Marianas Expedition Wildlife Surveys 2010

Long Beach, July 2010 (photograph by Tom Schils)

Marine Resource Surveys of Pagan,
Commonwealth of the Northern Mariana Islands
(Volume I of II)

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Marine Resource Surveys of Pagan,
Commonwealth of the Nothern Mariana Islands
(Volume I)

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1.0 Introduction

1.1 Proposed Action

During a recent review of its worldwide defense strategy, the Department of Defense (DoD) developed a new national security initiative to relocate U.S. Marine Corps (USMC) Forces from Okinawa, construct berthing for visiting aircraft carriers, and establish a U.S. Army Ballistic Missile Defense Task Force in the Mariana Islands (Department of the Navy 2008). The DoD foresees that these actions, proposed to occur over the four-year period between 2010 and 2014, will increase the military role of the Territory of Guam and the Commonwealth of the Northern Mariana Islands (CNMI), support U.S. alliance commitments, and strengthen U.S. national security.

Guam and the CNMI are geographically part of the Mariana Islands (Marianas) archipelago (See Figure 1.2.1 in Section 1.2). Guam and the CNMI represent the westernmost portion of the United States and are ideally located to support national security requirements in the region (Department of the Navy 2008).

The Department of the Navy (Navy), as the lead DoD agency for the project, proposes to develop and construct additional facilities and infrastructure on Guam and the CNMI to accommodate the proposed DoD initiative. As currently proposed, the primary facilities to accommodate the 12,849 Marines and 10,350 dependents from Okinawa will be constructed on Guam, and new training activities and associated facilities would be located in the CNMI, primarily on Tinian (Department of the Navy 2008). Additional training activities (non-firing and firing) have been proposed to occur on the island of Pagan. Training areas on Pagan would include weapons ranges (pistol, machine gun, mortar, and artillery ranges), vehicle ranges, and areas for embarkation and amphibious training. Two beaches on western Pagan and two beaches on eastern Pagan are under consideration for amphibious training activities (See Figure 1.2.2 in Section 1.2). After arriving on site in July 2010, the boundaries of the western beaches were changed from two to three to reflect three different beach approaches and three different marine habitats (See Figure 1.2.3 in Section 1.2). The southern end of Pagan would receive discharged materials from the weapons ranges, with the potential for these materials to land in the nearshore coastal environment. These six regions are discussed for evaluation in this report.

1.2 Survey Objective at Pagan Island

In support of the Navy planning effort and to foster a stronger partnership among DoD, federal regulatory agencies and the CNMI government, the U.S. Fish and Wildlife Service (USFWS), in coordination with the Navy, National Oceanic and Atmospheric Administration (NOAA), CNMI Coastal Resource Management Office, CNMI Division of Environmental Quality, CNMI Division of Fish and Wildlife, and the University of

Guam, agreed to conduct marine resource surveys on Pagan within the area of potential impact for the proposed DoD actions. The purpose of the surveys was to provide estimates of taxonomic diversity and abundance of both benthic and pelagic marine resources on reef flats and fore reef slopes (at depths <10 meters [m]) in the vicinity of the proposed amphibious landing beaches and the coastline along the firing range outfall zone.

The Navy requested that the surveys yield data on Pagan marine resources that could be used to help describe the environment that would be affected by the proposed DoD actions. While this report does not include an impact assessment of the proposed DoD action, it was the intention of the USFWS and its partners to obtain qualitative and quantitative data on the shallow coral reef communities that would facilitate a future impact analysis. In addition, the surveys were not designed to provide data for use as part of a short- or long-term monitoring effort. However, the surveys should provide relevant baseline information that would aid in the future development of a scientifically and statistically rigorous monitoring effort.

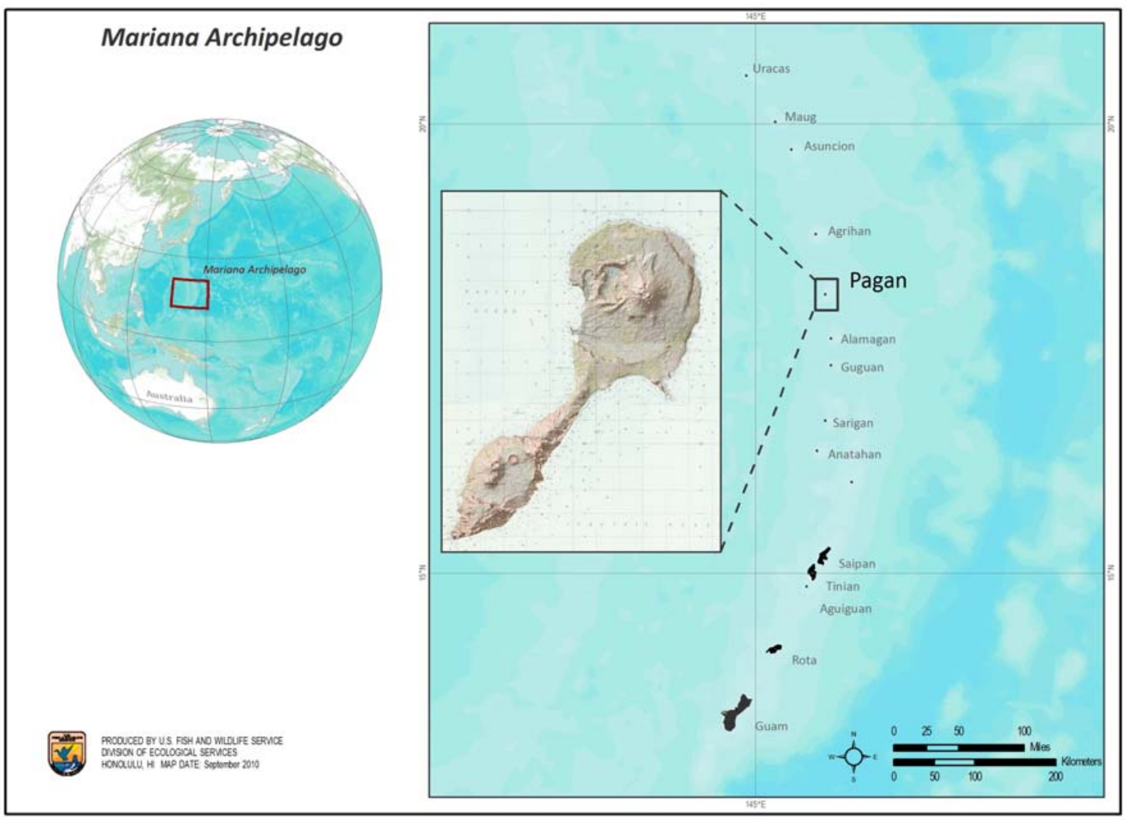

Figure 1.2.1. Geographic location of the Mariana Islands chain and Pagan Island.

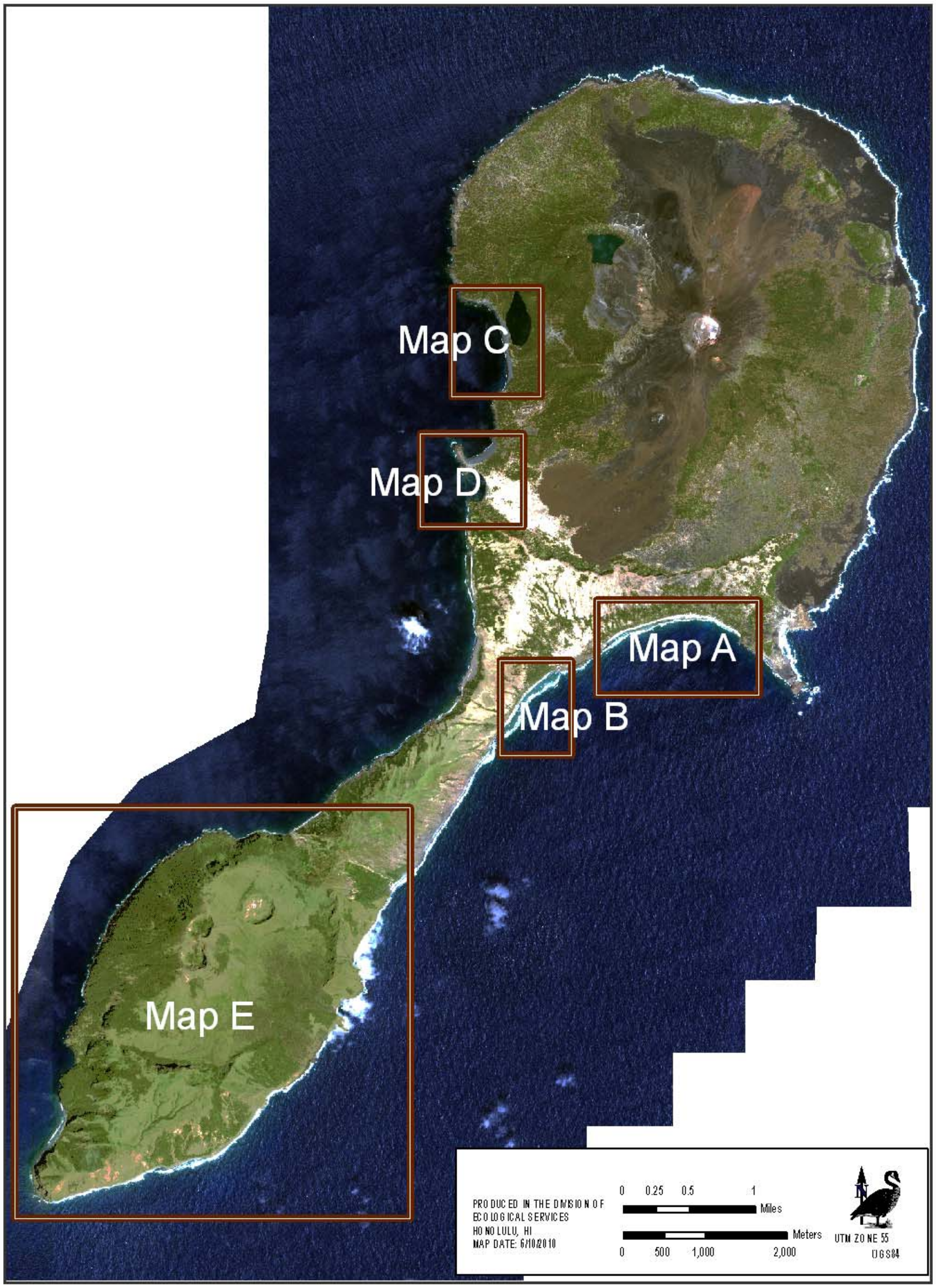

Figure 1.2.2. Geographic location of the five proposed survey areas around Pagan Island, June 2010.

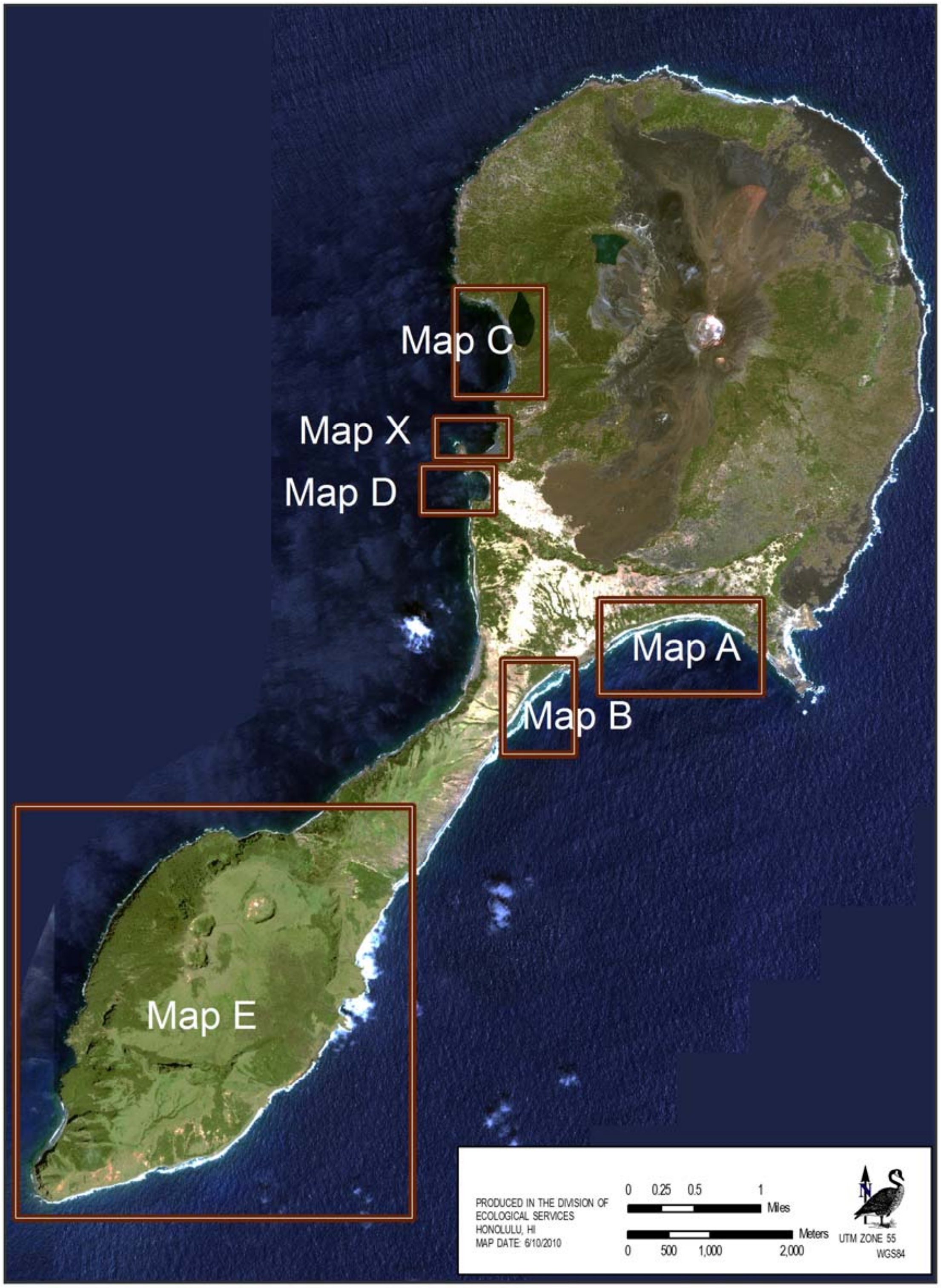

Figure 1.2.3. Geographic location of the six survey areas after arrival on Pagan Island, July 2010.

2.0 Pagan Coral Reefs

2.1 General Information

Pagan is located approximately 521 kilometers (km) north of Guam and 320 km north of Saipan at 18° 6′ 0″ N latitude and 145° 45′ 36″ E longitude. Pagan extends for 17 km north to south and is 7 km across at is widest point. At 47.75 km² in size, Pagan is the fourth largest island in the CNMI (Bearden *et al*. 2005). The last U.S. Census reported no residents (U.S. Census Bureau 2001). It consists of two stratovolcanoes joined by a narrow strip of land. The stratovolcano at the northeast end of the island, Mount Pagan, has an altitude of 570 m; the other, at the southwest end is 548 m high. Volcanic activity on Pagan has been recorded fairly regularly since the 17th century, with all of the verified activity originating from Mount Pagan volcano (Smithsonian 2009). The last major eruption occurred in 1981 and forced the evacuation of all of its inhabitants. At the time of the marine surveys, Mount Pagan was active, with plumes of steam and ash visible daily. The marine survey teams worked in an ash outfall zone in Map C (Figure 1.2.2) on the western coast of Pagan Island.

Pagan Island was included during Operation Christmas Drop 2006. A United States Air Force C-130 aircrew observed cattle and a small cluster of buildings, including a grass airstrip, located on the island. There have been no additional permanent structures added to the island since that observation.

Reef formations within the Marianas are believed to be geologically young, and their varied geomorphology is thought to be a result of their geological history and exposure to a variety of environmental disturbances (Randall 1985). Composed primarily of lava flows and deposits from eruption events, Pagan has no permanent rivers. Two lakes, Laguna Sanhalom and Laguna Sanhiyan, hold the only non-stream water present in the northern islands of the CNMI (Smithsonian 2009). Although much of the Pagan coastline is rocky, several beaches allow access to the northern part of the island.

Four distinct geomorphological reef types, with significantly different coral assemblages, have been identified (Houk and van Woesik, unpub. data): (1) Holocene “spur and groove,” which support high coral densities, species richness and large colony size; (2) Holocene high-relief, which support low coral species richness and high intra-site variation; (3) Holocene low-relief, which have low species richness and few large corals but many small corals; and (4) Pleistocene basement, which supported few corals and little 3-dimensional relief.

Considerable information exists concerning the nearshore fisheries and coral reef resources in the CNMI, including surveys conducted by the Mariana Achipelago Reef Assessment and Monitoring Program (MARAMP). Much of this information has been summarized by NOAA in an effort to create GIS-based maps of Pacific Island coral reef resources. However, in relation to specific USMC training activities being considered within the proposed project area, the resolution of these data is coarse and site-specificity is relatively low. Marine biological diversity in the Mariana Islands is high, with over 5,400 marine species documented from the archipelago (Paulay 2003). However, few comprehensive taxonomic marine surveys have been conducted on Pagan (see: Tsuda and Tobias 1977a, Tsuda and Tobias 1977b, Randall 1995, Donaldson *et al*. 1994, Donaldson 1994, Vermeij *et al.* 1983, Tribollet and Vroom 2007), and no surveys have been conducted specifically within the shallow reef areas proposed for this DoD action.

2.2 Western Beaches

Laguna Bay (Map Area C), Bandeera Bay (Map Area D), and Katchu Bay (Map Area X) (Figure 1.2.3.) have been identified by DoD for use in amphibious training exercises. All three beaches are located on the northern half of Pagan. The coastline in this region is characterized by raised basalt flows resembling low cliffs in some areas, basalt boulders, small embayments and a few small beaches. Shore access to the ocean is not limited and in most places along this coast no distinct reef flats exist. Instead the substratum is mainly composed of black sand or pavement and drops quickly into steep spur and groove formations.

Map Area X (Katchu Bay) (Figure 2.2.2) used to have a permanent pier structure, pieces of which are lying on the bottom. Surface bouys currently mark this area and quatititive data was collected at a random survey point that crossed the old pier location.

The NOAA Coral Reef Ecosystem Division Division (CRED) recently released preliminary data from their 2003, 2005, and 2007 Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP) research cruises (Brainard *et al*. 2008). Some of these data were collected during towed diver surveys and Rapid Ecological Assessments (REAs) conducted along the coastline of Pagan. None of these data were collected specifically at the relatively shallow areas (<10 m), that are anticipated to be affected by the proposed USMC training activities.

Both green sea turtles (*Chelonia mydas*) and hawksbills (*Eretmochelys imbricata*) are known to occur in the Mariana Islands, but no recent reports of hawksbills have been made for Pagan. Green sea turtles were observed by multiple researchers and base camp staff during Summer 2010. Map Area D (Figure 2.2.1.) has 3 resident green sea turtles on the south side of the bay entrance.

Figure 2.2.1. Aerial view of Map Area D, Bandeera Bay. Coral reef resources are visible throughout and at the mouth of the bay. Pagan Island, July 2010. (Photos: T. Schils)

Figure 2.2.2. Aerial view of Map Area X, Katchu Bay. Yellow oval in top picture shows surface buoys marking section of the old pier. Pagan Island, July 2010. (Photos: T. Schils)

2.3 Eastern Beaches

The eastern beaches, Long Beach (Map Area A) and Map Area B (Figure 2.3.1.), were not surveyed in July 2010, due to unsafe survey conditions, but have been identified by DoD for use in amphibious training exercises. Both beaches are located along the southern half of Pagan, below the southern boundaries of Mount Pagan. The coastline along this region varies: 1) spur and groove formations begin immediately in the submerged coastline past Map B and south to South Point and, 2) the selected beaches are not contained in protected embayments as on the western coast. Shore access to the ocean is limited due to large reef benches/platforms that are exposed at low tide and that drop quickly to deep depths beyond the outer reef flat margin. There is a distinct intertidal zone that was exposed for extended periods. Large swells and a rough surf zone caused by strong onshore winds can be seen in Figures 2.3.1. through 2.3.4.

Both green sea turtles (*Chelonia mydas*) and a large pod of spinner dolphins (*Stenella longirostris*) were spotted in the vicinity of Map Area B on July 16, 2010, during the flyover.

Figure 2.3.1. Aerial view of Long Beach (Map Area A) on eastern shore. Boundary of reef platform and intertidal zone is visible in bottom photograph. Pagan Island, July 2010. (Photos: T. Schils)

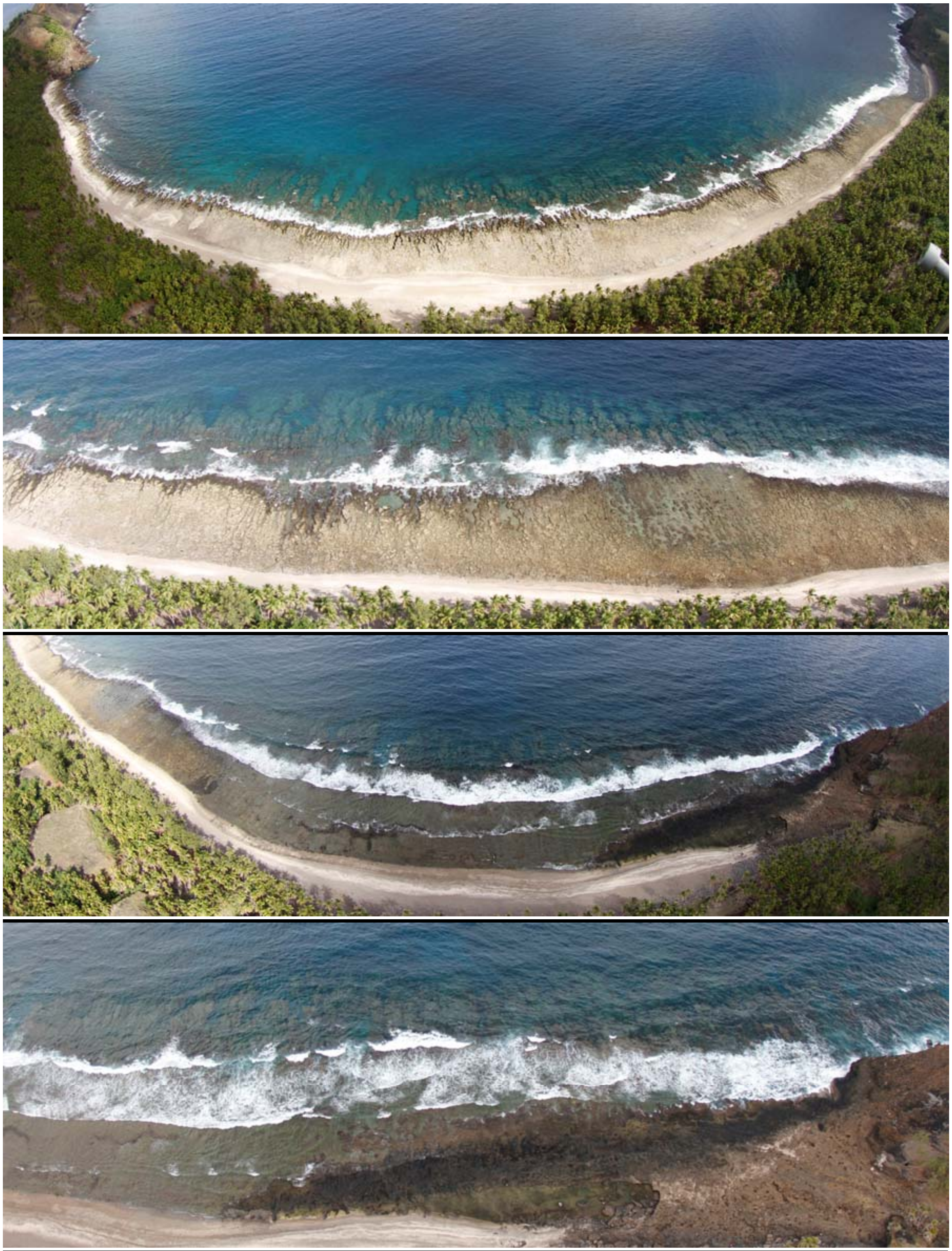

Figure 2.3.2. Aerial views of Long Beach (Map Area A) on eastern shore. Pagan Island, July 2010. (Photos: T. Schils)

Figure 2.3.3. Aerial views of Map Area B on eastern shore. Yellow oval indicates old bunker. Pagan Island, July 2010. (Photos: T. Schils)

Figure 2.3.4. Aerial views of Map Area B on eastern shore. Southern end of beach. Pagan Island, July 2010. (Photos: T. Schils)

3.0 Survey Design and Sampling Methodology

The sampling methodologies employed during the surveys were developed through an iterative process involving marine resource specialists within the partner agencies. Relevant attributes of the coral reefs at the survey sites were identified and appropriate methodologies needed to describe these attributes were developed by considering the scientific literature, and methodologies currently in use among the partner agencies. A final list of data needs and methods were agreed upon in June 2010 by all members of the working group prior to starting field surveys. A survey plan ("Marine Survey Design and Methodologies for Pagan, Commonwealth of the Northern Mariana Islands (CNMI)") was developed and is included in this report in Appendix A.

3.1 Survey Design

3.1.1 Basic Design

Five geographical areas were identified by the working group as areas of potential impact. Under the proposed action (Department of the Navy 2008), Map Areas A-E (Figure 1.2.2.) were under consideration for use in amphibious training operations. Upon arrival on Pagan, the beaches were divided into 6 regions (Figure 1.2.3). Three beach areas (Map Areas C, D and X) were the focus of the surveys conducted in July 2010. A few sites were attempted in Map Area X, on the western half of the coastline.

At each of the beaches, the area of potential impact was delineated using the shore line and the 10-m depth contour as east and west boundaries. In the planning period, a stratified random design, with two strata (reef flat and reef slope) was used to determine sample sites at each beach area. Survey areas were stratified by reef zones to account for differences between the reef flat and reef slope coral communities typical of Pacific coral reefs. Satellite images were inititally used to estimate the location of reef flats and reef slopes before survey points were randomly generated. Upon arrival on Pagan, the survey team had to readjust the sampling design due to the lack of a distinct reef flat in the attempted areas and depths.

Before arrival on Pagan, minimum targets for the number of benthic and reef fish sites to survey were calculated from data supplied by the CNMI Long-term Marine Monitoring Program and Division of Fish and Wildlife (Appendix A). Because adequate data were not available from Pagan, data from similar reef environments on Saipan were used to estimate the spatial and temporal variability of the abundance of invertebrate and fish taxa. These data were collected from monitoring sites along the leeward coast of Saipan over multiple years and represented the best available information on the spatial and temporal variability of the CNMI's coral reefs. These variability estimates were then used to calculate the sample size necessary within each of the Pagan survey areas needed to achieve a desired level of precision about a mean (±5% of the mean). For most taxa, this level of precision was unrealistic given the time and resources available for the surveys, so precision was maximized for coral and fish taxa (see Appendix A).

3.1.2 Selecting Survey Locations

Planned Design: For the western beaches, planned sampling design involved generating a random list of 100 potential survey sites using Geographical Information System (GIS) technology. Survey sites would be visited in the order in which they were drawn, and sites would be surveyed if they met the following three conditions:

1. Ocean conditions allowed the survey site to be sampled safely by divers
2. Survey site was <30 ft deep
3. Survey site was on hard reef bottom type

If a survey site failed to meet any of these three conditions, it would be discarded and the next sequential site would be selected for consideration.

Implemented Design: At the time of the survey, the sampling design was modified slightly and sites were randomly selected by survey teams when field work commenced so that spatial distribution could be maximized across all areas. (See 3.1.3. Adjustments to Survey Design and Data Collection) Western Pagan sites were surveyed if they met the following three conditions:

1. Ocean conditions allowed the survey site to be sampled safely by divers
2. Survey site was <30 ft deep
3. Survey site was less <50% sand, estimated from the surface

If a survey site failed to meet one of these conditions, it was discarded and the next sequential site was selected for consideration.

3.1.3. Adjustments to Survey Design and Data Collection

Adjustments to the survey plan and data collection were made after arrival on Saipan and Pagan due to unforeseen circumstances, including injuries. The approved dive schedule was initially altered in Saipan before departure, due to a change in the schedule of the *Micronesian*. All of the marine survey biologists met at the USFWS warehouse facility on Saipan to reorganize the data collection plan based on two less field days on Pagan.

Upon arrival on Pagan, the survey team learned of mechanical problems with the boats that were to be used for the marine surveys. One boat had a badly cracked transom, the other had problems with the throttle and incorrect wiring for the computer system. A third boat had to be used to carry SCUBA tanks only due to overweighting and to serve as a "tug" in case one of the other boats needed to be towed back in. Radio contact was maintained at all times and the boats had to remain within visual distance of each other. This severely limited the number of sites that could be sampled per day, as the boat with the fish team had to remain close to the boat with the benthic team. The mechanical problems also limited the distance that could be traveled. Attempts were made to transit to the eastern side of the island to Maps A and B via the southern route, but all failed. Mechanical problems, combined with swell, high winds, lightning and heavy rain, injured divers, and logistics of getting all divers and all equipment to the eastern coast and back safely led to a group decision to abandon sampling in Maps A and B. One day of sampling in either of those areas would not have provided enough data for analysis. With an already shortened schedule, the decision was made to concentrate survey methods on the western side of the island where practice amphibious landings and beach entries were more likely to occur.

The team did consider entering the beaches on Maps A and B by land and conducting shallow surveys. Tanks would have to be brought over from the western side of the island which meant multiple entries and exits across the uneven reef bench and heavy surf zone to switch out tanks. The transport time alone for biologists, equipment and gear, tanks, and support personnel would be approximately 5-6 hours per day. Filling the SCUBA tanks every afternoon via two air compressors took an additional 3 hours daily. There would be insufficient time every day to complete work in the water. It was proposed that a temporary camp be set up on the eastern beaches, however, that would involve moving the air compressors used for filling the SCUBA tanks and setting them up again on the beach. Then they would have to be moved back to base camp and set up again. Drinking water, gear rinsing water, food and charging capabilities for equipment would also need to be considered. Two additional in water days would be lost if that option was chosen.

Our recommendation for a future attempt of conducting surveys on the eastern side of the island would be to use a live-a-board vessel and dive directly off the vessel. Also diving earlier in the year (April or May) may avoid some of the high winds and swell that are associated with the summer months.

Though random sites had been generated before arriving on Pagan (Figures B.1. to B.6), it was decided that the approach needed to be modified slightly in order to maximize available survey time. Therefore, surveys sites were randomly selected by the survey teams at Pagan. An important consideration in the sample design was made to avoid dividing the western beaches into reef flat and reef slope zonations since collecting data at the the proposed number of sites for each strata would be problematic. After the first day in water, quantitative data was only collected by the fish team at one site because bottom type at all of the sites attempted was sand. Also, another important consideration was made when it was determined that a large number of survey sites had greater than 75% sand cover. By using the new method, all of the sand sites were still recorded but time was not wasted in the collection of quantitative baseline data.

Site selection was then approached in the following manner. A scouting trip was taken to each area C, D (later divided into D and X) and E. The two teams divided the task and visited all of the random generated points possible (some were on land or in the case of Map E, only the western points were attempted) and collected qualititative information. A pre-loaded GPS unit was used to locate each random point. One biologist would describe the bottom type/community while another would use the fathometer to estimate depth at that random point. A third biologist attempted to take an underwater photograph of the site if visbility allowed. The information collected is listed in Appendix C, Table C.1. "Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E and X)". It lists data collected for 200+ random points in the areas attempted. From this list, lower numbered sites were attempted first in numerical order (*i.e.*, 1, 2, 3, 4). If a site from the scouting activity was characterized as having a sand bottom or having a depth greater than 10m (~33 ft), it was skipped and the next number was selected. A few sand sites were included in the data collection in order to exclude bias by bottom type. The scouting activity maximized the amount of time spent on quantitative data collection as well as providing insight into the bottom substrate types on the western coast. This information can be used as guidance in the future when planning in-water activities.

3.2 Sampling Methods

3.2.1 Transects

Survey sites were located with a Global Positioning System (GPS) unit and marked with a surface float. Benthic transect lines (25-m long) were deployed along the depth contour starting at the anchoring point of the float line. The transect line was draped along the reef substratum to capture bottom irregularities. If there was no discernable depth contour, the transect line was laid approximately parallel to shore starting from the anchoring point of the float line. All reef fish, algal, coral and non-coral invertebrate sampling was conducted along the same benthic transect. Emphasis was given to identifying conspicuous diurnally active species. As a result, small, cryptic, and nocturnally active species are under represented in the data.

3.2.2 Algal Survey Methods

Six haphazardly placed 0.5 x 0.5 m quadrats were surveyed along the 25-m benthic transect line. Within each quadrat, the percent cover of all benthic taxa was visually estimated to the nearest 1 percent cover by a trained phycologist with significant experience in the Mariana Islands. Taxa that were rare were assigned a cover of <1 percent.

Algae were identified to the lowest possible taxonomic level and, as necessary, specimens were collected to confirm field identifications in the laboratory. Non-algal taxa were also identified to the lowest possible taxonomic level, but it was generally not possible to achieve the same level of taxonomic resolution as with the algae. Non-algal specimens were not collected.

3.2.3 Coral Survey Methods

Coral surveys were conducted along the 25-m benthic transect line. All coral colonies within one 5 x 1 m belt transect along the benthic transect line were identified to the lowest possible taxonomic level (generally species), and the longest dimension of each colony was measured by coral taxonomists with considerable experience in the Mariana Islands.

Each colony that had undergone complete fission was noted, sized as if the colony were whole across parts and its percent of live/dead tissue visually estimated. Fission is partial mortality of a coral colony that results in separation of a colony into pieces that are genetically identical (*i.e.*, ramets) and remain attached to the substratum. Unattached fragments were also noted and sized separately.

Photographs taken perpendicular and 1 m above the substratum were taken every meter along the entire length of the 25-m transect line. These photos were not analyzed for this report, but would be suitable for estimating planar percent cover. The photos have been archived in electronic format and are available upon request.

3.2.4 Fish Survey Methods

Fish surveys were conducted along the 25-m fish transect line by divers with taxonomic expertise in Mariana Islands coral reef fish. All reef fish within 5 m of the transect line were identified to the lowest possible taxonomic level (generally species) and their total length visually estimated to the nearest centimeter. These data are referred to hereafter as belt transect data.

One stationary point count (SPC) survey was conducted near the end point of the transect line. All reef fish >20 cm in total length within a 10 m radius of the diver were identified to the lowest possible taxonomic level (generally species) and their total length estimated to the nearest centimeter. Fish were identified and counted for eight minutes during each SPC survey.

In some situations (*e.g.*, a large school), it was difficult to estimate the length of all fish to the nearest centimeter. In these cases, fish were assigned to pre-determined size categories. Additional fish taxa not observed during the belt transect or SPC surveys were noted throughout the dive to help provide a complete taxa list at each survey site.

3.2.5 Non-Coral Invertebrates Survey Methods

Non-coral invertebrate surveys were conducted along the 25-m benthic transect by a diver with taxonomic expertise and experience with Mariana Islands invertebrate fauna. All unattached non-coral macro-invertebrates were identified to the lowest possible taxonomic level along a 25 x 4 m belt transect. The bottom was not disturbed during the surveys, but crevices and the entire surface of boulders were visually searched for non-coral invertebrates. At some sites, the cyanobacteria layer was brushed away on rocks and boulders in order to view the invertebrates (coral and non-coral) underneath.

Ten 1 x 1 m quadrats were surveyed along the 25-m benthic transect line. Quadrats were distributed along the entire length and to both sides of the transect line. To reduce selection bias, quadrats were tossed by the diver away from the line and allowed to land on the substratum. Within each quadrat, the presence/absence of all non-coral macro-invertebrates was recorded. At some sites, all sessile organisms, including algae and coral, were identified. These additional data were not consistently collected at all survey sites. With the changes encountered in the survey plan and changes in the survey teams due to injuries, the quadrat method was no longer used after the first 4 days of data collection. Instead, all sessile organisms were identified within the 25 x 4 m belt transect.

3.2.6. Rugosity Survey Methods

A light brass chain marked at 1-m intervals was draped over the bottom along a 10-m section of the fish transect line. An index of rugosity was calculated by dividing the total length of chain draped over the reef surface by the linear distance between the two end points of the chain, in this case 10 m (McCormick 1994). For this index, a value of one indicates a flat bottom. Higher index values correspond with increased bottom rugosity.

4.0 Results

A total of 41 sites were surveyed along the western coastline. (Table 4.1) The minimum target survey goals that were set during the planning period (Appendix A) were reached for each area except Maps A, B and E. An eastern swell made accessing and surveying the eastern sites hazardous during the time of the surveys. Swells were large enough to toss divers on the reef platform, causing injury, and made data collection unfeasible due to the inability of the vessels to travel to the eastern side of the island. GPS coordinates, survey dates, and site data are provided for each survey site in Appendix B.

Table 4.1. Number of sites at which reef fish and benthic data were collected for at four survey areas on Pagan: Laguna Bay (Map C), Bandeera Bay (Map D), near South Point (Map E), and Katchu Bay (Map X). Not all sites were surveyed for all taxanomic groups. Data collected for each site are identified in Tables C.1, C.2, C.3, C.4 and Appendices F-I.

	Fish	Coral	Invertebrates	Algae
Map C	14	12	12	12
Map D	14	8	7	8
Map E	5	4	4	4
Map X	8	8	8	7
Total All Sites	41	32	31	31

4.1 Laguna Bay (Map C)

Laguna Bay is a semi-protected embayment located on the northwest coast of Pagan. The beach is not fronted by a shallow reef flat. Instead, a sandy bottom with occasional rocks and boulders persists out to depths greater than 10m. The northern and southern end of the bay have hardened shoreline that extends into the marine environment; mainly basalt outcrops and large boulders.

Data for each survey site are available in Appendix F, and select photographs are located in Appendix E.

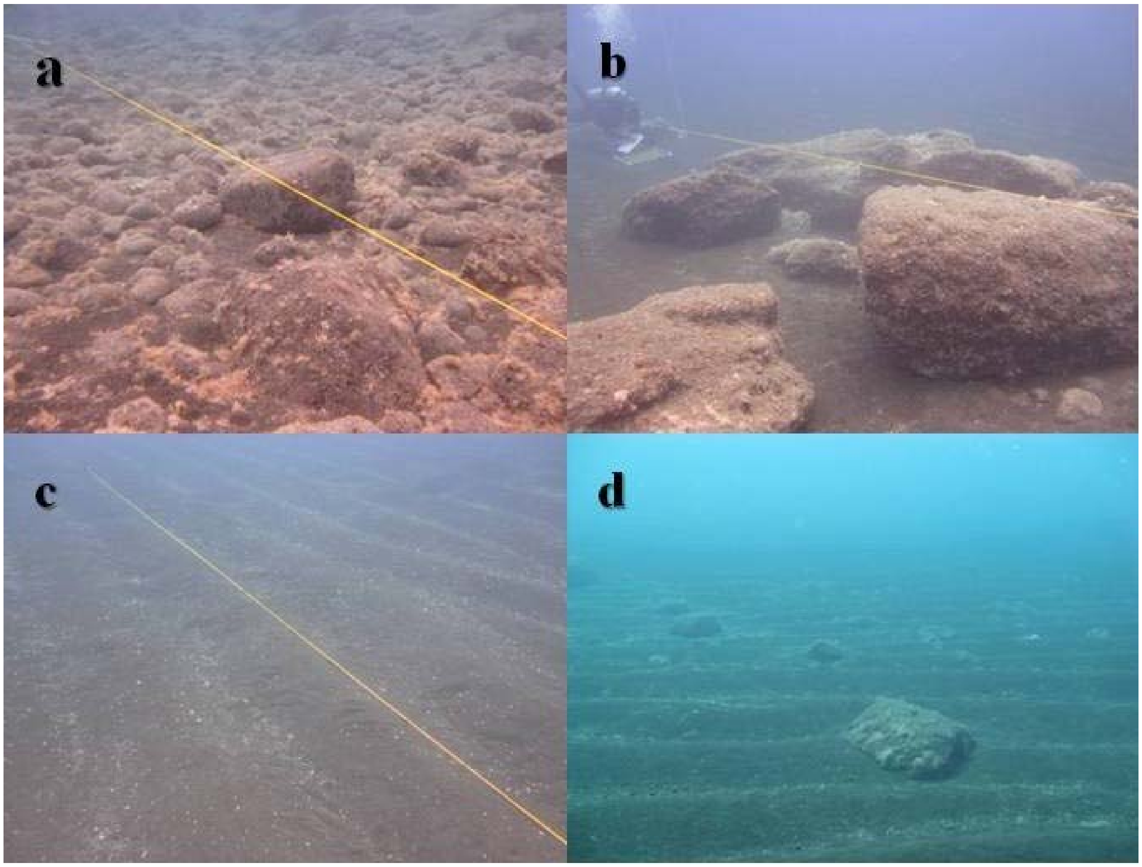

Figure 4.1. Example of bottom types at sites within Map C: (a) sand bottom with small and medium rocks at C 011; (b) sand bottom with large boulders at C024; (c) sand bottom at C003; and (d) sand bottom with small rocks at C001.

Table 4.2. Richness and abundance of taxa observed at sites within Map C. Abundance values are means across all survey sites: Algae=percent cover of the bottom; Fish=kg/100 m^2; coral=number of colonies/m^2; and Non-Coral=number of non-coral invertebrates/100 m^2.

			Invertebrates	
	Algae	**Fish[1]**	**Coral[2]**	**Non-Coral**
Taxa Richness	**Families (taxa)**	**Families (taxa)**	**Genera (taxa)**	**Families (taxa)**
Total	**23 (62)**	**37 (202)**	**22 (38)**	**30 (51)**
Abundance				
	30.6	5.91	18.45	1697.75

[1]Fish biomass estimated from belt transects only.
[2]Coral richness calculated from taxa observed within belt transects.

4.1.1 Algae

Marine algae from 23 families and 62 taxa were found at the sites surveyed within Map C. Turf algae were the dominant group accounting for approximately 51% of the observed algae (Table 4.2). The cyanobacteria *Hormothamnion enteromorphioides* was the second most abundant alga that comprised about 17% of the total algae observed. Other taxa were widespread and did not have patches of high occurrence. Fifty-five taxa (89%) had <1% mean cover and were considered rare.

The abundances of all algal taxa observed at the survey sites within Laguna Bay appear in Appendix F.

Table 4.3. The mean percent cover (±SE) of the five most common algal taxa observed at survey sites within Map C.

Map C Benthic Quadrats	**(n= 10)**
Turf algae	15.6 ± 6.9
Hormothamnion enteromorphioides	5.2 ± 2.5
Lobophora variegata	2.1 ± 0.6
Liagora sp.	2.0 ± 1.0
Hydrolithon onkodes	1.1 ± 0.6

4.1.2 Corals

As explained previously, surveys were not divided by reef zone (reef flat or reef slope) for analysis of this data set. At this site, coral abundance and richness was generally uniform throughout the observable survey area.

The coral community within Map C had 38 taxa in 22 genera. The community appeared to be indicative of a typical shallow water community dominated by algae and sand with patches of hard substrate. *Leptastrea purpurea*, *Cyphastrea agassizi*, *Porites lobata* and *Favia mathaii* (complex) accounted for 51% of all observations (Table 4.4).

Coral colonies did not show a wide range of sizes. Seventy-two percent of the colonies observed were <5cm in diameter and 96% of all coral colonies were <10cm in diameter. No colonies greater than 80 cm diameter were observed. The density of all coral taxa and the size class data for all taxa observed within Map C appear in Appendix F.

Table 4.4. The mean (±SE) density (colonies/m^2) of the five most common coral genera and taxa within Map C.

Map C	**(n= 12 sites)**
Genus	
Porites	17.50 ± 8.73
Favia	13.75 ± 6.29
Cyphastrea	12.50 ± 6.55
Leptastrea	11.25 ± 5.99
Psammocora	8.67 ± 6.99
Taxon	
Favia matthaii (complex)[1]	13.42 ± 4.94
Porites lobata	12.25 ± 6.85
Leptastrea purpurea	11.17 ± 4.72
Cyphastrea agassizi	10.33 ± 5.27
Psammocora haimeana	8.25 ± 5.62

[1]*Favia matthaii* (complex) includes: *F. danai, F. matthaii, F. pallida, and F. favus.*

4.1.3 Fish

Two hundred and two species in 37 families were observed at sites within Map C. That number was relatively high considering the amount of soft bottom fronting the beach. Pomacentridae, Labridae and Gobiidae were the most numerous fish families (Table 4.5), accounting for 61% of all fish counted along belt transects. These three families also contributed highly to the fish biomass (Table 4.6).

The average density for reef fish within Map C was 199.39 individuals/100 m^2, with the maximum at site C091 (650.50 ind./100 m^2) and the minimum at site C024 (56.00 ind./100 m^2). Large fish (>20cm) length were not common with an average density of 12.25 individuals/100 m^2. Lutjanidae and Acanthuridae were the most abundant families observed during the SPC surveys (Table 4.5). Biomass was highest at the north and south ends of the embayment where there was hard bottom substrate. Areas such as C014 have surprising biomass, density and species diversity. Site C014 appears to act as a juvenile nursery area but also attracts a wide range of species (82 total).

Sharks, but no rays, were observed in the area. The white tip reef shark (*Triaenodon obesus*) was observed at sites C005 and C091. The blacktip reef shark (*Carcharhinus melanopterus*) was observed at C023 and the grey reef shark (*Carcharhinus amblyrhynchos*) at C091. The Napoleon wrasse (*Cheilinus undulatus*) and bumphead parrotfish (*Bolbometopon muricatum*) were not observed by divers. The density and biomass of all fish taxa observed within Map C appear in Appendix F. Species presence is listed in Appendix J.

Table 4.5. The mean (±SE) density (individuals/100 m^2) by survey method of the five most common fish families (left) and species (right) found at sites within Map C. Belt transects focused on all individuals; SPCs focused on fish >20 cm. (See Sampling Methodologies for a complete description of the methods.)

Map C (n= 14)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Pomacentridae	73.00 ± 42.36	*Chromis acares*	53.57 ± 37.33
Lutjanidae	21.50 ± 9.26	*Lutjanus kasmira*	18.64 ± 8.89
Labridae	32.46 ± 6.33	Gobiidae sp.	30.43 ± 19.94
Gobiidae	32.71 ± 19.71	*Halichoeres ornatissimus*	12.43 ± 3.48
Acanthuridae	11.04 ± 3.26	*Mulloidichthys vanicolensis*	1.57 ± 1.63
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Lutjanidae	4.41 ± 3.00	*Lutjanus kasmira*	3.21 ± 2.47
Acanthuridae	3.98 ± 1.55	*Naso lituratus*	1.71 ± 0.84
Caesionidae	0.68 ± 0.55	*Lutjanus gibbus*	0.75 ± 0.46
Labridae	0.61 ± 0.27	*Pterocaesio tile*	0.52 ± 0.54
Scaridae	0.61 ± 0.27	*Scarus rubroviolaceus*	0.50 ± 0.23

Table 4.6. The mean (±SE) biomass (kg/100 m^2) by survey method of the five most common fish families (left) and species (right) found at sites within Map C. Belt transects focused on all individuals; SPCs focused on fish >20 cm. (See Sampling Methodologies for a complete description of the methods.)

Map C (n=14)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Pomacentridae	0.07 ± 0.02	*Chromis acares*	0.00 ± 0.00
Lutjanidae	1.37 ± 0.86	*Lutjanus kasmira*	0.32 ± 0.18
Labridae	0.33 ± 0.07	Gobiidae sp.	0.01 ± 0.00
Gobiidae	0.02 ± 0.01	*Halichoeres ornatissimus*	0.07 ± 0.01
Acanthuridae	1.28 ± 0.40	*Mulloidichthys vanicolensis*	0.01 ± 0.01
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Lutjanidae	0.41 ± 0.29	*Lutjanus kasmira*	0.04 ± 0.02
Acanthuridae	0.55 ± 0.22	*Naso lituratus*	0.06 ± 0.02
Caesionidae	0.03 ± 0.02	*Lutjanus gibbus*	0.11 ± 0.05
Labridae	0.09 ± 0.04	*Pterocaesio tile*	0.00 ± 0.00
Scaridae	0.31 ± 0.05	*Scarus rubroviolaceus*	0.27 ± 0.12

Table 4.7. Summary of reef fish data collected at all 4 survey regions: Maps C, D, E and X. All data contained in Appendices F-I and on accompanying data compact disc.

			C	D	X	E	COMBINED
# OF SPECIES		AVERAGE	49.9	49.7	72.4	80.6	58.0
		MEDIAN	56.0	47.5	74.5	80.0	59.0
		MAX	82.0	83.0	88.0	94.0	94.0
		MIN	8.0	10.0	43.0	68.0	8.0
BIOMASS kilograms per 100 m^2	BELT	AVERAGE	5.910	5.245	23.508	8.168	9.392
		MEDIAN	4.116	3.834	6.979	8.242	5.149
		MAX	18.263	18.281	112.390	11.043	112.390
		MIN	0.000	0.020	4.469	5.875	0.000
	SPC	AVERAGE	4.128	2.458	2.533	7.263	4.041
		MEDIAN	0.719	1.070	1.685	5.016	1.643
		MAX	33.683	16.437	6.047	15.904	46.766
		MIN	0.000	0.000	0.223	3.623	0.000
DENSITY # per 100 m^2	BELT	AVERAGE	199.39	133.32	193.19	192.60	174.79
		MEDIAN	132.00	122.00	159.00	187.00	137.50
		MAX	650.50	374.00	572.50	261.50	650.50
		MIN	56.00	4.00	34.50	117.50	4.00
	SPC	AVERAGE	12.25	10.39	14.16	22.73	13.27
		MEDIAN	4.14	7.64	12.25	20.05	10.50
		MAX	55.07	36.29	43.93	42.97	55.07
		MIN	0.00	0.00	0.32	10.50	0.00

4.1.4 Non-coral Invertebrates

Fifty-one species from 30 families were observed at survey sites within Map C. Molluscs were the dominant phyla due to the amount of soft bottom that was surveyed. The highest abundance of molluscs was observed at site C004, with an estimated 18,900 individuals/100 m^2 of the species *Atys semistriata*. *Atys semistriata* accounted for approximately 90% of all observed non-coral invertebrates. (Table 4.8) Standard error was high due to the non-normal distribution of density between sites. Some species were only found at one site and could be considered rare for this region.

The sea urchins (Families Diadematidae and Echinometridae) accounted for only 1% of the total even though 302 individuals were observed. Site C006 recorded the only Triton's trumpet (*Charonia tritonis*) found during the survey period. *Trochus* sp. and *Turbo* sp. were also found within Map C. The density of all non-coral invertebrate taxa observed at survey sites in this area appears in Appendix F.

Table 4.8. The mean (±SE) density (individuals/100m^2) of all observed invertebrate phyla and the five most common non-coral taxa at 12 sites within Map C, Laguna Bay.

Map C Belt Transects	**(n= 12)**
Phylum	
Crustacea	9.41 ± 2.93
Echinodermata	28.17 ± 10.92
Mollusca*	1660.17 ± 1514.4
Taxon	
Atys semistriata	1526.83 ± 1523.93
Notacmea persona	83.33 ± 83.33
Conus flavidus	14.17 ± 3.98
Echinostrephus aciculatus	9.08 ± 4.78
Echinothrix calamaris	8.42 ± 4.46

*Value high due to density of organisms at Site C003. Removing the outlier results in a new value of 148 ± 97.08 for Mollusca.

4.2 Bandeera Bay (Map D)

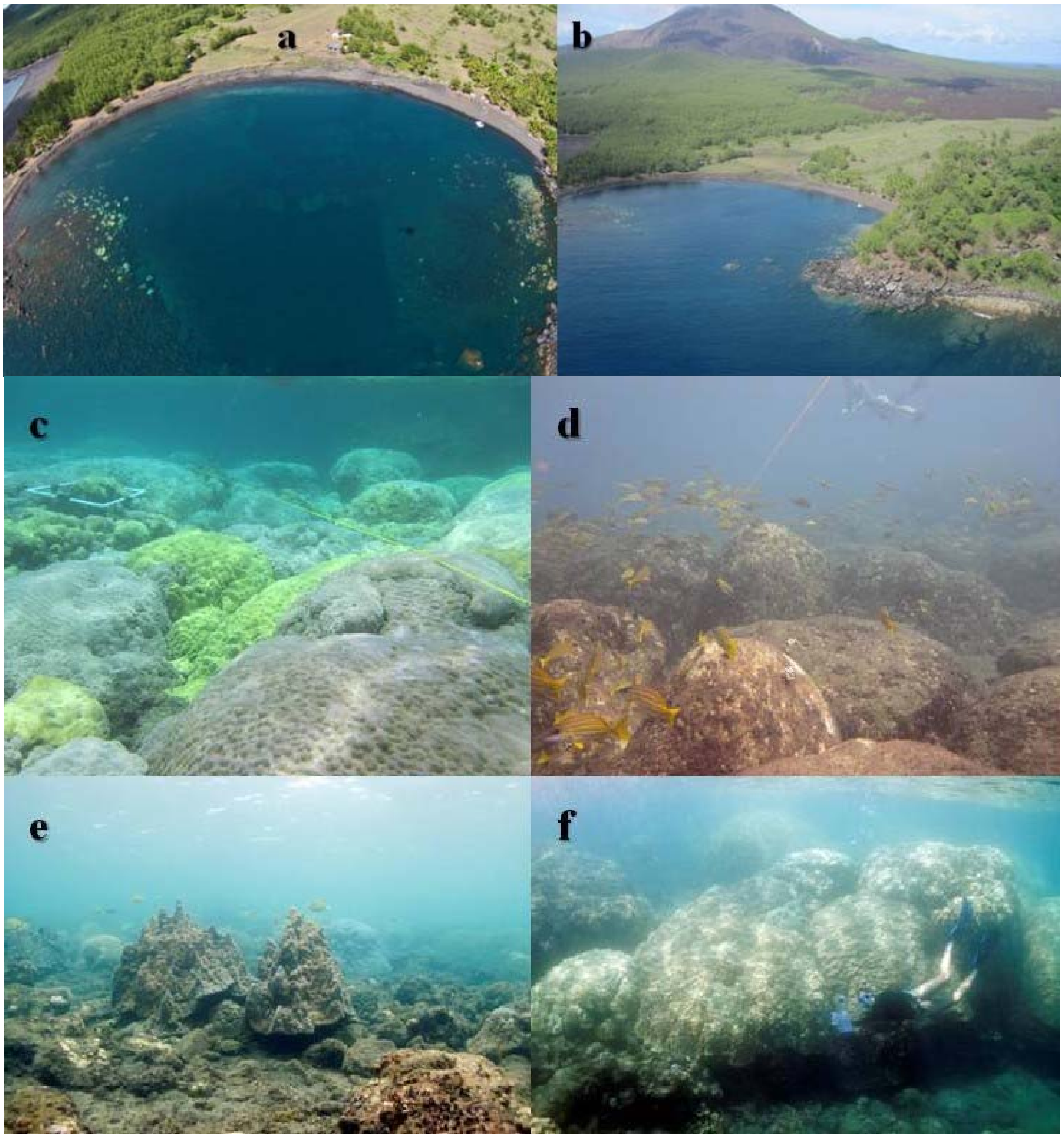

Figure 4.2. (a) and (b) Aerial view of shoreline and submerged habitat within Map D, Bandeera Bay, July 2010. Example of bottom types at sites within Map D: (c) shallow coral colonies at site D040; (d) large boulders with algae at site D014; (e) coral community at site D044; (f) size of large colonies common on northwest entrance of bay at site D046.

Bandeera Bay is a protected embayment located on the northwest coast of Pagan. During the field survey period, this bay was used as home base for daily operations as well as the home harbor for loading and unloading passengers and cargo. A specific route was used in order to avoid contact with hard bottom and damage to the vessels. The beach is not fronted by a shallow reef flat. Instead, there is a sandy bottom with occasional rocks bounded to the north and south by two unique patches of coral. These two unique coral features extend out to the deeper environment and provide a buffer from strong currents and high wave action. Upon arrival on Pagan, additional random survey points were added within the boundaries of the two coral patches in order to capture the unique resources there. These transects are located Appendix B, Figure C.5.

Data for each survey site are available in Appendix G, and select photographs are located in Appendix E. Additional photographs for the coral resources in the north and south patches are located in Appendix D.

Table 4.9. Richness and abundance of taxa observed at survey sites within Map D. Abundance values are means across all survey sites: Algae=percent cover of the bottom; Fish=kg/100 m^2; Coral=number of colonies/m^2; and Non-Coral=number of individuals/100 m^2.

			Invertebrates	
	Algae	**Fish**[1]	**Coral**[2]	**Non-Coral**
Taxa Richness	**Families (taxa)**	**Families (taxa)**	**Genera (taxa)**	**Families (taxa)**
Total	**24 (55)**	**38 (168)**	**15 (21)**	**30 (48)**
Abundance				
	58.24	5.24	12.1	267.14

[1]Fish biomass estimated from belt transects only.
[2]Coral richness calculated from taxa observed within belt transects.

4.2.1 Algae

Fifty-five species of marine algae from 24 families were found at the survey sites attempted within Map D. Algal cover was relatively high, with turf algae comprising ~41% of the macroalgae abundance. The cyanobacteria *Hormothamnion enteromorphioides* and the red (Rhodophyta) alga *Hydrolithon onkodes* contributed 17% and 16% respectively to the total of the algae observed. Other taxa were widespread and did not have patches of high occurrence. Fifty-one taxa (93%) had <1% mean cover and were considered rare.

The abundances of all algal taxa observed at the survey sites within Map D appear in Appendix G.

Table 4.10. The mean percent cover (±SE) of the five most common taxa observed at survey sites within Map D.

Map D Benthic Quadrats	**(n = 8)**
Porites lutea	24.3 ± 7.1
Turf algae	23.6 ± 4.0
Hormothamnion enteromorphioides	9.9 ± 3.6
Hydrolithon onkodes	9.4 ± 2.9
Peyssonnelia boergesenii	1.8 ± 0.8

4.2.2 Corals

The coral community within Map Area D was not highly diverse, but biomass was high compared to the other 3 survey areas attempted. Coral cover is especially high on the southern and northern boundaries of Bandeera Bay as referenced in aerial and underwater photos taken in July 2010 (Figure 4.2 and Appendix D). Colonies encountered in those areas were greater than 3m in diameter in some instances.

The coral community within Map D had 21 taxa in 15 genera. The southern community appeared to be indicative of a typical shallow water reef flat community, dominated by low growth forms of mostly *Porites* sp. The northern community had colonies of greater height due to a larger water column depth.

Coral colonies showed a wide range of sizes. Fifty percent of the colonies observed were >10 cm in diameter. Coral colonies greater than 1m in diameter were observed along the shoreline fronting the proposed landing beach.

The density of all coral taxa and the size class data for all taxa observed within transects in Map D appear in Appendix G.

Table 4.11. The mean (±SE) density (colonies/m^2) of the five most common coral genera and taxa within Map D.

Map D	**(n= 8 sites)**
Genus	
Favia	4.25 ± 3.49
Pavona	2.38 ± 2.25
Cyphastrea	2.25 ± 1.57
Leptastrea	2.13 ± 2.12
Porites	1.38 ± 1.32
Taxon	
Favia matthaii (complex)[1]	4.13 ± 3.36
Pavona varians	2.38 ± 2.25
Leptastrea purpurea	2.13 ± 2.12
Cyphastrea agassizi	1.38 ± 1.09
Cyphastrea spp.	0.75 ± 0.80

[1]*Favia matthaii* (complex) includes: *F. danai, F. matthaii, F. pallida, and F. favus.*

4.2.3 Fish

One hundred and sixty-eight species in 38 families were observed at sites within Map D. Species density, diversity and biomass were highly variable between survey sites. The two unique coral areas in the embayment supported juveniles, but did not support high levels of biomass or species diversity when compared to other sites. Labridae and Acanthuridae were the two most numerous fish families (Table 4.12), accounting for 41.3% of all fish counted along belt transects. The family Labridae did not contribute highly to the fish biomass (Table 4.13).

The average density for reef fish within Map C was 133.32 individuals/100 m^2, with the maximum at site D001 (374.00 ind./100 m^2) and the minimum at site D004 (4.00 ind./100 m^2). Large fish (>20cm) length were not common with an average density of 10.39 individuals/100 m^2. Lutjanidae and Acanthuridae were the most abundant families observed during the SPC surveys. With the exception of D010, biomass was highest outside of the bay entrance (D001, D002, D005, D014) due to the number of fish found there on the SPC surveys compared to within the embayment.

Sharks, but no rays, were observed in the area. The white tip reef shark (*Triaenodon obesus*) was observed at sites D001, D005, D010, and D014. The Napoleon wrasse (*Cheilinus undulates*) and bumphead parrotfish (*Bolbometopon muricatum*) were not observed by divers. The density and biomass of all fish taxa observed within Map D appear in Appendix G. Species presence is listed in Appendix J.

Table 4.12. The mean (±SE) density (individuals/100 m^2) by survey method of the five most common fish families (left) and species (right) found at survey sites within Map D. Belt transects focused on all individuals; SPCs focused on fish >20 cm. (See Sampling Methodologies for a complete description of the methods.)

Map D (n= 14)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	26.39 ± 3.52	*Lutjanus kasmira*	11.50 ± 7.72
Pomacentridae	1.11 ± 0.40	*Chrysiptera brownriggii*	14.71 ± 4.39
Labridae	28.64 ± 5.00	*Acanthurus lineatus*	11.86 ± 4.21
Lutjanidae	13.39 ± 8.57	*Acanthurus olivaceus*	3.04 ± 1.35
Mullidae	6.29 ± 1.88	*Pomachromis guamensis*	9.00 ± 9.34
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	5.27 ± 1.70	*Lutjanus kasmira*	1.80 ± 1.16
Lutjanidae	1.96 ± 1.25	*Acanthurus olivaceus*	1.43 ± 0.54
Lethrinidae	0.89 ± 0.64	*Naso lituratus*	1.32 ± 0.43
Caesionidae	0.48 ± 0.26	*Acanthurus lineatus*	1.11 ± 0.86
Mullidae	0.45 ± 0.27	*Acanthurus triostegus*	0.73 ± 0.76

Table 4.13. The mean (±SE) biomass (kg/100 m^2) by survey method of the five most common fish families (left) and species (right) found at survey sites within Map D. Belt transects focused on all individuals; SPCs focused on fish >20 cm (see Sampling Methodologies for a complete description of the methods)

Map D (n=14)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	1.44 ± 0.31	*Lutjanus kasmira*	0.22 ± 0.13
Pomacentridae	0.23 ± 0.09	*Chrysiptera brownriggii*	0.04 ± 0.01
Labridae	0.35 ± 0.11	*Acanthurus lineatus*	0.31 ± 0.11
Lutjanidae	0.36 ± 0.20	*Acanthurus olivaceus*	0.55 ± 0.17
Mullidae	0.29 ± 0.10	*Pomachromis guamensis*	0.00 ± 0.00
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	0.48 ± 0.15	*Lutjanus kasmira*	0.03 ± 0.02
Lutjanidae	0.15 ± 0.11	*Acanthurus olivaceus*	0.12 ± 0.04
Lethrinidae	0.14 ± 0.10	*Naso lituratus*	0.08 ± 0.02
Caesionidae	0.01 ± 0.01	*Acanthurus lineatus*	0.03 ± 0.01
Mullidae	0.08 ± 0.05	*Acanthurus triostegus*	0.00 ± 0.00

4.2.4 Non-coral Invertebrates

Forty-eight species from 30 families were observed at survey sites within Map D. Molluscs were again the dominant phyla (Table 4.14), accounting for 63% of all observed non-coral invertebrates. The highest density of organisms was found at site D001 (644 individuals/100 m^2) and the lowest at site D014 (55 individuals/100 m^2). Colonies of the petroglyph shrimp (*Alpheus deuteropus*) were recorded on the shallow water corals on the south coral patch. The colonies were counted as being present, but the individuals were not counted towards the overall density for the region.

Sea urchins (Families Diadematidae and Echinometridae) accounted for 20% of the total number of individuals that were observed. There was also a high proportion of cone snails (Conidae) observed, accounting for 30% of the total organism count. *Trochus* sp. and *Turbo* sp. were also found within Map D. The density of all non-coral invertebrate taxa observed at survey sites in this area appears in Appendix G.

Table 4.14. The mean (±SE) density (individuals/100m^2) of all observed invertebrate phyla and the five most common non-coral taxa at 7 sites within Map D, Katchu Bay.

Map D Belt Transects	**(n= 7)**
Phylum	
Crustacea[1]	42 ± 14.76
Echinodermata	56.29 ± 20.43
Mollusca	168.86 ± 51.45
Taxon	
Conus flavidus	64.71 ± 19.16
Echinometra mathaei (complex)[2]	20.14 ± 10.87
Calcinus spp.	19.71 ± 7.37
Echinothrix diadema	17.71 ± 4.78
Drupa ricinus	12.71 ± 6.1

[1]*Alpheus deuteropus* was removed for this estimate. The colonies were noted but each individual within the colony was not counted.
[2]This complex may contain one or more closely allied species that are difficult to distinguish in the field (see Arakaki and Uehara 1999).

4.3 South Point (Map E)

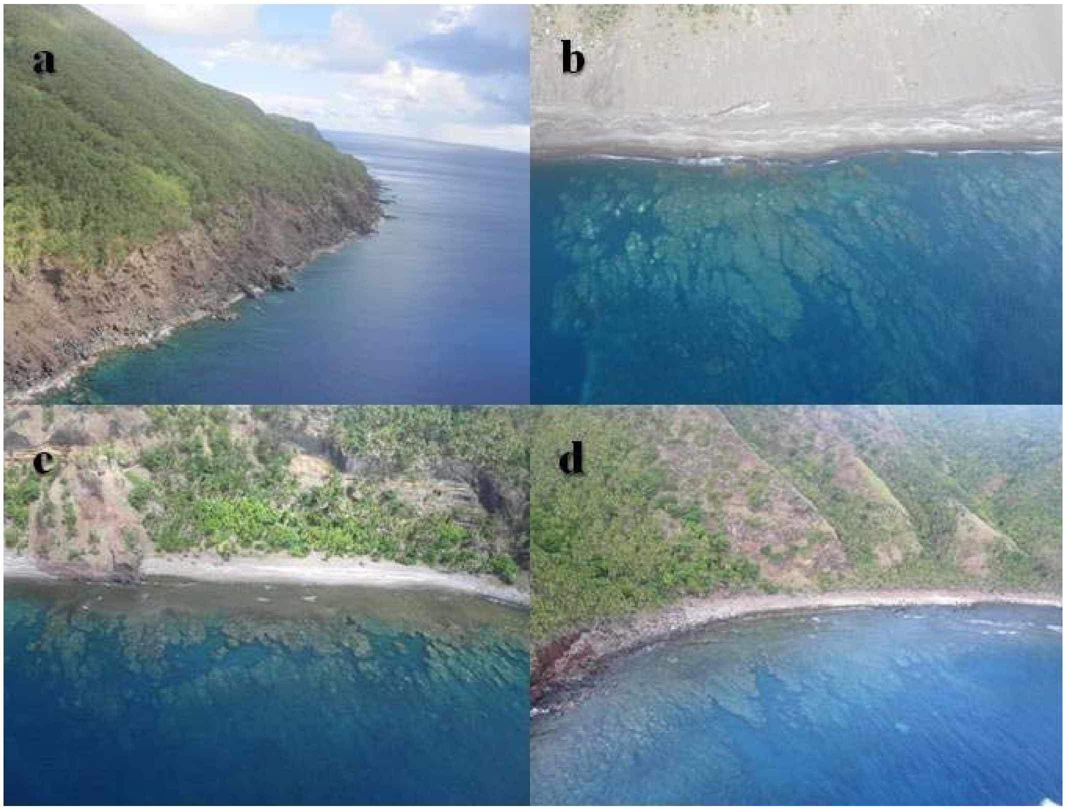

Figure 4.3. Aerial view of the coastline along the west side of the southern peninsula/point in Map E. (a) View towards the south; (b-d) Shallow water reef habitat along the coast.

Map E included the eastern and western coasts on the southern peninsula of Pagan island. Due to time restrictions, vessels operating restrictions and hazardous diving conditions, only a few sites were attempted on the western side. The habitat along the shoreline is typical of a spur and groove community not found in any of the other three embayments attempted. Areas of the coastline also have defined shallow reef flats and reef slopes as observed from aerial photographs (Figure 4.3). If firing ranges are set up on the northern half of the island, it is possible that projectiles will land in the nearshore reef environment on the eastern and western sides of South Point. If that option is considered, additional surveys should be conducted on both the eastern and western coastlines.

Data for each survey site are available in Appendix H, and select photographs are located in Appendix E.

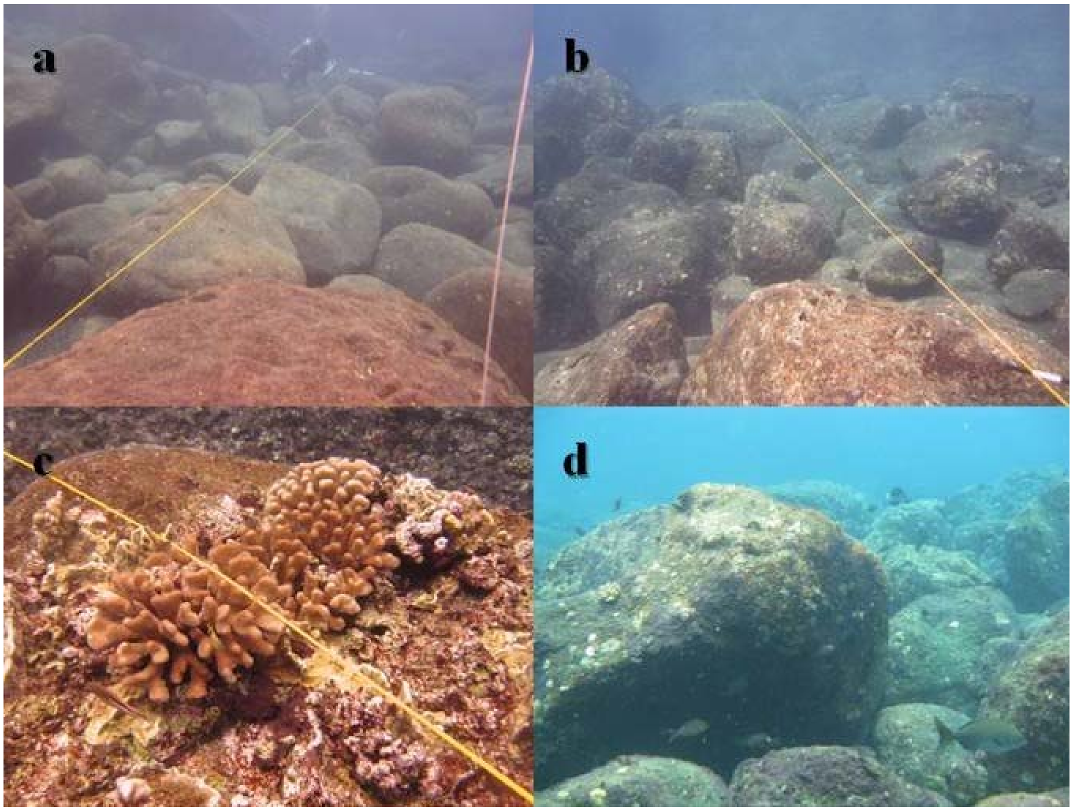

Figure 4.4. Example of bottom types at sites within Map E: (a) boulders at site E008; (b) sand bottom with large boulders at E018; (c) coral community at E012; (d) large boulders with coral at E023.

Table 4.15. Richness and abundance of taxa observed at survey sites within Map E. Abundance values are means across all survey sites: Algae=percent cover of the bottom; Fish=kg/100 m^2; Coral=number of colonies/m^2; and Non-Coral=number of individuals/100 m^2.

			Invertebrates	
	Algae	**Fish[1]**	**Coral[2]**	**Non-Coral**
Taxa Richness	**Families (taxa)**	**Families (taxa)**	**Genera (taxa)**	**Families (taxa)**
Total	**19 (45)**	**30 (105)**	**17 (40)**	**21 (35)**
Abundance				
	68.3	8.17	35.15	144

[1]Fish biomass estimated from belt transects only.
[2]Coral richness calculated from taxa observed within belt transects.

4.3.1 Algae

Marine algae from 19 families were observed at the sites surveyed within Map E. Turf algae were the dominant group accounting for approximately 38% of the observed algae (Table 4.16). The red (Rhodophyta) alga *Hydrolithon onkodes* was the second most abundant and the cyanobacteria *Hormothamnion enteromorphioides* was the third most abundant (14%) of the total algae observed. Other taxa were widespread and did not have patches of high occurrence. Thirty-five taxa (78%) had <1% mean cover and were considered rare.

Algal cover on the bottom did not change with depth. The abundances of all algal taxa observed at the survey sites within Map E appear in Appendix H.

Table 4.16. The mean percent cover (±SE) of the five most common algal taxa observed at sites within Map E.

Map E Benthic Quadrats	**(n= 4)**
Turf algae	25.9 ± 8.7
Hydrolithon onkodes	10.0 ± 3.6
Hormothamnion enteromorphioides	9.6 ± 6.5
Terpios hoshinota	5.9 ± 6.8
Peyssonnelia boergesenii	3.2 ± 1.1

4.3.2 Corals

Due to rough sea conditions and high winds, only sites on the western side of Map E were attempted. While surveys were limited due to hazardous conditions, there appeared to be a gradient in coral abundance and richness, with higher diversity and coral colony density on the northern end compared to the southern end of the coastline.

The coral community on the western side of Map E had 40 taxa in 17 families. The community appeared to be indicative of a typical spur and groove coral community (Figure 4.3). *Favia* and *Cyphastrea* corals accounted for 45% of all observations (Table 4.17).

Coral colonies did not show a wide range of sizes, but only 4 sites were surveyed. Sixty-eight percent of the colonies observed were <2cm in diameter and 98.6% of all observed coral colonies were <10cm in diameter. There were no colonies greater than 80cm recorded. The density of all coral taxa and the size class data for each taxa observed appear in Appendix H.

Table 4.17. The mean (±SE) density (colonies/m^2) of the five most common coral genera and taxa within Map E.

Map E	**(n= 4 sites)**
Genus	
Favia	49.50 ± 19.67
Cyphastrea	42.25 ± 24.50
Pavona	20.75 ± 15.13
Astreopora	13.72 ± 9.04
Pocillopora	13.75 ± 6.10
Taxon	
Favia matthaii (complex)[1]	47.50 ± 19.75
Cyphastrea agassizi	32.00 ± 26.98
Pavona varians	20.25 ± 15.11
Astreopora myriophthalma	13.25 ± 8.62
Pocillopora spp. (juv)	11.5 ± 6.51

[1]*Favia matthaii* (complex) includes: *F. danai, F. matthaii, F. pallida, and F. favus.*

4.3.3 Fish

One hundred and five species in 30 families were observed at sites within Map E. Site E009 had the highest species count (94 total) of any other site visited during the survey period. The limited number of sites attempted within Map E had relatively high diversity, density and biomass and were quite different from the other sites surveyed. Additional surveys should be conducted if activities are to take place on this area of the island. Acanthuridae and Labridae were the most numerous fish families (Table 4.18) accounting for 39.2% of all fish counted along belt transects. These two families also contributed highly to the fish biomass (Table 4.19)

The average density for reef fish within Map E was 192.60 individuals/100 m^2, with the maximum at site E009 (261.50 ind./100 m^2) and the minimum at site E023 (117.5 ind./100 m^2). Large fish (>20cm) length were more common here with an average density of 22.73 individuals/100 m^2. Acanthuridae and Scaridae were the most abundant families observed during the SPC surveys.

Sharks, but no rays, were observed in the area. The grey reef shark (*Carcharhinus amblyrhynchos*) was observed at site E012. The Napoleon wrasse (*Cheilinus undulatus*) and bumphead parrotfish (*Bolbometopon muricatum*) were not observed by divers. The density and biomass of all fish taxa observed within Map E appear in Appendix H. Species presence is listed in Appendix J.

Table 4.18. The mean (±SE) density (individuals/100 m^2) by survey method of the five most common fish families (left) and species (right) found at survey sites within Map E. Belt transects focused on all individuals; SPCs focused on fish >20. (See Sampling Methodologies for a complete description of the methods.)

Map E (n= 5)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Pomacentridae	2.70 ± 2.07	*Halichoeres ornatissimus*	21.20 ± 6.11
Acanthuridae	37.90 ± 8.04	*Chromis vanderbilti*	19.20 ± 16.46
Labridae	42.70 ± 4.23	*Ctenochaetus hawaiiensis*	10.40 ± 2.69
Microdesmidae	11.60 ± 9.96	*Stegastes fasciolatus*	14.00 ± 3.08
Blenniidae	9.20 ± 6.27	*Acanthurus nigrofuscus*	13.60 ± 2.77
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	15.22 ± 5.19	*Ctenochaetus striatus*	3.76 ± 1.28
Scaridae	1.97 ± 0.88	*Acanthurus olivaceus*	3.37 ± 2.30
Lutjanidae	1.66 ± 0.56	*Acanthurus lineatus*	3.12 ± 2.51
Lethrinidae	1.08 ± 0.63	*Acanthurus leucopareius*	2.67 ± 2.99
Serranidae	1.02 ± 0.44	*Naso lituratus*	1.78 ± 0.61

Table 4.19. The mean (±SE) biomass (kg/100 m^2) by survey method of the five most common fish families (left) and species (right) found at survey sites within Map E. Belt transects focused on all individuals; SPCs focused on fish >20 cm. (See Sampling Methodologies for a complete description of the methods.)

Map E (n=5)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Pomacentridae	0.20 ± 0.06	*Halichoeres ornatissimus*	0.05 ± 0.02
Acanthuridae	2.41 ± 0.28	*Chromis vanderbilti*	0.00 ± 0.00
Labridae	1.01 ± 0.44	*Ctenochaetus hawaiiensis*	0.46 ± 0.05
Microdesmidae	0.01 ± 0.01	*Stegastes fasciolatus*	0.14 ± 0.03
Blenniidae	0.01 ± 0.01	*Acanthurus nigrofuscus*	0.43 ± 0.06
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	0.73 ± 0.18	*Ctenochaetus striatus*	0.15 ± 0.05
Scaridae	1.32 ± 0.68	*Acanthurus olivaceus*	0.24 ± 0.13
Lutjanidae	0.86 ± 0.09	*Acanthurus lineatus*	0.07 ± 0.03
Lethrinidae	0.41 ± 0.20	*Acanthurus leucopareius*	0.00 ± 0.00
Serranidae	0.48 ± 0.20	*Naso lituratus*	0.14 ± 0.00

4.3.4 Non-coral Invertebrates

Thirty-five species from 21 families were observed at five survey sites within Map E. Molluscs were the dominant phyla (Table 4.20), accounting for 68% of all observed non-coral invertebrates. The highest density of organisms was found at site E018 (293 individuals/100 m^2) and the lowest at site E008 (36 individuals/100 m^2). The high proportion of molluscs could possibly be correlated to the amount of boulders and rocks available for attachment. Cone snails (Conidae) and drupes (Muricidae) accounted for 53% of the total non-coral invertebrates.

Sea urchin density was low compared to the 3 other study areas. Two species of crinoids (*Comaster schlegelii* and *Crinoid* sp. E [Guam]) were observed in the highly rugose environment at sites E009 and E012. A higher number of surveys are needed in order to make additional comparisons. The density of all non-cral invertebrate taxa observed at survey sites in this area appears in Appendix H.

Table 4.20. The mean (±SE) density (individuals/100m^2) of all observed invertebrate phyla and the five most common non-coral taxa at 5 sites within Map E.

Map E Belt Transects	**(n= 5)**
Phylum	
Crustacea	33 ± 12.37
Echinodermata	12 ± 9.9
Mollusca	98.6 ± 38.24
Taxon	
Conus flavidus	50.6 ± 30.68
Modulus tectum	8.8 ± 1.41
Morula granulata	7.6 ± 3.97
Echinostrephus aciculatus	7.4 ± 7.4
Drupa ricinus	4.8 ± 2.63

4.4 Katchu Bay (Map X)

Katchu Bay is a semi-protected embayment located on the northwest coast of Pagan. The beach is not fronted by a shallow reef flat. Instead, there is a sandy bottom with occasional rocks bounded to the north and south by hard substratum (Figure 2.2.2). The reef features on the north and south boundaries extend out to the deeper environment (>10m). The beach in Map X is in the direct ash outfall zone of Mt. Pagan.

Data for each survey site are available in Appendix G, and select photographs are located in Appendix E.

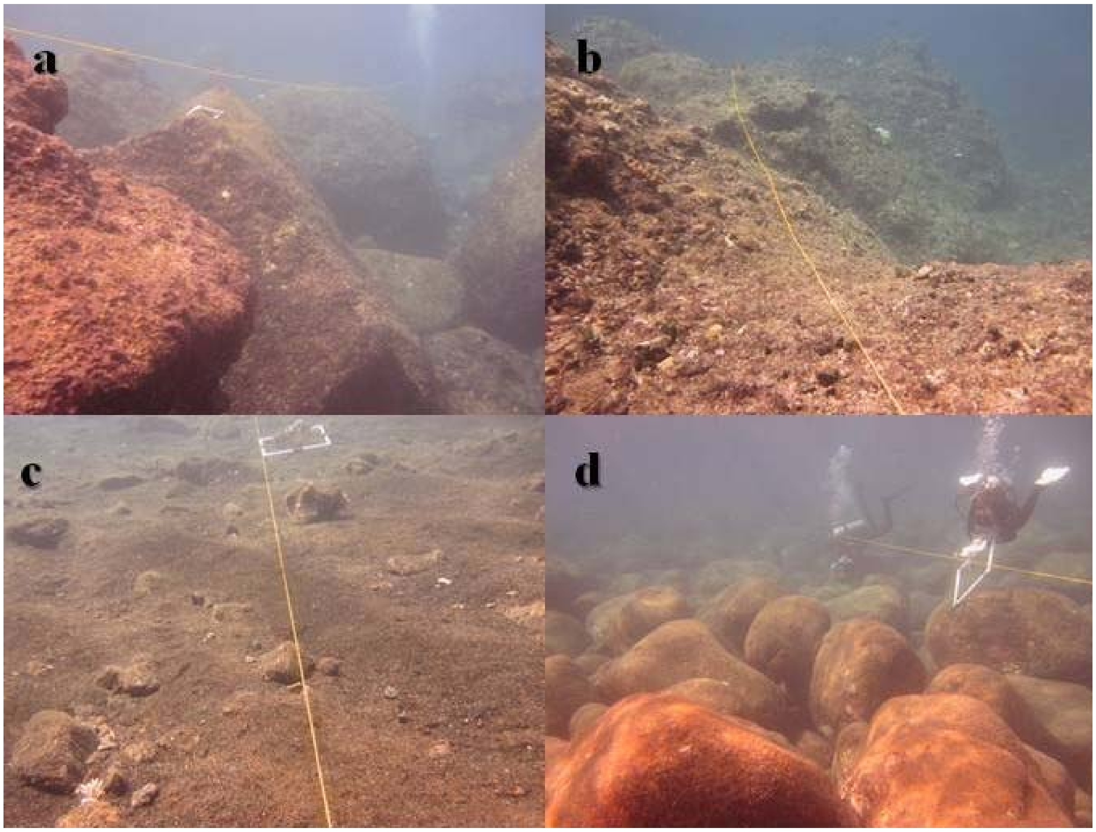

Figure 4.5. Example of bottom types at sites within Map X: (a) large boulders with coral at site X005; (b) hard bottom with coral at X006; (c) sand bottom with small rocks at X022; (d) large boulders on sand bottom at X039.

Table 4.21. Richness and abundance of taxa observed at sites within Map X. Abundance values are means across all survey sites: Algae=No absolute abundance data collected; Fish=kg/100 m^2; coral=number of colonies/m^2; and Non-Coral=number of individuals/100 m^2.

			Invertebrates	
	Algae	**Fish[1]**	**Coral[2]**	**Non-Coral**
Taxa Richness	**Families (taxa)**	**Families (taxa)**	**Genera (taxa)**	**Families (taxa)**
Total	**25 (63)**	**35 (179)**	**21 (45)**	**35 (53)**
Abundance				
	78.81	23.51	22.13	220

[1]Fish biomass estimated from belt transects only.
[2]Coral richness calculated from taxa observed within belt transects.

4.4.1 Algae

Marine algae from 25 families were observed at the sites surveyed within Map X. Turf algae were the dominant group accounting for approximately 37% of the observed algae (Table 4.22). The cyanobacteria *Hormothamnion enteromorphioides* was the second abundant, accounting for 22% of the total algae observed. Other taxa were widespread and did not have patches of high occurrence. Fifty-five taxa (87%) had <1% mean cover and were considered rare.

The abundances of all algal taxa observed at the survey sites within Map X appear in Appendix I.

Table 4.22. The mean percent cover (±SE) of the five most common algal taxa observed at sites within Map X.

Map X Benthic Quadrats	**(n= 7)**
Turf algae	29.4 ± 11.8
Hormothamnion enteromorphioides	17.5 ± 6.4
Peyssonnelia boergesenii	4.8 ± 1.5
Pneophyllum conicum	4.2 ± 2.7
Hydrolithon onkodes	4.1 ± 1.6

4.4.2 Corals

The coral community observed within Map X had 45 taxa in 21 families. The community did not resemble a typical spur and groove or shallow water coral community. The bottom was dominated by large boulders, soft bottom and some pavement. The community was dominated primarily by the taxa in the genera *Favia*, *Pavona*, and *Cyphastrea* (Table 4.23) which accounted for 49% of all observed families. No trend was apparent in the data from north to south in the submerged environment fronting the beach.

Coral colonies did not show a wide range of sizes. Sixty-four percent of the colonies observed were <2cm in diameter and 95.4% of all observed coral colonies were <10cm in diameter. There were no colonies greater than 40cm recorded. The density of all coral taxa and the size class data for each taxa observed appear in Appendix I.

Table 4.23. The mean (±SE) density (colonies/m^2) of the five most common coral genera and taxa at sites within Map X.

Map X	**(n= 8 sites)**
Genus	
Favia	23.12 + 6.79
Pavona	18.12 + 8.18
Cyphastrea	14.25 + 5.28
Astreopora	13.63 + 3.21
Porites	12.50 + 3.56
Taxon	
Favia matthaii (complex)[1]	22.88 + 6.72
Pavona varians	18.00 + 8.13
Cyphastrea agassizi	12.00 + 5.23
Astreopora myriophthalma	11.25 + 2.53
Leptastrea purpurea	9.13 + 3.71

[1]*Favia matthaii* (complex) includes: *F. danai, F. matthaii, F. pallida, and F. favus.*

4.4.3 Fish

One hundred and seventy-nine species in 35 families were observed at sites within Map X. Map X had a limited amount of samples, however, the sites sampled had relatively high biomass, density and species diversity. There were significant herbivore and apex predator populations at these sites and it is recommended that this area be avoided when possible.

Atherinidae, Acanthuridae and Labridae were the most numerous fish families (Table 4.24) accounting for 74.55% of all fish counted along belt transects. These three families also contributed highly to the fish biomass (Table 4.25)

The average density for reef fish within Map X was 193.19 individuals/100 m^2, with the maximum at site X003 (2214.50 ind./100 m^2) and the minimum at site X022 (34.5 ind./100 m^2). Large fish (>20cm) length were more not common here with an average density of 14.17 individuals/100 m^2. Acanthuridae and Lutjanidae were the most abundant families observed during the SPC surveys.

Sharks, but no rays, were observed in the area. The white tip reef shark (*Triaenodon obesus*) was observed at site X008. The Napoleon wrasse (*Cheilinus undulatus*) and the bumphead parrotfish (*Bolbometopon muricatum*) were not observed by divers. The density and biomass of all fish taxa observed within Map X appear in Appendix I. Species presence is listed in Appendix J.

Table 4.24. The mean (±SE) density (individuals/100 m^2) by survey method of the five most common fish families (left) and species (right) found at survey sites within Map X. Belt transects focused on all individuals; SPCs focused on fish >20 cm. (See Sampling Methodologies for a complete description of the methods.)

Map X (n= 8)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Atherinidae	250.00 ± 267.26	Atherinid sp.	250.00 ± 267.26
Pomacentridae	0.50 ± 0.35	*Pomachromis guamensis*	40.75 ± 33.98
Labridae	44.50 ± 6.66	*Acanthurus nigrofuscus*	28.50 ± 22.09
Acanthuridae	35.88 ± 22.65	*Halichoeres ornatissimus*	18.50 ± 6.60
Scaridae	5.50 ± 2.66	*Scarus forsteni*	3.69 ± 2.68
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	6.80 ± 3.47	*Naso lituratus*	2.51 ± 0.84
Lutjanidae	2.98 ± 1.60	*Lutjanus kasmira*	1.87 ± 1.32
Caesionidae	1.55 ± 1.43	*Ctenochaetus striatus*	1.71 ± 1.04
Serranidae	0.68 ± 0.29	*Pterocaesio tile*	1.35 ± 1.45
Labridae	0.60 ± 0.22	*Acanthurus leucocheilus*	1.03 ± 1.11

Table 4.25. The mean (±SE) biomass (kg/100 m^2) by survey method of the five most common fish families (left) and species (right) found at survey sites within Map X. Belt transects focused on all individuals; SPCs focused on fish >20 cm. (See Sampling Methodologies for a complete description of the methods.)

Map X (n=8)			
Belt Transects		**Belt Transects**	
Family (Top 5)		Species (Top 5)	
Atherinidae	not available	Atherinid sp.	not available
Pomacentridae	0.11 ± 0.03	*Pomachromis guamensis*	0.00 ± 0.00
Labridae	0.41 ± 0.06	*Acanthurus nigrofuscus*	0.32 ± 0.12
Acanthuridae	1.18 ± 0.43	*Halichoeres ornatissimus*	0.05 ± 0.02
Scaridae	2.12 ± 0.52	*Scarus forsteni*	0.55 ± 0.32
SPC		**SPC**	
Family (Top 5)		Species (Top 5)	
Acanthuridae	0.79 ± 0.31	*Naso lituratus*	0.14 ± 0.05
Lutjanidae	0.39 ± 0.14	*Lutjanus kasmira*	0.02 ± 0.02
Caesionidae	0.02 ± 0.01	*Ctenochaetus striatus*	0.14 ± 0.04
Serranidae	0.09 ± 0.04	*Pterocaesio tile*	0.01 ± 0.01
Labridae	0.17 ± 0.09	*Acanthurus leucocheilus*	0.02 ± 0.03

4.4.4 Non-coral Invertebrates

The highest number of families and species observed were recorded within Map X, fifty-three species from 35 families. Molluscs were the dominant phyla, accounting for 56% of all observed non-coral invertebrates. The highest density of organisms was recorded at site X001 (401 individuals/100 m^2) and the lowest at site X022 (49 individuals/100 m^2). Some species were only found at one site and could be considered rare for this region.

A large number of juvenile sea urchins from the families Diadematidae and Echinometridae were observed on the hard substrate and accounted for 28.5% of all non-coral invertebrates observed within the study area. Giant clams (Tridacnidae) were also common compared to the other study areas, with an average density of 18.5 indivuals/100 m^2 within Map X. *Trochus* sp. and *Turbo* sp. were also found within Map X. The density of all non-coral invertebrate taxa observed at survey sites in this area appears in Appendix I.

Table 4.26. The mean (±SE) density (individuals/100m^2) of all observed invertebrate phyla and the five most common non-coral taxa at 5 sites within Map X.

	(n= 8)
Phylum	
Crustacea	31.88 ± 9.51
Echinodermata	64.75 ± 23.35
Mollusca	123.38 ± 19.59
Taxon	
Echinostrephus aciculatus	49.88 ± 20.5
Conus flavidus	42.5 ± 8.33
Percnon planissimum	15.38 ± 8.56
Calcinus spp.	12.38 ± 4.05
Drupa morum	10.13 ± 2.11

5.0 Discussion

The hard coral communities encountered appeared to be diverse and displayed no gross growth anomalies or anomalous patterns of tissue loss. Corals were observed in all size classes, suggesting that active larval settlement is occurring on the reef, and colonies are surviving and actively growing. While the majority of corals tended be small (<20 cm), several corals greater than 100 cm in diameter were noted, mainly in Bandeera Bay (Map D, Figure 2.2.1).

All reefs in the southern Mariana Islands are subject to heavy fishing pressure (Starmer *et al*. 2008), and this can be manifested in low densities and biomass and small fish size when compared to reefs with little fishing (Friedlander and DeMartini 2002). In this study, fish >20 cm in length were observed in all study areas. Densities for large fish ranged from an average of 12.26 individuals/100 m^2 at Map C (Figure 1.2.2) to 22.72 individuals/100 m^2 at Map E (Figure 1.2.2). SPC densities were higher than those observed at Tinian in 2008, but all of these values are consistent with those observed elsewhere in the CNMI (Starmer *et al*. 2008).

This study found that non-coral invertebrate taxa with fisheries or commercial value were observed at a few survey areas, including *Trochus niloticus* at one site (C091) and multiple observations of spiny lobsters (*Panulirus* sp.). Diurnally active octopi (primarily *Octopus cyanea*) were also observed.

Additionally, large coral predators were rare or conspicuously absent from the surveys. Only five indigenous crown-of-thorns sea stars (*Acanthaster planci*) were observed, two at C005, two at X005, and one at X008. Another corallivorous sea star, the pin-cushion sea star (*Culcita novaeguineae*) was expected to be seen in the area in greater abundance, but was only observed at one site (one at D014).

6.0 Summary and Recommendations

These data represent a temporal "snap shot" of the coral reef communities at the four Pagan survey areas (Maps C, D, E and X) (Figure 1.2.3) and should not be considered a comprehensive assessment or biological inventory of these reefs. The completeness of the survey data for various taxa is variable. For example, absent a significant environmental event (*e.g.*, typhoon, disease, crown-of-thorns outbreak etc.), hard corals tend to display little seasonal or annual variation in abundance and taxa composition. In contrast, algae, fish, and some non-coral invertebrate taxa display marked seasonal patterns, can be cryptic, "secretive" (*e.g.*, burrowing) or nocturnal. Many may also have high annual variability. As a result, these taxa, while present on the reef, likely have been under-sampled by this survey effort.

The purpose of theses surveys was to provide estimates of taxonomic diversity and abundance of the most diurnally conspicuous benthic and pelagic marine resources on reef habitats in the vicinity of the proposed amphibious landing beaches on the eastern and western coastline of Pagan Island. The survey results provide the Navy with data that contribute to a description of the affected environment within the geographic areas that are proposed for future use.

While this report does not include an impact assessment of the proposed DoD action, it was the intention of the USFWS and its partners to obtain qualitative and quantitative data on the shallow coral reef communities that would potentially be useful in an impact analysis. However, since information on the specific alternatives to the proposed action was not available prior to development of the survey design, there was no way to ensure that all data necessary for a full impact assessment would be collected. For example, sufficient replication is needed within the footprint of each alternative in order to draw ecologically and statistically relevant conclusions on the anticipated impact. Insufficient replication can result in an erroneous assessment.

Additionally, while the data at Map C and Map D are adequate to meet NEPA requirements to describe the affected environment in that area, the data set that was collected for the Pagan beaches is not as complete as the data set collected at the Tinian beaches and will likely be inadequate for conducting a detailed impact assessment. A complete investigation would require additional data collection and sampling in Maps A, B and X.

Based on the results of this survey, the following guidelines to avoid and/or minimize potential damage are recommended:

1. Avoid hard substrate, including shallow reef areas, by accessing the beaches from the open ocean through sand channels.

   Channels in the bottom strata are present at all three proposed amphibious landing sites on the western coast. Use of these channels would minimize (but may not remove) the likelihood and extent of damage to marine resources such as coral, which are common on the north and south boundaries of each embayment, but relatively rare on predominantly sand bottom. The channels would need to be accurately mapped and operating procedures would need to be developed to ensure landing craft can locate and use the channels.

2. Conduct landing operations at high tide and during calm sea conditions.

   Amphibious training should be conducted at high tide to provide the greatest clearance of the bottom along the hard substratum and the shortest possible run across submerged resources. Calm sea conditions will reduce the chance of scraping vessel bottoms on the reef and large boulders when in wave troughs.

3. Map the shallow water areas at the selected landing beaches and along the southern peninsula.

   Marine resources, particularly within the predominantly soft bottom embayments are patchily distributed. Regions of low or zero coral density exist, but unique regions of high density also exist. Prior to conducting training operations, we recommend that a detailed map of the hard substratum at each landing beach and be developed so that reef areas with high resource value can be avoided to the greatest extent possible. Depending on the reef topography and distribution of sensitive resources, consideration should be given to establishment of permanently marked access corridors across at proposed landing beaches.

4. If possible, conduct amphibious training at Map C, Laguna Bay.

   Numerous parameters will be factored into the final selection of the best training beach. Based on the survey results, the beach at Laguna Bay appears to provide the best opportunity to minimize marine resource impacts from training activities. With the longest stretch of soft bottom parallel to shore, there would be a reduced probability of negatively impacting the resources on the hard bottom on the northern and southern boundary. Coral development was observed in these areas and, if possible, impacts to these areas should be avoided. However, there are coral reef patches on the soft bottom, evidenced in our sampling efforts, that could be adversely impacted. These resources could be avoided if other suggested guidelines are implemented. Map D, Bandeera Bay (Figure 2.2.1), would be expected to undergo the greatest direct impact from amphibious landings.

In closing, the process used to develop and conduct these surveys has been valuable to all of the project partners. Through this cooperative effort, all parties obtained greater understanding and appreciation of the needs and objectives of the partner agencies, and the results of this work have been greatly improved by the involvement of all parties. It is hoped that this survey effort has provided a solid foundation for continued cooperative work in the future.

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Appendices A-D

Appendices A-D are contained within this volume of the Survey Report and include:

- Appendix A. Marine Survey Design and Methods for Pagan, Commonwealth of the Northern Mariana Islands (CNMI)
- Appendix B. Survey Site Data for Laguna Bay (Map C), Bandeera Bay (Map D), South Point (Map E) and Katchu Bay (Map X)
- Appendix C. Brief habitat descriptions for random survey points in Map C, D, E and X. Initial scouting information was used for site selection due to limited time for quantitative surveys.
- Appendix D. Additional photographs of unique coral reef resources at the north and south coral patches in Bandeera Bay (Map D).

Appendices E-J are contained in Volume II of this report and consist of survey site photographs and all raw data used to generate this report.

Appendix A.

Marine Survey Design and Methods for Pagan, Commonwealth of the Northern Mariana Islands (CNMI)

Final Draft

Marine Survey Design and Methods for Pagan, Commonwealth of the Northern Mariana Islands (CNMI)

Prepared by

U.S. Fish and Wildlife Service

in cooperation with

NOAA National Marine Fisheries Service & Coral Reef Ecosystems Division
CNMI Division of Fish and Wildlife
University of Guam Marine Laboratory

June 22, 2010

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Purpose of the Pagan Marine Surveys

This survey design is intended to provide a statistically and scientifically creditable estimate of taxonomic diversity and abundance of the marine resources on reef flats and fore reef slopes (<10 m) that may potentially be impacted by actions proposed as part of Relocation of Marine Corps Forces to the Mariana Islands. These resources include both benthic and pelagic organisms.

Survey Design

Basic Design

A stratified random design will be employed with the following:

Specific Area of Interest: A specific bay or area that is proposed for marine-related activities or may be directly impacted by marine or land-based activities. These have been identified in Table 1. Additional areas may be identified as new information is made available by the Navy.

Table 1. Specific Areas of Interest for the Pagan Marine Surveys.

Location	Meters of Shoreline	Notes
Beach A (east side)	~1,600 meters	Long beach on east coast (App. B, Fig B.2)
Beach B (east side)	~1,200 meters	Beach on east coast to the southwest of Beach A (App. B, Fig B.3)
Beach C (west side)	~1,000 meters	Northern beach on west coast fronting wetland (App. B, Fig B.4)
Beach D (west side)	~800 meters	Two southern beaches on west coast (App. B, Fig B.5)
Beach E (south tip)	~13,600 meters	Southern tip of island (App. B, Fig. B.6)

These Areas of Interest have been as narrowly defined as possible to ensure that sampling occurs directly in the potential impact area. However, some sampling must occur across the entire area of interest to provide data to assess indirect impacts to adjacent areas. The boundaries of these surveys were set after consultation with the Navy and local experts familiar with Pagan and the Mariana Islands.

Strata: Reef Flat and Reef Slope. Reef flats are shallow water areas shoreward of the reef crest. Reef slopes are defined as areas seaward of the reef crest and down to 10 m. Samples will be divided across the two strata. In areas where a reef flat stratum could not be identified from satellite images, it has been excluded. Additional random sites were added to the reef slope strata and sites can be partitioned into the reef flat strata on site, as necessary.

Domain: It is expected that hard substrates will form the majority of the bottom and are at the greatest risk to significant long term impacts. Given the limited time available for field work, these surveys will focus on hard substrate.

Sampling Unit: A sampling unit will be a survey site. This survey site will be where one complete sample collection effort will occur (e.g. two 5-m belt transects for coral, one 25-m belt transect for non-coral invertebrates, etc.).

Number of Sampling Units

Number of sampling units will depend on available time in the field, which is subject to weather and availability of logistic support. We anticipate that approximately 10 sampling days will be available, resulting in approximately 30 survey sites for diving surveys and up to 20 sites for snorkel surveys. This would result in approximately 50 sites surveyed for this work.

Survey data from Saipan was previously analyzed to determine optimal sample sizes for survey work at Tinian. While more recent data is available from Tinian, the Saipan data can be used to estimate the effectiveness of the proposed sample sizes on Pagan. Sampling on Pagan will be constrained by time and access.

Previous analysis of fish, coral, and non-coral benthic survey data from Saipan (see Appendix A) suggests that 10-15 survey sites per area of interest would be needed to provide a narrow confidence range for the mean estimate for abundance (e.g., low standard error). Additionally, this sample size appears to adequately capture the majority of taxonomic diversity in the area. This optimal sample size has yet to be computed for pelagic organisms, but will be determined prior to entering the field.

Due to logistic and time constraints, this level of survey effort will not be possible on Pagan. Approximate 4-5 sites per beach area are proposed for Pagan. This survey effort will result in the following standards error of the means:

Taxonomic Group	Error (Percent of the Mean)
Fish	30-35%
Coral	10-20%
Non-coral	30-60%

Caveat: This sample data is only for hard bottom communities and represents the minimum number of sampling units for this habitat type. It is anticipated that unconsolidated sediments will be found in some or all Specific Areas of Interest. Sites with unconsolidated sediments will also be sampled, but it is anticipated that these surveys will yield low diversity and densities of most marine organisms. No more than five additional samples, or sampling sites, on unconsolidated sediments units per Specific Area of Interest will be surveyed (Note: no statistical basis is used to determine this particular sample size). It is anticipated these sites will be surveyed very quickly.

Benthic and Pelagic Sampling Units

The number of proposed sampling sites for each beach area appear in Table 2. These values are based on a maximum of 50 sites surveyed over the course of the survey effort. Fifty samples were estimated based on the logistic constraints present with the proposed survey effort.

Table 2. Proposed number of benthic sampling units. Samples were assigned to ensure that at least a minimum of 4 sample sites were conducted at each location within each beach survey area (e.g., Beach D has two coves, so each cove would have at least 4 sampling sites). Prior to entering the field, the sample sites will be prioritized and if possible one of the proposed beach sites will be removed from sampling. RF=Reef flat; RS=Reef slope. *Reflects total for priority beaches A-D.

Location	Miles of Shoreline	# of Sampling Units
Beach A	~1,600 meters	RF=6; RS=8
Beach B	~1,200 meters	RF=3; RS=8
Beach C	~1,000 meters	RF=3; RS=8
Beach D	~800 meters	RF=6; RS=8
Beach E	~13,600 meters	RF, RS TBD
Total*	~4,600 meters	50

Surveys effort should focus on the beaches on the eastern and western coast. As time permits, additional surveys should be conducted around the southern tip of Pagan (Beach E).

Selecting Sampling Units

A random list of sampling locations will be generated using GIS. Enough units will be drawn to ensure that at least twice the number of needed sampling units is drawn for both hard and unconsolidated bottom. Samples will be visited in the order in which they are drawn.

Sample sites can be discarded and the next in the list selected if it is determined on site that:

1. The sampling unit cannot be safely sampled
2. The sampling unit is not on the appropriate bottom type (hard vs. unconsolidated) or within the appropriate depth range.

Otherwise, the sampling unit will be surveyed.

Data Analysis

All data will be analyzed using appropriate statistical methods for determine means and confidence intervals.

Logistics

Surveys are proposed to occur for approximately two weeks in July 2010. It is anticipated that during this two-week stretch, there will be approximately 10 in-water survey days. Each survey day will consist of no more than 3 scuba surveys and 2 snorkel surveys for benthic teams. Due to the short time in-water at each site, fish survey teams may conduct more surveys, as necessary, provided the additional surveys comply with the requirements set forth in the Dive Safety Plan. An "off-gassing/data work-up" day will be held after every three days in-water.

Survey Teams

One survey team (Table 3) will be deployed, ideally in two separate boats. Having separate boats for the fish and benthic teams provides the greatest amount of flexibility to reach target sites and achieve the level the sampling targeted. If two boats are not available, teams will be consolidated into one craft.

Each survey team will have an assigned Team Lead. It is the responsibility of the Team Lead to ensure coordination between the two survey teams to maximize the efficiency of the survey effort.

Each taxonomic group will have a lead assigned. This individual will be responsible for ensuring that all data is collected using the appropriate methodologies and that all data field sheets are submitted to the U.S. Fish and Wildlife Service (USFWS) within in one week of the end of the survey. This position will also be responsible for ensuring that data is compiled electronically, field notes are entered, and a final (brief) Data Summary Report (see below) is submitted to the USFWS by an agreed upon date.

Table 3. Proposed survey participants. Names in bold represent individuals who have strongly indicated they will be involved in the survey (awaiting final confirmation).

Survey Task	Participant
Fish (2-3 divers)	**Val Brown, Steve McCagen, Mike Tenorio**
Coral (1 diver)	**Steve Kolinski**
Non-Coral (1 diver)	**Nadiera C. Sukhraj**
Algae (1 diver)	**Tom Schils**
Utility Diver[1] (1 diver)	**Amanda deVillars**

[1]will provide support primarily to the algae diver

Laying Transects

Fish and benthic teams will lay their own transects to meet the specific needs of their sampling protocols. However, all transects will be laid in a predetermined way, as follows:

Benthic Transects: Benthic transects will be laid along the depth contour, starting at a float line that was deployed from the boat prior to entering the water. If there is no discernable depth contour, the line will be approximately parallel to shore. The line will be laid along the bottom and will capture the bottom irregularities.

Fish Transects: Fish transects will be laid along the depth contour, starting at a float line that was deployed from the boat prior to entering the water. If there is no discernable depth contour, the line will be approximately parallel to shore. The line will be pulled taut over bottom irregularities.

Survey Method

Fish Survey Methods

A target number of fish survey sites to survey will be estimated from variability estimates derived from existing data.

A fish survey effort will include:

1. One 25m belt transect will be surveyed for all fish species. Survey will be conducted by one trained diver.
2. One Stationary Point Count survey (SPC) will be conducted at one end of the transect line for all species. The SPC survey will use a 7.5m radius tube
3. One 25 m belt transect will be surveyed for sea cucumbers, *Trochus* sp., and Crown-of-Thorns Sea Stars (COTS).

All individuals will be identified to the lowest taxonomic level and placed in to a predetermined size class.

These surveys should take somewhere between 20-30 minutes to complete.

Coral Survey Methods

One 10-m segment of the 25 m transect line will be surveyed by a single coral diver. This transect line will be one already surveyed by the fish survey team and will correspond with that used by the algae team and overlap a portion of the line used by the non-coral invertebrate team.

A target number of coral survey sites to survey will be estimated from variability estimates derived from existing data in the CNMI.

A coral survey effort will include:

1. A survey conducted along a 25 m transect line, with one randomly placed 5 to 10 m belt surveyed along the line. This transect would be the same line used by the fish survey team.

2. All coral individuals 0.5 m each side of the line will be identified to the lowest taxonomic level and placed in a predetermined size class.
3. Percent of dead/live tissue will be visually estimated and recorded for colonies that display evidence of having undergone complete fission.
4. Bleached and recently dead corals will be enumerated and sized. Photos of any unusual coral growth anomalies or tissue deterioration will be taken (to be forwarded to a coral disease specialist for general category classification). Coral/coral tissue will not be collected.
5. Photographs of the bottom will be taken, primarily for archival purposes.

These surveys will take approximately 45-60 minutes to complete

Non-Coral Invertebrates Survey Methods

Survey would be conducted along a 50 m transect line. This line would comprise the same 25-m line used by the fish, coral, and algae survey teams and would extend an additional 25 meters.

The non-coral invertebrate survey effort will include:

1. One 50 x 4 m belt transect in which all unattached non-coral macroinvertebrates are identified and counted.
2. Up to ten (10) randomly placed 1 x 1 m quadrats will be surveyed along the 50 m transect line. The presence/absence of all non-coral macroinvertebrates will be noted.

Algae Survey Methods

Survey would be conducted along a 25 m transect line. This line would be the same line used by the fish and coral survey team and would overlap part of the non-coral invertebrate line.

The algal survey effort will include:

1. Six 0.4 x 0.5 m quadrats surveyed along a 25 m transect line.
2. The percent cover of all benthic taxa will be visually estimated. Species that are rare will be assigned a cover of 1%.
3. Algae will be identified to the lowest possible taxonomic level. Other groups will also be identified as low as possible, but will not have the same resolution as algae. As necessary, specimens will be collected to confirm the field identification in the lab and voucher specimens will be deposited in the marine herbarium at the University of Guam.

These surveys will take approximately 45-60 minutes to complete

Rugosity Survey Methods
At all sites, rugosity will be measured by a diver to be assigned prior to entering the water. Rugosity will be surveyed using a rugosity chain along one 10-m section of the 25 meter transect line. This area will correspond with the coral belt transects on the benthic line.

These surveys will take approximately 10 minutes to complete

Reporting and Products

All "reports" should be submitted to the USFWS.

Data Sheets
The taxonomic lead will be responsible for ensuring that copies of all field data sheets are submitted to the USFWS by the conclusion of the project.

Data Summary Report
The taxonomic lead will be responsible for working with his/her team to compile a brief Data Summary Report that will submit to the USFWS within 21 calendar days of the completion of the field surveys a completed Data Summary Report. This will include:

1. All field data collected by the taxonomic team entered into an Excel data sheet provided by the USFWS
2. All data collected by the taxonomic team summarized into appropriate tables, as applicable
3. Copies of all field notes and site descriptions that include large-scale habitat observations, perceptions of reef condition, and notations pertaining to any species, habitats, or areas of special interest or with high natural resource value

Review of Working Draft Survey Report
A working Draft Survey Report will be assembled by the USFWS and provided to all taxonomic leads (and survey members if requested) for comment. This report should be checked for accuracy and completeness and comments provided to the USFWS by an agreed up date to allow revision of the Draft Survey Report prior to submission to the Navy.

Adaptive Implementation

Many aspects of this project continue to change as new information emerges from the Department of Defense. This may require alterations in the location of the surveys and the level of survey effort necessary to achieve the project objectives. However, methodologies and reporting requirements are not anticipated to change. Any changes in to this document will be made in cooperation and with the support of the technical staff at each partner agency.

Appendix A. Calculating Number of Survey Sites

Estimates of Number of Fish Survey Sites

Data was obtained from Mike Trianni at CNMI Division of Fish and Wildlife (DFW), and included counts of acanthurids (most common group) and counts of "all" fish. The data was collected over two years in a relatively small geographical area, so the variability is expected to be similar to what we might be seen at a given area of interest on Pagan.

Using the variability estimates obtained from the data, standard error of the mean (SEM) was determined for different numbers of survey sites (Table A.1). The SEM was expressed as a percent of the mean.

The following trends emerge:

1. As suspected, the variability in the fish data is higher than that observed in the coral estimates. Therefore, the precision of fish estimates will be lower.
2. In the data provided by DFW, "back reef" (=reef flat) has higher variability than the fore reef. It would take a large effort (~100 survey sites per area of interest) to obtain similar precision for back reef populations.
3. With about 15-20 survey sites per area, a 10-12% standard error on the fore reef and a 20-25% standard error on the back reef can be obtained. It would require ~100 samples to reduce the error of the back reef estimates to 10%.

Conclusions:

Approximately 15-20 survey sites per area are the target goal for this work.

Table A.1. Calculated estimates of the standard error of the mean (SEM) for Fish Counts. The SEM values are expressed as “Percent of the Mean.” Values are derived from variability estimates obtained from sample data provided by the CNMI Division of Fish and Wildlife.

		SEM (Percent of the mean)			
		Fore Reef		Back Reef	
Year	Sites (n)	Acan	"All" Fish	Acan	"All" Fish
2005	5	0.244997	0.272312	0.477766	0.331825
	10	0.173239	0.192554	0.337832	0.234636
	15	0.141449	0.157219	0.275839	0.191579
	20	0.122499	0.136156	0.238883	0.165913
	25	0.109566	0.121782	0.213664	0.148397
	30	0.100020	0.111171	0.195047	0.135467
2006	5	0.176066	0.157416	0.42926	0.472192
	10	0.124498	0.11131	0.303533	0.33389
	15	0.101652	0.090884	0.247834	0.27262
	20	0.088033	0.078708	0.21463	0.236096

	25	0.078739	0.070398		0.191971	0.211171
	30	0.071879	0.064265		0.175245	0.192772
All Spatial-Temporal	5	0.21639	0.219725		0.44638	0.39876
	10	0.153011	0.155369		0.315639	0.281966
	15	0.124933	0.126858		0.257718	0.230224
	20	0.108195	0.109863		0.22319	0.19938
	25	0.096772	0.098264		0.199627	0.178331
	30	0.088341	0.089702		0.182234	0.162793

Estimates of Number of Coral Survey Sites and Length of Coral Transect

Data was obtained from Peter Houk at CNMI Division of Environmental Quality (DEQ), and included counts of all coral species. The data was collected over a multi year period on the western side of Saipan. These sites are "similar" to what we can expect on Pagan, so they should provide best available information on population variability.

Using the variability estimates obtained from the data, standard error of the mean (SEM) was determined for different numbers of survey sites (Table A.2) and the amount of bottom that needs to be surveyed (Figures A.1 and A.2). The SEM was expressed as a percent of the mean.

Number of Survey Sites

From the Saipan coral data, which covered multiple years, a yearly variance and mean for the density of different coral function groups was calculated. From this changes in the standard error of the mean were examined with increasing sample size (Table A.2). The standard error was expressed as the percent of the mean.

Precise estimates could be obtained with modest sample sizes, ~10-15 survey sites per area. An overall SEM in the 5% range for all corals and an SEM in the 2-25% range for function groups appears likely.

Conclusions:

Approximately 10-15 survey sites per area is the target goal for this work.

Table A.2. Calculated estimates of the standard error of the mean (SEM) for Coral morphological group densities. The SEM values are expressed as "Percent of the Mean." Values are derived from variability estimates obtained from sample data provided by the CNMI Division of Environmental Quality. See text for explanation of the methods to generate the table values. Highlighted rows are the target number of survey sites.

		SEM (Percent of the mean)					
Year	Sites (n)	Branching	Columnar[1]	Cryptic	Encrusting	Massive	Grand Total
2003	3	0.3422	NA	0.2721	0.0147	0.4420	0.1037

	5	0.2651	NA	0.2108	0.0113	0.3424	0.0803
	10	0.1874	NA	0.1490	0.0080	0.2421	0.05681
	15	0.1530	NA	0.1217	0.0065	0.1977	0.0463
	20	0.1325	NA	0.1054	0.0057	0.1712	0.0401
	25	0.1185	NA	0.0942	0.0050	0.1531	0.0359
2005	3	0.2001	NA	0.6804	0.0120	1.0958	0.4893
	5	0.1108	NA	0.2874	0.0054	0.4112	0.2108
	10	0.0783	NA	0.2032	0.0038	0.2908	0.1490
	15	0.0639	NA	0.1659	0.0031	0.2374	0.1217
	20	0.0554	NA	0.1437	0.0027	0.2056	0.1054
	25	0.04957	NA	0.1285	0.0024	0.1839	0.0942
2006	3	0.2953	NA	0.7257	0.1324	0.4639	0.0563
	5	0.2287	NA	0.5621	0.1025	0.3593	0.0436
	10	0.1617	NA	0.3975	0.0725	0.2540	0.0308
	15	0.1320	NA	0.3245	0.0592	0.2074	0.0251
	20	0.1143	NA	0.2810	0.0512	0.1796	0.0218
	25	0.1023	NA	0.2514	0.0458	0.1607	0.0195
Average of	3	0.2792	NA	0.5594	0.0530	0.6672	0.2164
All Years	5	0.2015	NA	0.3534	0.0398	0.3710	0.1115
	10	0.1425	NA	0.2499	0.0281	0.2623	0.0789
	15	0.1163	NA	0.2040	0.0229	0.2142	0.0644
	20	0.1007	NA	0.1767	0.0199	0.1855	0.0557
	25	0.0901	NA	0.1580	0.0178	0.1659	0.0499

[1]Columnar corals occurred at only one survey site resulting in no variance or mean estimates.

Within Survey Site Effort

The effort to adequately sample a single survey site must be weighed against the need/desire to increase the number of survey sites visited. The goal is to adequately characterize the site without using more effort than is needed.

The DEQ data was collected in 0.25 m-sq intervals, so an accumulation curve was produced to examine the level effort is needed produce an adequate inventory and also to examine the behavior of density estimates. Ideally, sampling should continue until the effort needed to get additional precision outweighs the benefit provided.

A graph of the coral genera accumulation curves that were generated from 3 different sites on Saipan in different years is provided in Figure A.1. From the figure, after about 10 quadrats, little benefit is gained with additional effort. Ten quadrats correspond with 2.5 m-sq of bottom. (Note: The method employed here is not based on randomizations and will not be as accurate as results obtained using that method.)

Figure A.2. shows the behavior of the density estimate for coral functional groups. Graphs for the three sites for each year were generated; the two provided are typical of all of the graphs. These figures show that the density estimates change little after ~10 quadrats have been surveyed. This data is very consistent with the genera accumulation curves.

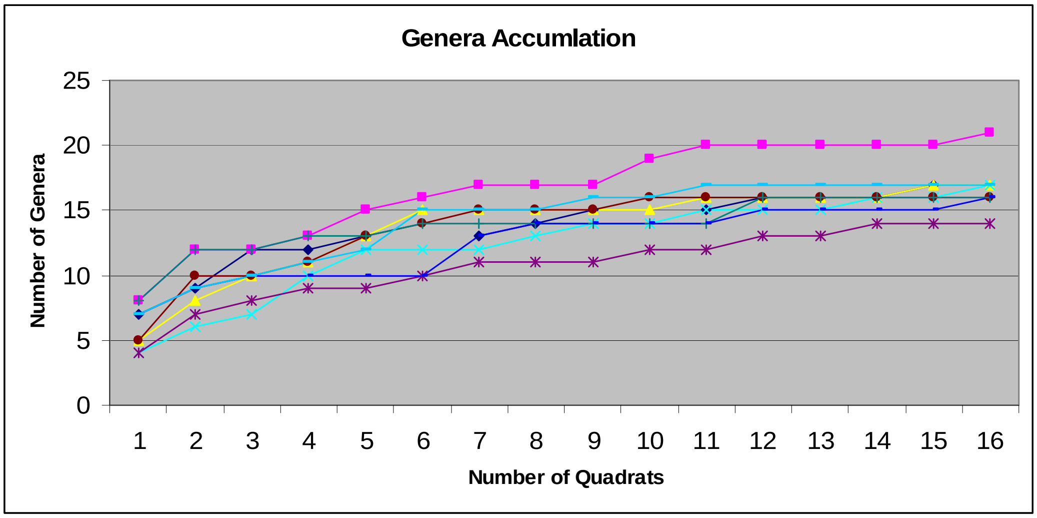
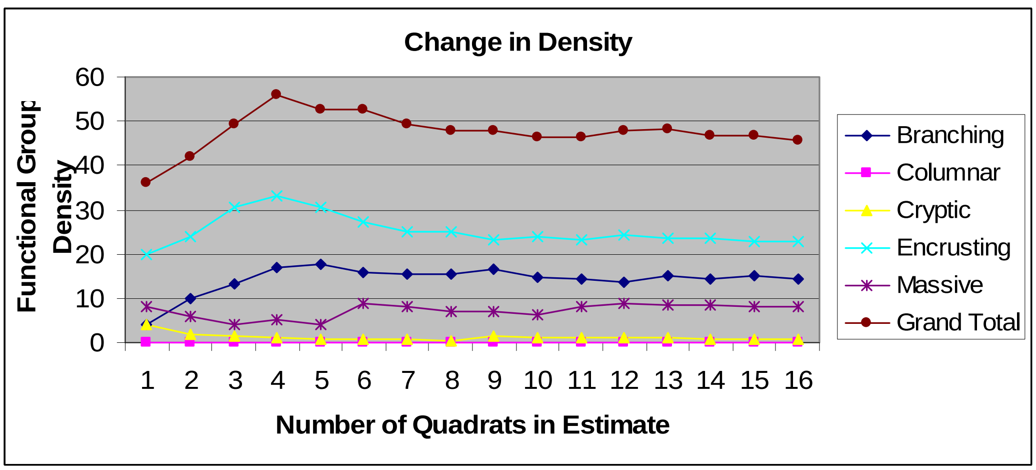


Figure A.1. Accumulation of coral genera with increasing numbers of quadrats. Each line represents a single site and year on Saipan. Data supplied by CNMI Division of Environmental Quality.



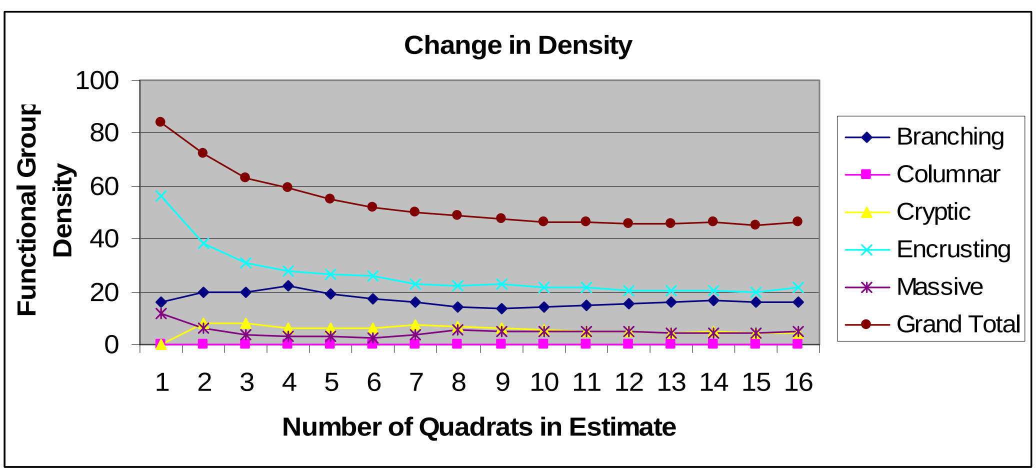


Figure A.2. Changes in mean density with additional quadrats. Each graph uses data from a single site and year on Saipan. The two graphs are typical of all sites examined. Each line represents the density of a coral morphological (=functional in this figure) group. Data supplied by CNMI DEQ.

Conclusions:

Based on these results, one 5-m belt transect should be sufficient to characterize most surveys areas. The proposal to survey two 5-m belt transects should provide adequate precision.

Estimates of Number of Non-Coral Invertebrate Survey Sites

Data was obtained from Peter Houk at CNMI Division of Environmental Quality (DEQ), and included counts of non-coral invertebrate species. The data was collected over a multi-year period on the western side of Saipan. These sites are "similar" to what we can expect on Pagan, so they should provide best available information on population variability.

Using the variability estimates obtained for three species for which there was adequate data, standard error of the mean (SEM) was determined for different numbers of survey sites (Table A.3). The SEM was expressed as a percent of the mean.

The variability within the non-coral invertebrate data is higher than that observed in the coral estimates. Therefore, the precision of non-coral invertebrate estimates will be lower. To get precision that is comparable to the coral data would require ~75 survey stations per site which is beyond what can be completed for this work. However, surveying the same number of sites as for coral (10-15) generates SEM less than 50% of the mean.

Conclusions:

While not ideal, 15-20 survey sites per area are the target goal for this work. It is not possible within the scope of this work to produce data with higher precision.

Table A.3. Calculated estimates of the standard error of the mean (SEM) for the density estimates of three species of non-coral invertebrates. The SEM values are expressed as "Percent of the Mean." Values are derived from variability estimates obtained from sample data provided by the CNMI Division of Environmental Quality. See text for explanation of the methods to generate the table values. Highlighted rows are the target number of survey sites.

		SEM (Percent of the mean)		
Year	Sites (n)	Echinometra	Echinostrephus	Echinothrix
2001	3	0.4117	0.5868	0.4302
	5	0.3189	0.4545	0.3332
	10	0.2255	0.3214	0.2356
	15	0.1841	0.2624	0.1924
	20	0.1594	0.2272	0.1666
	25	0.1426	0.2033	0.1490
2002	3	0.7204	0.4345	0.2705
	5	0.6324	0.0799	0.6324
	10	0.4472	0.0565	0.4472
	15	0.3651	0.0461	0.3651
	20	0.3162	0.0399	0.3162
	25	0.2828	0.0357	0.2828
2003	3	0.6881	0.2312	0.7012
	5	0.5330	0.1791	0.5431
	10	0.3769	0.1266	0.3840
	15	0.3077	0.1034	0.3136
	20	0.2665	0.0895	0.2715
	25	0.2383	0.0801	0.2429
2005	3	0.0199	0.5443	0.7508
	5	0.0154	0.4216	0.5816
	10	0.0109	0.2981	0.4112
	15	0.0089	0.2434	0.3358
	20	0.0077	0.2108	0.2908
	25	0.0068	0.1885	0.2601
2006	3	0.0462	0.8164	0.2332
	5	0.0357	0.6324	0.1807
	10	0.0253	0.4472	0.1277
	15	0.0206	0.3651	0.1043
	20	0.0178	0.3162	0.0903
	25	0.0160	0.2828	0.0808
All Spatial-Temporal	3	0.2482	0.4425	0.7563
	5	0.1923	0.3428	0.5858
	10	0.1359	0.2424	0.4142
	15	0.1110	0.1979	0.3382

Table A.3 (continued).

		SEM (Percent of the mean)		
Year	Sites (n)	Echinometra	Echinostrephus	Echinothrix
	20	0.0961	0.1714	0.2929
	25	0.0860	0.1533	0.2619

Appendix B. Randomly Selected Survey Sites

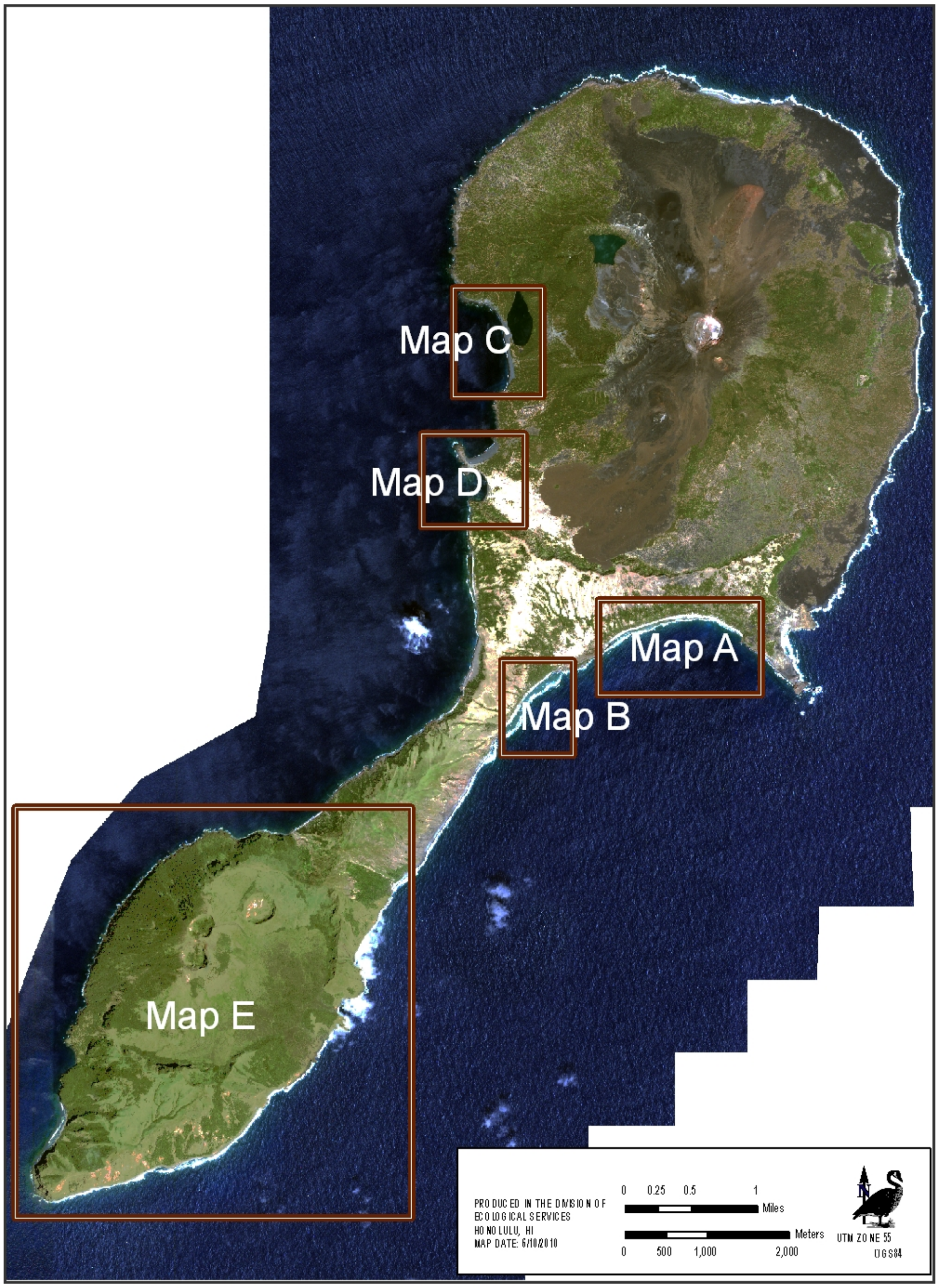


Figure B.1. Pagan Island aerial view showing focus areas for marine resource surveys.

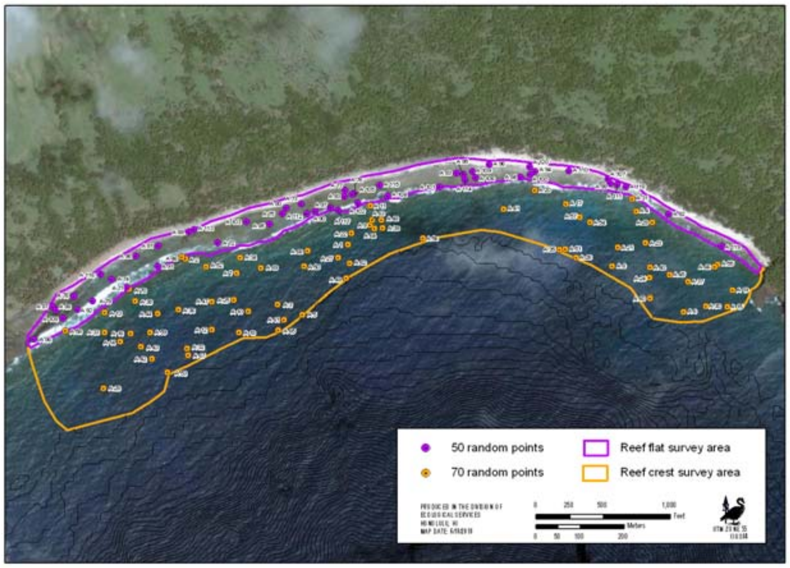


Figure B.2. Enlargement of inset Map A showing the random selected survey sites for the northern beach on the eastern side of Pagan.

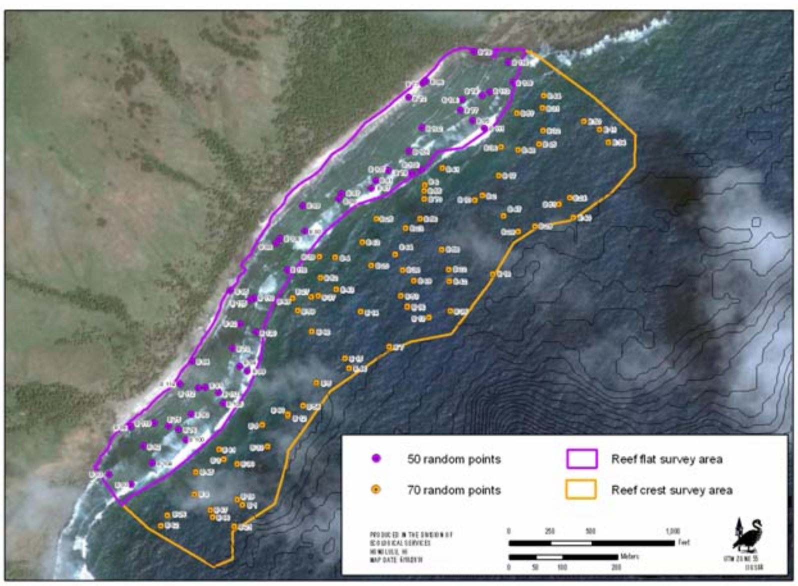


Figure B.3. Enlargement of inset Map B showing the random selected survey sites for the southern beach on the eastern side of Pagan.

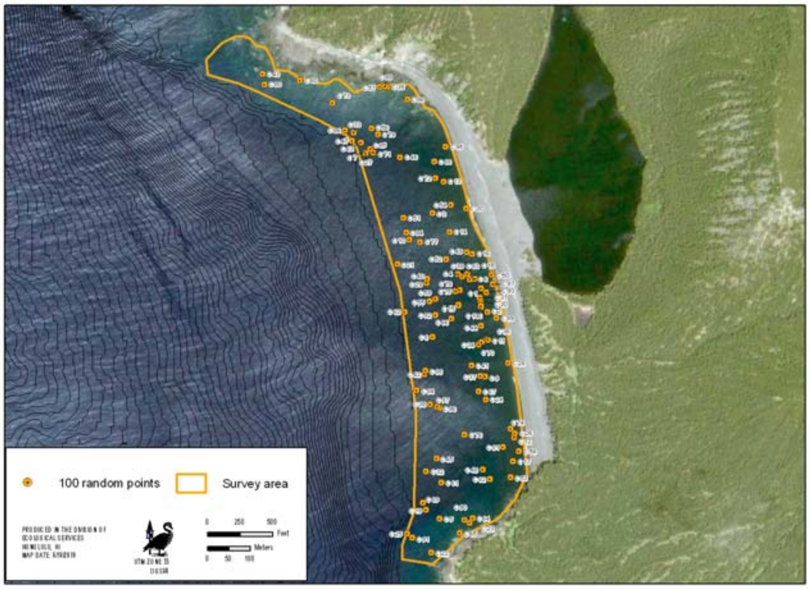


Figure B.4. Enlargement of inset Map C showing the random selected survey sites for the northern beach on the western side of Pagan.

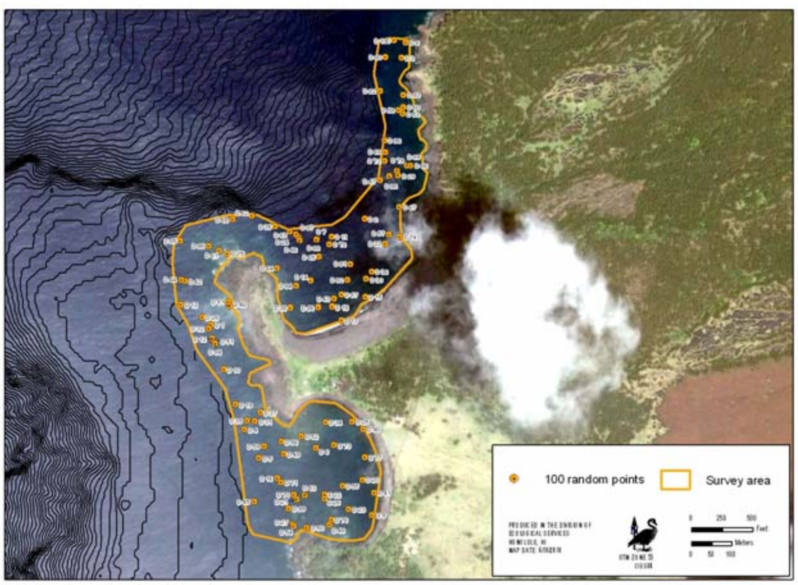


Figure B.5. Enlargement of inset MapD showing the random selected survey sites for the two southern beaches on the western side of Pagan.

Appendix A: Marine Survey Design and Methods

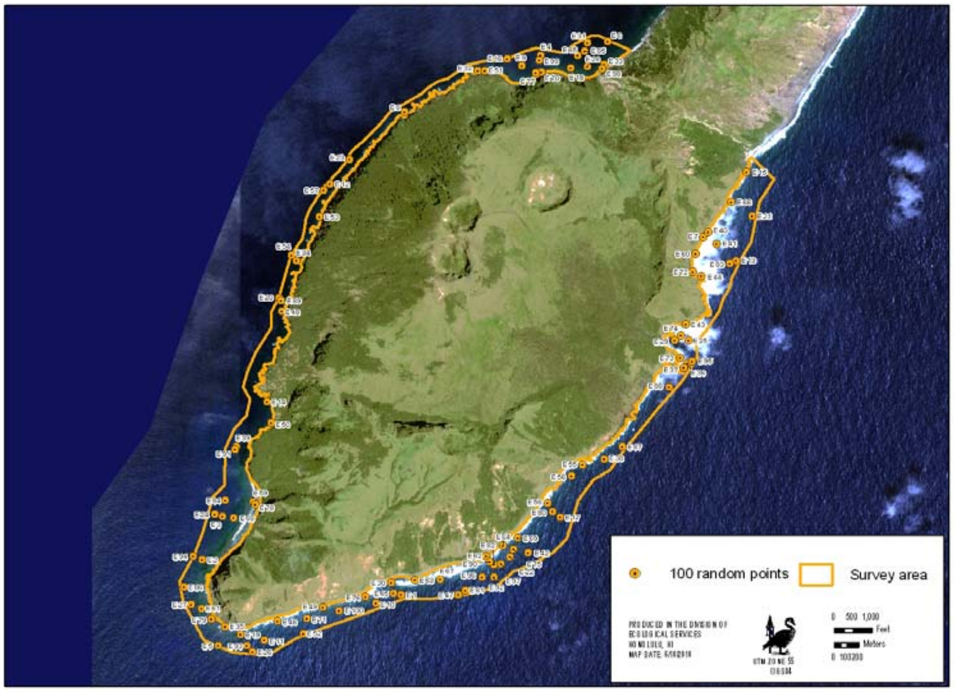


Figure B.6. Enlargement of inset Map E showing the random selected survey sites for the southern tip of Pagan.

Appendix B.

Survey Site Data for Map C (Figure C.1, Table C.1), Map D(Figure C.2, Table C.2), Map E (Figure C.3, Table C.3), and Map X(Figure C.4, Table C.4).

**New map letters and site identification numbers reflect changes that were made to data collection and reporting efforts after arriving at Pagan Island.

Figure C.1. Map C Random Survey Points (July 2010)

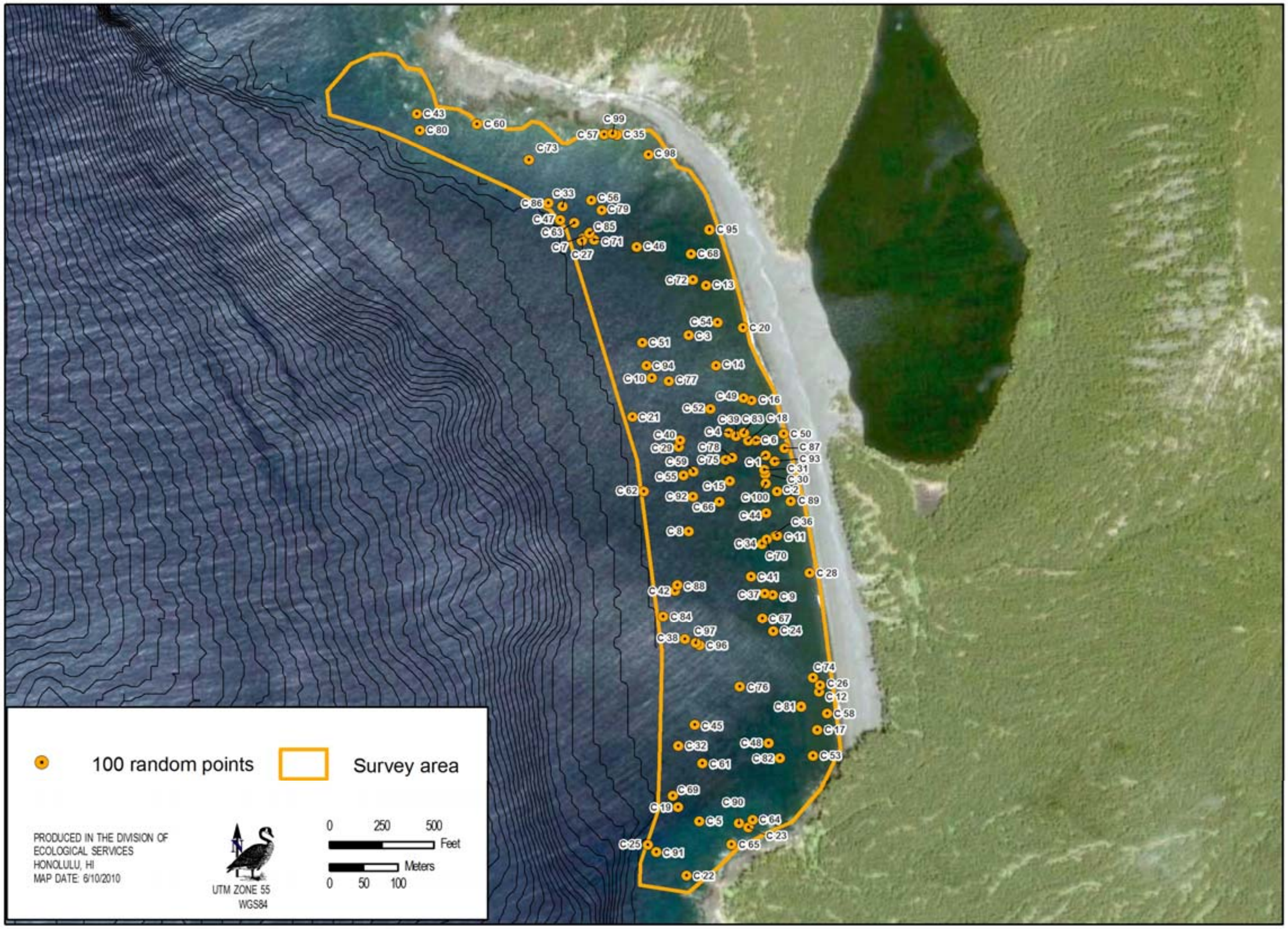


Figure C.2. Survey sites where quantitative data collected within Map C (July 2010)

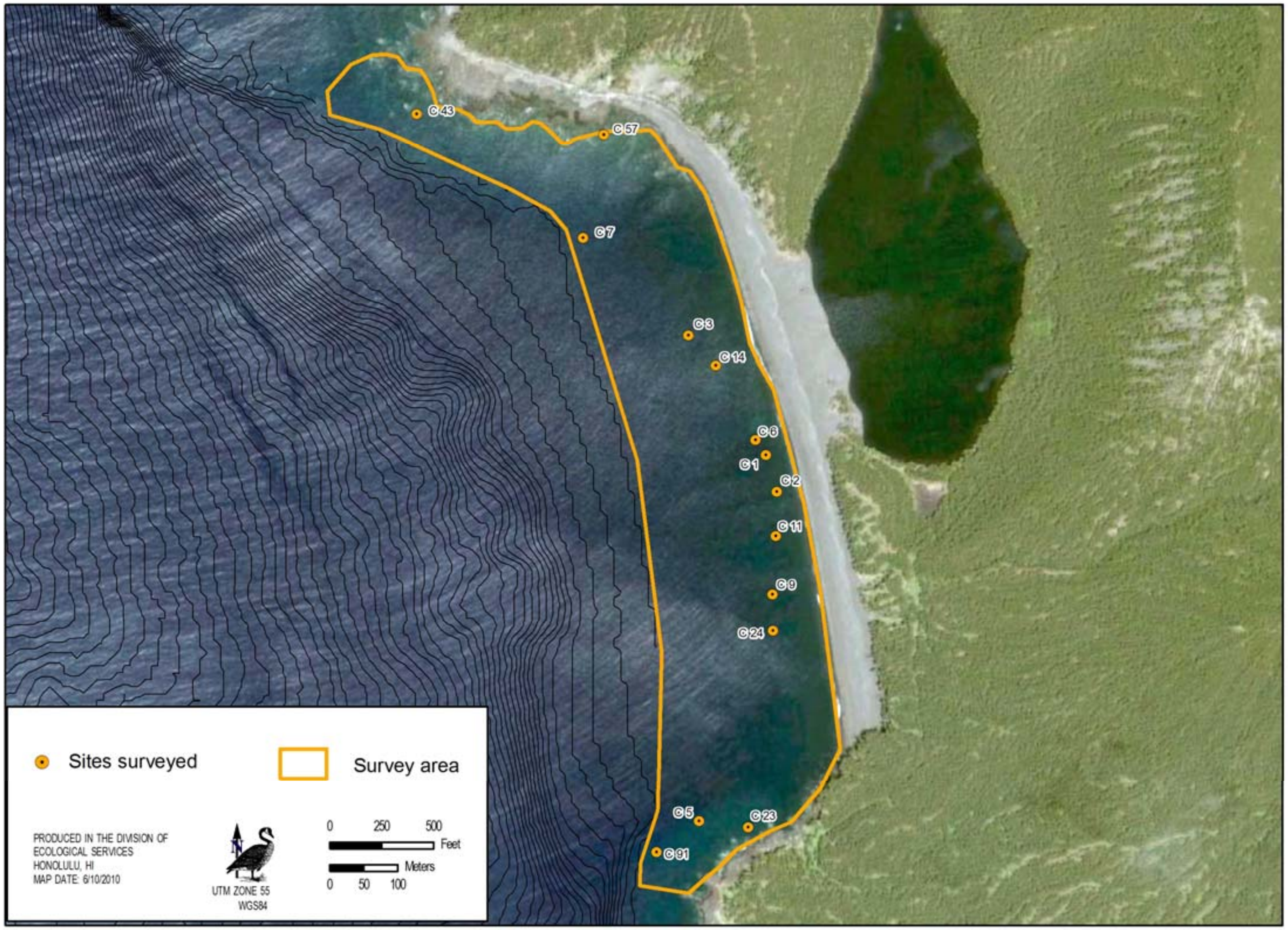


Table C.1. Survey sites where quantitative data collected within Map C

SiteName	Depth (m)	Rugosity	Start Latitude	Start Longitude	Date	Fish Surveyors[1]	Benthic Surveyors[2]
C 001	4.27		18.1390302823	145.761348367	10-July-10	VB, MT, SM	NS, SK, TS, AD
C 002	3.35		18.1385459643	145.761503712	11-July-10	VB, MT, SM	NS, SK, TS, AD
C 003	7.01		18.1406138404	145.760267715	15-July-10	VB, MT, SM	NS, TS, AD
C 005	5.49		18.1341673125	145.760462589	10-July-10	VB, MT, SM	NS, SK, AD
C 006	2.74		18.1392286551	145.761204718	11-July-10	VB, MT, SM	NS, SK, TS, AD
C 007	9.14		18.1418979459	145.758796082	10-July-10	VB, MT, SM	NS, SK, AD
C 009	6.4		18.1371770817	145.761454627	15-July-10	VB, MT, SM	NS, TS, AD
C 011	4.27		18.1379567961	145.761492664	15-July-10	VB, MT, SM	NS, TS, AD
C 014	6.71		18.1402143382	145.76064892	15-July-10	VB, MT, SM	NS, TS, AD
C 023	2.74		18.1340882711	145.76114173	11-July-10	VB, MT, SM	NS, SK, TS, AD
C 024	4.88		18.136694198	145.761465369	15-July-10	VB, MT, SM	NS, TS, AD
C 043	4.57		18.1435303726	145.75648133	11-July-10	VB, MT, SM	NS, SK, TS, AD
C 057	1.83		18.1432713395	145.759074785	10-July-10	VB, MT, SM	
C 091	9.14		18.13375695	145.759872406	10-July-10	VB, MT, SM	NS, SK, AD

[1]VB=V. Brown, MT=M. Tenorio, SM=S. McKagan
[2]NS= N. Sukhraj, SK=S. Kolinski, TS=T. Schils, AD=A. deVillers

Figure C.3. Map D Random Survey Points (July 2010)

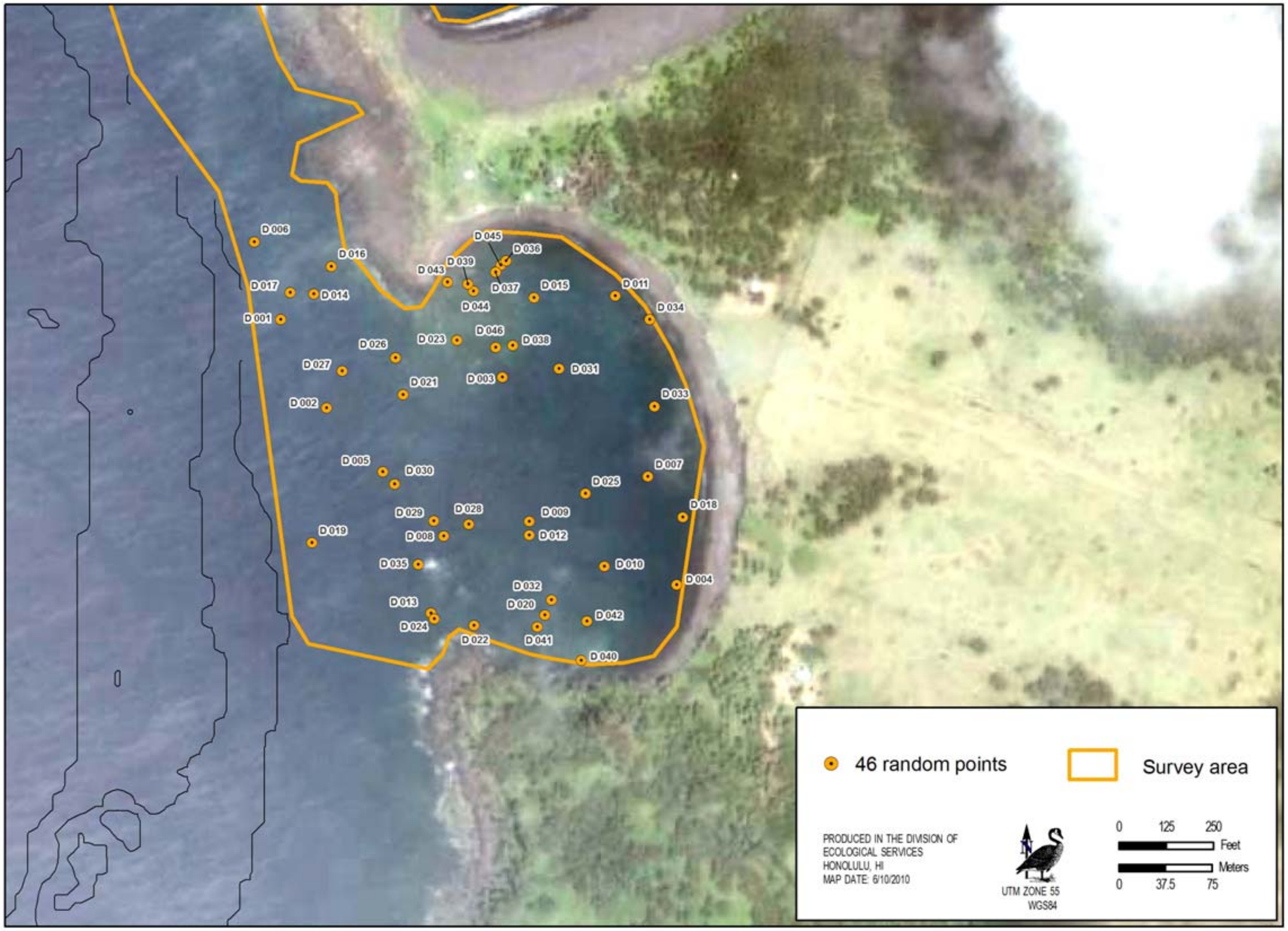


Figure C.4. Survey sites where quantitative data collected within Map D (July 2010)

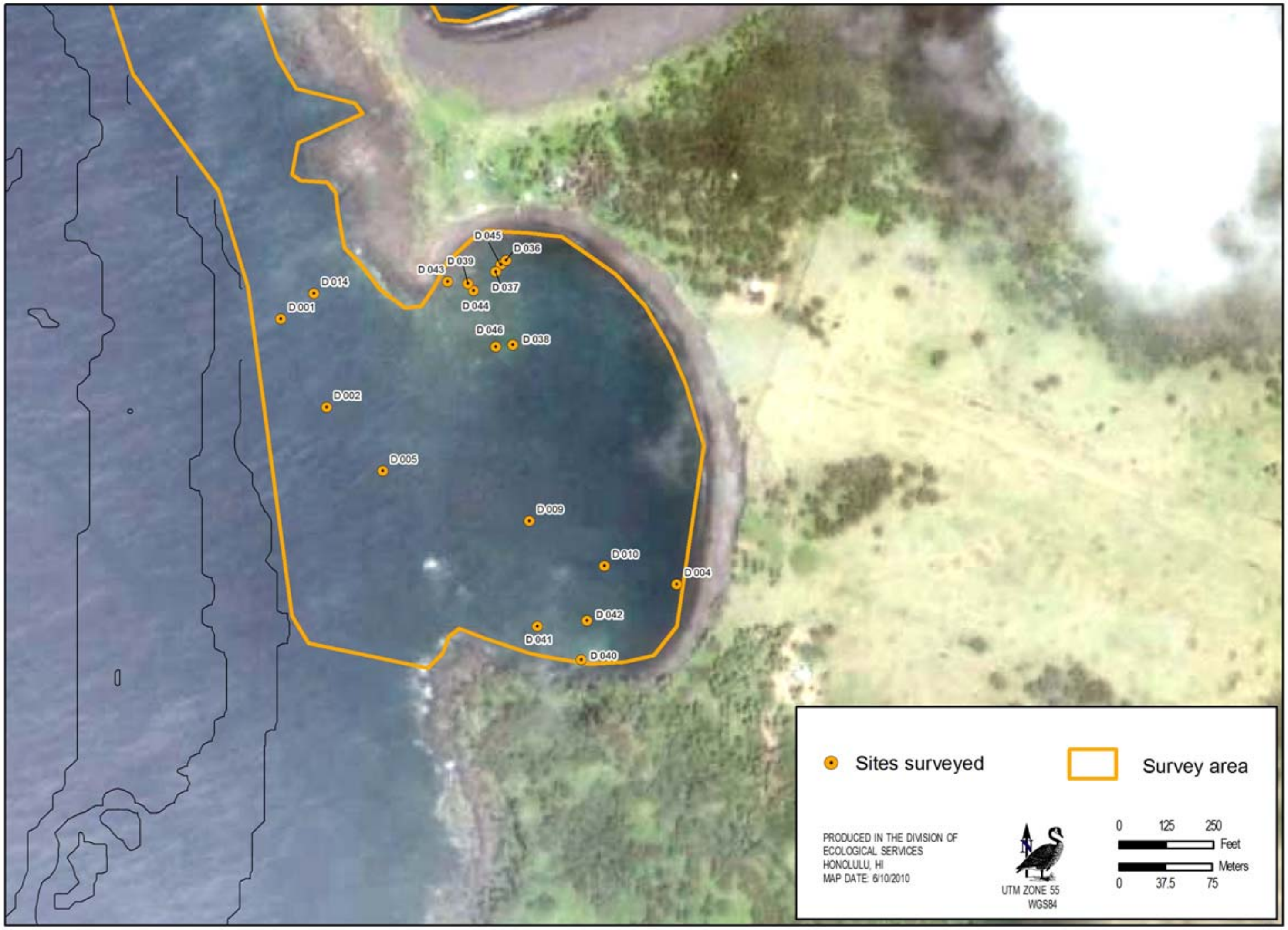


Figure C.5. Map D. Eleven 25m transects added to random survey points. Areas of high coral cover and diversity. (July 2010)

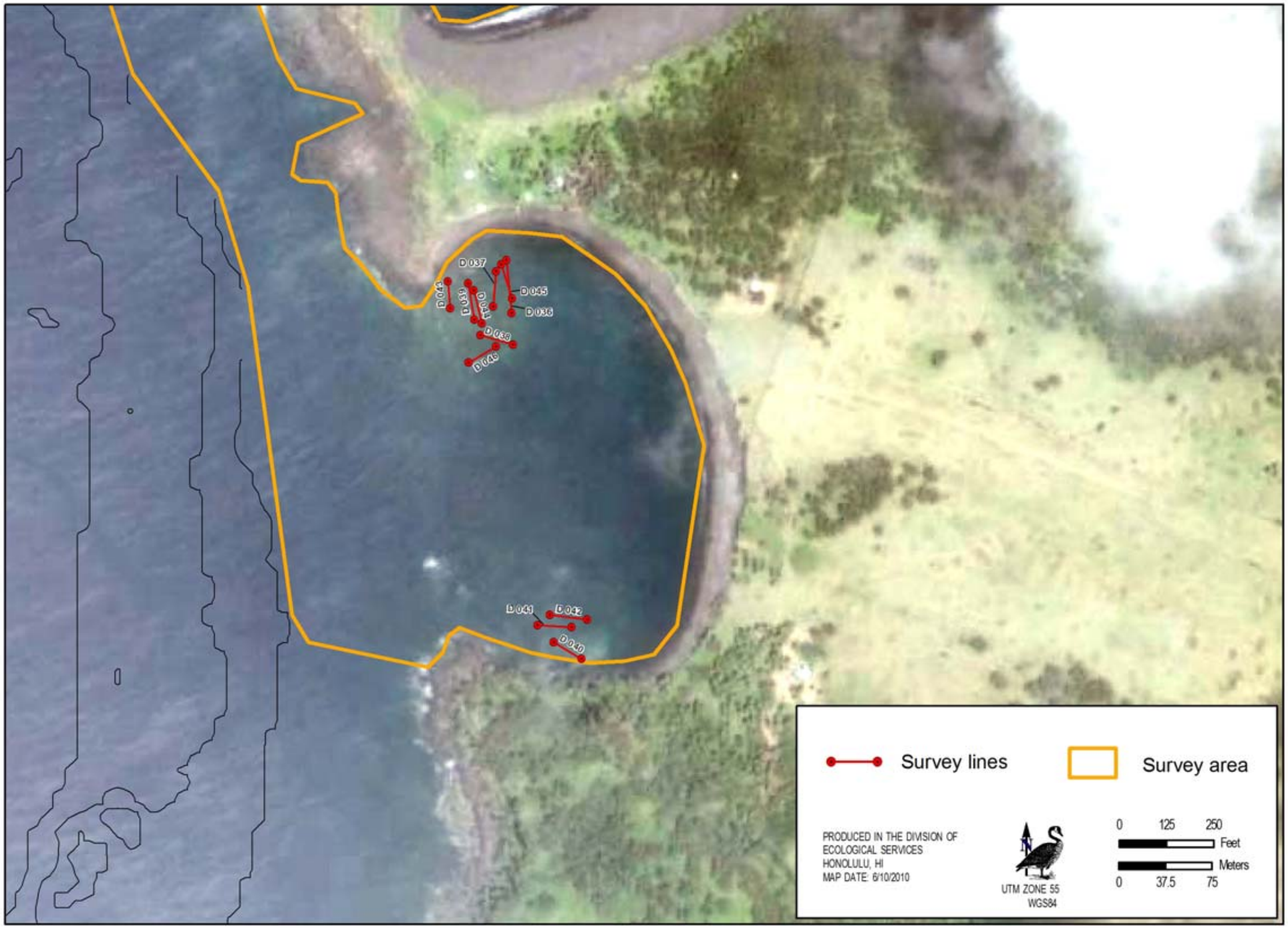


Table C.2. Survey sites where quantitative data collected within Map D

SiteName	Depth (m)	Rugosity	Start Latitude	Start Longitude	Date	Fish Surveyors[1]	Benthic Surveyors[2]
D 001	4.27		18.1244103119	145.756478259	12-July-10	VB, MT, SM	NS, SK, TS, AD
D 002	3.05		18.1237656748	145.756831503	12-July-10	VB, MT, SM	
D 004	0.76		18.1224974455	145.759509321	09-July-10	VB, MT, SM	
D 005	6.71		18.1233061724	145.757264848	20-July-10	VB, MT, SM	
D 009	4.27		18.1229493526	145.758382631	14-July-10	VB, MT, SM	NS, TS, AD
D 010	3.96		18.1226267335	145.758958988	20-July-10	VB, MT, SM	
D 014	7.62		18.1245949133	145.756729634	20-July-10	VB, MT, SM	NS, AD
D 036	4.88		18.12484545	145.75819326	17-July-10		SK, TS, AD
D 037	4.88		18.12476515	145.75811262	17-July-10		SK, TS, AD
D 038	4.88		18.12423122	145.75824556	17-July-10		SK, TS, AD
D 039	4.88		18.12467714	145.7579014	17-July-10		SK, TS, AD
D 040	1.52		18.12194011	145.75878577	18-July-10	VB, MT, SM	NS, SK, TS, AD
D 041	1.52		18.12218218	145.75844957	18-July-10	VB, MT, SM	NS, SK, TS, AD
D 042	1.52		18.12222837	145.75882743	18-July-10	VB, MT, SM	
D 043	3.05		18.12468812	145.75774633	18-July-10	VB, MT, SM	NS
D 044	3.05		18.12462509	145.75794482	18-July-10	VB, MT, SM	NS
D 045	2.74		18.12481401	145.75815312	18-July-10	VB, MT, SM	
D 046	2.44		18.12421697	145.75811908	18-July-10	VB, MT, SM	

[1]VB=V. Brown, MT=M. Tenorio, SM=S. McKagan, [2]NS= N. Sukhraj, SK=S. Kolinski, TS=T. Schils, AD=A. deVillers

Figure C.6. Map E Random Survey Points (July 2010)

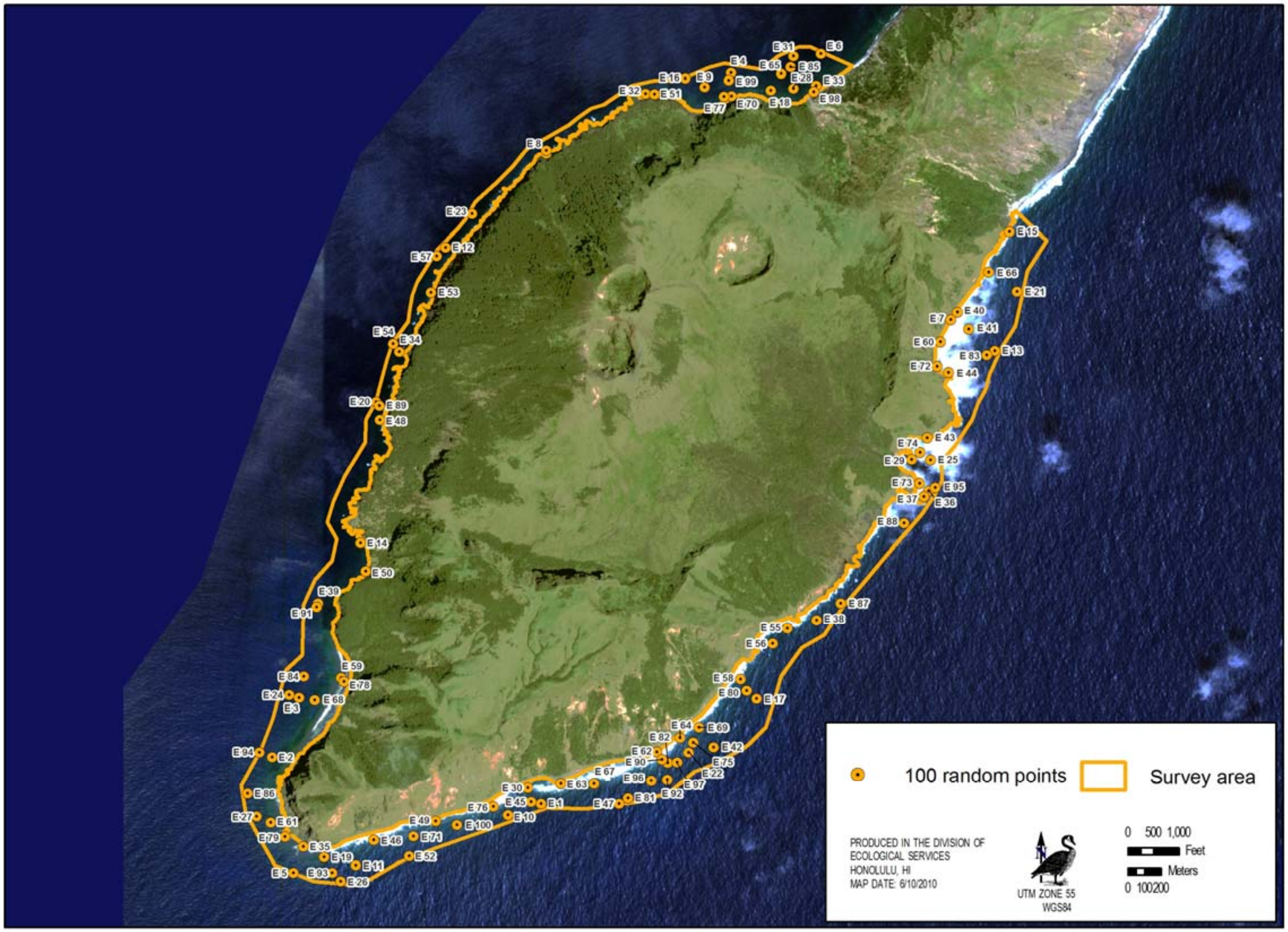


Figure C.7. Survey sites where quantitative data collected within Map E (July 2010)

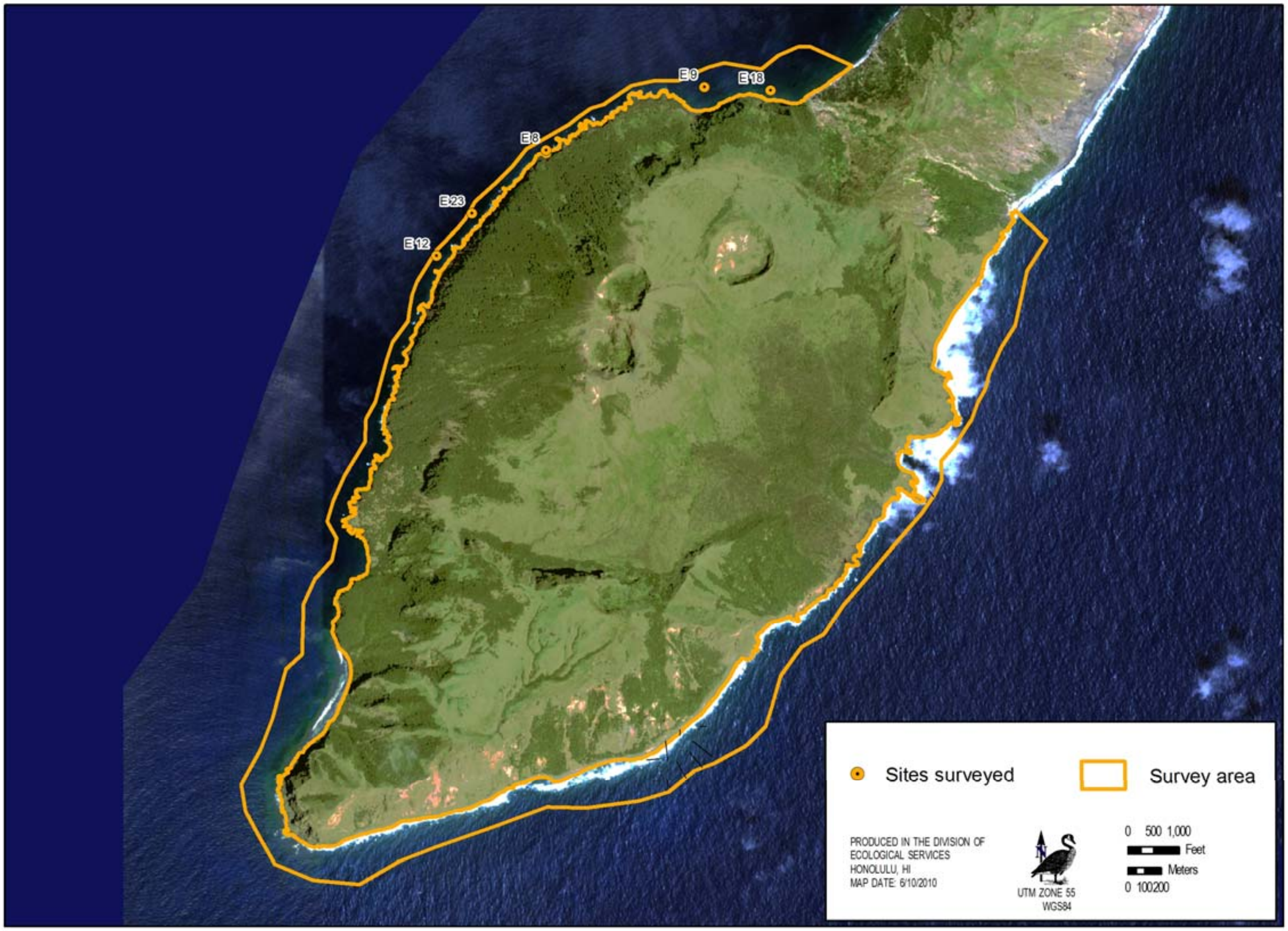


Table C.3. Survey sites where quantitative data collected within Map E

SiteName	Depth (m)	Rugosity	Start Latitude	Start Longitude	Date	Fish Surveyors[1]	Benthic Surveyors[2]
E 008	4.57		18.0824008881	145.722892981	19-July-10	VB, MT, SM	NS, SK, TS, AD
E 009	9.14		18.0858870015	145.731829984	19-July-10	VB, MT, SM	NS, SK, TS, AD
E 012	9.14		18.0766561682	145.716703676	19-July-10	VB, MT, SM	NS, SK, TS, AD
E 018	8.53		18.0857401238	145.735584441	19-July-10	VB, MT, SM	
E 023	8.84		18.0789354556	145.718698187	19-July-10	VB, MT, SM	NS, SK, TS, AD

[1]VB=V. Brown, MT=M. Tenorio, SM=S. McKagan
[2]NS= N. Sukhraj, SK=S. Kolinski, TS=T. Schils, AD=A. deVillers

Figure C.8. Map X Random Survey Points (July 2010)

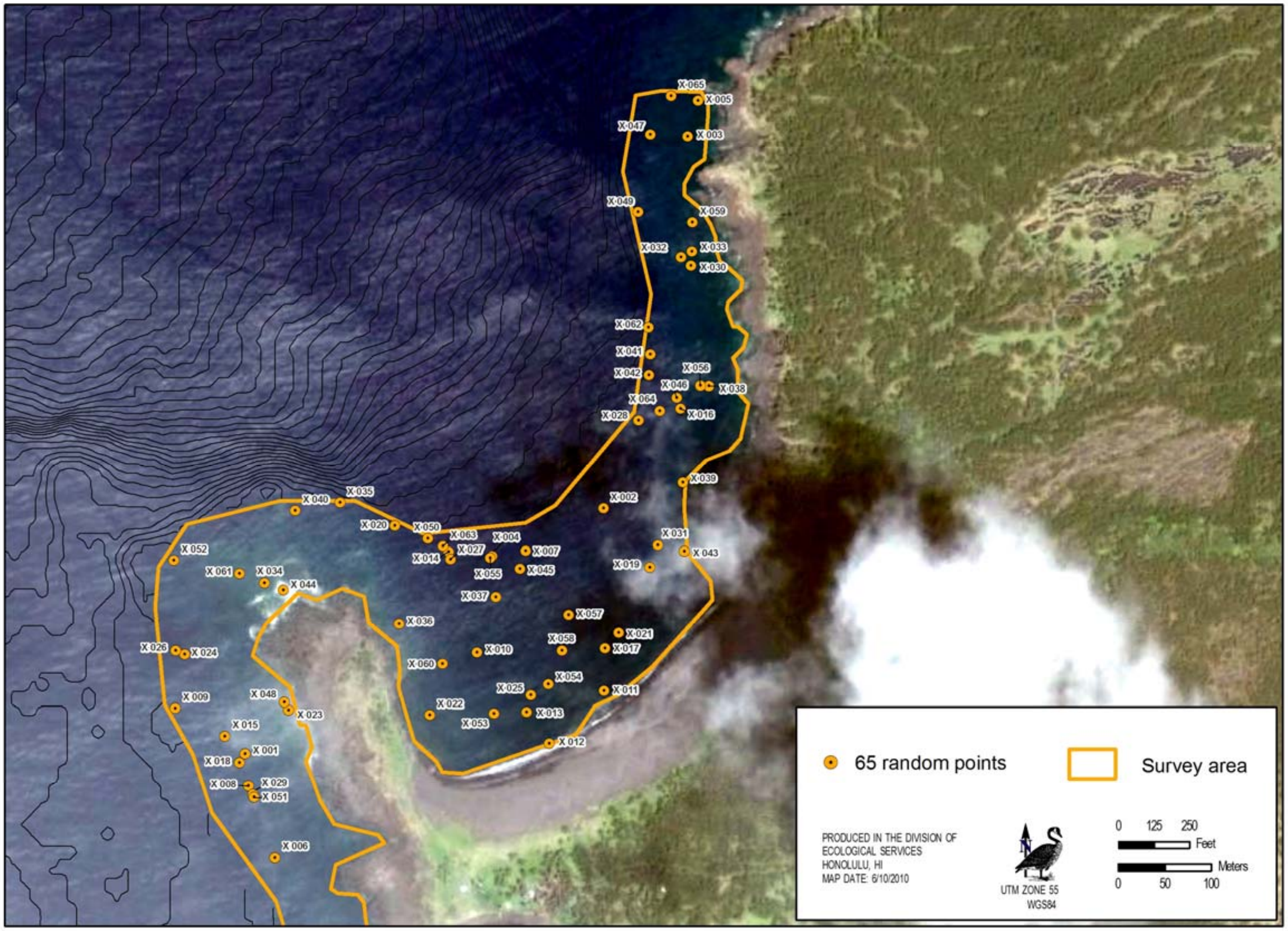


Figure C.7. Survey sites where quantitative data collected within Map X (July 2010)

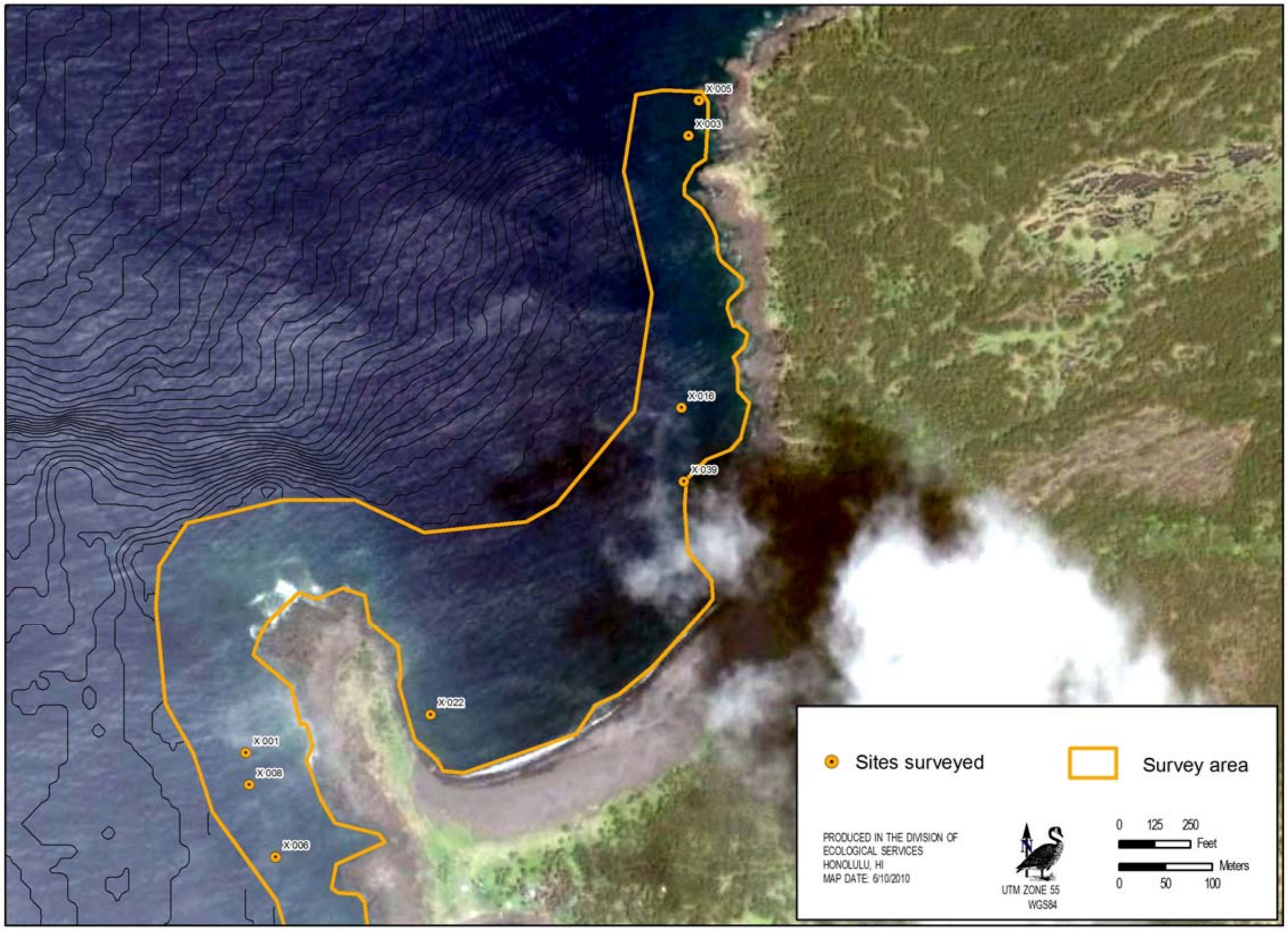


Table C.4. Survey sites where quantitative data collected within Map X

SiteName	Depth (m)	Rugosity	Start Latitude	Start Longitude	Date	Fish Surveyors[1]	Benthic Surveyors[2]
X 001	5.79		18.1267655838	145.755673192	12-July-10	VB, MT, SM	NS, SK, TS, AD
X 003	6.71		18.1328043194	145.760128965	12-July-10	VB, MT, SM	NS, SK, TS, AD
X 005	3.35		18.1331508375	145.760232161	12-July-10	VB, MT, SM	NS, SK, TS, AD
X 006	6.71		18.1257607002	145.755984483	20-July-10	VB, MT, SM	NS, SK, AD
X 008	7.01		18.1264555719	145.7557099	20-July-10	VB, MT, SM	NS, SK, TS, AD
X 016	6.4		18.1301545988	145.760075846	14-July-10	VB, MT, SM	NS, TS, AD
X 022	5.18		18.1271533861	145.757548801	20-July-10	VB, MT, SM	NS, TS, AD
X 039	6.71		18.1294356505	145.760106312	14-July-10	VB, MT, SM	NS, TS, AD

[1]VB=V. Brown, MT=M. Tenorio, SM=S. McKagan
[2]NS= N. Sukhraj, SK=S. Kolinski, TS=T. Schils, AD=A. deVillers

Appendix C.

Brief habitat descriptions for random survey points in Map C, D, E and X. Initial scouting information was used for site selection due to limited time for quantitative surveys.

Table C.1. Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected			
						Fish	Coral	Inverts	Algae
	Laguna Bay								
11-Jul-10	C001	C001	14	Shallow reef/lagoon. Sand and rock abundant	x	x	x	x	x
10-Jul-10	C002	C002	13	Shallow reef/lagoon. Boulders abundant					
11-Jul-10	C002	C002	11	Shallow reef/lagoon. Sand and rock abundant	x	x	x	x	x
10-Jul-10	C003	C003	26	Sand					
15-Jul-10	C003	C003	23	Sand		x	x	x	x
11-Jul-10	C004	C004	21	Sand					
10-Jul-10	C005	C005	18	Boulders abundant, scattered coral colonies Start of reef slope	x	x	x	x	x
11-Jul-10	C006	C006	9	Shallow reef/lagoon. Large boulders, rocks and turf algae	x	x	x	x	x
10-Jul-10	C007	C007	30	Predominantly sand with large boulders. Possible start of slope	x	x			
14-Jul-10	C008	C008	35.6	Sand	x				
10-Jul-10	C009	C009	22	Shallow reef/lagoon. Sting ray sightings Predominantly sand with large boulders					
15-Jul-10	C009	C009	21	Sand with rocks		x	x	x	x
10-Jul-10	C010	C010	32	Sand					
10-Jul-10	C011	C011	18	Shallow reef/lagoon Predominantly sand with large boulders.					
15-Jul-10	C011	C011	14	Sand with small rocks		x	x	x	x
10-Jul-10	C012	C012	on land	Boulders and sand					

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected Fish	Coral	Inverts	Algae
	Laguna Bay								
10-Jul-10	C013	C013	16.7	Shallow reef/lagoon					
				Sand with rocks					
10-Jul-10	C014	C014	22	Sand					
15-Jul-10	C014	C014	17-22	Large boulders with turf algae		x	x	x	x
11-Jul-10	C015	C015	22	Sand					
10-Jul-10	C016	C016	15	Sand					
10-Jul-10	C017	C017	on land	Large boulders and sand					
10-Jul-10	C018	C018	20	Sand					
10-Jul-10	C019	C019	43	Large boulders and sand					
				Too deep for photos from vessel					
14-Jul-10	C020	C020	13.3	Sand with small boulders	x				
10-Jul-10	C021	C021	39	Sand					
				Too deep for photos from vessel					
14-Jul-10	C022	C022	8	Large boulders, very close to shore	x				
10-Jul-10	C023	C023	10	Shallow reef/lagoon					
				Boulders abundant, scattered coral colonies					
11-Jul-10	C023	C023	9	Small rocks and coral colonies	x	x	x	x	x
				Possible start of slope					

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected: Fish	Data Collected: Coral	Data Collected: Inverts	Data Collected: Algae
	Laguna Bay								
11-Jul-10	C024	C024	19	Shallow reef/lagoon Sand with small rocks					
15-Jul-10	C024	C024	16	Sand with rocks High density juvenile reef fish and juvenile *Echinothrix diadema*		x	x	x	x
10-Jul-10	C025	C025	50	Rock and scattered coral colonies Too deep for photos from vessel					
14-Jul-10	C026	C026	on land	Sand	x				
10-Jul-10	C027	C027	36	Large boulders and sand Too deep for photos from vessel					
14-Jul-10	C028	C028	on land	Pavement and sand	x				
10-Jul-10	C029	C029	31	Sand					
11-Jul-10	C030	C030	14.5	Sand					
11-Jul-10	C031	C031	16.5	Sand					
10-Jul-10	C032	C032	41	Sand					
11-Jul-10	C033	C033	30	Large boulders and coral colonies Possibly on slope					
11-Jul-10	C034	C034	19	Shallow reef/lagoon Sand and small rocks					
14-Jul-10	C035	C035	10	Large boulders	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected Fish	Coral	Inverts	Algae
	Laguna Bay								
14-Jul-10	C036	C036	16.9	Mix of hard bottom, sand, and small boulders	x				
11-Jul-10	C037	C037	21	Shallow reef/lagoon Sand and small rocks					
14-Jul-10	C038	C038	39.6	Sand	x				
14-Jul-10	C039	C039	22.8	95% sand with some rocks	x				
14-Jul-10	C040	C040	31	San	x				
14-Jul-10	C041	C041	25.9	70% sand, 30% boulders	x				
14-Jul-10	C042	C042	39.1	Sand	x				
11-Jul-10	C043	C043	15	Small boulders with algae	x	x	x	x	x
14-Jul-10	C044	C044	18.9	Mix of hard bottom, sand, and small boulders	x				
14-Jul-10	C045	C045	38.9	Sand	x				
14-Jul-10	C046	C046	28.7	95% sand with some rocks	x				
14-Jul-10	C047	C047	40.4	Medium boulders and sand	x				
14-Jul-10	C048	C048	24.6	Large boulders (average 10 ft diameter)	x				
14-Jul-10	C049	C049	16	Sand with large table-like rocks	x				
14-Jul-10	C050	C050	on land	On land	x				
10-Jul-10	C051	C051	31	Sand					
14-Jul-10	C052	C052	26.1	Sand	x				
14-Jul-10	C053	C053	on land	Sand	x				
14-Jul-10	C054	C054	17.3	Sand	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected			
						Fish	Coral	Inverts	Algae
	Laguna Bay								
14-Jul-10	C055	C055	33.5	Sand	x				
14-Jul-10	C056	C056	28.6	Medium boulders and sand	x				
10-Jul-10	C057	C057	6	Shallow reef Sand with rocks	x	x			
14-Jul-10	C058	C058	on land	Sand	x				
14-Jul-10	C059	C059	31.1	Sand	x				
10-Jul-10	C060	C060	on land	Partially submerged boulders and rocks					
14-Jul-10	C061	C061	37.7	Sand	x				
14-Jul-10	C062	C062	42.7	Sand	x				
11-Jul-10	C063	C063	34	Large boulders					
14-Jul-10	C064	C064	10	Mix of hard bottom, sand, and coral	x				
14-Jul-10	C065	C065	on land	On a cliff	x				
14-Jul-10	C066	C066	28.8	Sand	x				
14-Jul-10	C067	C067	24.7	Sand with clumpy calcarious algae	x				
14-Jul-10	C067	C067	22.3	Mix of boulders and sand	x				
14-Jul-10	C068	C068	19.1	Sand with few large boulders	x				
10-Jul-10	C069	C069	43	Sand Too deep for photos from vessel					
14-Jul-10	C070	C070	20.6	50% boulders, 50% sand	x				
14-Jul-10	C071	C071	31.2	Medium boulders and sand	x				
14-Jul-10	C072	C072	20.9	Sand	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected			
						Fish	Coral	Inverts	Algae
	Laguna Bay								
11-Jul-10	C073	C073	21.2	Large boulders					
10-Jul-10	C074	C074	on land	Boulders and sand					
14-Jul-10	C075	C075	25.5	Sand	x				
14-Jul-10	C076	C076	30.7	Sand	x				
14-Jul-10	C077	C077	31.7	Sand	x				
14-Jul-10	C078	C078	24.3	Sand	x				
14-Jul-10	C079	C079	29.6	Medium boulders	x				
14-Jul-10	C080	C080	27.3	Hard bottom with coral colonies	x				
14-Jul-10	C081	C081	9.3	Sand	x				
14-Jul-10	C082	C082	21.3	Sand and large boulders (average 10 ft diameter)	x				
14-Jul-10	C083	C083	21.1	50% rock, 50% sand	x				
10-Jul-10	C084	C084	39	Sand					
14-Jul-10	C085	C085	34.4	Medium boulders and sand	x				
14-Jul-10	C086	C086	33.1	Mix of sand, medium boulders, and scattered coral colonies	x				
14-Jul-10	C087	C087	on land	On land	x				
10-Jul-10	C088	C088	35	Sand Too deep for photos from vessel					
14-Jul-10	C089	C089	8.7	Mix of sand, boulders and small rubble	x				
14-Jul-10	C090	C090	13.4	Hard bottom with coral and boulders	x				
10-Jul-10	C091	C091	30 ft	Boulders with coral and turf algae	x	x	x	x	x

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected: Fish	Coral	Inverts	Algae
	Laguna Bay								
14-Jul-10	C092	C092	32.9	Sand	x				
14-Jul-10	C093	C093	13.8	90% sand with small rocks	x				
14-Jul-10	C094	C094	33.1	Sand	x				
14-Jul-10	C095	C095	11.9	85% sand with some rocks	x				
14-Jul-10	C096	C096	34.9	Sand	x				
14-Jul-10	C097	C097	37.6	Sand	x				
14-Jul-10	C098	C098	7	Sand with rocks. Very close to shore	x				
14-Jul-10	C099	C099	7	Boulders and rocks. Very close to shore	x				
14-Jul-10	C100	C100	16.6	50% sand, 50% boulders Adjacent to hard bottom	x				
	Bandeera Bay								
12-Jul-10	D004	D001	14	Hard bottom with coral	x	x	x	x	x
11-Jul-10 12-Jul-10	D005 D005	D002 D002	16.8 10	Large boulders with coral Boulders	 x	 x			
12-Jul-10	D006	D003	15	Sand with large boulders					
9-Jul-10	D009	D004	2.5	Shallow reef/lagoon Sand	x	x			
20-Jul-10	D016	D005	19.5	Sand with a few large rocks	x	x			
14-Jul-10	D019	D006	17	Hard bottom/pavement with coral	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected			
						Fish	Coral	Inverts	Algae
	Bandeera Bay								
9-Jul-10	D020	D007	10.9	Sand	x				
12-Jul-10	D021	D008	16.2	Sand, many small boulders					
12-Jul-10	D022	D009	15.2	Small boulders with scattered coral					
14-Jul-10	D022	D009	14	Sand with rocks, *Dictyosphaeria* sp. abundant	x	x	x	x	x
				Large Porites colonies					
12-Jul-10	D023	D010	9.2	Sand with scattered coral colonies					
20-Jul-10	D023	D010			x	x			
9-Jul-10	D025	D011	5.7	Sand	x				
14-Jul-10	D026	D012	11.5	Sand. Large boulders with turf algae	x				
				Large *Porites lutea* colonies					
14-Jul-10	D027	D013	14.8	Large boulders with coral. Mostly *Pocillopora*	x				
				Big rock sticking out at surface					
20-Jul-10	D031	D014	27.8	Pavement with small coral colonies	x	x		x	
				High abundance of Terpios sponge					
14-Jul-10	D034	D015	15	Nearshore coral community, Large *Porites* colonies					
				Coral dense. Shallow reef/lagoon					
14-Jul-10	D037	D016	22.7	pavement, boulders, coral, COTS	x				
14-Jul-10	D039	D017	38.7	Too deep for photos from vessel					
9-Jul-10	D041	D018	5.4	Sand	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected: Fish	Coral	Inverts	Algae
	Bandeera Bay								
14-Jul-10	D045	D019	>40	Too deep for photos from vessel					
12-Jul-10	D048	D020	4.8	Sand with patches of coral colonies					
14-Jul-10	D049	D021	too shallow	Could not safely approach from vessel					
12-Jul-10	D050	D022	5.1	Boulders. Large Porites colonies.					
14-Jul-10	D052	D023	too shallow	Could not safely approach from vessel					
14-Jul-10	D054	D024	11.5	Medium boulders with coral Possible fungus on coral	x				
14-Jul-10	D055	D025	14.5	Sand, Small boulders with turf algae					
14-Jul-10	D056	D026	too shallow	Could not safely approach from vessel					
14-Jul-10	D059	D027	20.8	Mixture of boulders, sand, coral	x				
14-Jul-10	D063	D028	14	boulder with turf, sand, few coral	x				
14-Jul-10	D070	D029	15	Mixture of boulders, sand, and small coral heads	x				
14-Jul-10	D071	D030	22.5	Mixture of boulders, sand, and large coral heads	x				
14-Jul-10	D073	D031	19.4	Small boulders with turf, macroalgae	x				
12-Jul-10	D076	D032	5.9	Mixture of boulders, sand, and small coral heads					
9-Jul-10	D077	D033	9.7	Shallow reef/lagoon Sand and small rocks	x				
9-Jul-10	D090	D034	4.5	Sand Shallow reef/lagoon	x				
14-Jul-10	D099	D035	19	Mixture of boulders, sand, and small coral heads	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected Fish	Coral	Inverts	Algae
	Bandeera Bay								
17-Jul-10	D101	D036	3-16	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x		x		x
17-Jul-10	D102	D037	3-16	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x		x		x
17-Jul-10	D103	D038	3-16	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x		x		x
17-Jul-10	D104	D039	3-16	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x		x		x
18-Jul-10	D105	D040	<5	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x	x	x	x	x
18-Jul-10	D106	D041	<5	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x	x	x	x	x
18-Jul-10	D107	D042	<5	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x	x			
18-Jul-10	D108	D043	<10	Shallow reef/lagoon Boulders with turf. Small coral colonies	x	x		x	
18-Jul-10	D109	D044	<10	Shallow reef/lagoon Boulders with turf. Small coral colonies	x	x		x	
18-Jul-10	D110	D045	9	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x	x			

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected: Fish	Coral	Inverts	Algae
	Bandeera Bay								
18-Jul-10	D111	D046	8	Nearshore coral community, Large *Porites* colonies Coral dense. Shallow reef/lagoon	x	x			
	Western South Point								
17-Jul-10	E002	E002	27.9	Hard bottom with scattered coral High density of sea cucumbers	x				
17-Jul-10	E003	E003	41.1	Reef platform with shallow grooves Near sand edge of spur and groove/sand interface *Porites* and *Pocillopora* colonies					
17-Jul-10	E004	E004	45.5	Fractured reef framework Scattered coral colonies	x				
19-Jul-10	E008	E008	11-17	Boulders	x	x	x	x	x
19-Jul-10	E009	E009	27.7	Hard bottom. Old dead coral substrate with scattered coral. Big fissures	x	x	x	x	x
19-Jul-10	E012	E012	31.4	Large boulders with low coral cover	x	x	x	x	x
17-Jul-10	E014	E014	<5	Large boulders Could not safely approach from vessel					
17-Jul-10	E016	E016	44.9	Hard bottom with scattered coral	x				
19-Jul-10	E018	E018	14	Medium boulders. Pavement with encrusting coral	x	x			

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected			
						Fish	Coral	Inverts	Algae
	Western South Point								
17-Jul-10	E020	E020	dropoff	Pavement with coral. Scattered boulders Depth ~65 ft	x				
19-Jul-10	E023	E023	28.9	80% boulder, 10% hard bottom, 10% sand	x	x	x	x	x
17-Jul-10	E024	E024	55.8	Spur and groove with shallow grooves Near sand edge of spur and groove/sand interface					
17-Jul-10	E028	E028	15.2	Mix of hard reef framework, sand, Large Porites	x				
17-Jul-10	E031	E031	dropoff	Mix of sand and pavement Depth ~76 ft					
17-Jul-10	E032	E032	23.8	Boulders. Very close to shore	x				
17-Jul-10	E033	E033	8.9	Large boulders					
17-Jul-10	E034	E034	on land	Point on large rocks	x				
17-Jul-10	E039	E039	40.7	Pavement with low growth form of corals	x				
17-Jul-10	E048	E048	on land	Large boulders	x				
17-Jul-10	E050	E050	on land	Large boulders					
17-Jul-10	E051	E051	24	Close to shore. Submerged boulders	x				
17-Jul-10	E053	E053	on land	Boulders					
17-Jul-10	E053	E053	on land	Boulders	x				
17-Jul-10	E054	E054	30.6	Boulders with *Pocillopora* colonies	x				
17-Jul-10	E057	E057	23.3	Boulders with encrusting coral	x				
17-Jul-10	E059	E059	<10	Shallow reef with large *Porites* colonies					

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected: Fish	Coral	Inverts	Algae
	Western South Point								
17-Jul-10	E020	E020	dropoff	Pavement with coral. Scattered boulders Depth ~65 ft	x				
19-Jul-10	E023	E023	28.9	80% boulder, 10% hard bottom, 10% sand	x	x	x	x	x
17-Jul-10	E024	E024	55.8	Spur and groove with shallow grooves Near sand edge of spur and groove/sand interface					
17-Jul-10	E028	E028	15.2	Mix of hard reef framework, sand, Large *Porites*	x				
17-Jul-10	E031	E031	dropoff	Mix of sand and pavement Depth ~76 ft					
17-Jul-10	E032	E032	23.8	Boulders. Very close to shore	x				
17-Jul-10	E033	E033	8.9	Large boulders					
17-Jul-10	E034	E034	on land	Point on large rocks	x				
17-Jul-10	E039	E039	40.7	Pavement with low growth form of corals	x				
17-Jul-10	E048	E048	on land	Large boulders	x				
17-Jul-10	E050	E050	on land	Large boulders					
17-Jul-10	E051	E051	24	Close to shore. Submerged boulders	x				
17-Jul-10	E053	E053	on land	Boulders					
17-Jul-10	E053	E053	on land	Boulders	x				
17-Jul-10	E054	E054	30.6	Boulders with *Pocillopora* colonies	x				
17-Jul-10	E057	E057	23.3	Boulders with encrusting coral	x				
17-Jul-10	E059	E059	<10	Shallow reef with large *Porites* colonies					
17-Jul-10	E065	E065	46.8	Sand with scattered patches of coral colonies	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected: Fish	Coral	Inverts	Algae
	Western South Point								
17-Jul-10	E068	E068	17.8	Spur and groove with deep grooves Grooves are >10 ft	x				
17-Jul-10	E070	E070	15	Boulders and large *Porites* colonies	x				
17-Jul-10	E077	E077	10.5	Boulders	x				
17-Jul-10	E078	E078	<10	Shallow reef with large *Porites* mounds					
17-Jul-10	E084	E084	47.9	Sand with large *Porites* mound (>20 ft diameter) Large *Lutjanus bojar*, gray reef sharks					
17-Jul-10	E085	E085	36.4	Diploastrea, encrusting corals, soft corals Near sand edge of spur and groove/sand interface					
17-Jul-10	E086	E086	40.9	Pavement with scattered *Pocillopora* colonies	x				
17-Jul-10	E089	E089	26.8	Boulders and hard bottom/pavement *Pocillopora*, *Porites*, soft coral Close to shore	x				
17-Jul-10	E091	E091	41.1	Pavement with small coral colonies Relatively flat, high wave action Low growth forms of *Porites* and *Pocillopora* Seabird nesting cliff onshore directly from site					
17-Jul-10	E094	E094	47	Hard bottom/pavement with soft coral	x				
17-Jul-10	E098	E098	12.9	Big boulders					
17-Jul-10	E099	E099	29.7	Reef framework with encrusting coral	x				
	Katchu Bay								
12-Jul-10	D001	X001	19	Hard bottom/pavement with coral	x	x	x	x	x

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected Fish	Coral	Inverts	Algae
	Katchu Bay								
11-Jul-10	D002	X002	33	Sand					
11-Jul-10	D003	X003	18	Boulders with coral and turf algae					
12-Jul-10	D003	X003	22	Boulders with coral and turf algae	x	x	x	x	x
11-Jul-10	D007	X004	41	Sand					
11-Jul-10	D008	X005	16	Boulders	x				
12-Jul-10	D008	X005	11	Boulders	x	x	x	x	x
20-Jul-10	D010	X006	23	Boulders with coral and turf algae	x	x	x	x	
11-Jul-10	D011	X007	38	Sand					
20-Jul-10	D012	X008	24	Hard bottom/pavement with coral	x	x	x	x	x
11-Jul-10	D013	X009	42	Could not identify from surface/vessel					
11-Jul-10	D014	X010	25	Sand					
9-Jul-10	D015	X011	8.8	Sand	x				
9-Jul-10	D017	X012	on beach	Sand. Green sea turtle	x				
9-Jul-10	D018	X013	13.2	Sand	x				
11-Jul-10	D024	X014	47	Sand					
11-Jul-10	D028	X015	31	Hard bottom/pavement with coral					
14-Jul-10	D029	X016	21	Mix of sand, boulders and small coral heads Turf and cyanobacteria mats		x	x	x	x
9-Jul-10	D030	X017	16.1	Sand	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected Fish	Coral	Inverts	Algae
	Katchu Bay								
11-Jul-10	D032	X018	24	Hard bottom/pavement with coral					
11-Jul-10	D033	X019	22	Sand					
14-Jul-10	D035	X020	56.5	Could not identify from surface/vessel					
9-Jul-10	D036	X021	17.2	Sand	x				
20-Jul-10	D038	X022	17.4	Mix of sand, boulders and small coral heads Shallow reef/lagoon	x	x	x	x	x
14-Jul-10	D040	X023	6	Boulders with turf, small coral colonies	x				
11-Jul-10	D042	X024	35	Hard bottom/pavement with coral					
14-Jul-10	D043	X025	23.7	Sand	x				
11-Jul-10	D044	X026	29	Hard bottom/pavement with coral					
14-Jul-10	D046	X027	53	Could not identify from surface/vessel					
14-Jul-10	D047	X028	40.5	Could not identify from surface/vessel					
14-Jul-10	D051	X029	21.5	Sand with boulders	x				
11-Jul-10	D053	X030	19	Hard bottom/pavement with coral					
14-Jul-10	D057	X031	31.5	Sand	x				
14-Jul-10	D058	X032	35.6	Pavement with boulders *Porites lutea*, *Porites rus*, and *Terpios* sponge	x				
11-Jul-10	D060	X033	13	Hard bottom/pavement with coral					
11-Jul-10	D061	X034	8	Hard bottom/pavement with coral					
14-Jul-10	D062	X035	47	Could not identify from surface/vessel					
11-Jul-10	D064	X036	34	Sand and hard bottom/pavement					
14-Jul-10	D065	X037	41	Could not identify from surface/vessel					

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected			
						Fish	Coral	Inverts	Algae
	Katchu Bay								
11-Jul-10	D066	X038	15	Hard bottom/pavement					
14-Jul-10	D067	X039	8-15	Mix of rock, boulders and small coral heads Very close to wall/shore		x	x	x	x
14-Jul-10	D068	X040	43	Could not identify from surface/vessel					
14-Jul-10	D069	X041	17.3	Sand with rocks and turf algae	x				
14-Jul-10	D072	X042	28.5	Pavement with boulders *Porites lutea*, *Porites rus* and *Terpios* sponge	x				
11-Jul-10	D074	X043	13	Boulders with coral					
11-Jul-10	D075	X044	8	Medium rocks. Very close to shore					
14-Jul-10	D078	X045	23.5	Sand with rocks	x				
14-Jul-10	D079	X046	29	Sand with boulders	x				
14-Jul-10	D080	X047	86	Could not identify from surface/vessel					
14-Jul-10	D081	X048	19.2	Hard bottom/pavement with *Pocillopora*	x				
14-Jul-10	D082	X049	76	Could not identify from surface/vessel					
14-Jul-10	D083	X050	50	Could not identify from surface/vessel					
14-Jul-10	D084	X051	21.5	Sand with boulders	x				
11-Jul-10	D085	X052	27	Hard bottom/pavement with coral					
14-Jul-10	D086	X053	13.6	Sand	x				
14-Jul-10	D087	X054	18	Sand	x				
14-Jul-10	D088	X055	48	Could not identify from surface/vessel					
14-Jul-10	D089	X056	32	Sand with boulders	x				
14-Jul-10	D091	X057	23.5	Sand with rocks	x				
14-Jul-10	D092	X058	18	Sand	x				

Table C.1. (continued). Preliminary habitat characterization for random survey points in each survey region attempted (Maps C, D, E, and X). July 2010. Referred to in text as the "scouting surveys".

Date	Original Site ID	New ID	Depth (ft)	Description	Habitat Pictures	Data Collected Fish	Coral	Inverts	Algae
	Katchu Bay								
14-Jul-10	D093	X059	95	Could not identify from surface/vessel					
11-Jul-10	D094	X060	25	Sand					
11-Jul-10	D095	X061	8	Hard bottom/pavement with coral					
14-Jul-10	D096	X062	47	Could not identify from surface/vessel					
14-Jul-10	D097	X063	44	Could not identify from surface/vessel					
14-Jul-10	D098	X064	40.6	Could not identify from surface/vessel					
14-Jul-10	D100	X065	?	Too dangerous, up against rocks					

Appendix D.

Additional photographs of unique coral reef resources at the north and south coral patches in Bandeera Bay (Map D).

All photographs taken by T. Schils.


Figure D.1. Coral resources on north end of Bandeera Bay.

Figure D.2. Coral resources on south end of Bandeera Bay.

Figure D.3. Large Porites colonies on north patch. Diver is approximately 5.5 ft tall.

Figure D.4. Large Porites colonies on north patch. Diver is approximately 5.5 ft tall.

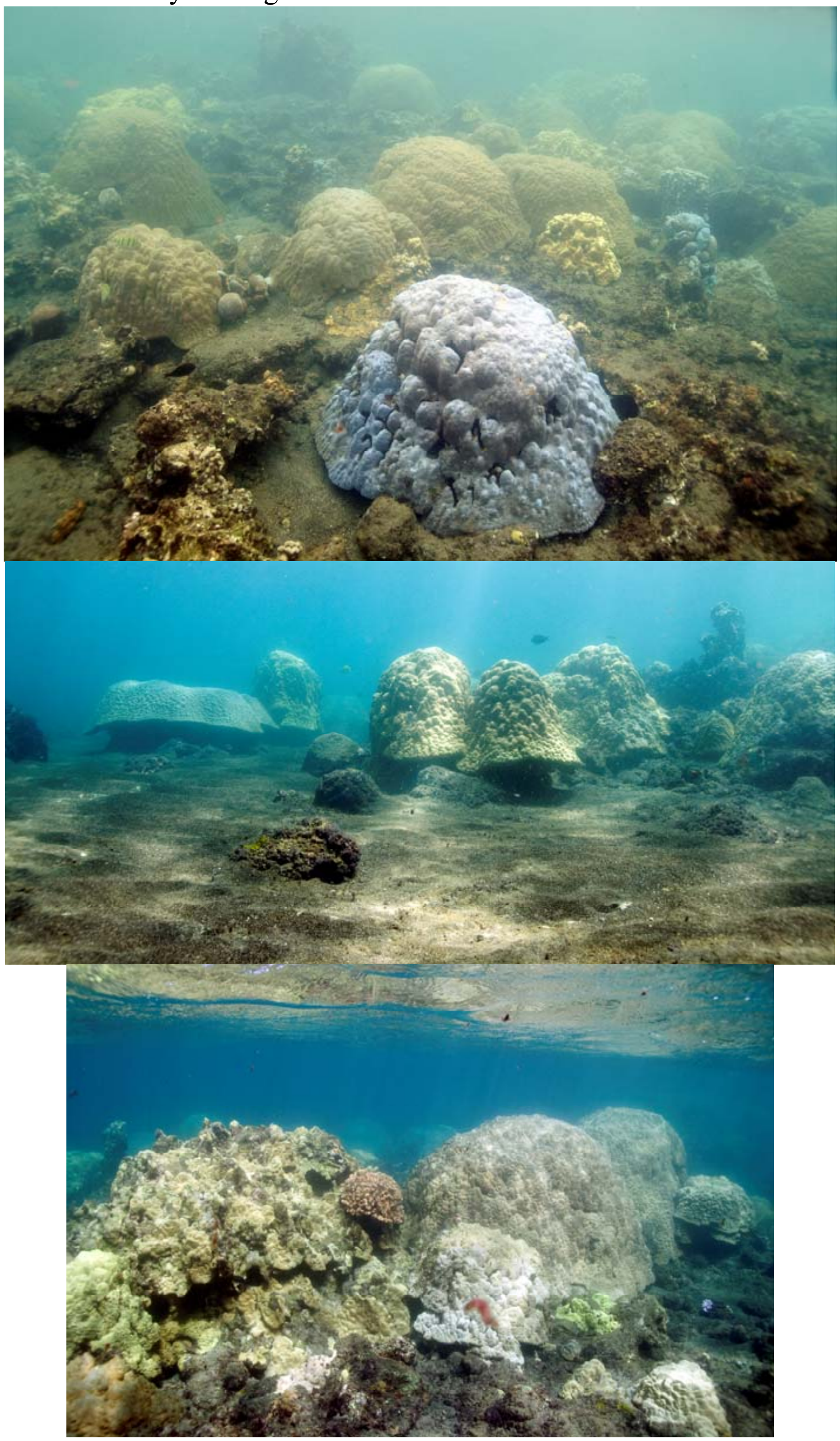


Figure D.5. (a,b,c). Shallow water coral community at north patch.

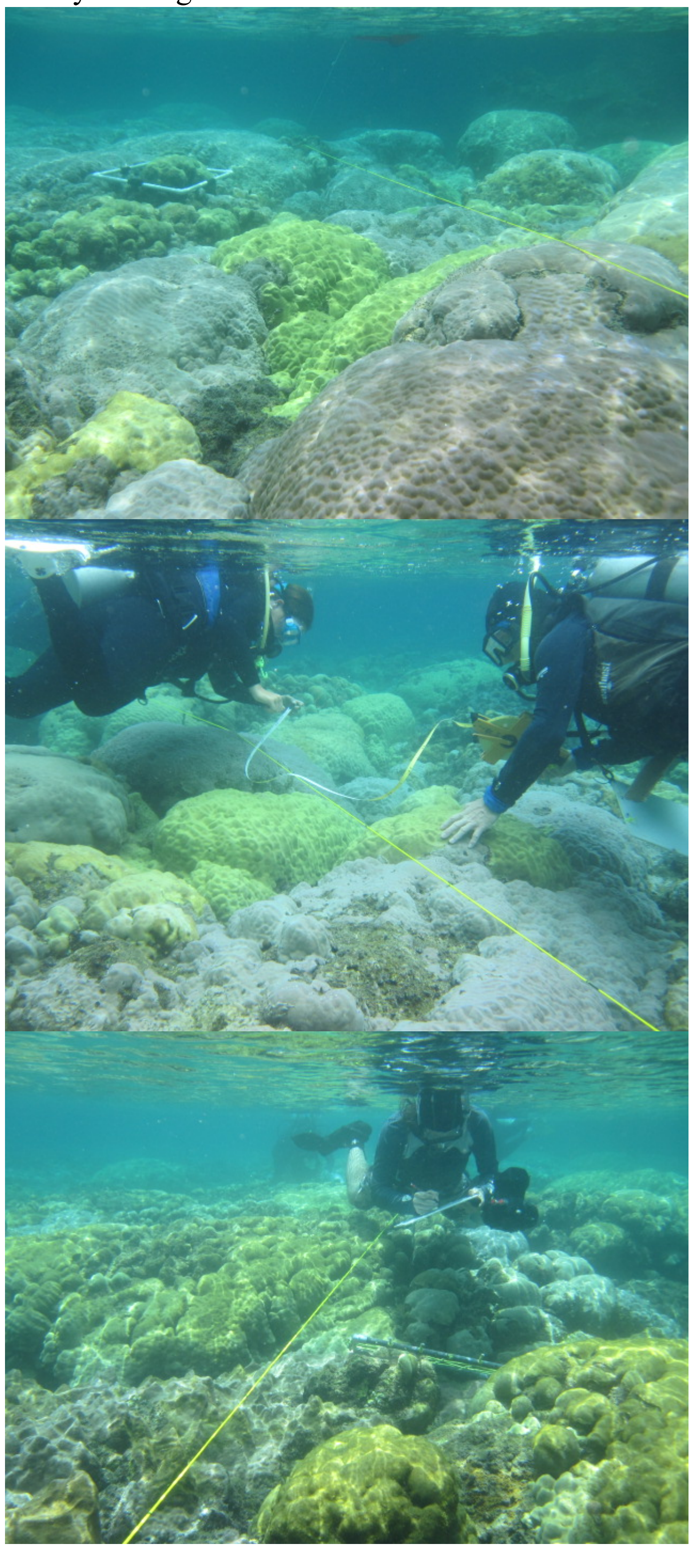


Figure D.6. (a,b,c). Shallow water coral community at south patch.