886° E

JINAPSAN BEACH

8 – Shallow, 9 – Deep

Located on the Anderson Air Force Base, this is one of Guam's well known turtle nesting beaches





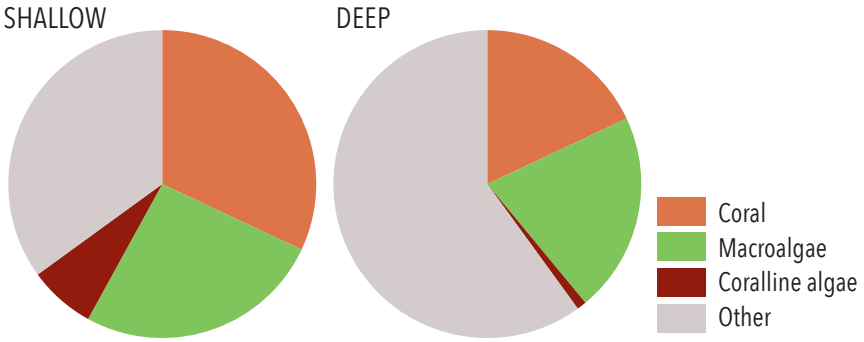
DEEP SCORE: **MED-HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**8/18**	0.84	0.75	0.48	0.97	0.43	0.81	0.08	1.00
Deep	**9/20**	0.82	0.34	0.40	0.95	0.75	0.89	0.18	1.00

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus blochii
Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus pyroferus
Aphareus furca
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Naso unicornis
Scarus forsteni

CORAL SPECIES

SHALLOW

Acanthastrea echinata
Acropora cerealis
Acropora globiceps
Acropora vaughani
Astrea curta
Astreopora myriophthalma
Cyphastrea microphthalma
Dipsastraea favus
Dipsastraea matthaii
Dipsastraea pallida
Echinophyllia echinata
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Isopora cuneate
Leptastrea purpurea
Montipora efflorescens
Montipora floweri
Montipora grisea
Montipora hoffmeisteri
Montipora monasteriata
Montipora nodosa
Montipora tuberculosa
Pavona varians
Platygyra pini
Pocillopora meandrina
Pocillopora verrucosa
Porites australiensis
Porites lutea
Porites vaughani

DEEP

Acropora globiceps
Acropora surculosa
Astreopora myriophthalma
Cyphastrea serailia
Dipsastraea danai
Dipsastraea favus
Dipsastraea heliathoides
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Dipsastraea speciosa
Favites colemani
Goniastrea edwardsi
Leptastrea purpurea
Montipora grisea
Montipora hoffmeisteri
Montipora nodosa
Montipora venosa
Paragoniastrea russelli
Pavona varians
Platygyra pini
Pocillopora verrucosa
Porites australiensis
Porites lichen
Porites lutea
Stylophora pistillata

DEEP

Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus binotatus
Ctenochaetus striatus
Lutjanus bohar
Naso lituratus
Scarus globiceps
Scarus psittacus
Siganus argenteus

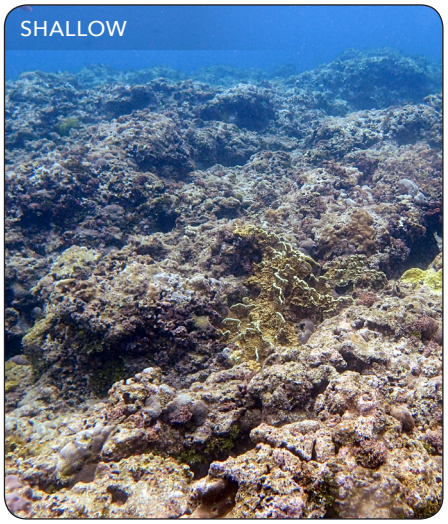
SHALLOW SCORE: **MED-LOW**

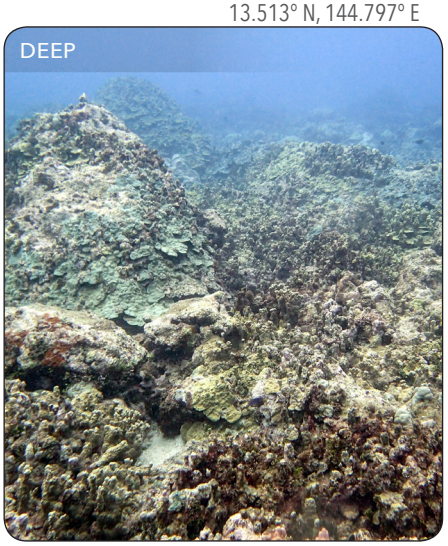
13.513° N, 144.797° E

TUMON BAY

9 – Shallow, 5 – Deep

*The original meaning of the word **Tumon** has been lost; the Tumon area is Guam's primary tourism district.*





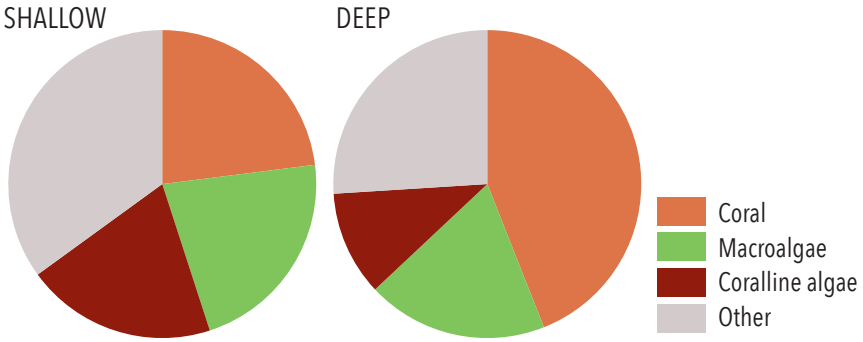
DEEP SCORE: **HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**9/18**	0.84	0.55	0.44	0.92	0.69	0.85	0.12	0.95
Deep	**5/20**	0.93	0.86	0.51	0.68	0.97	0.91	0.18	0.95

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus globiceps
Scarus psittacus
Scomberoides lysan

CORAL SPECIES

SHALLOW

Acanthastrea echinata
Acropora digitifera
Acropora surculosa
Dipsastraea matthaii
Galaxea fascicularis
Goniastrea retiformis
Goniastrea stelligera
Goniopora fruticose
Leptastrea purpurea
Leptastrea transversa
Leptoria phrygia
Pavona varians
Platygyra pini
Pocillopora damicornis
Pocillopora setchelli
Pocillopora verrucosa
Porites australiensis
Porites lobata
Porites rus
Psammocora nierstrazi
Stylocoeniella armata

DEEP

Cyphastrea serailia
Dipsastraea speciosa
Favites colemani
Goniastrea edwardsi
Goniastrea retiformis
Goniopora minor
Leptastrea purpurea
Merulina ampliata
Millepora dichotoma
Millepora platyphyllia
Paragoniastrea russelli
Pavona varians
Pocillopora verrucosa
Porites australiensis
Porites horizontalata
Porites lichen
Porites lobata
Porites lutea
Porites rus
Psammocora nierstrazi
Psammocora profundacella
Stylocoeniella armata

DEEP

Acanthurus nigricans
Acanthurus nigrofuscus
Aphareus furca
Cephalopholis argus
Chlorurus sordidus
Ctenochaetus striatus
Elagatis bipinnulata
Lutjanus fulvus
Macolor niger
Monotaxis grandoculis
Naso lituratus
Scarus forsteni
Zebrasoma flavescens

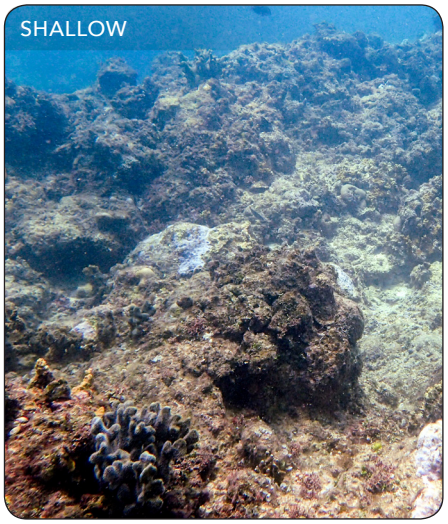
SHALLOW SCORE: **MED-LOW**

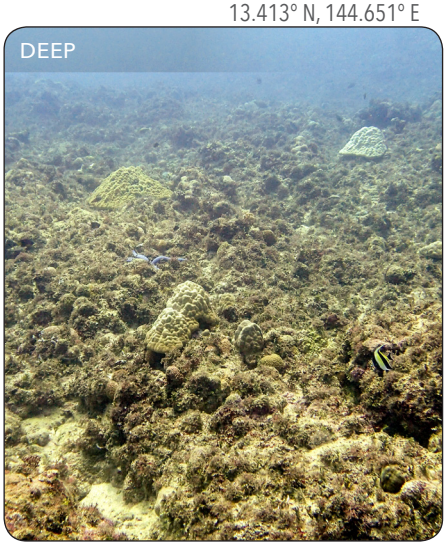
13.413° N, 144.651° E

DADI BEACH

10 – Shallow, 12 – Deep

This is the site of the Orote Village, which persisted well into the 17th century and is now located on the Naval Base of Guam.



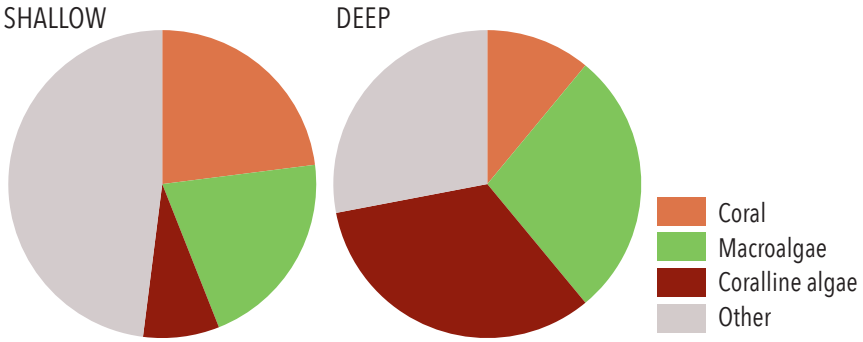


RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**10/18**	0.82	0.53	0.42	0.77	1.00	0.86	0.08	0.77
Deep	**12/20**	0.76	0.20	0.61	0.94	0.68	0.81	0.16	0.77

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigricans
Acanthurus nigrofuscus
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Naso unicornis
Scarus psittacus

CORAL SPECIES

SHALLOW

Dipsastraea danai
Dipsastraea maritima
Favites valenciennesi
Goniastrea edwardsi
Goniastrea pectinate
Goniastrea retiformis
Heliopora coerula
Leptastrea purpurea
Pavona chriquiensis
Pavona clavus
Pavona varians
Porites australiensis
Porites deformis
Porites horizontalata
Porites lichen
Porites lobata
Porites lutea
Porites rus
Porites vaughani
Stylocoeniella armata
Stylophora pistillata

DEEP

Astreopora myriophthalma
Astreopora ocellata
Astreopora randalli
Cyphastrea microphthalma
Cyphastrea serailia
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Favites colemani
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Leptastrea purpurea
Montipora nodosa
Montipora verrucosa
Pavona varians
Pocillopora damicornis
Pocillopora danae
Pocillopora eydouxi
Pocillopora setchelli
Pocillopora verrucosa
Porites australiensis
Porites deformis
Porites lichen
Porites lobata
Porites lutea
Porites rus
Psammocora haimeana
Psammocora nierstrazi
Stylocoeniella armata
Stylocoeniella guentheri

DEEP

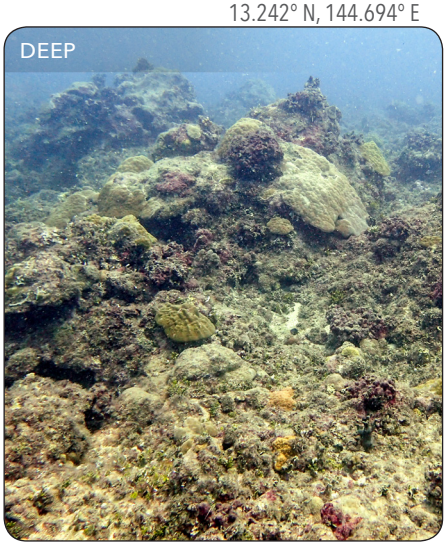
Acanthurus nigrofuscus
Calotomus carolinus
Chlorurus sordidus
Monotaxis grandoculis
Naso lituratus
Naso unicornis
Naso vlamingii
Scarus forsteni
Scarus psittacus
Scarus schlegeli

13.242° N, 144.694° E

MANELL CHANNEL

11 – Shallow, 16 – Deep

The channel provides access to Guam's southern reefs via a small boat ramp.

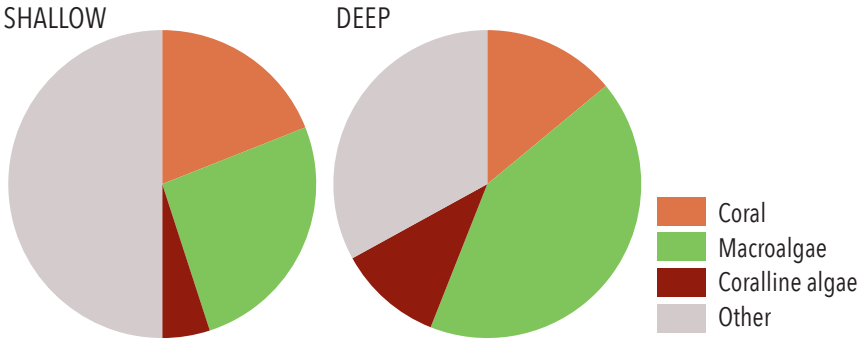


RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**11/18**	0.81	0.45	0.41	0.98	0.91	0.80	0.07	0.77
Deep	**16/20**	0.74	0.28	0.30	1.00	0.70	0.66	0.31	0.77

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus olivaceus
Calotomus carolinus
Caranx melampygus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus psittacus
Scarus schlegeli
Siganus spinus

CORAL SPECIES

SHALLOW

Acanthastrea brevis
Acanthastrea echinata
Acropora globiceps
Astreopora myriophthalma
Cyphastrea chalcidicum
Cyphastrea serailia
Diploastrea heliopora
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Dipsastraea rotundata
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Goniastrea retiformis
Goniopora fruticose
Leptastrea purpurea
Leptoria phrygia
Montipora efflorescen
Pavona varians
Pocillopora damicornis
Porites australiensis
Porites lichen
Porites lutea
Porites rus
Stylocoeniella armata
Stylophora pistillata

DEEP

Acanthastrea brevis
Acanthastrea echinata
Astreopora myriophthalma
Astreopora ocellata
Astreopora randalli
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Goniastrea pectinate
Goniastrea retiformis
Goniopora fruticose
Leptastrea purpurea
Montipora verrucosa
Paragoniastrea russelli,
Pavona varians
Pocillopora damicornis
Pocillopora meandrina
Pocillopora verrucosa
Porites australiensis
Porites lichen
Porites lobata
Porites lutea
Porites vaughani
Psammocora haimeana
Scapophyllia cylindrical
Stylocoeniella armata

DEEP

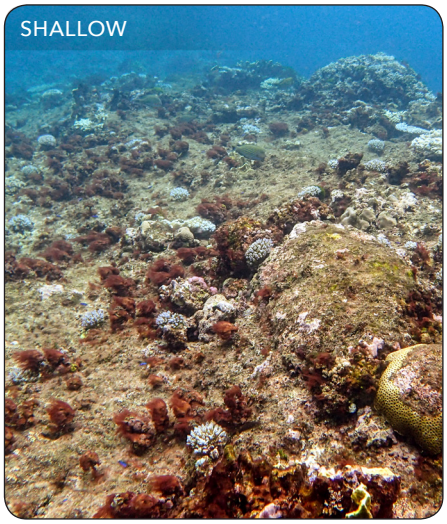
Acanthurus nigrofuscus
Acanthurus olivaceus
Aphareus furca
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus binotatus
Ctenochaetus striatus
Macolor macularis
Monotaxis grandoculis
Naso lituratus
Plectropomus laevis
Scarus psittacus
Scarus schlegeli
Siganus argenteus
Siganus spinus
Zebrasoma scopas

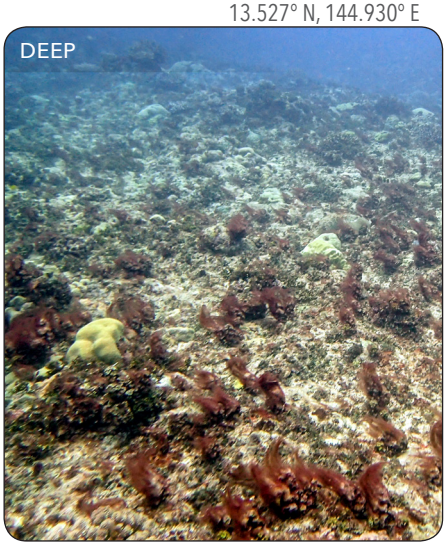
13.527° N, 144.930° E

JANOM POINT

12 – Shallow, 13 – Deep

Janom is the Chamorro word for water; this area has significant freshwater springs.





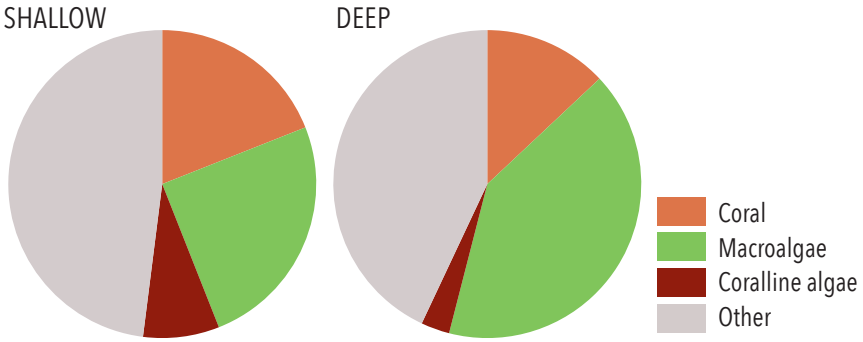
DEEP SCORE: **MED-LOW**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**12/18**	0.80	0.45	0.53	0.91	0.63	0.81	0.05	0.91
Deep	**13/20**	0.76	0.26	0.63	0.97	0.68	0.66	0.06	0.91

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus blochii
Acanthurus guttatus
Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus triostegus
Aphareus furca
Calotomus carolinus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus globiceps
Scarus psittacus

CORAL SPECIES

SHALLOW

Acanthastrea brevis
Acanthastrea echinata
Acropora azurea
Acropora cerealis
Acropora monticulosa
Acropora surculosa
Astreopora myriophthalma
Astrea curta
Cyphastrea microphthalma
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Galaxea fascicularis
Goniastrea retiformis
Goniastrea stelligera
Leptastrea purpurea
Leptoria phrygia
Montipora grisea
Montipora hoffmeisteri
Montipora tuberculosa
Paragoniastrea russelli
Pavona varians
Platygyra pini
Pocillopora verrucosa
Porites lutea
Psammocora nierstrazi

DEEP

Acanthastrea echinata
Acropora cf. quelchi
Acropora gemmifera
Acropora globiceps
Acropora tenuis
Acropora verweyi
Astreopora listeria
Astreopora myriophthalma
Cyphastrea chalcidicum
Cyphastrea microphthalma
Dipsastraea danai
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Goniastrea stelligera
Leptastrea purpurea
Montipora grisea
Montipora hoffmeisteri
Montipora nodosa
Montipora tuberculosa
Pavona varians
Pocillopora meandrina
Pocillopora verrucosa
Porites australiensis
Porites lichen
Porites lobata
Porites lutea
Porites vaughani
Stylocoeniella armata
Stylophora pistillata

DEEP

Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus triostegus
Acanthurus xanthopterus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus binotatus
Ctenochaetus striatus
Paracanthurus hepatus

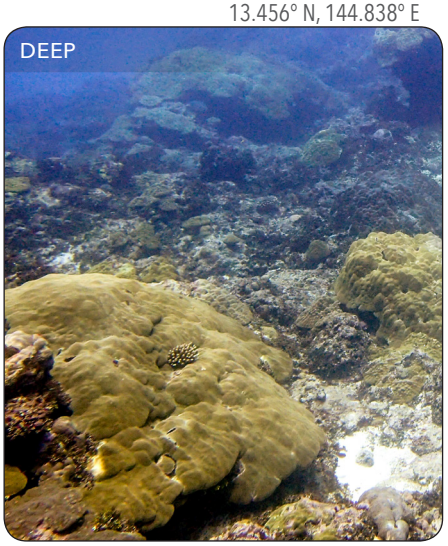
SHALLOW SCORE: **MED-LOW**

13.456° N, 144.838° E

MANGILAO GOLF COURSE

13 – Shallow, 11 – Deep

Located just off the Mangilao Golf Course, this reef bench provides an optimal place for reef growth despite the harsh environmental conditions on the windward coast.



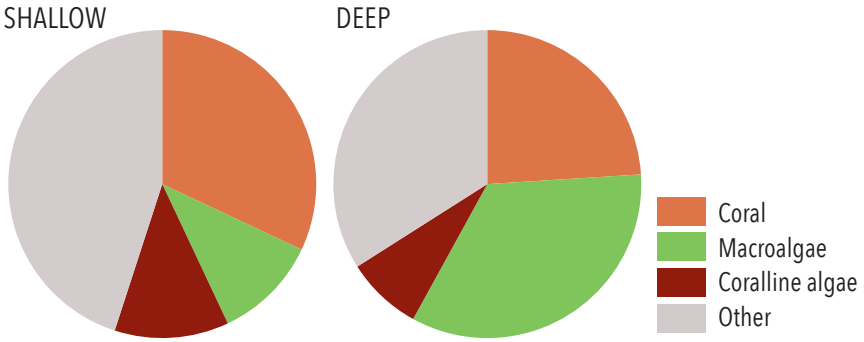
DEEP SCORE: **MED-LOW**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**13/18**	0.78	0.74	0.12	0.95	0.48	0.97	0.08	0.88
Deep	**11/20**	0.79	0.46	0.21	0.99	0.79	0.74	0.24	0.88

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus blochii
Acanthurus guttatus
Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus triostegus
Aprion virescens
Calotomus carolinus
Chlorurus frontalis
Chlorurus sordidus
Ctenochaetus striatus
Lethrinus harak
Naso lituratus
Scarus psittacus
Siganus spinus

CORAL SPECIES

SHALLOW

Acanthastrea echinata
Acropora azurea
Acropora cf. paniculata
Acropora gemmifera
Acropora robusta
Acropora surculosa
Astrea curta
Dipsastraea favus
Dipsastraea matthaii
Dipsastraea pallida
Favites colemani
Galaxea fascicularis
Goniastrea retiformis
Goniastrea stelligera
Leptoria phrygia
Millepora platyphyllia
Montipora tuberculosa
Paragoniastrea russelli
Pavona varians
Pocillopora meandrina

DEEP

Acropora surculosa
Astreopora myriophthalma
Astreopora ocellata
Cyphastrea microphthalma
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites colemani
Galaxea fascicularis
Goniastrea edwardsi
Goniastrea stelligera
Goniopora fruticose
Leptastrea purpurea
Montipora foveolata
Paragoniastrea russelli
Platygyra daedalea
Pocillopora danae
Porites australiensis
Porites horizontalata
Porites lichen
Porites lobata
Porites lutea
Porites deformis
Psammocora haimeana
Psammocora nierstrazi
Stylocoeniella armata

DEEP

Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus pyroferus
Acanthurus triostegus
Aphareus furca
Calotomus carolinus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Gymnocranius sp.
Kyphosus cinerascens
Lutjanus fulvus
Lutjanus monostigma
Macolor macularis
Naso lituratus
Plectorhinchus vittatus
Scarus forsteni
Scarus globiceps
Scarus psittacus
Scarus schlegeli
Siganus argenteus

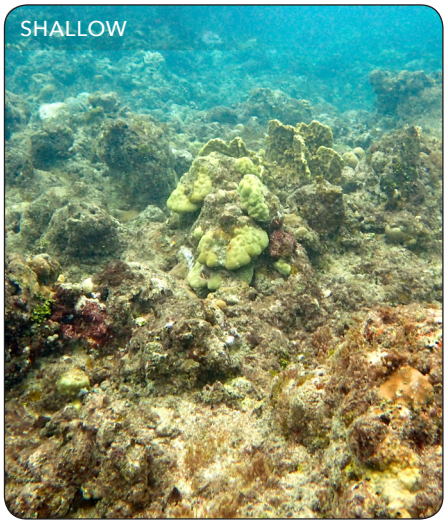
SHALLOW SCORE: **MED-LOW**

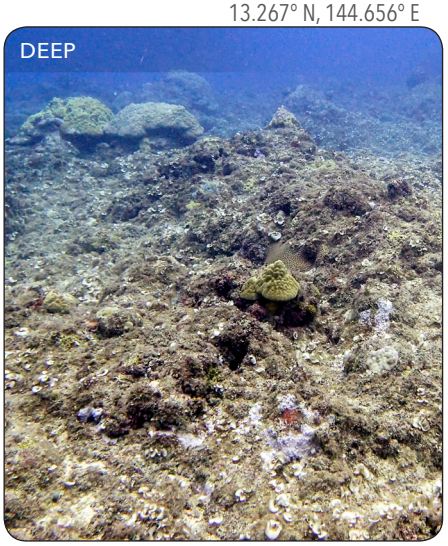
13.267° N, 144.656° E

COCOS BARRIER REEF WEST

14 – Shallow, 14 – Deep

Named after the island it surrounds, Cocos receives its name from the coconut trees that cover the tiny island. The original Chamorro name for the island is ***Islan Dåno.***



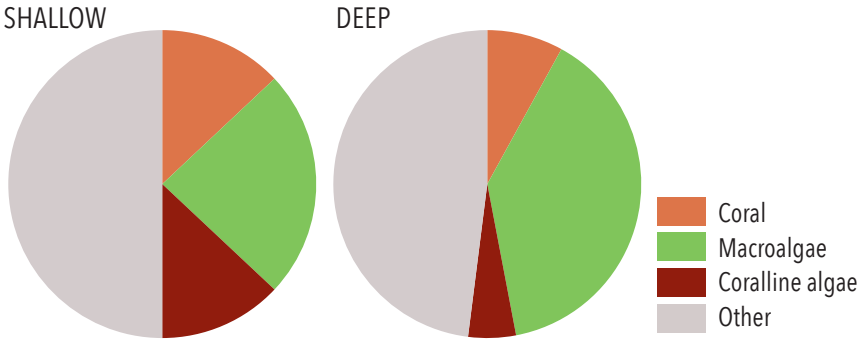


RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**14/18**	0.78	0.30	0.41	0.95	0.83	0.83	0.07	0.84
Deep	**14/20**	0.74	0.15	0.54	0.92	0.79	0.69	0.14	0.84

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus lineatus
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus olivaceus
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus globiceps
Scarus schlegeli
Siganus argenteus
Siganus spinus

CORAL SPECIES

SHALLOW

Acanthastrea echinata
Acropora globiceps
Acropora verweyi
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Goniastrea retiformis
Goniastrea stelligera
Hydnophora microconos
Leptastrea purpurea
Leptoria phrygia
Millepora platyphyllia
Pavona meandrina
Pavona varians
Porites australiensis
Porites horizontalata
Porites lichen
Porites lutea
Porites rus
Stylocoeniella armata

DEEP

Acanthastrea echinata
Astreopora listeria
Astreopora myriophthalma
Astreopora ocellata
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Favites colemani
Favites valenciennesi
Goniastrea edwardsi
Goniastrea pectinate
Goniastrea retiformis
Leptastrea purpurea
Paragoniastrea russelli
Pavona varians
Porites australiensis
Porites lobata
Porites lutea
Psammocora haimeana
Stylocoeniella armata

DEEP

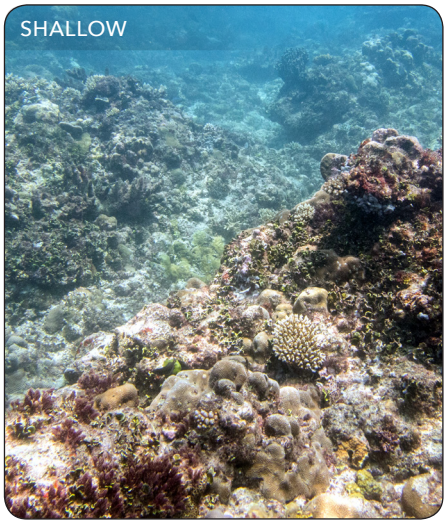
Acanthurus nigrofuscus
Aphareus furca
Calotomus carolinus
Carcharhinus melanopterus
Chlorurus sordidus
Ctenochaetus striatus
Gnathodentex aureolineatus
Lutjanus bohar
Monotaxis grandoculis
Naso lituratus
Naso unicornis
Naso vlamingii
Scarus psittacus
Scarus schlegeli
Zebrasoma flavescens

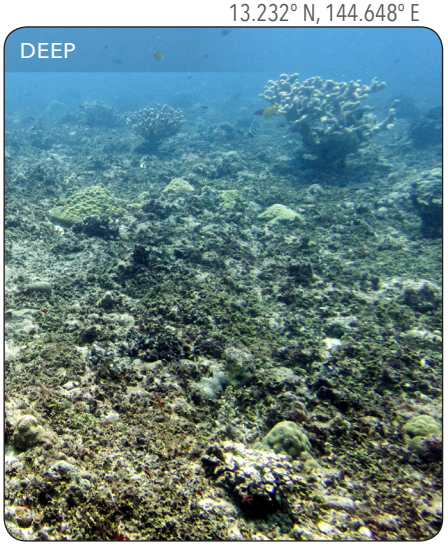
13.232° N, 144.648° E

COCOS BARRIER REEF EAST

15 – Shallow, 20 – Deep

Named after the island it surrounds, Cocos receives its name from the coconut trees that cover the tiny island. The original Chamorro name for the island is ***Islan Dåno.***





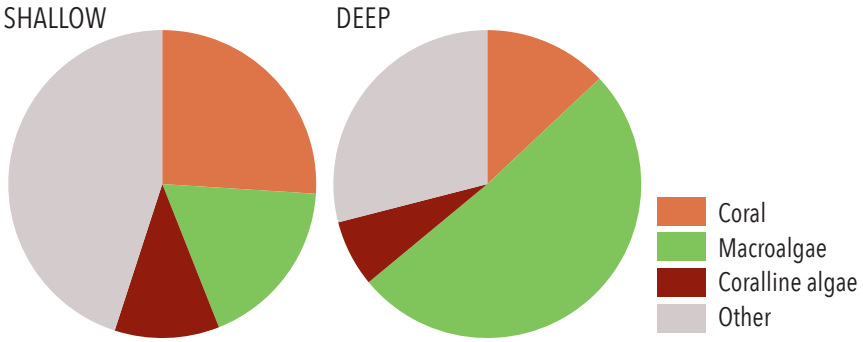
DEEP SCORE: **LOW**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**15/18**	0.78	0.60	0.19	0.99	0.67	0.89	0.07	0.78
Deep	**20/20**	0.64	0.26	0.32	0.92	0.53	0.56	0.12	0.78

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigricans
Acanthurus nigrofuscus
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus striatus
Lutjanus bohar
Naso lituratus
Scarus psittacus
Scarus schlegeli
Siganus spinus

CORAL SPECIES

SHALLOW

Acropora azurea
Acropora cerealis
Acropora cophodactyla
Acropora digitifera
Acropora surculosa
Acropora verweyi
Astrea curta
Cyphastrea chalcidicum
Dipsastraea favus
Dipsastraea maritima
Dipsastraea pallida
Favites colemani
Galaxea fascicularis
Goniastrea edwardsi
Goniastrea retiformis
Goniastrea stelligera
Goniopora fruticose
Heliopora coerula
Leptoria phrygia
Leptoseris mycetoseroides
Millepora platyphyllia
Montipora hoffmeisteri
Montipora tuberculosa
Pocillopora ankeli
Pocillopora eydouxi
Porites australiensis
Porites deformis
Porites lichen
Porites lobata
Porites vaughani
Psammocora nierstrazi

DEEP

Astreopora listeria
Astreopora myriophthalma
Astreopora randalli
Cyphastrea microphthalma
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Favites colemani
Galaxea fascicularis
Goniastrea edwardsi
Heliopora coerula
Leptastrea purpurea
Leptoseris incrustans
Montipora nodosa
Montipora tuberculosa
Montipora verrucosa
Pavona varians
Platygyra daedalea
Platygyra pini
Pocillopora verrucosa
Porites australiensis
Porites lutea
Psammocora haimeana
Stylocoeniella armata

DEEP

Acanthurus nigrofuscus
Acanthurus olivaceus
Chlorurus sordidus
Ctenochaetus binotatus
Ctenochaetus striatus
Ctenochaetus strigosus
Naso lituratus
Scarus fuscocaudalis
Scarus psittacus
Scarus schlegeli
Siganus argenteus
Zebrasoma flavescens

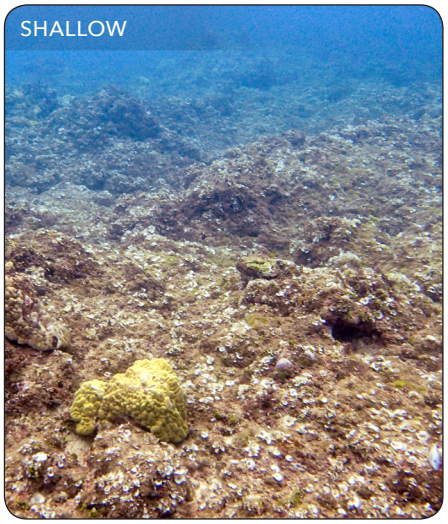
SHALLOW SCORE: **MED-LOW**

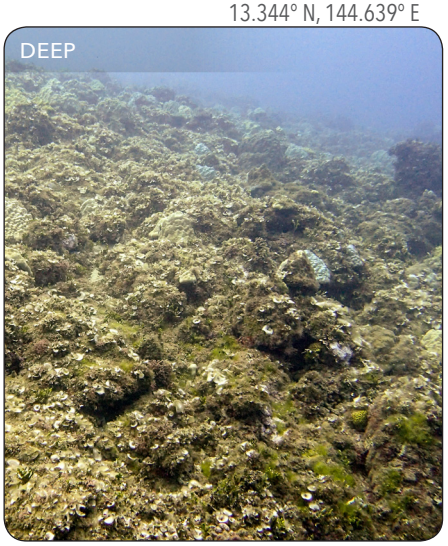
13.344° N, 144.639° E

FACPI POINT

16 – Shallow, 19 – Deep

A prominent feature of southwestern Guam, the Point contains a massive stack of black coralline limestone, resulting from a volcanic eruption. ***Facpi*** *is the Chamorro word for the Pacific frigate bird (****Fregata minor minor****).*





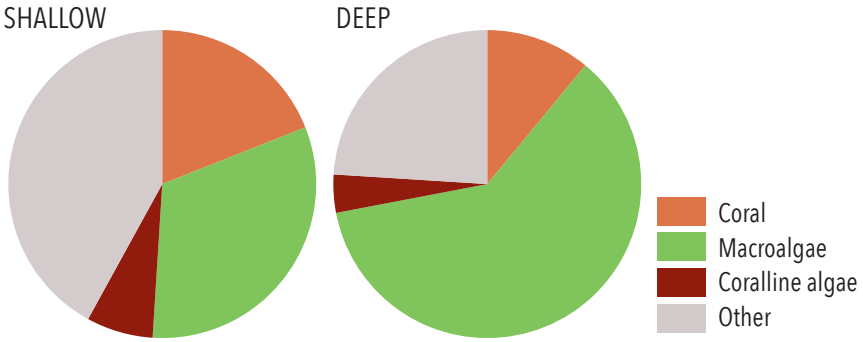
DEEP SCORE: **LOW**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**16/18**	0.77	0.44	0.30	0.94	0.88	0.73	0.04	0.82
Deep	**19/20**	0.66	0.20	0.19	0.97	0.88	0.44	0.13	0.82

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus pyroferus
Calotomus carolinus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Scarus psittacus

CORAL SPECIES

SHALLOW

Acanthastrea brevis
Acropora cerealis
Astreopora listeria
Astreopora myriophthalma
Astreopora ocellata
Cyphastrea serailia
Dipsastraea favus
Dipsastraea matthaii
Favites colemani
Galaxea fascicularis
Leptastrea purpurea
Leptastrea transversa
Pavona varians
Porites australiensis
Porites lichen
Porites lobata
Porites lutea
Porites rus
Psammocora haimeana
Stylocoeniella armata

DEEP

Acropora globiceps
Acropora selago
Astreopora cf. gracilis
Astreopora listeria
Astreopora myriophthalma
Astreopora ocellata
Cyphastrea chalcidicum
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites valenciennesi
Goniopora minor
Leptastrea purpurea
Pavona varians
Porites australiensis
Porites lobata
Porites lutea
Porites rus
Psammocora haimeana
Psammocora nierstrazi

DEEP

Acanthurus nigrofuscus
Acanthurus olivaceus
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus binotatus
Lutjanus bohar
Monotaxis grandoculis
Naso lituratus
Scarus schlegeli
Variola louti
Zebrasoma veliferum

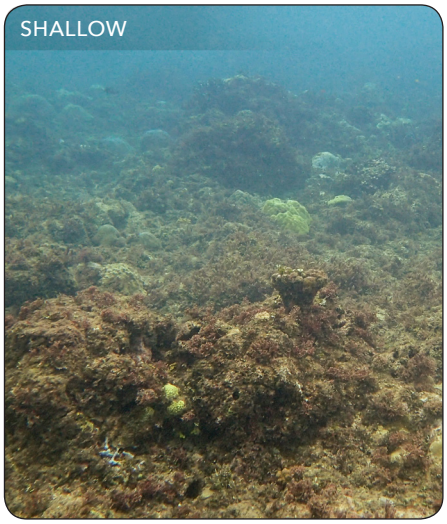
SHALLOW SCORE: **MED-LOW**

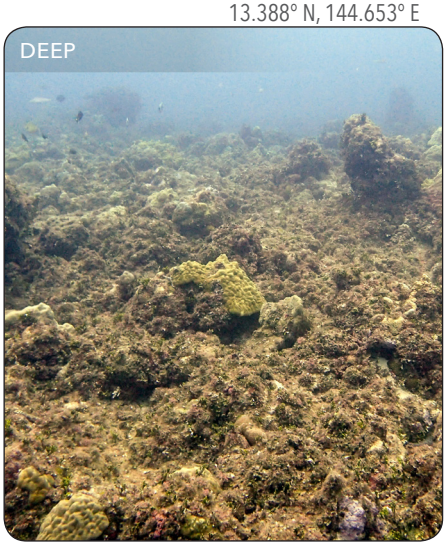
13.388° N, 144.653° E

GA'AN POINT

17 – Shallow, 17 – Deep

Ga'an Point was the site of a battle during World War II.





DEEP SCORE: **MED-LOW**

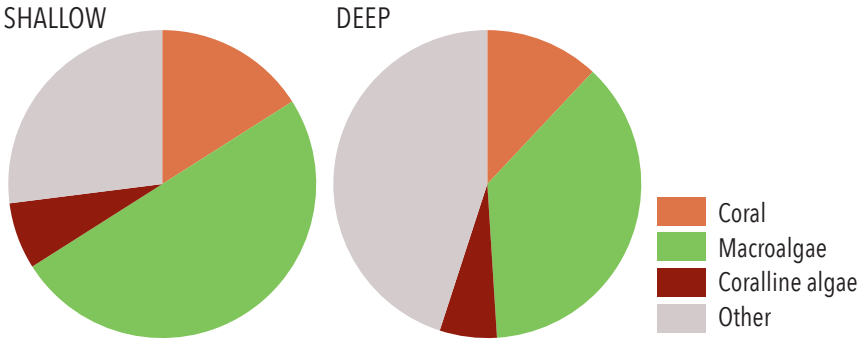
SHALLOW SCORE: **LOW**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**17/18**	0.72	0.36	0.23	0.95	0.96	0.54	0.08	0.77
Deep	**16/20**	0.72	0.24	0.31	0.89	0.94	0.71	0.09	0.77

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigrofuscus
Calotomus carolinus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Naso unicornis
Scarus globiceps
Scarus psittacus
Siganus spinus
Zebrasoma veliferum

CORAL SPECIES

SHALLOW

Dipsastraea danae
Dipsastraea favus
Dipsastraea matthaii
Echinopora pacificus
Fungia fungites
Galaxea fascicularis
Goniastrea retiformis
Heliopora coerulea
Leptastrea purpurea
Leptoria phrygia
Pavona chiriquiensis
Pavona maldivensis
Pavona sp. "albomarginata"
Pavona varians
Pocillopora damicornis
Pocillopora verrucosa
Porites lichen
Porites murrayensis
Porites rus
Porites vaughani
Psammocora contigua
Stylocoeniella armata

DEEP

Acanthastrea echinata
Acropora humilis
Astreopora myriophthalma
Astreopora randalli
Dipsastraea favus
Dipsastraea maritima
Dipsastraea pallida
Echinopora lamellosa
Favites valenciennesi
Galaxea fascicularis
Herpolitha limax
Leptastrea purpurea
Pavona varians
Pocillopora verrucosa
Porites deformis
Porites lichen
Porites lobata
Porites lutea
Porites rus
Stylocoeniella armata

DEEP

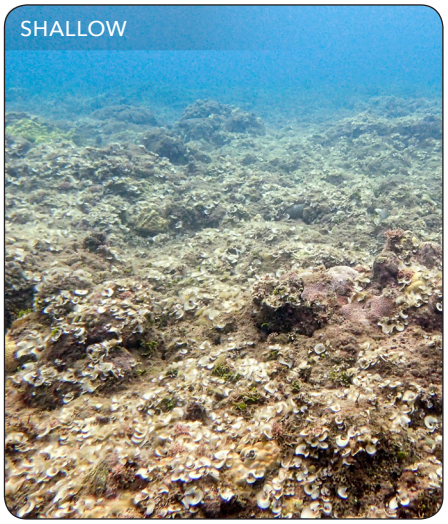
Acanthurus nigrofuscus
Acanthurus olivaceus
Aphareus furca
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus striatus
Naso lituratus
Naso unicornis
Scarus schlegeli

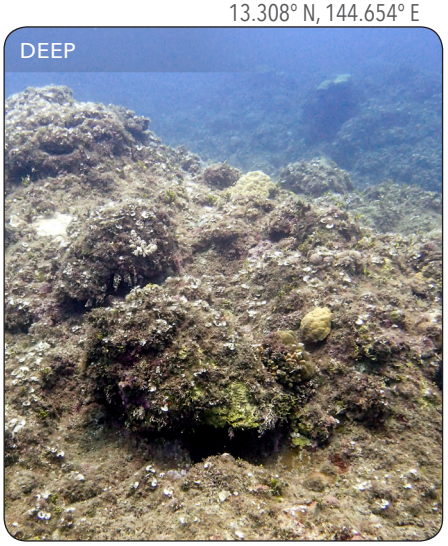
13.308° N, 144.654° E

FOUHA BAY

18 – Shallow, 18 – Deep

Fouha Bay is where the ancient Chamorro creation myth originates. The story says that the first humans emerged from Fouha Rock, which was formed by the creation gods ***Puntan*** *and* ***Fu'una.***





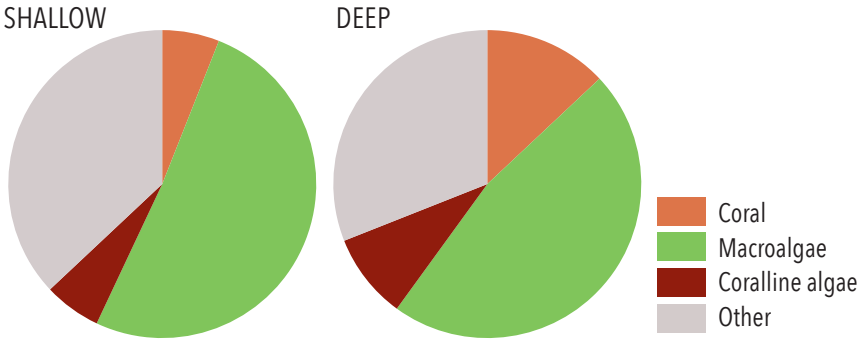
DEEP SCORE: **LOW**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**18/18**	0.62	0.14	0.13	0.74	0.94	0.54	0.04	0.82
Deep	**18/20**	0.67	0.25	0.15	0.96	0.87	0.60	0.04	0.82

High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY



FISH SPECIES

SHALLOW

Acanthurus nigricauda
Acanthurus nigrofuscus
Aphareus furca
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus striatus
Monotaxis grandoculis
Naso annulatus
Naso lituratus
Naso unicornis
Naso vlamingii
Scarus schlegeli

CORAL SPECIES

SHALLOW

Acropora humilis
Astreopora myriophthalma
Dipsastraea matthaii
Goniopora fruticosa
Leptastrea purpurea
Pavona bipartita
Porites lobata
Porites lutea
Psammocora haimeana

DEEP

Acanthastrea brevis
Astreopora myriophthalma
Astreopora randalli
Cyphastrea microphthalma
Cyphastrea serailia
Diploastrea heliopora
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea speciose
Favites valenciennesi
Goniastrea edwardsi
Goniastrea pectinata
Goniopora fruticose
Goniopora minor
Leptastrea purpurea
Montipora foveolata
Montipora verrucosa
Pavona varians
Porites lichen
Porites lobata
Porites lutea
Porites rus
Stylocoeniella armata

DEEP

Acanthurus nigricauda
Acanthurus nigrofuscus
Calotomus carolinus
Chlorurus sordidus
Ctenochaetus striatus
Epinephelus fasciatus
Epinephelus merra
Lutjanus fulvus
Monotaxis grandoculis
Naso lituratus
Naso unicornis
Scarus forsteni

SHALLOW SCORE: **LOW**

13.601° N, 144.950° E

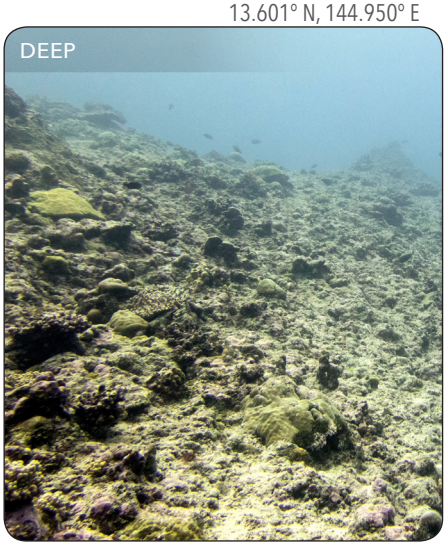
PATI POINT

N/A – Shallow, 8 – Deep

Guam's eastern most point, Pati Point is often inaccessible due to the near year-round presence of large waves.

SHALLOW

PHOTO NOT AVAILABLE



DEEP SCORE: **MED-HIGH**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Deep	**7/20**	0.84	0.38	0.41	0.98	0.69	0.94	0.33	0.85

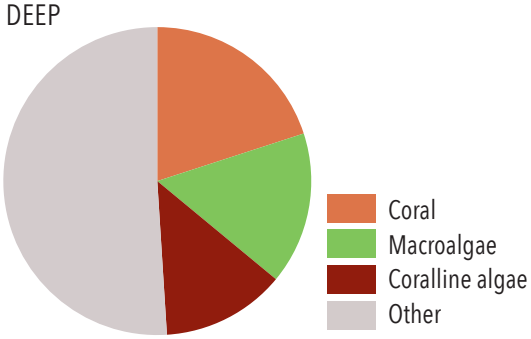
High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY

SHALLOW

N/A

DEEP



FISH SPECIES

SHALLOW

Not applicable

CORAL SPECIES

SHALLOW

Not applicable

DEEP

Acropora cerealis
Astrea curta
Astreopora myriophthalma
Astreopora ocellata
Cyphastrea chalcidicum
Cyphastrea serailia
Dipsastraea favus
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites valenciennesi
Galaxea fascicularis
Goniastrea edwardsi
Goniastrea stelligera
Leptastrea purpurea
Montipora caliculata
Montipora hoffmeisteri
Montipora nodosa
Montipora tuberculosa
Montipora verrucosa
Pavona clavus
Pavona varians
Pavona venosa
Platygyra pini
Pocillopora elegans
Porites lichen
Porites lobata
Porites lutea
Porites rus

DEEP

Acanthurus nigricans
Acanthurus nigricauda
Acanthurus nigrofuscus
Acanthurus olivaceus
Acanthurus triostegus
Acanthurus xanthopterus
Aethaloperca rogaa
Aphareus furca
Aprion virescens
Calotomus carolinus
Caranx melampygus
Cheilinus undulates
Chlorurus sordidus
Ctenochaetus striatus
Gymnosarda unicolor
Hipposcarus longiceps
Lutjanus bohar
Lutjanus monostigma
Macolor macularis
Monotaxis grandoculis
Naso hexacanthus
Naso lituratus
Naso vlamingii
Scarus forsteni
Scarus fuscocaudalis
Scarus psittacus
Scarus rubroviolaceus
Variola louti

SHALLOW SCORE: **N/A**

13.587° N, 144.952° E

LATTE POINT

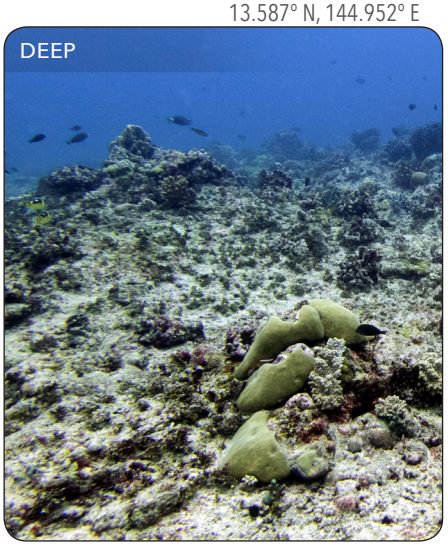
N/A – Shallow, 15 – Deep

*The **latte** is a symbol of Chamorro culture. The latte stones were architectural structures used to build ancient Chamorro homes.*

SHALLOW

PHOTO NOT AVAILABLE

DEEP



DEEP SCORE: **MED-LOW**

RELATIVE RESILIENCE

Depth	Rank	Resilience Score	Coral Cover	Coral Diversity	Coral Recruitment	Bleaching Resistance	Macroalgae Cover	Herbivorous Fish Biomass	Temperature Variability
Shallow	**N/A**	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Deep	**17/20**	0.74	0.23	0.34	0.96	0.59	0.86	0.21	0.85

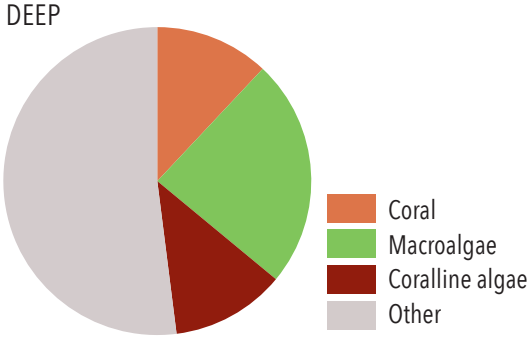
High (>avg+1 SD) Med-High (>avg and <avg+1 SD) Med-Low (<avg and >avg - 1 SD) Low (<avg - 1 SD)

BENTHIC COMMUNITY

SHALLOW

N/A

DEEP



FISH SPECIES

SHALLOW

Not applicable

CORAL SPECIES

SHALLOW

Not applicable

DEEP

Astreopora myriophthalma
Astreopora ocellata
Cyphastrea serailia
Dipsastraea maritima
Dipsastraea matthaii
Dipsastraea pallida
Favites valenciennesi
Goniastrea retiformis
Goniastrea stelligera
Heliopora coerula
Leptastrea purpurea
Lobophyllia hemprichii
Montipora caliculata
Montipora cf. venosa
Montipora hoffmeisteri
Montipora tuberculosa
Pavona clavus
Pavona varians
Pocillopora elegans
Pocillopora eydouxi
Pocillopora verrucosa,Porites australiensis
Porites lichen
Porites lutea
Porites vaughani
Stylocoeniella armata
Stylophora pistillata

DEEP

Acanthurus blochii
Acanthurus nigricans
Acanthurus nigrofuscus
Acanthurus olivaceus
Aethaloperca rogaa
Aphareus furca
Calotomus carolinus
Chlorurus microrhinos
Chlorurus sordidus
Ctenochaetus striatus
Gymnosarda unicolor
Lutjanus bohar
Macolor macularis
Naso lituratus
Naso unicornis
Naso vlamingii
Scarus psittacus
Scarus rubroviolaceus
Siganus argenteus

SHALLOW SCORE: **N/A**