National Park Service
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Natural Resource Program Center

Pacific Islands Network Benthic Marine Community Monitoring Protocol

Version 2.0

Natural Resource Report NPS/PACN/NRR—2011/339

ON THE COVER
Coral reef community at War in the Pacific National Historical Park
Photograph by: Dwayne Minton, WAPA, NPS

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Appendices

List of Standard Operating Procedures (SOPs)

The Benthic Marine Community Monitoring Protocol consists of this Protocol Narrative (Chapters 1 through 6) and the following Standard Operating Procedures (SOPs):

Within the narrative we explain the rationale for monitoring substrate cover, settlement, growth, and disease and the specific objectives to be met by the monitoring program. The SOPs will include specific instructions for conducting the Benthic monitoring.

Executive Summary

The benthic marine community in the Pacific Island Network (PACN) is a complex ecologic system and a diverse taxonomic environment, including algae and corals and other invertebrates. Reef-building corals are the primary architectural organism and are sensitive to environmental degradation; therefore, they are a good indicator of overall health for nearshore park's marine ecosystems. Primary stressors to coral reefs include disease, bleaching, sedimentation, eutrophication, storms, and global climate change. The United Nations Environment Programme (UNEP) has proposed using coral reefs as a worldwide indicator ecosystem for global climate change (Spalding et al. 2004). For these reasons, the PACN has nominated benthic marine communities as the #2 Vital Sign for network implementation. The benthic marine community Vital Sign is most closely linked with the marine fish Vital Sign, and monitoring efforts will be conducted at the same time and location to maximize data value.

The benthic marine protocol will be implemented initially in four parks: Kaloko-Honokohau National Historical Park (KAHO), Kalaupapa National Historical Park (KALA), National Park of American Samoa (NPSA), and War in the Pacific National Historical Park (WAPA). The protocol addresses two monitoring questions: 1) what are the changes over time in the composition (e.g., species or assemblage) and physical structure (rugosity) of the coral reef benthos? And, 2) what are the changes over time in settlement, growth, survival, and health of target coral assemblages, species, or individuals? The first monitoring question has two objectives. The first objective is to determine long-term trends in the abundance (percent cover of the benthic substrata) of sessile benthic marine macroinvertebrate (e.g., corals, zooanthids, octocorals, sponges, and echinoderms) and algal (including large fleshy macroalgae, crustose coralline, and turf algae) assemblages at sites that are randomly selected on hard substratum, between 10 and 20 meters depth. The second objective is to determine trends in benthic local scale topography or rugosity at a subset of these sites. The second monitoring question has three objectives. The first is to determine trends in settlement rate of hard corals to uniform artificial surfaces at monitoring sites on the fore-reef between 10 and 20 meters depth. The second objective is to determine trends in growth rate and survival of randomly selected coral colonies of a common, trans-Pacific species (e.g., *Pocillopora eydouxi*) growing at similar depth. The last objective is to determine long-term trends in the incidence of coral disease and bleaching. The sampling frame (hard substratum between 10 to 20 meters depth) was selected for ecologic and safety reasons.

A split panel sampling design will be implemented for monitoring, with thirty randomly selected sites sampled annually. Fifteen of the sites will be fixed (permanent) and revisited annually. The remaining sites will be randomly selected each year and will not be revisited. This sampling regime represents the maximum sustainable effort given current logistic and fiscal realities. Initially, this sampling design should have statistical power to have a 40% chance of detecting a 25% relative change in percent cover of the benthos. After several years, we anticipate the power will increase due to an increase in temporal replication to give an approximate power of an 80% chance to detect a 25% change. This increase in power over time will result from the ability to conduct parameter corrections because of repeated analysis.

Personnel requirements for implementing this Vital Sign monitoring identify a team approach from a variety of organizational levels. Individual park staff provide in-park coordination for field efforts and initial reporting, while the NPS Lead serves as the co-principal investigator and supervises a Marine Biological Technician. The NPS Lead provides coordination across parks to optimize consistency in implementation and data collection, and is the primary park-based liaison to ensure that this Vital Sign continues to address park management needs. The NPS Pacific Islands Coral Reef Program (PICRP) Science Advisor serves as the other co-principal investigator, and oversees the implementation and reporting for the protocol. The Marine Biological Technician is the only new position created to facilitate implementation of this Vital Sign. This individual is co-located with the NPS Lead and is responsible for pre- and post-season preparations, field work within each park, and conducts the bulk of initial data management, quality assurance, and analysis. The PACN Aquatic Ecologist and other PACN and park-based staff help facilitate Vital Sign operations, ensure database management, conduct detailed status and trend analyses and reporting, and provide other co-located reporting and operational assistance at a network and national level.

The complete Benthic Marine Community Monitoring Protocol consists of this narrative with appendices and Standard Operating Procedures (SOPs). A complete list of SOPs is found in Appendix E. Any changes in this narrative will be logged in the Revision Log found in Appendix A.

Acknowledgments

This Vital Sign monitoring protocol and associated Standard Operating Procedures (SOPs) were prepared with assistance from the Hawaii-Pacific Islands Cooperative Ecosystems Studies Unit (HPI-CESU) University of Hawaii at Manoa and the NPS Pacific Islands Coral Reef Program (PICRP).

Chapter 1: Background and Objectives

The Natural Resource Challenge (NRC), initiated in 1999 under the auspices of the Omnibus Act (1998), is an action plan for preserving natural resources throughout the National Park Service (NPS) system. The NPS established 32 Inventory and Monitoring (I&M) networks across the nation, including 270 national parks. Each network is comprised of NPS units that share geographic and natural resource characteristics, allowing these parks to share financial resources and expertise (NPS 2006a). The Inventory and Monitoring Program's first objective was to complete basic inventories of natural resources in all parks. This information formed the baseline for long-term monitoring efforts. Because program funding is limited and not everything within park ecosystems can be monitored, monitoring programs were built around measuring critical parameters (Vital Signs) within each network in order to gauge ecosystem health. The information gained by monitoring will be used for natural resource management decision-making. As defined by the NPS, "Vital Signs are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. This subset of monitored resources and processes is part of the total suite of natural resources that park managers are directed to preserve 'unimpaired for future generations' (National Park Service Organic Act of 1916), including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources…" Major challenges addressed in the NRC pertinent to the marine environment include native and endangered species, non-native species, environmental stewardship, and water quality. The Vital Signs monitoring plan and this protocol address these issues.

Long-term monitoring is a repeated information-gathering effort to better understand how to track changes in ecosystems (Likens 1988, Magnuson 1990, Rogers et al. 1994). Monitoring may serve as an "early warning system" to detect declining trends (as well as positive changes) in ecosystem integrity and species or population viability, ideally before irreversible change or loss occurs (Wiersma 1984, Davis 1989). The nature of the observed changes can guide managers to probable causes and suggest further investigations ultimately providing necessary information to support best management decisions and actions (White and Bratton 1980, Croze 1982, Jones 1986, Davis 1989, Quinn and van Riper 1990). In cases where natural systems in or near parks have been so highly altered that natural ecological processes no longer function properly, managers can use information from monitoring to understand how the altered systems operate, in order to determine the most effective approach(es) for restoration of systems and/or natural processes.

Setting

The shallow, nearshore benthic (or sea floor) marine communities in the Pacific Island Network (PACN) parks are comprised of a rich and diverse biota including algae, corals, and thousands of non-coral invertebrates. Nearshore or shallow-water benthic marine communities in the PACN include coral reefs, mangrove stands, seagrass beds, and intertidal habitats. Given multiple existing threats to coral reefs and resources, as well as limited funds, monitoring of this Vital Sign will focus at present on coral reef communities. If future needs or funds arise, monitoring of other marine communities or their specific constituent resources can be initiated.

Coral reef ecosystems provide many ecological and cultural goods and services (Cesar 2000). Coral reefs are essential to the traditional lifestyle and cultures of Pacific Islanders, including Hawaiian, Samoan, Chamorro, and Carolinean peoples in the PACN. Many types of culturally important marine life utilize the reef habitat. Furthermore, remnants of coral skeletons contribute to benthic substrates and beaches of coral rubble or sand. Coral reefs and associated benthic communities help protect shorelines from storm damage and wave erosion and thereby shelter human communities and coastal zone infrastructure (Moberg and Folke 1999, Cesar and Chong 2004). Coral reefs also provide critical elements of commerce from local and charter-sport fishing, as well as other visitor activities (e.g., snorkeling, scuba diving, boating), which are major economic drivers throughout the Pacific Islands (Cesar et al. 2002, Waddell 2005). Because of their ecological, cultural and economic importance, it is critical that the PACN parks have scientific rigorous data collected on the current health and long-term trends of the parks' coral reefs.

In most tropical marine parks, coral reefs form the geomorphologic framework of the ecosystem. These ecosystems have been compared to tropical rainforests in terms of their high species diversity and complex interactions (Connell 1978, Birkeland 1997). Corals are sensitive to various sources of environmental threats and cumulative degradation, making them a good indicator of tropical nearshore marine ecosystem health or condition in the PACN (Jameson et al. 1998). The United Nations Environment Programme (UNEP) has proposed coral reefs as a worldwide indicator ecosystem for global climate change (Spalding et al. 2004). For these reasons, the PACN has nominated benthic marine communities as the #2 ranked Vital Sign for implementation of long-term monitoring.

Many applicable laws pertain to coral reef conservation. The most directly important is the Coral Reef Conservation Act (2000), which created the U.S. Coral Reef Task Force and directed the Secretaries of Commerce and Interior to improve understanding, preservation, and restoration of coral reef ecosystems, while promoting wise management and sustainable use of these valuable marine resources. In the National Park Service, coral reefs at NPS units fall under the protections granted by the NPS Organic Act (1916), the Park System Resource Protection Act, and the Redwood Act (1978). The National Park Service has been directed by Congress, via the National Park Omnibus Management Act (1998), to conduct science-based management, prompting the development of the NPS Inventory and Monitoring Program and this monitoring protocol.

Chapter One of the PACN Monitoring Plan (HaySmith et al. 2005) outlines 33 general monitoring objectives for the network. The Benthic Marine Community Vital Sign will provide information to address eight of these objectives (Table 1.1) and the four corresponding Vital Signs. This information will provide a more complete picture of the factors that influence the benthic marine community.

Table 1.1. General monitoring objectives of the Benthic Marine Community protocol that apply to other Vital Signs of the PACN I&M Program.

General monitoring objectives	Level 1	Level 2	Vital Sign
Track spatial and temporal patterns in water quality in freshwater and marine systems.	Geology & Soils	Water Quality	Water Quality
Use monitoring data for early detection & predictive modeling of incipient invasive species.	Biological Integrity	Invasive Species	Invasive Species early detection
Document changes in established populations of invasive species, including response to treatment.		Invasive Species	Invasive Species early detection
Determine trends in incidence of disease and infestation in selected communities and populations.		Infestations and Disease	
Determine trends in composition, structure, and function of populations of selected focal species and communities within the parks.		Focal species or Communities	Marine Fish
Determine spatial and temporal patterns in benthic marine cover and community distribution.	Ecosystem Patterns and Processes	Land Use and Cover	Landscape dynamics
Determine whether viewsheds, landscapes and underwater seascapes are changing within and surrounding the park.		Land Use and Cover	Landscape dynamics
Track extreme disturbance events in parks.		Land Use and Cover	Landscape dynamics

This Vital Sign is closely linked with the Marine Fish Vital Sign. The Vital Signs will be co-located and co-visited to maximize logistics and to examine comparisons of interrelated monitoring data sets. The integration of information across datasets forms a more holistic understanding of community condition over time that is useful for management. The interrelationship of coral reefs and the associated fish community will provide additional explanatory power to both Vital Signs. Water Quality is currently proposed for co-location and some co-visitation. Data from this protocol will be useful for explaining changes in the benthic community as it relates to climate change and anthropogenic impacts. Other PACN Vital Signs that can potentially provide valuable information include the Groundwater and Erosion and Deposition Vital Signs. For example, composition and rates of groundwater and surface flow from upland watersheds can clarify patterns observed in adjacent benthic communities. Correlations among these variables will not establish causal links but can focus further research to examine the relationship between material transport and the downstream biota.

To design an effective monitoring program, a substantial base of information is necessary. Baseline information includes inventories of species and habitats, and measurements of natural variability (both spatial and temporal) for the monitoring variables of interest. Currently, little baseline information exists for marine systems in the national parks in the PACN, and while species inventories are available in some cases and some information on spatial and temporal variability exists – comprehensive measures of natural spatial and temporal variability for all PACN parks are lacking. Fortunately, this important information can be collected easily as part of a monitoring program. The development of the benthic marine community protocol, therefore, is designed to be an adaptive monitoring program, amendable as new data become available and as situations may change at any park(s). It is anticipated that the first few years of monitoring will serve as the pilot study to refine logistic, statistical, and financial issues.

Selection of effective monitoring variables, called Vital Signs by the NPS, is critical to the long-term success of the monitoring program. The Vital Signs selected by the NPS have been carefully chosen to be valuable indicators of coral reef health, are sufficiently sensitive to undergo change, and can be easily measured with, in many cases, comparatively small measurement error relative to levels of natural variability. The Vital Sign selection process is described in Chapter 3 of the PACN Vital Signs Monitoring Plan (HaySmith et al. 2005).

The responses of benthic marine communities to a variety of ecological and anthropogenic stressors have been studied in recent publications (Adams 2005), and predictions can now be made concerning the influence of various stressors on community structure and function. For example, in the presence of elevated nutrient levels, coral reef communities generally experience an increase in algal cover or biomass (Smith et al. 1981, McCook et al. 2001). This situation is compounded when top-down control (e.g., herbivorous fish) is removed from the ecosystem due to overfishing (e.g., Hughes 1993, Hughes et al. 2007). These ecological communities, however, are characterized by a complex set of interactions among drivers and community components (Carpenter et al. 1999). Although ecological monitoring is capable of documenting changes in community components as well as likely agents of change, monitoring alone cannot discern cause-effect relationships (Halpern et al. 2006). This relationship requires further investigation using targeted research to establish cause (e.g., HaySmith et al. 2005, Halpern et al. 2006). As a result of monitoring, managers and researchers can formulate adaptive management strategies accordingly.

System of Interest

The system of interest for this Vital Sign monitoring protocol is the nearshore hard bottom community between 10 and 20 m depth, encompassing primarily coral reef ecosystems. While this protocol focuses on hermatypic reefs, we recognize the importance of other habitats to the ecology and overall function of the ecosystem, such as seagrass beds, soft bottom sand and mud flats, intertidal habitats, and mangrove forests; these habitats serve important functions for different life stages such as spawning, recruitment, and growth of coral reef inhabitants (Ogden and Ehrlich 1977, Parrish 1989). Appendix H (Stephens and Daniel 2005) and the Marine Workgroup Overview of Appendix E (Daniel and Minton 2005) of the PACN monitoring plan (HaySmith et al. 2005) provides more detail on other systems found in the network.

Coral reefs are diverse and complex marine ecosystems, and are important components in shallow fringing and barrier reef ecosystems in PACN parks. Coral reef ecosystems are centers of biodiversity because of the habitat complexity available to different organisms. The reef provides substrate and microhabitats in which sessile and motile organisms live and feed. The architectural complexity is likely shaped by a heterogeneous combination of many factors, including nutrient availability, salinity, light, substrate type, temperature, and exposure to wave action (Lalli and Parsons 1995, Hoegh-Guldberg 1999, Szmant 2002, Leichter et al. 2003).

One of the most conspicuous aspects of coral reefs is the presence of distinct physiographic and biologic zones paralleling the long axis of a reef platform (Odum and Odum 1955, Done 1983, Huston 1985, Littler et al. 1989). Patterns of zonation form in response to environmental conditions and vary with distance from the shoreline and depth. Major factors determining zonation are leeward/windward position (aspect), depth, and geologic age of volcanic islands or atolls. Zonation of coral reef communities on windward shores may not be as well developed as those on leeward coasts. Localized factors affecting zonation include wave exposure (or wave energy) (Dollar 1975), light (Mundy and Babcock 1998), salinity (Jokiel et al. 1993), temperature (Loya 1972), and sedimentation (Chansang et al. 1981). Zonation can vary geographically based on depth contour (slope), and predominant species; however, some of these general ecological zonation characteristics are present within the PACN parks (Figure 1.1).

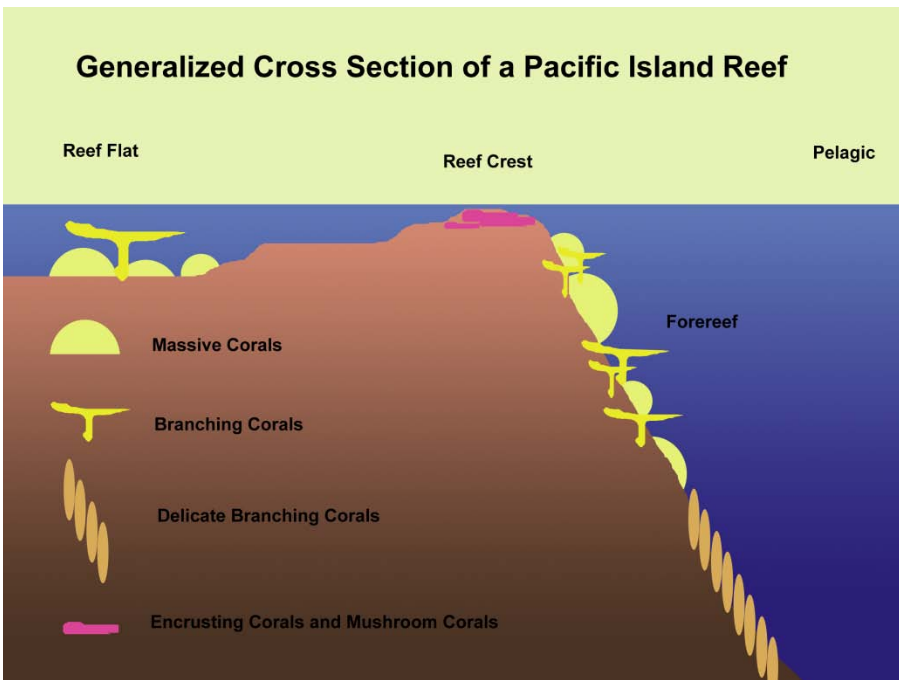

Figure 1.1. Generalized physiographic and biologic zonation of a coral reef ecosystem.

Reef zonation has been well studied in the Pacific Islands (Maragos 1972, Dollar 1982, Randall and Myers 1983). Most of the PACN parks are characterized by geologically young volcanic islands (Clague 1998). Commonly observed zones include the reef flat, the reef crest, the reef slope or fore-reef, and the deep fore-reef or pelagic zone (Odum and Odum 1955, Dollar 1982, Done 1983, Huston 1985, Littler et al. 1989, Kendall et al. 2001, Coyne et al. 2003). The reef flat zone is generally characterized by shallow water (less than 2 m), high light exposure, and moderate wave energy. Corals are sparse and coralline algae are the primary reef builder. In some cases, seaweed is prevalent with small invertebrates and some shore fish. The reef crest is characterized by high light exposure and generally high wave energy, depending upon orientation to predominant wave origin. The reef crest may have constant swell exposure on windward or exposed shores. Water depth is generally shallower than 10 m, with the actual reef crest often exposed at low tide.

Of particular ecological importance to the PACN parks is the fore-reef slope zone which is found at all of the park units with submerged resources. Compared to zones closer to shore, the reef slope is typically characterized by higher species diversity (Karlson 1999), more active growth (Stearn et al. 1977), and more oligotrophic water with lower concentrations of inorganic nitrogen (N) and phosphorus (P), (e.g., Tomascik and Sander 1987). At depths greater than 10 m (bottom limit varies based on the reef but usually exceeds 40 m), the fore-reef has high light penetration and relatively moderate wave energy. Anthropogenic stressors can impact this zone in the PACN because of its close proximity to shore and the steep geomorphology of Pacific coral reefs which facilitates transport of materials from the coastline to the open ocean (e.g., Dollar and Grigg 2004). Among the PACN parks these geomorphologic and biological characteristics will vary along with the anthropogenic stressors so the primary focus will be on temporal comparisons of the various metrics within a park. Comparisons among parks will tend to examine trends in more general metrics (e.g., what is the trend in total percent coral cover at the parks?).

Threats and Concerns

Many stressors affect coral reefs, including but not limited to: disease, bleaching, sedimentation, nutrients, contaminants, storms and smaller-scale physical disturbances, alien species, biotic outbreaks of voracious coral predators (e.g., Crown-of-Thorns, Sea Stars), coastal development and resulting population pressures, and global climate change. In this section, we discuss some of these prevalent issues in the PACN. Many stressors on the marine environment have a terrestrial origin, and most are associated with human activity (Bruckner et al. 2005). As a result, many Pacific Islands National Parks must address many of these ecological stressors.

In PACN parks, coral reef resources are found in shallow nearshore coastal waters, and therefore are exposed to a wide range of natural and anthropogenic threats. On Pacific islands, as elsewhere, human population densities are often highest near the coast, resulting in considerable human use with concomitant impact on marine resources (Craig et al. 2005, Waddell 2005). Coral reefs occur at the bottom of watersheds and are subject to multiple threats from both land-use practices in the adjacent watersheds and easy land-based access to exploitable marine resources (Jokiel and Cox 1996, Wilkinson 2000, Furnas 2003, Pew Oceans Commission 2003, Waddell 2005). While resource use is often zoned and enforced on land, marine zoning is a more difficult concept to embrace by the general public as exemplified by the “Tragedy of the Commons” (Jennings et al. 2001). Consequently, many marine activities are conducted in a lightly or entirely unregulated manner (Wilkinson 2000, Pew Oceans Commission 2003, U.S. Commission on Ocean Policy 2004, Bruckner et al. 2005, Waddell 2005).

Nearly all parks have land management issues either within park units or in surrounding watersheds that result in terrestrial runoff. Runoff-associated issues (e.g., sediments, nutrients, contaminants, and freshwater inputs) have been identified as one of the most significant threats to Pacific marine habitats (Birkeland 1997, Porter et al. 2005). Land-derived sediments, generally a result of runoff, increase coral mortality (e.g., Nowlis et al. 1997), decrease coral growth (Fabricius 2005) and recruitment (Fabricius 2005) and are often accompanied by associated inputs of nutrients or pollutants (Richmond 1997). Nutrient loading in the marine environment may result in an increase in growth and reproduction of phytoplankton and some macroalgae increasing the ability of macroalgae to compete with corals for space on the benthos (Done 1992, McCook et al. 2001, Smith et al. 2004). Algae, in the presence of high nutrients and reduced grazer populations, often proceed to dominate the benthos, excluding and reducing coral abundance and diversity (Smith et al. 1981, Lapointe 1997). This change in species dominance has caused a cascade of ecological change through the invertebrate community (Smith et al. 1981), and has often been termed a phase shift in the literature. For example, in Kaneohe Bay on the island of Oahu, nutrient-rich sewage discharge facilitated the growth and subsequent competition for space by the macroalga *Dictyosphaeria cavernosa* (Smith et al. 1981, Jokiel et al. 1993, Stimson and Larned 2000). Proliferating algae in nutrient-rich waters has also been found to contribute to seagrass decline (McGlathery 2001).

Climatic stressors are also prevalent across the national parks in the Pacific. These include El Niño/Southern Oscillation (ENSO) events, storms (e.g., tropical cyclones), and global climate change. While most of these “natural” events are outside of the direct management capabilities of the NPS, their effects on the marine ecosystem must be taken into account when attempting to monitor these and other stressors. The distinction between natural and anthropogenic agents of change is an important consideration when managing park ecosystems for ecological integrity, but this is often difficult to interpret. Many Pacific island ecosystems have co-evolved with disturbance from tropical cyclones and volcanic activity. In the absence of anthropogenic influence, these ecosystems may undergo natural succession when affected by a natural disturbance regime. However, very few Pacific island ecosystems are now unaffected by human activity or invasive species, which may severely compromise natural ecosystem succession, biological and physical processes (Brown 1997a, Bruckner et al. 2005).

Climate change is a real threat to PACN parks, particularly in coastal parks that are subject to sea level rise and elevated temperatures. The rate of climate change, including increasing atmospheric carbon dioxide along with ozone depletion and concomitant increases in air and sea surface temperatures is unprecedented (Hughes et al. 2003, Board on Atmospheric Sciences and Climate Change 2006, Solomon et al. 2007). Increases in atmospheric carbon dioxide have lowered sea water pH by 30% since the pre-industrial era (Orr et al. 2005). The resulting acidification could reduce calcification rates for corals, and many other marine shell-forming organisms, thus significantly impacting reef accretion rates (Langdon et al. 2000, Kleypas and Langdon 2002, McNeil et al. 2005, Orr et al. 2005, The Royal Society 2005, Kleypas et al. 2006). It is projected by the middle of the century that acidification may contribute to widespread coral reef loss (Solomon et al. 2007). Global mean sea surface temperatures have increased 0.76 ± 0.2 degrees Celsius during the twentieth century (Solomon et al. 2007). Increased sea surface temperatures contribute to bleaching, a process in which corals expel zooxanthellae (algal symbionts) leaving bleached tissue and white skeleton (e.g., Hoegh-Guldberg 1999). If prolonged, bleaching can result in coral mortality. The shallow lagoons of NPSA in American Samoa could be particularly susceptible to bleaching where water temperatures can reach 35°C (Hoegh-Guldberg et al. 2000, Craig 2005, Solomon et al. 2007). The 2007 Intergovernmental Panel on Climate Change (Solomon et al. 2007) predicts that increased coral bleaching events will occur with a global mean annual temperature change of up to one degree Celsius, with most corals bleached by two degrees Celsius, and widespread coral mortality by three degrees Celsius.

The magnitude of marine invasive species as a significant marine stressor is currently little known at most Pacific islands national parks, but the seriousness of this threat is well demonstrated by several highly visible and very costly cases in Hawaii (Carlton 2001), including KAHO. Further efforts should be placed on collecting baseline data on the identity, abundance, and distribution of marine invasive species and on their early control or eradication.

It is anticipated that the results of this protocol will identify areas within each park that are undergoing change in the benthic community structure. Annual sampling can also clarify rates of change and how areas respond to acute and/or chronic disturbances. Correlating changes in percent cover with acute disturbances such as hurricanes is relatively straightforward but establishing causal links with chronic disturbances such as climate change is much more difficult with a monitoring program (Clarke and Warwick 2001). For example, if coral settlement begins to gradually decline within the park, is it due to global climate change affecting fecundity of corals in the region or is it a more localized phenomena restricted to the park? The key will be the spatial scale at which the change is taking place. Examining similar data sets from other agencies will enable experimental research to focus on the area and ultimately the causal mechanism. Therefore, the purpose of any monitoring program is to identify areas of concern that will focus the efforts of resource managers and research scientists.

Natural and Anthropogenic Stressors

Nearshore coral reefs are subject to many natural and anthropogenic threats and stressors, which can be chemical (events that change water quality parameters, such as pollution), biological (such as invasive species), or geo-physical (such as seismic or extreme weather events). Some predicted ecosystem responses to the presence of stressors within this system are provided in Table 1.2. Ecosystem responses may vary by degree and consequence depending on a number of factors. These predicted responses are by no means definitive or comprehensive but serve as guidelines for interpretation of observations. The degree and consequence of ecosystem responses may also be affected if there are multiple stressors acting synergistically or sequentially. For example, if a natural event such as a hurricane devastates a reef system within a park, the recovery of that reef might be delayed or never occur due to chronic anthropogenic stressors that are compounding the damage from the hurricane.

Table 1.2. Agents of change and stressors with predicted possible ecosystem responses for the benthic marine community Vital Sign.

Agent of Change	Stressors	Ecosystem response	Citation(s)
Climatic drivers	Increasing Temperature	Increasing bleaching and disease occurrence- both contribute to a decrease in coral cover and changes in community composition.	Jokiel & Coles 1990, Porter et al. 1999, Hoegh-Guldberg 1999, Glynn 2000, Douglas 2003, Sutherland et al. 2004
	Increasing UV radiation	Increasing bleaching	Lesser et al. 1990, Gleason & Wellington 1993, 1995
	Extreme weather events (e.g., tropical cyclones, heavy rainfall)	Physical disturbance/damage; Change in benthic cover: decreasing coral cover = increasing algal cover	Dollar & Tribble 1993, Rogers 1993, Rogers et al. 1997, Connell et al. 1997, Friedlander et al. 2003, Jokiel et al. 2004
	ENSO effects (increase SST, change in rainfall)	Bleaching; Changes in salinity (decrease) and sedimentation (increase).	Nowlis et al. 1997, Hoegh-Guldberg 1999, Glynn 2000
Landscape dynamics	Land use (including coastal development)	Shoreline habitat change: Increasing erosion; Increasing sedimentation	Examples in Fabricius 2005
	Erosion	Increasing sedimentation; decreasing coral recruitment	Richmond 1993, Minton 2005
	Sedimentation	Decreasing light, calcification; increasing mortality & stress; Increasing disease occurrence; Increasing particulate matter, inorganic nutrients & pollutants; Decreasing species richness, coral cover, growth, recruitment	Rogers 1990, McLaughlin et al. 2003, Minton 2005, see Fabricius 2005 for more detailed response with many citations.
	Eutrophication (e.g., sewage, agricultural runoff)	Change in benthic cover: Increasing algae; decreasing coral; Increasing population outbreaks (e.g., COTS)	Smith et al. 1981, Birkeland 1982, Done 1992, Laws 1992, McCook et al. 2001, Smith et al. 2004, Brodie et al. 2005
	Stream flow	Change in salinity & water chemistry; facilitate sedimentation and may result in reef kills by freshwater.	Jokiel et al. 1993
	Groundwater intrusion	Provides terrestrial based nutrient and pollutant source and promotes algal growth	Smith 2003, Hunt 2007, Smith & Smith 2006
Marine-based human activity	Fisheries harvest	Decreasing fish numbers; Increasing fleshy algae and decreasing coral cover resulting in change in biodiversity of community	Murawaski 2000, Rice 2000, McManus et al. 2000; Vecchione et al. 2000, Bellwood et al. 2006, Hughes et al. 2007
	Aquarium fish collecting	Selective depletion of targeted species	Friedlander 2001, Tissot et al. 2004
	Recreational activities (e.g., snorkeling, fishing, diving)	Mechanical damage resulting in: decreasing coral cover, decreasing structural complexity, & increasing algal communities; Decreases in rugosity.	Riegl & Velimirov 1991, Rouphael & Inglis 1995, McManus et al. 1997, Jameson et al. 1999, Zakai & Chadwick-Furman 2002, Tratolos & Austin 2001, Barker & Roberts 2004, Yoshikawa & Asoh 2004,

Table 1.2. Agents of change and stressors with predicted possible ecosystem responses for the benthic marine community Vital Sign (continued).

Invasive species	Alien introductions & increased competition	Change in diversity: increasing alien algae or invertebrates; decreasing # native algal or invertebrate species; Decreasing coral cover and decreasing biodiversity	Done 1992, Rodgers & Cox 1999, Smith et al. 2002, Smith et al. 2004,
	Population outbreaks	Increasing predation and decreasing coral cover	Done 1992
Disease	CLOD, coral diseases	Change in benthic cover: decreasing coralline algae & decreasing coral cover	Littler & Littler 1995, Aeby 2005

Parks Where Protocol Implemented

This Vital Sign monitoring protocol will be implemented, initially, at four parks, Kaloko-Honokohau National Historical Park (KAHO), Kalaupapa National Historical Park (KALA), National Park of American Samoa (NPSA), and War in the Pacific National Historical Park (WAPA) (Table 1.3). All permits and permissions (Appendix C) will be obtained in advance for all federal, state, and territory agencies and from local villages or communities, where appropriate.

Table 1.3. Parks where this protocol will be initially implemented.

Park	Abbreviation	Location
Kaloko-Honokohau National Historical Park	KAHO	Island of Hawaii, state of Hawaii
Kalaupapa National Historical Park	KALA	Island of Molokai, state of Hawaii
National Park of American Samoa	NPSA	Islands of American Samoa, Territory of American Samoa
War in the Pacific National Historical Park	WAPA	Island of Guam, territory of Guam

The subtidal habitats vary considerably among the four parks. KAHO with approximately 600 acres of submerged lands, contains several coral habitat types ranging from extensive shallow volcanic benches or pavement in the south, to coral pinnacles, steep slopes and rich coral fields and sand channels in the north. Most of the coral reefs in the northern end of the park are typical of exposed areas on the Kona coast of the island of Hawaii (Big Island). Abundance of macroalgae is relatively low within the park boundaries with the exception of the coastal fishponds. Sand habitats exist in water depths greater than 25 meters.

At KALA, the park boundary extends from the shoreline to 0.42 km (1/4 mile) offshore where waters are about 30.48 m (100 feet) deep. The hard bottom substrate consists of basalt pavement and boulders colonized by coral communities with <25% coral cover. Sandy bottoms extend out from the rivers draining the three principal watersheds within the park. Several offshore islands within the park boundaries contain relatively intact marine assemblages typical of vertical, exposed coastlines. Species diversity is low in comparison to other tropical reef systems with approximately 20 coral and 200 fish species. The primary physical disturbance to the marine community consists of large (8 to10 m) northwest Pacific swells in the winter months (October – April). Most of the park waters are located away from anthropogenic sources, so nutrient enrichment and sedimentation are generally not an issue.

The legislated boundary at NPSA extends a quarter mile offshore with a steeply sloping bathymetry. NPSA has large amounts of crustose coralline algae, which has been identified as a key component to reef formation. Numerous other algae species occur within the park. Fagasa Bay, however has a higher diversity of fleshy macroalgae (Skelton 2003). NPSA’s coral reefs represent the only southern hemisphere reef systems in the National Park System. These fringing reefs are in fairly good health and contain species that are probably unique within the NPS. The lagoon within the fringing reefs in the Ofu unit represents an unusual microhabitat with high species diversity. Forereefs have well developed spur and groove formations with some sandy bottom zones interspersed. The reefs in NPSA have about 200 species of coral and 900 species of fish.

The legislated boundary of WAPA extends into the ocean and encompasses approximately 1000 acres of submerged land. WAPA has extensive coral reef resources with moderate macroalgal cover (20-30%). Fringing reefs with moderate coral cover (20-30%) extend as far as 100 meters offshore before dropping quickly to 25 to 30 m depths. Many of the coral species on the reef occur nowhere else in the National Park System and make this a unique natural resource. Extensive seagrass beds, comprised mostly of *Enhalus acoroides*, but containing all three seagrass species found in Guam, line the shores of the Agat Unit. These seagrass beds may serve as a nursery habitat for coral reef organisms. Other than at AMME, these seagrass beds occur nowhere else in the NPS. Sand plains do occur at around 25 and 30 meters, and extend an undetermined distance seaward.

Vital Sign Objectives

Most successful monitoring programs have been developed around specific questions (previously mentioned and below) and objectives (NPS 2006b). These objectives are specific statements that provide additional focus about the purpose or desired outcome of the monitoring program and should be consistent and justifiable with current scientific knowledge (NPS 2006b). In this protocol, two types of objectives are presented: Monitoring Objectives and Sampling Objectives.

Monitoring Questions and Objectives

An effective set of monitoring objectives should meet the test of being realistic, specific, and measurable (NPS 2006b). The benthic marine community Vital Sign addresses two monitoring questions with five objectives.

Question 1: What are the changes over time in the composition (e.g., species or assemblages) and physical structure (rugosity) of the coral reef benthos?

Objective 1a: Annually measure the abundance (density of individuals or percent cover of the benthic substrata) of sessile benthic marine macroinvertebrate (e.g., corals, zooanthids, octocorals, sponges, and echinoderms) and algal (including large fleshy macroalgae, crustose coralline, and turf algae) assemblages at randomly selected hard bottom sites between 10 and 20 meters depth.

Objective 1b: Annually measure the benthic local (site, transect) scale topography or rugosity at randomly selected, fixed (permanent) sites with hard substratum between 10 and 20 meters depth.

Question 2: What are the changes over time in settlement, growth, survival, and health of target coral reef benthic assemblages, species, or individuals?

Objective 2a: Annually measure the settlement rate of hard corals to uniform artificial surfaces at randomly selected, fixed hard bottom sites on the forereef between 10 and 20 meters depth.

Objective 2b: Annually measure the growth rate and fate of randomly selected coral colonies of a common, Pacific species (e.g., *Pocillopora eydouxi*) found in all parks and growing at similar depths.

Objective 2c: Annually measure the incidence of coral disease and bleaching within the photographic images sampled at randomly selected, fixed hard bottom sites on the forereef between 10 and 20 meters depth.

Sampling Objectives

Sampling objectives are usually written as companion objectives to management or monitoring objectives. Sampling (or statistical) objectives specify target levels of precision, power, acceptable Type I and II error rates, and magnitude of change we are hoping to detect.

The parameters of interest vary across space and time, and as such, no single design can provide maximum statistical precision, power, or acceptable error rates for all parameters simultaneously. Therefore, the design was developed to maximize the statistical power of the benthic cover data, with some consideration to the coral settlement data because both parameters were identified by the PACN as high priorities. Our sampling objectives for this Vital Sign protocol follow:

Sampling Objective 1: Achieve an 80% likelihood of detecting a 25% change in coral cover after 10 years of monitoring.

Sampling Objective 2: Achieve a 70% likelihood of detecting a 50% change in coral settlement after 10 years of monitoring.

Key System Components and Indicators

Desired Conditions**:** Ideal conditions for coral reefs across the PACN vary from park to park. Coral cover or biodiversity alone are poor indicators of reef health because many healthy reef ecosystems have low coral cover (e.g., many Hawaii reefs) relative to reefs in other areas such as the Indo-Pacific (e.g., Guam). Healthy reefs (e.g., Figure 1.2) are better characterized by the presence of no or few invasive species, a full complement of ecologic guilds (e.g., presence of apex predators and herbivores that have not been overfished), stable population dynamics (e.g., increasing or stable coral cover, adequate settlement and subsequent recruitment) among native species, and low stress on individuals resulting from balanced environmental conditions (Waddell 2005).

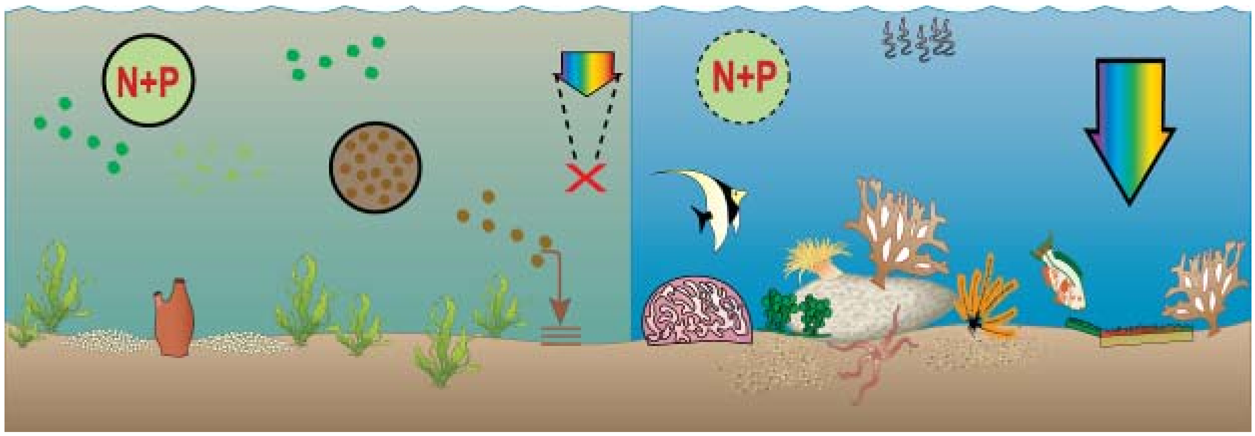

Figure 1.2. A conceptual comparison of an impaired (left frame) marine coral community versus a desired or "healthy" community (right frame). Healthy conditions include oligotrophic (low nutrient concentration) water with no suspended sediment, high light penetration, and high biological diversity. Impaired communities are characterized by increased levels of nitrogen (N) and phosphorus (P) with increased turbidity, sediment loading and burial of live coral; conditions that may promote algal growth and potentially decrease species diversity.

The indicators selected for this Vital Sign are relatively easy to measure and provide information on the state (healthy or degraded) of the system. The indicators selected for monitoring this Vital Sign include benthic substrate percent cover, reef rugosity, coral settlement rate, growth, and the incidence of coral disease and bleaching.

Percent Cover: Long-term change in the abundance of invertebrate and algal taxa or assemblages can often be correlated with variation in certain environmental stressors or drivers. For example, an increase in algal cover has often been associated with eutrophication (increased nutrient levels) or a reduction in the number of herbivorous invertebrates or fishes (Hughes 1993). Although Szmant (2002) argues that "Over-enrichment can be and has been the cause of localized coral reef degradation, but the case for widespread effects is not substantiated."

Increased nutrient levels in the marine environment result in conditions that facilitate an increase in growth and reproduction by phytoplankton and some species of macroalgae, increasing the ability of macroalgae to compete with corals for space on the benthos (Done 1992, McCook et al. 2001, Smith et al. 2004). Algae, in the presence of high nutrients, can dominate the benthos, excluding and reducing coral abundance and diversity (Smith et al. 1981). The substantial loss of coral cover accompanied by large increases in algal cover may cause a cascade of ecological change throughout the benthic community (Smith et al. 1981, Hughes et al. 1987, Jokiel et al. 1993, Lapointe 1997, McClanahan et al. 1999, Smith 2003).

The relative dominance model (Littler and Littler 1984, modified by Lapointe 1997) hypothesizes that there are four predominant space-occupying states of sessile reef organisms influenced by nutrient levels and disturbance, such as grazing activity (Figure 1.3). The relative dominance model components include corals, algal turf, crustose coralline algae (CCA), and fleshy macroalgae.

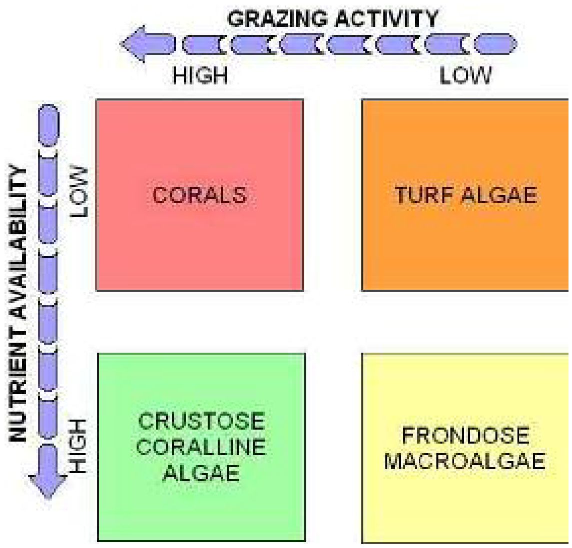

Figure 1.3. Relative Dominance Model suggests four functional forms of benthic community structure. The dominant photosynthetic space-occupying group is hypothesized to be a function of exposure to nutrients (vertical axis) and grazing/herbivory (horizontal axis) (Figure adapted from Littler and Littler 1984).

Both top-down and bottom-up influences are hypothesized to influence the outcome of benthic space occupation at a given reef location (Hughes et al. 1987, Hughes et al. 1999, Lapointe 1999, Rogers and Miller 2006). Low nutrient levels (bottom-up forcing) are predicted to promote a state of coral or algal turf dominance (top row Figure 1.3). Concomitantly, grazing activity (top-down forcing) influences the state of benthic cover by limiting turf and frondose macroalgal growth. Human activity may reduce grazer levels and increase nutrient availability, thus shifting reefs from coral to macroalgal dominance (Figure 1.4).

Smith (2003) tested top-down and bottom-up mechanisms causing quantifiable shifts in benthic assemblages on coral reefs in Hawaii. She found that nutrient enrichment and herbivore exclusion independently resulted in shifts to a benthic algal dominated system. To gain a better understanding of factors influencing community structure, a good understanding of stressors and past history is needed (Hatcher 1997, Hughes and Connell 1999, Smith 2003). Detecting shifts in community structure will come from collecting long-term data such as coral cover. Monitoring information coupled with research such as Smith's (2003), will elucidate causes of coral decline such as eutrophication or reduction in herbivores, and facilitate management decisions.

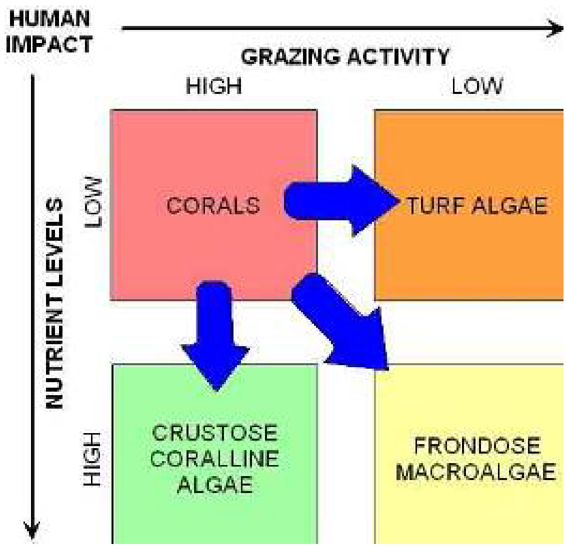

Figure 1.4. Relative Dominance Model with human impact on grazing activity and nutrient levels (Figure adapted from Smith 2003). Blue arrows indicate possible shift in benthic community structure with increasing human activity.

Rugosity: Rugosity is a measure of vertical structural/architectural complexity of the benthos. Changes in rugosity may influence large scale changes in benthic community structure, composition, function, and condition (Connell et al. 1997). Research has established a strong correlative link between rugosity and abundance of fishes (Friedlander and Parrish 1998) and mobile invertebrates (Aronson et al. 1994, Rogers et al.1994, Minton 2000). Consequently, this parameter will be useful in interpreting the results of other co-located Vital Signs (e.g., marine fish and water quality).

Settlement Rate: Coral reef populations must successfully reproduce and recruit to persist. Larvae and juveniles of corals and other benthic organisms are particularly sensitive to environmental stressors (Basch and Keesing 1996, Basch and Pearse 1996, Richmond 1997, Minton and Lundgren 2006). Many corals are long lived, and the presence of adult individuals that are less sensitive to stressors than earlier life history stages can mask serious incipient problems of population demography and community persistence and resilience. While not immediately evident (i.e., adult population appears healthy), failure of juveniles to recruit can result in relatively rapid degradation of the coral reef ecosystem as adults senesce or experience mortality from natural or anthropogenic disturbances (Basch et al. 2007). It should be noted that this protocol is focusing on settlement rate rather than actual recruitment. Settlement rate provides an integrated measure of larval supply and suitable substrate and water quality. Measuring recruitment, however, also includes tracking survival of the juveniles and the subsequent contribution to the adult community.

Growth: Coral growth rate and survival are indicative of coral reef health and water quality, providing a time-integrated measure of the condition of these factors. Calcification rates are affected by several factors, including light availability, turbidity, sedimentation, disease, bleaching, and global climate change (Gattuso et al. 1999, Fabricius 2005). Without continued calcification, coral reefs will be degraded through bio-erosion and physical damage (e.g., from cyclones and winter storms).

Disease and Bleaching: Monitoring emphasis will be on the proportion or incidence of disease and bleaching that occurs on the transects rather than the diagnosis and causation of disease. The identification of specific coral diseases requires specialized expertise that goes beyond the scope of this protocol. Disease in corals and other benthic organisms can cause mortality or produce sublethal effects. Until recently, coral disease was believed to be less prevalent in the Pacific Ocean compared with the Caribbean, but reports of incidence and variety of diseases are increasing in frequency (e.g., Aeby et al. 2003). In the Caribbean, coral disease has extirpated species (e.g., *Acropora cervicornis*) from some geographic areas (Aronson and Pretch 2001) and the two Caribbean *Acropora* species (*A.cervicornis, A. palmata*) were designated as threatened species under the Endangered Species Act, May 9, 2006 (50 CFR, part 223). Coral disease has been linked to anthropogenic stressors such as sewage (Lesser 2004) as well as changes in environmental conditions associated with global climate change such as an increase in sea surface temperature (Rosenberg and Ben-Haim 2002). Detecting changes through monitoring in the incidence and nature of coral diseases is important to long-term management and may facilitate research activities that examine causal mechanisms. In addition, physical conditions (e.g., temperature) that are often correlated with disease or bleaching will be monitored through other vital signs to help explain trends in this variable.

Invertebrate communities, particularly coral reefs, can be intolerant to even small temperature changes. Large scale coral bleaching has been correlated with elevated water temperature (Jokiel and Coles 1990, Glynn 1993, Brown 1997b, Berkelmans and Oliver 1999) which results in decreased photosynthetic rates and protein denaturation (Porter et al. 1999). Biological responses of corals to bleaching results in both increased mortality and decreased fecundity and potential changes in community structure (Hoegh-Guldberg 1999). These effects are magnified when other factors also reduce coral cover. For example, in the Great Barrier Reef, long-term monitoring has shown a steady decrease in coral cover after an initial reduction by a Crown of Thorns Seastar (COTS) outbreak followed by high temperature-related bleaching episodes (Bellwood et al. 2004).

Management Significance

Disturbance Events and Resilience

Disturbances are naturally occurring events affecting ecosystems, including coral reefs, and can vary by nature, degree, and scale. With a disturbance event, there is often a loss of coral cover, but given time, the ecosystem may regenerate to some former state (Figure 1.5). However, increasingly, the ability of many coral reef ecosystems to regenerate and recover has been hindered by other factors that are anthropogenic in nature, such as eutrophication and sedimentation (Bruckner et al. 2005). In addition, the increasing frequency of various disturbance events in time and space can lower community resilience and prevent recovery to a former state, facilitating “phase shifts” (Figure 1.5). Consequently, supplementary data on natural (e.g., possible wave height and frequency, and storm events) and anthropogenic (e.g., land use changes and pollutant spills) factors will be utilized to help explain “phase shifts” or other ecosystem changes that might occur. Data sources include other NPS Vital Signs (e.g., marine fish, water quality), NPS Pacific Islands Coral Reef Program (e.g., oceanographic monitoring), partner agencies (e.g., NOAA, USGS, State of Hawaii DAR), and academic institutions (University of Hawaii).

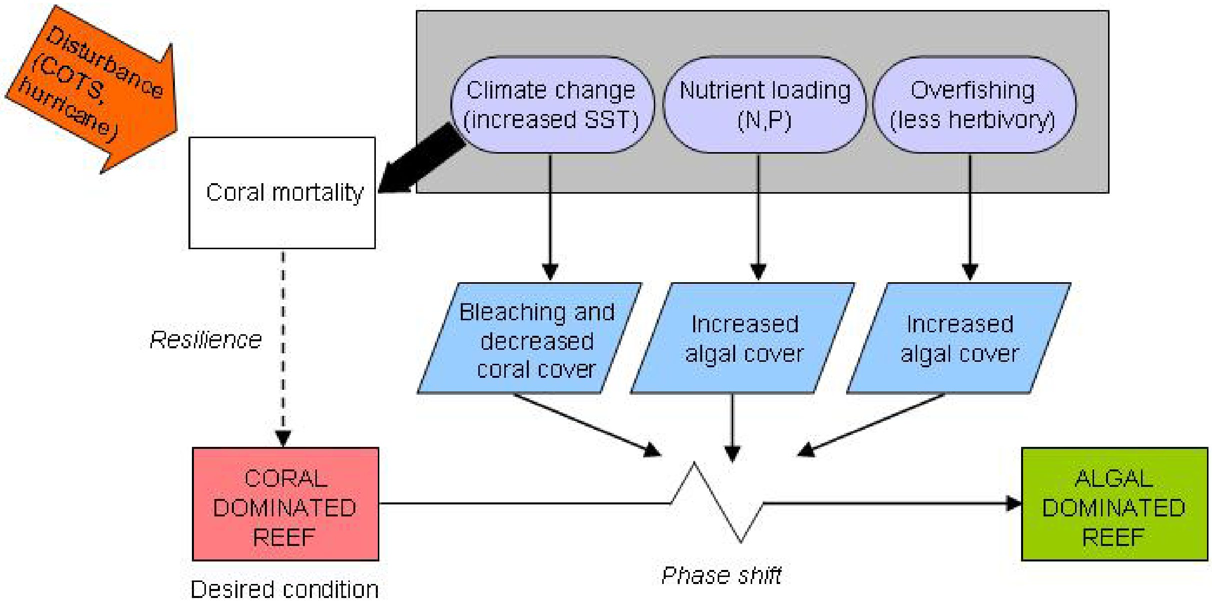

Figure 1.5. Alternate states conceptual model. Disturbance acts to decrease coral cover, which over time, may return to a former state. Multiple stressors may act to decrease resilience of the ecosystem, ultimately promoting a "phase shift" where substantial losses of coral are accompanied by large increases in algal cover (see also Figures 1.3 and 1.4). Gray box represents the resilience of individual corals, purple ovals represent multiple stressors, and blue parallelograms represent ecological effects.

Potential PACN Managerial Influence

By understanding the ecological stressors affecting coral reefs, and obtaining trend information by monitoring key Vital Signs, NPS managers are greatly aided in their ability to target potential problem areas that can be addressed through their managerial influence, both within and external to park jurisdictional boundaries (Figure 1.6). Stressors originating within or near park boundaries may be addressed through direct management action; stressors originating outside park boundaries may need to be addressed through indirect means, such as influencing other jurisdictional agencies and decision makers (e.g., through partnerships, policy input, or submitting comments on proposed development activities).

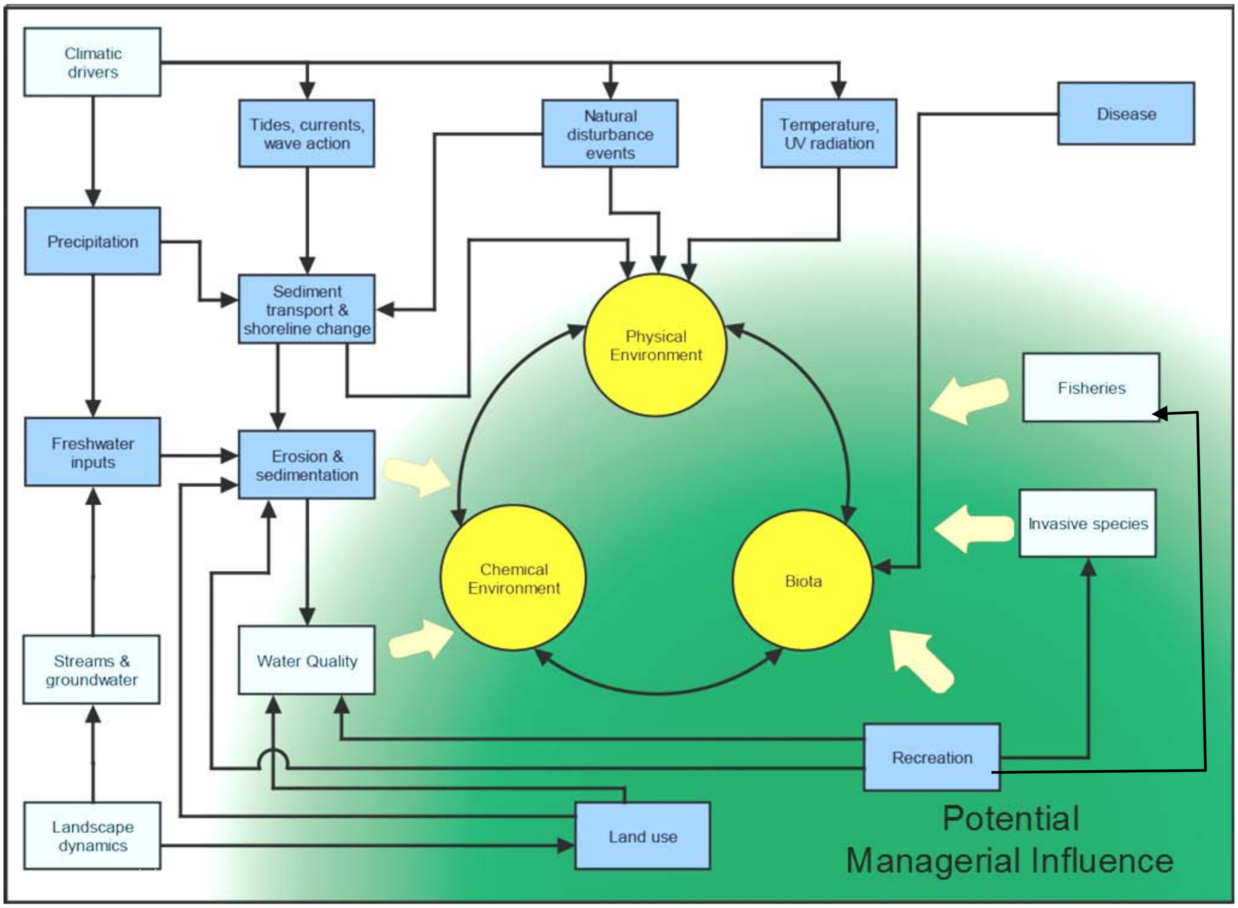

Figure 1.6. Some stressors of nearshore marine ecosystems of PACN parks are under the NPS sphere of managerial influence, while other stressors lie outside this sphere and may prove more difficult to manage directly. Areas generally within the parks managerial sphere (green) may be managed through direct NPS action. Areas outside of the NPS management sphere (grey) could potentially be managed by influencing other management agencies and decision makers outside of park jurisdictional boundaries. Rectangles indicate prominent agents of change and circles represent major components of the ecosystem. Light blue rectangles are other PACN vital signs. Large pink arrows link agents of change to the entire ecosystem, including biotic, physical, and chemical components.

Regardless, once problem areas are identified, park management can begin the process of prioritization necessary to address park resource needs. Stressors within parks that are prominent agents of change with multiple linkages, affecting the entire ecosystem, and within the managerial sphere of influence, may be considered a high priority. Park management may attempt to address these high priority stressors with the limited resources available, while prominent agents of change outside the managerial sphere of influence may only be able to be monitored for their effects, at least in the short term.

Other Monitoring Efforts Past and Present

Widely used, well-tested, peer-reviewed, published, and implemented protocols exist for monitoring all components of this Vital Sign. For example, existing NPS-approved prototype I&M methods have been developed at Channel Islands National Park (CHIS) for temperate rocky reefs, and at Virgin Islands National Park (VIIS) by NPS and USGS for tropical Caribbean coral reefs. Other existing protocols have been implemented by the Hawaii Coral Reef Initiative, Australian Institute of Marine Sciences/Great Barrier Reef Marine Park Authority, and many others (Table 1.4). Most of the protocols are similar to, and derive from those historic methods used in terrestrial vegetation, intertidal, subtidal, and bird ecology. Assuming that the monitoring question(s) are the same for each benthic habitat, protocol measures, sampling design, and statistical analyses are often similar for many tropical reef and other benthic marine communities.

Table 1.4. Summary of current monitoring programs for coral reef or benthic communities.

Organization	Description	References
Australian Institute of Marine Science (AIMS)	Monitoring Great Barrier Reef fish & coral communities	http://www.aims.gov.au/pages/research/research-groups/rg-conservation-biodiversity-01-teams-d.html
Atlantic & Gulf Rapid Reef Assessment (AGGRA)	International collaboration to examine condition of Caribbean reefs: corals, algae & fishes.	http://www.coral.noaa.gov/agra/method/methodhome.html
Caribbean Coastal Marine Productivity Network (CARICOMP)	Monitor Biodiversity of corals, seagrass, and mangroves in the Caribbean	http://www.ccdc.org.jm/methods_manual.html
Global Coral Reef Monitoring Network (GCRMN)	International Coral Reef Initiative, provides methods & assistance for monitoring	http://www.gcrmn.org/
US EPA Environmental & Monitoring Assessment Program (E-MAP)	Monitor reef health over island-wide scale using randomized sampling design. Used locally.	http://www.epa.gov/owow/oceans/coral/
Florida Keys National Marine Sanctuary Water Quality Protection Program	Collaborative effort between Florida International Univ., EPA, NOAA, Florida Department of Environmental Protection, Florida Fish and Wildlife Research Institute monitoring water quality, benthic, & seagrass communities.	Jaap et al. 2003, Fourquearean et al. 2003, http://www.fknms.nos.noaa.gov/wqpp/welcome.html, www.Floridamarine.org
National Park Service, (South Florida Caribbean Network) & USGS	Monitor coral reef invertebrate & fish communities.	Rogers et al. 1994, Miller and Rogers 2002 http://cars.er.usgs.gov/Coral_Reef_Ecology/Coral_Monitoring_Kit/coral_monitoring_kit.html http://www.nature.nps.gov/im/units/sfcn/benthic.cfm
NOAA Center for Coastal Monitoring & Assessment Biogeography Program	Develops tools & applications to interpret relationships of species & their surrounding environment.	http://biogeo.nos.noaa.gov/ Coyne et al. 2003
US Fish & Wildlife Service, Honolulu	Monitoring coral reef community throughout Pacific, including NW Hawaiian Islands. Monitoring primarily coral population estimates including species diversity & percent cover.	Maragos et al. 2002
CNMI Inter-Agency Marine Monitoring Team (MMT)	Multi-agency effort to monitor coral reef health throughout the Mariana Islands.	http://www.deq.gov.mp/mmt/marinehome.htm Houk 2001

Table 1.4. Summary of current monitoring programs for coral reef or benthic communities (continued).

Hawaii Coral Reef Assessment & Monitoring Program (CRAMP)	Developed network of monitoring sites throughout Hawaii for coral and fish species.	Brown et al. 2004, Jokiel et al. 2004. http://cramp.wcc.hawaii.edu/Overview/3._Methods/
State of Hawaii, Division of Aquatic Resources (DAR)	Long-term monitoring of benthic and fish communities in Maui County. Partnership with CRAMP	Gulko et al. 2000, Jokiel et al. 2001, 2004, Friedlander et al. 2005
West Hawaii Aquarium Project (WHAP)	Analyzing impacts of aquarium fish collecting on west coast Hawaii Is. Data include fish densities, recruitment, coral/benthic cover, abundance & rugosity.	Tissot & Hallacher 2003, Tissot et al. 2004, http://coralreefnetwork.com/kona/
Department of Marine & Wildlife Resources (DMWR), American Samoa Government	Monitor distribution, densities & condition of coral, fish, Crown-of-thorns surveys & giant clams.	Green 1996, Mundy 1996, Fisk & Birkeland 2002, Green 2002, Craig et al. 2005
Fagatele Bay National Marine Sanctuary, Tutuila Is., American Samoa	Long-term monitoring of benthic community, including coral identification, percent cover & fish abundance.	Birkeland et al. 2004
National Park Service, Kaloko-Honokohau National Historical Park	Kohanaiki monitoring related to development project.	In progress

Many marine monitoring programs have lacked statistical rigor and, as a result, have low power to detect ecological change (Brown et al. 2004). The monitoring design proposed in this protocol has been developed to have a high statistical power to detect meaningful change. The methods employed in this protocol, however, obtain similar metrics (e.g., percent substrate cover) to most other monitoring programs, especially those operating in the Pacific Islands. Therefore, valid comparisons can still be made over space and time not only within and among parks but also at larger spatial scales.

Data sharing across these programs is necessary and currently NPS participates with several partner agencies such as NOAA, State of Hawaii DAR, and UH-CRAMP to analyze these large data sets for regional patterns. For example, benthic community structure data, obtained by these agencies from across the state of Hawaii, was used to generate the biennial NOAA State of Coral Reef Ecosystems report (Friedlander et al. 2005). Spatial patterns in benthic community composition corresponded to factors such as wave exposure, geologic age of the islands, and anthropogenic activity. Temporal patterns in the monitoring data from several programs indicated that some islands were experiencing a decline in the condition of their coral reefs (Friedlander et al. 2005). The onset of new benthic community monitoring programs (e.g., NPS) will clarify local and regional trends as well as identify new areas of concern.

Chapter 2: Sampling Design

Background

Many commonly used monitoring methods lack statistical power (Brown et al. 2004, see Chapter 1) or may need modification in the sampling design to address differences in habitat and/or monitoring objectives within the PACN parks. For example, coral reef ecosystems within the Pacific are inherently variable over multiple scales in space and time within and among parks, and are markedly different from Atlantic-Caribbean coral reef systems. Pacific reefs typically have a greater diversity of coral habitats (Spalding et al. 2001) and species assemblages (Longhurst and Pauly 1987, Veron 2000) than reefs in the Caribbean. In addition, Pacific reefs have better developed reef structures (Longhurst and Pauly 1987), and more diverse environmental factors that shape these reefs (Birkeland 1997). In terms of sampling scale, many monitoring programs (e.g., Hawaii Coral Reef Assessment and Monitoring Program, [Jokiel et al. 2004]) focus their effort at the level of a site (spatial scale 100 m). In contrast, the sampling design for the benthic communities in the PACN parks is tailored to provide inference at the larger spatial scale of kilometers – across a park. Consequently, methods are not perfectly interchangeable between parks, programs, preserves, and oceans. Methods may also be modified over time to still adequately characterize the status and trends for each park without generating more data than necessary.

A comprehensive review of these methods along with thorough testing and evaluation of sampling designs are necessary to achieve the program's goal of developing protocols that are adaptive, yet rigorous scientifically and statistically. Variability may often be greater spatially than temporally, unless the reef(s) have been exposed to catastrophic disturbance such as from a tropical cyclone, significant wave heights associated with winter storms, or mass bleaching or disease events. Given these conditions, a split panel sampling design allows for increased spatial sampling while simultaneously examining multiple temporal scales and permitting broader ecological and statistical inference beyond that provided by fixed or permanent sampling locations alone (Skalski 2005).

The purpose of this chapter is to outline the factors considered in selecting the sampling design, outline the basic parameters, evaluate existing data sets, and discuss aspects of the sampling design. Based on various constraints, available data, discussions with NPS marine scientists, PACN staff, and contract statisticians, the sampling design for the benthic marine community Vital Signs monitoring will consist of 15 randomly selected permanent (fixed) 25 m long transect locations and an equal number of random non-fixed locations that are not re-visited. The 30 transects will be sampled annually and analyzed for the five parameters listed below.

General Considerations

This protocol examines five different parameters: (1) benthic percent cover; (2) coral settlement rate; (3) coral growth rate; (4) benthic rugosity; and (5) prevalence of disease-like conditions. These parameters vary differently across space and time, and as such, no single design can provide maximum statistical power for all five parameters simultaneously. Therefore, the design was developed to maximize the statistical power of the benthic cover data, with some consideration to the coral settlement data because both parameters were identified by the PACN as high priorities. Statistical power for the other parameters of interest will be evaluated after three years of sampling during the pilot study phase. Statistical robustness and scientific rigor, however, are not the only criteria that need to be considered in the selection of the sampling design. Additional criteria include:

Maximizing personnel safety
Conducting monitoring work in the marine environment presents special challenges and hazards. The safety of field personnel is a critical consideration in the sampling design selection process. Shallow water forereef habitats less than10 m, for example, can be dangerous to survey and are therefore excluded from this protocol;

Spatial coverage
Sufficient spatial coverage throughout parks that provides broad inference beyond the permanent transect locations;

Logistic constraints
The design limits the number of sites visited each year. Each park has a limited window of time when field activities can be safely conducted, usually during the park's summer months, restricting the number of sites that can be completed in this timeframe;

Fiscal constraints
Working in the marine environment is expensive, requiring specialized equipment and highly trained staff. Field work for this protocol will be conducted by NPS coral reef scientists in the Pacific Islands Coral Reef Program (PICRP) and PICRP trained PACN personnel (see Chapter 6). Fiscal constraints of this program, which affect staffing levels and equipment availability, restrict the number of monitoring transect locations that can be visited each year.

Basic Parameters
Target Population
The target populations are primarily scleractinean hermatypic (stony or hard, reef building) corals that create the foundational habitat structure. This habitat is utilized directly or indirectly by all other coral reef ecosystem-associated organisms.

Sampling Frame
The sampling frame includes all fore-reef slope, hard bottom communities between 10 and 20 m depths within the parks' legislated boundaries plus adjacent coastal areas that may impact (or be impacted by) the park (e.g., Figure 2.1). Adjacent-coastal areas extend to the edges of the watersheds in which the parks reside. It is necessary to restrict these sampling areas for logistic and cost reasons. Many reef areas outside this sampling frame are too hazardous to sample (e.g., shallow water reef crests) or too deep to safely conduct sampling within the available scuba bottom time limits. The sampling frames for each park are shown in Appendix D. Some parks (e.g., WAPA, KAHO) have sites with existing data sets and these sites will be included in the sampling frame to extend the historic perspective. The sites must meet the basic criteria (i.e., hard bottom, 10 and 20 m depth) listed above to be incorporated into the sampling frame.

Sampling Units
The fundamental sampling unit for monitoring of the Benthic Marine Community Vital Sign is the transect that has been determined from previous multiple parameter studies (Friedlander et al.

2006) to be 25 m in length. This unit should provide adequate characterization of the benthic community among all of the PACN parks. This transect length is also suitable for the marine fish community Vital Sign monitoring, which will be co-located.

Four standard methods will be used to collect data in each sampling unit: photoquadrats (Jaap et al. 2000), rugosity chains (McCormick 1994), Coral Settlement Arrays (CSAs) (Mundy 2000, Basch et al. 2007), and tracking growth change in individual coral colonies (Rogers et al. 1994, Brown 2004). The photoquadrats will be treated as subsamples within the transect sampling unit. The sampling design, however, will incorporate these methods with modifications from previous programs. For example, digital still photoquadrats along the transect will be used instead of captured frames from a video camera (e.g., Rogers et al. 2002). Digital stills now provide higher taxonomic resolution than digital video and the post processing time is significantly less. To compensate for the extensive reef overview that digital video can provide, four wide angle digital stills will be taken from a horizontal perspective at the beginning of each transect. The digital still images can also be incorporated into public documents with much greater ease than images captured from digital video.

For a more detailed account of these monitoring methods, see SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys,” SOP #8 “Conducting Coral Settlement Surveys,” and SOP #9 “Measuring Coral Growth.”

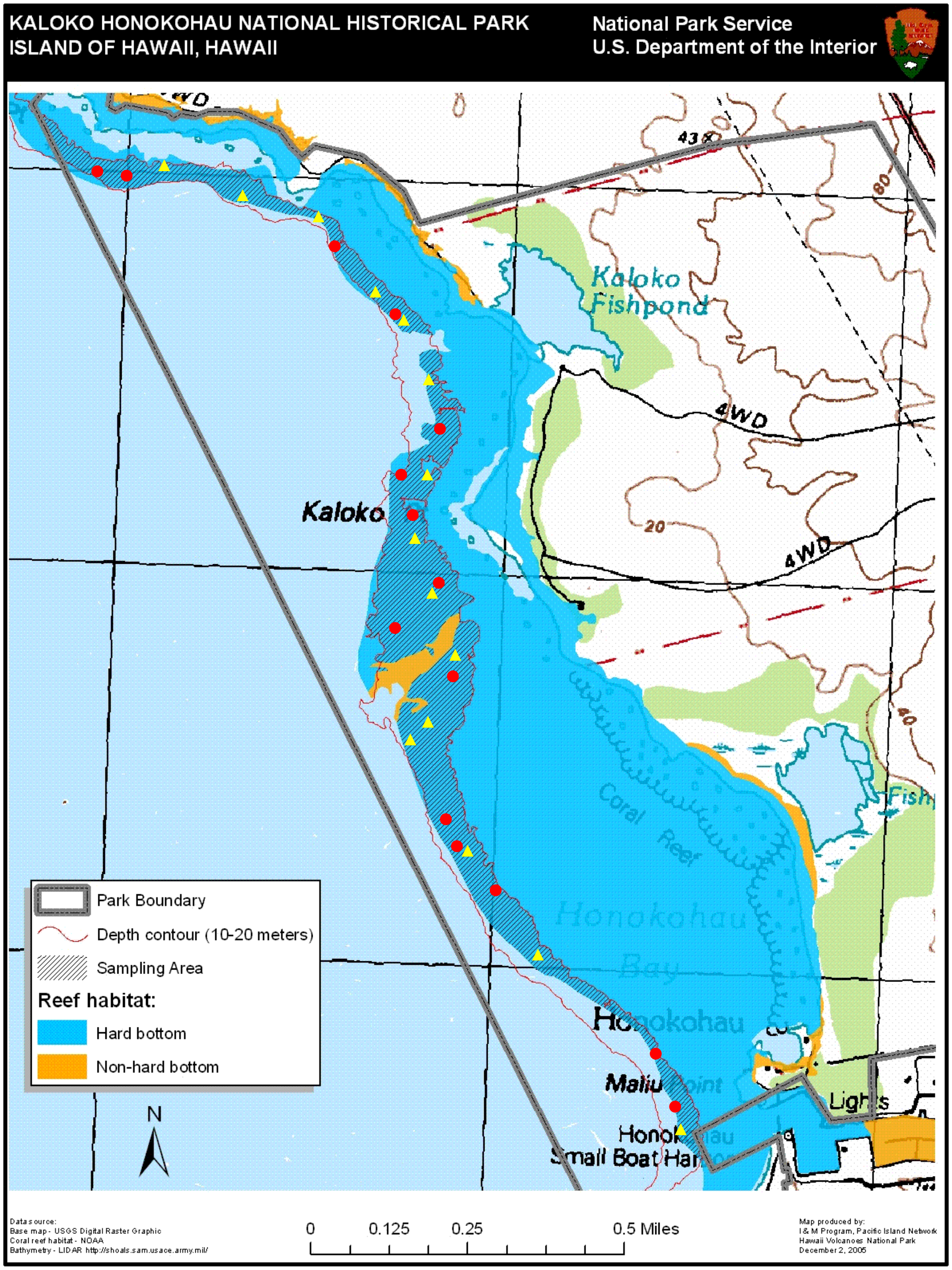

Figure 2.1. The sampling frame for Kaloko-Honokohau NHP (KAHO) showing15 randomly selected fixed sites (●) and 15 random sites ▽). Random sites are generated annually and never revisited. Park boundaries, benthic habitat maps, watershed boundaries and bathymetry data are used to define the sampling frame.

Statistical Evaluation of Existing Data Sets

Annual Precision

Precision in the estimates of variables is affected by multiple sources of variation, including spatial and temporal. Increasing precision is obtained by increasing replication within the largest component of variation. In the following example, equation 2.1 shows precision of the estimate (E) as a function of variability in the sample design. Precision in estimating benthic marine cover is affected by three sources of variability:

at the level of site - Coefficient of Variation$_1$ (CV_1)
at the level of transect within a site - Coefficient of Variation$_2$ (CV_2)
at the level of measurement error - Coefficient of Variation$_3$ (CV_3)

For the purposes of this example, a site refers to a location that is sampled on one dive. Each site may have one or more sampling units depending on the design. Annual precision is estimated using Equation 2.1 (Skalski 2005).

$$E = Z_{1-\alpha/2}\sqrt{\frac{(1-f_1)CV_1^2}{n}+\frac{(1-f_2)CV_2^2}{nm}+\frac{(1-f_3)CV_3^2}{nmk}} \qquad (2.1)$$

Where:

f_1 = fraction of area sampled by sites or strata (Assume that 1-f_1 = 1 for the sampled area within a park)
f_2 = fraction of area sampled by transects within a site (Assume that 1-f_2 = 1)
f_3 = fraction of area sampled by transects repeated for measurement error (Assume that 1-f_3 = 1)
Note that in most studies the actual area sampled is generally less than 0.1% of the total area of interest.

n = number of sites
m = number of transects per site
k = number of transects repeated for measurement error

and,

$Z_{1-\alpha/2}$ = distribution value for selected confidence interval

To calculate annual precision, the coefficient of variation needs to be estimated from historic data sets.

Existing estimates of expected variation

The percent cover of benthic organisms at a given site on Pacific coral reefs can vary from 0% to almost 100% for many organisms (e.g., Jokiel et al. 2004). Variability increases with spatial scale (Table 2.1) and is highest (e.g., variance-to-mean ratio of 3 to 4) when coral cover is intermediate (30-70%) (E. Brown unpublished data). This is due to habitat heterogeneity and the clumped distribution of various substrate types. As a result, precision is increased by maximizing replication at the level of park (n) (J. Skalski personal communication). Temporal variability in coral percent cover is often quite low (<5% annual change in absolute cover) (Jokiel et al. 2004).

Corals are long lived and, unless impacted by anthropogenic or natural disturbance events, are relatively stable in distribution and abundance over time.

Table 2.1. Coefficient of Variation (CV) among sites, within sites/among transects, and within transects for benthic cover and settlement (Data obtained from CRAMP for Hawaii [Jokiel et al. 2004]).

Type of Variability	Benthic Cover	Settlement
Among Sites (CV_1)	1.2540	0.6600
Within Sites/Among Transects (CV_2)	0.3622	0.3450
Within Transects – Measurement Error (CV_3)	0.1056	0.4295

For the purposes of this protocol we used:

$Z_{1-\alpha/2}$ = 1.96 = distribution value for “95% of the time”

n = 30 = number of sites within a park (See sample size rationale below)
m = 1 = number of transects within a site
k = 1 = number of transects repeated for measurement error. Note that analyzing measurement error will only be done in the preliminary assessment of the protocol and is not part of SOP #7: “Conducting Marine Benthic Cover and Rugosity Surveys”.

These sample sizes are based on what parks can feasibly survey due to logistic and financial constraints. Using Equation 2.1, and the CV values from Table 2.1, the annual relative precision of coral cover will be ± 46.9% of the mean coral cover, 95% of the time. It is important to note that most coral reef monitoring programs (e.g., CRAMP, Virgin Islands National Park) have focused on replication within a site to provide inference at this level. This protocol, however, is providing inference at the park level and therefore sampling effort is adjusted accordingly.

Coral settlement rates are highly variable spatially, temporally, and taxonomically. For instance, settlement rates can vary by one to two orders of magnitude at a spatial scale of one kilometer, and within a given site, rates can vary temporally by two to three times. Numerous factors influence coral settlement rates (e.g., adult fecundity, currents, sediment loading, nutrient loading, water motion, toxic chemicals, predation, and space availability [Richmond 1997]). As a result, variation in settlement dynamics and ultimately recruitment is not completely understood. The variance to mean ratio for samples at a site is often greater than one. For example, settlement studies conducted at Hanalei Bay, Hawaii (Friedlander and Brown 2006) showed high variability across multiple spatial scales (Table 2.2). Using Equation 2.1, the precision of coral settlement will be estimated with a relative error of ± 37.1%, 95% of the time.

Table 2.2. Average coral settlement rate (Individuals m^{-2} 3-$months^{-1}$) by taxon at each site within Hanalei Bay, Hawaii from 2003 to 2004. N = 5 Coral Settlement Arrays (CSA) per site (Data obtained from Friedlander and Brown 2006).

		2003			2004		
Site	**Taxon**	**Mean**	**SD**	**CV**	**Mean**	**SD**	**CV**
PuuPoa	Montipora	9,789.5	6,600.5	0.67	20,947.4	3,227.1	0.15
	Pocillopora	23.4	32.0	1.37	11.7	26.2	2.24
Waipa	Montipora	362.6	370.8	1.02	15777.8	5404.6	0.34
	Fungiidae 1	11.7	26.2	2.24	0.0	0.0	-
Hanalei	Culicea	0.0	0.0	-	23.4	32.0	1.37
	Montipora	23.4	32.0	1.37	35.1	52.3	1.49
	Pocillopora	0.0	0.0	-	35.1	78.5	2.24
	Fungiidae 1	105.3	76.2	0.72	432.7	187.7	0.43
	Agariciidae 1	11.7	26.2	2.24	117.0	41.4	0.35
	Faviidae 1	0.0	0.0	-	23.4	32.0	1.37
Makahoa	Montipora	4,093.6	1,098.0	0.27	11,520.5	5,514.9	0.48
	Porites	46.8	48.9	1.05	0.0	0.0	-

Coral growth rates vary spatially, seasonally, and taxonomically. For example, growth rates for *Pocillopora meandrina* and *Porites lobata* juveniles showed considerable variability off the island of Maui, Hawaii (Table 2.3) (Brown 2004). A combination of physical factors such as water motion, depth, light, suspended sediments, and turbidity, along with biological factors such as predation, competition, and bioerosion, all influence growth rates (Veron 2000). Growth rates for many organisms, including corals, can also be negative as they may shrink due to partial mortality or other factors (e.g., nutrient limitation). Different species have different growth rates that can be influenced by the above mentioned factors. To simplify growth rate measurements, one coral species found in all PACN parks (*Pocillopora eydouxi*) will be selected for monitoring. *Pocillipora eydouxi* is a suitable species to monitor growth rates because it is ubiquitous throughout the PACN parks and has readily discernible colony boundaries that facilitate accurate measurements. In addition, ancillary information on survival rates can be obtained by monitoring individual colonies.

Table 2.3. Average growth rate (mm^2 $week^{-1}$) for Pocillopora meandrina and Porites lobata juveniles at Maui, Hawaii sites from 1999 to 2002 (mean ± 1SD). Visible recruits (excluding asexual fragments) were defined as having a diameter ≥5 mm (Data obtained from Brown 2004).

Site	**Honolua North**	**Puamana**	**Puamana**	**Olowalu**	**Olowalu**
Depth (m)	**3**	**3**	**13**	**3**	**8**
Pocillopora meandrina	10.2±1.9	-19.5±1.9	4.2±2.3	-26.8±12.7	25.0±21.2
Porites lobata	-3.1±0.6	4.2±3.1	3.0±3.9	-20.1±26.4	-17.6±27.1

Disease/bleaching incidence will be determined by simple presence or absence data with a binomial distribution. Factors that might influence disease outbreaks include increased sea surface temperatures, virus levels, bacteria levels, human sewage, currents, and airborne pathogens (e.g., Sahara dust storms [Shinn et al. 2000]). Bleaching has been attributed to numerous stressors including increased water temperatures (Jokiel and Brown 2004) and sedimentation (Nowlis et al. 1997).

Rugosity will vary widely over space. Rugosity may not vary much temporally, but will be sensitive to large disturbance events (e.g., typhoons). Few studies have examined temporal variability of rugosity so sampling frequency within this protocol will be evaluated after several years during the pilot study period.

Proportion of Fixed Versus Random Panels (Transects)

The goal of this monitoring effort is to detect change in substrate cover over time with sufficient statistical power (e.g., Power >0.8). The split panel design selected for this protocol maximizes the spatial replication while reducing the within site effort using a combination of fixed and rotating panels to maximize power. The optimal proportion of fixed to rotating panels can be estimated from the correlation (r) between years within sites (Equation 2.2, from Skalski 2005).

$$\text{Proportion of fixed to random sites} = \frac{\sqrt{1-r^2}}{1+\sqrt{1-r^2}} \qquad (2.2)$$

With greater correlation between years, fewer fixed panels are needed. Coral cover at sites is highly correlated from year to year, ranging from 0.58 to 0.92 (Figure 2.2). Using Equation 2.2 and CRAMP data from two stations at one site on Molokai, the proportion of fixed to random sites can range from 28% to 45% for benthic cover. Coral settlement, however, has a lower inter-annual correlation of 0.20 to 0.38 resulting in a proportion of fixed to random sites between 48% and 50% (data obtained from Friedlander and Brown 2006). Therefore, a conservative design has been selected in which 50% of the panels are fixed and the remaining, rotating panels, are visited only once before replacement.

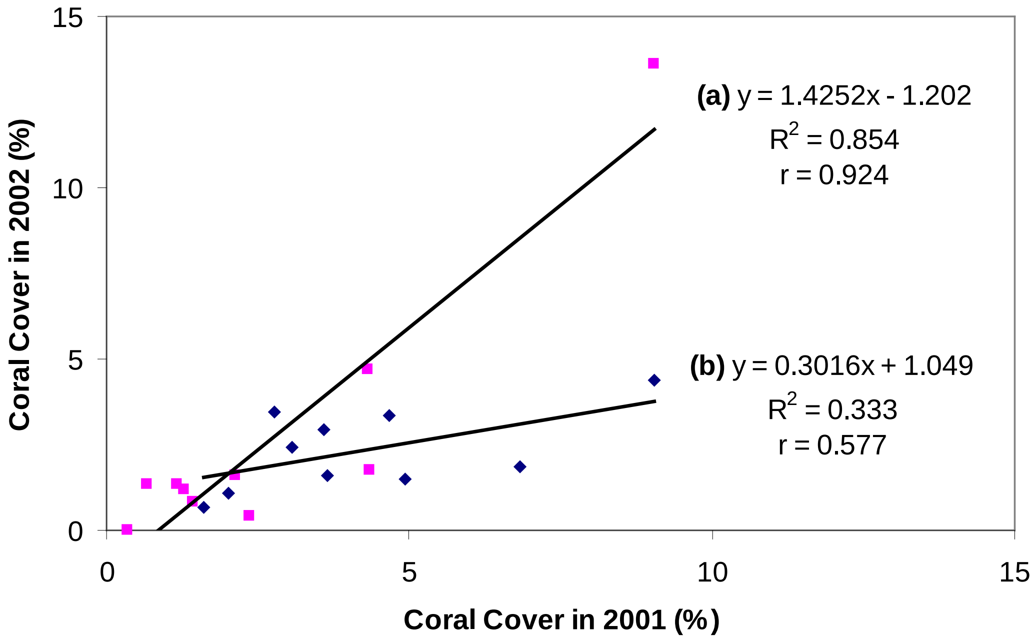

Figure 2.2. Inter-annual correlation in coral percent cover at the (a) 10 m (pink squares) and (b) 3 m stations (blue diamonds) at Kamiloloa, South shore, Molokai Island, Hawaii. Each point represents mean percent cover on each transect (N=10 transects per station at each site) (Data obtained from Coral Reef Assessment and Monitoring Program [Jokiel et al. 2004]).

Statistical Power Estimation

Logistic constraints, including staffing and fiscal considerations, were the primary determinants of sample size for this protocol. Sample size was determined to be 30 transects per year that could be surveyed within each park based on current park staff and resources. Statistical Power was calculated assuming 30 randomly selected transects each year and at a minimum, the protocol has a 40% chance of detecting a 25% change in benthic cover over 10 years (Table 2.4) and a 37% chance to detect a 50% change in coral settlement over 10 years (Table 2.5). Actual statistical power is expected to be higher in the proposed design because 50% of the sample sites will be re-surveyed annually, allowing for the refinement of parameter estimates using multiple years of data (e.g., increased parameter precision) (Skalski 2005). These methods have been used to significantly increase statistical power in other monitoring programs (Skalski 2005). It should be noted that statistical comparisons with other benthic marine monitoring programs is difficult because no known programs employ a similar sampling design using a split panel scheme.

The true power of this design will be revisited after 3 to 5 years of consecutive sampling in the pilot study, and the sample sizes adjusted accordingly. However, it is possible that this design will allow an 80% chance to detect a 25% change in coral cover over 10 years and a 70% chance to detect a 50% change in settlement over 10 years. For a benthic marine monitoring program, this level of statistical power would be very high (Brown et al. 2004).

Table 2.4. Statistical power for a 1-tailed F distribution at α = 0.05 and α = 0.10 for detecting relative changes of 10%, 25%, and 50% in benthic coral cover. Sample size is 30 randomly selected, independent sites. Values were calculated using coral cover data collected by CRAMP for Hawaii (Jokiel et al. 2004). The detection level selected for this protocol is highlighted in bold.

	α = 0.05		**α = 0.10**	
Relative Percent Change (%)	**After 5 years**	**After 10 years**	**After 5 years**	**After 10 years**
10	0.112	0.116	0.204	0.235
25	0.172	0.254	**0.308**	**0.401**
50	0.362	0.612	0.557	0.763

Table 2.5. Statistical power for a 1-tailed F distribution at α = 0.05 and α = 0.10 for detecting relative changes of 10%, 25%, and 50% in the coral settlement rate. Sample size is 15 randomly selected, independent sites. Values were calculated using coral settlement data collected by Friedlander and Brown (2006). The detection level selected for this protocol is highlighted in bold.

	α = 0.05		**α = 0.10**	
Relative Percent Change (%)	**After 5 years**	**After 10 years**	**After 5 years**	**After 10 years**
10	0.103	0.106	0.204	0.209
25	0.116	0.135	0.225	0.249
50	0.163	0.234	**0.295**	**0.377**

Statistical Considerations for Decreasing Variance and Increasing Power

Given that the statistical power in some of the above tables is low, there are several statistical approaches that can decrease the variance components and ultimately increase power. These methods include using a covariate, pooling or stratification, utilizing a split panel design, and modeling the error structure using a gamma distribution instead of a normal distribution.

(a) Covariate

For the coral settlement data, a covariate could be rugosity. The covariate can either be used to control for variation in the response variable or by utilizing a new dependent variable such as the ratio of settlement rate to rugosity. For example, using the ratio reduced the variation 63% in terms of the variance to mean ratio (Table 2.6).

Table 2.6. Comparison of means, variances, and variance to mean ratios for coral settlement rate, rugosity and the ratio of coral settlement to rugosity. Values were calculated using 2004 coral settlement rate data collected by Friedlander and Brown (2006).

Statistic	**Coral Settlement Rate (No. m^{-2} 3 mo^{-1})**	**Rugosity**	**Coral Settlement Rate/Rug**
Mean	12,230.99	1.82	8,177.81
Variance	73,455,359.18	0.75	31,294,177.10
Variance/Mean	6,005.67	0.41	3,826.72

The primary caveats with this approach are twofold. First, the relationship between the initial response variable and the covariate may change with time. For example, if the settlement rate changes but the rugosity stays the same then the variance may actually increase over time.

Second, the relationship may remain strong over time but actually mask changes in the initial response variable. Thus, the covariate and ultimately the ratio would be a poor predictor of trends. For example, if settlement rate declined due to some anthropogenic activity (e.g., pollutants) but the few remaining coral larvae selected areas of high rugosity then the ratio would remain relatively constant compared to prior years, but the actual rate would have declined.

(b) Pooling or stratification

Pooling/stratification can be done taxonomically or spatially. Ideally, this technique should be done *a priori* but levels of pooling or stratification are unknown for many of the parks. For example, benthic habitat maps do not exist for many of the parks so stratifying by habitat or depth would be difficult. Consequently, pooling or stratification is often performed post hoc as in the habitat example with benthic coral cover (Table 2.7). In the example below, stratification by habitat altered statistical power for the percent cover data (Table 2.7) compared to the unstratified data in Table 2.5. These results indicate that pooling can increase statistical power but it depends on the habitat type.

Table 2.7. Statistical power for a 1-tailed F distribution at α = 0.05 and α = 0.10 for detecting relative changes of 10%, 25%, and 50% after 5 and 10 years for benthic coral cover when stratified by habitat type. Sample size was 10 fixed sites per habitat type. Values were calculated using benthic coral cover data collected by CRAMP for Hawaii (Jokiel et al. 2004).

Pavement/Rubble Habitat				
Benthic coral cover	α = 0.05		α = 0.10	
Relative Percent Change (%)	5 years	10 years	5 years	10 years
10	0.079	0.102	0.158	0.202
25	0.108	0.118	0.213	0.225
50	0.132	0.169	0.249	0.295
Aggregated Coral Head Habitat				
Benthic coral cover	α = 0.05		α = 0.10	
Relative Percent Change (%)	5 years	10 years	5 years	10 years
10	0.260	0.434	0.431	0.599
25	0.999	0.975	0.999	0.993
50	0.999	0.999	0.999	0.999

Another approach to post-hoc stratification is to parse out sites with high variance (e.g., 2X) and analyze separately. This could be done with both fixed and random sites. It is advisable, however, to continue analyzing the entire suite of sites for comparison.

(c) Split panel design

The split panel design was developed to improve prior year estimates for both the mean and variance (Skalski 2005). Using the CRAMP species richness data, note that the adjusted year 1 estimator reduced the variance from 3.63 in year 1 to 3.23 or 11% (Table 2.8).

Table 2.8. Adjusted Year 1 estimates for benthic coral cover mean and variance using a sample size of 5 fixed transects and 5 random transects. Values were calculated using benthic coral cover data collected by CRAMP for Hawaii (Jokiel et al. 2004) and equations in Skalski (2005).

Statistic	Year 1 original data	Year 2 original data	Year 1 adjusted estimate
Mean	29.40	32.53	29.46
Variance	3.34	4.49	3.31

The increase in power for the one year was minimal (Table 2.9), but it is anticipated that over time the lower annual variance will improve overall power of the method.

Table 2.9. Comparison of statistical power between the original benthic coral cover data in year 1 and the adjusted data in year 2. Statistical power for a 1-tailed F distribution at α = 0.05 and α = 0.10 for detecting relative changes of 10%, 25%, and 50% after 5 and 10 years for benthic cover data. Sample size was 10 transects (5 fixed and 5 random). Values were calculated using benthic coral cover data collected by CRAMP for Hawaii (Jokiel et al. 2004).

Original Benthic Coral Cover	**α = 0.05**		**α = 0.10**	
Relative Percent Change (%)	5 years	10 years	5 years	10 years
10	0.225	0.364	0.383	0.527
25	0.677	0.936	0.854	0.977
50	0.999	0.999	0.999	0.999

Adjusted Benthic Coral Cover	α = 0.05		α = 0.10	
Relative Percent Change (%)	5 years	10 years	5 years	10 years
10	0.230	0.374	0.390	0.537
25	0.692	0.946	0.865	0.981
50	0.999	0.999	0.999	0.999

(d) Modeling the Error Structure using a Gamma Distribution

Typically, the error structure of benthic coral cover data does not follow a normal distribution used in conventional statistical procedures. Consequently, modeling the error using a gamma distribution within a generalized linear model (GLZ) should produce a better fit to the GLZ. In the example below, benthic coral cover data from two years was analyzed using a one way ANOVA GLZ Randomized Block design with year as an independent factor, transect as the block, and benthic coral cover as the dependent variable (Table 2.10).

Table 2.10. Statistical output from a one way ANOVA Generalized Linear Model using several types of distribution and link functions to model the error structure of the benthic coral cover data. Values were calculated using benthic coral cover data collected by CRAMP for Hawaii (Jokiel et al. 2004).

Normal Distribution - Link Identity	**df**	**Log- Likelihd**	**Chi- Square**	**p**
Intercept	1	-64.66		
Year	1	-63.99	1.34	0.247
Transect	9	-45.79	36.40	0.000
Goodness of Fit	df	Stat.	Stat/df	
Deviance	9	114.06	12.67	
Scaled Deviance	9	20.00	2.22	
Pearson Chi²	9	114.06	12.67	
Scaled P. Chi²	9	20.00	2.22	
Loglikelihood		-45.79		

Gamma Distribution - Link Identity	**df**	**Log- Likelihd**	**Chi- Square**	**p**
Intercept	1	-64.57		
Year	1	-63.91	1.32	0.251
Transect	9	-48.22	31.38	0.000
Goodness of Fit	df	Stat.	Stat/df	
Deviance	9	0.16	0.02	
Scaled Deviance	9	20.03	2.23	
Pearson Chi²	9	0.15	0.02	
Scaled P. Chi²	9	19.56	2.17	
Loglikelihood		-48.22		

Both models showed no difference in cover between years but the Gamma distribution approach more effectively modeled the error structure as indicated by the smaller Deviance and Pearson Chi^2 statistics.

Methodological Considerations for Decreasing Variance and Increasing Power

Increasing sample size is a useful sampling design method to lower the variance. As noted earlier, however, sample size in this protocol was evaluated in terms of park capacity for conducting surveys, post-processing the images, and synthesizing the results. Consequently, the maximum number of samples that could be annually worked up was 30 with statistical power evaluated in terms of this limitation. If the park or PACN I&M capacity to conduct this protocol increases then sample size and statistical power will be revisited.

Alternatively, if another method or modification to the current method is proposed that would increase statistical power then both methods need to be conducted concurrently for a minimum period of 3 years to evaluate and validate the alternative. In addition, the simultaneous use of both methods will be needed to develop correction factors for data from prior years.

Targeted Detection Level

Based on the analysis of the existing data sets and incorporating logistic and fiscal constraints, the targeted detection level for benthic cover measurements is ±25% of the baseline mean for the monitoring parameters, expressed as a relative measurement of change. For example, in regions where coral has a baseline percent cover of 48%, our target detection level is ±12% change in absolute cover (25% relative). For coral settlement measurements the targeted detection level is ±50% of the baseline mean, expressed as a relative measurement of change. This is based on sampling fifteen sites (n) each year, with each site consisting of a single transect (m) and replicated only once annually (k).

Rationale for Sampling Design

Several different spatial and temporal sampling designs were considered for this protocol. Spatial designs included simple random sample, systematic sample (grid), stratified random sample, cluster sample, and Generalized Random Tessellation Stratified (GRTS) (DeBacker et al. 2005). Each of these spatial designs has advantages and disadvantages. The PACN benthic marine community protocol has chosen the simple random sample for the following reasons:

(1) This is the simplest strategy to set up and implement within a Geographic Information System (GIS).

(2) This strategy ensures that every portion of the sampling frame has an equal probability of being selected. Many of the PACN parks have benthic marine areas that are relatively unknown (e.g., KALA); therefore it would be difficult to stratify or cluster sampling units based on known habitats, geomorphologic structures, or organismal distribution patterns.

(3) The GRTS system, while appealing, is complicated to implement without contracted statisticians (DeBacker et al. 2005). Limited resources within the PACN preclude use of this approach.

Temporal sampling designs considered in this protocol included sites always revisited, sites never revisited, rotating panels with sites sampled on *x* consecutive occasions, and split panels which partitions sites into two or more revisit designs (McDonald 2003). Again, each approach has strengths and weaknesses. The PACN benthic community protocol has selected the split panel design for the following reasons:

(1) A split panel sampling design allows for increased spatial sampling while simultaneously examining multiple temporal scales and permitting broader ecological and statistical inference beyond that provided by fixed or permanent sampling locations alone (Skalski 2005)

(2) Sampling a new set of sites annually minimizes the bias in estimates of status and continually updates prior year estimates (Skalski 1990). For example, dramatic loss of coral cover at some of the permanent sites could mask patterns at the scale of the entire park.

(3) Leaving fixed sites within the design is useful for several reasons. First, the majority of the historic data uses fixed transect locations so spatial and temporal comparisons will be simpler. Second, after the initial random setup, the fixed transects should be easier to resample, thus reducing preparation time and ultimately costs to generate the random grid for subsequent transect measurements (Green and Smith 1997). Third, utilizing exclusively

randomized sampling without fixed sites makes it difficult to detect change in coral cover if reefs change dramatically over time; random design measures inherent spatial variation at each sampling period, which adds variance associated with spatial heterogeneity of the reef rather than changes or patterns that are time-related (Green and Smith 1997). Fourth, fixed transects can provide additional information on population and community structure that is difficult to obtain with random transects (e.g., Connell et al. 1997). Finally, interpreting results from fixed transects is much easier for the general public and resource managers to comprehend than using a straight randomized sampling design.

Establishing Sampling Sites (Spatial Design)

Sample Site Selection Process

To determine the location of the sampling sites for monitoring, spatial coordinates for potential sampling sites will be randomly generated a *priori* in a GIS program (e.g., ArcInfo® 9.2) using benthic habitat characterization maps. Sampling sites must be between the depths of 10 and 20 m, have a hard substrate bottom, and be large enough in area to install the 25 m length transect.

Sample unit selection will continue until enough sites meeting the above criteria have been selected for that sampling year. Randomly selected alternative transect locations will also be generated in case the initial location is unsuitable with respect to benthic habitat type or depth. Full details can be found in SOP # 6 "Selecting and Marking Subtidal Sampling Transect Locations" but a brief narrative is provided below.

In addition to the 15 points selected for fixed sites, each year 15 points (plus five additional points for alternative transect locations, if needed) will be generated and sampled. These points will follow the same selection criteria as outlined above. If the generated random points have been used previously for either fixed or random transects then an alternative transect location will be used. When all sites are selected, they should be ordered according to proximity of the transect locations to each other, minimizing travel time. Before starting field work, the site coordinates and transect location numbers should be entered into a Global Positioning System (GPS) (See SOP #4 "Using GARMIN® Global Positioning System Units"). Fixed sites should have the letter F as a prefix to the transect location number. Random (non-fixed) sites should have the letter R as a prefix to the transect location number.

Establishing Fixed Study Sites

A full benthic monitoring transect location includes three separate monitoring components: 1) permanent steel pins to mark the start and end points of a transect location for obtaining percent cover, 2) three Coral Settlement Arrays (CSA) per transect, and 3) ten coral colonies per transect that are tracked for growth rate monitoring. Note that implementing component # 3 is valuable, but optional, depending upon time and park resources. Completing all three components of this protocol can be accomplished on one dive with two trained divers. The following is a brief narrative of the procedure. A more detailed description is provided in SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations."

One permanent transect will be installed at each fixed monitoring transect location. Stainless steel threaded rod stock will be used as transect marking pins in non-living hard substrate. Other programs have developed methods to install transects without the use of permanent pins; however, these are not feasible for the PACN parks because of environmental conditions (e.g., high wave energy) and the necessity that transects be easily revisited and highly reproducible. Refer to equipment list for installing transect pins in Table S6.2 found in SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”.

Once the transect origin is located using a GPS, a stainless steel threaded pin (See SOP #5 “Pre-Dive Equipment Preparation”) will be installed in solid substrate with epoxy. Installation can be done with either an underwater drill or sledgehammer. One cable tie will be installed around the rod to denote the start pin. The trailing end of the cable tie will be left intact to facilitate relocation. Divers will stretch a fiberglass transect tape along an isobath and install the end pin at the 25 m mark, as was done at the start (0 m) pin. Two cable ties around the rod will denote the end pin. Periodic maintenance of the cable ties will be required and can be done during the annual survey. Generally, the transect will run parallel to the reef crest as it follows the isobath but sometimes the transect may be oriented perpendicular to shore on a spur and groove structure. Note that the random transects will not have permanent pins to mark the start and end points.

Installing the Coral Settlement Arrays (CSA)
Refer to the equipment list (Table S5.a of SOP #5 “Pre-Dive Equipment Preparation”) and SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations” for a more detailed description of CSA installation.

CSA placements are done at pre-determined sites along the benthic transect line. Three rods are installed 2.5 meters off the transect on the shoreward side at the start pin, the end pin, and at the mid-point of the transect (12.5 m mark). This distance coincides with the fish transect width and will serve as a reference point for the fish surveys. Settlement tile pairs are fastened to the threaded rods using the appropriate hardware and tools (e.g., wrench and pliers). Again, installation of the rods can be done with either an underwater drill or sledgehammer.

(Optional) Tracking Individual Corals for Repeated Growth Rate Measures
Refer to the equipment list needed to track individual corals in Appendix S5.a of SOP #5 “Pre-Dive Equipment Preparation.” Growth rate measurement is an optional procedure and will take two divers one dive to identify the first ten coral colonies (e.g., *Pocillopora eydouxi*) encountered within 1 m of each side of each of the permanent transect lines. At each park, 150 coral colonies will be tracked for growth monitoring. Working in close proximity to coral colonies should be done with care to ensure that the colonies are not damaged, although minor damage will heal (Titlyanov et al. 2005).

All size classes of each colony encountered, with a basal diameter greater than approximately two to three centimeters should be considered. Basal diameter of colonies smaller than two centimeters are too small to accurately track over time. Once a colony is located, a prelabeled plexiglass or plastic tag is attached to the substrate in close proximity to the colony using stainless steel wire, plastic cable ties, or nails. The tag setup must be at a sufficient distance to avoid contact with the colony and allow for future growth. The tag should be marked with an individual identification number. Surveys will record the physical dimensions of the colony, their relative position and identification numbers along the transect line. Tags will periodically need to be cleaned to remove fouling organisms and maintain tag readability. This cleaning procedure can be done when performing other tasks on the transect.

Non-Fixed Study Sites

Fifteen randomly selected, non-fixed study sites will be visited each year. Because these sites will not be re-visited annually, only the methods for benthic percent cover and rugosity will be conducted. Temporary transects will be installed and measured as described in detail in SOP #6: “Selecting and Marking Subtidal Sampling Transect Locations.”

Transect Set-up and Spatial Summary

Figure 2.3 depicts a typical fixed transect design with the end marker pins, three coral settlement arrays and ten colonies that are tracked. Table 2.11 summarizes the spatial sampling effort for an entire park for a given year.

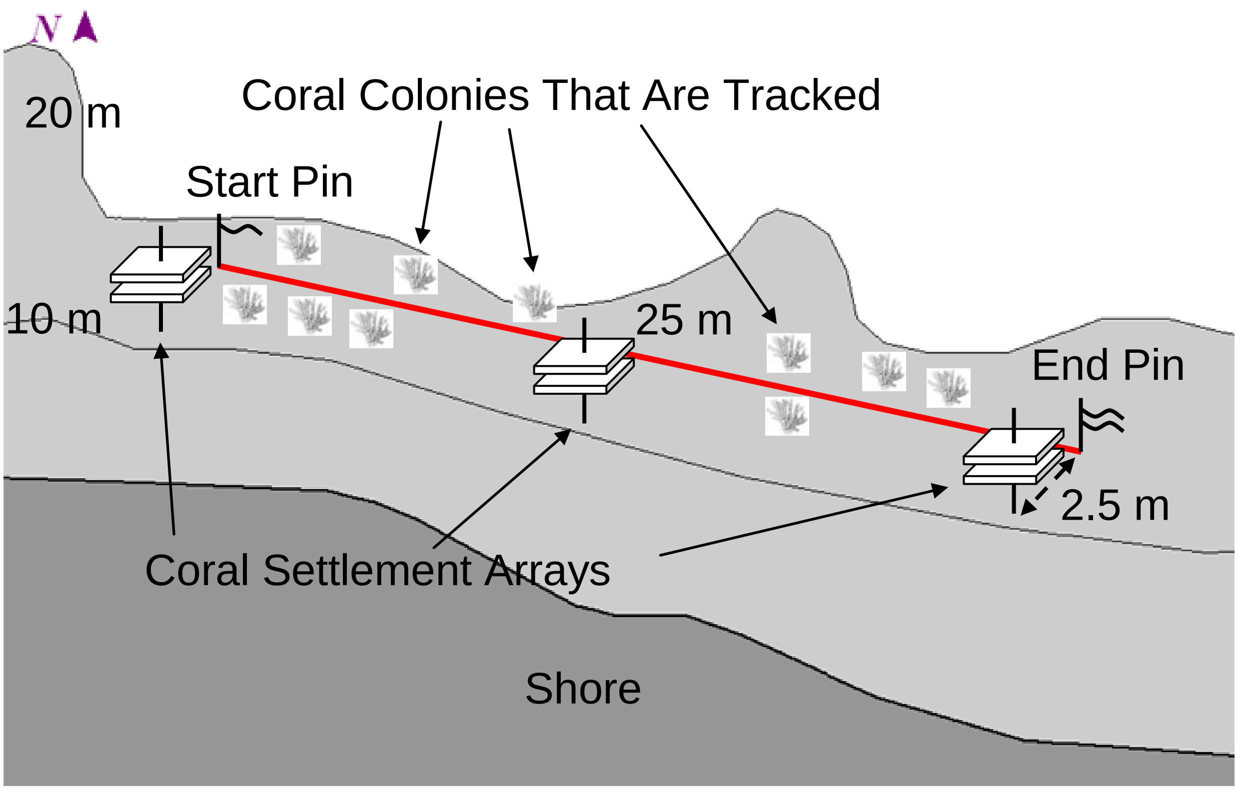

Figure 2.3. Graphic depiction of a typical fixed transect design with one 25 m transect line, three coral settlement arrays, and ten coral colonies that are tracked.

Table 2.11. Total number of sampling units surveyed on an annual basis within each park.

Sampling Unit	Variable(s)	Sample Size (N)	Units
Fixed benthic transect	Percent substrate cover, rugosity	15	
Random benthic transect	Percent substrate cover, rugosity	15	
Coral settlement array	Coral settlement rate	15	45
Individual coral colonies	Coral growth rate	15	150

Sampling Frequency (Temporal Design) Panel Description

Sampling the same sites within a park annually would greatly limit the level of spatial coverage, and the breadth of ecological and statistical inference that could be achieved. A split panel design will allow for monitoring on an inter-annual scale, but also maximize spatial sampling, and the breadth of inference by increasing the number of sites monitored. For example, after the first five years, monitoring 30 sites annually with 15 permanent sites and a second set of 15 randomly determined rotating sites, the total number of sites surveyed would be 90 (Table 2.12). Rotating panels will not be revisited. All sampling sites for benthic marine communities will be co-located at the same sites used for monitoring marine fish communities and water quality parameters. With the exception of bleaching, disease and possibly macroalgal blooms, intra-annual variation in other benthic marine monitoring parameter values is expected to be low, and multiple sampling events within a year should be unnecessary. In the case of bleaching, disease and macroalgal blooms, sampling at the same time each year should provide a relative frequency measurement among sites across years. In addition, identifying spatial patterns in these events can target research and management action. If noteworthy events do occur then sampling effort can be increased by park staff to capture the impact on the benthic community and examine the possible causal mechanisms (e.g., Miller et al. 2007) and rates of recovery. It should be noted that for coral settlement, sampling will occur at the 15 permanent transects, and will bracket an approximately six month period that includes the peak coral spawning and larval settlement period. This duration should provide sufficient time beforehand for coral settlement arrays (CSAs) to soak and form suitable substratum to capture peak annual settlement of coral larvae.

Sampling effort is based on current staffing and fiscal constraints (see above). At the present time, the PACN can sample up to 30 sites per year in each of the four parks with on-site and PICRP coral reef staff. This level of replication will be evaluated as data are collected in the 3 to 5 years following implementation of the monitoring program, and modified as needed. This period will be considered the pilot study to refine not only sample size but also examine logistic and financial issues.

Table 2.12. The panel survey schedule for the mixed panel design with 15 permanent/fixed panels and 15 rotating panels.

	Year				
Panel	**1**	**2**	**3**	**4**	**5**
1-15	X	X	X	X	X
15-30	X				
31-45		X			
46-60			X		
61-75				X	
76-90					X

The current sampling design has been based on consideration of safety issues, logistic limitations, financial constraints, analyses of sample data sets for the principal monitoring parameters, and consultations among statisticians and experienced marine benthic ecologists. The PACN parks, however, currently lack adequate coral reef benthic community parameter data on spatial and temporal variation within each park on which to develop a final sampling design. This requires collecting, analyzing, and interpreting several years of data. The design for this monitoring plan has been developed with the best available data, but it is anticipated that modifications within an adaptive sampling design framework will be necessary as implementation proceeds. It is critical to this monitoring program that the collected data be analyzed annually, and that the results be used to adaptively “fine-tune” the design to optimize effort, statistical power, and inference. It is also anticipated that the statistical power of this design will increase over the values estimated here from previous designs.

Chapter 3: Field Methods

The ability to reliably detect differences in resources over time or among sites is only assured if data are gathered in a consistent and well-documented manner (Beard et al. 1999). The field methods section is intended to ensure consistent methodology and repeatability in light of changing personnel (Beard et al. 1999). Those aspects of field methodology that are repeated in different locations or by different personnel are written in the form of a standard operating procedure (SOP). SOPs are detailed written instructions intended to ensure uniformity and consistency of a given procedure within the protocol. SOPs need to be easy to read and implement. For more information on specific field details, please see SOPs #5 - #10 (Appendix E provides a complete listing of SOPs).

Field Season Preparations, Field Schedule and Equipment Setup

Before beginning the field season, personnel should review this entire protocol, including all of the SOPs and recommended references listed at the end of this document. The staff should pay special attention to the tasks described in SOP #1 “Before the Field Season” and SOP #2 “Training Observers.” Training sessions using simulated sampling sites along with field checkout dives should be scheduled several weeks before the field season commences. Equipment and supplies listed in SOP #1 should be organized and made ready for the field season, and copies of the field data forms found in Appendix E “List of Field Dataforms” should be made on waterproof paper (e.g., Xerox never tear paper).

Sampling dates should be scheduled and logistics organized well before the start of each field season. For parks located in the northern hemisphere, the field season might begin in April and May whereas in the southern hemisphere, where seasons are reversed, this would be in October or November. However, flexibility is needed in scheduling sampling trips because of unpredictable weather, ocean conditions, and staff workloads. Please see SOP #1 “Before the Field Season” for details on chronological timing of logistics.

Conducting the Field Surveys

Sampling Methods

Benthic surveys will occur during the park’s respective summer months. Summer season for KAHO, KALA, and WAPA will be from June through August. Summer survey months for NPSA are December through April. There will be approximately 30 days of field work per park to complete one field season. Surveys will be conducted only in weather/sea conditions that are safe for field work. Benthic surveys can be accomplished with at least two observers. Three staff are recommended, as two observers are needed under water while a third person would remain at the surface.

Surveys conducted within one field season will consist of 30 study sites located within each park’s sampling frame. The study sites are randomly selected using ArcMap® 9.1, with 15 sites that are sampled yearly (permanent sites), and 15 that are randomly selected anew each year. The permanent sites are marked with stainless steel pins and are relocated using a GPS unit. Refer to SOP #4 “Using GARMIN® Global Positioning System (GPS) Units” and SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations” for navigation between sampling sites and site establishment instructions, respectively. The randomly selected sites are never revisited and therefore are not permanently marked. Study sites will be accessed on water by small boats outfitted with outboard motors. For details on preparation for field surveys, see SOP #5 "Pre-Dive Equipment Preparation."

At each study site one 25 m transect will be positioned parallel to the reef crest along a constant depth contour between 10 and 20 m on hard substrate. A full benthic monitoring transect consists of five separate monitoring components: 1) Percent Cover Surveys, 2) Rugosity, 3) Coral Settlement, 4) Coral Growth, and 5) Presence/Absence of Disease-Like Conditions. Not all monitoring sites will have all five benthic marine community protocol components. The amount of time spent in the water will vary depending on which components are surveyed.

Benthic Percent Cover Surveys

Permanent photoquadrats are a precise and quantitative, but not complete method to document temporal change in shallow benthic communities (Brown et al. 2004). More specifically, they are suitable for monitoring temporal change of individual corals for growth, recruitment, and condition and can also be used to estimate percent cover and relative abundance (English et al. 1997, Hill and Wilkinson 2004). Fixed photoquadrats, however, cover a small spatial area and require a lengthy post processing time so their use is limited in this monitoring protocol. Therefore, this protocol employs larger line transects as the sampling unit with photoquadrats at 1 m intervals as subsamples. In this case the photoquadrats are not fixed plots and are variable in space from one year to the next. Details of how to conduct benthic percent cover surveys are given in SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys" and are summarized here.

Once a site is located, observers descend below water and lay a transect line. At 1 m intervals along the transect, 25 quadrats will be photographed from a perpendicular angle at a height of 0.5 m above the substrate. Total area sampled on each transect (f_2 in equation 2.1) is approximately 4.5 m^2 (n=25 0.50 m X 0.36 m photoquadrats) for a total area of ~135 m^2 (f_1 in equation 2.1) across all 30 transects. Actual area sampled will vary according to surface topography/rugosity. One transect may be completed on one dive, unless sites are in close proximity (<200 m) and shallow enough (<15m). In this case several transects can be surveyed with the divers navigating to additional sites on the surface.

Annual field data collection consists of taking photographs to record benthic cover for each park site. Image analysis is conducted using Photogrid© software (or other suitable software such as CPCe, http://www.nova.edu/ocean/cpce/) on each non-overlapping photoquadrat on a transect with 50 randomly selected points per quadrat image. Percent cover is tabulated (by lowest possible taxon, preferably species) for coral, macroinvertebrates, and other benthic substrate types (e.g., crustose coralline algae, turf algae, fleshy macroalgae, or sand) on the hard bottom. Previous studies in Hawaii have found that at least 50 points per image were needed to adequately characterize the substrate (Brown et al. 2004). The variance structure for the number of points per quadrat image, however, will be re-evaluated after 3 to 5 years to see if changes need to be made in the number of points analyzed. Refer to SOP #12 "Data Management – Photographs" and SOP #13 "Data Management – Benthic Image Analysis" for post-dive data processing, manipulation, and management.

Rugosity

Rugosity provides information on the spatial heterogeneity of the reef. This index is important in long-term monitoring, and changes in the topographic complexity of the reef can be quantified and observed over time. Rugosity is measured using the chain and tape method (McCormick 1994). A light brass chain marked off in 1 m intervals is draped over the bottom contours along the entire length of each 25 m transect. The amount of chain necessary to span the distance between the two marker pins is divided by the straight line tape measurement to generate an index of rugosity for that transect. Typically the chain length is 10 m to facilitate transport and field operation so the chain must be spooled out and retrieved several time along the transect. Rugosity will be measured only on the fixed transect lines. Details of how to conduct rugosity measurements are given in SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys."

Coral Settlement Surveys

The larval supply of corals within a park can be examined by providing artificial substrates for larval settlement which can then be examined under a dissecting scope (English et al. 1997). Coral settlement involves placing terracotta tiles at three points near the same fixed transect established for the benthic cover surveys. Terracotta tiles were selected because of their convenience, similarity to other preferred surfaces (e.g., ceramic, Harriott and Fisk 1987), and their prominence in settlement studies (e.g., Hughes et al. 2000, Mundy 2000, Kojis and Quinn 2001, Basch et al. 2007), thereby facilitating comparisons of settlement rates at many spatial scales.

The tiles are deployed several weeks prior to the onset of the peak summer spawning period for the major reef-building coral genera (e.g., *Montipora* sp. and *Porites* sp.) and collected after a six month interval following the cessation of peak spawning. Then the newly settled coral juveniles are identified and counted in the laboratory. As noted earlier, this protocol is focusing on settlement and not actual recruitment. Settlement provides an integrated measure of larval supply and suitable substrate and water quality. Recruitment entails tracking survival of these new juveniles and the subsequent contribution to the adult community. For more detail on conducting these surveys, please refer to SOP #8 "Conducting Coral Settlement Sampling."

Coral Growth Surveys

Measuring coral growth is another important parameter in long-term monitoring. Ten colonies of *Pocillopora eydouxi* will be marked along the 25 m fixed transect. Tags will be placed on the substrate adjacent to the identified colonies to avoid physical damage. Colony surface area is based on growth forms defined by Veron (2000) such as massive, encrusting, branching, columnar, laminar, and free-living. In situ measurements of greatest basal diameter (length), greatest basal diameter at a right angle to length (width) and height are obtained for massive (hemispherical), branching or columnar colonies such as *Porites lobata*, *Porites compressa*, and *Pocillopora eydouxi* . Colony size is calculated for these colonies using a modified formula for a spherical cap.

$$\text{Surface Area in cm}^2 = \pi*((\text{Length}/2)*(\text{Width}/2) + (\text{Height})^2)$$

Colony fate will recorded (Alive, dead, partial mortality) with an estimate of percent partial mortality. This is qualitative measure and can be done by visually dividing the colony into 4 pie shaped sectors and then estimating the amount of dead tissue in each sector. For more detail on measuring coral growth, refer to SOP #9 "Measuring Coral Growth." Note that it can be difficult to consistently measure coral colonies but collecting data on population structure is valuable information (e.g., Brown 2004, Lirman and Fong 2007). Therefore this procedure is optional, depending on park resources.

Disease-Like Condition Surveys

Until recently, coral disease was believed to be less prevalent in the Pacific Ocean compared with the Caribbean, but reports of disease incidence are increasing (e.g., Aeby et al. 2003). Detecting changes in the incidence of coral diseases is important to long-term management and may prompt management-oriented research that can examine causal mechanisms. The presence/absence of disease like symptoms will be documented within the photoquadrats obtained for the benthic cover monitoring as well as opportunistic observations along transects (See SOP #13 "Data Management – Benthic Image Analysis"). These symptoms include a whitening of the skeleton, lesions on the coral surface, and definitive bands or rings demarcating live healthy tissue from bleached and dead tissue. Admittedly, the annual sampling frequency for coral disease may not detect sporadic events and therefore, may underestimate the incidence of disease in the park. Spatial patterns in disease, however, appear to be more critical at present from a management perspective.

Survey Effort and Time Allocation

The proposed sampling design requires that thirty sites be monitored each year. Fifteen of these sites are fixed and revisited annually. Each year fifteen additional sites are randomly selected and visited only once. Sites need to be established at the start of the field season in April (northern hemisphere) or September (southern hemisphere) (Table 3.1). The end of the field season is typically October (northern hemisphere) or March (southern hemisphere). The time required to establish a monitoring site will depend on the number of components monitored and the experience level of the dive team. For example, installing transects, coral settlement arrays, and identifying corals for growth measurements (but not collecting all survey data) will take approximately 60 minutes for a team of two experienced divers.

During a survey, a team of two divers will complete one transect conducting photoquadrats to document percent cover. The rugosity measurement will take place during the same dive immediately after completing the benthic percent cover photoquadrats. The time required to complete both of these tasks will be approximately 40 to 60 minutes.

Coral settlement surveys will consist of two dives – deployment and retrieval. Each activity will require approximately 15 minutes per site. Deployment of coral settlement arrays should occur in April and retrieval in October for parks in the northern hemisphere, and for parks in the southern hemisphere, deployment should occur in September with retrieval in March.

Coral growth measurements will be taken annually, and will require up to 20 to 30 minutes to complete per transect. Depending on air consumption, this task can be done immediately following the benthic percent cover and rugosity or on a later sampling dive following an appropriate surface interval for repetitive diving.

For more details on survey effort and time allocation, refer to Chapter 6 "Operational Requirements" and SOPs #6 "Selecting and Marking Subtidal Sampling Transect Locations", #7

"Conducting Marine Benthic Cover and Rugosity Surveys", #8 "Conducting Coral Settlement Sampling", and #9 "Measuring Coral Growth (Optional)".

After the Field Season

General equipment maintenance tasks need to be completed at the end of the field season. General post field season logistics and tasks are described in SOP #16 "After the Field Season." All gear and equipment will need to be rinsed and those pieces in need of repair or maintenance will be identified at this point. A service schedule will be prepared so that gear is ready for the next field season. Maintenance required for the boat, boat trailer, and motor may be park-specific and observers will need to refer to park-specific or manufacturer documents. For more details, see SOP #16 "After the Field Season."

Table 3.1. Schedule of field activities for PACN parks. In KAHO, KALA, and WAPA (northern hemisphere) the start of the field season is April and ends in October. In NPSA (southern hemisphere) the start of the field season is September and ends in March.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
KAHO, KALA, WAPA												
Install Sites				X								
Deploy CSAs				X								
Benthic Monitoring						X	X	X				
Growth						X	X	X				
Retrieve CSAs										X		
NPSA												
Install Sites									X			
Deploy CSAs									X			
Benthic Monitor	X										X	X
Growth	X										X	X
Retrieve CSAs			X									

Chapter 4: Data Handling, Analysis, and Reporting

Data handling, analysis, and reporting are treated as three interrelated steps in managing benthic marine community Vital Sign data and information. Many of the steps in managing and analyzing data are not explicitly represented in the final reporting and communication of Vital Sign findings to managers. These unreported steps are no less important, as they represent an integral part of the scientific method, including metadata documentation, and quality assurance and control processes.

Data Management Responsibilities and Procedures

Data management requirements for monitoring protocols include explicit procedures to enter, edit, document, store, and archive data according to the scope of each Vital Sign protocol as well as for programmatic analysis and reporting. Benthic marine monitoring data will be entered into standardized relational databases designed by the PACN data management staff, with input from park staff and subject matter experts regarding data elements, value ranges, and collection periods. The Benthic Marine Community Vital Sign principal investigator (PI) and park leads will ensure the integrity and security of the data during a given field season by adhering to standardized data processing procedures (data collection, data entry, quality assurance/quality control, and data backups), fully described in protocol standard operating procedures (SOPs). PACN data management staff will assist the PI in accomplishing any necessary modifications to the Benthic Marine database application, will provide for archiving and web-posting of annual data products (datasets, data analysis products, and metadata), and will facilitate dissemination of databases and datasets to appropriate audiences. Refer to Benthic Marine Community Vital Sign SOP #11 “Data Management” for details on how the Benthic Marine protocol will meet NPS Inventory & Monitoring standards for data management.

Metadata Procedures

Finalized metadata records for all datasets and data products, validated by the PI and park leads, will be posted to online NPS clearinghouses and archived by PACN data management staff. This includes both tabular and spatial data, and will be accomplished on an annual basis. Although specific software tools will change, current plans are to manage metadata for tabular data using the NPS Metadata Tools & Editor application (http://science.nature.nps.gov/nrgis/tools/editor.cfm) developed by the NPS as a metadata management tool that can function as a standalone application or within the ESRI ArcGIS® ArcCatalog® application. Spatial data will be managed using the ArcCatalog® application, employing the NPS Metadata Tools & Editor as appropriate. Final metadata records will be posted to the online NPS Data Store (http://science.nature.nps.gov/nrdata). All metadata for spatial data posted to the NPS Data Store will automatically become available on the NPS Data Clearinghouse website (http://www.nps.gov/gis/data_info/), satisfying requirements of Executive Order 12906 (http://www.archives.gov/federal-register/executive-orders/pdf/12906.pdf). In addition, annual project schedule timelines and status of product deliverables will be tracked by PACN staff using a project tracking database. This Microsoft Access® project tracking database, originally developed by the Southwest Alaska and Southeast Alaska Networks, will continue to be modified to meet specific PACN needs.

PACN has legitimate concerns regarding the public release of datasets that include information about sensitive, threatened, and endangered species. The PI and park leads can flag records as sensitive, where appropriate. PACN data management staff will assist with procedures for flagging sensitive data, and will not post such datasets to publicly-accessible online clearinghouses (only metadata will be posted if they do not contain sensitive information such as position). Requests for such datasets, digital or hardcopy will require approval from the PI and the PACN network coordinator.

Overview of Database Design

There are two principal data components used for management of benthic marine monitoring data: Photogrid, a commercial photo analysis software application, and the PACN Benthic Marine database, a Microsoft Access® application based on the I&M program's Natural Resource Database Template (http://science.nature.nps.gov/im/apps/template). Photogrid© software is already in use by the Pacific Islands Coral Reef Program (PICRP) ecologists closely involved in the development of this protocol. PACN data management staff designed the PACN Benthic Marine database following the hierarchical data table organization of the Natural Resource Database Template. This organization includes a "site" as the park in which sampling occurs, a "location" as a transect within a site laid out along the hard-bottom substrate of the benthic marine environment, an "event" as a sampling episode along that transect, and tables for capturing photo analysis data, lab data, and transect measurement data (Figure 4.1). The database also accommodates import of photo analysis data files exported from Photogrid.

Some tables can be easily modified at a later date to incorporate new coding for certain fields. For example, a field could be added to the table "tlu_Benthic_Cov_Taxon" that identifies certain coral taxa as zooxanthellate Scleractinia. The relational structure of the database would enable all records to be updated simultaneously. Then an existing query or report could be modified to display this group for important metrics such as species richness or percent cover.

As with most applications of the Natural Resource Database Template, the PACN Benthic Marine database application stores the protocol-specific data tables in a back-end database file and stores the user interface (forms, reports, queries, and programming code modules) in a front-end database file. Data entry is accomplished through the front-end database file, which is linked to the back-end database file. This arrangement allows for modification and update of the user interface with no disruption to data entry continuity (i.e., an improved front-end file can be distributed to data entry staff, who link it to the back-end file, discard the out-dated front-end file, and proceed with their data entry work). Using this approach, data entry staff do not have to open the back-end file, thereby reducing the risk of improper deletions or other inadvertent data loss occurring within the protocol-specific data tables. In addition, a multi-user environment can be accommodated by storing the back-end file on a server available to all users via a computer network.

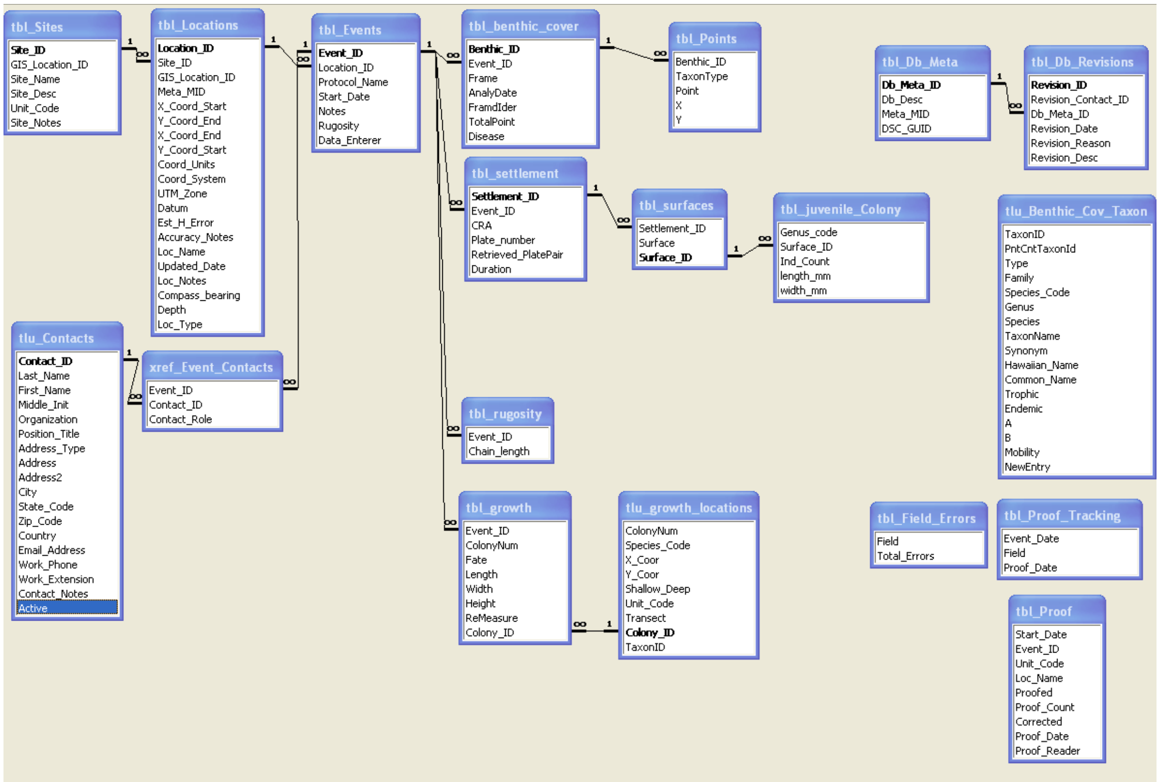

Figure 4.1. Schematic of the data model employed in the back-end database file of the PACN Benthic Marine Community Vital Sign monitoring database application.

Field-Data Management

Specific methods for acquiring (SOPs #7-9) and processing (SOPs #11-14) Marine Benthic Vital Sign data have been developed. Adherence to these SOPs within a clean, well organized work environment, as fostered by the PI and park leads, will help ensure data integrity. In general, data forms should be examined daily to correct obvious errors and incomplete information, and data entry into the digital database should occur as soon after field data collection as is practical. Hardcopy data forms, field notebooks, and/or photographic prints should be stored in a well organized fashion in a secure location (e.g., park fire-proof vault), with photocopies or duplicates stored in a separate location (e.g., PACN office in fire-proof vault) to minimize the possibility of data loss. At the end of a field season, copies of data forms, digital scans of field notebooks, and/or photographic prints should accompany project reports and other project products that are archived by curatorial staff or data manager at the park(s). If a park lacks such personnel then the material will be stored with the marine ecologist at that park.

Similarly, digital data files should be stored in a well organized, consistent fashion by the PI, park leads, or primary project staff assigned to managing data files. Specific procedures for processing and storing digital data files (namely the digital images from the transects) are described in SOPs #12-14. During the field season, the PI and park leads will ensure that digital data files are backed-up and are processed in a timely fashion. At the end of the field season, the PACN data manager, the PI, and primary staff will collaboratively ensure that all digital data files for that season are packaged together and appropriately archived.

The PACN data manager will ensure that the PI and pertinent staff understands relevant I&M standards regarding databases, data products, and metadata records, and that the PI and staff have access to all pertinent I&M guidance documents and training materials.

Data Entry, Verification and Editing

Analyses performed to detect ecological trends or patterns require data that are recorded properly and have acceptable precision and minimal bias. Poor quality data can limit detection of subtle changes in ecosystem patterns and processes, and may lead to incorrect conclusions. Quality assurance/quality control (QA/QC) procedures applied to ecological data include four procedural areas (or activities), ranging from simple to sophisticated, and inexpensive to costly:

- defining and enforcing standards for electronic formats, locally defined codes, measurement units, and metadata
- checking for unusual or unreasonable patterns in data
- checking for comparability of values between data sets
- assessing overall data quality

To the greatest extent possible, the Benthic Marine database application incorporates QA/QC strategies involving the first activity (defining and enforcing standards). The database design and the allowable value ranges assigned to individual fields within the data tables help to minimize the potential for data entry errors and/or the transcription of erroneously recorded data. The Benthic Marine protocol SOPs (SOPs #11-14) describe the steps that will be taken by the PI, marine, and PACN data management staff to ensure that 10% of the data records within a given season's dataset are verified (i.e., database values compared against hardcopy data sheets). The overall goal is to check 10% of records, correct and track any errors discovered, and enforce a threshold for an acceptable error rate. If, among the records checked, more than 10% are found to contain errors, then all of the records within that season's dataset will be reviewed. Some record reviewing tools will be built into the Benthic Marine database, while others will occur in the software applications (e.g., Photogrid©) being used by the marine staff within each park (see SOPs #11-14). Documented error rates should be noted in the dataset metadata, as well as details regarding any all-record review, if the 10% threshold is exceeded, and the resulting actions (e.g., percent of records corrected, nature of the errors, and any necessary re-entry of data).

Data Validation

The PI, marine, and PACN data management staff will collectively validate a given season's dataset. The PACN data management staff will also update queries and reports in the Benthic Marine database application as the PI and marine staff conduct exploratory data analysis. These validation tools will be fully described in the database user manual (in development), the protocol SOPs, and the database documentation. For the benthic image analysis and the coral settlement data, validation will involve comparison of results from two different observers to assess the potential for systematic data interpretation errors. Once a dataset has been validated, it will be archived and considered final. If subsequent edits are required, they must be documented in the edit log and the metadata. This progression from raw data to verified data to validated data implies increasing confidence in the quality of the data through time, as depicted in Figure 4.2.

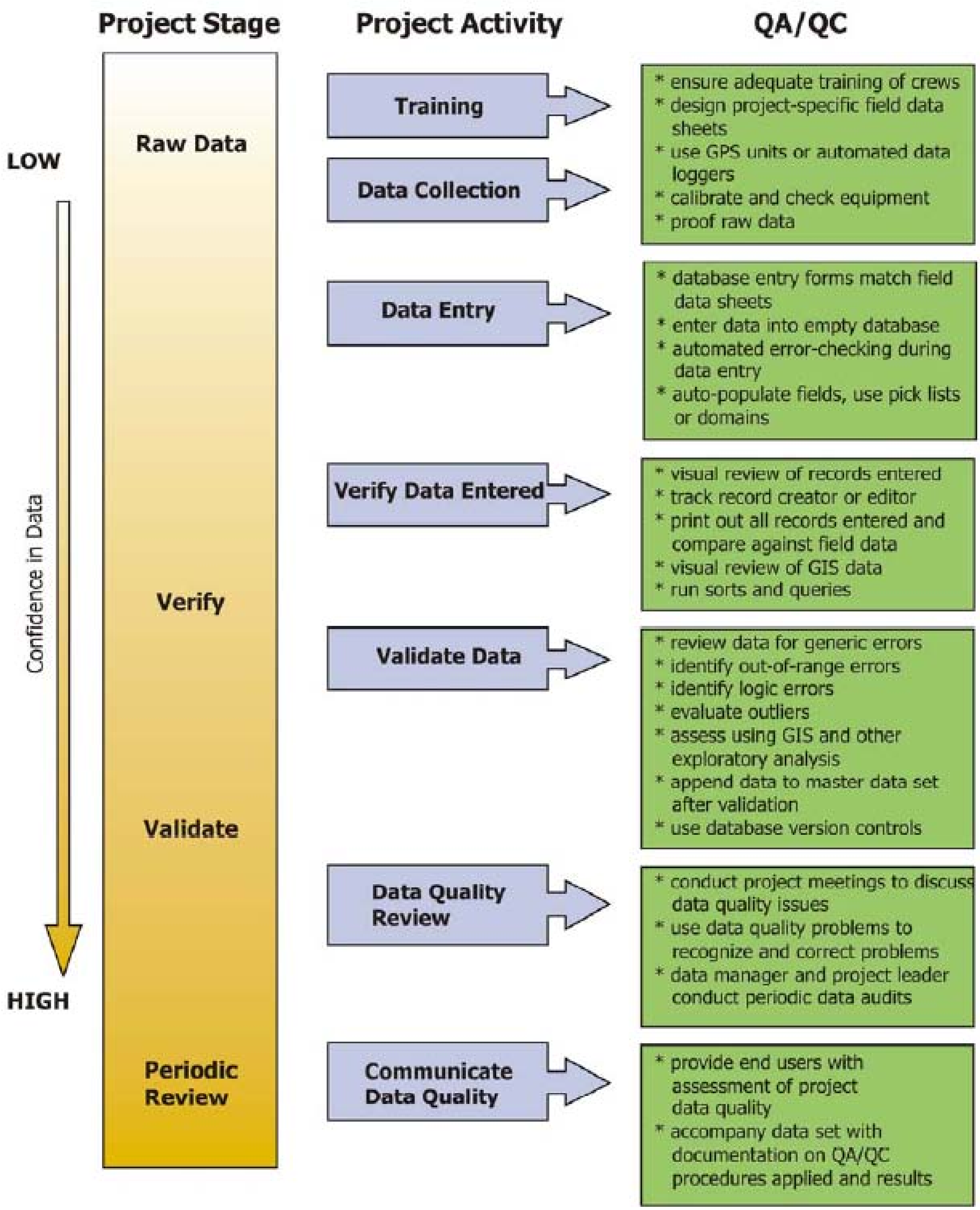

Figure 4.2. Schematic of the Quality Assurance/Quality Control procedures to be carried out during the project stages associated with the typical data life cycle.

Data Archival Procedures

Data archiving will focus on long-term storage and access through the network server with additional offsite storage being achieved by posting metadata and datasets, as appropriate, to the NPS Data Store maintained at the national level. Many of the procedural details for data archiving are taken from the Prairie Cluster I&M network (Rowell et al. 2005), and the general process is described below.

Initial archiving will be started once the PI and staff have completed the QA/QC procedures for a specific field season's data and have notified the PACN data manager that the dataset is ready for archiving (i.e., the dataset has been validated by the PI and park leads). At this point the PACN data manager will review the dataset and the associated metadata record provided by the PI and staff, and request revisions or corrections if necessary. Once the dataset and metadata are considered finalized, the PACN data manager will place a copy of the dataset and the metadata record into the appropriate folder within the archive directory on the network server. For example, a copy of the PACN Benthic Marine back-end database file (representing data for that specific field season) and the metadata record would be placed on the network server under Archives/Projects/Benthic_Marine/Data. This archived back-end file will be given an appropriate unique filename (e.g., referencing the field season year and park) and stored in a read-only format. Any subsequent changes made to this database must be documented in an edit log, and in the metadata. Secure data archiving is essential for protecting data files from corruption.

Additional digital files to be archived in a similar fashion will include all digital photos associated with that field season, and any digital files associated with data analysis products and project reporting. Official project reports will be cataloged in the online NR Info database.

Archiving of hardcopy materials associated with the specific field season represented by this digital dataset will be consistently handled according to the standards and desires of the park(s) where the data were collected. These procedures will depend on the curatorial staff at the park(s), and should be stipulated in all applicable research permits. The PI, PICRP, and the PACN staff will work with the curatorial staff at the park(s) to achieve timely and efficient archiving of hardcopy materials (e.g., field forms, field notebooks, photo prints, reports). Details of the data archival procedures can be found in SOP # 11 "Data Management".

Data Analyses

Data analysis addresses data validation issues and helps translate raw data into meaningful management information. Two initial steps for all Benthic Marine monitoring data have been identified: summarization and establishing range of variation. Ultimately, analyses of monitoring data are intended to detect change and assess resource status. These initial steps are encompassed in the larger construct of data management and data stewardship which are discussed in SOP #11 "Data Management," and in SOP #15 "Data Analysis and Reporting".

Analytical Approach

Four basic levels of analytical methods have been identified for our monitoring data: unit level, landscape level, trend assessment level, and synthesis (Table 4.1). The unit level addresses sample design questions regarding use of finite or infinite populations, and the establishment of relative, absolute, or index response variables (e.g., percent cover at each transect). The landscape level identifies the spatial nature of sampling and the temporal allocation of samples, such as the revisit scheme in use (e.g., mean percent cover each year by park). The trend assessment level integrates unit or landscape level data over time to detect change, where typically some form of regression is used to identify the slope or trend. Data analysis for the first three levels will primarily follow a univariate approach, but this does not preclude the descriptive techniques of multivariate analysis such as multidimensional scaling (e.g., Clarke and Warwick 2001). Finally, synthesis examines patterns within and across Vital Signs and ecological and oceanographic factors to gain broad insight on ecological processes and integrity. For example, incorporating predicators such as coral settlement and fish assemblage characteristics into a General Linear Model analysis may help explain percent coral cover within a park. Unit level, landscape level, and trend assessment level are addressed in this protocol. Synthesis will be addressed within and across multiple Vital Signs and is therefore left for future network consideration.

Table 4.1. Approaches to analyzing benthic marine community Vital Sign data.

Level of Analysis	Description
Unit Level	Quality assurance and control routines and calculation of site specific statistics from monitoring data
	Step 1 (Summarization): Measures of mean, median, variation, and other basic statistics. Include graphical presentation of data.
	Step 2 (Range of Variation): Establish historical or expected range of values, relation to regulatory levels, confidence estimates.
	Indices or other site-specific metrics may also be developed.
Landscape Level	Integration of unit level data across appropriate landscapes to address ecological status.
	Step 1: Integration of unit level summarization results across multiple locations and sites.
	Step 2: Integration of unit level variation results across multiple locations and sites. Additional refinement of spatial pattern analyses (e.g., cover, growth, and settlement).
	Sample design, assumptions about the target population, actual data relationships, and evolving status determination methods will guide selection of appropriate methods.
Trend Assessment Level	Evaluation of Vital Sign trends over time to detect change. Typically some form of regression will be among the methods used.
	Step 1: Integration of landscape level summarization over time.
	Step 2: Integration of landscape level variation results over time. Include establishing a direction and rate of change or variation that may be used to provide early warning. Confidence levels of documenting trend will be established.
	Parametric, nonparametric (design based) statistics, and models will be used. Trend assessment will also include accounting for influence from or correlating with drivers and stressors as feasible.

These analytical approaches will be applied to each of the three primary components of this Vital Sign: 1) benthic community cover (including rugosity and disease), 2) coral settlement, and 3) coral growth.

Status and Trend Analyses

The primary analytical strategies of interest to managers are anticipated to be status and long-term trends assessment (change detection). SOP #15 “Data Analysis and Reporting” identifies the specific processes and methods used when preparing these analyses. The unit level analyses identified above are anticipated to be an initial step in the analytical process. This level is not typically completed in preparation for peer-review reporting except for programmatic and protocol evaluations and where unit level analyses provide insight to existing management concerns. Sites with historical data sets will need to be evaluated by the PI and PACN marine ecologist to ensure that the correct conversion factors and metrics are utilized for comparisons with current data sets.

Additional analytical techniques (e.g., multivariate analysis) may also be employed beyond those specified here or in SOP #15 “Data Analysis and Reporting,” primarily in collaboration with other agencies and coral reef monitoring program partnerships (e.g., NOAA synthesis reports and biennial reports to Congress).

Reporting

Clearly identified communication outlets are critical to producing positive results in resource protection and stewardship. Two briefing types have been identified: manager’s briefings and executive briefings (Table 4.2). The manager’s briefing provides a broad array of concise summary information for managers, scientists, and other parties (Appendix G). The Executive Briefings will be similar to manager’s briefings and update superintendents/VIPs on park-specific findings. These briefings will apply non-technical language (e.g., high, low, twice, half, etc.) and graphics to potential resource issues. Both briefings are synthesis oriented and not intended to mirror a typical scientific presentation, but rather provide an opportunity to highlight key findings from the past year’s work and identify potential management action items. These summary presentations will be accompanied by one to two page briefing statements that can also be used in preparation of the annual status and trends report for the network. To facilitate communication, annual timeframes are identified for each briefing type (Table 4.2, See also SOP #15 “Data Analysis and Reporting”). After year two and following, the reporting should compile the temporal data for each park, detailing the trends. Over time each year's findings are incorporated into the summary graphics and put on the web page for each park and the I&M network.

The main audience for monitoring products and information is the resource managers and superintendents of each network park, as well as other managers (not limited to resource staff) in the NPS and other protected areas and appropriate partners who will use the information when making management decisions. Other target audiences are also important, including other federal and state/territorial agencies, scientists, educators, and the general public. Inventory and monitoring program managers are the typical audience for annual programmatic reporting and periodic protocol reviews.

Table 4.2. Schedule for recurring reporting to NPS management.

Briefing Type	Purpose	Primary Audience	Frequency
Manager's briefing	Communicate highlights and potential management action items, with 1-2 page briefing statements for each protocol	Park resource staff; Network staff; agency and academic scientists; other Federal, State, and Territorial Protected Area managers, discipline specialists, interpretive staff	Annually
Executive Briefings (results synthesis)	Update Superintendents and other VIPs on park-specific findings and potential resource issues; suggest action items where appropriate	Individual Superintendents and other VIPs	As needed

Report Types

We anticipate that all reports generated in association with this Vital Sign will encompass benthic marine cover (including rugosity and disease), coral growth, and coral settlement. Annual monitoring reports and park-based analyses for this Vital Sign will be prepared on a park-by-park basis, incorporating the network context as appropriate. A single annual 'Vital Sign Monitoring Protocol Report' will address monitoring results for all parks, treating each park individually. Abbreviated summaries of individual park results may also be prepared for park personnel (e.g., executive briefing for superintendent). At a three to five year interval, status and trend analysis will integrate data from multiple parks and assess monitoring strategies. This report will emphasize status and trend assessment over unit-level assessment. Within the status and trend report, the parks will be treated separately but will also include a network-wide synthesis. The first status and trend report will be completed after three years of monitoring, and will focus on reassessing the monitoring protocol including methodology, study design, and statistical rigor. From this report, the protocol will be revised as necessary to meet the stated objectives. As needed, additional report summaries for individual parks, components of this Vital Sign (benthic cover [including rugosity and disease], growth and settlement), and analytical strategy may be generated from existing report material. Reporting is identified in SOP #15 "Data Analysis and Reporting" by product type, purpose, targeted audience, responsible party, production frequency, and review process. This includes a cohesive suite of seven product categories: 1) program and protocol reviews, (2) monitoring protocol and project reports, (3) status and trends reports, (4) scientific writing and presentations, (5) management briefings, (6) website communication, and (7) interpretation and outreach.

Additional reporting, not explicitly identified here or in SOP #15 "Data Analysis and Reporting" includes partnership efforts with other regional, national, and international coral reef programs. Examples include NOAA coral reef reporting and other regional coral reef status and trends reporting programs such as the biennial report to Congress. This reporting will be handled by the PI and marine staff on a case by case basis as time and resources permit.

Adaptive Management of Vital Signs Monitoring

The six monitoring goals of the PACN, identified in the PACN monitoring plan, focus on providing relevant, timely, and reliable monitoring data and information to park managers on resource condition and trends. A well-communicated monitoring program may enhance expectations for resource protection and stewardship, potentially fostering a stronger monitoring program and more effective resource management. Adaptive management requires this communication, as well as collaboration and coordination in fulfilling these efforts (Holling 1978, Walters 1986).

One facultative communication strategy emphasized in this PACN monitoring plan is prompt data analysis and communication on a regular schedule. This will ensure greater communication between field resource managers, scientists, data analysts, park interpretation staff, managers, and others. A clear communication strategy will also preclude both quality control and quality assurance issues that arise with delays in communication processes. Additionally, prompt and timely analysis, reporting, and communication of monitoring data and information are essential for adaptive management.

With these adaptive monitoring and management strategies and improved scientific understanding, revisions to the protocol will be required. Careful documentation of any changes to the protocol, and a library of previous protocol versions, are essential for maintaining consistency in data collection, and for appropriate treatment of the data during data summary and analysis. The steps for changing the protocol (either the protocol narrative or the SOPs) are outlined in SOP #17 “Revising the Protocol”.

Chapter 5: Personnel Requirements and Training

Roles and Responsibilities

The benthic marine community protocol will be implemented using a combination of existing NPS staff and a centralized, predominantly-PACN-funded, technician for network level support and assistance. The primary point of contact is the principal investigator should questions/comments arise regarding the protocol and resulting products.

Appendix B to this protocol narrative identifies past and current names and contact information of various personnel.

Principal Investigator

In this protocol there are two Co-PIs, the Park Lead and the Pacific Islands Coral Reef Program (PICRP) Ecologist-Science Advisor.

The Co-PIs will ensure that the Vital Sign field work, data management, analysis, and reporting are to I&M program standards. The Co-PIs will also communicate budget, Vital Sign, and program needs to the PACN Network Coordinator and park staff. The Co-PIs will be responsible for I&M programmatic reporting as well as annual trend analysis and reporting, building upon park-based status reports. The Co-PIs will coordinate periodic programmatic reviews of this Vital Sign to ensure the applicability of the protocols and data, and suggest and implement changes to the protocol design, the latter in cooperation with Network and Park Leads. The Co-PIs will review reports and ensure that the Vital Sign continues to meet park management needs.

Park Lead (Co-PI)

Marine Ecologist or similar position with marine responsibilities, within a PACN Park. The Park Lead Co-PI will serve as the primary point of contact for dissemination of results and to address problems and inquiries from the field. The Park Lead Co-PI will be responsible for overseeing data collection and entry, data verification, data analysis, final report preparation and dissemination, and ensuring that data has been managed and archived appropriately. The Park Lead Co -PI works with the PACN Data Manager to edit any archived data. The Park Lead Co-PI will delegate each park's annual field program coordination, analysis, and reporting to the respective park's marine ecologist but will provide occasional evaluation and consultation. In addition to the responsibilities outlined above, the Park Lead assists the park's marine staff with tracking schedules and deadlines to help ensure all relevant park-based tasks are completed in a timely manner. The Park Lead Co-PI will supervise the Network Marine Biological Technician.

PICRP Ecologist-Science Advisor (Co-PI)

The PICRP Co-PI serves as the PACN I&M Program's liaison, providing scientific oversight, evaluative, and review roles, with the Park Lead Co-PI addressing concerns and facilitating revisions. The PICRP Co-PI will review effort in each park and help ensure that operations and results are consistent across parks, and meet the guidelines outlined in this protocol. The PICRP Co-PI will communicate with the PACN Network Coordinator and Park Lead Co-PI on budget issues and reporting requirements (e.g., protocol review reports and conference attendance). In addition to the responsibilities outlined above, the PICRP science advisor will provide guidance to the Park Lead Co-PI on the protocol and overall coral reef program support to each of the parks in the PACN in which this Vital Sign is implemented. Guidance and support will be in the form of scientific expertise, review of protocol products, logistics, and potential identification and, subject to funding availability, implementation of research projects to augment existing monitoring that further informs park management, and review of documents generated from these projects.

Marine Biological Technician

The NPS- GS 7/8 biological technician will be stationed in a park under the supervision of the Park Lead Co-PI.

This position will be 100% FTE devoted to this Vital Sign and co-located, covisited ones. The Marine Biological Technician will be responsible for pre- and post-field season preparations and will travel to parks where this Vital Sign monitoring has been implemented to assist with on-site field monitoring as needed (typically 2 to 3 weeks of in-park field support for each park). This would provide an opportunity to consistently launch the field season in each park and allow for this technician to maintain familiarity with species and conditions found in each park. The primary responsibilities will be field data collection, data entry, data management, and equipment management. This individual will conduct data (image) analyses for benthic cover. Benthic cover and disease data will be entered by the technician in the benthic marine database. This technician will work with the PI and data manager to merge all park databases into a final verified database. Initial preparation of analysis log files (see SOP #15 "Data Analysis and Reporting") will be prepared under the direction of the Park Lead and PACN data manager. Assistance with report preparation will also be provided as directed by the PIs and park marine ecologists.

Park-Based NPS Staff

Existing NPS marine (PICRP) resource staff, including ecologists and technicians, will work with the Marine Biological Technician to implement field data collection, data entry (site information, coral settlement, rugosity, and coral growth), data management, and equipment management.

Park staff will also work with the Co-PIs to schedule field data collection. Park-based staff will complete settlement tile analyses for their respective park, enter rugosity and growth data into the PACN Benthic Marine database, and prepare annual reports on park resource status.

PACN Data Manager

The Data Manager will provide guidance and, assistance with data management, archiving, adaptive database design and maintenance over time, data base integration, and data distribution. The PACN Data Manager will not be responsible for day-to-day activities required to implement this protocol, but will review the data and database-related practices of the PI, marine staff, and the Marine Biological Technician to ensure they meet programmatic and Vital Sign standards and needs.

Qualifications and Training

All technical staff will be trained in and responsible for being familiar with all relevant SOPs and database. Periodic training and recertification is required for maintenance of NPS dive certification, and motorboat operator certificates, and is outlined in SOP #2 "Training

Observers." Prior to the start of each field season, all participating field personnel must refresh their methodological and taxonomic skills by reviewing SOP #2 "Training Observers."

Each position demands a certain level of competency in background knowledge, skills, and abilities. The Co-PI positions require a graduate degree or equivalent experience in related discipline(s) (e.g., benthic marine ecology, coral reef biology, oceanography), taxonomic experience in the field, experience as a working scientific diver, and data manipulation and management experience. The Park Leads will typically be a park-based ecologist, with similar experience and expertise that enables them to assist with all aspects of the program.

The Marine Biological Technician requires, at a minimum a bachelor's degree and experience in related discipline(s) (e.g., biological sciences, marine ecology, oceanography). This position must remain capable of underwater field taxonomic identifications, and data collection, data management, post-processing, basic data analysis (e.g., photoquadrat point contact analysis, data summarization), and equipment maintenance.

Chapter 6: Operational Requirements

The “Operational requirements” chapter outlines preparatory work necessary before monitoring occurs (pre-monitoring documents), annual workloads and field schedule, facility and equipment needs, start-up costs, and annual budgets.

Pre-Monitoring Documents

Requisite preparations for annual monitoring activities are summarized in SOP #1 “Before the Field Season.” At minimum, the PIs, Park Leads, and Marine Biological Technician should review all SOPs, the associated database, and other products prior to initiating annual monitoring activities. As needed, the protocol narrative, appendices, SOPs, and databases shall be updated prior to initiating field-based monitoring efforts.

Annual Workload and Field Schedule

Benthic surveys will be conducted synoptically each year at KAHO, KALA, NPSA, and WAPA. The preferred field sampling window is during the (boreal or austral) summer months at all parks. Inclement weather, personnel workloads, biological cycles, or other factors may preclude the scheduling of certain sampling to specific annual dates (e.g., to encompass the peak coral spawning periods at each park). To limit sources of inter-annual variability, a three-month window will be adopted, when monitoring may occur at each park. Table 6.1 outlines an annual schedule of programmatic and monitoring related activities for this Vital Sign.

Table 6.1. Annual (fiscal year) schedule of monitoring activity benchmarks with responsible individual(s) identified.

Month	Preparation & Maintenance	Responsible Party
Oct	Finalize budget for fiscal year. Begin equipment purchases	PI, park leads, and PACN aquatic ecologist
Oct	Plan summer monitoring for NPSA	PI and NPSA park lead
Nov – Jan	Field monitoring in NPSA (Oct – Mar for coral settlement).	NPSA marine ecologist and marine biological technician
Mar	Complete WAPA, KALA, and KAHO data entry and initial data management (NPSA data entry and initial management is post-austral summer or March)	PI, park leads, and marine biological technician
Mar	Plan summer monitoring in WAPA, KALA, and KAHO	PI and KAHO, KALA & WAPA park leads
Apr	Re-evaluate budget status for fiscal year	PI and PACN aquatic ecologist
Apr	Mid-year equipment evaluation	PI and marine biological technician
May	Initial annual data analysis (depending on NPSA timing, NPSA data may be from previous year)	PI, park leads, and marine biological technician
June	Complete NPSA data entry and initial data management	Marine biological technician
Jun – Aug	Field monitoring in WAPA, KALA and KAHO (Apr – Oct for coral settlement)	NPS PICRP staff & marine biological technician
Sep	Close out year-end budget and finalize equipment purchases for previous fiscal year.	PI and PACN aquatic ecologist
Sep	Complete annual reporting (protocol summary and annual analysis may be completed earlier, this is the annual deadline for the previous calendar year.)	PI, park leads and PACN aquatic ecologist
Sep	Project documentation provided to designated museum collection repository for past fiscal year.	PACN aquatic ecologist and PI
Sep	End of the year equipment evaluation	PI and marine biological technician
Sep (or as needed)	Training/safety needs evaluation for PI, marine biological technician, NPS lead and park-based staff	PACN aquatic ecologist, PICRP staff

Facilities and Equipment

The PI, Park Leads, PACN Aquatic Ecologist, and existing park-based staff will have all facility and equipment needs met by their respective host park or office. Facility support, office space, and supply requirements for the Marine Biological Technician are outlined below, with budget considerations detailed in the Annual Budget section (Table 6.2).

Equipment and supply needs are outlined in SOP #1 “Before the Field Season” and SOP #5 “Pre-Dive Equipment Preparation.” Other than personal equipment for the Marine Biological Technician, items such as vehicles, boats, trailers, gas, dive gear, scuba tanks and air, and vital sign-specific field equipment (consumable and durable) will be provided by the park where monitoring is occurring, or from a PICRP pool of equipment.

Office space and equipment for the Marine Biological Technician may be co-located with the NPS Lead. The office space and task-related equipment items include desk, chair, computer, software, digital camera, peripherals, and miscellaneous supplies.

Park staff will be responsible for their own office space, laboratory space, and supplies as well as providing for the Marine Biological Technician during on-site visits. These items include a computer workstation, internet access, bench space, microscope, wet-sink, and limited chemical use (e.g., vinegar, water, and bleach for the coral settlement work). This arrangement will necessitate some long-term material storage and laboratory space.

Start-up Costs

Start-up costs are identified separately from annual, implemented monitoring and maintenance expenses. In general, start-up costs are not anticipated to be substantial, as this vital sign builds upon existing PICRP and park capacities and resource management needs. Also, most annual expenses are personnel, training, and travel-related, and are thus recurring fixed costs.

Approximately $1,500 per park in field monitoring supplies (transect marking, rugosity chain, digital underwater camera upgrades, and other miscellaneous supplies) are anticipated. These supplies will be provided using PICRP funds from each park as long as these funds are available.

For the Marine Biological Technician, approximately $17,000 in start-up costs are anticipated and include dive gear, training, computer equipment, office material, recruitment costs, and underwater drill (Table 6.2). These start-up costs assume existing office space, durable equipment, and consumable supplies are already in place. Subsequent new hires for the benthic technician position will incur startup costs of approximately $6,500.

Initial protocol development will be in collaboration with the Hawaii-Pacific Islands Cooperative Ecosystems Studies Unit. Implementation of this Vital Sign will largely be the responsibility of NPS staff with assistance from various partners and cooperators.

Table 6.2. Start up costs for the Benthic Marine Community Vital Sign Marine Biological Technician.

Start up costs	PACN
Dive equipment	$2,500
Training and certification	$3,000
Computer and software	$3,500
Position rating and recruitment	$3,000
Underwater drill	$5,000
TOTAL	$17,000

Annual Budget

Annual expense estimates (based on best practices) for the Benthic Marine Community Vital Sign are outlined in Table 6.3. These expenses are based on a single annual field season in each park, using the Marine Biological Technician during an intensive 2-3 week window, and existing park-based staff for all additional field work (approximately two additional weeks). As this protocol, sample design, field visit schedule, safety issues and other considerations evolve, this budget will need refining. In addition, these estimates are based on 2006 with expected annual increases.

These expenses are dedicated for implementation of this monitoring protocol, and are outlined in detail by park or office contribution. These include salary (with COLA and benefits), travel, computer and office supplies, office space, personal equipment, and mandatory training and certification expenses related to maintaining dive and boating certifications. The Marine Biological Technician's time will be devoted to this vital sign until the fish communities and water quality protocols come online. Then it is anticipated that approximately 25% of the Technician's time will be reallocated to assist in the implementation of the other protocols. It is also expected that the workload of the benthic vital sign will decrease over time as the field effort and image analysis become more routine.

For the PI and park-based staff existing coral reef program base funds will be used to support these individuals' personnel costs and associated equipment, supplies, travel, and training expenses with the exception of some PACN-related travel costs. The expenses directly related to this protocol are identified in Table 6.3. This includes all costs associated with boat use and scuba supplies, as well as field monitoring supplies such as rugosity chains, terracotta tiles for coral settlement, and cameras. Given the benthic substrate heterogeneity among parks, VS monitoring transects may need to be installed and maintained using a combination of inexpensive (hand sledge hammer) and costly equipment (underwater drills to be maintained and shared among parks). It is the responsibility of the park, with assistance from the Marine Biological Technician, to insure that all appropriate compliance and permitting has been completed prior to the start of each field season.

The total PACN contribution will be $133,100 or 37% of the annual budget for this protocol (Table 6.3). PACN Data management time and costs will initially be higher (~33% FTE, $28,300) during the first year of database development. Costs, however, are expected to decrease after the first year because much of the database structure has been borrowed from existing databases (e.g., CRAMP) and some capacity exists within PICRP to assist in database development. Once the database is operational then it is estimated that data management costs will be approximately 25-30% of the annual PACN budget for this protocol.

Costs associated with existing NPS PICRP staff are not requested from PACN, as these positions and their responsibilities already exist without this Vital Sign work. Should this collaboration not be available in the future, additional expenses must be anticipated. Additional partnerships and collaborators will be pursued regardless, to further the mission of NPS, the I&M program, PICRP Parks, and partners and collaborators.

Table 6.3. Annual expenses for Benthic Marine Community Vital Sign.

Categories	PACN	HAVO	WAPA	NPSA	KALA	KAHO	TOTAL
Salaries							
Co-PI (GS-13, step 5, 25% FTE, 2006 pay schedule with 25% COLA and 25% benefits)	$0	$28,000	$0	$0	$0	$0	$28,000
Park-based support (park lead co-PI [GS-11, step 5] and 1 biological technician [GS-7, step 5] for 6 pay periods/year [25% FTE] with 25% COLA, 25% hazard and 25% ben.)	$0	$0	$39,000	$39,000	$39,000	$39,000	$156,000
PACN I&M Aquatic Ecologist (GS-11, step 5, 20% FTE, 2006 pay schedule with 20% COLA and 20% benefits)	$17,300	$0	$0	$0	$0	$0	$17,300
PACN I&M data manager (GS-11, step 5, 5% FTE, 2006 pay schedule with 5% COLA and 5% benefits)	$4,300	$0	$0	$0	$0	$0	$4,300
Travel							
Bio-tech: training, misc.	$4,000	$0	$0	$0	$0	$0	$4,000
Bio-tech: WAPA (2 weeks)	$3,500	$0	$3,500	$0	$0	$0	$7,000
Bio-tech: NPSA (2 weeks)	$3,500	$0	$0	$3,500	$0	$0	$7,000
Bio-tech: KALA (2 weeks)	$0	$0	$0	$0	$3,000	$0	$3,000
Bio-tech: KAHO (2 weeks)	$0	$0	$0	$0	$0	$3,500	$3,500
PI (Implementation, etc.)	$31,500						$31,500
Equipment & Supplies							
Bio-tech laptop computer hardware, software and office supplies	$2,500	$0	$0	$0	$0	$0	$2,500
Bio-tech personal field equipment	$500	$0	$0	$0	$0	$0	$500
Park-based equipment and supplies (e.g., boat, fuel, trailer, vehicle, survey, safety, and pers. equipment)	$0	$0	$5,500	$5,500	$5,500	$5,500	$22,000
Other							
Bio-tech training and certifications	$1,000	$0	$0	$0	$0	$0	$1,000
Compliance and permits	$0	$0	$0	$0	$0	$0	$0
Museum collection management	$0	$0	$0	$0	$0	$0	$0
Park-based personnel training and certifications	$0	$1000	$1,000	$1,000	$1,000	$1,000	$5,000
TOTAL	$133,100	$29,000	$49,000	$49,000	$48,500	$49,000	$357,600

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Appendix A: Revision History Log

Only changes in the narrative will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

Previous Version #	Revision Date	Author	Changes Made	Reason for Change	New Version #
1.00	June 2007	Eric Brown	See Revision Log.doc	Response to reviewers' comments	2.00
2.00	July 2007	Larry Basch	See track changes this doc	Ditto, corrections	2.01

Appendix B: Personnel Names and Contact Information

This appendix to the protocol narrative identifies past and current names and contact information of various personnel identified in Chapter 5. Titles of positions are based on those in Chapter 5. Current personnel are listed in Table B.1. As personnel change, new names will be added and individual tables added for each position as the example in Table B.2.

Table Field Definitions

Name
Name of individual holding position. If no individual is assigned for a time period, designate as “Vacant”. If a responsibility is delegated, such as the PACN Data Manager delegates the role to a subordinate, identify the individual to whom responsibility is delegated. The most recent/present individual with this responsibility is always listed first, followed in reverse chronological order by predecessors.

Start Date
Initial date the named individual assumed this responsibility. Note, only a single, contiguous time period is referenced for each table row. If one individual assumes the same role for multiple non-contiguous time periods, each period of time shall be referenced in a separate table row.

End Date
Terminal date the named individual relinquished or was relieved of this responsibility.

Role
Formal or Acting: Boolean response indicating if this responsibility was assigned as part of standard job duties (formal), or assigned in a temporary capacity and temporary time period while other arrangements were being made (acting).

Physical Duty Station Address
Mailing address.

Park Administratively Assigned
Park or office where named individual is formally stationed.

Job Title
Official OPM type, including grade, if appropriate.

Email
Email address used.

Phone
Phone number used.

Table B.1. Current individuals holding positions listed in Chapter 5.

	PI	PICRP Science Advisor	Marine Biological Tech	KAHO	KALA	NPSA	WAPA	PACN Aquatic Ecologist	PACN Data Manager
Name	Tahzay Jones	Larry Basch	Kim Tice	Sallie Beavers	Eric Brown	Peter Craig	Mike Gawel	Tahzay Jones	Kelly Kozar
Start Date	01 July 2009	01 July 2006	01 Jan 2010	01 July 2006	01 July 2006	01 July 2006	01 Oct 2010	01 July 2006	01 July 2006
End Date	Present	Present	Present	Present	Present	Present	Present	Present	Present
Role	Formal	Formal	Formal	Formal	Formal	Formal	Formal	Formal	Formal
Physical Duty Station Address	PO Box 52, 1 Crater Rim Drive, Q22, Hawaii National Park, HI 96718	HI-PI CRP 300 Ala Moana Blvd Honolulu, HI 96850	PO Box 2222, Kalaupapa, HI 96742	73-4786 Kanalani St. Suite #14 Kailua-Kona, HI 96740	PO Box 2222, Kalaupapa, HI 96742	Pago Plaza Pago Pago, American Samoa 96799	460 North Marine Drive, Maintenance Facility, Piti, Guam 96915	PO Box 52, 1 Crater Rim Drive, Q22, Hawaii National Park, HI 96718	PO Box 52, 1 Crater Rim Drive, Q22, Hawaii National Park, HI 96718
Park Assigned	PACN	HAVO	KALA	KAHO	KALA	NPSA	WAPA	PACN	PACN
Job Title	PACN Aquatic Ecologist	Science Advisor Marine Ecologist	Biological Technician	Marine Ecologist	Marine Ecologist	Ecologist	Chief of Integrated Resources	PACN Aquatic Ecologist	PACN Data Manager
Email	Tahzay_Jones (at) nps.gov	Larry_Basch (at) nps.gov	Klmberly_Tice (at) nps.gov	Sallie_Beavers (at) nps.gov	Eric_Brown (at) nps.gov	Peter_Craig (at) nps.gov	Mike_Gawel	Tahzay_Jones (at) nps.gov	Kelly_Kozar (at) nps.gov
Phone	808-985-6188	808-541-2693 x743	808-567-6802x1510	808-329-6881	808-567-6802 x1502	684-633-7082	671-477-7278 x1010	808-985-6188	808-985-6182

Table B.2 Historical record of individuals holding Principal Investigator position.

	Co-PI #1	Co-PI #2	PI
Name	Eric Brown	Larry Basch	Tahzay Jones
Start Date	01 July 2006	01 July 2006	01 Jan 2009
End Date	01 Jan 2009	01 Jan 2009	present
Role	Formal	Formal	Formal
Physical Duty Station Address	P. O. Box 2222, Kalaupapa, HI 96742	HI-PI-CESU 3190 Maile Way, St. John Hall, 410, Honolulu, HI 96822	P.O Box 52,Q22 Hawaii National Park, HI 96718
Park Assigned	KALA	HAVO	HAVO
Job Title	Marine Ecologist	Science Advisor, Marine Ecologist	Marine Ecologist
Email	Eric_Brown@nps.gov	lbasch@hawaii.edu	Tahzay_Jones@nps.gov
Phone	808-567-6802 x1502	808-541-2693 x743	808-985-6188

Appendix C: Permits and Permission

Various research permits and environmental compliance procedures are required to implement this monitoring. As this protocol is implemented, the PI (or designee) in cooperation with NPS park leads will proceed through project compliance as appropriate for each park according to federal as well as state/commonwealth/territory guidelines (Table C.1). The PIs in cooperation with the PACN aquatic ecologist (or PACN staff designee) will ensure full compliance with all existing and future regulations. All permitting will be reviewed (if permit type applicable) by each park's person(s) responsible for NEPA, Section 106 of the National Historic Preservation Act, Section 7 of the Endangered Species Act, Park research permits, and approved by cultural resource staff. The PACN aquatic ecologist (or PACN staff designee) will be responsible for ensuring appropriate park permitting contacts are notified. Some specific permits required and identified by this protocol follow with descriptions.

Submerged Cultural Resources

When implementing and conducting this protocol, observers will look out for any submerged cultural resources and will report this information to park cultural resources staff as best as can.

Federal

NPS

NPS research permits will be obtained, in advance of any field activities, for each park where monitoring occurs. Permits will be evaluated on an annual basis, or other timeframe as stipulated in the permit itself. The research permit review process also includes NEPA compliance documentation, as discussed further below. The PI (or designee) in cooperation with NPS park leads will maintain all appropriate documentation.

US Army Corps of Engineers

US Army Corps permits may be required, where permanent markers are installed (such as rebar marking transects). Any permits will be obtained based on consultation with the US Army Corps. Should permits be required, they will be evaluated on an annual basis, or other timeframe as stipulated in the permit itself. The PI (or designee) in cooperation with NPS park leads will maintain all appropriate documentation.

NEPA

At present, under the National Environmental Policy Act (NEPA), we anticipate that this protocol falls under a Categorical Exclusion (CE) where "a category of actions which do not individually or cumulatively have a significant effect …and for which, therefore, neither an environmental assessment nor an environmental impact statement is required" (40 CFR 1508.4). Under Directors Order 12 a CE (or CX) is "an action with no measurable environmental impact which is described in one of the categorical exclusion lists in section 3.3 or 3.4 and for which no exceptional circumstances (section 3.5) exist." NEPA compliance review and documentation will occur as part of the NPS research permitting process.

State, Territorial, and Commonwealth

State of Hawaii

Department of Land and Natural Resources, The Division of Aquatic Resources issues permits, including ones for scientific research (http://www.state.hi.us/dlnr/dar/licenses.htm).

Territory of Guam

MPA and Live Rock permits will be required from the Department of Agriculture, Division of Aquatics and Wildlife Resources located at 163 Dairy Road, Mangilao, Guam 96913. Phone: (671) 735-3955 and Fax: (671) 734-6569.

And Submerged Lands Permits are required from the Bureau of Land Management

Territory of American Samoa

The territory requires a permit through the Department of Marine and Wildlife Resources.

Village permission should be obtained by personally contacting the village mayor to describe what the study is about, prior to initiating any work according to park cultural resource staff guidelines.

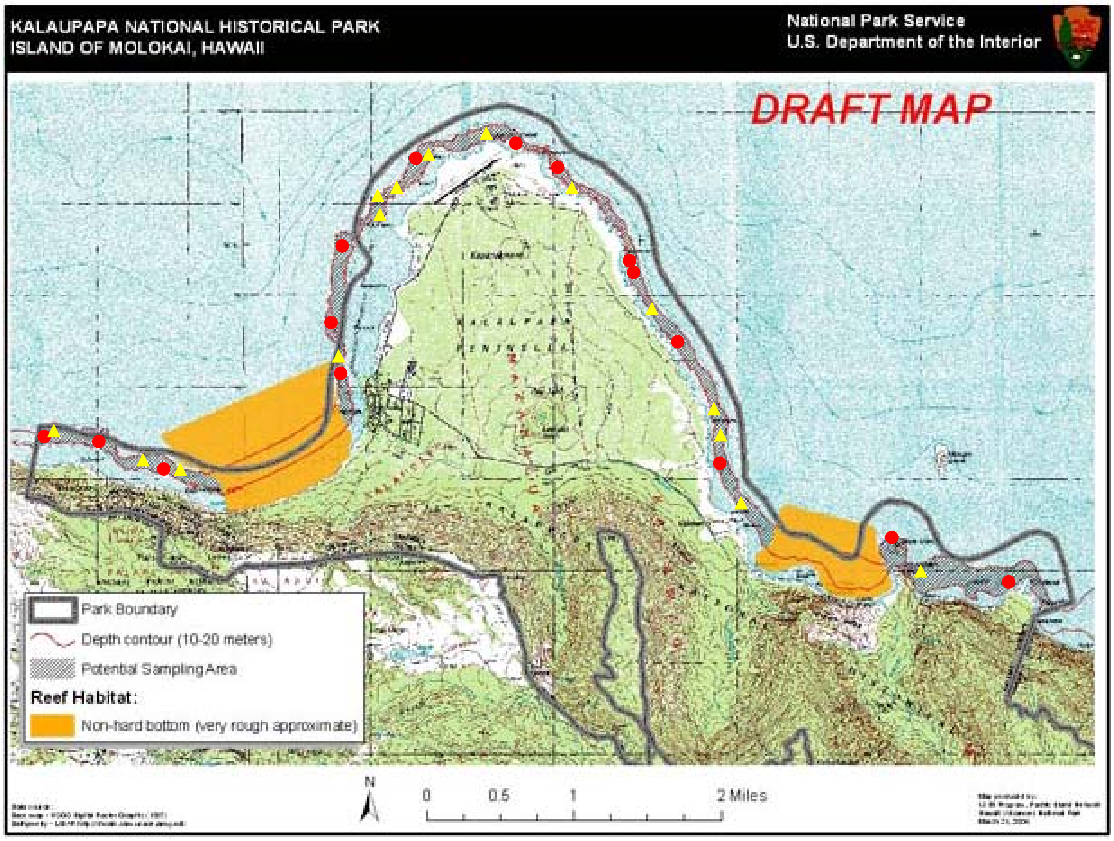
Table C.1. Permits and Compliance by Park.

Permit	WAPA	NPSA	KALA	KAHO
Park Research Permit	X	X	X	X
NEPA	X	X	X	X
Section 7	?	?	?	?
Section 106	N/A	N/A	?	?
Army Corp Engineers	X	N/A	N/A	N/A
State of Hawaii	N/A	N/A	X	X
Territory of Guam	X	N/A	N/A	N/A
American Samoa Territory	N/A	X	N/A	N/A
Village permission	N/A	X	N/A	N/A

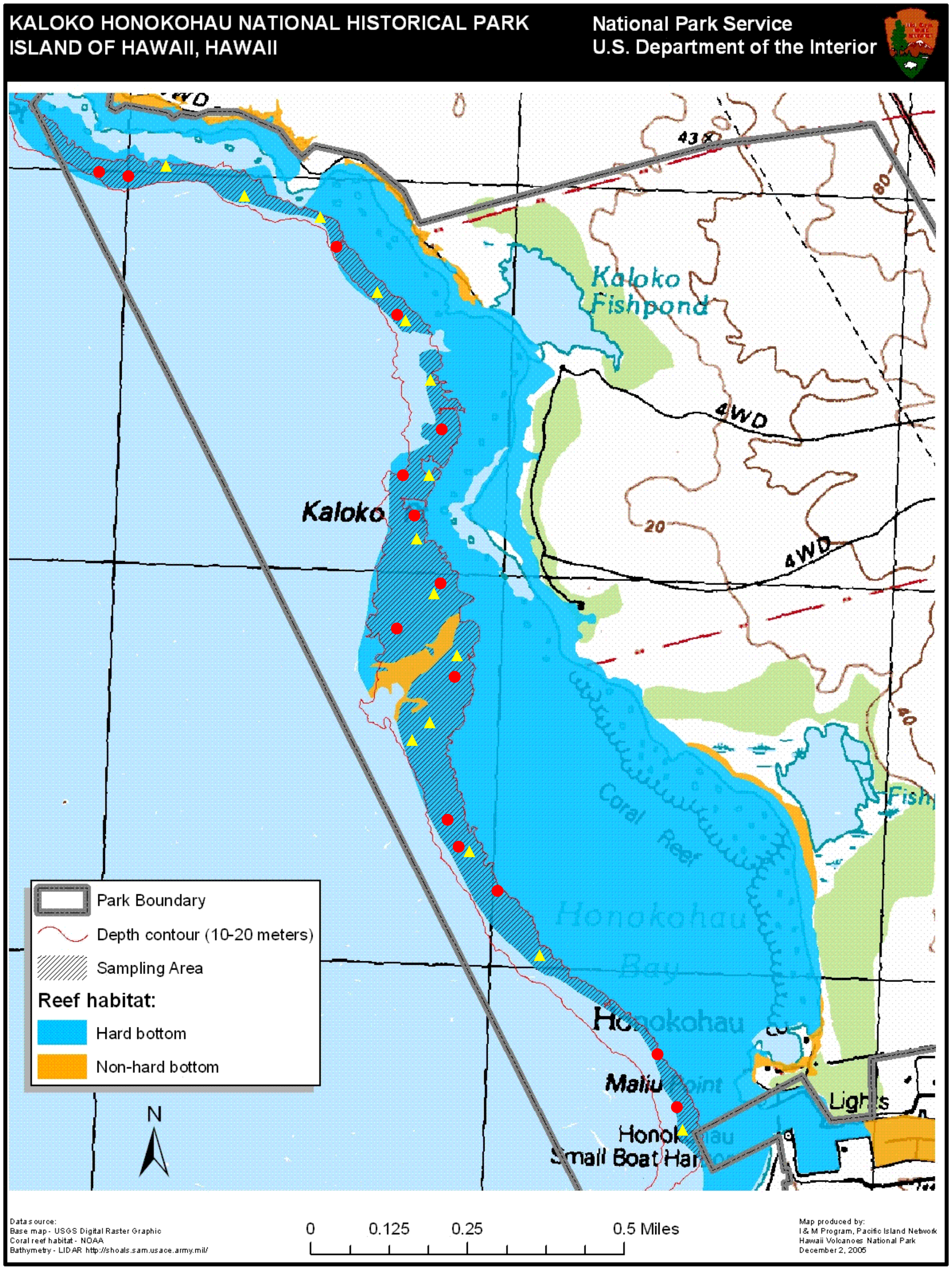
Appendix D: Sampling Frame

The following draft maps are examples of what park sampling frames will be like, once the fixed sites and random sampling sites are selected. These maps will be updated once these sites are determined and established.

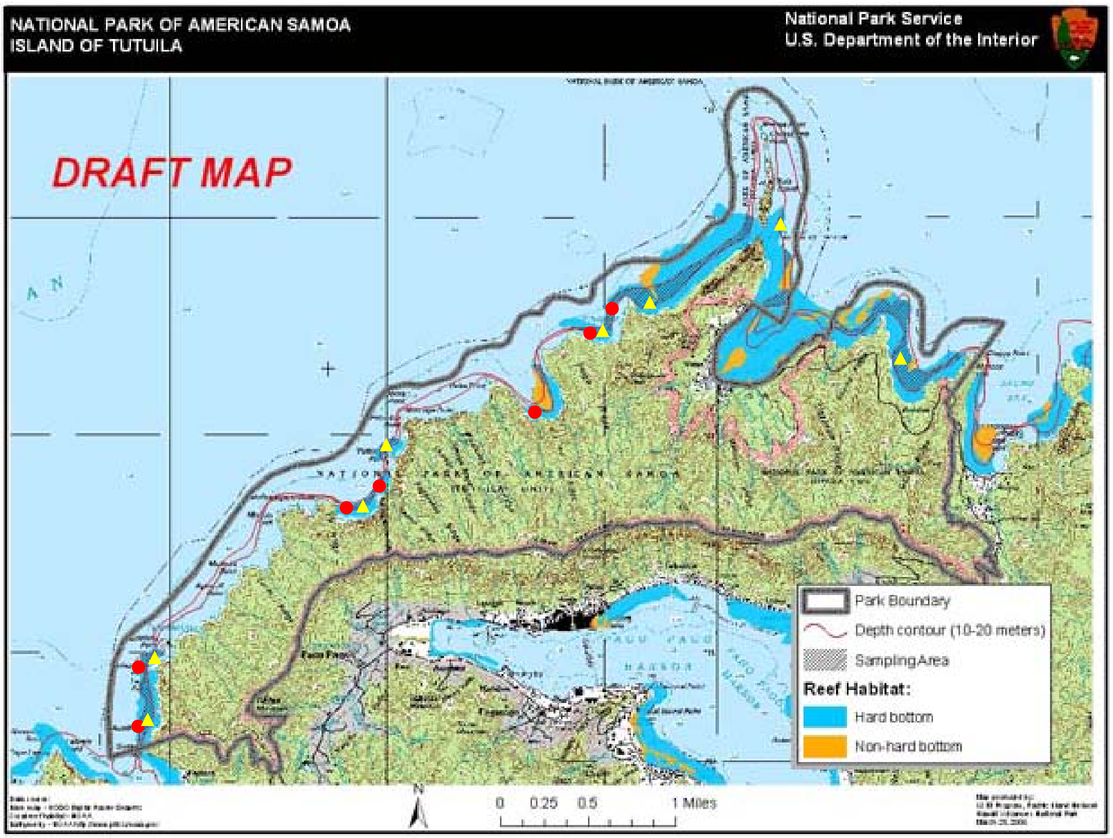
Sampling frame for Kalaupapa National Historical Park (KALA) with 15 randomly selected fixed sites (●) and 15 random sites (△) ; latter will be sampled in the first year and never revisited. Note, the sampling area has been extended to include the hard bottom habitat within the 10-20 m depth contour that is influenced by the watershed within or upslope of the park.



The Sampling frame for Kaloko-Honokohau National Historical Park (KAHO) with 15 randomly selected fixed sites (●) and 15 random sites (△); latter will be sampled in the first year and never revisited. Note, the sampling area has been extended to include the hard bottom habitat within the 10-20 m depth contour that is influenced by the watershed within or upslope of the park.

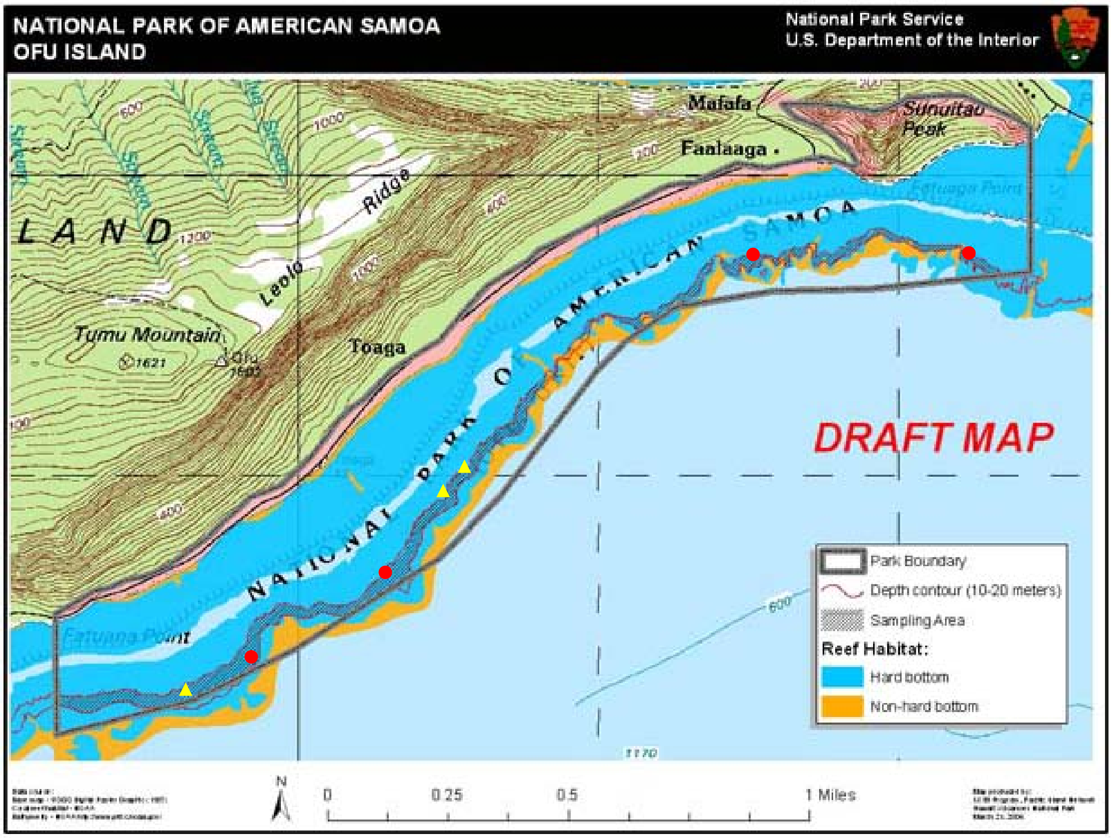


Sampling frame for National Park of American Samoa (NPSA), Tutuila Island unit displaying 15 randomly selected fixed sites (●) and 15 random sites (△); latter will be sampled in the first year and never revisited.



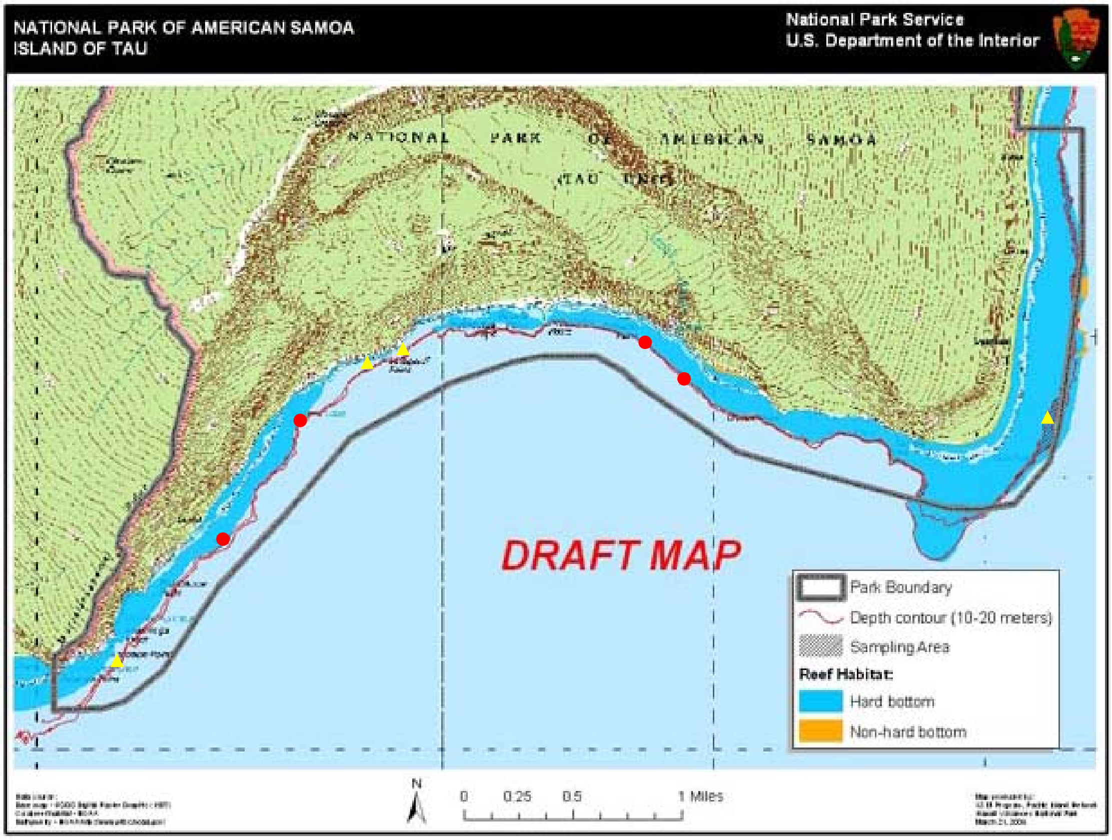
a) Tutuila Unit.

Sampling frame for National Park of American Samoa (NPSA), Ofu Island Unit displaying 15 randomly selected fixed sites (●) and 15 random sites (△); latter will be sampled in the first year and never revisited. Note, the sampling area has been extended to include the hard bottom habitat within the 10-20 m depth contour that is influenced by the watershed within or upslope of the park.



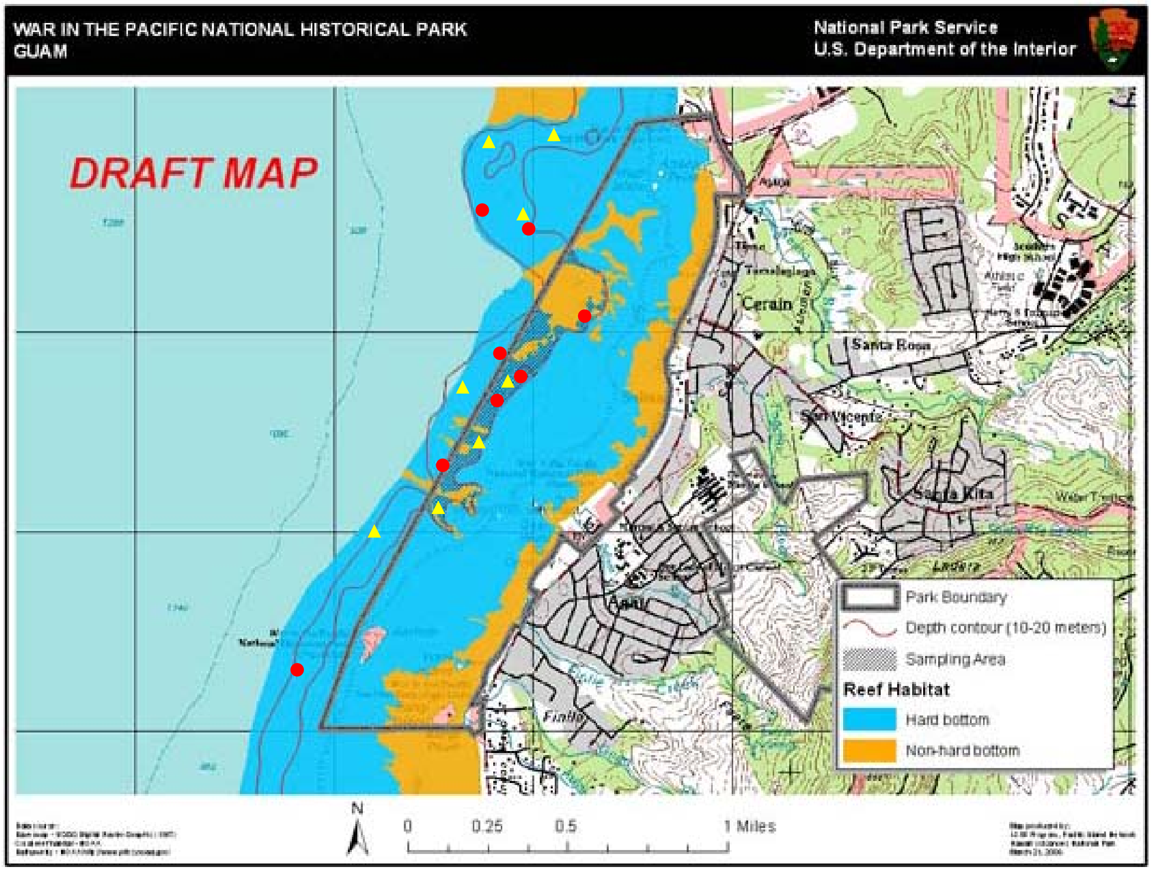
b) Ofu Unit.

Sampling frame for National Park of American Samoa (NPSA), Tau Island Unit displaying 15 randomly selected fixed sites (●) and 15 random sites (△); latter will be sampled in the first year and never revisited. Note, the sampling area has been extended to include the hard bottom habitat within the 10-20 m depth contour that is influenced by the watershed within or upslope of the park.



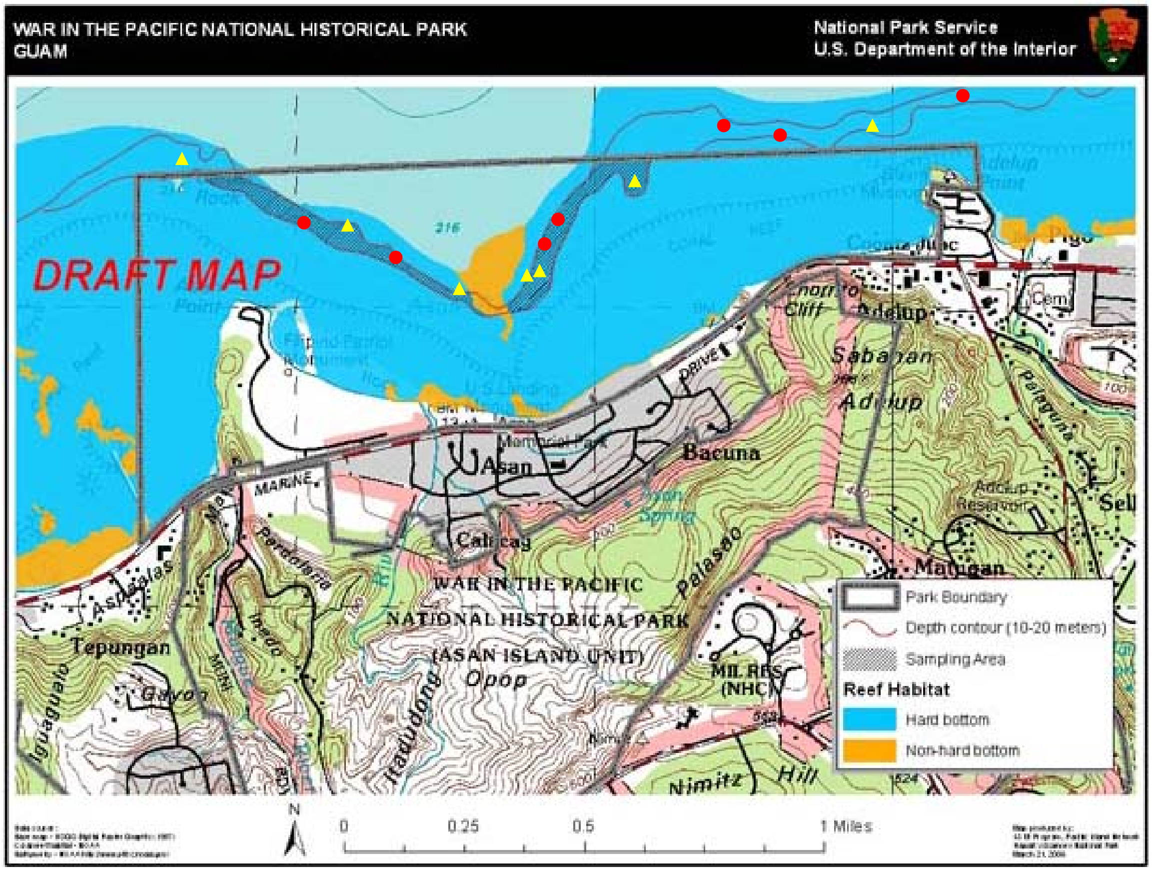
c) Tau Unit.

Sampling frame for War in the Pacific National Historical Park (WAPA) Agat unit displaying 15 randomly selected fixed sites (●) and 15 random sites (△); latter will be sampled in the first year and never revisited. Note, the sampling area has been extended to include the hard bottom habitat within the 10-20 m depth contour that is influenced by the watershed within or upslope of the park.



a) Agat Unit.

Sampling frame for War in the Pacific National Historical Park (WAPA) Asan Unit displaying 15 randomly selected fixed sites (●) and 15 random sites (△); latter will be sampled in the first year and never revisited. Note, the sampling area has been extended to include the hard bottom habitat within the 10-20 m depth contour that is influenced by the watershed within or upslope of the park.



b) Asan Unit.

Appendix E: List of Field Data Forms

Dataform	SOP #	Notes
Coral Settlement	6	Appendix S6.a: Field data form to record deployment and retrieval dates as well as photo log for photographs in between deployment and retrieval.
Benthic cover	7	Appendix S7.b: Field data form for benthic cover data fields, rugosity data, in air and in water environmental conditions.
Coral growth	9	Appendix S9.c: Field data form to enter growth data on first visit as well as follow-up measurements.
Settlement data entry	14	Appendix S14.b: Data form to enter settlement information during laboratory portion of analysis.

Appendix F: Sample Managers' Briefing – KALA 2006

Benthic Community Vital Sign Highlights

Current Status 2006

- Uniform Coral Cover (9.6 ± 1.2 %, Mean ± SE) but lowest at Nihoa

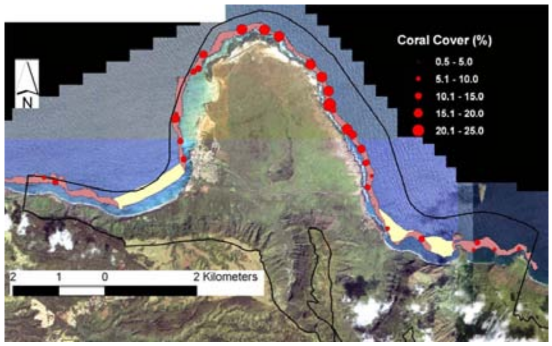


Figure 1. Percent coral cover at each transect in KALA in 2006.

- Overall low macroalgae cover (7.9 ± 1.5 %, Mean ± SE) but the highest cover is in front of Kalaupapa settlement. (21-37%).

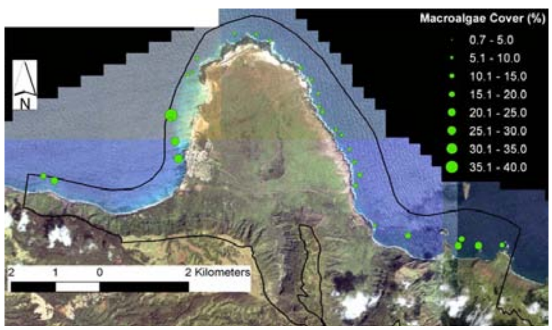


Figure 2. Percent macroalgae cover at each transect in KALA in 2006.

- Low incidence of disease/bleaching (5.0 ± 1.0 %, Mean ± SE). Highest incidence (12 - 15 %) at scattered points around park.

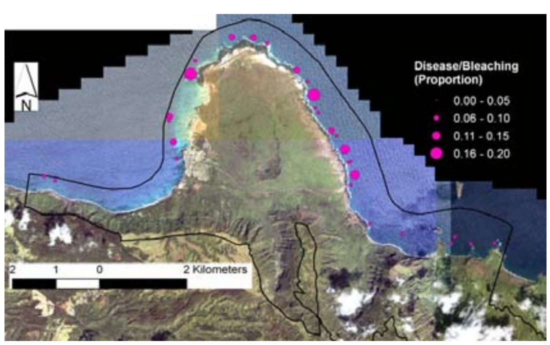


Figure 3. Proportion of coral disease/bleaching at each transect in KALA in 2006.

- Coral settlement is low (21.4 ± 7.5 recruits m^{-2} yr^{-1}, Mean ± SE) compared to other areas in the state. Highest settlement occurred at Kahiu Pt (104 recruits m^{-2} yr^{-1}). Lowest by Kalaupapa and Nihoa on the west end of the park (0 recruits/m^2).

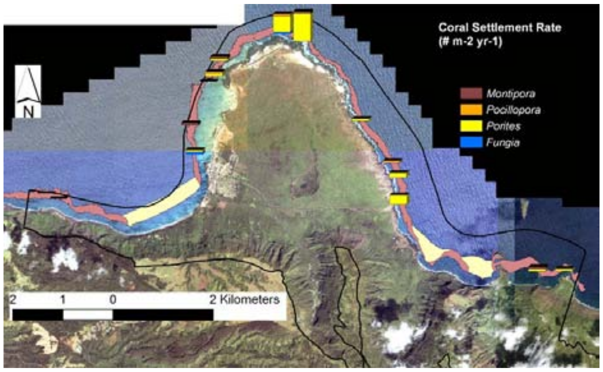


Figure 4. Coral settlement rate at fixed sites in KALA in 2006.

- Slight difference in benthic community structure between the front side and back side.
- KALA benthic communities substantially different from other sites around state in terms of high coverage of *Pocillopora meandrina* and low macroalgae coverage.

Trends from 2005-2006

All of the benthic marine variables in KALA appear to be stable at present (Table 1). The highest statistical power was observed for change in percent coral cover. In contrast, the coral settlement rate had high variability and consequently low statistical power.

Table 1. Park trends for the Benthic Marine Vital Sign showing the current values and desired levels for each variable. Color codes in the current column depict the trend. Red is decreasing, Yellow is stable, and Green is increasing. Line type in the current column depicts confidence or statistical power in the trend. Thick black line is high power (P>0.8), thin black line is medium power (P<0.8 and P>0.3), dashed black line is low power (P<0.3).

Resource	Indicator	Measure	Park	Current	Desired
Aquatic	Benthic Marine	Coral Cover (%)	KALA	9.6	10.0
		Macroalgae Cover (%)	KALA	7.9	5.0
		Disease/Bleaching (%)	KALA	5.0	5.0
		Coral Settlement Rate (No. m^{-2} yr^{-1})	KALA	21.4	50.0

Management Implications/Actions

Present conditions look good so therefore no management action is suggested other than continued monitoring.

Appendix G: Study Plan

Inventory & Monitoring Program

National Park Service
U.S. Department of the Interior

PACIFIC ISLAND NETWORK

BENTHIC VITAL SIGN PROTOCOL STUDY PLAN
INVENTORY & MONITORING PROGRAM
PACIFIC ISLAND NETWORK

Inventory and Monitoring Program

Pacific Island Network

Hawaii, American Samoa, Guam,
and Commonwealth of the Northern Mariana Islands

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Protocol Benchmark Dates

Protocol Study Plan Prepared: October 05

Protocol Work Started: June 05

Draft Protocol Submitted to Peer Review: June 2006

Final Protocol Completed: January 2007

Protocol Budget Summary, requested NPS funds

FY2005: $80,000

FY2006: $66,500

TOTAL: $146,500

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Acronyms:

NPS	U.S. National Park Service
PACN	Pacific Island Network
I&M	Inventory & Monitoring Program
HI-PI CESU	Hawaii-Pacific Islands Cooperative Ecosystem Studies Unit
PICRP	NPS Pacific Islands Coral Reef Program
USGS	United States Geological Survey
ALKA	Ala Kahakai National Historic Trail
AMME	American Memorial Park
HALE	Haleakala National Park
HAVO	Hawaii Volcanoes National Park
KAHO	Kaloko-Honokohau National Historical Park
KALA	Kalaupapa National Historical Park
NPSA	National Park of American Samoa
PUHE	Pu’ukohola Heiau National Historical Park
PUHO	Pu’uhonua o Honaunau National Historical Park
USAR	USS Arizona Memorial
WAPA	War In The Pacific National Historical Park

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ABSTRACT

The benthic marine protocol will be implemented initially in four National Parks in the Pacific Islands Network (PACN): Kalaupapa NHP (KALA), Kaloko-Honokahau NHP (KAHO), National Park of American Samoa (NPSA), and War in the Pacific NHP (WAPA). The benthic protocol addresses two monitoring questions: What are the changes over time in the composition (e.g., species and/or assemblage) and physical structure (rugosity) of the coral reef benthos? And, what are the changes over time in settlement, growth, survival and health of target coral species, and/or individuals? The objectives of the first question are twofold. First, determine long-term trends in the percent cover of sessile marine benthic macroinvertebrate (e.g., corals, zooanthids, octocorals, sponges, and echinoderms) and macroalgal (including large fleshy, articulated or crustose coralline, and turf algae) assemblages at randomly selected sites delineated by hard substrata, along an isobath between 10 and 20 meters depth. Second, determine trends in benthic small scale topography or rugosity at randomly selected, fixed (permanent) stations that have been selected as a subset from the entire pool of transects. The objectives addressing the second research question are threefold and include the following; first, determine trends in settlement rate of hard corals to uniform artificial surfaces at randomly selected sites on the fore reef along an isobath between 10 and 20 meters depth, second, determine trends in growth rate and survival of randomly selected coral colonies of a common, trans-Pacific species (e.g., *Pocillopora damicornis, P. verrucosa,* or *Porites lobata*) growing at similar depth, and, finally determine long-term trends in the incidence and severity of coral disease and bleaching. A split panel sampling design is proposed with permanent sites selected from a pool of random sites. Some sites will be sampled annually while other sites will be sampled on a rotating schedule at intervals of 3-5 years. This Protocol Study details the approach the PACN Inventory and Monitoring program will use to develop the protocols necessary to meet its monitoring objectives.

PROTOCOL TITLE

Protocols for Monitoring Marine Benthic Communities

VITAL SIGNS BEING ADDRESSED

The PACN has adopted a broad interpretation of what constitutes a vital sign. This protocol will address the Benthic Marine Communities (benthic marine, hereafter) vital sign, which includes the following measures: substrate percent cover, rugosity, coral settlement rate, growth rate and survival of a common trans-Pacific coral, and coral disease frequency.

PARKS WHERE PROTOCOL MAY BE IMPLEMENTED

The benthic marine vital sign is applicable to all PACN parks. Given anticipated funding levels, initial monitoring will be restricted to the four PACN parks currently with on-site staff that have the necessary training and expertise to conduct the monitoring work. These four parks include: KALA (on the island of Molokai), KAHO (on the west coast of Hawaii), NPSA (located in American Samoa), and WAPA (located in Guam). Detailed sampling designs will be generated for these four parks as part of this protocol development and implementation. The protocol will have sufficient detail to allow the development of sampling designs and selection of methodologies for other PACN parks as applicable, and as funding becomes available.

JUSTIFICATION / ISSUES BEING ADDRESSED

The benthic (or sea floor) marine communities in the PACN parks comprise rich and diverse biota including algae, corals, thousands of other invertebrates, and algae. Nearshore or shallow-water benthic marine communities in the PACN include coral reefs, mangrove stands, sea grass beds, and intertidal habitats. Given multiple existing threats to coral reefs and resources therein, and limited funds, monitoring of this vital sign will focus at present just on coral reef communities. If future needs or funds arise, monitoring of other marine communities or their specific constituent resources will be initiated not only in the aforementioned parks, but in other PACN parks as well.

Coral reef ecosystems provide many goods and services ecologically, culturally and economically. Coral reefs and associated benthic communities help protect shorelines from storm damage and wave erosion and thereby shelter coastal human communities and coastal zone infrastructure. Moreover, coral reefs are essential to the traditional life ways and cultures of Hawaiian, Samoan, Chammoro, Carolinean and other Pacific Islands peoples. Coral reefs also provide critical elements of commerce from local and charter-sport fishing, and from other visitor activities (e.g., snorkeling, scuba diving, boating), which are a, if not the, major economic driver throughout the Pacific Islands (Caesar 2000).

In most parks, coral reefs form the structural framework of an ecosystem that has been compared to tropical rainforests in terms of extremely high species diversity and complexity of interactions (Connell 1978). This vital sign is closely linked with the marine fish vital sign, and monitoring efforts will be co-located for both vital signs to maximize comparability and value of data collected.

Coral reefs in parks are often in close proximity to human populations, whose highest densities occur within coastal zones worldwide. Coral reefs are located at the down-stream end of coastal watersheds and are subject to multiple threats and impacts from both land-use practices in the watershed and land- or boat-based access to marine resources. Many PACN parks have little or no marine zoning, and where zoning is present, it is poorly enforced. Due to the role of corals as the primary architectural organism providing three dimensional habitat structure (analogous to trees in a forest) and their sensitivity to various sources of environmental threat or cumulative degradation, corals are a good indicator of overall environmental health or condition for tropical nearshore marine ecosystems in the PACN.

Primary stressors or impacts to coral reefs include; disease, sedimentation, eutrophication, contaminants, storms and other physical disturbances at different scales, alien species, biotic outbreaks of voracious coral predators (e.g., Crown-of-Thorns Seastar), coastal development, and global climate change. The United Nations Environment Programme (UNEP) has proposed coral reefs as a worldwide indicator ecosystem for global climate change (Spalding et al. 2004). For these reasons, PACN nominated benthic marine communities as the #2 vital sign (Vegetation Communities ranked #1) for implementation of long-term monitoring.

MONITORING OBJECTIVES

Long-term monitoring involves repeated surveys of organisms and/or environmental parameters at selected sites over time. Monitoring may serve as an "early warning system" to detect declining trends (as well as positive changes) in various ecosystem components (e.g., coral cover), hopefully before irreversible change or loss occurs. Monitoring information forms the basis for best management decisions and actions. In cases where natural systems in or near parks have been so highly altered that natural ecological processes no longer function properly, managers must use information from monitoring to understand how the altered systems operate in order to determine the most effective approach(es) for restoration of the ecosystem or natural processes. Chapter 1 of the PACN Monitoring Plan (NPS 2006) outlined 33 general monitoring objectives. Monitoring of the marine benthic vital signs will provide information to address eight of these objectives (Table 1) and the four corresponding vital signs. This information will provide a more complete picture of the factors that influence the benthic marine community.

Table 1. General monitoring objectives of the Benthic Marine Community protocol that apply to other Vital Signs of the PACN I&M Program.

General monitoring objectives	Level 1	Level 2	Vital Sign
Track spatial and temporal patterns in water quality in freshwater and marine systems.	Geology & Soils	Water Quality	Water Quality
Use monitoring data for early detection & predictive modeling of incipient invasive species.	Biological Integrity	Invasive Species	Invasive Species early detection
Document changes in established populations of invasive species, including response to treatment.		Invasive Species	Invasive Species early detection
Determine trends in incidence of disease and infestation in selected communities and populations.		Infestations and Disease	
Determine trends in composition, structure, and function of populations of selected focal species and communities within the parks.		Focal species or Communities	Marine Fish
Determine spatial and temporal patterns in benthic marine cover and community distribution.	Ecosystem Patterns and Processes	Land Use and Cover	Landscape dynamics
Determine whether viewsheds, landscapes and underwater seascapes are changing within and surrounding the park.		Land Use and Cover	Landscape dynamics
Track extreme disturbance events in parks.		Land Use and Cover	Landscape dynamics

Specifically, the marine benthic vital signs protocol will address two monitoring questions with five specific objectives.

Monitoring Questions and Objectives to Be Addressed by the Marine Benthic Protocol

Question 1: What are the changes over time in the composition (e.g., species and/or assemblages) and physical structure (rugosity) of the coral reef benthos?

Objective 1a: Annually measure percent cover of sessile marine benthic macroinvertebrates (e.g., corals, zooanthids, octocorals, sponges, and echinoiderms) and algal (including large fleshy macroalgae, crustose coralline, and turf algae) assemblages at randomly selected sites on hard substrata, along an isobath between 10 and 20 meters depth.

Justification: Long-term changes in the abundance of invertebrate and algal taxa or assemblages can often be correlated with variation in certain environmental stressors or drivers identified by other monitoring or research programs. For example, an increase in algal cover has often been associated with eutrophication and/or a reduction in the numbers of herbivorous invertebrates or fishes.

Objective 1b: Measure the benthic small scale topography or rugosity at randomly selected, fixed (permanent) benthic transects at time intervals relevant to changes in topographic relief (e.g., over 5 years and episodically to coincide with disturbances such as hurricanes or tsunamis).

Justification: Rugosity is a measure of vertical structural/architectural complexity of the benthos. Changes in rugosity suggest large scale changes in benthic community structure, composition, function, and condition. Research has established a strong correlative link between rugosity and abundance of fishes (Friedlander and Parrish 1998) and mobile invertebrates (Aronson et al. 1994, Rogers et al.1994, Minton 2000).

Question 2: What are the changes over time in settlement, growth, survival and health of target coral reef benthic assemblages, species, and/or individuals?

Objective 2a: Annually measure the settlement rate of hard corals to uniform artificial surfaces at randomly selected, fixed hard bottom sites on the fore reef between 10 and 20 meters depth.

Justification: Coral reef populations must successfully reproduce and recruit to persist. Due to their microscopic size and primarily planktonic dispersal stage, larvae and juveniles of corals and other benthic organisms are particularly sensitive to environmental stressors (Richmond 1995, Basch and Keesing 1996, Basch and Pearse 1996). Many corals and other reef animals are long lived, and the presence of adult individuals that are less sensitive to stressors than their young stages can mask serious incipient problems of stressors, population demography and community persistence and resilience. While not immediately evident (e.g., adult population appears healthy), failure of juveniles to settle, or low recruitment success over multiple years can result in the relatively rapid degradation of the coral reef ecosystem as adults senesce or experience mortality from natural biotic or physical disturbance(s) or anthropogenic impact(s) (Basch et al. 2007).

Objective 2b: Annually measure the growth rate and fate of randomly selected coral colonies of a common, Pacific species (e.g., *Pocillopora damicornis, P. verrucosa,* or *Porites lobata*) found in all parks and growing at similar depths.

Justification: Coral growth rate and survival are indicative of coral and reef health and water quality and provide a time integrated measure of the condition of these factors. Calcification rates are affected by several factors, including light availability, turbidity, sedimentation, disease, bleaching, and global climate change. Without continued calcification, coral reefs will be degraded through bio-erosion and mechanical damage. Smaller corals also have lower fecundity and hence reduced reproductive potential.

Objective 2c: Annually measure the incidence of coral disease and bleaching within the photographic images sampled at randomly selected, fixed hard bottom sites on the forereef between 10 and 20 meters depth.

Justification: Emphasis of monitoring will be on the physical conditions that are indicative of disease (e.g., the extent of bleaching) and environmental correlates (e.g., temperature) when possible, rather than the diagnosis and causation of disease. Disease in corals and other benthic organisms can cause mortality or produce sublethal effects. Until recently, coral disease was believed to be less prevalent in the Pacific Ocean, but reports of incidence are increasing in frequency (e.g., Aeby et al. 2003). In the Caribbean, coral disease has extirpated species (e.g., *Acropora cervicornis*) from some geographic areas (Aronson and Precht 2001) and the two Caribbean *Acropora* species have recently been proposed for Federal listing (50 FR 24359-24364). At present, only a few coral diseases have been linked to anthropogenic stressors (e.g., sewage/nutrients, Bruno et al., 2003) and changes in environmental conditions associated with global climate change (e.g., increase in sea surface temperature, Jones et al., 2004).

PROCEDURES / BASIC APPROACH

A number of existing protocols to monitor benthic marine communities are readily available, including NPS-approved coral reef monitoring methodologies developed by USGS for Virgin Islands NP (Rogers et al. 2002). Unfortunately, many commonly used monitoring methods violate statistical assumptions (Lewis 2004), lack statistical power (Brown et al. 1999), or may need modification to function at PACN parks (e.g., Caribbean coral reefs are different from Pacific reefs, and methods are not perfectly interchangeable). A comprehensive review of these methods, and thorough testing and evaluation of methods and sampling design is necessary to achieve the program’s goal of developing protocols with rigorous scientific merit. In addition, collecting data using a statistically rigorous design allows for comparisons with other monitoring programs at a larger spatial and temporal scale.

Brown et al. (1999) concluded that one of the most reliable and cost effective techniques to monitor change in composition of the marine benthos (Objective 1a) was to use photoquadrats along a transect line. Fixed or permanent transects are randomly selected at the onset from a pool of possible points within the strata of interest (e.g., hard substrates within the 10-20 m depth range) and then subsequently monitored on an annual basis. The number of starting points depends on the extent of available habitat, financial constraints, and available park resources. This technique can address multiple spatial scales, has sufficient statistical power to detect moderately small changes (25% relative change), and provides a permanent record of the coral reef community. However, photoquadrats alone are not sufficient to document changes in some benthic assemblages and use of simple, supplementary methods will be evaluated.

Rugosity (Objective 1b) will be simultaneously measured on the same benthic transects photographed for percent cover estimates. Specific methodologies will be evaluated during the protocol development and are beyond the scope of this document. Exploratory remote sensing approaches coupled with field rugosity measurements can provide broader spatial scale inference of changes in community structure (Kuffner et al. 2004).

Settlement (Objective 2a) of coral reef benthos is currently being measured off the Kona parks and coast and at WAPA using artificial substrates. These efforts will be further coordinated and expanded to additional parks where/when this vital sign is implemented. The focus of this monitoring protocol will be on settlement of juvenile corals on artificial surfaces rather than recruitment which also includes survival and the subsequent contribution to the adult community. Like other vital sign measures, coral growth and survival (Objective 2b) will be monitored using well-tested methods to be decided upon during initial planning and implementation of monitoring.

The presence of disease (Objective 2c) can also be measured with photoquadrats along the transect, but limitations of this method are clearly apparent. Positive disease diagnosis can only by done with appropriate laboratory work. Therefore, in-field monitoring will examine disease like conditions such as a whitening of the skeleton, lesions on the coral surface, other abnormalities, and definitive bands or rings demarcating live healthy tissue from bleached and dead tissue.

The anticipated methods to meet these objectives will require modification (e.g., specific transect length, necessary number of photos) to account for the variability among PACN parks in marine benthic habitat and species diversity and physical reef topography. After reviewing many of the monitoring programs, standard methods were selected to measure benthic cover (e.g.,photoquadrats along a transect line), rugosity (e.g., chain method), settlement (e.g., settling plates), and growth and survival (e.g., in situ coral tracking).

Where appropriate, the sampling design will co-locate the monitoring for each of the above objectives. Additional, co-location with other marine protocols (i.e., marine fishes), will occur. The specific sample design and protocol methods manual will incorporate guidance provided by the I&M Program (Fancy 2000). It is anticipated that the first few years of monitoring will serve as the pilot study to refine logistical, statistical, and financial issues specific to the PACN parks.

PROTOCOL DELIVERABLES / PRODUCTS

The Principal Investigators and NPS I&M staff will submit the following deliverables to the NPS I&M in fulfillment of a NPS vital sign monitoring protocol:

An annual protocol performance report that describes the expenditures, results, and accomplishments from the past year as well as any proposed changes in design or methods.

A draft monitoring protocol that will include the following narrative sections:

I. Background and Objectives. This section will address the rational for monitoring marine benthic communities at PACN parks and all measurable objectives.

II. Sampling Design. This section will include a description of the sampling design including an overview of site selection, population(s) to be monitored, and sampling frequency and replication. The rationale for selection over other sampling designs will be discussed.

III. Field Methods. This section will contain a discussion of field preparations, schedules and equipment set up and the sampling methods.

IV. Data Management. This section will include an overview of the field data sheet (including metadata) and database design and a discussion of data entry, verification, and editing procedures. Metadata and data archival procedures will also be addressed.

V. Analysis and Reporting. This section will contain recommendations for data summaries and analyses to detect ecological change over time (including long-term). Examples of summary tables and figures will be provided.

VI. Personnel Requirements and Training. The section will discuss the roles and responsibilities of all personnel involved in the benthic monitoring protocol, including minimum qualifications and training necessary to fulfill each role.

VII. Optional requirements. This section will discuss annual workloads and field schedule, facility and equipment needs, startup costs and budget considerations, compliance necessary to conduct the protocol, and procedures for making changes to and archiving previous versions of the protocol.

VIII. References. A complete list all references used for the development of the marine benthic monitoring protocol will be provided.

IX. Appendices. As appropriate, appendices will provide additional information not covered in the other sections. This can/will include examples of any field data forms, relevant species lists, or other information deemed necessary.

The final protocol will also contain detailed Standard Operating Procedures (SOPs) for each major, repeated task, including but not limited to: field preparations, site selection, data collection, data entry, quality assurance/quality control measures, maintenance/archiving of datasheets and/or data download files, and protocol revision.

A final monitoring protocol that addresses the comments on the draft protocol from two to three reviewers appointed by the Pacific West Regional I&M Coordinator. Information on this peer review is available at http://inside.nps.gov/regions/custommenu.cfm?lv=3&rgn=127&id=2716.

A normalized relational database that conforms to the I&M standards as outlined in the Natural Resource Database Template (NRDBT) and associated guidance documents found at http://science.nature.nps.gov/im/apps/template/index.htm and approved by the PACN Data Manager. In addition to the database, a data dictionary and database documentation will be provided.

The protocol will be delivered in Microsoft Word XP or compatible format unless specified above or in the appropriate guidance (e.g., database).

Style

All final products and deliverables will meet specifications as found in the Oakley et al. **(2003)** protocol standards for the NPS I&M program (http://science.nature.nps.gov/im/monitor/protocols/ProtocolGuidelines.pdf), the NPS I&M program's Protocol Development Process guidance document (http://science.nature.nps.gov/im/monitor/protocols/ProtocolDevelopmentProcess.doc), and the NPS I&M Program Guidance for Protocol Development Summary documents (http://science.nature.nps.gov/im/monitor/protocols/ProtocolDevelopmentSummary.doc).

Peer Review

The benthic marine community protocol study plan (this document) and draft final protocol deliverables are required to be peer-reviewed. The PIs are responsible for addressing all reviewer comments prior to submitting the final protocol report and database. For the protocol study plan, the coordinator of the PACN I&M program, Leslie HaySmith and at least two other people, who the PIs will select and identify, will serve as reviewers. Formal peer review of the final draft of the protocol is coordinated by the NPS Pacific West Region (PWR), Inventory and Monitoring Coordinator. Information on this peer review is available at http://inside.nps.gov/regions/custommenu.cfm?lv=3&rgn=127&id=2716.

Professor Jim Agee, University of Washington, functions as the Protocol Review Coordinator (PRC) for the PWR. Professor Agee will provide coordination, tracking, oversight, and synthesis of blind peer reviews for these protocols. He will also compile and maintain the protocol review file, providing a final copy (paper and digital) to both the Regional I&M Coordinator and the Network Coordinator. The process may take up to five (5) months to complete if re-review of protocols is needed. We are estimating approximately six weeks per review of each protocol.

The anticipated date for submitting this protocol to peer-review: December 2005

WORK SCHEDULE

A set of draft deliverables ready for regional peer review will require two to three months to complete. Regional peer-review can take up to five months to complete, and a final peer-reviewed set of deliverables is dependent upon the timeliness of this regional review and the nature and extent of the peer review comments. In the benchmarks outlined below, it is anticipated that revisions will require two months to complete.

Benchmarks

WORK SCHEDULE: A timeline for the Marine Benthic protocol is shown, and benchmark dates are highlighted:

Table 2. Timeline for developing the Benthic Community Protocol.

TASK	DEADLINE	LEAD RESPONSIBILITY
Study Plan		
Update Study Plan	14-Oct-05	Brown, Minton, Klasner, Daniel, Basch
Submit for Peer Review	14-Oct-05	Minton
Receive & Incorporate Peer Comments	21-Oct-05	Minton, Brown
Update Study Plan	Mar, 06	Klasner, Daniel
Finalize Study Plan	28-Mar-06	Brown, Minton, Daniel & Klasner
Annual Performance Report	11-Oct-05	Klasner
Study design		
Draft Study Design II	07-Oct-05	Brown
I&M Statistician Review	31-Oct-05	Skalski
Finalize Study Design	04-Nov-05	Brown
Database		
Design Completed	02-Nov-05	Dicus & Snyder
Draft Database	02-Nov-05	Dicus & Snyder
Receive Coral Reef Comments	04-Nov-05	
Incorporate Comments based on Penny's review	Mar, 06	Dicus & Snyder
Final Database	30-Mar-06	Dicus & Snyder
Protocol development		
Protocol Outline	03-Oct-05	Brown & Daniel
Protocol Draft	20-Oct-05	Brown et al.
Draft SOPs	20-Oct-05	Brown et al.
Protocol Development Workshop	31Oct-04Nov	Workshop participants
Incorporate Comments	11-Nov-05	Minton, Daniel, Klasner, DeVerse
Remaining SOPs Done	11-Nov-05	Minton et al.
Draft Protocol	14-Nov-05	Minton et al.
Send to I&M and PICRP for Comments	14-Nov-05	Daniel & Klasner
Receive I&M & PICRP Comments on draft protocol	01-Mar-06	Reviewers
Incorporate Comments	Mar, 06	Brown, Klasner, Daniel, Minton, Dicus, Snyder
Finalize Protocol	April, 06	
Submit for Peer Review	June, 06	I&M – Klasner & HaySmith / Latham
Receive Peer Review Comments	Nov, 2006	
Incorporate Regional Review Comments	Jan, 2007	Brown et al.
Submit Final to I&M PACN	Jan, 2007	Brown & Daniel

INVESTIGATORS, PARTNERSHIPS, AND COOPERATORS

As several individuals will participate in the preparation of this protocol, the role of each participant has been clearly identified below. Any changes in key participants or their roles will be subject to prior approval and will be specified via modification to the study plan.

Principal Investigators (PI):

Dr. Eric Brown (Co-PI, NPS)

Ecologist, Kalaupapa NHP,

Background: Dr. Brown has been involved with coral reef research and monitoring in the Pacific since 1989. Prior to joining the National Park Service, he was involved in the development of the Hawaii Coral Reef Assessment and Monitoring Program (CRAMP) and served as the database manager for the program (see Brown et al. 2004, Jokiel et al. 2004). In addition, he has been surveying reef ecosystems throughout Hawaii as part of the fish habitat utilization study (FHUS) for the State of Hawaii, Division of Aquatic Resources (DAR)

Responsibilities: Dr. Brown will be the lead Principal Investigator for the benthic marine community protocol development. He will be responsible for data collection in the field, development and writing of the protocol in cooperation with other technical experts, including Dr. Basch (co-PI), a marine database manager and the PACN I&M consulting statistician. Dr. Brown will work closely with Pacific Island Coral Reef Program (PICRP) colleagues at PACN parks to complete these protocols. See Table 3 for a comprehensive listing of responsibilities.

Dr. Larry Basch (Co-PI, NPS)

Marine Ecologist-Science Advisor (NPS), Hawaii-Pacific Islands CESU, University of Hawaii.

Background: Dr. Basch has worked as a marine ecologist in the Pacific and elsewhere for 25 years and has specialized in benthic population and community ecology of algae and invertebrates, the reproductive, larval, juvenile, and recruitment ecology of marine invertebrates, and related benthic fisheries and nearshore oceanography and water quality as these pertain to marine resource conservation and Marine Protected Areas. He has experience with long term ecological monitoring, dating back to 1982 when he worked in the Channel Islands NP as a contract research assistant/associate assisting with the NPS prototype long-term marine monitoring program. More recently, Dr. Basch worked as the NPS coastal ecologist and manager for the NPS Southeast Alaska Coastal Parks Cluster where he was involved in developing protocols to inventory and monitor coastal intertidal and subtidal marine ecosystems.

Responsibilities: Provides scientific advice, peer review, technical assistance and evaluation on the protocol development and field implementation. Dr. Basch will be involved in the editing of the draft protocol and responding to reviewer comments on the final protocol. See Table 3 for a comprehensive listing of responsibilities.

NPS Lead:

<u>Dr. Dwayne Minton</u>
Ecologist, War in the Pacific NHP,

<u>Background:</u> Dr. Minton has nearly 15 years of experience on Pacific coral reefs. He has been involved in the biological monitoring of sewage outfalls in Hawaii. For the past two years he has acted as the lead for the PACN I&M marine workgroup and oversaw the development of the marine portion of the PACN Monitoring Plan.

<u>Responsibilities:</u> Conducts periodic reviews to ensure that the PIs are on schedule and that the protocol meets the guidelines of the I&M Program. The NPS lead will meet with the PIs at minimum every month to discuss work, progress and provide informal review on products. The NPS lead will also assist in coordination with the PACN I&M Project manager. See Table 3 for a comprehensive listing of responsibilities.

I&M Project Manager:

<u>Mr. Fritz Klasner (or aquatic ecologist)</u>
Ecologist, PACN I&M Program

Responsibilities: Periodic reviews with the PACN I&M Project manager will ensure that the PIs and NPS lead are on schedule and that the protocol meets the guidelines of the I&M Program. The project manager will also assist coordination with the PACN I&M statistician and the PACN I&M data manager. See Table 3 for a comprehensive listing of responsibilities.

I&M Data Manager:

<u>Mr. Gordon Dicus</u>
Data Manager, PACN I&M Program

Responsibilities: Periodic reviews with the PACN I&M Data Manager will ensure that the PIs, NPS Lead and marine data base manager are on schedule and that the database and data management protocols meet the guidelines of the I&M Program. See Table 3 for a comprehensive listing of responsibilities.

<u>Ms. Allison Snyder</u>
Database Programmer, PACN I&M Program

Responsibilities: The I&M database programmer will oversee and be responsible for data management requirements and develop the appropriate databases and associated documentation in close association with PACN I&M Data Manager, PIs and others mentioned above. The database programmer will ensure that all protocols conform to the requirements of the I&M program as detailed in the “Data Management” sections below. See Table 3 for a comprehensive listing of responsibilities.

I&M Statistician:

Dr. John Skalski
Consulting Statistician, PACN I&M Program

Responsibilities: Provide assistance with the development and validation of the statistical and sampling designs for several related marine protocols and provide periodic reviews of protocols and SOPs associated with sampling design to insure their accuracy, applicability, and adaptiveness to future monitoring needs. Works in concert with other statisticians to fulfill responsibilities. See Table 3 for a comprehensive listing of responsibilities.

Dr. David Schneider
Consulting Statistician, PACN I&M Program

Responsibilities: Provide assistance with the development and validation of the statistical and sampling designs for several related marine protocols and provide periodic reviews of protocols and SOPs associated with sampling design to insure their accuracy, applicability, and adaptiveness to future monitoring needs. Works in concert with other statisticians to fulfill responsibilities. See Table 3 for a comprehensive listing of responsibilities.

I&M Marine Protocol Facilitator:

Ms. Raychelle Daniel
Marine I&M Facilitator, PACN I&M Program and CESU

Responsibilities: Assists with the information gathering, data entry, writing, and coordination as directed by the PIs or NPS lead. See Table 3 for a comprehensive listing of responsibilities.

Cooperators

Dr. David Duffy (CESU PI)
Professor of Botany, University of Hawaii

Responsibilities: Dr. Duffy will oversee the hiring and supervision of the marine protocol facilitator and the Biological technician. Dr. Duffy will be responsible for the administrative tasks associated with overseeing cooperators. See Table 3 for a comprehensive listing of responsibilities.

Biological Technician (TBD)
CESU Cooperator

Responsibilities: The biological technician will be stationed at KALA and his/her work will be guided by the PIs. This position's primary purpose is to conduct the field work with park staff and the PIs at each of the 4 PACN parks during the pilot study period (3-5 years).

Table 3. Tasks and responsibilities along with projected completion dates for individuals participating in the development of the benthic marine community monitoring protocol.

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Task	Name	Responsibilities	Completion Date
Draft Study Plan/ Final Study Plan			
	Eric Brown (Co-PI, Lead) & Larry Basch (co-PI; CESU PI)	Review and comment. Assist with development and approve budget. Select peer-reviewers and assist NPS lead with addressing peer-reviewer comments.	Aug 05- Draft Mar. 06- Final
	Dwayne Minton (NPS Lead)	Write draft study plan with input from PIs. Revise and address comments from PIs and I&M Project Manager. Coordinate with PACN I&M Project Manager and Database Manager to insure plan meets I&M requirements. Address peer reviewer comments. Submit final peer-reviewed study plan to PACN I&M Program	Aug 05- Draft Mar. 06- Final
	Raychelle Daniel (Protocol Facilitator)	Assist with writing of draft study plan under guidance from PIs and NPS lead.	Aug 05- Draft
	Fritz Klasner (I&M Project Manager) & Gordon Dicus (I&M Data Manager)	Review and provide comments.	Aug 05- Draft
Annual Performance Reports			
	Eric Brown	Write and submit to NPS lead and I&M Project Manager. Incorporate input from co-PI	Sep. 05
	Larry Basch	Provide input into content and review prior to submission.	Sep. 05

Task	Name	Responsibilities	Completion Date
Protocol Report			
	Eric Brown	Primary author of protocol report. Collaboratively develop initial methods. Communicate with park staff and other subject area experts. Compile park specific data to be used in methods and sampling design development. Coordinate with data manager to insure appropriate development of database. Communicate frequently with I&M statistician and other topic specialists to insure statistically rigorous results. Coordinate with other marine protocol PIs (fish and fisheries). Provide guidance to the benthic protocol facilitator. Provide frequent updates to NPS Lead and respond to queries from PACN I&M personnel.	Dec 05- Draft Jan. 07- Final
	Larry Basch	Collaboratively develop initial methods. Provide technical expertise to lead PI, especially for methodology and sampling design. Communicate frequently with I&M statistician and other topic specialists to insure statistically rigorous results. Insure protocol has adequate scope, especially across network parks. Review all drafts of protocol report and assist with addressing reviewer comments.	Dec 05- Draft Jan. 07- Final
	Allison Snyder	Provide input on protocols and SOPs regarding data management and handling and field data sheets.	Dec 05- Draft Jan. 07- Final
	Dwayne Minton	Provide guidance as needed. Assist with communications among PIs and I&M staff and subject area experts and PIs for other marine vital signs (fish and fisheries). Review draft final protocol.	Dec 05- Draft Jan. 07- Final
	Raychelle Daniel	Under guidance from Co-PIs, search for, assemble, and in some cases summarize background materials, assist with writing of report, facilitate contact with PIs and park staff and other subject area experts.	Dec 05- Draft Jan. 07- Final

Task	Name	Responsibilities	Completion Date
	Fritz Klasner & Gordon Dicus	Review and provide comments. Provide guidance regarding I&M requirements, formats, and reporting (e.g., financial, etc.). Communicate frequently with NPS Lead	Dec 05- Draft Jan. 07- Final
	I&M Statisticians	Assist with the development and validation of sampling design, including recommendation of alternatives and assistance in selection of statistical analyses appropriate to sampling design and methods, including issues of co-location of vital signs and monitoring measures. Review protocols and SOPs associated with the sampling design (e.g., sample site selection, adding/removing sites, etc.)	Dec 05- Draft Jan. 07- Final
Database			
	Eric Brown	Collaboratively provide guidance to the database programmer regarding data entry fields, methodology, and connectivity of data. Develop field data sheets.	Nov. 05
	Larry Basch	As above. Insure appropriate scope for database and connectivity with other I&M and PICRP databases.	Nov. 05
	Allison Snyder	Design, program, field test and modify the marine benthic database and related databases. Work with PIs to develop appropriate data fields, data structure, data handling SOPs, metadata and field data sheets.	Nov.-Mar. 06
	Dwayne Minton	Provide guidance as needed. Assist with communications among PIs and I&M staff.	Nov. 06
	Fritz Klasner	Provide guidance regarding I&M requirements, formats, and reporting (e.g., financial, etc.). Communicate frequently with NPS Lead.	Nov. 06
	Gordon Dicus	Assist with the hiring of the database programmer. Assist database programmer with the initial development of the database to insure appropriate I&M guidelines/protocols are followed. Provide	Nov.-Mar. 06

Task	Name	Responsibilities	Completion Date
		technical assistance as needed. Maintain frequent communication with database programmer.	
General			
	David Duffy (CESU PI)	Provide direct supervision to the CESU hires (marine protocol facilitator and biological technician). Oversee relevant CESU accounts.	Dec 05- Draft Jan. 07- Final
	Biological Technician	Provide assistance with protocol development as directed by the CESU PI.	Dec 05- Draft Jan. 07- Final

DATA MANAGEMENT

The PIs are responsible for the content and quality of all data associated with the project. Project databases will conform to the database design standards of the I&M Monitoring Program as outlined in the Natural Resource Database Template (NRDBT) and associated guidance documents found at http://science.nature.nps.gov/im/apps/template/index.htm. Data management components of project protocols will conform to I&M Program standards and guidance, and will incorporate the following: well-developed data collection protocols, use of normalized relational databases, use of data entry protocols and data QA/QC procedures, creation and maintenance of project logs, documentation of protocol and/or database modifications, development of data analysis protocols with contract statistician, regular project reporting, and regular submission of database/GIS products and FGDC metadata.

For this project, PACN Data Manager and Database Programmer will oversee data management requirements and develop the appropriate databases, associated documentation, and data product deliverables.

COMPLIANCE

This study plan and draft protocol requires no field work to complete and it is anticipated that no cultural or environmental compliance will be required under NPS categorical exclusions 3.4 B(4) and 3.4 E(6) for “plans, including priorities, justifications, and strategies for non-manipulative research, monitoring, inventorying, and information-gathering” and “non-destructive data collection, inventory, study, research, and monitoring activities.” Appropriate compliance screening forms will be filed by the PIs or designated field lead(s) prior to the start of any field work. Potential federal compliance needs that will be considered include NEPA, ESA, cultural, historical and Essential Fish Habitat.

Cultural resources

Cultural resource programs will be consulted if any specimens are to be collected, if documents are generated that will require archiving, or if any other aspect of the protocol development process will impact cultural resource programs.

Hazard assessment/safety certification

This study plan and protocol preparation requires limited, if any, field work. In the event that any marine field work is conducted, it will comply with all NPS dive regulations as well as any park specific dive regulations as detailed in the individual park's approved Dive Plan. NPS diving regulations (RM-4) are available at http://classicinside.nps.gov/documents/DiveDO4F%2Epdf. As per RM-4, each park's Dive Safety Officer will have final approval over all dive activities conducted in his/her park.

Animal care and use certification

This project will not require the use of animals requiring care or certification.

EDUCATION/OUTREACH

The I&M program will identify opportunities and criteria for producing interpretive and educational products in conjunction with the preparation or development of this protocol or for inclusion within this protocol. PIs will include the I&M criteria and deliverables as a part of the monitoring protocol in consultation with park's staff, including interpreters and marine educators, where appropriate.

BUDGET AND STAFF

Budget summary table follows:

Table 4. FY2005 costs.

	FY2005 NPS I&M funds	FY2005 NPS funds (in kind)	FY2005 HPI-CESU Agreement
Personnel			
Biological Tech. (Full time, 1 year)			$30,600
Biological Tech benefits (25%)			$7,700
Marine Protocol Facilitator (Full time, 6 months)			$18,000
Protocol Facilitator benefits (25%)			$4,500
1 x Ecologist (GS-11, 0.4 FTE, w/ 33% benefits, 3 months)		$6,000	
Science Advisor (GS-13, 0.4 FTE, w/ 33% benefits, 3 months)		$15,000	
1 x Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 3 months)		$3,000	
Travel			
1 x Hawaii-WAPA	$3,335		
Materials & Supplies			
Office supplies and misc. field supplies for PIs			$900
Misc. support supplies		$3,000	
Equipment			
Subtotal	$3,335	$27,000.00	$61,700.00
Overhead (17.5%)	NA	NA	$10,800
TOTAL (Subtotal + Overhead)	**$3,335**	**$27,000.00**	**$72,500.00**

Total FY05 funding requested from PACN I&M (I&M + CESU Agreement): $75,835

Table 5. FY2006 costs.

	FY2006 NPS I&M funds	FY2006 NPS funds (in kind)	FY2006 HPI-CESU Agreement
Personnel			
Biological Tech. (full time, 6 months; includes 10% pay increase)			$16,900
Biological Tech benefits (~25%)			$4,300
Marine Protocol Facilitator (Full time, 6 months; include 10% pay increase)			$19,900
Protocol Facilitator benefits (~25%)			$5,000
1 x Ecologist (GS-11, 0.4 FTE, w/ 33% benefits, 12 months)		$24,000	
Science Advisor (GS-13, 0.4 FTE, w/ 33% benefits, 12 months)		$60,000	
1 x Ecologist (GS-11, 0.2 FTE, w/ 33% benefits, 12 months)		$12,000	
Travel			
Protocol Development Workshop (Oct..31-Nov. 6) (7 days, HAVO). Includes: E. Brown (airfare: $400, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). L. Basch (airfare: $200, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). D. Minton (airfare: $2,000, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). R. Daniels (airfare: $200, hotel (6 x $80), per diem (6 x $30)). P. Craig (airfare: $2,000, hotel (6 x $105), per diem (6 x $80), rental car (6 x $32)). Conference Room Rental (7 x $250) Misc. Expenses (printing, taxes, etc) $747	$13,165		
Misc. Travel for I&M Marine Protocol Facilitator			$2,825
Materials & Supplies			
Equipment			
Subtotal	$13,165.00	$96,000.00	$48,925.00
Overhead (17.5%)	NA	NA	8,575
TOTAL (Subtotal + Overhead)	**$13,165.00**	**$96,000.00**	**$57,500.00**

Total FY06 funding requested from PACN I&M (I&M + CESU Agreement): $70,665

TOTAL REQUESTED I&M FUNDS: $146,500

Salaries for Facilitator and Technician

Funds are requested for a Marine Protocol Facilitator and biological technician for one year. These positions will be needed to meet the deadline and requirements of the Benthic Marine Protocol development and implementation. These positions are also intended to assist with the coordination, development and implementation of the marine fish and the fishery harvest protocols. The marine fish protocol will be co-located with the benthic marine protocol and implantation will be conducted by the same staff.

Sub-agreements or Sub-contracts

No sub-agreements or sub-contracts are anticipated to be issued.

Travel

Travel will be required by the Co-PIs to both NPSA and WAPA. This travel is necessary for the Co-PIs to assess field and resource conditions so that realistic protocols can be developed. Travel is scheduled to occur in August/September 2005. Travel funding has been set aside for FY06 to cover miscellaneous travel for the I&M Marine facilitator who need to attend appropriate staff meetings with I&M and may be required to assist the PIs on site.

Meetings and Workshops

Three meetings requiring I&M funding will be necessary for completion of this protocol.

Preliminary Statistical Meeting (Aug. 2005). Discussions among the PIs and the I&M Statistician about the efficacy of possible designs will be necessary to facilitate this early-stage decision making. This preliminary face-to-face meeting is necessary to introduce the participants and exchange vital preliminary information necessary for the development of the sampling design. This meeting will need to be attended by the PIs for the fish and water quality protocol because a single sampling design will be used for these three protocols. Funding for this travel has been included in this funding request to insure its inclusion and to ease review by centralizing the budget in one location.

Protocol Development Workshop (Nov. 2005). At this meeting, the bulk of the monitoring protocol will be drafted and revised by selected members of PICRP and the PACN I&M program. This meeting will allow all personnel an opportunity to interact and coordinate their varied tasks and allow direct contact among the PIs, PICRP and I&M personnel, database managers and programmers, and statisticians. At the conclusion of this meeting, the PIs will have a draft protocol, including narrative, necessary SOPs, study design, and data management procedures.

Follow-up Statistical Meeting (Nov. 2005). This meeting is essential to meeting the deadline for the final Sampling Design. This follow-up face-to-face meeting between the PIs and the I&M Statistician will assess the draft sampling design and clarify any questions/concerns held by the PIs or I&M Statistician prior to finalizing the design. This meeting will need to be attended by the PIs for the fish and water quality protocol because a single sampling design will be used for these three protocols. Funding for this travel has been included in this funding request to insure its inclusion and to ease review by centralizing the budget in one location.

ACKNOWLEDGMENTS

This study plan benefited from comments submitted by Raychelle Daniel and Fritz Klasner and was written in collaboration with the other marine-related protocols.

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REVIEWER COMMENTS – JOHN NAUGHTON

Reviewer: John Naughton, NOAA
National Park Service Responses: Dwayne Minton and Eric Brown

1.
Reviewer Comment: [Monitoring Questions and Objectives] Question 1a: Why not measure both densities of species and coral cover, as opposed to one or the other? The measures will tell you different things about the communities.

NPS Response: The reviewer's comments are correct, but only one measure of abundance will be decided upon for logistic and fiscal reasons. The National Park Service has limited funds to conduct the program, and while it measuring both cover and density may be valuable, to meet other objectives, only a single abundance measure can most likely be monitored.

2.
Reviewer Comment: [Monitoring Questions and Objectives] Question 1a & b: Why aren't abundance measures being proposed at fixed locations, as is proposed for rugosity measures? Will abundance at fixed rugosity stations be monitored?

NPS Response: The abundance measures will be conducted at fixed sites (as well as rotating,), but all sites are to be randomly selected initially as opposed to non-randomly selected (e.g., haphazard). The specifics of the design are to be worked out during the protocol development process. The intention in this planning document is to make it clear that the design will be statistically valid, and utilizes random sampling.

3.
Reviewer Comment: [Monitoring Questions and Objectives]Question 2: There is a suggestion that reproduction will be measured but there is no indication that it definitely will be. Reproduction and recruitment are two different parts of a larger life history entity. Should be clarified, or remove "reproduction".

NPS Response: This section will be clarified to reflect that NPS will develop methods to measure settlement. Measuring reproduction is difficult and costly. Ultimately, successful settlement and eventual recruitment to the reef is what is of interest to the managers.

4.
Reviewer Comment: [Monitoring Questions and Objectives]Question 2: Although monitoring will occur in all reef habitats, settlement will be measure on the fore reef only. What is the justification for this restriction?

NPS Response: This section has been clarified to indicate that monitoring will be restricted to specific depth zones. These zones will be along the fore reef. While monitoring all areas of the reef within the park are desirable, funding to conduct the program at this scale is not currently available. The NPS will need to restrict monitoring work into areas that are safe to operate, will not effect other important park values (e.g., park viewsheds), will not expose equipment to vandalism, can be conducted with limited personnel, and has peer-reviewed methods already developed that can be easily modified to meet park conditions.

5.

Reviewer Comment: [Monitoring Questions and Objectives]What rationale will drive the selection of common species for growth monitoring? Will different life history patterns be included?

NPS Response: Two rationales will serve as primary selectors for what species will be used for growth monitoring. 1) Can growth be accurately and easily be measured in a non-destructive way; and 2) Is the species present in sufficient number at the majority of Pacific National Parks. The NPS can afford to only monitor growth on one species, so multiple species with different life history patterns will not be measured.

6.

Reviewer Comment: [Monitoring Questions and Objectives]Alizarin staining for growth measurements requires sacrifice of coral branches or cores. Is this an appropriate method within a National Park?

NPS Response: Alizarin staining would require destructive methodology and is probably not appropriate for use in a National Park. This methodology will be removed as an example. The final method, as detailed in the protocol manual will not be destructive.

7.

Reviewer Comment: [Procedures/Basic Approach] Procedures/Basic Approach: Question of 10% change in absolute or relative terms? A 10% drop from 20% coral cover is huge. This needs clarification.

NPS Response: Change is in absolute cover. This has been clarified in the plan. Additionally, as a result of statistical calculations, the absolute change has modified from 10% to 25%.

REVIEWER COMMENTS – WILLIAM J. MILLER

Reviewer: William J. Miller, National Park Service
National Park Service Responses: Dwayne Minton and Eric Brown

1.
Reviewer Comment: [Cover Page] Is the document the specifications for the study plan or the study plan itself?

NPS Response: The word "specification" has been removed from the title. This document is intended to be the Protocol Study Plan.

2.
Reviewer Comment: [Cover page] Some timing seems weird.

NPS Response: Timing is correct. The development of this protocol was accelerated to meet agency goals, which has compressed the timeline on this protocol relative to other work. This protocol does not contain a separate pilot study. Data from the initial three years of this protocol will be used to fine-tune the methodology and design.

3.
Reviewer Comment: [Abstract] Does this mean the protocol developed for these 4 parks or implemented in these 4 parks?

NPS Response: The protocol, which includes sampling design and methodologies, will be developed specifically for these four Pacific National Parks, but will be general enough that it can be applied to other parks in the Network as funding become available

4.
Reviewer Comment: [Abstract] I don't think reproduction is the correct word here? How is reproduction going to be monitored? Didn't Bob Richmond say you can lead a larva to substrate but you can't make him settle.

NPS Response: Reproduction is difficult and costly to monitor and will be removed from this document. Settlement is more relevant to the aims of this proposal.

5.
Reviewer Comment: [Abstract] I think you would want a method that can differentiate out turf and crustose from macroalgae.

NPS Response: It is the goal to use a method that will have the highest taxonomic resolution and we are confident that a method is available that will distinguish between crustose and turf algae. This statement appears to be clear, but will be reworded as needed.

6.

Reviewer Comment: [Abstract] Recruitment rate doesn't necessarily equal trends in reproduction (see above comment)

NPS Response: Measuring settlement and recruitment does not equate to reproduction. This protocol is intended to address settlement, as measuring coral reproduction is difficult and costly. This will be clarified.

7.

Reviewer Comment: [Abstract] Is this the best approach, settling plates?

NPS Response: At present, settling plates appear to be the best approach to measure settlement on the reef. In the development of specific methodologies, we will attempt to review all peer-review methodologies prior to selection on a final method.

8.

Reviewer Comment: [Abstract] I'm confused with the title and then the timeline.

NPS Response: Confusion has resulted from a typographical error on the title page. The protocol work was started in June 2005, the Protocol Plan (this document) was ready for review in October 2005, A draft protocol will be submitted by the end of December 2005 and a final protocol is anticipated by July 2006. This has been clarified in the Protocol Plan text.

9.

Reviewer Comment: [Vital Signs Being Addressed] This may be my interpretation of the original use of Vital Signs, but isn't this a group of vital signs isn't the change in benthic cover or change in coral cover the vital sign?

NPS Response: The Pacific Islands Inventory and Monitoring Network has taken a broad interpretation of what constitutes a vital sign. The vital sign developed by the network was marine benthic communities which includes numerous measures..

10.

Reviewer Comment: [Parks Where Protocol May Be Implemented] Here again is my confusion as to what this document is, and when this will be done. This sentence says "protocol development", but is under a heading of protocol implementation, in a document on the Specifications of the study plan?

NPS Response: Revisions have been made to this section and the cover page to resolve confusion with the timing of this protocol development and implementation.

11.
Reviewer Comment: [Justification] What would be done with more funds?

NPS Response: Funding to conduct long term monitoring is limited. This protocol accounts for the fiscal realities that will limit the number of vital signs and the measures that can be monitored. If more funding were available, additional vital signs could be developed and monitored. A comprehensive, prioritized list of all vital sign is available and included in the PACN Monitoring Plan.

12.
Reviewer Comment: [Justification] Please provide more detail on the relationship of this protocol to the fish protocol. What does conducted in parallel mean?

NPS Response: At this time, it is intended that benthic marine vital sign and the marine fish vital sign will have considerable overlap in design and personnel. We anticipate that these two vital signs will be co-located (sampling design) and will be conducted by the same personnel. The investigators developing these two protocols are working closely together while developing their Protocol Manuals.

13.
Reviewer Comment: [Justification] Is it true that coral reefs all 4 parks are in close proximity to human populations. I have only been to KAHO and didn't get that impression. Maybe a more quantitative description here?

NPS Response: All four parks in this protocol are in close proximity to human populations, especially KAHO. While the park may have a feel of isolation, residential and commercial development is encroaching upon all of KAHO's authorized terrestrial boundaries, and include a major industrial park, a boat marina, and a golf course/residential sub-division. All of these developments either directly abut the coast or have significant connection s to the coastal waters through groundwater.

14.
Reviewer Comment: [Justification] I found this and the next sentence about marine zoning to be confusing. Marine protected areas in FL keys depend upon zoning and differential use and enforcement. Not sure of the comparison to land zoning practices?

NPS Response: This statement has been clarified. Marine zoning is not as well developed in many Pacific Islands as in the Florida Keys. Many islands have no or very little marine zoning, and where zoning may be present, it is poorly enforced.

15.

Reviewer Comment: [Justification] Commonly used in this way but isn't bleaching really a sign of stress more than a stressor?

NPS Response: Correct. The text has been changed to reflect this fact.

16.

Reviewer Comment: [Justification] What was the PACN's #1 vital sign?

NPS Response: Vegetation Communities ranked #1 in the PACN. This has been added to the text of the Study Plan.

17.

Reviewer Comment: [Justification] I thought this acronym (LTEM) had fallen out of favor?

NPS Response: The acronym has been removed from the text.

18.

Reviewer Comment: [Monitoring Objectives] The definition of monitoring supplied defines the development of a monitoring program or technique, not monitoring. Monitoring tracks changes, not tests how to track changes?

NPS Response: Correct. The first sentence has been modified to read "Long-term monitoring involves repeated surveys of organisms and/or environmental parameters at selected sites over time."

19.

Reviewer Comment: [Monitoring Objectives] "Ecosystem integrity" is jargon-y. What is really meant?

NPS Response: This term has been removed and the second sentence now reads "Monitoring may serve as an "early warning system" to detect declining trends (as well as positive changes) in various ecosystem components (e.g., coral cover), hopefully before irreversible change or loss occurs."

20.

Reviewer Comment: [Monitoring Objectives] The **vital sign** or the monitoring of the vital sign or the protocol for monitoring the vital sign will provide information for the following vital signs?

NPS Response: The monitoring of the marine benthic vital sign will provide information on the listed objectives. The text has been adjusted to clarify this point.

21.
Reviewer Comment: [Monitoring Objectives] I had trouble finding the connection here: how does monitoring corals provide information on hydrology?

NPS Response: The provided table has caused confusion with several reviewers and has been modified. However, corals are sensitive to freshwater and in the Pacific Islands, submarine freshwater inputs are important in many PACN parks. Monitoring benthic cover provide valuable information on the presence of submarine discharges.

22.
Reviewer Comment: [Monitoring Objectives] What is meant by "infestation"? Define infestations as it is being used here. Which selected communities?

NPS Response: The provided table has caused confusion with several reviewers and has been modified. However, infestation is terminology required by the National I&M Program. More information about national I&M objective categories can be obtained in the PACN I&M Monitoring Plan. The selected communities will be determined by the Principal Investigators. At this time, the appropriate "selected community" cannot be further defined, but an example has been added to illustrate.

23.
Reviewer Comment: [Monitoring Questions and Objectives] Does rugosity change so much that it can't be done every 5 years &/or episodically?

NPS Response: The Principal Investigator developing the specific Protocol Manuel will consider the appropriate frequency for monitoring. Barring a catastrophic storm, rugosity usually changes slowly over time, and will probably not require annual monitoring.

24.
Reviewer Comment: [Monitoring Questions and Objectives] Which driver or stressor will be measured in Objective 1a? Can driver & stressor be defined here.

NPS Response: No specific drivers or stressors have been identified for monitoring as part of this protocol. The purpose of this protocol is monitor the changes in the benthic community response variable(s) and provide "clues" as to what may responsible for any observed changes. Other protocols are specifically addressing drivers/stressors that may be of direct interest this protocol. These include the Marine Fish Protocol, Erosion and Deposition Protocol, Fisheries Protocol, Water Quality Protocol, and Land Use Protocol among others.

We have used these two terms (stressor/driver) consistent with the national I&M guidelines and the PACN Monitoring Plan.

25.
Reviewer Comment: [Monitoring Questions and Objectives] We're finding often with disease mortality, algae has is [sic] no competition for available space

NPS Response: Agree that algae has little competition for available space following coral mortality from disease. The purpose of this statement is intended to show that some inference as to cause/effect of observed changes can be hypothesized from monitoring results. The parenthetical statement is intended to be solely illustrative.

26.
Reviewer Comment: [Monitoring Questions and Objectives] If rugosity is measured with chain, doesn't this have the potential to cause damage to same place being monitored? Especially in surge prone environs.

NPS Response: Part of the selection criteria for the specific methodology will include the potential for damage. It is against the mission and policies of the NPS to cause damage to the resources under its jurisdiction and an appropriate monitoring method will be selected.

27.
Reviewer Comment: [Monitoring Questions and Objectives] Will rugosity be done at all sites?

NPS Response: The specifics of the monitoring design have not been developed at this time. The Principal Investigators will decide on the best way to measure and where to measure rugosity in the processing of developing the protocol manual.

28.
Reviewer Comment: [Monitoring Questions and Objectives] Same comments as in beginning on the use of this word (reproduction) and how it will be evaluated.

NPS Response: The term reproduction will be removed for reasons stated earlier.

29.
Reviewer Comment: [Monitoring Questions and Objectives] Why is monitoring limited to just between 10-20m?

NPS Response: For logistic and financial reasons, it was necessary to limit to certain aspects of this work. It was felt that a restriction of the sampling frame was necessary, and the 10-20 meter range was selected as the best area in which to focusing monitoring efforts. Many areas coral reef zones in the Pacific islands are hazardous in which to conduct work (e.g., reef crest). These areas were excluded. Deeper zones on the reef did not provide adequate SCUBA bottom time to conduct the necessary work, and exceeding the bottom time is dangerous and against NPS diving regulations. Reef flats posed additional logistic issues associated with public access and installation of monitoring equipment in these shallow water areas could negatively impact other park values (e.g., viewsheds). In the future, as additional funding comes available, it may be with the NPS's interest to investigate establishing monitoring in additional reef locations.

30.
Reviewer Comment: [Monitoring Questions and Objectives] Awkward. What is meant by "frequent occurrence" of planktonic stages for coral larvae?

NPS Response: Many, but not all, coral larvae in the Pacific are planktonic in nature. Larvae of these planktonic species are particular sensitive to wide ranging environmental stressors and large scale oceanographic processes. While corals with planular larvae are equally sensitive to environmental conditions, the non-planktonic nature of their larvae potentially reduces the importance of oceanographic conditions and reduces the potential for exposure to a wide range of adverse environmental conditions. As most planula larvae are planktonic this sentence has been simplified.

31.
Reviewer Comment: [Monitoring Questions and Objectives] I would suggest more frequent monitoring of disease and bleaching at fewer sites rather than annually at all sites. Active disease outbreaks can be easily missed if done just annually.

NPS Response: The timing of monitoring activities and the sampling design will be addressed by the Principal Investigators during the development of the Protocol Manual. For clarity, Objective 2c has been modified to read as follows: "Measure the incidence and severity of coral and algal disease and bleaching at time scales relevant to frequency of outbreaks and park specific needs (e.g., annual measurements and more frequently if physiological stress is deemed important indicator at a specific park)."

32.
Reviewer Comment: [Monitoring Questions and Objectives] "Federal Register 2005" is not found in References.

NPS Response: Reference to the Federal Register (2005) has been added

33.
Reviewer Comment: [Monitoring Questions and Objectives] The link of coral disease to human stressors has been overstated. Changes suggested.

NPS Response: Suggested changes about the links between coral disease and anthropogenic stressors will be adopted as suggested by the reviewer

34.
Reviewer Comment: [Monitoring Questions and Objectives] Add reference(s) for affects of global climate change and disease on reefs.

NPS Response: The following citation has been added: Jones et al., 2004

35
Reviewer Comment: [Monitoring Questions and Objectives] "Rogers et al. 2001" is not in references

NPS Response: Reference for Rogers et al. 2001 has been added.

36.
Reviewer Comment: [Procedures/Basic Approach] Although there are differences between Caribbean and Pacific reefs, it would be useful if we had comparable data for reporting.

NPS Response: This is a good and compelling statement. Comparable data can be obtained from different statistical methods, so while our methods may vary to some extent, data collection in a statistically rigorous design should allow for wider comparisons with other similar programs. Programs that fail to gathered data in a statistically rigorous manner are not comparable. The primary intention of the PACN I&M program is to collect scientifically defensible data that, and secondly to collect data that can be compared to as many other datasets as possible. The following sentence has been added to the end of the first paragraph "In addition, collecting data using a statistically rigorous design allows for comparisons with other monitoring programs at a larger spatial and temporal scale."

37.
Reviewer Comment: [Procedures/Basic Approach] How much area (sq km?) For each park and habitat type? What about other parks that will/might use this? Are there enough people to take enough samples annually?

NPS Response: It will be the responsibilities of the Principal Investigators to develop a monitoring program within the logistic and financial parameters of the PACN. The exact specifics of the design will be addressed in the Protocol Manuel and not in this document

38.

Reviewer Comment: [Procedures/Basic Approach] How will rugosity be measured? See earlier comment.

NPS Response: Specific methodologies will be developed in the Protocol Manuel and are beyond the scope of this document. As part of the process, many methodologies will examined, debated, and compared prior to selecting the methodology that will be the most appropriate to the PACN parks. This paragraph for objective 1b has been changed to read "Rugosity (Objective 1b) will be simultaneously measured on the same benthic transects photographed for percent cover estimates. Specific methodologies will be evaluated during the protocol development and are beyond the scope of this document. Exploratory remote sensing approaches coupled with field rugosity measurements can provide broader spatial scale inference of changes in community structure (Kuffner et al. 2004)." Further explanation of this section is beyond the scope of this study plan.

List of Standard Operating Procedures (SOPs)

The Benthic Marine Community Monitoring Protocol consists of this Protocol Narrative (Chapters 1 through 6) and the following Standard Operating Procedures (SOPs):

Within the narrative we explain the rationale for monitoring substrate cover, settlement, growth, and disease and the specific objectives to be met by the monitoring program. The SOPs will include specific instructions for conducting the Benthic monitoring.

SOP #1: Before the Field Season

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	7/20/2007	Larry Basch	See Track Changes	Corrections, additions		2.00

Purpose

Prior to the field season each year, usually beginning in early spring, observers are required to review the entire benthic protocol, including all SOPs listed in the protocol. This SOP outlines the annual steps to prepare for a field season ensuring the availability of proper equipment prior to the start of monitoring. More detailed descriptions of specific monitoring tasks are given in the SOPs for training observers (SOP #2), outlining safety procedures (SOP #3), using the GPS (SOP #4), preparing for a dive (SOP #5), establishing the sampling plots (SOP #6), and conducting the surveys (SOPs #7,8,9). In addition, this SOP provides procedures for the initial construction of the rugosity chain and coral settlement arrays (CSAs) that, once assembled, should provide years of service with minimal maintenance.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of this SOP. The master equipment list should be updated simultaneously if any SOP associated with or containing gear lists is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix S1.b.

General Preparation and Review

Notebooks and Dive Logs

Notebooks and dive logs from previous surveys need to be reviewed to identify unique events that may be encountered in the current field season. A field notebook for the current survey year should be prepared with columns indicating sampling schedule, observer names, field hours, and unique occurrences. These fields may influence how the data are interpreted and reported. Survey reports are based on information recorded in field notebooks; therefore it is imperative these are clearly organized for ease of field note entry.

Compile Species Lists

Lists of coral species and benthic cover types from previous surveys in a park or local area should be compiled from the existing database and reference manuals to identify benthic cover types which have a probability of being recorded. Prior knowledge of coral species and benthic cover types most likely to be encountered in a park will aid divers and image analysts. Copies of these combined lists should be updated and carried into the field as quick references in helping to identify corals and cover types. Appendix S1.c lists common benthic cover types and coral species at each of the PACN parks.

Load Waypoints

Waypoints for each benthic transect must be loaded onto the Global Positioning System (GPS) unit prior to the start of the field season. Waypoints are the X and Y coordinates for each transect start point and are used to navigate to sampling locations. SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations" contains instructions for generating transect locations in latitude and longitude for each of the PACN parks with their associated Universal Transverse Mercator (UTM) grid coordinates and SOP #4 "Using GARMIN® Global Positioning System (GPS) Units" contains instructions on loading transect locations into the GPS unit.

Prepare Compass Headings

A complimentary list of compass headings and depths should be compiled or updated in advance of the field season for each fixed transect within a park (see SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations"). Paper copies of these compass headings and depths, in addition to the GIS/GPS version, should be carried into the field to ensure that each fixed transect is located at the same point and surveyed as in previous years.

Scheduling Field Work

Sampling Dates

Sampling dates should be scheduled and logistics organized well before the start of each field season. In the northern hemisphere, benthic surveys can be conducted after the first full week of May until the end of September to coincide with diminished wave activity. In the southern hemisphere, surveys can be scheduled after the first full week of November until the end of March. It is preferable to sample at approximately the same time each year (± 1 month) and as early in time as possible at a given park. Inclement weather, rough sea conditions, or personnel workloads may preclude the scheduling of sampling events to specific annual dates. Ideally, the benthic monitoring needs to be scheduled at a time period that (± 1 month) coincides as close in time as possible with other marine protocols (e.g., marine fish) to examine any correlations with other data sets.

Crew

Monitoring efforts within each PACN park require a three to four person crew. Ideally, three people are needed to sample and one to serve as a boat operator/safety diver. Parks may possess site-specific safety requirements, SOP #3 “Safety Protocol” should be reviewed by all personnel prior to entering the field.

Timing and Co-location

Three to four benthic transects should be scheduled for completion each field day (30 total transects annually). Thus, at least ten field days per park will be needed to complete the field portion of this protocol. To maximize efficiency, this protocol can be completed simultaneously with the PACN Marine Fish Protocol. Once transects are set-up, if benthic monitoring is conducted on the same day as fish monitoring, the field work for the PACN Marine Fish Protocol must be completed prior to conducting the field work for Marine Benthic Protocol at each monitoring location to prevent disturbance to, and bias in data on, fish. If co-location and co-visitation occurs, depending on the number of trained personnel available, fewer benthic transects can be done per day, and more days should be scheduled to complete co-located monitoring to ensure safety.

Organizing Supplies and Equipment

Review Equipment Lists

The marine ecologist at each park ensures that all equipment and supplies listed in the tables of Appendix S1.a of this SOP have been compiled, organized, and made ready for the field season at least two months in advance. Advance preparation allows time to make needed repairs and order equipment.

Field Data Forms

Copies of the field data forms (see specific SOPs for each anticipated task) must be made on waterproof paper with waterproof photocopies or printer ink (e.g., Xerox laser/copier; never-tear paper, not Rite-in-rain™).

Reference Manuals

Suggested reference manuals to facilitate identification of organisms encountered in benthic surveys for each park should be available to pertinent staff and the image analyst (Table S1.1). Benthic assemblages vary by park so copies of appropriate reference materials must be available at the specific parks to which they apply and at the duty park or office of the image analysts.

Table S1.1. Suggested reference materials by region and park.

Region and Park	**Reference**
American Samoa	
NPSA	Gosliner, T.M, D.W. Behrens, and G.C. Williams. 1996. Coral Reef animals of the Indo-Pacific. Sea Challengers, Monterey, California, USA.
	Littler, D.S., and M.M. Littler. 2003. South Pacific Reef Plants. Offshore Graphics, Inc., Washington, D.C., USA.
	Madrigal, L.G. 1999. Field Guide of Shallow Water Marine Invertebrates of American Samoa. American Samoa Government Department of Education, Division of Curriculum and Instruction. Pago Pago, American Samoa, USA.
	Payri, C, A. de R. N'Yeurt, and J. Orempuller 2000. Algues de Polyne'sia francaise Algae of French Polynesia. Au Vent des Isles, Editions Tahiti.
	Veron, J.E.N. 2000. Corals of the World. Australian Institute of Marine Science.
Guam/CNMI	
WAPA	Gosliner, T.M, D.W. Behrens, and G.C. Williams. 2004. Coral Reef Animals of the Indo-Pacific. Sea Challengers, Danville, California, USA.
	Littler, D.S., and M.M. Littler. 2003. South Pacific Reef Plants. Offshore Graphics, Inc., Washington, D.C., USA.
	Pauley, G. editor. 2004. Marine biodiversity of Guam and the Marianas. Micronesica **35-36**:3-682.
	Payri, C, A. de R. N'Yeurt, and J. Orempuller 2000. Algues de Polyne'sia francaise Algae of French Polynesia. Au Vent des Isles, Editions Tahiti.
	Randall, R.H. 1977. Life on Guam: Coral Reef. Dept. of Education, Agana, Guam, USA.
	Veron, J.E.N. 2000. Corals of the World. Australian Institute of Marine Science, Townsville, Australia.
Hawaii Parks	
KALA & KAHO	Fenner, D. 2005. Corals of Hawaii: A Field Guide to the Hard, Black and Soft Corals of Hawaii and the Northwest Hawaiian Islands, Including Midway. Mutual Publishing, Honolulu, Hawaii, USA.
	Hoover, J. P. 1999. Hawaii's Sea Creatures, a Guide to Hawaii's Marine Invertebrates. Mutual Publishing.
	Huisman, J.M., I.A. Abbott, and C.M. Smith. 2007. Hawaiian Reef Plants. University of Hawai'i Sea Grant College Program, Honolulu, Hawai'i.
	Kay, E. A. 1979. Hawaiian Marine Shells Reef and Shore Fauna of Hawaii, Section 4: Mollusca. B.P. Bishop Museum, Special Publications **64(4)**:1-653.
	Littler, D.S., and M.M. Littler. 2003 South Pacific Reef Plants. Offshore Graphics, Inc., Washington, D.C., USA.
	Magruder, W.H., and J.W. Hunt. 1979. Seaweeds of Hawaii: A Photographic Identification Guide. Oriental Publishing, Honolulu, Hawaii, USA.
	Maragos, J. 1977 Section 1: Protozoa through Ctenophora. Pages 1-278 *in* D.M.Devaney and L.G. Eldredge, editors. Reef and shore fauna of Hawaii. Bishop Museum Press, Honolulu, Hawaii, USA.
	Veron, J.E.N. 2000. Corals of the World. Australian Institute of Marine Science, Townsville, Australia.

Table S1.1 Suggested reference materials by region and park (continued)

Region and Park	Reference
All Parks	
	Abbott, I.A. 1999. Marine Red Algae of the Hawaiian Islands. Bishop Museum Press, Honolulu, Hawaii, USA.
	Abbott, I.A., and J.M. Huisman. 2004. Marine Green and Brown Algae of the Hawaiian Islands. Bishop Museum Press, Honolulu, Hawaii, USA.
	Fabricius, K., and P. Alderslade. 2001. Soft corals and Sea Fans: A Comprehensive Guide to the Tropical Shallow Water Genera of the Central-West Pacific, the Indian Ocean and the Red Sea. Australian Institute of Marine Science, Townsville, Queensland, Australia.
	Payri, C, A. de R. N'Yeurt, and J. Orempuller 2000. Algues de Polyne'sia francaise Algae of French Polynesia. Au Vent des Isles, Editions Tahiti..
	Huisman, J.M., I.A. Abbott, and C.M. Smith. 2007. Hawaiian Reef Plants. University of Hawai'i Sea Grant College Program, Honolulu, Hawai'i.

Camera Gear

Camera gear will be overhauled and tested as appropriate. Camera functional tests and seal tests must be performed (see SOP #5 "Pre-Dive Equipment Preparation"), and replacement supplies ordered and tested. The Olympus® C-5050 or similar camera uses four AA size Nickel-Metal Hydride (NiMH) rechargeable batteries. Prior to loading new batteries, label each new battery with the date and number (using a permanent marker). Each park will have its own camera setup with a backup camera based at the I&M office at Hawaii Volcanoes National Park . It is anticipated that parks will eventually upgrade to digital SLR cameras as technology advances.

Boat, Motor and Trailer

Boat, trailer, and motor servicing should be independently verified for each park for field operation. Ensure that this required preparation has been done in accordance with the Department of Interior (DOI) Motorboat Operator Manual and park specific SOPs. Park-specific SOPs can be obtained from the Park Dive Officer or the certified motorboat operator at each park. Benthic Marine Protocol SOP #16 "After the Field Season" also outlines the required post-field season maintenance for each.

Dive Gear

Prior to the start of the field season all dive gear should be checked, serviced, and tested as required by Reference Manual #4 – Diving Management (RM-4). Verify that required annual inspections and maintenance were completed for the gear in Table S1.2.

Table S1.2. Scuba gear requiring periodic inspection and maintenance.

Equipment	Certification or Required Service
Air cylinders	VIP certification (annually), check o-rings, hydrostatic testing for expired cylinders (once every 5 years)
Regulators	Annual Service
Buoyancy compensators	Annual Service

Transect Lines

New transect lines should be purchased or old transect lines reconditioned for conducting the benthic cover survey as described in SOP #5 "Pre-Dive Equipment Preparation" and SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys."

Rugosity Equipment Preparation

This section details preparation of the rugosity chain used to conduct *in situ* rugosity measurements. It is important to standardize the link size across parks to insure comparability of the rugosity values. Once the initial chain has been assembled it should provides years of service with little maintenance. Use of the rugosity chain is described in detail in SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys"

Procedures:

Step 1: Use a 10 m light brass chain with 1.5 cm links (Figure S1.1). Plastic chain links may be interspersed between the metal links to minimize impact on the substrate but this is only advised in low water motion environments.

Step 2: Label the chain at 1 m intervals using orange or yellow flagging tape. At 5 m it is useful to label the chain with two markers so that it is easier to count the 1 m segments.

The chain should be on a spool that is easy to deploy. Often hardware stores will have extra plastic reels that they use for rope or chain that one can acquire for free. Dive reels (http://www.reefscuba.com/reelsindex.htm, accessed 9 June2006) are another option that is more convenient for deployment and retrieval, but they are costly.

A. 

B. 

Figure S1.1. Example of 2 links on a rugosity chain from a top (A) and side (B) view.

Coral Settlement Array (CSA) Construction and Preparation

This section details the materials and procedures to construct the Coral Settlement Arrays (CSAs). The finished product is a plate array (sampling unit) comprised of two terracotta tiles separated by a PVC spacer leaving a 1 cm gap between the tiles. The tile pair is installed on a CSA mounting pin (see SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations") such that the terracotta plate is approximately 15 cm off the substrate (Figure S1.2). The underlying PVC plate provides the array with a uniform underlying "substratum" that might not be present if the natural benthos is used. Details of CSA installation and retrieval can be found in SOP #8 "Conducting Coral Settlement Sampling."

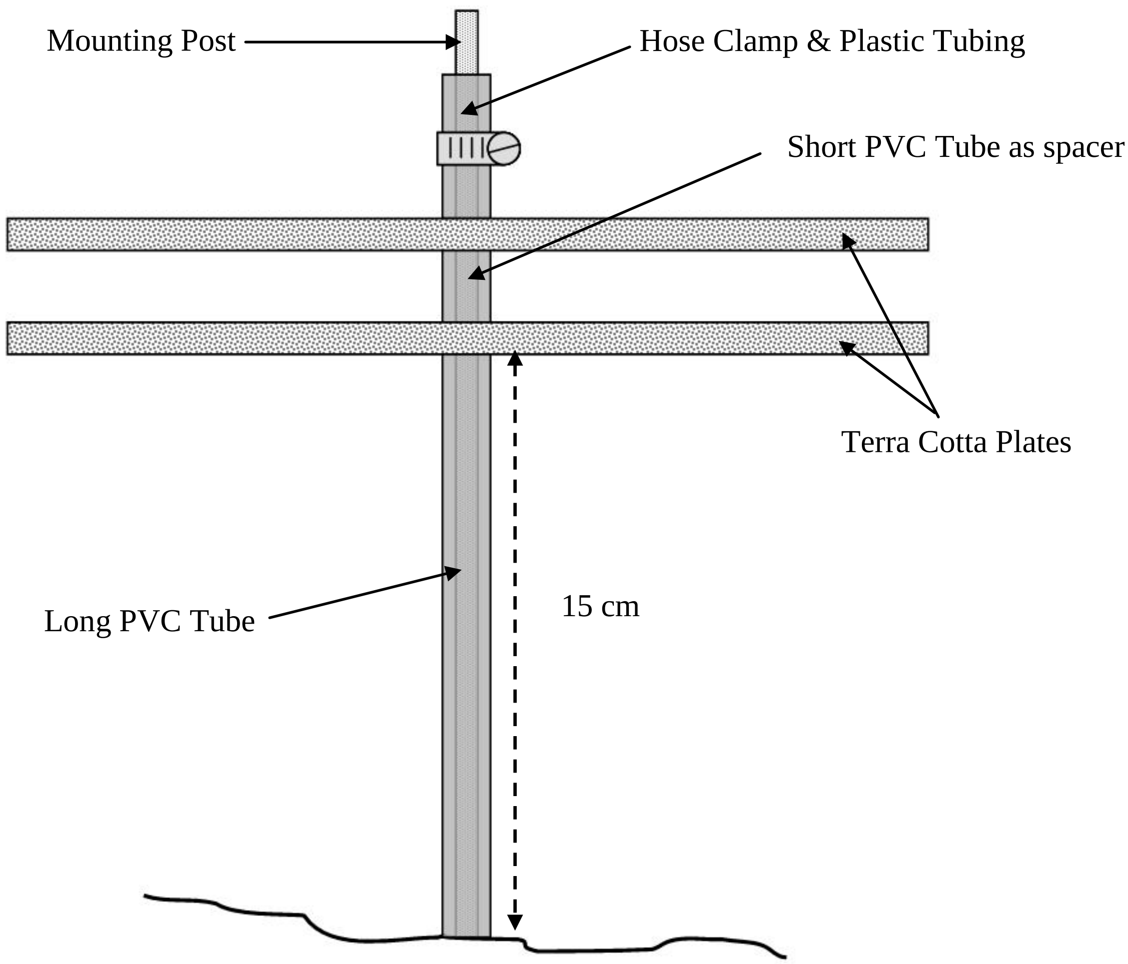


Figure S1.2. Settlement tile array showing the plate pair attached to the 45 cm stainless threaded rod.

Materials for Coral Settlement Array:
Equipment necessary to construct 45 CSAs (15 fixed sites x 3 CSAs each) can be found in Appendix S1.b. It is important that the material used for plate construction remain as uniform as possible among all CSAs. It is recommended that a large supply of red-brick colored terra cotta tiles be purchased at once for several years use. If replacement plates are required at a later date, the same manufacturer, plate material and finish should be used to maintain some level of consistency of the tile materials.

Construction of One Plate Pair:
Step 1: Cut the stainless steel threaded rods in quarters (approximately 45 to 50 cm lengths) with at least one end cut at an angle. Use a miter saw with a diamond edged blade to cut the steel rod. A hand-held grinder outfitted with a cutting wheel can also be used.

Step 2: At this and other steps, it is important to minimize handling of tiles and exposure to metal, filings, oil (from fingers, etc.), or any other possible contaminants that will affect larval settlement to the tiles, as these can severely bias data. If necessary, cut the Sunshine Paver tiles in half to yield two plates with dimensions of 10 cm (4”) X 10 cm (4”) X 1.3cm (1/2”). Use a table saw with a rock cutting blade and water cooling system to cut the tiles.

Step 3: Drill a 1.25 cm (1/2”) hole through the center point of both terracotta tiles. Use a standard drill press with a masonry bit. When drilling it is often good to pour water on the bit to keep it cool and prevent the tile from cracking. Tiles can even be placed in a clean water bath during the drilling operation to reduce cracking from heat expansion. Replace the drill bit after every 10 tiles, if necessary; a dull drill bit will cause the tiles to break during drilling.

Step 4: Construct a mock-up of the CSA using Figure S1.2 as a guide. The 15 cm PVC pipe should slide over the stainless steel rod and be on the bottom sitting on the substrate. The lower terracotta tile should sit on top of this section of pipe. Then, place the 1 cm PVC pipe section above the lower tile and upper terracotta tile. Next, slide the 5 cm plastic tubing over the stainless steel rod to lock in the upper tile. Finally, affix the 2 cm hose clamp to the plastic tubing and tighten to secure the assembly to the rod. Alternatively, one can use a stainless steel threaded rod as the post with stainless steel nuts and washers to construct the CSA. The nuts and washers would be placed above and below the tiles to position them in the appropriate locations. The 1 cm PVC pipe should still be used as a spacer between tiles.

Step 5: Using an ultra fine point Sharpie marker, or an engraver, label each plate pair on an edge noting transect, tile number, date deployed, and with an arrow indicate which tile face is placed up. The following notation should be used (T5-23U-20060715↑) indicating transect 5, tile number 23 Upper, deployed on July 15th, 2006, and with the arrow showing which tile face is oriented up toward to the surface. If the deployment date is unknown, leave blank until the required information is available.

Step 6: Deconstruct the mock-up of the CSA and prepare the tiles as outlined below in “Coral Settlement Tile Preparation.”

Step 7: Repeat the preceding steps until all plate pairs have been constructed

Coral Settlement Tile Preparation for re-use of the Tiles:
At least a month prior to the start of the field season, prepare the tiles for the current season by following these instructions. CSAs should provide many years of service with routine maintenance. Reusing the tiles each year also cuts down on the waste, reduces costs, shortens preparation time, and does not seem to adversely affect settlement rates (e.g., Friedlander and Brown 2006). To address possible biases in settlement, a paired experiment will be run during the first year at KALA and WAPA with both new and used plates. If differences are found in the settlement rate between tile treatments then the protocol will be altered accordingly.

Step 1: Once the coral settlement tiles have been examined microscopically, they should be soaked in vinegar two to three days to dissolve calcareous skeletons from the prior year. Previous experience has shown that the vinegar solution does not change the tiles surfaces and therefore does not result in a sampling bias among years.

Step 2: Gently scrub tiles with a toothbrush.

Step 3: Soak tiles in tap water for another two to three days.

Step 4: Allow tiles to dry.

Step 5: Using an ultra fine point Sharpie marker, label each plate pair on an edge noting transect, tile number, date deployed, and with an arrow indicating which tile face is placed up. The following notation should be used (T5-23U-20060715↑) indicating transect 5, tile number 23 Upper, deployed on July 15th, 2006, and with the arrow showing which tile face is oriented up toward the surface. If the deployment date is unknown, leave blank until the information is available.

Step 6: Store tile pairs in a safe place until ready to re-deploy.

References

Friedlander, A.M., and E.K. Brown. 2006. Hanalei Bay, Kaua`i marine benthic communities since 1992: Spatial and temporal tends in a dynamic Hawaiian coral reef ecosystem. Technical Report 003, HCSU [Hawaii Cooperative Studies Unit], Hawaii Cooperative Studies Unit, University of Hawai`i at Hilo, Hawaii, USA.

Appendix S1.a. Equipment Lists

1) Equipment list for preparing digital still camera for use in the Benthic Marine Communities Vital Sign Monitoring Protocol. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation.”

Equipment (#/quantity)	Preparation & Maintenance
Digital still camera	See SOP #5 “Pre-Dive Equipment Preparation”
U/W housing	See SOP #5 “Pre-Dive Equipment Preparation”
Flat port	See SOP #5 “Pre-Dive Equipment Preparation”
NiMH – rechargeable AA camera batteries (4)	Label and charge
Compact flash cards size/capacity (2)	See SOP #5 “Pre-Dive Equipment Preparation”
Lens cleaner	Ensure that this equipment is available
Lens paper	Ensure that this equipment is available
Clean, lint free cloth (2)	Ensure that this equipment is available
O rings	See SOP #5 “Pre-Dive Equipment Preparation”
Silicone	Ensure that this equipment is available
Monopod or photoquadrat	See SOP #5 “Pre-Dive Equipment Preparation”
Red filter for camera lens	See SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
Monopod with camera mount	Ensure that this equipment is available

2) Equipment list for installing permanent transect marking pins. This equipment list refers to SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”

Equipment (#/quantity)	Preparation and Maintenance
1 cm (3/8”) X 40 cm (16”) stainless steel threaded rod (2+)/transect	More, or longer pins may be necessary if conditions warrant
Z-spar or Powerfast Epoxy (1 ea.)	Ensure that 1 gallon of A&B (Z-Spar) or 1 tube (Powerfast) is available, in good condition
Mesh bag (1)	Ensure that this equipment is available
Tupperware containers for Z-spar (2)	One for each part of (A&B) of Z-spar compound; Ensure that this equipment is available
2 or 5 lb. Sledge hammer (2)	One for back up; Ensure this equipment is available
30 m transect line (2)	Labeled at 50 cm intervals; see SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, and/or maps of transect locations	See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS (1), with charged batteries	See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
Surface float marker (2)	One for back-up; Ensure that this equipment is available
U/W slate with pencil (2)	Ensure that this equipment is available
U/W lights (2)	Ensure that this equipment is available
U/W light rechargeable batteries (2 sets)	Ensure that this equipment is available
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation”
Boat, motor, trailer, and associated gear	See SOP #5 “Pre-Dive Equipment Preparation”

3) Equipment list for conducting marine benthic cover surveys. This equipment list is refers to SOP #5 “Pre-Dive Equipment Preparation” and SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys.”

Equipment (#/quantity)	Preparation & Maintenance
Digital still camera prepared and mounted into U/W housing and monopod	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
Small wire brush to clean pins and coral colony labels	Ensure that this equipment is available
30 m transect line	Labeled at 50 cm intervals, see SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, and/or maps of transect locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS (1)	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
Surface float marker (2)	One for back-up; Ensure that this equipment is available
U/W slate with pencil (2)	Ensure that this equipment is available
U/W field data forms	See SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
U/W lights (2)	Ensure equipment is in working order
U/W light rechargeable batteries (2 sets)	Ensure equipment has sufficient power
Pelican case to store equipment (e.g., GPS) on boat.	Ensure that this equipment is available
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

4) Equipment list for conducting benthic rugosity measurements. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” and SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys.”

Equipment (#/quantity)	**Preparation & Maintenance**
Marked 10 m rugosity chain on spool	See SOP #1 “Before the Field Season”
30 m transect line	See SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations” SOP #5, “Pre-Dive Equipment Preparation” and check database and log book.
GPS (1), with charged batteries	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencil (2)	Ensure that this equipment is available
U/W field data forms	See SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
U/W lights (2)	Ensure equipment is in working order
U/W light rechargeable batteries (2 sets)	Ensure equipment has sufficient power
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

5) Equipment list for installation and retrieval of the coral settlement arrays. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation,” SOP #6 “Selecting and Marking Subtidal Sampling Transect Location,” and SOP #8 “Conducting Coral Settlement Sampling.”

Equipment (#/quantity)	**Preparation & Maintenance**
Digital still camera prepared and mounted into U/W housing and monopod	See SOP #5 “Pre-Dive Equipment Preparation”
White slate to set white balance on camera	Ensure that this equipment is available
Coral settlement arrays	3 plate pairs per transect; See SOP #1 “Before the Field Season” for construction and labeling information
Cooler to hold CSAs (2-3)	Ensure that this equipment is available
Ice	Ensure that this equipment is available
Foam pad (1 per cooler)	Ensure that this equipment is available
Pliers and flat head screwdriver (2)	2 of each; Ensure that this equipment is available
5 pound sledge hammer (2)	Ensure that this equipment is available
1 cm (3/8”) x 50 cm (20”) stainless steel threaded rods (3)	Ensure that this equipment is available
Plastic 90 degree angle protractor	Ensure that this equipment is available
Z-spar or Powerfast Epoxy (1 ea.)	Ensure that 1 gallon of A&B (Z-Spar) or 1 tube (Powerfast) available
Underwater drill	Ensure equipment is in working order
Re-usable tags (at least 45 – 1/CSA))	See SOP #8 “Conducting Coral Settlement Sampling”
Engraver, dremel drill, or similar tool	See SOP #8 “Conducting Coral Settlement Sampling”
30 m transect line (2)	labeled at 50 cm intervals; see SOP #1 “Before the Field Season”
Heavy duty, pre-labeled re-sealable plastic bags	See SOP #8 “Conducting Coral Settlement Sampling”
Mesh gear bags (1)	Ensure that this equipment is available
Repair supplies (new threaded rods, epoxy, spare hardware)	See SOP #8 “Conducting Coral Settlement Sampling”
Coordinates, depths, compass headings, maps of CSA locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations” and SOP #8 “Conducting Coral Settlement Sampling”
GPS (1)	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencil (2)	Ensure that this equipment is available
U/W field data forms	Ensure sufficient number of copies available
U/W lights (2)	Ensure equipment is in working order

5) Equipment list for installation and retrieval of the coral settlement arrays. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation,” SOP #6 “Selecting and Marking Subtidal Sampling Transect Location,” and SOP #8 “Conducting Coral Settlement Sampling.” (continued)

Equipment (#/quantity)	Preparation & Maintenance
U/W light rechargeable batteries (2 sets)	Ensure equipment has sufficient power
Pelican case (1)	Ensure equipment is available
Surface float marker (2)	one for back-up; Ensure equipment is available
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

6) Equipment list for processing coral settlement arrays (CSAs). For more information, see SOP #14 “Data Management – Settlement Analysis.”

Equipment (#/quantity)	Preparation & Maintenance
10% bleach solution (3-4 gal/tray)	Solution can be re-used
Tray for bleach solution	Tray (s) can be any size as long as tiles are immersed in solution
Bubble wrap (1 sheet per plate)	Used for dry plate transport, storage

7) Equipment list for microscopic analysis of coral settlement arrays (CSAs). For more information, see SOP #14 “Data Management – Settlement Analysis.”

Equipment (#/quantity)	Preparation & Maintenance
Dissecting microscope (6-50x)	Ensure has swing arm stand, ocular micrometer, and phototube
Light source (1) and spare bulbs (2)	Ensure equipment is ready and available
Foam pad/bubble wrap (2-3)	Used for resting tile on
Blue or black fine tip permanent marker (2)	Ensure equipment is ready and available
Probe for cleaning debris on tile (2)	Ensure equipment is ready and available
Bench counter	Ensure equipment is ready and available
Digital camera with	Ensure equipment is ready and available

8) Equipment list for cleaning coral settlement plates. For more information, see SOP #14 “Data Management – Settlement Analysis.”

Equipment (#/quantity)	Preparation & Maintenance
Household vinegar (3-4 gal/tray)	Ensure equipment is ready and available
Tray for vinegar	Tray (s) can be any size as long as tiles are immersed in solution. Ensure equipment is ready and available
Bubble wrap (1 sheet per plate)	Used for plate storage; ensure equipment is ready and available
Toothbrush (1)	Ensure equipment is ready and available
Microscope or hand lens (1)	Ensure equipment is ready and available

9) Equipment list for tagging and conducting the coral growth measurements. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” and SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations.”

Equipment (#/quantity)	**Preparation & Maintenance**
1 m flexible fiberglass measuring tape with centimeter markings	Ensure that this equipment is available
Calipers	Ensure that this equipment is available
Stainless steel wire or cable ties (12 with 2 of these extra)/transect	Ensure that this equipment is available
Dymo labels made of plastic (10)	See SOP #1 “Before the Field Season”
Metal or plastic tags (10)	See SOP #9 “Measuring Coral Growth”
Small hole punch (2)	Ensure that this equipment is available
Small wire brush (2)	Ensure that this equipment is available
Flagging tape (2 rolls)	Ensure that this equipment is available
Mesh gear bags (2)	Ensure that this equipment is available
Weighted object for marking sites (e.g., Pelican float)	Ensure that this equipment is available
30 m transect line	Labeled at 50 cm intervals; see SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS (1)	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencil (2)	Ensure that this equipment is available
U/W field data forms	See SOP #9 “Measuring Coral Growth”
U/W lights (2)	Ensure equipment is in working order
U/W light rechargeable batteries (2 sets)	Ensure equipment has sufficient power
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

10) Equipment list for conducting diving activities. This equipment list refers to SOP #5 "Pre-Dive Equipment Preparation" section on Dive Equipment Preparation.

Equipment (#/quantity)	Preparation & Maintenance
Air cylinders	Verify hydro and VIP, fill with compressed air or NITROX. See SOP #16 "After the Field Season"
Fins	Ensure that this equipment is available
Booties	Ensure that this equipment is available
Wetsuit	Ensure that this equipment is available
Hooded vest (optional)	Ensure that this equipment is available
Weights	Ensure that this equipment is available
Belt/integrated weight container	Ensure that this equipment is available
BC	Verify annual service. See SOP #16 "After the Field Season"
Regulator	Verify annual service. See SOP #16 "After the Field Season"
Mask & Snorkel	Ensure that this equipment is available
Dive computer	Ensure that this equipment is available
Thermometer	Ensure that this equipment is available
Compass	Ensure that this equipment is available
Knife, dive tool, or shears	Ensure that this equipment is available
Rescue "sausage" (international orange)	Ensure that this equipment is available
Whistle or surface noise maker	Ensure that this equipment is available
Underwater noise maker (e.g., subduck, knife)	Ensure that this equipment is available
Save a dive kit	Ensure that this equipment is available
Dive tables as backup	Ensure that this equipment is available
Spare gear (mask, fin, snorkel, straps, cable ties, O-rings, other as needed)	Ensure that this equipment is available
Brass clips – attached to BC, gear bags, or equipment (e.g., camera housing, hammers)	Ensure that this equipment is available
Dive bag for boat work	Ensure that this equipment is available
Bucket for shore work	Ensure that this equipment is available

11) Equipment list for operating motor boats. This equipment list refers to SOP #16 “After the Field Season.”

Equipment (#/quantity)	Preparation & Maintenance
DAN O2 kit	Ensure that this equipment is available
Dive flag	Ensure that this equipment is available
Flares	Ensure that this equipment is available
Survival kit (with signal mirror)	Ensure that this equipment is available
Extra water	Ensure that this equipment is available
PFDs for each person	Ensure that this equipment is available
Spare tool and parts kit (See equipment list below.)	Ensure that this equipment is available
EPIRB	Ensure that this equipment is available
First aid kit	Ensure that this equipment is available
VHF and park radio or cell phone	Ensure that this equipment is available
Water intake “rabbit ears”	Ensure that this equipment is available
Water hose	Ensure that this equipment is available
Battery	Ensure that this equipment is available
Battery charger	Ensure that this equipment is available
Fuel tanks (ncluding one extra, full)	Ensure that this equipment is available
Fuel filter	Ensure that this equipment is available
Outboard motor leg oil	Ensure that this equipment is available
Impeller	Ensure that this equipment is available
Propeller	Ensure that this equipment is available
Mooring lines	Ensure that this equipment is available
Anchor, chain, and line	Ensure that this equipment is available
Bilge pump	Ensure that this equipment is available
Fire extinguisher	Ensure that this equipment is available, in operating condition
Compass	Ensure that this equipment is available
GPS/plotter	Ensure that this equipment is available
Depth finder	Ensure that this equipment is available

12) Equipment list for collecting information on environmental variables. This equipment list refers to conducting any of the surveys associated with this protocol.

Equipment (#/quantity)	Preparation & Maintenance
Hobo temperature pro data loggers	Ensure that this equipment is available
Cable ties	Ensure that this equipment is available
Wire cutters	Ensure that this equipment is available

13) Equipment list for permanent transect pin maintenance, as needed.

Equipment (#/quantity)	Preparation & Maintenance
Pins (threaded stainless steel rod)	Ensure that this equipment is available
Z-spar (or other 2-part marine epoxy)	Ensure that this equipment is available
Cable ties	Ensure that this equipment is available
Mesh bag	Ensure that this equipment is available
Tupperware containers	Ensure that this equipment is available
Sledge hammer	Ensure that this equipment is available
Slate and pencils	Ensure that this equipment is available

14) Equipment list for tools and repairs, as needed.

Equipment (#/quantity)	Preparation & Maintenance
Fin and mask straps	Ensure that this equipment is available
O rings	Ensure that this equipment is available
Electrical tape	Ensure that this equipment is available
Duct tape	Ensure that this equipment is available
Pliers	Ensure that this equipment is available
Wire cutters	Ensure that this equipment is available
Cable ties	Ensure that this equipment is available
Snorkel keepers	Ensure that this equipment is available
Multimeter	Ensure that this equipment is available
Multi purpose tool (e.g., Leatherman)	Ensure that this equipment is available
Boat equipment (e.g. spark plugs, fuel line, priming bulb, shackles, bailing wire, pliers, wrench, tape)	Ensure that this equipment is available

15) Equipment list for other equipment needed to complete any of the surveys in this protocol.

Equipment (#/quantity)	Preparation & Maintenance
Secchi disk	Ensure that this equipment is available
Dive float lines (10m and 15m)	Ensure that this equipment is available
Rubbermaid container with lid	Container can be any size to help stow equipment and/or tiles on the boat. Ensure that this equipment is available
GPS with waterproof cover	Ensure that this equipment is available
U/W paper	Ensure that this equipment is available
Dry bag for boat work	Ensure that this equipment is available
Pelican float for marking waypoints	Ensure that this equipment is available

16) Equipment list for paperwork needed to complete any of the surveys in this protocol.

Equipment (#/quantity)	**Preparation & Maintenance**
Permits	Ensure that this equipment is available
Log book for documenting dives and accomplishments.	Ensure that this equipment is available
Charts and grid layouts	Ensure that this equipment is available
Call local marine enforcement agency as appropriate (e.g., DOCARE 808 984-8110)	Ensure that this equipment is available
Pencils	Ensure that this equipment is available
Pens	Ensure that this equipment is available
Eraser	Ensure that this equipment is available
Permanent marker	Ensure that this equipment is available

Don’t forget lunch and liquids (to keep hydrated)!

Appendix S1.b. Equipment list for preparation of gear from this SOP

Equipment	Quantity	Notes
1 cm (3/8") X 183 cm (6') stainless steel threaded rod	12	Can be purchased from Fastening Specialty in Honolulu, Hawaii (808-486-3440) (Item # TR386SS-CNM). Each threaded rod will yield enough mounting brackets for 4 CSAs.
Sunshine Pavers 20cm (8") X 10cm (4") X 1.3cm (1/2") unglazed terracotta tiles that have a wire cut texture	60	Can be purchased from: Florida Brick and Clay Company, 1708 Turkey Creek Road, Plant City, Florida 33567. Or from: Tile Mart 855 Ahua St Honolulu, HI 96819 Phone: (808) 839-1952 Fax: (808) 834-0963 www.tilemart.com/products.html Purchasing a least 60 tiles will leave 30 tiles as spares in case some get broken in transport, construction or use.
15cm (5.5") X 2.5cm (1") diameter PVC pipe	45	PVC piping can be purchased from any local hardware store or plumbing supplier (rinse PVC to remove plastic dust and filings after cutting before assembling CSAs). Keep PVC and other parts clean to prevent contamination
1cm(1/2") X 2.5cm (1") diameter PVC pipe	45	PVC piping can be purchased from any local hardware or plumbing supplier (rinse PVC to remove plastic dust and filings after cutting before assembling CSAs).
5cm (2") by 2.5cm (3/8") length of clear food grade, plastic tubing	45	Plastic tubing can be purchased from any local hardware or plumbing supplier.
2cm (3/4") stainless steel hose clamp	45	Hose clamps can be purchased from any local hardware or plumbing supplier.
1.3cm (1/2") diameter masonry drill bit	12	Bit should be changed after every ~10 tiles, as necessary
Miter saw with diamond edged blade	1	Hacksaw also will work
Table saw with rock cutting blade	1	Bench model is ok.
Drill press	1	Bench model is ok.
Ultra fine point sharpie	1	

Appendix S1.c. Preliminary list of benthic cover types or substrates by park

Kalaupapa National Historical park - KALA	
Substrate Type	Taxon
Algae	*Acanthophora spicifera*
Algae	*Asparagopsis taxiformis*
Algae	Cyanobacteria
Algae	*Dictyota* sp.
Algae	*Gelidiopsis scoparia*
Algae	*Lobophora variegata*
Algae	*Melanamansia glomerata*
Algae	*Padina japonica*
Algae	*Padina melemele*
Algae	*Sargassum echinocarpum*
Algae	*Sargassum polyphyllum*
Algae	*Stypopodium flabelliforme*
Algae	Coralline algae
Algae	Macro algae
Algae	Turf algae
Coral	*Cyphastrea agassizi*
Coral	*Cyphastrea ocellina*
Coral	*Fungia scutaria*
Coral	*Leptastrea bewickensis*
Coral	*Leptastrea pruinosa*
Coral	*Leptastrea purpurea*
Coral	*Leptastrea transversa*
Coral	*Leptoseris incrustans*
Coral	*Leptoseris mycetoseroides*
Coral	*Montipora capitata*
Coral	*Montipora flabellata*
Coral	*Montipora incrassata*
Coral	*Montipora patula*
Coral	*Pavona duerdeni*
Coral	*Pavona varians*
Coral	*Pocillopora damicornis*
Coral	*Pocillopora eydouxi*
Coral	*Pocillopora ligulata*
Coral	*Pocillopora meandrina*
Coral	*Pocillopora molokensis*
Coral	*Porites brighami*
Coral	*Porites* cf. *bernardi*

Preliminary list of benthic cover types or substrates by park, for Kalaupapa National Historical Park (KALA) (continued)

Substrate Type	Taxon
Coral	*Porites compressa*
Coral	*Porites lobata*
Coral	*Porites lutea*
Coral	*Psammocora nierstraszi*
Coral	*Psammocora verrilli*
Invert	*Acanthaster planci*
Invert	*Anthelia edmondsoni*
Invert	*Diadema paucispinum*
Invert	*Echinometra mathaei*
Invert	*Echinostrephus aciculatus*
Invert	*Echinothrix calamaris*
Invert	*Echinothrix diadema*
Invert	*Heterocentrotus mammillatus*
Invert	Holothuroidea
Invert	*Palythoa caesia*
Invert	Porifera
Substrate	Other
Substrate	Non/Coral – for survey objects.
Substrate	Bare rock
Substrate	Sand
Substrate	Silt
Substrate	Unknown

War in the Pacific National Historical park - WAPA	
Substrate Type	Taxon
Algae	Chlorophyta
Algae	Corallinales
Algae	Cyanophyta
Algae	*Halimeda*
Algae	Heterokonta
Algae	Macro algae
Algae	Rhodophyta
Algae	Turf algae
Coral	*Acanthastrea echinata*
Coral	*Acropora specifera*
Coral	*Acropora* sp. (unknown)
Coral	*Astreopora gracilis*
Coral	*Astreopora myriopthalma*
Coral	*Astreopora randalli*
Coral	*Astreopora* sp.
Coral	*Coscinaraea columna*
Coral	*Cyphastrea chalcidicum*
Coral	*Cyphastrea serailia*
Coral	*Cyphastrea* sp.
Coral	*Diploastea heliopora*
Coral	*Echinopora lamellosa*
Coral	*Favia favus*
Coral	*Favia pallida*
Coral	*Favia stelligera*
Coral	*Favia* sp.
Coral	*Favites abdita*
Coral	*Favites russelli*
Coral	*Favites* sp.
Coral	*Galaxea fascicularis*
Coral	*Goniastrea edwardsi*
Coral	*Goniastrea pectinata*
Coral	*Goniastrea retformis*
Coral	*Goniastrea* sp.
Coral	*Goniopora* sp.
Coral	*Hydnophora microconos*
Coral	*Leptastrea purpurea*
Coral	*Leptastrea transversa*
Coral	*Leptastrea* sp.

Preliminary list of benthic cover types or substrates by park, for War in the Pacific National Historical park (WAPA) (continued)

Coral	*Leptoria phrygia*
Coral	*Lobophyllia corymbosa*
Coral	*Lobophyllia hemprichii*
Coral	*Lobophyllia* sp.
Coral	*Monastrea curta*
Coral	*Montipora foveolata*
Coral	*Montipora* sp.
Coral	*Montipora verrucosa*
Coral	*Oulophyllia crispa*
Coral	*Pavona decussata*
Coral	*Pavona* sp.
Coral	*Pavona varians*
Coral	*Pavona venosa*
Coral	*Platygyra daedalea*
Coral	*Platygyra pini*
Coral	*Platygyra* sp.
Coral	*Pocillopora damicornis*
Coral	*Pocillopora* sp.
Coral	*Pocillopora verrucosa*
Coral	*Porites annae*
Coral	*Porites cylindrica*
Coral	*Porites lichen*
Coral	*Porites lobata or lutea*
Coral	*Porites rus*
Coral	*Porites superfusa*
Coral	*Porites* sp.
Coral	*Psammocora contigua*
Coral	*Psammocora profundacella*
Coral	*Psammocora* sp.
Coral	*Scapophyllia cylindrica*
Coral	*Stylocoeniella armata*
Coral	*Stylocoeniella guentheri*
Coral	*Stylocoeniella* sp.
Invert	*Acanthaster planci*
Invert	Echinoid
Invert	Helioporacea (bluecoral)
Invert	Hexacorallia (anemone)
Invert	Millepora (firecoral)

Preliminary list of benthic cover types or substrates by park, for War in the Pacific National Historical park (WAPA) (continued)

Invert	Mollusk
Invert	Octocorallia
Invert	Porifera
Invert	Tunicata
Miscellaneous	Bleached
Miscellaneous	Cobble
Miscellaneous	Ref_Pole
Miscellaneous	Ref_Tape
Miscellaneous	Bare Rock
Miscellaneous	Rubble
Miscellaneous	Sand

These lists will be developed for KAHO and NPSA as the program develops.

SOP #2: Training Observers

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.0	6/30/2007	Eric Brown	See track changes	Response to reviewer's comments		1.00
2.01	7/20/2007	Larry Basch	See track changes	Additions, corrections		2.00

Purpose

This Standard Operating Procedure outlines the requirements and training procedures that field staff and office analysts should follow. All field personnel should: (1) have National Park Service (NPS) bluecard diving certification; (2) DOI Motorboat operator certification; (3) know how to operate survey gear such as underwater cameras, transect lines, Global Positioning System (GPS) units, and rugosity chains, and (4) know basic computer software such as MS-Word®, MS-Excel®, and Photogrid©. Office personnel need to know: (1) data management principles, infrastructure, and practices associated with this Vital Sign; (2) typical coral settlement species identification and general principles of identification for unanticipated/unknown species; (3) SOPs associated with field data collection practices; (4) Photogrid© and Photoshop® software and sound statistical background for analyses; (5) know how to identify substrate types, and; (6) analysis and reporting principles outlined in the SOPs associated with this protocol. The use of products identified in this protocol does not imply endorsement, effectiveness, or warranty by NPS.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Field Personnel

NPS Blue Card Certification

An essential component for conducting the underwater benthic marine community surveys is that divers maintain current NPS bluecard certification or have approved diving reciprocity. Divers from some outside organizations (e.g., AAUS, NOAA) may take part in diving operations provided they have obtained a letter of reciprocity (LOR) from their Dive Safety Officer (DSO) and this LOR has been approved by the Park Dive Officer (PDO) prior to diving within that specific park.

All scuba divers must adhere to the requirements outlined in NPS Reference Manual #4 "Dive Management" (RM-4) and the Dive Safety Manual specific to their park of origin. All scuba divers must be familiar with reference materials required for NPS bluecard certification (Table S2.1).

Table S2.1. References required for dive certification, including location where permanent copies can be located.

Reference	Location
Open Water Certification Manual for nationally recognized dive training organization (e.g., PADI, NAUI)	I&M Library
NPS RM-4 (complete manual)	I&M Library
Dive Safety Manual specific to each park	Available at each park

All field scuba diving personnel must spend time diving prior to the field season to obtain/maintain proficiency in buoyancy control. Someone skilled in maintaining buoyancy control underwater will have less trouble transporting gear, deploying and retrieving equipment, photographing the benthos, and conducting measurements on the substrate. In addition, divers with good buoyancy control will be less apt to damage the substrate during surveys.

NPS Motorboat Operator Certification

All employees who will operate motorboats must pass the DOI motorboat operator course prior to conducting field operations. Exceptions may be granted for personnel operating a boat under the supervision of an DOI motorboat operator instructor. All motorboat operators must be familiar with reference materials required of an DOI motorboat operator (Table S2.2).

Table S2.2. Reference materials required for DOI motorboat operator.

Reference	Location
DOI Motorboat Operator Certification Course (MOCC) Manual (DOI DM 485, Chapter 22)	I&M Library
Maloney, E.S., and C.F. Chapman. 1996. Chapman Piloting: Seamanship & Small Boat Handling, 62nd ed. William Morrow and Company.	I&M Library

Substrate Identification Procedure

Field and office personnel must be familiar with the general benthic cover or substrate categories (coralline algae, corals, macroalgae, sand, and turf algae) and the coral species specific to each PACN park (see Appendix S1.c in SOP #1 "Before the Field Season"). Office analysts must pass a substrate identification exam by correctly identifying at least 80% of the labeled substrates in digital still images from the park where analysis will occur (or network, if the staff member will be identifying substrates for multiple parks). Observers should be familiar with all pertinent reference materials for substrate identification (Table S2.3).

Table S2.3. Reference materials for substrate identification.

Reference	Location
Abbott, I.A. 1999. Marine Red Algae of the Hawaiian Islands. Bishop Museum Press, Honolulu, Hawaii, USA.	I&M Library – hard copy
Abbott, I.A., and J.M. Huisman. 2004. Marine Green and Brown Algae of the Hawaiian Islands. Bishop Museum Press, Honolulu, Hawaii, USA.	I&M Library – hard copy
Fenner, D. 2005. Corals of Hawaii: A Field Guide to the Hard, Black and Soft Corals of Hawaii and the Northwest Hawaiian Islands, Including Midway. Mutual Publishing, Honolulu, Hawaii, USA.	I&M Library – hard copy
Hoover, J. P. 1999. Hawaii's Sea Creatures, a Guide to Hawaii's Marine Invertebrates. Mutual Publishing.	I&M Library – hard copy
Huisman, J.M., I.A. Abbott, and C.M. Smith. 2007. Hawaiian Reef Plants. University of Hawaiʻi Sea Grant College Program, Honolulu, Hawaiʻi.	I&M Library – hard copy
Littler, D.S., and M.M. Littler. 2003. South Pacific reef plants. Offshore Graphics, Inc., Washington, D.C., USA.	I&M Library – hard copy
Maragos, J. 1977. Reef and shore fauna of Hawaii. Section 1: Protozoa through Ctenophora. *in* D.M. Devaney and L.E. Eldredge, editors. Bishop Museum Press, Honolulu, Hawaii, USA.	I&M Library – hard copy
Payri, C, A. de R. N'Yeurt, and J. Orempuller 2000. Algues de Polyne'sia francaise Algae of French Polynesia. Au Vent des Isles, Editions Tahiti..	I&M Library – hard copy
Veron, J.E.N. 2000. Corals of the World. Australian Institute of Marine Science, Townsville, Australia.	I&M Library – hard copy

Operating Survey Gear

Underwater Camera Gear: Field personnel must be familiar with the operation of the underwater camera. See SOP #5 "Pre-Dive Equipment Preparation" for information on how to set up the camera for surveys.

Transect Lines: Field personnel need to be familiar with the deployment of transect lines underwater by first deploying and spooling the lines on land. Once accomplished, they will proceed to practice deployment skills underwater while maintaining good buoyancy control. Keep in mind that some transect lines are weighted so buoyancy will change substantially while laying and spooling the line.

GPS: Field personnel need to know how to operate the GPS to navigate to various waypoints. See SOP #4 "Using GARMIN® Global Positioning System (GPS) Units" and practice using the unit before heading out into the field.

Rugosity Chain: Field personnel will need to know how to deploy the rugosity chain on land prior to deployment underwater. See SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys" on how to measure rugosity. Once skilled on land, practice this skill underwater while maintaining good buoyancy control. Keep in mind that the rugosity chain is weighted so buoyancy will change substantially as you lay out the chain or spool it up.

Reference materials related to operating survey gear can be found in Table S2.4.

Table S2.4. Survey gear reference materials.

Reference	Location
Coyer, J., and J.D. Witman. 1990. The underwater catalog: A guide to methods in underwater research. Shoals Marine Laboratory, Cornell University and New York Sea Grant, Ithaca, New York, USA.	I&M Library – hard copy
English, S., C. Wilkinson, and V. Baker. 1994. Survey manual for tropical marine resources. Australian Institute of Marine Science, Townsville, Australia.	I&M Library – hard copy
Operator manual for camera and underwater housing (e.g., Olympus® 5060 with PT-102 housing).	I&M Library – digital
Operator manual for GPS to be used in the field (e.g., Garmin 76).	I&M Library – digital
Rogers, C.S., G. Garrison, R. Grober, Z-M Hillis, and M.A. Franke. 1994. Coral reef monitoring manual for the Caribbean and Western Atlantic. National Park Service, US Virgin Islands, USA.	available online at: http://cars.er.usgs.gov/Monitoring_Manual.pdf (last accessed 26May2006) as well as I&M Library – digital

Computer Software

All field and office personnel should be familiar with using Microsoft Word® and Microsoft Excel® Programs. Other software that field and office personnel will need to know includes Photogrid©. Practice using Photogrid© with test images prior to any survey image identification. For information on obtaining and using Photogrid©, please refer to SOP #13 "Data Management – Benthic Image Analysis." Reference materials for operating computer software are listed in Table S2.5.

Table S2.5. Computer software references

Reference	Location
Microsoft Word® manual or third party manual	I&M library; and: http://office.microsoft.com/en-us/assistance/default.aspx (last accessed 26May2006)
Microsoft Excel® manual or third party manual	I&M Library; and visit: http://office.microsoft.com/en-us/assistance/default.aspx (last accessed 26May2006)
Photogrid© 1.0 software help section	HTML help section contained within program, no online sources, no pdf.

Office Personnel

All office personnel will need to be familiar with the PACN monitoring plan. The complete monitoring plan will be posted at:
http://www1.nature.nps.gov/im/units/pacn/monitoring/index.htm (last accessed 30 May 2006). All office personnel will be familiar with the Marine Benthic Community Monitoring Protocol, all chapters and all SOPs.

Data Management Principles, Infrastructure, and Practices

PACN: All office personnel will be familiar with the PACN I&M Program, infrastructure and practices. All office personnel will be required to read and be familiar with the PACN data management principles and infrastructure which can be found in Chapter 6, Data Management Plan of the PACN Monitoring Plan.

Marine Benthic Community Monitoring Protocol: The chapters and SOPs associated with data management include: Chapter 4 "Data Handling, Analysis and Reporting," SOP #11 "Data Management," SOP #12 "Data Management – Photographs," SOP #13 "Data Management – Benthic Image Analysis," and SOP #14 "Data Management – Settlement Analysis."

SOPs Associated with Field Data Collection Practices

All office personnel will need to be familiar with all chapters and SOPs associated with field data collection and methods. Chapters and SOPs related to these practices and procedures include Chapter 3 "Field Methods," SOP #6 "Selecting and Marking Subtidal Sampling Transect Location," SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys," SOP #8 "Conducting Coral Settlement Sampling," and SOP #9 "Measuring Coral Growth."

All office personnel will need to participate in at least one (1) on-site field visit during actual monitoring; even if they are only boat-based while divers conduct field data collection activities.

Photogrid© and Photoshop® Software and Sound Statistical Background for Analyses

All office personnel will be familiar with Microsoft Office®, and in particular, MS-Word®, MS-Excel® and preferably MS-Access®. Other software that office personnel will need to be familiar with includes Adobe Photoshop®, Photogrid© as well as the statistical package, Statistica®. Reference material for operating computer software is listed in Table S2.6.

Prior to using field data images, field office personnel will need to practice with test images using Photoshop® and Photogrid© as directed by the PI or designee. Field and office personnel must be familiar with the general substrate categories (e.g., coralline algae, coral, macroalgae, sand, turf algae) and the settling coral taxa specific to each PACN park (see Appendix S1.c in SOP #1 "Before the Field Season"). Office analysts must pass a substrate identification exam by correctly identifying at least 80% of the labeled substrates from digital still images from the park where analysis will occur (or network if the affected staff will be identifying substrates for multiple parks). Directions on how to use these programs with regard to this protocol can be found in SOP # 12 "Data Management – Photographs," and SOP #13 "Data Management – Benthic Image Analysis." The use of products identified in this protocol does not imply endorsement, effectiveness, or warranty by NPS.

Statistics: All personnel involved in this protocol will need to review the manual for Statistica® 7.0, the Statistical Software used for data analysis with the Benthic Marine Community Protocol. More information on data analysis can be found in SOP #15 "Data Analysis and Reporting."

Table S2.6. Reference material for operating computer software.

Reference	Location
Microsoft Word® manual or third party manual	I&M library; and: http://office.microsoft.com/en-us/assistance/default.aspx (last accessed 26May2006)
Microsoft Excel® manual or third party manual	I&M Library; and visit: http://office.microsoft.com/en-us/assistance/default.aspx (last accessed 26May2006)
Photoshop CS2® software manual or third party manual	
Photogrid© 1.0 software help section	HTML help section contained within program, no online sources, no pdf.
Statistica® 7.0 instructional manual	

Analysis and Reporting Principles

All personnel involved in this protocol will be required to read and be familiar with the chapters and SOPs in the PACN Monitoring Plan associated with analysis and reporting. In particular, Chapter 4 “Data Analysis and Reporting.”

All personnel involved in this protocol will be required to read and understand all chapters and SOPs associated with analysis and reporting in the Benthic Marine Community Protocol. In particular, personnel will need to be familiar with Chapter 4 “Data Handling, Analysis, and Reporting,” and SOP # 15 “Data Analysis and Reporting.” Furthermore, personnel will need to be familiar with PACN and this Vital Sign’s reporting needs and audiences both for the network and each park.

SOP #3: Safety Protocol

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.0	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	7/20/07	Larry Basch	See Track Changes	Additions, corrections		2.00

Purpose

This Standard Operating Procedure explains the safety protocol for the Benthic Marine Community Vital Sign Monitoring Protocol and associated Standard Operating Procedures (SOPs) for the Pacific Island Network. This document outlines safety considerations for conducting various aspects of the protocol. All personnel should be familiar with this SOP in order to identify and use the most current procedures and ensure optimum safety.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 “Before the Field Season.” The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

General Preparation and Review

Prior to the field season each year, usually beginning in early spring, all observers should review this entire protocol, including SOPs, and recommended references. In particular, all participants should be thoroughly familiar with the NPS Occupational Safety and Health Policies, scuba and watercraft manuals, various environmental and chemical safety guidelines, procedures outlined in SOP #2 "Training Observers," as well as the various equipment lists and local biota guides listed in SOP #5 "Pre-dive Equipment Preparation. The USGS National Field Manual (http://water.usgs.gov/owq/FieldManual/Chap9/content.html [last accessed 05July06]) is another recommended reference for safety procedures. Table S3.1 provides a partial list of reference materials and websites with information on specific safety topics.

Table S3.1. List of documents and websites for safety requirements and guidelines related to conducting the benthic marine monitoring protocol.

Safety Topic	Guidance	Website (if applicable)
Safety policies, regulations and requirements; training guidelines	NPS Reference Manual #50B Occupational Safety and Health Program	http://inside.nps.gov/waso/waso.cfm?prg=704&lv=3 (last accessed 05July06)
	DOI NPS SafetyNet	http://safetynet.smis.doi.gov/occHealthA.htm (last accessed 05July06)
	USGS National Field Manual Section 9.1	http://water.usgs.gov/owq/FieldManual/Chap9/A9.1.html (last accessed 05July06)
	29 CFR, Part 1960, "Elements for Federal Employee Occupational Safety and Health Programs," Subpart C	
	Departmental Manual (DM), Part 485, "Safety and Health Handbook," Chapter 4	
Safety training guidelines	DOI NPS SafetyNet	http://safetynet.smis.doi.gov/trainingA.htm (last accessed 05July06)
	DOI Office of Occupational Health and Safety	http://www.doi.gov/ohs/index.html (last accessed 05July06)
	29 CFR, Part 1960, "Elements for Federal Employee Occupational Safety and Health Programs," Subpart H	
	Departmental Manual (DM), Part 485, "Safety and Health Handbook," Chapter 13	
Scuba safety	NPS Reference Manual 4 Diving Management	http://inside.nps.gov/waso/custommenu.cfm?lv=3&prg=533&id=1137 (last accessed 05July06)
	Scuba certification materials (PADI, NAUI, SSI, YMCA)	
Boating safety	NPS Reference Manual 50B, Section 9.0 Watercraft Safety	http://inside.nps.gov/waso/custommenu.cfm?lv=3&prg=704&id=2863 (last accessed 05July06)

Table S3.1 List of documents and websites for safety requirements and guidelines related to conducting the benthic marine monitoring protocol (continued)

Safety Topic	Guidance	Website (if applicable)
	DOI Motorboat Operator Certification Course (MOCC) manual	
Transportation	NPS Reference Manual 50B, Section 6.0 Motor Vehicles	http://www.inside.nps.gov/waso/custommenu.cfm?lv=3&prg=704&id=2860 (last accessed 05July06)
	USGS National Field Manual Section 9.3	http://water.usgs.gov/owq/FieldManual/Chap9/A9.3.html (last accessed 05July06)
	State, Territory, and Commonwealth traffic laws	
Inclement weather and water activities	USGS National Field Manual Section 9.4	http://water.usgs.gov/owq/FieldManual/Chap9/A9.4.html (last accessed 05July06)
	National Weather Service	www.wrh.noaa.gov (last accessed 05July06)
Environmental conditions	USGS National Field Manual Section 9.8	http://water.usgs.gov/owq/FieldManual/Chap9/A9.8.html (last accessed 05July06)
	1992. USDHHS. CDC. HIOSH. "Working in Hot Environments"	
Chemical handling and storage	USGS National Field Manual Section 9.6	http://water.usgs.gov/owq/FieldManual/Chap9/A9.6.html (last accessed 05July06)
	MSDS file, right to know, for specific chemicals	
Contaminated water	NPS Reference Manual 83D1 Bathing Beaches	http://www.nps.gov/public_health/inter/info/rms/rm83d1.pdf (last accessed 05July06)
	Recreational Waters	http://www.nps.gov/public_health/inter/rec_water/rw.htm (last accessed 05July06)
	USGS National Field Manual Section 9.7	http://water.usgs.gov/owq/FieldManual/Chap9/A9.7.html (last accessed 05July06)
	EPA	http://www.epa.gov/OST/beaches/ (last accessed 05July06)
Animals and disease vectors	NPS Reference Manual 83G Vectorborne and Zoonotic Diseases	http://www.nps.gov/public_health/inter/info/rms/rm83g.pdf (last accessed 05July06)
	USGS National Field Manual Section 9.9	http://water.usgs.gov/owq/FieldManual/Chap9/content.html (last accessed 05July06)
	Local biota lists located in SOP #5 "Pre-Dive Equipment Preparation"	

Safety is "the condition of averting or not causing injury, danger, or loss" (Lane and Fay 1997). As a Federal employee, partner, or cooperator, you are required to know and follow safety policies and requirements documented in Reference Manual 50 B Occupational Safety and Health Program (http://inside.nps.gov/waso/waso.cfm?prg=704&lv=3 [last accessed 05July06]).

For divers and boat operators, Reference Manual 4 Diving Management (RM-4 located at http://inside.nps.gov/waso/custommenu.cfm?lv=3&prg=533&id=1137 [last accessed 05July06]) and Reference Manual 9 Watercraft Safety (http://inside.nps.gov/waso/custommenu.cfm?lv=3&prg=704&id=2863 [last accessed 05July06]) should be followed accordingly. In addition, individual parks also have park-specific safety procedures, dive manuals, and operational protocols. This SOP recommends that all these available reference materials be used to address the topics below.

Safety Policies, Regulations and Requirements

All individuals participating in activities related to this Vital Sign must adhere to applicable safety policies, regulations, and requirements outlined in RM 50 B Occupational Safety and Health Program. This includes both field and office activities and applies equally to NPS staff, cooperators, partners, volunteers, and others. The applicable policies, regulations, and requirements of each participating agency should be compiled and reviewed before the field season as part of this SOP. Ensure that all field personnel obtain First Aid, CPR, and Oxygen administration training. This is also highly recommended for office personnel. Supervisors should ensure that all field staff are well trained in the safety guidelines and policies outlined below.

Scuba Diving

Unique safety hazards of using scuba are detailed in RM-4 (http://inside.nps.gov/waso/custommenu.cfm?lv=3&prg=533&id=1137 [last accessed 05July06]). Each diver must adhere to the guidelines required by the NPS Diving program and follow the safety requirements specific to each park. Park-specific Diving Safety Manuals are on file at each park and should also be made available and reviewed before field work. All scuba is conducted at the discretion of the Park Dive Officer (PDO), who has final approval of all scuba activity within his/her park. The PDO should be consulted prior to the start of field activities for assistance with park-specific requirements or safety issues. Recommended maintenance procedures for scuba equipment can also be found in RM-4 and SOP #5 “Pre-dive Equipment Preparation.”

Transportation

Safety considerations for vehicles used to reach sampling sites should be reviewed for each park and field location. It is very important to inspect the vehicle before going into the field. Ensure that safety equipment required for the scheduled activity is stowed securely in the vehicle. During driving to and from sampling areas, it is particularly important to consider issues such as night-time driving, fatigue, storms, road flooding, driving in unfamiliar areas, and remote areas where large animals may be crossing the road. Additional details regarding transportation safety procedures and policies are listed in NPS Reference Manual 50B Section 6.0 Motor Vehicles (http://www.inside.nps.gov/waso/custommenu.cfm?lv=3&prg=704&id=2860 [last accessed 05July06]) and the USGS National Field Manual Section 9.3 (http://water.usgs.gov/owq/FieldManual/Chap9/A9.3.html [last accessed 05July06]).

In some cases, this protocol may require the transportation of a trailered vessel. Vehicles towing boat trailers should only be operated by individuals who have completed the DOI Motorboat Operator Certification Course (MOCC). All small boat operations must be conducted by DOI MOCC certified operators and must follow the operational and safety guidelines detailed in the

NPS Reference Manual 9 “Watercraft Safety” (http://inside.nps.gov/waso/custommenu.cfm?lv=3&prg=704&id=2863 [last accessed 05July06]) in addition to any park-specific guidelines. In some cases, approval to operate motorboats may be granted to individuals holding comparable or greater certifications (e.g., U.S. Coast Guard Captain’s License), but this is at the discretion of the park safety officer and/or Park Diving Officer (PDO).

Weather and Sea Conditions

Sampling during inclement weather and sea conditions are of particular concern in the marine environment. Weather can change rapidly on the ocean, creating hazardous conditions in a relatively short time period. Prior to departure, it is the responsibility of all personnel to be aware of the local weather, tide, and current forecasts for the day and to decide whether or not it is safe for sampling to commence. Consult the USGS National Field Manual Section 9.4 (http://water.usgs.gov/owq/FieldManual/Chap9/A9.4.html [last accessed 05July06]) for more weather related safety considerations. Also review Reference Manual 9 “Watercraft Safety,” Reference Manual 4 “Diving Management” (http://inside.nps.gov/waso/custommenu.cfm?lv=3&prg=533&id=1137 [last accessed 05July06]), and local sources for additional information regarding inclement weather or adverse sea conditions.

Sampling should be conducted during periods of calm winds and no or small ocean swell. If thunder is heard or lightning seen, sampling will be suspended and personnel should return to shore for at least 30 minutes. Do not stay in or on the water during a lightning storm. During intense rainfall events, visibility may drop and appropriate precautions should be taken to ensure that the boat does not ground. At any point during sampling, any personnel involved have the right and responsibility to abort a sampling trip if hazardous or potentially hazardous conditions are perceived.

Environmental Conditions

Individual parks have occupant emergency plans which cover safety procedures for medical emergencies, earthquakes, floods, fires, Tsunamis, and bomb threats. Be familiar with the procedures and emergency contact numbers of your duty station park as well as other parks you may visit during field sampling activities. Overall, be aware of your environment, use common sense, do not exceed your limits (for example, operation of equipment; lifting heavy objects and equipment; physical tolerance to exertion, heat, and cold), and trust your instincts (Lane and Fay 1997). The USGS National Field Manual Section 9.8 (http://water.usgs.gov/owq/FieldManual/Chap9/A9.8.html [last accessed 05July06]) covers environmental hazards in more detail.

The marine environment presents additional unique environmental hazards. Strong currents and ocean swell can present physically challenging and dangerous conditions. Extended hours in the water breathing compressed gas can cause hypothermia and dehydration, which increase the likelihood of Decompression Sickness. Open boats expose crews to intense tropical sunlight, wind, and rain.

Chemical and Material Safety Considerations

All chemicals should be handled and stored according to the recommendations found in the specific Material Safety and Data Sheet (MSDS) provided by the chemical supplier. All persons using or exposed to hazardous substances must be fully informed of the properties and potential hazards of the material in use as well as proper handling and disposal procedures. Park staff should always be consulted about local considerations when handling any chemicals of concern. Other chemical handling procedures can be found in the USGS National Field Manual Section 9.6 (http://water.usgs.gov/owq/FieldManual/Chap9/A9.6.html [last accessed 05July06]).

Contaminated Water

Waterborne pathogens that may survive or be transmitted in seawater include Enterococci and Staphylococci bacteria. Never consume seawater. Marine areas being sampled may be contaminated with pathogens or harmful chemicals, although this situation is rare in the PACN. Water quality issues in the PACN are outlined in the PACN Monitoring Plan Appendix I: Water Quality Report. When working with water that is known to be contaminated, use extra precautions such as not eating or drinking while sampling. In particular, keep hands away from nose, ears and mouth and wash hands thoroughly before eating. If no soap and water are available, use of an antibacterial hand cleanser is highly recommended. Consult NPS Reference Manual 83D1 Bathing Beaches (http://www.nps.gov/public_health/inter/info/rms/rm83d1.pdf [last accessed 05July06]) and the USGS National Field Manual Section 9.7 (http://water.usgs.gov/owq/FieldManual/Chap9/A9.7.html [last accessed 05July06]) for complete recommended safety procedures concerning contaminated water.

Animal Hazards and Disease Vectors

Any open cut has a high likelihood of becoming infected and all cuts should be carefully and immediately tended and monitored. Corals can scrape or cut and care should be taken to avoid contact with the bottom. Hazardous marine life, including jellyfish, scorpion fish, cone snails, and large fish, can sting or bite, and some of these conditions can be life threatening (Thomas & Scott 1997) Appropriate first aid should be administered and professional medical attention sought if necessary. Contacts for local emergency medical facilities are listed in individual park dive plans. It is the responsibility of all personnel to be familiar with the local hazardous marine life and to understand the appropriate treatment methods. Recommended reference material covering the biota for each region can be found in SOP #5 “Pre-dive Equipment Preparation.”

Field Trip Preparations and Emergency Contacts

Basic planning is required before each field sampling event. A large component of the planning effort involves gathering safety information and documenting all aspects of field sampling trip plans in advance. All field personnel should complete an Emergency Contact Form (Appendix S3.A) and a Medical Information Form (Appendix S3.B) prior to conducting field work. A trip plan (including a dive plan, as required by RM-4) must be completed. One copy should be left at the office, and additional copies should be given to the park safety officer and field personnel involved in the trip. Updated weather and marine forecasts should be obtained prior to departure. Upon completion of the field work it is imperative that personnel check in with the park safety officer, PDO, or other designated contact person(s) at the specified time noted on the dive plan. For details, please see SOP #2 “Training Observers.”

It is the responsibility of all personnel to ensure that the appropriate safety equipment is present and in working condition. Examples of safety equipment checklists are provided below (Appendix S3.C) and in SOP #5 “Pre-Dive Equipment Preparation.” These lists should be customized according to the specific field conditions, tasks, and the needs of personnel. Additional safety equipment may be required at some parks, and the park safety officer and PDO must be consulted prior to commencing field sampling activities. No sampling activities will be conducted without all necessary safety equipment present and in proper working condition.

Literature Cited

DeVerse, K., and E. DiDonato. 2005. Water Quality Report. Appendix I *in* L. HaySmith, S. Stephens, F. Klasner, and G. Dicus, editors. Pacific Island Network Vital Signs Monitoring Plan Natural Resource Report 2006/003, National Park Service, Fort Collins, Colorado.

Lane, S.L., and R.G. Fay. 1997. Safety in field activities: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A9, accessed __date__ at http://pubs.water.usgs.gov/twri9A9/ (accessed 01July06).

U.S. Geological Survey (variously dated) National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9, available online at http://pubs.water.usgs.gov/twri9A (accessed 01July06).

Appendix S3.a. Emergency contact form

(modified from USGS National Field Manual, Ch. A9)

Emergency Contact Form

Employee Name: ______________________

Personal contacts
- Name: ______________________
- Phone (home) (work): ______________________
- Name: ______________________
- Phone (home) (work): ______________________

Personal Physician
- Name: ______________________
- Phone: ______________________

PACN contacts:
- WAPA: ______________________
- NPSA: ______________________
- KALA: ______________________
- KAHO: ______________________

Local emergency contacts (or call 911):
- Hospital / Phone: ______________________
- Address: ______________________
- Walk-in clinic / Phone: ______________________
- Address: ______________________
- Police: ______________________
- Fire: ______________________
- Utility: ______________________

Health Information Centers:
- Center Disease Control: ______________________
- Information Hotline: ______________________
- Fax: Disease Directory: ______________________

Other: ______________________

____

____

____

____

Appendix S3.b. Medical information form for office personnel

(modified from USGS National Field Manual, CH. A9)

Medical Information for Office Personnel

Employee Name: ______________________
Home Phone: ______________________

Treatment preference:
Medical: ______________________
other: ______________________

Doctor
Name: ______________________
Phone: ______________________

Other Emergency Contact(s):
Name: ______________________
Phone: ______________________
Name: ______________________
Phone: ______________________
Name: ______________________
Phone: ______________________

Relevant Medical History:
____
____

Allergies & Medical Conditions:
Allergies: ______________________
____
Conditions: ______________________
____

Medications:
Current: ______________________
To avoid: ______________________

Special Instructions:
____
____

Appendix S3.c. Example of standard safety checklist

Standard Safety Checklist Item:	Check:
Climatic and UV protection	
Boots	______
Fluids (e.g., water, electrolyte drink)	______
Hat, wide-brimmed	______
Insect repellent (unscented)	______
Rain gear	______
Sunglasses	______
Sunscreen	______
Antibacterial soap or hand lotion	______
Temperature-modifying clothing	______
Items for Vehicles	
Vests and jackets w/reflective protection	______
First aid kit (see below)	______
Flares	______
Fire extinguisher	
Flashlight	
Tool kit	
Reflector triangles	
Chemical Protection and Storage	
Chemical spill kit	______
Personal Protective Equipment (eye wear, gloves, apron, close-toed shoes)	______
Eye wash kit (replace old/expired solution)	______
Material Safety Data Sheets (MSDS)	______
Chemical reagents (stored appropriately)	______
Flammable solvents (stored appropriately)	______
Pressurized gases (stored appropriately)	______
First Aid and Protective Equipment	
Complete change of clothes (stored dry)	______
Fire extinguisher (safely secured)	______
First aid kit and manual (ensure full/updated)	______
Orange reflective vest	______
Communications	
Cellular phone/communication equipment	______
Field folder (see below)	______
Field Folder:	
Maps	______
Medical facility numbers/location	______

Appendix S3.c. Example of standard safety checklist (continued).

Emergency contact numbers	________
Miscellaneous Equipment	
Bungie cords (to secure loose articles)	________
District flood plan (most current)	________
Flagging	________
Flares	________
Flashlight (include batteries)	________
Safety cones	________
Tool kit	________
USGS TWRI Book 9 Chapter A9	________

SOP #4: Using GARMIN® Global Positioning System (GPS) Units

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.0	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	7/20/2007	Larry Basch	See Track Changes	corrections		2.0

Purpose

This Standard Operating Procedure explains how to use an autonomous, non-differential Garmin® (or similar unit) GPS receiver and GPS transfer software. This protocol may be used for any Garmin® GPS that can average a waypoint and store tracklogs. The GPS transfer process uses DNR Garmin® Version 5.1.1 and GIS software. The use of products identified in this protocol does not imply endorsement, effectiveness, or warranty by NPS.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Pre-Field Preparation

Garmin® GPS Preparation

Step 1: Read and remain familiar with GPS user manual, hardware, and software.

Step 2: Load freshly charged batteries and have extra, charged sets available. Extra rechargeable batteries should be placed in a water tight "dry bag" or a re-sealable plastic bag and stored in an enclosed space or sealed container on the boat.

Step 3: Initialize and download a fresh almanac into a Garmin® if more than 1 week has passed since last use or if the GPS unit has moved more than a straight-line distance of 150 miles. Downloading the almanac takes roughly 20 minutes in open areas - away from buildings, canopy, and obstructions.

Step 4: Delete old waypoints and tracks from memory (but download beforehand and save data elsewhere if appropriate).

Step 5: Turn off active tracklog. Set "Tracklog" to the preferred collection method ("Time" is recommended) and an appropriate logging rate for the data collection ("5 seconds" is recommended for most walking collection, but keep in mind the total storage capacity of the GPS).

Step 6: Ensure Simulator Mode is *not* ON when collecting data.

Step 7: If necessary, transfer data (e.g., background maps) to the GPS unit using DNR Garmin® software. See below for DNR Garmin® instructions.

Step 8: Set Time and Date on the GPS Unit (note that no PACN parks use daylight savings time, rather the entire PACN is always in 'standard' time).

Step 9: Make sure that "Interface Protocol" is set to Garmin®.

Step 10: Make sure that WAAS is enabled.

Step 11: Set the Coordinate System (UTM or LAT/LONG) and Datum to ensure compatibility with any written coordinates you may need to navigate to or map. Recommended settings for UTM are in Table S4.1.

Table 4.1. Coordinate system and datum for PACN

Island	Datum	Projection
Hawaii Island	NAD83	UTM zone_5N
Maui Island	NAD83	UTM zone_4N
Molokai Island	NAD83	UTM zone_4N
Oahu Island	NAD83	UTM zone_4N
Guam	WGS84	UTM zone_2N
Saipan	WGS84	UTM zone_2N
American Samoa (all islands)	WGS84	UTM zone_55S

Step 12: Set Heading to Magnetic or True. If set to True, ensure compass has same declination.

Step 13: If needed, use Trimble Planning Software to ensure best time of day for GPS data collection.

Step 14: Prior to use in the field, ensure the GPS has been placed in a "dry bag" with a recently dried desiccant pack.

GPS Transfer Software for DNR Garmin®:

Step 1: Uninstall any previous versions of DNR Garmin®

Step 2: As of Spring 2006, download and install Version 5.1.1 to any computer that will receive GPS data from the Garmin®. DNR Garmin® can be downloaded from the State of Minnesota Department of Natural Resources http://www.dnr.state.mn.us/mis/gis/tools/arcview/extensions/DNRGarmin/DNRGarmin.html (accessed 05July06).

Step 3: In DNR Garmin®, set projection to ensure compatibility with data stored in GIS (Table S4.2).

Table S4.2. Projection settings for islands in PACN

Island	ESRI (or EPSG) POSC code	Datum	Projection
Hawaii Island	26905	NAD83	UTM zone_5N
Maui Island	26904	NAD83	UTM zone_4N
Molokai Island	26904	NAD83	UTM zone_4N
Oahu Island	26904	NAD83	UTM zone_4N
Guam	32602	WGS84	UTM zone_2N
Saipan	32602	WGS84	UTM zone_2N
American Samoa (all islands)	32775	WGS84	UTM zone_55S

Step 4: In ESRI ArcMap®, ensure that the Data Frames are set to the appropriate projection. Datum and projections are in the third and fourth columns, respectively, of Table S4.2.

GPS Field Procedures

Data Collection

Data collection is not anticipated to be a frequent task. Initially, actual data collection locations will need to be documented, relative to sample design specifications. Other data collection needs are not anticipated.

Step 1: Hold GPS unit or antenna at or above your head. Use an external antenna if needed to free hands.

Step 2: Electronically store all data (waypoints and tracks). Manually write down position coordinates for backup.

Step 3: Note that a Garmin® will collect data no matter what the GPS positioning quality is, so you will need to monitor the GPS Satellite Page continuously for anomalies and accuracy. Collect only when "3D GPS" or "3D Differential" is shown. Do not collect data in 2D unless absolutely necessary. 2D Differential should not be used either.

Step 4: Collect waypoints.
Collect waypoints in "Averaged Position" mode. To ensure greatest accuracy possibly, either (1) collect a minimum of 10 points per location, or (2) collect points for a minimum of 20 minutes at that site. Depth from the boat sounder can also be recorded if conducting benthic habitat surveys for mapping purposes. Otherwise, use dive computers to record depth when diving at a waypoint.

Step 5: TrackLogs
First: Use "Stop when Full" or "Fill" Record Mode to prevent overwriting TrackLog points when Active TrackLog becomes full.

Second: Begin collecting Active TrackLog when you know where you need to go and immediately begin moving when TrackLog begins collecting.

Third: Stop Active TrackLog when stopped.

Fourth: Always stop Active TrackLog when nearing the beginning point of a polygon area you want closed. A line between your last track point and the initial point will automatically be generated in order to close the polygon.

Fifth: Always turn Active TrackLog to OFF when finished collecting.

Sixth: NEVER 'store' or 'save' an active Tracklog unless you need to save space, rather choose to 'stop' an active TrackLog. Garmin® III+ receivers remove the ActiveTrack, while newer Garmin® models merely make a copy of the Active Track. In any case, saved tracklogs degrade original data, whereas a 'stopped' TrackLog retains data quality.

Office Procedure

Step 1: Connect GPS to PC with cable and place GPS in Simulator Mode

Step 2: Check that TrackLog is OFF! Again, do not save Track!

Step 3: Open DNR Garmin® from the desktop (for ArcGIS® users) or from within ArcView® by loading the extension.

Step 4: Check Projection in DNR Garmin® one more time. This will define the projection the GPS file will be stored in.

Step 5: Download waypoints and Tracks and save to Shapefile (if in ArcGIS®) or if saving a shapefile from the desktop DNR Garmin®, save to projected shapefile. Use naming conventions as below.
First: See SOP 12a "Data Management" to identify the folder location and hierarchy where this file is to be saved.

Second: The file-naming convention is to indicate the GPSModel, type of data (waypoint or Tracks), projection and datum, and date (YYYYMMDD) separated by an underscore (_). For example, a set of waypoints collected with a Garmin® GPS76c, using UTM and WGS84 as the projection and datum, on Christmas Day 2005, would be named "GPS76c_waypt_UTMWGS84_20051225".

Third: If additional notes about GPS collection exist, such as data collected in '2D' mode; create a simple text file with an identical filename in the same location which contains this information, with a .txt filename extension.

Step 6: Delete all waypoints and tracks for the next mapping mission.

Step 7: Turn off the GPS and disconnect cables, returning equipment to its proper storage location.

Step 8: Recharge batteries if appropriate

Options to Consider

Improve Accuracy: An external beacon, such as the Thales Mobile Mapper Beacon, for DGPS (Differential GPS) will improve the accuracy of your GPS location. Averaging will improve your GPS locations, if and only if, the satellite geometry improves during point collection. Otherwise, averaging can sometimes result in a less accurate position.

SOP #5: Pre-Dive Equipment Preparation

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	7/30/07	Larry Basch	See Track Changes	Corrections, additions		2.00

Purpose

This SOP outlines the camera setup and installation into the underwater housing. Directions for daily equipment preparation are included for: (1) benthic cover analysis; (2) benthic rugosity measurements; (3) coral settlement; (4) coral growth measurements; (5) diving equipment; and (6) boating equipment. See SOP # 1 "Before the Field Season" for further instruction on the preparation of the equipment and supplies needed prior to the start of each field season.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if SOP #1 is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix S5.a.

Camera Equipment Preparation and Handling

The following section explains the steps required to set up the camera and install it into the underwater housing. See Appendix S5.a for a complete equipment list for preparing the digital still camera for underwater use. These protocols have been written specifically for the Olympus® C-5050 digital camera and a Light and Motion Industries Tetra® Underwater Camera Housing; however, they should work for earlier and later models of the Olympus® (e.g., Olympus® 4040, 6060, 7070) and their associated Tetra® Housings. For detailed instructions on camera operation, see the Olympus® camera and Tetra® instruction manuals, found respectively at: http://www.Olympusamerica.com/files/C-5050Z_Reference_English.pdf (last accessed 26 May 2006) and http://www.uwimaging.com/support/downloads/pdfs/Tetra_5050_B.pdf (last accessed 26 May2006). In the future camera and housing models will change; this SOP and other parts of this protocol will be updated accordingly. At present, all PICRP parks and offices use this or similar equipment; every effort should be made to use similar equipment in the future across PACN. It is anticipated that each park will eventually upgrade to digital SLR cameras as technology advances, with a backup camera based at the Hawaii Volcanoes National Park I&M office.

Camera Batteries

Ensure the rechargeable batteries are fully charged. The day before the dive, charge the camera batteries (including at least one full set for back up). If the batteries have sat for awhile since they were last charged, they may discharge more quickly during use. Although batteries may have been charged after the camera's last use "top" them off. The Olympus® C-5050 camera uses four AA size Nickel-Metal Hydride (NiMH) rechargeable batteries. Use a permanent marker to label each new battery with the date. Check the camera clock, and reset it if necessary so that the camera stamps the proper time code on the photo file. If the flash is turned off, then new batteries will take approximately 500-600 high quality (2592 x 1944 pixel) images. A battery log will help determine when battery life diminishes and batteries need replacement.

Prepare the Camera Housing

Step 1: Check the lens port on the front of the housing and insure that the "flat port" is installed (Figure S5.1). If the flat port is not installed, see the section in this SOP "Additional Camera Maintenance – Changing Housing Optic."

Figure S5.1. Light and Motion Tetra® 5050 underwater housing with flat port. Photo by D. Minton, NPS.

Step 2: Ensure the housing lens cap is in place so that the housing port is not scratched while preparing, loading and transporting the camera.

Step 3: Remove the back of the Tetra® housing. If the backing is locked into placed, release the latch locks holding the latch wheels in place, and simultaneously rotate the wheels downward and toward the back of the housing body (Figure S5.2). The housing back will unseal from the front of the housing and lift out.

Figure S5.2. Remove the housing back by releasing the latch locks holding the latch wheels in place, and simultaneously rotating the wheels downward and to the backward of the housing body. Photo by D. Minton, NPS.

Step 4: Carefully remove the o-ring (o-ring #1) from the raised lip of the housing back and set aside. ***Never use a sharp object to remove the o-ring**. It may damage the o-ring and cause a loss of housing integrity. Damaged o-rings should be replaced immediately.

Step 5: Carefully remove the second o-ring (o-ring #2) on the flat of the housing back and set it aside. Keep the o-rings separate so that they will not be confused when re-installing them.

Step 6: With a clean cloth, clean both o-ring grooves on the housing. It is important that no foreign matter (e.g., dust, sand, lint, hair) be trapped in the o-ring grooves or the integrity of the seal may be compromised and the housing may leak.

Step 7: With a clean, lint free cloth, carefully clean o-ring #2. While cleaning o-ring #2, inspect it for any damage and replace the o-ring with a new one if necessary. Apply a thin layer of o-ring grease (silicone) to o-ring #2. The o-ring should appear shiny and should not have visible globs of o-ring grease on it. ***Too much silicone will actually reduce the effectiveness of the o-ring by trapping particles that might prevent a good seal.**

Step 8: Carefully return o-ring #2 to the groove on the flat of the housing back.

Step 9: Clean, inspect, and apply o-ring grease to o-ring #1 and return it to the groove on the lip of the housing back.

Step 10: Check to insure that the o-rings are seated in their respective grooves. Set aside the prepared housing back in a clean, dust-free area.

Prepare the Camera (Olympus® 4040, 5050, 6060, or 7070 Models)
Step 1: Install the batteries in the bottom of the camera. The battery compartment door will pop open when you press and slide the release latch (Figure S5.3). Align the batteries as indicated on the camera and slide them into the battery compartment. The compartment door will click shut when closed properly.

Step 2: Use rechargeable lithium hydride camera batteries for maximum camera life. Keep at least two sets of freshly charged batteries on hand so that one set is always charged and prepared in the event that the camera is needed on long, or consecutive field days.

Step 3: Ensure that a Compact Flash memory card has been inserted into the camera. The Compact Flash compartment is located on the right side of the camera and the card cover flips open from back to front. Use a compact flash card with at least 512 MB capacity to ensure adequate storage space for photoquadrat images. The card will fit into the camera in only one direction.

Step 4: Turn the camera on using the power switch located on the top right side of the camera.

Step 5: Ensure compact Flash Card is empty by following the next three sub-steps. Note: ensure all images on previously used cards have been downloaded, saved, and backed-up prior to these sub-steps.
First: Press the OK/Menu button on the back of the camera and use arrow buttons to scroll to the card tab.
Second: Press the OK/Menu button to select.
Third: Select format card and click yes.

Step 6: Ensure that the photo quality has been set to the highest resolution. Pictures should be saved in a raw image format (.tiff format) with the highest possible resolution for the camera.
First: Press the OK/Menu button on the back of the camera and use the arrow buttons to scroll to the pictures tab.
Second: Select the image quality symbol.
Third: Select “tiff,”

Step 7: Set the camera mode to Program Shooting Mode by turning the Mode Dial on the top right of the camera to the “P” symbol.

Step 8: Shoot a test image; if ok, delete. Optional, but recommended: Shoot an image of a slate with sampling information (e.g., transect number, date) written out.

Step 9: Turn the camera off.

Step 10: Put the camera in the housing.

For more information become familiar with the camera or housing manufacturers manual online documented for the specific model being used.

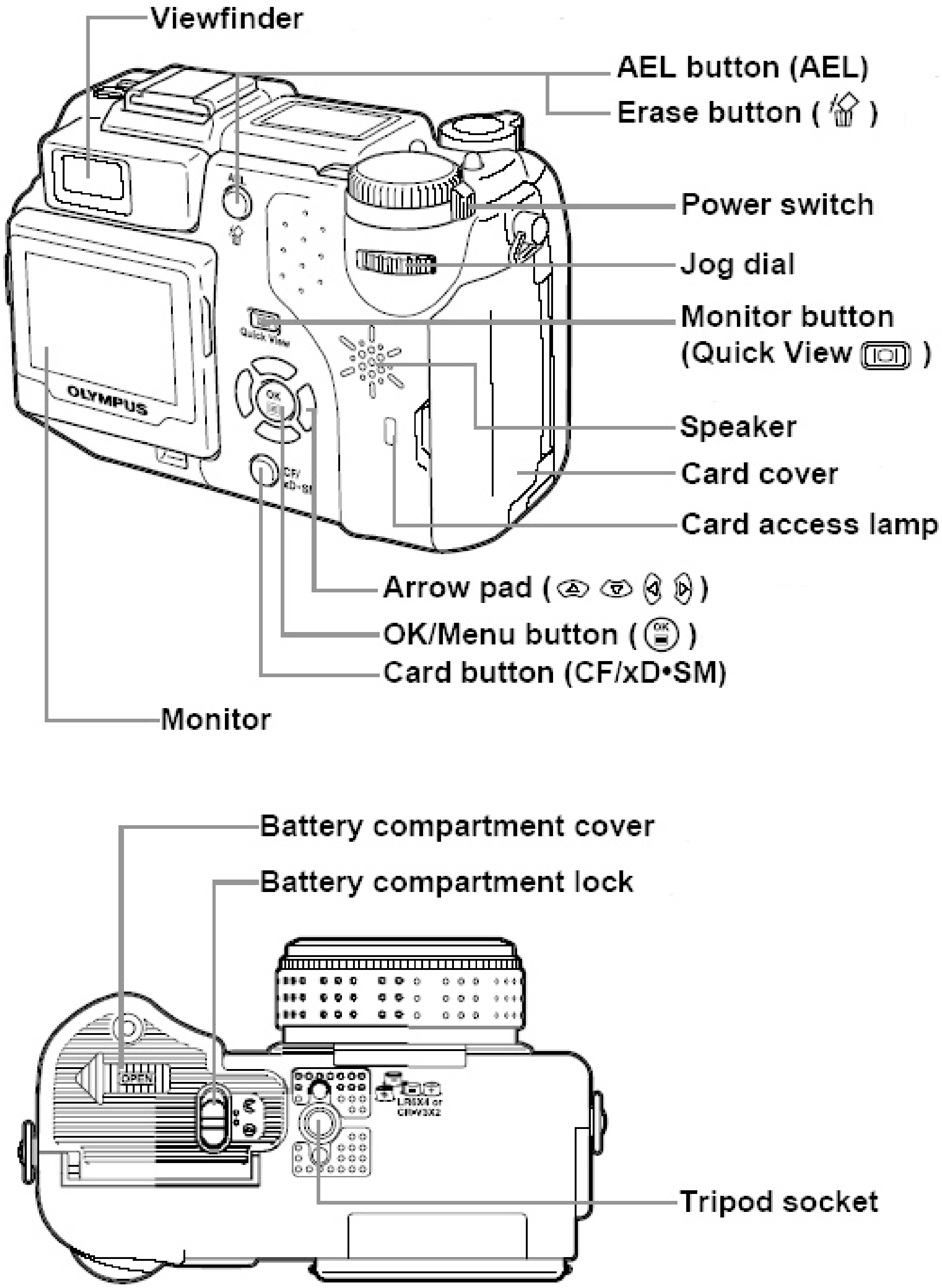


Figure S5.3. Back (top) and bottom (bottom) views of the Olympus® 5050Z. Image acquired from Light and Motion Industries Tetra® owner's manual.

Loading the Camera

Step 1: Locate the On/Off/Mode wheel on the top right of the housing and pull it up. The wheel will extend upward about one inch (Figure S5.4).

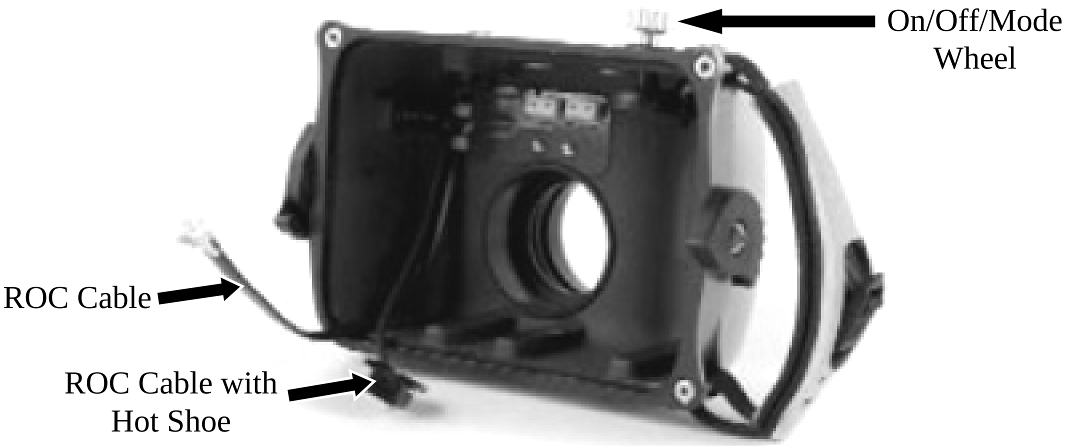


Figure S5.4. The Tetra® Housing for the Olympus® 5050 camera with the back removed and illustrating the location of the On/Off/Mode Wheel, the two ROC cables and the ROC hot shoe. Photo by D. Minton, NPS.

Step 2: Locate the ROC cables and using a finger hold them to the inside left of the housing to prevent them from being damaged and from interfering with the camera's alignment (Figure S5.4).

Step 3: Ensure that the lens cap has been removed from the camera and that the power has been turned off. Turn the mode dial on the top right of the camera to Program Shooting Mode. This setting is represented by the "P" icon.

Step 4: Slide the camera, lens first, into the housing while following Step 2. The camera should fit snuggly, but do not force it into the housing. If the camera will not slide all of the way into the housing, remove it and check the housing for an obstruction and then try to reseat the camera (Figure S5.5).

Step 5: Attach the ROC hot shoe to the camera's hot shoe mount (Figure S5.5).

Figure S5.5. The Olympus® 5050 camera inserted into the Tetra® housing. The ROC hot shoe has been attached to the camera's hot shoe mount. Photo by D. Minton, NPS.

Step 6: Rotate the On/Off/Mode wheel on the top of the housing until the arrow points to the "P" symbol. Push the knob down until the rubber shoe on the inside of the housing covers the mode button on the camera.

Step 7: Ensure that the cable for the ROC hot shoe is tucked into the housing and out of the way of the monitor window.

Installing the Back Plate

Step 1: Rotate the two locking wheels located on the sides of the housing toward the bottom of the housing, rotate until they stop.

Step 2: Locate the ROC cable. This cable looks like a telephone cord and is located along the inside left of the housing.

Step 3: Attach the ROC cable into the matching connector on the inside of the housing back. The connector is in the upper left corner of the housing (Figure S5.6).

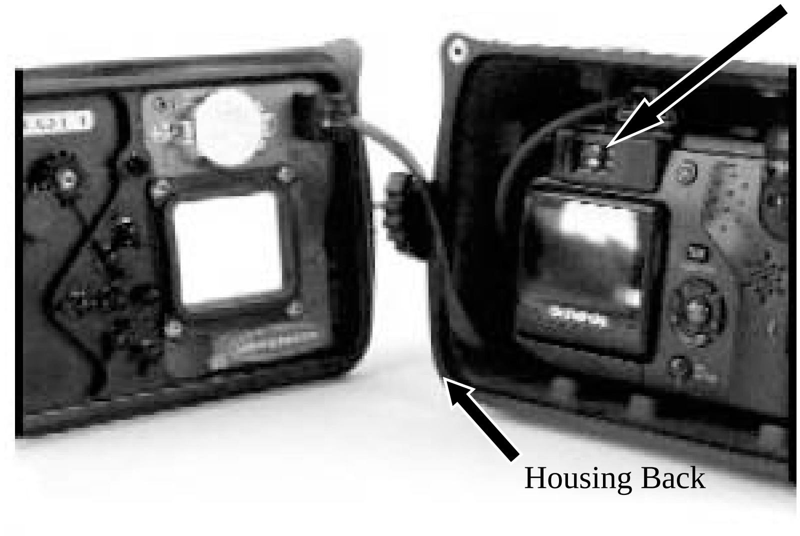


Figure S5.6. Attaching the ROC cable to the back of the camera housing. Photo by D. Minton, NPS.

Step 4: Align the housing back with the housing front.

Step 5: Rotate the two latch wheels around the latch pins until they audibly click into place. As the locking mechanism engages the housing back, it will be pulled securely against the housing front. Ensure the locking wheels have locked by trying to turn them in the opposite direction. The wheels should not rotate.

Step 6: Finally, mount the camera housing on the monopod so that the lens faces down to the foot.

Step 7: If you are using an aiming rod to maintain a constant distance from the substrate, place the straps that hold the rod around the housing, checking to make sure that you can access the camera switches without interference from the straps. Slide the aiming rod under the straps and gently tighten them so that the end of the rod is 40 cm from the front of the lens port of the housing.

Additional Camera Maintenance – Changing Housing Lens Port

It may be necessary to change and clean the housing port. When changing the port, three places in the front housing should be inspected and cleaned: the o-rings, the grooves into which the o-rings fit, and the sealing surface. Follow the steps outlined below.

Step 1: Position the housing vertically so that the “Tetra®” logo is at the bottom (6:00) as you look into the front port.

Step 2: Place your thumb on the black slider mechanism, to the right (at 3:00) of the optic, and push it toward the housing.

Step 3: Rotate the port counter-clockwise until it stops (~90 degrees).

Step 4: Pull the port out from the housing.

Step 5: Hold the housing so that you may focus your attention on the front view port.

Step 6: Inspect the o-rings and the sealing surface on the front of the housing for wear or any foreign matter. If necessary, remove and clean the o-rings, o-ring grooves, and sealing surface, and lubricate it with silicone. You can apply pressure with your fingers to cause a bubble or bend in the o-ring, and then slip it out of its groove.

Step 7: When the cleaning and lubricating is completed, replace the o-rings into their grooves.

Step 8: This is a good time to clean the inside of the front view port and the red filter if necessary. Use a soft, clean, dry cloth, taking care not to rub any silicone onto the lens or filter. Spots on these surfaces may cause the camera to focus on the dirty lens.

Step 9: Apply a thin film of silicone to the o-ring surface area and the sealing surface on the front of the housing. This will allow the black view port to slide more easily when re-installing.

Step 10: Place the port into the opening on the housing until it seats into place. There are three orientations for the port, all of which permit it to be installed correctly. This is best observed by rotating the port until it partially “drops” into the front plate.

Step 11: Once the port is seated, push it into the housing to fully seal it and allow it to turn. This may require some gentle pressure because you are engaging a bayonet-type bore seal on the port.

Step 12: With the optic flush against the housing, rotate the port clockwise until you hear a click (~90 degrees). The black slider should move and snap into place when the port is aligned. Do not move the black slider with your finger when installing ports. When the port is correctly installed, it should not be possible to rotate it or pull it out.

Step 13: Check all function buttons and knobs on housing to ensure proper operation of all camera features. If camera is not operating properly return to Prepare the camera” above and follow all steps. Double check all seals and do a dunk test of housing in a shallow container of fresh water, inspect housing interior through optical port to ensure no water leakage (this should also be done periodically, and when camera is used for first time in some time, when any o-rings are changed or after service.). If leakage, moisture or condensation appears immediately place and keep housing upright (lens forward), as soon as possible carefully remove camera from housing, inspect camera and housing interior, remove batteries, dry any moisture, allow camera and housing interior to dry fully, and if camera is operational repeat preparations above (if not operational the camera should be assessed for feasibility of repair or replacement). If no leakage, stow and transport camera in housing to and from field in a container that will minimize physical jarring or change of temperature (e.g., a cooler) that could cause leaks or condensation. Handle camera gently when entering, exiting, and in water. Observe inside of housing for leaks or moisture near water surface and on descent of every dive used. After each day of use fully immerse housing in fresh water for several minutes, while immersed operate function buttons and knobs several times each to ensure all salt is removed. Air dry fully before opening housing back in a dust-free area.

Benthic Cover Analysis Equipment Preparation

This section details preparation of the equipment which should be gathered and checked out prior to conducting marine benthic cover sampling. See Appendix S5.a for a complete equipment list for conducting marine benthic cover sampling.

Procedures:

Step 1: Gather all scuba gear as described in the section below on “Coral settlement array equipment preparation.” Verify that there are enough full air cylinders available for the planned number of divers and dives.

Step 2: Verify that the boat has adequate fuel and all boating safety equipment and supplies are available as described in the section below on “Boat preparation.”

Step 3: Prepare the digital camera, including batteries and Compact Flash card, and install it the underwater housing as described in the above section: “Camera equipment preparation and handling” above. Mount the camera housing on the monopod so that the lens faces down to the foot.

Step 4: Ensure that the transect line is marked with tape at 50 cm intervals.

Step 5: List the compass headings, depth, and coordinates and carry a waterproof map of the benthic transect locations and compass headings.

Step 6: Ensure that a GPS unit is available and in working order.

Step 7: Prepare the underwater slate, pencils, and the required number of field data forms to complete the planned number of transects.

Step 8: Confirm that underwater lights are in working order and the batteries are fully charged.

Rugosity Measurement Equipment Preparation

This section lists the materials which should be gathered and checked out prior to conducting *in situ* rugosity measurements. See Appendix S5.a for a complete equipment list needed for conducting benthic rugosity measurements.

Procedures:

Step 1: Gather all scuba gear as described in the section below describing “Dive equipment preparation.” Verify that there are enough full air cylinders available for the planned number of divers and dives.

Step 2: Verify that the boat has adequate fuel and all boating safety equipment and supplies are available as described in the section below “Boat preparation.”

Step 3: Check the rugosity chain to make sure that no links have corroded through, and replace any 1m markers with new flagging tape (see “Rugosity chain preparation” in SOP #1 “Before the Field Season” for initial setup). Also, be certain that the link size has been standardized across parks to insure comparability of the measurements.

Step 4: Ensure that the transect line is in good repair (no cuts, large missing sections, etc.) and marked with tape at 50 cm intervals.

Step 5: List the compass headings, depth, and coordinates and carry a waterproof map of the sampling locations.

Step 6: Ensure that a GPS is available and in working order.

Step 7: Prepare the underwater slate, pencils, and the required number of field data forms to complete the planned transects.

Step 8: Confirm that underwater lights are in working order and the batteries are fully charged.

Coral Settlement Array: Installation and Retrieval Equipment Preparation

This section details the equipment which should be gathered and checked out prior to the installation and retrieval of the Coral Settlement Arrays (CSA). See Appendix S5.a for a complete equipment list needed for the installation and retrieval of CSAs. Construction of the CSAs is detailed in SOP #1 “Before the Field Season.” Laboratory analysis of the coral settlement plates is described in SOP #14 “Data management – Settlement Analysis.”

Procedures:

Step 1: Gather all scuba gear as described in the section below on “Dive equipment preparation.” Verify that there are enough full air cylinders available for the planned number of divers and dives.

Step 2: Verify that the boat has adequate fuel and all boating safety equipment and supplies are available as described in the section below “Boat preparation.”

Step 3: Prepare the digital camera, including batteries and flash card, and install it into the underwater as described in the above section: “Camera equipment preparation and handling.”

Step 4: Place five CSAs in a cooler or tray for storage during transit. Initial construction of the CSAs is described in SOP #1 “Before the Field Season”

Step 5: Gather a pair of pliers, a five pound sledgehammer, and five, 1 m, stainless steel rods. Place these items in a sturdy container for storage during transit.

Step 6: List the compass headings, depth, and coordinates and carry a waterproof map of the CSA locations.

Step 7: Ensure that a GPS unit is available and in working order.

Step 8: Prepare the underwater slate, pencils, and the required number of field data forms to complete the planned transects.

Step 9: Confirm that the underwater lights are in working order and the batteries are fully charged.

Coral Growth Analysis Equipment Preparation

This section outlines the materials which should be gathered and checked out prior to conducting *in situ* coral growth measurements. See Appendix S5.a for a complete equipment list for conducting coral growth measurements.

Procedures:

Step 1: Gather all scuba gear as described in the section describing “Dive equipment preparation” as written below. Verify that there are enough full air cylinders available for the planned number of divers and dives.

Step 2: Verify that the boat has adequate fuel and all boating safety equipment and supplies are described in the section below on “Boat preparation.”

Step 3: Gather the manual label maker and plastic labeling material, stainless steel wire or cable ties, a small hole punch, calipers, and the flexible measuring tape. Place these in a secure container for storage during transit.

Step 4: Set aside the transect line.

Step 5: List the compass headings, depth, and coordinates and carry a waterproof map of the sampling locations.

Step 6: Ensure that a GPS is available and in working order.

Step 7: Prepare the underwater slate, pencils, and the required number of field data forms to complete the planned transects.

Step 8: Confirm that the underwater lights are in working order and the batteries are fully charged.

Dive Equipment Preparation

Scuba diving equipment must be maintained according to Reference Manual #4 – Diving Management (RM-4), Manufacturer, and park specific guidelines appearing in each park’s Dive Safety Manual. Care and maintenance of dive equipment is also detailed in SOP #16 “After the Field Season.” It is imperative that all dive gear is inspected before each use. See Appendix S5.a for a complete equipment list for conducting diving activities.

Procedures:

Step 1: Ensure scuba cylinders are full and there are enough for the planned number of dives and divers. If necessary, fill tanks as per park specifications.

Step 2: Check to ensure all appropriate personal and dive safety equipment is present and in proper working condition before departing for the field. See Reference Manual #4 – Diving Management (RM-4) for requirements in SOP #2: "Training Observers."

Step 3: Prepare personal dive equipment in accordance with safety measures in Reference Manual #4 – Diving Management, park specific Dive Safety Manuals and SOP #3: "Safety Protocol."

Boat Preparation

Boat, trailer, and motor servicing should be independently done and verified for each park where field operations will occur well in advance of field operations. Ensure that this required preparation has been done in accordance with DOI Motorboat Operator Certification Course Manual and park specific guidelines. Park-specific guidelines can be obtained from the Park Dive Officer or the certified motorboat operator(s) at each park. Care and maintenance of the boat, motor, and trailer is also detailed in SOP #16 "After the Field Season."

Procedures:

Step 1: Ensure that there are adequate fuel and oil supplies for the planned activities.

Step 2: Verify that all required safety equipment is aboard and in proper working condition. A list of this equipment is available in SOP #16 "After the Field Season" and in the DOI Motorboat Operator Certification Course Manual.

Appendix S5.a. Gear list for equipment needed in this SOP

Note that a master gear list is located in SOP #1 “Before the Field Season.” If any changes are made with regard to type, quantity, or required items, SOP #1 needs to be simultaneously updated.

1) This equipment list is for preparing digital still camera for use in the Benthic Marine Communities Vital Sign Monitoring Protocol. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” section on Camera Equipment Preparation and Handling.

Equipment (#/quantity)	Preparation & Maintenance
Digital still camera	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
U/W housing	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
Flat port	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
Fully charged NiMH – AA camera batteries (8)	Label and charge
Compact flash cards (2)	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
Lens cleaner	Ensure that this equipment is available
Lens paper	Ensure that this equipment is available
Clean, lint free cloth (2)	Ensure that this equipment is available
O rings	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
Silicone o-ring grease	Ensure that this equipment is available
Monopod or photoquadrat	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
Red filter for camera lens	See SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”

2) Equipment list for conducting marine benthic cover surveys. This equipment list is refers to SOP #5 “Pre-Dive Equipment Preparation” section on Benthic Cover Analysis Equipment Preparation.

Equipment (#/quantity)	**Preparation & Maintenance**
Digital still camera prepared and mounted into U/W housing and monopod	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
Small wire brush	Ensure that this equipment is available
30m transect line	Labeled at 50cm intervals, see SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, and maps of transect locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS	Ensure that this equipment is available
U/W compass	Ensure that this equipment is available
Surface float marker	Ensure that this equipment is available
U/W slate with pencils	Ensure that this equipment is available
U/W field data forms	See SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
U/W lights	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has recent full power charge
Pelican case	Ensure that this equipment is available
Scuba gear	See section on “Dive Equipment Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See section on “Boat Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

3) Equipment list for conducting benthic rugosity measurements. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” section on Rugosity Measurement Equipment Preparation.

Equipment (#/quantity)	**Preparation & Maintenance**
20m rugosity chain on spool	See SOP #1 “Before the Field Season”
30m transect line	See SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS	Ensure that this equipment is available
U/W compass	Ensure that this equipment is available
U/W slate with pencil	Ensure that this equipment is available
U/W field data forms	See SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
U/W lights	Ensure equipment is in working order
U/W light batteries (2)	Ensure equipment has recent full power charge
Scuba gear	See section on “Dive Equipment Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See section on “Boat Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

4) Equipment list for installation and retrieval of the coral settlement arrays. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” section on Coral Settlement Array: Installation and Retrieval Equipment Preparation.

Equipment (#/quantity)	**Preparation & Maintenance**
Digital still camera prepared and mounted into U/W housing and monopod	See section on “Camera Equipment Preparation & Handling” in SOP #5 “Pre-Dive Equipment Preparation”
White slate to set white balance on camera	Ensure that this equipment is available
Coral settlement arrays (5)	See SOP #1 “Before the Field Season”
Cooler or tray to hold the CSAs	Ensure that this equipment is available
Ice	Ensure that this equipment is available
Foam pad	Ensure that this equipment is available
Pliers or wrench	Ensure that this equipment is available
5 pound sledge hammer	Ensure that this equipment is available
1 meter stainless steel rods (5)	Ensure that this equipment is available
Plastic 90 degree angle protractor	Ensure that this equipment is available
Underwater drill	Ensure equipment is in working order
Re-usable tags (At least 45 – 1/CSA)	See SOP #8 “Conducting Coral Settlement Sampling”
Engraver, dremel drill, or similar tool	See SOP #8 “Conducting Coral Settlement Sampling”
Transect tape	Ensure that this equipment is available
Heavy duty, sealable plastic bags	See SOP #8 “Conducting Coral Settlement Sampling”
Mesh gear bags	Ensure that this equipment is available
Repair supplies (new threaded rods, epoxy, spare hardware)	See SOP #8 “Conducting Coral Settlement Sampling”
Coordinates, depths, compass headings, maps of CSA locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS	Ensure that this equipment is available
U/W slate with pencils	Ensure that this equipment is available
U/W field data forms	Ensure sufficient number of copies available
U/W lights	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has recent full power charge
Scuba gear	See section on “Dive Equipment Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See section on “Boat Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

5) Equipment list for conducting the coral growth measurements. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” section on Coral Growth Analysis Equipment Preparation.

Equipment (#/quantity)	Preparation & Maintenance
1m flexible fiberglass measuring tape with centimeter markings	Ensure that this equipment is available
Calipers	Ensure that this equipment is available
Stainless steel wire or cable ties (10)	Ensure that this equipment is available
Dymo® manual plastic labels	See SOP #1 “Before the Field Season”
Metal or plastic tags (10)	See SOP #9 “Measuring Coral Growth”
Small hole punch	Ensure that this equipment is available
Small wire brush	Ensure that this equipment is available
Flagging tape	Ensure that this equipment is available
Dive weights	Ensure that this equipment is available
Transect line	Ensure that this equipment is available
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS	Ensure that this equipment is available
U/W compass	Ensure that this equipment is available
U/W slate with pencils	Ensure that this equipment is available
U/W field data forms	See SOP #9 “Measuring Coral Growth”
U/W lights	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has recent full power charge
Scuba gear	See section on “Dive Equipment Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See section on “Boat Preparation” in SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

6) Equipment list for conducting diving activities. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” section on Dive Equipment Preparation.

Equipment (#/quantity)	Preparation & Maintenance
Air cylinders	Verify hydro and VIP, fill with compressed air. See SOP # 16 “After the Field Season”
Fins	Ensure that this equipment is available
Booties	Ensure that this equipment is available
Wetsuit (2)	Ensure that this equipment is available
Hooded vest	Ensure that this equipment is available
Weights	Ensure that this equipment is available
Belt/integrated weight container	Ensure that this equipment is available
BC	Verify annual service. See SOP #16 “After the Field Season”
Regulator	Verify annual service. See SOP #16 “After the Field Season”
Mask & Snorkel	Ensure that this equipment is available
Dive computer	Ensure that this equipment is available
Thermometer	Ensure that this equipment is available
Compass	Ensure that this equipment is available
Dive bag for boat work	Ensure that this equipment is available
Bucket for shore work	Ensure that this equipment is available

SOP #6: Selecting and Marking Subtidal Sampling Transect Locations

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See track changes	Responses to reviewer comments		1.00
2.01	7/31/07	L. Basch	See track changes	Clarifications		2.00

Purpose

This SOP describes how to select and mark subtidal transect locations. Benthic monitoring transect locations will have three separate components: 1) transects for obtaining percent cover, 2) coral settlement arrays and 3) individually tagged coral colonies along the transect.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if this SOP is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix S6.a in this SOP.

Selecting Transect Locations

Locations for transects will be randomly selected within ARCMap® 9.0 GIS using the criteria outlined below. Randomly selected alternative transect locations will also be generated in case the initial location is unsuitable with respect to benthic habitat type, area, or possesses conditions that make it unsafe to work. The following steps will be done prior to conducting any field work.

Generating Random Points for Fixed Transect Start Pins within ARCMap®

Step 1: Open ARCMap® on your computer

Step 2: Open park specific project file and associated layers which should include a map of the park, the park unit(s) boundaries, benthic habitats, and isobaths.

Step 3: Criteria for generating points are as follows.

First: Within park boundaries plus adjacent coastal areas that may impact (or be impacted by) the park. Adjacent coastal areas extend to the edges of the watershed(s) in which the park lies.

Second: Within 10 to 20 m depth contours

Third: On hard substrate (basalt or limestone, or coral reef) that has been predetermined from the benthic habitat map.

Step 4: Generate 30 points with X and Y coordinates that fall within depth contours and on hard substrate, using the following procedure.
First: Select the benthic contours shape file.

Second: Create a polygon or raster file within the 10 m to 20 m depth contour. This can be done by right clicking on the contour shape file and selecting “Open Attribute Table”. Note this file must be the original point file (e.g., Lidar data file) and not a line file that has been interpolated from a point file.

Third: Then select the “Options” button in the lower right hand corner of the window and choose “Select by Attributes” from the pull down menu. In the “Select by Attributes” dialog box enter in the query to select the appropriate depth contours (See example query phrase in Figure S6.1).

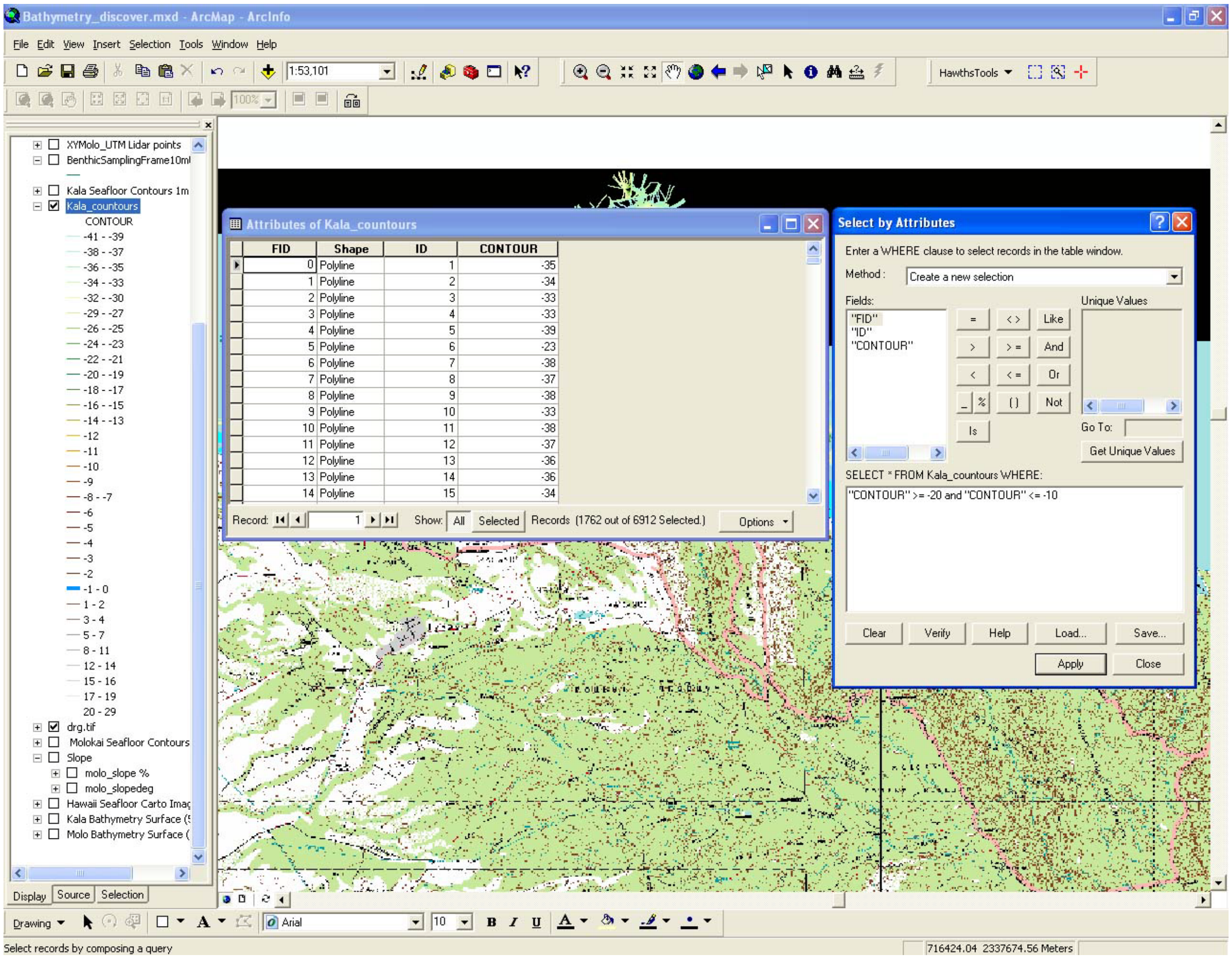


Figure S6.1. Sample screen display for selecting depth contours within a shape file in ARCMap® 9.0.

Fourth: Select this new layer and load the Hawth's tools from the View-Toolbar menu. Hawth's tools is a free extension that can be downloaded from http://www.spatialecology.com/htools/download.php (last accessed 05July06).

Fifth: Under the Hawth's Tools down arrow button, select the "Sampling Tools-Generate Random Points" option.

Sixth: Within the dialog box, select the polygon or raster file, check the "Prevent points from being located in the NODATA cells" box, enter 30 points within the "Generate this number of random points" box, and specify the output filename (Figure S6.2). It should be noted that some parks (e.g., WAPA, KAHO) have sites with existing data sets and these sites will be included in the sampling frame to extend the historical perspective, assuming initial selection of these sites was random. The sites must meet the basic criteria (i.e., hard bottom, 10 to 20 m depth) to be incorporated into the sampling frame. Therefore, simply subtract the number of historical sites from the total number of new points generated. For example, if three historical sites will be used in the sampling frame then simply generate 27 new points for consideration.

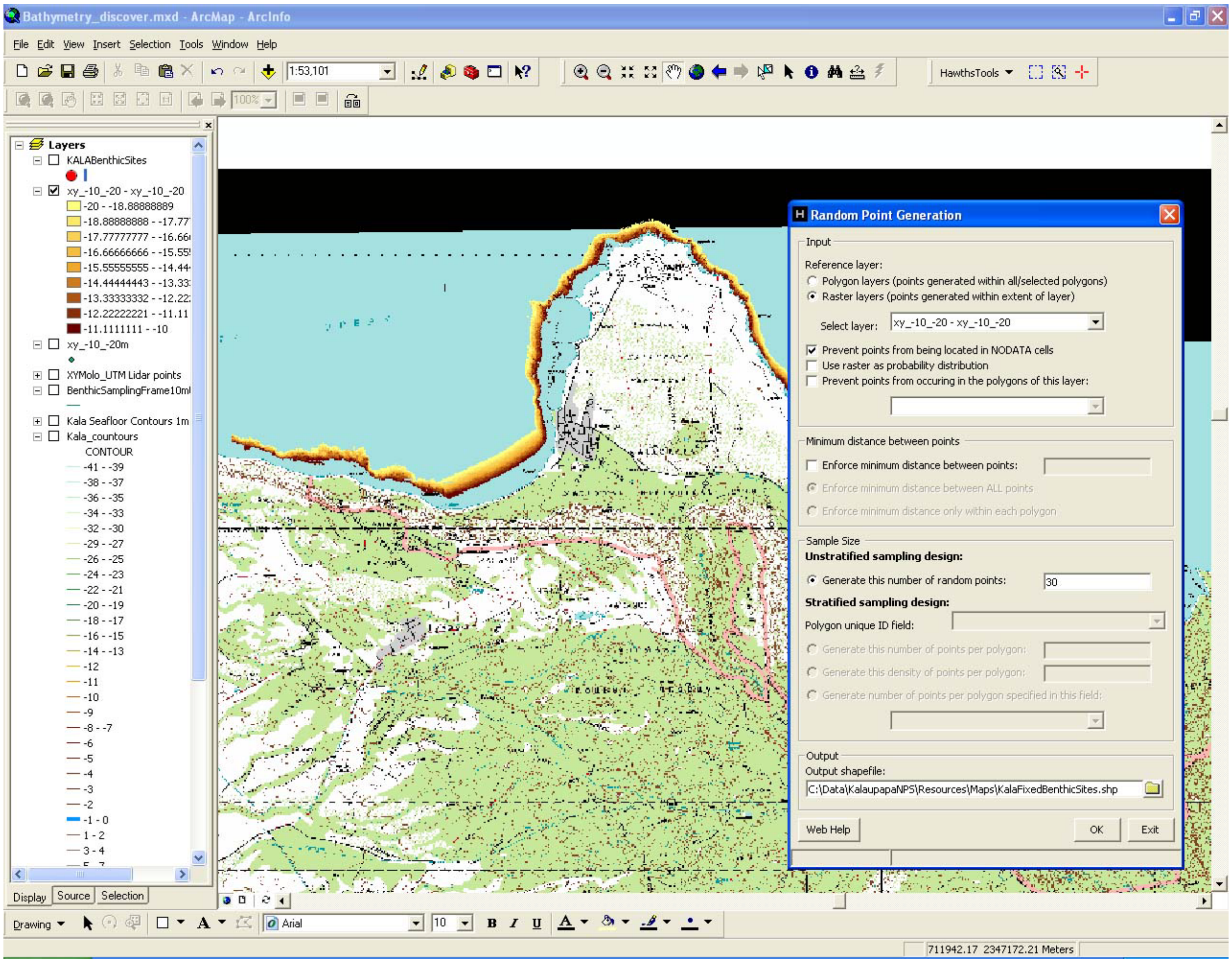


Figure S6.2. Sample screen display for generating 30 random points within a shape file using the Hawth's Tools extension in ARCMap® 9.0.

Seventh: Once the points have been displayed then use the Hawth's tools "Table Tools – Add XY to Table (points)" to create X and Y values for each of the random points within the newly created output shape file. Select the Point layer to identify the shape file and label the X and Y Fields within the Add new fields radio button.

Step 5: Randomly select 15 of the 30 points that will be fixed and sampled annually beginning in year 1. The other 15 points will be used as alternative locations should any of the first 15 points be deemed unsuitable (e.g., sand instead of hard substrate) during the field installation. Random selection can be done using the Microsoft Excel® "RANDBETWEEN" function or simply picking points out of a hat. For example, in Excel assign the 30 points to 30 cells and label them sequentially from 1 to 30 in another column. Then in a third column highlight 30 cells and enter the formula =Randbetween(1,30). Select the point whose number is generated in the first 15 cells.

Step 6: Establish a Microsoft Excel® file (e.g., KALA_transect metadata.xls) to record all XY coordinate pairs for transect start points that are used cumulatively over time, starting with year one. When new random points are generated, compare these against existing point coordinates to assure that no existing point coordinates are re-used, and add any new point coordinates to this list.

Generating Random Points for Random Transect Start Pins within ARCMap®

Step 1: Annually generate 15 points (plus fifteen additional points for alternative transect locations, if needed) that will be sampled during that year using the same procedure as above ("Generating random points for fixed transect start pins within ARCMap®").

Step 2: Each year a new set of random points will be generated and sampled.

Step 3: If the generated random points have been used previously for either fixed or random transects (see Step 6 above) then automatically use the alternative transect locations. In subsequent years you may have to generate more than 30 points to ensure that the random point coordinates have not been used for previous transect start points.

Printing Coordinates

Step 1: Print 15 random points for fixed transect locations:
First: Print out X and Y coordinates for the 15 primary fixed transect start points as successively numbered points in a list. To maximize efficiency in the field, the list should be ordered according to proximity of the transect locations to each other. Clearly label the list so that the primary points are not confused with the alternative points printed out in Step 2.

Second: Print the GIS map(s) showing the transect start points relative to each other.

Third: Laminate (two-sided: map on one side, list on the other) for field use.

Fourth: Coordinates should be in both Universal Transverse Mercator Geographic Coordinate System (UTM) and Latitude and Longitude (hddd'mm.mmm') formats.

Step 2: Print 15 random points for alternative fixed transect locations.
First: Print out X and Y coordinates for the 15 alternative sites as successively numbered points in a list. Clearly label the list so that the alternative points are not confused with the primary points printed out in Step 1.

Second: Print the GIS map(s) showing the transect start points relative to each other. Include all 30 points for fixed transects. This will allow field personnel to better plan their dives if an alternative site needs to be used.

Third: Laminate (two-sided: map on one side, list on the other) for field use.

Fourth: Coordinates should be in both UTM and Latitude and Longitude (hddd'mm.mmm') formats.

Step 3: Repeat steps 1 and 2 using points for random transect locations.

Step 4: Enter X and Y coordinates, with transect start location number into GPS (See SOP #4).

First: Fixed sites should have the letter F as a prefix to the transect location number.

Second: Random sites should have the letter R as a prefix to the transect location number. Use consecutive R#s prefixes (R06001, R07001, R08001…) across years (2006, 2007, 2008…) to facilitate identification of random points.

Third: Wayponts for each benthic transect within a park are stored in the park's annual copy of the marine database and the main database which resides on the I&M share drive (i.e., "I" drive) of the PACN data server at HAVO. Once a year the main database is updated with the waypoints from each park by the marine biological technician.

Establishing Fixed Study Sites

These procedures detail establishing a full benthic monitoring transect location with three separate monitoring components: 1) permanent steel pins to mark the start and end points of a transect location for obtaining percent cover, 2) installation of three Coral Settlement Arrays (CSA) per transect, and 3) ten individually tagged coral colonies per transect for growth rate monitoring. Note that implementing component # 3 is valuable, but optional depending upon time and park resources. Some parks may elect to implement component #3 after several years once experience has been obtained with the first two components. All three components listed above can be installed on a single 60 minute dive to establish one transect.

Before Entering the Field

Step 1: Collect the equipment necessary to complete all tasks that will be conducted (Appendix S6.a). Cut pins and other mounting rods to required lengths. As noted in SOP #1 "Before the Field Season.", transect pins should be approximately 0.40 meters long and CSA mounting rods should be at least 0.50 meters long.

Step 2: Ensure all random points have been generated, printed, and downloaded into the GPS.

Step 3: Print relevant forms on plastic coasted paper for in-water use. Forms for CSA installation and tagging corals are needed in-water.

Navigating to Selected Sites

Step 1: Using a Global Positioning System (GPS) unit in which the random transect location points are already stored, navigate by boat, or surface swim, to the location using the GPS's navigation feature. If surface swimming, put the GPS in a transparent waterproof container attached to a surface float such as an inner tube with dive flag and a line with a bottom weight to be set at the transect start point (see SOP #4 "Using Garmin® Global Positioning System (GPS) Units" for information on using GPS).

Step 2: When approaching the random point, assess the area for safety. If the point is not a location that is safe to dive or anchor the boat, discard the point and adopt one of the next closest alternative points. Move on to the next location. Repeat steps 1 and 2 until a random point is found that is determined to be safe for field work.

Step 3: When within approximately 3 meters of the site, carefully but quickly lower a surface float marker or Pelican® surface float with a bottom weight (~1 kg) so that it comes to rest as close as possible to transect start/terminus pin location.

Step 4: Allow the boat to drift a short distance off the site before lowering and setting the anchor, or tying boat's bow line to a mooring buoy (if available near the site).

Step 5: Always attempt to lower the anchor into a nearby sand or non-colonized rock or boulder patch. If no sand or rock patch is available, attempt to lower anchor so that it does not impact live coral or other live benthic organisms. If a permanent mooring buoy-line is available nearby, use it to securely tie off boat's bow line. Then, locate the deployed surface float by taking a compass bearing to it.

Step 6: Using mask, fins, and snorkel, determine the bottom substrate composition from the surface float along the predetermined compass bearing for a minimum of 25 to 30 m. If the underlying bottom includes unconsolidated material (e.g., sand) or too small of an area of contiguous hard bottom, discard the location and adopt an alterative random point to replace it. Collect the float and move to the next point. Repeat until a site with appropriate safety and bottom characteristics is located.

Installing Permanent Transect Marking Pins

The following protocol steps assume that divers have successfully navigated to and selected the fixed transect site and that it meets all suitability criteria for transect placement. Care must be taken when initially installing transect locating pins. One permanent transect will be installed at each monitoring transect location. Stainless steel threaded rod stock (All Thread) will be used as transect marking pins in non-living hard substrate. Other areas have developed methods to install transects without the use of permanent pins (e.g., large cable ties, marker floats). These methods are not feasible for the PACN parks because of environmental conditions and the necessity that transects be easily revisited and highly reproducible. In particular, large wave disturbances such as typhoons, and typical winter storm swells require that markers have a low cross-sectional area to reduce drag, do not physically degrade (e.g., cable ties), and are anchored deep enough in the substrate to survive substantial habitat disturbance. Refer to the equipment list needed to install permanent transect marking pins in Appendix S6.a.

Step 1: Upon descent, examine both possible transect directions along the isobath to ensure that at least one section contains a minimum 25 m length of contiguous habitat. If neither direction meets this criterion then resurface and select one of the alternative points.

Step 2: When a point is determined to be suitable, starting in appropriate substrate as close as possible to the weight on the bottom of the float marker, install a stainless steel threaded pin into solid substrate by hammering the pin into a crack or crevice with a 2 or 5 pound sledgehammer. Alternatively, an appropriate diameter hole is drilled into solid hard bottom (basalt, limestone or dead coral) using a rock or masonry drill bit in an underwater drill. Permanently epoxy the pin into a vertical position using a suitable fast-setting two-part marine epoxy, such as Powerfast or Z-Spar. Powerfast is packaged in dual "caulking" or syringe-like tubes, to mix epoxy parts and minimize epoxy handling. Z-Spar comes in separate metal containers; each part needs to be transferred to separate plastic containers for underwater use. Latex gloves should always be worn when handling epoxy, including underwater. Place an appropriate amount of epoxy in hole, then press rod into hole, tapping it gently with a hammer to set pin. If needed, apply epoxy around the base of the installed pin. The start and end pins of the transect should extend at least ten cm above the bottom.

Step 3: Install one cable tie around the rod to denote the start pin. Leave the trailing end of the cable tie intact to facilitate relocation.

Step 4: Randomly select a possible transect direction along the isobath unless only one direction contains contiguous habitat. One can use a preselected list of random numbers for compass bearings, or spin a knife handle to determine direction. Take a compass bearing at the depth of the pin along the isobath (using a wrist or diving console mounted underwater compass with side sighting capability), and record the bearing on an underwater slate. If the bottom is of uniform depth, the compass bearing should be run parallel to shore to ensure measurement of similar habitat. Care must be taken to keep the compass away from stainless steel pins or any other ferrous metals, including any dive gear and tools.

Step 5: Use a fiberglass transect tape marked in meters to measure the initial transect length. The transect tape should have a loop and small brass clip at the 0 m end and a loop and small brass clip on the handle. Loop and secure the 0 m end of the tape to the start pin. Two divers then swim the compass bearing along the isobath slightly above the bottom, one maintaining the bearing and the second holding the tape allowing it to feed out freely. The latter diver should look back at the tape often to ensure that it remains straight and taut. The divers should swim along the depth contour following the selected, or predetermined, random compass heading.

Step 6: Once the appropriate 25 m distance has been swum, the diver handling the tape should stop and slightly stretch the tape again so that it is tight along the bottom

Step 7: Temporarily secure it on the bottom (e.g., to a temporary stake, rock or dead coral head).

Step 8: The diver that swam the compass bearing should turn 180 degrees and swim back along the transect to check transect orientation, placement along the isobath, and tautness. If necessary, orientation or placement should be corrected to match the compass heading and isobath

Step 9: The two divers should then install the end pin at the 25 m mark, as was done at the start (0 m) pin.

Step 10: Install two cable ties around the rod to denote the end pin. Leave the trailing end of the cable ties intact to facilitate relocation.

Step 11: If relocating the end pin will be difficult (e.g., site typically has poor visibility) then divers can also install shorter threaded rods every 5 meters between end pins, ensuring the tape remains taut as they work. The pins should be installed as above, except that no more than ten cm of the threaded rods should extend above the substrate. Install the additional pins between the end pins only if necessary, because this procedure may detract from the underwater natural setting of each park.

Step 12: The transect tape is reeled up after all pins are installed. Once epoxy is set and monitoring commences, the 0 m tape end is looped or clipped to the start pin, the tape looped once around either the intermediate pins or natural anchor points, and then looped or clipped to the end pin. By clipping or looping the meter tape, this will ensure that it is pulled taut and does not move around a lot in surge. The tape cannot move much, or future measurements along the transects will have poor precision and reproducibility.

Step 13: If surge is a problem then an alternative approach is to use a 35 to 40 m ¼" diameter leaded line that is deployed as above between the end pins. This line is marked at every meter and laid along the bottom during photoquadrat sampling.

Step 14: Note: the random transects will not have permanent pins to mark the start and end points. Follow and repeat Step 1 for each transect. Instead of attaching transect tape to pins, temporarily attach tape ends to non-living natural anchors or temporary pins on the bottom. Continue with Steps 4 to 8.

Installing Coral Settlement Arrays (CSA)

The following protocol steps assume that divers have successfully navigated to and selected the fixed transect site and installed the permanent transect marking pins. To complete installation, three CSAs need to have been constructed, labeled, and conditioned as described in SOP #1 "Before the field season." Refer to the equipment list needed to install CSAs in Appendix S6.a.

Step 1: Selection of points for placement of the CSAs is done at pre-determined points along the benthic percent cover transect line. Three pins are installed 2.5 meters off the transect on the shoreward side at the following locations:
First: The start pin
Second: The end pin
Third: At the mid-point of the transect (12.5 m mark)

Step 2: The stainless threaded rod of the CSA should be set approximately 0.25 m into solid substrate (when ever possible, and no less than 0.1 to 0.15 m). Use protractor to drill holes and set rods vertically in substrate. The rod should be installed into a hole of approximate diameter, e.g., ½ inch and tapped with a hammer to set, and then affixed in place with a marine epoxy; excess epoxy can be molded around the rod on the surrounding substrate by hand, with latex gloves, which should always be worn when handling epoxy. Preferably, an underwater drill is used to make holes, the hole is partly backfilled with epoxy and the rod inserted. Care must be taken to ensure that all CSA rods are installed straight – vertical to the bottom. Excess epoxy can be molded around the rod by hand as described above.

Step 3: The epoxy must be cured for at least 24 hours before settlement tiles are mounted on rods, so that chemicals catalyzed when the two epoxy parts are mixed do not contaminate the settlement tiles. Coral and other larvae are extremely sensitive to chemical and other signals, including oils from fingers, which strongly bias any initial settlement micro-site preference and longer-term recruitment patterns.

Step 4: The settlement tile pairs are fastened to the threaded rods using the appropriate hardware and tools; (e.g., flat head screwdriver, pliers, as appropriate). Tool(s) should be tied to a short piece of thin, strong (parachute type) cord, which is attached to a gear bag or diver's BC with a small brass clip or carabiner.

Step 5: Place the long PVC tube (15 cm long) over the mounting rod (Figure S6.1).

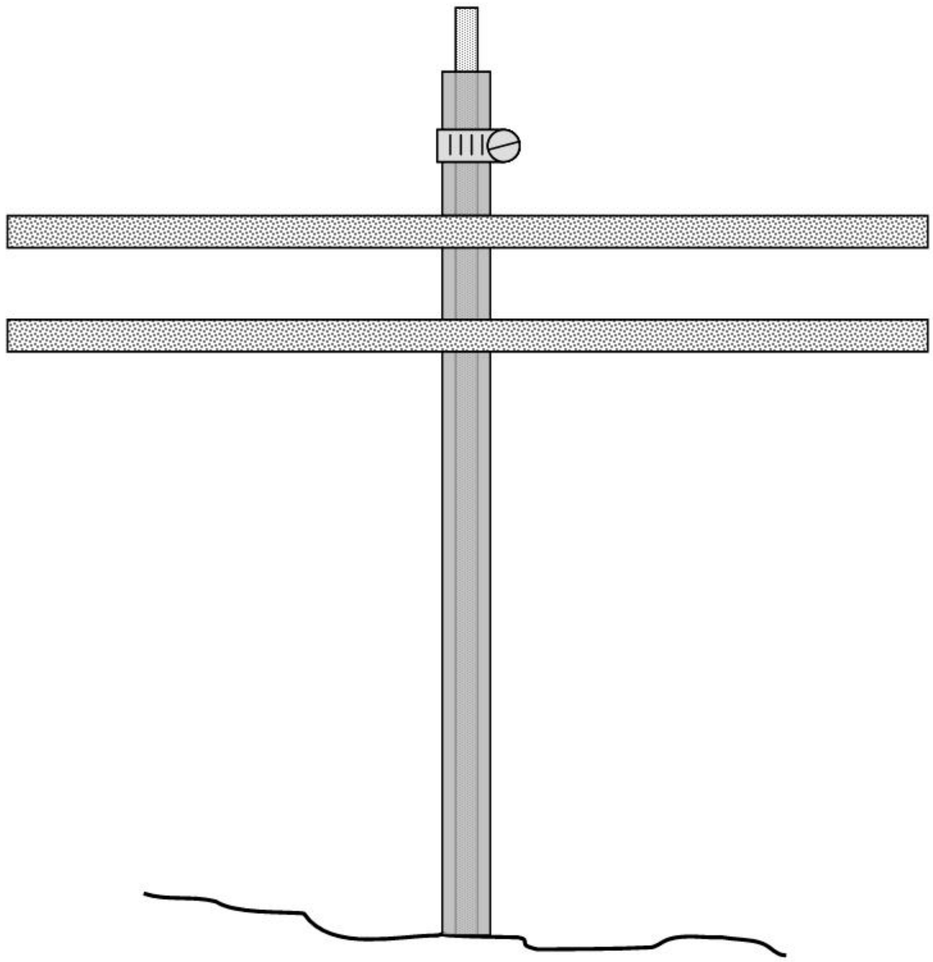


Figure S6.1. Settlement tile array showing the plate pair attached to the 45 cm stainless steel threaded rod.

Step 6: Place the lower terra cotta plate onto the rod with the edge arrow pointing upward. It should rest on the top of the PVC tube such that it is 15 cm off the bottom and parallel to the substratum. Double check to ensure the plate was installed with the edge arrow pointing up.

Step 7: Place a short PVC tube (1 cm long) on the mounting pin.

Step 8: Place the upper tile onto the pin with the edge arrow pointing upward so it rests on the top of the short PVC tube. A gap of 1 cm should be present between the tiles. Ensure the two tiles are parallel to each other. Double check to ensure the upper plate was installed with the edge arrow pointing up.

Step 9: Place a 5 cm section of 1 cm outer diameter clear plastic tubing over the top of the CSA pin and push until snug against the upper tile plate. Place a 2 cm diameter hose clamp over the plastic tubing and tighten it with a flat head screwdriver or pliers.

Step 10: Record the plate # information on the settlement dataform in Appendix S6.b.

(Optional) Tagging Individual Corals for Repeated Growth Rate Measurements

The following protocol steps assume that divers have successfully navigated to and selected the fixed transect site and installed the permanent transect marking pins. Growth rate measurement is an important, but optional procedure and will take two divers with one dive per transect. The first ten *Pocillipora eydouxi* colonies encountered within 1 m to each side of the permanent transect line will be identified and monitored for growth (See Veron 2000 for photograph and defining morphological traits of *P*. *eydouxi*). A total of 150 coral colonies (on 15 permanent transects) will be tracked for growth monitoring. Working in close proximity to coral colonies should be done with care to ensure that the colonies are not damaged, although minor damage will heal. Refer to the equipment list needed to tag individual corals in Appendix S6.A.

Step 1: Swim slowly along the transect and search for colonies of *Pocillipora eydouxi* within 1 m to either side of the line.

Step 2: Selection of colonies should begin when the first coral colony is encountered from the start of the transect and proceed in sequence toward the end of the transect.

Step 3: All colony size classes encountered with a basal diameter greater than two centimeters should be considered. Basal diameter of colonies smaller than two centimeters are too small to accurately track over time.

Step 4: The first ten colonies should be selected on each transect.

Step 5: Once a colony is located, attach a plexiglass or plastic tag, pre-labeled using an engraver (e.g., dremel tool) or dymo tape (embossed) labeler, to the substrate in close proximity to the colony using stainless steel wire, plastic cable ties, or nails. The tag setup must be at a sufficient distance to avoid contact with the colony and allow for future growth. The tag should be marked with an individual identification number using the following format: four letter park identifier - three digit number starting at 001 – two digit year (example: WAPA-001 - 05). See SOP #1: “Before the Field Season” for details on making coral colony tags.

Step 6: Sketch a map, on an underwater slate, the relative position of colonies, with their identification numbers, distance along, and to the transect line. After the dive transcribe this information into a log book for future reference when relocating the colonies. This information will also be documented in the benthic database.

Step 7: Periodically use gloved fingers to gently rub the tags to remove fouling organisms and maintain tag readability. Tags can be cleaned whenever performing other tasks along the transect line.

Appendix S6.a. Equipment necessary to install fixed transect locations

1) Equipment list for installing permanent transect marking pins. This equipment list refers to SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations"

Equipment (#/quantity)	Preparation and Maintenance
1 cm (3/8") X 40 cm (16") stainless steel threaded rod (2+)	More pins may be necessary if conditions warrant
Z-spar or Powerfast Epoxy (1 ea.)	Ensure that 1 gallon of both parts A&B (Z-Spar) or several tubes (Powerfast) are available
Mesh bag (1)	Ensure that this equipment is available
Tupperware containers for Z-spar (2)	One for each Z-spar compound part; Ensure that this equipment is available
2 or 5 lb. Sledge hammer (2)	One for back up; Ensure this equipment is available
30 m transect line (2)	Labeled at 50 cm intervals; see SOP #1 "Before the Field Season"
Coordinates, depths, compass headings, or maps of transect locations	See SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations"
GPS (1)	See SOP #4 "Using GARMIN® Global Positioning System (GPS) Units"
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
Surface float marker (2)	One for back-up; Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W lights (2)	Ensure that this equipment is available
U/W light batteries (2 sets)	Ensure that this equipment is charged and available
Scuba gear	See SOP #5 "Pre-Dive Equipment Preparation"
Boat, motor, trailer, and associated gear	See SOP #5 "Pre-Dive Equipment Preparation"

2) Equipment list for installation and retrieval of the coral settlement arrays. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation,” SOP #6 “Selecting and Marking Subtidal Sampling Transect Location,” and SOP #8 “Conducting Coral Settlement Sampling.”

Equipment (#/quantity)	Preparation & Maintenance
Digital still camera prepared and mounted into U/W housing	See SOP #5 “Pre-Dive Equipment Preparation”
White slate to set white balance on camera	Ensure that this equipment is available
Coral settlement arrays	3 CSA plate pairs per transect; See SOP #1 “Before the Field Season” for construction and labeling information
Cooler or tray to hold CSAs (2-3)	Ensure that this equipment is available
Ice	Ensure that this equipment is available
Foam pad (1 per cooler)	Ensure that this equipment is available
Pliers and flat head screwdriver (2)	2 of each; Ensure that this equipment is available
0.5 m long stainless steel threaded rods (3)	Ensure that this equipment is available
5 pound sledge hammer (2)	Ensure that this equipment is available
1 cm(3/8”) x 50 cm (20”) stainless steel threaded rods (3)	Ensure that this equipment is available
Plastic 90 degree angle protractor	Ensure that this equipment is available
Z-spar or Powerfast Epoxy (1 ea.)	Ensure that 1 gallon of A&B (z-Spar) or 1 tube (Powerfast) available
Underwater drill	Ensure equipment is in working order
Re-usable tag (at least 45 – 1/CSA)	See SOP #8 “Conducting Coral Settlement Sampling”
Engraver, dremel drill, or similar tool	See SOP #8 “Conducting Coral Settlement Sampling”
30 m transect line (2)	labeled at 50 cm intervals; see SOP #1 “Before the Field Season”
Heavy duty, sealable plastic bags	See SOP #8 “Conducting Coral Settlement Sampling”
Mesh gear bags (1)	Ensure that this equipment is available
Repair supplies (new threaded rods, epoxy, spare hardware)	See SOP #8 “Conducting Coral Settlement Sampling”
Coordinates, depths, compass headings, maps of CSA locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations” and SOP #8 “Conducting Coral Settlement Sampling”
GPS (1)	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	Ensure sufficient number of copies available
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has sufficient power charge
Pelican case (1)	Ensure equipment is available

2) Equipment list for installation and retrieval of the coral settlement arrays. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation,” SOP #6 “Selecting and Marking Subtidal Sampling Transect Location,” and SOP #8 “Conducting Coral Settlement Sampling.” (continued)

Equipment (#/quantity)	Preparation & Maintenance
Surface float marker (2)	one for back-up; Ensure equipment is available
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

3) Equipment list for tagging and conducting the coral growth measurements. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” and SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations.”

Equipment (#/quantity)	Preparation & Maintenance
1 m flexible fiberglass measuring tape with centimeter markings	Ensure that this equipment is available
Calipers	Ensure that this equipment is available
Stainless steel wire or cable ties (10)	Ensure that this equipment is available
Dymo embossed plastic labels (10)	See SOP #1 “Before the Field Season”
Metal or plastic tags (10)	See SOP #9 “Measuring Coral Growth”
Small hole punch (2)	Ensure that this equipment is available
Small wire brush (2)	Ensure that this equipment is available
Flagging tape (2 rolls)	Ensure that this equipment is available
Mesh gear bags (2)	Ensure that this equipment is available
Dive weight	Ensure that this equipment is available
30 m transect line	Labeled at 50 cm intervals; see SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS (1)	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
Surface float marker (2)	One for back-up; ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	See SOP #9 “Measuring Coral Growth”
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has sufficient power charge
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

Appendix S6.b. CSA dataform (with optional photo log)

Dataform used to record information on deployment and retrieval of coral settlement arrays (CSAs). Codes for the plate surfaces are as follows: UT=Upper Top; UB=Upper Bottom; LT=Lower Top; LB=Lower bottom. Copy of this dataform found in Appendix S8.b. If any changes are made to this dataform, update copy in SOP #8 “Conducting Coral Settlement Sampling.”

Settlement Log ***Observers:*** ***Year:***

Park Code	Transect	Depth (m)	Plate #	Deployed (ddmmyy)	Retrieved (ddmmyy)	Photo # (n if no photo)	Plate Surface (UT,UB,LT,LB)	Notes (broken, lost, etc.)

SOP #7: Conducting Marine Benthic Cover and Rugosity Surveys

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/07	Eric Brown	See track changes	Response to reviewer's comments		1.00
2.01	7/31/07	L. Basch	See track changes	clarifications		2.00

Purpose

This SOP explains how to conduct benthic photographic surveys to assess substrate composition (percent cover) of live corals, algae, and other benthic organisms or substrates. It also describes how to measure rugosity and acquire environmental metadata at each transect. The SOP assumes that a monitoring site has been previously established (see SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations"). Therefore, the SOP will detail relocating the monitoring site, relaying the transect line, and photographing the benthic substrate using a digital camera in an underwater housing. This SOP is designed to be completed by two divers (see SOP #2 "Training Observers"). Camera instructions have been written specifically for the Olympus® C-5050 digital camera and a Light and Motion® Tetra Underwater Camera Housing, but the instructions should also work for earlier and later models of the Olympus® (e.g., Olympus® 3030, 3040, 4040, 6060, 7070) and associated Tetra Housings. Other digital camera-housing combinations work using similar concepts but the actual mechanism of operation may vary. Use of this equipment, while shown to be effective, is not intended as an endorsement of any particular manufacturer or model. The amount of time needed to complete this procedure is approximately 10 minutes for relocating and retrieving the transect. An additional 15-20 minutes will be needed for photographing quadrats along a 25 m transect in ideal conditions. The procedure needed for obtaining a measurement of rugosity takes an additional 10 minutes. All safety precautions will be followed as outlined in SOP #3 "Safety Protocol."

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 “Before the Field Season.” The master equipment list should be updated simultaneously if this SOP is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix S7.a in this SOP.

Preparation

Equipment List

For a complete list of equipment needed to carry out these procedures, please refer to Tables in Appendix S7.a. Also refer to SOP #5 “Pre-Dive Equipment Preparation” and SOP #1 “Before the Field Season” for a complete listing of equipment needs. Observers will want to ensure that all equipment is available in working order prior to the scheduled survey dive day. For more detailed information on protocol prior to dive day, please see SOP #5 “Pre-Dive Equipment Preparation.”

Dataforms

Dataforms needed for this protocol can be found in Appendix S7.b. Forms should be photocopied or printed onto plastic paper for use underwater.

Laying and Photographing Transect Lines

(Re)Locating the Monitoring Site and Preparing to Photograph Transects

Step 1: Using a Global Positioning System (GPS) unit navigate by boat, or surface swim, to the transect location start points stored as waypoints in the GPS memory, using the GPS’s navigation feature. If surface swimming, put the GPS in a transparent waterproof container attached to a surface float such as an inner tube with dive flag and a line with a bottom weight to be set at the transect start point [see SOP #4 “Using GARMIN® Global Positioning System (GPS) Units” for information on using a GPS].

Step 2: At approximately 3 meters from the site, carefully but quickly lower a surface float marker or Pelican® surface float with a bottom weight (~1 kg) so that it comes to rest as close as possible to the transect start/terminus pin or point.

Step 3: Allow the boat to drift a short distance off the site before lowering and setting the anchor, or tying boat’s bow line to a mooring buoy (if available near the site).

Step 4: Always attempt to lower the anchor into a nearby sand or non-colonized rock or boulder patch. If no sand or rock patch is available, attempt to lower anchor so that it does not impact live coral or other live benthic organisms. If a permanent mooring buoy-line is available nearby, use it to securely tie off boat’s bow line. Then, locate the deployed surface float by taking a compass bearing to it.

Step 5: Check to ensure that the camera power is on and that the zoom is all the way out (i.e., wide angle). The camera mode should be set at “Program Shooting”, represented by the “P” icon on the On/Off/Mode dial of the camera housing. The flash setting should be set to “Off.”

Step 6: Ensure the camera is working at the surface by photographing a slate on which the monitoring site identifier metadata is written. The metadata identifier should include the following fields identified in Table S7.1.

Table S7.1. Metadata identifiers and format

Field	Format
Date and time	YYYYMMDD, XXXX:XX 24 hr or military time
Station Number	Park Code (four letter) and transect location number (e.g., NPSA001)

Step 7: Ensure the monopod is securely attached to the camera housing with the housing at a fixed height of 0.5 m.

Step 8: Affix the camera's red filter.

Step 9: Retake a compass bearing to surface float if needed. For detailed procedures on GPS and taking bearings see SOP # 4 "Using GARMIN® Global Positioning System (GPS) Units."

Step 10: Put on dive gear and enter the water.

Step 11: If a surface float is used, swim to the float and descend down the line.

Step 12: Once on the bottom, reposition the boat anchor so that its chain and line are secure and do not damage coral or other live organisms.

Locate Transect Pin and Lay Transect Line at Permanent Sites

Step 1: Underwater, locate the bottom float marker.

Step 2: Begin a systematic search for the transect start pin marked with one cable tie; clean the pin of fouling organisms as needed using gloved hand, scrub, or wire brush. If necessary move the bottom float marker to the vicinity of the transect start pin.

Step 3: Attach one end of the transect line securely to start pin.

Step 4: Take the known compass bearing to the end point of transect, pull the line taut, loop the line around the end pin at least twice so that it does not slip and loosen. Look at the transect, it should now be installed such that the line is straight, suspended just on the bottom and taut over its entire length; adjust as necessary.

Lay Transect Line at Random Sites

Step 1: Once you have arrived at the pre-determined waypoint, deploy the Pelican® surface float with a bottom weight (~1 kg).

Step 2: As there are no pins at temporary random transect locations, tie one end of the transect line securely around a dead coral colony or piece of rubble nearest the bottom weight.

Step 3: Once the line is secured, swim along a depth contour within a homogeneous habitat until 26 m of transect line has been spooled out. Pull the line taut and tie off securely to a dead coral colony or rock. The transect should now be installed such that the line is straight, suspended just above the bottom and taut along its entire length. Make sure to record the compass bearing of the transect lines from the starting point to facilitate plotting of the transects in ARCGIS®.

Taking Photographs

Check again to ensure that the camera's red filter is in place and that the power is on. Check to ensure the zoom is all the way out (i.e., wide angle). The camera mode should be set at "Program Shooting", represented by the "P" icon on the On/Off/Mode dial of the camera housing. The flash setting should be set to "Off."

Step 1: At the start point (0 meter mark) of the transect, take landscape (horizontally oriented) photographs facing magnetic north (0°) and in three subsequent 90 degree directions moving in a clockwise direction. These photographs will provide a general overview of the transect habitat at the transect location.

Step 2: Along the transect, begin photographing the benthos at the 0 m and at each successive one meter mark along the transect tape. Place the monopod foot at each line meter mark, perpendicular to the substrate and holding the camera as level as possible, depress the Shutter Button on the upper right of the camera housing to take a photo. Check the photo on the camera's LCD monitor back to ensure it is in focus and properly exposed. If it is not, take another exposure. Continue to take photos until a satisfactory one has been obtained.

This step may be easiest to do with two divers, especially in heavy surge. One diver controls the camera. The second diver positions the monopod foot in the appropriate position along the transect line and then moves out of the photograph. If necessary, for example, in surge conditions, the second diver can help steady the diver operating the camera by holding his or her tank valve with one hand and the bottom with the other hand.

It is important to take the photo perpendicular to the substrate even if the substrate is highly uneven (rugose) or nearly vertical. The resulting photograph will be much easier to process. If necessary reposition camera to be perpendicular, reshoot, and view image until a satisfactory one has been taken. As needed, take field notes of observations within photoquadrats (noting date, transect, and photoquadrat number [distance on tape]) to facilitate interpretation and accurate collection of data from photos on biotic or other substrate cover types. Although somewhat more time consuming, this step is important data, as photoquadrats alone do not always accurately record all cover categories.

Step 3: Continue to move along the transect, taking a photo at each meter mark on the line. Take the last photograph at the 24 m mark.

Rugosity Measurement

After the photoquadrat sampling is completed, a rugosity measurement is made on the transect line. Rugosity is measured using the chain and tape method described by McCormick (1994). A light brass "window sash" chain with a weight at the starting end (marked with flagging tape), and marked off in 1 m intervals (See SOP #1 "Before the Field Season" for construction) is closely draped over the bottom topography along the entire length of each 25 m transect. The amount of chain necessary to span the distance between the two transect marker pins is divided by the straight line tape measurement to generate an index of rugosity for that transect.

Step 1: Start at the beginning of the transect line with the 20 m rugosity chain and set one end of the chain by the transect marker pin. Note: the short length of chain is used due to its weight.

Step 2: Spool out and drape the chain on the bottom so that it closely contours the substrate.

Step 3: Use gravity to set the chain on the bottom in a straight line under the transect line.

Step 4: Place the chain down on the substrate manually but do not force the chain into holes or under ledges. Ideally, this would be a more accurate measure of topography, but it may be hazardous to insert your hand or fingers into cracks and crevices within the reef.

Step 5: Continue to drape the chain until the chain ends, mark that spot with a piece of flagging tape tied to a small weight (e.g., a fishing sinker or large bolt is usually sufficient), retrieve the chain and then redeploy it from the marked spot until the end of the 25 m transect tape is reached.

Step 6: Record the length of chain (to 0.1 m) used to reach the 25 m mark. For example, on a 25 m transect line if you have spooled out the first 20m and then spooled out an additional 18.6 m of line you will have used 38.6 m of chain to span the entire transect line. Retrieve the chain.

Step 7: Once finished, untie the transect line, reel it in, and collect the bottom float marker before ascending to your safety stop.

Step 8: The rugosity index is calculated by dividing the total length of chain laid over the entire transect line distance by the transect line length (25 m). In the preceding example, the rugosity index would be: 38.6 to 25.0 = 1.54. Note: there is no need to calculate this index in the field.

Environmental Metadata

Environmental data collected both above and below the water can provide valuable insight into the validity of, or limitations to, data collected and can be valuable for interpreting monitoring data. The data will be entered on dataforms in Appendix S7.b and ultimately into the environmental data table in the database. In air data should be filled out prior to entering the water, in water data can be entered during, or upon completion of the dive. Data that is required will be subject to all of the data entry and management requirements of the I&M program. Optional data can be collected by the parks but will not be managed by the I&M data management guidelines.

In Air/On Surface Environmental Variables

Required data collected include the variables and descriptions in Table S7.2.

Table S7.2. Data variables and description for on surface environmental variables

Data Variable	Description
Park code	Four letter code (e.g., KAHO, KALA, NPSA, WAPA)
Transect number	Site designation code
Date	Year, Month, Date (YYYY, MM, DD)
Time	24 hour universal or military time (HH:MM)
Observers	Specify names and initials of individuals responsible for specific tasks, including vessel operator, deck hands, other scientific divers
Weather conditions	Estimated percent cloud cover, precipitation (yes/no), air temperature (degrees Celsius)
Beaufort sea state conditions	Can be acquired from local weather station, or use Table S7.3

Table S7.3. Beaufort sea state conditions (Modified from Gross 1977)

Beaufort Number	Wind Speed (km/hr)	Seaman's term	Effects observed at sea
0	<1	Calm	Sea like a mirror
1	1-5	Light air	Ripples with appearance of scales; no foam crests
2	6-11	Light breeze	Small wavelets; crests of glassy appearance, not breaking
3	12-19	Gentle breeze	Large wavelets; crests begin to break; scattered whitecaps
4	20-28	Moderate breeze	Small waves, becoming longer; numerous whitecaps
5	29-38	Fresh breeze	Moderate waves, taking longer form; many whitecaps; some spray
6	39-49	Strong breeze	Larger waves forming; whitecaps everywhere; more spray
7	50-61	Moderate gale	Sea heaps up; white foam from breaking waves begins to be blown in streaks
8	62-74	Fresh gale	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks
9	75-88	Strong gale	High waves; sea begins to roll; dense streaks of foam; spray may reduce visibility
10	89-102	Whole gale	Very high waves with overhanging crests; sea takes white appearance as foam is blown in very dense streaks; rolling is heavy and visibility reduced
11	103-117	Storm	Exceptional high waves; sea covered with white-foam patches; visibility still more reduced
12	118-133	Hurricane	Air filled with foam; sea completely white with driving spray; visibility greatly reduced

Optional data include those fields and descriptions in Table S7.4.

Table S7.4. Optional data fields

Field	Description
Weather conditions	Estimate horizontal visibility in air, cloud types
Sea surface conditions	Specify water clarity from the water surface (is the bottom visible?)

In Water/Sub-Surface Environmental Variables

Required data include the variables and descriptions in Table S7.5.

Table S7.5. In-water required data variables

Data Variable	Description
Estimated horizontal visibility	Estimate horizontal visibility in water
Water temperature	Water temperature (degrees Celsius) at 5 to 7 m depth (Scuba safety stop)
Reef Geomorphology	Specify flat, crest, forereef slope, spur and groove, patch reef
Miscellaneous notes	Noteworthy observations (e.g., observed spawning, plankton (including larvae), thin layers, thermocline)

Optional data include those fields and descriptions in Table S7.6.

Table S7.6. In-water optional data variables

Field	Description
Schlieren layers	Presence or absence of “Schlieren layers” – if present approximate depth
Water motion at bottom	Specify calm, mild, moderate or strong surge, apparent current direction and speed

References

Gross, G. 1977. Oceanography a view of the earth. Prentice-Hall, Inc. Englewood Cliffs, New Jersey, USA.

McCormick, M.I. 1994. Comparison of field methods for measuring surface topography and their associations with a tropical reef fish assemblage. Marine Ecology Progress Series **112**:87-96.

Appendix S7.a. Equipment list

1) Equipment list for conducting marine benthic cover surveys. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation”

Equipment (#/quantity)	Preparation & Maintenance
Digital still camera prepared and mounted into U/W housing and monopod	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
Small wire brush	Ensure that this equipment is available
30 m transect line	Labeled at 50 cm intervals, see SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, or maps of transect locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS (1)	Ensure in working order; See SOP #4 “Using GARMIN® Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
Surface float marker (2)	One for back-up; Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	See SOP #7 “Conducting Marine Benthic Cover and Rugosity Surveys”
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has sufficient power
Pelican case	Ensure that this equipment is available
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

2) Equipment list for conducting benthic rugosity measurements. This equipment list refers to SOP #5 "Pre-Dive Equipment Preparation"

Equipment (#/quantity)	Preparation & Maintenance
20 m rugosity chain on spool	See SOP #1 "Before the Field Season"
30 m transect line	See SOP #1 "Before the Field Season"
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations" SOP #5, "Pre-Dive Equipment Preparation" and check database and log book.
GPS (1)	Ensure in working order; See SOP #4 "Using GARMI®N Global Positioning System (GPS) Units"
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	See SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys"
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 set)	Ensure equipment has sufficient power
Scuba gear	See SOP #5 "Pre-Dive Equipment Preparation" and SOP #16 "After the Field Season"
Boat, motor, and trailer	See SOP #5 "Pre-Dive Equipment Preparation" and SOP #16 "After the Field Season"

Appendix S7.b. Dataforms

Dataform for collection of benthic cover

Park:

Transect #:		Fixed / Random		
Start UTM X:		Start UTM Y:		
End UTM X:		End UTM Y:		
UTM Zone: Datum: Est. Horizontal Error: Accuracy Notes:				
Date: ***Observers:*** ***Notes:***				
Was rugosity measured? Rugosity Notes:		If yes, chain length =		meters

Benthic Cover: *Benthic Cover Photographer:* ***In Lab:*** *Analysis Date:* *Frame Identifier:* *Photo Location:*

Additional Comments:

SOP #8: Conducting Coral Settlement Sampling

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See track changes	Responses to reviewer comments		1.00
2.01	7/31/07	L. Basch	See track changes	Clarifications, corrections		2.00

Purpose

This SOP describes collecting and photographing Coral Settlement Arrays (CSAs) to document the settlement of coral larvae at transect locations. This SOP assumes that the CSA parts have been previously assembled (see SOP #1 “Before the Field Season”) and that the appropriate settlement tile mounting pins and CSAs have been installed at the monitoring transects (see SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”).

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 “Before the Field Season.” The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix S8.a.

Retrieving Coral Settlement Arrays (CSAs)

CSA tiles will be deployed for an approximately six-month period to bracket the peak period of coral spawning and larval settlement. Refer to SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations” for instructions on how to initially deploy the CSAs. Parks should, if at all possible, replace the tiles at six month intervals to examine settlement over the entire year and this is recommended for at least the initial three years. This step is beneficial but involves additional post-processing time (if need be these tiles could be archived for later processing).

Two divers will be needed to locate and retrieve or replace the three pairs of tiles per site, with an estimated completion time of 10 to 15 minutes.

The epoxy used to secure the mounting brackets must be cured for at least 24 hours before settlement tiles are mounted on rods to avoid contamination. These tiles must remain clean (i.e., handled minimally) to allow the formation of microbial films and to minimize bias in the settlement of coral and other invertebrate larvae (i.e., if tiles are contaminated with epoxy chemicals or skin oils, these can interfere with natural settlement cues and processes). It is equally critical that tile faces should never be touched for the same reasons; *always handle tiles by their edges only*. Conditioned tiles need to be pre-marked on their edge noting site, tile number, date deployed, and an arrow on the edge indicating which face side is placed up (See SOP #1 "Before the Field Season").

Before entering the field
Step 1: Collect the equipment necessary to retrieve and replace the CSAs (Appendix S8.a).

Step 2: Ensure the terra cotta tiles have been properly marked. Each tile should be marked along its edge using an ultra fine point Sharpie marker noting transect, tile number, date deployed, and with an arrow indicating which tile face is placed up. The following notation should be used (T5-23U-20060715↑) indicating transect 5, tile number 23 Upper, deployed on July 15th, 2006, and with the arrow showing which tile face is oriented up toward the surface. If the deployment date is unknown, leave blank until the required information is available.

Step 3: Ensure reseal-able plastic bags have been pre-labeled using an indelible magic marker with the same alpha-numeric information as in step 2, and the CSA number (1=start of transect; 2=mid-point of transect; 3=end of transect). This combined information is important in that it may indicate within-site spatial variation.

Relocating the Monitoring Site
Step 1: Refer to SOP #7 "Conducting Marine Benthic Cover and Rugosity Survey" for procedures to relocate fixed monitoring sites.

Step 2: Upon entering the water, locate the pin at the start of the transect; it is marked with one cable tie. CSA pins will be located 2.5 m shoreward of the start and end pins and 2.5 m shoreward of the midpoint of the benthic sampling transect (see Chapter 2 "Sampling Design", SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations").

Retrieving and Replacing Tiles
Step 1: Assign one diver to retrieve each tile off the threaded rod and help the other diver to put each tile in a pre-labeled plastic bag, which is then placed in separate mesh gear bags for each site. Plastic bags should be pre-labeled using a waterproof marker with transect, date, and CSA number (1=start of transect; 2=mid-point of transect; 3=end of transect)

Step 2: Remove hose clamp and section of plastic tubing. Holding the tiles carefully by the edges, twist gently then pull the top tile from the threaded rod and place in plastic bag. Remove short PVC spacer and repeat with lower PVC tile (Figure S8.1). Handle tiles by the edges only and to not to let the tiles touch each other.
As needed: Replace with new pre-conditioned and labeled tiles in reverse sequence.

Step 3: Continue to the next CSA(s) and repeat the procedure.

Step 4: Upon returning to the boat, gently hand up the bags with tiles to the boat operator/safety diver. Or attach mesh bags with tiles to a clip line and retrieve them when in the boat.

Step 5: Place each bagged tile in a vertical position into a cooler with a layer of ice on the bottom, covered by a thin foam pad, which provides more stability and better protects the tiles during transit to the office/laboratory.

Step 6: Record the deployment and retrieval information on the dataform in Appendix S6.b found in SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations."

Step 7: Once back at the lab, process the tiles as specified in SOP #14 "Data Management – Settlement Analysis."

Optional: Photographing CSAs Between Tile Retrievals

Parks may photograph CSAs between tile retrievals. Photograph tile top and bottom faces at approximately eight week intervals between tile deployments/retrievals. This additional information may provide qualitative information on competing benthic cover that is useful for interpreting monitoring data and results of statistical analyses. Plan on each dive taking 20 to 30 minutes to photograph the three CSAs at each site. The utility of this optional procedure will be evaluated after two to three years due to the time consuming nature of this task.

Photographing the Tiles in situ

Step 1: Prepare camera for use as described in SOP #5 "Pre-Dive Equipment Preparation." Set camera to macro mode by rotating the On/Off/Mode Wheel on the housing to the "Flower."

Step 2: List on an underwater slate when the three CSA tiles have been photographed and note camera image number.

Step 3: Refer to SOP #7 "Conducting Marine Benthic Cover and Rugosity Survey" for procedures to relocate fixed monitoring sites.

Step 4: Upon entering the water, locate the pin at the start of the transect; it is marked with one cable tie. CSA pins will be located 2.5 m shoreward of the start and end pins and 2.5 m shoreward of the midpoint of the benthic sampling transect (see Chapter 2 "Sampling Design", SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations").

Step 5: Prior to photographing tiles, make sure camera is zoomed out (on maximum wide angle setting).

Step 6: Position camera above the top tile so that it fills the full frame of photo, camera and tile planes are parallel, and the shadow on tile minimized.

Step 7: Shoot photo, check image quality on display back. Delete and re-shoot image if necessary.

Step 8: Keep track of the photo order by recording the photo number with the transect, date, and CSA number (1=start of transect; 2=mid-point of transect; 3=end of transect) on the photo log sheet (Dataform in Appendix S6.b in SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations"), so that digital photo-files can be labeled once back in the office.

Step 9: Photograph the top face of the upper tile (UT) (Figure S8.1). Using the wrench loosen the hose clamp, remove the plastic tube, and rotate the tile upside down by grasping the tile edges and turning tile over. Photograph the bottom of the tile (UB).

Step 10: Remove the upper tile and have one diver hold it carefully by the edges. Repeat step 7 for the lower tile surfaces (LT and LB).

Step 11: Return tiles to their original orientation and secure CSA hardware.

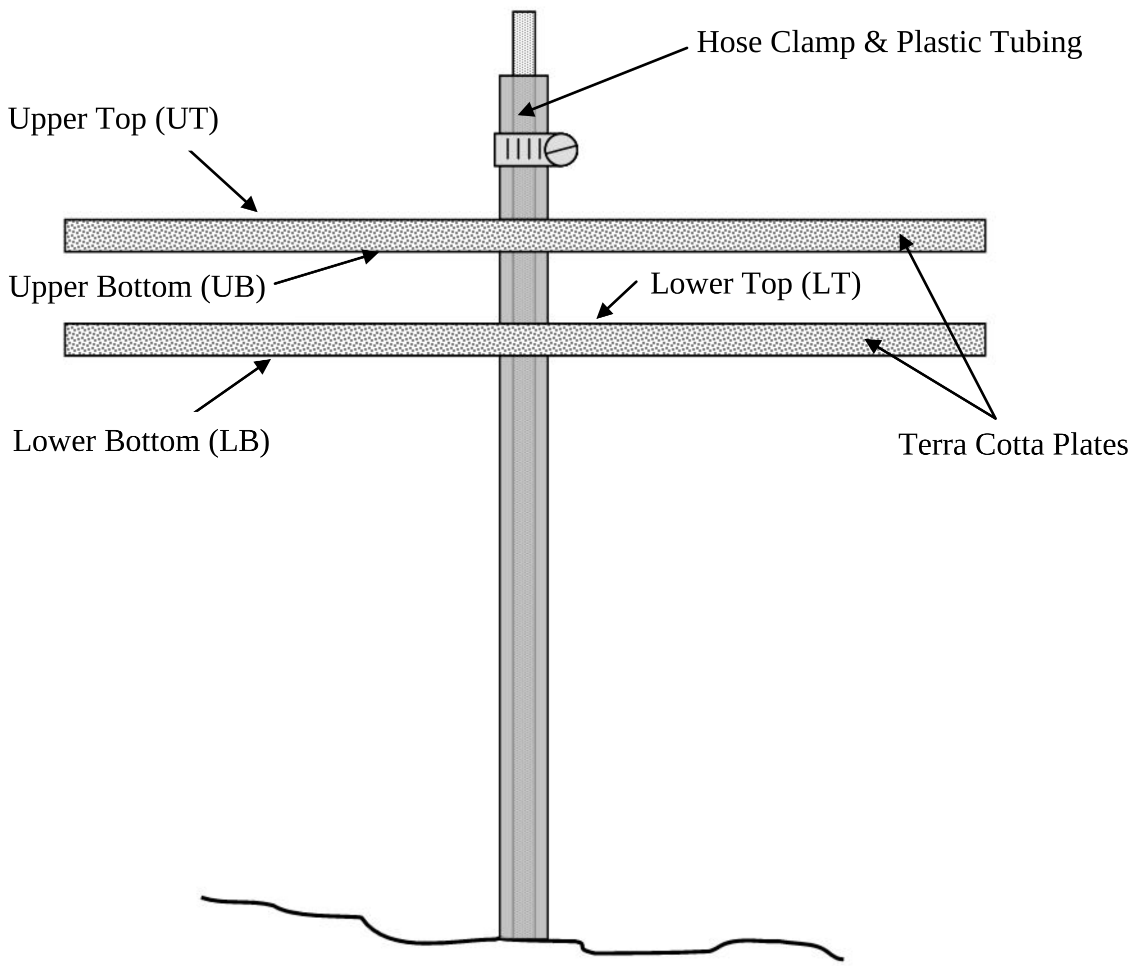


Figure S8.1. Schematic of an installed CSA. Pieces are not to scale. The four plate surfaces (UT, UB, LT, LB) have been marked.

Appendix S8.a: Supplies and Equipment to Retrieve and Replace CSAs

Equipment list for installation and retrieval of the coral settlement arrays. This equipment list refers to SOP #5 "Pre-Dive Equipment Preparation" section on Coral Settlement Array: Installation and Retrieval Equipment Preparation and SOP #8 "Conducting Coral Settlement Sampling."

Equipment (#/quantity)	Preparation & Maintenance
Digital still camera prepared and mounted into U/W housing and monopod	See section on "Camera Equipment Preparation & Handling" in SOP #5 "Pre-Dive Equipment Preparation"
White slate to set white balance on camera	Ensure that this equipment is available
Coral settlement arrays	3 plate pairs per transect; See SOP #1 "Before the Field Season" for construction and labeling information
Cooler or tray to hold CSAs (2-3)	Ensure that this equipment is available
Ice	Ensure that this equipment is available
Foam pad (1 per cooler)	Ensure that this equipment is available
Pliers and flat head screwdriver	2 of each; Ensure that this equipment is available
5 pound sledge hammer	Ensure that this equipment is available
1 meter stainless steel rods (5)	Ensure that this equipment is available
Plastic 90 degree angle protractor	Ensure that this equipment is available
Pneumatic drill	Ensure equipment is in working order
Re-usable tags (at least 45 – 1/CSA)	See SOP #8 "Conducting Coral Settlement Sampling"
Engraver, dremel drill, or similar tool	See SOP #8 "Conducting Coral Settlement Sampling"
30 m transect line (2)	labeled at 50 cm intervals; see SOP #1 "Before the Field Season"
Heavy duty, sealable plastic bags	See SOP #8 "Conducting Coral Settlement Sampling"
Mesh gear bags	Ensure that this equipment is available
Repair supplies (new threaded rods, epoxy, spare hardware)	See SOP #8 "Conducting Coral Settlement Sampling"
Coordinates, depths, compass headings, maps of CSA locations	Ensure that this equipment is available; See SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations" and SOP #8 "Conducting Coral Settlement Sampling"
GPS (1)	Ensure in working order; See SOP #4 "Using GARMIN® Global Positioning System (GPS) Units"
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	Ensure sufficient number of copies available
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has sufficient power
Pelican® case (1)	Ensure equipment is available
Surface float marker (2)	One of these for back-up; Ensure equipment is available
Scuba gear	See section on "Dive Equipment Preparation" in SOP #5 "Pre-Dive Equipment Preparation" and SOP #16 "After the Field Season"
Boat, motor, and trailer	See section on "Boat Preparation" in SOP #5 "Pre-Dive Equipment Preparation" and SOP #16 "After the Field Season"

SOP #9: Measuring Coral Growth (Optional)

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See track changes	Responses to reviewer comments		1.00
2.01	8/1/07	L. Basch	See track changes	Clarifications, corrections		2.00

Purpose

This SOP describes how to measure growth rates in individual coral colonies and requires at least two divers and approximately 30 minutes to complete. This SOP assumes that the ten coral colonies per transect have been marked as described in SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations.”

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 “Before the Field Season.” The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix S1.a.

Preparation

Equipment List

A complete list of equipment needed to carry out this procedure is contained in the master gear list found in Appendix S1.a in SOP #1 “Before the Field Season” and in Appendix S1.a in this SOP. Observers will want to ensure that all equipment is ready prior to the scheduled survey dive day.

Dataforms

Dataforms needed for this protocol can be found in Appendix S9.b. Forms should be photocopied or printed onto plastic paper for use underwater (plastic paper can damage some photocopiers; indelible laser jet printer ink works well).

Field Activities

Measuring Colonies

Colonies are defined as discrete colony structures of living tissue and dead skeleton that have discernable physical boundaries (see discussion below). The presence of distinctive calices in dead portions of the colonies is used to help distinguish colony areas to be included in the colony boundary.

Colony dimensions and surface area are based on growth forms defined by Veron (2000). Greatest basal dimension (= length), basal dimension perpendicular to the length (= width), and height are obtained for massive (hemispherical), branching, or columnar colonies such as *Porites lobata* (Figure S9.1), *Pocillopora meandrina*, and *Porites compressa*. The trans-Pacific species *Pocillopora eydouxi* was selected for monitoring growth across parks.

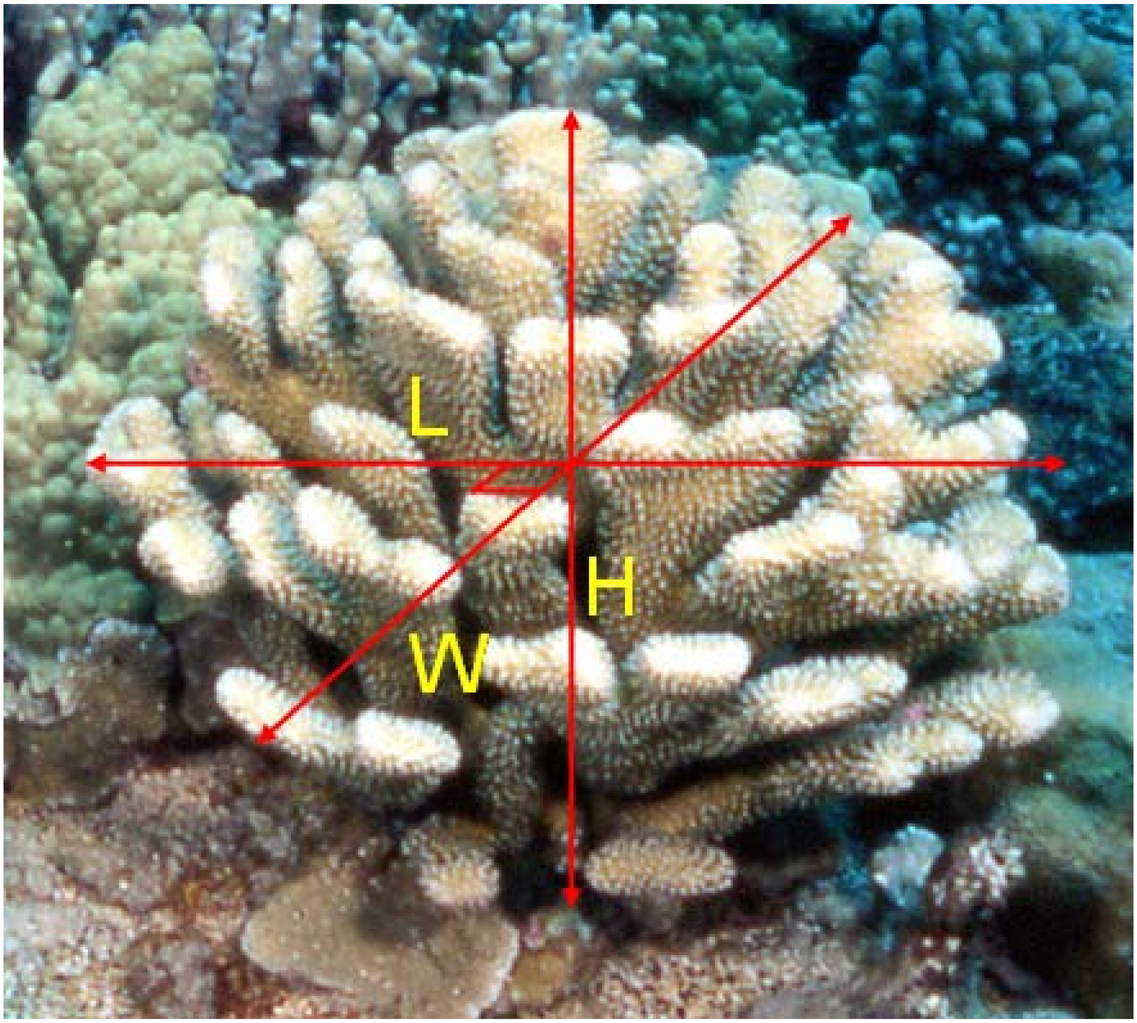


Figure S9.1. Coral colony measurements for a colony of *Pocillopora eydouxi*. Photo by E. Brown, NPS.

Relocating Colonies

Step 1: Relocate the monitoring site, enter water and locate the start pin of the permanent transect line as described in SOP #7 "Conducting Marine Benthic Cover and Rugosity Surveys."

Step 2: Locate the first labeled coral colony using a copy of the original data sheets with the X & Y coordinates along the fixed 25 m transects.

Step 3: Clean the colony tag using gloved hands, scrub, or small wire brushes. Inspect the tag and wires or cable ties for deterioration and replace as needed.

Step 4: Record the identifying code from the colony tag on the data sheet.

Measuring Dimensions for Alive (Living) Tagged Coral

Step 1: Determine the edges of the colony using the criteria below ("Criteria for distinguishing colony boundary"). If any difficulties arise in distinguishing the colony boundaries, record the decision process for determining the boundaries in the Notes section at the bottom of the datasheet. For future reference make sure to record which colonies were difficult to discern.

Step 2: Using a 1 m flexible measuring tape, measure the colony to the nearest 1.0 cm along the longest axis (Figure S9.1). Record on data sheet as colony length.

Step 3: Measure the greatest width of the coral perpendicular to the length measurement (Figure S9.1). Measure to the nearest 1.0 cm. Record on data sheet as colony width.

Step 4: Finally, measure the height of the colony to the nearest 1.0 cm. The height measurement is obtained by stretching the tape measure in a vertical plane from the lowest point of the colony on the substrate to the top of the colony (Figure S9.1). One can also use large calipers, however, these are cumbersome to handle underwater. Record on data sheet as colony height.

Step 5: Evaluate the fate of the colony (Alive, dead, partial mortality). Estimate the percentage of partial mortality on the colony surface area. This is a qualitative measure and can be done by visually dividing the colony into four pie shaped sectors and then estimating the amount of dead tissue in each sector.

Step 6: Locate the next tagged colony and repeat. Continue until all colonies have been located, measured, and recorded. Depending on colony sizes, two divers may be needed to make the most accurate measurements possible. The same observer should make repeated measurements whenever possible.

Measuring dimensions for dead (not living) tagged coral

Tagged colonies that are "dead" will continue to be monitored. If the colony is recorded as dead for 5 consecutive years, it will be dropped from the survey. "Dead" colonies will continue to be followed because all or part of a colony may experience a "phoenix" event, which occurs when the deep tissue regenerates even after several years of inactivity.

Step 1: Record the colony as "dead" on the data sheet.

Step 2: Locate the next tagged colony and repeat. Continue until all colonies have been located and measured or recorded as "dead."

Step 3: For each “dead” colony, tag an additional colony along the transect using procedures described in SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations.”

Criteria for distinguishing colony boundaries.

Difficulties can arise in distinguishing colony boundaries. Even the most experienced observers have trouble delineating separate colonies of the same species when they are contiguous with each other. Consequently, care should be taken to reduce these errors in the field.

Dive team members can consult with each other underwater on difficult colonies and generate a consensus on the individual colony dimensions.

Another area of difficulty is distinguishing between newly settled corals and fragments of larger colonies that have experienced partial mortality. Two techniques are used to the resolve this issue.

Step 1: First, the substrate between colonies/fragments in close proximity is examined to see if any residual skeleton can be discerned. If residual skeleton is found, then the separate colonies are assumed to be fragments from a larger colony that has experienced partial mortality.

Step 2: Second, newly settled corals tend to have a discrete colony edge that is slightly elevated above the adjacent substrate. Fragments, on the other hand, are flush with the adjacent substrate with residual structure connecting to other fragments.

References

Veron, J.E.N. 2000 Corals of the World. Australian Institute of Marine Science, Townsville, Australia

Appendix S9.a. Equipment list needed to complete this SOP

Equipment list for tagging and conducting the coral growth measurements. This equipment list refers to SOP #5 “Pre-Dive Equipment Preparation” and SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations.”

Equipment (#/quantity)	Preparation & Maintenance
1 m flexible fiberglass measuring tape with centimeter markings	Ensure that this equipment is available
Calipers	Ensure that this equipment is available
Stainless steel wire or cable ties (10)	Ensure that this equipment is available
Dymo® manual labels made of plastic (10)	See SOP #1 “Before the Field Season”
Metal or plastic tags (10)	See SOP #9 “Measuring Coral Growth”
Small hole punch (2)	Ensure that this equipment is available
Small wire brush (2)	Ensure that this equipment is available
Flagging tape (2 rolls)	Ensure that this equipment is available
Mesh gear bags (2)	Ensure that this equipment is available
Dive weight	Ensure that this equipment is available
30 m transect line	Labeled at 50 cm intervals; see SOP #1 “Before the Field Season”
Coordinates, depths, compass headings, maps of sampling locations	Ensure that this equipment is available; See SOP #6 “Selecting and Marking Subtidal Sampling Transect Locations”
GPS (1)	Ensure in working order; See SOP #4 “Using GARMI®N Global Positioning System (GPS) Units”
Transparent waterproof container for GPS (1)	Ensure that this equipment is available
Surface float marker (2)	One for back-up; ensure that this equipment is available
U/W compass (1)	Ensure that this equipment is available
U/W slate with pencils (2)	Ensure that this equipment is available
U/W field data forms	See SOP #9 “Measuring Coral Growth”
U/W lights (2)	Ensure equipment is in working order
U/W light batteries (2 sets)	Ensure equipment has sufficient power
Scuba gear	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”
Boat, motor, and trailer	See SOP #5 “Pre-Dive Equipment Preparation” and SOP #16 “After the Field Season”

Appendix S9.b. Dataforms
Dataform for conducting coral growth measurements

Coral Growth

Park: _ _	***Observers:***
Transect:	
Date:	

							Only fill out on first visit/tagging		
Colony Number	*Species Code*	*Fate**	*Length (cm)*	*Width (cm)*	*Height (cm)*	*Re-measure?*	*X Coordinate*	*Y Coordinate*	*Shallow or Deep*

Notes:

*Fate: Alive, Dead, PM% = Partial Mortality percentage, Fiss = Fission, Fus-# = Fusion with colony #, Pho = Phoenix event,

SOP #10: Post-Dive Procedures and Equipment Maintenance

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	8/01/2007	L. Basch	See Track Changes	Clarification, correction		2.00

Purpose

This SOP covers post dive equipment maintenance for scuba gear and the photographic equipment. While this procedure has been written specifically for the Olympus® C-5050 digital camera and a Light and Motion Tetra® Underwater Camera Housing, it should also work for earlier and later models of the Olympus® (e.g., Olympus® 4040, 6060, 7070) and associated Tetra® Housings.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Post-Dive Equipment Care and Maintenance

Rinse Equipment

At the end of each field day, all equipment must be rinsed with freshwater. Seawater left on the equipment for an extended period of time will reduce the safe, reliable, functional operational life of the equipment. For reference, a scuba equipment list can be found in Appendix S1.a of SOP #1 "Before the Field Season."

Step 1: Rinse all scuba gear including the regulators, inner bladder, and auto inflators of the buoyancy compensators (BCs).

Step 2: Rinse the research vessel, (if removed from the water), trailer, and vehicle. Apply WD40 or other lubricant to moving parts on the trailer (e.g., winch) and boat engine. Rinse the engine, and use a motor flusher attachment (rabbit ears) for the internal parts.

Step 3: Rinse each data sheet with fresh water. Then, dry data sheets by hanging sheets with clothes pins overnight in a secure area.

Step 4: Rinse all other gear used each day.

Once dry, all equipment should be stored until needed again. If this is the final dive of the season, see SOP #16 "After the Field Season" for additional steps required when storing equipment.

Equipment Maintenance – Camera

The camera will need to be rinsed and dried thoroughly prior to opening housing and storage of it.

Step 1: Rinse and soak the camera housing. Place camera housing in its own rinse container (e.g., bucket) to avoid damage. Never put anything heavy or hard in the rinse container with the camera housing. Fill rinse container with fresh water and soak camera housing for at least 30 minutes and push all buttons and other controls to flush out any seawater or embedded salt crystals.

Step 2: Remove the camera housing from the fresh water and allow it to air dry completely before opening. Using a towel to dry may be done, however care should be taken to use lint-free cloth to avoid introducing particles or contaminants that could stick to O-rings, etc., and cause flooding of housing. Ensure that the lens cap is in place on the housing so that it is not scratched or otherwise damaged while removing the back plate. Remove the back of the housing with the following four steps.
First: Pull the two locks in and rotate the latch wheels located on the sides of the housing downward and rearward of the housing. Rotate until they stop.

Second: Carefully lift the back of housing and locate the ROC cable. This cable looks like a telephone cord and connects the electronics of the housing back to those of the housing front. It is located along the left side inside the housing.

Third: Disconnect the ROC cable from the housing back.
Fourth: Set the back aside in a clean, dust-free place.

Step 3: Locate the On/Off/Mode knob along the top left of the housing and pull it up until it extends approximately one inch from the housing. This will lift the rubber shoe off the corresponding mode wheel on the camera.

Step 4: Remove the ROC hot shoe from the camera.

Step 5: Carefully remove the camera by reaching in along the sides and lifting it from the housing.

Step 6: Set the camera aside.

Step 7: Tuck the ROC hot shoe and the ROC cable into the housing and replace the back, but do not seal it.

Step 8: Return camera to its storage case. Never store the camera with batteries in it. Camera batteries can potentially leak, damaging the camera. Follow the steps outlined in SOP #12 "Data Management – Photographs" for instructions on how to download data from the camera.

Complete Dive Log

Each diver must log dive information as required by Reference Manual #4 (RM-4) "Dive Safety Management." For more detailed information on post-dive requirements, see SOP #2 "Training Observers."

Post-Dive Instructions for Handling Data

Data Sheets

Step 1: Once data sheets are dry, photocopy all data sheets and store them in a labeled three ring binder, preferably in a metal fire-proof filing cabinet.

Step 2: Archive original data sheets according to SOP #11 "Data Management" guidelines.

At this step, data for each type of sampling should then be treated according to further instructions found in respective data management SOPs. For general data archiving and entry see SOP #11 "Data Management." For settlement sampling, see SOP #14 "Data Management – Settlement Analysis." For percent cover sampling, first see SOP #12 "Data Management – Photographs" and SOP #13 "Data management – Benthic Image Analysis."

Download Photographs

Photographs should be downloaded from the camera soon as possible following the dive. The process of downloading photographs will be the same regardless of the sampling type. Further instruction on downloading images can be found in SOP #12 "Data Management – Photographs."

Once downloading is complete, check to see that all image files were transferred intact to the computer. Then delete images from memory storage (compact flash) card in camera, and reformat the card to ensure its proper function in the future. Then, turn the camera off and disconnect it from the computer. Remove the compact flash card and store. Remove the batteries and recharge them in the battery charger. Return the camera to its proper storage place. Never store the camera with batteries in it. Camera batteries can potentially leak, damaging the camera.

SOP #11: Data Management

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	8/02/07	L. Basch	See Track Changes	Clarification, correction, comments		2.00

Purpose

This SOP documents the Benthic Marine database and provides instructions for the development, maintenance, and distribution of monitoring data associated with the Benthic Marine Community protocol for the PACN. General procedures for data handling and quality assurance/quality control for all monitoring protocols implemented by the PACN monitoring program are described in the network's Data Management Plan posted both on the network data server and on the PACN website (http://www.nature.nps.gov/im/units/pacn/index.htm). Microsoft Access® is the primary software environment for managing benthic data. Metadata is managed using ESRI ArcGIS® software and the NPS Metadata Tools & Editor application. In addition, ArcGIS® software will serve as a tool for exploring the spatial component of the Benthic Marine data.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Benthic Database – Data Model

Marine monitoring at the PACN presently consists of four separate protocols: Benthic Marine, Marine Fishes, Water Quality, and Fisheries Harvest. The two monitoring protocols, Benthic Marine and Marine Fishes, will be co-located, with data managed within one database and data management framework. Combining the data for these two protocols is essential for effective analysis and interpretation. Although this SOP currently contains information pertaining only to the Benthic Marine protocol, future revisions will incorporate information relevant to the Marine

Fishes protocol (particularly regarding database structure), as the Marine Fishes protocol is developed.

The Benthic Marine database employs a front-end/back-end configuration in which the user interface resides in the front-end file and the front-end file is linked to the back-end file which holds the data tables. The user interface includes a Back-End Linking Utility that allows the user to control this front-end/back-end file link. The front-end file (benthic_marine_FE_v1.0.mdb) contains the forms, queries, modules, macros, and reports for the Benthic Marine database application. The back-end file (benthic_marine_BE_v1.0.mdb) contains the data tables. This front-end/back-end configuration allows for continual improvements to the user interface (i.e., the various forms and queries for getting data into and out of the database) without requiring duplication or modification of the underlying data tables. Figure S11.1 shows the relationships among the primary tables in the database. The database is based on the National Park Service Natural Resources Database Template Version 3. The table “tbl_Sites” contains the park name and any descriptions, notes, etc. Linked to this table is “tbl_locations” which includes location information about transects. The linked table “tbl_events” records each sampling event and therefore includes the date. This allows for easy repeat entry where multiple dates are tied to the same locations or transects. The actual sampling data is maintained through four different tables which are linked to events. These tables are “tbl_benthic_cover”, “tbl_rugosity”, “tbl_settlement”, and “tbl_growth”. Several sub-tables link from these data tables and contain more detailed information.

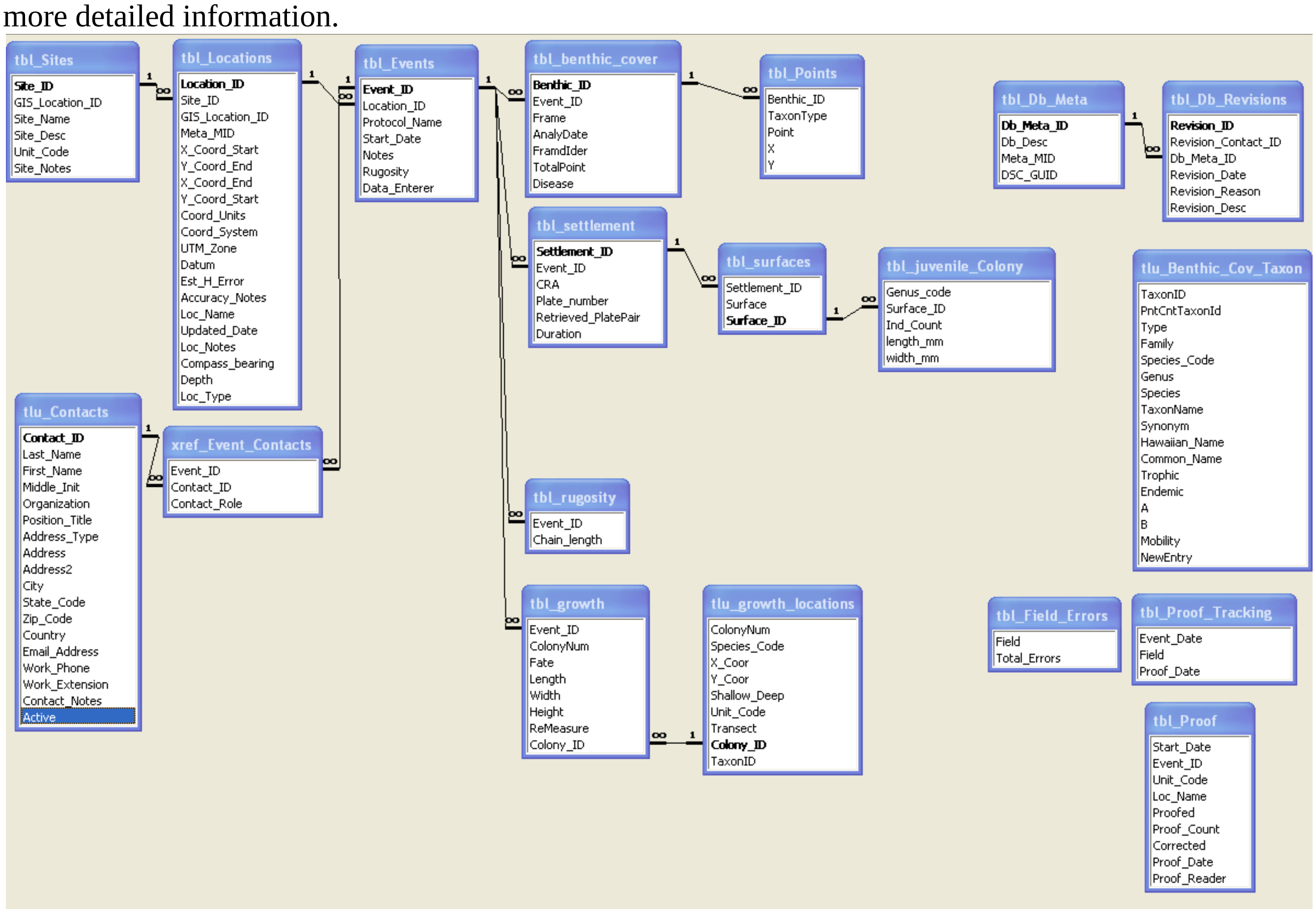


Figure S11.1. Data Model for the example database. There are four main data tables.

Documentation of Database Tables

Table: tbl_Sites

Description: Primary table that stores data about the broader location, which in this case is the park. There is one record for each park.

Field Name	Field Type	Size	Field Description
Site_ID	ReplicationID	16	Site identifier
GIS_Location_ID	ReplicationID	16	Link to GIS feature, equivalent to NPS_Location_ID
Site_Name	Text	100	Unique name or code for a site
Site_Desc	Text	255	Description for a site
Unit_Code	Text	12	4-letter Park, Monument or Network code
Site_Notes	Memo	NA	General notes on the site

Table: tbl_Locations

Description: Standardized table for storing information about the sampling location - in this case the location is each transect. Contains UTM coordinates for start and end of transects, as well as other spatial details such as UTM zone and datum. There is one record for each transect.

Field Name	Field Type	Size	Field Description
Location_ID	ReplicationID	16	Location identifier
Site_ID	ReplicationID	16	Link to tbl_Sites
GIS_Location_ID	ReplicationID	16	Link to GIS feature, equivalent to NPS_Location_ID
Meta_MID	ReplicationID	16	Link to NR-GIS Metadata Database
X_Coord_Start	Double	8	UTM X (easting) of transect start
Y_Coord_Start	Double	8	UTM Y (northing) of transect start
X_Coord_End	Double	8	UTM X (easting) of transect end
Y_Coord_End	Double	8	UTM Y (northing) of transect end
Coord_Units	Double	8	Coordinate distance units
Coord_System	Double	8	Coordinate system
UTM_Zone	Double	8	UTM Zone
Datum	Double	8	Datum of mapping ellipsoid
Est_H_Error	Double	8	Estimated horizontal accuracy
Accuracy_Notes	Memo	NA	Positional accuracy notes
Loc_Name	Text	4	Name of the location (F (fixed) or R (random) + Transect Number)
Updated_Date	Date/Time	10	Date of entry or last change
Loc_Notes	Memo	NA	General notes on the location
Compass_bearing	Single	4	Bearing of transect from starting point
Loc_Type	Text	50	Notes whether the transect is fixed or random
Depth	Double	8	Depth at start of transect.

Table: tbl_Events

Description: Standardized table containing information about each sampling event. There is one record for each sampling event.

Field Name	Field Type	Size	Field Description
Event_ID	ReplicationID	16	Sampling event ID code
Location_ID	ReplicationID	16	Link to tbl_Locations
Protocol_Name	Text	100	Protocol version used in this sampling event
Start_Date	Date/Time	8	Sampling Date (Format dd/mm/yy)
Notes	Memo	NA	Any notes for this sampling event
Rugosity	Yes/No	1	Indicates if rugosity was measured in this sampling event
Data_Enterer	Text	50	Person who entered this event data

Table: tbl_benthic_cover

Description: Table for storing information on benthic cover. Data for this table and linked table "tbl_Points" will be automatically imported from a data file which has been exported from the software "PhotoGrid".

Field Name	Field Type	Size	Field Description
Benthic_ID	ReplicationID	16	Field data table row identifier
Event_ID	ReplicationID	16	Link to tbl_Events
Frame	Long Integer	4	Sequence number of frames, as photographed along the transect. Range from 1-25.
AnalyDate	Date/Time	4	Date the photo was analyzed.
FramdIder	Text	50	The person who identified the species at specific points in the frame.
TotalPoint	Integer	2	Number of points within each photo frame where individual species were identified. In most cases this will be a set number (50); allows calculation of percent cover.
Disease	Text	50	Notes if disease was present in this frame

Table: tbl_rugosity

Description: Stores rugosity measurement. There is only one measurement per transect, but this can vary with time. It may not be measured every time a transect is sampled.

Field Name	Field Type	Size	Field Description
Event_ID	ReplicationID	16	Link to tbl_Events
Chain_length	Double	8	Actual length of chain draped under the transect. Rugosity will be calculated by dividing chain length (in meters) by transect length (25 meters).

Table: tbl_settlement

Description: Stores settlement data. Data include colonies that have settled on plates. While plates are not on transects, they are associated with them. Only sampled on fixed transects.

Field Name	Field Type	Size	Field Description
Settlement_ID	ReplicationID	16	Field data table row identifier
Event_ID	ReplicationID	16	Link to tbl_Events
CRA	Text	50	CRA number used (holds plate pairs)
Retrieved_PlatePair	Date/Time	8	Which day was the plate pair recovered?
Plate_number	Long Integer	4	Plate number (always unique) that was deployed/retrieved
Duration	Long Integer	4	Number of days the plate was in water

Table: tbl_growth

Description: Stores data about growth of coral colonies. Colonies are marked and measured over time. Only used on fixed transects. This sampling is optional and therefore this table may not be used.

Field Name	Field Type	Size	Field Description
Colony_ID	ReplicationID	16	Links to tlu_growth_locations.
Event_ID	ReplicationID	16	Link to tbl_Events
ColonyNum	Text	50	Number that identifies the colony
Fate	Text	50	Fate of colony - fission, phoenix, dead
Length	Single	4	Length of colony in cm
Width	Single	4	Width of colony in cm
Height	Single	4	Height of colony in cm
ReMeasure	Text	3	Was this a colony re-measurement?

Table: tbl_Points

Description: This is a sub-table to "tbl_benthic_cover". It is populated by importing data that has been exported from the software Photogrid©. It contains the raw data for each point that was identified within each frame of Photogrid©.

Field Name	Field Type	Size	Field Description
Benthic_ID	ReplicationID	16	Links to tbl_benthic_cover
TaxonType	Text	50	Code for taxon or (abiotic) substrate identified at this point
Point	Text	50	Point Number (1-50) (of the random points assigned by PhotoGrid©)
X	Text	50	X coordinate of the point within the Photogrid© frame
Y	Text	50	Y coordinate of the point within the Photogrid© frame

Table: tbl_surfaces

Description: Stores which surfaces were analyzed, per plate pair. This links both to tbl_settlement and tbl_juvenile_colony. Allows for multiple surfaces per plate.

Field Name	Field Type	Size	Field Description
Settlement_ID	ReplicationID	16	Links to tbl_settlement
Surface	Text	50	Which surface of plate pair: upper top, upper bottom, lower top, lower bottom, edges
Surface_ID	ReplicationID	16	Links to tbl_juvenile_colony

Table: tbl_juvenile_colony

Description: Stores data on lowest identifiable taxa per plate surface. Uses tlu_Benthic_Cov_Taxon for more in-depth taxonomic information.Field Name	Field Type	Size	Field Description
Surface_ID	ReplicationID	16	Links to tbl_surfaces
Genus_code	Text	50	Taxon identified on plate surface
length_mm	Single	4	Length of individual in mm
Width_mm	Single	4	Width of individual in mm
Ind_Count	Long Integer	4	The total count of each taxon identified

Table: tlu_Contacts

Description: Lookup table for observers and data enterers.

Field Name	Field Type	Size	Field Description
Contact_ID	ReplicationID	16	Contact identifier
Last_Name	Text	50	Last name
First_Name	Text	50	First name
Middle_Init	Text	4	Middle initial
Organization	Text	50	Organization or employer
Position_title	Text	50	Title or position description
Address_type	Text	50	Address (mailing, physical, both)
Address	Text	50	Street Address
Address2	Text	50	Address line 2, suite, apartment number
City	Text	50	City or town
State_Code	Text	8	State or province
Zip_Code	Text	50	Zip code (postal)
Country	Text	50	Country
Email_Address	Text	50	E-mail address
Work_phone	Text	50	Phone number
Work_extension	Text	50	Phone extension
Contact_notes	Memo	NA	Contact notes, if any

Table: xref_Event_Contacts

Description: Cross- reference table that links to both tbl_Events and tlu_Contacts. This keeps track of which contact is connected to each event, and the role of the contact.

Field Name	Field Type	Size	Field Description
Event_ID	ReplicationID	16	Link to tbl_Events
Contact_ID	ReplicationID	16	Link to tlu_Contacts
Contact_Role	Text	50	The contact's role in the protocol

Table: tlu_Benthic_Cov_Taxon

Description: Lookup table for taxon. This will be used in tbl_juvenile_colony and tbl_growth. Allows data enterer to choose a code and not enter taxonomic information for every record.

Field Name	Field Type	Size	Field Description
TaxonID	Integer	2	Taxon ID Code
PntCntTaxonId	Integer	2	Taxon ID Code for Point Counts
Type	Text	255	Taxon Type
Family	Text	255	Family Name
Species_Code	Text	255	4-letter species code
Genus	Text	255	Genus Name
Species	Text	255	Species Name
TaxonName	Text	255	Taxon Name (Genus and Species)
Synonym	Text	255	Name Synonym
Hawaiian_Name	Text	255	Hawaiian Name
Common_Name	Text	255	Common Name
Trophic	Text	10	Fish trophic guild: primary, secondary, and apex
Endemic	Text	2	Endemic codes: E (Endemic), I (Indigenous), and X (Introduced)
A	Double	8	Fish length-weight fitting parameter for allometric growth equation
B	Double	8	Fish length-weight fitting parameter for allometric growth equation
Mobility	Text	2	Fish mobility guild: S1 (Semi-vagile 1 – 10 m), S2 (Semi-vagile 2 – 100 m), T (Transient), R (Resident)
NewEntry	Boolean	1	Whether this is a new entry (yes or no)

Table: tlu_growth_locations

Description: Lookup table for colonies measured in tbl_growth. This keeps track of permanent information such as location and species.

Field Name	Field Type	Size	Field Description
ColonyNum	Text	50	Colony number
Species_Code	Text	50	4- letter species code- draws on tlu_Benthic_Cov_Taxon
Shallow_Deep	Text	50	Whether the colony is on the shallow or deep side of the transect
X_coor	Double	8	X coordinate-distance from transect (meters)
Y_coor	Double	8	Y coordinate-distance along the transect (meters)
Unit_Code	Text	50	Park code (4- letter)
Colony_ID	ReplicationID	16	Links to tbl_growth
Transect	Text	50	Transect Number
TaxonID	Integer	2	Taxon ID Code- draws on tlu_Benthic_Cov_Taxon

Table: tbl_DB_Meta

Description: Database description and links to I&M metadata tools.

Field Name	Field Type	Size	Field Description
DB_Meta_ID	ReplicationID	16	Local primary key
Db_Desc	Memo	NA	Description of database purpose
Meta_MID	ReplicationID	16	Link to NR-GIS Metadata Database
X_DSC_GUID	ReplicationID	16	Link to I&M Dataset Catalog desktop metadata tool

Table: tbl_DB_Revisions

Description: Database revision history data.

Field Nam	Field Type	Size	Field Description
Revision_ID	Text	50	Database revision (version) number or code
Revision_Contact_ID	ReplicationID	16	Link to tlu_Contacts
DB_Meta_ID	ReplicationID	16	Link to tbl_DB_Meta
Revision_Date	Date/Time	8	Database revision date
Revision_Reason	Memo	NA	Reason for the database revision
Revision_Desc	Memo	NA	Revision description

Table: tbl_Proof

Description: Table that stores information on which records have been proofed, and of those, which records have been corrected.

Field Name	Field Type	Size	Field Description
Corrected	Boolean	1	Was record corrected for errors?
Event_ID	Other	16	Unique event record identifier
Loc_Name	Text	50	Name of transect
Proof_Count	Long Integer	4	How many times the records were proofed
Proof_Date	Date/Time	8	Date record was proofed
Proof_Reader	Text	50	Who proofed the record
Proofed	Text	3	Was record proofed (Y/N)
Start_Date	Date/Time	8	Sampling event date
Unit_Code	Text	4	4 letter unit code of park

Table: tbl_Proof_Tracking

Description: Table that keeps a tally of which fields were corrected for errors and for which date. Used to populate tbl_Field_Data and generate reports.

Field Name	Field Type	Size	Field Description
Event_Date	Date/Time	8	Sampling event date
Field	Text	50	Field in table that was corrected for errors
Proof_Date	Date/Time	8	Date the record was proofed

Table: tbl_Field_Errors

Description: Stores the total number of errors per field. Data stored is temporary, and deleted after each calculation of total of field errors; used to populated report.

Field Name	Field Type	Size	Field Description
Field	Text	50	Field in table that was corrected for errors
Total_Errors	Long Integer	4	Total number of errors made in the field

Documentation of Database Queries

This SOP will be updated to reflect changes in queries. Basic queries follow.

Queries for forms

These queries are used as form sources.

Query: qfrm_Data_Gateway
Description: List of sample locations and associated sampling events
Query Type: Select
SQL: SELECT tbl_Sites.Site_ID, tbl_Sites.Unit_Code, tbl_Locations.Loc_Type, tbl_Locations.Location_ID, tbl_Locations.Loc_Name, tbl_Events.Start_Date, Year([start_date]) AS Sample_year, tbl_Events.Event_ID, tbl_Locations.Updated_Date, bl_Events.Protocol_Name, tbl_Locations.Loc_Type FROM tbl_Sites INNER JOIN (tbl_Locations INNER JOIN tbl_Events ON tbl_Locations.Location_ID = tbl_Events.Location_ID) ON tbl_Sites.Site_ID = tbl_Locations.Site_ID ORDER BY Year([start_date]) DESC;

Query: qfrm_DataEntry
Description: Data entry form record sources
Query Type: Select
SQL: SELECT tbl_Events.* FROM tbl_Events;

Queries for importing CSV files

A series of update and append queries were created to import benthic cover data from PhotoGrid© in the correct format. These include the following.

Query: qry_Import2
Description: Appends data from qry_Import1 to non-Temp table.
Query Type: Append
SQL: INSERT INTO tblCVSTemp ([ID Code], Point, X, Y, [File Name], [Total Points], [ID Date], Institution, [User Name], SurveyDate, FrameID, Loc_Name, Unit_Code, [ID Name]) SELECT tblCSVImportTemp.[ID Code] AS Expr2, tblCSVImportTemp.Point AS Expr3, tblCSVImportTemp.X AS Expr4, tblCSVImportTemp.Y AS Expr5, tblCSVImportTemp.[File Name] AS Expr10, tblCSVImportTemp.[Total Points] AS Expr11, tblCSVImportTemp.[ID Date] AS Expr12, tblCSVImportTemp.Institution AS Expr13, funname() AS Expr14, CDate((Mid(funD(),5,2)) & "/" & (Mid(funD(),7,2)) & "/" & (Left(fund(),4))) AS exp1, Mid([file name],10,3) AS Expr6, Mid([file name],8,2) AS Expr7, Left([file name],4) AS Expr8, tblCSVImportTemp.[ID Name] AS Expr1FROM tblCSVImportTemp WHERE ((([tblCSVImportTemp].[ID Name]) Not Like "yes" And ([tblCSVImportTemp].[ID Name]) Not Like "no"));

Query: qry_Import_Disease
Description: Appends to non-Temp disease table.
Query Type: Append
SQL: INSERT INTO tblCVSTempDisease ([ID Code], Point, X, Y, [File Name], [Total Points], [ID Date], Institution, [User Name], SurveyDate, FrameID, Loc_Name, Unit_Code, [ID Name]) SELECT tblCSVImportTemp.[ID Code] AS Expr2, tblCSVImportTemp.Point AS Expr3, tblCSVImportTemp.X AS Expr4, tblCSVImportTemp.Y AS Expr5, tblCSVImportTemp.[File

Name] AS Expr10, tblCSVImportTemp.[Total Points] AS Expr11, tblCSVImportTemp.[ID Date] AS Expr12, tblCSVImportTemp.Institution AS Expr13, funname() AS Expr14, CDate((Mid(funD(),5,2)) & "/" & (Mid(funD(),7,2)) & "/" & (Left(fund(),4))) AS exp1, Mid([file name],10,3) AS Expr6, Mid([file name],8,2) AS Expr7, Left([file name],4) AS Expr8, tblCSVImportTemp.[ID Name] AS Expr1 FROM tblCSVImportTemp WHERE ((([tblCSVImportTemp].[ID Name]) Like "yes" Or ([tblCSVImportTemp].[ID Name]) Like "no"));

Query: qry_benthic
Description: Rebuilds FileName for benthic cover data, so that it can be matched up with new data being imported from CSV file.
Query Type: Select
SQL: SELECT tbl_Sites.Unit_Code AS Park, tbl_Locations.Loc_Name AS Transect, Right([Start_Date],2) AS [Year], tbl_benthic_cover.Frame, IIf([loc_type]="Fixed","F") & IIf([loc_type]="Temporary","T") AS type, [park] & [transect] & [year] & [frame] & [loc_type] AS Combine, IIf(Len([transect])=1,"T0" & [transect]) & IIf(Len([transect])=2,"T" & [transect]) AS transect2, IIf(Len([frame])=1,"00" & [frame]) & IIf(Len([frame])=2,"0" & [frame]) & IIf(Len([frame])=3,[frame]) AS frame2, [park] & [year] & [type] & [transect2] & [frame2] AS FileName2, tbl_benthic_cover.Benthic_ID, tbl_benthic_cover.AnalyDate, tbl_benthic_cover.FramdIder, tbl_benthic_cover.TotalPoint, tbl_benthic_cover.Disease, tbl_benthic_cover.Event_ID FROM tbl_Sites INNER JOIN (tbl_Locations INNER JOIN (tbl_Events INNER JOIN tbl_benthic_cover ON tbl_Events.Event_ID = tbl_benthic_cover.Event_ID) ON tbl_Locations.Location_ID = tbl_Events.Location_ID) ON tbl_Sites.Site_ID = tbl_Locations.Site_ID;

Query: qry_import_error_data
Description: Checks to make sure data being imported doesn't already exist in the database.
Query Type: Select
SQL: SELECT Left([file name],4) AS Park, CInt(Mid([file name],9,2)) AS Transect, CDate((Mid(funD(),5,2)) & "/" & (Mid(funD(),7,2)) & "/" & (Left(fund(),4))) AS [Date], Mid([file name],5,2) AS [Year], CInt(Right([file name],3)) AS Frame, IIf(Mid([file name],7,1)="f","Fixed") & IIf(Mid([file name],7,1)="T","Temporary") AS Type, [park] & [transect] & [year] & [frame] & [type] AS Combine FROM tblCSVImportTemp;

Queries for proofing data

Query: qry_Field_Errors
Description: Provides details about errors that were corrected during the proofing process.
Query Type: Select
SQL: SELECT tbl_Proof_Tracking.Event_Date, tbl_Proof_Tracking.Field, Count(tbl_Proof_Tracking.Field) AS Total_Errors FROM tbl_Proof_Tracking GROUP BY tbl_Proof_Tracking.Event_Date, tbl_Proof_Tracking.Field;

Query: qry_Proof_Changes
Description: Source for frm_Proof. Lists records randomly chosen for proofing- tracks proofing efforts and if errors were corrected.
Query Type: Select

SQL: SELECT qry_Proof.Start_Date, tbl_Proof.Event_ID, qry_Proof.Unit_Code, qry_Proof.Loc_Name, tbl_Proof.Proofed, tbl_Proof.Corrected, qry_Proof.Loc_Type FROM tbl_Proof INNER JOIN qry_Proof ON tbl_Proof.Event_ID = qry_Proof.Event_ID

Query: qry_Proof
Description: Lists all sampling events and includes park and location. This is used to look for duplicate entries in qry_Proof_Changes and qry_Proof_Record_Count.
Query Type: Select
SQL: SELECT tbl_Sites.Unit_Code, tbl_Locations.Loc_Name, tbl_Events.Start_Date, tbl_Events.Event_ID, tbl_Locations.Loc_Type FROM tbl_Sites INNER JOIN (tbl_Locations INNER JOIN tbl_Events ON tbl_Locations.Location_ID = tbl_Events.Location_ID) ON tbl_Sites.Site_ID = tbl_Locations.Site_ID ORDER BY tbl_Events.Start_Date;

Query: qry_Proof_Record_Count
Description: Lists where record has been proofed more than one time so that duplicate entries in tbl_Proof can be deleted.
Query Type Select
SQL: SELECT tbl_Proof.Event_ID, Count(tbl_Proof.Event_ID) AS Number_of_Records FROM tbl_Proof INNER JOIN qry_Proof ON tbl_Proof.Event_ID = qry_Proof.Event_ID GROUP BY tbl_Proof.Event_ID HAVING (((Count(tbl_Proof.Event_ID))>1));

Queries for summary and analysis

A series of queries were created to provide summaries (e.g. percent cover by species and type). These include the following queries.

Query: qry_Ben_Cov_%_transect_type
Description: Benthic cover- Percent per transect, by type.
Query Type: Select
SQL: SELECT qry_Ben_Cov_by_transect_type.Year, qry_Ben_Cov_by_transect_type.Park, qry_Ben_Cov_by_transect_type.Loc_Type, qry_Ben_Cov_by_transect_type.Transect, qry_Ben_Cov_by_transect_type.Total, [algae]/[total]*100 AS [Algae%], ([coral]/[total])*100 AS [Coral%], [coralline algae]/[total]*100 AS [Coralline Algae%], [invert]/[total]*100 AS [Invert%], ([substrate]/[total])*100 AS [Substrate%], [turf algae]/[total]*100 AS [Turf Algae%], [other]/[total])*100 AS [Other%] FROM qry_Ben_Cov_by_transect_type WHERE (((qry_Ben_Cov_by_transect_type.Park) Is Not Null)) ORDER BY qry_Ben_Cov_by_transect_type.Loc_Type, qry_Ben_Cov_by_transect_type.Transect;

Query: qry_Ben_Cov_by Frame_type
Description: Benthic cover - Totals per frame, by type.
Query Type: Crosstab
SQL: TRANSFORM IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Expr1SELECT qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Loc_Type, qry_Benthic_Cover_summary.Frame, IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Total FROM qry_Benthic_Cover_summary INNER JOIN qry_Benthic_Cov_Taxon ON qry_Benthic_Cover_summary.TaxonType = qry_Benthic_Cov_Taxon.TaxonName WHERE (((qry_Benthic_Cover_summary.Park) Is Not Null)) GROUP BY

qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Loc_Type, qry_Benthic_Cover_summary.Frame ORDER BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect PIVOT qry_Benthic_Cov_Taxon.Type In ("algae","coral","invert","substrate","other");

Query: qry_Ben_Cov_by_Species_frame
Description: Benthic cover - total count of each species, per frame.
Query Type: Crosstab
SQL: TRANSFORM IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Expr1 SELECT qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Loc_Type, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Frame, IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Total FROM qry_Benthic_Cov_Taxon INNER JOIN qry_Benthic_Cover_summary ON qry_Benthic_Cov_Taxon.TaxonName = qry_Benthic_Cover_summary.TaxonType GROUP BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Loc_Type, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Frame ORDER BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Loc_Type, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Frame PIVOT [qry_benthic_cov_taxon].[Type] & ":" & [qry_benthic_cov_taxon].[Taxonname];

Query: qry_ben_cov_by_Species_frame_> 0
Description: Benthic cover - total count of each species, per frame. Only shows data where species count > 0.
Query Type: Crosstab
SQL: TRANSFORM IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Expr1 SELECT qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Type, qry_Benthic_Cover_summary.Frame, IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Total FROM qry_Benthic_Cover_summary
GROUP BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Type, qry_Benthic_Cover_summary.Frame ORDER BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Frame

Query: qry_Ben_Cov_by_transect_species
Description: Benthic cover - totals per transect, by species
Query Type: Crosstab
SQL: TRANSFORM IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Expr1 SELECT qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Loc_Type, qry_Benthic_Cover_summary.Transect, IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Total FROM qry_Benthic_Cover_summary INNER JOIN qry_Benthic_Cov_Taxon ON qry_Benthic_Cover_summary.TaxonType = qry_Benthic_Cov_Taxon.TaxonName GROUP BY qry_Benthic_Cover_summary.Park,

qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Loc_Type, qry_Benthic_Cover_summary.Transect

Query: qry_Ben_Cov_by_transect_species_ > 0
Description: Benthic cover - Totals per transect, by species where count >0.
Query Type: Crosstab
SQL: TRANSFORM IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Expr1SELECT qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Loc_Type, IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Total FROM qry_Benthic_Cover_summary INNER JOIN qry_Benthic_Cov_Taxon ON qry_Benthic_Cover_summary.TaxonType = qry_Benthic_Cov_Taxon.TaxonName GROUP BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Loc_Type ORDER BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year,

Query: qry_Ben_Cov_by_transect_type
Description: Benthic cover - Totals per transect, by type.
Query Type: Crosstab
SQL: TRANSFORM IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Expr1 SELECT qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Loc_Type, IIf(IsNull(Count([frame])),0,(Count([frame]))) AS Total FROM qry_Benthic_Cover_summary INNER JOIN qry_Benthic_Cov_Taxon ON qry_Benthic_Cover_summary.TaxonType = qry_Benthic_Cov_Taxon.TaxonName WHERE ((qry_Benthic_Cover_summary.Park) Is Not Null)) GROUP BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year, qry_Benthic_Cover_summary.Transect, qry_Benthic_Cover_summary.Loc_Type ORDER BY qry_Benthic_Cover_summary.Park, qry_Benthic_Cover_summary.Year,

Query: qry_Benthic_Cov_Taxon
Description: Shows all unique values from the tlu_benthic_cov_Taxon table.
Query Type: Select
SQL: SELECT tlu_Benthic_Cov_Taxon.Type, tlu_Benthic_Cov_Taxon.TaxonName FROM tlu_Benthic_Cov_Taxon GROUP BY tlu_Benthic_Cov_Taxon.Type, tlu_Benthic_Cov_Taxon.TaxonName;

Query: qry_Benthic_Cover_summary
Description: Summarizs benthic cover data and separated taxon into "types" (e.g. algae).
Query Type: Select
SQL: SELECT tbl_Sites.Unit_Code AS Park, tbl_Locations.Loc_Name AS Transect, Right([Start_Date],4) AS [Year], tbl_benthic_cover.Frame, tbl_benthic_cover.TotalPoint, tbl_Points.TaxonType, tbl_Points.Point,

Query: qry_disease
Description: Shows those frames that have disease.
Query Type: Select

SQL: SELECT tbl_Sites.Unit_Code, tbl_Locations.Loc_Type, tbl_Locations.Loc_Name, tbl_Events.Start_Date, tbl_benthic_cover.Frame, tbl_benthic_cover.Disease, IIf([disease]="yes",1) AS disease2 FROM tbl_Sites INNER JOIN (tbl_Locations INNER JOIN (tbl_Events INNER JOIN tbl_benthic_cover ON tbl_Events.Event_ID = tbl_benthic_cover.Event_ID) ON tbl_Locations.Location_ID = tbl_Events.Location_ID) ON tbl_Sites.Site_ID = tbl_Locations.Site_ID GROUP BY tbl_Sites.Unit_Code, tbl_Locations.Loc_Type, tbl_Locations.Loc_Name, tbl_Events.Start_Date, tbl_benthic_cover.Frame, tbl_benthic_cover.Disease, IIf([disease]="yes",1) HAVING (((IIf([disease]="yes",1)) Like 1)) ORDER BY tbl_Locations.Loc_Type, tbl_Locations.Loc_Name;

Query: qry_disease2
Description: Summarizes number of disease points per transect as well as the percent (# of frames with disease divided by number of transects).
Query Type: Select
SQL: SELECT qry_disease.Unit_Code, qry_disease.Loc_Type, qry_disease.Loc_Name, qry_disease.Start_Date, Sum(qry_disease.disease2) AS DiseaseTotal, (Sum([disease2])/Count([frame]))*100 AS [Percent] FROM qry_disease GROUP BY qry_disease.Unit_Code, qry_disease.Loc_Type, qry_disease.Loc_Name, qry_disease.Start_Date;

Query: qry_settlement_CRA
Description: Sum of individuals of each genus/species per sq. meter by CRA.
Query Type: Select
SQL: SELECT tbl_Sites.Unit_Code AS Park, tbl_Locations.Loc_Name AS Transect, tbl_Events.Start_Date AS [Date], tbl_settlement.CRA, tbl_settlement.Plate_number AS [Plate#], tbl_juvenile_Colony.Genus_code AS Taxon, Sum(tbl_juvenile_Colony.Count) AS SumOfCount, [sumofcount]/0.0416 AS [#/m^2] FROM (tbl_Sites INNER JOIN ((tbl_Locations INNER JOIN (tbl_Events INNER JOIN tbl_settlementON tbl_Events.Event_ID = tbl_settlement.Event_ID) ON tbl_Locations.Location_ID = tbl_Events.Location_ID) INNER JOIN tbl_surfaces ON tbl_settlement.Settlement_ID = tbl_surfaces. Settlement_ID) ON tbl_Sites.Site_ID = tbl_Locations.Site_ID) INNER JOIN tbl_juvenile_Colony ON tbl_surfaces.Surface_ID = tbl_juvenile_Colony.Surface_ID GROUP BY tbl_Sites.Unit_Code, tbl_Locations.Loc_Name, tbl_Events.Start_Date, tbl_settlement.CRA, tbl_settlement.Plate_number, tbl_juvenile_Colony.Genus_code;

Query: qry_settlement_Surface
Description: Sum of individuals of each genus/species per sq. meter by plate surface.
Query Type: Select
SQL: SELECT tbl_Sites.Unit_Code AS Park, tbl_Locations.Loc_Name AS Transect, tbl_Events.Start_Date AS [Date], tbl_settlement.CRA, tbl_settlement.Plate_number AS [Plate#], tbl_surfaces.Surface, tbl_juvenile_Colony.Genus_code AS Taxon, tbl_juvenile_Colony.Count, IIf([surface]="sides",0.0074,0.00855) AS SurfaceArea, Count]/[surfacearea] AS [#/m^2] FROM (tbl_Sites INNER JOIN ((tbl_Locations INNER JOIN (tbl_Events INNER JOIN tbl_settlement ON tbl_Events.Event_ID = tbl_settlement.Event_ID) ON tbl_Locations.Location_ID = tbl_Events.Location_ID) INNER JOIN tbl_surfaces ON tbl_settlement.Settlement_ID = tbl_surfaces. Settlement_ID) ON tbl_Sites.Site_ID =

Query: qry_settlement_transect
Description: Sum of individuals of each genus/species per sq. meter by transect.
Query Type: Select
SQL: SELECT tbl_Sites.Unit_Code AS Park, tbl_Locations.Loc_Name AS Transect, tbl_Events.Start_Date AS [Date], tbl_juvenile_Colony.Genus_code AS Taxon, Sum(tbl_juvenile_Colony.Count) AS SumOfCount, [sumofcount]/0.1248 AS [#/m^2], tbl_Locations.X_Coord_Start, tbl_Locations.Y_Coord_Start FROM (tbl_Sites INNER JOIN ((tbl_Locations INNER JOIN (tbl_Events INNER JOIN tbl_settlement ON tbl_Events.Event_ID = tbl_settlement.Event_ID) ON tbl_Locations.Location_ID = tbl_Events.Location_ID) INNER JOIN tbl_surfaces ON tbl_settlement.Settlement_ID = tbl_surfaces. Settlement_ID) ON tbl_Sites.Site_ID = tbl_Locations.Site_ID) INNER JOIN tbl_juvenile_Colony ON tbl_surfaces.Surface_ID = tbl_juvenile_Colony.Surface_ID GROUP BY tbl_Sites.Unit_Code, tbl_Locations.Loc_Name, tbl_Events.Start_Date, tbl_juvenile_Colony.Genus_code, tbl_Locations.X_Coord_Start, tbl_Locations.Y_Coord_Start;

Query: qry_RepeatedMeasured_Algae
Description: Shows percent cover of algae per park, year, and transect.
Query Type: Crosstab
SQL: TRANSFORM First([qry_Ben_Cov_%_transect_type].[Algae%]) AS [FirstOfAlgae%] SELECT qry_Ben_Cov_%_transect_type].Transect, qry_Ben_Cov_%_transect_type].Loc_Type FROM [qry_Ben_Cov_%_transect_type] WHERE (([qry_Ben_Cov_%_transect_type].Loc_Type)="fixed")) GROUP BY [qry_Ben_Cov_%_transect_type].Transect, [qry_Ben_Cov_%_transect_type].Loc_Type ORDER BY [qry_Ben_Cov_%_transect_type].Transect PIVOT [Park] & [Year] & "Algae";

Query: qry_RepeatedMeasures_Coral
Description: Shows percent cover of coral per park, year, and transect.
Query Type: Crosstab
SQL: TRANSFORM First([qry_Ben_Cov_%_transect_type].[Coral%]) AS [FirstOfCoral%] SELECT [qry_Ben_Cov_%_transect_type].Transect, [qry_Ben_Cov_%_transect_type].Loc_Type FROM [qry_Ben_Cov_%_transect_type] WHERE ((([qry_Ben_Cov_%_transect_type].Loc_Type)="fixed")) GROUP BY [qry_Ben_Cov_%_transect_type].Transect, [qry_Ben_Cov_%_transect_type].Loc_Type ORDER BY [qry_Ben_Cov_%_transect_type].Transect PIVOT [Park] & [Year] & "Coral";

Query: qry_SurveysDone
Description: Shows which transects have been sampled.
Query Type: Select
SQL: SELECT tbl_Sites.Unit_Code, tbl_Locations.Loc_Type, tbl_Locations.Loc_Name, Right([Start_Date],4) AS [Year], tbl_Events.Start_Date AS [Survey Date], First(tbl_benthic_cover.FramdIder) AS Analyzer FROM tbl_Sites INNER JOIN (tbl_Locations INNER JOIN (tbl_Events INNER JOIN tbl_benthic_cover ON tbl_Events.Event_ID = tbl_benthic_cover.Event_ID) ON tbl_Locations.Location_ID = tbl_Events.Location_ID) ON tbl_Sites.Site_ID = tbl_Locations.Site_ID GROUP BY tbl_Sites.Unit_Code,

tbl_Locations.Loc_Type, tbl_Locations.Loc_Name, Right([Start_Date],4), tbl_Events.Start_Date;

Query: qry_TemporalChangeInCoralCover
Description: Change in percent coral cover between two time periods
Query Type: Crosstab
SQL: TRANSFORM Avg([avgofcoral%]*1) AS CoralCover SELECT [qry_Ben_Cov_Avg%_Year_Park_type].Park AS Expr1, [qry_Ben_Cov_Avg%_Year_Park_type].Loc_Type AS Expr3, First([coralcover]) AS [Begin], Last([coralcover]) AS [End], [End]-[Begin] AS Change FROM [qry_Ben_Cov_Avg%_Year_Park_type] GROUP BY [qry_Ben_Cov_Avg%_Year_Park_type].Park, [qry_Ben_Cov_Avg%_Year_Park_type].Loc_Type ORDER BY [qry_Ben_Cov_Avg%_Year_Park_type].Park, [qry_Ben_Cov_Avg%_Year_Park_type].Year PIVOT [qry_Ben_Cov_Avg%_Year_Park_type].Year;

Database Administration

Database files will be distributed to individual parks at the beginning of the field season to facilitate prompt data entry and edits by park staff. At the end of the field season, files will be submitted to the PACN data management staff for consolidation into the master database file. While PACN recommends that parks store the database files on a park server with automatic backups, some parks lack these resources and will store the files on a local computer and employ their own backup strategy. PACN also recommends that the parks store the database files and backups in the appropriate I&M project folder (see Data Organization section), preferably with the back-end file on a shared server drive and the front-end file on the same server drive or on a local drive. At the beginning of each data entry session, the user must create a backup of the back-end data file, ensuring that the initial data entry starting point can be recovered should irreversible errors or problems occur during the data entry session. The backup will be done using a database utility which prompts the user to create the backup at the onset of a data entry session. This will not require a name change or revision change. The backup files will be named by adding the current date and time to the end of the back-end file name (e.g., benthic_marine_BE_v1.0_20060530_1711.mdb for a backup file created at 5:11 PM on May 30, 2006). Back-up copies are used for the current field season only and will not be archived.

The working Benthic Marine database must be stored in the specified I&M project folder, and all data entry and edits must occur in this database file only. It is the responsibility of the PI or designee(s) to ensure that multiple copies of the database are not created, with data entry and edits erroneously occurring in multiple database files. The PACN data management staff will work with the PI or designated staff to design appropriate exploratory data analysis tools (e.g., specific queries and reports tailored to the project's exploratory data analysis needs) and incorporate these tools into updated versions of the Benthic Marine database application. Such changes will be fully documented in the protocol or SOP edit logs and reflected in the protocol database filename (e.g., in version identifier) and metadata.

Data Entry from Data forms

Data entry should occur as soon as possible after data collection is completed and before the next sets of observations occur. Data entry should be completed by the person who collected the data or someone who is familiar with the project and data. The primary goal of data entry is to transcribe the data from paper and photographic records into the computer with 100% accuracy. If any sensitive data is collected (e.g., location of rare organisms or spawning aggregations) then make a note of this on the original data form and send a copy to the database manager to flag the data as sensitive.

Data entry will occur at multiple locations. At each park, a single database back-end should be used for all data entry and manipulation. Site information, coral settlement, rugosity, and coral growth data will be entered at each individual park by park staff. Photogrid© comma-separated-value (CSV) files containing data on benthic cover and disease will be generated (see SOP #13) by the Marine Biological Technician. These Photogrid© CSV files will be imported into the Benthic Marine database back-end file(s) at the end of the field season after QA/QC corrections have been made. Waiting until the end of the field season will facilitate matching the transect data from Photogrid© to the sampling event for the other data components (site information, coral settlement, rugosity, and coral growth) collected at the same time and place as the digital photos. Import of the Photogrid© CSV files will be accomplished collaboratively by the PACN data management staff and the Marine Biological Technician. Photo and Photogrid© CSV files will be backed up, with a copy retained at each park after these data are collected.

At the end of the field season, the PI or designee, the Marine Biological Technician, and PACN data management staff are collectively responsible for ensuring that all validated data have been migrated into a single back-end database file representing all work at all parks for that field season. This final verified database file will then be archived by the PACN data manager. Read-only copies of this final database file will be sent to each park for their data summary needs and their local archiving.

A database user manual is in development, and will provide step-by-step instructions accompanied by screen-capture images. This user manual will not be completed until after the initial phases of data entry following protocol implementation. Eventually, the user manual will be included as an appendix to this SOP. Ultimately, it is the PI's and park lead's shared responsibility to ensure that all data entry staff understand how to enter data and follow all applicable SOPs. Data entry technicians are responsible for becoming familiar with the field data forms, the database software, database structure, Photogrid© export file formats, and any standard codes for data entry.

Data Maintenance
Any editing of archived data is accomplished jointly by the PI or designee and PACN data manager. Every change must be documented in the edit log and accompanied by an explanation that includes pre- and post-edit data descriptions (Tessler and Gregson 1997). All data collected using this protocol are subject to the following three caveats:

- Only make changes that improve or update the data while maintaining data integrity.
- Once archived, document any changes made to the dataset through an edit log. At end of each fiscal year, the database manager will update the central database and will send out read-only versions.

- Mistakes can be made during editing so updates must be compared with the original data form prior to validating the data.

Data Organization

To help make file management intuitive and straight-forward, PACN recommends that each park store digital files related to the Benthic Marine protocol in a standardized file folder directory structure (Figure S11.2). This directory structure should be used on a shared server where files are automatically backed-up on an established schedule. If necessary, the directory structure can be used on a local computer drive with file back-ups accomplished by the PI or appropriate staff.

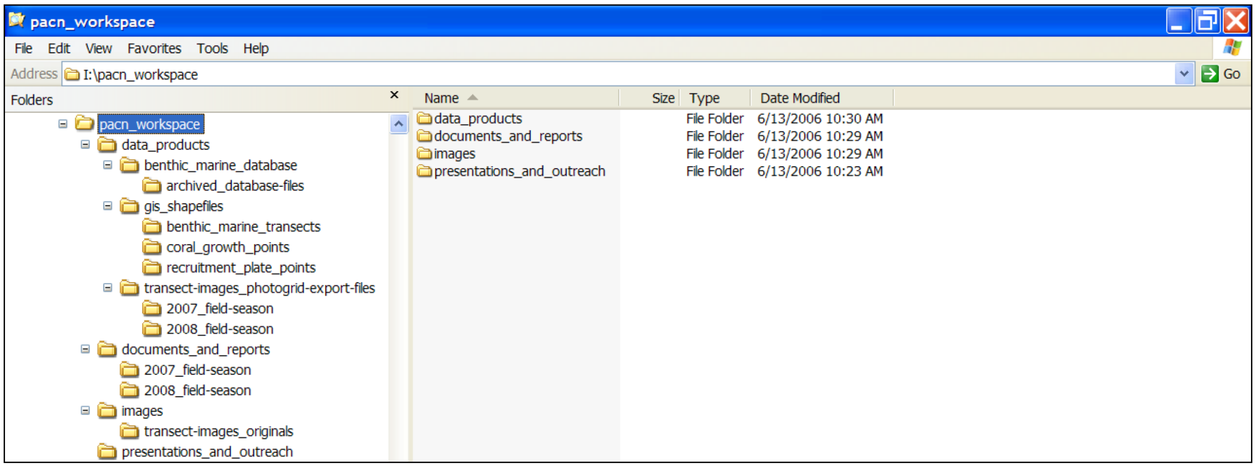


Figure S11.2. Recommended file folder directory structure for storing Benthic Marine digital files.

Version Control

Prior to any major changes of a dataset, a copy is stored with the appropriate version number to allow for tracking of changes over time. Versioning of archived datasets is handled by adding a three digit number to the file name, with the first version being numbered 001 (e.g., benthic_marine_BE_v1.0_validated-20071121_v001, for the first version of a back-end data file validated by the PI and data manager at the end of the 2007 field season). Each additional version is assigned a sequentially higher number. Frequent users of the data are notified of the updates, and provided with a copy of the most recently archived version.

Data Logs and Backups

Once the data are archived, any changes made to the data must be documented in an edit log. Original field forms will not be altered. Field forms can be reconciled to the database through the use of the edit log. Secure data archiving is essential for protecting data files from corruption. Once a dataset has passed the QA/QC procedures specified in the protocol, a formal metadata record is created and the PACN project tracking database is updated to reflect the validation of that year's dataset. The validated dataset is archived on the PACN I&M server in read-only format, and copies are distributed to the individual parks for their local read-only backup. At a minimum, the metadata record for the validated dataset is posted to the appropriate National Park Service online data store (e.g., the NPS Data Store, http://science.nature.nps.gov/nrdata). If there are no sensitive data issues, then the dataset file will also be posted to the online data store.

Verification of Data Entry

Quality control of data is a critical step in data management. Verification of data (ensuring data on field sheets match data entered into a database) is the responsibility of the PI and designees. See recommendations outlined in Chapter 4 of the Benthic Marine protocol. The specific data verification processes are described in the applicable Benthic Marine protocol SOPs, which will be updated as improvements are made to these data verification processes. Any modifications to the Benthic Marine database will be described in the edit log and the functionality of the verification routines will be explained in detail in the Benthic Marine database user manual (in development).

Data verification will occur in three steps.

Step 1: Park staff, working closely with the PI and Marine Biological Technician, will be responsible for reviewing 10% of all benthic image analysis records each field season. Review of benthic image analysis records will be accomplished using the Photogrid© software, and edits will be made prior to generating Photogrid© export files for import into the Benthic Marine database (see details in the Benthic Image Analysis SOP). This review will serve as both a data verification process and a data validation process. For the purposes of data verification, if more than 10% of the reviewed records are affected by data entry errors, then all of the records will be reviewed by the park lead and corrected by the Marine Biological Technician as needed.

Step 2: Using record review routines built into the Benthic Marine database, park staff will compare 10% of all transect site information, rugosity data, coral growth data, and coral settlement data against the original hardcopy data sheets. Corrections to data entry errors will be tracked in order to quantify data entry error rates. If more than 10% of the reviewed records are affected by data entry errors, then all of the records will be reviewed by the park lead and corrected by the marine biological technician as needed.

Step 3: The geospatial component of the Benthic Marine database will be verified each field season. A database utility linking the database to ArcGIS® software will be used to evaluate all geospatial coordinates. Any corrections will be tracked, and an error rate greater than 10% will require a detailed review of the coordinate fields for all records. As this database functionality is finalized, it will be fully described in this Data Management SOP and in the database user manual.

Validation of Datasets

At the end of each field season, the PI, designees, and the PACN data management staff are collectively responsible for finalizing a validated dataset for that field season. Park staff, working closely with the PI and the Marine Biological Technician, will complete all data validation. Some validation (ensuring that the data make sense) methods have been incorporated into the benthic marine database. Other, more specific validation routines will be worked out with the protocol PI and/or project staff and incorporated into the database as appropriate. These modifications will be described in the edit log and the functionality of the validation routines will be explained in detail in the Benthic Marine database user manual (in development).

Validation of benthic image analysis records will be accomplished using the Photogrid© software. A second observer, by comparing their own benthic cover interpretations for 10% of the images against the interpretations of the original observer, will validate the original observer's records. If there is disagreement with more than 10% of these reviewed records, then the two observers will review the benthic cover interpretation guidelines and the original observer will re-interpret all of the images. In this event, the validation of benthic image analysis records would then be repeated. This process of validating benthic image analysis records will be completed before that field season's Photogrid© export files are imported into the Benthic Marine database.

Validation of coral settlement analysis records will also be accomplished by park staff, in collaboration with the PI and Marine Biological Technician. As with the benthic image analysis records, park staff will select 10% of the coral settlement plates to be re-read by a second observer. If there is disagreement with more than 10% of the records, for the coral taxon identified and the number of juveniles counted, then the two observers will review the guidelines for identifying and counting coral juveniles, and the original observer will re-analyze all of the plates. In this event, the validation of 10% of the plates by a second observer would be repeated.

The PI, in conjunction with all relevant staff, will be responsible for evaluating all of the database records for a given field season in order to provide final approval for a validated dataset for that field season. PACN data management staff will work closely with the PI and PICRP personnel to provide any needed database queries, reports, graphs, or export file formats to assist with this overall validation. Once a given field season's dataset has been validated, the PACN data manger will be responsible for archiving the validated dataset, posting the metadata (and dataset, if appropriate) to the appropriate NPS online data store, and distributing read-only copies of the validated datasets to the parks.

File Management

Current Files

The master versions of all digital files relating to the Benthic Marine protocol are stored on the PACN file server, with regular file back-ups accomplished automatically. Presently, the main files include the protocol narrative, the SOPs, and the Benthic Marine database files. These files are stored according to the file folder directory structure recommendations outlined in the Data Organization section of this Data Management SOP.

Local Archiving of Files

An overview of the processing and disposition of project data is provided in Table S11.1.

Digital Data

Any time a revision of protocols requires a revision to the database, a complete copy of the database will be made and stored in an archive directory (see Version Control, above). In addition to this copy in its native database format, all tables will be archived in a comma-delimited ASCII format that is platform-independent by using the Access_to_ascii.mdb utility developed by CAKN. An abbreviation of benthic marine monitoring, the database version number, and the term Archive are incorporated into the filename of archives, with ascii files including a .txt file extension and Access files including an .mdb file extension. These files are saved in the 'version_archive' directory, with a subdirectory created for each version. Example:

\version_1.0\benthic_marine_BE_v1.0_Archive_001.mdb

\version_1.0\benthic_marine_BE_v1.0_Archive_001.txt
\version_1.04\benthic_marine_BE_v1.04_Archive_009.mdb
\version_2.02\ benthic_marine_BE_v2.02_Archive_013.txt

At the end of a field season when all data have been entered, verified, and validated, an annual archive copy of the front and back end database files will be made (see Version Control section). Archived datasets will be managed by PACN, and made available to the parks, PI, and to cooperators as needed. These archived files will be stored on the PACN file server, regularly backed-up, including an off-site storage rotation, and will be distributed in read-only format.

Hard Copies and Originals

Hard copies of all datasheets, maps, and protocols will be archived with the PI, at the park, and within the park museum/library. Table S11.1 identifies the processing and disposition of the project data.

Table S11.1. Processing and disposition of project data.

Data item	Action	Database	Project Binder	Archive
Benthic data form	Make two copies	Enter data	Park copy	Investigator keeps original. Museum keeps one copy
Growth data form	Make two copies	Enter data	Park copy	Investigator keeps original. Museum keeps one copy
Settlement data form	Make two copies	Enter data	Park copy	Investigator keeps original. Museum keeps one copy
Digital photographs of quadrats		Enter digital file name and storage location in database	Park copy of list of digital file names, date, and file size	Electronic copy on backed-up park server on hard disk. If unavailable then marine ecologist is responsible for storage.
Maps	Download GPS data	Enter new location data	Original	Museum keeps an annual copy
Protocol update		Create archive copy (both Access and ASCII) before update		Save on backed-up server or hard drive; send copy to PACN
End-of-season verified/validated database		Create archive copy		Save on backed-up park server or hard drive. If unavailable then marine ecologist is responsible for storage. Send copy to PACN
Metadata	Complete or update dataset catalog record		Park copy	Send updated record to PACN

Literature Cited

Tessler, S. and J. Gregson. 1997. Draft Data Management Protocol. Available at http://www1.nrintra.nps.gov/im/dmproto/joe40001.htm (accessed 18 June 2007).

SOP #12: Data Management – Photographs

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	8/03/2007	L. Basch	See Track Changes	Clarification, corrections		2.00

Purpose

This SOP documents the downloading, storing, and naming of photographs taken during marine benthic surveys.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised. A list of equipment required to complete the tasks specified in this SOP has been provided in Appendix S12.a.

Downloading Images

Data will be downloaded from the camera as soon as possible, following the dive. This SOP assumes that photos have been taken according to the procedures in SOP #7 "Conducting Benthic Marine and Rugosity Surveys." Refer to the equipment list needed for downloading images in Appendix S12.a.

Downloading Images Using Card Reader

Step 1: Turn on computer and make sure card reader is inserted into USB port

Step 2: Open the program "Explorer" from the "Start Menu" on a computer with the Microsoft Windows® system. An alternative is to press the Window + E keys to open Explorer.

Step 3: Insert the media card from the camera into the appropriate slot on the card reader. In the case of the Olympus® 5050, use the Compact Flash.

Step 4: The card reader will appear in Explorer as a separate drive.

Step 5: Click on the appropriate drive in Explorer. You will see a “DCIM” folder.

Step 6: Open the DCIM folder and inside is a “100OLMP” folder.

Step 7: Open the 100OLMP folder and examine the image files from the camera.

Step 8: Copy images to hard drive as in the “Storing Images” section below. Ensure that images have been copied to hard drive before deleting images on media card. Reformat media card to minimize potential problems in file storage or transfer.

Step 9: Eject the media card by right clicking on the drive within Explorer and selecting “Eject” from the menu. Then press OK on the button.

Step 10: Follow instructions in SOP #11 “Post-dive procedures and equipment maintenance” for other instructions on caring for the camera, storage media cards, and batteries.

Downloading the Images Using a Cable

Step 1: Connect the camera to the computer using the USB cable.

Step 2: Turn the camera on. Turn the mode wheel to the “Playback Mode” by turning the Mode dial to the green triangle. Computers with windows XP operating systems should recognize the camera as a new drive. If it does not, go to my computer, hit refresh and the camera should appear; or, consult camera manual to troubleshoot.

Step 3: Open the program “Explorer” from the “Start Menu”. An alternative is to press the Window + E keys to open Explorer.

Step 4: Open the new drive, which appears in Mircorsoft Windows® Explorer.

Step 5: Open the “DCIM” folder and the “100OLMP” subfolder.

Step 6: Copy the images to the hard drive as below in the “Storing Images” section. Ensure that images have been copied to hard drive before deleting images on media card. Reformat media card to minimize potential problems in file storage or transfer.

Step 7: Stop the removable drive using the “Safely Remove Hardware” icon in the system tray along the bottom of Microsoft Windows® XP.

Step 8: Turn the camera off.

Step 9: Disconnect the camera from the computer. Follow instructions in SOP #11 “Post-Dive Procedures and Equipment Maintenance” for other instructions on caring for the camera, memory cards, and batteries.

Storing Images

Storing Photographs for Benthic Analysis

Step 1: All of the raw benthic images will reside in a PhotoGrid© Image directory that can be easily backed up.

Step 2: Within this directory, create a master folder for the park and then subfolders for each year with transect folders inside (Figure S12.1).

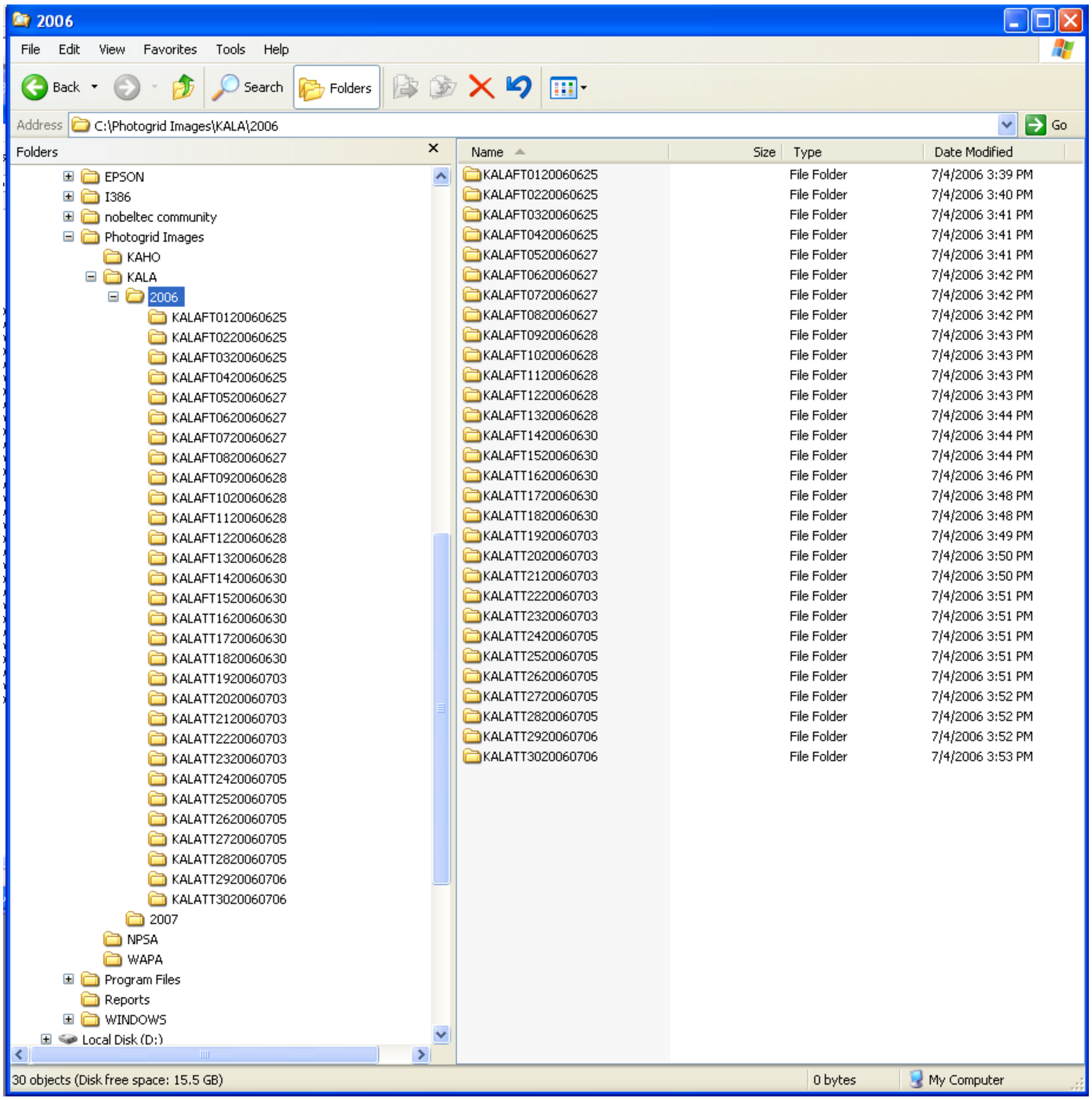


Figure S12.1. Folder structure for storage of PhotoGrid© images.

Step 3: Use the naming convention in Figure S12.2 for the folders that store raw images.

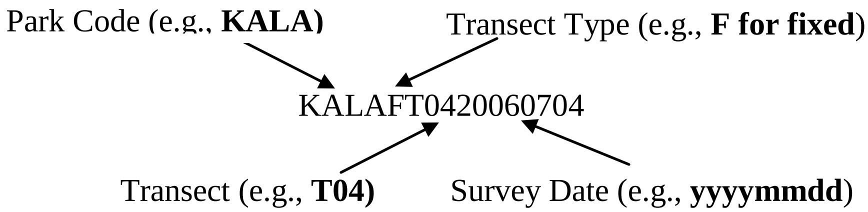


Figure S12.2. Directory naming convention for storing photographs.

Step 4: At the end of the year, each park needs to burn a CD(s) with the transect images and mail the images to the I&M database manager for backup.

Storing Photographs for Settlement

These procedures assume that images of settlement plates were made following SOP #8 "Conducting Coral Settlement Monitoring." Photographing coral settlement plates is presently an optional but recommended step in this SOP.

Step 1: All of the settlement images will reside in a "Settlement Image" directory that can be easily backed up.

Step 2: Within this directory, create a master folder for the park and then subfolders for each year with transect folders inside.

Step 3: Use the naming convention for the folders that store images (same as for benthic images) as given in Figure S12.2.

Step 4: At the end of the year, each park needs to burn a CD(s) with the settlement tile images and mail the images to the I&M database manager for backup.

Renaming Benthic Image Files

Step 1: Use the program ACDSee® v. 6 to rename the image files in a batch.

Step 2: Launch ACDSee® by clicking on the "Start" button, selecting all programs, and highlighting the ACDSee® program.

Step 3: Navigate to the folder with the images for a transect using the Explorer type window on the left portion of the screen.

Step 4: Click on any one of the images and then go into the "Browse" mode under the "File" menu.

Step 5: This execution will display all of the images within that folder/transect.

Step 6: Highlight all of the images by using the "Select All" command under the Edit menu; alternatively, you may simultaneously press the "Ctrl" and "A" keys.

Step 7: Select the “Rename” command under the Edit menu; alternatively you may use the function key “F2” to execute the command.

Step 8: Under “set rename options” check “Use template to rename files” and click “Use numbers to replace #’s” (Figure S12.3).

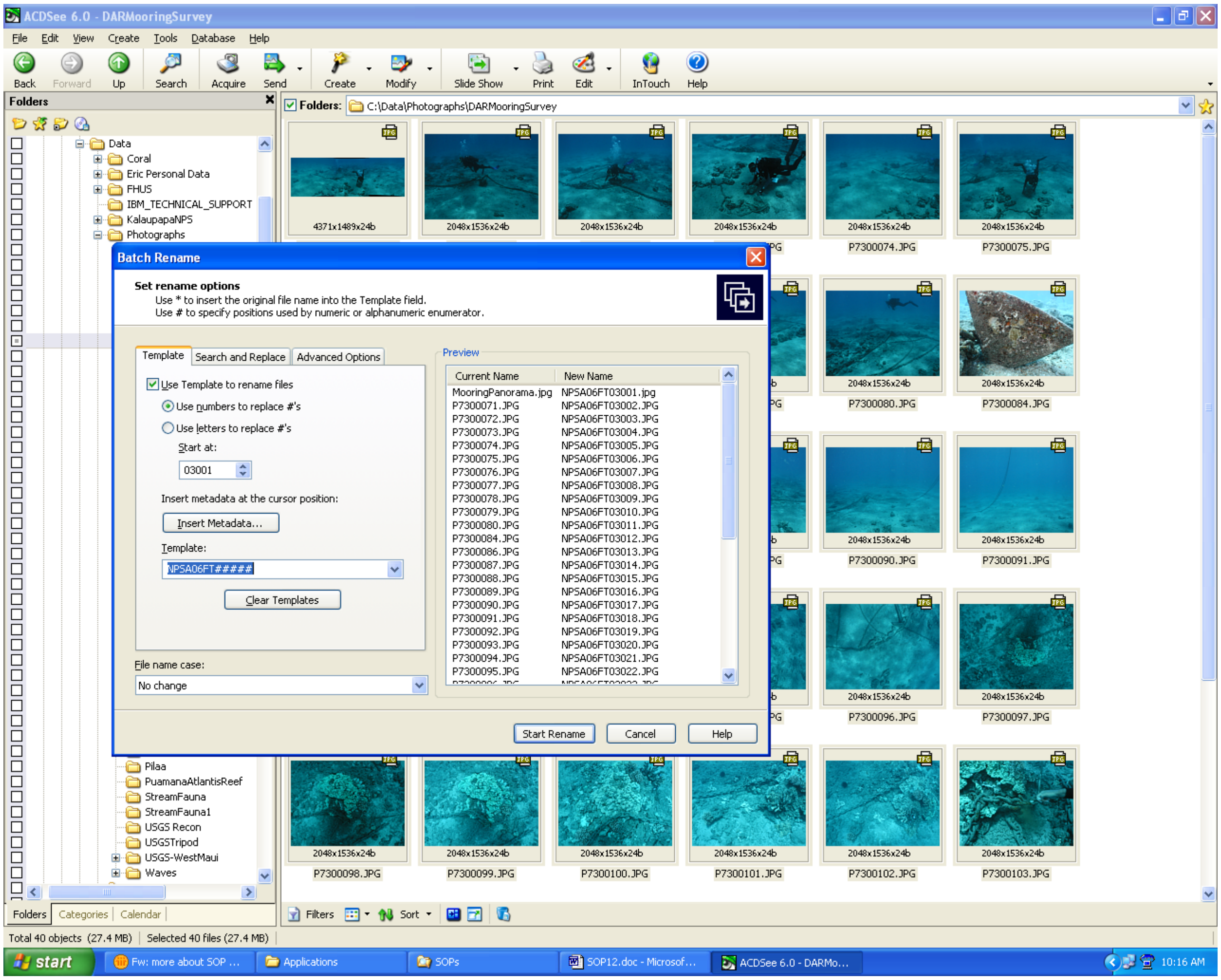


Figure S12.3. Sample screen in ACDSee® showing the file renaming options.

Step 9: In the “Start at” box, enter the transect number (e.g., 03 for fixed transect 3) followed by 001 (e.g., for fixed transect 3, enter “F03001”). This starts the numbering sequence with the number one corresponding to the first image and allows for up to 999 images/frames per transect.

Step 10: In the “Template” box, enter the Park Code, the calendar year, T or F (temporary or fixed) and an additional T for transect. For example in Figure S12.3, fixed transects at National Park of American Samoa in 2006 would be entered as “NPSA06FT”.

Step 11: Press “Start Rename”

Step 12: Files will be renamed following the template in Figure S12.4.

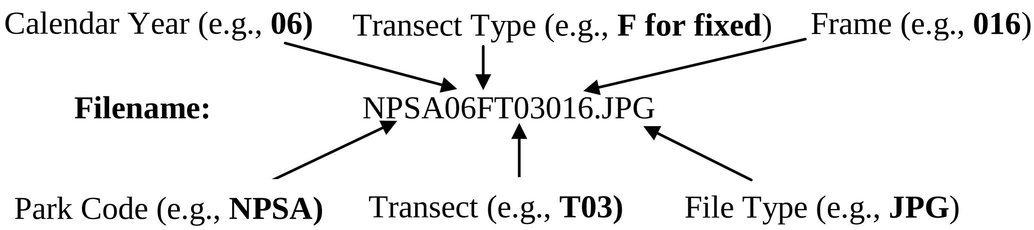


Figure S12.4. Example format for renaming files for benthic image analysis.

Renaming Settlement Image Files

Step 1: Use the program ACDSee v.6 to rename the image files in a batch.

Step 2: Launch ACDSee by clicking on the "Start" button, selecting all programs, and highlighting the ACDSee program.

Step 3: Navigate to the folder with the images using the Explorer type window on the left portion of the screen.

Step 4: Click on any one of the images and then go into the "Browse" mode under the "File" menu.

Step 5: This execution will display all of the images within that folder/transect.

Step 6: Highlight the first 4 images, which represent the pictures taken at the first CRA along a transect.

Step 7: Select the "Rename" command under the Edit menu; alternatively you may use the function key "F2" to execute the command.

Step 8: Under "set rename options" check "Use template to rename files" and click "Use numbers to replace #'s" (Figure S12.3).

Step 9: In the "Start at" box, enter the transect number, the CRA/plate pair number (01, 02, or 03), followed by a number for the surface (01, 02, 03, or 04 [for UT upper plate top surface; UB upper bottom; LT lower top, or; LB lower bottom, respectively) (e.g., for transect 3, the first CRA and plate surface 3, enter "030103")

Step 10: In the "Template" box, enter the Park Code, the calendar year, transect type (T= temporary or F= fixed) and an additional T for transect. For example, fixed transects at National Park of American Samoa in 2005 would be entered as "NPSA05FT".

Step 11: Press "start Rename"

Step 12: Files will be renamed following the template in Figure S12.5.

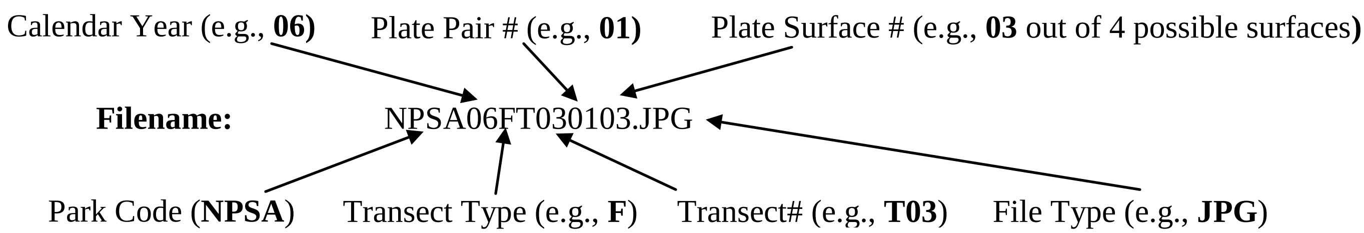


Figure S12.5. Example format for renaming files for settlement image analysis.

Appendix S12.a: Equipment Necessary to Download Images

Equipment list for downloading images

Equipment	Quantity	Notes
Compact Flash Card reader	1	If using a card reader
USB cable	1	If using the camera and cable
Camera	1	
Computer	1	

SOP #13: Data Management – Benthic Image Analysis

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/07	Eric Brown	See track changes	Response to reviewers' comments		1.00
2.10	8/03/2007	L. Basch	See track changes	Corrections, additions, clarifications		2.00

Purpose

This SOP documents the benthic image analysis protocol. The sections of this protocol are presented in order of execution. 1) Selecting the images for analysis, 2) PhotoGrid© analysis, 3) Identification standards, and 4) Exporting data from PhotoGrid©. Additionally, Appendix S13.a shows various examples of substrate types from digital still images taken in different parks. The use of products identified in this protocol does not imply endorsement, effectiveness, or warranty by NPS

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Benthic Image Analysis

Downloading Images for Analysis

Data will be downloaded from the camera as soon as possible following the dive. See SOP #12 "Data Management – Photographs" for instructions on downloading and storing photographs.

Selecting Images for Analysis

Step 1: Navigate to the folders that contain the images for each transect (see SOP #12 Data Management – Photographs). Check to ensure that folder transect names correspond to photo filenames.

Step 2: Select every image starting with frame 2 (frame 1 is a photograph of the transect header information.

Step 3: To select multiple files, hold the “Ctrl” key down while clicking the file names.

Step 4: Then, continuing to hold the “Ctrl” key down, drag these selected images to the new transect folders (with corresponding names) located inside the “Selected PhotoGrid© Images” folder. This technique will actually create a copy of the files in the new folders rather than move the original files from the old folders. Alternatively, you could use the “Copy” and “Paste” functions under the “Edit” menu. Ensure that copies of all photos remain in both original and new folders.

Setting up PhotoGrid©

Step 1: Photogrid© can be downloaded for free from the following website: http://www.photogrid.netfirms.com/ (last accessed 05July06).

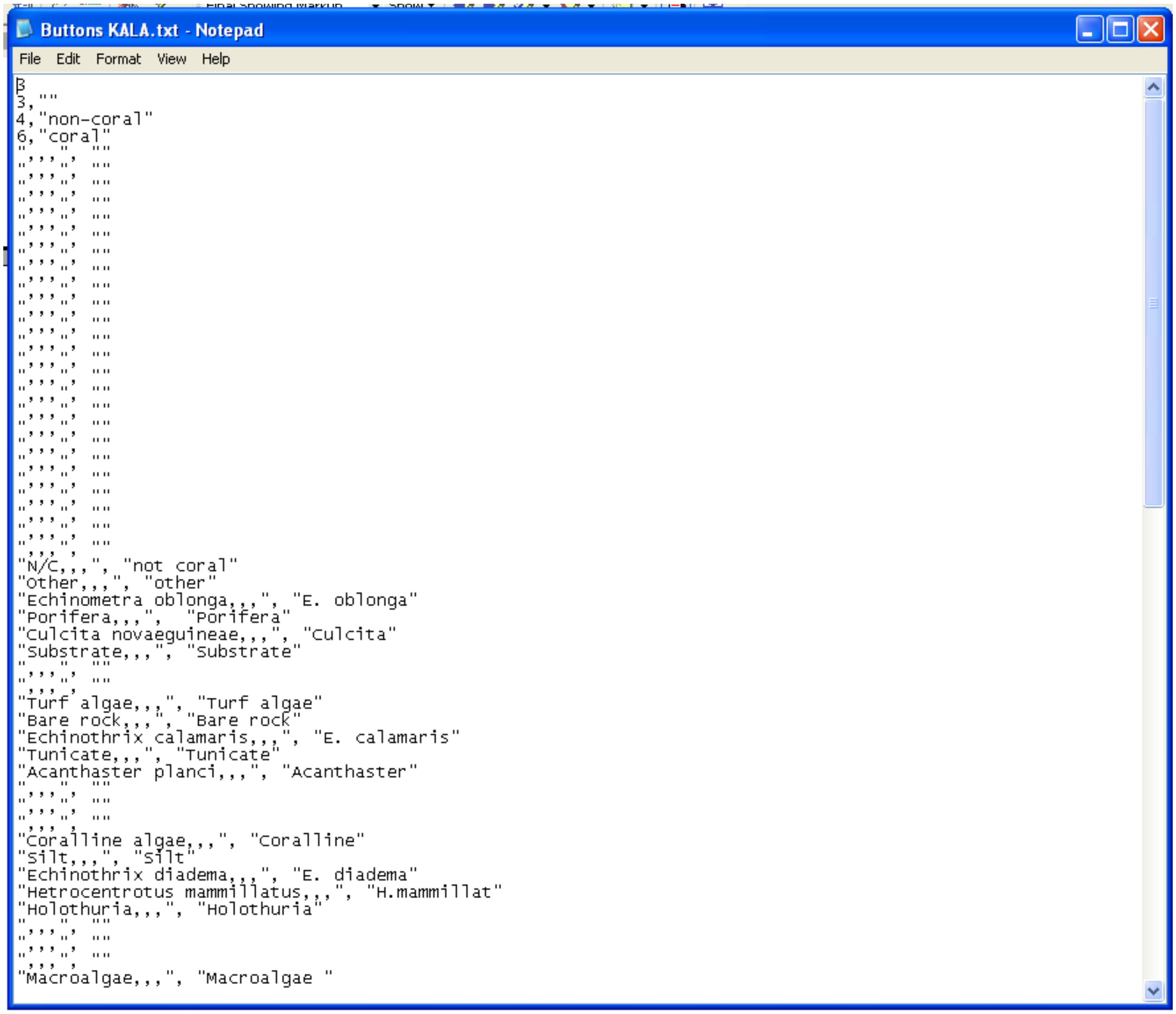
Step 2: The resulting zip file needs to be unzipped by double clicking on the file name in Microsoft Windows® XP or higher. This will create the necessary files (e.g., setup.exe) used in the installation process. The location of the unzipped files can be specified for any folder on the hard drive.

Step 3: Install PhotoGrid© on your hard drive in the folder of your choice by double clicking on the “setup.exe” file. The default folder is C:\Program Files\PhotoGrid which is adequate for this protocol.

Step 4: After installation, navigate to the PhotoGrid© folder in the Program Files folder on your hard drive. Optional: create a shortcut icon for PhotoGrid© on computer desktop.

Step 5: Select the “Species Buttons” folder and open one of the Buttons text files using a text editor such as Notepad®, Wordpad®, or Word®.

Step 6: Edit the text file to incorporate the species within your park (Figure S13.1). Some example files such as Buttons KALA.txt already exist at Kalaupapa NHP and can be acquired from the park staff to use as models for editing.




```
3
3,""
4,"non-coral"
6,"coral"
",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
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",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
",,,", ""
"N/C,,,", "not coral"
"Other,,,", "other"
"Echinometra oblonga,,,", "E. oblonga"
"Porifera,,,", "Porifera"
"Culcita novaeguineae,,,", "Culcita"
"Substrate,,,", "Substrate"
",,,", ""
",,,", ""
"Turf algae,,,", "Turf algae"
"Bare rock,,,", "Bare rock"
"Echinothrix calamaris,,,", "E. calamaris"
"Tunicate,,,", "Tunicate"
"Acanthaster planci,,,", "Acanthaster"
",,,", ""
",,,", ""
",,,", ""
"Coralline algae,,,", "Coralline"
"Silt,,,", "Silt"
"Echinothrix diadema,,,", "E. diadema"
"Hetrocentrotus mammillatus,,,", "H.mammillat"
"Holothuria,,,", "Holothuria"
",,,", ""
",,,", ""
",,,", ""
"Macroalgae,,,", "Macroalgae "
```

Figure S13.1. Sample Photogrid© species buttons text file showing format for taxa entry

Step 7: Save the text file in the "C:\Program Files\PhotoGrid 1.0(or most recent version)\Species Buttons" folder.

Photogrid© Analysis

Step 1: Launch Photogrid© by clicking on the "Start" button, selecting all programs, and highlighting the PhotoGrid© program

Step 2: Click the "Preferences" under the "Options" menu. A dialog box will appear, and the screen should look similar to Figure S13.2.

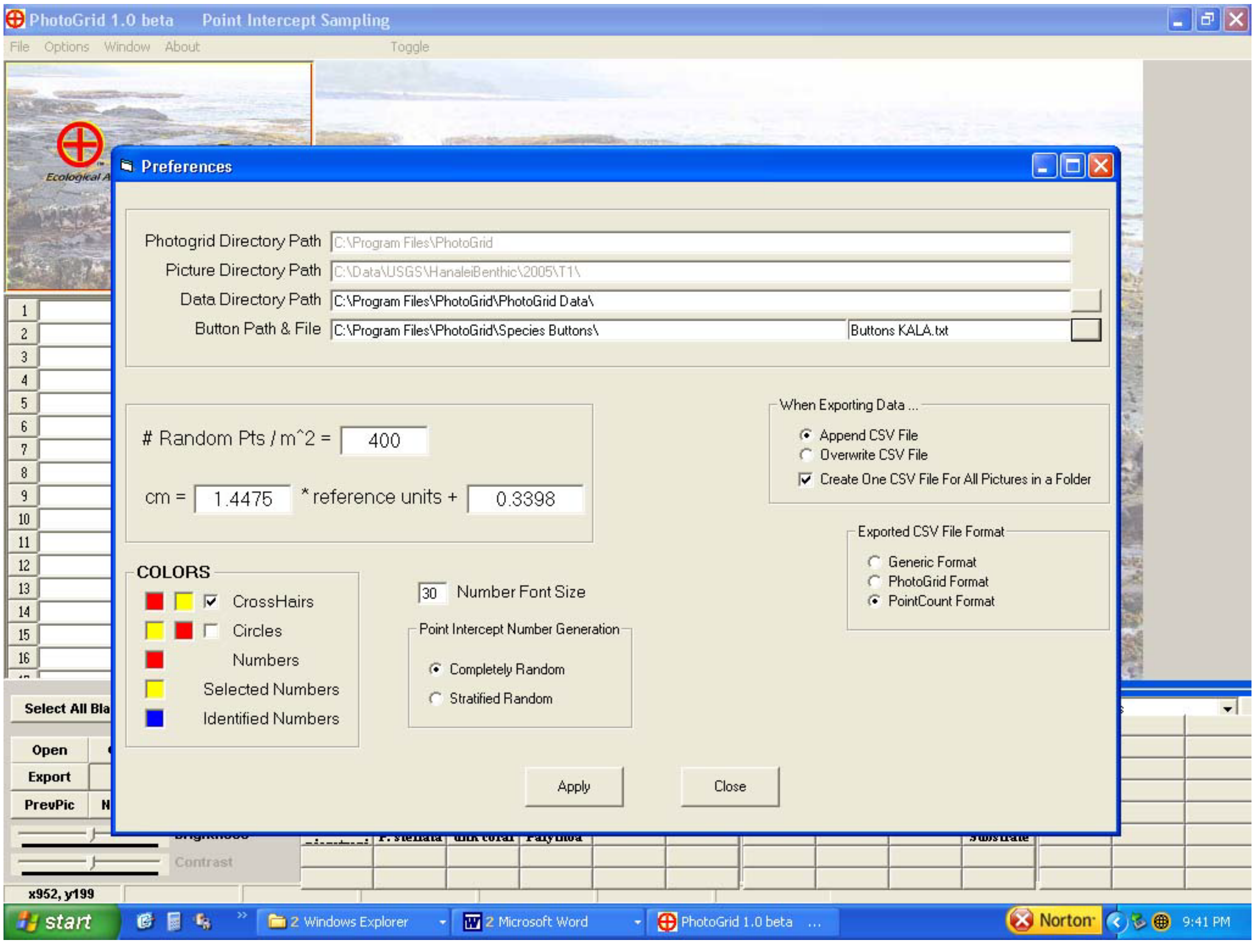


Figure S13.2. Photogrid© preferences screen under the "options" menu.

Step 3: In the "When Exporting Data" box, select "Append CSV file"

Step 4: In the "Exported CSV File Format" box, select "PointCount Format".

Step 5: Select the buttons file that will be used for substrate identifications within the park. In this example, "Buttons KALA.txt" is the file that has the species/substrate codes used for Kalaupapa NHP. This file is a good initial general species/substrate list for the Hawaii parks. Note the settings in Figure S13.2 that indicate that the current point will be highlighted in yellow with completed points labeled blue and points yet to be identified still in red.

Step 6: Disregard the "# Random Pts/m^2" box because the number of points projected on the screen will be entered on the main screen after an image has been loaded.

Step 7: Apply any changes to the screen and then close the window.

Step 8: Under the "Options" menu, ensure that the Sampling Mode has been set to Point Intercept.

Step 9: In the lower left-hand corner of the main screen set the number of random points (# Rnd Pts) to 51.

Step 10: On the menu select “File” and scroll to “Open” to bring up a new image and navigate to the image being analyzed.

Step 11: Press the “MakeRandPts” button to generate the 51 points on the image.

Step 12: The cursor appears in the blank space for point number one, and will advance automatically as subsequent identifications are made.

Step 13: Fill in the PhotoGrid© table on the left side of the screen using the buttons corresponding to the substrate type at the bottom of the screen. The pixel used to make the identification is in the lower right-hand quadrant of the + (Figure S13.3).

Figure S13.3. Location of pixel used to make identification of substrate type.

Step 14: To magnify a part of the screen, point the cursor in the area and left-click (once) on the mouse. To reduce the image then right-click on the mouse.

Step 15: Clicking on multiple point numbers and then assigning the appropriate identification to them with the corresponding substrate type button allows for multiple entries (of points on same substrate type) to be made with a single keystroke.

Step 16. When you reach point number 51 on the left side of the screen then enter a "Y" if coral disease or bleaching is present anywhere in the frame or an "N" if the corals appear to be disease free and unbleached. Disease symptoms include lesions and rings or bands that demarcate live healthy tissue from dead tissue. Bleaching is often indicated by whitening of the skeleton which signifies a loss of the symbiotic zooxanthellae. This whitening can sometimes be confused with Crown-of-Thorns (COTS) Sea Star predation, which may show a somewhat similar pattern. At present, treat any whitening as bleaching. However, when observed at field sites, record the following metadata: whether or not there are multiple bleached colonies, estimated number, species affected, approximate maximum diameter of patch(es) of bleached corals, presence-absence or (preferably) estimated number of COTS, and location(s) within the site relative to the transect start point (compass bearing, approximate distance in meters). Examples of coral disease will be provided for each park when image analysis commences. Appearances of various coral pathogen types have only recently begun to be categorized in the Pacific Islands. This information will be disseminated to parks in the future when available.

Step 17: After completing the identification of all 51 points then bring up the next image by clicking on the “Next Pic” button in the lower left of the screen. The data for each frame is being saved automatically in a PGC file for the transect in the folder "C:\Program Files\PhotoGrid 1.0\PhotoGrid Data."

Identification Standards

Identify the substrate under the lower right hand quadrant of the crosshair ("+") using the following standards (Table S13.1). See Appendix S13.a for examples of different substrate types.

Table S13.1. Substrate identification standards.

Substrate Type	Instructions
Unnatural objects	For unnatural objects such as pin, tape, reel, you can use the N/C (non-coral) category.
Dark areas	For dark areas (e.g., shadows obscuring objects) in the image use the Subs (substrate) category
Unknown substrates	For unknown substrate use the Subs (substrate) category
Other organisms	For organisms (e.g., feather-duster worm) not listed on the skin template, use the "Other" category.
Snapping shrimp burrows	For snapping shrimp burrows in coral, use the Talg (Turf Algae) category since this category lines the burrow.
Recent broken areas	For areas of the reef that were recently broken, try to identify what it was prior to the damage. If this is not possible categorize as Unknown. In the next survey year, simply identify the new substrate (e.g., turf algae) based on whatever it now is.
Structures within algae or no structure	If structure within the algae is observable, select Malg (Macro algae) or lowest possible algal taxon). Typically this is evaluated as height (2-3 cm) above the substrate. Use the Talg (Turf Algae) category when the substrate has absolutely no observable structure or height, and it appears like a fuzzy growth.

Distinguishing between dead coral with turf algae and macroalgae in images captured from a still photograph may be difficult, but is worth taking the time to try to do accurately. The predominance of either category of substrate can be an important ecological indicator. Greater levels of macroalgae may reflect elevated nutrient levels, or lower levels of fish or urchin grazing (and possibly over-fishing). In comparison, increased dead coral with turf may indicate recent coral disease or high levels of grazing. Height (~ <2-3 cm) and the absence of an identifiable macroalgal species can be considered in identifying dead coral with turf. Macroalgae generally attain a height/thickness >2-3 cm and may be fleshy, filamentous, or calcified, often with conspicuous branching, blades.

When deciding whether the photopoint is on dead coral with turf algae or macroalgae, you will need to evaluate other areas in the image for comparison. As with the hard corals, and other sessile benthic invertebrates, algae should be identified to the most descriptive level possible, i.e., lowest taxon possible, ideally genus or species. If this is not possible, but the alga appear fleshy and to have a height >2-3 cm, it should be identified as "macroalgae." As the photograph provides only a two-dimensional view of the reef, the component's "height" can be difficult to ascertain. This is where brief field notes of quadrat macrobiota composition are very important. Looking around the image, at substrates similar to and different from the one in question, will usually aid interpretation of the substrate features (colors, shading, textures, etc.). Also referring back to any field notes will help resolve the image in a third dimension resulting in more accurate identifications. When in doubt, dead coral with turf algae may be the more conservative category to record.

Data Verification

Prior to sending the annual CSV files to the PACN database manager it is important to check substrate identifications for at least 10% of the images. The marine ecologist at each park is responsible for completing this task.

Step 1: After the marine benthic biotechnician has identified all of the images for a park then they randomly select 10% of the images (~75 images per year) for re-examination.

Step 2: Random selection can be done using the Excel® "RANDBETWEEN" function or simply picking points out of a hat. For example, in Excel® assign the 750 images (30 transects X 25 images each) to 750 cells. Then label them sequentially from 1 to 750 in another column. Keep in mind that the image name will contain both the transect and image number.

Step 3: Then in a third column highlight 75 cells and enter the formula =Randbetween(1,75). Select the images whose number is generated in the 75 cells and create a list sorted by transect and image number. If duplicate numbers exist then simply add several more cells until a total of 75 cells (different images) are selected.

Step 4: Next, the marine benthic biotechnician sends all of the PGC files (~30 file folders total) for each transect that year on CD to the appropriate park marine ecologist. These PGC files are located in the "C:\Program Files\PhotoGrid 1.0\PhotoGrid Data" folder. The CD must also include the list of 75 images from that park that need to be re-examined.

Step 5: The marine ecologist for each park subsequently copies the PGC files to the "C:\Program Files\PhotoGrid 1.0\PhotoGrid Data" folder on their PC.

Step 6: The marine ecologist conducting the re-examination verifies that the correct substrate identifications have been recorded on the screen.

Step 7: If corrections need to be made then the marine ecologist updates the Photogrid© screen and logs the transect and image number using the dataform in Appendix S13.b. Logging the information will allow measurement error to be estimated.

Step 8: Updating the screen identifications also updates the PGC files.

Step 9: If the substrate identification error (overall measurement error for the 75 images) is lower than 10% (~375 total points) then the updated PGC files can now be sent back to the benthic biotechnician for exporting.

Step 10: If the substrate identification error (measurement error) is higher than 10% then the errors need to be evaluated and corrected. For example, consistent misidentification of certain taxa would necessitate the biotechnician going back and updating all of the images with the correct information.

Step 11: Once the errors have been resolved at the biotechnician level then the PGC files can be resent to the marine ecologist for another re-examination.

Step 12: Substrate identification error must be lower than 10% to proceed to the next exporting step.

Export Data from PhotoGrid©

Step 1: After receiving the updated PGC files from the marine ecologist then the benthic biotechnician copies the files to “C:\Program Files\Photogrid 1.0\Photogrid Data” which will overwrite the older files.

Step 2: The benthic biotechnician can now begin exporting the substrate identifications within each image along each transect.

Step 3: Open Photogrid© and bring up the first image in the first transect for that year.

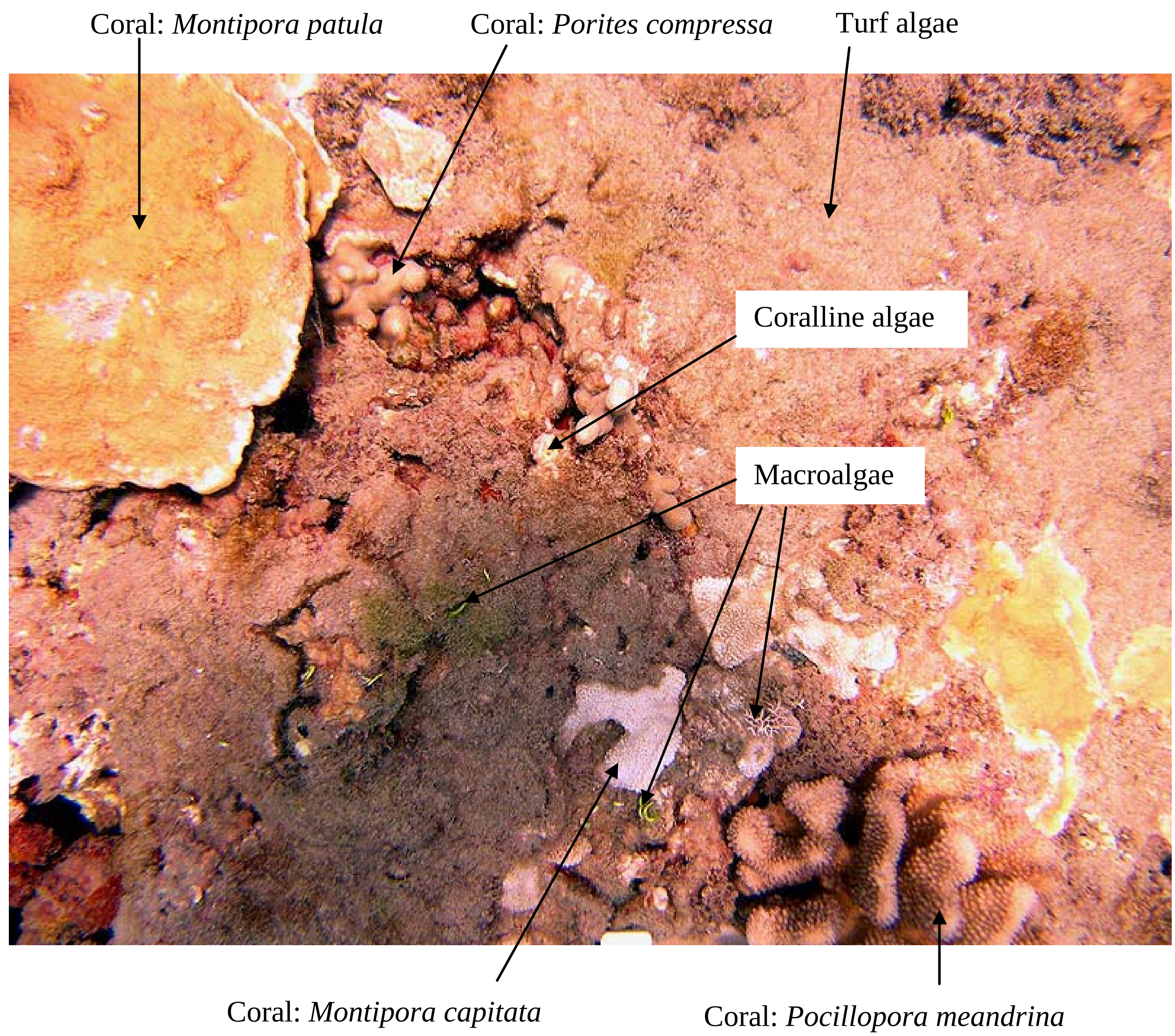
Step 4: Press the Export button in the lower left corner of the screen. This procedure appends the information to the CSV file for that folder. Note - you will not receive any message that the data has been exported. Clicking the button twice will export the data again, causing duplicate records. While this will be error checked when importing into the Access® database, take care here not to export the same data more than once.

Step 5: The CSV file is typically created in the “C:\Program Files\Photogrid 1.0\Photogrid Data” directory but alternative locations can be specified in the “Options – Preferences” menu.

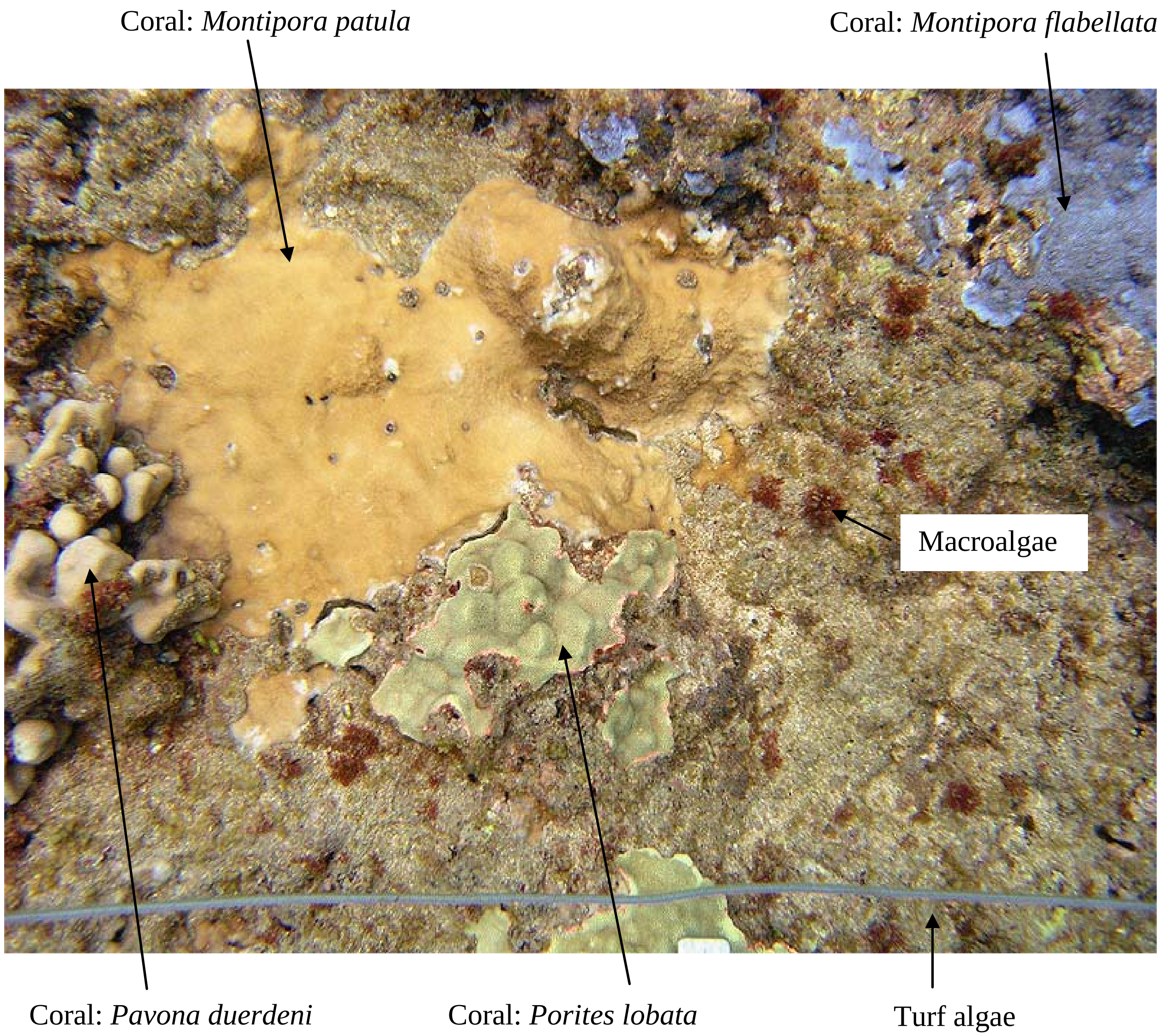
Step 6: The file naming convention for the Photogrid© format is: “c_TransectFolderName.CSV”. Data are now ready to import into the Marine Monitoring Database. Proceed to SOP # 12: “Data management”. The transect folder name typically contains the park code, transect number, and survey date.

Step 7: To close the Photogrid© program, select “File” and scroll down to “exit” on the file menu at the top of the window.

Appendix S13.a. Substrate examples



Examples of substrate types from digital still images from Hawaii.



Examples of substrate types from digital still images from Hawaii.

Appendix S13.b. Dataform for error checking of point identifications in photoquadrat images

Year:	________	Photogrid© IDer	________
Park:	________	Total Number of Images Checked:	________
Marine Ecologist:	________	Total Number of Points Checked:	________

Events	Transect	Image	Point #	Incorrect Substrate	Correct Substrate
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					
21					
22					
23					
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37					
38					
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40					

SOP #14: Data Management – Settlement Analysis

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See track changes	Response to reviewer's comments		1.00
2.10	8/03/2007	L. Basch	See track changes	Response to reviews, corrections, clarifications, additions		2.00

Purpose

This SOP details the processing of CSAs using bleach and the methodology for locating, identifying, counting and documenting coral settlers. This SOP also includes procedures for cleaning the tiles in preparation for the next deployment. Data handling and quality assurance/quality control for all monitoring protocols implemented by the PACN monitoring program are detailed in the program's Data Management Plan posted on drive I: at the HAVO data server. Microsoft Access® is the primary software environment for managing benthic data and the associated metadata. ESRI ArcMAP® 9 serves as a tool for validation of spatial data residing in Access®. The use of products identified in this protocol does not imply endorsement, effectiveness, or warranty by NPS

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Laboratory Analysis of Coral Settlement Plates

This SOP is to be followed once Coral Settlement Arrays (CSAs) have been collected from the field, properly stored, processed, and returned to the laboratory for analyses (see SOP #8 "Conducting Coral Settlement Sampling"). The time required to prepare the tiles for analysis takes approximately two days. The equipment needed for the preparation and analysis of the terracota settlement plates can be found in Appendix S12.a. The coral settlement data forms

(Appendix S6.a, SOP #6 "Selecting and Marking Subtidal Sampling Transect Locations") used during the collection of the CSAs should also be available for consultation.

Preparing Plates

The processing of the settlement plates is an important step and should be completed, with no delay, immediately as part of the daily post dive procedures. Do not allow the plates to sit longer than necessary, or overnight before processing. Handle the plates as little as possible and only by lifting up or lowering down while holding the edges. Excessive or improper handling can damage or destroy the coral juveniles. The equipment needed for the preparation of the plates can be found in Appendix S12.a.

Step 1: Prepare a 10% bleach solution by mixing 1 part of standard household bleach with nine parts of fresh water. Pour enough solution into plastic trays so the tiles will be completely immersed. Flat-bottom shallow trays with raised ridges on the bottom (such as photographic development trays) allow tiles to rest with minimal contact to their surfaces and expose tile bottom surfaces to bleach solution.

Step 2: Check each plate to make sure site code and other information is legible on plate edge. If necessary, re-write this information so that it is clear. Then, gently place the plates in trays filled with the bleach solution.

Step 3: Leave plates in the bleach solution for at least 24 hours. Remove from the bleach and rinse off in gently flowing fresh water to remove algae and sediment.

Step 4: Optional: Take macro photos of each plate after bleaching. See SOP #12 "Data Management – Photographs" for more information on photo storage.

Step 5: Allow the plates to air dry. Ensure that site code and other information is legible. If necessary retouch the site code with an ultra fine Sharpie marker.

Step 6: Wrap each tile in bubble wrap and store in box in a safe place until microscopic examination is possible.

Locating, Identifying, and Counting Coral Settlers

The following procedure outlines the routine used to find, identify, and count coral juveniles on the dried terra cotta plates. The amount of time needed to complete one plate varies, and could differ by season, soak duration, settlement intensity of sessile benthos, by transect site, park, and other variables. Pay particular attention to crevices/cracks and edges of tiles – Montiporid juveniles tend to occur in the crevices. The equipment needed for the microscopic analysis of the plates can be found in Appendix S12.a.

Step 1: Set up a dissecting microscope mounted on a stable "arm" stand according to its instructions. Set up in a comfortable location ensuring proper ergonomics. Make sure lighting is adequate. Fiber optic lights (2) that can be focused and positioned at various angles to the plate are needed. Two extra bulbs need to be kept available for these lights and reordered when one burns out.

Step 2: Always handling each plate carefully by the edges, unwrap from bubble wrap and place bubble wrap or other flat cushioned object (closed cell foam, a flat piece of neoprene, etc.) on microscope base. Always use a cushion of uniform thickness to avoid changes in magnification that would cause measurement error. Using the dissecting microscope at 6-10X magnification, systematically search the bottom then top plate surfaces, moving the plate edges with finger tips. "Raster scan" entire tile twice, once side-to-side and once top-to-bottom. Keep track of where you are on the tile using the thin permanent marker to make hash marks on the periphery.

Step 3: For each coral juvenile encountered, identify it to the lowest possible taxonomic level (typically genus) and record it in the appropriate location on the datasheet (Appendix S14b). Make sure that the appropriate site code, CSA number, plate number, and surface (upper top, upper bottom, lower top, lower bottom, and side; see Figure S8.1) has been noted for each observed juvenile. Record the approximate dimensions of each settler (in millimeters) using a calibrated ocular micrometer for particular magnification settings. An ocular micrometer and a stage micrometer (for calibrating) need to be installed and calibrated for each magnification used (which should be recorded with each measurement). A small table including magnifications, ocular micrometer units, and corresponding absolute units (e.g., micrometers µm) can be written on a piece of paper and taped to a nearby work surface for easy reference. If the microscope (e.g., Leica® MZ 12.5) has this feature, use the click stop setting on the magnification knob to ensure that discrete magnification settings are used. Continuous focus (non-click stop magnification knobs) can lead to magnification drift and error. If the microscope has the latter type of magnification knob, be careful to look at magnification knob and re-set it to the closest magnification mark before making each measurement. Coral juveniles of several taxa can be easily tallied using a multi-place lab bench counter available from scientific or laboratory equipment suppliers.

Step 4: To keep from recounting juveniles, (and to more easily relocate them as needed) circle each juvenile that has been tallied with a blue sharpie fine point pen. If notes on particular juveniles are desired and juveniles need to be relocated for any reason, note tile and surface (e.g., UT) and use a coordinate system to quickly relocate particular juveniles that have been circled. For example, on UT, the left, short side of the tile corresponds to the Y axis, and the bottom, long side, the X axis. A metric ruler held on these sides can be used to quickly record X and Y distances in cm or mm from the origin at the bottom left of the tile.

Step 5: Once all plate surfaces have been searched, re-wrap the plate in bubble wrap, and store as above until at least one year after all data have been verified, validated, and reported, at which time samples can be assessed, re-stored (only if needed), and disposed of.

Step 6: Review your work by quickly scanning plates, taking care to note site locations, CSA numbers, species identifications, size measurements, and plate surfaces for each coral juvenile.

Entering Data
For detailed procedures of data entry into the Benthic Marine Database, including quality control and verification, please see SOP #11 "Data Management."

Cleaning Plates

Once all plates have been searched, data has been entered and verified, plates should be cleaned and stored for re-deployment at a future date. The equipment needed for cleaning the plates can be found in Appendix S12.a.

Step 1: Completely submerge plates in household vinegar for at least 24 hours or until all CaCO3 material has dissolved from the plate surface. This can be confirmed through a thorough visual inspection of the plate surface using a microscope or a hand lens.

Step 2: Use a toothbrush or other soft plastic bristle brush to clean difficult spots. Rinse in freshwater. Dry for 24 hours in a clean place.

Step 3: Wrap each tile in bubble wrap and store until needed.

Create Photo-Guide of Coral Juveniles

Create a photographic reference guide of each park's coral juveniles. This guide should be assembled during the first year of monitoring and serve as a living document that is updated over time. The guide should include photographs of each coral juvenile taxon observed over the course of the year. In most cases, multiple individuals of each taxon should be photographed to record the range of natural variation in morphology, size, and development stage for each taxon. The photos should be assembled into a printable guide. Each photograph should be large enough to illustrate the juvenile and be accompanied by a caption detailing the taxon name, the time period the individual was collected, and an appropriate scale bar. Prior to including any photos in this guide, confirm the taxonomic identification by using the published scientific literature or a (preferably local) taxonomic specialist. Because coral juveniles can be easily confused with other benthic sessile marine organisms, it is helpful to include examples of locally common bryozoans and foraminifera. This guide is invaluable for training new observers and confirming identifications. Please see SOP # 2 "Training Observers" for an updated list of park taxonomic, including photographic, guides. Appendix S12.c shows an example of coral juveniles from Hawaii.

Data Verification

Prior to sending the working copy of the database to the PACN database manager it is important to check the plate surface locations, number of coral juveniles, juvenile measurements, and taxon identifications on at least 10% of the tile pairs. This effort equates to five tile pairs annually for each park. Typically the marine ecologist for each park conducts the initial examination of the tile pairs. Therefore, the marine ecologist is responsible for selecting another natural resources staff member to complete the re-examination of the tile pairs.

Step 1: After the marine ecologist has finished examining the 45 tile pairs for their park s/he randomly selects five tile pairs for re-examination by another natural resources staff member (usually a marine biotechnician).

Step 2: Random selection can be done using the Excel® "RANDBETWEEN" function or simply picking numbers out of a hat. For example, in Excel® assign the 45 tile pairs to 45 cells and label them sequentially from one to 45 in another column. Then in a third column highlight five cells and enter the formula =Randbetween(1,5). Select the tile pairs whose number is generated in the five cells.

Step 3: The person conducting the re-examination verifies that the correct number of juveniles have been recorded on the datasheet (Appendix S12.b) corresponding to the premarked tiles. In addition, taxon identification and sampling information written on tiles also needs to be validated.

Step 4: If the measurement error is less than 10% for both the incorrect number of settlers AND the number of misidentified settlers then proceed to step #7.

Step 5: If the measurement error is greater than 10%, either for the incorrect number of settlers OR the number of misidentified settlers, then the initial examiner must re-examine the remaining tile pairs.

Step 6: New sets of five tile pairs will be subsequently selected and re-examined by the natural resources staff member until the measurement error is less than 10%.

Step 7: All corrections should be completed on the working database copy for that park which will subsequently be sent to the PACN database manager by the park marine ecologist.

Appendix S14.a. Equipment needed to conduct laboratory analysis for CSAs

Master equipment list is located in SOP #1 “Before the Field Season.” If making any changes to this SOP, ensure that master equipment list is updated.

1) Equipment list for processing coral settlement arrays (CSAs). For more information, see SOP #14 “Data Management – Settlement Analysis.”

Equipment (#/quantity)	Preparation & Maintenance
10% bleach solution (3-4 gal/tray)	Solution can be re-used
Trays for bleach solution (1 per 8)	One tray per 8 tile pairs is needed (e.g., Rubbermaid® 30 qt, 28.3 L – dimensions 24” x 16” x 6”)
Bubble wrap (1 sheet per plate)	Used for plate storage

2) Equipment list for microscopic analysis of coral settlement arrays (CSAs). For more information, see SOP #14 “Data Management – Settlement Analysis.”

Equipment (#/quantity)	Preparation & Maintenance
Dissecting microscope (6-50x)	Ensure has swing arm stand and ocular micrometer
Light source (1) and extra bulbs (2)	Ensure equipment is ready and available
Magnification table for measurements	Ensure equipment is ready and available
Lens paper and optical cleaning fluid	Ensure equipment is ready and available
Taxonomic reference sheets	Ensure equipment is ready and available
Bench counter	Ensure equipment is ready and available
Foam pad/bubble wrap (2-3)	Used for resting tile on
Blue or black fine tip permanent marker (2)	Ensure equipment is ready and available
Probe for cleaning debris on tile (2)	Ensure equipment is ready and available

3) Equipment list for cleaning coral settlement plates. For more information, see SOP #14 “Data Management – Settlement Analysis.”

Equipment (#/quantity)	Preparation & Maintenance
Household vinegar (3-4 gal/tray)	Ensure equipment is ready and available
Trays for vinegar (1 per 8 tile pairs)	Ensure equipment is ready and available
Bubble wrap (1 sheet per plate)	Used for plate storage; ensure equipment is ready and available
Toothbrush (1)	Ensure equipment is ready and available
Microscope or hand lens (1)	Ensure equipment is ready and available

Appendix S14.b. Dataform used to record settlement data from terra cotta tiles.

Codes for the plate surfaces are as follows: UT = Upper Top, UB = Upper Bottom, LT = Lower Top, LB = Lower Bottom, E – Edge. Enter Notes on reverse side if necessary.

Settlement Data Entry ***Recorder:*** ***Year:***

Park Code	Transect	Depth (m)	CSA #	Plate #	Plate Surface (UT,UB,LT,LB,E)	Genus	Length x Width (mm)	Deployed (ddmmyy)	Retrieved (ddmmyy)

Appendix S14.c. Examples of photographs for inclusion in the settlement photo-guide

Photos should include pictures of common local coral juveniles as well as photographs of benthic sessile non-coral organisms that commonly occur on settlement tiles. The identities of all photographs should be confirmed either by comparison with scientific literature or by a subject area specialist.

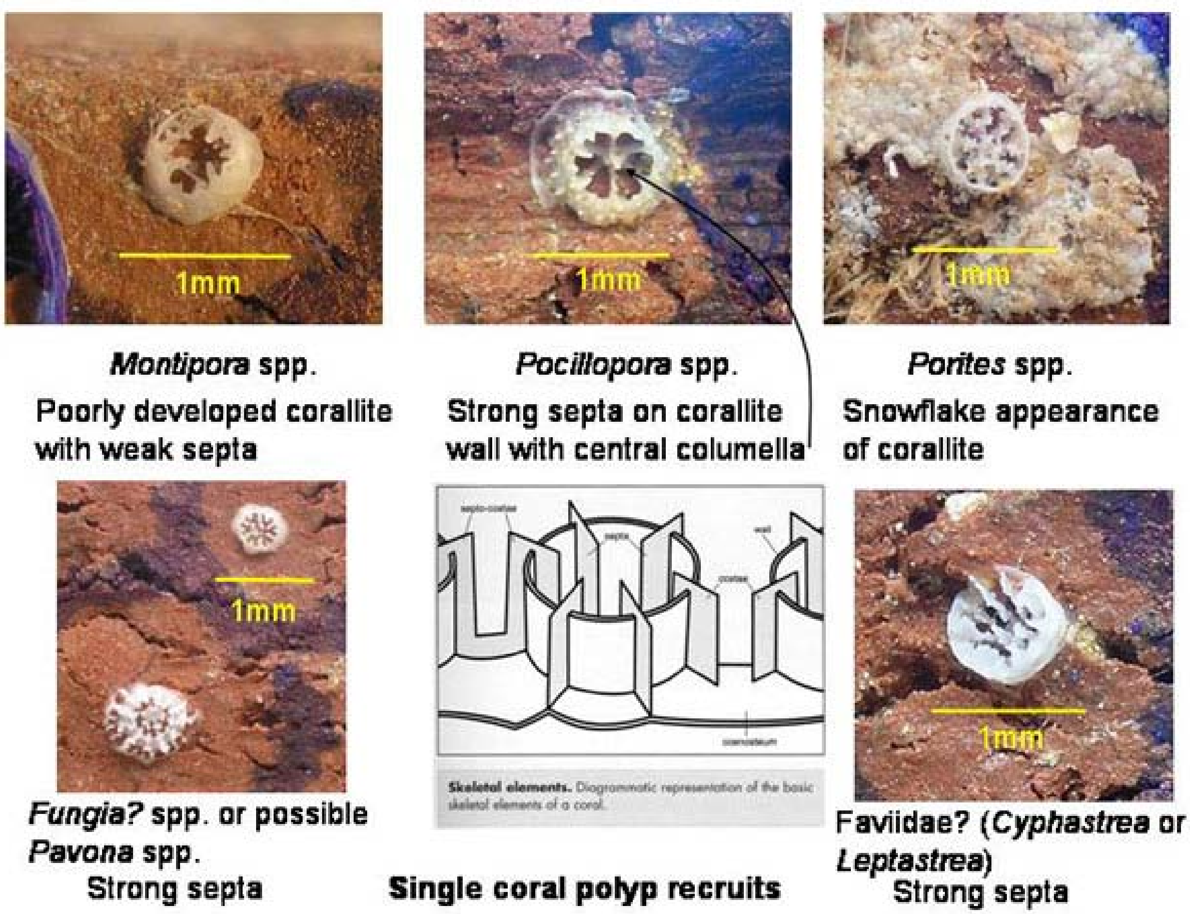


Figure S14.1. Common coral juveniles observed on terra cotta plates in Hawaii. Photos by E.Brown, NPS.

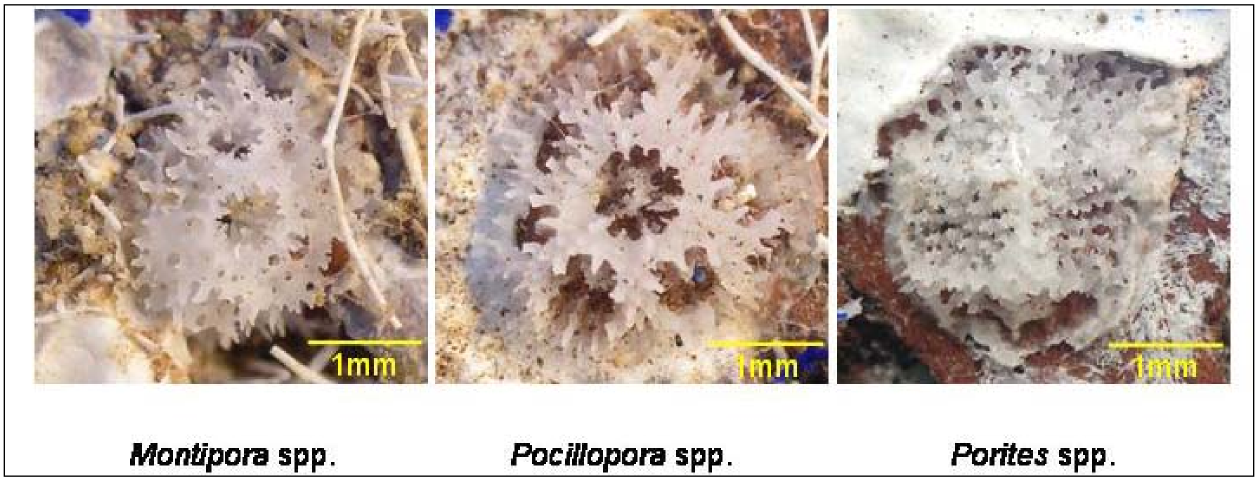


Figure S14.2. Common juvenile coral colonies observed on terra cotta plates in Hawaii. Photos by E.Brown, NPS.

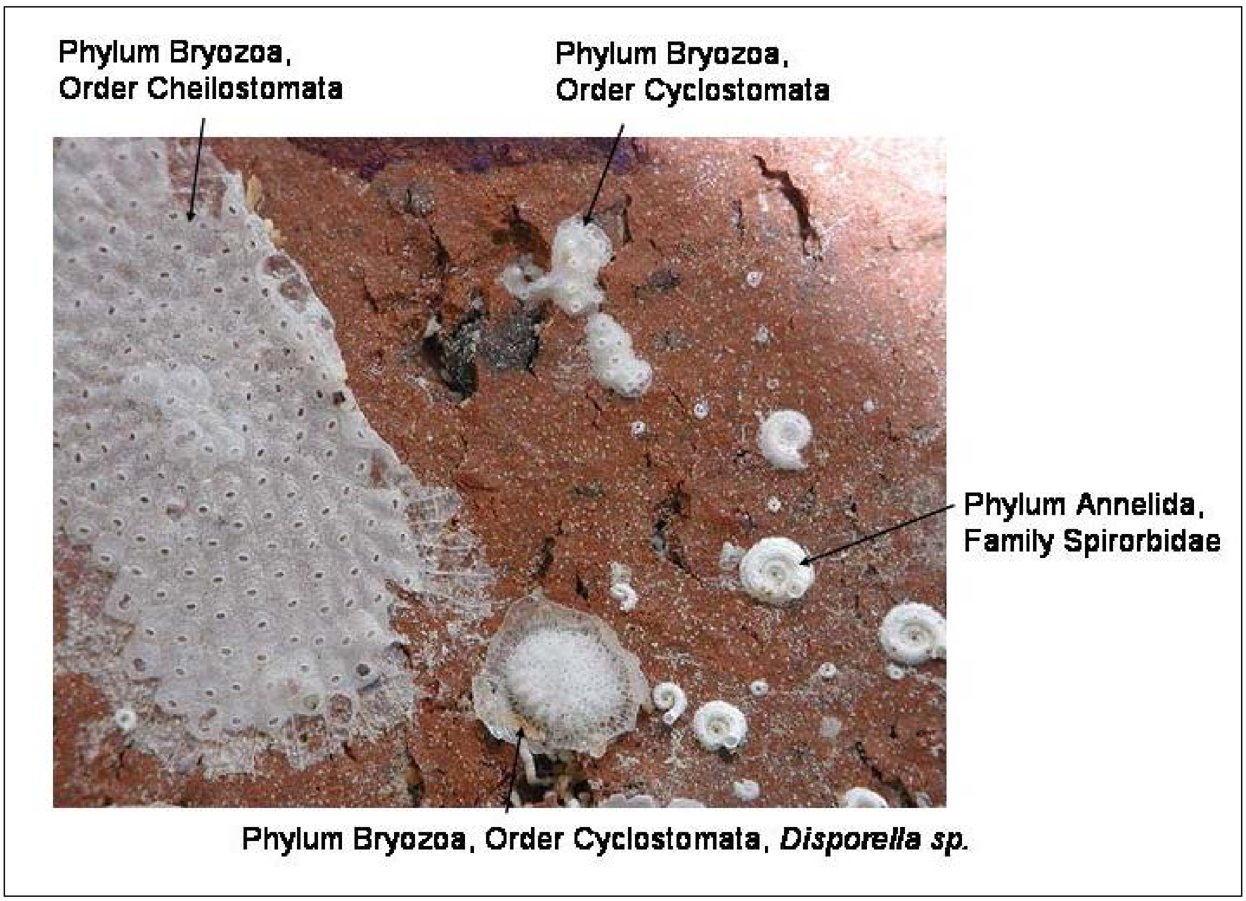


Figure S14.3. Common benthic sessile non-coral organisms present on terra cotta plates after six months of deployment in Hawaii. Photo by E. Brown, NPS.

SOP #15: Data Analysis and Reporting

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	8/04/2007	L. Basch	See Track Changes	Clarifications, corrections		2.00

Purpose

This SOP addresses data analysis and reporting for the benthic marine community Vital Sign in the Pacific Island Network. Data analyses for (1) benthic community cover, (2) coral settlement, (3) coral growth, (4) rugosity, and (5) disease/bleaching are outlined with examples to show data structure, statistical tests, and graphical plots. Integrated reporting of these five components is also outlined. This protocol outlines two initial steps of data analysis at each of the unit, landscape, and trend-assessment levels. These steps summarize and determine the range-of-variation for some parameters (based on present knowledge). Report types are identified according to the categories in the PACN monitoring plan, with most reporting occurring on an annual basis. Additional, multi-vital sign integration, synthesis, analysis, and reporting is not addressed in this SOP at present. The use of products identified in this protocol does not imply endorsement, effectiveness, or warranty by NPS.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Analysis Overview

Data analysis is defined here as the steps by which observations of the environment are processed for interpretion and synthesis into meaningful information that is accessible to managers. Data analysis also includes quality assurance and control efforts that occur in the field, during exploratory analysis, in summarization, during interpretation, and when drawing conclusions.

Analytical Strategies

Two basic initial steps are identified in data analysis for all Benthic Marine Community monitoring data: summarization, and establishing the range of variation. These steps are encompassed in the larger construct of data management and data stewardship which is discussed in the Data Management SOP (#11). Data analysis for (1) benthic community cover, (2) coral settlement, and (3) coral growth incorporate these two initial steps at each of the unit, landscape, trend-assessment, and synthesis levels.

Step one: Summarization

This step includes identification and documentation of outliers, missing data, quality control and quality assurance issues, mean or median values, variance estimates, and other descriptive statistics. Data visualization (see Cleveland 1993, 1994, Tufte 1983, 1990, 1997) and exploratory data analyses are an integral component of this process.

Step two: Range of Variation

This step includes establishing expected boundaries for response variables, typically as quantiles, and identifying data that falls outside these expected bounds. Establishing a range of normal variation may take years or decades for many parameters, but providing managers and decision-makers with the best available information will strengthen adaptive management feedback.

Analytical Approach

We identify four basic levels of analytical methods for our monitoring data: unit level, landscape level, trend assessment level, and synthesis (Table S15.1). The unit level, the most basic element, addresses sample design questions regarding use of finite or infinite populations, and the establishment of relative, absolute, or index response variables. The landscape level identifies the spatial nature of sampling and the temporal allocation of samples, such as the revisit scheme in use. The trend assessment level integrates unit or landscape level data over time, where typically some form of regression or repeated measures ANOVA is used to identify the slope or trend over time. Finally, synthesis examines patterns within and across Vital Signs, and with ecological factors, to gain broad insight on ecological processes and integrity. Unit level, landscape level, and trend assessment level are addressed here. Synthesis will be addressed within and across multiple Vital Signs and is therefore left for network level or broader scientific consideration in the future.

Table S15.1. Three approaches at the park level for analyzing Benthic Marine Community Vital Sign monitoring data

Level of Analysis	Description	Responsible Party
Unit Level	Quality assurance and control routines and calculation of individual, site specific statistics from monitoring data	Marine Biological Technician with oversight by PI and with assistance from Park Leads
	Step 1 (Summarization): Measures of mean, median, variation, and other basic statistics. Include graphical presentation of data.	
	Step 2 (Range of Variation): Establish historical or expected range of values, relation to relevant regulatory levels, confidence estimates.	
	Indices or other site-specific metrics may also be developed.	
Landscape Level	Integration of unit level data across appropriate landscapes to address ecological status.	Marine Biological Technician with oversight by PI and with assistance from Park Leads
	Step 1: Integration of unit level summarization results across multiple locations and sites.	
	Step 2: Integration of unit level variation results across multiple locations and sites. Additional refinement of spatial pattern analyses.	
	Sample design, assumptions about the target population, actual data relationships, and evolving status determination methods will guide selection of appropriate methods.	
Trend Assessment Level	Evaluation of Vital Sign trends over time to detect change. Typically some form of regression will be among the methods used.	PI and Marine Biological Technician, with assistance and oversight by PACN Aquatic Ecologist
	Step 1: Integration of landscape level summarization over time.	
	Step 2: Integration of landscape level variation results over time. Includes establishing a direction and rate of change or variation that may be used to provide early warnings of trends in resources condition. Confidence levels of documenting trend will be established.	
	Parametric, nonparametric (design-based) approaches, and models will be used. Trend assessment will also include accounting for influence from drivers and stressors as much as possible.	

The analyses outlined below will be applied to each of the three primary components of this Vital Sign: 1) benthic community cover, 2) coral settlement, and 3) coral growth, if monitored. These analyses should be completed within three months of completing the benthic cover photo-analyses for a given park. Analysis techniques for images (benthic cover), coral settlement, and growth measurement are identified in SOP #11 “Data Management,” and the analytical methods outlined here build upon these initial analyses.

Analysis Procedures

Analysis procedures are to be documented, for each park on an annual basis, in a compiled document (such as an MS Word® file), referred to hereafter as an analysis log file. This file would essentially be a ‘log’ of all the quantitative and qualitative steps taken, such as various transformations tested, and screen shots of data visualizations. A check list for the steps is provided in Appendix S15.a. Each year, four such files (one for each park that is slated for initial implementation of the benthic monitoring protocol) will be generated. These analysis log files are internal working documents, that while not subject to explicit peer-review for most reporting other than protocol and programmatic reviews, will serve as the documentation and foundation for analyses for reports which are peer-reviewed. Table S15.2 summarizes these analytical procedures for the parameters measured at the park level.

Table S15.2. Summary of analytical procedures including parameters measured at the park level.

Level of Analysis	Data Analysis Approach	Frequency of Analysis	Responsible Party
Unit	summarization and range-of-variation for annual benthic % cover by transect, rugosity ratios, settlement rate by site, and growth rates by site	Annually, within three months of field data collection for each of the three levels	Principal Investigator or designee
Landscape	annual status of benthic % cover, rugosity ratios, settlement rates, and growth rates for area of interest (e.g., entire park like KAHO, individual islands in NPSA or individual units in WAPA)	Annually, within three months of field data collection for each of the three levels	Principal Investigator or designee
Trend Assessment	multi-year change in benthic % cover, rugosity ratios, settlement rates, and growth rates for both unit level data (transects/sites) and landscape level areas of interest	Annually, within three months of field data collection for each of the three levels	Principal Investigator or designee

Benthic Community Cover: The benthic community cover section of the log file will reflect the following organization. Parameters or response variables of interest for the three levels are; coral species list, percent cover by coral, other sessile benthic species, and percent cover by substrate types (e.g., coral, macroalgae, coralline algae, turf algae, other).

Unit Level Analysis: This level is applied for all parameters in the current-year only. Text and Graphic Plots by individual transect of mean (or median), standard deviation (or skew and kurtosis), outliers, normal probability plot, and frequency histogram of the distribution. If multiple observers have been collecting data, the summaries should be grouped by observer to evaluate potential observer bias.

Landscape Level Analysis: This level is applied to each parameter of interest in the current-year only. Text and graphic plots grouped by area(s) of interest (e.g., multiple transects on individual islands in NPSA or individual park units in WAPA) of mean (or median), standard deviation (or skew and kurtosis), outliers, normal probability plot, and frequency histogram of the distribution. Graphical map of park that displays values for percent coral and algal cover.

Trend Assessment Level Analyses: This level is applied to the current year, previous year, five year, and ten year, and other to-be-determined integration intervals for each parameter of interest. Text and graphic plots grouped by specific transects of mean (or median), standard deviation (or skew and kurtosis). Change detection will include repeated measures ANOVA, regression, time-series evaluation (requires 50 or more data points [i.e., years]), or other appropriate technique. Text and graphic plots grouped by area(s) of interest (e.g., entire park such as KAHO, individual islands in NPSA or individual park units in WAPA) of: mean (or median), standard deviation (or skew and kurtosis) of benthic percent cover. Change detection will include repeated measures ANOVA, regression, evaluation of time-series (with 50 or more years of data), or other appropriate technique(s). It includes a graphical map by park that displays changes in percent coral and algal cover.

Coral Settlement: The coral settlement section of the log file will follow the same procedures as for benthic community cover except that the response variables of interest for the three levels are: taxon list and settlement rate (No. m^{-2} $year^{-1}$).

Coral Growth (Optional): The coral growth section of the log file will follow the same procedures as for benthic community cover except that the response variable of interest for the three levels is growth rate (mm^2 day^{-1}) by taxon.

Integrated Data Analysis: To be determined based on the first few years of monitoring data.

Example Procedure for Benthic Coral Cover Data Analysis

It should be noted that the following analytical procedures should only be conducted by an individual with advanced statistical training. In addition, many of the procedures described below may change over time due to advancements and updates in statistical tests, perspectives, techniques and software. Consequently, this example merely serves to illustrate the desirable sequence of steps necessary to examine and present the data.

Example #1: Unit analysis of coral cover at transect level.
Step 1: Copy annual data for a park from an Access® query into a statistical software package. The program Statistica® 7.0 will be used to illustrate this procedure. Keep in mind that data copied from Access® is treated as text and must usually be converted into value format prior to pasting the data into a statistical program. Programs like Excel® can do the value conversion. Therefore, paste the data into Excel® first and save the spreadsheet.

Step 2: Then copy the block of data from Excel®.

Step 3: In this example, the 2007 annual data for KALA is pasted into the KALABenthicCover file which already contains data from the prior year (Figure S15.1).

Data: KALABenthicCover.sta* (10v by 15c)

	1 Transect	2 Coral2006	3 MacroAlgae2006	4 Coral2007	5 MacroAlgae2007	6 Var6	7 Var7	8 Var8	9 Var9	10 Var10
1	1	10.70	14.82	11.43	12.82					
2	2	6.75	27.89	7.24	26.68					
3	3	7.29	14.56	6.27	14.04					
4	4	2.94	17.00	3.37	17.41					
5	5	6.67	7.53	7.93	6.94					
6	6	6.82	6.67	5.43	8.00					
7	7	6.78	24.82	7.27	26.48					
8	8	4.00	26.75	2.99	26.65					
9	9	10.00	28.11	10.59	30.06					
10	10	6.70	16.94	7.74	17.91					
11	11	8.20	21.98	6.21	23.46					
12	12	11.30	22.61	11.25	24.09					
13	13	7.90	16.48	8.78	15.94					
14	14	5.40	23.88	4.53	22.96					
15	15	8.30	24.51	6.31	22.75					

Figure S15.1. Benthic cover data structure in Statistica® 7.0. Variables are percent total coral and macroalgae cover on a transect.

Step 4: Examine outliers by generating a scatterplot of the current year coral cover data against the prior year coral cover data (Figure S15.2). Select Graphs – Scatterplot from the menu. the first year because there will be no prior year data.

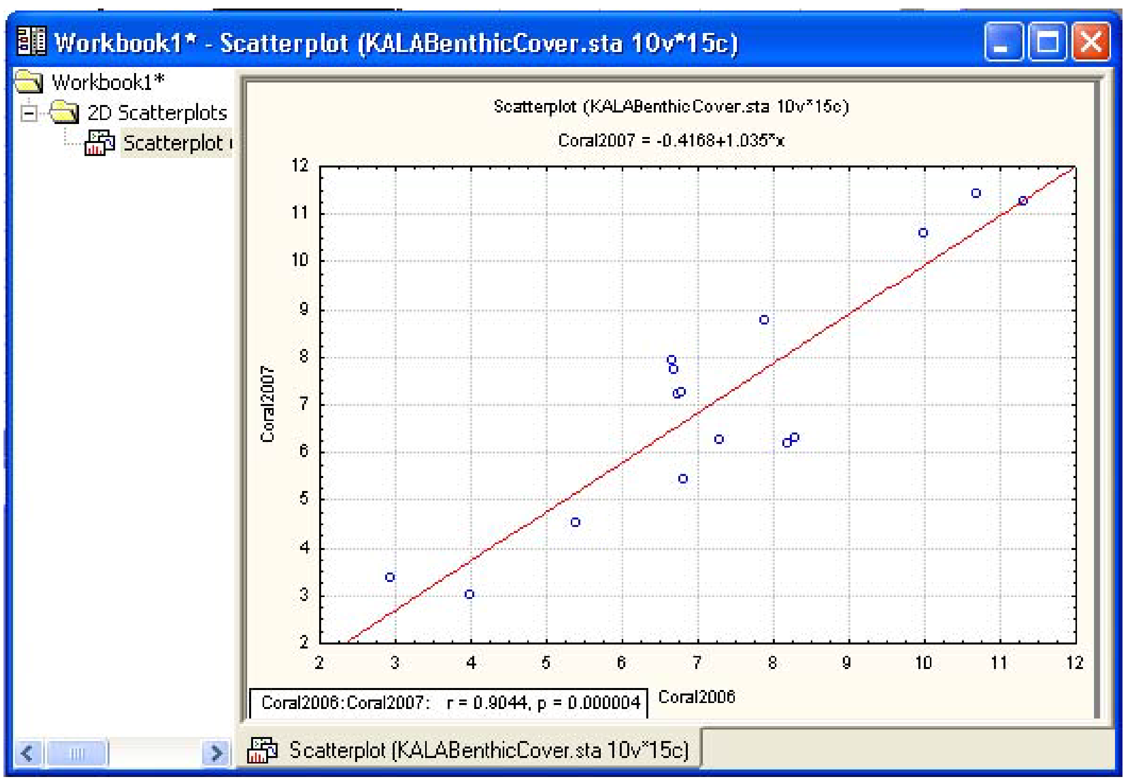


Figure S15.2. Scatterplot of coral cover in 2007 against coral cover in 2006.

Step 5: In the Scatterplot menu click on the tab bar and click on the "Corr. and p. (linear fit)" box.

Step 6: If the correlation between the two years is less than 0.5 then examine the plot for transects that are far away from the line.

Step 7: You may need to return to the original transect data and images to determine if the coral cover value is correct and whether to include it in the data set. In this example, r = 0.90 so it appears that the coral cover data is reasonable.

Step 8: Repeat this procedure with the macroalgal cover data.

Step 9: Next, check the normality of the data by plotting the normal probability plot for both coral cover and macroalgae cover. Click on the Statistics – Basic Statistics/Tables – Descriptive Statistics – Prob. & Scatterplots tab.

Step 10: Then press the Normal Probability plot and both graphs will be generated (Figure S15.3).

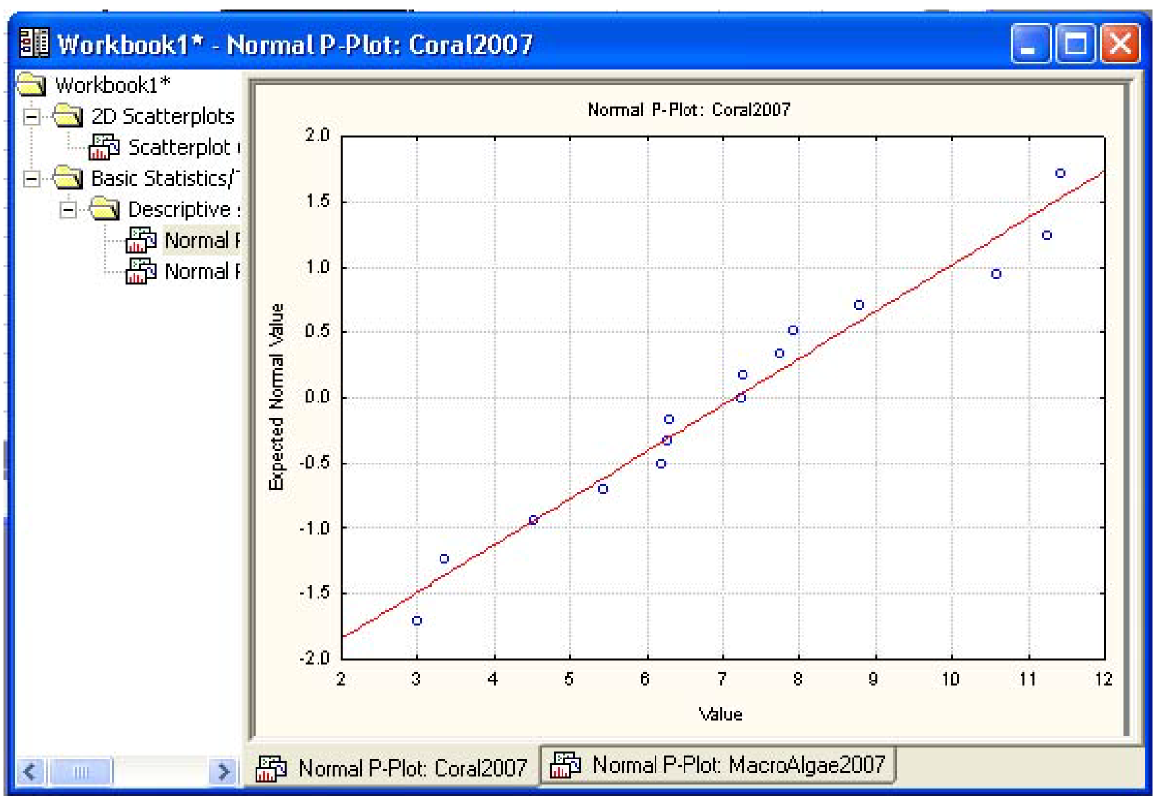


Figure S15.3. Normal probability plot of coral cover for the current year (e.g., 2007).

Step 11: Ideally, the scatterplots should show the points linearly distributed and not arranged in a sigmoid or curved pattern.

Step 12: Another test for normality is to plot the frequency histogram under Statistics – Basic Statistics/Tables – Descriptive Statistics – Normality tab (Figure S15.4). Make sure to check the "Kolmogorov-Smirnov & Lilliefors test for normality" box.

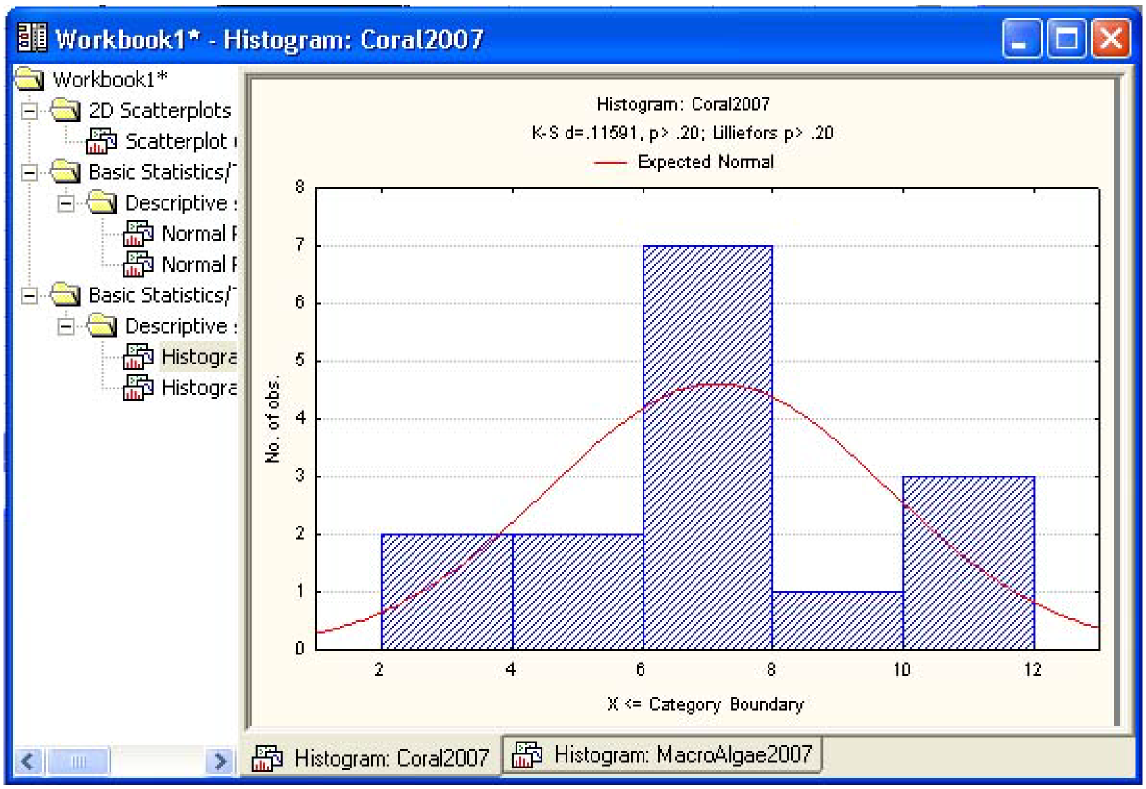


Figure S15.4. Frequency histogram of coral cover showing the Kolmogorov-Smirnov (K-S) & Lilliefors test for normality.

Step 13: The plots should look normally distributed with p values >0.05. It should be mentioned that the repeated measures ANOVA is fairly robust to departures from normality, especially with a large sample size. Consequently, don't worry too much if the plots are slightly skewed.

Step 14: Generating the table of mean and standard deviation of percent total coral cover and other major cover categories by transect is done from a query within the Access® database (See SOP #11 "Data Management"). This is useful to examine the variability of coral cover in the frames along the transect and ultimately determine if fewer frames are needed in subsequent analyses.

Example #2: Landscape analysis of benthic cover at park level
Step 1: Generating a table of current year mean and standard deviation of percent cover by substrate type/taxa is done in Statistica® 7.0 using the data set above.

Step 2: Select Statistics – Basics Statistics/Tables – Descriptive Statistics– Advanced tab. Make sure to check the Mean and Standard Deviation boxes.

Step 3: The bubble plots of coral cover at a park are created in ArcMap® which overlays proportional bubbles, representing percent cover by transect, on a georectified aerial image (Figure S15.5).

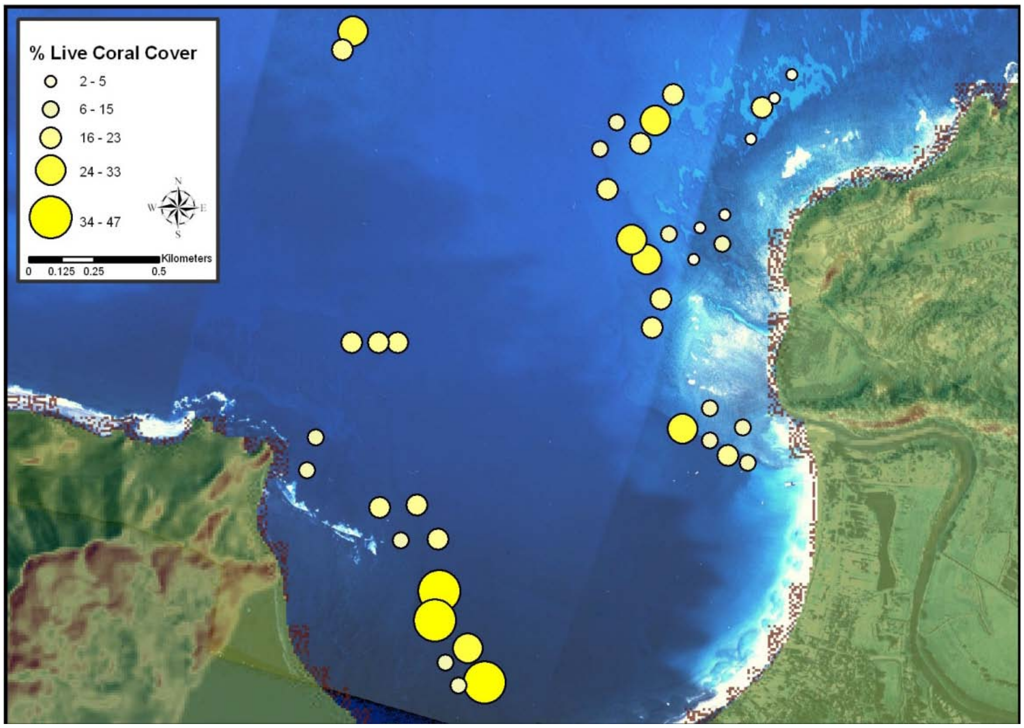


Figure S15.5. Example of proportional bubbles, representing percent coral cover on each transect, overlaid on a georectified aerial image. Classification based on quantiles.

Step 4: The benthic cover data by substrate type (e.g., coral, macroalgae) must first be copied from Statistica® to the attribute table in ArcMap® that has the transect locations. You can either edit the table and input the cover values into new fields or import a new table with the transect locations and cover values for each transect.

Step 5: Then create the graph in ArcMap® under Tools – Graphs – Create – Bubble. Follow the prompts on the screen to select the appropriate fields for "Bubble Size Field" (e.g., coral cover), "X axis field" (e.g., X or Longitude), and "Y axis field" (e.g., Y or Latitude).

Step 6: Press the "Next" button until you finish creating the graph with the selected options (e.g., show legend).

Step 7: The same procedure is used to create the ArcMap® bubble plot of percent algal cover (and any other major cover categories) within the park, except for the "Bubble Size Field" use the macroalgal cover field instead of coral cover.

Example #3: Trend analysis of percent benthic cover for fixed transect data.

Step 1: For all years after the first sampling year, it is possible to adjust the previous year's mean and standard deviation using the current year's data. To generate a table of adjusted mean and standard deviation of percent total coral cover at the level of park for the previous year it is necessary to refer back to Figure S15.2 (from Statistica® 7.0).

Step 2: The regression equation shown at the top of the chart is used to calculate a second estimated mean for year 1. For example, from Figure S15.2, input the year 2 mean into the equation along with the slope (1.035) and intercept (-0.4168) values and solve for Coral2007.

Step 3: The adjusted mean for year 1 is a weighted average (equation 29 in Skalski 2005) of the original year 1 estimate of coral cover and the second year 1 estimate of coral cover along with the associated variance values.

Step 4: These values are then used to correct the subsequent analyses and plots by using an Excel® spreadsheet "FixedSitePriorYearCorrection.xls" to calculate the prior year adjusted means and variance.

Step 5: Repeat this procedure with the current year macroalgae (and any other major category of) cover plotted against the prior year macroalgae cover.

Step 6: To plot the mean and standard deviation of coral and macroalgal cover it is easiest to conduct the repeated measures ANOVA in Statistica® 7.0 on the raw data and display the resulting graphs.

Step 7: First, select Statistics – Advanced Linear/Nonlinear Models – General Linear Models – Repeated Measures ANOVA.

Step 8: Under "Variables" select all of the annual coral and macroalgae cover variables for the "Dependent variable list:"

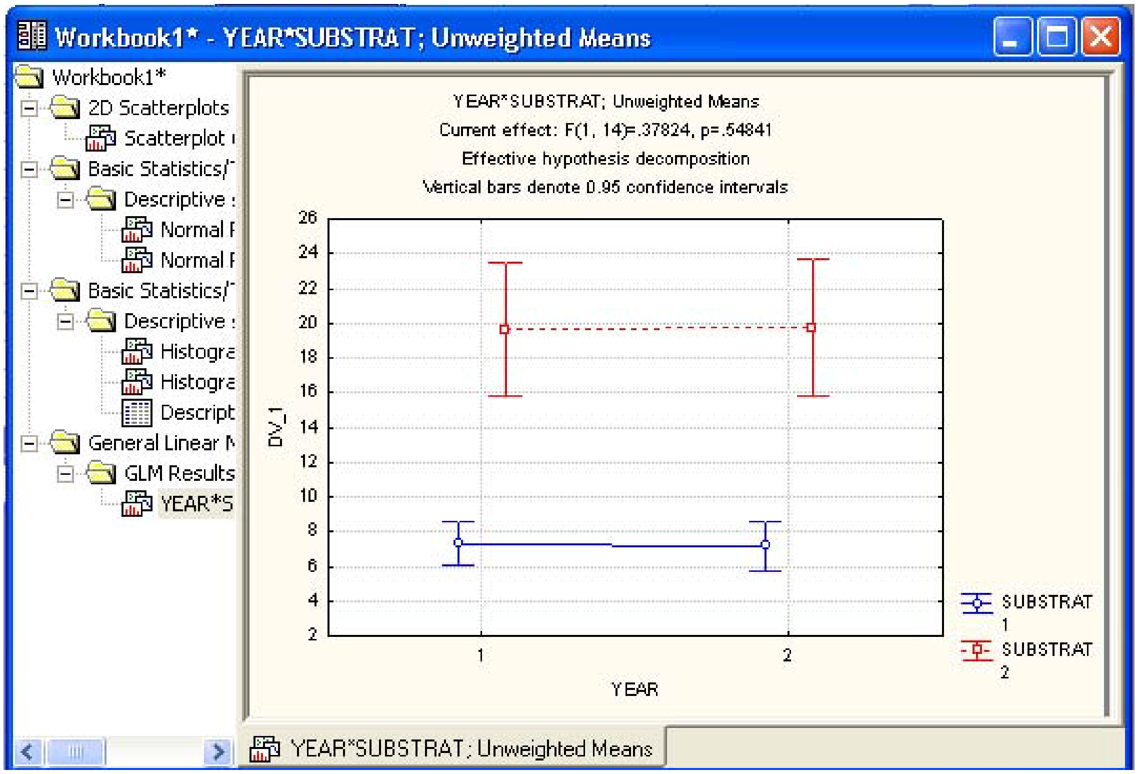
Step 9: Do not select any "Categorical predictors (factors):" and then press OK.

Step 10: Under "Within effects:", specify the number of years (current example =2) for levels and Year for Factor Name: in the first line. On the second line specify 2 for levels and Substrate for Factor Name.

Step 11: After pressing OK then press the All effects/Graph button.

Step 12: The resulting graph (Figure S15.6a) can be modified within Statistica® (Figure S15.6b) for reporting purposes. The chart modifications are beyond the scope of this protocol, but almost any statistical software package has the capability to edit charts for professional presentations.

(a)



(b)

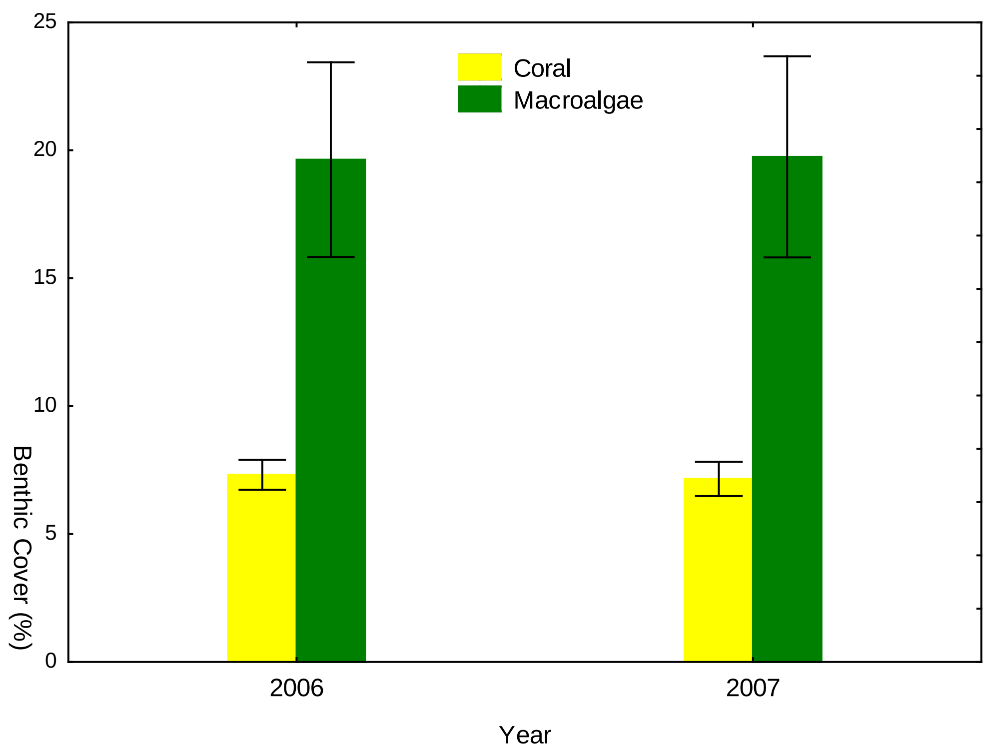


Figure S15.6. Examples of unmodified (a) and modified (b) charts depicting trends in average coral and macroalgae cover across time. Error bars are Mean +/- 1 Standard Deviation.

Step 13: A repeated measures ANOVA is then conducted on the arcsin-square root transformed data to determine if the temporal trends observed in Figure S15.6 are statistically significant.

Step 14: The transformation process is required for percent data to meet the assumptions of the statistical test (See Zar 1999).

Step 15: There are several ways to transform the data. One is to perform the function in Excel® and import the results below the existing raw data in the same worksheet. The transformed data can then be selected when conducting the statistical test.

Step 16: Another approach is to transform the data within Statistica® by creating new variables with functions that do the calculation. Either way will yield the same results.

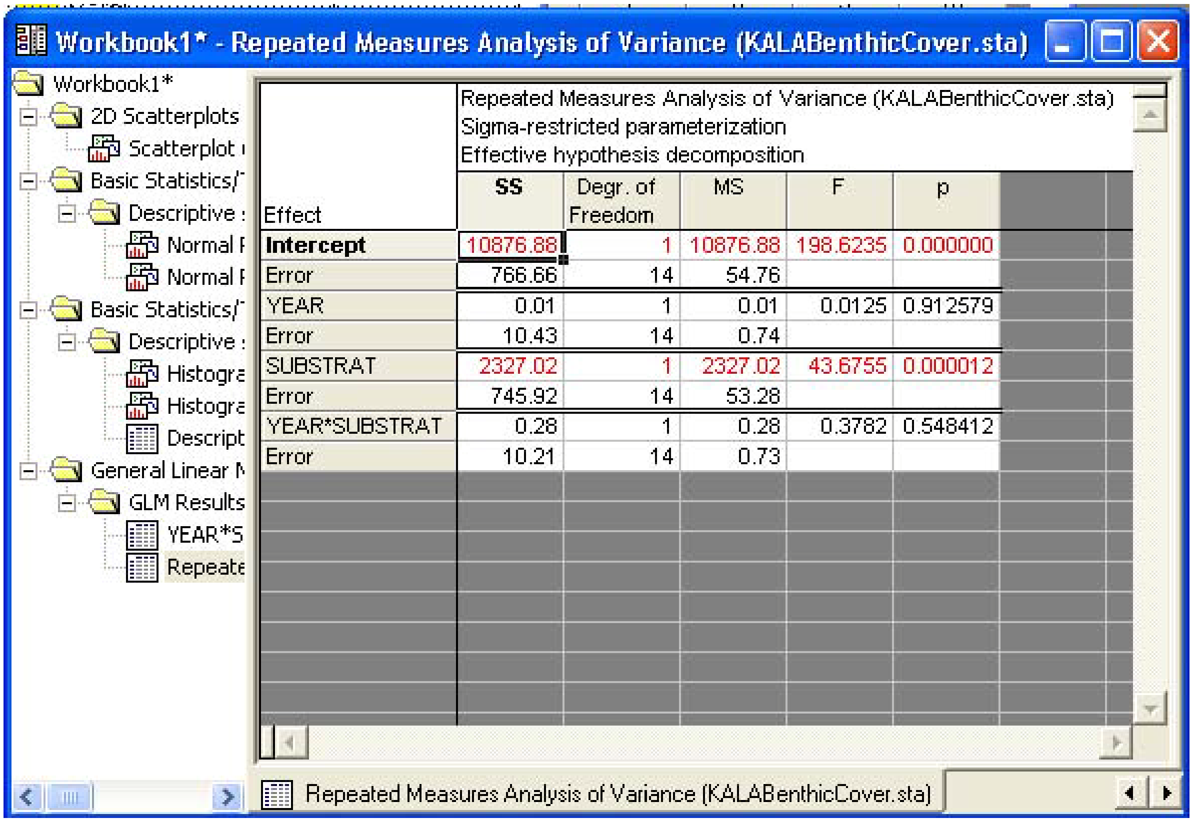
Step 17: Using the transformed data then select Statistics – Advanced Linear/Nonlinear Models – General Linear Models – Repeated Measures ANOVA.

Step 18: Under "Variables" select all of the annual coral and macroalgae (and any other major category of) cover variables for the "Dependent variable list:"

Step 19: Do not select any "Categorical predictors (factors):" and then press OK.

Step 20: Under "Within effects:" specify the number of years (Current example =2) for levels and Year for Factor Name: in the first line. On the second line specify 2 for levels and Substrate for Factor Name.

Step 21: Press the All effects button to see the ANOVA table (Figure S15.7). If any of the factors/effects are significant at the α=0.05 level then additional post-hoc tests can be performed to determine which level of the factor/effect is accounting for the significance.



Effect	SS	Degr. of Freedom	MS	F	p
Intercept	10876.88	1	10876.88	198.6235	0.000000
Error	766.66	14	54.76		
YEAR	0.01	1	0.01	0.0125	0.912579
Error	10.43	14	0.74		
SUBSTRAT	2327.02	1	2327.02	43.6755	0.000012
Error	745.92	14	53.28		
YEAR*SUBSTRAT	0.28	1	0.28	0.3782	0.548412
Error	10.21	14	0.73		

Figure S15.7. Results table for Repeated Measures ANOVA. Effects in red (e.g., SUBSTRAT) are significant at the α=0.05 level.

Step 22: This is done by pressing the "More results" button and then selecting the "Post-hoc" tab.

Step 23: Select the Effect of interest and use either the Tukey HSD or the Unequal N HSD for unequal sample sizes. Both are preferred over the other options because they are conservative and widely utilized.

Step 24: When reporting the results from the statistical tests using the transformed data it is important to back transform the data for presentation. For example, if the percent cover data were arcsine square root transformed for statistical analysis then the back-transformation would square the sine of the number for presentation.

Step 25: The ArcMap® bubble plots of trends in coral or other major benthic cover types at a park are created using the procedures outlined above. This chart overlays proportional bubbles, representing relative change in percent cover, on a georectified aerial image (Figure S15.8).

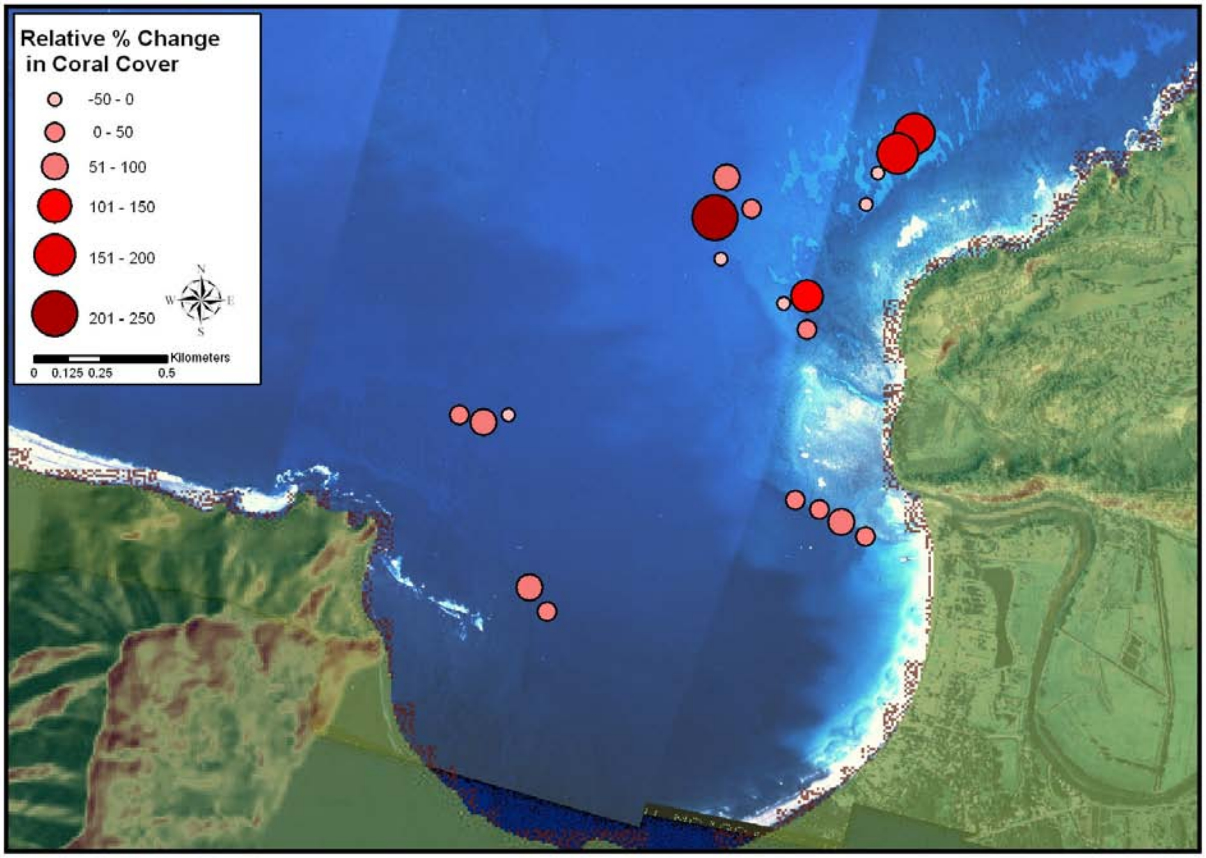


Figure S15.8. Example of proportional bubbles representing relative percent increase or decrease in coral cover on each transect.

Step 26: The same procedure is used to create the ArcMap® bubble plot of trends in percent algal or other major benthic cover types within the park except for the "Bubble Size Field" use the macroalgal cover field instead of coral cover.

The preceding section on data analysis follows a univariate approach, but this does not preclude the descriptive techniques of multivariate analysis such as multidimensional scaling (e.g., Clarke and Warwick 2001). For example, Brown (2004) used a multidimensional scaling plot to display trend analysis in benthic communities using similar data (Figure S15.9).

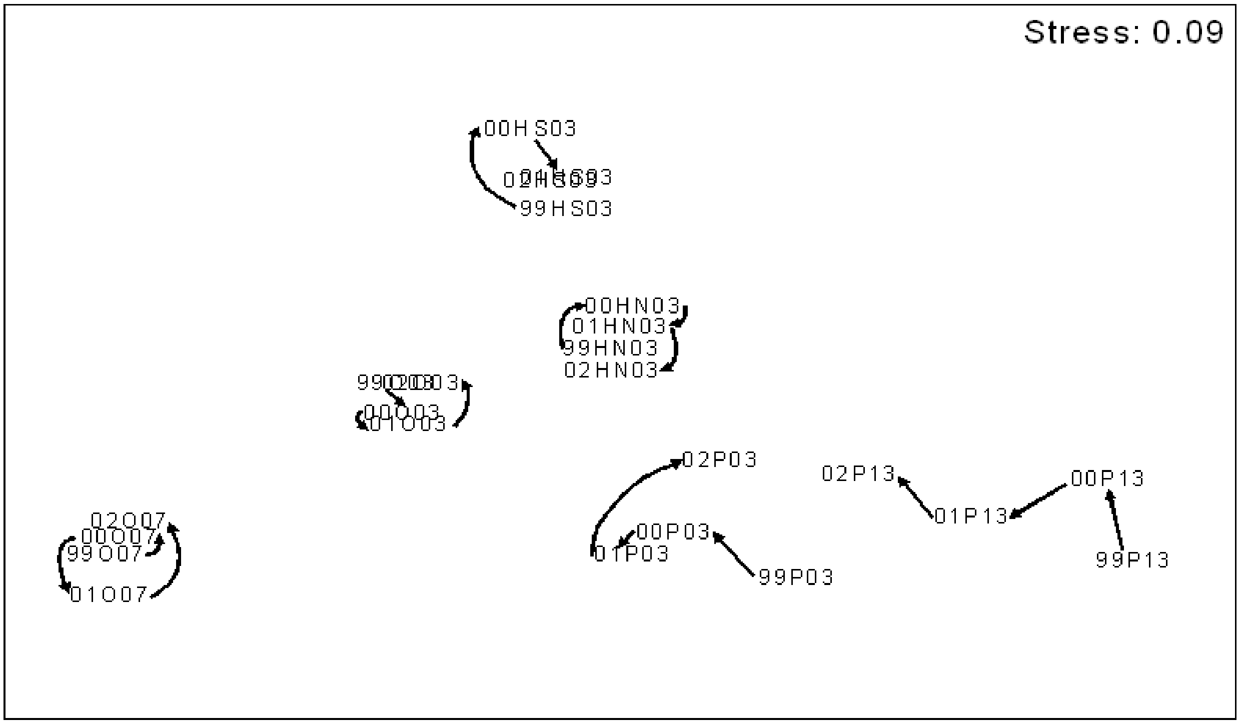


Figure S15.9: Non-metric multidimensional scaling (MDS) ordination of changing percent cover from 6 stations in each of 4 years. Stations are coded as follows (YYRDD) where YY = year, R or RR = reef abbreviation (HN= Honolua North, HS= Honolua South, P = Puamana, O = Olowalu), and DD = depth in meters.

Reporting Overview

Report Types

We anticipate that all reports generated in association with this Vital Sign will encompass benthic marine cover, coral settlement and coral growth (if conducted at the park). Unlike the analysis log files which will generate individual files for each park and each of the three analysis strategies (unit, landscape, and trend assessment levels), reporting documents will integrate both parks and analysis strategies. Table S15.3 identifies product types, purposes, targeted audiences, responsible parties, production frequency, and review processes. We have identified a cohesive suite of seven product categories: (1) program and protocol reviews, (2) monitoring protocol and project reports, (3) status and trends reports, (4) scientific writing and presentations, (5) management briefings, (6) website communication, and (7) interpretation and outreach.

Table S15.3. Summary of anticipated products, grouped by type and frequency.

Type of Report	Purpose of Report	Targeted Audience	Initiated by	Frequency of Reporting	Review Process
Program and Protocol Reviews					
Protocol Review Reports	Document where actual procedures fall short or exceed expectations, recommend necessary changes, document changes since last protocol review report; document overall quality of protocol – particularly in terms of protocol objectives and implementation, effectiveness, and data management.	Superintendents, park resource staff, I&M staff, service-wide program managers, external scientists, partners	PICRP Co PI, Principal Investigator	Within 1-3 years of implementation, 5-year intervals thereafter	Peer review at network and regional level
Monitoring Protocol and Project Reports					
Vital Signs Monitoring Protocol Reports	Document and archive annual monitoring activities and data, describe current resource condition and core analysis results, document related data management activities, document changes in monitoring protocol, communicate monitoring efforts to resource managers. During protocol development stages, will emphasize progress made and challenges encountered.	Park resource staff, PACN staff, external scientists, partners	PICRP Co PI, Principal Investigator, others?	Annually, compiled each March?	Peer review at network level
Summary of Vital Sign Monitoring Protocol Reports	Same as annual "Vital Sign Monitoring Protocol Reports" above, but highlights key points for non-technical audiences	Superintendents, NPS interpreters, public, partners	PICRP Co PI, Principal Investigator, others?	Annually, compiled each March?	Peer review at network level
Pilot Projects and Monitoring Research Reports	Provide background and methods of monitoring protocol development and other methods related investigations	Park resource managers, PACN Staff, external scientists, partners	PICRP Co PI, Principal Investigator	Variable with annual status reporting, as necessary	Peer review at network level plus review appropriate to final product
Status and Trends Reports					

Table S15.3. Summary of anticipated products, grouped by type and frequency (continued).

Type of Report	**Purpose of Report**	**Targeted Audience**	**Initiated by**	**Frequency of Reporting**	**Review Process**
Trend Analysis and Synthesis Reports	Describe and interpret patterns/trends of monitored resources, identify new characteristics of resources and correlations among monitored resources, identify relationships between drivers/stressors and responses at various scales, recommend changes to management of resources (adaptive management feedback). Analysis and reporting will occur at multiple scales, including park, multi-park, and network/regional.	Park resource managers, PACN staff, external scientists, partners	Principal Investigator, Park Leads	3-5 year intervals. Abbreviated annual edition, as necessary for PACN Vital Signs Program	Peer review at the network and regional level
Summary of: Trend Analysis and Synthesis Report	Executive summary of “Trend Analysis and Synthesis Report” above with key points on one page for non-technical audiences. Usually this is a bulleted list.	Superintendents, NPS interpreters, public, partners	Principal Investigator	Commensurate with reporting activity of “Trend Analysis and Synthesis Report”	Peer review at the network level
PACN contribution to NPS-wide “State of the Parks” Report	Describes current conditions of park resources, reports interesting trends and highlights of monitoring activities, identifies resource issues of concern, explores future issues and directions	Congress, budget office, NPS leadership, Superintendents, general public	Compiled by the Washington Support Office (WASO) from data provided by networks	Annual	Peer review at national level
Scientific Writing and Presentations					
PACN Vital Signs Monitoring Conference	Review and summarize information on this Vital Sign, help identify emerging issues and generate new ideas	Park resource staff, network staff, external scientists, partners	PICRP biologists, Principal Investigator, others	Biennial (around time PACN “Status and Trends Report” is published)	Peer review at national? level
Scientific journal articles and book chapters	Document and communicate advances in knowledge, provides a broader perspective on quality assurance and peer review	External scientists, Park resource managers, and professional staff	Principal Investigator, PICRP biologists	Variable	Peer review according to journal or book standards

Table S15.3. Summary of anticipated products, grouped by type and frequency (continued).

Type of Report	**Purpose of Report**	**Targeted Audience**	**Initiated by**	**Frequency of Reporting**	**Review Process**
Other symposia, conferences and workshops	Review and summarize information on this Vital Sign, help identify emerging issues and generate new ideas	External scientists, professional staff, Park resource managers, and other resource managers.	Principal Investigator, PICRP biologists	Variable (e.g., Hawaii Conservation Conference, George Wright Society)	Peer review at network level; for papers may also be peer reviewed
Management Briefings					
Protected area managers briefing	Communicate highlights and potential management action items, with 1-2 page briefing statements for each protocol	Park resource staff, Network staff, agency, academic scientists, other Federal, State, and Territorial Protected Area managers, discipline specialists, interpretive staff	Network Coordinator, PICRP biologists, Principal Investigator	Annually, likely in conjunction with Board of Directors administrative meetings	Peer review by network, PICRP, and monitoring staff
Executive briefings	Update Superintendents and other VIPs on park-specific findings and potential resource issues; suggest action items where appropriate	Individual Superintendents and other VIPs	Principal Investigator & PICRP biologists, Network Coordinator, Park Leads	As needed	Peer review by network, PICRP and monitoring staff
Website Posting					
Web-based media	Centralized repository of all final reports to ensure products are easily accessible in commonly-used electronic formats; other synthesized information on the PACN	Superintendents, Park resource staff, PACN staff, service-wide program managers, external scientists, partners, students, public	Variable, typically network webmaster	As media is completed	Peer review at network level to NPS web standards as finalized, reviewed products

Table S15.3. Summary of anticipated products, grouped by type and frequency (continued).

Type of Report	Purpose of Report	Targeted Audience	Initiated by	Frequency of Reporting	Review Process
Interpretation and Outreach					
Science Days	Communicate main monitoring findings as well as underlying data; discuss potential significance for management, further monitoring, potential additional research needs, and for outreach	Superintendents, park resource staff, PACN staff, protocol managers, partners, public	Principal Investigator, Technician, PICRP Co PI, and others as needed	Variable by park, annual when possible	Meeting / presentation itself is a form of review
Interpretive Conversations	Interactive conversations with park interpretive staff to discuss main monitoring findings as well as underlying data; discuss potential significance for management, further monitoring, potential additional research needs, and for outreach	Park interpretive staff, environmental educators, PACN staff	Principal Investigator, Technician, PICRP Co PI, and others as needed	Variable by park, at least annual when possible	Meeting / presentation itself is a form of review
Park Interpretive / outreach sessions	Review and summarize information on PACN Vital Signs; engage and involve greater participation in monitoring efforts	Park staff, public, partners	Principal Investigator, Technician, PICRP Co PI, and others as needed	Variable	Peer review by network, PICRP staff
Park staff meetings (results synthesis)	Communicate results to non-technical audiences, discuss potential significance for management, receive feedback on resource and monitoring issues in park operations	All park staff, volunteers, and partners, especially those not typically encountered in I&M program, RM, science operations	Principal Investigator, Technician and others as needed	Annually for each network park	Peer review by network, PICRP staff

Reporting Preparation Process

Reports identified in Table S15.3 are to be based on collected data and other science-based documentation. These reports will provide context and explanations for the results presented, as well as include any additional analyses that may result from initial investigations. The 'analysis log' files will serve as the basis for most of the reporting results. The biological technician for this Vital Sign is identified as the primary individual responsible for updating the analysis log files and will also be pivotal in preparation of subsequent reports. It is anticipated that the Principal Investigator, PICRP personnel or another statistically trained individuals will be responsible for the statistical analyses.

Drafts of the reporting products will be organized according to the categories outlined above, with key versions and review comments archived, and final versions clearly communicated to PACN network staff to ensure distribution via websites and other channels.

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Appendix S15.a. Analysis log file checklist

Park:		
Section	Analysis	Date Completed
Benthic Cover	<u>Unit</u>	
	Examine outliers and treat data accordingly	
	Plot normal probability plot	
	Plot frequency histogram of distribution	
	Generate table of mean and standard deviation of percent coral cover at the level of transect	
	<u>Landscape</u>	
	Generate table of current year mean and standard deviation of percent cover by substrate type/taxa at the level of park	
	Create ARC MAP bubble plot of coral cover at park	
	Create ARC MAP bubble plot of algal cover at park	
	<u>Trend</u>	
	Generate table of adjusted mean and standard deviation of percent total coral cover at the level of park for previous year.	
	Generate table of adjusted mean and standard deviation of percent total macroalgal cover at the level of park for previous year	
	Plot mean and standard deviation of percent coral and macroalgal cover over all sampling periods.	
	Conduct Repeated Measures ANOVA test on arcsin-square root transformed cover data for the fixed transects.	
	Create ARC MAP bubble plot of trend in coral cover at park	
	Create ARC MAP bubble plot of trend in algal cover at park	
Coral Settlement	<u>Unit</u>	
	Examine outliers and treat data accordingly	
	Plot normal probability plot	
	Plot frequency histogram of distribution	
	Generate table of mean and standard deviation of settlement rate at the level of transect	
	<u>Landscape</u>	
	Generate table of coral settlement genera for park	
	Generate table of current year mean and standard deviation of settlement rate by genera at the level of park	
Section	Analysis	Date Completed
	Create ARC MAP bubble plot of coral settlement rate at park	
	<u>Trend</u>	
	Generate table of adjusted mean and standard deviation of settlement rate at the level of park for previous year	
	Plot mean and standard deviation of settlement rate over time.	
	Conduct Repeated Measures ANOVA test on log(x+1) transformed settlement rate data	

Park:		
Section	Analysis	Date Completed
	Create ARC MAP bubble plot of trends in coral settlement rate at park	
Coral Growth	Unit	
	Examine outliers and treat data accordingly	
	Plot normal probability plot	
	Plot frequency histogram of distribution	
	Generate table of mean and standard deviation of growth rate at the level of transect	
	Landscape	
	Generate table of current year mean and standard deviation of growth rate at the level of park	
	Create ARC MAP bubble plot of coral growth rate at park	
	Trend	
	Generate table of adjusted mean and standard deviation of coral growth rate at the level of park for previous year	
	Plot mean and standard deviation of coral growth rate over time.	
	Conduct Repeated Measures ANOVA test on growth rate data.	
Rugosity	Create ARC MAP bubble plot of trends in coral growth rate at park Unit	
	Examine outliers and treat data accordingly	
	Plot normal probability plot	
	Plot frequency histogram of distribution	
	There is only one rugosity measurement per transect so cannot generate table of mean and standard deviation of rugosity at the level of transect	
Section	Analysis	Date Completed
	Landscape	
	Generate table of current year mean and standard deviation of rugosity at the level of park	
	Create ARC MAP bubble plot of rugosity at park	
	Trend	
	Generate table of adjusted mean and standard deviation of rugosity at the level of park for previous year	
	Plot mean and standard deviation of rugosity over time.	
	Conduct Repeated Measures ANOVA test on log (x) transformed rugosity data.	
	Create ARC MAP bubble plot of trends in rugosity at park	
Disease/Bleaching	Unit	
	Examine outliers and treat data accordingly	
	Plot normal probability plot	
	Plot frequency histogram of distribution	
	Generate table of frequency (# of frames) of disease/bleaching at the level of transect.	

Park:		
Section	Analysis	Date Completed
	<u>Landscape</u>	
	Generate table of current year frequency of disease/bleaching at the level of park	
	Create ARC MAP bubble plot of disease/bleaching frequency at park	
	<u>Trend</u>	
	Plot frequency of disease/bleaching over time.	
	Conduct Repeated Measures ANOVA test on frequency data for the fixed transects.	
	Create ARC MAP bubble plot of trends in disease/bleaching frequency at park	

SOP #16: After the Field Season

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	8/02/2007	L. Basch	See Track Changes	Clarification, correction, comments, additions		2.00

Purpose

This Standard Operating Procedure explains chronological actions after the field season for personnel involved in the Benthic Marine Community Vital Sign Monitoring Protocol and associated Standard Operating Procedures (SOPs) in the Pacific Island Network. The field season for this protocol begins with the start of field work, installation, or maintenance of any transect or sampling equipment (e.g., Coral Settlement Arrays) in the spring and ends with the final removal of Coral Settlement Arrays in the autumn or completion of field work and data validation. Observers should be familiar with and follow this SOP after the field season is completed. This SOP outlines the proper post-season maintenance and storage for the SCUBA gear, vessel, and survey equipment for each objective of the protocol. The post-field season will follow the last dive of the season.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Scuba Gear

Rinse

All scuba gear must be rinsed with fresh water following each dive, as described in SOP #10 "Post-Dive Procedures and Equipment Maintenance." Marine environments can accelerate wear and deterioration of sampling tools and equipment thus requiring special consideration for adequate maintenance and storage while not in use. After the final dive of the season, all field gear should be thoroughly immersed for one-half hour, and then rinsed with running clean fresh water. Once rinsed allow gear to dry completely prior to returning it to the proper storage area.

Inspect for Repairs
During the final rinse and storage of equipment, inspect and identify scuba gear that may be in need of repair, maintenance, or replacement. An equipment list for conducting diving activities can be found in Appendix S1.a in SOP #1 "Before the Field Season." Prepare a service schedule, and coordinate the maintenance activities identified in order to accommodate the next field season.

Storage
After servicing, store the scuba gear in a cool, dry location away from weathering elements (e.g., sun, rain, wind).

Maintenance Log
Prepare a maintenance log that clearly identifies each piece of gear, the date serviced, and the type of maintenance performed.

Survey Equipment
Marine Benthic Cover
Step 1: Rinse all equipment for monitoring benthic cover after each use at the end of the field season (Appendix S1.a in SOP #1 "Before the Field Season.") with freshwater (except camera). Allow equipment to dry thoroughly prior to returning it to the proper storage areas.

Step 2: After rinsing the transect tape/lines with freshwater, verify that they were functioning properly during their last use. To rinse thoroughly, unspool the transect tape in a container of freshwater. Repair or replace as necessary and respool on reels without twists, kinks or cuts. When dried, store the transect tapes/lines in a cool, dry location.

Step 3: Rinse the sealed camera housing in fresh water and dry before extracting the camera. After removing the camera from the underwater housing, remove and clean the housing o-rings and use cotton swabs to clean and dry the o-ring grooves. Lightly grease the o-rings and replace on the camera housing. See SOP #5 "Pre-Dive Equipment Preparation" for instructions on removing, greasing, and replacing o-rings. Store the camera with the housing and o-ring(s) together in a cool, dry location. Be sure that there are at least two clean, good quality (new) o-rings sets in a sealed plastic bag available for the next field season.

Step 4: Remove the memory card from the camera and store the card with the camera.

Step 5: Remove the camera batteries and place in the camera battery charger. Put the camera in its case and place in cool, dry, secure storage. After the power supply is recharged, place it in the case with the camera.

Step 6: After rinsing with freshwater, dry and store the aiming wand/monopod in a cool, dry location.

Step 7: After identification of the equipment that may require servicing, prepare a maintenance schedule in preparation for SOP #1 “Before the Field Season.”

Rugosity

Step 1: Rinse all underwater monitoring equipment (Appendix S1.a in SOP #1 “Before the Field Season”) with freshwater. Allow equipment to dry thoroughly prior to returning to the proper storage area.

Step 2: After rinsing with fresh water, inspect the rugosity chain for wear. Repair or replace as necessary. Store the dry chain in a cool, dry location.

Step 3: After rinsing with fresh water, verify that the transect tapes/lines were functioning properly during their last use. To rinse thoroughly, unspool the transect tape in a container of freshwater. Repair or replace as necessary and respool chain on reels without twists, kinks or cuts. When dried, store the transect tapes/lines in a cool, dry location.

Step 5: After identification of the equipment that may require servicing, prepare a maintenance schedule and coordinate the activities identified to be done in preparation for the next field season.

Coral Settlement

Step 1: Rinse all underwater monitoring equipment (Appendix S1.a in SOP #1 “Before the Field Season”) with fresh water (except camera) and allow to dry thoroughly prior to returning to the proper storage areas.

Step 2: After rinsing with freshwater, inspect the settlement array parts for wear and repair or replace as necessary. Store unused dry settlement array parts in a cool dry location.

Step 3: Remove the memory card from the camera and store the card with the camera.

Step 4: Remove the camera batteries and place in the camera battery charger. Put the camera in its case and place in cool, dry, secure storage. After the batteries are recharged, place it in the case with the camera.

Step 5: After identification of the equipment that may require servicing, prepare a maintenance schedule and coordinate the activities identified to be done in preparation for the next field season.

Coral Growth

Step 1: Rinse all monitoring equipment (Appendix S1.a in SOP #1 “Before the Field Season”) with fresh water and allow equipment to dry thoroughly prior to returning it to the proper storage area.

Step 2: After rinsing with freshwater, verify that the measuring tape was in working condition when last used. Repair or replace as necessary. When dried, store the measuring tape in a cool, dry location.

Step 3: Store the supply of plexiglass tags in a cool, dry location.

Step 4: After rinsing with freshwater, verify that the calipers were functioning properly during the last use. Repair or replace as necessary. When dried, store the calipers in a cool, dry location.

Step 5: After identification of the equipment that may require servicing, prepare a maintenance schedule and coordinate the activities identified to be done in preparation for the next round of field work.

Research Vessel

Boat Maintenance

Step 1: Inspect all boating supplies (Appendix S1.a in SOP #1 “Before the Field Season”) to verify that they are in working order and will be ready for use during the next scheduled field season. Remove and care for batteries as above for any relevant gear. Supplies or gear with expiration dates, electronics or batteries (1st aid kit, emergency oxygen kit, fire extinguisher, flares, e-pirb, VHF handheld back-up radio, etc.), need to be checked again before the next field season per SOP #1 “Before the Field Season”.

Step 2: Inspect the mooring lines, including chafing gear, and ensure that they are undamaged and secure. Repair or replace as necessary.

Step 3: Inspect anchor, shackle(s), wire(s), and chain/line for any rust, wear or breakage. Repair or replace as necessary.

Step 4: Ensure that the bilge pump is in working condition.

Step 5: Inventory the first aid kit (including sunscreen and water) and replace the items that have been used or are near their expiration date.

Step 6: Inspect personal floatation devices (PFDs) for damage, including any straps, whistles or lights. Service or replace as needed.

Step 7: Inspect emergency oxygen kit. Test equipment to insure masks and valves are working properly. Replace, refill, or service as needed.

Step 8: Ensure that all electronics are in working order. Electronics include any compasses, GPS/plotter, depth finder, or CB/VHS.

Step 9: Check the expiration dates for the fire extinguisher and flares and compare with the schedule for the next field season. Make arrangements to service or replace them before they expire.

Step 10: Note the expiration dates for the boat registration and ramp fees (if required). Arrange to have them updated as necessary before the next field season.

Step 11: Carefully do a visual inspection of the inner and outer hull, anchor locker, console, canopy, or antenna mounts (if any) for cracks, stress or other damage. Pay particular attention to stress areas including: cleats, line or lifting eyes, rails, and transom near engine mounts. Thoroughly flush cable channel with freshwater or clean other under deck spaces as recommended by manufacturer. Clean out and air dry under deck spaces and console interior to prevent mold, mildew or damage. Repair or replace any parts or areas as necessary. Cover the whole boat, including engine, and trailer chassis securely with a heavy duty, opaque high quality, waterproof material secured by ropes or bungie cords, to protect boat from the elements and store as per park specific guidelines.

Boat Motor Maintenance

Step 1: Follow the manufacturer's guidelines for scheduled boat motor maintenance.

Step 2: Inspect all boat motor equipment (Appendix S1.a in SOP #1 "Before the Field Season") to verify that it's in working order and will be ready for use during the next scheduled field season.

Step 3: After identification of the equipment that may require servicing, or seasonal/long-term storage, prepare a maintenance schedule and coordinate the activities identified to be done in preparation for the next field season.

Boat Trailer Maintenance

Step 1: Rinse in fresh water and allow to dry. Inspect the boat trailer to verify that it's in working order and will be ready for use during the next scheduled field season.

Step 2: Follow the manufacturer's guidelines for scheduled maintenance of the boat trailer's tires, axle bearings, frame and lights.

Step 3: Note the expiration dates for the trailer registration and safety check. Arrange to have these updated as necessary before the next field season.

Step 4: After identification of the equipment that may require servicing, prepare a maintenance schedule and coordinate the activities identified to be done in preparation for the next field season.

SOP #17: Revising the Protocol

Revision Log

Only changes in this specific SOP will be logged here. Version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, who approved the revision, and the reason for making the changes along with the new version number.

New Version Number	Revision Date	Author	Changes Made	Reasons for Change	Network Regional Reviewer Approval	Previous Version Number
2.00	6/30/2007	Eric Brown	See Track Changes	Response to reviewer's comments		1.00
2.01	8/02/2007	L. Basch	See Track Changes	Corrections, Clarifications		2.00

Purpose

This Standard Operating Procedure explains how to make and document changes to the Benthic Marine Community Vital Sign Monitoring Protocol narrative and associated Standard Operating Procedures (SOPs) for the Pacific Island Network. Anyone editing the Protocol Narrative or any one of the SOPs needs to follow this outlined procedure in order to eliminate confusion in how data is collected, managed, analyzed, or reported. All observers should be familiar with this SOP in order to identify and use the most current methodologies.

A master equipment list for the entire Benthic Marine Community Vital Sign Monitoring Protocol can be found in Appendix S1.a of SOP #1 "Before the Field Season." The master equipment list should be updated simultaneously if any SOP requiring an equipment list is revised.

Rationale

The Benthic Marine Community Vital Sign monitoring protocol narrative and associated SOPs for the Pacific Island Network represents an effort to document and employ scientifically rigorous methodologies for collecting, managing, analyzing, and reporting benthic marine community monitoring data and information. However, all protocols, regardless of initial rigor require editing as new and different information, techniques, or technologies become available. Required edits should be made in a timely manner and appropriate reviews undertaken. Careful documentation of changes to the protocol, and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate treatment of the data during data summary and analysis. The MS Access® database for each monitoring component contains a field that identifies which version of the protocol was in use when the data were collected.

In this context of revising the protocol, the rationale for dividing this document into a Protocol Narrative with supporting SOPs is based on the following:

- The Protocol Narrative is a general overview of the protocol that gives the history and justification for monitoring and an overview of the sampling methods, but does not provide all of the methodological details. The Protocol Narrative will only be revised if major changes are made to the protocol.
- The SOPs, in contrast, are very specific step-by-step instructions for performing a given task. They are expected to be revised more frequently than the protocol narrative.
- When an SOP is revised, in most cases, it is not necessary to revise the Protocol Narrative to reflect the specific changes made to the SOP.
- All versions of the Protocol Narrative and SOPs will be archived in a Protocol Library.

Procedure

All edits require review for clarity and technical soundness. Small changes or additions to existing methods should be reviewed in-house by Pacific Island Network staff (e.g., version changes by hundredths). However, if there is a complete or major change in methods, then an outside review may be required (e.g., version changes by whole numbers). If there is a major change in methodology, either to the entire protocol or individual SOPs or narrative components, The Pacific West Region Inventory and Monitoring Program coordinator should be consulted to determine the appropriate level of peer review required. Typically, Regional and National staff of the NPS, and outside experts in government, private sector, and academia with familiarity in benthic marine community monitoring in the Pacific Islands will be utilized as reviewers.

Metadata

Any changes to associated database design and organization are documented in the Metadata of the project database(s).

Notification

The Data Manager should be informed about changes to the Protocol Narrative or SOPs so the new version number can be incorporated in the Metadata of the project database. The database may have to be edited by the Data Manager to accompany changes in the Protocol Narrative or SOPs.

The appropriate PACN staff should be notified of the changes and appropriate level review process initiated as determined in collaboration between the network staff and protocol principal investigator.

Once review comments are received, incorporated, and approved, post revised versions on the internet and forward copies to all individuals with a previous version of the affected Protocol Narrative or SOPs, including the PACN Data Manager for inclusion in the network’s protocol library.

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 988/107130, March 2011

National Park Service
U.S. Department of the Interior

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