Chapter 8 Archipelagic Comparisons

Each of the previous five chapters provided comprehensive and detailed descriptions of coral reef ecosystems in the Territory of American Samoa (Tutuila and Aunu`u Islands, Ofu and Olosega Islands, Ta`u Island, Rose Atoll, Swains Island). These discussions included the following topics: geopolitical context, survey efforts, benthic habitat mapping and characterization, oceanography and water, coral and coral disease, algae, benthic macroinvertebrates, reef fish, and island summary and ecosystem integration. In this chapter, the same topics will be discussed but the focus will shift from individual islands to interisland comparisons across the American Samoa Archipelago. The spatial patterns and temporal variability of the island/atoll ecosystems will be examined on a regional scale. This broader-scale ecosystem examination explicitly provides important information for local management and conservation at these islands/atolls. However, it also presents useful insights which can be applied more generally towards the management and conservation of coral reefs on a regional, national, and international level.

8.1 Geopolitical Context

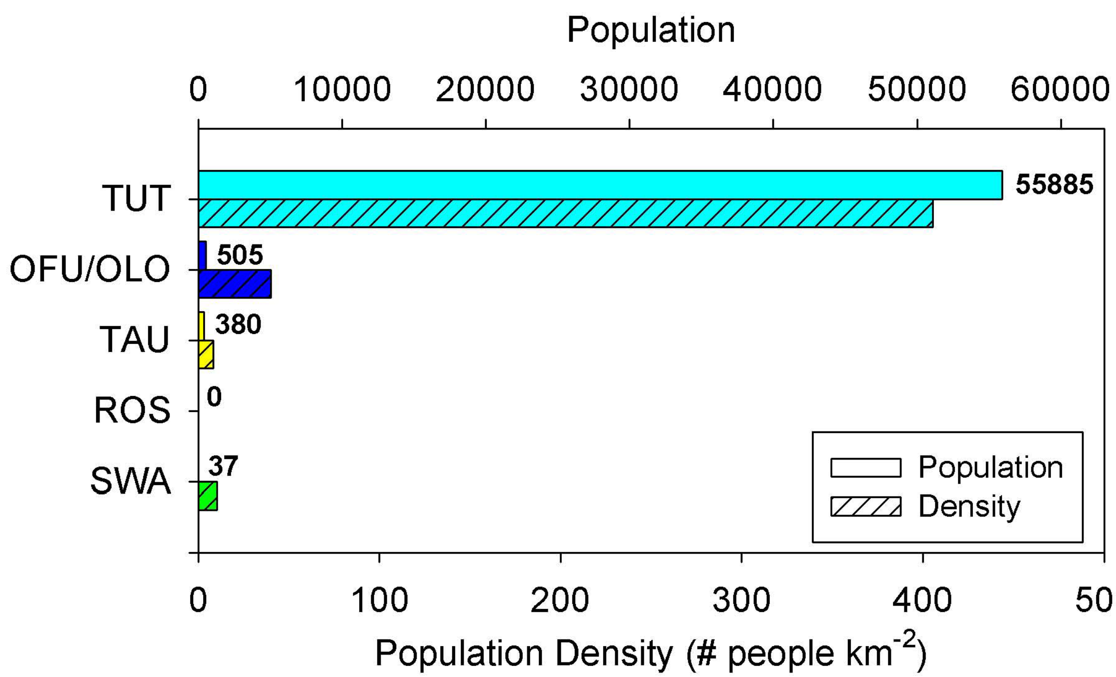

Figure 8.1a. Human population numbers and densities of Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS), and Swains (SWA). The solid bars indicate population numbers per island, while the striped bars indicate population densities (U.S. Census Bureau, 2000).

The Territory of American Samoa is composed of five volcanic high islands (Tutuila, Aunu`u, Ofu, Olosega, and Ta`u) and two low coral atolls (Swains and Rose). Tutuila (including Aunu`u) is the largest (145 km²) and most densely populated (55 885 residents) island in American Samoa (Figs. 8.1a and 8.1b). In addition, Tutuila harbors the most shallow-water coral reef habitat (315 km²) of any island in American Samoa (Fig. 8.1b).

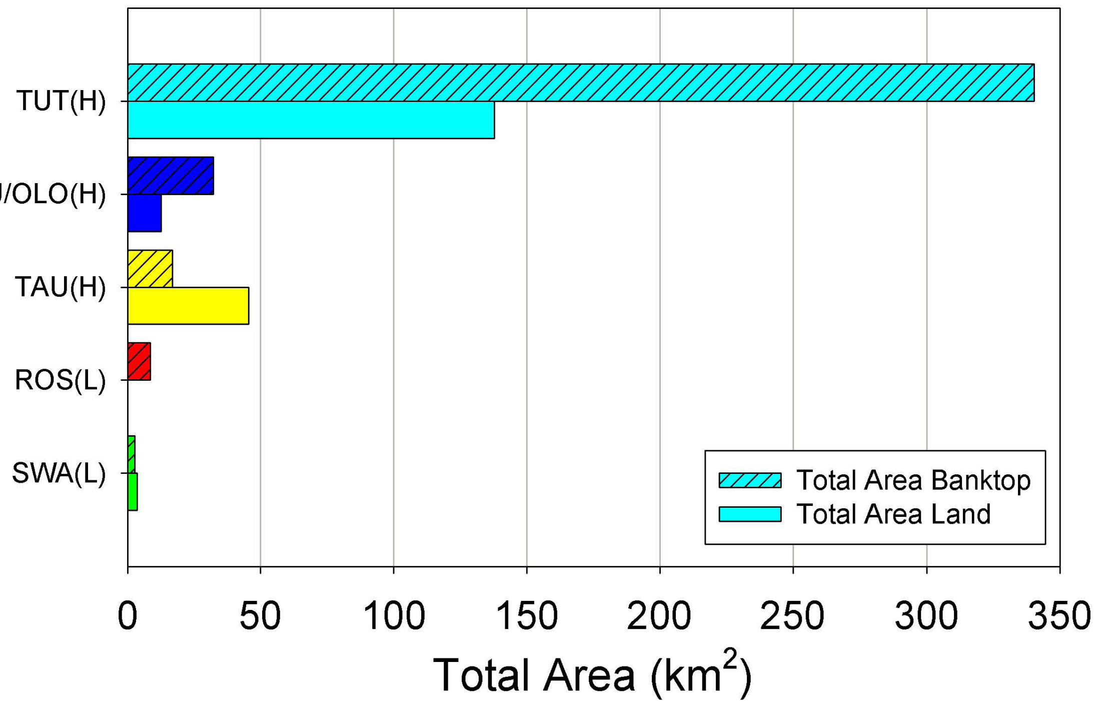

Figure 8.1b. Total banktop area and total terrestrial land area of Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS) and Swains (SWA). High volcanic islands are denoted with the letter H, low carbonate islands/atolls with the letter L.

Because of higher population densities and large areas of coral reef habitat on Tutuila (Figs. 8.1a and 8.1b), the potential for detrimental anthropogenic impacts (e.g., agricultural runoff, point and nonpoint source pollutants, and excessive resource use) is of concern. The Pago Pago Harbor/International Airport and densely populated coastline surrounding Pala Lagoon (Fig. 3.1b) are areas potentially subject to elevated industrial and commercial pressures. Several marine protected areas have been established on Tutuila, including: Fagatele Bay National Marine Sanctuary near Step's Point in the south point region (Fig. 3.1a); the National Park of American Samoa (NPAS), which spans a large stretch of northern coastline from Fagasa Bay to Cockscomb Point and Vatia Bay; and additional areas addressed by the community-based Fisheries Management Program of American Samoa. Despite their protected status, these areas may still be subject to anthropogenic pressure. In particular, during a 7-week record from an ecological acoustic recorder deployed in the NPAS, the majority of vessel detections (23 out of 35 instances) occurred at night (Fig. 3.4.4c), which may indicate local fishing effort in that marine park.

Human population numbers and densities decrease as one travels east along the American Samoa Archipelago (Fig. 8.1a). The Manu`a Islands are located approximately 100 km east of Tutuila, and include Ofu, Olosega, and Ta`u. The population of the Manu`a Islands has been steadily decreasing since the 1950s as a result of a migration to Tutuila for employment opportunities and several damaging storms affecting the Manu`a Islands.

Ofu, with a land area of 7.2 km^2, and Olosega, with a land area of 5.4 km^2, have a combined population of 505 people, with 289 living on Ofu and 216 living on Olosega (Figs. 8.1a and 8.1b). The populations are located around two primary villages: Ofu Village (northwestern coast of Ofu), which is the location of the small airport and protected harbor, and Olosega

Village (southwestern coast of Olosega). Sili Village, located on the northwestern coast of Olosega, remains sparsely inhabited. An estimated two-thirds of Ofu and Olosega remain undeveloped, with the majority of the southern coastline of Ofu under the administrative jurisdiction of the NPAS.

Ta`u, with a land area of 44 $km^2$, is home to 380 people primarily located in the villages of Ta`u and Faleasao in the northwest and Fiti`uta in the northeast (Figs. 8.1a and 8.1b). The undeveloped southeastern and southern coastlines of Ta`u are under the jurisdiction of the National Park Service. Coastal subsistence agriculture/agrofarming and subsistence fishing likely constitute the majority of potential anthropogenic stressors to the reef environment, along with the activities associated with the boat harbor and airport in Ofu Village and the small airport near Fiti`uta.

Rose Atoll is the uninhabited, easternmost territory under the joint administration of the Territory of American Samoa and the United States Fish and Wildlife Service. The barrier reef encloses approximately 6.5 km2 (~ 1600 ac) of lagoonal habitat, with a 40-m wide channel located in the northern corner of the atoll (Figs. 8.1a and 8.1b). Two small islands (Rose and Sand) constitute only 0.06 km2 (~ 15 ac) of land. While Rose Island is vegetated, both islands do not have any streams, associated watershed areas or notable freshwater sources. Potential anthropogenic stressors to Rose Atoll are probably not a result of continued habitation by residents. However, the effects of the 1993 shipwreck, wildlife poaching (anecdotal evidence) and unmonitored fishing pressure likely constitute the main anthropogenic impacts at Rose Atoll.

Swains is a geographically small island and is geologically isolated from the rest of the American Samoa Archipelago (Chapter 1, Fig. 1.1a). The island is only 1.9 km^2 and is consistently home to ≤ 30 residents who are concentrated in the village of Taulaga in the northwest (Figs. 8.1a and 8.1b). As a result of the small population and lack of industry on this island, the anthropogenic stresses on the coral reef ecosystems are limited to subsistence fishing pressures and localized subsistence agricultural runoff.

8.2 Survey Effort

A considerable amount of bathymetric, oceanographic, and biological data has been collected in the American Samoa Archipelago between 2002 and 2006. These data allow better understanding of the spatial and temporal variability of the coral reef ecosystems around each of the islands/atolls. Using spatially consistent Pacific Reef Assessment and Monitoring Program (RAMP) methodologies, a similar suite of observations and data have been collected for each island/atoll within the archipelago. Because of differences in the reef habitat areas, ship availability, and weather and sea conditions, the amount and spatial resolution of these data vary among islands. Details of survey efforts for each island/atoll are discussed in their respective chapters as follows: Tutuila and Aunu`u Islands (Chapter 3, Section 3.2: Survey Effort), Ofu and Olosega Islands (Chapter 4, Section 4.2: Survey Effort), Ta`u Island (Chapter 5, Section 5.2: Survey Effort), Swains Island (Chapter 6, Section 6.2: Survey Effort), and Rose Atoll (Chapter 7, Section 7.2: Survey Effort). The respective island/atoll datasets have been coalesced to produce the archipelagic comparative analyses presented in this chapter.

In addition to offering archipelagic comparisons of the mapping, oceanographic, and biological observations discussed in the five island/atoll chapters, these analyses explore information about the prevailing deep-water oceanographic environments surrounding each of the islands by using a series of the deep-water (to a ~ 500-m depth) conductivity, temperature, and depth (CTD) casts conducted from the National Oceanic and Atmospheric Administration (NOAA) Ships *Townsend Cromwell*, *Oscar Elton Sette*, and *Hi`ialakai* during American Samoa RAMP (ASRAMP) cruises in 2002, 2004, and 2006. The oceanographic data from these deep-water CTD casts are shown and discussed in Section 8.4.1: Vertical Structure. Regional oceanographic patterns on seasonal time scales were also examined.

8.3 Benthic Habitat Mapping and Characterization

The nearshore waters of the American Samoan Islands were surveyed using multibeam echosounders at depths between ~ 15 and at least 200 m, and in many cases, to depths as great as 3000 m. Optical imagery (video and still photographs) and diver observations of the seafloor at depths between ~ 3 and ~ 80 m were collected during Towed Optical Assessment

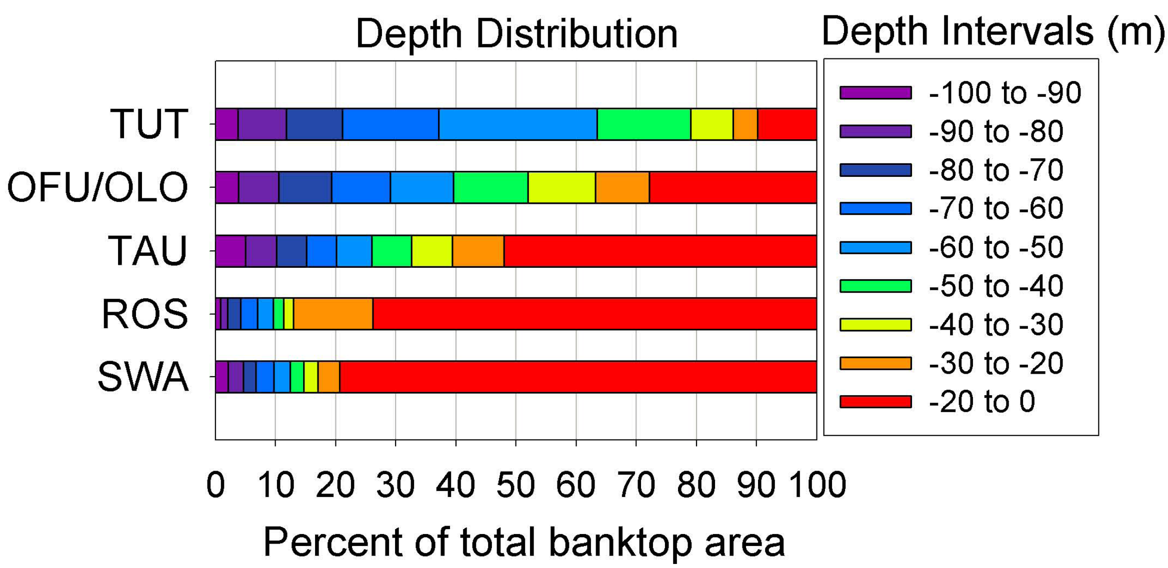

Figure 8.3a. Percentage of the total banktop area included in each depth interval. Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS) and Swains (SWA).

Device (TOAD) surveys and towed-diver surveys. Multibeam bathymetry of the different islands revealed a trend of smaller insular shelves progressing away from Tutuila to the east (toward the Manu`a Islands and Rose) and north (toward Swains). The amount of reef habitat area (depths < 100 m) is substantially higher around Tutuila when compared with the rest of the archipelago, followed by Ofu and Olosega (combined), Ta`u, Rose, and Swains (Fig. 8.1b). Possible reasons for this pattern will be discussed shortly.

As seen in Figure 8.1b, the relationship between total banktop area (defined as all submerged marine habitats at depths between the shoreline and 100 m) and total land area of the high islands (Tutuila, Ofu, Olosega, and Ta`u) is distinct from the low islands (Swains and Rose Atoll). Tutuila, the largest of the islands, has an extensive banktop surrounding the island. Depth intervals around Tutuila decline gradually from shoreline to ~ 100 m, an indication of the gently sloping and extensive banktop habitat surrounding the island (Figs. 8.1b and 8.3a). Ta`u, Ofu, and Olosega are all relatively small islands with significantly smaller surrounding banktop habitat areas. For these islands, bathymetric depth intervals surveyed from shoreline to ~ 100 m descend much more steeply than around Tutuila, with Ta`u descending the most steeply (Fig. 8.3a). Rose Island (within Rose Atoll) is so small that it cannot be displayed on Figure 8.1b; the total emergent land of the island is less than 8.2 ha. Both Rose Atoll and Swains have very limited shallow banktop (Fig. 8.1b). Figure 8.3a shows that depths rapidly descend from 20 to 100 m at both Rose Atoll and Swains. The percent that is shallower than 20 m (backreefs, reef flats, reef crests, and shallow forereef slopes) is greatest at the smallest islands/atolls (Swains and Rose Atoll) and smallest at the largest island (Tutuila; Fig. 8.3.a).

The American Samoan Islands rest on a portion of the earth's crust known as the Pacific Plate, which, in the vicinity of these islands, is drifting to the west at a rate of ~ 7 cm per year (McDougall, 1985). Most of these islands, as well as the islands of Savai`i and Upolu in Samoa (west of American Samoa), were formed by volcanic eruptions when the portion of the plate on which they are resting passed over a thermal plume in the Earth's mantle, the "Samoan hotspot" (Hart et al., 2000). Thus, islands farther to the southeast are generally younger, while the islands farther to the northwest are older. A new volcanic edifice named Vailulu`u that may one day become an island is currently being formed approximately 50 km east of Ta`u. Tutuila is about 1.5 million years old, while Ofu and Olosega, and Ta`u are about 300 000 and 100 000 years old, respectively. Although politically part of American Samoa, Swains and Rose are built on much older volcanoes and are, geologically speaking, not part of the Samoan volcanic chain (Hart et al., 2004).

For at least the last 800 000 years, global sea level has fluctuated about 120 m every 100 000 years or so in response to glacial-interglacial cycles. In the current interglacial period, sea level is near the top of its 120-m oscillation (Ruddiman et al., 1989). When sea level is static for a prolonged period, it tends to erode terraces into land areas. Tutuila has been exposed to erosion from glacial low-stands of sea level for far longer than the more easterly islands and consequently has an insular shelf that is ~ 4 km wide on average, with ~ 320 km^2 of coral reef ecosystem area shallower than 100 m. Ofu and Olosega have a narrow shelf that is ~ 1 km wide in most areas, and banks eroded into several corners of the islands that extend ~ 2 km offshore. Ta`u has an insular shelf that is narrower still, being generally absent on the south and eastern sides of the island. Elsewhere it is generally a few hundred meters wide, except off corners of the island and along the western half of the north shore, where it may be ~ 1 km wide. The volume of sediment stored on the shelves appears to be generally correlated with shelf area. Sediment reservoirs are found in channels offshore of terrestrial drainages, at the base of the forereef slope, and in mid-shelf depressions around Tutuila.

The greater age of Tutuila has enabled the development of other features in addition to the insular shelf itself. Multibeam bathymetry of Tutuila provides a detailed picture of an elevated ridge around the seaward rim of the insular shelf of the island, which probably corresponds to a drowned barrier reef complex. Fishing boats have been observed congregating along this feature, and high coral cover areas have been seen in TOAD imagery in a number of locations (Chapter 3, Section 3.3: Benthic Habitat Mapping and Characterization). Given the potential importance of coral reef resources along the ridge, it will be an area of increased focus during the ASRAMP 2008 cruise.

Multibeam bathymetry has also revealed details of other seafloor features of interest, including a series of small seamounts along an east-west tending ridge starting about ~ 2 km west of Ta`u. TOAD imagery has revealed a luxuriant coral reef on the top of the seamount closest to Ta`u at 38-m depths and deeper (Chapter 5, Section 5.3: Benthic Habitat Mapping and Characterization). Other coral reefs have also been found between 30 and 50 m or even deeper on several of the spurs extending seaward from corners of the Manu`a Islands.

Towed-diver benthic surveys indicate that, on average, the American Samoan Islands had live scleractinian coral cover ranging from ~ 5% to ~ 40%. The Manu`a Islands tended to have greater cover on the southeastern half of the islands and Ta`u, in particular, had areas with > 50% live scleractinian coral cover. In contrast, high coral cover areas around Tutuila tended to occur in sheltered locations, such as Fagatele Bay or on ridges that extend out towards the open ocean. Swains had markedly higher live coral cover than the rest of the islands with values ranging from 20% to exceptionally high values of 75%, with a trend of increasing coral cover to the northeast.

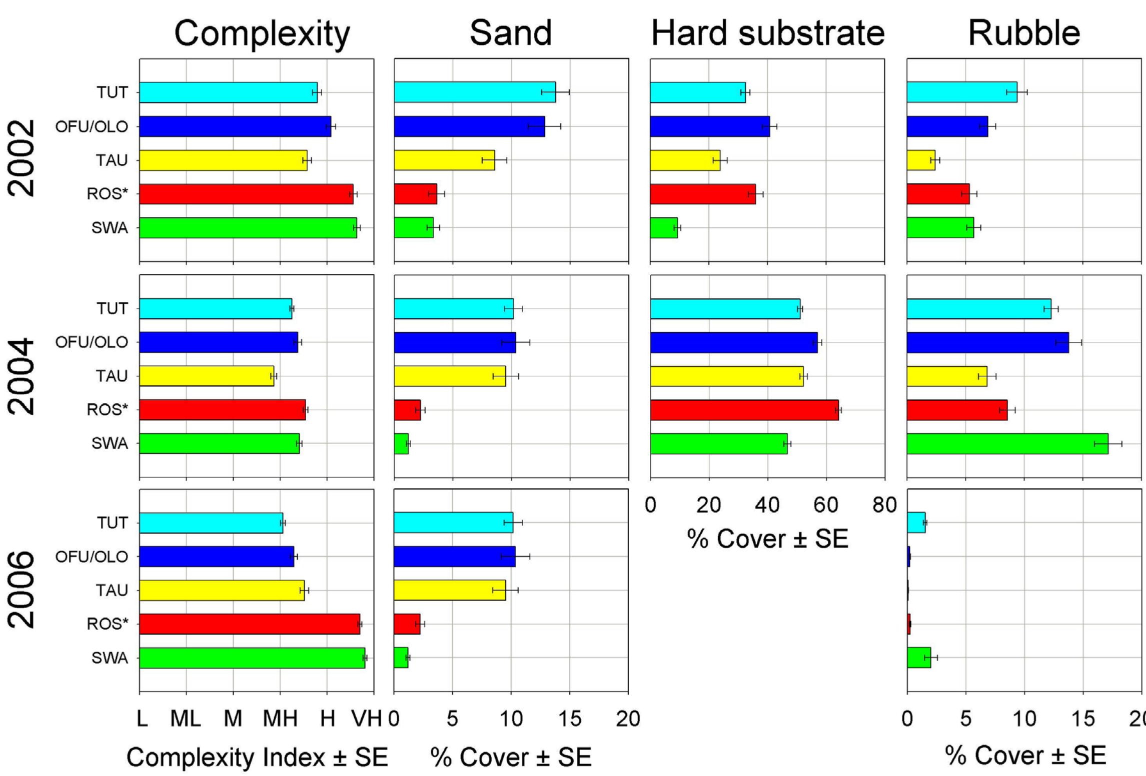

Figure 8.3b. Island-wide mean benthic habitat composition for each of the islands/atolls of the American Samoa Archipelago from towed-diver benthic survey observations during ASRAMP 2002, 2004 and 2006 for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS), and Swains (SWA). The shallow-water habitat was characterized by four measures: habitat complexity (L = low, ML = medium-low, M = medium, MH = medium-high, H = high, VH = very high), sand, hard substrate, and coral rubble. It is not clear at this time whether changes between years are indicative of actual changes in seafloor characteristics or are more reflective of variations in the location of towboard tracks and uncertainty in observer estimates. Note that lagoon data are not presented for Rose; only forereef data are presented for better comparison with the other islands that lack a lagoon.

Benthic habitat characterization data were collected at relatively shallow depths (majority < 20 m) during towed-diver surveys. Results varied within and between years because of changes in survey depths and locations, different divers, and changes in data collection protocols. However, even with these inconsistencies, trends were identified in benthic habitat characteristics from west (Tutuila) to east (Rose) to north (Swains).

Mean habitat complexity was fairly similar between islands and survey periods, generally falling in the range of medium to medium-high complexity from 2002 to 2006 (Fig. 8.3b). However, several notable trends were observed. Overall habitat complexity generally increased moving from west to east and north along the archipelago with Swains having the highest overall mean complexity in most years (2002 and 2006) followed closely by Rose. Habitat complexity was slightly lower around Tutuila versus the Manu`a Island group, possibly because of prolonged exposure to erosion, resulting in large sections of fairly flat shelf areas around Tutuila. Habitat complexity was highest at Swains and Rose partly because of the steepness of their slopes. In addition, both islands are subject to the full effects of large-scale westerly currents and trade wind waves from the east, without the mitigating influence of an insular shelf. The resulting greater nearshore water motion at these two islands (Swains in particular) is hypothesized to at least partly explain why they have higher live coral cover than the islands with greater shelf area, and why coral cover is highest on their more easterly sides.

In contrast, the percentage of benthic sand cover decreased from west to east and north across the archipelago, with Rose and Swains recording the least amount of sandy habitat. These results are supported by the bathymetric and backscatter data, which suggest that sand retention appears to be related to shelf area. Rose and Swains are older than Tutuila but lack the insular shelves found at other islands in American Samoa. The lack of an insular shelf is believed to be the reason for the almost complete lack of sandy habitat seaward of the reef crest. Note, however, that Rose lagoon is predominantly composed of sandy substrate.

Hard substrate/pavement composition varied between years and locations. However, an interesting, if perplexing, trend was noted between 2002 and 2004, with Swains recording the lowest overall hard substrate/pavement cover, followed by Ta`u and Tutuila. It is not clear at this time whether changes between years are indicative of actual changes in seafloor characteristics or are more reflective of variations in the location of towboard tracks and uncertainty in observer estimates. Ofu, Olosega, and Rose constituted the highest recorded hard substrate/pavement cover for 2002 and 2004.

Rubble composition varied by location and by year, which was mostly attributable to changes in classification protocol, with no obvious or discernable archipelago-wide relationship.

8.4 Oceanography and Water Quality

8.4.1 Vertical Structure

Shallow Nearshore Surveys

Nearshore mean-temperature profiles from the shallow-water CTD surveys around each of the islands/atolls during ASRAMP 2002, 2004, and 2006 were relatively consistent throughout the five islands, with depth-associated variability in the upper 30 m of the water column typically < 0.5°C (Fig. 8.4.1a). Swains, the northern and most isolated island of the group, had the warmest, least vertically stratified, least variable temperature profile, with a mean temperature of ~ 29.5°C from the surface to the bottom. Rose, the easternmost island/atoll in American Samoa, had the coolest, most vertically stratified, and most variable temperature profile in the upper 30 m of the water column. The greatest mean temperature variation was observed around Ta`u, with temperature reduced 0.5°C from ~ 29.6°C at the surface (1 m) to ~ 29.1°C at a 32-m depth.

Mean island-wide salinity profiles show much more noteworthy differences among the islands (Fig. 8.1a). Rose had the highest mean salinity (35.3 psu), the largest variability with depth, and the highest variance in surface waters (above the sill depth [~ 6 m] in the channel pass). This is reflected in the high salinity lagoonal waters below the sill depth. The high variance found in the surface waters could be caused by wave setup over the reef crest around the atoll. Mean salinity levels were lowest (~ 34.7 psu) around Swains, with little depth variation in the upper 30 m. Variability of salinity was also high in the surface layer (0–2 m) around Tutuila, probably reflecting a frequent freshwater lens caused by terrestrial runoff from high levels of precipitation. Mean transmission showed little depth variability around all islands. Rose and Ta`u had the highest transmission levels (97–98%) while Swains and Tutuila had the lowest transmission (~ 95%). The variance of transmission was generally low, except in the near-surface waters around Tutuila, probably reflecting terrigenous inputs from watershed runoff. Mean density profiles showed similar trends to that of salinity. Highest density water and most significant depth variation were found around Rose, while lowest density (21.75 kg m^{-3}) and least depth variability were observed around Swains. The highest variance of density was observed in the upper ~ 8 m around Tutuila, also probably reflecting watershed runoff.

Across the archipelago (Fig. 8.4.1b) mean profiles of water properties at each of the islands/atolls showed that Swains, located over 350 km north of the other islands/atolls, was an outlier characterized by significantly different physical water properties. Data from the top 1 m of the water column were potentially skewed because of surface heating and instrument temperature equilibration and should therefore be treated with caution. However, since the data are not unreasonable, they have been included for completeness.

Across the archipelago, Tutuila exhibited the highest concentrations of chlorophyll-a (Chl-a; 0.7 µg L^{-1}), silicates (SiO_2 2.5 µM), and nitrates (NO_2 0.025 µM), although these values were highly variable between sites, as indicated by the elevated standard deviations (Fig. 8.4.1b). Phosphate (PO_4) concentrations were similar amongst the five islands (0.10–0.15 µM), with the exception of Ofu and Olosega, which had slightly lower concentrations. Mean

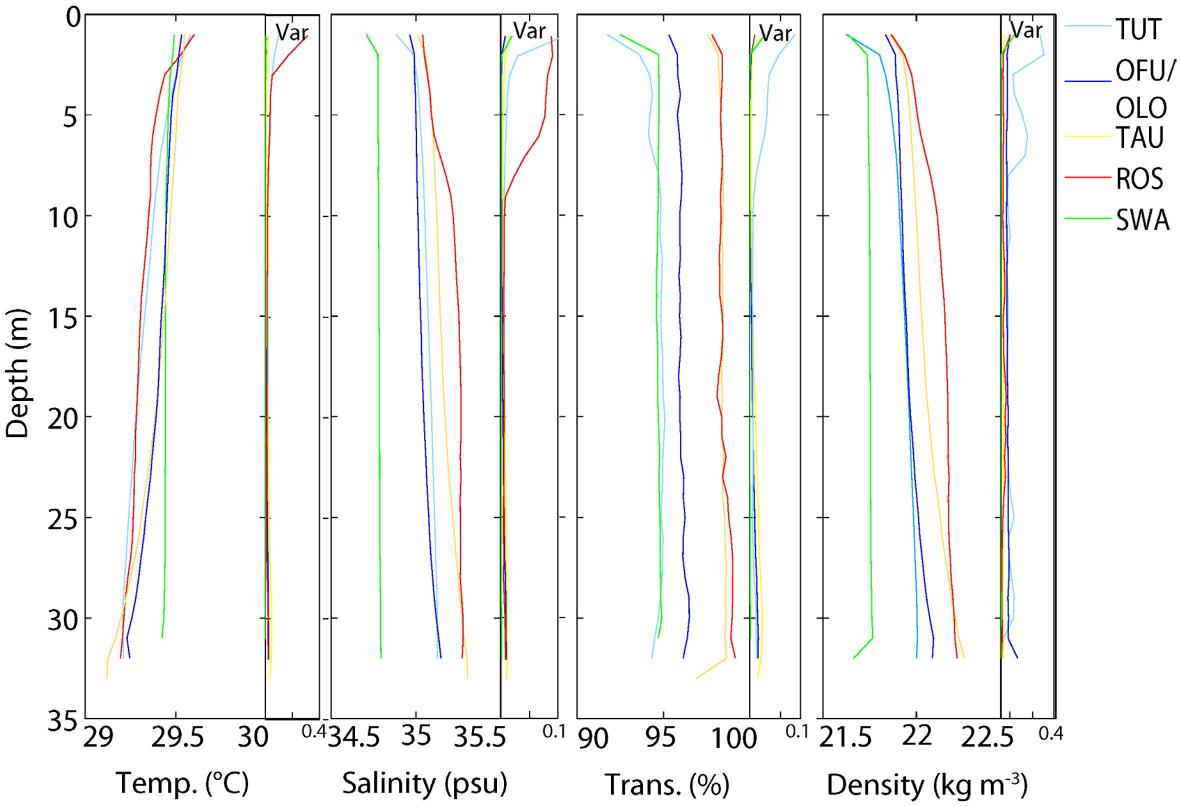

Figure 8.4.1a. Means and variances of temperature, salinity, beam transmission, and density were calculated from shallow-water (< 40 m) CTD casts around each island during ASRAMP 2002, 2004, and 2006 for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS) and Swains (SWA). Data obtained within the freshwater lagoon at Swains were removed before averaging as they were incomparable with the other CTD casts. Data from the lagoon at Rose were included for this analysis.

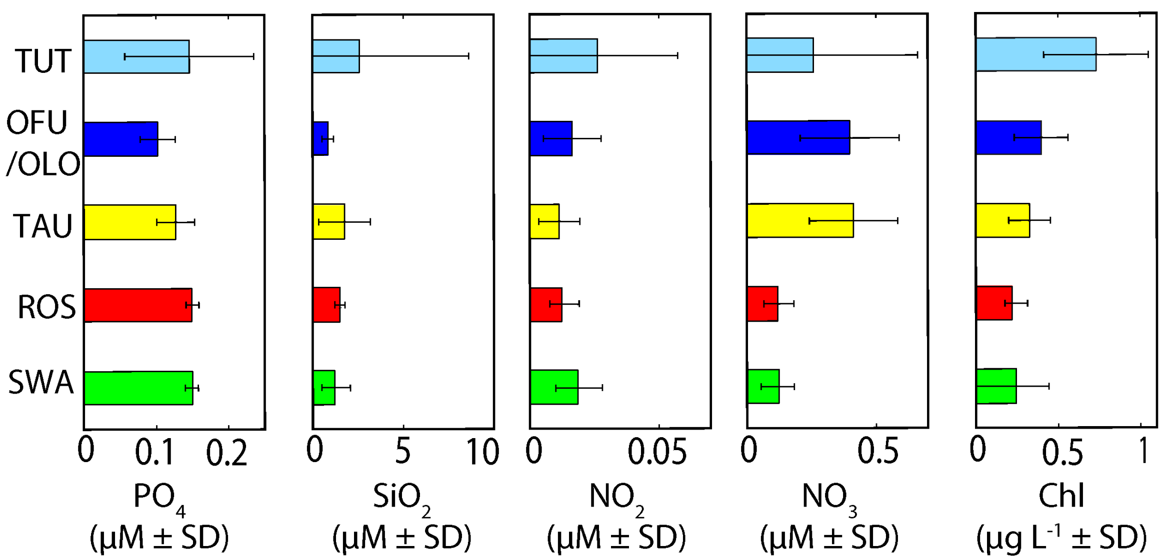

Figure 8.4.1b. Water sampling was conducted at American Samoa during ASRAMP 2006 for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS), and Swains (SWA). Island-wide averages were derived to compare chemical variability throughout the whole archipelago. Data obtained within the freshwater lagoon at Swains were removed as they were incomparable with nearshore oceanographic samples and skewed the results.

nitrite (NO_3 µM) concentrations were highest around Ofu, Olosega, and Ta`u (~ 0.4–0.5 µM), and lowest around Swains and Rose (~ 0.1 µM). Generally, variances of all water quality parameters were highest around Tutuila, probably reflecting the greater range of habitat types and exposures to ocean conditions, and terrigenous inputs from local watersheds.

Mean chemical concentrations from around the islands and atolls of American Samoa indicate that orographic relief, land mass, and population size strongly impact nearshore nutrient and water quality concentrations. The large landmass and higher elevation of Tutuila compared with the other islands produced more seasonal rainfall and increased sedimentation to surrounding waters. Because of these factors, combined with the large population and associated land use, it is not surprising that Tutuila had the highest nutrient and Chl-a concentrations across the archipelago. The large standard deviation in the data obtained from Tutuila were probably caused by spikes in nutrient concentrations near developed areas, where nutrient and contaminant runoff is generally high compared with more rural areas where contaminants are relatively low. The variability of water quality parameters at all other islands is most likely linked to island size and population, as islands of similar land area and number of inhabitants appear to have markedly similar nearshore chemical concentrations.

Deep-water Offshore Surveys

For the deep-water (~ 500 m) CTD casts completed around each island/atoll during the ASRAMP 2002, 2004, and 2006 cruises, each of the four mean vertical profiles of water properties (temperature, salinity, density, dissolved oxygen, and fluorometry) showed that Swains was again an outlier compared with the other islands and atolls (Fig. 8.4.1c). Temperature was consistent throughout the five islands/atolls, each varying from ~ 30°C at the surface to ~ 8°C at 500 m. Although Swains exhibited higher temperatures in the surface waters and slightly lower temperatures below 200 m, the overall temperature variance was < 1°C and was significantly less than this in the surface waters (< 100 m). The island's mean salinity profiles showed similar patterns with depth, peaking at ~ 270 m at 36 psu. The mean salinity profile around Swains followed the general pattern of the other islands but exhibited lower salinity in surface (< 100 m) and deeper (> 220 m) waters. Variability was limited to the surface water and never exceeded 0.1 psu. Oxygen saturation in surface waters was similar around all islands and diverged and undulated with depths below 70 m. Swains had the lowest oxygen saturation with two main troughs: one at ~ 100 m deep (2.6 ml L^{-1}) and another at ~ 350 m deep (at 2.4 ml L^{-1}). Fluorometer levels were low (< 0.1 ml L^{-1}) in surface waters, and peaked at depths around 100 m around each of the islands/atolls. Swains showed the greatest depth variability with a subsurface maximum of 0.35 ml L^{-1}. Rose had the smallest peak in fluorometry at < 0.2 ml L^{-1}. Fluorometry values tended to 0.0 ml L^{-1} below ~ 250-m depths, which corresponds to the deepest penetration of light into the water column. Variances of the fluorometry observations were greatest near the peak at 100-m depths.

Means from both deep- and shallow-water CTD casts show that the coral reef ecosystems around Swains consistently reside in a different oceanographic environment, with different temperatures, salinities, oxygen, and fluorometry readings than the other islands/atolls of the archipelago, at least during the austral summer months of the ASRAMP surveys.

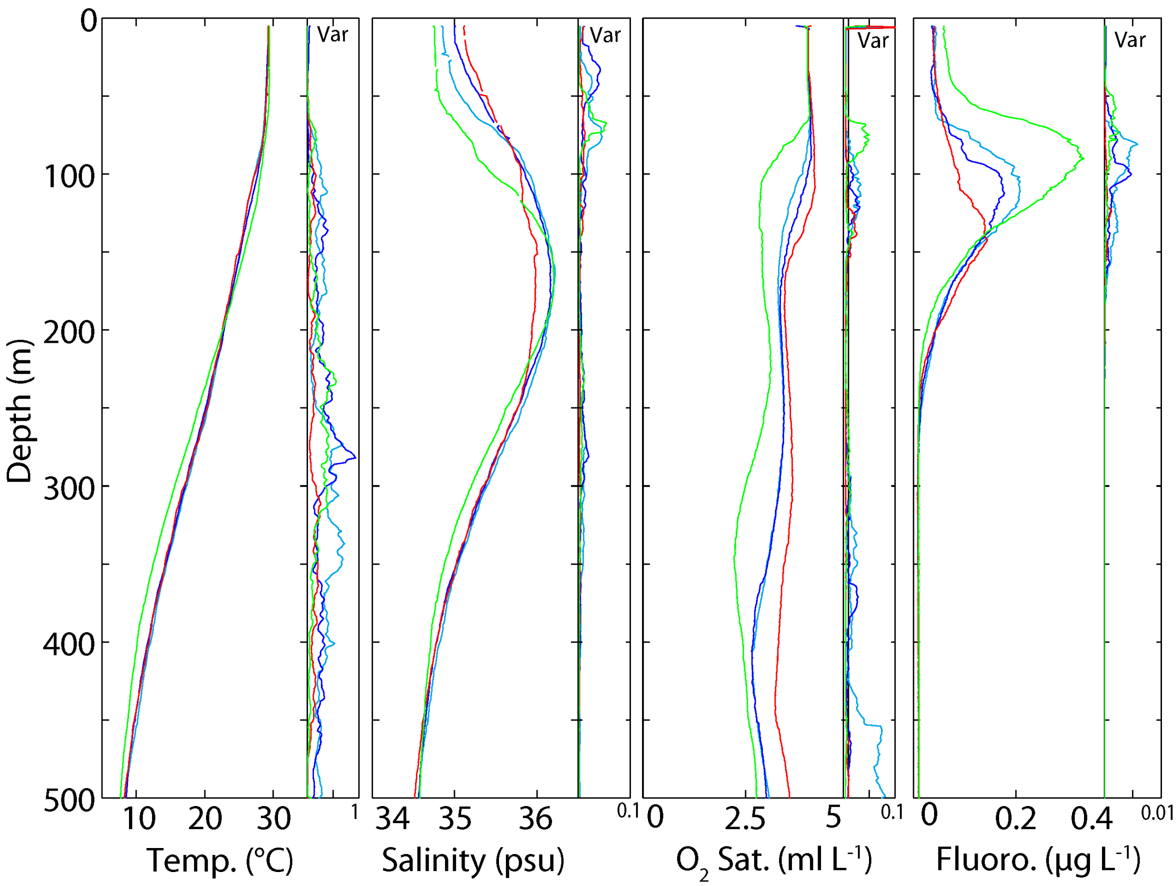

Figure 8.4.1c. Means and variances of temperature, salinity, O_2 saturation, and fluorometry were calculated from shipboard deep-water (~ 500 m) CTD casts taken around each island during ASRAMP 2002, 2004, and 2006 for Tutuila and Aunu`u (TUT), Ofu, Olosega, and Ta`u (MAN), Rose (ROS) and Swains (SWA).

8.4.2 Seasonal Variation

In the previous section, the spatial variability of the vertical structure of water properties around the American Samoa Archipelago was described. Those observations characterized the oceanographic and water quality environment influencing the coral reef ecosystems around the islands and atolls at the times of the surveys, which were conducted only during the austral summer months. In this section, satellite remote sensing observations are used to explore the seasonal variability of key sea surface properties (temperature, Chl-a, and wind speed) across the region in an effort to better understand the range of environmental conditions influencing these reef ecosystems.

Mean sea surface temperature (SST) climatologies for the American Samoa region (10°–15° S; 167°–173° W) are presented for each season (summer [Jan–Mar], fall [Apr–Jun], winter [Jul–Sep], and spring [Oct–Dec]) to examine the seasonal temperature variability across the archipelago (Fig. 8.4.2a). This figure shows an annual temperature range across the region of ~ 3°C; warm temperatures were observed during summer months (~ 29°–30°C) with cooler temperatures during the winter (~ 27°–28°C). During fall, winter, and spring, a pronounced SST gradient occurred between 12° and 13° S, with warmer waters observed to the north of this gradient and cooler waters observed to the south. The gradient weakened and became more diffuse during the summer months; however, north-south differences in SST are still

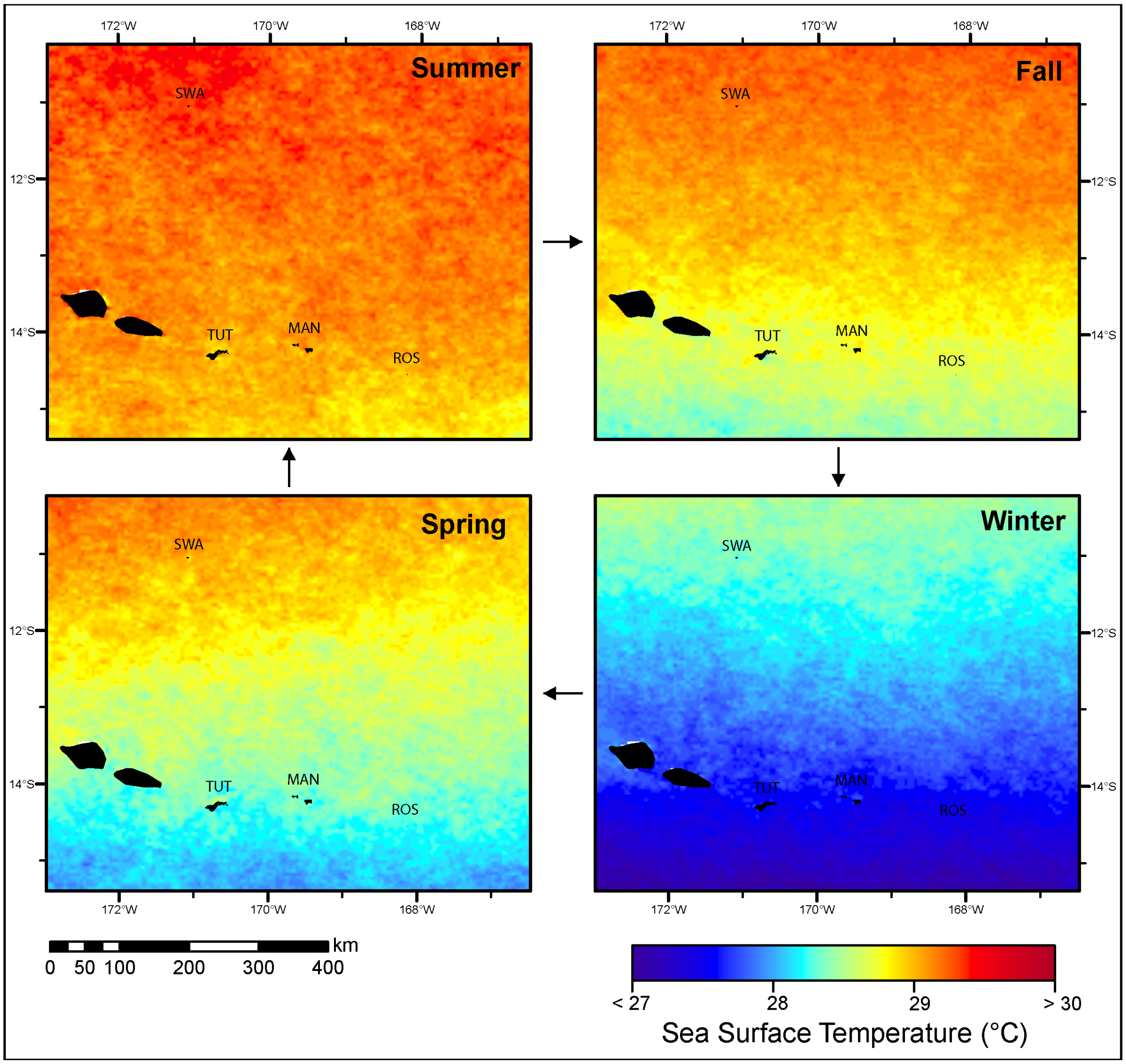

Figure 8.4.2a. Seasonal SST climatology for the American Samoa region (10°–15° S, 167°–173° W). Data is from NOAA Pathfinder 5.0 SST seasonal climatology from 1985 to 2001 produced by National Oceanographic Data Center (NODC; http://www.nodc.noaa.gov/sog/pathfinder4km). Seasons are defined as: Summer = Jan–Mar, Fall = Apr–Jun, Winter = Jul–Sep, and Spring = Oct–Dec. Island abbreviations: TUT = Tutuila, MAN = Manu`a, ROS = Rose, and SWA = Swains.

apparent. As shown in Figure 8.4.2a, Swains is sufficiently far north to lie within a different temperature regime, which is typically 0.5°–1.5°C warmer throughout the year than the waters surrounding the other islands of the archipelago.

Mean climatological Chl-a concentration showed seasonal variability in the American Samoa region (Fig. 8.4.2b), with the lowest concentrations occurring during the austral summer and the highest concentrations during the winter. Latitudinal gradients of Chl-a concentration were absent in the summer, weak in the fall, and relatively strong during the spring and winter, with a south to north increase in Chl-a occurring at ~ 11° S. Swains is located in the middle of this seasonal Chl-a gradient and was in a region of relatively high productivity during the winter and spring. The other islands in the archipelago are located well south of this Chl-a gradient and are surrounded by generally oligotrophic (low productivity) waters throughout the year. When examining specific island effects, it appears clearly that Chl-a values increase to the southwest of Tutuila and Samoa, which may be caused by terrigenous input or topographically induced upwelling influencing local productivity. Rose was observed to have relatively high Chl-a throughout the year; however, this was perhaps an artifact of enhanced reflectance associated with the lagoon, aliasing ocean color in the area.

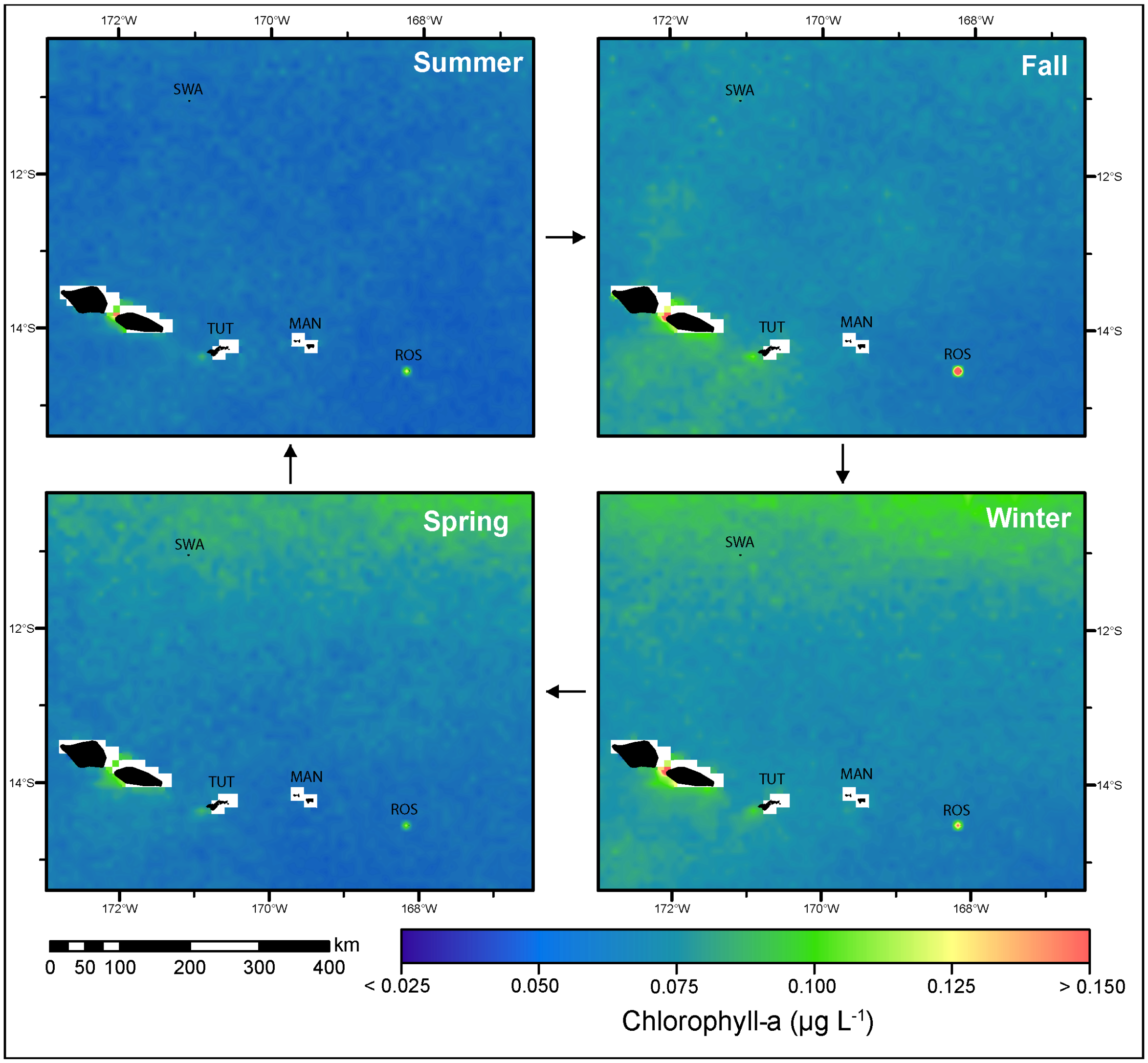

Figure 8.4.2b. Seasonal Chl-a climatology using National Aeronautics and Space Administration (NASA) SeaWiFS imagery for the American Samoa region (10°–15° S, 167°–173° W; http://oceancolor.gsfc.nasa.gov/SeaWiFS). Climatology from 2000 to 2003 produced by Pacific Islands Fisheries Science Center Coral Reef Ecosystem Division (CRED) and NODC for OceanEye project. Seasons are defined as: Summer = Jan–Mar, Fall = Apr–Jun, Winter = Jul–Sep, and Spring = Oct–Dec. Island abbreviations: TUT = Tutuila, MAN = Manu`a, ROS = Rose, and SWA = Swains.

Mean climatological wind speed around the American Samoa region showed seasonal differences with greater speeds in the fall (7–8 m s^{-1}) and winter (8–9 m s^{-1}) compared to winds in the spring (6–7 m s^{-1}) and summer (5–6 m s^{-1}; Fig. 8.4.2c). Overall, winds in the American Samoa region decrease in strength towards the equator. Southeast trades are the dominant winds in this area; however, because of the northerly geographic location of Swains, the island is subject to both weaker annual mean wind speeds, as well as lower variability throughout the year. Weaker mean wind speeds in the vicinity of Swains would be expected to locally increase upper ocean and nearshore water temperatures by decreasing vertical

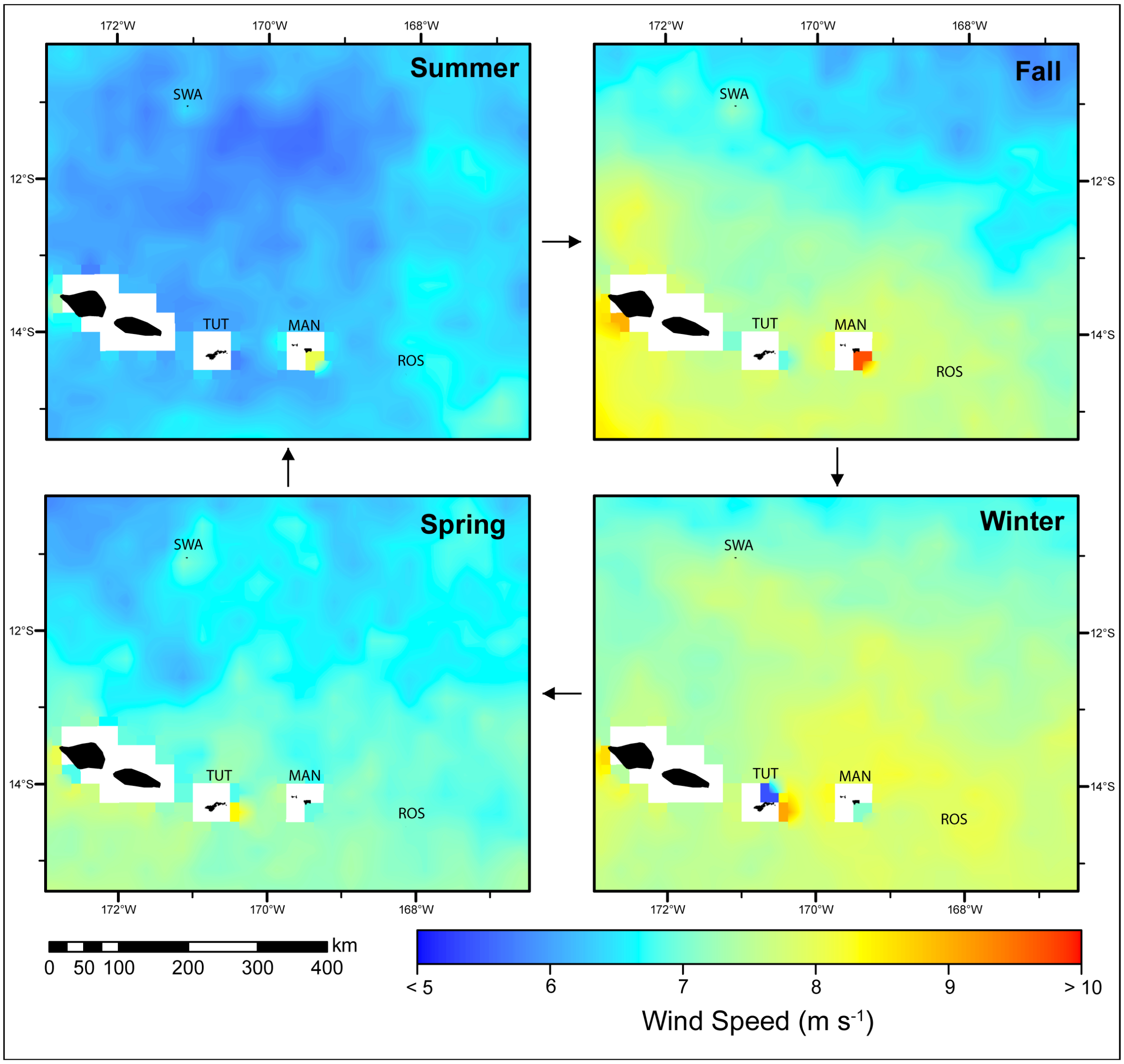

Figure 8.4.2c. Seasonal wind climatology using NASA QuikScat Scatterometer Winds for the American Samoa region (10°–15° S, 167°–173° W; http://winds.jpl.nasa.gov/missions/quikscat/index.cfm). Climatology from 2000 to 2003 produced by CRED and NODC for OceanEye project. Seasons are defined as: Summer = Jan–Mar, Fall = Apr–Jun, Winter = Jul–Sep, and Spring = Oct–Dec. Island abbreviations: TUT = Tutuila, MAN = Manu`a, ROS = Rose, and SWA = Swains.

wind and wave-induced mixing.
Satellite-derived seasonal climatologies for SST, Chl-a, and wind speed were highly variable in the region surrounding American Samoa. Winter conditions were characterized by stronger winds, increased surface productivity, and decreased SST, all of which show strong latitudinal gradients. In contrast, summer conditions exhibit weak latitudinal gradients with generally weak winds, low surface productivity, and increased SST across most of the region.

Satellite-derived climatologies of oceanographic and meteorological data provide a regional and seasonal context for which in situ observations can be interpreted. Although in situ data from each island are discrete with respect to both space and time, incorporating remotely sensed climatological data allows, to a limited extent, for space-time discrepancies to be resolved and general conclusions to be made regarding interisland environmental variability.

Swains is geographically separate from the rest of American Samoa resulting in appreciably different physical oceanographic conditions, as seen via in situ observations and satellite climatologies. However, each of the three ASRAMP surveys occurred during late austral summer (February–March), when minimal gradients in climatological SST and wind were observed. Presumably, in situ oceanographic condition disparities at Swains compared with the rest of the islands in American Samoa would be accentuated during austral winter, when latitudinal gradients in SST and wind are more pronounced.

Conversely, mean in situ Chl-a concentrations in American Samoa seem to be principally dependent on individual island characteristics rather than differences in geographical distribution. For example, Rose and Swains, nearly equal in size, have similar mean chlorophyll values, despite the substantial difference in latitude between them. Island means and interisland comparisons would undoubtedly change if ASRAMP surveys had occurred during the austral winter, when a pronounced north-south gradient and an overall increase in Chl-a are observed (Chapter 7, Fig. 7.3d). While satellite-derived data products are an excellent tool for illustrating temporal changes in Chl-a surface concentrations in the greater American Samoa region, they typically are not dependable for nearshore environments because of complex ocean color issues related to bottom reflectance. The measured in situ Chl-a values, for example, are orders of magnitude greater than satellite-derived climatological values. This demonstrates the significance of using high-resolution (spatial) in situ subsurface and nearshore data, in addition to remotely sensed data, to best describe and understand the oceanographic and water quality properties influencing the reef ecosystems around each island/atoll in the region.

8.5 Coral and Coral Disease

8.5.1 Coral Surveys

In all survey years, visual estimates recorded by towed divers indicated the highest coral cover was observed around Swains (Fig. 8.5.1a; Table 8.5.1a). Rose and Ta`u consistently showed the next highest coral cover values in all survey years. The relative ranking of Tutuila and Ofu and Olosega with regard to coral cover values varied among survey years, though mean coral cover around Tutuila exceeded the coral cover around Ofu and Olosega during 2 of the 3 survey years. Thus, the ranking of island-wide coral cover among American Samoan Islands and atolls, as determined through towed-diver surveys, is best described as Swains > Rose ≥ Ta`u > Tutuila > Ofu and Olosega.

Based on towed-diver surveys, mean island-wide live coral cover values around all islands declined from 2002 to 2004 (Fig. 8.5.1a; Table 8.5.1a). Between 2004 and 2006, mean live coral cover again declined around Tutuila, Ta`u, and Rose, but increased at Ofu and Olosega and Swains (although not to 2002 values). However, these data are based on visual estimates, which are subject to observer variability between survey years. Also, while every effort is made to replicate tracklines between survey years, slight differences in the lateral surface

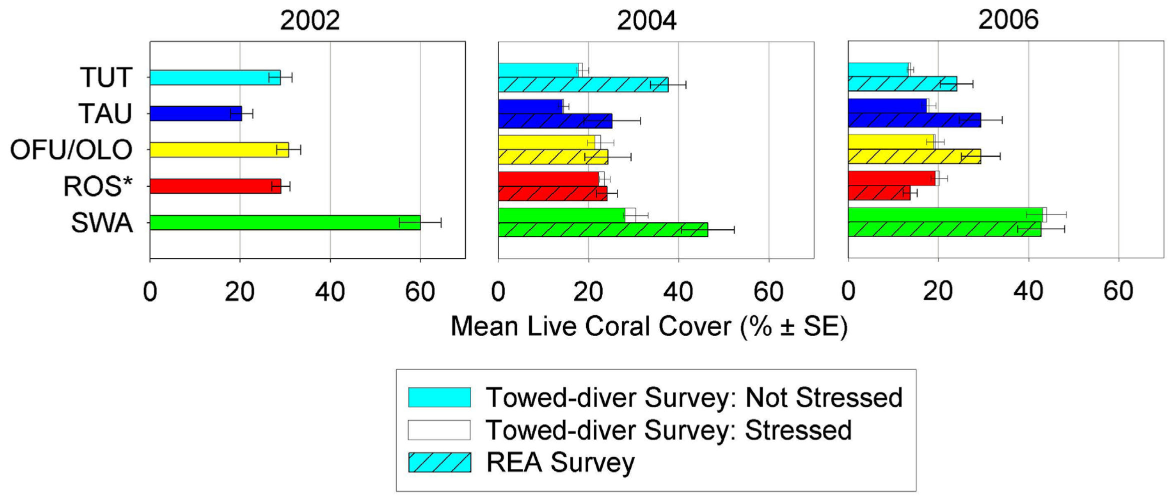

Figure 8.5.1a. Mean percent live coral cover measured from towed-diver and Rapid Ecological Assessment (REA) surveys around Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS), and Swains (SWA) during ASRAMP 2002, 2004, and 2006. Note that lagoon data are not presented for Rose; only forereef data are presented for better comparison with the other islands that lack a lagoon.

position of the towboat can translate to the divers being in different depth strata between survey years. See depth histograms in towed-diver survey track figures in chapter texts (e.g., Chapter 4, Figs. 4.5.1a, 4.5.1d, and 4.5.1j). This effect is particularly pronounced at Rose and Swains, which have steeply sloping forereefs. Therefore, the apparent net decline in coral cover at all locations between 2002 and 2006 should be interpreted with caution.

Table 8.5.1a. Mean percent live coral cover values (as presented in Fig. 8.5.1a). N.A. = not available

Mean Live Coral Cover				
Island	**Year**	**REA Survey**	**Towed-diver Survey**	
			Unstressed	**Stressed**
Tutuila	2002	N.A.	29.0	N.A.
Ofu/Olo	2002	N.A.	20.3	N.A.
Ta`u	2002	N.A.	30.8	N.A.
Rose*	2002	N.A.	29.1	N.A.
Swains	2002	N.A.	60.0	N.A.
Tutuila	2004	37.7	18.7	4.9
Ofu/Olo	2004	25.3	14.5	2.4
Ta`u	2004	24.3	22.7	5.8
Rose*	2004	23.6	23.5	5.6
Swains	2004	46.5	30.5	7.8
Tutuila	2006	24.1	13.7	3.2
Ofu/Olo	2006	29.4	17.9	3.3
Tau	2006	29.7	19.3	2.0
Rose*	2006	13.8	20.1	4.5
Swains	2006	42.8	43.9	1.9

**Forereef only*

"Stressed" is an inclusive category including coral that may exhibit the effects of bleaching, disease, sedimentation or predation. It is not usually possible to clearly determine the cause of stress while being towed above the benthos. During 2004 and 2006, the survey years in which the stressed coral percent cover was estimated, island-wide mean values suggested that 1.9–7.8% of live coral exhibited some form of stress. Swains showed the extremes of this range, with the highest values of stressed coral in 2004 (7.8%) but the lowest values in 2006 (1.9%; Fig. 8.5.1a; Table 8.5.1a). Between 2004 and 2006, stress values declined at all locations except Ofu and Olosega, which showed a slight increase. As with coral cover, these values are based on visual estimates, which are subject to observer variability between survey years.

During 2004 and 2006, the years in which quantitative surveys were conducted, the REA methodologies also indicated the highest island-wide mean live coral percent cover to be around Swains (Fig. 8.5.1a; Table 8.5.1a). The relative ranking of the other islands with regard to coral cover varied between survey years and also varied from that determined during towed-diver surveys. Thus, except for the highest coral cover being found at Swains, it is difficult to generalize archipelago-wide trends of coral cover from data collected during REA surveys. For all islands and survey years, except for Swains in 2006, mean estimates of island-wide live coral percent cover derived from REA surveys were higher than mean estimates derived from towed-diver surveys. Because towed-diver surveys include soft-bottom substrate (e.g., sand) while site-specific REA surveys target hard-bottom substrate, and because towed divers survey substantially more area than free-swimming divers during site-specific REA surveys, the estimates derived from towed-diver surveys probably provide a better measure of mean coral cover across large expanses of habitat than do site-specific surveys. Even though data from the two methods are not strictly comparable, they can be used to make broad generalizations that complement each other. The towed-diver surveys are designed to obtain estimates of benthic composition (including both hard- and soft-bottom substrates) over broad spatial scales, whereas the REA surveys are site specific and designed to better detect changes at target locations.

Between 2004 and 2006, REA surveys showed a decline in live coral percent cover around Tutuila, Rose, and Swains, and an increase around Ofu and Olosega, and Ta`u. The declines around Tutuila and Rose, and the increase at Ofu and Olosega, are congruent with the changes indicated by towed-diver surveys over the same time period and are, therefore, more likely to represent an accurate trend. While the declines in coral cover around Tutuila and Rose appear to be substantial (13.6% and 9.1%, respectively), these data must also be interpreted with caution, as different methods of estimating coral cover were used in 2004 and 2006 (visual estimates and line intercept method, respectively), and estimates derived from the two methods can vary substantially. The line point intercept method will be retained on future surveys to facilitate comparability of data over time.

During both 2004 and 2006 surveys, the total number of coral genera recorded for all REA sites at each island showed the same pattern; the highest number of coral genera was found around Tutuila, followed by Ofu and Olosega, Ta`u, Rose, and Swains (Fig. 8.5.1b). Summing observations over both years, at least 37 scleractinian genera were observed around Tutuila, 34 around Ofu and Olosega, 34 around Ta`u, 23 around Rose, and 18 around Swains (Table

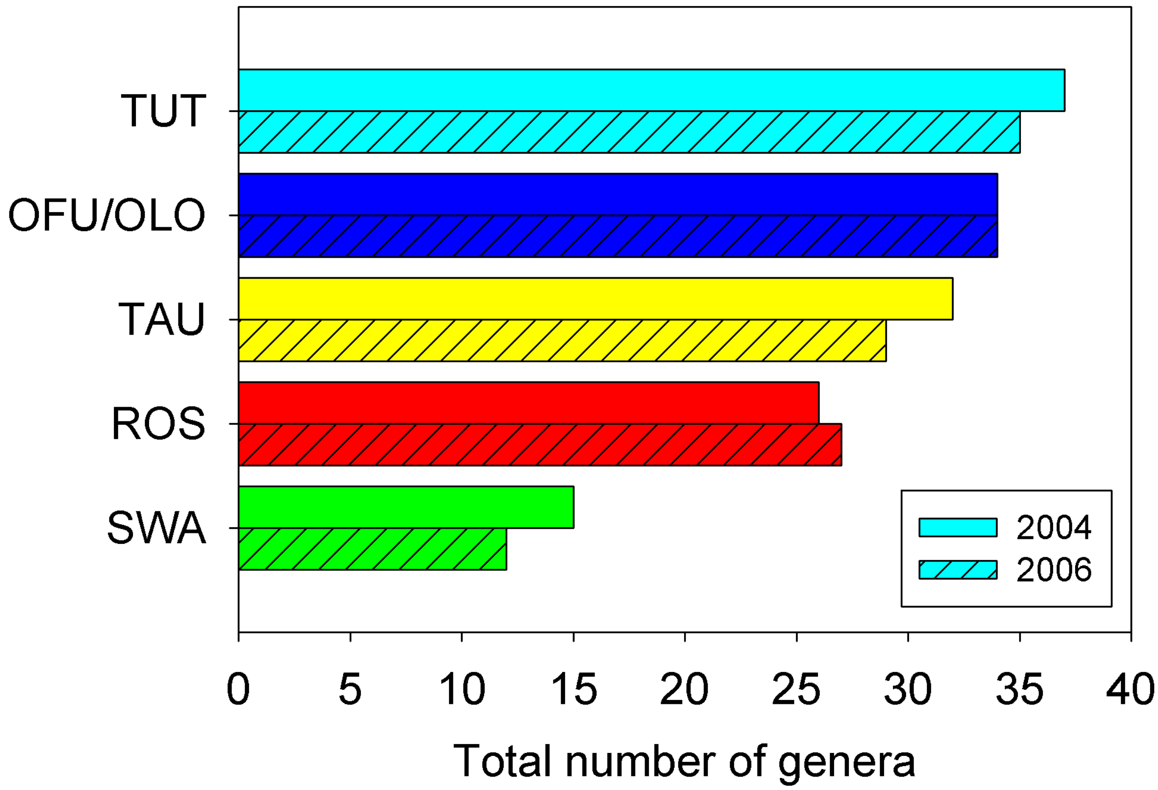

Figure 8.5.1b. Number of coral genera recorded at all REA sites during ASRAMP 2004 and 2006 for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS) and Swains (SWA).

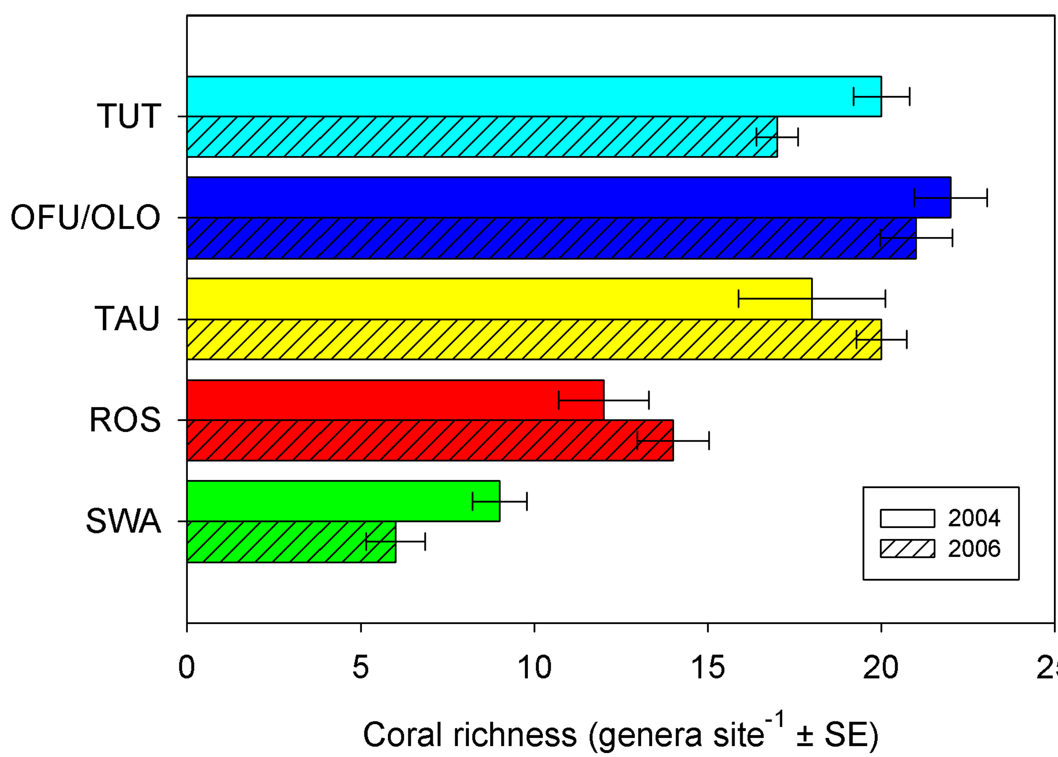

Figure 8.5.1c. Mean coral generic richness per site for REA surveys conducted during ASRAMP 2004 and 2006 around Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS) and Swains (SWA).

Table 8.5.1b. Number of colonies of each coral genus (or group of similar genera) enumerated during 2004 and 2006 REA surveys. Yellow boxes indicate no colonies of these taxa were observed.

Taxa	TUT 04	TUT 06	OFU 04	OFU 06	TAU 04	TAU 06	ROS 04	ROS 06	SWA 04	SWA 06
Acanthastrea	10	4	14	10	9	12		16	1	
Acropora	414	191	67	98	187	207	179	157	3	
Astreopora	172	65	169	162	364	489	196	120		
Coscinaraea	53	23	7	3	11	3	15	20	11	
Cyphastrea	15	5	10	16	6	22	45	38		
Diploastrea	8	2	0	4	5					
Echinophyllia	24	14	10	5		4	2	3		
Echinopora	95	29	13	14	6	5		1		1
Favia	144	64	271	108	344	76	499	287	19	8
Favites	44	29	61	190	105	304	7	1		
Fungia/Cycloseris	141	107	31	63	6	22	40	30	61	6
Galaxea	194	115	285	215	79	112		1		
Gardineroseris	1	8		3						
Goniastrea	70	19	509	581	183	320	3	3		1
GonioporaAlveopora	27	26	6	2	1		2	2		
Heliopora			2	3		5			8	2
Hydnophora	68	36	13	16	5	292	5	6	2	
Leptastrea	452	133	145	188	138	1	43	25		
Leptoseris/Pachyseris	92	31	6	7	2	8	30	15	38	12
Lobophyllia/Symphyllia	186	27	6	10	2	8	7	2		
Merulina/Scapophyllia	23	2	8		5		2			
Millepora	29	8	23	7	1	2	1			
Montastrea	584	337	153	289	102	218	711	514		
Montipora	2123	569	832	1026	627	547	631	367	1037	1642
Mycedium	2	2	2	5		8				
Oulophyllia			23	3	16	26				
Palythoa/Zoanthus	90	7	7	4	11	26	1		1	
Pavona	804	412	76	190	40	116	148	121	19	40
Platygyra/Leptoria	65	30	257	186	91	108	2	1		
Plesiastrea	1									
Pocillopora	461	305	306	451	164	203	1402	1375	1527	859
Porites	857	366	462	208	300	258	314	283	138	97
Psammocora	82	43	23	9	1	6	41	22	53	8
Sandalolitha/Halomitra/Herpolitha	6	3	2	5	7	2				
Sinularia/Lobophytum/ Sarcophyton/Cladiella	854	392	228	60	38	56	368	312		
Stylaster/Distichopora								5		16
Stylocoeniella	1		1					10		
Stylophora	4	2							154	47
Tubastrea	1									
Turbinaria	1	12	7	44	16	4	1			

8.5.1b). This trend is in agreement with the theory of Island Biogeography; the larger the area, the greater number of species occur. Although the relative proportions of the number of coral genera are not the same as the relative proportions of banktop area among islands (Fig. 8.1b), the same trend holds from "most" to "least." However, the evenness with which these genera are distributed at REA sites around the islands varied slightly from this pattern (Fig. 8.5.1c). Although Ofu and Olosega had fewer genera than Tutuila (Fig. 8.5.1b), a higher number of genera per site were observed during both 2004 and 2006 around Ofu and Olosega than around Tutuila, indicating greater generic evenness around Ofu and Olosega than around Tutuila.

Using the number of colonies enumerated at REA sites as a metric, some taxa were ubiquitous and abundant (e.g., *Montipora, Pocillopora, Porites*), some were ubiquitous but uncommon (e.g., *Acanthastrea*, *Leptoseris/Pachyseris, Psammocora*), and others ranged from relatively common (e.g., *Astreopora, Favia, Leptastrea*) to rare (e.g., *Gardineroseris*, *Mycedium, Plesiastrea, Stylocoeniella, Tubastrea*) at the islands where they occurred (Table 8.5.1b). In Table 8.5.1b, the yellow boxes indicate the absence of observed colonies and provide a visual aide for island-wide variability in generic diversity and abundance. Figure 8.5.1d shows in graphic form the relative abundance of primary coral genera during REA surveys during both 2004 and 2006. With the exception of *Acropora*, all the genera shown represent > 10% of colony abundance in at least one of the islands in American Samoa (Fig. 8.5.1d).

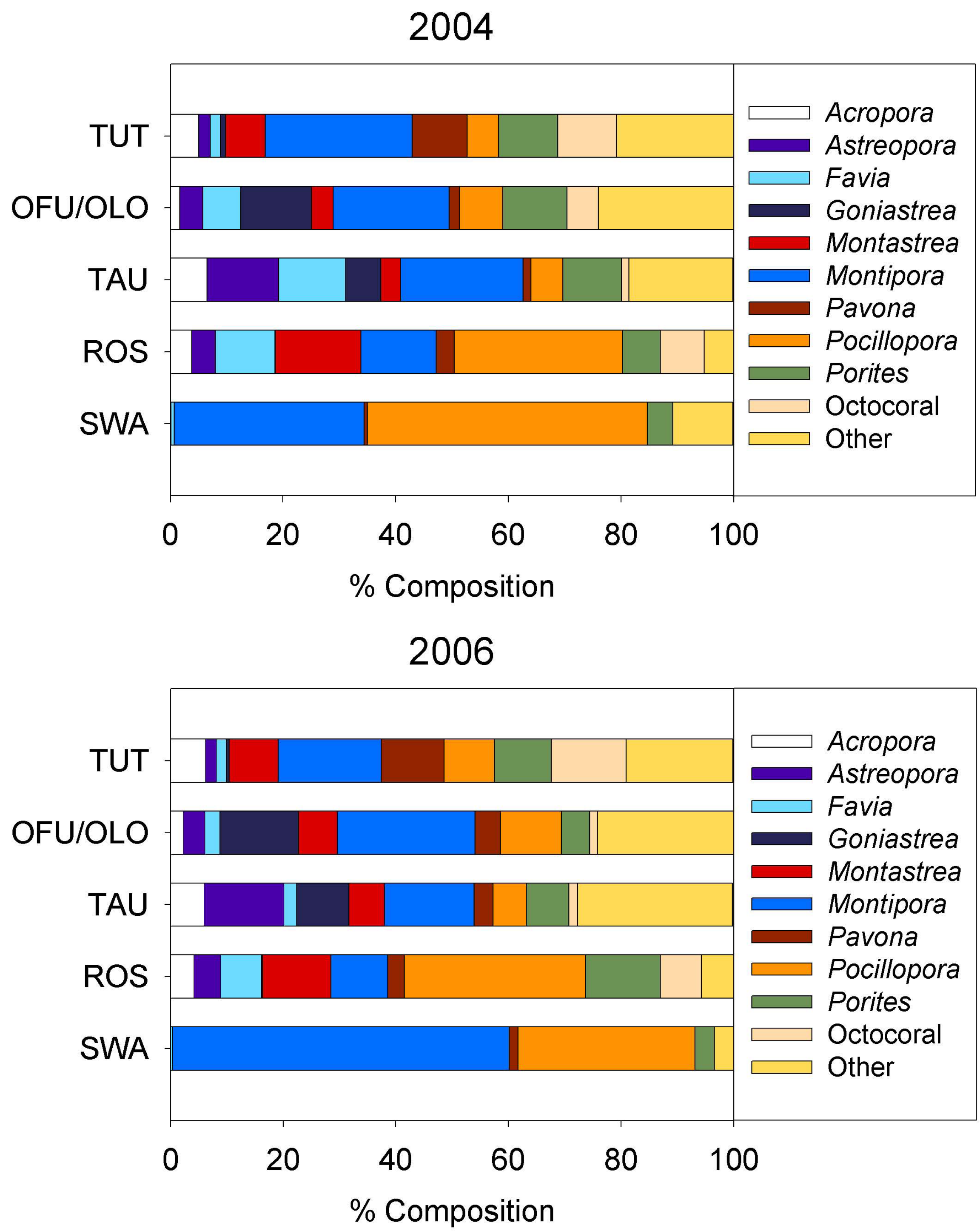

Figure 8.5.1d. Relative abundance of coral genera from ASRAMP 2004 and 2006 REA surveys around Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS), and Swains (SWA).

Montipora numerically dominated all locations with the exception of Rose (both years) and Swains (2004), where *Pocillopora* dominated. The rank order of generic abundance thereafter varies among islands, though generally *Porites*, *Pocillopora*, *Astreopora*, or *Goniastrea* are the next most abundant genera.

Figure 8.5.1e shows island-wide mean coral colony density per site at each island/atoll from

REA surveys during ASRAMP 2004 and 2006. Mean colony densities were greatest around Ofu and Olesega (~ 9 colonies m^{-2}) and Ta`u (~ 7.5 colonies $m^{-2}$) and least around Tutuila (~ 5 colonies $m^{-2}$). Mean colony densities around both Rose and Ta`u appeared to increase somewhat between survey years. Increased density can result from larval recruitment, fragmentation, and fissioning (partial mortality). However, it should be noted that site ROS-23 was not surveyed in 2006 because of strong current, and that transect deployment at TAU-10 was shifted in 2006 relative to 2004; 2004 transects were occasionally deployed over habitats with partial composition of sand, whereas 2006 transects were more strictly deployed over hard substrates. These between-year variations in the assemblage of sites or substrate surveyed may contribute to the apparent difference in mean coral densities observed around Rose and Ta`u.

Figure 8.5.1e also shows colony size distributions around each island/atoll from REA surveys during ASRAMP 2004 and 2006. Colonies around Tutuila and Swains appear to have undergone a general shift towards smaller size classes. However, as discussed elsewhere in the individual chapter texts, field judgments regarding the boundaries of individual colonies are prone to variability among observers because of the highly clonal nature of most coral taxa. In this vein, it is noteworthy that Tutuila and Swains were surveyed by two different coral biologists in 2004 and 2006, whereas one of the coral biologists conducting 2004 surveys also collected the majority of 2006 size class data at Ofu, Olosega, Ta`u, and Rose. Caution must therefore be exercised when examining datasets collected by different observers around Tutuila and Swains. At Ofu, Olosega, Ta`u, and Rose, where the same observer recorded most of the size data in both years, size class distributions did not change substantially between survey years.

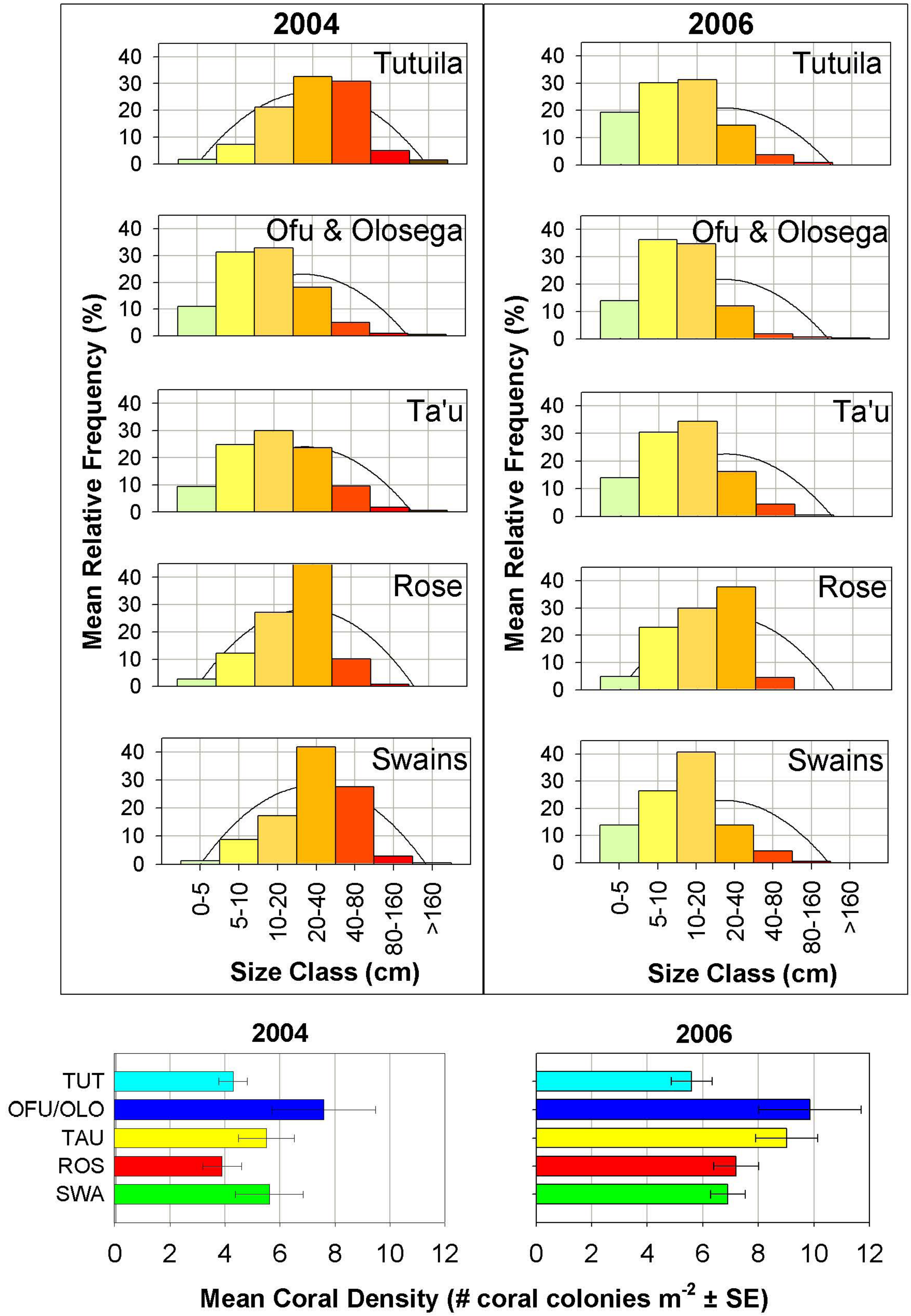

Figure 8.5.1e. Coral colony size class distributions and densities from ASRAMP 2004 and 2006 REA surveys around Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS), and Swains (SWA).

8.5.2 Coral Disease Surveys

Sixty-two coral disease surveys, totaling 25 375 m^2 were conducted around Tutuila, Ofu, Olosega, Ta`u, Swains, and Rose. Within this area, an estimated total of 192 850 colonies were examined. Except for two lagoon surveys conducted at Rose, all belt transects were placed along forereef communities at depths ranging from 10 to 15 m. Within this context, a total of 352 individual cases of coral bleaching and disease, in addition to 217 cases of *Acanthaster* and *Drupella* predation, were enumerated. Disease conditions occurred at all islands, but not at all sites. Sixty-three percent of the sites surveyed exhibited disease, with Rose, Ta`u and Swains reporting cases at 81%, 88%, and 100% of the sites surveyed, respectively. Comparatively, only 55% of sites surveyed around Tutuila, Ofu, and Olosega exhibited the conditions mentioned above.

During the ASRAMP 2006 surveys, at least four disease states (i.e., bleaching, growth anomalies, band disease, and 'other lesions') with the potential for more were observed on corals in American Samoa. This is low compared to the nearly 30 diseases states reported for the Caribbean and western Atlantic (Green and Bruckner, 2000; Weil, 2004). Our surveys also revealed that the mean disease prevalence for all 62 sites combined was 0.34% (SE 0.1). This number is at least one order of magnitude lower than those reported for either the Caribbean or the Great Barrier Reef (Weil, 2004; Willis, 2004). Distribution and overall mean prevalence of disease varied greatly. Figure 8.5.2a shows overall prevalence of disease and predation; predation was highest at Swains, but overall disease prevalence was the lowest, 0.04% (SE 0.03), for all islands surveyed. The highest overall disease prevalence, 0.96% (SE 0.6), was recorded at Rose. At Tutuila, Ofu and Olosega, and Ta`u, disease prevalence values were moderately low: 0.12% (SE 0.04), 0.05% (SE 0.03), and 0.1% (SE 0.03), respectively (Fig. 8.5.2a; Vargas-Ángel et al., in prep.).

Of the ~ 45 different scleractinian coral genera enumerated during the ASRAMP REA surveys, 15 exhibited signs of disease and predation. Figure 8.5.2b illustrates the percentage of coral genera affected by disease and predation derived from the 2006 disease survey data. The greatest number of afflicted genera (9) was detected around Ta`u, Ofu, and Olosega, contrasted by only 6 at Swains. Around Tutuila, 7 different coral genera exhibited disease and predation, compared to 8 at Rose. Figure 8.5.2b also shows that only a limited number of coral genera were disproportionately affected by disease and predation at the study locations. These patterns may be dictated by host/prey and predator abundance, as well as modes of disease transmission, pathogen life history and virulence. In the American Samoa Archipelago, the rank order of coral generic propensity to disease and predation appears to be *Montipora*, *Pocillopora*, and *Porites*. With respect to other taxa, the rank order varies among islands, although *Acropora*, *Astreopora*, and *Montastrea* appear to be the next more commonly afflicted coral genera. Trends like these suggest that the ecological impacts of disease and predation may be more severe in populations of infrequent or rare coral taxa.

Of the 352 cases of disease itemized in this study, the category 'other lesions' represented 75.3%. Around Rose alone, 98% of lesions involved this condition affected, in decreasing order of importance, corals in the genera Favia, Montastrea, and Porites. Comparatively, 'other lesions' represented only 30% of cases for Tutuila and Ta`u combined. 'Other lesions' were not encountered at any of the sites surveyed around Ofu and Olosega. Lesions involving skeletal growth anomalies represented 13.3% of all disease cases. Skeletal growth anomalies were also detected around all islands, but affected predominantly corals in the genera Acropora and Astreopora. Within colonies of Acropora, the greatest mean occurrence of growth anomalies was recorded around Ofu and Olosega, particularly on specimens of A. abrontanoides and A. cytherea. Coral bleaching was also detected around all islands; bleaching represented 9.4% of all disease cases and was most commonly observed around Ofu and Olosega. All lesions were small and focal, and severity was mild. Bleaching occurred most commonly on Porites, Montastrea, and Montipora. Lesions involving tissue loss represented 1.7% of all disease cases; a total of 6 instances were enumerated for all islands combined. Acroporid acute tissue loss (a.k.a. white syndrome) was registered at Tutuila and Rose only. Finally, black band disease was the least common type of lesion, with 1 case detected among the 62 sites surveyed; estimated prevalence was 0.02% (Vargas-Ángel et al., in prep.). Acanthaster and Drupella predation were also ubiquitous, with Rose exhibiting 58% of cases and the majority of these occurred on colonies of Pocillopora. Acanthaster and Drupella predation were also common around Swains, where 34% of cases were encountered mainly on plate-like colonies of Montipora and Pocillopora. The remaining cases were observed around Tutuila, Ofu, and Olosega. No Acanthaster and Drupella predation were observed around Ta`u (Vargas-Angel et al., in prep.).

Disease prevalence and predation, together with other coral reef ecosystem bio-indicators, such as changes in live coral percent cover, diversity, size class distribution, and changes in abundance and diversity of algae, fish density and biomass, and key macroinvertebrate assemblages, may provide proxies to ecosystem integrity and health. Although it appears

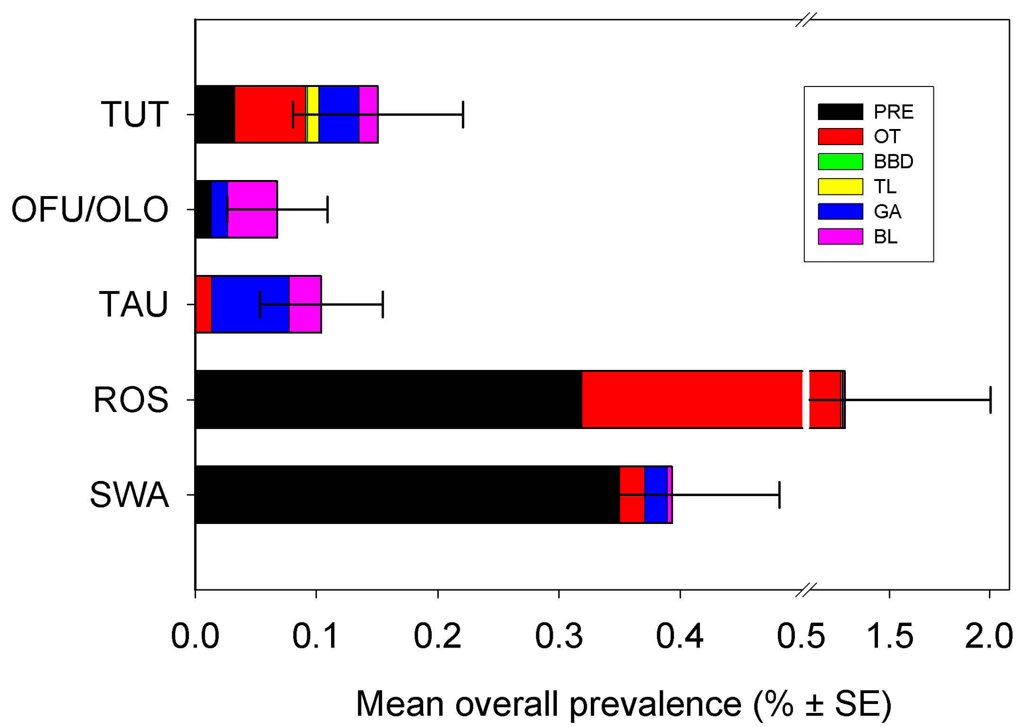

Figure 8.5.2a. Mean overall prevalence of coral disease and predation determined from REA surveys during ASRAMP 2006 around Tutuila and Aunu`u (TUT), Ta`u (TAU), Ofu and Olosega (OFU), Rose (ROS), and Swains (SWA). PRE = Acanthaster and/or Drupella predation; OT = other lesions, including hyperpigmented irritations and discolorations other than bleaching; BBD = black band disease; TL = tissue loss; GA = skeletal growth anomalies; and BL = bleaching.

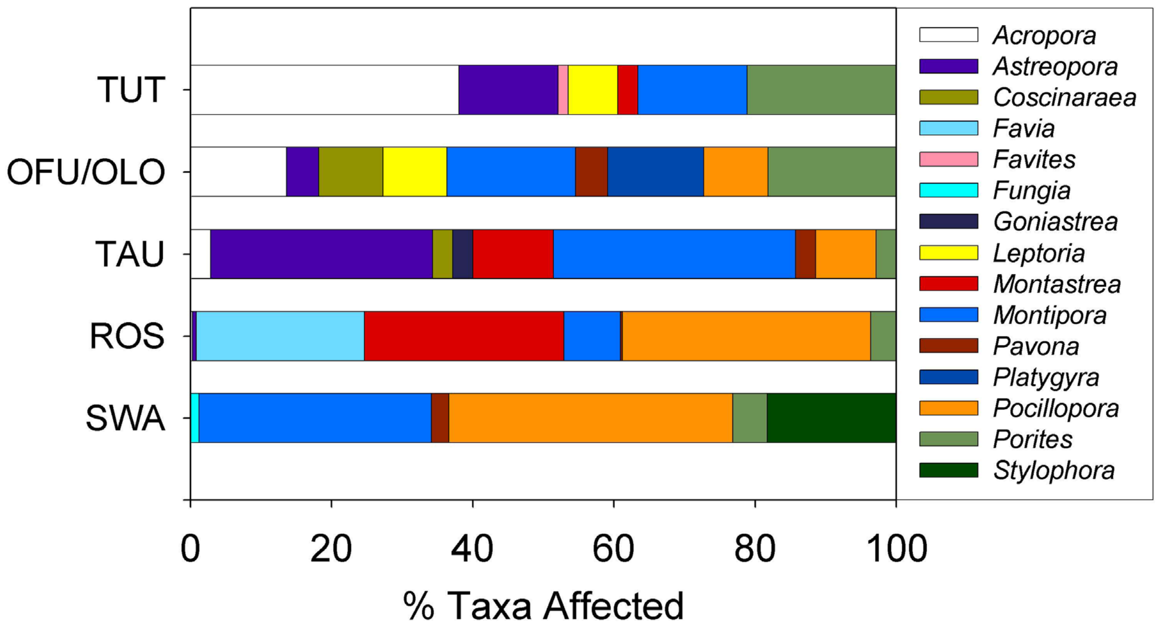

Figure 8.5.2b. Percent scleractinian coral taxa affected by disease and predation, based on the ASRAMP 2006 REA surveys around Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS), and Swains (SWA).

that mean overall disease prevalence and predation were low in the American Samoa Archipelago, until extensive surveys are conducted and more is known about the etiology of Indo-Pacific coral diseases, it is difficult to compare prevalence levels in American Samoa with other parts of the Indo-Pacific.

Disease and predator outbreaks are among several other recurrent natural disturbances of corals including episodic sea warming and storms. Coral disease may be exacerbated by human activities, which have been increasing in Indo-Pacific coral reef ecosystems, including those in the American Samoa Archipelago (Craig et al., 2005). At Tutuila, for example, deforestation and urban development along the south-facing shores, in concert with increased levels of rainfall, have the potential for adversely affecting coastal water quality and therefore the well being of nearshore coral communities. In addition to detrimental direct effects of siltation stress on coral reefs (see review by Rogers, 1990), equally important is the potential for increased occurrence and prevalence of coral disease, such as those observed at Rose. 'Other lesions', particularly hyperpigmented irritations with algal overgrowth, reached the greatest levels of prevalence for any disease (4.9%) at site ROS-23. It has been proposed that the iron leaching from the corroding metal debris scattered during the 1993 Jin Shiang Fa shipwreck is likely responsible for stimulating and maintaining elevated cover of benthic turf algae/cyanobacteria at the wreck and neighboring sites at Rose (Green et al., 1997; Schroeder et al., in prep.). Little is known about the secondary effects of this disturbance on adjacent and neighboring sites. However, it is plausible that the conditions mentioned above are connected to the prominent number of cases of coral irritations and algal overgrowth enumerated at Rose. Further research on this topic is needed.

8.6 Algae

8.6.1 Algal Surveys

During the ASRAMP 2002 and 2004 survey periods, the towed-diver benthic survey protocol aggregated observations of turf and macroalgae into a single category. In contrast during ASRAMP 2006, macroalgae were recorded as a distinct category and turf algae were not recorded. Therefore, it is not surprising to see a two- to threefold decrease in algal cover around Tutuila, the Manu`a Islands, and Rose in 2006 over what was recorded in previous years (Fig. 8.6.1a).

This does not indicate that macroalgal cover decreased across American Samoa from 2002 to 2006. In fact, an increase in macroalgal cover is evident around Swains (Fig. 8.6.1a) despite the change in protocol to no longer include turf algae. The percent cover of macroalgae or macroalgae and turf algae was generally similar among all islands in all years (15–30% cover when turf algae and macroalgae were combined; typically < 10% cover when macroalgae were considered alone); the main exceptions being a higher turf and macroalgae cover around Rose in 2002 (~ 40%) and a higher macroalgae cover around Swains in 2006 (~ 40%) than at other islands. The reason for the observed high mean macroalgae percent cover around Swains in 2006 is not clear, although it could reflect the perturbations to the ecosystem at Swains caused by both coral breakage associated with tropical cyclones Heta (observed) in 2004 and Percy and Olaf in 2005, and the ongoing increase of crown-of-thorns seastar (COTS) populations observed around Swains in both 2004 and 2006.

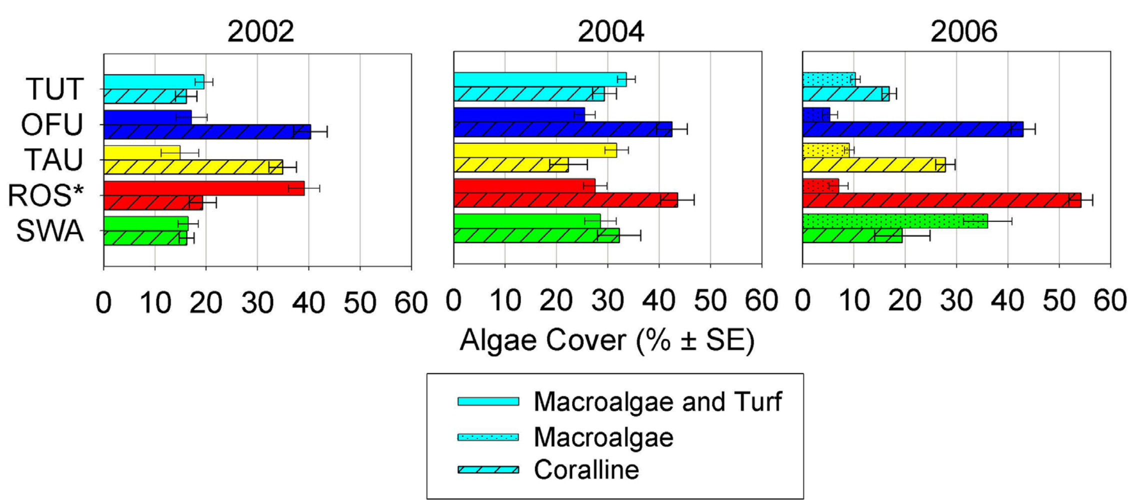

Figure 8.6.1a. Percent cover of algal functional groups from towed-diver surveys in the American Samoa Archipelago during ASRAMP 2002, 2004 and 2006 for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS forereef only) and Swains (SWA). Note that lagoon data are not presented for Rose; only forereef data are presented for better comparison with the other islands that lack a lagoon.

During ASRAMP 2002, the Manu`a Islands (Fig. 8.6.1a) appeared to have a substantially higher crustose coralline algae percent cover (> 30%) than Tutuila, Rose, or Swains (all < 20%). During ASRAMP 2004, crustose coralline algal cover appeared similar at all islands and ranged from ~ 25% to 45%, with Rose and Ofu and Olosega both having observed values of ~ 45%. During ASRAMP 2006, the crustose coralline algae percent cover around Rose was almost 55%, while other islands ranged from 15% to 45%, with Ofu and Olosega again having ~ 45% cover. Differences among years may be attributed to other benthic organisms covering crustose coralline algae (e.g., macroalgal overgrowth), thereby influencing diver observations.

During ASRAMP 2004, 13 genera of green algae, 27 genera of red algae, 3 genera of brown algae, and 4 algal functional groups were reported from REA sites surveyed across American Samoa (Table 8.6.1a). The number of genera found at each site will increase as detailed taxonomic laboratory analyses at the species level are completed. During 2006, 17 genera of green algae, 32 genera of red algae, 2 genera of brown algae, and 4 algal functional groups were reported. The theory of Island Biogeography states that larger islands will contain greater biodiversity because they generally exhibit a greater number of habitat types. Table 8.6.1a reveals that field surveys around Tutuila, with the largest area of habitat and number of habitat types in American Samoa, documented substantially more algal genera or functional groups than other islands surveyed during both years of field sampling. The three geographically close, high, volcanically derived Manu`a Islands that are situated east of Tutuila exhibited the second highest number of recorded algal genera. The two smallest islands in American Samoa, Rose and Swains (both low, oceanic atoll systems), contained the least amount of algal diversity. Swains had less than half the number of algal genera as Tutuila, which is consistent with the small habitat area and number of habitat types.

Table 8.6.1a. Number of green, red, and brown macroalgal genera and functional groups (non-geniculate branched red coralline algae, crustose coralline red algae, turf algae, cyanophytes) reported during in situ surveys around each island or island group in American Samoa during ASRAMP 2004 and 2006 cruises. The number of genera found at each site will increase as detailed taxonomic laboratory analyses are completed. Xs represent genera or functional groups found during 2004, Ys represent genera or functional groups found during 2006.

	Manu`a Islands	Rose	Swains	Tutuila
Total # Green Macroalgal Genera	6 – 2004 12 – 2006 12 – total	6 – 2004 12 – 2006 12 – total	5 – 2004 8 – 2006 8 – total	11 – 2004 12 – 2006 14 – total
Boergesenia				X
Boodlea	XY	Y		XY
Bornetella	Y			
Bryopsis	Y	XY		XY
Caulerpa	Y	XY	XY	XY
Chaetomorpha		Y	Y	
Chlorodesmis	XY	Y		XY
Cladophora	Y	Y		Y
Codium			Y	Y
Dictyosphaeria	XY	XY	XY	XY
Halimeda	XY	XY	XY	XY
Microdictyon		XY	XY	
Neomeris	XY	Y		XY
Rhipilia			XY	
Tydemania	XY			X
Udotea	Y	Y		Y
Valonia	Y	XY		XY
Ventricaria			Y	XY
Total # Red Macroalgal Genera	10 – 2004 24 – 2006 25 – total	4 – 2004 13 – 2006 14 – total	4 – 2004 6 – 2006 7 – total	24 – 2004 28 – 2006 32 – total
Actinotrichia	XY	Y		XY
Acrosymphyton				X
Amansia	Y			
Amphiroa	XY	XY		XY
Botryocladia				Y
Callophycus				X
Carpopeltis	XY			
Champia	Y	Y		Y
Cheilosporum	Y	Y		XY
Chrysymenia	Y			XY
Corynocystis				XY
Dasya	Y	Y	Y	Y
Dudresnaya				X
Galaxaura	XY	XY	XY	XY
gelid	XY	Y		XY
Gelidiopsis	Y	Y	Y	XY
Gibsmithia	Y			XY
Gracilaria	Y			
Grateloupia	Y	Y		Y
Griffithsia		Y		Y
Haloplegma	XY			XY

Halichyrsis	Y			Y
Halymenia				XY
Hypoglossum	Y			Y
Jania	Y	Y	XY	XY
Laurencia/Chondrophycus	XY	X	Y	XY
Liagora	X			XY
Lithanophora				Y
Martensia	Y	Y		XY
Peyssonnelia	XY	XY	XY	XY
Portieria	XY			XY
Predaea				XY
Titanophora	Y			XY
Trichogloea				X
Tricleocarpa				XY
Wrangelia	Y		X	
Total # Brown Macroalgal Genera	1 – 2004 2 – 2006 2 – total	3 – 2004 2 – 2006 3 – total	2 – 2004 2 – 2006 2 – total	2 – 2004 2 – 2006 2 – total
Dictyota	Y	XY	XY	XY
Lobophora	XY	XY	XY	XY
Stypopodium		X		
Total # Algal Functional Groups	3 – 2004 4 – 2006 4 – total	3 – 2004 4 – 2006 4 – total	4 – 2004 4 – 2006 4 – total	4 – 2004 4 – 2006 4 – total
non-geniculate branched coralline red algae	Y	X	XY	XY
crustose coralline red algae	XY	XY	XY	XY
turf algae	XY	XY	XY	XY
cyanophytes	XY	XY	XY	XY
Total # of macroalgal genera or functional groups documented	43	33	21	52

To gain a sense of which algae were the most common at each island, the percentage of quadrats in which a genus or functional group occurred at a given island within each sampling period was calculated (Table 8.6.1b). These were then added together, and the contribution of each single genus or functional group divided by the total to determine the relative proportion of occurrence for each genus or functional group at each island (Fig. 8.61d). If algal species composition at a single island begins to change temporally, the relative proportion of occurrence of algal genera or functional groups will change.

Table 8.6.1b. Percentage of quadrats in which select macroalgal genera or functional groups occurred at each island. Data without parentheses represent 2004, data within parentheses represent 2006. **The person recording data had difficulty identifying algal genera at Rose in 2006, so these numbers may be incorrect.*

	Ofu	Olosega	Ta`u	Tutuila	Rose	Swains
Green Macroalgal Genera						
Dictyosphaeria	11.1 (6.7)	4.2 (1.7)	4.6 (28.1)	5.3 (10.8)	16.7 (40.8*)	13.5 (19.8)
Halimeda	22.2 (33.3)	20.8 (10.0)	11.1 (19.8)	29.6 (38.8)	37.1 (36.7*)	1.0 (0)
Microdictyon	0	0	0	0	31.9 (91.7*)	58.3 (51.6)
Rhipilia	0	0	0	0	0	74.0 (74.0)
Red Macroalgal Genera						
Peyssonnelia	47.2 (83.3)	10.4 (58.3)	3.7 (79.2)	45.8 (43.0)	2.1 (74.2*)	13.5 (20.8)
Brown Macroalgal Genera						
Lobophora	30.6 (0)	33.3 (0)	10.2 (12.5)	10.2 (6.3)	38.2 (74.2*)	6.3 (16.7)
Algal Functional Groups						
turf algae	97.2 (96.7)	83.3 (98.3)	91.7 (95.8)	93.9 (92.5)	83.0 (94.2)	85.4 (55.2)
crustose coralline red algae	97.2 (95.0)	100.00 (93.3)	73.2 (88.5)	76.1 (82.1)	86.1 (95.0)	93.8 (76.0)
non-geniculate branched coralline red algae	0 (3.3)	0	0	1.5 (1.3)	45.8 (0*)	32.3 (0)
cyanophytes	30.6 (86.7)	54.2 (55.0)	14.8 (58.3)	24.2 (12.5)	62.5 (93.3*)	46.9 (17.7)

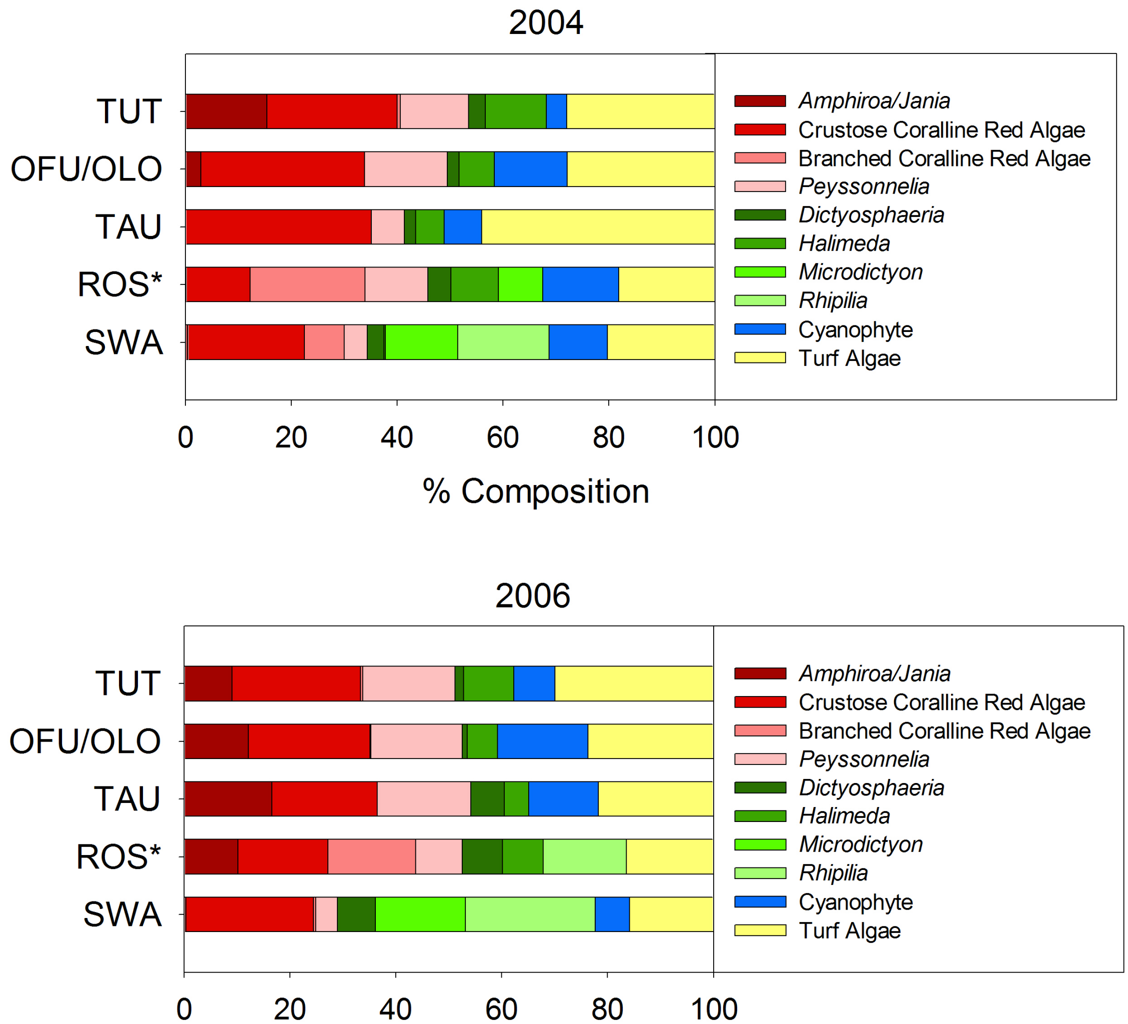

Figure 8.6.1b. Percent occurrence of select algal genera and functional groups at REA sites around American Samoa during ASRAMP 2004 and 2006 for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS) and Swains (SWA). Note that lagoon data are not presented for Rose; only forereef data are presented for better comparison with the other islands that lack a lagoon.

Figure 8.6.1b clearly shows how algal composition at the various islands compare within a given year. Table 8.6.1b lists the percentage of quadrats in which select macroalgal genera or functional groups occurred around each island. It is clear that the algal functional groups of turf algae and crustose coralline red algae were the most commonly encountered algae in almost every quadrat across all islands during both years sampled. This is not surprising since dense turf algal communities rapidly colonize available substrate. Crustose coralline red algae have also been found to be an early colonizer with rapid rates of growth. Crustose red algae play a critically important role in reef ecosystems by cementing together loose rubble and serving as a suitable settling surface for invertebrate (especially coral) larvae.

Some macroalgal genera reveal distinct differences among islands and may be useful in terms of spatially describing differences in reefs across American Samoa. Swains was the only ecosystem reported to contain the green alga, *Rhipilia*, where it was very common. Similarly, both Rose and Swains, two island systems remote from the rest of American Samoa, supported communities of the green alga, *Microdictyon*, and non-geniculate branched coralline red algae. Because these algae were either not found or else scarce on larger, high islands, these algal distributional patterns may suggest oceanographic or geomorphic differences between islands. Other macroalgal genera, such as the green alga, *Dictyosphaeria*, appear ubiquitous across islands, appearing with similar frequency everywhere. Such genera might be useful indicators of reef health, signaling a decline in health if their presence is no longer recorded or if blooms occur.

Temporal comparison of 10 common algal genera or functional groups found at islands in American Samoa (Fig. 8.6.1b) reveal genera such as the green alga, *Dictyosphaeria*, to be a common component of reef systems across the American Samoa Archipelago, although in relatively low density (Fig. 8.6.1b). Other genera such as the green alga *Halimeda* (Fig. 8.6.1b) are fairly prevalent on some islands (Tutuila, Manu`a, and Rose), but less common on others (Swains). Finally, other genera are only found in specific locations (e.g., *Rhipilia orientalis* only occurs at Swains, *Microdictyon* [Fig. 8.6.1b] only occurs on Rose and Swains). Such island differences may be useful in helping to define attributes of a healthy reef system. For instance, if the ubiquitous alga, *Dictyosphaeria*, suddenly disappears from certain reef settings, this may indicate a decrease in reef health. Alternatively, if an alga that is only known from one island suddenly appears on geographically distant islands, it may indicate a human introduction that will necessitate monitoring to ensure than it does not become invasive in its nonnative environment.

8.6.2 Coralline Algal Disease Surveys

Surveys during ASRAMP 2006 enumerated a total of 504 cases of coralline algal disease in the American Samoa Archipelago (Vargas-Ángel et al., in prep.); this is nearly 45% higher than the incidence of coral diseases. Of this number, nearly 94% of cases occurred around Tutuila, Ofu, and Olosega and 6% around Ta`u and Rose; no cases were reported for Swains. Of the 504 cases, 92% corresponded to coralline lethal orange disease (CLOD). Cases of CLOD were highly abundant around Tutuila and around the more remote Ofu and Olosega (Fig. 8.6.2a). Around Tutuila, CLOD occurred preponderantly along the south-facing shores, in both relatively pristine as well as impacted locales, such as Fagatele Bay (TUT-21) and the area south of the airport (TUT-09), respectively. Comparatively, around Ofu and Olesega, CLOD was ubiquitous, occurring at 11 out of 12 survey sites. For both islands, CLOD was distributed in an aggregated pattern, suggesting that this disease pathogen(s) may be readily transmitted by organisms such as grazers. CLOD is caused by a bacterium that moves in a band, similar to the black band disease of corals (Littler and Littler, 2003) and leaving behind the dead algal carbonate structure.

Coralline fungal disease and other coralline discolorations were also present in the American Samoa Archipelago, but in low abundance (Fig. 8.6.2a). Because these pathogens can result in elimination/reduction in coralline algal cover with subsequent replacement by mats of cyanobacteria or turf algae, CLOD, coralline fungal disease, and other coralline diseases can adversely affect successful coral larval recruitment (Vargas-Ángel et al., in prep.). Further research is indicated in this matter.

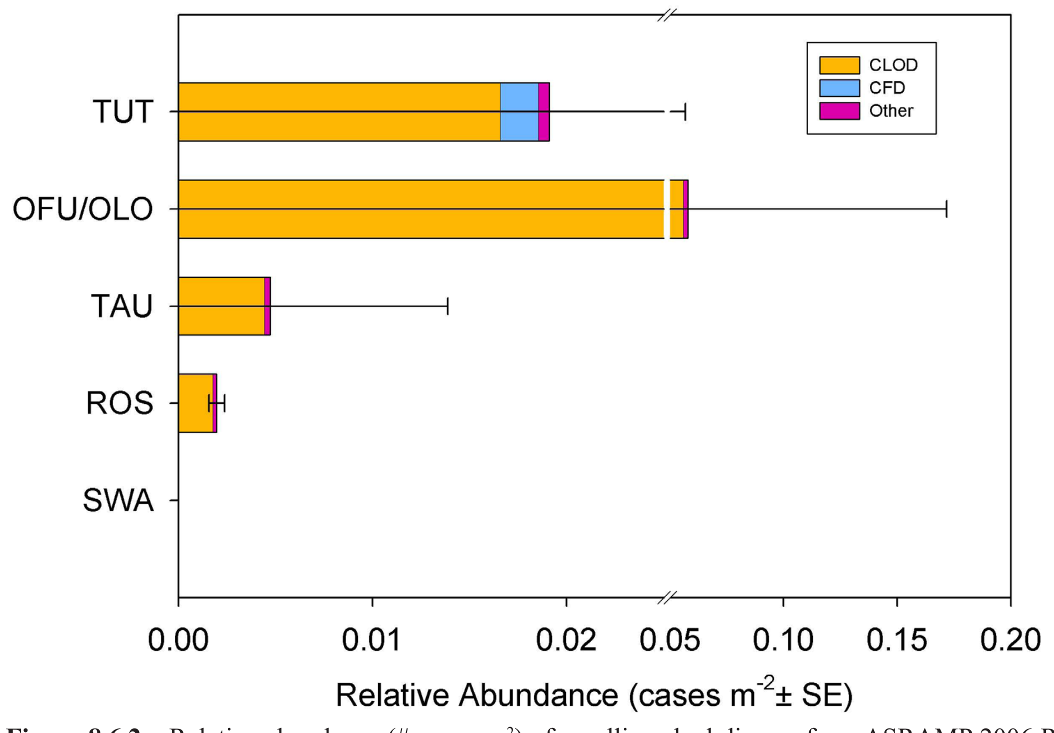

Figure 8.6.2a. Relative abundance (# cases m^{-2}) of coralline algal disease from ASRAMP 2006 REA surveys for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU), Ta`u (TAU), Rose (ROS) and Swains (SWA). CLOD = coralline lethal orange disease; CFD = coralline fungal disease; Other = undetermined coralline discolorations.

8.7 Benthic Macroinvertebrates

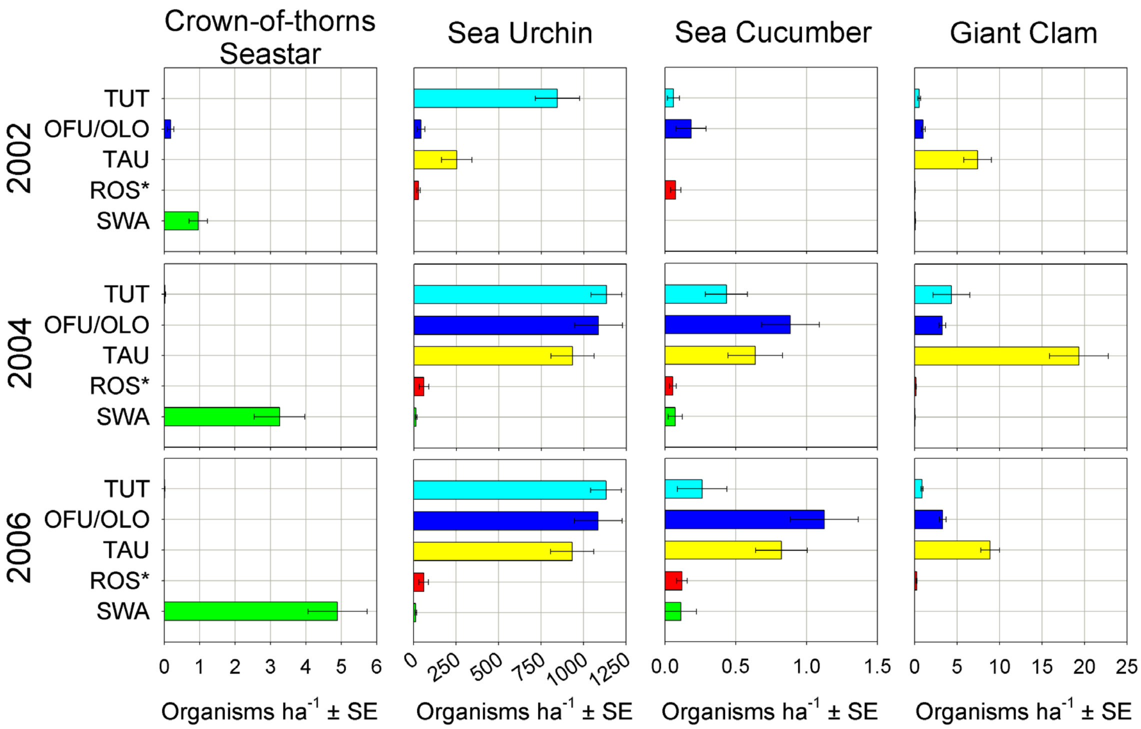

Figure 8.7a. Island-wide mean densities of key macroinvertebrates from towed-diver surveys around American Samoa during ASRAMP 2002, 2004 and 2006 for Tutuila and Aunu`u (TUT), Ofu and Olosega (OFU/OLO), Ta`u (TAU), Rose (ROS) and Swains (SWA). *Only forereef communities at Rose were included in this analysis for continuity across islands. See Chapter 6, Section 6.6: Benthic Macroinvertebrates, for a discussion on the unique lagoonal communities at Rose. Note that lagoon data are not presented for Rose; only forereef data are presented for better comparison with the other islands that lack a lagoon.

Island-wide mean densities (organisms ha-1) of key macroinvertebrates, including COTS, giant clams, sea cucumbers, and sea urchins around the islands and atolls of American Samoa during ASRAMP 2002, 2004, and 2006 cruises are shown in Figure 8.7a. Archipelago-wide densities of COTS were extremely low, with the exception of large and increasing numbers of COTS observed around Swains in successive years where a 300% increase in mean density of COTS was observed between 2002 and 2004, and a nearly 500% increase between 2002 and 2006 (50% between 2004 and 2006). The spatial distribution of COTS was variable between years. In 2004, COTS were more abundant along the southern tip of Swains, while in 2006 they were more abundant on the southeastern, western, and eastern shores and relatively uncommon in the north. Cyclone Heta, nearly a category 5 typhoon, passed to the west of Swains (traveling south to north) in January 2004, shortly before ASRAMP 2004, generating high winds and damaging swells. REA sites along the northern and northeastern shore displayed the greatest degree of coral breakage and dispersal, and towed-diver surveys around Swains recorded high values of stressed coral (7.8%). This may have corresponded with the overall island-wide increase in COTS between 2002 and 2004. An additional category 3 tropical cyclone (Percy), which produced 6-m wave heights, passed within 50 km of Swains in 2005; however, lower coral stress values were recorded in 2006 (1.9%) in comparison with 2004. The effects of such disturbances on COTS population dynamics are poorly understood and the topic needs further study.

Only 3 COTS were observed around Tutuila during all 3 survey years; around Ofu and Olosega, 5 were recorded in 2002 with no subsequent sightings in 2004 and 2006, and 7 were recorded in a localized area inside the lagoon at Rose in 2004. There were no sightings of COTS around Ta`u during any of the 3 survey years.

Island-wide mean densities of sea urchins for each of the islands and atolls of American Samoa displayed a significant degree of spatial and temporal variation, which could be attributed to differences in survey attributes, sea urchin population dynamics, and other factors (Fig. 8.7a). The highest numbers and densities of sea urchins were consistently reported around Tutuila, Ofu, Olosega, and Ta`u. Mean densities of sea urchins were consistently very low around Rose and Swains.

Around Tutuila, higher densities of sea urchins were consistently reported in the northwest and north regions in 2002 and 2004. Densities were much lower in 2006 (Figs. 3.6a, 3.6b, and 3.6d). High densities were also reported along the southern coastline in 2004 and 2006, although surveys immediately to the east and west of Pago Pago Harbor entrance were surprisingly devoid of sea urchins over large areas of habitat. Mean density of sea urchins around Ofu and Olosega was relatively similar between years. Sea urchins were observed in high densities off the west coast of Nu`utele in 2004 and 2006. Other areas that recorded higher densities included the northernmost point of Olosega (2004/2006) and the southern points of both Ofu and Olosega (2004). Around Ta`u, a similar trend was noted with the highest densities being observed around the southwest and northwest points in 2004 and 2006, with consistent, but lower, densities noted in the southeast and northeast corners in both years. Coastline surveys between those points generally encountered low densities of sea urchins. The numbers and densities of sea urchins around Rose and Swains were very low, with specimens observed only along the western, northern, and eastern points of the island at Rose and the west forereef of Swains.

Island-wide mean densities of sea cucumbers around the islands and atolls of American Samoa were fairly consistent, with the highest numbers and densities reported around Ofu and Olosega in all survey years. Ta`u recorded the next highest numbers for all years surveyed, followed by Tutuila in 2004 and 2006. Few sea cucumbers were reported around Rose and Swains in all survey years.

Around Tutuila, Ofu, and Olosega, sea cucumbers were widely distributed, albeit at low densities. At Ta`u, sea cucumbers were also evenly distributed, although slightly higher densities were reported along the western and northern coasts.

Island-wide mean densities of giant clams were relatively consistent between islands, with Ta`u recording the highest mean densities of all islands in the American Samoa Archipelago in 2002, 2004, and 2006, followed by Ofu and Olosega and Tutuila in 2002 and 2006. In 2004, densities were slightly higher around Tutuila than Ofu and Olosega. At Rose and Swains, giant clams were recorded in low numbers along the forereef and fringing reef habitats. In the lagoon at Rose, on the other hand, giant clams were extremely dense in localized areas.

Towed-diver and REA surveys around Tutuila found giant clams to be widely and evenly distributed in low densities. Giant clams were relatively common around Ofu and Olosega, with no apparent skew towards any particular coastline or region. Around Ta`u, giant clams were generally present at all but one REA site and were evenly distributed around the island. High densities were reported within the inner lagoon of Rose Atoll, with over 1000 individuals noted during each survey year; the highest concentration was observed along the southern end of the lagoon (see Chapter 6, Section 6.6: Benthic Macroinvertebrates). The forereef surveys recorded few giant clams and at low mean densities. Giant clams were mostly distributed in the northwest on either side of the channel. Around Swains, REA survey records indicate that giant clams were evenly distributed in low numbers .

8.8 Reef Fish

Figure 8.8a shows island-wide mean fish biomass recorded during ASRAMP 2002, 2004, and 2006. Total fish biomass around the populated high islands of American Samoa (Tutuila and Aunu`u, Ofu and Olosega, and Ta`u) was stable in 2002 and 2004 at around 1.0 ton ha-1 (SE 0.3), but fell to 0.5 ton ha-1 (SE 0.1) in 2006. Conversely, fish biomass around Rose went from 1.5 ton ha-1 (SE 0.8) in 2002 to 2.3 ton ha-1 (SE 1.2) in both 2004 and 2006. Future surveys will confirm whether these changes form clear trends or are simply within the range of natural population variability. The fish biomass around Swains was dominated by large transient schools and is thus harder to quantify with site-scale surveys. This is apparent in the highly variable interyear averages for total fish biomass around Swains (0.6 ton ha-1 (SE 0.3) in 2002, 2.9 ton ha-1 (SE 2.0) in 2004, and 0.7 ton ha-1 (SE 0.3) in 2006). It is clear, however, that Swains harbors a high fish biomass (average 1.4 ton ha-1 (SE 0.8) over all survey years) which is comparable to Rose. This is confirmed by towed-diver surveys which show that Swains consistently has the highest biomass of large fish (> 50 cm) in the archipelago. When all years are averaged, the total fish biomasses around the two low islands, Swains (1.4 ton ha-1) and Rose (2.1 ton ha-1), was substantially higher than the mean for the high island group (~ 0.8 ton ha-1).

The fish communities around the entire archipelago were mainly composed of herbivores (> 50% of total biomass), with the exception of Swains where herbivores represented only 10% of biomass. Nearly 60% of the biomass around Swains was composed of large schools of predators (barracudas, snappers, and jacks).

Similar to total fish biomass, large fish biomass (> 50 cm total length) was consistently low in the high island group for all years surveyed (0.03–0.04 ton ha-1 (SE 0.01)). The two remote islands, Rose and Swains, had clearly higher large fish biomasses, but observed values declined from 0.20 ton ha-1 (SE 0.09) in 2002 to 0.13 ton ha-1 (SE 0.08) in 2004, and 0.10 ton ha-1 (SE 0.05) in 2006 (Fig. 8.8a). When all years were averaged, Rose and Swains had a fish biomass almost 4 times greater than that of the high islands (0.14 ton ha-1 vs. 0.04 ton ha-1).

The total fish biomass values around the populated high islands (~ 0.8 ton ha-1; 50% herbivores) were comparable to values reported for the populated Main Hawaiian Islands (MHI; ~ 0.7 ton ha-1; 55% herbivores; Friedlander and DeMartini, 2002). Conversely, the biomass values for the two low islands (~ 1.7 ton ha-1) compare more closely to those reported in the uninhabited Northwestern Hawaiian Islands (NWHI; ~ 2.4 ton ha-1), with the

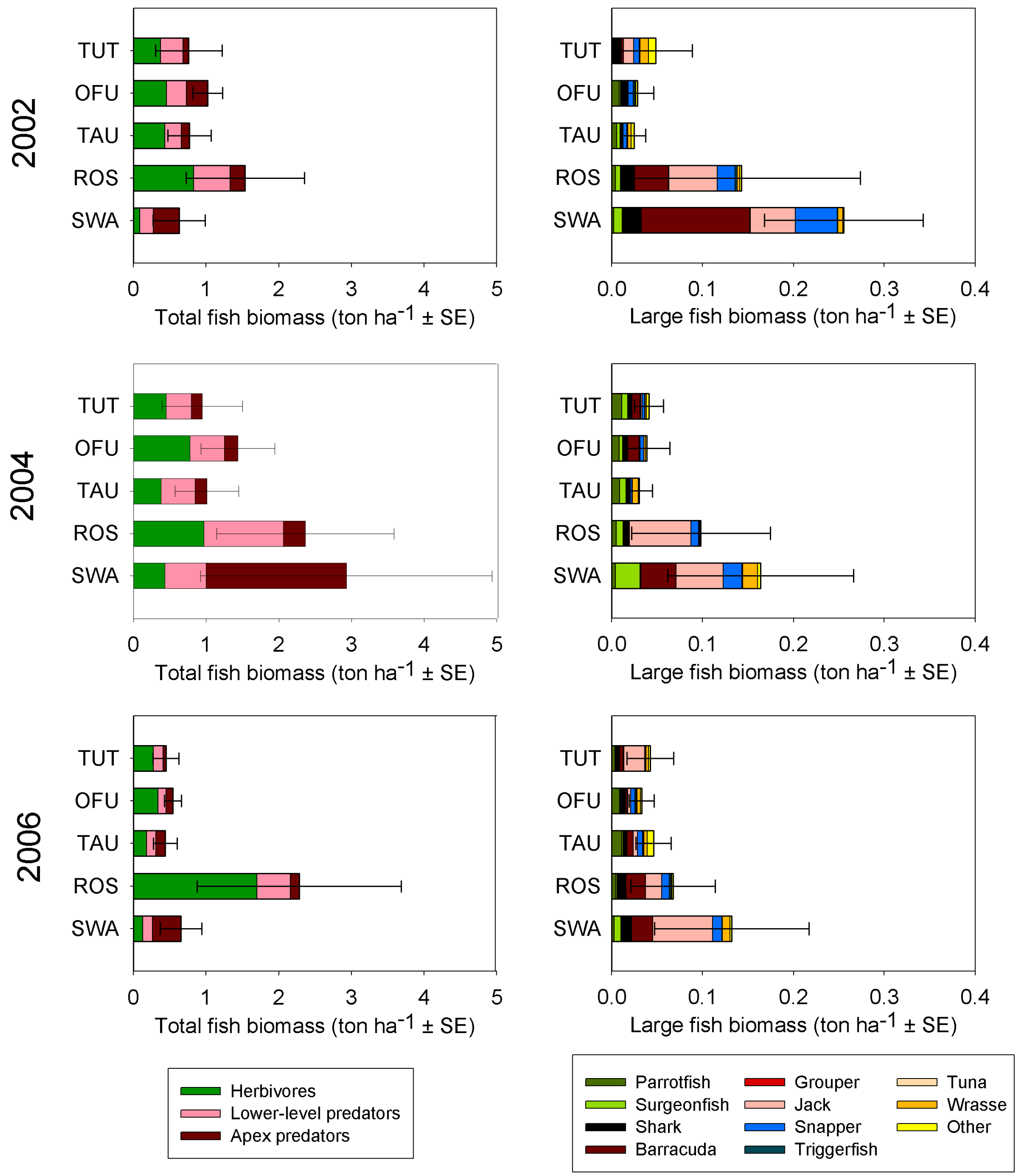

Figure 8.8a. Total (all families and sizes) and large fish (> 50 cm length) mean biomasses observed during AS-RAMP 2002, 2004, and 2006. Total fish biomasses are divided into trophic groups, while large fish biomasses are divided into the 10 main families.

higher top predator biomass proportion found on Swains (60%) also matching the average value reported in the NWHI (55%; Friedlander and DeMartini, 2002). Similarly, the large fish biomass around the populated high island group in American Samoa (~ 0.037 ton ha-1) was only slightly higher than the value for the MHI (~ 0.028 ton ha-1; Zgliczynski and Richards, unpubl. data). The large fish biomass around Rose and Swains (~ 0.143 ton ha-1) was also closely comparable to the NWHI values (~ 0.126 ton ha-1; Zgliczynski and Richards, unpubl. data). However, the relatively high large fish biomass recorded on the two remote atolls is still low compared to the very high values encountered in the U.S. Pacific

Remote Island Areas, which are on the order of 0.700 ton ha-1 (Zgliczynski and Richards, unpubl. data).

Finally, reef fish diversity, measured as the number of species encountered per 100 m2, is a more variable measure than fish biomass, making comparisons between years less clear. When all years are combined, a pattern of diversity similar to that for biomass emerges where the two isolated atolls, Rose and Swains, have slightly higher fish diversity (36 and 32 species 100 m-2, respectively) compared to the populated high islands of Ofu and Olosega (31 species 100 m-2), Ta`u (29 species 100 m-2), and Tutuila (28 species 100 m-2).

8.9 Archipelagic Summary

The archipelagic comparison of biotic and abiotic components of the coral reef ecosystems of American Samoa reveals diverse and complex spatial patterns coupling together human populations, biogeography, oceanographic, and environmental conditions. Not surprisingly, human population was an order of magnitude greater at Tutuila than at the other islands, presumably due to substantially greater land area, complex island topography which affords numerous separate watersheds and protected embayments, and relatively level coastal terrain to support more nearshore villages and higher population densities. Tutuila also has extensive shallow water coral reef habitats, including significant submerged relic reef structures located 3 to 5 km offshore around most of the island. These areas likely provide more marine food sources than the other islands, which have comparatively limited shallow water benthic habitats.

Human populations generally deceased eastward from Tutuila to Ofu, Olesega, Ta`u, and uninhabited Rose Atoll. Though Ta`u is substantially larger in total land area than Ofu and Olesega combined, the steep topography of the island probably limits the areas suitable for human habitation. North of these geologically-linked islands, Swains had a small caretaker population of 37 residents during the 2000 census, though there were less than 10 residents on the island during each of the three ASRAMP surveys in 2002, 2004, and 2006. Both Rose and Swains have small land and shallow habitat areas that are probably not capable of supporting large human populations.

The high islands (Tutuila, Ofu, Olosega, and Ta`u) generally had slightly lower benthic habitat (topographic) complexity and significantly higher percent cover of sand habitats than the low islands (Rose and Swains), likely reflecting greater terrigenous inputs from the watershed drainages into the nearshore ecosystems. A suite of oceanographic observations indicated that Swains, which is located at 11° S, is situated in a different oceanographic environment that the other four islands located along 14°S, with warmer water, lighter winds, and higher chlorophyll a. Nutrient levels, on the other hand, were generally highest and most variable around Tutuila, most likely due to a combination of larger landmass of higher elevation producing more seasonal runoff and sedimentation in local watersheds, nutrient loading from agriculture, and contaminant runoff from urban areas

As a likely function of island biogeography, greater shallow water habitat area, and a more diverse range of habitat types and oceanographic conditions, diversity of coral and algae, as measured by mean coral richness, coral genera, and algal genera/functional groups, was greater around the high islands than around the low islands. Swains was similar to Rose with smaller benthic habitat and land areas, lower numbers of coral genera and mean coral generic richness, and fewer algal genera and functional groups. While lower in coral diversity, the overall mean coral cover, as measured by both towed-diver surveys covering all habitats and REA surveys, were consistently highest around Swains, presumably due to the different oceanographic environment and lack of significant terrigenous inputs and sedimentation.

Despite localized impacts around portions of the high islands, the mean overall prevalence of coral disease for all of the islands was an order of magnitude less than equivalent contemporary surveys have indicated for well surveyed sites in either the Caribbean or Great Barrier Reef ecosystems. Coral disease prevalence levels were generally very low (less than 0.5%), with the highest disease prevalence values observed around Rose. That said, a large proportion of these elevated prevalence values were the result of predation by Drupella snails. The second highest disease prevalence values were observed around Swains, of which about 85% was recorded as predation by elevated numbers of COTS.

The presence and distribution of coralline algae disease across an archipelagic continuum (94% of all recorded cases for Tutuila, Ofu and Olosega, 6% for Ta`u and Rose, and 0% for Swains) indicates that there may be a direct or indirect link with higher human population numbers and densities, or that these diseases may be propagating naturally through localized grazer movements.

Invertebrate surveys across the archipelago found extremely low densities of COTS around each of the islands except Swains, where high densities and associated coral predation were observed in 2004 and 2006. Sea urchins were observed in moderate densities around the high islands and in extremely low densities around the low islands. Mean densities of giant clams were consistently highest around Ta`u, although some extremely high giant clam densities were found at localized sites within the lagoon at Rose.

Finally, total reef fish (all sizes) and large fish biomass (TL<50 cm), were lowest around the most populated islands (Tutuila, Ofu, Olosega, Ta`u) and highest around the least populated (Swains and Rose). This suggests that a combination of anthropogenic stressors, including but not limited to fishing, coastal development, sedimentation, and pollution are likely impacting reef fish populations.

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