Chapter 5 Ta`u Island

5.1 Geopolitical Context

Ta`u Island is the easternmost member of the Manu`a Island group, located ~ 150 km northeast of Tutuila Island and ~ 20 km east of Olosega Island. Ta`u, with a land area of 44 km$^2$, is an extremely steep volcanic island ringed by sea cliffs, some nearly 600 m high, with limited low altitude, level land areas. The seafloor surrounding Ta`u drops steeply, sometimes almost vertically, to abyssal. Collapse and landslides off the remnants of the southern caldera resulted in a south-facing embayment with a steep headwall that overlooks several flat benches, with the most prominent being the Liu Bench overlooking Papaloaloa Point (Fig. 5.1a). Between Olosega and Ta`u lies an unnamed submerged volcanic ridge and cone that was previously active in 1866 (Craig, 2002), and more recently mapped between 2004 and 2006. The broader area is still considered to be geologically active since the submerged volcanic cone of Vailulu`u Seamount is rapidly (in a geologic sense) forming approximately 50 km east of Ta`u.

Ta`u is divided into three counties: Faleasao County, Fiti`uta County, and Ta`u County. The population of Ta`u has mirrored similar trends reported at Ofu and Olosega Islands, with larger populations recorded in the mid-20th century that have seen a steady decline over the course of the last 60 years. Cyclones Tusi (1987), Ofa (1990), and Val (1991) resulted in

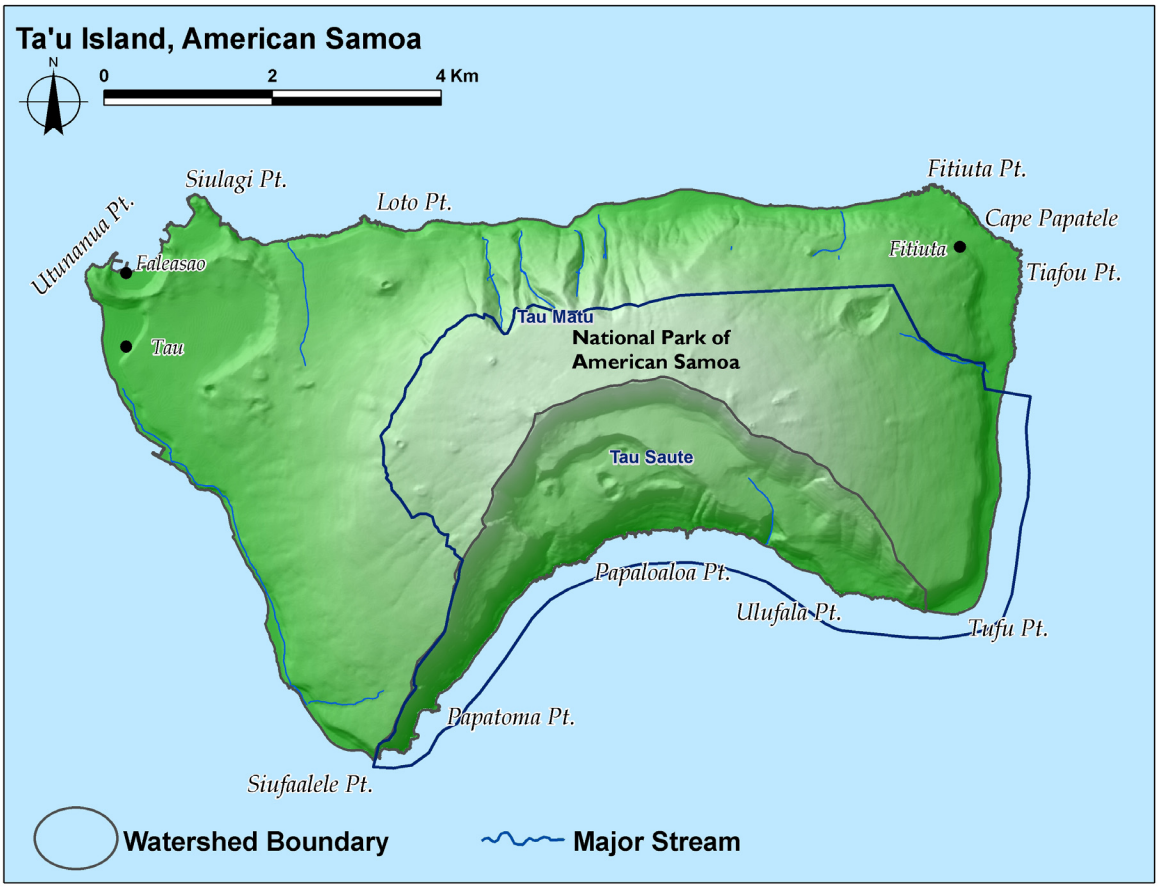

Figure 5.1a. Watershed boundaries, streams, landmarks and villages for Ta`u. Also shown is the boundary for the National Park of American Samoa (NPAS).

approximately one-third of the population moving to Tutuila (Meehl, 1996). The current population of Ta`u was recently estimated at a total of 873 people (U.S. Census Bureau, 2000), with 135 people in Faleāsao County, 380 in Ta`u County, and 358 in Fiti`uta County. The residents of Ta`u rely primarily on subsistence farming, agroforestry, and fishing. There is a relatively low level of tourism to the island. The majority of the residential, agricultural, and commercial land remains in the north and west sides of the island, while the southern and eastern portions remain mostly under the jurisdiction of the NPAS.

Several particular areas and landmarks of Ta`u are notable. A boat harbor is located in the northwestern corner of the island between Utumanu`a Point and Si`ulagi Point near the village of Faleāsao (Fig. 5.1a). The village of Ta`u is located to the south of Faleāsao, along a road that ends halfway down the western coastline. From Ta`u, the same road continues east of Faleāsao passing the airport runway, located near Fiti`uta Point and the village of Fiti`uta, and continues along the eastern coastline before ending near Tufu Point in the southeast. Finally, the NPAS begins halfway between Fiti`uta Point and Tufu Point, and continues along the southern coastline, ending near Si`ufa`alele Point in the southwest.

5.2 Survey Effort

A large amount of physical and biological data have been collected around Ta`u since 2002 as

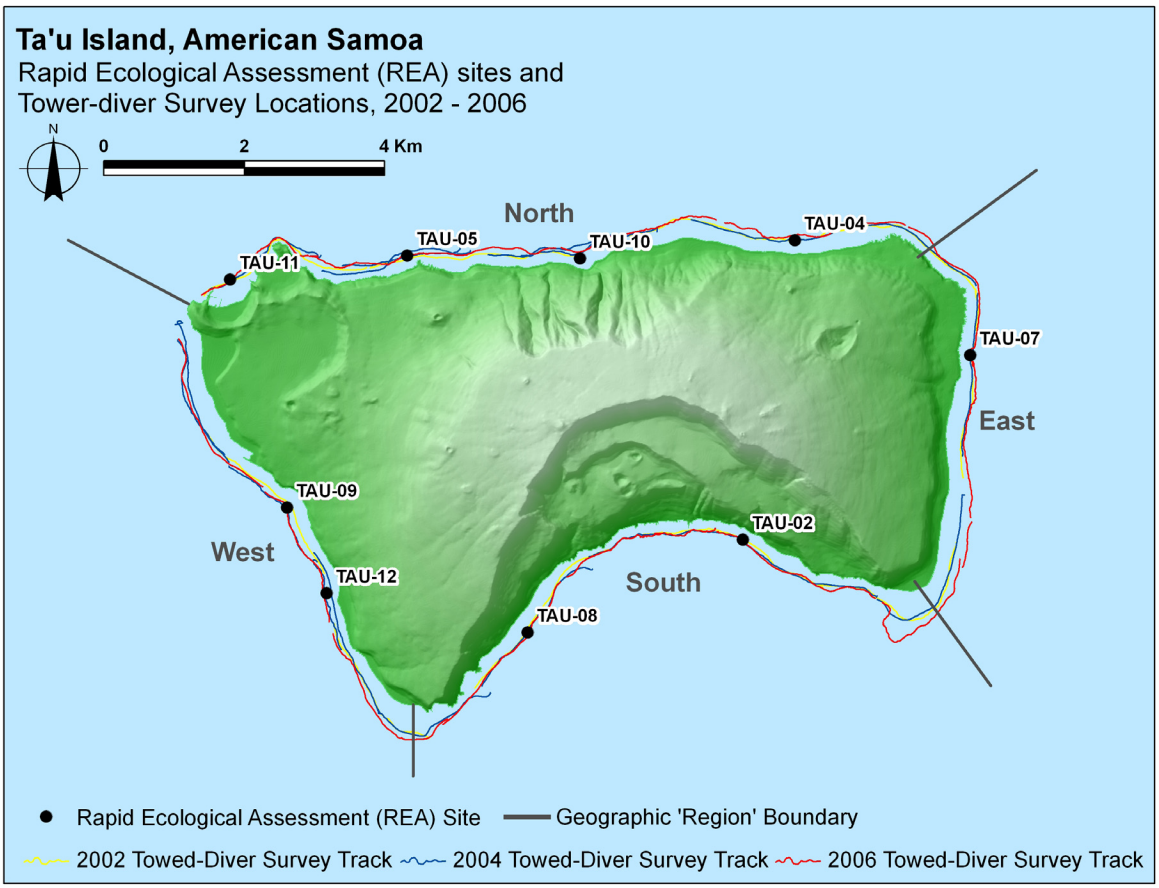

Figure 5.2a. Locations of (Rapid Ecological Assessment [REA] and towed-diver surveys around Ta`u during ASRAMP 2002, 2004, and 2006. Four arbitrary geographic regions have been delineated to aid in discussion of spatial patterns.

part of the Pacific Islands Fisheries Science Center (PIFSC) Coral Reef Ecosystem Division's (CRED's) American Samoa Reef Assessment and Monitoring Program (ASRAMP). The extent and timeframe of these survey efforts are discussed below. To aid in the discussion of spatial patterns of ecological and oceanographic observations around Ta`u throughout this chapter, four geographic regions were delineated based on cardinal directions (Fig. 5.2a).

Benthic habitat mapping data were collected around Ta`u using a combination of acoustic and optical survey methods, the extent of which is summarized in Table 5.2a. These are further examined in Section 5.3: Benthic Habitat Mapping and Characterization.

The locations of REA and towed-diver survey efforts during ASRAMP cruises in 2002, 2004, and 2006 are shown in Figure 5.2a. The number, mean depth, and area of these surveys are presented by year in Table 5.2b.

Table 5.2a. Total area of benthic habitat surveyed from acoustic multibeam sonar and Towed Optical Assessment Device (TOAD) surveys around Ta`u during ASRAMP efforts between 2002 and 2006.

Survey Type	2002	2004	2006
Acoustic Multibeam Sonar	0	82.3 km^2*	gap filling only
TOAD	0 tows	11 tows	5 tows

** Total multibeam surveying conducted across the Manu`a Islands.*

Table 5.2b. Numbers, areas, and mean depths of REA and towed-diver surveys around Ta`u during ASRAMP 2002, 2004, and 2006.

Year	REA Surveys		Towed-diver Surveys		
	Number of Surveys	Mean Depth (m)	Number of Surveys	Survey Area (ha)	Mean Depth (m)
2002	5*	13.7 (SD 0.0)	10	28.3	8.8 (SD 2.7)
2004	9*	15.2 (SD 0.7)	18	36.9	11.3 (SD 4.7)
2006	9	14.3 (SD 0.6)	15	35.8	14.9 (SD 2.6)

** No coral disease surveys were conducted in 2002 and 2004.*

Depth ranges from towed-diver surveys are presented for each year in Figures 5.5.1a (2002), 5.5.1d (2004), and 5.5.1j (2006). Although the towed-diver survey methodology is aimed at following specific isobaths, the actual depths surveyed are often quite variable. These figures illustrate the variability of depths observed during towed-diver surveys and can be referenced when further exploring the towed-diver datasets.

Spatial and temporal observations of key oceanographic and water quality parameters influencing reef conditions around Ta`u were collected using a diverse suite of long-term moored instrumentation packages and closely spaced conductivity, temperature, and depth (CTD) surveys of the vertical structure of water properties during ASRAMP 2002, 2004, and 2006 (see Chapter 2, Section 2.3: Oceanography and Water Quality). A summary of deployed instruments/collection activities is provided in Table 5.2c, and are further examined in Section 5.4: Oceanography and Water Quality.

Table 5.2c. Numbers of oceanographic instrument deployments and shallow- and deep-water CTD casts around Ta`u during ASRAMP 2002, 2004, and 2006. Instrument types include sea surface temperature (SST) buoys, and subsurface temperature recorders (STRs). Deep-water CTD casts were conducted from the surface to a 500-m depth. Deep-water CTD cast information is presented in Chapter 8: Archipelagic Comparisons.

Observation type	2002	2004	2006
SST	2	1	2
STR	0	2	1
Shallow-water CTD casts	30	37	35
Deep-water CTD casts	15*	7*	17*

** Total deep-water CTD casts conducted across the Manu`a Islands.*

5.3 Benthic Habitat Mapping and Characterization

Benthic habitat mapping and characterization of the nearshore waters around Ta`u were conducted using acoustic multibeam sonar, underwater video and still imagery, and towed-diver survey observations between ~ 1 and ~ 250 m (and deeper). Acoustic multibeam sonar mapping provided bathymetric and backscatter data products for depths between ~ 20 and ~ 250 m. Optical validation and benthic characterization via underwater video, still imagery, and diver observations were performed using both shipboard towed cameras (i.e., TOAD) in depths between ~ 20 and ~ 80 m and towed-diver surveys in depths between ~ 1 and 30 m.

5.3.1 Acoustic Mapping and Optical Validation

Because Ta`u is a steep volcanic island with almost no offshore bank areas, depths of 350 m and greater were found less than 1 km offshore (Fig. 5.3.1a). A series of small, relatively shallow, seamount features were discovered ~ 2 km to the northwest of Utumanu`a Point on the northwestern corner of Ta`u. Some of these seamount summits are as shallow as 38 m.

The backscatter imagery acquired during the ASRAMP 2004 surveys was successfully used as a predictive guide for determining sites for the optical surveys conducted during ASRAMP

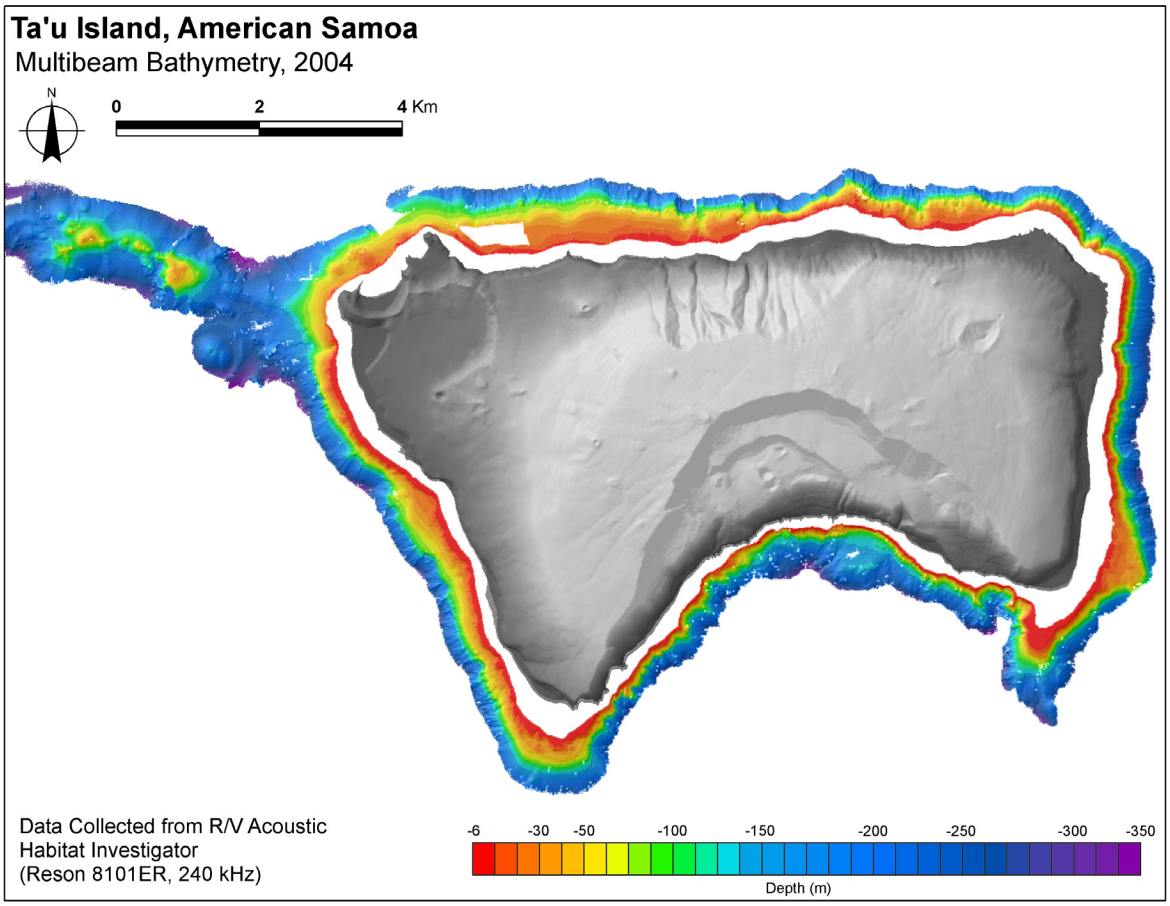

Figure 5.3.1a. Multibeam bathymetry acquisition around Ta`u in depths between ~ 10 and ~ 350 m was completed in March 2004, from the R/V *Acoustic Habitat Investigator* (*AHI*). The island drops steeply from all sides and is connected to Olosega via a series of small seamounts along a submerged ridge tending toward the northwest.

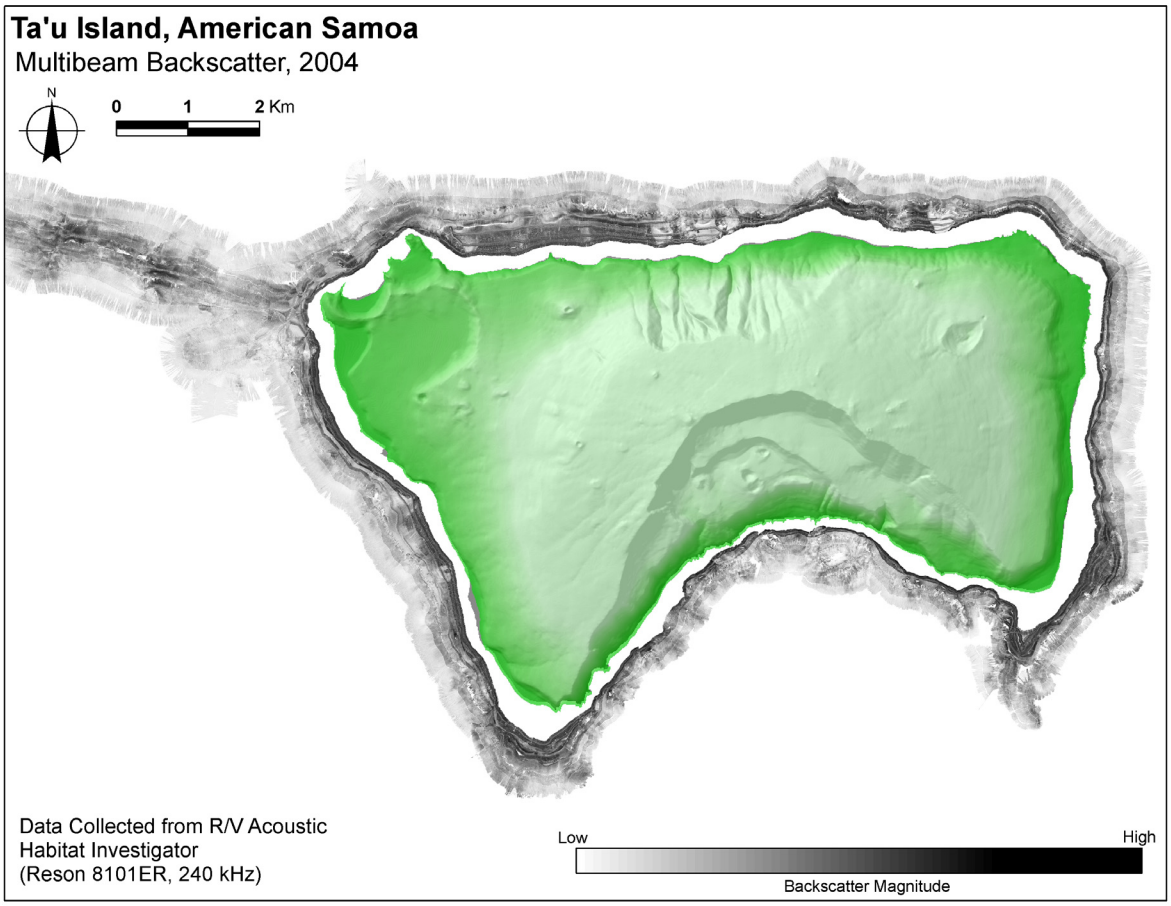

Figure 5.3.1b. Backscatter imagery was acquired in March 2004 during multibeam surveys around Ta`u from the R/V *AHI*. Lighter shades represent low intensity backscatter and likely indicate substrates that are acoustically absorbent and typically indicate unconsolidated sediment. Darker shades represent high-intensity backscatter and likely indicate consolidated hard-bottom and coral substrates.

2006 (Fig. 5.3.1b). For example, observations of high backscatter intensity on the seamounts to the northwest of Ta`u suggested they were likely composed of hard-bottom habitat, possibly including some live coral. During TOAD camera surveys of these seamounts during ASRAMP 2006, video observations confirmed the presence of living corals. Similarly, the southwest point of Ta`u was ground-truthed as hard-bottom habitat and areas in the west region with lower backscatter intensity were determined to include more sedimentary habitats.

Only a limited amount of optical data were collected around Ta`u (Fig. 5.3.1c) because of the difficulties and inherent hazards of maneuvering large vessels close to the island, along with the inherent depth limits imposed on TOAD optical equipment (~ 80 m). Eleven optical data videos were collected from the National Oceanic and Atmospheric Administration (NOAA) Ship *Oscar Elton Sette* in 2004 (examples seen in Fig. 5.3.1d), and an additional five tows were conducted aboard the R/V *AHI* in 2006. Optical data collected during the 2006 TOAD surveys are still being processed and are not included in these results. However, surveys from both 2004 and 2006 indicate the presence of significant coral communities, both off the southeastern corner of the island and the seamount 2 km northwest of Utumanu`a Point.

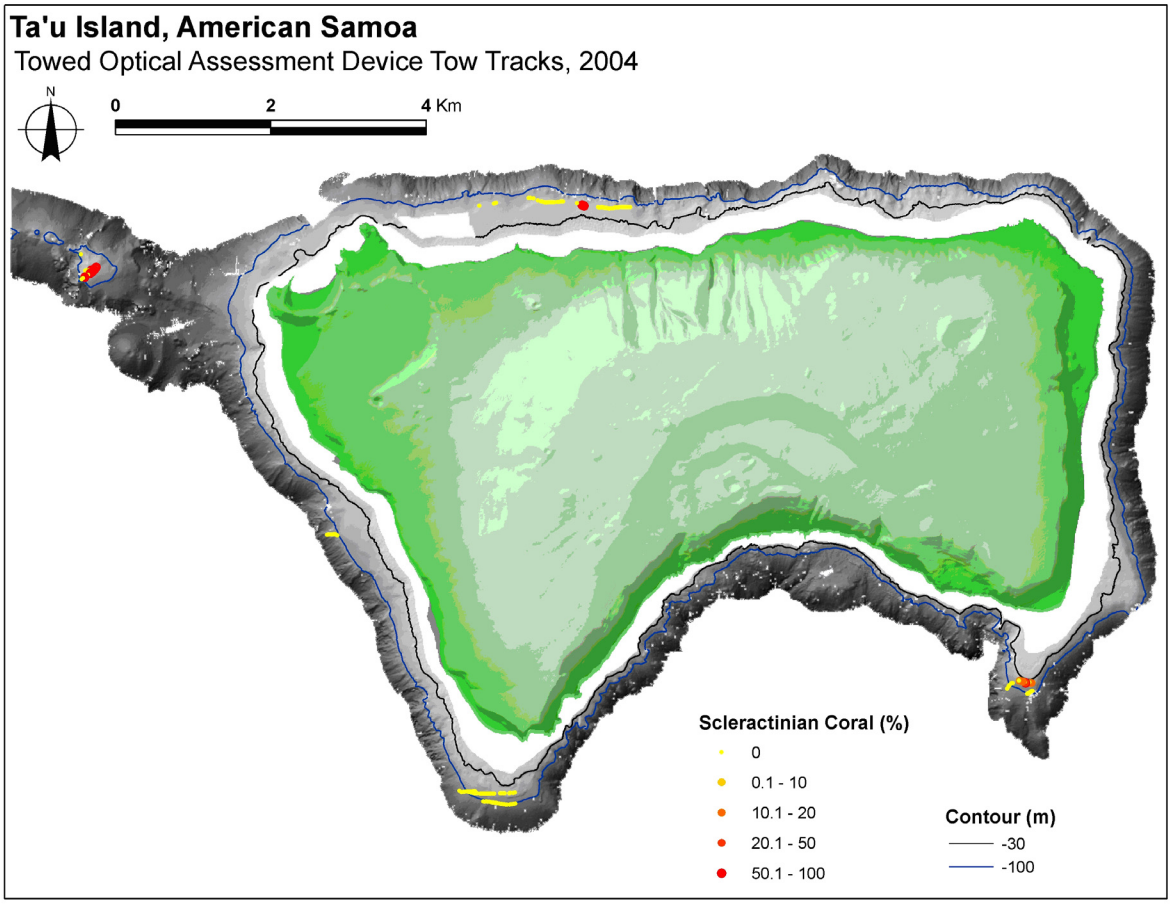

Figure 5.3.1c. TOAD tracks around Ta`u during ASRAMP surveys in 2002 and 2004. The video imagery are post processed to identify substrate type (e.g., sand, rock), living cover (e.g., coral, macroalgae), and other characteristics. The TOAD survey tracks display percentage of live scleractinian coral classified using a point count method with a mean spacing of 20 m along each track. Yellow indicates 0% coral cover, orange colors indicate 0–20% coral cover, and red colors indicate 20–50% and 50–100% coral cover.

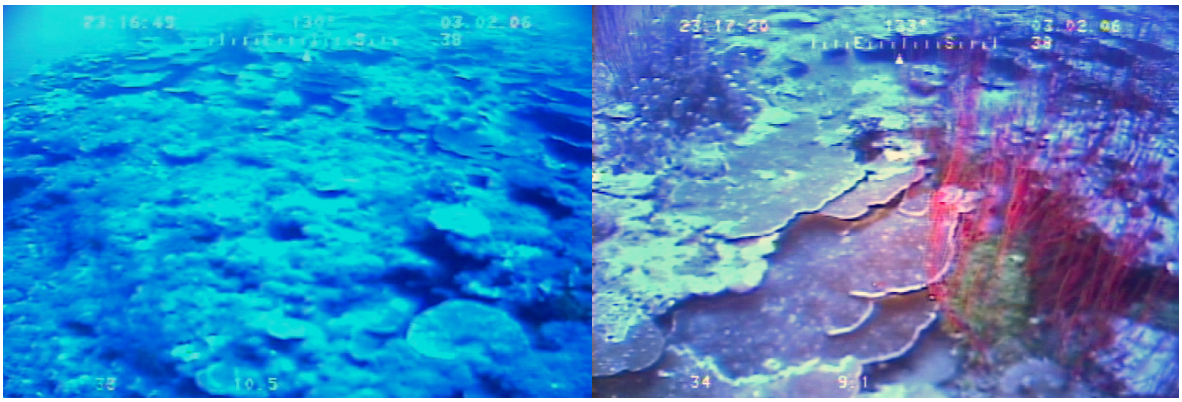

Figure 5.3.1d. Optical validation images acquired during TOAD surveys over the small seamount northwest of Ta`u, showing an abundance of live scleractinian corals at depths of ~ 40–45 m. (*Photographs provided by NOAA PIFSC CRED*)

5.3.2 Habitat Characterization

Towed-diver benthic survey observations around Ta`u from ASRAMP 2002, 2004, and 2006 were concatenated into mean spatial distributions of benthic composition (see Chapter 2, Section 2.2.3: Optical Validation Surveys). These analyses for Ta`u are presented as mean distributions of habitat complexity (Fig. 5.3.2a) and percent cover of sand (Fig. 5.3.2b), hard substrate/pavement (Fig. 5.3.2c), rubble (Fig. 5.3.2d), and live coral (Fig. 5.3.2e). Since these habitat characterization maps represent different complementary components of the same habitat, it is useful to analyze them in relation to each other, the local watersheds, and exposure to prevailing oceanographic conditions.

Habitat complexity was observed to vary significantly around Ta`u, with observations ranging from low to very high (Fig. 5.3.2a). Habitat complexity appeared high to very high in portions of the east, south, and north regions. High to very high habitat complexity was observed along an ~ 1 km stretch of the forereef slope in the east region, specifically the area near the midpoint between Tiafou Point at the northeast corner and Tufu Point at the southeast corner. In this particular area, towed divers have recorded observations of extremely large massive Porites coral heads, some exceeding 5-6 m in height and 14 m in diameter (Figs. 5.3.2f and

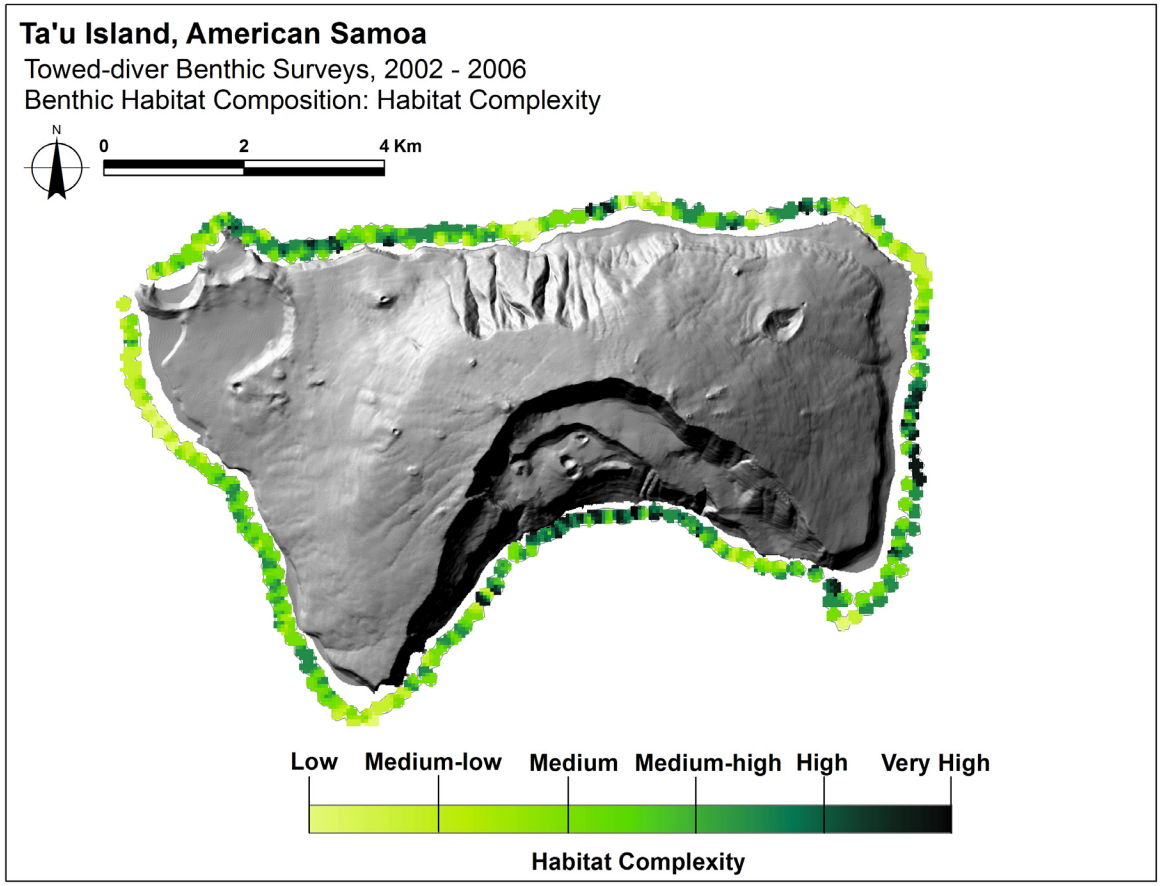

Figure 5.3.2a. Mean benthic habitat complexity concatenated from towed-diver survey observations around Ta`u during ASRAMP 2002, 2004, and 2006. Habitat complexity was subjectively rated by divers over 5-min ensembles (~ 200 m × 10 m) on a 6-point scale representing low (1), medium-low (2), medium (3), medium-high (4), high (5), and very high (6) topographic complexity. Yellow colors indicate low habitat complexity, and dark green colors indicate high habitat complexity.

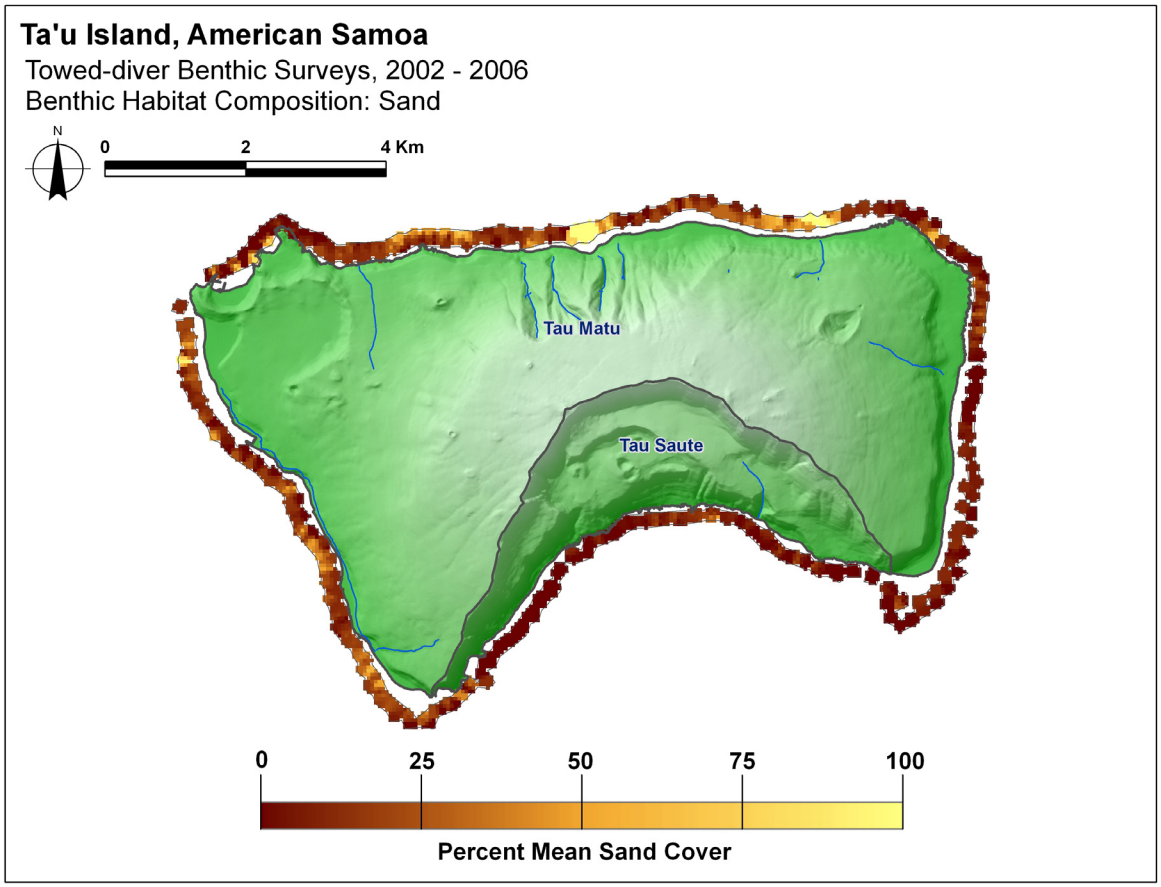

Figure 5.3.2b. Mean percent cover of sand concatenated from towed-diver benthic survey observations around Ta`u during ASRAMP 2002, 2004, and 2006. Major streams (blue lines) overlay the topographic map of the islands, indicating the location of inputs of freshwater runoff into the marine ecosystem. Sand composition was subjectively rated by divers over 5-min ensembles (~ 200 m × 10 m) over a 1–100% scale. Light shades indicate high percent cover of sand, and dark shades indicate low percent cover of sand.

5.3.2g). An additional area of high complexity was noted along the south coast, specifically under the Liu Bench embayment and underneath the headwall surrounding Papaloaloa Point. In this area, divers observed a dramatic vertical rock wall descending as far as visibility allowed (~ 40 m). Few areas of high habitat complexity were also observed widely scattered in the north region. Areas of lower habitat complexity were recorded in a number of regions, specifically near Si`ufa`alele Point along the southwest corner of the island, in the vicinity of the village of Ta`u in the west region and in isolated, clearly defined areas in the north region.

Towed-diver observations concur with backscatter imagery and towed-diver benthic complexity data on the location of several prominent sand channels scattered in the north region, and with the presence of accumulations of sand at the base of the forereef slope in the west region (Fig. 5.3.2b). Both sources suggest that the sand deposits are patchier and less substantial than similar deposits on the islands with more pronounced insular shelves (i.e., Tutuila, Ofu, and Olosega).

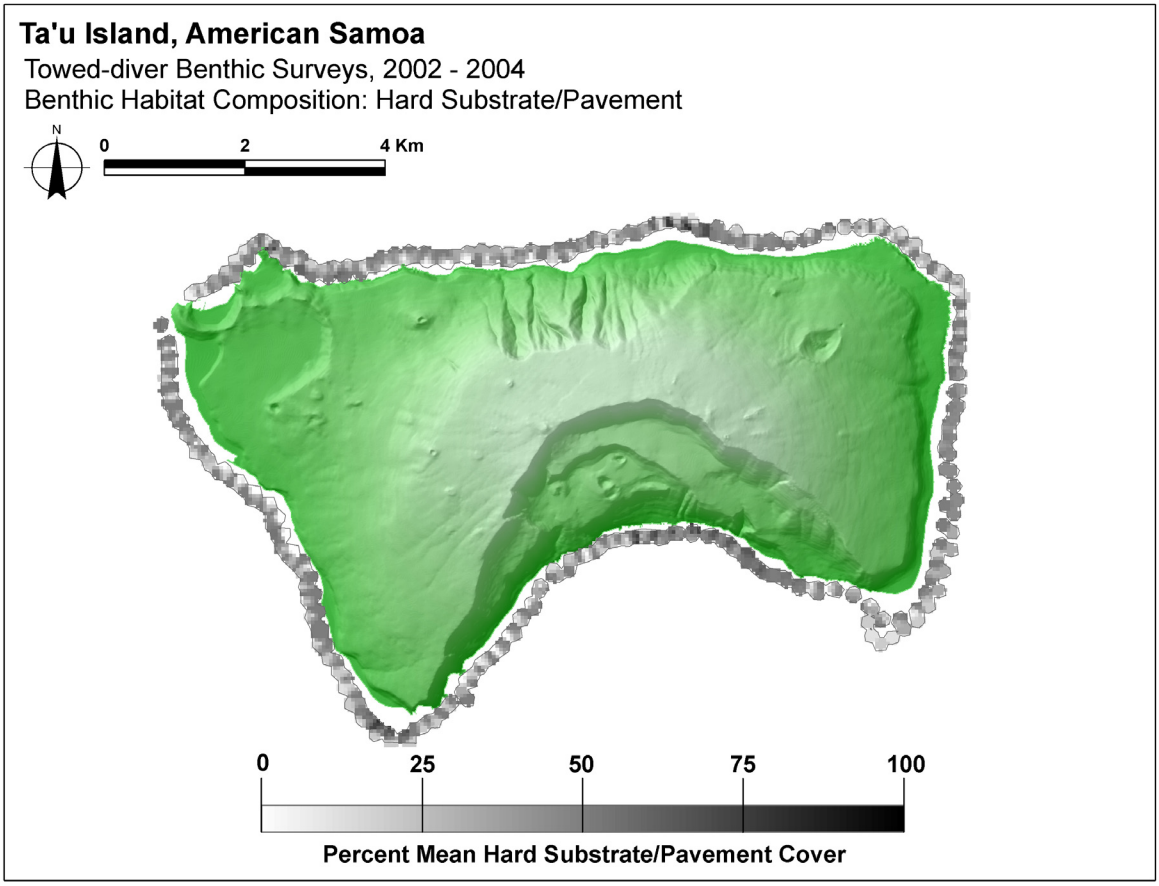

Figure 5.3.2c. Mean percent cover of hard substrate/pavement concatenated from towed-diver benthic survey observations around Ta`u during ASRAMP 2002 and 2004. Hard substrate/pavement composition was subjectively rated by divers over 5-min ensembles (~ 200 m × 10 m) over a 1–100% scale. Dark shades indicate high percent cover of hard substrate, and light shades indicate low percent cover of hard substrate.

The mean percent cover of hard substrate/pavement around Ta`u was generally evenly distributed, with several localized increases (Fig. 5.3.2c) near the base of the Liu Bench and Papaloaloa Point in the south region, around Si`ufa`alele Point at the southwest corner of the island, and in the north in a region directly adjacent to one of the sand channels previously identified with backscatter, complexity, and percent sand cover.

Generally, the mean percent cover of coral rubble around Ta`u from towed-diver survey observations was consistently low, with typical values less than 5% (Fig. 5.3.2d). In a few areas, particularly along the forereef slope in the west region, there were stretches where observed values were closer to 25%. There appeared to be a slight correlation between the increases of sand and rubble in the west region, suggesting the area may be subjected to increased runoff, weathering, bioerosion or combination of these and/or other unknown causes.

The highest observed mean percent covers of live scleractinian coral were recorded in the east region between Tiafou Point and Tufu Point, with values ranging from 30% to 75%, and in the eastern portion of the south region near Ulufala Point, with similar high values (Fig. 5.3.2e). The high coral cover area in the central portion of the east region coincides with observed high levels of habitat complexity and observations of extremely large colonies of massive *Porites* sp. discussed previously in this section. These massive colonies are thought to be among the oldest known living coral colonies in the world. A similar community of ancient massive *Porites* sp. colonies was also discovered on the opposite side of the island in the southern portion of the west region (Figs. 5.3.2f and 5.3.2g). Several colonies were huge and were estimated to be between 500 and 1000 years old. Unfortunately, many of these massive corals in this region had also suffered mortality or near-mortality events. It is not

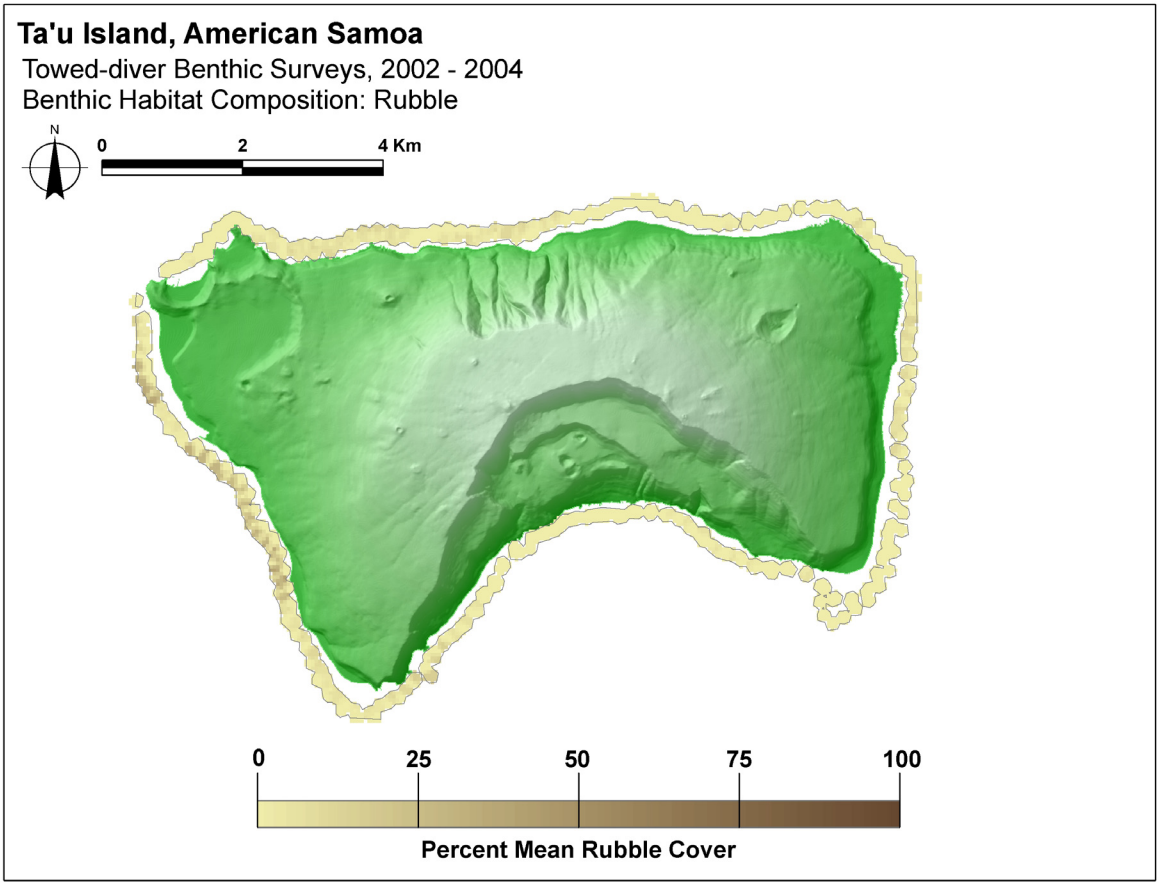

Figure 5.3.2d. Mean percent cover of rubble concatenated from towed-diver survey observations around Ta`u during ASRAMP 2002 and 2004. Rubble composition was subjectively rated by divers over 5-min ensembles (~ 200 m × 10 m) over a 1–100% scale. Light shades indicate low percent cover of coral rubble, and dark shades indicate high percent cover of coral rubble.

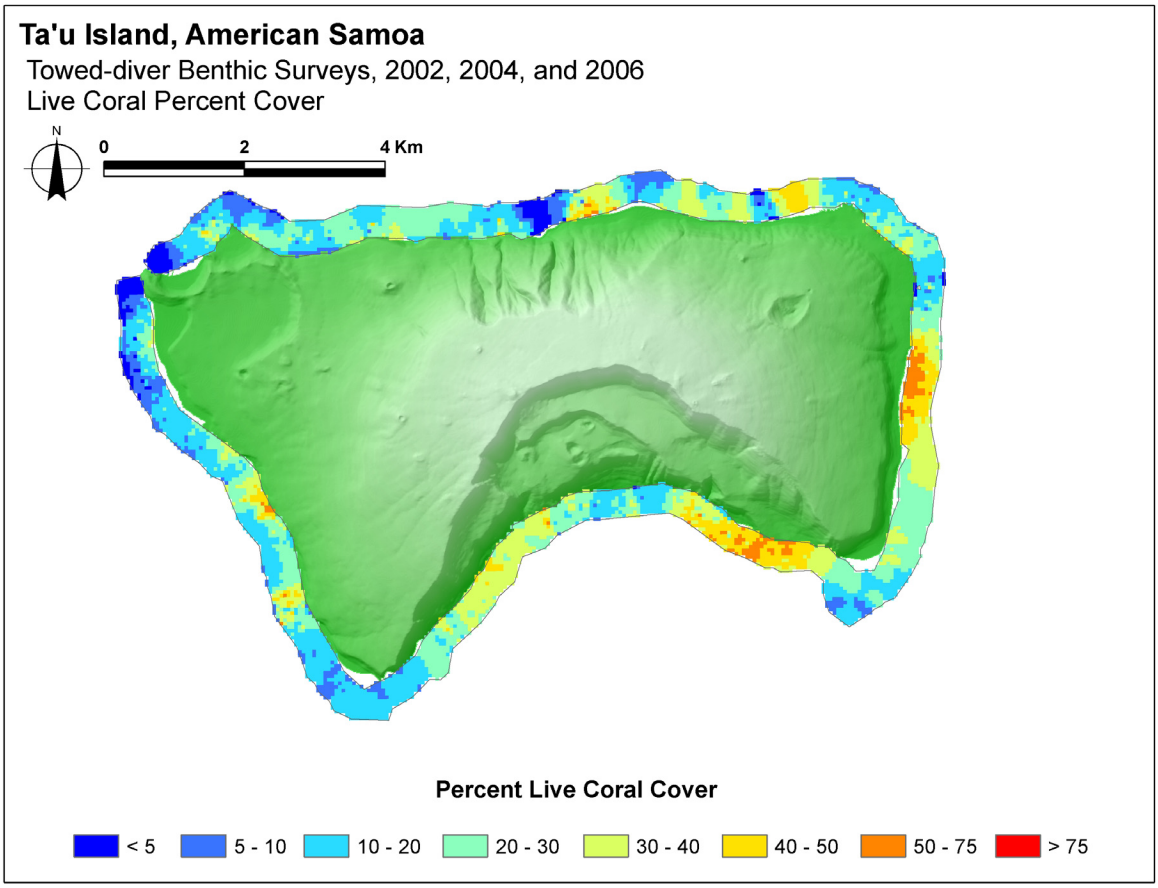

Figure 5.3.2e. Mean percent cover of live scleractinian (stony) coral concatenated from towed-diver survey observations around Ta`u during ASRAMP 2002, 2004, and 2006. Live coral cover composition was subjectively rated by divers over 5-min ensembles (~ 200 m × 10 m) on a 1–100% scale. Blue colors indicate low percent cover of coral, and reddish colors indicate high percent cover of coral.

known when or why these massive colonies died off.

In the south region, and to a lesser extent, percent cover of live coral was moderately high (20–50%) in the area east of Papaloaloa Point. Interestingly, the area in between the two high coral cover areas in the south region was highly complex, but generally contained much lower coral cover (0–20%). This may be a result of freshwater inputs running off the southern-facing, stair-step caldera complex off of the Liu Bench, geologic activity (e.g., rockslides) or a combination of these and/or other environmental factors. Additional areas of high coral cover included several areas in the north region between REA sites TAU-10 and TAU-04 and two sites in the west region, north of Si`ufa`alele Point near REA sites TAU-09 and TAU-12 (Figs. 5.2a and 5.3.2e).

Figure 5.3.2f. Massive *Porites* sp. coral heads first discovered by the CRED towed-diver observers on the southwest side of Ta`u during ASRAMP 2002. (*Photograph provided by NPAS*)

Figure 5.3.2g. Massive *Porites* sp. coral heads thought to be roughly 500–1000 years old, possibly among the oldest known coral colonies in the world, and are one of the most unique findings by CRED scientists in American Samoa. (*Photograph provided by NPAS*)

5.4 Oceanography and Water Quality

Oceanographic and water quality data have been collected in the waters surrounding Ta`u over the period between 2002 and 2006. Instrumentation and equipment descriptions, deployment dates and locations, and a subset of the results are discussed below. Specific details of deployments and additional data are presented in Appendix II, Figure II. iii.

5.4.1 Hydrographic Data

2002 Spatial Surveys

During ASRAMP 2002, 30 shallow-water CTD casts were conducted in nearshore waters around Ta`u between February 11 and 13 (Figs. 5.4.1a and 5.4.1b). Data from these profiles show evidence of vertical stratification of the water column around all sides of the island surveyed (A–J; Fig. 5.3.1b), although this stratification was weaker around the southwest sector of the island (G–J) in the south and west regions. The mid-depth (~ 10–30 m) portion of the water column in the north region (A–D) was generally cooler, more saline (> 35.5 psu) and more dense (> 22.4 kg m^{-3}) than in the south and west regions (E–J). The western portion of this north region (A–B) had particularly strong stratification with warmer surface waters (~ 30°C) and relatively cool bottom water (~ 28.5°C). Though temperature was stratified in

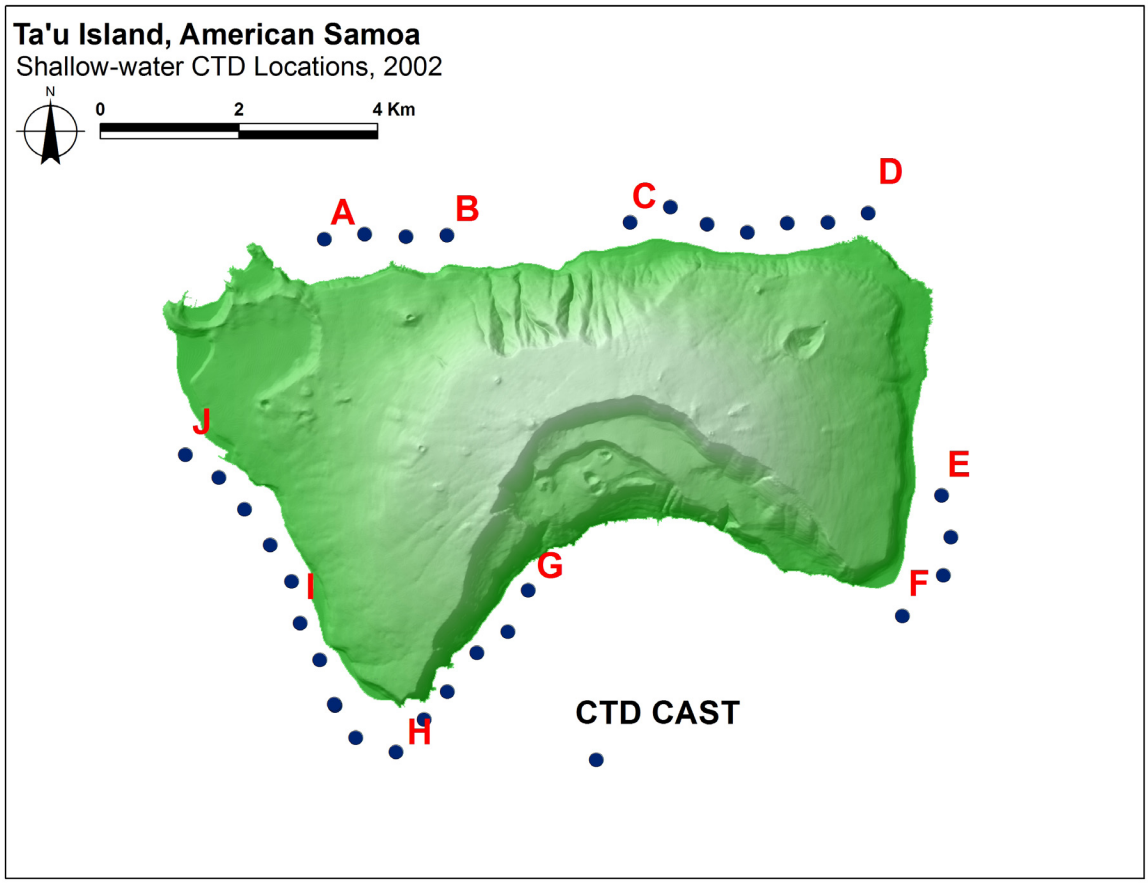

Figure 5.4.1a. Shallow-water CTD cast locations, shown as blue dots, expressed sequentially in a clockwise direction around Ta`u (A–J) during ASRAMP 2002, February 11–13.

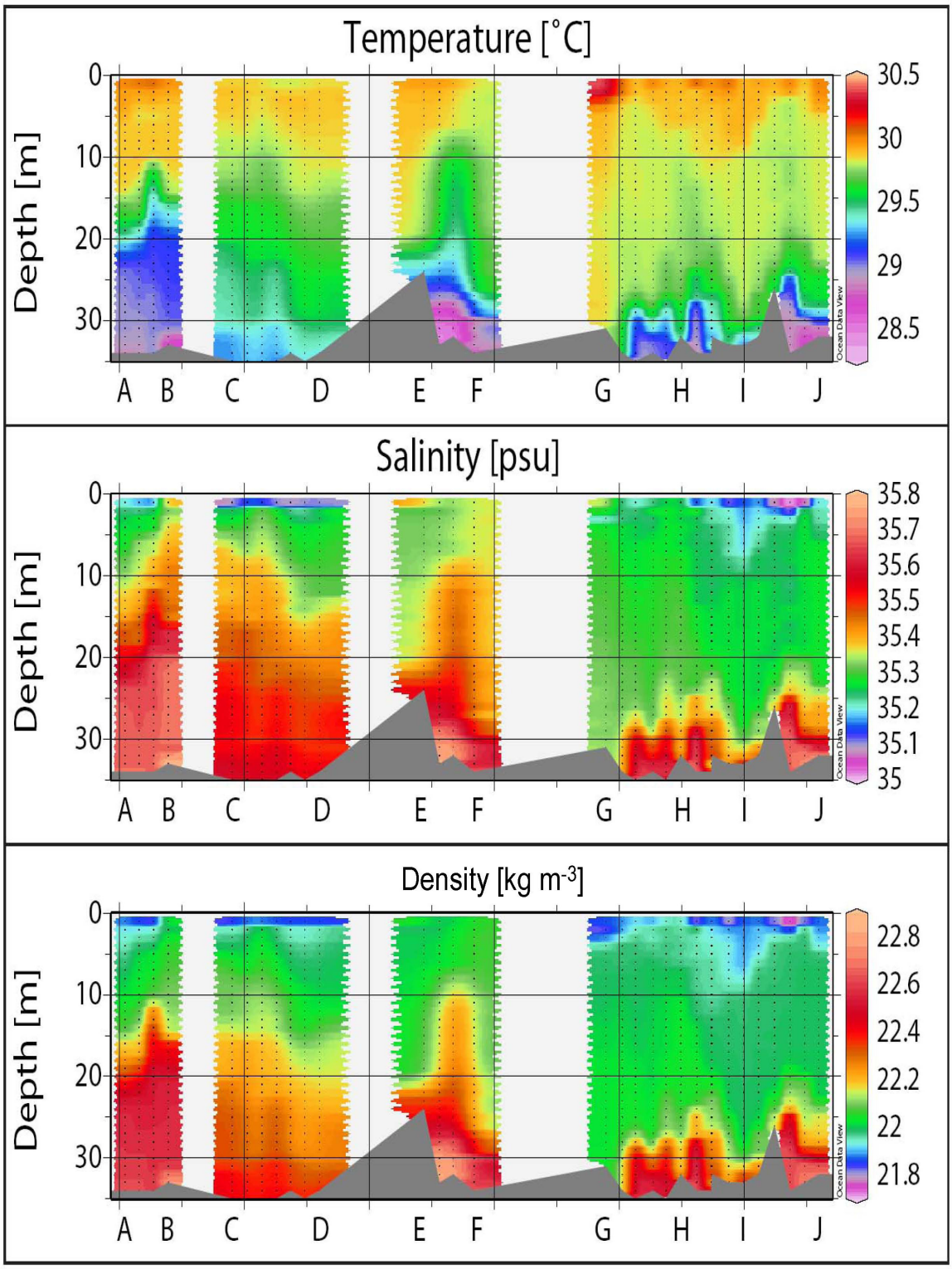

Figure 5.4.1b. Shallow-water CTD cast profiles to a 30-m depth around Ta`u during ASRAMP 2002, February 11–13, including temperature (°C), salinity (psu), and density (kg m^{-3}). Profiles are shown sequentially in a clockwise direction around the island (A–J), as shown in Figure 5.3.1a.

the southwest sector (G–J), with warm surface water (< 5 m) and cool bottom water (> 20 m), salinity (~ 35.2 psu) and density (~ 22 kg m^{-3}) were relatively well-mixed in the mid-depth portion of the water column. These observations suggest surface heating with limited vertical

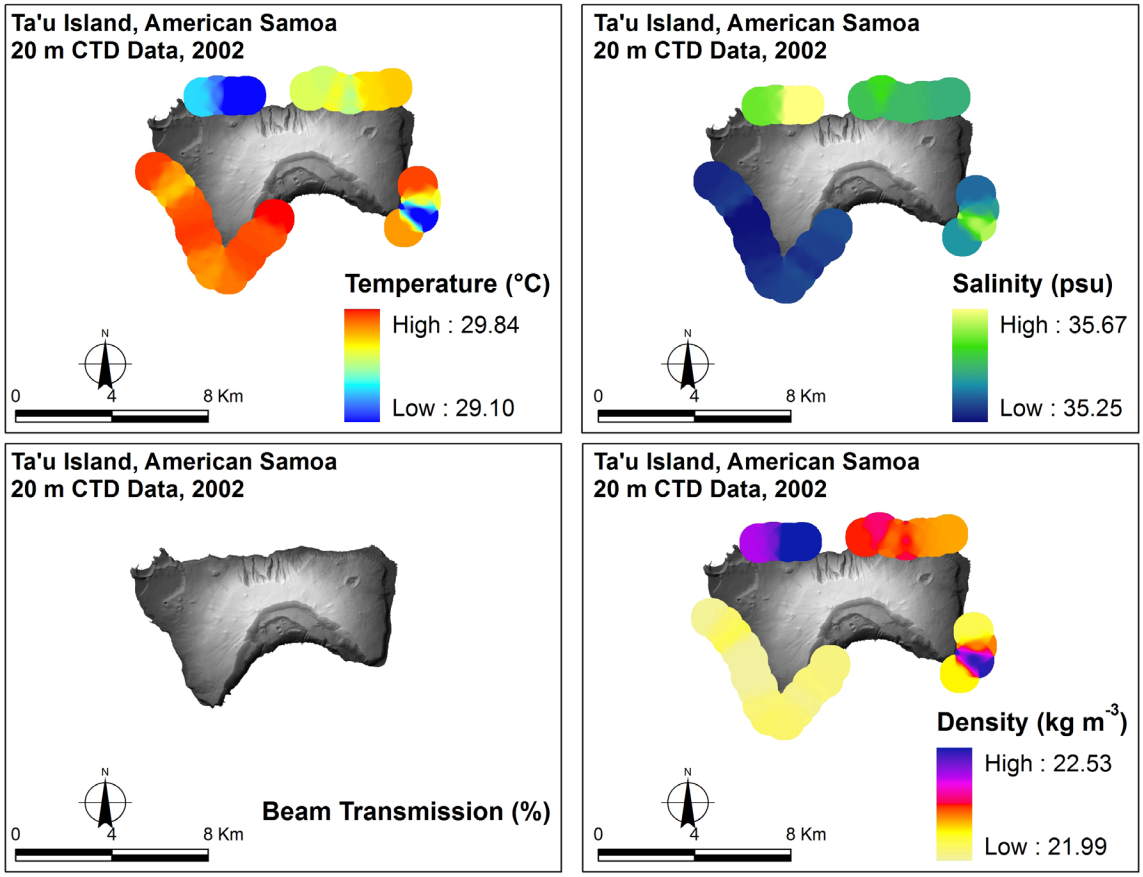

Figure 5.4.1c. Interpolated water temperature (top left), salinity (top right), and density (bottom right) at a 20-m depth derived from shallow-water CTD casts around Ta`u during ASRAMP 2002, February 11–13. Beam transmission data (bottom left) were not collected.

mixing because of this sector's location in the lee of the island.

Spatial analyses of these physical water properties at a 20-m depth from the ASRAMP 2002 surveys shows moderate ranges in temperature (29.09°–29.83°C), salinity (35.13–35.33 psu), and computed density values (21.99–22.53 kg m^{-3}; Fig. 5.4.1c). In general, waters in the south and west regions of Ta`u were warmer, less saline, and less dense than observations in the north region of Ta`u where the waters were notably cooler and more saline, particularly the western portion (A–B) of the north region.

2004 Spatial Surveys

During ASRAMP 2004, 37 evenly spaced shallow-water CTD casts were conducted in the nearshore waters around Ta`u between February 4 and 5 (Fig. 5.4.1d). Data from these CTD profiles show a relatively well-mixed water column along the north coast (A–C) from just north of Utumanu`a Point on the northwest corner to Tiafou Point on the northeast corner, with increased stratification in the waters below ~ 25 m, where waters were noticeably cooler and more saline than the waters above (Fig. 5.4.1e). Around the southeast point of Ta`u (D–E), a pronounced increase in temperature from ~ 29.45° to ~ 29.7°C throughout the upper ~ 25 m was not obviously correlated with significant changes in salinity or density. There was an observed increase in beam transmission in this warm water tongue. Along the entire south

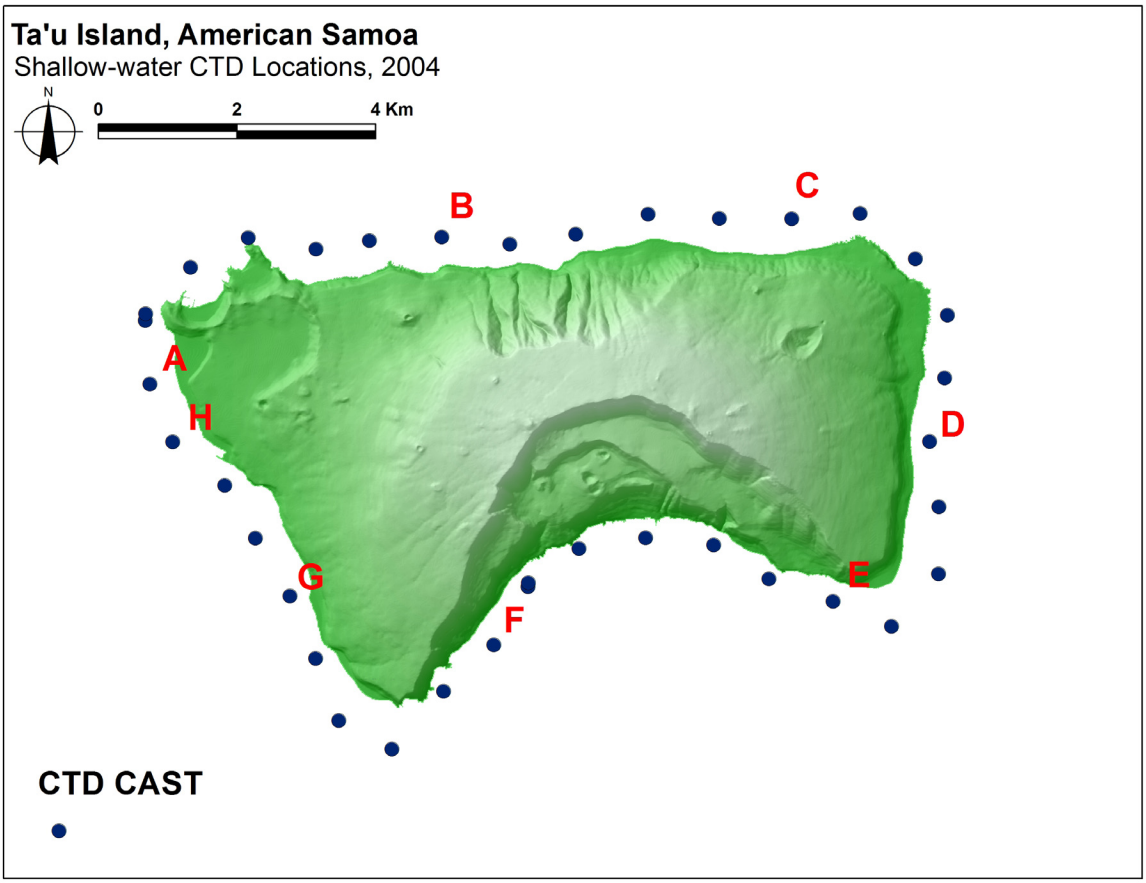

Figure 5.4.1d. Shallow-water CTD cast locations, shown as blue dots, expressed sequentially in a clockwise direction around Ta`u (A–H) during ASRAMP 2004, February 4–5.

coast from Tufu Point to just past Si`ufa`alele Point (E–G), the most striking feature was the presence of relatively cold (29.2°C), saline (35.4 psu) bottom water (~ 30–35 m depths), and moderate vertical stratification through the water column. The stratification of the water off the southern shores was likely because of the calmer waters within the embayment allowing surface heating and limited mixing from wind and wave forcing.

The patterns of observed physical water properties at a 20-m depth around Ta`u during ASRAMP 2004 showed clear spatial structure with small to moderate ranges in temperature (29.35°–29.69°C), salinity (34.78–35.09 psu), computed density (21.87–22.26 kg m^{-3}), and beam transmission (92.27–93.94%; Fig. 5.4.1f). For temperature, warmest waters were observed along most of the coast in the east region, in the same area with the highest observed coral cover, high habitat complexity, and large *Porites* coral heads. Coolest waters at a 20-m depth were observed along most of the south shore region, including Si`ufa`alele Point at the southwest corner of the island. For salinity, the entire north region had relatively low salinity water compared to the more saline south region. These combined temperature and salinity patterns at the 20-m depth resulted in low-density waters along the north coast and high-density waters along the south region. For beam transmission, the patterns appeared more variable with highest values (low turbidity) and lowest values scattered at three separated areas along the north region of the island.

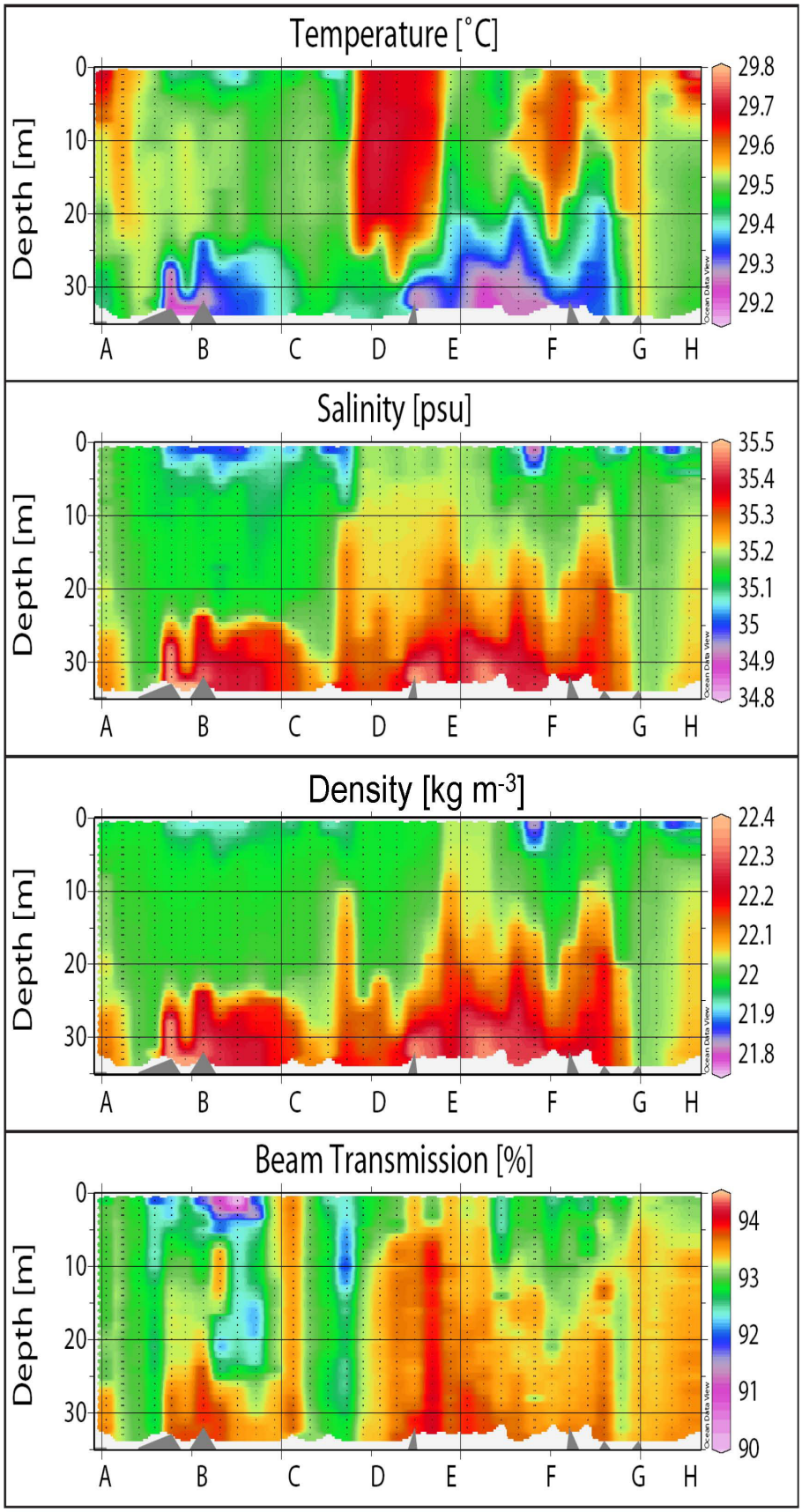

Figure 5.4.1e. Shallow-water CTD cast profiles to a 30-m depth around Ta`u during ASRAMP 2004, February 4–5, including temperature (°C), salinity (psu), density (kg m^{-3}), and beam transmission (%). Profiles are shown sequentially in a clockwise direction around the island (A–L), as shown in Figure 5.3.1d.

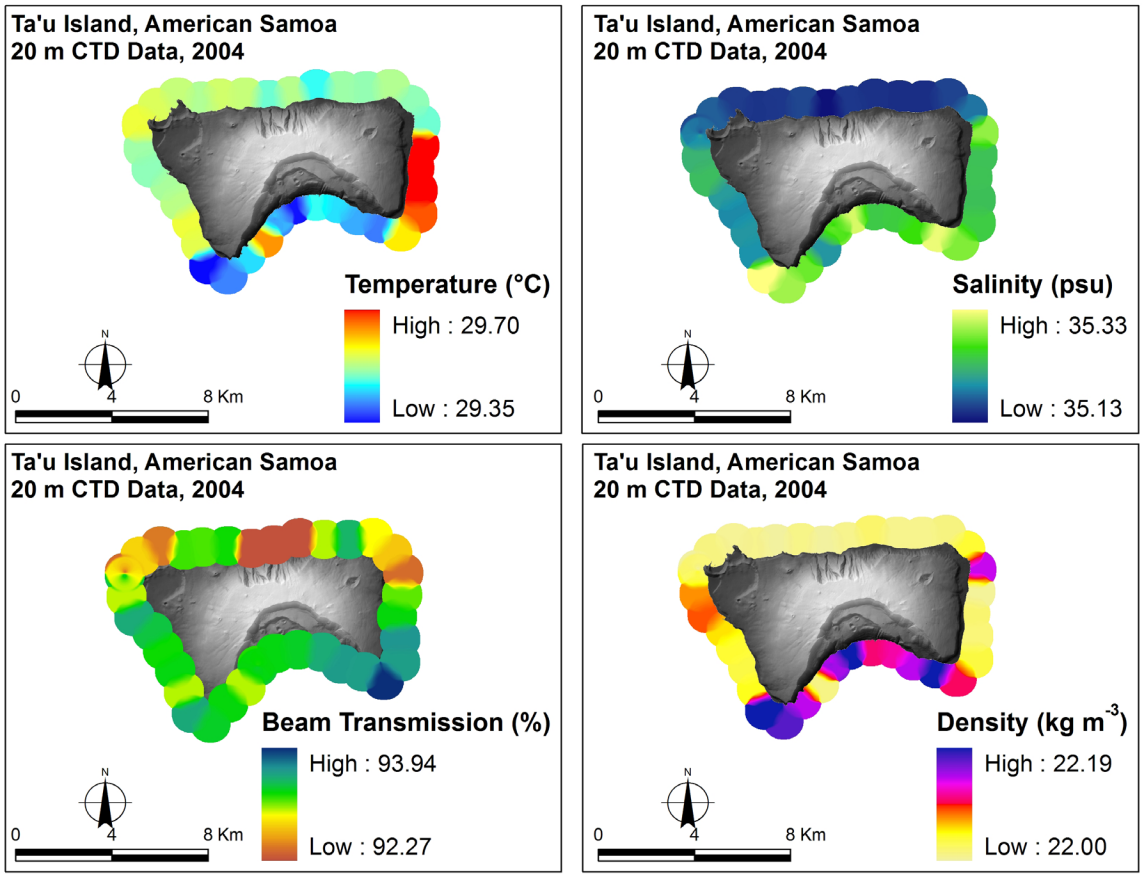

Figure 5.4.1f. Interpolated water temperature (top left), salinity (top right), beam transmission (bottom left), and density (bottom right) at a 20-m depth derived from shallow-water CTD casts around Ta`u during ASRAMP 2004, February 4–5.

2006 Spatial Surveys

During ASRAMP 2006, 35 CTD casts were conducted in nearshore waters surrounding Ta`u between March 2 and 4 (Fig. 5.4.1g). In addition, water samples for nutrient and chlorophyll analysis were collected at 1-, 10-, 20-, and 30-m depths, where possible, at seven of these shallow-water CTD sites. Dissolved inorganic carbon (DIC) samples were collected at each of these seven sites (Fig. 5.4.1j).

Vertical profiles of water properties from shallow-water CTD surveys around Ta`u during ASRAMP 2006 indicate three main features (Fig. 5.4.1h). The first feature was an alternating pattern of well-mixed regions of the water column along the north and east coasts of the island (B–E) with different characteristics. Most of this stretch was characterized by relatively cool (29°C) water with moderate salinity values. At the northeast corner near Cape Papatele, a well-mixed warm (29.3°C) tongue was observed from the surface to the bottom. Although salinity was not different in this area, the warm temperature resulted in a corresponding tongue of low density water. The second feature was a region of warm (> 29.5°C), low salinity (< 34.5 psu) surface water and a moderately well-mixed subsurface water column along the south coast (E–F). The third feature was a stratified, relatively cool (< 28.75°C), dense (>

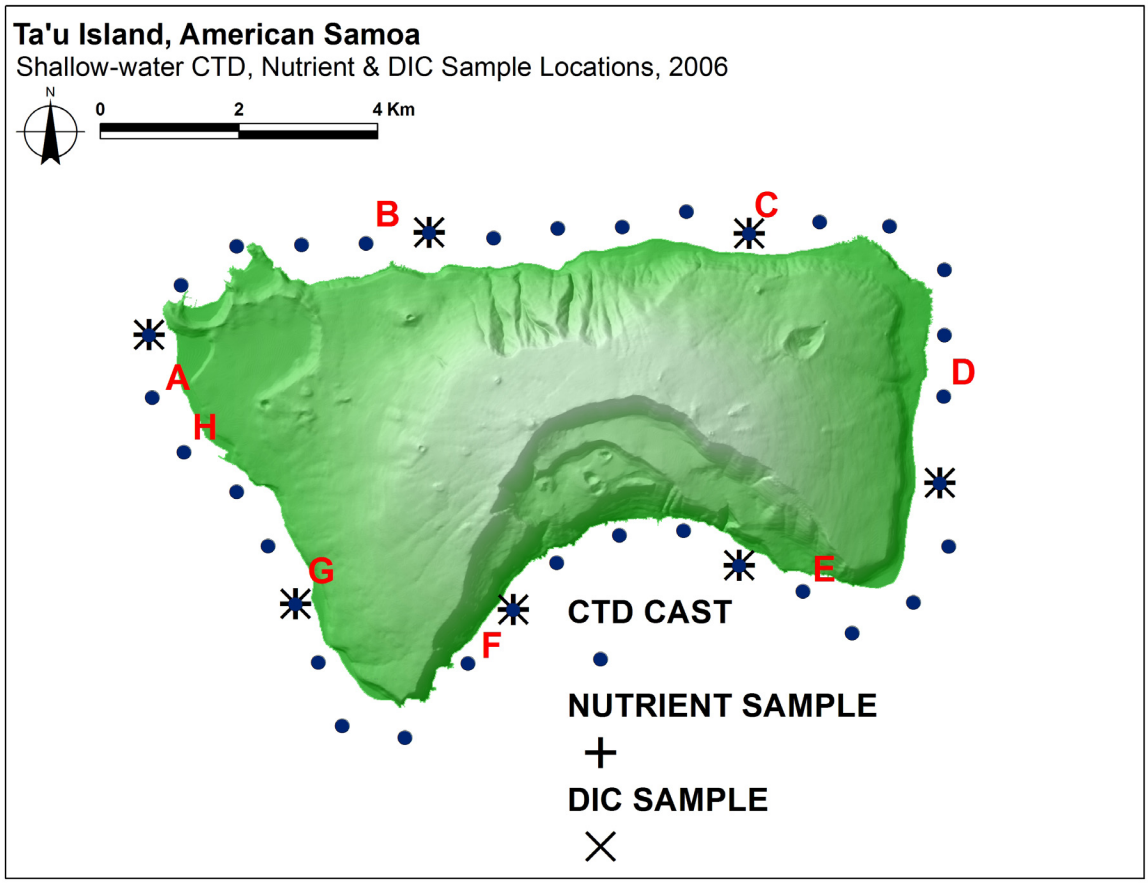

Figure 5.4.1g. Shallow-water CTD cast and nutrient and DIC water sample locations around Ta`u (A–H) during ASRAMP 2006, March 2–4.

22.2 kg m^{-3}), saline (> 35 psu) mass of bottom water in the leeward west region of the island (G–A). These bottom temperatures were strikingly lower than any others observed around the island. Because of a faulty sensor, beam transmission data collected during ASRAMP 2006 were insufficient to develop any conclusions.

The moderately well-mixed waters of the north and east regions (B–E) of Ta`u were exposed to wave and wind action during the observation period, causing mechanical mixing of warm surface water with cooler bottom waters. Relatively protected waters in the embayment on the south side of Ta`u (E–F) may have been subjected to surface heating and limited, wave-induced mixing in the upper water column. Additionally, river and land runoff, and possibly subsurface springs, are likely to be prevalent within this embayment. Runoff may be indicated by the low salinity (34.4 psu) and density (21.5 kg m^{-3}) values observed in the upper water column (E–F).

Physical water properties at a 20-m depth during the 3-day survey around Ta`u in 2006 showed a moderate range in temperature (28.64°–29.23°C), with cooler waters observed to the west and warmest waters observed around Cape Papatele at the northeast corner of the island (Fig. 5.4.1j). As with temperature, observed salinity showed moderate variability (34.78–35.09 psu) around the island. The spatial pattern in salinity was marked by low salinities on the west half of the island and moderate salinities on the eastern half. The lowest salinities are observed at Utumanu`a Point in the northwest and Si`ufa`alele Point at the southwest

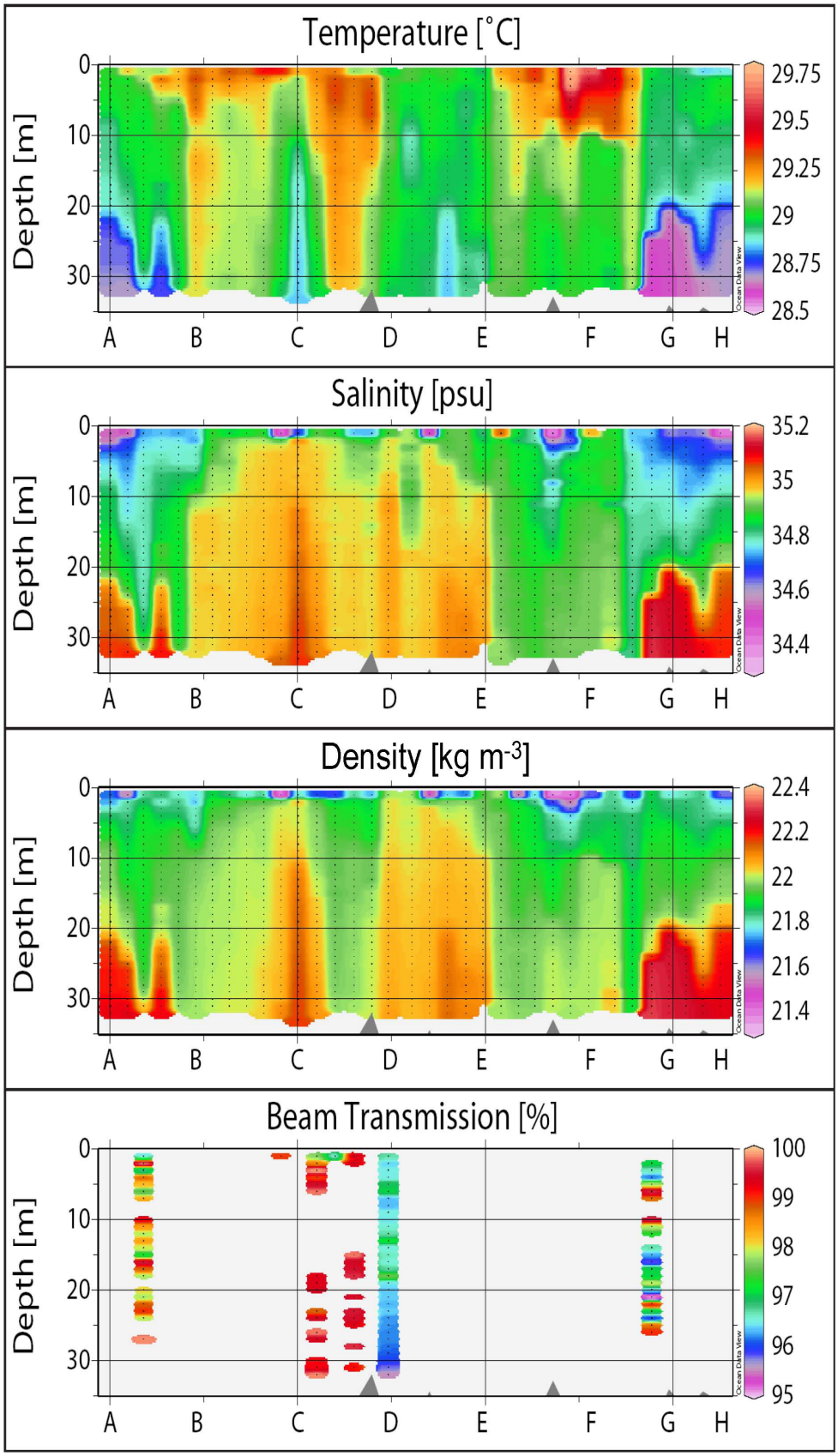

Figure 5.4.1h. Shallow-water CTD cast profiles to a 30-m depth around Ta`u during ASRAMP 2006, March 2–4, including temperature (°C), salinity (psu), density (kg m^{-3}), and beam transmission (%). Profiles are shown sequentially in a clockwise direction around the island (A–J), as shown in Figure 5.4.1g.

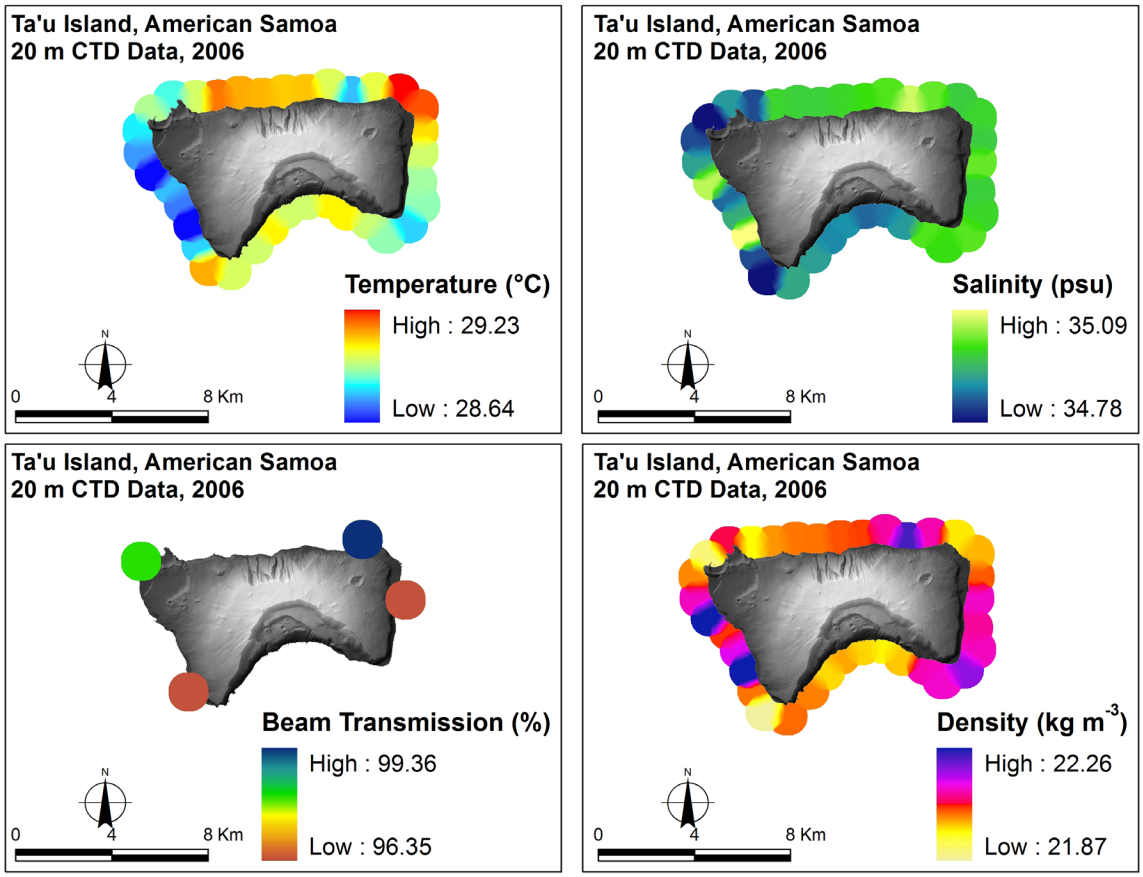

Figure 5.4.1i. Interpolated water temperature (top left), salinity (top right), beam transmission (bottom left), and density (bottom right) at a 20-m depth derived from shallow-water CTD casts around Ta`u during AS-RAMP 2006, March 2–4.

corner. Beam transmission observations were limited because of instrument problems but varied between 96.35% and 99.36%, with highest values (lowest turbidity) observed in the northeast corner and lowest values observed in the east and west regions (near Si`ufa`alele Point). A point source of terrigenous input, or land-based sediment, was potentially the cause of the notable increases in turbidity, particularly since Si`ufa`alele Point also had low salinity. More data are needed to properly assess the nature of the signal. Computed density values (21.87–22.26 kg m^{-3}) show similar distributions as salinity; the lowest and highest density values occurred on the northwest, west, and southwest portions of the island.

The in situ nutrient data collected at Ta`u displayed the following ranges: chlorophyll-a (Chl-a), 0.26–0.69 µg L^{-1}; phosphate (PO_4), 0.04–0.15 µM; silicate (SiO_2), 0.6–1.21 µM; and total nitrogen ($N_{tot} = NO_3 + NO_{2-}$), 0.23–0.64 µM. Water samples showed an increase in Chl-a concentrations near the harbor area, while most other nutrient concentrations showed increased values along the south shore of Ta`u (Fig. 5.4.1j). The south shore of Ta`u has the highest SiO_2 values in the American Samoa Archipelago. The south shore also exhibited a spike in PO_4 and NO_{2-} values. The vast majority of the population resides on the west coast, where nitrogen levels appeared elevated. There is also a small airport on the northeast corner of the island, although no increase in nutrients was observed in that area.

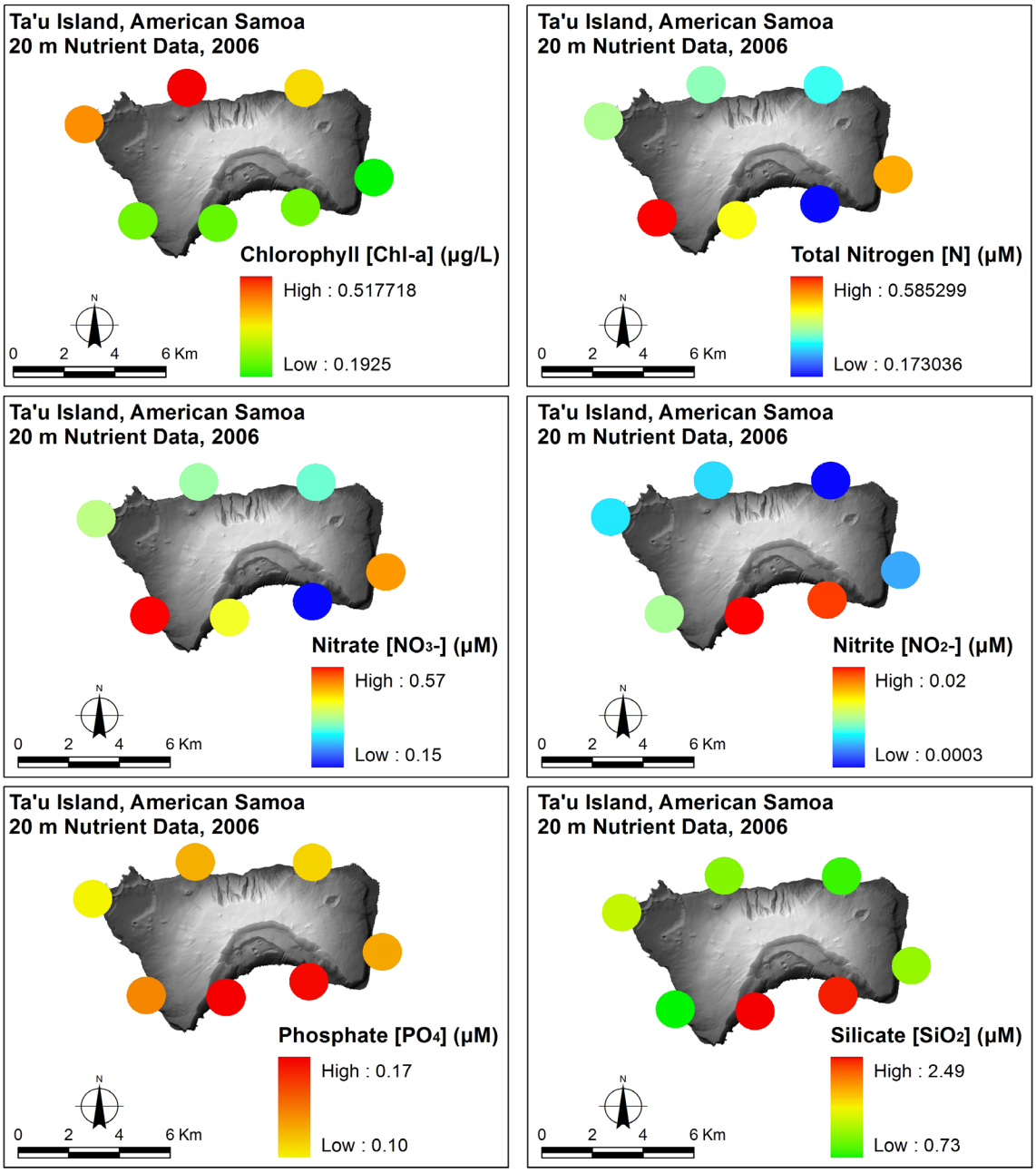

Figure 5.4.1j. Interpolated Chl-a (top left), total nitrogen (top right), nitrate (middle left), nitrite (middle right), phosphate (bottom left) and silicate (bottom right) concentrations, at a 20-m depth derived from water samples collected in concert with shallow-water CTD casts around Ta`u during ASRAMP 2006, March 2–4.

5.4.2 Temporal Comparison—Hydrographic Data

During each of the ASRAMP survey periods in 2002, 2004, and 2006, the nearshore shallow-water CTD and water quality observations showed noteworthy spatial structure. Temperature, salinity, and density values each varied spatially during each survey periods, although observed patterns were not consistent between survey periods. Ta`u was similar to Ofu and Olosega in terms of nutrient results. Site-to-site variability within nutrient value results was slightly less than the variability seen around Tutuila. These results are a baseline for comparison with future nutrient datasets. It is important to note that substantial rainfall

occurred during the survey period and that resulting terrestrial runoff affected results of the nutrient sampling.

5.4.3 Time Series Observations

A suite of moored instruments were deployed around Ta`u over the period between 2002 and 2006 to collect time series observations of key oceanographic properties influencing reef conditions (Fig. 5.4.3a). Deployment and retrieval dates of each instrument are detailed in Appendix II, Table II.iii. Figure 5.4.3b shows a time series of in situ and remotely sensed SST and modeled wave properties from January 2002 to April 2006.

Pathfinder SST data from Ta`u showed predominantly seasonal variability with warmest temperatures (~ 30.0°C) observed during January–March and coolest temperatures (~ 27.5°C) in June–August (Fig. 5.3.2b, top panel). A particularly cool episode, with temperatures reaching nearly 1.5°C below SST climatology, was observed in austral winter 2002 before temperatures rose sharply to climatologically normal values in late 2002. In situ SST data were observed to be cooler and more variable when compared to Pathfinder SST temperature. Throughout most of the in situ record (July 2002–2004), moored SST values were observed to be 0°–3.5°C cooler than that observed via satellite and, for the most part, cooler when compared to the SST climatology. Telemetered in situ SST data from March 2004 to February 2005 correlated well with both Pathfinder SST and climatology.

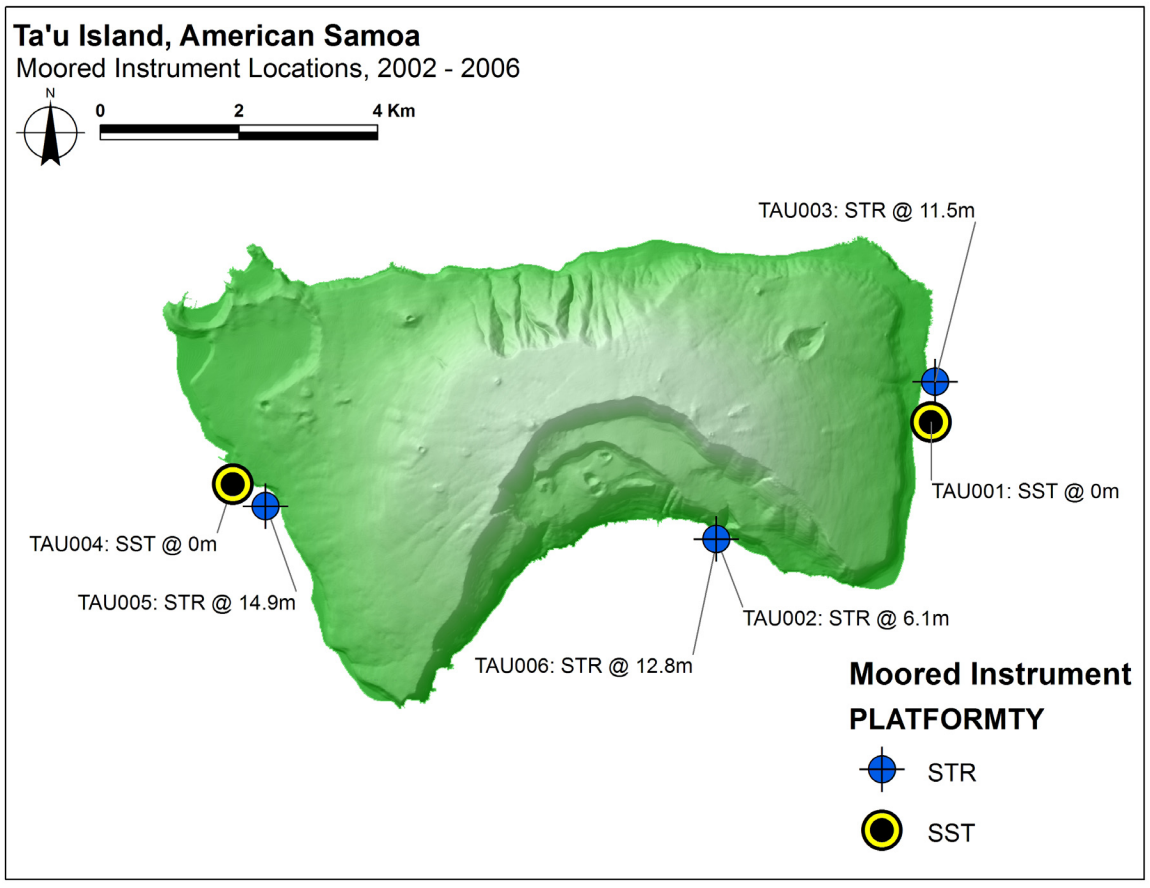

Figure 5.4.3a. Locations and types of oceanographic instrument moorings deployed around Ta`u between 2002 and 2006. Moored instrument types include STR and SST.

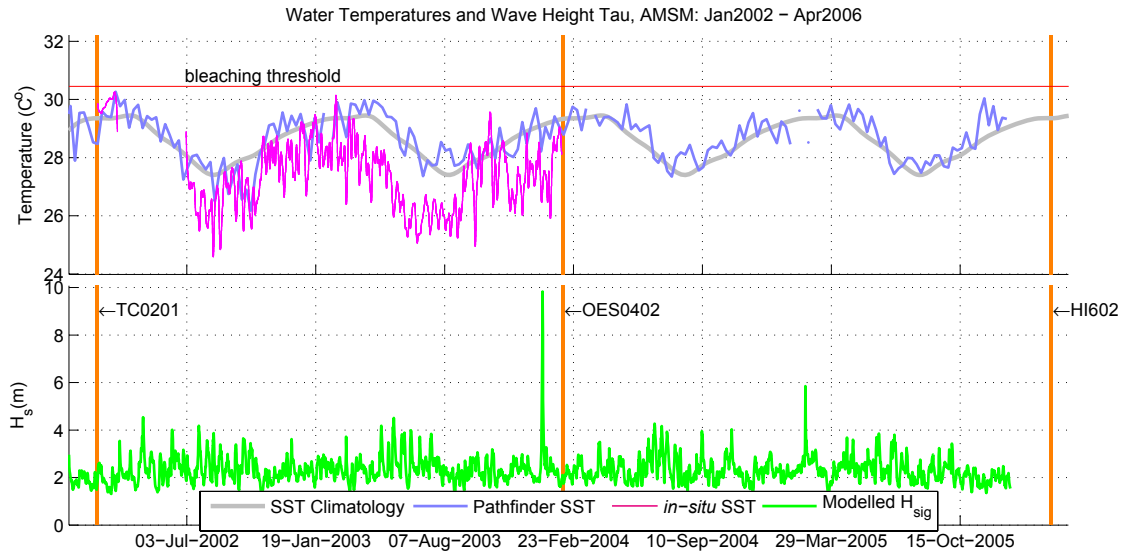

Figure 5.4.3b. SST and wave height time series around Ta`u between January 2002 and April 2006. Remotely sensed data (SST climatology and weekly Pathfinder-derived SST) and modeled significant wave height derived from Wave Watch III are overlaid with CRED in situ temperature observations. The horizontal red and vertical orange bars represent the bleaching threshold and the ASRAMP research cruise dates, respectively. In situ (15-min sampling frequency) and telemetered data (4-hour mean) were used to produce the Ta`u time series record shown.

Temperature time series from three STRs during the 2004 to 2006 time period show 2°–3°C temperature fluctuations because of seasonal variability (Fig. 5.4.3c). In each of the time series, minimal (< 1°C) diurnal temperature fluctuations were observed.

Modeled significant wave height data for Ta`u showed weak seasonal variation superposed with episodic, cyclone-derived extreme wave events. Larger wave heights (~ 3–4 m) typically occurred during winter months compared to smaller wave heights (~ 2 m) during the summer months. Two extremely large swell events were observed in the time series: one in January 2004 produced by Cyclone Heta and the other in February 2005 produced by Cyclones Olaf and Percy (Fig. 5.3.2b, bottom panel).

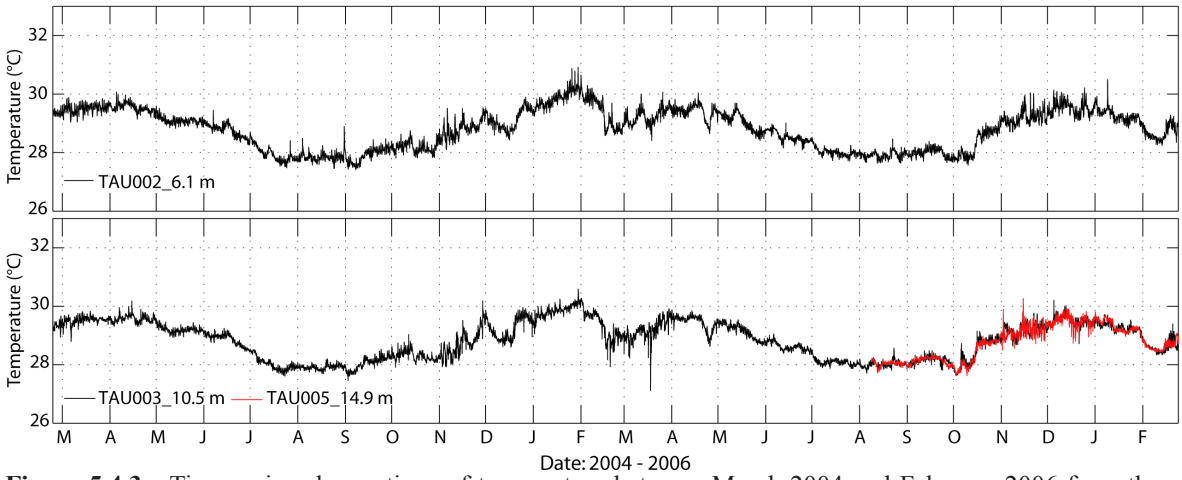

Figure 5.4.3c. Time series observations of temperature between March 2004 and February 2006 from three STRs deployed at different locations and depths around Ta`u, American Samoa (see Figure 5.3.2a for mooring locations).

5.5 Coral and Coral Disease

5.5.1 Coral Surveys

2002 Spatial Surveys

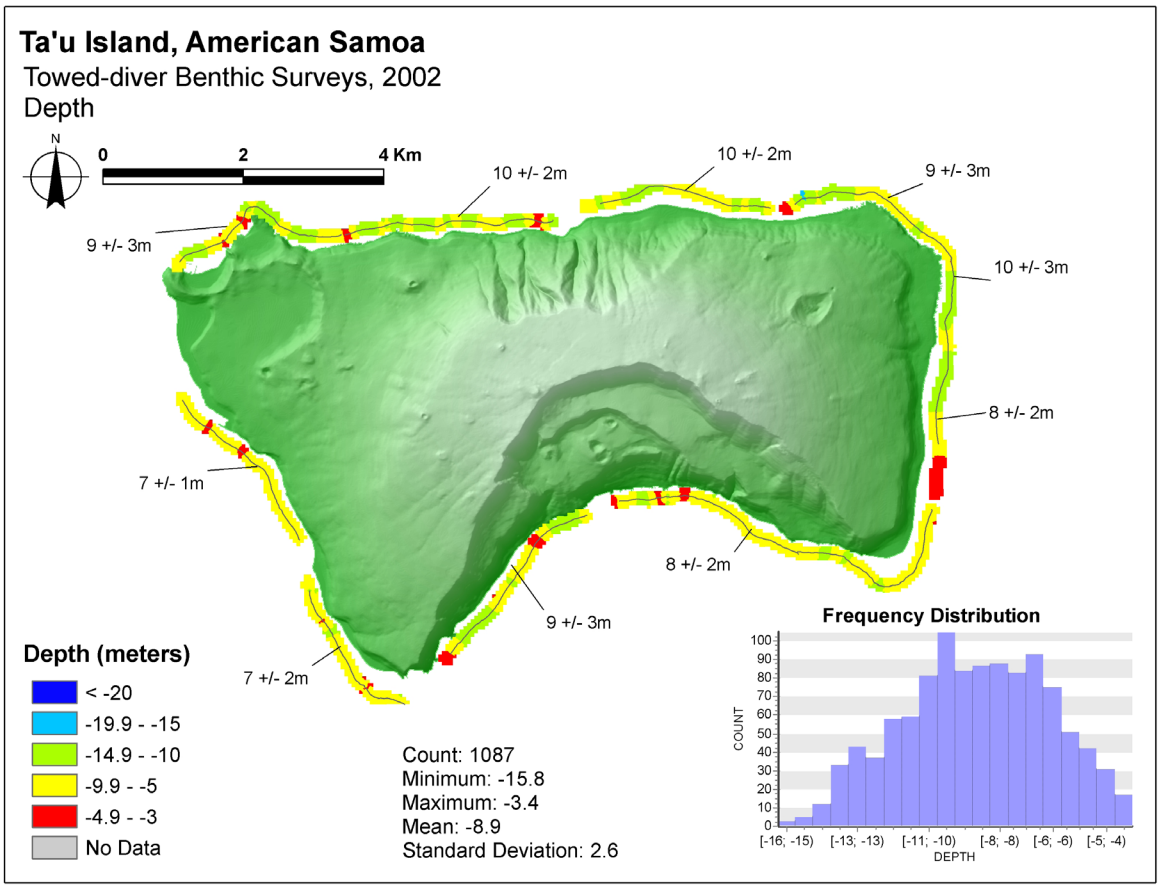

Figure 5.5.1a. Towed-diver survey tracks around Ta`u during 2002 ASRAMP. Towed-diver survey tracks are color coded with mean depths for each 5-min segment. Mean depths and standard deviations for each towed-diver survey are shown in black text. Depth histogram and statistics (counts, minimum depth, maximum depth, mean, and standard deviation) from 30-sec depth recordings during towed-diver surveys are included.

Ten towed-diver surveys along the forereef slopes of Ta`u were conducted in 2002, with a mean depth of 8.9 m (Fig. 5.5.1a). Individual towed-diver survey depths varied from 7 m (SD 1) to 10 m (SD 3). Estimates of live coral percent cover were 30.8% (SE 2.7; Fig. 5.5.1b), and estimates of recently dead coral cover were 2.4% (SE 0.6; Fig. 5.5.1c).

The highest live coral cover was observed during two towed-diver segments within the north region of Ta`u (mean: 62.5%). Other areas of high coral cover included the northeast windward coastline, beginning at Fiti`uta Point and heading south past Tiafou Point (6 tow segments, mean: 51.7%) and two tow segments along the west region of Ta`u (mean: 52.5%). Estimates of dead coral were low and variable around most of Ta`u, with the highest dead coral (up to 10%) observed on the northwest corner, from Cape Papatele south past Tiafou Point, as well in the south region, from Ulufala Point west to Papaloalaoa Point.

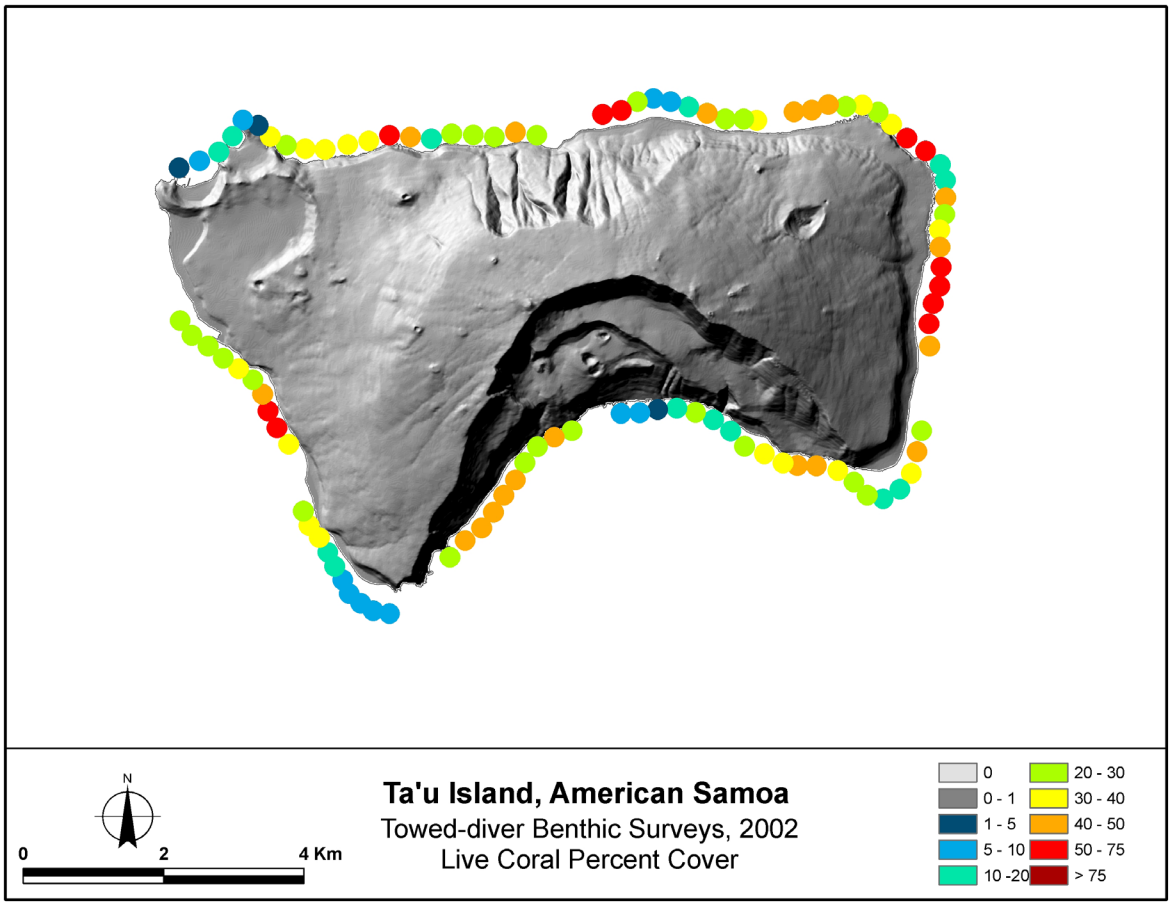

Figure 5.5.1b. Percent live scleractinian (stony) coral cover around Ta`u from towed-diver benthic survey observations during ASRAMP 2002. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). The ramped color scheme expresses the range of percent live coral cover on the benthic habitat. Note that coral cover was measured as a direct percentage of overall benthic cover in 2002.

During ASRAMP 2002, towed-diver observers first discovered unique massive *Porites* sp. communities in the east and west regions of Ta`u, as first mentioned in Section 5.3.2: Habitat Characterization. In the west region, these massive coral colonies were estimated to be 5-6 m in height and 14 m in diameter (Figs. 5.3.2f and 5.3.2g). Through simple comparisons with known coral cores, these massive coral heads within this unique and isolated community are estimated to be between 500 and 1000 years old and are among the oldest known living coral colonies in the world. The finding of this massive and ancient community in 2002 is one of the most unique and exciting discoveries by CRED scientists in all of American Samoa.

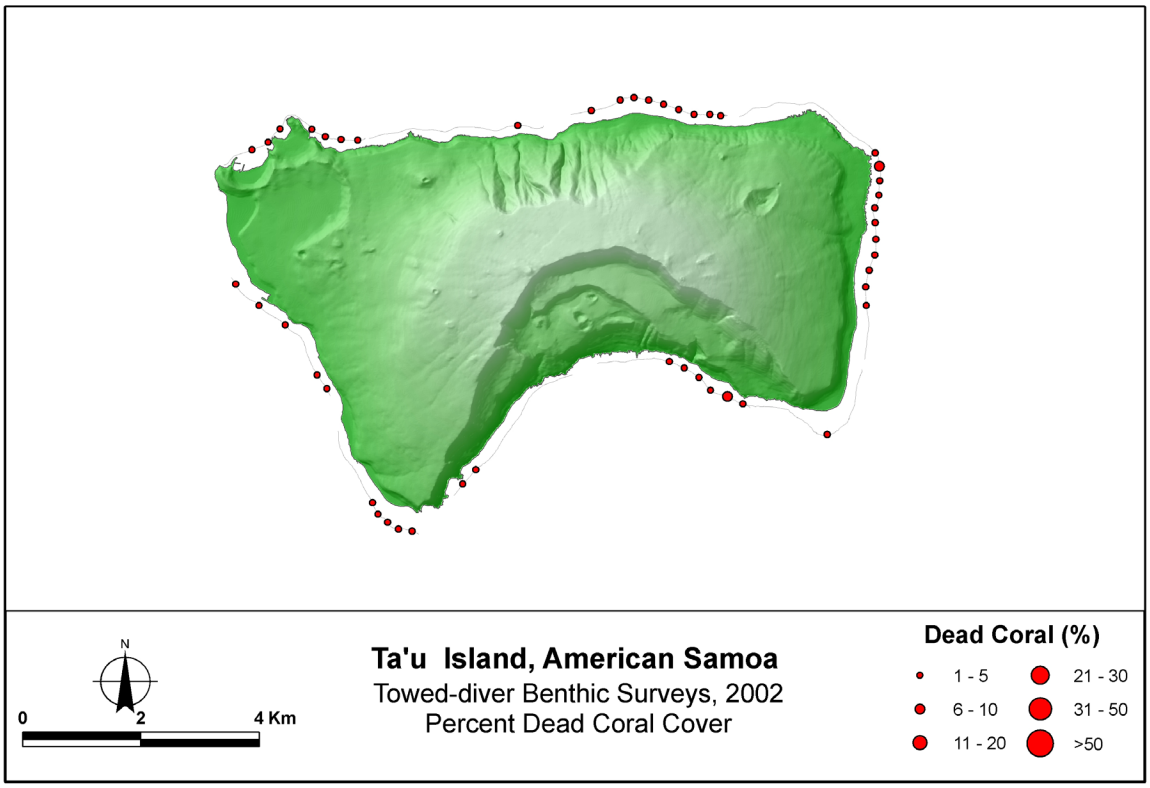

Figure 5.5.1c. Towed-diver benthic survey observations of dead coral cover around Ta`u during ASRAMP 2002. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent dead coral cover on the benthic habitat.

REA coral surveys during ASRAMP 2002 were the first surveys conducted in American Samoa by CRED. Although six sites were surveyed around Ta`u by a CRED coral biologist, the main focus of those surveys was to explore different coral monitoring methodologies. Since the surveys were exploratory and qualitative in nature, no data are presented in this more quantitative report.

2004 Spatial Surveys

Eighteen towed-diver benthic surveys along the forereef slopes of Ta`u were conducted during ASRAMP 2004, with a mean depth of 11.4 m (Fig. 5.5.1d). Individual towed-diver survey depths varied from 6 m (SD 3) to 17 m (SD 5). Island-wide live coral percent cover was 22.7% (SE 2.9; Fig. 5.5.1e), with an estimate of 5.8% (SE 1.2) of the live coral appearing stressed (pale or white; Fig. 5.5.1f).

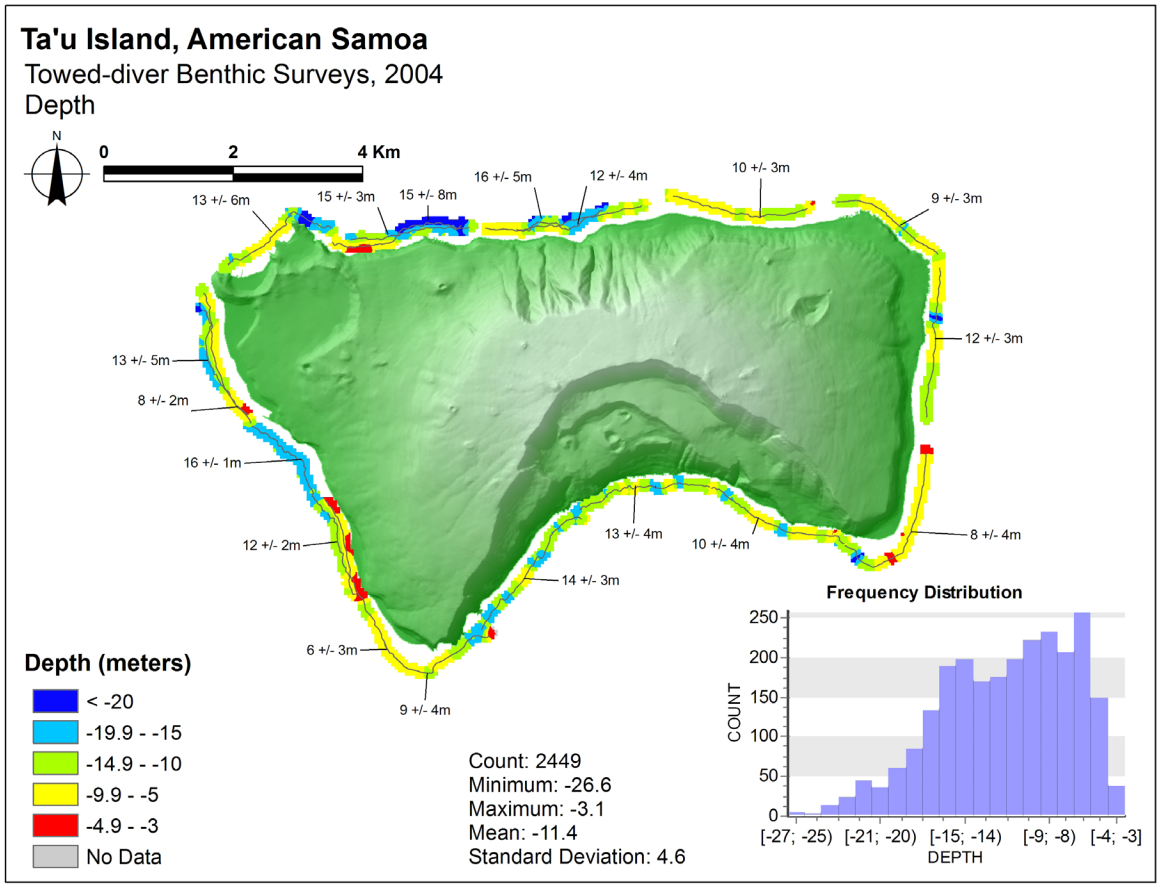

Figure 5.5.1d. Towed-diver survey tracks around Ta`u during ASRAMP 2004. Towed-diver survey tracks are color coded with mean depths for each 5-min segment. Mean depths and standard deviations for each towed-diver survey are shown in black text. Depth histogram and statistics (counts, minimum depth, maximum depth, mean, and standard deviation) from 30-sec depth recordings during towed-diver surveys are included.

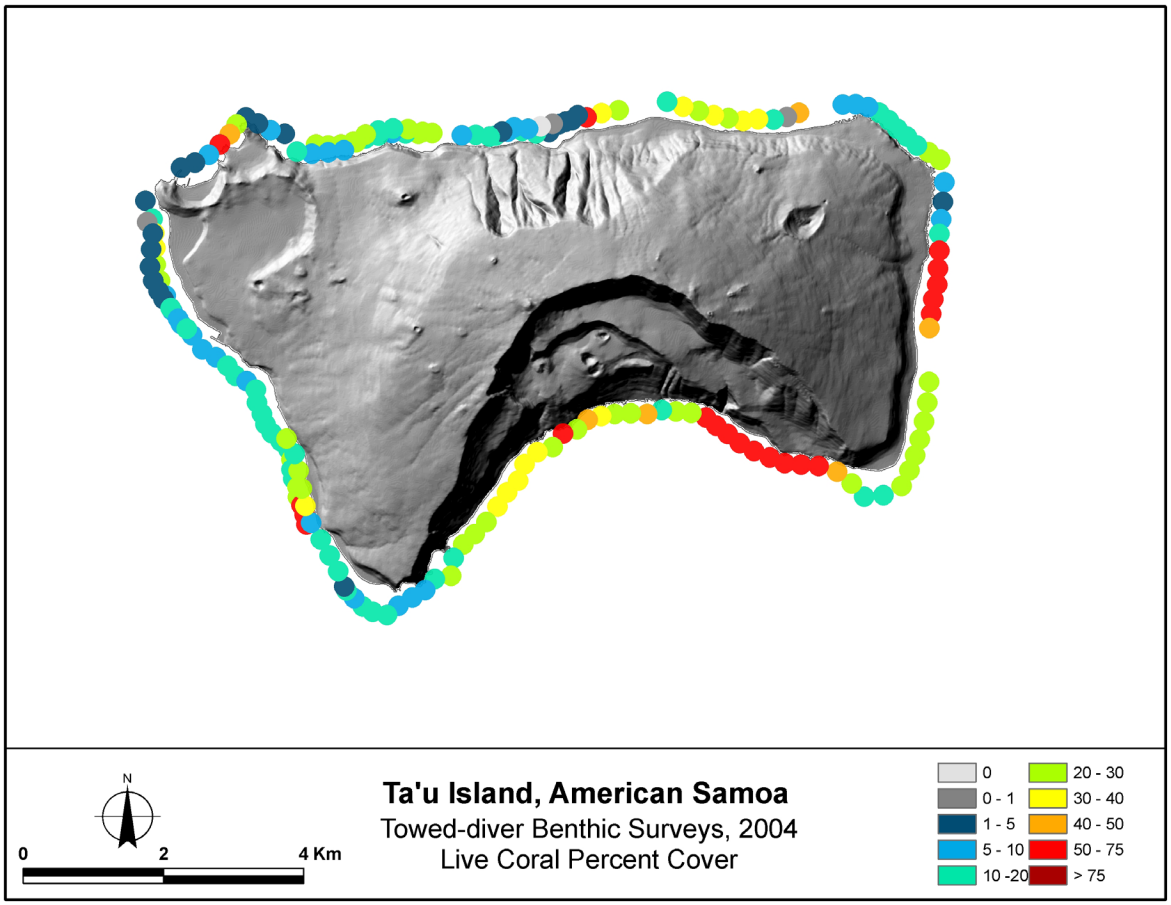

Figure 5.5.1e. Towed-diver benthic survey observations of live scleractinian (stony) coral cover around Ta`u during ASRAMP 2004. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent live coral cover on the benthic habitat.

Estimates of live scleractinian (stony) coral cover were variable, with generally higher coral cover observed within the east and south regions. The highest live stony coral cover was recorded during nine towed-diver segments along the south region forereef, close to Ulufala Point (mean: 60.4%). Other areas of higher coral cover included the area surveyed along the east region, south of Tiafou Point (5 tow segments, mean: 59.0%).

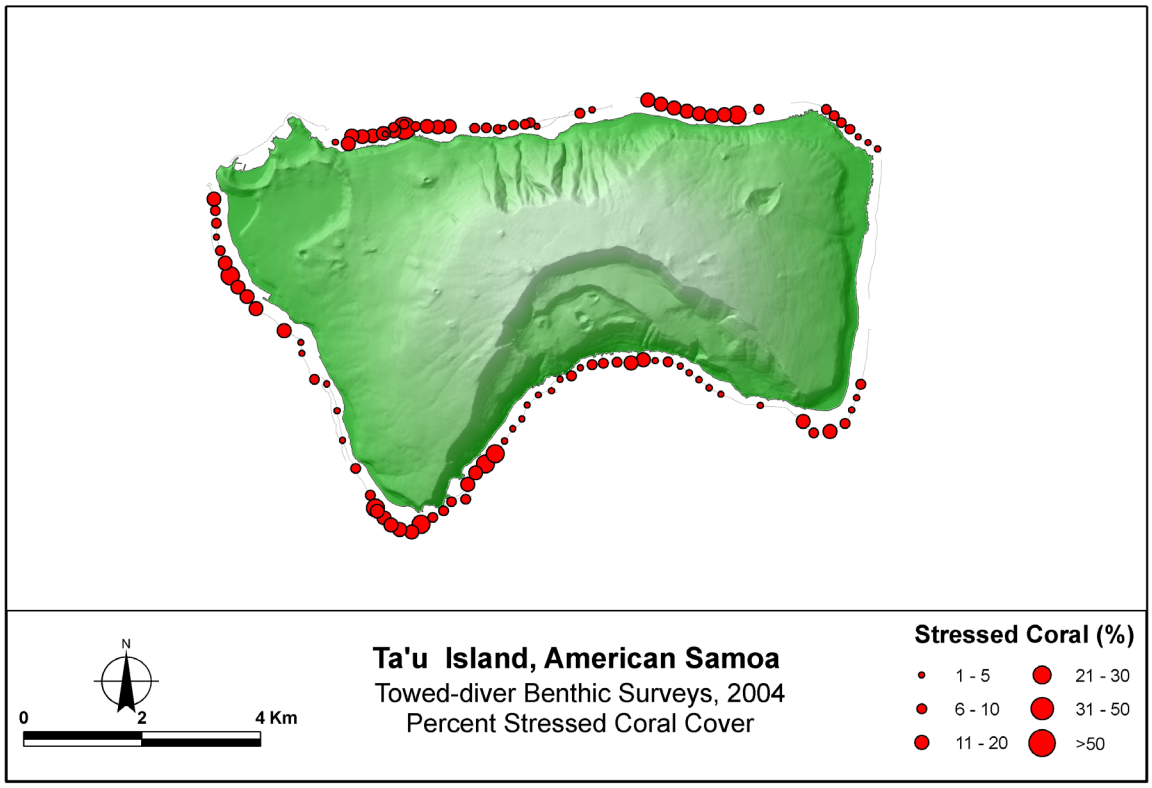

Figure 5.5.1f. Towed-diver benthic survey observations of stressed coral cover around Ta`u during ASRAMP 2004. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent of stressed coral cover of the total coral benthic coverage. Note that stressed coral cover was measured as a percentage of overall coral cover in 2004.

Estimates of stressed corals (pale and white) were variable with relatively high percentages of stressed coral recorded in a number of areas. Continuous areas of high coral stress were observed on the southwestern point, from Papaotoma Point west to Si`ufa`alele Point (15 tow segments, mean: 16.5%), along the west region south of Utumanu`a Point (9 tow segments, mean: 12.7%), and along two stretches off the north region, from Siulagi Point east to Loto Point (10 tow segments, mean: 16.6%) and west of Fitu`ata Point (10 tow segments, mean: 14.7%).

It is important to note that most areas exhibiting high percentages of stressed coral had relatively low percent live coral cover. In 2004, the towed-diver methodology reported an estimate for percent live coral cover and stressed (pale/white) coral cover separately for each 5-min observation segment. To standardize the presentation of towed-diver benthic cover data between 2002 and 2004, live coral and stressed coral values from 2004 were summed to produce the total live coral category and then stressed coral was calculated as the percentage of live coral that was estimated as stressed. This may partially explain the high coral stress values reported for most areas where low coral cover was reported.

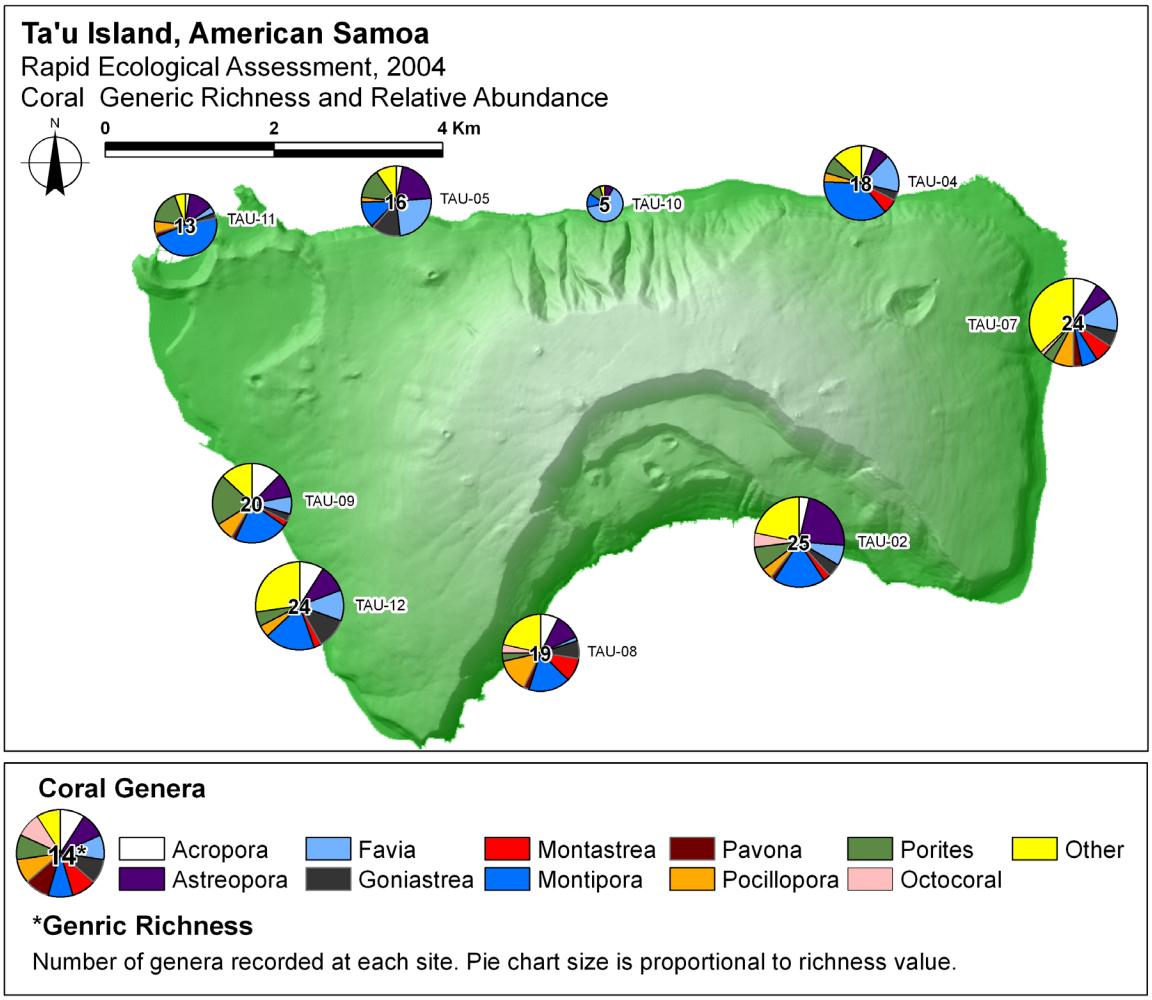

Figure 5.5.1g. Relative abundance of coral genera and generic richness from REA surveys around Ta`u during ASRAMP 2004. Percent relative abundance of key coral genera are indicated by color-coded portions of the pie charts. Size of the pie charts and black numbers in the center of the pie charts indicate the number of coral genera observed at each REA site.

Nine coral REA surveys were conducted around Ta`u during ASRAMP 2004. At least 32 anthozoan/hydrozoan genera were observed around Ta`u with members of the genera *Montipora*, *Astreopora*, *Favia*, and *Porites* each contributing more than 10% of the total number of colonies recorded around the island (Fig. 5.5.1g). *Montipora* was the most common coral genus at most sites, making up on average 21% of each site's coral community. Corals of the genus *Favia* were generally more common at sites TAU-04, TAU-05, and TAU-10 in the north region, especially at site TAU-10 where *Favia* was the dominant coral genus (64% of coral colonies). *Porites* was generally more common at sites TAU-05, TAU-10, and TAU-11 in the north region and at site TAU-09 in the west region, accounting for an average of 15.6% of the coral community compared to only 4.8% of the coral community at the other sites around the island.

Generic richness was variable with a mean of 18.2 (SE 2.1) coral genera recorded per site. Patterns of generic richness were similar to those for percent coral cover and coral density, with the lowest generic diversity (5 coral genera) recorded at site TAU-10 in the north region and the highest generic diversity (25 coral genera) recorded at site TAU-02 in the south

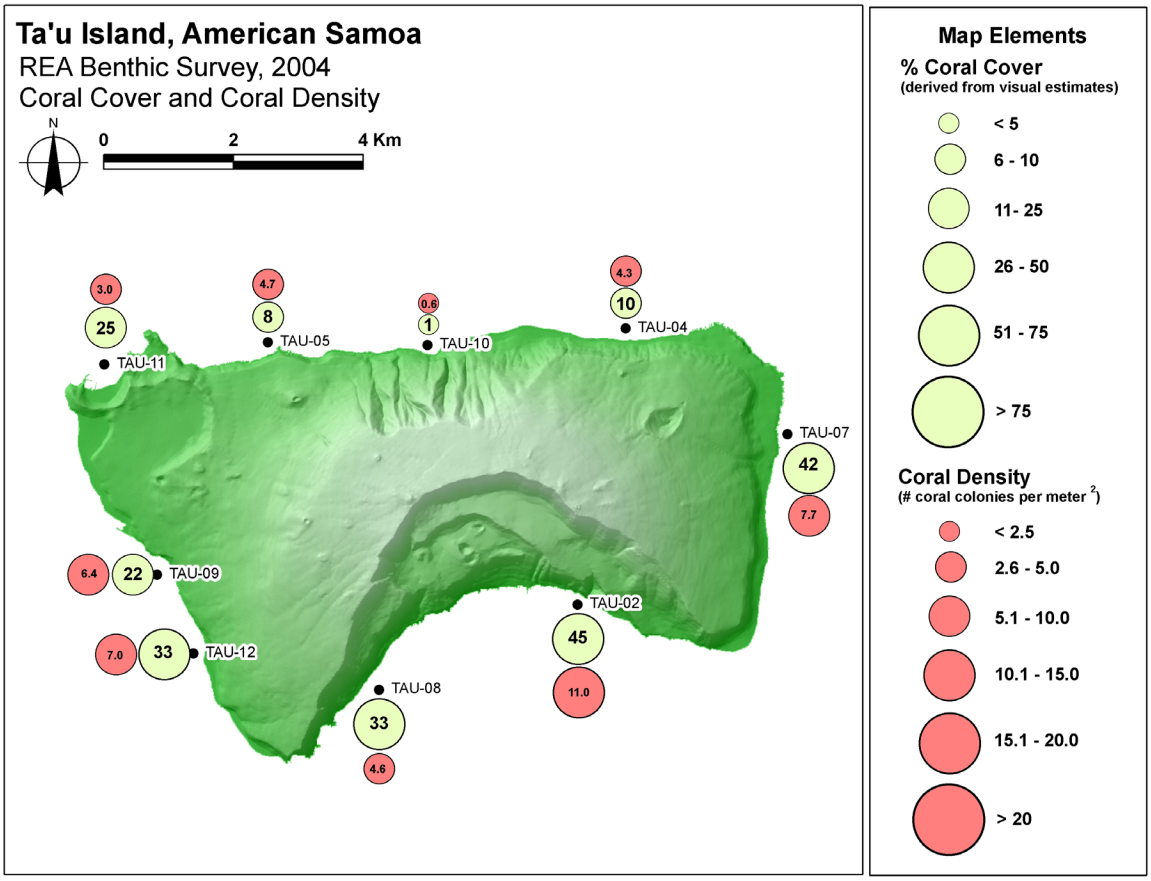

Figure 5.5.1h. Live scleractinian (stony) coral cover and coral colony density from REA surveys around Ta`u during ASRAMP 2004. The size of the symbol is proportional to the value of each parameter. It is important to note that coral percent cover was determined by qualitative visual estimates.

region (Fig. 5.4g). Site-specific data regarding the relative abundance of coral genera, by colony counts within belt transects, are available in Appendix III, Table III. v.

The mean percent live scleractinian coral cover around Ta`u was 24.3% (SE 5.2; Fig. 5.5.1h). Visual estimates of coral cover were relatively low at REA sites TAU-04, TAU-05, and TAU-10 in the north region of Ta`u, ranging between 1% and 10%. Percent coral cover was relatively higher at sites TAU-07 in the east region and sites TAU-02 and TAU-08 in the south region of Ta`u, with the highest live coral cover being recorded at site TAU-02, near the Lafuti stream outfall on the south shore.

During ASRAMP 2004 surveys around Ta`u, a total of 2887 coral colonies were counted within a total survey area of 610 $m^2$. Mean coral densities per site at Ta`u were 5.5 colonies m^{-2} (SE 1.1; Fig. 5.5.1h). Coral density was fairly consistent at sites throughout the island, except for site TAU-10 in the north region (0.6 colonies m^{-2}) and site TAU-02 in the south region (11.2 colonies m^{-2}), where the lowest and highest coral densities were recorded, respectively.

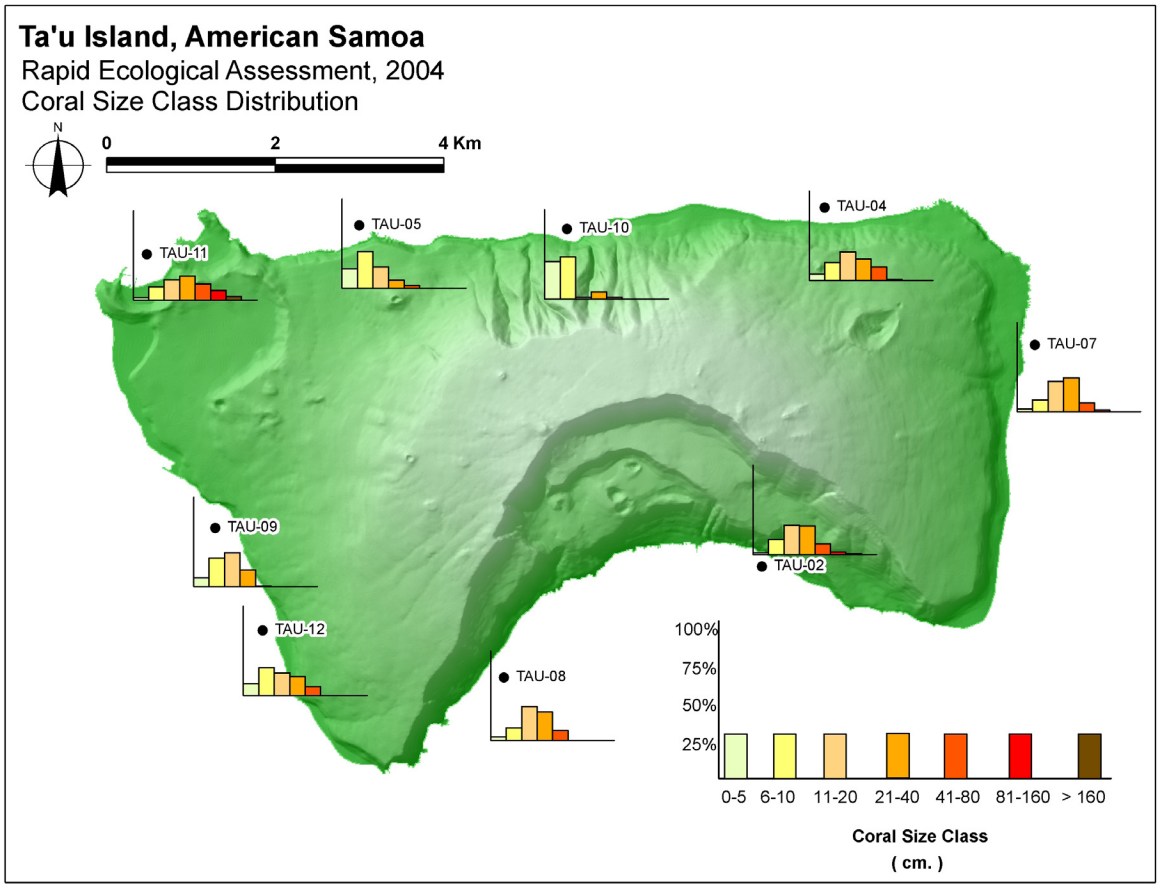

Figure 5.5.1i. Scleractinian coral size-class distribution around Ta`u from REA surveys during ASRAMP 2004. The height of the *y*-axis in each size-class chart represents 100%. The seven observed size classes (0–5, 6–10, 11–20, 21–40, 41–80, 81–160, and > 160 cm), are color coded in size frequency diagrams at each REA site.

Size-class distribution of scleractinian corals shows the majority of corals (63.9%) had diameters less than 20 cm (Fig. 5.5.1i). High abundance of small corals (diameters less than 5 cm) was generally observed at sites TAU-05 and TAU-10 in the north region and at sites TAU-09 and TAU-12 in the west region of Ta`u. Abundant large corals were only observed at TAU-11, off the northwest tip of Ta`u, with corals greater than 80 cm accounting for 14% of all colonies recorded. Interestingly, sites TAU-07, TAU-02, and TAU-08, which contained the highest proportions of the larger coral size classes, also had some of the highest coral cover seen around Ta`u. Coral size-class information is not recorded during towed-diver benthic survey observations; however, the divers noted many large *Porites* coral heads in the area south of REA site TAU-07 and in the area near TAU-12.

2006 Spatial Surveys

Fifteen towed-diver benthic surveys were conducted along the forereef slopes of Ta`u during ASRAMP 2006, with a mean depth of 14.9 m (Fig. 5.5.1j). Individual towed-diver survey depths varied from 14 m (SD 3) to 17 m (SD 3). Island-wide estimates of live coral percent cover were 19.3% (SE 2.0; Fig. 5.5.1k), and estimates of stressed (pale and white) coral were 2.0% (SE 0.3; Fig. 5.5.1l).

The highest live scleractinian stony coral cover was observed during a towed-diver survey along the south region forereef, close to Ulufala Point (3 tow segments, mean: 45%) and east of Papaotoma Point (7 tow segments, mean: 26.4%). Other areas of higher coral cover included the area surveyed along the east region coast (16 tow segments, mean: 30%) and along the east side of the north region (7 tow segments, mean: 25%).

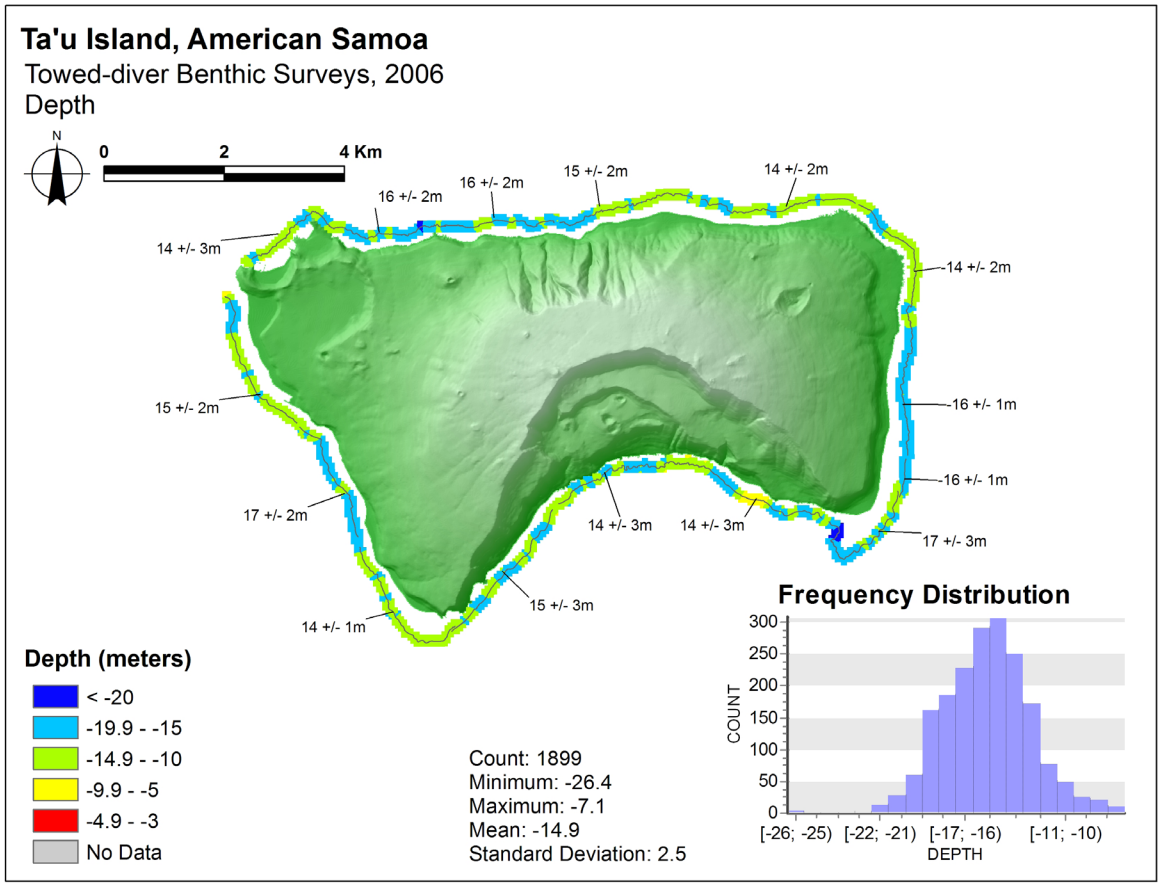

Figure 5.5.1j. Towed-diver survey tracks around Ta`u during ASRAMP 2006. Towed-diver survey tracks are color coded with mean depths for each 5-min segment. Mean depths and standard deviations for each towed-diver survey are shown in black text. Depth histogram and statistics (counts, minimum depth, maximum depth, mean, and standard deviation) from 30-sec depth recordings during towed-diver surveys are included.

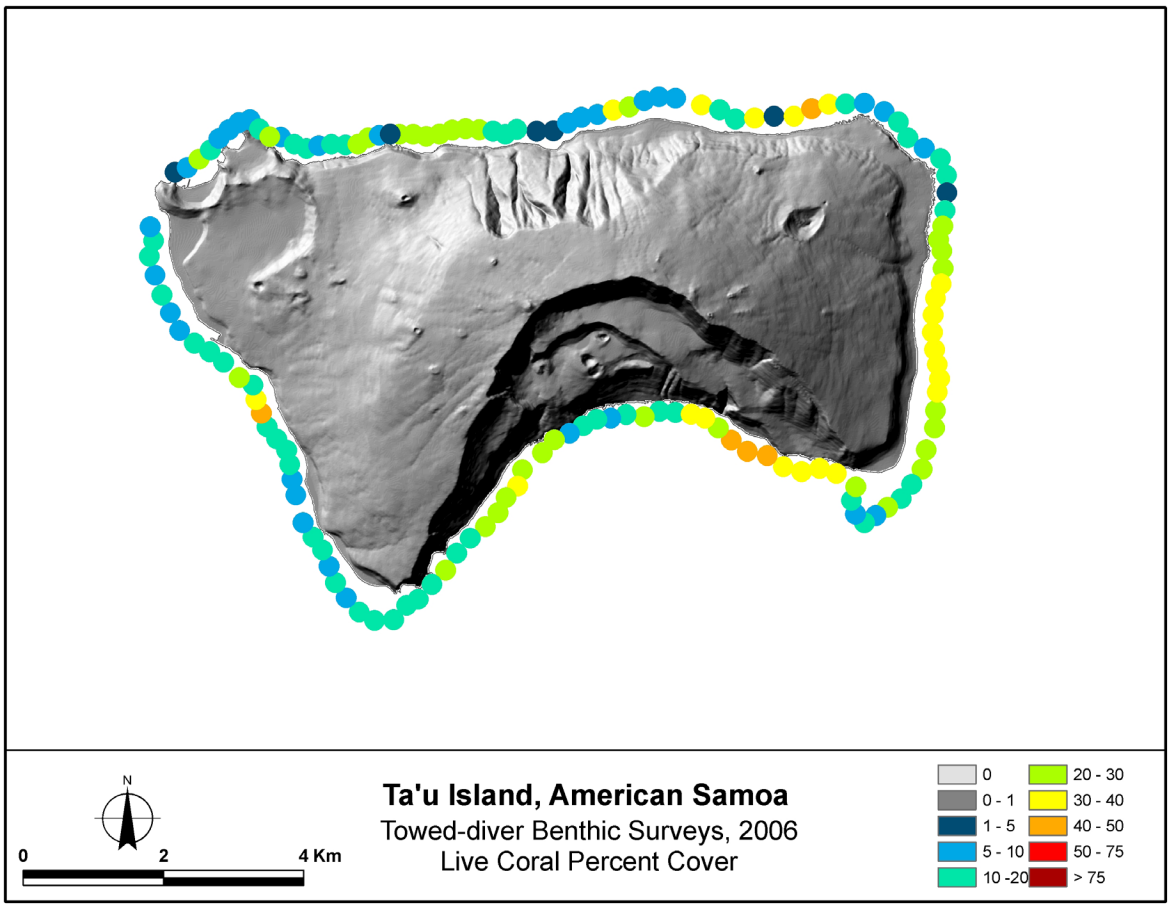

Figure 5.5.1k. Towed-diver benthic survey observations of live scleractinian (stony) coral cover around Ta`u during ASRAMP 2006. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent live coral cover on the benthic habitat. See Chapter 2, Table 2.4.2b for more information on benthic towed-diver binning categories during ASRAMP 2006.

Estimates of stressed coral were low for most of the forereef around Ta`u. Areas of elevated coral stress were noted along the north region shoreline from Siulagi Point to Loto Point (8 tow segments, mean: 7.5%) and past Loto Point heading east (3 tow segments, mean: 7.5%), as well as along the east region shoreline near Tiafou Point (2 tow segments, mean: 7.5%).

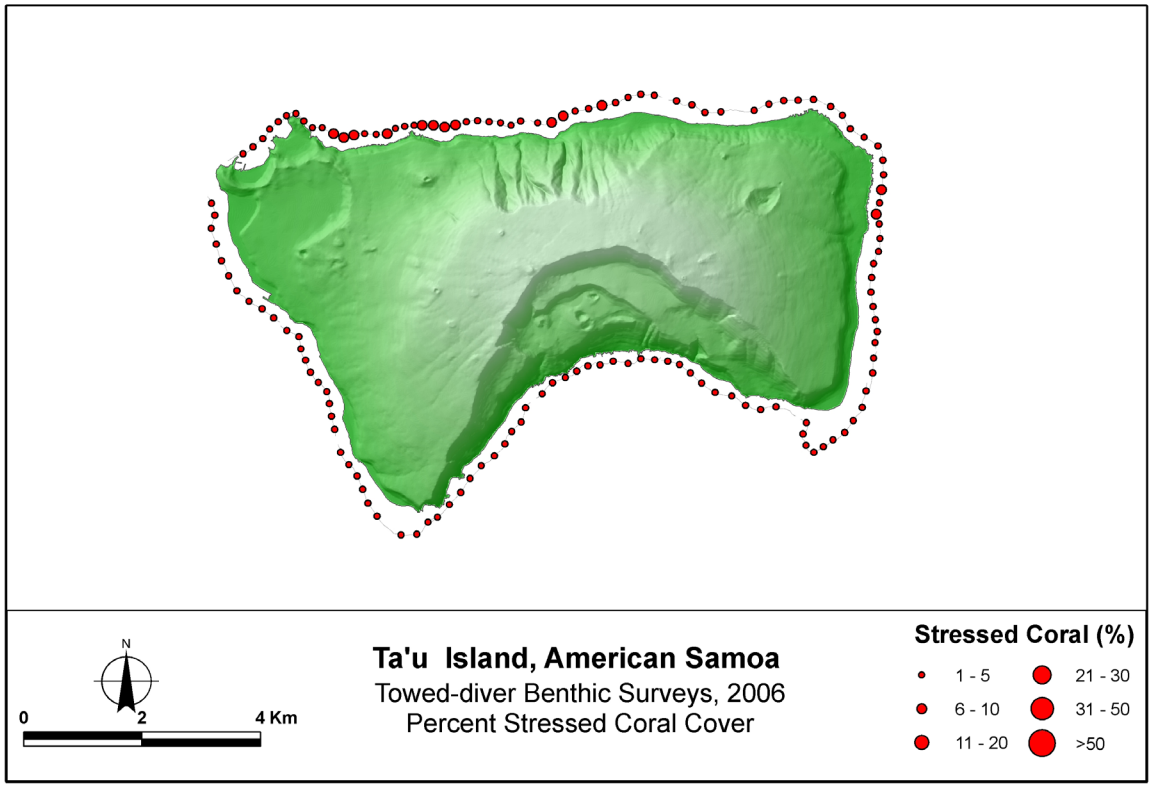

Figure 5.5.1l. Towed-diver benthic survey observations of stressed coral cover around Ta`u during ASRAMP 2006. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent of stressed coral cover of the total coral benthic coverage. See Chapter 2, Table 2.4.2b for more information on benthic towed-diver binning categories during ASRAMP 2006.

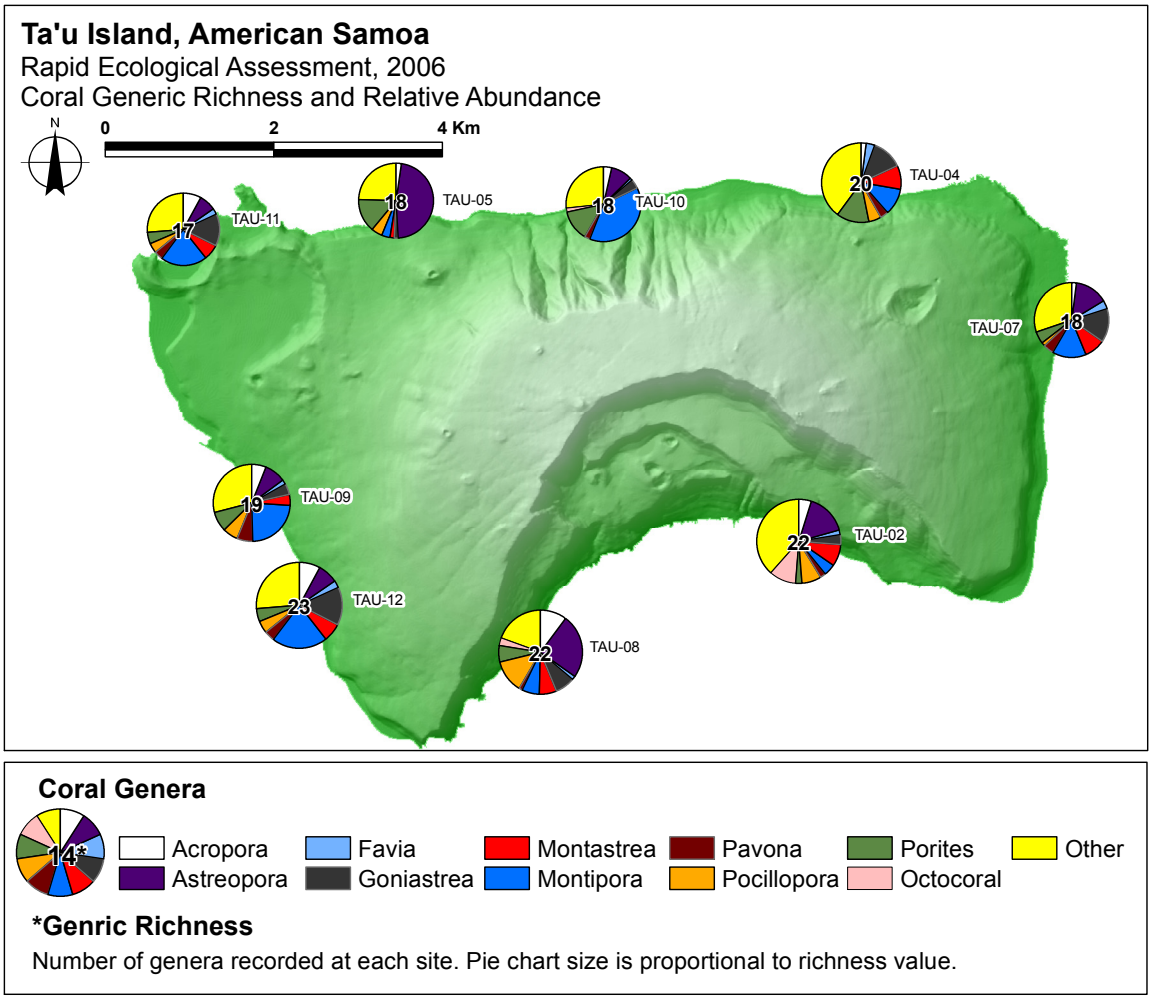

Figure 5.5.1m. Relative abundance of coral genera and generic richness from REA surveys around Ta`u during ASRAMP 2006. Percent relative abundance of key coral genera are indicated by color-coded portions of the pie charts. Size of pie charts and black numbers in the center of the pie charts indicate the number of coral genera observed at each REA site.

A total of nine coral REA surveys were conducted around Ta`u during ASRAMP 2006. Colonies belonging to at least 29 anthozoan/hydrozoan genera were reported around Ta`u. Members of the genera *Montipora* and *Astreopora* were the most common corals found, composing a mean of 16% and 15% of the coral community at each site, respectively (Fig. 5.5.1m). *Porites* was common at REA sites TAU-04, TAU-05, and TAU-10 in the north region of Ta`u, with a mean of 14% of the total coral community, in comparison to only 5% of the total coral community at all other sites off Ta`u. Other coral genera that were locally abundant include octocorals at site TAU-02 in the south region, *Pocillopora* at site TAU-08 in the south region, and *Goniastrea* at several sites.

Generic richness of corals was relatively high with 19.7 (SE 0.1) coral genera recorded per site (Fig. 5.5.1m). Coral richness was relatively similar at most sites around Ta`u, ranging from 17 to 23 coral genera per site. Interestingly, site TAU-11 in the northwest corner had both the lowest generic diversity (17 genera) and the highest percent coral cover (54%). Site-specific data regarding the relative abundance of coral genera, by colony counts within belt transects, are available in Appendix III, Table III. vi.

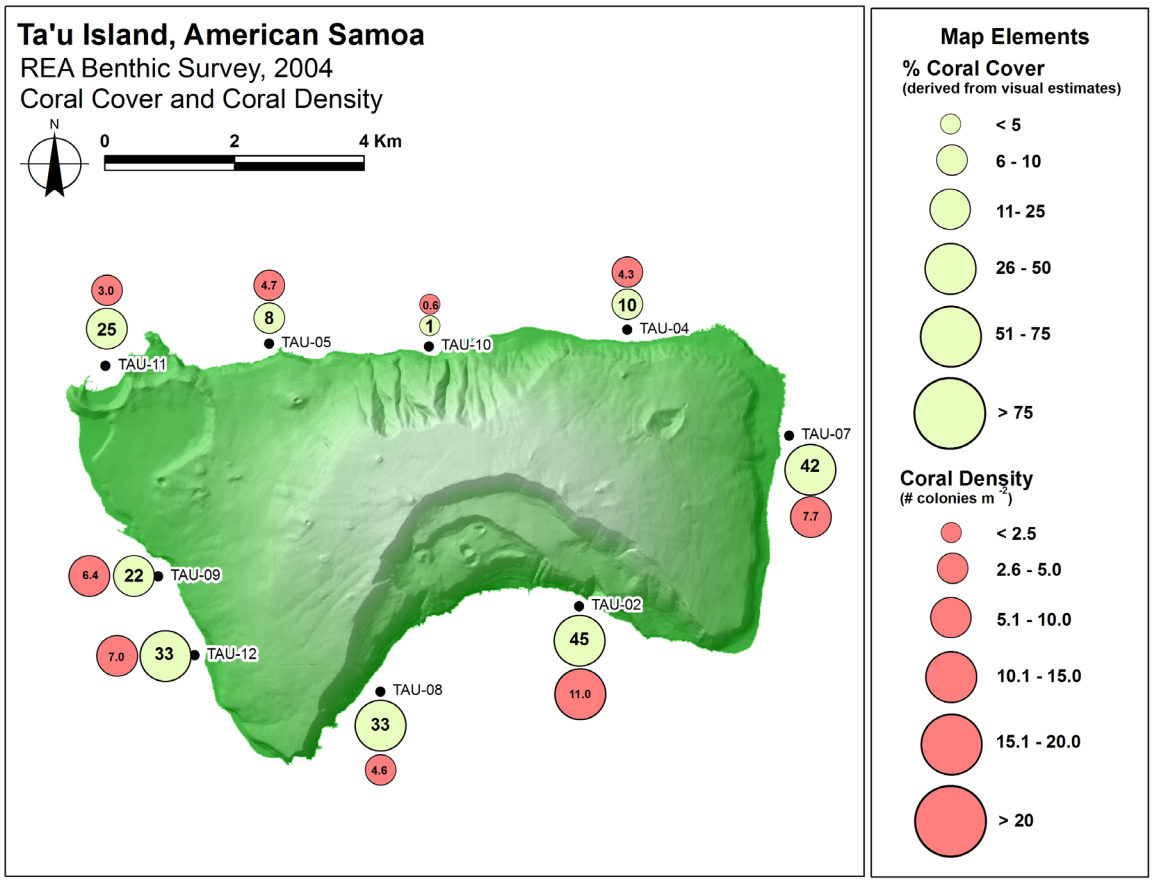

Figure 5.5.1n. Live scleractinian (stony) coral cover and coral colony density from REA surveys around Ta`u during ASRAMP 2006. The size of the symbol is proportional to the value of each parameter.

Percent live scleractinian coral cover around Ta`u, derived from the line point intercept method, was 29.7% (SE 4.3; Fig. 5.5.1n). Live coral cover was highest (54%) at site TAU-11 off the northwest point of the island. Relatively high coral cover (38–45%) was also observed at sites TAU-02 and TAU-08 in the south region of Ta`u. Coral cover was similar at the remaining six sites (19–25%).

During ASRAMP 2006 surveys around Ta`u, a total of 3436 of coral colonies were counted within a total survey area of 400 m^2. Coral density per site was variable, with a mean of 9.0 colonies m^{-2} (SE 1.1; Fig. 5.5.1n). High coral densities were generally observed off the west and south coasts, with most sites having densities greater than 10 colonies m^{-2}. The lowest coral density (3.5 colonies m^{-2}) was observed at site TAU-10 in the north region.

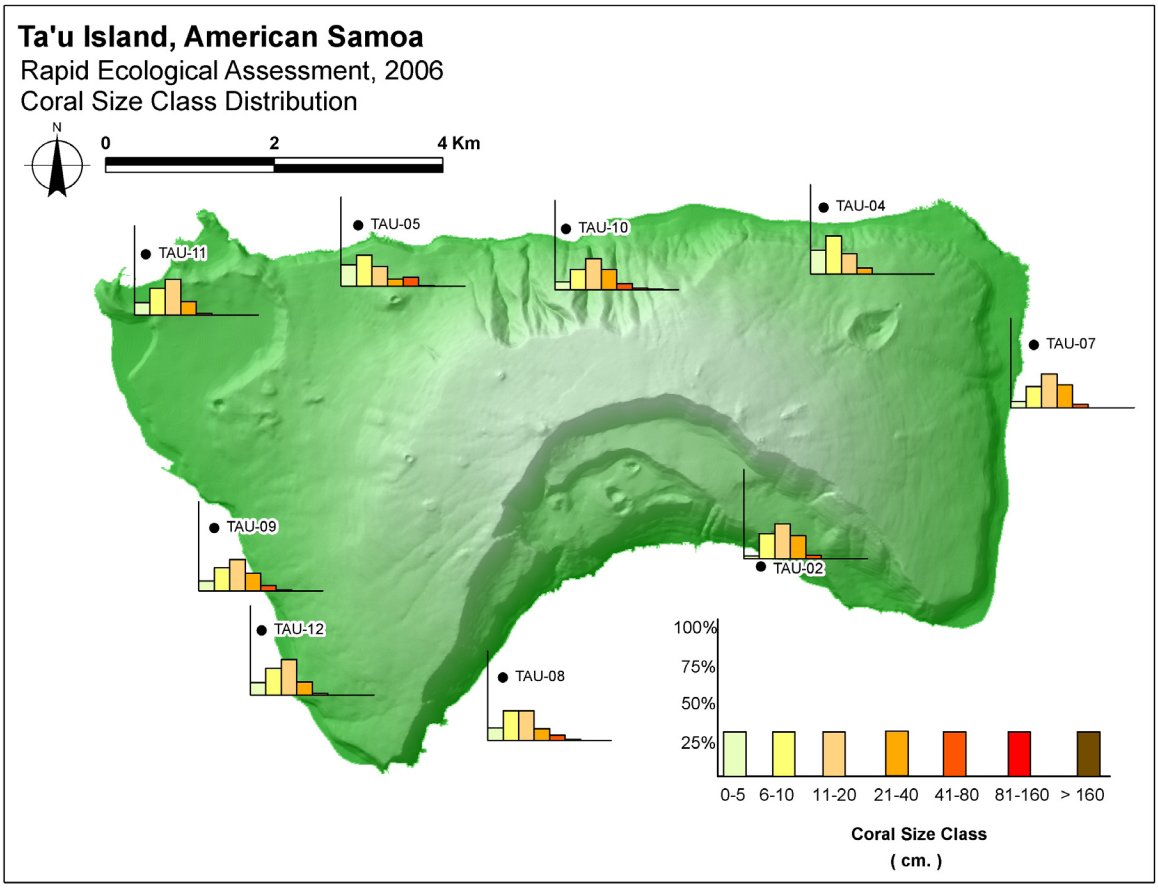

Figure 5.5.1o. Scleractinian coral size-class distribution around Ta`u from REA surveys during ASRAMP 2006. The height of the *y*-axis in each size-class chart represents 100%. The seven observed size classes (0–5, 6–10, 11–20, 21–40, 41–80, 81–160, and > 160 cm), are color coded in size frequency diagrams at each REA site.

Size-class distribution of scleractinian corals indicated the majority of corals (78.8%) had maximum diameters less than 20 cm, with the greatest number of colonies occurring in the 10–20 cm size class (Fig. 5.5.1o). Corals less than 5 cm in diameter were common, with six out of nine sites around Ta`u having more than 10% of their coral colonies within this size class. Larger corals were common at only two sites, TAU-05 and TAU-10, both off the north coast. At both sites, more than 10% of coral colonies had maximum diameters greater than 40 cm.

5.5.2 Coral Disease Surveys

2006 Spatial Surveys

Coral health and disease REA surveys were conducted at nine sites around Ta`u during ASRAMP 2006 and covered a total survey area of 3850 m^2. Within this area, a total of 56 cases of coral disease, predation, and other types of lesions were enumerated. Of the nine sites surveyed, eight (89%) contained disease (Fig. 5.5.2a). Figure 5.5.2b illustrates the variation in prevalence of disease and predation among sites. Overall mean prevalence was 0.10% (SE 0.03). REA sites TAU-11 in the northwest corner and TAU-07 in the east region exhibited the greatest prevalence (0.27% and 0.29%, respectively; Fig. 5.5.2b).

Skeletal growth anomaly was the most prevalent coral disease; 22 cases were detected, and within this disease category the scleractinian genera *Astreopora* and *Montipora* exhibited 50% of the documented cases. At site TAU-11, on the northwest corner, 50% of island-wide cases were detected. Bleaching was also detected at Ta`u, although with low prevalence (0.03%). Similarly to the other islands in the archipelago, bleaching was mild and focal. Scleractinian genera exhibiting bleaching included: *Montipora*, *Porites*, *Pocillopora*, and *Montastrea*. Other coral diseases observed at the survey sites included four cases of hyperpigmentation (dark spots) on *Astreopora*, *Pavona varians*, *Montipora*, and *Coscinaraea* (Fig. 5.5.2b).

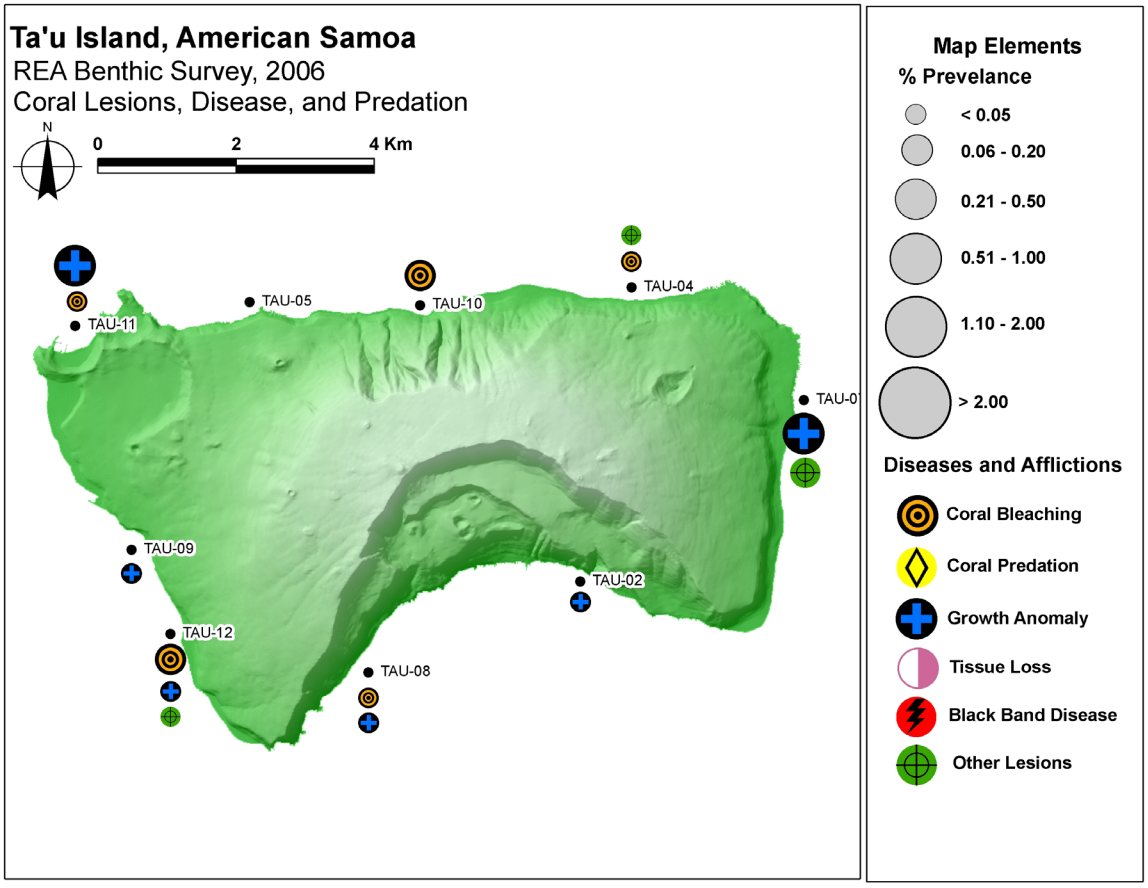

Figure 5.5.2a. Prevalence of predation, bleaching, growth anomalies, tissue loss, black band disease, and other lesions at Ta`u during ASRAMP 2006. Prevalence was calculated relative to the average colony density estimates and is indicated by the size of the respective symbols.

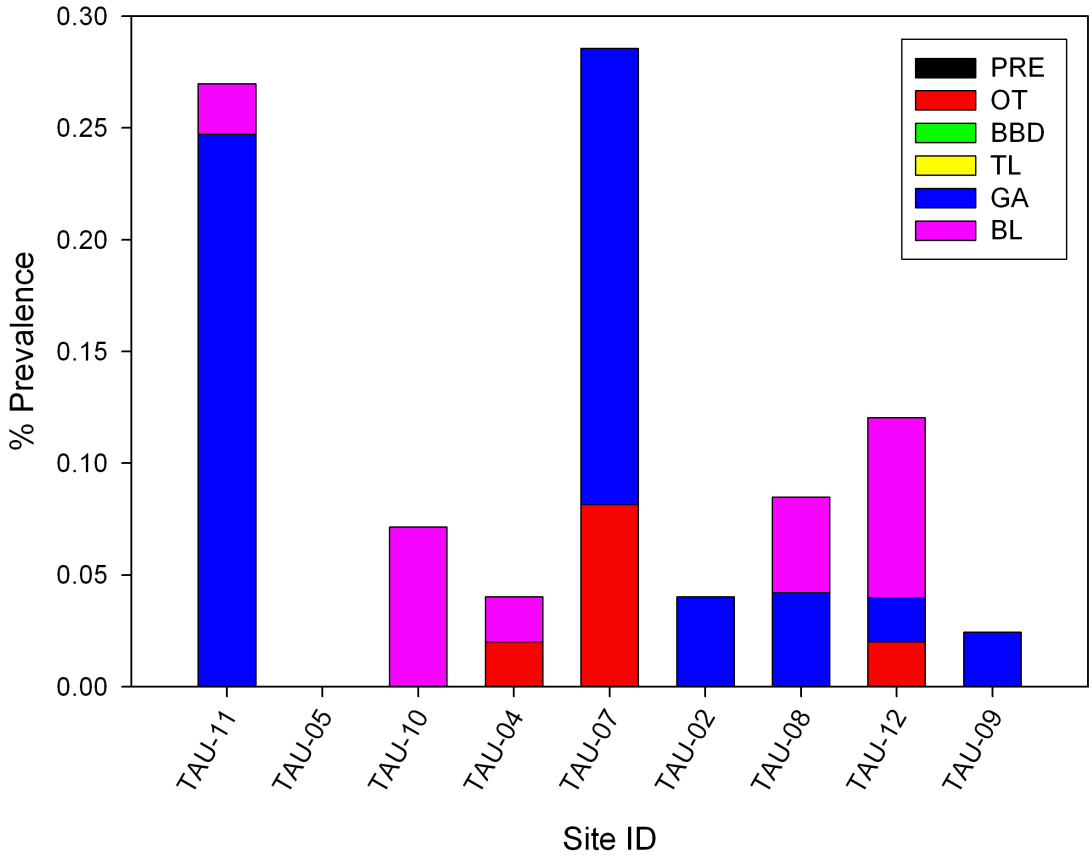

Figure 5.5.2b. Prevalence of predation, bleaching, growth anomalies, tissue loss, black band disease, and other lesions at Ta`u during ASRAMP 2006. Prevalence was calculated relative to the average colony density estimates. PRE—*Acanthaster* and/or *Drupella* predation; OT—other lesions, including hyperpigmented irritations; BBD— black band disease; TL— tissue loss; GA—skeletal growth anomalies; and BL— bleaching.

5.5.3 Temporal Comparison—Coral and Coral Disease

High live scleractinian coral cover was consistently reported by towed-diver observers for surveys completed in 2002, 2004, and 2006 (Fig. 5.5.3a), specifically along the east region windward coastline, beginning at Tiafou Point and heading south (42%, 38%, and 33%). Area surveyed along the south shore also recorded high coral cover in 2004 and 2006. Variations between years may be because of natural variation, changes in data collection protocol, trackline spacing (i.e., variation between towed-diver survey tracks between years), and observer variability resulting from changes in scientific personnel.

Average percent live coral cover from 2004 REA surveys (24.3%, all nine sites) compared favorably with 2006 REA surveys (29.4%, same nine sites; Fig. 5.5.3a). When site TAU-10 is removed from the analysis (as transect lines were laid over substantially different substrate in each year), the cover estimates for both years become even more congruent (27.3% in 2004 vs. 30.5% in 2006). When comparing the estimates between years from site TAU-11, there are substantial differences (25% in 2004 vs. 54% in 2006). Visual estimates were used in 2004 to report coral cover whereas the line point intercept technique was used in 2006, and visual

estimates can vary from those derived from the line point intercept technique even when made concurrently. CRED's coral survey methods have evolved over time; ideally, there should be two observers conducting coral surveys and the surveys should include quantitative population parameters and coral disease observations. This will allow for improved site-specific comparisons to be made to surveys conducted in the future.

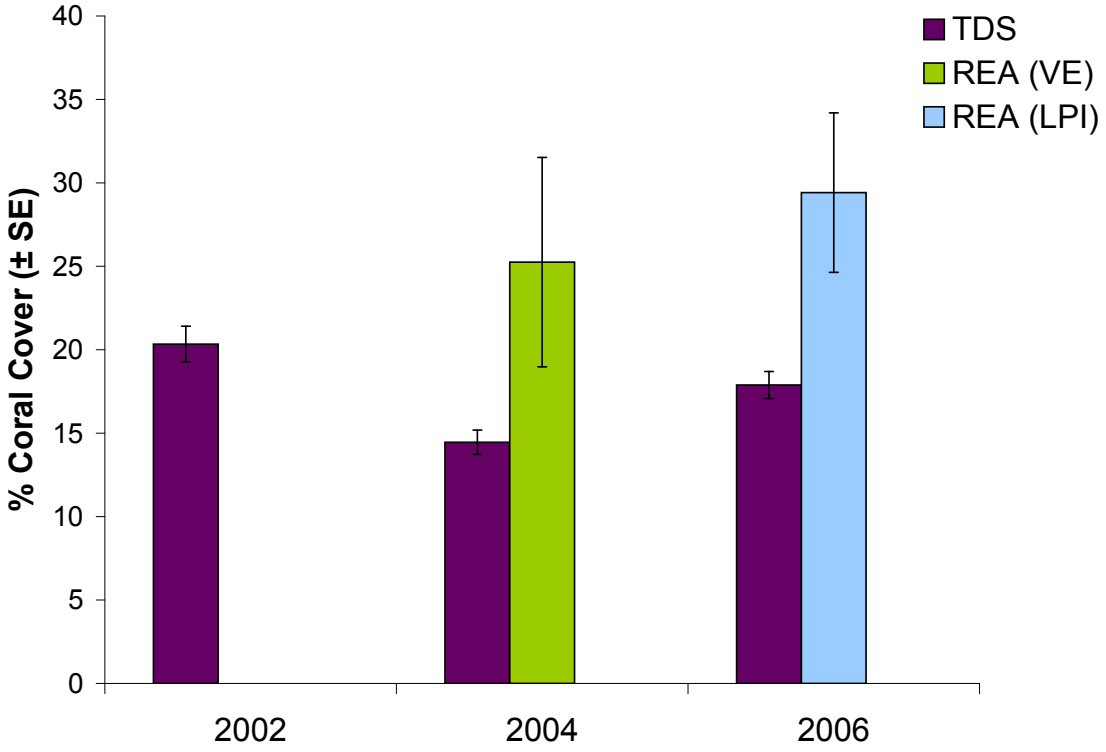

Figure 5.5.3a. Temporal comparison of mean percent live coral cover from REA surveys and towed-diver surveys around Ta`u during ASRAMP 2002, 2004, and 2006. The purple bars represent observations collected during towed-diver habitat surveys. The green bar represents REA data collected by visual estimates during REA surveys and the blue bar represents data collected by the line point intercept technique during REA surveys. See Chapter 2, Section 2.4: Reef Benthic (Coral, Algae, Macroinvertebrate) and Fish Surveys for considerations when comparing the results of these methodologies.

Overall, mean generic richness did not vary substantially between 2004 and 2006 (Fig. 5.5.3b). Mean colony densities increased from 5.5 colonies m^{-2} (SE 1.1) in 2004 to 9.0 colonies m^{-2} (SE 1.1) in 2006 (Fig. 5.5.3c). Even when site TAU-10 is removed from the analysis, there is a substantial difference in mean coral density around Ta`u between 2004 and 2006 (6.1 colonies m^{-2} [SE 0.9] vs. 9.7 colonies m^{-2} [SE 1.0], respectively). As with the apparent increase in coral density at Ofu and Olosega from 2004 to 2006, it is difficult to know if this apparent change, which could result from new recruits to the population or fragmentation/fissioning of existing colonies, is real or is an artifact of survey area. That is, 610 m^2 of benthic substrate were surveyed in 2004 (by two biologists), but only two-thirds of that area (400 m^2) could be examined by the single biologist allocated to coral population parameters in 2006. Again, it is hoped that personnel allocations and survey protocols will be the same in future years so that improved comparisons can be made.

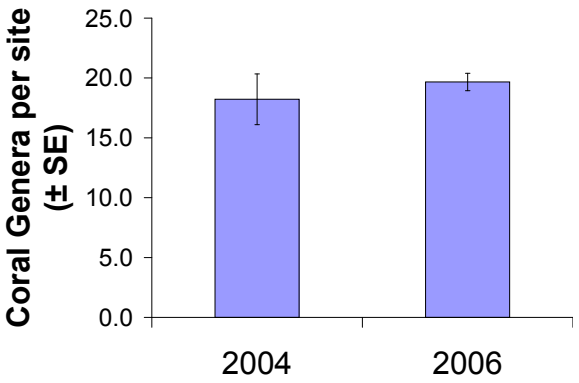

Figure 5.5.3b. Temporal comparison of mean coral genera per site from around Ta`u during ASRAMP 2004 and 2006 REA surveys.

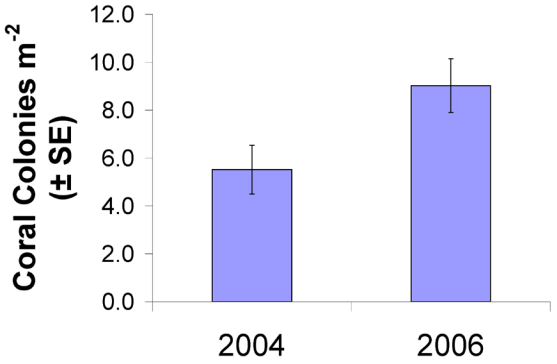

Figure 5.5.3c. Temporal comparison of mean coral colony density from around Ta`u during ASRAMP 2004 and 2006 REA surveys.

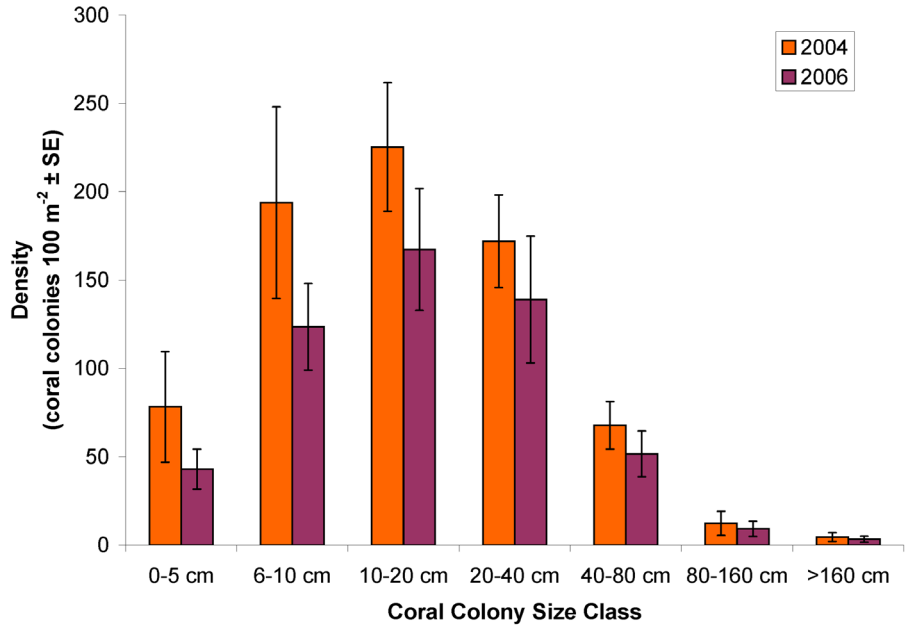

Figure 5.5.3d. Coral colony size-class mean density around Ta`u for ASRAMP 2004 and 2006 REA surveys.

In total, three fewer genera were reported from Ta`u in 2006 than in 2004 (29 vs. 32, respectively). Those genera that were only reported in a single year, however, were rare (*Diploastrea*, *Echinophyllia*, *Goniopora*/*Alveopora*, *Heliopora*, and *Merulina*; 1–5 colonies). In both years, *Montipora*, *Astreopora*, and *Porites* were among the four most abundant genera. In 2004, *Favia* was the third most abundant genus (11.9% of colonies) while in 2006 *Goniastrea* was the third most abundant genus (9.3% of colonies). This apparent difference in generic dominance could easily result from the difference in survey area, as discussed in the preceding paragraph. In both 2004 and 2006, site TAU-02 on the south region was the site with the greatest generic diversity. It is interesting to note that biodiversity was highest along the south region of both Ofu/Olosega and Tutuila. TAU-10, despite placing the transect lines to include more hard-bottom substrate in 2006, displayed the lowest coral diversity in both years. Overall coral colony size-class distributions computed from 2004 and 2006 REA surveys are highly similar (Fig. 5.5.3d).

5.6 Algae

5.6.1 Algal Surveys

2002 Spatial Surveys

It is important to note when considering these results that turf algae, crustose coralline red algae, branched non-geniculate coralline red algae, and cyanophytes (blue-green algae) all need to be analyzed microscopically for proper taxonomic identification, and therefore, must be lumped into functional group categories in the field. Of these functional groups, turf algae are the most diverse with the possibility of up to 100 species occurring in a 10 cm^2 area. As well, macroalgae are large, fleshy, sometimes calcified entities that may be identifiable to genus or species in the field but often require microscopic analysis to confirm taxonomic identities.

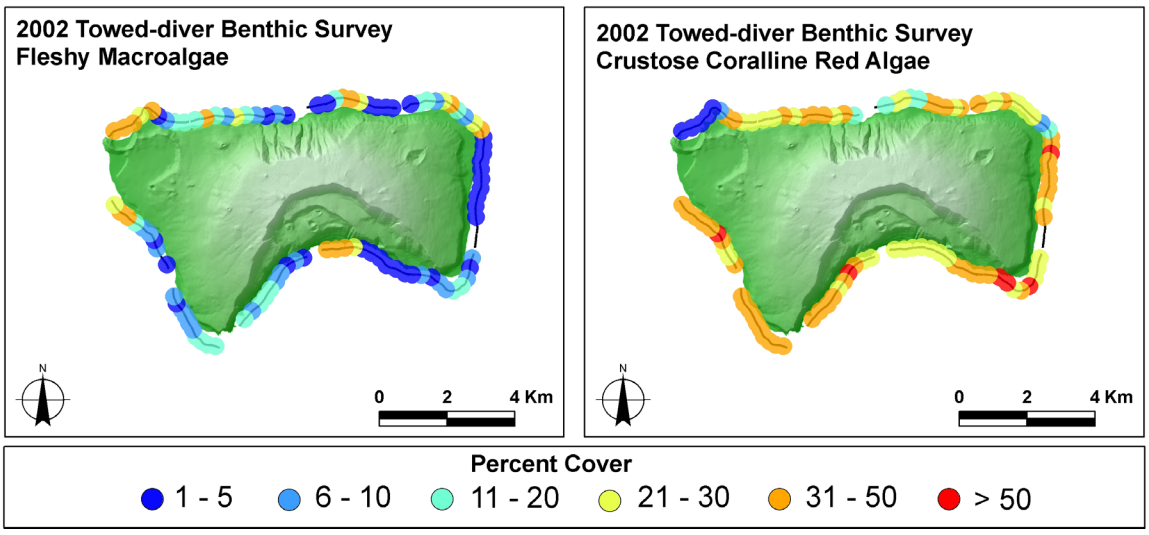

Figure 5.6.1a. Percent cover of fleshy macroalgae (including turf algae) and crustose coralline algae from towed-diver benthic surveys around Ta`u during ASRAMP 2002. Each colored point represents an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2).

Ten towed-diver surveys around Ta`u during ASRAMP 2002 found that combined fleshy macroalgal and crustose coralline red algal cover was 49.8%. The percent cover of crustose coralline red algae was relatively higher than fleshy macroalgae around Ta`u, with each functional group covering 34.9% (SE 1.3) and 14.9% (SE 1.2) of the benthic substrate, respectively (Fig. 5.6.1a). Crustose coralline red algal cover abundance was lowest along the northwestern corner of the island, while fleshy macroalgal cover abundance was among the highest.

Qualitative REA algal surveys were conducted in 2002 around Ta`u, and six bags of algal voucher specimens were collected. These surveys provided baseline data used to design and scale the future methodology of algal REA surveys.

2004 Spatial Surveys

Eighteen towed-diver surveys were conducted around Ta`u during ASRAMP 2004 and revealed that 54% of the benthic substrate was covered with fleshy macroalgae and crustose coralline red algae. Fleshy macroalgae were slightly more common than crustose coralline red algae, with each category averaging 31.7% (SE 1.1) and 22.3% (SE 1.0), respectively (Fig. 5.6.1b). Fleshy macroalgae were relatively uniform along the forereefs of Ta`u except for one towed-diver benthic survey near Siulagi Point in the north region, where percent cover averaged 58%.

Algal surveys were conducted at nine sites around Ta`u during ASRAMP 2004 (Fig. 5.6.1c). A total of 14 macroalgal genera (7 green, 6 red, and 1 brown) and 3 additional algal functional groups (turf algae, crustose coralline red algae, and cyanophytes) were observed in the field. Diversity of large, easily observed macroalgal genera (some of which contain multiple species) at each site ranged from 0 to 8. However, once laboratory-based taxonomic

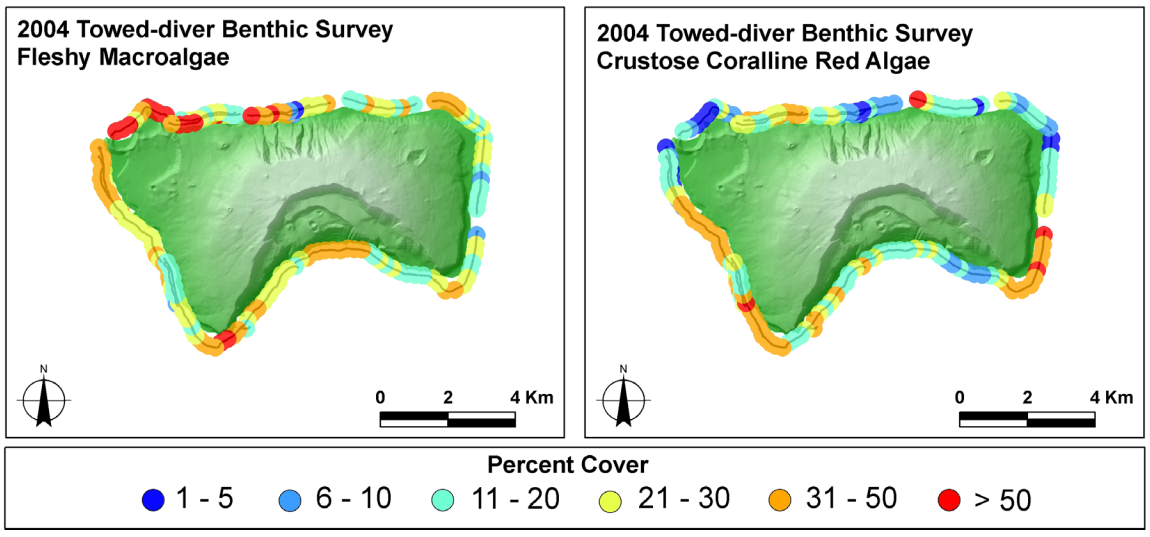

Figure 5.6.1b. Percent cover of fleshy macroalgae (including turf algae) and crustose coralline algae from towed-diver benthic surveys around Ta`u during ASRAMP 2004. Each colored point represents an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2).

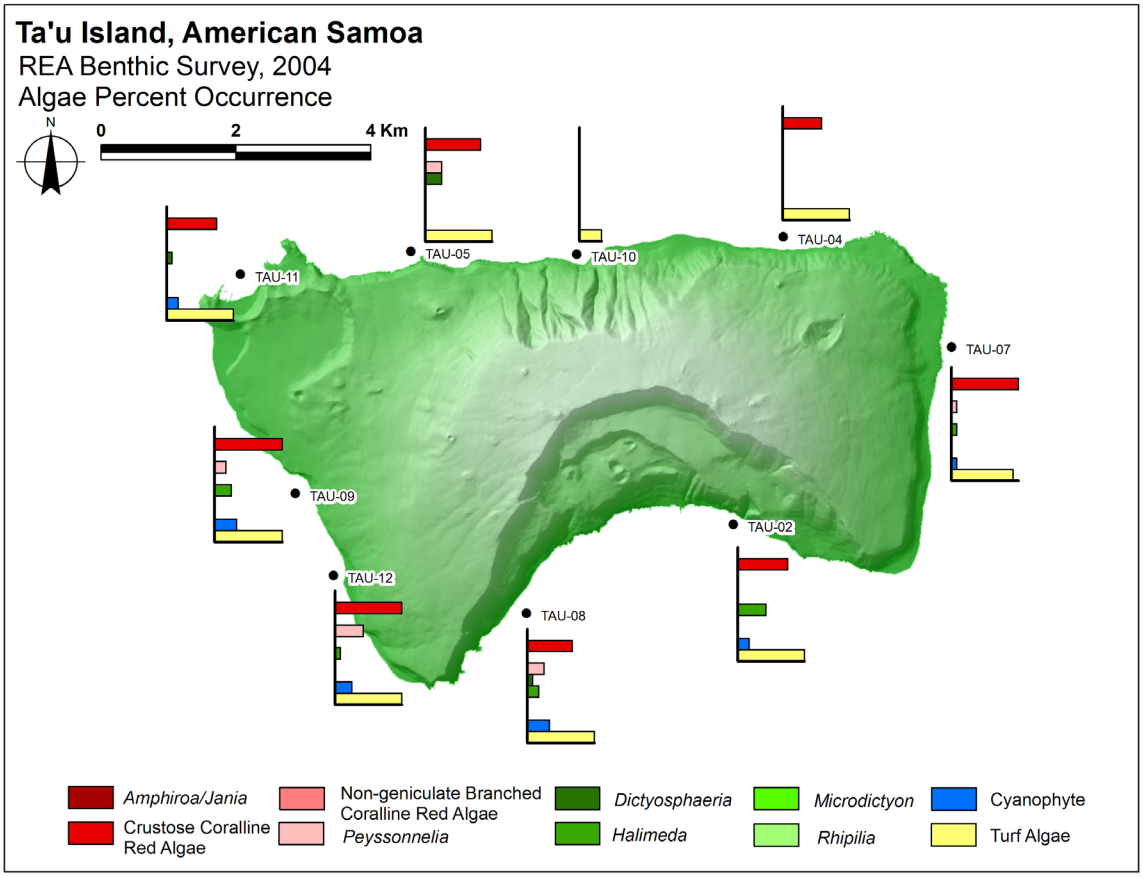

Figure 5.6.1c. Percent occurrence of select macroalgal genera and algal functional groups from REA algal surveys around Ta`u during ASRAMP 2004. Percent occurrence is equivalent to the percentage of photoquadrats in which an algal genus or functional group was observed. Length of *x*-axis denotes 100% occurrence.

identification of all algal species (including turf algae, epiphytes, and crustose coralline red algae) from each site is completed, algal diversity for each site will be much higher. Site TAU-12 in the west region had more than twice the recorded macroalgal generic diversity as observed at most other sites with eight genera recorded. Five genera were recorded at site TAU-05 in the north region; all other sites contained four or fewer macroalgal genera. No macroalgae were found at site TAU-10, located on the north central side of the island.

Around Ta`u, turf algae were the dominant marine flora found, being observed in more than 75% of sampled quadrats in all locations except site TAU-10 in the north region (Fig. 5.6.1c). Similarly, crustose coralline red algae were dominant at most sites around the island (50–100% of sampled photoquadrats per site),

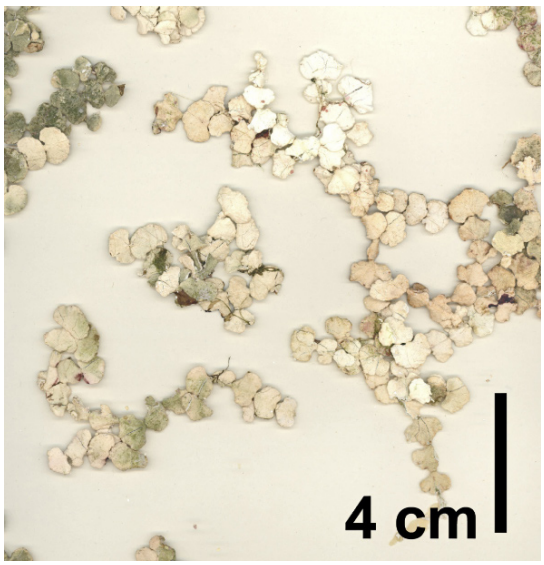

Figure 5.6.1d. A species of the calcified, sand-producing alga, *Halimeda*, from Ta`u. This alga can often form extensive draperies or mats over the benthic substrate. (*Photograph provided by NOAA PIFSC CRED; P. Vroom, JIMAR*)

but as with turf algae, were completely lacking at site TAU-10. Cyanophytes were lacking from photoquadrats at all three northern stations but were found in relatively low abundance at western, eastern, and southern sites with the highest abundance in the southwest corner.

Macroalgae were not abundant around Ta`u, with the calcified sand producing green alga *Halimeda* (Fig. 5.6.1d), being the most abundant by occurring in 42% of photoquadrats at site TAU-02. The green alga *Dictyosphaeria*, the brown alga *Lobophora*, and the red alga *Peyssonnelia* were found in 25% of photoquadrats at only one site each: TAU-09, TAU-05, TAU-08, and TAU-12, respectively. Macroalgae were extremely scarce at all other locales. The northern shores were essentially depauperate of macroalgal genera, with only turf algae being recorded in select photoquadrats at site TAU-10.

2006 Spatial Surveys

Fifteen towed-diver surveys around Ta`u during ASRAMP 2006 reported an average algal substrate cover of 37%. The percent cover of crustose coralline red algae was relatively higher than fleshy macroalgae around Ta`u, with each functional group covering 27.8% (SE 1.3) and 9.1% (SE 0.5) of the benthic substrate, respectively (Fig. 5.6.1e). Crustose coralline red algae were most abundant during tows along the east coast of the island, from Tiafou Point to Tufu Point, covering up to 50% of the benthic habitat.

Quantitative algal surveys were conducted at eight of the same nine sites around Ta`u as were monitored in 2004 (site TAU-08 was not resurveyed; Fig. 5.6.1f). A total of 24 macroalgal genera (9 green, 13 red, and 2 brown) and 3 additional algal functional groups (turf algae, crustose coralline red algae, and cyanophytes) were observed in the field. Diversity of large, easily observed macroalgal genera (some of which contain multiple species) at each site ranged from 8 to 18, although once laboratory-based taxonomic identification of all algal species (including turf algae, epiphytes, and crustose coralline red algae) from each site is completed, algal diversity for each site will be much higher. Sites TAU-05 and TAU-09 in the north and west regions, respectively, exhibited the highest macroalgal generic diversity with 18 and 15 genera recorded, respectively. Divers recorded 8–9 genera at most other sites.

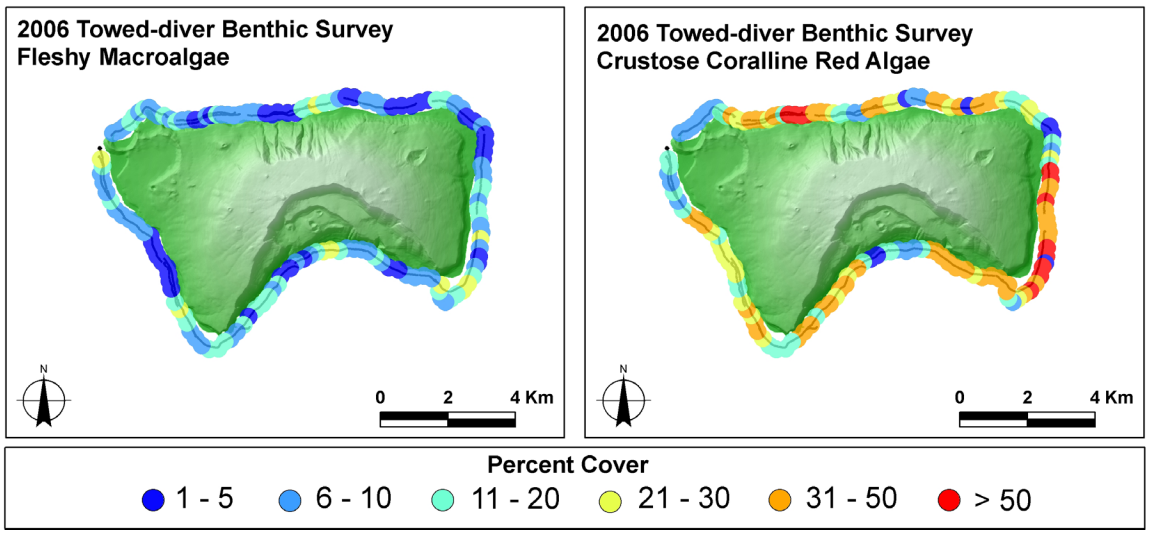

Figure 5.6.1e. Percent cover of fleshy macroalgae (excluding turf algae) and crustose coralline algae from towed-diver benthic surveys around Ta`u during ASRAMP 2006. Each colored point represents an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2).

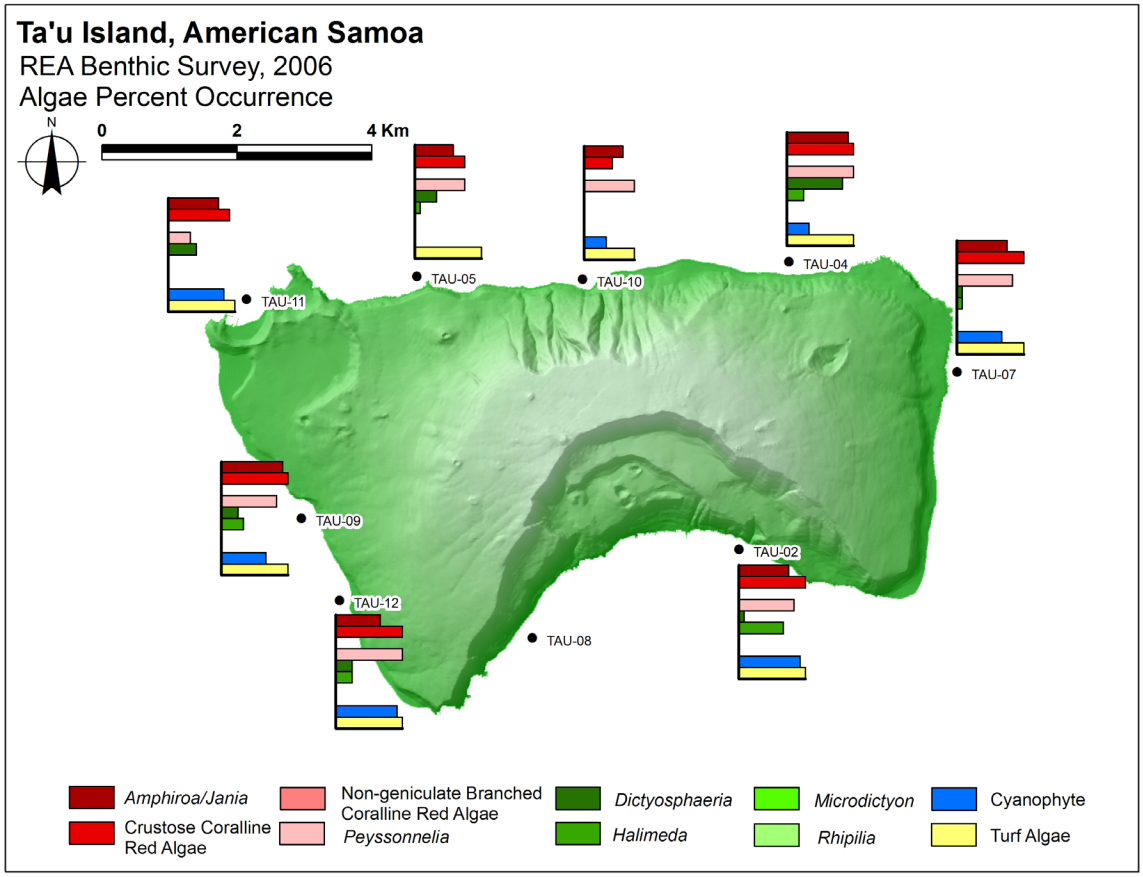

Figure 5.6.1f. Percent occurrence of select macroalgal genera and algal functional groups from REA surveys around Ta`u during ASRAMP 2006. Percent occurrence is equivalent to the percentage of photoquadrats in which an algal genus or functional group was observed.

Around Ta`u, turf algae were the dominant marine flora found, being observed in more than 75% of sampled quadrats in all locations (Fig. 5.6.1f). Similarly, crustose coralline red algae were dominant at most sites around the island (50–100% of sampled photoquadrats per site). Cyanophytes were surprisingly high in abundance, being found in more than 50% of photoquadrats at eastern, western, and southern sites. They were of lowest abundance on the north shore, being completely lacking at site TAU-05.

Macroalgae were extremely abundant around Ta`u during ASRAMP 2006 with several genera occurring in more than 75% of sampled photoquadrats at multiple sites. Site TAU-04, on the northeast corner of the island, had among the highest abundances of several taxa with the red algal genera *Peyssonnelia* and *Jania*, and the green algal genus *Dictyosphaeria* occurring in more than 75% of sampled photoquadrats (Fig. 5.6.1f). Additionally, an unidentified genus in the red algal order Gelidiales occurred in more than 80% of photoquadrats sampled at the site. In addition to their high abundance at TAU-04, *Peyssonnelia*, the unidentified member of the Gelidiales, and *Jania* were among the most common macroalgae found around the island, occurring at every site sampled. The brown alga, *Dictyota*, and the green alga, *Dictyosphaeria*, occurred at all sites except TAU-11 and TAU-10 in the north region, respectively.

5.6.2 Coralline Algal Disease Surveys

2006 Spatial Surveys

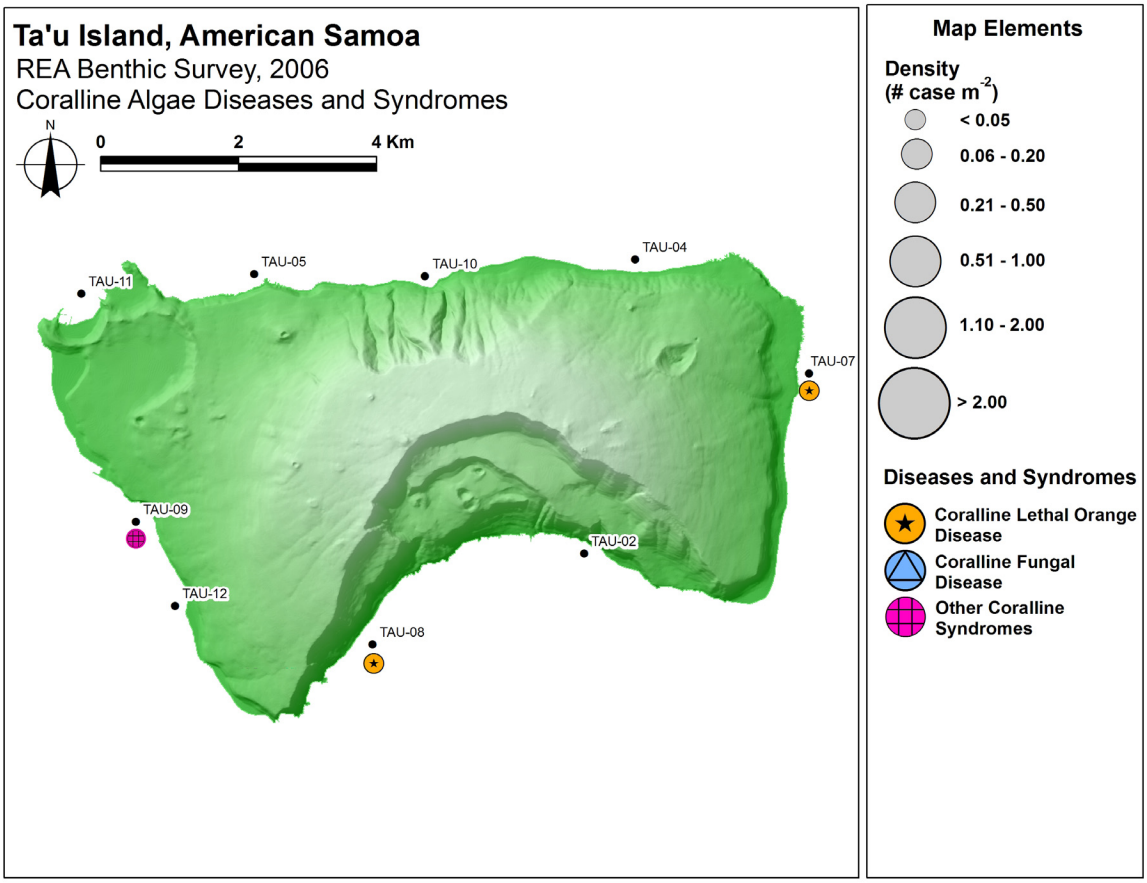

Figure 5.6.2a. Relative abundance of coralline algal diseases around Ta`u during ASRAMP 2006. Disease density is indicated by the size of the respective symbols.

Afflictions to coralline algae were also observed at the study sites, but in low abundances (Fig. 5.6.2a). Figure 5.6.2b illustrates the variation in the relative abundance of coralline algal disease among sites. Around Ta`u, only 21 cases of coralline algal disease (CLOD and CFD) were detected, mainly concentrated at sites TAU-07 (52%) on the east-facing shore, and TAU-08 (43%) on the south shore.

5.6.3 Temporal Comparison—Algae

A dramatic difference between the number of algal genera and their abundance was reported at Ta`u between the 2004 and 2006 sampling periods. In 2004, Ta`u exhibited the most meager algal community of all islands in American Samoa, but by 2006 it contained the most diverse and healthy algal community observed. Although Hurricane Heta did not pass over the Manu`a Island group, possibly severe wave energy generated from the storm in 2004 scoured benthic communities around Ta`u shortly before 2004 surveys were conducted, shredding algal communities and making the island appear to have low algal diversity. By

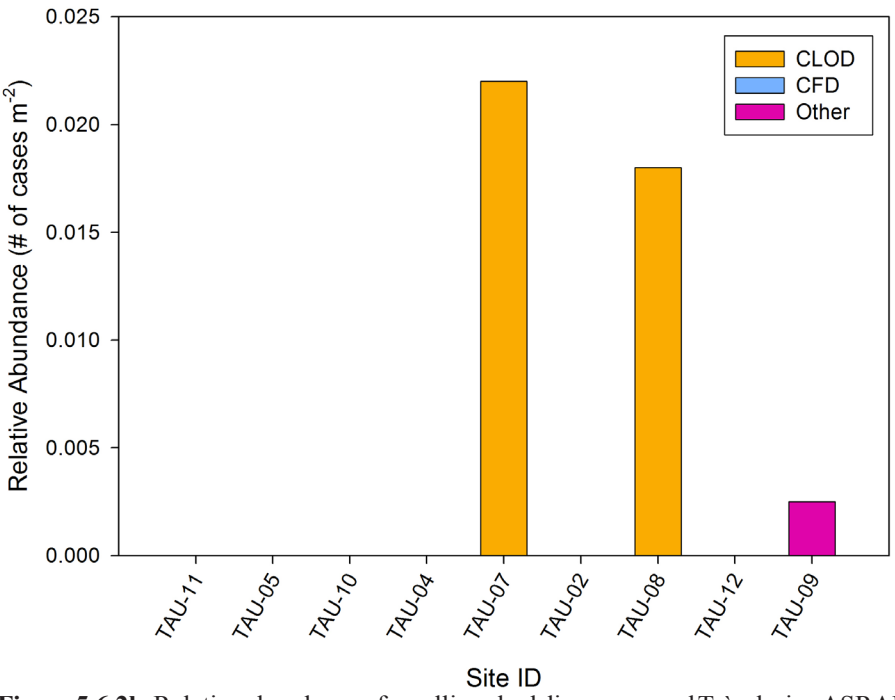

Figure 5.6.2b. Relative abundance of coralline algal disease around Ta`u during ASRAMP 2006. CLOD: coralline lethal orange disease; CFD: coralline fungal disease; and Other: undetermined coralline discolorations.

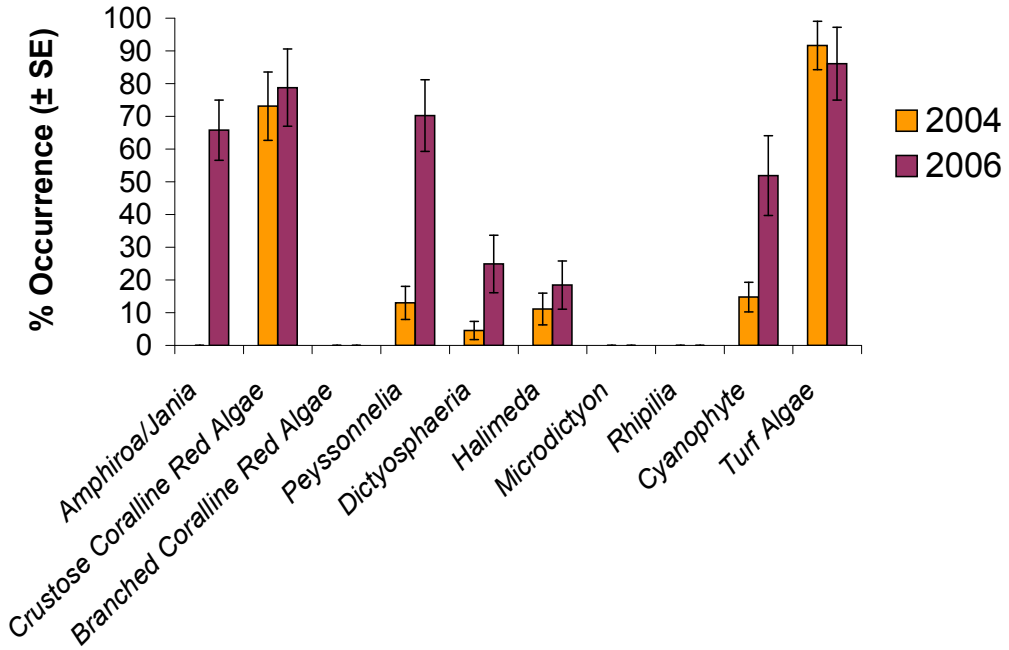

Figure 5.6.3a. Temporal comparison of REA algal genera and functional group percent occurrence around Ta`u between ASRAMP 2004 and 2006.

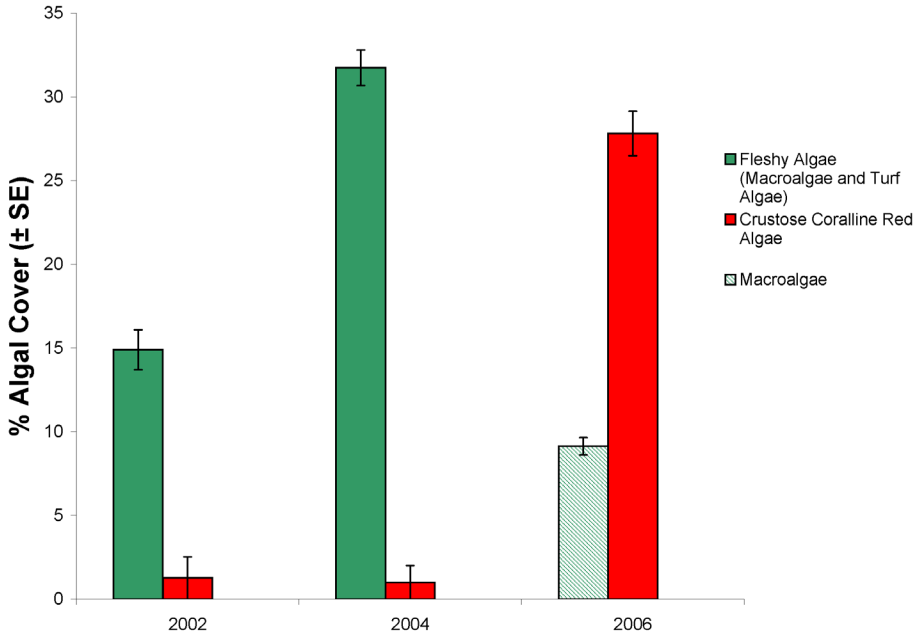

Figure 5.6.3b. Temporal comparison of towed-diver benthic survey algal percent cover results for fleshy, crustose coralline and macroalgae for ASRAMP 2002, 2004 and 2006 surveys around Ta`u.

2006, the algal communities had fully recovered. Almost twice the number of genera was recorded in 2006 compared to 2004, and abundances of macroalgae in photoquadrats increased from < 25% to almost 100% at most sites (Fig. 5.6.3a). Macroalgal diversity, as determined through field observations of the relative abundance of macroalgae, was exceptionally higher along the northern shore of the island in 2006 as compared to 2004. As at Tutuila, a major difference between the 2004 and 2006 sampling periods was the presence of the red algal genera, *Amphiroa*/*Jania*, which were not recorded in 2004, but were extremely prevalent at almost every site in 2006. Populations of the green algae *Halimeda* and *Dictyosphaeria* remained relatively constant in both years, although *Dictyosphaeria* was very abundant at TAU-04 in 2006, whereas it was completely lacking in 2004.

5.7 Benthic Macroinvertebrates

5.7.1 Benthic Macroinvertebrate Surveys

2002 Spatial Surveys

Towed-diver benthic macroinvertebrate surveys around Ta`u during the 2002 ASRAMP cruise found no crown-of-thorns seastars (COTS) or sea cucumbers (Fig. 5.7.1a). Giant clams were found mostly along the north shore of the island (mean: 18.8 organisms ha^{-1}). Sea urchin distribution was concentrated on the northwestern corner of the island. As mentioned in the introduction (Chapter 1, Section 1.6: Limitations of Pacific RAMP), surveys in 2002 were limited by shipboard logistics and methods development, which may have contributed to the low numbers of macroinvertebrates observed in 2002.

A total of six qualitative REA invertebrate surveys, focusing on general information about the macroinvertebrate communities, were conducted around Ta`u during ASRAMP 2002. These surveys provided baseline data used to design and scale the future methodology of REA surveys. No data are presented.

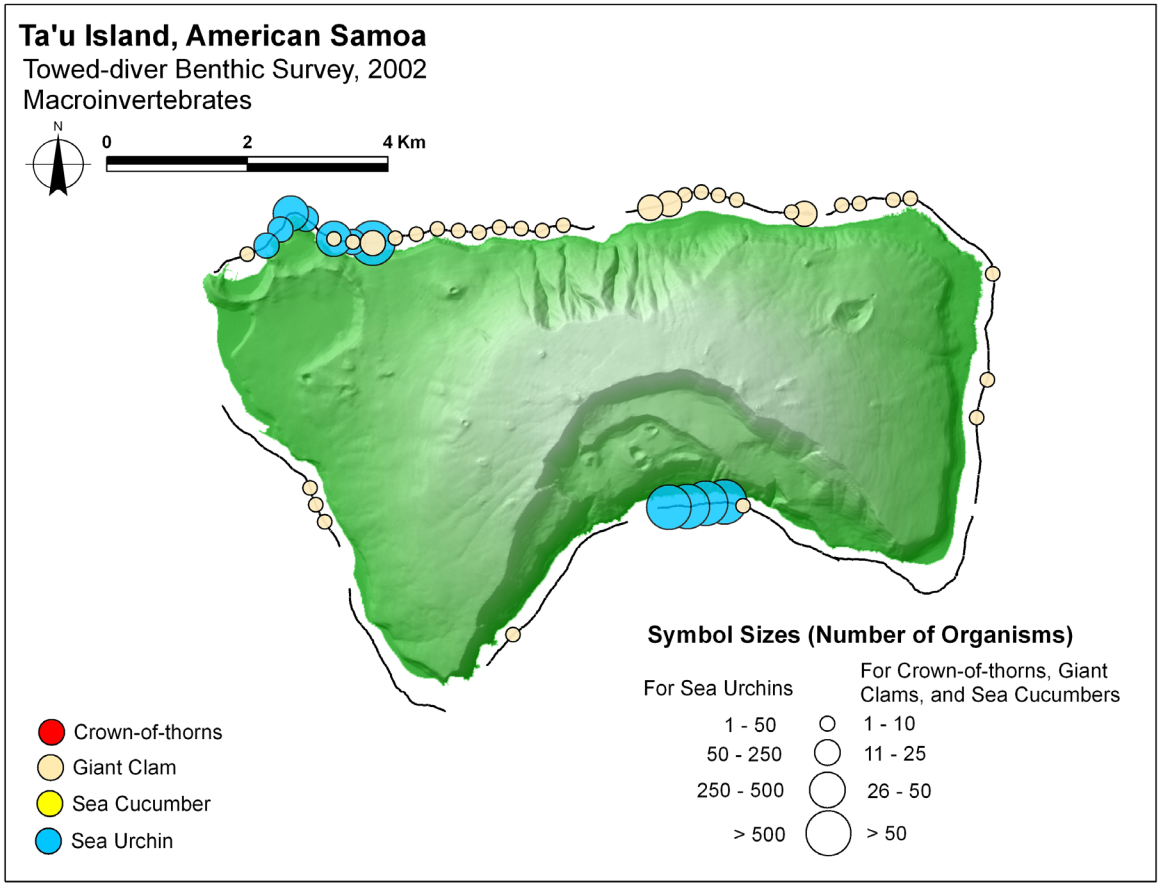

Figure 5.7.1a. Distribution of estimated population densities of COTS, giant clams, sea cucumbers, and sea urchins around Ta`u from towed-diver benthic surveys during ASRAMP 2002. Circle locations represent an integrated estimate over 5-min observation segments covering survey swaths of ~ 200 m × 10 m (~ 2000 m^2). The sizes of the circles indicate the number of organisms counted or estimated in each ~ 2000 m^2 segment with one scale for COTS, giant clams, and sea cucumbers (1–10, 11–25, 26–50, and > 50) and another scale for sea urchins (1–50, 51–250, 251–500, and > 500).

2004 Spatial Surveys

Towed-diver benthic macroinvertebrate surveys around Ta`u during ASRAMP 2004 found variable distributions of giant clams, sea cucumbers, and sea urchins (Fig. 5.7.1b). No COTS were observed. Giant clams were found predominantly in the north (mean: 36.7 organisms ha^{-1}) and west regions (mean: 18.0 organisms ha^{-1}). Sea urchins appeared at their highest numbers and densities on the northwestern and the southwestern corners (mean: 1620 organisms ha^{-1}) of the island, while sea cucumbers remained rare and were found predominantly in the west region of the island (mean: 1.3 organisms ha^{-1}).

Invertebrate species richness at REA sites around Ta`u was variable, ranging from 9 to 27 invertebrate species (Fig. 5.7.1c). High richness was observed at sites TAU-02 and TAU-07 in the south and east regions. Sea urchins were present at five of seven REA sites, with *Echinostrephus* sp. being the most common urchin. Giant clams were present at all but one site, TAU-04 off the north coast of Ta`u. Three species of sea cucumbers were observed (*Holothuria cinerascens*, *Bohadschia argus*, and *Holothuria whitmaei*) around Ta`u at site TAU-11 in the northwest corner and site TAU-12 in the west region.

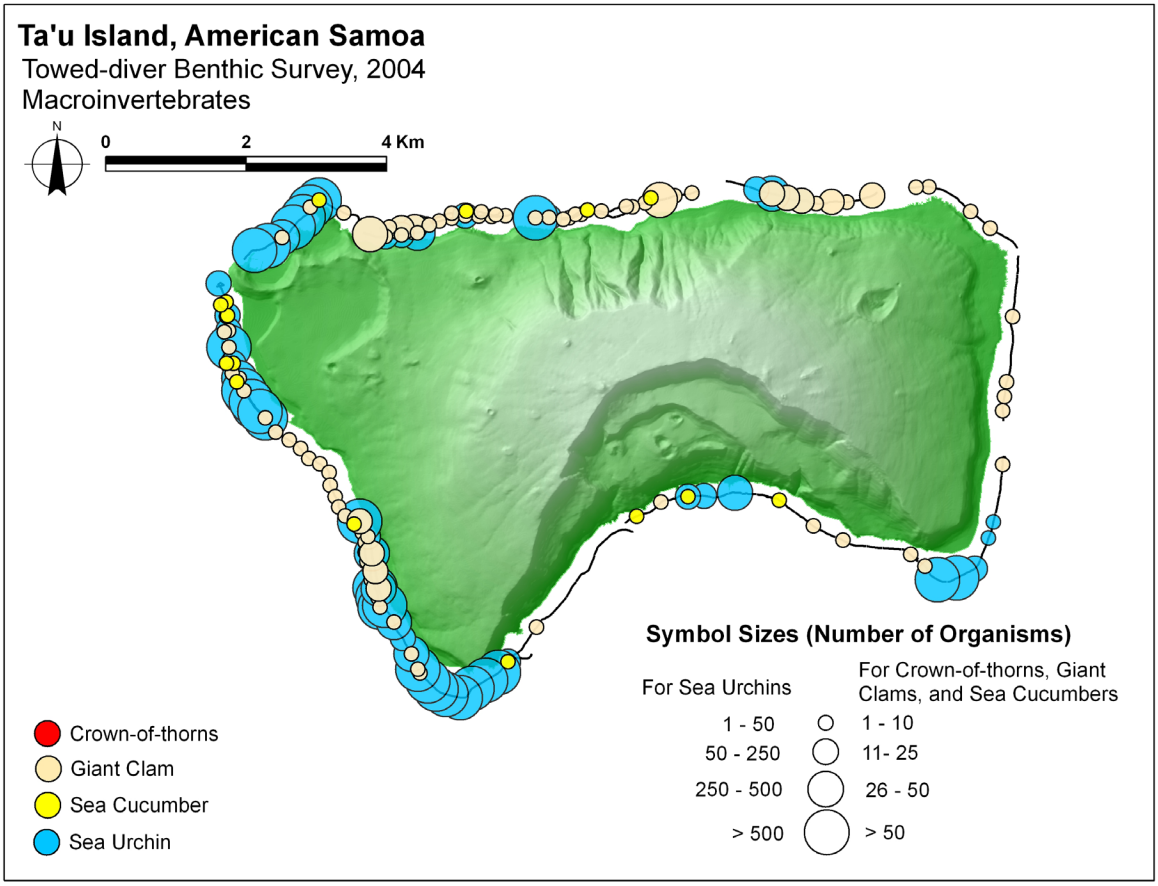

Figure 5.7.1b. Distribution of estimated population densities of COTS, giant clams, sea cucumbers, and sea urchins around Ta`u from towed-diver benthic surveys during ASRAMP 2004. Circle locations represent an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). The sizes of the circles indicate the number of organisms counted or estimated in each ~ 2000 m^2 segment with one scale for COTS, giant clams, and sea cucumbers (1–10, 11–25, 26–50, and > 50) and another scale for sea urchins (1–50, 51–250, 250–500, and > 500).

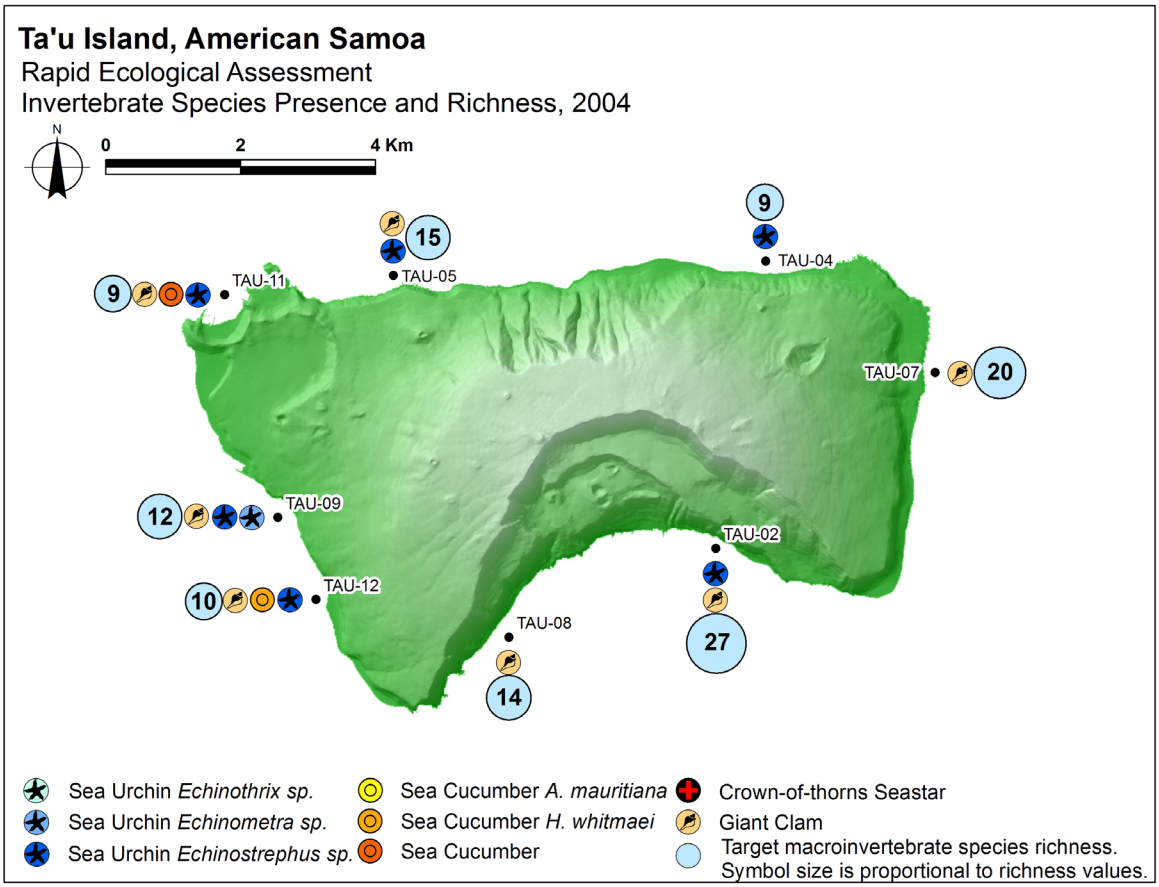

Figure 5.7.1c. Macroinvertebrate species richness, and target macroinvertebrate distribution around Ta`u from REA surveys during ASRAMP 2004. Size of light blue circles and values in circles indicate target species richness values for each REA site. Other symbols indicate the presence of specific target species.

2006 Spatial Surveys

Towed-diver benthic macroinvertebrate surveys around Ta`u during the 2006 ASRAMP cruise found varying distributions of giant clams, sea cucumbers, and sea urchins, and the absence of COTS (Fig. 5.7.1d). Giant clams were most common in the north region of Ta`u (mean: 14.6 organisms ha^{-1}), but were also relatively common in the west region (mean: 9.7 organisms ha^{-1}) and east region (mean: 6.7 organisms ha^{-1}). As in previous years, sea cucumbers remained uncommon, with the highest sea cucumber density found in the west region of the island (mean: 1.7 organisms ha^{-1}). Similar to 2004, sea urchins were found in the highest densities on the northwestern, southwestern, and northeastern corners of the island.

Target macroinvertebrates were common around Ta`u during ASRAMP 2006, with sea urchins present at all nine REA sites (Fig. 5.7.1e). The boring urchin, *Echinostrephus aciculatus*, was the most common urchin species seen around Ta`u. Giant clams were present at eight of the nine REA sites. Sea cucumbers present at REA sites included *Actinopyga mauritiana* and an unidentified holuthuroid seen at one site each. No COTS were observed during REA surveys.

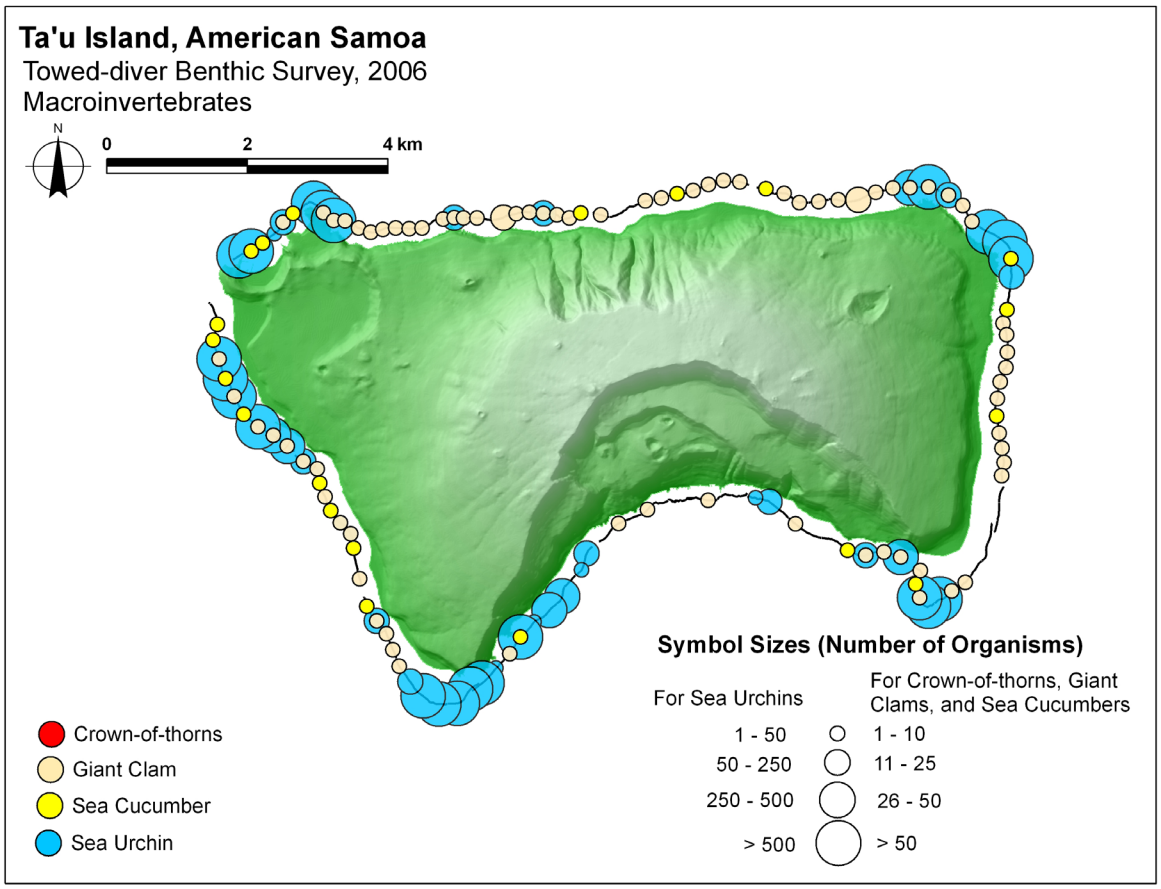

Figure 5.7.1d. Distribution of estimated population densities of COTS, giant clams, sea cucumbers, and sea urchins around Ta`u from towed-diver benthic surveys during ASRAMP 2006. Circle locations represent an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). The sizes of the circles indicate the number of organisms counted or estimated in each ~ 2000 m^2 segment with one scale for COTS, giant clams, and sea cucumbers (1–10, 11–25, 26–50, and > 50) and another scale for sea urchins (1–50, 51–250, 251–500, and > 500).

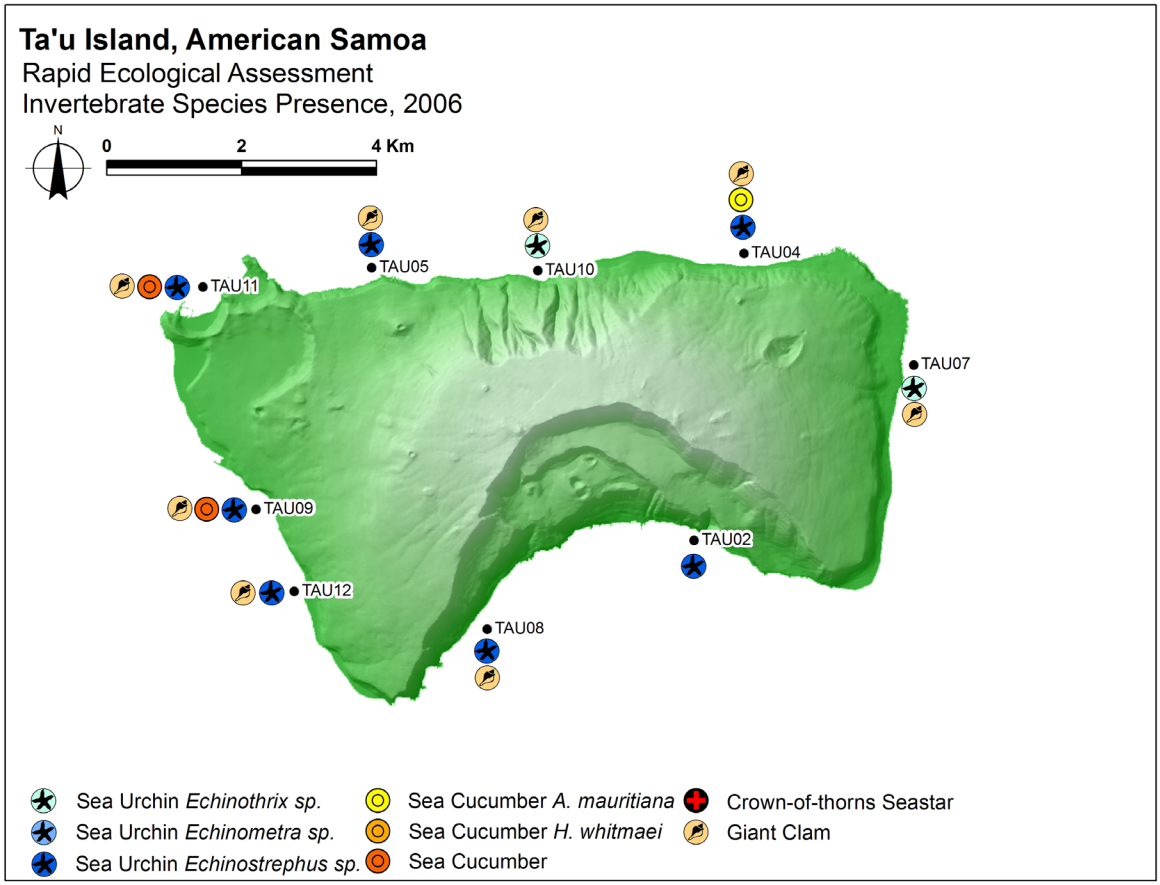

Figure 5.7.1e. Target macroinvertebrate distribution around Ta`u from REA surveys during ASRAMP 2006.

5.7.2 Temporal Comparison—Benthic Macroinvertebrates

Macroinvertebrate distributions were relatively similar along the forereefs of Ta`u, especially during 2004 and 2006 towed-diver surveys. However, results did show some temporal trends in organism densities. COTS were not present around Ta`u during any of the sampling years. Mean giant clams densities (Fig. 5.7.2a) were shown to fluctuate between sampling periods, which could be attributed to natural causes (e.g., population changes), changes in towed-diver survey depths and encounter rates, storm effects or through other (un)known causes. However, giant clams were common with slightly higher occurrences found off the north and west coasts of Ta`u in both 2004 and 2006. Sea cucumbers remained uncommon in both sampling years, with only small increases between years in the numbers encountered (Fig. 5.7.2b). Most sea cucumbers were found in the west region of Ta`u. Finally, sea urchins were the most common invertebrates and were observed mainly along the west coast of Ta`u (Fig. 5.7.2c). However, densities appeared highest along the northwestern and southwestern corners of the island, and also appeared in elevated numbers along the northeastern corner for surveys completed in both 2004 and 2006.

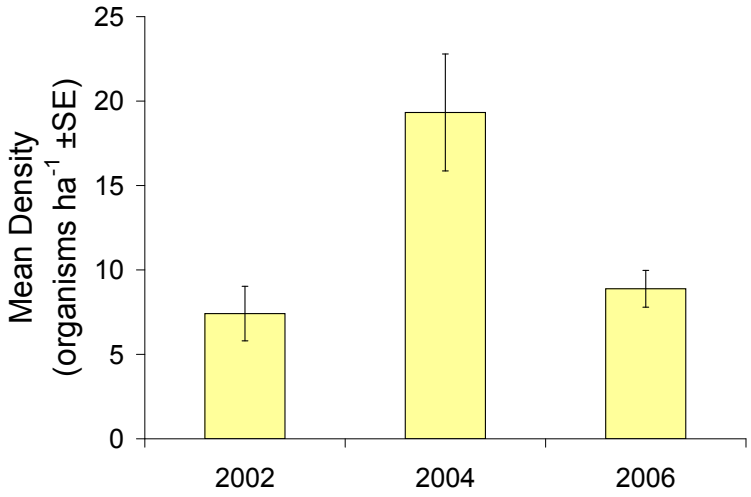

Figure 5.7.2a. Mean density of giant clams around Ta`u from towed-diver surveys during ASRAMP 2002, 2004, and 2006.

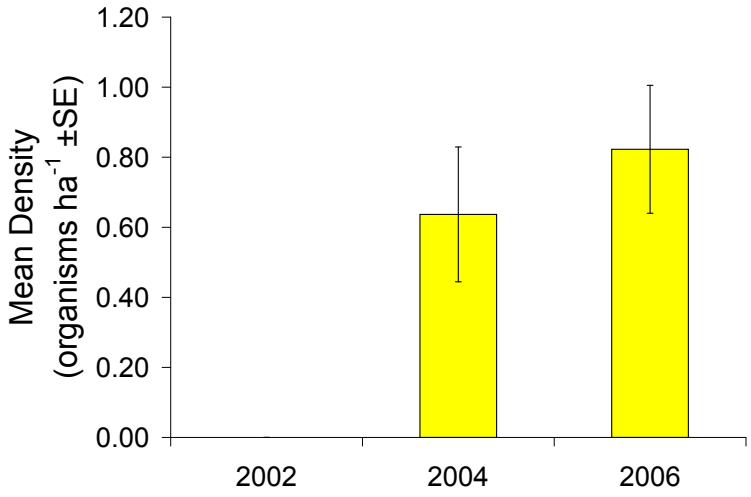

Figure 5.7.2b. Mean density of sea cucumbers (holothuroids) around Ta`u from towed-diver surveys during ASRAMP 2002, 2004, and 2006 cruises.

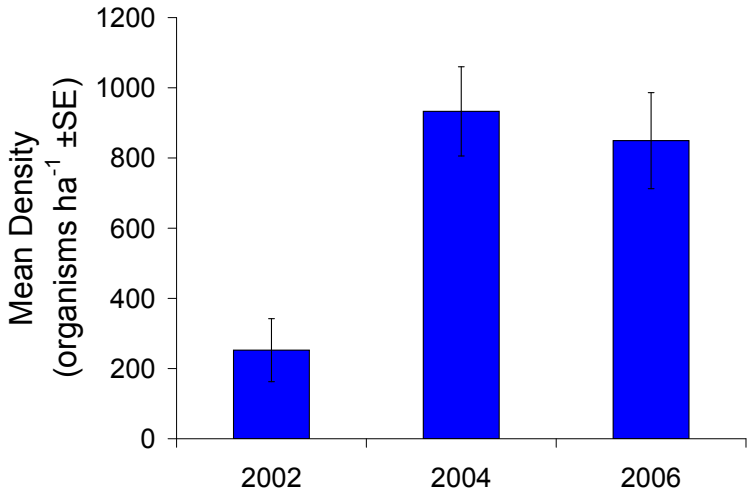

Figure 5.7.2c. Mean density of sea urchins (echinoids) around Ta`u from towed-diver surveys during ASRAMP 2002, 2004 and 2006.

5.8 Reef Fish

5.8.1 Reef Fish Surveys

2002 Spatial Surveys

The biomass of large fish (length > 50 cm) around Ta`u, as surveyed by towed divers during ASRAMP 2002, was predominantly characterized by elevated abundances of parrotfish and snappers at most sites around the island, with a patchy distribution of sharks, surgeonfish, and groupers. Overall, large fish biomass was around 0.024 tons ha^{-1} (SE 0.013) and was distributed evenly around the island (Fig. 5.8.1a).

Two rare bumphead parrotfish (*Bolbometapon muricatum*) were sighted on the northern side of Ta`u. Only two sharks and a few humphead wrasses were observed, mostly in the east

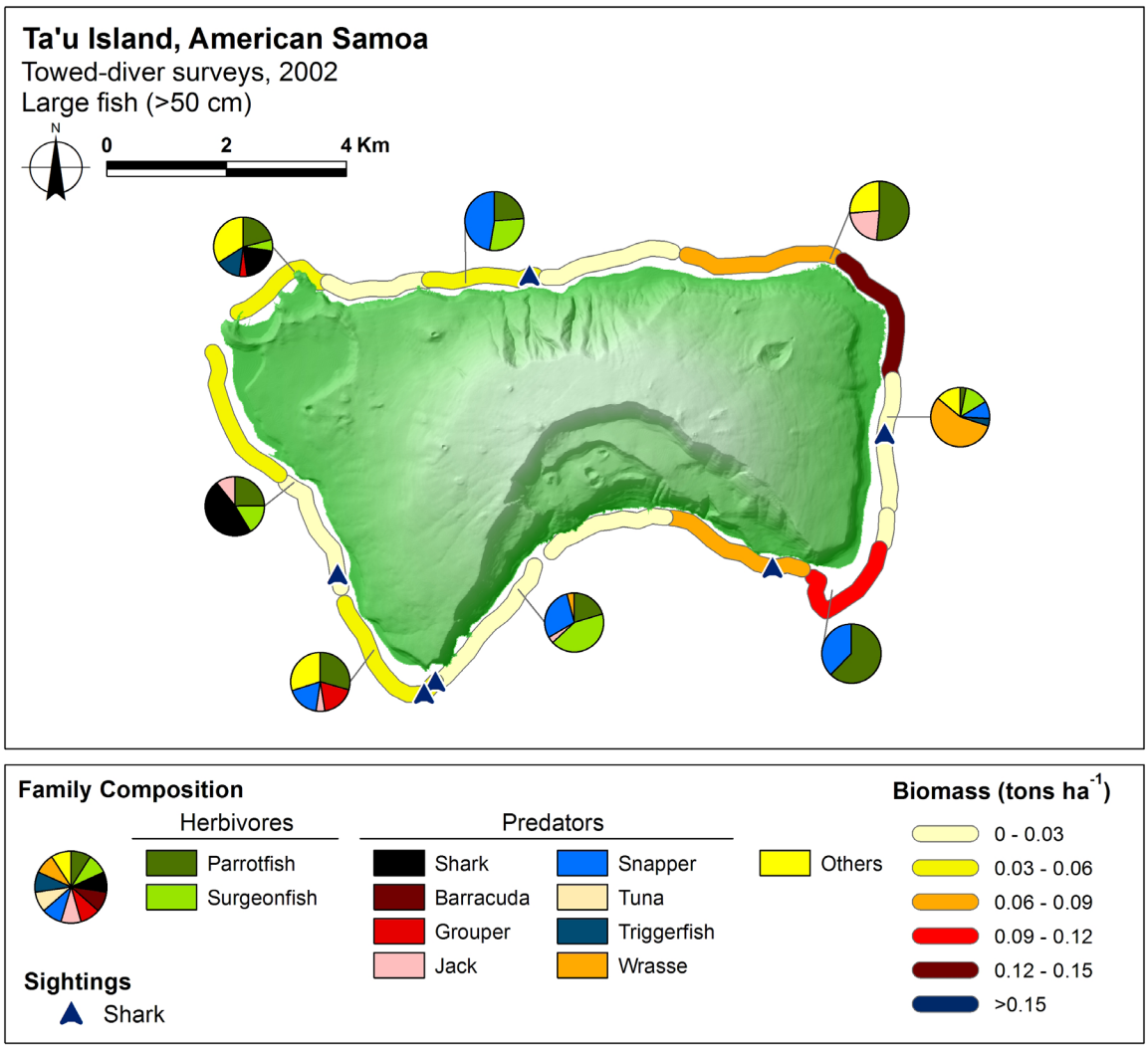

Figure 5.8.1a. Large fish biomass, family composition, and individual shark sightings around Ta`u recorded during ASRAMP 2002 towed-diver surveys. Large fish (length > 50 cm) biomass on each individual towed-diver survey is represented by the color of the survey track (tons ha^{-1}). Composition by trophic group is indicated by the family colors (green—mostly herbivores; other colors—mostly predators or mixed). Individual shark sightings, observed inside or outside the survey area, are represented by blue triangles.

section of the island (Fig. 5.8.1a).

Total fish biomass was similar around Ta`u during the 2002 ASRAMP surveys (7.7 kg 100 m^{-2} [SE 3.0]). Herbivores, mainly surgeonfish, were generally the most abundant fish group, but this was not clear at all sites (Fig. 5.8.1b). Lower-level predators (emperors and triggerfish) were also abundant, especially at TAU-02 in the south region of Ta`u.

Peacock grouper (*Cephalopholis argus*) were the most dominant grouper species present and were also the most common species on stationary point counts (> 20 cm total length). Several snappers—the smalltooth jobfish (*Aphareus furca*), the twinspot snapper (*Lutjanus bohar*), and the blue-lined snapper (*L. kasmira*)—were also common.

Fish species richness was similar around Ta`u with averages of ~ 20 species 100 m^{-2} (Fig. 5.8.1b).

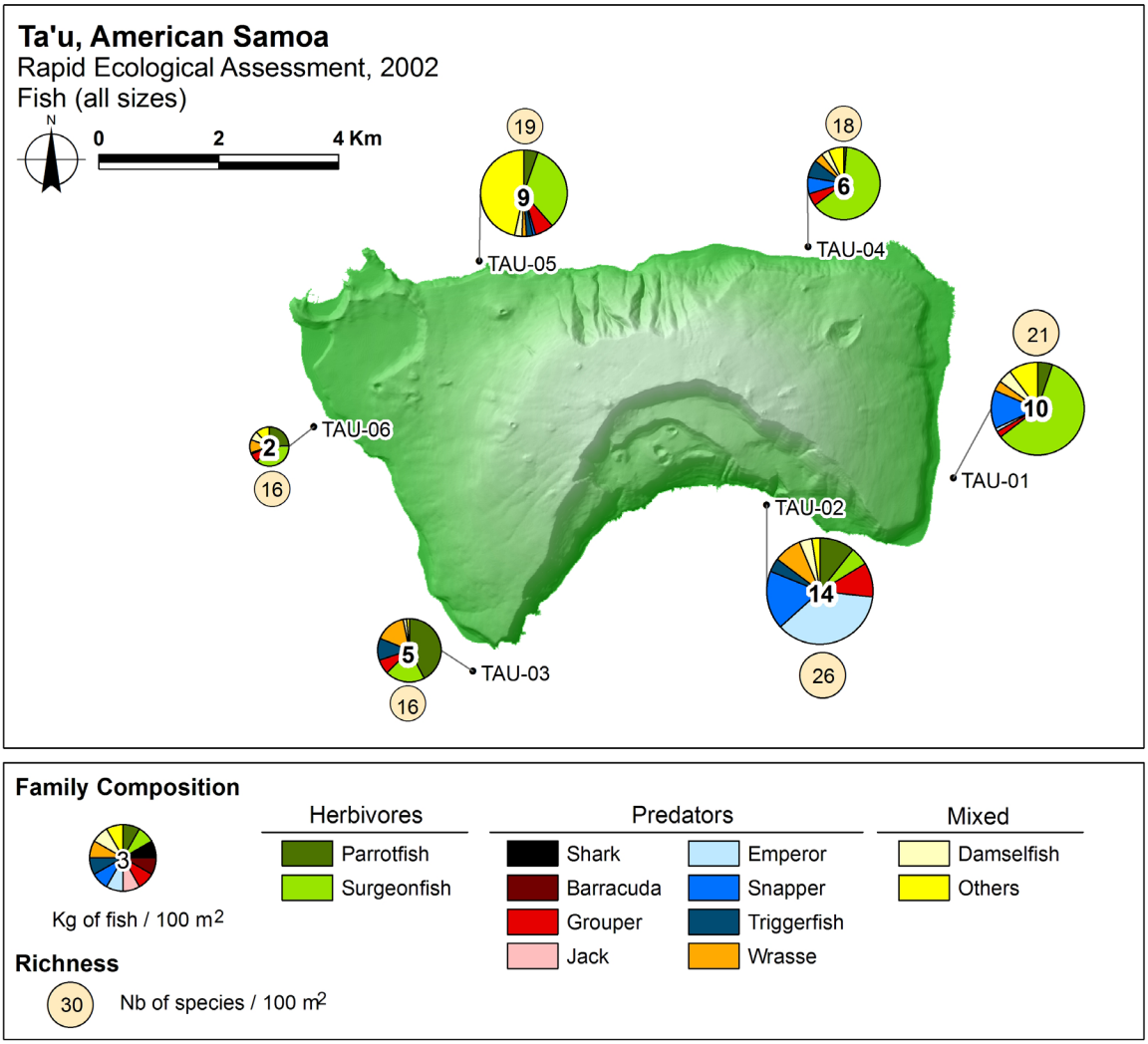

Figure 5.8.1b. Total fish biomass, family composition, and species richness of fishes around Ta`u recorded during ASRAMP 2002 REA belt-transect surveys. Total fish biomass (all species and size classes) is represented at each site by the size of the pie chart with the actual biomass value in the center (kg 100 m^{-2}). Composition by trophic group is indicated by the family colors (green—mostly herbivores; other colors—mostly predators or mixed). Species richness at each REA site is indicated by numbers (# species 100 m^{-2}) and the size of the beige circles.

2004 Spatial Surveys

Large fish biomass around Ta`u during ASRAMP 2004 was mostly composed of parrotfish, followed by surgeonfish and wrasses. On average, large fish biomass was around 0.030 tons ha^{-1} (SE 0.015) for the island. No particular side of the island harbored higher fish biomass, although particularly high fish biomass was recorded on the northwest tip of the island, mostly because of shark and humphead wrasse sightings (Fig. 5.8.1c).

Two bumphead parrotfish were observed in the vicinity of the 2002 sightings, while a few sharks and humphead wrasses were seen at scattered locations around the island (Fig. 5.8.1c).

During 2004, total fish biomass was highest on the south and east sides of Ta`u (~ 18 kg 100 m^{-2}) compared to the north and west sides (~ 6 kg 100 m^{-2}). Herbivores (e.g., surgeonfish)

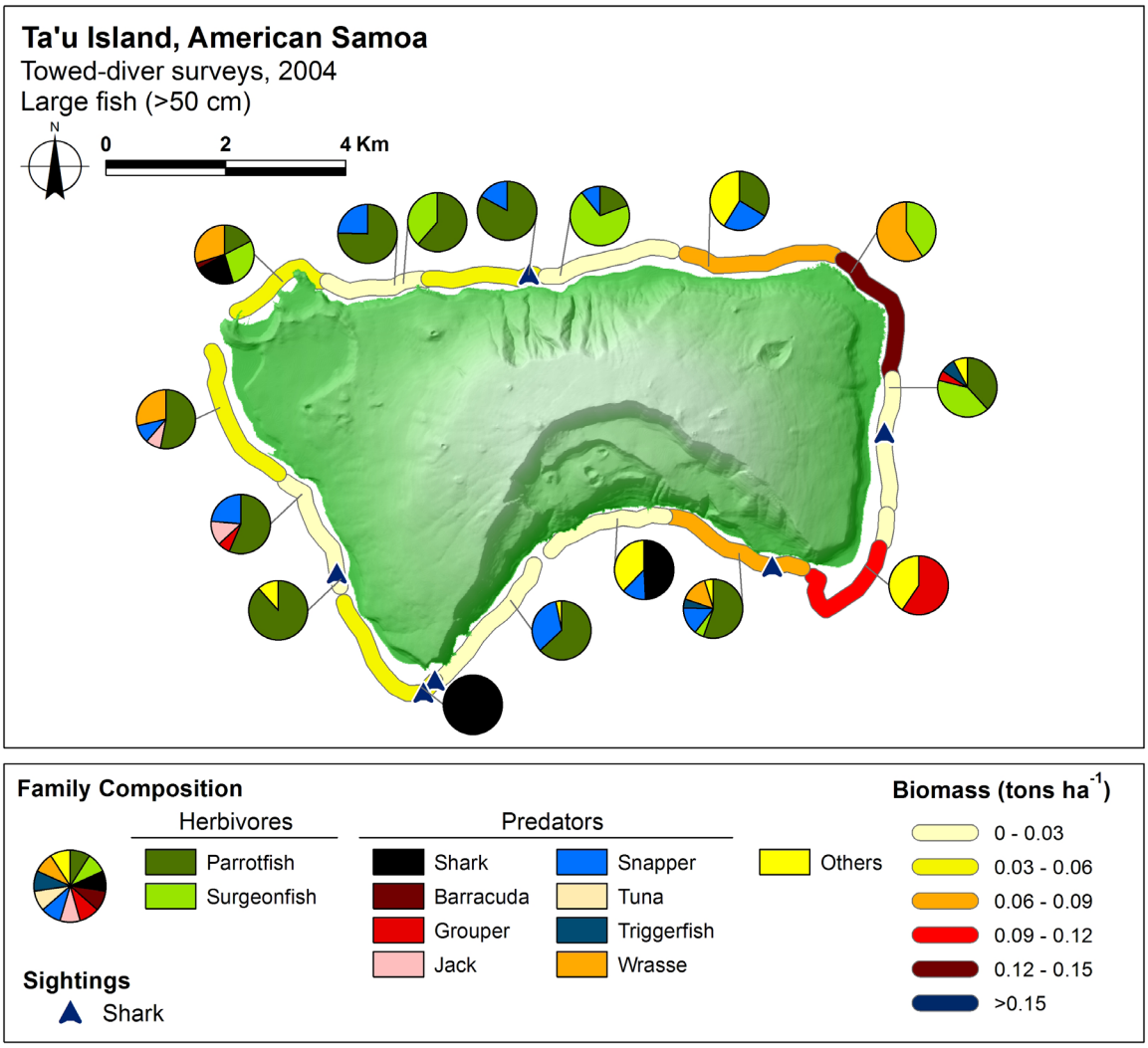

Figure 5.8.1c. Large fish biomass, family composition, and individual shark sightings around Ta`u recorded during ASRAMP 2004 towed-diver surveys. Large fish (length > 50 cm) biomass on each individual tow is represented by the color of the survey track (tons ha^{-1}). Composition by trophic group is indicated by the family colors (green—mostly herbivores; other colors—mostly predators or mixed). Individual shark sightings, observed inside or outside the survey area, are represented by blue triangles.

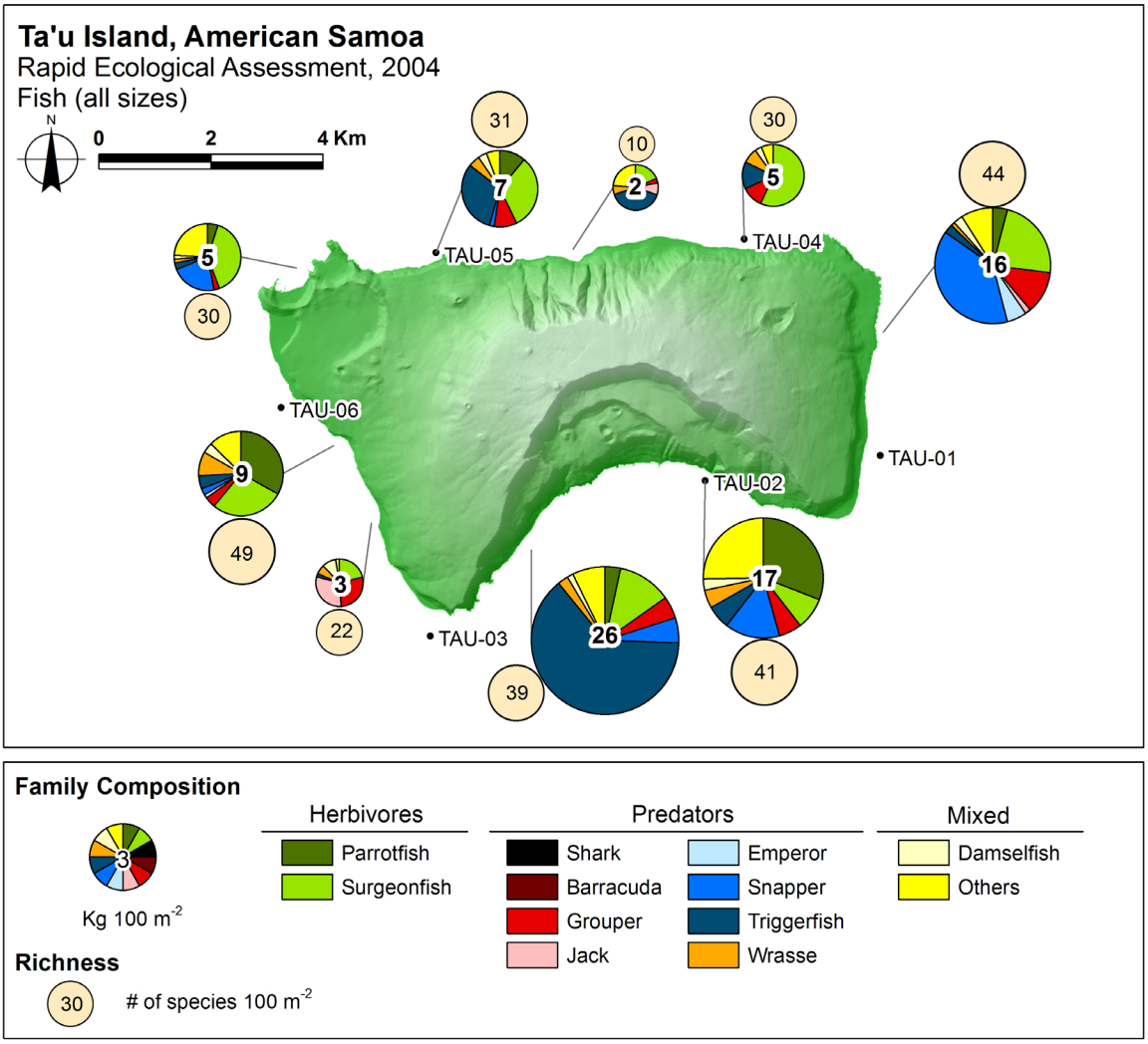

Figure 5.8.1d. Total fish biomass, family composition, and species richness of fishes around Ta`u recorded during ASRAMP 2004 REA belt-transect surveys. Total fish biomass (all species and size classes) is represented at each site by the size of the pie chart with the actual biomass value in the center (kg 100 m^{-2}). Composition by trophic group is indicated by the family colors (green—mostly herbivores; other colors—mostly predators or mixed). Species richness at each REA site is indicated by numbers (# species 100 m^{-2}) and the size of the beige circles.

made up most of the biomass, but lower-level predators (mainly triggerfish) were also noticeably abundant, especially at sites TAU-08 and TAU-05 in the south and north regions, respectively (Fig. 5.8.1d). Mean total fish biomass around Ta`u was around 10.1 kg 100 m^{-2} (SE 4.4) in 2004.

Parrotfish, surgeonfish, and snappers had the highest biomass for medium-large fish recorded on stationary point counts (> 25 cm total length) around Ta`u during ASRAMP 2004. Also relatively abundant were wrasses, triggerfish, and emperors.

Species richness ranged from 30 to 45 fish species 100 m^{-2} at most sites (Fig. 5.8.1d) and was slightly lower along the north side of this island.

2006 Spatial Surveys

Mean biomass for large fish (> 50 cm total length, all families pooled) around Ta`u during ASRAMP 2006 was similar to previous years (0.046 tons ha^{-1} [SE 0.019]). Large parrotfish and snappers represented most of the biomass in this size class. Large fish biomass was mostly evenly distributed around the island, although with some particularly elevated biomass values around the northeast tip of the island attributed to schools of barracuda (Fig. 5.8.1e).

Several humphead wrasses (50–120 cm total length) were observed around the island, especially around the southeastern point. Sharks were sighted regularly at scattered locations (Fig. 5.8.1e). Contrary to previous years, no bumphead parrotfish were observed in 2006.

During 2006, total fish biomass was similar around Ta`u, 4.4 kg 100 m^{-2} (SE 1.6), with the exception of site TAU-11 in the north region, where a large school of barracuda was recorded

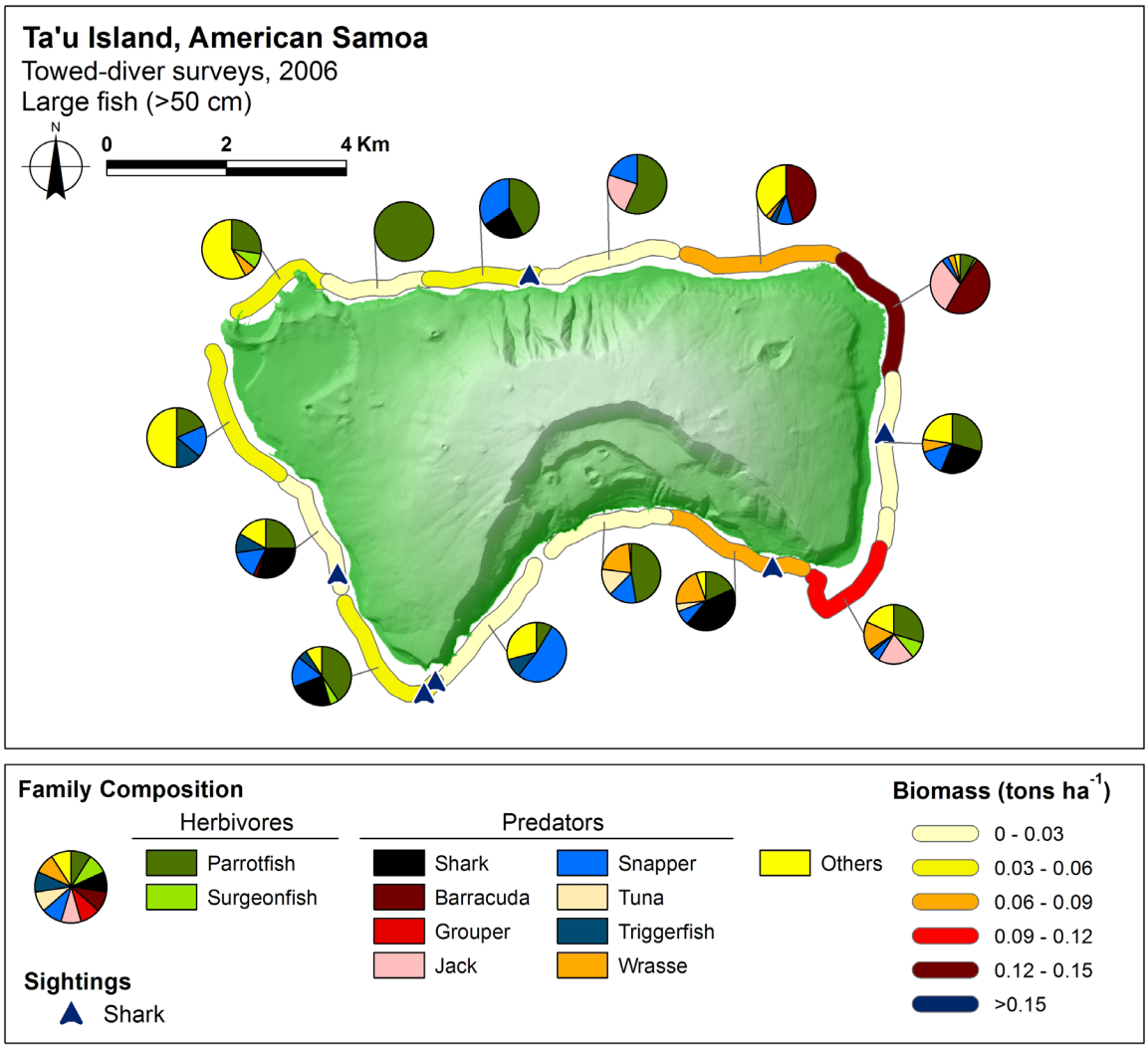

Figure 5.8.1e. Large fish biomass, family composition, and individual shark sightings around Ta`u recorded during ASRAMP 2006 towed-diver surveys. Large fish (length > 50 cm) biomass on each individual tow is represented by the color of the survey track. Composition by trophic group is indicated by the family colors (green—mostly herbivores; other colors—mostly predators or mixed). Individual shark sightings, observed inside or outside the survey area, are represented by blue triangles.

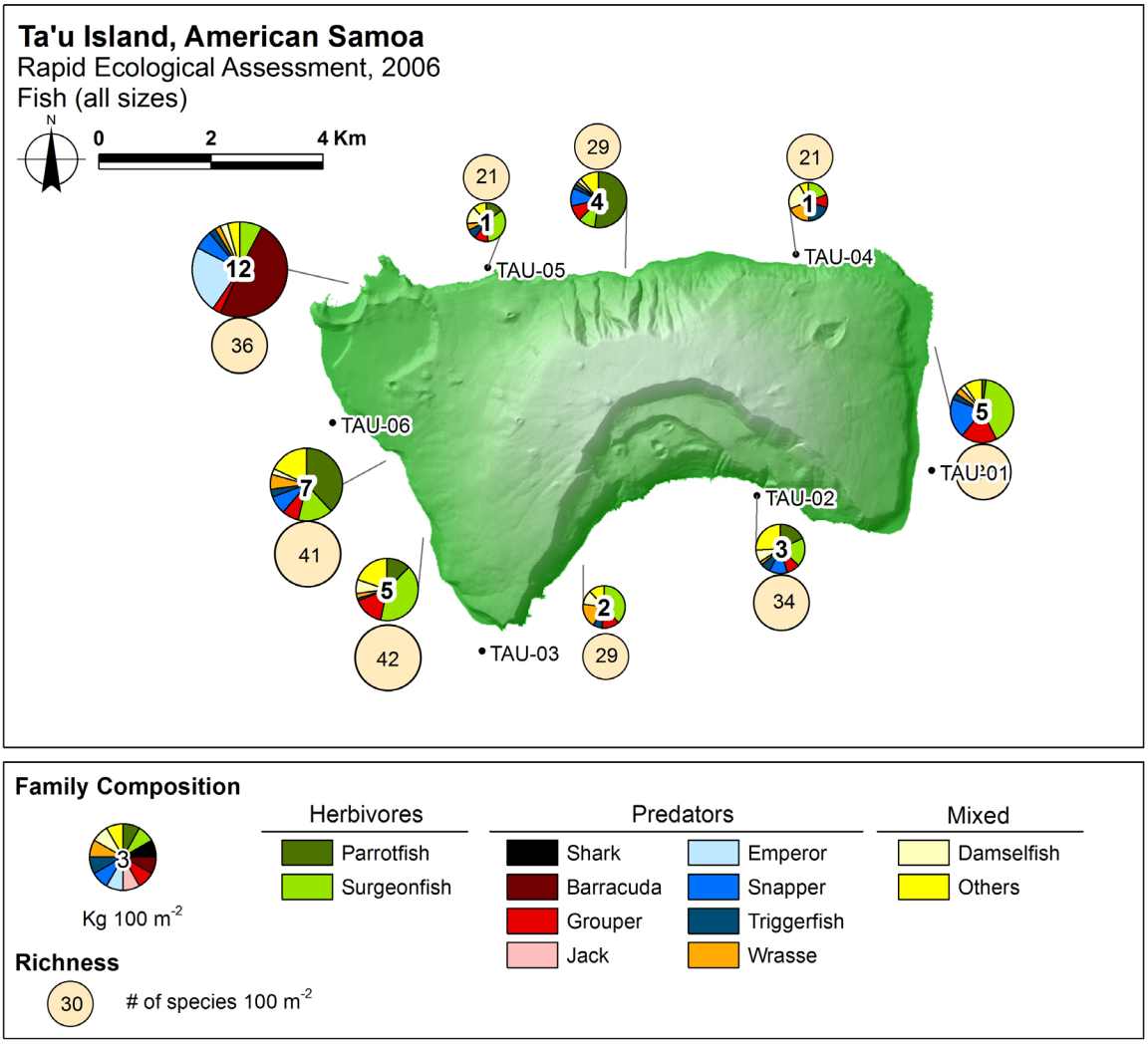

Figure 5.8.1f. Total fish biomass, family composition, and species richness of fishes around Ta`u recorded during ASRAMP 2006 REA belt-transect surveys. Total fish biomass (all species and size classes) is represented at each site by the size of the pie chart with the actual biomass value in the center (kg 100 m^{-2}). Composition by trophic group is indicated by the family colors (green—mostly herbivores; other colors—mostly predators or mixed). Species richness at each REA site is indicated by numbers (# species 100 m^{-2}) and the size of the beige circles.

(Fig. 5.8.1f). Herbivores were the dominating group, with parrotfish and surgeonfish equally abundant.

In descending order, snappers, parrotfish, groupers, and surgeonfish dominated the biomass of medium-large fishes recorded on stationary point counts (> 25 cm total length). Families with moderate biomass included emperors, wrasses, and goatfish.

Around the island, species richness was around 30 species 100 m^{-2} but was slightly lower on the north side of the island (Fig. 5.8.1f).

5.8.2 Temporal Comparison—Reef Fish

Total fish biomass is not systemically higher on a particular side of the island and is generally dominated by herbivores and a noticeable presence of small predators (e.g., triggerfish, emperors, and wrasses). Total fish biomass was constant between 2002 and 2004 at around 0.9 tons ha^{-1} but appears to have decreased to 0.4 tons ha^{-1} in 2006 (Fig. 5.8.2a). Considering all years surveyed, total fish biomass around Ta`u was around 0.74 tons ha^{-1} (SE 0.31).

In a similar fashion to other islands, large fish biomass is generally evenly distributed and is composed mostly of parrotfish, snappers, and surgeonfish. Large fish biomass appears to be slightly increasing from 0.024 tons ha^{-1} in 2002 to 0.046 tons ha^{-1} in 2006 (Fig. 5.8.2b). The overall average, all years combined, was around 0.034 tons ha^{-1} (SE 0.015).

The only clear richness pattern that emerges is a generally lower species count 100 m^{-2} on the northern side of Ta`u.

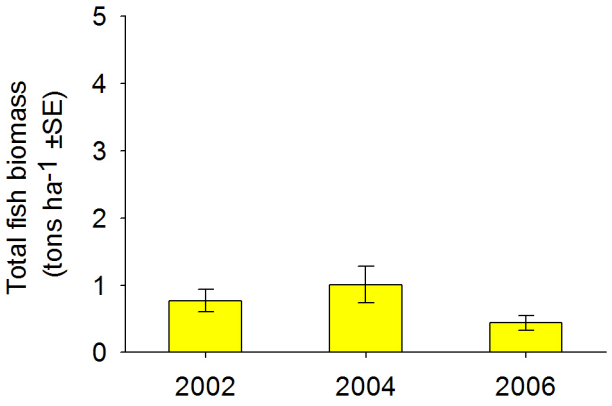

Figure 5.8.2a. Total fish biomass around Ta`u during ASRAMP 2002 (6 sites), 2004 (9 sites), and 2006 (9 sites) REA surveys.

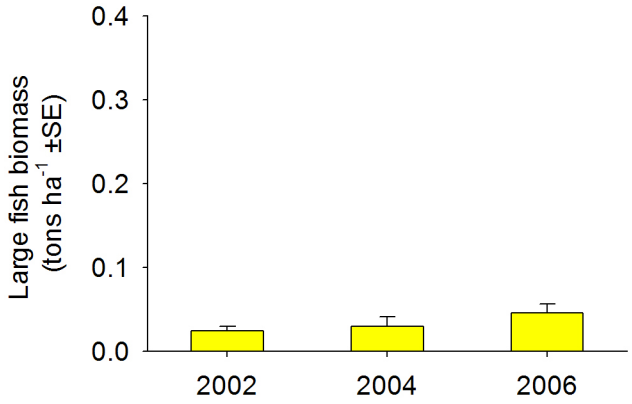

Figure 5.8.2b. Large fish biomass around Ta`u during ASRAMP 2002 (8 tow surveys), 2004 (18 tow surveys), and 2006 (15 tow surveys) towed-diver surveys.

5.9 Island Summary and Integration

Ta`u is a small, steeply sloped island in the Manu`a Island chain. Bathymetric data from multibeam surveys around Ta`u reveal the presence of a narrow (< 1 km) shelf that is wider along the north and west sides of the island (Fig. 5.3.1a). A series of small seamounts are ~ 2 km northwest of Ta`u, along an east-west tending ridge, with depths as shallow as 38 m. The upper portions of this ridge of small, shallow seamounts were probably exposed during periods of lower sea level.

Similarity between biota around neighboring islands probably derives from their spatial proximity which allows for substantial contemporary gene flow. Moreover, mapping efforts indicate a relatively shallow bridge between the islands that was likely historically exposed during lower stands of sea level, which may have provided stepping stones for colonization by taxa with short larval lifespans. TOAD optical validation surveys confirmed that these northwestern seamounts are colonized by coral communities (Fig. 5.3.1c).

The benthic composition surrounding Ta`u was highly variable (Figs. 5.3.2a, 5.3.2b, 5.3.2c, 5.3.2d, and 5.3.2e). However, spatial and temporal patterns of the distributions of habitat types are apparent within the data. Low benthic topographical complexity was roughly correlated to the spatial distribution of sand (Fig. 5.3.2a). The south region, over the three survey periods, had consistently high benthic complexity, especially around Papaloaloa Point and the shoreline adjacent to the Liu Bench. High benthic complexity also was seen on the northern shore, but in smaller, more isolated areas.

Because of the steeply sloped nature of Ta`u, terrestrial watersheds and existing drainages modify the marine benthic habitat (Fig. 5.1a). This is evident from concatenated towed-diver benthic habitat maps (Fig. 5.3.2b) and multibeam backscatter maps (Fig. 5.3.1b). Sand and/or soft-bottom distribution on particularly the north shore benthos is directly correlated to terrestrial watersheds. There are also a few sand fields at the base of the forereef slope, especially off the western side of the island (Fig. 5.3.1b).

While on a larger scale, physical oceanographic properties appeared to be somewhat homogeneous, distinct spatial patterns of all measured parameters were observed around Ta`u at smaller scales. There is believed to be a large-scale east-to-west current in the vicinity of Ta`u; however, no nearshore current data are available to resolve finer-scale patterns. Because of the steeply sloped nature of the island (Fig. 5.3.1a), the coral reef communities around Ta`u may be more exposed to wave energy than those at some of the other islands in American Samoa, such as Tutuila, which has a broad submerged bank that rises to depths as shallow as 20 m and extends several kilometers offshore. The north and west sides of Ta`u are exposed to infrequent, long-period swells from North Pacific boreal winter storms during the austral summer (Fig. 5.4.3b). The east and south sides of the island predominantly experience frequent short period (8–12 sec) waves (~ 2 m) from trade wind swell; they are also exposed to less frequent, larger (~ 3 m), longer period (12–18 sec) swells generated by winter storms in the Southern Ocean (Appendix II, Figure II. II. iv). A large swell event from tropical cyclone Heta in January 2004 (Fig. 5.4.3b) appears to have had at least some impact on all sides of the island.

During each of the ASRAMP survey periods in 2002, 2004, and 2006, the nearshore shallow-water CTD and water quality observations exhibited spatial heteorgeneity, although in many cases the magnitudes of the spatial changes were relatively modest (Figs. 5.4.1b, 5.4.1e, and 5.4.1h). Waters in the east region were generally found to be well-mixed in the upper ~ 20 m of the water column, likely because of the influence of southeasterly trade winds. Interestingly, during mostly light-to-moderate winds for the survey periods, waters on the east side were generally stratified below ~ 20 m. The west region of the island was generally observed to have increased stratification in the upper water column, with the northern and southern sides falling in between. Water turbidity was highest along the central north region of Ta`u (Figs. 5.4.1c, 5.4.1f, and 5.4.1i). Interpretation of salinity values from CTD data indicates there are likely point sources of fresh, cool water on the north side, probably from watersheds or subsurface springs. This would additionally account for the increase in turbidity values on the north side, as sediment input from terrigenous sources is often associated with freshwater outflows. Increases in turbidity could also be explained by austral summer swell from the northwest that could be stirring up benthic sediments. In situ SST values (July 2002–February 2004) were observed to be 0°–3.5°C cooler than those observed via satellite and, for the most part, cooler when compared to the SST climatology (Fig. 5.4.3b). Nutrient concentrations show increased values along the south shore of Ta`u, and elevated nitrogen levels were found on the west side (Fig. 5.4.1j). Water samples indicated an increase in Chl-a concentrations near the harbor area on the northwestern side of the island. In both 2004 and 2006, this area was observed to have elevated turbidity and low salinity, which may be indicative of a point source of sediment and freshwater input.

A total of 32 coral genera have been observed around Ta`u, with higher diversity in the south region, and *Montipora*, *Astreopora*, *Favia*, and *Porites* being the most common. Approximately 64% of the coral colonies measured in 2004 (Fig. 5.5.1i), and 79% of them in 2006 (Fig. 5.5.1o), were relatively small (< 20 cm maximum diameter). The high percentages of small colonies may reflect periodic disturbances from large wave events. In contrast to most areas, abundant large colonies have been found at some sites on the northwestern and northern sides of the island, which are hypothesized to be have been somewhat more sheltered than other areas from large but infrequent Southern Ocean swell and tropical cyclones. That said, towed-diver benthic surveys along the central portion of the east region have observed, without quantification, areas with large *Porites* colonies. Massive *Porites* colonies were also observed in the west, and are believed to be among the largest known (~ 6 m in height and ~ 14 m in diameter), and possibly the oldest observed coral colonies in the world. Towed-diver benthic surveys also found a region in the southern portion of the west region that had similar, but slightly smaller, coral skeletons. Although the coral communities appear to mostly be healthy, 88% of REA sites on Ta`u were observed to contain minor amounts (< 0.3%) of diseased coral, mainly growth anomalies and bleaching (Figs. 5.5.2a and 5.5.2b). SST profiles between February 2002 and February 2004 reveal a short spike above the coral bleaching threshold in March 2002 (Fig. 5.4.3b). However, this spike was not of sufficient duration to be expected to trigger bleaching, and no substantial coral bleaching was observed during 2002 or 2004 surveys.

Figure 5.3.2e shows towed-diver survey estimates of live scleractinian coral cover integrated between years and probably provides the most complete picture of higher coral cover areas. It indicates higher percent cover to the southeast and lower percent cover to the northwest.

All four corners of the island have relatively low coral percent cover in nearshore waters, possibly a result of wave energy refracting and concentrating onto these areas during high wave events. Generally higher coral percent cover to the southeast may possibly reflect increased circulation, flushing, and mixing in response to increased exposure to persistent southeastern trade winds. Interestingly, these findings are similar to those on the east side of Olosega.

Towed-diver surveys, most notably in 2006, suggested that high live coral cover and increased topographical complexity are tightly coupled (Fig. 5.5.1k). High coral cover recorded by towed-diver surveys was variably distributed around Ta`u and showed temporally consistent hotspots on the eastern and south coasts.

The towed-diver and REA survey mean percent coral cover for all years was found to be approximately 25% for nearshore waters (Fig. 5.5.3a). Island-wide percentages of coral cover steadily declined between 2002 and 2006 in the towed-diver survey observations, while REA results showed an increase between 2004 and 2006. Towed-diver survey estimates of the percentage of stressed coral declined between 2004 and 2006 from ~ 6% to 2% (Figs. 5.5.1f and 5.5.1l). Locations around the island showing the highest coral cover varied between years, and to some degree results also varied by method. It is likely that the variations in results among different years (2002, 2004, and 2006) and survey methods (towed-diver surveys, visual estimates, and line point intercept) reflect differences in survey locations, changes in data collection protocols from year to year, and heterogeneity of coral distribution more than they do changes in coral community structure over time.

Corals were mostly absent in the TOAD optical imagery from deeper (~ 30–80 m) areas. However, a coral community was found off the southeastern corner of the island. An additional luxuriant coral reef was observed over the summit of a shallow seamount 2 km northwest of Ta`u (Fig. 5.3.1c).

It is important to include the extremely large and ancient communities of *Porites* sp. corals found on the east and west sides of the island (Figs. 5.3.2f and 5.3.2g) when characterizing the coral communities of Ta`u. In the more protected southern portion of the west region, the colonies were mostly dead and decaying; however, these ancient and massive corals are thought to be between 500 and 1000 years old and may be among the oldest known living coral colonies found in the world. At the request of Governor Tulafono of American Samoa, CRED scientists provided images, video, and background information about these unique coral colonies for his presentation at the United States Coral Reef Task Force meeting in May 2006. At the time of publication, the American Samoa government is considering designation of this area as a Marine Protected Area.

These massive and ancient coral colonies, some living and some dead, are unique and deserve special attention as objects of study to advance the conservation and management of coral reef ecosystems in American Samoa and elsewhere. Combined, they contain within their cores a unique history of climate and ecological impacts of climate change over the past 500–1000 years. Important questions concerning why the ancient corals have continued to thrive on the both the east and west sides of Ta`u, while their companion colonies on the west side have not, may improve our understanding of the ecological impacts of climate change

and therefore provide guidance on how to better manage and conserve coral reefs during upcoming climate changes.

Turf algae and crustose coralline red algae were the dominant benthic organisms at most nearshore areas around Ta`u and were usually fairly uniformly distributed around the island with a few exceptions (Figs. 5.6.1a, 5.6.1b, and 5.6.1e). The lowest cover of crustose coralline algae and the highest cover and diversity of macroalgae were found off the northwestern corner of the island. We hypothesize that the high concentration of macroalgae may be a result of the high influx of fresh water and terrestrial sediments mentioned previously and possibly terrestrial nutrients. Macroalgae also exhibited high local abundance in other areas, but were absent at REA site TAU-10, located in a predominantly sandy area. *Halimeda* was the most abundant macroalgae, occurring at 42% of the sampled sites in 2006 (Fig. 5.6.1f). A dramatic difference in the number of algal genera and their abundance around Ta`u was reported between the 2004 and 2006 survey periods (Fig. 5.6.3a). It is hypothesized that that the macroalgal community, in particular, may have been scoured by high wave energy generated by tropical cyclone Heta in January 2004, but that the community had recovered by 2006. Crustose coralline algae were most abundant in the east region, covering up to 50% of the substrate during ASRAMP 2004 (Fig. 5.6.1a). Low occurrence and abundance of coralline algal diseases were noted around Ta`u. Ta`u contained only 4.2% of the region-wide total of coralline algae disease cases (21 infections observed), and the cases were distributed over only 30% of the surveyed sites (Figs. 5.6.2a and 5.6.2b).

Macroinvertebrate distributions were relatively similar along the forereefs of Ta`u during the 2004 and 2006 surveys (Figs. 5.7.1b and 5.7.1d). Giant clams were present at all but one site, TAU-04, off the north coast of Ta`u (Figs. 5.7.1c and 5.7.1e). In general, giant clams have been more prevalent in the north and west regions and least common on the south side of the island. No COTS were recorded during any survey. Sea urchins have been observed at most REA sites around the island during most years of surveying, with the boring urchin *Echinostrephus* sp. being the most common species. During each of the three ASRAMP cruises, the distribution of sea urchins has been observed to be concentrated on the northwestern corner of the island (Figs. 5.7.1a, 5.7.1b, and 5.7.1d), with concentrations on the northeastern and southwestern corners in some years as well. Interestingly, the corners of the island have relatively low percentages of coral (Fig. 5.3.2e), but it is not known if there is a link between the coral and urchin distributions. Sea cucumbers were most prevalent in the west region of the island, but have also been observed at other locations. Three sea cucumber species were observed around Ta`u (*Holothuria cinerascens*, *Bohadschia argus*, *Holothuria whitmaei*) and were present at all REA sites along the west coast.

Total fish biomass was fairly consistent around the island, and relatively low at 0.7 tons ha^{-1} (Figs. 5.8.1a, 5.8.1c, and 5.8.1e). Fish communities were dominated by herbivores and a noticeable presence of small predators (e.g., triggerfish, emperor, and wrasse). The biomass of large (> 50 cm total length) fish was distributed relatively evenly around the island, considering data from all survey years, and was dominated by parrotfish, snappers, and surgeonfish. The only clear richness pattern that emerges is a generally lower species count 100 m^{-2} on the northern side of Ta`u (Figs. 5.8.1b, 5.8.1d, and 5.8.1f). By way of comparison, at the uninhabited Rose Atoll, large fish biomass was mostly composed of barracuda, jacks, and snappers. Sharks were also common around the outside of the atoll.

Similar differences in the composition of fish communities at inhabited and uninhabited islands have been observed at sites across the Pacific and may be indicative of higher fishing pressure at the inhabited islands.

References

Craig P (2002) Natural history guide to American Samoa: a collection of articles. National Park of American Samoa, Pago Pago, American Samoa. 76 pp.

Meehl GA (1996) Vulnerability of freshwater resources to climate change in the tropical Pacific region. Water Air Soil Pollut 92:203–213.

U.S. Census Bureau (2000) Census 2000 Data for American Samoa. Online at http://www.census.gov/census2000/americansamoa.html. Accessed May 17, 2007.