

Executive Summary

This *Coral Reef Ecosystem Monitoring Report for American Samoa: 2002–2006* provides the most comprehensive integrated ecosystem assessment of the coral reefs of American Samoa performed to date. This benchmark report is the culmination of interdisciplinary surveys accomplished during three American Samoa Reef Assessment and Monitoring Program (ASRAMP) research cruises completed in 2002, 2004, and 2006. These ASRAMP cruises were part of the National Oceanic and Atmospheric Administration (NOAA) Coral Reef Conservation Program's broad-scale Pacific RAMP, which conducts extensive benthic habitat mapping, ecological and environmental assessment and monitoring, and applied management-relevant research to support improved ecosystem-based management and conservation of the United States (U.S.)-affiliated Pacific Islands. Each of the Pacific RAMP research cruises, including ASRAMP, are led by the Coral Reef Ecosystem Division (CRED) of the Pacific Islands Fisheries Science Center, in close collaboration with key partners from other NOAA offices, federal, state, and territorial agencies, academia, and nongovernmental organizations. In particular, late Governor Sunia and Governor Tulafono, and the many individuals of the American Samoa Coral Reef Advisory Group agencies played pivotal roles in planning and implementing all three ASRAMP surveys discussed in this report.

The vast quantity of ecosystem information gathered during the three ASRAMP surveys has been thoroughly processed and analyzed for user-friendly graphical presentation and discussion in this report, thus allowing complex ecosystem observations and concepts to be more easily interpreted by resource managers, policymakers, and key stakeholders. Since these integrated ecosystem observations are consistent with and comparable to other Pacific RAMP observations in the Hawaiian Archipelago, the Territory of Guam, the Commonwealth of the Northern Mariana Islands, and the Pacific Remote Island Areas, they provide an unprecedented opportunity to better understand the condition and health of the coral reefs of American Samoa relative to other reefs across the Pacific.

The first chapter of the *Coral Reef Ecosystem Monitoring Report for American Samoa: 2002–2006* presents the background, goals, objectives, operational and research scope, and inherent limitations of Pacific RAMP. The second chapter describes the methodologies used to collect, process, and analyze field observations and discipline-specific datasets. Chapters three through seven provide detailed spatial and temporal analyses for each of the five island/atoll groups within American Samoa (Tutuila and Aunu'u Islands, Ofu and Olosega Islands, Ta'u Island, Swains Island, and Rose Atoll). Each of these island/atoll chapters includes presentations of data and discussions on each of the following topic areas: geopolitical context, survey effort, benthic habitat mapping and characterization, oceanography and water quality, coral and coral disease, algae, benthic macroinvertebrates, reef fish, and an island summary and integration that discusses relationships among these different ecosystem components. The final chapter examines similarities and differences in each of these ecosystem components between the different islands across American Samoa.

The benthic habitat mapping and characterization sections present comprehensive results based on extensive multibeam bathymetry, backscatter, and photographic data collected during the three ASRAMP surveys. These data revealed a number of previously unknown, unrecognized, or poorly understood submarine features.

- A large and complex relict barrier reef and several submerged bank structures were comprehensively mapped around most of Tutuila, northwest of Ofu, and southeast of Olosega. These relict reefs and submerged banks include some areas with high (> 50%) live coral cover in waters deeper than 20 m.
- Towed-diver habitat surveys completed during ASRAMP 2002 discovered two areas with massive (5-6 m × ~ 14 m) and ancient *Porites* coral colonies (estimated to be between 500 and 1000 years old) off the east and southwest coasts of Ta`u. The areas around the largest coral colonies are currently under consideration for designation as possible marine protected areas by the American Samoa Government.
- Multibeam bathymetric surveys in 2004 and 2006 revealed a series of small seamounts between Ta`u and Olosega. Underwater video cameras showed the discovery of a luxuriant coral reef in water depths of 38 m and deeper.

With respect to the inherent geographic, geologic, and geopolitical factors, analyses of the extensive biological, benthic habitat, and oceanographic observations reveal both direct and inverse relationships with parameters such as island area and topography, location, population, and/or temporal events (e.g., hurricanes). In some instances, it was relatively straightforward to ascertain relationships among certain ecosystem parameters. However, because many of the geographic, geologic, and geopolitical parameters are themselves interrelated, many of the ecosystem relationships are complex and difficult to interpret. For example, the largest islands generally have the highest human population densities (coupled with the associated anthropogenic impacts), as well as the more extensive surrounding bank habitat areas. Some of these complex relationships may eventually be better understood as additional comparative analyses are completed using the broader basin-wide surveys of Pacific RAMP.

Some of the more consistent and straightforward observed correlations may be explained by the theory of island biogeography, which states that larger islands support greater biodiversity as a result of an increased number of habitat types. Tutuila, which has both the largest land area and bank area (almost 10 times larger than any other island) in American Samoa, was observed to have greater diversity of corals, algae, and noncoral invertebrates than the smaller islands, although fish diversity was not.

- Island-wide, the number of coral genera was greatest around Tutuila (~ 35 genera) and least around Swains (~ 14 genera). More genera were observed around each of the larger high Manu`a Islands (Ofu, Olosega, and Ta`u) than the smaller low islands/atolls (Swains and Rose).
- Mean coral generic richness was highest around the larger high islands (e.g., ~ 22 genera per site around Ofu and Olosega) and lowest around the smaller low islands (e.g., ~ 7 genera per site around Swains).
- Significantly more algal genera and functional groups were found around Tutuila than the other smaller islands. The three geographically close, high volcanic Manu`a Islands exhibited the second highest number of recorded algal genera and Rose and Swains the lowest.

Although the numbers of both coral and algal genera exhibited positive correlations with

island size, both habitat complexity and live coral cover were negatively correlated with island size. Island-wide mean habitat complexity was estimated to be very high around both Swains and Rose, but only high to medium-high around the larger high islands. Mean live coral cover was highest around Swains with a value of ~ 45% and consistently lower around the other islands with values between 20% and 30%.

Sea urchins and sea cucumbers were relatively more abundant around the larger, high islands and uncommon around Rose and Swains. Although the mean density of giant clams was highest around Ta`u, the largest localized concentration was found at Rose.

Rose and Swains are both small, low islands with no substantive terrigenous inputs to the nearshore water and no surrounding bank or shelf habitats, with slopes plunging steeply to abyssal depths. In contrast, the larger high islands (Tutuila, Ofu, Olosega, and Ta`u) have surrounding banks where sand can accumulate. Towed-diver surveys observed that mean sand covers around Rose and Swains were less than 5%, while it was 9–15% around the larger islands. Sand habitats generally had low topographic complexity and coral cover. Since both Rose and Swains have no or very low human populations, higher habitat complexities than the larger islands, and fewer low complexity/low coral cover sand flats, it is hypothesized that the steepness of the forereef slopes, island area, and/or the low human populations could be causative factors for the higher coral or crustose coralline algae cover around Swains and Rose, respectively.

Swains, which had substantially higher mean live coral cover than any other island in American Samoa, lies 350 km north of the other islands and experiences notably different oceanographic conditions. The waters around Swains were generally warmer, less saline, more productive (higher chlorophyll-a), and less windy than the waters around the other islands. The relatively high coral cover around Swains, which ranged from 20% to 75%, can most likely be explained by its geographic location and more favorable oceanographic conditions.

Quantitative observations of coral and crustose coralline algal disease were initiated during ASRAMP 2006. The mean overall prevalence of coral diseases and afflictions (e.g., predation lesions) around American Samoa was relatively low with a recorded value of 0.34%. In contrast, observations from both the Caribbean and the Great Barrier Reef have reported prevalence values an order of magnitude higher. Coral disease prevalence values around American Samoa were comparable to values reported at other remote Pacific Island locations. While the highest mean coral disease prevalence values were observed around Rose (~ 0.96%), most of these afflictions were caused by predation. The next highest disease prevalence values were recorded around Tutuila (~ 0.15%), the largest and most populated island. Interestingly, the disease prevalence was higher on the less populated north side of the island than on the more populated south side of the island. The lowest mean coral disease prevalence values were found around Ofu and Olosega (0.05%) and the remote Swains (0.04%). Swains had the most evidence of predation lesions of any of the islands caused by an ongoing crown-of-thorns seastar (COTS) infestation.

The mean prevalence of crustose coralline algal disease was about 45% higher than that observed for coral diseases across the archipelago. Nearly 94% of these cases occurred

around Tutuila and Ofu and Olosega, 6% around Ta'u and Rose, and none around Swains. Intriguingly, Ofu and Olosega exhibited the highest relative abundance of coralline algal disease (higher than Tutuila), but the second lowest prevalence of coral disease. The most abundant type of coralline algal disease (92%) was the coralline lethal orange disease, which was distributed in an aggregated pattern, suggesting that this disease pathogen may be readily transmitted by grazing organisms. In contrast to coral diseases, coralline algal diseases were more prevalent on the south coast of Tutuila than the north coast, particularly in the region adjacent to Pago Pago Harbor watersheds. Distribution and abundance of disease, together with other coral reef ecosystem metrics, can provide proxies to ecosystem integrity and health.

While the impact of human activity on several parameters (e.g., percentage of live coral cover, habitat complexity, and disease) can sometimes be difficult to interpret, a number of ecosystem observations reported here appear to be related to human activities:

- Total reef fish (all sizes) and large fish (> 50 cm) biomass were comparatively depleted around the populated islands of Tutuila and the Manu'a Islands (similar values for Tutuila and Manu'a Islands). This difference follows patterns throughout the U.S.-affiliated Pacific Islands, where populated islands have depleted reef fish biomass and uninhabited areas have greater reef fish biomass (Schroeder et al., in press).
- Total reef fish (all sizes) and large fish (> 50 cm) biomass were highest around the unpopulated islands. Total mean biomass around Rose (2.1 tons ha⁻¹) and Swains (1.4 tons ha⁻¹) greatly exceeded the mean for the high islands (0.8 tons ha⁻¹). Although higher than the populated islands, Rose had significantly lower biomass values than other uninhabited National Wildlife Refuge islands in the more remote parts of the Pacific (Schroeder et al., in press).
- Total reef fish (all sizes) and large fish (> 50 cm) biomass appeared to decline from a mean of ~ 1.0 tons ha⁻¹ in 2002 and 2004 to a mean of ~ 0.5 tons ha⁻¹ in 2006.
- Nutrient levels were generally highest and most variable around Tutuila, most likely caused by highly varying watersheds and population distributions.
- Over a 7-week period in 2006, 23 of 34 vessels (67%) detected by an Ecological Acoustic Recorder in the National Park of American Samoa were detected during nighttime hours, providing resource managers a new awareness of local threats from human activity.
- Biological data collected around Rose have further elucidated the long-term impacts of shipwrecks on nearby coral reef ecosystems. In October 1993, a ship grounded on the reef at Rose and caused a fuel spill that killed corals and coralline algae over a broad reach 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. Although the U.S. Fish & Wildlife Service has removed much of the wreckage debris, the cyanobacteria mats have apparently slowed the recovery of coralline algae and corals, both of which show low diversity and low richness in the area of the grounding. In addition, the numbers and biomass of pooled herbivorous fish (surgeonfishes, parrotfishes, and angelfishes) were greater at the wreck site than at neighboring control sites.

One of the key goals of the CRED integrated ecosystem observation and monitoring effort

is to effectively detect and differentiate spatial patterns and temporal changes in ecosystem health metrics to inform resource managers and improve decision making. Temporal events and trends include storms and their aftereffects, global warming, coral bleaching, ocean acidification, disease afflictions, and COTS infestations. Since the biennial ASRAMP surveys have been conducted only three times from 2002 to 2006, and some of the methodologies continued to evolve during that period, it is difficult to make statistically rigorous temporal comparisons over this short period. However, some notable spatial patterns and temporal effects and trends have been described.

Since CRED initiated ecosystem monitoring around American Samoa, two major storms, Hurricane Heta (2004) and Hurricane Olaf (2005), have impacted the area. High levels of coral breakage and stress were observed at Swains one month after the passage of Hurricane Heta. The mean density of COTS was higher around Swains during the 2004 and 2006 surveys than any of the other islands/atoll, where COTS were rarely observed. Whether COTS population levels increased at Swains as a result of the destructive activity of hurricanes on coral communities cannot be determined from the available data. In addition, low algal diversity and scoured benthic communities observed in the Manu`a Islands during ASRAMP 2004 were hypothesized to be related to the passage of Hurricane Heta. By the time of the ASRAMP 2006 surveys algal diversity had apparently rebounded. No obvious direct ecosystem impacts were observed during the ASRAMP 2006 surveys despite the passage of Hurricane Olaf a year earlier.

Although these initial time series observations do not cover a period sufficient for rigorous statistical analysis, long-term trends associated with climate change, such as ocean warming and acidification, sea-level rise, and changing storm tracks and intensities, are significant threats now facing coral reef ecosystems globally, including American Samoa. Known ecological impacts of these climate-change-induced threats include coral bleaching and disease, reduced calcification or even dissolution, decreased coral-growth rates, and localized destruction caused by storms. As noted previously, prevalence of coral disease was generally low throughout American Samoa. Some mild coral bleaching was observed around each of the islands of American Samoa in 2006. There was also an apparent overall net decline in coral cover between 2002 and 2006, but this observation might be the effect of different observers, survey locations, and/or methods rather than actual ecological changes and should be interpreted with caution. However, these initial integrated ecosystem observations around American Samoa and each of the other U.S.-affiliated Pacific Islands establishes an unprecedented baseline that can be used to measure future changes.

Scientists are only beginning to understand the effects from global warming and ocean acidification on coral reef ecosystems, and the 5 years spanned thus far during ASRAMP surveys is much too short of a period in which to detect change in a statistically robust manner. However, this report provides an essential scientific foundation for informed decision making for the long-term conservation and management of the coral reef ecosystems of American Samoa. The spatial maps of all observed ecosystem components in this report allow managers the unique ability to evaluate spatial management options, such as determining the preferred locations of marine protected areas, based on multiple scientific criteria. The temporal comparisons and time series observations are useful in distinguishing between natural and anthropogenic ecosystem variability, which can be used to assist resource managers

in evaluating the effectiveness of both existing and proposed management measures. In conclusion, the islands/atoll and archipelagic comparison chapters give resource managers and policymakers an unprecedented ability to examine the status and trends of each ecosystem around and among their respective islands, with the hope of protecting and conserving these unique resources for generations to come.

References

Schroeder RE, Nadon M, Richards BL, Zgliczynski BJ, Sabater M (In press) Reef fish densities inversely follow human population levels across American Samoan Islands. In: Proceedings of the 11th International Coral Reef Symposium, Fort Lauderdale, FL, July 7–11, 2008. Available from Pacific Islands Fisheries Science Center Coral Reef Ecosystem Division, 1125B Ala Moana Blvd., Honolulu, HI 96814.