



Pacific Island Network Anchialine Pool Monitoring Protocol

Narrative, Version 1.0

Natural Resource Report NPS/PACN/NRR—2018/1809



ON THE COVER

An anchialine pool featuring the macroalga *Ulva reticulata*.
NPS photograph by Anne Farahi.

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Standard Operating Procedures (SOPs)

Thirty standard operating procedures are associated with the Pacific Island Network anchialine pool monitoring protocol. To accommodate frequent changes, each SOP is informally published online through the National Park Service Integrated Resources Management Applications (IRMA) portal (<https://irma.nps.gov/Portal>). The SOPs can be retrieved from IRMA using the citation or the hyperlinked reference code shown in Table SOP-1 below. Versioning tools in IRMA will offer the most current version from these links.

Table SOP-1. Titles, citations, and IRMA reference codes for all SOPs utilized for this protocol.

Title	Citation	IRMA Reference Code
SOP #1: Safety (w/JHA, GAR, Communication examples)	Raikow DF and Farahi AC. 2018. SOP #1: Safety (w/JHA, GAR, Communication examples). Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256840
SOP #2: Training Field Personnel	Farahi AC. 2018. SOP #2: Training Field Personnel. Version 1.0. Pacific Island Network Anchialine Monitoring Pool Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256848
SOP #3: Preparation for Field Sampling	Farahi AC. 2018. SOP #3: Preparation for Field Sampling. Version 1.0. Pacific Island Network Anchialine Monitoring Pool Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256849
SOP #4: Preventing the Spread of Invasive Species	Farahi AC. 2018. SOP #4: Preventing the Spread of Invasive Species. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256850
SOP #5: Seasonal and Annual Task Sequence	Farahi AC. 2018. SOP #5: Seasonal and Annual Task Sequence. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256851
SOP #6: Data Sheets	Farahi AC. 2018. SOP #6: Data Sheets. Version 1.0. Pacific Island Network Anchialine Monitoring Pool Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256852
SOP #7: Light Measurement	Raikow DF. 2018. SOP #7: Light Measurement. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256853
SOP #8: Using Garmin Global Positioning System (GPS) Units	Kichman S and Wasser M. 2018. SOP #8: Using Garmin Global Positioning System (GPS) Units. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256854

Table SOP-1 (continued). Titles, citations, and IRMA reference codes for all SOPs utilized for this protocol.

Title	Citation	IRMA Reference Code
SOP #9: Downloading and Uploading Data between Garmin GPS and ArcGIS	Kichman S and Wasser M. 2018. SOP #9: Downloading and Uploading Data from/to a Garmin GPS. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256855
SOP #10: Using the Ricoh GPS Camera	Farahi AC. 2018. SOP #10: Using the Ricoh GPS Camera. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256856
SOP #11: Water Quality Sampling	Farahi AC. 2018. SOP #11: Water Quality Sampling. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256857
SOP #12: Pool Mapping and Photographing	Farahi AC. 2018. SOP #12: Pool Mapping and Photographing. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256858
SOP #13: Baited Trap Shrimp Survey	Farahi AC. 2018. SOP #13: Baited Trap Shrimp Survey. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256859
SOP #14: Visual Shrimp Survey	Farahi AC. 2018. SOP #14: Visual Shrimp Survey. Version 1.0. Pacific Island Network Anchialine Monitoring Pool Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256860
SOP #15: Fish Survey	Farahi AC. 2018. SOP #15: Fish Survey. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256861
SOP #16: Odonate Survey	Farahi AC. 2018. SOP #16: Odonate Survey. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256862
SOP #17: Riparian Vegetation Survey	Farahi AC. 2018. SOP #17: Riparian Vegetation Survey. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256863
SOP #18: Geomorphology	Farahi AC. 2018. SOP #18: Geomorphology. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256864

Table SOP-1 (continued). Titles, citations, and IRMA reference codes for all SOPs utilized for this protocol.

Title	Citation	IRMA Reference Code
SOP #19: Snail Survey	Farahi AC. 2018. SOP #19: Snail Survey. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256865
SOP #20: Post-Field Activities	Farahi AC. 2018. SOP #20: Post-Field Activities. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256866
SOP #21: Workspace Setup and Project Records Management	Kozar K. 2018. SOP #21: Workspace Setup and Project Records Management. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256867
SOP #22: Field Form Handling Procedures	Kozar K. 2018. SOP #22: Field Data Sheet Handling Procedures. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256868
SOP #23: Data Entry and Verification	Kozar K. 2018. SOP #23: Data Entry and Verification. Version 1.0. Pacific Island Network Anchialine Monitoring Pool Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256914
SOP #24: Data Quality Review and Certification	Kozar K. 2018. SOP #24: Data Quality Review and Certification. Version 1.0. Pacific Island Network Anchialine Monitoring Pool Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256919
SOP #25: Managing Photographic Images	Kozar K. 2018. SOP #25: Managing Photographic Images. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256920
SOP #26: Product Delivery Specifications	Kozar K. 2018. SOP #26: Product Delivery Specifications. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256921
SOP #27: Metadata Development	Kozar K. 2018. SOP #27: Metadata Development. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256922
SOP #28: Sensitive Information Procedures	Kozar K. 2018. SOP #28: Sensitive Information Procedures. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256923

Table SOP-1 (continued). Titles, citations, and IRMA reference codes for all SOPs utilized for this protocol.

Title	Citation	IRMA Reference Code
SOP #29: Product Posting and Distribution	Kozar K. 2018. SOP #29: Product Posting and Distribution. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256924
SOP #30: Protocol Revision	Raikow DF. 2018. SOP #30: Protocol Revision. Version 1.0. Pacific Island Network Anchialine Pool Monitoring Protocol. Unpublished National Park Service Report, Pacific Island Inventory and Monitoring Network, Hawaii National Park, Hawaii.	2256925

Version History

Version 1.0

To create a new version of this document, carefully follow the instructions in [SOP #30: Protocol Revision](#). Use the Revision History Log below to describe the revisions.

Revision History Log. Populate the revision history log by providing the previous version number, new version number, revision date, author of the change, location of changes, reasons for the changes made, and the name of the person who approved the revision.

Previous Version Number	New Version Number	Revision Date	Author	Location of Changes Made	Reasons for Change	Network Regional Reviewer Approval
–	–	–	–	–	–	–
–	–	–	–	–	–	–
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–	–	–	–	–	–	–

For minor changes, version numbers increase incrementally by hundredths (e.g., version 1.01, version 1.02). Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0).

Executive Summary

The National Park Service created the Inventory and Monitoring Division to obtain information on the long-term trends in the condition of National Park System natural resources. This protocol defines methods to monitor animal populations of anchialine pools in Kaloko-Honokōhau National Historical Park (KAHO) and Pu‘uhonua O Hōnaunau National Historical Park (PUHO). The protocol consists of a narrative (this document), quality assurance plan (QAP), and set of standard operating procedures.

Anchialine pools are brackish coastal waterbodies receiving no regular overland flow, with groundwater inputs from both freshwater and marine sources that fluctuate with tides. Occurring on arid coastlines where freshwater is scarce, anchialine pools are a significant natural and cultural resource. Development, nutrient influx, groundwater withdrawal, and the introduction of non-native species threaten anchialine pool ecosystem health. Data obtained under this protocol will be used to help inform park management decisions in the face of such threats.

The primary objective of this protocol is to quantify the annual abundance of select crustacean, mollusc, odonate, and fish species in order to determine if the population size of these species declines or increases over time within each pool. Pool selection was determined primarily by park management priorities, with the overall number of sites limited by logistical constraints of PACN. Native and non-native crustacean, mollusc, odonate, and fish species will be monitored in five pools at KAHO and three pools at PUHO. Additionally, only odonates will also be monitored at seven pools in KAHO, the only locations where the endangered orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*) is consistently observed.

A secondary objective of this protocol is to annually measure abiotic and biotic characteristics of the eight pools where crustacean, mollusc, odonate, and fish species are monitored. The abiotic and biotic characteristics selected for monitoring include: riparian vegetation species and % cover; a pool map and photographic record; geomorphology characteristics represented by canopy closure, substrate particle sizes, water depth, and detritus depth; light exposure measurements; and a suite of water quality measurements. Anchialine pools included in this protocol were identified as important resources by the parks and some of them are being actively restored. Thus, while they will not be analyzed statistically, abiotic and biotic data of pool characteristics will aid managers in understanding the effectiveness of management techniques and changes in the abundance of anchialine pool animals, should this occur.

Animal abundance data will be reported to parks in an annual briefing that contains data for each species in each pool, a summary of data collection efforts to date, notable changes in pool habitat, and potential management concerns. A trend report and scientific review and revision of the full protocol will be produced after 10 years of data collection.

Acknowledgments

The authors wish to thank Matthew Miller, Meghan L. Jerolaman, Tahzay Jones, David K. Chai, Lisa Garrett, Jonathan Bakker, and David Foote for providing methodological information, insights, and reviews.

List of Terms

GPS:	Global Positioning System
IMD :	Inventory and Monitoring Division
KAHO:	Kaloko-Honokōhau National Historical Park
NPS:	National Park Service
PACN:	Pacific Island Network
PUHO:	Pu‘uhonua O Hōnaunau National Historical Park
QAP:	Quality Assurance Plan
SOP:	Standard Operating Procedure

1. Introduction

1.1. National Park Service Inventory and Monitoring Division

The National Parks Omnibus Management Act of 1998 instructed the Secretary of the Interior to (Public Law 105–391)

...undertake a program of inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources...

In response, the National Park Service (NPS) issued The Natural Resource Challenge, describing a vision, set of actions, and budget strategy to (NPS 1999)

...expand existing inventory programs and develop efficient ways to monitor the vital signs of natural systems...

Subsequently, the NPS created the Inventory and Monitoring Division (IMD) and divided the national park system into biogeographically coherent regions. NPS units within those regions were grouped into networks of parks to facilitate collaboration, information sharing, and leverage economies of scale when conducting selected natural resource management efforts. This protocol is a program of the Pacific Island Network (PACN), which consists of 12 national park units in Hawai‘i, Guam, Saipan, and American Samoa (Figure 1).

Monitoring by IMD is organized around “vital signs”, or biological, physical, and chemical ecosystem parameters and processes, known or hypothesized effects of stressors, and elements with important human values (HaySmith et al. 2006), for the purpose of gauging ecosystem health. The vital sign addressed by this protocol is “Focal Species or Communities”, targeting native animal species in anchialine pools.

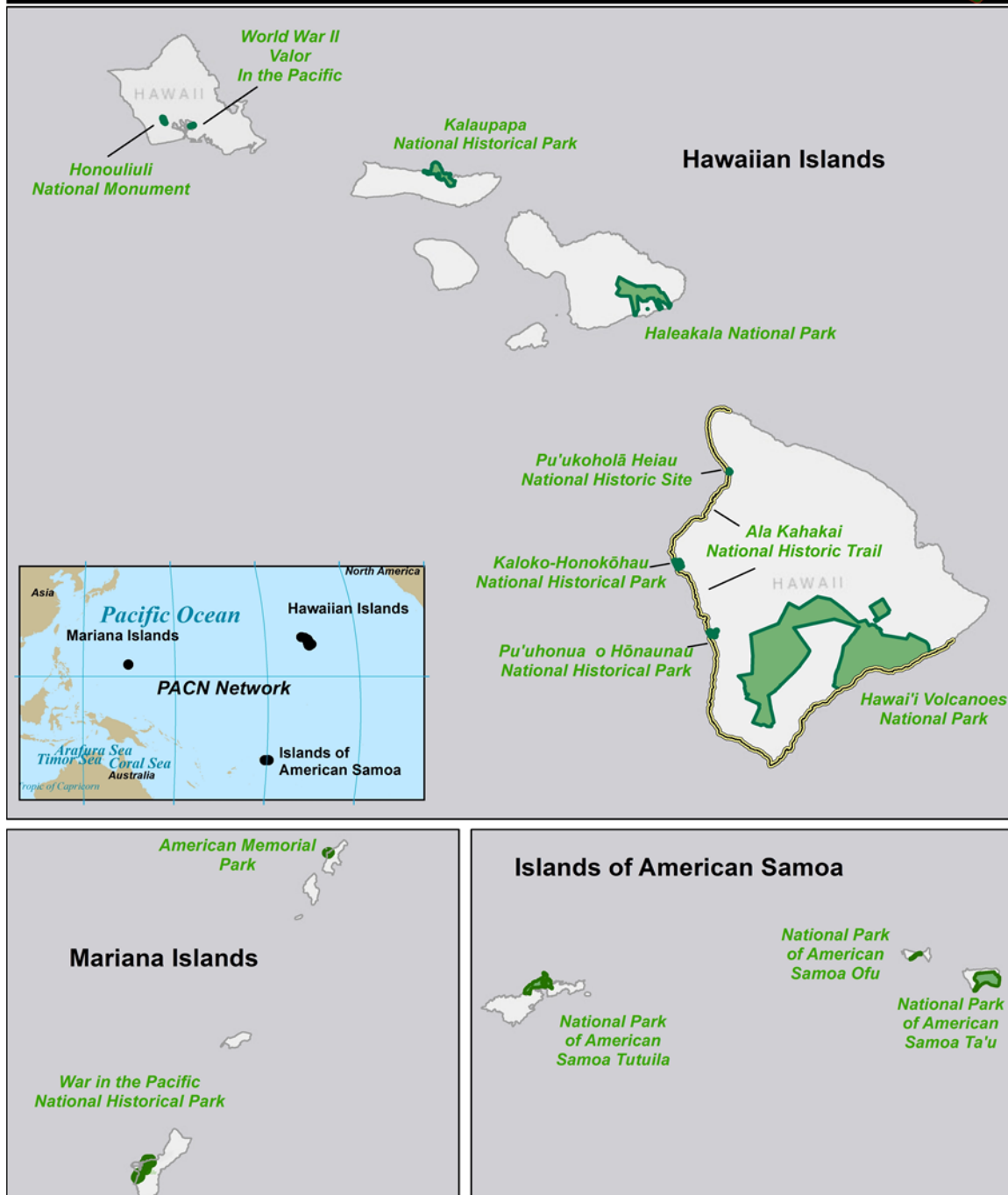


Figure 1. The National Park Service, Inventory and Monitoring Division, Pacific Island Network.

1.2. Definition of an Anchialine Pool

An anchialine pool is a body of water receiving no regular overland flow, with groundwater inputs from both freshwater and marine sources that fluctuate with tides (Holthuis 1973, Stock et al. 1986). This broad physical definition encompasses pools that vary widely within PACN parks. Pools can be found in lava-tube caves, within pits in young lava fields, and along beaches (Figure 2).



Figure 2. Variability in anchialine pools. Top row: small rocky pools without vegetation; Second row: pools with peripheral and emergent vegetation, partial canopy cover, and fine sediment substrate; Third row: modified pools (fishponds); Bottom row: cave pool (left) and deep fissure with rock substrate and varying exposure to sunlight (right; all photos by NPS).

Ala Kahakai National Historic Trail (ALKA), Kaloko-Honokōhau National Historical Park (KAHO), Pu‘uhonua O Hōnaunau National Historical Park (PUHO), and Hawai‘i Volcanoes National Park (HAVO) contain anchialine pools. Approximately 80% of the world’s known anchialine pools are found in the state of Hawai‘i (The Nature Conservancy of Hawai‘i 1987, Mitchell et al. 2005), with the greatest concentration occurring along the Kona coast of the island of Hawai‘i. A 1987 survey estimated that around 400 pools existed along the Kona coast (Maciolek and Brock 1974, Brock 1987, The Nature Conservancy of Hawai‘i 1987). Since then an additional 119 pools were documented in KAHO, raising that park’s total to 183. See Appendix A for descriptions of pools surveyed in 2010 Hawai‘i Volcanoes National Park and Pu‘uhonua o Honaunau National Historical Park.

1.3. Cultural Significance

Anchialine pools are significant natural and cultural resources because they often occur on arid coastlines where freshwater is scarce (Oceanic Institute 1992, Hoover and Gold 2006). There are no streams on the Kona coast, so anchialine pools likely played an important role during Hawaiian settlement. The Hawaiian word for freshwater is “wai”, which also means “to retain, earn, deposit” (Pukui and Elbert 1986), and is closely related to the word for wealth, “waiwai”, indicating the high value ancient Hawaiians placed on water resources (Handy and Handy 1991). Hawaiians regulated pool use; designating pools for drinking, bathing, washing, and agriculture. Hawaiians also designated large-scale land division, or ‘Ahupua’a’. Water from some pools was used for irrigation of agricultural crops such as sweet potatoes, gourds, medicinal plants, and to water livestock. Perhaps the most developed aquaculture system in the Pacific occurred in Hawaii, and included anchialine pools (Apple and Kikuchi 1975). Coastal fishponds and associated resources were “kapu” (prohibited) to commoners, as they were reserved for providing food for “ali‘i” (nobility) and their courts (Bryan and Emory 1986, Greene 1993). On the Kona coast, an active ‘ōpelu (mackerel scad, *Decapterus pinnulatus*) fishing culture was established. ‘Ōpae‘ula, the collective term for several species of small red anchialine pool shrimp, were used as bait for general and ‘ōpelu fishing (Roy 2001a, Roy 2001b). ‘Ōpelu fishing continues to be an important economic activity for Hawaiians today. Preservation of anchialine pools and ‘ōpae‘ula populations supports preservation of traditional fishing. Hawaiians also collected other anchialine pool fauna, including snail species such as hapawai (*Neripteron vespertinum*) and pīpīwai (*Neripteron cariosum*) for consumption (Yamamoto and Tagawa 2000).

1.4. Hydrology

While anchialine pools are surface waterbodies, the visible pool, or “epigeal” habitat, is only a portion of the ecosystem. Tidal fluctuations cause water levels to rise and fall due to the highly porous nature of the underlying lava or limestone substrate. Connectivity with the aquifer varies, frequently causing tidal response to lag behind the ocean. Water-filled subterranean or interstitial space can be referred to as the “hypogeal” habitat. The rise and fall of water levels is frequently described as having a “flushing” effect. Some pools may be entirely dry at low tide, preventing the establishment of some species if they cannot retreat to interstitial spaces. Salinity varies with distance from shore and over time within a pool due to tides and rain. Connectivity with the aquifer means that pools that appear independent on the surface may be connected underground, and thus not

entirely independent. This connection may be greater in the downstream direction (upslope or “mauka” to downslope or “makai”), and could be compartmentalized by watershed. Some pools in close proximity exchange surficial flow high tides, and can be referred to as “pool complexes.”

1.5. Variability and Senescence

In addition to highly variable geomorphology, recent studies have demonstrated high variability between pools in terms of microbial biofilm community structure (Hoffman et al. 2017) and animal community structure (Seidel et al. 2016). A process called “senescence” can occur, characterized by sedimentation and the encroachment of vegetation leading to marsh-like conditions (Maciolek and Brock 1974). Younger anchialine pools tend to have clear water and an orange benthic biofilm consisting of periphyton (cyanobacteria, filamentous algae and diatoms) and entrained organic material (Bailey-Brock and Brock 1993). Low turbidity and minimal sedimentation is maintained in these pools by tidally-driven flushing. Over time, salt-tolerant terrestrial plants, such as the native ‘ākulikuli (*Sesuvium portulacastrum*) and introduced pickleweed (*Batis maritima*), may grow in the riparian zone. Vegetation contributes to sedimentation, reducing aquifer connectivity and periphyton abundance. Late stage senescence is characterized by shallow water depths, deep organic sediments, restricted water exchange rates, densely matted algae and encroaching riparian and emergent vegetation (Maciolek and Brock 1974). Sedges and grasses colonize late-stage pools and create habitats for terrestrial insects. Terrestrially-derived leaf litter and organic sediment produced by cyanobacterial mats can accelerate sediment retention and senescence, and affect water quality.

1.6. Biota

High primary productivity driven by algae can occur in anchialine pools. Over 140 algal species have been identified in pools including diatoms, chlorophytes, chrysophytes, cyanophytes, pyrophytes and rhodophytes (Maciolek and Brock 1974, Maciolek 1986). The most ubiquitous algae are species of *Hildenbrandtia*, a dark-red, thin crustose coralline periphyton. Two types of crusts formed by algae, diatoms, bacteria and protozoa are common. Well-lit open pools often host *Schizothrix* spp., and have a thick, mineralized, white to orange colored periphytic biofilm. Shaded pools host *Lyngbya*/*Rhizoclonium*, visible as thick, dark- green, non-mineralized crusts.

‘Ōpae‘ula shrimp are common inhabitants of anchialine pools (Table 1). The most widely-spread shrimp are the grazing *Halocaridina rubra* and the primarily nocturnal predator *Metabetaeus lohena*. *Vetericaris chaceorum* and *Procaris hawaiana* are endangered (Endangered and Threatened Wildlife and Plants 2013). ‘Ōpae‘ula use interstitial hypogean spaces to travel between pools and the ocean. Shrimp quickly colonize newly formed pools, even if the nearest known pool is more than 10 kilometers away (Mitchell et al. 2005). Invertebrate community structure varies over the course of a day, with both greater abundance and diversity present at night (Sakihara 2012).

Table 1. Anchialine pool animals of Hawaii.

Group	Species	Common Name	Status
Crustaceans	<i>Antecaridina lauensis</i>	–	Indigenous
	<i>Calliasmata pholidota</i>	–	Indigenous
	<i>Halocaridina rubra</i>	‘Ōpae‘ula	Endemic
	<i>Macrobrachium grandimanus</i>	‘Ōpae ‘oeha’a	Endemic
	<i>Macrobrachium lar</i>	Tahitian prawn	Introduced
	<i>Metabetaeus lohena</i>	‘Ōpae‘ula	Indigenous
	<i>Metapograpsus thukuhar</i>	Thukuhar shore crab	Indigenous
	<i>Palaemon debilis</i>	‘Ōpae huna	Indigenous
	<i>Palaemonella burnsi</i>	–	Endemic
	<i>Periclimenes pholeter</i>	–	Indigenous
	<i>Procaris hawaiana</i>	–	Endemic
	<i>Vetericaris chaceorum</i>	–	Endemic
Fish	<i>Bathygobius sp.</i>	Frillfin goby	Indigenous
	<i>Chanos chanos</i>	Awa, milkfish	Indigenous
	<i>Eleotris sandwicensis</i>	O‘opu akupa	Endemic
	<i>Gambusia affinis</i>	Mosquitofish	Introduced
	<i>Kuhlia xenura</i>	Āholehole, Hawaiian flagtail	Endemic
	<i>Kuhlia sandvicensis</i>	Āholehole, Hawaiian flagtail	Indigenous
	<i>Osteomugil engeli</i>	Kanda	Introduced
	<i>Mugil cephalus</i>	‘Ama‘ama, ‘anae, striped mullet	Indigenous
	<i>Neomyxus leuciscus</i>	Uouoa, sharpnose mullet	Indigenous
	<i>Poecilia reticulata</i>	Guppy	Introduced
	<i>Poecilia sphenops complex</i>	Molly	Introduced
	<i>Oreochromis mossambicus</i>	Tilapia	Introduced
	<i>Sphyræna barracuda</i>	Kākū, Great barracuda	Indigenous
	<i>Xenoconger fryeri</i>	Fryer's false moray	Indigenous
Molluscs	<i>Melanoides tuberculata</i>	Thiarid snail	Introduced
	<i>Tarebia granifera</i>	Thiarid snail	Introduced
	<i>Neripteron cariosum</i>	Pipīwai	Endemic
	<i>Neripteron vespertinum</i>	Hapawai	Endemic
	<i>Nerita picea</i>	Pipipi	Endemic

Table 1 (continued). Anchialine pool animals of Hawaii.

Group	Species	Common Name	Status
Molluscs (continued)	<i>Assiminea parvulus (nitida)</i>	–	Indigenous
	<i>Neritilia hawaiiensis</i>	–	Endemic
Odonates	<i>Megalagrion xanthomelas</i>	Orangeblack Hawaiian Damselfly	Endemic
	<i>Ischnura posita</i>	Fragile Forktail	Introduced
	<i>Ischnura ramburii</i>	Rambur's Forktail	Introduced
	<i>Enallagma civile</i>	Familiar Bluet	Introduced
	<i>Anax junius</i>	Common Green Darner	Indigenous
	<i>Orthemis ferruginea</i>	Roseate Skimmer	Introduced
	<i>Pantala flavescens</i>	Globe Skimmer	Indigenous
	<i>Pantala hymenea</i>	Spot-Winged Glider	Introduced
	<i>Tramea abdominalis</i>	Vermilion Saddlebags	Introduced
	<i>Tramea lacerata</i>	Black Saddlebags	Introduced

Halocaridina rubra occurs on five Hawaiian islands and have a well-documented life history (Bailey-Brock and Brock 1993, Maciolek 1983, Couret Jr. and Wong 1978). *H. rubra* typically feeds as a microphagous grazer scraping biofilm, and can filter-feed when phytoplankton is abundant (Bailey-Brock and Brock 1993). The morphological features of *H. rubra* vary by island, with Kona coast individuals being the largest and most intensely red (Bailey-Brock and Brock 1993). Reproduction is assumed to occur in the subterranean portion of the habitat biannually in the spring and fall (Aquatic Resources Management and Consulting 1995). Although ovigerous (egg-bearing) females are rarely seen in the field, it has been estimated that 12 to 42% of the females have eggs at any given time, with reproduction triggered by food availability (Brock 2001). *H. rubra* appear to have few natural enemies, resulting in a high susceptibility to introduced fish and prawn, and can be extirpated from the epigeal habitat containing introduced fish (Brock 2001, Capps et al. 2009). Genetic studies of *H. rubra* show distinct populations along each coast of the Hawaiian Islands originating from two distinct colonization events (Santos 2006). Populations along each coast are further subdivided due to little or no gene flow occurring between populations separated by more than 30 km. Rift zones appear to form barriers to gene flow, although there is interisland marine larval dispersal (Craft et al. 2008).

Other animals commonly found in anchialine pools in Hawaii include a variety of snails, fish and odonates (damselflies and dragonflies, Table 1). The most common native snail is the neritid snail, *Neripteron cariosum* (pīpīwai). Anchialine pools also provide critical habitat for the endangered native orangeblack Hawaiian damselfly *Megalagrion xanthomelas* (Polhemus and Asquith 1996,

Endangered and Threatened Wildlife and Plants 2016). Some species found in anchialine pools also reside in estuaries, intertidal zones, and freshwater streams. Most anchialine pool species are tolerant of a wide range of salinities, but cannot survive in highly saline conditions.

1.7. Threats

Hawaii's anchialine pools currently have no state or federal protected status. Anthropogenic threats to anchialine pools include habitat loss due to development, reduced freshwater inputs due to groundwater withdrawal, degraded water quality due to the transport of pollutants and nutrients from upslope development, the introduction of non-native species, and unregulated harvest of 'ōpae'ula for the aquarium trade (Brock 1987, Jackson and Rosenlieb 1989, Stone 1989). Pools are filled-in during the creation of resorts, golf courses and residential areas (Titcomb 1972, Maciolek and Brock 1974, Brock 1987, Wiegner et al. 2006). Water quality in pools declines in developed areas (Wiegner et al. 2006). Seawater infiltration of the aquifer causing raised salinity in pools could result from upslope freshwater withdrawal (Oki et al. 1999).

Exotic species introduction is a significant threat to all Hawaiian aquatic ecosystems (Chai 1991, Brock and Kam 1997, Yamamoto and Tagawa 2000, Brasher et al. 2006). Non-native fish known to occur in anchialine pools include guppies (*Poecilia reticulata*), mosquitofish (*Gambusia affinis*), and tilapia (likely *Oreochromis mossambicus* and *Sarotherodon melanotheron*). Fish produce many effects, including: reduced epigeal shrimp populations (Brock and Kam 1997, Marrack et al. 2015b), impaired habitats (Brasher and Hayes 2011), and induced avoidance behavior in shrimp (Capps et al. 2009, Carey et al. 2010). For example, *H. rubra* are typically nocturnal but have been observed to emerge only during the day when a pool is dominated by the introduced nocturnal predator *Macrobrachium lar* (Tahitian prawn, Carey et al. 2010). Additionally, the native damselfly *Megalagrion xanthomelas* breeds only in pools lacking predators (Foote 2005). Odonate nymphs are consumed by fish (Englund 1999) and possibly also by *Enallagma civile* and *Ischnura ramburii* nymphs (Daigle 2000).

Anchialine pools can also be impacted by nutrients and contaminants in groundwater and salinization caused by upland groundwater withdrawal. Ammonia (N-NH₄) has been observed to increase by 134% in anchialine pools near KAHO following development of an adjacent golf course (Jackson and Rosenlieb 1989). Similarly, pools located in developed areas have been observed to have nutrient concentrations 45 – 96x higher than those in KAHO (Brock and Kam 1997, Wiegner et al. 2006). Algae are adapted to different levels of nutrient concentrations, and alterations in the concentrations of nitrogen and phosphorus could result in changing what species are present and their relative abundances. Shrimp could be negatively affected if algal communities shift to dominance by less palatable species. It should be noted that such increases in nutrient concentration (fertilization) are not the same as eutrophication, which may or may not be a natural phenomenon. Eutrophication is a general term describing an overabundance of autotrophs, usually algae, which can be induced by fertilization. Decay of large amounts of biomass derived from high primary production, including algal blooms, can result in copious bacterial activity, and lead to reduced oxygen concentrations (hypoxia), decreasing habitat quality and potentially killing aquatic animals (Wetzel and Likens 2000). Sea level rise is expected to increase salinity and both eliminate or impair anchialine pools

near-shore but also create new anchialine pool habitat in areas further from the coastline, which could allow non-native fish to also spread among pools via increased surface water flows (Marrack 2015a).

1.8. Objectives

The primary objective of this protocol is to quantify the annual abundance of select crustacean, mollusc, odonate, and fish species in order to determine if the population size of these species declines or increases over time within each pool (Table 2). Additionally, this data will allow PACN to better understand the annual variability associated with available monitoring techniques, a key piece of data that does not currently exist.

Table 2. Summary of objectives and species and characteristics associated with each objective.

Objective	Category	Measure
Primary: Quantify abundance to determine if a native species declines or increases over time within each pool.	Crustaceans	<i>Halocaridina rubra</i> ('Ōpae'ula), <i>Macrobrachium grandimanus</i> ('Ōpae 'oeha'a), <i>Metabetaeus lohena</i> ('Ōpae'ula), <i>Procaris hawaiiiana</i> (no common name)
	Molluscs	<i>Neripteron cariosum</i> (Pīpīwai), <i>Neripteron vespertinum</i> (Hapawai)
	Odonates	<i>Megalagrion xanthomelas</i> (Orangeblack Hawaiian Damselfly)
	Non-native species	Fish: <i>Gambusia affinis</i> (mosquitofish), <i>Oreochromis mossambicus</i> (tilapia), <i>Poecilia</i> spp. Crustacean: <i>Macrobrachium lar</i> (Tahitian prawn)
Secondary: Annually measure abiotic and biotic characteristics of each pool.	Riparian Vegetation	Species list and % cover of each plant species within 1.5 m of high tide line; most common species in KAHO or PUHO include Christmas berry (<i>Schinus terebinthifolius</i>), milo (<i>Thespesia populnea</i>), 'ākulikuli, (<i>Sesuvium portulacastrum</i>), makaloa (<i>Cyperus laevigatus</i>), and `ahu`awa (<i>Cyperus javanicus</i>)
	Pool mapping/photos	Map pool, mark animal survey, water quality, transect, and photo locations; estimate surface area; photograph pool condition from several angles
	Geomorphology	Canopy closure, substrate particle sizes, water depth, detritus depth, substrate type
	Exposure	Light exposure measurements
	Water quality	Temperature, pH, conductivity/salinity, dissolved oxygen, chlorophyll, turbidity, total dissolved nitrogen, total dissolved phosphorous, nitrates/nitrites; each measure taken at low and high tide as outlined in Jones et al. (2011)

A secondary objective of this protocol is annual measurements of abiotic and biotic characteristics of each pool where crustacean, mollusc, odonate, and fish species are monitored (Table 2). The abiotic

and biotic characteristics selected for monitoring include: riparian vegetation species and % cover; a pool map and photographic record; geomorphology characteristics represented by canopy closure, substrate particle sizes, water depth, and detritus depth; light exposure measurements; and a suite of water quality measurements as outlined in Jones et al. (2011). Anchialine pools included in this protocol were identified as important resources by the parks and some of them are being actively restored. Thus, while they will not be analyzed statistically, abiotic and biotic data of pool characteristics will aid managers in understanding 1) effectiveness of management techniques and 2) changes in the abundance of anchialine pool animals, should changes occur.

2. Sampling Design

Pool selection was determined primarily by park management priorities, with the overall number of sites limited by logistical constraints of PACN (Table 3, Figure 3 and Figure 4). Where possible, we co-located sites with fixed water quality monitoring sites that are monitored on a quarterly basis (five of eight sites co-located; Table 3). This will allow for a better understanding of how much water quality may fluctuate and interact with anchialine pool animals; and it is possible that these sites may be used to characterize long-term changes in other nearby pools with animal populations that are being monitored.

Table 3. Anchialine pool animal monitoring sample sites.

Park	Park Pool ID (PACN ID)	High Tide Surface Area m ²	Species Observed	Rationale for inclusion
KAHO	HA_Kaloko_005 (FKAHO01_ap)	2	<i>Halocaridina rubra</i> , <i>Metabetaeus lohena</i> , <i>Tarebia</i> <i>granifera</i> , <i>Pantala flavescens</i>	Permanent water quality monitoring site located in the central ahupua'a
	HA_Kaloko_011 (N/A)	295	<i>Halocaridina rubra</i> , <i>Neripteron</i> <i>cariosum</i> , <i>Kuhlia sandvicensis</i>	Important to park management due to <i>Neripteron</i> spp.
	HA_Kaloko_012 (N/A)	567	<i>Neripteron cariosum</i> , <i>Nerita</i> <i>picea</i> , <i>Palaemon debilis</i> , <i>Kuhlia</i> <i>sandvicensis</i> , <i>Poecilia reticulata</i>	Important to park management due to <i>Neripteron</i> spp. and <i>Nerita</i> <i>picea</i>
	HA_Kaloko_014 (N/A)	15	<i>Halocardina rubra</i> , <i>Neripteron</i> <i>cariosum</i>	Important to park management due to <i>Neripteron</i> spp.
	HA_Kealak_084 (FKAHO03_ap)	2	<i>Halocaridina rubra</i> , <i>Palaemon</i> <i>debilis</i> , <i>Metabetaeus lohena</i>	Permanent water quality monitoring site located in the southern ahupua'a and adjacent to Honokōhau Harbor
PUHO	HA_Honaun_004 (FPUHO04_ap)	179	<i>Palaemon debilis</i> , <i>Neripteron</i> <i>vespertinum</i> , <i>Tarebia granifera</i> , <i>Ischnura ramburii</i> , <i>Orthemis</i> <i>ferruginea</i> , <i>Pantala flavescens</i> , <i>Oreochromis mossambicus</i> , <i>Mugil cephalus</i> , <i>Kuhlia</i> <i>sandvicensis</i> , <i>Bathygobius</i> sp., <i>Gambusia affinis</i>	Permanent water quality monitoring site, one of the central pools on royal grounds, and focus for park restoration efforts

Table 3 (continued). Anchialine pool animal monitoring sample sites.

Park	Park Pool ID (PACN ID)	High Tide Surface Area m ²	Species Observed	Rationale for Inclusion
PUHO (cont.)	HA_Honaun_002 (FPUHO05_ap)	594	<i>Kuhlia sandvicensis</i> , <i>Oreochromis mossambicus</i> , <i>Mugil cephalus</i> , <i>Anax junius</i> , <i>Ischnura ramburii</i> , <i>Tarebia</i> <i>granifera</i>	Permanent water quality monitoring site, one of the central pools on royal grounds, important to park purpose
	HA_Keokea_004 (FPUHO08_ap)	7	<i>Halocaridina rubra</i> , <i>Metabetaeus lohena</i> , <i>Anax</i> <i>junius</i> , <i>Ischnura ramburii</i> , <i>Pantala flavescens</i>	Permanent water quality monitoring site, previously a green waste site, native animals still occur in it, potential restoration site
KAHO	HA_Kaloko_007, 045, 050, 058, 062, 064, and 065	2 - 22	N/A - only odonates will be monitored at these pools	Each of these pools are locations where the endangered damselfly <i>Megalagrion xanthomelas</i> is consistently observed

Native crustacean, mollusc, and odonate species will be monitored in five pools at KAHO and three pools at PUHO. Additionally, only odonates will be monitored at seven pools in KAHO, the only locations where the endangered orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*) is consistently observed. Abiotic and biotic characteristics will not be collected at the pools where only odonates are recorded. The list of pools, maximum surface area and species observed to date, and rationale for selection of each pool is in Table 3. Sampling will occur annually between October 1st and December 31st (fourth calendar quarter) so as to not conflict with the field work of the stream animal (Brasher et al. 2011), water quality (Jones et al. 2011), and marine benthic and fish (Brown et al. 2011a, 2011b) monitoring protocols.

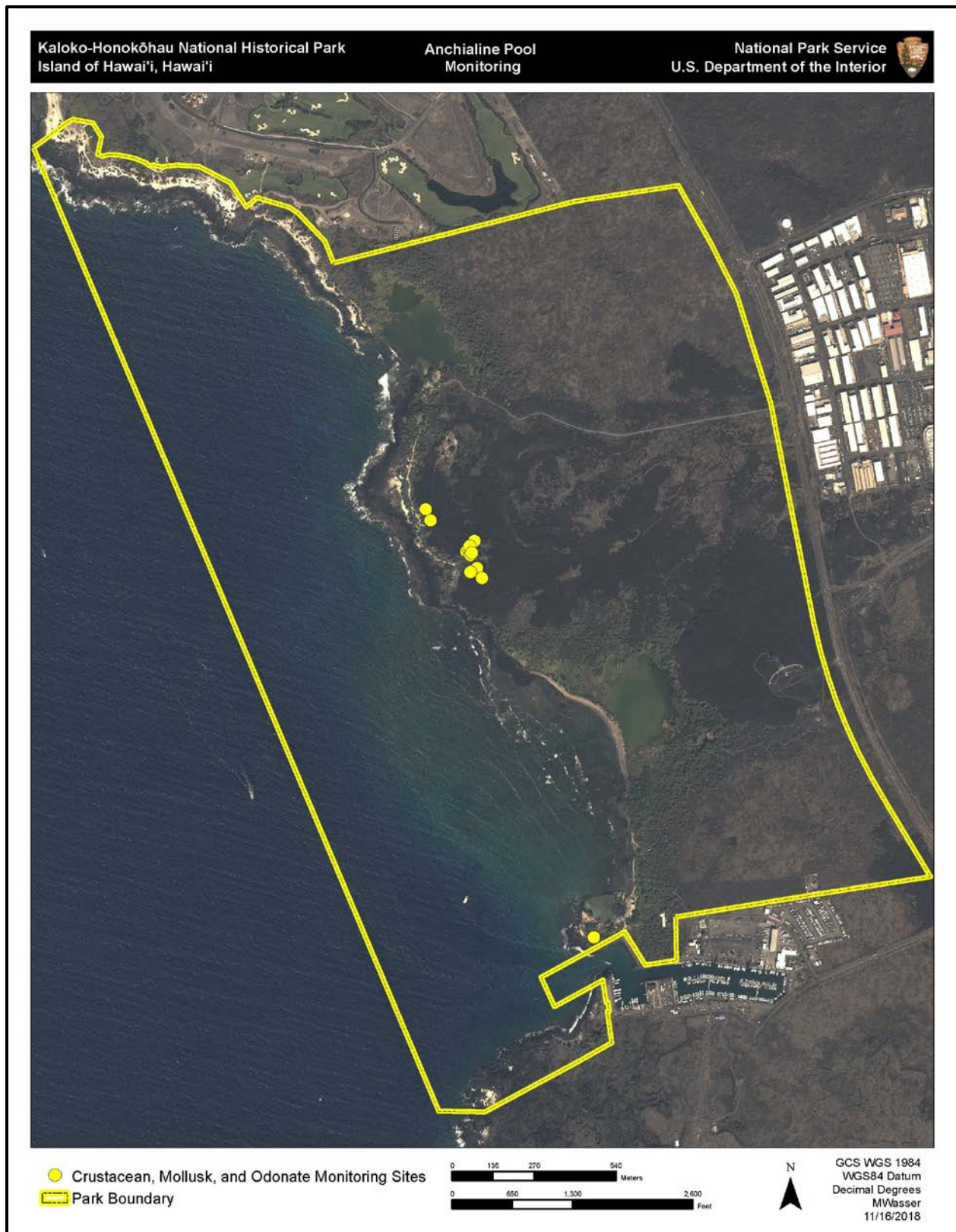


Figure 3. Monitoring sites in Kaloko-Honokōhau National Historical Park.

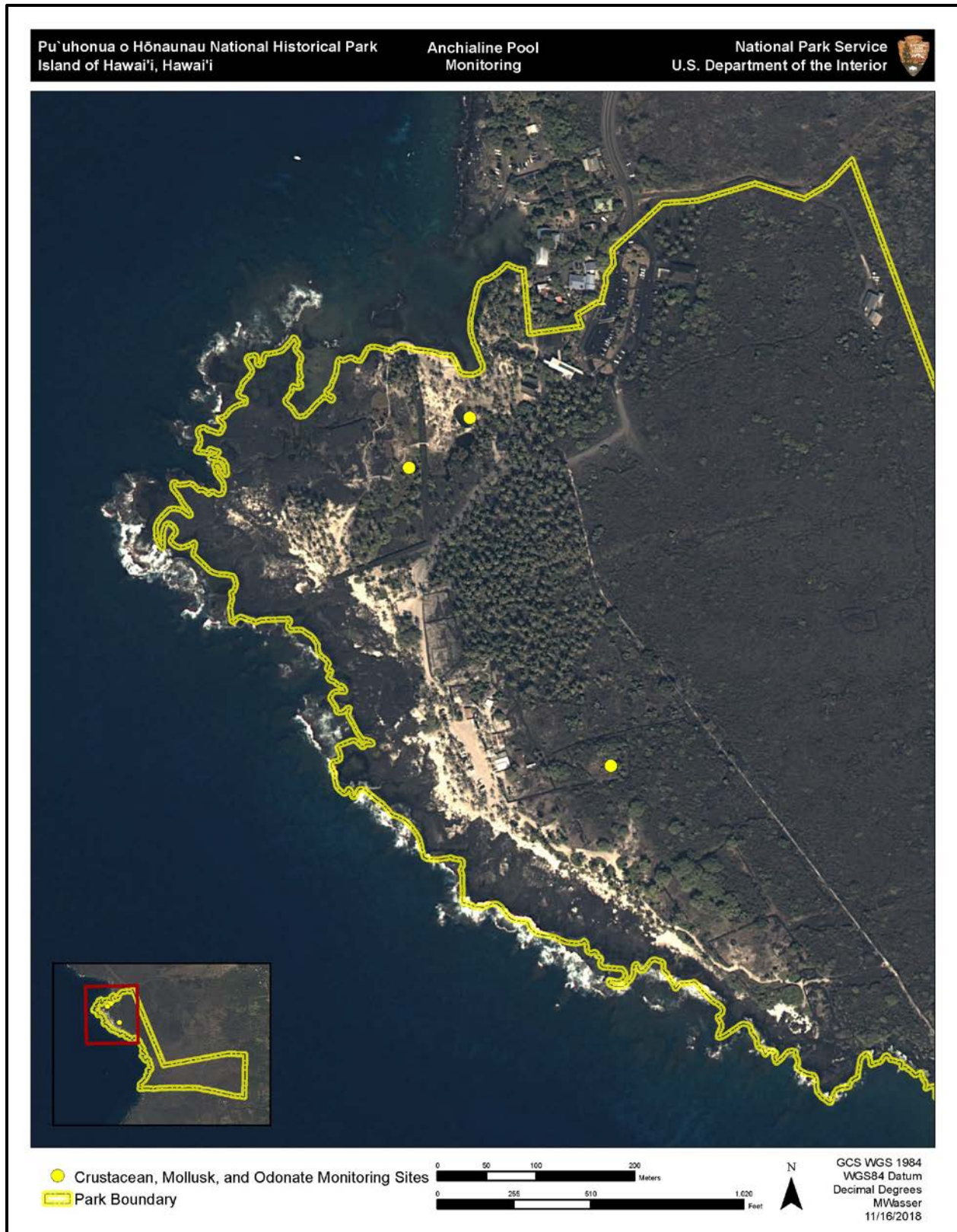


Figure 4. Monitoring sites in Pu'uhonua O Hōnaunau National Historical Park.

2.1. Field Methods

Pools will be sampled within two hours before and four hours after high tide, as some pools can dry out completely at low tide. Additional samples will be taken during low tide for water quality purposes (see below). Each pool visit will follow a prescribed workflow (SOP #5) that is summarized here and described in greater detail in the SOPs that accompany this protocol. The sequential steps and associated methods for sampling follow below. Data will be entered on a datasheet (SOP #6).

2.1.1. Visual Crustacean Surveys

The visual survey is focused on crustacean species (shrimp, prawn) and will be the first thing done on arrival, before conducting any other activities (SOP #14). Surveys will consist of repeated counts within a square quadrat that is 20 cm to a side. The number of quadrat counts and observers at a pool will vary according to the following surface areas of water: 0-5 m² (water surface area) will have two quadrat counts by one observer; 5-10 m² will have three quadrat counts by one observer; 10-20 m² will have four quadrat counts by two observers; and greater than 20 m² will have six quadrat counts by two observers. Quadrats will be non-overlapping and evenly dispersed in a haphazard fashion around the edge of the pool at easily accessible locations that allow for good visibility and quadrat placement from shore without disturbing the water.

The quadrat should be gently placed approximately 0.5 m from shore. After placement, the observer will wait one minute and count all crustaceans in the quadrat. Observations will be made for three minutes. The observer will then move to the next location and repeat the quadrat count. Locations for quadrat counts will be marked on the pool map (see below) and conducted in roughly the same location each year.

2.1.2. Water Quality Sampling

Water quality preparation, measurement, sampling, and storage will be conducted in accordance with standard practices used in the most current version of the PACN water quality protocol (Jones et al. 2011; see also SOP #11). However, because anchialine pool animal sampling is done at high tide, and standard water quality sampling is done at low tide, both high tide and low tide water samples and sonde measurements should be taken at both times. Pools sampled at high tide for water quality during annual anchialine pool sampling must be resampled at low tide within 24 hrs. Pools that dry at low tide will only be characterized by high tide conditions.

Sonde measurements will record temperature, pH, conductivity/salinity, dissolved oxygen, chlorophyll, and turbidity. Water samples will be taken and analyzed in a lab to measure total dissolved nitrogen, total dissolved phosphorous, and nitrates and nitrites. It is assumed that gently placing and removing the quadrats in the pool for visual crustacean surveys will not have an effect on water quality sampling.

2.1.4. Odonate Survey

Odonates will be surveyed at all pools (SOP #16), and will be the only survey conducted at seven pools where the endangered orangeblack Hawaiian damselfly (*Megalagrion xanthomelas*) is consistently observed. The number of surveys per pool will depend on size and visibility; surveys should cover the entire pool area, which may include pool complexes (pools that appear independent

at low tide, but are connected at high tide). Larger pools may require multiple surveys by one observer or simultaneous surveys by more than one observer to cover the entire area and be able to record species. Prior to the start of the survey observers should be familiar with commonly observed odonates (damselflies and dragonflies – see SOP #16 for identification guide). The number of observed adult odonates, species, and gender (if possible) are recorded. Weather conditions at the time of the survey should also be noted on the data sheet. The number and locations for odonate surveys will be marked on the pool map (see below) and conducted in roughly the same location each year.

2.1.5. Riparian Vegetation Survey

Vegetation surveys (SOP #17) will be completed after animal surveys. All plant species found within 1.5 m of the high tide line around the entire pool should be listed on the data sheet. Unknown species should be photographed or collected for identification by the PACN botanist. Observers will then independently record the coverage category (0-25%, 25-50%, 50-75%, or 75-100%) of each species around the entire pool (i.e., coverage is not based on the vegetated area but on the entire area within 1.5 m of the high tide line). Observers should compare results when done and resolve any differences in coverage categories through on-site discussion and additional observations.

2.1.6. Pool Mapping and Photography

Pool mapping and photographs will document pool senescence, change in physical habitat and surrounding area over time, and trap, transect, survey, and photo locations. Mapping will have three phases: field sketch, transcription into a drawing program, and updating maps using the previous year's transcribed map. Observers may need to step into the pool to conduct some measures, but this should be the first time anyone enters the pool and kept to a minimum.

A detailed description of mapping and photo procedures can be found in SOP #12. Briefly, the field sketch will consist of designating easily recognizable benchmarks close to the water edge; photographing and mapping the benchmarks; outlining the watered edge of pool at high tide; measuring distance from the various benchmarks; drawing and labeling relevant features such as plants, substrate types, rock overhangs, and trees and their canopies (overlapping features are ok); measuring pool widths at several locations; and designating north and the locations of trap, transect, survey, and photos. When taking photos, take several shots that show the entire pool at once. There should be a white board with a North arrow in the picture to show which direction is north for spatial reference. The purpose is to record the benchmarks and overall condition of the pool in its entirety and immediate surroundings. Do this from multiple angles. Additional information on photographs can be found in SOP #10.

Transcription to a drawing program will be done by scanning the sketch and importing into a vector drawing program that can define shapes by on-the-ground measures. The scale should be 1 in : 1 m and always be sure to note the date and version of the map. Features can be added as necessary; the more information the better. Map updates will require a hard copy of the most recent version in the field, with substantive changes noted and measured and then adjusted in the drawing program.

2.1.7. Transect Methods (Geomorphology, Mollusc, and Light Measures)

Remaining animal and pool measures will be conducted along a transect that stretches from one bank to another, crossing through the center of the pool at a randomly determined angle. A taut tape measure will be set up along the length of the transect; if possible this should be done without stepping in the water until it is time to take habitat measurements (SOP #18). The location and angle of the transect should be included on the pool map with distance to benchmarks noted; the same transect will be used on future site visits.

Once the transect tape is in place observers will measure riparian canopy closure, substrate particle size, water depth, detritus depth, light, and conduct the mollusk survey. Each measure is covered in depth in SOP #18 and summarized here. Canopy density is measured with a concave spherical densiometer at four locations along the bank of the pool facing outward: the northern, southern, eastern, and western points relative to the center of the pool. The densiometer is modified by drawing a right angle on the mirror surface with an indelible marker, a standard practice in aquatic systems (Brasher et al. 2011, Fitzpatrick et al. 1998). The densiometer is held 20 cm above the water surface and at an angle so that your forehead appears in the top-center of the mirror. The measurement is made by counting the number of point intersections covered by vegetation. This number is recorded on the data sheet.

Substrate particle size

The transect starts on “bank 1” where the measuring tape reads zero. Clearly note on the map which end this is, as it will ensure future measures can be used for comparative purposes. Starting at bank 1 the observer will place a meter stick straight into the water until it touches substrate. The widest width of the substrate that is touched by the meter stick should be measured, if particulate; entry on to the data sheet should be handled by someone other than the observer. If the meter stick lands on bedrock, a value of “999” is recorded, if it lands on silt a value of “0” is recorded, and if it lands on sand a value of “0.1” is recorded. This process is repeated every 0.25 meters until the observer reaches the opposite end of the transect (bank 2).

Water depth, detritus depth, and substrate type

At the same locations where substrate size is measured (every 0.25 meters from bank 1 to 2), the observer should also measure water and detritus depth and substrate type. Water depth is defined as the vertical distance between the water surface and the top of the substrate. Detritus depth is measured by inserting the meter stick to the bottom of the detritus layer, marking the intersection between the top of the detritus layer and the bottom of the water column with your hand, and then removing the meter stick from the water to read the depth of the detritus layer. Substrate type is recorded as detritus, sand, rock, aquatic plants, algae, or other material.

Light measurement

The purpose of measuring light exposure of anchialine pools is to evaluate the influence of light on animal populations. Light exposure is not expected to change over time at a pool unless the riparian canopy or aquatic macrophyte cover changes. Sampling for light exposure may be conducted at a time other than the annual sampling trip. Mean light exposure is used to characterize the pond.

Light measurements will be taken between 11 AM and 1 PM, Oct.1 to Dec 31st, when there is <10% cloud cover. Because light measurement is not dependent on regular sampling, measurements may be opportunistically taken during quarterly water quality sampling trips, when scouting locations, or whenever cloud conditions are suitable. Additional details on measuring light exposure can be found in SOP #7.

Mollusc survey

All native neritid snails, pīpīwai (*Neripteron cariosus*) and hapawai (*Neripteron vespertinum*), that are within 0.25 m on each side of the transect line will be counted and measured (SOP #19). The presence of introduced thiarid snails (such as *Melanoides tuberculata* and *Tarebia granifera*) will be noted, but they will not be measured or counted. A photo identification guide to the snail species is provided in SOP #19.

2.1.3. Shrimp and Fish Trapping

Shrimp and fish trapping efforts (SOP #13 and #15) will begin after water quality measurements are complete. The number of fish and shrimp traps placed in a pool will vary according to the following surface areas of water; 0 - 5 m² (water surface area) will have two shrimp and two fish traps, 5 - 10 m² will have three shrimp and three fish traps, 10 - 20 m² will have four shrimp and four fish traps, and greater than 20 m² will have six shrimp and six fish traps. Traps will be haphazardly placed around the pool, at least 0.5 m from shore and with different substrate types if evident. Locations should be noted on the pool map and deployed in roughly the same location each year. Shrimp traps are baited with five pieces of a moist or semi-solid cat treat (e.g. Purina Whisker Licken's Tender Moments) in the bait holder. Collapsible fish traps are not baited. Shrimp traps are retrieved and processed after 15 minutes and fish traps after 30 minutes. All shrimp and fish species are identified and counted; gravid shrimp will be noted as well as the sex of each individual fish. Care should be taken to ensure that methods used to enumerate native crustacean species are not fatal or highly stressful to the animals. Native species will be returned to the pool and non-native species should be collected as a voucher specimen or otherwise removed per park management guidelines. Traps will be marked on pool map (see below) and conducted in roughly the same location each year.

3. Data Management

Data management, analysis, and reporting are interrelated activities. Additional details and context for this section may be found in the PACN Data Management Plan (Dicus 2006), which describes the overall information management strategy for the network, and the Anchialine Pool QAP (Raikow 2018). Project information management may be best understood as an ongoing cyclic process.

3.1. Overview of Database Design

PACN data management staff have designed customized relational database applications to store and manipulate the data associated with this project. The design of the PACN anchialine pool monitoring database follows the hierarchical data table organization of the Natural Resource Database Template which is the standard for the NPS I&M Program (see the database documentation in Appendix B). The PACN data management staff is responsible for development and maintenance of the database, including customization of data summarization and export routines.

The database is divided into two components: one for entering, editing and error-checking data for the current season (i.e., the “working database copy”), and one that contains the complete set of certified data for the monitoring project (i.e., the “master project database”). Although PACN databases are currently implemented in Microsoft Access to permit flexibility when implementing on computers with limited or unreliable network access, new technologies may be implemented in the future. PACN databases have an associated front-end database application (“user interface” with forms and queries) implemented in Microsoft Access. The working database application has separate screens for data entry, data review, and quality validation tools. The master database application contains the analysis and summarization tools, including pre-formatted report output and exports to other software for analysis and graphics production. This front-end application arrangement allows for modification and update of the user interface with no disruption to data entry continuity. The improved front-end file can be distributed to data entry staff, who links it to the back-end file, discards outdated front-end files, and proceeds with their data entry work. Under this arrangement, data entry staff has no need to directly open the back-end file, thereby reducing the risk of improper deletions or other inadvertent data loss. 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.

During the field season, each project crew will be provided with their own copy of a working database into which they enter, process, and quality-check data for the current field season. Once data for the field season have been certified they will be uploaded into the master database, which is then used in analysis and reporting. This upload process is performed by the data manager.

3.2. Data Entry, Processing, Validation, and Certification

Each data entry form is patterned after the structure of the field form, and has built-in quality assurance components such as pick lists and validation rules to test for missing data or illogical combinations (Raikow 2018). Although the database permits users to view the raw data tables and other database objects, users are strongly encouraged only to use these pre-built forms as a way of ensuring the maximum level of quality assurance.

3.2.1. Regular data backups

Upon opening the working database, the user will be prompted to make a backup of the underlying data. It is recommended that this be done every day that new data are entered to save time in case of mistakes or database file corruption. These periodic backup files should be compressed to save drive space, and may be deleted once enough subsequent backups are made. All such backups may be deleted after the data have passed verification and certification.

3.2.2. Field form handling procedures

As the field data forms are part of the permanent record for project data, they should be handled in a way that preserves their future interpretability and information content. To minimize the possibility of data loss, hardcopy data forms and field notebooks should be stored in a secure location, with photocopies and scanned data forms stored in a separate location (e.g., on the PACN data server).

3.2.3. GPS data procedures

The following general procedures should be followed for GPS:

1. GPS data should be downloaded by the field crew at the end of each field trip and stored in the project workspace.
2. Raw files should be sent to the GIS Specialist for processing and correction.
3. The GIS Specialist will process raw GPS data and store it in the project workspace.
4. The GIS Specialist will upload corrected coordinate information into the database and create any GIS data sets.

The Field Lead should periodically review the processed GPS data to make sure that any problems are identified early on in the data collection process.

3.2.4. Data Verification and Certification

Following entry of data from hard copy data sheets, digital data is reviewed line by line by someone who did not enter the data (Raikow 2018). The purpose of this “verification” is to make sure that data has been entered correctly. Following verification, data is “certified” by the aquatic ecologist for quality, completeness, and logical consistency. The aquatic ecologist or Program Manager may also designate someone else to certify the data, but this should only be done if necessary and in collaboration with the aquatic ecologist (or Program Manager in their absence). The working database application facilitates the certification process by providing pre-built queries that organize data. The aquatic ecologist will then explore that data for outliers or anomalies. The aquatic ecologist may then flag data in the database, or review data with field crews to explore whether data can be corrected. Not all errors and inconsistencies are due to instrumentation or human error, and the aquatic ecologist must determine whether unusual data should be certified. Valid data that is the result of unusual environmental conditions may not be considered within the inference space of the protocol, and thus should be flagged accordingly. A description of problems with data and any edits is then documented and included in the metadata and certification.

Due to the potentially high volume of changes or corrections during data entry, it is not efficient to log all changes until after data are certified and uploaded into the master database. Prior to

certification, daily backups of the working database provide a crude means of restoring data to the previous day's state. After certification, all data edits in the master database are tracked in an edit log so that future data users will be aware of changes made after certification. In case future users need to restore data to the certified version, we also retain a separate, read-only copy of the original, certified scanned data for each year in the PACN Digital Library.

Data certification is a benchmark in the project information management process that indicates that the data are complete for the period of record, have undergone and passed QA/QC checks and are appropriately documented and in a condition for archiving, posting and distribution. Certification is not intended to imply that the data are completely free of errors or inconsistencies which may or may not have been detected during quality assurance reviews. To ensure that only quality data are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The aquatic ecologist is primarily responsible for completing a PACN Project Data Certification Form, available from the data manager. It is critical that data certification be done in a timely manner to prevent backlogs of data that need to be certified. Typically, this means certifying all data that was collected in the prior year, although this can be delayed, particularly when non-PACN lab analyses are still pending.

3.2.5. Geospatial data

The aquatic ecologist and GIS specialist will work together to review the surveyed coordinates and other geospatial data for accuracy. The purpose of this joint review is to make sure that geospatial data are complete and reasonably accurate, and to determine which coordinates will be used for subsequent mapping and field work.

3.3. Metadata Procedures

Data documentation is a critical step toward ensuring that data sets are usable for their intended purposes well into the future. This involves the development of metadata, which can be defined as structured information about the content, quality, condition, and other characteristics of a given data set, both tabular and spatial. Additionally, metadata provide the means to catalog and search among data sets, thus making them available to a broad range of potential data users. At the conclusion of the field season, the aquatic ecologist will be responsible for providing a completed, up-to-date metadata interview form to the data manager. The data manager and GIS specialist will facilitate metadata development by consulting on the use of the metadata interview form, by creating and parsing metadata records from the information in the interview form, and by posting such records to national clearinghouses.

3.4. Archival and Records Management

All project files should be reviewed, cleaned up, and organized by the aquatic ecologist on an annual or regular basis. Decisions on what to retain and what to destroy should be made following guidelines stipulated in NPS Director's Order 11D, which provides a schedule indicating the amount of time that the various kinds of records should be retained.

3.5. Data analysis and reporting

The primary objective of this protocol is to determine if the abundance of crustacean, mollusc, odonate, and fish species declines or increases over time within each pool. Due to extensive differences in animal communities and characteristics of each pool, only individual species within each pool will be examined. This will provide basic information on the status and trend of each species within a pool. It is possible that similar trends among species in different pools will be identified over time. This may allow for additional opportunistic or comparative analyses, but that is not the objective of this protocol.

Annual reporting to the parks will consist of a 1–5 page briefing that contains all available certified data for each species in each pool. The briefing will include one or more graphs for each of the eight pools that monitor the abundance of crustacean, fish, and mollusc species. Each graph will include species-specific abundance data from the pool of interest (additional graphs can be added if necessary for clarity; e.g., if too many species make the graph hard to read). For species with replicate samples within a pool (crustaceans, fish), standard deviation will be estimated on an annual basis, and graphs will be made to identify potential intra-annual patterns in variation. For those species with only one sample per year (e.g., molluscs), standard deviation will be pooled across all years. An example of such a graph using fictional data for pool 11 in KAHO (HA_Kaloko_011) is shown after the fourth year of data collection in Figure 5.

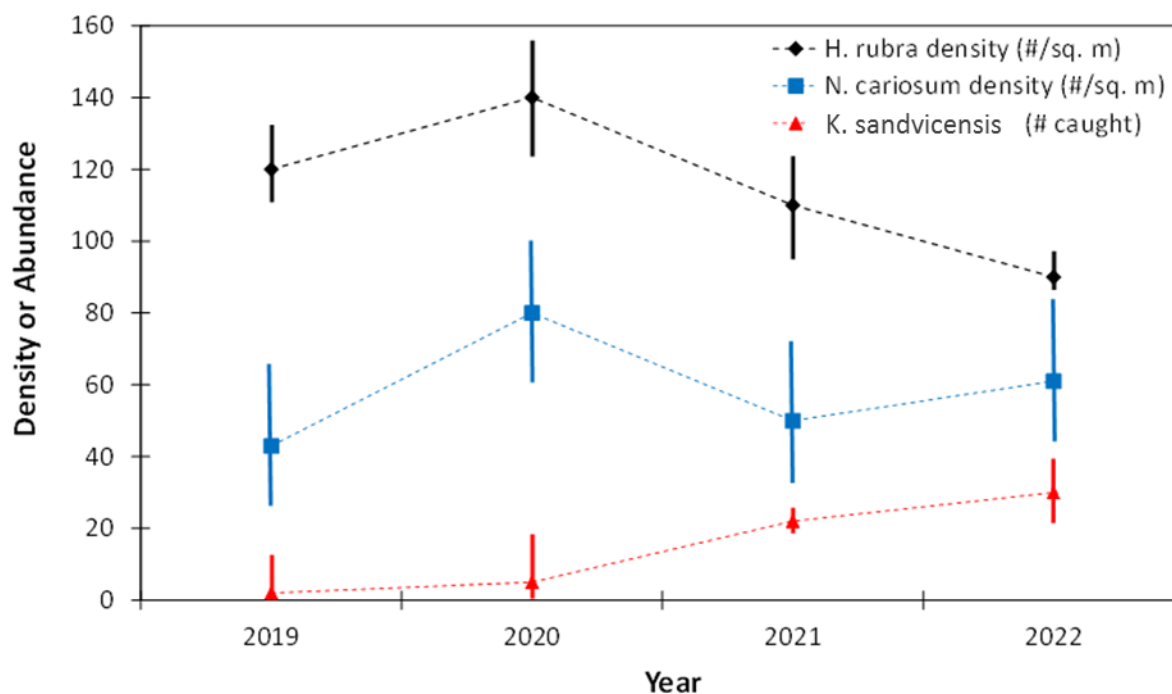


Figure 5. Example of how density or abundance ($\pm$ SD) results will be displayed in the annual briefing for this protocol; this example uses fictional data for species known to occur in HA_Kaloko_011.

Additional information that will always be included in the annual briefing includes: a summary of annual data collection efforts; status of data for each year collected to date (entered, verified,

certified); a table of raw count data for endangered orangeblack Hawaiian damselflies (*Megalagrion xanthomelas*) at the seven pools where they are consistently observed; notable issues observed during sampling; and any potential concerns regarding invasive or native species abundance (e.g., novel or lost species, sharp declines in abundance). Briefings will be reviewed and approved by the program manager, completed annually before the start of field work on this protocol, and uploaded to the NPS Integrated Resource Management Applications (IRMA) data system.

Statistical analyses will be limited to comparing species abundance within individual pools. This will be done using a z-test after five years to compare the first and fifth year of sampling for each species and within each pool. Additional comparisons can be made using data from years 1-10 as it becomes available; however, this should be done conservatively, as multiple comparisons will increase the potential for spurious statistical differences. Abiotic and biotic characteristics of pools will not be analyzed, but will be used to describe any notable changes that have been observed in the eight pools where anchialine pool animals are monitored.

The first trend report will be produced after 10 years of data collection as a Natural Resource Report (NRR) or journal publication. The primary focus of the trend report will be to summarize and examine all animal abundance data collected to date, including statistical tests for increases or decreases in the pools over time using z-tests; synthesis of the abiotic and biotic characteristics of each sampling site and any notable changes during the first decade; and a discussion of animal abundance stability or lack thereof and contributing factors to such observations. The NRR should also evaluate and recommend design, methodological, or analytical changes to be considered during subsequent reviews of the protocol.

Mitchell et al. (2018) provide protocol revision guidance. Operational reviews will be conducted before or in the first quarter of each calendar year (i.e., following completion of field work) and uploaded to IRMA. Operational reviews will document suggestions and decisions made to improve the protocol, deviations from the protocol, updated documents (SOPs), and plans to address safety concerns. At a minimum, a scientific review of the full protocol will occur following the first trend report (i.e., after 10 years of data collection). Although scientific reviews are not necessarily prescribed ahead of time, it is considered appropriate in this protocol due to the current logistical constraints of PACN, which limits the number of pools that can be sampled and the design that can be implemented. The lack of information on the variability of annual abundance estimates in anchialine pools, which prevents an understanding of statistical power, warrants scientific review as well. Ideally, the monitoring protocol will be expandable to other pools using a panel design. We can then begin to incorporate comparisons among pools and their abiotic and biotic characteristics to gain a fuller understanding of animal dynamics and contributing factors to observed population trends.

3.6. Protected Information

Some project information (e.g., the specific locations of rare or threatened taxa or other protected resources) should not be shared outside NPS, except where a written confidentiality agreement is in place. Requests for pool information should be made to the Chief of Integrated Resources at the respective park. Before preparing data in any format for sharing outside NPS, including in

presentations, reports, and publications, data users should refer to the guidance in SOP #28: Sensitive Information Procedures, and SOP #29: Product Posting and Distribution.

PACN will retain information on anchialine pool names, codes, and locations. Information that may reveal the specific location of sensitive resources or treatments should be screened or redacted from products meant for public consumption prior to release. The “PACN Restricted Document: anchialine pool coordinates and directions” is an internal NPS document that lists the locations of pools with coordinates and directions.

4. Operational Requirements

4.1. Facilities and Equipment

Facility support, office space, and supply requirements will be coordinated through the PACN program manager, in consultation with the aquatic ecologist. In some instances, parks will provide space for long-term storage of field gear.

4.2. Start-up Costs

Startup costs are enumerated separately from annual monitoring and related maintenance expenses. Startup costs for this protocol are relatively low, as costs related to hiring the lead field technician and water quality equipment are covered in other protocols (Brasher et al. 2011, Jones et al. 2011). Startup costs for this protocol include purchasing light-measuring equipment (~\$2500-3000), fish traps, materials for building shrimp traps, waterproof paper for data sheets, and miscellaneous supplies such as aerators, buckets and small dip nets (~\$1500). Total startup cost is expected to be less than \$5,000. Annually recurring fixed costs include equipment maintenance, salaries, training, certification, and travel-related expenses, almost all of which are shared among the anchialine pool animal, stream animal, and water quality protocols.

4.3. Annual Budget

Expenses are based on calculating the cost per day of staff with one technician stationed at HAVO and one technician stationed at KAHO (Table 4). Travel costs are based on the “Isle of Hawaii: other” per-diem category. Estimates are based on 2018 expenses and pay schedules. Expenses include salary (with COLA and benefits), travel, and supplies, all supported by base funding.

Table 4. Annual salary, travel, and supply expenses.

Staff	Daily salary (\$)	Prep work (days)	Full-rate Travel (days)	In-transit Travel (days)	Data & Report Tasks (days)	Non-travel field (days)	Total work (days)	Total Salary(\$)	M&IE full rate (\$) ^{1,2}	M&IE in transit (\$) ^{1,3}	Lodging (\$) ^{1,4}	Total Travel (\$)	Total costs (\$) ⁵
Program Manager (GS-13)	547	1	0	0	4	0	5	2,735	0	0	0	0	2,735
Aquatic Ecologist (GS-11)	396	0	3	2	12	0	17	6,732	483	242	916	1,641	8,373
Data Manager (GS-11)	402	0	0	0	13	0	13	5,226	0	0	0	0	5,226
Lead Biotech (GS-9)	284	2	6	4	8	0	18	5,112	966	483	1134	2,583	7,695
Aquatic/ Marine Biotech (GS-9)	270	2	0	0	8	12	22	5,940	0	0	0	0	5,940
Grand total (\$)												30,469	

¹ "Isle of Hawaii: other" travel allowance.

² \$161 M&IE.

³ 75% of full M&IE rate.

⁴ \$189 + tax and fees (~40) = \$229.

⁵ Grand total includes an additional \$500 for annual supplies.

5. Personnel Requirements and Training

5.1. Training Overview

Training can be divided into safety, field, and data management. Primary training requirements apply to all PACN staff and include operational leadership training, first aid and CPR, and knowledge of the PACN safety plan and all associated safety documents. Wilderness first aid or wilderness first responder are highly recommended for staff that are frequently in the field. The PACN program manager and aquatic ecologist are responsible for ensuring that all aspects of the safety plan are fully implemented and all staff are appropriately trained and versed in the network safety approach before starting field work.

Field training requirements are outlined in SOP #2 and focus on species identification and data collection methodologies. The PACN aquatic ecologist and lead aquatic biological science technician are responsible for ensuring that staff can accurately identify species and correctly implement data collection methods in the field. Data management requirements are covered in SOPs #23 and #24. The PACN data manager and aquatic ecologist are responsible for ensuring that each staff member has the appropriate level of training. In particular, the lead aquatic biological science technician should be capable of training field staff in data entry and verification; all field staff should be trained in data entry and verification, and the aquatic ecologist should understand and carry out data certification activities.

5.2. PACN Aquatic Ecologist

The PACN aquatic ecologist is responsible for successfully implementing the protocol and serves as the primary liaison with parks working to ensure that monitoring efforts address park management needs in a safe and effective manner. The aquatic ecologist is responsible for acquiring state and federal science permits, ensuring that all safety training required for field crews is completed, and that all safety policies and procedures are clearly communicated and followed by field crews (SOP #1). The aquatic ecologist works in the office and field as needed to ensure that the lead aquatic biological science technician is trained and capable of training others in the field methods associated with this protocol (SOP #2). When present, the aquatic ecologist will be the field lead during sampling activities. The PACN aquatic ecologist works with the PACN data manager and field lead to ensure proper data management and timely data entry, validation, certification, analysis, and archiving. The aquatic ecologist works with the PACN data manager to ensure that the data management needs of the protocol are met, that data products are available according to schedule, and that any required edits to archived data are documented according to network standards.

The aquatic ecologist is responsible for all PACN programmatic reporting including annual briefings and trend reports and publications. Researchers from universities and other agencies may assist in data analysis and reporting activities. Each year, the program manager, aquatic ecologist, and field lead will conduct an operational review and upload to IRMA (Mitchell et al. 2018). The aquatic ecologist will communicate budget and other program needs to the PACN program manager.

5.3. Lead Aquatic Biological Science Technician

The lead aquatic biological science technician for PACN (i.e., lead biotech) is responsible for field implementation activities, including logistical coordination, equipment preparation and maintenance oversight, data verification, and training staff in field safety, data collection, entry, and verification activities (SOPs #1, #2, and #23). In general, the lead biotech will be the daily field lead for field data collection

efforts. The lead biotech will keep the aquatic ecologist informed of the sampling schedule, progress, and potential concerns or issues; and will travel to each of the parks to lead, conduct, and train other staff in field activities. The lead field technician also assists the PACN aquatic ecologist in overall project coordination, data management and quality assurance, basic data analysis, and assistance with annual reporting. Data will be entered into an established database and/or verified by the lead field technician, other PACN biological science technicians or data staff, or other trained park staff.

In order to complete visual animal population surveys, field staff must be able to rapidly identify and enumerate crustacean, odonate, mollusc and fish species that occur in and around anchialine pools. This requires field staff to be able to discern behavioral characteristics as well as key physical attributes that distinguish species that may require use of a hand lens. The lead biotech will ensure field staff are familiar with the identification guides in the SOPs associated with this protocol and provide on-site training until field staff are capable of carrying out identification duties without direct oversight (SOPs # 13, 15-17, and 19).

5.4. Park-Based NPS Staff

When available, park staff are encouraged to assist PACN with equipment needs, field logistics, and when trained, protocol implementation and data collection. In some cases, park staff may be trained to conduct monitoring independently of PACN staff due to fiscal or scheduling constraints. Park staff are responsible for communicating park-specific safety concerns, safety plans, communication plans, or other special procedures to the PACN aquatic ecologist or lead biotech.

5.5. PACN Data Manager

The PACN data manager will provide guidance, training, and assistance with data management, archiving, adaptive database design, maintenance, database 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 PACN aquatic ecologist and lead field technician to ensure they meet programmatic and vital sign standards and needs. The aquatic ecologist works with the PACN data manager to ensure that the data management needs of this protocol are met, that data products are made available according to schedule, and that any required edits to archived data are documented according to network standards.

5.6. PACN GIS Specialist

The PACN GIS specialist will provide park maps with geo-referenced sampling locations to field crews prior to field sampling. The PACN GIS specialist will also be responsible for training staff as needed in the use of GPS equipment (SOPs #8-10) and generating spatial representations of geo-referenced site data for reports and presentations.

5.7. PACN Program Manager

The PACN program manager will be responsible for safety and technical oversight of the anchialine pool monitoring protocol and peer review management of reports. Oversight includes review and approval of briefing materials and reports, decisions regarding allocation of funds and staffing plans, ensuring the PACN safety plan is followed, and the overall quality and performance of the PACN aquatic ecologist. The program manager is responsible for bringing any general issues beyond the scope of the responsibilities of the PACN

aquatic ecologist to the PACN steering committee and board of directors and regional program manager for the IMD program.

5.8. NPS Volunteers

NPS volunteers will provide support for field implementation activities when necessary. The PACN aquatic ecologist and lead field technician will determine how many volunteers are needed and at what time to complete field implementation. The PACN aquatic ecologist will coordinate appropriate sign-up procedures and supervise volunteers. However, it may be necessary for the lead field technician to provide direct supervision in the field. Volunteers will provide assistance with protocol data collection as well as data entry and management under the supervision of the lead field technician.

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Appendix A: 2010 Anchialine Pool Survey

February 23, 2010 – March 25, 2010

General Description

A total of five anchialine pools were surveyed at Halape located in Hawai'i Volcanoes National Park on Hawai'i Island. Pools were surveyed at high and low tides during the day and night. Surveys consisted of time intervals of 15, 30, and 60 minutes. Three types of quadrats were tried: .5m x .5m squares and 1.77m circles both made of plastic coated wire and 1.77m circles made of mason string. The mason string was not effective because when placed in water it was unable to form a circle; however, both wire squares and circles were effective quadrats. Quadrats were placed in pools by using random polar coordinates and targeted areas. In pools big enough to only fit one quadrat inside, a targeted area was chosen for quadrat placement. Five different types of bait were placed in the center of each quadrat for the allotted time interval. Bait used were: coconut, dried cat food, dried fish, dried seaweed, and nothing. After the allotted time interval, a photo of each quadrat was taken using a monopod at the edge of the quadrat. The photos were later uploaded on a PC to identify shrimp species and count individuals. The circumference of each pool was measured every time as well as a photo of the surface area was taken from the same location and height. These photo locations were marked with a GPS.

Equipment Used

- Olympus Stylus Tough-8000 camera
- Camera housing
- Cannon Tripod extension of 5 ft.
- 1.77m circle and .5m square plastic coated wire quadrats
- 1.77m circle Mason line quadrats
- 100 ft. transect tape
- Large metal sizing rods marked every 10 cm
- Small sizing rods marked every 1 cm
- Compass
- Metal label plate
- Monopod
- Random Polar Coordinate sheet
- GPS
- Weighted plastic mesh (bait holder)
- Tent rain fly, umbrella, tarp (reduce sun glare)
- Flagging

Week 1: February 23-26

February 23, 2010

Survey Components

Tide: Low

Bait: Dried seaweed

Time Interval: 30 min

Time: Day

Description: The first pool was completely dried so only a photo of the area was taken. At the second pool surveyed, mason line and wire quadrats were tried. The mason line quadrat was unsuccessful because it could not form a circle when placed in water. Two square and two circle plastic coated wire quadrats were successfully used. The dried seaweed was also successful and attracted shrimp. The sun set before the 30 minute interval was complete, making the survey no longer during the day. Photos were taken after the allotted time interval but were not successful due to the flash going off and emitting a white spot inside the quadrat. The flash also refracted the light under the water and particulate matter was shown on the photo. Several types of settings on the camera were used, but none were very effective.

February 24, 2010

Survey Components

Tide: High

Bait: Dried cat food

Time Interval: 15 min

Time: Day

Description: All five pools were surveyed. Plastic coated wire square and circle quadrats were used, and the dried cat food was successful. All pools experienced major sun glare reflecting off of the water. KAPAPA007 contains about 90% canopy cover of *Thespesia populnea* (milo), resulting in an abundance of leaf litter and debris. This adds another challenge for photographing the quadrat, because the leaf litter and debris float on the surface of the pool. Furthermore, there is a high amount of decomposition occurring, which causes turbidity when working in the pool. KAPAPA006 had crabs steal the entire bait and bait holders. At KAPAPA001, no bait was used due to *Macrobrachium* lar (Tahitian prawn) stealing the bait from previous surveys. It took over five hours to complete a survey of all five pools. This time span is of concern due to performing the surveys at specific tide levels. Moreover, the next survey was not conducted due to there not being enough time between surveys. To account for this, for every survey thereafter, random pools were selected. The number of pools selected for each survey varied on time of day, tidal level, and length of survey time interval. Another challenge was trying to place the small sizing rods next to the quadrat. The pools are filled with uneven rocks and in many circumstances the small sizing rods fell away from quadrats. Therefore, every 1 cm was marked on sections of each quadrat and the small sizing rods were eliminated.

February 25, 2010

Survey Components

Tide: Low

Bait: Dried Seaweed

Time Interval: 15 min

Time: Day

Description: To maximize effort, the two pools surveyed, KAPAPA002 and KAPAPA003, which are located in close proximity to each other, were able to have some components of both pools surveyed within one allotted time interval. One issue with KAPAPA004 is that during certain low tides, this pool is only big enough to fit one targeted quadrat inside it. Again major sun glare reflecting off the water made it difficult to photograph the quadrats. One technique to minimize sun glare was holding a tent rain fly over the pool. However, this was unsuccessful because the rain fly was too transparent.

Survey Components

Tide: Low

Bait: None

Time Interval: 60 min

Time: Night

Description: KAPAPA001 was the only pool surveyed. Six plastic coated wire quadrats both circles and squares were placed in the pool. No bait was used during this survey. The large sizing rods were difficult to see in the surface area photos. This was corrected by marking the rods with blue and orange flagging every 10cm. The photos of the quadrats were much clearer than during the day. However, the flash still produces a white spot in the quadrat and refracts light. Also the metal label plate absorbs the flash, washing out the label and making it unable to read.

February 26, 2010

Survey Components

Tide: High

Bait: None

Time Interval: 30 min

Time: Day

Description: Three pools were surveyed. The tide was significantly higher than previous high tides therefore for KAPAPA006 the location of the surface area photo was relocated. By the time the last pool was surveyed, KAPAPA002, a time span of two hours had passed from the time of the high tide. Again the sun glare made it difficult even when using a tent rain fly to minimize the glare.

Survey Components

Tide: Low

Bait: Dried fish

Time Interval: 15 min

Time: Night

Description: Two pools were surveyed. KAPAPA003 was only able to fit one plastic coated wire square quadrat inside it. The dried fish was successful because it attracted shrimp. When the entire survey was completed, one hour had passed after the time of the low tide. Again, the photos were clearer at night than daytime, but the flash still created the same problems.

Week 2: March 1-5

March 1

Survey Components

Tide: High

Bait: Dried cat food

Time Interval: 30 min

Time: Day

Description: KAPAPA003 was the only pool surveyed due to the wind blowing so hard the water in the pools was constantly moving. The water movement made it impossible to see below the surface of the water, therefore photographing the quadrats was unsuccessful. The wind was so strong that the night survey was not conducted due to safety concerns and poor quality of quadrat photos.

March 2

Survey Components

Tide: Low

Bait: Dried seaweed

Time Interval: 60 min

Time: Day

Description: Two pools were surveyed. At KAPAPA001 the bait was tied down to rocks preventing the *Macrobrachium lar* to steal it from the quadrat. This method worked well enabling bait being used at this pool. Again the wind was extremely strong and the sun glare created poor quality photos of the quadrats.

Survey Components

Tide: High

Bait: Coconut

Time Interval: 60 min

Time: Day

Description: Only KAPAPA006 was surveyed due to the sun setting. The survey was cut short 30 minutes in order to keep it a daytime survey. Coconut is a very successful type of bait attracting

several *Halocaridina spp.* The same problems with the leaf litter, debris, and decomposition as well as the sun glare remain in effect. These factors also affect the visualization of the metal label plate.

March 3

Survey Components

Tide: High

Bait: Dried fish

Time Interval: 60 min

Time: Night

Description: This survey again was cut short due to the sun rising. Therefore, only one pool could be surveyed. When selecting the survey times correlating with the tides, the time interval of the survey was not accounted for. This later resulted in having some surveys being cut short to keep the time of day effective.

Week 3: March 8-11

March 8

Survey Components

Tide: Low

Bait: Dried cat food

Time Interval: 15 min

Time: Day

Description: Pools KAPAPA005 and KAPAPA003 were surveyed. A tarp was used to successfully minimize the sun glare. However, the wind was strong again resulting in surface water movement and poor quality photos. Again, in pool KAPAPA006 crabs stole the bait holders. In the future bait should be tied down to rocks. Photo quality was best at KAPAPA003 because its location is more sheltered from the wind.

March 9

Survey Components

Tide: High

Bait: Dried cat food

Time Interval: 15 min

Time: Night

Description: Only KAPAPA001 was surveyed. The bait was tied down to rocks however, *Macrobrachium lar* were able to get the bait holder out from under the string. The photo quality was a little better due to decrease in wind. The flash is still causing previous problems.

Survey Components

Tide: Low

Bait: Dried fish

Time Interval: 30 min

Time: Day

Description: The survey was started five minutes before low tide in order to complete the full survey before sunset. KAPAPA003 and KAPAPA002 were surveyed. Again KAPAPA003 only had enough area to put in one targeted quadrat. There was minimal sun glare present because the pools were shadowed due to time of day.

March 10

Survey Components

Tide: High

Bait: Nothing

Time Interval: 60 min

Time: Night

Description: KAPAPA006 was surveyed and the *Thespesia populnea* provided shelter from the wind. There were no shrimp observed in the quadrats. Turbidity was high again causing poor visualization of the quadrat and metal label plate.

Survey Components

Tide: Low

Bait: Nothing

Time Interval: 60 min

Time: Night

Description: Two pools were surveyed and the same previous problems with the flash and wind occurred during this survey. Again, to maximize efforts some components were surveyed in both pools during one time interval.

March 11

Survey Components

Tide: High

Bait: Coconut

Time Interval: 30 min

Time: Night

Description: KAPAPA001 was the only pooled surveyed. The wind and the flash created poor photos.

Survey Components

Tide: Low

Bait: Coconut

Time Interval: 30 min

Time: Day

Description: Two pools were surveyed. In KAPAPA001 it was challenging to minimize sun glare, because the pool is so large. The wind was also factor, but KAPAPA002 was more sheltered from the wind. The tarp was used to minimize sun glare. There were significant amounts of shrimp observed in KAPAPA002.

Survey Components

Tide: Low

Bait: Dried cat food

Time Interval: 15 min

Time: Night

Description: Two pools were surveyed. Once again, only one targeted quadrat fit in KAPAPA003. It may be more effective to survey this pool at higher tides. There was a significant amount of shrimp observed in KAPAPA002. The photos taken for this survey were better quality. The same problems occur with the flash and metal label plate. In the future, try the camera in the housing to see if the housing diffuses intensity of the white spot from flash.

Week 4: March 22- 25

March 22

Survey Components

Tide: Low

Bait: Nothing

Time Interval: 60 min

Time: Day

Description: Two pools were surveyed. Only one quadrat fit in KAPAPA003. A polarized lens was used to try to minimize sun glare, but was not effective. The best method still is using a tarp to block out the sun. Shrimp were counted, identified, and sized after allotted time intervals, by using a snorkel mask. Close up photos of individual shrimp were also taken. This addition is very effective of surveying the pools instead of just taking a full sized photo of individual quadrats.

Survey Components

Tide: High

Bait: dried fish

Time Interval: 15 min

Time: Night

Description: KAPAPA006 was surveyed. The photos were not effective due to the water being very turbid from the mud. No shrimp were observed in two of the quadrats, but a small brown eel was observed in the pool.

March 23

Survey Components

Tide: Low

Bait: dry cat food

Time Interval: 60 min

Time: Day

Description: Three pools were surveyed. In pool KAPAPA005 crabs took bait in one quadrat even though it was tied down to a rock. During late afternoon surveys for KAPAPA002 a dive light should be used when counting, sizing, and identifying shrimp due to the lack of sunlight in cave section.

Survey Components

Tide: High

Bait: seaweed

Time Interval: 15 min

Time: Night

Description: KAPAPA001 was the only pool surveyed. It was extremely windy which made the water ripple and photo quality was poor. Only one *M. lar* and one *P. debilis* were observed after the allotted time interval.

March 24

Survey Components

Tide: Low

Bait: dried fish

Time Interval: 60 min

Time: Day

Description: Two pools were surveyed. Again KAPAPA003 was very dark and a dive light is needed to count, size, and identify the shrimp.

March 25

Survey Components

Tide: High

Bait: seaweed

Time Interval: 30 min

Time: Night

Description: KAPAPA003 was surveyed due to extreme wind; this pool is the most sheltered. It is also more effective to survey this pool at a high tide due to being able to place more than one targeted quadrat in the pool.

Survey Components

Tide: High

Bait: dried fish

Time Interval: 15 min

Time: Day

Description: KAPAPA006 and KAPAPA005 were surveyed. KAPAPA006 was significantly smaller than before at high tide. One polar quadrat was completely out of the water. No shrimp were observed. Again there was a strong wind and the quadrat photos were poor.

Week 5: March 29-April 02

March 29

Survey Components

Tide: High

Bait: seaweed

Time Interval: 30 min

Time: Day

Description: KAPAPA001 was surveyed. Plants surrounding the pool include Kou tree (*Cordia subcordat*), Sour bush (*Pluchea carolinensis*), and Swordfern (*Nephrolepis spp.*) creating a 30% canopy cover. Again there was a strong wind, creating surface water movement and poor quality photos.

Survey Components

Tide: Low

Bait: Nothing

Time Interval: 30 min

Time: Night

Description: KAPAPA003 was surveyed, because it is the most sheltered pool. Again, it was extremely windy. Due to the low tide, only one targeted quadrat was placed in pool.

March 30

Survey Components

Tide: High

Bait: coconut

Time Interval: 30 min

Time: Day

Description: KAPAPA006 and KAPAPA005 were surveyed. The wind was strong again, creating poor quality photos. At KAPAPA006, there was a substantial amount of leaf litter and mud. Some photos were not taken due to the turbidity of the water.

Survey Components

Tide: Low

Bait: dry cat food

Time Interval: 60 min

Time: Night

Description: Experiment not conducted due to extremely high winds. It seems like the month of March is not a good month to monitor coastal pools due to weather conditions. Experiment was later conducted on April 12, 2010.

March 31

Survey Components

Tide: High

Bait: seaweed

Time Interval: 15 min

Time: Day

Description: KAPAPA003 and KAPAPA002 were surveyed. The tide was significantly higher than normal, making it impossible to get to the back wall in KAPAPA002.

Survey Components

Tide: Low

Bait: Nothing

Time Interval: 15 min

Time: Night

Description: KAPAPA001 was surveyed. The wind finally died and the photos were of better quality. *M. lar* were observed in every quadrat, but by the time the photo was taken only few remained.

April 1

Survey Components

Tide: Low

Bait: Coconut

Time Interval: 60 min

Time: Day

Description: KAPAPA003, KAPAPA005, and KAPAPA002 were surveyed. Tide was very low. In fact, some polar quadrats were out of the water. *M. grandimanus*, *H. rubra*, *P. debilis*, and *M. lohena* were found in pool KAPAPA002, and a small fish was observed in KAPAPA005.

April 2

Survey Components

Tide: Low

Bait: dry cat food

Time Interval: 30 min

Time: Night

Description: KAPAPA002 was surveyed. There were many shrimp observed in the pool. *M. grandimanus*, *H. rubra*, *P. debilis*, and *M. lohena* were found in pool.

Week 6: April 05-09

April 5

Survey Components

Tide: High

Bait: dried fish

Time Interval: 30 min

Time: Night

Description: KAPAPA003 was surveyed. *M. grandimanus* was interested in the dried fish bait, while *H. rubra* were inactive in the pool.

April 6

Survey Components

Tide: High

Bait: dried fish

Time Interval: 30 min

Time: Day

Description: KAPAPA005 and KAPAPA003 were surveyed. In KAPAPA005 there were many *M. grandimanus*. In KAPAPA003 there were *H. rubra* and *M. grandimanus*. Again, *H. rubra* were not interested in the bait.

Survey Components

Tide: High

Bait: Coconut

Time Interval: 15 min

Time: Night

Description: KAPAPA002 was surveyed. *M. lohena*, *M. grandimanus*, and *H. rubra* were observed in the pool.

April 7

Survey Components

Tide: High

Bait: Nothing

Time Interval: 60 min

Time: Day

Description: KAPAPA001 and KAPAPA002 were surveyed. In KAPAPA001 *P. debilis* and *M. lar* were observed. In KAPAPA002 *M. lohena*, *M. grandimanus*, and *H. rubra* were observed in the pool. Only surveyed two pools due to heavy rain

April 8

Survey Components

Tide: High

Bait: dry cat food

Time Interval: 60 min

Time: Night

Description: KAPAPA001 was surveyed. Only one quadrat had *M. lar* observed in it. 60 minutes might be too long of a time interval.

Survey Components

Tide: High

Bait: nothing

Time Interval: 15 min

Time: Day

Description: KAPAPA006 and KAPAPA005 were surveyed. Nothing was observed in KAPAPA006. However, the pool was extremely low and there were a lot of leaves and sticks in the pool. In KAPAPA005 *P. debilis* were observed in two quadrats.

Survey Components

Tide: Low

Bait: Coconut

Time Interval: 30 min

Time: Night

Description: KAPAPA005 and KAPAPA003 were surveyed. In KAPAPA005 *M. grandimanus* were observed on the bait. In KAPAPA003 *M. grandimanus* and *H. rubra* were observed.

April 9

Survey Components

Tide: High

Bait: dry cat food

Time Interval: 30 min

Time: Night

Description: KAPAPA003 was surveyed. *M. grandimanus* were observed on the bait, while *H. rubra* were foraging on the rocks.

Week 7: April 12-16

April 12

Survey Components

Tide: High

Bait: seaweed

Time Interval: 60 min

Time: Day

Description: KAPAPA002 and KAPAPA003 were surveyed. In KAPAPA003 *H. rubra* were observed. However, in the polar quadrat the bait was in the water in the beginning of experiment, but after 60 minutes the bait was out of the water. In KAPAPA002 *H. rubra* and *M. lohena* were observed. *M. lohena* was observed foraging on seaweed bait.

Survey Components

Tide: Low

Bait: dried fish

Time Interval: 60 min

Time: Night

Description: KAPAPA001 was surveyed. *M. lar* and *H. rubra* were observed in the same shallow quadrats.

Survey Components

Tide: High

Bait: dry cat food

Time Interval: 60 min

Time: Night

Description: This experiment was done to make up the experiment that was not conducted on March 30, 2010. KAPAPA002 was surveyed. *M. grandimanus*, *M. lohena*, and *H. rubra* were observed in pool.

April 13

Survey Components

Tide: High

Bait: dried fish

Time Interval: 60 min

Time: Day

Description: KAPAPA005 and KAPAPA003 were surveyed. In KAPAPA005 *P. debilis* and *M. grandimanus* were observed on the bait. In KAPAPA003 *H. rubra* and *M. grandimanus* were observed in pool.

Survey Components

Tide: Low

Bait: Coconut

Time Interval: 60 min

Time: Night

Description: KAPAPA005 was surveyed. A goby was observed in targeted square quadrat. *M. grandimanus* were observed on the coconut bait.

April 14

Survey Components

Tide: High

Bait: coconut

Time Interval: 15 min

Time: Day

Description: KAPAPA003 and KAPAPA006 were surveyed. Only two pools were surveyed due to the setting sun. In KAPAPA006 *M. lohena* and *H. rubra* were observed. *M. lohena* was observed on coconut bait. Some photos were not taken due to turbidity and leaf litter of the water column. In KAPAPA003 *P. debilis*, *M. grandimanus*, and *H. rubra* were observed.

Survey Components

Tide: Low

Bait: coconut

Time Interval: 15 min

Time: Night

Description: KAPAPA001 was surveyed. Only identification, count, and size were done. It was too windy for photos. Two baits were missing by the end of the experiment. Again, *M. lar* and *H. rubra* were observed in the same quadrat.

April 15

Survey Components

Tide: Low

Bait: nothing

Time Interval: 15 min

Time: Day

Description: KAPAPA005, KAPAPA003, KAPAPA002, and KAPAPA001 were surveyed. In KAPAPA005 *P. debilis* were observed and a large fish. In KAPAPA003 *H. rubra* were observed in abundance. The water level in the pool was extremely low. In KAPAPA002 *M. lohena* and *H. rubra* were observed in pool. In KAPAPA001 only *H. rubra* were observed.

Survey Components

Tide: Low

Bait: seaweed

Time Interval: 30 min

Time: Night

Description: KAPAPA002 was surveyed. *M. grandimanus* and *P. debilis* were observed in pool.

Week 8: April 19-21

April 19

Survey Components

Tide: High

Bait: nothing

Time Interval: 15 min

Time: Night

Description: KAPAPA003 was surveyed. Only *H. rubra* were observed in quadrats.

April 20

Survey Components

Tide: Low

Bait: dried fish

Time Interval: 30 min

Time: Night

Description: KAPAPA001 was surveyed. Only *M. lar* was observed in one quadrat. Also, the wind was strong, producing poor quality photos.

Survey Components

Tide: Low

Bait: Coconut

Time Interval: 15 min

Time: Day

Description: KAPAPA005, KAPAPA003, KAPAPA002, and KAPAPA001 were surveyed. In KAPAPA005 a snail was seen. Also *P. debilis* and *M. grandimanus* were observed. In KAPAPA003 the water level was really low. Only *H. rubra* was observed in pool. In KAPAPA002 *M. lohena*, *M. grandimanus*, and *H. rubra* were observed in pool. In KAPAPA001 only *P. debilis* was observed.

Survey Components

Tide: High

Bait: nothing

Time Interval: 30 min

Time: Night

Description: KAPAPA001 was surveyed. *H. rubra* were observed in the same quadrat as *M. lar*.

April 21

Survey Components

Tide: Low

Bait: Seaweed

Time Interval: 15 min

Time: Night

Description: KAPAPA002 was surveyed. *M. grandimanus*, *M. lohena*, and *H. rubra* were observed in pool.

May 4, 2010- May 13, 2010

General Description

A total of five anchialine pools at Pu'uhonua o Honaunau National Historical Park were surveyed. Pools were surveyed at high and low tides during the day. Surveys consisted of time intervals of 15 and 30 minutes. Two types of quadrats were used: .5m x .5m squares and 1.77m circles both made of plastic coated wire. Quadrats were placed in pools by using random polar coordinates and targeted areas. Targeted areas were determined by shrimp activity. In pools big enough to fit only one quadrat inside, a targeted area was chosen for quadrat placement. Three different types of bait were placed in the center of each quadrat for the allotted time interval. Baits used were: coconut, dried cat food, and nothing. After the allotted time interval, shrimps were identified by species, size, and quantity and a photo of each quadrat was taken using a monopod at the edge of the quadrat. The photos were later uploaded on a PC to verify identification and quantity of shrimp species. The circumference of each pool was measured every time, as well as photographs of the surface area were taken from four different locations and heights of the tripod were recorded for each photo point. These photo locations were marked with a GPS. See pool descriptions for pool names and locations.

Equipment Used

- Olympus Stylus Tough-8000 camera
- Cannon Tripod extension of 5 ft.
- 1.77m circle and .5m square plastic coated wire quadrats
- 100 ft. transect tape
- Large metal sizing rods marked every 10 cm
- Compass
- Metal label plate
- Monopod
- Random Polar Coordinate sheet
- GPS
- Mason Line
- Weighted plastic mesh (bait holder)
- Tarp (reduce sun glare)

Week 1: May 4- 7 2010May 4, 2010*Survey Components***Tide:** Low**Bait:** Coconut**Time Interval:** 15 min**Time:** Day**Description:** All five pools were surveyed (see pool description sheet for names).

HA_HONAUN_003 and HA_HONAUN_004 are pools with tilapia. These two pools in particular have a lot of fish feces, making it hard to see the quadrats at the bottom of the pool. Also, the bait had to be tied to the quadrats so fish would not steal the bait. No shrimp were observed in either of these pools. HA_HONAUN_005 and HA_HONAUN_007 were both dry due to the low tide. Overall pool photos were taken of vegetation for plant encroachment survey. HA_KEOKEA_003 pool is only big enough to lower, using mason line, one square quadrat into the pool. *Halocaridina rubra* and *Metabetaeus lohena* were observed in many numbers in the pool and on the bait.

May 5, 2010*Survey Components***Tide:** High**Bait:** Nothing**Time Interval:** 15 min**Time:** Day

Description: All five pools were surveyed. No shrimp were observed in either HA_HONAUN_003 or HA_HONAUN_004. HA_HONAUN_005 had very little water present. Therefore, only one quadrat was able to fit into the pool and no shrimp were observed at this low of a high tide in the pool. HA_HONAUN_007 had no water. HA_KEOKEA_003 had many *H. rubra* and *M. lohena*.

*Survey Components***Tide:** Low**Bait:** Cat food**Time Interval:** 30 min**Time:** Day

Description: All five pools were surveyed. Again, no shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. The fish in these two pools ate most of the bait in the allotted 30 minutes. Also, HA_HONAUN_005 and HA_HONAUN_007 had no water in the pools. However, at pool HA_KEOKEA_003 there were many *M. lohena* (50) and *H. rubra* (25) observed. Furthermore, there was a mass of shrimp on the bait sack and the pool was extremely low (<.30 m).

May 6, 2010*Survey Components***Tide:** High

Bait: Coconut

Time Interval: 15 min

Time: Day

Description: All five pools were surveyed. Again no shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. The fish were observed eating the coconut. HA_HONAUN_005 had only one *H. rubra* in the quadrat. In HA_HONAUN_007 there was only one *H. rubra* observed. However, there were numerous (~25) outside the quadrats around the cave. In HA_KEOKEA_003 there were *M. lohena* and *H. rubra* observed on the bait and in the pool.

Survey Components

Tide: Low

Bait: Cat food

Time Interval: 15 min

Time: Day

Description: All five pools were surveyed. There was not that much tidal difference between high and low tides. Therefore, there was not a huge difference in pool surface area and depth. Again no shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. HA_HONAUN_005 had very little water in it. Only a few *H. rubra* were observed. There was no water in pool HA_HONAUN_007. In HA_KEOKEA_003 there were many *M. lohena*(40) and *H. rubra*(25) observed on the bait and in the pool.

May 7, 2010

Survey Components

Tide: Low

Bait: Nothing

Time Interval: 30 min

Time: Day

Description: All five pools were surveyed. No shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. HA_HONAUN_005 and HA_HONAUN_007 had no water in the pools. HA_KEOKEA_003 even at extremely low tides (.1m) has many *H. rubra* and *M. lohena* in the pool.

Survey Components

Tide: High

Bait: Nothing

Time Interval: 30 min

Time: Day

Description: All five pools were surveyed. No shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. *H. rubra* (~30) were observed in pool HA_HONAUN_005. Tide was considerable higher. In HA_HONAUN_007 there were *H. rubra* observed in the pool. Again, HA_KEOKEA_003 had numerous *H. rubra* and *M. lohena* in the pool.

Week 2: May 10-13 2010

May 10, 2010

Survey Components

Tide: High

Bait: Cat food

Time Interval: 30 min

Time: Day

Description: All five pools were surveyed. No shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. HA_HONAUN_005 had a lot more water than normal. It seemed like the tides were more drastic, probably from the new moon. There were around 150 *H. rubra* between two quadrats placed in the pool. Also, there were many more rubras observed outside the quadrat. As well, HA_HONAUN_007 had over 120 *H. rubra* among four quadrats. Also, snails were observed on the bait sack. *M. lohena* was observed in the pool, but was not present in the quadrats at the end of the time interval. HA_KEOKEA_003 had many sizes of *M. lohena* ranging from 1cm to 2cm that totaled around 40 individuals in the quadrat. *H. rubra* was observed as well.

May 11, 2010

Survey Components

Tide: Low

Bait: Nothing

Time Interval: 15 min

Time: Day

Description: All five No shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. Again, there was no water in either HA_HONAUN_005 or HA_HONAUN_007. There was very little water (.07m) in HA_KEOKEA_003 and only a few *H. rubra* and *M. lohena* were observed in the pool.

Survey Components

Tide: High

Bait: Cat food

Time Interval: 15 min

Time: Day

Description: All five pools were surveyed. No shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. However, in HA_HONAUN_004 crabs were observed. HA_HONAUN_005 had a lot of water that the akulikuli was now in the pool. *H. rubra* was observed on the bait. In HA_HONAUN_007 there were many (~150) *H. rubra* observed in the pool. In HA_KEOKEA_003 there were *H. rubra* (75) and *M. lohena* (20) observed in the pool.

May 13, 2010

Survey Components

Tide: Low

Bait: Coconut

Time Interval: 30 min

Time: Day

Description: All five pools were surveyed. No shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. Again, there was no water in either HA_HONAUN_005 or HA_HONAUN_007. Only one *H. rubra* was observed in HA_KEOKEA_003.

Survey Components

Tide: High

Bait: Coconut

Time Interval: 30 min

Time: Day

Description: All five pools were surveyed. No shrimp were observed in HA_HONAUN_003 and HA_HONAUN_004. HA_HONAUN_005 had large amounts (120) of *H. rubra* in pool. Also, there were a few *H. rubra* observed carrying off dead rubras. *H. rubra* were observed in HA_HONAUN_007 and snails were present on the bait again. In HA_KEOKEA_003 there were many lohenas and rubras observed on the bait and in quadrat.

Appendix B: Database Documentation

The database for this project consists of four types of tables: core tables describing the “who, where, and when” of data collection, project-specific tables, lookup tables that contain domain constraints for other tables, and cross reference tables that link lookup tables with data tables. Although core tables are based on PACN standards, they may contain fields, domains or descriptions that have been added or altered to meet project objectives.

Table B1. List and description of the standard tables used in the protocol database.

Table Name	Description
tbl_Sites	Sample sites – individual parks
tbl_Locations	Sample unit locations – anchialine pools
tbl_Events	Sampling events

Table B2. List and description of the data tables used in the protocol database.

Table Name	Description
tbl_Alt_Pool_Names	Lists the LocationID for each pool and any other alternate names given for the same pool, and the originator of the name.
tbl_Habitat	Habitat description of the anchialine pool for each sampling event
tbl_Hydrolab_Data	Water quality data
tbl_Images	Anchialine pool images
tbl_Intercept	Point intercept transect characteristic data
tbl_Odonate_Survey	Odonate survey information
tbl_Odonate_Taxa	Odonate taxa associated with the odonate survey
tbl_Traps	Information about trap type used
tbl_Transects	Transect survey information

Table B3. List and description of the more prominent standard lookup and cross reference tables used in the protocol database.

Table Name	Description
tlu_Contacts	Contact data for project-related personnel and authors
tlu_Datum	Lookup table of datums for the Pacific Island Network
tlu_Taxa	Taxon lookup table for sampling events

Table B3 (continued). List and description of the more prominent standard lookup and cross reference tables used in the protocol database.

Table Name	Description
xref_Biological_Sampling	Cross reference table between sampling events and biological taxa for each pool
xref_Events_Contacts	Cross-reference table between events and contacts
xref_Habitat_Taxa	Cross-reference table between habitat and taxa
xref_Trap_Taxon	Cross reference table between traps and taxa.

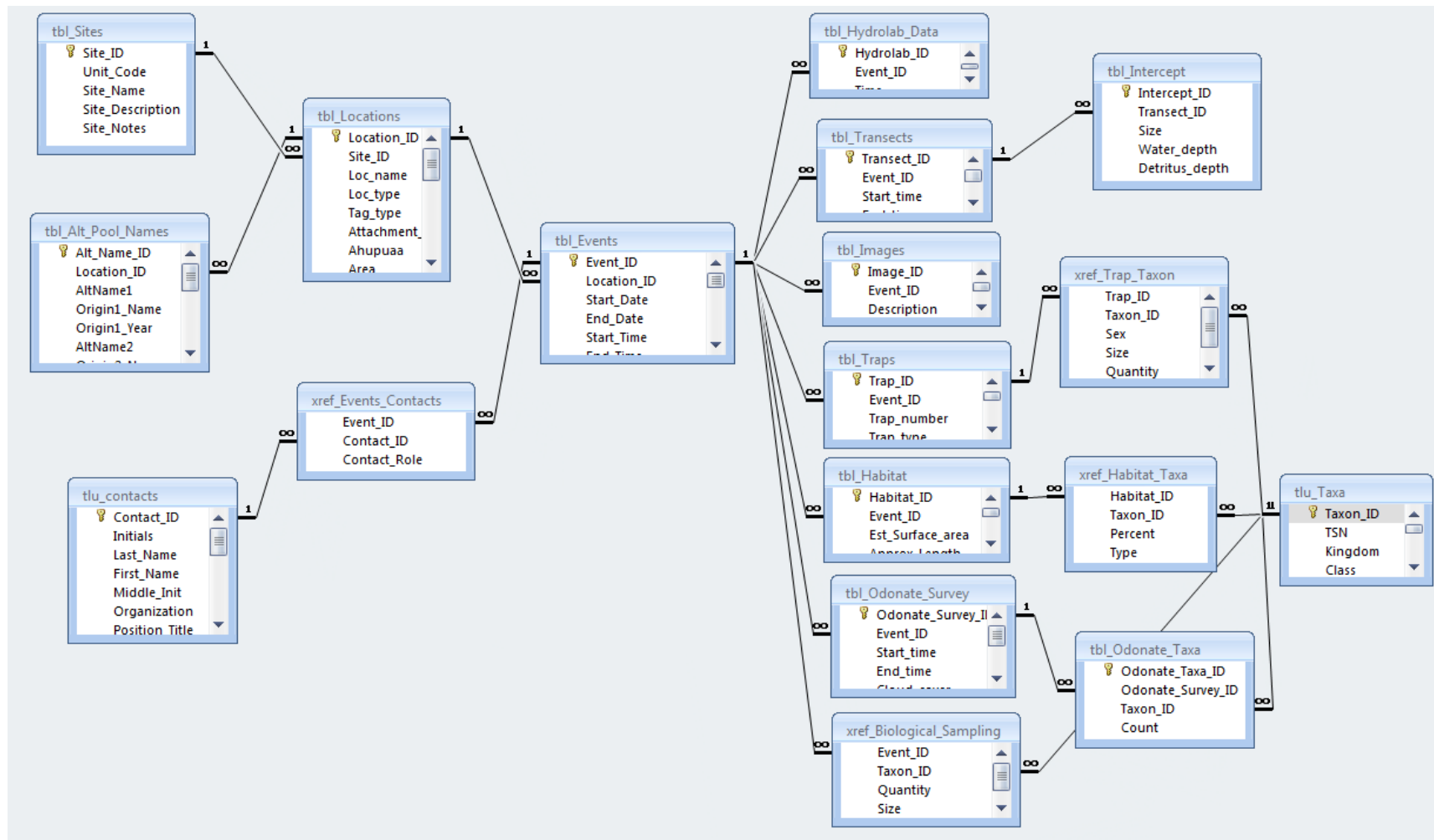


Figure B.1. Data model for the PACN Anchialine Pool Monitoring database.

Table B.4. List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Alt_Pool_Names	Alt_Name_ID	Yes	Text	50	Unique record identifier for alternate pool names.
	AltName1	No	Text	255	Alternative name used by others
	AltName2	No	Text	50	Alternative name used by others
	AltName3	No	Text	50	Alternative name used by others
	AltName4	No	Text	50	Alternative name used by others
	AltName5	No	Text	50	Alternative name used by others
	Location_ID	No	Text	255	Link to tbl_Locations
	Notes	No	Text	255	Any notes on alternative name and origin
	Origin1_Name	No	Text	255	Origin of alternative name
	Origin1_Year	No	Text	255	Year the alternative name was used
	Origin2_Name	No	Text	255	Origin of alternative name
	Origin2_Year	No	Text	255	Year the alternative name was used
	Origin3_Name	No	Text	255	Origin of alternative name
	Origin3_Year	No	Text	255	Year the alternative name was used
	Origin4_Name	No	Text	255	Origin of alternative name
	Origin4_Year	No	Text	255	Year the alternative name was used
	Origin5_Name	No	Text	255	Origin of alternative name
	Origin5_Year	No	Text	255	Year the alternative name was used
tbl_Events	Event_ID	Yes	Text	50	No description
	Certified_by	No	Text	50	Person who certified data for accuracy and completeness

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Events (continued)	Certified_date	No	Date/ Time	8	Date on which data were certified
	End_Date	No	Date/ Time	8	Ending date for the event if applicable
	End_Time	No	Date/ Time	8	Ending time for the event
	Entered_by	No	Text	50	Person who entered the data for this event
	Entered_date	No	Date/ Time	8	Date on which data entry occurred
	Location_ID	No	Text	50	Link to tbl_Locations
	Project	No	Text	50	Which research organization has conducted the sampling event data collection
	QA_notes	No	Memo	0	Quality assurance comments for the selected sampling event
	Start_Date	No	Date/ Time	8	Starting date for the event
	Start_Time	No	Date/ Time	8	Starting time for the event
	Tide_Height	No	Double	8	Predicted tide height at time of event (feet). Predicted using http://tbone.biol.sc.edu/tide/ website
	Tide_State	No	Text	50	Tide state at time of event
	Updated_by	No	Text	50	Person who made the most recent updates
	Updated_date	No	Date/ Time	8	Date of the most recent edits
	Verified	No	Boolean	1	Whether the data has been verified

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Events (continued)	Verified_by	No	Text	50	Person who verified accurate data transcription
	Verified_date	No	Date/ Time	8	Date on which data were verified
	Water_Depth	No	Double	8	Water depth at time of event (cm)
tbl_Habitat	Habitat_ID	Yes	Text	50	Unique record identifier for habitat description
	Algal_cover	No	Long Integer	4	The percent cover of the floating algal mats
	Algal_mats	No	Boolean	1	Whether there are floating algal mats in the pool
	Approx_Length	No	Double	8	Approximate Length of Pool (meters). Measured as close to high tide water mark as possible
	Approx_Width	No	Double	8	Approximate Width of Pool (meters). Measured as close to high tide water mark as possible
	Avg_depth	No	Double	8	Average depth of the pool (meters)
	Canopy	No	Long Integer	4	Total percentage of canopy overhang
	Deep_depth	No	Double	8	Deepest depth of the pool (meters). Measured at various tide heights
	Detrital_cover	No	Long Integer	4	Detrital cover of the pool
	Emergent	No	Long Integer	4	Total percentage of emergent vegetation
	Est_Surface_area	No	Double	8	Estimated surface area of the pool (square meters). Calculated as the area of an ellipse using approx. width and length. $\text{Area} = \text{Pi}((\text{approx. length} + \text{approx. width})/2)$

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Habitat (continued)	Event_ID	No	Text	50	Link to tbl_Events
	Species	No	Long Integer	4	Total percentage of species periphery
	Substrate_comp	No	Text	50	Substrate composition of the pool
tbl_Hydrolab_Data	Hydrolab_ID	Yes	Text	50	Unique record identifier for hydrolab data
	Batt-v	No	Double	8	Battery voltage
	Circ	No	Boolean	1	On / Off
	Depth	No	Double	8	Depth in meters. Accuracy +/-0.3 m
	DO	No	Double	8	Dissolved oxygen in mg/L. Accuracy +/-0.2 mg/L <= 20mg/L or +/-0.6 mg/L >20 mg/L
	DO_perc	No	Double	8	Dissolved oxygen saturation in %
	Event_ID	No	Text	50	Link to tbl_Events
	Notes	No	Memo	0	Any additional information
	Obs_Initials	No	Text	50	Initials of person sampling
	ORP	No	Long Integer	4	Oxidation-reduction potential in mV. Accuracy +/- 25 mV
	pH	No	Double	8	Accuracy +/-0.2 units
	Sal	No	Double	8	Salinity in PPS. Accuracy +/-1% of reading +/-1 count
	Sonde_type	No	Text	50	Type of sonde used to collect data
	SpC	No	Double	8	Specific conductance. Accuracy +/- 1% of reading +/-1 count
	TDS	No	Double	8	Total dissolved solids in g/L
	Temp	No	Double	8	Temperature in degrees Celsius. Accuracy +/- 2

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Hydrolab_Data (continued)	Tide_Height	No	Text	50	Tide height in feet. Predicted using "http://tbone.biol.sc.edu/tide/" website
	Tide_State	No	Text	50	Tide state
	Time	No	Date/ Time	8	Time of the hydrolab data collection.
	Turbidity	No	Double	8	Turbidity in NTU. Accuracy +/-5% of reading +/-1
tbl_Images	Image_ID	Yes	Text	50	Unique record identifier for images
	Aspect	No	Text	2	Aspect/position the photographer is facing when the image is taken
	Description	No	Text	50	Part of the pool where image was taken (overview/close-up/northern part/eastern part etc.)
	Event_ID	No	Text	50	Link to tbl_Events
	File_Name	No	Text	255	Name of image file
	File_Path	No	Memo	0	
	Update_TS	No	Date/ Time	8	Date/Time of last update - automatically stamp today's date/time in before update event
tbl_Intercept	UserID	No	Text	8	Who last updated the record - automatically filled in
	Intercept_ID	Yes	Text	50	Unique record identifier for point transect intercept
	Detritus_depth	No	Double	8	Detritus depth in centimeters
	Size	No	Double	8	Pebble size in centimeters
	Transect_ID	No	Text	50	Look up to tbl_Transects
	Water_depth	No	Double	8	Water depth in centimeters

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Locations	Location_ID	Yes	Text	50	Unique record identifier for pool locations
	Acc_notes	No	Text	50	Positional accuracy notes. GeoXT and Xh are Trimble units. Prior to 2009 diff correction with NPS Base Station has some unknown offset
	Ahupuaa	No	Text	50	Ahupua'a in which pool is located
	Arch_obs	No	Text	50	Archeological observations of the pool
	Area	No	Text	50	General area where the pool is located
	Attachment_method	No	Text	50	The method with which the tag is attached at the pool
	Datum	No	Text	50	Datum of mapping ellipsoid
	Description	No	Text	50	Description of the pool
	Entered_by	No	Text	50	Person who entered the data for this event
	Entered_date	No	Date/ Time	8	Date on which data entry occurred
	Est_H_error	No	Double	8	Estimated horizontal accuracy
	Est_V_error	No	Long Integer	4	Estimated vertical l accuracy
	Lava_type	No	Text	50	Type of lava; pahoehoe or aa
	Loc_name	No	Text	50	Anchialine pool name
	Loc_type	No	Text	20	Indicates the type of pool
	Notes	No	Memo	0	General notes on the location
	Shore_distance	No	Long Integer	4	Distance from the shore in meters

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Locations (continued)	Site_ID	No	Text	50	Link to tbl_Sites
	Tag_type	No	Text	50	Type of tag located at the pool
	Updated_by	No	Text	50	Person who made the most recent updates
	Updated_date	No	Date/ Time	8	Date of the most recent edits
	UTM_zone	No	Text	50	UTM Zone
	UTMX	No	Double	8	X coordinate for the center of the pool
tbl_Odonate_Survey	Odonate_Survey_ID	Yes	Text	50	The unique record identifier for odonate survey
	Cloud_cover	No	Text	25	The cloud cover at the start of the odonate survey
	End_time	No	Date/ Time	8	The end time of the odonate survey
	Event_ID	No	Text	50	Link to tbl_Events
	Notes	No	Memo	0	Notes for the odonate survey
	Precip	No	Long Integer	4	The precipitation at the start of the odonate survey
	Start_time	No	Date/Time	8	The start time of the odonate survey
	Temperature	No	Long Integer	4	The temperature at the start of the odonate survey
	Wind	No	Long Integer	4	The wind speed at the start of the odonate survey
tbl_Odonate_Taxa	Odonate_Taxa_ID	Yes	Text	50	The unique record identifier for odonate taxa
	Count	No	Long Integer	4	The number of individuals

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Odonate_Taxa (continued)	Odonate_Survey_ID	No	Text	50	Link to tbl_Odonate Surveys
	Taxon_ID	No	Text	50	Link to tlu_Taxa
tbl_Sites	Site_ID	Yes	Text	50	Unique record identifier for Sites (Parks)
	Site_Description	No	Text	50	Description for a site
	Site_Name	No	Text	50	Unique name or code for a site
tbl_Traps	Site_Notes	No	Text	50	General notes on the site
	Unit_Code	No	Text	50	Park, Monument or Network code
	Trap_ID	Yes	Text	50	Unique record identifier for trap data
	Bait_type	No	Text	255	Type of bait used for the trapping session
	Event_ID	No	Text	50	Link to tbl_Events
	Notes	No	Memo	0	Any notes about the trap session
	Tide_height	No	Double	8	Tide height at time of trap deployment
	Tide_level	No	Text	255	Tide level at time of trap deployment
	Tide_time	No	Date/Time	8	Time of associated time level
	Time_deployed	No	Date/Time	8	Time the trap was deployed
	Time_retrieved	No	Date/Time	8	Time the trap was retrieved
	Trap_number	No	Text	255	Trap number
	Trap_type	No	Text	255	Type of trap used for the trapping session
tbl_Transects	Transect_ID	Yes	Text	50	Unique record identifier for transects
	End_time	No	Date/Time	8	End time of the transect survey

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tbl_Transects (continued)	Event_ID	No	Text	50	Look up to tbl_Events
	Length	No	Double	8	Length of the transect
	Ocean_tide	No	Double	8	Ocean tide height at the survey time
	Start_time	No	Date/Time	8	Start time of the transect survey
tlu_Ahupuaa	Ahupuaa	No	Text	50	Ahupuaa name
	Site_ID	No	Text	50	Link to tbl_Sites
tlu_Archaeology	Archealogy_ID	Yes	Text	50	The unique record identifier for archaeology features
	Feature	No	Text	50	Archaeology feature
tlu_Area	Area	No	Text	50	Area name
	Site_ID	No	Text	50	Link to tbl_Sites
tlu_Contacts	Contact_ID	Yes	Text	50	Contact identifier
	Address	No	Text	50	Street address
	Address_Type	No	Text	50	Address (mailing, physical, both) type
	Address2	No	Text	50	Address line 2, suite, apartment number
	City	No	Text	50	City or town
	Contact_Notes	No	Memo	0	Contact notes
	Country	No	Text	50	Country
	Email_Address	No	Text	50	E-mail address
	Fax_Number	No	Text	50	Fax number
	First_Name	No	Text	50	First name

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tlu_Contacts (continued)	Home Phone	No	Text	50	Home phone number
	Initials	No	Text	50	Three letter initials of observer
	Last_Name	No	Text	50	Last name
	Middle_Init	No	Text	4	Middle initial
	Organization	No	Text	50	Organization or employer
	Position_Title	No	Text	50	Title or position description
	State_Code	No	Text	8	State or province
	Work_Extension	No	Text	50	Phone extension
	Work_Phone	No	Text	50	Phone number
	Zip_Code	No	Text	50	Zip_Code
tlu_Datum	Datum	Yes	Text	5	No description
	Datum_desc	No	Text	50	No description
	Sort_order	No	Byte	1	No description
tlu_Location_Type	Location_type	Yes	Text	20	No description
	Loc_type_desc	No	Text	200	No description
	Sort_order	No	Byte	1	No description
tlu_Marker_Status	Marker_status	Yes	Text	12	No description
	Marker_status_desc	No	Text	100	No description
	Sort_order	No	Byte	1	No description
tlu_Marker_Type	Marker_type	Yes	Text	20	No description
	Sort_order	No	Byte	1	No description

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tlu_Substrate	Substrate_ID	No	Text	50	Unique record identifier for substrate record
	Substrate_type	No	Text	10	Substrate type
tlu_Substrate_Size	Sort_order	No	Long Integer	4	Sort order
	Substrate_description	No	Text	50	Substrate description
	Substrate_size	No	Text	10	Substrate size
tlu_Taxa	Taxon_ID	Yes	Text	50	Unique record identifier for taxon
	Author	No	Text	50	Taxon author
	Class	No	Text	50	Class
	Common_name	No	Text	50	Common name of taxon
	Family	No	Text	50	Family
	Genus	No	Text	50	Genus
	Hawaiian_name	No	Text	50	Hawaiian name of taxon
	Kingdom	No	Text	50	Kingdom
	Nativity	No	Text	50	Nativity of taxon
	Notes	No	Memo	0	Taxon notes
	Order	No	Text	50	Order
	Species	No	Text	50	Species
	TSN	No	Long Integer	4	Taxonomic serial number

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
tlu_UTM_zone	Description	No	Text	50	Description of the UTM Zone
	Sort_order	No	Long Integer	4	Sort order
	UTM_zone	No	Text	50	UTM Zone
xref_Biological_Sampling	Event_ID	No	Text	50	Link to tlu_Events
	Size_Class	No	Text	50	Size class
	Taxon_ID	No	Text	50	Link to tlu_Taxa
xref_Events_Contacts	Contact_ID	No	Text	50	Link to tlu_Contacts
	Contact_Role	No	Text	50	The contact's role
	Event_ID	No	Text	50	Link to tbl_Events
xref_Habitat_Substrate	Habitat_ID	No	Text	50	Link to tbl_Habitat
	Substrate_ID	No	Text	50	Link to tlu_Substrate
xref_Habitat_Taxa	Habitat_ID	No	Text	50	Link to tbl_Habitat
	Percent	No	Long Integer	4	Percent coverage of the plant species.
	Taxon_ID	No	Text	50	Link to tlu_Taxa.
	Type	No	Text	50	Type of vegetation description; canopy, emergent,
xref_Locations_Archaeology	Archealogy_ID	No	Text	50	Link to tlu_Archealogy
	Location_ID	No	Text	50	Link to tbl_Locations
xref_Trap_Taxon	Notes	No	Memo	0	Notes about trap data
	Quantity	No	Long Integer	4	The number of species individuals found in the trap

Table B.4 (continued). List of database tables and field descriptions.

Table Name	Field	Primary?	Data Type	Size	Description
xref_Trap_Taxon (continued)	Size	No	Text	255	Size of the species found in trap in cm
	Taxon_ID	No	Text	50	Link to tlu_Taxa
	Trap_ID	No	Text	50	Link to tbl_Traps

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.

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National Park Service
U.S. Department of the Interior



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