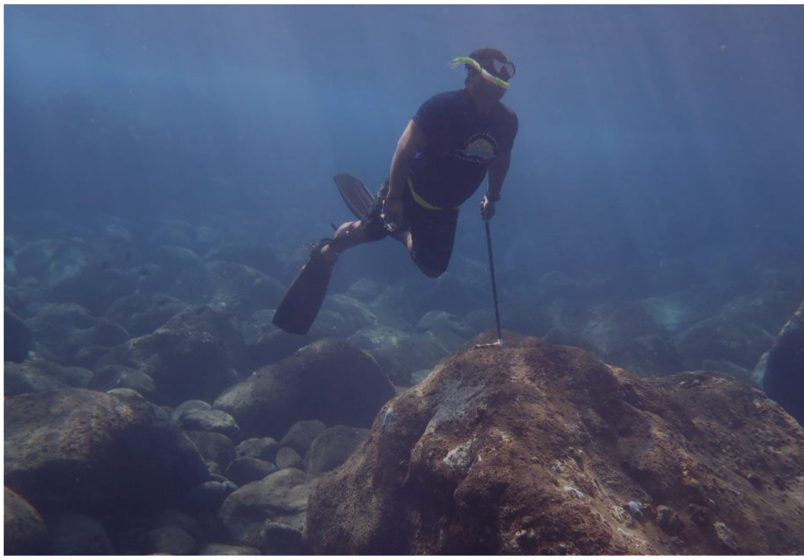



CNMI State of the Reef Report 2020 – 2021


Division of Coastal Resources Management

Bureau of Environmental and Coastal Quality

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Cover Page: First row, 1st photo: Close up of crown-of-thorns starfish at Liyang Rai Cave, Rota in 2021; first row, 2nd photo: *Tridacna* sp. taken in Pagan in 2021; second row, 1st photo: School of hamoktan or white-spotted surgeonfish (*Acanthurus guttatus*) taken in Pagan in 2021; second row, 2nd photo: Marine monitoring team member, Jordan Suel, conducting benthic surveys in Pagan in 2021; [Photo Credit: Denise Perez]. Third row: Photo of *Acropora tenuis* taken in Pagan in 2021 [Photo Credit: Rodney Camacho].

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ACRONYMS

BECQ	Bureau of Environmental and Coastal Quality
CBMA	Commonwealth Bureau of Military Affairs Office
CCA	Crustose coralline algae
CNMI	Commonwealth of the Northern Mariana Islands
CoRIS	Coral Reef Information System
COTS	Crown-of-thorns starfish
CPCe	Coral Point Count with Excel extensions
CRI	Coral Reef Initiative
DCRM	Division of Coastal Resources Management
DEM	Digital elevation model
DEQ	Department of Environmental Quality
LBSP	Land-based sources of pollution
LTMMP	Long-term marine monitoring program
MC	Micronesia Challenge
MINA	Mariana Islands Nature Alliance
MMT	Marine monitoring team
NCEI	National Centers for Environmental Information
NFWF	National Fish and Wildlife Foundation
NOAA	National Oceanographic Atmospheric Administration
PCO	Principal coordinate ordination
QA/QC	Quality assurance and quality control
SPC	Stationary point count

EXECUTIVE SUMMARY

The State of the Reef report summarizes activities conducted within the long-term marine monitoring program under the Division of Coastal Resources Management from 2020-21. Within the program, the marine monitoring team (MMT) completed > 55 field surveys encompassing coral reef, seagrass, and boulder habitat across the Northern Marians Islands, including: Rota, Aguijan, Tinian, Saipan, and Pagan. Overall, coral reefs in the CNMI are still recovering from previous mass bleaching events that caused mass coral mortality. In particular, forereef areas around Saipan and Rota have had continued decline in live coral cover due to crown-of-thorns starfish (COTS) predation during outbreaks that began in 2019. The MMT has since documented COTS densities 48x higher than the average recorded over the past twenty years. In 2021, the MMT observed a decline in reported outbreaks, but are continuing surveillance and eradication efforts as needed.

Since there has been a break in bleaching events since 2017, coral recovery has been noted at several sites including lagoon areas outside of Marianas Resort and San Antonio back reef. However, Staghorn corals, which decreased by 30.6 – 98.7% in the past ten years, have yet to recover at most of the lagoon reef sites. Seagrass cover in Saipan Lagoon is stable or increasing for many areas. However, a sharp decline in seagrass has been noted at several sites along the shoreline, such as Hafa Adai Drainage and 13 Fish *Halodule*. These two sites are located outside of the Garapan watershed area, and may be vulnerable to land-based sources of pollution.

In June 2021, the MMT was invited to join a multi-agency effort to survey Pagan's natural resources. Surveyed areas were comprised of boulder and fringing reef habitat along the west and north side of the island. The MMT documented 93 species of corals, and were able to revisit sites previously surveyed in the summer of 2014, when a mass bleaching event occurred. Unfortunately, live coral cover at revisited sites dropped from 13% to 8% cover, a decline of 38% since 2014, indicating that Pagan has yet to recover from previous coral bleaching events.

In 2020, the long-term marine monitoring program was expanded to include coral restoration as one of its objectives. The MMT led the development of a coral restoration action plan for the CNMI, in coordination with non-profit, and local and federal partners. In addition, the MMT is responsible for managing the state-funded coral nursery, which currently stocks 3 Acroporid species with planned expansion of nursery capacity and species collection in 2022.

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INTRODUCTION

The long-term marine monitoring program, established in 1996, focuses on four of the southern islands of the Commonwealth of the Northern Mariana Islands (CNMI): including Rota, Tinian, Aguijan, and Saipan. In the past ten years, CNMI's reefs have been severely impacted by ocean warming through back to back bleaching events in 2013, 2014, 2016, and 2017 (Heron et al., 2016; Reynolds et al., 2014). In addition, the CNMI has experienced two super typhoons, Soudelor in 2015 and Yutu in 2018. Although mass bleaching events have not occurred since 2017, coral reefs within the Marianas Archipelago are continuing to struggle to recover live coral cover and diversity due to multiple factors, including a crown-of-thorns outbreak that started in 2019. This report focuses on the time period, 2020-21, and documents the current status of reef and seagrass systems within the CNMI, and provides updates on recovery from the above-mentioned disturbances. The past two years have proved to be a unique period for the history of the long-term marine monitoring program (LTMMP), because of the drop in tourism and closure of popular tourist sites that reduced demand on marine resources during the Covid-19 pandemic. The marine monitoring team was able to survey 45 long-term monitoring sites, adding to the 20-year record established by the LTMMP (Figure 1). The additional data for this 2-year period will determine if coral reef and seagrass systems benefited from any drop in human use, as well as provide critical information to local resources managers, help evaluate success and planning of conservation management actions, and with the expansion of coral restoration activities will prove even more critical to measure level of success and coral recovery of CNMI's reefs.

In 2008, the long-term monitoring plan was formalized to outline the program goals, methods, data handling, and other logistics currently used today (Houk & Starmer, 2008). Since then, the Division of Coastal Resources Management (DCRM) has been the lead agency responsible for data collection and monitoring at long-term sites, and continues to partner with the Division of Environmental Quality (DEQ) and Division of Fish and Wildlife (DFW) to complete program goals. Currently, the marine monitoring team (MMT) consists of Bureau of Environmental and Coastal Quality (BECQ) staff, with periodic support from local non-profits, the local NOAA field office, and faculty and students from the Northern Marianas College and the University of Guam.

The overarching goals of the program are to evaluate the status of CNMI's marine resources including seagrass and coral reef systems, monitor variability through time, and determine how these systems are impacted by natural and anthropogenic disturbances. This information is critical to guide local resource managers and policy decisions that promote sustainable development and the conservation of natural resources. Long-term monitoring data are consistently used by local and federal partners to evaluate island or regional trends, and help guide management plans. For example, the MMT was able to contribute data to a project assessing bleaching impacts on Pacific coral reefs, aid in a habitat mapping project for the Marianas Archipelago, and assist with coral restoration site prioritization and planning. Additionally, data are used by DEQ to assess water quality impacts on CNMI's reef flat sites.

The current objectives of the long-term monitoring program (LTMMP) are to:

- Continue to fill gaps in monitoring coverage, including assessment of climate change associated parameters.
- Continue to monitor changes in biological communities through time with respect to natural and human influences, including climate change.
- Where disturbances are noted, examine recovery trends with respect to localized stressors (fish abundance and watershed pollution).
- Examine the efficacy of management actions such as watershed improvement projects and marine protected areas.
- Use datasets to prioritize where new management actions will be most effective.
- Document and respond to acute disturbances such as crown-of-thorns outbreaks, ship groundings, storms, marine debris removal, etc.
- Provide support for coral restoration activities including managing the state-funded coral nursery, collection of coral species, and assist with out-planting efforts.

The following report summarizes the current status of the CNMI's coral reef and seagrass systems, and documents activities and progress of the marine monitoring team during the 2020-2021 period. The report includes survey methods and database management, as well as up to date analysis of lagoon and forereef habitats. Additional projects are also summarized including management of crown-of-thorns outbreaks, coral restoration activities, and an update on Pagan's reefs surveyed in 2021.

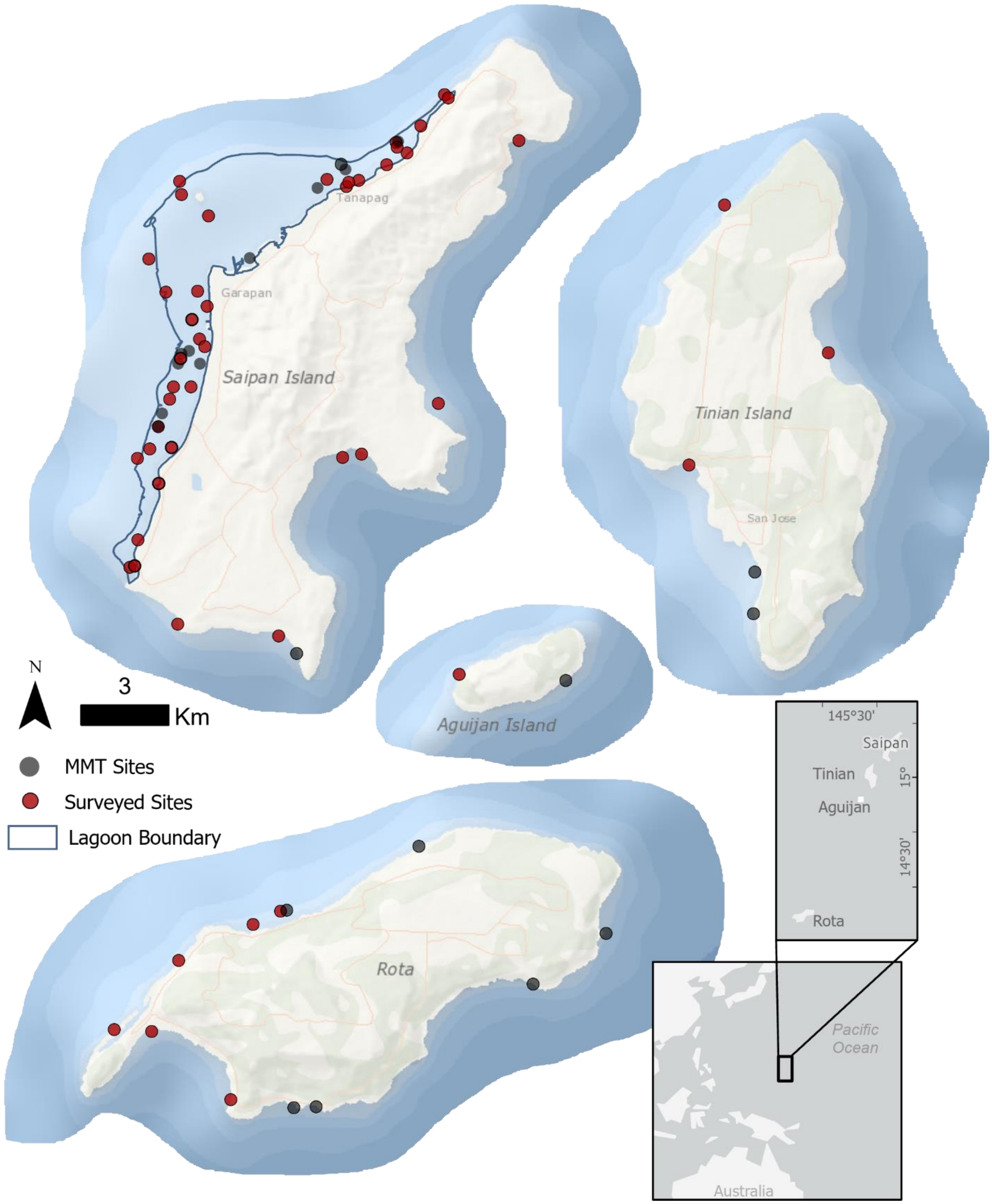

Figure 1. Long-term marine monitoring sites around Rota, Aguijan, Tinian, and Saipan. Red circles denote sites surveyed during the 2020-21 period.

METHODS

OVERVIEW

Currently, over 50 long-term monitoring sites across Saipan, Tinian, Aguijan (Goat Island), and Rota are surveyed on a rotating biennial basis (Figure 1). Surveys are conducted across two broad habitat types, forereef and lagoon habitat. Forereef sites are surveyed across the 4 islands, and lagoon habitat is surveyed along Saipan's western shoreline. Forereef sites are stratified by exposure to wind and waves, as well as geomorphological reef type. Although Saipan Lagoon contains 19 unique ecological habitats (Houk & van Woesik, 2008), monitoring is focused on Staghorn *Acropora* thickets and *Halodule* seagrass beds. Most sites within habitat types have been selected based on their association with management concerns (e.g., runoff, sewage outfalls, urban development, etc.) and/or management actions (e.g., watershed restorations efforts, marine protected areas, etc.), and include impacted sites and relatively non-impacted reference sites where possible.

All surveys are conducted along 50 meter transect lines laid out along the depth contour (7 – 9 m depth) on the forereef, and across homogeneous habitat in the lagoon (1 – 5 m depth). Three to five replicate transects are surveyed per site, depending on the availability of homogenous habitat. While benthic cover analysis provides the foundation of the CNMI marine monitoring program, the current protocol uses several survey methods per habitat type (forereef or lagoon) to measure a broad suite of ecological indicators for assessing reef condition. Survey methods have remained the same since the last award period, with the addition of using structure-from-motion techniques for assessing structural complexity at forereef sites. Methodology for each habitat type is briefly described in the following section.

FOREREEF METHODS

At forereef sites, information is collected to describe benthic cover, coral and algae diversity, coral colony size distribution, fish biomass and size, and diversity of coral, fish, and invertebrates. Depending on the availability of reef habitat, 3 – 5 transect lines (50 m long) are laid out along the depth contour. Photos are taken every meter along the transect line using a 0.25 m^2 quadrat frame, for a total of 250 photos at each site. Photos are analyzed with point count software, CPCe version 4.1 (Kohler & Gill, 2006), to identify biota or substrate type under five random points for each quadrat. Organisms are identified to the genus level, whenever possible. This analysis provides percent cover of major benthic categories and community diversity.

Twelve stationary point counts (SPC) are conducted at each site to evaluate fish assemblages. Each SPC is systematically positioned throughout the length of the site (250 m). The species and size (fork length) of all food fishes within a 5-meter radius are recorded in a three-minute period.

Sixteen, 0.25 m^2 quadrats are haphazardly tossed along the length of the site and every coral colony within the quadrat is identified to the species level and measured. This method provides relative diversity, abundance, and size class of the coral community. Within these same quadrats all algae species present are identified to the species level to provide a measure of community composition and species richness. Finally, non-coral macro-invertebrates including sea cucumbers, urchins, crown-of-thorns starfish (COTS), giant clams, and others are identified and counted within 1 m of each side of the transect lines (i.e., 5, 2 m x 50 m belt transects).

SAIPAN LAGOON METHODS

At lagoon sites, benthic cover is quantified using a 0.25 m^2 string quadrat with six intersections, placed every meter along the transect line. The biota or substrate under each intersection is recorded to the genus level, in situ. Additionally, ten, 1 m^2 quads are haphazardly placed across the length of the site (250 m) and all seagrass, algae, coral, and macro-invertebrates are identified to the species level and recorded. This method captures the relative diversity and abundance of lagoon communities. Species diversity of non-coral macro-invertebrates within 2 m x 50 m belt transects are identified and counted as described above.

DATA MANAGEMENT

Once surveys are completed in the field, the individual observer(s) transfers the data into Microsoft Excel® spreadsheets. Separate workbooks exist for each survey protocol. Validation mechanisms, such as drop-down menus that only allow appropriate names and values are in place within the Excel environment. Further quality assurance & quality control (QA/QC) checks are conducted by the observer before uploading data into the master database files. All data are stored on the local BECQ network server. Excel spreadsheets have provided the monitoring program with an intuitive, inexpensive, and efficient means to store, query, and subset data for use. However, as the monitoring program and associated datasets grow and become more complex, the current database may become limiting.

MMT staff are currently in the process of migrating the data into the online Micronesia Challenge (MC) database. At present, the forereef data are undergoing migration to the online database, and once completed, lagoon datasets will also be transferred online. Migration to the MC database will allow for improvements in QA/QC procedures, as well as querying and reporting processes, while maintaining database integrity as it grows in size and complexity. In addition, the online database provides an improved platform for long-term storage that will maintain data integrity during future program changes, including staff turnover. Presently, only MMT staff can view and access the data. The LTMMP datasets are available for download after a two-year embargo on the National Centers for Environmental Information (NCEI) Geoportal (https://www.ncei.noaa.gov/metadata/geoportal/#searchPanel) or NOAA's Coral Reef Information System (CoRIS) website (https://www.coris.noaa.gov/search/catalog/main/home.page).

STATUS AND TRENDS

From 2020-21, the marine monitoring team surveyed 45 sites including forereef and lagoon habitats; a full list is provided in the Appendix (Table 3). The following summarizes current status and trends for Saipan Lagoon, and forereef sites surveyed around Rota, Tinian, Aguijan, and Saipan.

LAGOON HABITAT

From 2020-21, the marine monitoring team were able to survey 25 long-term marine monitoring sites within Saipan Lagoon. Thirteen of the sites occurred in sandy bottom habitat dominated by seagrass and macro-algae, while the other twelve occurred in back reef habitat (Figure 1). Reef sites in Saipan Lagoon have been in severe decline due to back-to-back mass bleaching events, which resulted in live coral cover losses ranging from 30.6 – 98.7% at long-term monitoring sites in the past ten years. The most severely impacted areas being Staghorn dominant reef sites. From 2020-21, only isolated coral bleaching has been observed among highly susceptible corals, such as *Acropora* and *Pocillopora* spp. Despite a break from mass bleaching events since 2017, recovery has been observed at only two reef sites, Marianas Resort and San Antonio back reef. In 2020, both sites were observed to have 18.7% live coral cover, close to previously recorded levels. In 2009, Marianas Resort had live coral cover of 20%, and San Antonio back reef had cover of 24.3% in 2010. However, a coral community shift from Staghorn coral dominance occurred at San Antonio with a shift to *Pavona* and *Psammocora* spp. Staghorn habitat previously occurring outside of Fishing Base, Diamond Hotel, Oleai, Quartermaster, and Wing Beach sites are still struggling to recover to previously recorded levels of live coral cover (Figure 2).

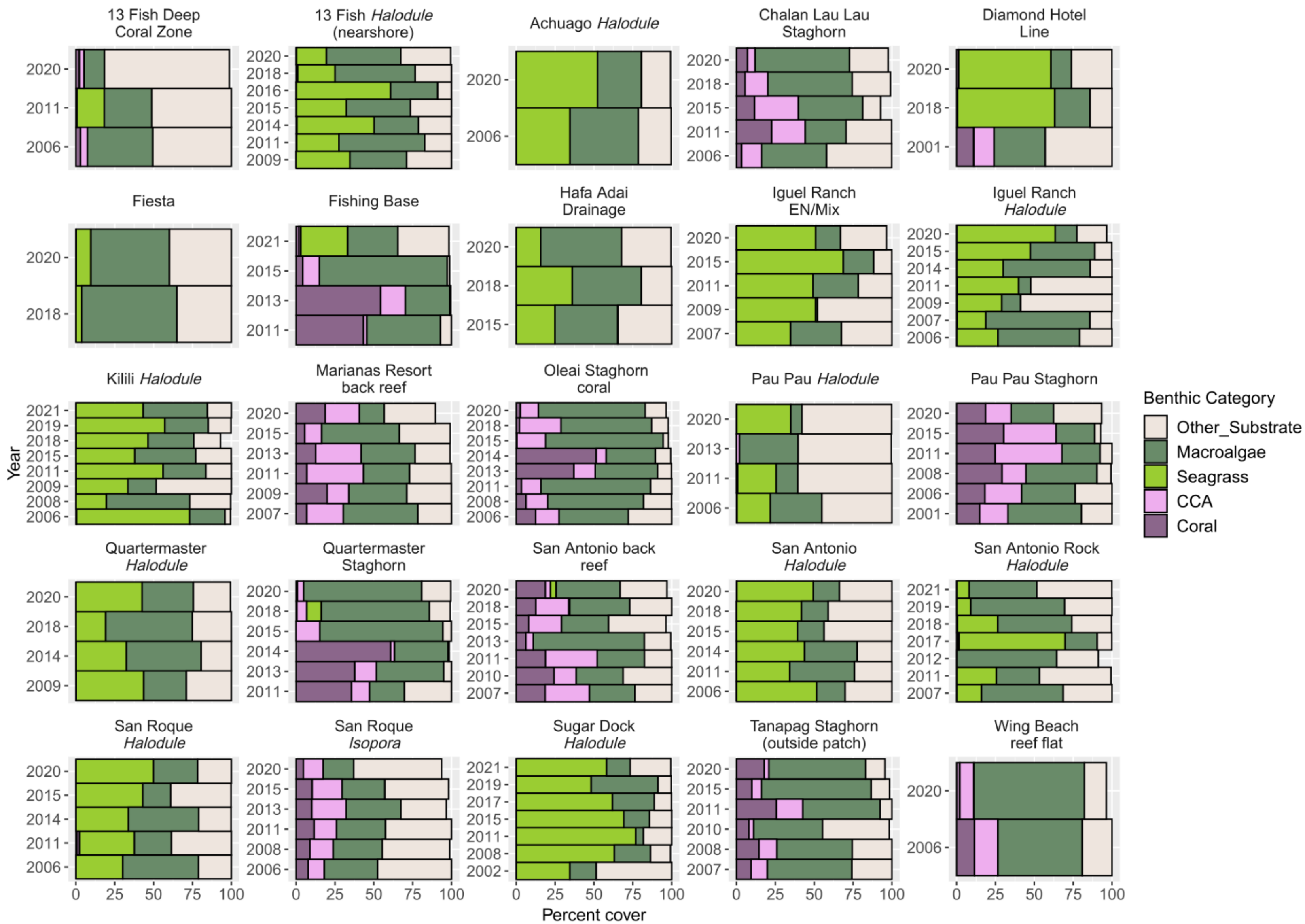

Figure 2. Percent benthic cover for lagoon sites surveyed during 2020-21. The other substrate category is inclusive of sand, pavement, and rubble.

Changes in coral community composition are most evident post mass bleaching events in 2013, 2014, 2016, and 2017, when Staghorn corals were most severely impacted (Figure 3). Although up to 27 coral genera were identified at lagoon sites, the majority make up less than 5% of live coral cover, and continue to persist at similar levels post-bleaching years. The most prevalent coral genera (non-Staghorn species) include: digitate and corymbose Acroporids, *Heliopora coerulea, Porites, Goniastrea, Psammocora, Montipora*, and *Pavona* spp. However, one species *Isopora palifera* has yet to recover to previously recorded levels that were highest during the years, 2008-11. The loss of live coral has led to an increase in turf and macroalgae covering dead coral stands, as well as reef substrate degrading into rubble.

Seagrass habitat is the dominant benthic community within Saipan Lagoon, comprising ~7 km^2 area, and is composed of three species: *Enhalus acoroides*, *Halodule uninervis*, and *Halophila minor* (Perez, 2020). Long-term monitoring sites focus on areas dominated by *Halodule uninervis*, and can also comprise of *Halophila minor*, which typically occurs in lower densities (> 1-10%) and can be less conspicuous. Seagrass and macroalgae cover can be variable due to seasonality, rainy/dry or winter/summer season, ephemeral algae blooms, or adverse impacts such as land-based sources of pollution (LBSP) and coastal development. In Saipan Lagoon, algal blooms are most commonly made of Chrysophytes and/or cyanobacteria, such as *Phormidium* sp. and others, which typically occur during cooler, drier months (Camacho & Houk, 2020).

Overall seagrass and macroalgae cover have been relatively stable at San Antonio *Halodule*, San Roque *Halodule*, and Sugar Dock *Halodule* (Figure 2). However, community shifts are occurring at Fishing Base and Diamond Hotel Line, where seagrass is now expanding into previously dominated Staghorn habitat. The substrate at these sites is predominantly composed of rubble from collapsed dead coral stands and sand. Out of all sites, Iguel Ranch *Halodule* has had the largest increase in seagrass cover, with a 33.8% increase since 2015, and in 2020 had the highest recorded seagrass cover for all years at 63.4% benthic cover. San Antonio Rock *Halodule* has had the most severe decline in seagrass cover, with -88.1% since 2017, followed by 13 Fish *Halodule* (nearshore) with -68.1% since 2016, and Hafa Adai drainage with -56.3% drop in seagrass cover since 2016. These sites are spread far across the lagoon, several kilometers along the shoreline, so one factor may not be causing decline at all sites. Hafa Adai drainage and 13 Fish *Halodule* are within the Garapan watershed, which is the most developed area on Saipan, therefore LBSPs could be contributing to seagrass decline at this site. Other factors that can explain the decline are shifting habitats from sand erosion/accretion, or shifting boundaries of seagrass patches.

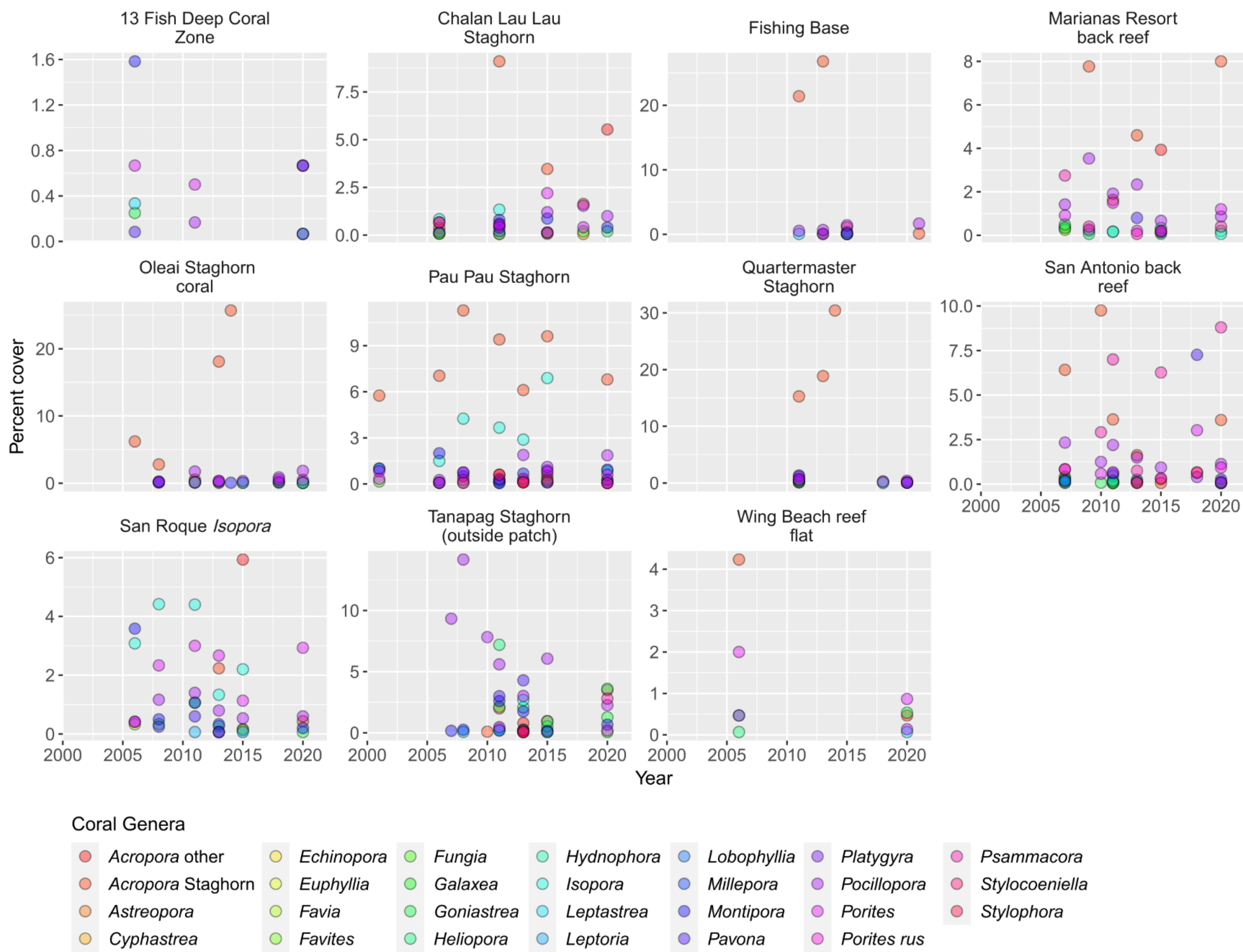

Figure 3. Percent cover of coral genera for Saipan Lagoon sites surveyed during 2020-21.

FOREREEF HABITAT

Since 2013, CNMI's reefs have been exposed to above average sea surface temperatures almost annually, with the largest bleaching event occurring in 2017. In October 2018, Typhoon Yutu devastated Saipan and Tinian, damaging nearshore reefs with surge and debris crushing or overturning coral colonies. Additionally, there have been an increase in sightings of *Acanthaster planci*, crown-of-thorns starfish (COTS), throughout the CNMI. The continued monitoring efforts, for this award period, looks to further document the effects of climate-change-related disturbances on CNMI's reefs. Though the effects of these events naturally vary between each reef type, a continuing trend of declining coral cover can be seen at monitoring sites as a result of past and recent disturbance events.

ANALYSIS BY ISLAND

In Saipan, the majority of the surveyed reefs show that coral cover continues to decline, with the exemption of one site (Figure 4). The coral cover for Obyan Beach was observed to have increased to 10.7% cover, while sites such as Tank beach, Outside Grand, Coral Ocean Point, and Mañagaha Patch Reef have had little to no coral recovery from previous bleaching events. The continued decline in coral cover for Bird Island and Wing Beach are of growing concern. Bird Island's coral cover has decreased to 13.47% and Wing Beach to 5.52% based on previous survey years. For Bird Island, a localized outbreak of COTS was observed in 2019 and 2020, that likely contributed to the continued decline in coral cover after the 2017 bleaching event (Figure 4). There were community-reported sightings of COTS at Wing Beach, but the MMT did not observe any presence or evidence of COTS. Regrettably, Saipan's reefs are still experiencing the effects caused by past bleaching events and COTS predation.

Coral cover for Tinian has historically been lower compared to Saipan, due to the geomorphology of the area, but the cover has remained stable in comparison to previous survey years (Figure 5). In Aguijan, coral cover is showing a slight increase compared to 2018, but has not yet recovered to levels last observed in 2012. (Figure 5). Macroalgal cover is continuing to increase, at the loss of crustose coralline algae (CCA) cover at Aguijan and Barcinas Bay.

In the past, monitoring has focused on the Talakhaya watershed because of its status as a priority watershed. In recent years, efforts have shifted to monitor the impacts due to bleaching and COTS outbreaks throughout Rota. The bleaching events of 2013 and 2014 had little to no effect on the coral cover around the island. However, the 2017 bleaching event and a COTS outbreak that lasted from 2019-20, have negatively impacted Rota's reefs. These cumulative impacts continue to impede coral recovery at long-term monitoring sites surveyed during 2020-21 (Figure 6).

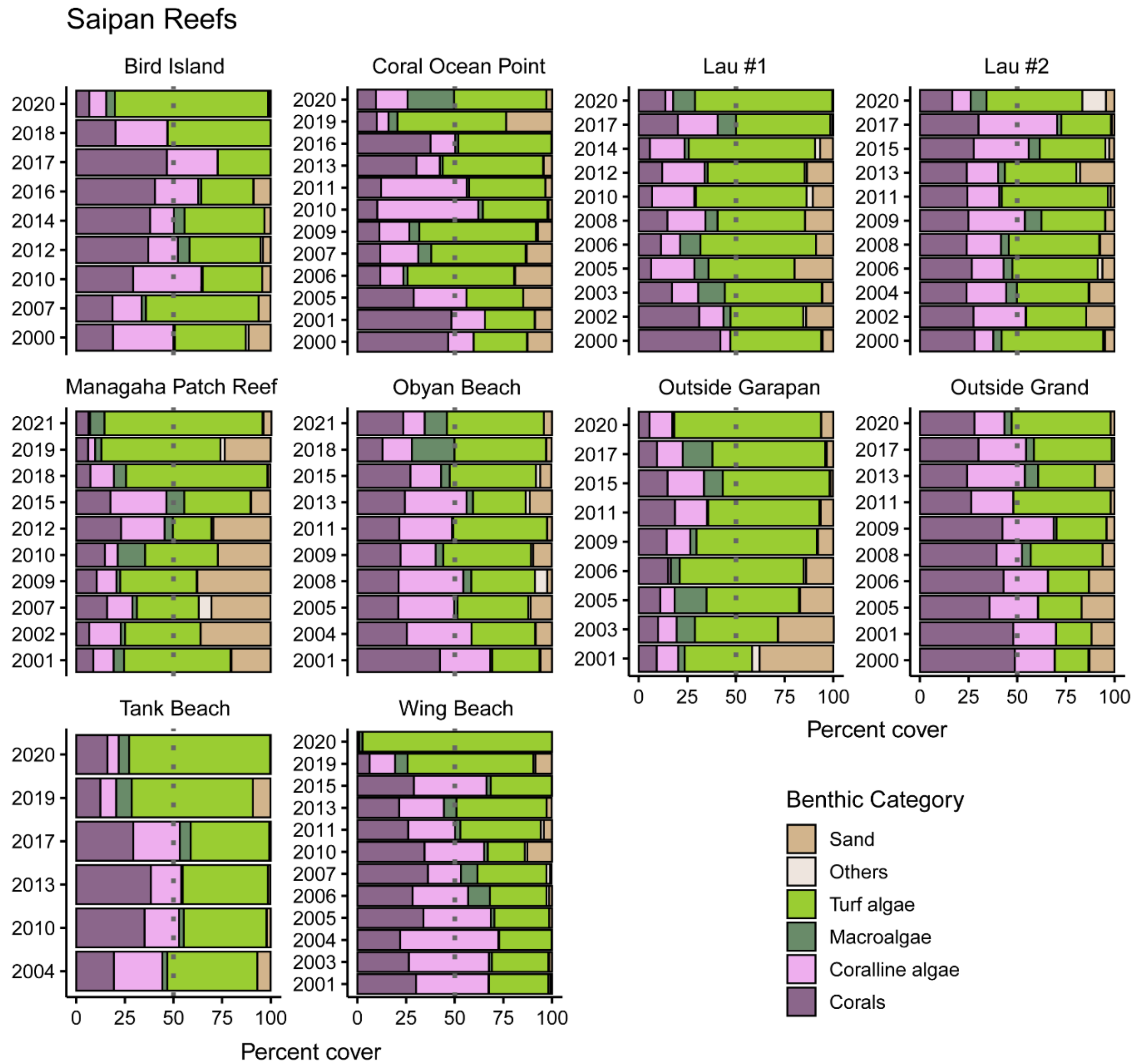

Figure 4. Percent benthic cover for Saipan forereef sites surveyed during 2020-21. The coral category is inclusive of hard and soft corals. The coralline algae category is inclusive of crustose and branching coralline algae. The turf category is inclusive of turf (algae <2cm in size) and *Peyssonnelia* sp., an encrusting coralline algae. The "Others" category is inclusive of sponges, anemones, Chrysophytes, Gorgonians, *Discosoma*, Zoanthids, and Ascidians.

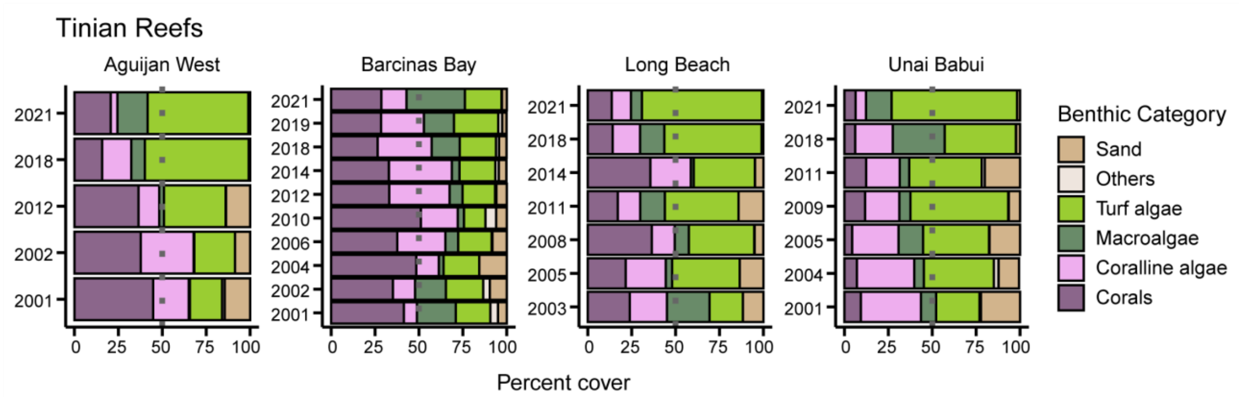

Figure 5. Percent benthic cover for Aguijan and Tinian forereef sites surveyed during 2020-21. The coral category is inclusive of hard and soft corals. The coralline algae category is inclusive of crustose coralline algae and branching coralline algae. The turf category is inclusive of turf (algae <2cm in size) and *Peyssonnelia* sp., an encrusting coralline algae. The "Others" category is inclusive of sponges, anemones, Chrysophytes, Gorgonians, *Discosoma*, Zoanthids, and Ascidians.

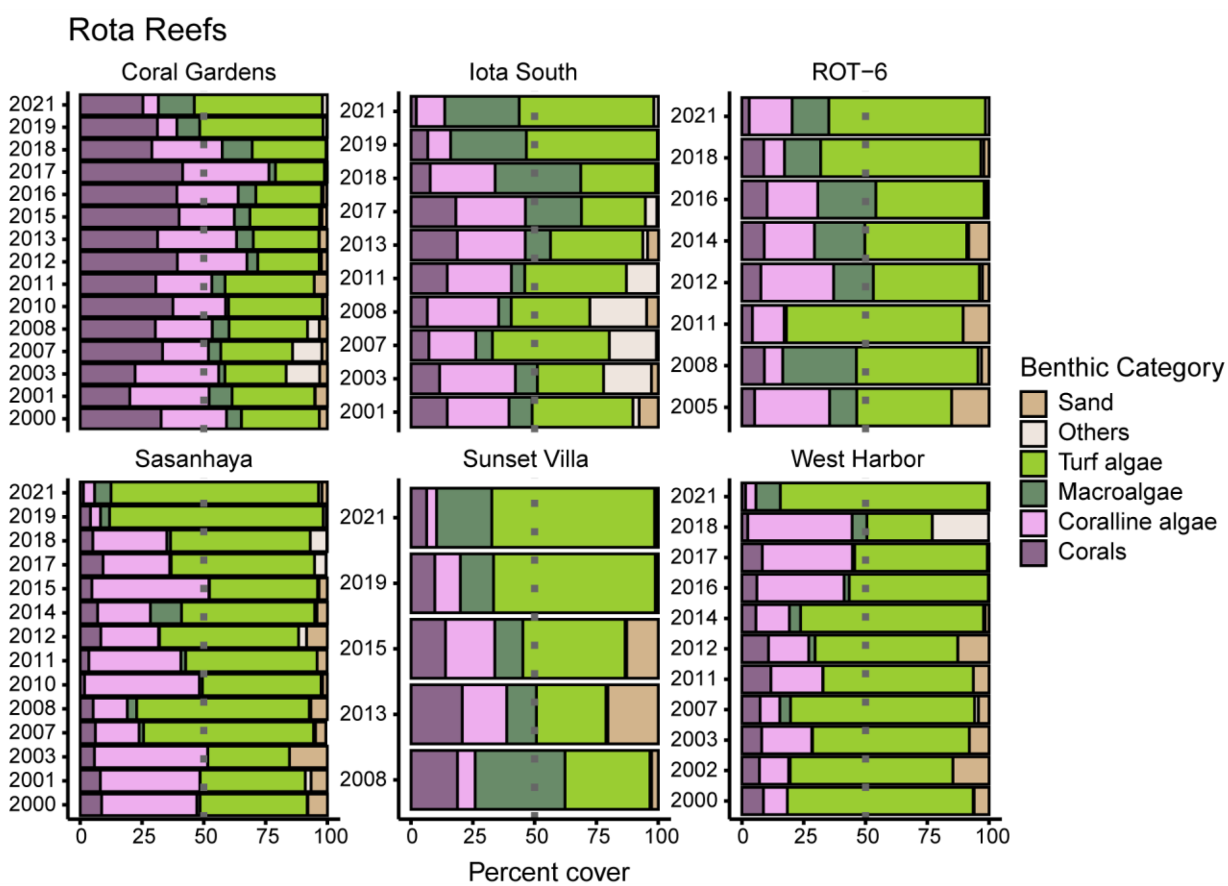

Figure 6. Percent benthic cover for Rota forereef sites surveyed during 2020-21. The coral category is inclusive of hard and soft corals. The coralline algae category is inclusive of crustose coralline algae and branching coralline algae. The turf category is inclusive of turf (algae <2cm in size) and *Peyssonnelia* sp., an encrusting coralline algae. The "Others" category is inclusive of sponges, anemones, Chrysophytes, Gorgonians, *Discosoma*, Zoanthids, and Ascidians.

ANALYSIS BY REEF TYPE

Long-term monitoring sites cover four different reef types around Saipan, Tinian, Aguijan, and Rota; including: [1] spur-and-groove (Figure 7), [2] interstitial (Figure 8), [3] low-relief slope (Figure 9), and [4] patch reef (Figure 10). Spur-and-groove reefs are the dominant reef type surveyed on Saipan. These reef types are characterized by having coral ridges or “spurs” that are separated by sediment channels or “grooves”. Low-relief sloping reefs are only surveyed on Rota, and are characterized by having little to no structural complexity. Interstitial reef types can be found in all three islands and are generally *Porites* spp. dominant or of the Merulinid family of encrusting corals, such as *Leptastrea* and *Astreopora spp*. Patch reefs can be found in all three islands, but these types are only surveyed in Saipan and Tinian. Patch reefs are isolated reef outcroppings that are generally surrounded by sandy bottoms.

Coral composition within spur-and-groove reefs mainly consists of coral colonies in the Acroporidae family, more specifically the *Montipora, Pocillopora*, and *Acropora* genera. However, coral cover for these genera have been in decline and are being replaced by *Porites rus*, such as at Obyan Beach and Outside Grand (Figure 7). Coral cover at interstitial reefs dominated by *Porites* spp. assemblages have remained relatively stable over time. During the 2020-21 period, however, a decline in coral cover was observed, most notably in Lau #2 (Figure 8). For the other interstitial reef sites, coral cover has decreased, and interestingly, the dominant colonies have shifted from *Goniastrea* and *Favites* spp. to *Leptoria* and *Favia* spp. (Unai Babui, Figure 8). A decline in coral cover and diversity was also observed at low-relief reef sites. Previous surveys conducted at Sasanhaya recorded 13 genera, but in 2020, the number decreased to a mere six genera, and *Porites rus*, a weedy species, was not recorded in the most recent survey (Figure 9). Patch reef sites saw no change in coral cover when compared to the previous survey year, however, Outside Garapan saw a loss of the genus *Favia* (Figure 10).

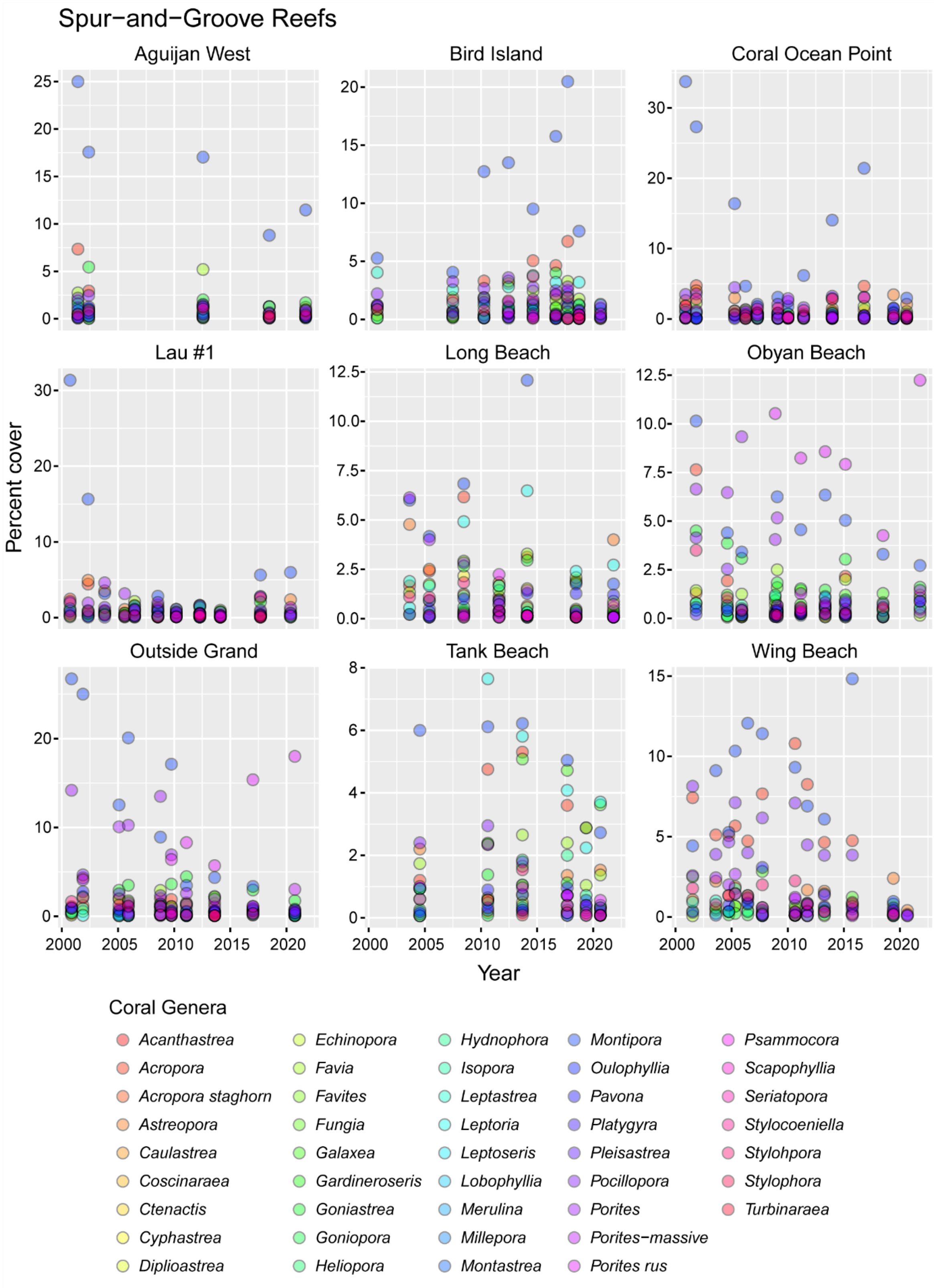

Figure 7. Percent coral cover by genera within spur and groove reefs surveyed during 2020-21.

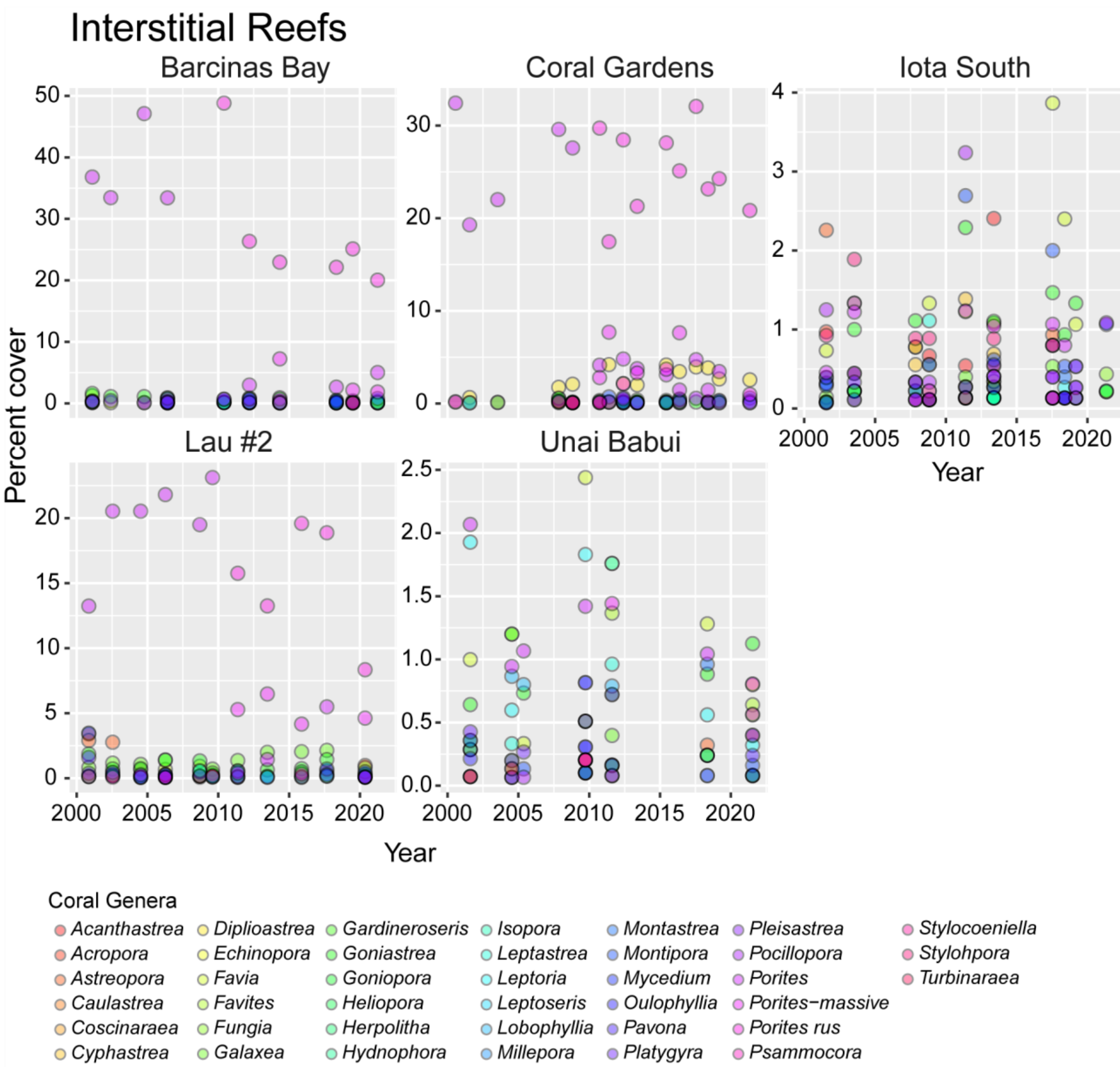

Figure 8. Percent coral cover by genera within interstitial reefs surveyed during 2020-21.

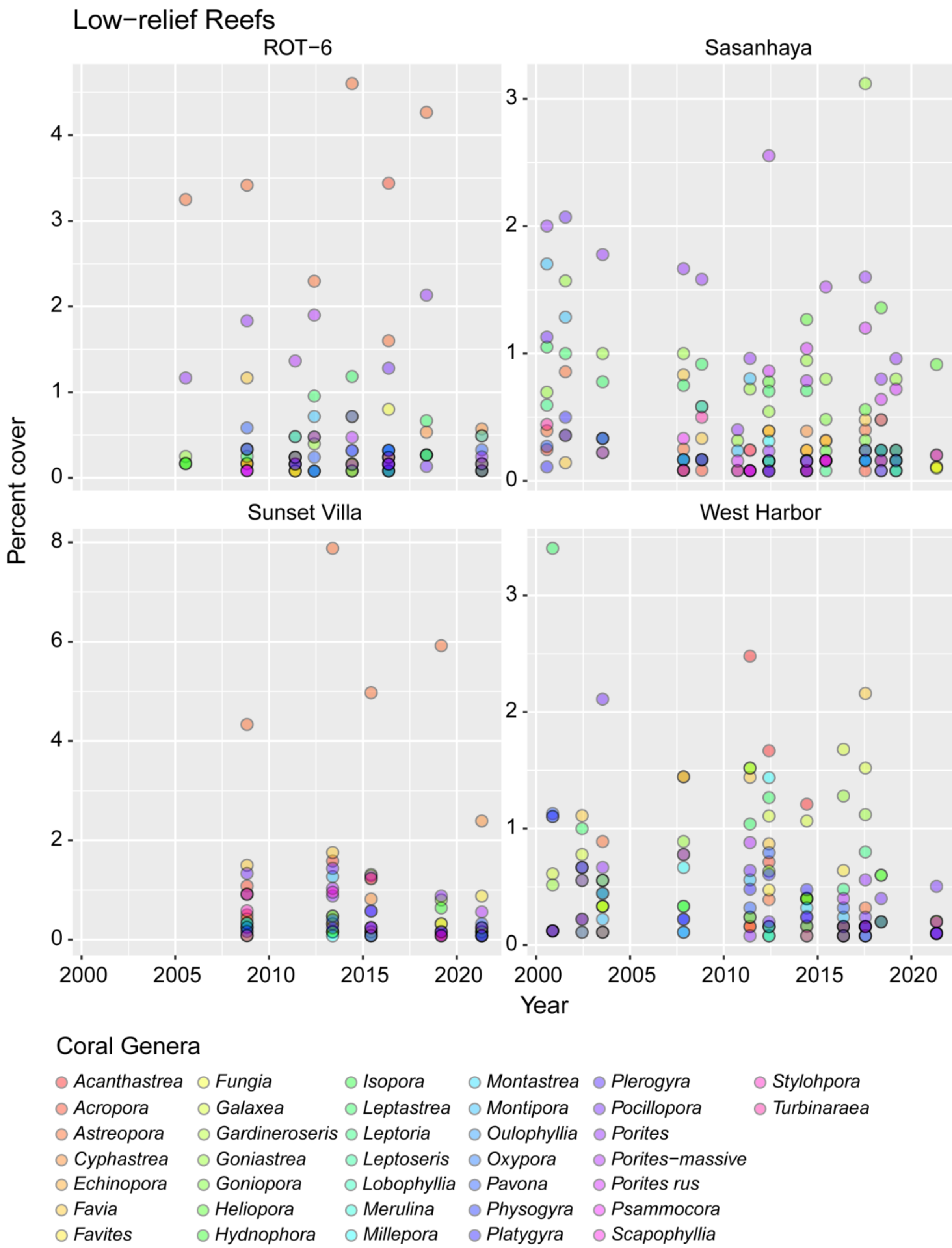

Figure 9. Percent coral cover by genera within low relief sloping reefs surveyed during 2020-21.

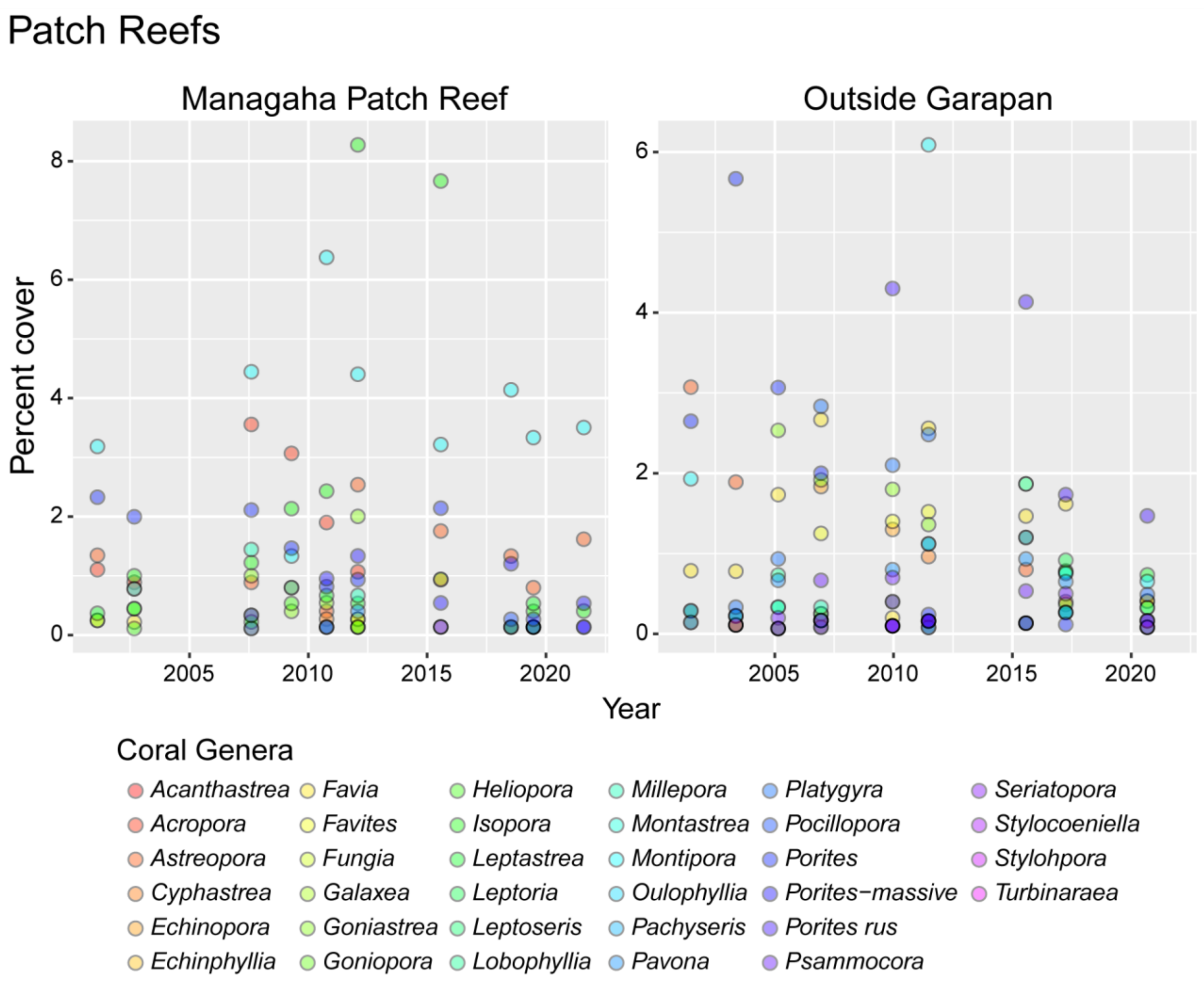

Figure 10. Percent coral cover by genera within patch reefs during 2020-21.

OTHER PROJECTS

PHOTOMOSAICS

OVERVIEW

For the past two years, the CNMI's LTMMP has been working on incorporating photomosaics into our survey protocol to address knowledge gaps in reef structural complexity. Due to the widespread loss of coral from bleaching events in the past 8 years, and increasing frequency in typhoons and crown-of-thorns outbreaks within the CNMI, there is concern that erosion will outpace reef accretion and coral growth. This may result in reef flattening, or loss of reef structure that is important for coastal protection and habitat for a diverse set of species. Data collection for photomosaic construction are conducted at current long-term marine monitoring sites established along the forereef of Saipan, Tinian, and Aguijan (Figure 1). Since Rota sites are limited to one survey per year, due to travel distance and cost, we may expand surveys to Rota if time and diver capacity is available on the annual field trips. The following section outlines the methods for data collection and photomosaic construction.

PHOTOMOSAIC METHODS

Data Collection

Photos for model construction are collected from the long-term marine monitoring program's forereef sites, at ~7 – 9 m depth. A 10 m x 10 m grid is set up on the reef substrate with the use of nine PVC markers at the corners and center of the square, with 4 of the markers placed in the grid for scale. Compass bearings are recorded at one corner of the square by a SCUBA diver to note orientation of the survey area, and depth is recorded for each marker in the grid. A waypoint is collected at the surface by a snorkeler for later georeferencing the model in ArcGIS Pro©. A Nikon DSLR camera in an underwater housing is used for collecting photos at 1-sec intervals. A diver with the camera swims a lawnmower pattern along the grid to photograph the reef at ~1-1.5 m from the substrate.

Mosaic Construction

The photos are used for construction of high resolution (cm-scale) digital elevation models (DEMs). The DEMs are analyzed for structural complexity metrics, including rugosity and fractal dimension. Rugosity, a common index used in coral reef studies, is calculated as the ratio of the distance over the three-dimensional surface to the linear distance. Fractal dimension is another index used to describe structural complexity over several scales (0.1 cm to m scale). Photomosaics are constructed using the software program, Agisoft Metashape Professional. The software program aligns photos through matching points and estimating camera positions. A reference scale is set for the model, utilizing the scale markers. A dense point cloud is constructed from the photo alignment, and is then used to build the digital elevation model.

The digital elevation model is analyzed with several methods to test different structural complexity metrics. The DEM is analyzed using the benthic terrain modeler toolbox in ArcGIS Pro©, Esri software, using the surface to planar area roughness tool to provide a rugosity metric (Storlazzi et al., 2016; Walbridge et al., 2018). Theoretical rugosity and fractal dimension are also calculated using open-source R code developed by Torres-Pulliza et al. (2020).

ACTIVITIES AND PROGRESS

In 2020, six additional sites in Saipan were surveyed, and collection of photomosaics was expanded to Tinian and Aguijan in 2021 (Table 1). Analysis of the DEMs for structural complexity is ongoing for all sites. In Figure 11, an example is given of Coral Ocean Point covering the same reef area in consecutive years from 2019 and 2020. New coral growth was observed for a *Pocillopora grandis* colony, and erosion of the reef line. Although the modeled depth accuracy was high, 13 cm in 2019 and 6 cm in 2020 for construction of the DEMs, there was a meter difference in depth between model years. This additional error may have been dependent on placement of the ground control points and height of the camera while capturing photos between years, which is difficult to replicate for repeated surveys.

Table 1. List of long-term marine monitoring sites where photomosaics have been completed.

Site	Island	2019	2020	2021
AGU-2	Aguijan			x
Akino Reef	Saipan		x	
Barcinas Bay	Tinian			x
Bird Island	Saipan		x	
Boy Scout	Saipan	x		
Coral Ocean Point	Saipan	x	x	
Lao Lao 1	Saipan	x		
Lao Lao 2	Saipan		x	
Long Beach	Tinian			x
Obyan	Saipan			x
Outside Garapan	Saipan		x	
Outside Grand Hotel	Saipan		x	
Outside Mañagaha	Saipan			x
Tank Beach	Saipan	x	x	
Unai Babui	Tinian			x
Wing Beach	Saipan	x	x	

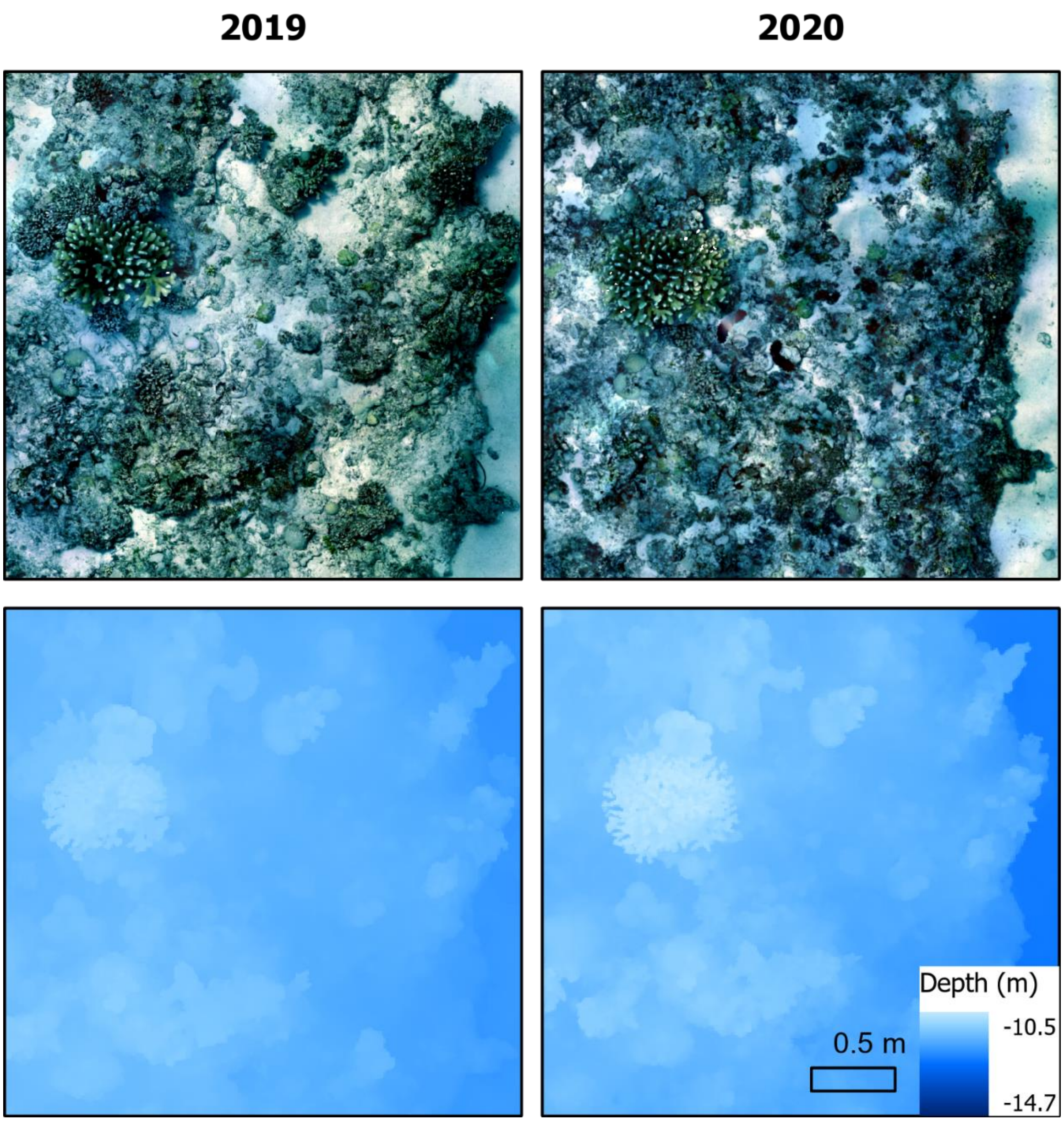

Figure 11. Orthomosaic and digital elevation model for long-term marine monitoring site at Coral Ocean Point taken in 2019 and 2020.

PAGAN SURVEYS

Notable for its dual volcanoes, Pagan is also one of the only northern CNMI islands with a long history of settlement. While a major eruption of the northern volcano (Mt. Pagan) forced the evacuation of residents in 1981, the island is currently occupied by several families who wish to reestablish permanent residences on their home island. The US military, however, has submitted a controversial proposal to take over Pagan for use in live-fire training exercises. In June of 2021, a project funded and coordinated by the Commonwealth Bureau of Military Affairs Office (CBMA) invited the MMT to take part in surveying Pagan's natural resources. The MMT's primary objective in the project was to obtain marine benthic data for the northern half of the island using the MMT's already established sites, previously surveyed in 2014 (Figure 12). The secondary objective, for the MMT, was to collect benthic data for the remaining long-term monitoring sites on the southern half of the island.

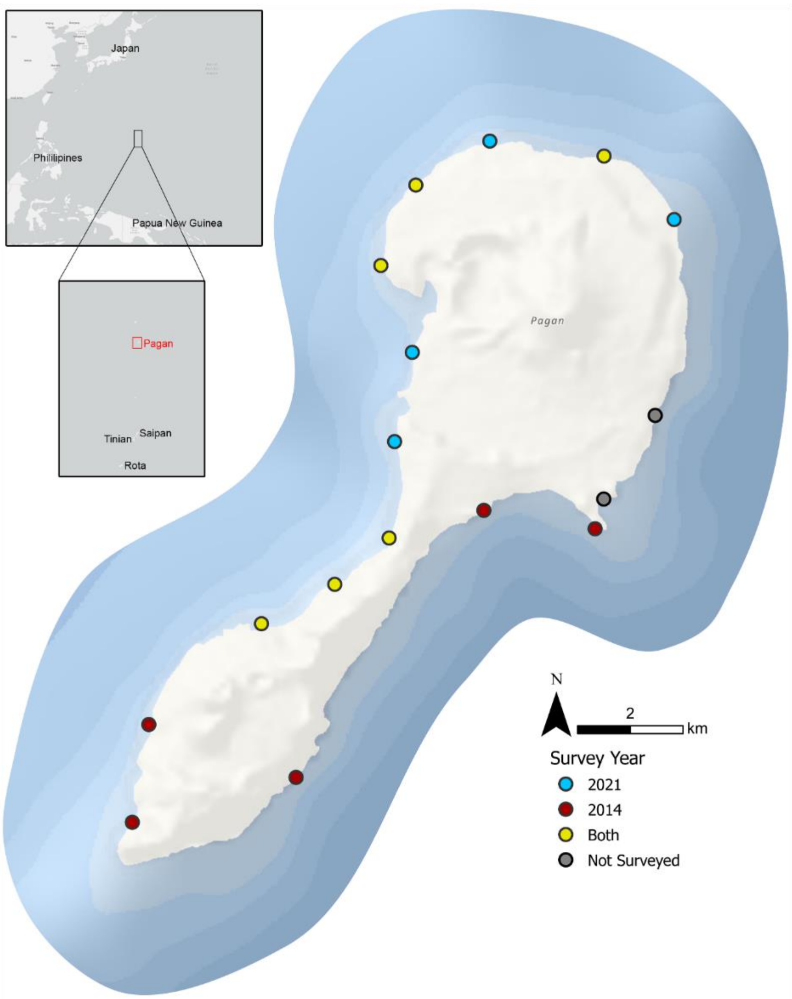

Figure 12. Long-term marine monitoring sites at Pagan. Red circles denote sites surveyed in 2014. Blue circles denote sites surveyed in 2021. Yellow denotes sites that were surveyed in years 2014 and 2021.

From the 2021 surveys, 93 species of corals were identified along the western side of the island, where a majority of the growth forms are of the massive and branching variety (Figure 13; Table 2). Pagan was last surveyed in July 2014, just as a bleaching event was occurring. From the 11 sites surveyed in 2014, the average live coral cover from benthic photoquadrat surveys was 13%, and the average for bleached corals was 64%. In 2021, there was no bleaching recorded, and the average coral cover from 10 sites was 8%. Bray-Curtis matrices were used to describe the ecological similarity between each pair of sites based upon summed differences in pairwise species abundances (Anderson et al., 2008). When comparing at the site level between both years, similarity matrices and PERMANOVA tests were performed and evaluated based upon pseudo F-statistics (analogous to ANOVA F-statistics). A principal coordinate ordination (PCO) was performed on the similarity matrices to depict the PERMANOVA results in two-dimensional space. The results of the analyses show that there is a greater shift towards a macroalgal dominant reef (Pseudo-F = 5.2346, p-value = 0.002, PERMANOVA; Figure 14).

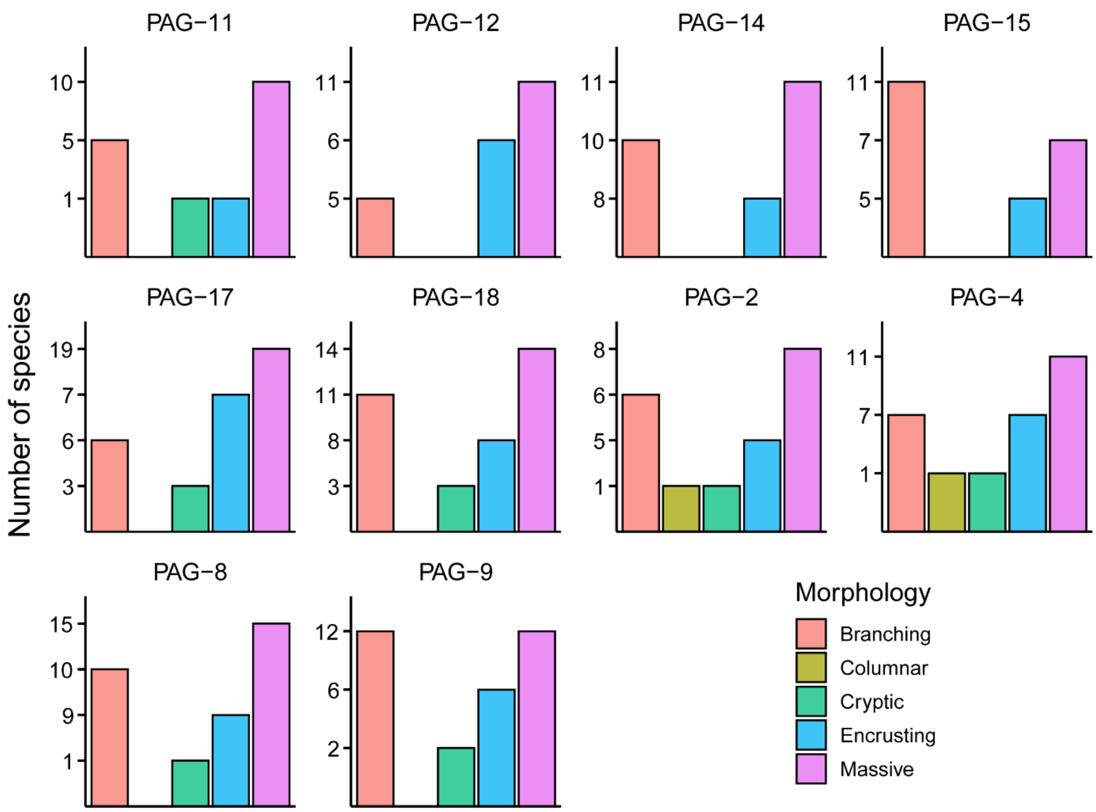

Figure 13. Number of coral species at each site by morphology recorded during the Pagan surveys completed in June 2021.

Table 2. List of species identified during the Pagan surveys in 2021.

Species	Morphology
Acanthastrea brevis	Cryptic
Acanthastrea echinata	Cryptic
Acanthastrea hemprichii	Encrusting
Acropora abrotanoides	Branching
Acropora cf. nasuta	Branching
Acropora digitifera	Branching
Acropora globiceps	Branching
Acropora humilis	Branching
Acropora minuta	Branching
Acropora nana	Branching
Acropora nasuta	Branching
Acropora palmerae	Encrusting
Acropora sp. 1	Branching
Acropora sp. 2	Branching
Acropora surculosa	Branching
Acropora tenuis	Branching
Acropora valida	Branching
Acropora verweyi	Branching
Astrea annuligera	Massive
Astrea curta	Massive
Astrea sp. 1	Massive
Astreopora myriophthalma	Massive
Astreopora ocellata	Massive
Astreopora randalli	Massive
Cyphastrea agassizi	Massive
Cyphastrea microphthalma	Massive
Cyphastrea sp.	Massive
Cyphastrea sp. 1	Massive
Cyphastrea sp. 2	Massive
Diploastrea heliopora	Massive
Dipsastrea sp. 1	Massive
Dipsastrea sp. 2	Massive
Dipsastrea sp. 3	Massive
Dipsastrea sp. 4	Massive
Dipsastrea sp. 5	Massive
Favites colemani	Massive
Favites paraflexuosa	Massive
Favites rotundata	Massive
Favites sp. 1	Massive
Favites sp. 2	Massive
Favites sp. 3	Massive
Favites sp. 4	Massive
Favites vasta	Massive
Galaxea astreata	Encrusting
Galaxea fascicularis	Encrusting
Goniastrea edwardsi	Massive
Goniastrea minuta	Massive
Goniastrea retiformis	Massive
Goniastrea stelligera	Encrusting
Heliopora coerulea	Branching
Hydnophora microconos	Massive
Leptastrea bewickensis	Encrusting
Leptastrea purpurea	Encrusting
Leptastrea sp. 1	Encrusting
Leptastrea sp. 2	Encrusting
Leptoria phrygia	Massive
Lobophyllia hemprichii	Massive
Montipora floweri	Encrusting
Montipora grisea	Encrusting
Montipora informis	Encrusting
Montipora nodosa	Encrusting
Montipora sp. 1	Encrusting
Montipora sp. 2	Encrusting
Montipora turgescens	Encrusting
Oulophyllia bennettae	Massive
Pavona chiriquiensis	Massive
Pavona duerdeni	Massive
Pavona sp. 1	Cryptic
Pavona varians	Encrusting
Platygyra pini	Massive
Platygyra sinensis	Massive
Platygyra sp.	Massive
Platygyra sp. 1	Massive
Plesiastrea versipora	Massive
Pocillopora ankelli	Branching
Pocillopora brevicornis	Branching
Pocillopora elegans	Branching
Pocillopora grandis	Branching
Pocillopora meandrina	Branching
Pocillopora sp.	Branching
Pocillopora sp. 1	Branching
Pocillopora verrucosa	Branching
Porites densa	Massive
Porites evermanni	Massive
Porites massive	Massive
Porites rus	Columnar
Porites sp.	Massive
Porites sp. 1	Massive
Porites sp. 2	Massive
Porites sp. massive	Massive
Porites vaughani	Cryptic
Scapophyllia cylindrica	Columnar
Stylophora pistillata	Branching
Turbinaria stellulata	Cryptic

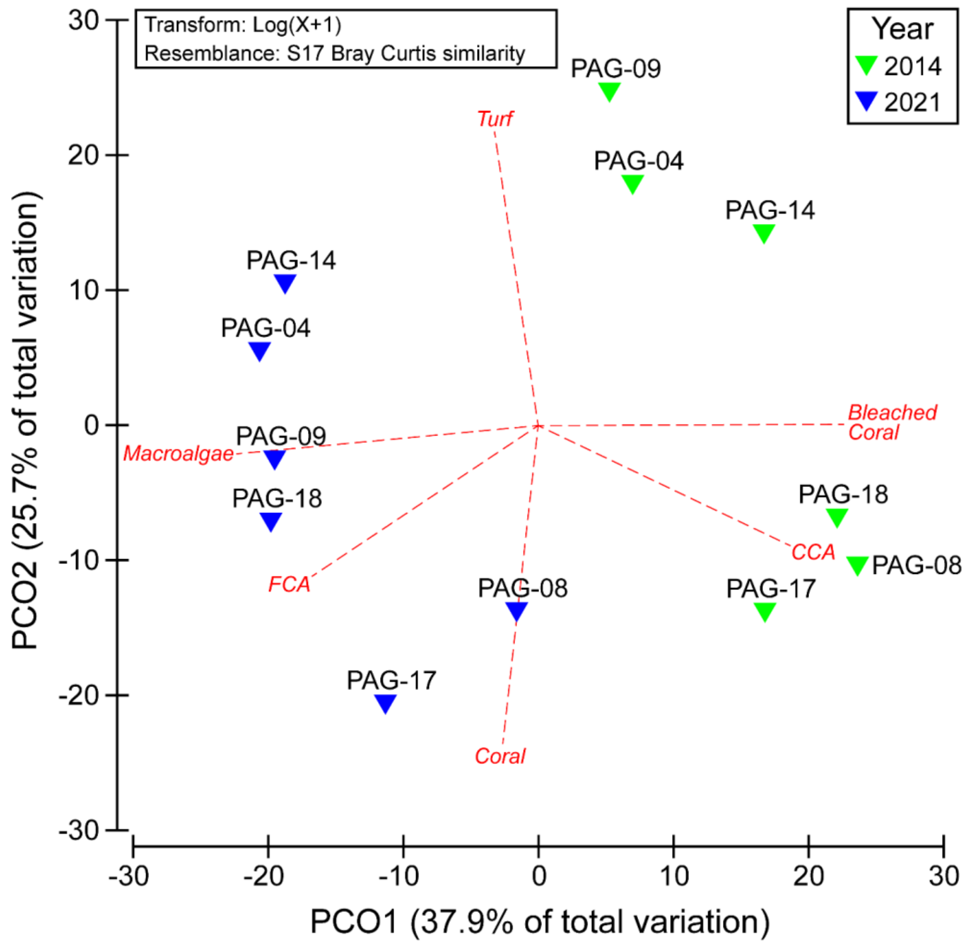

Figure 14. Each PCO axis represents an eigenvector and has an associated eigenvalue that describes the maximum amount of variation in the multivariate assemblages that could be explained by a single axis.

CROWN-OF-THORNS MANAGEMENT

Since 2018, an increase in *Acanthaster planci* density has been observed throughout CNMI's long-term forereef sites (Figure 15). The MMT has documented in a single dive, aggregations of > 120 individuals in 2019, and > 150 individuals at Bird Island sanctuary in 2020, which surpass outbreak thresholds. The definition of an outbreak depends on the survey method used and typically is considered as > 40 COTS observed on a 20-minute swim (Timmers et al., 2012). There have also been multiple reports from dive groups of > 10 COTS at several dive sites, including Wing Beach, Ice Cream, Lao Lao, and Grotto in 2020. In 2019 and 2020, Dive Rota recorded aggregations of > 50 COTS at several dive sites off the west and southern coast of Rota, including Coral Gardens and Senhanom Cave (pers. comm. with Mark Michaels). The MMT has documented prevalence of scarring on coral colonies from COTS predation on forereef sites around Saipan. Although, COTS prefer to feed on *Acropora* spp., the MMT has observed frequent feeding on *Astreopora* and *Montipora* spp. In 2021, the MMT observed for the first-time adult COTS within Saipan

Lagoon outside of Pau Pau Beach, Mañagaha Patch Reef, and San Antonio. In the past 20 years of monitoring (including during outbreak years), the average density of COTS was 0.27 ± 1 per 100 m^2 on forereef sites. Since 2018, the MMT has documented densities 48x higher than the overall average at forereef sites.

Outbreak reports have declined in 2021, however, the MMT are preparing a response plan to address future outbreaks and conduct eradication with the use of household vinegar and modified injectors. Use of vinegar is an efficient eradication method, which causes 100% mortality in adult COTS within 24 – 48 hours (Boström-Einarsson & Rivera-Posada, 2016). The MMT employed such methods during a recent aggregation of COTS at Lau Lau Bay in August 2021, where 31 adult COTS were injected on a single dive.

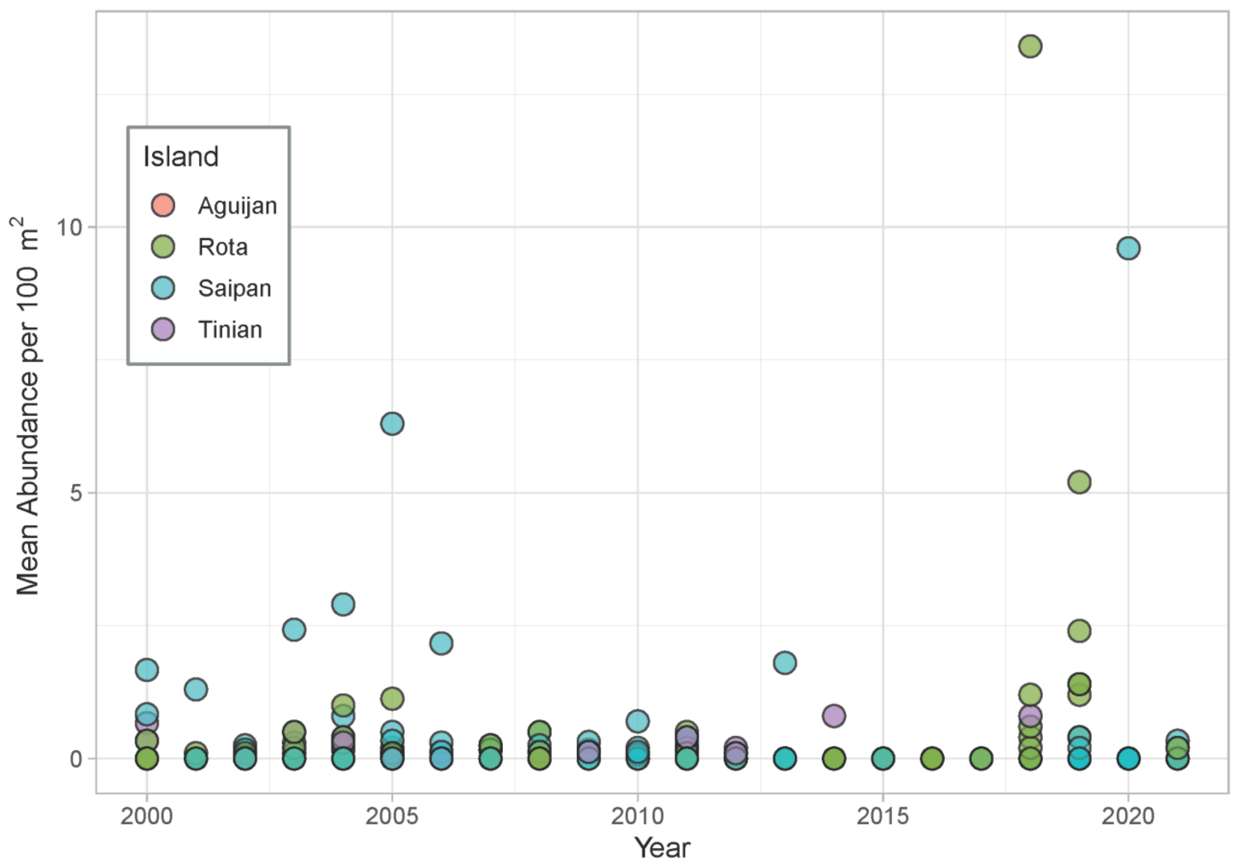

Figure 15. Mean abundance of *Acanthaster planci* per 100 m^2 for long-term marine monitoring sites around Aguijan, Rota, Tinian, and Saipan.

CORAL RESTORATION

In 2019, stakeholders and scientists met to update the CNMI's coral reef management priorities for the next ten years. Coral restoration was added as a new priority for the CNMI to help improve recovery to past acute disturbances, such as previous massive bleaching events, as well as assist with resiliency to current and future stressors (DCRM, 2019). The marine monitoring team has taken the lead in several projects and partnered with local agencies to help expand coral restoration within the CNMI. This includes leading the restoration working group in drafting the CNMI Restoration Action Plan, with mentorship from The Nature Conservancy from 2020-21.

In 2021, a second coral nursery was installed in Saipan Lagoon managed by the marine monitoring team and funded through the Department of Interior. The nursery currently includes 6 nursery trees and 2 tables with planned expansion of additional structures in 2022. In addition, the MMT is serving as a lead role in managing the coral restoration goals for a new project started in 2021, funded by the NFWF Coastal Resilience Fund, "Coastal Community Resilience Initiative for Wetlands and Corals in Saipan's Priority Management Watershed."

Collection of fragments for the coral nursery began in mid-May 2021 and is currently ongoing. Suitable collection sites were identified using benthic data from long-term marine monitoring and habitat maps of Saipan Lagoon (Houk & van Woesik, 2008). Fragments were collected from parent colonies in Chalan Lao Lao, San Antonio, and Pau Pau Beach with targeted focus on collecting Staghorn species (Figure 16). Fragments collected from colonies were broken off using angled pliers, with care to remove no more than 10% of the colony. Parent colonies were tagged to monitor recovery 3-6 months following collection, and all colonies showed signs of healing and regrowth at breakage points. Corals of opportunity, loose fragments that have broken off from a colony, were also collected, but were unable to be assigned to a parent colony.

There are presently 160+ fragments stocked in the nursery from 3 Acroporid species: *Acropora pulchra*, *A. muricata*, and *A. surculosa*. Fragments are monitored monthly to track growth and any tissue loss from disease or predation. Bi-monthly cleaning and removal of algae is ongoing, but there have been noted increases in algal growth after several rain events. Future plans for the nursery include collection of additional Acroporid species, along with other branching and massive corals from forereef areas around Saipan.

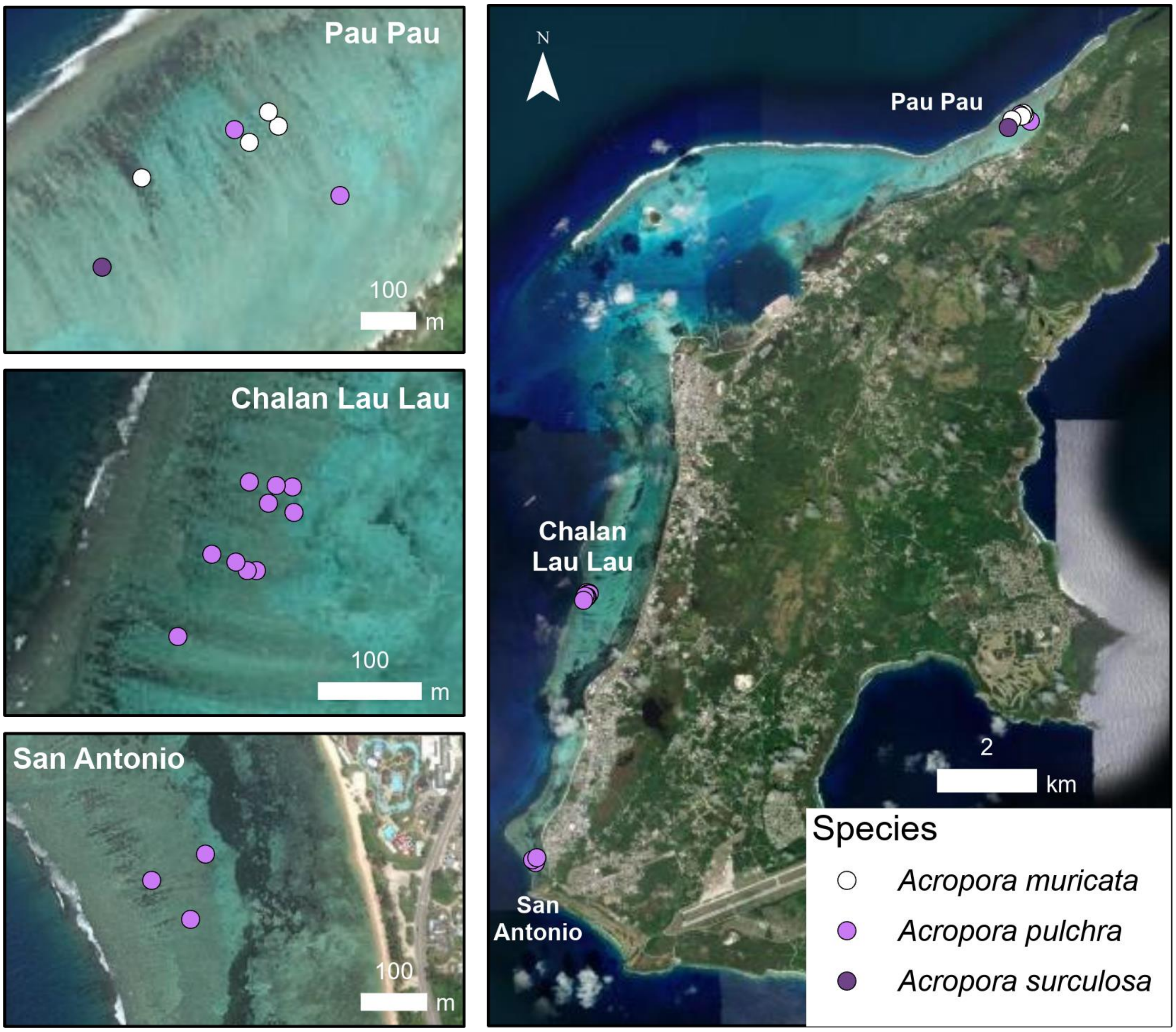

Figure 16. Location of parent colonies, including 3 Acroporid species: *A. muricata*, *A. pulchra*, and *A. surculosa*, where coral fragments were collected to stock the coral nursery in 2021.

NON-POINT SOURCE REEF FLAT SURVEYS

The marine monitoring team continues to provide training to BECQ Non-Point Source Pollution program in field techniques for conducting benthic surveys and species identification. One member of the MMT travels to Rota and Tinian to assist DEQ staff in conducting biological reef flat surveys in conjunction with water quality sampling. In 2020, MMT staff were unable to travel to Rota due to COVID restrictions, but were able to join the annual reef flat surveys in October 2021. For Tinian, one MMT staff member joined the surveys in July 2020. The reef flat surveys were conducted along a 50m transect that traversed the point designated for water quality sample collection. Benthic percent cover was assessed using the string quadrat method using a 0.25 m^2 quadrat with six points, placed every meter along the transect. Non-coral macro-invertebrate abundances were also assessed by identifying and counting all organisms within one meter of the transect, on both sides (i.e., 2 m x 50 m belt transect). The reef flat data and reports are available through the Water Quality Program at BECQ's Division of Environmental Quality.

EDUCATION AND OUTREACH

During 2020-21, members of the MMT participated in numerous education and outreach events and initiatives, including, but not limited to, the following:

- CRI Summer Internship Program held from June-August. The MMT consistently supports 2 summer interns.
- Hosted CNMI Snorkels events at annual Oceans Fair, Project Hope, and MINA Schools for Environmental Conservation. The MMT participates in the CNMI snorkels event as experts available to answer snorkeler's questions about the marine environment.
- Various beach cleanups and the International Coastal Cleanup, held annually in September.
- Various community meetings and school events.
- Serve as Science Fair judges at elementary schools.
- Eyes of the Reef Training – Citizen Science Program to train community members on how to identify and report reef disturbances.

OUTCOMES AND PRODUCTS

The LTMMP continues to be a resource for data and expertise on CNMI's coral reefs to local and federal government, non-profit, and community partners, and has provided a 20-year long dataset that is a source of critical information on coral reef status at the local and regional scale. This information is especially important in the light of increased and future proposed military activity on Tinian and Pagan, in combination with reefs already under stress from ocean warming and acidification, land-based sources of pollution, COTS outbreaks, and more.

The main product of the LTMMP is the long-term database that consists of data covering coral diversity and colony-size distribution, algae, fish, and macro-invertebrate diversity, and benthic cover composition. In the current award period, this dataset proved critical to development of the CNMI Restoration Action plan for prioritizing lagoon and forereef sites to outplant corals, as well as identifying key areas for collecting coral species to stock the state-managed nursery. The dataset was also used for calibration/validation of the Allen Coral Atlas habitat maps for the Mariana Islands, and helped inform distribution of the threatened species, *Acropora globiceps* as requested by local and federal partners. The twenty-year dataset was also critical to identifying thresholds for crown-of-thorns populations to be included in the CNMI COTS outbreak response plan.

Marine monitoring data is consistently used to inform natural resource managers when developing and evaluating management activities, such as restoration of priority watersheds. Most importantly, through routine monitoring, the MMT identified and documented COTS aggregations, which will be an important factor for evaluating future coral recovery at outbreak sites around Saipan and Rota. In addition, the MMT's work in the past two years has documented reef status during a unique period where there were minimal to no tourist arrivals in the CNMI, which subsequently reduced marine sports and boating activities, and closures of popular destinations such as Mañagaha Island and the Grotto on Saipan. Data collected during the 2020-21 period will be useful for future analysis assessing coral recovery or loss, surveillance of COTS populations, and future assessments regarding success of management actions that involve coral and/or watershed restoration efforts.

LTMMP products from this award period are listed below including peer-reviewed scientific articles and data publications. Data and information on the LTMMP are also made available through presentations at various symposia, workshops, lectures, and informational meetings. Graphics, photos, and metadata can be viewed on DCRM's website (https://dcrm.gov.mp/our-programs/marine-monitoring-program). To further broaden awareness of the program beyond the management and scientific community, a Facebook© page is maintained and updated by marine monitoring personnel (www.facebook.com/cnmimmt). In addition, restoration staff manage an Instagram© account to distribute information about coral restoration, marine monitoring, and other activities conducted by the MMT (https://www.instagram.com/cnmireefrestoration). Restoration staff also facilitate and lead quarterly CNMI Coral Restoration Working Group meetings to engage federal and local government agencies, non-governmental organizations, and coral restoration stakeholders within the CNMI to discuss updates, advice, and support for restoration efforts. Previous meeting notes and agendas can be viewed on DCRM's website (https://dcrm.gov.mp/our-programs/marine-monitoring-program/cnmi-coral-restoration-working-group/). The marine monitoring program has contributed to the following data publications and peer-reviewed scientific papers over the award period:

Camacho, R., Perez, D., Iguel, J., Okano, R., Johnson, S., Johnston, L., & Benavente, D. (2021). Assessment of coral reef benthic communities and reef fish survey data from locations in the Commonwealth of Northern Marianas Islands from 2014-10-01 to 2018-09-30 (NCEI Accession 0225446). NOAA National Centers for Environmental Information. Dataset. Retrieved from https://www.ncei.noaa.gov/archive/accession/0225446

Camacho, R., & Houk, P. (2020). Decoupling seasonal and temporal dynamics of macroalgal canopy cover in seagrass beds. Journal of Experimental Marine Biology and Ecology, 525, 151310. https://doi.org/10.1016/j.jembe.2019.151310

Perez, D. I. (2020). Mapping Coral Reef Primary Production and Calcification from a Light-Use Efficiency Model with In-Situ and Remotely Sensed Data. The University of Queensland. https://doi.org/10.14264/uql.2020.170

Perez, D. I., Phinn, S. R., Roelfsema, C., & Shaw, E. (2020). Reflectance spectra of coral reef and seagrass communities from Heron Reef, southern Great Barrier Reef and Saipan Lagoon, Commonwealth of the Northern Marianas Islands. PANGAEA. Retrieved from https://doi.pangaea.de/10.1594/PANGAEA.920939

OBSTACLES AND DELAYS

Due to loss of staff and COVID shutdowns, monitoring activities were delayed in 2020. All government offices were shut down for a two-month period from March – May 2020, which resulted in canceling the annual Rota surveys that year. Throughout 2020, reports of increased COTS aggregations continued at several sites on the west and east coast of Saipan, which the MMT took the lead in conducting outbreak response. In addition, delays in boat repairs impaired the MMT's ability to reach forereef sites for long-term monitoring in 2020. The departure of the lead biologist in December 2020, reduced the MMT's capacity to conduct fish surveys and identification. The reduction of staff and limited boating capacity, caused the MMT to refocus monitoring efforts to complete lagoon surveys that can be reached from shore. The MMT continues to look for training opportunities in fish identification and survey techniques to address the loss in expertise.

In 2021, the lead biologist position was filled, and the CNMI was awarded a three-year funded grant through the NFWF Coastal Resilience Fund to support the restoration project, "Coastal Community Resilience Initiative for Wetlands and Corals in Saipan's Priority Management Watershed." The grant award allowed the marine monitoring program to expand and hire an additional 3 staff members that comprise the coral restoration team. The additional staff have allowed the MMT to fill gaps in monitoring, especially coral species identification, increase capacity for analyzing data, help to catch up with surveys at forereef sites in 2021, and assist in COTS outbreak response and monitoring. The MMT is now at full capacity with 6 total staff for the first time since 2017. Despite the delays experienced in 2020, the MMT were able to complete 45 surveys at long-term marine monitoring sites during the award period.

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APPENDIX

Table 3. Checklist of long-term marine monitoring sites established in 2000, including forereef and lagoon habitats surveyed across Saipan, Tinian, Aguijan, and Rota. Only surveys conducted between 2010-21 are displayed here. Data is available upon request from 2000-2021, or is available for download online from the NOAA NCEI database (Camacho et al., 2021; Johnston et al., 2015).

Site	Habitat	Island	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
13 Fish Deep Coral Zone	Lagoon	Saipan											x	
13 Fish *Halodule* (near shore)	Lagoon	Saipan		x			x	x	x		x		x	
13 Fish out *Halodule*	Lagoon	Saipan		x					x		x			
Achugao *Halodule*	Lagoon	Saipan			x		x						x	
Chalan Laolao Staghorn	Lagoon	Saipan		x				x			x		x	
Gold Beach Staghorn/Reef Flat	Lagoon	Saipan		x				x			x			
Iguel Ranch EN/Mix	Lagoon	Saipan		x		x		x					x	
Iguel Ranch *Halodule*	Lagoon	Saipan		x		x	x	x					x	
Kilili *Halodule*	Lagoon	Saipan		x	x		x	x			x	x		x
Marianas Resort Back Reef	Lagoon	Saipan				x		x					x	
Oleai Staghorn Coral	Lagoon	Saipan		x		x	x	x			x		x	
Pau Pau *Halodule*	Lagoon	Saipan		x		x		x					x	
Pau Pau Staghorn	Lagoon	Saipan		x		x		x					x	
Quartermaster *Halodule*	Lagoon	Saipan				x		x			x		x	

Site	Habitat	Island	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
San Antonio *Halodule*	Lagoon	Saipan				x		x			x		x	
San Antonio Rock *<u>Halodule</u>*	Lagoon	Saipan		x	x	x				x	x	x		x
San Roque *Halodule*	Lagoon	Saipan		x				x					x	
San Roque *Isopora*	Lagoon	Saipan		x		x		x					x	
Sugar Dock *Halodule*	Lagoon	Saipan			x		x	x		x		x		x
Tanapag *Halodule*	Lagoon	Saipan		x		x		x						
Tanapag Staghorn (outside patch)	Lagoon	Saipan	x	x		x		x					x	
Wing Beach Reef flat	Lagoon	Saipan				x							x	
Hafa Adai South	Lagoon	Saipan			x		x	x			x		x	
Fiesta	Lagoon	Saipan			x		x				x		x	
San Roque *Acropora* beds	Lagoon/Stag	Saipan												
Pau Pau *Acropora* beds	Lagoon/Stag	Saipan												
Pump Station	Lagoon/Stag	Saipan												
Moylans	Lagoon/Stag	Saipan						x						x
Moylans *Halodule*	Lagoon	Saipan					x	x						
Quartermaster Staghorn	Lagoon/Stag	Saipan				x	x	x			x		x	
Dump Line	Lagoon/Stag	Saipan												
MVA	Lagoon/Stag	Saipan												
Oleai Line	Lagoon/Stag	Saipan												
Diamond Hotel Line	Lagoon/Stag	Saipan				x					x		x	

Site	Habitat	Island	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fishing Base	Lagoon/Stag	Saipan		x		x		x						x
Achu Dankulu	Outer Reef	Saipan				x	x							
AGU-1	Outer Reef	Aguigan												
AGU-2	Outer Reef	Aguigan			x						x			x
Coral Gardens	Outer Reef	Rota	x		x	x		x	x	x	x	x		x
Iota South	Outer Reef	Rota				x				x	x	x		x
ROT-6	Outer Reef	Rota			x		x		x		x			x
Sasanhaya	Outer Reef	Rota	x		x		x	x		x	x	x		x
Sunset Villa	Outer Reef	Rota				x		x				x		x
Talakhaya	Outer Reef	Rota	x		x	x	x	x	x	x	x	x		
Rota Resort	Outer Reef	Rota			x		x		x	x	x			
West Harbor	Outer Reef	Rota			x		x		x	x	x			x
Oguk	Outer Reef	Rota	x			x		x	x	x	x	x		
Iota North	Outer Reef	Rota							x					
ROT-1	Outer Reef	Rota			x		x		x		x			
ROT-2	Outer Reef	Rota												
Bird Island	Outer Reef	Saipan	x		x		x		x	x	x		x	
Boy Scout	Outer Reef	Saipan	x			x		x	x		x	x		
Coral Ocean point	Outer Reef	Saipan	x		x				x			x	x	
Laolao #1	Outer Reef	Saipan	x		x		x			x		x	x	
Tank Beach	Outer Reef	Saipan	x		x	x				x		x	x	
Akino Reef	Outer Reef	Saipan					x				x	x	x	
Laolao #2	Outer Reef	Saipan				x		x		x			x	
Mañagaha MPA	Outer Reef	Saipan	x			x	x			x	x			x
Mañagaha Patch Reef	Outer Reef	Saipan	x		x			x			x	x		x
Obyan	Outer Reef	Saipan		x	x	x		x			x			x
Outside Garapan	Outer Reef	Saipan						x		x			x	
Outside Grand	Outer Reef	Saipan		x		x				x			x	

Site	Habitat	Island	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Outside Mañagaha	Outer Reef	Saipan					x				x			x
Wing Beach	Outer Reef	Saipan	x			x		x				x	x	
Barcinas Bay	Outer Reef	Tinian	x		x		x				x	x		x
South Point	Outer Reef	Tinian	x		x					x				
Unai Babui	Outer Reef	Tinian									x			x
Dynasty	Outer Reef	Tinian			x		x				x	x		
Long Beach	Outer Reef	Tinian					x				x			x