U.S. DEPARTMENT OF COMMERCE
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NATIONAL MARINE FISHERIES SERVICE
Pacific Islands Fisheries Science Center
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CRUISE REPORT[1]

VESSEL: *Hi'ialakai*, Cruise HI-07-03

CRUISE PERIOD: 25 May–09 June 2007

AREA OF OPERATION: Commonwealth of the Northern Mariana Islands (CNMI: Anatahan, Sarigan, Zealandia, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply, and Uracas [or Farallon de Pajaros])

TYPE OF OPERATION: Personnel from the Coral Reef Ecosystem Division (CRED), Pacific Island Fisheries Science Center (PIFSC), National Marine Fisheries Service (NMFS), NOAA, and their partner agencies conducted coral reef assessment/monitoring and mapping studies in waters surrounding Anatahan, Sarigan, Zealandia Bank, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply Reef, and Uracas.

ITINERARY:

25 May — Start of cruise: Saipan Harbor. Embarked Robert Schroeder (Chief Scientist, REA – Fish), Mike Tenorio (REA – Fish), Allison Palmer (REA – Fish), Peter Houk (REA – Corals), Bernardo Vargas Angel (REA – Corals), Tom Schils (REA – Algae), Edson Limes (REA – Algae), John Starmer (REA – Invertebrates), Brian Zgliczynski (Tow Team – Fish), Benjamin Richards (Tow Team – Fish), Jacob Asher (Tow Team – Benthic), Edmund Coccagna (Tow Team – Benthic), Jamison Gove (Oceanography), Daniel Merritt (Oceanography), Ellen Smith (Oceanography), Chip Young (Oceanography), James Bostick (Divemaster/Chamber Operator), Russell Moffitt (Data Manager, Support Diver), Joyce Miller (Mapping), Jonathan Weiss (Mapping), Emily Lundblad (Mapping), Robert O'Conner (Mapping). Acoustic Habitat Investigator (R/V *AHI*) left Saipan Harbor at 0900 to conduct Tinian anchorage area with a late pick up at 1700. The ship left the harbor at 1000. Conducted dive safety briefings and chamber Launched small boats for oceanography, tow, and Rapid Ecological Assessment (REA) teams. Oceanography team deployed a wave and tide recorded (WTR) in Laulau Bay, Saipan. All teams transited to Tinian. Conducted 1 REA survey and 1 towed-diver survey. Oceanography

[1]PIFSC Cruise Report CR-07-012
Issued 6 July 2007

mapping along the 100-fm contour around the east and south sides of Tinian. The R/V *AHI* also filled most of the data gaps in the drills. team performed checkout dive for Chip Young. Ship mapped opportunistically and filled 3 small gaps in offshore data on the S and SE sides of Tinian. Initiated nighttime operations with shipboard mapping during transit to Sarigan.

26 May — Arrived at Sarigan and commenced operations. Completed 3 REA surveys and 6 towed-diver surveys around the whole island. Collected 9 shallow water conductivity-temperature-depth (CTDs), 18 water samples (4 sites), and replaced one subsurface temperature recorder (STR) and added one new STR. R/V *AHI* was launched on the S side of Sarigan and mapped the bank top down to 250 m. Shipboard mapping continued the coverage of the slope substrate from 200 m to about 2000 m during daytime operations. In the evening and at night, the ship surveyed offshore from Sarigan in the easterly direction, filling large gaps between transit data from past expeditions. Transited to Zealandia Bank.

27 May — Arrived at Zealandia Bank; commenced limited operations. Oceanography team replaced 1 WTR on the NE pinnacle and placed a new STR there. Tow team and two additional scientists made an observational dive on the SW pinnacle. R/V *AHI* was launched on the S side of Zealandia Bank and surveyed around the barely emergent pinnacle between depths of ~11 m and 250 m; a sizable band extension was discovered along the S side. Shipboard mapping was also conducted around Zealandia. By late morning, ship retrieved all small boats and transited south to Anatahan (after obtaining special entry permission from CNMI’s Emergency Management Office [EMO]).

Arrived at Anatahan. Oceanography team replaced 1 STR and took several CTD casts and water samples from two sites. Shipboard mapping around Anatahan was conducted during the afternoon and early evening. Later in the evening, the ship began transiting to Alamagan, edge mapping existing data via a pass by Guguan. Shipboard mapping was conducted during the entire transit.

28 May — Arrived at Alamagan and commenced operations. Completed 3 REA surveys and 6 towed-diver surveys. Collected 16 shallow water CTDs, 32 water samples (4 sites), and recovered/replaced 1 STR and deployed 1 new STR. R/V *AHI* achieved complete coverage of the island between ~15 and 250 m. Shipboard mapping overlapped R/V *AHI* coverage around most of the island and mapped about two laps of offshore bathymetry around the island. Nighttime mapping was conducted while transiting north to Agrihan, edge matching existing data.

29 May — Arrived at Agrihan and commenced operations. Completed 3 REA surveys and 6 towed-diver surveys. Collected 15 CTDs, 28 water samples (3 sites), and recovered/replaced 1 STR. The R/V *AHI* completed mapping between depths of ~ 15 and 250 m. The ship was able to map between ~250 m and 2000 m, matching R/V *AHI* coverage in most places. The steep terrain added the limiting factor of proximity to shore for ship coverage. Shipboard mapping continued throughout the night during the transit to Maug, edge mapping existing data.

30 May — Arrived at Maug and commenced operations. Completed 3 REA surveys and 6 towed-diver surveys. Tow team performed one calibration tow to compare observer variation. Collected 19 CTDs and 38 water samples (9 sites), and recovered/replaced 1 sea surface temperature (SST) buoy and one STR. Early morning shipboard mapping began with a circumnavigation around Maug until small boat launch time. The R/V *AHI* mapped the inside of the lagoon (an old submerged caldera) at Maug, completing coverage between ~10 m and 250 m depth. R/V *AHI* also began mapping around the outside of the islands. Shipboard mapping completed coverage, overlapping most of the R/V *AHI's* coverage, between ~250 m and 1000 m, and continued at night to complete mapping down to ~2500 m depth.

31 May — Continued operations at Maug. Completed 3 REA surveys and 5 towed-diver surveys. Recovered/replaced 3 STRs and deployed a new fourth STR. Performed focused sampling at gas vent site inside the lagoon. R/V *AHI* completed mapping around the outside of Maug. In the early afternoon, ET Don Jones boarded the R/V *AHI* to help assess a time difference problem between systems on the R/V *AHI*. With the problem solved, the R/V *AHI* finished shallow water mapping at Maug during the afternoon. The ship stayed close to shore to support dive boats and mapped small data gaps opportunistically and continued deep water mapping at night.

1 June — Continued operations at Maug. Completed 3 REA surveys. Tow team and oceanography teams performed several deep observational and invertebrate collection dives. Oceanography team collected a deep (~200 m) CTD inside the lagoon from the ship, including water samples, and collected water and gas samples from the hot vent site inside of East Island. The R/V *AHI* did not launch. The ship entered the lagoon at Maug for the CTD and stayed inside to support small boat operations for the rest of the day. At night shipboard mapping in deep waters around Maug commenced and continued during a transit to Supply Reef.

2 June — Arrived at Supply Reef and commenced limited operations. Oceanography team recovered/replaced 1 WTR and deployed 1 STR. Members of other teams made several observational and collection dives.

The R/V *AHI* mapped two small pinnacles (~10 m – 250 m). Shipboard mapping was conducted around Supply reef during the day to overlap the R/V *AHI's* coverage and continued during a transit to Uracas later that night. Before transiting north to Uracas, the ship mapped toward the south for exploratory mapping of features to the east of Maug.

3 June — Arrived at Uracas and commenced operations. Completed 3 REA surveys and 4 towed-diver surveys along the NE to NW sides of the island. Collected 7 CTDs and 14 water samples (3 sites), recovered/replaced 1 STR, and deployed 5 new STRs at various depths to investigate possible upwelling. The R/V *AHI* mapped the entire island between depths of ~15 m and 250 m. Shipboard mapping overlapped R/V *AHI* coverage and completed coverage to depths of ~ 1500 m. The ship continued mapping during the evening/night around Uracas and along the transit to Asuncion.

4 June — Arrived at Asuncion and commenced operations. Completed 3 REA surveys and 5 towed-diver surveys. Collected 12 CTDs and 32 water samples (4 sites) and recovered/replaced 1 STR. The R/V *AHI* mapped the entire island between depths of ~10 m and 250 m. The ship mapped down to ~1400, with overlap of most of the shallow R/V *AHI* data between ~200 m and 250 m. The ship continued nighttime mapping while transiting ~100 nmi south to Pagan in time to launch small boats in the morning.

5 June — Arrived at Pagan. Commenced operations at Pagan. Completed 3 REA surveys and 6 towed-diver surveys along the north and west sides. Collected 17 CTDs (including 1 in the lake below the volcano) and 42 water samples (6 sites) and recovered/replaced one SST buoy and deployed 1 STR. The R/V *AHI* mapped along the north and west sides of Pagan, obtaining coverage between ~10 m and 250 m. Daytime mapping on the ship overlapped the R/V *AHI* coverage around ~200 m to 250 m depth and completed mapping to depths of ~1000 m on the west side of the island. Mapping continued through the evening and night to complete offshore coverage on the east and south sides from ~1500 m to 2000 m deep.

6 June — Continued operations at Pagan. Completed 3 REA surveys and 6 towed-diver surveys along the SE side. Collected 8 CTDs and 8 water samples (1 site), and exchanged 1 shallow (~1 m) STR and deployed a new STR near a REA station. R/V *AHI* finished mapping the east side of Pagan. The ship's coverage overlapped the R/V *AHI's* to fill the gap between ~200 m and the previous night's coverage. Shipboard mapping continued, after picking small boats, to map inside current coverage on the south end of Pagan and finished another lap around the island in deep waters.

7 June	Continued operations at Pagan. Completed 3 REA surveys and 5 towed-diver surveys along the southwest side of the island. Oceanography team remained onboard ship to process data. The R/V *AHI* finished shallow water mapping around the south end of the island. During the morning, the ship mapped around the south end of the island from ~100 m, overlapping the R/V *AHI*. Shipboard mapping continued during the overnight transit to Guguan.
8 June	Arrived at Guguan. Ship commenced deepwater mapping on the east side in early morning, prior to launching of small boats. Commenced operations at Guguan. Completed 3 REA surveys and 5 towed-diver surveys. Collected 9 CTDs and 28 water samples (3 sites), and exchanged 1 STR on the west side of the island. The R/V *AHI* mapped around the island between ~15 m and 200 m, and the ship met the coverage around most of the island, mapping in depths between ~75 m and 2000 m. Ship began return transit to Saipan.
9 June	Arrived at Saipan. Entered Saipan Harbor at ~1000. End of cruise.

Table 1: Cruise statistics for HI-07-03 (excluding one day of Saipan/Tinian operations from HI-07-03 included in HI-07-02

Cruise Statistics – HI-07-03 *(Day 1 Saipan/Tinian operations in HI0702 summary)*

	Sarigan 26-May	**Zealandia** 27-May	**Anatahan** 27-May	**Alamagan** 28-May	**Agrihan** 29-May	**Maug** 30 May to 1-Jun	**Supply Reef** 2-Jun	**Uracas** 3-Jun	**Asuncion** 4-Jun	**Pagan** 5-7-Jun	**Guguan** 8-Jun	**GRAND TOTAL**
Towed-diver Habitat/Fish Surveys	5			6	6	11		4	5	16	5	58
Combined tow lengths (km)	12			13	13	17		17.5	11	33	10	126.5
Fish Rapid Ecological Assessments	3			3	3	9		3	3	9	3	36
Benthic Rapid Ecological Assessments	3			3	3	9		3	3	9	3	36
Invertebrate collection dives	3			3	3	9		3	3	9	3	36
WTRs recovered		1					1					2
WTRs deployed		1					1					2
SST buoys recovered						1				1		2
SST buoys deployed						1				1		2
STRs recovered	1		1	1	1	4		1	1	1	1	12
STRs deployed	2	1	1	2	1	5	1	6	1	3	1	24
Shallow water samples collected (Chl and Nutrients)	36		8	32	28	76		28	32	50	28	318
Deepwater sample profiles collected						2						2
Deepwater CTDs (from Hi`ialakai)	2	1		1	1	6	2	1	1	4	1	20
Shallow water CTDs (oceanography team)	10		3	16	15	20		7	12	25	9	117
Shallow water CTDs (AHI)												14
Multibeam mapping (sq. km)	2228 *(SAR, ZEA, ANA, ALA, GUG)*				2511 *(PAG, AGR)*	3856 *(ASU, SUP, MAU, URA)*				2511 *(PAG,AGR)*	2228 *(SAR, ZEA, ANA, ALA, GUG)*	8595
SCUBA dives	35	6	2	37	35	99	6	41	33	105	33	432

report).

MISSIONS:

A. Conduct ecosystem monitoring of the species composition, abundance, percent cover, size distribution, and general health of the fish, corals, other invertebrates, and algae of the shallow water (<35 m) coral reef ecosystems of Anatahan, Sarigan, Zealandia Bank, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply Reef, and Uracas.

B. Conduct benthic habitat mapping of the reefs and submerged banks surrounding Anatahan, Sarigan, Zealandia Bank, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply Reef, and Uracas, using ship-based and launch-based multibeam echosounders and underwater towed cameras.

C. Deploy an array of SST buoys, and subsurface temperature recorders, to allow remote long-term monitoring of oceanographic and environmental conditions affecting the coral reef ecosystems of the Northern Mariana Islands.

D. Collect water samples for analysis of nutrients and chlorophyll levels.

E. Conduct shipboard CTDs to a depth of 500 m, shallow water CTDs from small boats to a depth of ~30 m, and shipboard acoustic Doppler current profiler (ADCP) surveys around reef ecosystems to examine physical and biological linkages supporting and maintaining these coral reef ecosystems.

F. Determine the existence of threats to the health of these coral reef resources from anthropogenic sources, including marine debris.

G. Collect ADCP data during all transits.

RESULTS:

(See Appendices B through L for details)

A. Ecosystem monitoring of the species composition, abundance, percent cover, size distribution, and general health of the fish, corals, other invertebrates, and algae of the shallow water (<35 m) coral reef ecosystems of Anatahan, Sarigan, Zealandia Bank, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply Reef, and Uracas, was completed at 36 REA sites and 58 km of towed-diver survey transects.

B. Mapping from the *Hi'ialakai* and the survey launch R/V *AHI* resulted in the collection of high resolution multibeam bathymetry and backscatter imagery along the Northern Mariana Archipelago, including Anatahan, Sarigan, Zealandia Bank, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply Reef, and Uracas.

C. Two SST buoys, 24 STRs, and two WTR instruments were deployed at Anatahan, Sarigan, Zealandia Bank, Guguan, Alamagan, Pagan, Agrihan, Asuncion, Maug, Supply Reef, and Uracas to allow remote long-term monitoring of oceanographic and environmental conditions affecting coral reef ecosystems. Two SST buoys, 12 STRs, and 2 WTRs were recovered at these locations.

D. Three-hundred eighteen shallow water and two deepwater stations were visited to collect water samples for analysis of nutrient and chlorophyll levels.

E. Twenty shipboard CTDs to a depth of 500 m, 14 shallow water CTDs from R/V *AHI*, and 117 shallow water CTDs from the oceanography small boat to a depth of ~30 m, were completed.

F. The existence of threats to the health of these coral reef resources from anthropogenic sources, including marine debris were noted.

G. ADCP data was collected during all transits.

SCIENTIFIC PERSONNEL:

Robert Schroeder, Chief Scientist, Joint Institute for Atmospheric Research (JIMAR), University of Hawaii (UH)
Michael Tenorio, Fishery Biologist, Commonwealth of the Northern Mariana Islands (CNMI)/Division of Fish and Wildlife
Allison Palmer, Biologist, National Park Service/Guam
Peter Houk, Coral Biologist, CNMI/Division of Environmental Quality (DEQ)
Bernardo Vargas Angel, Coral Biologist, JIMAR, UH
John Starmer, Invertebrate Biologist, CNMI/Office of Coastal Resources Management
Tom Schils, Algal Biologist, University of Guam
Edson Limes, Biologist, CNMI/DEQ
Brian Zgliczynski, Research Biologist, Pacific Islands Fisheries Science Center, National Marine Fisheries Service
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Russell Moffitt, Atlas Coordinator, JIMAR, UH
Joyce Miller, Oceanographer, JIMAR, UH
Jonathan Weiss, Seafloor Mapping, JIMAR, UH
Emily Lundblad, GIS Specialist, JIMAR, UH
Robert O’Conner, GIS Specialist, Pacific Islands Regional Office, National Marine Fisheries Service

DATA COLLECTED:

Fish REA numerical and biomass densities by species
Digital images of fish-habitat associations
Target REA macroinvertebrate counts
Macroinvertebrate voucher specimens
Algal voucher specimens
Coral voucher specimens
Coral REA numerical abundance and size class by genus
Digital still images of REA site characteristics
Digital still images of coral species
Digital video along transects at REA sites
Invertebrate voucher specimens
Algal REA field notes of species diversity and relative abundance
Digital images from algal photoquadrats
Quantitative towed-diver surveys of large fish species (>50 cm TL)
Digital video surveys of habitat from towed-diver transects
Benthic composition estimations from towed-diver surveys
Macroinvertebrate counts from towed-diver surveys
Digital images of the benthic habitat from towed-diver surveys
Habitat lineation from towed-diver surveys
Shallow-deep conductivity, temperature and depth (CTD) profiles
Water samples to be tested for chlorophyll and nutrient content
Dissolved inorganic carbon from deepwater CTDs
Raw and processed multibeam digital data

Submitted by: ____
Robert Schroeder, Ph.D.
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Approved by: ____
Samuel Pooley, Ph.D.
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Attachments

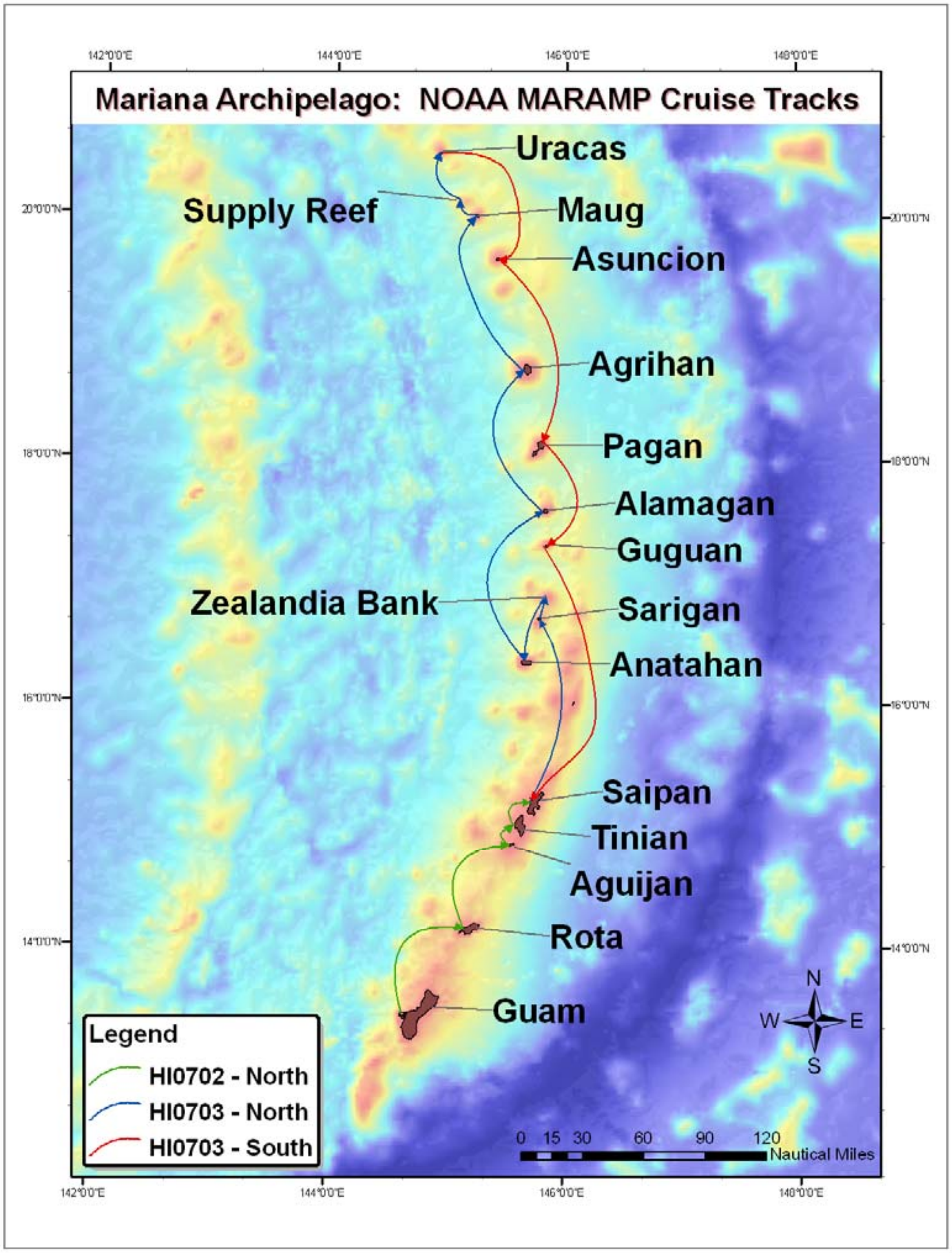


Figure 1.--Track of NOAA ship *Hi'ialakai* during cruise HI-07-03 in the Northern Mariana Islands, 25 May to 9 June 2007.

Appendix A: Methods

A.1 Benthic Habitat Mapping Methods

(Joyce Miller, Jonathan Weiss, Emily Lundblad, Robert O'Conner, Senior Survey Technician (SST) Jeremy Taylor)

System Descriptions

Multibeam mapping capability for cruise HI0703 included two shipboard multibeam echosounders (Kongsberg EM300 and EM3002D) and the Reson 8101ER multibeam aboard the 8-m launch R/V *Acoustic Habitat Investigator* (*AHI)*. Table A.1-1 provides an overview of the three multibeam sonars and their capabilities.

Table A.1-1. Sonar System Capabilities.

Sonar	Vessel	Freq. (kHz)	Depth Range (m)	Beam Size (deg)	Number of Beams
EM300	*Hi'ialakai*	30	30-3000	1 ½ x 1 ½	135
EM3002D	*Hi'ialakai*	300	2-150	1 x 1	320-508
Reson 8101ER	*AHI*	240	2-250	1 ½ x 1 ½	101

In addition to the multibeam sonars, each vessel is equipped with an Applanix Position Orientation Sensor for Marine Vessels (POS/MV) vertical reference system, which provides timing, position, velocity pitch, roll, heave, and heading information for correction of motion in the multibeam data. Three different conductivity-temperature-depth (CTD) sensors were used to provide sound velocity profiles (SVPs) that are critical for proper correction of sound velocity errors associated with multibeam data.

All sensors on both vessels were interfaced to the SAIC ISS-2000 data acquisition and survey control system, which includes survey planning, data acquisition, and data processing capabilities.

During the 2006/2007 winter yard period, the main mast on the *Hi'ialakai* was replaced and the POS-MV antennae were relocated. These changes necessitated a recalibration of the multibeam system, including entering of new antennae offsets in the POS-MV software, performing a POS-MV GAMS calibration, and running of patch tests. The GAMS calibration and EM300 patch tests were done on April 2-3, 2007, and the patch test for the EM3002D sonar was completed on April 19-20, 2007, to determine new bias parameters for entry into the EM300 and EM3002 software. These tests are documented in the *Hi'ialakai* Patch Test update, "Summary of April 2007 Patch Test Results: NOAA Ship *Hi'ialakai*: EM3002D and EM300 Multibeam Sonars."

Vessel offset and patch tests for the R/V *AHI* were also conducted with the cooperation of Office of Coast Survey representatives, Lt. Mark Van Waeas and Erin Campbell, Physical Scientist. These patch tests were performed during the week of March 12-16, 2007, in Honolulu in preparation for collaborative harbor charting surveys in CNMI that

Methods

are planned during HI0703. Two reports that document the R/V *AHI* tests are “Report on Vessel Offsets for R/V *AHI* (F2505)” and “Hydrographic Survey Readiness Review (F2505).”

Methods for acquisition and post processing
Prior to the cruise, existing bathymetry data were assembled to provide a baseline for acquisition of multibeam data. These data included (1) Simrad EM300 multibeam bathymetry collected aboard the R/V *Thompson* during the NOAA Ocean Exploration Ring of Fire cruises in 2003 and 2004; (2) Hydrosweep DS2 (HS-DS2) multibeam bathymetry collected aboard the R/V *Maurice Ewing* during cruises EW0202 and EW0203; (3) Hawaii MR-1 bathymetry collected aboard the R/V *Herman Melville* during cruises COOK06MV and COOK07MV; (4) and SeaBeam 2000 multibeam data collected aboard the R/V *Herman Melville* during the NOAA Ocean Exploration Submarine Ring of Fire cruise in 2006 and the COOK0107 cruise. Additionally, IKONOS imagery for all islands (if available) and predicted tides for Guam Island station 1630000 were assembled. These data were used to create preliminary survey plans that were integrated into the ISS-2000 software before the cruise. These data were also assembled and integrated into the Arc 9 Geographic Information System (GIS).

The ISS-2000 survey system is used on both the ship and the launch, enabling seamless sharing of data between the two vessels. The Generic Sensor Format (GSF), which is implemented in the ISS-2000 system, allows logging of multibeam data from a variety of multibeam sonars into a single, standardized format; the GSF also provides integrated metadata within the real-time multibeam files. In addition, the ISS-2000 creates digital message logs that allow full traceability of software and real-time events.

During system configuration, all vessel offsets are entered into either the POS/MV, the sonar, or into the ISS-2000. In addition, predicted tides are calculated for all tide zones to be surveyed and then recorded into the data in real time. Survey plans can be loaded into the real-time system on both vessels; coverage grids that are generated in real time during data acquisition can be viewed during planning, acquisition, and processing phases.

SVPs are taken at the beginning of each 12-hour period of surveying on the ship and each 8-hour day of surveying on the *AHI* or as needed when the multibeam data indicate that a new SVP is needed. Standardized survey procedures, including a 2-minute warm up on deck and a 2-minute surface equilibration, are used on every cast. After the sound velocity cast is done, the data are downloaded with VelocWin software on the ship and with the SeaBird software on the launch. Sound velocity profiles are loaded using the ISS-2000 download utility; the downloaded profiles are sent to the two Kongsberg sonars on the ship and to the Reson sonar on the *AHI*, and the sound velocity information is logged as a part of the GSF. A real-time probe is used on the ship to monitor the surface sound velocity (SSV); if a difference between the SSV and the SVP at the surface is greater than 3 m/sec, an alarm is generated. The sonar on the *AHI* is less susceptible to SSV errors, and the daily casts are generally sufficient to correct for sound velocity. In all cases, the data are carefully monitored for sound velocity artifacts using the real-time displays.

During real-time operations, the ISS-2000 operator starts the ISS-2000 software, making sure to load the appropriate system configuration file. The System Control and Message windows are loaded at that time. The operator creates a dataset for the entire cruise that is named with the corresponding cruise delineator; *Hi'ialakai* and *AHI* data were logged into separate datasets (HI0703 and AHI0703) for file management purposes. After the dataset is created and all configurations are checked, "Start Survey" is selected and the Navigation Manager, Multibeam Manager, and Helm Display windows are opened. Text icons for all programs appear in the System Control window; the icons can be colored white, yellow, red, or green. White means that the program is selected but not activated; yellow means the program is activated but not logging; red means that there is a problem with the program; and green means that the program is operating and data are being logged. Files are automatically created for all multibeam sensors, for navigation inputs, for the POS/MV vertical reference, and for the messages generated by the system. Predicted tide files that can be used throughout 2007 were prepared before the cruise and were applied to the multibeam data in real time.

After the ISS-2000 Navigation Manager is started, a survey plan is chosen and one or more surveys are selected for execution. Tide zones, existing coverage grids, and navigational charts can be loaded into the display, if desired. The navigated ship icon appears on the screen. Survey lines are then selected from the survey file or made in real time and loaded into a Survey Schedule; lines can be selected in any order and their azimuth can be reversed; these lines appear on the screen when loaded into the schedule. When survey lines are being run in Survey Mode, the multibeam data is almost always logged (if logging is activated), but may be flagged as either "online" or "off-line." During transits, survey can be done in the "Underway Mode," but a flag must be set to not flag the off-line data during transits. If a coverage grid is loaded using the Coverage Monitor program and enabled for real-time logging, multibeam data are added to the coverage grid in real-time.

The Helm Display is also activated when the survey is started. This Helm Display appears both on the survey lab screens and on a screen on the bridge, and screen display parameters can be manipulated at either location. The same coverage grids, navigation charts, and survey lines selected in the Navigation Manager interface appear on the Helm Display as well; however, the display of these grids, charts, and lines can be turned on and off in the Helm Display independently of the Navigation Manager. The Helm Display can also be changed to different scales and color schemes than what is displayed on the Navigation Manager. The ISS-2000 feature, display of the coverage grids on the Helm Manager, enabled the bridge to steer lines in survey mode based upon existing coverage rather than always needing to create a formal survey line for the bridge to follow.

The Multibeam Manager is used to monitor the status of data files, to view and apply SVPs, and to view the multibeam bathymetry and backscatter data in real time. Many problems with the data can be detected immediately using feedback from these real-time displays. The Kongsberg SIS interfaces for the EM300 and the EM3002 are mounted above the two ISS-2000 screens, and other multibeam displays that provide different views of the data are available through SIS. Backscatter displays for all systems showed distinct and intriguing bottom types, but the ultimate quality of the data from the different sonars cannot be evaluated until data processing is complete.

During HI0703 multibeam data were collected around the clock aboard the *Hi'ialakai*. Deeper water mapping was usually conducted at night and daytime operations occurred closer to shore, with a focus on delineating the 100-fathom boundaries around all of the islands. Due to the steep nature of many of the islands, the Simrad EM300 was the primary multibeam used to map depths between 100 m and 3000 m. The Simrad EM3002 was used as the ship entered and departed Saipan Harbor to map depths between 15 and 200 m. The ship also continued collecting multibeam data during transits between islands and banks, filling in areas that were not previously mapped by other expeditions.

The *AHI* surveyed for the first day of HI-07-03 around Tinian Island; those data are in the HI-07-02 cruise report. The *AHI* surveyed areas with depths between ~10 m and 300 m at most islands that were visited.

Aboard ship, data were logged to two disks simultaneously in real time. The ISS-2000 AutoArchive program, which copies the data to a third permanent archive disk was run as needed during post processing. The AHI0703 dataset was logged on the real-time computer in the launch, and a second copy of the data was manually made on a portable disk; the disk was then moved to the ship and connected to the shipboard computers, and the data were read to the permanent archive disk. A final copy of all data was made to the PIBHMC network disks, and data processing was done on only this copy of the data. The SABER data processing package, which provides full multibeam processing capability, was primarily used to manually edit the multibeam data in GSF, to plot tracklines, to update SVPs and tide data when necessary, and to create gridded data sets using the Pure File Magic (PFM) format that enables editing the integrated data set within the grid as well as reading any edits made in the grid back to the GSF multibeam files. CUBE, a recently implemented SABER software module that provides error estimates on the integrated data files and a more automated procedure for cleaning of the data set, was installed and tested with the new SABER version (4.0.14) installed on this cruise. Tape backups of all processed data were made approximately every two days. The gridded data sets were converted to ASCII files for conversion to Arc raster grids. Map products were made as grids were created and added to the GIS product archive.

Backscatter data are logged as part of the GSF multibeam file and will be processed at PIBHMC after return to Honolulu.

A.2 Oceanography and Water Quality

(Jamison Gove, Daniel Merritt, Ellen Smith, Charles Young, SST Jeremy Taylor)

The Coral Reef Ecosystem Division (CRED) has been conducting oceanographic research throughout the Hawai'ian Archipelago and the U.S. remote Pacific Territories since 2001. Research around the Marianas Archipelago was first conducted in 2003. CRED's oceanographic investigations include *in situ* surveys and the deployment and recovery of instrument platforms to monitor and assess important physical, chemical, and biological variables in the coral reef ecosystem. Due to logistical constraints, visits to the Marianas region are limited to periods every 2 years. Long-term oceanographic monitoring is accomplished via moored instrument platforms that internally record data and/or telemeter data via satellite.

Knowledge of oceanographic conditions and water quality at islands and banks in the Marianas Archipelago is fundamental to understanding the structure and function of coral reef ecosystem dynamics such as reef morphology, larvae distribution, productivity, species richness and diversity, growth rates, and overall ecosystem health.

The following *in-situ* oceanographic assessments were accomplished:

1. Shallow water (~30 m water depth) conductivity (salinity), temperature, and depth (CTD) profiles, including transmissometry (water clarity) measurements conducted at regular intervals around Sarigan, Zealandia Bank, Anatahan, Alamagen, Agrihan, Maug, Supply Reef, Uracas, Asuncion, Pagan and Guguan providing information on small scale distributions of water masses, circulation, and local seawater chemistry changes (Table A.2-1).
2. Shallow water chlorophyll *a* and nutrient samples were collected at 1 m, 10 m, 20 m, and 30 m at selected CTD sites around each island linking water quality with water masses and providing insight into localized nutrient enrichment and/or eutrophication.
3. Continuous recording of surface and subsurface water temperatures as a function of depth during all towed-diver operations, providing a broad and diverse spatial and thermal sampling method. Refer to the Towed Diver Habitat/Fish Survey Team Activity summary information.

Long-term oceanographic monitoring was accomplished by deploying a variety of both internally recording and near real-time telemetered instrument platforms and oceanic drifters. For Sarigan, Zealandia Bank, Anatahan, Alamagen, Agrihan, Maug, Supply Reef, Uracas, Asuncion, Pagan and Guguan these instruments included (Table A.2-2):

1. Sea Surface Temperature (SST) buoys that measure high-resolution water temperature. These buoys telemeter their data in near real time.
2. Subsurface Temperature Recorders (STR) that measure high-resolution subsurface temperatures. STRs are deployed around the island, including on the SST and EAR anchors.
3. Wave and tide recorder (WTR) that measures water pressure (waves and tides) and water temperature.

All moorings, shallow water CTDs, and shallow water samples were collected from a small boat during daylight hours.

Table A.2-1: Shallow water Oceanographic Sampling Summary

Site	CTD Sites	Water Sample Sites	Chlorophyll samples collected	Nutrient samples collected
Sarigan	10	4	18	18
Zealandia Bank	0	0	0	0
Anatahan	3	3	4	4
Alamagen	16	4	16	16
Agrihan	15	3	14	14
Maug	20	9	38	38
Supply Reef	0	0	0	0
Uracas	7	3	14	14
Asuncion	12	4	16	16

Site	CTD Sites	Water Sample Sites	Chlorophyll samples collected	Nutrient samples collected
Pagan	25	7	25	25
Guguan	9	3	14	14

Table A.2-2: Oceanographic Moorings Summary

Site	STR	SST	WTR	Comments
Sarigan	2	0	0	One new STR was deployed at Sarigan
Zealandia Bank	1	0	1	
Anatahan	1	0	0	
Alamagen	2	0	0	One new STR was deployed at Alamagen
Agrihan	1	0	0	
Maug	5	1	0	One new STR was deployed at Maug

Site	STR	SST	WTR	Comments
Supply Reef	1	0	1	
Uracas	6	0	0	Five new STRs were deployed at Uracas
Asuncion	1	0	0	
Pagan	3	1	0	Two new STRs were deployed at Pagan
Guguan	1	0	0	

A.2.1 Circum-Island Water Quality

A YSI6600EDS water quality sonde provided by CNMI Coastal Resources Management Office was experimentally deployed with towed divers. Divers attached the sonde to themselves with clips, facing the sonde's meters in the direction of travel. The sonde was set to collect temperature, conductivity, depth, turbidity and pH. Downloaded data were synchronized with Tow Team tracks by matching time signatures from corrected tracks and 6600EDS meter. A file including salinity, Latitude, Longitude and Tow Team Temperature and Depth was imported into an ArcView project file. Further processing to correct variation in conductivity/salinity caused by temperature, depth and tidal variation will be needed to produce a final product.

A.3 Rapid Ecological Assessment Methods
(Fish: Robert Schroeder, Mike Tenorio, Allison Palmer; Corals:Peter Houk; Coral Disease: Bernardo Vargas Angel; Algae: Tom Schils and Edson Limes; Invertebrates: John Starmer)

The survey methodology used during HI-07-02 is the same as previous rapid ecological assessment (REA) surveys conducted by Coral Reef Ecosystem Division (CRED) cruises. At each REA site, three 25-m transect lines were laid out by the fish team, separated from each other by approximately 2–3 m. At most sites, transects were laid out at 13–15 m (40–45 ft) depth. REA methods for each specific discipline are as follows.

A.3.1 Fish

The REA Fish Team conducted three types of surveys at REA sites: Belt Transects (BLT), Stationary Point Counts (SPC), and Roving Diver Rapid Ecological Assessments (REA). BLTs were performed along three consecutive 25-m lines set along a single depth contour. As each line was set, two observers swam about 2 m apart along either side of the line, identifying to the lowest possible taxon, counting, and recording size classes for all fishes >20 cm total length (TL) within an area 4 m wide and 4 m high. At the end of each 25-m line, the divers turned around and returned along their respective sides of the line identifying, counting and recording size classes of all fishes <20 cm TL within 2 m of their side of the line and 4 m off the bottom. The third fish team diver simultaneously conducted four SPCs at each REA site, generally ~15 m from the transect line. SPCs consist of the diver identifying, counting, and recording the size classes for all fishes >25 cm total length observed in a cylindrical volume 10 m in radius during a 5-minute period. Following and opportunistically during the BLT and SPC surveys, all three fish team divers recorded the presence of all fish species seen outside the transect area and outside the SPC counts. The fish REA team's species presence records are combined with fish species observed by other divers (benthic team, tow team, or oceanography team) to develop an island-wide record of all fishes observed. No collection efforts were made by the fish REA team during HI0703.

A.3.2 Algae

Standardized quantitative sampling methods for remote tropical Pacific islands were developed and published for marine algae (Preskitt *et al.* 2004). To allow for vertical sampling in areas of high relief (walls), the method was modified slightly by Vroom *et al.* (in review, Coral Reefs) and entails photographing quadrats, collecting algal voucher specimens, creating in situ algal species lists, and ranking relative algal abundance. This modified "Preskitt method" has been used by CRED since 2003 in the Northwestern Hawaiian Islands, Sarigan/Mariana Islands, Pacific Remote Island Areas, and American Samoa.

Macroalgae were tentatively identified to genus (species-level when possible) in the field, and ranked abundance of algal genera was collected from 12 quadrats (0.18 m^2) at each site (1 being the most abundant, 2 being the next most abundant, etc., with 10 being the maximum number of genera found in a single quadrat). Six quadrats were located at random points along the first two transects (3 per transect), and six quadrats were located at points 3 m perpendicular from each random point, in the direction of shallower water. Additionally, samples of macroalgae present within each quadrat were collected as voucher specimens (Preskitt *et al.*, 2004) for microscopic analysis and species verification. A random swim at the end of each dive and between quadrats augmented macroalgal collections attained from quadrats and allowed cryptic species that predominantly occurred in shaded areas to be qualitatively recorded and collected.

Methods

Because of difficulties with identification, algae that fell within the functional groups of turf, cyanophytes and crustose coralline algae were usually lumped into their respective categories.

<u>A.3.3 Corals</u>

At each site, the transect lines laid by the fish team served as the focal point for coral quantitative studies. The point quadrat method was used to collect coral assemblage data. At ~5-m intervals along the combined transect lines a 0.5 m x 0.5 m quadrat was haphazardly tossed (total = 16 quadrats/site); each coral colony whose center point lay inside the quadrat was recorded to species level, and the maximum and perpendicular diameters were measured. Abundances, population densities, and geometric diameters were calculated for each coral species from these measurements.

Geometric diameters (Z) were calculated based upon the geometric formula

$$Z\ (cm) = (x.y)^{1/2}$$

where (x) and (y) are the cross sectional diameters of each coral colony. Coverage (A) for each individual species was calculated assuming that the coral colonies were circular using the formula

$$A\ (cm2) = 3.1416(z/2)^2$$

where (z) is the geometric diameter from (1). Total coverage was simply the sum for all species. Population density (D) was calculated based upon

$$D\ (colonies/m^2) = n / 4$$

where n is the total number of colonies of each coral species and 4 represents the total area surveyed (m^2) by 16 quadrat tosses. Coral species richness was calculated as the total number of species found within the quadrat surveys.

A.3.3.1 Percent benthic cover

Only the first two, 25-m transect lines, previously laid out by the fish team, were surveyed for percent cover of benthic elements. Transect lines were previously labeled at 50-cm intervals. As the scientist swam along the transect lines, he inspected the benthic elements falling directly underneath each 50-cm mark on the transect line. Each such element was tallied and recorded to the lowest taxonomic level possible, and then classified under the following scheme: live coral, dead coral, carbonate pavement, coral rubble, sand, rock, macroalgae, and other. These data are used to provide the basis for quantitative estimates of live coral cover, as well as percent cover of the divrese benthic and substrate components.

A.3.3.2. Coral health and disease assessment

At each site, using the first two transect lines laid by the fish team, an area of 3 m (depending on bottom time) on each side of the transect lines (approx. 300–400 m^2) was surveyed to document incidence of coral bleaching and/or disease. Within this survey area, each diseased/afflicted coral colony was identified to the lowest taxonomic level possible, and the following information was recorded: 1) colony size; 2) type of affliction [bleaching, skeletal growth anomaly, tissue loss/white syndrome, trematodiasis, necrosis, other: coral-algal interactions with pigmentation responses, and cyanobacterial infections); 3) area affected (percent live/dead); 4) severity of the affliction (based on the number of polyps affected, and the possible effect on the overall ability of the colony to function normally; and ranked as follows mild: 1; moderate: 2; marked: 3; severe: 4; and acute: 5); and 5) photographic records and tissue samples were procured as needed. Tissue samples were catalogued and fixed in buffered, zinc-formalin solution for further histopathological analyses. The disease data, together with coral colony density estimates by the second coral biologist, will be used to estimate disease prevalence; samples and photographs will be used to aid in further disease characterization.

A.3.4.1 Macroinvertebrate surveys

The 2007 invertebrate surveys were conducted using belt transects along 25-m lines laid by the fish team. The belt transects were 4 m wide and were performed along three transects lines, providing three 100 m^2 samples per site. Species searched for along the belt transects included non-cryptic, mobile taxa: anemones, echinoids, holothurians, crinoids, asteroids, urchins, large gastropods, cephalopods, and large crustaceans. Tridacnid bivalves (Tridacna spp., Hippopus sp.) were also counted.

Given the small area covered by the three transects, it was important that lines were placed over homogenous stubstrate. Placement over inappropriate habitat (sand, deep crevices) generally resulted in low or zero invertebrate counts and is problematic for later statistical analysis.

After the transect and diversity counts (next section) were finished a random swim and collections were conducted if there was remaining time. Species seen or collected during the random swim were added to a species list for the site.

A.3.4.2 Benthic and Sediment Diversity

Ten 1 m^2 quadrats were surveyed for overall benthic diversity at each site. A 0.25 m^2 quadrat (50 cm x 50 cm) was haphazardly placed in the vicinity of the transects. Quadrats that landed on sand were not counted and instead were placed again. The quadrat was flipped three times at each quadrat site, in order to expand the area surveyed to 1m^2. All non-cryptic taxa >2 cm were recorded to the highest possible taxonomic resolution for each 1 m quadrat. For organisms not identifieable in the field, an in situ photograph was taken and a specimen collected, if possible. Such organisms were given a descriptive field name and referenced to the photograph or specimen. This survey

Methods

provides an assessment of site diversity (total species/genera per site) and abundance (number of occurences species/genera per site).

Sediment diversity surveys focus on shelly microfauna (bivalves, gastropods, ostracods and foraminifera). Ideally two liters of sand were collected at 60 ft from the leeward and windward sides of each island. Samples were frozen during the cruise. Post-cruise, sediment is rinsed in fresh water and air dried. A 250-ml subsample is sorted and the first 500 intact shelly organisms are sorted to morphospecies for identification. If less than 500 shells are recovered, additional 250-ml subsamples are sorted. Initial analysis is at the level of morphospecies.

A.3.4.4 Crown-of-Thorns Collection

Tissue samples from *Acanthaster planci* (crown-of-thorns starfish (COTS)) were collected during HI0702 and HI0703 to examine the connectivity of COTS in the central Pacific using mitochondrial DNA and gene flow analysis.

Previous studies conducted on the urchin, *Echinothrix diadema*, and the soldierfish, *Myripristis berndti*, found high gene flow between the Line Islands and the Hawaiian Archipelago. A study conducted on the flame angelfish, *Centropyge loriculus*, found high gene flow between the Line Islands, Johnston Atoll and Hawaii. Together these studies provide clear evidence that connectivity exists between Hawaii, Johnston and the Line Islands. Molly Timmers, a researcher at the University of Hawaii, is currently examining connectivity among COTS populations, specifically testing the hypothesis that the outbreak levels at Kingman and the increasing numbers present at Johnston of this highly fecund starfish could potentially seed an outbreak along the Hawaiian Archipelago.

Several theories exist that gene flow is present between the Northwest Pacific and the Northwestern Hawaiian Islands (NWHI) via eddies spinning off of the Kuroshio Current or from the Kuroshio Extension Current. The presence of fish such as the Japanese angelfish, *Centropyge interrupta*, suggests such a connection exists since this fish is known only in Japan, Taiwan, and the NWHI. To date, few genetic studies have been conducted to examine gene flow between the NWHI and the Northwest Pacific. A secondary aspect of the COTS research, in collaboration with a Japanese research group, is to examine *Acanthaster* gene flow between Japan, NWHI, and possibly the Marianas.

Based on towed-diver surveys from 2005 at Pagan and Guguan, where large populations of adult COTS and some juveniles were observed, populations levels at these islands may be high once again in 2007.

Ideally for microsatellite analyses it is best to have 50 individuals and for mtDNA to have 25 per island, or, for the larger islands, these numbers per east/west side. While such numbers may be difficult to achieve, all dive teams during HI-0702 and HI-0703 had COTS sampling kits onboard to be used opportunistically, either during other survey operations or after normal operations had been completed. At some REA survey sites, one diver was deployed to search solely for *Acanthaster*.

To collect the tissue samples for microsatellite and mtDNA analysis, divers used a knife or shears to remove one arm from an individual *Acanthaster planci* starfish near the base. These arms were then handled using tongs and placed in a hard plastic container. Collected samples were placed in EtOH back on board the ship to preserve the DNA for analysis. Samples from the same dive site were stored together in pint jars and 50-ml falcon tubes. Site metadata were recorded for each sampling location, including latitude and longitude, location name, collocation with another survey site, and general observations about the individual when it was collected. Containers were labeled with the year, four-digit #, and three-digit island code, e.g., 07_0001_PAG.

A.4. Towed-diver Survey Team Methods

(Jacob Asher, Edmund Coccagna, Brian Zgliczynski, Benjamin Richards)

Shallow water habitats around each island, bank, or reef were surveyed using pairs of divers towed 60 meters behind the 19-ft SAFE Boat survey launch. In each towed-diver buddy team, one diver is tasked with quantifying the benthos while the other is tasked with quantifying fish populations. Each towed-diver survey lasts 50 minutes and covers approximately 2 km. A GPS track of the survey launch track is recorded at 5-second intervals. A custom algorithm is used to calculate the track of the divers based on the track of the boat taking into account speed, course, and diver depth. Both towboards are equipped with precision temperature and depth recorders (Seabird SBE39) recording at 5-second intervals. At the end of each day data are downloaded, processed and presented in ArcGIS and can be displayed in conjunction with IKONOS satellite imagery, NOAA chart data and/or other spatial data layers.

Benthic Methods

The benthic towboard is equipped with a downward high resolution digital still camera with dual strobes. The downward-looking camera is maintained 1-2 m off the bottom and is programmed to photograph benthic substrate every 15 seconds. The diver on the benthic towboard observes and records habitat composition (hard coral, stressed hard, soft coral, macroalgae, coralline algae, sand and rubble) and tallies conspicuous macroinvertebrates (crown-of-thorns starfish (COTS)), urchins, sea cucumbers, and giant clams) along a 10-m swath.

Fish Methods

The fish towboard is equipped with a forward-looking digital video camera which creates a visual archive of the survey track and can be used to quantify habitat composition, complexity as well as abundance and distribution of ecologically and economically important fish and macroinvertebrate taxa. The diver on the fish towboard records, to the lowest possible taxon, all fish greater than 50 cm total length (TL) along a 10-m swath in 5-minute segments for a total of 10 segments (50 minutes). Species of particular concern observed outside the survey swath are classified as presence/absence data and are recorded separately from the quantitative swath data.

Appendix B: Anatahan

B.1. Oceanography and Water Quality

Operational time was severely limited at Anatahan due to cruise day cuts; however, the one instrument deployed at Anatahan was recovered and replaced at approximately 4 m depth during HI0703. (Figure B.1-1)

Three shallow water conductivity, temperature, depth (CTD) casts were conducted along the south shore of Anatahan. At all of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin for a total of 8 discrete water samples measuring chlorophyll and nutrient concentrations (Figure B.1-1).

In situ temperature data at 3.5 m obtained from October 2003 to May 2007 shows seasonal variability with warm temperatures observed from July to November and cooler temperatures from January to April (Figure B.1-2). On intraseasonal time scales, large changes in temperature (> 2.0 °C) occur periodically throughout the time series. In late June through early July, 2004, temperature dropped from 29.5 to 27.3 ˚C in less than 15 days, then sharply increased 2.5 C less than 7 days later. Such large temperature fluctuations are not observed via monthly Satellite (red line) data.

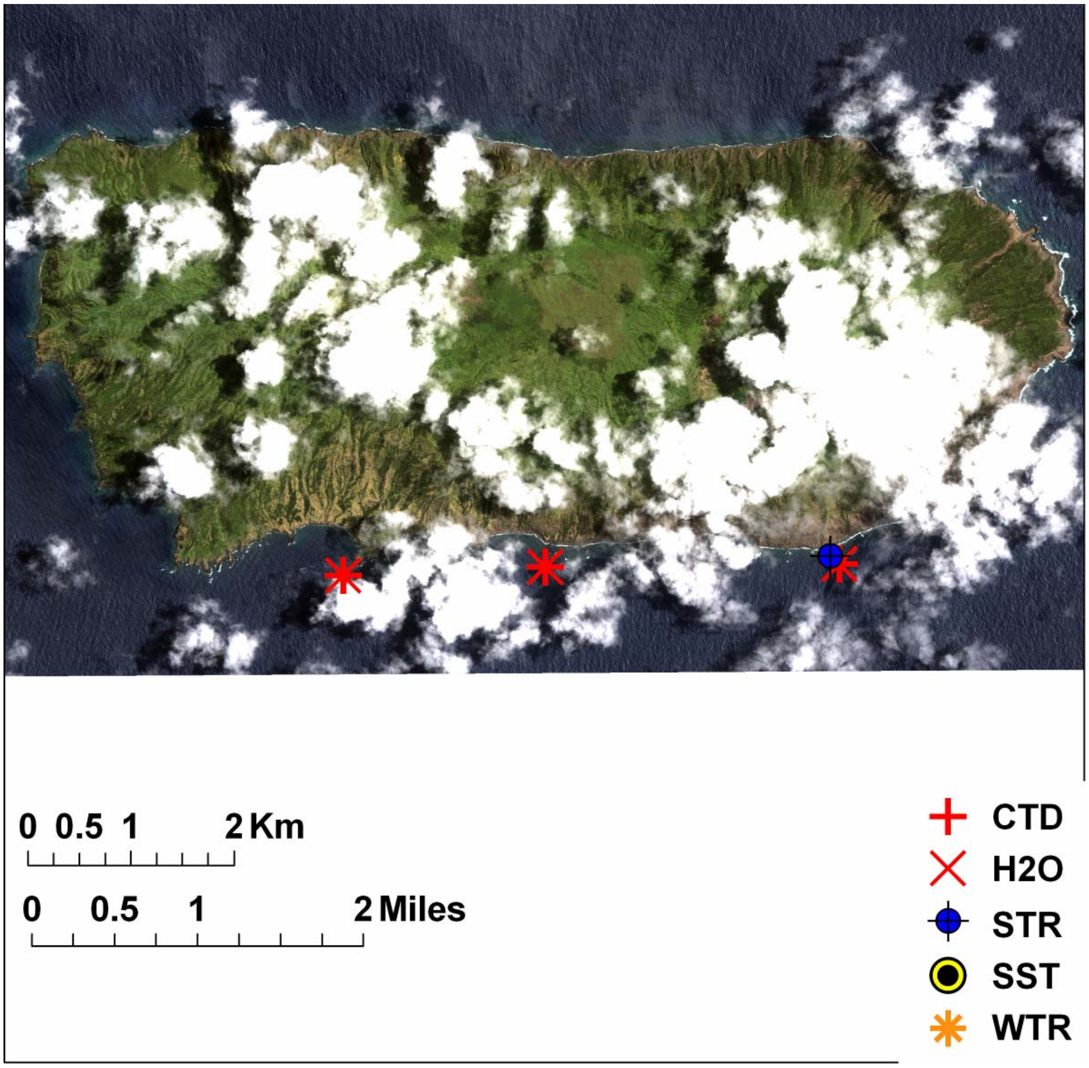


Figure B.1-1: Positions of CTDs, water samples and moorings at Anatahan.

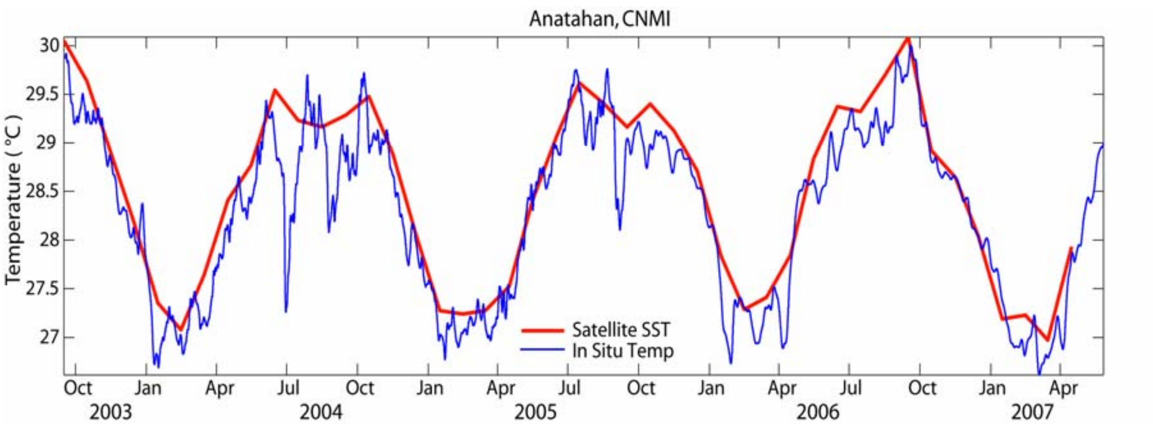


Figure B.1-2: *In situ* temperature at 6.7 m from October 2005 to June 2007. The red line is data sampled at a 30-minute interval; the blue line is a weekly mean from AVHRR satellite data.

B.2. Benthic environment

B.2.1. Algae

The oceanography team observed and collected a green alga that thrived on the black volcanic ash surrounding Anatahan. Further determination using a microscope will be needed to identify the taxon. This alga was very abundant at the site and formed large tufts (about 20 cm high).

Appendix C: Sarigan

C.1. Benthic Habitat Mapping

Sarigan Island is located at ~16º 42'N, 145º 46'E and approximately 11 nmi south of Zealandia and 23 nmi north of Anatahan Island. Its location on nautical chart 81086_4 corresponds well to observations made during HI0703.

Multibeam mapping surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars. The ship transited to and worked at Sarigan Island from May 26-27, 2007 (JD 146-147), and the *AHI* was deployed on May 26, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~15 m and 250 m, and the *Hi'ialakai* collected data down to about 1900 m on the eastern side of the island and to 1500 m on the west side of the island. Additional multibeam data were collected 22 nmi to the east of the island chain; these data complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the previous data were collected primarily to the west of the island chain. The multibeam data collected around Sarigan and to the east represents approximately 40% of the 2228 km^2 (roughly 900 km^2) of HI0703 coverage around the southern section of the Mariana Archipelago, which includes Alamagan, Guguan, and Sarigan Islands, Zealandia Bank, and the deeper area to the east of Sarigan Island. Anatahan is not included in this estimate of the multibeam coverage because only transit data were collected around the island.

Sarigan is classified as a dormant volcano by Bloomer *et al.* (1989). There is a shallow shelf that extends 1.2 nmi to the east of the island with depths ranging from 30 to 150 m. A few sea-level terraces are superposed atop the shelf. As with other volcanoes in the Mariana Islands, blocks of material and submarine canyons and channels on the submarine island flanks imply mass wasting and erosion. Some of the seafloor highs surrounding Sarigan are probably small volcanic edifices.

Reference:

Bloomer, S.H., Stern, R.J. and Smooth N.C. 1989. Physical volcanology of the submarine Mariana and Volcano Arcs. Bulletin of Volcanology, p. 210-224.

Sarigan

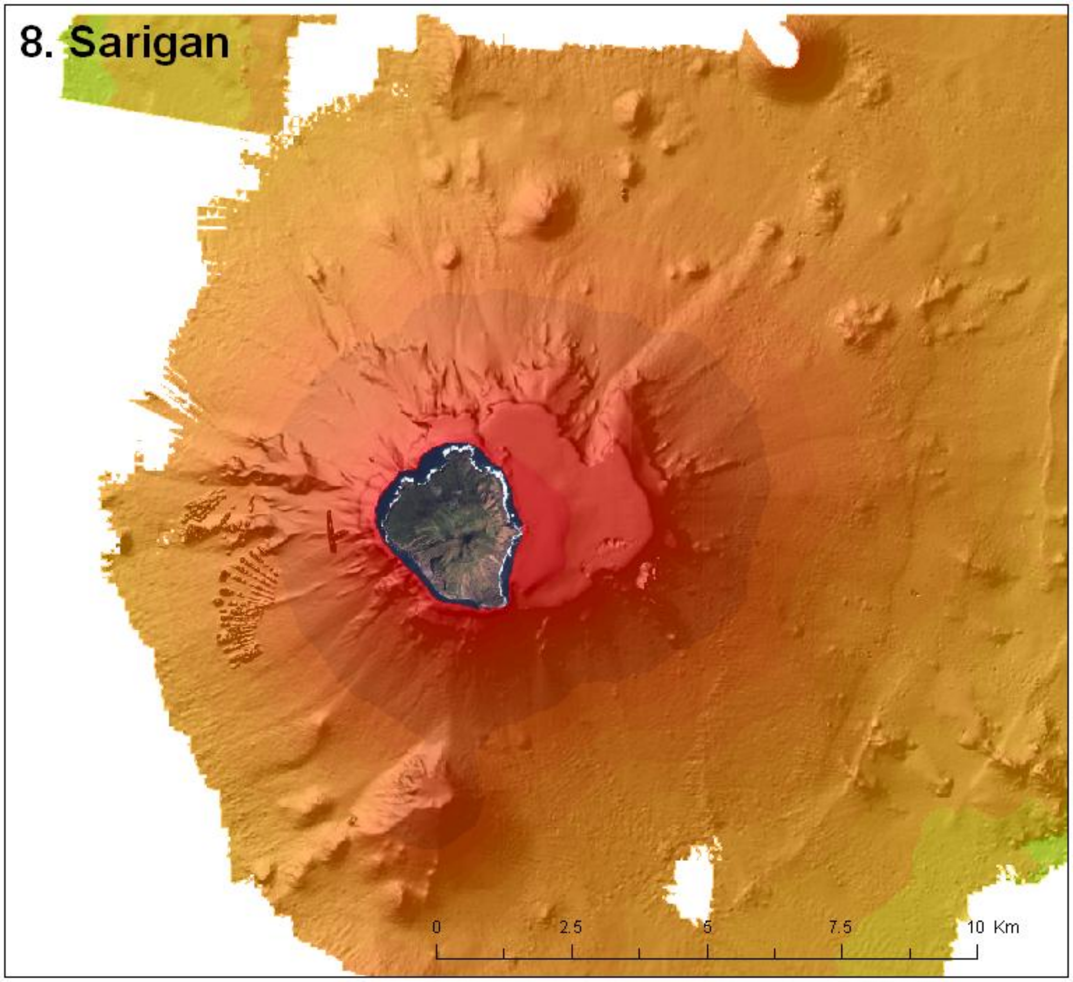


Figure C.1-1: Multibeam bathymetric data collected during HI0703 around Sarigan Island.

C.2. Oceanography and Water Quality

In total, one instrument was recovered and two instruments were deployed at Sarigan during HI0703. One subsurface temperature recorder (STR) was recovered and replaced at approximately 6 m depth, and a second STR was deployed near REA site 4 at approximately 11 m depth. (Figure C.2-1)

Ten shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter of Sarigan at approximately 0.8 mile intervals following the 30 m contour. At 4 of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depths, for a total of 36 discrete water samples measuring chlorophyll and nutrient concentrations (Figure C.2-1).

In situ temperature data at 5.8 m obtained from October 2005 to June 2007 shows mostly seasonal variability with warm temperatures observed from June to November and cooler temperatures from January to April (Figure C.2-2). The seasonal transition between winter-time and summer-time temperatures occurs rather abruptly at Sarigan, particularly in April 2005 when a 2.5 °C temperature increase is observed in less than a month.

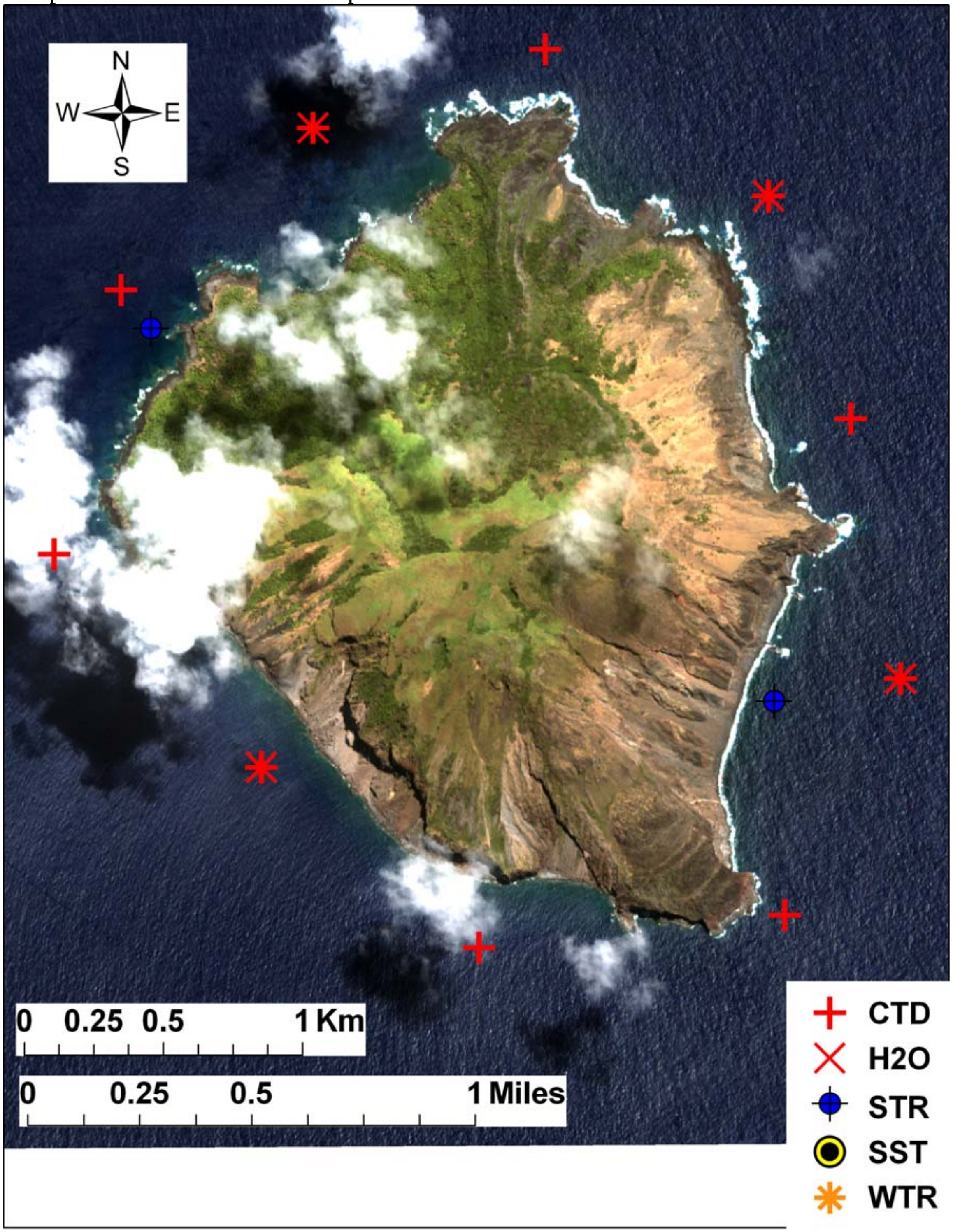


Figure C.2-1 Positions of CTDs, water samples and moorings at Sarigan.

Sarigan

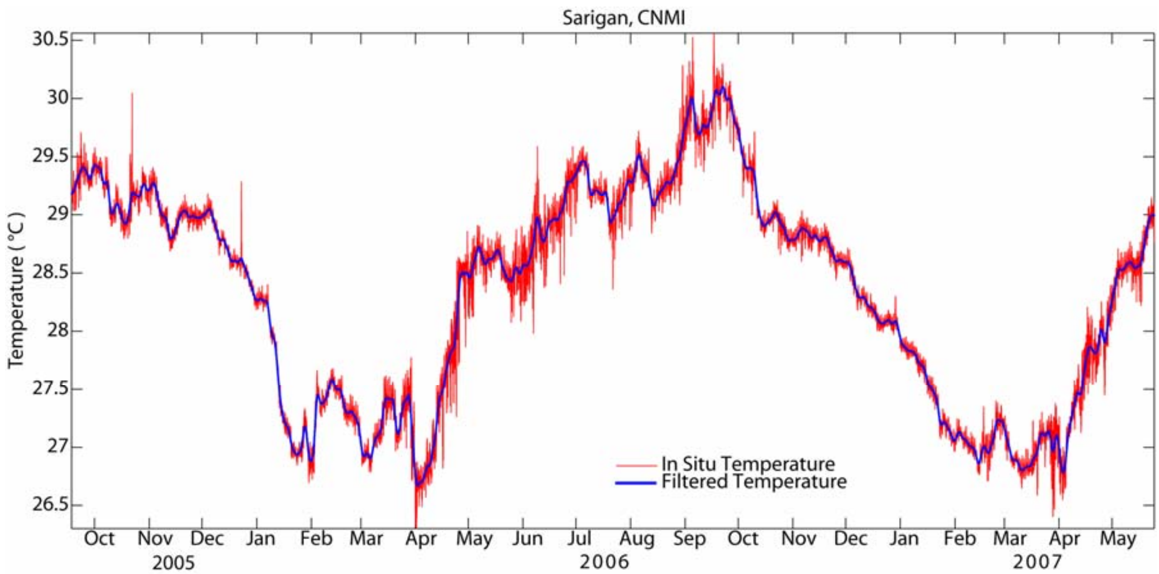


Figure C.2-2: In situ temperature at 5.8 m from October 2005 to June 2007. The red line is data sampled at a 30-minute interval; the blue line is a weekly mean.

C.3 Rapid Ecological Assessment (REA) Site Descriptions

Sarigan has gone through a feral animal eradication program. The U.S. Fish and Wildlife Service is focusing on Sarigan for habitat restoration after the successful eradication of feral animals. Similar to the neighboring island of Guguan, a majority of the vessels able to reach this island focus mainly on bottomfishing. Minimal reef fishing activity occurs in the waters of this island.

REA surveys were conducted at three sites at Sarigan (Table C.3-1). Locations of all REA sites around Sarigan are shown in Figure C.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table C.3-1. Sites surveyed by REA team at Sarigan, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.

Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, °C
SAR-2	5/26/2007	16	42.984	145	46.499	11 - 13	16.8	28.3
SAR-4	5/26/2007	16	41.929	145	47.329	9 - 11	16.8	28.3
SAR-1	5/26/2007	16	41.952	145	46.202	10 - 13		28.3

Sarigan

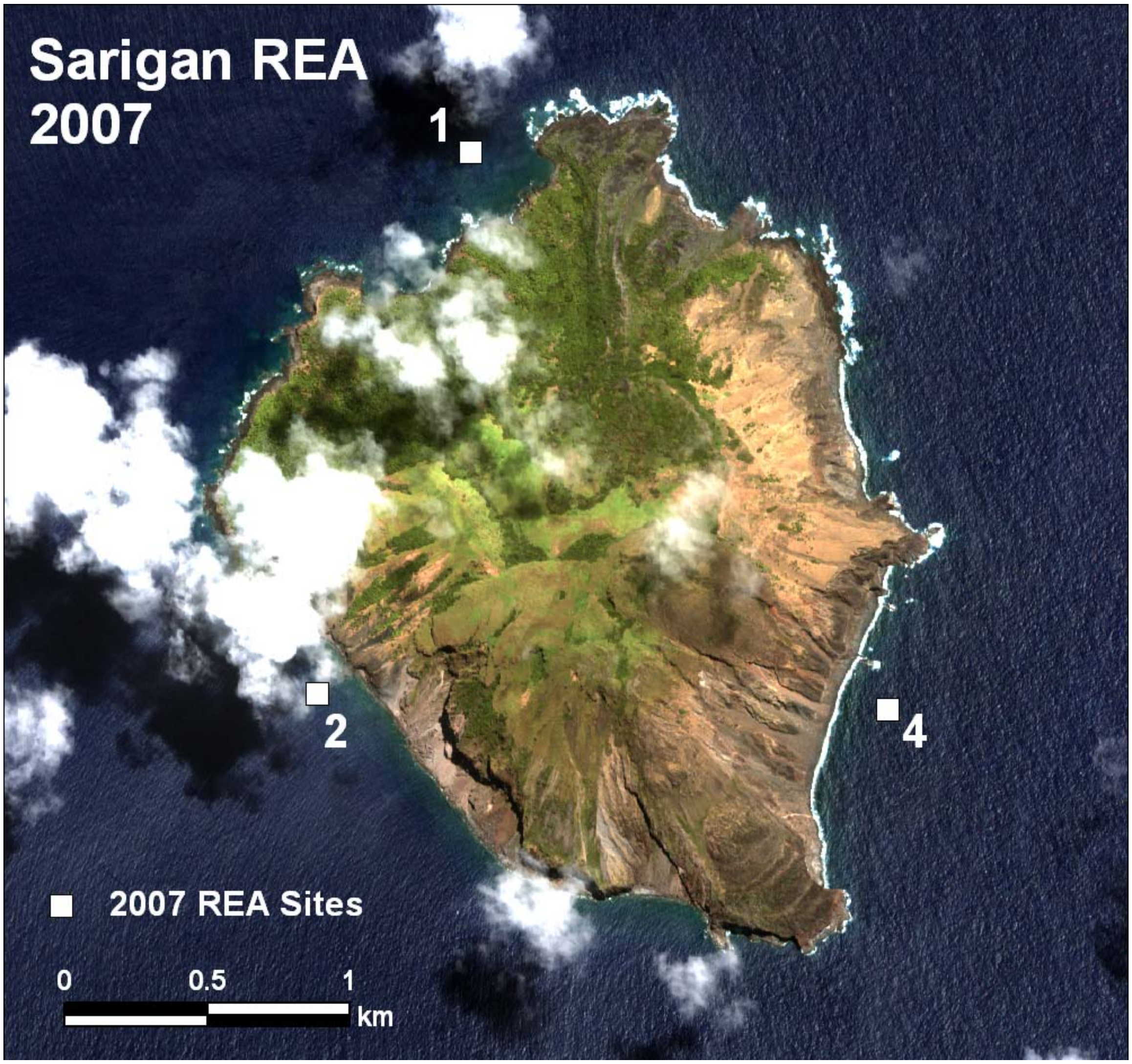


Figure C.3-1. Location of 2007 REA survey sites at Sarigan.

SAR-2

<u>May 26, 2007</u>

Western leeward side, transect depth range: 11–13 m. Aggregate relief; basalt boulders, rubble and sand. Best-developed patch reef of the three sites at Sarigan. Coral cover was more important than algal cover. Moderately high percent live coral cover (34.3%). Basalt boulders covered with turf-algae comprised over 29% and siliciclastic band represented nearly 12% of benthos. Within the survey area (250 m^2), one case of mild bleaching was observed on *Porites* sp. In addition, two specimens of *Acanthaster planci* were observed, but no feeding scars were noted in the survey area. As in most sites *Halimeda* spp. are key elements of the algal communities. Small tufts of *Boodlea vanbosseae* were significantly present amongst small coral colonies and on rocks covered with sediment. *Rhipiliopsis* was abundantly present on the shaded sides of larger rocks, together with *Halimeda hederacea*.

Sarigan

SAR-4

May 26, 2007

East windward side, transect depth range: 9–11 m. Basalt boulders and sand. Moderate percent live coral cover (18.6%). Basalt boulders covered with turf-algae comprised over 40% and siliciclastic sand represented nearly 30% of benthos. Within the survey area (300 m^2), eight cases of dark discolorations were observed on *Cyphastrea* and *Porites*. *Halimeda hederacea*, *Boodlea vanbosseae*, and *Caulerpa filicoides* cover the shaded sides of the boulders, but these macroalgae are less abundant than at SAR02 and SAR01. Crustose coralline algae, cyanobacteria and turf algae cover the upper side of the boulders.

SAR-1

May 26, 2007

North side, transect depth range: 10–13 m. This site has a similar geomorphology to SAR-4: large boulders on a bed of black volcanic sand. Coral communities are less developed compared than at SAR-2. Moderately low percent live coral cover (10.8%). Basalt boulders covered on turf-algae comprised nearly 50% of benthic cover. Within the survey area (350 m^2), five cases of sponge (*Terpios*) overgrowth were observed on *Porites*, *Astreopora*, *Turbinaria*, *Pavona*, and *Montipora*. Besides the omnipresent *Halimeda* species, *Boodlea vanbosseae* is very common. Here we also found a small, conspicuous *Anadyomene* sample. Crustose coralline algae, cyanobacteria and turf algae generally form a dense cover on the boulders. The black sand is devoid of algae.

C.4. Benthic environment

C.4.1. Algae

Algal species were surveyed and collected at three sites around Sarigan.

Table C.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table C.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table C.4.1-3. Specimens collected at Sarigan in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Turf algae (SAR04-004)	SAR04; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Cyanobacteria (SAR04-002)	SAR04; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Cyanobacteria (SAR04-003)	SAR04; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Florideophycidae epiphyte on hydroid (SAR04-001)	SAR04; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Wrangelia growing on Holimeda (SARXX-001)	SAR01; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Laurencia sp. (SAR02-007)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Corallinaceae crustose (SAR02-005)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26				X	
Corallinaceae crustose (SAR02-006)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26				X	
Halimeda lacunalis (SAR04-005)	SAR04; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X	X		
Halimeda sp. (SAR02-001)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X	X		
Halimeda sp. (SAR02-002)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X	X		
Halimeda sp. (SAR02-007)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X	X		
Halimeda sp. (SARXX-002)	SAR01; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X	X		
Anadyomene sp. (SAR01-001)	SAR01; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X	X		
Boodlea vanbosseae (SAR02-003)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X	X		
Boodlea vanbosseae (SAR02-004)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Boodlea vanbosseae (SAR02-007)	SAR02; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			
Boodlea vanbosseae (SAR04-001)	SAR04; Sarigan, CNMI, Mariana Islands; collection date: 2007_05_26		X			

C.4.1.2 Benthic towed-diver surveys – Macroalgae

The average macroalgae and coralline algae cover was recorded at 16% and 8% respectively (range 0.1 – 40% and 1.1 – 20%) The highest macroalgae cover was noted during a towed-diver survey along the western coastline (average 25%, range 5.1 – 40%), where a sizable patch of *Halimeda* occurred in segment 2, and an increase in *Asparagopsis* was observed during segment 7. Coralline algae cover was highest in the same area where the highest coral cover was recorded for Sarigan (south/southwestern forereef, dominated by boulders/boulder reef, continuous reef, and boulder patch reefs).

C.4.2. Corals

C.4.2.1 Coral Populations

Coral Diversity and Population Parameters

Three sites were visited on Sarigan Island (SAR-1, SAR-2, and SAR-4). Reef type varied at all three sites from boulders with little coral growth (SAR-4) to a large accreting framework (SAR-2). At SAR-4 the dominant, encrusting and massive corals were *Cyphastrea chalcidicum*, *Favia mathaii*, *Pavona varians*, and *Leptastrea purpurea* of small sizes but large population densities. Conversely, *Porites* and *Pocillopora* create the framework at the other two surveyed sites, which have increased in colony size and relative abundance from previous years' surveys. Common at all sites were juvenile *Pocillopora* corals; however adult colonies were only seen where favorable conditions exist.

C.4.2.2 Percent Benthic Cover

The line-intercept methodology quantified a total of 306 points along 150 m of forereef coral communities. Patterns of intra-island variability in percent benthic cover, derived from the 3 independent REA surveys are reflected in Figure C4.2.2-1. Mean percent live coral cover for all sites combined was moderate 21.1 ± 7.0% (mean ± SE). Highest coral cover was recoded at site SAR-2 (34.3%) on the north-facing shore; lower percent coral cover (10.8%) was encountered as sites SAR-1 on the eastern side of the island. Basalt boulders covered with turf-algae comprised over 39% and sand represented over 29% of the benthos. A total of 10 scleractinian genera and one hydrocoral were enumerated along the point-count transects, with *Porites* being the most numerically abundant scleractinian (28.5 ± 11.5%), followed by *Pocillopora* (22.8 ±.11.5%), and *Leptastrea* (17.4%). Figure C.4.2.2-2 illustrates the contribution of the different scleractinain genera to the total percent live coral cover.

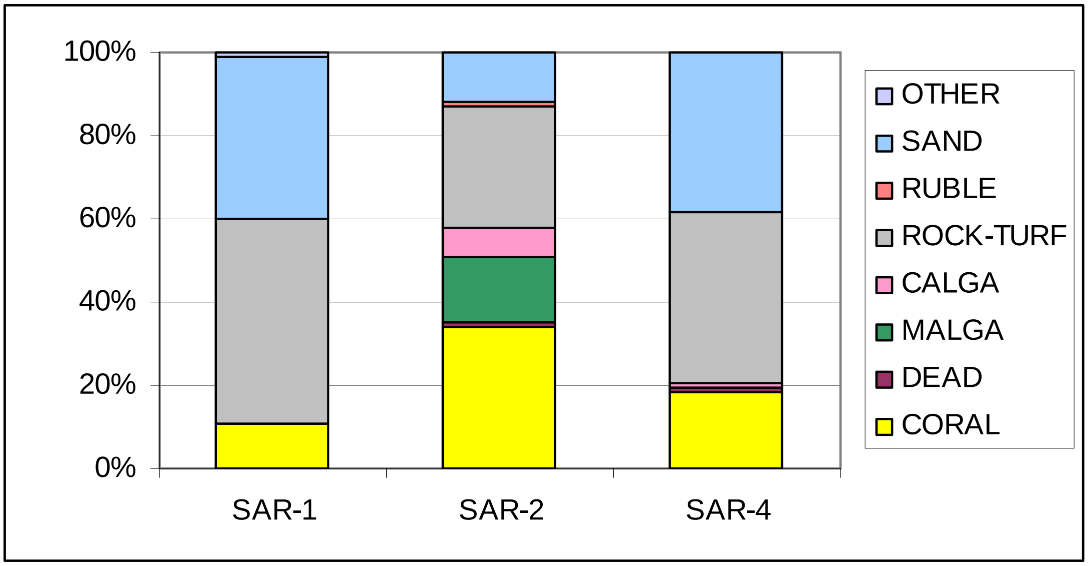


Figure C.4.2.2-1 Mean percent cover of selected benthic elements derived from 3 independent REA surveys at Sarigan, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; MALGA: fleshy macroalgae; CALGA: crustose coralline algae; ROCK-TURF: turfalgae-covered basalt boulders and platforms; RUBLE: coral rubble (including recent and old coral rubble covered with turf-algae); SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats.

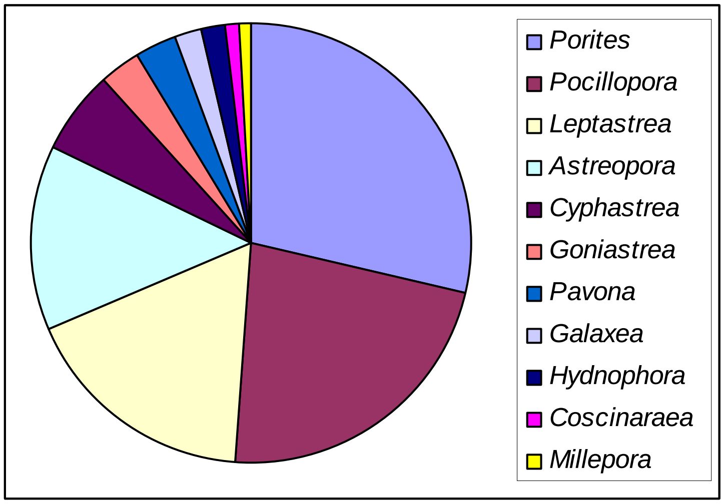


Figure C.4.2.2-2 Percent contribution of the different coral genera to the total live coral cover at Sarigan Island, MAR-RAMP 2007.

C.4.2.3 Coral Disease

The coral disease REA surveyed a total area of ~900 m^2 at 3 different sites. A summary of disease occurrence is presented in Table C.4.2.3-1. Overall occurrence of disease was low. A total of 14 cases were enumerated for all the survey areas combined. We observed one case of mild bleaching on *Porites*, 8 cases of patchy dark discolorations on *Cyphastrea* and *Porites*, and 5 cases of sponge (*Terpios*) overgrowth. No predation scars by *Acanthaster* were noted, although two individuals were observed at site SAR-2.

Table C.4.2.3-1 Cumulative number of cases of disease conditions enumerated at each survey site around Sarigan Island during the 2007 RAMP cruise. BLE: bleaching; DIS: dark discolorations; OTH: 'other lesions' sponge (*Terpios*) overgrowth. Total survey area ~900 m^2.

DZ/HS1	Species	SAR-1	SAR-2	SAR-4	Grand Total
BLE	*Porites*		1		1
DIS	*Cyphastrea*	5		1	6
	Porites		2		2
OTH	*Astreopora*			1	1
	Montipora			1	1
	Pavona duerdeni	1			1
	Porites			1	1
	Turbinara			1	1
Grand Total		**6**	**3**	**5**	**14**

C.4.2.4 Benthic towed-diver surveys – Corals

The average hard coral cover for Sarigan was recorded at 14% (range 1.1 – 40%), with stressed coral averaging 1% (range 0 – 10%). The highest overall coral cover recorded during a single towed-diver survey was noted in the south/southwest forereef area (average 17%, range 10.1 – 30%), where terrain consisted of big boulders/boulder reef on moderately sloped habitat, shifting to continuous reef and boulders in sand (boulder patch reef). Coral stress was highest during the towed-diver survey recorded completed in the east/southeast area of Sarigan (average 4%, range 0.1 – 10%). No COTs or other potential indicators of coral stressors were noted.

Several large *porites* (c.f. *rus*) colonies were noted at:

N16 41.747, E145 46.396
N16 41.781, E145 46.359
N16 41.817, E145 46.327
N16 41.839, E145 46.297
N16 42.006, 145 46.122 (Deep; outside transect).

Large porites colonies (c.f. *Lobata orLlutea*?) were also noted at N16 42.082, E145 46.039 and N16 43.00, E145 46.991.

Soft coral cover averaged 4% island-wide (range 1.1 – 20%), with the highest overall soft coral cover recorded during a survey in the west/southwestern region of the island (average 9%, range 5.1 – 20%). Large patches of *sarcophyton* were noted during the survey.

C.4.3 Macroinvertebrates

C.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

The overall macroinvertebrate averages per survey for the island of Sarigan were 2.9 sea urchins, 7.7 sea cucumbers, and 0.9 giant clams. No COTs were recorded. Sea urchin numbers were low for the entire island with the exception of ten minutes of survey time along the western side of the island where 37 individuals were counted per segment. No other urchins were recorded during surveys at Sarigan. Sea cucumbers were the most abundant macroinvertebrate recorded, especially along the west side where *Stichopus chloronutus* dominated the habitat. Giant clams were primarily observed along the west side of the island in the same pavement habitat as the majority of all macroinvertebrate recordings. Eighty percent of all recorded giant clams were from two surveys along the western coastline.

C.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Sarigan. The survey methods employed at each site and notable observations are summarized in Table C.4.3.2-1.

Table C.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Sarigan.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
SAR-2	X	X		
SAR-4	X	X		Coral encrusted pinnacles, boulders and volcanic sand. *Linkia multiflora* was present in notable abundance. Terpios sponge moderately abundant. No evidence of *Acanthaster planci*.
SAR-1	X	X		Transects at this site were laid across two habitat types. Transect 1 and 2 were in a sand and boulder habitat with sparse coral growth on boulders. Transect 3 was laid along the edge of a well-developed, *Porites rus*-dominated Holocene reef. This placement resulted in invertebrate belt transect 3 sampling a different habitat than 1 and 2. Quadrat surveys were only conducted within the boulder/sand habitat.

C.4.3.3 Opportunistic invertebrate collections

Acanthaster planci, *Linckia multiflora*, and *Holothuria atra* were not collected at Sarigan.

C.5. Fish

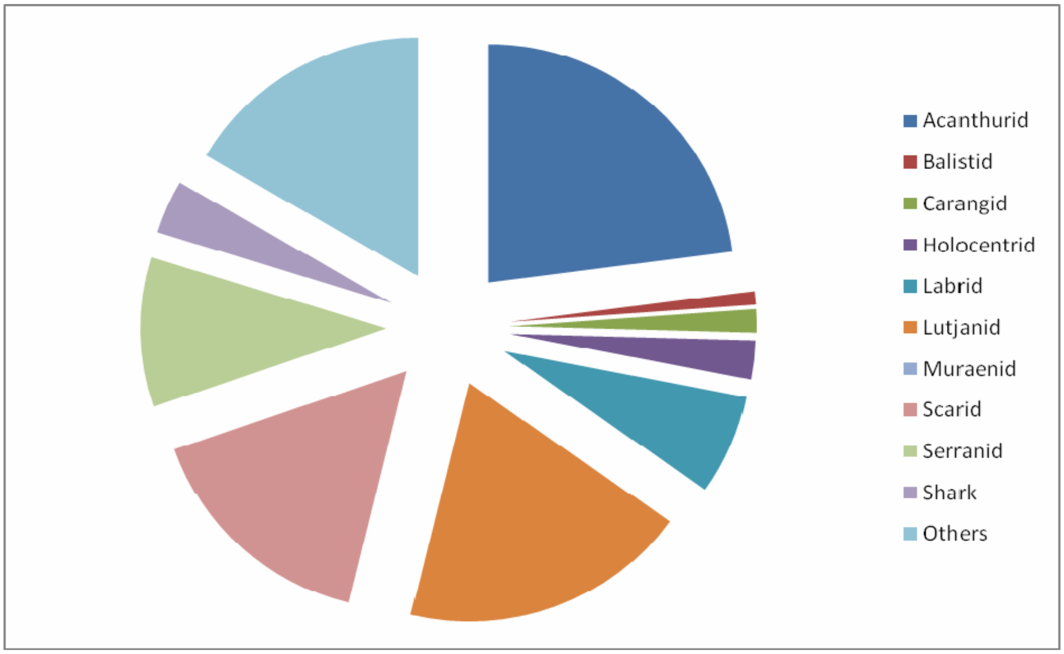
C.5.1 REA Fish Surveys

Stationary Point Count data
A total of 12 individual SPC surveys were conducted at 3 forereef sites around the island of Sarigan. Snappers (Lutjanidae) were the largest contributor to biomass with 0.09 ton per hectare. Parrotfishes (Scaridae) and surgeonfish (Acanthuridae) were nearly as common, each with a biomass of 0.07 ton per hectare.

Belt-Transect data
During the survey period, 9 belt-transect surveys were conducted at 3 forereef sites around the island of Sarigan. Surgeonfish (Acanthurids) and snapper (Lutjanidae) were the primary contributors to biomass with 0.09 and 0.08 ton per hectare respectively. (Fig. C.5.1-1).

Overall observations
A total of 126 species were observed during the survey period by all divers. The average medium to large fish biomass at the sites in Sarigan during the survey period was 0.31 ton/ha for the SPC surveys (Table C.5.1-1), and the average fish biomass was 0.40 ton/ha for the belt transect surveys (Table C.5.1-2).

Figure C.5.1-1 – Family composition of the total fish biomass (0.40 ton per hectare) around Sarigan Island.



Sarigan

Table C.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Sarigan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
SAR-1	0.10	0.01	0.00	0.01	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.01
SAR-2	0.50	0.13	0.00	0.00	0.01	0.03	0.11	0.13	0.02	0.04	0.00	0.03
SAR-4	0.31	0.06	0.00	0.03	0.00	0.00	0.13	0.04	0.00	0.01	0.00	0.03
Average	0.31	0.07	0.00	0.01	0.00	0.01	0.09	0.07	0.01	0.02	0.00	0.02

Table C.5.1-2 – Total fish biomass around Sarigan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
SAR-1	0.37	0.07	0.00	0.00	0.00	0.04	0.04	0.00	0.09	0.04	0.00	0.08
SAR-2	0.34	0.08	0.01	0.00	0.01	0.02	0.01	0.00	0.07	0.07	0.00	0.08
SAR-4	0.47	0.12	0.00	0.02	0.02	0.02	0.17	0.00	0.03	0.01	0.04	0.04
Average	0.40	0.09	0.00	0.01	0.01	0.03	0.08	0.00	0.06	0.04	0.01	0.07

C.5.2 Fish towed-diver surveys

At Sarigan the Towboard team conducted 6 tows totaling 12 kilometers in length and covering 12 hectares of ocean bottom. Mean survey length was 2.03 km and 152 fish (>50 cm TL, all species spooled) comprising 18 different species were observed. Overall numeric density was 12.66 fish per hectare. Bigeye trevally (*Caranx sexfasciatus*), twinspot snapper (*Lutjanus bohar*), gray reef sharks (*Carcharhinus amblyrhynchos*), bulbnose unicornfish (*Naso tonganus*) and sleek unicornfish (*Naso hexacanthus*) were the five most commonly observed species (>50 cm TL) at Sarigan (Table C.5.2-1).

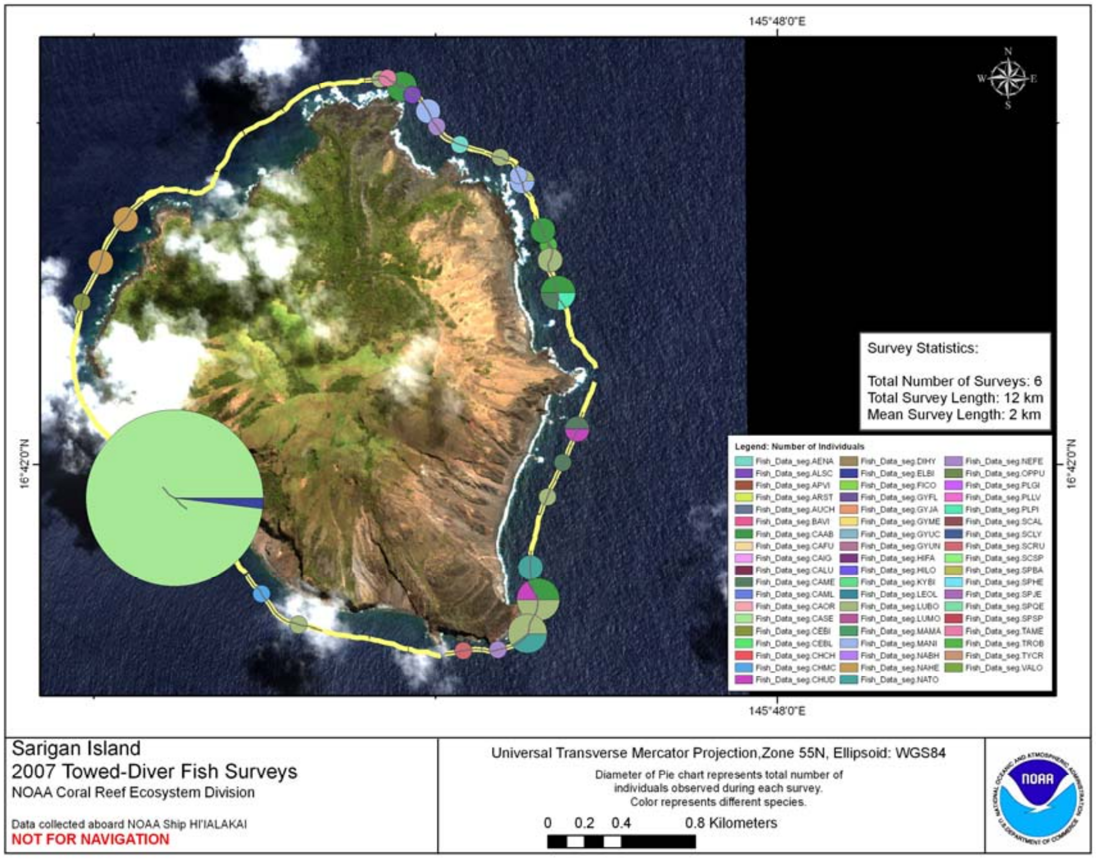


Figure C.5.2-1. Distribution of Large Fishes around Sarigan Island.

Table C.5.2-1. Number of individuals of each species observed at Sarigan.

Island	Taxon Name	#
Sarigan	Caranx sexfasciatus	100
	Lutjanus bohar	13
	Carcharhinus amblyrhynchos	9
	Naso tonganus	4
	Naso hexacanthus	4
	Caranx melampygus	4
	Macolor niger	4
	Nebrius ferrugineus	2
	Cheilinus undulatus	2
	Elagatis bipinnulata	2
	Triaenodon obesus	1
	Aluterus scriptus	1
	Centropyge bispinosa	1
	Aetobatus narinari	1
	Chlorurus microrhinos	1
	Plectorhinchus picus	1
	Scarus rubroviolaceus	1
	Taeniura meyeni	1
Sarigan Total		152

Appendix D: Zealandia Bank

D.1. Benthic Habitat Mapping

Zealandia Bank is located at ~16º 53'N, 145º 51'E and is approximately 25 nmi south of Guguan Island and 11 nmi north of Sarigan Island.   Its location on nautical chart 81004_1 corresponds to observations made during HI0703, although only a partial survey of the bank was completed.

Multibeam mapping surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars.   The ship transited to and worked at Zealandia from May 26-27, 2007 (JD 146-147), and the *AHI* was deployed on May 27, 2007.

The R/V *AHI* surveyed only a portion of Zealandia Bank in depths between 15 and 250 m. The mapped location corresponded with CRED dive surveys. The southern half of the charted banktop was crossed with only one swath and depths range from 100 to 200 m in that location. The second pinnacle shown to the south on the nautical chart was not surveyed.   Multibeam data were collected on the eastern side of the island chain during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the previous data were collected primarily to the west of the island chain.   The multibeam data collected around Zealandia Bank represents approximately 10% of the 2228 km^2 (roughly 225 km^2) of HI0703 coverage around the southern section of the Mariana Archipelago, which includes Alamagan, Guguan, and Sarigan Islands, Zealandia Bank, and a deeper area to the east of Sarigan Island. Anatahan is not included in this estimate of the multibeam coverage because only transit data were collected around the island of Anatahan.

Zealandia is classified as an extinct volcano by Bloomer *et al.* (1989). Seafloor surrounding the bank is incised by some deep canyons that terminate in ~1000 m of water, and some debris is present on the volcanic flanks. A seafloor high southeast of Zealandia Bank reaches depths of ~400 m and it is probably an extinct volcanic edifice built on the flank of Zealandia.

Reference:

Bloomer, S.H., Stern, R.J. and Smooth N.C. 1989. Physical volcanology of the submarine Mariana and Volcano Arcs. Bulletin of Volcanology, p. 210-224.

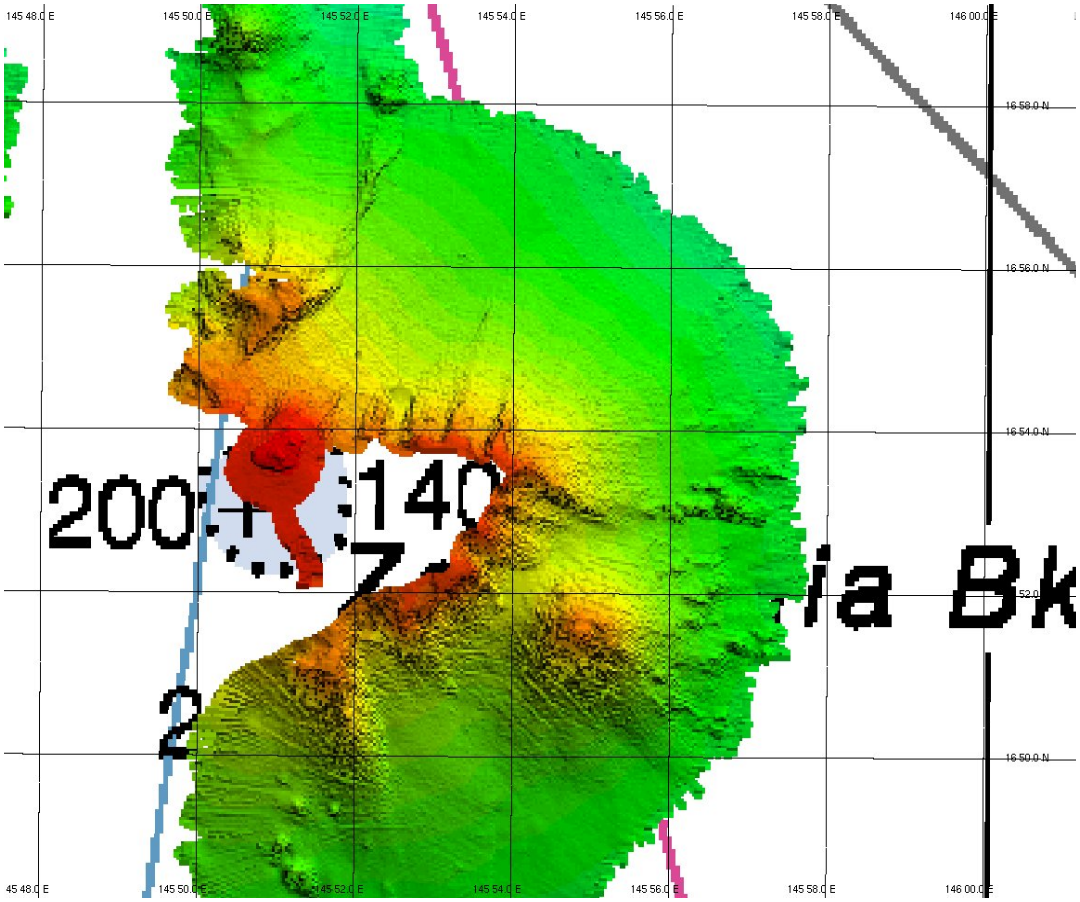


Figure D.1-1: Multibeam bathymetric data collected during HI0703 around Zealandia Bank.

D.2. Oceanography and Water Quality

In total, one instrument was recovered and two instruments were deployed at Zealandia during HI0703. One wave and tide recorder (WTR) was recovered and replaced at approximately 25 m depth. Additionally, one subsurface temperature recorder was deployed alongside the WTR.

Appendix E: Guguan

E.1. Benthic Habitat Mapping

Guguan Island is located at ~17º 18'N, 145º 50'E and is approximately 17 nmi south of Alamagen Island and 25 nmi north of Zealandia Bank.   Its location on nautical chart #81086_7 corresponds to observations made during HI0703.

Multibeam mapping surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars.   The ship transited to and worked at Guguan from June 7-8, 2007 (JD 158-159), and the AHI was deployed on June 8, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~15 m and 250 m, and the *Hi'ialakai* collected data down to about 2000 on the eastern side of the island and to 1000 m on the west side of the island. Multibeam data were collected on the eastern side of the island chain during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the previous data were collected primarily to the west of the island chain.   The multibeam data collected around Alamagan represents approximately 20% of the 2228 km^2 (roughly 450 km^2) of HI0703 coverage around the southern section of the Mariana Archipelago, which includes Alamagan, Guguan, and Sarigan Islands, Zealandia Bank, and a deeper area to the east of Sarigan Island. Anatahan is not included in this estimate of the multibeam coverage because only transit data were collected around the island.

Guguan is an active volcano that last erupted in 1886 (Trusdell, 2005). There is a shallow on the southern side of the island, and the edge of the shelf is irregularly shaped and incised by large canyons on the southwest. Shelf depths range from 25 to 65 m. The submarine flanks of Guguan are relatively smooth and only a few blocks of material were mapped on the southern side. Submarine channels are also present.

It is worth noting the presence of a small seafloor high ~11 km north of Guguan. The high was not charted and reaches a depth of ~1700 m. There appears to be features related to flank deformation at the base of the high.

Reference:

Trusdell, F.A., Moore, R.B., Sako, M., White, R.A., Koyanagi, S.K., Chong, R., and Camacho, J.T. 2005. The 2003 eruption of Anatahan volcano, Coomonwealth of the Northern Mariana Islans; Chronology, volcanology, and deformation. Journal of Volcanology and Geothermal Research, v. 146, p. 184-207.

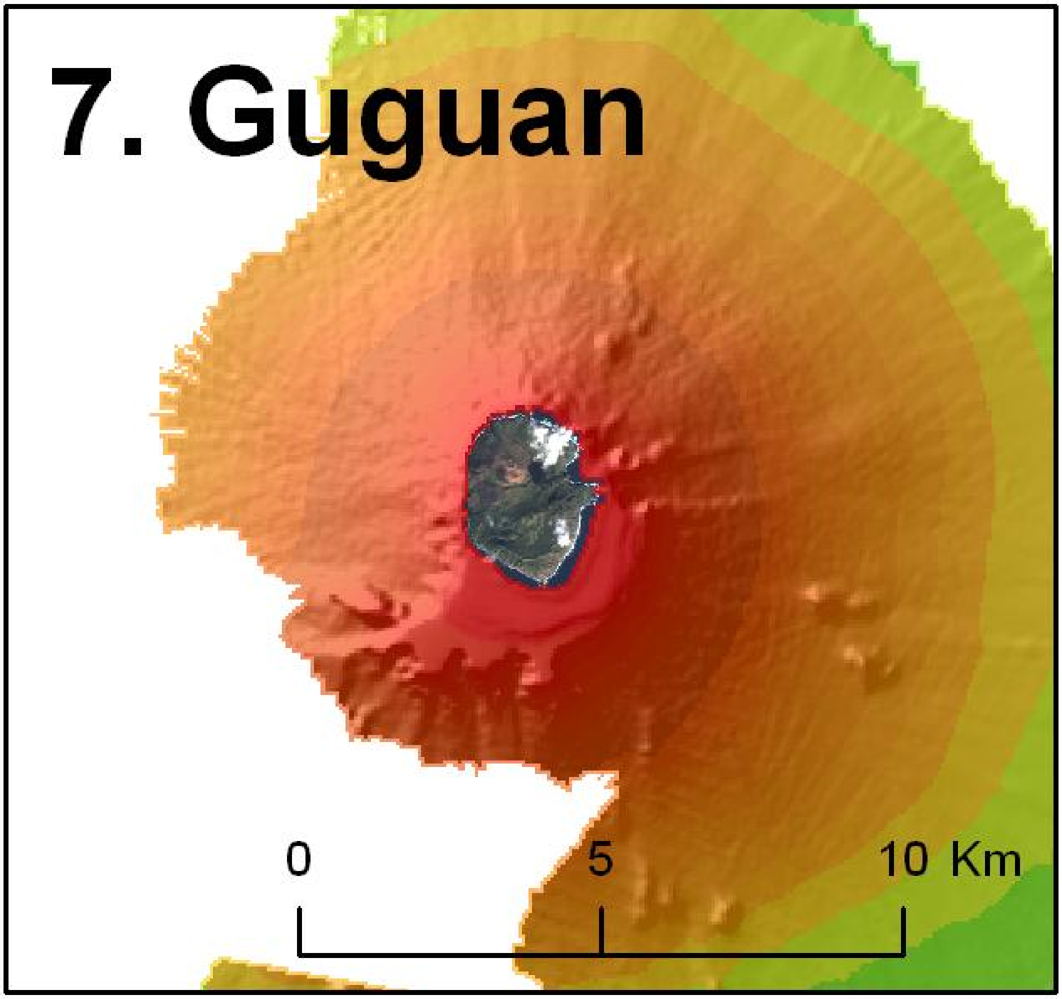


Figure E.1-1: Multibeam bathymetric data collected during HI0703 around Guguan Island.

E.2. Oceanography and Water Quality

In total, one subsurface temperature recorder (STR) was recovered and replaced at Guguan during HI0703. There was a problem with the recovered STR, however, and no data appears to have been recorded. (Figure F.5-1)

Nine shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter of Guguan at approximately 0.8 km intervals following the 30-m contour. At three of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depths, for a total of twenty-eight water samples measuring chlorophyll and nutrient concentrations. (Figure F.5-1).

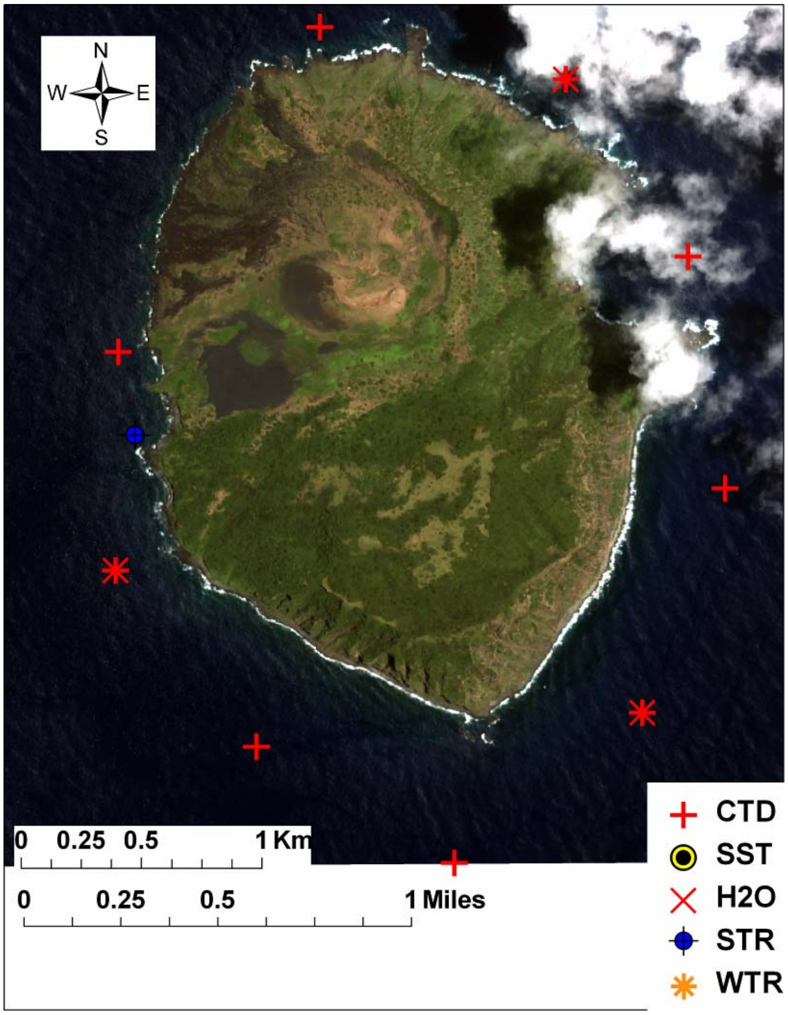


Figure F. 5-1: Positions of CTDs, water samples and moorings at Guguan.

E.3 Rapid Ecological Assessment (REA) Site Descriptions

Guguan is constitutionally designated as a terrestrial reserve; access is allowed through permit only. Legislation was drafted to include the waters surrounding the island out to 1 kilometer as a no-take marine protected area. A majority of the vessels able to reach this island focus mainly on bottomfishing. Minimal reef fishing activity occurs in the waters of this island.

REA surveys were conducted at three sites at Guguan (Table E.3-1). Locations of all REA sites around Guguan are shown in Fig. E.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table C.3-1. Sites surveyed by REA team at Sarigan, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.								
Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, ^{o}C
GUG-1	6/8/2007	17	18.360	145	51.102	13 - 15	17.7	28.9
GUG-2	6/8/2007	17	17.976	145	50.085	12 - 14	18.9	28.9
GUG-3	6/8/2007	17	19.008	145	49.930	14 - 18	18.9	28.9

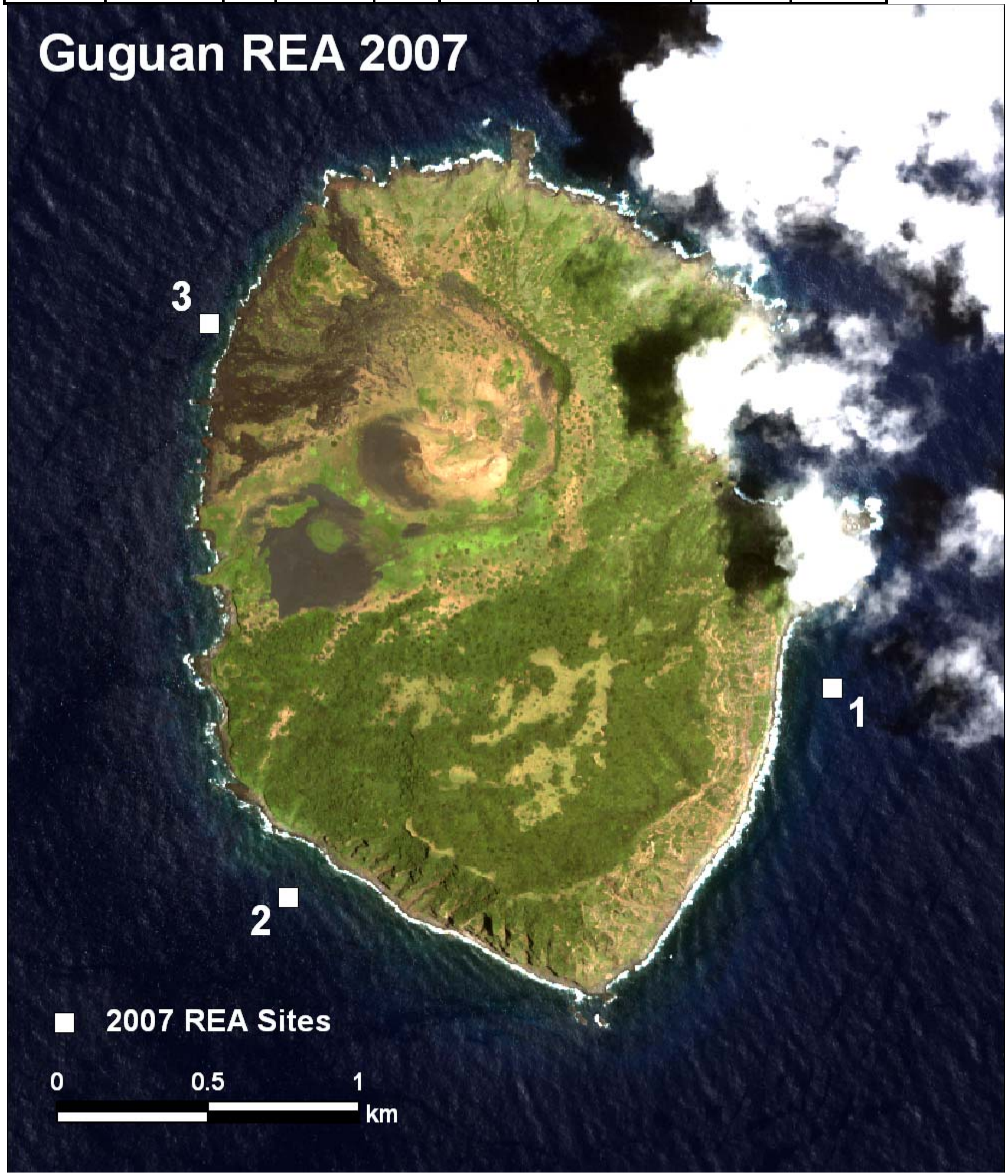


Figure E.3-1. Location of 2007 REA survey sites at Guguan.

Guguan

GUG-1

June 8, 2007

East windward side. Transect depth range: 13–15 m. Fringing coral buildups, following the benthic topography. Aggregate relief composed of carbonate spur-and-groove-like system, integrated into the main basalt boulder and sand topography. Moderate percent live coral cover (20.6%). Turf-algae over rock, carbonate pavement, and dead eroded coral comprised >53% of bottom cover. Important development of *Acropora* cf. *robusta* and *Acropora palifera* forming reef framework; diverse coral fauna; 25 different scleractinian genera were observed in the general area. No coral or coralline algal diseases were observed within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting Corallinaceae, encrusting *Peyssonnelia*, encrusting *Lobophora*, and *Halimeda*.

GUG-2

June 8, 2007

Southwest leeward side. Transect depth range: 12–14 m. Smooth undulating basalt platform traversed by sand gullies and pits. Low percent live coral cover (8.8%). Benthic community primarily composed of turf algae on carbonate and basalt surfaces, *Halimeda*, and scattered coral colonies. The coral assemblage was comprised of an amalgam of small-sized, highly fissoned colonies of *Pavona varians*, *Astreopora* sp., *Montipora* sp., and *Favia stelligera*. The coral community at this site was less diverse than at the previous site. No coral or coralline algal diseases were observed within the survey area (300 m^2). One case of coralline algal disease (CLOD) detected outside the survey area. The dominant algal categories (up to a rank average of 4) on this site were turf algae, *Halimeda*, *Tolypiocladia*, Cyanobacteria, encrusting Corallinaceae, and *Jania*.

GUG-3

June 8, 2007

Northwest leeward side. Transect depth range: 14–18 m. Fringing coral buildups, following the benthic topography. Aggregate relief composed of carbonate spur-and-groove-like system, integrated into the main basalt boulder and sand topography. Moderately low percent live coral cover (15.4%). Benthic community primarily dominated by turf algae growing on the carbonate and basalt surfaces; which amounted to > 62% or the benthic cover. The coral assemblage was comprised primarily of an amalgam of *Porites*, *Pocillopora*, *Goniastrea*, *Goniopora* and *Pavona varians*. One case of coralline algal disease (CLOD) was observed within the survey area (150 m^2; only one transect accomplished due to diver recall); no coral diseases were detected. However, 8 cases of encrusting sponge (*Terpios*) overgrowth on corals were noted. The dominant algal categories (up to a rank average of 4) on this site were encrusting Corallinaceae, turf algae, encrusting Lobophora, Cyanobacteria, and Jania.

E.4. Benthic environment

E.4.1. Algae

Algal species were surveyed and collected at three sites around Guguan.

Table E.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table E.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table E.4.1-3. Specimens collected at Guguan in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Portieria hornemannii (GUG01-002)	GUG01; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08		X	X		X
Peyssonnelia sp. (GUG02-001)	GUG02; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08				X	
Dichotomaria marginata (GUG01-003)	GUG01; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08		X	X		
Lobophora sp. (GUG02-001)	GUG02; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08				X	
Bryopsis sp. (GUG03-001)	GUG03; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08		X			
Caulerpa nummularia (GUG01-004)	GUG01; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08		X	X		
Caulerpa webbiana (GUG03-001)	GUG03; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08		X	X		
Halimeda lacunalis (GUG01-001)	GUG01; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08		X	X		
Halimeda lacunalis (GUG02-002)	GUG02; Guguan, CNMI, Mariana Islands; collection date: 2007_06_08		X	X		

E.4.1.2 Benthic towed-diver surveys – Macroalgae

Macroalgae and coralline algae cover at Guguan averaged 20% and 13% (range 5.1 - 40% and 1.1 - 30%, respectively). The highest macroalgae cover was recorded during a survey along the east/southeastern coastline (average 23, range 10.1 - 40%). The terrain consisted of sparse patch reef in sand, which progressed to solid reef with a light slope. During segment seven, the terrain switched to high-relief spur and groove. *Asparagopsis* was noted within the survey. The highest coralline algae cover (average 19%, range 5.1 – 30%) was recorded during the survey along the northwestern/northeastern coastline.

E.4.2. Corals

E.4.2.1 Coral Populations

Coral Diversity and Population Parameters

Three sites were visited on Guguan Island (GUG-1, GUG-2, and GUG-3). Coral dominated reefs were only present at GUG-1, where *Acropora abrotanoides*, *Acropora danae*, *Acropora palifera*, *Favia stelligera*, and *Pavona duerdini* were found. Overall colony sizes were larger than previous survey at this site, suggesting recovery from the 2000/01 bleaching event and a documented *Acanthaster planci* outbreak in 2003/4. The other two sites had limited coral growth consisting mainly of small encrusting and massive corals at high population densities. Common at GUG-2 and 3 were juvenile *Pocillopora* corals; however, adult colonies were rarely encountered during the coral surveys.

E.4.2.2 Percent Benthic Cover

Patterns of intra-island variability in percent benthic cover, derived from the 3 independent REA surveys in 2007, are reflected in FigureE.4.2.2-1. Sites GUG-1 and -3 consisted of fringing coral buildups, following the benthic topography, forming a quasi-spur and grove system, integrated into the main basalt boulder and sand topography. At these sites, percent live coral cover was moderate (16-20%), with turf algae growing over rock, carbonate pavement, and dead eroded coral comprised >50-65% of bottom cover. Site GUG-1 exhibited important development of *Acropora* cf. *robusta* and *Acropora palifera* contributing to the reef framework formation. Conversely, site GUG-2 was characterized by a smooth undulating basalt topography traversed by sand gullies and pits. GUG-2 exhibited low percent live coral cover (8.8%), and the benthic community was primarily composed of turf algae on carbonate and basalt surfaces, *Halimeda*, and scattered coral colonies. The coral assemblage at this site consisted of an amalgam of small-sized, highly fissoned colonies of *Pavona varians*, *Astreopora* sp., *Montipora* sp., and *Favia stelligera*.

The point-count surveys indicated that percent live coral cover was the greatest at site GUG-1 where it attained a value of 20.6%. Mean percent live coral cover for the three sites surveyed amounted to 15.7 ± 3.4%. Additionally, a total of 12 scleractinian genera and one stony octocoral (*Heliopora*) were enumerated along the point-count transects, with *Goniopora* being the most numerically abundant scleractinian (19.4 ± 8.0%), followed by *Favia* (18.7 ± 7.4%), *Porites* (11.5 ± 6.9%), and *Pocillopora* (11.2 ± 3.7%). Figure E.4.2.2-2 illustrates the contribution of the different stony coral genera to the total percent live coral cover. Outside the survey transect lines, however a total of 30 different scleractinian genera, one hydrocoral and one octocoral were enumerated (see Table E.4.2.2-1)

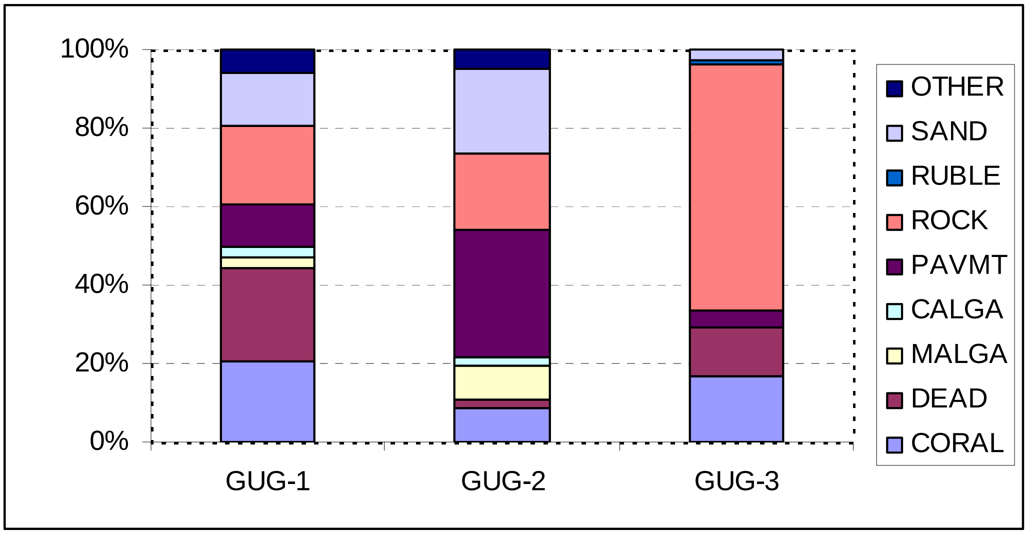


Figure E.4.2.2-1 Mean percent cover of selected benthic elements derived from 3 independent REA surveys at Guguan, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; MALGA: macroalgae; CALGA: calcareous coralline and red algae; PAVMT: carbonate pavement covered with turf algae; ROCK: turf-algae covered basalt boulders; RUBLE: coral rubble; SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats.

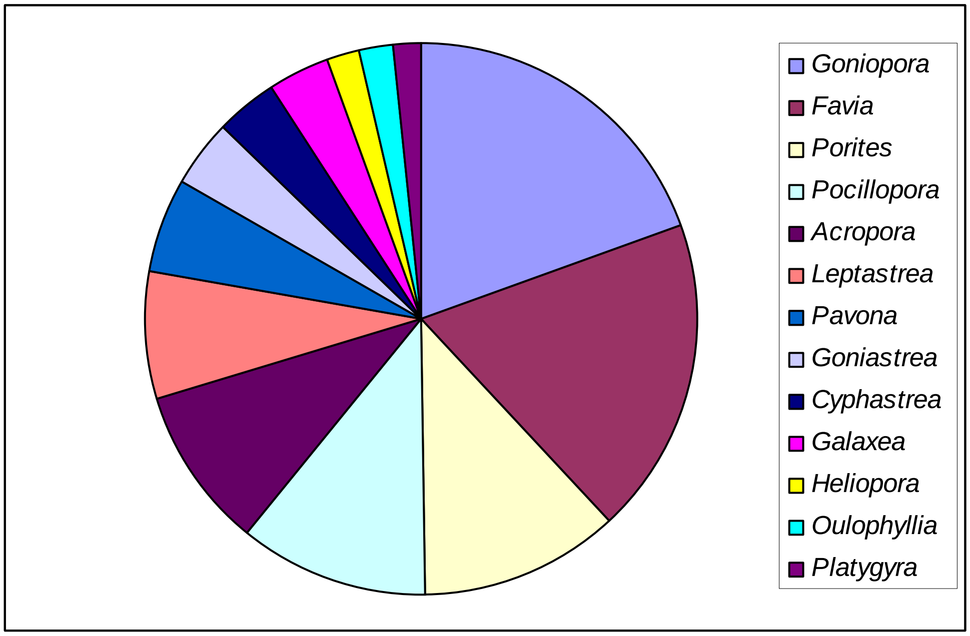


Figure E.4.2.2-2 Percent contribution of the different coral genera to the total live coral cover at Guguan, MAR-RAMP 2007.

Table E.4.2.2-1 list scleractinian, hydrocoral, and stony octocoral genera enumerated at Guguan Island during the 2007 REA surveys.		
Acanthastrea	*Goniastrea*	*Oulophyllia*
Acropora	*Goniopora*	*Pavona*
Astreopora	*Hydnophora*	*Platygyra*
Coscinaraea	*Leptastrea*	*Plesiastrea*
Echinopora	*Leptoria*	*Pocillopora*
Favia	*Leptoseris*	*Porites*
Favites	*Lobophyllia*	*Psammocora*
Fungia	*Millepora*	*Scapophyllia*
Galaxea	*Montastrea*	*Stylocoeniella*
Gardineroseris	*Montipora*	*Turbinaria*

E.4.2.3 Coral Disease

The coral disease REAs surveyed a total area of ~700 m^2 at 3 different sites around Guguan. Overall occurrence of disease was low. Sites GUG-1 and -2 exhibited absence of coral or coralline algal diseases within the survey area (300 m^2, respectively); one case of coralline algal disease (CLOD) was detected outside the survey area at site GUG-2. At REA site GUG-3, one case of coralline algal disease (CLOD) was observed within the survey area (150 m^2; only one transect accomplished due to diver recall); no coral diseases were detected. However, 8 cases of encrusting sponge (*Terpios*) overgrowth on corals were noted.

E.4.2.4 Benthic towed-diver surveys – Corals

The average hard coral cover for Guguan was recorded at 27% (range 5.1 - 75%), with stressed coral averaging <1% (range 0 - 5%). The highest overall coral cover recorded during a single towed-diver survey was noted in the northwestern/northeastern coastline, with an average of 42% coral cover (range 20.1 - 75%). Terrain consisted of medium relief spur and groove and switched to high-relief spur and groove in segment three. This terrain continued throughout the remainder of the survey with the exception of some pavement flats encountered in segment 6. Large populations of *porites rus* were encountered from segment seven and on, with segment 7 recording 62.6 – 75% coral cover.

The average soft coral cover for Guguan was recorded at 6% (range 0 – 30%). The highest soft coral cover recorded during a single towed-diver survey (average 11%, range 1.1 – 30%) occurred along the south/southwestern coastline. The terrain initially consisted of sparse patch reef in sand, eventually leading to solid reef with a light slope. During segment seven, the terrain switched to high-relief spur and groove which remained for the rest of the survey. *Sinularia* and *sarcophyton* were prevalent in several areas (segment 1; segment 4 – 6).

E.4.3 Macroinvertebrates

E.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

The overall macroinvertebrate averages per survey for the island of Guguan were 69.6 sea urchins, 1.0 sea cucumbers, and 2.8 giant clams. Sea urchins were most abundant on the eastern side of the island where an average of 248.2 individuals per segment were recorded along the continuous reef. Urchin populations numbered around 45 individuals per segment along the northern coastline. Sea cucumber numbers were low around the entire island. The spur-and-groove habitat of the west side hosted the majority recorded with an average of 3.1 per time segment, while the remaining coastline all had fewer than 1 individual per segment. Giant clams were abundant along the southwest and west sides of the Guguan. The predominant habitat was high-relief spur and groove with the majority of clams occurring along the top of the ridges (spurs). Clams averaged 8.1 individuals per segment on the third survey of the day and numbers reached as high as 37 for one time segment. No COTs were observed for Guguan.

E.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Guguan. The survey methods employed at each site and notable observations are summarized in Table E.4.3.2-1.

Table E.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Guguan.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
GUG-1	X	X	X	Boulder sand, nearshore. Pavement groove 20-40 ft. At 40 ft. rich coral community begins. *Acanthaster* under *A. robusta* colonies. Good diversity of large sponges. *Linkia guildingi*. Dolphins present.
GUG-2	X	X	X	Gradually sloping reef, with boulder filled patches. *Linkia guildingi* present. Good fish diversity.
GUG-3	X	X	X	Steep slope, volcanic boulders. Good potential for inverts, decent sponge diversity. Quads interrupted due to diver recall.

E.4.3.3 Opportunistic invertebrate collections

Acanthaster planci, *Linckia multiflora*, and *Holothuria atra* were not collected at Guguan.

E.5. Fish

E.5.1 REA Fish Surveys

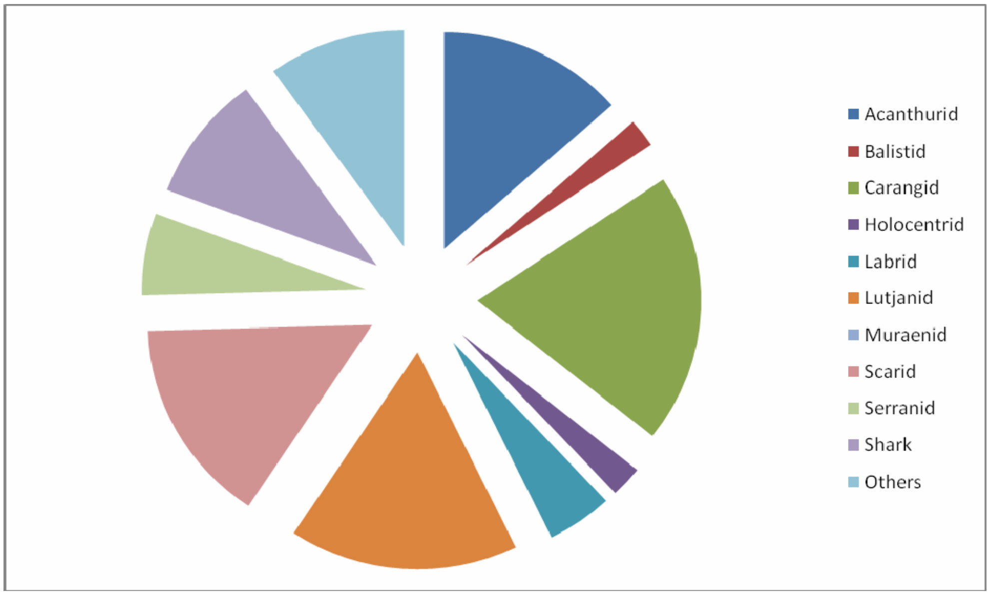
Stationary Point Count data
A total of 12 individual SPC surveys were conducted at 3 forereef sites around the island of Guguan. Parrotfishes (Scaridae) were the largest contributor to biomass with 0.09 ton per hectare. Surgeonfish (Acanthuridae) and snappers (Lutjanidae) were also commonly observed during the SPCs yielding biomass of 0.08 and 0.06 ton per hectare, respectively.

Belt-Transect data
During the survey period, 9 belt-transect surveys were conducted at 3 forereef sites around the island of Guguan. Jacks (Carangidae) and snappers (Lutjanidae) were the primary contributors to biomass with 0.15 and 0.13 ton per hectare, respectively. (Fig. E.5.1-1).

Overall observations
A total of 135 species were observed during the survey period by all divers. The average medium to large fish biomass at the sites in Guguan during the survey period was

0.38 ton/ha for the SPC surveys (Table E.5.1-1) and the average fish biomass was 0.77 ton/ha for the belt transect surveys (Table E.5.1-2).

Figure E.5.1-1 – Family composition of the total fish biomass (0.77 ton per hectare) around Guguan Island.



Guguan

Table E.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Guguan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
GUG-1	0.59	0.16	0.00	0.06	0.02	0.01	0.12	0.15	0.00	0.02	0.02	0.02
GUG-2	0.33	0.05	0.00	0.01	0.02	0.02	0.05	0.04	0.00	0.05	0.08	0.02
GUG-3	0.21	0.02	0.00	0.02	0.01	0.00	0.02	0.07	0.00	0.03	0.00	0.04
Average	0.38	0.08	0.00	0.03	0.02	0.01	0.06	0.09	0.00	0.04	0.03	0.03

Table E.5.1-2 – Total fish biomass around Guguan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
GUG-1	0.46	0.12	0.00	0.00	0.01	0.04	0.04	0.00	0.16	0.05	0.00	0.03
GUG-2	0.81	0.09	0.02	0.06	0.03	0.05	0.32	0.00	0.09	0.06	0.00	0.09
GUG-3	1.04	0.10	0.03	0.40	0.01	0.02	0.02	0.00	0.09	0.03	0.22	0.11
Average	0.77	0.10	0.02	0.15	0.02	0.04	0.13	0.00	0.12	0.05	0.07	0.08

E.5.2 Fish towed-diver surveys

At Guguan the Towboard team conducted 5 surveys totaling 10 kilometers in length and covering 10 hectares of ocean bottom. Mean survey length was 2.1 km. Sixty-four fish (>50 cm TL, all species spooled) were observed totaling 15 different species. Overall numeric density was 6.4 fish per hectare. Black and white snappers (*Macolor niger*), rainbow runners (*Elagatis bipinnulata*), redlip parrotfish (*Scarus rubroviolaceus*), whitetip reef sharks (*Triaenodon obesus*) and gray reef sharks (*Carcharhinus amblyrhynchos*) were the five most commonly observed species (>50 cm TL) at Guguan during the survey period.

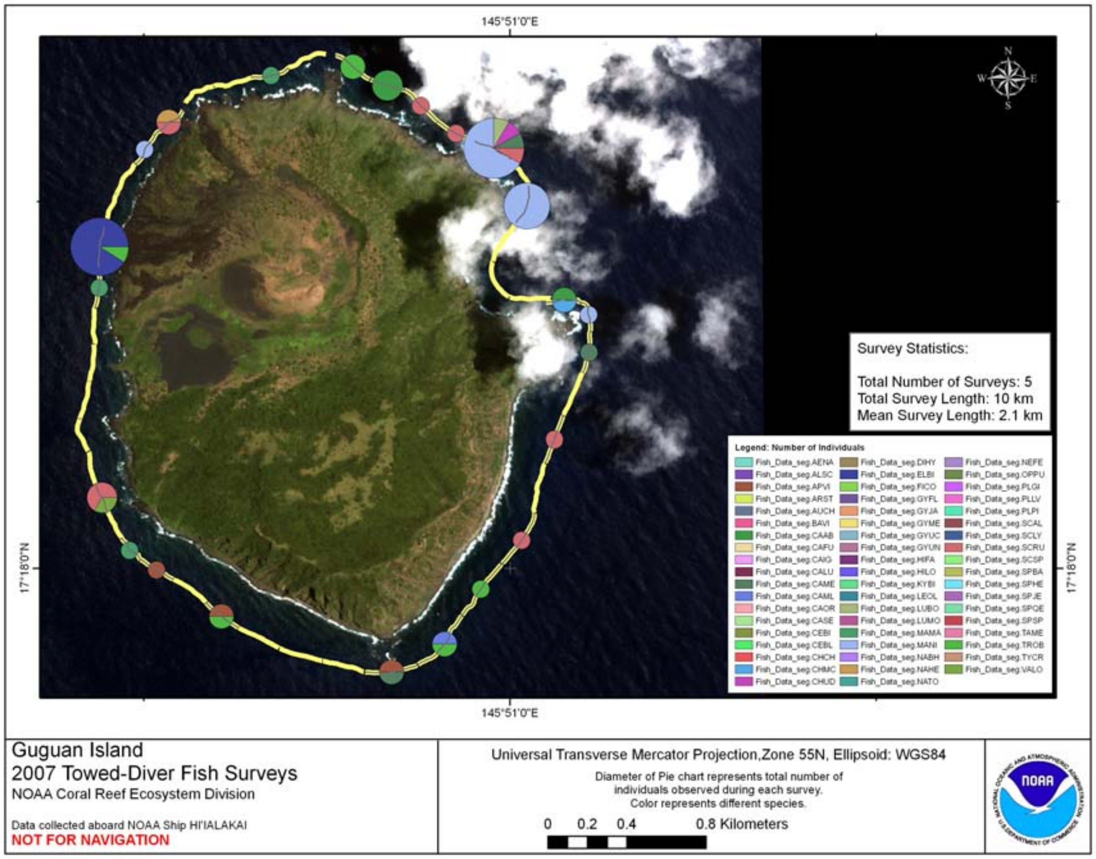


Figure E.5.2-1. Distribution of Large Fish Observations at Guguan.

Guguan

Table E.5.2-1. Total number of individuals of each species observed at Guguan.

Island	Taxon Name	#
Guguan	Macolor niger	17
	Elagatis bipinnulata	10
	Scarus rubroviolaceus	8
	Triaenodon obesus	6
	Carcharhinus amblyrhynchos	4
	Caranx melampygus	3
	Naso hexacanthus	3
	Aprion virescens	3
	Macolor macularis	3
	Lutjanus bohar	2
	Variola louti	1
	Caranx ignobilis	1
	Chlorurus microrhinos	1
	Cheilinus undulatus	1
	Carcharhinus melanopterus	1
Guguan Total		64

Appendix F: Alamagan

F.1. Benthic Habitat Mapping

Alamagan Island is located at ~17º 36'N, 145º 49'E and is approximately 31 nmi south of Pagan Island and 17 nmi north of Guguan Island.   Its location on nautical chart 81086_6 corresponds to observations made during HI0703.

Multibeam mapping surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars. The ship transited to and worked at Alamagan from May 27-28, 2007 (JD 147-148), and the *AHI* was deployed on May 28, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~15 m and 250 m, and the *Hi'ialakai* collected data down to about 2300 on the eastern side of the island and to 1000 m on the west side of the island. Multibeam data were collected on the eastern side of the island chain during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the previous data were collected primarily to the west of the island chain.   The multibeam data collected around Alamagan represents approximately 20% of the 2228 km^2 (roughly 450 km^2) of HI0703 coverage around the southern section of the Mariana Archipelago, which includes Alamagan, Guguan, and Sarigan Islands, Zealandia Bank, and a deeper area to the east of Sarigan Island. Anatahan is not included in this estimate of the multibeam coverage because only transit data were collected around the island.

Alamagan was classified as a dormant volcano by Bloomer *et al.* (1989). There is a small shallow shelf on the southeastern side of the island and a larger, irregularly shaped shelf on the southwestern side, both with depths of 25-50 m. Blocky material litter the seafloor surrounding the volcano and a number of seafloor highs surrounding the volcano are likely volcanic in origin. These include a broad platform that reaches depths of 750 m north of Alamagan and a smaller bathymetric high between the platform and Alamagan.

Reference:

Bloomer, S.H., Stern, R.J. and Smooth N.C. 1989. Physical volcanology of the submarine Mariana and Volcano Arcs. Bulletin of Volcanology, p. 210-224.

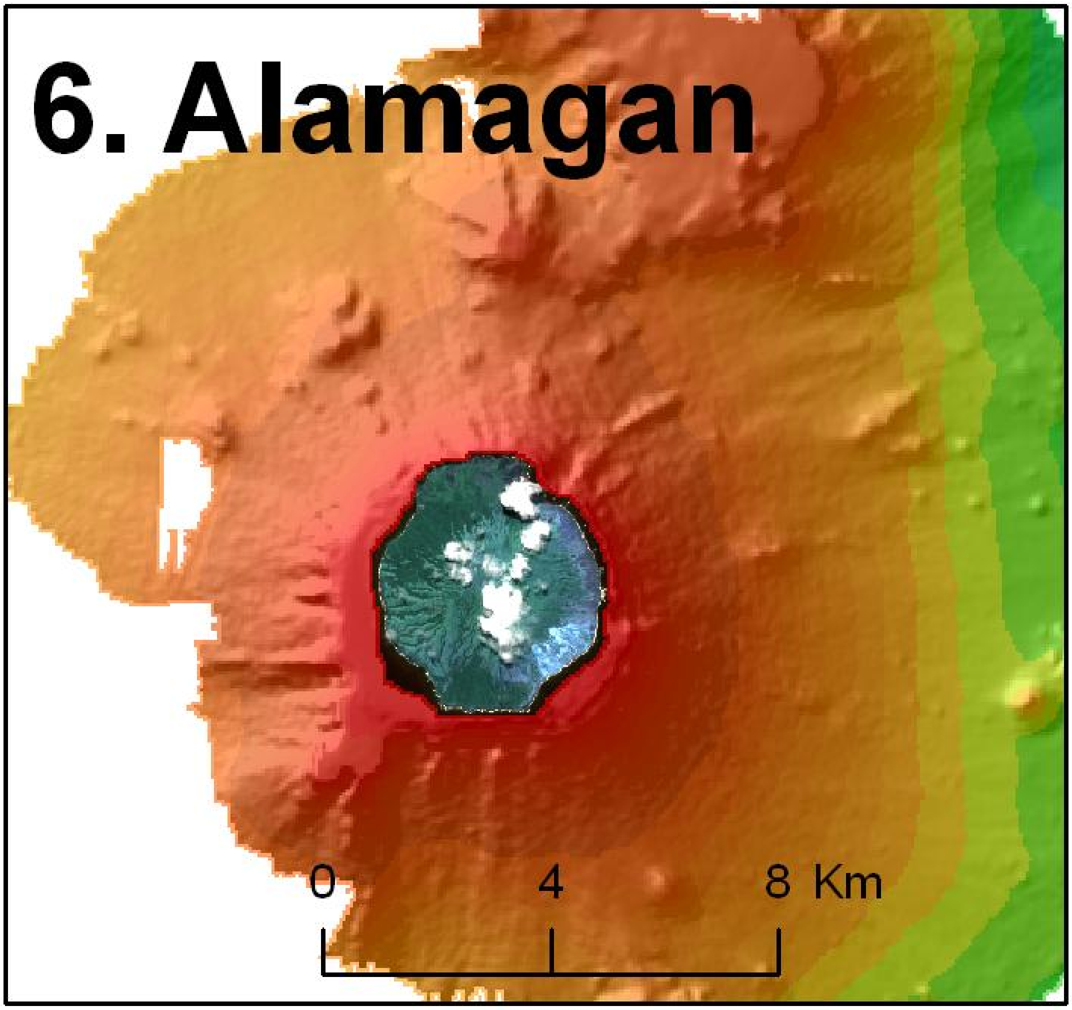


Figure F.1-1: Multibeam bathymetric data collected during HI0703 around Alamagan Island.

F.2. Oceanography and Water Quality

In total, one instrument was recovered and two instruments were deployed at Alamagan during HI0703. One subsurface temperature recorder (STR) was recovered and replaced at approximately 7 m depth, and a new STR was deployed near REA site 1 at approximately 16 m depth. (Figure F.2-1)

Sixteen shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter of Alamagan at approximately 0.8 km intervals following the 30-m contour. At four of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depths, for a total of 32 discrete water samples measuring chlorophyll and nutrient concentrations. (Figure F.2-1).

In situ temperature data at 6.7 m obtained from October 2005 to June 2007 shows seasonal variability with warm temperatures observed from June to November and cooler temperatures from January to April (Figure F.2-2). Temperature changes of greater than 1 °C on intraseasonal time scales (e.g., April-May, 2006) are common, with a particular significant change occurring in September 2006 when temperature increased 2 °C in approximately 7 days.

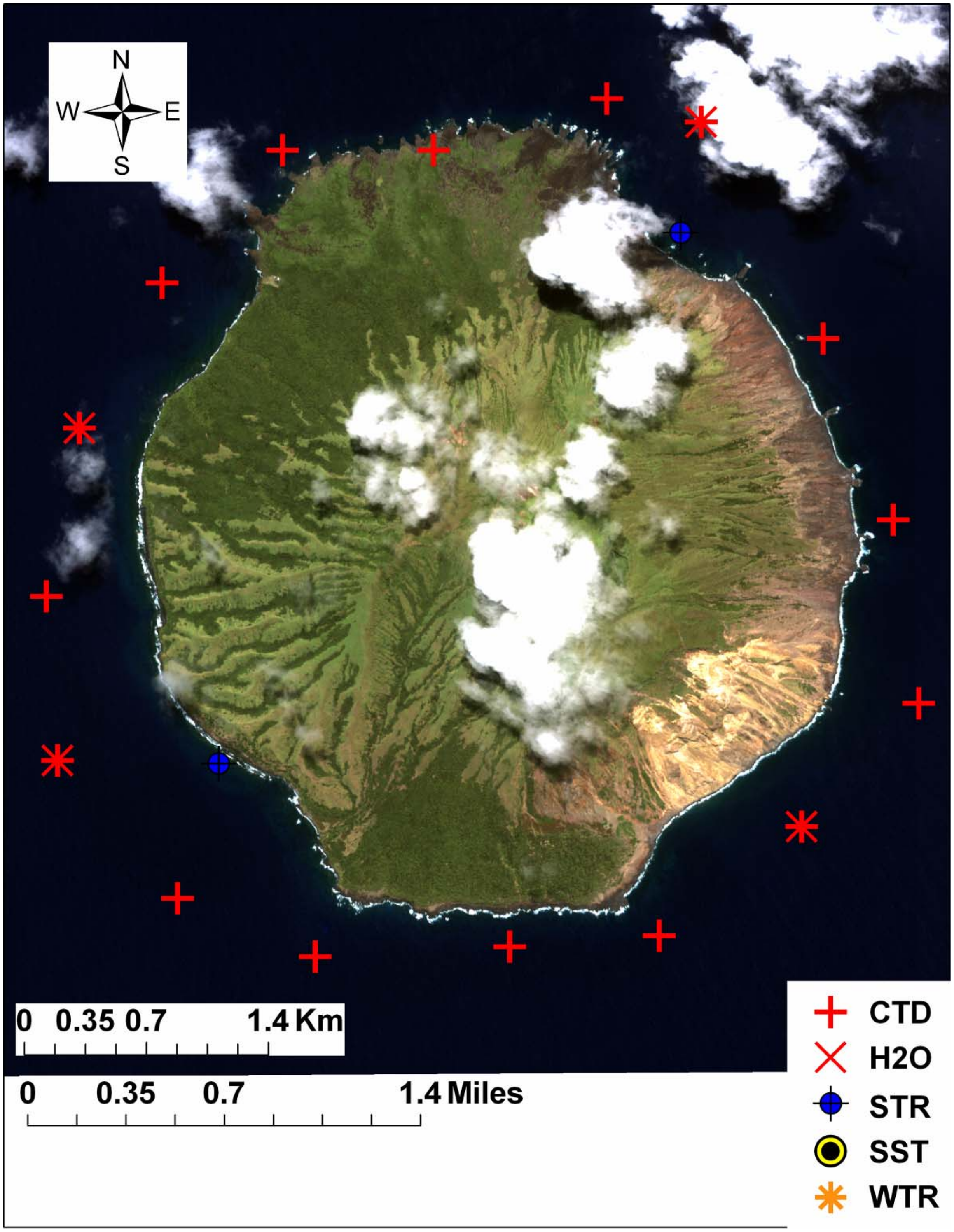


Figure F.2-1: Positions of CTDs, water samples and moorings at Alamagan.

Alamagan

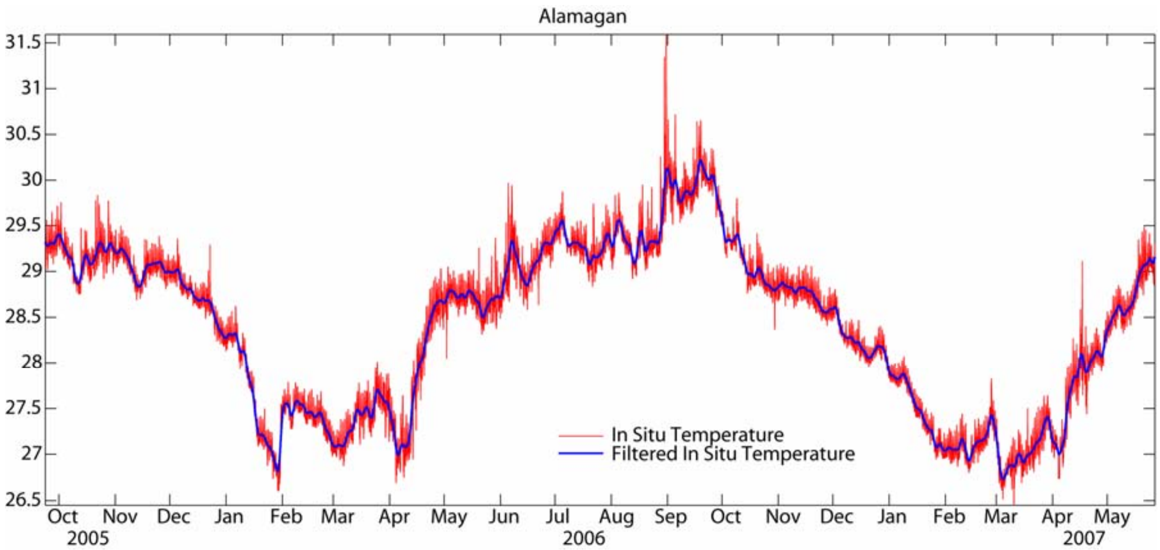


Figure F.2-2: *In situ* temperature at 6.7 m from October 2005 to June 2007. The red line is data sampled at a 30-minute interval; the blue line is a weekly mean.

F.3 Rapid Ecological Assessment (REA) Site Descriptions

A remote fishing station is established on Alamagan. Fishing activities, however, are sporadic. Approximately four to six people live on this island. The Northern Island Mayors Office (NIMO) contracts a private vessel to transport supplies and people to this island on an as needed basis. Spearfishing and bottomfishing are the common fishing activities during these trips. Privately owned vessels also frequent this island.

REA surveys were conducted at three sites at Alamagan (Table F.3-1). Locations of all REA sites around Alamagan are shown in Figure F.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table C.3-1. Sites surveyed by REA team at Sarigan, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.

Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, °C
ALA-2	5/28/2007	17	36.476	145	48.894	12 - 13	15.2	28.9
ALA-1	5/28/2007	17	36.887	145	50.553	13 - 14	15.2	28.9
ALA-3	5/28/2007	17	35.247	145	49.072	14 - 16	18.3	28.9

Alamagan

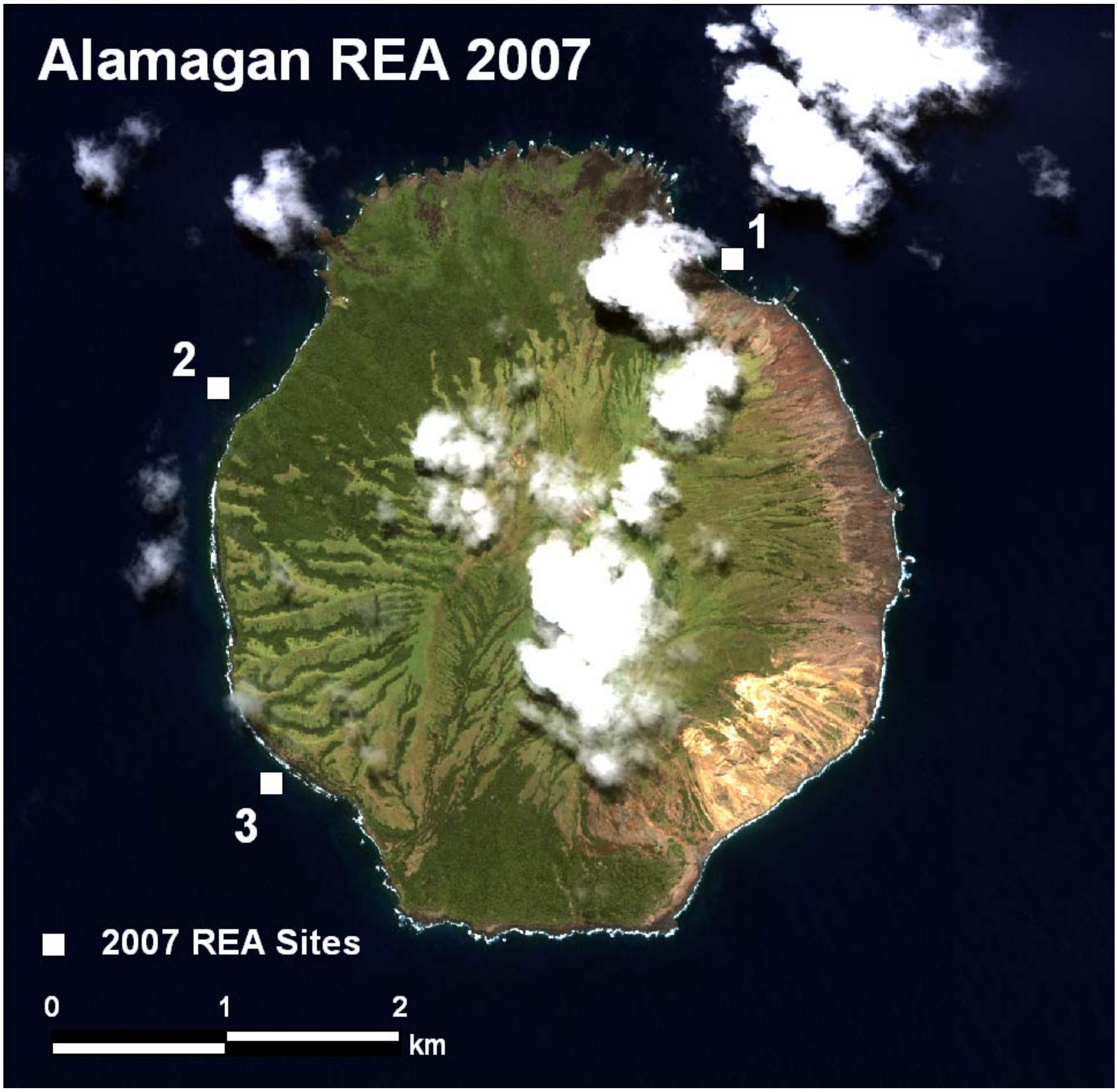


Figure F.3-1. Location of 2007 REA survey sites at Alamagan.

ALA-2

May 28, 2007

West leeward side, transect depth range: 12–13 m. Flattened relief pavement with a carpet of highly fissoned *Astreopora*, *Montipora*, *Porites*, and *Goniopora* and well-developed stands of turf algae, Cyanobacteria tufts, *Asparagopsis,* encrusting Corallinaceae, and *Halimeda*. Moderately high percent live coral cover (20.6%). Turf-algae comprised over 37%. Within the survey area (300 m^2), one case of mild, focal tissue loss was observed on *Goniopora*.

ALA-1

May 28, 2007

East, northeast windward side, transect depth range: 13–14 m. Aggregate relief; pavement with scattered coral colonies and well-developed stands of turf algae, *Neomeris*, Asparagopsis, encrusting Corallinaceae, and Halimeda. Moderate-low live coral cover (16.7%). Basalt boulders and carbonate pavement covered with turf-algae comprised over 38% and siliciclastic sand represented nearly 25% of benthos. Within the survey area (300 m^2), one case of mild bleaching was observed on *Plesiastrea*.

ALA-3

May 28, 2007

West-southwest leeward side, transect depth range: 14–16 m. Aggregate relief with basalt boulders and carbonate buildups; spurs and gullies. Moderately high percent live coral cover (33.3%). Basalt boulders and carbonate pavement and buildups covered on turf-algae comprised over 53% of benthic cover. Three cases of mild bleaching were observed; two on *Echinopora* and one on *Platygyra*. Additionally one case of encrusting sponge overgrowth on *Goniopora* was observed. No algal transect data due to a mechanical failure of the dive tank.

F.4. Benthic environment

F.4.1. Algae

Algal species were surveyed and collected at three sites around Alamagan.

Table F.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table F.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table F.4.1-3. Specimens collected at Alamagan in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Cyanobacteria (ALA02-001)	ALA02; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Cyanobacteria (ALA02-002)	ALA02; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Cyanobacteria (ALA02-004)	ALA02; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Cyanobacteria (ALA02-005)	ALA02; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Cyanobacteria (ALA03-001)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Cyanobacteria (ALA03-001)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Cyanobacteria (ALA03-002)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Cyanobacteria (ALA03-008)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Wrangelia anastomosans (ALA03-003)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Hypnea saidana (ALA03-004)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Portieria hornemannii (ALA01-001)	ALA01; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Liagora ceranoides (ALA01-004)	ALA01; Alamagan, CNMI, Mariana Islands; depth: ~6 m depth; collection date: 2007_05_28		X	X		
Cutleria sp. (ALA02-003)	ALA02; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Sphacelaria sp. (ALA01-005)	ALA01; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X			
Caulerpa filicoides (ALA03-007)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Halimeda lacunalis (ALA01-006)	ALA01; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Halimeda tuna (ALA03-006)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Halimeda velasquezii (ALA01-007)	ALA01; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Halimeda velasquezii (ALA03-005)	ALA03; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Bornetella nitida (ALA01-002)	ALA01; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		
Neomeris sp. (ALA01-003)	ALA01; Alamagan, CNMI, Mariana Islands; collection date: 2007_05_28		X	X		

F.4.1.2 Benthic towed-diver surveys – Macroalgae

The average macroalgae and coralline algae cover was recorded at 16% and 10%, respectively (range 0 – 62.5% and 0 – 40%) The highest macroalgae cover was noted during a towed-diver survey along the east side (tow #4), with an average 29 (range 10.1 – 62.5%). *Halimeda* was noted as dominant within the first four time segments.

The highest coralline algae cover was recorded at 18% (range 5.1 – 40%) during a towed-diver survey along the northwest to north side of island. Refer to the site description for Alamagan towed-diver site 2 for additional information.

F.4.2. Corals

F.4.2.1 Coral Populations

Coral Diversity and Population Parameters

Three sites were visited on Alamagan Island (ALA-1, ALA-2, ALA-3). ALA-1 was unique due to the increased abundance of large *Montipora* colonies and several species of adult *Acropora* and *Pocillopora*. Notably, *Porites* corals attained larger sizes than the other two sites surveyed. ALA-2 and 3 were similar and visualized as low-relief, *Astreopora* and *Halimeda* reefs. Many other species of coral were present in sufficient population densities, including common reef-building *Porites* and *Pocillopora* corals, but growth has not occurred since surveys began in 2003.

F.4.2.2 Percent Benthic Cover

The line-intercept methodology quantified a total of 306 points along 150 m of forereef coral communities, and patterns of intra-island variability in percent benthic cover are reflected in Figure F.4.2.2-1. Mean percent live coral cover for all sites combined was moderate 23.5 ± 5.0% (mean ± SE), with the highest percent coral cover recoded at site ALA-3 (33.3%) on the southwest-facing shore; lower percent coral cover (16.7%) was encountered at site ALA-1 on the northeastern side of the island. Basalt boulders and carbonate pavement covered with sand turf-algae comprised over 41% of the benthic cover, and sand represented over 13% of the benthos. A total of 11 scleractinian genera and one hydrocoral and one stony octocoral (*Heliopora*) were enumerated along the point-count transects, with *Astreopora* being the most numerically abundant scleractinian (23.6 ± 3.4%), followed by *Montipora* (19.5 ± 2.7%), and *Pocillopora* (13.6%). Figure F.4.2.2-2 illustrates the contribution of the different scleractinain genera to the total percent live coral cover.

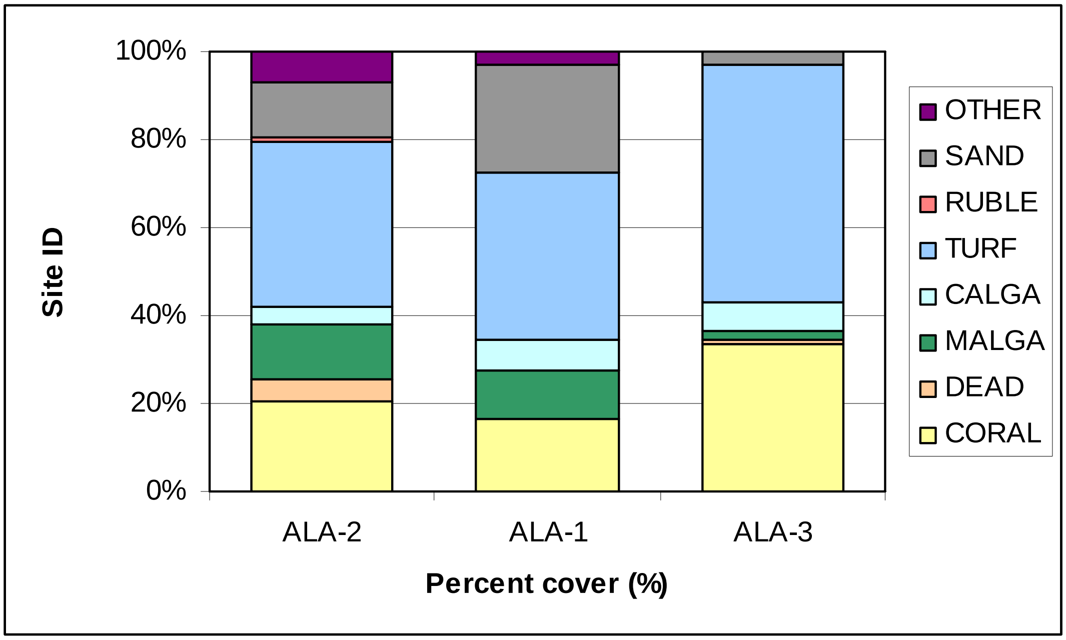


Figure F.4.2.2-1 Mean percent cover of selected benthic elements derived from 3 independent REA surveys at Alamagan, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; MALGA: fleshy macroalgae; CALGA: crustose coralline algae; TURF: turf-algae covered basalt boulders and carbonate buildups; RUBLE: coral rubble (including recent and old coral rubble covered with turf-algae); SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats.

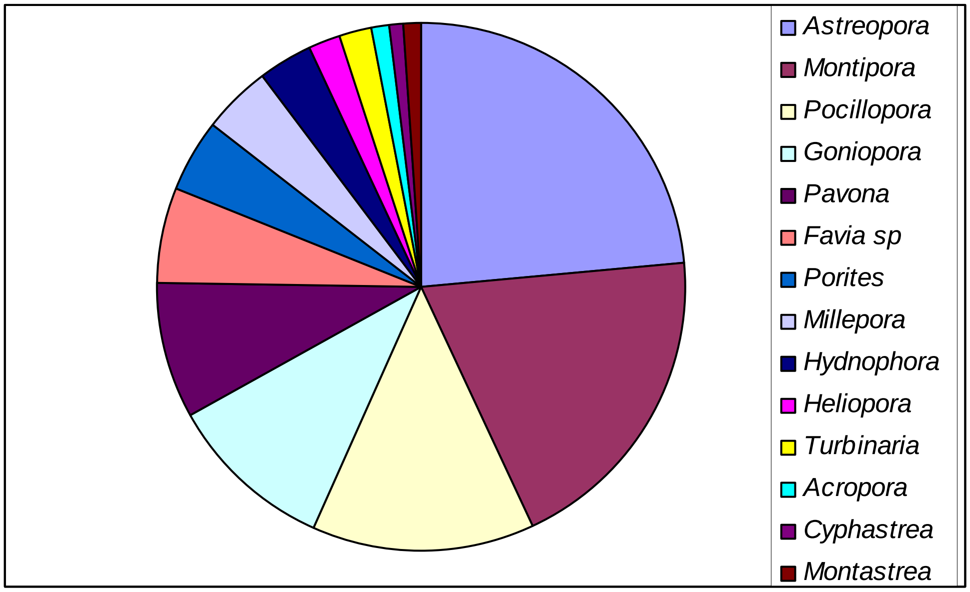


Figure F.4.2.2-2 Percent contribution of the different coral genera to the total live coral cover at Alamagan Island, MAR-RAMP 2007.

F.4.2.3 Coral Disease

Overall occurrence of disease was low. A total of 6 cases were enumerated for all the survey areas combined. We observed four cases of mild bleaching on *Plesiastrea*, *Platygyra,* and two on *Echinopora*; one case of focal tissue loss in *Goniopora,* and one case of sponge overgrowth on *Goniopora*. No predation scars by *Acanthaster* were noted at any of the sites visited.

F.4.2.4 Benthic towed-diver surveys – Corals

The average hard coral cover for Alamagan was recorded at 22% (range 0 - 50%), with stressed coral averaging 1% (range 0 - 10%). The highest overall coral cover recorded during a single towed-diver survey was noted in a towed-diver survey moving from the northwest to north side of island, where terrain consisted of continuous reef, broken by areas of boulders and rubble. The slope was relatively moderate, but grew steeper towards the end with high rock ridges running perpendicular from shore. Coral cover grew steadily higher from the initial time segments, with segments 4, 6, 7, and 10 recording 30.1 – 40% cover, while segments 5, 8, and 9 recorded 40.1 – 50% coral cover. Encrusting corals and *Pocillopora* species were noted 8 and 6 time segments, respectively.

A large *Porites* colony (*Lobata* or *Lutea*) was noted at N 17 37.269, E145 49.885, while a large *Diploastrea* colony (outside of transect) was noted at N17 37.212, E145 49.566.

In addition, several large *Porites* colonies (c.f. *Lobata* or *Lutea*) were noted in the following locations during a towed-diver survey along the south/southwest:

N17 34.757, E145 49.521
N17 34.770, E145 49.478
N17 34.778, E145 49.466 (x 2 colonies)
N17 34.791, E145 49.449
N17 34.803, E145 49.426
N17 35.259, E145 49.008 (huge)

The average coral stress for Alamagan was low, averaging 1% (range 0 – 10%). Coral stress was highest during the towed-diver survey completed in the north to northeast area of Alamagan (average 4%, range 0 – 10%). No COTs or other potential indicators of coral stressors were noted.

Soft coral averaged 6% island-wide (range 0 – 40%). The highest average soft coral cover (8%) was noted in several areas in the west, north/northeast, and east sides of the island (refer to towed diver surveys 1, 3, and 4 in the Alamagin site descriptions; ranges were recorded at 1.1 – 40%, 1.1 – 20%, and 5.1 – 20%, respectively). *Distichopora violacea* was noted during the 3rd towed-diver survey under most overhangs of the 6th time segment, while the 4th towed-diver survey noted localized increases in *sarcophyton* (4th time segment) and a number of *sinularia* species (6th time segment).

F.4.3 Macroinvertebrates

F.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

The overall macroinvertebrate averages per survey for the island of Alamagan were 0.6 urchins, 0.3 sea cucumbers, and 0.7 giant clams. No COTs were recorded. Sea urchins were observed during all surveys, but numbers never exceeded 11 individuals per survey. The highest concentration of urchins was recorded in one segment along the southeast side of the island amongst a boulder field on pavement reef. Sea cucumbers were also most abundant during the same survey, although only 6 individuals were recorded. Giant clams averaged 4 individuals per survey, with the exception of the survey along the western coast where 19 individuals were recorded.

F.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Alamagan. The survey methods employed at each site and notable observations are summarized in Table F.4.3.2-1.

Table F.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Alamagan.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
ALA-2	X	X		
ALA-1	X	X	X	Good soft coral diversity. Abundant *Linkia multiflora*. Yellow *Chromodoris* abundant.
ALA-3	X	X		

F.4.3.3 Opportunistic invertebrate collections

Acanthaster planci, *Linckia multiflora*, and *Holothuria atra* were not collected at Alamagan.

Alamagan

F.5. Fish

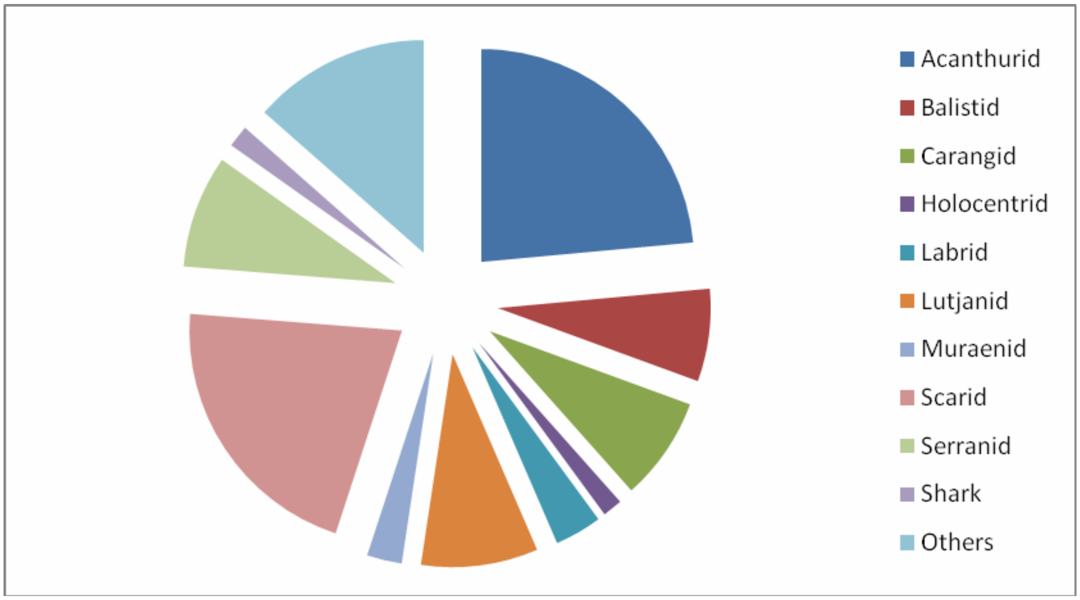
F.5.1 REA Fish Surveys

Stationary Point Count data
A total of 12 individual SPC surveys were conducted at 3 forereef sites around the island of Alamagan. Snappers (Lutjanidae), wrasses (Labridae), and parrotfish (Scaridae) were most common on SPC surveys yielding biomass of 0.08, 0.07, and 0.06 ton per hectare, respectively.

Belt-Transect data
During the survey period, 9 belt-transect surveys were conducted at 3 forereef sites around the island of Alamagan. Surgeonfish (Acanthurids) and parrotfish (Scarids) were the primary contributors to biomass with 0.08 and 0.07 ton per hectare, respectively. (Fig. F.5.1-1).

Overall observations
A total of 150 species were observed during the survey period by all divers. The average medium to large fish biomass at the sites in Alamagan during the survey period was 0.43 ton/ha for the SPC surveys (Table F.5.1-1) and the average fish biomass was 0.34 ton/ha for the belt transect surveys (Table F.5.1-2).

Figure F.5.1-1 – Family composition of the total fish biomass (0.34 ton per hectare) around Alamagan Island.



Alamagan

Table F.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Alamagan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
ALA-1	0.28	0.08	0.00	0.02	0.02	0.00	0.08	0.07	0.00	0.02	0.00	0.00
ALA-2	0.46	0.09	0.00	0.02	0.01	0.02	0.07	0.10	0.00	0.07	0.08	0.01
ALA-3	0.55	0.00	0.00	0.07	0.19	0.01	0.09	0.02	0.00	0.02	0.14	0.02
Average	0.43	0.05	0.00	0.04	0.07	0.01	0.08	0.06	0.00	0.03	0.07	0.01

Table F.5.1-2 – Total fish biomass around Alamagan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
ALA-1	0.39	0.16	0.02	0.01	0.01	0.01	0.06	0.00	0.05	0.01	0.02	0.05
ALA-2	0.08	0.00	0.01	0.00	0.00	0.01	0.00	0.03	0.00	0.02	0.00	0.01
ALA-3	0.54	0.08	0.04	0.07	0.00	0.02	0.03	0.00	0.17	0.06	0.00	0.07
Average	0.34	0.08	0.02	0.03	0.01	0.01	0.03	0.01	0.07	0.03	0.01	0.05

F.5.2 Fish towed-diver surveys

At Alamagan the Towboard team conducted 6 tows totaling 13 kilometers in length and covering 13 hectares of ocean bottom. Mean survey length was 2.18 km. One-thousand one-hundred fifty-eight fish (>50 cm TL, all species spooled) were observed totaling 23 different species. Overall numeric density was 89.07 fish per hectare. Garden eels *(Conger sp.)* were by far the most numerous species and are not shown in Figure F.5.2-1. Apart from Garden Eels, twinspot snapper (*Lutjanus bohar*), sleek unicornfish (*Naso hexacanthus*), midnight snapper (*Macolor macularis*), whitetip reef sharks (*Triaenodon obesus*), *and* gray reef sharks (*Carcharhinus amblyrhynchos*) were the five most commonly observed species (>50 cm TL) at Alamagan during the survey period (Table F.5.2-1).

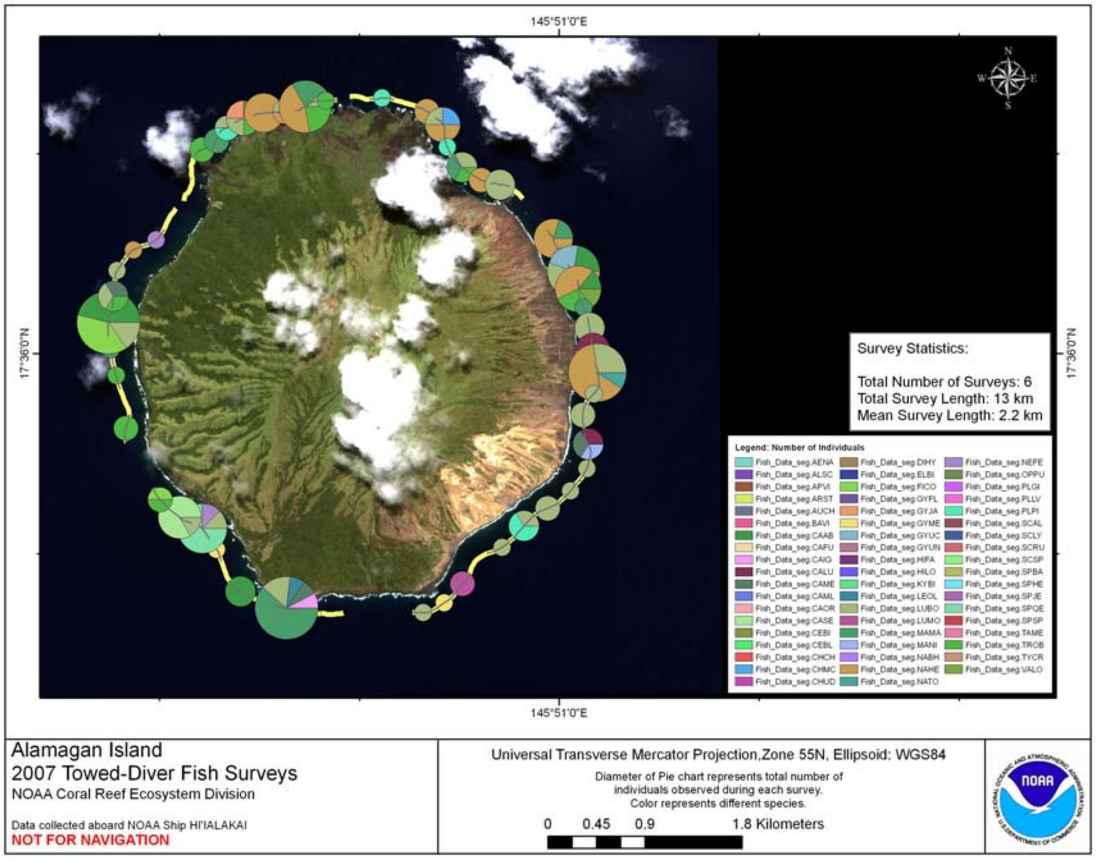


Figure F.5.2-1. Distribution of Large Fish Observations at Alamagan.

Table F.5.2-1. Number of individuals of each species observed at Alamagan.

Island	Taxon Name	#
Alamagan	Conger sp.	1000
	Lutjanus bohar	38
	Naso hexacanthus	33
	Macolor macularis	17
	Triaenodon obesus	14
	Carcharhinus amblyrhynchos	13
	Sphyraena qenie	6
	Fistularia commersonii	6
	Plectorhinchus picus	5
	Caranx sexfasciatus	5
	Caranx melampygus	3
	Caranx lugubris	3
	Gymnosarda unicolor	2
	Nebrius ferrugineus	2
	Lutjanus monostigma	2
	Gymnothorax meleagris	2
	Variola louti	1
	Macolor niger	1
	Naso tonganus	1
	Gymnothorax javanicus	1
	Lethrinus olivaceus	1
	Caranx ignobilis	1
	Chlorurus microrhinos	1
Alamagan Total		1158

Appendix G: Pagan

G.1. Benthic Habitat Mapping

Pagan Island is located at ~18º 07'N, 145º 46'E and is located approximately 40 nmi south of Agrihan Island and 31 nmi north of Alamagan Island. Its location on nautical chart 81092_1 is approximately 0.6 nmi northeast of its observed position on HI0703. It is the largest of the Northern Mariana Islands at 8 nmi by 3.1 nmi and has a small number of seasonal residents, since its permanent population was evacuated after an eruption in 1981. Numerous artifacts from the Japanese occupation during WWII can still be found on the island.

Multibeam mapping surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars. The ship transited to and worked at Pagan from June 4-6, 2007 (JD 155-157), and the *AHI* was deployed on May 29, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~15 m and 250 m, and the *Hi'ialakai* collected data down to about 2400 m on all sides of the island. Multibeam data were also collected on the eastern side of the island chain during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the previous data were collected primarily to the west of the island chain. The multibeam data collected around Agrihan represents approximately 40% of the 2511 km^2 (roughly 1000 km^2) of HI0703 coverage around the central section of the Mariana Archipelago, which includes both Agrihan and Pagan.

Pagan is classified as an active volcano, and the large Plinian eruption that occurred in 1981 was followed by 15 years of minor volcanic activity (Trusdell et al., 2006). Additionally, according to the United States Geologic Survey, eleven eruptions occurred between the early 1800's and 1981. There are two volcanoes that make up Pagan Island: Mount Pagan is 570 m with a 7-km wide caldera, and South Pagan is 548 m high with a 4-km wide caldera. There are small submarine shelves and anchorages on the east and west sides of the island. The eastern shelf is 20-30 m deep and the western is 25-60 m deep. A larger area (~2 nmi by 1.6 nmi) on the southwest side of the island has two distinct shelves with depths ranging from 25 to 40 m and 110 to 130 m, respectively. The submarine slopes surrounding Pagan are littered with block material. The material is concentrated on the northern and southern sides of the island, and three somewhat linear trails of debris radiate away from the northern tip of Pagan to the E, NNE, and NW. The NNE trail of debris is the largest. Channels incise the submarine flanks of Pagan and are most abundant on the western side of the island. The shallow water surveys conducted by the *AHI* revealed various seafloor substrates including flat and sandy bottom, boulder fields, and coral-rich regions.

Reference:

Trusdell, F.A., Moore, R.B., Sako, M.K., 2006. Preliminary geologic map of Mount Pagan Volcano, Pagan Island, Commonweath of the Northern Mariana Islands, USGS Open-File Report, 2006-1386.

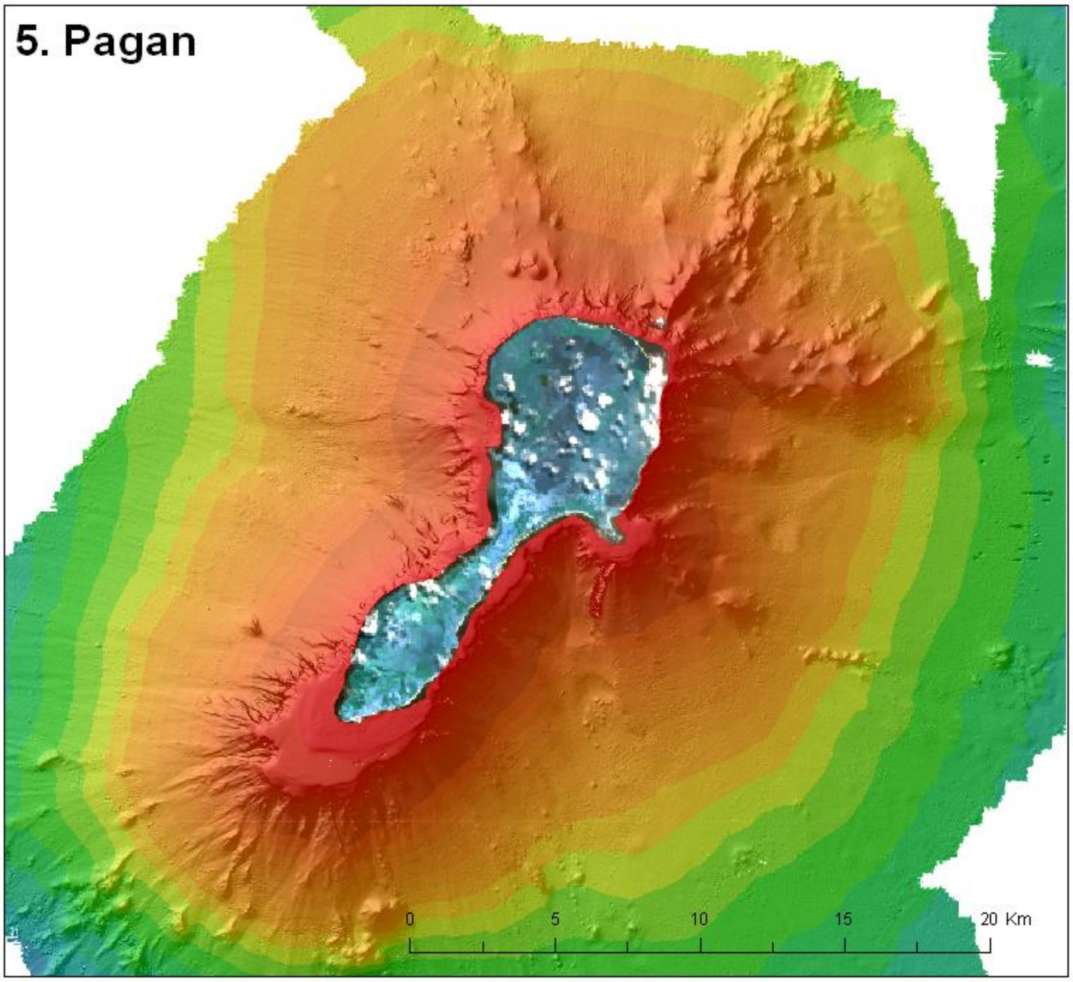


Figure G.1-1: Multibeam bathymetric data collected during HI0703 around Pagan Island.

G.2. Oceanography and Water Quality

In total, two instruments were recovered and four instruments were deployed at Pagan during HI0703. A sea surface temperature (SST) buoy located near the village on the west side of Pagan was recovered and replaced. A subsurface temperature recorder (STR) was added to the SST anchor at approximately 6 meters depth to measure temperature variation over that depth range. Additionally, an STR was recovered and replaced on the East side of the island and a new STR was deployed near REA site 13. (Figure G.2-1)

Twenty-five shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter of Pagan at approximately 1.6-km intervals following the 30-m contour. At seven of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1m, 10m, 20m and 30m depths, for a total of fifty water samples measuring chlorophyll and nutrient concentrations. (Figure G.2-1).

In situ sea surface temperature (SST) obtained from October 2005 to June 2007 at Pagan shows seasonal variability with warm temperatures observed from July to October and cooler temperatures from January to April (Figure G.2-2). Large diel temperature oscillations, some as great as 1.5 °C, are also observed and are persistent throughout the time-series.

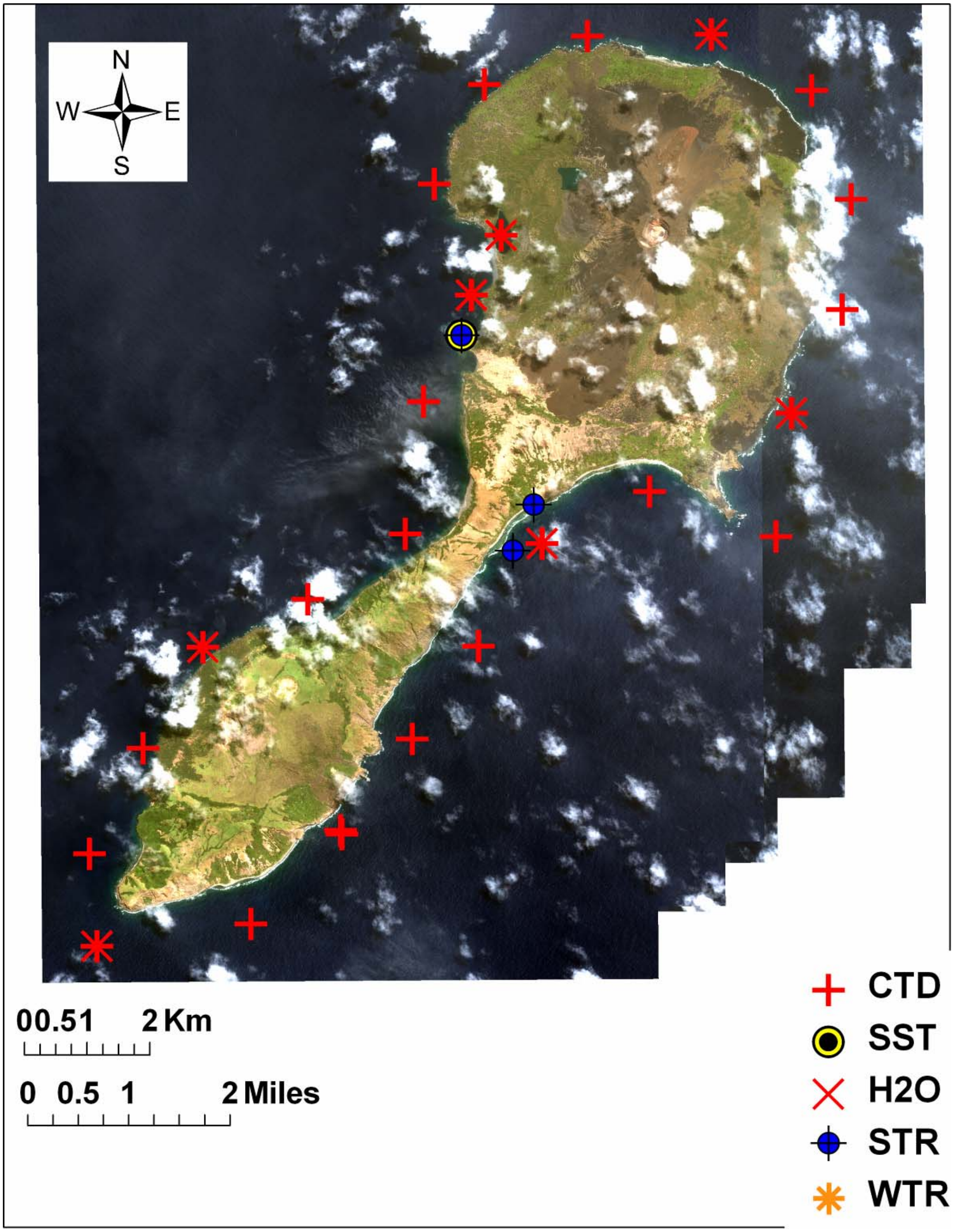


Figure G.2-1: Positions of CTDs, water samples and moorings at Pagan.

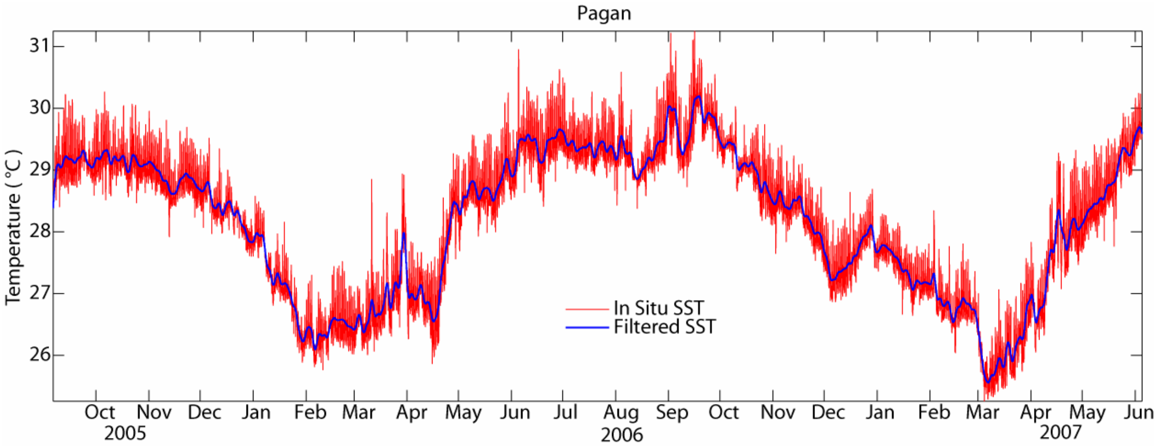


Figure G.2-2: In situ SST from the west side of Pagan Island, CNMI. The red line is data sampled every 15 minutes; the blue line is a 7-day mean.

G.3 Rapid Ecological Assessment (REA) Site Descriptions

Six to eight people inhabit Pagan throughout the year. Fishing on this island is minimal to moderate. This island receives a majority of vessel traffic, making it more susceptible to fishing pressure. The Northern Island Mayors Office (NIMO) contracts a private vessel to transport supplies and people to this island on an as needed basis. Privately owned vessels also frequent this island during leisure trips. Spearfishing and bottomfishing are the common fishing activities during these trips.

REA surveys were conducted at nine sites at Pagan (Table G.3-1). Locations of all REA sites around Pagan are shown in Figure G.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table C.3-1. Sites surveyed by REA team at Sarigan, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.

Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, °C
PAG-3	6/5/2007	18	10.120	145	47.291	11 - 13	15.8	28.9
PAG-12	6/5/2007	18	09.986	145	46.004	11 - 13	18.3	28.9
PAG-5	6/5/2007	18	07.196	145	45.307	10 - 12	15.8	28.9
PAG-1	6/6/2007	18	06.443	145	47.094	13 - 14	16.8	28.9
PAG-13	6/6/2007	18	05.815	145	45.916	11 - 13	17.7	28.9
PAG-8	6/6/2007	18	03.658	145	44.526	10 - 12	15.2	28.9
PAG-9	6/7/2007	18	04.219	145	42.812	12 - 13	17.4	28.9
PAG-11	6/7/2007	18	05.184	145	43.785	12 - 14	19.2	28.9
PAG-6	6/7/2007	18	05.561	145	44.638	12 - 13		28.9

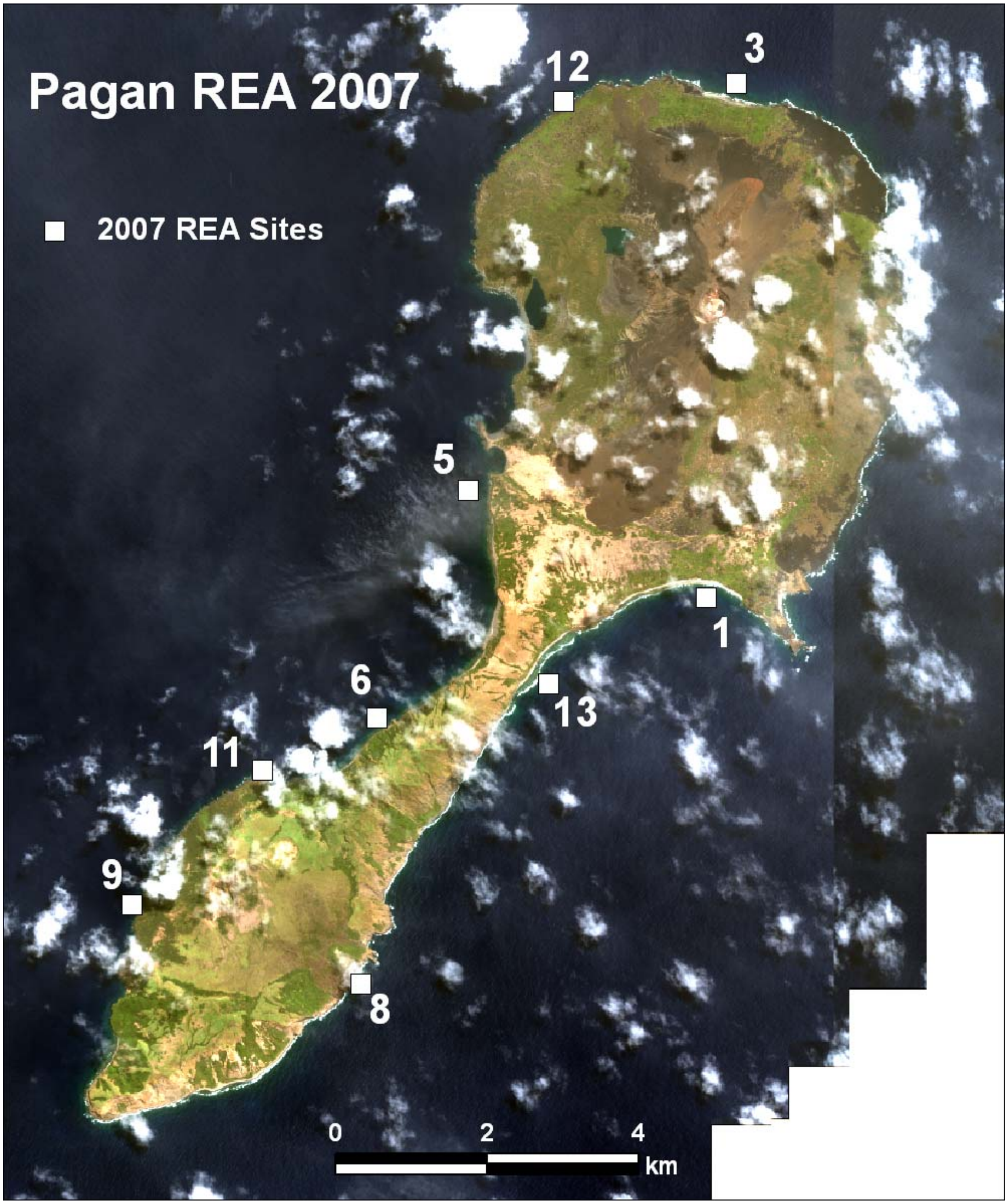


Figure G.3-1. Location of 2007 REA survey sites at Pagan.

PAG-3
June 5, 2007
North windward side. Transect depth range: 11–13 m. Smooth undulating rocky platform traversed by gullies with siliciclastic sand. Low percent live coral cover (8.8%). Turf-algae over rock comprised >21% of the bottom cover, sand represented 37%, and

macroalgae (mainly *Halimeda*) 27.5% of the benthos. Within the survey area (300 m^2) numerous cases of dark discolorations were observed on colonies of *Cyphastrea*. It is not clear whether this condition represents a disease state or perhaps a response to local environmental conditions. A voucher sample was collected for further histological examination. Additionally numerous cases of COTS predation were observed, particularly on colonies of *Pocillopora* spp. The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting *Peyssonnelia*, *Asparagopsis*, encrusting Corallinaceae, *Jania*, and encrusting *Lobophora*.

PAG-12
June 5, 2007
Northwest side. Transect depth range: 11–13 m. Aggregate relief; basalt boulders, carbonate biogenic buildups, and sand gullies and pits. Low percent live coral cover (9.8%). Coral carbonate pavement and rock covered on turf algae comprised > 67% of the benthic cover. Encrusting calcareous red algae was also an important component of the benthos, representing 10% live cover. Within the survey area (300 m^2) several cases of COTS predation were observed on *Favia stelligera*, *Goniastrea edwardsi*, and *Pocillopora* spp. The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting Corallinaceae, cyanobacteria, encrusting *Lobophora*, and *Jania*.

PAG-5
June 5, 2007
West leeward side. Transect depth range: 10–12 m. Aggregate relief with sparse reef development; carbonate biogenic buildups, basalt boulders, and sand gullies and pits. Low percent live coral cover (7.8%). Coral carbonate pavement covered on turf algae comprised > 68% of the benthic cover. No coral or coralline algal diseases were observed within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were turf algae, *Haematocelis*, encrusting Corallinaceae, *Actinotrichia*, *Jania*, *Amphiroa*, and cyanobacteria.

June 6, 2007
PAG-1
June 6, 2007
East side. Transect depth range: 13–14 m. Aggregate relief; basalt boulders, carbonate biogenic buildups, and sand gullies and pits. Low percent live coral cover (5.9%). Turf-algae over carbonate pavement comprised >41 % of the bottom cover and sand represented 31% of the benthos. Within the survey area (300 m^2) two cases of coralline lethal orange disease were observed. The dominant algal categories (up to a rank average of 4) on this site were turf algae, *Asparagopsis*, encrusting Corallinaceae, *Neomeris*, *Jania*, and cyanobacteria.

PAG-13
June 6, 2007
East windward side. Transect depth range: 11–13 m. Aggregate relief; basalt boulders, carbonate biogenic buildups, and sand gullies and pits. Moderate percent live coral cover

(20.6%). Coral carbonate pavement and rock covered on turf algae comprised > 68% of the benthic cover. No coral or coralline algal diseases were observed within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were turf algae, cyanobacteria, *Jania*, *Asparagopsis*, and *Halimeda*.

PAG-8
June 6, 2007
Southeast windward side. Transect depth range: 10–12 m. Large basalt boulders and sand. Low percent live coral cover (8.8%). Turf-algae over basalt boulders represented > 80% of the benthic cover. Numerous cases of dark discolorations were observed on colonies of *Cyphastrea*. It is not clear whether this condition represents a disease state or perhaps a response to local environmental conditions. The dominant algal categories (up to a rank average of 4) on this site were *Acrosymphyton*, turf algae, *Jania*, encrusting corallines, *Asparagopsis*, and cyanobacteria.

PAG-9
June 7, 2007
Southwest leeward side. Transect depth range: 12–13 m. Large basalt boulders and volcanic sand. Low percent live coral cover (3.9%). Turf-algae over rock comprised >67 % of the bottom cover and sand represented 15% of the benthos. No coral or coralline algal diseases were observed within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were Caulerpa, encrusting Corallinaceae, turf algae, *Haematocelis*, and encrusting *Lobophora*.

PAG-11
June 7, 2007
West leeward side. Transect depth range: 12–14 m. Aggregate relief pavement with little coral development; basalt boulders, carbonate biogenic buildups, and sand gullies and pits. Moderately low percent live coral cover (13.7%). Coral carbonate pavement and rock covered on turf algae comprised > 70% of the benthic cover. Two cases of sponge overgrowth (*Terpios*) were observed within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting Corallinaceae, encrusting *Peyssonnelia*, and encrusting *Lobophora*.

PAG-6
June 7, 2007
West leeward side. Transect depth range: 12–13 m. Aggregate relief; basalt boulders, carbonate biogenic buildups, and sand gullies and pits. Moderately low percent live coral cover (15.7%). Coral carbonate pavement and rock covered on turf algae comprised >64% of the benthic cover. No coral or coralline algal diseases were observed within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting *Lobophora*, encrusting Corallinaceae, cyanobacteria, and *Amphiroa*.

G.4. Benthic environment

G.4.1. Algae

Algal species were surveyed and collected at nine sites around Pagan.

Table G.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table G.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table G.4.1-3. Specimens collected at Pagan in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Wrangelia anastomosans (PAG01-003)	PAG01; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06		X	X		
Martensia sp. (PAG01-002)	PAG01; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06		X	X		
Martensia sp. (PAG08-002)	PAG08; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06		X	X		
Laurencia sp. (PAG11-003)	PAG11; Pagan, CNMI, Mariana Islands; collection date: 2007_06_07		X	X		
Amphiroa fragilissima (PAG06-001)	PAG06; Pagan, CNMI, Mariana Islands; collection date: 2007_06_07		X			
Amphiroa tribulus (PAG06-001)	PAG06; Pagan, CNMI, Mariana Islands; collection date: 2007_06_07		X			
Cheilosporum spectabile (PAG11-001)	PAG11; Pagan, CNMI, Mariana Islands; collection date: 2007_06_07		X	X		
Haliptilon sp. (PAGXX-002)	PAG12; Pagan, CNMI, Mariana Islands; collection date: 2007_06_05		X	X		
Jania sp. (PAG06-002)	PAG06; Pagan, CNMI, Mariana Islands; collection date: 2007_06_07		X			
Acrosymphyton taylorii (PAG08-001)	PAG08; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06	X	X	X		
Portieria hornemannii (PAG11-002)	PAG11; Pagan, CNMI, Mariana Islands; collection date: 2007_06_07		X	X		
Grateloupia sp. (PAGXX-001)	PAG12; Pagan, CNMI, Mariana Islands; collection date: 2007_06_05		X	X		
Actinotrichia fragilis (PAG05-002)	PAG05; Pagan, CNMI, Mariana Islands; collection date: 2007_06_05		X	X		
Titanophora sp. (PAG01-001)	PAG01; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06		X	X		
Renouxia antillana (PAG05-003)	PAG05; Pagan, CNMI, Mariana Islands; collection date: 2007_06_05		X	X		
Halichrysis sp. (PAG08-003)	PAG08; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06		X	X		
Dictyota friabilis (PAG12-001)	PAG12; Pagan, CNMI, Mariana Islands; collection date: 2007_06_05		X	X		
Trichosolen sp. (PAG08-005)	PAG08; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06		X	X		
Caulerpa mexicana (PAG08-004)	PAG08; Pagan, CNMI, Mariana Islands; collection date: 2007_06_06		X	X		
Caulerpa pickeringii/webbiana (PAG03-001)	PAG09; Pagan, CNMI, Mariana Islands; collection date: 2007_06_05		X	X		
Neomeris sp. (PAG05-001)	PAG05; Pagan, CNMI, Mariana Islands; collection date: 2007_06_05		X	X		

G.4.1.2 Benthic towed-diver surveys – Macroalgae

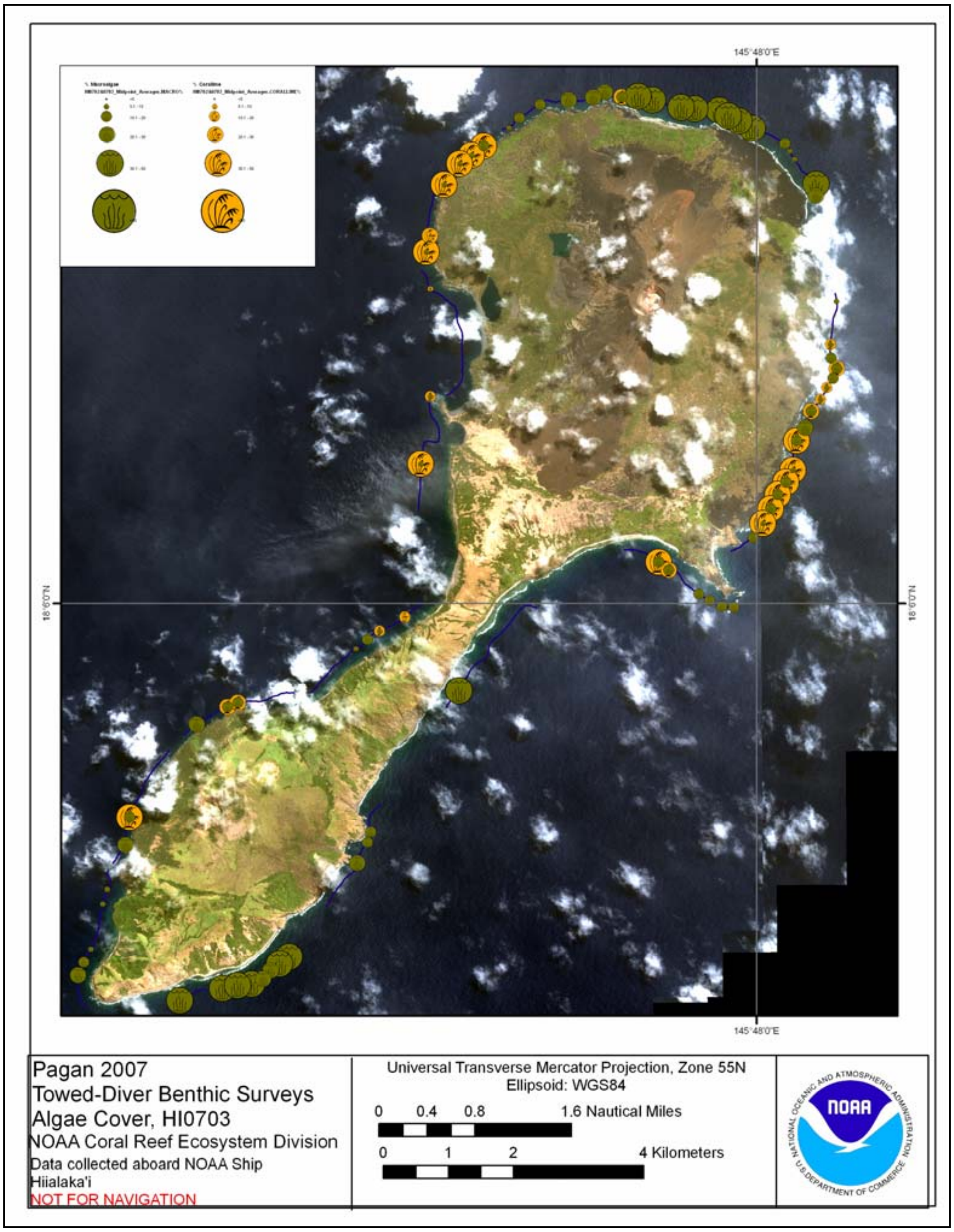


Figure G.4.1.2.1: Macroalgae and coralline algae cover around Pagan (2007).

Macroalgae and coralline algae cover at Pagan averaged 17% and 14% (range 0 - 75% and 0 - 50%, respectively). The highest macroalgae cover was recorded during a survey along the southeast side of island, passing Piarama, ending near the southern-most point of Pagan (average 39%, range 20.1 – 62.5%). *Asparagopsis* and *Halimeda* were both relatively common. The highest coralline algae cover (average 28%, range 5.1 - 40%) was located during the survey along the northeast side, ending near Togari rock. Terrain consisted of rocky reef, boulders, sand channels, and spur-and-groove habitat for the majority of the towed-diver survey, with ridges perpendicular to shore increasing habitat complexity locally.

G.4.2. Corals

G.4.2.1 Coral Populations

Coral Diversity and Population Parameters

A total of nine sites encompassing three days of surveys were undertaken on Pagan. Among all sites, three general reef types were encountered. PAG-3 and 5 consisted of flat *Halimeda*-dominated reefs with very little modern coral growth since 2003. Most abundant were small *Favia mathaii*, *Leptastrea purpurea*, *Psammacora haimeana*, and *Pavona varians* corals. PAG-8 and 9 consisted of volcanic boulders with varying levels of Holocene deposits. Modern assemblages had many juvenile *Pocillopora* corals but similar to other islands, a failure of adult growth. PAG-12 and 13 were indicative of CNMI's typical Holocene reefs with adult *Pocillopora*, *Stylophora*, *Porites*, *Goniastrea*, and *Astreopora* colonies present. These sites have showed a strong recovery since the 2003 surveys, a recovery from bleaching (2000/01) and *Acanthaster planci* (2003/4) that led to a more positively skewed colony size distribution. The remaining sites (PAG-6, PAG-11, and PAG-1) all have a dead, unconsolidated reef matrix with many juvenile massive and cryptic species currently growing; including *Echinophyllia aspera*, *Goniastrea edwardsi*, *Psammacora haimeana*, *Echinopora lamellosa*, and *Stylocoeniella armata*. These reefs have shown little to no change since 2003, suggesting slow or halted growth of the underlying reef matrix.

G.4.2.2 Percent Benthic Cover

In June 5-7, 2007, the REA team revisited 9 sites around the island of Pagan; same sites surveyed in 2003 and 2005. In 2007, the line-intercept methodology quantified a total of 918 points along 450 m of forereef coral communities; patterns of intra-island variability in percent benthic cover are presented in Figure G.4.2.2-1. REA sites PAG-8 and -9 consisted of basalt boulders intermingled with sand patches, with a few scattered coral colonies growing on the basal masses. By contrast sites PAG-5, -8 and -11 presented more prominent carbonate buildups. Percent live coral cover around Pagan was relatively low, with a mean of 10.6 ± 1.7% (mean ± stder) for all sites combined. Percent coral cover was the greatest at REA site PAG-13 (20.6%) on east-facing shore and the lowest at site PAG-9 on the southwest portion of the island. Turf algae growing over basalt boulders and pavement amounted to over 62% for all sites combined. Additionally, the point count survey enumerated a total of 17 scleractinian genera and one hydrocoral (*Millepora*), with *Astreopora* being the most numerically abundant scleractinian (15.92%), followed by *Galaxea* (13.8%), *Pavona* (13.7%,), *Montipora* (11.9%), and *Cyphastrea* (11.2%). Figure G.4.2.2-2 illustrates the contribution of the different stony coral genera to the total percent live coral cover. In the general area, however a total of

Pagan

35 different scleractinian genera, one hydrocoral, and one octocoral were enumerated (see Table G.4.2.2-1)

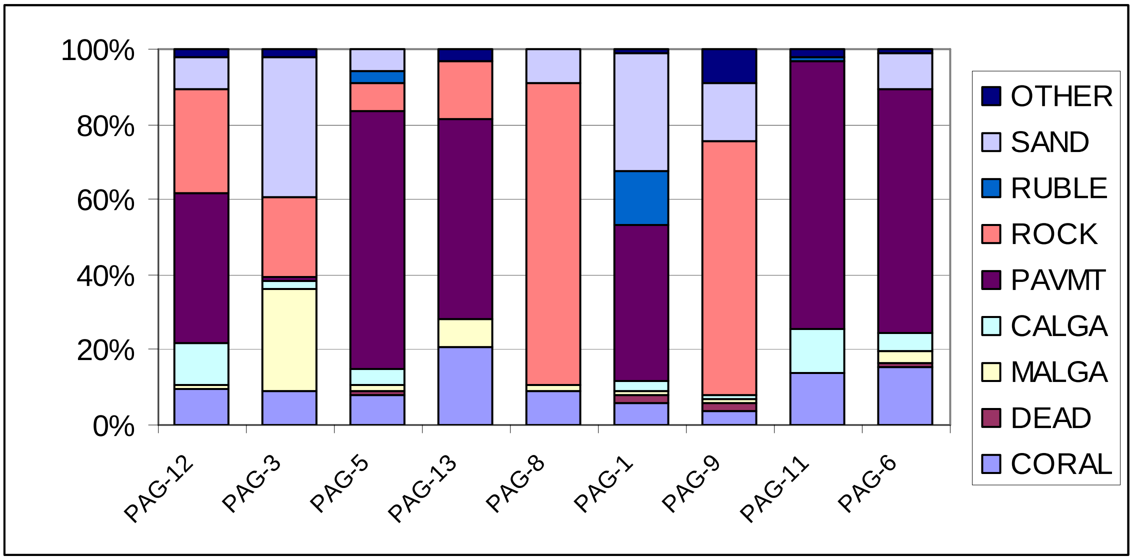


Figure G.4.2.2-1 Mean percent cover of selected benthic elements derived from 9 independent REA surveys at Pagan, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; MALGA: macroalgae; CALGA: calcareous coralline and red algae; PAVMT: carbonate pavement covered with turf algae; ROCK: turf-algae covered basalt boulders; RUBLE: coral rubble; SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats.

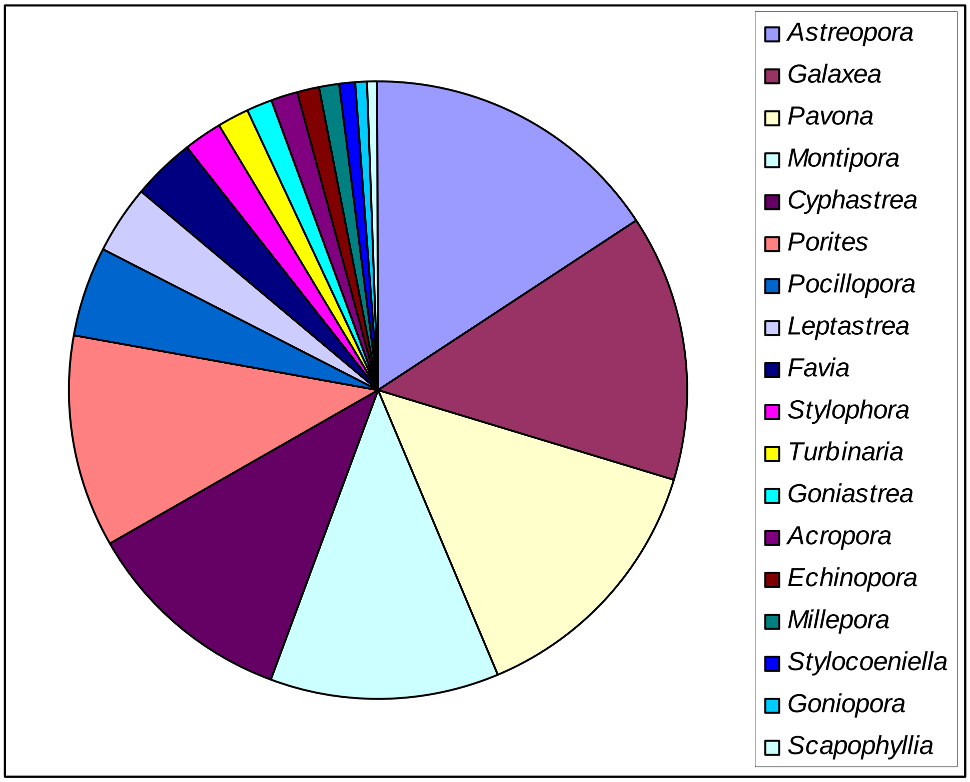


Figure G.4.2.2-2 Percent contribution of the different coral genera to the total live coral cover at Asuncion Island, MAR-RAMP 2007.

Table G.4.2.2-1 List scleractinian, hydrocoral, and stony octocoral genera enumerated at Pagan Island during the 2007 coral disease REA surveys**.**			
Acanthastrea	*Favites*	*Lobophyllia*	*Porites*
Acropora	*Fungia*	*Millepora*	*Psammocora*
Astreopora	*Galaxea*	*Montastrea*	*Scapophyllia*
Coscinaraea	*Gardineroseris*	*Montipora*	*Scolymia*
Cyphastera	*Goniastrea*	*Oulophyllia*	*Stylocoeniella*
Diploastrea	*Goniopora*	*Pavona*	*Stylophora*
Echinophyllia	*Heliopora*	*Platygyra*	*Turbinaria*
Echinopora	*Herpolitha*	*Pleogyra*	
Euphyllia	*Leptastrea*	*Plesiastrea*	
Favia	*Leptoseris*	*Pocillopora*	

G.4.2.3 Coral Disease

The 2007 coral disease REAs surveyed a total area of ~2650 m^2 at 9 different sites. Coral reef communities at Pagan exhibited high diversity, relatively low percent live cover, and low occurrence of disease. Of particular interest were numerous cases of dark discolorations observed on colonies of *Cyphastrea* cf *chalcidium*, particularly at REA sites PAG-3 and -8. It is not clear whether this condition represents a disease state or perhaps a response to local environmental conditions; a voucher sample was collected for further histological examination. We also detected two cases of coralline algal lethal disease (CLOD) and several cases of *Acanthaster* predation, particularly at sites PAG-6, -11, and -12. Coral reef communities at sites PAG-6, -11, and -13 indicated persistent bioerosion, in excess of carbonate framework buildup and accretion. It appears as if these communities had been impacted in the past, perhaps by volcanic activity or sea-warming conditions, and currently may be undergoing a phase dominated by encrusting sponges and calcareous algae and turf-algae; substantial coral recruitment is also noticeable in some of these areas.

G.4.2.4 Benthic towed-diver surveys – Corals

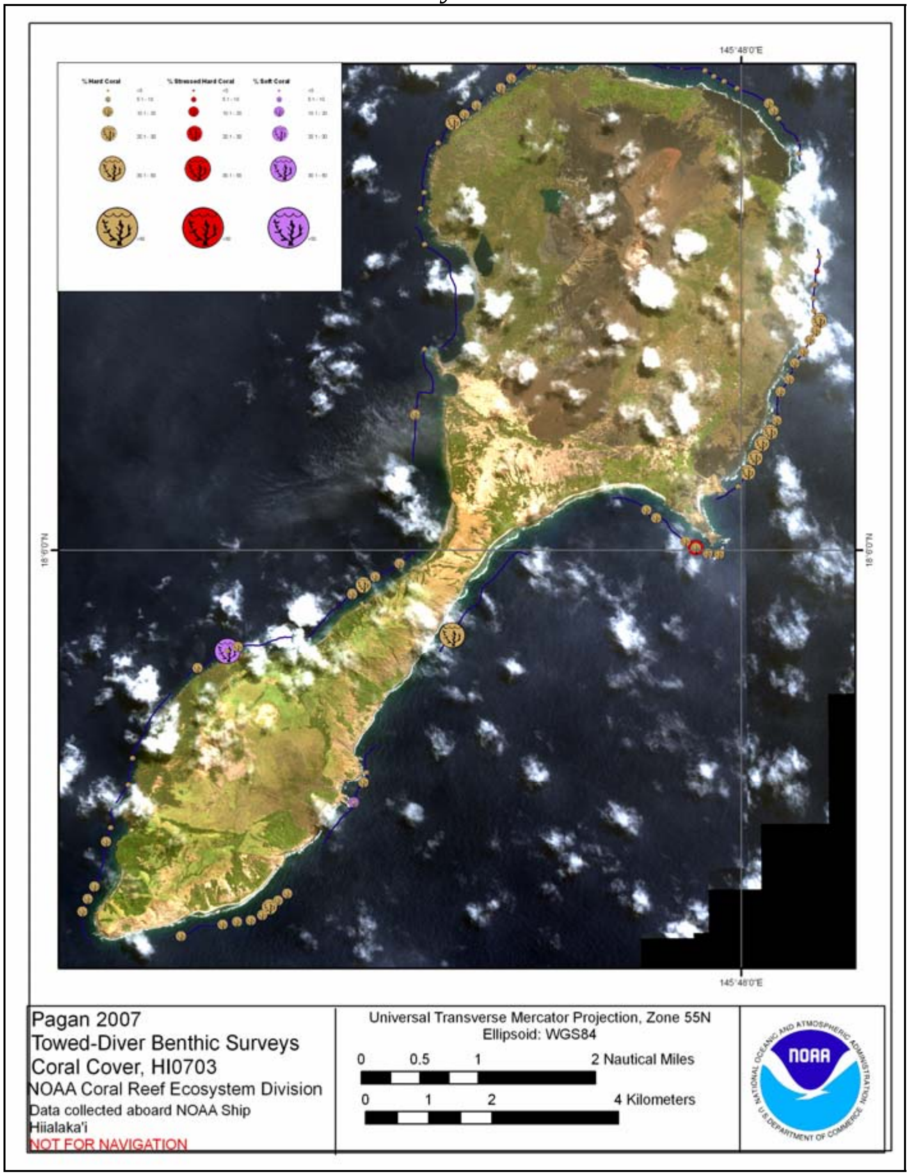


Figure G.4.2.4.1: Hard coral, stressed coral and soft coral cover around Pagan (2007).

The average hard coral cover for Pagan was recorded at 12% (range 0 – 62.5%), with stressed coral averaging 2% (range 0 - 30%). The highest overall coral cover recorded during a single towed-diver survey was noted in a survey completed in the area immediately east of Pontanjaburo, progressing along the western coast of the "saddle", with an average of 20% coral cover (range 10.1 – 62.5%). The bottom habitat was composed of predominantly continuous reef/spur-and-groove habitat. Coral cover was relatively stable, ranging from 10.1 – 30% for 8/10 time segments. Time segment 8 recorded 50.1 – 62.5% coral cover, which consisted of large monotypic areas of *Euphyllia ancora*, along with large stands of *Porites rus*.

The highest overall stressed coral (average 7%, range 0 – 30%) was recorded in the northeast/eastern portion of the island near Togari rock, heading along the beach near Degusa and Apansantare. Time segment 3 recorded the highest level of stress during the tow (20.1 – 30%), with 17 COTs recorded within the 5-minute time segment (33 total for the towed-diver survey).

The average soft coral cover for Pagan was recorded at 6% (range 0 – 20%). The highest overall soft coral cover recorded during a single towed-diver survey (average 7%, range 5.1 – 20%) was recorded along the southeast side of the island, passing Piarama, ending near the southern-most point. Terrain consisted of continuous reef, occasionally broken by sand channels, patch reefs, and boulders. Seven time segments fell in the 10.1 – 20% range (*sinularia*/*sarcophytum*)

During the same survey in the southeast, large *Porites* colonies (c.f. *Lobata* or *Lutea*) were observed in a number of locations:

- N18 02.838, E145 43.815;
- N18 02.819, E145 43.665 (2 colonies within transect; 3rd colony outside transect = an estimated 2-3 meters tall x 5 – 7 meters tall);
- N18 02.786, E145 43.508 (outside of transect; estimated 2-3 wide x 5 – 7 meters tall).

Finally: an area of warm water/hot sand with a yellowish (sulfuric?) surface was observed within a sand flat in the vicinity of N18 02.754, E145 43.327, which was encountered during the same survey.

G.4.3 Macroinvertebrates

G.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

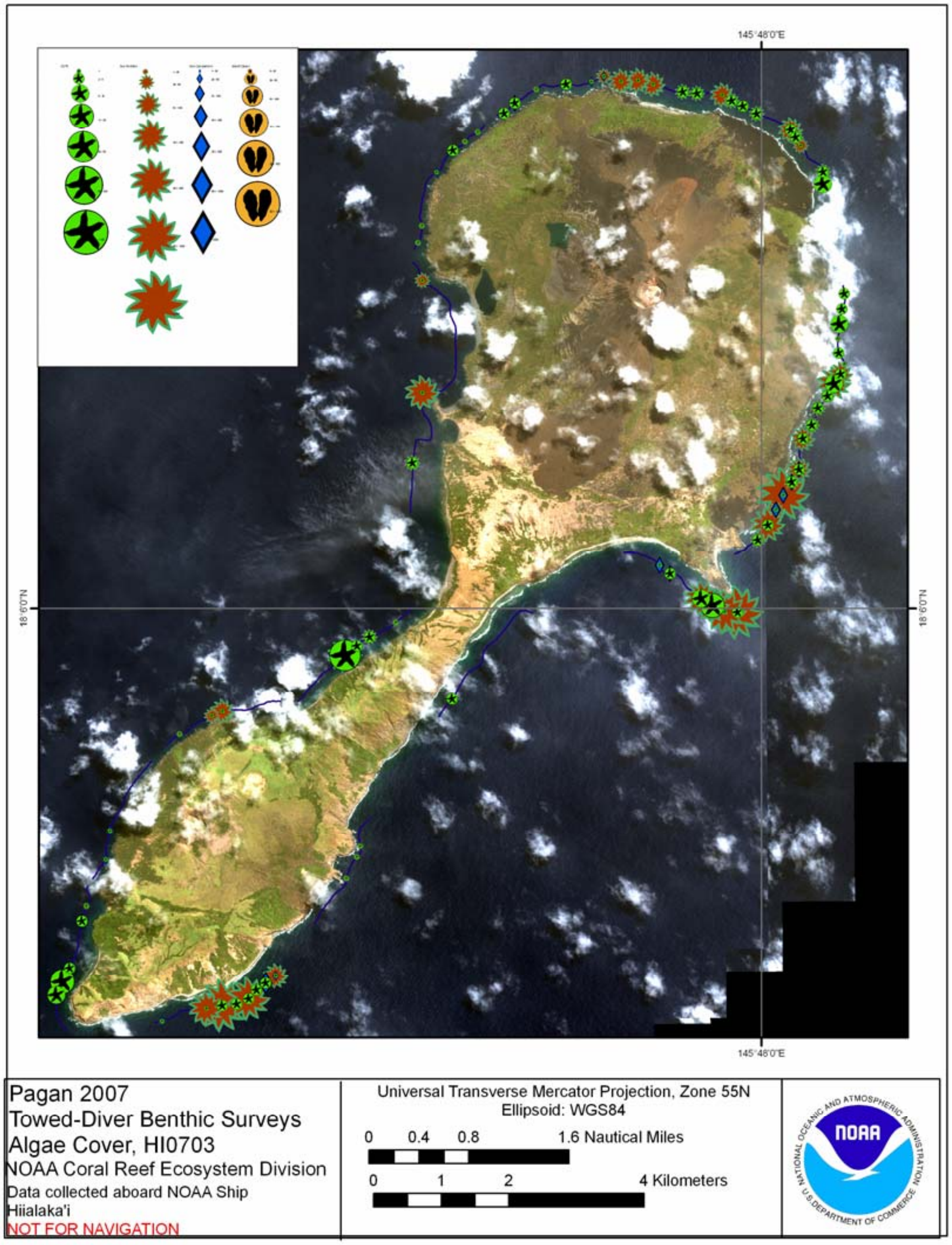


Figure G.4.3.1.2 Towed-diver macroinvertebrate observations at Pagan for HI0703.

The overall macroinvertebrate averages per survey for the island of Pagan were 1.5 COTs, 77.9 sea urchins, 16.9 sea cucumbers, and 0.7 giant clams. COTs were most abundant along the western spur and groove habitat of Pagan where an average of 4.5

individuals were recorded each segment. The northeastern area of the island also experienced high numbers of COTs, averaging 3.5 individuals per segment. Additionally, each survey area was the site of stressed hard corals. Sea urchins were the dominant macroinvertebrate along the continuous reef sections of the southeastern side of the island, where an average of 445.2 individuals were recorded per segment. High numbers were also recorded along the remainder of the east coast, as well as the western coast. Sea urchin averages were consistently above 100 individuals per segment. Sea cucumbers were most abundant along the north and eastern coastlines of Pagan. *Stichopus chloronutus* consistently averaged above 30 individuals per time segment with averages reaching as high as 42.6 individuals in the east. Giant clam numbers were low for the entire island. The highest numbers were recorded along the west coast where 16 individuals were recorded in a 50-minute survey.

G.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Pagan. The survey methods employed at each site and notable observations are summarized in Table G.4.3.2-1.

Table G.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Pagan.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
PAG-3	X	X		Forereef pavement. Low coral abundance, ample urchins. Triton eating *Acanthaster*. Carpet anemone. Bottle (plastic) on bottom.
PAG-12	X	X		Steeply sloping fore reef. Good coral cover on ridges, valleys less so. *Acanthaster* on *Millepora*. ~10 *Acanthaster* in shallows 15-30 ft.
PAG-5	X	X		Silty environment with moderate slope. Abundant *Echinothrix*.
PAG-9	X	X		Steeply sloping forereef. *Acabaria* and sclerosponges under overhangs. *Rumphella*.
PAG-11	X	X		"Dead" FCA dominated reef. *Acanthaster* present. Gradual slope, with large deep channels to "wall" of sorts.
PAG-6	X	X		Snorkel only. Divers reported abundant *Thelenota ananas*, *Holothura whitmaei*, *Pearsonothuria*, *Bohadschia*. *Echinothrix* (M. Tenorio obs.) Nice reef development at shoreline, collected soft corals. *Acanthaster* present.

Pagan

G.4.3.3 Opportunistic invertebrate collections

Acanthaster planci, *Linckia multiflora*, and *Holothuria atra* were collected at several locations around Pagan (Table G.4.3.3-1).

Table G.4.3.3-1: Opportunistic collections of *Acanthaster planci*, *Linckia multiflora*, and *Holothuria atra* around Pagan during HI0703.

Location	Date	Collector	Species	# of Samples	REA site	Site location	Habitat	Outbreak population	Depth-ft	Latitude	Longitude
Pagan	6/5/07	John Starmer	*Acanthaster planci*	6	12	NW Corner	Forereef	N	25	18.1664	145.7667
Pagan	6/7/07	John Starmer	*Acanthaster planci*	8	6		Forereef	N	50	18.0927	145.7440

G.5. Fish

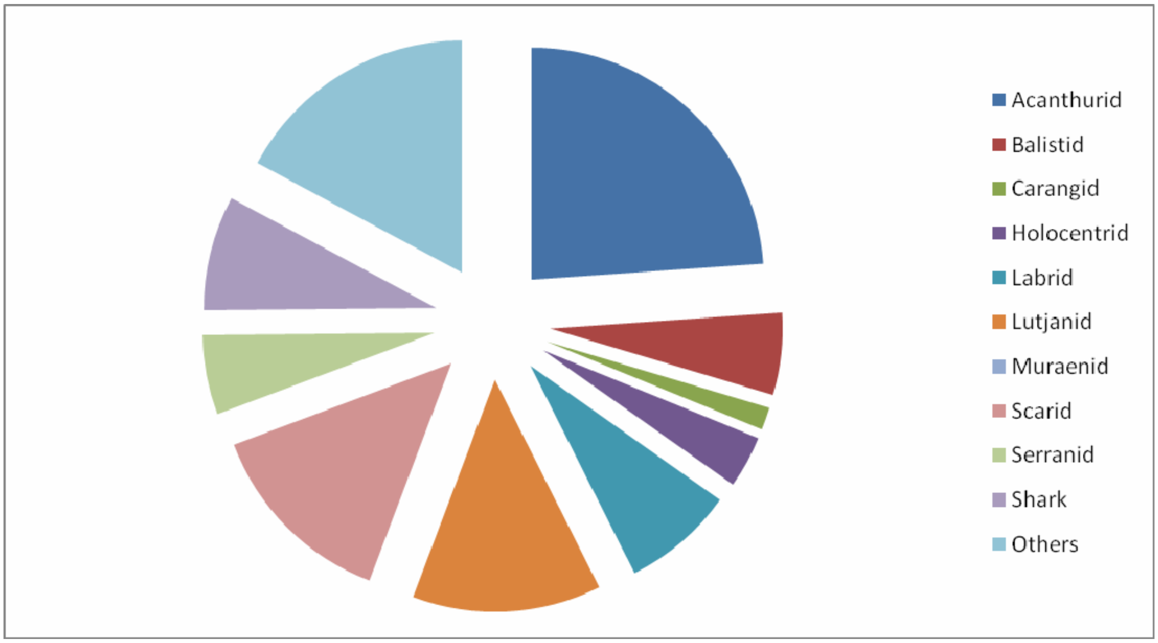
<u>G.5.1 REA Fish Surveys</u>

Stationary Point Count data
A total of 12 individual SPC surveys were conducted at 3 forereef sites around the island of Pagan. Snappers (Lutjanidae), and parrotfish (Scaridae) were most common on SPC surveys, yielding biomass of 0.07 and 0.05 ton per hectare, respectively.

Belt-Transect data
During the survey period, 9 belt-transect surveys were conducted at 3 forereef sites around the island of Pagan. Surgeonfish (Acanthurids) were the primary contributors to biomass with 0.10 ton per hectare, followed by snapper (Lutjanidae) and parrotfish (Scarids), each with 0.05 ton/ha. (Fig. G.5.1-1).

Overall observations
A total of 190 species were observed during the survey period by all divers. The average medium to large fish biomass at the sites in Pagan during the survey period was 0.51 ton/ha for the SPC surveys (Table G.5.1-1), and the average fish biomass was 0.40 ton/ha for the belt transect surveys (Table G.5.1-2).

Figure G.5.1-1 – Family composition of the total fish biomass (0.40 ton per hectare) around Pagan Island.



Pagan

Table G.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Pagan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
PAG-1	0.39	0.07	0.00	0.03	0.00	0.05	0.10	0.10	0.00	0.01	0.00	0.01
PAG-11	0.07	0.02	0.00	0.00	0.00	0.00	0.02	0.01	0.00	0.01	0.00	0.00
PAG-12	0.18	0.02	0.00	0.03	0.01	0.00	0.02	0.05	0.00	0.05	0.00	0.01
PAG-13	0.13	0.05	0.00	0.01	0.03	0.00	0.01	0.02	0.00	0.00	0.00	0.01
PAG-3	0.24	0.07	0.00	0.00	0.03	0.00	0.08	0.04	0.00	0.01	0.00	0.01
PAG-5	2.61	0.00	0.00	0.01	0.00	0.02	0.09	0.04	0.00	0.01	2.43	0.01
PAG-6	0.40	0.04	0.00	0.00	0.02	0.04	0.07	0.03	0.00	0.02	0.14	0.04
PAG-8	0.29	0.06	0.01	0.01	0.01	0.00	0.15	0.03	0.00	0.00	0.00	0.01
PAG-9	0.31	0.10	0.00	0.00	0.00	0.02	0.05	0.08	0.00	0.04	0.00	0.01
Average	0.51	0.05	0.00	0.01	0.01	0.01	0.07	0.04	0.00	0.02	0.29	0.01

Table G.5.1-2 – Total fish biomass around Pagan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
PAG-1	0.44	0.06	0.00	0.00	0.04	0.02	0.11	0.00	0.10	0.02	0.00	0.09
PAG-11	0.51	0.09	0.01	0.00	0.02	0.01	0.06	0.00	0.01	0.02	0.29	0.02
PAG-12	0.63	0.16	0.02	0.00	0.03	0.02	0.06	0.00	0.09	0.05	0.00	0.18
PAG-13	0.31	0.08	0.02	0.00	0.01	0.05	0.02	0.00	0.09	0.00	0.00	0.04
PAG-3	0.15	0.02	0.01	0.00	0.00	0.03	0.00	0.00	0.04	0.02	0.00	0.03
PAG-5	0.24	0.08	0.02	0.01	0.01	0.04	0.02	0.00	0.01	0.01	0.00	0.05
PAG-6	0.27	0.06	0.04	0.00	0.00	0.02	0.03	0.00	0.06	0.03	0.00	0.03
PAG-8	0.68	0.20	0.09	0.03	0.00	0.05	0.11	0.00	0.07	0.01	0.00	0.13
PAG-9	0.36	0.11	0.00	0.02	0.02	0.05	0.07	0.00	0.01	0.04	0.00	0.05
Average	0.40	0.10	0.02	0.01	0.01	0.03	0.05	0.00	0.05	0.02	0.03	0.07

G.5.2 Fish towed-diver surveys

At Pagan the Towboard team conducted 16 surveys totaling 33 kilometers in length and covering 33 hectares of ocean bottom. Mean survey length was 2.1 km. 8541 fish (>50 cm TL, all species spooled) were observed totaling 22 different species. Overall numeric density was 258.81 fish per hectare. Garden eels *(Conger sp.)* were by far the most abundant species seen and are not shown in Figure G.5.2-1. Aside from *Conger sp.*, Heller's barracuda (*Sphyraena helleri*), twinspot snapper (*Lutjanus bohar*), black and white snapper (*Macolor niger*), redlip parrotfish (*Scarus rubroviolaceus*) and pink whiprays (*Himantura fai*) were the five most commonly observed species (>50 cm TL) at Pagan during the survey period (Table G.5.2-1).

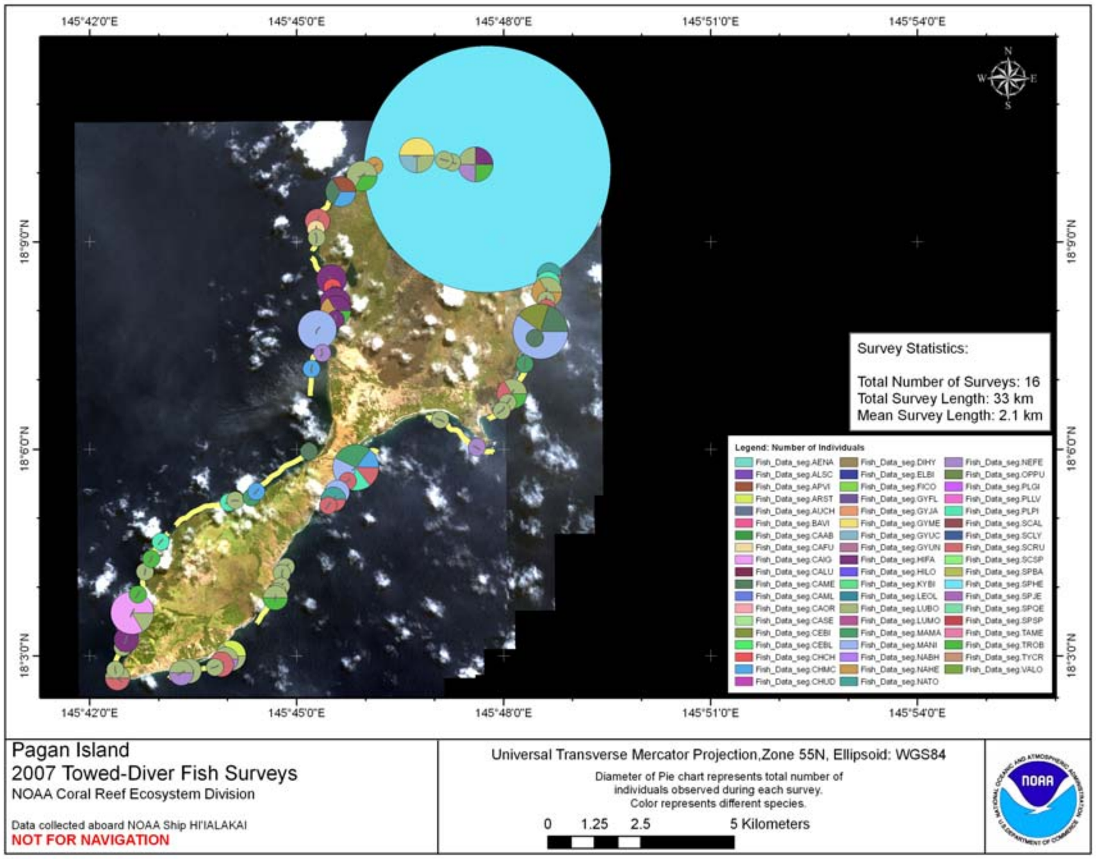


Figure G.5.2-1. Distribution of Large Fish Observations at Pagan.

Table G.5.2-1. Total number of individuals of each species observed at Pagan.

Island	Taxon Name	#
Pagan	Conger sp.	8200
	Sphyraena helleri	200
	Lutjanus bohar	42
	Macolor niger	23
	Scarus rubroviolaceus	14
	Himantura fai	12
	Triaenodon obesus	7
	Caranx melampygus	5
	Plectorhinchus picus	5
	Nebrius ferrugineus	5
	Caranx ignobilis	5
	Chlorurus microrhinos	4
	Naso hexacanthus	4
	Macolor macularis	4
	Centropyge bispinosa	2
	Gymnothorax meleagris	2
	Naso tonganus	2
	Chanos chanos	1
	Gymnosarda unicolor	1
	Aprion virescens	1
	Carangoides fulvoguttatus	1
	Arothron stellatus	1
Pagan Total		8541

Appendix H: Agrihan

H.1. Benthic Habitat Mapping

Agrihan (also called Agrigan) Island is located at ~18º 46'N, 145º 40'E and is approximately 57 nmi south of Asuncion Island and 40 nmi north of Pagan Island. Its location on nautical chart 81086_8 corresponds well to observations from HI0703.

Multibeam mapping surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars.   The ship transited to and worked at Agrihan on May 28-29, 2007 (JD 148-149) and the *AHI* was deployed on May 29, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~20 m and 250 m, and the *Hi'ialakai* collected data down to about 2100 m around the island. Multibeam data were also collected during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the previous data were collected primarily to the west of the island chain.   The multibeam data collected around Agrihan represents approximately 40% of the 2511 km^2 (roughly 1000 km^2) of HI0703 coverage around the central section of the Mariana Archipelago, which includes both Agrihan and Pagan.

Agrihan is an active volano that last erupted in 1917 (Trusdell et al., 2005). The size of the island is approximately 5.5 by 3.6 nmi and below sea level there is a narrow shelf between 25 and 35 m where mass wasting has not obscured the feature. The submarine flanks are incised by channels and canyons, the largest of which are present on the north side of the volcano. Large blocks of material are present on all sides of the volcano and the largest of these blocks are associated with the canyons on the northern side. The majority of the blocks are probably related to mass wasting. A small, flat-topped edifice on the northwest flank of Agrihan reaches depths of 480 m and may be volcanic in origin.

Reference:

Trusdell, F.A., Moore, R.B., Sako, M., White, R.A., Koyanagi, S.K., Chong, R., and Camacho, J.T. 2005. The 2003 eruption of Anatahan volcano, Coomonwealth of the Northern Mariana Islans; Chronology, volcanology, and deformation. Journal of Volcanology and Geothermal Research, v. 146, p. 184-207.

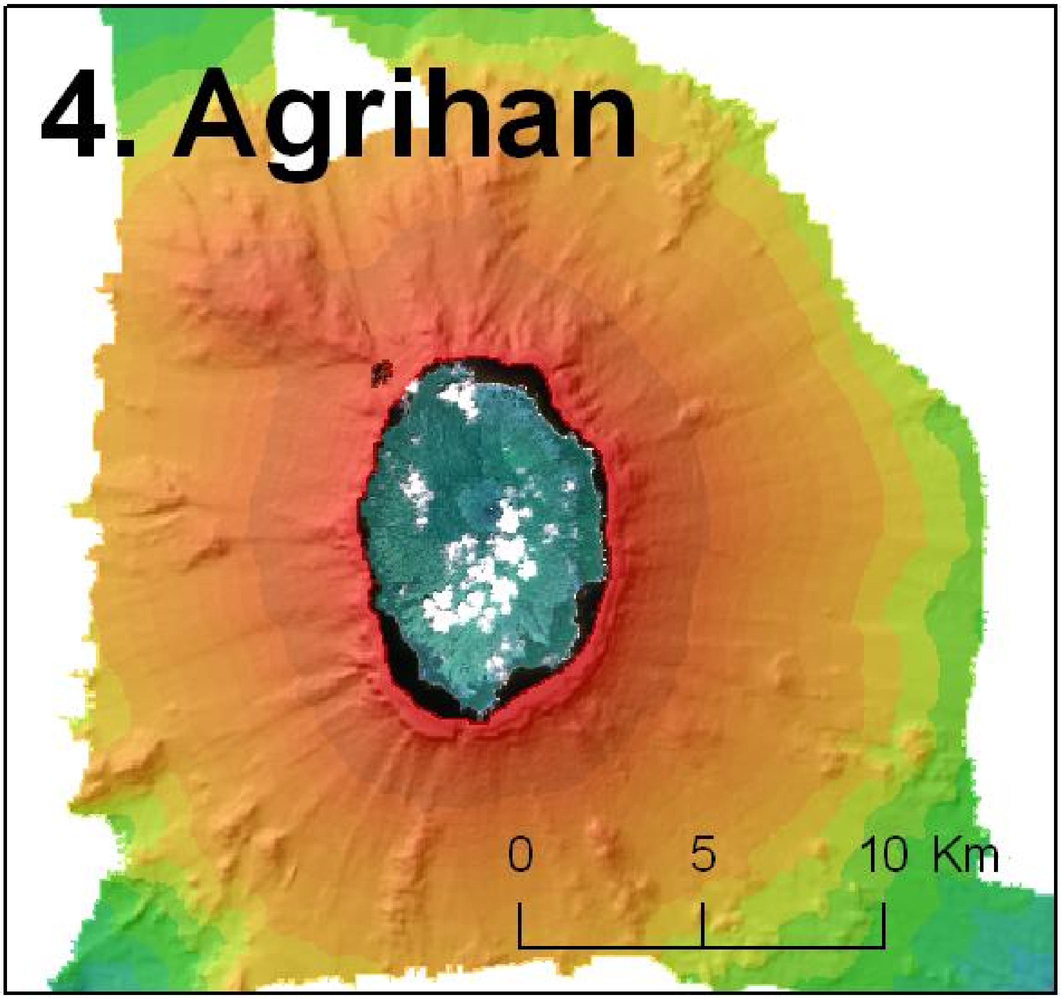


Figure H.1-1: Multibeam bathymetric data collected during HI0703 around Agrihan Island.

H.2. Oceanography and Water Quality

In total, one subsurface temperature recorder (STR) was recovered and replaced at Agrihan during HI0703. (Figure H.2-1)

Fifteen shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter of Agrihan at approximately 1.6-km intervals following the 30-m contour. At three of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1m, 10m, 20m and 30m depths, for a total of 28 discrete water samples measuring chlorophyll and nutrient concentrations. (Figure H.2-1).

In situ temperature data at 1.5 m obtained from October 2005 to June 2007 shows seasonal variability with warm temperatures observed from June to November and cooler temperatures from January to April (Figure H.2-2). The seasonal transition between winter-time and summer-time temperatures occurs rather abruptly at Agrihan, particularly in April/May 2005 when a 3 °C temperature increase is observed in less than a 3-week period.

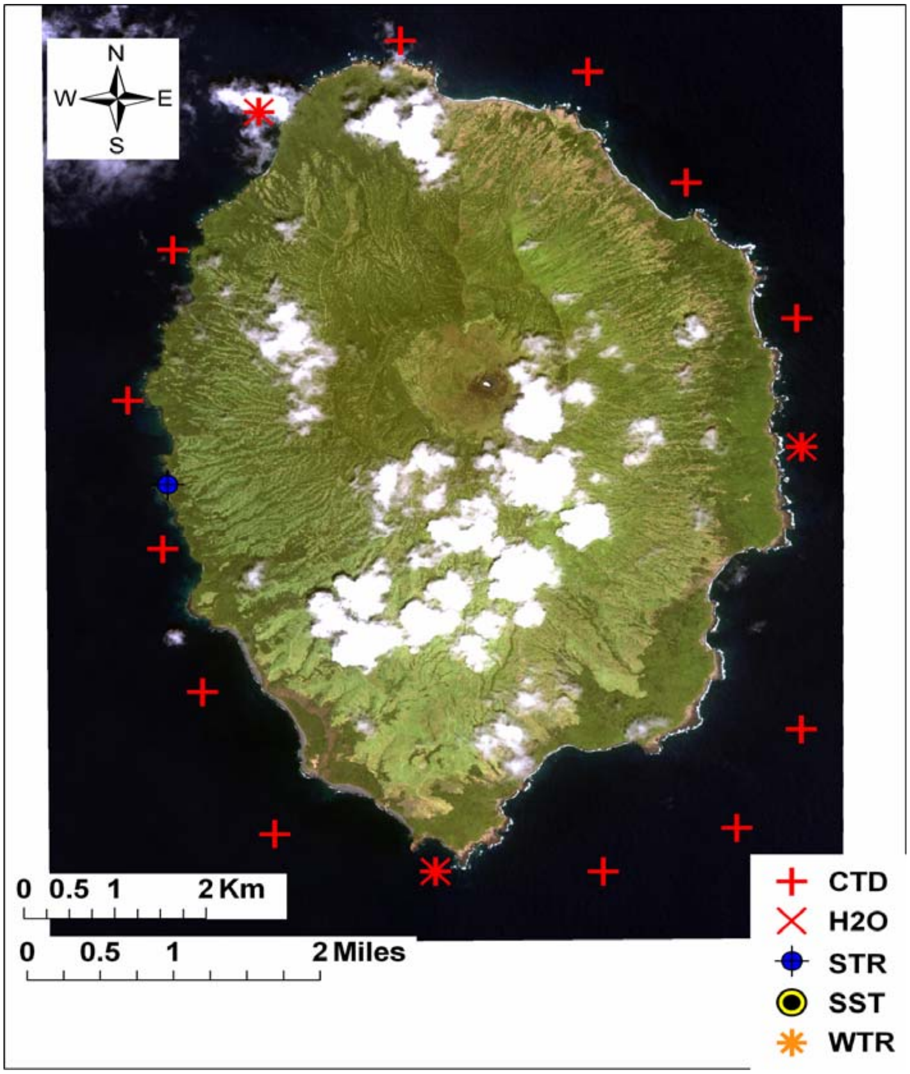


Figure H.2-1: Positions of CTDs, water samples and moorings at Agrihan.

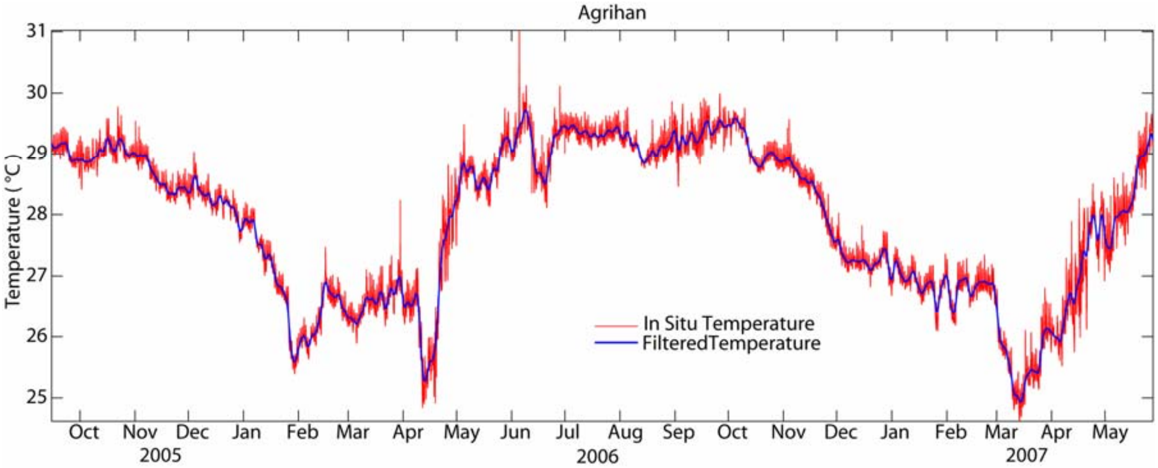


Figure H.2-2: *In situ* temperature at 1.5 m from October 2005 to June 2007. The red line is data sampled at a 30-minute interval; the blue line is a 7-day mean.

H.3 Rapid Ecological Assessment (REA) Site Descriptions

Three to five people inhabit Agrihan throughout the year. Fishing pressure, however, is minimal on this island. The Northern Island Mayors Office (NIMO) contracts a private vessel to transport supplies and people to this island as needed.

REA surveys were conducted at three sites at Agrihan (Table C.3-1). Locations of all REA sites around Agrihan are shown in Figure H.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table H.3-1. Sites surveyed by REA team at Agrihan, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.

Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, °C
AGR2	5/29/2007	18	43.608	145	39.792	12 - 13	15.8	28.9
AGR1	5/29/2007	18	44.879	145	41.669	12 - 14	15.8	29.4
AGR4	5/29/2007	18	48.467	145	38.959	11 - 13	17.4	29.4

Agrihan

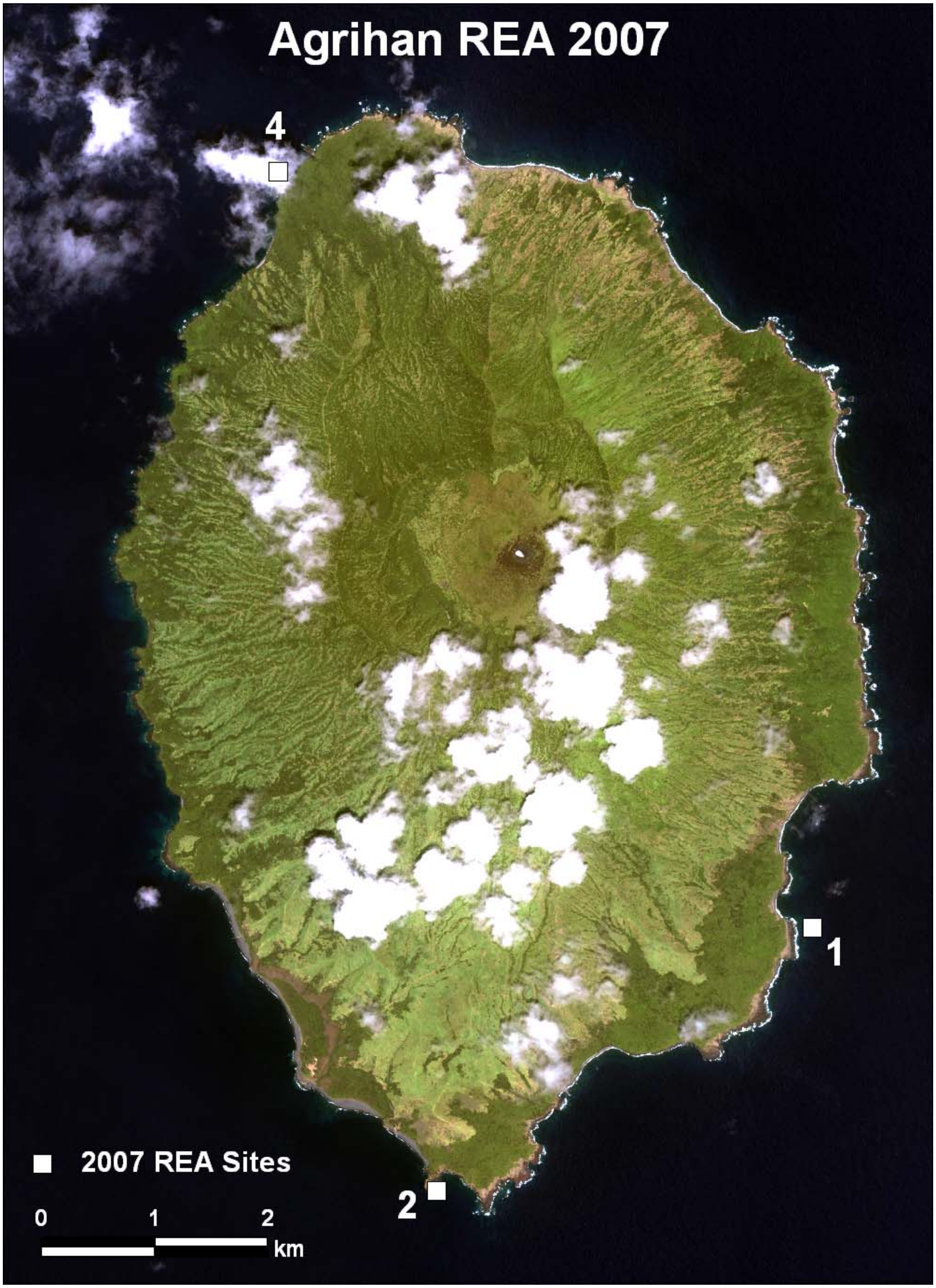


Figure H.3-1. Location of 2007 REA survey sites at Agrihan.

AGR-2
May 29, 2007
South leeward side, transect depth range: 12–13 m. Aggregate relief; large boulders with coral colonies on volcanic sediment. Moderately high percent live coral cover (38.2%). Abundant *Astreopora*, and Montipora. Turf-algae comprised nearly 31%. Within the survey area (300 m^2), two cases of growth anomalies were detected; one on *Astreopora*, and the other one on a colony of *Lobophytum*. The dominant algal categories (up to a rank average of 4) on this site were turf algae, *Neomeris*, encrusting Corallinaceae, *Padina*, cyanobacteria, and *Haematocelis*.

AGR-1
May 29, 2007
East windward side, transect depth range: 12–14 m. Aggregate relief; pavement with well-developed coral colonies. Moderately low coral cover (17.6%). Abundant alcyonarian corals: *Sinularia*, *Sarcophyton* and *Lobophytum*. Basalt boulders and carbonate pavement covered with turf-algae comprised over 49% and siliciclastic sand represented nearly 14% of benthos. Within the survey area (300 m^2), one case discoloration was observed on *Astreopora*. Several cases of pallor were detected on *Platygyra* and numerous cases of bite scars on *Astreopora*. The dominant algal categories (up to a rank average of 4) on this site were turf algae, *Halimeda*, encrusting Corallinaceae, and *Haematocelis*.

AGR-4
May 29, 2007
North leeward side, transect depth range: 11–13 m. Forereef with well-developed coral colonies; aggregate relief with basalt boulders and carbonate buildups; spurs and gullies. Moderately high percent live coral cover (36.3%). Basalt boulders and carbonate pavement and buildups covered on turf-algae comprised over 45% of benthic cover. One case of growth anomaly was detected on *Acropora* cf. *robusta*, one case of white syndrome on *Goniastrea* cf. *edwardsi*, and one case of yellow band on Coscinaraea of mild bleaching were observed; two on *Echinopora* and one on *Platygyra*. Additionally, one case of encrusting sponge overgrowth on *Goniopora* was observed. The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting Corallinaceae, *Haematocelis*, and cyanobacteria tufts.

H.4. Benthic environment

H.4.1. Algae

Algal species were surveyed and collected at three sites around Agrihan.

Table H.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table H.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table H.4.1-3. Specimens collected at Agrihan in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Cyanobacteria (AGR01-004)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Cyanobacteria (AGR02-001)	AGR02; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Tolypiocladia sp. (AGR04-001)	AGR04; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X			
Corallinaceae sp. (AGR01-006)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29				X	
Corallinaceae sp. (AGR01-007)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29				X	
Pterocladiella large (AGR01-009)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Peyssonnelia sp. (AGR01-008)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29				X	
Actinotrichia fragilis (AGR01-005)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Dichotomaria marginata (AGR01-003)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Gelidiopsis sp. (AGR04-001)	AGR04; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X			
Chrysymenia ornata (AGR01-002)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Chlorophyceae sp. (AGR02-001)	AGR02; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X			
Caulerpa crassifolia (AGR01-001)	AGR01; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Caulerpa nummularia (AGR04-002)	AGR04; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X	X		
Dictyosphaeria sp. (AGR04-001)	AGR04; Agrihan, CNMI, Mariana Islands; collection date: 2007_05_29		X			

H.4.1.2 Benthic towed-diver surveys – Macroalgae

The average macroalgae and coralline algae cover for Agrihan were both recorded at 9% (range 0 – 62.5% and 0 – 30%, respectively). The highest macroalgae cover was recorded during a survey along the northeastern coastline (average 22%, range 1.1 – 62.5%), where the habitat was predominantly rock ridges with boulders in between that quickly changed to boulders on sand. Macroalgae coverage (especially *Liagora* and *Padina* species) increased dramatically towards the ending segments of the survey. The highest coralline algae cover (average 21%, range 10.1 – 30%) was recorded during the survey in the northwest, where terrain was predominantly composed of continuous reef with ridges (some with very high vertical relief and depth changes) and occasional boulder fields.

H.4.2. Corals

H.4.2.1 Coral Populations

Coral Diversity and Population Parameters

Three sites were surveyed on Agrihan (AGR-1, AGR-2, and AGR-4). AGR-2 had the most substantial coral growth dominated by massive, branching, and columnar corals: *Goniastrea edwardsi, Heliopora coerula, Favia stelligera, Leptoria phrygia, and Astreopora*. This site has shown recovery in colony size and community evenness since 2003, recovery from bleaching (2000/01) and *Acanthaster planci* (2003/4) that led to a more positively skewed colony size distribution. AGR-1 had a similar community as AGR-2, however small colony sizes have remained intact since 2003, suggesting conditions are not favorable for growth to occur. AGR-4 consists of large boulders with substantial reef deposits within. Many large, unconsolidated coral skeletons remain with modern communities very similar to the AGR-2 site.

H.4.2.2 Percent Benthic Cover

The line-intercept methodology quantified a total of 306 points along 150 m of forereef coral communities and the patterns of intra-island variability in percent benthic cover are reflected in Figure H.4.2.2-1. Mean percent live coral cover for all sites combined was moderately high 30.7 ± 6.6% (mean ± SE). Highest coral cover was recoded at site AGR-2 (38.2%) on the south-facing shore; lower percent coral cover (17.6%) was encountered as sites AGR-1 on the eastern side of the island. Basalt boulders and carbonate pavement covered with sand turf-algae comprised over 41.8% of the benthic cover, and sand represented over 16.3% of the benthos. A total of 14 scleractinian genera and one hydrocoral (*Millepora*) and one stony octocoral (*Heliopora*) were enumerated along the point-count transects, with *Astreopora* being the most numerically abundant scleractinian (29.1 ± 14.2%), followed by *Favia* (12.5 ± 6.3%), and *stylophora* (11.7%). Figure H.4.2.2-2 illustrates the contribution of the different scleractinain genera to the total percent live coral cover. Outside the survey transect lines, however, a total of 30 scleractinian genera were enumerated.

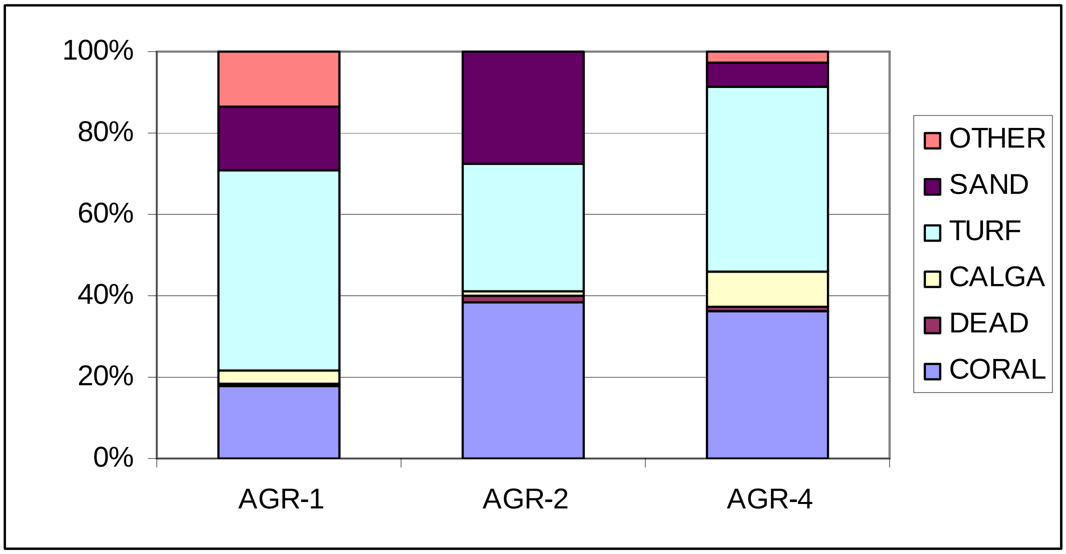


Figure H.4.2.2-1 Mean percent cover of selected benthic elements derived from 3 independent REA surveys at Agrihan, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; MALGA: fleshy macroalgae; CALGA: crustose coralline algae; TURF: turf-algae covered basalt boulders and carbonate buildups; RUBLE: coral rubble (including recent and old coral rubble covered with turf-algae); SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats.

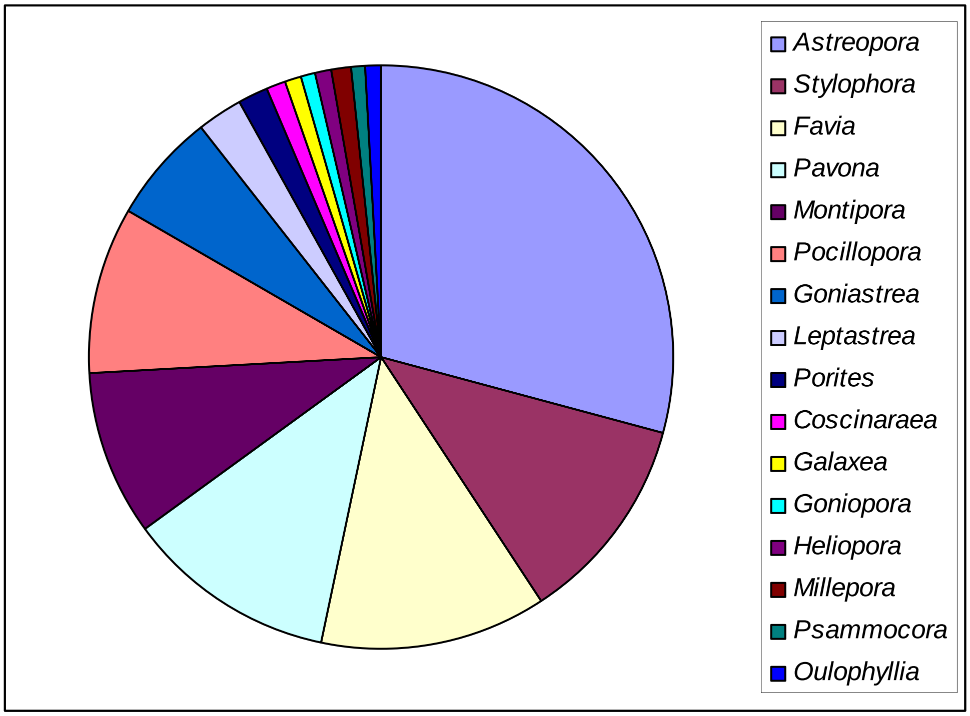


Figure H.4.2.2-2 Percent contribution of the different coral genera to the total live coral cover at Agrihan Island, MAR-RAMP 2007.

H.4.2.3 Coral Disease

Overall occurrence of disease was low. A total of 6 cases were enumerated for all the survey areas combined. We observed one case of mild bleaching on *Platygyra*, two cases of growth anomalies on *Acropora* cf *robusta* and *Astreopora*, one case of white syndrome on *Goniastrea* cf. *edwardsi*, one case of discoloration on *Astreopora*, and one case of sponge overgrowth on *Coscinaraea*. In addition numerous cases of fish bite scars were observed on *Astreopora*. No predation scars by *Acanthaster* were noted at any of the sites visited.

H.4.2.4 Benthic towed-diver surveys – Corals

The average hard coral cover for Agrihan was recorded at 11% (range 0 - 75%), with stressed coral averaging 1% (range 0 - 20%). The highest overall coral cover recorded during a single towed-diver survey was noted in the northwest, with an average of 27% coral cover (range 5.1 – 50%). The area was composed of continuous reef with ridges (some with very high vertical relief and depth changes) and occasional boulder fields, which eventually evolved towards the end of the survey into a boulder field/gravel flat. 3/10 of segments recording 30.1 – 40% cover, and 1 segment recording 40.1 – 50% cover. Both *Pocillopora* and encrusting corals were noted (in 5/10 and 3/10 segments, respectively).

Coral stress was highest along the west side (average 4%, range 0 – 20%), where COT predation was evident throughout the survey, although only 6 COTs were recorded during the 50-minute tow.

An extensive area of COT scarring was recorded during the safety stop of a towed-diver survey in the southeast, in the vicinity of N18 45.874, E145 42.080. An estimated 100+ COTs were observed within the line of sight.

The area of the highest soft coral cover was noted during towed-diver surveys in the southeast and northeast, averaging 7% cover (range 0.1 – 40% and 1.1 – 30%, respectively). During the survey in the southeast, the survey diver noted that soft coral cover was high during the first two time segments (30.1 – 40% and 20.1 – 30%, respectively), with *sinularia* and *sarcophytum* species dominating. The northwestern survey recorded similar soft coral cover.

H.4.3 Macroinvertebrates

H.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

The overall macroinvertebrate averages per survey for the island of Agrihan were 0.37 *Acanthaster planci* (COTs), 8.75 sea urchins, 0.12 sea cucumbers, and 0.73 giant clams. COTs were evenly distributed from the northwest to southern side of the island with a total of 18 recorded. COT predation was evident by the elevated levels of stressed hard corals where the COTs were observed. The same area hosted the largest number of sea cucumbers, although only 6 individuals were recorded in all surveys. Sea urchin numbers were high along the northern coast of the island in comparison to the rest of the island. The habitat was characterized as pavement reef, which provides a good substrate for the boring urchins. Giant clams were most abundant on the west side of the island, numbering 25, while very few individuals were recorded elsewhere.

H.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Agrihan. The survey methods employed at each site and notable observations are summarized in Table H.4.3.2-1.

Table J.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Agrihan.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
AGR-2	X	X	X	High numbers of *Linkia multiflora*. *Klyxum* abundant.
AGR-1	X	X	X	High diversity of soft corals, *Lobophytum*, *Sinularia*, *Sarcophyton*.
AGR-4	X	X		*Linkia multiflora* abundant. Transects again ended at (just short of) *Porites rus* reef. *Sinularia* colonies showed evidence of die back and recovery based on exposed lithified bases.

H.4.3.3 Opportunistic invertebrate collections

Linckia multiflora was collected at two locations around Agrihan (Table H.4.3.3-1).

Table H.4.3.3-1: Opportunistic collections of *Linckia* multiflora around Agrihan during HI0703.

Location	Date	Collector	Species	# of Samples	REA site	Site location	Habitat	Outbreak population	Depth-ft	Latitude	Longitude
Agrihan	5/29/07	John Starmer	*Linckia multiflora*	11	2		Forereef	N	30	18.7268	145.6632
Agrihan	5/29/07	John Starmer	*Linckia multiflora*	7	4		Forereef	N	40	18.8078	145.6493

H.5. Fish

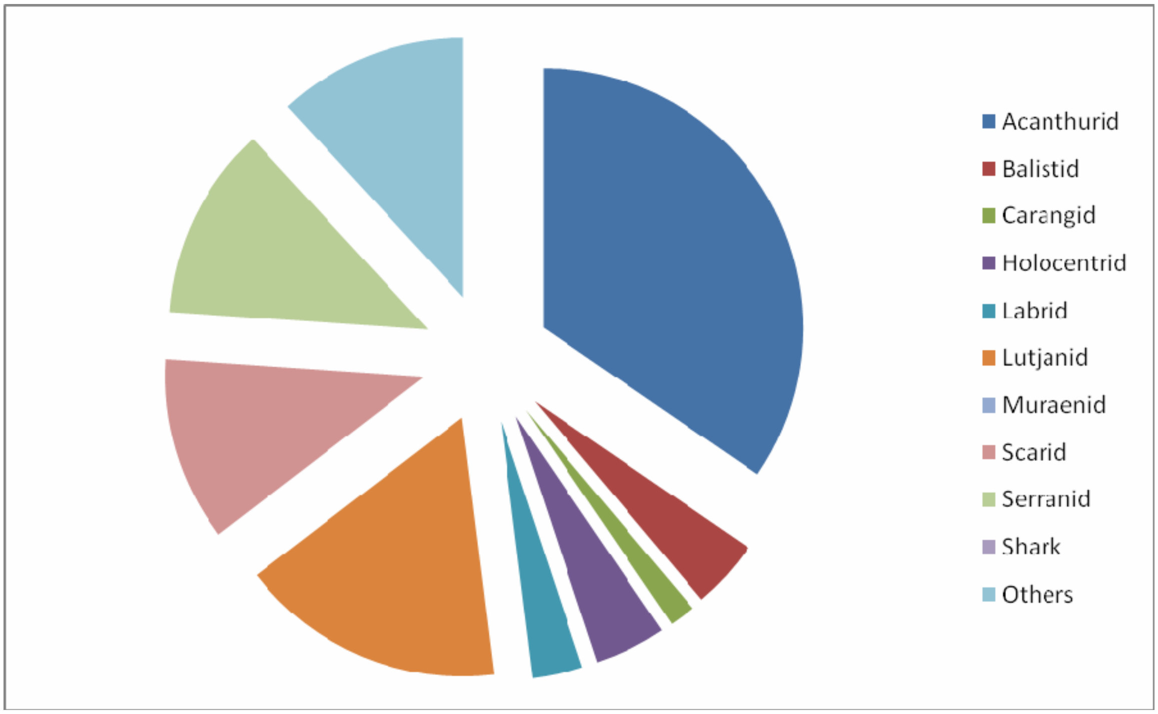
H.5.1 REA Fish Surveys

Stationary Point Count data
A total of 12 individual SPC surveys were conducted at 3 forereef sites around the island of Agrihan. Parrotfishes (Scaridae) were the largest contributor to biomass with 0.06 ton per hectare, followed by grouper (Serranidae) with 0.04 tons/ha.

Belt-Transect data
During the survey period, 9 belt-transect surveys were conducted at 3 forereef sites around the island of Agrihan. Surgeonfish (Acanthurids) and snapper (Lutjanidae) were the primary contributors to biomass with 0.13 and 0.06 ton per hectare, respectively. (Fig. H.5.1-1).

Overall observations
A total of 112 species were observed during the survey period by all divers. The average medium to large fish biomass at sites around Agrihan during the survey period was 0.51 ton/ha for the SPC surveys (Table H.5.1-1), and the average fish biomass was 0.36 ton/ha for the belt transect surveys (Table H.5.1-2).

Figure H.5.1-1 – Family composition of the total fish biomass (0.36 ton per hectare) around Agrihan Island.



Agrihan

Table H.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Agrihan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
AGR-1	0.17	0.02	0.00	0.00	0.01	0.00	0.03	0.07	0.00	0.02	0.00	0.01
AGR-2	0.86	0.09	0.00	0.01	0.00	0.04	0.09	0.07	0.00	0.07	0.47	0.01
AGR-4	0.50	0.04	0.01	0.06	0.02	0.02	0.18	0.04	0.01	0.02	0.08	0.03
Average	0.51	0.05	0.00	0.02	0.01	0.02	0.10	0.06	0.00	0.04	0.18	0.02

Table H.5.1-2 – Total fish biomass around Agrihan Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
AGR-1	0.19	0.04	0.02	0.00	0.00	0.01	0.00	0.00	0.08	0.03	0.00	0.02
AGR-2	0.25	0.07	0.01	0.00	0.02	0.01	0.01	0.00	0.04	0.04	0.00	0.04
AGR-4	0.64	0.27	0.01	0.02	0.03	0.01	0.17	0.00	0.00	0.06	0.00	0.07
Average	0.36	0.13	0.02	0.01	0.02	0.01	0.06	0.00	0.04	0.04	0.00	0.04

H.5.2 Fish towed-diver surveys

At Agrihan the Towboard team conducted 6 tows totaling 13 kilometers in length and covering 13 hectares of ocean bottom. Mean survey length was 2.17 km. One-thousand two-hundred eighteen fish (>50 cm TL, all species spooled) were observed totaling 15 different species. Overall, numeric density was 93.69 fish per hectare. Garden Eels *(Conger sp.)* were by far the most numerous species and are not shown in Figure H.5.2-1. Apart from garden eels, bigeye trevally (*Caranx sexfasciatus*), gray reef sharks (*Carcharhinus amblyrhynchos*), twinspot snapper (*Lutjanus bohar*), sleek unicornfish (*Naso hexacanthus*) and midnight snapper (*Macolor macularis*) were the five most commonly observed species (>50 cm TL) at Agrihan during the survey period (Table H.5.2-1).

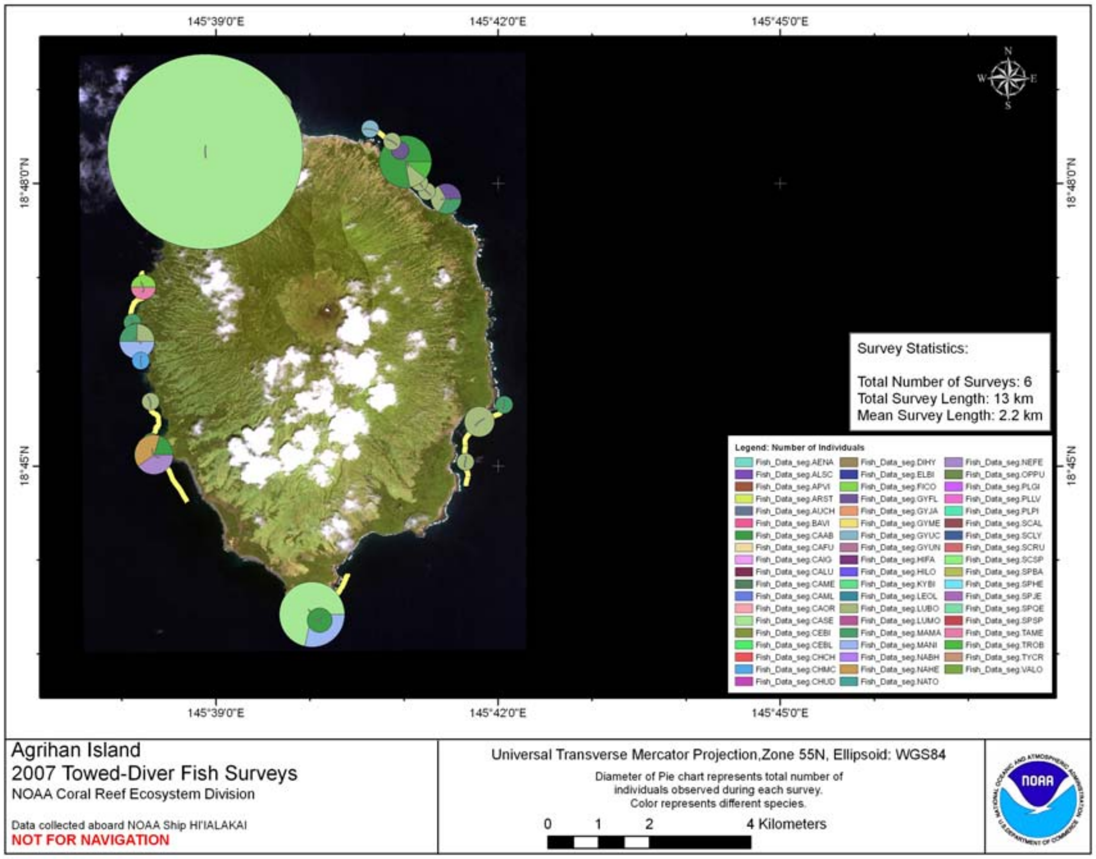


Figure H.5.2-1. Distribution of Large Fish Observations at Agrihan.

Table H.5.2-1. Total number of individuals of each species observed.

Island	Taxon Name	#
Agrihan	Conger sp.	1000
	Caranx sexfasciatus	135
	Carcharhinus amblyrhynchos	29
	Lutjanus bohar	17
	Naso hexacanthus	8
	Macolor macularis	8
	Macolor niger	6
	Triaenodon obesus	3
	Nebrius ferrugineus	3
	Gymnosarda unicolor	3
	Gymnothorax flavimarginatus	2
	Fistularia commersonii	1
	Caranx lugubris	1
	Chlorurus microrhinos	1
	Taeniura meyeni	1
Agrihan Total		1218

Appendix I: Asuncion

I.1. Benthic Habitat Mapping

Asuncion Island is centered at ~19º 40’N, 145º 24’E and is located approximately 21 nmi south of Maug Island and 58 nmi north of Agrihan Island. The location on nautical chart 81086_3 is approximately 1.5 nmi south of the position observed during HI0703.

Multibeam mapping surveys were conducted using the R/V *AHI*’s Reson 8101ER and the *Hi’ialakai’s* EM300 multibeam sonars. The ship transited to and worked at Ascuncion on June 3-4, 2007 (JD 154-155) and the *AHI* was deployed around Asuncion deployed on June 4, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~10 m and 250 m, and the *Hi’ialakai* collected data down to about 1400 m. Multibeam data were collected on the eastern side of the chain during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the existing data were collected primarily to the west of the island chain. The multibeam data collected around Ascunsion represents approximately 20% of the 3856 km^2 (roughly 750 km^2) of HI0703 coverage around the northern section of the Mariana Arc, which includes Uracas, Maug, and Ascunsion Islands and Supply Reef.

Asuncion is classified as an active volcano by Bloomer *et al.* (1989) and it last erupted in 1906 (Trusdell et al., 2005). It is the highest of the islands in the northern Mariana Archipelago, rising to 857 m although it is only about 1.7 nmi wide (EW) and 1.9 nmi long (NS). The emergent slopes are extremely steep with extensive evidence of mass wasting, particularly on the eastern slides where minor landslide activity was observed during R/V *AHI* surveys at the island. A small bank is present on the southwest side of the island, extending approximately 1 nmi offshore with depths ranging from 20 to 110 m. As opposed to the narrow submarine channels that characterize the flanks of other active volcanoes in the Marianas, well-developed canyons are present on the western half of the Asuncion submarine slope. The canyons walls extend down to ~1000 m.

References:

Bloomer, S.H., Stern, R.J. and Smooth N.C. 1989. Physical volcanology of the submarine Mariana and Volcano Arcs. Bulletin of Volcanology, p. 210-224.

Trusdell, F.A., Moore, R.B., Sako, M., White, R.A., Koyanagi, S.K., Chong, R., and Camacho, J.T. 2005. The 2003 eruption of Anatahan volcano, Coomonwealth of the Northern Mariana Islans; Chronology, volcanology, and deformation. Journal of Volcanology and Geothermal Research, v. 146, p. 184-207.

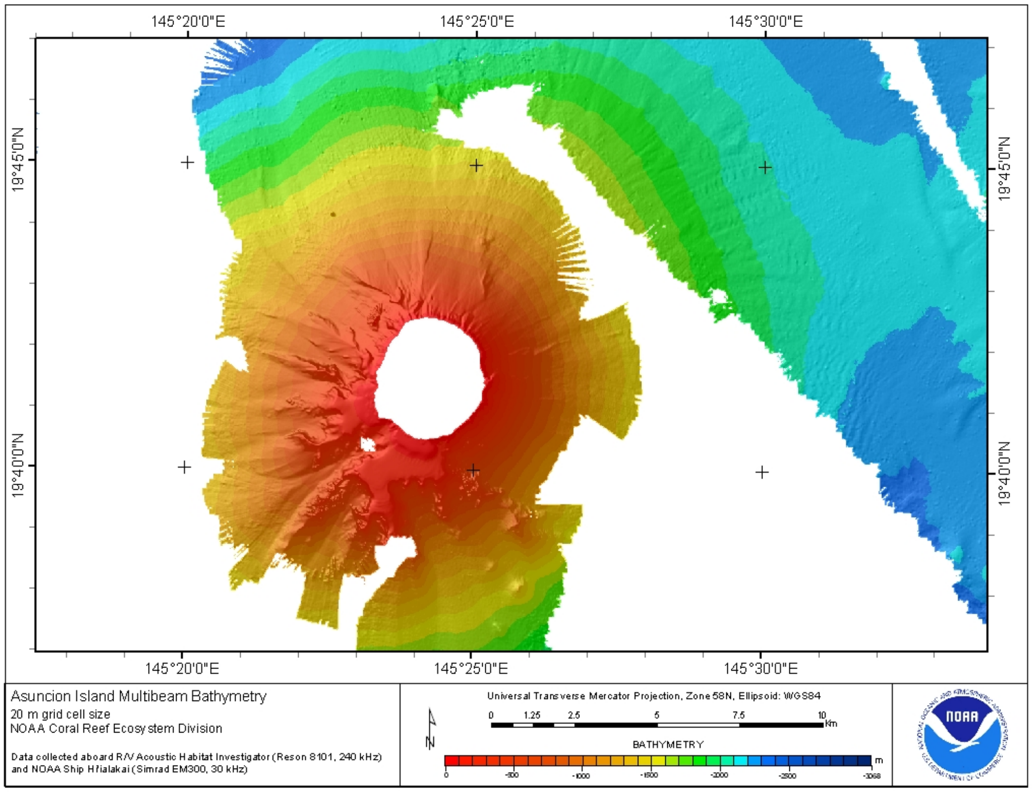


Figure I.1-1: Multibeam bathymetric data collected during HI0703 around Asuncion Island.

I.2. Oceanography and Water Quality

In total, one subsurface temperature recorder (STR) instrument was recovered and replaced at Ascuncion during HI0703; however, no data appears to have been recorded on the instrument. (Figure I.2-1)

Twelve shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter of Ascuncion at approximately 0.8 km intervals following the 30-m contour. At four of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depths, for a total of 32 discrete water samples measuring chlorophyll and nutrient concentrations (Figure I.2-1).

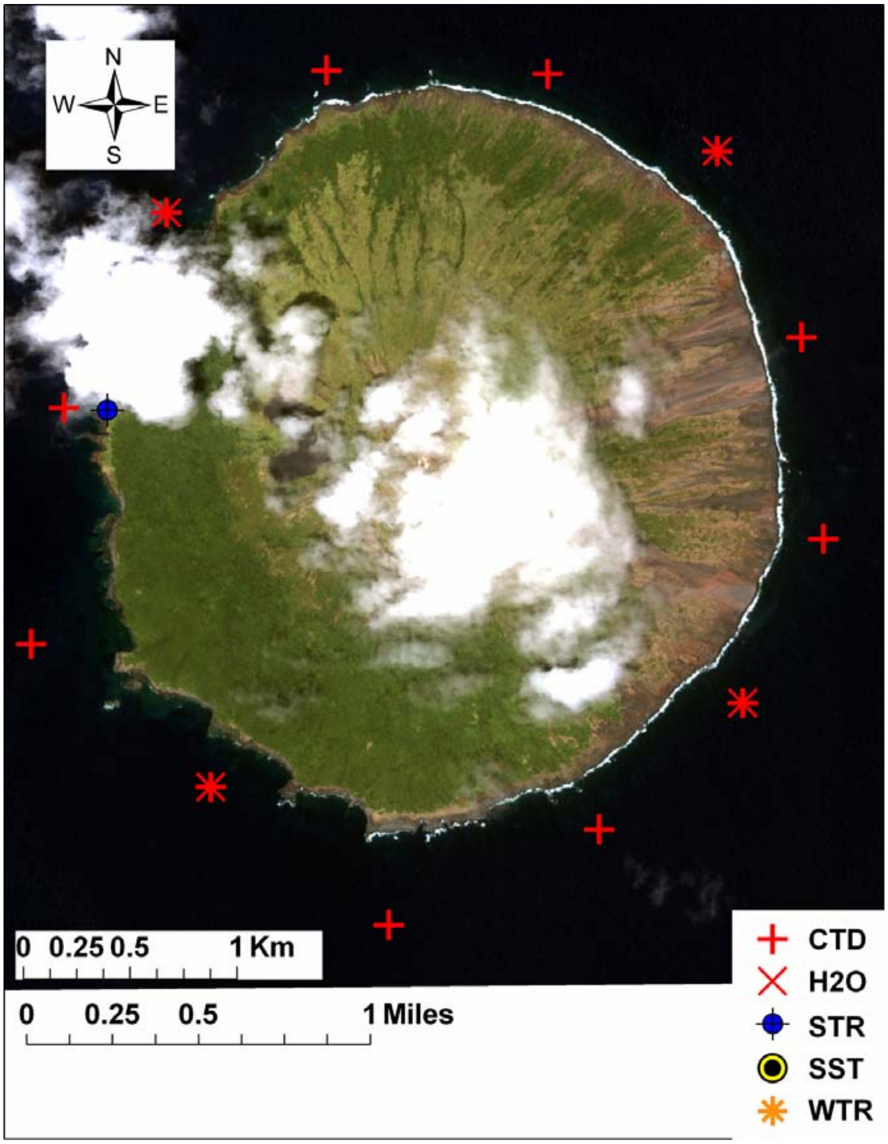


Figure I.2-1: Positions of CTDs, water samples and moorings at Asuncion.

I.3 Rapid Ecological Assessment (REA) Site Descriptions

Asuncion is constitutionally designated as a terrestrial reserve, and access is allowed through permit only. Legislation was drafted to include the waters surrounding the island down to 1 kilometer as a no-take marine protected area. Minimal fishing activity occurs in the waters of this island.

REA surveys were conducted at three sites at Asuncion (Table I.3-1). Locations of all REA sites around Asuncion are shown in Figure I.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table I.3-1. Sites surveyed by REA team at Asuncion, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.								
Site #	**Date**	**Latitude (north)**		**Longitude (east)**		**Transect depth range, m**	**Max Depth, m**	**Temp, °C**
ASU-1	6/4/2007	19	42.003	145	25.046	11 - 13	15.8	28.9
ASU-2	6/4/2007	19	40.834	145	23.516	11 - 13	21.3	28.3
ASU-3	6/4/2007	19	42.151	145	23.621	12 - 13	18.3	28.9

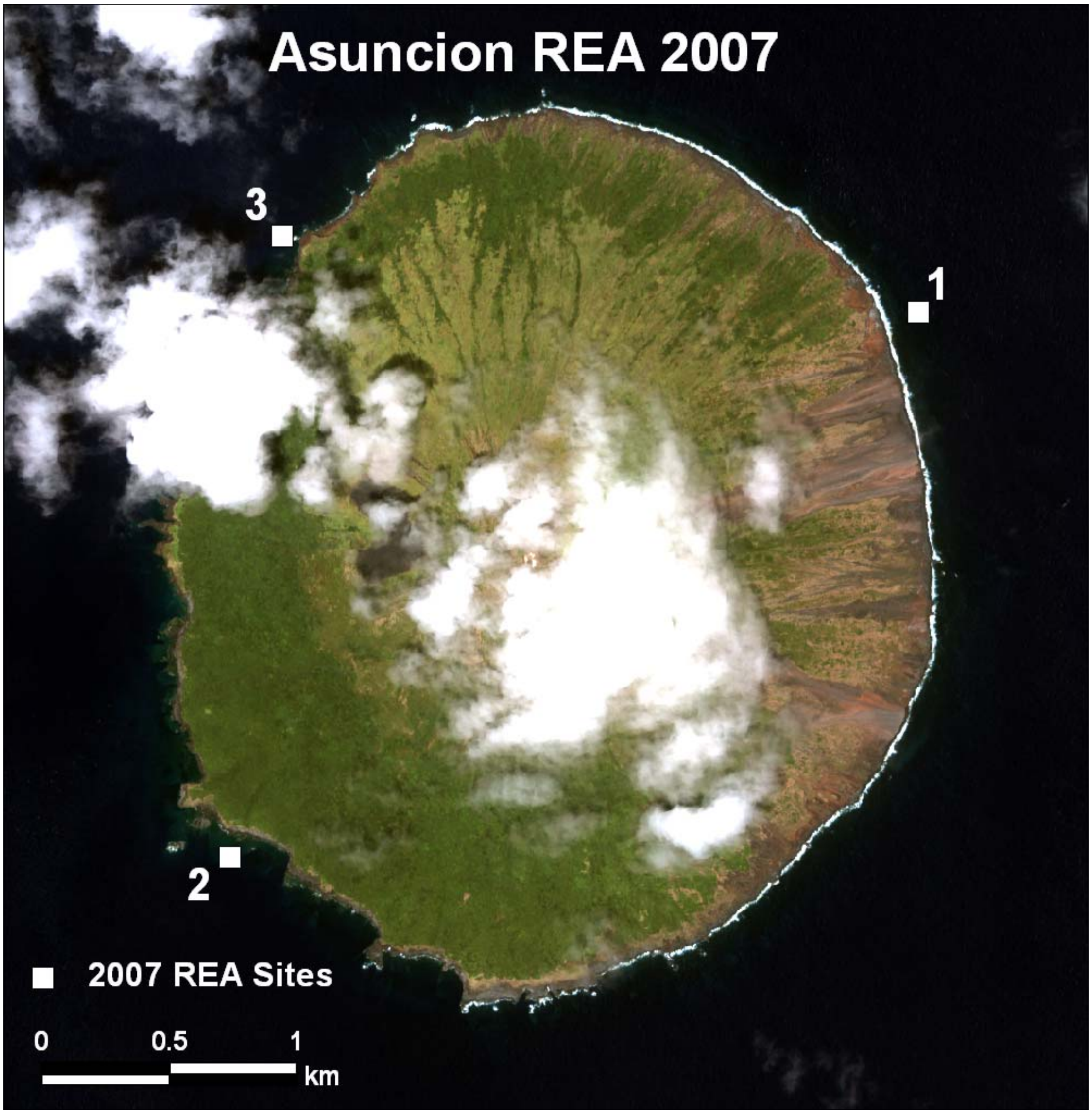


Figure I.3-1. Location of 2007 REA survey sites at Asuncion.

Asuncion

ASU-1

June 4, 2007

East windward side. Transect depth range: 11–13 m. Relief composed of basalt boulders intermingled with siliciclastic sand. Low percent live coral cover (8.8%). Turf-algae over rock comprised >85% of bottom cover. Within the survey area (300 m^2) numerous cases of dark discolorations were observed on colonies of *Cyphastrea*, *Pavona varians*, *Favia*, *Psammocora*, and *Favites* cf. *pentagona*. It is not clear whether this condition represents a disease state or perhaps a response to local environmental conditions. Voucher samples were collected for further histological examination. Mainly turf and encrusting algae. The dominant algal categories (up to a rank average of 4) on this site were turf algae, Jania, encrusting *Lobophora*, encrusting Peyssonnelia, Padina, encrusting Corallinaceae, and Neomeris.

ASU-2

June 4, 2007

Southwest leeward side. Transect depth range: 11–13 m. Transects started on an aggregate reef, went over a large groove, and ended along a steep wall. Relief composed of basalt boulders and carbonate pavement. Moderately low percent live coral cover (12.7%). Encrusting red algae comprised nearly 40% of the live cover. One case of coralline lethal orange disease was observed within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were encrusting Corallinaceae, turf algae, encrusting *Peyssonnelia*, *Halimeda*, *Ventricaria*, cyanobacteria, and encrusting *Lobophora*.

ASU-3

June 4, 2007

Northwest leeward side. Transect depth range: 12–13 m. Aggregate relief; boulders on volcanic sand, limited coral development. Moderate percent live coral cover (25.5%). Dead coral and basalt boulders covered by turf algae comprised >60% of bottom cover. Two cases of skeletal growth anomalies were observed on *Porites*. Additionally, 25 cases of *Acanthaster* predation were enumerated within the survey area (300 m^2). The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting Corallinaceae, encrusting *Lobophora*, and *Caulerpa*.

I.4. Benthic environment

I.4.1. Algae

Algal species were surveyed and collected at three sites around Asuncion.

Table I.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table I.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table I.4.1-3. Specimens collected at Asuncion in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Laurencia sp. (ASU03-002)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X			
Jania sp. (ASUXX-001)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X			
Peyssonnelia sp. (ASUXX-001)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X			
Chrysymenia sp. (ASU03-005)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X	X		
Dictyopteris sp. (ASU02-001)	ASU02; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X			
Lobophora sp. (ASUXX-001)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X			
Caulerpa filicoides (ASU03-001)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X	X		
Caulerpa velasquezii (ASU03-004)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X	X		
Halimeda fragilis (ASU03-003)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X	X		
Rhipidosiphon sp. (ASU02-001)	ASU02; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X	X		
Tydemania expeditionis (ASUXX-001)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X			
Valonia sp. (ASUXX-001)	ASU03; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X			
Boodlea composita (ASU02-002)	ASU02; Asuncion, CNMI, Mariana Islands; collection date: 2007_06_04		X	X		

I.4.1.2 Benthic towed-diver surveys – Macroalgae

Macroalgae and coralline algae cover at Asuncion averaged 19% and 10% (range 1.1 – 62.5% and 0 – 40%, respectively). The highest macroalgae cover was recorded during a survey along the northern coastline (average 43%, range 30.1 – 62.5%). Large patches of *Padina* were noted throughout the survey, often involving a mixture of *Liagora*. Another species which was common in other towed-diver surveys along the northeast/eastern coastline and southwestern to northwestern coastline was *Caulerpa filicoides*, especially along the wall sections of the spurs/ridges. The highest coralline algae cover (average 21%, range 5.1 – 20%) was located during the survey completed between the southwestern to northwestern section of the coast.

I.4.2. Corals

I.4.2.1 Coral Populations

Coral Diversity and Population Parameters

Three sites were surveyed on Asuncion (ASU-1, ASU-2, and ASU-3). ASU-1 consists of large volcanic boulders and sand, with minimal coral growth consistently found since 2003. ASU-2 has a large reef terrace development with modern communities consisting mainly of *Leptoria phrygia*, *Heliopora coerula*, *Goniastrea edwardsi*, and many smaller colonies of *Astreopora*, *Pocillopora*, *Pavona*, and *Favia*. Interestingly, the site has changed little since 2003 in terms of its coral size class frequency distribution and species relative abundances. ASU-3 is considered the most favorable location for modern growth with large *Pocillopora*, *Acropora*, *Millepora*, and *Porites* present. Little change was noted between 2003 and 2005; however, the recent emergence of *Acanthaster planci* sometime prior to our 2007 survey has led to declines in the above noted coral abundance.

I.4.2.2 Percent Benthic Cover

The line-intercept methodology quantified a total of 306 points along 150 m of forereef coral communities and the patterns of intra-island variability in percent benthic cover are reflected in Figure I.4.2.2-1. REA site ASU-1 was comprised of basalt boulders intermingled with sand patches, with a few scattered coral colonies growing on the basal masses. REA site ASU-2 surveyed part of a vertical wall, mainly covered by encrusting red algae with prominent population of zoanthids. REA site ASU-3 surveyed a fringing reef with aggregate relief, composed mainly of *Goniastra*, *Favia stelligera*, and *Acropora palifera*. The point-count surveys indicated that percent live coral cover was the greatest at site ASU-where it attained a value of 25.5%. Mean percent live coral cover for the three sites combined amounted to 15.7 ± 5.1 (mean ± stder). Other important benthic components included: encrusting coralline algae and turf algae over basalt boulders, particularly at site ASU-1. A total of 11 scleractinian genera, one hydrocoral (*Millepora*) and one stony octocoral (*Heliopora*) were enumerated along the point-count transects, with *Porites* being the most numerically abundant scleractinian (21.5 ± 12.2%), followed by *Cyphastrea* ~11%, and *Goniopora* 10%. Outside the survey transect lines, however a total of 23 different scleractinian genera and one hydrocoral and one octocoral were enumerated (see Table I.4.2.2-1)

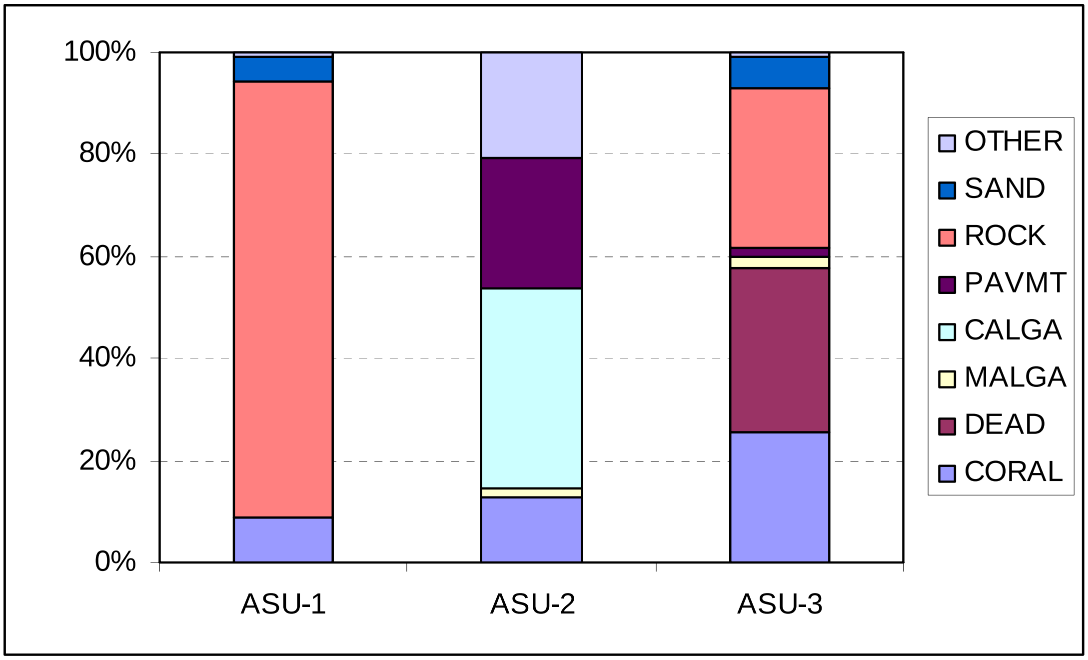


Figure I.4.2.2-1 Mean percent cover of selected benthic elements derived from 3 independent REA surveys at Asuncion, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; MALGA: macroalgae; CALGA: calcareous coralline and red algae; PAVMT: carbonate pavement covered with turf algae; ROCK: turf-algae covered basalt boulders; PAVMT: turf-algae covered carbonate pavement; SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats.

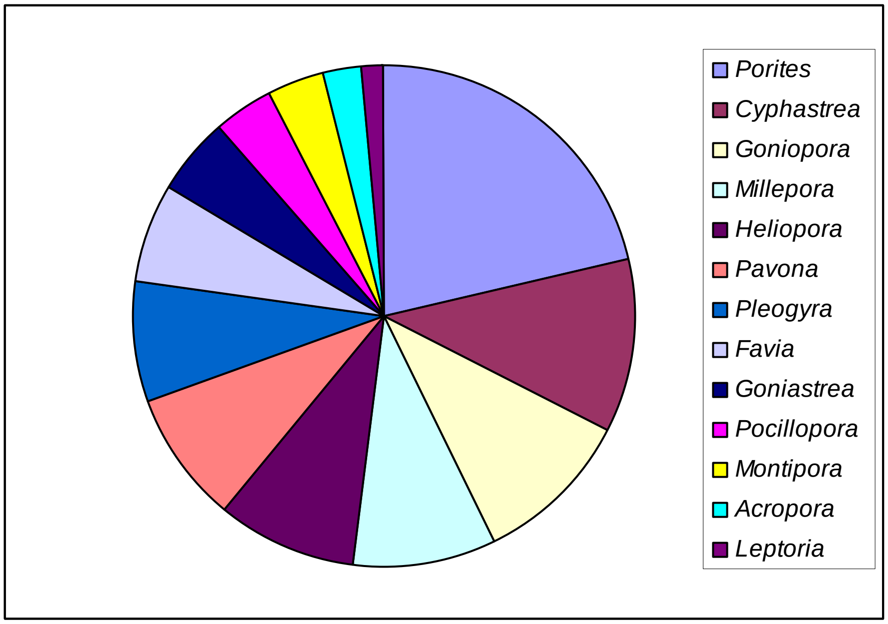


Figure I.4.2.2-2 Percent contribution of the different coral genera to the total live coral cover at Asuncion Island, MAR-RAMP 2007.

Asuncion

Table I.4.2.2-1 list scleractinian, hydrocoral, and stony octocoral genera enumerated at Asuncion Island during the 2007 REA surveys.

Acanthastrea	*Gardineroseris*	*Pavona*
Acropora	*Goniastrea*	*Platygyra*
Astreopora	*Goniopora*	*Pleasiastrea*
Astreopora	*Heliopora*	*Pleogyra*
Coscinaraea	*Hydnophora*	*Pocillopora*
Cyphastrea	*Lepotoria*	*Porites*
Echinopora	*Leptastrea*	*Psammocora*
Euphyllia	*Leptoseris*	*Scapophyllia*
Favia	*Lobophyllia*	*Stylophora*
Favites	*Millepora*	*Turbinaria*
Fungia	*Montastrea*	
Galaxea	*Montipora*	

I.4.2.3 Coral Disease

At site ASU-1 numerous cases of dark discolorations were observed on colonies of *Cyphastrea*, *Pavona varians*, *Favia*, *Psammocora*, and *Favites* cf. *pentagona*. It is not clear whether this condition represents a disease state or perhaps a response to local environmental conditions. Voucher samples were collected for further histological examination. At REA site ASU-2 only one case of coralline lethal orange disease was observed. Comparatively, at site ASU-3 two cases of skeletal growth anomalies were detected on colonies of *Porites*; also, 25 cases of *Acanthaster* predation were noted mainly on colonies of *Goniastrea edwardsi*, *Acropora palifera*, *Favia stelligera*, as well as on *Favites* cf *pentagona*, *Leptoria phrygia*, *Pocillopora* sp. and *Stylophora* sp. Additionally within this area surveyed five specimens of *Acanthaster* were observed. Reports from the Oceanography and Towed-diver teams also indicated elevated densities of corallivorus starfishes in the vicinity of this site.

I.4.2.4 Benthic towed-diver surveys – Corals

The average hard coral cover for Asuncion was recorded at 16% (range 1.1 - 50%), with stressed coral averaging 2% (range 0 - 20%). The highest overall coral cover recorded during a single towed-diver survey was noted in a survey completed between the southwestern to northwestern section of the coast, with an average of 28% coral cover (range 20.1 – 50%). The area was composed of high-relief spur-and-groove habitat which dominated the survey, with the exception of a coral-dominated area at the beginning of the tow. Coral cover was highest, with numbers up to 50%, in the first segment of the tow. Eight of 10 segments included coral cover of above 20%.

Coral stress was highest in the same area (average 6%, range 0.1 – 20%), where a cumulative total of 25 COTs were recorded during the 50-minute survey. In a previous survey along the southwestern coastline, coral stress ranged from 0 to 10%, with COT predation noted in time segments 4 and 7-10. A more extensive area of COT predation was seen outside of the transect line, in the vicinity of N19 40.813, E145 23.414. Divers returned to the area later in the day to collect COT arm samples (21 individuals) for future mtDNA analyses.

The area of the highest soft coral cover was noted during a towed-diver survey from the east to southeastern section of coastline, averaging 10% cover (range 1.1 – 30%). *Sinularia* was common along the pavement stretches in shallower water (35 feet and shallower).

I.4.3 Macroinvertebrates

I.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

The overall macroinvertebrate averages per survey for the island of Asuncion were 0.7 COTs, 15.5 urchins, 0.3 cucumbers, and 1.3 clams. Twenty-five COTs were recorded along the western side of the island where coral gardens and spur-and-groove habitat was the dominant terrain. Stressed hard coral was also recorded along this section of abundant COTs, although stress levels only exceeded 10% during one segment. Eight additional individuals were recorded in the remaining four surveys at Asuncion. The highest concentration of sea urchins occurred along the southeastern side of the island where an average of 50 individuals were recorded every time segment. The remaining southern coastline also hosted comparatively high sea urchin numbers, averaging 25 individuals per segment. Sea cucumbers were most abundant along the western side of the island with the COTs, although numbers were low. An average of 1.3 cucumbers were recorded every time segment along this survey. Giant clams were most abundant along the boulder habitat of the southwestern side of the island, although present in all areas except the north. The northern reefs of Asuncion hosted no macroinvertebrates.

I.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Asuncion. The survey methods employed at each site and notable observations are summarized in Table I.4.3.2-1.

Table I.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Asuncion.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
ASU-1	X	X	X	Large boulders (~6-10 ft. dia), and coarse sand. Good sponge variety. Wood fibreglass float retreived with fouling organisms just after leaving site to ASU-2.
ASU-2		X	X	Forereef to wall (30-70+ ft.) Nondescript for inverts. Sediment sample (65ft). No belts as transects were laid on wall, with benthos at approximately 80 ft. depth. Diver retrieved part of large mesh net fouled on bottom.
ASU-3	X	X		Steeply sloping forereef. *Colobocentrotus*, *Coralliophilids*, limpets intertidal. *Acanthaster* in abundance in localized area down to ~50 ft.

I.4.3.3 Opportunistic invertebrate collections

Acanthaster planci specimens were collected at several locations around Asuncion (Table I.4.3.3-1).

Table I.4.3.3-1: Opportunistic collections of *Acanthaster planci* around Asuncion during HI0703.

Location	Date	Collector	Species	# of Samples	REA site	Site location	Habitat	Outbreak population	Depth-ft	Latitude	Longitude
Asuncion	6/4/07	J. Asher	*Acanthaster planci*	21		W. Side	Forereef	Y	80 - 100	19.6802	145.3897
Asuncion	6/4/07	Danny Merritt	*Acanthaster planci*	21		W. Side	Forereef	Y	50	19.7032	145.3937
Asuncion	6/4/07	John Starmer	*Acanthaster planci*	7	3	W. Side	Forereef	Y	40	19.7025	145.3937

I.5. Fish

I.5.1 REA Fish Surveys

Stationary Point Count data
A total of 12 individual SPC surveys were conducted at 3 forereef sites around the island of Asuncion. Jacks (Carangids) dominated the SPCs yielding biomass of 0.26 ton per hectare, followed by snapper (Lutjanids) at 0.10 ton/ha.

Belt-Transect data
During the survey period, 9 belt-transect surveys were conducted at 3 forereef sites around the island of Asuncion. Jacks (Carangids) also dominated the biomass in belt transects with 0.91 ton/ha, followed by snappers (Lutjanids), parrotfish (Scarids), and surgeonfish (Acanthurids) with 0.20, 0.12, and 0.10 ton per hectare, respectively. (Fig. I.5.1-1).

Overall observations
A total of 140 species were observed during the survey period by all divers. The average medium to large fish biomass at the sites in Asuncion during the survey period was 0.63 ton/ha for the SPC surveys (Table I.5.1-1), and the average fish biomass was 1.89 ton/ha for the belt transect surveys (Table I.5.1-2).

Figure I.5.1-1 – Family composition of the total fish biomass (1.89 ton per hectare) around Asuncion Island.

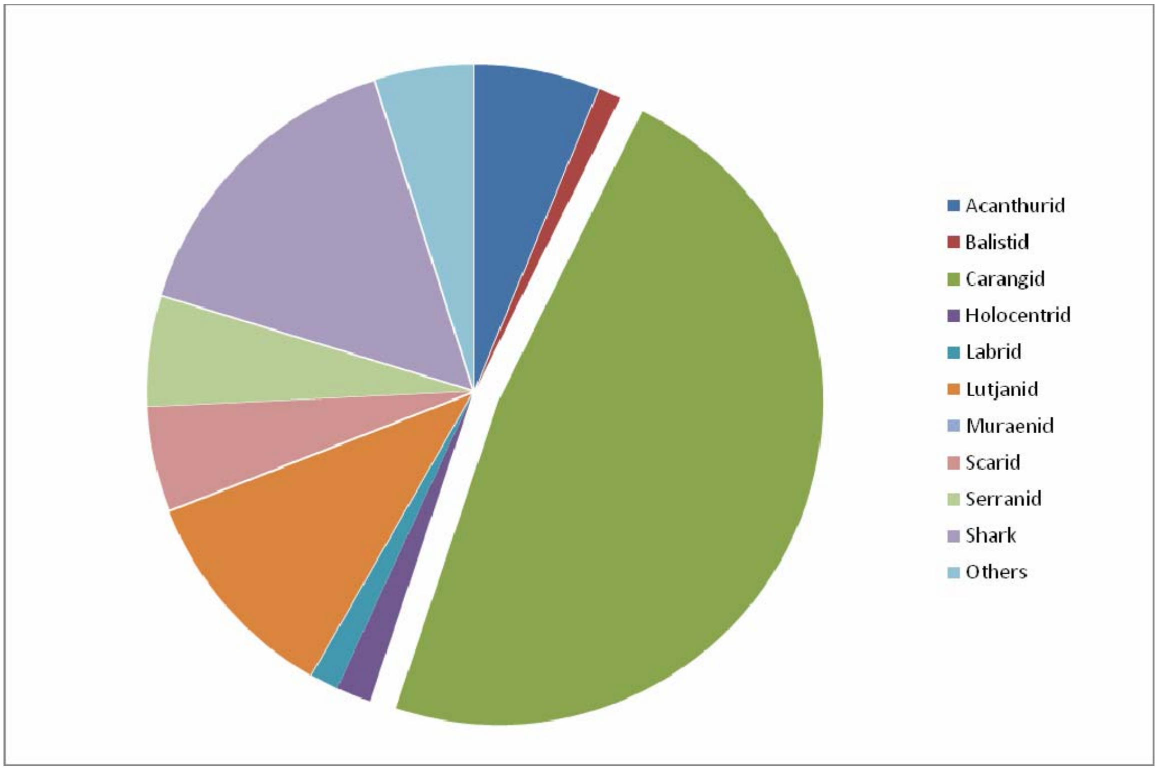


Table I.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Asuncion Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
ASU-1	0.74	0.07	0.02	0.02	0.00	0.00	0.14	0.04	0.00	0.01	0.42	0.03
ASU-2	0.98	0.06	0.00	0.74	0.01	0.01	0.07	0.07	0.00	0.02	0.00	0.00
ASU-3	0.16	0.00	0.00	0.02	0.03	0.00	0.07	0.00	0.01	0.02	0.00	0.01
Average	0.63	0.04	0.01	0.26	0.01	0.00	0.10	0.03	0.00	0.02	0.14	0.01

Table I.5.1-2 – Total fish biomass around Asuncion Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
ASU-1	0.49	0.10	0.00	0.02	0.02	0.01	0.29	0.00	0.01	0.03	0.00	0.02
ASU-2	4.68	0.17	0.03	2.67	0.06	0.03	0.32	0.00	0.22	0.17	0.87	0.14
ASU-3	0.50	0.09	0.04	0.03	0.02	0.03	0.01	0.00	0.06	0.11	0.00	0.12
Average	1.89	0.12	0.02	0.91	0.03	0.03	0.20	0.00	0.10	0.10	0.29	0.09

I.5.2 Fish towed-diver surveys

At Ascuncion the Towboard team conducted 5 surveys totaling 11 kilometers in length and covering 11 hectares of ocean bottom. Mean survey length was 2.2 km. One-hundred sixty-nine fish (>50 cm TL, all species spooled) were observed totaling 20 different species. Overall numeric density was 15.36 fish per hectare. Black and white snapper (*Macolor niger*), sleek unicornfish (*Naso hexacanthus*), twinspot snapper (*Lutjanus bohar*), gray reef sharks (*Carcharhinus amblyrhynchos*), and midnight snapper (*Macolor macularis*) were the five most commonly observed fish species (>50 cm TL) at Ascuncion during the survey period (Table I.5.2-1).

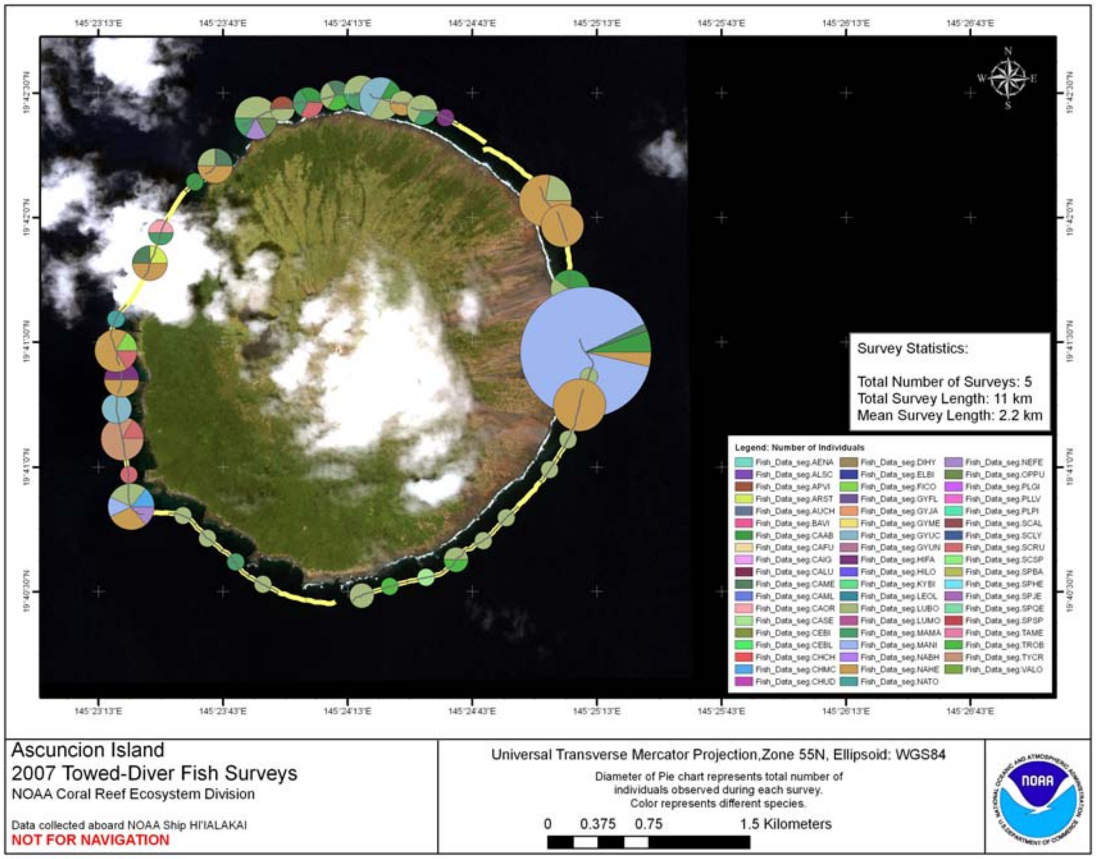


Figure I.5.2-1. Distribution of Large Fish Observations at Ascuncion.

Table I.5.2-1. Total number of individuals of each species observed at Ascuncion.

Island	Taxon Name	#
Asuncion	Macolor niger	51
	Naso hexacanthus	40
	Lutjanus bohar	29
	Carcharhinus amblyrhynchos	8
	Macolor macularis	6
	Gymnosarda unicolor	6
	Tylosurus crocodilus	5
	Scarus rubroviolaceus	4
	Caranx melampygus	4
	Triaenodon obesus	3
	Himantura fai	3
	Nebrius ferrugineus	2
	Chlorurus microrhinos	1
	Aprion virescens	1
	Arothron stellatus	1
	Naso tonganus	1
	Caranx sexfasciatus	1
	Oplegnathus punctatus	1
	Fistularia commersonii	1
	Carangoides orthogrammus	1
Asuncion Total		169

Appendix J: Maug

J.1. Benthic Habitat Mapping

Maug Island is centered at ~20º 01'N, 145º 11'E and is located approximately 38 nmi south of Uracas Island. While surveying around Maug it was apparent that the location of the island on nautical chart 81092_2 is shifted approximately 0.15 nmi northeast of the actual position.

Multibeam surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars. The ship transited to and worked at Uracas from May 30 to June 1, 2007 (JD 150-152) and the *AHI* was deployed on May 30-31, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~10 m and 250 m and the *Hi'ialakai* collected data down to ~2300 m. Because three nights of survey were conducted around the island, this data set provides a complete view of the bathymetry around the entire island. These data compliment existing bathymetry that was synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into the ongoing synthesis being conducted by a consortium of scientists working in the Mariana Archipelago. The multibeam data collected around Uracas represent approximately 40% of the 3856 km^2 (roughly 1500 km^2) of HI0703 coverage around the northern section of the Mariana Arc, which includes Uracas, Maug, and Ascunsion Islands and Supply Reef.

Maug is classified an extinct volcano by Bloomer *et al.* (1989) The geomorphology is unique in the Mariana Archipelago in that the center of the volcano is breached and is open to the ocean on the NE, NW, and S sides. Passes on the S and NE sides are large and deep enough for boats to pass through. Large blocks of material lie on the submarine slopes surrounding the volcano roughly down slope from the three passes suggesting that the blocks are slump that originated as large portions of the crater walls. However, the large block south of Maug differs from the material on the other sides in that it is a single, coherent block with a triangular shape. It may be volcanic in origin. Canyons incise the flanks of Maug and include the channels that extend down to the broad, flat region at 2100 m mentioned in Appenix K. A post-collapse dome occupies the center of the crater, rises to depths of less than 20 m, and is surrounded by a moat as deep as 240 m. Blocky material is also present in the moat.

Reference:

Bloomer, S.H., Stern, R.J. and Smooth N.C. 1989. Physical volcanology of the submarine Mariana and Volcano Arcs. Bulletin of Volcanology, p. 210-224.

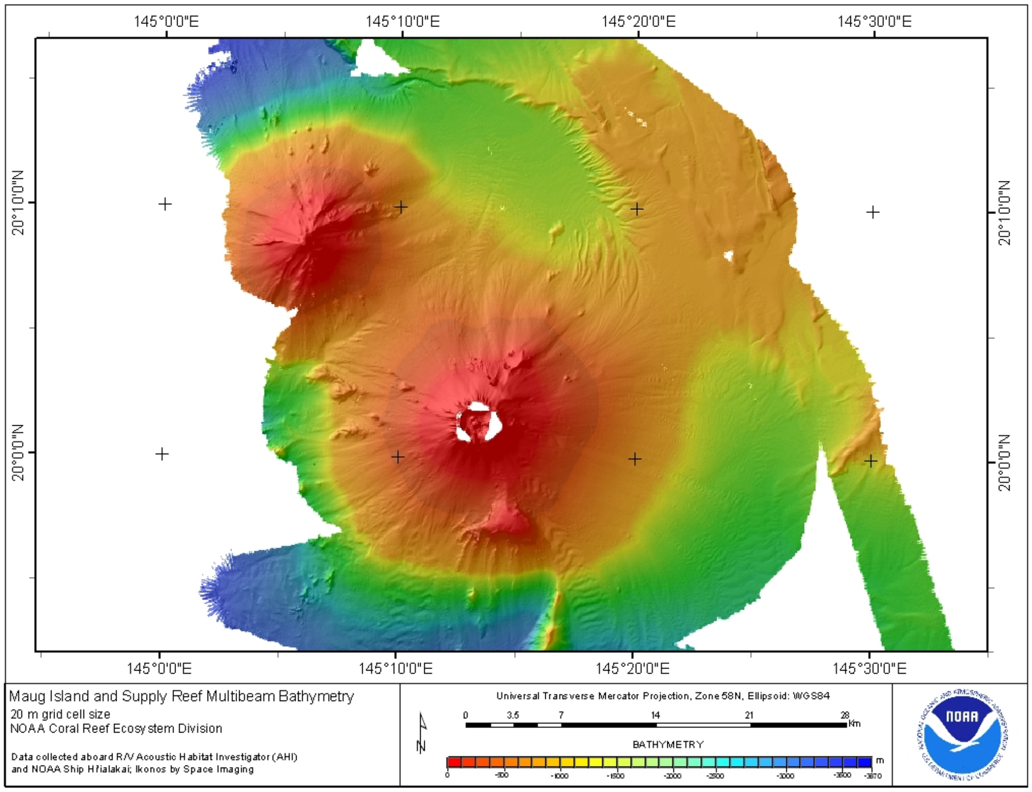


Figure J.1-1: Multibeam bathymetric data collected during HI0703 around Supply Reef and Maug Island.

J.2. Oceanography and Water Quality

In total, five instruments were recovered and six instruments were deployed at Maug during HI0703. A sea surface temperature (SST) buoy was recovered and replaced with a new ATI style buoy inside the caldera. This SST buoy provides surface temperature readings in near real-time via satellite communications. A subsurface temperature recorder (STR) was also recovered and replaced from the SST anchor location at a depth of approximately 11 meters. Two STRs were recovered and replaced from the west side of Maug outside the caldera at approximately 2 m and 10 m, and a new STR was deployed at approximately 30 m to study cold water pulses captured by previous CTD casts, diver input and data recovered from the 10-m STR near the location. Finally, an STR was deployed and recovered from an active volcanic vent site near the east island inside the caldera at approximately 6 m depth. (Figure J.2-1)

Twenty shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter and inside the caldera of Maug at approximately 0.5 km intervals following the 30-m contour. At nine of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and

30 m depths, for a total of 76 discrete water samples measuring chlorophyll and nutrient concentrations. (Figure J.2-1).

In situ temperature data at 10 m obtained from October 2005 to May 2007 on the west side of Maug shows seasonal variability with warm temperatures observed from July to November and cooler temperatures from January to April (Figure J.2-2). Temperature fluctuations of 2-3 °C on diurnal and semidiurnal return periods are observed during select time periods (e.g., May 2006). High-frequency temperature fluctuations are likely due to either internal tides causing vertical displacements of the background stratification or baratropic tidal advection of temperature gradients. Further data is needed to identify the primary source of the observed fluctuations.

Maug Island Vent Sampling Overview:
The NOAA research vessel *Hi'ialakai* was on station at Maug Island, CNMI, from May 30 to June 1, 2007. During that time the Coral Reef Ecosystem Division's (CRED) Oceanography team was able to conduct two shipboard CTD casts and one research dive dedicated to collecting water samples for hydrothermal vent studies. Each location has the associated alkalinity, trace metal, nutrient, and major element water samples requested by PMEL. Vent gases were also collected at the dive site. The collection and processing protocols provided by PMEL were clear. Little changes were made by the CRED personnel during sample collection. No changes were made in sample processing protocol, as the lab processing of the samples was straightforward and occurred without difficulty. Drawing the water from the CTD rosette's Niskin bottles was straightforward and the water samples were taken to the ship's wet lab for processing right away. During the dive on the vent system, the Teflon tube-syringe technique used to draw vent water worked well. The tubing system which incorporated the stopcock could be better assembled as it came untaped under water, but this event ultimately did not hinder sample collection. Of interesting note was that the CRED divers performed an exploratory dive on the vent site the day prior to the scheduled vent sample collection day with the goal of performing a site overview. That day the divers observed what seemed to be plenty of bubbles emerging from the seafloor, just awaiting collection. Unfortunately, on the sample day, it seemed there was less bubbling. That made it more difficult to collect the needed 200 ml of vent gas per sample bag. Other than not having a "good" source of venting gases, the actual collection of vent gas using the funnel-syringe technique was effortless and worked fairly well. Every effort was made to not include water into the gas collection bags, but some water did manage to get past the stopcock system controlling the flow in and out of the bag. This was because there was not enough vent gas to fully inflate the sample collection bags and then discharge any water that may have entered the bag. In the event of not having ample gas to collect, maybe this collection technique could remove the use of the syringe from the collection process by using a calibrated volume funnel. That way, the funnel-stopcock system could be used to release a measured amount of gas directly into the collection bag, without having to use the syringe. If the divers had been able to collect larger volumes of gas, then it would have been possible to overfill the collection bags and, while at depth, release some of the gas in a forceful manner, pushing out any water that may have been allowed into the bag

during gas collection. As it turned out, it took 55 minutes to collect just less than 600 ml of vent gas. The collected gas was divided into two sample bags of ~240 ml each.

The three sites for water collection were:

1. Shipboard CTD, outside Maug caldera:
Cast HI0703007, depths 3 m, 10 m, 25 m, 75 m, 100 m, 150 m, 175 m
Latitude: N 19°59.92' Longitude: E 145°11.71'
UTC date, time: 05/30/07, 08:35
Samples processed at each depth: alkalinity (in glass bottles for KF), trace metals, nutrients (filtered and unfiltered), and major elements.

2.Vent Site Grab Samples, within Maug caldera along coastline of the eastern island:
Four diver team, vent depth: 36 ft
Latitude: N 20°01.3840' Longitude: E 145°13.7898'
UTC date, time: 05/31/07, 04:07
Samples processed: alkalinity, trace metals, nutrients (filtered and unfiltered), major elements, and vent gases. Duplicates were taken for each sample.
NOTE: The vent gas samples are a collection of gas bubbles from numerous sites around the vent site from which the water samples were taken. The vent site which provided the water for analysis was determined as being the most consistent and highest volume source of water the divers could find during the exploratory dive. As mentioned above, a source of consistent bubbles wasn't found and in order to get the necessary amount of gas volume, the diver tasked with collecting the gas in the funnel had to chase bubbles across the seafloor. The gases collected were never more than 5m away from the site where the vent water was collected.

3.Shipboard CTD, inside Maug caldera:
Cast HI0703010, depths 3 m, 10 m, 25 m, 75 m, 100 m, 150 m, 175 m
Latitude: N 20°01.50' Longitude: E 145°13.40'
UTC date, time: 05/31/07, 20:39
Samples processed at each depth: alkalinity (in glass bottles for KF), trace metals, nutrients (filtered and unfiltered), and major elements.

Dive overview:
The vent site floor was mostly composed of rubble and boulders which had fallen into the ocean from the island's cliffs above. A *Spatoglossum* sp. was the dominant alga covering every hard surface. Also, there was a yellowish fluffy material present over everything. It was easily suspended by any turbulence made by the divers and can be viewed in the still photos and video provided. Not more than 15 m south of the vent site was an area of 100% coral coverage. The dominant species was *Porites rus*. This area was studied by the Rapid Ecological Assessment (REA) team, REA site "MAU2." A gradient of sediment color around the vent site could also be observed. Near the vents, the seafloor was covered with the above-mentioned yellowish material and as the distance from the vents increased, the seafloor sediments were clearly more affected by bioturbation. Furthest away, the yellowish material was gone and the seafloor was composed of coarse

black sand. The dive plan was to have Ellen Smith video and take still photography of the dive site and the collection process. Jamie Gove was to record vent water temperature. He measured the sample site and found and recorded vent water source temperatures no more than 3 m north, south, east and west of the sampled vent. He recorded the sampled vent waters at 59^{o} C. Additionally, he found a north vent measured at 54^{o} C, a south vent at 53^{o} C, an east vent at 45^{o} C, and a west vent at 48^{o} C. Additionally, he sampled various locations to the northwest of the sample site and found a vent with temperatures up to 63^{o}C, the highest temperature found that day. Jamie also swam a 5.0 L Niskin bottle ~40 m to the west of the sample site to collect "clearer" water at the same depth as the vent. Danny Merritt was to help Chip Young with the collection of vent water and gases. Once the two divers realized that the lack of vent gas in the collection area was hindering dive efficiency, Danny went on his own to collect gas samples from what gas sources he could capture. Chip stayed at the original vent site and collected water samples. Once back on the dive boat, all water samples were stored in an iced cooler, and the divers returned to the *Hi'ialakai* to process the collected water and gas samples.

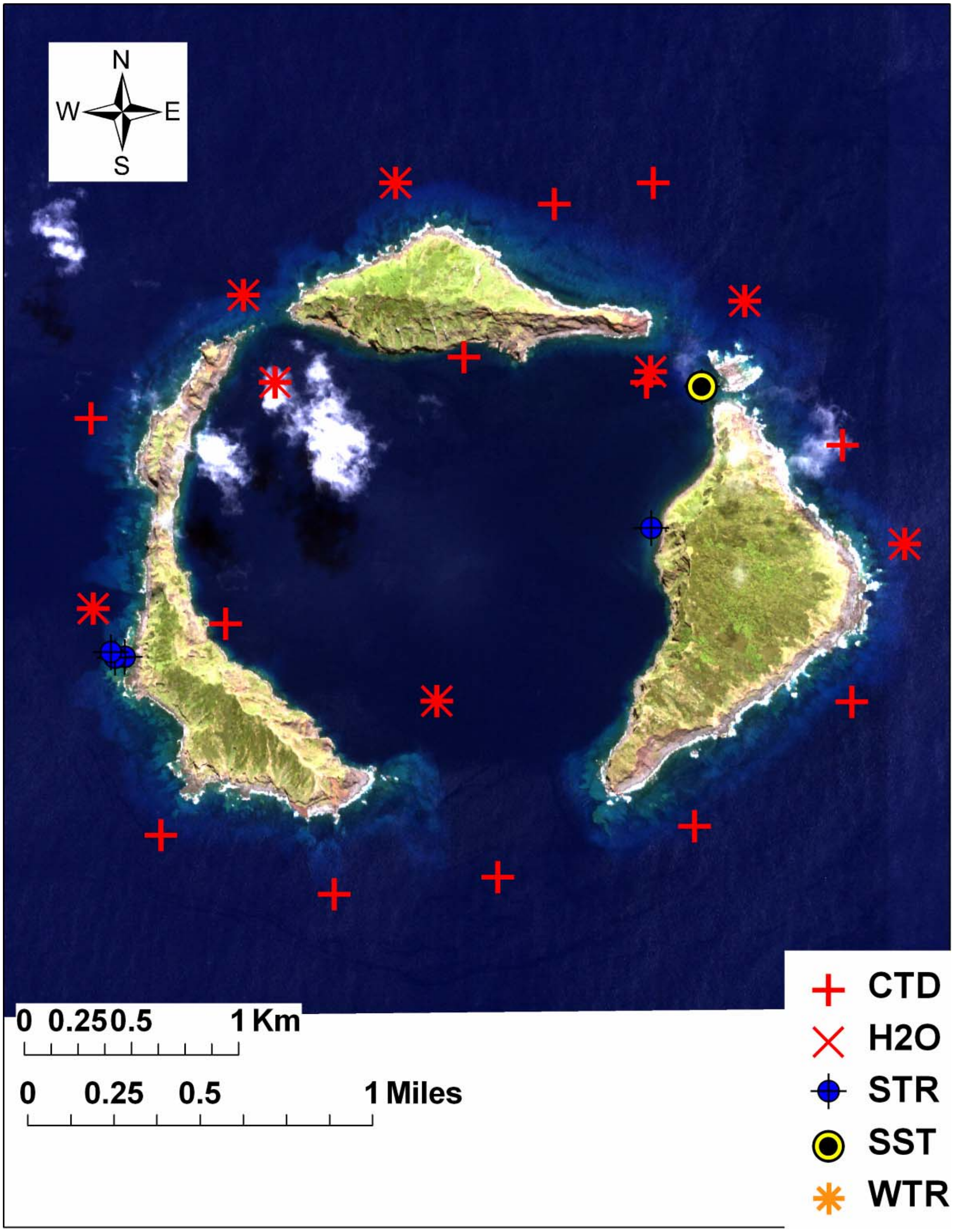


Figure J.2-1: Positions of CTDs, water samples and moorings at Maug.

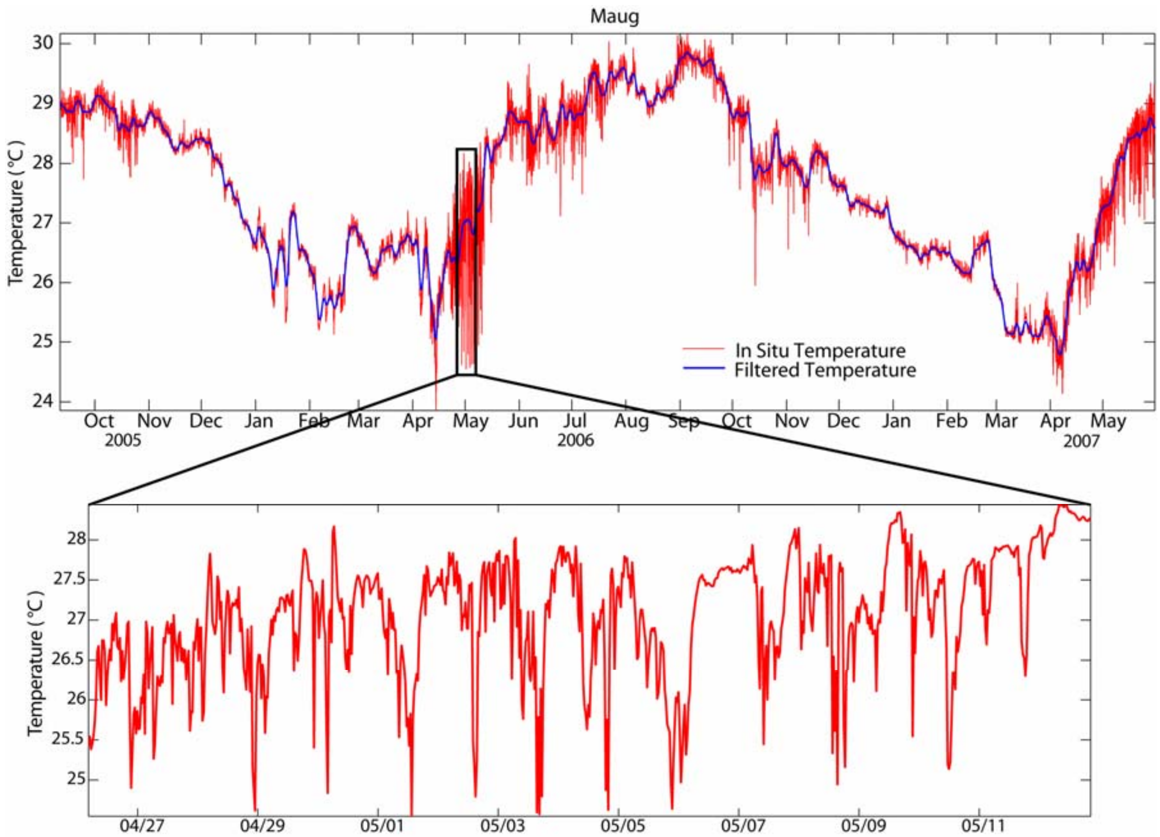


Figure J.2-2: *In situ* temperature at 6.7 m from October 2005 to June 2007. The red line is data sampled at a 30-minute interval; the blue line is a weekly mean.

J.3 Rapid Ecological Assessment (REA) Site Descriptions

Maug is located just south of Uracas. There are some signs of fishing within the crater of the island. This island is constitutionally designated as a terrestrial reserve; access is allowed through permit only. Legislation was drafted to include the waters surrounding the island down to 1 kilometer as a no-take marine protected area. This area also receives minimal fishing activity given its distance from the island of Saipan.

REA surveys were conducted at nine sites at Maug (Table J.3-1). Locations of all REA sites around Maug are shown in Figure J.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table J.3-1. Sites surveyed by REA team at Maug, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.

Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, °C
MAU-4	5/30/2007	20	00.877	145	14.058	12 - 14	15.2	28.9
MAU-5	5/30/2007	20	02.145	145	13.459	12 - 13	15.2	27.8
MAU-6	5/30/2007	20	01.833	145	13.651	12 - 13	14.3	28.3

Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, °C
MAU-10	5/31/2007	20	01.081	145	12.728	12 - 13	15.2	28.9
MAU-1	5/31/2007	20	01.433	145	12.476	11 - 12	15.8	28.9
MAU-2	5/31/2007	20	01.350	145	13.787	13 - 14	18.3	28.9
MAU-12	6/1/2007	20	01.213	145	14.380	11 - 13	18.3	28.3
MAU-11	6/1/2007	20	00.833	145	12.532	13 - 14	14.6	28.3
MAU-9	6/1/2007	20	01.754	145	12.487	12 - 14	16.5	28.9

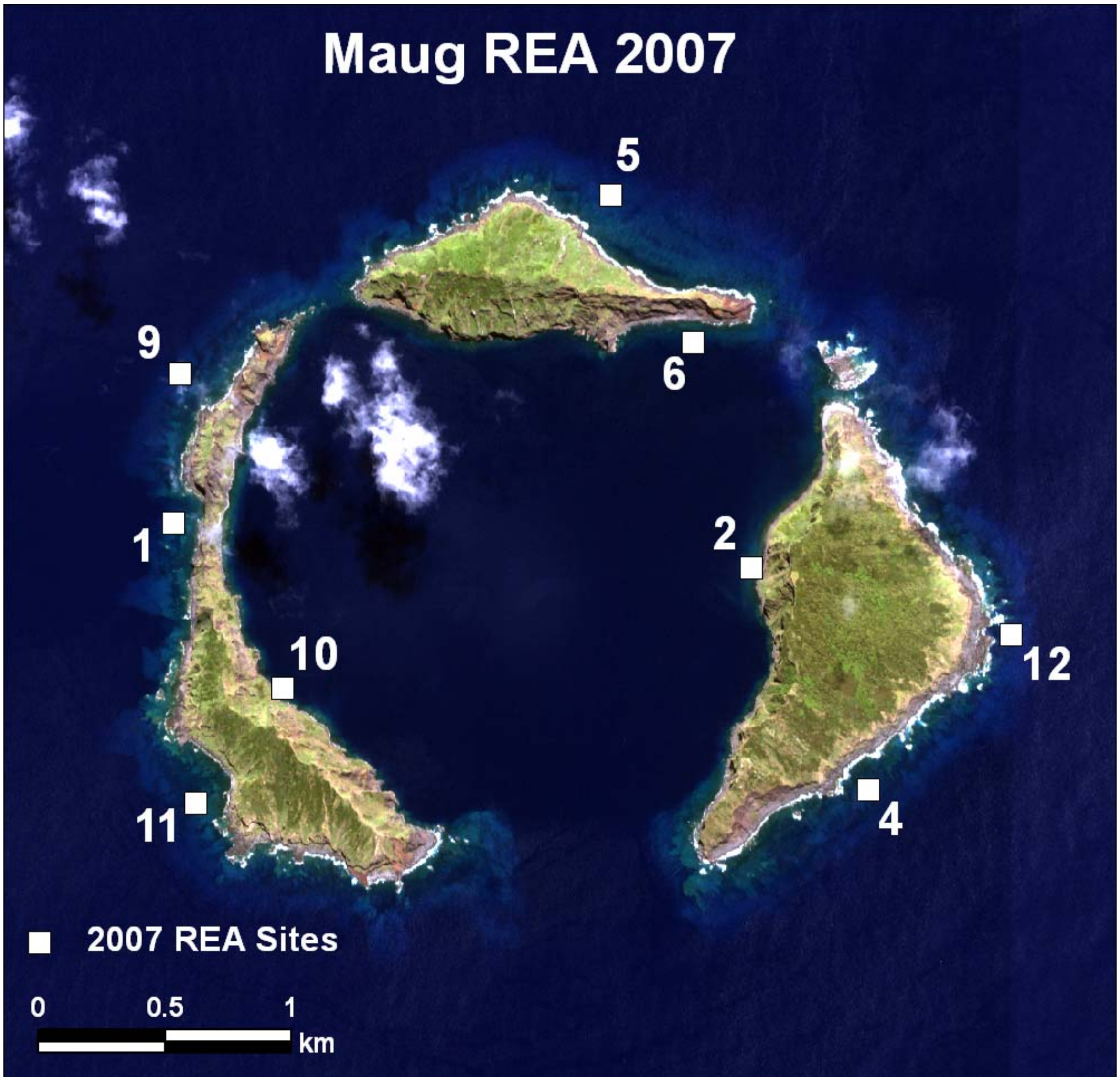


Figure J.3-1. Location of 2007 REA survey sites at Maug.

Maug

MAU-4

May 30, 2007

East island, windward side, transect depth range: 12–14 m. Forereef with relief composed of basalt boulders intermingled with siliciclastic sand. Low percent live coral cover (8.8%). Turf-algae over rock comprised nearly 60% of bottom cover, and macro-algae represented nearly 25% of the living benthos. Within the survey area (300 m^2), no coral or coralline algal disease were observed. The dominant algal categories (up to a rank average of 4) on this site were *Halimeda*, encrusting Corallinaceae, *Liagora*, *Lobophora*, *Haematocelis*, turf algae, cyanobacteria tufts, and *Turbinaria*.

MAU-5

May 30, 2007

North island, windward side, transect depth range: 12–13 m. Forereef with well-developed coral communities. Aggregate relief. High percent coral cover (50%). Abundant *Porites* and *Astreopora*. Carbonate pavement covered with turf-algae comprised over 30% of benthos. Within the survey area (300 m^2) the following disease states were enumerated: Five cases of tissue loss in *Porites* and *Montipora*; three cases of patchy discoloration in *Porites*; and three cases of skeletal growth anomalies on *Porites* and *Acropora*. The dominant algal categories (up to a rank average of 3) on this site were *Bornetella*, *Haematocelis*, encrusting Corallinaceae, turf algae, and *Halimeda*.

MAU-6

May 30, 2007

North island, lagoon, transect depth range: 12–13 m. Aggregate relief; carbonate buildup, spurs and gullies. Moderately high percent live coral cover (24.5%). Coral buildups many covered with highly fissioned Goniastrea (potentially due to bleaching and partial mortality). Dead standing coral buildups covered on turf-algae, comprising over 42% of benthic cover. Within the survey area (300 m^2) 15 cases of white syndrome were detected on colonies of *Goniastrea cf. edwardsi*. The dominant algal categories (up to a rank average of 3) on this site were turf algae, *Neomeris*, encrusting Corallinaceae, *Dictyota*, and *Sarcinochrysis*. This site has a lower algal species richness compared to the two outer sites, MAU-4 and MAU-5.

MAU-10

May 31, 2007

West island, East shore, lagoon. Transect depth range: 12–13 m. Inclined at ~45 degree slope; assemblage of *Astreopora*, *Goniastrea*, *Pavona*, and *Porites*. Moderately high percent live coral cover (39.2%). Carbonate pavement covered with turf-algae comprised nearly 30% of bottom cover. Within the survey area (300 m^2), five cases of white syndrome on *Goniastrea* and *Astreopora*, one case of bleaching on *Porites*, and one case of skeletal growth anomaly on *Porites*. Additionally seven cases of *Acanthaster* predation (scars) were enumerated. The dominant algal categories (up to a rank average of 3) on this site were turf algae, *Peyssonnelia*, *Dictyosphaeria*, *Haematocelis*, and encrusting Corallinaceae.

MAU-2

May 31, 2007

East island, West shore, lagoon. Transect depth range: 13–14 m. Near the shallow vent site in the lagoon. Aggregate relief. High percent coral cover (~70%). Abundant *Astreopora*, Goniastrea and Goniopora. Second transect heavily dominated by large colonies (4-5 m diameter) of *Porites rus*, which dominated the landscape to ~ 20-30 m depth. Within the survey area (300 m^2) the following disease states were enumerated: two cases of tissue loss on *Goniastrea and Goniopora*, respectively, and one case of skeletal growth anomalies on *Astreopora*. The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting Corallinaceae, cyanobacteria, *Lobophora*, *Dictyota*, and *Jania*.

MAU-1

May 31, 2007

West island, West shore. Transect depth range: 11–12 m. Aggregate relief; carbonate buildup, spurs and gullies. *Goniastrea* cf. *edwardsi* important reef builder, with dead colony summits probably due to prior bleaching. Elevated generic diversity: (25 genera, including *Heliopora* and *Millepora*). Moderately high percent live coral cover (47%). Within the survey area (300 m^2) one case of white syndrome on *Goniastrea cf. edwardsi* was detected, and 7 cases of coralline lethal orange disease (CLOD). The dominant algal categories (up to a rank average of 4) on this site were encrusting Corallinaceae, turf algae, *Haematocelis*, and cyanobacteria.

MAU-12

June 1, 2007

East island, East windward shore. Transect depth range: 11–13 m. Aggregate relief, coral buildups, basalt boulders and sand channels. Moderately low percent live coral cover (18.6%). *Astreopora*, *Goniastrea*, *Goniopora*, and *Pocillopora* were common. Within the survey area (300 m^2) two cases of pallor and mild bleaching were observed on *Platygyra*. The dominant algal categories (up to a rank average of 4) on this site were encrusting Corallinaceae, *Haematocelis*, *Peyssonnelia*, turf algae, cyanobacteria, and *Halimeda*.

MAU-11

June 1, 2007

West island, West leeward shore. Transect depth range: 13–14 m. Aggregate relief forereef; coral buildup and basalt boulders. Moderate percent live coral cover (26.5%). Assemblage of *Pocillopora* and *Sinularia*. Within the survey area (300 m^2), two cases of coralline lethal orange disease were detected. Dominated by turf and encrusting algae: turf algae, encrusting Corallinaceae, *Peyssonnelia*, and *Haematocelis* (rank average up to 3).

MAU-9

June 1, 2007

West island, West leeward shore. Transect depth range: 12–14 m. Alternation of well-developed aggregate relief and sand patches; carbonate buildup, spurs and sand gullies.

Moderately high percent live coral cover (38.2%). *Goniastrea* cf. *edwardsi* important reef builder, with dead colony summits probably due to prior bleaching; also numerically abundant: *Pocillopora*, *Montipora*, *Astreopora*, and *Acropora* (*Isopora*). Within the survey area (300 m^2) three cases coralline lethal orange disease (CLOD) were detected. The dominant algal categories (up to a rank average of 4) on this site were turf algae, encrusting Corallinaceae, *Haematocelis*, cyanobacteria, and encrusting *Lobophora*.

J.4. Benthic environment

J.4.1. Algae

Algal species were surveyed and collected at nine sites around Maug.

Table J.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table J.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table J.4.1-3. Specimens collected at Maug in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Cyanobacteria (MAU06-002)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Cyanobacteria (MAU10-004)	MAU10; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Symploca sp. (MAU06-007)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Schizothrix sp. (MAU06-006)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Wrangelia anastomosans (MAU09-001)	MAU09; Maug, CNMI, Mariana Islands; collection date: 2007_06_01	X	X	X		
Wrangelia anastomosans (MAU10-001)	MAU10; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Laurencia sp. (MAU11-002)	MAU11; Maug, CNMI, Mariana Islands; collection date: 2007_06_01		X	X		
Amphiroa fragilissima (MAU10-002)	MAU10; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Corallinaceae sp. (MAU09-002)	MAU09; Maug, CNMI, Mariana Islands; collection date: 2007_06_01				X	
Porolithon sp. (MAU01-002)	MAU01; Maug, CNMI, Mariana Islands; collection date: 2007_05_31				X	
Sporolithon sp. (MAU01-003)	MAU01; Maug, CNMI, Mariana Islands; collection date: 2007_05_31				X	
Hypnea saidana (MAU02-004)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Peyssonnelia sp. (MAU09-002)	MAU09; Maug, CNMI, Mariana Islands; collection date: 2007_06_01				X	
Galaxaura filamentosa (MAU10-006)	MAU10; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Sarcinochrysis marina (MAU06-005)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30	X	X	X		
Sarcinochrysis marina (MAU10-005)	MAU10; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Dictyopteris sp. (MAU02-003)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X			
Lobophora sp. (MAU02-003)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Padina sp. (MAU06-004)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Zonaria with stalk (MAU02-001)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_05_31	X	X	X		
Zonaria with stalk (MAUXX-003)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_06_01	X	X	X		
Turbinaria conoides (MAU05-003)	MAU05; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Caulerpa filicoides (MAUXX)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_06_01					
Caulerpa mexicana (MAUXX-004)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_06_01	X	X	X		

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Caulerpa serrulata (MAU01-001)	MAU01; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Caulerpa sp. (MAU04-002)	MAU04; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Caulerpa webbiana (MAU04-001)	MAU04; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Avrainvillea sp. (MAUXX-001)	MAU; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Halimeda macrophysa (MAU11-001)	MAU11; Maug, CNMI, Mariana Islands; collection date: 2007_06_01		X	X		
Halimeda minima (MAU11-002)	MAU11; Maug, CNMI, Mariana Islands; collection date: 2007_06_01		X	X		
Halimeda sp. (MAU05-002)	MAU05; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Halimeda velasquezii (MAU01-004)	MAU01; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Tydemania expeditionis (MAU10-003)	MAU10; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Dictyosphaeria intermedia (MAU06-001)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Dictyosphaeria sp. (MAU06-008)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Ventricaria ventricosa (MAUXX)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_06_01					
Valonia aegagropila (MAU11-002)	MAU11; Maug, CNMI, Mariana Islands; collection date: 2007_06_01		X	X		
Valonia sp. (MAU02-002)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_05_31		X	X		
Bornetella nitida (MAU06-002)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Bornetella sp. (MAU05-001)	MAU05; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Bornetella sphaerica (MAU06-003)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Neomeris sp. (MAU06-002)	MAU06; Maug, CNMI, Mariana Islands; collection date: 2007_05_30		X	X		
Polyphysa sp. (MAUXX)	MAU02; Maug, CNMI, Mariana Islands; collection date: 2007_06_01					

J.4.1.2 Benthic towed-diver surveys – Macroalgae

The average macroalgae and coralline algae cover at Maug averaged 12% and 20% (range 0 – 30% and 0 – 40%, respectively). The highest macroalgae cover was recorded during a survey along the east/northeastern outer forereef of East Island, rounding the corner of the northeastern channel (average 12%, range 0.1 – 30%). *Halimeda* and *Liagora* dominated the algal components of the habitat. The highest coralline algae cover (average 20%, range 10.1 – 40%) was located along the southern corner of East

Island, moving north along the forereef/eastern slope where the habitat was composed predominantly of continuous reef and spur-and-groove habitat of moderate to steep slope which changed to boulder/rubble areas.

J.4.2. Corals

J.4.2.1 Coral Populations

Coral Diversity and Population Parameters

A total of three survey days were spent on Maug Island which holds the best coral growth found throughout the northern islands. Sites visited were MAUG-1, 2, 4, 5, 6, 9, 10, 11, and 12, six on the outer reef slope and three on the inner, protected reefs. The reefs inside the caldera of Maug have consistently been dominated by *Goniastrea edwardsi*, *Goniastrea pectinata*, *Astreopora myriophthalma*, and *Astreopora randalli* since 2003. One site, Maug-2, has a unique mono-stand of *Porites rus* that extends down to at least 30 m. The outer reefs had substantial modern growth consisting of *Pocillopora eydouxi*, *Pocillopora elegans*, several *Porites*, *Heliopora coerula*, *Acropora monticulolsa*, and *Favia stelligera*. These reefs have shown a strong recovery since the disturbances noted above in 2000 and 2003, with the exception of Maug-1. Maug-1 has consistently been dominated by living coral, where a large stand of *Pavona bipartita* creates an underlying reef matrix. This site is noted as the most diverse reef with the largest colonies among all sites surveyed throughout the archipelago.

Size Class Structure

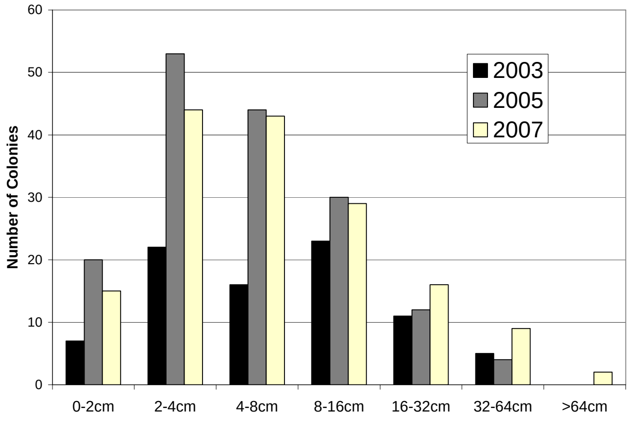


Figure J.4.2.1-1. Change in size class distributions of coral communities that have shown substantial recovery from a bleaching event (2000/01) and *Acanthaster planci* outbreak (2003/4). In 2003 coral growth was limited, in 2005 juveniles started to appear, and in 2007 the return of a positively skewed population with high percent cover had returned. Data taken from the Maug-5 site, however, several sites noted followed this trend.

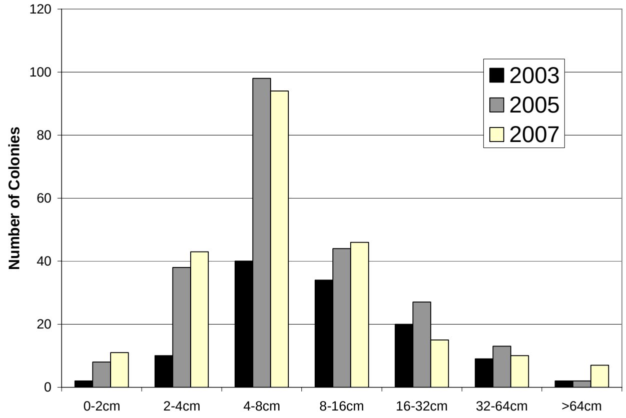


Figure J.4.2.1-2. Change in size class distributions of coral communities that held high coral diversity and cover in 2003, and did not show any change in 2005 or 2007. Data taken from the Maug-1 site, however, a few other locations show this same trend.

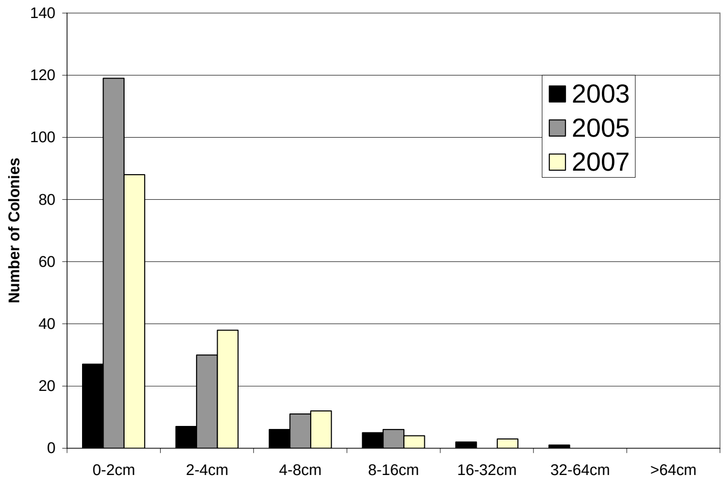


Figure J.4.2.1-3. Change in size class distributions of coral communities upon volcanic boulders with little Holocene deposition. The same trend emerges each year; juvenile corals are present but fail to grow. The large abundance of small corals in 2005 and 2007 are due to high densities of juvenile *Pocillopora*.

J.4.2.2 Percent Benthic Cover

The line-intercept methodology quantified a total of 861 points along 425 m of lagoonal and forereef coral communities, and the patterns of intra-island variability in percent benthic cover are reflected in Figure J.4.2.2-1. Point-count surveys indicated that percent live coral cover ranged between 8.8 and 66.4%, for a grand mean of 35.5 ± 5.9% (mean ± SE) for all sites combined. Highest coral cover was recoded at site MAU-2 (66.7%) on the west-facing shore of East Island. Conversely low percent coral cover (8.8%) was encountered as sites MAU-4 on the southeastern side of East Island. Basalt boulders and carbonate pavement covered with sand turf-algae comprised over 30% of the benthic cover, and sand represented over 15% of the benthos. A total of 17 scleractinian genera and one hydrocoral (*Millepora*) and one stony octocoral (*Heliopora*) were enumerated along the point-count transects, with *Astreopora* being the most numerically abundant scleractinian (15.9 ± 2.2%), followed by *Pocillopora* (13.0 ± 1.7%), and *Goniastrea* (12.8%). Figure J.4.2.2-2 illustrates the contribution of the different scleractinain genera to the total percent live coral cover. Outside the survey transect lines however, up to 26 different scleractinian genera were enumerated.

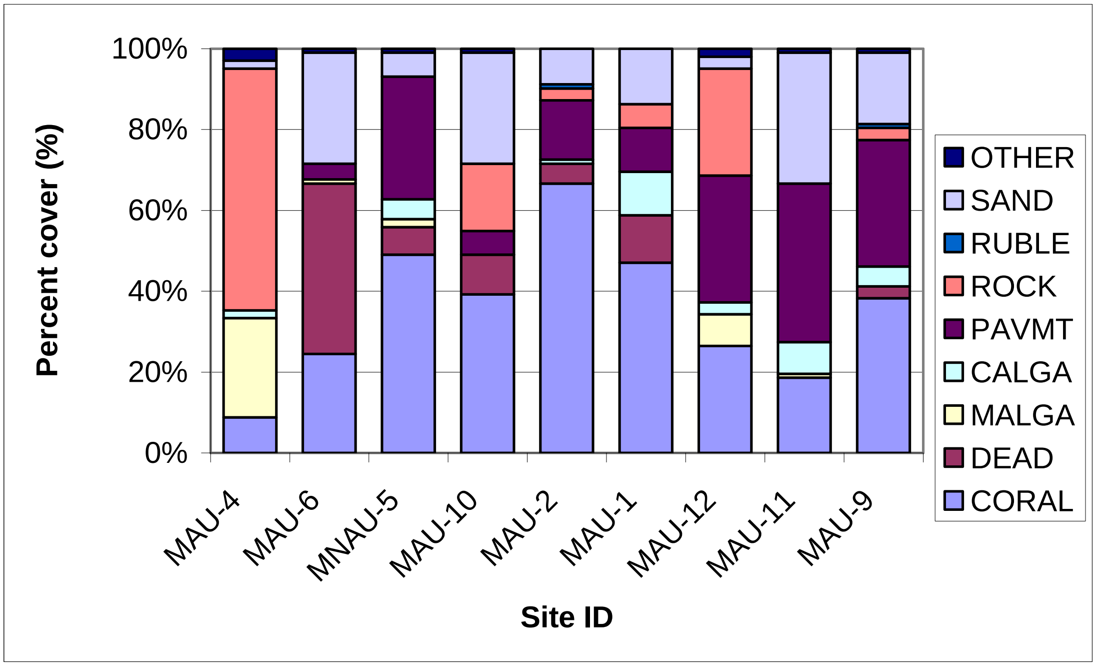


Figure J.4.2.2-1 Mean percent cover of selected benthic elements derived from 9 independent REA surveys at Maug, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; MALGA: fleshy macroalgae; CALGA: crustose coralline algae; ROKK: turf-algae covered basalt boulders; PAVMT: turf-algae covered carbonate pavement; RUBLE: coral rubble (including recent and old coral rubble covered with turf-algae); SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats.

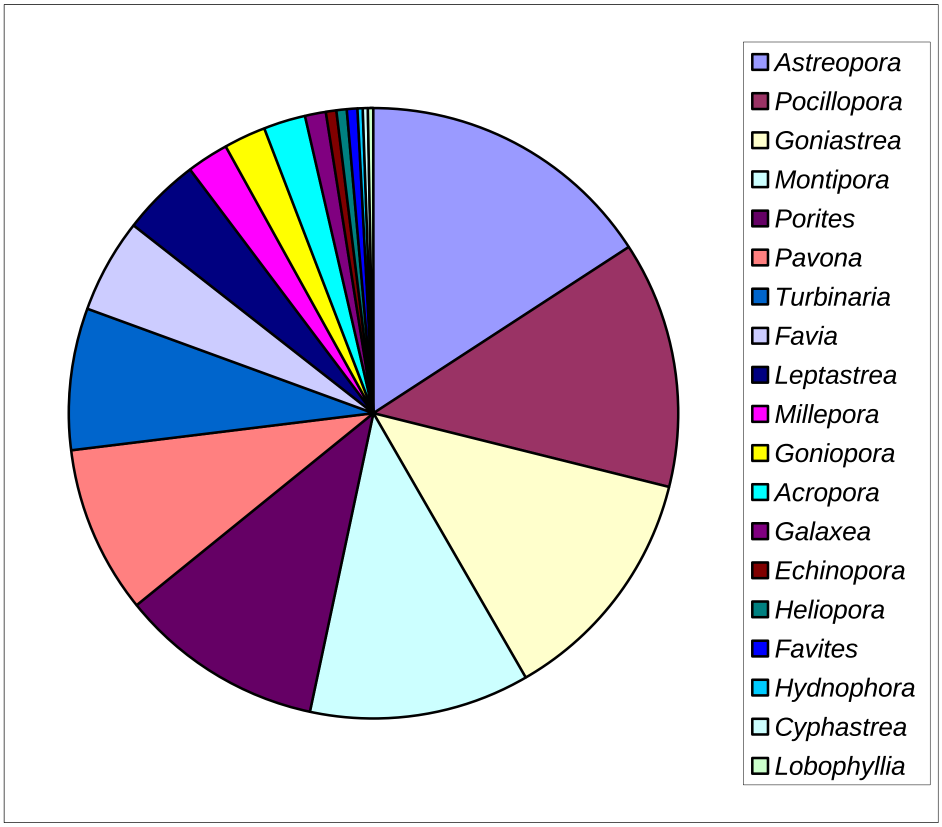


Figure J.4.2.2-2 Percent contribution of the different coral genera to the total live coral cover at Maug Island, MAR-RAMP 2007.

J.4.2.3 Coral Disease

The coral disease REA surveyed a total area of ~2550 m^2 at 9 different sites; overall occurrence of disease was relatively low (Table J.4.2.3-1). A total of 39 cases were enumerated for all the survey areas combined. The main disease state encountered was white syndrome (54%) affecting colonies of *Goniastrea* cf. *edwardsi*, followed by skeletal growth anomalies (~13%). Among sites, MAU-6 exhibited the greatest occurrence of disease; 38% of cases. Disease states, including bleaching and discoloration were registered on *Porites* and *Platygyra* only; a total of 6 cases were enumerated for all sites combined. Skeletal growth anomalies were detected on *Acropora*, *Porites*, and *Astreopora*. Additionally, tissue loss and white syndrome were detected on several genera, including *Montipora*, *Porites*, *Goniastrea*, *Astreopora*, and *Goniopora*. Of particular interest was the higher incidence of white syndrome lesions on colonies of *Goniastrea* cf. *edwardsi*. Coralline Lethal Orange Disease (CLOD) was also detected at Maug; a total of 12 lesions were recorded for all sites combined. For the most part, CLOD lesions were small (0.5- 10 cm diameter). Finally predation scars due to *Acanthaster planci* were also enumerated within the total survey area.

Table J.4.2.3-1 Cumulative number of cases of disease conditions enumerated at each survey site around Maug during the 2007 RAMP cruise. DIS: discoloration; SGA: skeletal growth anomalies; TLS: tissue loss; WSY: white syndrome; BLE: bleaching; PRE: predation scars due to *Acanthaster planci*; and CLOD: Coralline lethal orange disease. Total survey area ~2550 m^2.

DZ/HS1	Species	MAU-4	MAU-5	MAU-6	MAU-10	MAU-2	MAI-1	MAU-12	MAU-11	MAU-9	Grand Total
DIS	*Porites* cf *lobata*		2								2
	Porites cf *lutea*		1								1
SGA	*Acropora cf abrontanoides*		1								1
	Porites cf *lobata*		2								2
	Astreopora sp					1					1
	Porites sp				1						1
TLS	*Montipora* sp		1								1
	Porites cf *lobata*		4								4
WSY	*Goniastrea* cf *edwardsi*			15	4	1	1				21
	Astreopora sp				1						1
	Goniopora sp					1					1
BLE	*Porites* sp				1						1
	Platygyra								2		2
PRE	*Astreopora sp*				7						7
CLOD	Coralline algae						7	2		3	12

J.4.2.4 Benthic towed-diver surveys – Corals

The average hard coral cover for Maug was recorded at 25% (range 0.1 - 75%), with stressed coral averaging 1% (range 0 - 20%). The highest overall coral cover recorded during a single towed-diver survey was noted along the outer reef slope of West Island, with an average of 40% coral cover (range 20.1 – 75%). Habitat consisted of reef crest along a series of steep walls/canyons that eventually turned into high-relief spur and groove as well as rolling reef. The walls returned in the final two segments of the survey. High coral coverage was recorded throughout most of the survey, never dropping below 20% per time segment.

Large *Porites* colonies (c.f. *Lobata* or *Lutea*) were noted in a number of locations including N20 00.616, 145 13.069; N20 00.958, 145 12.393; N20 01.199, 145 12.453; N20 02.201, E145 13.404 (observed outside of transect); N20 02.206, E145 13.394 (observed outside of transect); N20 02.180, E145 13.493.

The highest stressed coral cover (average 5%, range 0 – 20%) was recorded during the survey along the southern corner of West Island, moving along the interior of the lagoon (west island, towing north along the West Island interior slope). Only 10 COTs were noted during the survey; however, this represented the highest number of COTs seen during all combined towed-diver surveys of Maug.

The highest soft coral cover (average 9%, range 0 – 30%) was recorded in the east/northeastern outer forereef of East Island. The end of the towed-diver survey rounded the corner of the northeastern channel, moving into the lagoonal slope of East Island. The first time segment recorded 20.1 – 30% soft coral cover, with *Sinularia* noted as the predominant soft coral genera.

Finally, it is worth noting that several large, yellow sea fans (*Annella*) were noted during the beginning of the towed-diver survey near the southernmost tip of West Island at an estimated 80 – 85 feet at N20 00.612, 145 12.871.

J.4.3 Macroinvertebrates

J.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

The overall macroinvertebrate averages per survey for the islands of Maug were 0.3 COTs, 42.3 sea urchins, 1.0 sea cucumbers, and 6.0 giant clams. COTs were recorded in all surveys except for the waters surrounding East Island and the west side of West Island. COTs numbers remained low in all surveys, never exceeding 1 individual per segment, which was recorded along the east side of West Island. This area coincides with the highest levels of stressed hard corals for all three of the islands. The eastern side of West Island additionally hosted the greatest concentration of sea cucumbers, averaging 1.6 individuals per segment. The habitat was characterized as a steep reef slope, high in coral cover with occasional rock slides. Sea urchins were most abundant along the eastern forereef sections of pavement and spur and groove of East Island. Populations were observed in all surveys, except within the lagoon waters. Forereef populations remained relatively steady with the one exception of East Island. The largest concentration of giant clams occurred on the lagoon slope of North Island where 75 individuals were recorded in the first two time segments. As the survey progressed to the forereef of North Island, numbers decreased, but remained steady in comparison to the rest of Maug at 2-3 individuals per time segment.

J.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Maug. The survey methods employed at each site and notable observations are summarized in Table J.4.3.2-1.

Table J.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Maug.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
MAU-4	X	X	X	Bouldery shallow, drop off- ~20-45 ft. *Liagora* abundant, *Padina*. *Echinothrix diadema* present. Good "cave like" community under overhangs. Partial sediment sample from under overhang, full sample from groove formation cutting into wall.
MAU-5	X	X	X	Slow slope from shore. Good coral near shore, low cover 15-30 ft, good cover again at dive depths. White tip shark near shore. Gray reef at dive site. Massive *Porites* abundant.
MAU-6	X	X	X	Inside caldera, Dominated by *Goniastrea*. High abundance of *Tridacna*. Silty. *Briareum* abundant. Sediment (60ft) from "groove"/valley.
MAU-10	X	X	X	Inside caldera. Steep slope. *Holothuria edulis* abundant, *Pearonothuria graeffi*. Orange large osculed sponge. *Leiaster glabra_* dark coloration, similar to NWHI specimens. Sediment sample (60 ft.)
MAU-2	X	X		Inside Caldera. Volcanic bubbly sand. Massive *Porites rus* colonies. *Pearsonothuria graeffi* common. Black crinoid, fine arms, common.
MAU-1	X	X		Outer reef, good coral community. Fair numbers of giant clams.
MAU-12	X	X		Wave washed reef with large boulder and sand channels, transects 2 and 3 were on shoreline wall.
MAU-11	X	X		Sloping forereef. Nondescript for inverts.
MAU-9	X	X		Sloping forereef. Nondescript for inverts.

J.4.3.3 Opportunistic invertebrate collections

Acanthaster planci, *Linckia multiflora*, and *Holothuria atra* were collected at a number of locations around Maug (Table J.4.3.3-1).

Table J.4.3.3-1: Opportunistic collections of *Acanthaster planci*, *Linckia multiflora*, and *Holothuria atra* around Maug during HI0703.

Location	Date	Collector	Species	# of Samples	REA site	Site location	Habitat	Outbreak population	Depth-ft	Latitude	Longitude
Maug	5/30/07	Russell Moffitt	*Acanthaster planci*	1	6		Forereef	N	35	20.0306	145.2275
Maug	5/31/07	Russell Moffitt	*Acanthaster planci*	1		Outer west side	Forereef	N	35	20.0177	145.2073
Maug	6/1/07	Danny Merritt	*Acanthaster planci*	2		Outer west side	Forereef	N	70	20.0182	145.2071
Maug	6/1/07	R. Moffitt/E. Coccagna	*Linckia multiflora*	4		Outer west side	Forereef	N	~60	20.0207	145.2067
Maug	6/1/07	R. Moffitt	*Linckia multiflora*	7		Outer west side	Forereef	N	~60	20.0224	145.2070
Maug	6/1/07	J. Asher	*Linckia multiflora*	6		Outer west side	Forereef	N	~60	20.0224	145.2070
Maug	6/1/07	R. Moffitt/E. Coccagna	*Linckia multiflora*	4		Outer west side	Forereef	N	~60	20.0235	145.2073
Maug	6/1/07	R. Moffitt	*Holothuria atra*	1		Outer west side	Forereef	N	~60	20.0235	145.2073
Maug	6/1/07	John Starmer	*Linckia multiflora*	8	12		Forereef	N	45	20.0202	145.2397

J.5. Fish

J.5.1 REA Fish Surveys

Stationary Point Count data
A total of 36 individual SPC surveys were conducted at 9 forereef sites around Maug. Snapper (Lutjanidae) were the largest contributor to biomass with 0.09 ton per hectare. Surgeonfish (Acanthuridae) were also commonly observed during the SPCs yielding biomass of 0.06 ton per hectare.

Belt-Transect data
During the survey period, 27 belt-transect surveys were conducted at 9 forereef sites around Maug. Surgeonfish (Acanthurids) were the primary contributors to biomass with 0.08 ton per hectare, followed by snappers (Lutjanidae) and parrotfish (Scaridae), with 0.06 and 0.05 ton/ha, respectively. (Fig. J.5.1-1).

Overall observations
A total of 145 species were observed during the survey period by all divers. The average medium to large fish biomass at Maug during the survey period was 0.43 ton/ha for the SPC surveys (Table J.5.1-1), and the average fish biomass was 0.38 ton/ha for the belt transect surveys (Table J.5.1-2).

Figure J.5.1-1 – Family composition of the total fish biomass (0.38 ton per hectare) around Maug Island.

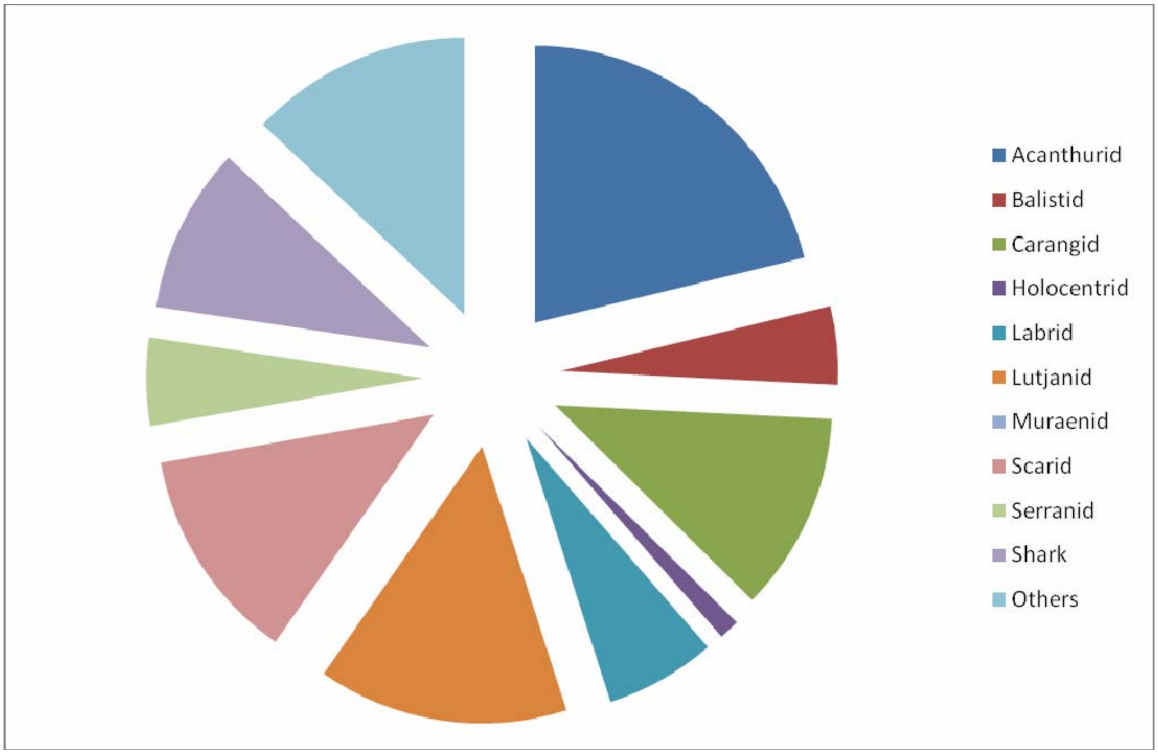


Table J.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Maug Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
MAU-1	0.15	0.03	0.00	0.03	0.01	0.01	0.02	0.00	0.01	0.02	0.00	0.01
MAU-10	0.37	0.10	0.00	0.00	0.00	0.02	0.08	0.06	0.09	0.00	0.00	0.01
MAU-11	0.17	0.04	0.00	0.00	0.00	0.00	0.06	0.05	0.00	0.01	0.00	0.02
MAU-12	0.80	0.17	0.00	0.09	0.00	0.01	0.11	0.07	0.00	0.03	0.29	0.03
MAU-2	0.40	0.00	0.00	0.00	0.01	0.00	0.33	0.04	0.00	0.00	0.00	0.01
MAU-4	0.19	0.04	0.00	0.01	0.00	0.00	0.03	0.06	0.00	0.01	0.00	0.02
MAU-5	1.65	0.17	0.00	0.18	0.01	0.00	0.13	0.01	0.00	0.01	1.14	0.00
MAU-6	0.07	0.03	0.01	0.00	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.00
MAU-9	0.12	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.01	0.08	0.00
Average	0.43	0.06	0.00	0.04	0.01	0.01	0.09	0.04	0.01	0.01	0.17	0.01

Table J.5.1-2 – Total fish biomass around Maug Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
MAU-1	0.35	0.12	0.03	0.03	0.00	0.02	0.01	0.00	0.03	0.06	0.00	0.05
MAU-10	0.21	0.07	0.01	0.00	0.00	0.03	0.00	0.00	0.07	0.00	0.00	0.02
MAU-11	0.39	0.15	0.01	0.00	0.01	0.03	0.02	0.00	0.07	0.02	0.00	0.08
MAU-12	1.13	0.04	0.02	0.37	0.00	0.03	0.20	0.00	0.07	0.01	0.33	0.07
MAU-2	0.34	0.05	0.02	0.00	0.00	0.03	0.13	0.00	0.07	0.01	0.00	0.03
MAU-4	0.26	0.08	0.01	0.00	0.00	0.04	0.00	0.00	0.04	0.02	0.00	0.06
MAU-5	0.26	0.05	0.01	0.00	0.02	0.03	0.10	0.00	0.02	0.01	0.00	0.03
MAU-6	0.17	0.04	0.00	0.00	0.00	0.01	0.02	0.00	0.03	0.01	0.00	0.05
MAU-9	0.30	0.13	0.03	0.00	0.00	0.01	0.00	0.00	0.04	0.04	0.00	0.04
Average	0.38	0.08	0.02	0.04	0.00	0.02	0.06	0.00	0.05	0.02	0.04	0.05

J.5.2 Fish towed-diver surveys

At Maug the Towboard team conducted 8 surveys totaling 17 kilometers in length and covering 17 hectares of ocean bottom. Mean survey length was 2.17 km. Two thousand one-hundred six fish (>50 cm TL, all species spooled) were observed totaling 23 different species. Overall numeric density was 123.88 fish per hectare. Garden eels *(conger sp.)* were by far the most abundant species seen and are not shown in Figure J.5.2-1. Aside from *Conger sp.*, twinspot snapper (*Lutjanus bohar*), sleek unicornfish (*Naso hexacanthus*), black and white snapper (*Macolor niger*), mignight snapper (*Macolor macularis*) and whitetip reef sharks (*Triaenodon obesus*) were the five most commonly observed species (> 50 cm TL) at Maug during the survey period (Table J.5.2-1).

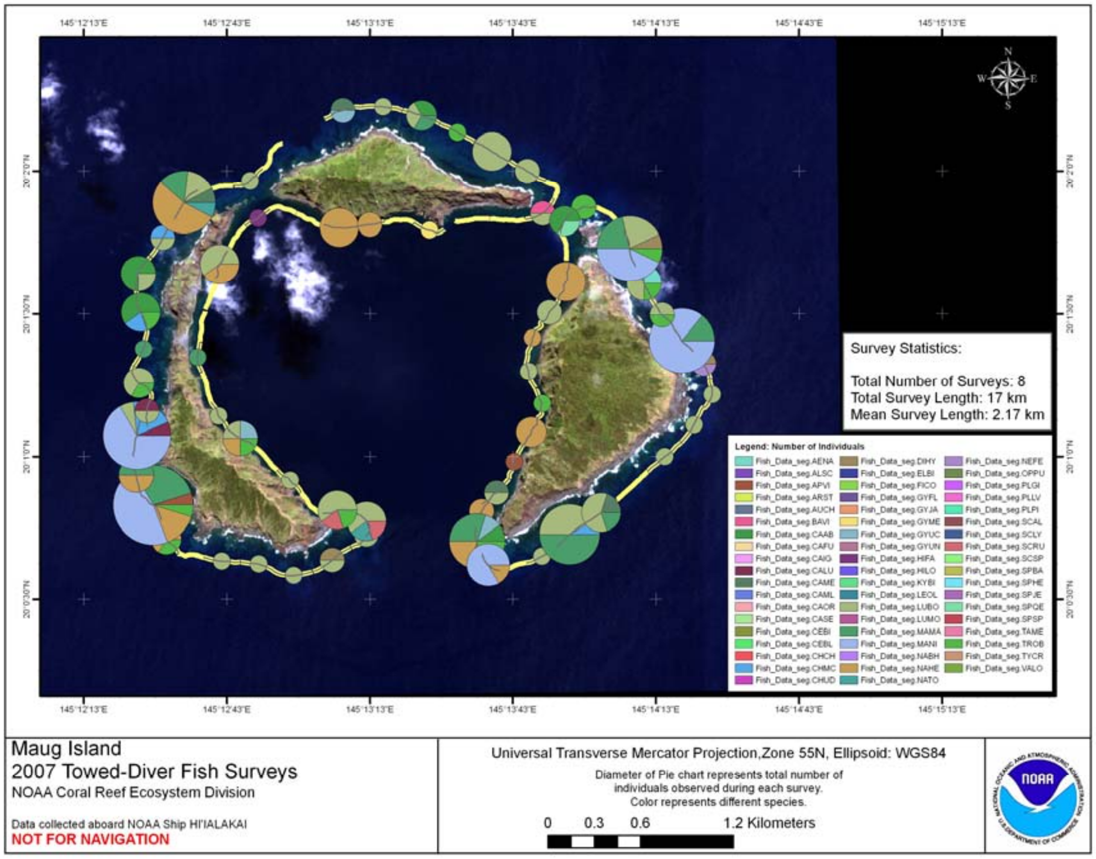


Figure J.5.2-1. Distribution of Large Fish Observations at Maug.

Table J.5.2-1. Total number of individuals of each species observed at Maug.

Island	Taxon Name	#
Maug	Conger sp.	1800
	Lutjanus bohar	66
	Naso hexacanthus	58
	Macolor niger	53
	Macolor macularis	35
	Triaenodon obesus	21
	Caranx sexfasciatus	14
	Carcharhinus amblyrhynchos	10
	Chlorurus microrhinos	10
	Gymnosarda unicolor	8
	Caranx melampygus	5
	Elagatis bipinnulata	5
	Caranx lugubris	4
	Naso tonganus	3
	Diodon hystrix	3
	Scarus rubroviolaceus	2
	Aprion virescens	2
	Nebrius ferrugineus	2
	Aetobatus narinari	1
	Himantura fai	1
	Balistoides viridescens	1
	Gymnothorax meleagris	1
	Sphyraena qenie	1
Maug Total		2106

Appendix K: Supply Reef

K.1. Benthic Habitat Mapping

Supply Reef is a submarine bank located approximately 17 nmi south of Uracus and 19 nmi north of Maug Island. It is shown on nautical chart 81004_1 at two, 5 fathom (~9 m) pinnacles about 9 nautical miles apart. As mapped on HI0703, Supply Reef is located at approximately 20° 08' N, 145° 06' E and rises to ~10 m. It is considered to be a dormant volcano (Stern et al., 1989).

Multibeam mapping surveys were conducted using the R/V *AHI*'s Reson 8101ER and the *Hi'ialakai's* EM300 multibeam sonars.   The ship transited to and worked at Supply Reef on June 2, 2007, (JD 153) and the *AHI* was also deployed on June 2, 2007.

The R/V *AHI* completed multibeam coverage of Supply Reef between depths of ~10 m and 250 m, and the *Hi'ialakai* collected data down to about 2700 m around the bank. Multibeam data were collected on the eastern side of the chain during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this on-going synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the previously existing data were collected primarily to the west of the island chain.   The multibeam data collected around Supply Reef represents approximately 20% of the 3856 km^2 (roughly 750 km^2) of HI0703 coverage around the northern section of the Mariana Arc, which includes Uracas, Maug, and Ascunsion Islands and Supply Reef.

Supply Reef is a dormant volcano (Bloomer et al.,1989) and although it is not subaerial, the submarine morphology of Supply Reef is similar to the other Mariana volcanoes mapped during HI0703. The slopes are steep and dissected by channels and canyons. Small blocks of material litter the seafloor around Supply Reef and are most abundant on the north side between ~1700 and 2500 m. A number of curious features occupy the deep seafloor east of Supply Reef at ~2100 m. An expansive, flat region with subdued sediment waves lies to the west of an elevated region with bumps and ridges on its top. The boundary between the two regions is incised by linear channel-like features. Some of the features are straight but others are sinuous and terminate downslope on the flat plan in long fingers. Similar features further south correlate upslope with Maug submarine channels.

Reference:

Bloomer, S.H., Stern, R.J. and Smooth N.C. 1989. Physical volcanology of the submarine Mariana and Volcano Arcs. Bulletin of Volcanology, p. 210-224.

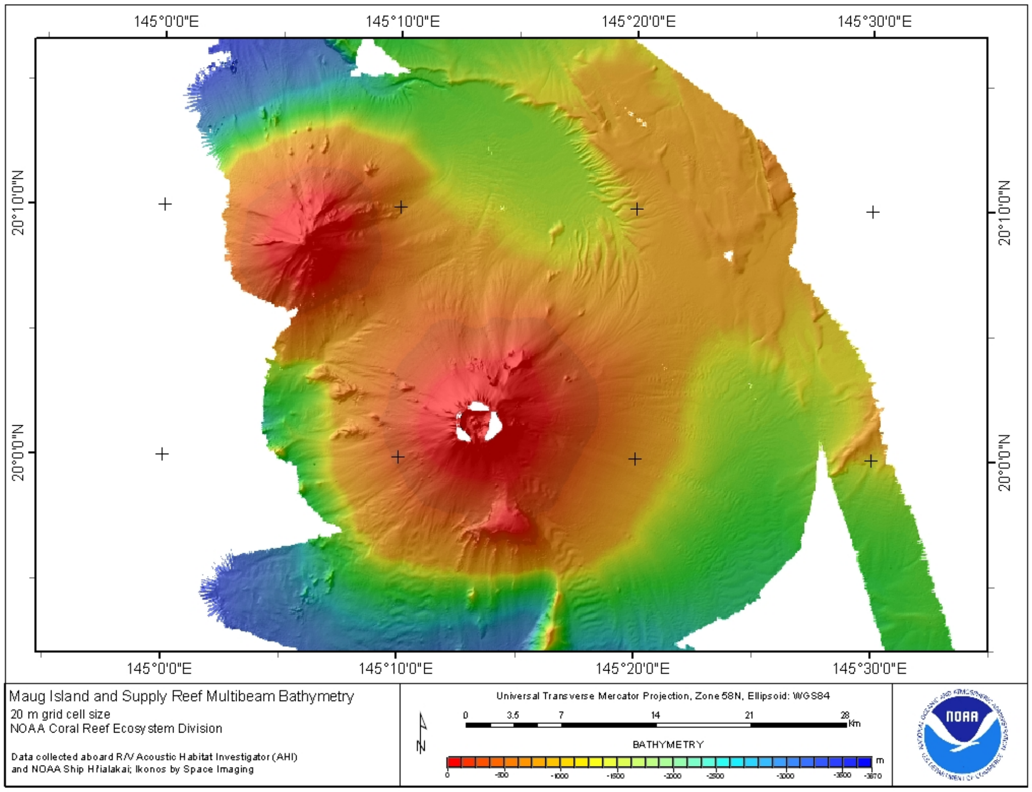


Figure K.1-1: Multibeam bathymetric data collected during HI0703 around Supply Reef and Maug Island

K.2. Oceanography and Water Quality

In total, one instrument was recovered and two instruments were deployed at Supply Reef during HI0703. One wave and tide recorder (WTR) was recovered and replaced at approximately 27 m depth. Additionally, one subsurface temperature recorder was deployed alongside the WTR.

Appendix L: Uracas

L.1. Benthic Habitat Mapping

Uracas is northernmost of the volcanic islands belonging to the Commonwealth of the Mariana Islands and it is also called Farallon de Parajos. It is located at ~20° 32’ N, 144° 53’ E, but the location of the island on nautical chart 81086_1 is ~0.5 nmi southeast of the position that was observed during HI0703.

Multibeam mapping surveys were conducted using the R/V *AHI*’s Reson 8101ER and the *Hi’ialakai’s* EM300 multibeam sonars.   The ship transited to and worked at Uracas on June 3 and 4, 2007, (JD 153-154); the *AHI* was deployed on June 4, 2007.

The R/V *AHI* completed multibeam coverage of the volcano between depths of ~15 m and 250 m, and the *Hi’ialakai* collected data down to about 1600 m around the island. Multibeam data were collected on the eastern side of the chain during the transits to and from the island to complement existing multibeam data sets that were synthesized in preparation for HI0703. All data collected on HI0703 will be incorporated into this on-going synthesis being conducted by a consortium of scientists working in the Mariana Archipelago; the existing data were collected primarily to the west of the island chain. The multibeam data collected around Uracas represents approximately 10% of the 3856 km^2 (roughly 375 km^2) of HI0703 coverage around the northern section of the Mariana Islands, which includes Uracas, Maug, and Ascunsion Islands and Supply Reef.

Uracas is an active volcano that rises to 319 m and last erupted in 1967 (Bloomer et al., 1989; Trusdell et al., 2005). The slopes of the emergent island and the undersea flanks are uniformly steep with no shallow shelves around the volcano. Evidence of mass wasting was observed on the subaerial volcanic slopes and some blocky material was mapped on the submarine flanks. An elevated portion of seafloor on the eastern flank of the volcano reaches ~200 m and is possibly related to an older portion of the volcano. Erosional features such as narrow submarine channels are abundant on the submarine flanks of Uracas and can be seen extending to depths >2500 m where data were collected east of the volcano.

References:

Bloomer, S.H., Stern, R.J. and Smooth N.C. 1989. Physical volcanology of the submarine Mariana and Volcano Arcs. Bulletin of Volcanology, p. 210-224.

Trusdell, F.A., Moore, R.B., Sako, M., White, R.A., Koyanagi, S.K., Chong, R., and Camacho, J.T. 2005. The 2003 eruption of Anatahan volcano, Coomonwealth of the Northern Mariana Islans; Chronology, volcanology, and deformation. Journal of Volcanology and Geothermal Research, v. 146, p. 184-207.

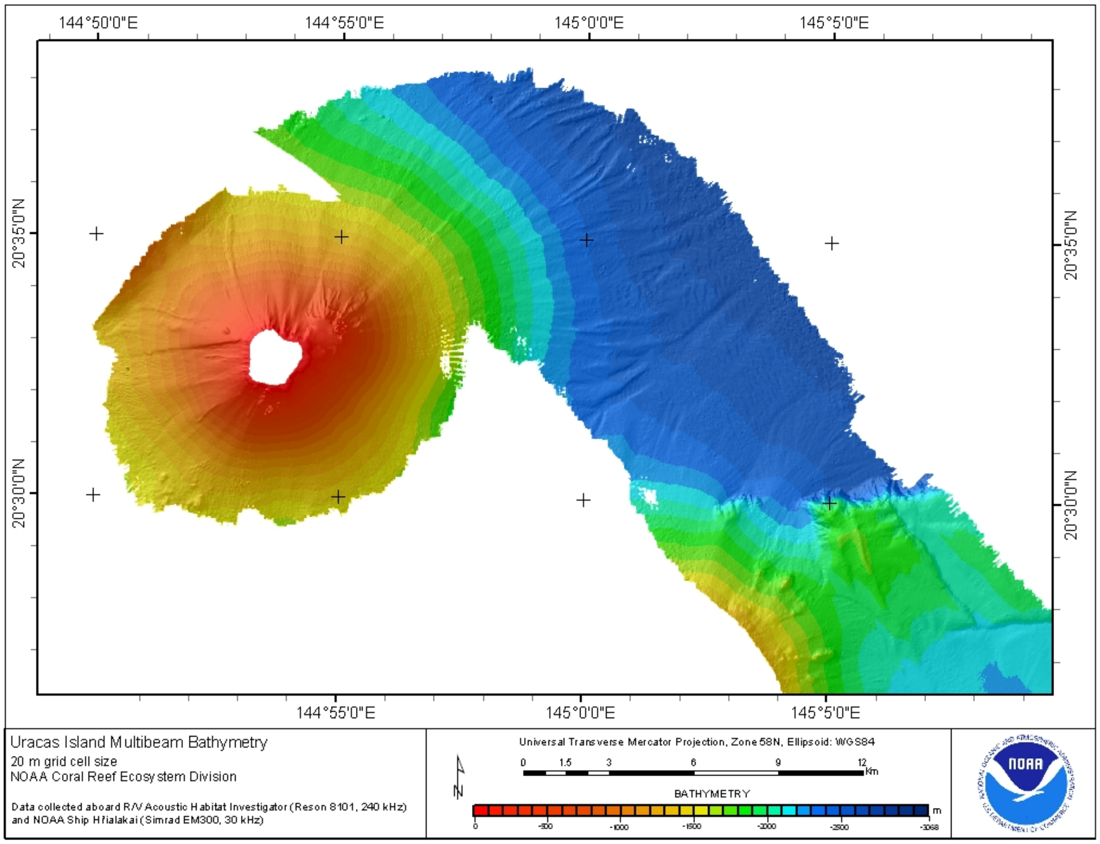


Figure L.1-1: Multibeam bathymetric data collected during HI0703 around Uracas Island.

L.2. Oceanography and Water Quality

In total, one instrument was recovered and six instruments were deployed at Uracus during HI0703. One subsurface temperature recorder (STR) was recovered; however, no data appears to have been recorded on the instrument. The STR was replaced and five new STRs were deployed in two depth transects on opposing sides of the island near REA sites 1 and 2. The STRs were placed at approximately 10 m, 20 m and 30 m depths to capture cold water pulses that appear to have a large influence on both the benthic and fish communities (Figure L.2-1)

Seven shallow water conductivity, temperature, depth (CTD) casts were conducted around the perimeter of Uracus at approximately 0.8 km intervals following the 30-m contour. At three of these CTD locations, water sample profiles were performed concurrently, using a daisy chain of Niskin bottles at 1 m, 10 m, 20 m and 30 m depths, for a total of 28 discrete water samples measuring chlorophyll and nutrient concentrations (Figure L.2-1).

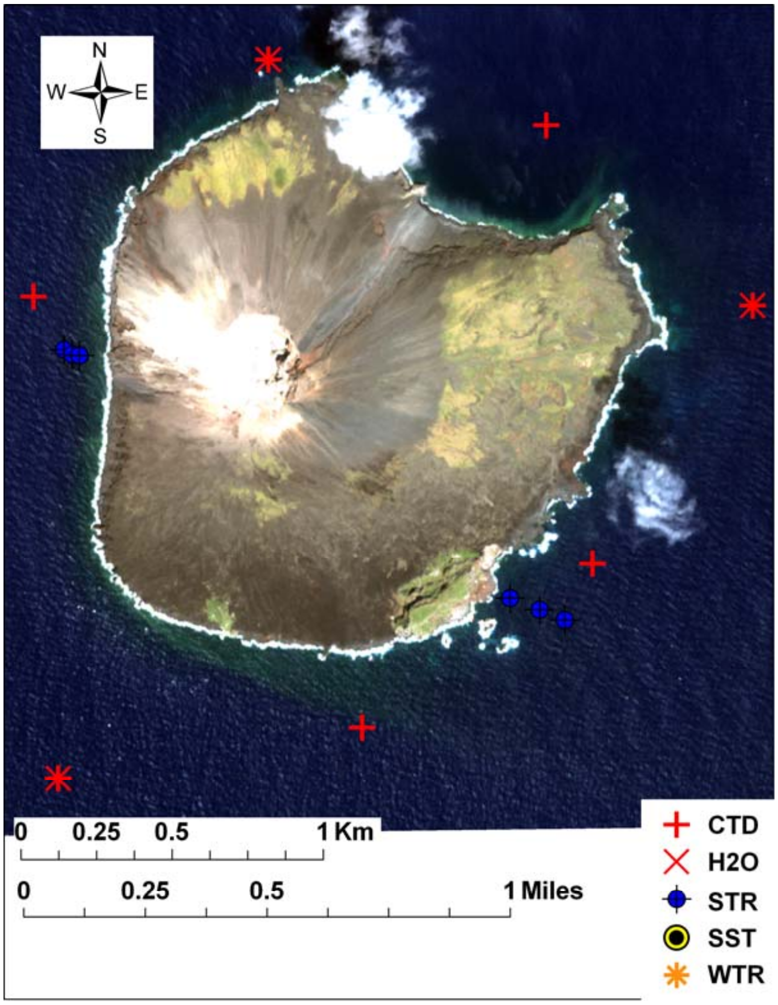


Figure L.2-1: Positions of CTDs, water samples and moorings at Uracas.

L.3 Rapid Ecological Assessment (REA) Site Descriptions

Uracas is the northernmost island in the Marianas Archipelago. The island receives fairly limited fishing pressure, given its relative distance from Saipan. This island is constitutionally designated as a terrestrial reserve, and access is allowed through permit only. Legislation was drafted to include the waters surrounding the island out to 1 kilometer as a no-take marine protected area. The area is patrolled by the U.S. Coast Guard, based out of Guam.

REA surveys were conducted at three sites at Uracas (Table L.3-1). Locations of all REA sites around Uracas are shown in Figure L.3-1. The descriptions of each site are listed in the order they were occupied by the REA team.

Table L.3-1. Sites surveyed by REA team at Uracas, HI-07-03, May-June 2007. Depths and temperature are from Vargas Angel's dive gauge.								
Site #	Date	Latitude (north)		Longitude (east)		Transect depth range, m	Max Depth, m	Temp, °C
URA-2	6/3/2007	20	32.269	144	53.954	12 - 14	18.3	28.9
URA-1	6/3/2007	20	32.753	144	53.133	12 - 13	18.6	27.8
URA-4	6/3/2007	20	33.191	144	53.436	7 - 13	24.4	28.9

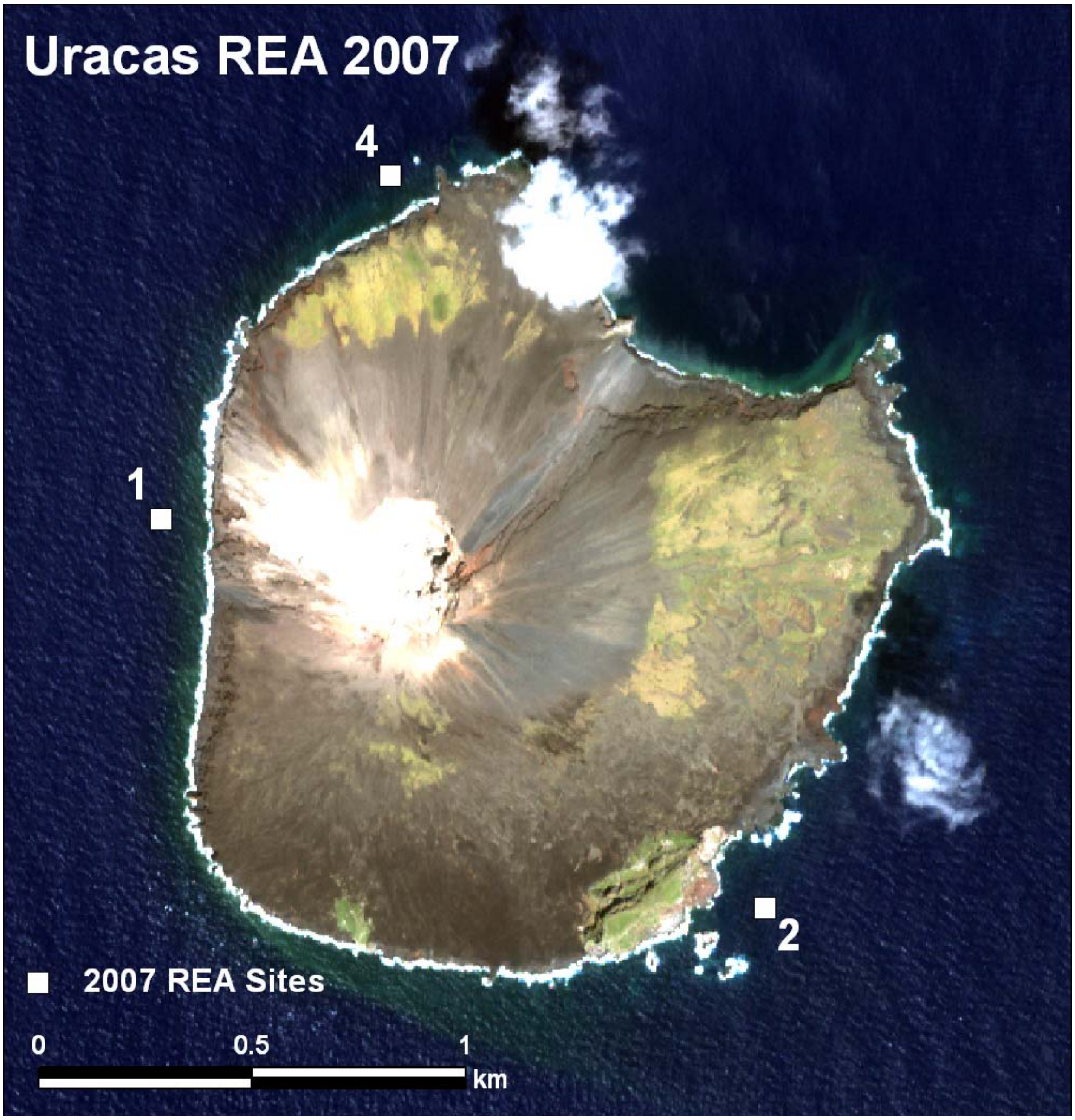


Figure L.3-1. Location of 2007 REA survey sites at Uracas.

Uracas

URA-2

June 3, 2007

Southeast side, transect depth range: 12–14 m. Relief composed of basalt boulders intermingled with black siliciclastic sand. Low percent live coral cover (2.9%). Turf-algae over rock comprised >85% of bottom cover. No coral diseases were observed within the survey area (300 m^2). Turf algae, encrusting *Lobophora* sp., and *Jania* sp. are very abundant on the large boulders; encrusting corallines are less abundant compared to well established reef communities; rocks covered by a fine sandy layer contain the small and slender *Caulerpa* sp. (provisionally identified as *Caulerpa crassifolia*); other species that occurred in lower densities on the rocks are *Caulerpa nummularia, C. webbiana, Dictyosphaeria cavernosa, D. intermedia,* small *Halimeda* thalli, *Neomeris, Padina* sp., and a encrusting *Peyssonnelia*. Coral cover is low and a small colonial ascidian was very abundant on the rocks.

URA-1

June 3, 2007

West leeward side, transect depth range: 12–13 m. Relief composed of basalt boulders intermingled with siliciclastic sand. Low percent live coral cover (2.9%). Turf-algae over rock comprised >83% of bottom cover. No coral diseases were observed within the survey area (300 m^2). Similar to URA02, but an even lower macroalgal cover and a lower species richness along the transect.

URA-4

June 3, 2007

North side, transect depth range: 7–13 m. Relief composed of basalt boulders intermingled with siliciclastic sand. Low percent live coral cover (4.9%). Turf-algae over rock comprised >94% of bottom cover. No coral diseases were observed within the survey area (300 m^2). Algal cover is similar to URA01. At the start of the transect the boulders are more dense in comparison to URA02 and URA01.

L.4. Benthic environment

L.4.1. Algae

Algal species were surveyed and collected at three sites around Uracas.

Table L.4.1-1. Rank averages of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		5.8		7.0		5.4	3.0		
Bornetella		3.0			1.0	6.6			
Bryopsis				7.0		4.0			
Caulerpa	4.7	5.7	3.4	8.0	4.9	4.6			3.5
Dictyosphaeria	6.0		6.0		4.9	7.1	3.0		4.8
Halimeda	2.0	3.7	4.6	3.1	3.6	3.6	1.9	1.9	7.0
Neomeris	3.3	2.0	4.3	7.0	4.3	6.0	3.0	9.0	4.0
Rhipidosiphon			5.0			4.0			
Trichosolen					3.0				
Tydemania	5.0		4.0	6.0	4.5	6.0			
Ventricaria	6.0		3.0	5.5	6.0	5.7			
FLORIDEOPHYCEAE									
Acrosymphyton						1.0			
Actinotrichia	5.7					5.0			
Amansia								6.0	
Amphiroa	5.0	4.3	6.5	5.0	3.4	4.2		3.0	
Asparagopsis	4.3	2.5				3.4			
Ceramium						8.0			
Cheilosporum						6.0			
Corallinaceae_crus	2.3	2.9	2.0	2.4	1.8	2.5	2.8	2.6	3.3
Galaxaura								4.0	
Haematocelis	3.4	4.7			2.4	2.7	3.0		
Hypnea	4.0		7.0						
Jania	4.2	4.6	3.3	4.2	4.0	3.8	3.6	7.0	3.0
Liagora					2.5	5.0			
Lomentaria						6.0			
Martensia	4.0					8.0			
Peyssonnelia	8.0	5.5	2.4	3.0	3.2	4.2			3.0
Portieria				5.0		8.0			
Tolypiocladia	4.2			3.0	5.0	5.0			
Tricleocarpa						9.0			
Wrangelia					4.0	4.0	4.0		
PHAEOPHYCEAE									
Cutleria	4.5	6.0							
Dictyota	4.5	5.0	5.2	6.0	4.0	5.5	6.0	5.0	
Lobophora			2.9	3.4	3.3	3.7			1.9
Padina	5.0		3.5		4.5	7.0			5.0
Sphacelaria	6.0				5.3				
Turbinaria					4.4				
OTHER									
Cyanobacteria	3.6	3.1	3.9	3.6	3.2	3.7	2.4	3.1	3.0
Sarcinochrysis					3.5	5.5	2.0		
Turf algae	1.1	1.0	1.5	1.6	1.7	1.4	1.5	1.7	1.4

Table L.4.1-2. Standard deviations of rank order of algal categories for the Northern Marianas by island.

	AGR	ALA	ASU	GUG	MAU	PAG	SAR	TIN	URA
ULVOPHYCEAE									
Boodlea		1.6				2.3	0.9		
Bornetella						1.3			
Bryopsis									
Caulerpa	3.1	0.6	1.6		1.8	2.4			2.1
Dictyosphaeria					2.2	2.2			1.0
Halimeda		1.3	1.8	1.3	1.4	2.5	1.4	0.9	
Neomeris	2.3		0.9		1.3	2.0			1.0
Rhipidosiphon									
Trichosolen									
Tydemania					0.7	0.0			
Ventricaria				0.7	0.7	1.3			
FLORIDEOPHYCEAE									
Acrosymphyton						0.0			
Actinotrichia	2.9					1.9			
Amansia									
Amphiroa	1.3	1.1	0.7	1.0	1.0	1.4		0.0	
Asparagopsis	2.1	1.1				2.1			
Ceramium									
Cheilosporum									
Corallinaceae_crus	1.0	1.0	1.1	1.4	0.7	1.5	0.8	1.2	0.8
Galaxaura									
Haematocelis	1.0	1.7			1.2	1.2	0.0		
Hypnea									
Jania	1.4	0.5	1.5	1.6	1.3	1.7	0.5		0.7
Liagora					2.1				
Lomentaria									
Martensia									
Peyssonnelia		2.1	0.5	1.6	1.6	1.9			
Portieria				0.8					
Tolypiocladia	2.6				0.0	1.4			
Tricleocarpa									
Wrangelia						0.0			
PHAEOPHYCEAE									
Cutleria	2.1								
Dictyota	1.4		1.1	2.0	1.9	1.4			
Lobophora			1.0	1.2	0.8	1.2			0.8
Padina	2.8		0.5		0.6	1.4			1.0
Sphacelaria	1.6				0.6				
Turbinaria					1.0				
OTHER									
Cyanobacteria	1.4	1.4	1.0	1.5	1.1	1.5	1.3	2.2	0.8
Sarcinochrysis					1.8	2.1			
Turf algae	0.3	0.2	1.0	0.8	1.1	0.7	0.8	0.8	0.8

Table L.4.1-3. Specimens collected at Uracas in the Northern Marianas during the MARAMP 2007 cruise and deposited in Guam.

Taxon	Site	Herb	Form	Silica	Dry	EtOH
Padina small (URA02-001)	URA02; Uracas, CNMI, Mariana Islands; collection date: 2007_06_03		X			
Caulerpa crassifolia (URA02-001)	URA02; Uracas, CNMI, Mariana Islands; collection date: 2007_06_03		X	X		
Caulerpa nummularia (URA02-001)	URA02; Uracas, CNMI, Mariana Islands; collection date: 2007_06_03		X			
Dictyosphaeria cavernosa (URA02-001)	URA02; Uracas, CNMI, Mariana Islands; collection date: 2007_06_03		X			

L.4.1.2 Benthic towed-diver surveys – Macroalgae

Macroalgae and coralline algae cover at Uracas averaged 3% and 4% respectively, (range 0 – 10% and 0 – 20%). Macroalgae never exceeded an overall average of 5%/survey, while coralline algae had a high of 9% cover recorded during the survey of the south to southwest section of the island. No additional algal observations were noted.

L.4.2. Corals

L.4.2.1 Coral Populations

Coral Diversity and Population Parameters

Three sites were surveyed on the northernmost island of the chain (URA-1, URA-2, and URA-4). They all consisted of volcanic boulders with sand, yielding little coral growth. Notably, there continues to be a large presence of juvenile *Pocillopora* corals that fail to grow. Other corals in high population density and small size are *Porites, Favia*, *Leptastrea*, and *Pavona*. Little change is noted in the coral community since 2003.

L.4.2.2 Percent Benthic Cover

In 2007, the line-intercept methodology quantified a total of 306 points along 150 m of forereef coral communities. Patterns of intra-island variability in percent benthic cover, derived from the 3 independent REA surveys are reflected in Figure L.4.2.2-1. For the most part, REA survey sites were comprised by basalt boulders intermingled with sand patches, and a few scattered coral colonies growing on the basalt boulders. Point-count surveys indicated that percent live coral cover was low, ranging between 2.9 and 4.9%, for a grand mean of 3.6% for all sites combined. Basalt boulders covered with turf-algae dominated the underwater seascape comprising over 87% of the benthic cover. Only a total of 4 scleractinian genera were enumerated along the point-count transects (*Pocillopora*, *Pavona*, *Goniastrea*, and *Porites*) with *Pocillopora* being the most numerically abundant scleractinian ~64%, followed by *Pavona* (~12%). Outside the survey transect lines, however, up to 15 different scleractinian genera and one hydrocoral were enumerated.

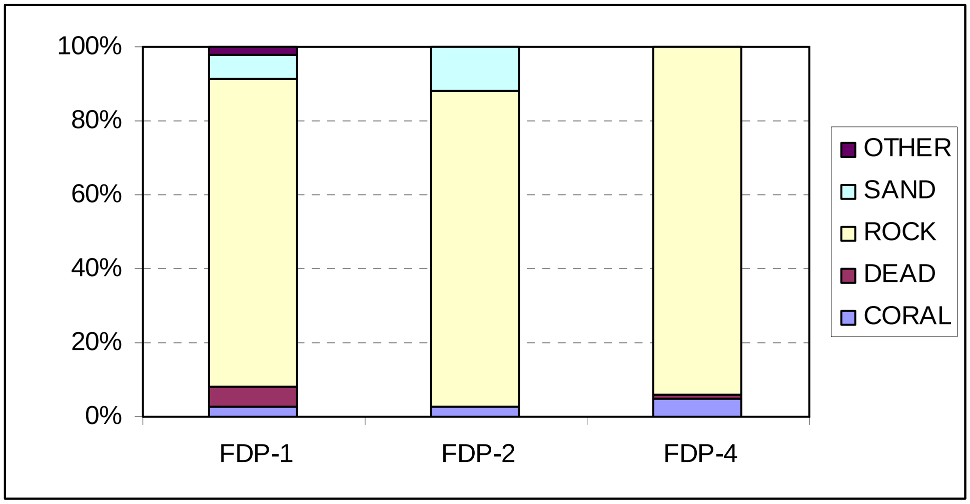


Figure L.4.2.2-1 Mean percent cover of selected benthic elements derived from 3 independent REA surveys at Uracas, MAR-RAMP 2007. CORAL: live scleractinian and hydrozoan stony corals; DEAD: dead coral; ROKK: turf-algae covered basalt boulders; PAVMT: turf-algae covered carbonate pavement; SAND: sand; and OTHER: other sessile invertebrates including alcynoarian corals, echinoderms, sponges, tunicates, as well as cyanobacterial mats. Site names are presented as FDP (Farallón de Pájaros)-1,2,4, equivalent to URA-1,2,4.

L.4.2.3 Coral Disease

A total area of ~850 m^2 at the 3 REA sites was surveyed and no coral diseases were encountered in the area surveyed. We did encounter, however, numerous senescing colonies of *Pocillopora*, exhibiting partial mortality, with turf and macroalgal overgrowth on the dead portions. Additionally, numerous fissioned colonies of *Pavona varians*, *Astreopora*, and *Leptastrea* were also observed.

L.4.2.4 Benthic towed-diver surveys – Corals

The average hard coral cover for Uracas was recorded at 5% (range 0.1 - 20%), with stressed coral averaging <1% (range 0 - 30%). The highest overall coral cover was recorded during towed-diver surveys in the south/southwest and northeast/east, with an average of 6% coral cover each (range 5.1 - 20%). Both surveys contained similar terrain consisting of uniform boulder and sand habitat of moderate slope, with occasional ridges and elevated rocky reef providing additional vertical relief.

The highest stressed coral (average 6%, range 0 – 30%) was noted during a towed-diver survey progressing from the southwest to northern coastline of the island. Evidence of a possible recent rock slide was evident by the presence of broken *Pocillopora* colonies throughout the survey.

The soft coral cover for Uracas was noted at an average of < 1% (range 0 – 5%), with the vast majority of time segments recording 0% soft coral cover.

L.4.3 Macroinvertebrates

L.4.3.1 Benthic towed-diver surveys - Macroinvertebrates

The overall macroinvertebrate averages per survey for the island of Uracas were 49.6 sea urchins and 0.3 giant clams. Sea urchins were most abundant along the eastern side of the island where numbers exceeded 175 individuals per segment for half of the survey. The habitat was characterized as pavement with boulders or spur-and-groove habitat. Only eight additional sea urchins were counted during the remaining surveys at Uracas. The highest concentration of giant clams occurred along the southern side of the island where six individuals were recorded in a survey. Only four additional clams were recorded along the remaining coastline of Uracas. There were no records of COTs or sea cucumbers.

L.4.3.2 Invertebrate REA surveys – belt, quadrat, and sediment diversity

Quantitative sampling of non-cryptic invertebrates along belt transects and benthic and sediment diversity surveys were conducted at REA sites around Uracas. The survey methods employed at each site and notable observations are summarized in Table L.4.3.2-1.

Table L.4.3.2-1. Summary of invertebrate quantitative belt transect surveys, benthic diversity quadrat surveys, and sediment diversity sampling at REA sites around Uracas.

Site	Quantitative Belt	Diversity Quadrat	Diversity Sediment	Notes
URA-2	X	X		Boulders and sand. *Sarcostrea*? sp. abundant. *Linkia multiflora* abundant. Picked up rope with gooseneck barnacles on the way to URA-1. Dolphins at URA-2.
URA-1	X	X	X	Boulder field with sparse sand pockets. *Sarcostrea*? sp. abundant. Sediment sample (75 ft.). Nearshore: coral recruits, indeed all sessile invertebrate fauna disappeared several meters from shore. Water became hazy yellow. Turf/cyano present on boulders, however intertidal lacked any evidence of animal life. A belt of yellow water was evident along the shore from the boat.
URA-4	X	X	X	Boulders and wall. Minimal sand. Minimal invertebrate (or algal) life of any significant size above ~40 ft. Antipitharians and small gorgonians ~20 cm in diameter. Present. Three species of ahermatypic corals. Sediment sample (65 ft.)

L.4.3.3 Opportunistic invertebrate collections

Linckia multiflora was collected at several locations around Uracas (Table L.4.3.3-1).

Table L.4.3.3-1: Opportunistic collections of *Linckia multiflora* around Uracas during HI0703.

Location	Date	Collector	Species	# of Samples	REA site	Site location	Habitat	Outbreak population	Depth-ft	Latitude	Longitude
Uracas	6/3/07	R. Moffitt	*Linckia multiflora*	24	2	SE Corner	Forereef	N	40	20.5378	144.8992
Uracas	6/3/07	J. Asher	*Linckia multiflora*	11	4	NW Corner	Forereef	N	80	20.5532	144.8906

L.5. Fish

L.5.1 REA Fish Surveys

Stationary Point Count data
A total of 12 individual SPC surveys were conducted at 3 forereef sites around the island of Uracas. Sharks (Carcharhinidae) were the largest contributor to biomass with 0.43 ton per hectare. Snappers (Lutjanidae), and surgeonfish (Acanthuridae) were also commonly observed during the SPCs yielding biomass of 0.23 and 0.09 ton per hectare, respectively.

Belt-Transect data
During the survey period, 9 belt-transect surveys were conducted at 3 forereef sites around the island of Uracas. Snappers (Lutjanids) were the largest contributor to the overall biomass with 0.30 ton per hectare. Surgeonfish (Acanthurids) were also common with 0.11 ton per hectare (Fig. L.5.1-1).

Overall observations
A total of 127 species were observed during the survey period by all divers. The average medium to large fish biomass at Uracas sites during the survey period was 0.85 ton/ha for the SPC surveys (Table L.5.1-1), and the average fish biomass was 0.62 ton/ha for the belt transect surveys (Table L.5.1-2).

Figure L.5.1-1 – Family composition of the total fish biomass (0.62 ton per hectare) around Uracas Island.

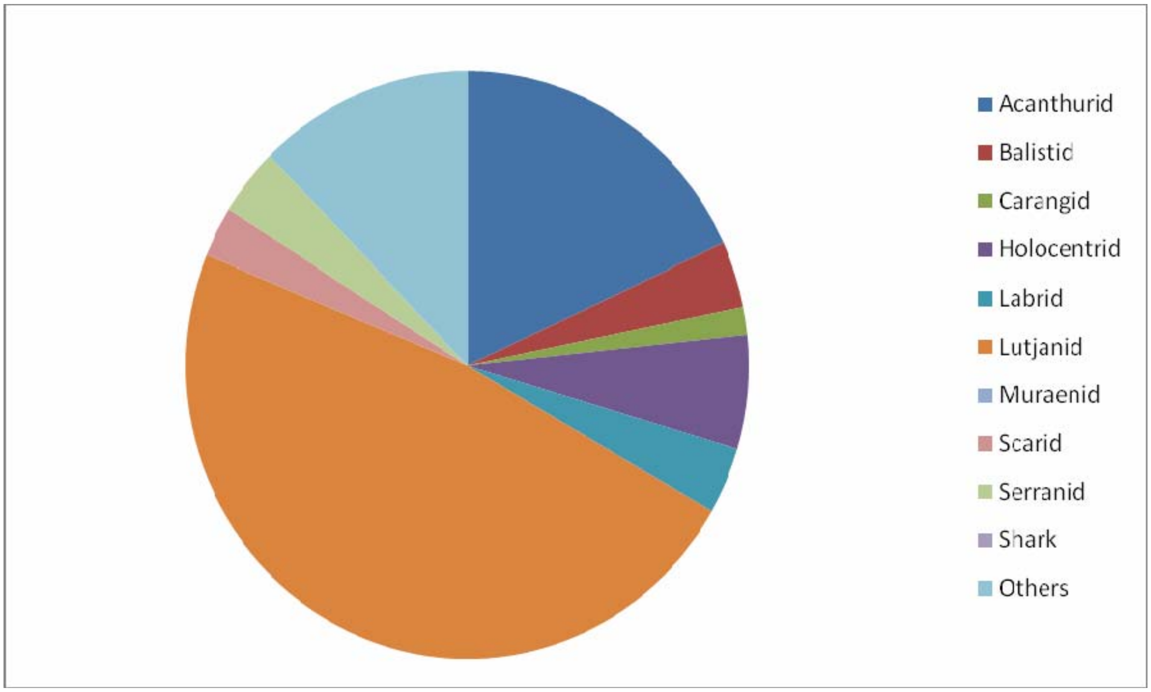


Table L.5.1-1 – Average medium to large fish biomass (tail length >25 cm) around Uracas Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Labrid	Lethrinid	Lutjanid	Scarid	Scombrid	Serranid	Shark	Others
URA-1	0.27	0.09	0.00	0.01	0.00	0.00	0.12	0.01	0.00	0.02	0.00	0.02
URA-2	1.25	0.13	0.00	0.01	0.01	0.01	0.46	0.05	0.00	0.03	0.53	0.01
URA-4	1.04	0.05	0.00	0.02	0.02	0.00	0.13	0.00	0.00	0.01	0.76	0.05
Average	0.85	0.09	0.00	0.01	0.01	0.00	0.23	0.02	0.00	0.02	0.43	0.03

Table L.5.1-2 – Total fish biomass around Uracas Island (ton per hectare).

Site	Total	Acanthurid	Balistid	Carangid	Holocentrid	Labrid	Lutjanid	Muraenid	Scarid	Serranid	Shark	Others
URA-1	0.41	0.16	0.04	0.01	0.03	0.01	0.03	0.00	0.04	0.04	0.00	0.07
URA-2	0.88	0.11	0.02	0.00	0.05	0.03	0.62	0.00	0.00	0.02	0.00	0.04
URA-4	0.57	0.08	0.01	0.02	0.04	0.03	0.24	0.00	0.01	0.02	0.00	0.12
Average	0.62	0.11	0.02	0.01	0.04	0.02	0.30	0.00	0.02	0.02	0.00	0.08

<u>L.5.2 Fish towed-diver surveys</u>

At Uracas the Towboard team conducted 7 surveys totaling 17.5 kilometers in length and covering 17.5 hectares of ocean bottom. Mean survey length was 2.5 km. Two-hundred sixty-five fish (>50 cm TL, all species spooled) were observed totaling 17 different species. Overall numeric density was 15.14 fish per hectare. Bigeye trevally (*Caranx sexfasciatus*), sleek unicornfish (*Naso hexacanthus*), twinspot snapper (*Lutjanus bohar*), garden eels (*Conger sp.*) and black and white snapper (*Macolor niger*) were the five most commonly observed species (>50 cm TL) at Uracas during the survey period.

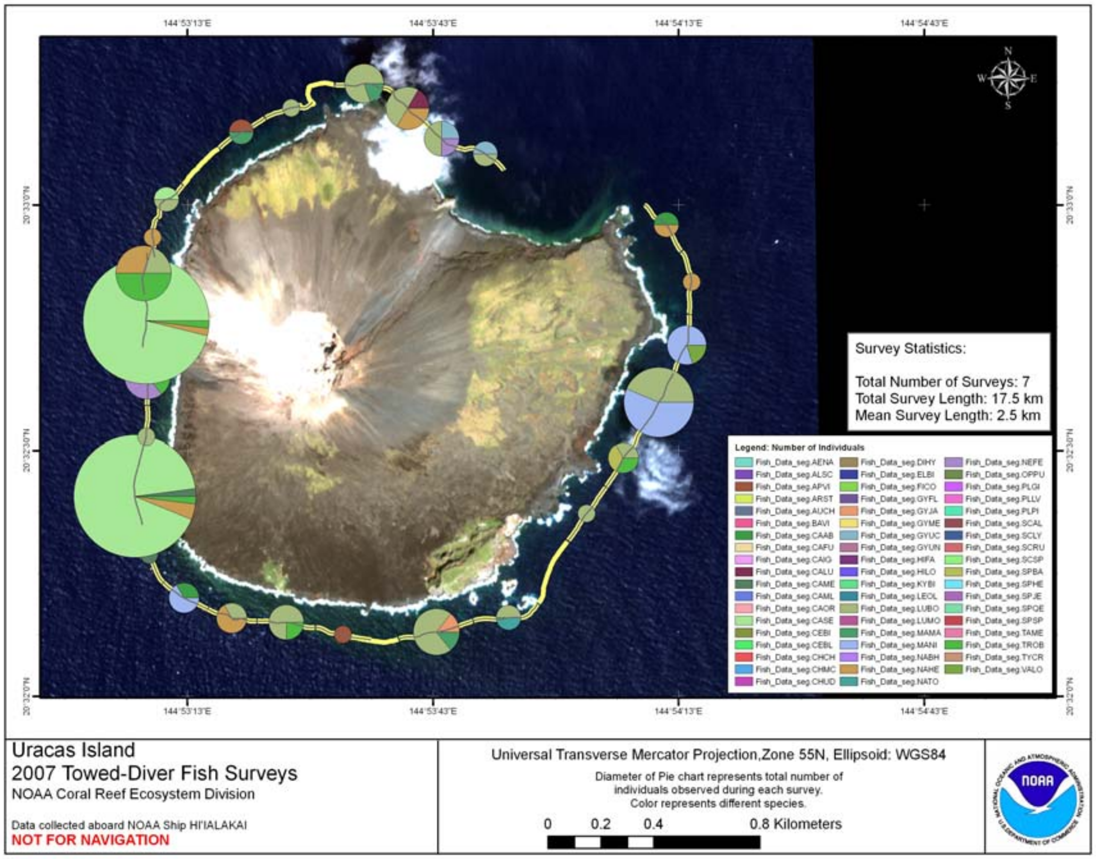


Figure L.5.2-1. Distribution of Large Fish Observations at Uracas.

Uracas

Table L.5.2-1. Total number of individuals of each species observed at Uracas.

Island	Taxon Name	#
Uracas	Caranx sexfasciatus	96
	Naso hexacanthus	46
	Lutjanus bohar	39
	Conger sp.	30
	Macolor niger	18
	Triaenodon obesus	11
	Nebrius ferrugineus	7
	Macolor macularis	4
	Gymnosarda unicolor	3
	Aprion virescens	2
	Caranx melampygus	2
	Carcharhinus amblyrhynchos	2
	Variola louti	1
	Naso tonganus	1
	Caranx lugubris	1
	Sphyraena barracuda	1
	Gymnothorax javanicus	1
Uracas Total		265