Chapter 1 Introduction to the Monitoring Report

1.1 The Territory of American Samoa

Geographic Context

American Samoa is a territory of the United States (U.S.) located approximately 4200 km south of Hawai`i in the central South Pacific Ocean directly east of Samoa (Fig. 1.1a). It is the southernmost U.S. possession and the only U.S. jurisdiction in the southern hemisphere. American Samoa includes five volcanic islands (Tutuila, Aunu`u, Ofu, Olosega, and Ta`u) and two coral atolls (Swains Island and Rose Atoll), with a combined land area of ~ 200 km^2 and total area of coral reef habitat (to a 100-m depth) of ~ 355 km^2 (~ 315 km^2 around Tutuila alone). Each island has unique, defining geographic characteristics. Tutuila is a highly eroded, volcanic structure bounded by a bank that extends more than 3 km from the shore in most locations. The shallow-water habitats of the Manu`a Islands (Ofu, Olosega, and Ta`u) consist primarily of narrow reef flat lagoons and fringing coral reefs, with only limited shallow submerged banks surrounding each of the islands. Swains and Rose are small coral atolls with fringing coral reef and inner lagoonal habitats.

The islands and atolls of American Samoa vary in geographic size, isolation, and population. Tutuila, including nearby Aunu`u, is the largest (145 km^2) and most populated (55 885 people)

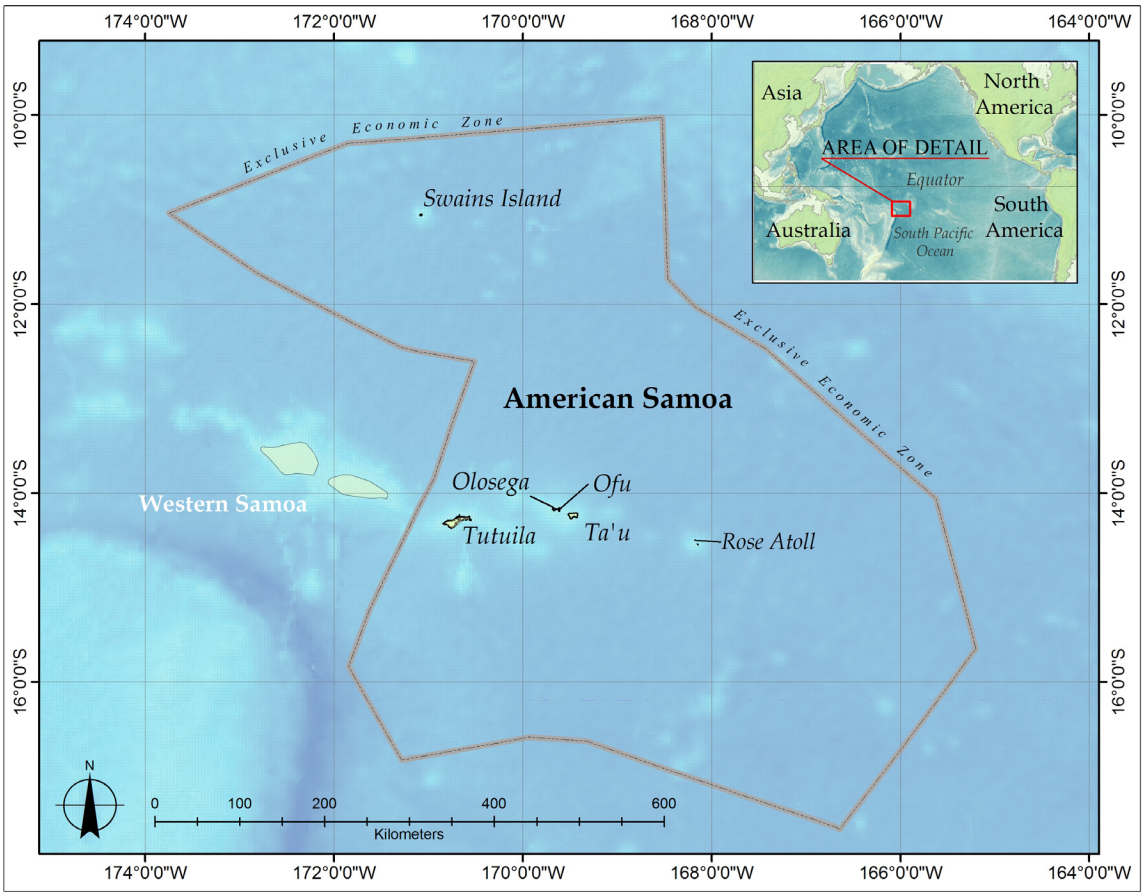

Figure 1.1a. The Territory of American Samoa in relation to the Pacific Ocean Basin (inset map) and Samoa. (Federal Register).

island in American Samoa and serves as the center of government, commerce, and business. The Manu`a Islands, which include Ofu (289 people), Olosega (216 people) and Ta`u (380 people), lie approximately 100 km east of Tutuila and have a combined land area of less than 56 km^2. With respect to marine protected areas, the National Park of American Samoa encompasses 4250 ha (170 of which are marine areas), which are located on Ofu, Ta`u, and Tutuila and are leased by the National Park Service from Samoan families under communal Samoan traditions. Fagatele Bay National Marine Sanctuary, on the south coast of Tutuila, is the smallest of the nation's 13 marine sanctuaries administered by the National Oceanic and Atmospheric Administration (NOAA). Swains, a small coral atoll with a completely enclosed brackish lagoon located approximately 350 km north of Tutuila, has a population of 37 people. Uninhabited Rose, a national wildlife refuge that lies 140 km east-southeast of Ta`u, is under the jurisdiction of the U.S. Fish and Wildlife Service (U.S. Census Bureau, 2007).

Political Structure

As a political entity, American Samoa is an unincorporated, unorganized, and self-governing territory of the U.S., administered by the Office of Insular Affairs, U.S. Department of the Interior. It is "unincorporated" because not all provisions of the U.S. Constitution apply to the territory. The U.S. Congress gave plenary authority over the territory to the Secretary of the Interior, and American Samoans were able to draft their own constitution under which their government functions. The American Samoa Constitution, which was ratified in 1966 and went into effect in 1967 (Office of Insular Affairs, 2007), provides for an elected governor, lieutenant governor, and legislature. The bicameral legislature of American Samoa, known as the Fono, is made up of a Senate (18 members chosen according to Samoan custom in each of the 14 political counties) and a House of Representatives (20 members elected by popular vote).

The traditional village system of the "Fa`amatai" and "Fa`asamoa" operates as a locally based political and social governing collective. The Fa`asamoa is the language and customs, and the Fa`amatai includes the protocols of the "Fono" (council) and the chiefly system. The Fa`amatai and the Fono take place at all levels of Samoan political organization, from the family, to the village, to the region, to national matters. The "matai" (chiefs) are elected by consensus within the Fono of the extended family and village(s). The matai and the Fono (which is made up of matai) decide on the distribution of family exchanges and tenancy of communal land; thereby the majority of land in American Samoa and Samoa is communal. A matai can represent a small family group or a great extended family that reaches across islands, and to both American Samoa and Samoa. This political and social construct is unique and fundamental to the integrity of the Samoan people and culture (Lal and Fortune, 2000).

1.2 Coral Reef Management

National Coral Reef Management

In 1998, President Clinton signed Executive Order (E.O.) #13089 to preserve and protect the biodiversity, health, heritage, social, and economic value of U.S. coral reef ecosystems and the marine environment. This E.O. created the U.S. Coral Reef Task Force (CRTF), with

the Secretary of the Interior and the Secretary of Commerce acting as co-chairs and Federal Agencies as participants. Their primary task was to work with state, territorial, commonwealth, and local government, nongovernmental organizations, and commercial interests:

1. To coordinate a comprehensive program to map and monitor U.S. coral reefs;
2. To develop and implement research aimed at identifying the major causes and consequences of degradation to coral reef ecosystems;
3. To develop, recommend, and seek or secure implementation of measures necessary to reduce and mitigate coral reef ecosystem degradation and to restore damaged coral reefs; and
4. To assess the U.S. role in international trade and protection of coral reef species and implement appropriate strategies and actions to promote conservation and sustainable use of coral reef resources worldwide.

The E.O. set the stage for national coral reef conservation efforts by emphasizing the need to undertake a comprehensive rather than state-specific program of ecosystem research, mapping, and monitoring of all U.S. coral reefs. In 2000, the CRTF developed the *National Action Plan to Conserve Coral Reefs* (National Action Plan) as the first U.S. blueprint to address the loss and degradation of U.S. and international coral reef ecosystems. Coral reef conservation was framed into two broad themes:

Figure 1.2a. Snapper (*Lutjanus kasmira)* in American Samoa. (*Photograph provided by NOAA PIFSC CRED*)

1. Understanding coral reef ecosystems; and
2. Reducing the adverse impacts of human activities.

The National Action Plan stated, "Ultimately, our success – or failure – in conserving these highly complex and extremely fragile ecosystems will depend on a parallel approach of proactive, precautionary management measures coupled with a much more sophisticated level of understanding about their fundamental ecology and response to environmental stressors". The four goals outlined for the first theme were:

1. To develop comprehensive maps of all U.S. reefs;
2. To develop a nationally coordinated coral reef inventory, assessment, and monitoring program;
3. To support strategic research focused on the determinants of coral reef health and recovery, including basic ecological processes, bleaching and disease, and best management practices for coral reefs and closely linked marine and terrestrial habitats; and
4. To conduct socioeconomic studies of the human dimension of successful coral reef conservation.

As with the E.O., the National Action Plan emphasized a nationally coordinated, comprehensive investigation of coral reef ecosystems from a mapping, research, and monitoring perspective.

The Coral Reef Conservation Act (CRCA) of 2000 (P.L. 106–562; 16 U.S.C. 6401 et seq; December 23, 2000), which served as the congressional response to the E.O., laid out a national framework to address these issues. It required the development of a national coral reef action strategy, wherein its goals and objectives would include mapping, information management, research, and monitoring. The CRCA of 2000 also created the national Coral Reef Conservation Program (CRCP) under the direction of the Secretary of Commerce. The CRCA requires NOAA to conduct collaborative research, mitigation, and outreach activities that would directly contribute to the conservation of coral reefs and coral reef ecosystems. Some of the authorized activities included:

1. Mapping, monitoring, assessment, restoration, and scientific research that benefits the understanding, sustainable use, and long-term conservation of coral reef ecosystems;
2. Enhancing public awareness, education, understanding, and appreciation of coral reef ecosystems;
3. Collaborating with local, regional or international programs, and partners for the cooperative conservation and management of coral reefs and coral reef ecosystems.

NOAA, in cooperation with the CRTF, produced the *National Coral Reef Action Strategy* (National Action Strategy) in 2002 to fulfill the requirements of the CRCA, and to help track the implementation of the National Action Plan. Among other things, two actions to address the needs of the National Action Strategy included:

- *Map all U.S. coral reef ecosystems*, to address the threats of overfishing, habitat destruction, coastal development, and coastal pollution; and
- *Assess and monitor coral reef health*, to address the threats of global warming/climate change, diseases, overfishing, destructive fishing practices, habitat destruction, invasive species, coastal development, coastal pollution, sedimentation/runoff, and overuse from tourism.

Coral Reef Management in American Samoa

The American Samoa Coral Reef Advisory Group (CRAG) was created by the American Samoa Government in 1998 and is a collaboration of the following five agencies having links to the management and conservation of the coral reef resources of American Samoa:

- Department of Marine and Wildlife Resources;
- Department of Commerce;
- American Samoa Environmental Protection Agency;
- American Samoa Community College; and
- National Park of American Samoa.

Initially established as an informal entity, CRAG now receives its mandate via the Governor's Office as a functioning advisory task force (American Samoa Coral Reef Advisory Group, 2007).

NOAA's reports, *The State of Coral Reef Ecosystems of the United States and the Pacific Freely Associated States: 2002* (Turgeon et al., 2002) and *The State of Coral Reef Ecosystems of the United States and the Pacific Freely Associated States: 2005* (Waddell, 2005), were created to provide overall assessments of coral reef ecosystems in U.S. jurisdictions at the time and are organized based on the primary threats, topics, and goals outlined in the National Action Strategy. The American Samoa chapter in the 2005 Report (Craig et al., 2005) provides an overview of monitoring activities, a summary of known results, current management activities, and overall conclusions and recommendations. According to this report, the coral reefs of American Samoa face immediate disturbances and threats. Local stressors/threats are variable and originate from multiple sources, including, but not limited to, coastal development, sedimentation, point and nonpoint source pollution (e.g., human-waste runoff) and marine resource extraction (e.g., fishing). Specifically, "The Territory's high population growth rate (2.1% per year) continues to strain the environment with issues such as extensive coastal alterations, fishing pressure, loss of wetlands, soil erosion and coastal sedimentation, solid and hazardous waste disposal, and pollution" (Craig et al., 2005).

Figure 1.2b. One of the high islands of the Manu`a group. (*Photograph provided by NOAA PIFSC CRED*)

As with coral reef ecosystems globally, the reefs of American Samoa are vulnerable to natural and anthropogenic disturbances. Examples of natural disturbance events include hurricanes, which occasionally cause mechanical damage to coral skeletons, and outbreaks of coral predators, such as the crown-of-thorns seastar (e.g., *Acanthaster planci*) or the gastropod *Drupella*, which can destroy vast tracts of live coral tissue. Physical threats to coral reef ecosystems, such as increasing sea surface temperatures and the acidification of seawater as a result of increased carbon dioxide uptake, are often coupled with associated acute or chronic biological effects. For example, evidence suggests that certain coral species experience reduced calcification when exposed to elevated CO_2 (Gattuso et al., 1998; Kleypas et al., 2006). Other effects include increased levels and incidents of coral beaching and the elevated prevalence of marine diseases.

With recent rapid population growth in American Samoa, concerns about anthropogenic threats, including overfishing, land-based sources of pollution, and coastal development, are

Figure 1.2c. The islands of Ofu and Olosega in American Samoa. (*Photograph provided by NOAA PIFSC CRED; A. Hall, JIMAR*)

likewise increasing. In response to these concerns and a resolution by the CRTF, CRAG has created 3-year Local Action Strategies to prioritize local management efforts to address the following key stressors: population pressure, overfishing, land-based sources of pollution, and climate change (American Samoa Coral Reef Advisory Group, 2007).

1.3 Ecosystem Approach to Management

Fishery and marine resource managers are required to make management decisions that will allow humans to sustainably interact with and use complex ecosystems while ensuring long-term ecosystem conservation and viability for future generations. To date, fishery management plans have traditionally focused on single stocks or, at most, commercially important groupings of stocks. Under these types of plans, fishery managers typically set biomass harvest or mortality rate goals with limited consideration of other characteristics of the stock or of broader ecosystem concerns. In recent years, however, there has been a growing understanding that exploited marine resources must be considered an integral component of a functioning ecosystem instead of phenomena that operate independently of the broader biological community and the environment.

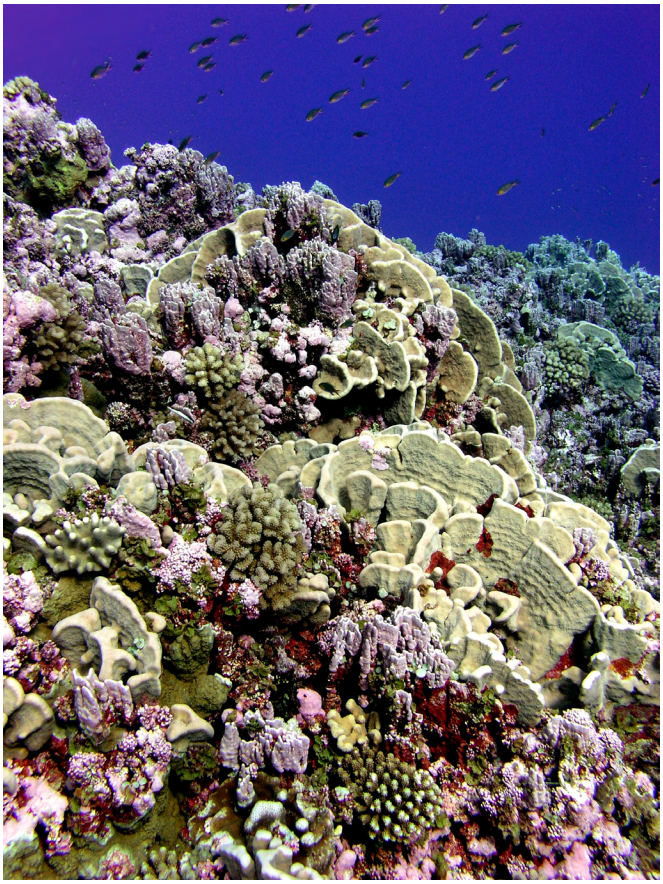

Figure 1.3a. American Samoa coral reef community. (*Photograph provided by NOAA PIFSC CRED*)

Internationally, there has been widespread recognition of the need to move toward an ecosystem-based approach to fisheries management, a development spearheaded by the Food and Agriculture Organization of the United Nations through the Code of Conduct for Responsible Fisheries, and supported by numerous regional and national institutions as well as academia, nongovernmental organizations and the public-at-large (Cury and Christensen, 2005). In the U.S., the 2005 Report of the U.S. Commission on Ocean Policy stated that our understanding of marine ecosystems should ground our ocean policy, and our management approach should account for the complex interrelationships between

abiotic environmental factors driving oceanic, atmospheric, and terrestrial processes and their interaction with living organisms on systematic ecological levels (Committee on Ocean Policy, 2005). In theory, an ecosystem-based approach to management might overcome the challenges in addressing issues that cross traditional jurisdictional boundaries (local, state, national, and international) and continually adapt to new scientific information and improved management tools.

While agencies generally agree on the need to transition to ecosystem-based fisheries management and marine resource management, vigorous debate continues at all levels on how to implement policies to accomplish the transition. However, agencies agree on the need for unbiased, credible, and up-to-date scientific information examining the status and trends of ecosystem health and increasing the understanding of mechanistic functions that determine ecosystem processes. As an example of on-going efforts in the Pacific Islands Region, the Western Pacific Regional Fishery Management Council has initiated the development and implementation of ecosystem-based fisheries management through the establishment of the *Coral Reef Ecosystem Fishery Management Plan*, and more recently, the development of archipelagic Fishery Ecosystem Plans (FEP) for the U.S.-affiliated Pacific Islands regions. A draft American Samoa Archipelago FEP, which represents the first steps in an incremental and collaborative approach to implement ecosystem approaches to fisheries management in the archipelago, was originally drafted in 2005. Moreover, there is likewise consensus on the need to translate scientific findings into useful and timely information products for policy makers, managers, educators, and the public. Resource managers and policy makers need scientific feedback to make informed decisions and to effectively implement ecosystem-based management principles with the objective of balancing sustainable use and long-term ecosystem conservation.

1.4 Background and Purpose of the Pacific Reef Assessment and Monitoring Program (RAMP)

In response to the executive and legislative mandates and policies outlined in Section 1.2: Coral Reef Management and Section 1.3: Ecosystem Approach to Management (including E.O. #13089, the National Action Plan, and the CRCA of 2000), the NOAA Pacific Islands Fisheries Science Center (PIFSC) Coral Reef Ecosystem Division (CRED) was formed in 2001 with the support of the CRCP. CRED's mission is to lead an integrated, multidisciplinary, ecosystem-based program of research, mapping, and long-term monitoring of coral reef ecosystems of the U.S.-affiliated Pacific Islands to promote conservation, management, and public awareness through innovative and collaborative science of the highest integrity.

Sustainable management and long-term conservation of coral reef ecosystems of the U.S.-affiliated Pacific Islands require comprehensive habitat mapping, and multidisciplinary assessment and monitoring of environmental conditions, biological communities, and human-use practices. CRED's goal is to provide high quality, unbiased ecosystem-based data and value-added information products to resource managers and policy makers on local, regional, national, and international levels in a timely manner.

As a key component of these efforts, CRED leads the Pacific RAMP, which conducts comprehensive ecosystem monitoring surveys every 1 to 3 years at ~ 50 U.S.-affiliated Pacific islands, atolls, and shallow banks in the Hawaiian Archipelago (Main Hawaiian Islands

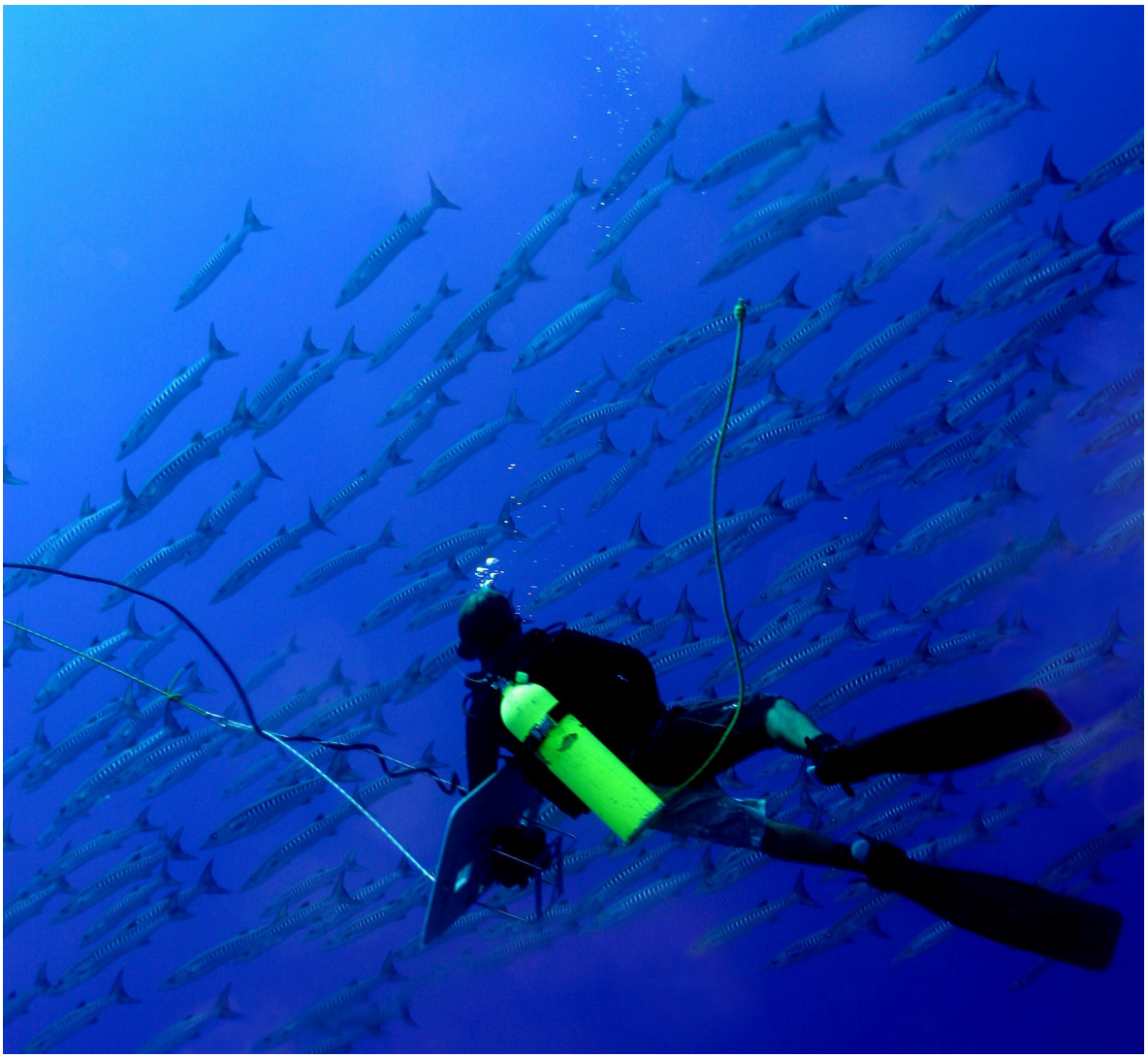

Figure 1.4a. CRED towed diver estimating the number and sizes of fish within a school of barracuda (*Sphyraena genie*). (*Photograph provided by NOAA PIFSC CRED; E. Keenan, JIMAR*)

and Northwestern Hawaiian Islands), the Mariana Archipelago (Territory of Guam and the Commonwealth of the Northern Mariana Islands), Territory of American Samoa, and the Pacific Remote Island Areas (Wake, Johnston, Palmyra, and Kingman Atolls and Howland, Baker, and Jarvis Islands). To accomplish this, CRED uses NOAA research vessels capable of supporting multidisciplinary research teams of 20 to 22 scientists for extended voyages lasting 2 to 3 months.

All Pacific RAMP research cruises are conducted in collaboration with colleagues and partners from other NOAA offices, federal, state, and territorial agencies, academia, industry, and nongovernmental organizations. These partnerships are essential to the effectiveness of long-term ecosystem monitoring in the region since they bring together marine scientists and managers with local, regional, national, and international experience over a broad range of scientific and management issues. They also provide much needed logistical and operational support that could not be accomplished on an on-going basis by CRED staff alone.

CRED's approach to integrated coral reef ecosystem monitoring uses a suite of complementary

methods across key biotic (corals, algae, macroinvertebrates, and fish) and abiotic (benthic habitats, oceanography, and water quality) components of the ecosystem. These methods are used consistently across the Pacific Islands Region to conduct biogeographic and ecological comparisons examining diverse ecological, environmental, oceanographic, and socioeconomic gradients. Ecological gradients include biodiversity, endemism, geomorphology (high island/low island), island landmass, reef classification and zonation, and others. Environmental and oceanographic gradients include temperature (based on seasonal/interannual variability or geographic location), wave energy, tropical storm frequency and intensity, current patterns, precipitation and runoff, water quality (nutrient availability and carbon chemistry), and others. Socioeconomic gradients include population density, coastal development, fishing pressure, agricultural use, cultural practices, and others. By having similar multidisciplinary datasets for coral reef ecosystems across these complex and diverse gradients, it is possible to significantly improve our understanding of ecosystem relationships and implicate cause-and-effect mechanisms that influence the health and resilience of these reef ecosystems.

As described in Chapter 2: Program Design, Operational Background, Data Collection, and Processing Methodologies, CRED uses a diverse array of research platforms, tools, and methods to support the CRCP's Coral Reef Ecosystem Integrated Observing System (CREIOS) for the U.S.-affiliated Pacific Islands. Generally, the CRED-led components of CREIOS in the Pacific include the following:

- Benthic habitat mapping and characterization: to better understand the benthic environment that provides shelter and habitat for the living reef resources. Methods for benthic habitat mapping and characterization include the use of multibeam acoustic surveys to acquire data for moderate depth bathymetric mapping and backscatter image analyses, towed-camera systems and towed-diver surveys for optical validation and ground-truthing, and other experimental technologies to improve efficiencies for optical ground-truthing (laser line scan, LIDAR (Light Detection and Ranging), remotely operated vehicles [ROVs], and autonomous underwater vehicles [AUVs]).
- Oceanographic and water quality observations: to better understand the physical and chemical processes controlling, supporting, and maintaining the health of the living reef resources. Oceanographic observations are collected using shipboard and small boat-based vertical profilers of water properties, moored surface and subsurface instrument arrays, satellite remote sensing of surface properties, and numerical ocean modeling. In addition, CRED conducts bioacoustic monitoring of benthic soniferous organisms and water column scatterers.
- Biological observations: to better understand living reef resources (corals, algae, macroinvertebrates, and fish). Rapid Ecological Assessment (REA) and towed-diver surveys are used to collect biological and ecological observations on shallow reefs (0–30 m), and towed cameras, ROVs, and AUVs are used to document deeper reef resources.

1.5 Scope of the Pacific RAMP

The Pacific RAMP encompasses comprehensive efforts to map, assess and monitor, and observe the coral reef ecosystems of the U.S.-affiliated Pacific Islands. In the process, CRED strives to provide high quality, unbiased, ecosystem-based data and value-added information

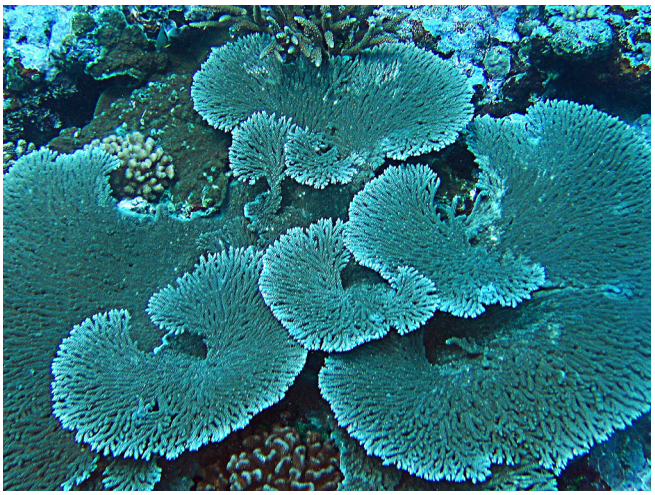

Figure 1.5a. Table coral (*Acropora*) growth at a Tutuila reef. (*Photograph provided by NOAA PIFSC CRED; J. Kenyon, JIMAR*)

products to resource managers and policy makers on local, regional, national, and international levels to support informed decision making for the long-term management and conservation of coral reef ecosystems. The broader scope reflects the reality that coral reef ecosystems are influenced by local, regional, and global processes and stressors.

Though local resource managers generally implement policies influencing human uses of and impacts to local resources, the ecosystems themselves are significantly influenced by processes both within and well beyond local jurisdictional boundaries, including those occurring on regional and global scales. The Pacific RAMP aims to assist local and regional resource managers by providing essential information about these broader-scale biogeographic and ecological processes that are influencing the local and regional resources. As such, the Pacific RAMP is envisioned as a key component of the national backbone to provide broad-scale baseline assessments for the Pacific region. These baseline assessments are explicitly expected to be complemented by local, more focused monitoring programs within each of the jurisdictions, including those funded by the coral reef monitoring grants administered by the CRCP. The Pacific RAMP efforts provide the ecological and oceanographic context within which the local ecosystems are embedded. These broad spatial and temporal surveys across the Pacific region support and guide local monitoring efforts by helping to identify ecological concerns and defining the appropriate questions for more focused research and monitoring at the local level.

One of the key goals of the Pacific RAMP is to provide essential observations to describe, understand, and predict ecological and environmental conditions across broad, and inherently variable, spatial and temporal scales. Though local and regional resource managers and policy makers cannot manage or directly influence these large-scale processes, it is important to recognize that they cannot effectively manage local resources without good information, knowledge, and predictions about these large-scale processes. While there are certainly ecological processes and changes that occur at finer spatial and temporal scales than can be addressed by the Pacific RAMP, many of the pervasive and chronic threats facing coral reef ecosystems are on global and climatic scales.

The temporal scope of the Pacific RAMP, with surveys conducted every 1 to 3 years, is to observe and improve our understanding of ecosystem variability over time scales ranging from many years to decades or centuries. More specifically, the program is designed to examine the potential ecological impacts of long-term threats facing coral reefs, including those related to climate change such as: mass coral bleaching and increased incidence of coral diseases in response to ocean warming; decreased calcification rates of corals, crustose coralline algae, and other calcifying organisms in response to ocean acidification based on changing water

chemistry (increased uptake of carbon dioxide from the atmosphere); and restructuring of many coastal and reef communities in response to rising sea levels, changing storm tracks and intensities, and modified ocean circulation patterns. Though most of these forecasted threats and scenarios are poorly understood at present, they clearly pose significant risks to coral reef ecosystems across all scales ranging from local to regional to global. Recent analyses (Kleypas et al., 2006) suggest that the combined impacts of ocean acidification and warming could potentially dwarf those of many of the traditional local stressors (fishing, coastal development, pollution, etc.) that marine resource managers struggle to address. As these global- and climate-scale processes are becoming better understood, the need for long-term, broad-scale ecosystem observations (biotic and abiotic) provided by the Pacific RAMP are becoming more evident.

Accurate and up-to-date characterizations of the coral reef ecosystems of American Samoa are necessary to develop and evaluate effective management strategies to aid economically and culturally dependent local populations and the scientific management community. The ecosystem "snapshots" acquired during the Pacific RAMP surveys incorporate baseline data from the previously listed marine disciplines to identify both short-term and long-term spatial and temporal changes of coral reef organisms and their environment. CRED's unique, ecosystem-based approach to reef assessment and monitoring in American Samoa will provide local, regional, and national resource managers with an effective scientific tool to begin implementing ecosystem approaches to management.

Figure 1.5b. Pufferfish (*Arothron meleagris)* found on coral in Ta`u, America Samoa. (*Photograph provided by NOAA PIFSC CRED; R. Schroeder, JIMAR*)

RAMP in American Samoa

As part of the Pacific-wide monitoring effort, CRED conducted its first American Samoa RAMP (ASRAMP) cruise in 2002, with subsequent ASRAMP cruises in 2004 and 2006. Partners from the local management agencies, including the scientists and managers from American Samoa's Department of Marine and Wildlife Resources and Department of Commerce, the National Park of American Samoa, and NOAA's Fagatele Bay National Marine Sanctuary worked alongside CRED scientists to plan and conduct the surveys and determine and establish monitoring sites, and conduct the surveys. Chapter 2, Section 2.1: Operational Background lists specific individuals from American Samoa who participated in the planning and/or implementation of ASRAMP cruises.

The value of the ASRAMP effort may not have been fully realized during earlier stages of the program. Based on the observations to date, scientists and managers can begin to characterize the spatial patterns of variability of the reef ecosystems around American Samoa and compare them to other regions in the Pacific. The value of the program will increase steadily as observations are extended in time and the ability to detect significant ecological changes and climate fluctuations increases. Over time, ecological and environmental trends may include biodiversity shifts, population increases or decreases, sudden species die-offs, disease outbreaks or bleaching pandemics, and introductions of bioinvasive species. With continually improved observations and understanding, our ability to develop predictive models will likewise increase, thereby providing managers with improved tools for protecting and conserving reef resources. CRED is committed to providing high quality, unbiased, integrated ecosystem observations of the reefs of American Samoa, as well as other U.S. Pacific Islands jurisdictions, well into the future.

1.6 Limitations of Pacific RAMP

As with any large research effort, the Pacific RAMP has limitations based on logistical, operational, and scientific constraints. These constraints shape the nature of the data presented within the body of this document and provide a matrix for future improvement and continued program development. The program limitations are discussed here to clarify the current state of the program, the nature of the data, and the future of CRED's Pacific RAMP research.

Since the beginning of the program, CRED has worked with partners in each jurisdiction to adaptively develop and implement comprehensive Pacific RAMP ecosystem monitoring surveys. During the initial years (2000–2003), many monitoring programs were in place across the Pacific and although many monitoring workshops had evaluated scientific methods and approaches, there was (and still is) little consensus within the scientific community on any singular investigative approach. Moreover, as CRED and the Pacific RAMP were being established, few, if any, examples existed of coral reef monitoring programs of this geographical scale or multidisciplinary, ecosystem-based scope from which the program could draw lessons. As a newly established program, CRED and affiliated partners needed to:

- Determine, develop, test, and adapt sampling methods and protocols;
- Create protocols, algorithms, and tools for data processing, quality control, and

analysis; and
- Devise and implement a data management, integration, and dissemination infrastructure.

As the program was established, a significant majority of the ~ 50 islands, atolls, and banks surveyed by the Pacific RAMP had virtually no prior ecological surveys, bathymetric or habitat maps, or in situ oceanographic observations. There was little or no information about what to expect in terms of habitats, biogeographic structure, oceanographic conditions, or species compositions. In almost all regards, those prior surveys of the Pacific RAMP were exploratory baseline assessments. Perhaps more than anything else, the logistical and financial challenges presented by the vastness and remoteness of the region structured the initial scope of the program and continue to shape its evolution.

The primary role of an ecosystem-based monitoring program is to characterize natural variability within the environment and biological community to enable detection and understanding of anthropogenic impacts. In the marine environment, and specifically for dynamic coral reef ecosystems, this is a unique challenge. Quantifying the patterns of natural variability is done over broad temporal and spatial scales. Temporal scales include diurnal, seasonal, episodic (e.g., weather and storms), interannual (e.g., El Niño Southern Oscillation), decadal (e.g., Pacific Decadal Oscillation), and longer-term climate changes. Spatially, reef ecosystems vary over scales ranging from meters to thousands of kilometers. Ecological zones, such as intertidal, lagoonal, or barrier reef, and habitat types, such as reef slope, forereef, reef crest, backreef, and patch reefs, often vary as a function of prevailing or episodic oceanographic conditions (waves and currents, water quality, terrestrial inputs, etc.).

As previously stated, the Pacific RAMP surveys are conducted every 1 to 3 years to document the climate frequency oscillations. With the exception of oceanographic and bioacoustic moorings, which observe nearly continuously, the Pacific RAMP cannot detect high-frequency ecological fluctuations. The periodic Pacific RAMP surveys are designed to examine longer-term ecological variability (interannual to multidecadal), taking 'snapshots' of each ecosystem at the time of the surveys. As such, it is necessary to have many years of these so-called 'snapshots' before it is possible to rigorously discuss longer-term changes.

Operational and dive safety protocols limit the large majority of the biological observations to daylight hours in areas experiencing 'workable' weather, sea, and current conditions. Though some of the survey methodologies provide a safe working environment in harsher conditions (e.g., towed-diver surveys), all have working safety limits. Based on these operational limitations, it is probable that many species remain spatially or behaviorally isolated from our surveys. For example, nocturnal species of fish and invertebrates and/or species found preferentially in high wave energy environments cannot be effectively monitored using the existing sampling protocols.

Methodological improvements among different Pacific RAMP cruises introduce a degree of variability into the data. Such changes are necessary and common during developmental stages of long-term monitoring programs and reflect the relative infancy of Pacific RAMP. For American Samoa, much of the data generated during ASRAMP 2002 was qualitative in nature, providing baseline data and allowing the program to test different methodologies.

Figure 1.6a. CRED diver amongst a large school of jacks (*Caranx* sp.) off of Swains. (*Photograph provided by NOAA PIFSC CRED*)

Subsequent sampling years (2004 and 2006) used the qualitative analyses from 2002 to design more efficient and effective quantitative sampling methodologies. While this evolution was necessary, it made temporal comparisons across the sampling years challenging because of the intrinsic difficulties in comparing qualitative data to quantitative data. In addition, numerous methodological and survey protocol changes occurred in response to the improved understanding of these ecosystems or as a result of logistical constraints imposed on the program by external forces (funding, safety, etc.). Given these changes and limitations, it is difficult (with the existing American Samoa datasets) to rigorously distinguish real temporal changes within the ecosystem from artifacts resulting from changing methods and/or observers. The multiyear development of this Monitoring Report has assisted CRED scientists to better identify and evaluate potential shortcomings of the existing monitoring methods. While troublesome in these earlier stages, these findings and adaptive adjustments will ensure the program's ability to provide managers with the information needed to implement ecosystem-based approaches to conservation and management in the years ahead.

REA and towed-diver surveys are the two general methodologies used to assess biological communities around each of the islands and reefs surveyed during Pacific RAMP cruises. However, the spatial repeatability of these methods to date is still under consideration by CRED. As Figure 1.6b demonstrates, both towed-diver survey tracks and REA sites vary across years in location between ~ 10 and 500 m; therefore biennial surveys to date have not explicitly surveyed precisely the same reef community. Instead, the repeated surveys to date

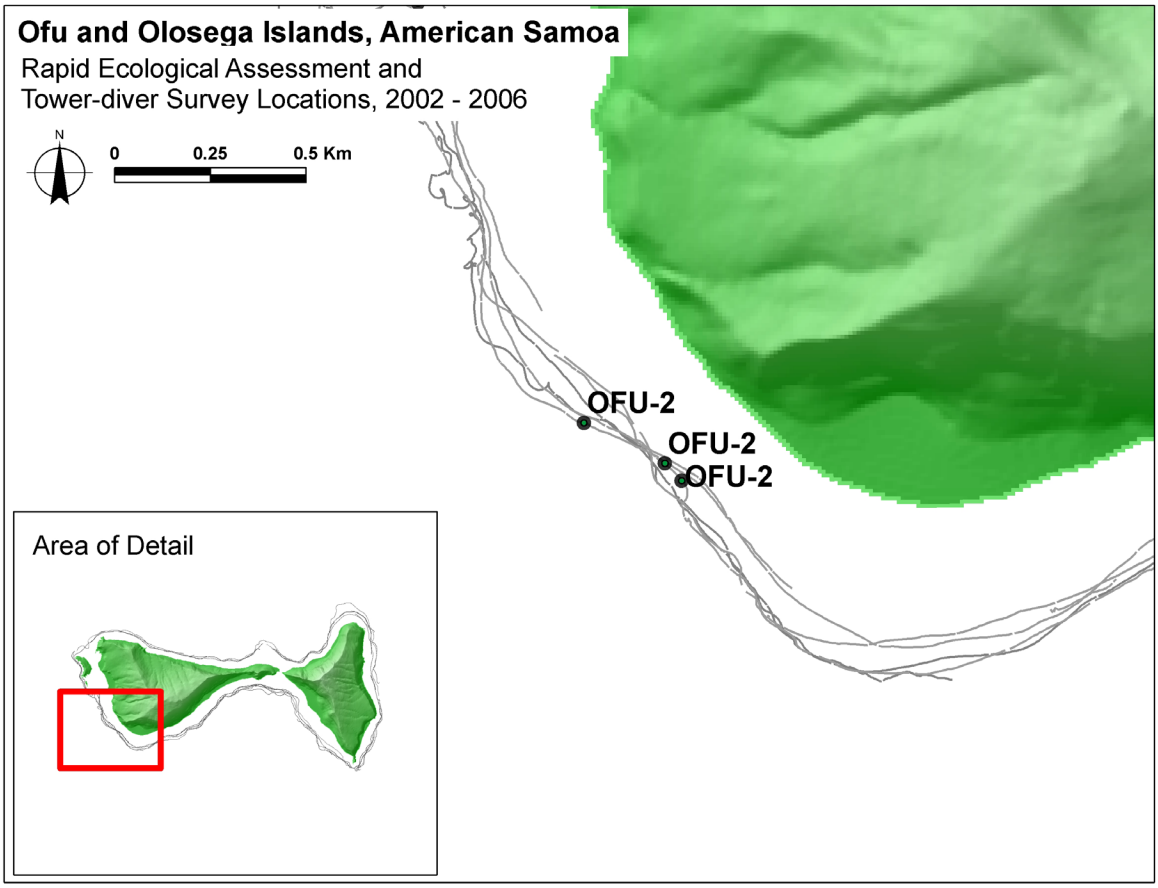

Figure 1.6b. REA site and towed-diver survey track location variability among 2002, 2004 and 2006 Pacific RAMP cruises.

reflect similar reef habitats. Take into consideration the inherent spatial heterogeneity often observed in coral reef communities, and it becomes clear that a high degree of variability between biennial datasets could be based on variability of site or towed-diver survey track locations. While this does not decrease the viability of CRED's datasets, it should be included into the context of the data analyses presented within the body of this document.

Research that relies on consistent observer objectivity and training presents unique challenges with respect to the reduction of errors and biases. The decrease of observer bias is based on repeated field observations completed in the same areas by the same scientific observers over subsequent RAMP deployments, consistent research protocol, and proper training. Lack of continuity among scientific personnel and reciprocity divers from multiple institutions among RAMP cruises, changing methodologies, and implementation of the proper training protocols have all created large challenges necessary to reduce interobserver variability. While many of these will continue to evolve in subsequent years, recent analyses for this Monitoring Report have highlighted the need to focus more resources toward improving consistency in field methodologies, onsite data collection, and comprehensive training protocols to help reduce interobserver variability.

The CRCP and its predecessor, the Office of Habitat Conservation of the National Marine Fisheries Service, have provided the significant majority of the financial support for CRED and the Pacific RAMP since 2001. In addition to program management and administrative

support, this funding provides for the staffing of research cruises, the purchase of equipment and instrumentation, the completion of data analyses and integration/management, and the publications associated with processed data. The availability of funds drives CRED's capacity, directly influencing the level of staffing in each of the disciplines. Staff members are often at sea for 2 to 5 months per year, which impacts the speed of data processing and dissemination. As a result, CRED is highly dependent on its local partners for staffing support of research cruises, thus enhancing local knowledge and understanding of coral reef resources, but possibly increasing variability in data consistency.

Large-scale data organization, quality control, and database structure are high priorities for the CRED scientific team. Proper data management and data flow practices are vital for streamlining and organizing the huge datasets that are an inherent part of CRED's research effort in the Pacific. Though significant progress has been made, as evidenced by this Coral Reef Ecosystem Monitoring Report for American Samoa, the implementation of data management protocols remains an effort in progress. This area, in particular, has suffered from long-term level funding that does not allow for annual cost of living increases. In essence, actual ship and field operational costs have increased annually, which has led to net decreases in funding for data management infrastructure over the past several years.

While keeping in mind these constraints, CRED strives to increase efficiencies and improve all aspects of its scientific program. This initial Monitoring Report represents the first installment of the ongoing effort to bring resource managers and interested stakeholders the best available, ecosystem-based data to help them make informed decisions about the sustainable use and conservation of their resources.

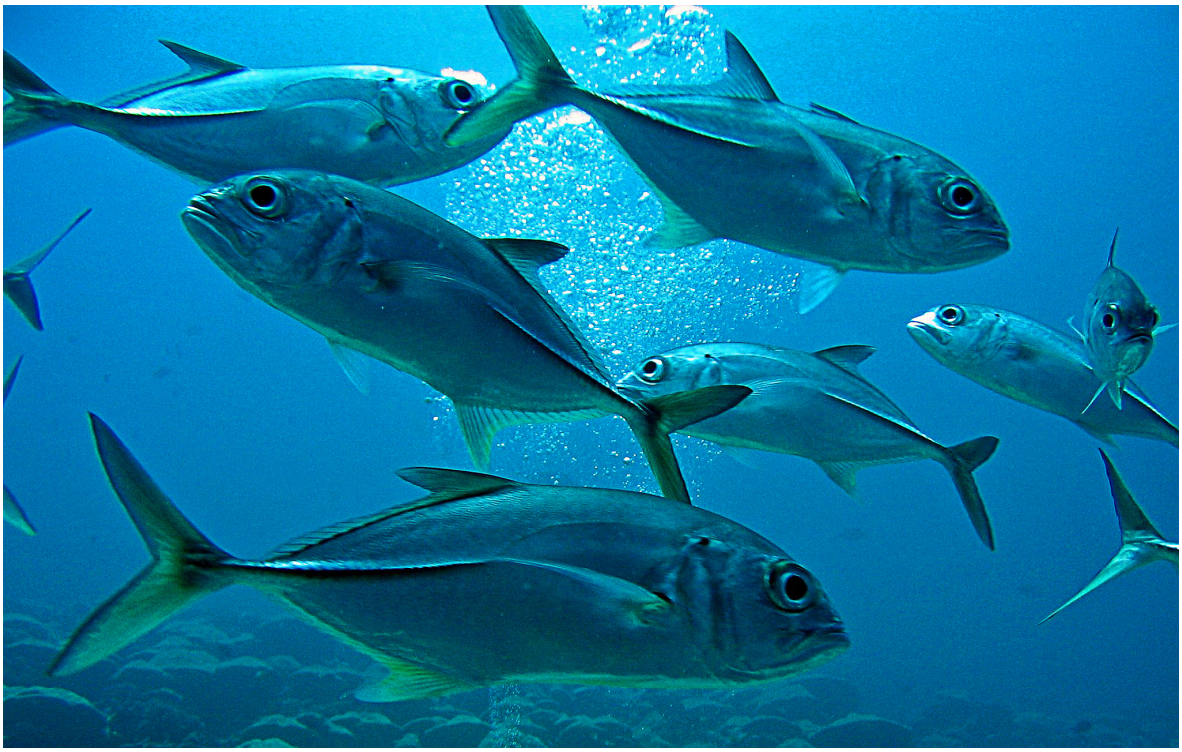

Figure 1.6c. Jacks (*Caranx sexfasciatus*) in the waters of American Samoa. (*Photograph provided by NOAA PIFSC CRED*)

1.7 Structure of Report

This report is designed to present large-scale spatial and temporal "snapshots" of the coral reef resources in American Samoa, based on data collected during the CRED-led ASRAMP cruises in 2002, 2004, and 2006. Methodological descriptions and resultant analyses of habitat, oceanographic, and biological datasets are presented within discipline-specific categories. These categories include habitat mapping and characterization (multibeam bathymetry and acoustic backscatter, Towed Optical Assessment Device optical validation, and towed-diver benthic assessments), oceanographic and water quality monitoring (spatial hydrographic surveys and moored time series observations), and biological community monitoring (coral, coral/coralline algae disease, algae, macroinvertebrates, and reef fish).

Each chapter shows comprehensive multidisciplinary data analyses for each island or atoll system. Habitat mapping and characterization data for each island/atoll are presented as multiyear composite analyses across all survey years. Oceanographic and biological monitoring data are presented in a cruise-specific format so that temporal and spatial patterns of abundance and distribution can be distinguished. The main body of the text provides data collected for each island or atoll, spatial and temporal analyses of the data, as well as an integrated, ecosystem-based assessment of findings. The report includes a final chapter that examines archipelagic comparisons of each of the datasets to compare similarities and differences among the islands on a regional scale, including the large-scale processes that influence these coral reef ecosystems.

This document provides unbiased scientific data to assist local, territorial, and federal stakeholders with the challenges they face in the long-term management and conservation of their coral reef ecosystem resources. This report is intended to provide baseline information to:

- Obtain overall spatial and temporal "snapshots" of the coral reef resources and ecosystem conditions around each of the islands in American Samoa during each survey period; and
- Present an effective monitoring tool for stakeholders and resource managers to investigate marine areas of interest and formulate evolving management questions about how to best manage marine resources.

In all years, data collected by CRED scientists and local partners have been presented to the resource management agencies in American Samoa in the form of cruise reports at the conclusion of each ASRAMP cruise. The cruise reports contain summary information, including area and type of operations, itinerary and daily activities, cruise statistics, missions and results, a list of scientific personnel, and types of data collected. Appendices to these cruise reports have provided more in-depth data and information, including an expansive description of methods for each of the disciplines, and qualitative and quantitative data for each discipline by island. The American Samoa Monitoring Report is intended to provide the in-depth analyses to complement the summary data provided in the cruise reports.

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