



**Comprehensive Long-term Coral Reef Monitoring at Permanent Sites on Guam:
NA11NOS4820007 End-of-Grant Report**

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Photo: Bleached corals from a reef front community in Pago Bay, Guam, in September 2013. By the end of the 2013 bleaching event, which is believed to be the most severe to-date, Guam's reefs experienced 12 degree heating weeks of temperature and UV light associated stress. Significant coral mortality was observed, with the shallow reef front and reef flat corals the hardest hit. The site depicted in the image above, as well as 44 other reef front sites, were surveyed by the Monitoring Program Coordinator and a team of University of Guam faculty and students between October and December, 2013. The results of the continued analysis of the data will yield information critical to understanding the full impact of the 2013 bleaching event on Guam's reefs, and continued data collection will aid in our understanding of recovery and response of Guam's reefs to future events.

I. Program overview

The *Comprehensive Long-term Monitoring at Permanent Sites in Guam* project involves the regular collection of data for a suite of coral reef ecosystem health parameters at several high priority reef sites around the island. While Guam's reefs have been the subject of numerous studies and the NOAA Coral Reef Ecosystem Division's Reef Assessment and Monitoring program collects data from sites around the island on a triennial basis, until the establishment of this program there has not been a continuous coral reef monitoring program on Guam that comprehensively addresses benthic habitat, water quality, and associated biological communities at high priority reef areas. This lack of baseline information has limited managers' ability to evaluate natural and anthropogenic impacts to Guam's reefs and to gauge the effectiveness of management activities at the scale of individual sites. In order to address this major gap, the Government of Guam natural resource agencies, with the assistance of the University of Guam Marine Laboratory (UOGML) and the National Oceanic and Atmospheric Administration's Pacific Islands Regional Office (NOAA PIRO), developed a long term monitoring strategy aimed at addressing the management needs of local resource agencies and the objectives set by the National Coral Reef Ecosystem Monitoring Program (NCREMP).

As part of the project, referred to hereafter as the Guam Long-term Monitoring Program, data are collected on a regular basis by a team of highly-trained field biologists from the UOGML and NOAA PIRO, with occasional assistance by staff from the Guam Environmental Protection Agency and the Department of Agriculture's Division of Aquatic and Wildlife Resources. The monitoring team collects data for a number of important parameters related to ecosystem health; many of these parameters are indicators of stressors, and significant changes in these parameters may raise concern and possibly trigger management actions. Data collected for these indicators also provide important information about the resilience of high priority reef areas around Guam. Monitoring these parameters also allows resource managers to evaluate the effectiveness of specific management strategies at the individual site level, and inform the development of new management actions. This site-based approach to coral reef monitoring is complementary to the site- or watershed-based approach to coral reef management utilized on Guam and in many other jurisdictions, wherein an array of management actions are focused on addressing all or most key sources of coral reef stress within a defined, often relatively small area, rather than implementing projects at various sites across a jurisdiction.

While obstacles have been presented in the procurement of equipment, supplies, and a private boat charter, and despite a period of major transition of the program from the Bureau of Statistics and Plans (BSP) to the UOGML, progress continues to be made in addressing these obstacles, and a considerable amount of field work has been conducted since funding first became available. A large amount of baseline data for a number of key ecosystem health parameters is now available for several high priority reef areas that are currently the focus of a number of management actions aimed at improving reef health. Subsequent data collection has occurred at some of these reef areas, and with continued data collection, including the incorporation of water quality monitoring, critical information will be provided to managers about the effectiveness of management efforts, and will alert managers to emerging threats that may not otherwise be detected.

II. Summary of activities conducted prior to current reporting period

A Monitoring Coordinator was hired in January 2007 to further develop and implement the monitoring strategy, as well as coordinate the development of the Guam section of NOAA's 2008 *Status of the Coral Reef Ecosystems of the U.S. and Freely Associated States* report. After the hiring of monitoring assistants and the procurement of essential equipment, supplies, and services, data collection began in June 2009, with initial surveys targeting the Tumon Bay Marine Preserve.

The 2009 data collection effort in Tumon involved video transect surveys, coral quadrat surveys, and reef fish surveys (Stationary Point Counts at all but one station, belt transects for two stations) at a total of two permanent and five non-permanent sampling stations; these surveys were carried out using three transects at each sampling station. While rebar were not installed at the five non-permanent sampling stations, four of the stations were re-surveyed in 2010.

In 2010, after revising the sampling design and survey methodologies based upon lessons learned with the 2009 work, a more extensive data collection effort was carried out along a portion of the Tumon Bay outer reef slope and an equivalent area along the outer reef slope in East Agana Bay; benthic cover, coral size/condition, reef fish community, and macroinvertebrate community surveys were conducted at 10 permanent and 10 non-permanent sampling stations within each site. The 2010 data collection effort was carried out over 18 field days and required a total of 108 individual team member dives.

In 2011, just prior to the commencement of the current reporting period, benthic cover, coral size/condition, reef fish, and macroinvertebrate surveys were conducted at 11 permanent and 12 non-permanent sampling stations at Western Shoals, Apra Harbor (with fish surveys conducted at an additional non-permanent station). The 2011 data collection effort was carried out across 8 field days and required 71 individual team member dives.

III. Monitoring program activities conducted during current reporting period

a. Summary of data collection efforts: FY2012-FY2014

In 2012, baseline benthic cover, coral size/condition, fish, and macroinvertebrate surveys were carried out at 20 sampling stations in Piti Bay and benthic cover, coral size/condition, and macroinvertebrate surveys were carried out at 21 sampling stations in Tumon Bay and at 10 stations in East Agana Bay. An injury prevented the collection of reef fish data at all but five Tumon sampling stations and at all of the East Agana stations in 2012. The 2012 data collection effort was carried out across 22 field days and required 207 individual team member dives.

With the exception of qualitative data collected during three exploratory dives along the East side of the Cocos Barrier Reef system, no Long-term Monitoring Program data was collected in 2013 due to administrative issues that prevented the Monitoring Coordinator from scuba diving between May and October (when the Long-term Monitoring Program, including the Monitoring Coordinator, was transferred to the UOGML). However, a significant amount of data was collected at over 40 reef front sites around the island by the Monitoring Coordinator and a team of University of Guam faculty and students between October and December, 2013, as part of an effort carried out in response to a severe coral bleaching event. The Monitoring Coordinator carried out coral community surveys and occasionally other surveys on 35 dives across 13 field days. More information about the 2013 coral bleaching response effort is provided on page 19.

In 2014, benthic cover, coral size/condition, and macroinvertebrate surveys were carried out at all 12 permanent sampling stations in Tumon Bay and at all 10 permanent stations in East Agana Bay. Benthic cover, coral size/condition, fish, and macroinvertebrate surveys were also completed at 6 permanent and one non-permanent sampling station in Piti Bay prior to the end of the current reporting period. Work in 2014 continued beyond the current reporting period, with baseline data (for all surveys, except coral quadrat surveys for three permanent stations) carried out at 11 permanent and two non-permanent sampling stations in the newly-established Achang site in October. Benthic cover, fish, and macroinvertebrate surveys were also completed at 3 permanent stations within the newly-established Cocos-East site and only fish surveys were carried out at four additional Cocos-East sites (one of which will later be established as a permanent station). The five days' worth of work at the Achang and Cocos-East sites was made possible through the considerable in-kind support contributed by NOAA PIRO, which included the continued support of Valerie Brown, a Guam-based Coral Reef Ecologist with PIRO, as well the use of a private boat charter. The remaining field work for 2014 was completed in November, with all surveys carried out at the remaining four permanent sampling stations and one non-permanent station in Piti Bay, and at four non-permanent stations in Tumon Bay; reef fish surveys were also carried out at an additional station in Tumon Bay.

A table of all sampling station survey dates between 2009 and 2014 is presented in Appendix A and maps of all the monitoring sites/sampling stations are presented in appendices B through H.

b. Detailed account of program activities

i. *FY2012*

Upon completion of data collection during the 2011 field season (which ended just prior to the current reporting period), the Monitoring Coordinator and Brown, with the assistance of Dr. Peter Houk of the Pacific Marine Resources Institute, carried out a preliminary analysis of the benthic cover and reef fish data sets. The preliminary analysis of these datasets included power analyses, exploration of the data in multivariate space using PRIMER/PERMANOVA, and the generation of basic descriptive statistics. In addition to providing baselines for key parameters, the results of the analysis will inform changes to the sampling design for each site in an effort to improve statistical power for these parameters. The results of the preliminary analysis of the benthic cover and reef fish community data were presented in a report entitled *Comprehensive Long-term Monitoring at Permanent Sites in Guam: Report of program status and presentation of preliminary baseline data and power analyses results for Tumon Bay, East Agana Bay, and Western Shoals sites*. The report was submitted to NOAA CRCP in January 2012.

Soon after the submission of the report, preparations for the 2012 field season began with the procurement of scuba cylinder rental services, a boat charter service, a replacement point and shoot camera/housing, an additional set of dive gear, and consumables. Field season preparations also included providing assistance to Brown in the cleaning and maintenance of the newly-acquired 18' Achilles inflatable, engine, and trailer. The Achilles allowed access to relatively sheltered sites and those sites in relatively close proximity to a marina, such as Western Shoals, East Agana Bay, and sites located along the southwestern coast. The Achilles also provided a cost-effective means of installing, maintaining, and retrieving datasondes, temperature/conductivity loggers, and other water quality instrumentation. The larger and more stable platforms provided by the UOGML boats and a private boat charter service continued to be used for Tumon Bay, Piti Bay, and sites located on the Southeast coast.

In order to prepare for the eventual use of the Achilles for monitoring program activities, several monitoring program staff received training and certification as NOAA small boat operators. The Monitoring Coordinator and Brown participated in a three-day NOAA/Department of Interior Motorboat Operator Certification Course (MOCC) and a two-day Open Water Module (OWM) in Hawai'i from March 26-30. The 2012 NOAA Technical Support Specialist (who in 2013 became the NOAA Coral Fellow), Roxanna Miller, as well as staff from partnering agencies, participated in the same courses when brought to Guam in September 2012. The Monitoring Coordinator, Brown, Miller, along with other federal and Government of Guam staff, also participated in a NOAA Component Course and an Operational Risk Management Workshop held on Guam on May 1-2; these courses are required in addition to the MOCC/OWM prior to operating a NOAA vessel. During this time the 18' Achilles inflatable boat, engine, and trailer acquired by the NOAA PIRO Guam Field Office from the National Park Service was also inspected by NOAA PIRFSC staff. The Monitoring Coordinator, Brown, and Miller, and several other staff from partnering agencies are now able to operate the Achilles, which will be used to access a limited number of monitoring sites, for responding to vessel groundings and other rapid response activities, and for other surveys and related work.

Prior to the commencement of data collection efforts in 2012, monitoring program staff participated in several training/survey calibration dives. Time was also spent delineating the initial site boundaries for the Piti Bay monitoring site. Images taken during a series of exploratory dives along the length of the outer reef slope in Piti Bay in November 2011 were georeferenced using the software application GPS-

Photo Link, and were then added to a Geographic Information System (GIS). The georeferenced images were critical in the accurate delineation of the site's eastern boundary, where a more topographically complex reef structure typical of the western and central portion of the bay's outer reef slope transitions into a reef structure with relatively low rugosity. LIDAR bathymetry data were used to constrain the site boundaries to a depth range of between 7 and 15 meters.

Data collection for the 2012 field season began at the Piti Bay monitoring site in July 2012. A total of nine field days and a total of 90 team member dives between July 23 and August 31 were required to complete all benthic surveys and the majority of fish surveys at the site's 20 sampling stations. Fish surveys were not conducted at four of the Piti Bay sampling stations due to the unavailability of Brown during those field days.

Upon completion of the benthic surveys within the Piti site, data collection efforts began in the Tumon Bay site. The results of a preliminary analysis of data collected in the Tumon Bay site in 2010 indicated that the eastern and western halves of the site possess distinctly different benthic communities, and suggested that the site boundaries may need to be re-drawn in order to minimize variance in key ecosystem health parameters and increase the ability to detect relatively small changes with a relatively small sample size. In order to collect data to inform the re-delineation of the Tumon site, a series of three exploratory dives were carried out on Sept. 7 along approximately 2.4 kilometers of the outer reef slope of the southern half of Tumon Bay, beginning at the far southwestern extent of the original monitoring site boundary and ending approximately 0.75 km beyond the northeastern boundary. Photos taken during the exploratory dives were georeferenced and used in a GIS to delineate new site boundaries that enclose a more homogeneous benthic community. The new Tumon site boundary includes about half of the original site and extends northwestward. Prior to the end of FY2012, the monitoring team carried out photo transect, coral quadrat, macroinvertebrate, and rugosity surveys at five sampling stations within the new Tumon Bay site, including two permanent stations surveyed in 2010 and three new non-permanent stations. Fish surveys were carried out at a total of four sampling stations.

In FY2012 a NOAA-funded technical support specialist was hired by BSP to assist with various aspects of the long-term coral reef monitoring program and related monitoring and assessment activities, such as carrying out different types of field surveys, assisting with the development of the program's water quality monitoring component, helping to coordinate the activities of the monitoring assistants, assisting with data management and analysis, and developing outreach materials and participating in outreach events. The position proved critical in the continued development of the long-term monitoring program, significantly improving the capacity of the program, which had previously been dependent on a single full-time staff (the Monitoring Coordinator) and several part-time monitoring assistants who sometimes required a considerable amount of training and whose course schedules sometimes presented challenges to completing the required field work in a timely manner. The success of the one-year position led to consensus that the position should be continued, and for FY2013 the responsibilities carried out by the Technical Support Specialist were funded through the NOAA Coral Reef Fellowship Program. Funding was also requested to support the continuance of the Fellow/Technical Support Position through FY2014 and FY2015.

In May 2012, the Monitoring Coordinator began his involvement in the review process for the proposed ESA listing of 83 coral species by providing occurrence and extinction risk information to the National Marine Fisheries Service (NMFS) prior to the release of the Management and Status Review

reports. In August 2012 the Monitoring Coordinator, with the assistance of the 2012 NOAA Technical Support Specialist, reviewed both reports and developed 48 pages of detailed comments that were included with a letter submitted to NMFS by BSP.

i) FY2013

Data collection at the Tumon Bay site continued into FY2013. Including the work carried out at the end of FY2012, data collection at the Tumon Bay monitoring site required a total of nine field days and 82 team member dives conducted between September 5 and November 9, 2012. Photo-transect, coral quadrat, macroinvertebrate, and rugosity surveys were carried out at 21 sampling stations. A total of nine new permanent sampling stations were established and surveyed, 6 new non-permanent stations were resurveyed, and one permanent station established in 2010 was resurveyed in Tumon Bay. Once surveys were completed within the Tumon Bay site, work began in the East Agana Bay site. A total of four field days and 35 team member dives between November 16 and 28 were required to complete all photo transect, coral quadrat, macroinvertebrate, and rugosity surveys at nine permanent stations established in 2010 and one newly established permanent station. Surveys were not carried out at 10 new non-permanent stations due to the lack of charter boat time and the unavailability of the NOAA PIRO Achilles. Fish surveys were not carried at any of the Tumon or East Agana sampling stations in 2013, as Brown, the lead for the monitoring team's fish surveys, was not available during this time due to an injury sustained while carrying out fish surveys in the Republic of the Marshall Islands. While some fish community data were conducted by a UOGML monitoring assistant at many of the stations, these surveys were considered training surveys and the potential uses of the data are limited.

The procurement of scuba cylinder rental services, a boat charter service, dive gear maintenance services, dive reels, a surface float, transect reels, and a NIST-traceable thermometer (to be used for calibrating the data loggers) was completed during FY2013.

In May 2013, the Monitoring Coordinator and the other members of the monitoring team collected qualitative data and georeferenced images during a series of three site exploration dives along the outer reef slope along the east side of Cocos Lagoon; the information collected during this site exploration informed the delineation of the Cocos monitoring site. However, due to administrative issues, diving operations were ceased shortly after this trip and did not resume until October 2013. As a result of the interruption in diving operations, data collection did not occur at the Cocos, Achang, Fouha Bay or Western Shoals monitoring sites during the 2013 field season. While monitoring activities requiring scuba diving did not occur during the remainder of the current reporting period, some members of the monitoring team carried out several data collection efforts that did not require scuba diving. These efforts, including coral bleaching reconnaissance surveys and reef flat transect surveys are summarized beginning on page 19.

The Monitoring Coordinator continued to collaborate with the NOAA CRED Information Services team, as well as with BSP and Department of Administration Data Services Division staff in the development of a database and web-based application for the management of data collected during monitoring program activities. Detailed information about the data management system is provided on page 15. In FY2013, the coral quadrat, macroinvertebrate, and reef fish community datasets were migrated to a Microsoft SQL Server relational database housed on a virtual server at the Guam Dept. of Administration Data Services Division using a database schema previously developed by the CRED team. A web-based application, also developed by the CRED team, was deployed on the virtual server and the Monitoring Coordinator, the 2013 NOAA Coral Fellow, and Brown began testing the application.

In April 2013, after extensive review of the revised list of coral species proposed for ESA protection, the Monitoring Coordinator, with the assistance of the 2013 NOAA Coral Fellow, provided NMFS with an additional 13 pages of detailed comments.

ii) FY2014

The beginning of FY2014 occurred at a time when the monitoring program was transitioning from BSP to the UOGML. Shortly after the Monitoring Coordinator began employment at the UOG, he participated in a large-scale effort to collect quantitative and semi-quantitative data at sites located around the island in order to document the extent and severity of what appears to be the most severe coral bleaching event known to affect Guam's coral reefs. The Monitoring Coordinator also carried out coral health assessments and coral tissue sampling at several sites in support of a closely-related, NSF-funded effort to document post-bleaching recovery. This informal partnership could lead to future collaboration between our NOAA-funded monitoring program and a long-term bleaching response/recovery project funded by NSF. More information about the bleaching response effort and the NSF project is provided beginning on page 19.

Upon completion of the bleaching response surveys, the benthic images generated from the photo transect surveys were analyzed using CPCe. A subset of the 2011 CRED benthic towed divers surveys were also analyzed; the 2011 CRED benthic towed diver images had been previously analyzed by CRED, but were analyzed again in order obtain genera-level information for corals for comparison to the benthic cover data derived from photos taken at reef front sites during the 2013 coral bleaching event. The analysis of benthic images was carried out by two monitoring assistants, the Monitoring Coordinator, and a UOGML graduate student, Travis Reynolds, who is using the data as part of his Master's thesis. Additional information about the analysis of the bleaching response data and the presentation of some of the results at the Asia-Pacific Coral Reef Symposium is provided beginning on page 19.

The Monitoring Coordinator also carried out coral quadrat surveys in support of a NOAA PIRO project involving a Moving Window Analysis of benthic communities in Fouha Bay. More information about this project is provided on page 22.

Data collection at long-term monitoring sites began in early September, much later than originally intended, due to scheduling conflicts, but work proceeded quickly once it began. As a result of limited boat charter time and the desire to collect data for a third time period for as many sites as possible, it was decided that only permanent sampling stations would be surveyed in 2014. Work began at the Tumon Bay site, with all 12 permanent sampling stations surveyed, followed by surveys at all 10 permanent stations at the East Agana Bay site. Photo transect, coral quadrat, macroinvertebrate, and rugosity surveys were conducted at the Tumon Bay and East Agana Bay sites; reef fish community surveys were carried out at the 12 permanent stations by one of the monitoring assistants, but because this person had not yet been calibrated with our primary fish observer, Brown, and because the surveys were conducted while the benthic survey observers were in the water, this data is of limited value. However, the monitoring team, including Brown, returned to the Tumon Bay site in November and carried out fish surveys at five non-permanent sampling stations; photo transect, coral quadrat, and macroinvertebrate surveys were carried out at four of the stations. The fish team carried out a photo-transect survey at the fifth station, but coral quadrat and macroinvertebrate surveys were not conducted. After the benthic work was completed at the permanent sampling stations in the Tumon Bay and East Agana Bay sites, the full monitoring team, including Brown, began data collection at the Piti Bay site. All survey methods, including fish surveys, were employed at all 10 permanent stations and one non-permanent station. Due to the unexpected availability of five boat days remaining with a boat originally chartered by NOAA PIRO for a NOAA PIRO-CRED collaboration to carry out fish surveys at

locations off the Southern coast of Guam, work at the Piti site was temporarily interrupted and attention was diverted to the establishment of sites off Achang Bay and the East side of the Cocos Barrier Reef. During these five days most surveys were carried out at 11 permanent and three non-permanent stations in the Achang site and at three permanent stations in the Cocos-East site. Fish surveys, which include the photo transects that are a standard part of the NOAA SPC methodology, were carried out at three additional Cocos-East sites. Coral quadrat surveys were not carried out at three of the Achang stations and all of the Cocos-East stations, as the Monitoring Coordinator, who normally carries out this survey, was unavailable due to an illness.

The Monitoring Coordinator continued to collaborate with the NOAA CRED Information Services team, as well as with BSP and Department of Administration Data Services Division staff in the development of a database and web-based application for the management of data collected during monitoring program activities. Early in FY2014 the initial end-user testing of the web-based application was completed and the entry of new data had begun. By the end of FY2014, data from 2012 macroinvertebrate surveys were entered and most of the 2012 coral quadrat survey data were entered. The effort to incorporate the benthic cover data into the database continued, with the Monitoring Coordinator re-naming, re-organizing, and generating output files for benthic cover data collected between 2010 and 2012; the bulk of these files were provided to NOAA CRED in November 2014. During this time the Monitoring Coordinator reached out to Brown and Marybelle Quinata in order to obtain sample datasets collected through the community-based monitoring program they coordinate. These sample datasets were provided to the NOAA CRED team in order to allow them to develop a schema for incorporating the data into an expanded version of the database and web application. Data from Dr. Laurie Raymundo's reef flat monitoring program were also sought, but the data were currently being entered into a comprehensive Access database and were not available at the time. The community-based monitoring program and reef flat monitoring program data, along with water quality data from the Long-term Monitoring Program were intended for inclusion in the data management system, but a recent proposal to CRCP submitted by CRED for this work had been rejected. In addition to expanding the data management system to include additional datasets, the proposed project would have also included a web-base data sharing application, which would have significantly improved end-user access to the copious data generated by these programs. The Monitoring Coordinator also worked with CRED Data Services staff to develop metadata for available data sets. Metadata records for the fish, coral quadrat, and macroinvertebrate data have been finalized and will be posted to CoRIS by CRED staff. The Monitoring Coordinator also worked with CRED Data Services staff in the completion of NOAA data management questionnaires.

During FY201 re-programmed funds were used to procure a desktop computer tower, two office chairs, two dive computers, a BCD and regulator, an external hard drive, calibration buffer solutions, a replacement pH sensor, three digital point-and-shoot cameras and housings, digital camera accessories, a GPS receiver and waterproof pack, and the maintenance of four BCDs and four regulators.

The Monitoring Coordinator also provided the available coral quadrat data, as well as additional information, to a NMFS contractor tasked with development of a geographically-referenced database that includes the known and potential occurrences of the ESA-listed coral species as well as other coral species. The Monitoring Coordinator later reviewed a draft of the geodatabase and provided additional information regarding the occurrence of the list species, including specific location information for colonies of the four threatened species that occur in Guam's waters culled from a review of photographs and notes taken since his arrival on Guam in 2004.

c) Data analysis

Between FY2012 and FY2014, a limited amount of statistical analysis was carried out on data collected through the long-term monitoring program and related activities. These analyses included the following:

- 1) Preliminary analysis and power analysis of baseline (2010) benthic cover and reef fish data from the Tumon Bay, East Agana Bay, and Western Shoals sites
- 2) Preliminary analysis of baseline (2010) coral colony size data from the Tumon Bay, East Agana Bay, and Western Shoals sites
- 3) Quantitative description of Guam's reef front coral communities and a preliminary analysis of their robustness to local stressors

The results of the analyses listed in items 1 and 2 above were presented in reports submitted to CRCP in December 2011 and December 2012, respectively. The results of the preliminary analysis of data collected during the 2013 coral bleaching response effort (item 3 above) were presented at the 2014 Asia-Pacific Coral Reef Symposium in Taiwan.

While robust statistical analyses have not yet been carried, a substantial amount of effort has been dedicated to generated benthic cover data from the photo transect images. Between FY2012 and FY2014, benthic cover data for all sites surveyed between FY2011 and FY2013 were generated through the analysis of hundreds of images using CPCe. In addition to the effort to generate the benthic cover data, significant effort was also employed by the Monitoring Coordinator to carry out quality analysis/quality control on the data, which were generated primarily by monitoring assistants.

d) Data management

A database server and associated applications for data entry, quality control, management, analysis and reporting have been in development through collaboration with NOAA PIFSC Coral Reef Ecosystem Division, and with support by the BSP and the Department of Administration. Hardware and software for the Guam Monitoring Data Management System were procured and are currently housed at the Government of Guam's Department of Administration. NOAA CRED Data Services staff, through regular consultation with the Monitoring Coordinator, designed data models and first migrated the coral quadrat, fish, and macroinvertebrate datasets to a temporary database server that was used for the testing of the web-based applications. During this early stage of the system's development, the BSP hired a contractor to assist the Monitoring Coordinator and the NOAA Technical Support Specialist in compiling coral reef monitoring/assessment datasets and associated metadata from various organizations. The information gathered through the effort, which was completed in December 2012, served as the initial stages of the planned integration of data sets generated by the NOAA PIRO-supported Community-based Coral Reef Monitoring Program and Dr. Laurie Raymundo's Reef Flat Monitoring Program. At a later date, metadata for these and a number of other Guam coral reef assessment/monitoring efforts may be made searchable through a web application.

In 2013, the coral quadrat, macroinvertebrate, and reef fish community datasets were migrated to a Microsoft SQL Server relational database housed on a virtual server at the Guam Department of Administration Data Services Division using a database schema previously developed by the CRED team. A web-based data entry application, also developed by the CRED team, was also deployed on the virtual server and underwent testing by the Monitoring Coordinator, the 2013 NOAA Coral Fellow, and Brown.

In early FY2014, initial end-user testing of the web-based application was completed and the entry of new data had begun. The entry of data into the system continued through FY2014, with all 2012 macroinvertebrate survey data and most of the 2012 coral quadrat survey data entered. The effort to incorporate the benthic cover data into the database continued, with the Monitoring Coordinator re-naming, re-organizing, and generating output files for benthic cover data collected between 2010 and 2012; the bulk of these files were provided to NOAA CRED in November 2014. During this time the Monitoring Coordinator continued to work with Brown and Quinata in order to obtain sample datasets collected through the community-based monitoring program they coordinate. These sample datasets were provided to the NOAA CRED Data Services team in order to allow them to develop a schema for incorporating the data into an expanded version of the database and web application. Data from Raymundo's reef flat monitoring program were also sought, but the data were currently being entered into a comprehensive Access database and were not available at the time. The community-based monitoring program and reef flat monitoring program data, along with water quality data from the Long-term Monitoring Program were intended for inclusion in the data management system, but a recent proposal to CRCP submitted by CRED for this work had been rejected. In addition to expanding the data management system to include additional datasets, the proposed project would have also included a web-base data sharing application, which would have significantly improved end-user access to the copious data generated by these programs and would have streamlined the reporting process through the automated generation of descriptive statistics and summary reports.

As mentioned above, the Monitoring Coordinator worked with CRED Data Services staff to develop metadata for available data sets. Metadata records for the fish, coral quadrat, and macroinvertebrate

data have been finalized and will be posted to CoRIS by CRED staff. The Monitoring Coordinator also worked with CRED Data Services staff in the completion of NOAA data management questionnaires.

e) Reporting, publications and outreach

As mentioned above, two reports that included the results of preliminary analyses of data generated through the monitoring program were released during the current reporting period. The results of the preliminary analysis of the benthic cover and reef fish community data were presented in a report entitled *Comprehensive Long-term Monitoring at Permanent Sites in Guam: Report of program status and presentation of preliminary baseline data and power analyses results for Tumon Bay, East Agana Bay, and Western Shoals sites*. The report was submitted to NOAA CRCP in January, 2012 and is now available through CoRIS. A second report, entitled *Comprehensive Long-term Monitoring at Permanent Sites in Guam: 2012 Status Report*, was submitted to NOAA CRCP in December 2012; this report provided a summary of monitoring program activities in 2012 and included a preliminary analysis of baseline coral colony size data collected at the Tumon Bay (2010), East Agana Bay (2010), and Western Shoals (2011) sites. The reports will also be made available on the Guam Long-term Coral Reef Monitoring Program website, which will be launched in 2015.

As described in more detail on page 20, some of the results of a preliminary analysis of benthic cover data collected during the 2013 bleaching event were presented at the 2014 Asia-Pacific Coral Reef Symposium. The Monitoring Coordinator also co-authored a brief “Reef Sites” article in the June 2014 volume (33, issue 2) of the journal *Coral Reefs* entitled “Unprecedented coral bleaching across the Mariana Archipelago”.

The Monitoring Coordinator also gave a presentation entitled, “*Where are Guam’s canaries in the coal mine? Mapping the island’s staghorn thickets*”, at the 2013 Guam Coral Reef Symposium, held on June 24, 2013, at the Hyatt Regency Guam.

While the highly technical reports mentioned above were not broadly distributed on Guam, general information about the monitoring program was presented to the public via an informational pamphlet, several blog articles written by the NOAA Technical Support Specialist and the Monitoring Coordinator, presentations at the NOAA PIRO and NPS sponsored Science Sunday lecture series, and other presentations to students of various ages. A few examples of outreach materials generated by monitoring team members and by others who wished to highlight the work of the monitoring team can be found at the following links:

- Article in *Man, Land, and Sea* newsletter – “Coral monitoring gears up for field season”: http://www.bsp.guam.gov/index.php?option=com_content&view=article&id=154:man-land-and-sea-2012-v5-i2&catid=38:coastal-management&Itemid=37
- Article in Governor’s PROA newsletter, Issue 29, p. 29 – “Gathering data about Guam’s reefs”: http://issuu.com/governor_calvo/docs/proa_i29
-
- Episode VI (Parts 2 and 3) of *Into the Islands* series: <http://intotheislands.com/>
- Blog posts at <http://www.micronesiachallenge.org/> (Scroll down to “Saving our Micronesia” community blog link in the left-hand navigation bar)
 - “GUAM: ‘tis the season for monitoring!” (March 2012)
 - “When you were a kid, what did you want to be when you grew up?” (April 2012)

- “Monitoring Season: REDUX” (May 2012)
- “Monitoring, and weather, and presentations...Oh my!” (November 2012)
- “Adios 2012!” (December 2012)

A few other examples for which active URLs are not available are as follows:

- Article in Man, Land, and Sea newsletter – “Love Guam, love the Earth!”
- Article on Governor’s PROA newsletter, Issue 39 – “Guam SECORE workshop 2013”
- Brochure “Guam’s Long-term Coral Reef Monitoring Program”

In addition the brochure, the online and printed articles, and the presentations mentioned above, the Monitoring Coordinator and the 2012 NOAA Technical Support Specialist/2013 NOAA Coral Fellow presented information about the monitoring program and closely related topics to audiences of all ages. Examples of these presentations include talks for high school career days, regular (nearly every semester) talks to a University of Guam Environmental Biology class, a presentation to a University of Guam Introduction to Geography class, a presentation to a University of Guam Scientific Photography class, presentations for the NOAA PIRO and NPS-supported Science Sunday lecture series, presentations for the University of Guam’s POETS lecture series, and several other presentations to school students of various ages.

IV. Other Monitoring Program activities/collaborations

a. 2013 coral bleaching response effort

i. Response plan development and coral bleaching reconnaissance

In the late summer and fall of 2013 the Monitoring Coordinator contributed a significant amount of time to the organization and implementation of a coral bleaching response effort. The 2012 NOAA Coral Fellow also contributed to the effort. Between August and October of 2013 the coral reefs of Guam and other Southern Mariana Islands experienced a significant bleaching event associated with anomalously high sea surface temperatures and an extended period of calm weather. In late August monitoring team members, including the Monitoring Coordinator and the 2013 NOAA Coral Fellow, contributed to efforts coordinated through Guam's rapid response team to assess the extent and severity of a coral bleaching event. Monitoring team members investigated the reef flat and shallow reef slope communities at Marbo Pt., Hila'an (Sharks Hole), Tanguisson Pt., and West Hagatna Bay, while other members of the rapid response group visited other areas around the island. In addition to photo-documenting the bleaching impacts at each site visited during the reconnaissance effort, the monitoring team members also utilized a GPS on a float in order georeference the photos taken at each site; these images can be used to help to better understand the spatial pattern of bleaching as well as contribute to improved benthic habitat maps. The monitoring team members met with the rapid response team several times over a month-long period to share observations and develop a standard protocol for collecting quantitative data.

ii. Quantitative data collection

Once the rapid response team had decided the event was severe enough to justify further action, a UOGML -led team set out to document the event's scale and severity. The survey effort was carried out by a team consisting of the Monitoring Coordinator, Raymundo and Houk of the UOGML, and several UOG students, with occasional support from the 2013 NOAA Coral Fellow and Guam EPA. Benthic photos, 2 m-wide macroinvertebrate belts, and semi-quantitative coral community diversity and condition assessments were carried out along three 25 m transects laid end-to-end at a total of 45 shallow (5-6 m) reef front sites randomly distributed around the island. The majority of sites were coincident with randomly-generated sites at which NOAA CRED carried out reef fish surveys in 2011. The Monitoring Coordinator carried out coral community surveys and occasionally other surveys on 35 dives across 13 field days.

Work at the beginning of the FY2014 involved the analysis of The benthic images collected during the 2013 coral bleaching event survey effort, as well as images for a subset of 2011 CRED benthic towed divers surveys were analyzed in the first half of FY2014. The 2011 CRED benthic towed diver images had already been analyzed by CRED, but were analyzed again in order obtain genera-level information for corals for comparison to the benthic cover data derived from photos taken at reef front sites during the 2013 coral bleaching event. The analysis of benthic images was carried out by two monitoring assistants, the Monitoring Coordinator, and a UOGML graduate student, Travis Reynolds, who is using the data as part of his Master's thesis.

Once benthic cover values were derived from the benthic images using CPCe, the Monitoring Coordinator, with assistance from Houk of the UOGML, carried out statistical analyses of the data using

PRIMER/PERMANOVA and R. The preliminary results of the analyses were presented by the Monitoring Coordinator at the 2014 Asia-Pacific Coral Reef Symposium held in Taiwan in June. The results of the analyses yielded the first quantitative description of the structure of the reef front benthic communities around the island and a preliminary analysis of potential drivers of differences in structure across sites. The analysis relied upon an assumption that recently killed coral colonies were alive prior to the bleaching event, in essence reconstructing the state of Guam's shallow reef front zone pre-bleaching. The reef front benthic cover data were also compared to benthic cover data derived from the analysis of the CRED benthic towed diver images. The results showed that coral cover and generic diversity was significantly higher in the reef front than in the lower reef slope, and that the high wave energy of the reef front zone is a potential driver of the coral cover and diversity differences between the reef front and lower reef slope through the deterrent effect of high wave energy on the coral predator *Acanthaster planci* and the mitigating effect high wave energy may have on sediment impacts to benthic organisms.

The Monitoring Coordinator, along with two UOGML faculty members, assisted a graduate student, Travis Reynolds, with his analysis of the bleaching event response data. While the analysis of the data carried out by the Monitoring Coordinator was used to reconstruct a baseline for Guam's reef front communities and to better understand the environmental factors driving the structure of these communities, the student's analysis focused on the impacts of the bleaching event on reef front benthic communities. The preliminary results of his analysis were also presented at the Asia-Pacific Coral Reef Symposium, and yielded a brief "Reef Sites" article in the June 2014 issue of the journal *Coral Reefs* (for which the Monitoring Coordinator is a co-author). The student is continuing his analysis as part of his Master's thesis.

iii. Other bleaching response-related efforts

In late September, the Monitoring Coordinator and the 2013 NOAA Coral Fellow carried out quantitative surveys to assess the prevalence of bleaching and bleaching-associated mortality within an extensive staghorn community on the reef flat in West Hagatna Bay. Data was collected within quadrats placed every meter along 25 m transects; data were collected for a total of 12 transects. Transect locations were generated randomly using a GIS; a GPS receiver was used to locate the transect locations in the field. Monitoring team members have also recently begun carrying out quantitative surveys at 50 random sites around the island as part of a rapid response team effort to assess the impacts of the coral bleaching event island-wide.

The Monitoring Coordinator also assisted Raymundo with the tagging and follow-up monitoring of bleached and healthy coral colonies at several sites around Guam. The intent of the tagging effort, which occurred at two of Raymundo's reef flat monitoring sites as well as behind the UOGML, was to gain some insight into survivorship and recovery of several coral species in response to the bleaching event. The effort included tagging a total of 10 *Acropora azurea* colonies from the reef front behind the UOGML, 15 *Acropora* spp. colonies from a reef flat in Agat, and 19 *Porites annae* and *Porites rus* from the reef flat in Tumon Bay. All the *Acropora azurea* colonies from behind the UOGML had died, only two of the *Acropora* spp. colonies at the Agat site had died, and none of the colonies at the Tumon Bay site had died. However, the tagged colonies in Agat and Tumon Bay have not been revisited since a brief but severe bleaching and associated mortality were observed in May-June of 2014.

b. Staghorn coral mapping, assessment, and monitoring

At various periods during the current reporting period the monitoring team members continued to opportunistically document the extent, community composition, and general condition of staghorn coral communities at sites around the island in an on-going effort to develop an island-wide baseline inventory of these vulnerable coral communities and to track changes in these communities over time. To-date all known staghorn coral thickets on Guam's reef flats have been mapped, and many have been revisited after the 2013 bleaching event. A GIS layer has been developed, and is regularly updated as new information regarding the extent, species composition, and condition of Guam's staghorn corals is obtained. This GIS layer has been used as a critical component of a study (see below) carried out by Dr. Jenny McIlwain and Dr. Andrew Halford (both formerly of the UOGML) and has aided a recently-commenced study carried out by Raymundo and Dr. Daniel Lindstrom (see below). While the mapping effort was focused on staghorn coral communities, georeferenced images obtained across various reef flat and outer reef slope habitats during these site investigations will contribute to further development of nearshore benthic habitat data for Guam.

c. Sexual Coral Reproduction (SCORE) workshops and associated research

The Monitoring Coordinator served as one of the local organizers of two workshops led by the SCORE Foundation and supported by several public and private aquarium partners, the Nanyang Technical University in Singapore, the University of Guam, and the Government of Guam. The workshops, held at the UOGML between July 25-August 4, 2013 and July 14-24, 2014, were aimed at providing training to participants in the capture of coral gametes and the culture of coral larvae and at improving sexual reproduction-based coral restoration and breeding techniques. The workshops also included community outreach opportunities, such as public lectures and coral spawning viewing, and gained attention from local media. In addition to serving as one of the local organizers for both workshops, the Monitoring Coordinator also provided lectures, including an overview of the status of Guam's coral reefs, an introduction to coral reef ecology, the impacts of the 2013 coral bleaching event, and an introduction to coral taxonomy, morphology, and field identification; he also guided workshop participants on excursions to several reef sites.

The Monitoring Coordinator also provided support to SCORE efforts by assisting with the establishment of an in-water coral nursery in Piti Bay, assisting with an investigation into coral recruit survivorship on different settlement tile designs, and assisting with a study of the movement of an experimental coral settlement tile and coral survivorship in a high-energy reef zone.

d. Micronesia Challenge – Marine measures development

During the current reporting period the Monitoring Coordinator continued to participate in the Micronesia Challenge Marine Measures Subgroup. The aim of the subgroup is to develop a set of indicators and methods used across the region to measure progress towards the Micronesia Challenge goals pertaining to marine resources. The Monitoring Coordinator's participation during this reporting period followed two previous workshops, including the 1st Measures Workshop in Pohnpei (Federated States of Micronesia) in 2008 and the 1st Marine Measures Subgroup workshop held in Palau in 2010. The workshops that occurred during the current reporting period include the 2nd Marine Measures Subgroup workshop held in Palau from February 6-9, 2012, and the 3rd Marine Measures Subgroup workshop held at the University of Guam from September 21-213, 2014.

e. NOAA PIRO Fouha Bay Moving Window Analysis project

The Monitoring Coordinator carried out coral quadrat surveys in support of a NOAA PIRO project involving a Moving Window Analysis of benthic communities in Fouha Bay. Fouha Bay is the next site planned for establishment for long-term monitoring and the data collected as part of the MWA project, and the comparison to historical MWA data, will yield valuable insight into the spatial and temporal changes in the bay's reef community. The coral quadrat surveys required sizing and identifying coral colonies within 1 m² quadrats placed every five meters along transects of lengths between 400 and 450 m. Brown carried out the benthic cover surveys and provided boat support when needed. A monitoring assistant assisted with the project by providing boat and safety support while the Monitoring Coordinator and Brown were diving. The project required data that benthic cover and coral colony data be collected along a total of four transects, including one shallow (1 m depth) and one deep (6-7 m depth) transect on both the North and South sides of the bay. The shallow transect surveys were carried out while snorkeling and required a total of six field days between April 22 and May 7, 2014. The 400 meter-long South-Deep transect was completed with four dives carried out on May 28 and August 29. The shortened 150 meter North-Deep transect was completed with three dives carried out on November 19 (beyond the current reporting period). The Monitoring Coordinator will review the results of an analysis carried out by a NOAA PIRO contractor and will co-author any resulting peer-reviewed publications.

e. Assistance with University of Hawai'i Ph.D. candidate research

On October 31st and November 1st, the Monitoring Coordinator and the NOAA Technical Support Specialist participated in two site visits to Fouha Bay. As discussed in previous reports, Fouha Bay has been selected as a monitoring site, primarily in support of on-going watershed restoration work aimed at improving water quality. Work carried out during these site visits included the exploration of the site to help inform the development of site boundaries and the sampling regime, as well as assisting with the installation and retrieval of sediment traps and CTDs being used by Austin Shelton, a University of Hawai'i at Manoa Ph.D. candidate student, as part of his thesis project and associated community-based watershed restoration effort. The site exploration involved snorkeling over the bay's reef community with a GPS in tow; the numerous images taken with a digital point-and-shoot camera while snorkeling in the bay were georeferenced using the software application GPS-Photo Link and imported into ArcGIS. The georeferenced images, along with lidar bathymetry data and existing reef community data, were used to develop tentative site boundaries and a sampling regime.

f. Ga'an Point marine debris cleanup

The Monitoring Coordinator and the 2012 NOAA Technical Support Specialist participated in a public-private collaboration involving Underwater World, Micronesian Divers Association, UOGML, BSP – Guam Coastal Management Program, and Guam Environmental Protection Agency staff to clean up thousands of aluminum cans and other trash items that were found at a reef site near Ga'an Point, in Southern village of Agat. The cleanup event, which occurred in December 12, 2012, generated local as well as regional media attention. Examples of some of the online news articles published about the event are provided below:

- <http://www.radioaustralia.net.au/international/radio/onairhighlights/social-media-video-leads-to-big-offshore-cleanup-in-guam/1060428>

- <http://www.pacificnewscenter.com/component/content/article?id=29825:divers-collect-more-than-20-bags-of-trash-from-seafloor-in-joint-cleanup-effort>
- <http://mvguam.com/local/news/27378-guam-epa-coordinates-dive-cleanup.html#.Vlpm7cnnLuo>
- <http://www.fishchannel.com/fish-news/2013/01/15/guam-reef-gets-trashed.aspx>

g. Mcllwain-Halford staghorn connectivity study

The Monitoring Coordinator collaborated with Mcllwain and Halford on a project entitled “Measuring the degree of connectivity between remnant staghorn patches at risk of anthropogenic impacts.” The project aimed to measure the total population size and genetic diversity of staghorn corals on Guam, and by use of a bio-physical model determine which sites are source populations that will need comprehensive protection. In addition, by providing information on the species diversity, resilience and connectivity of staghorn corals, the effectiveness of the existing Marine Preserves in maintaining coral biodiversity and enhancing ecosystem structure. The Monitoring Coordinator contributed to the development of the project proposal, aided in the location and identification of targeted staghorn coral species, carried out staghorn mapping efforts with Halford in Apra Harbor and Cocos Lagoon, carried out additional independent staghorn coral mapping, updated the staghorn coral GIS layer, and with the support of the 2013 NOAA Coral Fellow collected 95 tissue samples from staghorn corals in Tumon Bay and Cocos Lagoon.

h. Raymundo staghorn coral loss project

The Monitoring Coordinator has provided support to Raymundo and Lindstrom of UOGML for a NOAA CRCP-funded study entitled “Addressing the loss of a key functional group, staghorn *Acropora*, on Guam reefs.” The study aims to establish reproductive timing of Guam’s staghorn coral species and to develop a genomic archive and DNA sequence characterization of remaining populations (building on the Mcllwain-Halford staghorn connectivity study) that can guide rehabilitation and culture options. A second phase of the project will involve pilot projects for the culture and reestablishment of populations by testing established methods of nursery rearing and outplanting. The Monitoring Coordinator provided input during the development of the project proposal in FY2013, and more recently (beyond the current reporting period) has assisted Raymundo in determining which staghorn sites should be assessed and monitored, has aided in the identification of staghorn species, and visiting two sites along with Raymundo and a graduate student, Valeri Lapacek.

i. Coral Health Impacts Workshop

The Monitoring Coordinator and the 2013 NOAA Coral Fellow, Roxanna Miller, provided support to Raymundo in the organization and implementation of a NOAA CRCP-funded Coral Health Impacts workshop held at the UOGML between January 14-18, 2013. The intent of the workshop was to train regional coral reef managers in assessing impacts to coral health. The workshop was attended by four individuals from Government of Guam agencies, four from Saipan’s Department of Environmental Quality, one from University of Hawaii, two from the Chinese University of Hong Kong, two from De La Salle University, Philippines, and two from the Korean South Pacific Oceanographic Research Center (including, Sun Kim, a former UOGML student). The workshop consisted of a series of morning lectures by local experts on coral diseases of the Indo-Pacific, underwater disease diagnosis, assessment and monitoring, coral taxonomy, and descriptive statistics and data organization. The Monitoring

Coordinator presented an overview of the Long-term Coral Reef Monitoring Program and how the program addresses coral health impacts, as well as an overview of coral taxonomy, morphology, and field identification. The 2013 NOAA Coral Fellow gave a lecture entitled “Impacts to Indo-Pacific corals: A Decision Tree for Underwater Assessment of Disease and Compromised Health.” Both the Monitoring Coordinator and the 2012 NOAA Coral Fellow served as guides for two field excursions.

j. Bleaching susceptibility and resilience study

The Monitoring Coordinator contributed to an NSF RAPID-funded study entitled “Documenting bleaching susceptibility and resilience in Guam, Micronesia” and carried out by Dr. Kiho Kim of American University, Dr. David Baker of the University of Hong Kong, and Raymundo of the UOGML. The researchers are examining patterns of mortality and recovery from the 2013 coral bleaching event in the context of reef resilience and hypothesize that exposure differences between the east and west sides of the island will result in differential recovery, and sites that showed lower bleaching severity during initial surveys will show higher recovery post-bleaching. The researchers predicted that differential bleaching is due, in part, to the presence of coral and zooxanthellae genotypes and clades, respectively, and that they are less sensitive to extreme temperature anomalies. The Monitoring Coordinator carried out coral health assessments at Ipan-Deep (Jan 24 2014), Tanguisson-Shallow (Jan 23 2014), Tanguisson-Deep (March 20 2014), and Achang-Shallow (Feb 13 2014) sites, and also collected coral tissue samples at the Ipan-Deep site.

k. Vessel grounding response

The Monitoring Coordinator participated in a vessel grounding response effort coordinated by Brown with NOAA PIRO and supported by Guam EPA staff. On February 21, 2014, the Monitoring Coordinator joined Brown and the Guam EPA staff for a qualitative assessment of a reef area impacted by the 54' Daiki Maru, a Japanese fishing vessel that came aground near Orote Pt., in Apra Harbor. The results of the assessment were used to inform the planning of the salvage operation, with the aim of minimizing impacts to marine resources.

l. Guam Community Coral Reef Monitoring Program

The 2013 NOAA Coral Fellow, Roxanna Miller, and one of the UOG monitoring assistants provided support to the NOAA PIRO-supported Guam Community Coral Reef Monitoring Program. The program, which is organized by Brown and Quinata with the NOAA PIRO Guam Field Office, involves community members in reef flat monitoring efforts through the provision of training and the organization of regular monitoring efforts at reef sites near interested communities. Miller and Andrea Hersberger, a UOGML graduate student and one of the monitoring assistants, both provided regular assistance to the program through the training of community members and serving as safety support for field outings.

m. UOG Reef Flat Monitoring Program

Between FY2012 and FY2014, one of the monitoring assistants assisted Raymundo with the Reef Flat Monitoring Program (described in detail below) by carrying out Line Intercept Transect (LIT) surveys at multiple reef flat sites on a regular basis. The Monitoring Coordinator carried out coral condition surveys at the Tanguisson site in March 2014.

n. RARE Pride project support

In FY2012 the Monitoring Coordinator and the 2012 NOAA Technical Support Specialist carried out macroinvertebrate surveys in support of the “Piti Pride, Tepungan Wide” RARE Pride campaign organized by Jane Dia, Resource Information and Education Officer with the Guam Department of Agriculture. The Monitoring Coordinator again carried out macroinvertebrate surveys for a follow-up effort in November 2014 (beyond the current reporting period). The Monitoring Coordinator also participated in an MPA Effectiveness Evaluation meeting in December, 2012.

V. Program challenges

While the monitoring team carried out a total of 215 team member dives over the course of 24 field days; established and collected baseline data for new monitoring sites in Piti Bay, Achang Bay, and Cocos-East (partial); collected a second set of data for Piti site; collected a second and third set of data for the Tumon and East Agana Bay sites; provided critical support to a large-scale coral bleaching response effort and contributed to several other projects, some challenges limited the collection of reef fish community data at several sites between FY2012-FY2014 and prevented the completion of data collection at the full set of non-permanent stations in East Agana Bay and Tumon Bay in FY2012 and FY2014.

During the current reporting, field seasons started later than originally planned, sometimes as a result of procurement challenges, but also as a result of scheduling conflicts. The result was that the field season was extended into the time of the year when tropical disturbances are more common, and, indeed, dangerous water conditions sometimes limited the number of available field days.

Data collection at sampling stations required more time than in previous years, primarily due to the time required to train and calibrate a new monitoring assistant with the Stationary Point Count (SPC) method used by Brown to census reef fish communities. During the training/calibration period, which was only recently completed and is necessarily intensive due to the high potential for inter-observer bias when surveying reef fish communities, Brown had to complete two SPCs during a single dive instead of two divers each simultaneously completing one, causing the total dive time to be nearly double that of the previous two years. As a result, only two sampling stations (and sometimes only) could be completed during a field day. The reduced number of sampling stations that could be surveyed in a given day, in turn, reduced the total number of sampling stations that could be surveyed utilizing the limited number of boat days available through the boat charter service. The limited availability of Brown also contributed to the limited amount of reef fish community data collected in 2013 and 2014. The class schedules of the monitoring assistants also presented challenges once the semester began in mid-August, with the monitoring team having to return earlier than usual to attend class.

While temperature loggers were established in the Tumon, East Agana, Piti, and Achang sites in 2014, the deployment of datasondes and temperature/conductivity loggers have not yet occurred, primarily as a result of the lack of staff training in the proper deployment of the instrumentation and the discovery that several calibration standards for the multiparameter datasondes had expired. However, hands-on hands-on training has been provided by Guam EPA staff to the Monitoring Coordinator and the NOAA Technical Support Specialist in the calibration of the datasonde sensors, and the calibration standards have been procured; once the full-time technical support position is filled in early FY2015 preparations will be made to deploy the datasondes.

The administrative issue that prevented the Monitoring Coordinator from scuba diving between May and September 2013 resulted in the cancellation of the 2013 field season and necessitated the transfer of the Long-term Monitoring Program from the BSP to UOGML. The transfer of the program require a significant amount of time, including numerous meetings with relevant parties and as well as the time required to clean out a lab/office space and move equipment, supplies, and other items to the new space.

The nearly one-year delay of the receipt of funds intended for FY2014 resulted in the significant delay of the hiring of the full-time technical support specialist. As a result, field survey efforts were not as efficient as would be possible with the additional help, data management and analysis was slowed, outreach efforts were significantly scaled back, and datasonde deployment did not occur.

VI. Program plans for 2015

A full-time technical support specialist will be hired in February 2015; this individual will provide critical support to the program by contributing to data collection efforts (including water quality data collection), data management and analysis, outreach, as well as program administration.

Upon completion of the CPCe analysis of the photo transect images collected in 2014, a comprehensive analysis of all benthic cover, reef fish, and macroinvertebrate data collected since the program's inception will be carried out. The analysis will include a description of baseline data and a power analysis of key benthic cover parameters for the Piti, Achang, and Cocos-East sites, as well as an examination of changes in key parameters at the Tumon and East Agana sites between 2010-2014, and changes at the Piti site between 2012 and 2014. The results of this comprehensive analysis will be included in a major technical report that will likely be released at the end of 2015. This annual report will be the first report in which baseline data for all monitoring sites will be presented; the report will be technical in nature and will be aimed at managers, researchers, and technicians, but newsletter articles, a pamphlet or one-pager, blog posts, and possibly other accompanying publications will target policy makers and the general public.

Preparations for the 2015 field season will begin in early 2015, with the field season potentially starting as early as February with the establishment of the Fouha Bay monitoring site. The sampling design for the Fouha Bay site (Appendix I) has been established, and will involve surveys at three replicate 25 m transects placed at four distinct parts of the bay (a total of 12 transects): North-inside, North-outside, South-inside, and South-outside. The usually calm conditions along the Southwest coast makes it possible to access the Fouha Bay site using the NOAA PIRO Achilles, even when trade winds make access to other West-coast sites difficult. Once trade winds subside, usually around May, data collection efforts will begin at the other sites, to include all permanent and non-permanent stations at the Tumon, East Agana, and Piti sites as well as all stations at the Western Shoals site. Depending on boat availability and monitoring team member schedules additional stations may be set up at the Cocos-East site.

As described above, the limited availability of Brown and the lack of a second reef fish survey specialist calibrated with Brown significantly hindered the collection of reef fish community data, and also reduced the total number of sampling stations surveyed in 2012 and 2014. The UOGML monitoring assistants who carried out numerous training dives with Brown throughout the 2012 field season was cleared to conduct official reef fish surveys in late 2014, but after carrying out surveys at the Achang site and at the non-permanent Tumon Bay stations in October and November 2014 this individual was offered and accepted the Reef Resilience Coordinator position. It is hoped that this individual can still carry out fish surveys as part of the responsibilities for her new position. In an effort to increase the pool of available reef fish community survey specialist and improve program efficiency and redundancy in the longer-term, the Monitoring Coordinator and the full-time technical support staff, and at least two other Government of Guam biologists will pursue training in the SPC survey protocol used by Brown.

After considerable delay, water quality sampling is planned for the 2015 field season. Water column profiles will be performed at each sampling station using an electronic multiparameter water quality monitoring system/datasonde equipped for conductivity/salinity, depth, dissolved oxygen, pH, temperature and turbidity. Temperature loggers deployed in 2014 will be collected and redeployed at all sites. At least one, possibly two datasondes equipped for conductivity/salinity, depth, dissolved oxygen,

pH, temperature and turbidity will be deployed at select sites for long term in situ monitoring. Additionally, an array of conductivity/temperature loggers will be deployed along the Tumon Bay and East Agana Bay sites in order to improve our understanding of the impacts of submarine discharge on reef communities at those sites.

VII. Reef Flat Monitoring Program: FY2012-FY2014

The Reef Flat Monitoring Program began in 2009, with six reef flats along the northwestern coast of Guam selected for a study examining the impacts of sewage-based nitrogen eutrophication on coral health. The results of that study showed that increasing nitrogen is significantly correlated with the severity of white syndrome (Raymundo et al. 2011; Redding et al. 2013), which affects eight genera and at least 15 species on Guam (Myers and Raymundo 2009). As a result of these two studies, local managers requested that monitoring of the reef flat sites be continued.

To date, reef flats on Haputo, Tanguisson, Tumon Bay, West Agaña, Piti Bomb Holes and Luminao (Figure 1) have been surveyed at least twice a year (with a maximum of four times per year), along three permanently established 20 m x 1 m belt transects per site. In two of the sites (Tumon Bay and Tanguisson), permanent markers were lost, which required the repositioning of transects within the same locations. Care was taken to position new markers within the same communities, to ensure subsequent data are as comparable as possible. Data collected along these transects include: species identification and colony counts per species, coral disease, predation, bleaching, recruitment (measured as corals <5cm diameter), coral colony size, and benthic composition. In addition, temperature data loggers (Onset Corp[®]) have been continually deployed at four of these sites (Haputo, Tumon, Piti and Luminao). To date, 11 graduate students of the M.S. Biology program at UOG have received training in basic field ecological methods and data management under this program.

The data are currently being reorganized and reformatted, for ease in future analysis and standardization of data entry. A manuscript presenting the results of an analysis of four years of reef flat monitoring data was planned for early 2013 but has been delayed due to the longer-than-expected time and effort required to compile the copious data generated by the program; the manuscript will provide information about changes in live coral cover, coral community structure, and disease impacts at the reef flat sites. However, a preliminary analysis of benthic cover data derived from the LIT dataset was carried out in anticipation of this report and the results are presented in Appendix J.

Appendix A. Long-term Monitoring Program data collection activities to to-date.

Site Name	Site Location (lat/long)		Date					
			2009	2010	2011	2012	2013	2014
TUM-01-10	13.511539	144.790475	-	8/26	-	-	-	-
TUM-02-10	13.510719	144.786276	-	8/27	-	-	-	-
TUM-03-10	13.511342	144.792448	-	9/2	-	-	-	-
TUM-04-10	13.509778	144.786392	-	8/27	-	-	-	-
TUM-05-09	13.510616	144.793549	8/29	-	-	-	-	-
TUM-05-10	13.511426	144.793549	-	9/2	-	-	-	-
TUM-06-10	13.510956	144.789757	-	9/3	-	9/5	-	9/3
TUM-08-10	13.512194	144.792858	-	9/3	-	10/10	-	9/4
TUM-11-10	13.509338	144.785796	-	8/13	-	-	-	-
TUM-12-10	13.510893	144.792047	-	8/20	-	-	-	-
TUM-13-10	13.510006	144.788443	-	8/25	-	-	-	-
TUM-14-10	13.510839	144.787866	-	8/18	-	-	-	-
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WS-6-11	13.453547	144.65416	-	-	7/19	-	-	-
WS-7-11	13.45169	144.654395	-	-	7/11	-	-	-
WS-8-11	13.451273	144.654545	-	-	8/12	-	-	-
WS-9-11	13.452662	144.654055	-	-	7/19	-	-	-
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WS-18-11	13.450373	144.655295	-	-	8/19	-	-	-
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WS-20-11	13.451098	144.655814	-	-	7/22	-	-	-
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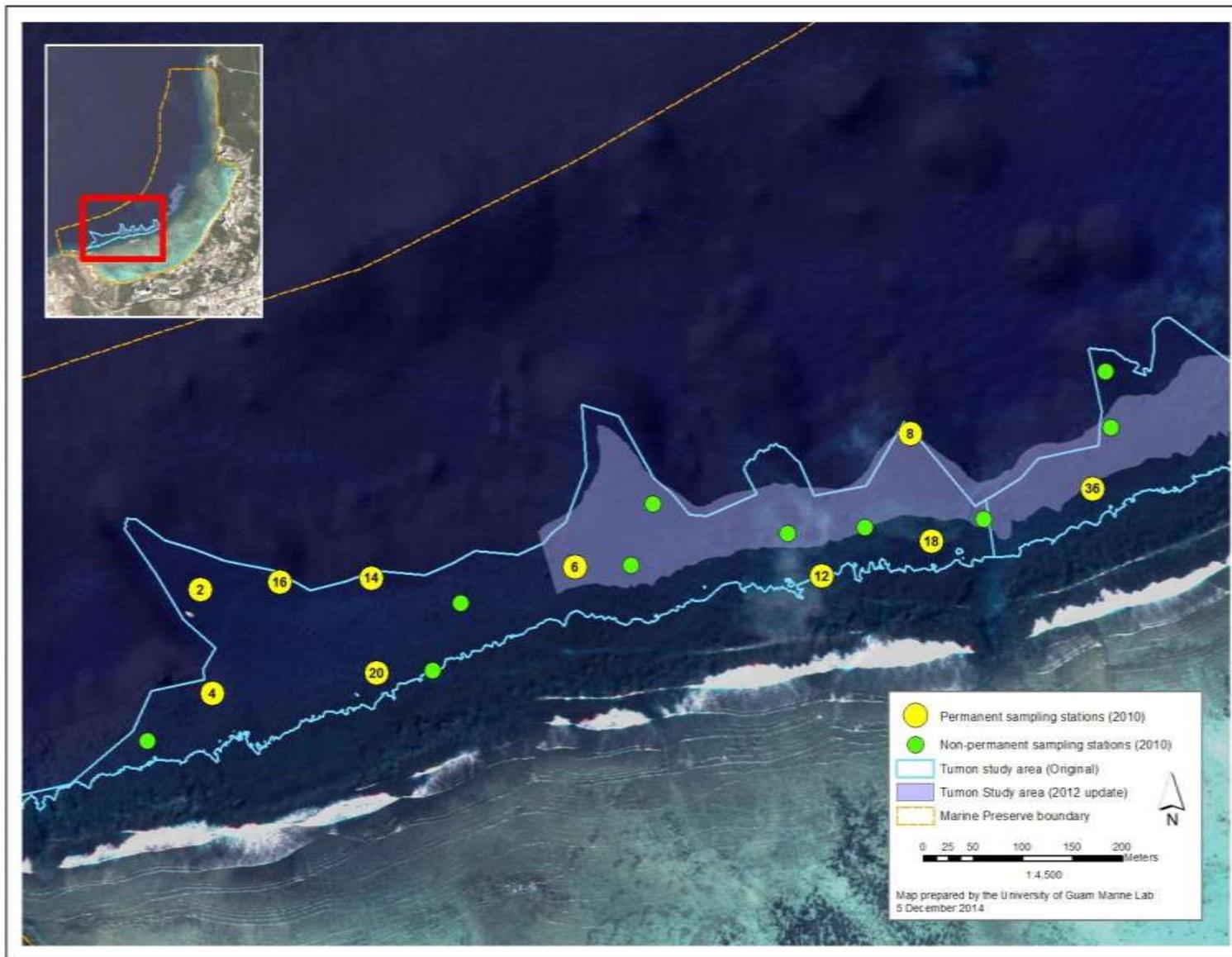
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PIT-02A-14	-	-	-	-	-	-	-	9/17
PIT-03-12	13.469279	144.686032	-	-	-	7/23	-	-
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PIT-05-12	13.470095	144.688996	-	-	-	8/8	-	-
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PIT-07-12	13.469727	144.687814	-	-	-	7/27	-	-
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PIT-18-12	13.474127	144.69436	-	-	-	8/29	-	11/12
PIT-19-12	13.473711	144.693623	-	-	-	8/17	-	-
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COC-03-14	13.237819	144.680907	-	-	-	-	-	10/27
COC-06-14	13.23874	144.685532	-	-	-	-	-	10/28
COC-10-14	13.237832	144.68346	-	-	-	-	-	10/28
COC-16-14	13.237778	144.679736	-	-	-	-	-	10/28
COC-18-14	13.237184	144.675508	-	-	-	-	-	10/28
Cocos East (Site exploration – Dive 1)	13.240429	144.689784	-	-	-	5/16	-	-
Cocos East (Site exploration – Dive 2)	13.23646	144.681071	-	-	-	5/16	-	-
Cocos East (Site exploration – Dive 3)	13.235869	144.673991	-	-	-	5/16	-	-
Marbo Cave (bleaching recon)	13.485117	144.870348	-	-	-	8/27	-	-
Hila'an/Sharks Hole (bleaching recon)	13.55899	144.815638	-	-	-	8/27	-	-
Tanguisson Pt. (bleaching recon)	144.809898	13.54807	-	-	-	8/27	-	-
West Hagatna Bay (bleaching recon)	144.743888	13.480415	-	-	-	8/28	-	-
Ritidian National Wildlife Refuge (bleaching recon/habitat mapping)	144.866905	13.654225	-	-	-	8/30	-	-
Ritidian National Wildlife Refuge (bleaching recon/habitat mapping)	144.874775	13.648847	-	-	-	9/9	-	-
West Hagatna (bleaching survey – Transect 6)	13.479765	144.743921	-	-	-	9/13	-	-
West Hagatna (bleaching survey – Transect 8)	13.479609	144.745426	-	-	-	9/13	-	-
West Hagatna (bleaching survey – Transect 10)	13.480967	144.743862	-	-	-	9/25	-	-
West Hagatna (bleaching survey – Transect 12)	13.480166	144.743134	-	-	-	9/25	-	-
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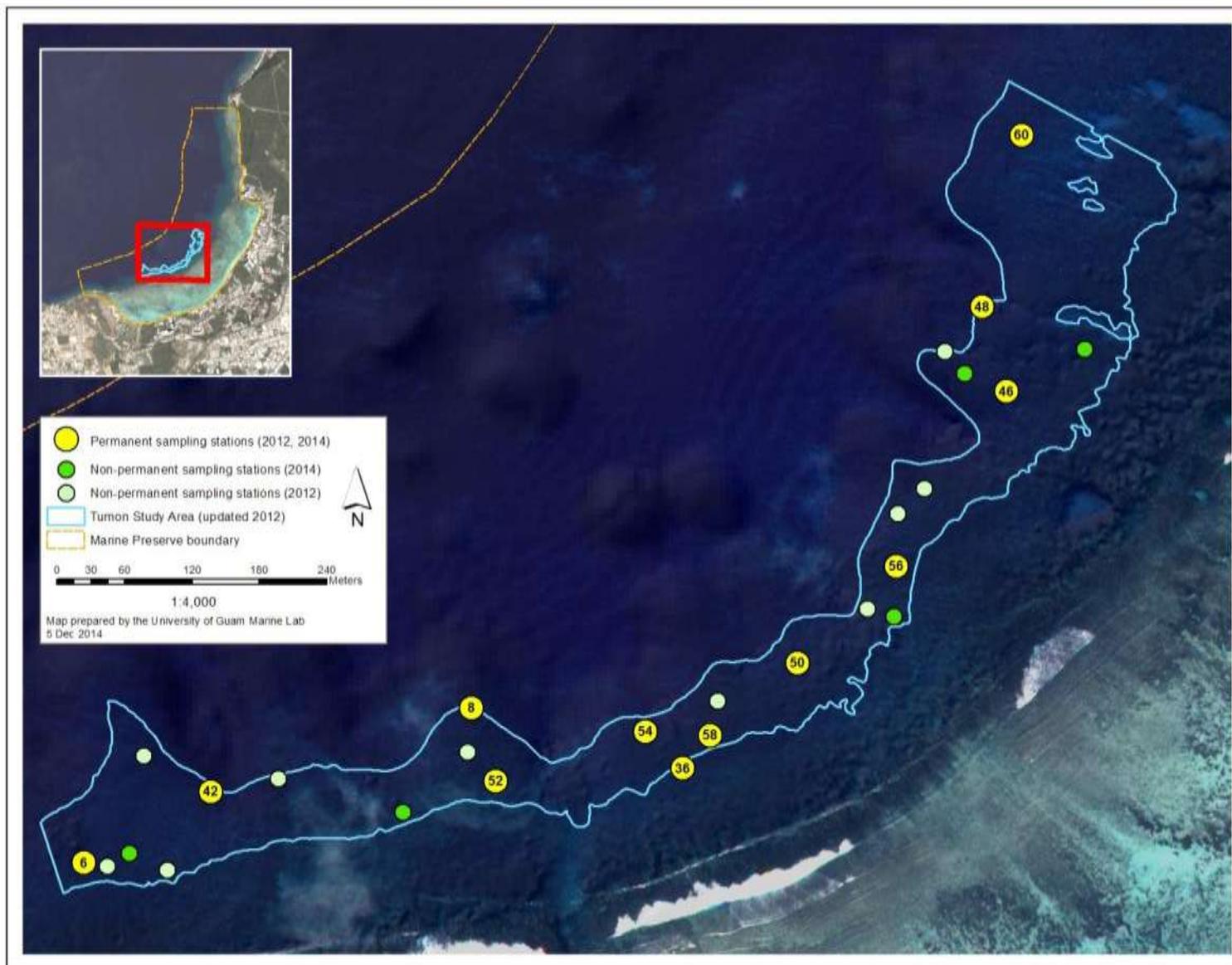
Transect 7)								
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West Hagatna (bleaching survey – Transect 31)	13.480001	144.742275	-	-	-	9/26	-	-
West Hagatna (bleaching survey – Transect 29)	13.48028	144.741026	-	-	-	9/26	-	-
West Hagatna (bleaching survey – Transect 13)	13.480557	144.742853	-	-	-	9/26	-	-
West Hagatna (bleaching survey – Transect 4)	13.480327	144.742795	-	-	-	9/26	-	-
West Hagatna (bleaching survey – Transect 32)	13.479812	144.742476	-	-	-	9/26	-	-
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Coral bleaching survey site GUA-488	13.426133	144.806164	-	-	-	-	10/3	-
Coral bleaching survey site GUA-510	13.418808	144.791677	-	-	-	-	10/3	-
Coral bleaching survey site GUA-470	13.24405	144.714006	-	-	-	-	10/4	-
Coral bleaching survey site GUA-527	13.293692	144.768677	-	-	-	-	10/8	-
Coral bleaching survey site GUA-454	13.240606	144.686455	-	-	-	-	10/9	-
Coral bleaching survey site GUA-579	13.241692	144.693527	-	-	-	-	10/9	-
Coral bleaching survey site GUA-644	13.241822	144.702166	-	-	-	-	10/9	-
Coral bleaching survey site GUA-NE1	13.456017	144.838391	-	-	-	-	10/14	-
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Coral bleaching survey site GUA-NE7b	13.51336	144.906118	-	-	-	-	10/14	-
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Coral bleaching survey site GUA-NE8	13.587251	144.951781	-	-	-	-	10/23	-
Coral bleaching survey site GUA-NE5	13.547314	144.937696	-	-	-	-	10/24	-
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Coral bleaching survey site GUA-478	13.412995	144.65122	-	-	-	-	10/25	-
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Coral bleaching survey site GUA-582	13.356246	144.638424	-	-	-	-	10/25	-
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Coral bleaching survey site GUA-610	13.479668	144.706896	-	-	-	-	11/18	-
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Coral bleaching survey site GUA-559	13.540587	144.804559	-	-	-	-	11/27	-
Coral bleaching survey site GUA-634	13.571862	144.823485	-	-	-	-	11/27	-
Coral bleaching survey site GUA-492	13.601488	144.927942	-	-	-	-	12/6	-
Coral bleaching survey site GUA-583	13.640854	144.88577	-	-	-	-	12/6	-
Coral bleaching survey site GUA-732	13.601356	144.949811	-	-	-	-	12/6	-
Coral bleaching survey site GUA-734	13.613945	144.906976	-	-	-	-	12/6	-
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Staghorn tissue sampling site TUM-N	13.512736	144.799618	-	-	-	-	-	1/10
Staghorn tissue sampling site TUM-C	13.509430	144.796832	-	-	-	-	-	1/16
NSF-RAPID site TAN-S	13.548459	144.810098	-	-	-	-	-	1/23
NSF-RAPID site IPN-D	13.372754	144.776771	-	-	-	-	-	1/24
NSF-RAPID site ACH-S	13.2464	144.68613	-	-	-	-	-	2/13
NSF-RAPID site TAN-D	13.549192	144.80861	-	-	-	-	-	3/20

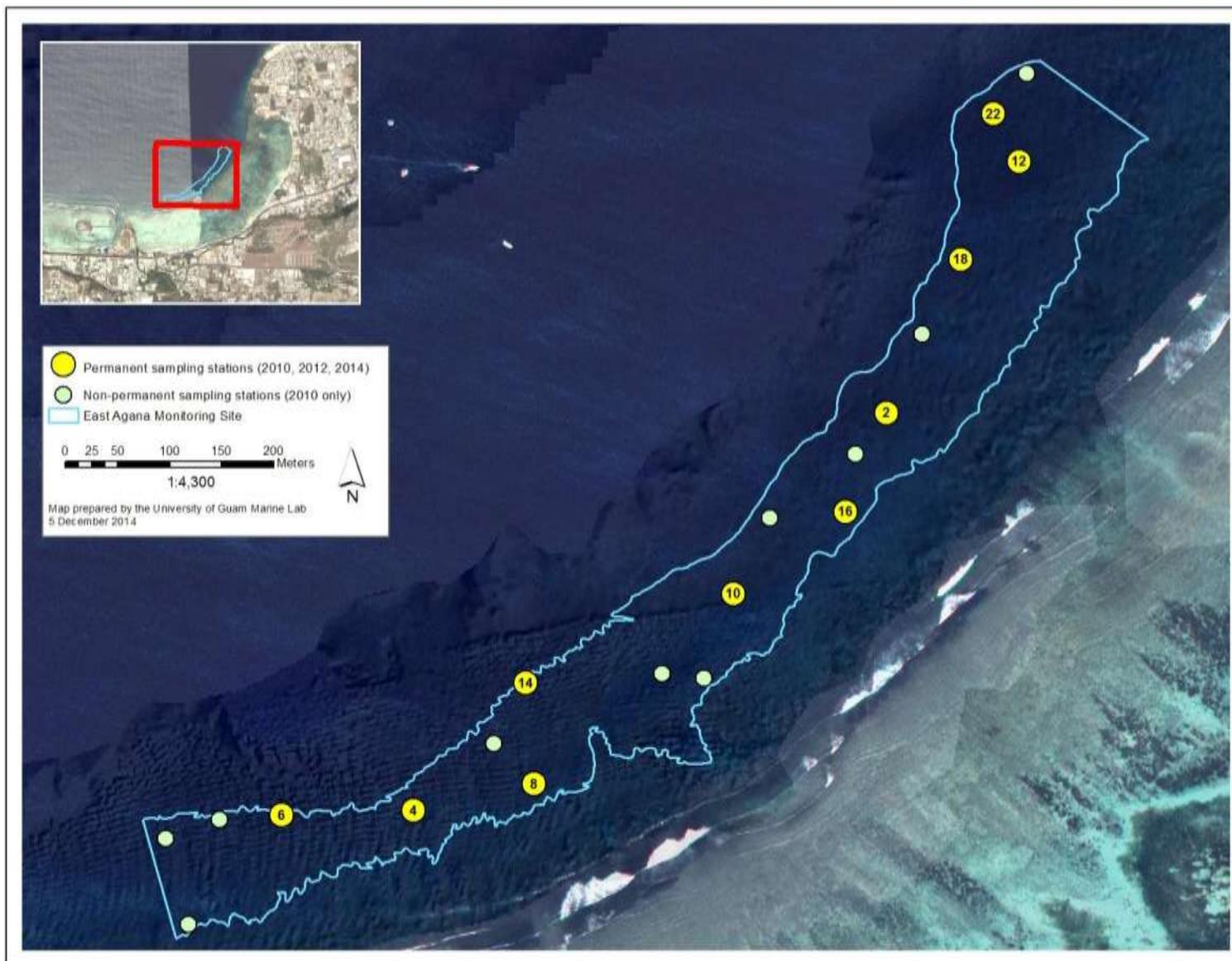
Appendix B. Map of original site boundaries and sampling station locations for the Tumon Bay site.



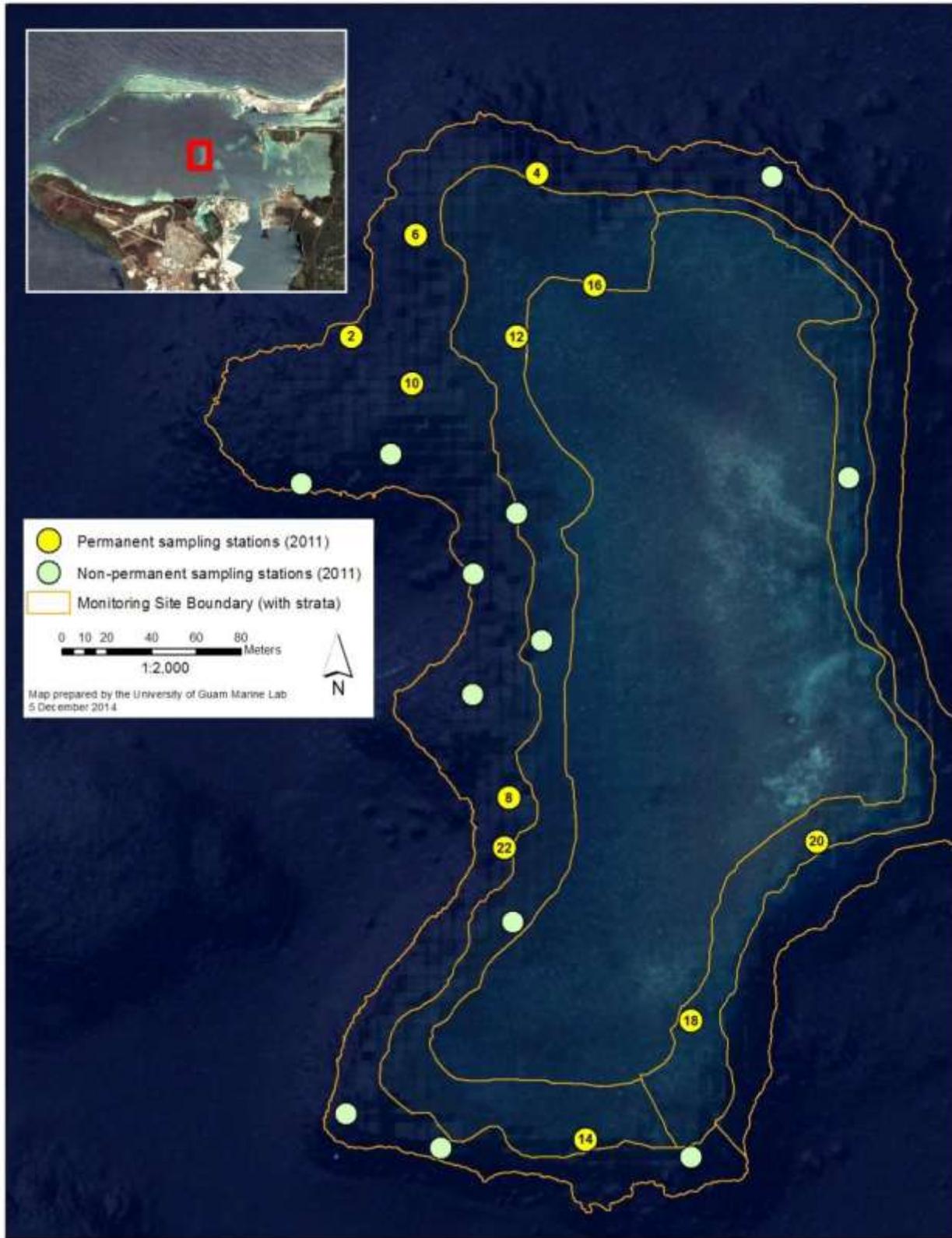
Appendix C. Map of updated site boundaries and sampling station locations for the Tumon Bay site.



Appendix D. Map of site boundaries and sampling station locations for the East Agana Bay site.



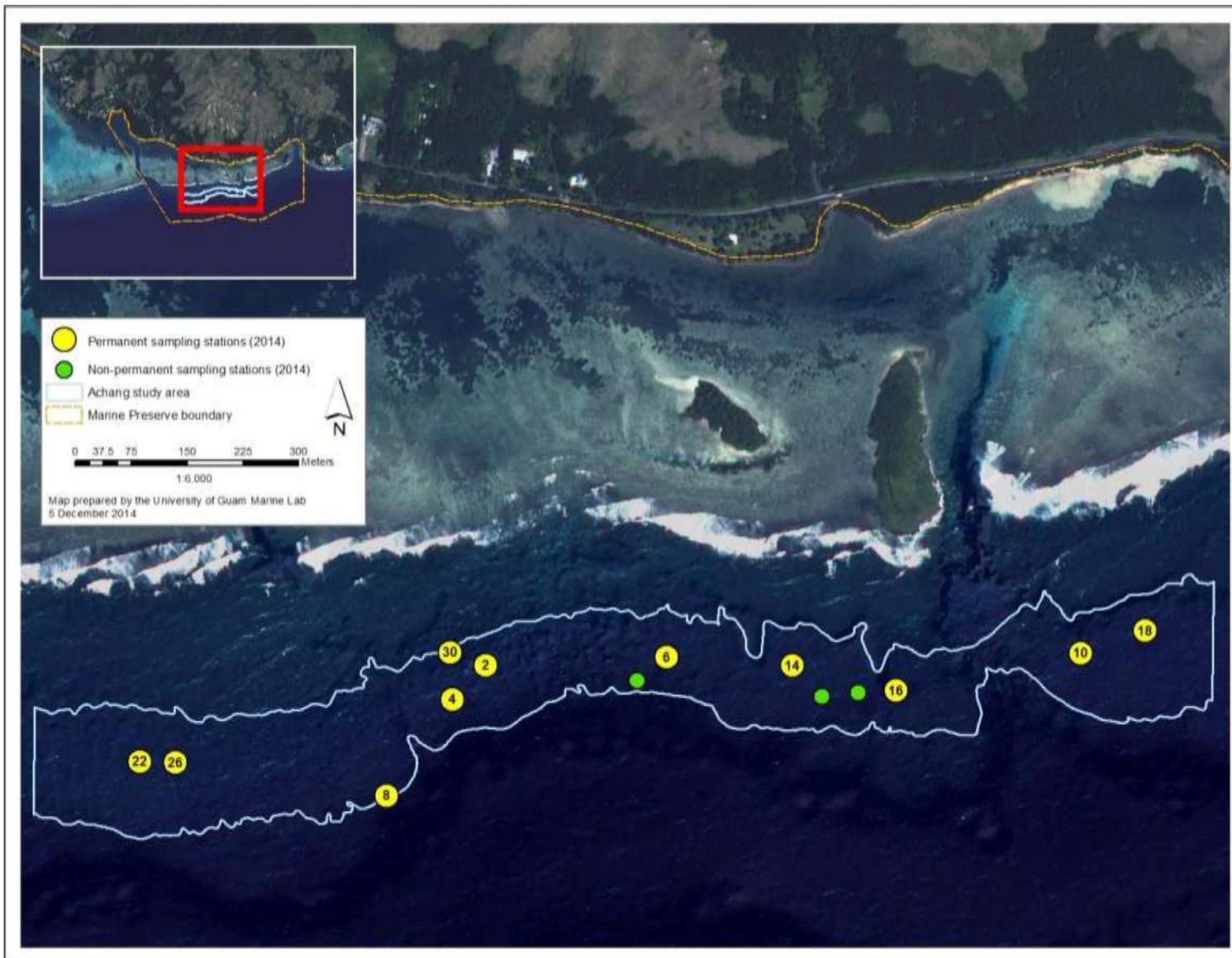
Appendix E. Map of site boundaries and sampling station locations for the Western Shoals site.



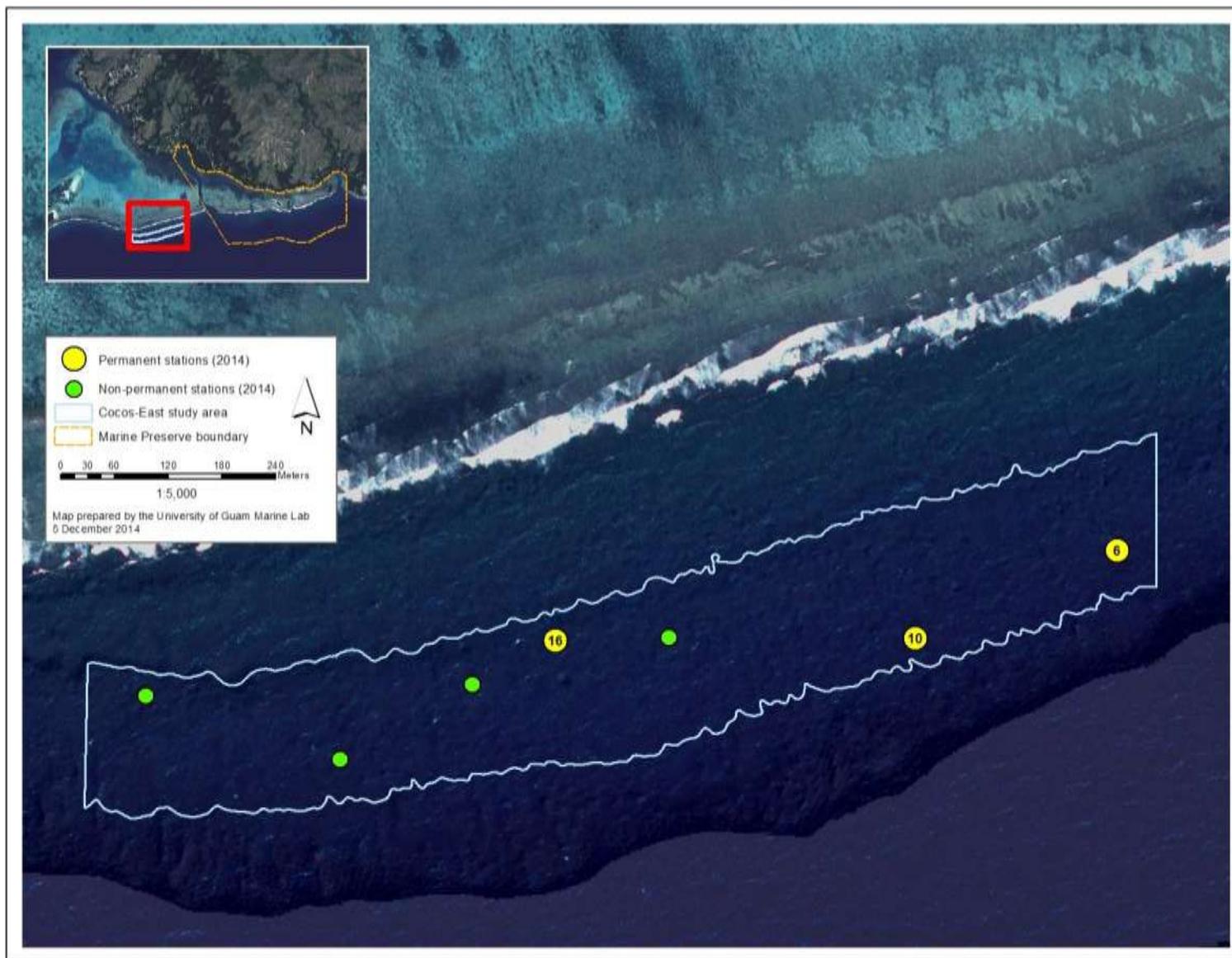
Appendix F. Map of site boundaries and sampling station locations for the Piti Bay site.



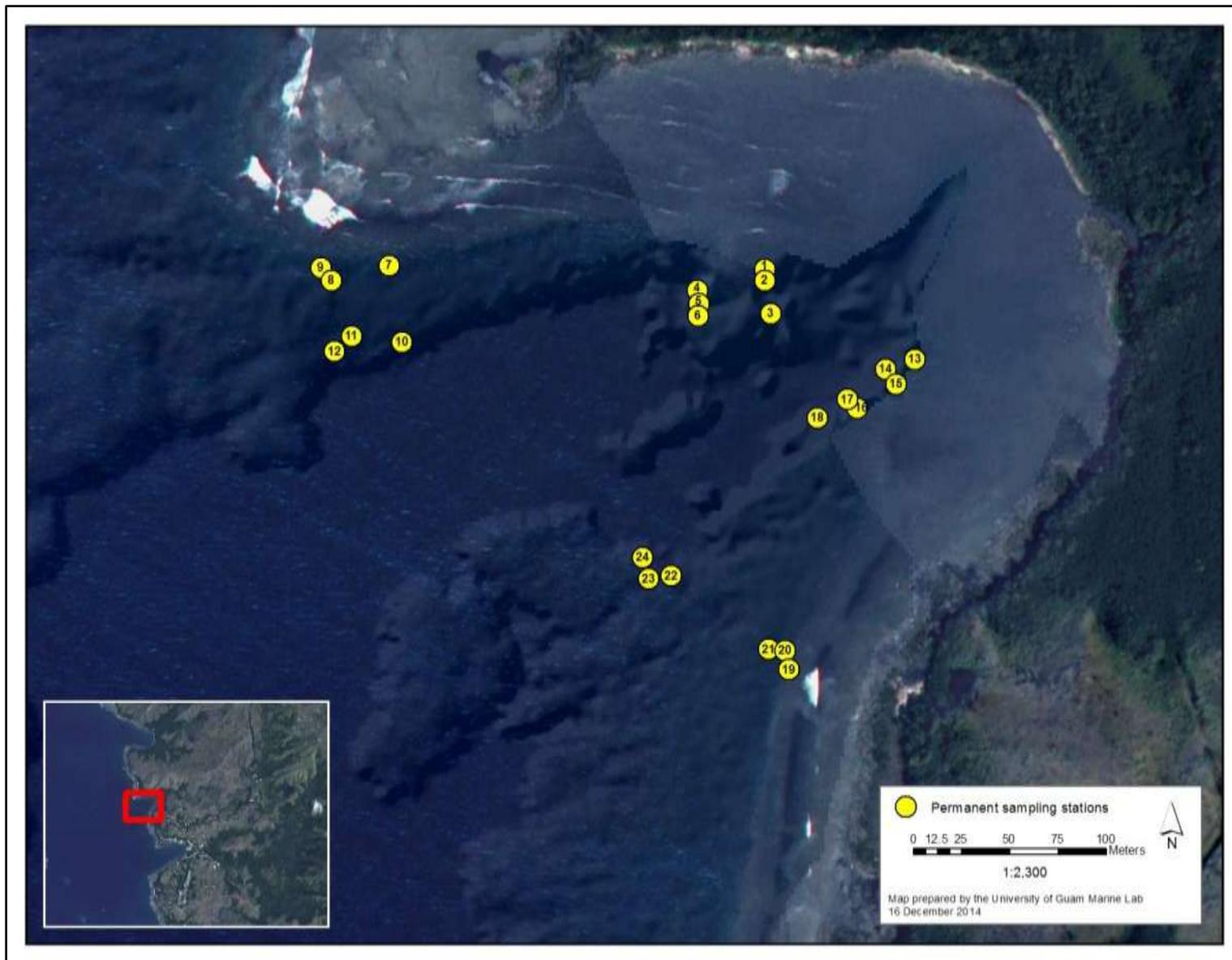
Appendix G. Map of site boundaries and sampling station locations for the Achang site.



Appendix H. Map of site boundaries and sampling station locations for the Cocos-East site.



Appendix I. Map of the proposed sampling station locations for a monitoring site in Fouha Bay.



Appendix J. Results of preliminary analysis of benthic cover data generated by the Reef Flat Long-Term Monitoring Program: 2009-2014. Prepared by Dr. Laurie J. Raymundo, University of Guam Marine Laboratory, *Principle Investigator*

In this brief report, the current results of changes in coral cover from 2009 to 2014 (Figure 2) are presented. This time period encompassed a major bleaching event in 2013 and numerous minor storms. The graphs below represent only a subset of the substrate categories that we encounter; for brevity, only those categories that are ecologically relevant are included (e.g., live hard coral, macroalgae and cyanobacteria, recently-killed coral and dead coral/coral rubble). Soft coral, pavement, sand, turf algae are lumped into a single category “Other” and are not presented in the graphs below.

Figure 2, A through C, and Figure 3, A through C, show variability between sites and years, but not extreme differences within these very similar communities. Tumon showed stable coral cover over time, averaging 30% cover. West Agaña showed the least amount of living coral, with high variability in non-living substrate material. This is largely due to wave exposure and a high percentage of unconsolidated material such as rubble and sand. Piti Bomb Holes has shown a steady decline in coral cover over the past four years, with an average of 10% coral loss over this period.

When examining mean coral cover over the six year period, per site, these differences are more clearly illustrated (Figure 4). West Agana shows the lowest cover, by far, with Tumon showing the highest, with the least between-year variability. It would appear that protection from harvesting and other extractive activities is having a positive effect on live coral in Tumon, despite the high recreational use which regularly results in physical damage to corals.

Between-year variability across these six sites is relatively low; mean coral cover ranged from a low of 27.4% in 2010 to highs of 33-34% in 2011 and 2014 (Figure 5). Interestingly, there did not seem to be a major decline in coral cover after the island-wide bleaching event of 2013 within these communities. However, impacts from a second bleaching episode in June 2014 are still being examined. Those data will be available in 2015.

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- Raymundo, L.J., Kim, K., Redding, J., Miller, R., Pinkerton, K., and Baker, D. 2011. Links between deteriorating coral health and sewage pollution of Guam reef flats. UOG Tech Rep. 131. 19 pp.
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Figure 1. Map of Guam showing location of reef flat monitoring sites along the western coast.

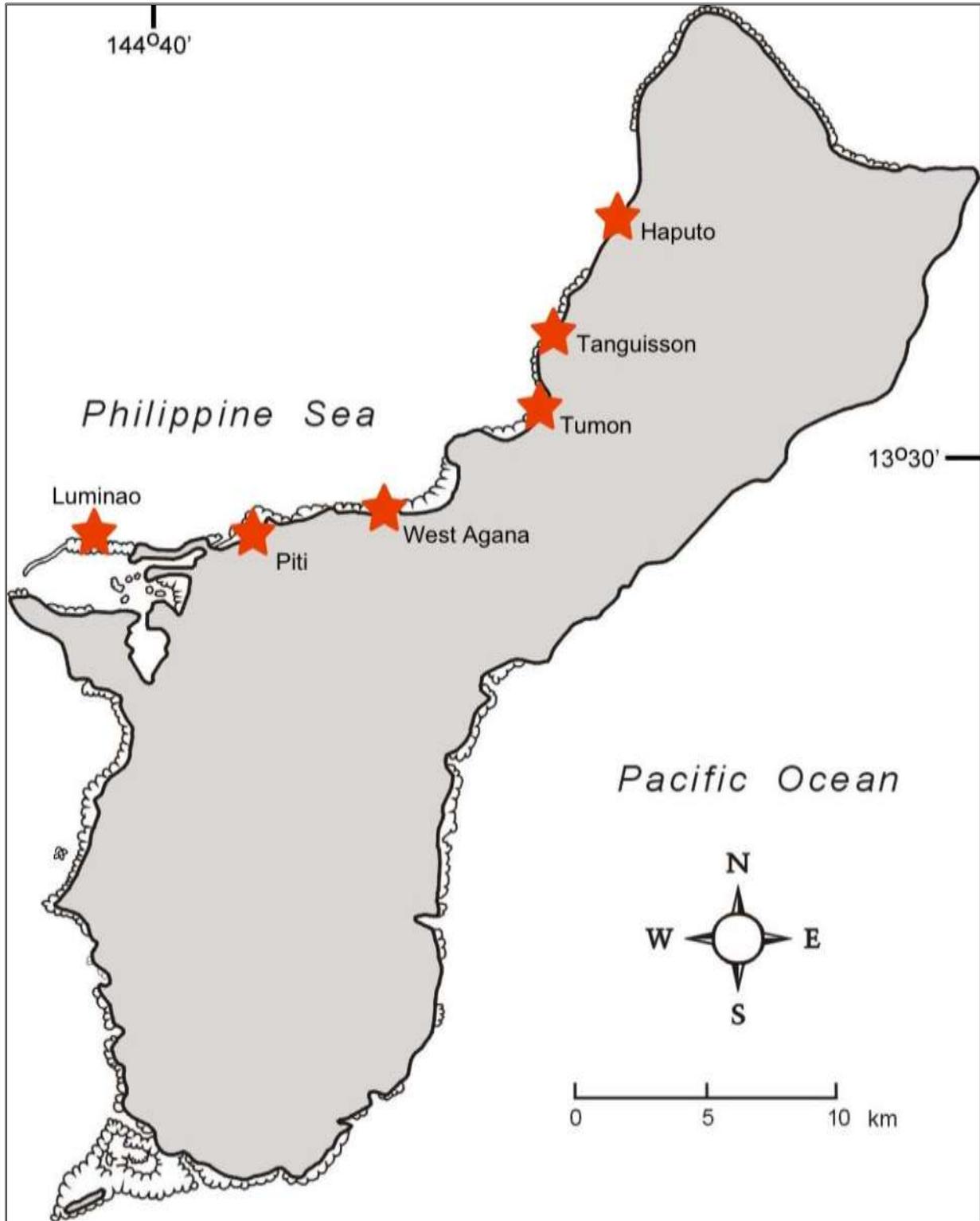


Figure 2. Graphs A through C present benthic composition of major categories over a six-year monitoring period, for the Haputo, Tanguisson, and Tumon monitored reef flats. RUB/DC = rubble/dead coral; RKC = recently-killed coral; CYA/MA = cyanobacteria and macroalgae; LHC = live hard coral.

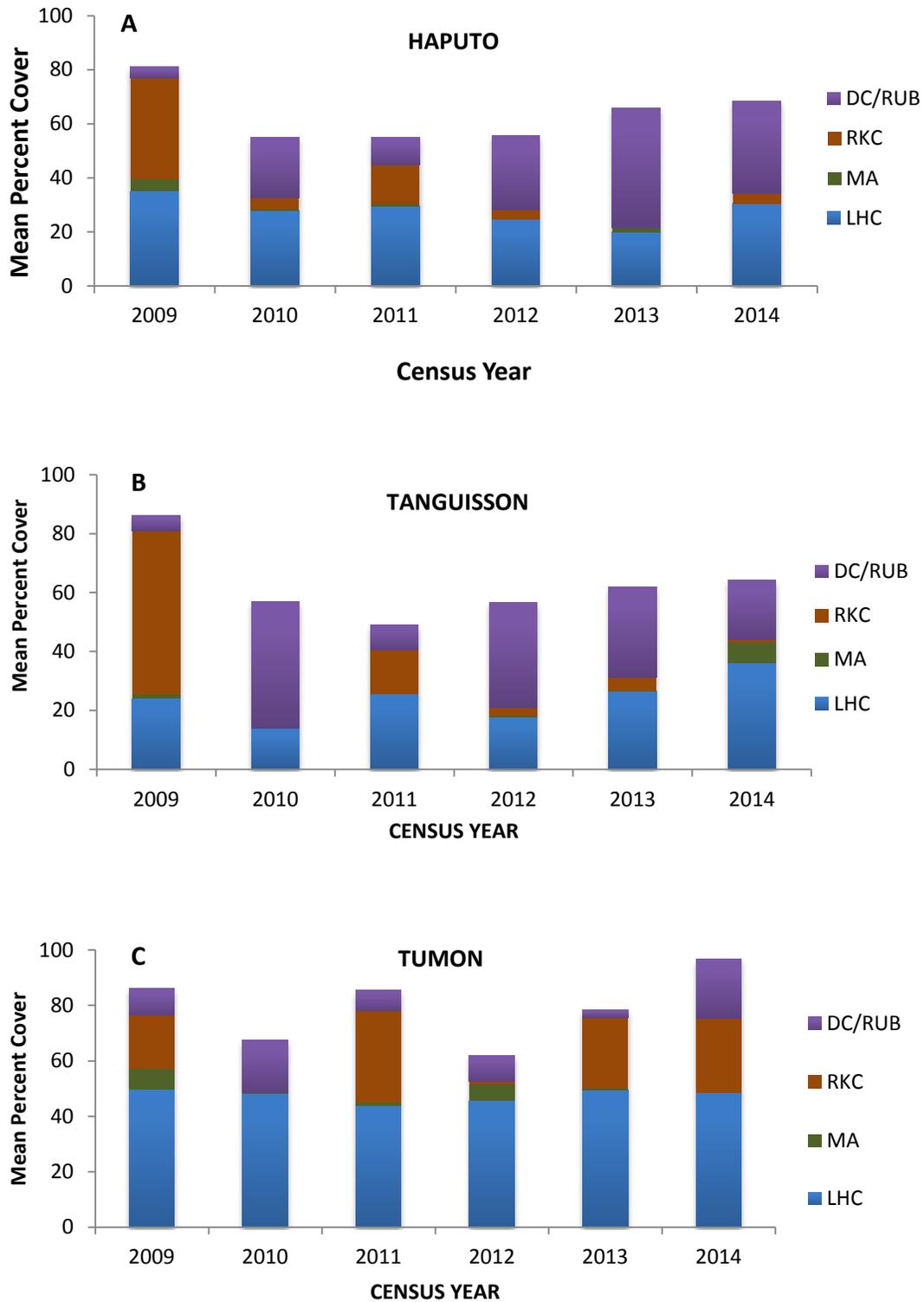


Figure 3. Graphs A through C present benthic composition of major categories over a six-year monitoring period, for the West Agana, Piti, and Luminao monitored reef flats. RUB/DC = rubble/dead coral; RKC = recently-killed coral; CYA/MA = cyanobacteria and macroalgae; LHC = live hard coral.

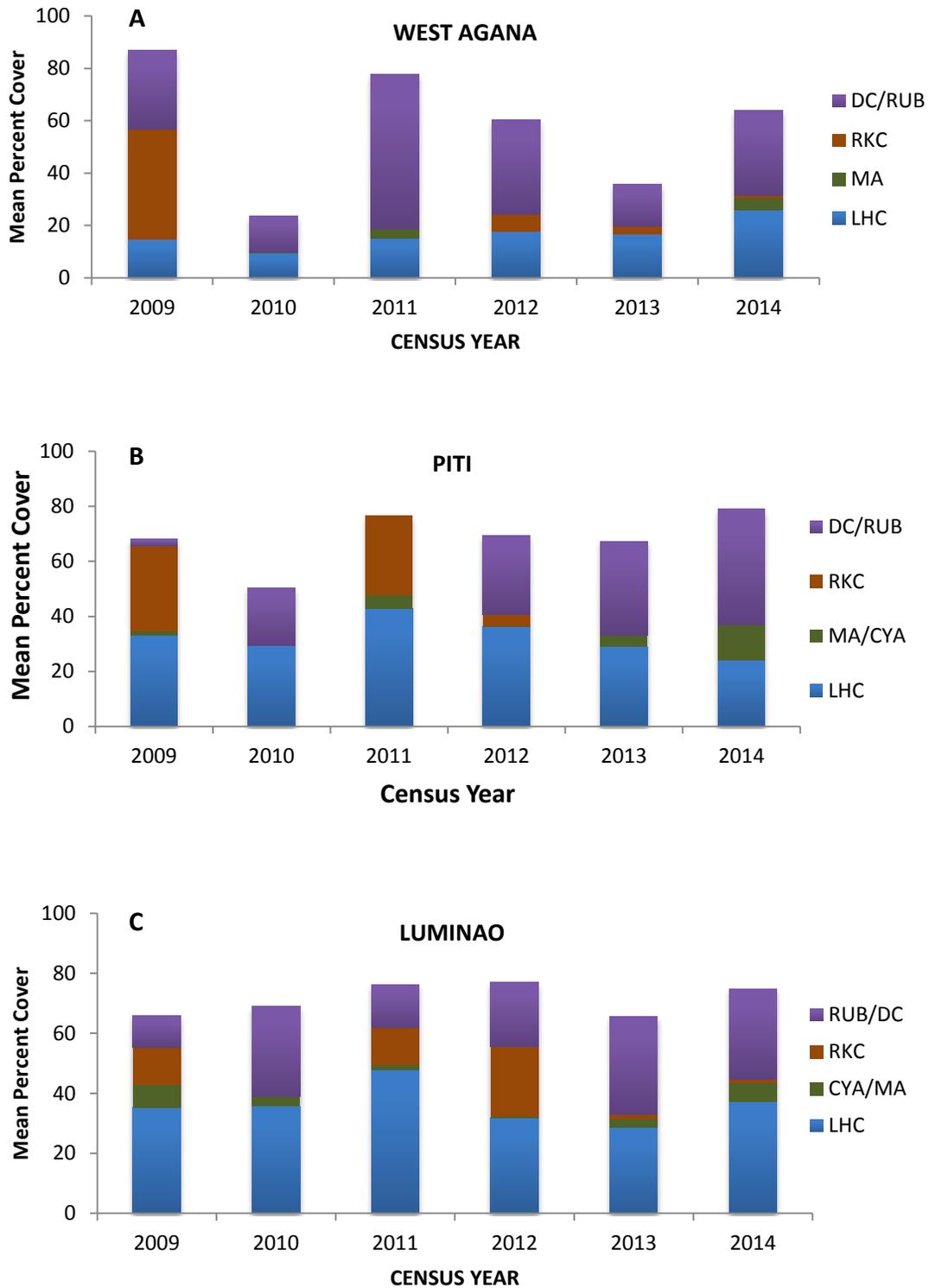


Figure 4. Six-year mean (+/- SD) percent live coral cover of six monitored reef flats.

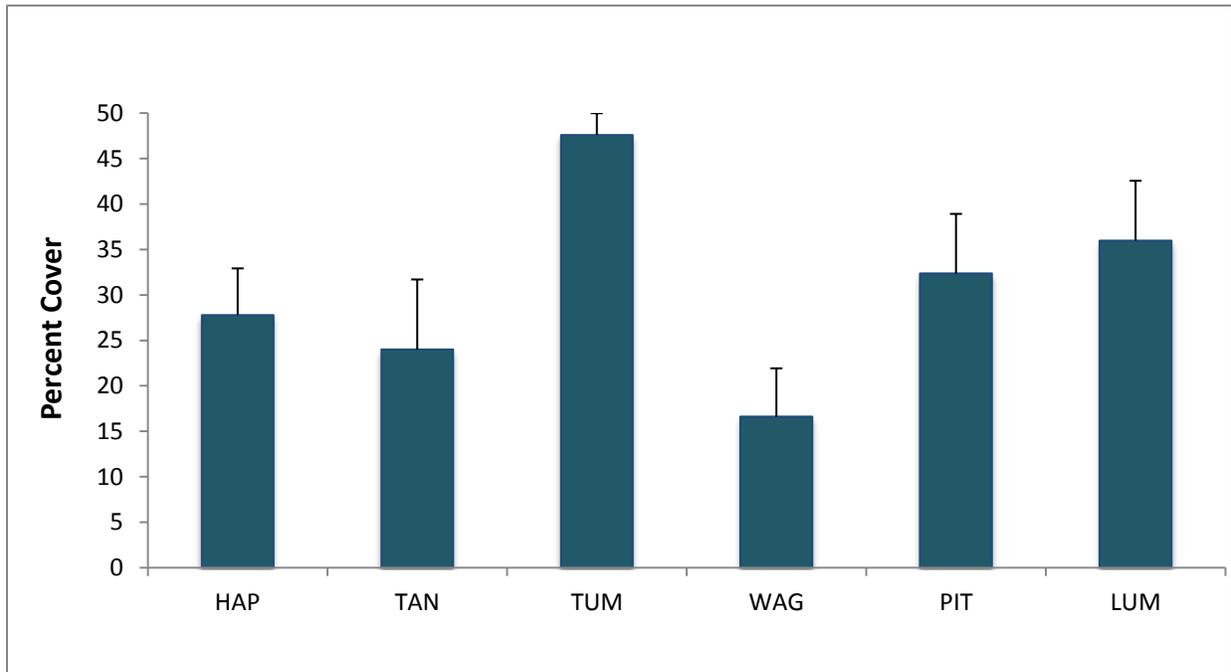


Figure 5. Mean (+/- SD) live coral cover per year, averaged across six monitored sites.

