Chapter 6 Rose Atoll

6.1 Geopolitical Context

Rose Atoll is an uninhabited, diamond-shaped atoll located at the far eastern end of the American Samoa Archipelago, approximately 300 km east of Tutuila Island. The barrier reef encloses approximately 6.5 km^2 (~ 1600 acres) of lagoonal habitat, with a 40-m wide channel located in the northern corner of the atoll. It remains one of the smallest atolls in the world, with Sand Island located in the north and Rose Island located in the east. These land areas total around 0.06 km^2 (~ 15 acres; United States Fish and Wildlife Service). While Rose Island is vegetated, neither island has any streams, associated watershed areas or notable freshwater sources.

Rose is a National Wildlife Refuge administered by the United States Fish and Wildlife Service within the Pacific Remote Islands National Wildlife Refuge Complex.

6.2 Survey Effort

A large amount of physical and biological data has been collected around Rose since 2002 as part of the American Samoa Reef Assessment and Monitoring Program (ASRAMP). The

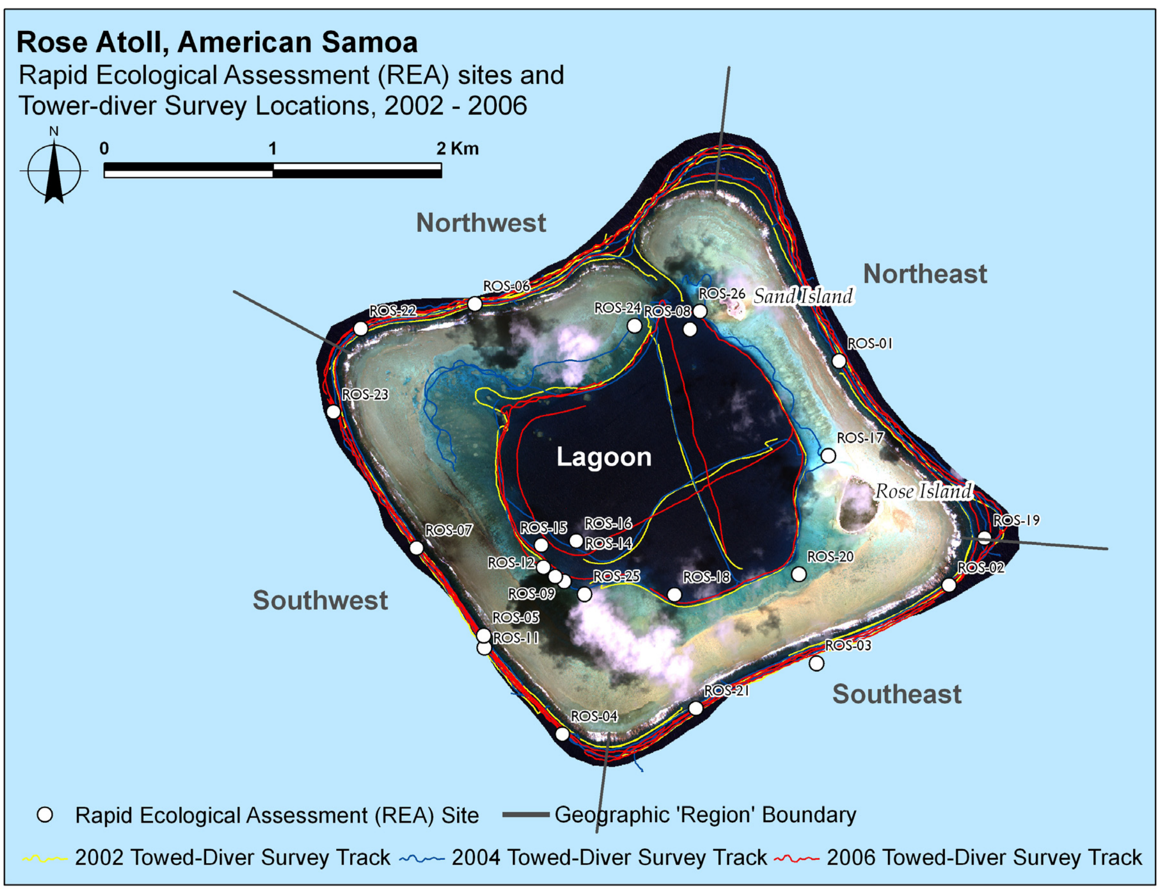

Figure 6.2a. Locations of Rapid Ecological Assessment (REA) and towed-diver surveys around Rose during ASRAMP 2002, 2004, and 2006. Five arbitrary geographic regions have been delineated to aid in discussion of spatial patterns.

extent and timeframe of these surveys are discussed below. To aid in the discussion of spatial patterns of ecological and oceanographic observations around Rose throughout this chapter, five geographic regions are delineated in Figure 6.2a.

Benthic habitat mapping data were collected around Rose using acoustic multibeam survey methods, which mapped a total of 269 km^2 in and around Rose during ASRAMP 2006. These data are further examined in Section 6.3: Benthic Habitat Mapping and Characterization.

Figure 6.2a shows the locations of REA and towed-diver surveys around Rose during ASRAMP 2002, 2004, and 2006. The number, mean depth, and area of these surveys are presented by year in Table 6.2a.

Table 6.2a. Numbers, areas, and depths of REA and towed-diver surveys around Rose 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	9*	13.2 (SD 2.0)	18	38.3	5.5 (SD 6.8)
2004	12*	16.1 (SD 2.6)	22	46.1	11.1 (SD 7.0)
2006	13	13.0 (SD 2.5)	21	48.7	13.0 (SD 5.2)

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

The ranges of survey depths from towed-diver surveys are presented for each year in Section 6.5: Corals and Coral Disease; Figures 6.5.1a (2002), 6.5.1d (2004), and 6.5.1k (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 Rose 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 (see Chapter 2, Section 2.3: Oceanography and Water Quality). A summary of deployed instruments and collection activities is provided in Table 6.2b. Results are examined further in Section 6.4: Oceanography and Water Quality.

Table 6.2b. Numbers of oceanographic instrument deployments and shallow and deep CTD casts around Rose during ASRAMP 2002, 2004, and 2006. Instrument types include recording current meters (RCMs), Coral Reef Early Warning System (CREWS), wave and tide recorders (WTRs), and subsurface temperature recorders (STRs). Shallow-water CTD casts were conducted from the surface to a 30-m depth. 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
RCM	1	0	0
CREWS	1	0	0
WTR	0	1	1
STR	0	4	6
Shallow-water CTD casts	28	44	31
Deep-water CTD casts	12	10	17

6.3 Benthic Habitat Mapping and Characterization

Benthic habitat mapping and characterization around Rose were accomplished using acoustic multibeam sonar between water depths of ~ 1 m and ~ 3000 m. Acoustic multibeam sonar mapping provided bathymetric and acoustic backscatter data in the depth range between ~10 m and 3000 m. Nearshore habitat mapping was conducted using towed-diver benthic surveys between ~ 1 m (lagoon) and 30 m (forereef).

6.3.1 Acoustic Mapping and Optical Validation

Multibeam mapping operations were conducted around Rose in early 2006 by the R/V *Acoustic Habitat Investigator* (*AHI*) and the NOAA Ship *Hi`ialakai* (Fig. 6.3.1a). Favorable conditions allowed the *AHI* to enter the lagoon through the narrow pass on the NW arm of the island to survey in the interior lagoon area. No optical data were collected around Rose because of the difficulty of maneuvering vessels close to this extremely steep atoll and limited areas within the depth range of the optical equipment.

Much like Swains Island, Rose is a steeply sloped, conical emergent atoll with rift zones that extend from each corner of the reef down to at least 3000 m. The bathymetry immediately

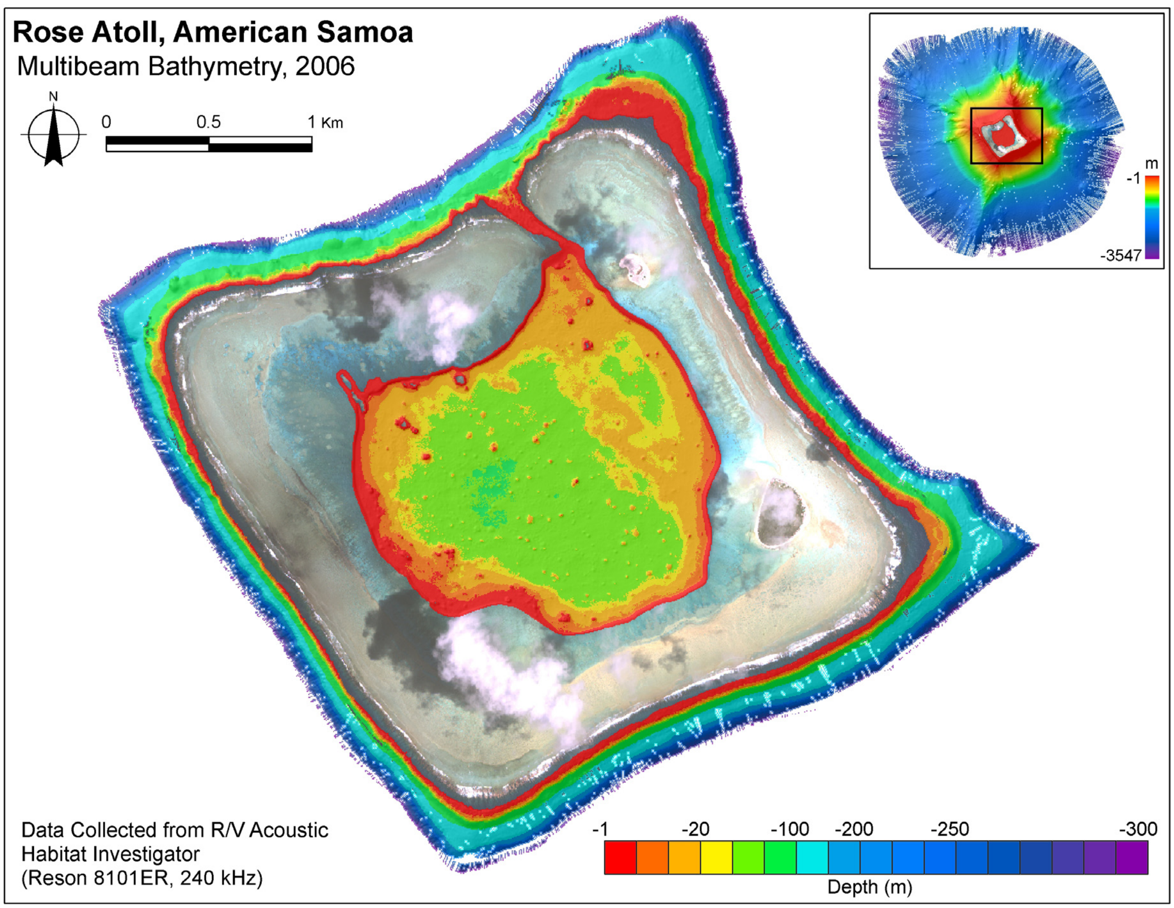

Figure 6.3.1a. Multibeam bathymetry acquisition around Rose was conducted between 10 and 205 m in March 2004 and March 2006 from the R/V *AHI* and the NOAA Ship *Hi'ialakai*. The north side of the atoll has a small shelf, while the rest is surrounded by steep underwater slopes. The lagoon contains a scattering of small coral heads and a few large coral outcrops; it reached a maximum recorded depth of 27 m in some places.

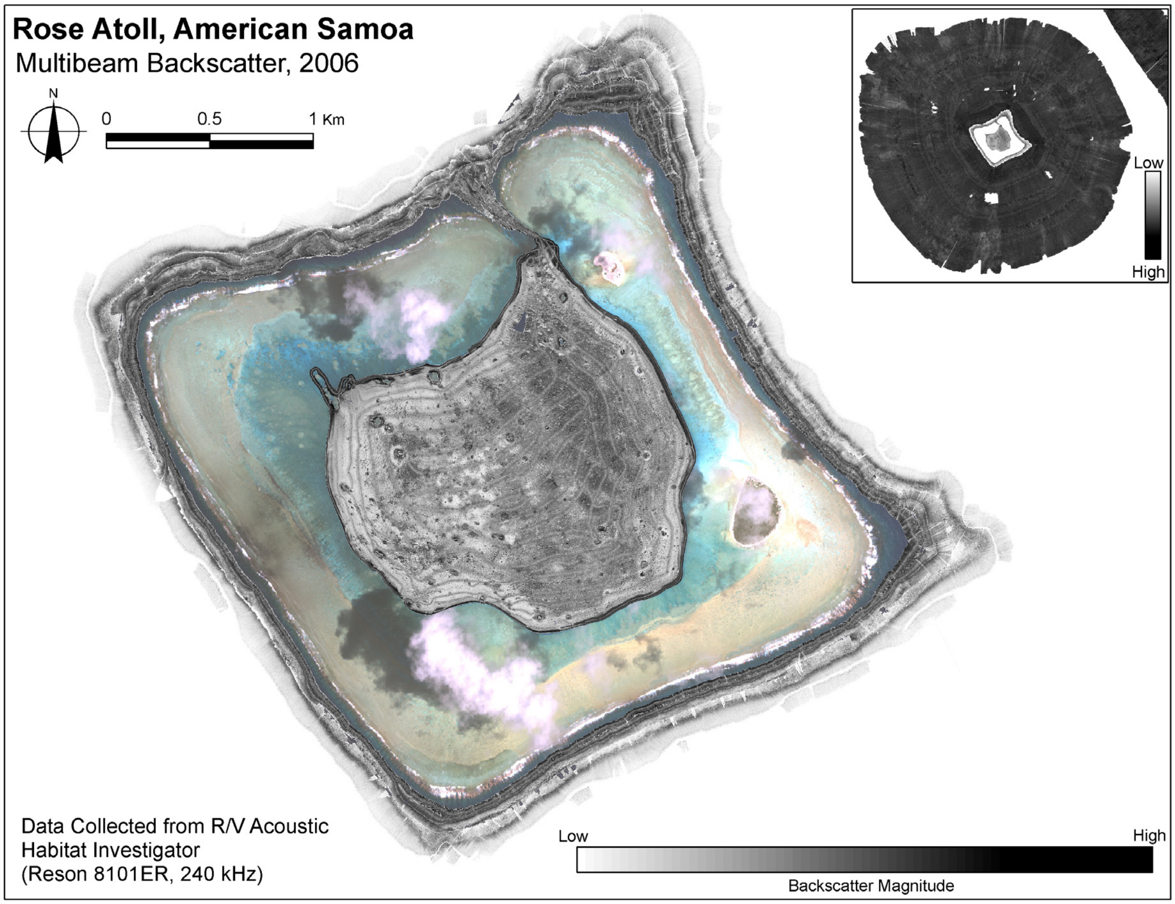

Figure 6.3.1b. Backscatter imagery was acquired in March 2004 and March 2006 during multibeam surveys around Rose from the R/V *AHI*. Lighter shades represent low-intensity backscatter and likely indicate substrates that are acoustically absorbent and typically indicate unconsolidated sediment. Darker shades represent high-intensity backscatter and likely indicate consolidated hard-bottom and coral substrates.

adjacent to the exposed reef is very steep, with smooth sides that exhibit few signs of mass wasting. Inside the lagoon, the bathymetry indicates the presence of many coral heads and colonial aggregates, ranging in size from a few centimeters up to 1 m or larger.

These bathymetric data are corroborated with backscatter imagery (Fig. 6.3.1b), which shows soft-bottom habitat within the lagoon, interspersed with hard-bottom coral pinnacles. Outside the lagoon, backscatter intensity is high, indicating a predominantly hard substrate. Towed-diver survey observations indicate that much of the benthos within at least the top 30 m of the water column is populated by coral and crustose coralline algae dominated communities.

6.3.2 Habitat Characterization

Towed-diver benthic survey observations around Rose from ASRAMP 2002, 2004, and 2006 were concatenated into mean spatial distributions (see Chapter 2, Section 2.2.3: Optical Validation Surveys) of the following benthic components: habitat complexity (Fig. 6.3.2a), percent cover of sand (Fig. 6.3.2b), hard substrate/pavement (Fig. 6.3.2c), rubble (Fig. 6.3.2d), and live coral (Fig. 6.3.2e). Since these habitat characterization maps represent different and complementary components of the same habitats, it is useful to analyze them in relation to each other and exposure to prevailing oceanographic conditions.

Towed-diver survey observations indicate that benthic complexity was generally high on the outside of Rose, especially in the northwest and southwest forereef regions, while more moderate complexity was recorded for the northeast forereef (Fig. 6.3.1a). Habitat complexity was generally low within the lagoon (Fig. 6.3.2a).

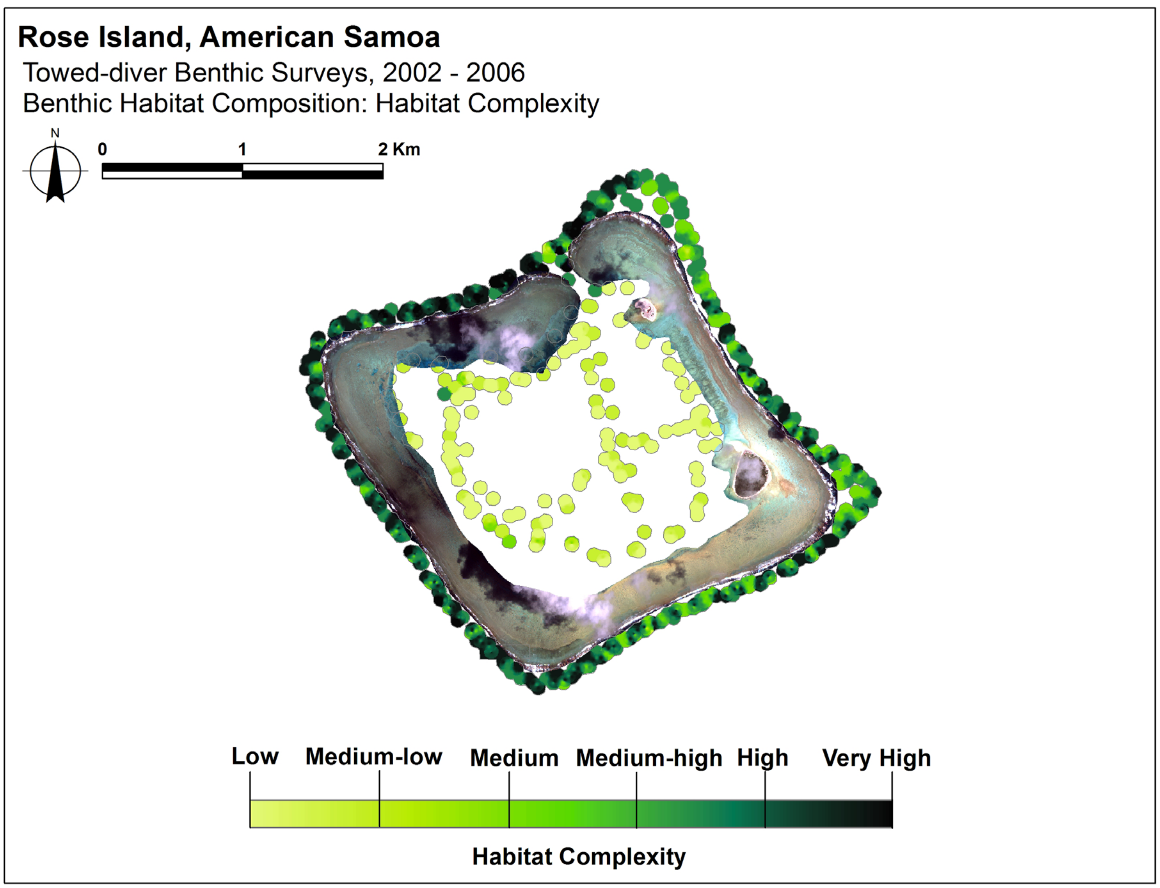

Figure 6.3.2a. Mean benthic habitat complexity concatenated from towed-diver survey observations around Rose during ASRAMP 2002, 2004, and 2006. Habitat complexity was subjectively rated by diver-observers over 5-min ensembles (~ 200 x 10 m) on a 6-point scale representing low (1), medium-low (2), medium (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.

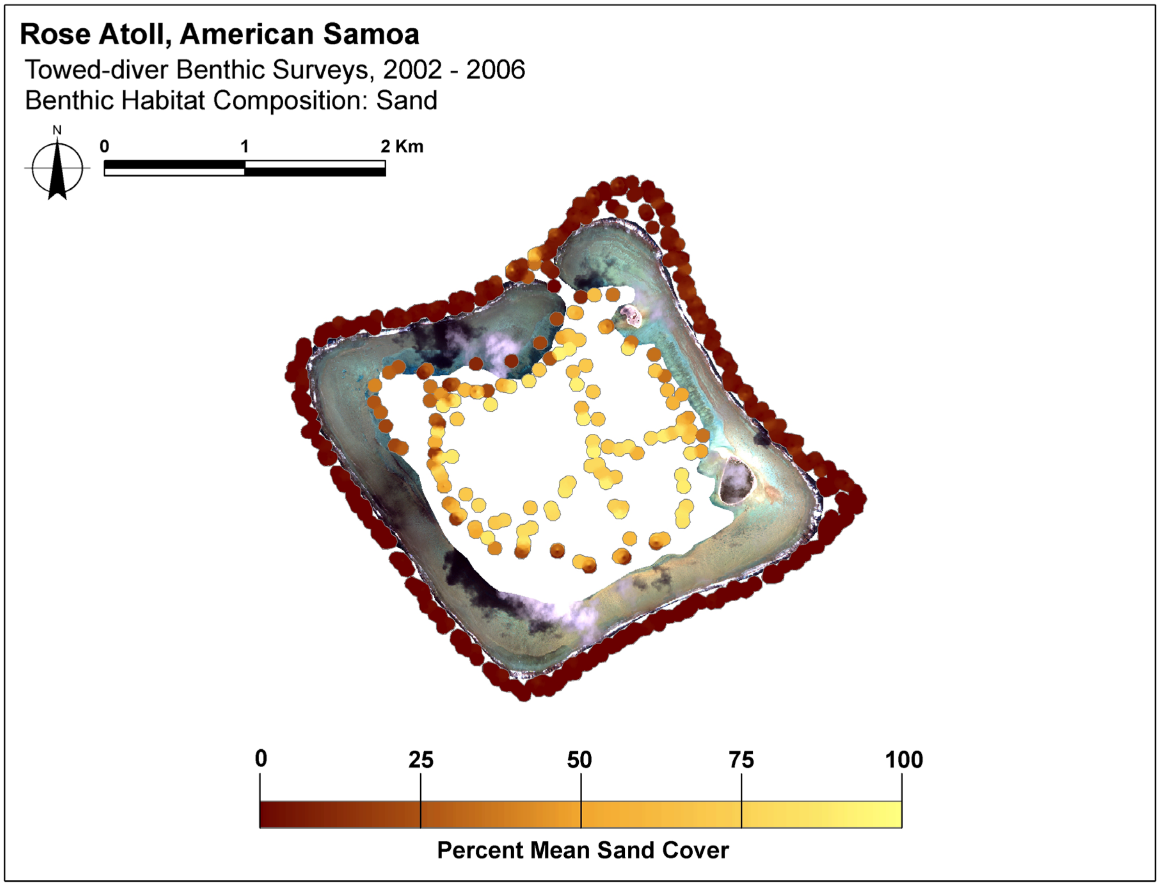

Figure 6.3.2b. Mean percent cover of sand concatenated from towed-diver habitat survey observations around Rose during ASRAMP 2002, 2004, and 2006. Sand composition was subjectively rated by diver-observers over 5-min ensembles (~ 200 m x 10 m) over a 1–100% scale. Light shades indicate high percent cover of sand, and dark shades indicate low percent cover of sand.

The bottom of the lagoon was primarily composed of sand (Fig. 6.3.2b), with isolated areas of hard substrate (Fig. 6.3.2c) and rubble (Fig. 6.3.2d) scattered around the central lagoon. True to its nature as a steeply sloped, conical atoll, there was very low sand cover along the forereef. The only sand that was found outside of the lagoon was located just outside of the northwestern channel entrance.

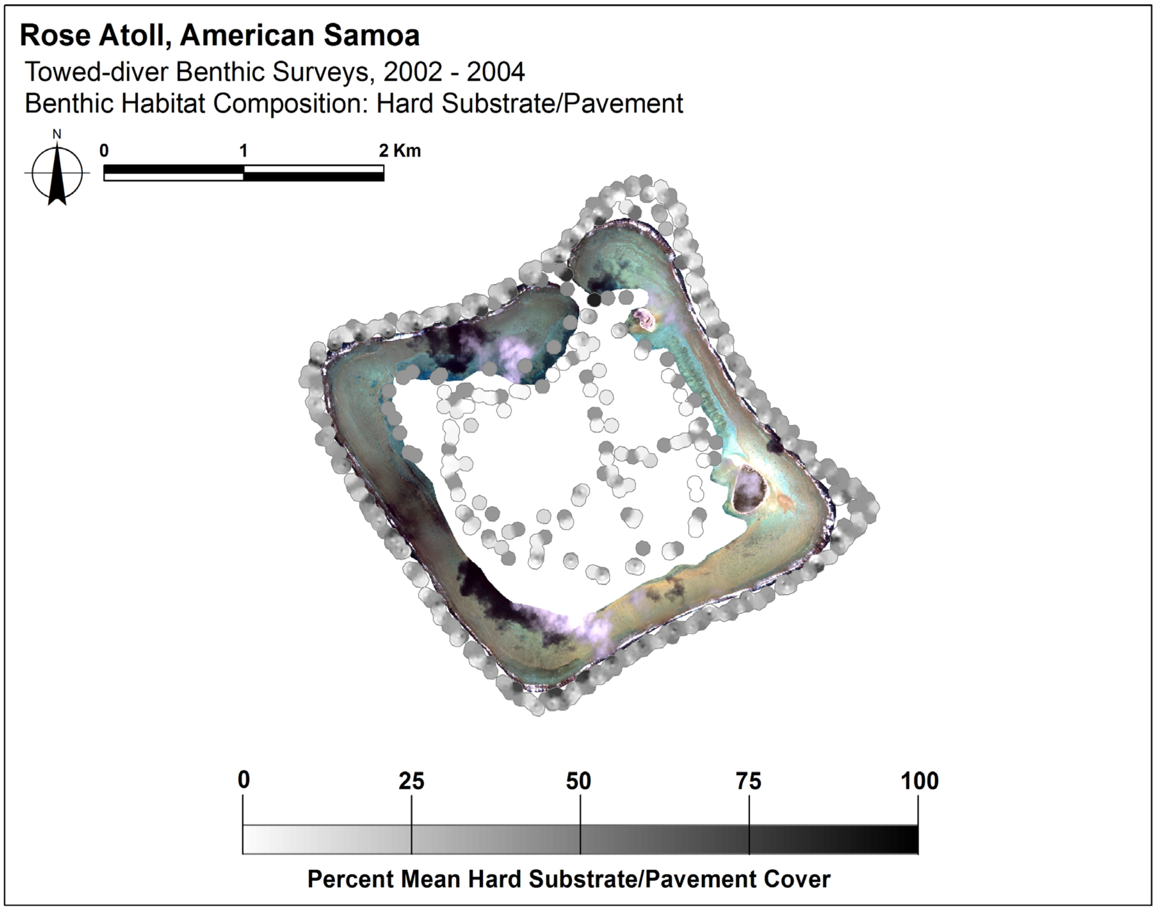

Figure 6.3.2c. Mean percent cover of hard substrate/pavement, concatenated from towed-diver survey observations around Rose during ASRAMP 2002 and 2004. Hard substrate/pavement composition was subjectively rated by diver-observers over 5-min ensembles (~ 200 m x 10 m) over a 1–100% scale. Dark shades indicate high percent cover of hard substrate, and light shades indicate low percent cover of hard substrate.

While percent cover of hard substrate/pavement inside the lagoon was patchy, the outside of the atoll was characterized by moderate, evenly distributed hard substrate/pavement cover, although the northeast and southeast regions appeared to have slightly higher percent cover (Fig. 6.3.2c). High levels of coral rubble were primarily found inside the lagoon, with highest rubble cover recorded along the base of the backreef slopes of the lagoon perimeter (Fig. 6.3.2d). Along the outer forereef, the most elevated levels of rubble were found in the northeast region; however, because of the steep nature of the outer reef, rubble was low on all sides.

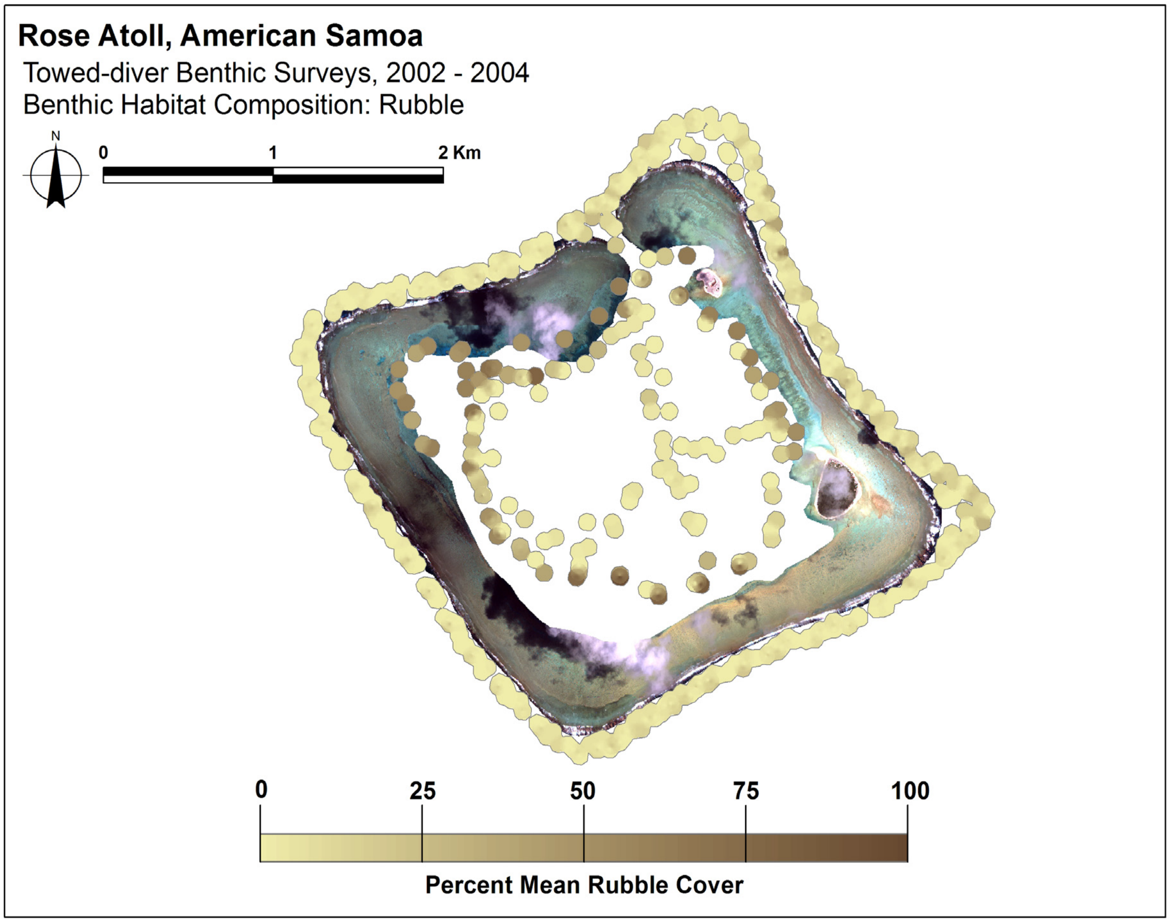

Figure 6.3.2d. Mean percent cover of coral rubble, concatenated from towed-diver survey observations around Rose during ASRAMP 2002 and 2004. Rubble composition was subjectively rated by diver-observers over 5-min ensembles (~ 200 m x 10 m) over a 1–100% scale. Light shades indicate low percent cover of coral rubble, and dark shades indicate high percent cover of coral rubble.

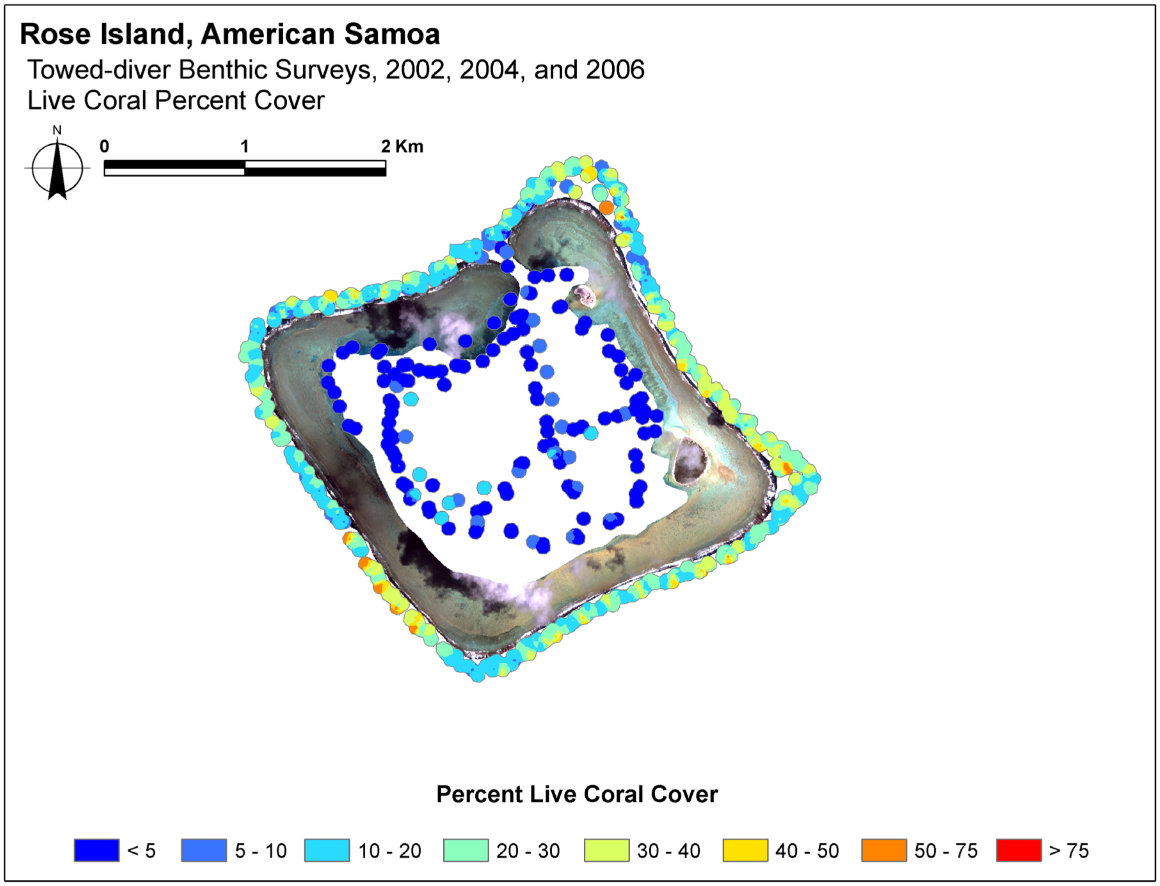

Figure 6.3.2e. Mean percent cover of live scleractinian (stony) coral, concatenated from towed-diver survey observations around Rose during ASRAMP 2002, 2004, and 2006. Live coral cover composition was subjectively rated by diver-observers over 5-min ensembles (~ 200 m × 10 m) over a 1–100% scale. Blue colors indicate low percent cover of coral, and reddish colors indicate high percent cover of coral.

Percent mean live coral cover ranged from 10% to 50% along the forereef slope, with the highest percentages in the northeast region just north of the eastern-most point of the atoll and the southwest region, immediately west of the southern corner of the atoll (Fig. 6.3.2e). Percentages recorded within the lagoon were much lower, ranging from 0 to 10%. The highest levels of coral cover within the lagoon were generally recorded along the southwestern corner.

6.4 Oceanography and Water Quality

Oceanographic and water quality observations were collected in the waters surrounding Rose over the period between 2002 and 2006. Instrumentation and equipment descriptions, deployment locations, and a subset of results are detailed below. Specific details of deployments and additional data are presented in Appendix II, Table II. v.

6.4.1 Hydrographic Data

2002 Spatial Surveys

During ASRAMP 2002, 28 shallow-water CTD casts were conducted in the nearshore and lagoonal waters around Rose on February 26 (Figs. 6.4.1a and 6.4.1b). Data from these vertical profiles around the outside of the atoll showed two main water masses: warmer (> 30°C), lower salinity (< 35.3 psu), less dense (< 22 kg m^{-3}) water off the northwest and northeast regions (A–C), and cooler (~ 29.5°C), higher salinity (> 35.3 psu), higher density (> 22 kg m^{-3}) waters off the southwest and southeast regions (C–E) (Fig. 6.4.1b). The southwest and southeast sides of the atoll showed greater stratification, with warm surface water, a temperate central water column, and cooler bottom (> 20 m) waters. These data suggest that the southern sides of the atoll may have been more protected from wind and wave-induced mixing, while the northern sides were more exposed to these forces, resulting in vertical mixing (or overturning) of warm surface waters into the main water column.

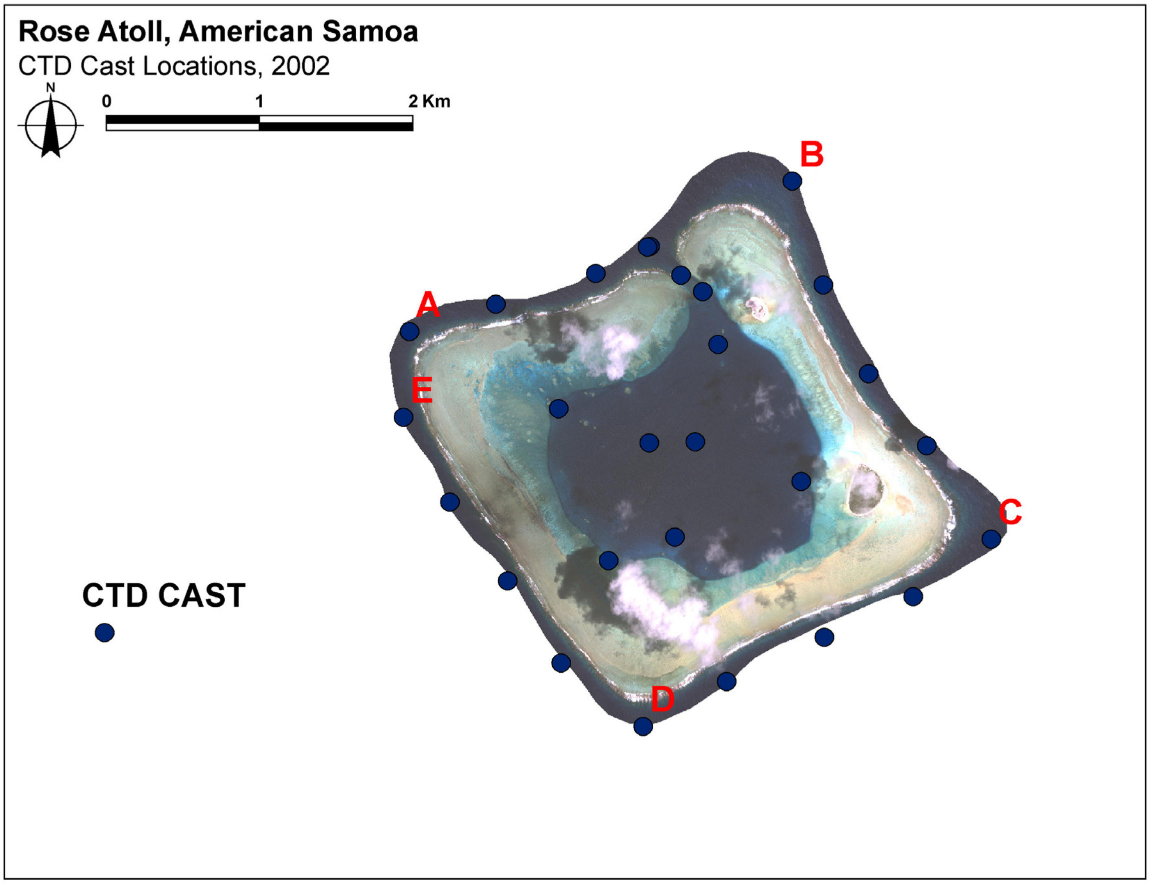

Figure 6.4.1a. Shallow-water CTD cast locations, shown as blue dots, expressed sequentially in a clockwise direction around Rose (A–E) during ASRAMP 2002, February 26.

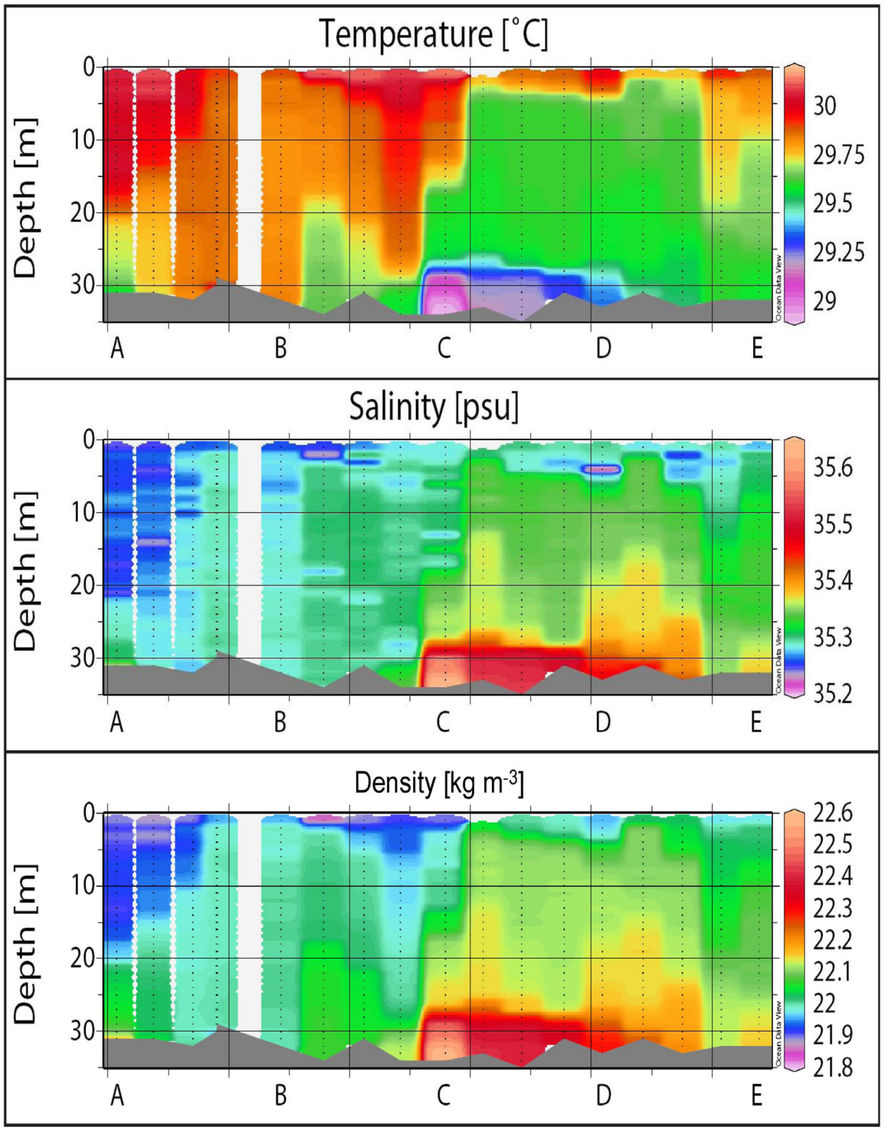

Figure 6.4.1b. Shallow-water CTD cast profiles to a 30-m depth around Rose during ASRAMP 2002, February 26, including temperature (°C), salinity (psu), and density (kg m^{-3}). Profiles are shown sequentially in a clockwise direction around the island (A–E), as shown in Figure 6.4.1a.

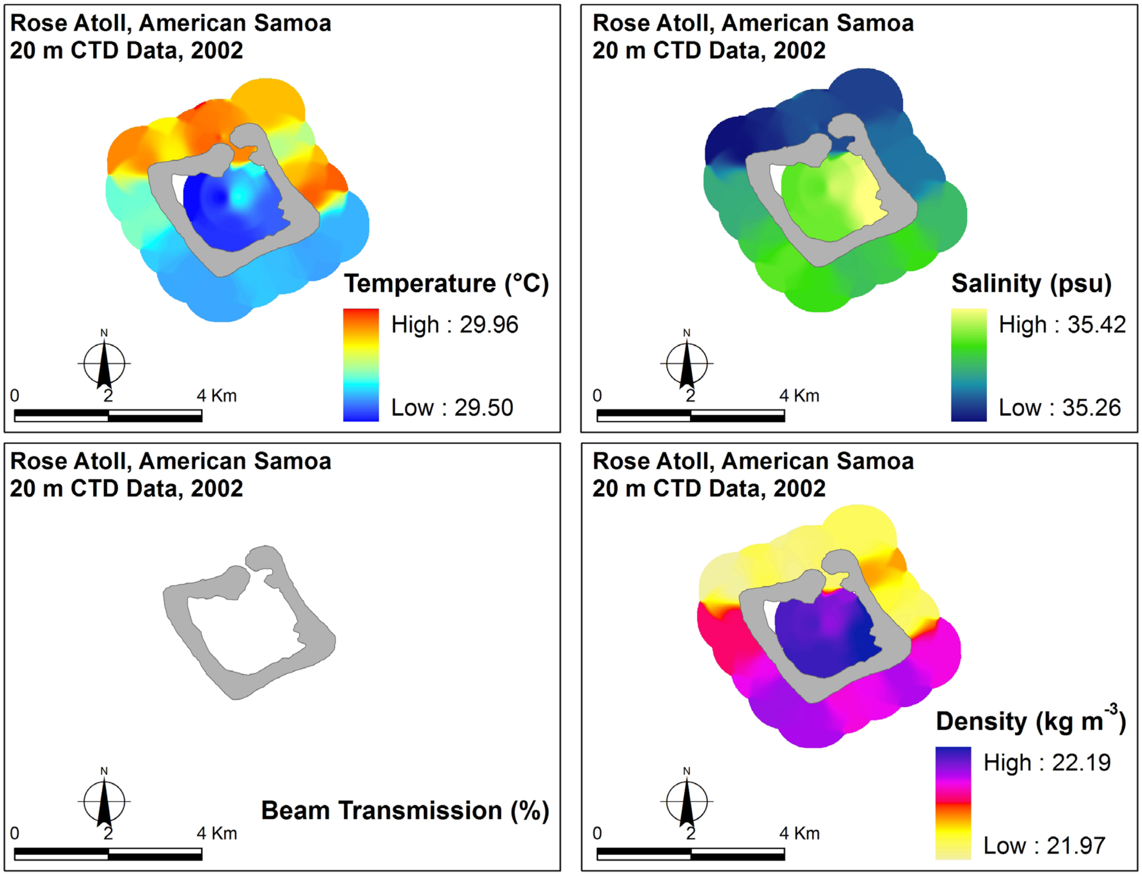

Figure 6.4.1c. Interpolated water temperature (top left), salinity (top right), and density (bottom right) at a 20-m depth derived from shallow-water CTD casts around Rose during ASRAMP 2002, February 26. Beam transmission data were not collected.

Physical water properties at a 20-m depth around Rose during ASRAMP 2002 showed moderate ranges in temperature (29.50–29.96°C), density (21.97–22.19 kg m^{-3}), and salinity (35.26–35.42 psu; Fig. 6.4.1c). The warmer, less saline, less dense waters of the northern regions of the atoll indicate a distinctive hydrographic structure. More data are needed to further investigate the cause of this feature. Interestingly, the waters in the lagoon at a 20-m depth, which is below the sill depth of the only channel, were substantially cooler, more saline, and denser than any of the waters outside the atoll.

2004 Spatial Surveys

During ASRAMP 2004, 44 evenly spaced, shallow-water CTD casts were conducted in nearshore waters around Rose between February 9 and 11 (Fig. 6.4.1d). These vertical profiles conducted along the steep forereef slopes around the atoll show significant spatial and vertical structure (Fig. 6.4.1e). Near the west point (A) of the northwest region, the water column was well mixed vertically with warm temperatures (> 29.1°C), low beam transmission (< 91%), and moderate salinity (35.4 psu) throughout the column. Strikingly, the area near the channel and around the north point (B) had cool (~ 28.9°C), low salinity (34.8 psu), and low density (21.9 kg m^{-3}) water in the surface layer (0– ~ 10 m) overlaying a mid-depth water mass with warm (29.1°C) temperatures in depths between 10 and 20 m, and cool (28.9°C), high salinity (35.5 psu) and density (22.4 kg m^{-3}) water in depths between 20 and 35 m). This complex, highly stratified feature appears to reflect a discharge of fresh surface water from the lagoon out the channel. The remainder of the northeast forereef (B–C) was well mixed with moderate values for each of the observed water properties. The southeast region (C–D), on the other hand, was characterized by significant vertical structure, with an interesting plume of cool (28.7°C), high salinity (35.5 psu), and high beam transmission (~ 94%) water near the bottom (20–35 m), particularly near the eastern point (C). This feature appeared to disperse upward and southward.

Physical water properties at a 20-m depth around the steep forereef slopes and within the lagoon at Rose during ASRAMP 2004 showed relatively small ranges in temperature (29.50–

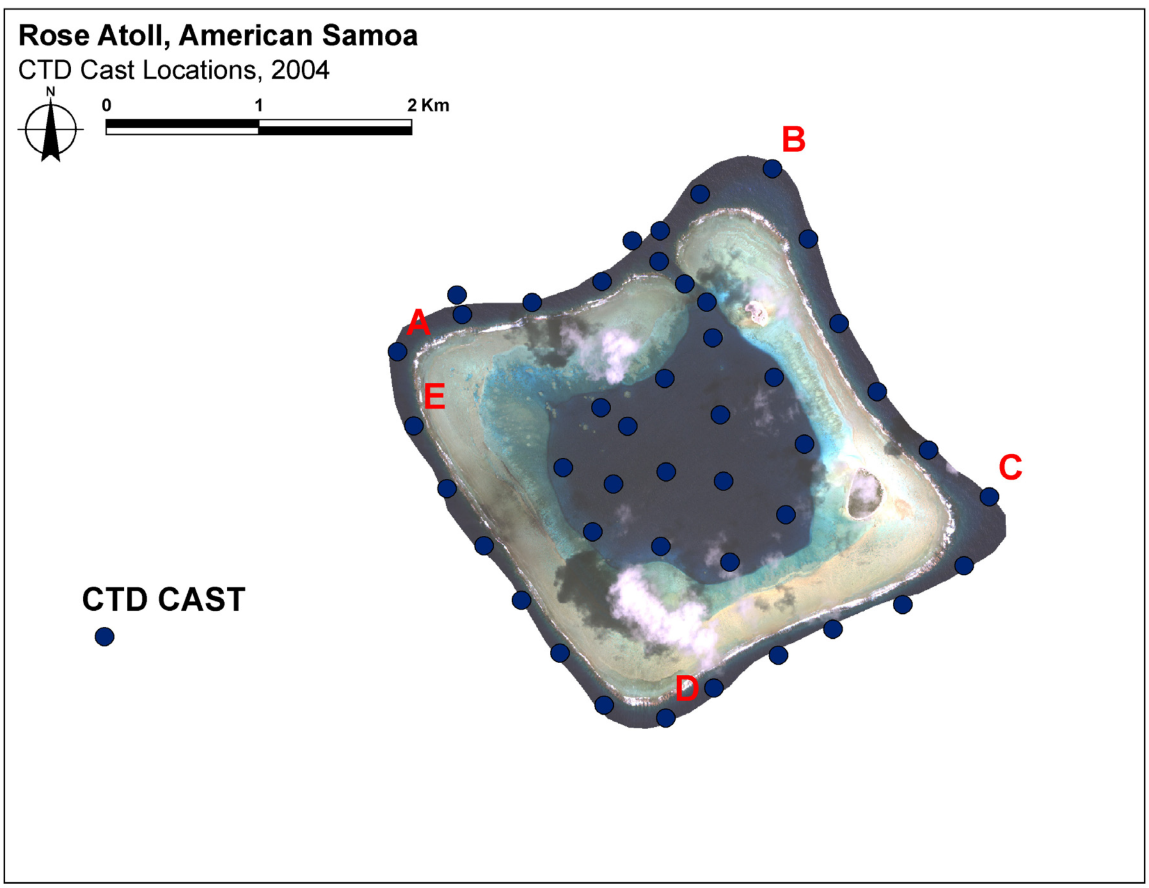

Figure 6.4.1d. Shallow-water CTD cast locations, shown as blue dots, expressed sequentially in a clockwise direction around Rose (A–E) during ASRAMP 2004, February 9–11.

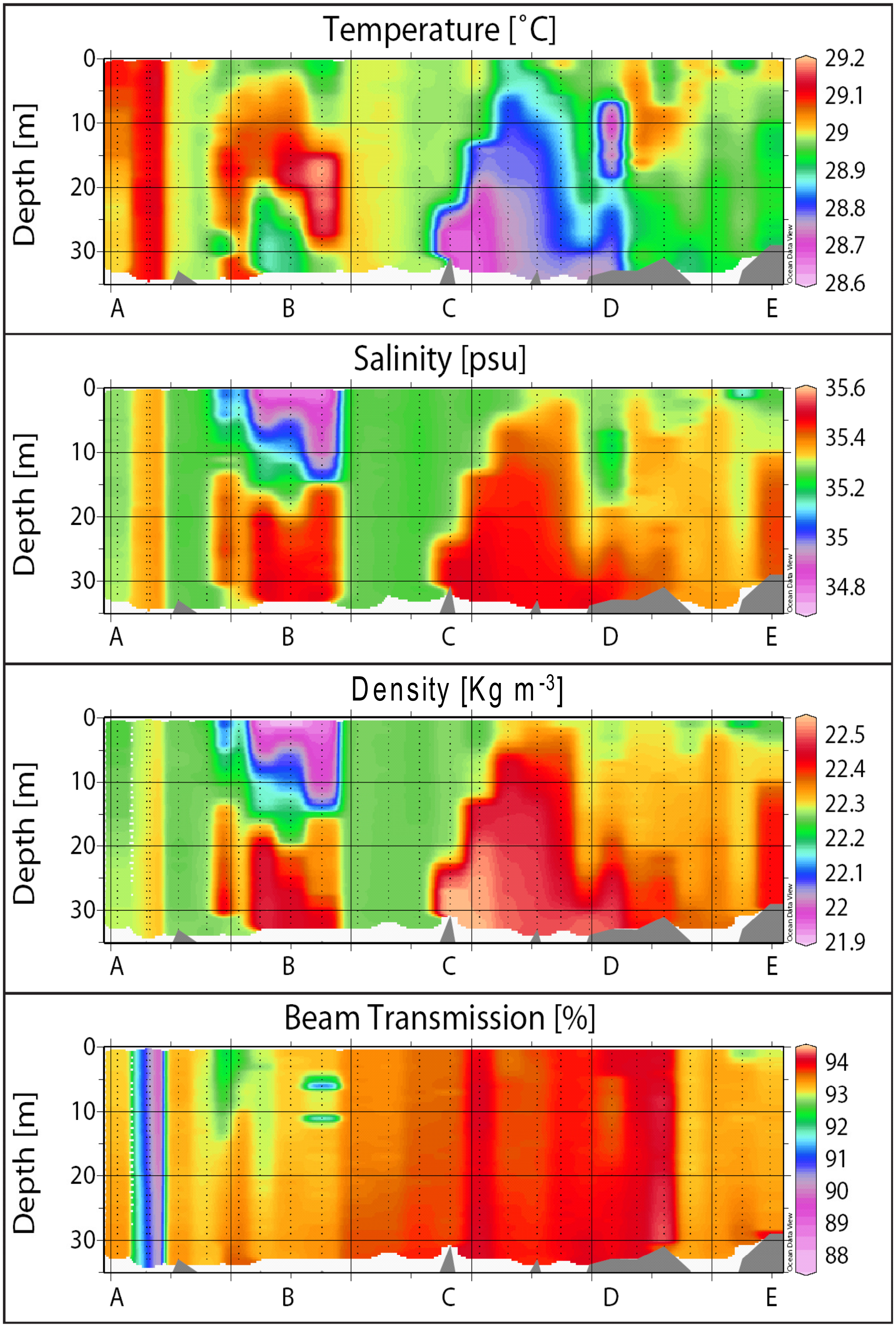

Figure 6.4.1e. Shallow-water CTD cast profiles to a 30-m depth around Rose during ASRAMP 2004, February 9–11, including temperature (°C), salinity (psu), density (kg m^{-3}), and beam transmission (%). Profiles are shown sequentially in a clockwise direction around the island (A–E), as shown in Figure 6.4.1d.

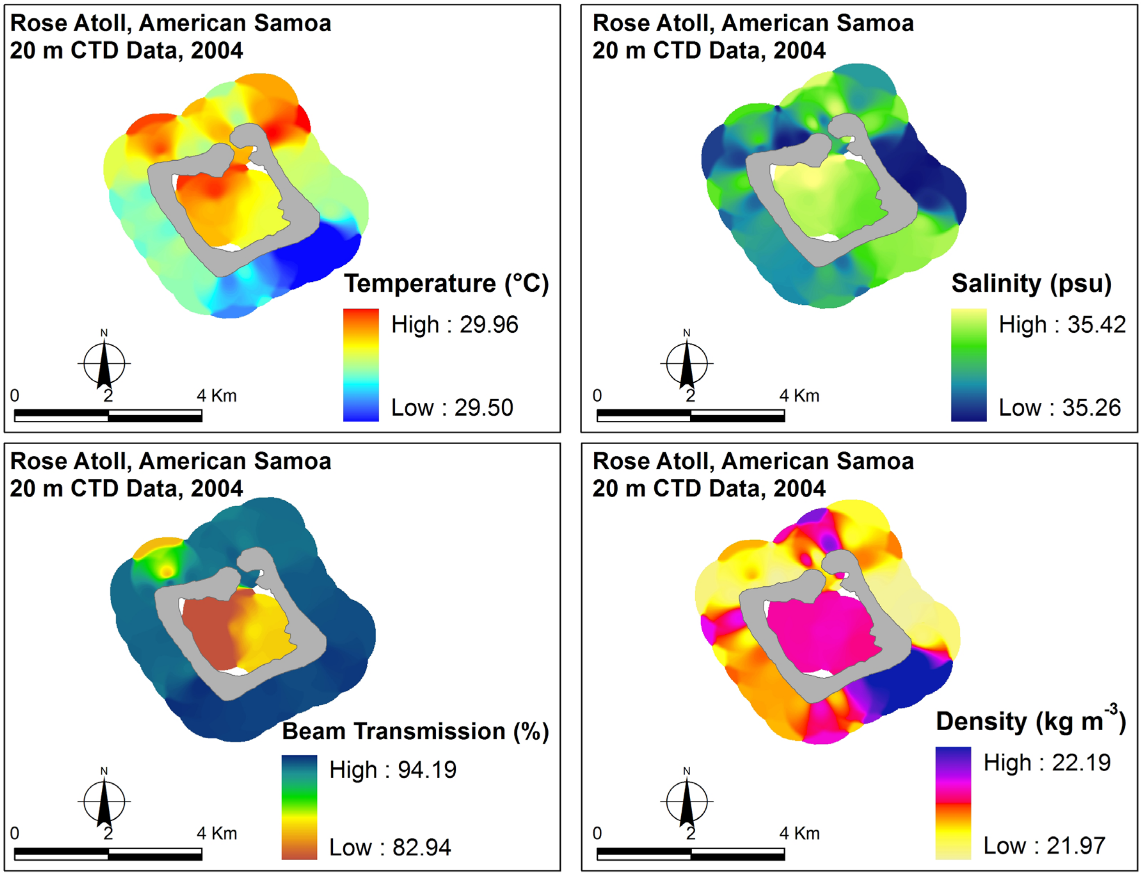

Figure 6.4.1f. Interpolated water temperature (top left), salinity (top right), beam transmission (bottom left) and density (bottom right) at a 20-m depth derived from shallow-water CTD casts around Rose during ASRAMP 2004, February 9–11.

29.96°C) and density (21.97–22.19 kg m^{-3}), and moderate ranges in salinity (35.26–35.42 psu) and beam transmission (82.94–94.19%; Fig. 6.3.1f). The warmest, saltiest, and most turbid waters at the 20-m depth occurred in the western half of the lagoon. The waters of the forereef slopes showed increased spatial variability in water properties at a 20-m depth. The easternmost portion of the island exhibited a hydrographic feature where two slightly different water masses appeared to meet. The northern water was warmer, less saline and less dense, and the southern waters were colder, more saline, and denser. Though density at the 20-m depth within the lagoon was high (~ 22.2 kg m^{-3}) in 2004, as during the 2002 surveys, the density at the 20-m depth was higher over the southeast forereef (~ 22.5 kg m^{-3}) in 2004 than in 2002.

2006 Spatial Surveys

During ASRAMP 2006, 31 evenly spaced, shallow-water CTD casts were conducted around the steep, nearshore forereef slopes and lagoon of Rose between March 5 and 9 (Fig. 6.4.1g). Water samples were collected for nutrient analyses at 1, 10, 20, and 30-m depths, where possible, at seven of these shallow CTD sites. At these locations, 15 Dissolved Inorganic Carbon (DIC) samples, 23 nutrient samples, and 23 chlorophyll-a (Chl-a) water samples were collected (Fig. 6.4.1g).

Shallow-water CTD profiles around the steep forereef slopes of Rose during ASRAMP 2006 indicated horizontal and vertical structure (Fig. 6.4.1h). In the northwest region (A–B), particularly near the channel and northern point, the water column was well-stratified with warm (~ 29.7°C), relatively low salinity (> 35 psu) surface waters (0–10 m) over a body of cool (< 29.2°C), saline (> 35 psu), and relatively dense water (> 22 kg m^{-3}). At the CTD site directly off the channel, these properties were locally deeper than surrounding areas. The southeast and southwest sides of the island (C–E) showed evidence of mixing during this period, with the exception of a single cast taken immediately south of the eastern point which showed a well-stratified water column, possibly indicative of two waters masses converging in this area. Just north of this point at the site labeled (C), a well-mixed, very low salinity (~ 34.95 psu) water column was observed.

Physical water properties at a 20-m depth around the steep forereef slopes and within the lagoon at Rose during ASRAMP 2006 showed moderate ranges in temperature (28.711–29.17°C), salinity (35.26–35.52 psu), and density (21.91–22.19 kg m^{-3}) (Fig. 6.4.1i), with interesting spatial structure. The warmest waters at the 20-m depth were observed in the northern portion of the northeast region and immediately offshore of the channel into the lagoon. The coolest waters at the 20-m depth were found inside the lagoon, where the most saline and highest density waters were observed. Water density values in the lagoon (22.19 kg m^{-3}) were similar to those recorded in 2002. The least saline waters were observed along the forereefs of the northeast region and around the southern point where the southeast and southwest regions meet.

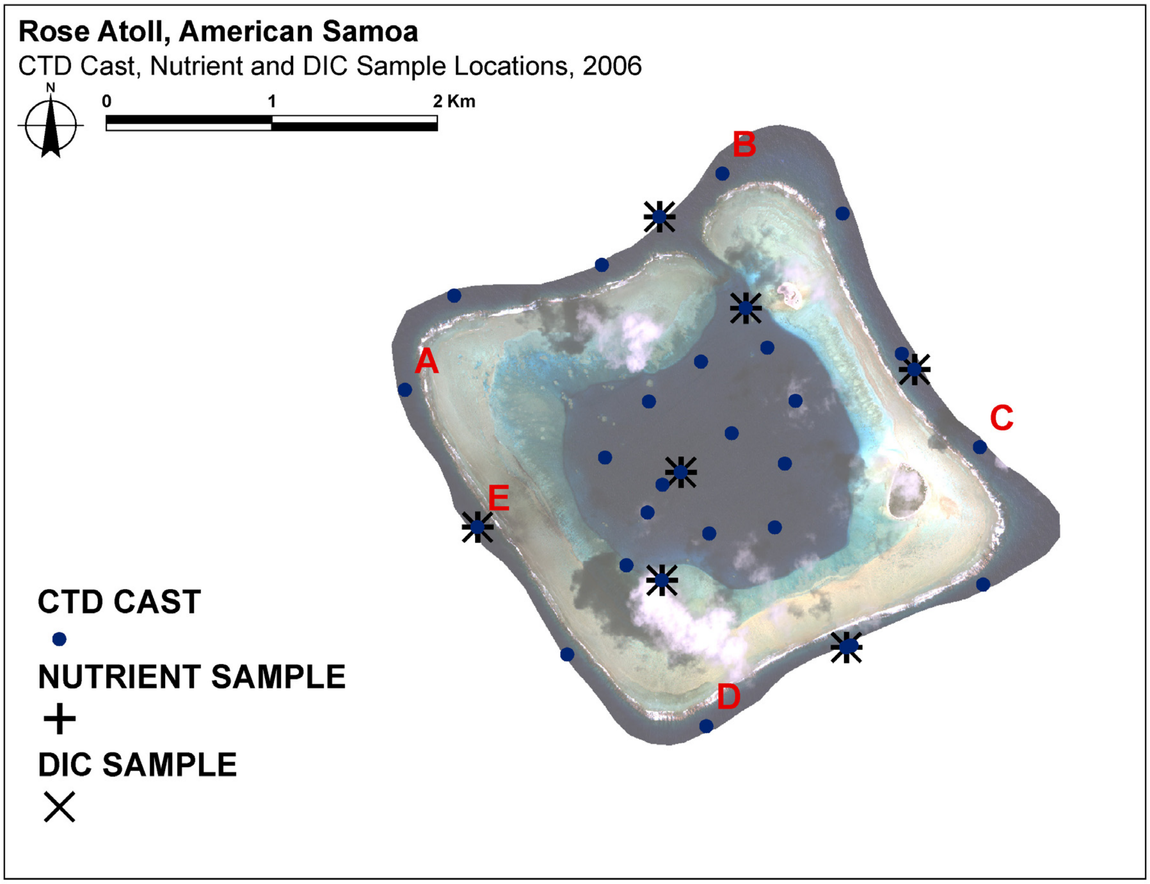

Figure 6.4.1g. Shallow-water CTD cast nutrient and DIC water sample locations around Rose (A–E) during ASRAMP 2006, March 5–9.

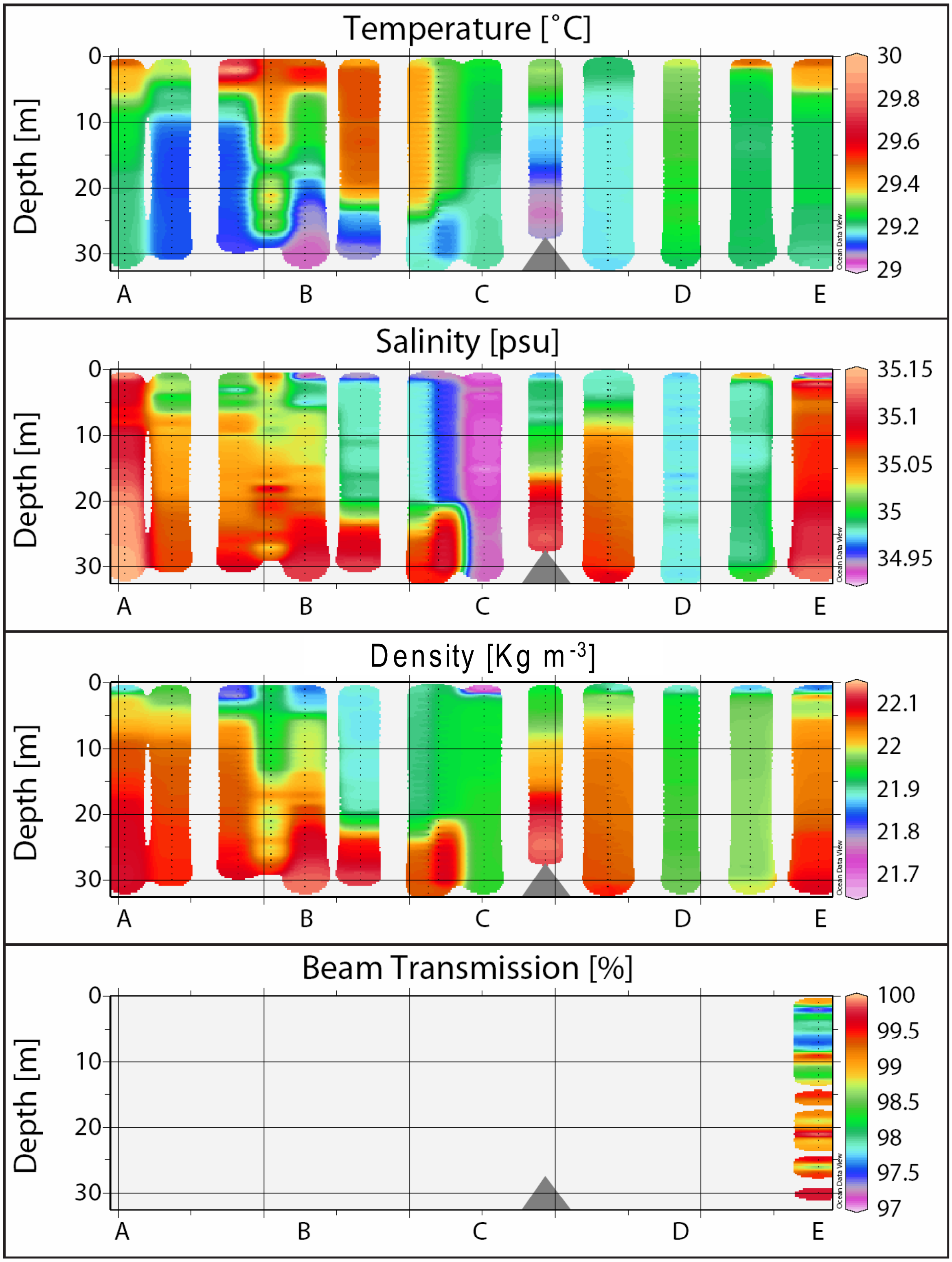

Figure 6.4.1h. Shallow-water CTD cast profiles to a 30-m depth around Rose during ASRAMP 2006, March 5–9, including temperature (°C), salinity (psu), density (kg m^{-3}), and beam transmission (%). Profiles are shown sequentially in a clockwise direction around the island (A–E), as shown in Figure 6.4.1g. The beam transmission sensor in 2006 was faulty and corrupted data were removed.

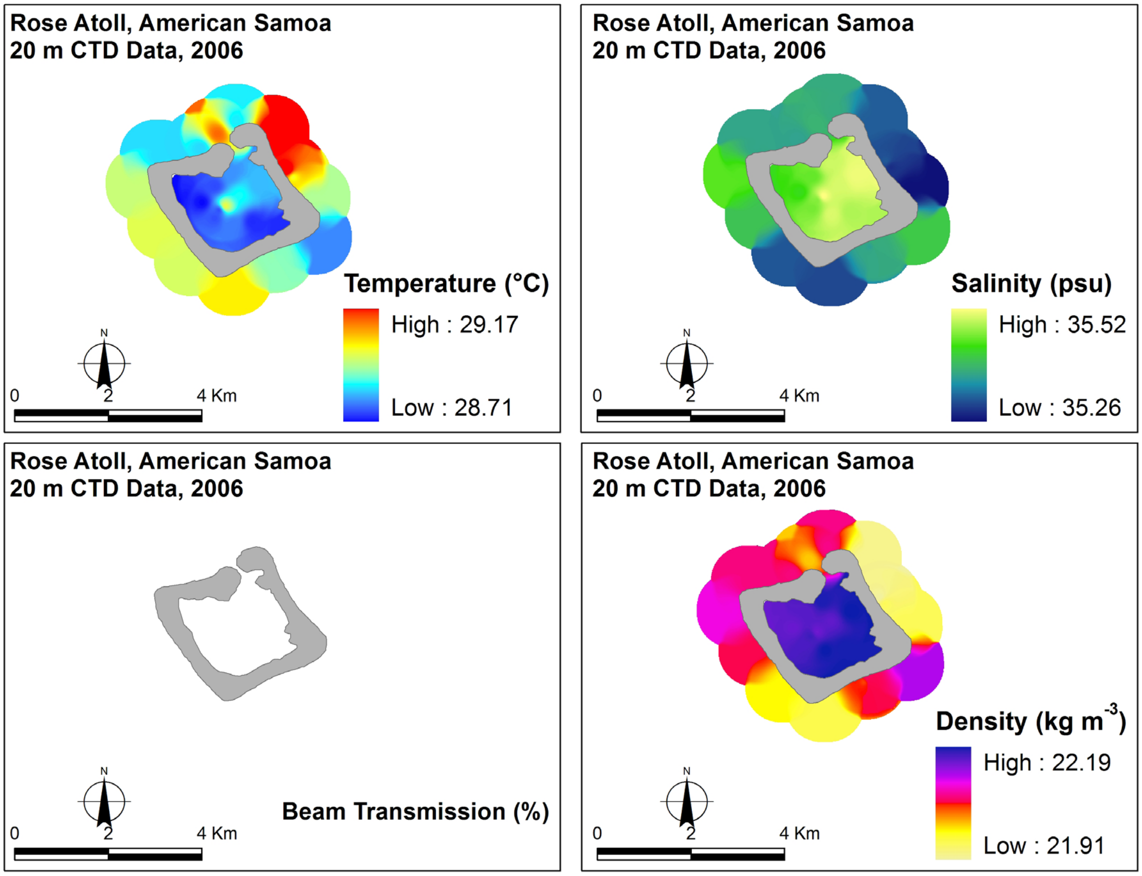

Figure 6.4.1i. Interpolated water temperature (top left), salinity (top right), beam transmission (bottom left), and density (bottom right) at a 20-m depth derived from shallow-water CTD casts around Rose during ASRAMP 2006, March 5–9. Beam transmission values for 2006 were removed because of faulty instrumentation.

Water quality analyses of the in situ water samples collected at a 20-m depth around Rose during ASRAMP 2006 exhibit the following ranges (Fig. 6.4.1j): Chl-a, 0.04–0.41 µg L^{-1}; nitrite (NO_{2-}) 0.005–0.01 µM; phosphate (PO_4) 0.14–0.16 µM; and silicate (SiO_2) 0.93–1.23 µM. The highest values of chlorophyll-a, nitrites, and silicates were observed in the lagoon, where the most saline and dense waters were also observed. The lowest values of nitrites and phosphates were observed along the southeast forereef. Phosphate had the highest observed values outside the lagoon, along the southwest forereef. Interestingly, values of chlorophyll-a, nitrite, and silicate at the site immediately adjacent to the channel entrance were substantially different from those within the lagoon.

6.4.2 Temporal Comparison—Hydrographic Data

During each of the ASRAMP survey periods in 2002, 2004 and 2006, the nearshore CTD and water quality observations exhibited surprisingly high levels of spatial heterogeneity, given the small area of the atoll and its exposure to the surrounding ocean environment. Though somewhat small in magnitude, temperature and salinity variations around and within the atoll were notable. While some of the spatial patterns changed, the actual range of values of most of the water properties did not vary considerably among survey years. Lagoon salinity and density values were consistently high at a 20-m depth, suggesting that water residence times below the sill depth may be substantial. Outside the lagoon, spatial patterns of water

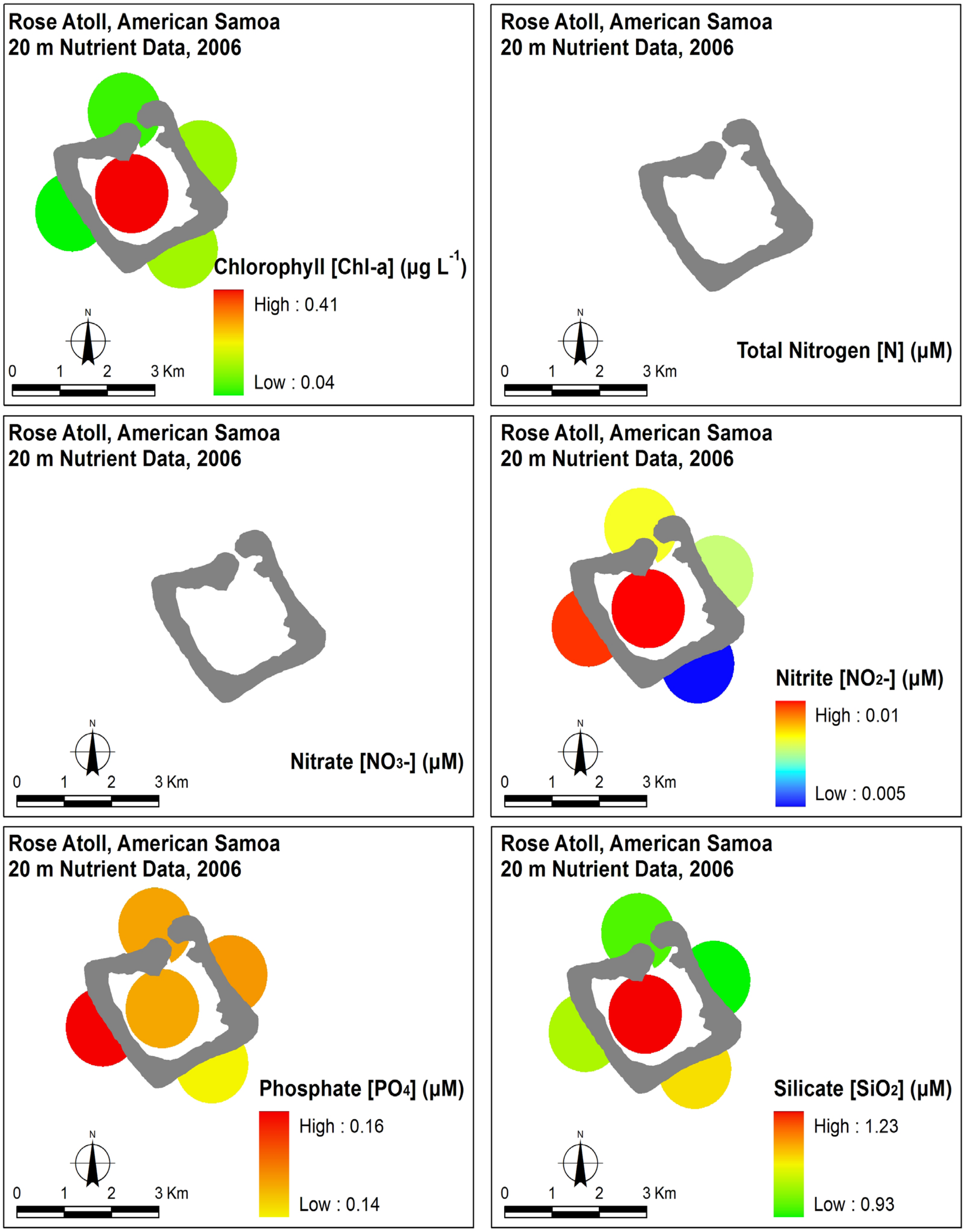

Figure 6.4.1j. Interpolated chlorophyll-a (top left), total nitrogen (top right - no data presented), nitrate (middle left - no data presented), nitrite (middle right), phosphate (bottom left) and silicate (bottom right) concentrations, at a 20-m depth derived from water samples collected in concert with shallow-water CTD casts around Rose during ASRAMP 2006, March 5–9.

properties over the forereefs varied between years. Nearshore conditions observed around Rose are likely representative of the ambient oceanographic conditions influencing the atoll during the austral summer season.

Prevailing, light, easterly winds measured by the moored in situ CREWS buoy may influence local surface currents that affect the oceanographic and water quality properties of this region (Fig. 6.4.3c). Datasets collected during ASRAMP cruises will act as a baseline for comparing future oceanographic and water quality datasets.

6.4.3 Time Series Observations

Between 2002 and 2006, a suite of moored instruments were deployed around Rose to collect time series observations of key oceanographic parameters influencing reef conditions (Fig. 6.4.3a). Deployment and retrieval dates and other details about the deployments are provided in Appendix II, Table II. v.

Figure 6.4.3b shows a time series of in situ and remotely sensed SST and modeled wave properties from January 2002 to April 2006. Pathfinder SST and in situ temperature observations around Rose show strong seasonal variation, with warmest temperatures (~ 29.5°C) observed during January–March and coolest temperatures (~ 27.5°C) in June–August

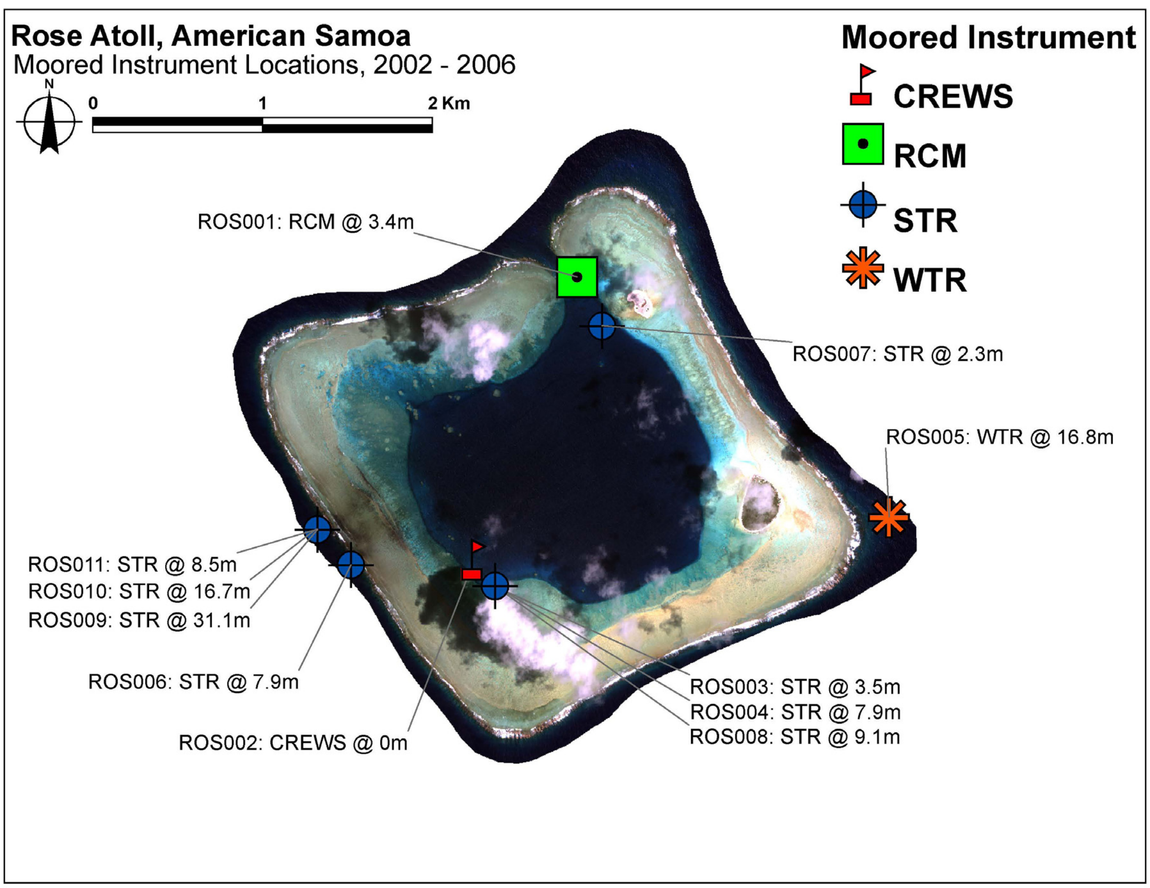

Figure 6.4.3a. Locations and types of oceanographic instrument moorings deployed around Rose between 2002 and 2006. Moored instrument types include: ecological acoustic recorder (EAR), RCM, STR, sea surface temperature (SST) buoy, and WTR.

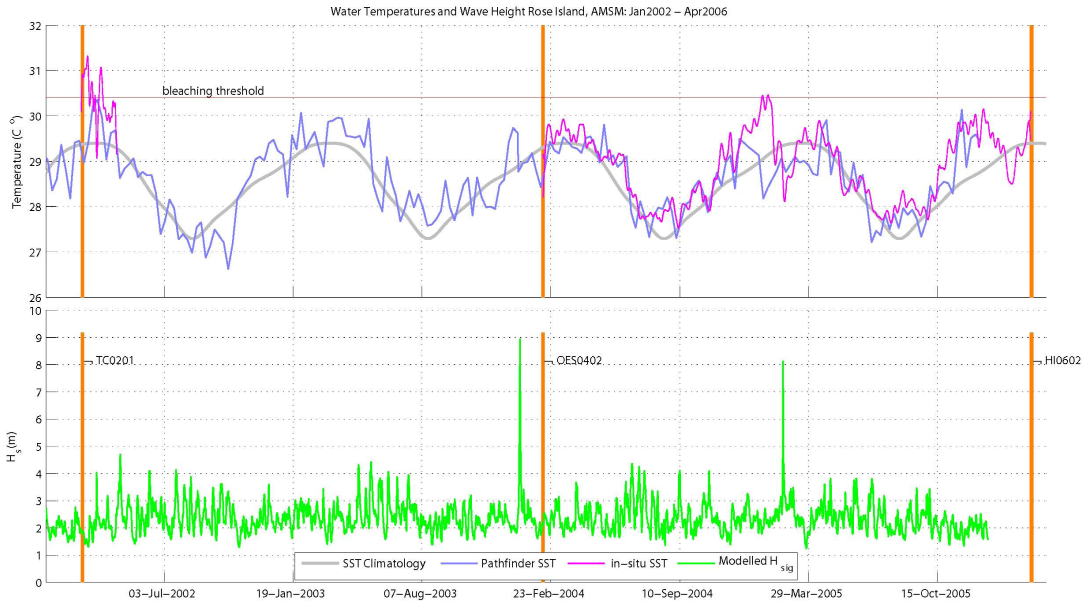

Figure 6.4.3b. SST and wave height time series around Rose between January 2002 and April 2006. Remotely sensed data (SST Climatology and weekly Pathfinder-derived SST) and modeled significant wave height derived from Wave Watch III are overlaid with Pacific Islands Fisheries Science Center (PIFSC) Coral Reef Ecosystem Division (CRED) in situ temperature observations from (CREWS buoy at ROS-06). The horizontal red and vertical orange bars represent the bleaching threshold and the ASRAMP research cruise dates, respectively.

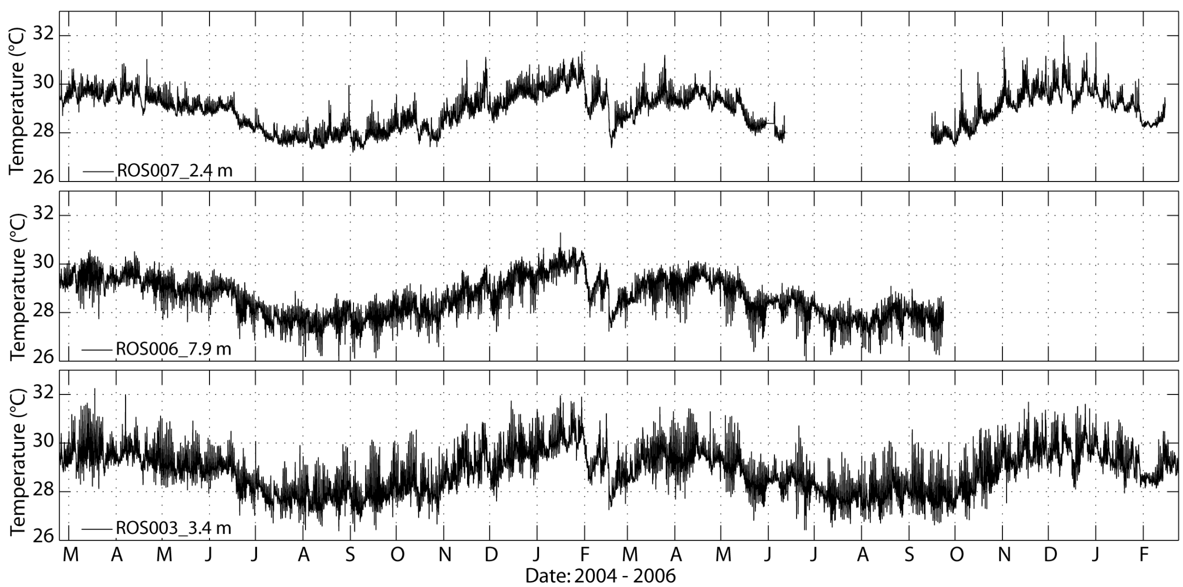

Figure 6.4.3c. Time series observations of temperature from March 2004 to February 2006 collected from six STRs deployed at different locations and depths around Rose. See Figure 6.4.3a for mooring locations.

(Fig. 6.3.2b; top panel). A particularly cool episode, with Pathfinder SST dropping nearly 2°C below the SST climatology, was observed during austral winter 2002 prior to sharply rising 3°C to return to climatological temperatures later that year. Another cool episode, captured via in situ measurements, was observed in February 2005, when SST dropped by ~ 2°C in a matter of days. This SST change was not observed via satellite-based measurements, as no data for Rose existed during that time period (possibly caused by cloud cover or other atmospheric conditions).

Modeled significant wave-height data for Rose revealed weak seasonal variability superposed with episodic, cyclone-derived extreme wave events. Larger wave heights (~ 3–4 m) typically occurred during winter months and smaller wave heights (~ 2 m) during the summer months. Two extreme swell events were observed during the time series record: the first, in January 2004, was produced by Cyclone Heta, and the second in February 2005, was produced by Cyclones Olaf and Percy (Fig. 6.4.3b, bottom panel).

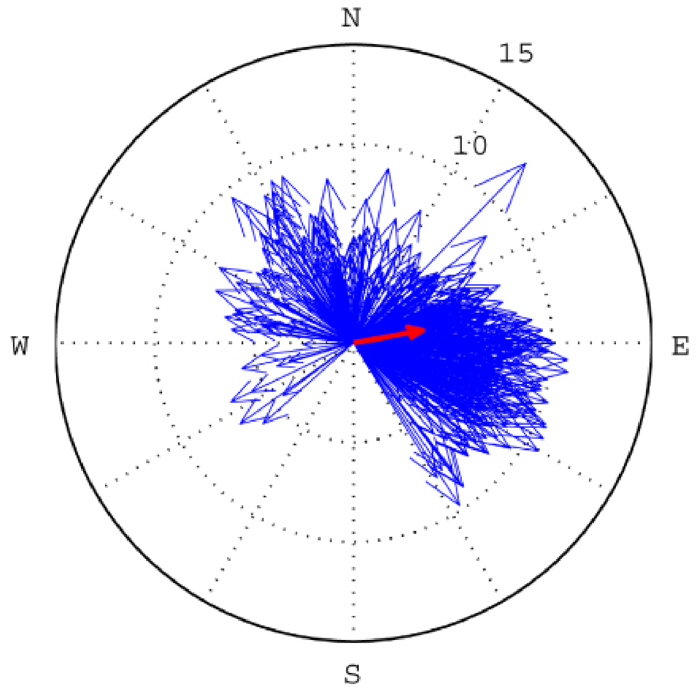

Figure 6.4.3d. Wind rose derived from CREWS buoy wind observations at a height of 2 m above the sea surface at Rose over the period February 8, 2004, to April 11, 2006. Blue arrows represent the daily average wind direction. Length of the blue arrows indicates wind speed (0–15 m s^{-1}). The red arrow represents the average for the entire time period, depicting the prevailing light easterly winds. The wind vectors point to the direction from which the wind is blowing. Data points outside three standard deviations from the mean were removed prior to plotting.

Time series observations of temperature from four STRs deployed around Rose during the 2004 to 2006 time period showed maximum temperature fluctuations of ~ 6°C caused by seasonal variability (Fig. 6.4.3c). Shallow STRs recorded significant diurnal warming and cooling with diurnal temperature fluctuations of up to 3°C. The temperatures recorded on STRs deployed deeper along the forereef slopes and within the lagoon indicated less high frequency (diurnal) variability.

When comparing the two datasets, it appears the large wave event (6-m wave heights) in February 2005 coincided with observed decreases in water temperatures at each of the in situ recorders. Rose is enclosed by emergent reef with a small opening to the north, which is the only opening for water exchange to the surrounding environment. It is likely that the lagoon, where several in situ temperature recorders were deployed, experienced rapid cooling caused by the large waves breaking over the emergent reef and flushing of the lagoon with pelagic-based waters.

Local surface wind direction and speed observations recorded by the in situ CREWS buoy are shown in Figure 6.4.3d. Though variability is high, mean wind speeds were typically light (~ 4 m s^{-1}; 8 knots) and mean wind direction was typically from the east. The figure also shows that winds are frequently ~ 10 m s^{-1} (20 knots) from the east-southeast. These wind observations were recorded at a height of 2 m above the sea surface. When corrected for boundary layer effects, actual winds at the standard meteorological height of 10 m will substantially increase these values.

6.5 Coral and Coral Disease

6.5.1 Coral Surveys

2002 Spatial Surveys

A total of 22 towed-diver surveys, with a mean depth of 10.1 m, were conducted around the forereef and lagoon habitats of Rose during ASRAMP 2002. Individual towed-diver survey track depths varied from 5 m (SE 1) to 23 m (SE 3; Fig. 6.5.1a). Percent cover of live scleractinian coral and dead coral, both of which were independent benthic observations, were separated into two separate zones: ocean-exposed forereef habitat (18 surveys) and lagoonal/backreef habitat (4 surveys). No towed-diver survey track depths were recorded within the lagoon because of faulty instruments.

During ASRAMP 2002, the percent cover of live scleractinian (stony) coral in forereef habitats around Rose was calculated as 29.2% (SE 2.0; Fig. 6.5.1b), while the percent cover of recently dead coral in forereef habitats was calculated as 0.4% (SE 0.1; Fig. 6.5.1c). The percent cover of live coral of lagoonal habitats was 1.7% (SE 0.5). No recently dead coral was recorded for lagoonal habitats.

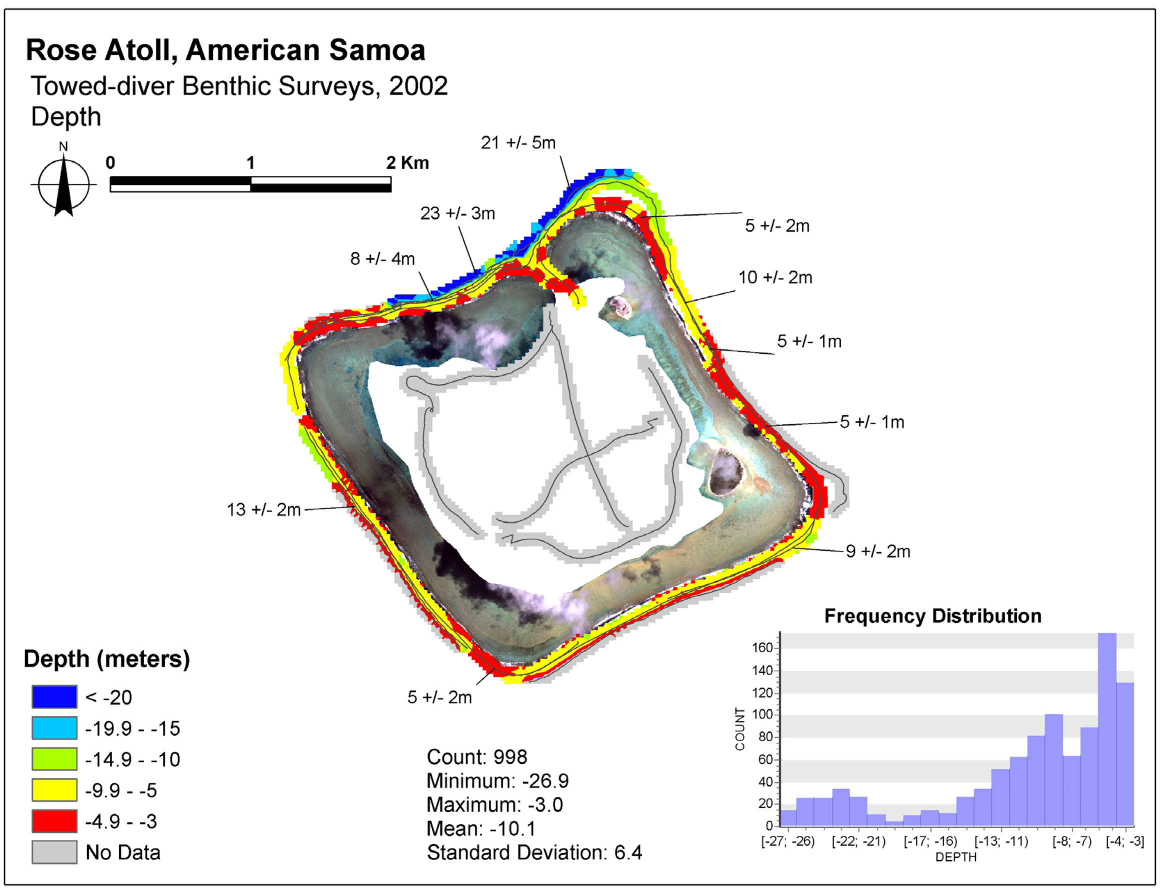

Figure 6.5.1a. Towed-diver survey tracks around Rose during ASRAMP 2004. Towed-diver survey tracks are color coded with mean depths for each 5-min segment. Mean depths and standard deviations for each towed-diver survey are shown in black text. Depth histogram and statistics (counts, minimum depth, maximum depth, mean, and standard deviation) from 30-sec depth recordings during towed-diver surveys are included.

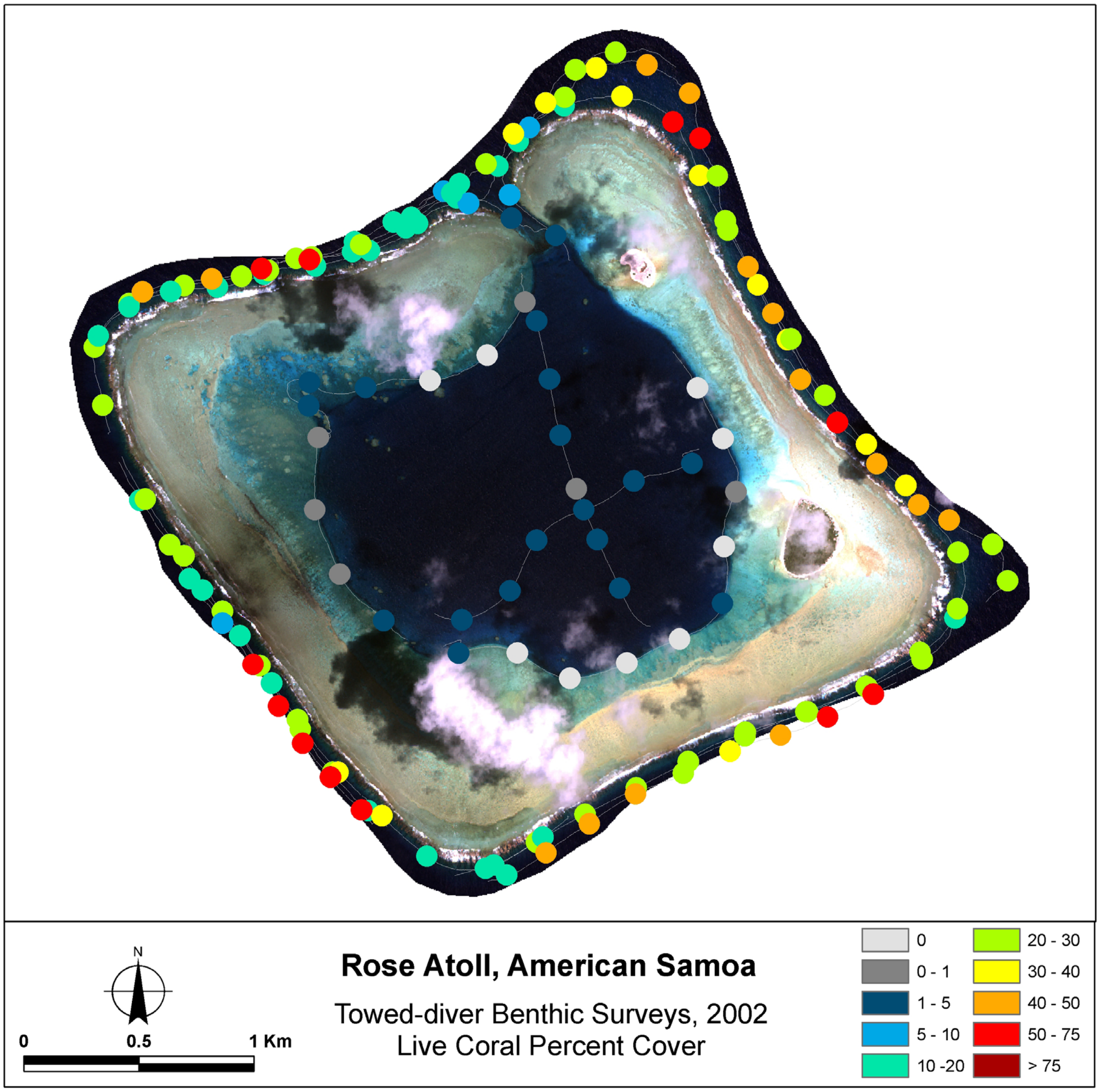

Figure 6.5.1b. Towed-diver benthic survey observations of live scleractinian (stony) coral cover around Rose during ASRAMP 2002. Each colored point represents an integrated estimate computed over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m²). Symbol size represents the percent live coral cover on the benthic habitat. Coral cover was measured as a direct percentage of overall benthic cover in 2002.

The percent cover of live scleractinian (stony) coral in forereef habitats around Rose was relatively uniform in distribution during 2002. Elevated live coral cover was observed sporadically distributed around the atoll. Five tow segments in the southwest region (mean: 61.0%) were deeper than their adjacent tow segments and had elevated coral cover. The northeast region (most northern corner, 4 tow segments, mean: 55%) also exhibited patches of elevated coral cover. The percent cover of recently dead coral was very low (0–5%), and had a uniform distribution around the island. The largest difference in coral cover was noted between the forereef and lagoonal habitats. Towed-diver survey track depth did not directly correspond to variable live or recently dead coral cover values.

In October 1993, Rose experienced a ship grounding (the Taiwanese fishing vessel *Jin Shaing Fa*) and associated fuel spill that killed corals and coralline algae over a broad reach

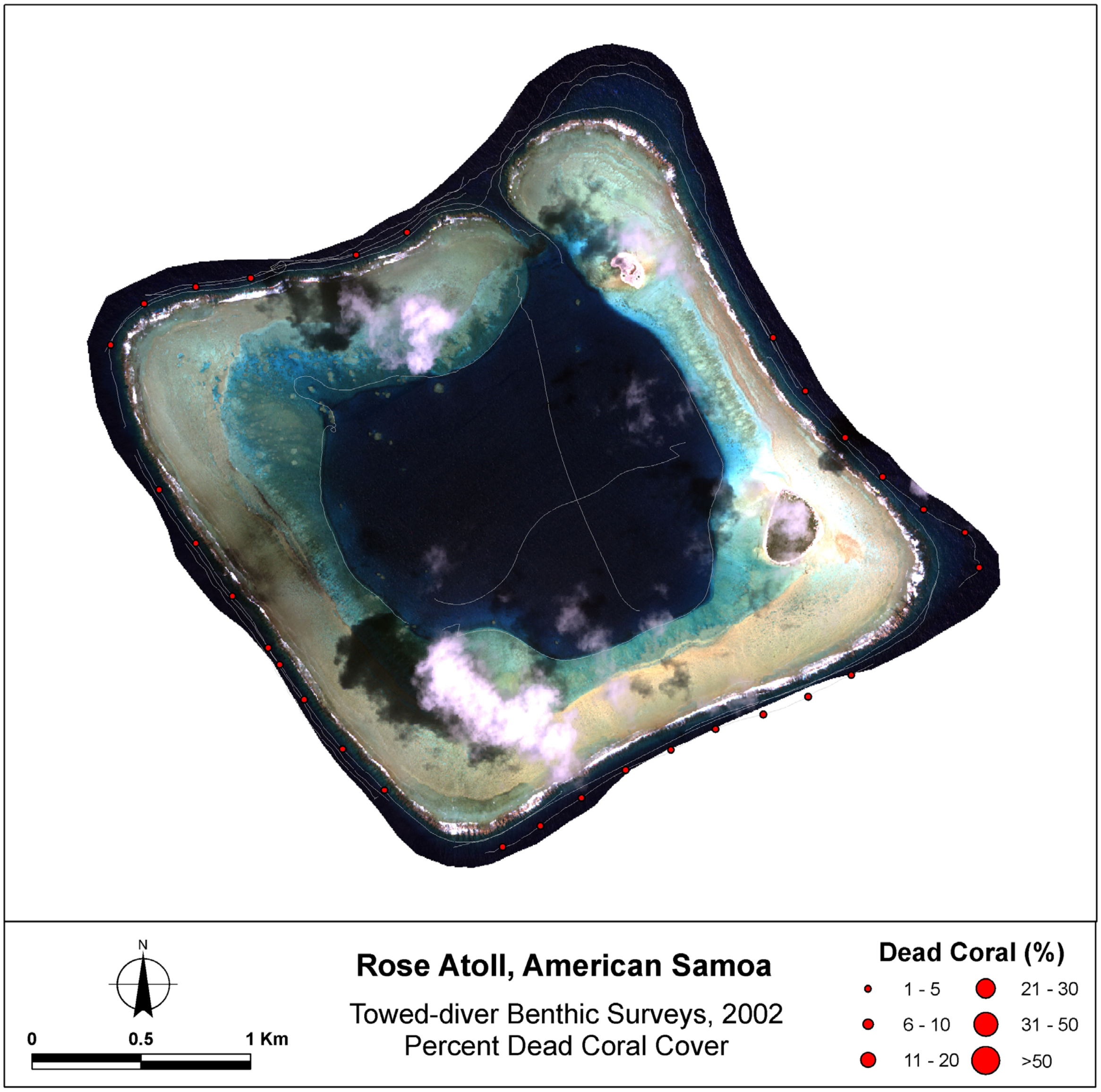

Figure 6.5.1c. Towed-diver benthic survey observations of dead coral cover around Rose during ASRAMP 2002. Each colored point represents an integrated estimate computed over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent dead coral cover on the benthic habitat.

of the southwest reef crest and upper reef margins. Later, dissolved iron from the wreckage stimulated growth of invasive cyanobacteria that still carpets much of the southwest reef crest and slopes, which has slowed the recovery of coralline algae and corals (Schroeder et al., 2008). In April 1994, shortly after the grounding, Rose experienced massive coral bleaching in all habitats to depths of ~ 20–25 m[1]. The bleaching was observed during the first post-shipwreck coral surveys at ocean-facing reef slopes and lagoon backreefs around all four sides of the atoll led by the U.S. Fish and Wildlife Service (USFWS). In 1999–2000, Dr. Jim Maragos revisited Rose as part of an emergency partial cleanup of the ship debris and established eight permanent transects at the base of patch reefs in the lagoon, but was unable to resurvey ocean reefs.

[1] Maragos, J, USFWS. Pers. Commun.

USFWS REA coral surveys during ASRAMP 2002 were the first surveys conducted in American Samoa by CRED. During that deployment, four of the lagoon sites were revisited and three new permanent transects were established: one in the central lagoon and two off the southwest ocean-facing reef at sites ROS-05 and ROS-07). Additional qualitative REA surveys were also conducted around all four ocean-facing sides of the atoll in 2002. Though a total of 13 sites were surveyed around Rose by a coral biologist, much of the focus of those surveys was to compile species inventories. Since the surveys were exploratory and qualitative in nature, no data are presented in this more quantitative report.

2004 Spatial Surveys

A total of 27 towed-diver benthic surveys, with a mean depth of 13.0 m, were conducted around the forereef and lagoon habitats of Rose during ASRAMP 2004 (Fig. 6.5.1d). Individual towed-diver survey track depths ranged from 5.0 m (SE 2.0) to 21.0 m (SE 3.0), with purposeful efforts to target three depth ranges: shallow (~ 5 m), mid-depth (~ 10–15 m), and deep (~ 20–25 m), as reflected in the depth histogram. For analysis, the percent live scleractinian coral and stressed coral were separated into two separate zones: ocean-exposed forereef habitat (20 surveys) and lagoonal/backreef habitat (7 surveys). The percent cover of live scleractinian (stony) coral in forereef habitats was 23.5% (SE 1.2; Fig. 6.5.1e), while the

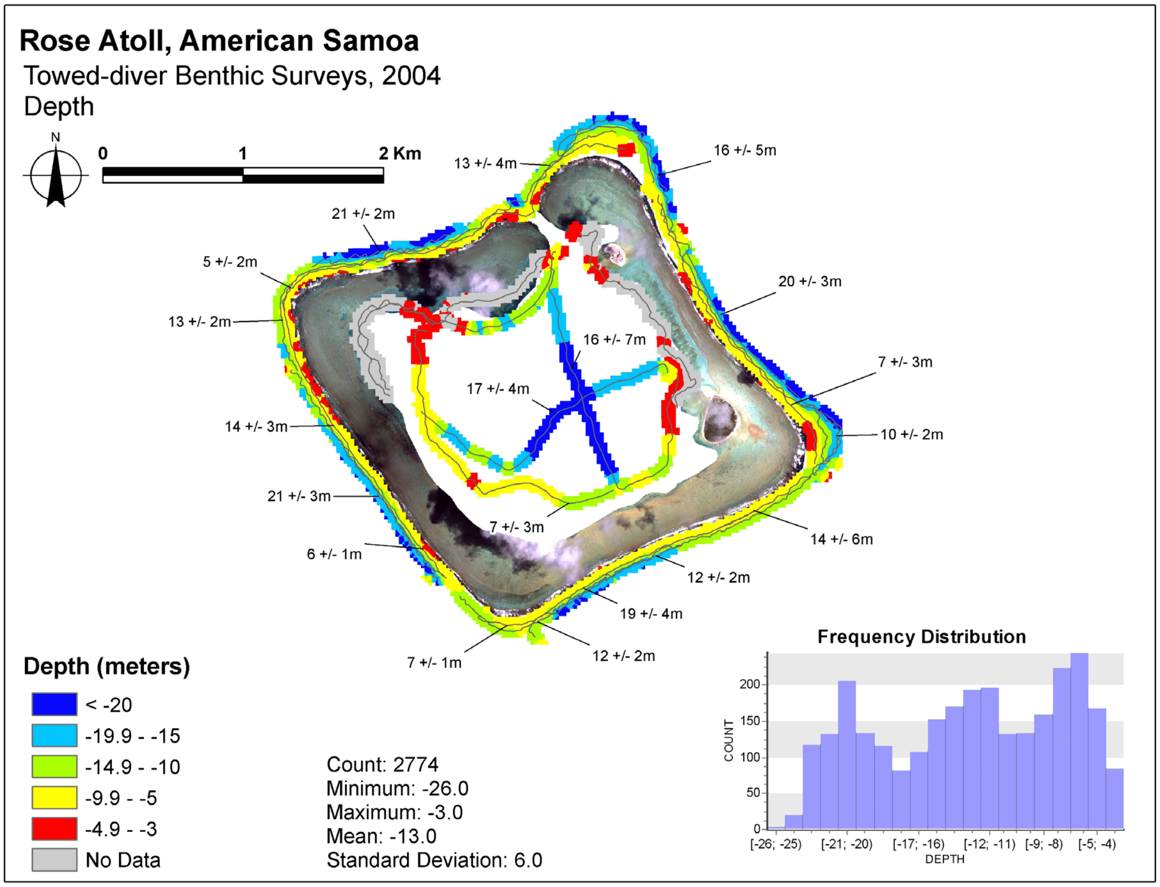

Figure 6.5.1d. Towed-diver survey tracks around Rose during ASRAMP 2004. Towed-diver survey tracks are color coded with mean depths for each 5-min segment. Mean depths and standard deviations for each towed-diver survey are shown in black text. Depth histogram and statistics (counts, minimum depth, maximum depth, mean, and standard deviation) from 30-sec depth recordings during towed-diver surveys are included.

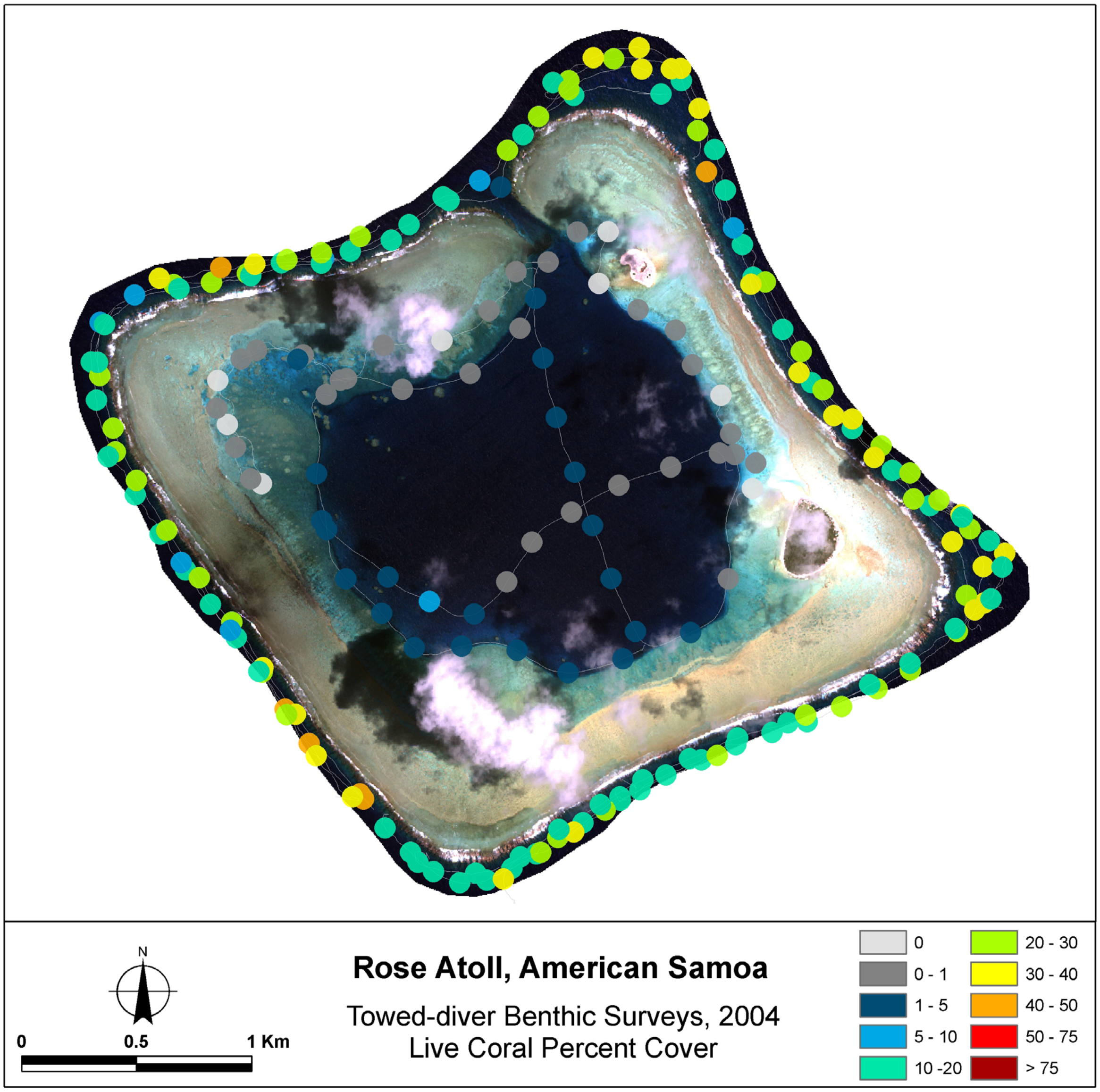

Figure 6.5.1e. Towed-diver benthic survey observations of live scleractinian (stony) coral cover around Rose during ASRAMP 2004. Each colored point represents an integrated estimate computed over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent live coral cover on the benthic habitat.

percent cover of stressed coral, which is a subset of live coral cover, was 5.6% (SE 1.0; Fig. 6.5.1f). The percent cover of live coral of lagoonal habitats was 1.5% (SE 0.3; Fig. 6.5.1e), while the percent cover of stressed coral was 0.4% (SE 0.4; Fig. 6.5.1f).

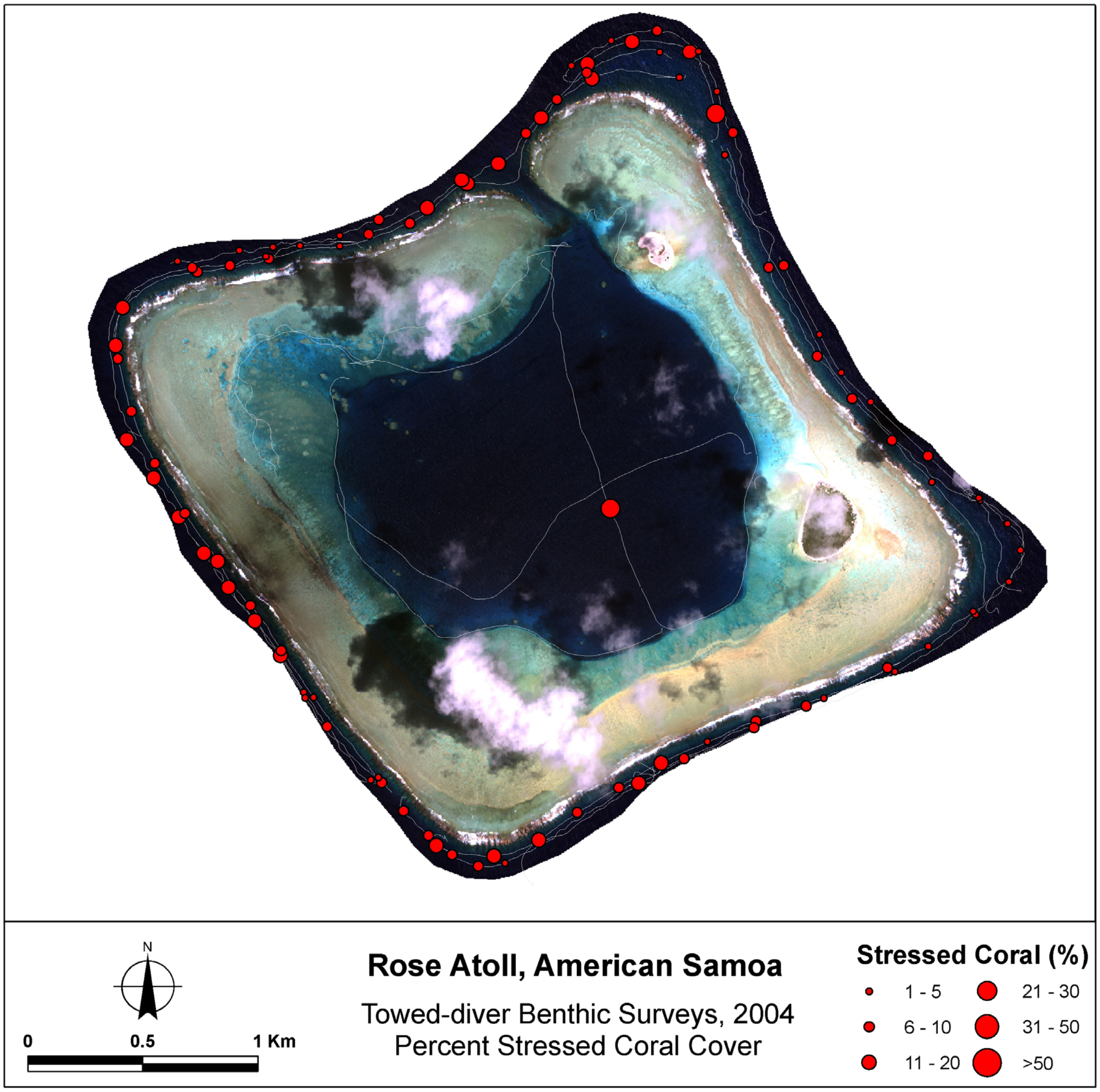

Figure 6.5.1f. Towed-diver benthic survey observations of stressed coral cover around Rose during ASRAMP 2004. Each colored point represents an integrated estimate computed over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent of stressed coral cover of the total coral benthic coverage. Stressed coral cover was measured as a percentage of overall coral cover in 2004.

Percent cover of live scleractinian coral and stressed coral from towed-diver survey observations around Rose during ASRAMP 2004 showed a relatively uniform island-wide coral community. The most noteworthy spatial pattern observed indicated large differences in percent cover between forereef and lagoonal habitats; the lagoon was largely a soft-bottom community, with sporadic coral pinnacles and low coral cover, while the forereef was composed primarily of hard substrate with moderate levels of live coral cover (10–40%). Percent cover of stressed coral was generally low, but occasionally as high as 11–20% of the live coral, apparently most focused on the north, west, and south points. Very little stressed coral was observed on the windward east point of Rose.

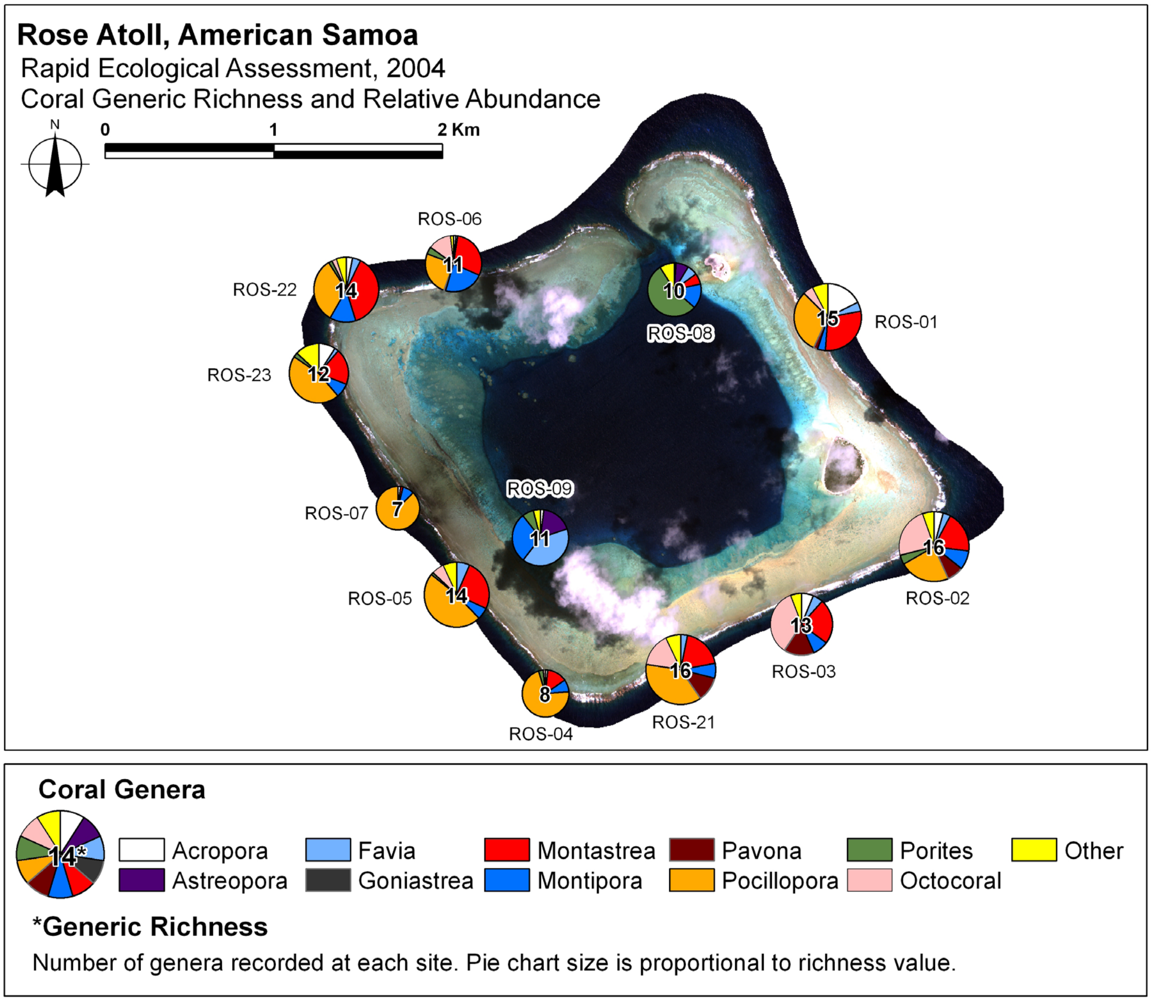

Figure 6.5.1g. Relative abundance of coral genera and generic richness from REA surveys around Rose during ASRAMP 2004. Percent relative abundance of key coral genera are indicated by color-coded portions of the pie charts. Size of the pie charts and black numbers in the center of the pie charts indicate the number of coral genera observed at each REA site.

Twelve REA coral surveys were conducted around Rose during ASRAMP 2004. At least 26 anthozoan/hydrozoan genera were recorded around Rose (Fig. 6.5.1g). As expected, the coral communities at ocean-facing forereef sites were substantially different than at sites within the lagoon. Members of the genera *Pocillopora* and *Montastrea* dominated the forereef communities, accounting for, on average, 42% and 21% of the coral community, respectively. Octocorals were also common at sites ROS-02, ROS-03, and ROS-21 along the southeast forereef, accounting for 23.1% of the corals at these three sites. Sites ROS-09 and ROS-08 inside the lagoon had unique coral communities compared to sites on the forereef. *Porites* constituted over half of the coral colonies found at site ROS-08 in the lagoon near the channel, while *Favia* (40%) and *Astreopora* (18%) were dominant genera at site ROS-9P.

Generic richness was consistent at all forereef sites around Rose during ASRAMP 2004, averaging 12.3 (SE 0.9) coral genera per site, except at site ROS-07, where the ship grounding occurred, and site ROS-04, where only seven and eight coral genera were recorded, respectively (Fig. 6.5.1g). Site-specific data regarding the relative abundance of coral genera, by colony counts within belt transects, are available in Appendix III, Table III. ix.

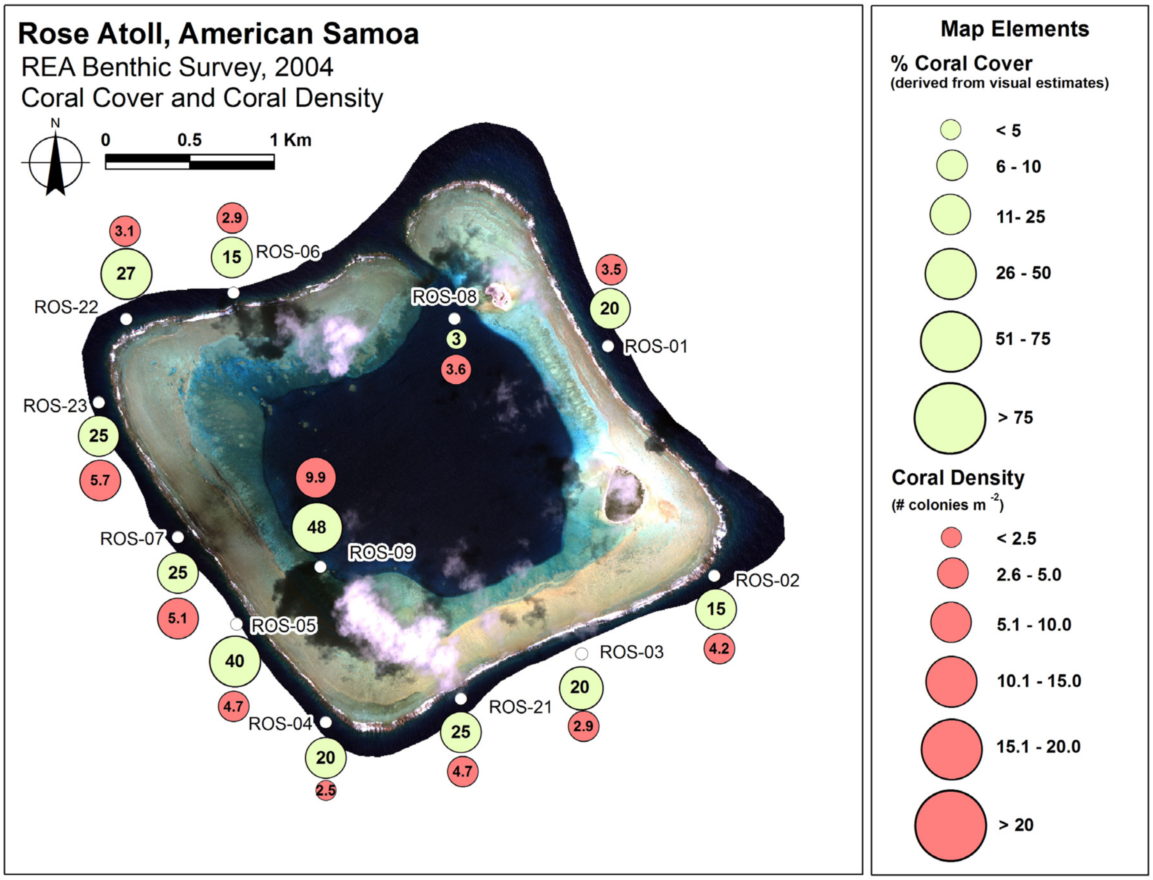

Figure 6.5.1h. Live scleractinian (stony) coral cover and coral colony density from REA surveys around Rose during ASRAMP 2004. The size of the symbol is proportional to the value of each parameter. Coral percent cover was determined by qualitative visual estimates.

The mean percent cover of live scleractinian (stony) coral observed around forereef sites during ASRAMP 2004 REA surveys (derived through visual estimates) was 23.6% (SE 4.1; Fig. 6.5.1h). Coral cover at forereef sites was consistent and ranged from 15% to 27%. The only exception was site ROS-05, off the southwest region of the atoll, where cover was recorded as 40%. Visual estimates of coral cover within the lagoon were variable, with low coral cover (~ 3%) recorded near the channel at site ROS-08. In contrast, the lagoon pinnacle at site ROS-09 had the highest coral cover (48%) of any REA site around Rose.

During ASRAMP 2004, a total of 4695 coral colonies were counted within a total survey area of 1086 m^2 (Fig. 6.5.1h). Coral densities around Rose were variable, with a mean coral density per site of 4.3 colonies m^{-2} (SE 0.7). Coral density was low at all forereef sites (2.5 colonies m^{-2} to 5.7 colonies m^{-2}). The highest coral density (9.9 colonies m^{-2}) around Rose was found inside the lagoon at ROS-09.

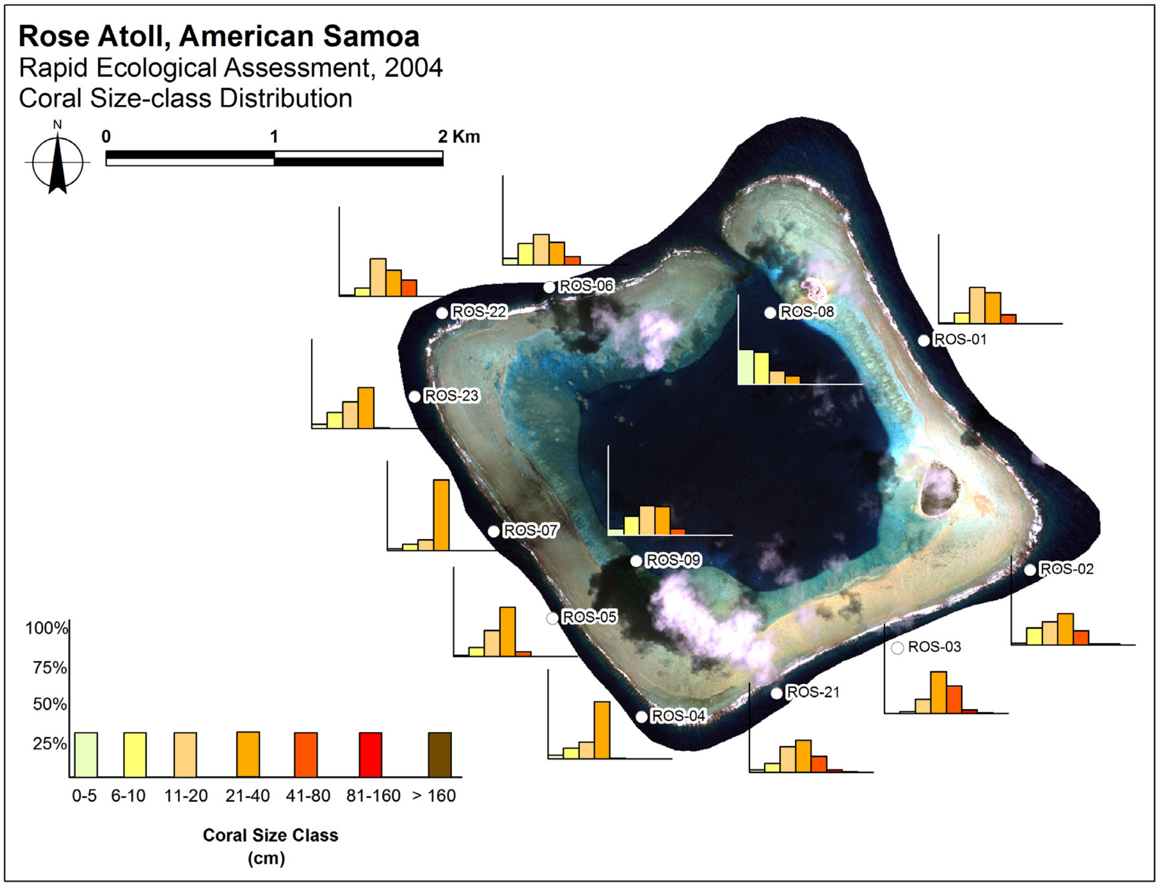

Figure 6.5.1i. Scleractinian coral size-class distribution around Rose from REA surveys during ASRAMP 2004. The height of the *y*-axis in each size class chart represents 100%. The seven observed size classes (0–5, 6–10, 11–20, 21–40, 41–80, 81–160, and > 160 cm) are color coded in size frequency diagrams at each REA site.

During ASRAMP 2004, size class distributions around Rose show that 48.9% of coral colonies had maximum diameters less than 20 cm (Fig. 6.5.1i). Corals greater than 40 cm were common at forereef sites around Rose, with five of the eight forereef sites having more than 10% of corals within these larger size classes. Only one site, ROS-08 inside the lagoon, had abundant small corals, with almost 40% of corals having maximum diameters less than 5 cm.

Site ROS-07 is unique at this atoll, because it is located at a 1993 ship grounding site. Coral cover at this site is relatively low (Fig. 6.5.1h), and the community is dominated by *Pocillopora*, a genus known to quickly colonize available substrate. Large blooms of cyanobacteria have been observed at ROS-07, suggesting a causal relationship between the ship grounding and the algal bloom (Fig. 6.5.1j). The long-term effects of this grounding are examined in a recent manuscript (Schroeder et al., 2008).

Figure 6.5.1j. Corals in the genus *Pocillopora* are among the first to colonize disturbed benthic areas, as seen at site ROS-07. Cyanobacteria (seen here as the dark green coloration between coral colonies) are abundant as a result of persistent effects stemming from a 1993 vessel grounding. (*Photograph provided by NOAA PIFSC CRED; J. Kenyon, JIMAR*)

2006 Spatial Surveys

A total of 26 towed-diver benthic surveys, with a mean depth of 13.0 m, were conducted around the forereef and lagoon habitats of Rose during ASRAMP 2006 (Fig. 6.5.1k). Individual towed-diver survey track depths ranged from 4.0 m (SE 2.0)to 21.0 m (SE 3.0), with purposeful efforts to target three depth ranges: shallow (~ 5 m), mid-depth (~ 10–15 m), and deep (~ 20–25 m), as reflected in the depth histogram.

Percent cover of live scleractinian (stony) coral and stressed coral were analyzed within two separate zones: ocean-exposed forereef habitats (21 surveys) and lagoonal/backreef habitats (5 surveys). The percent cover of live scleractinian (stony) coral on forereef habitats was 20.1% (SE 1.8; Fig. 6.5.1l), while stressed coral, which was a subset of live coral cover, was 4.5% (SE 1.2; Fig. 6.5.1m). The percent cover of live coral on lagoonal/backreef sites was 5.9% (SE 0.9; Fig. 6.5.1l), while the percent cover of stressed coral was 0.9% (SE 0.4; Fig. 6.5.1m).

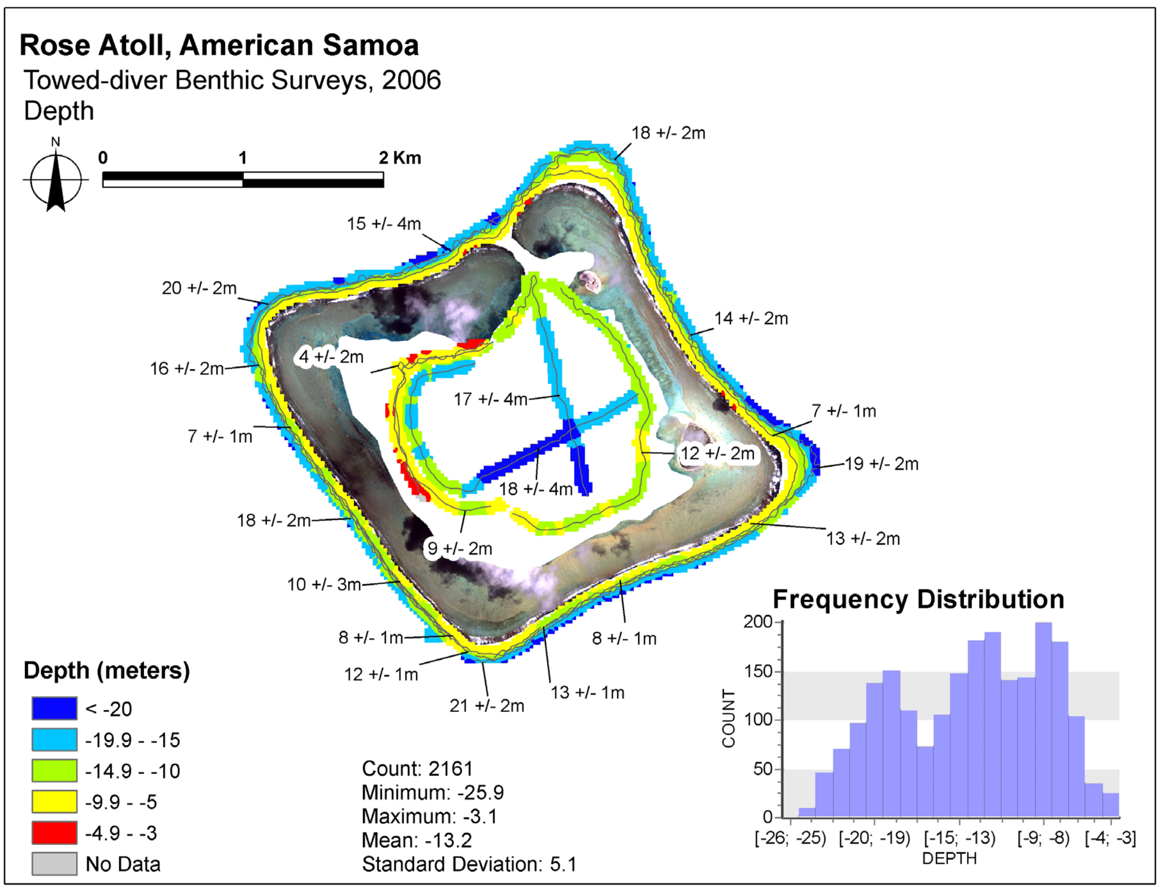

Figure 6.5.1k. Towed-diver survey tracks around Rose during ASRAMP 2006. Towed-diver survey tracks are color coded with mean depths for each 5-min segment. Mean depths and standard deviations for each towed-diver survey are shown in black text. Depth histogram and statistics (counts, minimum depth, maximum depth, mean, and standard deviation) from 30-sec depth recordings during towed-diver surveys are included.

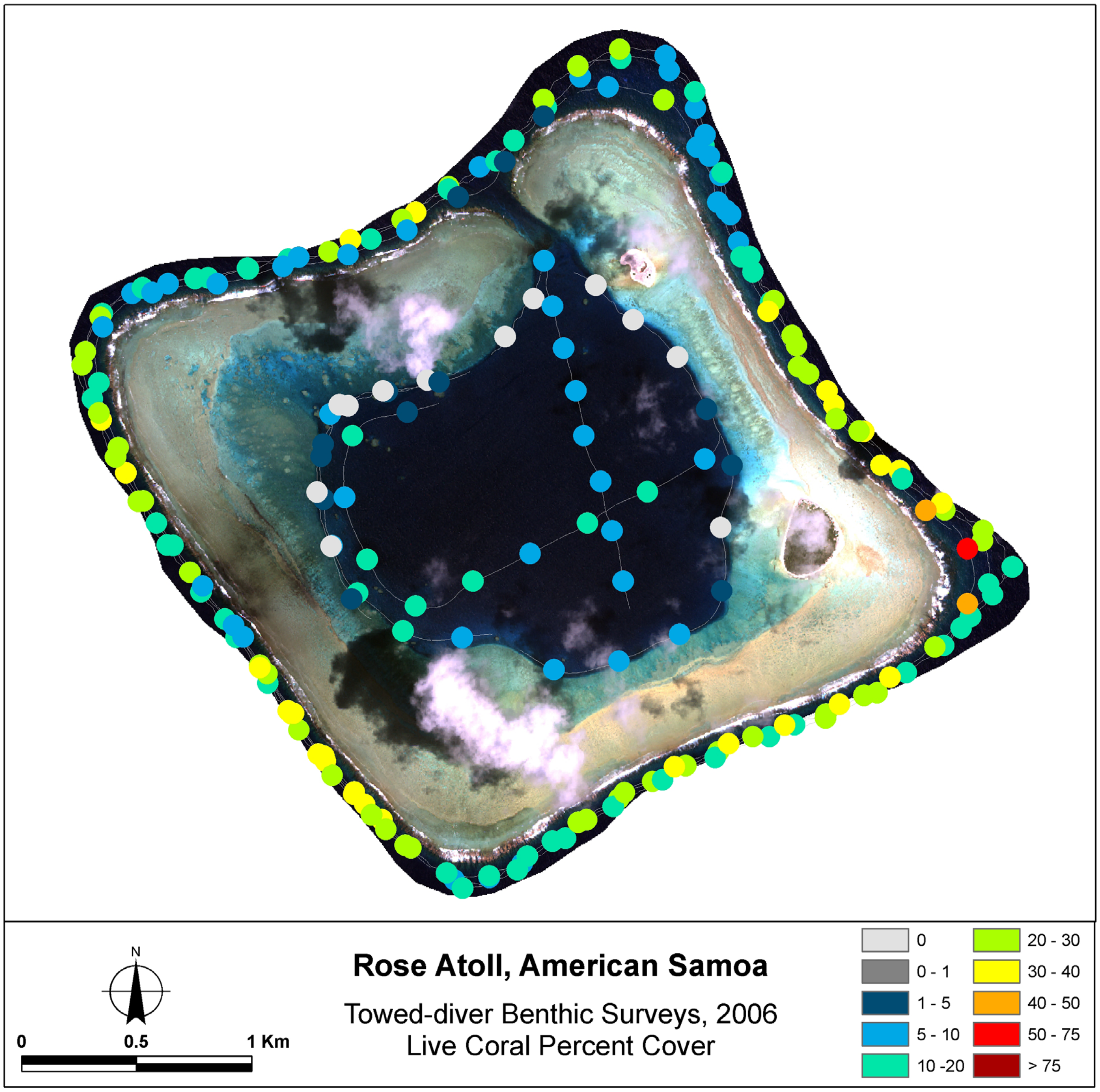

Figure 6.5.1l. Towed-diver benthic survey observations of live scleractinian (stony) coral cover around Rose during ASRAMP 2006. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent live coral cover on the benthic habitat. See Chapter 2, Section 2.4.2, Table 2.4.2b for more information on benthic towed-diver binning categories during ASRAMP 2006.

Spatially, the percent cover of live coral around Rose was relatively uniform, with notable high coral cover areas: tow segments in the southwest region (7 tow segments, mean: 33.6%), northeast region (5 tow segments, 33.2%), and the southeast region (6 tow segments, 28.3%). Stressed coral cover was low island-wide, with the only localized increases recorded along the northwest region of the island, where six contiguous segments from the shallow, inshore survey track found relatively high coral stress (36.3%).

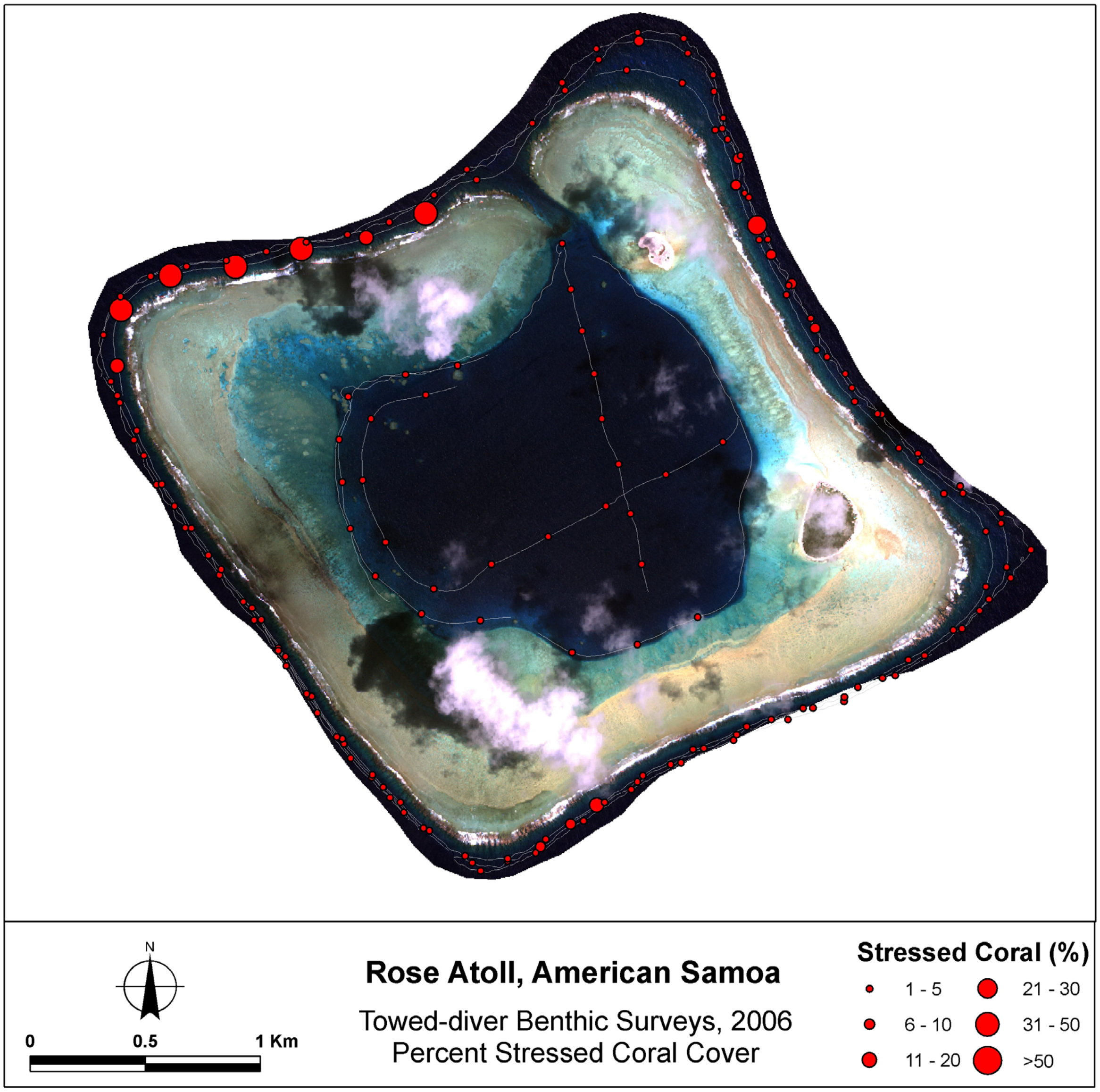

Figure 6.5.1m. Towed-diver benthic survey observations of stressed coral cover around Rose during ASRAMP 2006. Each colored point represents an integrated estimate over a 5-min observation segment covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2). Symbol size represents the percent of stressed coral cover of the total coral benthic coverage. See Chapter 2, Section 2.4.2, Table 2.4.2b for more information on benthic towed-diver binning categories during ASRAMP 2006.

Eleven REA coral surveys were conducted around the steep forereef slopes and lagoon/ backreef habitats of Rose during ASRAMP 2006. Colonies belonging to at least 27 anthozoan/hydrozoan genera were counted at Rose, with members of the genera *Pocillopora*, *Porites*, *Montastrea*, and *Montipora* each contributing more than 10% of the total number (Fig. 6.5.1n). *Pocillopora* dominated the forereef communities, accounting for, on average, 48% of the coral colonies. *Astreopora* was only common inside the lagoon at sites ROS-08 and ROS-09. Site-specific data regarding the relative abundance of coral genera, by colony counts within belt transects, are available in Appendix III, Table III. x.

Generic richness was similar among REA sites (excluding the shipwreck site, ROS-07) with 13.5 coral genera (SE 1) recorded per site. Lower richness was seen inside the lagoon (Fig.

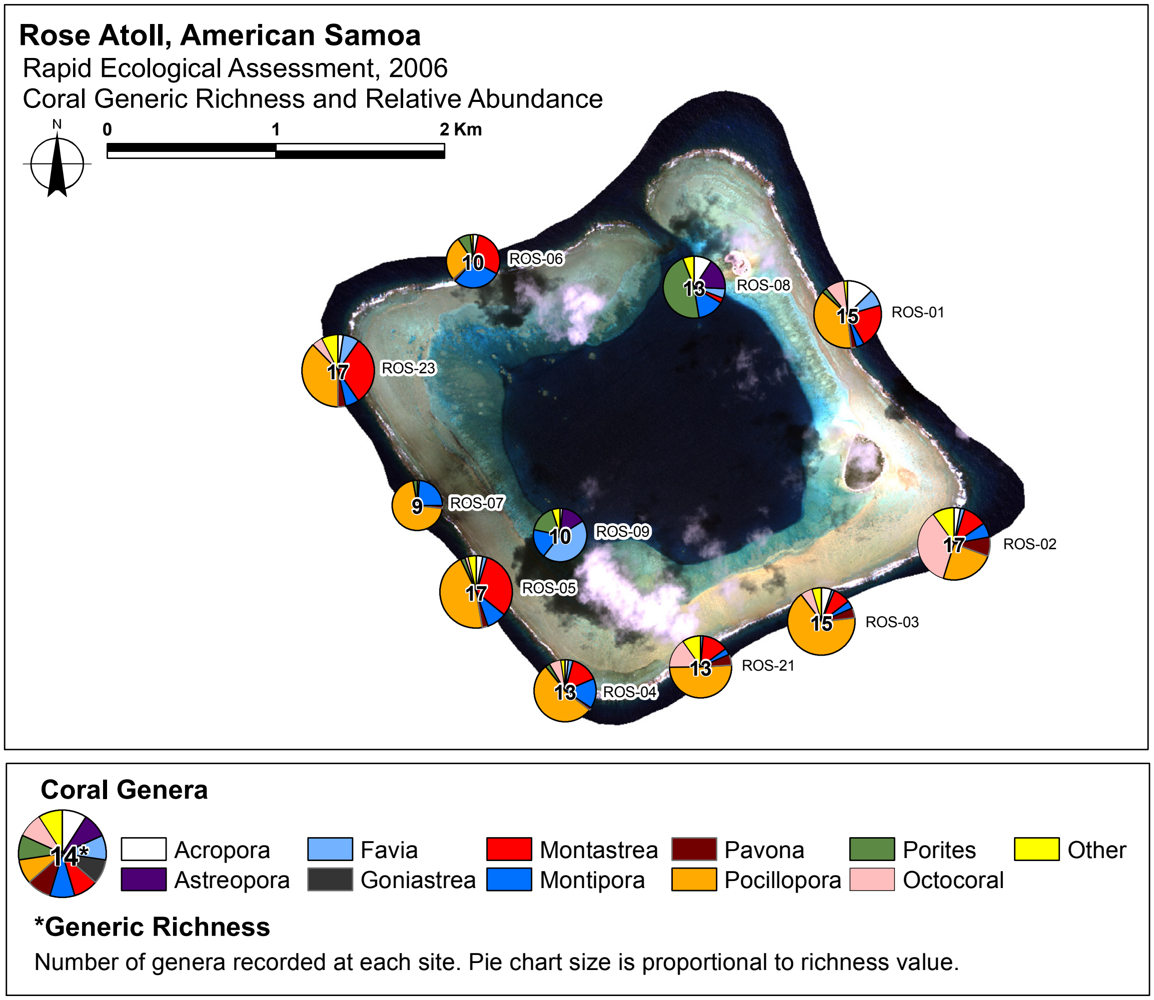

Figure 6.5.1n. Relative abundance of coral genera and generic richness from REA surveys around Rose during ASRAMP 2006. Percent relative abundance of key coral genera are indicated by color-coded portions of the pie charts. Size of pie charts and black numbers in the center of the pie charts indicate the number of coral genera observed at each REA site. ROS-22 was not surveyed in 2006 because of inclement environmental conditions.

6.5.1n). Lower coral richness at ROS-07, the site of the 1993 ship grounding, may be a result of the narrow range of recruiting coral species colonizing the substrate.

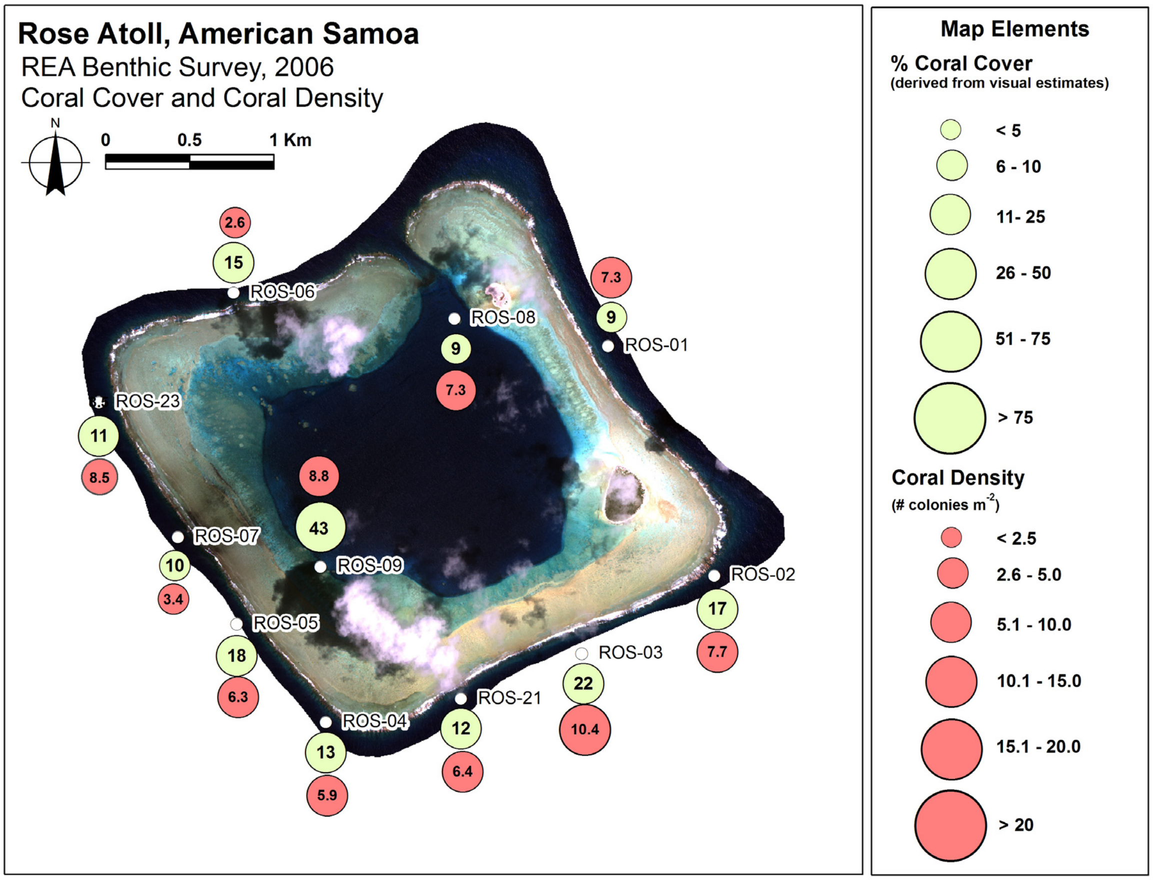

Figure 6.5.1o. Live scleractinian (stony) coral cover and coral colony density from REA surveys around Rose during ASRAMP 2006. The size of the symbol is proportional to the value of each parameter. ROS-22 was not surveyed in 2006 because of inclement environmental conditions.

Island-wide mean percent cover of live scleractinian (stony) coral in the forereef habitats of Rose, derived from the line point intercept method, was 13.8% (SE 1.3; Fig. 6.5.1o). The percent cover of live coral at forereef sites was highest (17.6%) at site ROS-05 in the southwest region, and lowest (8.8%) at site ROS-01 in the northeast region. ROS-07 site of the 1993 ship grounding exhibited low coral cover (9.8%). Coral cover at the lagoon site near the channel (ROS-08) was low (8.8%) while the lagoon pinnacle site farther from the channel (ROS-09) had the highest coral cover of any site at Rose (43.1%).

During ASRAMP 2006 surveys around Rose, a total of 4267 coral colonies were counted within a total survey area of 605 m^2. Mean coral density between REA sites was variable, with 6.8 colonies m^{-2} reported (SE 0.8; Fig. 6.5.1o). The highest coral density (10.4 colonies m^{-2}) was observed at site ROS-03 on the southeast forereef, while the lowest coral density (2.6 colonies m^{-2}) was recorded at site ROS-06 on the northwest forereef.

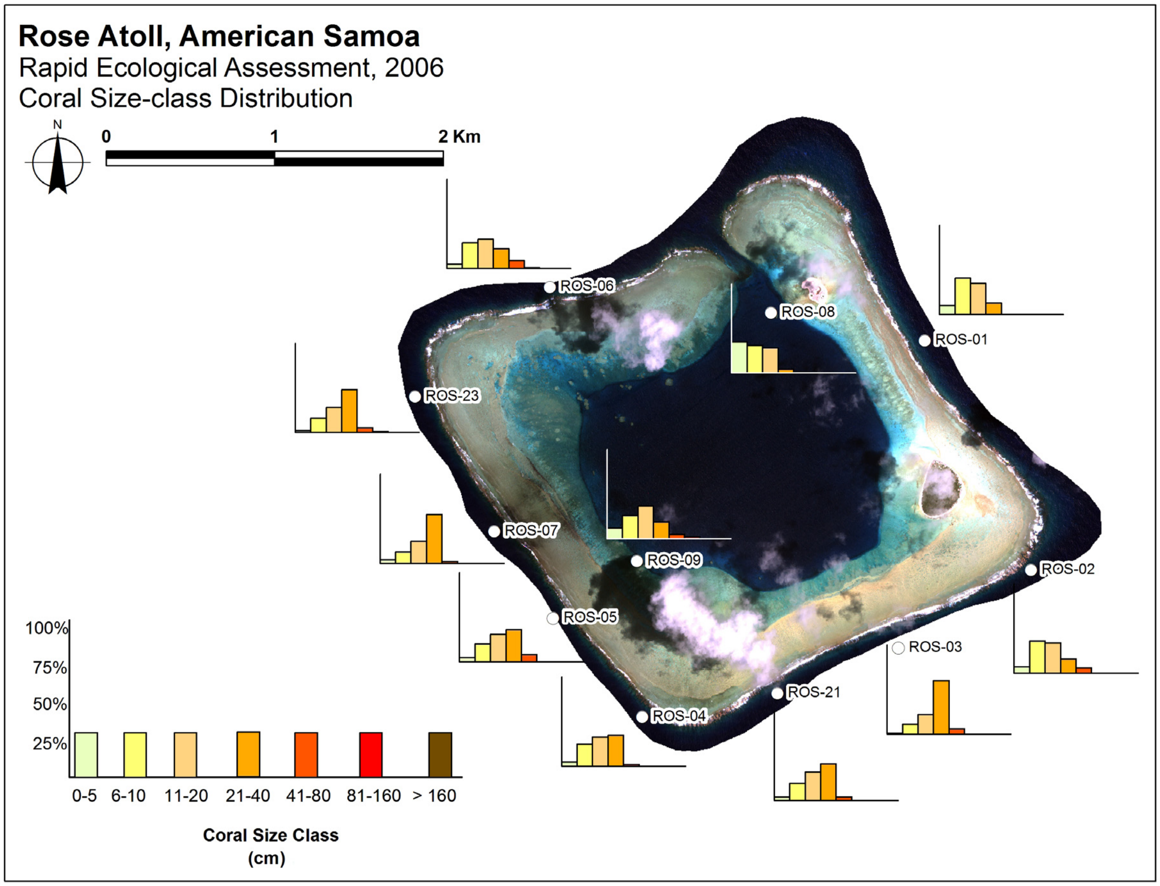

Figure 6.5.1p. Scleractinian coral size-class distribution around Rose from REA surveys during ASRAMP 2006. The height of the *y*-axis in each size class chart represents 100%. The seven observed size classes (0–5, 6–10, 11–20, 21–40, 41–80, 81–160, and > 160 cm), are color coded in size frequency diagrams at each REA site. ROS-22 was not surveyed in 2006 because of inclement environmental conditions.

During ASRAMP 2006, size class distributions showed that the majority (68.9%) of coral colonies had maximum diameters less than 20 cm (Fig. 6.5.1p). Corals greater than 40 cm maximum diameter were not common at any site. Abundant small corals were common at sites ROS-08 and ROS-09 inside the lagoon and at site ROS-01 on the northeast forereef, with more than 10% of corals having maximum diameters less than 5 cm at each site.

6.5.2 Coral Disease Surveys

2006 Spatial Surveys

Coral disease surveys during ASRAMP 2006 covered a total survey area of 4425 m^2 around Rose, with 361 cases of coral disease, predation, and other lesions observed. This number translates to an overall average prevalence of 1.0% (SE 0.5). Of the eleven sites surveyed, nine (82%) contained disease. Figure 6.5.2a illustrates the variation in prevalence of disease and predation among sites. Overall, the most common type of affliction encountered was 'other lesions,' which involved hyperpigmented irritations. This condition was observed at all sites surveyed, except for site ROS-01 in the northeast region and site ROS-07 in the southwest region (shipwreck grounding site). For this type of lesion, 64% of the cases (149) were enumerated at site ROS-23 on the western point, which amounts to a prevalence of 4.9%. Site ROS-06, in the northwest region, also exhibited elevated prevalence (4.3%) for this affliction with 55 cases detected (Fig. 6.5.2b). Hyperpigmented irritations affected corals in all size classes and in varying degrees of severity, ranging from mild to acute, and were found mainly in the genera *Montastrea* (42%), *Favia* (35%), *Montipora* (10%), and *Porites* (5%). Filamentous algal overgrowth was associated with many of the above-mentioned lesions (Fig. 6.5.2c).

Lesions attributable to predation ranked as the second most prevalent fitness-impairing

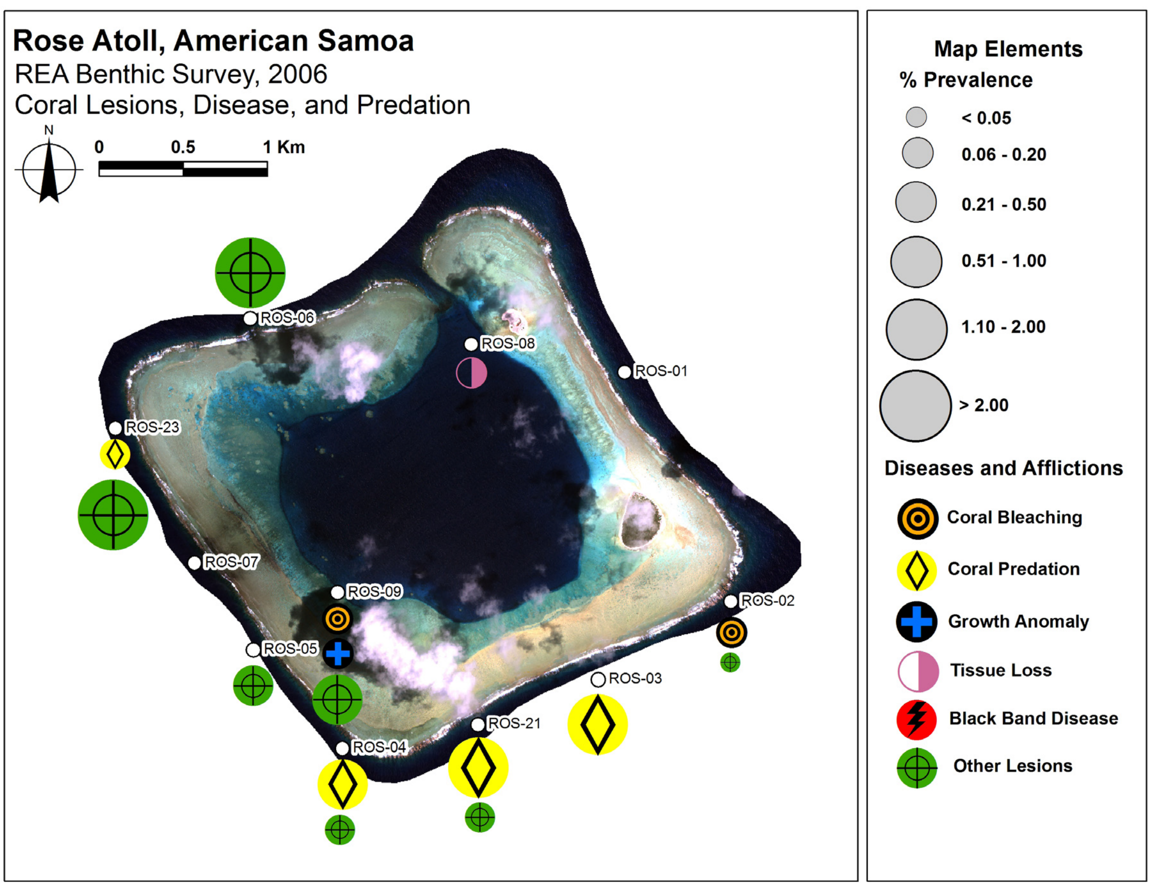

Figure 6.5.2a. Prevalence of predation, bleaching, growth anomalies, tissue loss, black band disease, and other lesions at Rose during ASRAMP 2006. Prevalence was calculated relative to the average colony density estimates and is indicated by the size of the respective symbols.

condition around Rose during ASRAMP 2006. Predation was observed at sites ROS-03, ROS-04, and ROS-21 around the southern point, and site ROS-23 at the western point, mostly affecting colonies of the genus *Pocillopora*. Prevalence values ranged between 0.9% and 1.3% (Figs. 6.5.2a and 6.5.2b). The type and size of feeding scars is indicative of *Drupella* predation. Because of the lack of coral health and disease assessments at Rose prior to 2006, an evaluation of the impact of predation is precluded; further research on this matter is needed.

Other coral diseases and lesions detected on corals around Rose during ASRAMP 2006

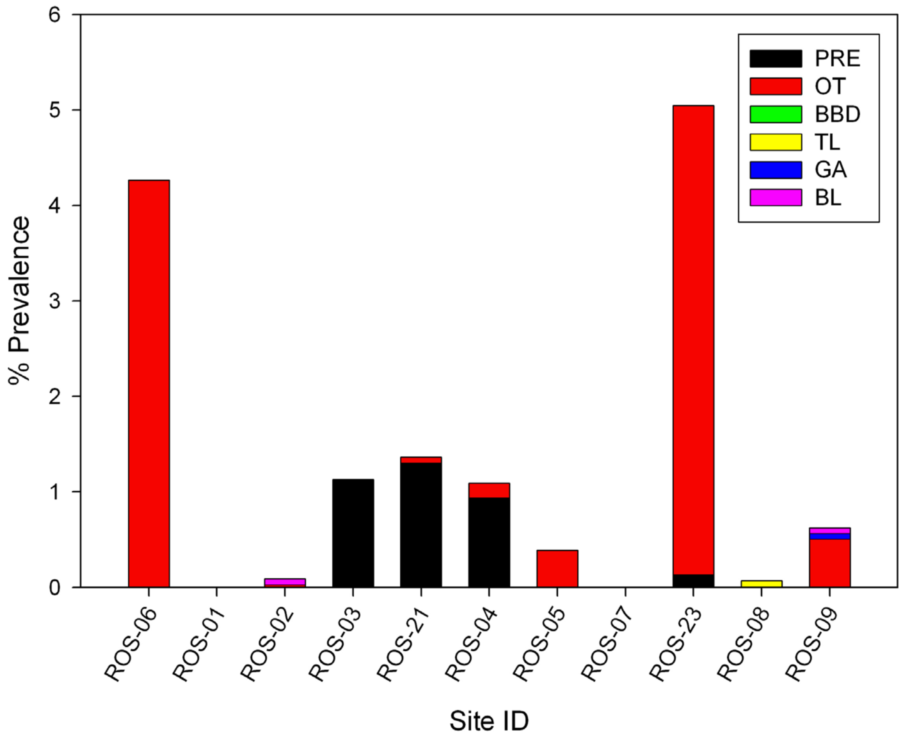

Figure 6.5.2b. Prevalence of predation, bleaching, growth anomalies, tissue loss, black band disease, and other lesions at Rose during ASRAMP 2006. Prevalence was calculated relative to the average colony density estimates. PRE—*Acanthaster* and/or *Drupella* predation; OT—other lesions, including hyperpigmented irritations; BBD— black band disease; TL— tissue loss; GA—skeletal growth anomalies; and BL— bleaching.

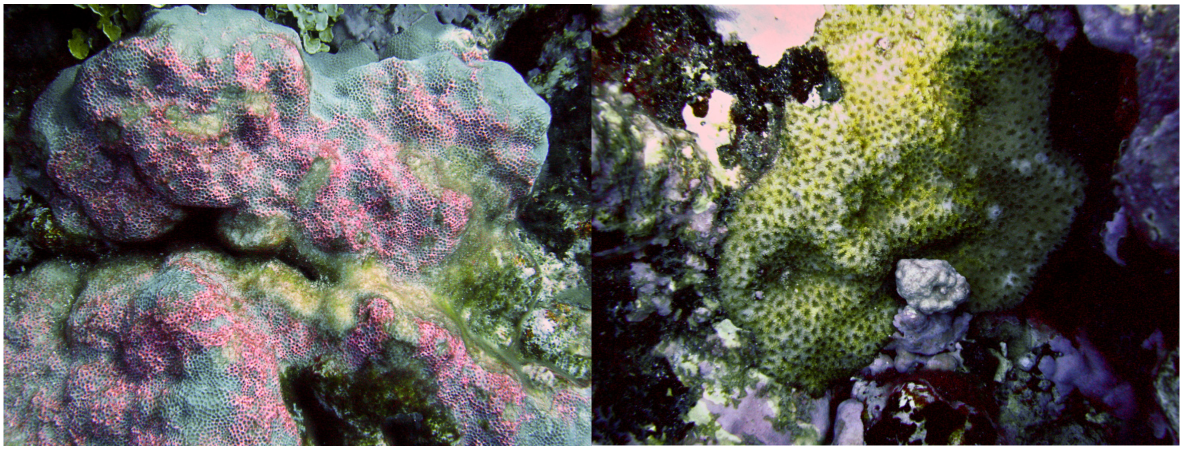

Figure 6.5.2c. Rose; pink-shaded irritation on *Porites* sp. (left panel) and yellow-shaded, irritation with filamentous algal overgrowth on *Favia stelligera* (right panel). Close-up inspection revealed yellow discoloration corresponding to areas of filamentous algal overgrowth. (*Photograph provided by NOAA PIFSC CRED; B. Vargas-Angel, JIMAR*)

included three cases of bleaching, one case of skeletal growth anomaly, and one case of tissue loss. The two latter cases were observed at site ROS-08 inside the lagoon. The above-mentioned diseases were detected on colonies of *Pocillopora*, *Astreopora*, and *Acropora*, respectively. As at other sites in the American Samoa Archipelago, coral bleaching at Rose was generally mild and focal.

6.5.3 Temporal Comparison—Coral and Coral Disease

Live scleractinian coral cover observed in towed-diver benthic surveys around Rose during the three ASRAMP cruises remained relatively consistent. Coral cover on the forereef habitats ranged from 20.1% (SE 1.8; 2006) to 29.1% (SE 2.0; 2002; Fig. 6.5.3a). Coral cover in the lagoon was markedly lower, ranging from 1.5% (SE 0.5; 2004) to 5.9% (SE 0.9; 2006; Fig. 6.5.3b). Forereef coral cover data from towed-diver surveys and REA surveys were relatively similar, with island-wide mean differences no greater than ~ 15%.

In contrast, the estimate of REA mean live coral cover in the lagoon was extremely uncertain, as depicted by the high standard error (Fig. 6.5.3b). Percent cover of live coral from REA surveys was consistently higher than values recorded during the towed-diver benthic surveys (Fig. 6.5.3b). This difference was probably a result of REA site selection, which targeted hard-bottom substrate and coral pinnacles. The majority of the lagoon at Rose was composed of soft, sandy bottom interspersed with coral rubble, with little coral cover aside from coral

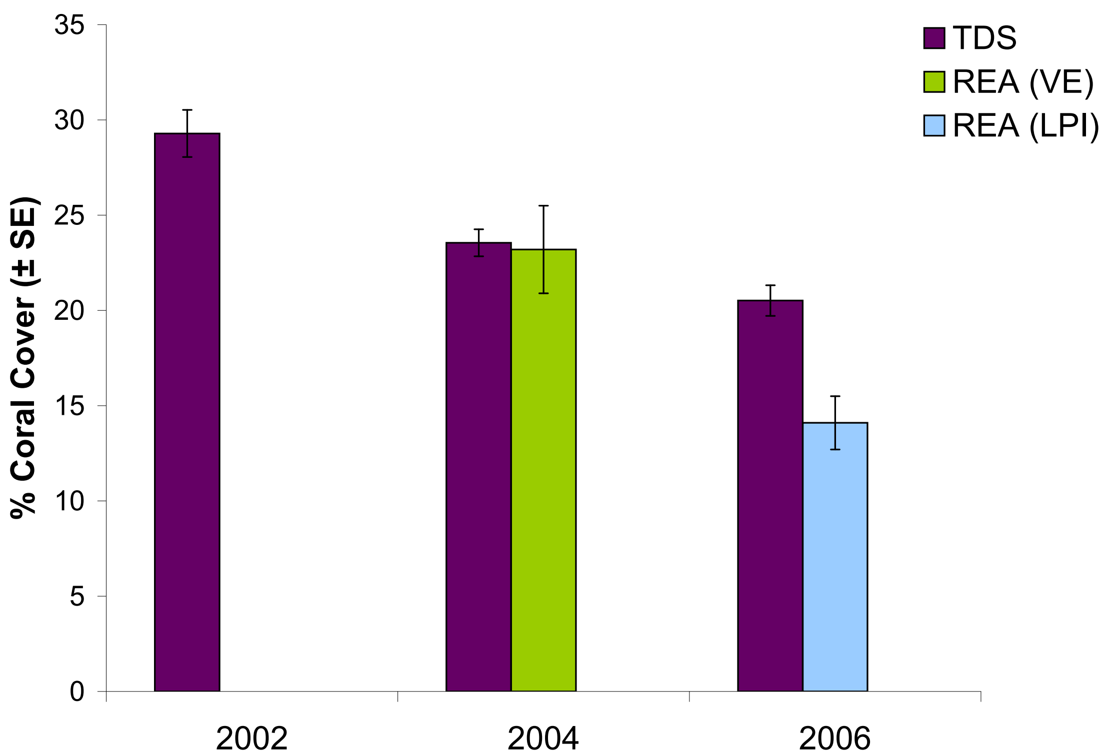

Figure 6.5.3a. Temporal comparison of mean percent live coral cover from REA surveys and towed-diver surveys around the forereef Rose during ASRAMP 2002, 2004, and 2006 surveys. The purple bars represent observations collected during towed-diver habitat surveys. The green bar represents REA data collected by visual estimates (VE) during REA surveys, and the blue bar represents data collected by the line point intercept (LPI) 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.

pinnacles and small isolated patch reefs. Because towed-diver surveys averaged benthic cover over 5-min, 200-m (approx.) observation segments, it is not surprising that mean live percent coral cover was significantly lower than in REA surveys.

General trends in coral cover and coral density were observed around Rose, with low coral cover and density recorded at site ROS-06 in the northwest region of the atoll, while high cover and density were found at site ROS-09 inside the lagoon (Fig. 6.5.1o). Mean generic

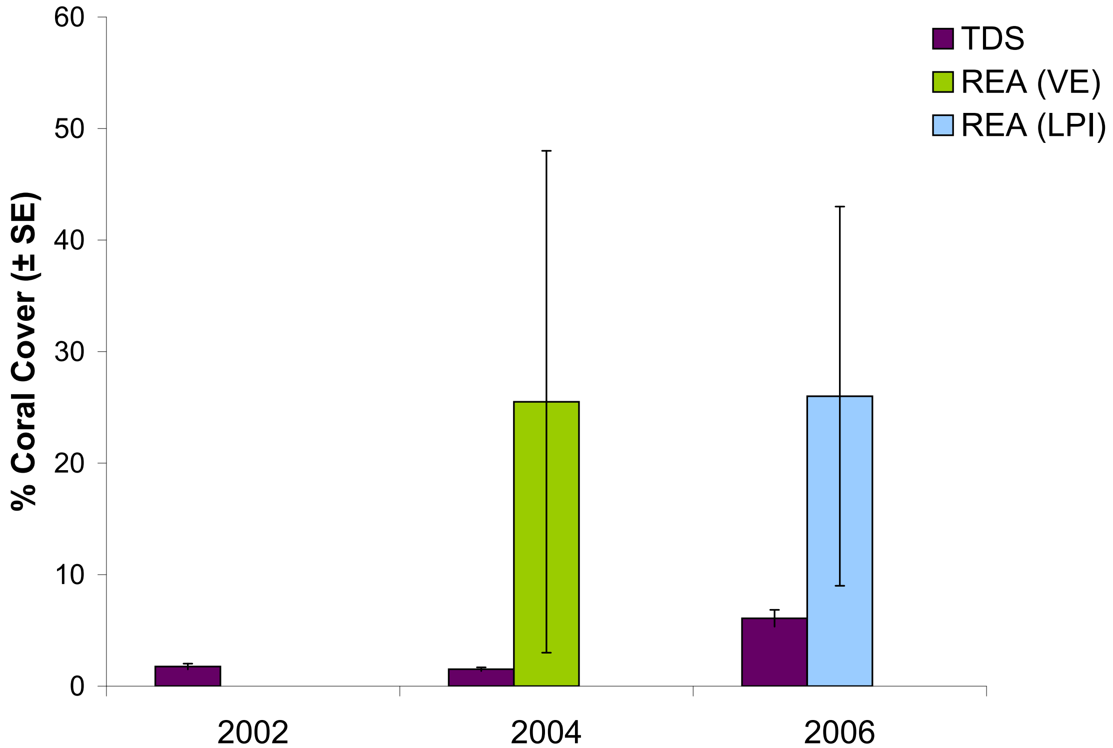

Figure 6.5.3b. Temporal comparison of mean percent live coral cover from REA surveys and towed-diver surveys in the lagoon of Rose Atoll during ASRAMP 2002, 2004, and 2006 surveys. The purple bars represent observations collected during towed-diver habitat surveys. The green bar represents REA data collected by visual estimates (VE) during REA surveys, and the blue bar represents data collected by the line point intercept (LPI) 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.

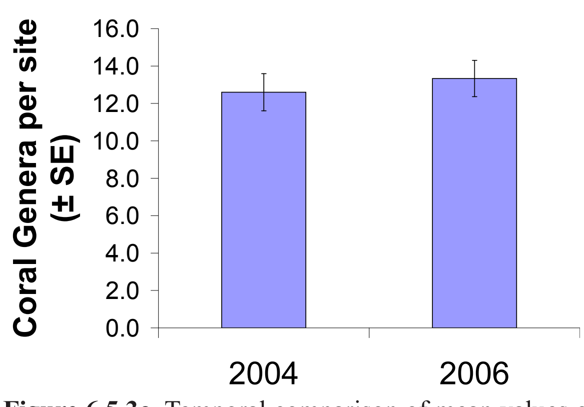

Figure 6.5.3c. Temporal comparison of mean values of coral genera per site on forereef habitats around Rose during ASRAMP 2004 and 2006 REA surveys.

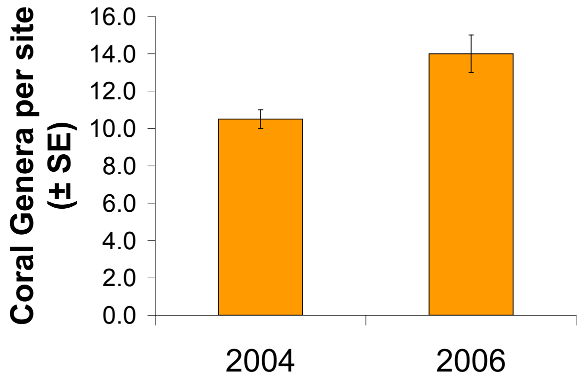

Figure 6.5.3d. Temporal comparison of mean values of coral genera per site on lagoon habitats at Rose during ASRAMP 2004 and 2006 REA surveys.

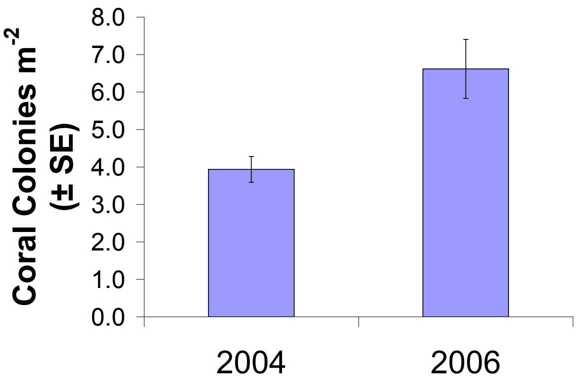

Figure 6.5.3e. Temporal comparison of mean coral colony density from REA surveys on forereef sites around Rose during ASRAMP 2004 and 2006.

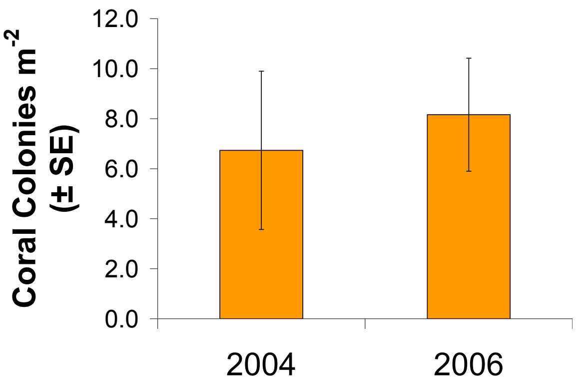

Figure 6.5.3f. Temporal comparison of mean coral colony density from REA surveys on lagoon habitats at Rose during ASRAMP 2004 and 2006.

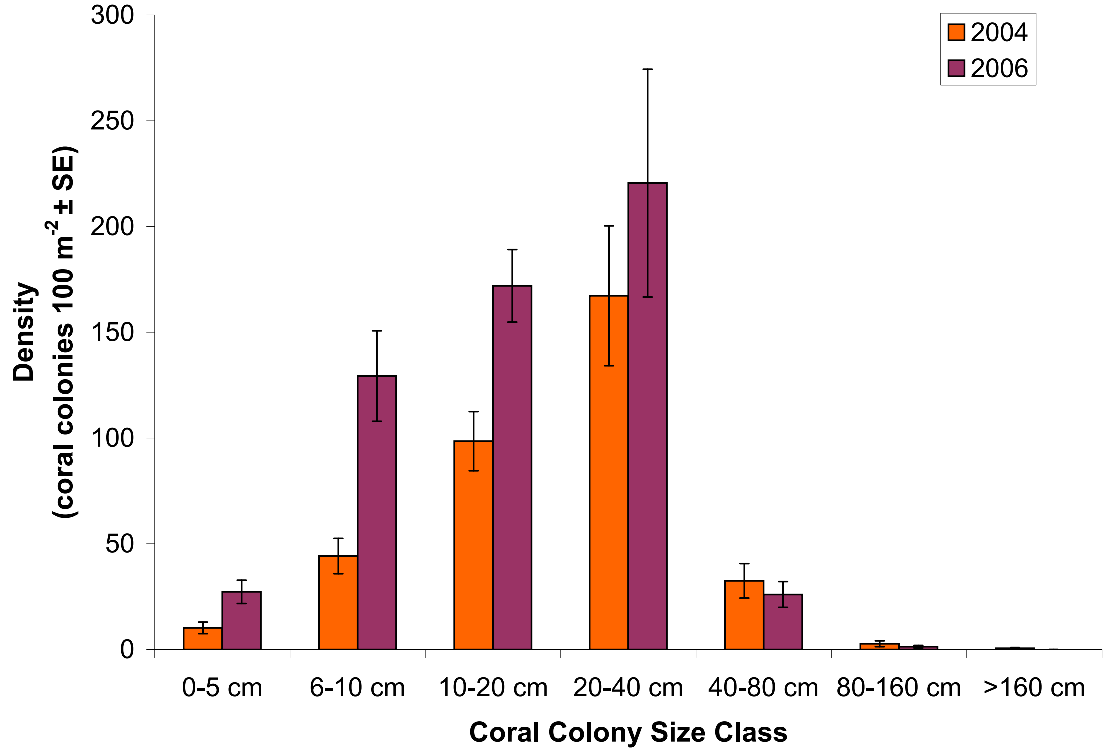

Figure 6.5.3g. Coral colony size class mean density from REA surveys at forereef sites around Rose during ASRAMP 2004 and 2006.

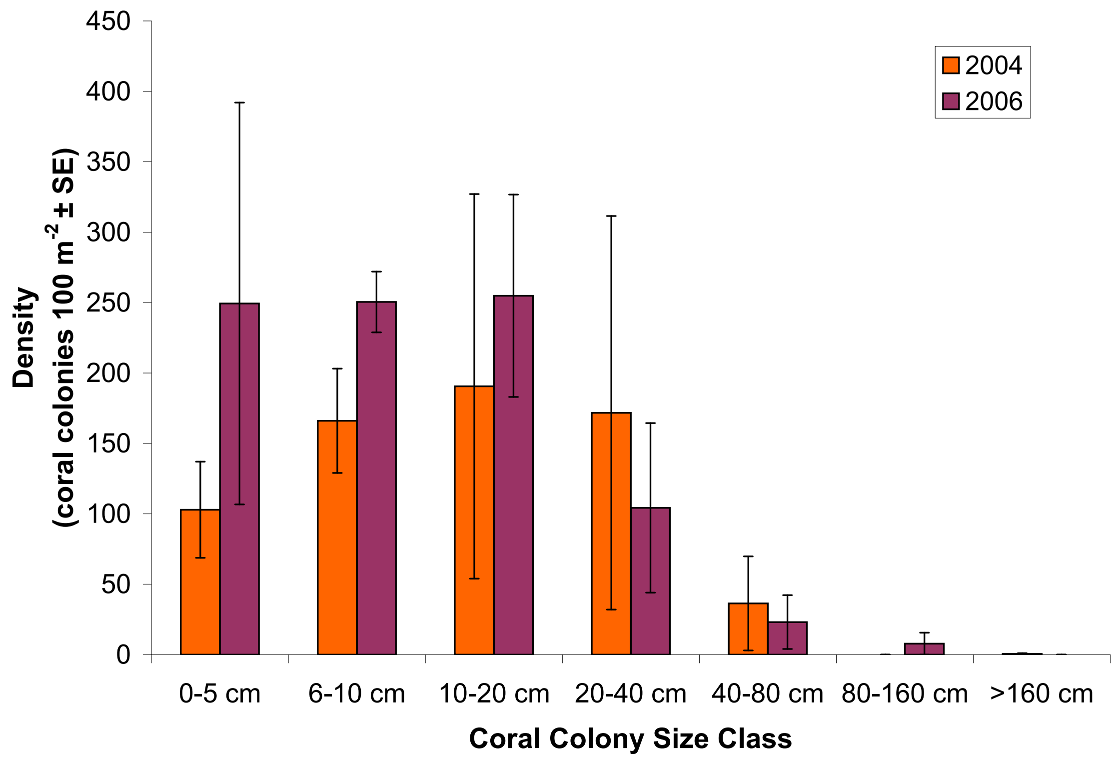

Figure 6.5.3h. Coral colony size class mean density from REA surveys on lagoon habitats at Rose during ASRAMP 2004 and 2006.

richness at forereef sites did not vary substantially between 2004 and 2006 (Fig. 6.5.3c), but somewhat higher generic richness was documented at the two lagoon sites in 2006 than in 2004 (Fig. 6.5.3d); site ROS-02 off the southeast corner of Rose exhibited the highest diversity (16-17 genera) and site ROS-07 in the southwest region (the ship grounding site) with the lowest recorded diversity (7-9 genera) in both quantitative survey years. Interestingly, site ROS-02, which had the highest generic diversity, also had low coral cover, thereby supporting two points stressed throughout this report: (1) different quantitative parameters describing coral communities (percent cover, colony density, diversity) were not necessarily congruent in the magnitude of their values at a given site, and (2) more than a single parameter should be considered in assessing the value or condition of coral communities.

Atoll-wide, mean coral colony densities increased from 4.4 colonies m^{-2} in 2004 to 6.8 colonies m^{-2} in 2006 (Figs. 6.5.3e and 6.5.3f). Even when site ROS-22, which was not resurveyed in 2006, was removed from the analysis, there was a substantial difference noted between mean coral density at Rose between 2004 and 2006. As with the apparent parallel increase in coral density at Ofu/Olosega and at Ta`u from 2004 to 2006, it is difficult to know if this potential change, which could result from new recruits to the population or fragmentation/fissioning of existing colonies, is “real” or an artifact of interobserver error. In this regard, it is interesting to note that site ROS-03 was observed to have among the lowest coral densities in 2004 (2.9 colonies m^{-2}) but the highest coral density in 2006 (10.4 colonies m^{-2}).

During ASRAMP 2006, two coral biologists conducted population parameter surveys. One biologist enumerated all colonies > 5 cm maximum diameter, while the second biologist closely inspected the benthos for very small (< 5 cm) colonies. While this experimental alteration of survey protocols, which was undertaken only at site ROS-03, may result in more accurate data, it appeared to have biased temporal comparisons as a result of the increased small colony search effort. This provided another useful lesson for stabilizing personnel allocations and method protocols in 2008 so that improved comparisons could be made in future surveys.

The lack of large (> 80 cm) colonies at Rose in 2004 and 2006 suggests that most large corals at the shallow depths died after the 1994 bleaching event, and that coral recovery remains ongoing (Figs. 6.5.3g and 6.5.3h). The proportion of corals in medium (20–40 cm) and medium-large (40–80 cm) size classes was reduced in 2006 compared to 2004. Overall, 48% of corals belonged to these size classes (i.e., 20–80 cm) in 2004, compared to 31% in 2006. The correspondingly higher proportion of corals in smaller size classes in 2006 (i.e. 0–20 cm) was consistent with the calculated higher density values. Hurricanes Olaf and Percy in early 2005, which may have moved the anchored 1200-lb CREWS buoy inside the protected lagoon, could potentially explain the smaller corals observed in 2006. These tropical cyclones may have caused considerable damage to the shallower reefs, including fragmentation of corals, resulting in increased densities and a shift to smaller size classes.

6.6 Algae

6.6.1 Algal 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.

2002 Spatial Surveys

A total of 18 towed-diver benthic surveys were conducted around Rose during ASRAMP 2002. Fleshy macroalgae and crustose coralline red algae covered, on average, 58.1% of the forereef and 10.3% of the backreef and lagoon substrate. On the forereef habitats, mean fleshy macroalgal cover was 19.0% (SE 0.9) and mean crustose coralline algal cover was 39.1% (SE 1.5) of the benthic substrate (Fig. 6.6.1a). On the backreef and lagoon habitats, mean fleshy macroalgal cover was 10.2% (SE 1.6), and mean crustose coralline algal cover was 10.2% (SE 0.8; Fig. 6.6.1a). Highest percent cover of fleshy macroalgae was observed along the northwest, southwest, and southeast forereef slopes of the atoll. The highest percent cover of crustose coralline algae was observed near the westernmost, easternmost, and southernmost points of the atoll, all likely areas of moderate-to-high wave energy and current flow. Lowest coralline algal cover was observed in the lagoon.

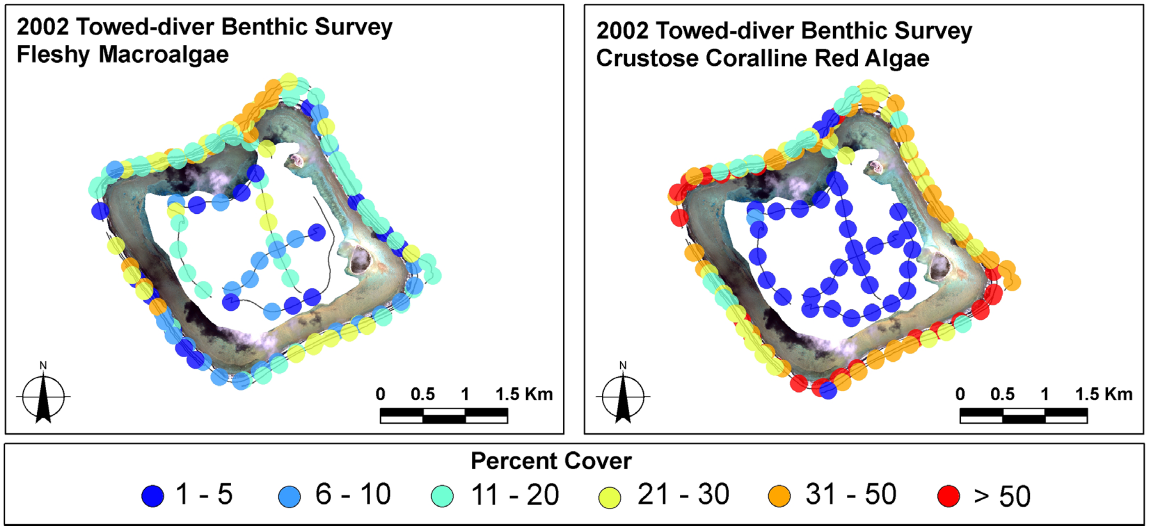

Figure 6.6.1a. Percent cover of fleshy macroalgae (including turf algae) and crustose coralline algae from towed-diver benthic surveys around Rose during ASRAMP 2002. Each colored point represents an integrated estimate computed over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2).

Qualitative REA algal surveys were conducted in and around Rose during ASRAMP 2002, and 11 bags of algal voucher specimens were collected. These surveys provided baseline data to be used in designing and scaling the future methodology of algal REA surveys.

2004 Spatial Surveys

A total of 22 towed-diver benthic surveys around Rose during ASRAMP 2004 recorded a mean combined algal cover (including macroalgae, turf, and crustose coralline algae) of 71.1% in the forereef habitats and 37.8% in the lagoon habitats. On the forereef, mean fleshy macroalgal cover (including turf) was 27.6% (SE 1.1), and mean crustose coralline algal cover was 43.5% (SE 1.3; Fig. 6.6.1b). In the lagoon habitats, mean fleshy macroalgal cover (including turf) was 25.5% (SE 2.0), and mean crustose coralline algal cover was 11.2% (SE 2.0; Fig. 6.6.1b). Generally, higher cover of macroalgae was observed along the southwest and southeast forereefs and in lagoonal areas. Coralline algae were most abundant near the westernmost, easternmost, and southernmost points of the island, all likely areas of moderate-to-high wave energy and current flow.

During ASRAMP 2004, quantitative algal REA surveys were conducted at 12 sites around Rose (Fig. 6.6.1c). A total of 13 macroalgal genera (6 green, 4 red, and 3 brown) and 4 additional algal functional groups (turf algae, crustose coralline red algae, branched non-geniculate coralline red algae, and cyanophytes) were observed in the field. Once completed, laboratory-based taxonomic identification of all algal species (including turf algae, epiphytes, and crustose coralline red algae) will greatly increase the known algal diversity. Crustose coralline red algal and turf algal functional groups (each of which contain numerous species) were the dominant algae found, being observed in more than 50% of sampled quadrats at 83% of sites. The lagoon sites at Rose were dominated by algal turf, low abundances of crustose coralline red algae, and a few cyanophytes. No macroalgal genera were found at the lagoon sites.

Several clear distributional trends were observed among macroalgal populations around Rose during ASRAMP 2004. Most outer forereef sites around Rose contained high abundances of the sand producing green alga, *Halimeda*, although population numbers of this genus were low on east-facing forereefs, and at site ROS-07 (shipwreck grounding site). At southeast

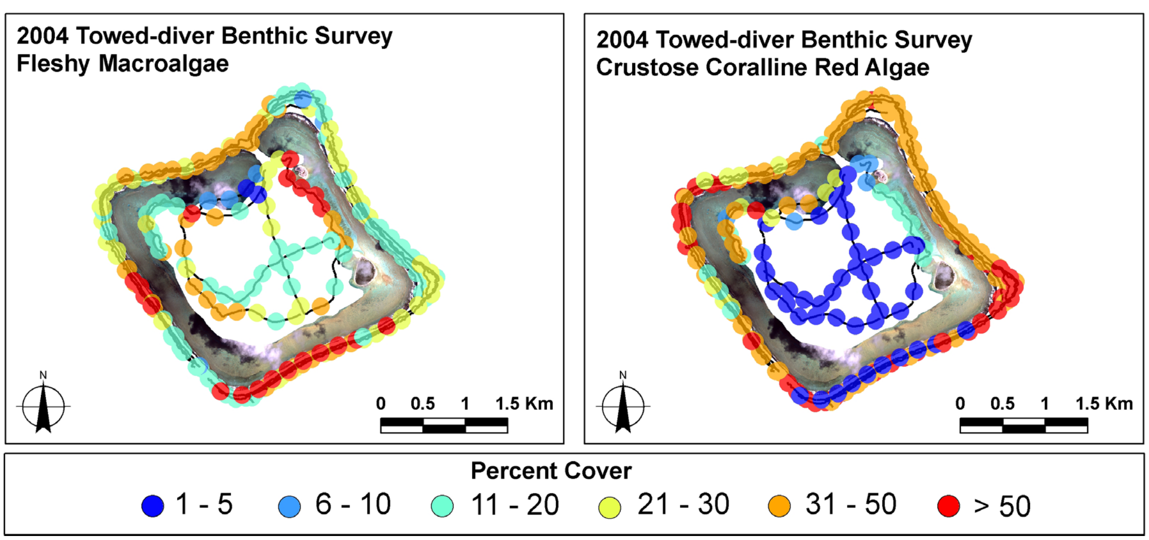

Figure 6.6.1b. Percent cover of fleshy macroalgae (including turf algae) and crustose coralline algae from towed-diver benthic surveys around Rose during ASRAMP 2004. Each colored point represents an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m^2).

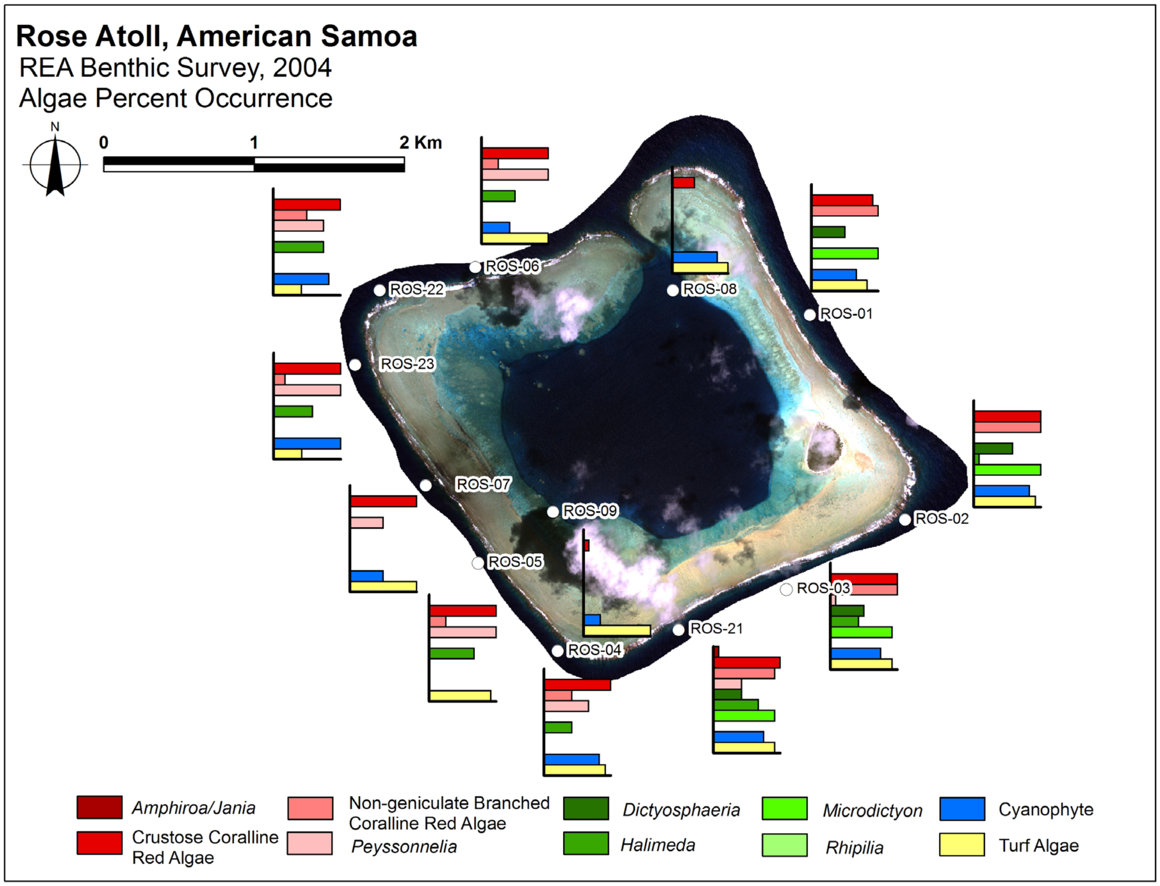

Figure 6.6.1c. Percent occurrence of select macroalgal genera and algal functional groups from REA surveys around Rose during ASRAMP 2004. Percent occurrence is equivalent to the percentage of photoquadrats in which an algal genus or functional group was observed. Length of *x*-axis denotes 100% occurrence.

and northeast sites, *Microdictyon umbilicatum* (Velley) Zanardini formed large blades that occurred in more than 90% of the photoquadrats assessed; however, it was completely lacking from photoquadrats at southwest and northwest sites. Another green siphonocladean algal genus *Dictyosphaeria*, a common component of marine algal floras only on the northeast and southeast sides of the island, followed this trend. In contrast to *M. umbilicatum* and species of *Dictyosphaeria*, the red algal genus *Peyssonnelia* was not recorded from photoquadrats at sites ROS-01, ROS-02, and ROS-03 in the northeast and southeast regions on the east side of island but was very abundant at the remaining forereef sites on west and north-facing shores. Although crustose coralline red algae were extremely abundant in all photoquadrats at sites around the perimeter of Rose, other calcified red algal genera were less abundant. The geniculate red algal genera *Amphiroa*/*Jania* were only found in photoquadrats at site ROS-21 in the southeast region and in relatively low abundance. Non-geniculate branched red algae, although found at sites around the perimeter of the island, were most abundant at eastern and southern sites. Of interest, the green alga *Caulerpa cupressoides* (Vahl C. Agardh) was recorded at Rose for the first time and will be a new addition to the species list for American Samoa.

2006 Spatial Surveys

A total of 21 towed-diver benthic surveys that were conducted around Rose during ASRAMP

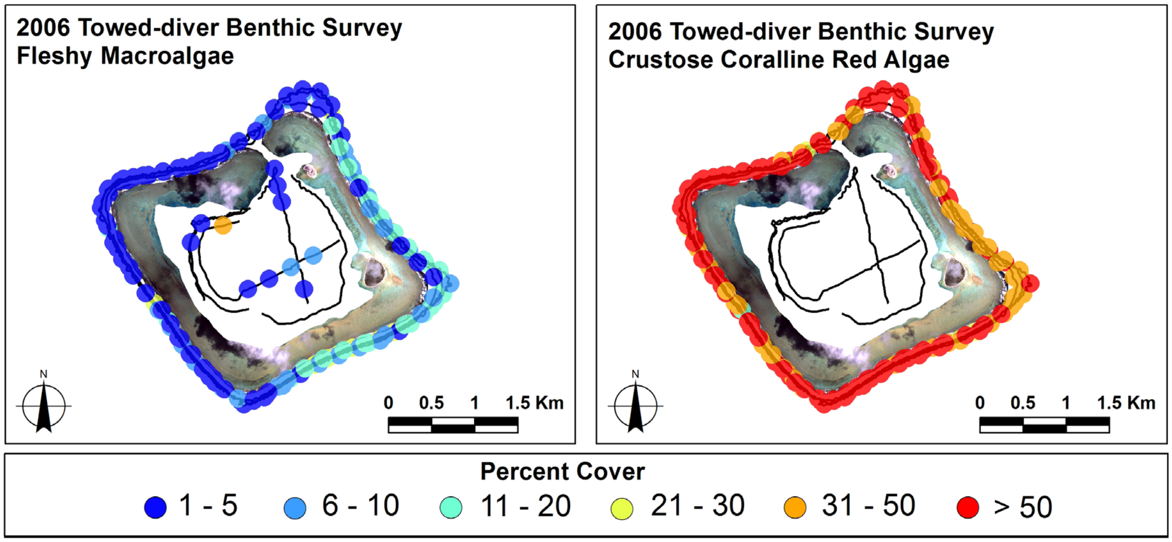

Figure 6.6.1d. Percent cover of fleshy macroalgae (including turf algae) and crustose coralline algae from towed-diver benthic surveys around Rose during ASRAMP 2006. Each colored point represents an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 2000 m²).

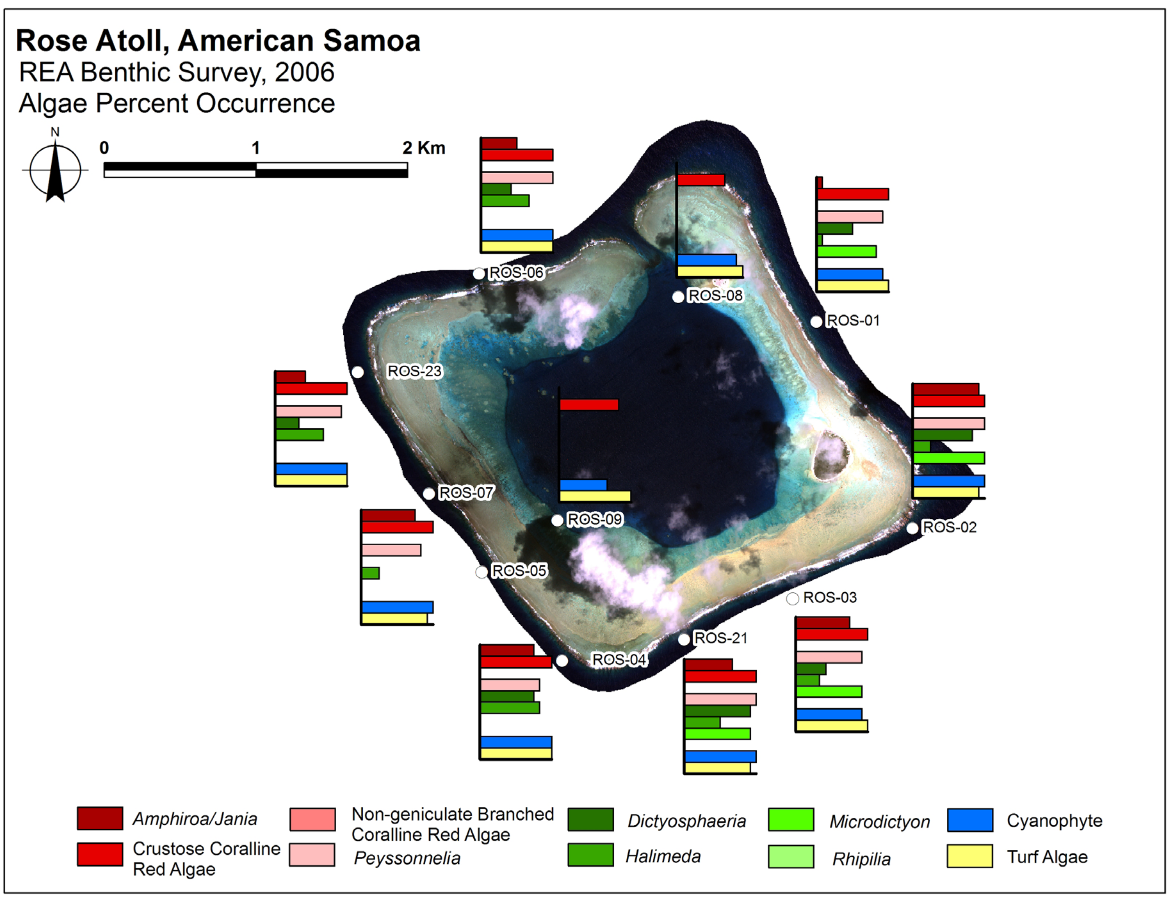

Figure 6.6.1e. Percent occurrence of select macroalgal genera and algal functional groups from REA surveys around Rose during ASRAMP 2006. Percent occurrence is equivalent to the percentage of photoquadrats in which an algal genus or functional group was observed. Length of *x*-axis denotes 100% occurrence.

2006 recorded a mean combined algae cover (fleshy macroalgae and crustose coralline, excluding turf algal) of 62.5% on the forereef habitats. On the forereef, mean fleshy macroalgal cover was 7.0% (SE 0.5), and mean crustose coralline algal cover was 55.5% (SE 1.2; Fig. 6.5d). In the lagoon, mean fleshy macroalgal cover was 1.4% (SE 0.8), and crustose coralline red algae was not recorded (Fig. 6.6.1d). Crustose coralline algae were prevalent around the outer portion of the atoll, but were scarce in the lagoon. Macroalgal populations were low around the island but exhibited the highest percent cover along eastern shores and in a single, localized spot in the northwestern part of the lagoon.

During ASRAMP 2006, quantitative algal REA surveys were conducted at 11 sites that were previously surveyed in 2004, with 9 sites on the outer forereef, and 2 sites within the lagoon (Fig. 6.6.1e). At site ROS-05, only qualitative information was collected because of weather conditions. Twenty macroalgal genera (11 green, 7 red, and 2 brown) and 3 additional algal functional groups (turf algae, crustose coralline red algae, and cyanophytes) were observed in the field. Crustose coralline red algal and turf algal functional groups (each of which contain numerous species) were the dominant algae found, being observed in more than 50% of sampled quadrats at 100% of the sites. The central lagoon of Rose was dominated by algal turf, low abundances of crustose coralline red algae, and a few cyanophytes. No macroalgal genera were found within the lagoon. With the exception of the red alga *Peyssonnelia*, which was very abundant at most outer reef sites, many of the distributional trends of macroalgal populations observed around Rose in 2004 were observed again in 2006. At southeast and

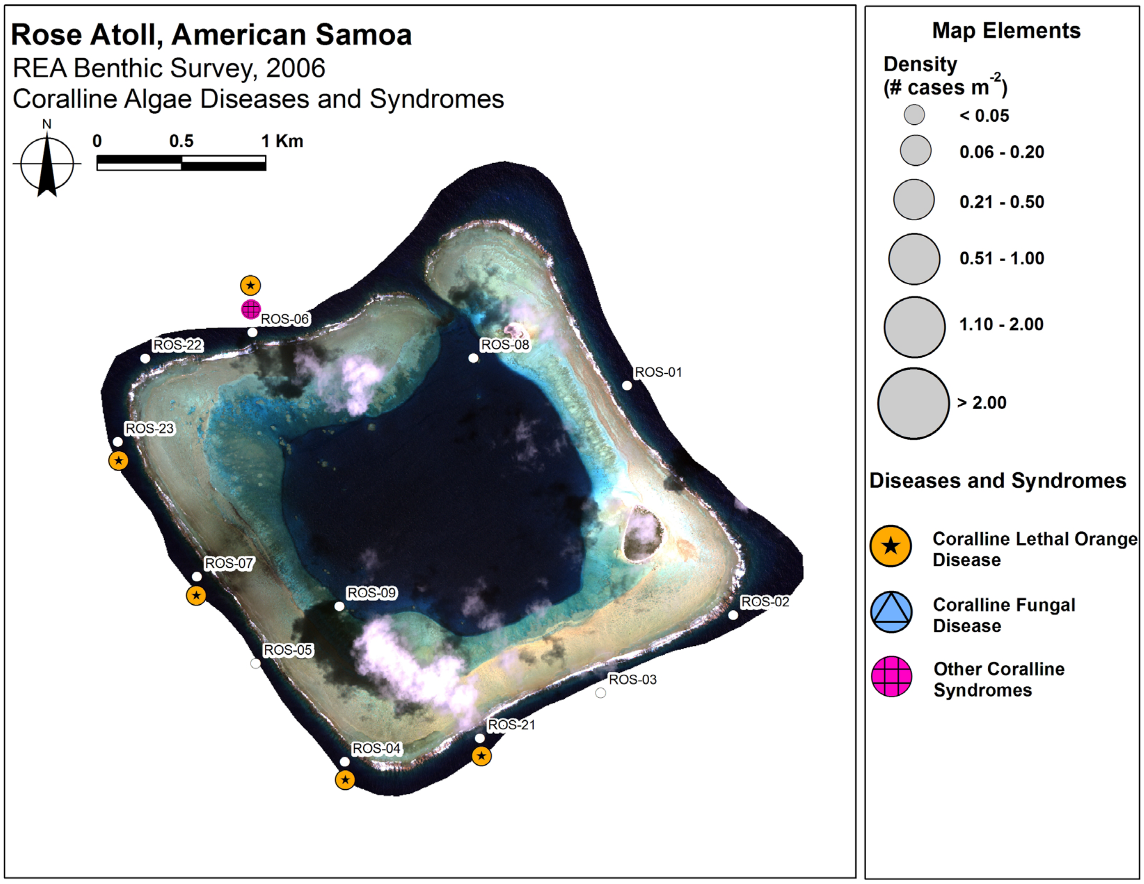

Figure 6.6.2a. Relative abundance of coralline algal diseases around Rose during ASRAMP 2006. Disease density is indicated by the size of the respective disease symbols.

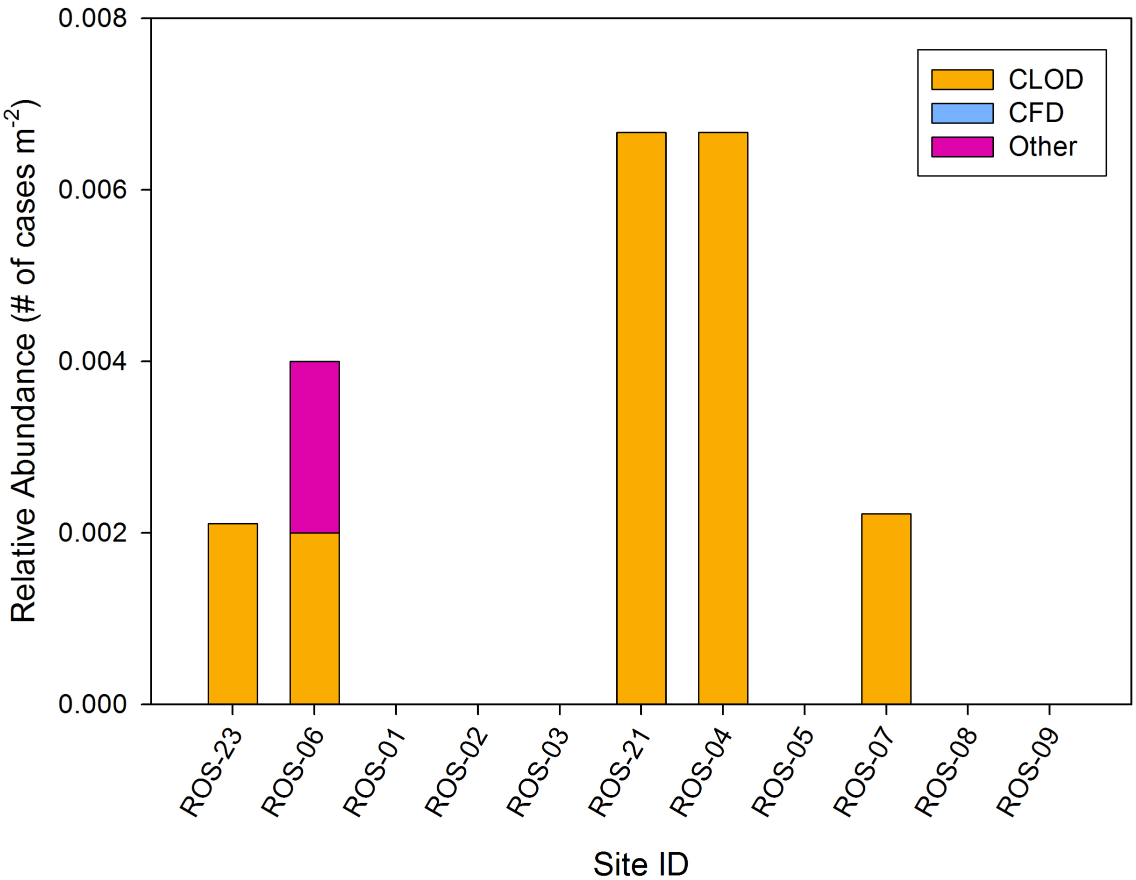

Figure 6.6.2b. Relative abundance (# cases m^{-2}) of coralline algal disease around Rose during ASRAMP 2006. CLOD: coralline lethal orange disease; CFD: coralline fungal disease; and Other: undetermined coralline discolorations.

northeast sites, *Microdictyon umbilicatum* (Velley) Zanardini formed large blades that occurred in more than 90% of photoquadrats assessed; however, it was completely lacking from photoquadrats on northwest and southwest sites and inside the central lagoon. Most outer forereef sites around Rose contained high abundances of the sand producing green alga *Halimeda*.

6.6.2 Coralline Algal Disease Surveys

2006 Spatial Surveys

Relatively few coralline algae diseases and syndromes were noted around Rose during ASRAMP 2006 REA surveys. Nine cases of coralline lethal orange disease and one case of unidentified coralline discoloration were observed. Figures 6.6.2a and 6.6.2b illustrate the variation in relative abundance of coralline algal disease among sites around Rose.

6.6.3 Temporal Comparison—Algae

Temporal comparisons of both REA algal data and towed-diver benthic survey data are shown in Figures 6.6.3a, 6.6.3b, and 6.6.3c, respectively. The number of macroalgal genera observed

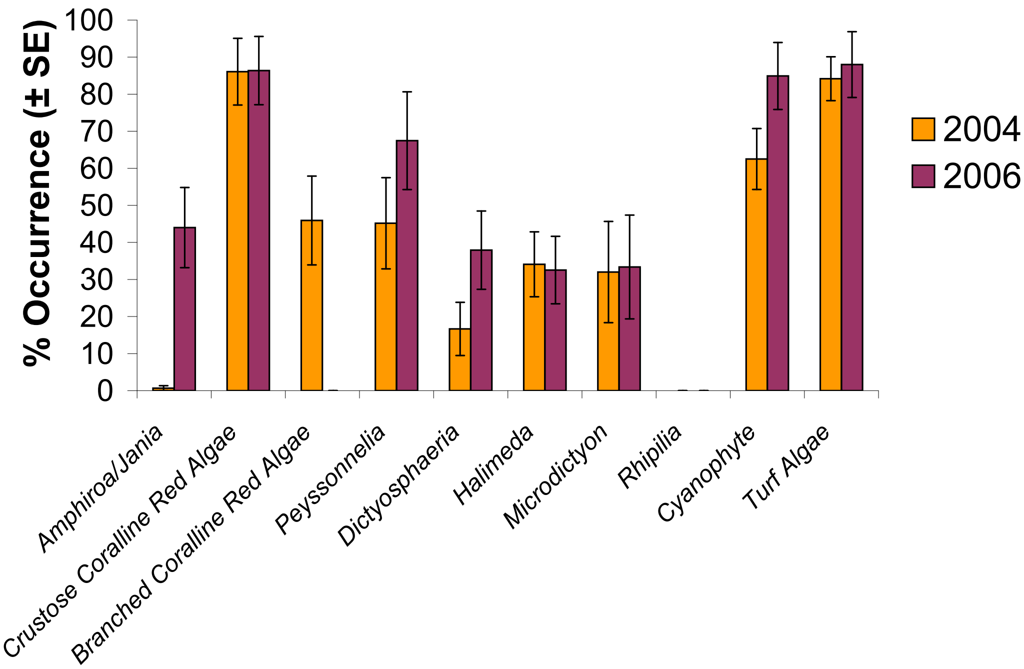

Figure 6.6.3a. Temporal comparison of REA algal genera and functional group percent occurrence around Rose between ASRAMP 2004 and 2006. See Chapter 2, Section 2.4: Reef Benthic (Coral, Algae, Macroinvertebrate) and Fish Surveys for considerations when comparing the results of these methodologies between years.

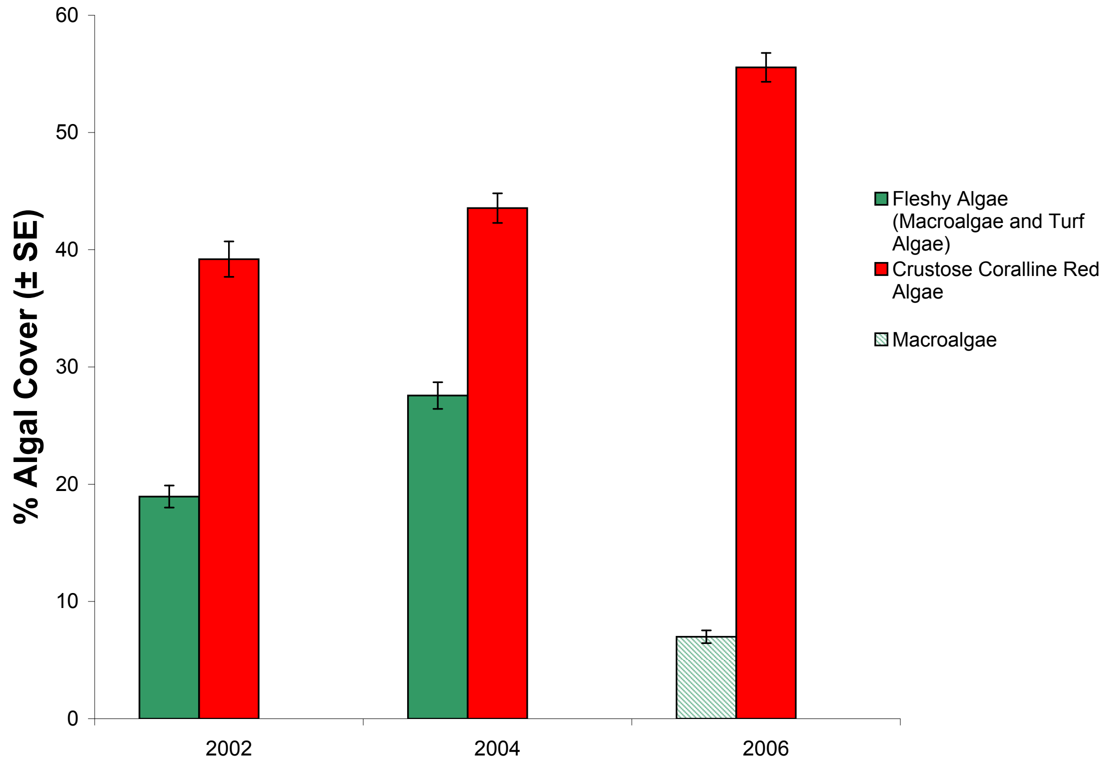

Figure 6.6.3b. Temporal comparison of towed-diver benthic survey algal percent cover results for fleshy, crustose coralline, and macroalgae for ASRAMP 2002, 2004, and 2006 surveys around Rose forereef habitats.

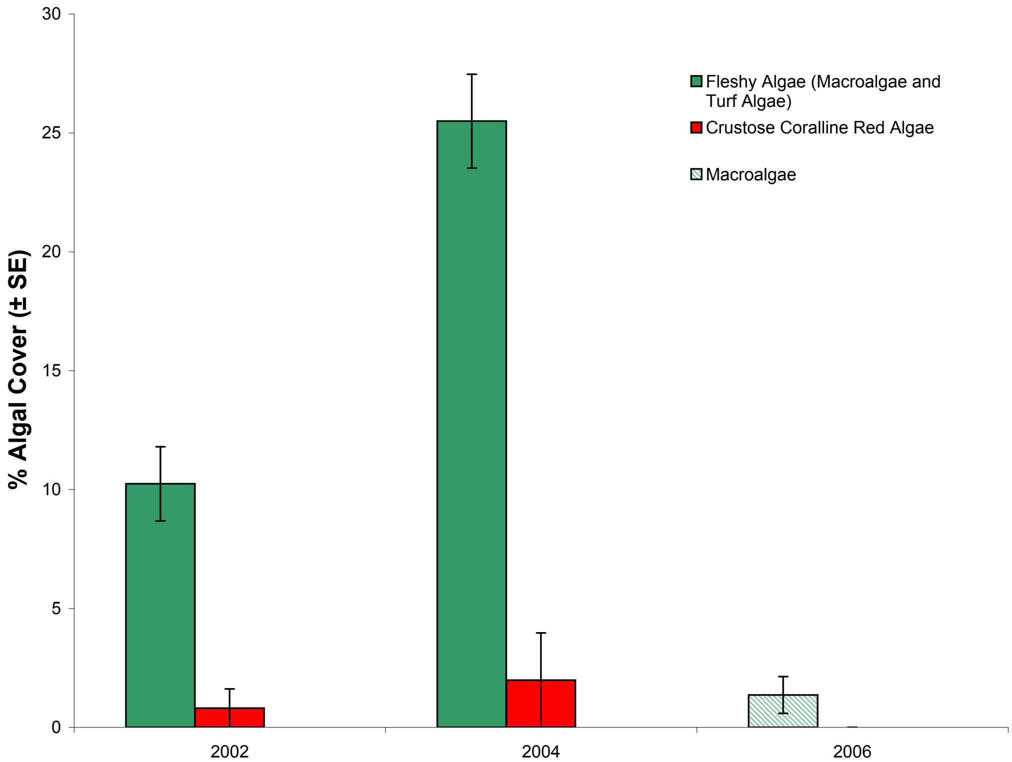

Figure 6.6.3c. Temporal comparison of towed-diver benthic survey algal percent cover results for fleshy, crustose coralline and macroalgae for ASRAMP 2002, 2004, and 2006 surveys in Rose lagoon habitats.

around Rose increased from 13 in 2004 to 20 in 2006, and the relative abundance of fleshy and calcified macroalgal genera also appeared to increase between sampling years. The apparent lower algal diversity and abundance in 2004 was likely caused by the passage of Hurricane Heta close to Rose in January of 2004, immediately prior to surveys. A manuscript currently being written by Cooper-Alletto and Vroom explores changes to benthic algal communities at Rose among sampling years.

Unlike the 2004 surveys, where the red alga *Peyssonnelia* was restricted to the northwest and southwest regions of the island, this genus was a very common component of most sites sampled in 2006. Populations of other algae remained similar. As in 2004, the central lagoon was dominated by turf algae and cyanophytes, with no low abundance of crustose coralline algae and no macroalgal genera encountered in the photoquadrats. No large cyanobacterial outbreaks or monotypic stands of invasive algae were discovered at Rose in 2004 or 2006.

6.7 Benthic Macroinvertebrates

6.7.1 Benthic Macroinvertebrate Surveys

2002 Spatial Surveys

Towed-diver benthic macroinvertebrate surveys around Rose during ASRAMP 2002 found few target macroinvertebrates (Fig. 6.7.1a). 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 paucity of macroinvertebrates observed in 2002.

A total of 6 qualitative REA invertebrate surveys, focusing on general macroinvertebrate biodiversity, were conducted around Rose during ASRAMP 2002. These surveys provided baseline data to be used in designing and scaling the future methodology of macroinvertebrate REA surveys. No data are presented.

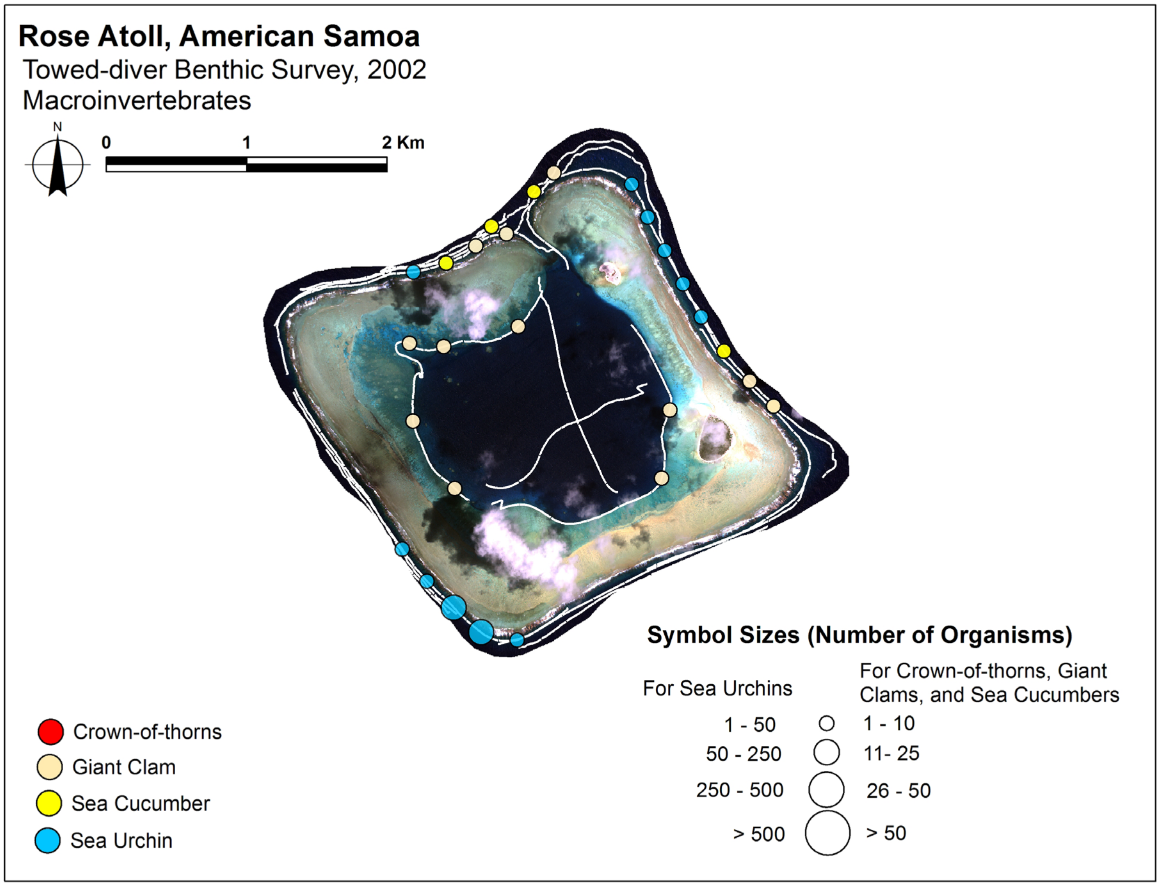

Figure 6.7.1a. Distribution of estimated population densities of crown-of-thorns seastar (COTS), giant clams, sea cucumbers, and sea urchins at Rose from towed-diver benthic surveys during ASRAMP 2002. Circle locations represent an integrated estimate over 5-min observation segments covering a survey 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).

2004 Spatial Surveys

Towed-diver benthic macroinvertebrate surveys around Rose during ASRAMP 2004 found variable distributions of giant clams and sea cucumbers and few sea urchins (Fig. 6.7.1b). Giant clams were found predominantly inside the lagoon (mean density 102.5 organisms ha^{-1}). Sea cucumbers mean densities were highest inside the lagoon (0.7 organisms ha^{-1}) and within the northeast region (0.7 organisms ha^{-1}). A total of 7 COTS were observed within the lagoon (mean density 0.6 organisms ha^{-1}).

Diversity of macroinvertebrates at REA sites across Rose was variable, ranging from 6 to 22 invertebrate species (Fig. 6.7.1c). Relatively high richness was observed at site ROS-23 within the northwest region. Sea urchins were present at 8 of 12 REA sites, with *Echinostrephus aciculatus* being the most common urchin species encountered. Giant clams were present at sites ROS-06, ROS-21, and ROS-22 on forereef sites in the northwest and southeast regions and at site ROS-09 in the lagoon. One species of sea cucumber, *Holothuria whitmaei*, was observed at sites ROS-06 and ROS-09 in the lagoon. No COTS were recorded.

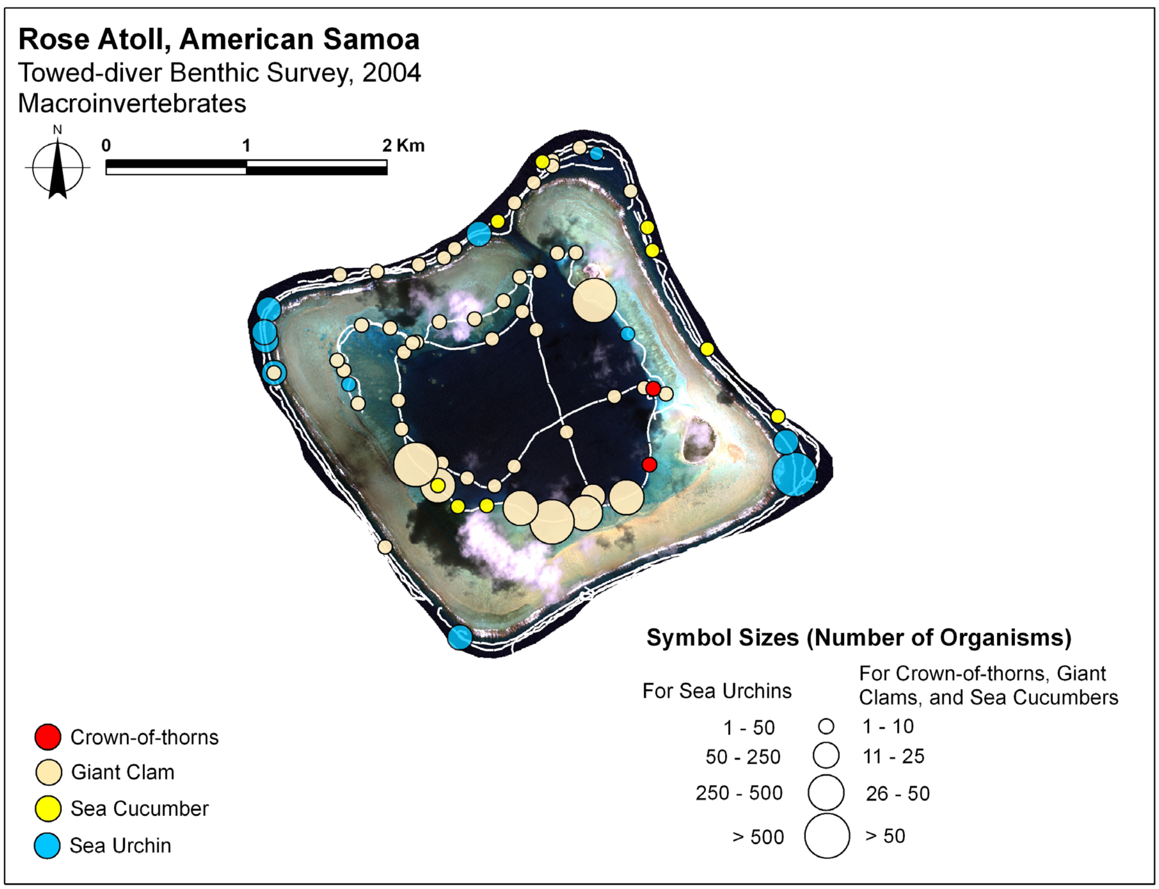

Figure 6.7.1b. Distribution of estimated population densities of COTS, giant clams, sea cucumbers, and sea urchins at Rose from towed-diver benthic surveys during ASRAMP 2004. Circle locations represent an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 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).

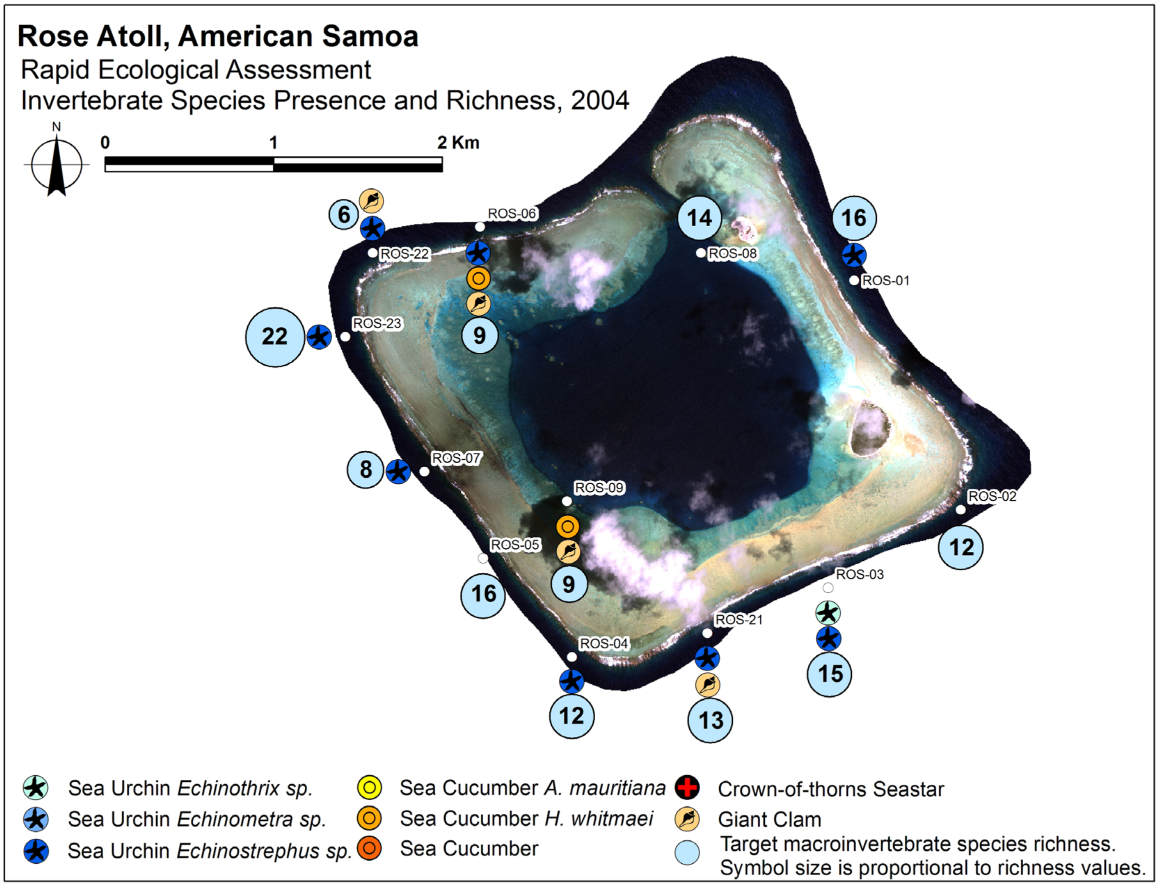

Figure 6.7.1c. Macroinvertebrate species richness, and target macroinvertebrate distribution at Rose from REA surveys during ASRAMP 2004. Size of light blue circles and values in circles indicate target species richness values for each REA site. Other symbols indicate the presence of specific target species.

2006 Spatial Surveys

A total of 21 towed-diver benthic macroinvertebrate surveys around Rose during ASRAMP 2006 found variable distributions of giant clams and sea cucumbers, few sea urchins, and no COTS (Fig. 6.7.1d). Giant clam mean densities were highest inside the lagoon (44.4 organisms ha^{-1}). Relatively high mean densities of sea cucumbers were observed in the northeast region (1.3 organisms ha^{-1}) and inside the lagoon (0.7 organisms ha^{-1}).

REA surveys around Rose during ASRAMP 2006 resulted in a low presence of target invertebrate species (Fig. 6.7.1e). Giant clams were observed at sites ROS-08 and ROS-09 within the lagoon and sites ROS-03 and ROS-05 on the southeast and southwest forereefs, respectively. REA surveys showed urchins to be present at sites ROS-03, ROS-04, and ROS-21 around the southern point in the southeast and southwest forereefs and site ROS-06 on the northwest forereef. *Echinothrix diadema* was the most common urchin species. Only one species of sea cucumber, *Holothuria whitmaei*, was present and was found at site ROS-09 within the lagoon. No COTS were encountered during REA surveys.

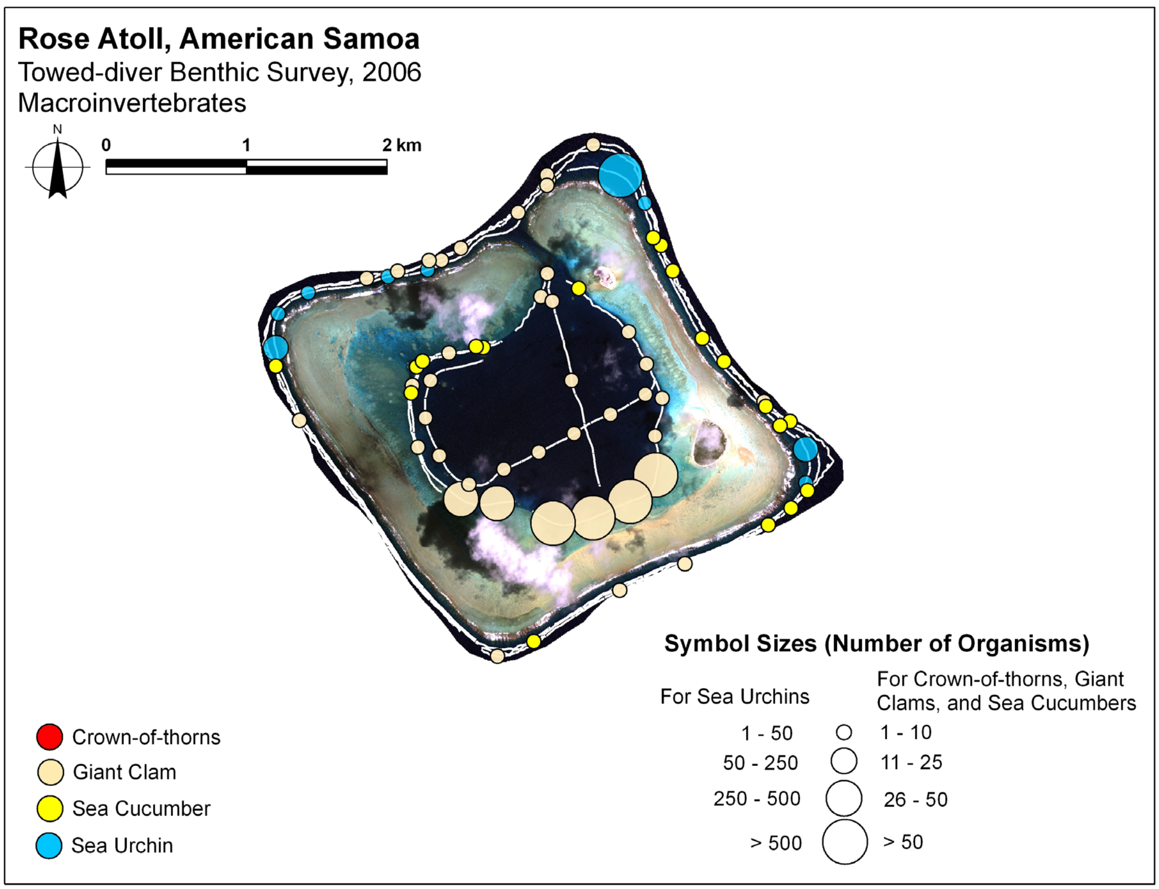

Figure 6.7.1d. Distribution of estimated population densities of COTS, giant clams, sea cucumbers, and sea urchins at Rose from towed-diver benthic surveys during ASRAMP 2006. Circle locations represent an integrated estimate over 5-min observation segments covering a survey swath of ~ 200 m × 10 m (~ 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, 250–500, and > 500).

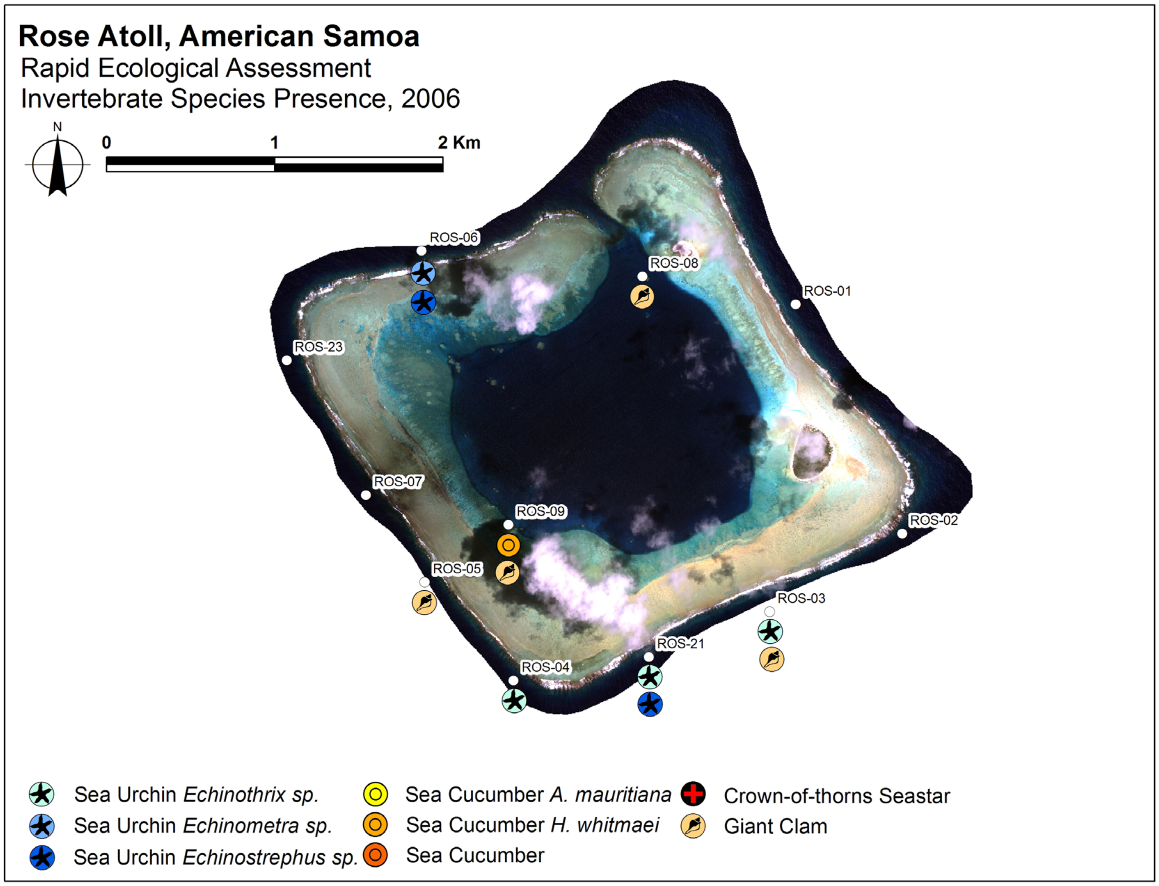

Figure 6.7.1e. Target macroinvertebrate distribution at Rose from REA surveys during ASRAMP 2006.

6.7.2 Temporal Comparison—Benthic Macroinvertebrates

Temporal patterns of island-wide mean benthic macroinvertebrate density (organisms ha^{-1}) around Rose from towed-diver benthic surveys during the 2002, 2004, and 2006 ASRAMP cruises are shown in Figure 6.7.2a (COTS: forereef and lagoon), Figure 6.7.2b (giant clams: forereef), Figure 6.7.2c (giant clams: lagoon), Figure 6.7.2d (sea cucumbers: forereef and lagoon), and Figure 6.7.2e (sea urchins: forereef and lagoon).

Macroinvertebrate communities were distinct between the forereef and the lagoon. Despite significant survey effort over the forereef habitats in each of the 3 survey years, no COTS were observed during any of the towed-diver surveys of the forereefs, and only 7 were observed in the lagoon, all during ASRAMP 2004 in the east side of the lagoon near Rose Island (Fig. 6.7.1b). More than 1000 giant clams were observed in both 2004 and 2006 in Rose, with the vast majority of observations occurring within the lagoon (Figs. 6.7.2b and 6.7.2c). Between 2004 and 2006, mean giant clam densities on forereef habitats were observed to increase slightly, while densities appeared to decline substantially on lagoon habitats. The cause of this decline is unknown, although there has often been speculation about poaching for giant clams within the lagoon at Rose. Mean density of sea cucumbers, which were found predominantly within the sheltered soft-bottom habitats of the atoll lagoon, did not change substantially between 2004 and 2006 (Fig. 6.7.2d). Mean density of sea urchins, which were found predominantly on the forereef habitats, did not change substantially between 2002 and 2006, though the density was noticeably higher during the 2004 surveys (Fig. 6.7.2e).

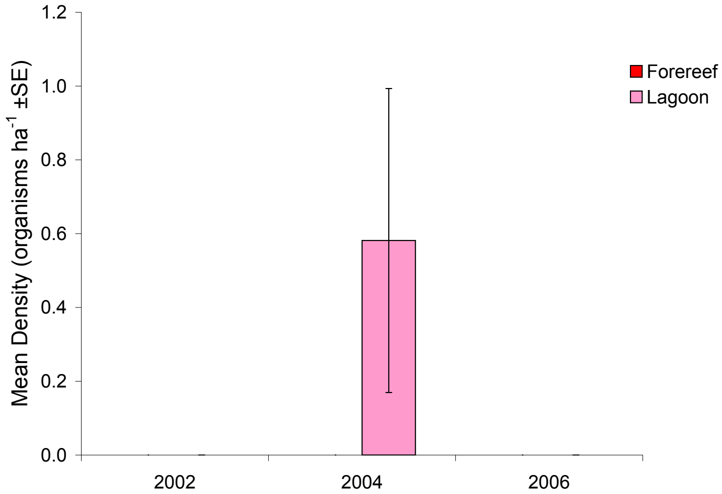

Figure 6.7.2a. Mean density of COTS at Rose from towed-diver surveys during ASRAMP 2002, 2004 and 2006.

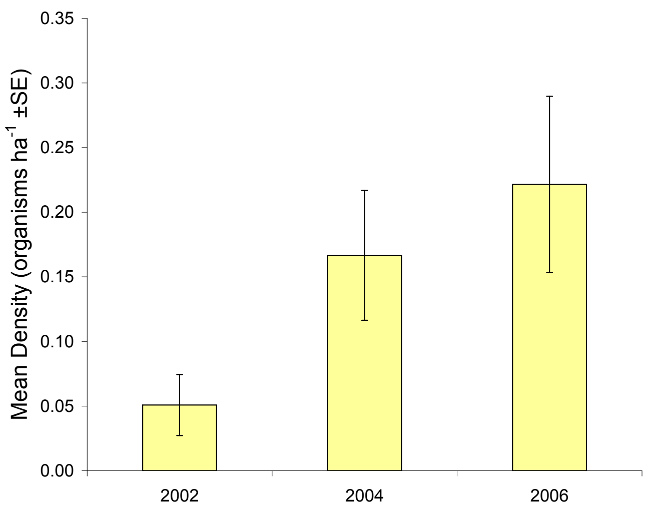

Figure 6.7.2b. Mean density of giant clams in Rose forereef habitats from towed-diver surveys during ASRAMP

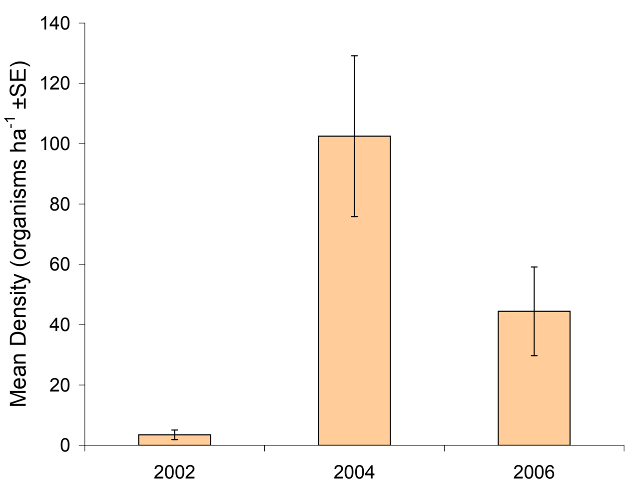

Figure 6.7.2c. Mean density of giant clams in Rose lagoon habitats from towed-diver surveys during ASRAMP 2002, 2004, and 2006.

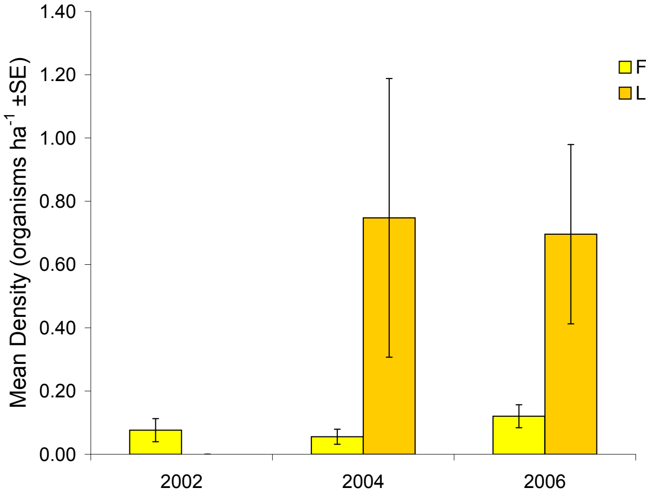

Figure 6.7.2d. Mean density of sea cucumber (holothuroids) at Rose from towed-diver surveys during ASRAMP 2002, 2004, and 2006 for forereef (yellow) and lagoon (orange) habitats.

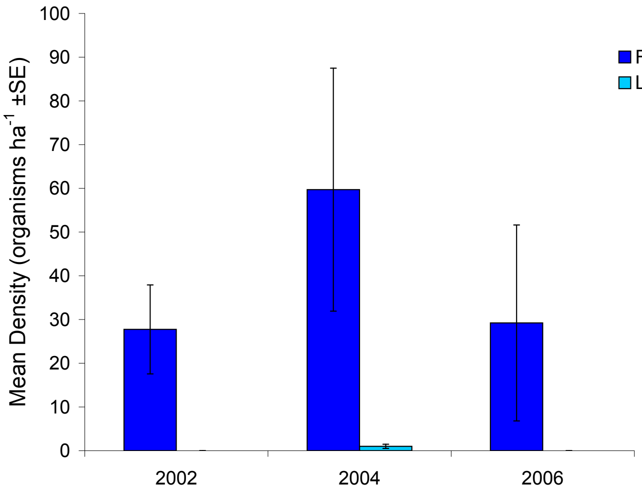

Figure 6.7.2e. Mean density of sea urchins (echinoids) at Rose from towed-diver surveys during ASRAMP 2002, 2004, and 2006.

6.8 Reef Fish

6.8.1 Reef Fish Surveys

2002 Spatial Surveys

During ASRAMP 2002 towed-diver surveys of large fish (> 50 cm total length) around Rose, large fish biomass was around 0.143 tons ha^{-1} (SE 0.087) for the atoll as a whole, with the bulk of the biomass located in the northwest region near the channel into the lagoon (Fig. 6.8.1a). This pass, which has a predominantly strong outgoing ebb tidal current modulated by large swell events pushing water over the atoll barrier reef, attracted large schools of predatory fish, including persistent schools of (~ 200–700) *Caranx sexfasciatus* and barracudas. Jacks dominated the largest size class (> 50 cm total length) followed by lower levels of snappers and barracudas.

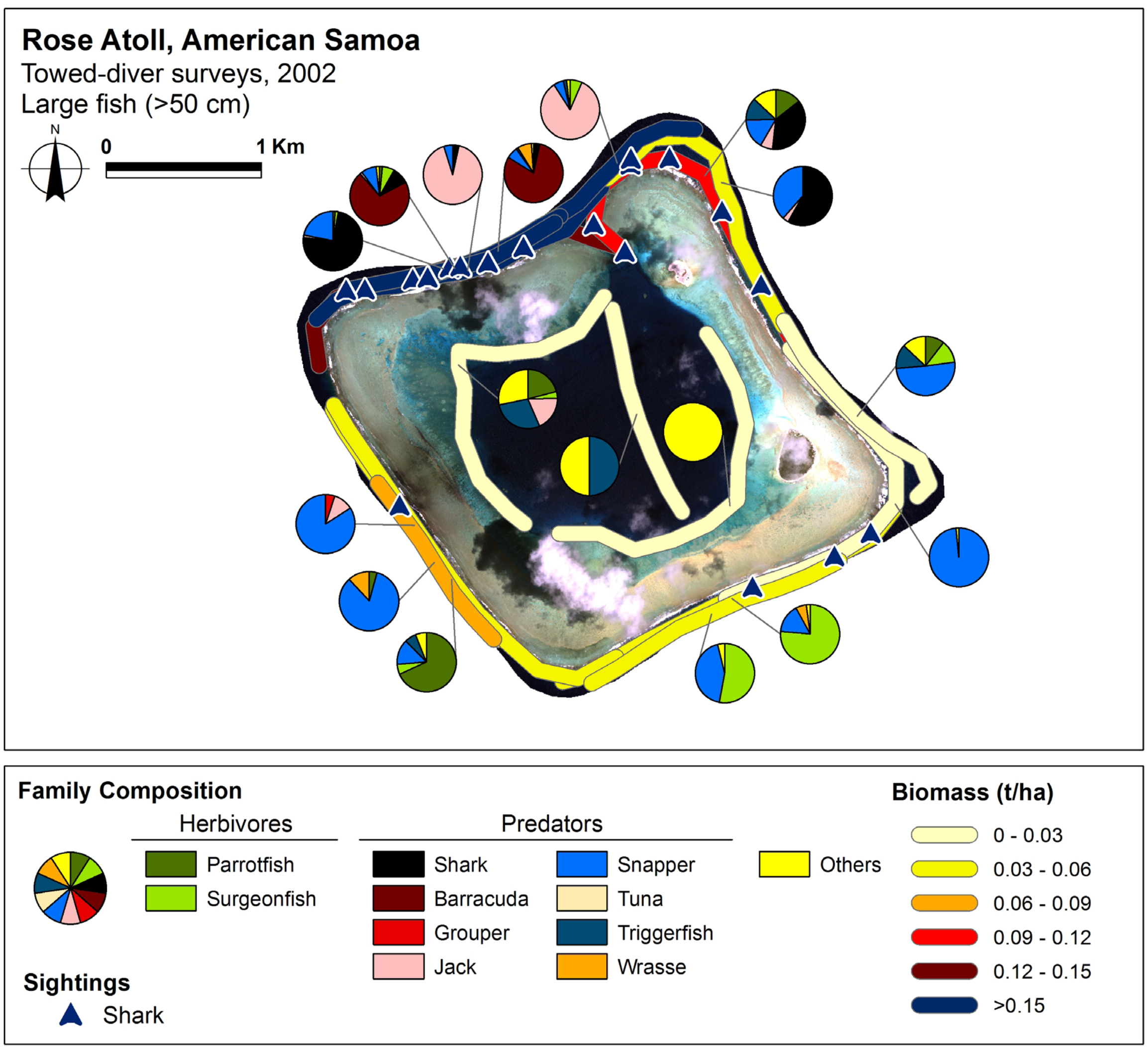

Figure 6.8.1a. Large fish biomass, family composition, and individual shark sightings at Rose recorded during ASRAMP 2002 towed-diver surveys. Large fish (length > 50 cm) biomass on each individual towed-diver survey is represented by the color of the survey track (tons ha^{-1}). Composition by trophic 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.

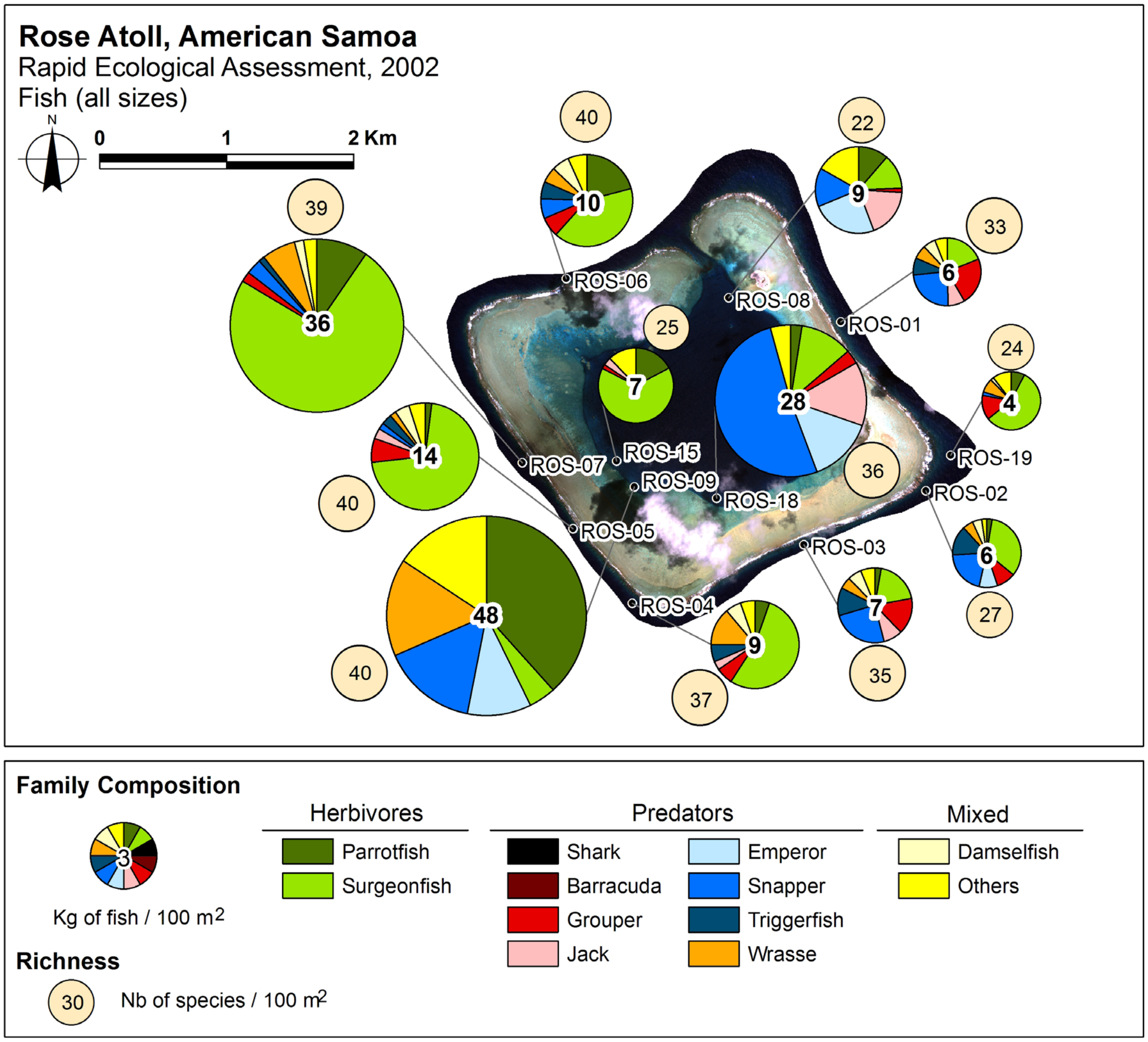

Figure 6.8.1b. Total fish biomass, family composition, and species richness of fishes at Rose recorded during ASRAMP 2002 REA belt-transect surveys. Total fish biomass (all species and size classes) is represented at each site by the size of the pie chart with the actual biomass value in the center (kg 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.

Groupers were mostly represented by large peacock (*Cephalopholis argus*) and flagtail groupers (*Cephalopholis urodeta)*. The smalltooth jobfish (*Aphareus furca*), twinspot snapper (*Lutjanus bohar*), and blue-lined snapper (*L. kasmira*) were also relatively common. Jacks were primarily represented by the bluefin trevally (*Caranx melampygus*). Several large dogtooth tunas (*Gymnosarda unicolor*) were also recorded. Humphead wrasses (*Cheilinus undulatus*) were rarely seen. Sharks were frequently observed, including blacktips, whitetips (*Triaenodon obesus*), and gray reef sharks (*Carcharhinus amblyrhynchos*), especially on the northwest forereef habitat of the island (Fig. 6.8.1a).

Certain species of jacks were observed exhibiting spawning behavior, with dark and light fish pairs swimming side-by-side, and may have been taking advantage of the predictable out flowing current from the lagoon to transport spawn away from the reef.

Twelve sites were surveyed by the REA Fish team in 2002. Results show total fish biomass was highest on the southwest forereef habitat of Rose (~ 25 kg 100 m^{-2}), as well as inside the lagoon (~ 23 kg 100 m^{-2}; Fig. 6.8.1b). These large biomass values were related to high abundances of the surgeonfish *Naso lituratus* on the southwest side and the parrotfish *Chlorurus frontalis* and the snapper *Lutjanus kasmira* in the lagoon. Overall total fish biomass for the atoll was around 15.4 kg 100 m^{-2} (SE 8.1).

Species richness around Rose during the ASRAMP 2002 surveys was around 30 species 100 m^{-2}, with high diversity sites (~ 40 species) located on all sides of the atoll and on patch reefs inside the lagoon (Fig. 6.8.1b). Diversity was slightly higher in the southwest region compared to the northeast region.

2004 Spatial Surveys

During ASRAMP 2004 towed-diver surveys for large fish (> 50 cm total length), biomass

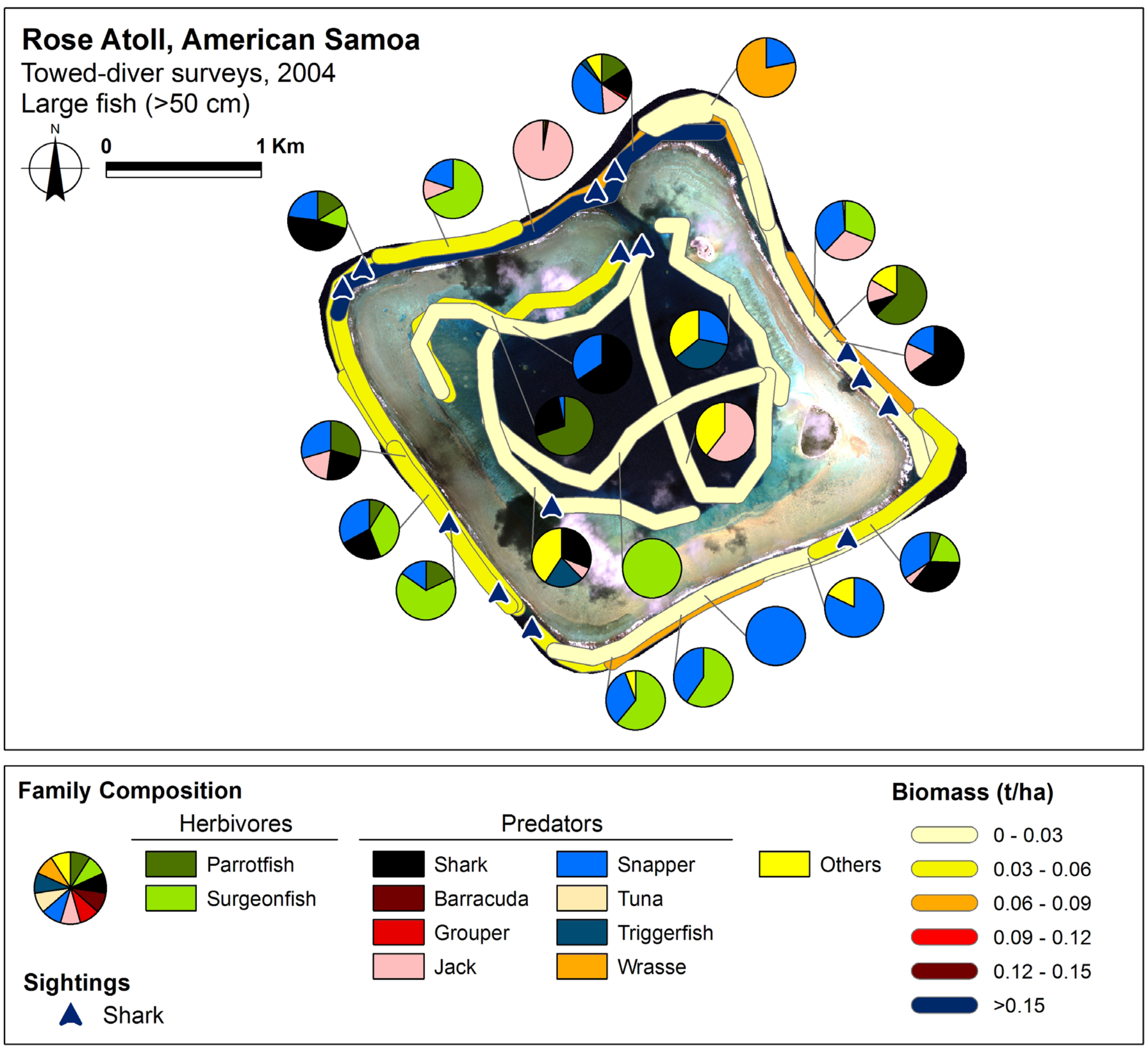

Figure 6.8.1c. Large fish biomass, family composition, and individual shark sightings at Rose recorded during ASRAMP 2004 towed-diver surveys. Large fish (length > 50 cm) biomass on each individual towed-diver survey is represented by the color of the survey track (tons ha^{-1}). Composition by trophic 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.

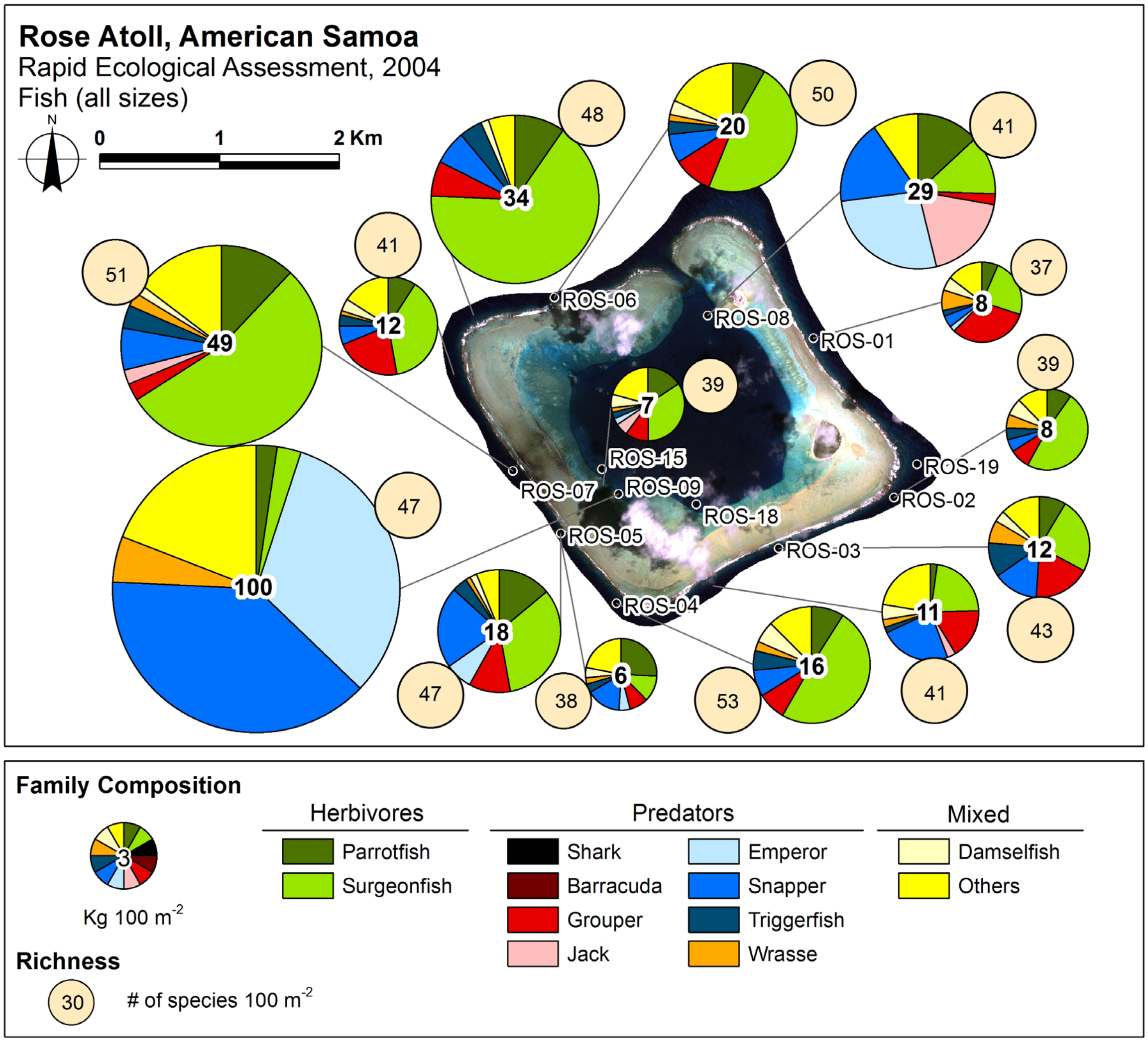

Figure 6.8.1d. Total fish biomass, family composition, and species richness of fishes around Rose recorded during ASRAMP 2004 REA belt-transect surveys. Total fish biomass (all species and size classes) is represented at each site by the size of the pie chart with the actual biomass value in the center (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 within the beige circles (species 100 m^{-2}) and the size of the circles.

was mostly composed of jacks, snappers, and sharks (Fig. 6.8.1c). Aside from the massive abundance of jacks at the lagoon entrance, large fish were distributed evenly around the remainder of the atoll. Overall, large fish biomass was near 0.098 tons ha^{-1} (SE 0.076).

Sharks were also frequently sighted, both inside the lagoon and on forereef habitats on all sides of the atoll (Fig. 6.8.1c). Only two humphead wrasses were sighted.

As in 2002, total fish biomass around Rose during 2004 was highest along the southwest (26 kg 100 m^{-2}) and northwest (~ 27 kg 100 m^{-2}) forereefs, and inside the lagoon (~ 45 kg 100 m^{-2}; Fig. 6.8.1d). The northwest and southwest forereef habitats also harbored large quantities of herbivorous surgeonfish (e.g., *Naso lituratus*; Fig. 6.8.1d,e), while the lagoon was mostly inhabited by predators (*Lutjanus kasmira* and *Gnathodentex aureolineatus*). Overall biomass around Rose was around 23.7 kg 100 m^{-2} (SE 12.2).

During ASRAMP 2004 stationary point count surveys around Rose for medium-to-large fish (> 25 cm total length), snappers showed the highest biomass. Moderately high densities were recorded for surgeonfish, parrotfish, and groupers.

In 2004, species richness was clearly higher than during surveys completed in 2002, averaging around 44 species100 m^{-2}. In addition, the southwest forereef habitat of the atoll had slightly higher species richness than the eastern side when compared with 2002 survey data (Fig. 6.8.1d).

2006 Spatial Surveys

During ASRAMP 2006 towed-diver surveys around Rose for large fish (> 50 cm total length), barracudas (*Sphyraena qenie*), seen in several large schools near the channel entrance, had the highest biomass, followed by jacks and sharks. Sharks accounted for a sizeable portion of large fish biomass in 2006, as opposed to previous years. Overall, large fish biomass was 0.068 tons ha^{-1} (SE 0.046) which was mostly concentrated on the northwest forereef of the atoll (Fig. 6.8.1f).

A few large humphead wrasses were sighted on all sides of the atoll. A dozen whitetip sharks and 5 other sharks (grouped in three other species) were also sighted outside the lagoon (Fig. 6.8.1f). No bumphead parrotfish were observed around Rose during 2006 by either towed-diver or REA survey teams.
As in previous years, total fish biomass was highest on the southwest forereef of the atoll (~ 32 kg 100 m^{-2}) and in the lagoon (~ 60 kg 100 m^{-2}; Fig. 6.8.1g). Fish biomass inside the lagoon mainly consisted of the parrotfish *Chlorurus frontalis*, the snapper *Lutjanus kasmira*,

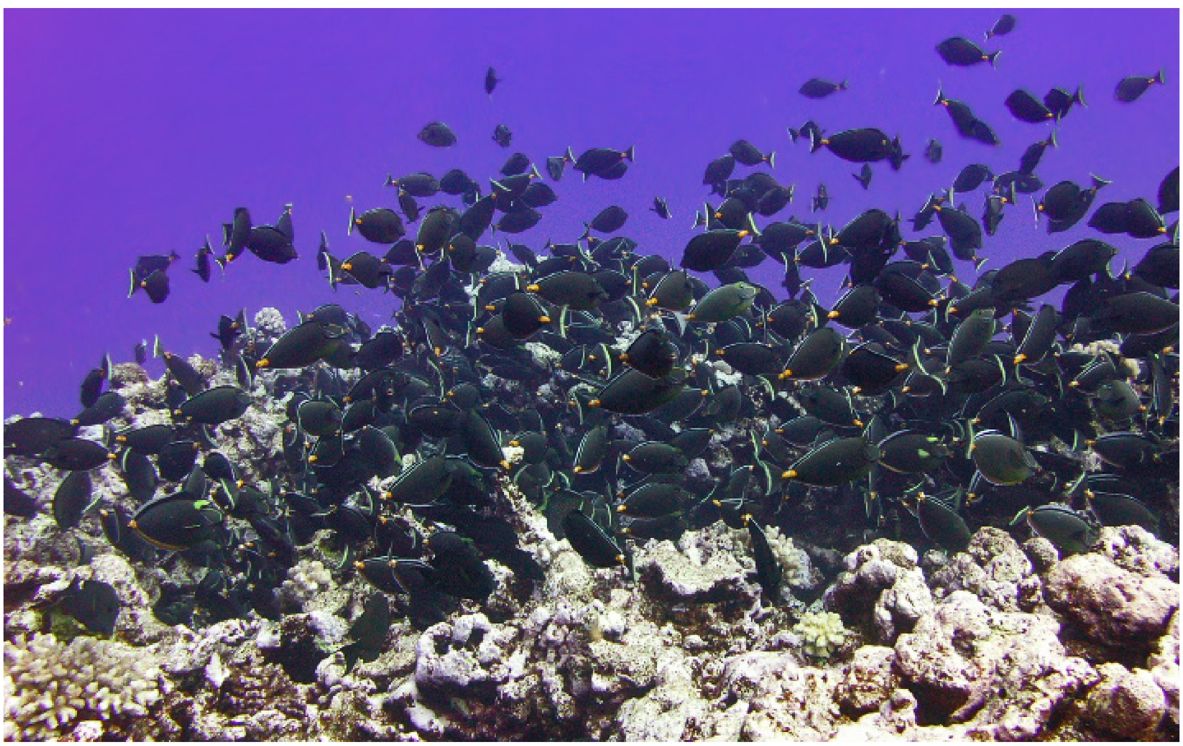

Figure 6.8.1e. Herbivorous surgeonfish (mostly orangespine unicornfish, *Naso lituratus*) near site of the 1993 ship grounding at Rose. (*Photograph provided by NOAA PIFSC CRED; R. Schroeder, JIMAR*)

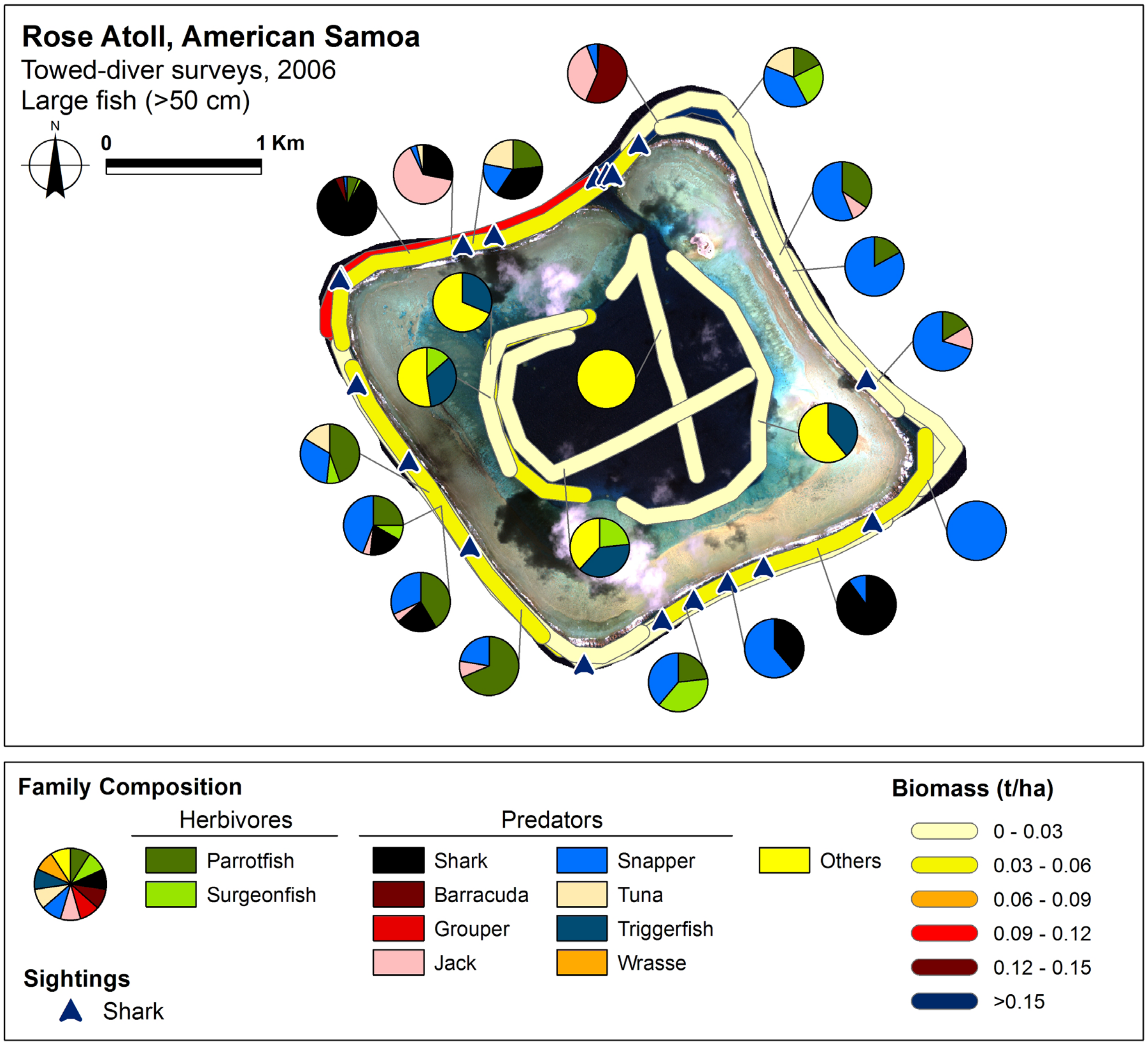

Figure 6.8.1f. Large fish biomass, family composition, and individual shark sightings around Rose recorded during ASRAMP 2006 towed-diver surveys. Large fish (length > 50 cm) biomass on each individual towed-diver survey is represented by the color of the survey track (tons ha^{-1}). Composition by trophic 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.

and the emperor *Gnathodentex aureolineatus*. The average for the whole atoll was 22.8 kg 100 m^{-2} (SE 14.0).

During ASRAMP 2006 stationary point count surveys for medium-to-large fish (> 25 cm total length), snappers and parrotfish were nearly equal as the highest biomass taxa around Rose. In lesser numbers were groupers, surgeonfish, and wrasses.

Patterns of reef fish diversity were less clear in 2006, with all sides of the atoll having a uniformly lower richness of about 30 species 100 m^{-2} (Fig. 6.8.1g).

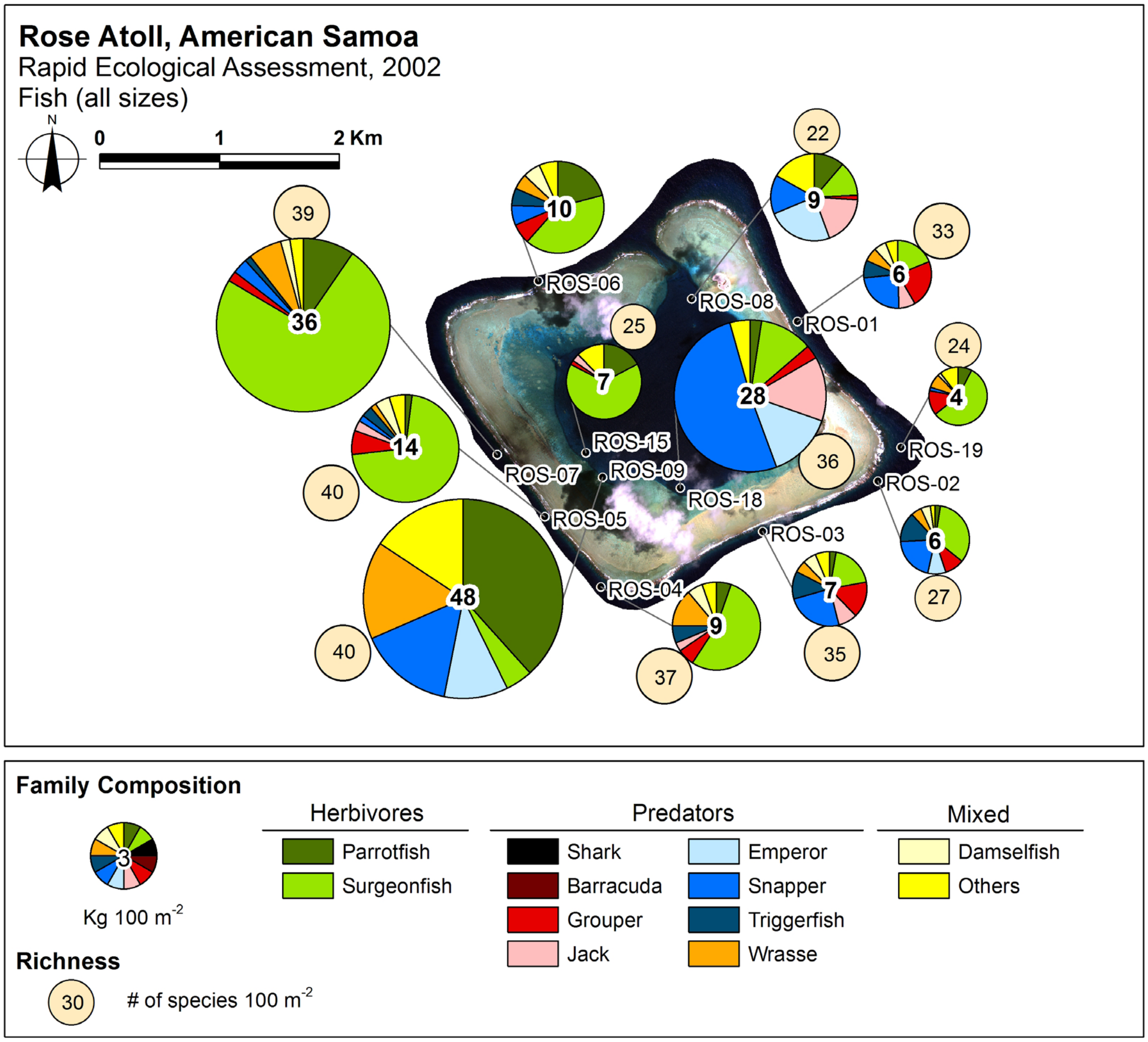

Figure 6.8.1g. Total fish biomass, family composition, and species richness of fishes around Rose recorded during ASRAMP 2006 REA belt-transect surveys. Total fish biomass (all species and size classes) is represented at each site by the size of the pie chart with the actual biomass value in the center (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 within the beige circles (species 100 m^{-2}) and the size of the circles.

6.8.2 Temporal Comparison—Reef Fish

Over all surveys years, total fish biomass around Rose appeared to be highest on the southwest forereef of the atoll and inside the lagoon. Predators (snappers and emperors) were more common in the lagoon, while herbivores (surgeonfish and parrotfish) were highly abundant on the southwest forereef. Parrotfish, mainly *Chlorurus frontalis*, were also common inside the lagoon. The northeast and southeast forereefs of Rose consistently had relatively lower fish biomass compared to the island-wide mean (2.1 tons ha^{-1}). Total fish biomass was slightly lower in 2002 (1.5 tons ha^{-1} [SE 8.1]) compared to 2004 and 2006 (2.3 tons ha^{-1} [SE 1.1]; Fig. 6.8.2a).

Large fish biomass was mostly concentrated around the lagoon channel on the northwest and northeast sections of the atoll. As with Swains Island (Chapter 7), most of the large fish biomass around Rose consisted of barracudas, jacks, and snappers. Contrary to total fish biomass, large fish biomass appeared to be decreasing from 0.143 tons ha^{-1} (SE 0.087) in 2002 to 0.068 tons ha^{-1} (SE 0.046) in 2006 (Fig. 6.8.2b). The overall multiyear mean of large fish biomass from towed-diver surveys was around 0.103 tons ha^{-1} (SE 0.061).

Sharks were frequently sighted around Rose, although they were seldom observed inside the lagoon. Humphead wrasses were present, but relatively rare. Within the constraints of ASRAMP methodologies (daytime only, 0–30 m), no bumphead parrotfish population appears to be present at Rose based on these multiyear observations.

Considering all years surveyed, the diversity of fish communities around Rose appeared to be uniform.

The mean biomass estimates per island referenced in the above section are given in Appendix IV, Tables IV. i and IV. ii. Mean fish densities per island are given in Appendix IV, Tables IV. iii and IV. iv.

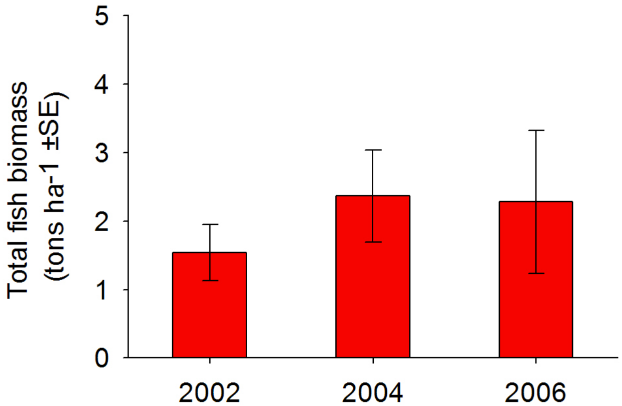

Figure 6.8.2a. Large fish biomass at Rose during ASRAMP 2002 (17 tow surveys), 2004 (22 tow surveys), and 2006 (21 tow surveys) towed-diver surveys.

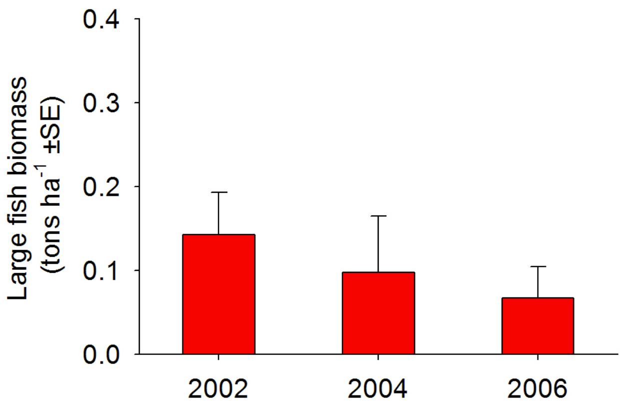

Figure 6.8.2b. Large fish biomass around Rose from towed-diver surveys during ASRAMP 2002 (17 surveys), 2004 (22 surveys), and 2006 (21 surveys).

6.9 Island Summary and Integration

Rose is a small, uninhabited, remote coral atoll at the far eastern end of the American Samoa Archipelago, approximately 140 km east-southeast of Ta`u Island. Multibeam-derived bathymetry showed that the forereef around the outside of the atoll slopes drops steeply into deep water (to at least 3000 m), with a slightly wider shallow bank around the northern and eastern points (Figs. 6.3.1a and 6.3.1b). Towed-diver survey observations indicated high benthic habitat complexity along most of the forereef habitats, especially in the northwest and southwest regions. Lower habitat complexity was noted on the northeast forereef of the atoll, consistent with multibeam bathymetry and backscatter data. Habitat complexity was generally low within the confines of the lagoon (Fig. 6.3.2a), which was primarily composed of sand and rubble (Figs. 6.3.2b and 6.3.2d) substrate interspersed with numerous small coral heads and a few pinnacles and small patch reefs. True to Rose's nature as a steeply sloped, conical atoll, there was very low sand cover along the forereef of the atoll, with only low levels recorded just outside of the channel in the northwest region.

During each of the ASRAMP survey periods in 2002, 2004, and 2006, the nearshore CTD and water quality data were both heterogeneous and highly variable, though differences in water properties were typically small. However, several distinct differences were noted within the confines of the lagoon.

Modeled significant wave height data for Rose revealed weak seasonal variability superposed with episodic, cyclone-derived extreme wave events. Larger wave heights (~ 3-4 m) typically occurred during austral winter months and smaller wave heights (~ 2 m) prevailed during the summer months. When comparing 2004 and 2006 data, it appears the large wave event (6-m wave heights) in February 2005 coincided with observed decreases in water temperatures at each of the in situ recorders. Rose is enclosed by emergent reef with a small opening to the north, the only opening for water exchange to the surrounding environment. It is likely that the lagoon, where several in situ temperature recorders were deployed, experienced rapid cooling caused by the large waves breaking over the emergent reef and flushing of the lagoon with pelagic-based waters through the opening of the 40 m channel in the north (channel current speeds were estimated at several knots through the pass during the 2006 ASRAMP survey).

Beam transmission (turbidity), effectively measured only during shallow-water CTD casts in 2004 (Fig. 6.4.1f), was notably lower inside the lagoon compared with other surveyed areas outside of the atoll[2]. The lagoon also displayed higher values of Chl-a, NO_{2-}, and SiO_2, (Fig. 6.4.1j), when compared with the forereef. Finally, the lagoon consistently registered the densest and most saline waters at Rose for each ASRAMP cruise, especially well below the sill depth of the single channel into and out of the lagoon (~ 5 m). These elevated nutrient concentrations, coupled with increased or variable turbidity, suggest prolonged periods of mixing, flushing, and nutrient cycling within the surface water layers of the protected shallow-water lagoon. The RCM current meter deployed in the channel near the sill between 2002 and 2004 recorded strong outbound currents for most of the period, even during periods of flood tides, suggesting an elevated sea-level within the lagoon driven by wave setup over the reef crest on all sides of the island, depending on wave height and tidal cycle. Wave-induced lagoonal circulation is tidally modulated as more wave set-up occurs during high

[2] 2006 shallow-water beam transmission values were removed from analysis because of equipment malfunction.

tides and less during low tides. The net effect, however, is that surface waters in the lagoon likely have short residence times. The high-salinity and high-density subsurface waters in the lagoon, on the other hand, have no obvious means to circulate and flush out of the lagoon. Hence, lagoonal bottom waters likely have very long residence times.

The coral reef ecosystem along the steep forereef slopes surrounding Rose was found to be generally healthy, with exceptions noted at the vessel grounding site. Towed-diver surveys recorded relatively uniform live scleractinian (stony) coral cover, with high live coral cover noted in several isolated areas in the northeast region, and a consistent, linear stretch of elevated live coral cover in the southwest region (Fig. 6.3.2e). This area, in particular, appeared to coincide with the elevated habitat complexity recorded in the southwest (Fig. 6.3.2e). Mean towed-diver coral cover on the forereef ranged from 20.1% (SE 1.8; 2006) to 29.1% (SE 2.0; 2002; Fig. 6.5.3a), while lagoonal coral cover ranged from 1.5% (SE 0.5; 2004) to 5.9% (SE 0.9; 2006) (Fig. 6.5.3b). Forereef coral cover data from towed-diver surveys and REA surveys were relatively similar, with island-wide mean differences no greater than approximately 15% (Fig. 6.5.3a). In contrast, percent live coral cover in the lagoon was consistently much higher in REA surveys than towed-diver surveys (Figs. 6.5.1h, 6.5.1o, and 6.5.3b). At site ROS-09 around a coral pinnacle within the lagoon, live coral cover doubled in comparison with island-wide averages. This difference was probably a result of REA site selection. The REA surveys targeted hard-bottom substrate at the coral pinnacles, whereas towed-diver surveys collected data by sampling multiple segments of the benthic substrate totaling 2000 m^2. These differences in average coral cover together with benthic habitat data, confirm that the protected waters of the lagoon were primarily composed of shallower, soft benthic components (Figs. 6.3.2b, 6.3.2c and 6.3.2d) with sporadic coral pinnacles and patch reefs, while the forereef was mostly a steeply sloped, exposed hard-bottom community (Fig. 6.3.1b) with few unconsolidated elements.

With respect to coral densities, it is difficult to know if observed interannual changes were a result of new recruits added, fragmentation/fissioning of existing colonies caused by storm events, interobserver error, or a combination of these or unknown factors. In particular, site ROS-03 showed among the lowest coral densities in 2004 (2.9 colonies m^{-2}), but the highest coral density in 2006 (10.4 colonies m^{-2}). Future ASRAMP cruises will focus on stabilizing field collection methods to reduce bias.

The lack of large (> 80 cm) colonies at Rose in both 2004 and 2006 suggests that large shallower corals may have died after the reported mass coral bleaching event at Rose in 1994[3] and that coral recovery remains ongoing (Figs. 6.5.3g and 6.5.3h). In addition, the proportion of corals in medium (20–40 cm) and medium-large (40–80 cm) size classes was reduced in 2006 compared to 2004 (2004: 48% vs. 2006: 31% of corals 20–80 cm) which may possibly be attributed to coral fragmentation and fissioning associated with the large swell event recorded in 2005 with the passage of Hurricanes Percy and Olaf, or other environmental events, sampling and observer biases, or a combination of these and other unknown factors.

Spatial patterns in coral generic richness were observed around Rose, with site ROS-02 off the southeast forereef exhibiting the highest diversity (16–17 genera), and site ROS-07 (the ship grounding site) on the southwest forereef recording the lowest diversity (7–9 genera) in both quantitative survey years. The effects of the 1993 ship grounding were still evident

[3] See footnote 1.

in both coral cover and diversity at site ROS-07. Visual estimates of percent live coral cover ranged from 7% at the site of impact to 28% at a “control” site > 650 m to the southeast, with the lowest consistent coral diversity at ROS-07 in both 2004 and 2006 (Figs. 6.5.1g and 6.5.1n). Pocilloporids, which are among primary habitat colonizers, were especially numerous at sites clearly impacted by the grounding. Finally, the resident cyanobacteria bloom noted in the region, in response to iron from the shipwreck (Schroeder et al., 2008) may be limiting coral recruitment in this area.

The prevalence of diseased corals was generally low, although shallow-water corals appeared to exhibit higher levels of stress than deeper corals. The primary genera affected by coral disease were *Montastrea* (42%), *Favia* (35%), and *Montipora* (10%), with hyperpigmented lesions and predation vastly outnumbering other diseases and syndromes (Figs. 6.5.2a and 6.5.2b). Sea surface temperature in the lagoon spiked over the bleaching threshold in March 2002 and again almost to the bleaching level in December 2004. However, no major bleaching events were recorded at Rose, and only three cases of bleached coral colonies were observed during ASRAMP 2006. During towed-diver surveys in 2006, stressed coral cover was low island-wide, with the only localized increase recorded during a single shallow survey on the northwest forereef of the island (Fig. 6.5.1m). Though the cause is not known, observed levels of stressed coral from towed-diver surveys were elevated island-wide in 2004, with a mean percent of 5.6% (SE 1.0) for forereef habitats (Fig. 6.5.1f) and a mean percent of 0.4% (SE 0.4) for lagoon/backreef habitats.

The shallow reefs around Rose were dominated by crustose coralline red algae, which contribute to both the primary structure of the atoll reefs and provide their inherent “rose” color (hence the name of Rose). It was noted that the green alga *Halimeda* was in lower abundance at the wreck site (ROS-07). Comparing 2004 and 2006 observations, lower algae species diversity in 2004 may have resulted from the passage of Hurricane Heta immediately prior to the 2004 surveys (Figs. 6.6.1c and 6.6.1e). Crustose coralline algae were especially prevalent along the outer reef slopes around the entire atoll, especially at the points of the atoll, which experience high wave energy and current flow.

The target species of macroinvertebrates were generally rare around Rose during all years. COTS were only recorded in 2004 and only in very low numbers (7 total) inside a small area of the lagoon near Rose Island (Fig. 6.7.1b). An exception was noted for giant clams (i.e., *Tridacna maxima*), with over 1000 observed in both 2004 and 2006, primarily in southern areas of the lagoon (Figs. 6.7.1b and 6.7.1d). The towed-diver surveys of the forereefs around Rose recorded low mean numbers/densities of giant clams, which were mostly distributed in the northwest on either side of the channel. Though the cause remains unknown, mean density of giant clams within the lagoon declined from 2004 to 2006, leaving open on-going speculation about poaching within this National Wildlife Refuge. The fact that Rose has a single entrance makes it an ideal location for deployment of a passive EAR to detect vessel traffic including potential visits by poachers.

Low numbers of sea cucumbers were noted around the atoll, with the highest numbers observed in the west and southwest side of the lagoon, and northeast side of the forereef. Interestingly, both Rose and Swains Islands, separated by hundreds of kilometers, but having similar forereef bathymetry, consistently reported low densities of sea urchins during all years. By contrast, however, nearly zero COTS were observed around Rose in all years, while large numbers/densities have been observed around Swains during both 2004 and 2006.

Fish communities around Rose were relatively abundant and diverse. Total fish biomass (2.1 tons ha^{-1}) at Rose was the highest recorded in American Samoa and appeared to be highest on the southwest forereef of the atoll and inside the lagoon versus other areas of the atoll. Reef predators (snappers and emperors) were more common inside the protected waters of the lagoon (Fig. 6.8.2a), while herbivores (surgeonfish and parrotfish) were present in high abundance on the southwest forereef.

The highest densities of large fish (> 50 cm total length), such as jacks and barracuda, were recorded just outside the pass along the northwest side. Coupled with strong outgoing currents reaching several knots, this may be a preferred site for feeding on prey or plankton flowing out of the lagoon or may be a preferred site for spawning activity. Close by, REA site ROS-08 is a pinnacle/patch reef located just inside the channel pass that is believed to be heavily and historically poached[4]. This may be reflected in the overall biomass of large fish at Rose reported by towed-divers, which appears to have decreased from 0.143 tons ha^{-1} (SE 0.087) in 2002 to 0.068 tons ha^{-1} (SE 0.046) in 2006 (Fig. 6.8.2b).

Fish diversity (species richness) was relatively high. Fish were abundant and diverse, with very high densities (~ 100–200 individuals 100 m^{-2}) of small damselfish (mainly the planktivore *Chromis acares*). As found elsewhere in American Samoa, this damselfish was overwhelmingly the most abundant species by number. Common larger bodied fishes included grouper, snapper, and parrotfish. Towed-diver surveys found sharks to be uncommon, mainly seen in shallow water just below the surf. The highest densities of large fish (> 50 cm total length) were recorded just outside the pass along the northwest side, and were represented primarily by jacks and barracuda. This may be a preferred site for preying on fish and plankton flowing out of the lagoon or for spawning activity.

Fish surveys in the lagoon were only conducted around several of the larger pinnacle patch reefs, where small-to-medium sized fish were very abundant. These pinnacle patch reefs appeared to serve as refuges for fish inside the lagoon, where parrotfish, snapper, emperor, goatfish, and jacks were common.

CRED reef ecosystem surveys around Rose over the period 2002-2006 found that both the numbers and biomass of pooled herbivores (surgeonfishes, parrotfishes, angelfishes) were greater at the wreck site, (ROS-07), than at neighboring sites (“controls”) along this southwest forereef and elsewhere around the atoll. This greater abundance of herbivores at the impact site, where some corroding steel debris was still present, was associated with significantly greater substrate cover of turf algae and cyanobacteria (Schroeder et al., 2008). While multiple removal efforts by the USFWS over the past decade have significantly reduced the amount of debris at the wreck site (ROS-07), local ecosystem impacts continue to persist. The high concentration of herbivorous fish, dominance of turf algae/cyanobacteria, the low coral cover, and the abundance of primary coral colonizers at the ship grounding site suggest that the reef is still undergoing ecological successional changes that may persist for an indeterminate length of time.

[4] See footnote 1.

References

Schroeder RE, Green AL, DeMartini EE, Kenyon JC (2008) Long-term effects of a ship-grounding on coral reef fish assemblages at Rose Atoll, American Samoa. BULL MAR SCI 82(3):345–364.