UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL OCEAN SERVICE
Silver Spring, Maryland 20910

CRUISE REPORT[1]

VESSEL: *Hi'ialakai*, Cruise HA-09-02

CRUISE PERIOD: 5 April–14 April 2009

AREA OF OPERATION: Guam and the Commonwealth of the Northern Mariana Islands (CNMI: Guam, Rota, Aguijan, Tinian, and Saipan) (Fig. 1)

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 oceanographic studies in waters surrounding Guam, Rota, Aguijan, Tinian, and Saipan.

ITINERARY:

2 April — Commenced calibration dives for benthic and fish rapid ecological assessment (REA) divers in Apra Harbor. This included divers that were aboard for the Wake leg as well as divers that were embarking for the Guam and CNMI leg. Divers included: Robert Schroeder (Chief Scientist, REA Fish), Paula Ayotte (REA Fish), Valerie Brown (REA Fish), Dave Burdick (Line Point Intersect [LPI]), Kerry Grimshaw (REA Benthic), Kaylyn McCoy (REA Fish), Marc Nadon (REA Fish), Kevin O'Brien (REA Fish), Laurie Raymundo (REA Benthic), Cristi Richards (REA Benthic), Stephanie Schopmeyer (REA Benthic), Bernardo Vargas-Angel (REA Benthic) and Rodney Withall (REA Benthic).

3 April — Continued calibration dives for benthic tow team, one inside and two outside of Apra Harbor. Divers included: Edmund Coccagna, Kerry Grimshaw, Kevin Lino, and Jason Helyer. (Note: fish tow team calibration dives were not possible due to lack of large fish around Guam.)

4 April — Teams worked independently on final pre-cruise logistical preparations, as remaining scientists arrived and settled into their berths.

5 April — Start of cruise. Embarked Robert Schroeder (Chief Scientist, REA Fish), Paula Ayotte (REA Fish), James Bostick (Divemaster/Chamber Operator),

[1] Cruise Report CR-09-018
Issued 15 December 2009

Valerie Brown (REA Fish), Dave Burdick (Line Point Intersect), Edmund Coccagna (Benthic Tow Team), Kerry Grimshaw (Education/Outreach, [Alt. Benthic REA]), Jason Helyer (Benthic Tow Team), Kevin Lino (Fish Tow Team), Frank Mancini (Oceanography), Kaylyn McCoy (Data Manager, [Alt. Fish REA]), Tracey McDole (Oceanography), Danny Merritt (Oceanography), Russell Moffitt (REA Benthic, Autonomous Reef Monitoring Systems [ARMS]), Marc Nadon (REA Fish), Noah Pomeroy (REA Benthic, ARMS), Laurie Raymundo (REA Benthic), Russell Reardon (Oceanography), Benjamin Richards (Fish Tow Team), Cristi Richards (REA Benthic), Bernardo Vargas-Angel (REA Benthic), Oliver Vetter (Oceanography). Conducted ship orientation and neurological exams for new scientists and conducted dive-safety briefing. Launched small boats for tow, oceanography and REA fish and benthic teams; began research operations. The fish and benthic REA teams surveyed two established REA sites (GUA-04, and GUA-10), and one new site in Apra Harbor (GUA-12), where three ARMS were deployed. The independent fish and LPI benthic REA teams surveyed three new sites (GUA-50, GUA-51, and GUA-52). The tow team completed five tows on the north end of the island, covering 11.2 km. The oceanography team exchanged one sea surface temperature (SST) buoy and one subsurface temperature recorder (STR), collected 18 shallow water conductivity-temperature-depth (CTD) casts, took 6 chlorophyll/nutrient water samples and one microbial sample. Total dives for all teams: 49.

6 April — Continued operations at Guam. The fish and benthic REA teams surveyed three established sites (GUA-07, GUA-09 and GUA-05) along the north and west sides. Three ARMS were deployed at site GUA-05. The independent fish and LPI benthic teams surveyed four new sites, two deep and two shallow (GUA-53, GUA-54, GUA-55, and GUA-56) along the north and west sides. The tow team completed six tows, five surveys and one calibration, along the east and north sides of the island, covering 12.3 km. The oceanography team exchanged one ecological acoustic recorder (EAR) on the north side of the island, exchanged two STRs, collected 12 shallow water CTD casts, collected 6 chlorophyll/nutrient water samples and one microbial sample. Nighttime oceanography operations consisted of one deepwater CTD and five nutrient and chlorophyll samples. Total dives for all teams: 57.

7 April — Continued operations at Guam. The fish and benthic REA teams surveyed two established sites (GUA-03 and GUA-02) and one new site (GUA-13) around the southern part of the island. Three ARMS were deployed at site GUA-02. The independent fish and LPI benthic teams surveyed four new sites, two deep and two shallow (GUA-57, GUA-58, GUA-59, and GUA-60). The tow team completed six tows covering 13 km along the south and west sides of the island. The oceanography team exchanged 1 STR, collected 19 shallow-water CTD casts, and collected 6 chlorophyll/nutrient water samples and one microbial sample. Nighttime oceanography operations consisted of one

deepwater CTD and five nutrient and chlorophyll samples. Total dives for all teams: 56.

8 April Continued operations at Guam on the east side. The fish and benthic REA teams surveyed one established site (GUA-08), where three ARMS were deployed, and one new site (GUA-14). The independent fish and LPI benthic teams surveyed three new sites, two deep and one shallow (GUA-61, GUA-62, and GUA-63). Both REA teams did not reach the last desired sites due to increased swell and winds. The tow team completed six tows covering 11 km. The oceanography team collected 12 CTD casts, collected 6 chlorophyll/nutrient samples, and collected one microbial sample. No nighttime oceanography took place due to transit to Rota. Total dives for all teams: 41.

9 April Commenced operations at Rota. The fish and benthic REA teams surveyed three established sites (ROT-01, ROT-02, and ROT-03). The independent fish and LPI benthic teams surveyed four new sites, two deep and two shallow (ROT-50, ROT-51, ROT-52 and ROT-53). The tow team completed five tows covering 10.4 km covering the south side of the island. The oceanography team deployed one EAR at REA site ROT-03, deployed one SST and two STRs, collected ten shallow water CTD casts, collected six nutrient/chlorophyll samples, and collected one microbial sample, also at REA site ROT-03. Nighttime oceanography operations consisted of one deepwater CTD and five nutrient/chlorophyll samples. Total dives for all teams: 56.

10 April Continued operations at Rota. The fish and benthic REA teams surveyed three established sites (ROT-05, ROT-06, and ROT-07). The independent fish and benthic LPI teams surveyed four new sites, two deep and two shallow (ROT-54 [fish only], ROT-55, ROT-56, and ROT-57). The tow team completed six tows covering 14 km. The oceanography team deployed and recovered one existing STR and deployed one new STR, collected nine shallow water CTD casts, collected four nutrient/chlorophyll samples, and collected one microbial sample. Nighttime oceanography operations consisted of one deepwater CTD and five nutrient/chlorophyll samples. Total dives for all teams: 60.

11 April Commenced operations at Aguijan. The fish and benthic REA teams surveyed two established sites (AGU-03 and AGU-02). The independent fish and LPI benthic teams surveyed four new sites, two deep and two shallow (AGU-50, AGU-51, AGU-52, and AGU-53). The tow team completed five tows circumnavigating the island, covering five km. The oceanography team recovered one STR and deployed one STR, collected nine shallow-water CTD casts, collected four nutrient/chlorophyll samples, and collected one microbial sample. Total dives for all teams: 44.

12 April Commenced operations at Tinian. The fish and benthic REA teams surveyed three established sites (TIN-01, TIN-04, and TIN-02). The independent fish

and LPI benthic teams surveyed three new sites, one deep and two shallow (TIN-50, TIN-51, and TIN-52). The tow team completed six tows covering 15 km. The oceanography team recovered one STR and deployed one STR, collected 13 shallow-water CTD casts, collected 6 nutrient/chlorophyll samples, and collected one microbial sample. Total dives for all teams: 50.

13 April — Continued operations at Tinian. The fish and benthic REA teams surveyed three established sites (TIN-06, TIN-03, and TIN-05). The independent fish and LPI benthic teams surveyed four new sites, one deep and three shallow (TIN-53, TIN-54, TIN-55, and TIN-56). The tow team completed five tows covering 11 km. The oceanography team recovered one STR and deployed one STR, collected seven shallow water CTD casts, collected four nutrient/chlorophyll samples, and collected one microbial sample. Total dives for all teams: 46.

14 April — Commenced operations at Saipan. The fish and benthic REA teams surveyed two established sites (SAI-08, and SAI-04). The independent fish and LPI benthic teams surveyed three new sites, one deep and two shallow (SAI-50, SAI-51, and SAI-52). The tow team completed five tows covering 10 km. The oceanography team recovered two STRS and deployed two STRs, recovered and deployed one SST buoy, collected one shallow water CTD cast, collected two nutrient/chlorophyll samples, and collected one microbial sample. (*Note: Detailed results for Saipan are appended to the Northern MARAMP cruise report (HA0903), as most of the Saipan surveys were conducted during this subsequent cruise.*)

Table 1.--Cruise statistics for HA-09-02 (excluding one day of Saipan operations from HA-09-02, included in HA-09-03).

	Guam 5-8 April	**Rota** 9-10 April	**Aguijan** 11 April	**Tinian** 12-13 April	**Grand Totals**
Towed-diver Habitat/Fish Surveys	22	11	5	11	49
Towed Diver Habitat Diver Calibration Tows/Dives	1	0	0	0	1
Combined tow lengths (km)	47.5	24.4	5	26	102.9
Fish Rapid Ecological Assessments	25	14	6	14	59
Benthic Rapid Ecological Assessments	25	13	6	14	58
Invertebrate Assessment/collection dives	9	5	2	6	22
ARMS deployed (3 per site)	9	3	0	0	12
SST buoys recovered	1	0	0	0	1
SST buoys deployed	1	1	0	0	2
STRs recovered	4	1	1	2	8
STRs deployed	4	3	1	2	10
SBE37 deployed	0	0	0	0	0
ADCP/Wave gauges deployed	0	0	0	0	0
EARs recovered	1	0	0	0	1
EARs deployed	1	1	0	0	2
Wave and tide recorders (WTRs) recovered	0	0	0	0	0
WTRs deployed	0	0	0	0	0
Shallow-water CTDs (oceanography team)	61	19	9	20	109
Nutrient and chlorophyll samples collected in conjunction with shallow water CTDs	24	10	4	10	48
Microbial Oceanography dives	4	2	1	2	9
Deepwater CTDs (from Hi'ialakai)	1	1	0	0	2
Nutrient and chlorophyll samples collected in conjunction with deep water CTDs	5	5	0	0	10
Acoustic Doppler Current Profiler (ADCP)Transects	0	0	0	0	0
SCUBA dives	203	116	44	96	459

MISSIONS:

A. Conduct ecosystem monitoring of the species composition, abundance, percent cover, size distribution, and general health of the fishes, corals, other invertebrates, and algae of the shallow water (< 35 m) coral reef ecosystems of Guam, Rota, Aguijan, Tinian, and Saipan. In addition, this cruise included the establishment of new line-point-intercept benthic sites, stationary-point-count fish sites, and the deployment of new ARMS.

B. Recover and replace existing environmental acoustic recorder and service existing array of SST buoys, subsurface ADCPs, subsurface wave gauges, STRs and temperature and salinity recorders to allow remote long-term monitoring of oceanographic and environmental conditions affecting coral reef ecosystems of Guam, Rota, Aguijan, Tinian, and Saipan.

C. Collect both deep (> 35 m) and shallow-water (< 35 m) samples for analysis of nutrient and chlorophyll levels to examine chemical and biological linkages supporting and maintaining these island ecosystems.

D. Conduct shipboard CTDs to a depth of 350 m, shallow-water CTDs from small boats to a depth of ~ 30 m, and shipboard ADCP surveys around reef ecosystems to examine physical and biological linkages supporting and maintaining these island and atoll ecosystems.

E. Collect ADCP data during all transits. The ADCP unit shall be configured to collect narrow-band data in 16-meter bins (deepwater mode).

F. Assist partner scientists with microbial oceanography sampling and invertebrate collections.

G. Conduct calibration dives to improve accuracy of data collected.

RESULTS:

See Appendices B-E.

SCIENTIFIC PERSONNEL:

Robert Schroeder, Chief Scientist, Senior Reef Fish Researcher, University of Hawaii-Joint Institute for Marine and Atmospheric Research (UH-JIMAR), Pacific Islands Fisheries Science Center-Coral Reef Ecosystem Division (PIFSC-CRED)
Paula Ayotte, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Valerie Brown, , UH-JIMAR, Pacific Islands Regional Office, Habitat Conservation Division (PIRO-HCD, Guam)
Dave Burdick, , Guam Coastal Management Program
Edmund Coccagna, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Kerry Grimshaw, Education/Outreach (Benthic REA), UH-JIMAR, PIFSC-CRED
Jason Helyer, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Kevin Lino, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Frank Mancini, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Kaylyn McCoy, Data Manager, UH-JIMAR, PIFSC-CRED
Tracey McDole, Microbial Oceanographer, San Diego State University
Danny Merritt, Oceanographic Engineer, UH-JIMAR, PIFSC-CRED
Russell Moffitt, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Marc Nadon, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Noah Pomeroy, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Laurie Raymundo, Marine Laboratory, Univ. of Guam
Russell Reardon, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED

Benjamin Richards, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Cristi Richards, Marine Ecosystem Research Specialist, UH-JIMAR, PIFSC-CRED
Bernardo Vargas-Angel, Coral Biologist, UH-JIMAR, PIFSC-CRED
Oliver Vetter, Oceanographer, UH-JIMAR, PIFSC-CRED

DATA COLLECTED:

Digital images from photoquadrats
Algal voucher specimens necessary for algal species identification
Benthic Line Point Intercept data
Number of coral colonies, by species, within belt transects of known area, and overall coral colony density at each site
Qualitative assessment (DACOR) of coral species' relative abundance at each site
Size class distributions of corals (by species and overall) at each site
Digital images of diseased coral
Field notes on signs of coral bleaching or disease
Samples of diseased coral for histopathological analysis
Density counts of targeted organisms within belt transects
Urchin test size diameters
Installation of ARMS to eventually provide an index of biodiversity
Digital images of non-coral marine invertebrates
Samples of targeted species undergoing genetic connectivity work
Digital still photos of overall site character and typical benthos at each site
Transect surveys of all diurnally active, non-cryptic fishes in 600 m^2 – ID to species and estimate size to nearest cm
Stationary Point Count (SPC) surveys of all diurnally active, non-cryptic fishes in 707 m^2 – ID to species and estimate size to nearest cm
Fish species presence checklists for community diversity estimates at each site
Digital images of rare or interesting fish species
Digital images of the benthic habitat from towed-diver surveys
Macroinvertebrate counts from towed-diver surveys
Quantitative surveys of reef fishes (larger than 50 cm TL) to species level from towed divers
Habitat lineation from towed-diver surveys
Benthic composition estimations from towed-diver surveys
Acoustic Doppler Current Profile (ADCP) data
Shipboard Conductivity, Temperature and Depth (CTD) profiles to 350 m with fluorometer and dissolved oxygen sensor attached
Water Samples to 500 m: Chlorophyll and Nutrients five depths per cast
Shallow water Conductivity, Temperature, Depth (CTD) casts to 30 m (or water column depth with transmissometer and dissolved oxygen sensor attached
Shallow water samples (30 m): chlorophyll and nutrients two depths per cast
Shallow water microbial analysis samples
Sea surface and subsurface temperature at variable depths
Sea surface and subsurface salinity at variable depths
Spectral wave energy and tidal elevation
Moored Acoustic Doppler Current Profiler (ADCP) data

Solar radiation, air temperature, barometric pressure, wind speed and direction, and photosynethtic active radiation
Shipboard Surface Temperature and Salinity Gauge (TSG) data
Shipboard Acoustic Doppler Current Profiler (SADCP) transects
Ecological Acoustic Recorder (EAR) data

Submitted by: Robert E. Schroeder
Robert Schroeder, PhD
Chief Scientist

Approved by: Kacky Andrews
Kacky Andrews
Program Manager
Coral Reef Conservation Program

Attachments: Figure 1
Appendices A-F

Figure 1.--Track of NOAA ship *Hi'ialakai* during cruise HA0902 around Guam, Rota, Aguijan, Tinian, and Saipan, 5–14 April 2009.

Appendix A: Methods

A.1 Oceanography and Water Quality
(Oliver Vetter, Frank Mancini, Tracy McDole, Daniel Merritt, Russell Reardon)

The Coral Reef Ecosystem Division (CRED) started conducting oceanographic research at U.S.-held islands in the tropical Pacific in 2001. Research in Guam and Commonwealth of the Northern Mariana Islands (CNMI) waters was first conducted in 2003. CRED's oceanographic investigations include in situ surveys, conductivity-temperature-depths (CTDs), water samples, and the replacement of instrument platforms to monitor and assess important physical, chemical and biological variables in the coral reef ecosystem. As a result of logistical constraints, voyages to remote sites, such as Guam, Rota, Aguijan, Tinian, and Saipan, are limited to biannual visits.

Long-term oceanographic monitoring and assessment is accomplished by deployment and retrieval of a variety of internally recording and near real-time telemetered instrument platforms. These instruments include:

- Sea Surface Temperature (SST) buoys: Measure and internally record high resolution surface water temperature and telemeter a subset of collected data in near real-time.

- Wave and Tide Recorders (WTR): Measure surface gravity waves, tides and subsurface water temperature.

- Subsurface Temperature Recorders (STR): Measure high resolution subsurface water temperature.

- Environmental Acoustic Recorders (EAR): Record ambient subsurface sound.

Detailed in situ oceanographic and water quality surveys are accomplished with the following sampling techniques:

- Shallow-water CTD casts (max depth 30 m) conducted from small boats at regularly spaced intervals on the 30 m contour around each island/atoll/shoal with an SBE 19+ and an auxiliary transmissometer (Wetlabs C-Star) and oxygen 18 sensor (SBE 43). Shallow vertical water profiles can provide insight into local water property variation and water mass interactions.

- Shallow-water samples for nutrient and chlorophyll analysis are taken at select rapid ecological assessment (REA) sites. Nutrient and chlorophyll samples are taken at the surface and at the reef near REA sites.

- Integrated macro and microbiological coral reef ecosystem data. Collect water samples at REA sites from 0.5-1 m above the reef surface for microbial related analyses including: dissolved organic carbon (DOM), particulate organic material

(POM), protist, microbial and viral abundance and microbial community composition.

- Shipboard deepwater CTD casts conducted from the NOAA Ship *Hi'ialakai* with an SBE 911+ and an auxiliary SBE 43 Dissolved Oxygen (DO) sensor and Wetlabs ECO FLNTU combination fluorometer and turbidity sensor. Shipboard CTD casts were conducted at 500 m. The cast was complemented by water samples collected at 350 m. These will be analyzed during post-cruise for nutrient (NUT) and chlorophyll (CHL) concentrations.

- Surface and subsurface water temperatures, as a function of depth, are continuously recorded during all towed-diver operations, providing a broad and diverse spatial and thermal sampling method. (See towed-diver surveys for more detail.)

- Habitat/Fish Survey Team Activity Summary for site and isobath information. These data are part of the tow team Arcview project.

- Shipboard meteorological observations including wind speed and direction, relative humidity, air temperature, and barometric pressure.

- Shipboard oceanographic measurements of sea surface temperature, salinity, and currents using an acoustic Doppler current profiler (ADCP).

A.1.1 Microbial Water Chemistry Analysis

1) Microscopy

It is well known that bacteriophages (bacterial viruses) are the most abundant form of life in the ocean, ranging from 1×10^6 virus-like particles (VLPs) per ml of seawater in the open ocean to 1×10^8 VLPs per ml in more productive coastal waters. The number of microbial and protistan cells in seawater is typically 1×10^6 and 1×10^3 cells per ml, respectively. Microbial and viral loading and the dominance of heterotrophic bacteria in reef water are linked to coral disease (Dinsdale et al., 2008). Trophic-level interactions among bacteria, phages, and protists also affect global nutrient and carbon cycling. The most direct method for assessing and monitoring changes in abundance of these microbiological components is by fluorescent microscopy using nucleic acid staining.

Enumeration of microbes and viruses: Five ml of water from each sample was fixed with paraformaldehyde, stained with the dsDNA stain SYBR-Gold, and filtered onto a 0.02 um filter.

Enumeration of protists: Fifty ml of water from each sample was fixed with glutaraldehyde, stained with the dsDNA stain DAPI, and filtered onto a 0.8 um black polycarbonate filter.

Frequency of dividing cells: Ten ml of water from each sample was fixed with glutaraldehyde, stained with the dsDNA stain DAPI, and filtered onto a 0.2 um filter.

Enumeration of microbial components and quantification of actively dividing microbial cells will be counted using fluorescent microscopy at San Diego State University (SDSU). All filters will be stored at - 20ºC for archival purposes.

2) Water chemistry
Spatial assessment of microbial, viral, and protist components with respect to dissolved organic carbon, nutrient levels, and particulate organics within coral reef ecosystems may identify important predictors of coral reef ecosystem degradation; information that will be essential for designing the most effective monitoring strategy possible.

Water samples were pushed through GF/F glass filters and the filtrate collected in pre-combusted glass bottles. Hydrochloric acid was added to each bottle to remove dissolved inorganic carbon, and the bottles were stored upright at 4ºC. These samples will be analyzed for dissolved organic carbon levels at SDSU. The GF/F filters will be also be stored at - 20ºC and analyzed for particulate organic carbon and stable isotopes of carbon and nitrogen at SDSU.

3) Archive microbial DNA samples
The structure of the bacterial community will be assessed by metagenomic analysis. This involves collection of environmental DNA via filtration followed by 454 sequencing. Metagenomics is a powerful tool for studying environmental populations as less than 1% of all environmental microbial diversity is currently cultivable (Rappe and Giovannoni, 2003).

The remaining water in each Niskin bottle was pushed through a 20 um pre-filter to remove large eukaryotic organisms. The 20 um filtrate was then pushed through 0.22 um Sterivex filters. The filters were stored at - 20ºC. DNA isolation and metagenomic analysis will be completed at SDSU.

4) Flow cytometry
Flow cytometry will be primarily used to characterize microbial community size structure. This technique will also provide complementary data for abundance counts, metagenomic analysis, and chlorophyll analysis.

Five ml of water from each site was pushed through a 20 um filter. The filtrate was dispensed into 5 × 1 ml cryovials, and glutaraldehyde added to each. Vials were inverted to mix, and incubated in the dark for 15 min. Glutaraldehyde preserved samples were flash frozen in liquid nitrogen contained in a dry shipper. The samples will be shipped on dry ice to SDSU for flow cytometry analysis.

A.2 Benthic REA Methods

(Bernardo Vargas-Angel, Dave Burdick, Kerry Grimshaw (Alt.), Russell Moffitt, Noah Pomeroy, Laurie Raymundo, and Cristi Richards)

A.2.1 Algae

Using the line point-intercept (LPI) method, macroalgal species, algal functional group, coral species, non-coral invertebrate functional group, or substrate type at 20-cm (for permanent REA monitoring sites) and 50-cm (at new independent monitoring sites) intervals along two

25-m transect lines, were recorded. Algal inventories and percent cover were generated from data collected at each site. Permanent historical records of benthic marine substrates at each permanent REA site were collected using a high resolution digital camera mounted on a 0.18 m^2 photoquadrat.

Additionally, when time permits, a roving diver swim at the end of the dive that covers a swath on 3 m on either side of the transect line is used to record algal species not observed along the transects themselves. Only one specimen of each species that cannot be identified in the field will be collected by hand and frozen. Ultimately, field-collected algal specimens will be critically analyzed in the laboratory to ensure positive species identification, cataloged, and subsequently placed in institutions where they can be accessed by researchers interested in a suite of topics. After identification, provisions are made to ensure appropriate preservation and curation of each algal specimen, and provide a historical record that will be available to future researchers.

A.2.2 Corals

At each permanent REA monitoring site, two 25-m belt transects were laid out. Five 2.5-m segments were surveyed for each transect (beginning at points: 0, 5, 10, 15, and 20 m for a total of 25 m^2 per site). For each segment, all coral colonies whose center fell within 0.5 m of either side of the transect were identified to species and measured for size (maximum diameter and diameter perpendicular to the maximum diameter). In addition, the extent of mortality, both recent and long dead, was estimated for each colony. Observers paid special attention to identifying, as best as possible, the extent of the former live colony. When a coral colony exhibited signs of disease or compromised health, additional information was recorded including type of affliction (bleaching, skeletal growth anomaly, white syndrome, tissue loss other than white syndrome, trematodiasis, necrosis, other, pigmentation responses, algal overgrowth, and predation), severity of the affliction (mild, moderate, marked, severe, acute), as well as photographic documentation and, sometimes, tissue samples. Tissue samples were catalogued and fixed in buffered zinc-formalin solution for further histopathological analyses. Percent coral cover analysis was derived from the 20- and 50-cm LPI methods conducted by the algal divers.

A.2.3. Non-coral Invertebrate Surveys

Quantitative counts and percent cover for specific target marine invertebrates are conducted along the two 25-m REA belt transects and the independent LPI transects at 5-m intervals. All invertebrates which fall within 1 m along either side of the transect are surveyed. Size frequency distribution of urchin species will be recorded for the first 25 individuals of each species. Based on data from previous rapid ecological assessments, a group of target species was chosen for quantitative counts. The species in this list have been shown to be common components of the reef habitats of the central and southern Pacific, and they are species that are generally visible (i.e., non-cryptic) and easily enumerated during the course of a single 50–60 min dive. Additionally, all species of urchins are counted and the test size diameter for the first 25 of all species present are measured and recorded.

These target species are:
CNIDARIA
Octocorals – soft corals (*Sinularia, Cladiella, Lobophyton, Sarcophyton,* etc.)
Zoanthids – rubber corals
Actiniaria – Anemones (*Heteractis, Stichodactyla, Phymanthus,* etc.)
ECHINODERMS
Echinoids – sea urchins
Holothuroids – sea cucumbers
Asteroids – sea stars
MOLLUSCA
Bivalves – spondylid oysters, pearl oysters, tridacnid clams (Giant Clams)
Large Gastropods – *Charonia* (Triton's Trumpet) and *Lambis* sp. (Spider Conch)
Coralliophilidae gastropods
Cephalopods - octopus
CRUSTACEA
hermit crabs, lobsters, large crabs

A.2.3.1 Autonomous Reef Monitoring Systems (ARMS)
ARMS were deployed at four forereef habitats (GUA-12, GUA-05, GUA-02, and GUA-08) in the island systems. ARMS provide a mechanism to quantify marine invertebrates that are not easily identifiable or accountable on the transect lines. ARMS are installed on the benthos by pounding stainless steel rods by hand into bare substrate. They will remain on the benthos for 2 years enabling the recruitment and colonization of lesser known, cryptic marine invertebrates upon which time they will be collected and analyzed.

A.3 Fish Team Methods
(Marc Nadon, Paula Ayotte, Valerie Brown, Robert Schroeder, [Kaylyn McCoy, Alt.])

The fish team, composed of four divers, conducted two types of surveys at preselected sites: Belt transects (BLT) and complete Stationary Point Counts (SPC). Two separate teams were deployed to conduct the surveys; each team consisted of two divers conducting either two SPCs and two BLTs, or just two SPCs.

The first team accompanied the Benthic REA team and surveyed previously visited sites. Surveys were performed using a 30-m line set along a single depth contour. As the line was set, two observers swam along either side of the line identifying, counting, and sizing all fishes >20 cm in total length (TL). Each diver counted and sized fish within an area 25 m long and 4 m wide. Afterwards, the divers returned along their respective sides of the line identifying, counting, and sizing all fishes ≤ 20 cm TL in a 2 m wide by 25 m long belt.

Once the belt transect was completed, the divers moved to the 7.5 m and 22.5 m marks on the transect line to start the stationary point counts (7.5 m radius). For this method, each diver counted fish in a cylindrical survey area by staying in the middle of their respective cylinders that had a 7.5 m radius. During the first 5 min of the SPC, the divers only recorded the presence of species within their survey areas. Afterwards, the divers proceeded down their respective species list, sizing and counting all diurnally active, non-cryptic individuals within their 7.5 m radius cylinder, one species at a time. Individuals from a single species were only recorded once. More sedentary species missed during the initial 5 min survey could still be added to the list. Once completed, the transect line was moved to another location 5-10 m away at the same depth stratum, and the procedure was repeated.

The second team was deployed on a separate boat and surveyed new, randomly chosen sites that were in an either shallow (0–6 m) or deep (18–30 m) depth stratum using the SPC method. After settling on the bottom, a two-person team laid a 30-m transect and then performed the SPC as described above. Once completed, the transect line was moved to another location 5–10 m away at the same depth stratum, and the procedure was repeated. (*Note: This SPC method, denoted in the database as nSPC for new, differs from the previous SPC surveys used in the Marianas (2003–2007), which employed a 10 m radius, but only recorded fish >25 cm total length during 5-min periods at four replicate sites around the belt-transect line.*)

Fishes observed off transect or after the initial 5 min of the SPC were recorded for presence data. No collection efforts were made by the fish team during the survey period.

A.4 Towed-diver Survey Methods

(Edmund Coccagna, Jason Helyer, Kevin Lino, and Benjamin Richards)

Shallow-water habitats around each island, bank, or reef were surveyed using pairs of divers towed 60 m behind a 19-ft SAFE Boat survey launch. In each towed-diver buddy team, one diver is tasked with quantifying the benthos while the other quantifies fish populations. Each towed-diver survey lasts 50 min, broken into ten 5-min segments, and covers approximately 2 km. A Global Positioning System (GPS) track of the survey launch track is recorded at 5-sec intervals using a Garmin GPS76Map GPS unit. A custom algorithm is used to calculate the track of the divers based on the track, speed, and course of the boat and depth of the diver. Each towboard is equipped with a precision temperature and depth recorder (Seabird SBE39) recording at 5-sec 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.

A.4.1. Benthic Towed-diver 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 sec, creating a permanent visual record to evaluate and track potential changes in the benthos between subsequent cruises. The diver on the benthic towboard also observes and records habitat composition (habitat complexity, prevalent habitats and substrate types, hard coral, stressed hard, soft coral, macroalgae, coralline algae, sand and rubble), tallies conspicuous macroinvertebrates (crown-of-thorns starfish [COTS]), boring and free sea urchins, sea cucumbers, and giant clams) along a 10-m swath in 10 × 5-min time segments. Additional fields, including prevalent coral and algae genera (when applicable/time permitting) are also tracked. At the end of each day, the data are transcribed from field data sheets into a centralized MS Access database.

A.4.2. Fish Towed-diver 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 evaluate stochastic changes in the reef environment, particularly following episodic events such as coral bleaching and vessel grounding. The diver on the fish towboard records, to species or lowest possible taxon, all fish greater than 50 cm total length (TL) along a 10-m swath in each time segment. Fish are recorded in terms of species and length in centimeters. Species of particular concern observed outside the survey swath are classified as presence/absence data and are recorded separately from the quantitative swath data. At the end of each day, the data are transcribed from field data sheets into a centralized MS Access database. Biomass values are calculated using species specific length-weight parameters and are normalized by area (i.e., kg/100 m^2).

Appendix B: Guam Results

B.1. Oceanography and Water Quality

Moorings recovered and replaced during HA0902 at Guam included four subsurface temperature recorders (STRs) a sea surface temperature (SST) buoy and an ecological acoustic recorder (EAR) (Fig. B.2-1). All the STRs show very similar pattern and temperature ranges, with a clear annual fluctuation due to seasonal warming and cooling (Fig. B.2-2). Warmest temperatures peaked at ~ 30.5°C and occurred during the summer months of July to October. Winter temperatures reached a low of ~ 27.5°C, lowest temperatures occurred during November through June.

Four REA sites (GUA-50, GUA-08, GUA-07 and GUA-03) were visited to collect water samples for microbiological, nutrient and chlorophyll analyses, and the remaining REA sites were sampled for just nutrients and chlorophyll. Samples were obtained from the surface and approximately 1 m above the reef. Microbial water samples were taken using diver-deployable Niskin bottles to collect 8 liters of seawater (4 bottles; 2 liters per bottle) at each study site. Chlorophyll samples were filtered and nutrient samples were frozen at - 30°C for post-cruise analysis. These samples were collected at 10–15 meters of depth and transported back to the ship. Shallow-water conductivity temperature and depth (CTD) casts were also conducted at these sites. Additional CTD casts were taken around at the 30-m depth contour around Guam.

Table B.1.1--Moorings.

Instrument	Island	Action	Serial number	Latitude	Longitude	Action date	Depth (m)
SST	GUA	Retrieval	10018141	13.52898	144.80048	2009/04/05	11.58
STR	GUA	Retrieval	39368591648	13.52898	144.80048	2009/04/05	11.58
SST	GUA	Deployment	DTX5C/4501	13.52898	144.80048	2009/04/05	11.58
STR	GUA	Deployment	39331791199	13.52898	144.80048	2009/04/05	11.58
STR	GUA	Deployment	3933179-1203	13.60312	144.92357	2009/04/05	13.11
EAR	GUA	Deployment	9300494B108	13.60312	144.92357	2009/04/05	13.11
STR	GUA	Retrieval	3920707-0161	13.60312	144.92357	2009/04/05	13.11
EAR	GUA	Retrieval	9300314 26	13.60312	144.92357	2009/04/05	13.11
STR	GUA	Deployment	3933179-1371	13.63243	144.89297	2009/04/06	9.14
STR	GUA	Retrieval	3939038-1866	13.63243	144.89297	2009/04/06	9.14
STR	GUA	Deployment	3933179-1145	13.24217	144.70542	2009/04/07	4.57
STR	GUA	Retrieval	3936859-1569	13.24217	144.70542	2009/04/07	4.57

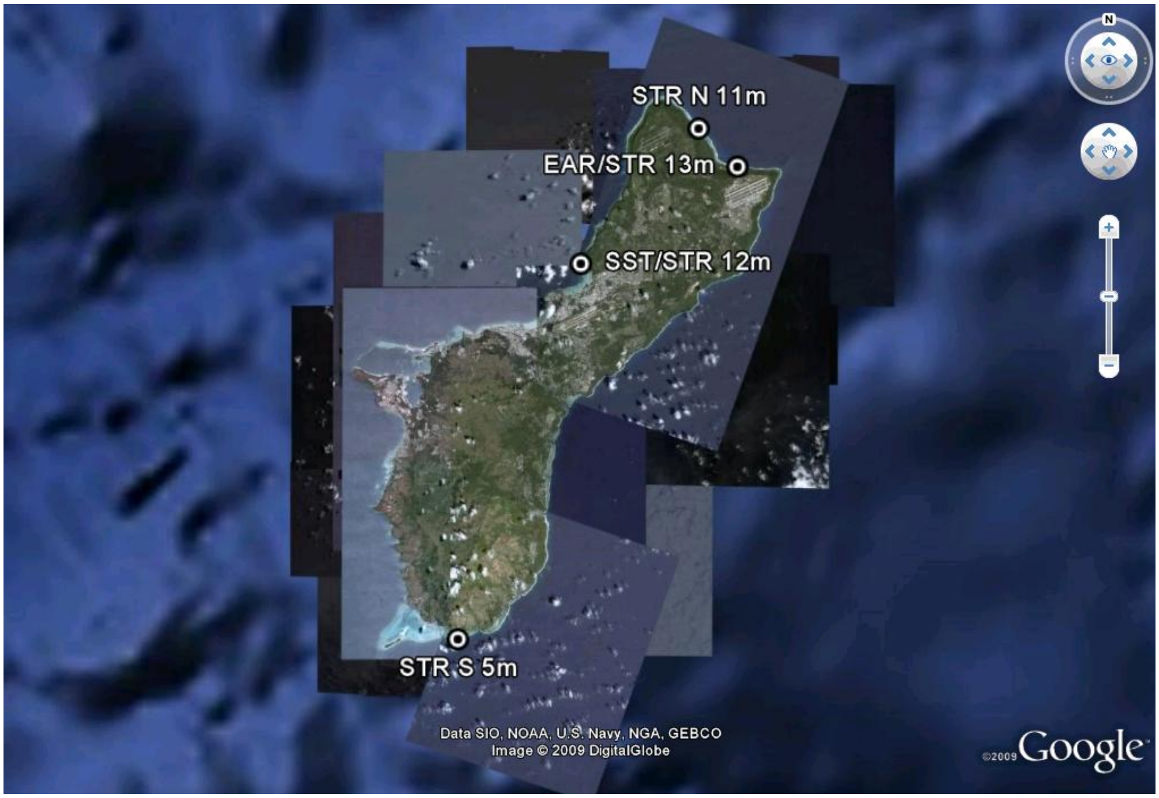


Figure B.1.1--Deployed Instrument Moorings Guam, HA0902.

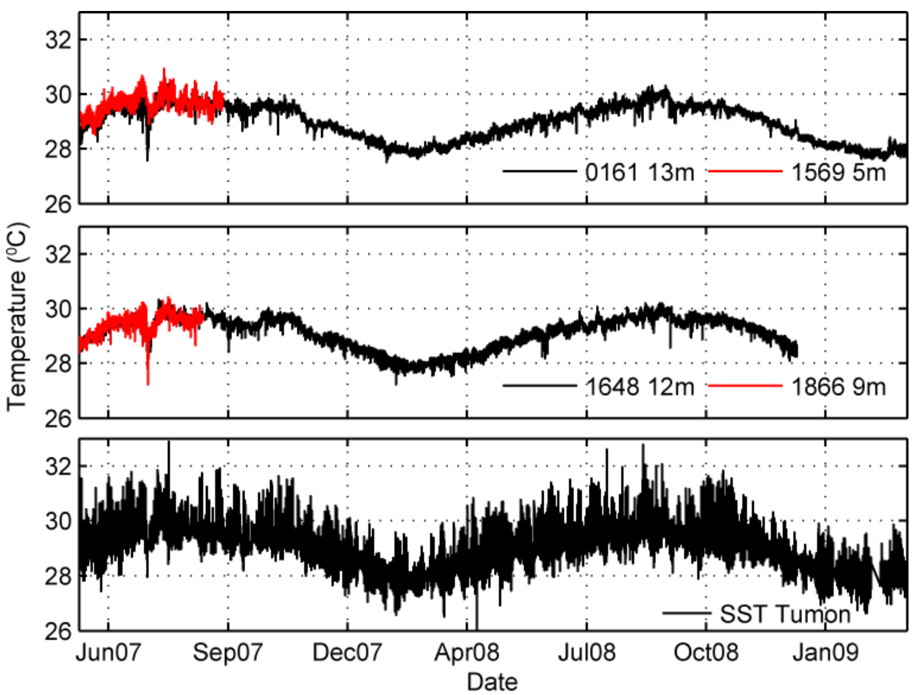


Figure B.1.2:--Temperature Time-series from STR and SST moorings at Guam, HA0902.

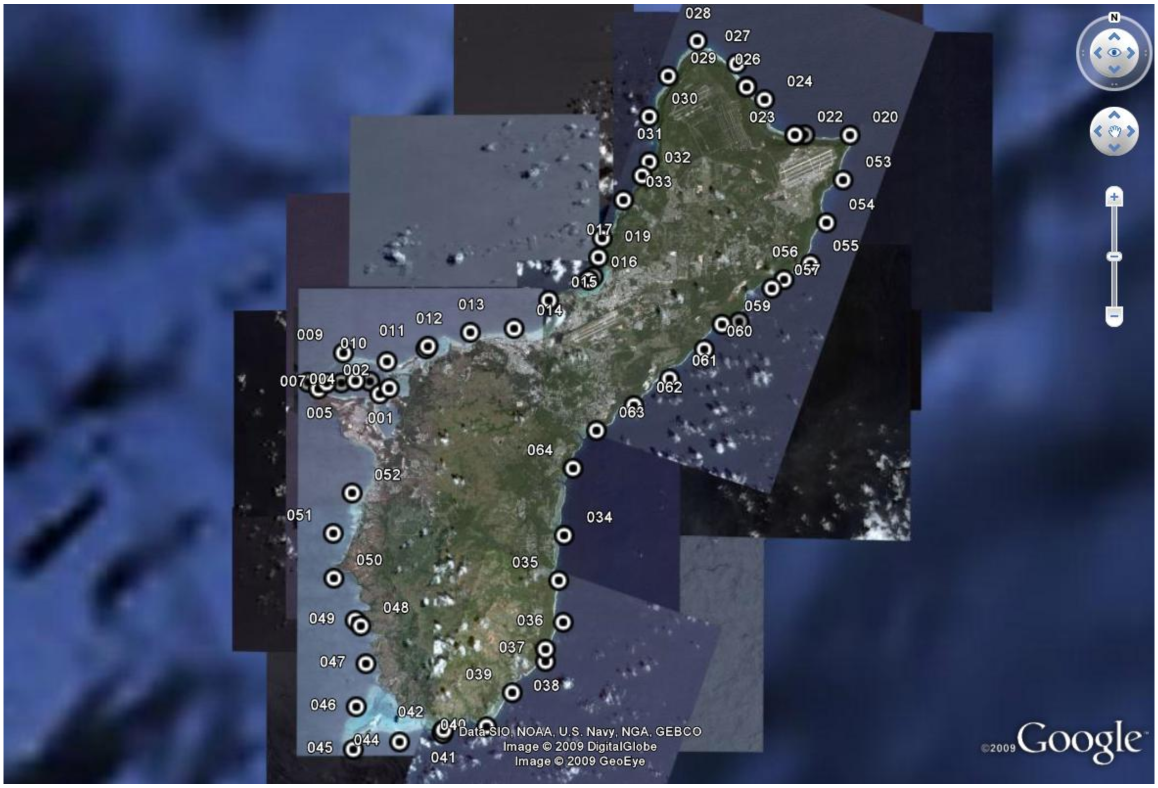


Figure B.1.3—Shallow-Water CTD, Guam, HA0902.

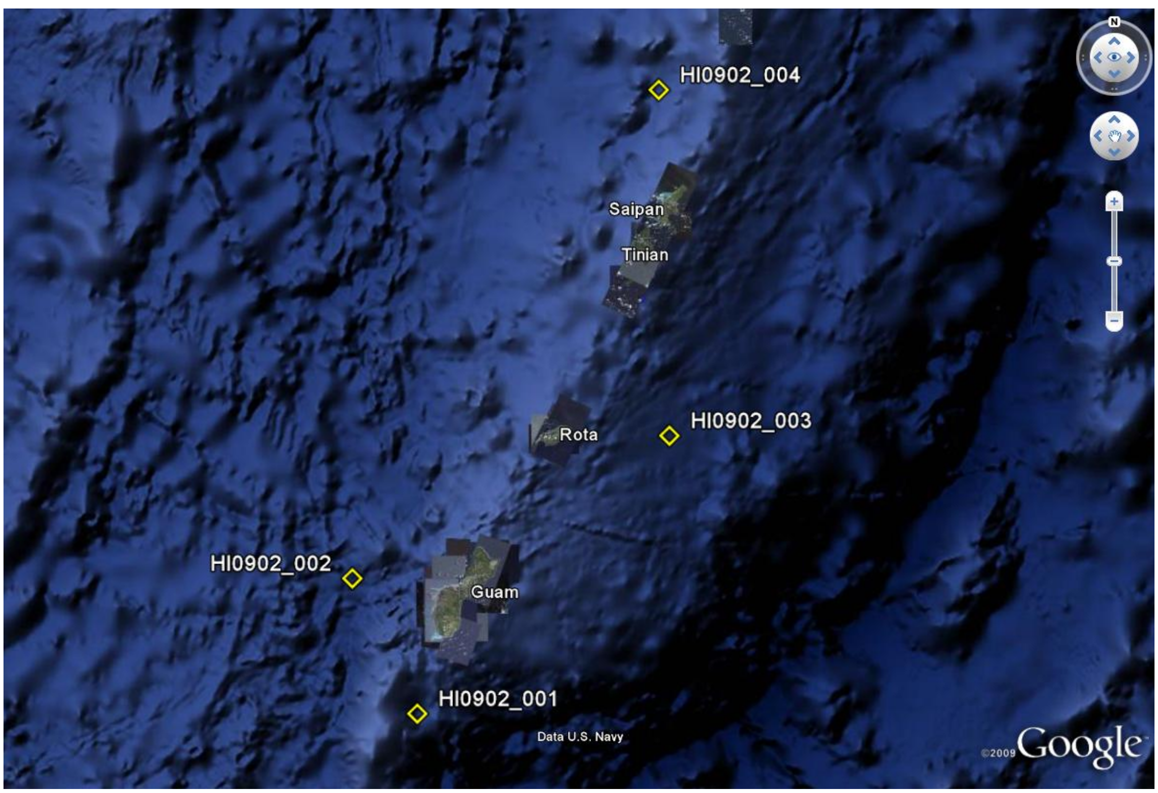


Figure B.1.4--Deepwater CTDs Guam, Rota, Tinian and Saipan, HA0902.

B.2. Rapid Ecological Assessment (REA) Site Descriptions

Eleven established REA sites were visited by a team of up to seven scientists around Guam between April 5 and April 8, 2009 (Fig. B.2.1). In addition, 14 stratified random fish, line point intercept (LPI), and invertebrate surveys were conducted. The site locations are listed below along with site photos taken in 2009. Site descriptions are included for the following discipline communities: coral, coral disease, macroinvertebrates, algae, and fish.

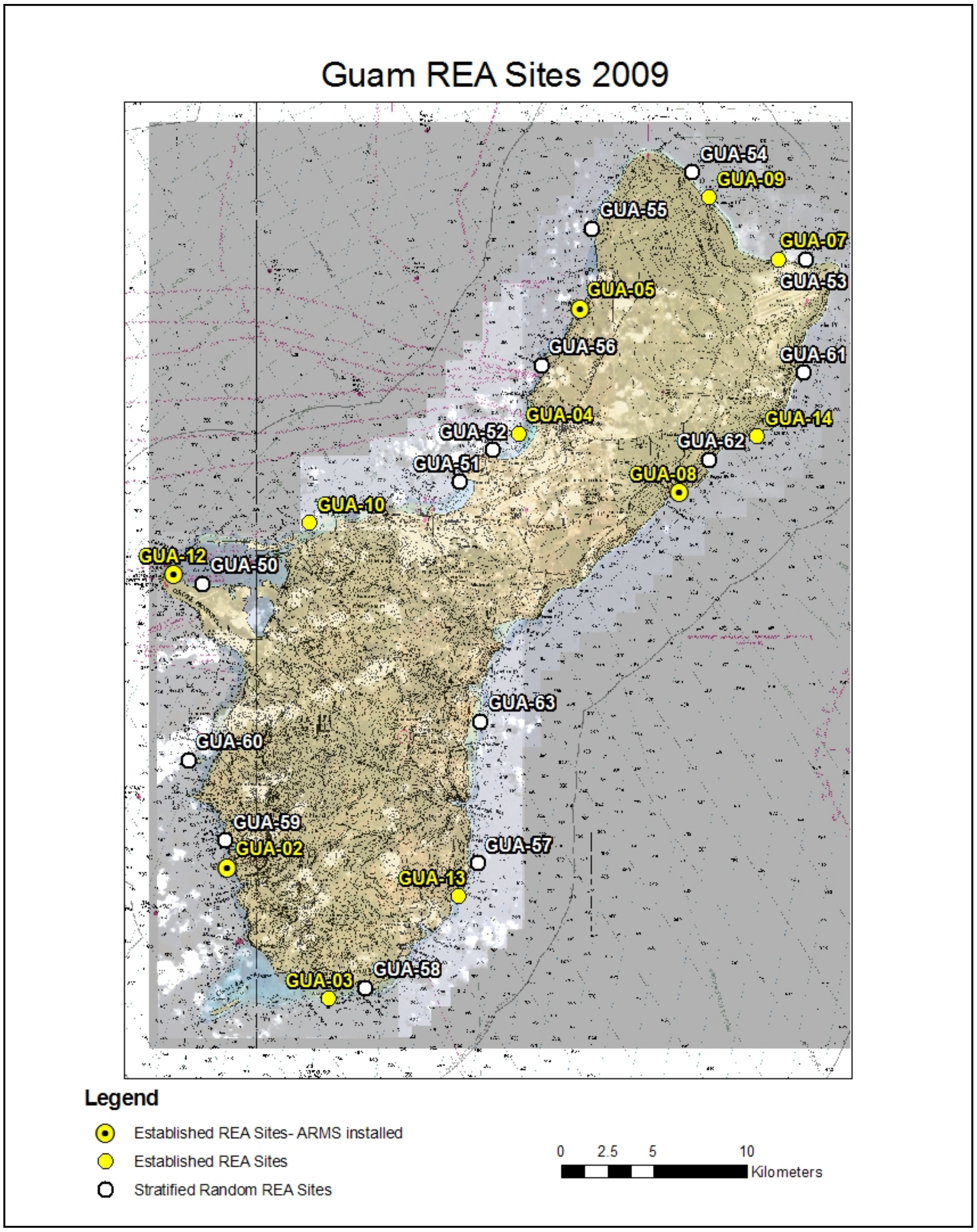


Figure B.2.1--Locations of REA, stratified random and Autonomous Reef Monitoring Systems installation sites visited at Guam Island in 2009.

GUA-02
4/7/2009

E 144° 39.184
N 13° 18.317

Forereef
Mid

Depth: 12–13 m

Site description: Fouha Bay; moderate topographic complexity; low coral cover; high algal cover; sedimentation.

GUA-03
4/7/2009

E 144° 42.169
N 13° 14.495

Forereef
Mid

Depth: 10–13 m

Site description: Achang Marine Protected Area (MPA); southeast region; moderate topographic complexity; low coral cover.

GUA-04
4/5/2009

E 144° 47.859
N 13° 31.019

Forereef
Mid

Depth: 9–14 m

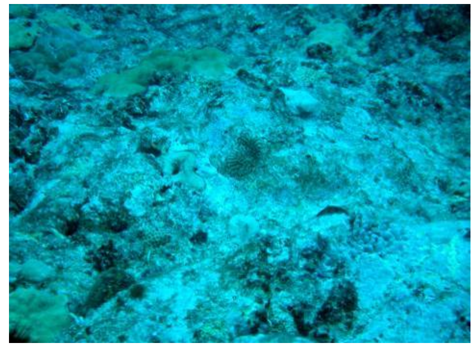
Site description: Tumon bay off Heldi; mooring site, moderate topographic complexity; moderate coral cover.

GUA-05
4/6/2009

E 144° 49.706
N 13° 34.719

Forereef
Mid

Depth: 11–13 m



Site description: Northwest side Haputa Beach; near small arms firing range; moderate/high topographic complexity; moderate coral cover.

GUA-07
4/6/2009

E 144° 55.644
N 13° 36.136

Forereef
Mid

Depth: 13–16 m

Site description: North side Pati Point; high topographic complexity; moderate coral cover; moderate/high macroalgal cover.

GUA-08
4/8/2009

E 144° 52.648
N 13° 29.328

Forereef
Mid

Depth: 10–12 m

Site description: Northeast side of Pagat; low topographic complexity; low coral cover; moderate macroalgal cover.

GUA-09
4/6/2009

E 144° 53.567
N 13° 37.956

Forereef
Mid

Depth: 10–13 m

Site description: North side Jinapsan Beach; low topographic complexity; low/moderate coral cover; high macroalgal cover.

GUA-10
4/5/2009

E 144° 41.611
N 13° 28.414

Forereef
Mid

Depth: 13–14 m

Site description: Site inside Piti Bay; low/moderate topographic complexity; moderate coral cover; low macroalgal cover.

GUA-12
4/5/2009

E 144° 37.555
N 13° 26.927

Forereef
Mid

Depth: 13 m

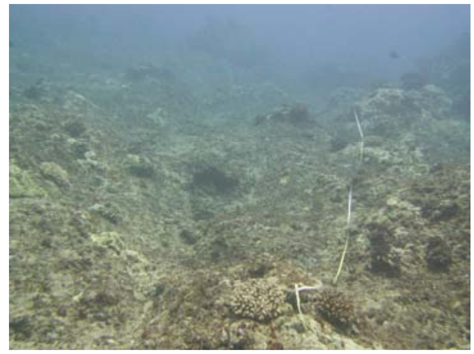
Site description: Apra Harbor west of Kilo Wharf; steep slope; moderate topographic complexity; moderate coral cover; high macroalgal cover.

GUA-13
4/7/2009

E 144° 46.062
N 13° 17.498

Forereef
Mid

Depth: 9 m



Site description: South of Talafofo River; moderate topographic complexity, low coral cover; high macroalgal cover.

GUA-14
4/8/2009

E 144° 54.989
N 13° 30.948

Forereef
Mid

Depth: 13 m

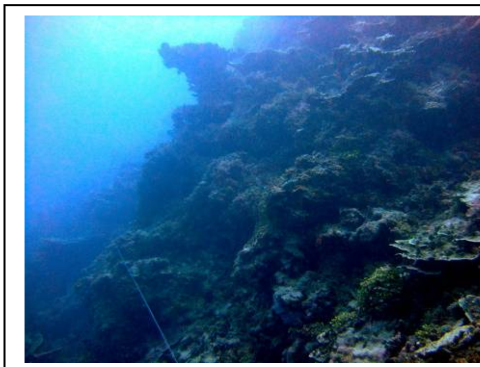
Site description: South of Pati Point MPA; moderate topographic complexity; moderate coral and macroalgal cover; COTS present.

GUA-50
4/5/2009

E 144° 38.410
N 13° 26.632

Forereef
Deep

Depth: 20–21 m



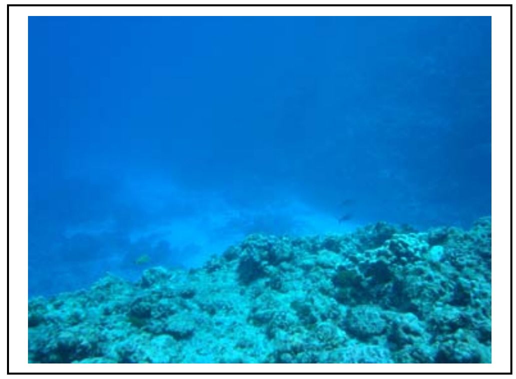
Site description: Deep Apra Harbor site off Gab Gab Beach; high topographic complexity; steep slope; moderate coral cover.

GUA-51
4/5/2009

E 144° 46.088
N 13° 29.623

Forereef
Shallow

Depth: 6 m

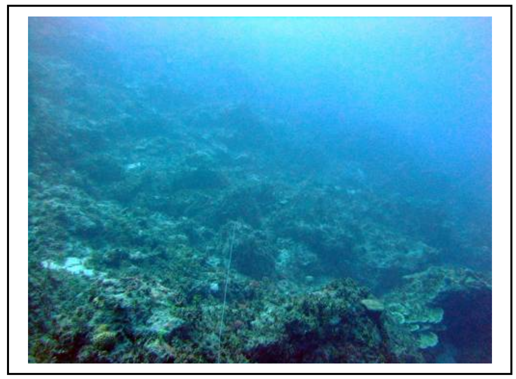
Site description: Shallow site in front of small island; moored at buoy; moderate topographic complexity; high coral cover; low algal cover.

GUA-52
4/5/2009

E 144° 47.073
N 13° 30.557

Forereef
Deep

Depth: 25–27 m

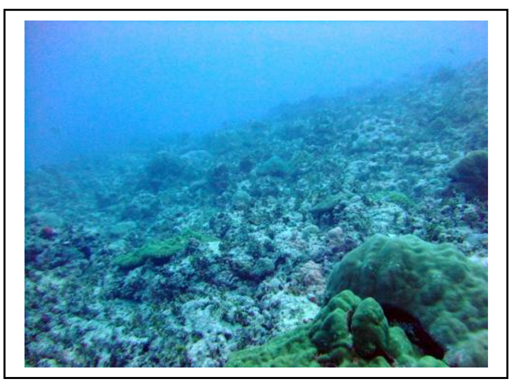
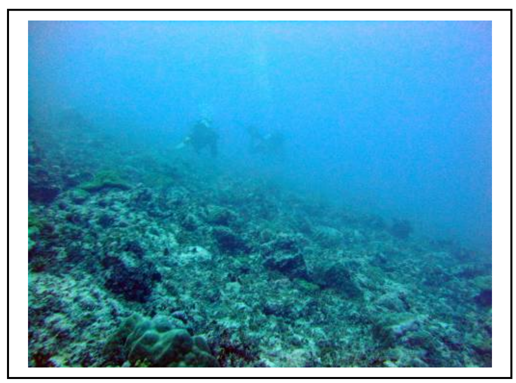
Site description: Deep Tumon Bay site in front of Hilton hotel; moderate topographic complexity; low coral cover; high macroalgal cover.

GUA-53
4/6/2009

E 144° 56.459
N 13° 36.121

Forereef
Deep

Depth: 21 m

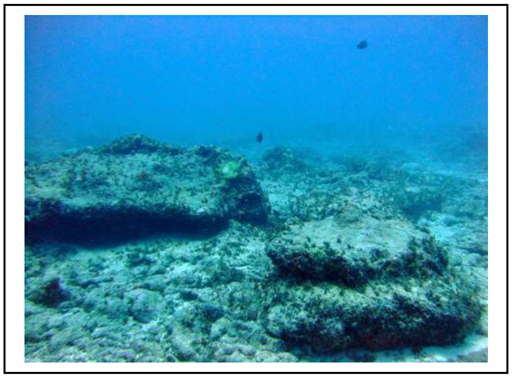
Site description: Deep northern site inside reserve; low topographic complexity; moderate coral cover; high macroalgal cover.

GUA-54
4/6/2009

E 144° 53.065
N 13° 38.684

Forereef
Deep

Depth: 17–20 m



Site description: Deep site in northern region; low topographic complexity; low coral cover; high macroalgal cover.

GUA-55
4/6/2009

E 144° 50.058
N 13° 37.044

Forereef
Shallow

Depth: 3–4 m

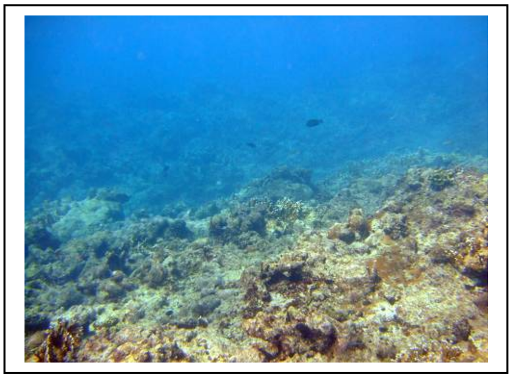
Site description: Shallow site in northwestern region; moderate topographic complexity; low/moderate coral cover; low macroalgal cover.

GUA-56
4/6/2009

E 144° 48.537
N 13° 33.036

Forereef
Shallow

Depth: 3 m



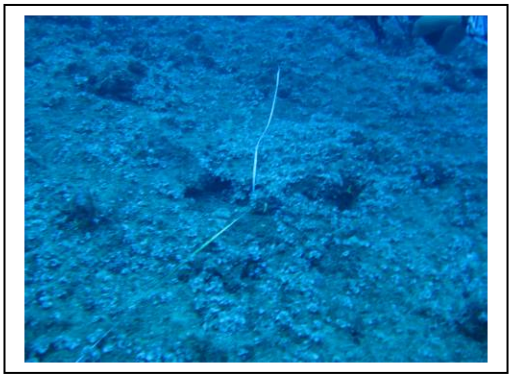
Site description: Shallow western site north of Tumon Bay; moderate topographic complexity; high coral cover; high turf algal cover.

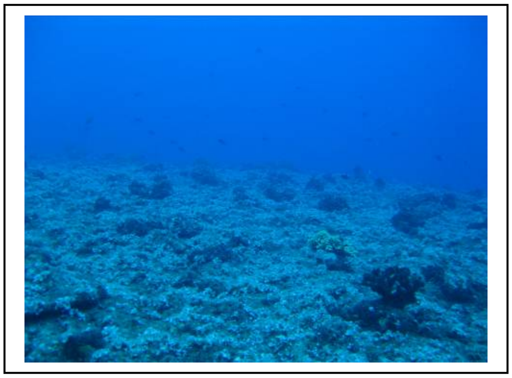
GUA-57
4/7/2009

E 144° 46.624
N 13° 18.457

Forereef
Deep

Depth: 24 m





Site description: Deep southeastern site next to sheer drop-off; "blue hole" dive site; low topographic complexity; very low coral cover; high macroalgal cover.

GUA-58
4/7/2009

E 144° 43.271
N 13° 14.806

Forereef
Shallow

Depth: 3–5 m

Site description: Shallow southern site near Achang Reserve; low topographic complexity; high coral cover; low/moderate macroalgal cover.

GUA-59
4/7/2009

E 144° 39.085
N 13° 19.130

Forereef
Shallow

Depth: 1–3 m

Site description: Very shallow southwestern site; moderate topographic complexity; high coral cover; low macroalgal cover.

GUA-60
4/7/2009

E 144° 37.982
N 13° 21.466

Forereef
Deep

Depth: 24 m

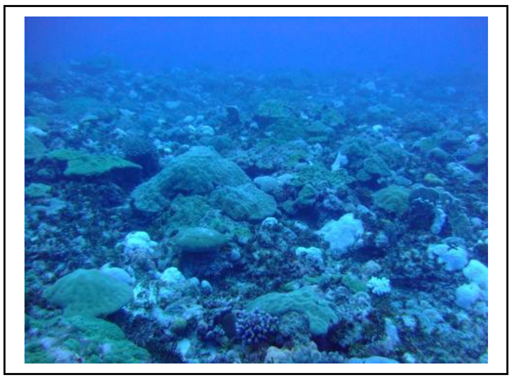
Site description: Deep western site off small island; low topographic complexity; low coral cover; high macroalgal cover.

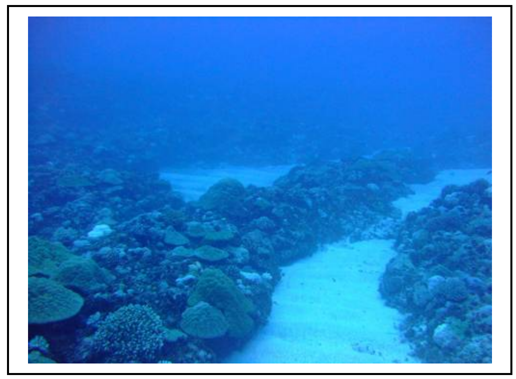
GUA-61
4/8/2009

E 144° 56.367
N 13° 32.823

Forereef
Deep

Depth: 24 m





Site description: Northeastern deep site just south of Pati Point reserve; low topographic complexity; high coral cover; high macroalgal cover; many crown-of-thorn seastars (COTS) present.

GUA-62
4/8/2009

E 144° 53.550
N 13° 30.261

Forereef
Mid

Depth: 6–7 m

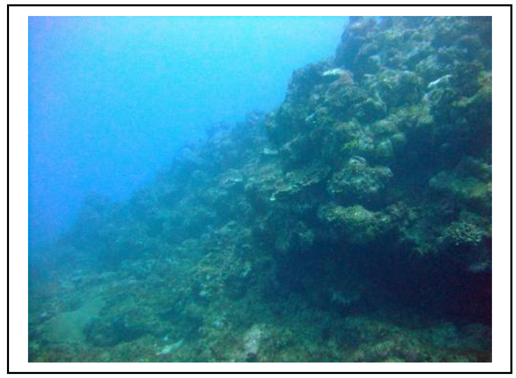
Site description: Northeastern shallow site off small cove; low topographic complexity; high coral cover and moderate/high macroalgal cover.

GUA-63
4/8/2009

E 144° 46.722
N 13° 22.609

Forereef
Deep

Depth: 20 m



Site description: Eastern deep site in front of Togcha Bay; high complexity; steep slope; low coral cover; high macroalgal cover.

B.3. Benthic Environment

B.3.1. Algal and Coral Communities- Line Point Intercept Method

During the Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP) 2009, 11 permanent, long-term REA monitoring sites were surveyed around Guam for percent benthic cover using the 20-cm interval LPI methodology. Benthic communities around Guam were dominated by macroalgal and turf algal functional groups (Table B.3.1.1). Turf algal percent cover exceeded that of other functional groups at 5 of the 11 sites surveyed and macroalgae were the dominant cover at 4 of the 11 sites (Table B.3.1.1). At site GUA-08 percent cover of cyanobacteria and macroalgae were approximately equal (28.4% and 24.4%, respectively). At site GUA-12, scleractinian coral percent cover exceeded that of all other functional groups (48.4%). A combined total of 29 species of macroalgae were observed (20 chlorophytes, 4 ochrophytes, 5 rhodophytes) from the 11 sites surveyed (Tables B.3.1.2, B.3.1.3). *Halimeda taenicola* dominated the macroalgal community at 5 of the 11 sites with a percent cover range of 0% to 24.8% (B.3.1.3). Overall, *Halimeda* was the most prevalent macroalgal genus at 9 of the 11 sites with a percent cover range of 3.2% to 35.6% (Table B.3.1.3). Species of *Padina* dominated the macroalgal community at site GUA-02 with 53.2% cover, however percent cover of this genus ranged from only 0% to 8% cover at all other sites (Table B.3.1.3).

Table B.3.1.1--Percent cover of algal functional groups at long-term monitoring sites around Guam in 2009.

Site	Macroalgae	Turf Algae	Coralline Red Algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Octocoral
GUA-02	62.4%	19.2%	5.2%	1.6%	10.0%	-
GUA-03	35.6%	32.8%	12.0%	0.8%	14.8%	2.0%
GUA-04	18.4%	48.0%	8.0%	0.8%	23.2%	1.6%
GUA-05	16.8%	46.0%	10.8%	0.8%	25.6%	-
GUA-07	39.6%	27.2%	14.8%	-	17.6%	0.8%
GUA-08	28.4%	14.0%	14.4%	24.4%	10.8%	-
GUA-09	47.6%	23.6%	15.6%	1.2%	12.0%	-
GUA-10	17.2%	40.8%	19.6%	0.8%	14.8%	4.8%
GUA-12	31.2%	17.2%	2.8%	0.4%	48.4%	-
GUA-13	33.6%	35.2%	18.0%	-	12.4%	0.4%
GUA-14	20.0%	25.2%	18.8%	14.8%	19.2%	0.8%

Table B.3.1.2--Additional species recorded at each site at Guam during roving diver surveys.

Site	**Chlorophyta**
GUA-13	*Avrainvillea* sp.
GUA-08 GUA-14	*Caulerpa racemosa*
GUA-08	*Caulerpa serrulata*
GUA-13	*Chlorodesmis* sp.
GUA-05 GUA-08 GUA-09 GUA-10	*Dictyosphaeria versluysii*
GUA-12 GUA-14	*Halimeda distorta*
GUA-07	*Halimeda gracilis*
GUA-13	*Halimeda taenicola*
GUA-14	*Halimeda tuna*

Site	**Chlorophyta**
GUA-10	*Rhipilia* sp.
GUA-03	*Tydemania expeditionis*
GUA-14	*Udotea* sp.
GUA-05	*Valonia ventricosa*
	Ochrophyta
GUA-13 GUA-14	*Turbinaria ornate*
	Rhodophyta
GUA-07 GUA-09	*Asparagopsis taxiformis*

Table B.3.1.3--Percent cover of macroalgal species at long-term monitoring sites around Guam. Sum totals for each row equal the percent cover of macroalgae recorded in Table B.3.1.1.

Site	*Caulerpa filicoides*	*Chlorodesmis sp*	*Dictyosphaeria cavernosa*	*Halimeda distorta*	*Halimeda gracilis*	*Halimeda micronesica*	*Halimeda opuntia*	*Halimeda sp*	*Halimeda taenicola*	*Halimeda tuna*	*Neomeris sp*	*Rhipidosiphon sp*	*Rhipilia sp*	*Udotea sp*	*Valonia ventricosa*	*Dictyota sp*	*Lobophora variegata*	*Padina sp*	*Turbinaria ornata*	*Amphiroa sp*	*Asparagopsis taxiformis*	*Gibsmithia sp*	*Peyssonnelia sp*	*Portieria hornemannii*
GUA-02	-	-	-	1.6%	-	0.4%	-	-	2.0%	0.8%	0.4%	-	-	0.8%	-	0.4%	-	53.2%	-	2.4%	-	-	0.4%	-
GUA-03	-	-	-	-	-	5.2%	-	-	12.0%	7.6%	0.4%	-	0.4%	4.8%	0.4%	0.4%	0.8%	2.4%	0.4%	-	-	-	-	0.8%
GUA-04	-	-	-	11.2%	-	-	-	-	-	-	0.8%	-	-	-	-	-	-	4.0%	-	1.6%	-	-	-	0.8%
GUA-05	-	-	4.8%	-	-	-	-	-	1.6%	8.0%	2.0%	-	-	-	-	-	-	-	-	0.4%	-	-	-	-
GUA-07	-	-	-	-	0.4%	7.2%	-	-	17.6%	-	-	0.4%	11.6%	-	-	-	0.4%	0.4%	0.8%	-	-	-	-	0.8%
GUA-08	-	-	2.4%	-	-	-	16.0%	-	5.6%	1.2%	2.4%	-	-	-	-	-	0.4%	0.4%	-	-	-	-	-	-
GUA-09	-	6.4%	-	-	-	10.8%	-	-	24.8%	-	1.6%	-	-	-	-	-	-	2.0%	-	-	-	-	-	2.0%
GUA-10	-	-	-	-	3.2%	-	-	0.4%	12.0%	-	0.4%	-	-	-	-	-	1.2%	-	-	-	-	-	-	-
GUA-12	6.8%	-	-	-	9.2%	10.8%	-	-	-	1.6%	0.4%	-	-	-	-	0.8%	1.2%	-	-	-	-	0.4%	-	-
GUA-13	0.4%	-	-	-	0.8%	-	-	-	2.4%	-	0.4%	-	6.8%	0.4%	-	-	2.8%	8.0%	-	-	9.6%	-	0.4%	1.6%
GUA-14	-	-	-	-	-	-	6.0%	-	8.0%	4.0%	0.8%	-	-	-	-	-	0.8%	-	-	-	-	-	-	0.4%

Benthic communities around Guam at deep and shallow randomly stratified monitoring sites were documented along two 25-m transect lines at 0.5-m intervals. Sites located at less than 10 m deep were dominated by turf algae and scleractinian coral (Table B.3.1.4, Fig. B.3.1.1). Turf algal percent cover exceeded that of other cover types at five of the six shallow sites surveyed, while scleractinian coral was the dominant cover type at one of the sites (Table B.3.1.4, Fig. B.3.1.1). Benthic communities at sites greater than 20 m deep were dominated by turf algae and macroalgae (Table B.3.1.4, Fig. B.3.1.1). Turf algal percent cover exceeded that of other cover types at five of the eight deep sites surveyed, while macroalgae were the dominant cover at three of the eight sites (Table B.3.1.4, Fig. B.3.1.1). Preliminary analysis indicates that scleractinian coral cover was greater at shallow sites than at deep sites, with mean scleractinian coral cover across all shallow sites at 27.5 ± 15.0% and 11.2 ± 9.1% for the deep sites. Macroalgal cover, on the other hand, was greater at deep sites, with mean macroalgal cover at 6.4 ± 6.6% for the shallow sites and 32.7 ± 13.3 for the deeper sites. The cover of recently-dead coral was low (< 2%) at most sites, with the exception of GUA-61 (10.8%), which was the site of an active *Acanthaster planci* outbreak. An estimated 92 species of scleractinian coral were observed across the 14 sites surveyed around Guam. This total should only be considered a conservative estimate of species richness and not an absolute figure, as it was sometimes difficult to discriminate between scleractinian coral species within certain genera (e.g., *Montipora*, *Favia*, *Porites*).

Table B.3.1.4--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Guam.

Site	Depth	Macroalgae	Turf Algae	Coralline Red Algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Dead Coral	Octocoral
GUA-51	< 10 m	0.0%	51.0%	9.8%	0.0%	31.4%	0.0%	0.0%
GUA-55	< 10 m	2.9%	59.8%	20.6%	2.0%	14.7%	0.0%	0.0%
GUA-56	< 10 m	0.0%	66.7%	9.8%	0.0%	21.6%	0.0%	2.0%
GUA-58	< 10 m	8.8%	59.8%	6.9%	0.0%	20.6%	0.0%	0.0%
GUA-59	< 10 m	9.8%	39.2%	9.8%	3.9%	36.3%	0.0%	0.0%
GUA-62	< 10 m	16.7%	26.5%	10.8%	2.9%	40.2%	2.0%	0.0%
GUA-50	> 20 m	52.0%	24.5%	8.8%	0.0%	14.7%	0.0%	0.0%
GUA-52	> 20 m	16.7%	35.3%	6.9%	0.0%	8.8%	0.0%	1.0%
GUA-53	> 20 m	30.4%	41.2%	2.0%	0.0%	16.7%	1.0%	0.0%
GUA-54	> 20 m	34.3%	52.9%	0.0%	0.0%	9.8%	0.0%	1.0%
GUA-57	> 20 m	29.4%	48.0%	3.9%	12.7%	1.0%	1.0%	0.0%
GUA-60	> 20 m	52.9%	14.7%	7.8%	0.0%	3.9%	0.0%	0.0%
GUA-61	> 20 m	24.5%	9.8%	4.9%	2.9%	29.4%	10.8%	0.0%
GUA-63	> 20 m	21.6%	42.2%	13.7%	14.7%	4.9%	0.0%	0.0%

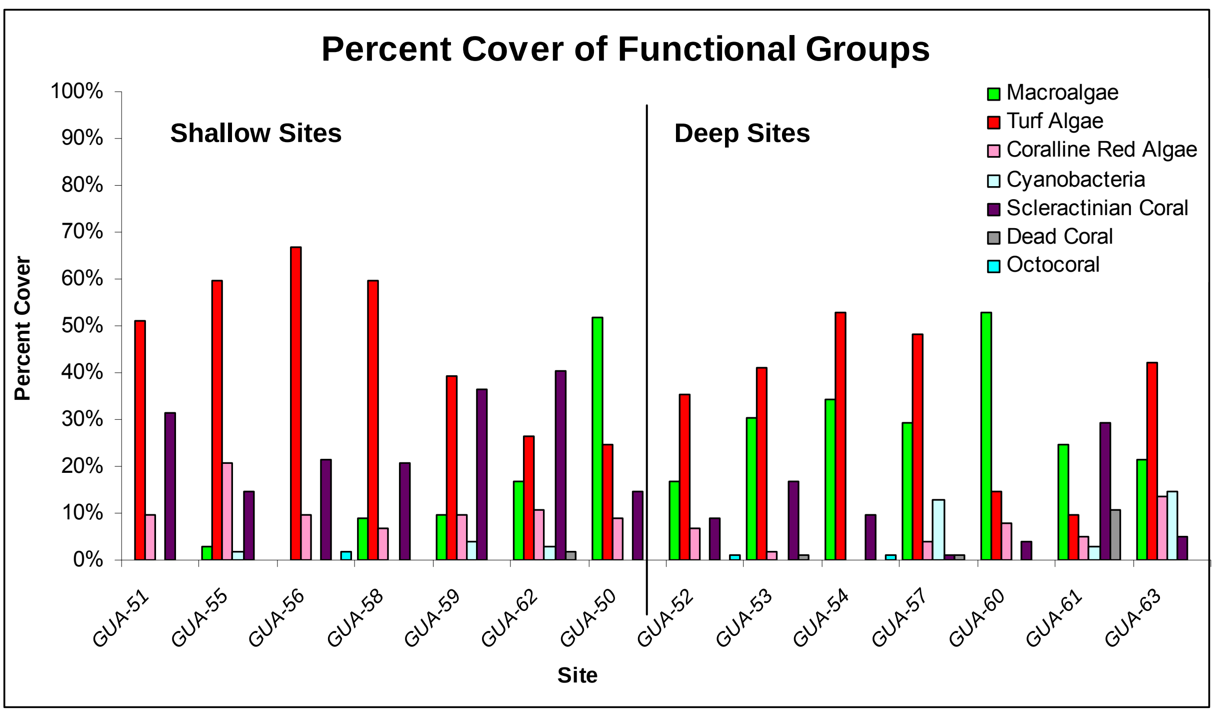


Figure B.3.1.1--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Guam.

B.3.2. Coral Communities

B.3.2.1 Percent Benthic Cover

Percent benthic cover surveys at Guam were conducted in concert with the fish, coral, algae, and invertebrate REA surveys, at eight permanent sites established between 2003 and 2007, and three new sites established in 2009 (GUA-12, GUA-13, and GUA-14). Mean live scleractinian coral cover around Guam was 19.0% (SE 0.1) based on LPI surveys at 11 permanent REA survey sites during MARAMP 2009. Percent cover was the greatest at GUA-12 (Apra Harbor) and the lowest at GUA-02 on the southeast side of the island (Fig. B.3.2.1.1).

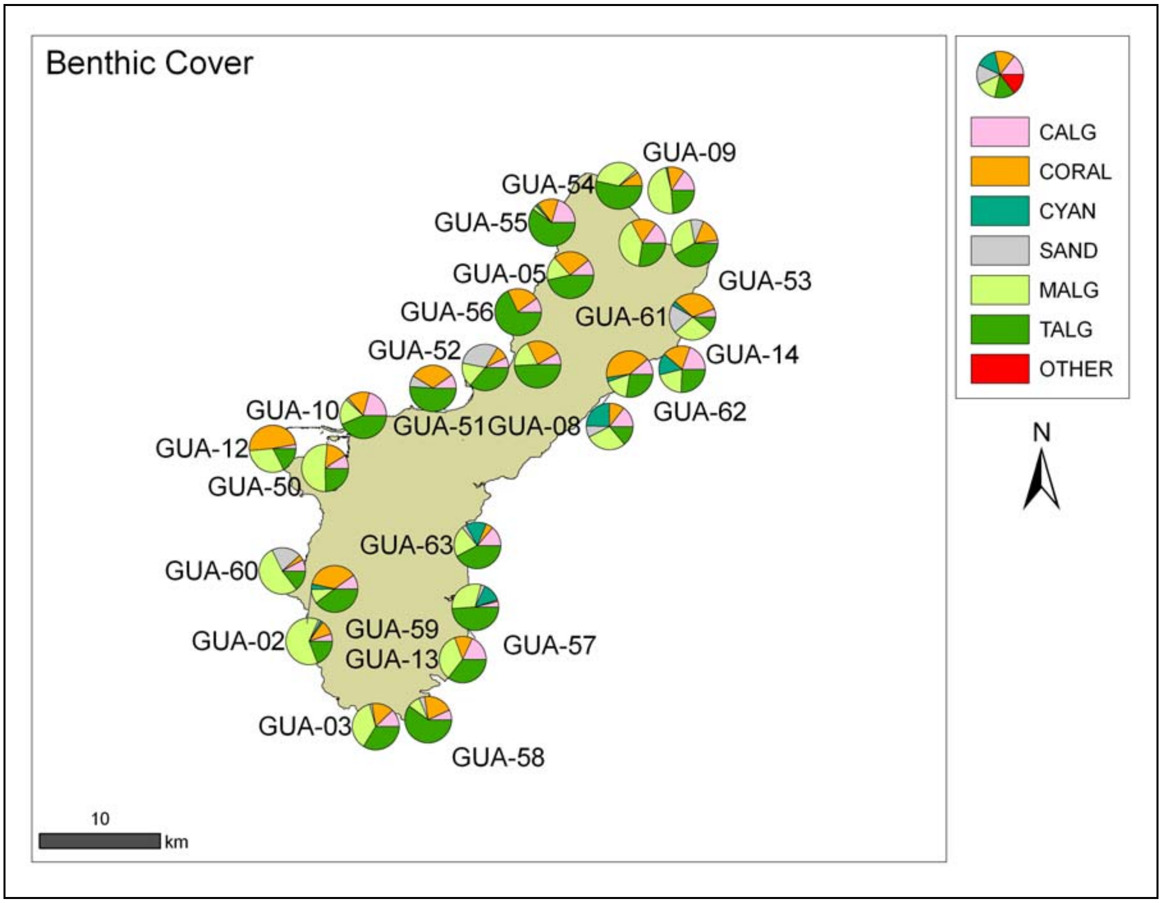


Figure B.3.2.1.1--Percent benthic cover of functional groups at shallow, intermediate, and deep established permanent REA and independent LPI monitoring sites at Guam. CALG = crustose coralline red algae, CYAN = cyanobacteria, MALG = macroalgae, TALG = turf algae.

During MARAMP 2009, 14 additional stratified random REA sites were surveyed around Guam for percent benthic cover (based on 50-cm interval LPI surveys) and generic diversity data (Fig. B.3.2.1.1). Results derived from the 14 stratified random REA sites surveyed in 2009 yielded the following results: benthic communities surveyed at eight sites greater than 20 m deep were dominated by turf algal (33.6% ± 5.5), macroalgal (32.7% ± 4.7) and scleractinian coral (11.2% ± 3.2) functional groups (Fig. B.3.2.1.2). Six shallow sites (< 10 m deep) were dominated by turf algal (50.5% ± 6.2), scleractinian coral (27.5% ± 4.1) and calcareous algal (11.3% ± 1.9) functional groups (Fig. B.3.2.1.2). Coral generic diversity was highest at site GUA-62 with 22 different genera observed (Table B.3.2.1.1). In contrast, site GUA-50 had the lowest coral generic diversity with only 10 different genera observed. The average number of genera recorded at each site was 16. Common coral genera observed at most sites included *Porties*, *Leptastrea*, *Pocillopora*, *Favia*, *Acanthastrea*, *Acropora*, *Galaxea*, *Goniastrea*, and *Montipora*. Macroalgal generic diversity was highest at site GUA-57 with 15 genera observed (Table B.3.2.1.1). Site GUA-56 had the lowest generic diversity with five genera observed. The average number of macroalgal genera recorded for each site was 9. The most common macroalga observed at most sites was *Halimeda*.

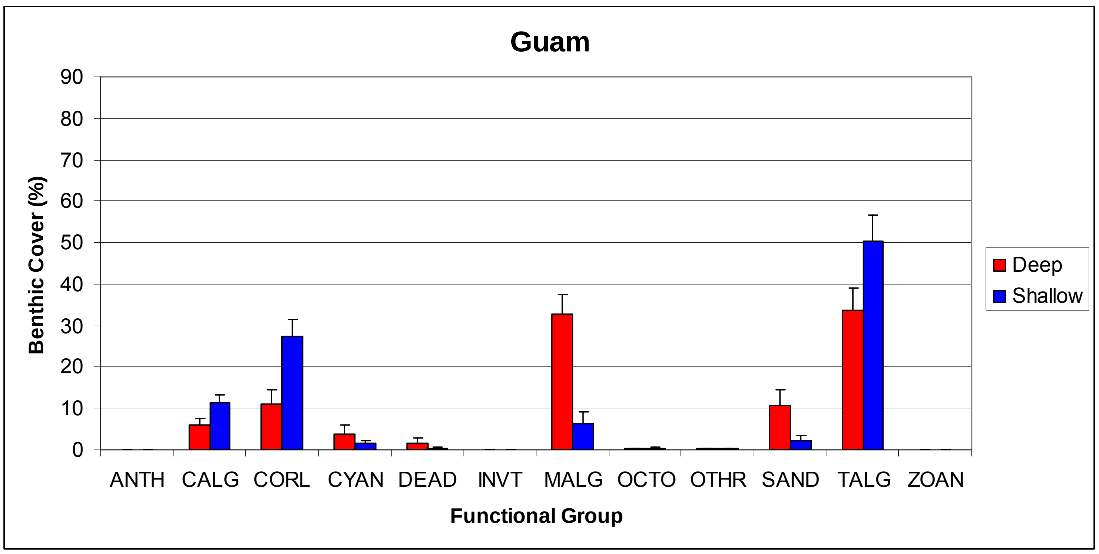


Figure B.3.2.1.2--Percent cover of functional groups at shallow and deep independent LPI monitoring sites established in 2009 at Guam. ANTH = anthozoan, CALG = crustose coralline red algae, CORL = coral, CYAN = cyanobacteria, DEAD = dead coral, INVT = non-coral invertebrate, MALG = macroalgae, OCTO = octocoral, OTHER = other, TALG = turf algae, ZOAN = zoanthid.

Table B.3.2.1.1--Coral generic diversity of stratified random sites around Guam.

	GUA-50	GUA-51	GUA-52	GUA-53	GUA-54	GUA-55	GUA-56	GUA-57	GUA-58	GUA-59	GUA-60	GUA-61	GUA-62	GUA-63
Acanthastrea		X		X	X	X	X	X	X	X		X	X	X
Acropora		X	X	X	X	X		X	X	X	X	X	X	
Alveopora		X											X	
Astreopora			X		X	X		X		X	X	X	X	
Cladiella*														
Corallimorph*							X							
Coscinarea														
Cyphastrea			X	X	X			X	X	X	X	X	X	
Diploastrea	X		X											X
Distichopora*														
Echinopora											X			

	GUA-50	GUA-51	GUA-52	GUA-53	GUA-54	GUA-55	GUA-56	GUA-57	GUA-58	GUA-59	GUA-60	GUA-61	GUA-62	GUA-63
Euphyllia														
Favia			X	X	X	X	X	X	X	X	X	X	X	X
Favites							X		X		X	X	X	
Fungia	X		X	X								X		
Galaxea		X	X	X		X	X	X	X	X	X		X	X
Gardinoseris	X													
Goniastrea		X		X	X	X	X	X	X	X		X	X	X
Goniopora														X
Heliopora*		X		X										
Herpolitha			X	X							X			
Hydnophora														
Isopora									X	X			X	
Leptastrea	X	X	X	X	X	X	X		X	X	X	X	X	X
Leptoria				X	X	X	X		X	X			X	
Leptoseris	X		X											X
Lobophyllia						X							X	
Lobophytum*		X		X		X			X				X	
Merulina														
Millepora*		X				X	X		X	X			X	
Montastrea														
Montipora			X	X	X	X	X	X	X	X	X	X	X	
Ouphyllia									X		X	X		
Pachyseris								X						
Palythoa*		X												
Pavona	X			X		X						X	X	
Platygyra		X			X		X		X	X		X	X	X
Pleisiastrea														X
Plerogyra														
Pocillopora	X		X	X	X	X	X	X	X	X	X	X	X	
Porites	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Psammocora				X	X						X			X
Sarcophyton*			X	X										
Scapophyllia												X		
Scolymia														
Seriatopora	X													
Sinularia*		X	X	X	X		X	X	X			X	X	X
Stylaster*														
Stylocoeniella	X		X			X			X	X				X
Stylophora		X		X		X		X		X		X	X	X
Turbinaria											X	X		X
Wire coral*								X						
Zoanthus*														
Total Genera per Site	10	14	16	20	14	17	14	14	19	17	15	19	22	16

B.3.2.2 Coral Populations

During MARAMP 2009, belt transect surveys were conducted at 11 permanent, long-term REA sites around Guam, covering a total reef area of more than 141 m^2 and totaling 2918 anthozoan colonies enumerated. This translates to an estimated mean colony density of 20.6 colonies m^{-2}. Islandwide taxonomic richness varied between sites with 37 anthozoan genera (32 scleractinian, 5 octocoral) being represented within belt transects (Table B.3.2.2.1). *Porites* and *Leptastrea* were the most abundant genera, contributing 33.5.9% and 16.5% of the total number of colonies enumerated islandwide during MARAMP 2009. All other genera individually contributed less than 10% of the total number of colonies. Colonies of the genus *Porites* were the most abundant scleractinian at all sites except for GUA-05 and GUA-13. *Porties* were particularly abundant at sites GUA-12 (Apra Harbor), GUA-10 (Siti Point), and GUA-04 (Tumon Bay) where it represented over 50% of all scleractinians. *Leptastrea* was the most numerically abundant coral genus at sites GUA-05, while *Montipora* were the dominant taxon at site GUA-13 (Fig. B.3.2.21).

Table B.3.2.2.1--Relative abundance of anthozoan genera enumerated within belt transects around Guam in 2009.

Island	Genus	Relative abundance
Guam	*Porites*	33.48
	Leptastrea	16.45
	Montipora	9.25
	Astreopora	6.79
	Goniastrea	6.65
	Favia	5.07
	Montastrea	4.97
	Cyphastrea	3.12
	Pocillopora	2.26
	Pavona	1.64
	Psammocora	1.30
	Platygyra	1.23
	Galaxea	0.96
	Acanthastrea	0.93
	Acropora	0.82
	Goniopora	0.72
	Stylocoeniella	0.69
	Lobophytum	0.55
	Dendronephthya	0.48
	Sinularia	0.48
	Stylophora	0.48
	Leptoria	0.41
	Heliopora	0.24
	Favites	0.21
	Diploastrea	0.17
	Fungia	0.14
	Echinopora	0.07
	Hydnophora	0.07
	Isopora	0.07
	Turbinaria	0.07
	Cycloseris	0.03

Island	Genus	Relative abundance
	Echinophyllia	0.03
	Gardineroseris	0.03
	Herpolitha	0.03
	Oulophyllia	0.03
	Scolymia	0.03
	Sinularia/*Lobophytum*/*Sarcophyton*& other soft corals	0.03

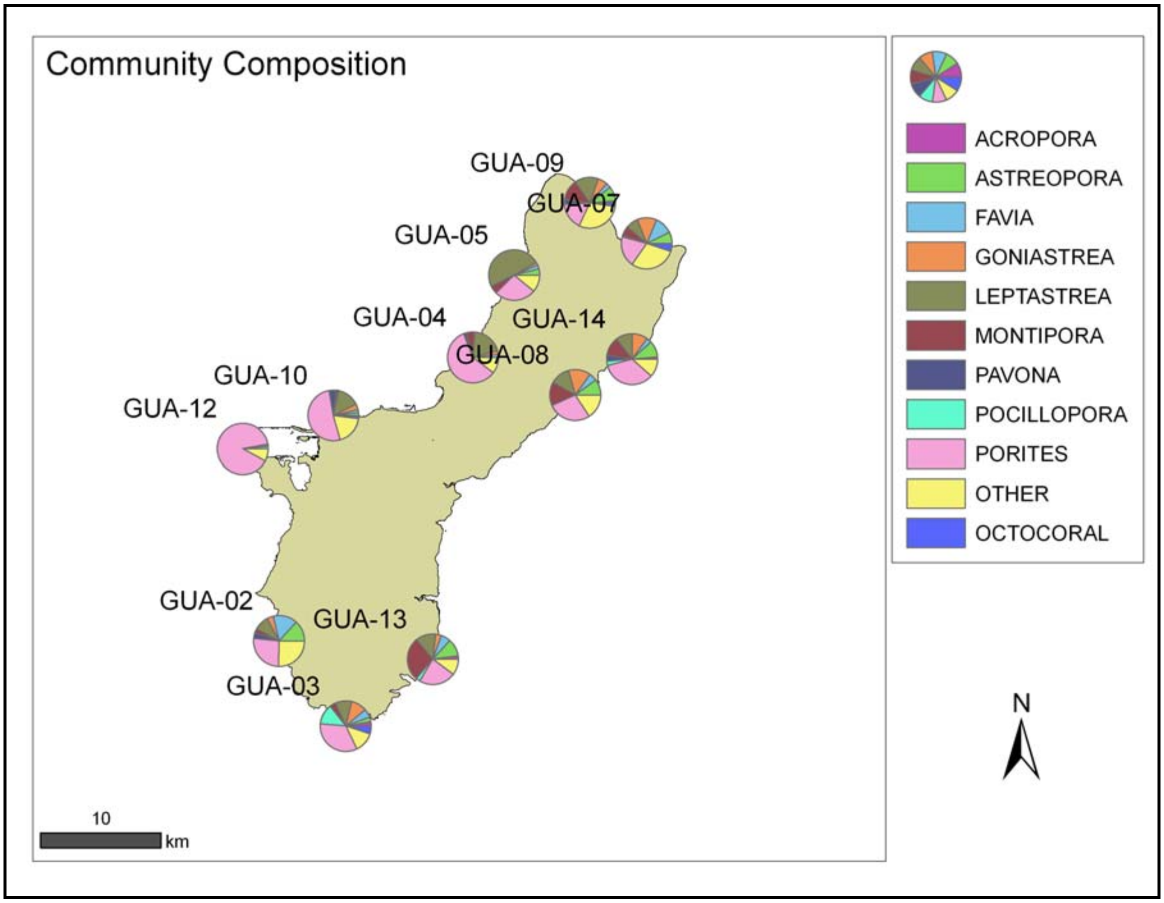


Figure B.3.2.2.1--Relative abundance of coral genera from REA surveys around Guam in 2009.

Size class distribution of all corals enumerated within belt transects are shown in Figure B.3.2.2.2. Of the 2918 anthozoan colonies enumerated (average diameter estimated as the arithmetic mean of two planar measurements), 44.1% had a diameters of < 5 cm, and 30% had mean diameters between 6 and10 cm.

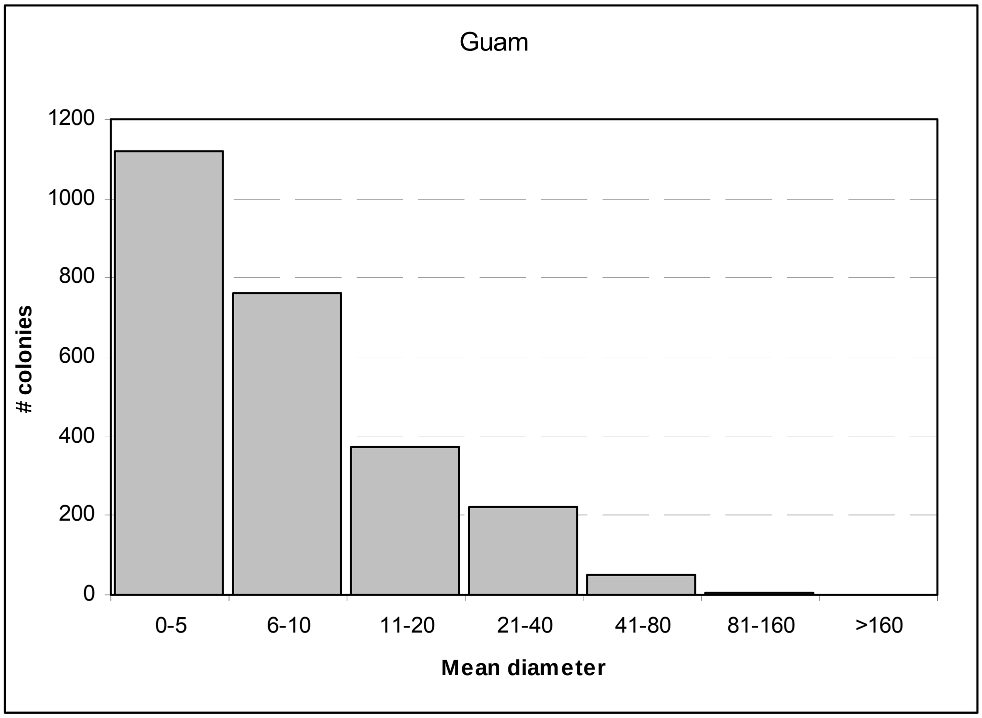


Figure B.3.2.2.2--Size class distribution of 2918 coral colonies enumerated within belt transects around Guam in 2009.

B.3.3 Coral Health and Disease

During MARAMP 2009, occurrence of disease, heath impairments, and predation around Guam was relatively high, with a total of 342 lesions tallied. A summary of disease and predation occurrence, relative abundance, is presented in Table B.3.3.1. Acute tissue loss (white syndrome) and hyperpigmentated irritations were the most common afflictions to scleractinian corals, particularly on colonies of the genus *Porites*. Bleaching conditions were the third most numerically abundant type of affliction, with a total of 38 cases tallied islandwide. Lesions affecting coralline algae were infrequent, with only seven cases enumerated islandwide. Two types of coralline algal diseases were observed: coralline orange lethal disease (CLOD) and the coralline white band syndrome (CLD).

Table B.3.3.1--Number of cases of scleractinian and coralline algal diseases enumerated during REA surveys, around Guam during MARAMP 2009. ALG: algal infections, BIN: barnacle infestation; BLE: bleaching; CYA: cyanophyte infections; DIS: discolorations other than bleaching; EFI: endolithic fungal infections; FUG: other fungal infections; HYP: hyperpigmented irritations/pigmentation response; PRE: *Acanthaster*/*Drupella* predation scars; SGA: skeletal growth anomalies; TIN: tubeworm infestation; TLS: tissue loss; WSY: white syndrome; OTH: other diseases and lesions of unknown etiology; CLOD: coralline lethal orange disease; and CLD; coralline white band syndrome/lethal disease.

DZCode	GUA-02	GUA-03	GUA-04	GUA-05	GUA-07	GUA-08	GUA-09	GUA-10	GUA-12	GUA-13	GUA-14	Grand Total
ALG	4	1			3		2	4	3	5	10	32
BLE	3	6	1	3	3	2	3	4	7	4	2	38
CYA			2		2					1	4	9
DIS										1		1
FUG		6	1			2		7	3	6	5	22
HYP		3	2	4	7	4	3	13		1	4	41
SGA					1		1				2	4
TLS			1				2	1	2		3	9
WSY	3	5	4	5	2	4	6		11	3	4	47
OTH	9	14		9	5	6	6	7	13	8	4	81
PRE		2	5	18	5	9	5	1	3		2	50
Total	**19**	**37**	**16**	**39**	**28**	**27**	**28**	**37**	**42**	**29**	**40**	**342**
CLD								1				1
CLOD						1				1	5	7

B.3.4 Macroinvertebrate Surveys (non-coral)

A total of 899 individuals belonging to 60 benthic invertebrate target species or taxa groups were enumerated from 15 belt transects at 9 sites (Table B.3.4-1). Guam had the lowest densities of macroinvertebrates at REA reef habitats of the southernmost Mariana Islands of Guam, Rota, Aguijan, and Tinian (59.97 organisms/50 m² for core target groups, or 229.46 organisms/50 m² including sponges, vermetids, and *Spirobranchus* Christmas tree worms). GUA-04 had the greatest density of invertebrates of the Guam sites when considering only core target groups (106 organisms/50 m²), but GUA-14 had the highest overall density if sponges, vermetids, and Christmas tree worms are considered (218.9 organisms/50 m²). Vermetid worm snails were quite common at almost all sites surveyed (31.86 organisms/ 50 m²), and *Spirobranchus* worms were abundant at four sites, especially GUA-14 (13.64 organisms/50 m² island mean, 57.78 organisms/50 m² at GUA-14). Guam had the lowest average site species richness (mean 15.67 species/site) of the four southern islands.

Small hermit crabs (e.g., of the genus *Calcinus*) were moderately abundant at most sites (11.6 organisms/50 m²), especially at GUA-14 (34.44 organisms/50 m²). Guard crabs of the genus *Trapezia*, associated with branching coral heads, were not highly abundant at most sites around Guam, with GUA-03 being an exception with 30 organisms/50 m² observed. Coral eating Coralliophilid snails were moderately common on corals (8.69 organisms/50 m²). The boring urchins, *Echinostrephus aciculatus* and *Echinometra mathaei*, were also moderately abundant at many sites (9.83 organisms/50 m²). Additionally, sponges were seen along transects at most sites around Guam, especially GUA-02 and GUA-14 (32.5 organisms/50 m² and 35.56 organisms/50 m², respectively).

Tridacna clams were present at most REA sites around Guam, but at low densities of only 1-3 organisms per 50 m².

Table B.3.4-1--Densities of organisms observed at REA sites around Guam during cruise HA0902. Sponges, vermetids, and *Spirobranchus* polychaete worms are not explicit target groups, but observations are recorded here.

GUAM Invertebrate Surveys 2009		Density (# / 50m²)									
Phylum	TaxaGroup	GUA-02	GUA-03	GUA-04	GUA-07	GUA-09	GUA-10	GUA-12	GUA-13	GUA-14	Guam Mean
Annelida	***Polychaetes***	30	2		1	16	15		1	57.78	13.64
Arthropoda	***Shrimp***	20		2	7	1	7		3	6.67	5.19
	Hermit Crabs: Large (e.g. Dardanus sp.)		1	2		1	1				0.56
	Hermit Crabs: Small (e.g. Calcinus sp.)		19	4	16	9	1	4	17	34.44	11.6
	Crabs: Other Brachyurans								1	1.11	0.23
	Crabs: Coral Guard Crabs (Trapezia, etc)	2.5	30		3				7	8.89	5.71
Echinodermata	***Asteroids (Sea Stars): Other***		1	12			3			1.11	1.9
	Asteroids (Sea Stars): Crown of Thorns				1					1.11	0.23
	Echinoids (Urchins): Boring Echinometrids	7.5	14		16	6	6		39		9.83
	Echinoids (Urchins): Diadematoids			4	1		3		2		1.11
	Holothuroids (Sea Cucumbers)			22	6	1	12				4.56
	Ophiuroids (Brittle Stars)		10							4.44	1.6
Mollusca	***Bivalves: Tridacnids (Giant Clams)***	2.5	2	2	1	1	2		1	3.33	1.65
	Bivalves: Pteriomorphs	7.5	1								0.94
	Snails: Other			2	5	2	5	2	7	1.11	2.68
	Snails: Large (Lambids/Tritons)			2							0.22
	Snails: Coralliophilids (Coral Eating)		18	46					2	12.22	8.69
	Snails: Trochus		1	4	3		2		1		1.22
	Snails: Vermetids (Worm Snails)		11	24	109	47	4	10	34	47.78	31.86
	Opisthobranchs (Sea Slugs)									1.11	0.12
Porifera	***Sponges***	32.5	1	6		2	5	18		35.56	11.12
Chordata	***Ascidians***		1	4	4	1	1	4		2.22	1.91
Grand Total		**102.5**	**112**	**136**	**173**	**87**	**67**	**38**	**115**	**218.9**	**116.6**

B.3.4.1. Urchin Measurements

The test diameters of urchin species and the valve width of Tridacnid clams were recorded at REA sites around Guam. Mean measurements by site are presented in Figure B.3.4.1-1 for species where the sample size is 5 or greater.

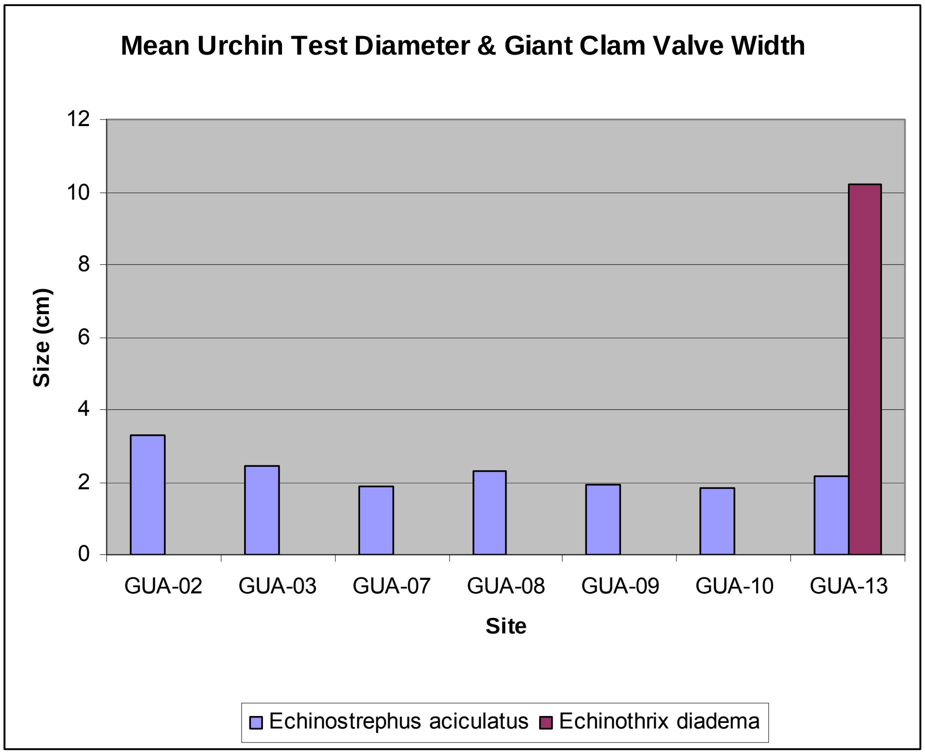


Figure B.3.4.1-1--Reveals the average test diameter of urchins and valve width of giant clams encountered at each site around Guam. Only sites where ≥ 5 measurements were recorded for a species are represented.

B.3.4.2. ARMS Deployment

ARMS were deployed at the following REA sites around Guam. Each site contains three ARMS.

Table B.3.4.2-1--ARMS deployment locations around Guam.

REA Site	Latitude	Longitude
GUA-12	13° 26.927'	144° 37.555'
GUA-05	13° 34.708'	144° 49.700'
GUA-02	13° 18.332'	144° 39.152'
GUA-08	13° 29.324'	144° 52.674'

B.3.4.3 Invertebrate Collections

No specimens were collected around Guam during HA-09-02.

B.3.5 Benthic Towed-diver Surveys

Twenty-two benthic towed-diver surveys were completed at Guam in 2009. Habitats covered during surveys varied with the majority of tow segments conducted over hard bottom (a mixture of continuous pavement reefs and pavement separated by thin sand channels).

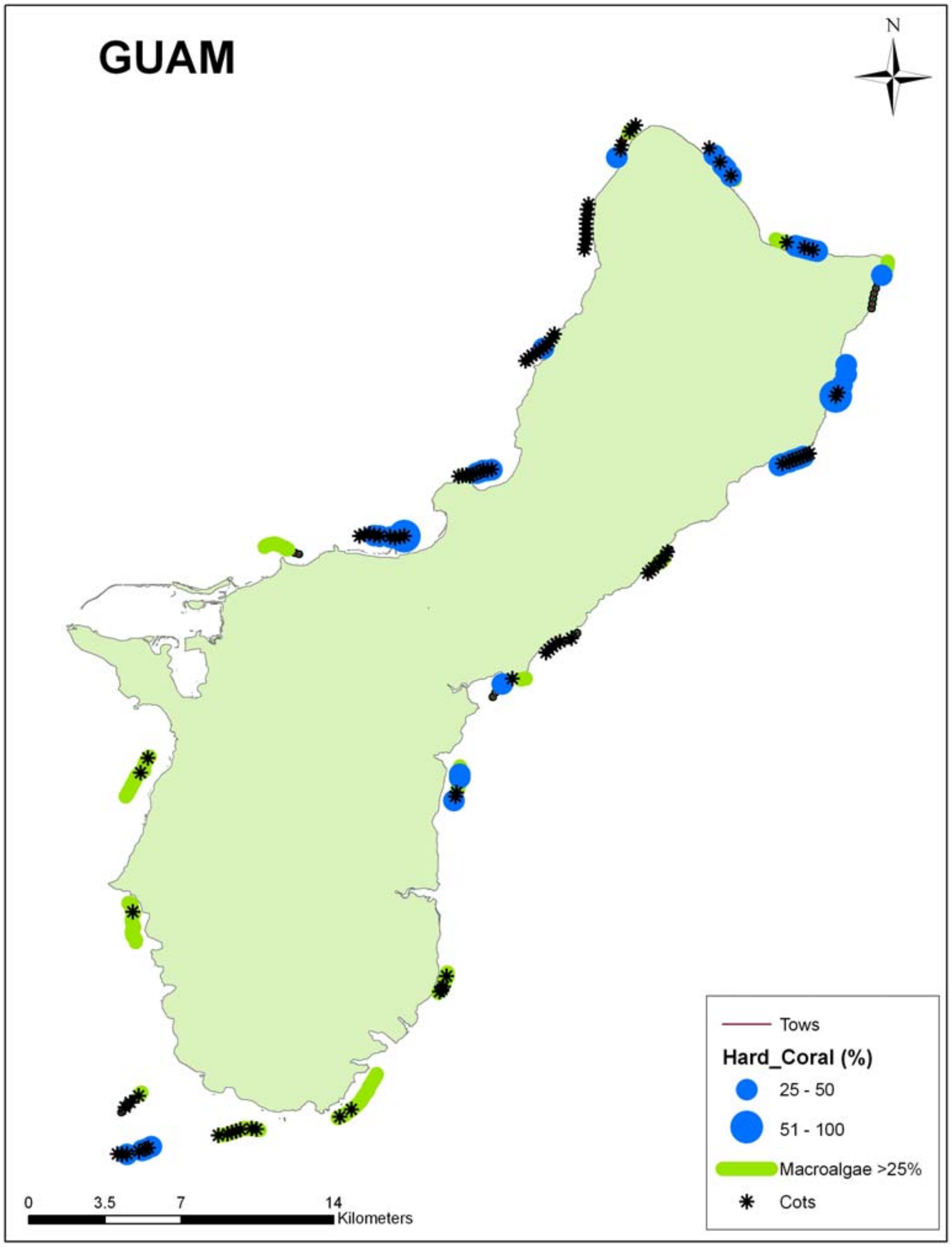


Figure B.3.5.1--Hard coral cover (≥ 25%) elevated macroalgae cover (> 25%), and COTs sightings during tow segments at Guam in 2009.

Macroalgal cover was the most common benthic category recorded during towed-diver surveys around Guam in 2009 with an island mean of 25.7 ± 1.1%. Generally, macroalgal cover was higher on southern tows compared to northern tows with species of *Halimeda*, *Padina*, and *Asparagopsis* being most notable.

Coral cover was moderately low island wide (Mean ± SE: 15.2 ± 0.8) with higher cover seen in the northern portion of the island. Coral communities observed during tows in the northeast consisted of a diverse assemblage of branching corals (*Acropora* and *Pocillopora* species) as well as *Montipora* and *Astreopora*. One tow segment which had the highest coral cover also had an unusually high number of COTs estimated at more than 150 individuals. Scarring of *Montipora* and *Astreopora* corals was evident and the spike in COTs abundance seemed to be localized as they were seen from the beginning of the tow survey for only ~ 2 min. Although the density dropped off considerably after those two minutes, density was high at the point where the divers entered the water; therefore, the southern extent of the "localized" distribution was not quantified. Other areas of high coral cover were mostly composed of massive *Porites* colonies and some areas where *Porites rus* was dominant.

Benthic category	Mean ± SE
Hard Coral	15.2 ± 0.8
Soft Coral	1.2 ± 0.1
Macroalgae	25.7 ± 1.1
Coralline Algae	6.2 ± 0.3
Sand	5.7 ± 0.8
Rubble	1.7 ± 0.4
COTs	652
Free Urchins	26
Boring Urchins	5016
Sea Cucumbers	1323
Giant Clams	122

* Sum of observed individuals

The most abundant macroinvertebrate was the boring urchin which was common during most tows. Sea cucumbers were also abundant and were generally found in higher densities off the western coast of Guam. Giant clams were seen across the island but in low densities. COTs, as mentioned earlier, were most abundant during one tow segment in the northeast region of Guam, but were seen in low numbers during most tows.

Observer Calibration: A total of 34 paired observations of benthic cover were made during the Southern Mariana leg in 2009 to investigate interobserver calibration between benthic divers. For each paired observation, the difference between binned observations from both observers was calculated and then cumulative relative frequencies of the difference were calculated (Table B.3.5). Hard coral, soft coral, sand, rubble and coralline algae all had high agreement between observers with almost 90% of observations being within 1% cover bin. Macroalgae had the lowest agreement between divers possibly due to some issues with changing habitat with tow segments which cover roughly 200 meters of reef.

Table B.3.5.

Difference	Hard coral	Soft coral	Sand	Rubble	Macro-algae	Coralline algae
0	23.52941	58.82353	58.82353	50	32.35294	61.76471
1	91.17647	100	88.23529	88.23529	76.47059	85.29412
2	100	100	97.05882	97.05882	100	97.05882
+2	100	100	100	100	100	100

B.4 Fish Surveys

B.4.1 REA Fish Surveys

Stationary point count data (SPC)

During the survey period, SPC surveys were conducted at 25 sites around Guam. Surgeonfish were the largest contributor to total biomass with 0.43 kg 100 m^{-2}. Parrotfish were the second largest contributor to total biomass with 0.21 kg 100 m^{-2}, followed by wrasses at 0.20 kg 100 m^{-2} (Fig. B.4.1.1).

Overall observations

A total of 217 fish species were observed during the survey period by all divers. The average total fish biomass around Guam during the survey period was 1.4 kg 100 m^{-2} for the SPC surveys (Fig. B.4.1.1).

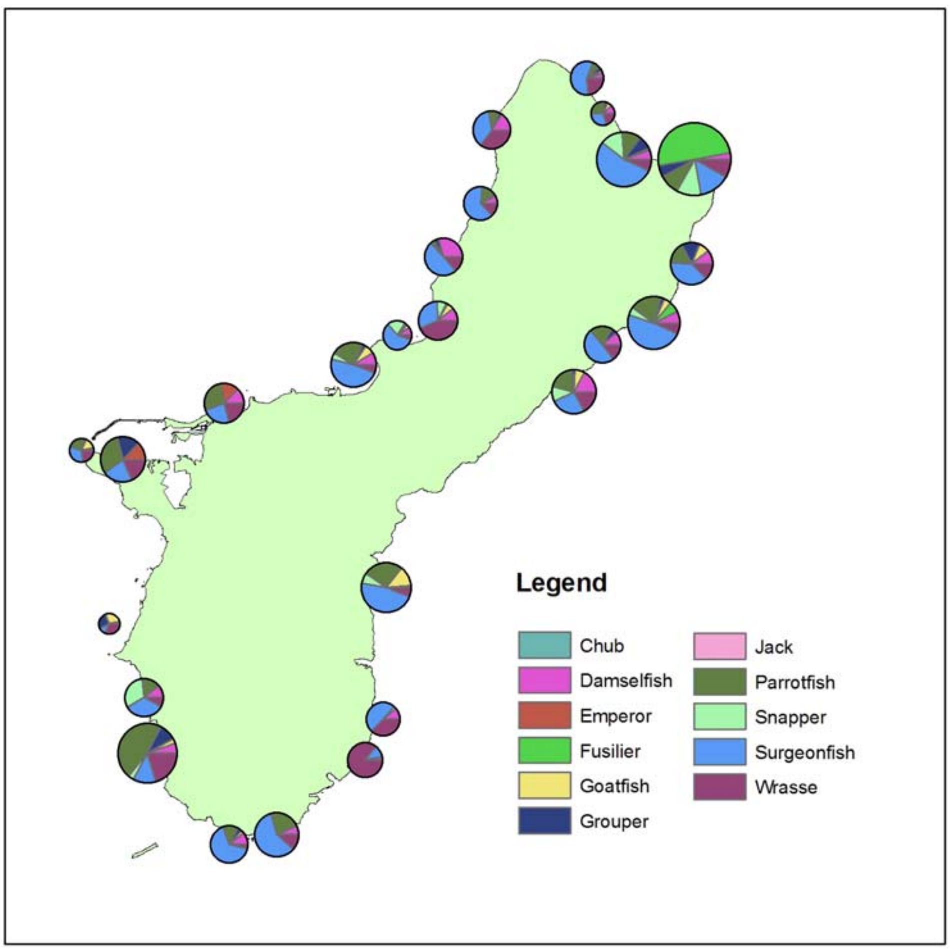


Figure B.4.1.1--Site location and distribution of total fish biomass by family. The size of the pie charts are proportional to fish biomass.

B.4.2 Towed-diver Surveys

During HA0902, the CRED towed-diver team completed 23 surveys at Guam covering 46.88 km (46.88 ha) of ocean floor (Table B.4.2.1). Mean survey length was 2.0 km with a maximum length of 2.8 km and a minimum of 1.4 km. Mean survey depth was 14.7 m with a maximum depth of 16.4 m and a minimum of 12.1 m. Mean temperature on these surveys was 28°C with a maximum temperature of 28.3°C and a minimum of 27.8°C.

Table B.4.2.1--Survey statistics for towed-diver sampling during HA0902.

		Length (km)					Depth (m)				Temperature (ºC)				Numeric		Biomass	
Island/Atoll/Reef	#	Sum	Mean	Max	Min	SD	Mean	Max	Min	SD	Mean	Max	Min	SD	Density (#/ha)	STDev	Density (t/ha)	STDev
Tinian	11	25.87	2.35	3.58	1.66	0.50	15.06	20.09	12.96	1.86	27.95	28.06	27.78	0.08	20.88	1.095	0.08	0.006
Aguijan	5	11.73	2.35	2.89	2.05	2.44	14.12	15.15	12.62	1.06	27.97	28.11	27.69	0.15	7.67	0.713	0.07	0.011
Rota	11	24.21	2.20	2.90	1.80	3.40	14.90	17.50	12.06	1.56	28.09	28.15	27.98	0.06	14.04	0.731	0.16	0.019
Guam	23	46.88	2.04	2.78	1.41	3.30	14.68	16.42	12.10	1.25	28.09	28.33	27.84	0.15	14.50	1.072	0.06	0.004
Guam/SCNMI Total	50	108.7	2.2	3.6	1.4		14.7	20.1	12.1		28.0	28.3	27.7		14.27		0.09	

Sixty-eight individual large-bodied reef fish (> 50 cm TL) of 17 different species and 14 different families were encountered around Guam (Table B.4.2.2). Overall numeric density for this class of reef fishes was 0.145 #/100 m^2 (14.504 #/ha) with a biomass density of 0.597 kg/100 m^2 (0.060 t/ha) (Figs. B.4.2.1 and B.4.2.2). Numeric density was dominated by *Plectorhinchus gibbosus* while biomass density was dominated by *Sphyraena qenie.*

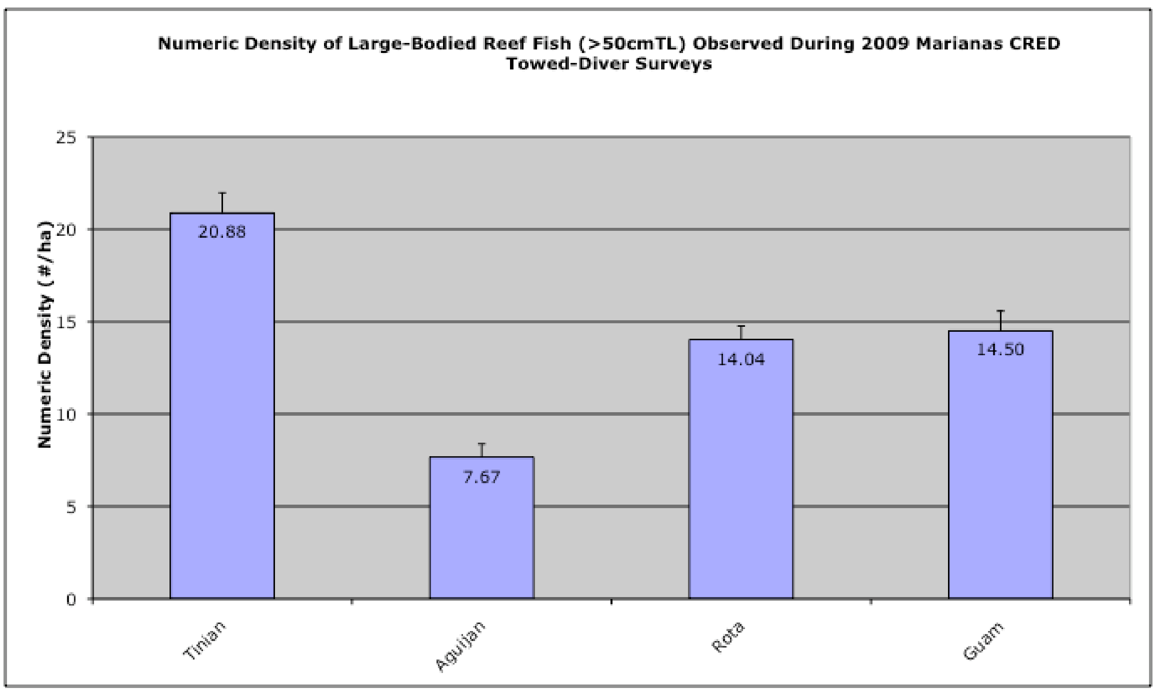


Figure B.4.2.1--Island comparison of numeric density of large-bodied reef fish (> 50 cm TL) observed during HA0902 CRED towed-diver surveys

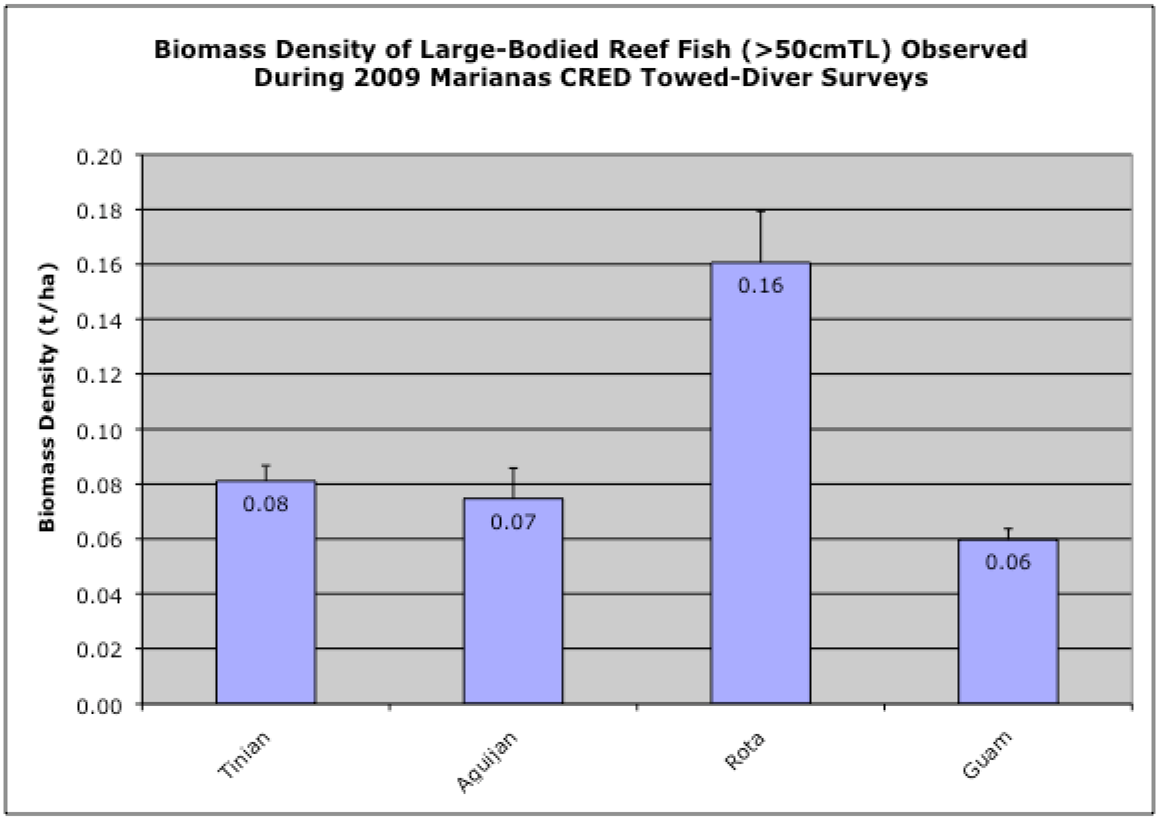


Figure B.4.2.2--Island comparison of biomass density of large-bodied reef fish (> 50 cm TL) observed during HA0902 CRED towed-diver surveys.

The most prevalent families, in terms of numeric and biomass density, were Sphyraenids (ND=24%, BD=26%), Haemulids (ND=24%, BD=13%), and Acanthurids (ND=13%, BD=11%) (Figs. B.4.2.3, B.4.2.4).

Biomass of large-bodied reef fish appeared to be concentrated at the northern and southern tips of the island where *Plectorhinchus gibbosus, Kyphosus* sp., *Plectropomus laevis,* and *Sphyraena qenie* were found (Fig. B.4.2.5).

Table B.4.2.1--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Guam during HA0902 CRED towed-diver surveys.

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Carcharhinus_melanopterus	1	0.002	0.213	10.38172917	0.022	0.002
Cetoscarus_bicolor	1	0.002	0.213	1.9625	0.004	0.000
Cheilinus_undulatus	3	0.006	0.640	23.44465481	0.050	0.005
Diodon_hystrix	2	0.004	0.427	11.40432834	0.024	0.002
Gymnosarda_unicolor	1	0.002	0.213	4.74695147	0.010	0.001
Gymnothorax_javanicus	2	0.004	0.427	21.93743557	0.047	0.005
Hipposcarus_longiceps	1	0.002	0.213	2.475	0.005	0.001
Kyphosus_sp	8	0.017	1.706	23.16066477	0.049	0.005
Lutjanus_bohar	2	0.004	0.427	9.77551416	0.021	0.002
Monotaxis_grandoculis	1	0.002	0.213	3.13076161	0.007	0.001
Naso_brachycentron	1	0.002	0.213	6.6337446	0.014	0.001
Naso_tonganus	8	0.017	1.706	27.1718232	0.058	0.006
Plectorhinchus_gibbosus	16	0.034	3.413	38.96727533	0.083	0.008
Plectropomus_laevis	2	0.004	0.427	16.0021437	0.034	0.003
Sphyraena_qenie	16	0.034	3.413	78.6723	0.168	0.017
Urogymnus_africanus	1	0.002	0.213	18.1273036	0.039	0.004
Variola_louti	2	0.004	0.427	4.1532035	0.009	0.001
Grand Total	68	0.145	14.504	279.867	0.597	0.060
# of Species	17					

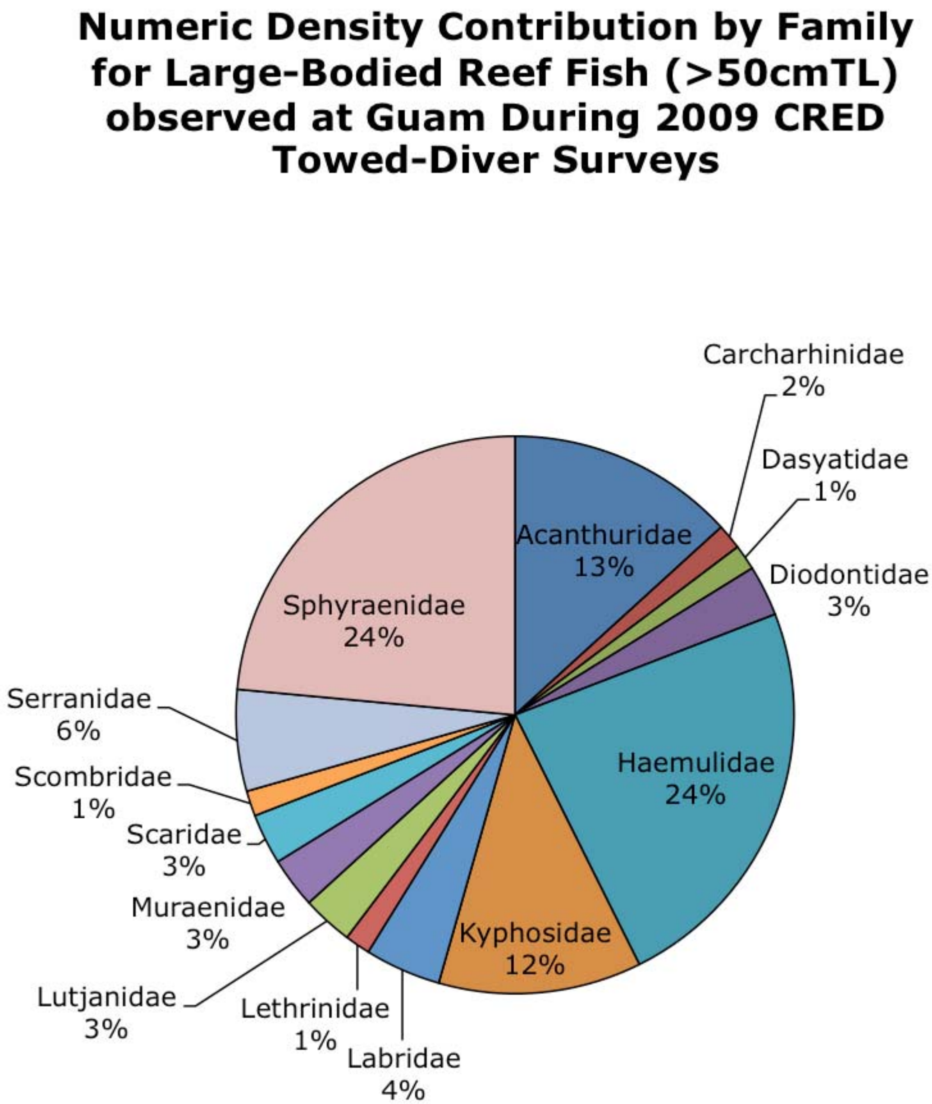


Figure B.4.2.3--Numeric density by Family.

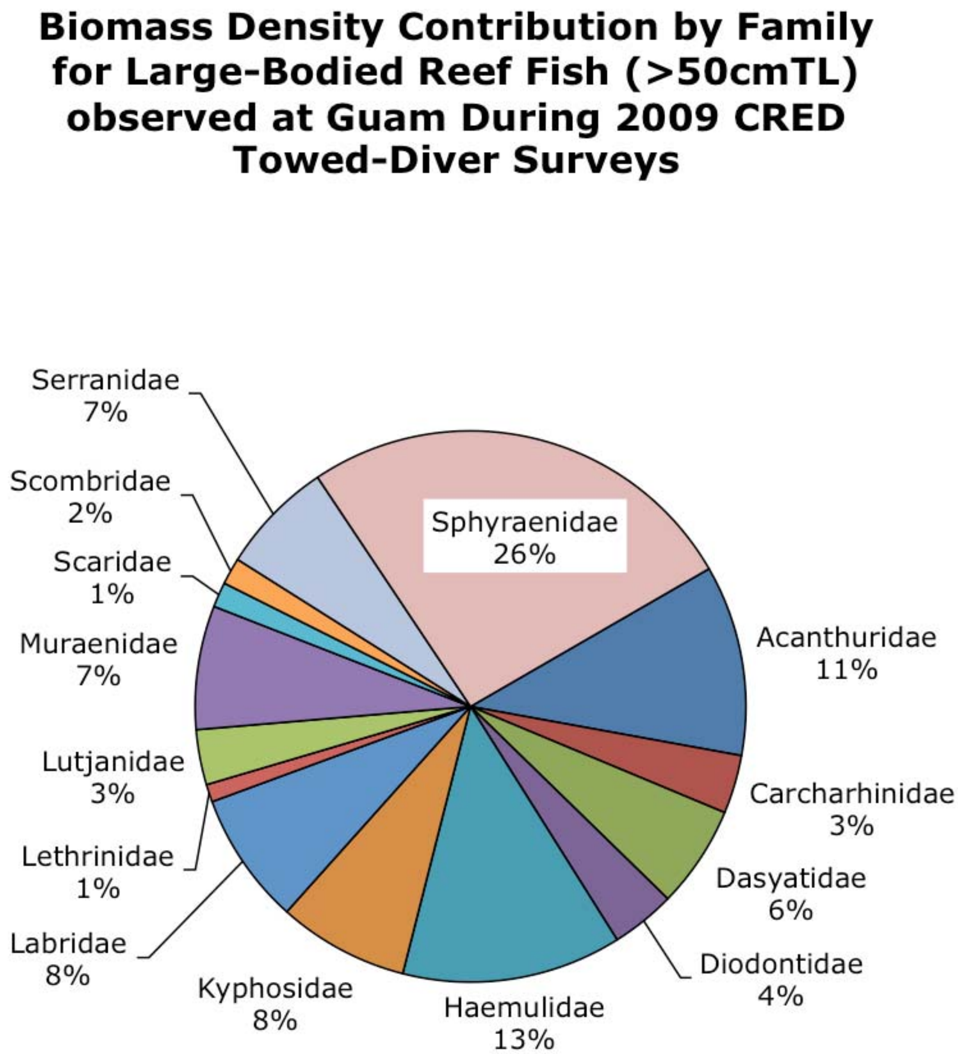


Figure B.4.2.4--Biomass density by Family.

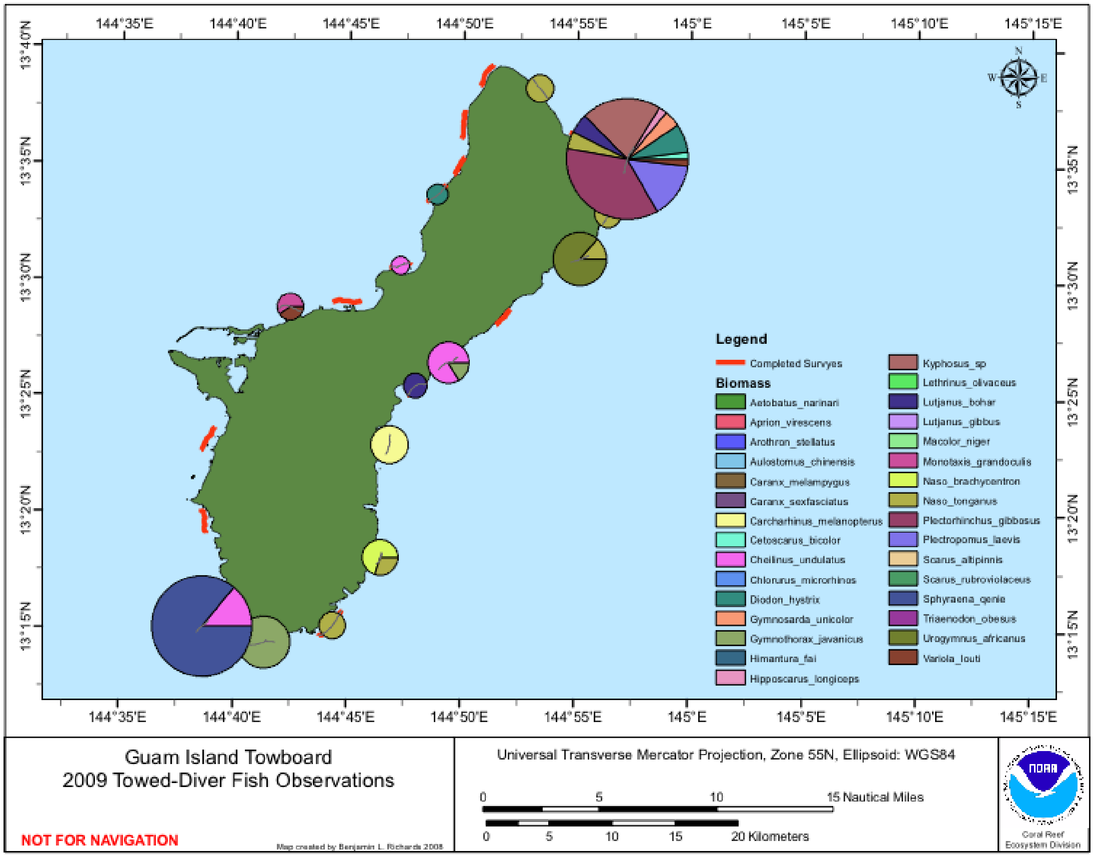


Figure B.4.2.5--Geographic distribution of biomass of fish species around Guam. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

Appendix C: Rota Island

C.1. Oceanography and Water Quality

Moorings recovered and replaced during HA0902 at Rota included one subsurface temperature recorder (STR), one sea surface temperature (SST) buoy, and one ecological acoustic recorder (EAR) (Fig. C.1.1). The STR showed a typical pattern and temperature range, with a clear annual fluctuation due to seasonal warming and cooling (Fig. C.1.2.). Warmest temperatures peaked at ~ 30.2°C and occurred during the summer months of July to October. Winter temperatures reached lows of 27.8°C and occurred during November through June. The STR site on the east side could not be reached because of weather and sea state. The previously deployed SST buoy was found washed ashore after a tropical storm.

Two REA sites (ROT-03 and ROT-05) were visited to collect water samples for microbiological, nutrient and chlorophyll analyses, and the three of remaining four REA sites were sampled for just nutrients and chlorophyll. Samples were obtained from the surface and near the bottom. Microbial water samples were taken using diver-deployable Niskin bottles to collect 8 liters of seawater (4 bottles; 2 liters per bottle) at each study site. All samples were collected between 10 and18 m. At each rapid ecological assessment (REA) site, water samples for analysis of nutrient and chlorophyll levels were collected. Chlorophyll samples were filtered and nutrient samples were frozen at - 30°C for post-cruise analysis. These samples were collected at 10–15 meters deep and transported back to the ship. Shallow-water conductivity temperature and depth (CTD) casts were also conducted at these sites. Additional CTD casts were taken around the 30-m depth contour of Rota (Figs. C.1.2 and C.1.3).

Table C.1.1--Moorings.

Instrument	Island	Action	Serial number	Latitude	Longitude	Action date	Depth (m)
SST	ROT	Missing Buoy		14.1283	145.1638		10
STR	ROT	Missing STR		14.1283	145.1638		10
STR	ROT	Not Retrieved		14.1752	145.2863		16
SST	ROT	Deployment	39530054499	14.1283	145.1638	4/9/2009	11
STR	ROT	Deployment	39331791143	14.1283	145.1638	4/9/2009	11
STR	ROT	Retrieval	39368591668	14.1828	145.2068	4/9/2009	10
STR	ROT	Deployment	39510234478	14.1828	145.2068	4/9/2009	10
STR	ROT	Deployment	39331791153	14.11337	145.1667	4/9/2009	13.2
EAR	ROT	Deployment	9300491B102	14.11337	145.1667	4/9/2009	13.2

Figure C.1.1--Deployed instrument moorings Rota, HA0902.

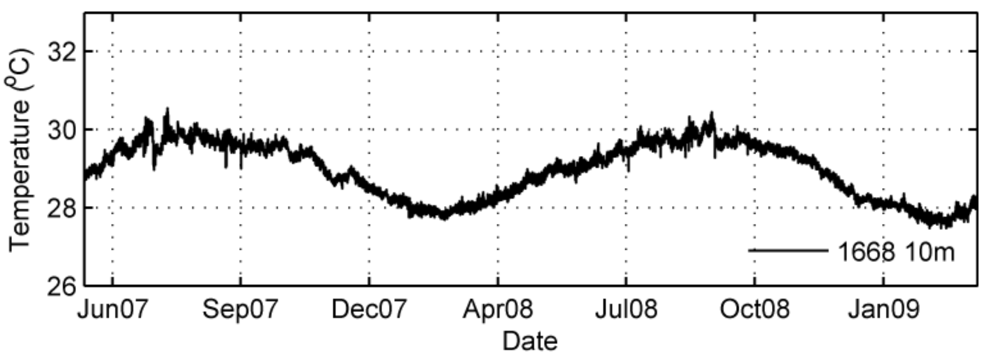


Figure C.1.2--Temperature time-series from STR mooring retrieved from Rota, HA0902.

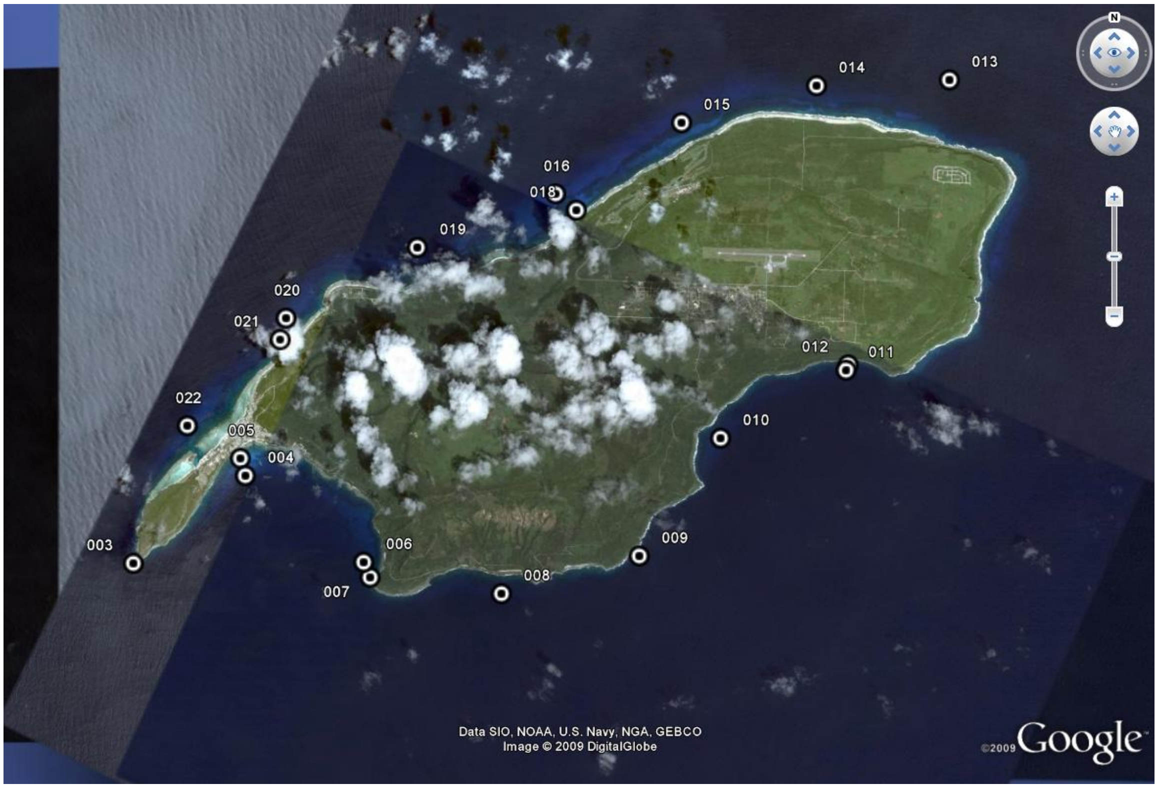


Figure C.1.3–Shallow-water CTDs, Rota, HA0902.

C.2. Rapid Ecological Assessment (REA) Site Descriptions

Six REA sites were visited by a team of up to seven scientists around Rota Island between April 8 and April 9, 2009 (Fig. C.2.1). In addition, eight stratified random fish, LPI, and invertebrate surveys were conducted. The site locations are listed below along with site photos taken in 2009. Site descriptions are included for the following discipline communities: coral, coral disease, macroinvertebrates, algae, and fish.

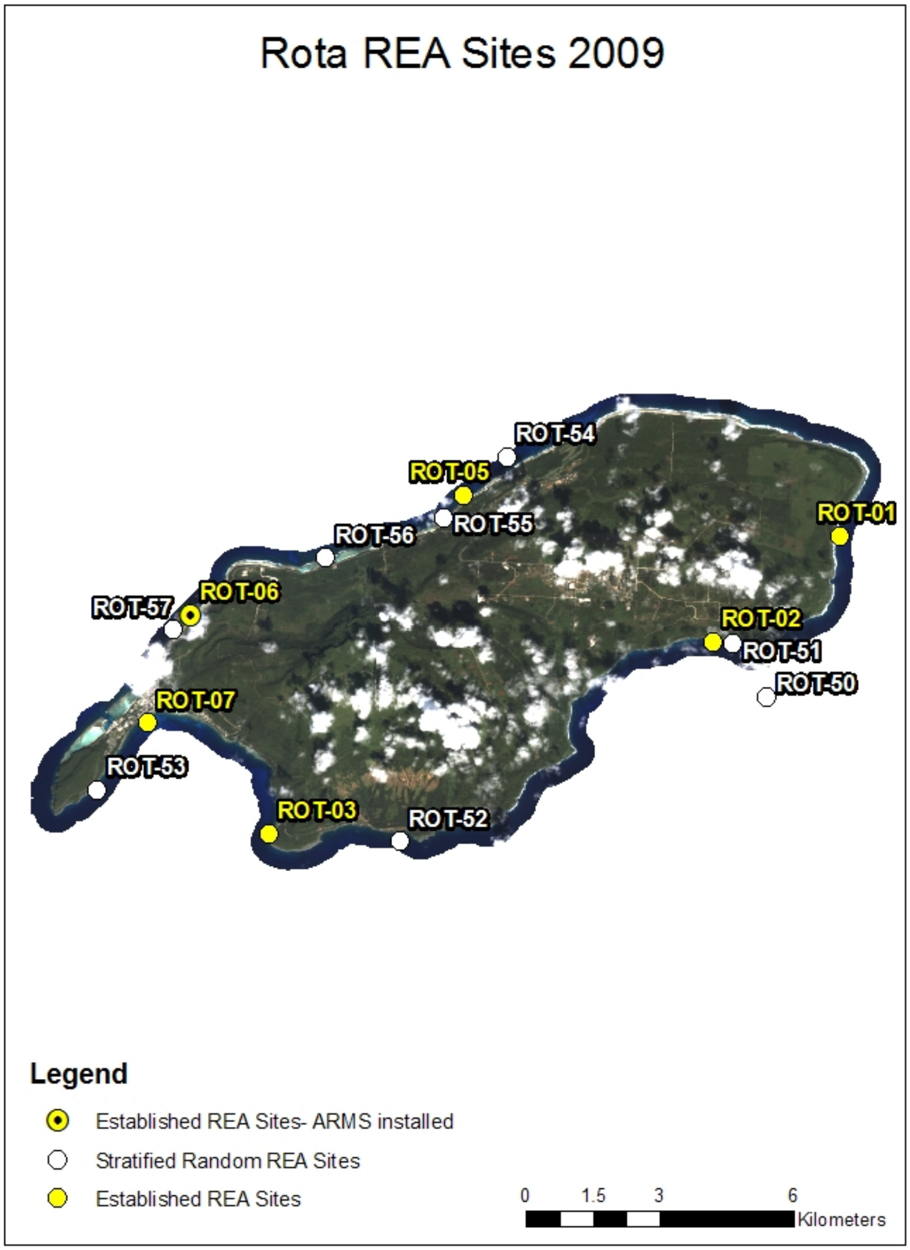


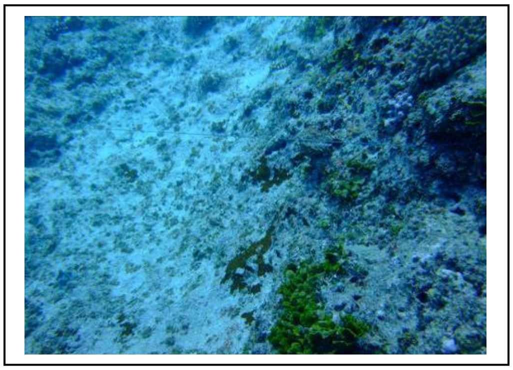
Figure C.2.1--Locations of REA, stratified random and Autonomous Reef Monitoring Systems installation sites visited at Rota Island in 2009.

ROT-01
4/9/2009

E 145° 17.146
N 14° 10.540

Forereef
Mid

Depth: 11–13 m



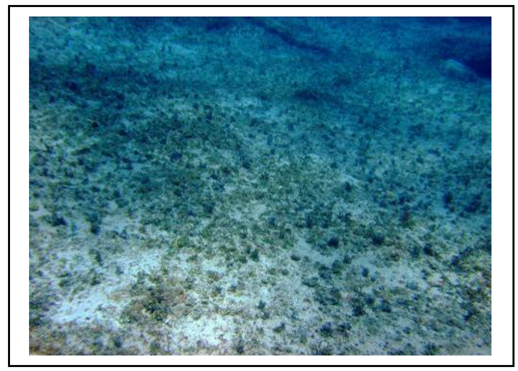
Site description: Northeastern region; moderate topographic complexity, moderate coral cover; high macroalgal cover.

ROT-02
4/9/2009

E 145° 15.563
N 14° 09.227

Forereef
Mid

Depth: 11–13 m



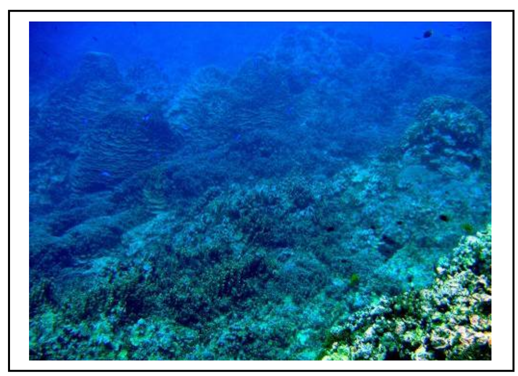
Site description: Southeastern region; Aalaguaw Bay; low topographic complexity; low coral cover; high macroalgal cover.

ROT-03
4/9/2009

E 145° 10.030
N 14° 06.840

Forereef
Mid

Depth: 12–15 m



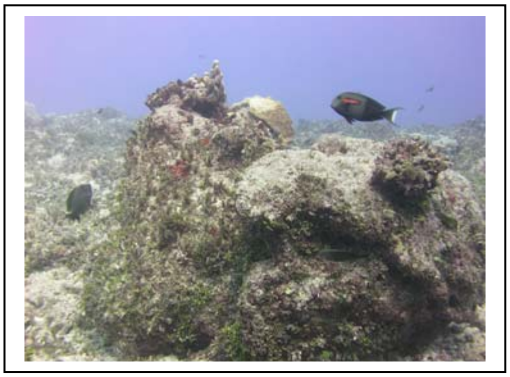
Site description: Southwestern region; Pona Point; inside bay; moderate topographic complexity; moderate coral cover; low macroalgal cover.

ROT-05
4/10/2009

E 145° 12.421
N 14° 10.973

Forereef
Mid

Depth: 12–13 m



Site description: Northwestern region; low topographic complexity; low coral cover; high macroalgal cover.

ROT-06
4/10/2009

E 145° 09.024
N 14° 09.503

Forereef
Mid

Depth: 12–13 m

Site description: Southwestern region; low topographic complexity; moderate coral cover; high macroalgal cover.

ROT-07
4/10/2009

E 145° 08.503
N 14° 08.202

Forereef
Mid

Depth: 7–8 m

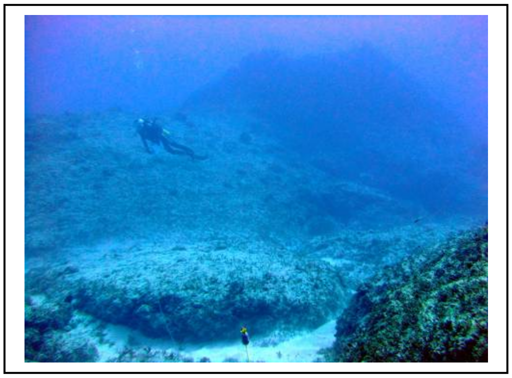
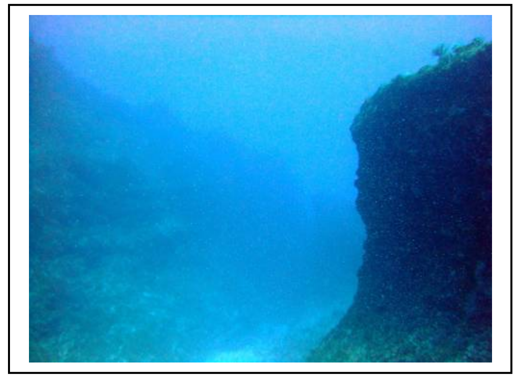
Site description: Sasawahaya Bay south of dock; low/moderate complexity; surrounded by sand channels; moderate coral cover; low macroalgal cover.

ROT-50
4/9/2009

E 145° 16.235
N 14° 08.558

Forereef
Deep

Depth: 23 m

Site description: Deep site near southeastern tip; large rock formations surrounded by sandy channels; high topographic complexity; low coral cover; high macroalgal cover.

ROT-51
4/9/2009

E 145° 15.807
N 14° 09.202

Forereef
Shallow

Depth: 4–6 m


Site description: Shallow site in southern bay; large rock formations (boulders) near cliffs; high topographic complexity; low coral cover; low macroalgal cover.

ROT-52
4/9/2009

E 145° 11.663
N 14° 06.765

Forereef
Shallow

Depth: 4–5 m

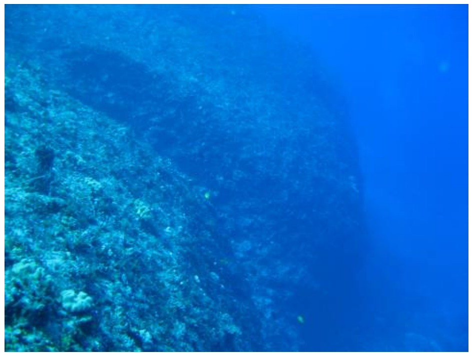

Site description: Shallow southern site; low/moderate topographic complexity; low/moderate coral cover; moderate macroalgal cover.

ROT-53
4/9/2009

E 145° 07.876
N 14° 07.363

Forereef
Deep

Depth: 28 m



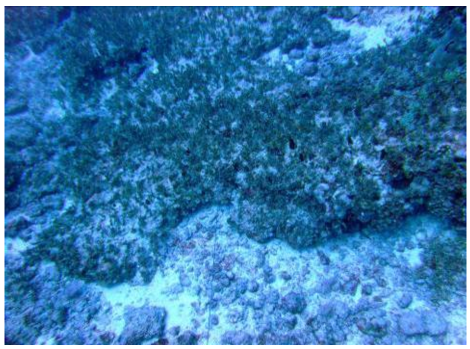
Site description: Deep site on the south side of western Rota Peninsula; base of a wall near sea fans; steep slope; high topographic complexity; low coral cover; low macroalgal cover.

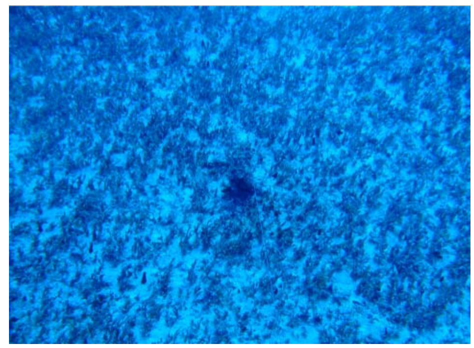
ROT-54
4/10/2009

E 145° 12.964
N 14° 11.464

Forereef
Deep

Depth: 23 m





Site description: Deep site on the south side of Rota; low topographic complexity; low coral cover; high macroalgal cover.

ROT-55
4/10/2009

E 145° 12.185
N 14° 10.711

Forereef
Shallow

Depth: 3–4 m

Site description: Shallow site on south side of Rota; moderate topographic complexity; high coral cover; low macroalgal cover.

ROT-56
4/10/2009

E 144° 48.537
N 13° 33.036

Forereef
Shallow

Depth: 3–4 m

Site description: Shallow site on the south side of Rota; high topographic complexity; high coral cover; low macroalgal cover.

ROT-57
4/10/2009

E 144° 46.624
N 13° 18.457

Forereef
Deep

Depth: 21 m

Site description: Deep site on south side of Rota; moderate topographic complexity; gentle slope; low coral cover; moderate macroalgal cover.

C.3. Benthic Environment

C.3.1 Algal Communities

During the Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP) 2009, six long-term REA monitoring sites were surveyed around Rota Island for percent benthic cover, based on the 20-cm interval line point intercept (LPI) methodology. Benthic communities around Rota were dominated by turf and macroalgae (Table C.3.1.1). Turf algal percent cover exceeded that of other functional groups at two of the six sites surveyed, including ROT-03 and ROT-07 with a percent cover range of 24.4% to 54.8% (Table C.3.1.1). Macroalgae were the dominant cover at three of the six sites with a percent cover range of 0.4% to 62.4% (Table C.3.1.1). At site ROT-01, percent cover of turf and macroalgae were approximately equal (28.9% and 29.9%, respectively). A combined total of 26 species of macroalgae were observed (18 chlorophytes, 3 ochrophytes, 5 rhodophytes) from the six sites surveyed (Tables C.3.1.2 and C.3.1.3). A species of *Microdictyon* dominated the macroalgal community at sites ROT-01 and ROT-02 with 11.4% and 21.2% cover (C.3.1.3). *Lobophora variegata* dominated the macroalgal community at site ROT-03 with 3.2% cover, and a species of *Halimeda* was the dominant the macroalgae at sites

ROT-05 and ROT-06 with 16.4% and 4% cover, respectively (Table C.3.1.3). Site ROT-07 had only 0.4% macroalgal cover, with turf algae being the dominant functional group.

Table C.3.1.1--Percent cover of algal functional groups at long-term monitoring sites at Rota.

Site	Macroalgae	Turf Algae	Coralline red algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Octocoral
ROT-01	29.9%	28.9%	13.7%	0.5%	16.6%	4.3%
ROT-02	43.6%	27.2%	5.6%	2.8%	7.2%	-
ROT-03	3.6%	54.8%	10.0%	9.2%	13.6%	5.6%
ROT-05	62.4%	24.4%	4.4%	0.8%	6.4%	0.4%
ROT-06	46.5%	26.0%	5.0%	2.5%	13.0%	-
ROT-07	0.4%	54.0%	15.6%	1.2%	16.4%	2.0%

Table C.3.1.2--Additional species recorded at each site at Rota during roving diver survey.

Site	**Chlorophyta**
ROT-02 ROT-07	*Avrainvillea* sp.
ROT-06	*Caulerpa filicoides*
ROT-07	*Caulerpa serrulata*
ROT-02	*Caulerpa urvilleana*
ROT-01 ROT-05	*Caulerpa webbiana*
ROT-03 ROT-05	*Dictyosphaeria versluysii*
ROT-05	*Halimeda macroloba*
ROT-03	*Halimeda opuntia*
ROT-03	*Halimeda* sp.
ROT-01	*Rhipilia* sp.
ROT-07	*Tydemania* sp.
ROT-07	*Udotea* sp.
ROT-06	*Valonia ventricosa*
	Rhodophyta
ROT-05	*Asparagopsis taxiformis*
ROT-05 ROT-07	*Dichotomaria* sp.
ROT-01 ROT-02	*Ganonema* sp.
ROT-07	*Portieria* sp.

Table C.3.1.3--Percent cover of macroalgal species at long term monitoring sites at Rota. Sum totals for each row equal the percent cover of macroalgae recorded in Table C.3.1.1

Site	*Caulerpa serrulata*	*Caulerpa webbiana*	*Codium* sp	*Dictyosphaeria cavernosa*	*Dictyosphaeria versluysii*	*Halimeda opuntia*	*Halimeda* sp	*Microdictyon setchellianum*	*Neomeris* sp	*Dictyota ceylanica*	*Lobophora variegata*	*Padina* sp	*Galaxaura* sp	*Portieria hornemannii*
ROT-01	-	2.4%	-	2.4%	0.9%	5.7%	-	11.4%	0.9%	-	0.9%	-	-	-
ROT-02	0.4%	0.4%	0.4%	1.2%	2.4%	5.6%	2.4%	21.2%	-	-	0.4%	-	0.8%	-
ROT-03	-	-	-	-	-	-	0.4%	-	-	-	3.2%	-	-	-
ROT-05	-	-	-	-	-	6.8%	9.6%	-	-	4.0%	0.4%	0.8%	0.4%	1.2%
ROT-06	-	-	-	2.0%	0.5%	3.0%	1.0%	-	1.0%	-	1.0%	1.0%	0.5%	1.5%
ROT-07	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Benthic communities around Rota at deep and shallow randomly stratified monitoring sites were documented along two 25-m transect lines at 0.5-m intervals. Sites located at less than 10 m deep were dominated by turf algae and scleractinian coral (Table C.3.1.3, Fig. C.3.1.1). Turf algae percent cover exceeded that of other cover types at 2 of the 4 shallow sites surveyed, while scleractinian coral was the dominant cover at the other 2 sites (Table C.3.1.3, Fig. C.3.1.1). Benthic communities at the three sites greater than 20 m deep were each dominated by a different cover type (turf algae, macroalgae, and coralline red algae) (Table C.3.1.3, Fig. C.3.1.1). Preliminary analysis indicates that scleractinian coral cover was noticeably greater at shallow sites than at deep sites, with mean scleractinian coral cover across all shallow sites at 28.9 ± 25.2% and 2.2 ± 3.7% for the deep sites. Macroalgal cover, on the other hand, was greater at deep sites, with mean macroalgal cover at 8.1 ± 10.3% for the shallow sites and 22.9 ± 22.1 for the deep sites. Coralline red algal cover was generally low, but a shallow site (ROT-55) and a deep site (ROT-53) exhibited coralline red algal cover > 20%. An estimated 84 species of scleractinian corals were observed across the 7 sites surveyed. This total should only be considered a conservative estimate of species richness and not an absolute figure, as it was sometimes difficult to discriminate between scleractinian coral species within certain genera (e.g., *Montipora*, *Favia*, *Porites*).

Table C.3.1.3--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Rota.

Site	Depth	Macroalgae	Turf Algae	Coralline Red Algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Dead Coral	Octocoral
ROT-51	< 10m	10.8%	65.7%	8.8%	1.0%	2.9%	0.0%	0.0%
ROT-52	< 10m	21.6%	30.4%	8.8%	18.6%	11.8%	0.0%	0.0%
ROT-55	< 10m	0.0%	24.5%	22.5%	0.0%	49.0%	0.0%	0.0%
ROT-56	< 10m	0.0%	26.5%	11.8%	0.0%	52.0%	0.0%	6.9%
ROT-50	> 20m	44.1%	16.7%	6.9%	2.0%	5.9%	0.0%	0.0%
ROT-53	> 20m	0.0%	36.8%	42.1%	15.8%	0.0%	0.0%	5.3%
ROT-57	> 20m	24.5%	54.9%	7.8%	1.0%	6.9%	0.0%	0.0%

.

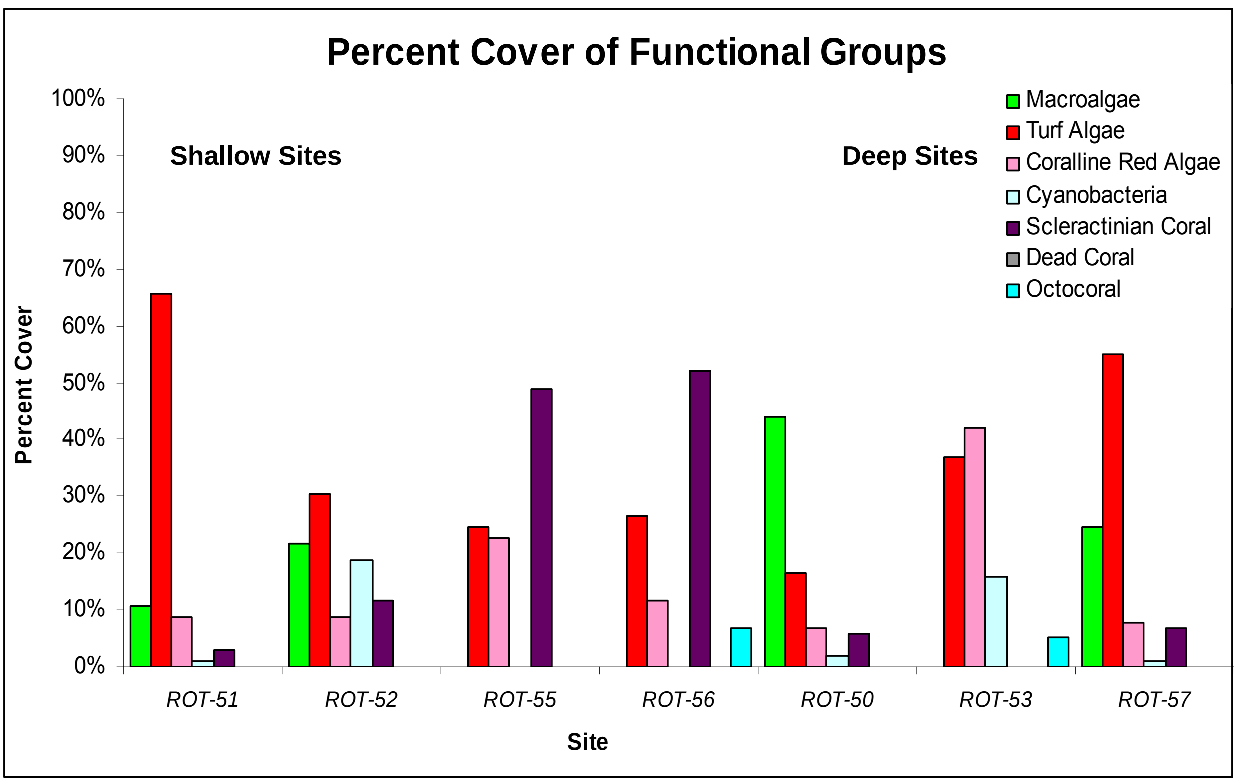


Figure C.3.1.1--Percent cover of benthic functional groups at shallow and deep monitoring sites established in 2009 around Rota.

C.3.2 Coral Communities

C.3.2.1 Percent Benthic Cover

Percent benthic cover surveys at Rota were conducted in concert with the fish, coral, algae, and invertebrate REA surveys at six permanent sites established between 2003 and 2007. Percent coral cover around Rota derived from LPI surveys conducted at the permanent long-term REA sites yielded an islandwide mean of 12.2% (Fig. C.3.2.1.1). The greatest percent coral cover occurred at ROT-01 on the east-facing shore, and the lowest at ROT-02 at a south-facing site.

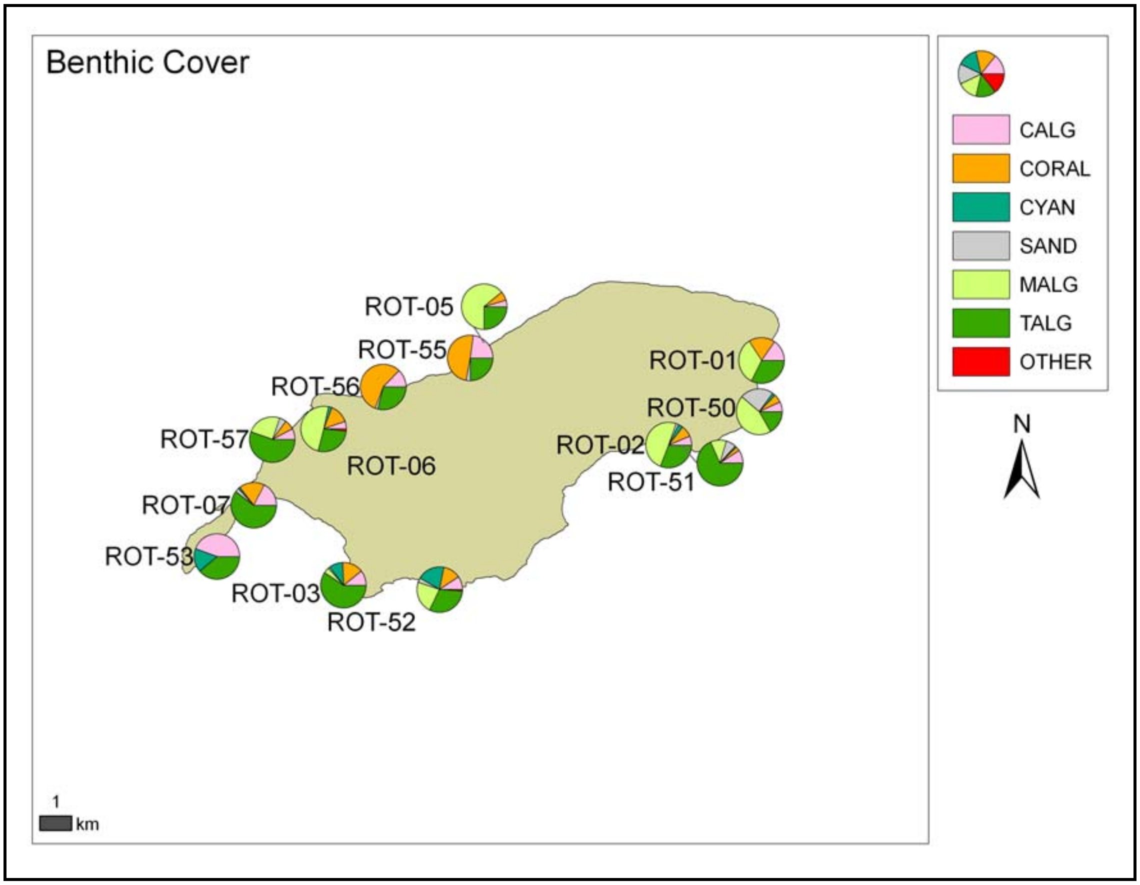


Figure C.3.2.1.1--Percent cover of benthic functional groups at the random stratified and permanent REA monitoring sites around Rota during MARMP 2009. CALG = crustose coralline red algae, CYAN = cyanobacteria, 2010. MALG = macroalgae, TALG = turf algae.

During MARAMP 2009, seven additional stratified random REA sites were surveyed around Rota for percent benthic cover (based on 50-cm interval LPI surveys) and generic diversity data. Results derived from the seven stratified random REA sites surveyed in 2009 yielded the following results: benthic communities surveyed at two sites greater than 20 m deep were dominated by turf algal (36.1% + 11.0), macro algal (22.9% + 12.8) and calcareous algal (18.9% + 11.6) functional groups (Fig. C.3.2.1.2). Four shallow sites (< 10 m deep) were dominated by turf algal (36.6% + 9.8), scleractinian coral (28.9% + 12.6) and calcareous algal (13.0% + 3.3) functional groups (Fig. C.3.2.1.2). Coral generic diversity was highest at site ROT-57 with 24 different genera observed (Table C.3.2.1.1). In contrast, site ROT-50 had the lowest coral generic diversity with 13 different genera observed. The average number of genera recorded at each site was 20. Common coral genera observed at most sites included *Porites*, *Pocillopora*, *Favia*, *Astreopora*, *Cyphastrea* and *Stylophora*. Macroalgal generic diversity was highest at site ROT-56 with 15 genera observed (Table C.3.2.1.2). Site ROT-57 had the lowest generic diversity with 7 genera observed. The average number of macroalgal genera recorded for each site was 10. Common macroalgae observed at most sites included *Halimeda*, *Portieria*, and *Neomeris*.

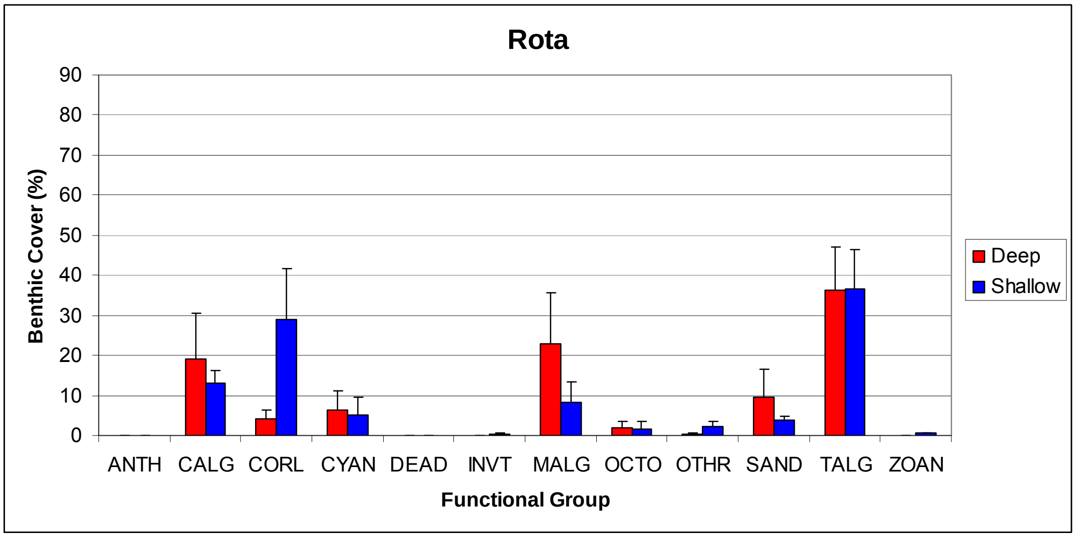


Figure C.3.2.1.2--Percent cover of functional groups at shallow and deep independent LPI monitoring sites established in 2009 at Rota.

Table C.3.2.1.1--Coral generic diversity of stratified random sites around Rota.

	ROT-50	ROT-51	ROT-52	ROT-53**	ROT-54**	ROT-55	ROT-56	ROT-57
Acanthastrea			X			X	X	X
Acropora	X	X	X			X	X	
Alveopora								
Astreopora	X	X	X			X	X	X
Cladiella*						X	X	X
Corallimorph*								
Coscinarea								
Cyphastrea	X	X	X			X	X	X
Diploastrea								
Distichopora*								
Echinopora		X				X	X	X
Euphyllia								
Favia	X	X	X			X	X	X
Favites						X	X	
Fungia	X							
Galaxea			X			X	X	
Gardinoseris								
Goniastrea			X			X	X	X
Goniopora						X		

	ROT-50	ROT-51	ROT-52	ROT-53**	ROT-54**	ROT-55	ROT-56	ROT-57
Heliopora*	X							X
Herpolitha								X
Hydnophora						X		
Isopora			X					
Leptastrea	X	X	X				X	
Leptoria						X	X	X
Leptoseris								
Lobophyllia							X	
Lobophytum*		X				X	X	X
Merulina								
Millepora*			X			X	X	
Montastrea		X	X			X	X	X
Montipora			X			X	X	X
Ouphyllia								X
Pachyseris								
Palythoa*							X	
Pavona		X	X			X	X	X
Platygyra	X	X	X			X		X
Pleisiastrea								X
Plerogyra								
Pocillopora	X	X	X			X	X	X
Porites	X	X	X			X	X	X
Psammocora	X		X					X
Sarcophyton*						X		
Scapophyllia								
Scolymia								
Seriatopora								
Sinularia*	X	X	X				X	X
Stylaster*								
Stylocoeniella			X					X
Stylophora	X	X	X			X	X	X
Turbinaria		X	X					X
Wire Coral*								
Zoanthus*								
Total Genera per Site	13	15	21			23	23	24

*non-scleractinian genera, **no benthic surveys conducted

Table C.3.2.1.2--Macroalgal generic diversity of stratified random sites around Rota.

	ROT-50	ROT-51	ROT-52	ROT-53**	ROT-54**	ROT-55	ROT-56	ROT-57
Amphiroa		X				X		X
Asparagopsis			X				X	
Avrainvillea	X							
Boergesenia							X	
Boodlea		X						
Bryopsis						X	X	
Caulerpa	X	X	X				X	X
Chlorodesmis								
Crustose Coralline	X	X	X			X	X	X
Cyanobacteria		X	X				X	

	ROT-50	ROT-51	ROT-52	ROT-53**	ROT-54**	ROT-55	ROT-56	ROT-57
Dichotomaria						X	X	
Dictyosphaeria	X	X				X		X
Dictyota						X	X	
Galaxaura						X	X	
Gibsmithia								
Halimeda	X	X	X			X		X
Halymenia								
Lobophora		X					X	
Microdictyon	X	X						
Neomeris	X	X	X			X	X	
Non-geniculate calcified branched								
Padina							X	X
Peyssonnelia								
Portieria		X	X			X	X	X
Rhipilia	X							
Turbinaria								
Tydemania								
Udotea								
Valonia	X	X	X				X	
Unknown							1	
Total Genera per site	9	12	8			10	15	7

**no benthic surveys conducted

C.3.2.2 Coral Populations

During MARAMP 2009, belt transect surveys were conducted at six long-term REA sites around Rota, covering a total reef area of nearly 130 m^2 and totaling 2254 anthozoan colonies enumerated. This translates to an estimated mean colony density of 17.5 colonies m^{-2}. Taxonomic richness varied between sites with a total of 33 anthozoan genera (30 scleractinian, 3 octocoral) being represented within belt transects (Table C.3.2.2.1). *Porites*, *Leptastrea*, and *Favia* were the most abundant scleractinian genera, contributing 18.5% 16.5%, and 11.5% of the total number of colonies enumerated islandwide. All other genera individually contributed less than 10% of the total number of colonies.

Table C.3.2.2.1--Relative abundance of anthozoan genera enumerated within belt transects around Rota in 2009.

Island	Genus	Relative Abundance
Rota	*Porites*	18.54
	Leptastrea	16.46
	Favia	11.49
	Astreopora	9.41
	Montastrea	9.32
	Pavona	4.84
	Goniastrea	4.79
	Pocillopora	3.95
	Cyphastrea	3.19
	Heliopora	2.57
	Lobophytum	2.13

	Psammocora	1.95
	Cladiella	1.55
	Galaxea	1.46
	Stylophora	1.42
	Montipora	1.29
	Sinularia	1.11
	Stylocoeniella	0.89
	Sarcophyton	0.71
	Acanthastrea	0.44
	Acropora	0.44
	Oulophyllia	0.40
	Goniopora	0.31
	Platygyra	0.22
	Turbinaria	0.22
	Favites	0.18
	Fungia	0.18
	Coeloseris	0.13
	Cycloseris	0.13
	Unknown	0.13
	Echinophyllia	0.04
	Palythoa	0.04
	Scapophyllia	0.04

Spatial patterns of generic relative abundance based on colony counts at two long-term REA sites in 2009, are reflected in Figure C.3.2.2.1. Colonies of the genus *Porites* were particularly abundant at sites ROT-01 and ROT-03 on the east and southwest facing shores of the island. *Leptastrea* was the most numerically abundant coral at sites ROT-02, ROT-03, and ROT-07, while *Favia* were dominant at site ROT-05 and ROT-06. Interestingly the genus *Astreopora* was the most abundant at ROT-05 (Fig. C.3.2.2.1).

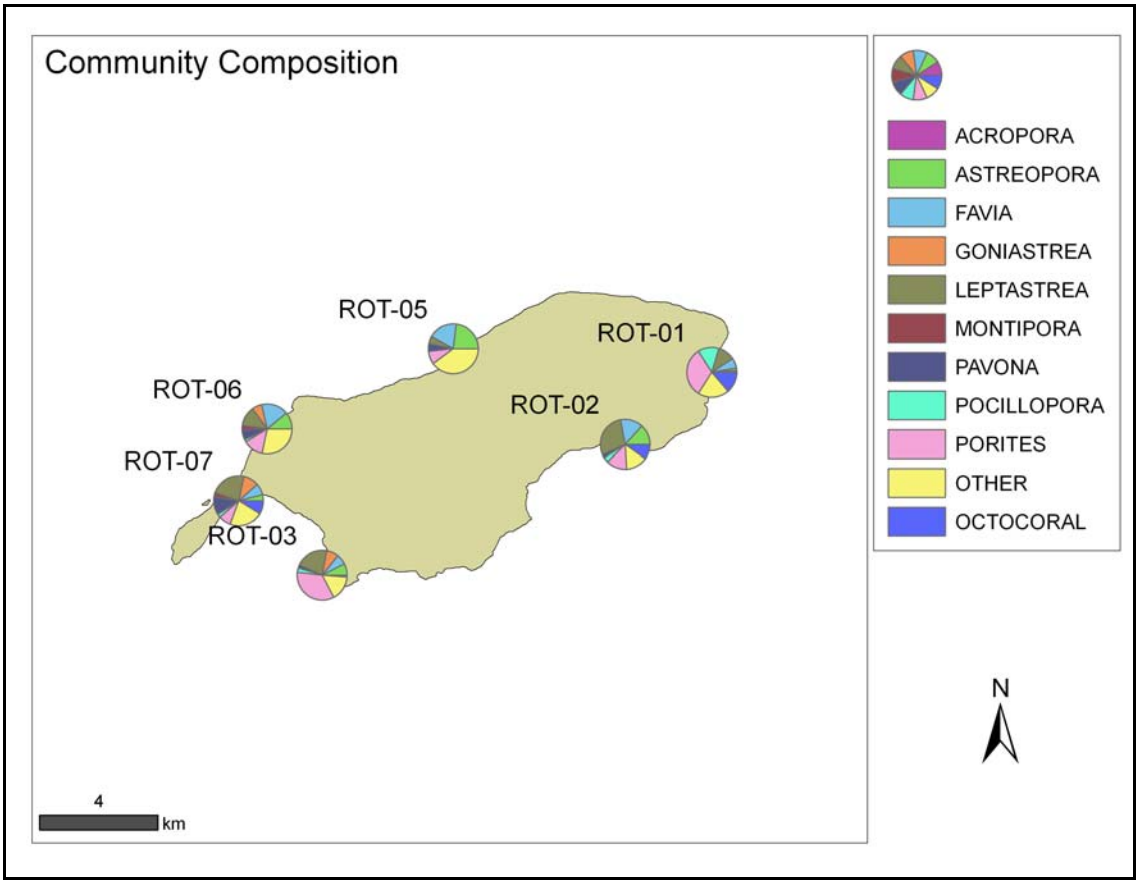


Figure C.3.2.2.1--Relative abundance of coral genera from REA surveys around Rota during MARAMP 2009.

Size class distribution of all corals enumerated within belt transects are shown in Figure C.3.2.2.2. Of the 2554 anthozoan colonies enumerated (average diameter estimated as the arithmetic mean of two planar measurements), 54% had a diameters of < 5 cm, and 32% had mean diameters between 6 and10 cm.

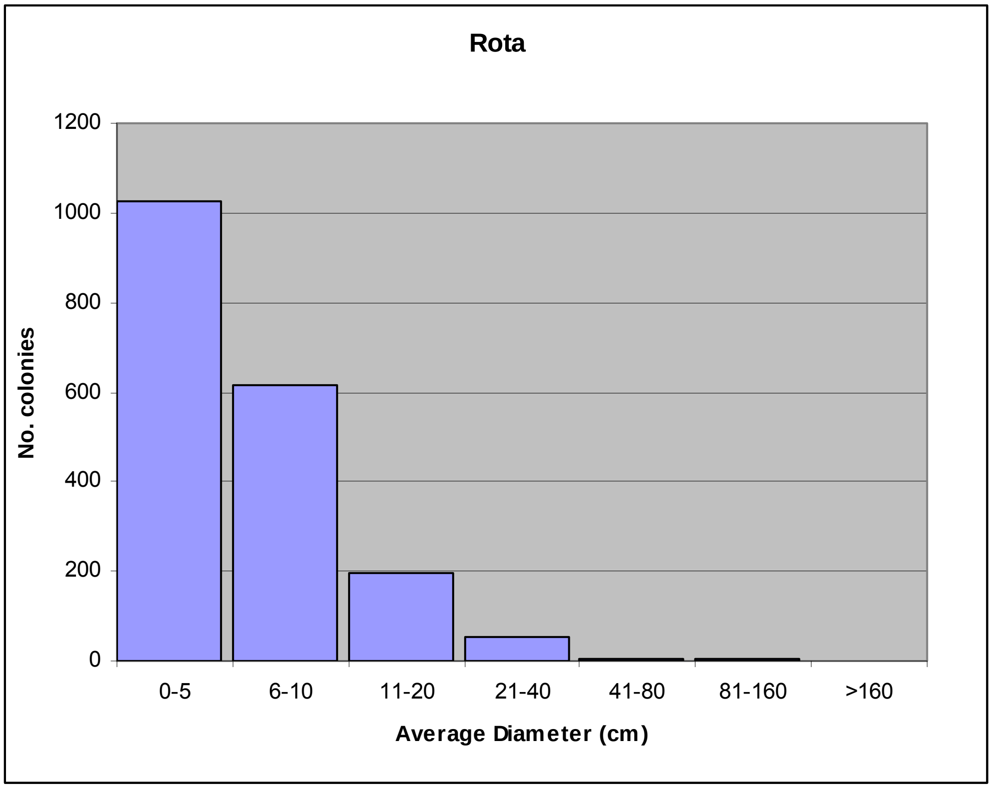


Figure C.3.2.2.2--Size class distribution of 2254 coral colonies enumerated within belt transects around Rota in 2009.

C.3.3 Coral Health and Disease

During MARAMP 2009, occurrence of disease, heath impairments, and predation around Rota was moderate, with a total of 112 cases of diseases and predation enumerated. A summary of disease occurrence, relative abundance, is presented in Table C.3.3.1 The most numerically abundant type of lesion recorded on corals around Rota was algal infections and overgrowth; these were detected at all sites, except for ROT-02 and on a variety of coral genera including *Porite*s, *Montastrea*, *Goniastrea*, and *Astreopora*. Bleaching conditions were the second most numerically abundant type of affliction, with a total of 19 cases tallied islandwide. Nearly 60% of all cases of bleaching were detected on *Porites* and *Astreopora*. Lesions affecting coralline algae were uncommon, with one case enumerated islandwide. The coralline lethal orange disease (CLOD) was the only type of coralline affliction detected around Rota.

Table C.3.3.1--Number of cases of scleractinian and coralline algal diseases and predation enumerated during REA surveys, around Rota in 2009. ALG: algal infections, BIN: barnacle infestation; BLE: bleaching; CYA: cyanophyte infections; DIS: discolorations other than bleaching; FUG: fungal infections; HYP: hyperpigmented irritations/pigmentation response; PRE: *Acanthaster*/*Drupella* predation scars; SGA: skeletal growth anomalies; TIN: tubeworm infestation; TLS: tissue loss; WSY: white syndrome; OTH: other diseases and lesions of unknown etiology; CLOD: coralline lethal orange disease; and CLD; coralline white band syndrome/lethal disease.

DZCode	ROT-01	ROT-02	ROT-03	ROT-05	ROT-06	ROT-07	Grand Total
ALG		6	4	5	2	3	20
BLE	3	7	3	2	3	1	19
CYA		1	3	1			5
FUG		1			2	8	11
HYP	2		1	1	2	1	7
PRE	1		1				2
WSY	1			1	1	2	5
OTH	2	12	7	11	8	3	43
Total	9	27	19	21	18	18	112
CLOD	1						1

C.3.4. Macroinvertebrate Surveys (non-coral)

A total of 1118 individuals belonging to 53 benthic invertebrate target species or taxa groups were enumerated from 10 belt transects at 5 sites (Table C.3.4-1). Rota had the second highest densities of target species of macroinvertebrates at REA reef habitats of the southernmost Mariana Islands of Guam, Rota, Aguijan, and Tinian (175.4 organisms/50 m² for core target groups, 223.6 organisms/50 m² including sponges, vermetids, and *Spirobranchus* worms). This was due to the fact that boring urchins, particularly the species *Echinostrephus aciculatus*, were highly abundant at Rota sites, particularly ROT-01 (362 organisms/50 m² for *E. aciculatus*). Additionally, Rota had the second lowest average site species richness (mean 2.6 species/site) of the four southern islands.

Small hermit crabs (e.g., of the genus *Calcinus*), vermetids, and *Spirobranchus* worms were moderately abundant at most sites (19.4, 10.4, and 25.4 organisms/50 m², respectively). Guard crabs of the genus *Trapezia*, associated with branching coral heads, were not highly abundant at sites around Rota (1.6 organisms/50 m²). Coral eating Coralliophilid snails were only abundant on corals at sites ROT-01 and ROT-03 (12 and 18 organisms/50 m², respectively). The sea cucumber *Stichopus chloronotus* was locally abundant at site ROT-24 with 22 organisms per 50 m².

High sponge cover was encountered at all Rota sites (at least 12.4 organisms/50 m²). *Tridacna* clams were present at four out of five REA sites around Rota at low densities of 1–5 organisms per 50 m² (2.4 organisms/50 m² island mean).

Table C.3.4-1--Densities of organisms observed at REA sites around Rota during cruise HA0902. Sponges, vermetids, and *Spirobranchus* polychaete worms are not explicit target groups, but observations are recorded here.

ROTA Invertebrate Surveys 2009		Density (# / 50m²)					
Phylum	TaxaGroup	ROT-01	ROT-02	ROT-03	ROT-05	ROT-07	Rota Mean
Annelida	*Polychaetes*	91	5	16	3	12	25.4
Arthropoda	*Shrimp*	1	1		5	2	1.8
	Hermit Crabs: Large (e.g. Dardanus sp.)			3			0.6
	Hermit Crabs: Small (e.g. Calcinus sp.)	26	28	5	22	16	19.4
	Crabs: Other Brachyurans	2			2		0.8
	Crabs: Coral Guard Crabs (Trapezia, etc)	4	1		3		1.6
Echinodermata	*Asteroids (Sea Stars): Other*		3	3		4	2
	Echinoids (Urchins): Boring Echinometrids	369	161	42	21	16	121.8
	Echinoids (Urchins): Diadematoids	4	4			14	4.4
	Holothuroids (Sea Cucumbers)			3	3	24	6
	Ophiuroids (Brittle Stars)	1			1		0.4
	Crinoids			4			0.8
Mollusca	*Bivalves: Tridacnids (Giant Clams)*		2	5	1	4	2.4
	Snails: Other	2	3	2	7	7	4.2
	Snails: Coralliophilids (Coral Eating)	12		18	1		6.2
	Snails: Trochus					3	0.6
	Snails: Vermetids (Worm Snails)	16		5	15	16	10.4
	Opisthobranchs (Sea Slugs)			5	2	2	1.8
Porifera	*Sponges*	11	13	18	14	6	12.4
Chordata	*Ascidians*			1	1	1	0.6
Grand Total		**539**	**221**	**130**	**101**	**127**	**223.6**

C.3.4.1. Urchin Measurements

The test diameters of urchin species and the valve width of Tridacnid clams were recorded at REA sites around Rota. Mean measurements by site are presented in Figure C.3.4.1-1 for species where the sample size is 5 or greater.

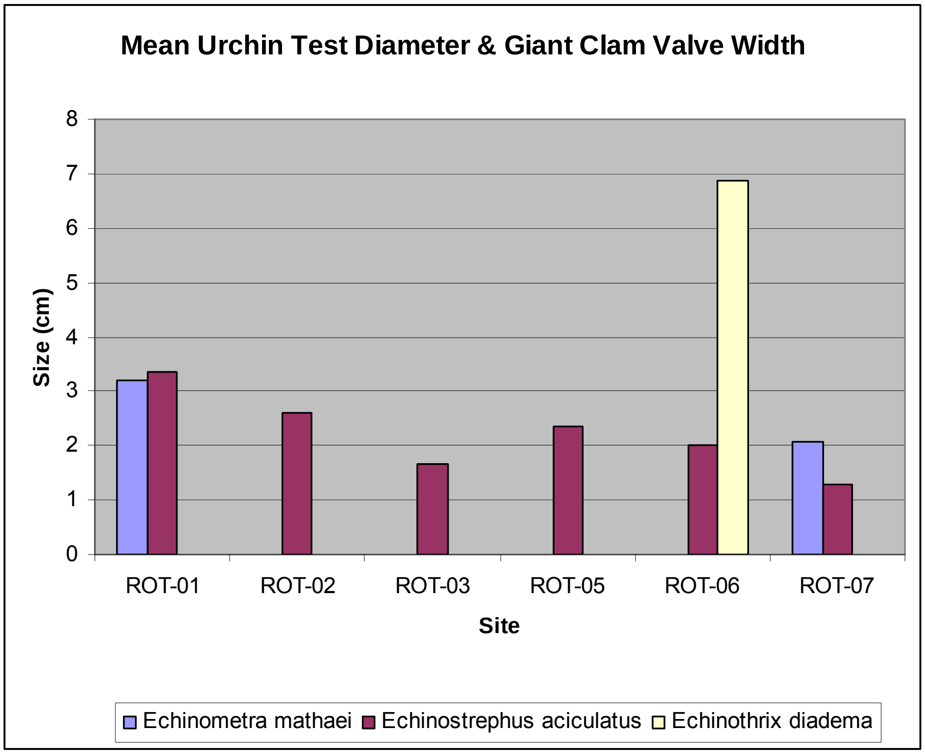


Figure C.3.3.1-1--Reveals the average test diameter of urchins and valve width of giant clams encountered at each site around Rota. Only sites where ≥ 5 measurements were recorded for a species are represented.

C.3.3.2. ARMS Deployment

ARMS were deployed at the following REA sites around Rota. Each site contains three ARMS.

Table C.3.4.2-1--ARMS deployment locations around Rota.

REA Site	Latitude	Longitude
ROT-06	145° 9.019'	145° 9.019'

C.3.4.3 Invertebrate Collections

No specimens were collected around Rota during HA-09-02.

C.3.5 Benthic Towed-diver Surveys

Eleven benthic towed-diver surveys were completed at Rota in 2009. Habitats covered during surveys varied with the majority of tow segments conducted over hard bottom (a mixture of continuous pavement reefs and pavement separated by thin sand channels).

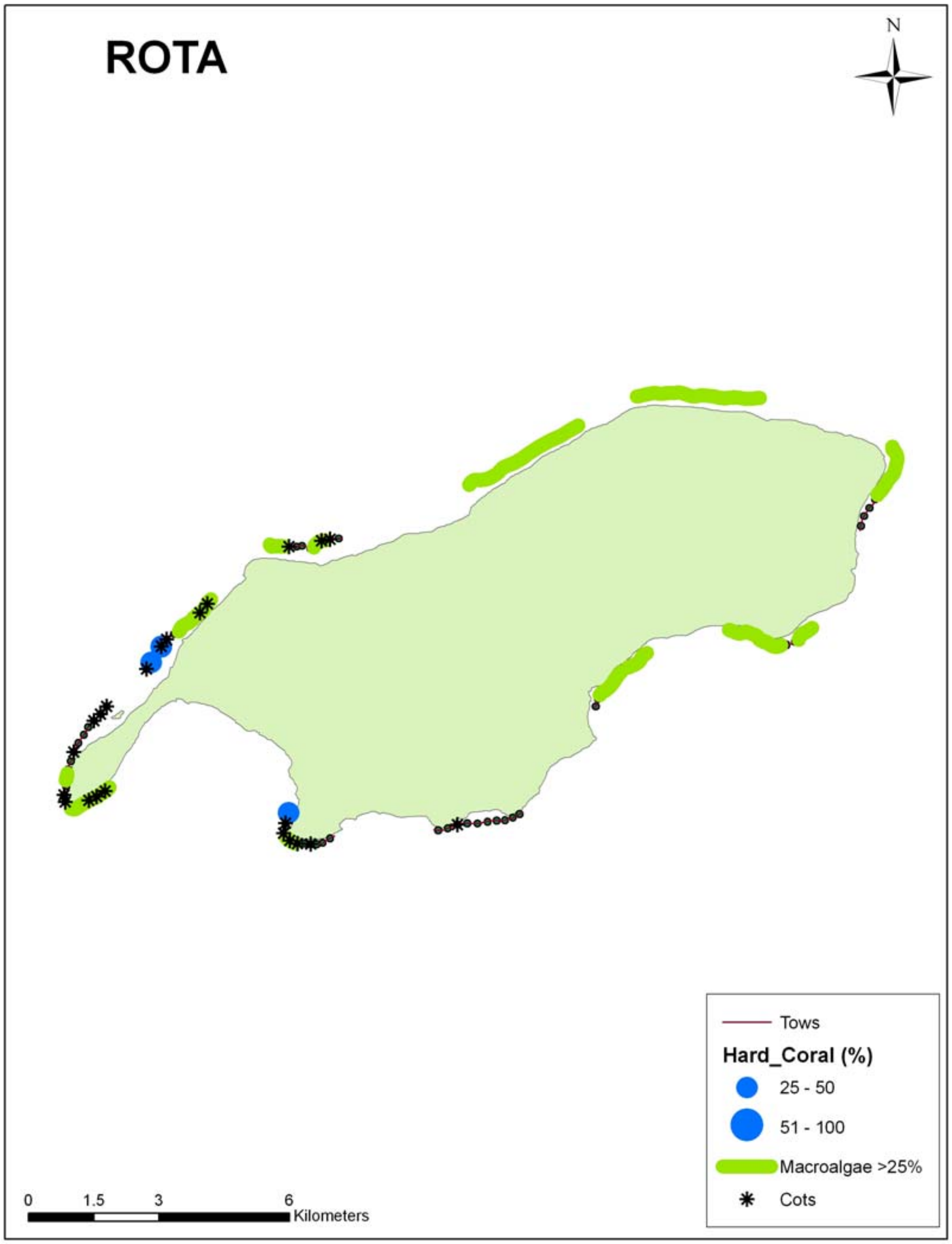


Figure C.3.5.1--Hard coral cover (≥ 25%) elevated macroalgae cover (> 25%), and crown-of-thorns (COTs) sightings during tow segments at Rota in 2009.

Macroalgal cover was the most common benthic category recorded during towed-diver surveys around Rota in 2009 with an island mean of 31.0 ± 2.0%. Generally, macroalgal cover was higher on northern tows compared to southern tows with species of *Halimeda*, *Dictyota*, and *Microdictyon* being most notable.

Coral cover was relatively low across the island except for localized elevated cover noted in the western portion of the bay where *Porites rus* gardens and two tow segments on the west side of the island where massive *Porites* and *P. rus* colonies were common.

Boring urchins were the dominant macroinvertebrate at Rota with sea cucumbers also being common. COTs were seen in low densities, mostly on southern tows.

Benthic category	Mean ± SE
Hard Coral	4.5 ± 0.6
Soft Coral	2.2 ± 0.2
Macroalgae	31 ± 2
Coralline Algae	5.2 ± 0.5
Sand	6.4 ± 1.2
Rubble	1.4 ± 0.4
COTs	31
Free Urchins	0
Boring Urchins	22502
Sea Cucumbers	1114
Giant Clams	25

* Sum of observed individuals

C.4 Fish Surveys

C.4.1 REA Fish Surveys

Stationary point count data (SPC)

During the survey period, SPC surveys were conducted at 14 sites around Rota. Surgeonfish were the largest contributor to total biomass with 0.99 kg 100 m^{-2}. Parrotfish were the second largest contributor to total biomass with 0.29 kg 100 m^{-2}, followed by wrasses at 0.24 kg 100 m^{-2} (Fig. C.4.1.1).

Overall observations

A total of 220 fish species were observed during the survey period by all divers. The average total fish biomass around Rota during the survey period was 3.1 kg 100 m^{-2} for the SPC surveys (Fig. C.4.1.1).

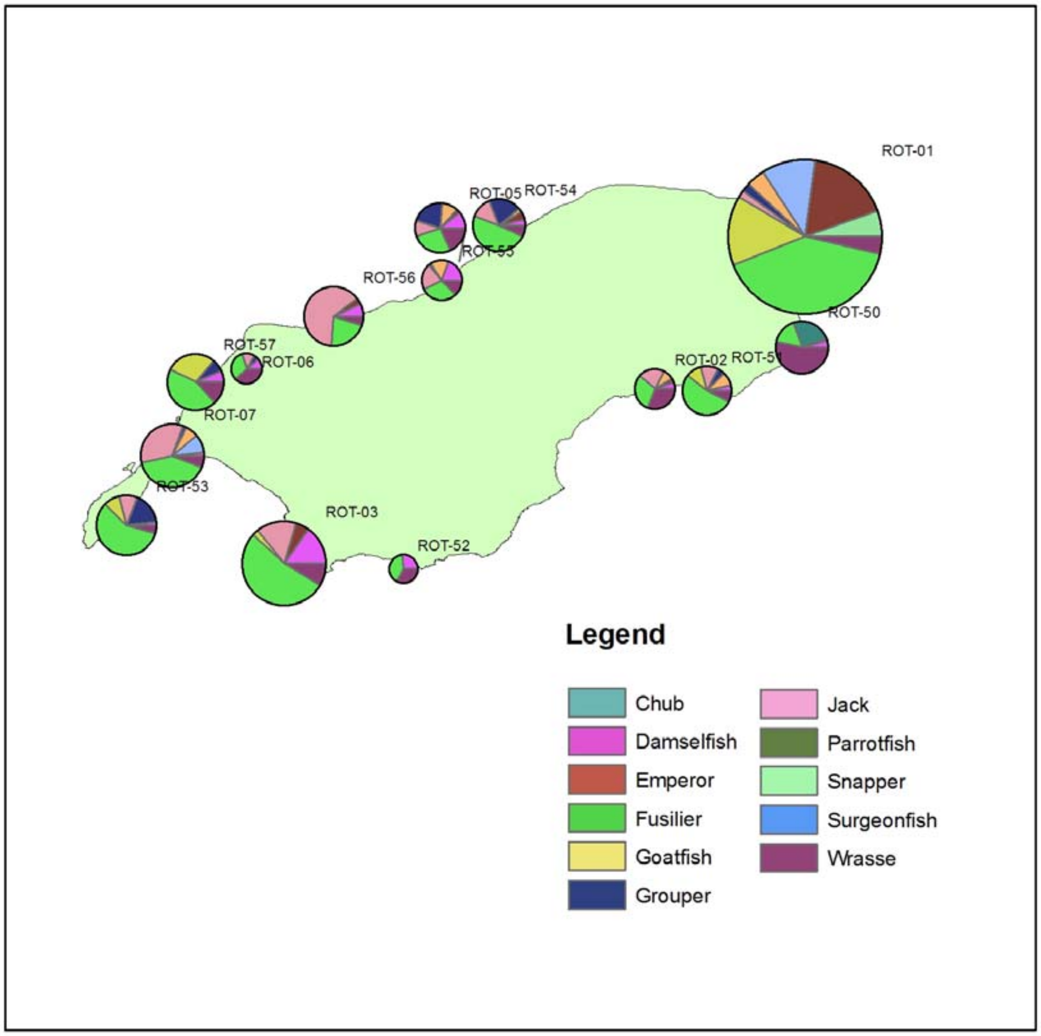


Figure C.4.1.1--Site location and distribution of total fish biomass by family. The size of the pie charts are proportional to fish biomass.

C. 4.2 Towed-diver Fish Surveys

During HA0902, the CRED towed-diver team completed 11 surveys at Rota covering 24.21 km (24.21 ha) of ocean floor (Table C.4.2.1). Mean survey length was 2.2 km with a maximum length of 2.9 km and a minimum of 1.8 km. Mean survey depth was 14.9 m with a maximum depth of 17.5 m and a minimum of 12.1 m. Mean temperature on these surveys was 28°C with a maximum temperature of 28.2°C and a minimum of 28.0°C.

Thirty-six individual large-bodied reef fish (> 50 cm TL) of 16 different species and 11 different families were encountered around Rota (Table C.4.2.1). Overall numeric density for this class of reef fishes was 0.149 #/100 m^2 (14.87 #/ha) with a biomass density of 1.606 kg/100 m^2 (0.161 t/ha) (Figs. C.4.2.1 and C.4.2.2). Numeric and biomass density were dominated by *Cheilinus undulates*.

The most prevalent families in terms of numeric density were Lutjanids (ND=25%) and Labrids (ND=22%) (Figure C.C.4.2.1). In terms of biomass density, the most prevalent families were Labrids (BD=41%) and Dasyatids (BD=21%) (Figure C.4.2.2).

Biomass of large bodied reef fish appeared to be concentrated at the southwestern tip of Rota and at a point on the southeastern coast where *Sphyraena quenie, Cheilinus undulates* were found. (Fig. C.4.2.3).

Table C.4.2.1--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Rota during HA0902 CRED towed-diver Surveys.

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Cheilinus_undulatus	8	0.03	3.30	175.33	0.72	0.07
Macolor_niger	4	0.02	1.65	7.25	0.03	0.00
Naso_tonganus	3	0.01	1.24	8.48	0.04	0.00
Caranx_melampygus	3	0.01	1.24	7.05	0.03	0.00
Triaenodon_obesus	2	0.01	0.83	32.28	0.13	0.01
Arothron_stellatus	2	0.01	0.83	22.30	0.09	0.01
Aprion_virescens	2	0.01	0.83	13.08	0.05	0.01
Diodon_hystrix	2	0.01	0.83	6.12	0.03	0.00
Scarus_rubroviolaceus	2	0.01	0.83	5.21	0.02	0.00
Lutjanus_bohar	2	0.01	0.83	4.92	0.02	0.00
Himantura_fai	1	0.00	0.41	87.61	0.36	0.04
Aetobatus_narinari	1	0.00	0.41	38.20	0.16	0.02
Carcharhinus_melanopterus	1	0.00	0.41	4.58	0.02	0.00
Plectropomus_laevis	1	0.00	0.41	3.38	0.01	0.00
Lutjanus_gibbus	1	0.00	0.41	2.80	0.01	0.00
Scarus_altipinnis	1	0.00	0.41	2.58	0.01	0.00
Grand Total	36	0.15	14.87	418.56	1.73	0.17
# of Species	16					

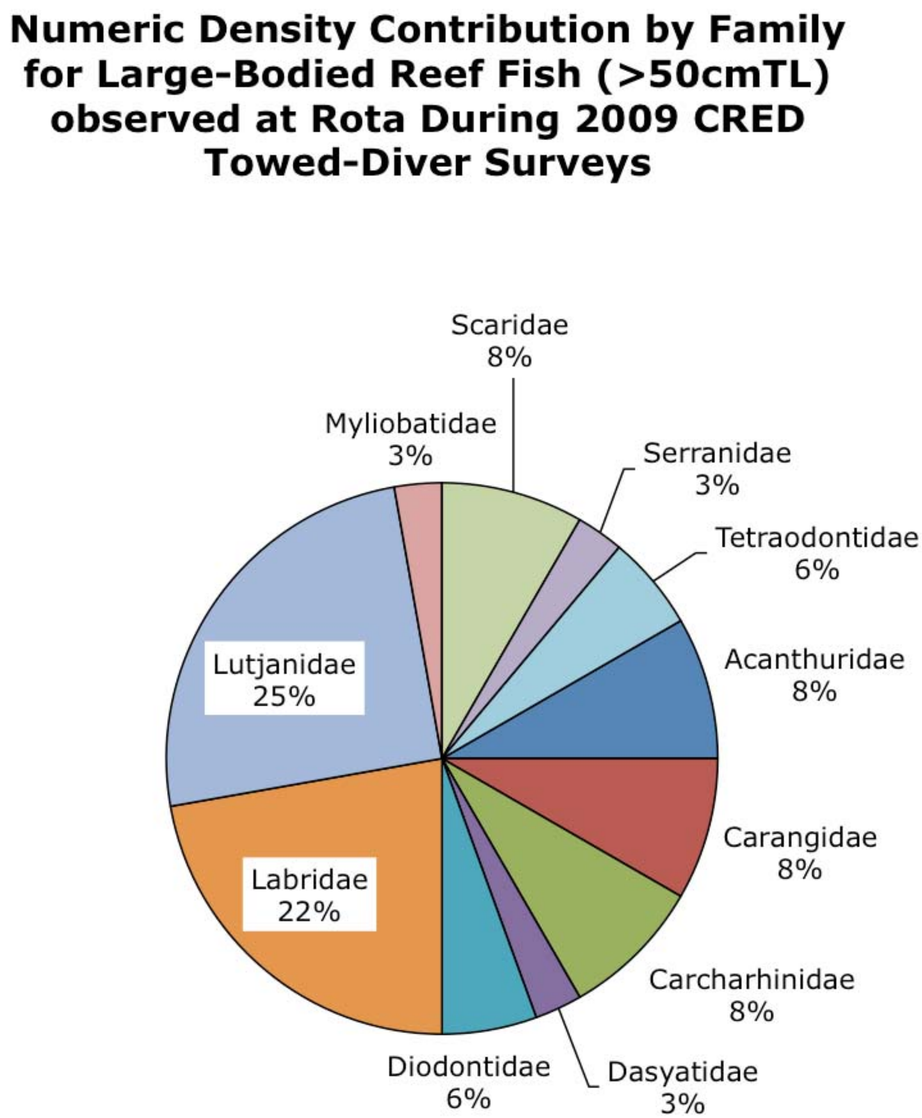


Figure C.4.2.1--Numeric density by Family.

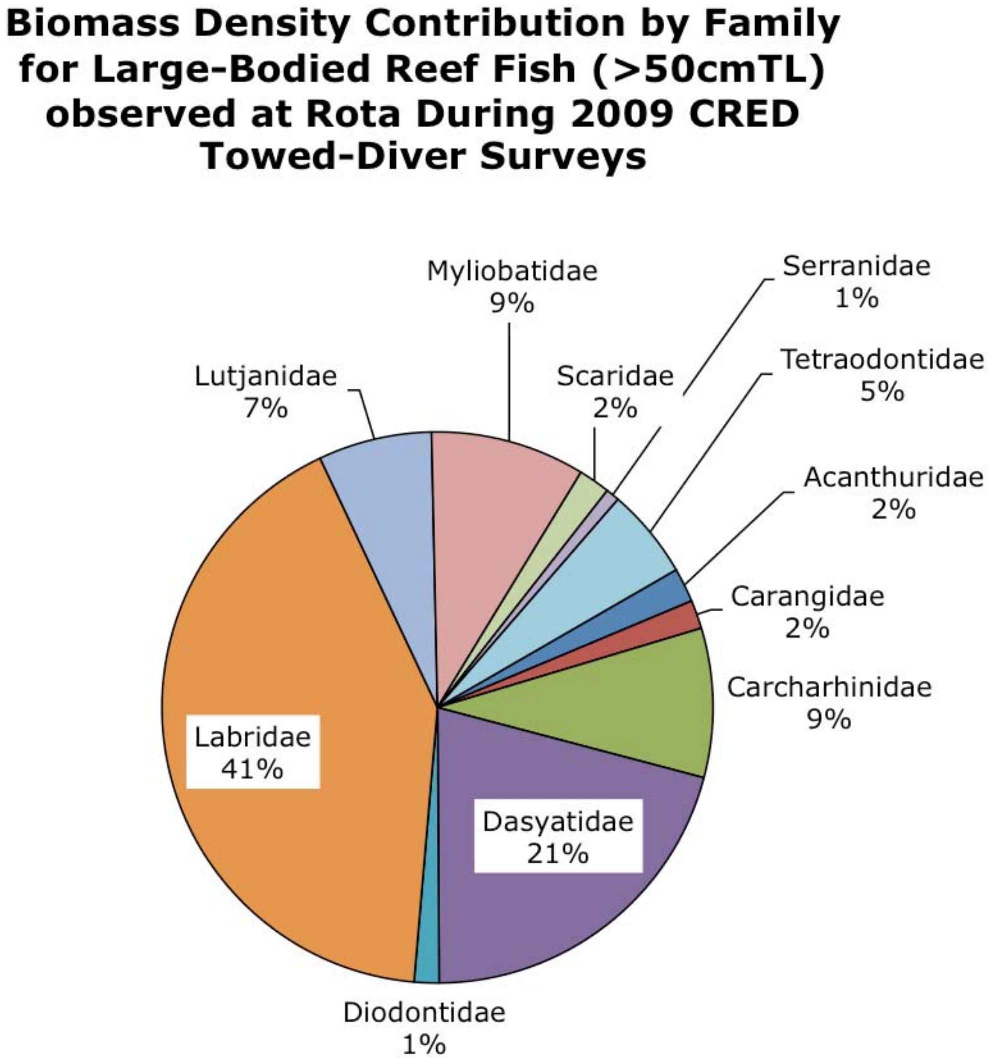


Figure C.4.2.2--Biomass density by Family.

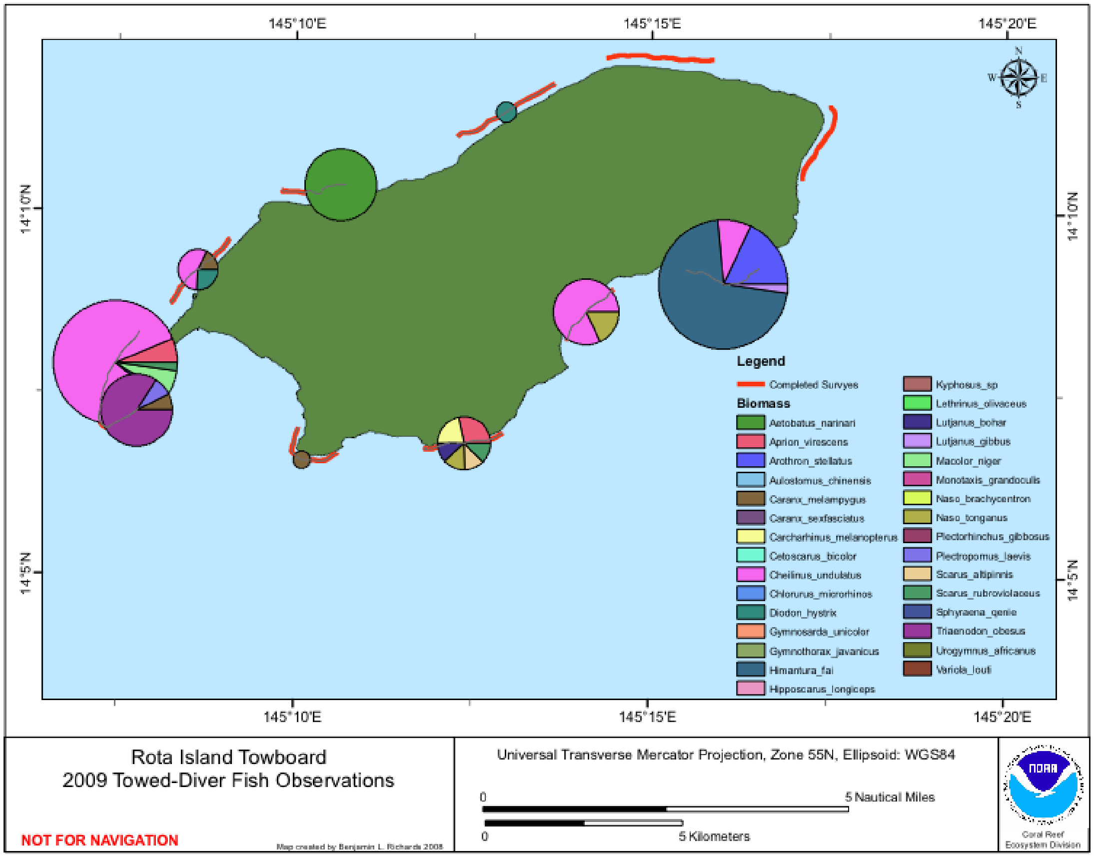


Figure C.4.2.3--Geographic distribution of biomass around Rota. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

Appendix D: Aguijan

D.1 Oceanography and Water Quality for Aguijan and Tinian

Moorings recovered and replaced during HA0902 at Aguijan and Tinian included three subsurface temperature recorders (STRs); one from Aguijan and two from Tinian. The STRs show a typical pattern and temperature range for the region, with a clear annual fluctuation due to seasonal warming and cooling (Figs. D.1.2 and D.1.3). Warmest temperatures peaked at ~ 31.5°C and occurred during the summer months of July to October. Winter temperatures reached lows of ~ 27.5°C and occurred during November through June.

Water samples for microbiological, nutrient and chlorophyll analyses were collected from one REA site from Aguijan and Tinian. Samples for nutrients and chlorophyll were taken at four REA sites on Tinian (TIN-01, TIN-02, TIN-03, and TIN-04), and from two REA sites at Aguijan (AGU-03 and AGU-02). Samples were obtained from the surface and near the bottom. Microbial water samples were taken using diver-deployable Niskin bottles to collect 8 liters of seawater (4 bottles; 2 liters per bottle) at each study site. All samples were collected between 10 and18 m. At each REA site, water samples for analysis of nutrient and chlorophyll levels were collected. Chlorophyll samples were filtered, and nutrient samples were frozen at - 30°C for post-cruise analysis. These samples were collected from 10 to 15 m deep and transported back to the ship. Shallow-water conductivity temperature and depth (CTD) casts were also conducted at these sites. Additional CTD casts were taken around the 30-m depth contour of Aguijan and Tinian (Figs. D.1.2-D.1.4).

Table D.1.2--Moorings.

Instrument	Island	Action	Serial Number	Latitude	Longitude	Action Date	Depth (m)
STR	AGU	Retrieval	39327181047	14.8478	145.5372	4/11/2009	8
STR	AGU	Deployment	39368591564	14.8478	145.5372	4/11/2009	8
STR	TIN	Retrieval	39443093082	15.0808	145.6216	4/12/2009	12
STR	TIN	Deployment	39487873907	15.0808	145.6216	4/12/2009	12
STR	TIN	Retrieval	39368591644	15.0355	145.6507	4/12/2009	6
STR	TIN	Deployment	39487873909	15.0355	145.6507	4/12/2009	6

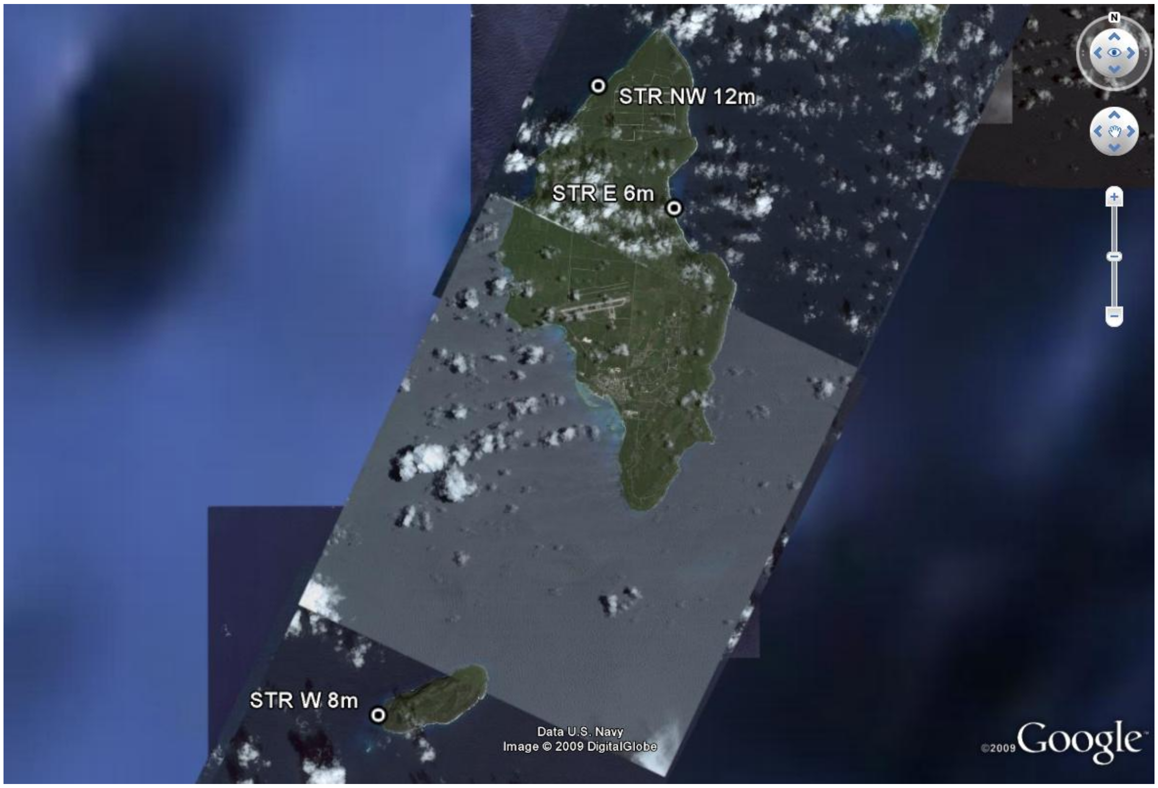


Figure D.1.1--Deployed instrument moorings. Aguijan and Tinian, HA0902.

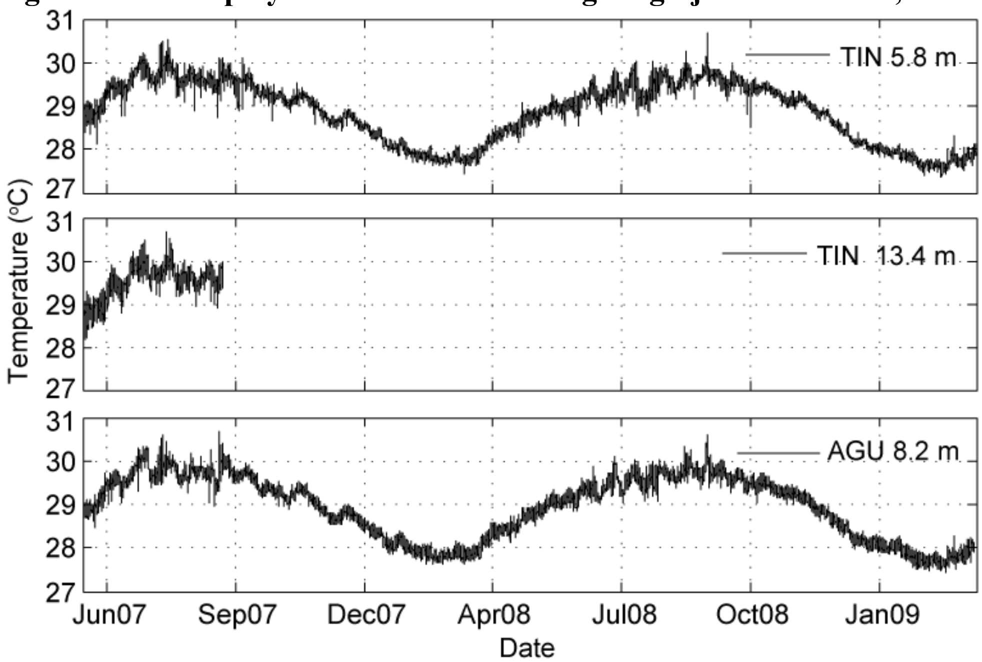


Figure D.1.2--Temperature time-series from STR and SST moorings. Aguijan and Tinian, HA0902.

Figure D.1.3–Shallow-water CTD, Aguijan and Tinian, HA0902.

D. 2 Rapid Ecological Assessment Site Descriptions
Two REA sites were visited by a team of up to seven scientists around Aguijan Island on 11 April 2009 (Fig. D.2.1). In addition, four stratified random fish, LPI, and invertebrate surveys were conducted. The site locations are listed below along with site photos taken in 2009. Site descriptions are included for the following discipline communities: coral, coral disease, macroinvertebrates, algae, and fish.

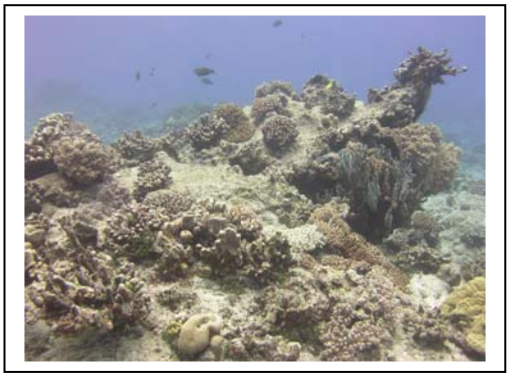
Figure D.2.1--Location of REA, stratified random and ARMS installation sites visited at Aguijan Island in 2009.

AGU-02
4/11/2009

E 145° 32.200
N 14° 50.864

Forereef
Mid

Depth: 11–15 m




Site description: Southwestern tip of island; moderate complexity; moderate coral cover; low macroalgal cover.

AGU-03
4/11/2009

E 145° 33.334
N 14° 51.585

Forereef
Deep

Depth: 13–47 m

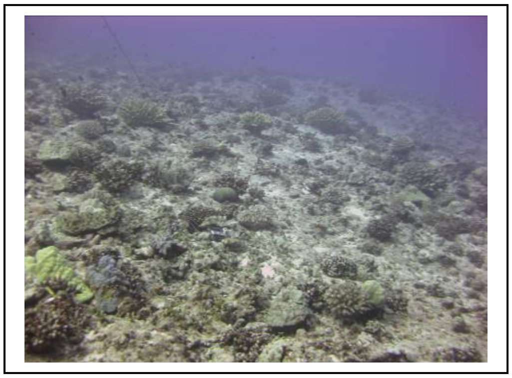
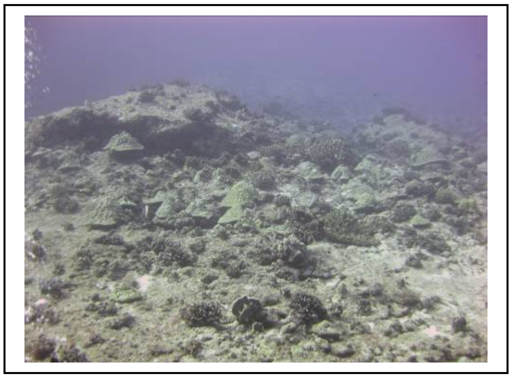

Site description: Northwestern region; moderate topographic complexity; moderate coral cover; moderate macroalgal cover.

AGU-50
4/11/2009

E 145° 33.972
N 14° 51.849

Forereef
Deep

Depth: 23 m

Site description: Deep site in northwestern region; gradual slope near drop-off; low topographic complexity; low coral cover; low macroalgal cover.

AGU-51
4/11/2009

E 145° 32.955
N 14° 51.406

Forereef
Shallow

Depth: 4–5 m

Site description: Shallow northern site; moderate topographic complexity; high coral cover; low macroalgal cover.

AGU-52
4/11/2009

E 145° 32.239
N 14° 50.769

Forereef
Shallow

Depth: 4–5 m

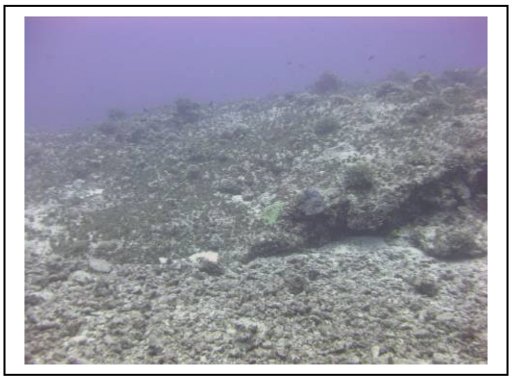
Site description: Shallow northwestern site; large boulders; high topographic complexity; high coral cover; low macroalgal cover.

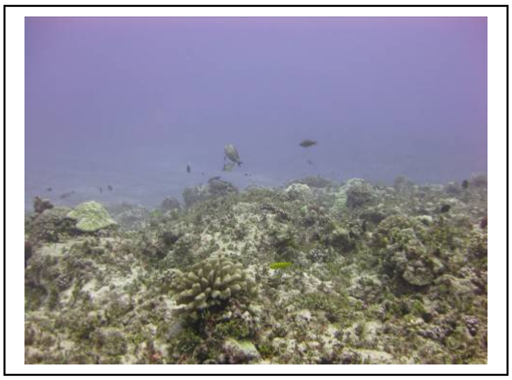
AGU-53
4/11/2009

E 145° 31.684
N 14° 50.207

Forereef
Deep

Depth: 23 m





Site description: Deep site on western plateau off small island; patch reefs; low coral cover; moderate macroalgal cover.

D.3. Benthic Environment

D.3.1 Algal Communities

During the Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP) 2009, 2 long-term, REA monitoring sites were surveyed around Aguijan Island for percent benthic cover, based on the 20-cm interval LPI methodology. Benthic communities at sites surveyed around Aguijan were dominated by turf algae, scleractinian coral, and coralline red algae (Table D.3.1.1). Turf algal percent cover exceeded that of other functional groups at both sites surveyed (43.2% and 32.4%; Table D.3.1.1). At site AGU-03, percent cover of turf algae and coralline red algae were approximately equal (32.4% and 29.6%, respectively). A combined total of 10 species of macroalgae were observed (9 chlorophytes, 1 ochrophyte) from the 2 sites surveyed (Tables D.3.1.2 and D.3.1.3). *Lobophora variegata* was the dominant macroalga at both sites with a percent cover of 3.2% at AGU-02 and 9.2% at AGU-03 (Table D.3.1.3). *Halimeda opuntia* also had a relatively high percent cover at AGU-03 (6%; Table D.3.1.3).

Table D.3.1.1--Percent cover of benthic functional groups at long term monitoring sites at Aguijan.

Site	Macroalgae	Turf Algae	Coralline red algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Octocoral
AGU-02	14.4%	43.2%	16.4%	2.0%	20.4%	2.4%
AGU-03	17.2%	32.4%	29.6%	-	17.6%	0.8%

Table D.3.1.2--Additional species recorded at each site at Aguijan during roving diver survey.

Site	**Chlorophyta**
AGU-02 AGU-03	*Caulerpa filicoides*
AGU-02	*Caulerpa racemosa*
AGU-02 AGU-03	*Chlorodesmis* sp.
AGU-03	*Dictyosphaeria versluysii*
AGU-03	*Halimeda taenicola*
AGU-02	*Neomeris* sp.

Table D.3.1.3--Percent cover of macroalgal species at long-term monitoring sites at Aguijan. Sum totals for each row equal the percent cover of macroalgae recorded in Table D.3.1.1.

Site	Caulerpa serrulata	Halimeda opuntia	Microdictyon setchellianum	Lobophora variegata
AGU-02	-	2.0%	2.0%	3.2%
AGU-03	1.2%	6.0%	-	9.2%

Benthic communities around Aguijan at deep and shallow randomly stratified monitoring sites were documented along two 25-m transect lines at 0.5-m intervals. Sites located at less than 10 m deep were dominated by turf algae, coralline red algae, and scleractinian coral (Table D.3.1.4, Fig. D.3.1.1). Turf algal percent cover exceeded that of other cover types at two of the four shallow sites surveyed, while scleractinian coral was the dominant cover at the other two sites (Table D.3.1.4, Fig. D.3.1.1). Benthic communities at sites greater than 20 m deep were dominated by turf algae and coralline red algae (Table D.3.1.4, Fig. D.3.1.1). Preliminary analysis indicates that scleractinian coral cover was noticeably greater at shallow sites than at deep sites, with mean scleractinian coral cover across all shallow sites at 19.6 ± 16.5% and 5.4 ± 0.7% for the deep sites. Macroalgal cover, on the other hand, was greater at deep sites, with mean macroalgal cover at 6.4 ± 11.8% for the shallow sites and 11.8 ± 15.3 for the deeper sites. Turf algal cover was > 50% at five of the six sites, while coralline red algal cover ranged from approximately 12% to 35%. An estimated 77 species of scleractinian corals were observed across the six sites surveyed. This total should only be considered a conservative estimate of species richness and not an absolute figure, as it was sometimes difficult to discriminate between scleractinian coral species within certain genera (e.g., *Montipora*, *Favia*, *Porites*).

Table D.3.1.4--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Aguijan.

Site	Depth	Macroalgae	Turf Algae	Coralline Red Algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Dead Coral	Octocoral
AGU-50	< 10m	1.0%	56.9%	31.4%	1.0%	5.9%	0.0%	2.0%
AGU-51	< 10m	2.0%	21.6%	34.3%	2.0%	31.4%	0.0%	0.0%
AGU-52	< 10m	0.0%	42.2%	18.6%	0.0%	36.3%	0.0%	0.0%
AGU-53	< 10m	22.5%	52.9%	11.8%	1.0%	4.9%	0.0%	0.0%
AGU-50	> 20m	1.0%	56.9%	31.4%	1.0%	5.9%	0.0%	2.0%
AGU-53	> 20m	22.5%	52.9%	11.8%	1.0%	4.9%	0.0%	0.0%

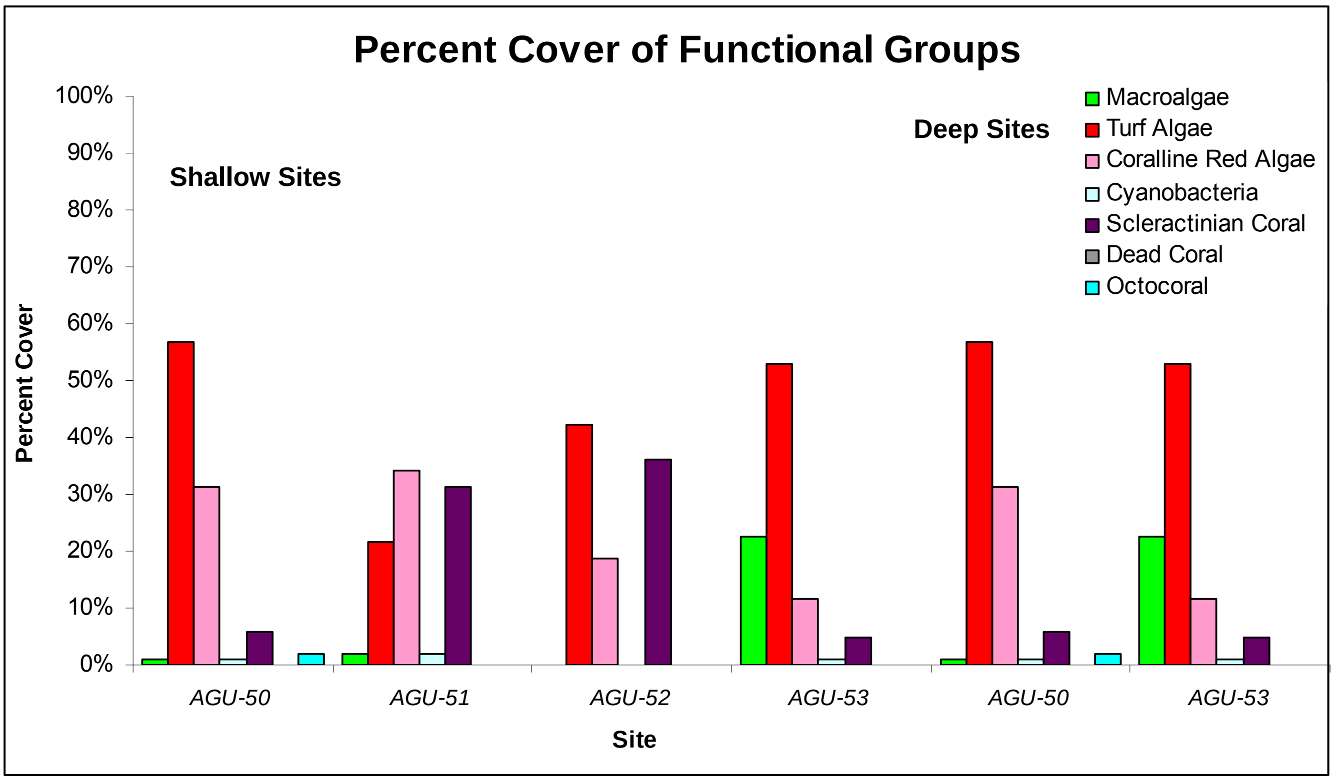


Figure D.3.1.1--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Aguijan.

D.3.2 Coral Communities

D.3.2.1 Percent Benthic Cover

In 2009, percent benthic cover surveys around Aguijan were conducted in concert with coral, algae, and invertebrate REA surveys, at 2 permanent sites established between 2003 and 2005. Percent coral cover around Aguijan derived from LPI surveys conducted at the permanent long-term REA sites yielded an islandwide mean of 14.8% (Fig. D.3.2.1.1).

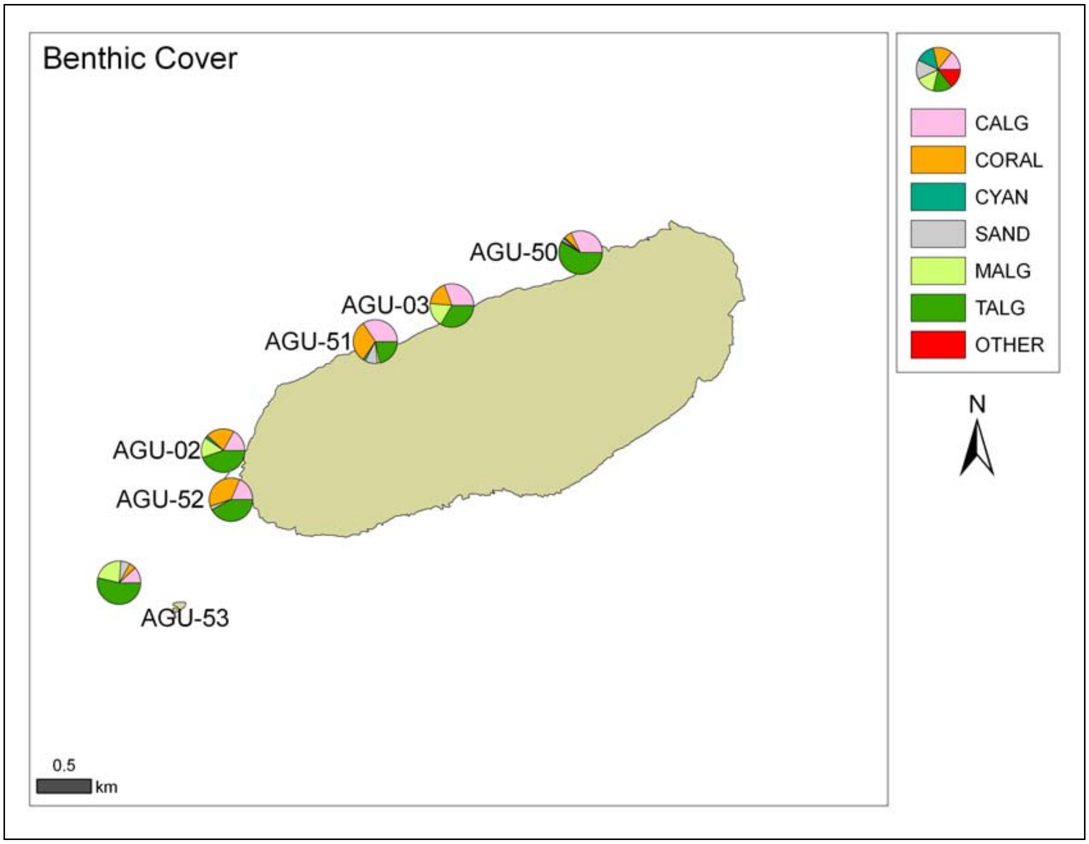


Figure D.3.2.1.1--Percent cover of benthic functional groups at long term monitoring sites at Aguijan. CALG = crustose coralline red algae, CYAN = cyanobacteria, MALG = macroalgae, TALG = turf algae.

During MARAMP 2009, four additional stratified random REA sites were surveyed around Aguijan for percent benthic cover (based on 50-cm interval LPI surveys) and generic diversity data. Spatial patterns of percent benthic cover variability derived from the long-term and stratified random REA surveys in 2009 are reflected in Figure D.3.2.1.1. The four stratified random REA sites surveyed in 2009 yielded the following results: benthic communities surveyed at two sites greater than 20 m deep were dominated by turf algal (47.4% ± 7.6), calcareous algal (24.2% ± 6.3) and macroalgal (13.6% ± 6.5) functional groups (Fig. D. 3.2.1.2). Two shallow sites (< 10 m deep) were dominated by scleractinian coral (33.8% ± 2.5), turf algal (31.9% ± 10.3) and calcareous algal (26.5% ± 7.8) functional groups (Fig. D.3.2.1.2). Coral generic diversity was highest at sites AGU-50 and AGU-53 with 21 different genera observed at both (Table D.3.2.1.1). In contrast site AGU-51 had the lowest coral generic diversity with 15 different genera observed. The average number of genera recorded at each site was 19. Common coral genera observed at most sites included *Porites*, *Montipora*, *Favia*, *Astreopora*, *Cyphastrea* and *Stylophora*. Macroalgal generic diversity was highest at site AGU-52 with 14 genera observed (Table D.3.2.1.2). Site AGU-51 had the lowest generic diversity with six genera observed. The average number of macroalgal genera recorded for each site was 9. Common macroalgae observed at most sites included *Halimeda*, *Caulerpa*, and *Lobophora*.

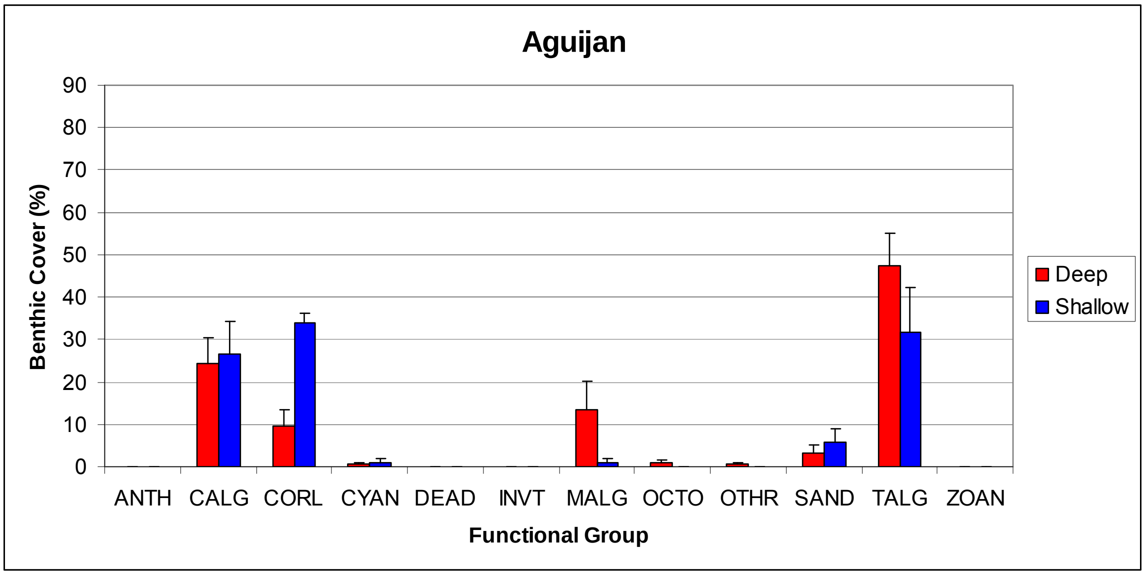


Figure D.3.2.1.2--Percent cover of functional groups at shallow and deep independent LPI monitoring sites established in 2009 at Aguijan.

Table D.3.2.1.1--Coral generic diversity of stratified random sites around Aguijan.

	AGU-50	AGU-51	AGU-52	AGU-53
Acanthastrea			X	X
Acropora		X	X	X
Alveopora				
Astreopora	X	X	X	X
Cladiella*	X			
Corallimorph*				
Coscinarea				
Cyphastrea	X	X	X	X
Diploastrea				
Distichopora*				
Echinopora				
Euphyllia				
Favia	X	X	X	X
Favites	X	X		
Fungia	X			X
Galaxea	X	X	X	
Gardinoseris				
Goniastrea		X	X	X
Goniopora				
Heliopora*				X
Herpolitha				

	AGU-50	AGU-51	AGU-52	AGU-53
Hydnophora				
Isopora				
Leptastrea	X		X	X
Leptoria	X	X	X	
Leptoseris				
Lobophyllia		X	X	
Lobophytum*	X		X	
Merulina				
Millepora*		X	X	X
Montastrea			X	
Montipora	X	X	X	X
Ouphyllia				
Pachyseris	X			
Palythoa*				
Pavona		X	X	X
Platygyra	X	X	X	
Pleisiastrea	X			
Plerogyra				
Pocillopora	X	X	X	X
Porites	X		X	X
Psammocora	X			X
Sarcophyton*				
Scapophyllia				
Scolymia				
Seriatopora				
Sinularia*	X			
Stylaster*				
Stylocoeniella				
Stylophora	X	X	X	X
Turbinaria	X		X	X
Wire Coral*	X			
Zoanthus*			X	
Total Genera per Site	21	15	21	17

* non-scleractinian genera

Table D.3.2.1.2--Macroalgal generic diversity of stratified random sites around Aguijan.

	AGU-50	AGU-51	AGU-52	AGU-53
Amphiroa				
Asparagopsis				
Avrainvillea				
Boergesenia				
Boodlea				
Bryopsis	X			
Caulerpa	X	X	X	X
Chlorodesmis		X	X	
Crustose Coralline	X	X	X	X
Cyanobacteria			X	
Dichotomaria			X	
Dictyosphaeria	X	X		

	AGU-50	AGU-51	AGU-52	AGU-53
Dictyota			X	
Galaxaura				
Gibsmithia				
Halimeda	X	X	X	X
Halymenia				
Lobophora	X	X	X	
Microdictyon				X
Neomeris			X	
Non-geniculate calcified branched				
Padina			X	X
Peyssonnelia				
Portieria			X	
Rhipilia				
Turbinaria			X	X
Tydemania				
Udotea				
Valonia	X			X
Unknown			2	
Total Genera per site	7	6	14	7

D.3.2.2 Coral Populations

During MARAMP 2009, belt transect surveys were conducted at 2 long-term REA sites around Aguijan, covering a total reef area of nearly 30 m^2 with 802 anthozoan colonies enumerated. This translates to an estimated mean colony density of 27.2 colonies m^{-2}. Taxonomic richness varied between sites with a total of 29 anthozoan genera (26 scleractinian, 2 octocoral, and one hydrocoral) being represented within belt transects (Table D.3.2.2.1). Colonies of the genus *Porites* were most abundant, contributing 25.8% of the total number of corals enumerated islandwide. *Favia*, *Goniastrea*, *Leptastrea*, and *Pavona* all contributed between 10 and 12% to the total number of colonies, while all the other genera individually contributed less than 10%.

Table D.3.2.2.1--Relative abundance of anthozoan genera enumerated within belt transects around Rota during MARAMP 2009.

Island	Genus	Relative Abundance
Aguijan	*Porites*	25.81
	Favia	11.60
	Goniastrea	11.35
	Leptastrea	10.97
	Pavona	10.10
	Astreopora	5.86
	Montastrea	3.62
	Psammocora	3.49
	Pocillopora	2.87
	Cyphastrea	2.00
	Montipora	1.87
	Galaxea	1.75
	Favites	1.12
	Platygyra	1.12
	Acropora	0.87
	Coscinaraea	0.87
	Leptoria	0.75
	Oulophyllia	0.75
	Acanthastrea	0.50
	Stylophora	0.50
	Plesiastrea	0.37
	Sinularia	0.37
	Turbinaria	0.37
	Gardineroseris	0.25
	Heliopora	0.25
	Leptoseris	0.25
	Hydnophora	0.12
	Lobophytum	0.12
	Stylaster	0.12

Spatial patterns of generic relative abundance, based on colony counts at two long-term REA sites in 2009, are reflected in Figure D.3.2.2.1 Colonies of the genus *Porites* were particularly abundant at site AGU 2 but not AGU-03. *Leptastrea* was the most numerically abundant scleractinian genus. Colonies of the genera *Pavona*, *Goniastrea*, and *Favia* were also important contributors to the scleractinian community at site AGU-03 (Fig. D.3.2.2.1).

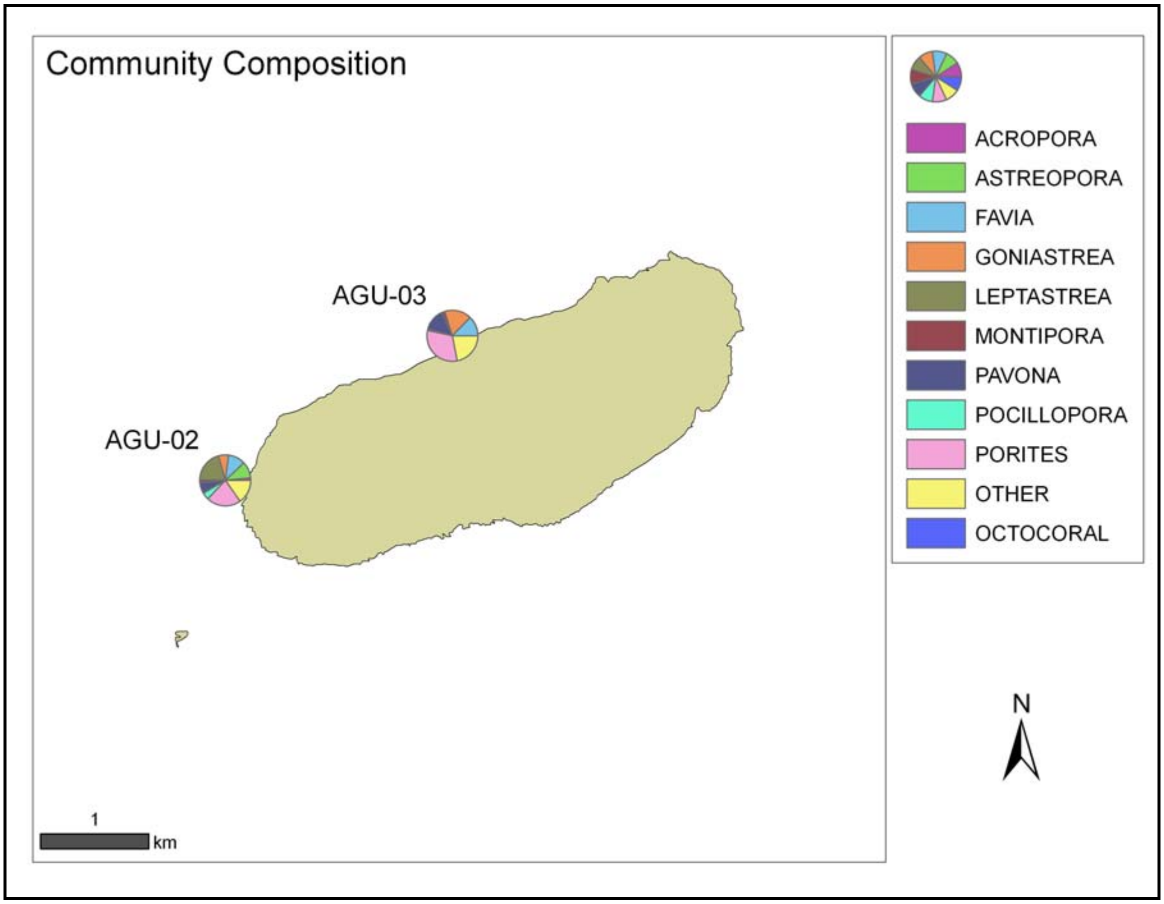


Figure D.3.2.2.1--Relative abundance of coral genera from REA surveys around Aguijan during MARAMP 2009.

Size class distribution of all corals enumerated within belt transects are shown in Figure D.3.2.2.2. Of the 802 anthozoan colonies enumerated (average diameter estimated as the arithmetic mean of two planar measurements), 52% had a diameters of < 5 cm, and 28% had mean diameters between 6 and10 cm. No coral colonies were enumerated exhibiting average diameters > 80 cm.

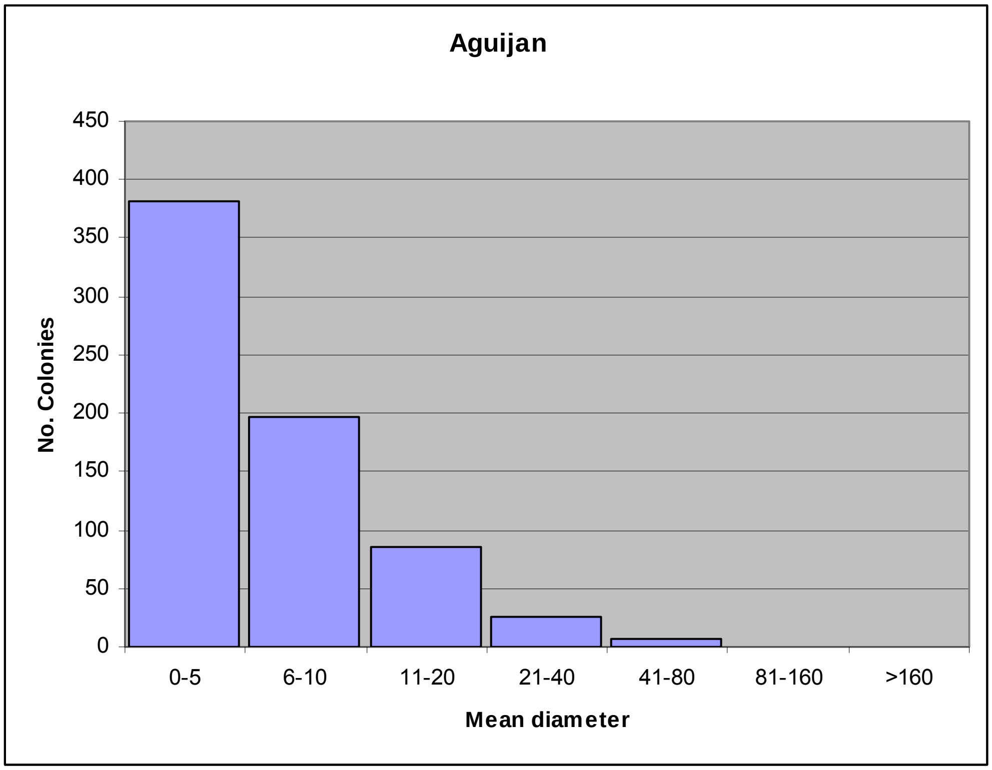


Figure D.3.2.2.2--Size class distribution of 809 coral colonies enumerated within belt transects around Aguijan in 2009.

D.3.3 Coral Health and Disease

During MARAMP 2009, occurrence of disease, predation, and other health impairments around Aguijan was moderate, with a total of 30 lesions enumerated at the two REA sites surveyed. A summary of disease occurrence, relative abundance, is presented in Table D.3.3.1. The most numerically abundant type of lesion was acute tissue loss (white syndrome), detected at both sites, but more numerous at AGU-03 (60% of cases); these lesions were detected predominantly on corals of the genus *Porites* (90% of cases). Poritid corals were also affected by hyperpigmented irritations; these lesions were detected at both sites surveyed. Finally, lesions affecting coralline algae were relatively common with a total of 14 cases detected within the area surveyed (~ 30 m^2). The coralline lethal orange disease (CLOD) was the only type of coralline affliction observed around Aguijan.

Table D.3.3.1--Number of cases of scleractinian and coralline algal diseases and predation enumerated during REA surveys, around Aguijan Island, MARAMP 2009. ALG: algal infections, BIN: barnacle infestation; BLE: bleaching; CYA: cyanophyte infections; DIS: discolorations other than bleaching; FUG: fungal infections; HYP: hyperpigmented irritations/pigmentation response; PRE: *Acanthaster*/*Drupella* predation scars; SGA: skeletal growth anomalies; TIN: tubeworm infestation; TLS: tissue loss; WSY: white syndrome; OTH: other diseases and lesions of unknown etiology; CLOD: coralline lethal orange disease; and CLD; coralline white band syndrome/lethal disease.

DZCode	AGU-02	AGU-03	Grand Total
ALG	1	2	3
BLE	2	1	3
FUG	1		1
HYP	4	4	8
TLS		3	3
WSY	4	6	10
OTH		1	1
PRE		1	1
Total	**12**	**18**	**30**
CLOD	5	9	14

D.3.4 Macroinvertebrate Surveys (non-coral)

A total of 702 individuals belonging to 43 benthic invertebrate target species or taxa groups were enumerated from four belt transects at 2 sites (Table D.3.4-1). Aguijan had the highest densities of target species of macroinvertebrates at REA reef habitats of the southernmost Mariana Islands of Guam, Rota, Aguijan, and Tinian (339.29 organisms/50 m^2 for core target groups, 410.4 organisms/50 m^2 including sponges, vermetids, and *Spirobranchus* worms). Aguijan also had the highest average site species richness of the four southern islands (mean 32.5 species/site). Only two sites were sampled here, so there is likely sample bias.

At each of the two sites, several groups of invertebrates were highly abundant. At AGU-02, boring urchins were sparse (3.75 organisms/50 m^2), but small hermit crabs (e.g., genus *Calcinus*), vermetids, *Spirobranchus* worms, coral guard crabs of the genus *Trapezia*, and coral eating Coralliophilid snails were highly abundant (116.3, 73.75, 46.25, 38.75, and 21.25 organisms/50 m^2, respectively). AGU-03 was dominated by boring urchins of the species *Echinostrephus aciculatus* (288.9 organisms/50 m^2), followed by small hermit crabs (e.g., *Calcinus* spp.) (51.1 organisms/50 m^2), and coral eating Coralliophilid snails (47.78 organisms/50 m^2). Other snails, besides Coralliophilids, were fairly common at both sites (17.65 organisms/50 m^2 island mean).

Tridacna clams were highly abundant at AGU-02 (11.25 organisms/50 m^2) and moderately abundant at AGU-03 (3.33 organisms/50 m^2).

Table D.3.4-1--Densities of organisms observed at REA sites around Aguijan during cruise HA0902. Sponges, vermetids, and *Spirobranchus* polychaete worms are not explicit target groups, but observations are recorded here.

Aguijan Invertebrate Surveys 2009		Density (# / 50 m^2)		
Phylum	TaxaGroup	AGU-02	AGU-03	Aguijan Mean
Annelida	*Polychaetes*	46.25	2.22	24.24
Arthropoda	*Shrimp*	6.25	10	8.13
	Hermit Crabs: Small (e.g. Calcinus sp.)	116.3	51.1	83.68
	Crabs: Other Brachyurans	7.5	3.33	5.42
	Crabs: Coral Guard Crabs (Trapezia, etc)	38.75	1.11	19.93
Echinodermata	*Asteroids (Sea Stars): Other*	1.25		0.63
	Asteroids (Sea Stars): Crown of Thorns		1.11	0.56
	Echinoids (Urchins): Boring Echinometrids	3.75	288.9	146.32
	Holothuroids (Sea Cucumbers)	1.25	3.33	2.29
	Ophiuroids (Brittle Stars)	6.25	2.22	4.24
	Crinoids	11.25	1.11	6.18
Mollusca	*Bivalves: Tridacnids (Giant Clams)*	11.25	3.33	7.29
	Snails: Other	15	15.55	15.28
	Snails: Large (Lambids/Tritons)	1.25		0.63
	Snails: Coralliophilids (Coral Eating)	21.25	47.78	34.52
	Snails: Trochus	1.25	2.22	1.74
	Snails: Vermetids (Worm Snails)	73.75	17.78	45.77
	Opisthobranchs (Sea Slugs)	2.5		1.25
Porifera	*Sponges*		2.22	1.11
Chordata	*Ascidians*	2.5		1.25
Grand Total		367.5	453.3	410.4

D.3.4.1. Urchin Measurements

The test diameters of urchin species and the valve width of Tridacnid clams were recorded at REA sites around Aguijan. Mean measurements by site are presented in Figure D.3.4.1-1 for species where the sample size is 5 or greater.

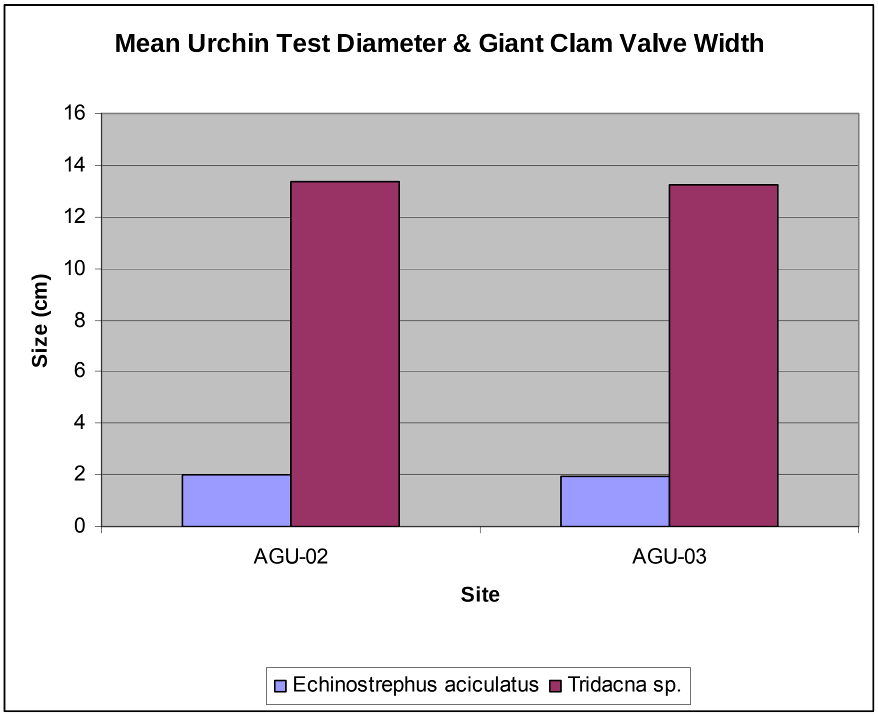


Figure D.3.4.1-1--Reveals the average test diameter of urchins and valve width of giant clams encountered at each site around Aguijan. Only sites where ≥ 5 measurements were recorded for a species are represented.

D.3.4.2. ARMS Deployment

No ARMS were deployed around Aguijan during HA-09-02.

D.3.4.3 Invertebrate Collections

No specimens were collected around Aguijan during HA-09-02.

D.3.5 Benthic Towed-diver Surveys

Five benthic towed-diver surveys were completed at Aguijan in 2009. Habitats covered during surveys varied with the majority of tow segments conducted over hard bottom (a mixture of continuous pavement reefs and pavement separated by thin sand channels).

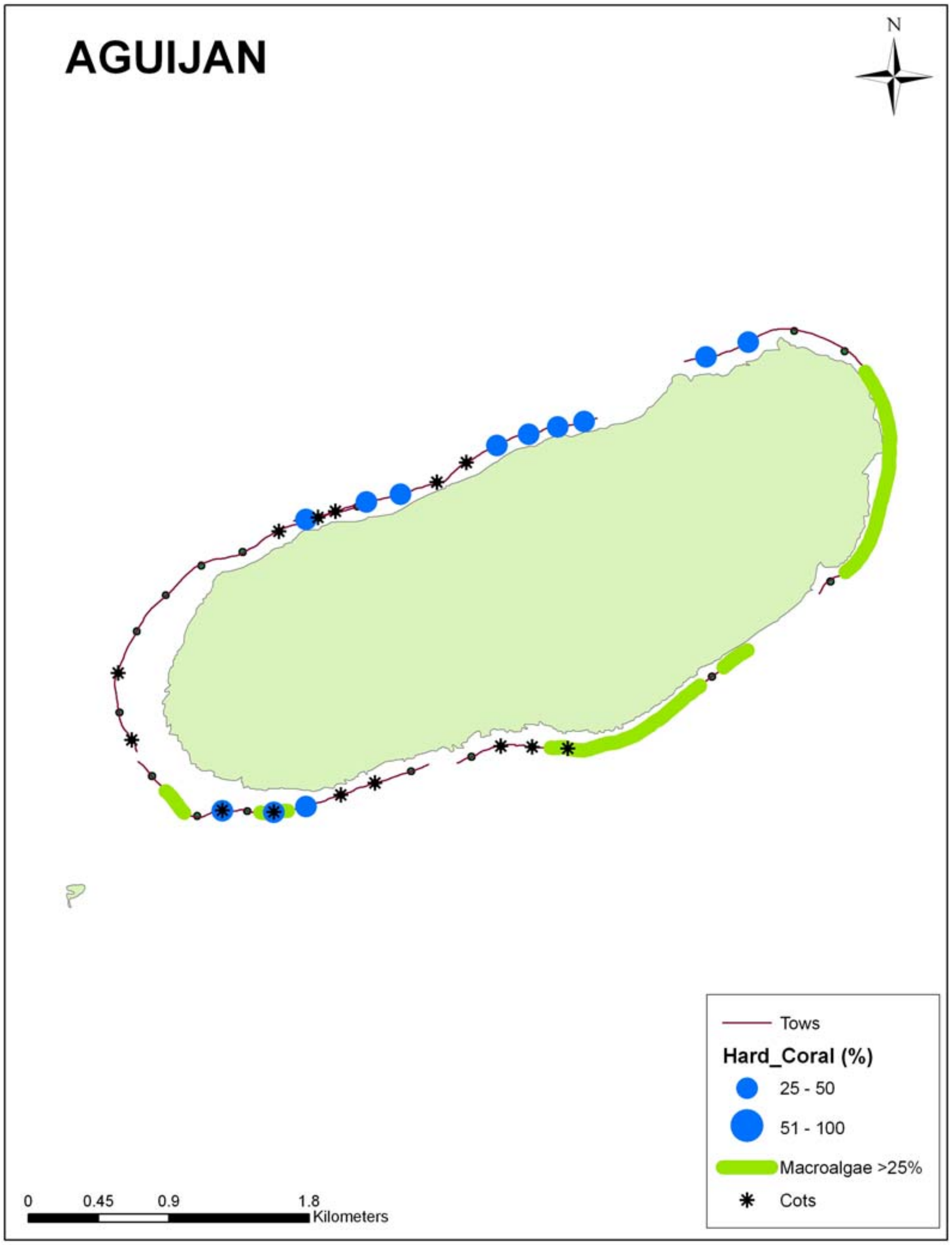


Figure D.3.5.1--Hard coral cover (≥ 25%) elevated macroalgae cover (> 25%), and crown-of-thorns (COTs) sightings during tow segments at Aguijan in 2009.

Benthic cover at Aguijan showed some spatial patterns with the eastern coast dominated by macroalgae and portions of higher coral cover in the north and south regions of the island. Interestingly, partial mortality in many *Astreopora* colonies in the east was noted associated with what appeared to be a band of greenish pigmentation of unknown origin.

Benthic Category	Mean ± SE
Hard Coral	15.6 ± 1.2
Soft Coral	3.4 ± 0.4
Macroalgae	20.8 ± 2.5
Coralline Algae	7.3 ± 0.9
Sand	4.6 ± 1.1
Rubble	5.5 ± 1.6
COTs	31
Free Urchins	0
Boring Urchins	3448
Sea Cucumbers	137
Giant Clams	113
* Sum of observed individuals	

Similar to the other islands in the southern Mariana Archipelago, boring urchins were the most common macroinvertebrate. Giant clams and sea cucumbers were also relatively common but in low numbers. COTs were seen in low densities in most regions except for the eastern coast of the island.

D.4 Fish Surveys

D.4.1 REA Fish Surveys

Stationary point count data (SPC)

During the survey period, SPC surveys were conducted at six sites around Aguijan. Surgeonfish were the largest contributor to total biomass with 0.73 kg 100 m^{-2}. Parrotfish were the second largest contributor to total biomass with 0.23 kg 100 m^{-2}, followed by groupers at 0.19 kg 100 m^{-2} (Fig. D.4.1.1).

Overall observations

A total of 151 fish species were observed during the survey period by all divers. The average total fish biomass around Aguijan during the survey period was 2.9 kg 100 m^{-2} for the SPC surveys (Fig. D.4.1.1).

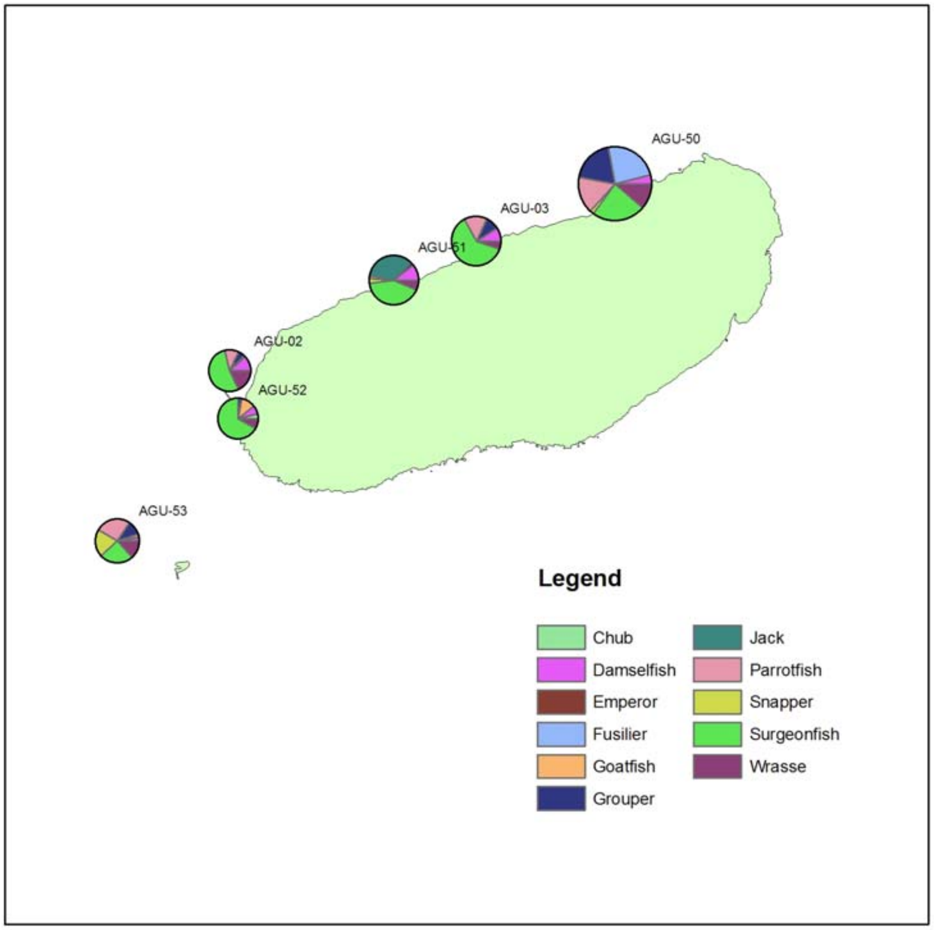


Figure D.4.1.1--Site location and distribution of total fish biomass by family. The size of the pie charts are proportional to fish biomass.

D.4.2 Towed-diver Fish Surveys

During HA0902, the CRED towed-diver team completed 11 surveys at Aguijan covering 11.73 km (11.73 ha) of ocean floor (Table B.4.2.1). Mean survey length was 2.4 km with a maximum length of 2.9 km and a minimum of 2.1 km. Mean survey depth was 14.1 m with a maximum depth of 15.2 m and a minimum of 12.6 m. Mean temperature on these surveys was 28°C with a maximum temperature of 28.1°C and a minimum of 27.7°C.

Nine individual large-bodied reef fish (>50 cm TL) of five different species and five different families were encountered at Aguijan (Table D.4.2.2). Overall numeric density for this class of reef fishes was 0.077 #/100 m^2 (7.67 #/ha) with a biomass density of 0.747 kg/100 m^2 (0.075 t/ha) (Figs. D.4.2.1 and D.4.2.2). Numeric and biomass density were dominated by *Aetobatus narinari*.

The most prevalent families in terms of numeric biomass density were Lutjanids (ND=25%) and Labrids (ND=22%) (Figure C. D.4.2.1). In terms of biomass density, the most prevalent families were Labrids (BD=41%) and Dasyatids (BD=21%) (Fig. D.4.2.2).

Biomass of large bodied reef fish was distributed fairly evenly around the island (Fig. D.4.2.3).

Table D.4.2.3--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Aguijan during HA0902 CRED towed-diver Surveys.

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Aetobatus_narinari	3	0.026	2.558	37.45366739	0.319	0.032
Triaenodon_obesus	2	0.017	1.705	22.77183979	0.194	0.019
Diodon_hystrix	2	0.017	1.705	8.91897206	0.076	0.008
Gymnosarda_unicolor	1	0.009	0.853	14.16411027	0.121	0.012
Lutjanus_bohar	1	0.009	0.853	4.29241101	0.037	0.004
Grand Total	9	0.077	7.673	87.601	0.747	0.075
# of Species	5					

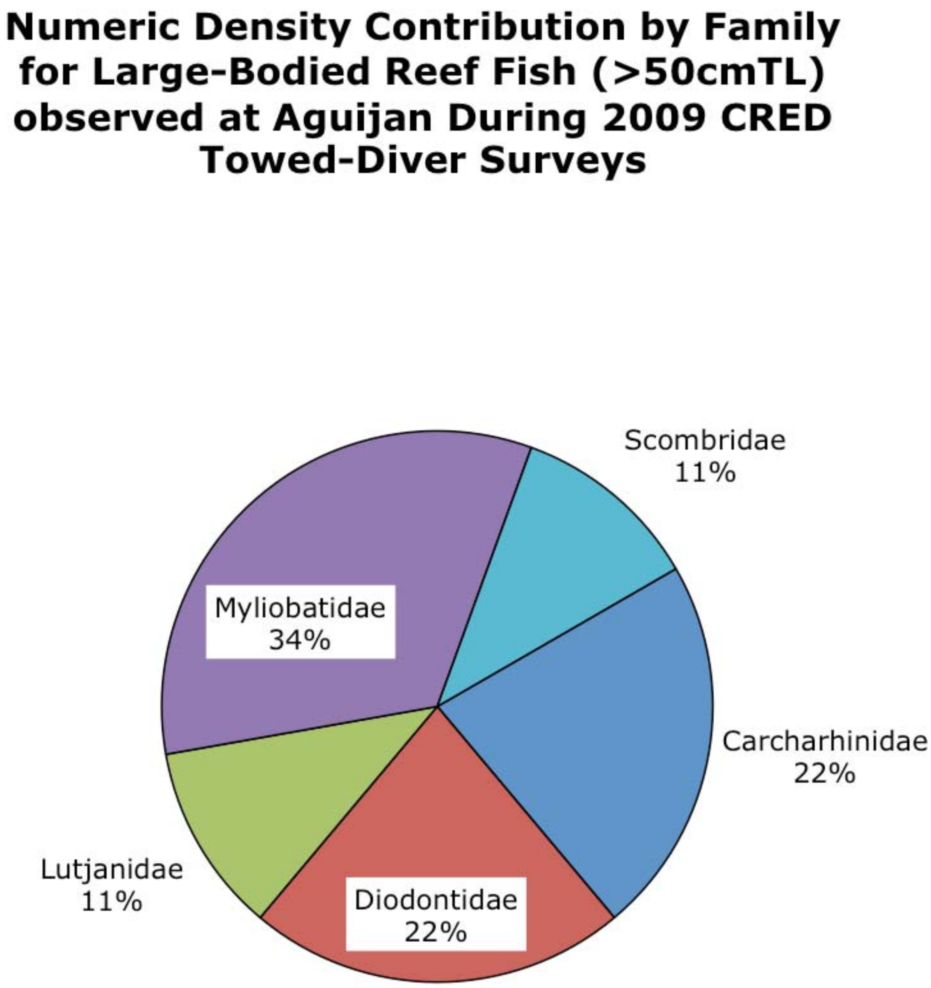


Figure D.4.2.1--Numeric density by Family.

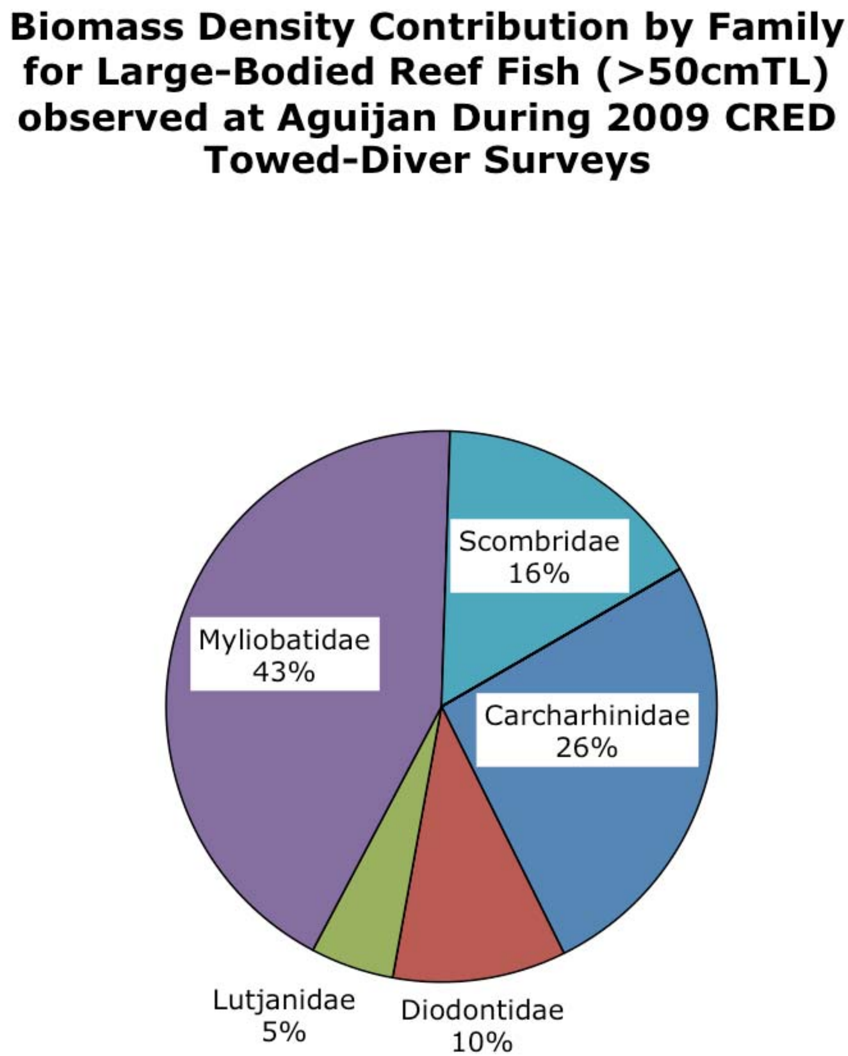


Figure D.4.2.2--Biomass density by Family.

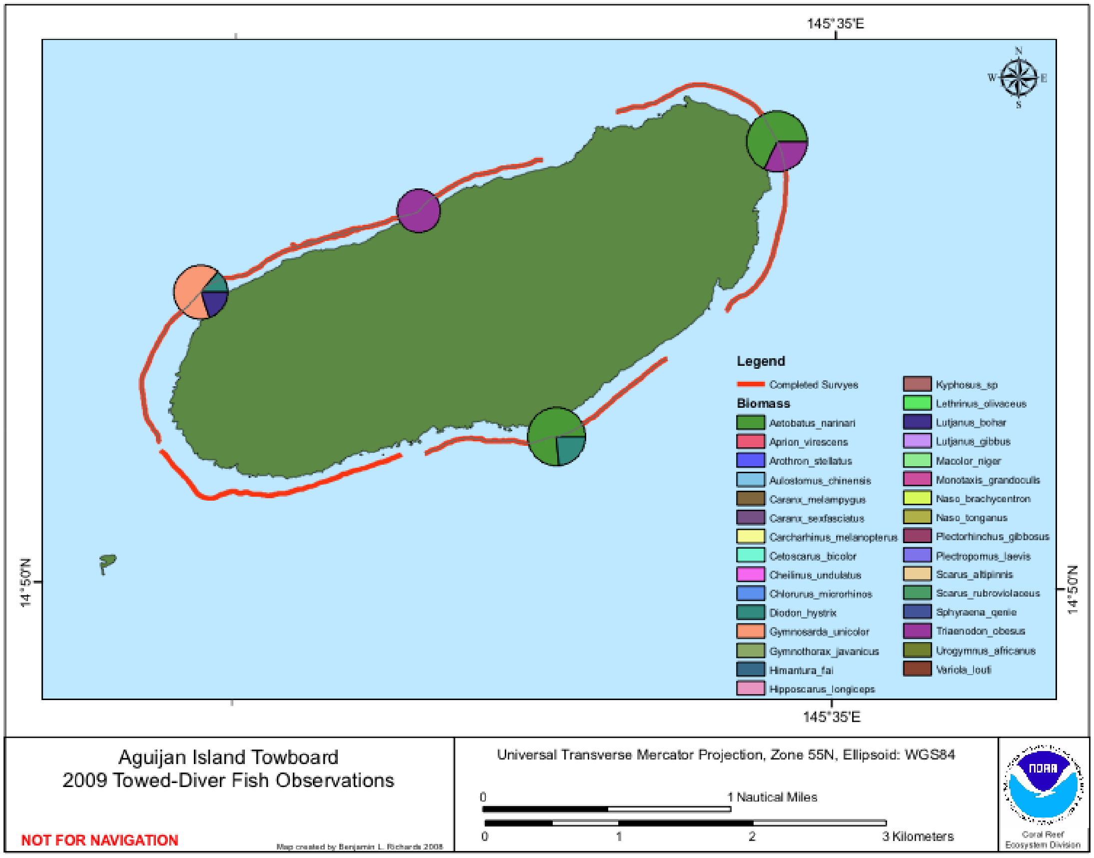


Figure D.4.2.3--Geographic distribution of biomass around Aguijan. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

Appendix E: Tinian

E.1. Oceanography and Water Quality

(see D.1 Aguijan)

E.2. Rapid Ecological Assessment Site Descriptions

Six REA (Rapid Ecological Assessment) sites were visited by a team of up to seven scientists around Tinian Island from 12 to 13 April 2009 (Fig. E.2.1). In addition, eight stratified random fish, line point intercept (LPI), and invertebrate surveys were conducted. The site locations are listed below along with site photos taken in 2009. Site descriptions are included for the following discipline communities: coral, coral disease, macroinvertebrates, algae, and fish.

Figure E.3.1--Location of REA, stratified random and Autonomous Reef Monitoring Systems (ARMS) installation sites visited at Tinian Island in 2009.

TIN-01
4/12/2009

E 145° 39.062
N 15° 02.086

Forereef
Mid

Depth: 10–13 m

Site description: Eastern region; Unai Dankolo (Long Beach); moderate topographic complexity; high coral cover; moderate macroalgal cover.

TIN-02
4/12/2009

E 145° 37.675
N 14° 56.429

Forereef
Mid

Depth: 10–13 m

Site description: Southwestern region; south of Dynasty Hotel; moderate topographic complexity; moderate slope; moderate coral cover; low/moderate macroalgal cover.

TIN-03
4/13/2009

E 145° 36.181
N 14° 59.443

Forereef
Mid

Depth: 9–12 m

Site description: West Barcinas Bay; shallow site; high topographic complexity; high coral cover; low macroalgal cover; Porites rus fields.

TIN-04
4/12/2009

E 145° 39.783
N 14° 56.870

Forereef
Mid

Depth: 10–14 m

Site description: Southern region; low/moderate topographic complexity; moderate coral cover; moderate macroalgal cover.

TIN-05
4/13/2009

E 145° 37.713
N 14° 57.342

Forereef
Mid

Depth: 6–7 m

Site description: Tinian Harbor; shallow; low topographic complexity; moderate coral cover; low macroalgal cover; mixed *Porites rus* aggregates

TIN-06
4/13/2009

E 145° 37.279
N 15° 04.816

Forereef
Mid

Depth: 12–14 m

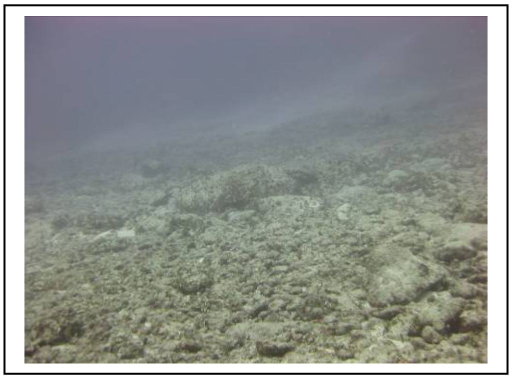
Site description: Northwestern region; moderate depth; low/moderate topographic complexity; moderate coral cover; moderate macroalgal cover; abundant cyanophytes.

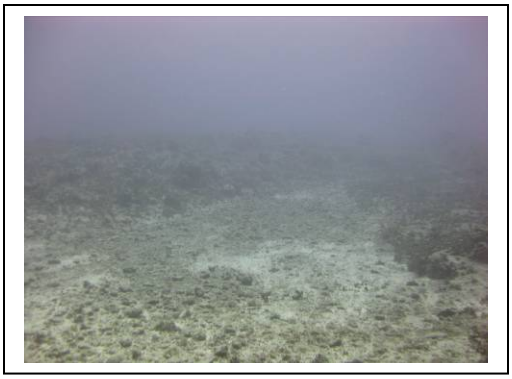
TIN-50
4/12/2009

E 145° 39.390
N 15° 04.053

Forereef
Deep

Depth: 21 m





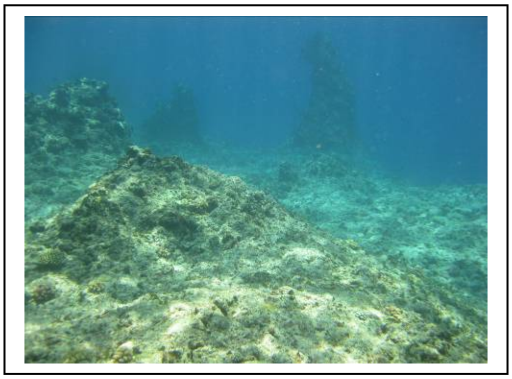
Site description: Northeastern deep site; low topographic complexity; low coral cover mixed with sand patches; low macroalgal cover (high turf cover).

TIN-51
4/12/2009

E 145° 37.755
N 14° 56.269

Forereef
Shallow

Depth: 4 m



Site description: Southwestern shallow site; moderate topographic complexity; moderate coral cover; low macroalgal cover

TIN-52
4/12/2009

E 145° 37.820
N 14° 57.143

Forereef
Shallow

Depth: 3 m

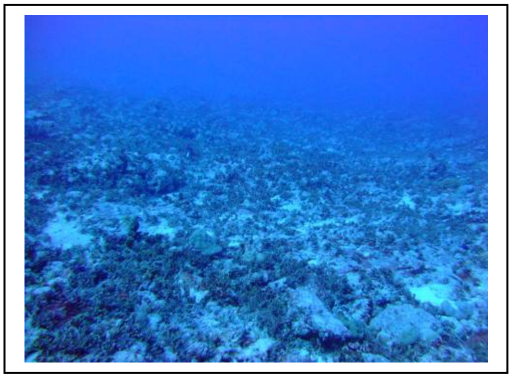
Site description: Shallow western site; high topographic complexity; high coral cover; moderate macroalgal cover.

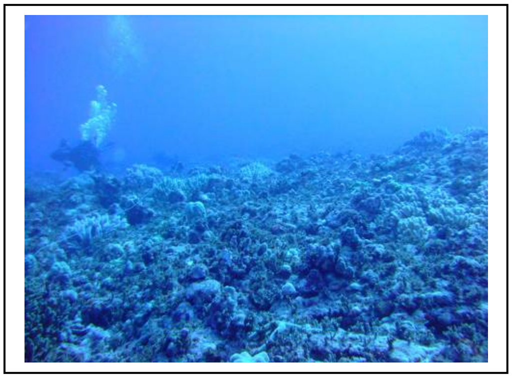
TIN-53
4/13/2009

E 145° 38.368
N 15° 05.955

Forereef
Deep

Depth: 21 m





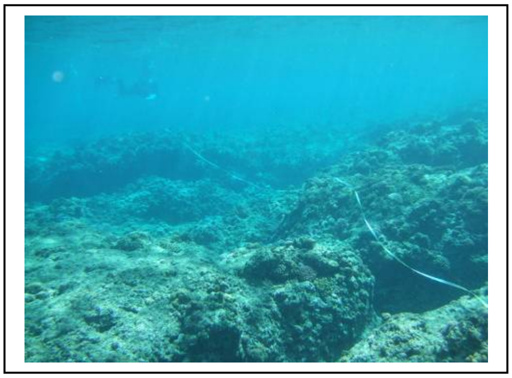
Site description: Northern region; low topographic complexity; moderate coral and macroalgal cover.

TIN-54
4/13/2009

E 145° 36.850
N 15° 04.332

Forereef
Shallow

Depth: 1–2 m



Site description: Western region; deep spurs (potential naval training landing beaches); low topographic complexity; high coral cover; low macroalgal cover.

TIN-55
4/13/2009

E 145° 37.317
N 15° 04.766

Forereef
Shallow

Depth: 1 m

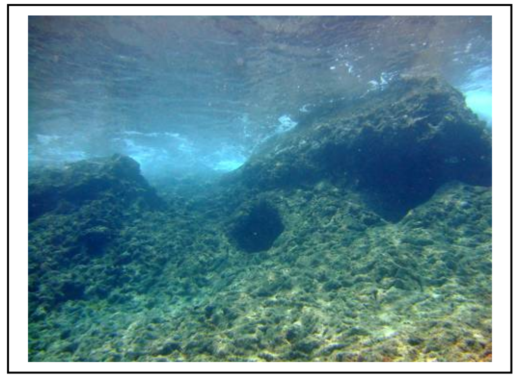
Site description: Very shallow western site; (potential naval training landing beaches); low topographic complexity; low coral cover; low macroalgal cover.

TIN-56
4/13/2009

E 145° 35.203
N 15° 00.255

Forereef
Shallow

Depth: 3–5 m



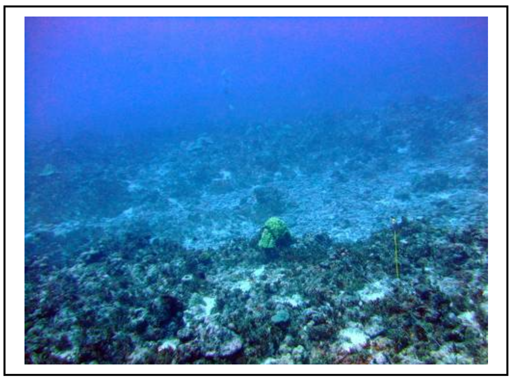
Site description: Shallow western site; first transect on wall; second transect at bottom of wall; high topographic complexity; moderate coral and macroalgal cover.

TIN-57
4/13/2009

E 145° 36.565
N 14° 58.507

Forereef
Deep

Depth: 23 m



Site description: Deep southwestern site; near large bay; patch reefs and sand channels; low topographic complexity; low coral cover; moderate macroalgal cover.

E.3 Benthic Environment

E.3.1. Algal and Coral Communities—Line Point Intercept Method (LPI)

During the Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP) 2009, six permanent, long-term REA monitoring sites were surveyed around Tinian Island for percent benthic cover, based on the 20-cm interval LPI methodology. Benthic communities were dominated by turf algae and scleractinian corals (Table E.3.1.1). Turf algal percent cover exceeded that of other functional groups at five of the six sites surveyed with a range of 12% to 46.4% (Table E.3.1.1). Scleractinian coral was the dominant cover at site TIN-03 with a percent cover of 40.4% (Table E.3.1.1). A combined total of 24 species of macroalgae were observed (13 chlorophytes, 4 ochrophytes, 7 rhodophytes) from the six sites surveyed (Tables E.3.1.2 and E.3.1.3). *Halimeda opuntia* was a dominant macroalga at four of the six sites surveyed with a percent cover range of 0% to 6% (Table E.3.1.3). *Lobophora variegata* dominated the macroalgal community at site TIN-03 with 4.4% cover, and *Dictyosphaeria versluysii* was the dominant macroalga at site TIN-04 with 2.8% cover (Table E.3.1.3).

Table E.3.1.1--Percent cover of algal functional groups at long-term monitoring sites at Tinian.

Site	Macroalgae	Turf Algae	Coralline red algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Octocoral
TIN-01	16.0%	40.3%	7.4%	0.9%	29.9%	1.3%
TIN-02	16.4%	31.6%	2.8%	14.0%	14.8%	-
TIN-03	8.8%	12.0%	26.0%	3.2%	40.4%	-
TIN-04	18.0%	38.8%	24.0%	1.6%	16.8%	0.8%
TIN-05	3.2%	46.4%	2.4%	2.0%	19.2%	-
TIN-06	16.8%	46.4%	6.0%	5.6%	13.6%	-

Table E.3.1.2--Additional species recorded at each site at Tinian during roving diver surveys.

Site	**Chlorophyta**
TIN-01 TIN-04	*Caulerpa filicoides*
TIN-01	*Caulerpa racemosa*
TIN-01	*Caulerpella ambigua*
TIN-06	*Dictyosphaeria versluysii*
TIN-03	*Halimeda opuntia*
TIN-03	*Halimeda taenicola*
TIN-06	*Halimeda tuna*
TIN-04	*Microdictyon setchellianum*

Site	**Chlorophyta**
TIN-04	*Neomeris* sp.
TIN-01	*Udotea* sp.
TIN-06	*Valonia* sp.
TIN-02 TIN-04 TIN-06	*Valonia ventricosa*
	Ochrophyta
TIN-03 TIN-06	*Dictyota* sp.
TIN-01 TIN-03	*Padina* sp.
TIN-01 TIN-06	*Turbinaria ornata*
	Rhodophyta
TIN-06	*Amphiroa* sp.
TIN-06	*Asparagopsis taxiformis*
TIN-03 TIN-04 TIN-05	*Dichotomaria* sp.
TIN-01	*Galaxaura* sp.
TIN-04	*Ganonema* sp.
TIN-03	*Portieria* sp.

Table E.3.1.3--Percent cover of macroalgal species at long-term monitoring sites at Tinian. Sum totals for each row equal the percent cover of macroalgae recorded in Table E.3.1.1

Site	Caulerpa serrulata	Dictyosphaeria versluys	Halimeda opuntia	Lobophora variegata	Padina sp	Galaxaura sp	Peyssonnelia sp	Portieria hornemannii
TIN-01	-	-	2.6%	2.2%	-	-	2.2%	0.9%
TIN-02	-	-	1.2%	-	-	-	-	-
TIN-03	-	0.4%	-	4.4%	-	0.4%	-	-
TIN-04	0.8%	2.8%	-	-	-	-	-	-
TIN-05	-	-	1.6%	-	-	-	-	-
TIN-06	-	-	6.0%	3.2%	0.4%	-	-	-

Benthic communities around Tinian at deep and shallow randomly stratified monitoring sites were documented along two 25-m transect lines at 0.5-m intervals. Sites located at less than 10 m deep were dominated by turf algae, coralline red algae, and scleractinian coral (Table E.3.1.4, Fig. E.3.1.1). Turf algal percent cover exceeded that of other cover types at four of the five shallow sites surveyed, while scleractinian coral was the dominant cover at one of the sites (Table E.3.1.4, Fig. E.3.1.1). Turf algal percent cover exceeded that of other cover types at all of the deep sites surveyed. Preliminary analysis indicates that scleractinian coral cover was greater at shallow sites than at deep sites, with mean scleractinian coral cover across all shallow sites at 20.2 ± 14.6% and 9.2 ± 4.4% for the deep sites. Macroalgal cover, on the other hand, was greater at deep sites, with mean macroalgal cover at 7.3 ± 7.1% for the shallow sites and 14.1 ± 5.4 for the deeper sites. An estimated 93 species of scleractinian corals were observed across the six sites surveyed. Because discriminating between scleractinian coral species within certain genera (e.g., *Montipora*, *Favia*, *Porites*) can be difficult, this total should only be considered an estimate and not an absolute figure.

Table E.3.1.4--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Tinian.

Site	Depth	Macroalgae	Turf Algae	Coralline Red Algae (crustose + upright)	Cyanobacteria	Scleractinian Coral	Dead Coral	Octocoral
TIN-51	< 10m	7.8%	47.1%	27.5%	1.0%	13.7%	0.0%	0.0%
TIN-52	< 10m	13.7%	37.3%	9.8%	4.9%	27.5%	0.0%	0.0%
TIN-54	< 10m	0.0%	34.3%	23.5%	0.0%	42.2%	0.0%	0.0%
TIN-55	< 10m	0.0%	80.4%	13.7%	0.0%	5.9%	0.0%	0.0%
TIN-56	< 10m	14.7%	57.8%	12.7%	1.0%	11.8%	0.0%	0.0%
TIN-50	> 20m	7.8%	62.7%	4.9%	5.9%	4.9%	0.0%	0.0%
TIN-53	> 20m	17.6%	43.1%	7.8%	3.9%	13.7%	0.0%	5.9%
TIN-57	> 20m	16.7%	27.5%	16.7%	7.8%	8.8%	0.0%	0.0%

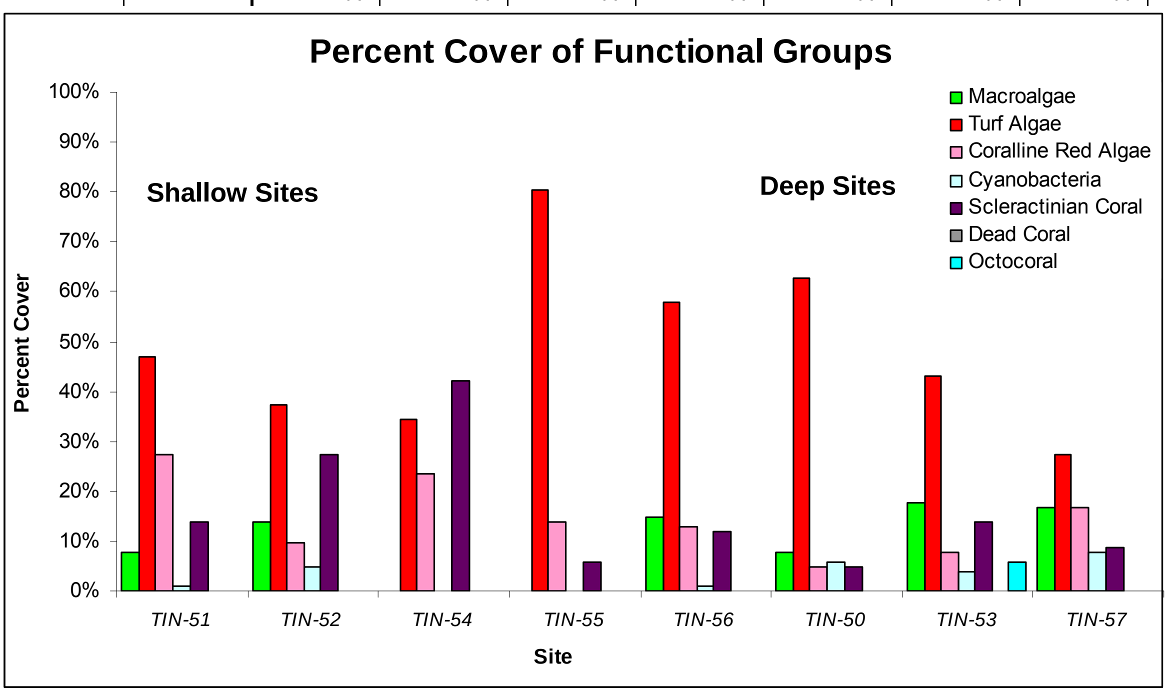


Figure E.3.1.1--Percent cover of functional groups at shallow and deep monitoring sites established in 2009 around Tinian.

E.3.2 Coral Communities

E.3.2.1 Percent Benthic Cover

In 2009, percent benthic cover surveys around Tinian were conducted in concert with coral, algae, and invertebrate REA surveys, at six permanent sites established between 2003 and 2005. Percent coral cover derived from LPI surveys conducted at the permanent long-term REA sites around Tinian yielded an islandwide mean of 22.4.8% (Fig. E.3.2.1.1). Percent coral cover was the greatest at TIN-03 and TIN-01, on the west and northeastern regions, respectively (Fig. E. 3.2.1.1).

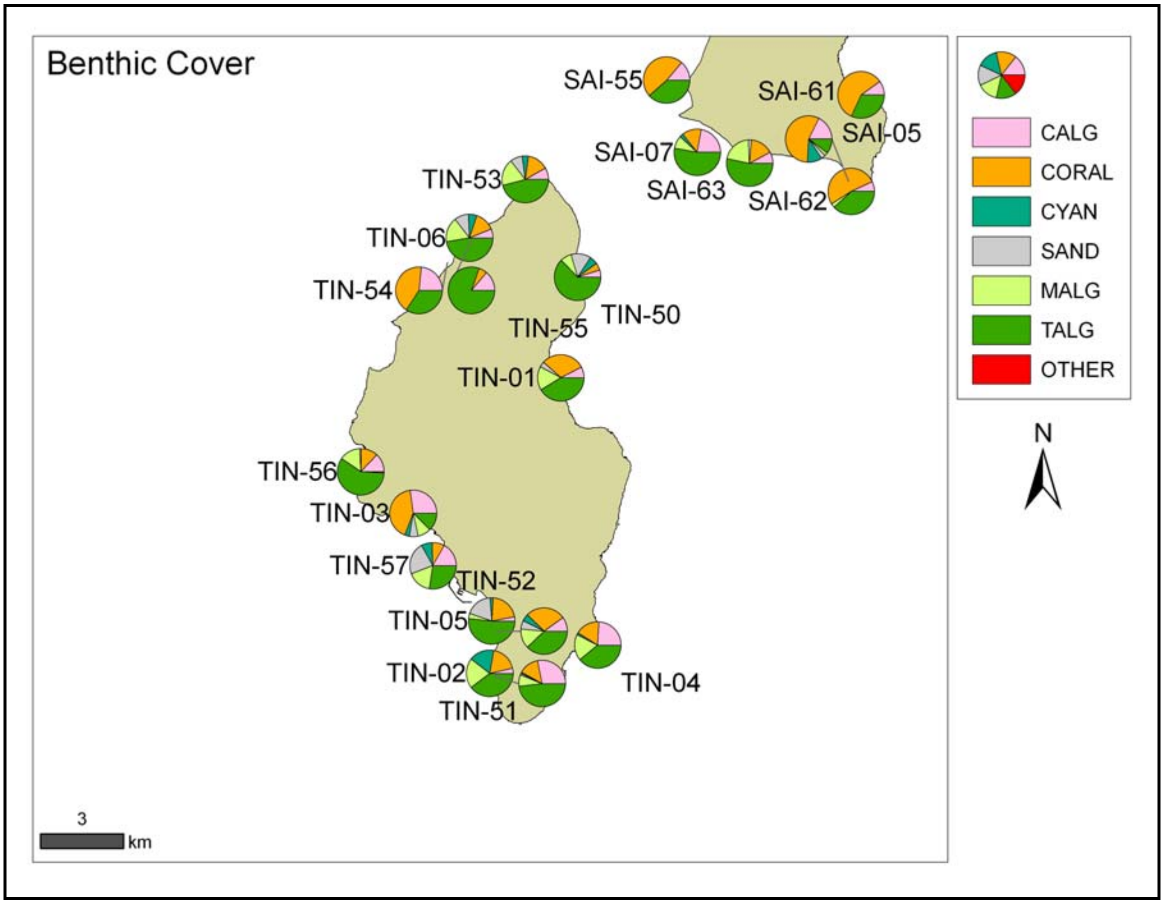


Figure E. 3.2.1.1--Percent cover of benthic functional groups at 14 random stratified and permanent REA monitoring sites around Tinian during MARAMP 2009. CALG = crustose coralline red algae, CYAN = cyanobacteria, MALG = macroalgae, TALG = turf algae.

Eight additional stratified random REA sites were surveyed around Tinian for percent bethic cover (based on 50-cm interval LPI surveys) and generic diversity data in 2009. Results from the eight stratified random REA sites surveyed in 2009 yielded the following results. Benthic communities surveyed at two sites greater than 20 m deep were dominated by turf algal (44.4% ± 10.2), sand (14.7% ± 4.3) and macroalgal (14.1% ± 3.1) functional groups (Fig. E.3.2.1.2). Five shallow sites (< 10 m deep) were dominated by turf algal (51.4% ± 8.3), scleractinian coral (20.2% ± 6.5) and calcareous algal (17.5% ± 3.4) functional groups (Fig.

E.3.2.1.2). Coral generic diversity was highest at site TIN-52 with 24 different genera observed (Table E.3.2.1.1). In contrast, site TIN-55 had the lowest generic diversity with 10 different genera observed. The average number of coral genera recorded at each site was 19. Common coral genera observed at most sites included *Porites*, *Pocillopora*, *Favia*, *Acropora*, *Goniastrea* and *Platygyra*. Macroalgal generic diversity was highest at site TIN-56 with 13 genera observed (Table E.3.2.1.2). Site TIN-53 had the lowest generic diversity with six genera observed. The average number of macroalgal genera recorded for each site was 9. The most common macroalga observed at most sites was *Halimeda*.

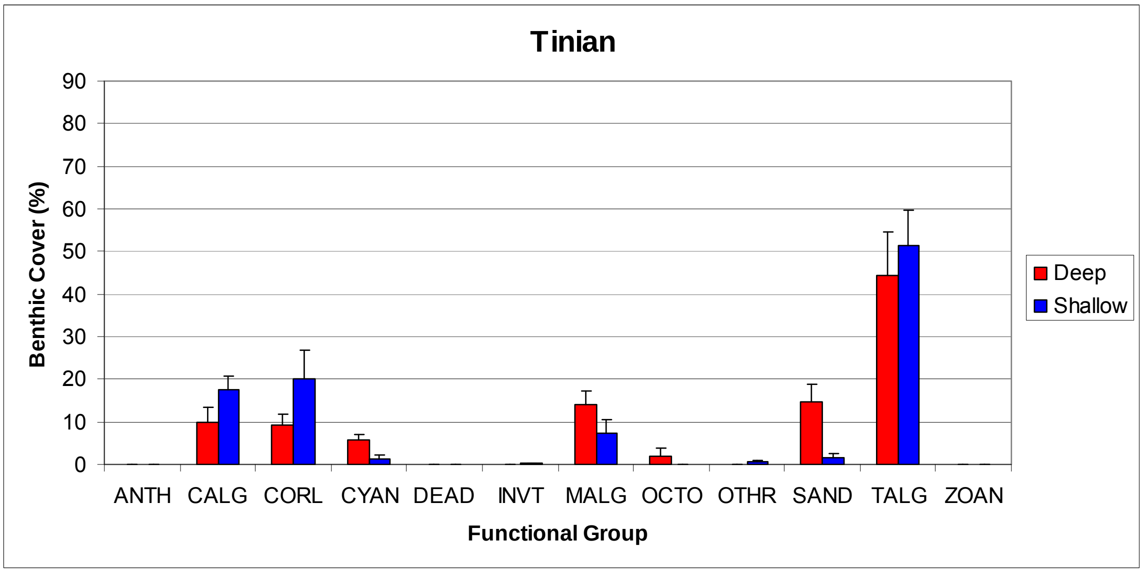


Figure E.3.2.1.2--Percent cover of functional groups at shallow and deep independent LPI monitoring sites established in 2009 at Tinian.

Table E.3.2.1.1--Anthozoan generic diversity of stratified random REA sites around Tinian.

	TIN-50	TIN-51	TIN-52	TIN-53	TIN-54	TIN-55	TIN-56	TIN-57
Acanthastrea	X	X	X	X	X		X	X
Acropora	X	X	X	X	X	X	X	X
Alveopora								
Astreopora	X	X		X	X		X	X
Cladiella*					X			
Corallimorph*								
Coscinarea			X					X
Cyphastrea	X	X	X	X			X	X
Diploastrea								
Distichopora*		X					X	
Echinopora		X	X		X			
Euphyllia								
Favia	X	X	X	X	X	X	X	X
Favites			X		X	X		
Fungia	X		X	X				X
Galaxea		X	X				X	
Gardinoseris								
Goniastrea	X	X	X	X	X	X	X	X

	TIN-50	TIN-51	TIN-52	TIN-53	TIN-54	TIN-55	TIN-56	TIN-57
Goniopora		X	X				X	
Heliopora*								
Herpolitha								
Hydnophora			X					
Isopora								
Leptastrea	X	X	X	X	X		X	X
Leptoria		X	X		X	X	X	X
Leptoseris								X
Lobophyllia			X	X				
Lobophytum*	X		X					
Merulina								X
Millepora*		X			X		X	
Montastrea			X		X			
Montipora	X	X			X	X	X	X
Ouphyllia	X		X	X				
Pachyseris								
Palythoa*		X			X			
Pavona		X	X	X	X		X	X
Platygyra	X	X	X	X	X	X	X	X
Pleisiastrea								X
Plerogyra								
Pocillopora	X	X	X	X	X	X	X	X
Porites	X	X	X	X	X	X	X	X
Psammocora	X	X		X				X
Sarcophyton*								
Scapophyllia								
Scolymia								
Seriatopora								
Sinularia*				X				X
Stylaster*								
Stylocoeniella	X		X					X
Stylophora	X	X	X		X		X	
Turbinaria	X			X				X
Wire Coral*								
Zoanthus*						X		
Total Genera per Site	18	21	24	17	19	10	18	22

* non-scleractinian genera

Table E.3.2.1.2--Macroalgal generic diversity of stratified random REA sites around Tinian.

	TIN-50	TIN-51	TIN-52	TIN-53	TIN-54	TIN-55	TIN-56	TIN-57
Amphiroa	X	X	X					X
Asparagopsis								
Avrainvillea								
Boergesenia								
Boodlea							X	
Bryopsis	X				X			
Caulerpa		X	X				X	X
Chlorodesmis			X		X	X	X	
Crustose Coralline	X	X	X	X	X	X	X	X
Cyanobacteria	X		X	X				X
Dichotomaria			X		X			
Dictyosphaeria		X					X	
Dictyota							X	X
Galaxaura					X		X	
Gibsmithia								
Halimeda	X	X	X	X	X		X	X
Halymenia								
Lobophora		X			X			X
Microdictyon	X						X	
Neomeris	X	X				X	X	
Non-geniculate calcified branched		X	X	X	X	X		
Padina	X		X				X	
Peyssonnelia								
Portieria							X	
Rhipilia								
Turbinaria						X	X	
Tydemania								
Udotea	X			X				X
Valonia	X	X		X				X
Unknown			1					
Total Genera per site	10	9	10	6	8	5	13	9

E.3.2.2 Coral Populations

During MARAMP 2009, belt transect surveys were conducted at six long-term REA sites around Tinian, covering a total reef area of nearly 88 m^2 and totaling 2029 anthozoan colonies enumerated. Taxonomic richness varied between sites with 34 anthozoan genera (32 scleractinian, 2 octocoral) being represented within belt transects (Table E.3.2.2.1). *Porites*, *Leptastrea*, and *Favia* were the most abundant scleractinian genera, contributing 15.8% 13.5%, and 11.2% of the total number of colonies enumerated islandwide. All other genera individually contributed less than 10% of the total number of colonies.

Table E.3.2.2.1--Relative abundance of anthozoan genera enumerated within belt transects around Tinian during MARAMP 2009.

Island	Genus	Relative abundance
Tinian	*Porites*	15.8
	Leptastrea	13.5
	Favia	11.2
	Montastrea	9.8
	Astreopora	8.6
	Goniastrea	8.0
	Cyphastrea	5.8
	Montipora	5.5
	Pavona	4.0
	Stylophora	3.0
	Psammocora	2.6
	Acropora	1.9
	Platygyra	1.8
	Pocillopora	1.5
	Galaxea	1.4
	Favites	0.9
	Leptoria	0.9
	Acanthastrea	0.7
	Sinularia	0.6
	Stylocoeniella	0.5
	Hydnophora	0.3
	Isopora	0.3
	Oulophyllia	0.2
	Echinophyllia	0.2
	Lobophyllia	0.2
	Turbinaria	0.2
	Fungia	0.1
	Unknown	0.1
	Coscinaraea	0.1
	Cycloseris	0.1
	Heliopora	0.0
	Lobophytum	0.0
	Scapophyllia	0.0
	Scolymia	0.0

Colonies of the genus *Porites* were particularly abundant at sites TIN-03 and TIN-05 on the west and southwest facing shores of the island, while *Leptastrea* was the most numerically abundant coral at sites TIN-02; corals of the genus *Favia* were dominant at sites TIN-06 and TIN-01 (Fig. E.3.2.2.1).

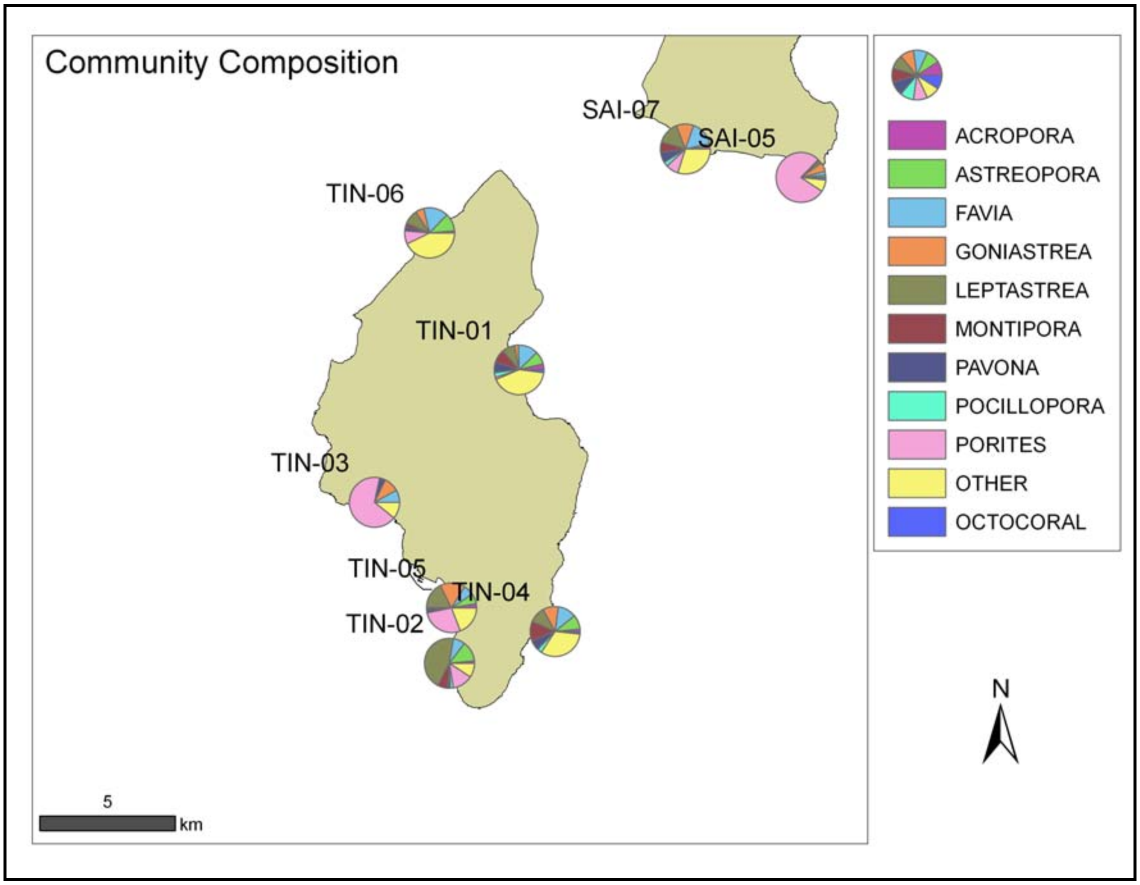


Figure E.3.2.2.1--Relative abundance of coral genera from REA surveys around Tinian during MARAMP 2009.

Size class distribution of all corals enumerated within belt transects are shown in Figure E.3.2.2.2. Of the 2092 anthozoan colonies enumerated (average diameter estimated as the arithmetic mean of two planar measurements), 47% had a diameters of < 5 cm, and 32% had mean diameters between 6 and10 cm. No colonies larger than 80 cm in mean diameter were enumerated.

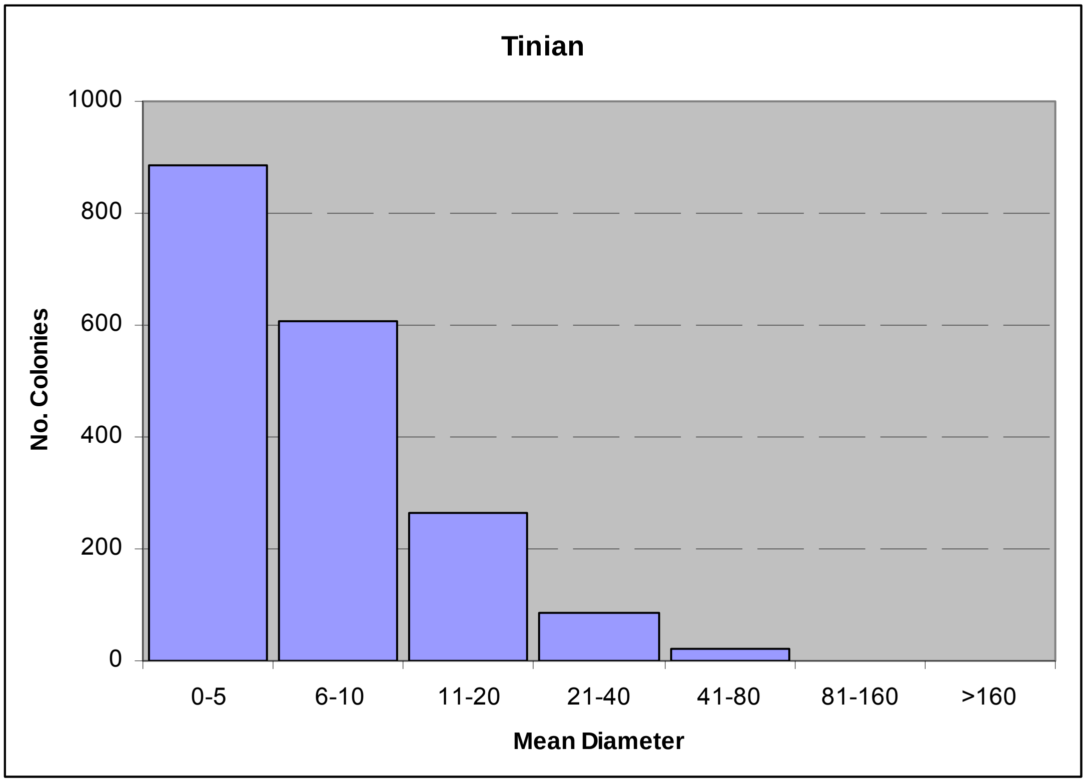


Figure E.3.2.2.2--Size class distribution of 2254 coral colonies enumerated within belt transects around Tinian in 2009.

E.3.3 Coral Health and Disease

During MARAMP 2009, occurrence of disease, predation, and other health impairments around Tinian was moderate, with a total of 80 cases enumerated. A summary of lesion occurrence and relative abundance is presented in Table E.3.3.1. The most numerically abundant type of lesion was acute tissue loss (white syndrome).These were detected in a variety of coral genera including *Porite*s, *Montipora*, *Goniastrea*, and *Astreopora*. Fungal infections and bleaching conditions were the second and third most numerically abundant type of afflictions, with a total of 18 and 11 cases tallied islandwide, respectively. Fungal infections were mainly detected on *Cyphastrea*, while bleaching affected mainly *Astreopora*, and *Leptastrea*. Lesions affecting coralline algae were relatively common, with a total of 21 cases enumerated islandwide. Two types of coralline algal diseases were observed: coralline orange lethal disease (CLOD) and the coralline white band syndrome (CLD), of which the latter was the most common.

Table E.3.3.1--Number of cases of scleractinian and coralline algal diseases and predation enumerated during REA surveys around Tinian, MARAMP 2009. ALG: algal infections, BIN: barnacle infestation; BLE: bleaching; CYA: cyanophyte infections; DIS: discolorations other than bleaching; FUG: fungal infections; HYP: hyperpigmented irritations/pigmentation response; PRE: *Acanthaster*/*Drupella* predation scars; SGA: skeletal growth anomalies; TIN: tubeworm infestation; TLS: tissue loss; WSY: white syndrome; OTH: other diseases and lesions of unknown etiology; CLOD: coralline lethal orange disease; and CLD; coralline white band syndrome/lethal disease.

DZCode	TIN-01	TIN-02	TIN-03	TIN-04	TIN-05	TIN-06	Grand Total
ALG	1	1			1	1	4
BIN		1					1
BLE	4			3	3	1	11
CYA		1					1
FUG		3		2	2	11	18
HYP						6	6
PRE				6		2	8
TIN		3				1	4
TLS	1		1				2
WSY	10			3	7	5	25
Total	**16**	**9**	**1**	**14**	**13**	**27**	**80**
CLD		10		2			12
CLOD			2	6		1	9

E.3.4 Macroinvertebrate Surveys

A total of 1312 individuals belonging to 84 benthic invertebrate target species or taxa groups were enumerated from 12 belt transects at 6 sites (Table E.3.4-1). Tinian had the second lowest densities of target species of macroinvertebrates at REA reef habitats of the southernmost Mariana Islands of Guam, Rota, Aguijan, and Tinian (156.33 organisms/50 m²for core target groups, 229.46 organisms/50 m² including sponges, vermetids, and *Spirobranchus* worms), but it had the second highest average site species richness (mean 30.67 species/site).

Small hermit crabs (e.g., *Calcinus* spp. as well as *Paguritta kroppi*) were highly abundant on Tinian reefs (46.26 organisms/50 m²), followed by vermetids (41.98 organisms/50 m²), boring urchins (31.43 organisms/50 m²), *Spirobranchus* worms (26.78 organisms/50 m²), and coral eating Coralliophilid snails (23.53 organisms/50 m²). At site TIN-02, 101 individuals per 50 m² of the species *Paguritta kroppi* were encountered inhabiting abandoned worm and vermetid tubes in corals. Again, the boring urchins were dominated by the species *Echinostrephus aciculatus*. *Echinometra mathaei* were present (2.72 organisms/50 m²), and an undescribed species of *Echinometra* was encountered at sites TIN-03 and TIN-05 (2 and 3 organisms/50 m², respectively).

Coral guard crabs of the genera *Trapezia*, *Tetralia*, and *Cymo*, associated with branching coral heads, were locally abundant only at sites TIN-01 and TIN-04 (37.5 and 20 organisms/50 m², respectively). Species of *Tetralia* and *Cymo* were not encountered at any sites on islands south of Tinian. Holothuroids were locally abundant at TIN-06, dominated by *Stichopus chloronotus* (6 organisms/50 m²). Additionally, the coral scallop, *Pedum spondyloideum*, was locally abundant at site TIN-02 (13 organisms/50 m²).

Tridacna clams were present at four out of six REA sites around Rota at a mean density of 2.9 organisms per 50 m². Tridacnids were most abundant at TIN-04 (8.89 organisms/50 m²).

Table E.3.4-1-- Densities of organisms observed at REA sites around Tinian during cruise HA0902. Sponges, vermetids, and *Spirobranchus* polychaete worms are not explicit target groups, but observations are recorded here.

Tinian Invertebrate Surveys 2009		Density (# / 50m²)						
Phylum	TaxaGroup	TIN-01	TIN-02	TIN-03	TIN-04	TIN-05	TIN-06	Tinian Mean
Annelida	*Polychaetes*		39	9	26.7	77	9	26.78
Arthropoda	*Shrimp*	16.3		10	6.66			5.49
	Hermit Crabs: Large (e.g. Dardanus sp.)	2.5	1	1	1.11	2	3	1.77
	Hermit Crabs: Small (e.g. Calcinus sp.)	31.3	119	24	43.3	25	35	46.26
	Crabs: Other Brachyurans	16.3			24.4			6.78
	Crabs: Coral Guard Crabs (Trapezia, etc)	37.5			20			9.58
Cnidaria	*Anemones*			2			1	0.5
Echinodermata	*Asteroids (Sea Stars): Other*		2	3	2.22	1	4	2.04
	Echinoids (Urchins): Boring Echinometrids	21.3	89	3	53.3	8	14	31.43
	Echinoids (Urchins): Diadematoids	2.5	1	4	2.22	5		2.45
	Holothuroids (Sea Cucumbers)	1.25		2		1	8	2.04
	Ophiuroids (Brittle Stars)	3.75			6.66			1.74
	Crinoids				4.44		10	2.41
Mollusca	*Bivalves: Tridacnids (Giant Clams)*	2.5		5	8.89	1		2.9
	Bivalves: Pteriomorphs		13	1		5		3.17
	Snails: Other	1.25	5	18	7.77	13	17	10.34
	Snails: Large (Lambids/Tritons)	1.25					1	0.38
	Snails: Coralliophilids (Coral Eating)	7.5	34	43	6.67	17	33	23.53
	Snails: Trochus	1.25	1	2			1	0.88
	Snails: Vermetids (Worm Snails)	35	94	21	68.9	29	4	41.98
	Opisthobranchs (Sea Slugs)		1	1			2	0.67
Platyhelminthes	*Polyclad Flatworms*					1		0.17
Porifera	*Sponges*			12	2.22	12		4.37
Chordata	*Ascidians*		1			10		1.83
Grand Total		**181**	**400**	**161**	**286**	**207**	**142**	**229.46**

E.3.4.1. Urchin Measurements

The test diameters of urchin species and the valve width of Tridacnid clams were recorded at REA sites around Tinian. Mean measurements by site are presented in Figure E.3.4.1-1 for species where the sample size is 5 or greater.

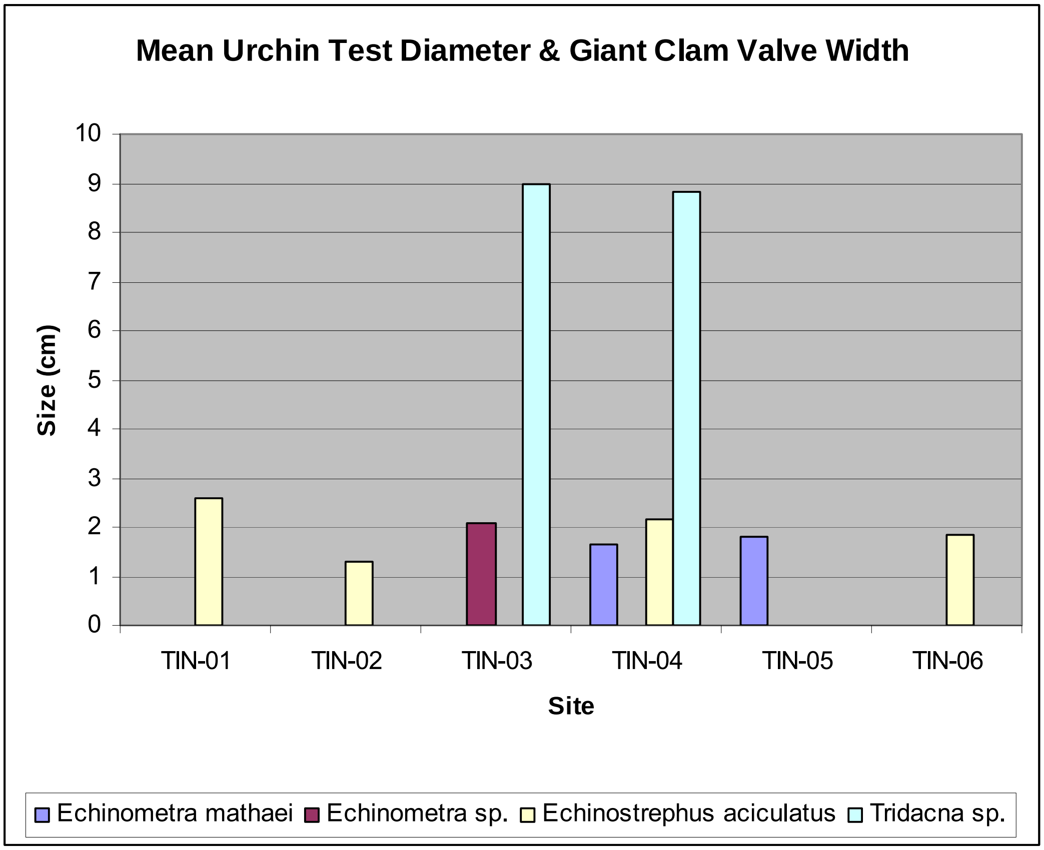


Figure E.3.4.1-1--Reveals the average test diameter of urchins and valve width of giant clams encountered at each site around Tinian. Only sites where ≥ 5 measurements were recorded for a species are represented.

E.3.3.2. ARMS Deployment

No ARMS were deployed around Tinian during HA-09-02.

E.3.3.3 Invertebrate Collections

No specimens were collected around Tinian during HA-09-02.

E.3.5 Towed-diver Benthic Surveys

Eleven benthic towed-diver surveys were completed at Tinian in 2009. Habitats covered during surveys varied with the majority of tow segments conducted over hard bottom (a mixture of continuous pavement reefs and pavement separated by thin sand channels).

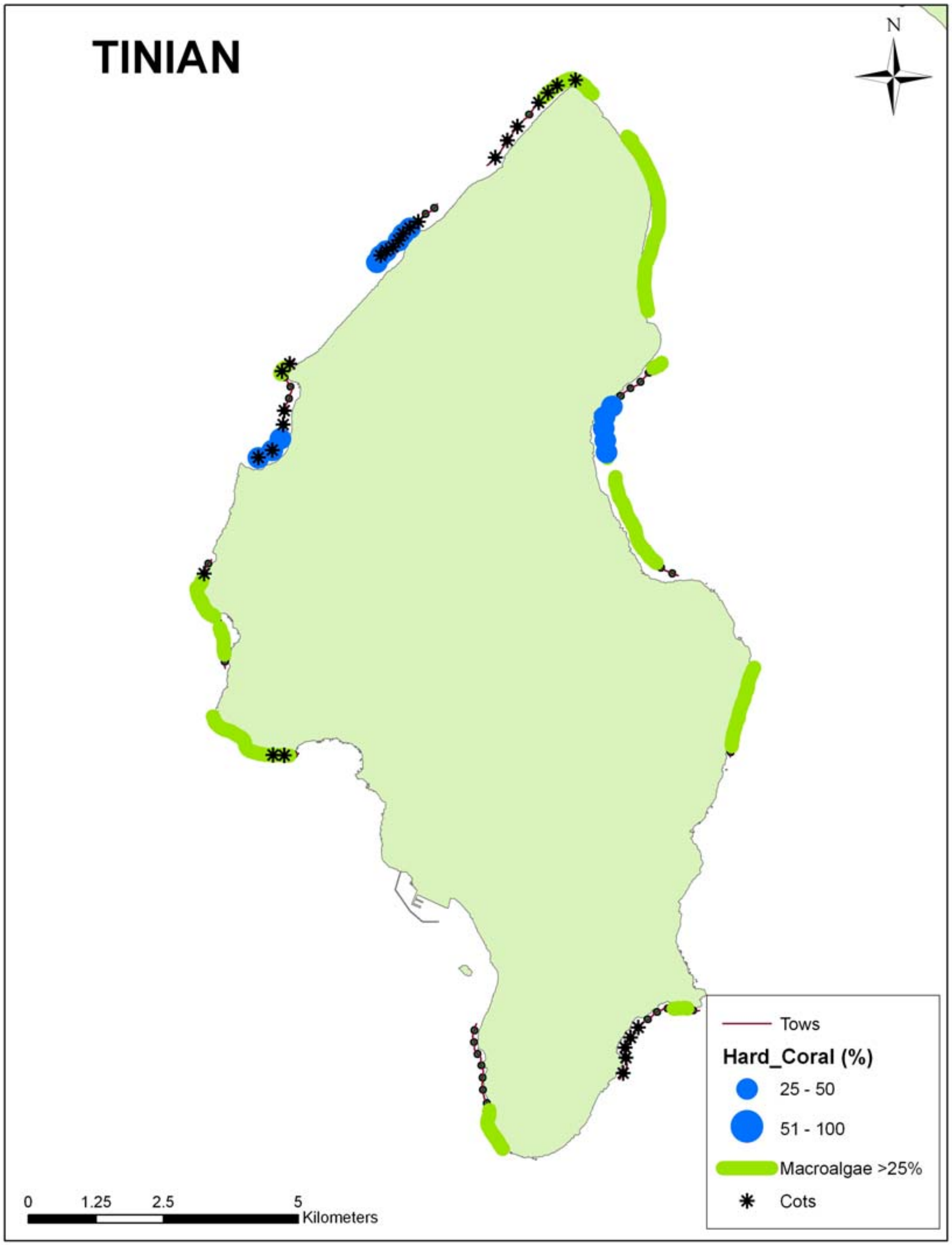


Figure E.3.5.1--Hard coral cover (≥ 25%) elevated macroalgae cover (> 25%), and COTs sightings during tow segments at Tinian in 2009.

Benthic cover around most of Tinian was dominated by macroalgae. Three localized areas of elevated coral cover were also noted with massive *Porites* and *Porites rus* most common. The most ubiquitous macroalgal species were *Halimeda*, *Microdictyon*, and *Padina*.

Benthic Category	Mean ± SE
Hard Coral	9.3 ± 0.9
Soft Coral	1.3 ± 0.2
Macroalgae	30.4 ± 1.9
Coralline Algae	4.1 ± 0.5
Sand	4.2 ± 0.7
Rubble	1.6 ± 0.4
COTs	60
Free Urchins	2
Boring Urchins	13585
Sea Cucumbers	588
Giant Clams	57

* Sum of observed individuals

Boring urchins were the most common macroinvertebrate with sea cucumbers and giant clams also common but in much, much lower densities. COTs were most common in the northwestern region of Tinian, but were found in low densities in most areas.

E.4 Fish Surveys

E.4.1 REA Fish Surveys

Stationary point count data (SPC)

During the survey period, SPC surveys were conducted at 14 sites around Tinian. Surgeonfish were the largest contributor to total biomass with 1.0 kg 100 m^{-2}. Damselfish were the second largest contributor to total biomass with 0.21 kg 100 m^{-2}, followed by parrotfish at 0.18 kg 100 m^{-2} (Fig. E.4.1.1).

Overall observations

A total of 202 fish species were observed during the survey period by all divers. The average total fish biomass around Tinian during the survey period was 2.0 kg 100 m^{-2} for the SPC surveys (Fig. E.4.1.1).

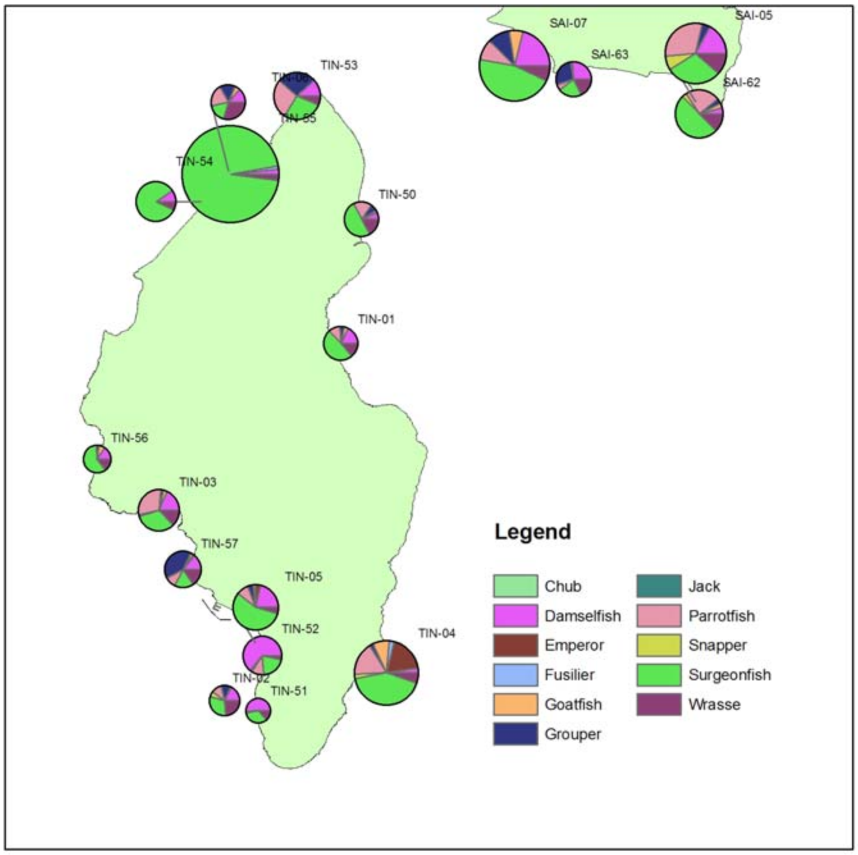


Figure E.4.1.1--Site location and distribution of total fish biomass by family. The sizes of the pie chart are proportional to fish biomass.

E.5.2 Towed-diver Fish Surveys

During HA0902, the CRED towed-diver team completed 11 surveys at Tinian covering 25.87 km (25.87 ha) of ocean floor. Mean survey length was 2.4 km with a maximum length of 3.6 km and a minimum of 1.7 km. Mean survey depth was 15.1 m with a maximum depth of 20.1 m and a minimum of 13 m. Mean temperature on these surveys was 28°C with a maximum temperature of 28.1°C and a minimum of 27.8°C.

Fifty-four individual large-bodied reef fish (> 50 cm TL) of 17 different species and 12 different families were encountered at Tinian (Table E.4.2.1). Overall numeric density for this class of reef fishes was 0.209 #/100 m^2 (20.876 #/ha) with a biomass density of 0.811 kg/100 m^2 (0.081 t/ha) (Figs. E.4.2.1 and E.4.2.2). Numeric density was dominated by *Caranx sexfasciatus*, while biomass density was dominated by *Triaenodon obesus.*

The most prevalent families, in terms of numeric and biomass density, were Lutjanids (ND=28%) and Carangids (ND=20%) (Fig. E.4.2.1), while biomass density was dominated by Myliobatids (ND=21%), Carcharhinids (ND=21%) and Lutjanids (ND=19%) (Fig. E.4.2.2).

Biomass of large bodied reef fish appeared to be distributed fairy evenly around the island. (Fig. E.4.2.3).

Table E.4.2.1--Species numeric and biomass density for large-bodied reef fish (> 50 cm TL) observed at Tinian during HA0902 CRED towed-diver surveys.

Species	#	#/100m2	#/ha	Biomass (kg)	kg/100m2	t/ha
Lutjanus_bohar	10	0.039	3.866	30.08052745	0.116	0.012
Caranx_sexfasciatus	10	0.039	3.866	23.43093521	0.091	0.009
Diodon_hystrix	5	0.019	1.933	16.12400722	0.062	0.006
Triaenodon_obesus	4	0.015	1.546	44.78573826	0.173	0.017
Aetobatus_narinari	3	0.012	1.160	44.63375317	0.173	0.017
Scarus_rubroviolaceus	3	0.012	1.160	7.81192215	0.030	0.003
Lethrinus_olivaceus	3	0.012	1.160	6.13803216	0.024	0.002
Aprion_virescens	3	0.012	1.160	5.52037275	0.021	0.002
Aulostomus_chinensis	3	0.012	1.160	0.76553122	0.003	0.000
Gymnosarda_unicolor	2	0.008	0.773	3.95925036	0.015	0.002
Macolor_niger	2	0.008	0.773	3.625	0.014	0.001
Arothron_stellatus	1	0.004	0.387	9.38244579	0.036	0.004
Caranx_melampygus	1	0.004	0.387	3.61279588	0.014	0.001
Naso_tonganus	1	0.004	0.387	2.8253447	0.011	0.001
Chlorurus_microrhinos	1	0.004	0.387	2.5950442	0.010	0.001
Hipposcarus_longiceps	1	0.004	0.387	2.475	0.010	0.001
Variola_louti	1	0.004	0.387	2.07660175	0.008	0.001
Grand Total	54	0.209	20.876	209.842	0.811	0.081
# of Species	17					

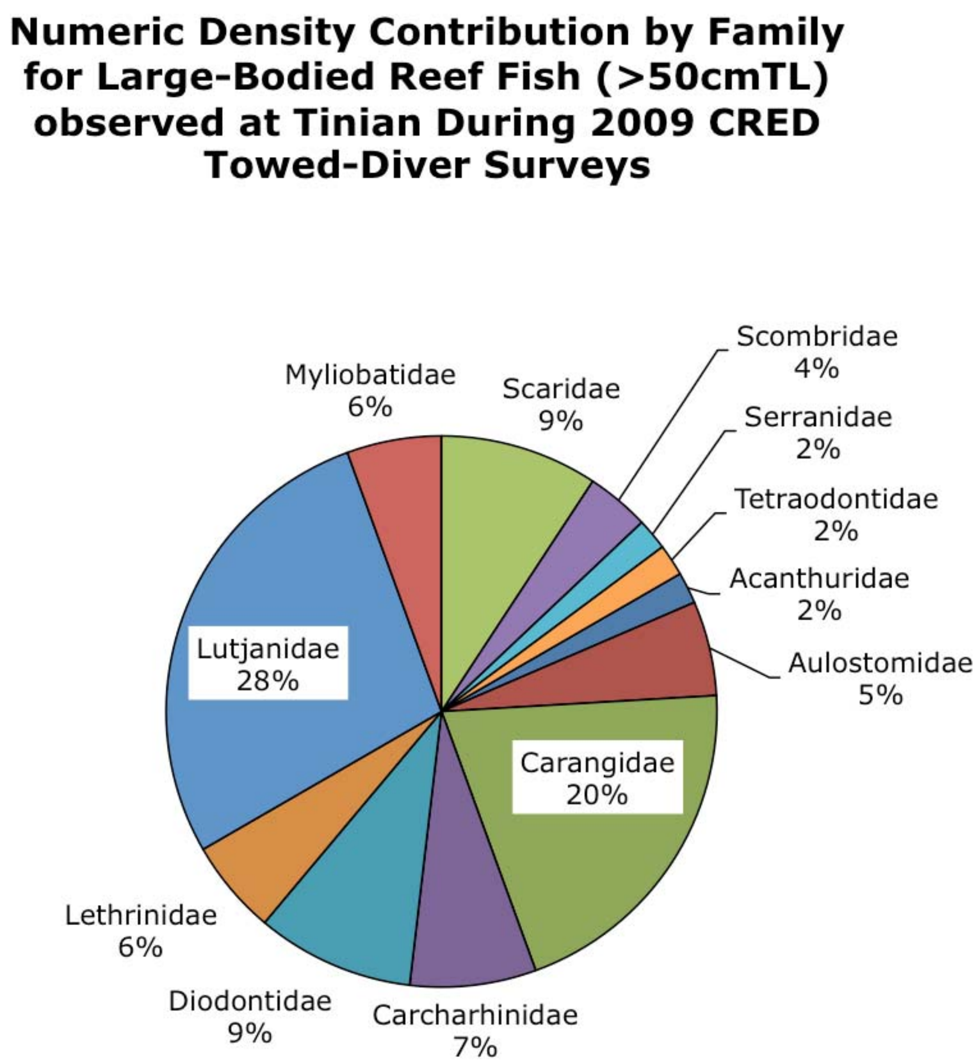


Figure E.4.2.1 Numeric density by Family

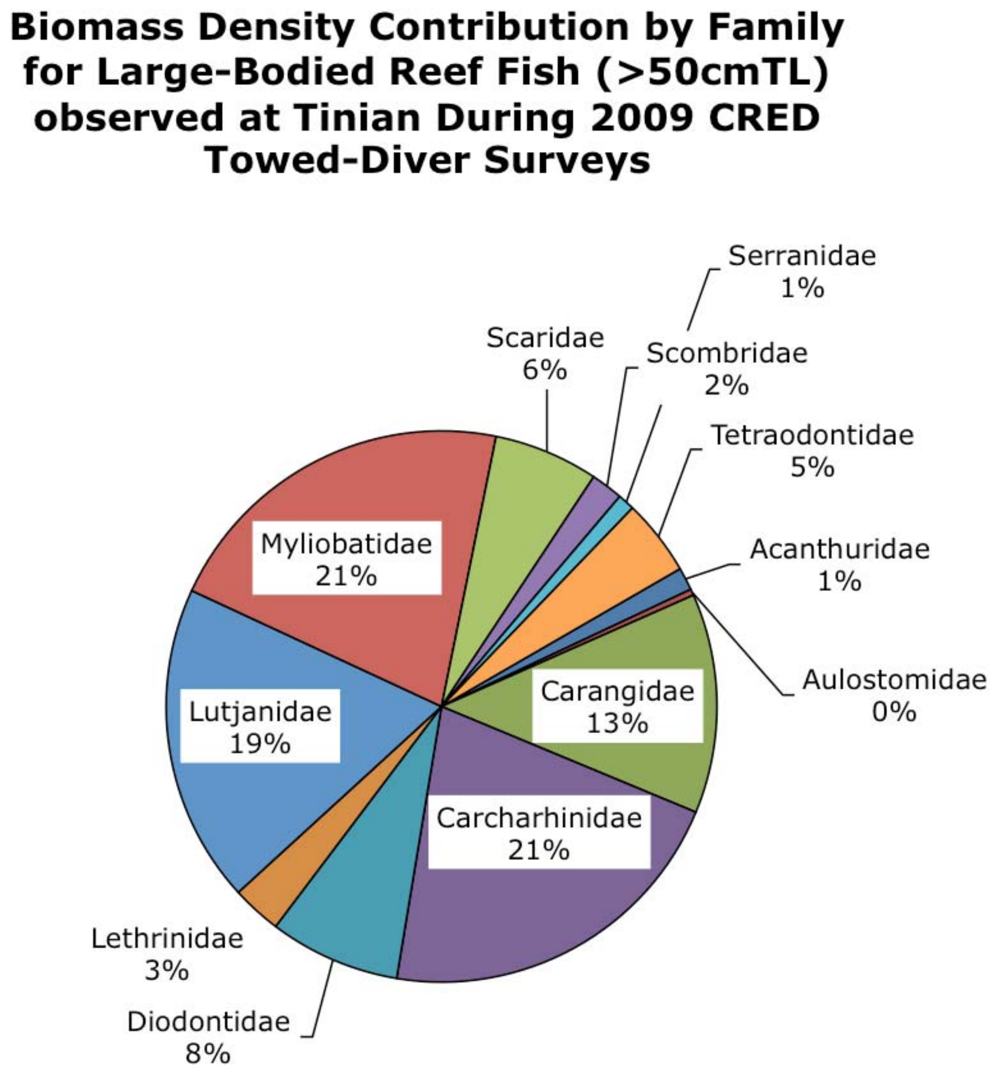


Figure E.4.2.2--Biomass density by Family.

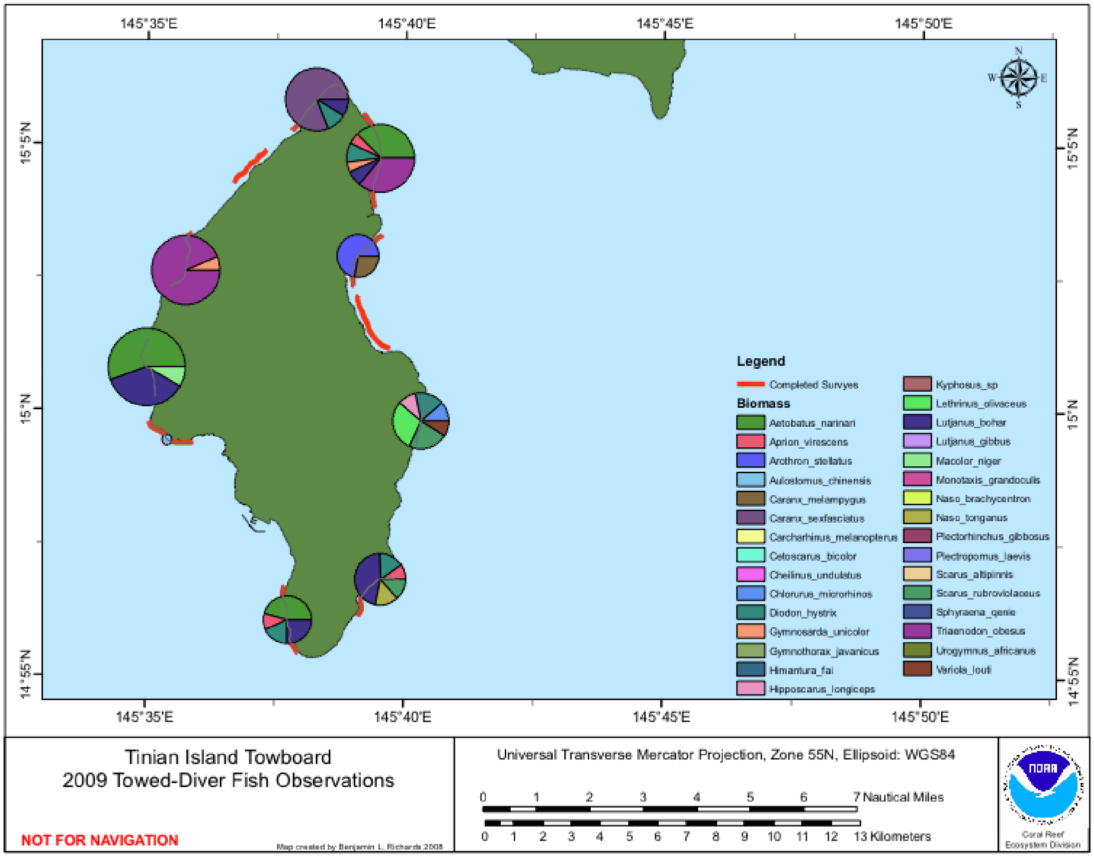


Figure E.4.2.3--Geographic distribution of biomass around Tinian. Each species is represented by a legend color. Diameter of pie chart is proportional to total biomass of all species encountered on the underlying survey.

Appendix F: Saipan

Details of the first survey day (14 April 2009) at Saipan are included in the report for the subsequent N-MARAMP cruise (HA0903), during which time most of this island was surveyed.