FINAL

CORAL MARINE RESOURCES SURVEY REPORT

in support of the
Commonwealth of the Northern Mariana Islands Joint Military Training Environmental Impact Statement/Overseas Environmental Impact Statement

Department of the Navy
Naval Facilities Engineering Command, Pacific
258 Makalapa Drive, Suite 100
JBPHH HI 96860-3134

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Prepared for:

Department of the Navy

Naval Facilities Engineering Command, Pacific

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Under the:

TEC-AECOM Pacific Joint Venture

Contract: N62742-11-D-1801 Task Order: 0002

February 2014

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EXECUTIVE SUMMARY

The purpose of the coral survey was to collect data about the presence and distribution of corals and coral reefs in selected areas on Tinian and Pagan. This survey supports the development of the Commonwealth of the Northern Mariana Islands Joint Military Training (CJMT) Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS). The demographics of Endangered Species Act (ESA)-proposed coral species were given particular attention. The survey focused on substrate shallower than 12 feet (4 meters), or 144 inches derived from the depths potentially exposed to select training activities.

The beaches surveyed were Unai Chulu, Unai Babui, Unai Lamlam, and Unai Masalok on Tinian, and Green, Red, Blue, and South Beaches on Pagan. There were 12 ESA-proposed species on Tinian beaches and 12 ESA-proposed species on Pagan beaches. On Tinian, the total estimated number of ESA-proposed corals shallower than 12 feet (4 meters) in front of Unai Chulu, Unai Babui, Unai Lamlam, and Unai Masalok is approximately 50,000 to 163,000 colonies among 12 species. On Unai Chulu, Unai Babui, Unai Lamlam, and Unai Masalok, all locations shallower than 12 feet (4 meters) contain ESA-proposed corals. If proposed military activities avoid contacting the reef crest, then the vehicles could set down on the Unai Masalok reef flat with relatively few ESA-proposed corals exposed to stressors (approximately 1,300 ESA-proposed colonies among three species).

ESA-proposed corals were abundant at Unai Chulu and Unai Babui, and three of the eight ESA-proposed species at those locations were dominant in patches. The aggregate density of ESA-proposed corals is on the order of 0.02 to 0.1 colony per square foot (0.25 to 1 colony per square meter), ranging from zero to at least 3.3 ESA-proposed colonies per square foot (35 colonies per square meter). Many spurs at Unai Chulu and Unai Babui were undercut by a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest and occasionally under the reef flat. These features were also noted at other sites, but to a lesser extent. Without a geotechnical investigation, it is difficult to speculate about the structural integrity of the spurs, reef crest, or reef flat.

On Pagan, the estimated number of ESA proposed corals shallower than 12 feet (4 meters) in front of Green, Red, Blue, and South Beaches is approximately 350,000 colonies among 12 species. Approximately 300,000 of these ESA-proposed colonies were found at South Beach, the best-developed coral reef of the those surveyed on Pagan.

Proposed amphibious vehicle activities could be conducted at Red and Blue Beaches, with zero exposure of ESA-proposed corals to physical strike stressors if the activities are kept clear of the adjacent headlands. There are no ESA-proposed corals shallower than 12 feet (4 meters) in front of those two beaches, leaving no potential interaction between corals and amphibious vehicles. Density of ESA-proposed coral colonies shallower than 12 feet (4 meters) in front of Gold and South beaches is relatively high and generally about 0.03 colonies per square foot (0.3 colonies per square meter). South Beach has an area dominated by sand about 328 feet (100 meters) wide, just to the east of center. These areas could host amphibious activities, with relatively minimal effects on ESA-proposed corals. Amphibious activities at Gold Beach, or the well-developed reef areas along South Beach would have relatively greater effects on ESA-proposed corals.

Eight ESA-proposed species of coral are found within the potential construction area at Red Beach. There are an estimated 400 to 5,000 colonies of ESA-proposed species within the potential construction area.

A total of 9,192 coral colonies were identified, measured, and mapped on both islands (5,963 on Tinian and 3,229 on Pagan). This data set is supplemented by 10,500 photos and approximately 20 hours of video to support the demographic findings.

Coral Marine Resources Survey Report

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List of Acronyms and Abbreviations

AAV	Amphibious assault vehicle
aff.	"affinity" in Latin, and in the context of taxonomy means the specimen is very similar to the named species, but is almost certainly different.
cf.	"compare with" in Latin, and in the context of taxonomy, means the specimen is almost certainly the named species, but is slightly different.
CJMT	Commonwealth of the Northern Mariana Islands Joint Military Training
CNMI	Commonwealth of the Northern Mariana Islands
CRED	Coral Reef Ecosystem Division
CSA	Continental Shelf Associates
CVN	Carrier vessel-nuclear
DoN	Department of the Navy
EIS	Environmental Impact Statement
ESA	Endangered Species Act
HDR	Henningson, Durham & Richardson, Inc.
ID	Identification or identity
MARAMP	Mariana Archipelago Reef Assessment and Monitoring Program
MARFORPAC	Marine Corps Forces, Pacific
MRS	Marine resource survey
NAVFAC	Naval Facilities Engineering Command
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OEIS	Overseas Environmental Impact Statement
PT	Proposed-threatened
RHIB	Rigid-hulled, inflatable boats
U.S.	United States

CHAPTER 1 INTRODUCTION

1.1 PROPOSED ACTION

The proposed action is to establish a series of live-fire and maneuver ranges and training areas on two islands, Tinian and Pagan, within the Commonwealth of the Northern Mariana Islands (CNMI; Figure 1-1). The proposed action is needed to meet United States (U.S.) Pacific Command Service Components' unfilled unit level and combined level military training requirements in the Western Pacific. The U.S. Pacific Command designated the U.S. Marine Forces Pacific (a part of the Marine Corps) as Executive Agent to oversee development and implementation of the proposed action. Analysis of this proposed action, which involves land, air, and sea space, follows the National Environmental Policy Act (NEPA) and will include an Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS).

Aspects of the proposed action are available via the website supporting the CJMT EIS/OEIS at www.CNMIJointMilitaryTrainingEIS.com/. The proposed actions with relevance to corals and coral reefs include proposed training and landings of amphibious and small craft, operation of vessels in nearshore waters, and coastal construction. These actions are proposed on Tinian and Pagan at select landing locations (Figure 1-2 and Figure 1-3). The principal nature of potential impacts on corals is physical disturbance and strike stressors. Additional relevant potential stressors include increased suspended sediment or other stressors affecting water quality. Corals and coral reefs potentially exposed to physical disturbance and strike stressors from vessels are considered to be any feature between 0 and 10 feet (0 and 3 meters) deep in the path of the vessels. Corals and coral reef features downslope of the vessel path may also be affected by mobilized rubble and sediments.

1.2 SURVEY OBJECTIVES

The purpose of this project was to conduct a marine resource survey (MRS) in the CNMI to support the development of the CJMT EIS/OEIS. The MRS developed under Contract Number N62742-11-D-1801, Task Order Number 0002, focuses, in particular, on the demographics of proposed endangered and threatened species in three areas: marine mammals, sea turtles, and coral (Department of the Navy [DoN] 2013b, 2013d). The MRS supports Department of Defense compliance with federal environmental and natural resources laws and regulations, to evaluate potential environmental impacts, and to avoid and minimize potential impacts during the planning process. Each of the three surveys will be delivered in a separate report.

This report includes only the results of the coral surveys as specified in the Coral Work Plan and the associated Dive Plan (DoN 2013a, 2013b, 2013c, 2013e). The report itself consists of a field survey in the nearshore waters around two islands in the CNMI, Tinian and Pagan, where data was collected on the presence and distribution of corals and coral reefs (Figure 1-2 and Figure 1-3). The coral survey consisted of one field survey in July 2013, consisting of dive surveys based from the *SS Thorfinn*, a live-aboard support vessel.

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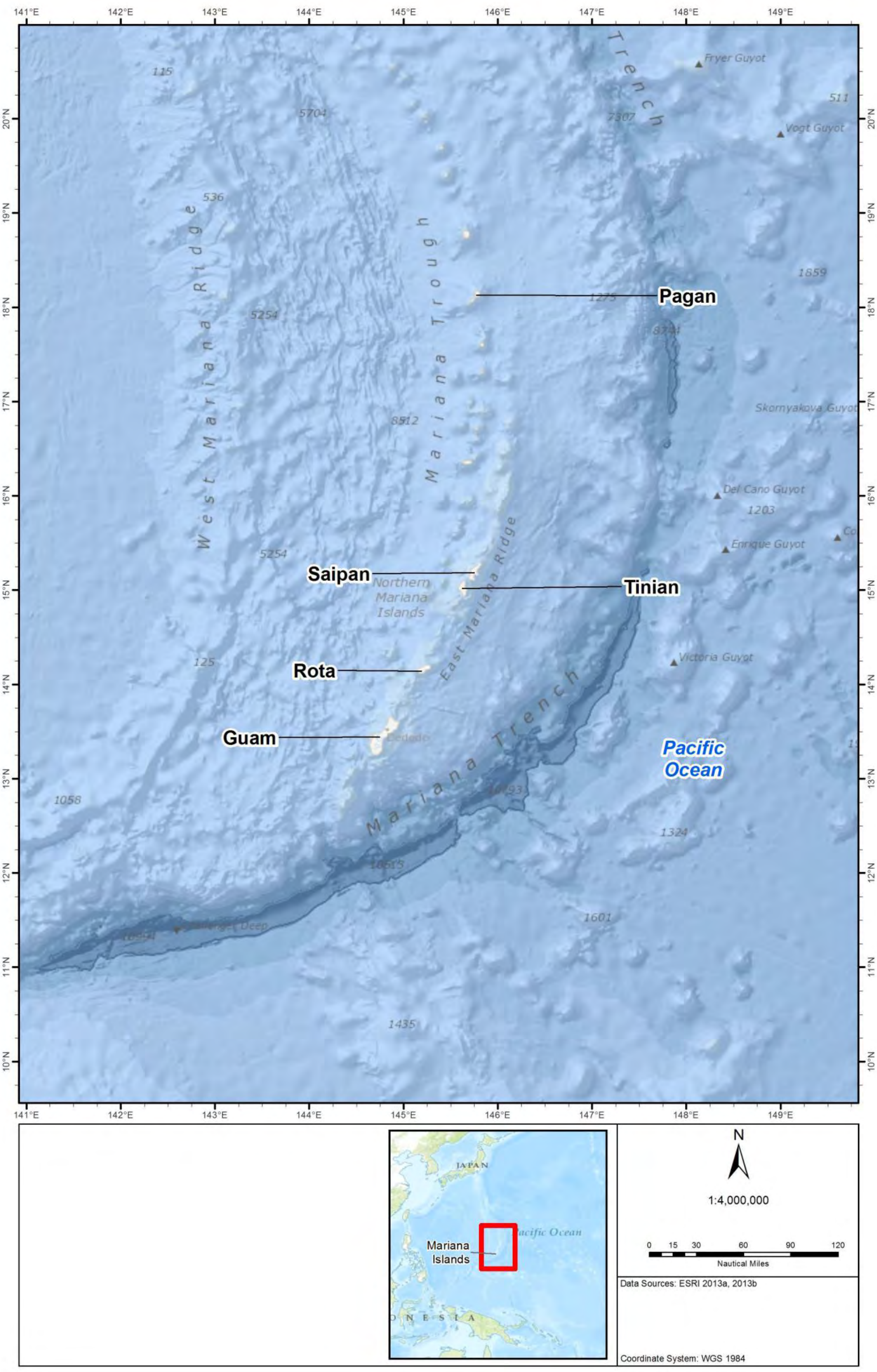

Figure 1-1. Geographical Context of the Study Area in the Mariana Islands

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Figure 1-2. Coral Survey Locations on Tinian

Survey area extents are described in Chapter 3, Methods. On Tinian, the extent of in-water survey areas is almost entirely coincident with the ESA and coral species search areas; only one layer is presented for visual clarity.

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Figure 1-3. Coral Survey Locations on Pagan

Survey area extents are described in Chapter 3, Methods.

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CHAPTER 2
SETTING

2.1 GEOMORPHOLOGY

The islands of the CNMI are principally surrounded by fringing spur-and-groove reefs; barrier, lagoon, patch, and bank reefs are infrequent (Riegl et al. 2008). Four distinct geomorphological reef types encompass most of the CNMI (Minton et al. 2009; Houk and Starmer 2010; Houk and van Woesik 2010):

- Holocene spur-and-groove: typically high coral densities, high coral species richness, and large colony size;
- Holocene high-relief slope: typically low coral species richness and high intra-site variation;
- Holocene low-relief: typically low coral species richness, few large corals, many small corals; and
- Pleistocene basement: typically few corals and little three-dimensional relief.

Constructional spur-and-groove reefs surrounding much of Tinian and parts of Pagan support larger coral colonies and higher coral species richness compared to other habitat types in the CNMI (Minton et al. 2009; Houk and van Woesik 2010). The most developed and oldest coral reefs of the CNMI are the southern islands, which include Tinian (Bearden et al. 2008). Pagan is a younger active volcanic island, and its coral communities are mostly a veneer atop igneous substrate rather than constructional limestone reef (Suhkraj et al. 2010). Though prior studies indicate an increase in generic richness in the Mariana Islands from north to south (Randall 1995; Brainard et al. 2012), this may be an artifact of search effort and the logistical difficulties of reaching the northern islands.

Common reef morphology terms describe zonation and principally are composed of the fore reef and back reef, separated by a reef crest (Riegl et al. 2008; DoN 2013b). Fringing reefs typical of the Mariana Islands usually have reduced or absent back reef zones because the reef crest is typically attached to the shoreline (Riegl et al. 2008). Definition of zones within this survey report follow Riegl et al. (2008). Fringing and fore reefs (less than 650 feet [200 meters] wide) occur next to the western shoreline (National Oceanic and Atmospheric Administration and National Centers for Coastal Ocean Science 2005).

2.2 CORALS OF MICRONESIA

The Mariana Islands form a chain of islands (Figure 1-1) often grouped in two ways: political and geological. Politically, the Territory of Guam and the CNMI are administered as separate insular areas. Geologically, the older five southern islands are limestone capped, and the younger northern islands retain volcanic features (Riegl et al. 2008). Other geomorphological factors differentiate the islands including more intense typhoon activity in the southern end of the Mariana Islands.

The 2012 Mariana Archipelago Reef Assessment and Monitoring Program (MARAMP) report describes a decrease in generic richness from the southern Islands to the northern islands (Brainard et al. 2012). As described in Riegl et al. (2008), the northern islands refer to those "…north of Farallon de Medinilla" that "have no limestone cap and are geologically distinct from the southern islands…." Factors that are favorable for reef development include islands large enough to provide a variety of habitats, yet small enough that reef-inhibiting effects of rivers and runoff are generally trivial (Riegl et al. 2008; Brainard et al. 2012). Guam is an exception, where radical land cover changes have degraded nearshore reefs (DoN 2010).

Coral cover throughout the Mariana Islands estimated from satellite imagery is about 27.8% of the coral reef area; data for individual islands have been compiled from in-water surveys (Bearden et al. 2008; Brainard et al. 2012). Coral growth and distribution in the Mariana Islands are positively influenced by relatively high salinity levels, low-to-moderate wave action, and minimal volcanic activity in the past 90 years (Houk and Starmer 2010). Reef flats, lagoons, and benches are almost always found on the back reef side of the reef crest. Seaward of the reef crest is the fore reef, often subdivided by depth (e.g., shallow and deep fore reef), or by geomorphology (e.g., spur and groove, apron, and sand channel).

The diversity of Mariana reef-building corals (254 species in 56 genera [Randall 1995], 377 species in 99 genera [Randall 2003; includes non-Scleractinian corals and also ahermatypic Scleractinia], and 189 species [Veron et al. 2009]) is somewhat lower than other western Pacific regions; for example Philippine Islands (around 411 species [Veron and Hodgson 1989] and 523 species [Fenner, unpublished data]) and Ryukyu and Japan Islands (around 381 species [Randall 1995] and 400 species [Veron 1992]). However, the Mariana reef corals are more diverse than other U.S. states or territory islands in the north Pacific (Richmond et al. 2008; Riegl and Dodge 2008).

2.2.1 Tinian

The coral reefs on the west side of Tinian are more developed than other parts of the island (Bearden et al. 2008), and the overall coral cover around the island ranges from 10% to 50% (National Oceanic and Atmospheric Administration and National Centers for Coastal Ocean Science 2005). Fringing and fore reefs (less than 650 feet [200 meters] wide) occur along much of the shoreline (National Oceanic and Atmospheric Administration and National Centers for Coastal Ocean Science 2005). Portions of the Tinian shoreline with beaches generally have reef flats, and areas without beaches generally have shore-attached reef crests. Typical reef crests and reef flats were less than 2 feet (0.6 meter) deep in some areas, with some grooves that were 20 feet (6 meters) deep, but less than 3 feet (1 meter) wide (Smith 2012). Randall (1995) reports 40 genera and 141 species of coral collected on Tinian. Work by Minton et al. (2009) provides much of the detailed information available on Unai Chulu, Unai Babui, and Unai Dankulo, but did not include Unai Lamlam and Unai Masalok.

Based on a review of the limited data available, 36 species of ESA-proposed corals could occur on Tinian reefs at depths of 0 to 131 feet (0 to 40 meters). In 2009, Minton et al. confirmed 11 of those species (11 proposed-threatened [PT]) on Tinian reefs in the areas of interest.

2.2.2 Pagan

Suhkraj et al. (2010) provided much of the existing detailed information available at Green, Red, and Blue Beaches on Pagan. Suhkraj et al. (2010) did not use identical names or boundaries for these locations, but they are near the areas of interest for this report. The baseline data for North and Gold Beaches are limited and were not covered in Suhkraj et al. (2010).

Suhkraj et al. (2010) survey sites were not divided by reef flat and reef slope, but all of the randomly selected sites were less than 30 feet (10 meters) deep (Suhkraj et al. 2010). Coral surveys along benthic transects were conducted by coral taxonomists with considerable experience in the Mariana Islands. In addition, algae quadrats included coral identification. All coral colonies were identified to the lowest possible taxonomic level. MARAMP surveys provided additional information from towed diver surveys conducted at each of the areas of interest (Brainard et al. 2012).

Based on a review of the limited data available, 36 species of ESA-proposed corals could occur on Pagan reefs at depths of 0 to 131 feet (0-40 meters). Previous surveys conducted by Eldredge and Kropp (1985) and Suhkraj et al. (2010) confirmed three ESA-proposed coral species on Pagan reefs in the areas of interest.

2.3 CHALLENGES WITH CORAL IDENTIFICATION

Corals present a persistent challenge to Darwin's (1872) species concept. This is exacerbated by their lineage of reticulate evolution (Veron 2000), which shows multiple successful hybridization events. Variation makes some species of coral inherently difficult to pigeonhole into one type or another. Great strides have been made in identifying and describing coral species in recent decades (e.g., Randall and Myers [1983]; Hoeksema [1989]; Wallace [1999]; Veron [2000]). In 1758, Linneaus initiated the system of describing species used today. It works as a voluntary system in which participants follow the rules in order to gain acceptance of the names they apply to new species. Until very recently, taxonomy of all species was based entirely on morphology. However, corals are relatively difficult to work with for morphological taxonomy, primarily because of their high levels of variation. Corals exhibit variations in the microstructure, in the morphology of individual corallites, in different parts of individual colonies, in different colonies, in colonies in different microenvironments and reef zones, in colonies on different reefs, and in colonies in different island groups and biogeographic zones. Coral taxonomy is more difficult than most other marine organisms.

The most authoritative taxonomic works relevant for the project area are Randall and Myers (1983), Randall (2003), Veron (2000, 2002), Fenner (2005), Wallace (1999), and Burdick (2012). While these coral taxonomists agree on the identification of most corals based on morphological characteristics, there are a handful of instances where the experts' opinions diverge. For example, Wallace (1999) recognizes 111 species of *Acropora*, while Veron (2000) recognizes 165 species. Randall and Myers (1983) use some of the same names as Veron (2000) and Wallace (1999), but also use different names, often for what appears to be the same species. Hoeksema (1989) and Veron (2000) appear to mostly recognize the same species but use a slightly different naming system. Hoeksema's nomenclature was subsequently revised (Gittenberger et al. 2011) based on genetics. In some cases, the same name appears to be applied to different species by different authors. For instance, Wallace (1999) and Veron (2000) describe *Acropora lokani* and *Acropora speciosa* differently. Both of these species are proposed for ESA status.

Because scientists must be specific about how a species is identified when taxonomic authorities differ, the term *sensu* is used to specifically identify the pertinent descriptions. *Sensu* is Latin for "in the sense [of]," which in the context of taxonomy, means a species determination is according to a particular authority. For example, *Acropora studeri* was found on Tinian and Pagan and identified using the diagnostic characteristics of only one taxonomic authority. Therefore, the species notation in this report is *Acropora studeri sensu* Randall and Myers (1983). Also, the so-called common names are not commonly used for coral species; scientific literature and enthusiasts almost invariably use their scientific names.

In addition to legitimate differences of opinion, these authorities also make mistakes and occasionally publish corrections. A noteworthy example is Veron (2002), correcting procedural errors in presenting more than 100 new species in Veron (2000). Also, two other factors prevent coral taxonomy from ever being stable and certain. One is the slow pace of taxonomic review, often taking the better part of a decade. For example, changing a species' name or synonymizing two old species under one name has substantial ramifications. A slow pace helps to reduce the rate of new errors at the cost of old errors persisting. Second is taxonomy reviews based on genetics. While powerful and relatively certain (see Stat et al. [2012] and Losos et al. [2012] for weaknesses), genetic taxonomy reviews do not always synchronize with readily observable phenotypic characters. These reviews sometimes combine species that look distinctly different despite their having closely related genotypes. In this case, the benefit of using relatively certain taxonomy comes at the cost of it being difficult to implement in the field.

Compounding these systematic issues, many scientists conducting reef surveys misidentify species or lump together difficult-to-distinguish specimens. This goes beyond divergent species identifications legitimately introduced by experts that are "lumpers" versus "splitters" into data collection that is imprecise by design. Pooling difficult to distinguish specimens into a single bin is most often done, for example, to facilitate field data collection without onerous observer training or to artificially enhance inter-observer agreement. In most cases the subsequent reports will stipulate which species may be represented by a species name, but these caveats are not always acknowledged by later users of the same data. Consequently, some species are reported as common and others as rare or absent based on methods that were not designed to detect all the species in the first place.

This uncertainty in coral identification has great bearing on some of the results in this report. The project experts identified a handful of species known from the literature as rare or absent in the CNMI (e.g., omissions from prior studies or genuine range expansions) and also uncovered potential errors in the authoritative works for the region. Some of the species in question are proposed for ESA listing, and results of this survey report are germane to the ESA listing process itself. ESA designations are based on morphological species definitions, not genetic definitions, and the protection is conferred to the species not to the name; thus taxonomic revisions do not affect an established listing. The National Marine Fisheries Service ESA coral biological review team devoted considerable effort to review and discuss the relevant taxonomic issues for the proposed corals (Brainard et al. 2011; National Marine Fisheries Service 2012).

Because species identification is centrally important to this report, a precise naming scheme is used to define what is meant by a particular species name, whenever there are relevant discrepancies among the authoritative taxonomic works for the region. This naming scheme incorporates the initial description set into the context of the authoritative taxonomies for the region and is espoused by taxonomists in circumstances of disagreement among experts (Fautin 2013). For example, Randall and Myers (1983) and Randall (2003) refer to one of the species recorded during the survey as *Stylophora mordax*, but Veron (2000) refers to the same species as *Stylophora pistillata*. These species and the species we recorded have large branches. Veron (1986) used the name *Stylophora pistillata* to refer to colonies with both thin and thick branches, while Veron (2000) referred to the thick branch species as *S. pistillata* and the thin branched species as *Stylophora subseriata*. *S. pistillata* was first described by Esper in 1797, *S. mordax* was first described by Dana in 1846, and *S. subseriata* was first described by Ehrenberg in 1834. Following the recommended naming scheme (Fautin 2013), sightings in this survey of *S. mordax* carry this nomenclature:

> *Stylophora mordax* (Dana 1846), *sensu* Randall and Myers (1983), and Veron (1986) =
> *S. pistillata* (Esper 1797), *sensu* Veron (2000).

While somewhat cumbersome, this notation helps clarify what is intended for particular species in context of the authoritative identification guides for the area. A single name is used when there is no difference of opinion among the authoritative taxonomic works for the region, which applies to most of the species in this report.

CHAPTER 3
METHODS

3.1 DEFINITION OF BEACHES

The areas of interest were defined in Contract Number N62742-11-D-1801, Task Order Number 0002, and were refined during subsequent discussions with the Navy Technical Representative. Table 3-1 gives the beaches and their priorities, based on these discussions.

Table 3-1. Beach Names and Priorities

Island	*Marine Corps Beach Name*[1]	*Local Name(s)*	*Priority – Planned Sampling Intensity*
Tinian	Unai Chulu	Unai Chulu	Primary – Quantitative
	Unai Babui	Unai Babui	Primary – Quantitative
	Unai Lamlam	Unai Lamlam	Secondary – Qualitative
	Unai Dankulo	Unai Dangkulo Unai Dångkolo	Secondary – Qualitative
	Unai Masalok	Unai Masalok	Primary – Quantitative[2]
Pagan	Green Beach	Bandera Bay	Primary – Quantitative
	Red Beach	Katchu Bay	Primary – Quantitative
	Blue Beach	Laguna Bay	Primary – Quantitative
	North Beach	--	Secondary – Qualitative
	Gold Beach	--	Secondary – Qualitative
	South Beach	Long Beach	Secondary – Qualitative

Notes:
[1]Sequence of beach listing is arbitrary, clockwise from the westernmost.
[2]Quantitative on reef crest and reef flat, qualitative on fore reef. See Figure 1-2, Figure 1-3 and Appendix C for actual coordinates corresponding to these areas.

3.2 SURVEY DESIGN

3.2.1 Basic Design

The data needs of the survey objectives were best met with a nested approach to data collection and resolution. At the highest level was a broad-scale, spatially coarse survey of each beach collecting a wide range of data. At the lowest level was a small-scale (at the scale of individual coral colonies) spatially fine survey within each beach collecting a narrow range of data. The topographic complexity, coral cover, macroalgae cover, and sand cover data were collected *in situ*, meaning they were observed where they occurred.

3.2.2 Selection of Broad-Scale Survey Areas

The length of the beach plus approximately 20% of its length added to each side defined each beach-associated sampling area. For example, on a beach 3,300 feet (1,000 meters) long, approximately 4,600 feet (1,400 meters) would be included in the sampling area to ensure potentially affected areas were included. Some beaches, such as Unai Dankulo, did not undergo broad-scale habitat mapping due to time constraints and assigned priority levels (Table 3-1).

3.2.3 Selection of Colony-Scale Survey Areas

Under direction from NAVFAC Pacific, demographic surveys for ESA-proposed corals were conducted at Unai Chulu, Unai Babui, Unai Masalok reef flat, Green, Red, and Blue beaches as priority activities; similar surveys at Unai Lamlam, Unai Dankulo, Unai Masalok fore reef, North, Gold, and South beaches were secondary priorities (Table 3-1). The depth of interest for these methods was 120 inches (305 centimeters); 84 inches [213 centimeters], equivalent to the draft of a laden amphibious assault vehicle [AAV], and training usually takes place in sea-states of 3 feet [1 meter] or less). Adding a buffer of 24 inches, the survey focused on substrate shallower than 12 feet (4 meters). The Final CJMT Coral Survey Work Plan defined depths of interest as 49 feet (15 meters) (DoN 2013b), but this was changed based on revised direction from NAVFAC and MARFORPAC.

The Red Beach pier and breakwater potential construction areas were investigated as an area distinct from the whole or Red Beach. The boundaries of the potential construction areas at Red Beach were provided by AECOM on July 5, 2013. See Section 5.3 (Red Beach Pier and Breakwater Potential Construction areas) for additional details.

3.2.4 Survey Platforms

Two 33-foot (10-meter), rigid-hulled, inflatable boats (RHIB) were used to collect supporting data (Figure 3-1). In general, RHIB 1 was principally engaged in the broad-scale towed-diver surveys, and RHIB 2 was principally engaged in the coral colony surveys (DoN 2013b, 2013c). Both RHIBs were occasionally diverted from their principal data collection tasks to support sea turtle surveys, discussed in a separate report (DoN 2013d).

Figure 3-1. Diving Platform

Underway [left] and during pre-dive safety briefing [right].

3.3 SURVEY METHODS

The Final CJMT Coral Survey Work Plan and the Final CJMT Diving Operations Plan detail the planned implementation of this work (DoN 2013b, 2013c). The survey was planned and executed under the EM-385-1-1 diving regulations (DoN 2013c). Only American Academy of Underwater Scientists (AAUS) divers participated in in-water work. Areas where scientific divers intended to contact the seafloor were first visually scanned for unexploded ordnance (UXO) by UXO technical experts. Many spurs were undercut by grooves that interconnected with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest and occasionally under the reef flat. These features were investigated as far as allowed by the EM-385-1-1 diving regulations. Safety was of primary importance, and was supported by safety planning documents (DoN 2013a, 2013c, 2013e).

Appropriate methods were selected to reduce experimental error (DoN 2013b, 2013c), and different results among methods were highlighted as appropriate. All survey methods attempt to determine the true value of the parameter being measured; but methods can only estimate the true value rather than establishing it exactly. The divergence between the measured value and the true value is termed *experimental error*. For example, the size of an object can be estimated with a ruler, but this measurement is not likely to equal the object's true size. Similarly, counting individuals within an area can give an estimate of population, but the true number of individuals in the area is likely to be different.

3.3.1 Broad-Scale Surveys

The objective of the broad-scale survey was habitat mapping. Broad-scale habitat mapping followed the towed-diver protocols used by the National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Ecosystem Division (CRED). These protocols are deployed on MARAMP surveys of the Mariana Islands (Brainard et al. 2012) using similarly outfitted towboards. The major modification of the MARAMP method was a more frequent reporting interval, giving the survey far greater spatial resolution.

Towing was typically at 0.5 to 1.5 knots (0.9 to 2.8 kilometers per hour) in waters deeper than approximately 6.5 feet (2 meters). Speeds were somewhat faster over homogeneous substrate. Towed divers estimated from a 164 feet (50 meters) swath (82 feet [25 meters] on all sides) and adjusted to a smaller swath when visibility was restricted. Divers towed and scanned much of each area of interest more than once and from different directions to enhance resolution in heterogeneous areas. The divers reported categorical data to the vessel by voice communications approximately every 20 seconds or whenever the seafloor characteristics changed. In shallow waters that were unsafe or inaccessible to the vessel but safely accessible to snorkelers, the GPS buoy was pushed at swimming speed and data reporting continued unchanged. Data were cross-referenced with the track line, time, and speed so that the actual areas and locations could be linked with the ecological data (Figure 3-2).

Topographic complexity was estimated using a modification of the MARAMP method (Brainard et al. 2012). The survey used the same six categories used by NOAA for rugosity/physical complexity (low, medium-low, medium, medium-high, high, and very high), modified to match the spatial scale of the nearshore habitat mapping component of the broad-scale surveys. These categories were reported as numbers 1 (low) through 6 (very high).

Percent cover of coral, macroalgae, and sand were estimated to the nearest 10% in each swath. Coral was defined as scleractinia or hydrocorals. Macroalgae was defined broadly as fleshy or crustose red, green, or brown algae, including "turf," and filamentous diatoms or cyanobacteria. Sand was defined as mobile sediments. Grain sizes in this category ranged from sand to pebble to cobble, but the distinguishing characteristic was mobile; cobbles were often polished smooth and were clearly distinguishable from immobile rubble. This polishing character of cobble-size clasts was especially prevalent on Pagan.

Data processing included quality assurance and calculations of Theissen polygons to represent the raw data on maps. This approach to representation of mapping data (i.e., on the broad-scale habitat maps for each site) was selected because it best represented the data by interpolating locations (e.g., the nearest neighbor approach) without making inferences about the data (e.g., step-wise transitions between categories). It is important to avoid inferences about the data because step-wise transitions are common in ecological data (e.g., the transition from 100% sand to 100% coral occurs abruptly at the coral colony margin). For this reason gradient-style color schemes were not used.

Shallow fringing reefs of the Mariana Islands include only a trivial complement of sponges, soft corals, tunicates, and other sessile benthos typical of reefs (Minton et al. 2009; Houk and Starmer 2010; Houk and van Woesik 2010; Suhkraj et al. 2010; Brainard et al. 2012). This was also observed during the survey, and only a trivial component of the total percent cover was omitted by excluding sponges, soft corals, tunicates, and other sessile benthos from the broad-scale surveys.

Though the classes were reliable and quality-assured by sampling the same area multiple times with different observers, the estimates are purely categorical and remain consistent with the needs of an essential fish habitat functional value assessment. The 0% class indicates zero cover, the 10% class represents cover greater than 0% to approximately 10%, and the classes from 20% to 100% represent estimates to the nearest 10%. Note that 40% to 50% coral cover is high for a coral reef. An extensive body of literature addresses the apparent paradox that coral reefs are not typically dominated by corals in terms of percent cover (Connell et al. 1997; Vroom et al. 2006; Hughes et al. 2010; Hughes et al. 2011; Vroom 2011). Patches of extremely high percent cover (e.g., 50% to 100%) are not uncommon, and reefs surveyed on Tinian and Pagan are no exception; however, this report emphasizes that 50% coral cover is high rather than merely half.

Figure 3-2. Broad-Scale Survey Methods

Divers reported data to the support boat as they were towed in deeper waters or as they roved in the shallows.

3.3.2 Coral Species Richness

Species richness is simply a count of different species represented in an ecological community. Coral species lists were generated for all high- and low-priority sites. From inshore to offshore, the survey was generally restricted to the shallows (0 to 12 feet [0 to 4 meters]) but would extend deeper following grooves (for example, the floor of a groove could be ~20 feet [~6 meters] and next to a spur-top at ~6.5 feet [~2 meters]). Alongshore, the survey extent was predetermined based on the length and geometry of the adjacent beach. At Green, Red, and Blue Beaches on Pagan, the species list survey included portions of the rocky headlands adjacent to the sandy beach. Investigations of the Red Beach proposed construction areas included all substrate, from shallowest to deepest (85 feet [26 meters]). The limits of each survey are depicted on the figures in each subsection of the results, as appropriate.

Coral species lists were collected in two stages. The first was a dedicated search by all four coral experts lasting 40 to 60 minutes. This included in-water and follow-up conferences to maximize the agreement on the identification of corals. As a rule, the search for coral species was the first task completed at each site. The second stage of coral species list collection was to maintain a running list during all subsequent methods deployed at the site. Voucher photos were taken of all species at their first sighting such that a comprehensive reference set accumulated, documenting particular characteristics used to discriminate between species. Rarely, a specimen will have clear characteristics of one species at the base of the colony and clear characteristics of a different species at the top of the colony. This occurred on occasions during the work, principally involving colonies of *Astreopora*, *Acropora*, *Porites*, and *Psammocora*. After conference and quality assurance, identifications were positive or irresolvable.

The positive ID category represents species identifications that, based on the consensus of the four coral experts, are distinct groups. There are four types of positive identifications in this category: *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # (description). The abbreviation *cf*. is “compare with” in Latin, and in the context of taxonomy, means the specimen is almost certainly the named species, but is slightly different. The abbreviation *aff*. is “affinity” in Latin, and in the context of taxonomy means the specimen is very similar to the named species, but is almost certainly different. For example, Unai Chulu has specimens described as *Echinopora aff. lamellosa* (Appendix A), meaning the specimens were very similar to *Echinopora lamellosa* but almost certainly a different species. *Genus* sp. # (description) is typical taxonomic notation for something that is almost certainly a novel undescribed species and is represented by many individuals rather than a single atypical colony. For example, Unai Chulu has specimens described as *Acropora* sp. 5 (small corymbose colony, neat radials, white polyps; Appendix A). This species is sufficiently dissimilar from other corals and presents a morphology that consistently fits the description. *Acropora* sp. 5 has been described from similar habitats on the CNMI, Guam, and Fiji.

Collecting the species for microscopic examination of the skeleton and comparing it with taxonomic authorities would resolve most of the coral species labeled *Genus cf. species*, *Genus aff. species*, and *Genus* sp. # (description) into a species already described in literature. Those that are not resolved via this research are very likely to be novel species.

The irresolvable ID category principally represents methodological error, underdeveloped juveniles, or ambiguous specimens; these are all named *Genus* sp. The abbreviation sp. in the context of taxonomy means the specimen does not exhibit enough diagnostic characters to be assigned to a particular species. The identity of some colonies will always be irresolvable to species-level depending on one or more of these three factors. In total, the identity of 14 species across the study could not be resolved positively beyond genus (see Sections 2.3, Challenges with Coral Identification). Actual counts of irresolvable records are nearly meaningless when taken out of context. This is because they may include members of a well represented genus, or may be the sole representative of the genus. For example, records of *Porites* sp. at Unai Chulu may, in fact, belong to one or more of the nine positively identified *Porites* species from that site (Appendix A). In contrast, records of *Distichopora* sp. at Unai Chulu certainly represent at least one species that does not occur elsewhere in the coral species richness dataset (Appendix A).

3.3.3 Coral Demographics

Coral demographics were collected using a minor modification of methods employed by Henningson, Durham & Richardson, Inc. (HDR) and Continental Shelf Associates (CSA; 2011), following guidance in McManus and McManus (2012). Corals were included in each 10.7 square foot (1 square meter) quadrat, if the colony center was within the quadrat frame (Figure 3-3). All colonies within the frame were identified to species, and demographic data were collected from each. Two measurements of colony size were taken: the maximum dimension and the dimension orthogonal to the maximum dimension at its midpoint. Each size was measured to the nearest 4 inches (10 centimeters), except for colonies smaller than 4 inches (10 centimeters), which were measured to the nearest of 0.8 inch (2 centimeters) or 2 inches (5 centimeters) depending on which size class was appropriate.

Data were collected for each colony for growth form, partial mortality, bleaching, fragmentation, clumping, remnant, disease, predation, and other comments. The "partial mortality" parameter was recorded as the estimated percent of the once-whole colony; however, this parameter excluded occasions when a species' ordinary growth included partial mortality (e.g., the lowermost branches of some species are typically dead). The parameters "bleaching," "fragmentation," "clumping," "remnant," "disease," and "predation" were recorded as presence/absence, and comments were added as appropriate. Each of these parameters is useful for demographic analyses and most are recommended for mitigation planning (McManus and McManus 2012). Only the four divers—A. Reyes, V. Bonito, D. Fenner, and E. Lovell—each with particular expertise in species-level identification of Micronesian corals - participated in this method (Appendix E). V. Bonito and D. Fenner worked previously with National Marine Fisheries Service (NMFS) coral experts to develop acceptable methods, and used these same methods (HDR and CSA 2011).

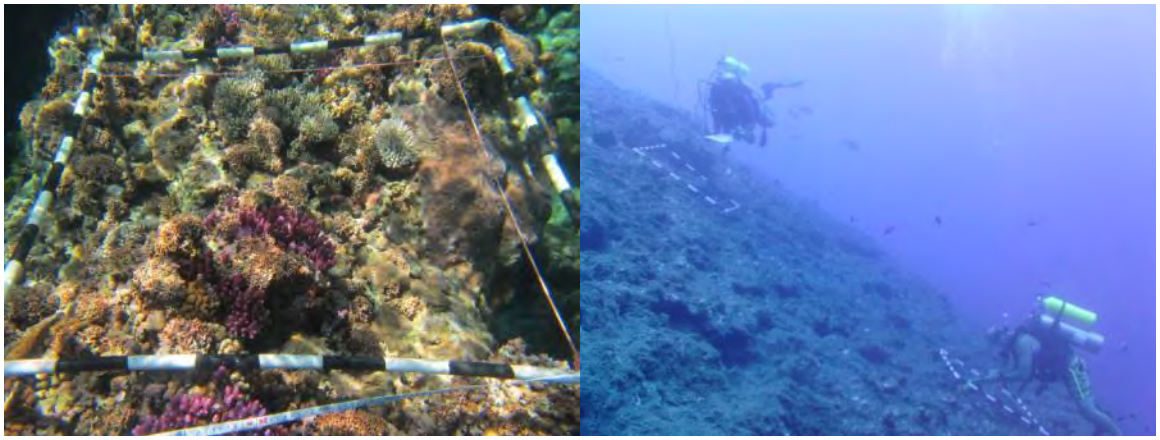

Figure 3-3. Quadrat Methods

Left, 4-inch (10-centimeter) size indicators; right, divers sampling quadrats on a transect alignment at the deep portions of the potential Red Beach potential construction area.

Quadrat placement focused on the uppermost 12 feet (4 meters), but occasionally quadrats fell in deeper habitat. All quadrat placements were haphazard with respect to the substrate, and several random numbers were used to determine quadrat spacing. Equal allocation among the habitat zones on each reef was attempted, but some zones were inaccessible under particular wave and tide conditions.

At each of the seven sites surveyed with quadrats for coral demographics, the minimum number of quadrats collected was 14 and the minimum number per zone was four at each site. Quadrat placement was systematic among zones, and random within zones, using one of the random numbers as appropriate to the spatial scale being sampled. Select demographic data are summarized in the Results, and the raw dataset will be presented in the electronic data deliverable. Baseline characterization has already been completed for all leeward sites in this survey (Minton et al. 2009; Suhkraj et al. 2010). The areas sampled by Minton et al. (2009) and Suhkraj et al. (2010) almost perfectly matched the areas sampled in this survey. Consequently, this survey used the power analyses conducted by Minton et al. (2009) and Suhkraj et al. (2010) to ensure adequate sampling sufficiency. These analyses informed the survey plan (DoN 2013b), which collected between two- and eight-fold more coral demographic data than required for adequate sampling sufficiency, as identified by the prior studies' power analyses (Minton et al. 2009; Suhkraj et al. 2010).

Random numbers were generated to guide quadrat placement at the three relevant spatial scales: multiples of 20 meters, multiples of 10 meters, and multiples of 10 meters along a transect tape.

- A random whole number from 0 to 20 was generated using the Microsoft Excel function "RANDBETWEEN(0,20)," and the result was 6.
- A random whole number from 0 to 10 was generated using the Excel function "RANDBETWEEN(0,10)," and the result was 3.
- A random integer rounded to tenths from 0 to 10 was generated using the Excel functions "RANDBETWEEN(0,10)" and "RAND()," and the result was 1.5.

Each observer used the most appropriate of these three randomly generated numbers to guide quadrat placement (e.g., quadrat placement 6 meters after the start of a 20-meter transect, or quadrat spacing 1.5 meters apart along a 10-meter transect).

Colony size is a useful approximation of biomass, and particular dimensions are recommended for community-scale assessments (McManus and McManus 2012). Measuring a single dimension (e.g., the maximum diameter) assumes the colony size can be approximated by the area of a circle. Measuring two dimensions (e.g., the maximum dimension and the dimension orthogonal to the maximum dimension at its midpoint) assumes the colony size can be approximated by the area of an ellipse. The latter, plus growth form, is recommended as the best practice for community assessments (McManus and McManus 2012). The elliptical area was calculated using the formula for the area of a regular ellipse (i.e., $A = \pi r_1 r_2$) and presented as square centimeters. The results present colony size as elliptical area and convert these sizes to approximate circular diameter only for casual comparisons on figures. See Table 3-2 for a quick-reference guide to these conversions, but most colonies are poorly approximated by circular diameters. Elliptical areas were used for all quantitative comparisons.

Table 3-2. Quick-Reference Conversion from Area to Approximate Circular Diameter

Area (cm^2)	20	80	320	1,280	2,900	5,100	7,900
Approximate Circular Diameter (cm)	5	10	20	40	61	81	100

Notes:
cm = centimeter; cm^2 = square centimeter

3.3.4 ESA Coral Demographics

ESA-proposed corals were quantified using three methods: by incidental sampling during the coral demographics sampling; by direct-mapping survey, where ESA-proposed colonies were relatively sparse; and by belt-transect sampling, where ESA-proposed colonies were relatively dense. Planning was based on the foundational assumption that ESA-proposed corals were likely to be uncommon relative to other colonies, and the belt-transect method was deployed only when direct-mapping was impractical. The participating divers A. Reyes, V. Bonito, D. Fenner, and E. Lovell have particular expertise in species-level identification of Micronesian corals. Other members of the scientific crew assisted as needed with site logistics and GPS buoy management, but they did not conduct species identifications. Select demographic data are summarized in the results, and the raw dataset is presented in the electronic data deliverable (DoN 2014a).

3.3.4.1 Incidental Sampling by Coral Demographics

ESA-proposed corals were incidentally sampled during the coral demographics sampling using the 10.7-square-foot (1-square-meter) quadrats. Quadrats usually under-sample uncommon organisms, and the survey planning included an assumption that ESA-proposed corals were likely to be uncommon relative to other colonies. Consequently, survey plans did not include use of 10.7-square-foot (1-square-meter) quadrats to adequately sample ESA-proposed colonies. Although some ESA-proposed species are dominant in particular zones, meaning that 10.7-square-foot (1-square-meter) quadrats could adequately represent their populations (Figure 3-3), such an effort would be biased to those particular zones.

3.3.4.2 Survey by Direct-Mapping

Where ESA-proposed corals were relatively uncommon, each colony within the survey area was individually mapped with the GPS buoy (Figure 3-4). Each colony was assessed for the same data as was collected for the quadrats (Section 0). Occasionally, multiple colonies were included with a single GPS point, but this included only those colonies within 3 feet (1 meter) of the point. Where ESA-proposed corals were more abundant, individual colony mapping was abandoned in favor of assigning corals to a larger subarea, with borders defined by GPS (Figure 3-4). These subareas, employed only at Unai Chulu, were 66 feet by 66 feet (20 meters by 20 meters) or 39 feet by 66 feet (12 meters by 20 meters).

Direct-mapping was employed at Green Beach, the Red Beach Potential Action Area, Red Beach, Blue Beach, and portions of Unai Chulu.

3.3.4.3 Sampling ESA-Proposed Colony Demographics by Belt-Transects

Belt transects were used to sample ESA-coral colonies where they were abundant or dominant (Figure 3-4 and Figure 3-5). GPS-referenced belt-transects were “short,” 33 feet by 66 feet (10 meters by 20 meters) or “long,” 66 feet by 66 feet (20 meters by 20 meters). Repetitive belt transects of 164 feet (50 meters) to 328 feet (100 meters) were deployed in series across the area to be sampled. Each colony was assessed for the same data collected for the quadrats.

A series of nominal long transects was 6.5 feet (2 meters) wide and 330 feet (100 meters) long and was laid within a single zone when oriented parallel to shore (Figure 3-5). A series of nominal short transects was 6.5 feet (2 meters) wide and 164 feet (50 meters) long and laid perpendicular to shore, crossing all zones from 12 to 0 feet (4 to 0 meters). Each transect was subdivided into short segments, 6.5 feet by 33 feet (2 meters by 10 meters) or long segments, 6.5 feet by 66 feet (2 meters by 20 meters). GPS locations were recorded at each node (0, 66, 131, 197, 262, and 328 feet [0, 20, 40, 60, 80, and 100 meters]). ESA-proposed coral colonies with centers within the belt were assessed for the same data collected for the quadrats.

The location of belt transects was systematic, at least 10 long belt-transects within each reef zone (fore reef, reef crest, outer reef flat, and inner reef flat). The location was determined before divers entered the water so that the sampling was haphazard with respect to the reef. Haphazard sampling preserves most of the statistical power of the effort. Sampling ESA-proposed colony demographics by belt-transect was employed at Unai Chulu, Unai Babui, Unai Lamlam, and Unai Masalok.

Figure 3-4. ESA Coral Demographics Methods

Clockwise from top left: direct-mapping GPS buoy; subareas defined by tapes; a scientist surveying a 6.5-foot-wide (2-meter-wide) belt transect; adjacent belt transects on a deeper and shallower fore reef.

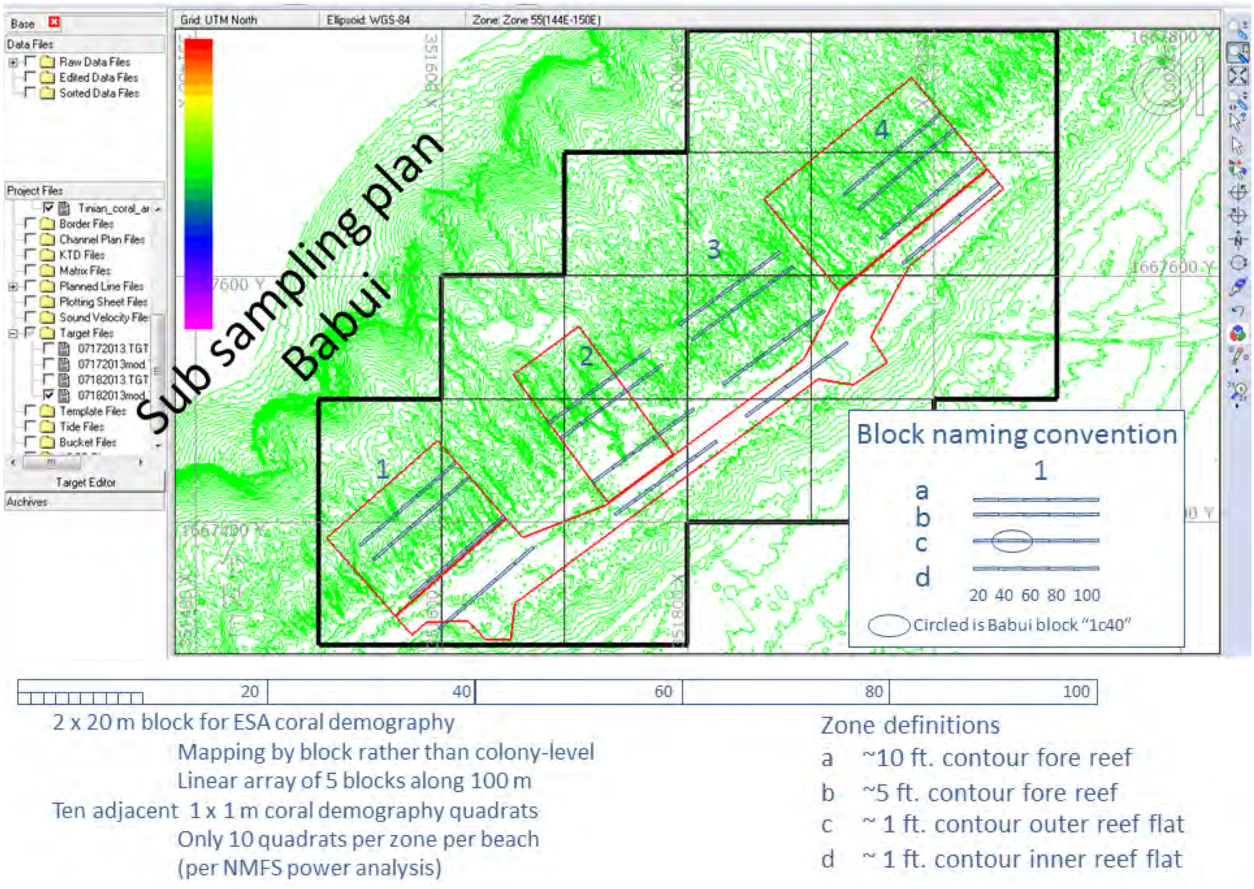

Figure 3-5. Sub-Sampling Plan Layout Using Belt Transects for ESA Corals

CHAPTER 4
RESULTS - TINIAN

4.1 UNAI CHULU

4.1.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at Unai Chulu was low to moderate topographic complexity, low to moderate coral cover, and low sand cover (Figure 4-1, Figure 4-2, Figure 4-3, Figure 4-4, and Table 4-1). However, patches of Unai Chulu had very high coral cover (Figure 4-2 and Table 4-1). The reef area was physically complex, with very deep, irregularly spaced grooves (e.g., 20-26 feet [6-8 meters]) in the fore reef, with a relatively steep transition to the deep fore reef, with rubble scree in the grooves. The bases of grooves often had polished surfaces and polished cobble-sized clasts, indicating high-energy sediment transport and erosion.

Many spurs were undercut by grooves that interconnect with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest and occasionally under the reef flat (see Section 3.3, Survey Methods). Reef zonation was quite clear and includes distinct deep fore reef, shallow fore reef, reef crest outer reef flat, inner reef flat, and beach (See Section 2.1, Geomorphology, for a description of zonation). To the south of the beach, the reef flat zone transitions to a shallow bench. This zone was much richer with coral cover than the reef flat; Figure 4-2 shows this patch of 50% coral cover at approximately 15° 4′ 15″ N by 145° 36′ 50″ E. Figure 4-2, Figure 4-3, and Figure 4-4 present data summarized for visual clarity. The detailed data for every class is presented in Table 4-1. See Section 3.3.1, Broad-Scale Surveys, for descriptions of the method and caveats. Representative images of Unai Chulu are presented in Figure 4-7.

4.1.2 Coral Species Richness

Summary species richness results for Unai Chulu and all the other Tinian sites are presented in Table 4-2, and records of individual species for Unai Chulu and all the other sites are presented in Appendix A. Among the 121 records are 8 ESA-proposed coral species and 10 irresolvable species (see Appendix D for representative images of ESA-proposed species). At least 1 of the 10 irresolvable records, *Distichopora* sp., represents an additional species record for the site (see Section 2.3, Challenges with Coral Identification, and Section 3.3.2, Coral Species Richness). In the demographic data below, irresolvable colonies are relatively uncommon. Collection for microscopic examination of the skeleton and comparison with taxonomic authorities would resolve most of the coral species identifications in this category. Those not resolved via this research are very likely to be novel species.

4.1.3 Coral Demographics

Unai Chulu was sampled with 53 quadrats, each 10.7 square feet (1 square meter; Appendix B, DoN 2014a). A total of 69 species of corals fell within quadrats, the most abundant of which was *Goniastrea retiformis*, with an estimated density of 0.5 colonies per square foot (5.6 colonies per square meter; Table 4-3). Size-structure of the most frequently occurring species is shown in Figure 4-5. Within this set, most colonies are smaller than 7.9 inches (20 centimeters; approximate circular diameter); however, several species attained maximum sizes approaching 1 square meter (Table 4-3). Size distribution was skewed toward small colonies (compare average with median size in Table 4-3), though size distribution of some species was relatively homogenous (e.g., *Galaxea fascicularis*). The maximum sizes in Table 4-3 represent only the single largest colony and five species have colonies that attained 0.25 square meter, or larger. The habitat was heterogeneous among depth zones, particularly the shallow bench to the south of the beach, but was relatively homogeneous within depth zones. In total, 1,072 corals were counted within 53 quadrats; the average quadrat contained about 16 coral colonies. However, most of the quadrats on the inner reef flat had few or zero colonies, and quadrats on the outer reef flat and reef crest had about 2.8-5.6 colonies per square foot (30-60 colonies per square meter).

4.1.4 ESA Coral Demographics

In total, 2,277 ESA-proposed coral colonies were directly assessed during the sampling and surveys at Unai Chulu. The size frequency distribution of the four most abundant ESA-proposed species shows two main patterns.

First, most colonies of *Acropora globiceps*, *Acropora verweyi*, and *Acanthastrea brevis* were smaller than 7.9 inches (20 centimeters; Figure 4-6 and Table 4-4). Second, many colonies of the encrusting *Acropora palmerae* are very large (Figure 4-6 and Table 4-4), with one colony attaining a maximum area of more than 36.6 square feet (3.4 square meters). Large colonies of *Acropora palmerae* were typical of the innermost fore reef and the outer reef crest, and were most often categorized into the fore reef zone, occupying depths of 4 to 6 feet (1.3 to 2 meters; See Coral Data Deliverable Table 6-1 for details of each colony). Four species were relatively uncommon, including *Astreopora cucullata*, *Millepora tuberosa*, *Pocillopora danae*, and *Montipora lobulata* (Table 4-4).

The spatial heterogeneity of ESA-proposed coral colonies can be qualitatively estimated using the number of belts and quadrats with zero ESA-proposed colonies (Table 4-4). This provides a useful reference for other sites for which direct-mapping was too time-consuming to be effective (Section 3.3.4, ESA Coral Demographics). Almost 8% of the quadrats at Unai Chulu had zero ESA-proposed colonies (n=4 of 53 1-m^2 quadrats), but none of the long belt transects had zero ESA colonies (n=0 of 20 2x20-m belt transects).

ESA-proposed coral demographics were estimated by direct mapping, yielding a low-end estimate of 1,877 colonies within the proposed activity areas, extrapolating from the quadrat data yields an estimated 26,038 corals and the 6.5 feet by 66 feet (2 meters by 20 meters) belt transects yields an estimated 13,275 ESA-proposed corals potentially exposed to activities (Figure 4-6, Table 4-4, and Appendix B, DoN 2014a). This is equivalent to 0.03, 0.08, 0.04 colonies per square foot (0.3, 0.9, and 0.4 colonies per square meter), respectively. Each of these extrapolations are valid estimates of the total population of ESA-proposed coral colonies at Unai Babui, though each carries different assumptions that should be considered for further analyses (see Section 3.3.4, ESA Coral Demographics, and Section 6.1, Extrapolating from the Sample to the Population).

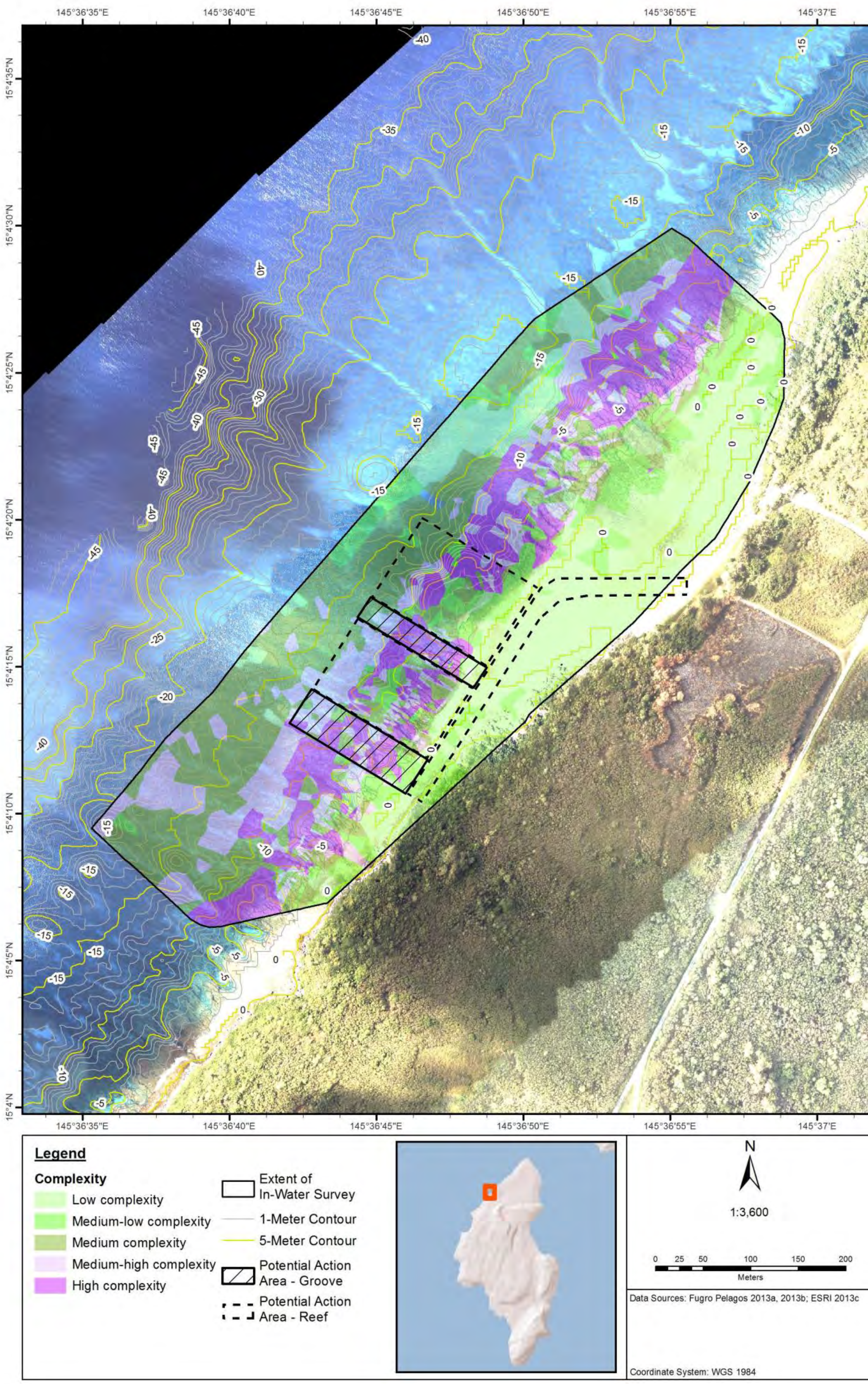

Figure 4-1. Unai Chulu In Situ Broad-Scale Topographic Complexity

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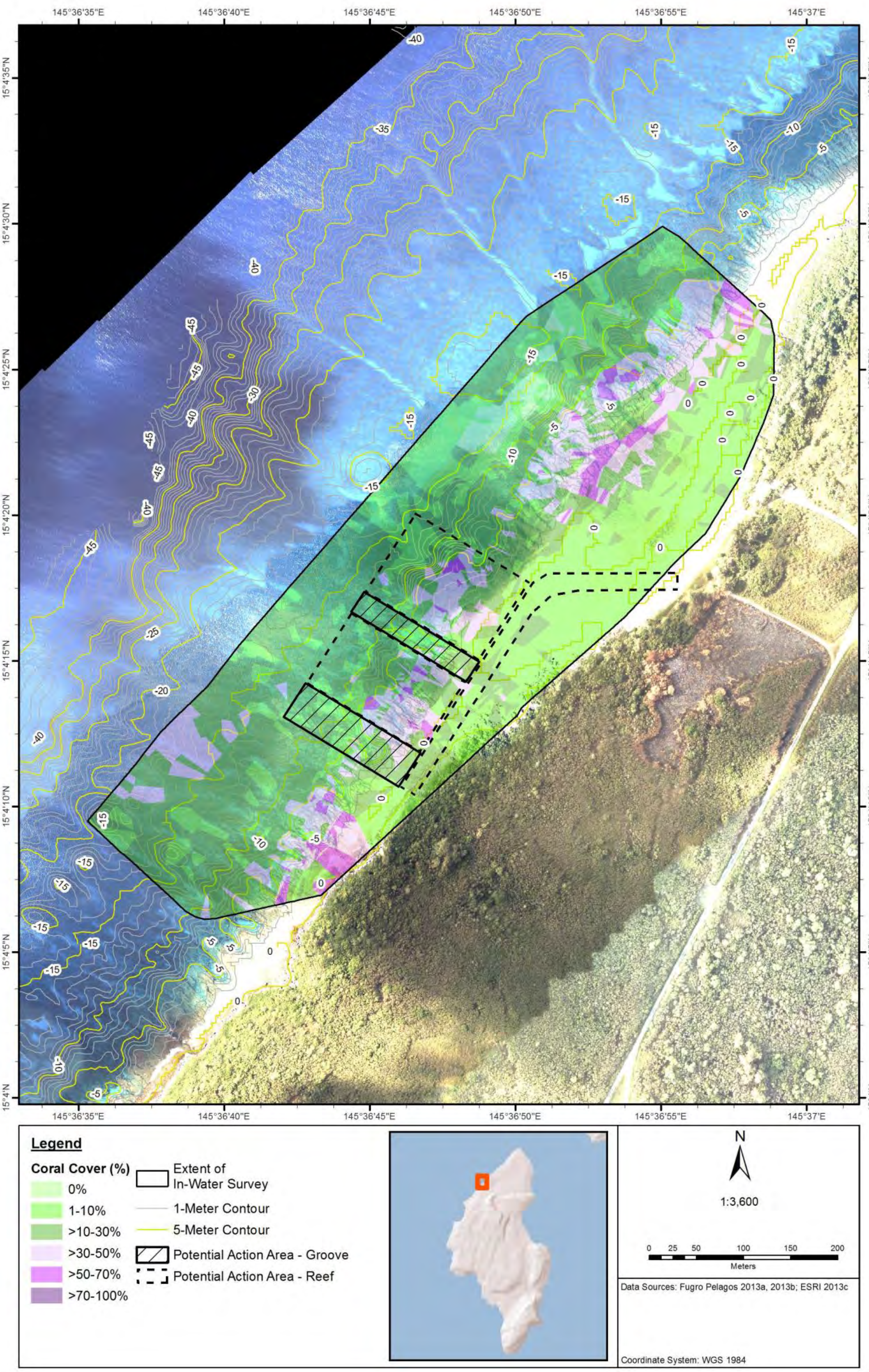

Figure 4-2. Unai Chulu In Situ Broad-Scale Coral Cover

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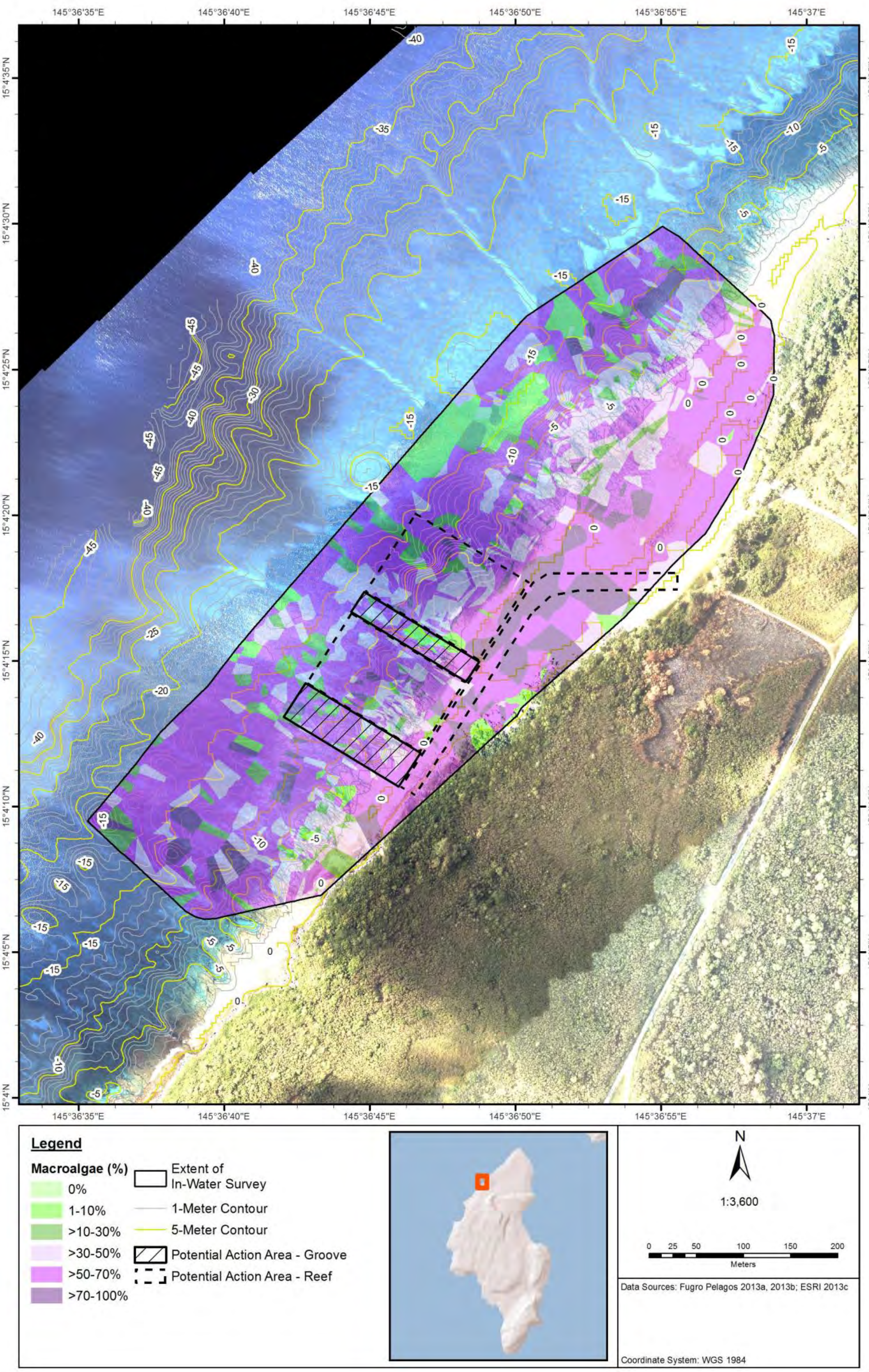

Figure 4-3. Unai Chulu In Situ Broad-Scale Macroalgae Cover

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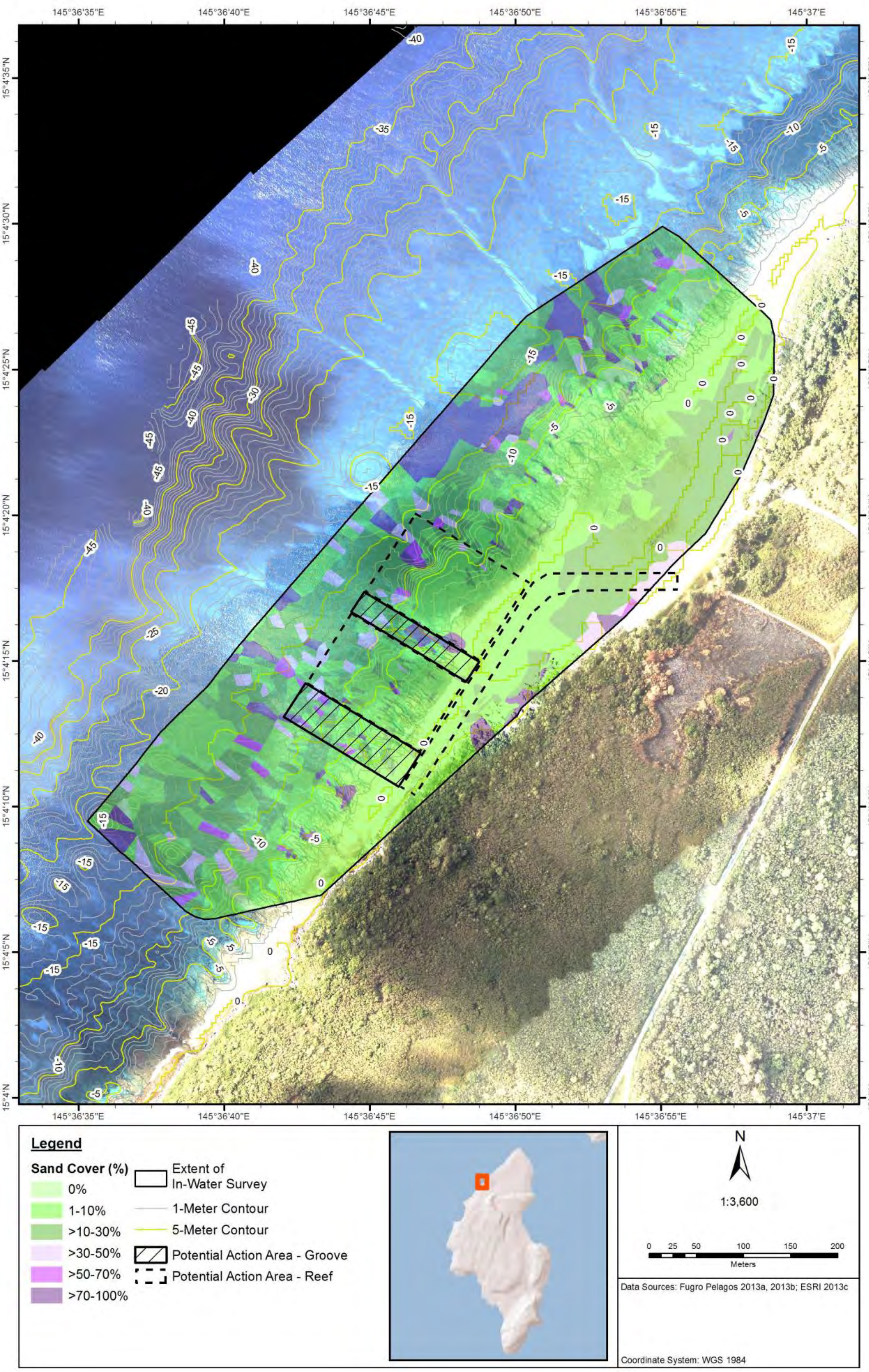

Figure 4-4. Unai Chulu In Situ Broad-Scale Sand Cover

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Table 4-1. Broad-Scale Surveys at Unai Chulu (Square Meter, % Cover)

Unai Chulu Beach Total Area[1] = 216,441 Square Meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	59,180	27,348	59,636	32,498	37,780	0	--	--	--
	--	27%	13%	28%	15%	17%	0.0%	--	--	--
Coral	4,026	74,151	70,556	29,596	19,284	12,311	4,175	2,293	48	0
	1.9%	34%	33%	14%	8.9%	5.7%	1.9%	1.1%	0.0%	0.0%
Macroalgae	445	13,541	4,895	9,007	9,198	35,331	64,934	59,121	19,708	261
	0.2%	6.3%	2.3%	4.2%	4.2%	16%	30%	27%	9.1%	0.1%
Sand	3,964	108,329	62,331	12,058	5,004	5,053	1,029	2,061	4,602	12,011
	1.8%	50%	29%	5.6%	2.3%	2.3%	0.5%	1.0%	2.1%	5.5%

Notes:
[1]See Figure 4-1 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed; “Not Applicable” indicated by “--“.

Table 4-2. Summary Species Richness at All Tinian Sites

	Unai Chulu	*Unai Babui*	*Unai Lamlam*	*Unai Dankulo*[2]	*Unai Masalok*	*Cumulative Tinian (n=5 Sites)*
Total Species Richness[1, 2, 3]	121	107	108	119	113	164
Total Irresolvable ID[1]	10	9	6	4	5	12
Subset of Positive ID Unique to Tinian versus Pagan	--[4]	--	--	--	--	27
Total ESA-Proposed Species[3]	8	7	7	11	9	12

Notes:
[1]Total species richness includes all identifications. Irresolvable includes those identified only to genus (i.e., "Genus sp."). All other identifications represent species that are positively identified or are likely to become positive with additional field collections, taxonomic work, or definition of potential novel species.
[2]Unai Dankulo included deeper fore reef habitat than the other sites (to 66 feet [20 meters]).
[3]See Appendix A for the full list of the 164 coral species found at Tinian sites.
[4]"Not Applicable" indicated by "--".

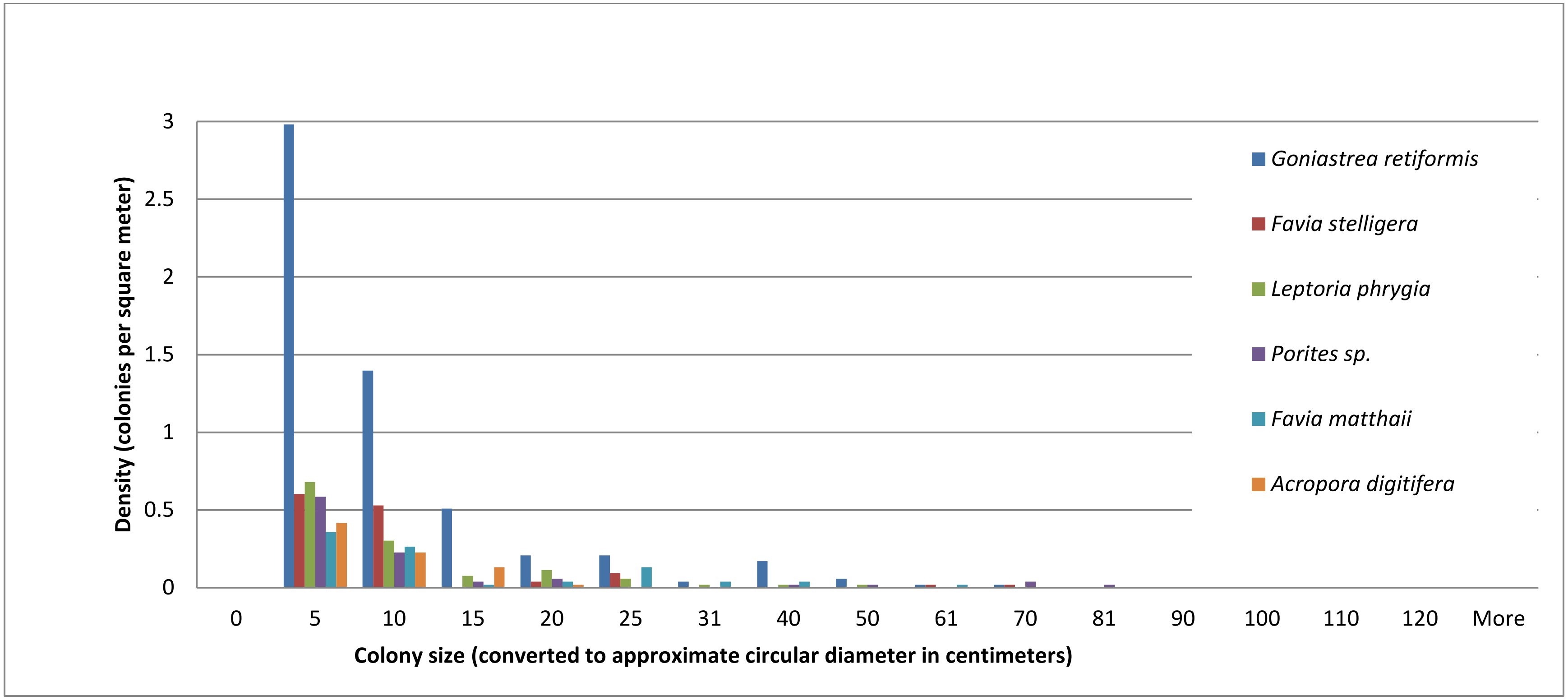

Figure 4-5. Size-Frequency Histogram of the Most[1] Abundant Corals at Unai Chulu[2]
(see Table 4-3 for Summary Statistics)

Notes:
[1]Six species make up the top 50th percentile at Unai Chulu.
[2]Includes 53 10.7-square foot (1-square meter) quadrats at Unai Chulu. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

Table 4-3. Coral Demographics Summary Statistics from All Quadrats at Unai Chulu (n=53)

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Goniastrea retiformis	5.60	297	1	3,299	132	20	20
Favia stelligera	1.30	69	1	3,848	167	39	39
Leptoria phrygia	1.28	68	1	1,963	132	20	20
Porites sp.	1.00	53	1	4,398	296	1	20
Favia matthaii	0.91	48	1	2,356	232	20	59
Acropora digitifera	0.79	42	8	236	57	20	20
Favia pallida	0.68	36	3	79	23	20	20
Leptastrea purpurea	0.66	35	1	157	12	3	3
*Stylophora mordax**	0.60	32	3	628	108	20	20
Platygyra pini	0.51	27	1	471	106	20	20
Pavona varians	0.47	25	3	628	65	39	39
*Acropora ocellata**	0.38	20	20	157	68	20	59
Galaxea fascicularis	0.38	20	3	79	17	20	20
*Acropora globiceps** PT	0.34	18	3	471	87	20	29
Goniastrea edwardsi	0.34	18	3	1,571	120	20	20
Montipora ehrenbergii	0.32	17	1	79	18	3	3
Acanthastrea brevis PT	0.26	14	1	157	43	79	29
Montipora grisea	0.25	13	1	157	32	3	12
Montastrea cf. valenciennesi	0.23	12	3	79	30	39	29
Pocillopora verrucosa	0.23	12	3	157	55	79	59
Acropora verweyi PT	0.21	11	1	157	48	3	8
Acropora valida	0.19	10	3	157	48	39	39
Montipora sp.	0.17	9	3	236	72	39	39
Acropora sp.	0.15	8	1	20	12	20	14
*Acropora surculosa**	0.15	8	3	157	32	20	20
Cyphastrea sp.	0.15	8	3	20	9	8	8

Species (ranked by abundance; aggregate for the whole beach)	Density	Count	Minimum Size (cm^2)	Maximum Size (cm^2)	Average Size (cm^2)	Mode Size (cm^2)	Median Size (cm^2)
Hydnophora microconos	0.15	8	1	157	55	20	20
Montipora species 2 (spikey)	0.15	8	1	20	9	20	3
Pavona chiriquensis	0.15	8	3	39	13	3	8
Pocillopora meandrina	0.15	8	8	314	120	79	79
Pocillopora sp.	0.15	8	1	157	22	3	3
Pocillopora species 1	0.15	8	39	314	118	79	79
Acropora cophodactyla	0.13	7	20	79	31	20	20
Montipora peltiformis	0.13	7	1	157	93	157	79
Pocillopora eydouxi	0.13	7	157	550	370	314	314
Pavona duerdeni	0.11	6	1	942	165	20	11
*Acropora studeri**	0.09	5	3	20	16	20	20
Cyphastrea microphthalma	0.09	5	1	20	9	--	8
Cyphastrea serailia	0.09	5	20	628	169	79	79
Pocillopora ankeli	0.09	5	8	330	83	20	20
Favites abdita	0.08	4	3	236	80	3	41
Acropora palmerae PT	0.06	3	20	39	26	20	20
Acropora tenuis	0.06	3	20	157	85	--	79
Favia favus	0.06	3	20	79	59	79	79
Galaxea astreata	0.06	3	3	8	6	8	8
Leptastrea transversa	0.06	3	20	6,362	2,134	20	20
Montastrea curta	0.06	3	20	157	72	--	39
Montipora tuberculosa	0.06	3	1	79	33	--	20
Montipora informis	0.04	2	39	79	59	--	59
Psammocora contigua	0.04	2	8	8	8	8	8
Acropora wardii	0.02	1	79	79	79	--	79
Astreopora listeri	0.02	1	79	79	79	--	79
Astreopora myriophthalma	0.02	1	79	79	79	--	79

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Fungia scutaria	0.02	1	3	3	3	--	3
Goniastrea sp.	0.02	1	3	3	3	--	3
Lobophyllia hemprichii	0.02	1	20	20	20	--	20
Montipora foveolata	0.02	1	20	20	20	--	20
Montipora verrucosa	0.02	1	20	20	20	--	20
Pavona clavus	0.02	1	79	79	79	--	79
Pocillopora damicornis	0.02	1	20	20	20	--	20
Pocillopora setchelli	0.02	1	20	20	20	--	20
Porites annae	0.02	1	79	79	79	--	79
Porites lobata	0.02	1	79	79	79	--	79
Porites rus	0.02	1	707	707	707	--	707
Psammocora profundacella	0.02	1	8	8	8	--	8
Psammocora species 1 (low, smooth ridges/collines)	0.02	1	471	471	471	--	471
Scapophyllia cylindrica	0.02	1	39	39	39	--	39
Turbinaria reniformis	0.02	1	8	8	8	--	8

Notes:
PT = Proposed Threatened
See Section 3.3.2, Coral Species Richness, for a description of species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # [description]).
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.
"Not Applicable" is indicated by "--".

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)
* *Acropora ocellata* (Klunzinger 1879) *sensu* Randall and Myers (1983); not *sensu* Veron (2000)
* *Acropora studeri sensu* Randall and Myers (1983)
* *Acropora surculosa sensu* Veron (2000), not = *Acropora hyacinthus sensu* Wallace (1999)
* *Montipora turgescens sensu* Veron and Wallace (1984); Veron (2000). *cf. Montipora hoffmeisteri sensu* Randall and Myers (1983)
* *Stylophora mordax* (Dana 1846) *sensu* Randall and Myers (1983) = *Stylophora pistillata* (Esper, 1797) *sensu* Veron and Pichon (1976); Veron (2000)

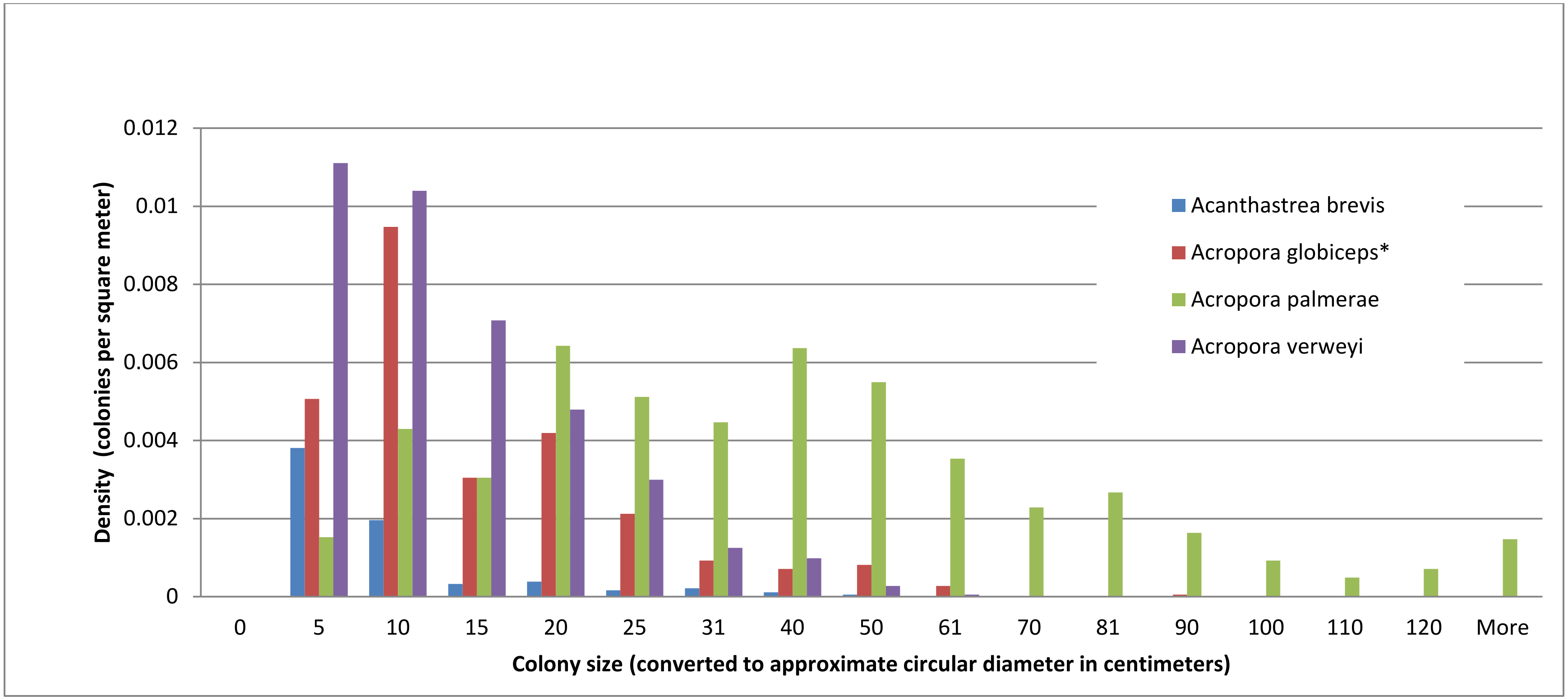

Figure 4-6. Size-Frequency Histogram of the 4 Most[1] Abundant ESA-Proposed Coral Species from All Samples and Surveys[2] at Unai Chulu.

Notes:
[1]Four of eight ESA species in this sample have densities high enough to display on this y-axis
[2]Includes all sample and survey units (n=18,373 square meters). Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

* *Acropora globiceps* (Dana 1846) *sens*u Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

Table 4-4. ESA-Proposed Coral Colony Demographics from all Samples and Surveys[1] at Unai Chulu[2]

Species (ranked by abundance: aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Acropora palmerae PT	0.05	927	20	34,557	2,126	314	785
Acropora verweyi PT	0.04	715	1	2,827	183	157	79
Acropora globiceps * PT	0.03	490	1	6,283	272	79	79
Acanthastrea brevis PT	0.01	129	1	1,649	111	20	20
Astreopora cucullata * PT	0.00	5	3	157	48	20	20
Millepora tuberosa PT	0.00	5	20	6,126	1,284	--[3]	79
Pocillopora danae PT	0.00	4	157	471	295	--	275
Montipora lobulata PT	0.00	2	79	707	393	--	393

Notes:
[1]Includes all sample and survey units (n=18,373 square meters). Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.
[2]See Figure 4-2, Figure 4-8, and Figure 4-9 for a depiction of the areas.
[3]"Not Applicable" indicated by "--".

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana, 1846) *sens*u Randall and Myers (1983)

* *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)

Figure 4-7. Representative Images of Unai Chulu

Clockwise from top left: rocky fore shore; shallow bench; reef flat; grotto underneath reef crest; shallow fore reef; reef crest.

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4.2 UNAI BABUI

4.2.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at Unai Babui was moderate to high topographic complexity, low to moderate coral cover, and low sand cover (Figure 4-8, Figure 4-9, Figure 4-10, Figure 4-11, and Table 4-5). However, patches of Unai Babui had very high coral cover (Figure 4-9 and Table 4-5). The reef area was physically complex, with irregularly spaced grooves that were very deep (e.g., 20-26 feet [6-8 meters]) in the fore reef, with a relatively steep transition to the deep fore reef, with rubble scree in the grooves. The bases of grooves often had polished surfaces and polished cobble-sized clasts, indicating high-energy sediment transport and erosion. Many spurs were undercut by grooves that interconnect with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest, and occasionally under the reef flat (see Section 3.3, Survey Methods). Reef zonation was quite clear and includes distinct deep fore reef, shallow fore reef, reef crest outer reef flat, inner reef flat, and beach (See Section 2.1, Geomorphology, for a description of zonation). To the south of the beach, the reef flat zone transitions to a shallow bench, which was much richer with coral cover than the reef flat; Figure 4-9 shows the patch of 90% coral cover at approximately 15° 4′ 42″ N by 145° 37′ 15″ E. Figure 4-9, Figure 4-10, and Figure 4-11 present data summarized for visual clarity. The detailed data for every class is presented in Table 4-5. See Section 3.3.1, Broad-Scale Surveys, for descriptions of the method and caveats. Representative Images of Unai Babui are shown in Figure 4-14.

4.2.2 Coral Species Richness

Summary species richness results for Unai Babui and all the other Tinian sites are presented in Table 4-2, and detailed records of individual species for Unai Babui and all the other sites are presented in Appendix A. Among the 107 records are 7 ESA-proposed coral species and 9 irresolvable species (see Appendix D for representative images of ESA-proposed species). At least 2 of the 9 irresolvable records, *Distichopora* sp. and *Symphyllia* sp. represent additional species records for the site (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness). In the demographic data below, that irresolvable colonies are relatively uncommon.

4.2.3 Coral Demographics

Unai Babui was sampled with 44 quadrats, each 10.7 square feet (1 square meter; Appendix B, DoN 2014a). A total of 56 species of corals fell within quadrats, and the most abundant was *Goniastrea retiformis*, with an estimated density of 0.26 colony per square foot (2.8 colonies per square meter; Table 4-6) Size-structure of the most frequently occurring species is shown in Figure 4-12. Within this set, the majority of colonies are smaller than 7.9 inches (20 centimeters; approximate circular diameter); however, several species attained maximum sizes approaching 1 square meter (Table 4-6). Size distribution was skewed towards small colonies (compare average with median size in Table 4-6), though size distribution of some species was relatively homogenous (e.g., *Galaxea fascicularis*). The maximum sizes in Table 4-6 represent only the single largest colony, and that six species have colonies that attained a 2.7 square feet (0.25 square meter), or larger. The habitat was heterogeneous among depth zones, particularly the shallow bench to the south of the beach, but was relatively homogeneous within depth zones. In total, 424 corals were counted within 44 quadrats; the average quadrat had about 10 coral colonies. However, most of the quadrats on the inner reef flat had few or zero colonies, and quadrats on the outer reef flat and reef crest had many more than 0.9 colony per square foot (10 colonies per square meter).

4.2.4 ESA Coral Demographics

Unai Babui, like Unai Chulu, had patches where ESA-proposed corals were dominant (Figure 4-9, Figure 4-13, Table 4-7, Appendix B, and DoN 2014a). Direct mapping was not conducted at Unai Babui because the method had been too inefficient at Unai Chulu. Instead, only quadrats and belt transects were used to sub-sample the area of the proposed activities. The sample size for ESA-proposed colonies at Unai Babui included 44 10.7-square foot (1-square meter) quadrats, 60 2x20-meter shore-parallel belt transects, and 25 2x10-meter shore perpendicular belt transects (See Section 3.3.4, ESA Coral Demographics for details of the methodology). In total, 917 ESA-proposed coral colonies were directly assessed during the surveys at Unai Babui. The size-frequency distribution of the four most abundant ESA-proposed species shows two main patterns. First, most colonies of *Acropora globiceps*, *Acropora verweyi*, and *Acanthastrea brevis* were smaller than 7.9 inches (20 centimeters) Second, many colonies of the encrusting *Acropora palmerae* are very large (Figure 4-13 and Table 4-7), with one colony attaining a maximum area of more than 33.4 square feet (3.1 square meters). Large colonies of *Acropora palmerae* were typical of the innermost fore reef and the outer reef crest, and they were most often categorized into the fore reef zone, occupying depths of 4 to 6 feet (1.3 to 2 meters; See Coral Data Deliverable Table 6-1 for details of each colony). The encrusting *Millepora tuberosa* was represented by only five colonies though one of them was also very large, attaining a maximum area of nearly 16 square feet (1.5 square meters) (Table 4-7).

The spatial heterogeneity of ESA-proposed coral colonies can be qualitatively estimated using the number of belts and quadrats with zero ESA-proposed colonies (Table 4-7), in the absence of direct-mapping for ESA-proposed colonies. Almost 64% of the quadrats had zero ESA-proposed colonies (n=28 of 44 1 m^2 quadrats), but less than 5% of the belt transect sample area had zero ESA-proposed colonies (n=3 of 60 2x20-m belts; n=1 of 25 2x10-m belts). Relatively few larger areas have zero ESA-proposed colonies, but relatively many smaller areas have zero ESA-proposed colonies.

ESA-proposed coral populations at Unai Babui were estimated by extrapolating from the demographic data (quadrats, long belt transects, and short belt transects) to yield an estimated 51,705, 18,227, or 27,170 ESA-proposed coral colonies, respectively in the 699,654 square foot (65,000 square meter) sampling area at Unai Babui (Figure 4-9, Figure 4-13, Table 4-7, and Appendix B). This is equivalent to 0.07, 0.03, 0.04 colonies per square foot (0.8, 0.3, and 0.4 colonies per square meter), respectively. Each of these extrapolations are valid estimates of the total population of ESA-proposed coral colonies at Unai Babui, though each carries different assumptions that should be considered for further analyses (See Section 3.3.4, ESA Coral Demographics and Section 6.1, Extrapolating from the Sample to the Population for these discussions).

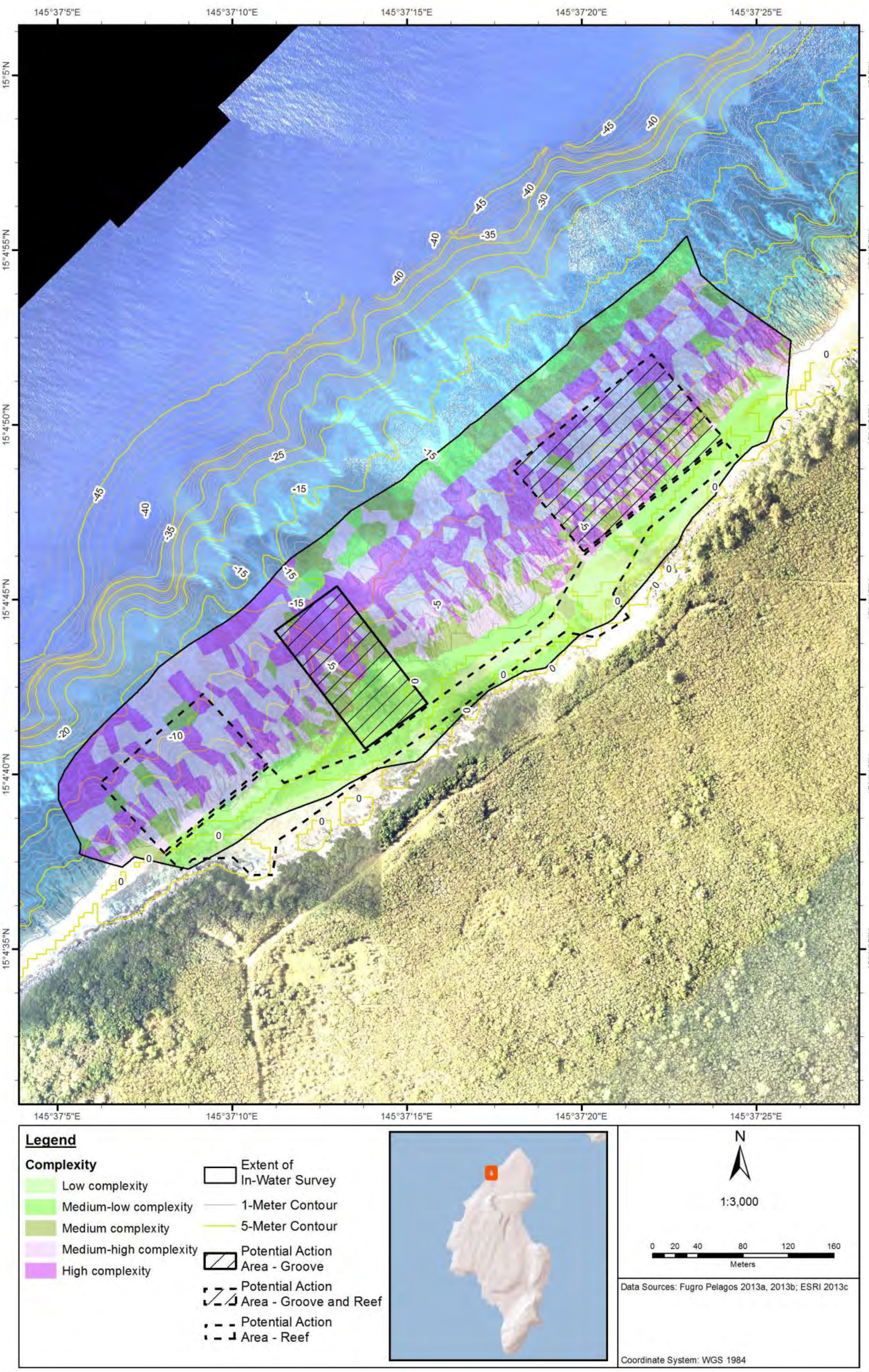

Figure 4-8. Unai Babui In Situ Broad-Scale Topographic Complexity

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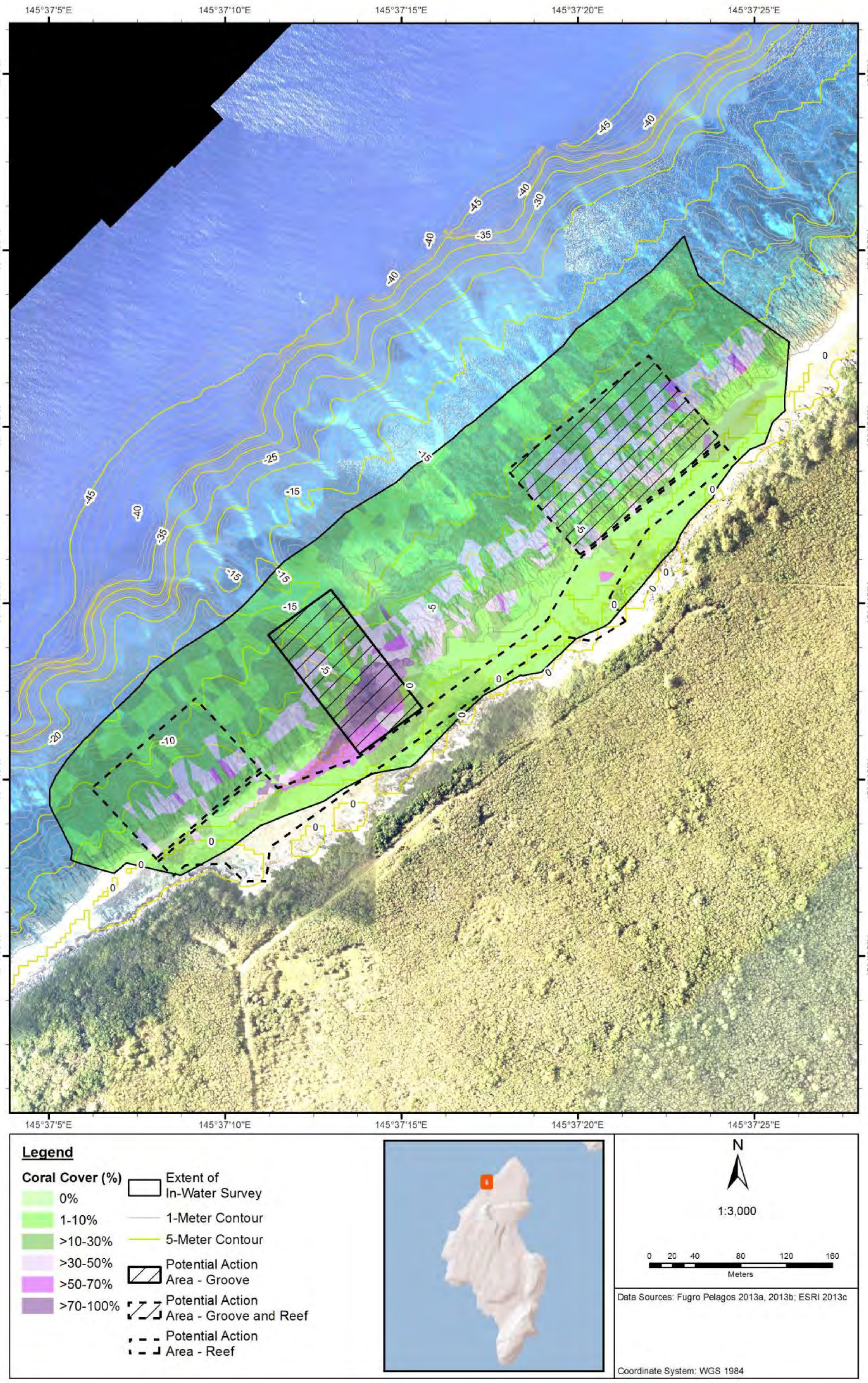

Figure 4-9. Unai Babui In Situ Broad-Scale Coral Cover

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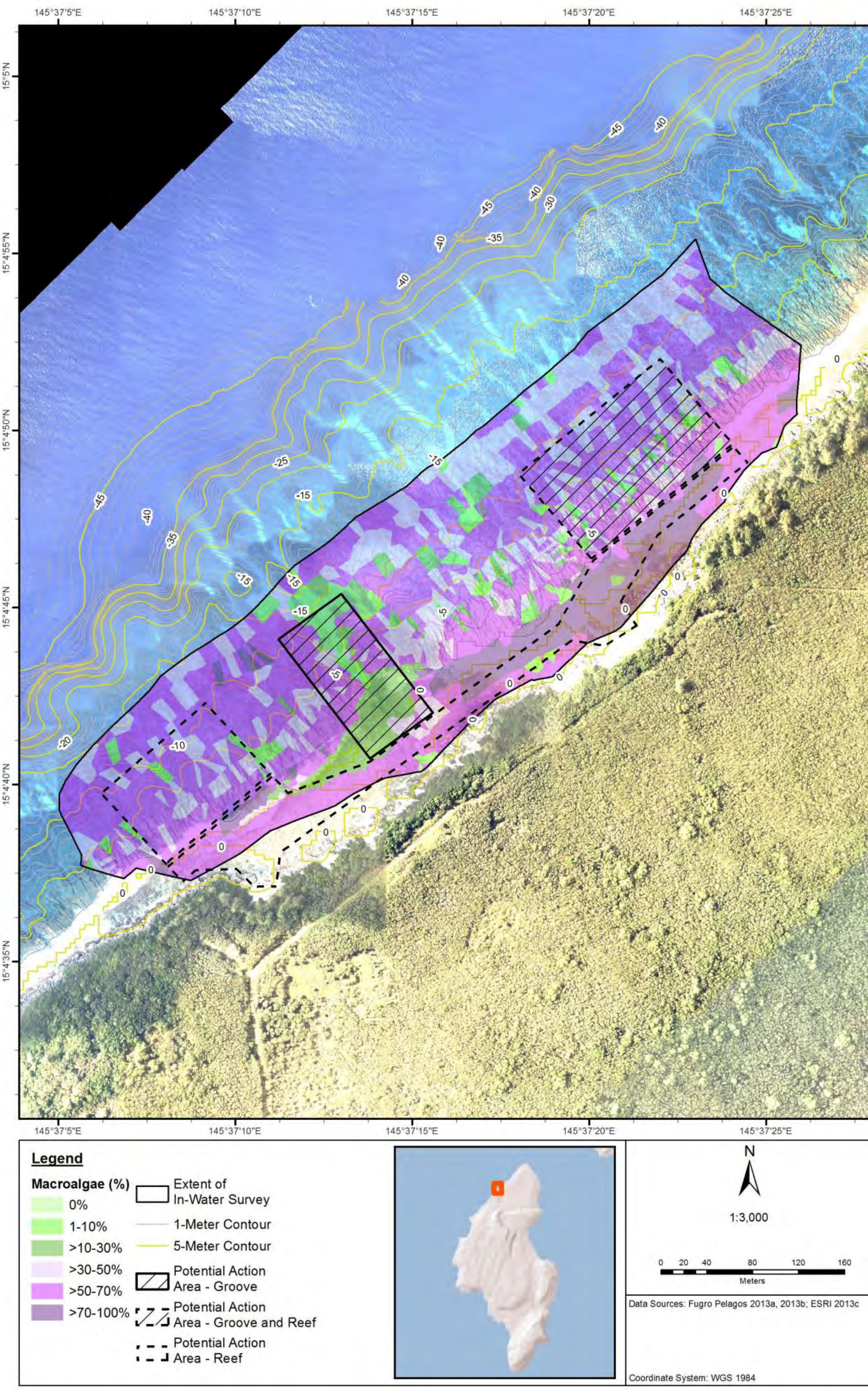

Figure 4-10. Unai Babui In Situ Broad-Scale Macroalgae Cover

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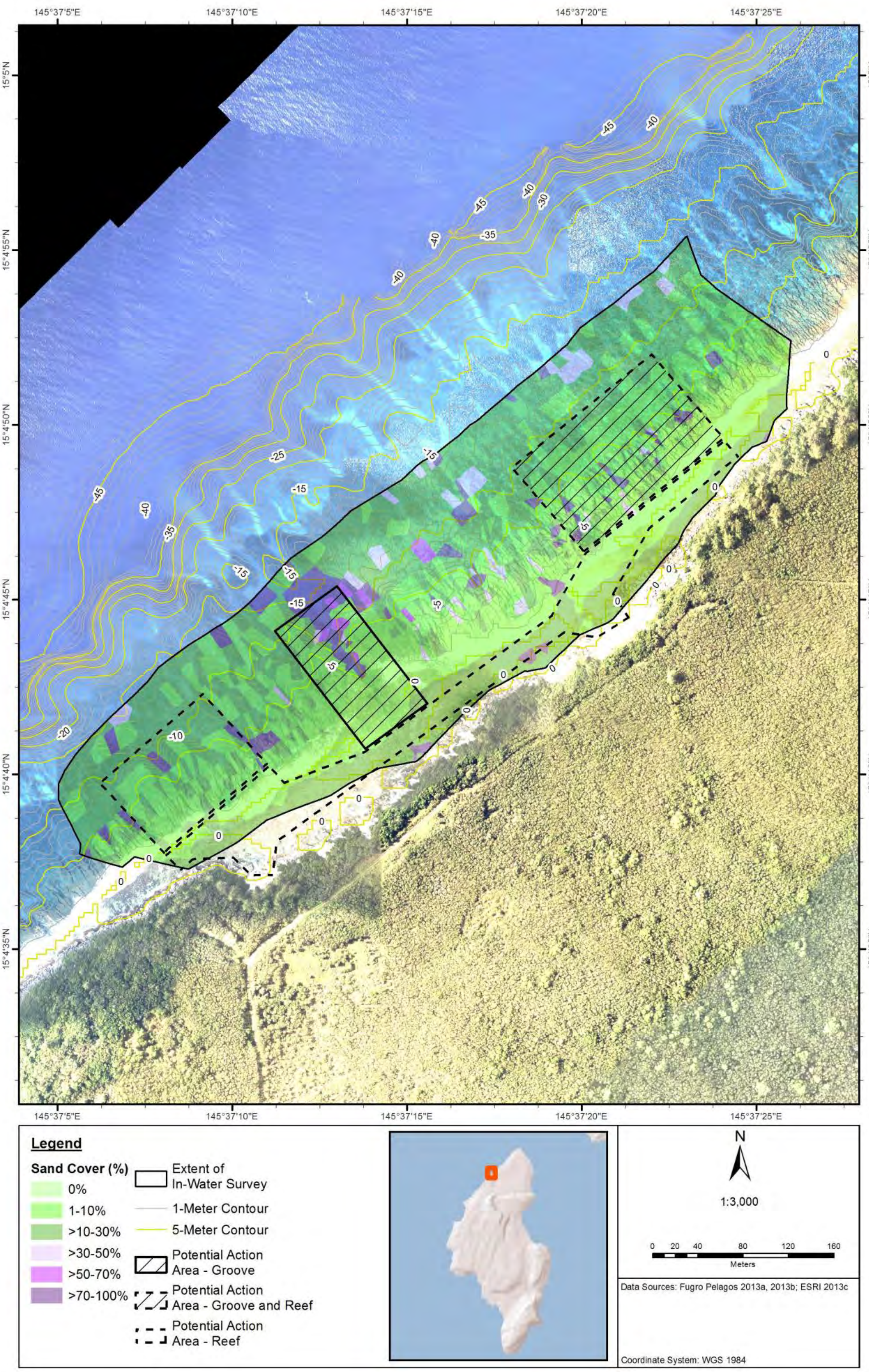

Figure 4-11. Unai Babui In Situ Broad-Scale Sand Cover

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Table 4-5. Broad-Scale Surveys at Unai Babui (Square Meters, % Cover)

Unai Babui total area[1] = 131,071 square meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	10,288	26,430	17,063	40,791	36,499	0	--	--	--
	--	7.8%	20%	13%	31%	28%	0.0%	--	--	--
Coral	0	52,936	40,390	15,398	9,793	7,118	1,418	1,175	2,772	71
	0.0%	40%	31%	12%	7.5%	5.4%	1.1%	0.9%	2.1%	0.1%
Macroalgae	0	6,927	5,635	2,082	4,546	27,495	51,305	19,759	13,321	0
	0.0%	5.3%	4.3%	1.6%	3.5%	21%	39%	15%	10%	0.0%
Sand	0	58,738	42,697	18,002	1,824	1,787	740	167	606	6,511
	0.0%	45%	33%	14%	1.4%	1.4%	0.6%	0.1%	0.5%	5.0%

Notes:
-- = not applicable
[1]See Figure 4-8 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

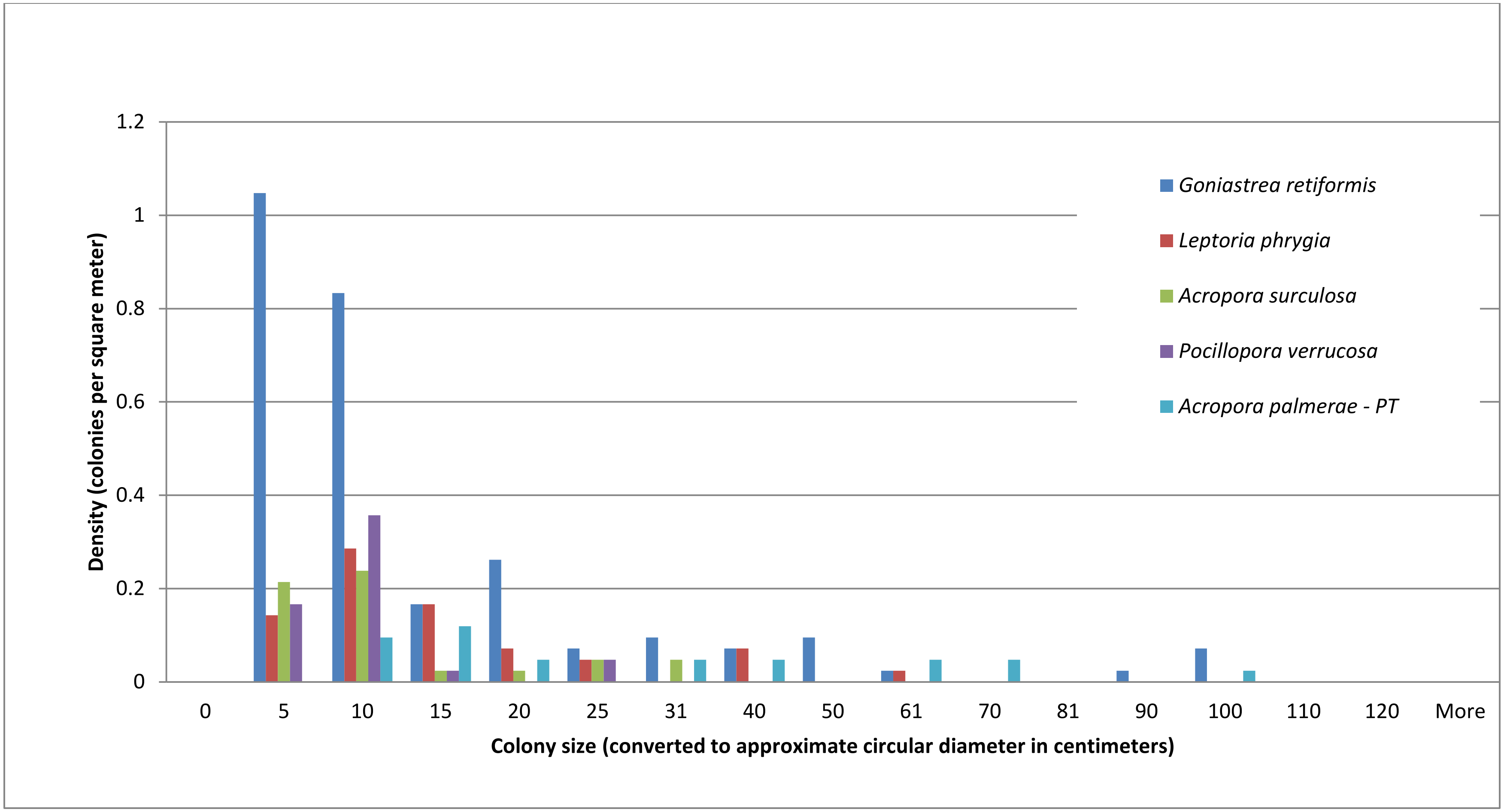

Figure 4-12. Size-Frequency Histogram of the Most[1] Abundant Corals at Unai Babui[2].
Data Source = All Quadrats (n=44) (See Table 4-6 for Summary Statistics)

Notes:
PT = Proposed Threatened
[1]Five species make up the top 50th percentile at Unai Babui.
[2]Includes 44 10.7-square foot (1-square meter) quadrats at Unai Babui. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

Table 4-6. Coral Demographics Summary Statistics from All Quadrats at Unai Babui (n=44)

Species (ranked by abundance) (aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Goniastrea retiformis	2.76	116	1	7,854	463	20	79
Leptoria phrygia	0.81	34	20	2,356	290	157	79
Acropora surculosa *	0.60	25	3	707	146	79	79
Pocillopora verrucosa	0.60	25	8	471	93	79	79
Acropora palmerae PT	0.48	20	39	7,697	1,278	157	314
Favia matthaii	0.38	16	20	1,257	337	79	79
Acropora valida	0.29	12	7	471	171	39	98
Favia stelligera	0.29	12	3	1,885	247	39	39
Galaxea fascicularis	0.24	10	3	79	45	39	39
Pocillopora meandrina	0.24	10	8	314	140	79	79
Acropora ocellata *	0.21	9	20	314	109	79	79
Montipora grisea	0.21	9	20	628	254	--	236
Acropora digitifera	0.19	8	20	471	142	79	79
Acropora monticulosa	0.17	7	20	3,534	777	79	79
Acropora verweyi PT	0.14	6	39	314	111	79	79
Goniastrea pectinata	0.14	6	50	471	179	79	79
Pocillopora setchelli	0.14	6	79	79	79	79	79
Porites sp.	0.14	6	20	2,356	632	471	393
Stylophora mordax *	0.14	6	3	707	212	3	43
Acropora globiceps * PT	0.12	5	20	79	43	20	20
Acropora secale	0.12	5	79	79	79	79	79
Montipora ehrenbergii	0.12	5	3	1,178	243	8	8
Montipora sp.	0.12	5	79	707	346	707	157
Montipora tuberculosa	0.12	5	39	707	338	--	314
Pavona varians	0.12	5	20	314	177	314	157
Platygyra pini	0.12	5	20	2,199	569	157	157

Species (ranked by abundance) (aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Pavona chiriquensis	0.10	4	20	79	34	20	20
Acanthastrea brevis PT	0.07	3	79	314	183	--	157
Goniastrea edwardsi	0.07	3	20	79	39	20	20
Montastrea curta	0.07	3	79	314	157	79	79
Psammocora digitata	0.07	3	39	157	92	--	79
Favia pallida	0.05	2	12	79	45	--	45
Hydnophora exesa	0.05	2	39	39	39	39	39
Hydnophora microconos	0.05	2	79	236	157	--	157
Montastrea cf. valenciennesi	0.05	2	20	157	88	--	88
Pocillopora ankeli	0.05	2	79	314	196	--	196
Acanthastrea echinata	0.02	1	1	1	1	--	1
Acropora abrotanoides	0.02	1	1,178	1,178	1178	--	1,178
Acropora aff. humilis	0.02	1	79	79	79	--	79
Acropora cophodactyla	0.02	1	39	39	39	--	39
Acropora selago	0.02	1	314	314	314	--	314
Acropora sp.	0.02	1	1	1	1	--	1
Cyphastrea microphthalma	0.02	1	314	314	314	--	314
Cyphastrea sp.	0.02	1	39	39	39	--	39
Favia favus	0.02	1	20	20	20	--	20
Goniopora minor	0.02	1	79	79	79	--	79
Leptastrea purpurea	0.02	1	79	79	79	--	79
Leptastrea transversa	0.02	1	20	20	20	--	20
Leptoseris incrustans	0.02	1	79	79	79	--	79
Montipora cf. turgescens * PT	0.02	1	942	942	942	--	942
Pavona duerdeni	0.02	1	1,178	1,178	1,178	--	1,178
Pocillopora eydouxi	0.02	1	157	157	157	--	157
Pocillopora sp.	0.02	1	3	3	3	--	3

Species (ranked by abundance) (aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Psammocora nierstraszi	0.02	1	157	157	157	--	157

Notes:

PT = Proposed Threatened; -- = not applicable

See Section 3.3.2, Coral Species Richness, for a description of the species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # [description]).

Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

* *Acropora ocellata* (Klunzinger 1879) *sensu* Randall and Myers (1983); not *sensu* Veron (2000)

* *Acropora surculosa sensu* Veron (2000), not = *Acropora hyacinthus sensu* Wallace (1999)

* *Montipora turgescens sensu* Veron and Wallace (1984); Veron (2000). *cf. Montipora hoffmeisteri sensu* Randall and Myers (1983)

* *Stylophora mordax* (Dana 1846) *sensu* Randall and Myers (1983) = *Stylophora pistillata* (Esper 1797) *sensu* Veron and Pichon (1976); Veron (2000)

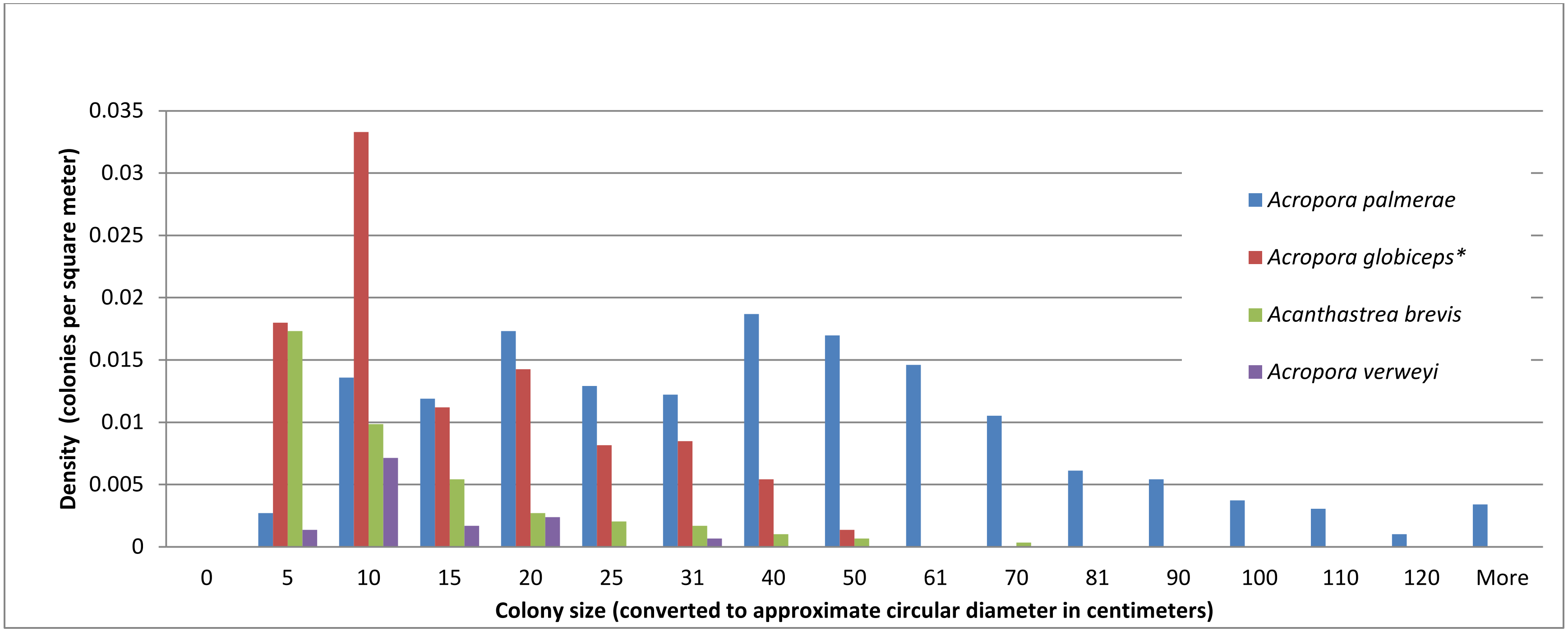

Figure 4-13. Size-Frequency Histogram of the 4 Most[1] Abundant ESA-Proposed Coral Species from all Samples at Unai Babui (Belt Transects[2] and Quadrats)

Notes:
[1]Four of seven ESA species in this sample have densities high enough to display on this y-axis
[2]Includes 60 2x20-meter shore-parallel belt transects and 25 2x10-meter shore perpendicular belt transects, and 44 10.7-square foot (1-square meter) quadrats at Unai Babui. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

Table 4-7. ESA-Proposed Coral Colony Demographics from all Samples at Unai Babui (Belt Transects[1] and Quadrats)[2]

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Belts with no ESA colonies	0.00	4					
Quadrats with no ESA colonies	0.00	28					
***Acropora palmerae* PT**	0.15	454	3	31,416	2,154	314	942
***Acropora globiceps** PT**	0.10	295	3	1,963	262	79	79
***Acanthastrea brevis* PT**	0.04	121	1	3,770	202	20	39
***Acropora verweyi* PT**	0.01	39	20	707	148	79	79
***Millepora tuberosa* PT**	0.00	5	79	14,137	3,063	--	393
***Astreopora cucullata** PT**	0.00	2	20	20	20	20	20
***Montipora cf. turgescens** PT**	0.00	1	942	942	942	--	942

Notes:
PT = Proposed Threatened
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.
[1]Includes 60 2x20 meter shore-parallel belt transects and 25 2x10-meter shore perpendicular belt transects at Unai Babui.
[2]See Figure 4-2, Figure 4-8, and Figure 4-9 for a depiction of the areas.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

* *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)

* *Montipora turgescens sensu* Veron and Wallace (1984); Veron (2000). *cf. Montipora hoffmeisteri sensu* Randall and Myers (1983)

Figure 4-14. Representative Images of Unai Babui

Clockwise from top left: deeper fore reef; shallow fore reef; reef crest; shallow fore reef adjoining reef crest; fissure through reef crest; large *Acropora palmerae* colonies – ESA-proposed threatened species were common on the reef crest and shallow fore reef.

4.3 UNAI LAMLAM

4.3.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at Unai Lamlam was moderate to high in topographic complexity, moderate coral cover, and low sand cover, except for one large offshore patch of 90-100% sand (Figure 4-15, Figure 4-16, Figure 4-17, Figure 4-18, and Table 4-8). Patches of Unai Lamlam had very high coral cover (Figure 4-16 and Table 4-8). The reef area was physically complex, with regularly spaced grooves that were very deep (e.g., 13-26 feet [4-8 meters]) in the fore reef, with a relatively steep transition to the deep fore reef. The groove aligned with the center of the pocket beach was strewn with cobble and boulder-sized rubble, while most other grooves were lined with coarse carbonate sand. This is a sign of past physical disturbance to the groove aligned with the center of the pocket beach. Many spurs were undercut by grooves interconnecting with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest and occasionally under the reef flat (see Section 3.3, Survey Methods). Reef zonation was quite clear and includes distinct deep fore reef, shallow fore reef, reef crest outer reef flat, inner reef flat, and beach. (See Section 2.1, Geomorphology, for a description of zonation).The reef crest and outer reef flat were very broad and well developed relative to adjacent Unai Chulu and Unai Babui. To the south of the beach, the reef flat zone transitions to a shallow bench; Figure 4-16 shows the patch of 90% coral cover at approximately 15° 5′ 15″ N by 145° 37′ 55″ E. Like Unai Chulu and Unai Babui, this zone was very rich, with exceptionally high coral cover. Representative images of Unai Lamlam are shown in Figure 4-21.

4.3.2 Coral Species Richness

Summary species richness results for Unai Lamlam and all the other Tinian sites are presented in Table 4-2, and detailed records of individual species for Unai Lamlam and all the Tinian sites are presented in Appendix A. Among the 108 records are 7 ESA-proposed coral species and 6 irresolvable species (see Appendix D for representative images of ESA-proposed species). At least 1 of the 9 irresolvable records, *Distichopora* sp., represents a unique species that occurs nowhere else in the coral species richness dataset (see Section 2.3, Challenges with Coral Identification, and Section 3.3.2, Coral Species Richness).

4.3.3 Coral Demographics

Unai Lamlam was sampled with 14 quadrats, each 10.7 square feet (1 square meter; Appendix B, DoN 2014a). A total of 52 species of corals fell within quadrats, the most abundant of which was *Goniastrea retiformis*, with an estimated density of 0.57 colonies per square foot (6.1 colonies per square meter). Size-structure of the most frequently occurring species is shown in Figure 4-20. Within this set, most colonies are smaller than 7.9 inches (20 centimeters; approximate circular diameter); however, several species attained maximum sizes approaching 10.7 square feet (1 square meter) (Table 4-9). Size distribution was skewed toward small colonies (compare average with median size in Table 4-9), though size distribution of some species was relatively homogenous (e.g., *Galaxea fascicularis*). The maximum sizes in Table 4-9 represent only the single largest colony and that two species have colonies that attained 2.7 square feet (0.25 square meter) or larger. The habitat was somewhat heterogeneous among depth zones and relatively homogeneous within depth zones, but this distinction was less pronounced than at Unai Chulu and Unai Babui. Zonation was still identifiable, but each zone was richer than its counterpart at Unai Chulu and Unai Babui.

In total, 371 corals were counted within 14 quadrats; the average quadrat contained about 27 coral colonies. Unlike Unai Chulu and Unai Babui, Unai Lamlam has no depauperate inner reef flat habitat (Figure 4-16); consequently, there are zero quadrats with no corals (Appendix B).

4.3.4 ESA Coral Demographics

Unai Lamlam, like Unai Chulu and Unai Babui, has patches where ESA-proposed corals are dominant, particularly *Acropora palmerae* and *Acropora verweyi* (Table 4-10, Appendix B, and DoN 2014a). Direct mapping was not conducted at Unai Lamlam; instead, only quadrats and belt transects were used to subsample the area of the proposed activities. The sample size for ESA-proposed colonies at Unai Lamlam included 14 10.7-square-foot (1-square-meter) quadrats, 40 2-by-20-meter shore-parallel belt transects, and 36 2-by-10-meter shore perpendicular belt transects (see Section 3.3.4, ESA Coral Demographics, for details of the methodology).

In total, 609 ESA-proposed coral colonies were directly assessed during the surveys at Unai Lamlam. The size-frequency distribution of the four most abundant ESA-proposed species shows two main patterns. First, most colonies of *Acropora verweyi*, *Acropora palmerae*, *Acropora globiceps* and *Acanthastrea brevis* were smaller than19.7 inches (50 centimeters). Second, many colonies of the encrusting *Acropora verweyi* are very large (Figure 4-20 and Table 4-10), with one colony attaining a maximum area of more than 3.1 square meters. Large colonies of *Acropora palmerae* were typical of the innermost fore reef and the outer reef crest. They were most often categorized into the fore reef zone, occupying depths of 4 to 6 feet (1.3 to 2 meters; see Coral Data Deliverable, Table 6-1, for details of each colony). The encrusting *Millepora tuberosa* was represented by only one colony but it was very large, attaining a maximum area of nearly 18 square feet (1.7 square meters) (Table 4-10).

The spatial heterogeneity of ESA-proposed coral colonies can be qualitatively estimated using the number of belts and quadrats with zero ESA-proposed colonies (Table 4-10), in the absence of direct-mapping for ESA-proposed colonies. Almost 57% of the quadrats had zero ESA-proposed colonies (n=8 of 14 1 m^2 quadrats), but only 4% of the belt transect sample area had zero ESA-proposed colonies (n=2 of 40 2x20-m belts; n=3 of 36 2x10-m belts). Relatively few larger areas have zero ESA-proposed colonies, but relatively many smaller areas have zero ESA-proposed colonies.

ESA-proposed coral demographics were estimated by extrapolating from the demographic data to yield an estimated 36,571, 7,860, or 7,956 ESA-proposed coral colonies in the 344,445 square foot (32,000 square meter) sampling area at Unai Lamlam (Table 4-9, Table 4-10, and Appendix B). This was extrapolated from each of the three relevant methods (quadrats, long belt transects, and short belt transects, respectively; Table 4-10, and Appendix B). This is equivalent to 0.11, 0.23, and 0.23 colonies per square foot (1.14, 0.25, and 0.25 colonies per square meter). Each of these extrapolations are valid estimates of the total population of ESA-proposed coral colonies at Unai Lamlam, though each carries different assumptions that should be considered for further analyses (see Section 3.3.4, ESA Coral Demographics, and Section 6.1, Extrapolating from the Sample to the Population, for these discussions).

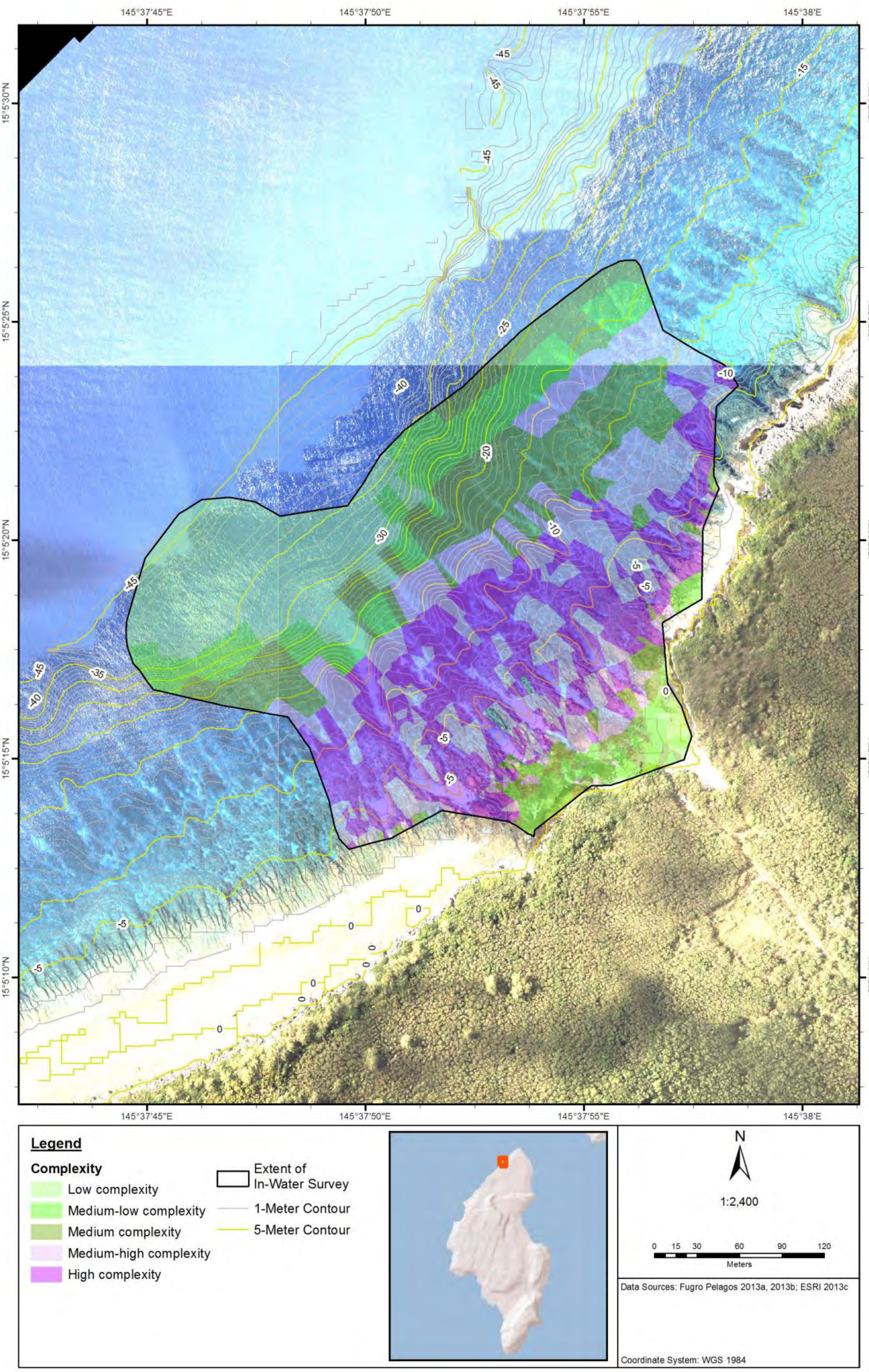

Figure 4-15. Unai Lamlam In Situ Broad-Scale Topographic Complexity

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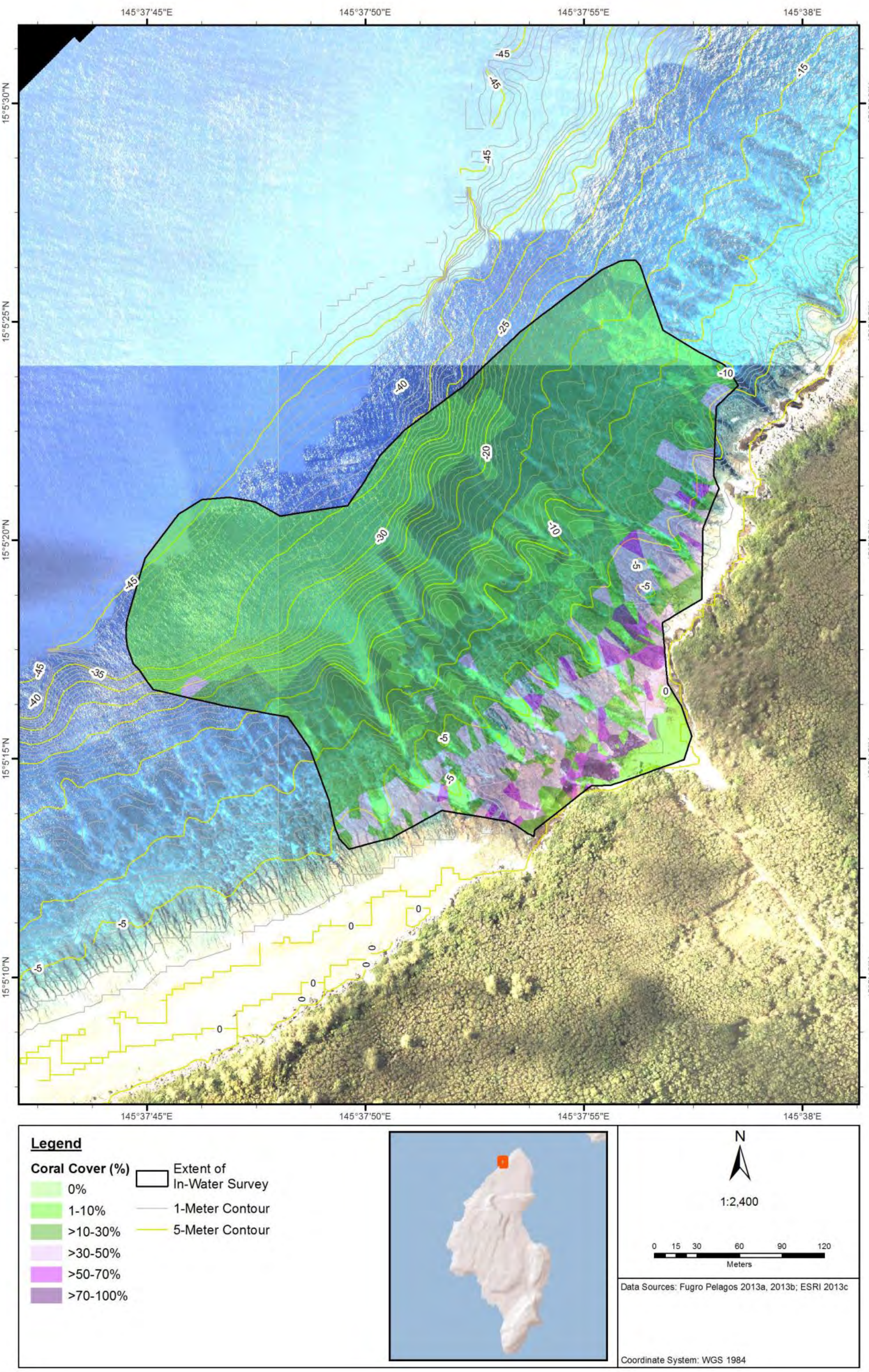

Figure 4-16. Unai Lamlam In Situ Broad-Scale Coral Cover

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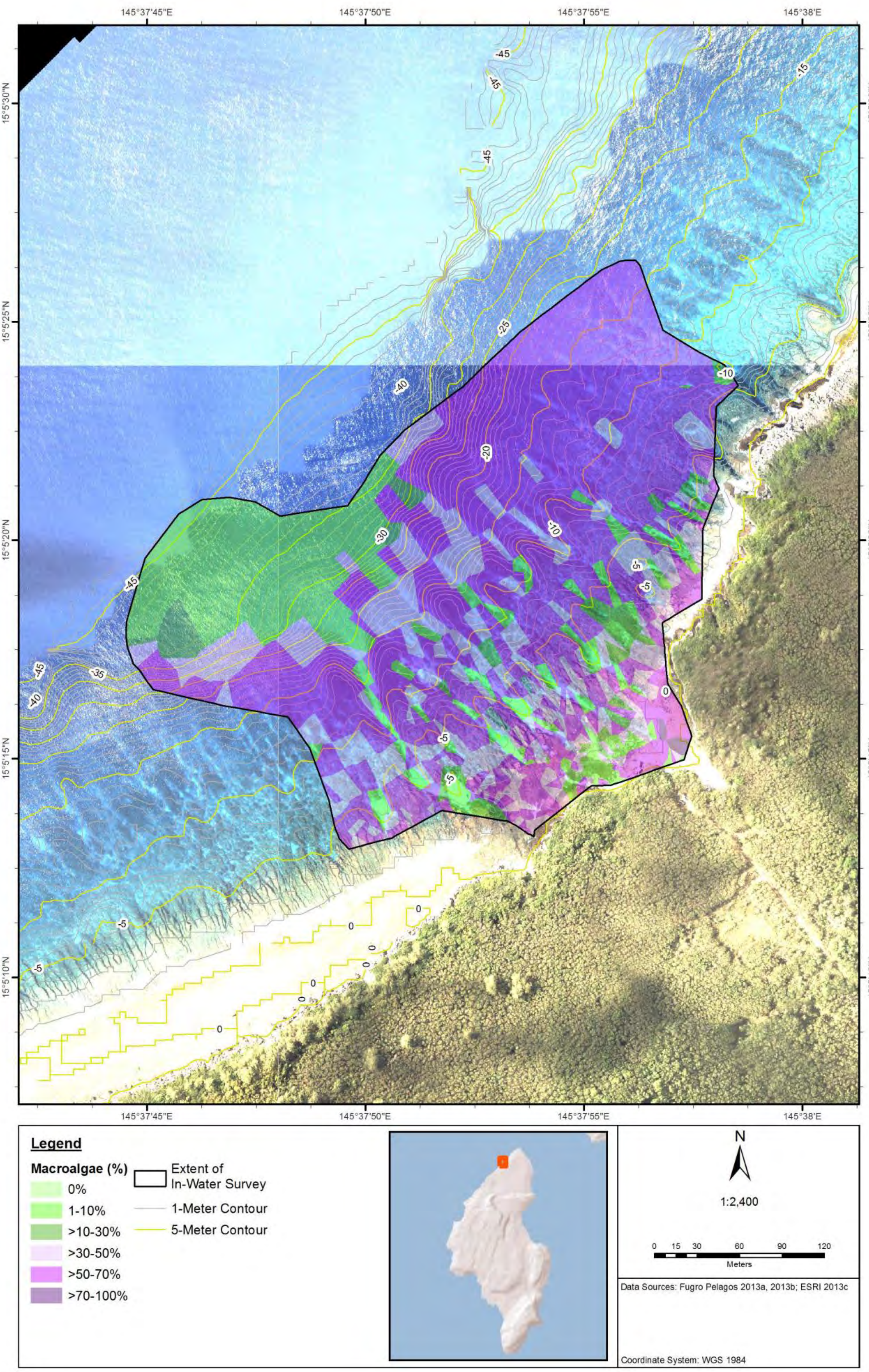

Figure 4-17. Unai Lamlam In Situ Broad-Scale Macroalgae Cover

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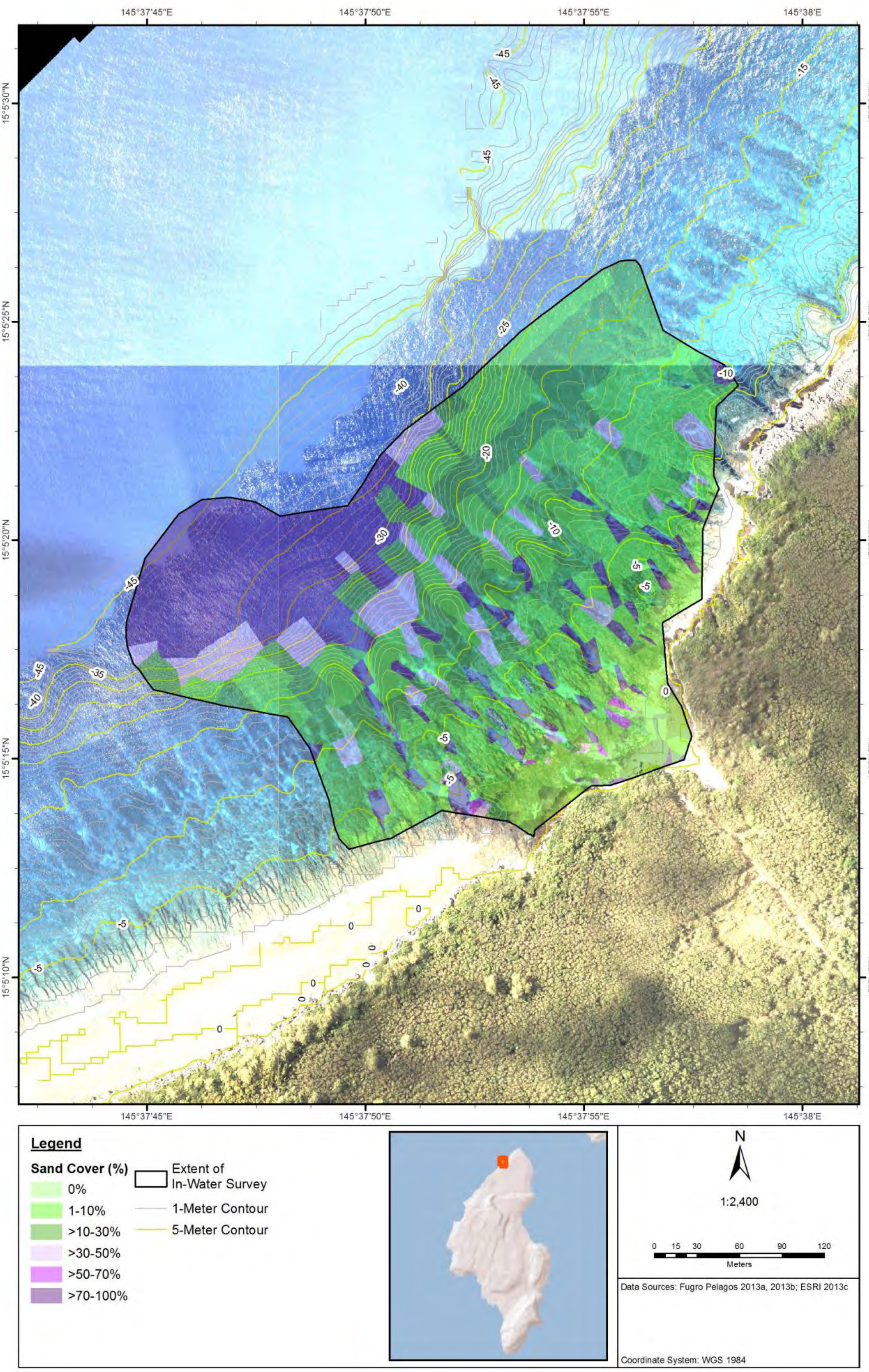

Figure 4-18. Unai Lamlam In Situ Broad-Scale Sand Cover

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Table 4-8. Broad-Scale Surveys at Unai Lamlam (Square Meter, % Cover)

Unai Lamlam total area[1] = 98,087 square meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	16,181	13,778	19,874	23,002	25,252	0	--	--	--
	--	16%	14%	20%	23%	26%	0.0%	--	--	--
Coral	0	42,363	27,733	12,251	9,357	3,271	1,713	304	641	454
	0.0%	43%	28%	12%	9.5%	3.3%	1.7%	0.3%	0.7%	0.5%
Macroalgae	0	20,311	2,996	598	8,554	10,454	47,178	7,783	212	0
	0.0%	21%	3.1%	0.6%	8.7%	11%	48%	7.9%	0.2%	0.0%
Sand	196	39,522	22,647	6,354	7,257	904	88	279	1,585	19,256
	0.2%	40%	23%	6.5%	7.4%	0.9%	0.1%	0.3%	1.6%	20%

Notes:
[1]See Figure 4-15 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

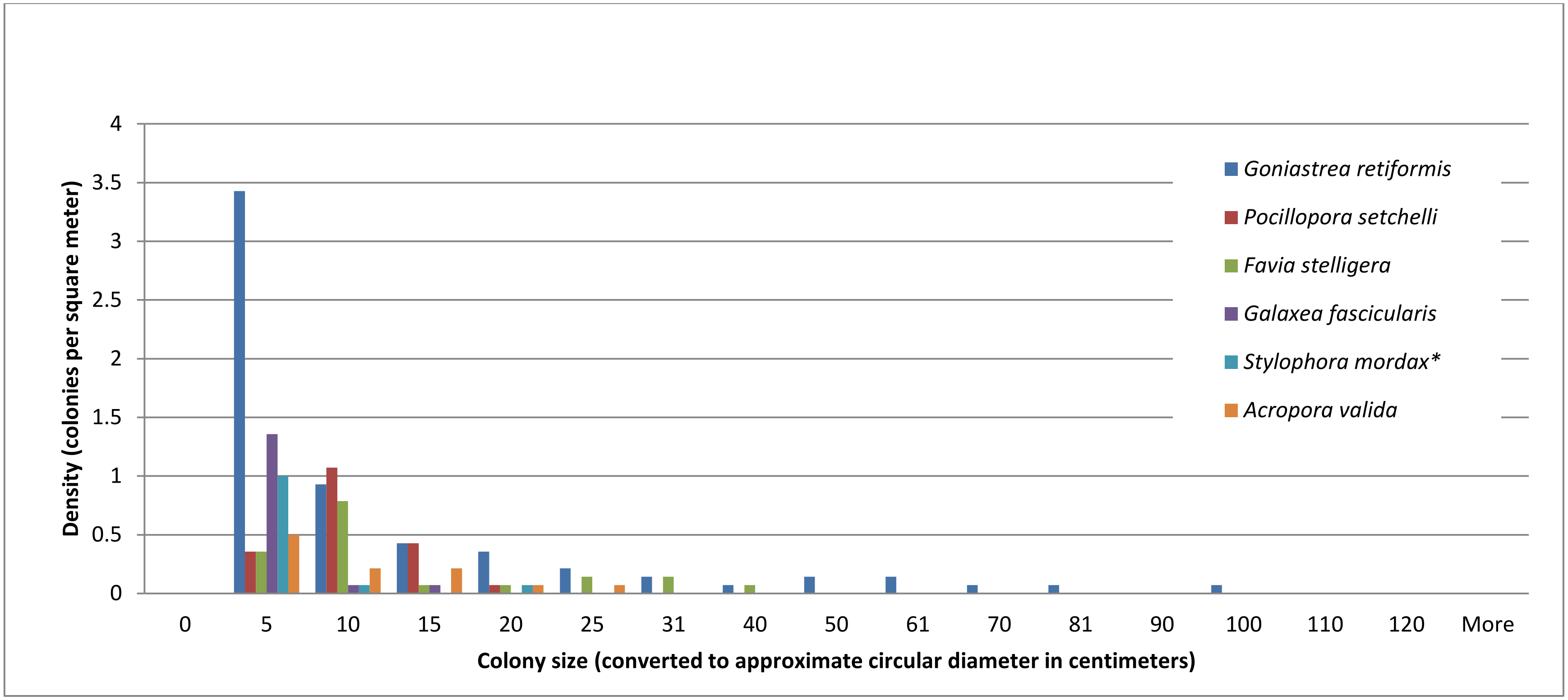

Figure 4-19. Size-Frequency Histogram of the Most[1] Abundant Corals at Unai Lamlam[2].
See Table 4-9 for Summary Statistics.

Notes:
[1]Six species make up the top 50th percentile at Lamlam.
[2]Includes 14 10.7-square-foot (1-square-meter) quadrats at Unai Lamlam. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

Table 4-9. Coral Demographics Summary Statistics from All Quadrats at Unai Lamlam (n=14)

Species (ranked by abundance; aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
Goniastrea retiformis	6.07	85	1	7,854	376	20	20
Pocillopora setchelli	1.93	27	3	314	92	79	79
Favia stelligera	1.64	23	20	864	185	79	79
Galaxea fascicularis	1.50	21	3	157	26	20	20
Stylophora mordax *	1.14	16	1	314	28	1	5
Acropora valida	1.07	15	1	471	99	3	39
Montipora grisea	0.93	13	1	471	58	20	20
Pocillopora sp.	0.93	13	1	3	1	1	1
Platygyra pini	0.86	12	20	707	116	20	39
Leptoria phrygia	0.79	11	3	471	131	79	79
Favia pallida	0.64	9	3	471	105	157	39
Acropora cophodactyla	0.57	8	1	157	36	3	14
Acropora palmerae PT	0.57	8	20	1,885	535	79	118
Montipora peltiformis	0.57	8	1	3,299	469	1	29
Acropora surculosa *	0.50	7	8	157	40	20	20
Cyphastrea microphthalma	0.50	7	3	157	37	3	3
Acropora ocellata *	0.43	6	3	39	18	20	20
Montipora hoffmeisteri *	0.43	6	3	157	42	3	5
Montipora informis	0.43	6	1	157	60	157	20
Montipora sp.	0.43	6	39	314	170	314	137
Pavona chiriquensis	0.43	6	3	39	15	3	11
Leptastrea purpurea	0.36	5	3	20	10	3	3
Acropora sp.	0.29	4	1	20	5	1	1
Favia matthaii	0.29	4	20	39	25	20	20
Pocillopora meandrina	0.29	4	8	471	218	--	196
Acropora verweyi PT	0.21	3	8	79	35	--	20

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Montipora ehrenbergii	0.21	3	20	39	33	39	39
Pavona varians	0.21	3	20	79	39	20	20
Pocillopora verrucosa	0.21	3	20	39	26	20	20
Acanthastrea brevis PT	0.14	2	8	20	14	--	14
Acropora cf. cerealis	0.14	2	20	79	49	--	49
Acropora globiceps * PT	0.14	2	20	471	245	--	245
Acropora secale	0.14	2	79	314	196	--	196
Montastrea cf. valenciennesi	0.14	2	20	79	49	--	49
Montipora elshneri	0.14	2	8	1,885	946	--	946
Acropora abrotanoides	0.07	1	2,356	2,356	2,356	--	2,356
Acropora digitifera	0.07	1	8	8	8	--	8
Acropora monticulosa	0.07	1	471	471	471	--	471
Acropora studeri *	0.07	1	157	157	157	--	157
Astreopora randalli	0.07	1	20	20	20	--	20
Favia helianthoides	0.07	1	8	8	8	--	8
Favia sp.	0.07	1	39	39	39	--	39
Hydnophora microconos	0.07	1	20	20	20	--	20
Isopora palifera	0.07	1	3	3	3	--	3
Montastrea curta	0.07	1	39	39	39	--	39
Montipora tuberculosa	0.07	1	20	20	20	--	20
Pavona maldivensis	0.07	1	20	20	20	--	20
Pocillopora elegans PT	0.07	1	471	471	471	--	471
Porites lichen	0.07	1	39	39	39	--	39
Porites rus	0.07	1	8	8	8	--	8
Porites solida	0.07	1	20	20	20	--	20
Porites sp.	0.07	1	1	1	1	--	1

Notes:
PT = Proposed Threatened
See Section 3.3.2, Coral Species Richness, for a description of the species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # [description]).
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)
* *Acropora ocellata* (Klunzinger 1879) *sensu* Randall and Myers (1983); not *sensu* Veron (2000)
* *Acropora surculosa sensu* Veron (2000), not = *Acropora hyacinthus sensu* Wallace (1999)
* *Acropora studeri sensu* Randall and Myers (1983)
* *Montipora hoffmeisteri sensu* Veron and Wallace (1984); Veron (2000). Not *sensu* Randall and Myers (1983)
* *Stylophora mordax* (Dana 1846) *sensu* Randall and Myers (1983) = *Stylophora pistillata* (Esper 1797) *sensu* Veron and Pichon (1976); Veron (2000)

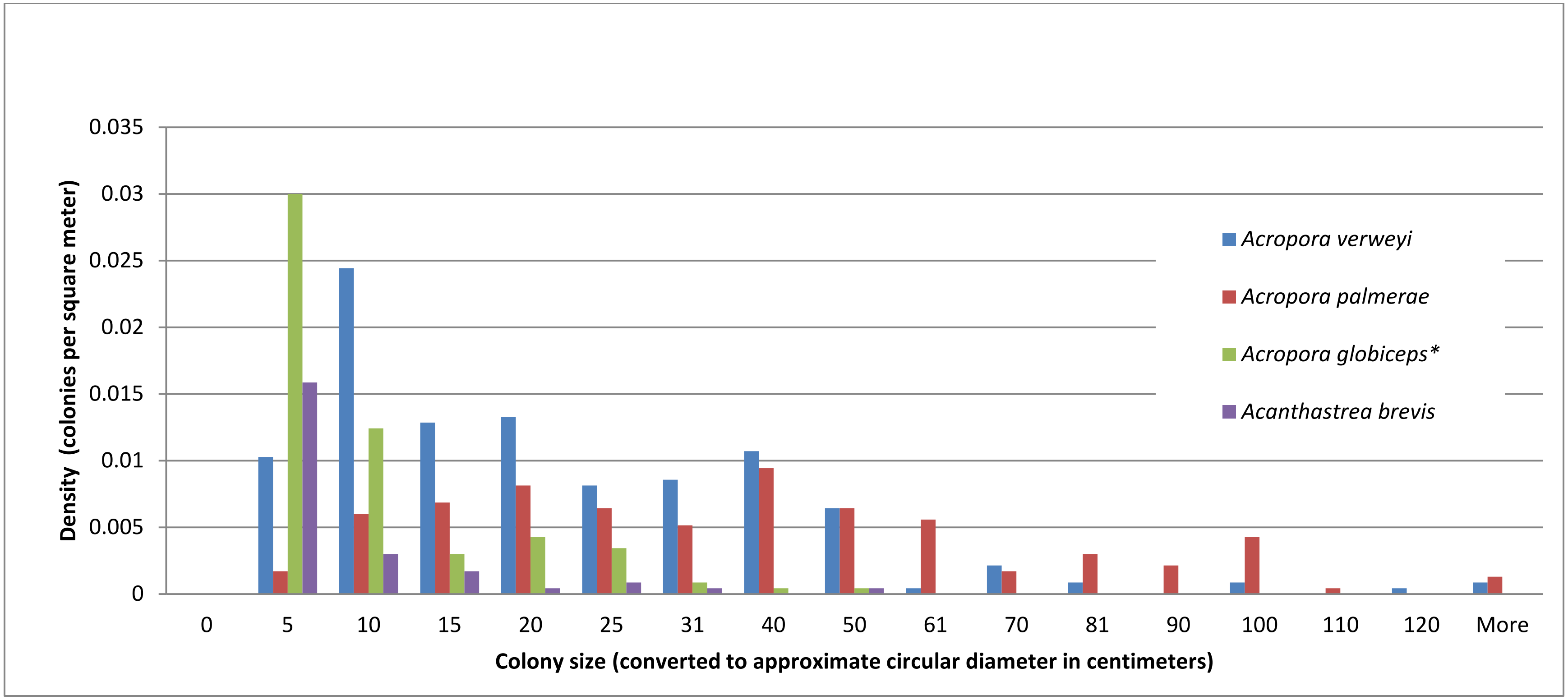

Figure 4-20. Size-Frequency Histogram of the 4 Most[1] Abundant ESA-Proposed Coral Species from All Samples at Unai Lamlam[2]

Notes:
PT = Proposed Threatened.
[1]Four of seven ESA species in this sample have densities high enough to display on this y-axis.
[2]Includes 40 2x20-meter shore-parallel belt transects, 36 2x10-meter shore perpendicular belt transects, and 14 10.7-square foot (1-square meter) quadrats at Unai Lamlam. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

Table 4-10. ESA-Proposed Coral Colony Demographics from all Samples at Unai Lamlam (Belt Transects[1] and Quadrats)[2]

Species (ranked by abundance; aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
Acropora verweyi PT	0.10	234	3	31,416	874	79	236
Acropora palmerae PT	0.07	160	20	15,080	1,922	157	746
*Acropora globiceps** PT	0.05	128	3	1,414	116	20	20
Acanthastrea brevis PT	0.02	53	3	1,571	96	20	20
*Astreopora cucullata** PT	0.00	6	20	39	23	20	20
Pocillopora elegans PT	0.00	5	79	707	377	471	471
Millepora tuberosa PT	0.00	1	17,279	17,279	17,279	--	17,279

Notes:
PT = Proposed Threatened.
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.
[1]Includes 40 2x20-meter shore-parallel belt transects and 36 2x10-meter shore perpendicular belt transects at Unai Lamlam.
[2]See Figure 4-2, Figure 4-15, and Figure 4-16 for a depiction of the areas.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

* *Astreopora cucullata* (Lamberts, 1980) *sensu* Lamberts, 1982; not *sensu Astreopora cucullata* Veron (2000)

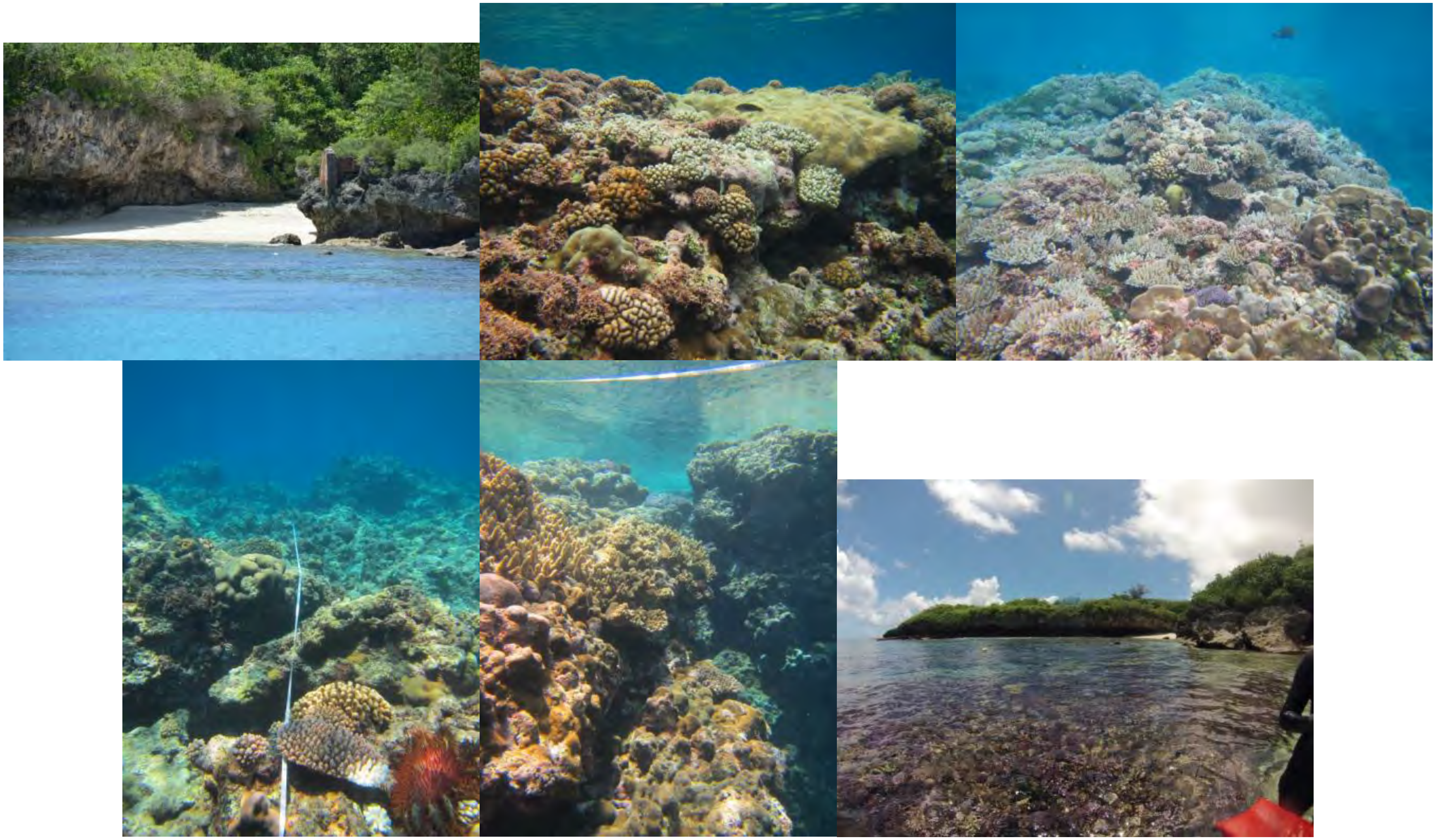

Figure 4-21. Representative Images of Unai Lamlam

Clockwise from top left: Lamlam Beach; reef crest from inside a groove; shallow fore reef; shallow bench; fissure through reef crest; transition from shallow to deeper fore reef.

4.4 UNAI DANKULO

Broad-scale habitat mapping was not conducted at Unai Dankulo. Due to time constraints, this beach was set as a low priority for coral demographics. The survey team conducted a cursory investigation of the area, principally because the reef flat is geomorphologically different than others on Tinian. The reef flat is larger and more than twice the depth of other reef flats, in part because it has a nearly complete emergent seaward margin that appears to be a relict reef crest about 1.6 feet (0.5 meter) above the elevation of the modern reef crest. This feature has been previously erroneously described as a rubble ridge.

As with other fringing reefs on Tinian, the reef crest and outer reef flat of Unai Dankulo is riddled with tunnels, fissures, grottoes, and chimneys. Also, the reef flat has several conspicuous freshwater springs. These are found in and under most of the Tinian coast (Brainard et al. 2012) and likely contribute to the erosion seen under the shore-attached reefs.

4.4.1 Coral Species Richness

Summary species richness results for Unai Dankulo and all the other Tinian sites are presented in Table 4-2, and detailed records of individual species for Unai Dankulo and all the other sites are presented in Appendix A. Among the 119 records are 11 ESA-proposed coral species and 4 irresolvable species (see Appendix D for representative images of ESA-proposed species). None of the 4 irresolvable records necessarily represents a unique species that occur nowhere else in the coral species richness dataset for Unai Dankulo (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness).

Representative images of Unai Dankulo are shown in Figure 4-22. The Unai Dankulo coral species list includes the geomorphologically distinct reef flat and the deep fore reef (to 66 feet [20 meters]).

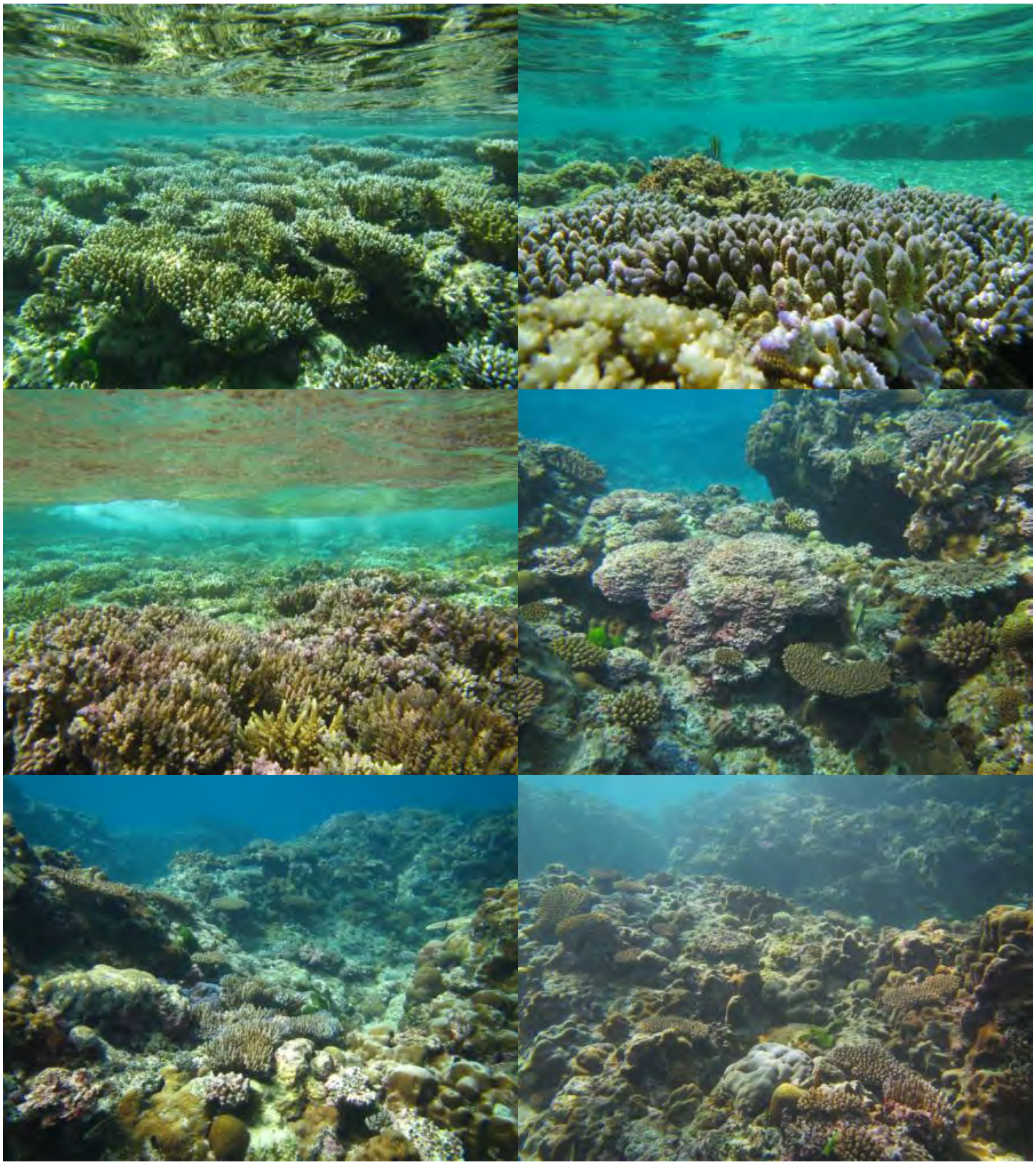

Figure 4-22. Representative Images of Unai Dankulo

Clockwise from top left: inner reef crest; outer reef flat; shallow fore reef; deeper fore reef; deeper fore reef; outer reef crest.

4.5 UNAI MASALOK

All work at Unai Masalok was conducted in two discrete efforts, offshore and reef flat, because the reef crest was unworkable in the surf conditions. It was unsafe to approach the reef crest with the RHIB, and unsafe to swim across the reef crest for data collection. The offshore area was staged from the RHIB, and the reef flat work was staged from the beach and accessed by driving from Tinian Harbor.

4.5.1 Broad-Scale Surveys

Most of the offshore area surveyed for habitat mapping at Unai Masalok was of high topographic complexity, high coral cover, and low sand cover (Figure 4-23, Figure 4-24, Figure 4-25, Figure 4-26, and Table 4-11). The reef area was physically complex (Section 3.3.1, Broad-Scale Surveys), with regularly spaced grooves that were moderately deep (e.g. 12-26 feet [4-6 meters]) in the fore reef, with a relatively steep transition to the deep fore reef that was much more topographically complex than the deep fore reef on the leeward sites (Figure 4-24). Relatively few spurs were undercut or tunneled (See Section 2.1 Geomorphology, for a description of zonation).

Most of the reef flat area surveyed for habitat mapping at Unai Masalok was low topographic complexity, low coral cover, and low sand cover (Figure 4-23, Figure 4-24, Figure 4-25, Figure 4-26, and Table 4-12). The reef flat area was physically and biologically homogenous. The reef crest had no formal survey because of the surf, but the zone appeared to have relatively high coral cover. Representative images of Unai Masalok are shown in Figure 4-29.

4.5.2 Coral Species Richness

Summary species richness results for Unai Masalok and all the other Tinian sites are presented in Table 4-2, and detailed records of individual species for Unai Masalok and all the other sites are presented in Appendix A. Among the 113 records are 9 ESA-proposed coral species and 5 irresolvable species (see Appendix D for representative images of ESA-proposed species). None of the 5 irresolvable records necessarily represents a unique species that occurs nowhere else in the coral species richness dataset for Unai Masalok (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness).

4.5.3 Coral Demographics

Unai Masalok was sampled with 14 quadrats, six on the reef flat and eight on the fore reef, each 10.7 square feet (1 square meter; Appendix B, DoN 2014a). A total of 47 species of corals fell within quadrats, the most abundant of which was *Goniastrea retiformis*, with an estimated density of 0.15 colony per square foot (1.6 colonies per square meter). Size-structure of the most frequently occurring species is shown in Figure 4-27. Within this set, the majority of colonies are smaller than 7.9 inches (20 centimeters; approximate circular diameter); however, several species attained maximum sizes approaching 4.3 square feet (0.4 square meters) (Table 4-13). Size distribution was skewed towards small colonies for most species with more than two colonies in the sample (compare average with median size in Table 4-13). The maximum sizes in Table 4-13 are generally smaller than the maximum sizes for the same species on the leeward reefs. This is a function of the increased wave energy on the windward side, and is typical of windward-leeward comparisons for most species throughout the Pacific.

The habitat was highly stratified among depth zones and relatively homogeneous within depth zones. Due to surf and surge, the reef crest was inaccessible at high and low tides, on two separate days of typical weather. In total, 153 corals were counted within 14 quadrats, meaning that a hypothetical average quadrat had about 11 coral colonies. Most of the reef flat at Unai Masalok was depauperate and characteristic of typical inner reef flat habitat (Figure 4-24); consequently, there are quadrats with no corals (Appendix B).

4.5.4 ESA Coral Demographics

Unlike the leeward reefs at Tinian, Unai Masalok did not have patches where ESA-proposed corals were dominant (Figure 4-28, Table 4-14, Appendix B, and DoN 2014a). Direct mapping was not conducted at

Unai Masalok. Instead, only quadrats and belt transects were used to sub-sample the area of the proposed activities. The sample size for ESA-proposed colonies at Unai Masalok included 14 10.7-square foot (1-square meter) quadrats and 32 2x20-meter shore-parallel belt transects (See Section 3.3.4 ESA Coral Demographics for details of the methodology). In total, 268 ESA-proposed coral colonies were directly assessed during the surveys at Unai Masalok. The size-frequency distribution of the four most abundant ESA-proposed species shows two main patterns. First, most colonies of *Acropora globiceps*, *Acropora verweyi*, and *Acanthastrea brevis* were smaller than 15.7 inches (40 centimeters). Second, many colonies of the encrusting *Acropora palmerae* are very large (Figure 4-28 and Table 4-14), with one colony attaining a maximum area of more than 27 square feet (2.5 square meters). Large colonies of *Acropora palmerae* were typical of the innermost fore reef and the outer reef crest, and they were most often categorized into the fore reef zone, occupying depths of 4 to 6 feet (1.3 to 2 meters; See Coral Data Deliverable Table 6-1 for details of each colony). *Astreopora cucullata* was represented by only seven colonies though one of them was also very large, attaining a maximum area of nearly 4.7 square feet (0.44 square meters) (Table 4-14).

The spatial heterogeneity of ESA-proposed coral colonies can be qualitatively estimated using the number of belts and quadrats with zero ESA-proposed colonies (Table 4-14), in the absence of direct-mapping for ESA-proposed colonies. Half of the quadrats had zero ESA-proposed colonies (n=7 of 14 1-m^2 quadrats), but less than 16% of the belt transects had zero ESA-proposed colonies (n=5 of 32 2x20-m belts). All 7 of the quadrats and 3 of the belt transects with zero ESA-proposed colonies were on the reef flat. Seaward of the reef flat relatively few areas larger areas have zero ESA-proposed colonies, and no smaller areas have zero ESA-proposed colonies. However, much of the reef flat sample area had zero ESA colonies at smaller and larger spatial scales.

ESA-proposed coral populations at Unai Masalok were estimated by extrapolating from the demographic data (quadrats and long belt transects) to yield an estimated 30,994 and 7,458 ESA-proposed coral colonies respectively, in the 39,447-square meter sampling area at Unai Masalok (Table 4-13, Table 4-14, and Appendix B). This is equivalent to 0.07 and 0.02 colony per square foot (0.79 and 0.19 colony per square meter), respectively. Each of these extrapolations are valid estimates of the total population of ESA-proposed coral colonies at Unai Masalok, though each carries different assumptions that should be considered for further analyses (See Section 3.3.4, ESA Coral Demographics and Section 6.1, Extrapolating from the Sample to the Population).

Reporting only from Unai Masalok reef flat, there are far fewer corals. In total, only 16 ESA-proposed coral colonies were directly assessed during the surveys at the Unai Masalok reef flat. Extrapolating from the quadrat data is not useful because only one ESA-proposed coral was recorded with quadrats on the Unai Masalok reef flat. Extrapolating from the 6.5 feet by 66 feet (2 meters by 20 meters) belt transects yields an estimated 1,280 ESA-proposed corals (Table 4-13, Table 4-14, and Appendix B). This is equivalent to 0.19 colony per square foot (0.02 colony per square meter). Among the four reef flats quantitatively surveyed at Tinian (Unai Chulu, Unai Babui, Unai Lamlam, and Unai Masalok), the Unai Masalok reef flat represents the largest area with the fewest ESA-proposed corals (Figure 4-24).

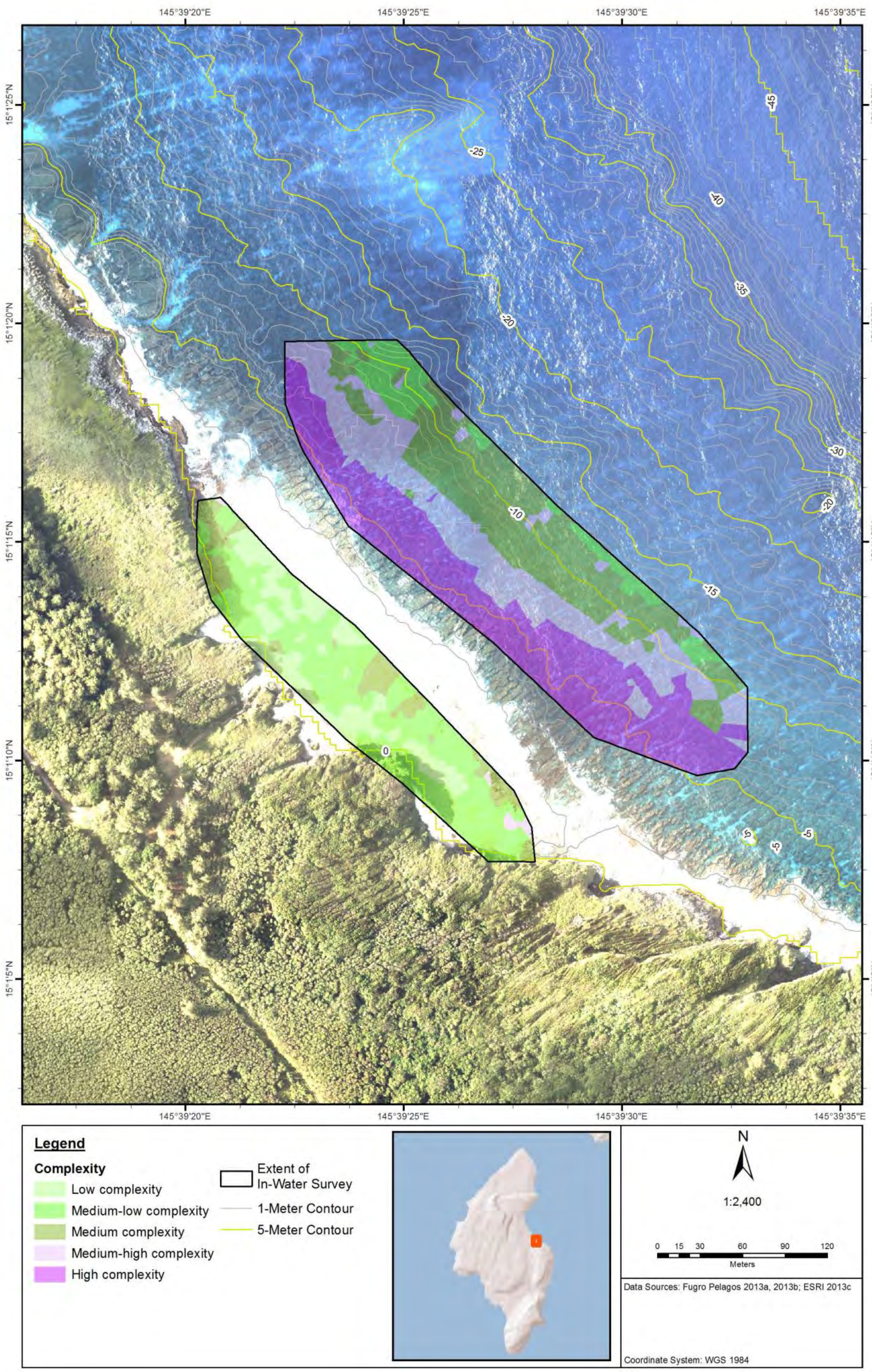

Figure 4-23. Unai Masalok In Situ Broad-Scale Topographic Complexity

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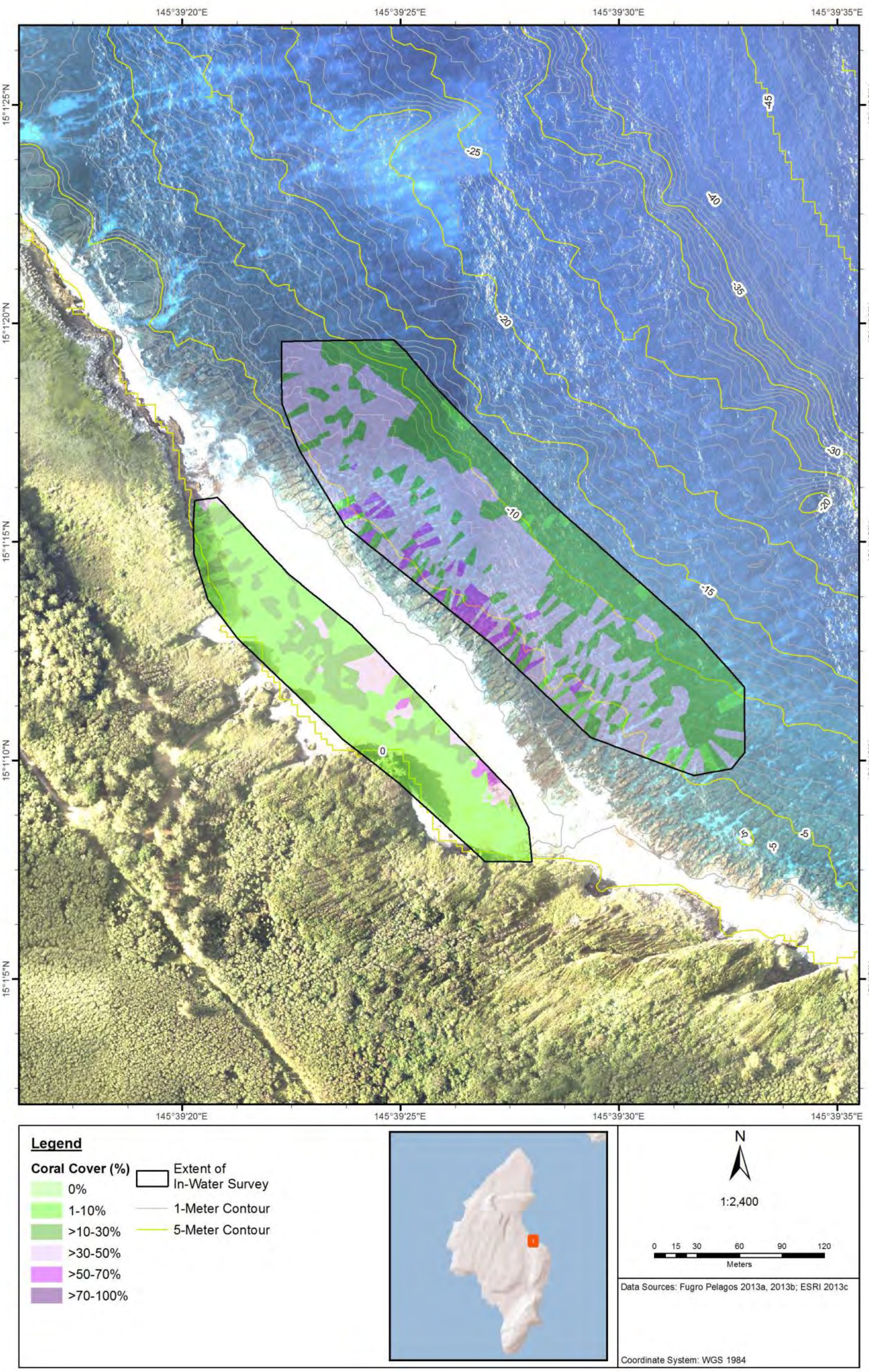

Figure 4-24. Unai Masalok In Situ Broad-Scale Coral Cover

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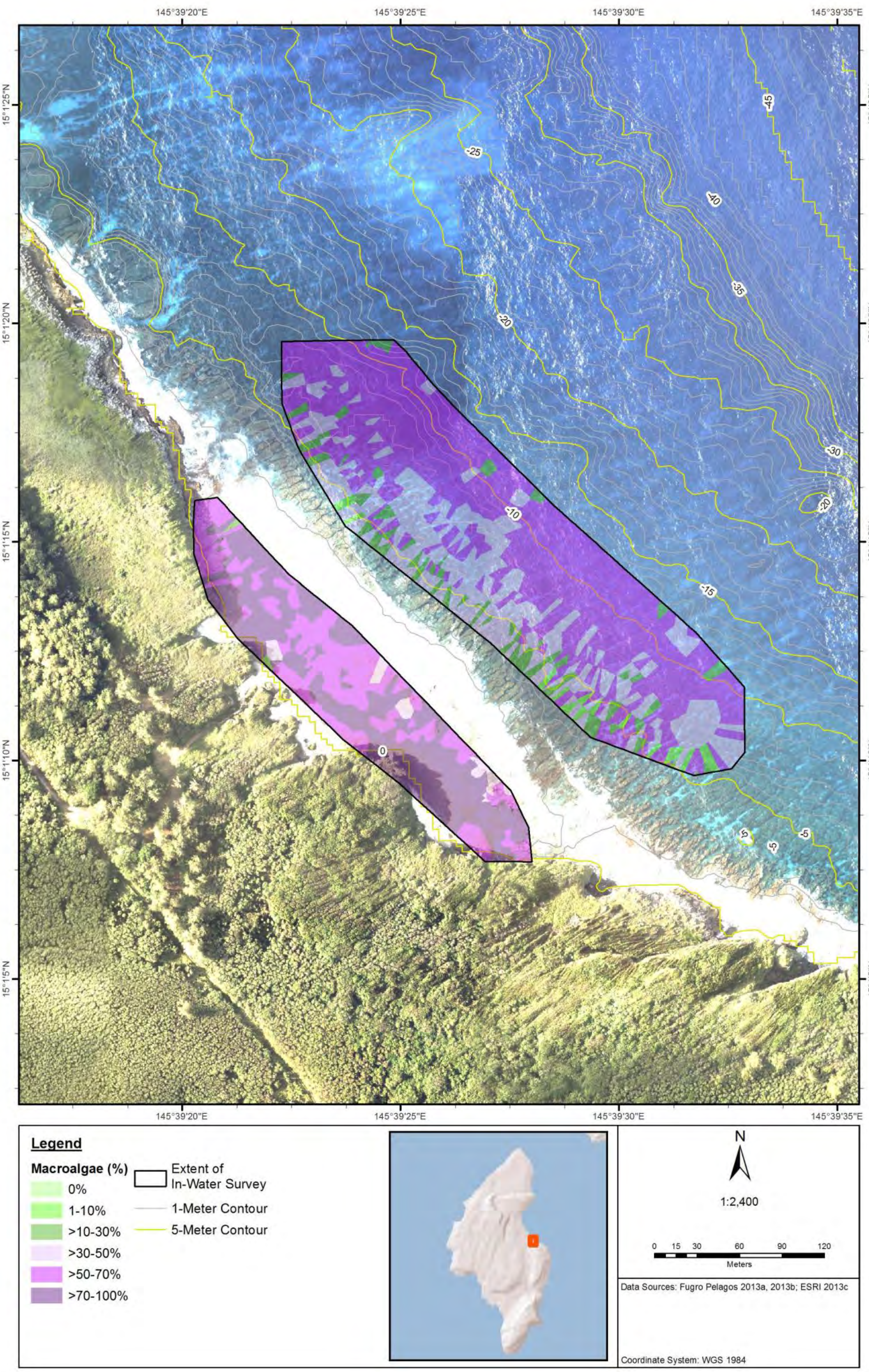

Figure 4-25. Unai Masalok In Situ Broad-Scale Macroalgae Cover

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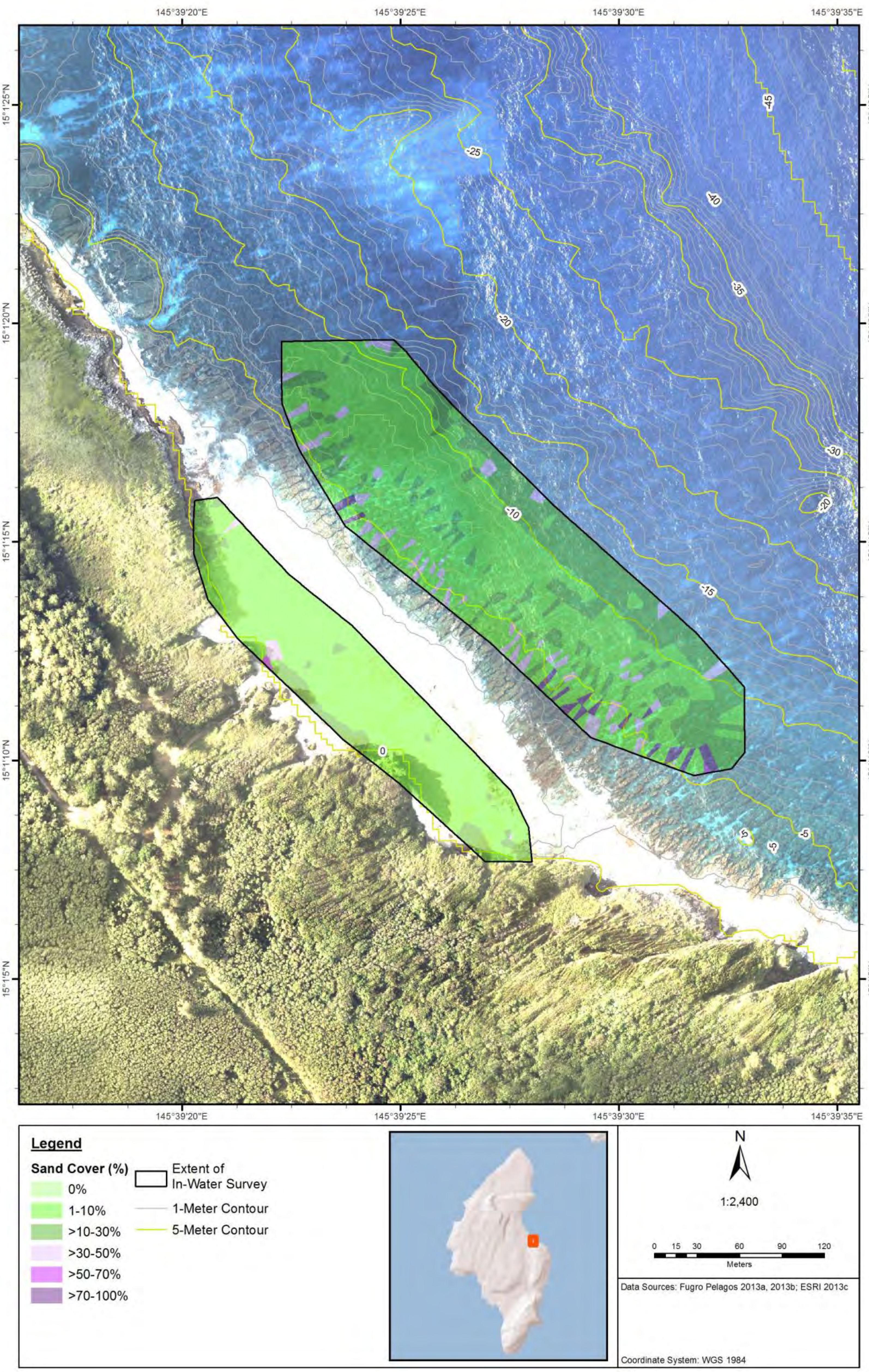

Figure 4-26. Unai Masalok In Situ Broad-Scale Sand Cover

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Table 4-11. Broad-Scale Surveys at Unai Masalok Offshore (Square Meters, % Cover)

Unai Masalok offshore total area[1] = 39,447 square meters										
Class[2]	*0%*	*1 - 10%*	*2 - 20%*	*3 – 30%*	*4 – 40%*	*5 – 50%*	*6 – 60%*	*70%*	*80%*	*90%*
Complexity[3, 4]	--	0	3,160	11,173	10,168	14,947	0	--	--	--
	--	0.0%	8.0%	28%	26%	38%	0.0%	--	--	--
Coral	0	1,479	6,950	9,295	13,051	6,914	1592	166	0	0
	0.0%	3.7%	18%	24%	33%	18%	4.0%	0.4%	0.0%	0.0%
Macroalgae	0	819	156	2,595	2,199	9,604	23,746	327	0	0
	0.0%	2.1%	0.4%	6.6%	5.6%	24%	60%	0.8%	0.0%	0.0%
Sand	0	25,366	8,512	2,466	145	2,115	23	0	0	819
	0.0%	64%	22%	6.3%	0.4%	5.4%	0.1%	0.0%	0.0%	2.1%

Notes:
[1]See Figure 4-23 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

Table 4-12. Broad-Scale Surveys at Unai Masalok Reef Flat (Square Meters, % Cover)

Unai Masalok reef flat total area[1] = 17,001 square meters

Class[2]	*0%*	*1 - 10%*	*2 - 20%*	*3 – 30%*	*4 – 40%*	*5 – 50%*	*6 – 60%*	*70%*	*80%*	*90%*
Complexity[3, 4]	--	4,214	10,069	2,502	215	0	0	--	--	--
	--	25%	59%	15%	1.3%	0.0%	0.0%	--	--	--
Coral	0	11,894	2,262	1,379	971	284	212	0	0	0
	0.0%	70%	13%	8.1%	5.7%	1.7%	1.2%	0.0%	0.0%	0.0%
Macroalgae	0	0	81	0	339	284	4,645	1,857	9,794	0
	0.0%	0.0%	0.5%	0.0%	2.0%	1.7%	27%	11%	58%	0.0%
Sand	0	14,761	1,935	90	134	41	40	0	0	0
	0.0%	87%	12%	0.5%	0.8%	0.2%	0.2%	0.0%	0.0%	0.0%

Notes:
[1]See Figure 4-23 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

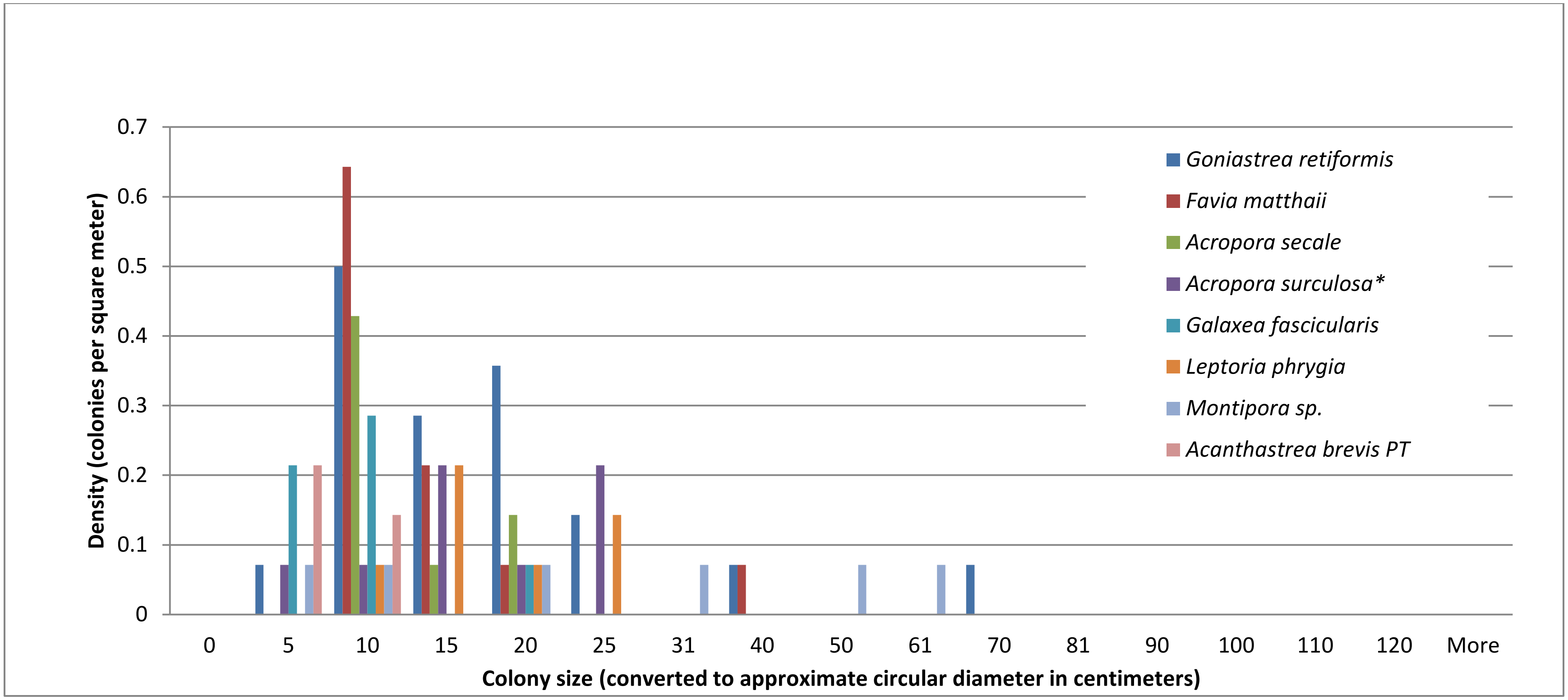

Figure 4-27. Size-Frequency Histogram of the Most[1] Abundant Corals at Unai Masalok[2].
Data Source = All Quadrats (n=14). See Table 4-13 for Summary Statistics.

Notes:
[1]Eight species make up the top 50th percentile. PT = Proposed Threatened.
[2]Includes 14 (10.7-square foot) 1-square meter quadrats. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

* *Acropora surculosa sensu* Veron (2000), not = *Acropora hyacinthus sensu* Wallace (1999)

Table 4-13. Coral Demographics Summary Statistics from All Quadrats at Unai Masalok (n=14).

Species (ranked by abundance; aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
Goniastrea retiformis	1.50	21	20	3,142	379	79	157
Favia matthaii	1.00	14	79	942	174	79	79
Acropora secale	0.64	9	79	314	140	79	79
Acropora surculosa *	0.64	9	20	471	242	157	157
Galaxea fascicularis	0.57	8	20	314	86	79	79
Leptoria phrygia	0.50	7	79	471	258	157	157
Montipora sp.	0.43	6	3	2,749	956	--	511
Acanthastrea brevis PT	0.36	5	3	79	40	79	20
Acropora selago	0.36	5	157	707	346	157	236
Favia pallida	0.36	5	20	79	67	79	79
Pocillopora verrucosa	0.36	5	20	314	130	79	79
Porites lutea	0.36	5	20	785	212	20	79
Acropora globiceps * PT	0.29	4	79	471	334	471	393
Acropora valida	0.29	4	157	314	275	314	314
Favia stelligera	0.29	4	39	314	147	--	118
Leptastrea purpurea	0.29	4	20	471	260	471	275
Goniastrea edwardsi	0.21	3	79	157	105	79	79
Hydnophora microconos	0.21	3	39	2,827	1,479	--	1,571
Pocillopora ankeli	0.21	3	79	157	105	79	79
Acropora cf. cerealis	0.14	2	79	314	196	--	196
Acropora cophodactyla	0.14	2	79	314	196	--	196
Astreopora myriophthalma	0.14	2	39	942	491	--	491
Pavona chiriquensis	0.14	2	20	20	20	20	20
Platygyra pini	0.14	2	20	314	167	--	167
Acanthastrea echinata	0.07	1	8	8	8	--	8
Acropora digitifera	0.07	1	471	471	471	--	471

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Acropora palmerae PT	0.07	1	314	314	314	--	314
Acropora sp.	0.07	1	20	20	20	--	20
Acropora tenuis	0.07	1	314	314	314	--	314
Acropora verweyi PT	0.07	1	314	314	314	--	314
Cyphastrea serailia	0.07	1	79	79	79	--	79
Favia helianthoides	0.07	1	314	314	314	--	314
Favia sp.	0.07	1	79	79	79	--	79
Favites abdita	0.07	1	785	785	785	--	785
Leptastrea pruinosa	0.07	1	471	471	471	--	471
Montastrea curta	0.07	1	1,257	1,257	1,257	--	1,257
Montipora tuberculosa	0.07	1	3,770	3,770	3,770	--	3,770
Pavona clavus	0.07	1	314	314	314	--	314
Pavona varians	0.07	1	79	79	79	--	79
Pocillopora meandrina	0.07	1	79	79	79	--	79
Porites rus	0.07	1	79	79	79	--	79
Psammocora nierstraszi	0.07	1	471	471	471	--	471
Turbinaria reniformis	0.07	1	628	628	628	--	628

Notes:
PT = Proposed Threatened
See Section 3.3.2, Coral Species Richness, for a description of the species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # [description]).
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

* *Acropora surculosa sensu* Veron (2000), not = *Acropora hyacinthus sensu* Wallace (1999)

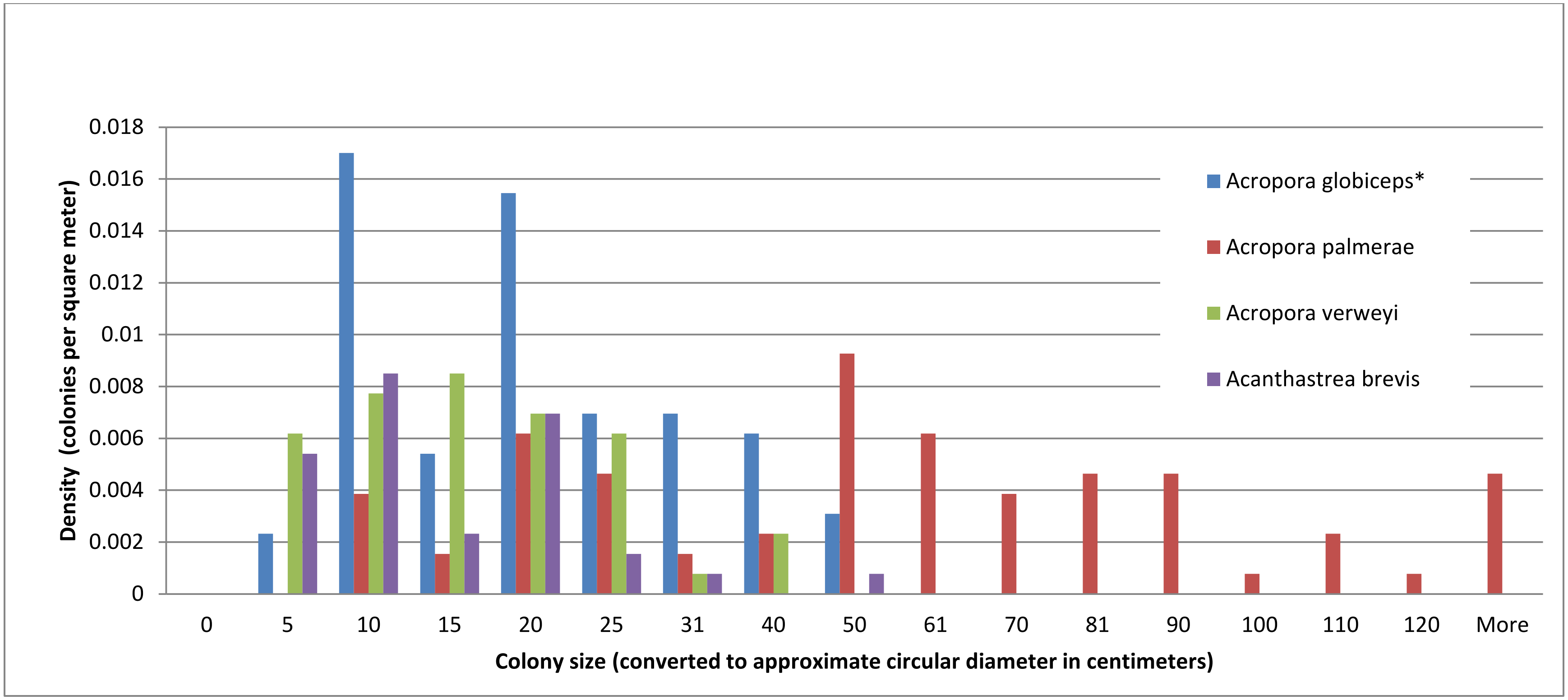

Figure 4-28. Size-Frequency Histogram of the 4 Most[1] Abundant ESA-Proposed Coral Species from all Samples at Unai Masalok (Belt Transects[2] and Quadrats).

Notes:
[1]Four of eight ESA species in this sample have densities high enough to display on this y-axis
[2]Includes 32 2x20-meter shore-parallel belt transects at Unai Masalok, and 14 10.7-sqaure foot) 1-square meter quadrats. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

Table 4-14. ESA-Proposed Coral Colony Demographics from All Samples[1] at Unai Masalok (Belt Transects[1] and Quadrats).

Species (ranked by abundance; aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
*Acropora globiceps** PT	0.06	82	7.9	1,885.0	413.4	78.5	314.2
Acropora palmerae PT	0.06	74	39.3	25,132.7	3,823.5	314.2	1,963.5
Acropora verweyi PT	0.04	50	19.6	1,256.6	262.3	157.1	157.1
Acanthastrea brevis PT	0.03	34	3.1	1,570.8	218.4	78.5	78.5
*Astreopora cucullata** PT	0.01	7	78.5	4,398.2	1,862.5	2,827.4	2,199.1
Pocillopora danae PT	0.00	4	314.2	942.5	726.5	942.5	824.7
Acropora vaughani PT	0.00	1	314.2	314.2	314.2	--	314.2
Montipora caliculata PT	0.00	1	471.2	471.2	471.2	--	471.2

Notes:
PT = Proposed Threatened
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.
[1]Includes 32 2x20-meter shore-parallel belt transects at Unai Masalok

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

* *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)

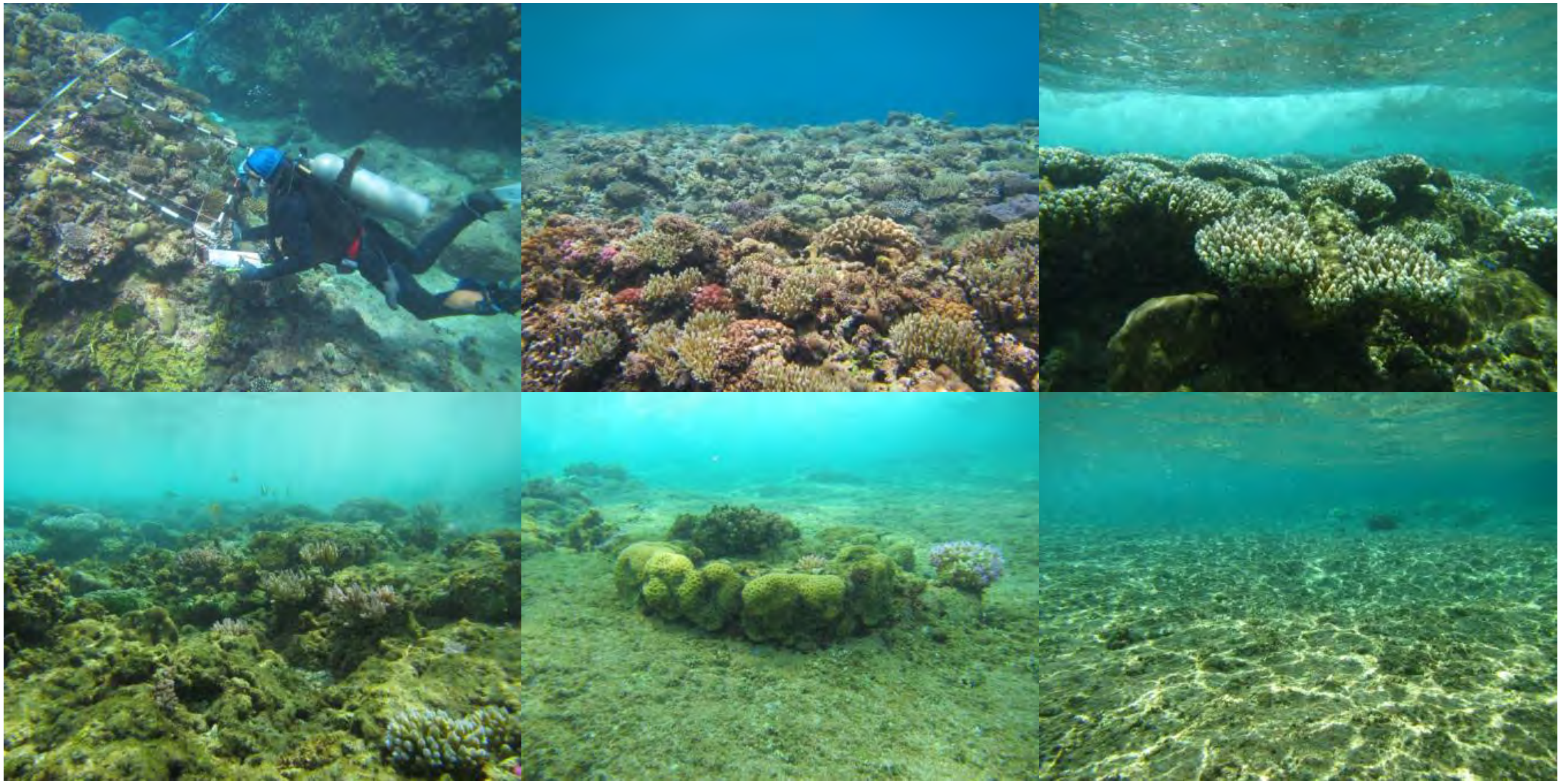

Figure 4-29. Representative Images of Unai Masalok

Clockwise from top left: deeper fore reef; shallow fore reef; outer reef crest; inner reef flat; outer reef flat; inner reef crest.

4.6 INCIDENTAL SIGHTINGS OF OTHER MARINE ORGANISMS

Sightings of sea turtles and marine mammals were reported separately (DoN 2014b, 2014c). Giant clams (*Tridacna* spp.) were observed at all sites on Tinian. Spider conch (*Lambis* spp.) were observed at Unai Chulu, Unai Babui, and Unai Masalok. The ESA-candidate humphead wrasse (*Cheilinus undulatus*) was observed at Unai Lamlam, and no other ESA fish were observed at Tinian sites.

4.7 SUMMARY – TINIAN BEACHES

Using available materials regarding the potential actions on Tinian (DoN 2013b; MARFORPAC 2013; U.S. Marine Corps, Pacific 2013;) and guidance from the Navy and MARFORPAC, conclusions about the presence and distribution of corals and coral reefs at the five beaches are:

- There is no approach from the sea to the beaches at Unai Chulu, Unai Babui, Unai Lamlam, Unai Dankulo, or Unai Masalok free of ESA-proposed corals in the uppermost 2-12 feet (0.6-4 meters) of water column.
- ESA-proposed coral colonies are unexpectedly numerous within portions of the areas surveyed.
- Any hypothetical corridor from the sea to a beach 33 feet (10 meters) wide and in contact with the seafloor at 10 feet (3 meters), would likely affect several thousand ESA-proposed coral colonies.
- The center of Unai Lamlam includes a narrow approach free of ESA-proposed coral colonies in the uppermost 2 feet (0.6 meter) at high tide only. This approach could offer a low-impact option for potential small vessel approaches to Unai Lamlam; however, navigation would need to be precise because the channel edges are lined with ESA-proposed Acropora verweyi.
- Among the four reef flats quantitatively surveyed at Tinian (Unai Chulu, Unai Babui, Unai Lamlam, and Unai Masalok), the Unai Masalok reef flat represents the largest area with the fewest ESA-proposed corals.

CHAPTER 5
RESULTS—PAGAN

One full day of work at Pagan was completed before Typhoon Soulik caused a 2-day interuption. The storm organized rapidly from a tropical depression just southeast of Pagan during July 8, 2013 and by noon the southwest winds were gusting to 50 knots. From July 8 to 9 the *SS Thorfinn* jogged in the modest lee near to the north shore of the island as the storm intensified to a typhoon. As the storm passed to the west of Pagan, seas were 10 to 15 feet (2 to 3 meters) on the west side and 15 to 20 feet (5 to 7 meters) on the east side of Pagan. The small wind-waves had dissipated when work re-commenced the morning of July10, but a long-period western swell continued to organize and build as the storm strengthened to a super typhoon. Though several hundred miles away, the storm-driven swell ultimately reached a period of approximately 15 seconds, causing 6 to 21-foot surge (2 to 7 meters) and 6 foot (2-meter) surf at the Green Beach headlands. Apart from the swell which slowly diminished for the next 3 days, wind and seas were notably calm – a typical phenomenon in the wake of tropical cyclones. This calm afforded the survey crews the opportunity to work on the eastern side of Pagan, which is usually too rough for small vessels under typical trade wind conditions (Suhkraj et al. 2010).

5.1 GREEN BEACH

5.1.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at Green Beach had low topographic complexity, low coral cover, and high sand cover (Figure 5-1, Figure 5-2, Figure 5-3, Figure 5-4, and Table 5-1). There is a relatively large and contiguous area in the center of Green Beach that is especially low cover for biota and high cover for sand. Notably, there were no portions of the Green Beach seafloor that had high complexity and almost none that had very high coral cover within this method's search area. This seeming absence of high coral cover areas is a methodological artifact. High complexity and high coral cover areas along the northern and southern portions of Green Beach were unworkable for this method through July 13, 2013 in the swell conditions that persisted following Typhoon Soulik. These areas are visible in the aerial imagery (Figure 5-1) and were described categorically by Suhkraj et al. (2010). Nevertheless, the central portion of Green Beach is largely devoid of sessile biota (Figure 5-2, Figure 5-3, and Figure 5-4).

Figure 5-2, Figure 5-3, and Figure 5-4 present data that has been summarized for visual clarity. The detailed data for every class is presented in Table 5-1. See Section 3.3.1, Broad-Scale Surveys, for descriptions of the method and caveats. The visibility and apparent water quality was degraded relative to the other leeward beaches, potentially from anthropogenic sources. Furthermore, the seafloor had a number of kitchen scraps including poultry and cow bones.

The rocky formations at the north and south boundaries of Green Beach are a mixture of igneous boulders, exposed igneous outcroppings, igneous substrate encrusted with corals, and massive coral colonies. The northern boundary of Green Beach includes concrete rubble and the remains of a structure. Most of the areas are shallower than 6 feet (2 meters), and all of the rocky formations are shallower than 16 feet (5 meters; see bathymetric contours in Figure 5-2 and calculations in Appendix C). Because of wave and surf refraction around the rocky formations and reflection from the opposite formation, the vicinity of the outcroppings presented a substantial hazard to navigation during the days, with modest long-period swells following Typhoon Soulik.

5.1.2 Coral Species Richness

Summary species richness results for Green Beach and all other Pagan sites are presented in Table 5-2, and detailed records of individual species for Green Beach and all other sites are presented in Appendix A. Among the 70 records are 8 ESA-proposed coral species and 2 irresolvable species (see Appendix D for representative images of ESA-proposed species). Neither of the 2 irresolvable records necessarily represents an additional species record for Green Beach (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness). In the demographic data below, irresolvable colonies are relatively uncommon. Representative images of Green Beach are shown in Figure 5-7.

Green Beach featured relatively large heads of *Porites* corals, one of the largest measuring 98 feet (30 meters) in circumference. These large corals were mostly across the entrance to Green Beach from north to south, though many were also growing throughout the northern and southern rocky formations (Figure 5-7). The elevation of these large *Porites* heads ranged from within inches (0.10 meter) of mean low water to well below the 12-foot (4-meter) survey limit.

5.1.3 Coral Demographics

Green Beach coral demographics data was collected by quadrats along the rocky formations at the north and south boundaries of Green. Quadrats under-sample large colonies and inadequately represent spatially heterogeneous habitats unless the number is high. Green Beach fits both of these criteria; therefore quadrats were unreliable. A methodology such as replicate 2 x 20-meter belt transects to sample all corals would be a better choice for future coral demographic data collection. Summary statistics from the 10 10.7-square foot (1-square meter) quadrat samples at Green Beach are presented in Figure 5-5 and Table 5-3, but they are a relatively poor representation of the coral community (Figure 5-2 and Figure 5-7).

5.1.4 ESA Coral Demographics

Green Beach has many corals directly in front of the sandy beach, and coral demographics data was collected by quadrats and direct-mapping (see Section 5.1.3, Coral Demographics for a description of the limitations of quadrat sampling for Green Beach). Ten quadrats, each 10.7 square feet (1 square meter), were collected from the southern patch reef within Green Beach, but did not meaningfully inform the demographics of ESA-proposed corals (Appendix B, DoN 2014a). ESA-proposed coral demographics were estimated by direct mapping (see Section 3.3.4, ESA Coral Demographics).

The sample size for direct mapping at Green Beach was approximately 46,000 square meters, and this area included the entire interior of Green Beach and the north and south headlands, from 0 to 12 feet (3.7 meters) depth (see Section 3.3.4, ESA Coral Demographics for details of the methodology). In total, 114 ESA-proposed coral colonies were directly mapped during the surveys at Green Beach. The size-frequency distribution of all seven ESA-proposed species shows two main patterns. First, most colonies of *Acanthastrea brevis* is dominant and most colonies were smaller than 4 inches (10 centimeters). Second, many colonies of the encrusting *Acropora palmerae, Astreopora cucullata*, and *Montipora caliculata* have relatively homogenous size distributions (Figure 5-6 and Table 5-4; see Coral Data Deliverable Table 6-1 for details of each colony). The encrusting *Acropora palmerae* was represented by only 19 colonies, and one of them was also very large, attaining a maximum area of nearly 16 square feet (1.5 square meters) (Table 5-4).

The aggregate density of ESA-proposed coral species at Green Beach is <0.003 colonies per square meter. However, the spatial distribution of corals at Green Beach is quite heterogeneous, and a broadly calculated number such as this is misleading. Corals at Green Beach are concentrated in the patch reefs to the north and south sides, and there were zero ESA-proposed corals found in the central 600 feet (200 meters) of the beach shallower than 12 feet (4 meters; Figure 5-2 and Figure 5-3).

Figure 5-1. Green Beach In Situ Broad-Scale Topographic Complexity

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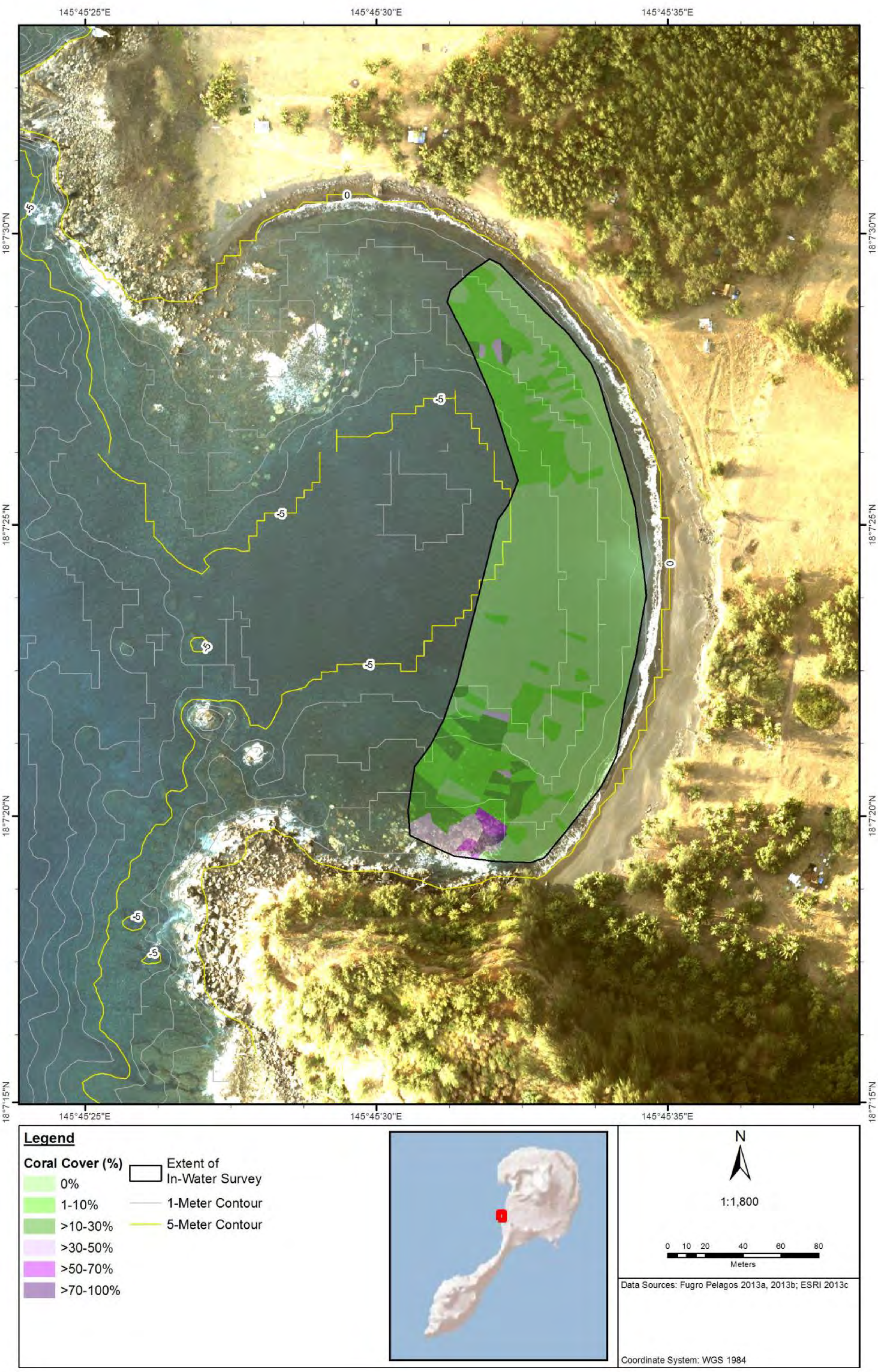

Figure 5-2. Green Beach In Situ Broad-Scale Coral Cover

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Figure 5-3. Green Beach In Situ Broad-Scale Macroalgae

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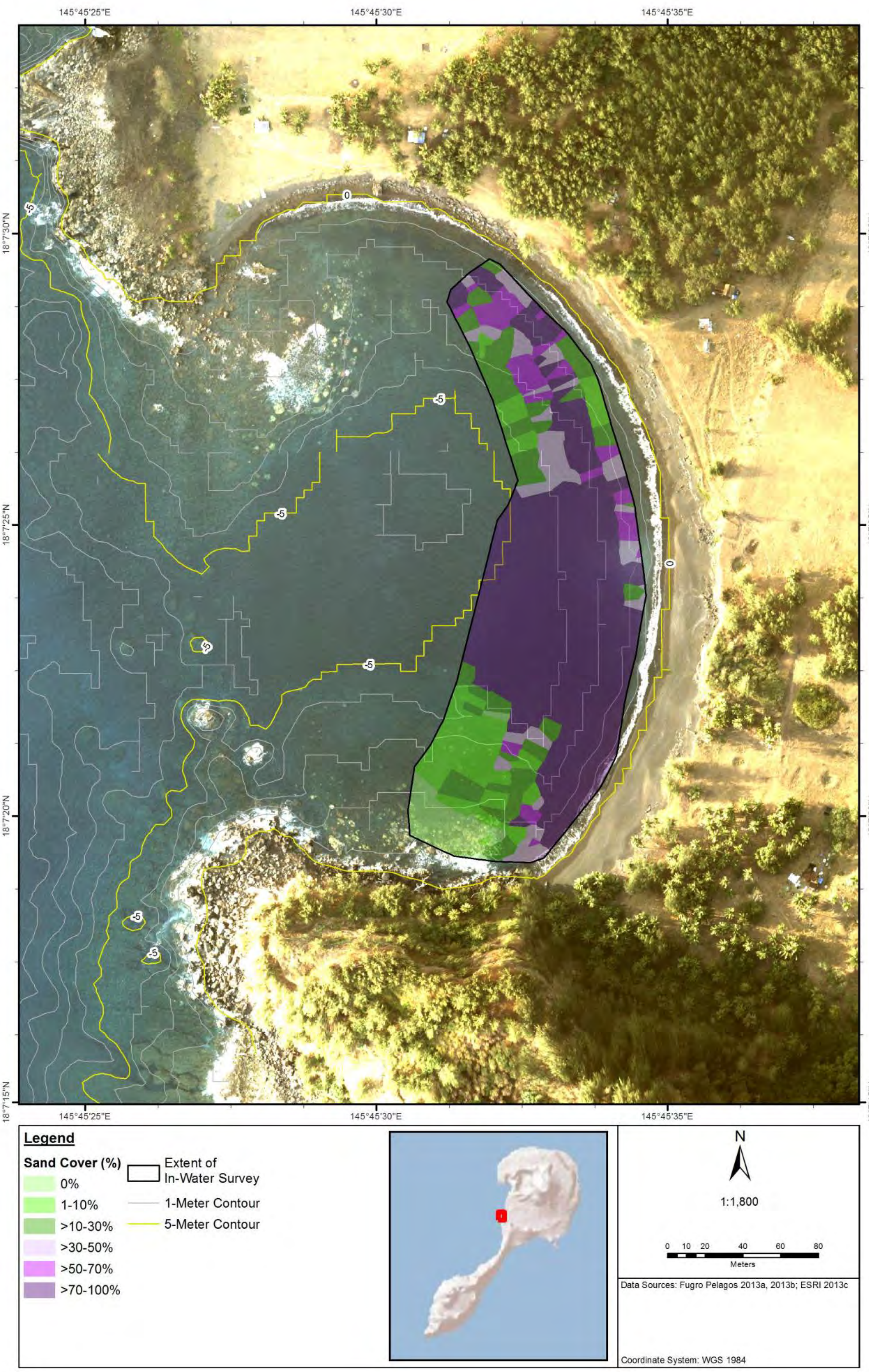

Figure 5-4. Green Beach In Situ Broad-Scale Sand Cover

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Table 5-1. Broad-Scale Surveys at Green Beach (Square Meters, % Cover)

Green Beach total area[1] = 22,232 square meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	12,648	6,536	3,014	33	0	0	--	--	--
	--	57%	29%	14%	0.2%	0%	0%	--	--	--
Coral	14,653	5,372	554	745	171	455	180	67	35	0
	66%	24%	2.5%	3.4%	0.8%	2.0%	0.8%	0.3%	0.2%	0%
Macroalgae	8,621	3,648	1,826	1,295	918	3,917	1,543	465	0	0
	39%	16%	8.2%	5.8%	4.1%	18%	6.9%	2.1%	0%	0%
Sand	1,082	2,694	1,926	1,104	609	1,243	353	1,047	701	11,473
	4.9%	12%	8.7%	5.0%	2.7%	5.6%	1.6%	4.7%	3.2%	52%

Notes:
[1]See Figure 5-1 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

Table 5-2. Summary Species Richness at All Pagan Sites

	Green Beach	***Red Beach***	***Red Beach Potential Construction Area***	***Blue Beach***	***North Beach***	***Gold Beach***	***South Beach***	***Cumulative Pagan (n=7 Sites)***
Total Species Richness[1, 2, 3]	70	90	128	108	33	82	101	**160**
Total Irresolvable ID[1]	2	6	11	5	3	2	7	11
Subset of Positive ID Unique to Pagan versus Tinian								24
Total ESA-Proposed Species[3]	8	8	10	11	3	5	7	**12**

Notes:
[1]Total species richness includes all identifications. Irresolvable includes those identified only to genus (i.e., “Genus sp.”). All other identifications represent species that are positively identified, or are likely to become positive with additional field collections, taxonomic work, or definition of potential novel species.
[2]“Red Beach” is not inclusive of the potential construction area.
[3]See Appendix A for the full list of the 160 coral species found at Pagan sites

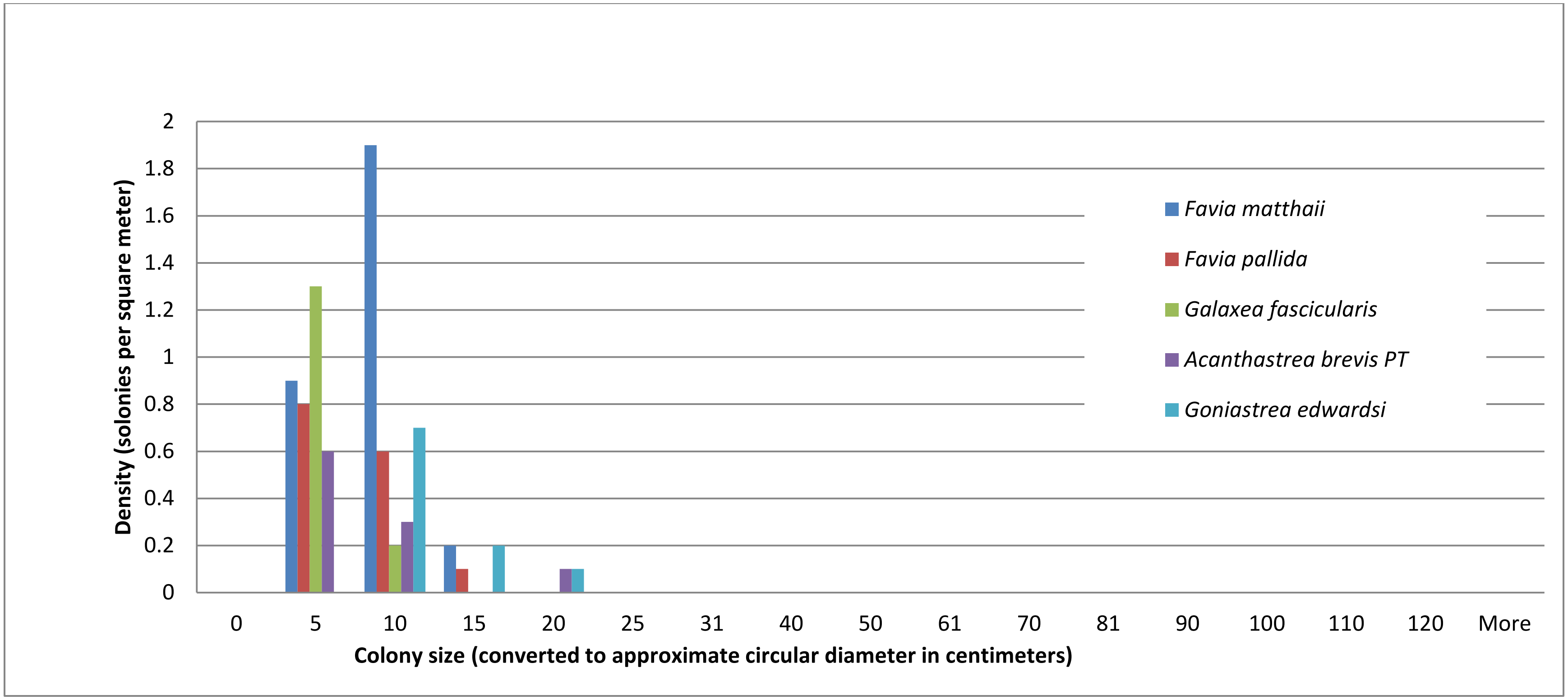

Figure 5-5. Size-Frequency Histogram of the Most[1] Abundant Corals at Green Beach[2].
See Table 5-3 for Summary Statistics

Notes:
PT = Proposed Threatened
[1]Five species make up the top 50th percentile at Green Beach.
[2]Includes 10 10.7-square foot (1-square meter) quadrats at Green Beach. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

Table 5-3. Coral Demographics Summary Statistics from All Quadrats at Green Beach (n=10)

Species (ranked by abundance) (aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
Favia matthaii	3.00	30	20	157	63	79	79
Favia pallida	1.50	15	3	157	49	20	20
Galaxea fascicularis	1.50	15	3	79	23	20	20
Acanthastrea brevis PT	1.00	10	3	314	61	20	20
Goniastrea edwardsi	1.00	10	63	314	110	79	79
Pocillopora meandrina	1.00	10	20	314	100	79	79
Acanthastrea echinata	0.90	9	20	79	46	20	39
Goniastrea retiformis	0.90	9	20	471	157	79	79
Leptoria phrygia	0.60	6	20	236	92	20	59
Pavona clavus	0.60	6	20	157	82	79	79
Pavona maldivensis	0.60	6	39	314	164	157	157
Gardineroseris planulata	0.50	5	20	79	59	79	79
Cyphastrea serailia	0.30	3	3	20	14	20	20
Platygyra daedalea	0.30	3	8	39	22	--	20
Favia favus	0.20	2	20	20	20	20	20
Montastrea curta	0.20	2	79	79	79	79	79
Pavona varians	0.20	2	8	39	24	--	24
Platygyra pini	0.20	2	79	79	79	79	79
Acropora tenuis	0.10	1	942	942	942	--	942
Favia stelligera	0.10	1	79	79	79	--	79
Pavona minuta	0.10	1	79	79	79	--	79
Pocillopora ankeli	0.10	1	20	20	20	--	20

Notes:

PT = Proposed Threatened; -- = not applicable

See Section 3.3.2, Coral Species Richness, for a description of the species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species number [description]).

Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.

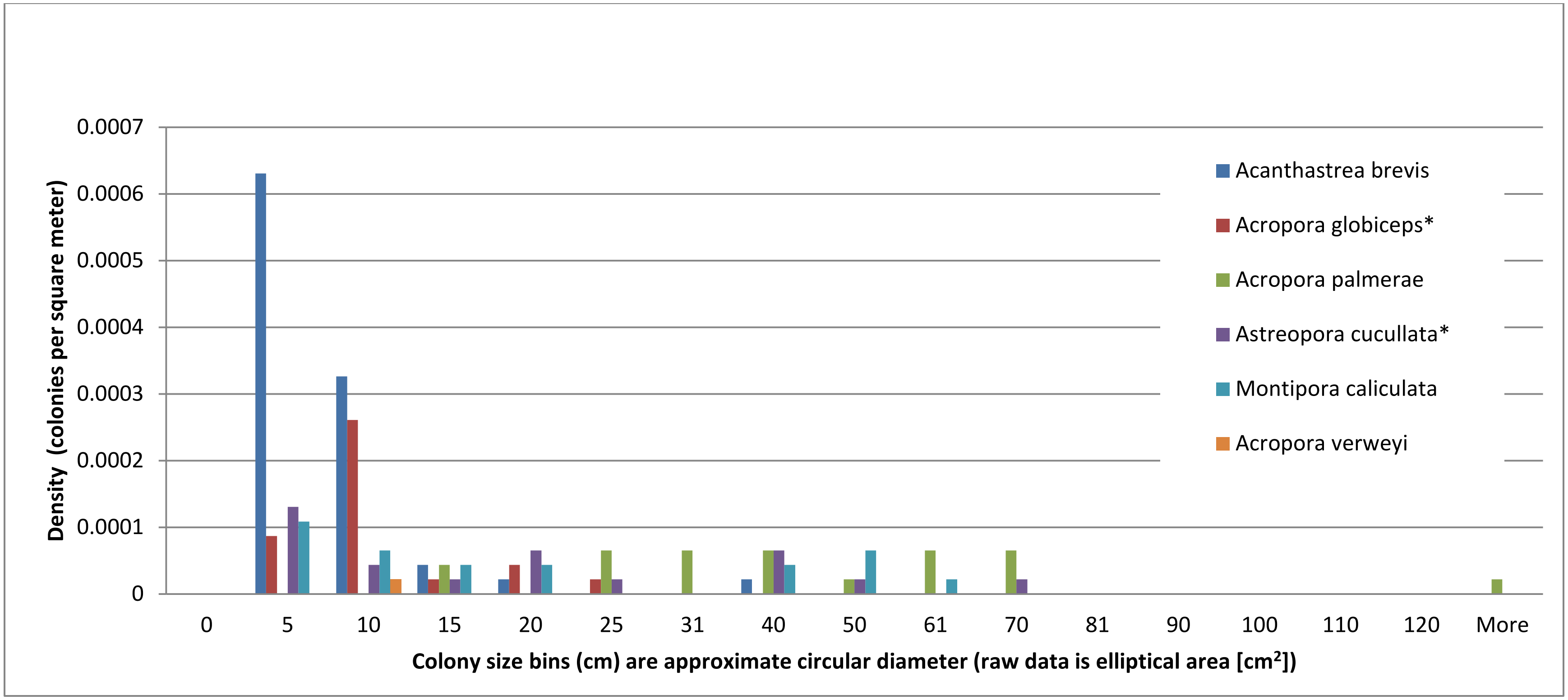

Figure 5-6. Size-Frequency Histogram of the All[1] ESA-Proposed Coral Species from All Samples and Surveys[2] at Green Beach.

Notes:
[1]All six ESA species in this sample are displayed, though *Acropora verweyi* is represented by a single colony. The densities (y-axis) are two orders of magnitude smaller than all other sites.
[2]Includes 10 10.7-sqaure foot (1-square meter) quadrats, and direct-mapping of approximately 495,140 square feet (46,000 square meters) at Green Beach. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana, 1846) *sensu* Randall and Myers (1983)

* *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)

Table 5-4. ESA-Proposed Coral Colony Demographics from All Samples and Surveys[1] at Green Beach

Species (ranked by abundance) (aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
Acanthastrea brevis PT	0.0010	48	1	942	61	20	20
*Acropora globiceps** PT	0.0004	20	8	471	106	79	79
Acropora palmerae PT	0.0004	19	157	15,708	2,228	471	1,178
*Astreopora cucullata** PT	0.0004	18	1	3,142	574	20	236
Montipora caliculata PT	0.0004	18	3	2,749	600	3	157
Acropora verweyi PT	0.0000	1	79	79	79	--	79

Notes:
PT = Proposed Threatened; -- = not applicable
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.
[1]Includes 10 10.7-square foot (1-square meter) quadrats, and direct-mapping of approximately 495,140 square feet (46,000 square meters) at Green Beach.
See Figure 1-3, Figure 5-1, and Figure 5-2 for a depiction of the areas.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

* *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)

Figure 5-7. Representative Images of Green Beach

Clockwise from top left: northern rocky outcrop; center of beach; center of beach; view of green beach from northern rocky outcrop; corals on northern rocky outcrop; northern rocky outcrop.

5.2 RED BEACH

5.2.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at Red Beach was low topographic complexity, zero coral cover, and high sand cover (Figure 5-8, Figure 5-9, Figure 5-10, Figure 5-11, and Table 5-6). The occasional rock substrate along the beachfront was flagged and surveyed for ESA-proposed corals. No ESA corals were recorded from the beachfront area shallower than 12 feet (4 meters). Notably, there were no portions of Red Beach seafloor that were high complexity and none that were moderate or high coral cover within this method's search area. The basement substrate is coarse-grain igneous sand and cobble. Where corals occur, particularly at the headlands, the dominant substrate is igneous and there is no evidence of buildup of carbonate framework.

5.2.2 Coral Species Richness

Summary species richness results for Red Beach and all other Pagan sites are presented in Table 5-2, and detailed records of individual species for Red Beach and all other sites are presented in Appendix A. Among the 90 records are 8 ESA-proposed coral species and 6 irresolvable species (see Appendix D for representative images of ESA-proposed species). None of the six irresolvable records necessarily represent an additional species record for the site (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness). The demographic data below, that irresolvable colonies are relatively uncommon.

The basement substrate is coarse-grain igneous sand and cobble. Where corals occur, principally at the adjoining headlands, the dominant substrate is igneous and there is no evidence of buildup of carbonate framework.

5.2.3 ESA Coral Demographics

Red Beach has zero ESA-proposed coral colonies directly in front of the sandy beach, at depths shallower than 12 feet (4 meters), making the site a candidate for the proposed activities with minimal potential effects on coral. The headlands to the north and south have ESA-proposed corals (Table 4-2, Appendix A), but these headlands seem unlikely to be exposed to the proposed activities except for potential pier and breakwater construction. Representative images of Red Beach are shown in Figure 5-12.

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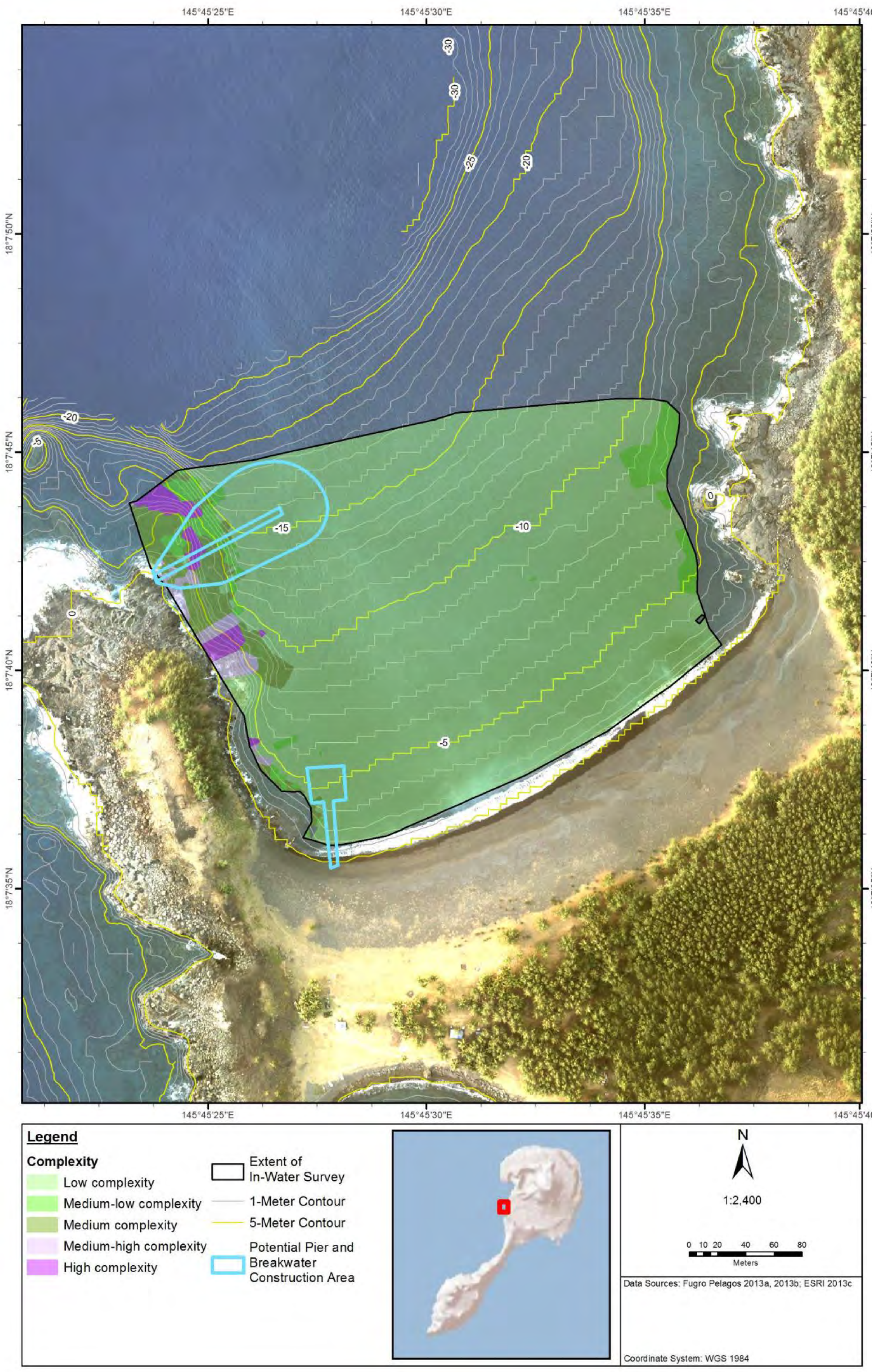

Figure 5-8. Red Beach In Situ Broad-Scale Topographic Complexity

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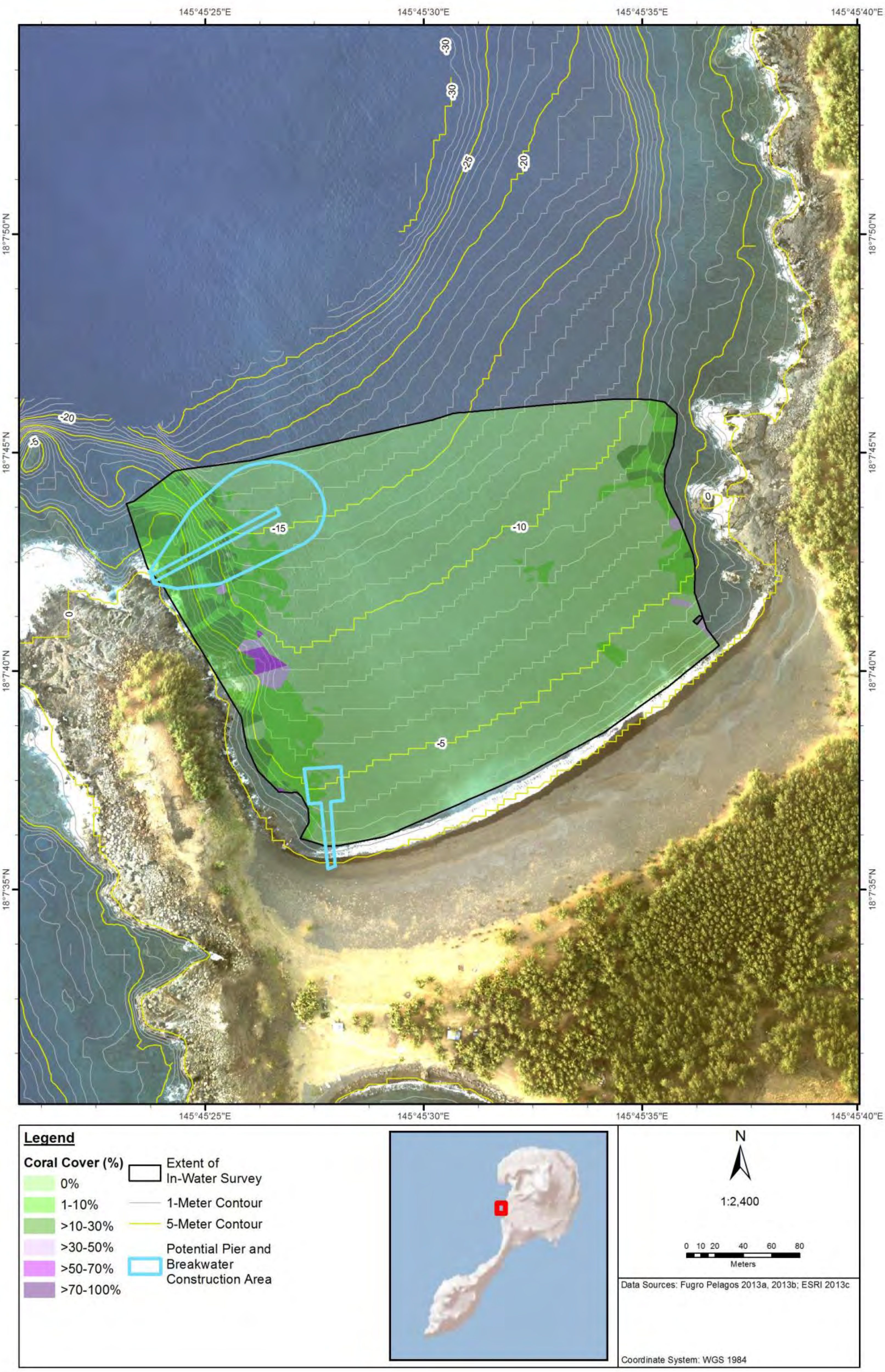

Figure 5-9. Red Beach In Situ Broad-Scale Coral Cover

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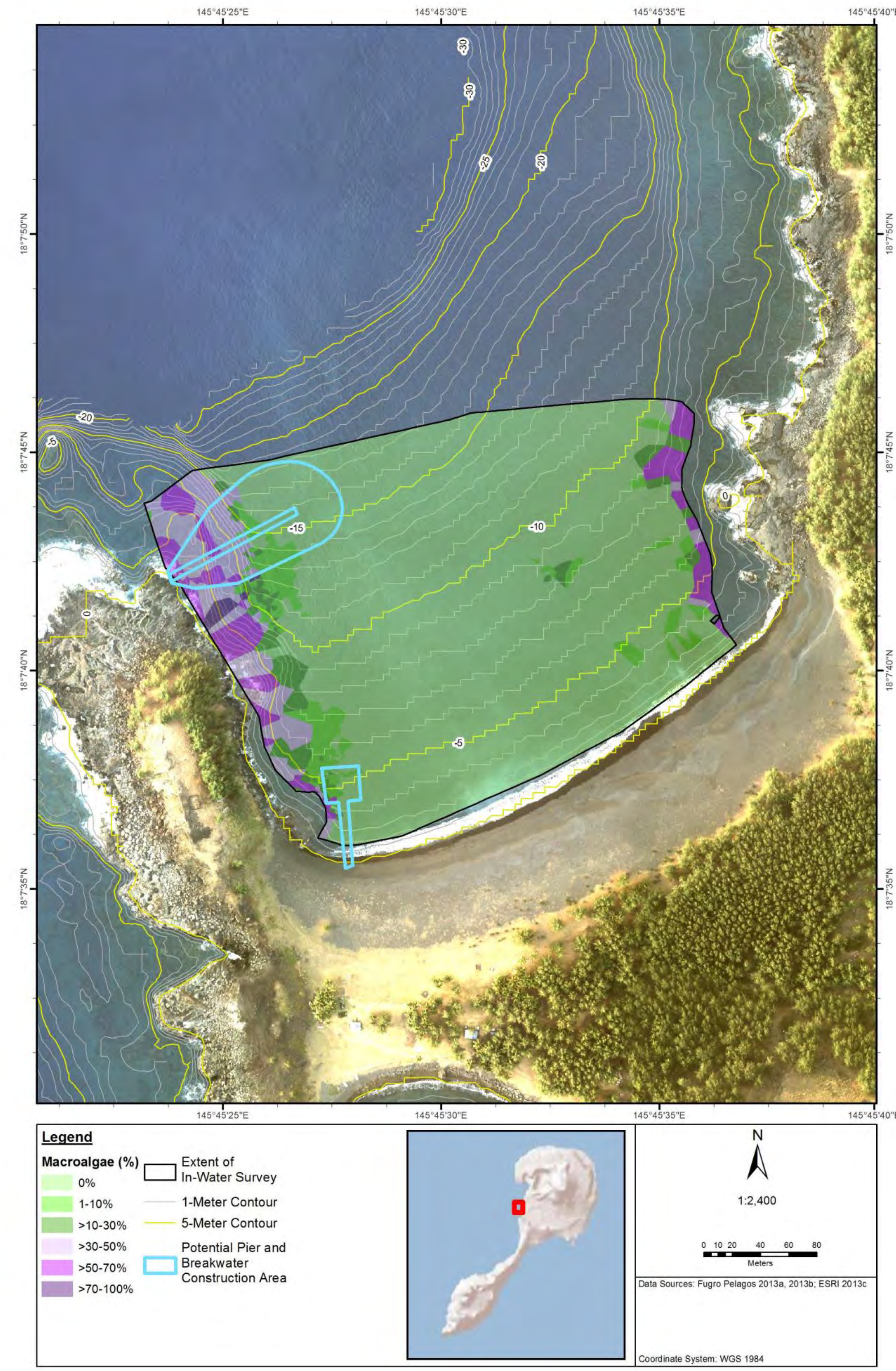

Figure 5-10. Red Beach In Situ Broad-Scale Macroalgae Cover

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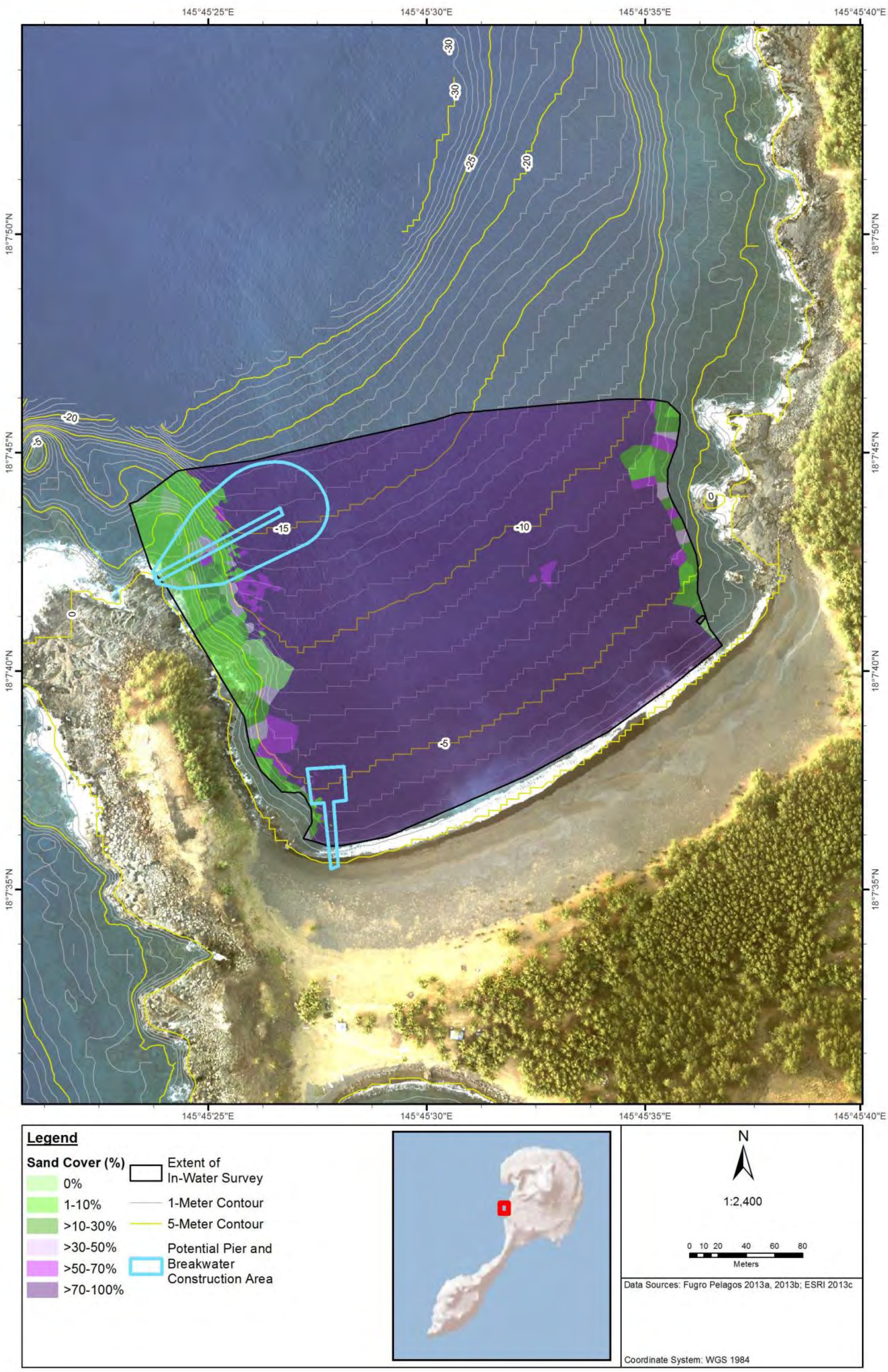

Figure 5-11. Red Beach In Situ Broad-Scale Sand Cover

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Table 5-5. Broad-Scale Surveys at Red Beach – Cumulative Search Areas (Square Meter, % Cover)

Red Beach total area[1] = 83,895 square meters										
Class[2]	***0 - 0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***7 – 70%***	***8 – 80%***	***9 – 90%***
Complexity[3, 4]	--	73,973	3,665	4,224	1,004	1,030	0	--	--	--
	--	88%	4.4%	5.0%	1.2%	1.2%	0.0%	--	--	--
Coral	68,401	9,864	4,073	701	37	522	97	200	0	0
	82%	12%	4.9%	0.8%	0.0%	0.6%	0.1%	0.2%	0.0%	0.0%
Macroalgae	67,068	4,166	1,228	1,272	830	4,647	1,962	2,415	284	22
	80%	5.0%	1.5%	1.5%	1.0%	5.5%	2.3%	2.9%	0.3%	0.0%
Sand	1,534	5,674	1,453	1,156	301	544	163	1,664	1,032	70,374
	1.8%	6.8%	1.7%	1.4%	0.4%	0.6%	0.2%	2.0%	1.2%	84%

Notes:
-- = no data
[1]See Figure 5-1 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover, where 1 = 10%, 2 = 20%, etc. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

Table 5-6. Broad-Scale Surveys at Red Beach Outside the Proposed Construction Area (Square Meter, % Cover)

Red Beach outside pier/breakwater total area[1] = 73,997 square meters

Class[2]	0%	1 - 10%	2 - 20%	3 – 30%	4 – 40%	5 – 50%	6 – 60%	70%	80%	90%
Complexity[3, 4]	--	67,204	2,800	2,779	579	634	0	--	--	--
	--	91%	3.8%	3.8%	0.8%	0.9%	0.0%	--	--	--
Coral	62,838	6,824	2,777	701	37	522	97	200	0	0
	85%	9.2%	3.8%	0.9%	0.1%	0.7%	0.1%	0.3%	0.0%	0.0%
Macroalgae	61,610	3,085	1,085	1,231	687	2,534	1,207	2,274	284	0
	83%	4.2%	1.5%	1.7%	0.9%	3.4%	1.6%	3.1%	0.4%	0.0%
Sand	980	3,733	1,118	999	281	442	77	1,540	670	64,157
	1.3%	5.0%	1.5%	1.4%	0.4%	0.6%	0.1%	2.1%	0.9%	87%

Notes:
-- = no data
[1]See Figure 5-1 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

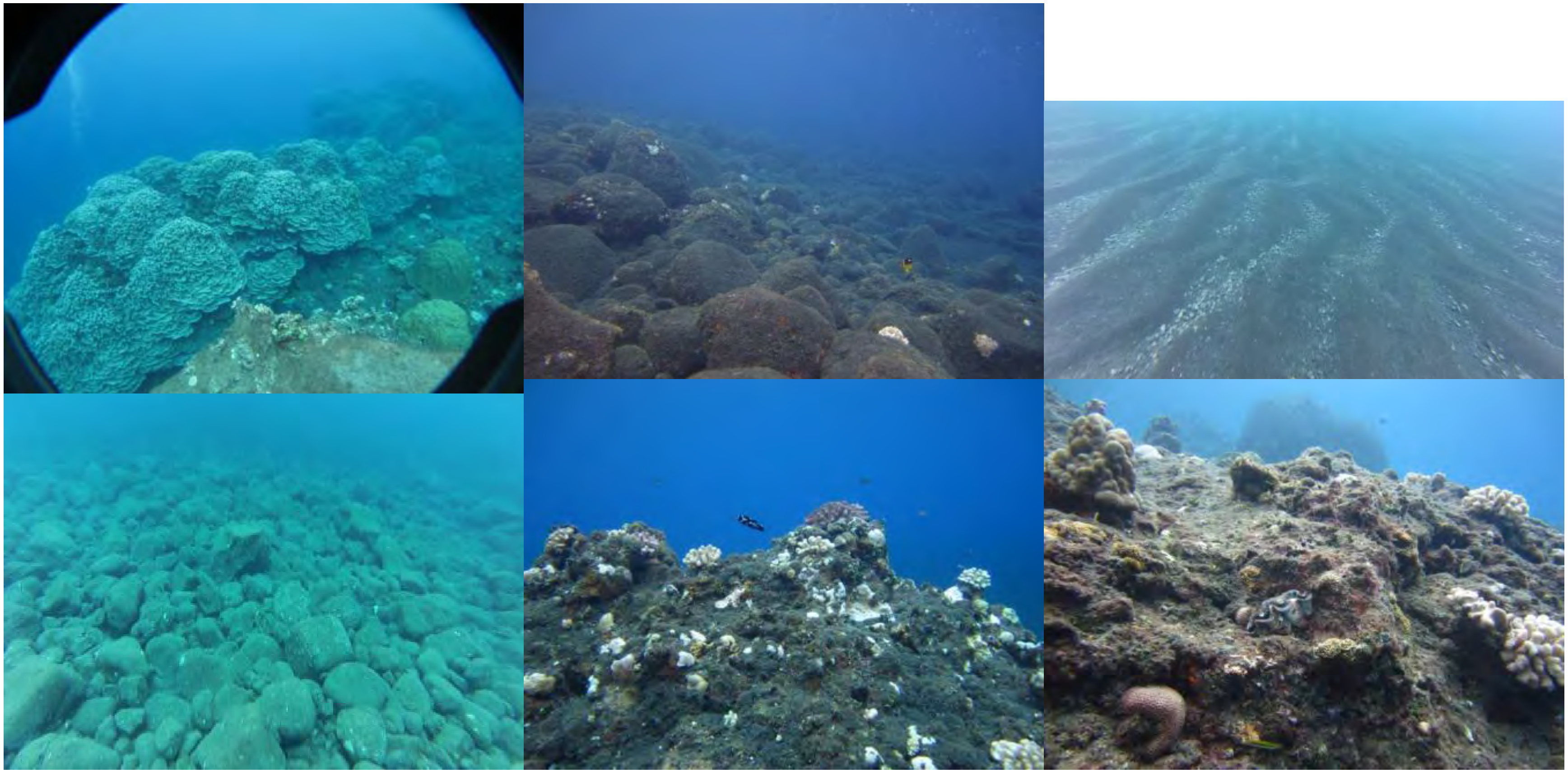

Figure 5-12. Representative Images of Red Beach

Clockwise from top left: Large *Porites rus* colony on southern headland; northern headland – inner; center of beach; southern headland, showing many small coral colonies and juvenile giant clam; southern headland, showing many small coral colonies; center of beach.

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5.3 RED BEACH PIER AND BREAKWATER POTENTIAL CONSTRUCTION AREAS

5.3.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping in the proposed construction area has moderate topographic complexity, low coral cover, and low sand cover (Figure 5-8, Figure 5-9, Figure 5-10, Figure 5-11, and Table 5-7). The basement substrate is coarse-grain igneous sand and cobble. Where corals occur, the dominant substrate is igneous and there is no evidence of buildup of carbonate framework. Between the proposed pier and breakwater areas is a patch of very high coral cover (Figure 5-9) including a colony of *Porites rus* approximately 66 by 33 feet (20 by 10 meters).

The basement substrate in the pier proposed construction area is principally coarse-grain igneous sand and cobble. Concrete and steel debris is large and frequent in this area. Physical and geotechnical investigations of the area were detailed by Sea Engineering Inc. (2011). The basement substrate in the breakwater proposed construction area is principally igneous and there is very little evidence of buildup of carbonate framework. Deeper portions of the potential breakwater construction area have a veneer of carbonate sediments, but this seems to be only a few centimeters thick as the igneous substrate shows through in many places. Representative images of the Red Beach potential pier and breakwater construction area are shown in Figure 5-15.

5.3.2 Coral Species Richness

Summary species richness results for the Red Beach Potential Construction Area and all other Pagan sites are presented in Table 4-2, and detailed records of individual species for the Red Beach Potential Construction Area and all other sites are presented in Appendix A. Among the 128 records are 10 ESA-proposed coral species and 11 irresolvable species (see Appendix D for representative images of ESA-proposed species). At least one of the 11 irresolvable records, *Tubastraea* sp., represent an additional species record for the site (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness). In the demographic data below, irresolvable colonies are relatively uncommon.

5.3.3 Coral Demographics

The 9,899 square meter Red Beach potential pier and breakwater construction areas were sampled with 43 quadrats, each 10.7 square feet (1 square meter; Appendix B, DoN 2014a). A total of 61 species of corals fell within quadrats, and the most abundant was *Leptastrea purpurea*, with an estimated density of 0.33 colony per square foot (3.5 colonies per square meter). Size-structure of the most frequently occurring species is shown in Figure 5-13. Within this set, the majority of colonies are smaller than 4 inches (10 centimeters; approximate circular diameter), and the maximum sizes for the area are much smaller than in comparable surveys on Pagan (Green Beach and South Beach). The habitat within the proposed construction area was heterogeneous among depth zones but was relatively homogeneous within depth zones. In particular, the coral assemblage in the shallowest 16 feet (5 meters) of the breakwater proposed construction area was distinctly different than the deeper habitat with smaller colonies and larger areas of bare igneous substrate between them, which is consistent with its exposure to high-energy water motion. In both shallow and deep areas, small colonies were abundant and large colonies were uncommon. This, also, is a signature of episodic physical disturbance (Connell 1997; Aronson et al. 2012).

5.3.4 ESA Coral Demographics

The Red Beach potential pier and breakwater construction areas contain many ESA-proposed corals (Figure 5-9, Figure 5-13, Figure 5-14, Table 5-9, Appendix B, and DoN 2014a). The habitat within the proposed construction area was heterogeneous among depth zones but was relatively homogeneous within depth zones. ESA-proposed coral demographics were estimated by direct mapping, yielding a low-end value of 369 ESA-proposed corals within the proposed construction area. Extrapolating from the quadrat data yields an estimated 4,834 corals potentially exposed to activities in the 9,899 square meter area (Figure 5-14, Table 5-9, and Appendix B). Each of these extrapolations are valid estimates of the total population of ESA-proposed coral colonies in the Red Beach potential activity area, though each carries different assumptions that should be considered for further analyses (See Section 3.3.4, ESA Coral Demographics and Section 6.1, Extrapolating from the Sample to the Population for these discussions). See Appendix D for representative images of ESA-proposed species.

Table 5-7. Broad-Scale Surveys at Red Beach Potential Construction Area (Square Meter, % Cover)

Red Beach proposed construction area total[1] = 9,899 square meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	6,769	865	1,445	425	395	0	--	--	--
	--	68%	8.7%	15%	4.3%	4.0%	0.0%	--	--	--
Coral	5,563	3,039	1,296	0	0	0	0	0	0	0
	56%	31%	13%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Macroalgae	5,458	1,082	144	41	143	2,113	755	141	0	22
	55%	11%	1.5%	0.4%	1.5%	21%	7.6%	1.4%	0.0%	0.2%
Sand	554	1,941	335	157	20	102	87	124	362	6,217
	5.6%	20%	3.4%	1.6%	0.2%	1.0%	0.9%	1.3%	3.7%	63%

Notes:
-- = no data
[1]See Figure 5-8 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

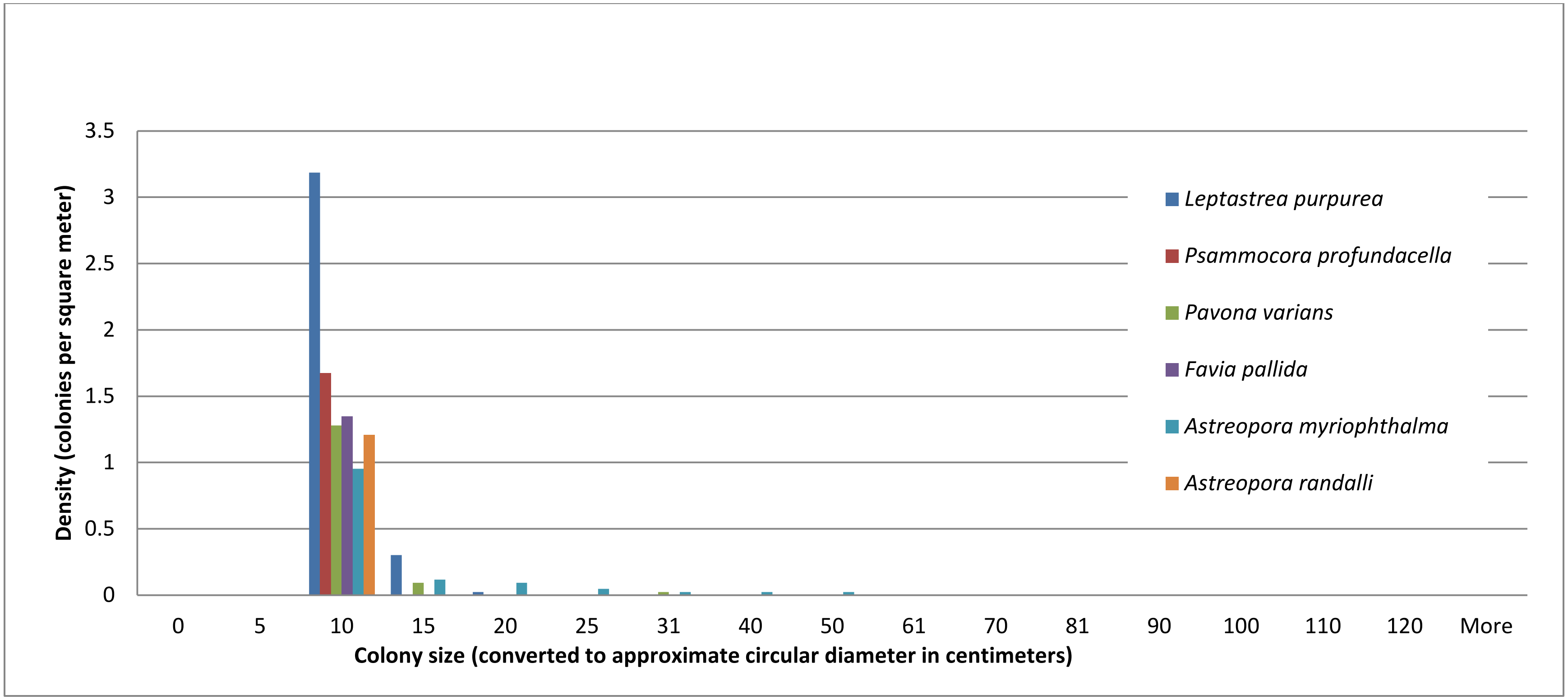

Figure 5-13. Size-Frequency Histogram of the Most[1] Abundant Corals at Red Beach Potential Construction Area[2].
Data Source = All Quadrats (n=43) (see Table 5-8 for Summary Statistics)

Notes:
[1]Six species make up the top 50th percentile at Red Beach potential construction area.
[2]Includes 43 10.7-square foot (1-square meter) quadrats at Red Beach potential construction area. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

Table 5-8. Coral Demographics Summary Statistics from All Quadrats at Red Beach Potential Construction Area (n=43)

Species (ranked by abundance) (aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
Leptastrea purpurea	3.51	151	1	157	13	3	3
Psammocora profundacella	1.67	72	1	20	3	3	3
Pavona varians	1.40	60	1	393	15	3	3
Favia pallida	1.35	58	1	8	3	3	3
Astreopora myriophthalma	1.28	55	1	785	69	20	20
Astreopora randalli	1.21	52	1	20	4	3	3
Cyphastrea serailia	0.91	39	1	236	20	3	3
Favia matthaii	0.84	36	1	157	10	3	3
Porites sp.	0.77	33	1	1,257	75	3	3
Pocillopora meandrina	0.70	30	1	314	68	20	20
Cyphastrea chalcidicum	0.60	26	1	79	16	3	6
Stylocoeniella guentheri	0.56	24	1	942	57	3	3
Porites solida	0.53	23	1	157	35	8	8
Astreopora cucullata * PT	0.37	16	1	314	26	8	5
Pocillopora sp.	0.35	15	1	3	2	1	1
Astreopora gracilis	0.33	14	1	39	10	8	8
Montipora foveolata	0.26	11	8	39	20	20	20
Montipora verrucosa	0.23	10	3	157	30	20	20
Pocillopora eydouxi	0.21	9	8	314	80	8	39
Goniastrea edwardsi	0.19	8	1	39	7	3	3
Galaxea fascicularis	0.16	7	3	39	18	20	20
Pocillopora verrucosa	0.16	7	3	20	15	20	20
Astreopora elliptica	0.14	6	8	314	90	20	20
Leptastrea transversa	0.14	6	3	39	19	39	14
Pavona chiriquensis	0.14	6	3	79	26	--	18
Leptoseris incrustans	0.12	5	3	20	10	3	3

Species (ranked by abundance) (aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Montastrea cf. valenciennesi	0.12	5	3	39	11	3	3
Montipora sp.	0.12	5	3	236	72	3	39
Turbinaria reniformis	0.12	5	8	1,257	507	8	8
Acanthastrea brevis PT	0.09	4	3	39	15	8	8
Echinophyllia aspera	0.09	4	8	20	17	20	20
Favia favus	0.09	4	8	20	17	20	20
Favia rotumana	0.09	4	8	157	85	157	88
Favia stelligera	0.07	3	3	79	40	--	39
Goniopora minor	0.07	3	3	8	5	3	3
Goniopora sp. 'long tentacles'	0.07	3	1	39	20	--	20
*Montipora hoffmeisteri **	0.07	3	3	236	82	--	8
Pavona venosa	0.07	3	3	20	10	--	8
Porites lutea	0.07	3	8	20	16	20	20
Acropora tenuis	0.05	2	8	157	82	--	82
Coscinaraea wellsi	0.05	2	3	8	5	--	5
Cyphastrea microphthalma	0.05	2	20	20	20	20	20
Goniastrea retiformis	0.05	2	8	39	24	--	24
Goniopora fruticosa	0.05	2	20	20	20	20	20
Montastrea curta	0.05	2	3	8	5	--	5
Platygyra pini	0.05	2	16	20	18	--	18
Plesiastrea versipora	0.05	2	20	20	20	20	20
Acropora globiceps * PT	0.02	1	79	79	79	--	79
Astreopora listeri	0.02	1	3	3	3	--	3
Cyphastrea sp.	0.02	1	20	20	20	--	20
Favia sp.	0.02	1	3	3	3	--	3
Fungia scabra	0.02	1	3	3	3	--	3
Goniastrea pectinata	0.02	1	157	157	157	--	157

Species (ranked by abundance) (aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Leptoseris mycetoseroides	0.02	1	3	3	3	--	3
Millepora platyphylla	0.02	1	314	314	314	--	314
Montipora cf. planiscula	0.02	1	20	20	20	--	20
Montipora ehrenbergii	0.02	1	8	8	8	--	8
Montipora grisea	0.02	1	8	8	8	--	8
Pocillopora damicornis	0.02	1	8	8	8	--	8
Porites rus	0.02	1	20	20	20	--	20

Notes:
PT = Proposed Threatened; -- = not applicable
See Section 3.3.2, Coral Species Richness of the species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # [description]).
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)
* *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)
* *Montipora hoffmeisteri sensu* Veron and Wallace (1984); Veron (2000). Not *sensu* Randall and Myers (1983)

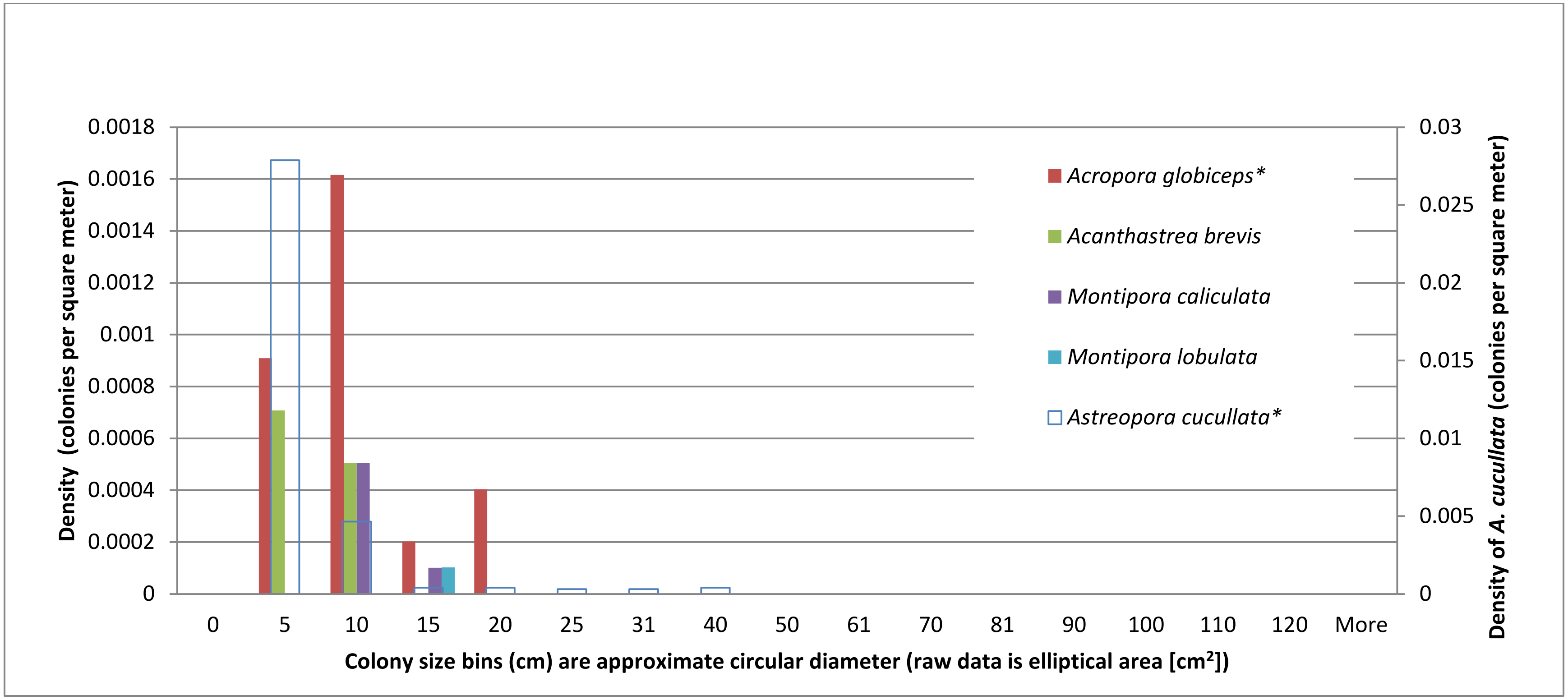

Figure 5-14. Size-Frequency Histogram of the All[1] ESA-Proposed Coral Species from All Samples and Surveys[2] at the Red Beach Potential Construction Area.

Notes:
[1]All five ESA species in this sample are displayed. The *Astreopora cucullata* is displayed on the secondary y-axis (at right) because its abundance is approximately one order of magnitude greater than all other ESA coral species in this location.
[2]Includes 43 10.7-square foot (1-square meter) quadrats, and direct-mapping of approximately 9,899 square meters at the Red Beach Potential Construction Area. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

- * *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)
- * *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)

Table 5-9. ESA-Proposed Coral Colony Demographics from All Samples and Surveys[1] at the Red Beach Potential Construction Area[2]

Species (ranked by abundance) (aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
*Astreopora cucullata** PT	0.0343	340	1	1,178	44	20	20
*Acropora globiceps** PT	0.0031	31	1	201	73	79	79
Acanthastrea brevis PT	0.0012	12	1	79	27	8	14
Montipora caliculata PT	0.0006	6	79	157	92	79	79
Montipora lobulata PT	0.0001	1	157	157	157	--	157

Notes:
PT = Proposed Threatened; -- = not applicable
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.
[1]Includes 43 10.7-square foot (1-square-meter) quadrats, and direct-mapping of approximately 106,552 square feet (9,899 square meters) at the Red Beach Potential Construction Area.
[2]See Figure 1-3, Figure 5-8, and Figure 5-9 for a depiction of the areas.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

* *Astreopora cucullata* (Lamberts 1980) *sensu* Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)

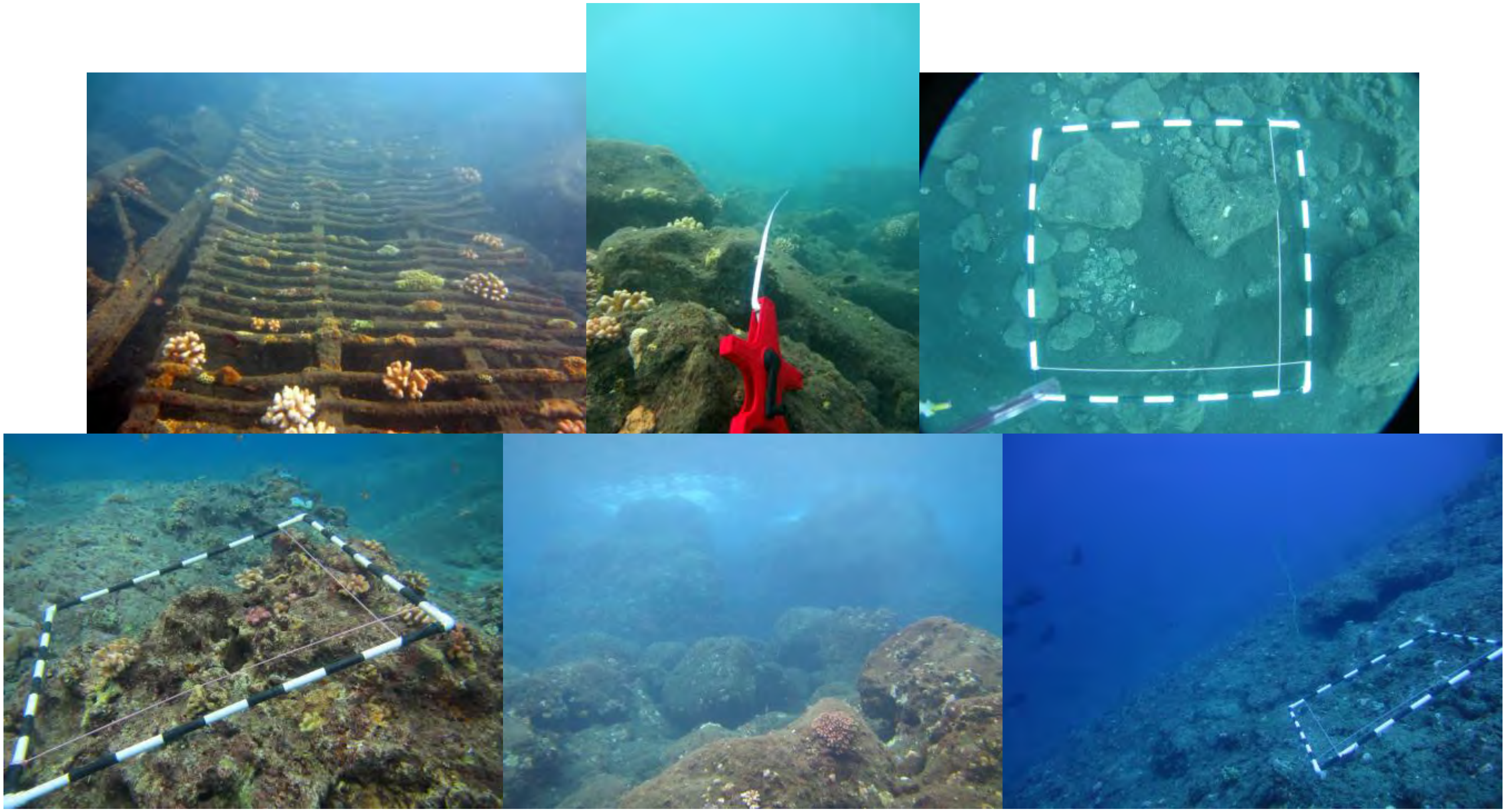

Figure 5-15. Representative Images of the Red Beach Potential Construction Area

Clockwise from top left: Debris within proposed pier construction area; typical seafloor within potential pier construction area; typical seafloor within potential pier construction area; deeper portion of potential breakwater construction area [note slope]; shallower portion of potential breakwater construction area; typical shallow seafloor within potential breakwater construction area

5.4 BLUE BEACH

5.4.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at Blue Beach has low topographic complexity, zero coral cover, and high sand cover (Figure 5-16, Figure 5-17, Figure 5-18, Figure 5-19, and Table 5-10). The occasional rock substrate along the beachfront was flagged and surveyed for ESA-proposed corals (Figure 5-16 and Figure 5-19). No ESA-proposed corals were recorded from the beachfront area shallower than 12 feet (4 meters). Within this method's search area, there were no portions of Blue Beach seafloor that were high complexity and none that were moderate or high coral cover. The basement substrate is coarse-grain igneous sand and cobble. Where corals occur, the dominant substrate is igneous and there is no evidence of carbonate framework buildup. Representative images of Blue Beach are shown in Figure 5-20.

5.4.2 Coral Species Richness

Summary species richness results for Blue Beach and all other Pagan sites are presented in Table 4-2, and detailed records of individual species for Blue Beach and all other sites are presented in Appendix A. Among the 108 records are 11 ESA-proposed coral species and 5 irresolvable species (see Appendix D for representative images of ESA-proposed species). None of the 5 irresolvable records necessarily represent an additional species record for the site (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness).

5.4.3 ESA Coral Demographics

Blue Beach has zero ESA-proposed coral colonies directly in front of the sandy beach, at depths shallower than 12 feet (4 meters), making the site a candidate for the proposed activities with unlikely potential effects on coral. The headlands to the north and south have ESA-proposed corals (Table 4-2, Appendix A), but these headlands seem unlikely to be exposed to the proposed activities.

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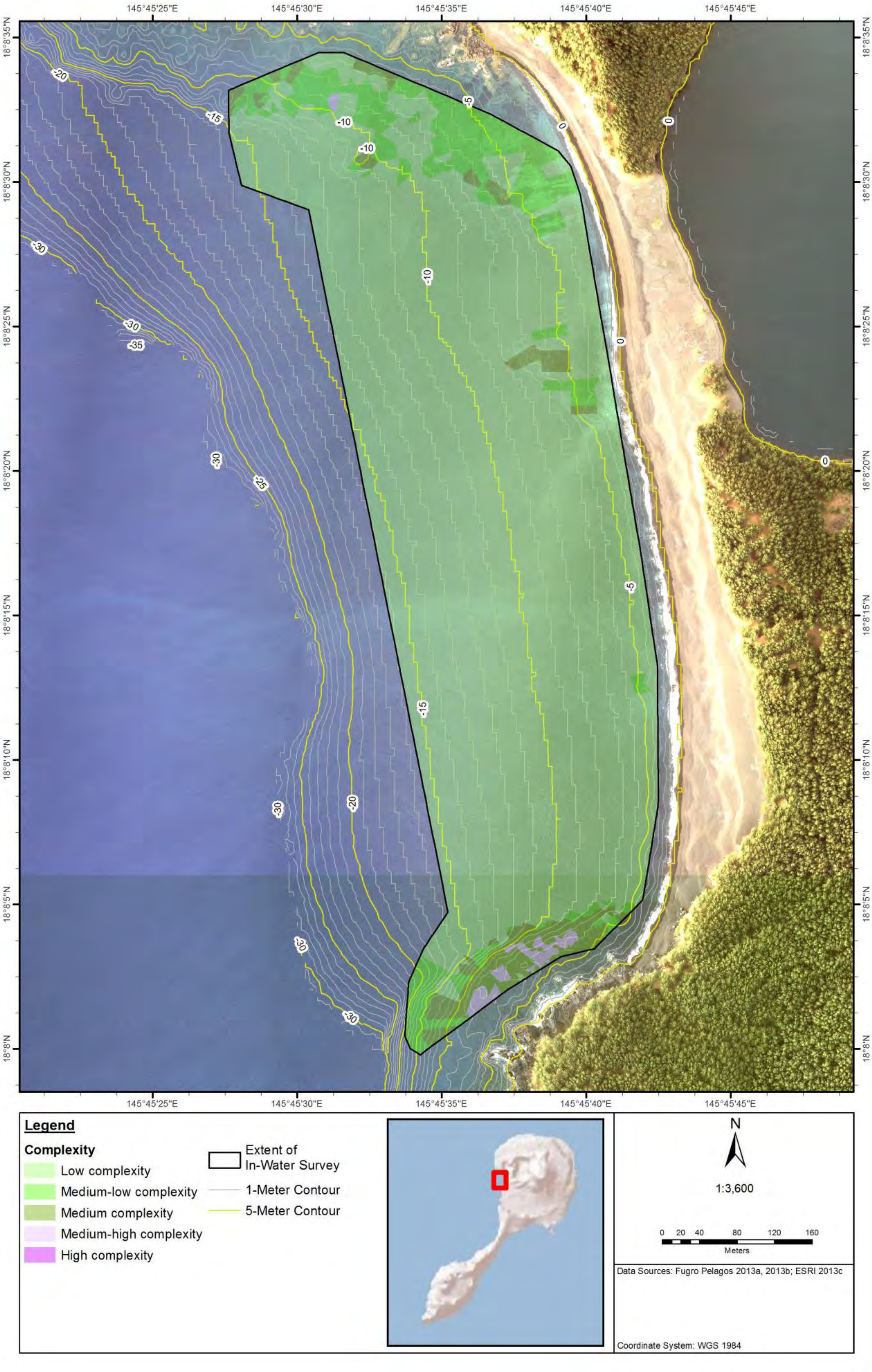

Figure 5-16. Blue Beach In Situ Broad-Scale Topographic Complexity

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Figure 5-17. Blue Beach In Situ Broad-Scale Coral Cover

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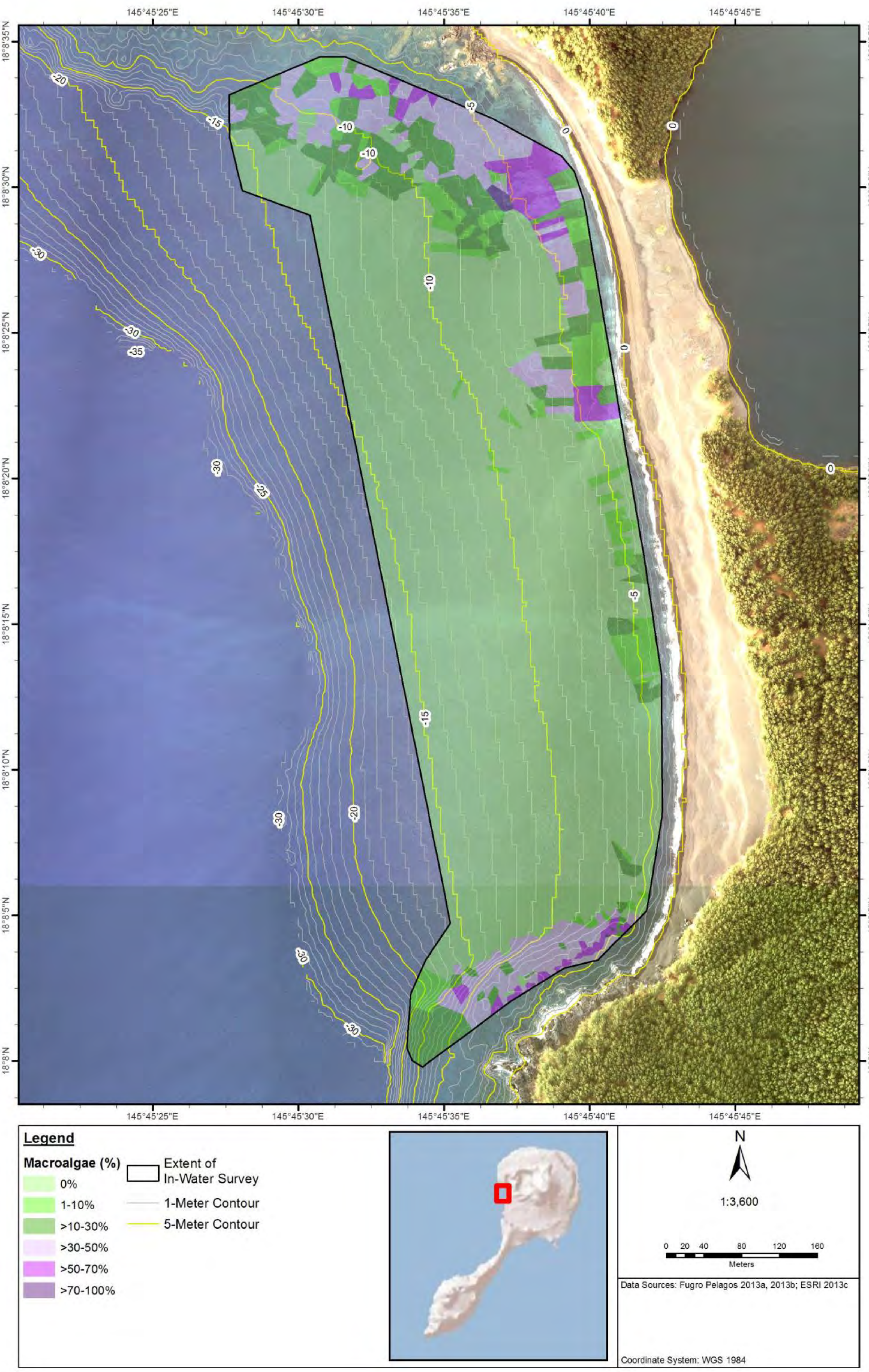

Figure 5-18. Blue Beach In Situ Broad-Scale Macroalgae Cover

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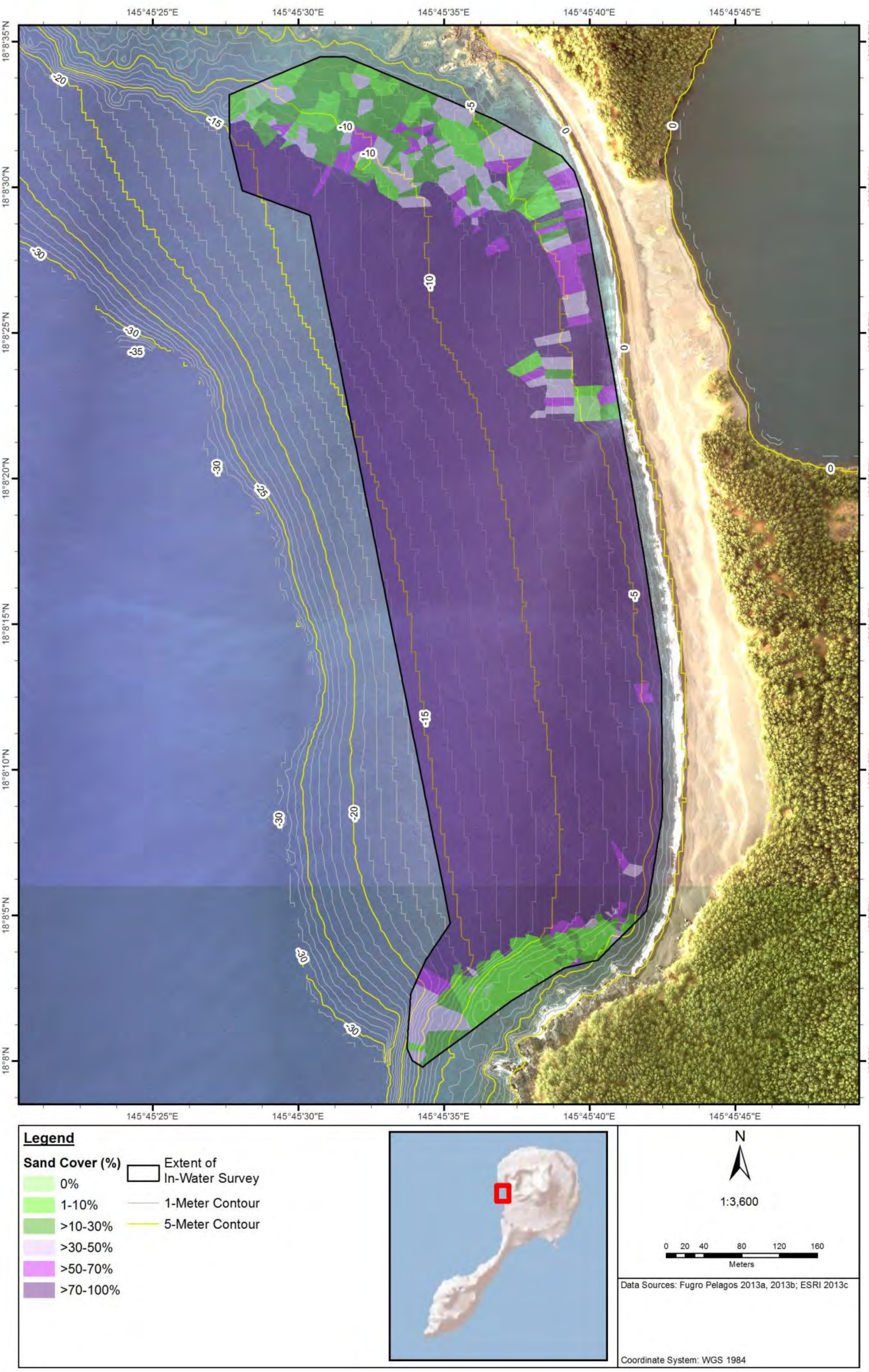

Figure 5-19**. Blue Beach In Situ Broad-Scale Sand Cover**

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Table 5-10. Broad-Scale Surveys at Blue Beach (Square Meter, % Cover)

Blue Beach total Area[1] = 252,856 square meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	219,019	22,059	9,793	1,985	0	0	--	--	--
	--	87%	8.7%	3.9%	0.8%	0.0%	0.0%	--	--	--
Coral	211,222	30,687	6,608	2,028	844	257	1,053	159	0	0
	84%	12%	2.6%	0.8%	0.3%	0.1%	0.4%	0.1%	0.0%	0.0%
Macroalgae	184,442	14,549	8,546	13,653	13,393	9,994	5,521	2,320	34	404
	73%	5.8%	3.4%	5.4%	5.3%	4.0%	2.2%	0.9%	0.0%	0.2%
Sand	1,385	15,212	7,030	9,191	8,093	6,015	3,206	5,108	5,206	192,411
	0.5%	6.0%	2.8%	3.6%	3.2%	2.4%	1.3%	2.0%	2.1%	76%

Notes:
-- = no data
[1]See Figure 5-1 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

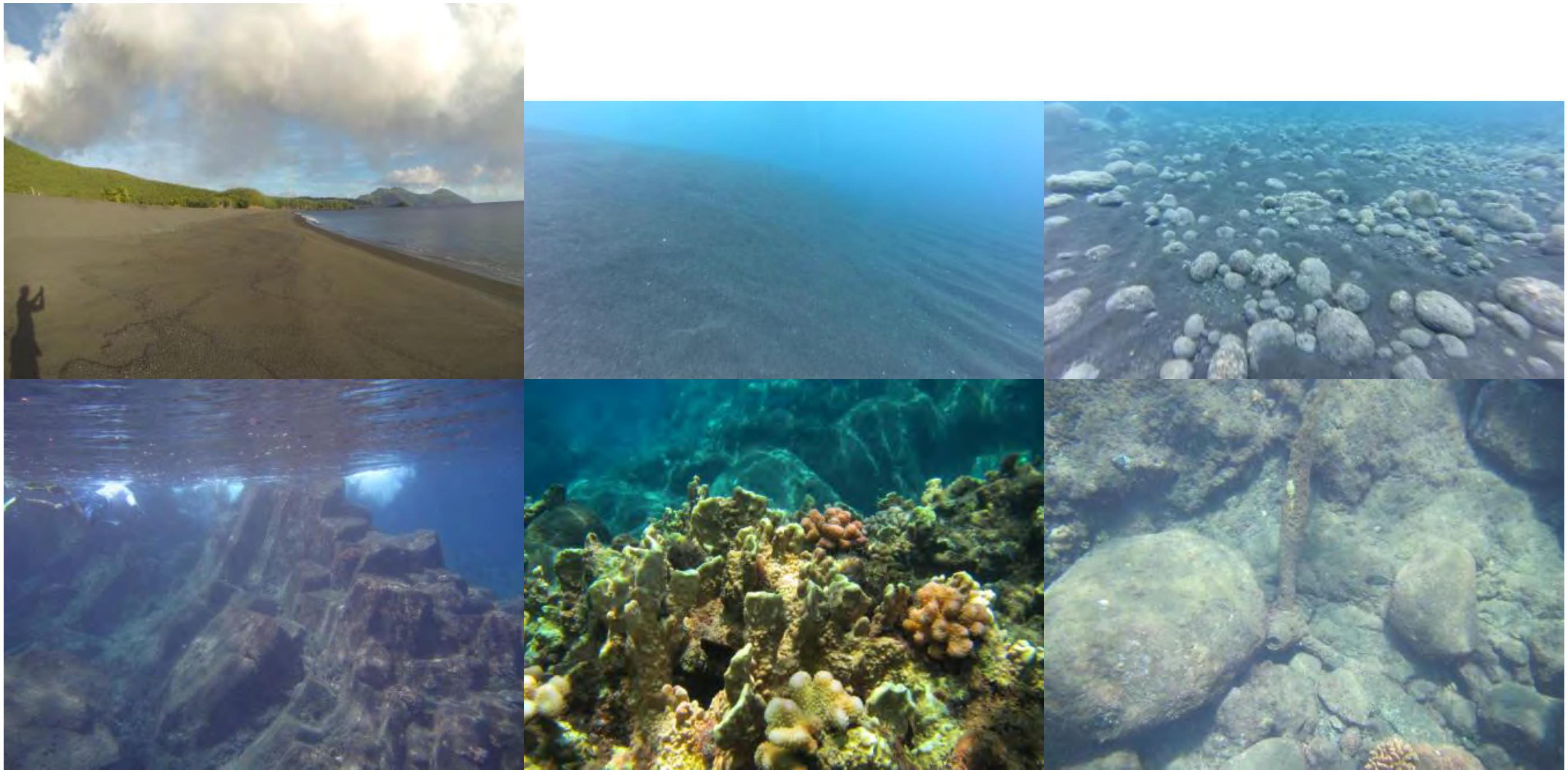

Figure 5-20. Representative Images of Blue Beach

Clockwise from top left: Blue Beach from north end; center of beach; center of beach; debris at southern headland; patches of richer coral growth at northern headland; southern headland

5.5 NORTH BEACH

Broad-scale habitat mapping, coral demographics, and ESA coral demographics were not conducted at North Beach because it was a low priority objective. The shoreline of North Beach is a shore-attached fringing reef crest with karst characteristics (chemically weathered limestone). Compared with Gold and South beaches, grooves are relatively regular, narrow, and deep. Other narrow grooves run diagonally to the shore-normal spur and groove pattern, and have the physical characteristics of cracks or fissures. Many of the spurs are deeply undercut, and fracturing seems likely in this geologically active setting (Riegl et al. 2008). The bases of grooves often have polished surfaces indicating high-energy sediment transport and erosion.

5.5.1 Coral Species Richness

Summary species richness results for North Beach and all other Pagan sites are presented in Table 4-2, and detailed records of individual species for North Beach and all other sites are presented in Appendix A. Among the 33 records are 3 ESA-proposed coral species and 3 irresolvable species (see Appendix D for representative images of ESA-proposed species). None of the 3 irresolvable records necessarily represent an additional species record for the site (see Section 2.3, Challenges with Coral Identification and Section 3.3.2, Coral Species Richness). Notably absent from the list of ESA-proposed corals were the *Montipora* species encountered at all of the leeward sites. The low species number at North Beach is only partially an artifact of restricted search effort. While it is likely that additional effort would find additional coral species, all observers agreed that North Beach has a depauperate coral assemblage relative to other sites on Pagan. Representative images of North Beach are shown in Figure 5-21.

Figure 5-21. Representative Images of North Beach

Clockwise from top left: North Beach from east end; blowhole at east end of beach; corals on shallow fore reef; fissures in shallow fore reef; typical shallow fore reef; fissures in fore reef

5.6 GOLD BEACH

Coral demographics and ESA coral demographics were not conducted at Gold Beach because it was a low-priority objective. Even on an atypically calm day, July 12, 2013, conditions shallower than 12 feet (4 meters) were too rough for fine-scale surveys, and habitat shallower than 6 feet (2 meters) was inaccessible. The cliff walls and steep fringing reef reflected incoming waves from several directions, resulting in steep and confused seas on a remarkably calm day (July 12, 2013) and dangerous standing waves on a typical day (July 15, 2013). The exaggerated water motion likely transports much of the sand to deeper water as would be expected. Because of these rough conditions, habitat mapping could not be safely conducted in the shallows of Gold Beach.

5.6.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at Gold Beach has moderate topographic complexity, high coral cover, and low or zero sand cover (Figure 5-22, Figure 5-23, Figure 5-24, Figure 5-25, and Table 5-1). The reef area was highly physically complex, with deep irregular groves and fractures. The shoreline of Gold Beach is a shore-attached fringing reef crest with karst characteristics (chemically weathered limestone). Gold Beach sits at the end of an irregularly shaped, cliff-lined cove. The basement substrate is limestone, and away from the adjacent cliffs no igneous substrate or clasts were visible. The bases of grooves often had polished surfaces, indicating high-energy sediment transport and erosion.

5.6.2 Coral Species Richness

Summary species richness results for Gold Beach and all other Pagan sites are presented in Table 4-2, and detailed records of individual species for Gold Beach and all other sites are presented in Appendix A. Among the 82 records are 5 ESA-proposed coral species and 2 irresolvable species (see Appendix D for representative images of ESA-proposed species). Neither of the 2 irresolvable records necessarily represents an additional species record for the site (see Section 2.3, Challenges with Coral Identification, and Section 3.3.2, Coral Species Richness). Representative images of Gold Beach are shown in Figure 5-26.

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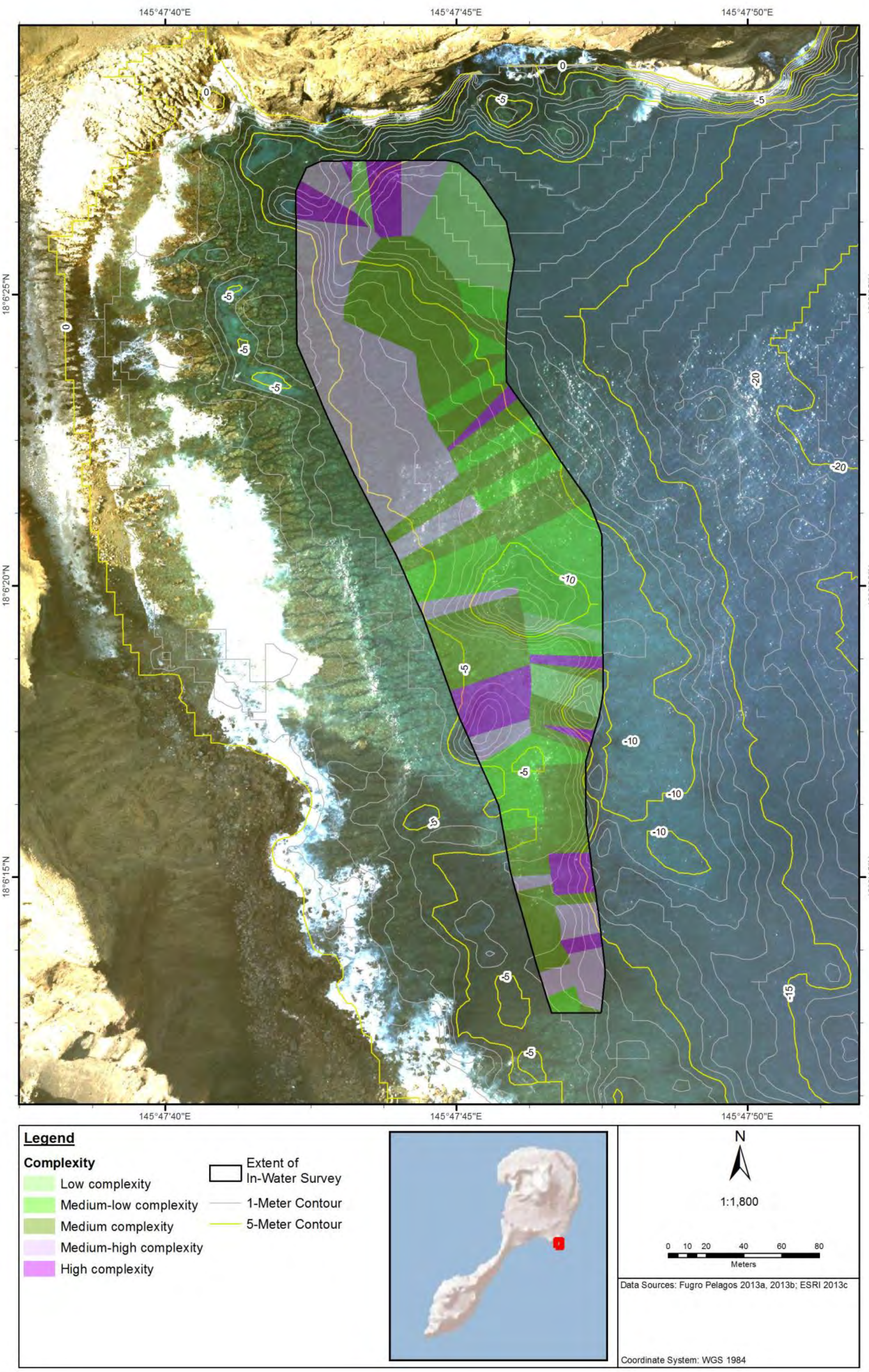

Figure 5-22. Gold Beach In Situ Broad-Scale Topographic Complexity

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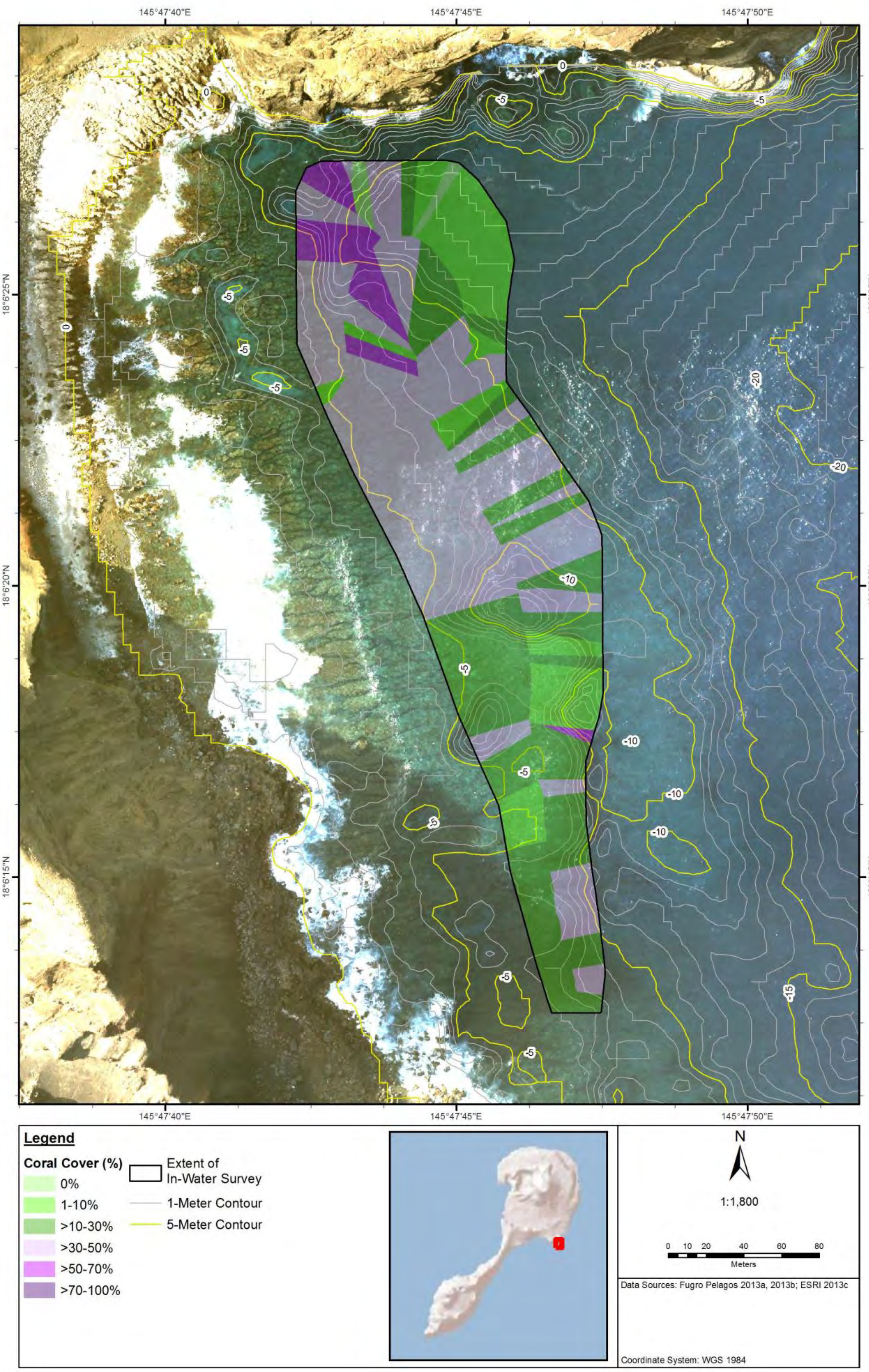

Figure 5-23. Gold Beach In Situ Broad-Scale Coral Cover

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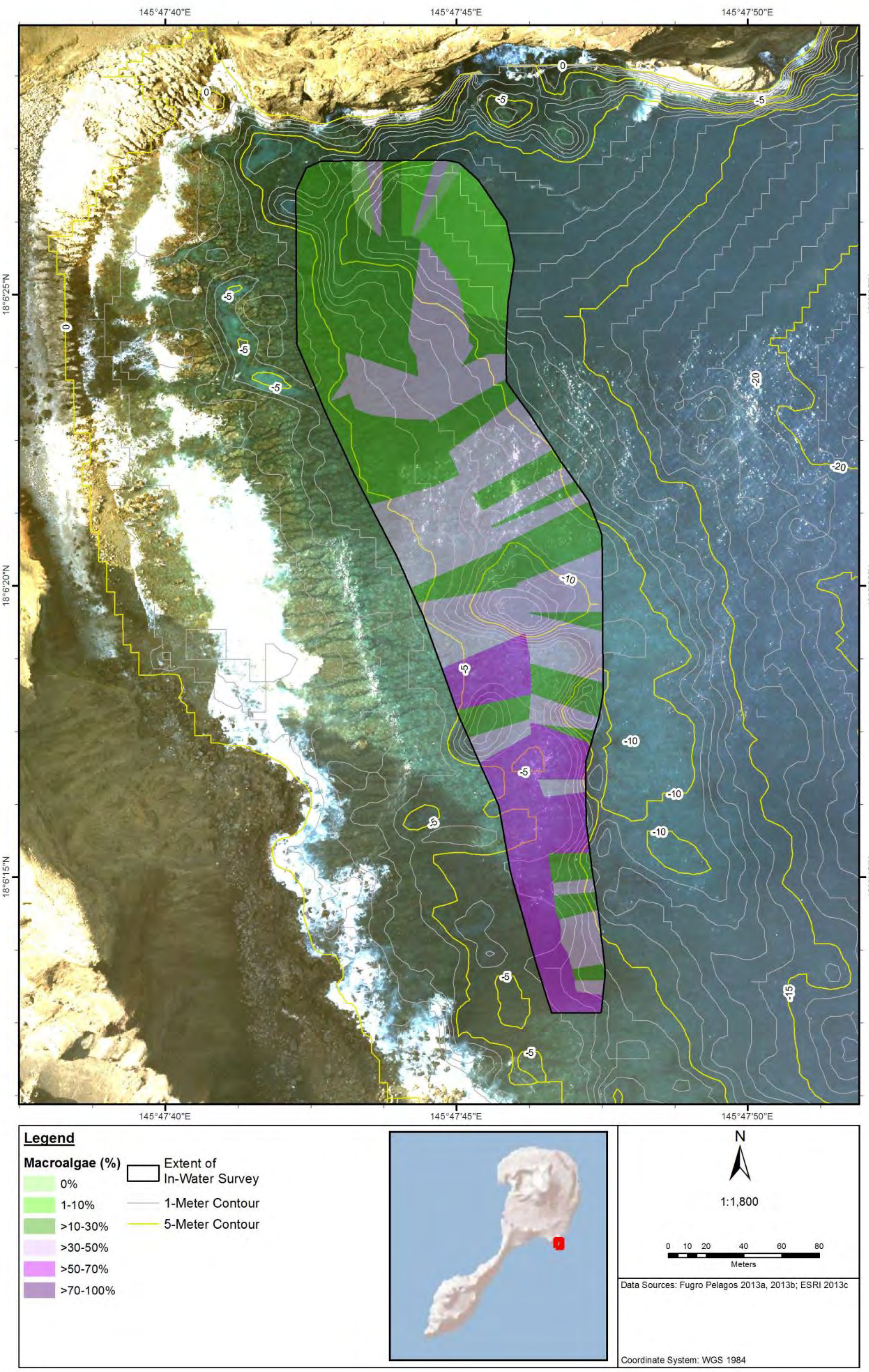

Figure 5-24. Gold Beach In Situ Broad-Scale Macroalgae Cover

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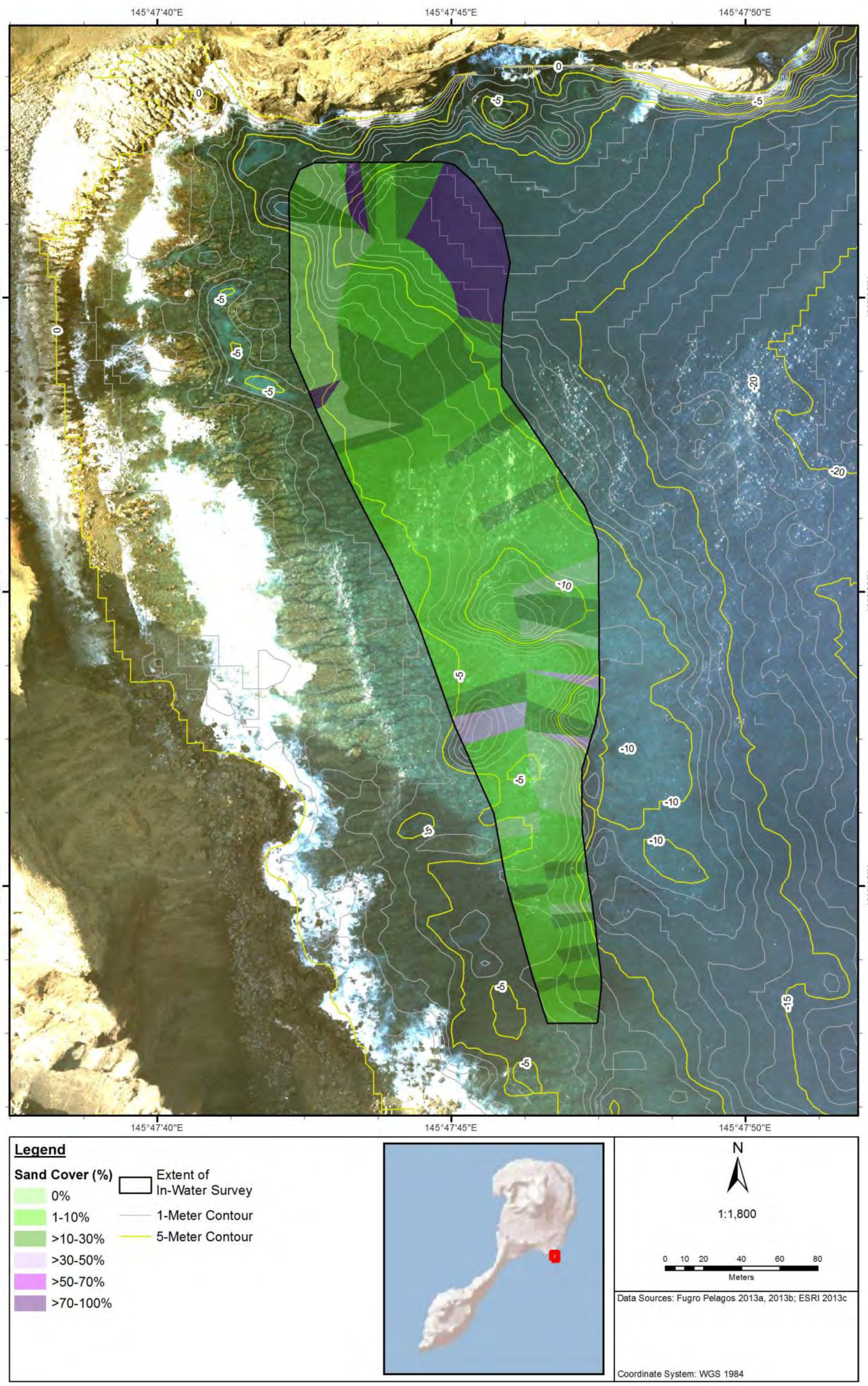

Figure 5-25. Gold Beach In Situ Broad-Scale Sand Cover

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Table 5-11. Broad-Scale Surveys at Gold Beach (Square Meter, % Cover)

Gold Beach total area[1] = 35,881 square meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	3,325	7,267	12,086	9,937	3,265	0	--	--	--
	--	9.3%	20%	34%	28%	9.1%	0.0%	--	--	--
Coral	475	5,728	3,281	7,808	7,640	8,752	1,727	469	0	0
	1.3%	16%	9.1%	22%	21%	24%	4.8%	1.3%	0.0%	0.0%
Macroalgae	475	2,730	1,348	12,445	8,507	4,935	5,318	122	0	0
	1.3%	7.6%	3.8%	35%	24%	14%	15%	0.3%	0.0%	0.0%
Sand	5,282	19,428	6,050	1,519	100	623	0	0	1,401	1,476
	15%	54%	17%	4.2%	0.3%	1.7%	0.0%	0.0%	3.9%	4.1%

Notes:
-- = no data
[1]See Figure 5-22 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

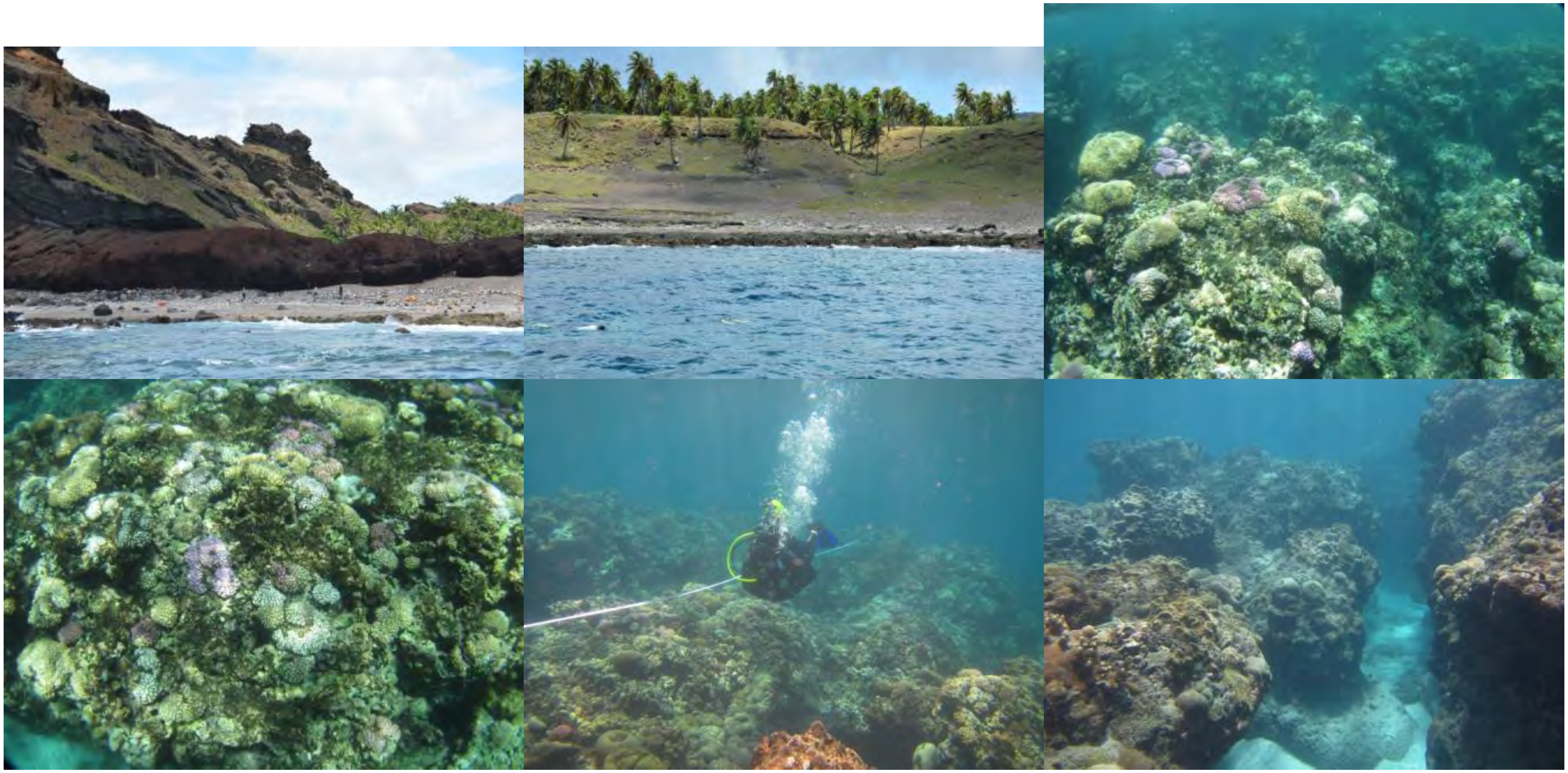

Figure 5-26. Representative Images of Gold Beach

Clockwise from top left: Southern half of Gold Beach; northern half of Gold Beach; topographically complex shallow fore reef; topographically complex deeper fore reef; typical deeper fore reef; typical shallow fore reef

5.7 SOUTH BEACH

5.7.1 Broad-Scale Surveys

Most of the area surveyed for habitat mapping at South Beach had low to moderate topographic complexity, low to moderate coral cover, and bi-modal sand cover at both low and very high (Figure 5-27, Figure 5-28, Figure 5-29, Figure 5-30, and Table 5-12). The shallow fore reef and reef crest area was physically complex, with narrow regular groves in the shallow fore reef, with a relatively steep transition to the deep fore reef morphology of low-relief relict spurs punctuated by massive *Porites* colonies (typically 10-20 feet [3-6 meters] diameter; Figure 5-33). The basement substrate is limestone, and no igneous substrate or clasts were visible. The bases of grooves shallower than 16 feet (5 meters) often had polished surfaces and polished cobble-sized clasts, indicating high-energy sediment transport and erosion. The shoreline of South Beach is a shore-attached fringing reef crest with karst characteristics (chemically weathered limestone). Shallower than 10 feet (3 meters), the South Beach fringing reef is remarkably homogenous. An exception is the prominent sand channel running from offshore to inshore just east of the center of South Beach. This sand channel is about 330 feet (100 meters) wide and runs up to the exposed shore-attached fringing reef crest with karst characteristics; Figure 5-30 shows this wide sand channel at approximately 18° 6′ 28″ N by 145° 47′ 06″ E.

5.7.2 Coral Species Richness

Summary species richness results for South Beach and all other Pagan sitesare presented in Table 4-2, and detailed records of individual species for South Beach and all other sites are presented in Appendix A. Among the 101 records are 7 ESA-proposed coral species and 7 irresolvable species (see Appendix D for representative images of ESA-proposed species). None of the 7 irresolvable records necessarily represent an additional species record for the site (see Section 2.3, Challenges with Coral Identification, and Section 3.3.2, Coral Species Richness). The demographic data below, that irresolvable colonies are relatively uncommon. Representative images of South Beach are shown in Figure 5-33.

5.7.3 Coral Demographics

South Beach was sampled with 69 quadrats, each 10.7 square feet (1 square meter; Appendix B, DoN 2014a). A total of 66 species of corals fell within quadrats, the most abundant of which was *Favia pallida*, with an estimated density of 0.35 colonies per square foot (3.7 colonies per square meter). Size-structure of the most frequently occurring species is shown in Figure 5-31. Within this set, most colonies are smaller than 4 inches (10 centimeters; approximate circular diameter); however, several species attained maximum sizes approaching 4.3 sqaure feet (0.4 square meter) (Table 5-13). Size distribution was skewed toward small colonies for most species with more than two colonies in the sample (compare average with median size in Table 5-13).

The habitat was relatively homogeneous along the entire shallow fore reef zone in the uppermost 12 feet (4 meters). Due to surf and surge, the shore-attached reef crest and shallowest 3 feet (1 meter) of the fore reef was inaccessible at high and low tides, on two separate days of typical weather. The easternmost reaches of South Beach were in the wave-shadow of the headlands farther to the east, and surf was relatively small even on days of typical trade-wind weather. In total, 1,721 corals were counted within 69 quadrats, meaning that a hypothetical average quadrat had about 24 coral colonies. Corals were so numerous that some quadrats required 40 to 60 minutes each.

5.7.4 ESA Coral Demographics

South Beach contains many ESA-proposed corals in front of the sandy beach because, unlike the leeward beaches, the entire beach has a shore-attached fringing reef (Appendix B, DoN 2014a). Four "blocks" of habitat were surveyed with quadrats (Figure 1-3). The habitat was heterogeneous among depth zones but was relatively homogeneous within depth zones. An exception to this homogeneity was the prominent sand channel found during the broad-scale surveys; however, this feature was not sampled with quadrats because it was not known until after the quadrat surveys were complete. Sixty-nine quadrats, each 10.7 square feet (1 square meter), were collected from the four sites, and these informed the demographics of ESA-proposed corals as well as coral species in general.

ESA-proposed coral demographics were estimated by extrapolating from the 69 quadrats to the approximate area of South Beach shallower than 16 feet (5 meters). The most commonly found ESA-proposed species was *Acanthastrea brevis*, with 143 colonies from quadrats (or nearly 270,000 when extrapolated to the beach area; Appendix B, and see Appendix D for representative images of ESA-proposed species). This high number is largely due to the great size of the reefs at South Beach.

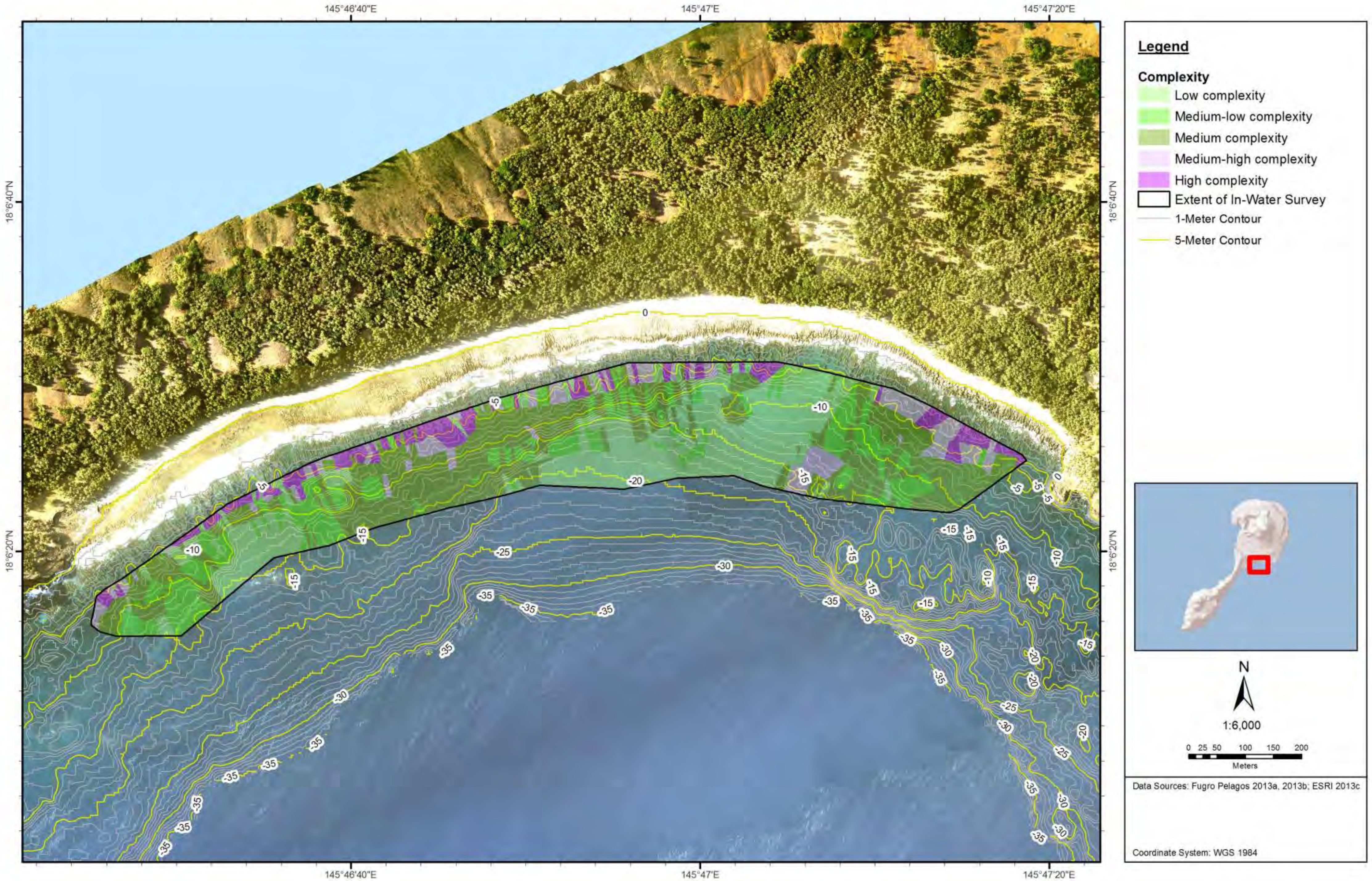

Figure 5-27. South Beach In Situ Broad-Scale Topographic Complexity

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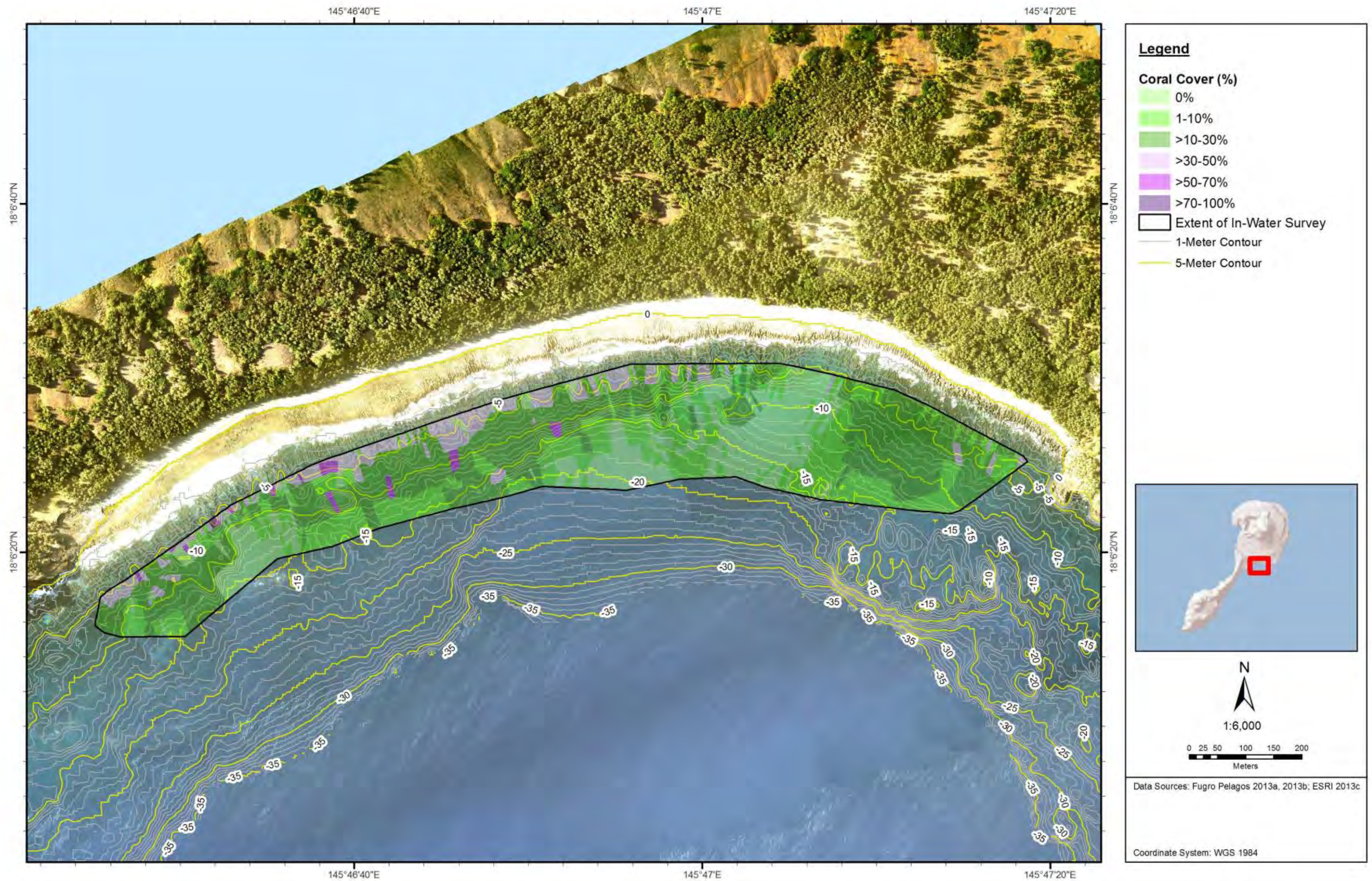

Figure 5-28. South Beach In Situ Broad-Scale Coral Cover

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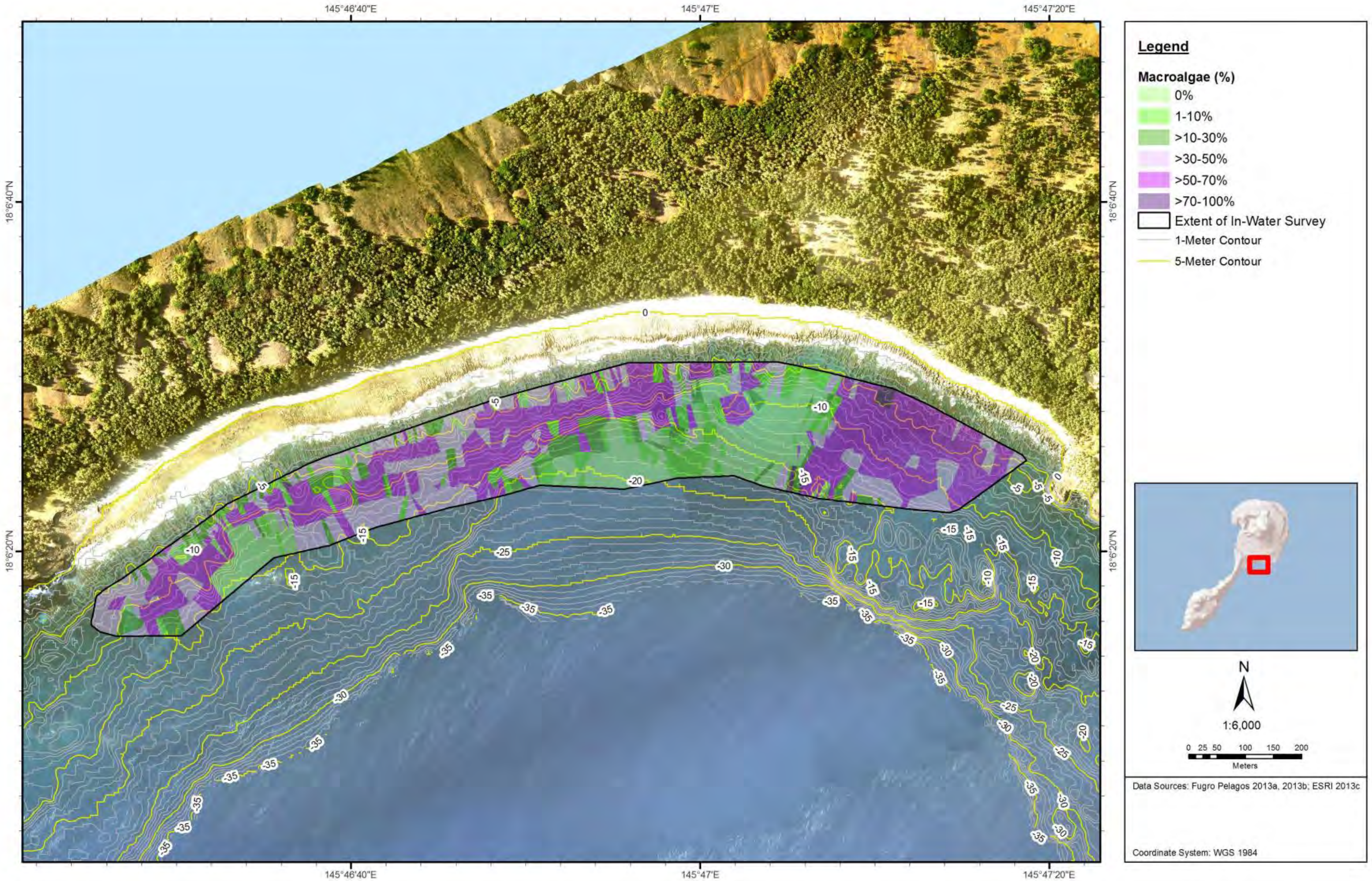

Figure 5-29. South Beach In Situ Broad-Scale Macroalgae Cover

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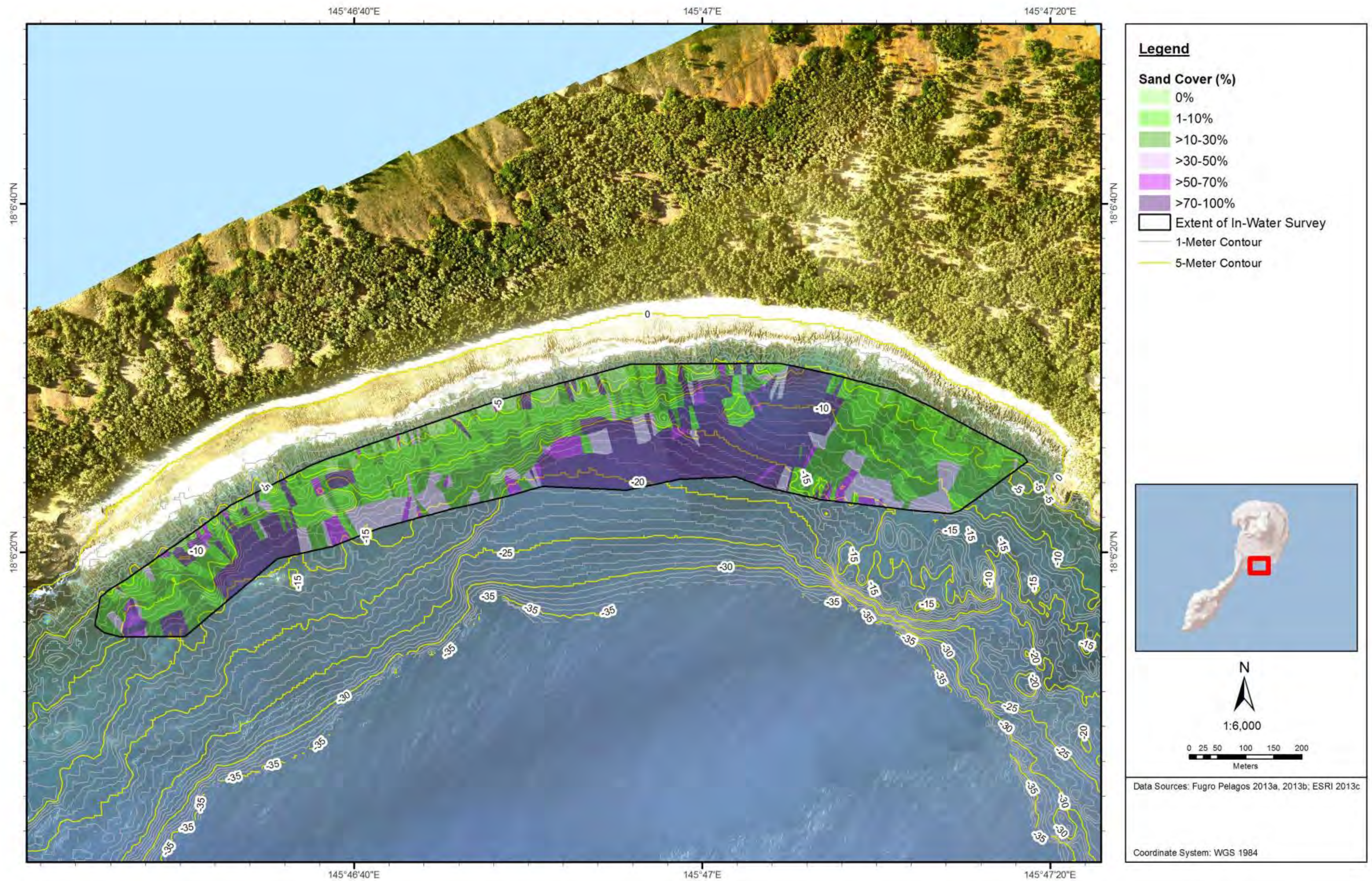

Figure 5-30. South Beach In Situ Broad-Scale Sand Cover

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Table 5-12. Broad-Scale Surveys at South Beach (Square Meter, % Cover)

Gold Beach total area[1] = 268,541 square meters										
Class[2]	***0%***	***1 - 10%***	***2 - 20%***	***3 – 30%***	***4 – 40%***	***5 – 50%***	***6 – 60%***	***70%***	***80%***	***90%***
Complexity[3, 4]	--	79,116	51,203	94,501	22,789	20,932	0	--	--	--
	--	30%	19%	35%	8.5%	7.8%	0.0%	--	--	--
Coral	58,776	75,284	63,980	44,124	12,197	10,879	1,984	1,189	128	0
	22%	28%	24%	16%	4.5%	4.1%	0.7%	0.4%	0.0%	0.0%
Macroalgae	54,884	22,684	8,840	11,672	10,511	52,569	52,644	52,980	1,638	118
	20%	8.4%	3.3%	4.3%	3.9%	20%	20%	20%	0.6%	0.0%
Sand	11,776	77,024	43,489	21,229	11,936	14,824	4,365	6,317	7,450	70,130
	4.4%	29%	16%	7.9%	4.4%	5.5%	1.6%	2.4%	2.8%	26%

Notes:
-- = no data
[1]See Figure 5-27 for a depiction of the area boundaries.
[2]Class refers to topographic complexity on a scale of 1-6 or percent cover. See Section 3.3, Survey Methods.
[3]Topographic complexity on a scale of 1-6. See Section 3.3, Survey Methods.
[4]% indicates the area within each class divided by the total area surveyed.

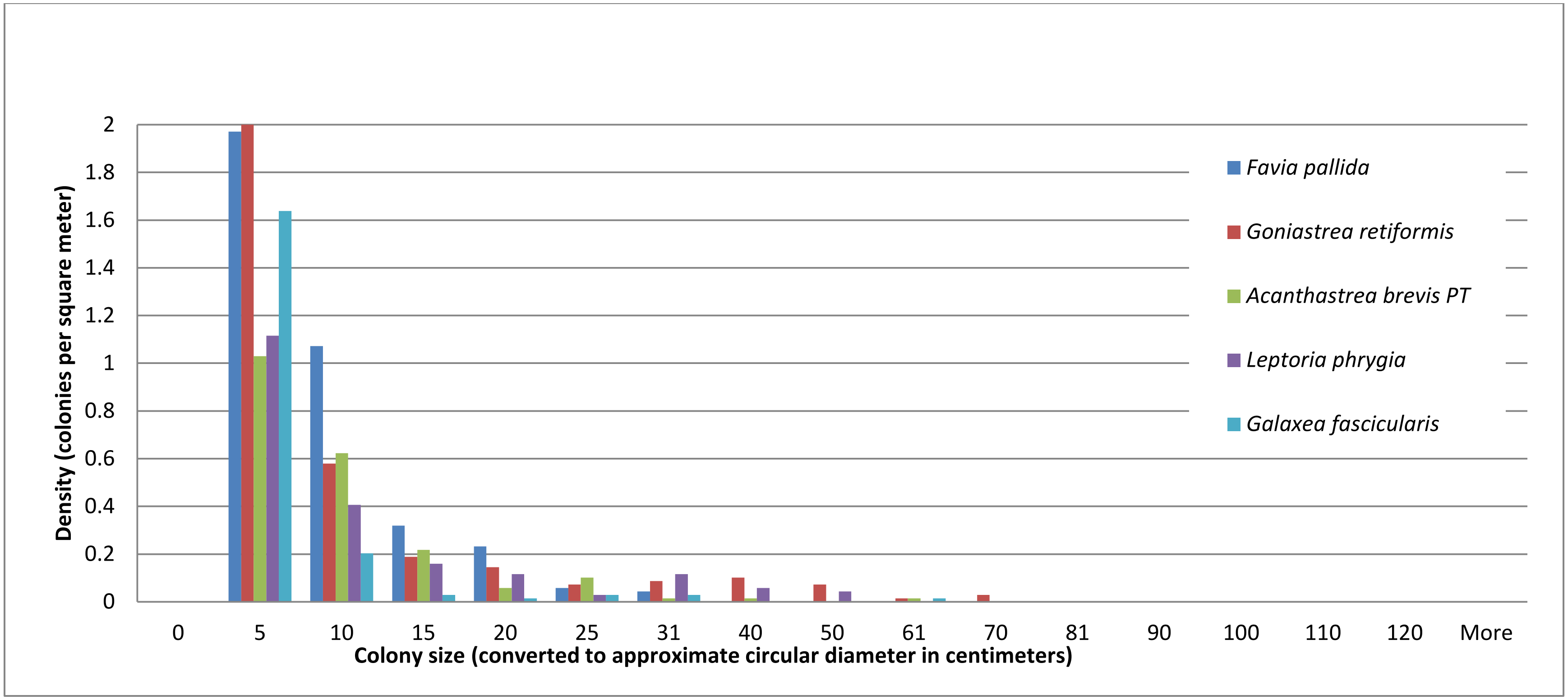

Figure 5-31. Size-Frequency Histogram of the Most[1] Abundant Corals at South Beach[2].
See Table 5-13 for Summary Statistics

Notes:
PT = Proposed Threatened
[1]Five species make up the top 50th percentile at South Beach.
[2]Includes 69 10.7-square foot (1-square-meter) quadrats at South Beach. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

Table 5-13. Coral Demographics Summary Statistics from All Quadrats at South Beach (n=69)

Species (ranked by abundance; aggregate for the whole beach)	*Density*	*Count*	*Minimum Size (cm^2)*	*Maximum Size (cm^2)*	*Average Size (cm^2)*	*Mode Size (cm^2)*	*Median Size (cm^2)*
Favia pallida	3.70	255	1	707	71	20	20
Goniastrea retiformis	3.29	227	1	3,299	175	3	20
Acanthastrea brevis PT	2.07	143	1	2,749	102	20	39
Leptoria phrygia	2.04	141	1	1,571	151	20	20
Galaxea fascicularis	1.96	135	1	2,749	58	20	20
Favia matthaii	1.74	120	1	942	148	20	79
Favia stelligera	1.35	93	1	3,770	172	39	39
Pavona varians	1.23	85	1	942	52	3	8
Acanthastrea echinata	0.97	67	1	707	66	39	20
Montastrea curta	0.70	48	1	628	46	20	20
Platygyra pini	0.67	46	1	707	141	3	39
Goniastrea edwardsi	0.54	37	3	471	87	79	79
Porites rus	0.39	27	3	2,749	288	3	39
Pocillopora verrucosa	0.38	26	20	157	60	20	59
Cyphastrea microphthalma	0.33	23	1	39	8	3	3
Cyphastrea chalcidicum	0.30	21	1	39	7	3	3
Pavona chiriquensis	0.28	19	1	39	11	3	3
Cyphastrea serailia	0.25	17	1	236	58	8	20
Pocillopora meandrina	0.20	14	3	79	42	79	39
Favia favus	0.19	13	20	785	201	39	79
Pavona species 1 (high, narrow collines, tentacle tips always visible	0.17	12	3	314	55	79	20
Pocillopora sp.	0.16	11	1	79	12	3	3
*Acropora ocellata **	0.09	6	3	20	17	20	20
*Acropora surculosa **	0.09	6	20	471	252	236	236
Leptastrea purpurea	0.09	6	3	314	63	20	20
Pavona clavus	0.09	6	20	314	160	314	118

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm²)***	***Maximum Size (cm²)***	***Average Size (cm²)***	***Mode Size (cm²)***	***Median Size (cm²)***
Pavona duerdeni	0.09	6	20	157	65	79	59
Pocillopora eydouxi	0.09	6	20	157	69	39	59
Pocillopora setchelli	0.09	6	3	236	57	20	20
Porites solida	0.09	6	3	1,885	325	20	20
Acropora globiceps * PT	0.07	5	39	471	196	79	79
Acropora verweyi PT	0.07	5	39	707	401	--	471
Cyphastrea sp.	0.07	5	8	79	31	8	20
Hydnophora microconos	0.07	5	3	39	18	20	20
Montastrea cf. valenciennesi	0.07	5	20	157	55	39	39
Montipora sp.	0.07	5	3	314	191	314	314
Platygyra daedalea	0.07	5	20	79	47	20	39
Acropora tenuis	0.06	4	157	1,571	628	--	393
Porites sp.	0.06	4	12	628	173	12	26
Stylocoeniella armata	0.06	4	1	1	1	1	1
Acropora abrotanoides	0.04	3	20	39	26	20	20
Favites flexuosa	0.04	3	20	785	295	--	79
Goniastrea sp.	0.04	3	3	39	19	--	16
Montipora grisea	0.04	3	3	707	315	--	236
Porites lutea	0.04	3	157	2,749	1,597	--	1,885
Psammocora digitata	0.04	3	79	1,963	759	--	236
Acropora palmerae PT	0.03	2	8	314	161	--	161
Acropora sp.	0.03	2	20	39	29	--	29
Echinopora aff. lamellosa	0.03	2	20	39	29	--	29
Goniopora somaliensis	0.03	2	39	157	98	--	98
Montipora verrucosa	0.03	2	79	157	118	--	118
Porites annae	0.03	2	20	79	49	--	49
Porites lobata	0.03	2	236	314	275	--	275

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Stylocoeniella guentheri	0.03	2	3	20	11	--	11
Acropora wardii	0.01	1	157	157	157	--	157
Cyphastrea agassizi *	0.01	1	157	157	157	--	157
Favites sp.	0.01	1	31	31	31	--	31
Gardineroseris planulata	0.01	1	20	20	20	--	20
Heliopora coerulea	0.01	1	3	3	3	--	3
Millepora tuberosa PT	0.01	1	707	707	707	--	707
Montastrea annuligera *	0.01	1	8	8	8	--	8
Pavona maldivensis	0.01	1	8	8	8	--	8
Pocillopora ankeli	0.01	1	79	79	79	--	79
Pocillopora cf. ligulata	0.01	1	39	39	39	--	39
Pocillopora elegans PT	0.01	1	471	471	471	--	471
Scolymia australis	0.01	1	1	1	1	--	1

Notes:
PT = Proposed Threatened; -- = no data
See Section 3.3.2, Coral Species Richness, for a description of the species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # [description]).
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)
* *Acropora ocellata* (Klunzinger 1879) *sensu* Randall and Myers (1983); not *sensu* Veron (2000)
* *Acropora surculosa sensu* Veron (2000), not = *Acropora hyacinthus sensu* Wallace (1999)
* *Cyphastrea agassizi* (Vaughan 1907) *sensu* Veron (2000) = *Leptastrea bottae* (Milne Edwards and Haime 1849) *sensu* Randall and Myers (1983)
* *Montastrea annuligera sensu* Veron (2000)

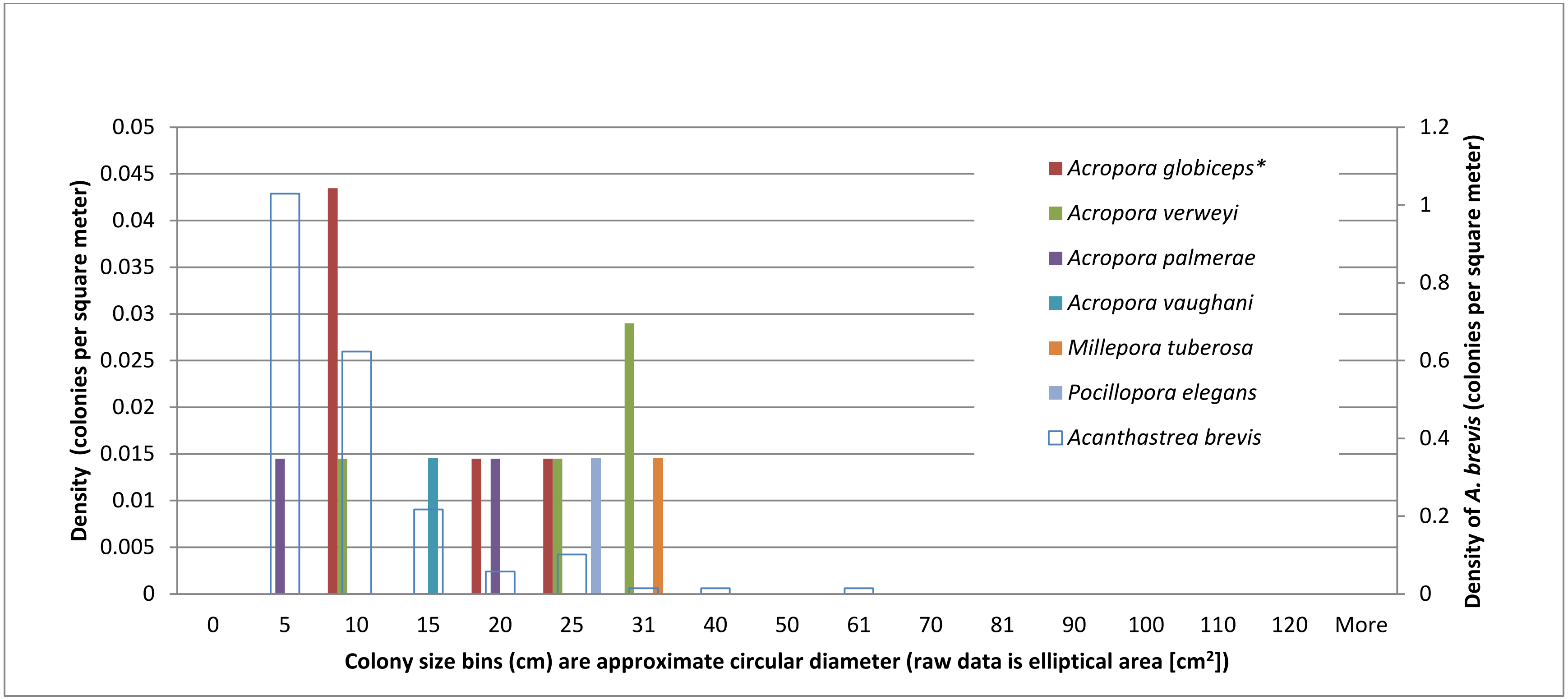

Figure 5-32. Size-Frequency Histogram of the All[1] ESA-Proposed Coral Species from All Samples and Surveys[2] at South Beach

Notes:

[1]All seven ESA species in this sample are displayed. The *Acanthastrea brevis* is displayed on the secondary y-axis (at right) because its abundance is approximately one order of magnitude greater than all other ESA coral species in this location.

[2]Includes 69 10.7-square foot (1-square meter) quadrats at South Beach. Coral colony sizes converted to approximate circular diameter for display only. See Table 3-2 for conversion between elliptical area and approximate circular diameter. All analyses are based on the elliptical area (cm^2) of each colony.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

Table 5-14. ESA-Proposed Coral Colony Demographics from All Samples[1] at South Beach.

Species (ranked by abundance; aggregate for the whole beach)	***Density***	***Count***	***Minimum Size (cm^2)***	***Maximum Size (cm^2)***	***Average Size (cm^2)***	***Mode Size (cm^2)***	***Median Size (cm^2)***
Acanthastrea brevis PT	2.07	143	1	2,749	102	20	39
*Acropora globiceps** PT	0.07	5	39	471	196	79	79
Acropora verweyi PT	0.06	4	39	707	461	--	550
Acropora palmerae PT	0.03	2	8	314	161	--	161
Acropora vaughani PT	0.01	1	157	157	157	--	157
Millepora tuberosa PT	0.01	1	707	707	707	--	707

Notes:
PT = Proposed Threatened; -- = no data
Coral colony sizes show elliptical area, see Table 3-2 for conversion between elliptical area and approximate circular diameter.
[1]Includes 69 10.7-square foot (1-square meter) quadrats at South Beach. See Figure 1-3, Figure 5-27, and Figure 5-28 for a depiction of the areas.

* *Acropora globiceps* (Dana 1846) *sensu* Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)

Figure 5-33. Representative Images of South Beach

Clockwise from top left: South Beach, showing survey team; typical shallow fore reef; typical deeper fore reef; deeper sand channel; typical large *Porites* head; typical shallow fore reef

5.8 INCIDENTAL SIGHTINGS OF OTHER MARINE ORGANISMS

Sightings of sea turtles and marine mammals were reported separately (DoN 2014b, 2014c). Giant clams (*Tridacna* spp.) were observed at all six sites on Pagan. Spider conch (*Lambis* spp.) were observed at Green and Red Beaches. No ESA fish were observed at Pagan sites.

5.9 SUMMARY – PAGAN BEACHES

Using available materials regarding the potential actions on Pagan (DoN 2013b; MARFORPAC 2013; U.S. Marine Corps, Pacific 2013) and guidance from Navy and MARFORPAC, conclusions about the presence and distribution of corals and coral reefs at the five beaches and one proposed construction site are:

- Red and Blue Beaches are the least coral-obstructed approaches for vessels (Figure 5-9 and Figure 5-17). There are zero ESA-proposed corals shallower than 10 feet (3 meters) along any shore-perpendicular approach. Much of the seafloor is sand and turf-covered rubble.
- Green Beach offers an approach free of ESA-proposed corals along the central 600 feet (200 meters) of the beach, with relatively rich reef areas to the sides and a relatively narrow opening to the bay (Figure 5-2).
- North Beach and the 330-foot (100-meter) sand channel at South Beach offer approaches that would affect relatively fewer ESA-proposed corals shallower than 12 feet (4 meters) from the proposed actions than other portions of Gold, and South Beaches (Figure 5-21 and Figure 5-28).
- Gold Beach and most of South Beach are rich and complex reefs. Nearshore vessel activities would affect a relatively large number of ESA-proposed coral colonies and species (Figure 5-21 and Figure 5-28).
- The proposed construction areas include a relatively large number of ESA-proposed coral colonies and species. The sites of proposed construction are not uniquely rich or depauperate. The headlands adjacent to all three leeward beaches have coral assemblages similar to the sites of proposed construction at Red Beach (Figure 5-9, Figure 5-12, and Figure 5-15).

CHAPTER 6 DISCUSSION

6.1 EXTRAPOLATING FROM THE SAMPLE TO THE POPULATION

Every sampling method has biases that affect interpretations, particularly out-of-context extrapolation or analyses. This survey deployed several different methods to collect demographic data, usually deploying two methods most appropriate for the site. This report presents these data and extrapolations with equal weight; the results are often a wide range of counts for the same parameter. For example, Unai Babui has an estimated 51,705, 18,227, or 27,170 ESA-proposed coral colonies potentially exposed to activities, depending on the method used to estimate the population (i.e., quadrats, long belt transects, or short belt transects). Analysts should evaluate the biases inherent in each method and select the one, or combination, most appropriate for their needs.

All ecological methods are sensitive to the degree of habitat homogeneity and sampling intensity. Broad area surveys, such as the belt transect method, tend to underrepresent small colonies and overrepresent species with patchy distributions. Small-scale sampling, such as the quadrat method, tends to underrepresent large colonies and species that have patchy distributions. These are just a few of the more important biases associated with the demographic methods employed.

The seemingly simple question, “How many ESA-proposed coral colonies are at Unai Babui?” is too simplistic to answer using a single method. The hypothetical true number of colonies is likely close to the estimated values of 51,705, 18,227, or 27,170 ESA-proposed colonies (from quadrats, long belt transects, and short belt transects, respectively). However, the true number is not necessarily more likely to be closer to the middle or the ends of the range of estimates.

6.2 ESA-PROPOSED CORALS WITHIN PROPOSED ACTIVITY AREAS ON TINIAN

The total number of ESA-proposed corals shallower than 12 feet (4 meters) in front of Unai Chulu, Unai Babui, Unai Lamlam, and Unai Masalok Beaches on Tinian is approximately 50,000 to 163,000 colonies. The survey area included 12 ESA-proposed coral species, all proposed threatened. Among the ESA-proposed species, only *Montipora* species had distinctly different distributions among the Tinian beaches. The ESA-proposed *Montipora* species occurred more frequently on the two windward beaches and were uncommon on the three leeward beaches. However, the number of ESA-proposed species would likely increase if the survey area were extended into deeper waters adjoining the same beaches.

There are no locations at Unai Chulu, Unai Babui, Unai Lamlam, or Unai Masalok devoid of ESA-proposed corals. Among these four, the reef flat at Unai Masalok has the fewest ESA-proposed coral colonies by several orders of magnitude. If proposed landing craft air cushion (LCAC) activities avoid coming in contact with the Unai Masalok reef crest, then the vehicles could set down on the Unai Masalok reef flat with relatively few ESA-proposed corals exposed to physical disturbance and strike stressors (approximately 1,300 ESA-proposed colonies). If proposed activities at Unai Lamlam are restricted to small craft, and if the craft are constrained to the channel directly in front of the beach, then small craft activities at Unai Lamlam would affect relatively few ESA-proposed coral colonies. Different interpretations of coral taxonomy will cause these numbers to change.

ESA-proposed coral colonies are abundant at Unai Chulu and Unai Babui and, in patches, are dominant. This is counterintuitive because species are generally rare when proposed for ESA listing. However, ESA-proposed populations are assessed over their full geographic range, and some species may be globally rare even if locally abundant. The aggregate density of ESA-proposed corals is on the order of 0.02 to 0.1 colony per square foot (0.25 to 1 colony per square meter). The number ranges from zero to at least 35 ESA-proposed colonies per square meter, depending on the exact location and reef zone, but 0.02 to 0.1 colony per square foot (0.25 to 1 colony per square meter) is a useful rough approximation for Unai Chulu and Unai Babui. ESA-proposed colony densities are greatest in the shallow bench zones at Unai Chulu, Unai Babui, and Unai Lamlam. Dominance of ESA-proposed corals in these shallow bench zones was unexpected.

6.3 TUNNELS, GROTTOES, FISSURES, AND CHIMNEYS ON TINIAN REEFS

Many spurs at Unai Chulu and Unai Babui were undercut by grooves that interconnect with other grooves, resulting in a network of tunnels, grottoes, fissures, and chimneys penetrating from the fore reef under the reef crest, and occasionally under the reef flat (see Section 3.3, Survey Methods). These features were also noted at Unai Lamlam, Unai Dankulo, and Unai Masalok but the features were somewhat fewer in number and smaller in size. Representative images are shown in Figure 6-1. Observers on the outer reef flat could occasionally see diver's bubbles rising up from what seemed to be solid substrate. The health and safety plan did not allow deep penetration of these tunnels, but many are wide and long, offering ample opportunity for investigation (DoN 2013c). The intent of the study was to identify and quantify coral demographics; therefore, there was no geotechnical investigation into the supporting substrate of the reefs.

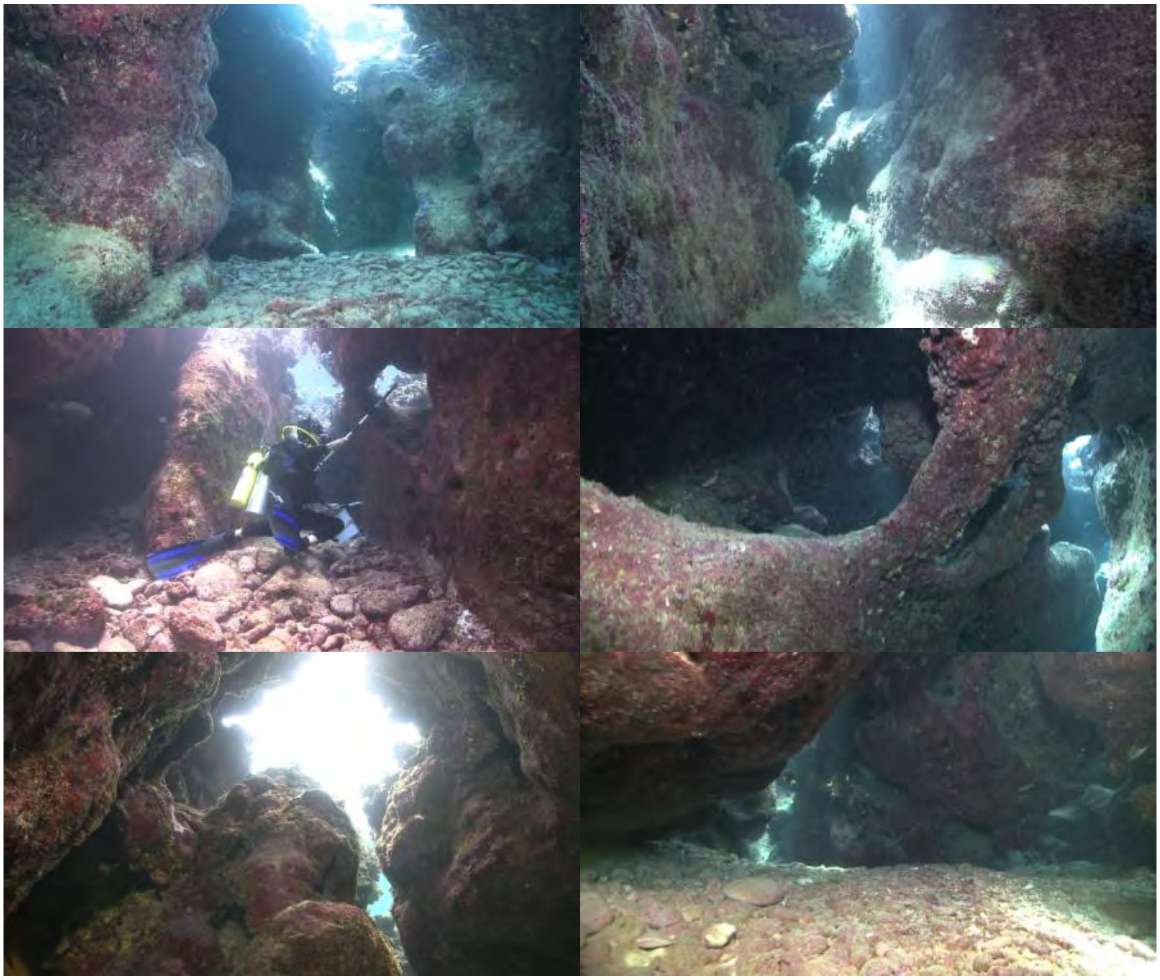

Figure 6-1. Representative Images of Tunnels and Undercutting Beneath the Reef Structures at Unai Chulu and Unai Babui.

Patches of light open to the reef crest and shallow fore reef in depths of 3-5 feet [1-1.6 meters]

6.4 CORALS WITHIN PROPOSED ACTIVITY AREAS ON PAGAN

The total number of ESA-proposed corals shallower than 12 feet (4 meters) in front of Green, Red, Blue, and South Beaches on Pagan is approximately 350,000 colonies, of which about 300,000 are at South Beach. The survey area included 12 ESA-proposed coral species, all proposed threatened. The ESA-proposed *Montipora* species were conspicuously absent from the three windward beaches and were common on the three leeward beaches. This distribution is opposite of Tinian.

Proposed amphibious landings could be conducted at Red and Blue Beaches, with zero exposure of ESA-proposed corals to physical disturbance and strike stressors. Assuming activities are kept clear of the adjacent headlands, there are no ESA-proposed corals shallower than 12 feet (4 meters) in front of those two beaches, and no potential interaction with protected corals. A similar situation could exist at Green Beach if the proposed activities are constrained to the center of the beach, away from the patch reefs to the north and south. North, Gold, and South Beaches have relatively well-developed shore-attached fringing reefs, each with many ESA-proposed coral colonies shallower than 12 feet (4 meters) in front of the beaches. Among these three, North Beach has the least developed coral community, and potential impacts would be lower than similar activities at Gold and South Beaches. Because of waves reflecting from cliff walls at Gold Beach, the sea state is dangerous for small craft under typical weather conditions. South Beach has an area dominated by sand that is about 330 feet (100 meters) wide, just to the east of center. If used for proposed activities, this area would have relatively few ESA-proposed corals exposed to stressors.

Potential pier and breakwater construction at Red Beach would affect eight species of ESA-proposed corals. The total number of ESA-proposed corals within the potential construction area is estimated to be 400 to 5,000, and this broad range is in part a reflection of extrapolation errors between direct-mapping and the quadrat methods.

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APPENDIX A

Coral Species Richness

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Species	*Unai Chulu*	*Unai Babui*	*Unai Lamlam*	*Unai Dankulo*	*Unai Masalok*	*Green Beach*	*Red Beach*	*Red Beach Proposed Construction Area*	*Blue Beach*	*North Beach*	*Gold Beach*	*South Beach*	*Cumulative Tinian (n=5 Sites)*	*Cumulative Pagan (n=7 Sites)*	*Cumulative Tinian and Pagan (n=12 Sites)*
Acanthastrea brevis PT	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Acanthastrea echinata	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Acanthastrea hillae *					x						x		1	1	2
Acanthastrea subechinata							x			x	x		0	3	3
Acropora abrotanoides	x	x	x	x	x	x		x	x	x	x	x	5	6	11
Acropora aculeus				x	x				x				2	1	3
Acropora cf. cerealis	x	x	x	x	x								5	0	5
Acropora cophodactyla	x	x	x	x	x	x				x	x	x	5	4	9
Acropora digitifera	x	x	x	x	x		x	x	x	x			5	4	9
Acropora diversa *				x									1	0	1
Acropora globiceps * PT	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Acropora aff. humilis *	x	x	x		x		x	x	x		x	x	4	5	9
Acropora monticulosa	x	x	x	x	x	x			x	x	x	x	5	5	10
Acropora ocellata *	x	x	x	x	x		x		x		x	x	5	4	9
Acropora palmerae PT	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Acropora quelchi *				x	x								2	0	2
Acropora secale *	x	x	x		x	x	x						4	2	6
Acropora aff. secale *	x	x	x	x	x			x					5	1	6
Acropora selago	x	x			x			x			x		3	2	5
Acropora studeri *	x	x	x	x	x							x	5	1	6
Acropora surculosa *	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Acropora tenuis	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Acropora valida	x	x	x	x	x		x				x	x	5	3	8
Acropora verweyi *	x	x	x	x	x	x		x			x	x	5	4	9
Acropora wardii	x				x			x			x	x	2	3	5
Acropora species 1 (naroform - photo)							x						0	1	1
Acropora species 2 (while/blue tip, dark hairy lower branch)				x				x					1	1	2
Acropora sp. 3 (aff. valida)										x	x		0	2	2
Acropora sp. 4 (small colony photo)									x			x	0	2	2
Acropora sp. 5 (small corymbose colony, neat radials, white polyps)	x	x	x										3	0	3
Acropora sp. 7 (small tubular)		x											1	0	1
Acropora sp. 8 (irregularis like w/ x-mas tree-like digits)			x										1	0	1
Acropora sp. 9 (long, tubular radials)				x									1	0	1
Acropora sp.	x	x	x		x			x				x	4	2	6
Astreopora cucullata * PT	x	x	x	x	x	x	x	x	x			x	5	5	10

Species	***Unai Chulu***	***Unai Babui***	***Unai Lamlam***	***Unai Dankulo***	***Unai Masalok***	***Green Beach***	***Red Beach***	***Red Beach Proposed Construction Area***	***Blue Beach***	***North Beach***	***Gold Beach***	***South Beach***	***Cumulative Tinian (n=5 Sites)***	***Cumulative Pagan (n=7 Sites)***	***Cumulative Tinian and Pagan (n=12 Sites)***
Astreopora elliptica			x	x	x		x	x			x		3	3	6
Astreopora gracilis				x	x		x	x	x		x		2	4	6
Astreopora listeri	x	x		x			x	x	x		x	x	3	5	8
Astreopora myriophthalma	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Astreopora ocellata								x					0	1	1
Astreopora randalli		x	x	x	x		x	x	x				4	3	7
Coscinaraea columna		x	x	x				x	x		x		3	3	6
Coscinaraea exesa				x									1	0	1
Coscinaraea wellsi							x	x	x				0	3	3
Ctenactis albitentaculata				x									1	0	1
Cycloseris costulata					x								1	0	1
Cycloseris tenuis				x			x	x	x				1	3	4
*Cyphastrea agassizi **	x			x	x		x	x	x		x	x	3	5	8
Cyphastrea chalcidicum	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Cyphastrea microphthalma	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Cyphastrea serailia	x	x	x	x	x	x	x	x	x			x	5	5	10
Cyphastrea sp.	x	x		x			x	x	x			x	3	4	7
Diploastrea Heliopora				x	x								2	0	2
Distichopora sp.	x	x	x										3	0	3
Echinophyllia aspera	x	x	x		x	x	x	x	x			x	4	5	9
Echinophyllia echinata			x	x	x		x	x	x				3	3	6
Echinopora aff. lamellosa	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Euphyllia ancora								x					0	1	1
Euphyllia glabrescens								x					0	1	1
Favia favus	x	x	x	x	x	x		x	x			x	5	4	9
Favia helianthoides	x		x	x	x	x		x	x		x	x	4	5	9
Favia matthaii	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Favia pallida	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Favia rotumana						x	x	x	x				0	4	4
Favia speciosa					x				x		x		1	2	3
Favia stelligera	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Favia sp.		x	x		x		x	x					3	2	5
Favites abdita	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Favites flexuosa	x	x	x	x	x	x		x	x		x	x	5	5	10
Favites sp.	x					x		x	x			x	1	4	5
Fungia concinna					x								1	0	1
Fungia scabra								x	x				0	2	2
Fungia scutaria	x	x	x	x	x			x					5	1	6

Species	Unai Chulu	Unai Babui	Unai Lamlam	Unai Dankulo	Unai Masalok	Green Beach	Red Beach	Red Beach Proposed Construction Area	Blue Beach	North Beach	Gold Beach	South Beach	Cumulative Tinian (n=5 Sites)	Cumulative Pagan (n=7 Sites)	Cumulative Tinian and Pagan (n=12 Sites)
Fungia sp.								x					0	1	1
Galaxea astreata	x						x	x					1	2	3
Galaxea fascicularis	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Gardineroseris planulata	x	x	x	x		x		x				x	4	3	7
Goniastrea edwardsi	x	x	x	x	x	x	x	x	x		x	x	5	6	11
*Goniastrea aff. favulus **								x					0	1	1
Goniastrea pectinata	x	x	x	x	x			x	x		x		5	3	8
Goniastrea retiformis	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Goniastrea sp.	x			x			x	x		x		x	2	4	6
Goniopora fruticosa	x			x				x					2	1	3
Goniopora lobata	x												1	0	1
Goniopora minor		x	x	x		x	x	x	x				3	4	7
Goniopora somaliensis						x	x	x	x		x	x	0	6	6
Goniopora sp. 'long tentacles'								x					0	1	1
Heliopora coerulea				x							x	x	1	2	3
Herpolitha limax				x	x								2	0	2
Hydnophora exesa	x	x	x		x						x		4	1	5
Hydnophora microconos	x	x	x	x	x	x					x	x	5	3	8
Isopora palifera	x	x	x										3	0	3
Leptastrea bewickensis						x			x		x		0	3	3
Leptastrea pruinosa				x	x			x					2	1	3
Leptastrea purpurea	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Leptastrea transversa	x	x	x	x	x		x	x	x	x	x	x	5	6	11
Leptoria phrygia	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Leptoseris incrustans		x	x	x	x		x	x	x				4	3	7
Leptoseris mycetoseroides		x	x				x	x	x				2	3	5
Lobophyllia corymbosa		x							x		x		1	2	3
Lobophyllia hemprichii	x	x	x	x	x			x	x		x		5	3	8
Merulina ampliata												x	0	1	1
Millepora platyphylla	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Millepora tuberosa PT	x	x	x	x					x			x	4	2	6
Millepora sp.	x							x		x			1	2	3
*Montastrea annuligera **	x						x	x	x			x	1	4	5
Montastrea cf. valenciennesi	x	x	x	x	x		x	x	x		x	x	5	5	10
Montastrea curta	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Montipora cf. berryi / efflorescens				x									1	0	1
Montipora caliculata				x	x	x	x	x	x				2	4	6
Montipora capitata				x			x	x	x				1	3	4

Species	*Unai Chulu*	*Unai Babui*	*Unai Lamlam*	*Unai Dankulo*	*Unai Masalok*	*Green Beach*	*Red Beach*	*Red Beach Proposed Construction Area*	*Blue Beach*	*North Beach*	*Gold Beach*	*South Beach*	*Cumulative Tinian (n=5 Sites)*	*Cumulative Pagan (n=7 Sites)*	*Cumulative Tinian and Pagan (n=12 Sites)*
Montipora conicula	x		x					x	x			x	2	3	5
Montipora ehrenbergii	x	x	x	x	x	x		x		x	x	x	5	5	10
Montipora elshneri	x	x	x	x	x		x	x	x		x	x	5	5	10
Montipora foveolata	x		x	x	x		x	x	x			x	4	4	8
Montipora grisea	x	x	x	x	x		x	x	x	x	x	x	5	6	11
Montipora hoffmeisteri *	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Montipora informis	x		x	x			x		x				3	2	5
Montipora lobulata	x			x				x	x				2	2	4
Montipora monasteriata		x											1	0	1
Montipora peltiformis	x	x	x	x	x	x			x		x	x	5	4	9
Montipora cf. planiscula								x	x				0	2	2
Montipora socialis				x									1	0	1
Montipora tuberculosa	x	x	x	x	x		x	x	x		x	x	5	5	10
Montipora aff. tuberculosa		x	x	x	x								4	0	4
Montipora cf. turgescens * PT		x		x		x	x	x	x				2	4	6
Montipora verrucosa	x			x	x		x	x	x			x	3	4	7
Montipora species 1 (crunchy)									x				0	1	1
Montipora species 2 (spikey)	x		x										2	0	2
Montipora sp.	x	x	x		x		x	x	x		x	x	4	5	9
Oulophyllia levis *	x	x	x	x	x		x	x	x		x	x	5	5	10
Pachyseris speciosa								x					0	1	1
Pavona chiriquensis	x	x	x	x	x		x	x	x		x	x	5	5	10
Pavona clavus	x	x	x		x	x	x	x			x	x	4	5	9
Pavona duerdeni	x	x	x	x	x	x		x	x		x	x	5	5	10
Pavona explanulata					x								1	0	1
Pavona maldivensis	x	x	x	x	x	x	x	x	x			x	5	5	10
Pavona minuta						x						x	0	2	2
Pavona varians	x	x	x	x	x	x	x	x	x		x	x	5	6	11
Pavona venosa	x			x			x	x	x				2	3	5
Pavona species 1 (high, narrow collines, tentacle tips always visible)	x	x	x	x	x				x			x	5	2	7
Pavona species 2 (high ridged collines)	x	x	x	x		x	x	x	x		x	x	4	6	10
Pavona sp.	x	x		x	x								4	0	4
Platygyra daedalea	x	x	x	x	x	x			x	x	x	x	5	5	10
Platygyra pini	x	x	x	x	x	x		x	x		x	x	5	5	10
Plerogyra sinuosa								x					0	1	1
Plesiastrea versipora				x	x	x	x	x	x			x	2	5	7

Species	*Unai Chulu*	*Unai Babui*	*Unai Lamlam*	*Unai Dankulo*	*Unai Masalok*	*Green Beach*	*Red Beach*	*Red Beach Proposed Construction Area*	*Blue Beach*	*North Beach*	*Gold Beach*	*South Beach*	*Cumulative Tinian (n=5 Sites)*	*Cumulative Pagan (n=7 Sites)*	*Cumulative Tinian and Pagan (n=12 Sites)*
Pocillopora ankeli	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Pocillopora cf. capitata	x												1	0	1
Pocillopora damicornis	x	x		x	x		x	x					4	2	6
Pocillopora danae PT	x				x		x	x	x				2	3	5
Pocillopora elegans PT			x	x	x	x	x	x	x		x	x	3	6	9
Pocillopora eydouxi	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Pocillopora cf. ligulata	x											x	1	1	2
Pocillopora meandrina	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Pocillopora setchelli	x	x	x	x	x	x		x	x	x	x	x	5	6	11
Pocillopora verrucosa	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Pocillopora woodsjonesi					x								1	0	1
Pocillopora species 1	x					x						x	1	2	3
Pocillopora sp.	x	x	x				x	x	x			x	3	4	7
Polyphyllia talpina								x					0	1	1
Porites annae	x	x	x	x	x			x	x		x	x	5	4	9
Porites australiensis	x	x	x	x	x	x		x	x				5	3	8
Porites aff. evermanni/lutea												x	0	1	1
Porites lichen			x										1	0	1
Porites aff. lichen	x	x	x	x				x					4	1	5
Porites lobata	x				x	x		x				x	2	3	5
Porites lutea	x		x	x	x	x	x	x	x	x	x	x	4	7	11
Porites rus	x	x	x	x	x		x	x			x	x	5	4	9
Porites solida	x	x	x	x		x	x	x	x			x	4	5	9
Porites superfusa	x						x						1	1	2
Porites cf. vaughni	x	x	x		x								4	0	4
Porites sp.	x	x	x	x	x	x	x	x	x	x	x	x	5	7	12
Psammocora contigua	x	x	x	x	x								5	0	5
Psammocora digitata	x	x	x	x	x	x		x			x	x	5	4	9
Psammocora haimeana							x	x	x		x	x	0	5	5
Psammocora nierstraszi	x	x	x	x	x			x	x		x	x	5	4	9
Psammocora obstuangula		x											1	0	1
Psammocora profundacella	x	x	x	x	x		x	x	x		x		5	4	9
Psammocora species 1 (low, smooth ridges/collines)	x	x	x	x	x				x			x	5	2	7
Sandalolitha robusta								x					0	1	1
Scapophyllia cylindrica	x		x	x	x	x		x				x	4	3	7
Scolymia australis	x	x			x	x	x	x	x		x	x	3	6	9
Stylocoeniella armata	x						x		x			x	1	3	4

Species	*Unai Chulu*	*Unai Babui*	*Unai Lamlam*	*Unai Dankulo*	*Unai Masalok*	*Green Beach*	*Red Beach*	*Red Beach Proposed Construction Area*	*Blue Beach*	*North Beach*	*Gold Beach*	*South Beach*	*Cumulative Tinian (n=5 Sites)*	*Cumulative Pagan (n=7 Sites)*	*Cumulative Tinian and Pagan (n=12 Sites)*
Stylocoeniella guentheri	x	x					x	x	x			x	2	4	6
Stylophora mordax *	x	x	x	x	x			x				x	5	2	7
Symphyllia sp.		x											1	0	1
Tubastrea sp.								x					0	1	1
Turbinaria reniformis	x		x	x	x	x	x	x	x		x	x	4	6	10
Turbinaria stellata			x	x		x	x	x	x			x	2	5	7

Notes:
PT = proposed threatened; x = present
See Section 3.3.2, Coral Species Richness, for a description of the species definition types (e.g., *Genus species*, *Genus cf. species*, *Genus aff. species*, and *Genus* species # [description]).
aff. is an abbreviation for the Latin *affinis*, which in the context of taxonomy means the specimen is very similar to the named species, but is almost certainly different.
cf. is an abbreviation which in the context of taxonomy means the specimen is slightly different than the named species but almost certainly is the named species.
sp. is an abbreviation which in the context of taxonomy means the specimen does not exhibit enough diagnostic characters to be assigned to a particular species.
sensu is Latin for “in the sense [of],” which in the context of taxonomy means a species determination is according to a particular authority, implying the determination is not according to another authority.

* *Acanthastrea hillae* (Wells 1955) *sensu* Randall and Myers (1983); *sensu* Veron (2000)
* *Acropora diversa* (Brook 1891) *sensu* Randall and Myers (1983). Not *sensu* Veron (1986). Not *sensu Acropora secale* Veron and Wallace (1984), Wallace (1999), Veron (2000)
* *Acropora globiceps* (Dana 1846) sensu Wallace et al. (2012); Wallace (1999); and Veron (2000) = *Acropora humilis* (Dana 1846) *sensu* Randall and Myers (1983)
* *Acropora aff. humilis sensu* Veron and Wallace (1984); Wallace (1999)
* *Acropora ocellata* (Klunzinger 1879) *sensu* Randall and Myers (1983); not *sensu* Veron (2000)
* *Acropora quelchi* (Randall and Myers 1983), not *Acropora nasuta sensu* (Veron and Wallace 1984), not *sensu Acropora secale* (Wallace 1999; Veron 2000)
* *Acropora aff. secale sensu* Veron and Wallace (1984); Wallace (1999) and Veron (2000)
* *Acropora studeri sensu* Randall and Myers (1983)
* *Acropora surculosa sensu* Veron (2000), not = *Acropora hyacinthus sensu* Wallace (1999)
* *Astreopora cucullata* (Lamberts 1980) sensu Lamberts (1982); not *sensu Astreopora cucullata* Veron (2000)
* *Cyphastrea agassizi* (Vaughan 1907) *sensu* Veron (2000) = *Leptastrea bottae* (Milne Edwards and Haime 1849) *sensu* Randall and Myers (1983)
* *Goniastrea favulus sensu* Veron (2000)
* *Montastrea annuligera sensu* Veron (2000)
* *Montipora hoffmeisteri sensu* Veron and Wallace (1984); Veron (2000). Not *sensu* Randall and Myers (1983)
* *Montipora turgescens sensu* Veron and Wallace (1984); Veron (2000). *cf. Montipora hoffmeisteri sensu* Randall and Myers (1983)
* *Oulophyllia levis* (Nemenzo 1959) *sensu* Nemenzo (1986); Veron (2000)
* *Stylophora mordax* (Dana 1846) *sensu* Randall and Myers (1983) = *Stylophora pistillata* (Esper 1797) *sensu* Veron and Pichon (1976); Veron (2000)

APPENDIX B

Coral Demographics Database Sample

Sample data table showing the nature of information in the raw demographic dataset (DoN 2014a). The full raw dataset will be presented in the electronic data deliverable.

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Unique ID	Date (2013)	Island	Beach	Unique Sample Name	Data Type (Quadrat, Belt, Area, Point)	Station Name	Station Type (Transect, Block, Area)	Unit Name	Unit Type (1m Quadrat, 2x20 Belt, etc.)	GPS Target Reference	Observer	Habitat Type	Depth (feet)	Genus	Species	Genus Species	Size A	Size B	Elliptical Area	Growth Form	Partial Mortality (%)	Bleaching P/A	Fragment P/A	Clump P/A	Remnant P/A	Disease P/A	Predation P/A	Comments	Unique ID on Raw Datasheet
6214	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A1	Reyes	ForeReef	20	Acanthastrea	brevis	Acanthastrea brevis	10	10	78.53975	encrusting									9220
6217	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A2	Reyes	ForeReef	20	Acropora	selago	Acropora selago	20	10	57.0795	branching								Originally Acropora delicatula	9223
6216	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A3	Reyes	ForeReef	20	Acropora	selago	Acropora selago	30	30	706.8578	branching								Originally Acropora delicatula	9222
6215	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A4	Reyes	ForeReef	20	Acropora	selago	Acropora selago	30	20	471.2385	branching								Originally Acropora delicatula	9221
6209	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A5	Reyes	ForeReef	20	Acropora	surculosa	Acropora surculosa	30	20	471.2385	branching									9215
6213	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A6	Reyes	ForeReef	20	Astreopora	myriophthalma	Astreopora myriophthalma	40	30	942.477	massive									9219
6208	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A7	Reyes	ForeReef	20	Favia	helianthoides	Favia helianthoides	20	20	314.159	massive									9214
6221	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A8	Reyes	ForeReef	20	Favia	matthaii	Favia matthaii	20	20	314.159	massive									9227
6223	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A9	Reyes	ForeReef	20	Favia	matthaii	Favia matthaii	40	30	942.477	massive	50								9229
6222	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A10	Reyes	ForeReef	20	Favia	matthaii	Favia matthaii	10	10	78.53975	massive									9228
6224	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A11	Reyes	ForeReef	20	Goniastrea	retiformis	Goniastrea retiformis	40	40	1256.636	massive	50								9230
6212	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A12	Reyes	ForeReef	20	Hydnophora	microconos	Hydnophora microconos	50	40	1570.795	massive	30								9218
6219	7/23	Tinian	Masalok	Transect1A 1mQuad46 Reyes	Quadrat	1A	Transect	46	1mQuad	1A13	Reyes	ForeReef	20	Leptoria	phrygia	Leptoria phrygia	20	10	157.0795	massive	10								9225
6205	7/24	Tinian	Masalok	Transect2C 1mQuad2 Lovell	Quadrat	2C	Transect	2	1mQuad	1A373	Lovell	ReefFlatInner	2	Acropora	secale	Acropora secale	20	20	314.159	branching									7218
6202	7/24	Tinian	Masalok	Transect2C 1mQuad2 Lovell	Quadrat	2C	Transect	2	1mQuad	1A374	Lovell	ReefFlatInner	2	Porites	lutea	Porites lutea	5	5	19.63494	massive									7215
6200	7/24	Tinian	Masalok	Transect2C 1mQuad2 Lovell	Quadrat	2C	Transect	2	1mQuad	1A375	Lovell	ReefFlatInner	2	Porites	lutea	Porites lutea	10	10	78.53975	massive									7213
6199	7/24	Tinian	Masalok	Transect2C 1mQuad2 Lovell	Quadrat	2C	Transect	2	1mQuad	1A376	Lovell	ReefFlatInner	2	Porites	lutea	Porites lutea	50	20	785.3975	massive									7212
6201	7/24	Tinian	Masalok	Transect2C 1mQuad2 Lovell	Quadrat	2C	Transect	2	1mQuad	1A377	Lovell	ReefFlatInner	2	Porites	lutea	Porites lutea	20	10	157.0795	massive									7214
6203	7/24	Tinian	Masalok	Transect2C 1mQuad2 Lovell	Quadrat	2C	Transect	2	1mQuad	1A378	Lovell	ReefFlatInner	2	Porites	lutea	Porites lutea	5	5	19.63494	massive									7216
6108	7/24	Tinian	Masalok	Transect2C 2x20Belt100 Fenner	Belt	2C	Transect	100	2x20Belt	1A379	Fenner	ReefFlatOuter	1	No ESA corals	No ESA corals	No ESA corals No ESA corals	-9	-9	63.6172										6137
6102	7/24	Tinian	Masalok	Transect2C 2x20Belt20 Fenner	Belt	2C	Transect	20	2x20Belt	1A380	Fenner	ReefFlatOuter	1	Acropora	verweyi	Acropora verweyi	5	5	19.63494	branching									6131
6103	7/24	Tinian	Masalok	Transect2C 2x20Belt40 Fenner	Belt	2C	Transect	40	2x20Belt	1A381	Fenner	ReefFlatOuter	1	Acropora	palmerae	Acropora palmerae	20	20	314.159	encrusting									6132
6104	7/24	Tinian	Masalok	Transect2C 2x20Belt40 Fenner	Belt	2C	Transect	40	2x20Belt	1A382	Fenner	ReefFlatOuter	1	Acropora	palmerae	Acropora palmerae	40	40	1256.636	encrusting									6133
6105	7/24	Tinian	Masalok	Transect2C 2x20Belt60 Fenner	Belt	2C	Transect	60	2x20Belt	1A383	Fenner	ReefFlatOuter	1	Acropora	globiceps	Acropora globiceps	10	10	78.53975	branching									6134

Unique ID	Date (2013)	Island	Beach	Unique Sample Name	Data Type (Quadrat, Belt, Area, Point)	Station Name	Station Type (Transect, Block, Area)	Unit Name	Unit Type (1m Quadrat, 2x20 Belt, etc.)	GPS Target Reference	Observer	Habitat Type	Depth (feet)	Genus	Species	Genus Species	Size A	Size B	Elliptical Area	Growth Form	Partial Mortality (%)	Bleaching P/A	Fragment P/A	Clump P/A	Remnant P/A	Disease P/A	Predation P/A	Comments	Unique ID on Raw Datasheet
6106	7/24	Tinian	Masalok	Transect2C 2x20Belt60 Fenner	Belt	2C	Transect	60	2x20Belt	1A384	Fenner	ReefFlatOuter	1	Acropora	verweyi	Acropora verweyi	20	10	157.0795	branching									6135
6107	7/24	Tinian	Masalok	Transect2C 2x20Belt80 Fenner	Belt	2C	Transect	80	2x20Belt	1A385	Fenner	ReefFlatOuter	1	No ESA corals	No ESA corals	No ESA corals No ESA corals	-9	-9	63.6172										6136
6110	7/24	Tinian	Masalok	Transect2D 2x20Belt100 Fenner	Belt	2D	Transect	100	2x20Belt	1A386	Fenner	ReefFlatInner	1	No ESA corals	No ESA corals	No ESA corals No ESA corals	-9	-9	63.6172										6139
6109	7/24	Tinian	Masalok	Transect2D 2x20Belt80 Fenner	Belt	2D	Transect	80	2x20Belt	1A387	Fenner	ReefFlatInner	1	Acropora	palmerae	Acropora palmerae	30	20	471.2385										6138
5918	7/24	Tinian	Masalok	Transect3C 1mQuad1 Bonito	Quadrat	3C	Transect	1	1mQuad	1A388	Bonito	ReefFlatOuter	2	Acropora	valida	Acropora valida	20	20	314.159	branching				y					269
5919	7/24	Tinian	Masalok	Transect3C 1mQuad2 Bonito	Quadrat	3C	Transect	2	1mQuad	1A389	Bonito	ReefCrest	2	Favites	abdita	Favites abdita	50	20	785.3975	massive									927
5920	7/24	Tinian	Masalok	Transect3C 1mQuad3 Bonito	Quadrat	3C	Transect	3	1mQuad	1A390	Bonito	ReefFlatOuter	2	None	None	None None	-9	-9	63.6172	no coral									1972
6000	7/24	Tinian	Masalok	Transect3C 2x20Belt100 Bonito	Belt	3C	Transect	100	2x20Belt	1A391	Bonito	ReefFlatOuter	2	No ESA corals	No ESA corals	No ESA corals No ESA corals	-9	-9	63.6172	no coral									4370
5993	7/24	Tinian	Masalok	Transect3C 2x20Belt20 Bonito	Belt	3C	Transect	20	2x20Belt	1A392	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	30	10	235.6193	branching		y		y					4363
5992	7/24	Tinian	Masalok	Transect3C 2x20Belt20 Bonito	Belt	3C	Transect	20	2x20Belt	1A393	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	10	10	78.53975	branching		y							4362
5991	7/24	Tinian	Masalok	Transect3C 2x20Belt20 Bonito	Belt	3C	Transect	20	2x20Belt	1A394	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	5	5	19.63494	branching		y							4361
5990	7/24	Tinian	Masalok	Transect3C 2x20Belt20 Bonito	Belt	3C	Transect	20	2x20Belt	1A395	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	20	20	314.159	branching		y		y					4360
5994	7/24	Tinian	Masalok	Transect3C 2x20Belt40 Bonito	Belt	3C	Transect	40	2x20Belt	1A396	Bonito	ReefFlatOuter	2	Acropora	palmerae	Acropora palmerae	10	10	78.53975	encrusting									4364
5995	7/24	Tinian	Masalok	Transect3C 2x20Belt40 Bonito	Belt	3C	Transect	40	2x20Belt	1A397	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	5	5	19.63494	branching									4365
5996	7/24	Tinian	Masalok	Transect3C 2x20Belt40 Bonito	Belt	3C	Transect	40	2x20Belt	1A398	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	20	10	157.0795	branching									4366
5997	7/24	Tinian	Masalok	Transect3C 2x20Belt40 Bonito	Belt	3C	Transect	40	2x20Belt	1A399	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	10	10	78.53975	branching									4367
5998	7/24	Tinian	Masalok	Transect3C 2x20Belt60 Bonito	Belt	3C	Transect	60	2x20Belt	1A400	Bonito	ReefFlatOuter	2	Acropora	verweyi	Acropora verweyi	5	5	19.63494	branching		y							4368
5999	7/24	Tinian	Masalok	Transect3C 2x20Belt80 Bonito	Belt	3C	Transect	80	2x20Belt	1A401	Bonito	ReefFlatOuter	2	No ESA corals	No ESA corals	No ESA corals No ESA corals	-9	-9	63.6172	no coral									4369

APPENDIX C

Data Sources for Figures

- ESRI Ocean Basemap:
  Data Type: ArcGIS Map Service
  Connection: Internet
  Server: http://goto.arcgisonline.com/
  Name: Ocean_Basemap

  Description: Designed to be used as a base map by marine GIS professionals and as a reference map by anyone interested in ocean data. The base map includes bathymetry, marine water body names, undersea feature names, and derived depth values in meters. Land features include administrative boundaries, cities, inland waters, roads, overlaid on land cover and shaded relief imagery. The map was compiled from a variety of best available sources from several data providers, including General Bathymetric Chart of the Oceans GEBCO_08 Grid version 20091120, IHO-IOC GEBCO Gazetteer of Undersea Feature Names, August 2010 version National Oceanic and Atmospheric Administration (NOAA), and National Geographic, AND, and ESRI. The base map currently provides coverage for the world down to a scale of ~1:1m. The base map was designed and developed by ESRI.

- ESRI Topographic Basemap:
  Data Type: ArcGIS Map Service
  Connection: Internet
  Server: http://goto.arcgisonline.com/
  Name: World_Topo_Map

  Description: Designed to be used as a base map by GIS professionals and as a reference map by anyone. The base map includes administrative boundaries, cities, water features, physiographic features, parks, landmarks, highways, roads, railways, airports, and buildings overlaid on land cover and shaded relief imagery for added context. The map was compiled from a variety of best available sources from several data providers, including the U.S. Geological Survey, Food and Agriculture Organization of the United Nations, National Park Service, Tele Atlas, AND, and ESRI. The base map currently provides coverage for the world down to a scale of ~1:1m and coverage for the continental United States and Hawaii to a scale of ~1:20k. The base map also includes detailed maps for selected cities in the United States. The base map was designed and developed by ESRI based on the topographic map templates available through the ArcGIS Resource Centers. For more information on this map, see http://goto.arcgisonline.com/maps/World_Topo_Map. Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, iPC, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community.

- LIDAR-Derived Bathymetry and Topography (Fugro Pelagos, Inc.)

  Data was collected using the SHOALS-1000T and VQ-820-G lidar systems simultaneously. Aircraft position, velocity, and acceleration information is collected through a POS AV 510 equipment. All logged raw data streams are transferred to the office for downloading and processing in Optech SHOALS-GCS and Riegl RiProcess software. Aircraft position data are processed using POSPac software, and the results were combined with the sensor data to produce 3D positions for each lidar shot on the WGS84 reference datum. Vertical elevations were converted to orthometric mean sea level using the EGM2008 geoidal model. The minimum horizontal accuracy of the data is 16 feet (5 meters) + 5% of depth. The minimum vertical accuracy of the data is around 1.6 feet (0.5 meters), or more precisely

± (0.5^2 + (d * 0.013)^2)^0.5, where d is the water depth (IHO SP-44 5th ed.). Data is loaded into Terrascan software for point classification and further filtering. Inspection and QA/QC was carried out in QPS Fledermaus and Fugro LASEdit software package. Data was gridded in Quick Terrain Modeler software v 8.0.0 to produce 32-bit floating point raster type in geotiff format. Data was gridded at 1 meter cell size. Data gap interpolation did not exceed 6 meters (SHOALS-1000T spot spacing point tolerance). DEM was created with ground and bathymetry points.

- Aerial Imagery (Fugro Pelagos, Inc.)

  The imagery data was collected with the SHOALS-1000T system. It is owned by Fugro Pelagos and operated through contract. The system collects bathymetric lidar data at 2 kHz and true color imagery at 1 Hz using a Prosilica GX3300 camera. Aircraft position, velocity, and acceleration information is collected through a POS AV 510 equipment. All logged raw data streams are transferred to the office for downloading and processing in SHOALS GCS software. Aircraft position data are processed using POSPac software, and the results are combined with the sensor data to produce 3D positions for each camera frame shot. True color frames are exported to JPEG files along with an index file containing timing, position, and attitude for each image file. Each frame is ortho-rectified on ERDAS software package for correct georeferencing aided by a lidar DTM or other terrain elevation sources. All rectified frames are processed in Orthovista software for final mosaic and color balancing. SHOALS mosaics are presented in 5 km tiles for organization and faster display on GIS packages. Final pixel resolution is approximately 0.3 meters.

- Tetra Tech derived data from reef mapping surveys

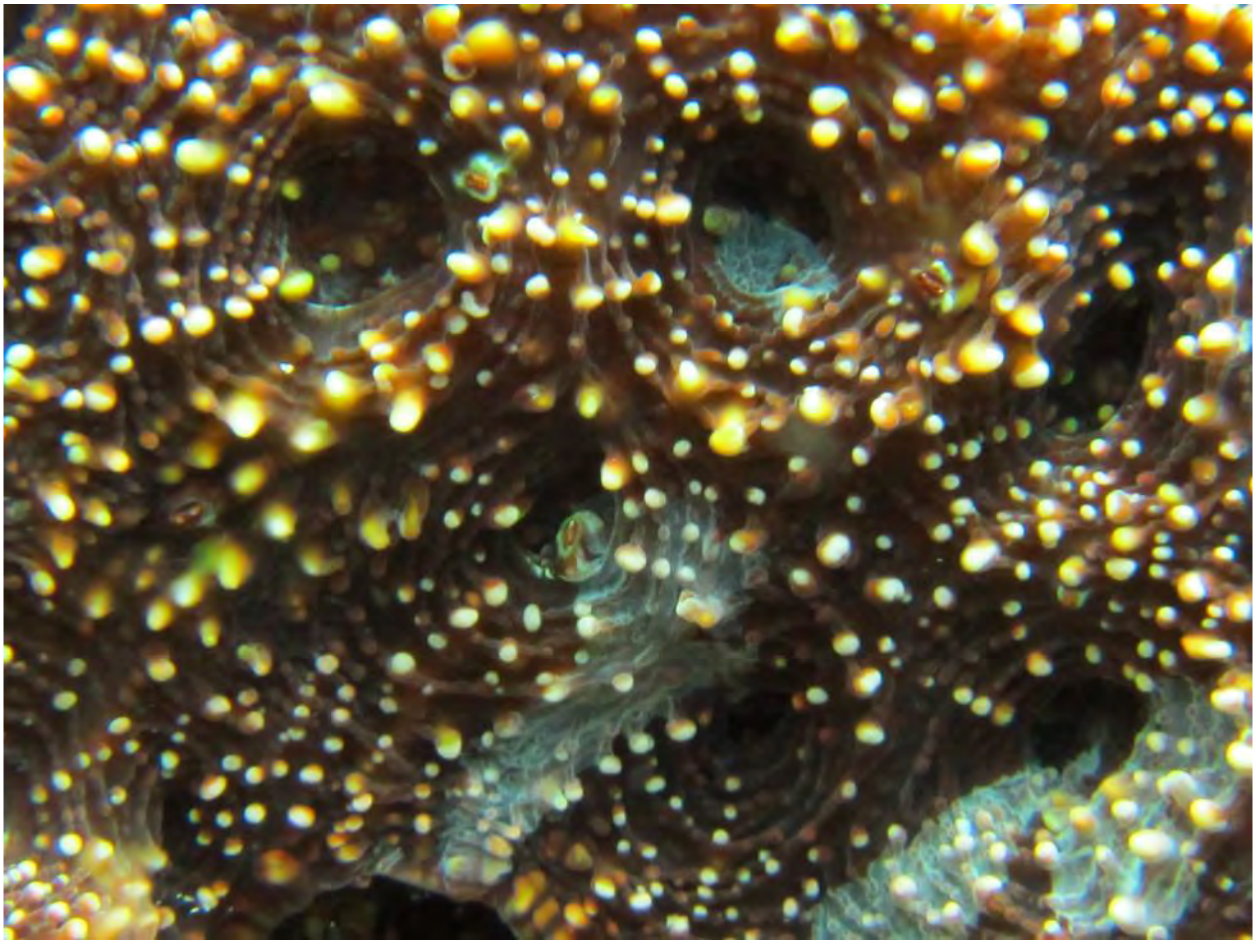
  Citation: DoN (Department of the Navy). 2013. Mariana Islands Marine Resource Surveys. Coral Data for Pagan and Tinian: 2013. Naval Facilities Engineering Command, Pacific Division, Pearl Harbor, Hawaii. Contract N62742-11-D-1801, CTO 0002. Prepared by Tetra Tech, Inc., Oakland, California. Under Subcontract to: Sea Engineering, Inc., Waimanalo, Hawaii

  Purpose: These data layers were created for use in a Naval Facilities Engineering Command, Pacific Division project in support of the Commonwealth of the Northern Mariana Islands (CNMI) Joint Military Training (CJMT) Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS). These data are the result of a coral survey at Tinian and Pagan in the CNMI in July 2013. These data layers were collected from selected reefs on Pagan and Tinian in the CNMI to collect data about the presence and distribution of corals and coral reefs in support of the development of the CJMT EIS, with particular attention to reef habitat and the demographics of endangered and threatened species.

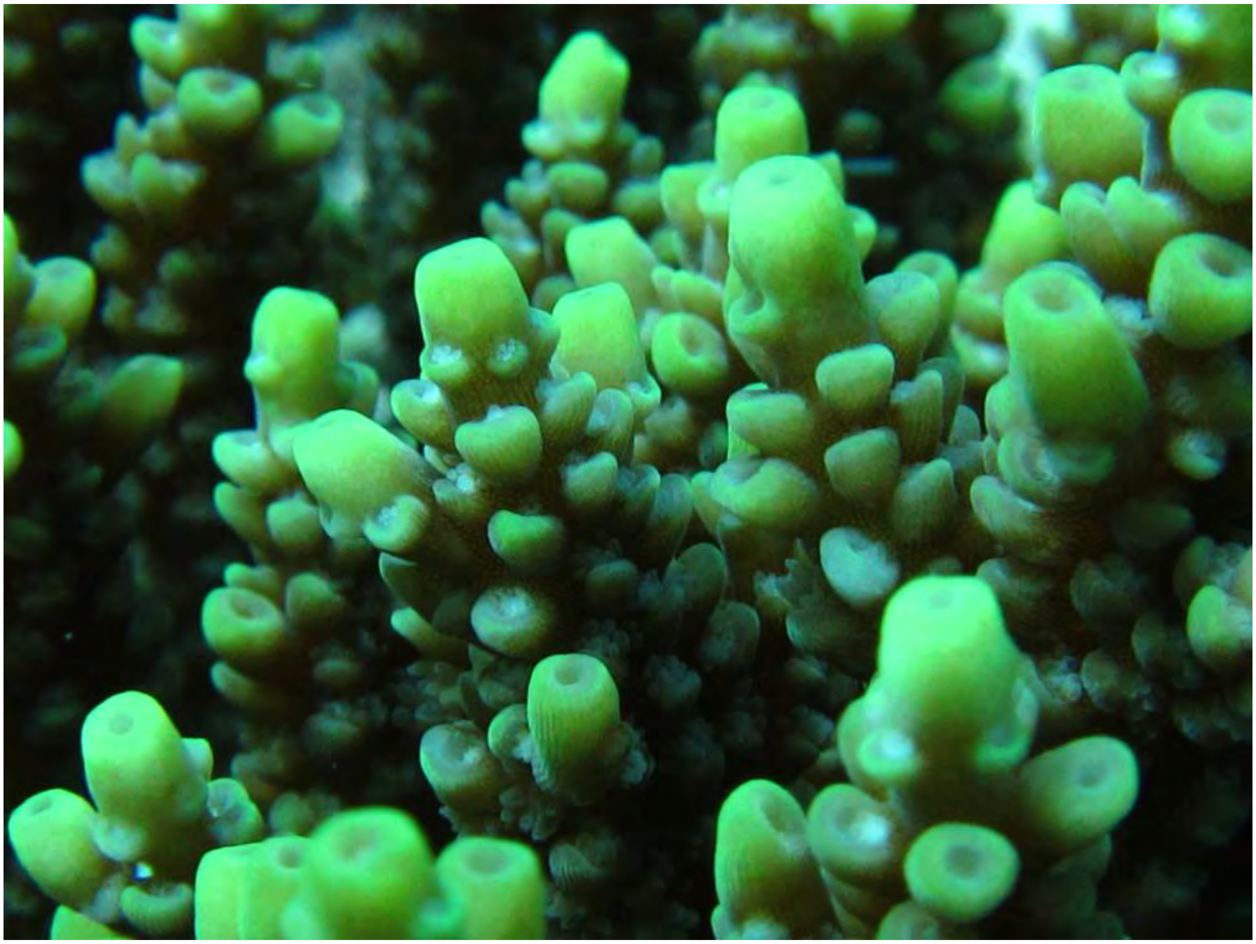
APPENDIX D

Representative Images of ESA-Proposed Coral Species

(Only selected images are reproduced in the report.
A comprehensive image library is included with the data deliverable.)



Acanthastrea brevis



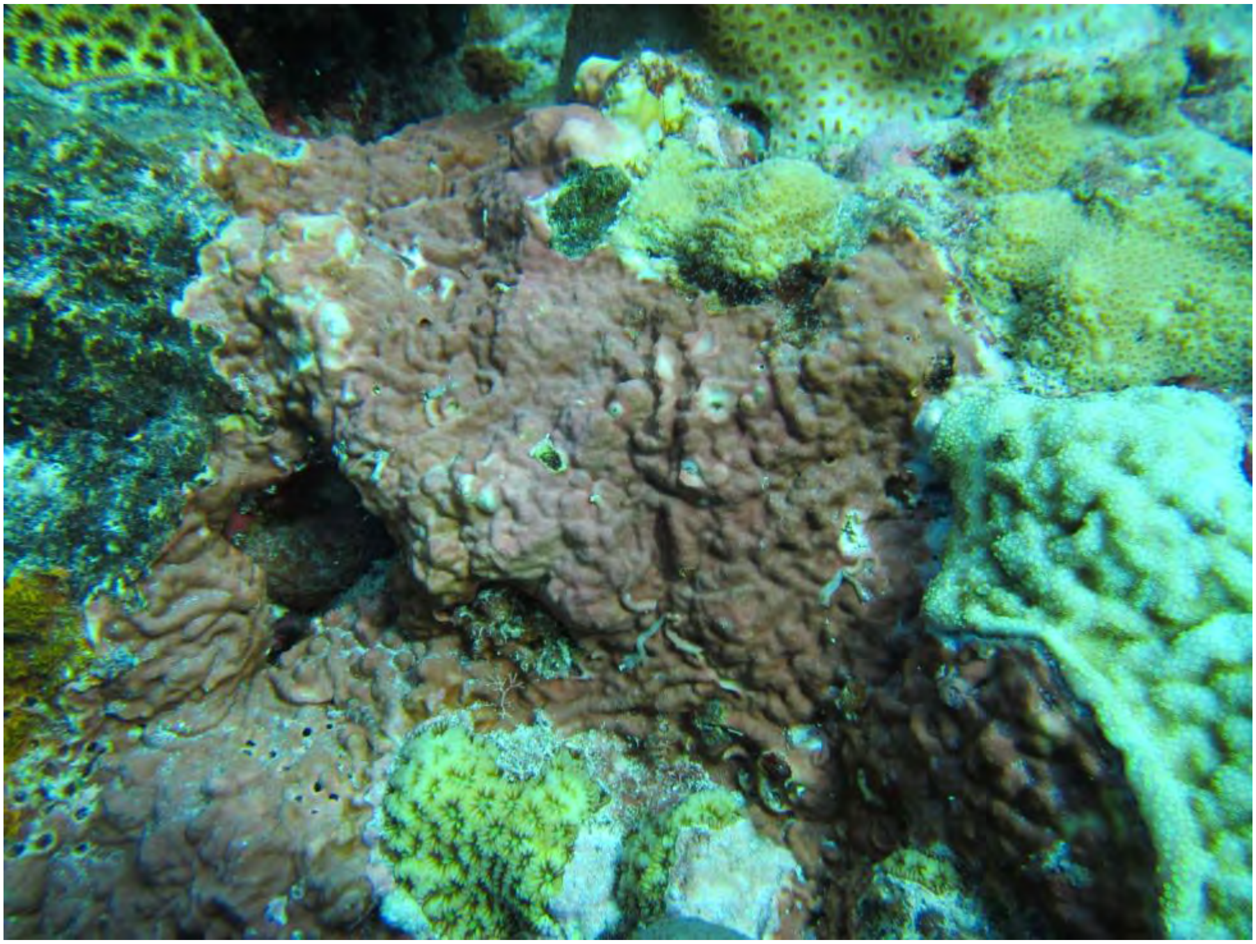
Acropora aculeus

Acropora globiceps

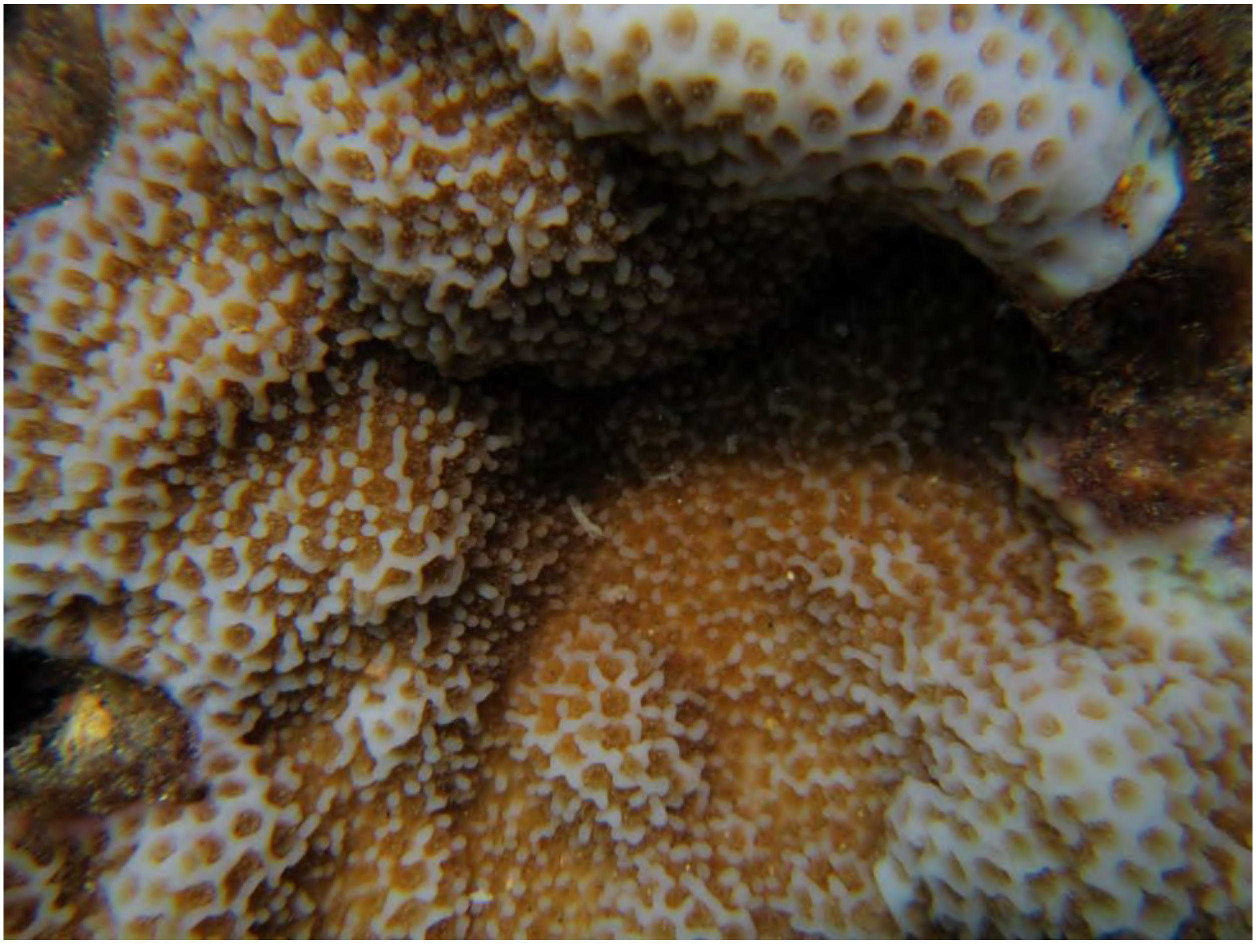
Acropora palmerae

Acropora verweyi

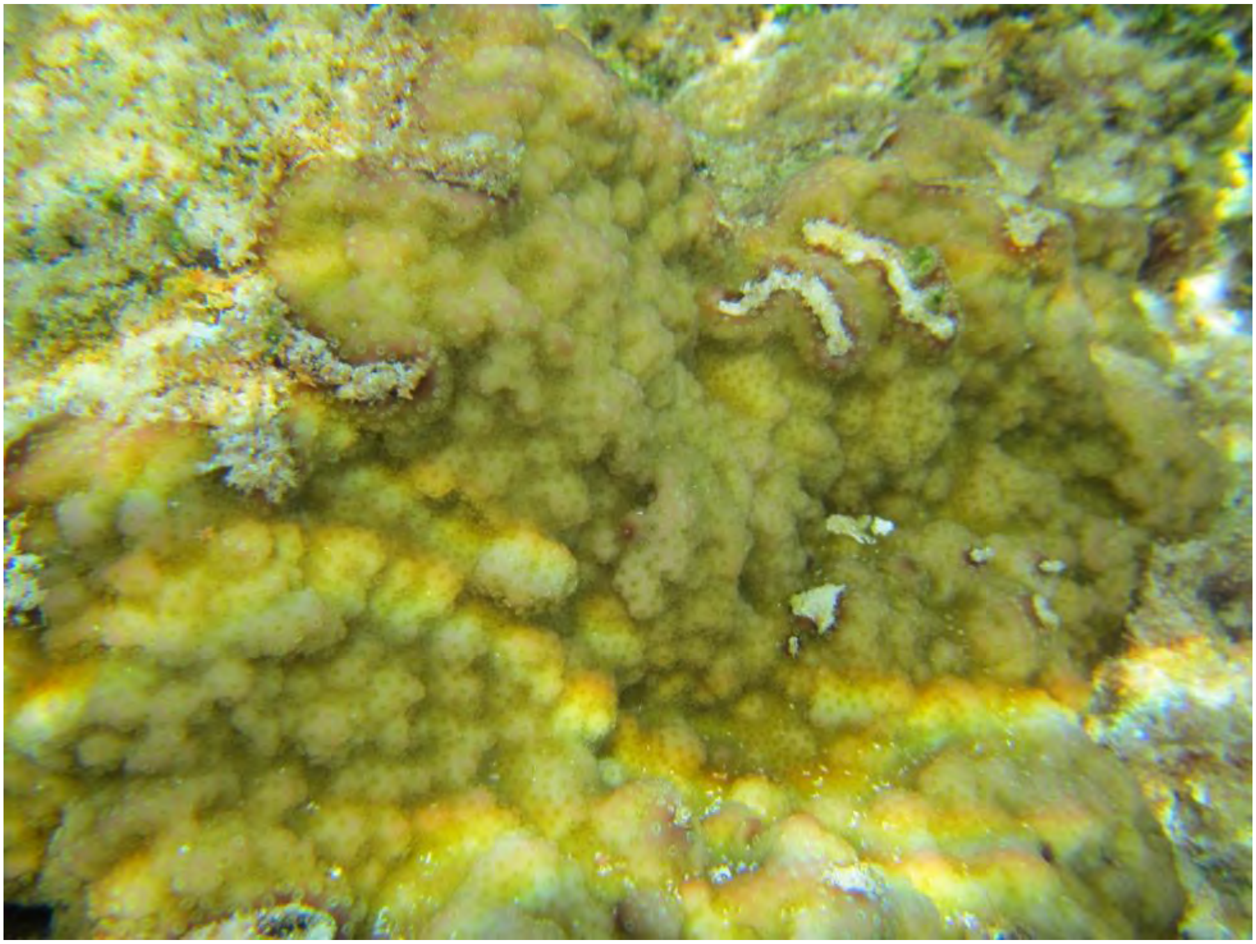
Astreopora cucullata



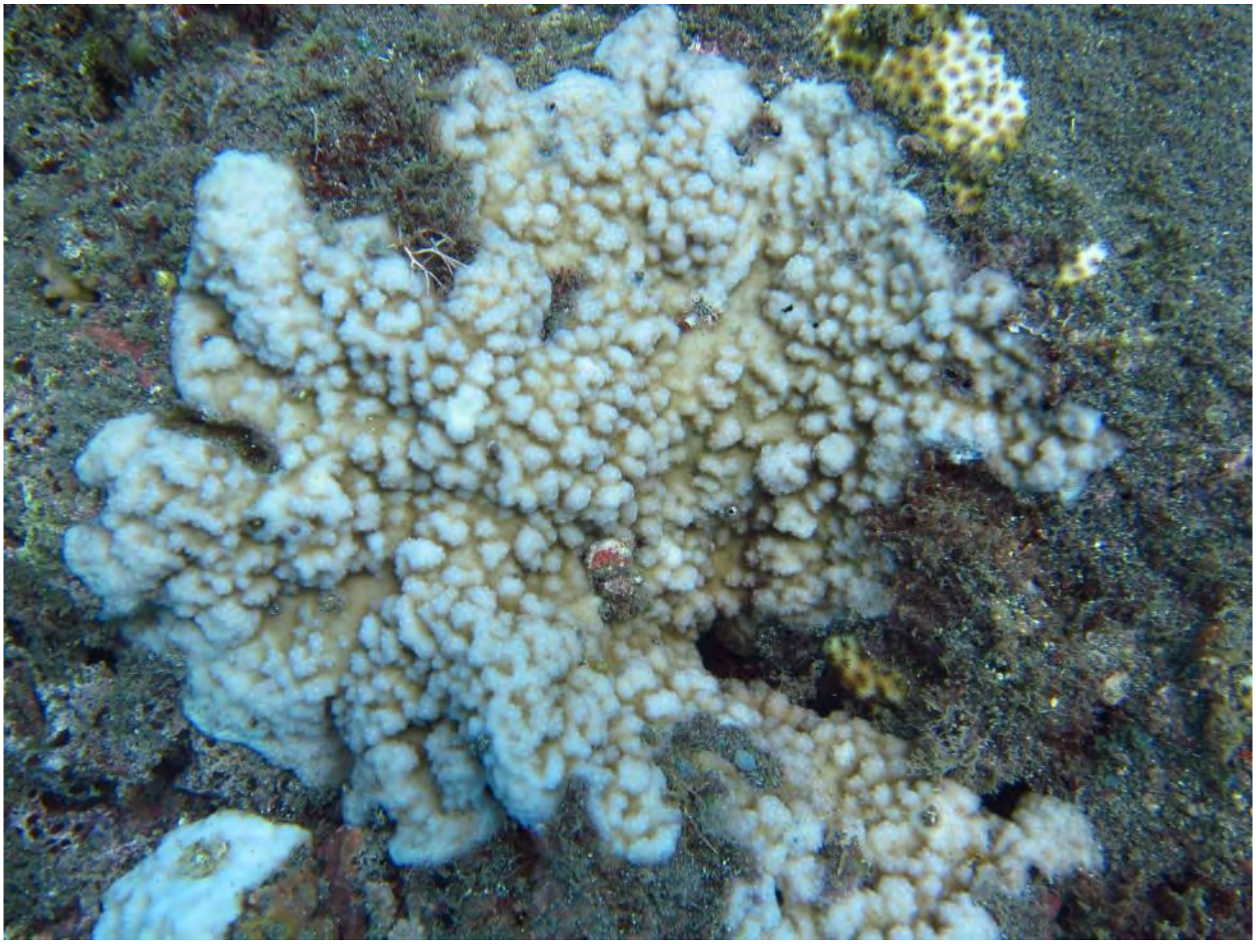
Millepora tuberosa



Montipora caliculata



Montipora lobulata



Montipora turgescens cf. M. hoffmeisteri sensu Randall and Myers (1983)

Pocillopora danae

Pocillopora elegans PT

APPENDIX E

List of Preparers and
Bio Sketches of Key Coral Field Survey Personnel

List of Preparers

Name	Affiliation	Contact	Role
Matthew Lybolt, PhD	Tetra Tech, Inc.	matthew.lybolt@tetratech.com	Lead Author
Douglas Fenner, PhD	Tetra Tech, Inc.	doug.fenner@tetratech.com	Author
Victor Bonito	Tetra Tech, Inc.	victor.bonito@tetratech.com	Author
Patrick Zuloaga	Tetra Tech, Inc.	patrick.zuloaga@tetratech.com	Author
Ed Lovell	Tetra Tech, Inc.	ed.lovell@tetratech.com	Technical Reviewer
Aja Reyes	Tetra Tech, Inc.	aja.reyes@tetratech.com	Technical Reviewer
Joel Peters	Tetra Tech, Inc.	joel.peters@tetratech.com	GIS/Figures
Ann Zoidis	Tetra Tech, Inc.	ann.zoidis@tetratech.com	Project Manager/Quality Control
Emmy Andrews	Tetra Tech, Inc.	emmy.andrews@tetratech.com	Deputy Project Manager/Quality Control

Bio Sketches of Key Coral Field Survey Personnel

Name	Affiliation	Function*
Matthew Lybolt, PhD	Tetra Tech, Inc.	Lead Marine Scientist
Douglas Fenner, PhD	Tetra Tech, Inc.	Coral Expert
Ed Lovell	Tetra Tech, Inc.	Coral Expert
Victor Bonito	Tetra Tech, Inc.	Coral Expert
Aja Reyes	Tetra Tech, Inc.	Coral Expert
Patrick Zuloaga	Tetra Tech, Inc.	Lead Broad-Scale Habitat Survey
Lisa Canty	Tetra Tech, Inc.	Broad-Scale Habitat Survey
Kate Lomac-MacNair	Tetra Tech, Inc.	Broad-Scale Habitat Survey
Andrea Von Burg Hall	AECOM	Broad-Scale Habitat Survey
Travis Niederhauser	Sea Engineering, Inc.	Broad-Scale Habitat Survey
Robert Whitton	Tetra Tech, Inc.	Videographer

*Only the primary function with respect to data collection is listed. Other roles of personnel listed (n=11) and not-listed (n=7) in this table are defined in the Final CJMT Coral Survey Work Plan (DoN 2013b). All personnel were selected based on their suite of capabilities.

Matthew Lybolt, PhD

Dr. Lybolt is a coral reef ecologist with 15 years of professional experience and a strong background in marine ecology, statistical analyses, coral reefs, and climate change. The underlying theme of his career is ecological research and monitoring aimed at detecting change on short- and long-time scales and identifying the primary drivers of those changes. Dr. Lybolt has extensive field, laboratory, and desktop research experience in the disciplines of coral reef ecology (including ESA threatened, endangered, and candidate species), mangrove and sea grass ecology, geomorphology, climate change, and beaches and coastal processes, particularly in the tropics and subtropics. He was a member of the reef data collection team for the CVN expansion in Apra Harbor, Guam. His degrees are a PhD in marine ecology from the University of Queensland, Australia, and an MS in biological oceanography from the University of South Florida, St. Petersburg.

Douglas Fenner, PhD

Dr. Fenner was serving as a coral reef ecologist in American Samoa at the time of data collection for this report. He is a prolific author of scientific, technical, and lay publications, including the book *Corals of Hawaii* and field guides and e-books on identification of corals in American Samoa. For six years he worked for the world’s top coral taxonomist, Dr. “Charlie” Veron, at the Australian Institute of Marine Science. Dr. Fenner named and described seven new species of coral with Dr. Veron. He was a coauthor on the *Science* paper that provided the first-ever evaluation of the endangered species status of all the world’s reef corals, in which he reported that one-third of the corals had heightened levels of risk of extinction. Dr. Fenner has been an active participant in the National Marine Fisheries Service review process for ESA-proposed coral species. He was a key member of the reef data collection team for the CVN expansion in Apra Harbor, Guam. His degrees are a PhD in psychology (Animal Learning & Behavior) from the University of Pennsylvania and a BA in biology from Reed College.

Ed Lovell

Mr. Lovell is the director of Biological Consultants, Fiji, with a 21-year track record of marine biodiversity, contribution to Fiji’s Marine Biodiversity Action Plan, environmental impact assessments, and analyses of coral bleaching events and crown-of-thorns starfish infestations. For seven years he worked with the world’s top coral taxonomist, Dr. “Charlie” Veron at the Australian Institute of Marine

Science and had a major role in the publication of Dr. Veron's multivolume coral taxonomy guides. Mr. Lovell is an author of scientific and technical publications and has been involved with data collection in support of the National Marine Fisheries Service review process for ESA-proposed coral species. His degrees include an MS in marine biology from the University of Queensland, Australia.

Victor Bonito

Mr. Bonito currently serves as director and head scientist for Reef Explorer in Fiji, working to improve local knowledge of marine ecology and conservation, conducting research for management planning and evaluation, and assisting in developing sustainable livelihood opportunities. He has extensive experience with field identification of corals and other reef organisms in the Pacific. Mr. Bonito is an author of scientific, technical, and lay publications, including key reports on the CVN expansion in Apra Harbor, Guam. Over the last 10 years, Mr. Bonito has conducted field work on reefs in the U.S. Virgin Islands, Belize, the Florida Keys, the main Hawaiian islands, American Samoa, Madagascar, Micronesia (Palau, Yap, Saipan, and Guam), and Southeast Asia (Indonesia, Singapore, Malaysia, and Thailand), as well as Fiji. His degrees include an MS in biology from the University of Guam and a BS in biology from the University of North Carolina.

Aja Reyes

Ms. Reyes is a project management coordinator for GHD, Inc., in Guam. She is a professional diver and dive instructor with extensive experience conducting biological surveys and identifying reef organisms in Micronesia. For five years, Ms. Reyes provided guidance to visitors and visiting scientists to the University of Guam Marine Laboratory. Her degrees include a BS in marine biology from the University of Hawaii at Manoa.

Patrick Zuloaga

Mr. Zuloaga is an ecologist specializing in the integration and performance of habitat restoration, assessment and monitoring, mapping, contamination assessments, remedial designs, expert testimony, and NEPA compliant documents, particularly for coral reef, sea grass, mangrove, and wetland habitats. Mr. Zuloaga has extensive field experience with ecological studies for habitat monitoring, habitat mapping and surveys, wildlife monitoring, and surveys of ESA-listed species. Mr. Zuloaga is an expert with cutting-edge underwater habitat mapping tools and techniques. His degrees include a BS in organismic biology and ecology from Florida Atlantic University.

Lisa Canty

Ms. Canty is a professional marine biologist with extensive experience performing impact assessments and surveys of environmentally sensitive areas, including coral reef and sea grass habitat. She is active in the field of mitigation and restoration ecology, particularly for reef and sea grass habitats within the National Park System. Ms. Canty is an expert with cutting-edge underwater habitat mapping tools and techniques. Her degrees include a BS in marine biology from the University of Hawaii at Manoa.

Kate Lomac-MacNair

Ms. Lomac-MacNair has a background in environmental training, field and research, and pertinent studies, with an emphasis on ecology and biological resources. Her education and previous work have focused in marine biology, with an emphasis on marine mammal resources. Working at Tetra Tech Ms. Lomac-MacNair has gained experience implementing NEPA and has worked on several large EIS, BA, and marine resource assessment projects. She is an experienced marine mammal observer and has worked on surveys from various platforms, including aerial, shore, and vessel-based studies. She has worked on small and large vessels and has been project manager of several Alaska-based marine mammal surveys. In addition, Ms. Lomac-MacNair is an AAUS-certified research SCUBA diver and is experienced in offshore marine survey work in remote locations. She is adept in all aspects of planning and execution of marine surveys.

Andrea Von Burg Hall

Ms. Von Burg Hall is an experienced technician and project manager for AECOM and has conducted human health and ecological risk assessments for a wide range of environmental pollutants. In addition, Ms. Von Burg Hall is experienced in marine ecology and is an AAUS-certified research SCUBA diver, which has enabled her to conduct underwater surveys of coral reefs for the Navy and other institutions. Her degrees include a MSPH in risk assessment and regulatory toxicology from Tulane University and a BS in marine biology from Fairleigh Dickinson University.

Travis Niederhauser

Mr. Niederhauser is a professional commercial diver, scientific diver, and diver medic technician. He has extensive experience on coral reefs, primarily conducting restoration projects in Hawaii. At the time of the coral data collection cruise, Mr. Niederhauser was a professional diver and emergency health care provider for Sea Engineering, Inc.

Robert Whitton

Mr. Whitton is an expert technical diver, photographer, and videographer. In addition he has extensive experience in the field identification of reef fish and has assisted in identifying many novel species. Mr. Whitton has extensive practical experience with the best scientists in the field, including field experience in the Mariana Islands. His technical diving and videography techniques have allowed him to work with National Geographic and the Bishop Museum, among others.