National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Vegetation Inventory Project

Pu‘uhonua o Hōnaunau National Historical Park

Natural Resource Report NPS/PUHO/NRR—2011/461

ON THE COVER
Royal Compound; Hale o Keawe Heiau Reconstruction
Photograph by: Jim VonLoh

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Contents

Contents (continued)

Figures

Page

Tables

Page

Appendices

Page

Executive Summary

Pu‘uhonua o Hōnaunau National Historical Park (PUHO) covers approximately 177 ha (437 ac) on the southwestern coast of the island of Hawai‘i. The park was established to preserve, protect, and interpret ancient Hawaiian temples, ki‘i (wooden statues), burial sites, stone house platforms, royal canoe landing areas, royal fish ponds, sledding tracks, anchialine pools, and coastal village sites. PUHO supports over 180 vascular plant species including examples of coastal strand and wetland native plants. Most of the remaining vegetation has been extremely altered over the years and consists primarily of non-native koa hoale (*Leucaena leucocephala*) shrubs and kiawe (*Prosopis pallida*) trees with guinea (*Panicum maximum*) and natal redtop (*Melinis repens*) grasses common in the canopy openings. To better understand the distribution of the plant assemblages located on this site, the National Park Service (NPS) Pacific Island Network (PACN) Inventory and Monitoring Program (I&M) started a vegetation inventory effort at PUHO in 2007.

A three-year, four phase program was initiated to complete the task of mapping and classifying the vegetation at PUHO. Phase one conducted by PACN staff in 2008, collected 42 field plots and 13 observation points. In phase two, NatureServe’s Western Regional Office used this field data in conjunction with data collected at two other West Hawai‘i parks to classify 20 new plant associations for PUHO based on the revised US National Vegetation Classification (rUSNVC). Phase three, directed by Cogan Technology, Inc produced a digital vegetation map and supporting accuracy assessment (AA) materials. In the final phase, PACN staff collected 82 accuracy assessment points in 2009/10 used to check and finalize the map.

To produce the spatial database and map layer, year 2006 0.6-meter, 4-band Quickbird satellite imagery was provided by PACN. By comparing the signatures on the imagery to field and ground data 40 map units (23 vegetated, five barren or geologic, and 12 land-use / land-cover) were developed and directly crosswalked or matched to their corresponding rUSNVC plant associations. The interpreted and remotely sensed data were converted to Geographic Information System (GIS) databases and maps were printed, field tested, reviewed, and revised. The final map layer was accessed for thematic accuracy by overlaying 77 independent accuracy assessment points. The final overall accuracy of the map layer was determined to be 86% with a Kappa value of 88%.

Products developed for PUHO are described and presented in this report, as well as stored on the accompanying DVD. These include:

- A *Final Report* that includes keys to the vegetation and imagery signatures, AA information, and all of the project methods and results;
- A *Spatial GIS Database* containing spatial data for the vegetation, plots, and AA points;
- *Digital Photos* from the field sampling efforts;
- *Metadata* for all spatial data (Federal Geographic Data Committee -compliant);
- *Vegetation Descriptions and Photo Signature Key* to the map classes and associations/alliances.

Please access the following website for posting of this information:
http://biology.usgs.gov/npsveg/index.html.

Acknowledgments

The production of this vegetation inventory for an important cultural and historic site required the enthusiasm and energy of many people over several years. The authors gratefully acknowledge the dedication of all involved in the production of this report.

We would like to specifically thank Penny Latham with the Pacific West Region Inventory and Monitoring Program and Julie Christian, Corie Yanger, Kelly Kozar, Sandy Margriter and all the staff at the Pacific Island Network Inventory and Monitoring Program for their support and assistance with contracting, work flow, and technical review through all aspects of this project. In addition we would like to acknowledge Viet Doan (formerly with PACN) for his assistance with GIS data acquisition, map creation and general support.

We would also like to thank Marion Reid and Jim Drake with NatureServe. Marion was the NatureServe project manager for the Pu‘uhonua o Hōnaunau National Historical Park project and Jim analyzed data for the classification and wrote the vegetation community descriptions.

We are grateful to the staff at Pu‘uhonua o Hōnaunau National Historical Park especially Adam Johnson and Malia Hayes, who went out of their way to assist with field checking, assisting the field crews and providing expert advice. They were very professional and extremely helpful throughout the process.

Special recognition goes to Karl Brown with NPS for prioritizing the need for this project and providing funding. Without the financial support from the NPS Vegetation Inventory Program the project would not have been possible.

Introduction

National Vegetation Inventory Program

The National Vegetation Inventory Program (NVIP) was started as a cooperative effort between the National Park Service (NPS) and the United States Geological Survey (USGS) to classify, describe, and map existing vegetation communities in more than 270 national parks across the United States. The primary objective of the NVIP is to produce high-quality plant community classifications, standardized maps and associated data sets of the vegetation currently occurring within the parks. This information fills data gaps and complements a wide variety of resource assessments, park management, and conservation needs. Among its many uses, the NVIP products have helped park managers better identify and conserve plant biodiversity; manage non-native and rare species, monitor insect and disease effects; and provide a baseline to examine wildlife habitat relationships and the effects of wildland fires.

In 1999, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation's natural heritage through science, natural resource inventories, and expanded resource monitoring. The Natural Resource Challenge provided funding for 12 baseline inventories to be completed in each of 270 parks with significant natural resources. The vegetation mapping inventory is considered one of these 12 baseline inventories.

NVIP follows well-established procedures that are compatible with other agencies and organizations. The inventory uses the USNVCv1, a system that is integrated with the major scientific efforts in the taxonomic classification of vegetation, and is a Federal Geographic data Committee (FGDC) standard. In addition, stringent quality control procedures ensure the reliability of the vegetation data and encourage the use of resulting maps, reports, and databases at multiple scales.

A complete vegetation mapping project for a park includes the following products:

- Detailed vegetation report
- Digital vegetation map
- Vegetation plot data
- Accuracy assessment data and analysis
- Dichotomous vegetation key
- Photo-interpretation key

Maps are produced in Universal Transverse Mercator (UTM) coordinates (NAD 83) with a 1:24,000 scale and a minimum mapping unit of 0.5 ha (1.2 ac). The vegetation maps must meet the National Map Accuracy Standards for positional accuracy, and the minimum class accuracy goal across all vegetation and land cover classes of 80 percent.

National Vegetation Classification Standard

In 1994, NPS formed the NVIP to inventory and map the vegetation in the United States National Parks. Shortly thereafter, the USGS joined into a partnership, which continues to operate today. The goals of this program are to provide baseline ecological data for park resource managers, obtain data that can be examined in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities. In the same year, the NVIP also adopted the U.S. National Vegetation Classification (USNVC) (Grossman et al. 1998) as a basis for the *a priori* definition of vegetation units to be inventoried. The USNVC has since been revised by NatureServe and in 2008 the FGDC formally endorsed the National Vegetation Standard, Version 2 (NVCSv2) (FGDC 2008).

Use of a standardized vegetation classification system, such as the NVCSv2 helps ensure data compatibility throughout the NPS and other agencies (FGDC 2008). This is critical for a systematic inventory and classification of the nation's biological resources to foster efficient stewardship and prioritize conservation efforts. The revised US National Vegetation Classification (rUSNVC) is being used for vegetation classification and mapping projects at Pu'uhonua o Hōnaunau National Historical Park (PUHO) and other Pacific Island Inventory and Monitoring Network (PACN) parks. It evolved from the original USNVC, which was developed jointly by The Nature Conservancy (TNC), NatureServe, and the Natural Heritage Program network over more than two decades (TNC and ESRI 1994a, Grossman et al. 1998) and adopted in part by the FGDC (1997).

The NVCSv2 is a hierarchical system that allows for vegetation classification at multiple scales (FGDC 2008). There are eight levels with specific criteria set for each level (Table 1). The upper three levels are based on climate and physiognomic characteristics that reflect geographically widespread (global) topographic and edaphic factors. The middle three levels focus largely on broad sets of diagnostic plant species and habitat factors along regional-to-continental topographic, edaphic, and disturbance gradients. These middle levels have been drafted and are undergoing peer review. The lower two levels, as in the original NVC, are the alliance and association and are distinguished by differences in local floristic composition. The broader alliances are physiognomically distinct groups of plant associations sharing one or more differential or diagnostic species (Mueller-Dombois and Ellenberg 1974). These are commonly the dominant(s) found in the uppermost strata of vegetation. The plant association is the fundamental base unit of the classification, and following the International Botanical Congress of 1910, is defined as a community of definite floristic composition (i.e., a repeating assemblage of species), uniform physiognomy and habitat conditions (Mueller-Dombois and Ellenberg 1974).

The rUSNVC is maintained by NatureServe and the network of affiliated Natural Heritage Programs and Conservation Data Centers for use by government agencies and the public (Faber-Langendoen et al. 2009). The rUSNVC database allows for tracking of vegetation at all scales and provides narrative descriptions of many alliances and associations (Faber-Langendoen et al. 2009). Descriptions of MacroGroups and Groups are being written in three phases. Phase one descriptions are currently undergoing peer review (Faber-Langendoen et al. 2010). The content of this database is available to the public and is regularly updated through NatureServe Explorer (http://www.natureserve.org/explorer).

Table 1. Summary of USNVC Revised Hierarchy Levels and Criteria for Natural Vegetation.

Hierarchy Level	Criteria
Upper:	**Physiognomy plays a predominant role**.
L1 – Formation Class	Broad combinations of general dominant growth forms that are adapted to basic temperature (energy budget), moisture, and substrate/aquatic conditions.
L2 - Formation Subclass	Combinations of general dominant and diagnostic growth forms that reflect global macroclimatic factors driven primarily by latitude and continental position, or that reflect overriding substrate/aquatic conditions.
L3 – Formation	Combinations of dominant and diagnostic growth forms that reflect global macroclimatic factors as modified by altitude, seasonality of precipitation, substrates, and hydrologic conditions.
Mid:	**Floristics and physiognomy play predominant roles**
L4 – Division	Combinations of dominant and diagnostic growth forms and a broad set of diagnostic plant species that reflect biogeographic differences in composition and continental differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.
L5 – Macrogroup	Combinations of moderate sets of diagnostic plant species and diagnostic growth forms, that reflect biogeographic differences in composition and sub-continental to regional differences in mesoclimate, geology, substrates, hydrology, and disturbance regimes.
L6 – Group	Combinations of relatively narrow sets of diagnostic plant species (including dominants and co-dominants), broadly similar composition, and diagnostic growth forms that reflect regional mesoclimate, geology, substrates, hydrology and disturbance regimes.
Lower:	**Floristics plays a predominant role**
L7 – Alliance	Diagnostic species, including some from the dominant growth form or layer, and moderately similar composition that reflect regional to subregional climate, substrates, hydrology, moisture/nutrient factors, and disturbance regimes.
L8 – Association	Diagnostic species, usually from multiple growth forms or layers, and more narrowly similar composition that reflect topo-edaphic climate, substrates, hydrology, and disturbance regimes.

Associations are generally the same as the original USNVCv1, although revisions have begun in certain areas such as PACN projects. Substantial revisions of the alliances have begun and will continue in the future. PUHO alliances have been reviewed and revised for this project and NatureServe will continue alliance review and revision as other PACN vegetation inventory projects are completed. Although NatureServe's documentation of vegetation alliances and associations is the most accessible national listing, the data within the USNVC are not complete, and projects such as this one constantly add to the documentation and listing of USNVC types.

USNVCv1 associations and alliance are commonly used for vegetation inventory projects. Their use within the NVIP facilitates effective resource stewardship by ensuring compatibility and widespread use of the information throughout the NPS as well as by other federal and state agencies. These vegetation maps and associated information support a wide variety of resource assessment, park management, and planning needs. In addition they can be used to provide a structure for framing and answering critical scientific questions about vegetation communities and their relationship to environmental conditions and ecological processes across the landscape.

Pacific Island Inventory and Monitoring Network

PACN was established to provide an efficient means of carrying out expanded natural resource inventory and monitoring activities for 11 national parks within the Pacific Ocean (Figure 1). Currently PACN contains a mixture of both small and large parks including Ala Kahakai National Historic Trail (ALKA), American Memorial Park (AMME), Haleakalā National Park (HALE), Hawai‘i Volcanoes National Park (HAVO), Kalaupapa National Historical Park (KALA), Kaloko-Honokōhau National Historical Park (KAHO), National Park of American Samoa (NPSA), Pu‘uhonua o Hōnaunau National Historical Park (PUHO), Pu‘ukoholā Heiau National Historic Site (PUHE), War in the Pacific National Historical Park (WAPA), and World War II Valor in the Pacific National Monument (VALR). The larger parks, HAVO, HALE, and KALA are located on the islands of Hawai‘i, Maui, and Molokai, respectively and VALR (formally the USS Arizona Memorial) is located on the island of O‘ahu. National Park of American Samoa spans three America Samoa Islands and the smaller parks KAHO, PUHE, and PUHO along with the ALKA are located on the island of Hawai‘i. American Memorial is located on the island of Saipan, and WAPA is located on Guam. All of the parks in the PACN occur on remote islands ranging from approximately 4,000 to 10,000 km (2,500 to 6,200 mi) west and southwest of the United States mainland.

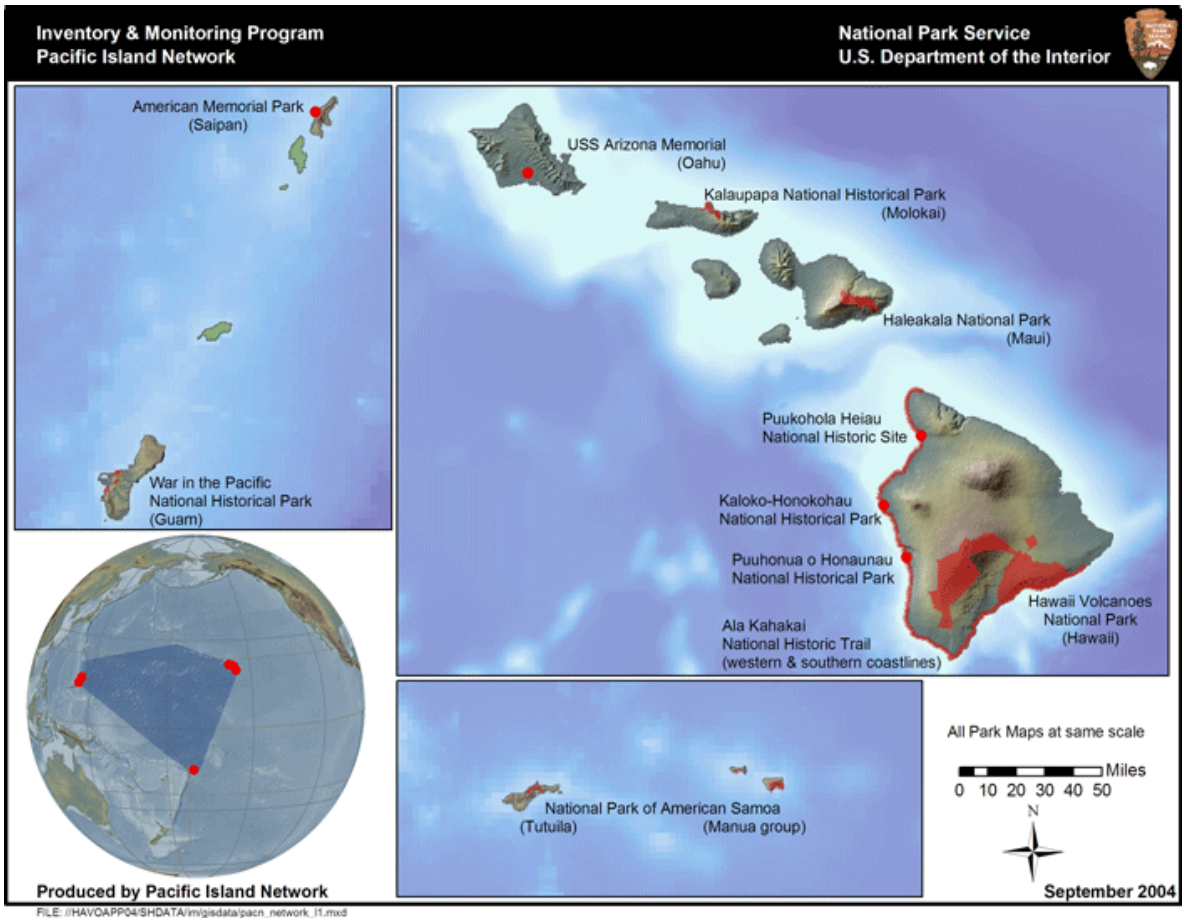


Figure 1. The 11 national parks included within the Pacific Island Network.

PACN I&M program personnel are involved in numerous activities including organizing and cataloging data, data analysis and synthesis, modeling, providing data and expertise to national park planners, providing data and expertise for resource assessments and resource stewardship strategies, and contributing to performance reporting. The I&M program is a key source and supplier of reliable, organized, and retrievable information about the Pacific island parks. The programs primary responsibilities include facilitating baseline inventories, collecting, managing, analyzing and reporting long-term data on vital signs (measurements of resource condition), and effective delivery of data and information on resource condition to park managers, planners, interpreters, and other key audiences. Data and reports for PACN I&M program projects can be accessed online at: http://science.nature.nps.gov/im/units/pacn/index.cfm.

Pu‘uhonua o Hōnaunau National Historical Park

PUHO originally encompassed approximately 74 ha (182 ac) of upland and beach to the high tide line of the Pacific Ocean in the Kona District of Hawai‘i County on the southwestern coast of the island of Hawai‘i (leeward coast). PUHO is accessed from either the City of Refuge Road or Keala o Keawe Road off State Highway 11 (Mamalahoa Highway) near Holualoa (Figure 2). PUHO is located south of Keone‘ele Cove of Honaunau Bay and includes/abuts Pu‘uhonua Point, Alahaka Bay and Ki‘ilae Bay, extending inland and upslope 0.8 km (0.5 mi) (USGS-NPS 2008). PUHO preserves a revered site to the Native Hawaiians where up until the early 19th century, Hawaiians who broke one of the ancient laws could avoid punishment by fleeing to this place of refuge or “pu‘uhonua”. In addition this site also includes numerous archeological ruins and restored examples of the Ki‘ilae royal village, the Hale o Keawe Heiau, temple platforms, ki‘i (wooden statues), burial sites, stone house platforms, royal canoe landing areas, royal fish ponds, sledding tracks (holua or stone slide) (Figure 3), anchialine pools, and other satellite village sites. A portion of the Coastal Trail (Ala Kahakai National Historic Trail) passes through PUHO.

In 2001, by an act of congress, PUHO was expanded by 96 ha (238 ac). The expansion occurred southeast of the original PUHO and was adjacent and contiguous to the park’s current boundary. The additional lands were primarily acquired to help complete the Ki‘ilae village landscape and help preserve one of the best and most complete examples of the historic Kona field system. The ancient field system employed by early chiefs was a complex agricultural and economic organization that supported and sustained a dense population with finite resources. The cultural archeological landscape in this area includes residential, religious, agricultural and ceremonial sites (Akaka and Inouye 2001). For the vegetation mapping project, the project area was further expanded to include an approximate 2.3 km (1.4 mi) linear east-west NPS easement and a 1.6 ha (4 ac) NPS management site located just east of State Highway 11. The total acreage for all four PUHO sites (i.e. PUHO’s authorized boundary) totaled 177 ha (437 ac) (Figure 2).

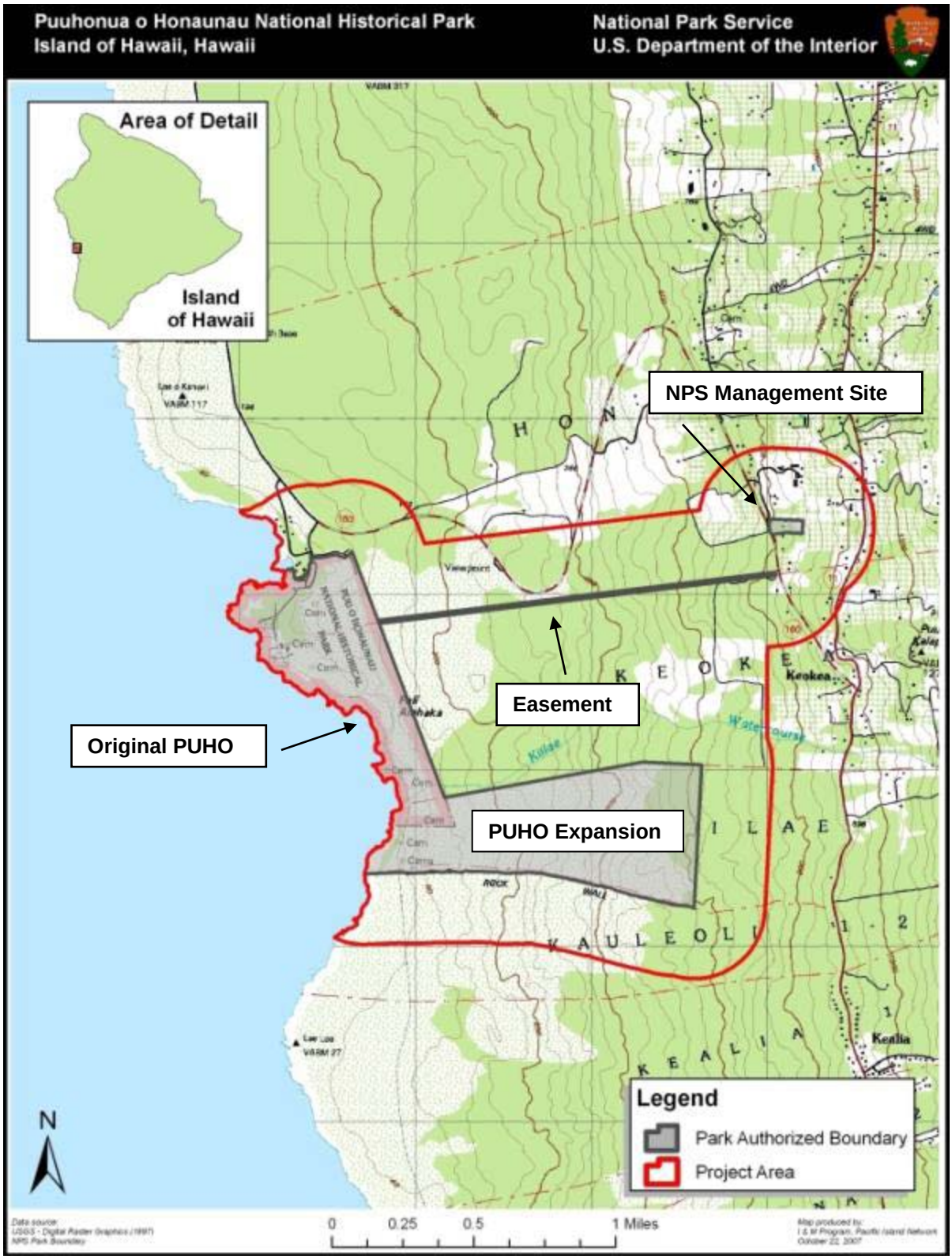


Figure 2. NPS Pu‘uhonua o Hōnaunau National Historical Park map.

Figure 3. Holua or sledding track on pahoehoe basalt (top) and Coastal Trail on a‘a lava basalt (bottom).

Natural Setting

A warm sub-tropical climate encompasses the PUHO area, with periodic rains and periods of drought due to its location at the base of Mauna Loa Volcano (USGS-NPS 2008). Daylight hours are characterized by clear mornings with thermal clouds developing in the afternoon; humidity ranges between 50-80% (USGS-NPS 2008). The trade winds blow offshore at this site, but are often replaced by afternoon onshore ocean breezes. Gusts from 20-40 knots can occur with both upslope and downslope winds contributing to soil aridity. Temperatures range from average lows of 55 to 75^{o} F (January) to average highs of 60 to 80^{o}F (August). Annual precipitation at nearby Holualoa averages 533 mm (21 in) with January being highest rainfall month (USGS-NPS 2008).

Hawai‘i Island is the youngest island in the Hawaiian chain and was formed by five large volcanoes; Kīlauea and Mauna Loa plus several smaller volcanoes along the Chain of Craters remain active (NPS undated). PUHO is located on the gently sloping base of Mauna Loa and is characterized by the Holocene Kau Basalt lava flows from that source (USGS-NPS 2008). Kau Basalt consists of pahoehoe rocks formed and deposited from elongated fissures on the flank of Mauna Loa. The Kau Basalt is shield-stage lava consisting of tholeiitic basalt, olivine tholeiitic basalt, and pictric tholeiitic basalt overlying Pahala Ash and Kahuku Basalt (USGS-NPS 2008). PUHO contains prominent examples of the Kahuku basalt as evidenced by the Keanai‘e Pali volcanic cliff and the coastal shore platform (Figure 4).

Because the basaltic lava flows occurred recently coupled with PUHO’s dry climate only thin and poorly developed soils have formed, typically less than 15 cm (6 in) deep (USGS-NPS 2008). Pahoehoe lava basalt bedrock covering the northern two-thirds of PUHO is characterized by no soil to very thin soil that forms/collects in bedrock pockets and low to moderate vegetation cover. A‘a soils occur in the southern one-third of PUHO characterized by rough broken land bisected by drainage channels with the most well-known being the Ki‘ilae Watercourse (USGS-NPS 2008).

Topographically, PUHO slopes gently to the Pacific Ocean from east to west with the highest elevation measured at approximately 30 m (100 ft) along the eastern border and approximately 37 m (120 ft) on the Keanai‘e Pali near the Pacific Ocean (NPS 2008). Distributed across this rugged landscape are numerous mounds, lava beds, slopes, basalt cliffs, small drainages, and beaches. The beaches at PUHO are extensive along the shoreline extending from Pu‘uhonua Point to the north end of Alahaka Bay. Unvegetated sands at PUHO are primarily active during large wave events as surmised from their perched location on top of the gently-sloping pahoehoe basalt coastal terrace (Figure 4). In contrast, where the beaches are more stable, they support a variety of coastal strand vegetation as described in this report (Figure 5).

Figure 4. Portion of the Keanaiʻe Pali cliff (top) and basalt shore platform with carbonate sand (bottom).

Figure 5. Stable beach deposits supporting stands of niu or coconut palm.

Vegetation

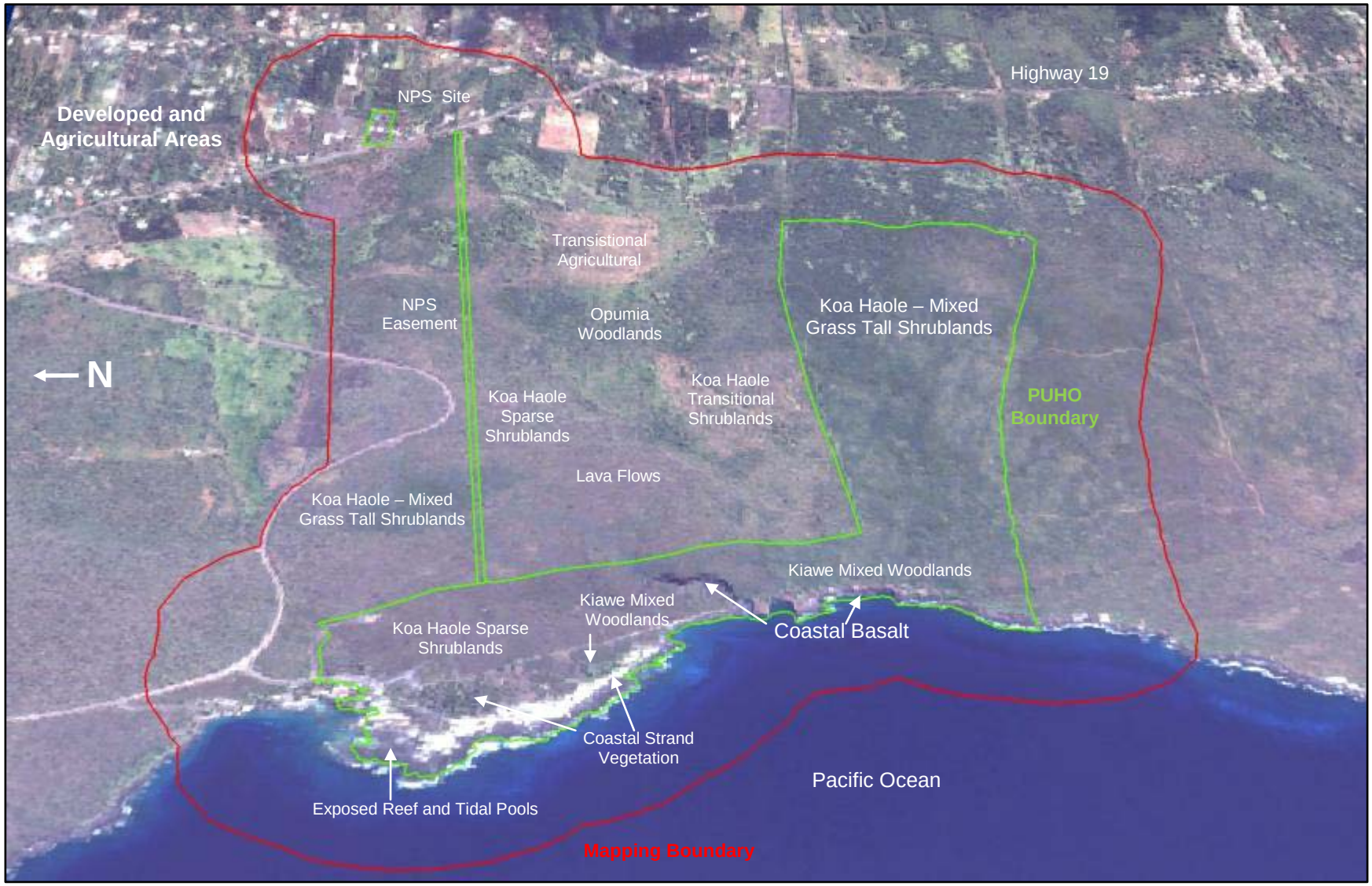
Prior to this project, the vegetation at PUHO was surveyed in 1986 (Smith et al.) and 1996 (Pratt and Abbott 1996); of the 134 plant species identified, nearly 72% are non-native species introduced historically. The most widespread of the non-natives found throughout the entire park include kiawe (*Prosopis pallida*), Christmas berry (*Schinus terebinthifolius*), koa haole (*Leucaena leucocephala*), natal redtop (*Melinis repens*) and guinea grass (*Panicum maximum* = *Urochloa maxima*). Other less common non-natives include klu (*Acacia farnesiana*), ‘opiuma (*Pithecellobium dulce*), and lantana (*Lantana camara*) (Pratt and Abbott 1996).

PUHO supports four native plant species that are considered common (NPS 2005), they are: (1) ‘uhaloa (*Waltheria indica*), a low shrub common throughout the park; (2) makaloa (*Cyperus laevigatus*), occurring on the banks of anchialine pools; (3) naupaka kahakai (*Scaevola taccada*), common to the sandy beaches; and (4) mau‘u (*Fimbristylis cymosa*) established in sparse cover on the pahoehoe basalt flats near the Pacific Ocean.

Polynesian plant species are also common in the park especially around the visitor center. They inlcude ti (*Cordyline fruiticosa*), kamani (*Calophyllum inophyllum*), kō (*Saccharum officinarum*), and wauke (*Broussonetia papyrifer*). The presence of these species along with the planting of pili grass (*Heteropogon contortus*), loulu palm (*Pritchardia affinis*), noni (*Morinda citrifolia*), and niu or coconut palm (*Cocos nucifera*) trees are intended to recreate the historic scene and contribute to the interpretation of PUHO (NPS 2005). Restoration of native shrubs and grasses is ongoing at PUHO and consists of plantings in the vicinity of the Visitor Center, parking lot and coastal strand areas (Figure 6). The plantings are augmented with irrigation water through a drip system when necessary to insure their success. Some of these tree and shrub plantings are species native to Hawai‘i but may not occur naturally in PUHO.

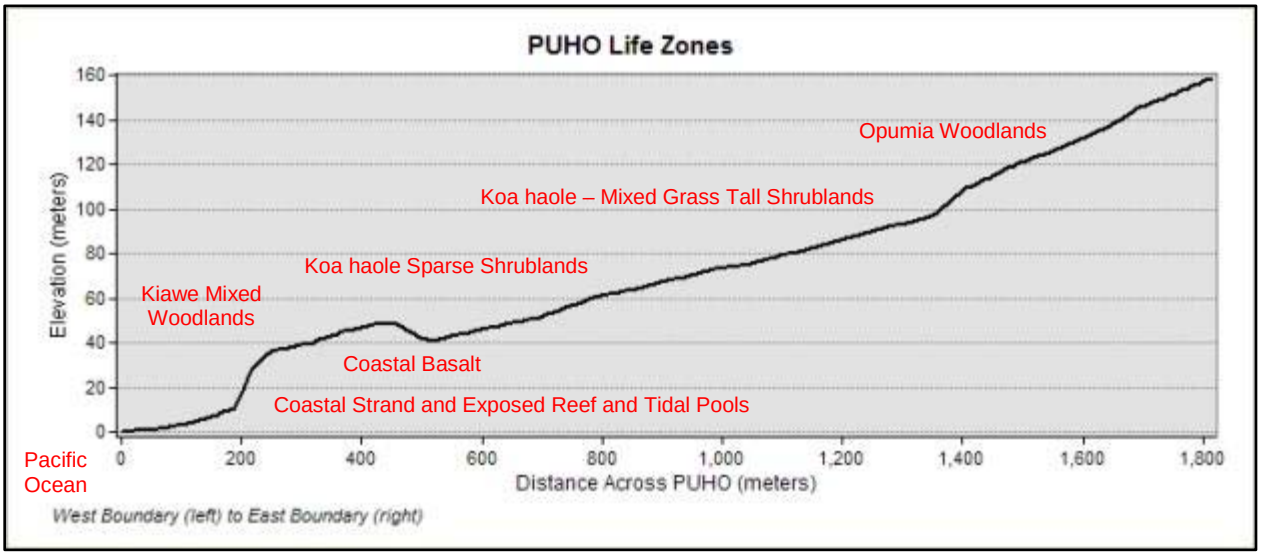
All of the native, non-native, and Polynesian introduced species at PUHO intermingle in various plant communities trending from the more native beach and coastal strand associations (low and west) to non-native dominated uplands (high and east) (Figure 6). The gently sloping nature of park combined with the lava substrate and close proximity to the Pacific Ocean creates unique vegetation life zones (Figure 7). Starting with the Pacific Ocean and working east, the vegetation south of the picnic area to the Alahaka Ramp is primarily coastal strand consisting of coconut palm, naupaka kahakai, and scattered non-native plant species. The picnic area to the northern PUHO boundary is also coastal strand with low cover of coconut palm, kiawe, noni, kou (*Cordia subcordata*), hala (*Pandanus tectorious*), and non-native plant species. The coconut palm grove located east of the picnic area access road primarily supports coconut palm, noni, and ‘uhaloa, with scattered ‘opiuma shrubs and non-native ground cover. Intermixed in these coastal strand areas are sparse stands of mau‘u and patches of naupaka kahakai shrubs. Mixed woodland stands of kiawe dominate the upper beach margin and the lower edge of the coastal basalt lava adjacent to the coast. The higher area east of the 1871 Trail supports both stands of the non-native shrubs koa haole with sparse understories of klu, and ‘opiuma. The Ki‘ilae Village area extending from the top of the Alahaka Ramp to the southern boundary supports large stands of kiawe, koa haole and guinea grass. Above the village and the 1871 trail and in the newly acquired lands are extensive stands of koa haole with mixed tall grasses (natal redtop and guinea grass) and Christmas berry. Finally east of PUHO along the easement and in the eastern management unit the vegetation becomes dominated by ‘opiuma woodlands as agricultural fields/orchards and mixed development become more common.

Ground photo examples of PUHO’s more prominent vegetation communities contained in these life zones are shown in Figure 8.



Source: CTI, USGS 10-meter DEM, and 2006 Digital Globe Imagery

Figure 6. 3D overview image of PUHO and surrounding areas showing common vegetation patterns.



Source: CTI and USGS 10-meter DEM

Figure 7. Representative cross-section of PUHE's topography showing general vegetation life zones.

Non-native Vegetation Control and Revegetation

Non-native species at PUHO have been continuously removed in some areas using various control efforts including mechanical, chemical and fire treatments. In the past, foliar herbicides were widely used in and around the archeological sites, but recent efforts have used more site specific approaches like cutting koa haole shrubs and treating the stumps with herbicide (Figure 9). Fire has also been an important factor at PUHO with two recorded wildfires and three prescribed burns occurring since the 1970s (NPS 2005). Following control efforts, NPS staff has begun an active revegetation project that has reintroduced native plants to the park, especially in the coastal strand areas. Native species plantings have included ʻākia (*Wikstroemia pulcherrima*), aʻaliʻi (*Dodonaea viscosa*), and pōhinahina (*Vitex rotundifolia*).

Sparse mauʻu on pahoehoe basalt

Naupaka kahakai coastal strand

Coconut palm woodland with noni and ʻopiuma

Naupaka kahakai (front) and kiawe woodland (back)

Mature kiawe woodlands in upper beach area

ʻOpiuma woodlands

Figure 8. Common vegetation types at PUHO.

Christmas berry woodland

Guinea grass herbaceous vegetation

Koa haole upland shrublands (overview)

Koa haole shrub stand

Natal redtop grass patches in koa haole treated area

Pili and loulu tree restoration

Figure 8. Common vegetation types at PUHO (continued).

Figure 9. Example of a cultural site following koa haole shrub mechanical and herbicide treatment.

Vegetation Inventory Project

The specific decision to classify and map the vegetation at PUHO was made in response to guidelines set forth by the NVIP and implemented by the Pacific Island Network. The PACN initiated a vegetation inventory for PUHO in 2008 as part of a larger effort to complete vegetation inventory maps for each of the 10 parks in the Network that contain significant natural terrestrial resources (World War II Valor in the Pacific National Monument was excluded).

Planning for the inventory projects began with an initial multi-year study plan developed for the PACN by Cogan Technology, Inc. (CTI) in 2007. The PACN study plan provided recommendations for completing the plant community classification, digital database, and map products for each of the 10 PACN parks. The work plan received approval from the Washington Area Service Office (WASO) Inventory Coordinator in 2008.

An initial planning meeting was held at the PUHO Visitor Center on September 11, 2007 to discuss the project. Subsequent to this meeting, PACN staff ecologists were detailed to complete the vegetation plot field data collection during 2008 and collect the accuracy assessment data in 2009/10. The Western Regional Office of NatureServe was also contracted at this time to provide the preliminary and final vegetation classification including field keys and descriptions. CTI, as part of an interagency agreement through the Bureau of Reclamation, was tasked with providing the mapping and support services.

As a team, the objectives were to produce data consistent with the national program's mandates. These include the following:

Spatial Data

- Map classification based on PUHO-specific requirements;
- Map classification description and key;
- Spatial database of vegetation communities;
- Digital and hardcopy maps of vegetation communities;
- Metadata for spatial databases;
- Complete accuracy assessment of spatial data.

Vegetation Information

- rUSNVC-based vegetation data;
- Dichotomous field key of vegetation associations;
- Formal description for each vegetation association;
- Ground photos of vegetation associations;
- Field data in database format.

Scope of Work

Vegetation mapping for PUHO occurred within an approximate 850 ha (2,100 ac) project boundary, encompassing the authorized boundary of PUHO (as provided by PACN) and a general 0.4 km (0.25 mi) environ radius (Figure 10). The final project area determination was based on management needs, financial constraints, and time limitations. The nominal 0.4 km environs were used in this project to insure completeness and to capture some minimal data for various management considerations outside of PUHO (such as non-native plant vectors). Also the size of the environs corresponded to the size proposed in the work plan and matches the other vegetation mapping protocols in the PACN.

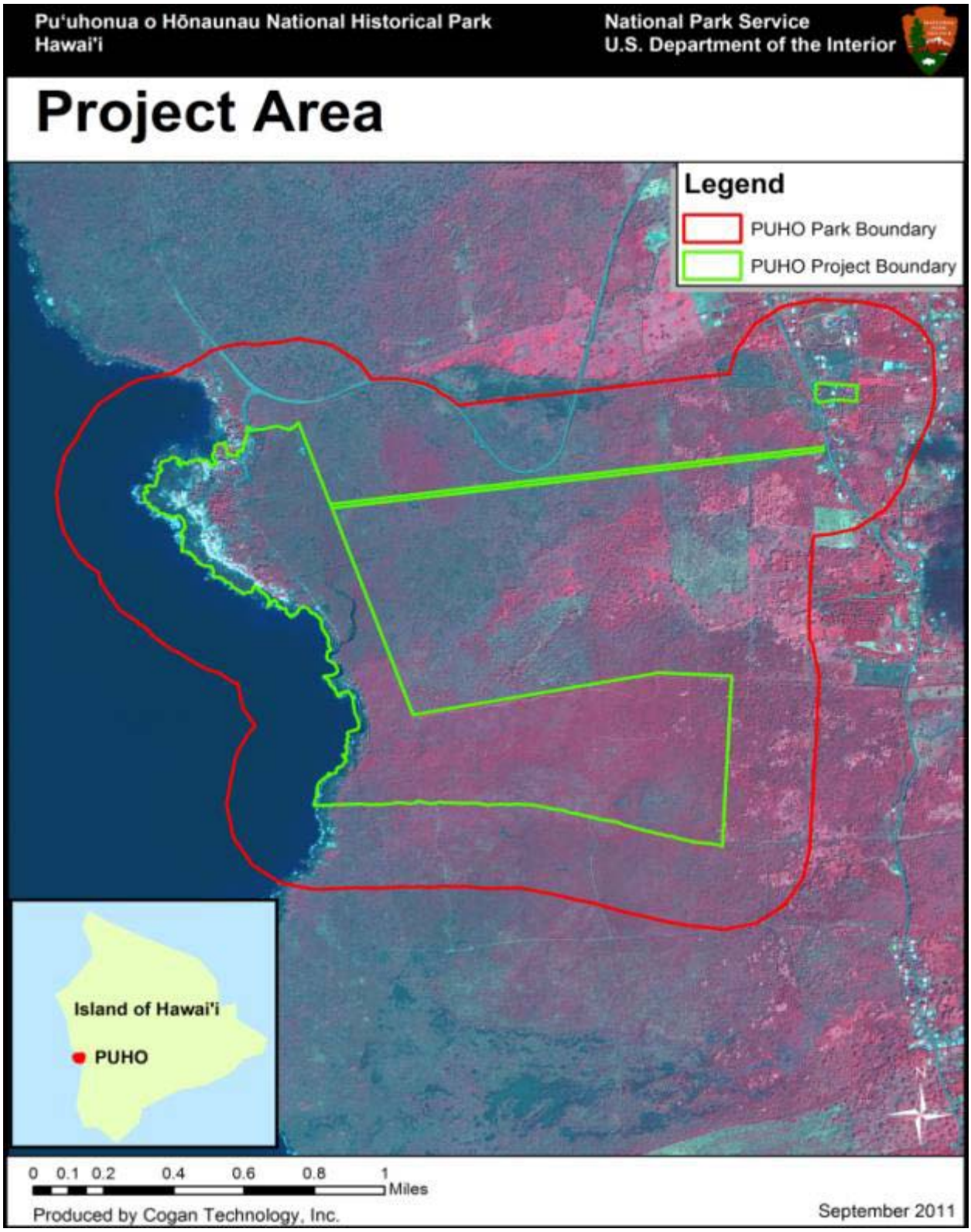


Figure 10. The vegetation mapping project boundary and PUHO park boundary.

Methods

The vegetation mapping project at PUHO was considered to be in the "small park" category based on the overall size of the project area (TNC and ESRI 1994b). As such, the standard methodology for sampling and mapping is to visit the entire park and select representative sites. These sites are used to characterize the vegetation types and explain their distribution across the park without having to survey each stand of vegetation. Based on this approach the assignment of responsibilities was divided into five major steps following the 12 Step Guidance for NPS Vegetation Inventories (NPS 2009).

1. Plan, gather data, and coordinate tasks;
2. Survey PUHO to understand and sample the vegetation;
3. Classify the vegetation using the field data to rUSNVC standard associations and alliances and crosswalk these to recognizable map units;
4. Acquire current digital imagery and interpret the vegetation from these using the classification scheme and a map unit crosswalk;
5. Assess the accuracy of the final map product.

All protocols for this project as outlined in the following sections can be found in the original program documents produced by The Nature Conservancy and Environmental Research Systems Institute (1994a, 1994b, and 1994c) and later revisions (Lea and Curtis 2010) and can be found at this website: http://biology.usgs.gov/npsveg.

Planning, Data Gathering and Coordination

A series of planning conference calls were held throughout 2008 and attended by representative CTI, PACN and PUHO staff. The goals of these calls were to (1) discuss the project, (2) learn about the management issues and concerns, (3) discuss availability of existing data, (4) develop a schedule, (5) discuss procedural issues and data, (6) define potential cooperators, and (7) define a project scope.

Once the boundary was finalized copies of 2006 Quickbird Imagery were obtained from the PACN. This imagery was obtained as pan-sharpened, cloud-free, 4-band, 0.6-meter resolution digital ortho-photos that covered the entire island of Hawai‘i. The specific imagery tiles covering the PUHO project area were selected, clipped and mosaiced to provide the basemap for mapping purposes. In addition to the Quickbird imagery, 1-meter, 3-band (true color) 2002 Ikonos imagery was also obtained for PUHO, but due to cloud cover and ensuing changes at PUHO since 2002 this product was only used in an ancillary role.

The remaining work responsibilities were assigned to the following participants:

NPS-PACN

- Provide oversight and project funding;
- Provide the PUHO plant list;
- Supply digital boundary files and ancillary data files;
- Assist with fieldwork and logistical considerations;
- Work with NatureServe to develop the vegetation classification;
- Provide project management;
- Coordinate the field work with PUHO;
- Collect representative plot data;
- Collect less detailed observations about the draft vegetation map;
- Collect accuracy assessment data;
- Provide a section for the final report describing the field portion of this project;
- Compile, review, and update drafts of the vegetation map, classification and report;
- Accept the final products and finalize the project.

NatureServe (Western Regional Office)

- Work with NPS to develop a vegetation classification for the study area based on the rUSNVC using quantitative analysis and ecological interpretation of the field data;
- Provide guidance regarding the crosswalk of vegetation types to map units;
- Write descriptions of the vegetation types found at PUHO;
- Write a field key to the vegetation types found at PUHO;
- Write vegetation sections (classification methods, results and discussion) of final report;
- Revise field methods document and review other deliverables including database and final report.

Cogan Technology, Inc.

- Help with overall project facilitation and coordination;
- Verify vegetation and land use/land cover signatures on the imagery;
- Develop map units linked to the rUSNVC;
- Provide field maps and GIS support to the field crews;
- Interpret and delineate the final vegetation and land use types;
- Transfer and automate interpreted data to a digital spatial database;
- Produce spatial layers of plot and accuracy assessment site locations;
- Assist with the accuracy assessment by picking the stratified random target points, creating field maps and providing GIS support;
- Provide a visual guide to the photo signatures of each map unit;
- Provide a final report describing the project;
- Document FGDC-compliant metadata for all vegetation data;
- Create a DVD with reports, metadata, guides, vegetation classification, plot data, spatial data, vegetation database (map), graphics, and ground photos.

Field Surveys

The field methods used for developing the classification and conducting the accuracy assessment at PUHO followed the methodology outlined by the NVIP (TNC and ESRI 1994b) for small sized park units. Field crews were led by PACN ecologists with plant community sampling experience in the Hawaiian Islands and other landscapes. The list of ecological systems, vegetation alliances, and component plant associations prepared by NatureServe ecologists provided a starting point for naming the plant communities sampled in the field. The sampling goal was to collect between three and five classification plots in every plant association within the PUHO project area. However, some common associations were sampled more often and some rare types were sampled less often. An effort was made to achieve a good spatial distribution of plots across the landscape and to capture the full range of variation of each association.

When a representative stand of vegetation was located a relevé macroplot was established to record stand characteristics; transitional areas such as ecotones were usually avoided unless they exceeded the project minimum mapping unit (MMU) of 0.5 ha (1.2 ac). Highly disturbed areas were also avoided unless they supported a distinct plant community. Classification plots were generally located in stands exceeding the MMU; however a few plots were sampled in smaller patches if the vegetation was rare and distinctive (such as coastal strand sites). Plot size and shape requirements were consistent with NVIP guidelines (TNC and ESRI 1994b). Measuring tapes were used to establish 11.28 m radius circular sampling plots for all five physiognomies sampled at PUHO (Table 2).

Table 2. Plot Sizes Used for Classification Sampling at PUHO.

Dominant physiognomy	Plot size	Plot area
Forest: trees have their crowns overlapping, usually forming 60-100% cover, and **Woodland**: open stands of trees with crowns usually not touching. Canopy tree cover 25-60%, OR exceeds shrub, dwarf-shrub, herb, and nonvascular cover.	Circular 11.28 m radius	400 m^2
Shrubland: shrubs greater than 0.5 m tall are dominant, usually forming more than 25% cover OR exceeding tree, dwarf-shrub, herb, and nonvascular cover, and **Dwarf-shrubland** (e.g., heath): Shrubs less than 0.5 m tall are dominant, usually forming more than 25% cover OR exceeds tree, shrub, herb, and nonvascular cover.	Circular 11.28 m radius	400 m^2
Herbaceous (e.g., grassland, meadow, marsh): Herbs dominant, usually forming more than 25% cover OR exceeds tree, shrub, dwarf-shrub, and nonvascular cover.	Circular 11.28 m radius	400 m^2
Nonvascular (e.g., fen, bog, cliff): nonvascular cover dominant, usually forming more than 25% cover.	Circular 11.28 m radius	400 m^2
Sparse vegetation (e.g., blowout, beach): less than 10% total vegetation cover.	Circular 11.28 m radius	400 m^2

Following the establishment of each plot, environmental data were recorded on the plot field forms (Appendix A). Environmental data included: elevation, slope, aspect, landform, topographic position, soil texture and drainage, hydrologic (flooding) regime, and evidence of disturbance or wildlife use. The unvegetated surface was estimated and recorded as percent cover of: bedrock, litter and duff, wood, bare soil, large rocks (>10 cm), small rocks (0.2 to10 cm), sand (0.1 to 2 mm), lichens, and mosses. Next the vegetation was visually divided into strata, with the height and canopy cover of the dominant vegetation estimated for each stratum. Within each stratum, all taxa within the plot area were identified and the foliar cover of each taxon was estimated using cover classes (Table 3).

Table 3. Cover classes and vegetation strata

Cover scales	Vegetation strata
T 0–1%	T1 Emergent Canopy:
P >1–5%	T2 Main Canopy
1 >5–15%	T3 Subcanopy
2 >15–25%	S1 Tall Shrubs
3 >25–35%	S2 Short Shrubs
4 >35–45%	S3 Dwarf-shrubs
5 >45–55%	H1 Herbaceous (Graminoids)
6 >55–65%	H2 Herbaceous (Forbs)
7 >65–75%	H3 Herbaceous (Ferns)
8 >75–85%	H4 Herbaceous (Tree seedlings)
9 >85–95%	A1 Floating-leaved aquatics
10 >95%	A2 Submerged-leaved aquatics

Additional species within the vegetation unit that occurred outside of sampled plots were listed separately to assist with the creation of local descriptions. Species that were not identifiable in the field were collected for later identification and specimens were typically destroyed in analysis. Species were recorded by scientific epithet familiar to researchers and a provisional vegetation type was assigned to the plot. Appendix B contains all species found within sample plots and common names used throughout the document.

Field crews documented the vegetation plots as follows: (1) a species list was developed and recorded; (2) UTM NAD83 X-Y, field note headers (Identifiers/Locators), environmental descriptions, and elevation were recorded both manually on the plot forms and stored as waypoints in the GPS receiver; and (3) eight representative digital photographs were acquired for each plot. Four photos were captured facing each of the cardinal directions (N, E, S, and W), one photo was used to capture the center of the plot (Figure 11), and a total of 3 photos were used to capture the complete pages of the field forms.

In addition to the vegetation classification plots, PACN field crews collected vegetation and environmental data at several observation points. Data recorded at observation points reflected the vegetation of an area of variable spatial extent around the point rather than a measured plot, and were less detailed (Appendix A). Overall conditions at each observation point were documented by one or more digital photographs. These data were intended primarily to support modeling and interpretation of the base imagery, but were also used to help describe plant

associations when local descriptions were prepared. Specifically, observation point data were collected when:

- The vegetation was homogenous, representative, and several classification plots had been sampled;
- Sampling the environs outside the PUHO boundary;
- The vegetation was highly disturbed, ecotonal, or otherwise anomalous and therefore unlikely to be classified under the rUSNVC;
- CTI requested documentation of a specific photo-signature or area;
- To document special features as requested by PUHO staff including invasive plant stands;
- To document a vegetation type that consistently occurred in stands smaller than the 0.5 ha (1.24 acre) MMU;
- The sample point could not be safely accessed to complete the full plot.

The classification data was collected between June and July 2008.

Vegetation sampling included 40 classification plots and 14 observation points (Figure 12).

Figure 11. Plot photo data collection during field sampling.

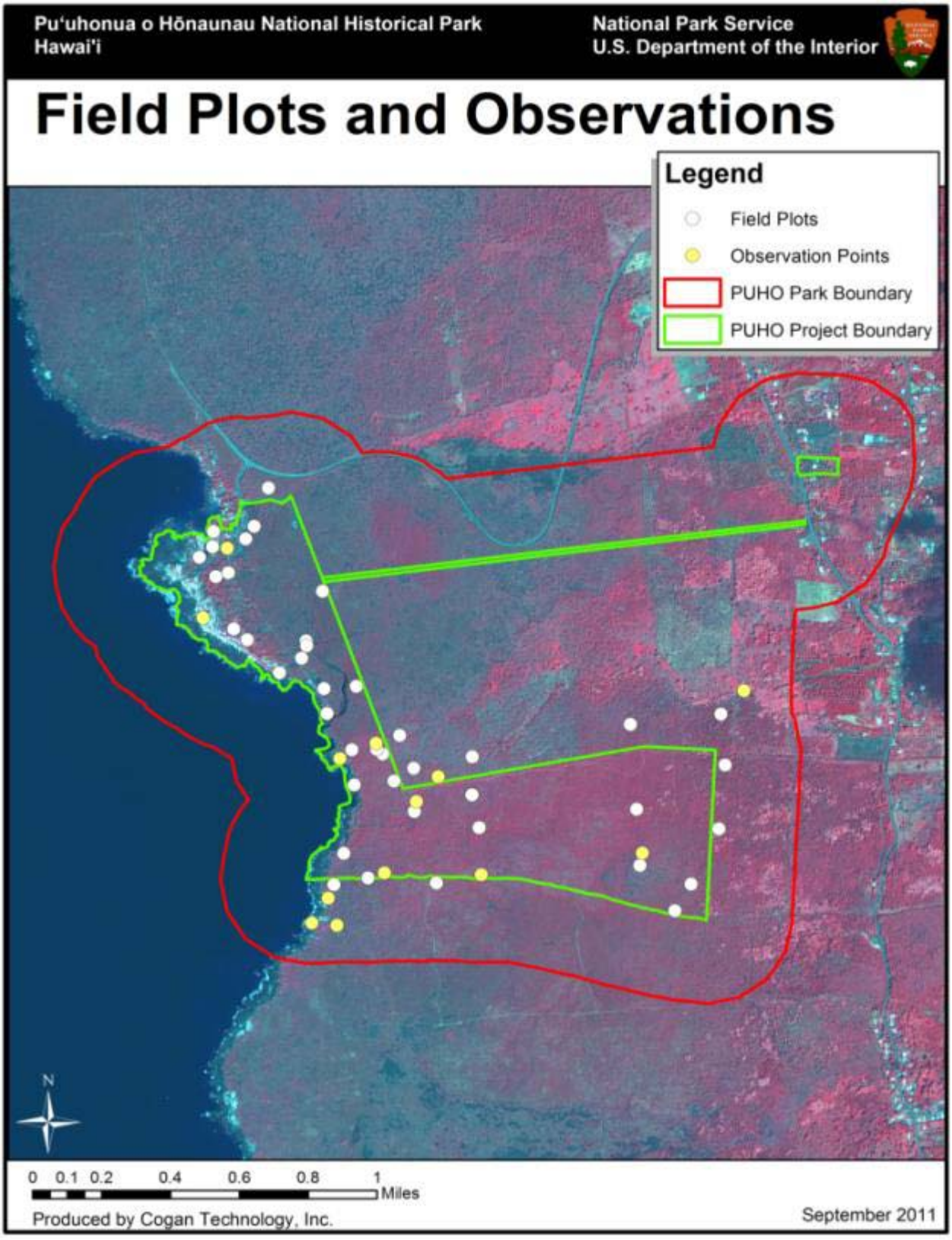


Figure 12. Location of vegetation plots and observation points collected at PUHO.

Vegetation Classification

The first step in classifying the vegetation at PUHO was to prepare a preliminary classification prior to vegetation sampling. NatureServe provided PACN staff an USNVCv1 tabular report of all vegetation associations and alliances attributed to Hawai'i. This list covered a much broader area than the PUHO project area and included many types that occur in the park, as well as associations that may occur in other park units in the PACN. In addition, NatureServe provided descriptions of wetland and riparian Terrestrial Ecological Systems. Ecological Systems approximate the scale of NVCSv2 Groups and were available in 2008 when this project started.

Upon completion of the plot data collection, all data were transferred by PACN staff to a Microsoft Access database. For ease of use the MS Access database mirrored the standard field form with fields and tables that matched all of the data recorded on the field forms. Following data entry, quality assurance checking was performed to minimize errors associated with duplicate entries or erroneously selected plant or association names or types.

Unknown species identification, especially those with high cover were resolved, as were other taxonomic issues such as accepted nomenclature. Plot locations were verified by field crew members by overlaying coordinate data on the Quickbird imagery. At the completion of the field work the final database was used by NatureServe for quantitative analysis.

NatureServe began the formal classification work by combining the PUHO plot and observation data contained within the database with the similar data obtained at PUHE and KAHO (137 plots total). The first review indicated 49 field observation points did not have enough detail to fit analyses protocol and were removed from the dataset prior to multivariate analyses. However, all field observations were used during qualitative analysis and final classification. Next, the database was converted to meet NatureServe standards and all of the plant taxonomy was standardized to the USDA Plants database.

After standardizing the database, NatureServe found some additional inconsistencies when the field crews assigned taxa to strata. To correct these issues, NatureServe ecologists equalized the strata so that all shrub and herbaceous vegetation (included tree seedlings) were in the proper strata and then merged individual taxa into one of four strata (Table 4). For example, noni was listed in as many as six strata but was combined into three strata (tree, shrub, and herbaceous vegetation) for classification purposes. Merging individual taxa within a plot meant combing the cover values of two records using the following formula: A + (B*(1-A)). Where A is the cover of the taxon in one occurrence and B is the cover of the taxon in the other occurrence. This formula takes into account that individual plants within strata will likely shade each other so a simple addition of the cover values is rarely accurate, particularly when the cover values are moderate to high.

The final dataset used in multivariate analysis for the classification had 85 unique taxa that occurred across 88 plots yielding 713 taxa records (combinations of taxa and strata).

Table 4. Conversion of strata from original data to final stratum used in analyses.

Original Stratum	Description	Final Stratum	Code
T1	Emergent	Tree	T
T2	Canopy	Tree	T
T3	Subcanopy	Tree	T
S1	Tall Shrub	Shrub	S
S2	Short Shrub	Shrub	S
S3	Dwarf Shrub	Shrub	S
H	Herbaceous	Herbaceous	H
H1	Graminoids	Herbaceous	H
H2	Forbs	Herbaceous	H
H3	Ferns and Allies	Herbaceous	H
H4	Tree Seedlings	Herbaceous	H
N	Nonvascular	Nonvascular	N

Plant nomenclature in the NVCS is that of the Integrated Taxonomic Information System (ITIS) as reflected by the PLANTS Database (USDA -NRCS 2007). For this study, some NVCS names were modified based on Wagner and Herbst (2003) and Wagner et al. (1999) and these changes are identified throughout the document. Naming the plant associations used indicator (dominant or diagnostic) species for each of the vegetative strata present. The indicator species of the upper strata was listed first, followed by successively lower strata (e.g., canopy, subcanopy, tall shrub, short shrub, herbaceous vegetation, etc.). Plant species that may only be occasionally present in the same stratum are separated by parentheses ( ). Species that always occurred in the same stratum (or were the same lifeform) are separated by a hyphen (-). Indicator species that occurred in different strata (or are a different lifeform) were separated by a slash (/). Alliance names were concluded with the word "Alliance" to differentiate them from association names. Plant association names incorporated the physiognomic class in which the association was classified (e.g., Forest, Woodland, or Herbaceous)(FGDC 1997, 2008).

Data Analysis

The data from PUHO, KAHO, and PUHE were combined for analysis because of significant overlap in species composition and vegetation structure between these parks which are all located along the western coast of the island of Hawai‘i. It was expected that the parks would have similar and overlapping vegetation biodiversity. A combined analysis allowed NatureServe to compare and contrast parks, and solved the statistical problem of analyzing small data sets, which tend to have high variance.

NatureServe exported the combined data into PC-Ord version 5 (McCune and Mefford 1999) and used an analytical, iterative classification process beginning with all plots and systematically removed groups of plots that were clearly different at each stage. Quantitative analytical methods have different strengths and weaknesses so results from several techniques were used and compared. The primary quantitative analytical methods included both ordination, specifically Nonmetric Multidimensional Scaling (NMS) and Detrended Correspondence Analysis (DCA) and clustering techniques (Flexible Beta linkage method). Once the qualitative analyses were completed the classification process was finalized by expertly reviewing the plant assemblages using qualitative methods and matching them to any existing known plant associations.

Initial results of the analyses found 15 groups defined by the cluster analysis (Table 5) and were graphed using the two ordination methods to compare results (Figures 13 and 14). The final classification of the 88 plots in the dataset resulted in 20 types. Ten of the 15 analysis groups exactly matched types in the final classification (all plots in the group were classified the same type). Two analysis groups matched all but one plot. The three remaining analysis groups had to be interpreted plot by plot, using qualitative assessments based on the presence of indicator species or cover break thresholds by canopy characteristics e.g., shrublands versus grasslands with scattered shrubs. One of these groups, kikuyu grass (*Pennisetum clandestinum*) w/ sparse koa haole, was erroneously generated due to a data entry error. Kikuyu grass does not occur in PUHO or KAHO and only occurs in PUHE as a lawn grass. Once this entry error was discovered this group was lumped with koa haole / fountain grass.

Table 5. Names of 15 groups defined by the cluster analysis of West Hawai'i park's plots with number of plots per group.

Code	Analysis Group Name	# Plots
1	*Leucaena leucocephala / Pennisetum setaceum*	13
3	*Pennisetum clandestinum* w/ sparse *Leaucaena leucocephala*[1]	2
8	*Prosopis pallida – (Leucaena leucocephala) / Pennisetum setaceum*[1]	11
15	*Batis maritima – (Tournefortia argentea - Sesuvium portulacastrum)*	3
16	*Waltheria indica - Sida fallax*[1]*	5
19	*Thespesia populnea*[1]	1
20	*Paspalum vaginatum*[1]	2
34	*Cenchrus ciliaris*[2]	11
43	*Macroptilium lathyroides - Aster spp.* [1]	1
49	*Leucaena leucocephala – (Pithecellobium dulce) / Talinum fruticosum*	11
50	*Scaevola taccada*[1,2]	1
56	*Cocos nucifera / Melinis repens*[1]	2
57	*Leucaena leucocephala / Panicum maximum*[2]	18
60	*Pithecellobium dulce – (Leucaena leucocephala) / Panicum maximum*[1.2]	5
73	*Samanea saman - Schinus terebinthifolius*[1]	2

[1] The 10 analysis groups that exactly matched types in the final vegetation classification.
[2] rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

Naturserve also ran an indicator species analysis on the 15 groups defined by the preliminary qualitative classification to generate a list of species that were important in defining the various groups (Table 6).

Table 6. Indicator species with the highest Observed Indicator Values.

Species Name	Observed Indicator Value	Species Name	Observed Indicator Value
Cocos nucifera	100	*Sida fallax*	80.3
Samanea saman	100	*Lantana camara*	78.7
Melinis repens	96.7	*Panicum maximum*	76.2
Paspalum vaginatum	95.6	*Waltheria indica*	75.7
Morinda citrifolia	95.5	*Thespesia populnea*	75.0
Cenchrus ciliaris	92.2	*Pennisetum setaceum*	73.9
Batis maritima	88.0	*Tournefortia argentea*	66.7
Schinus terebinthifolius	85.0	*Sesuvium portulacastrum*	66.7
Pithecellobium dulce	80.8	*Leucaena leucocephala*	59.1
Prosopis pallida	80.6	*Bidens pilosa*	57.7

To supplement the initial classification results and to finalize the vegetation classification, NatureServe ecologists also used ordination to examine a portion of the draft classification and displayed the types over the ordination results (quantitative analysis) again using DCA and NMS methods. The results indicated that the draft classification was split too finely (30 types) and resulted in overlap of some of the types due to floristic similarities between plots.

After much review and examination of the results NatureServe decided to lump types based on the ordinations and qualitative analysis resulting in 20 plant associations. Six additional types were added to this list based on qualitative review of the remaining 49 plots, yielding a total of 26 plant associations.

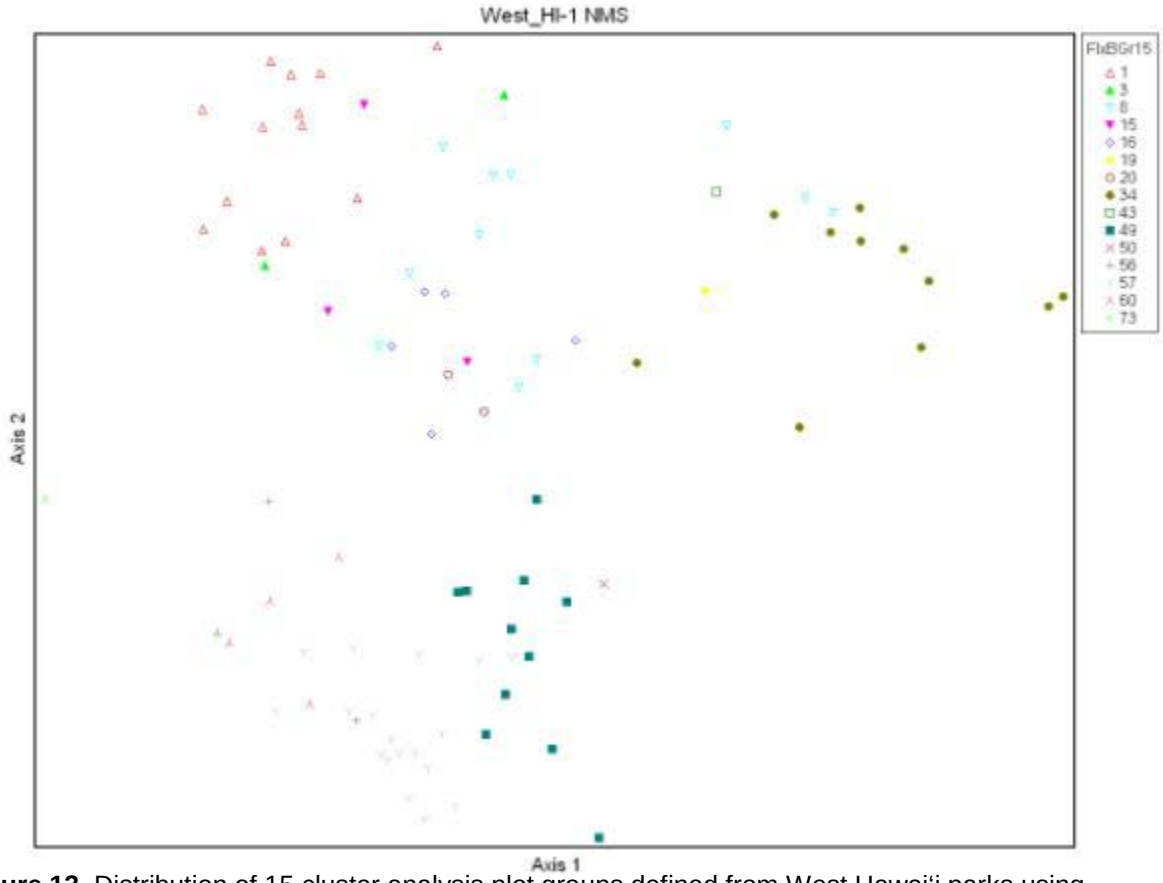


Figure 13. Distribution of 15 cluster analysis plot groups defined from West Hawai'i parks using Nonmetric Multidimensional Scaling (NMS) ordination.

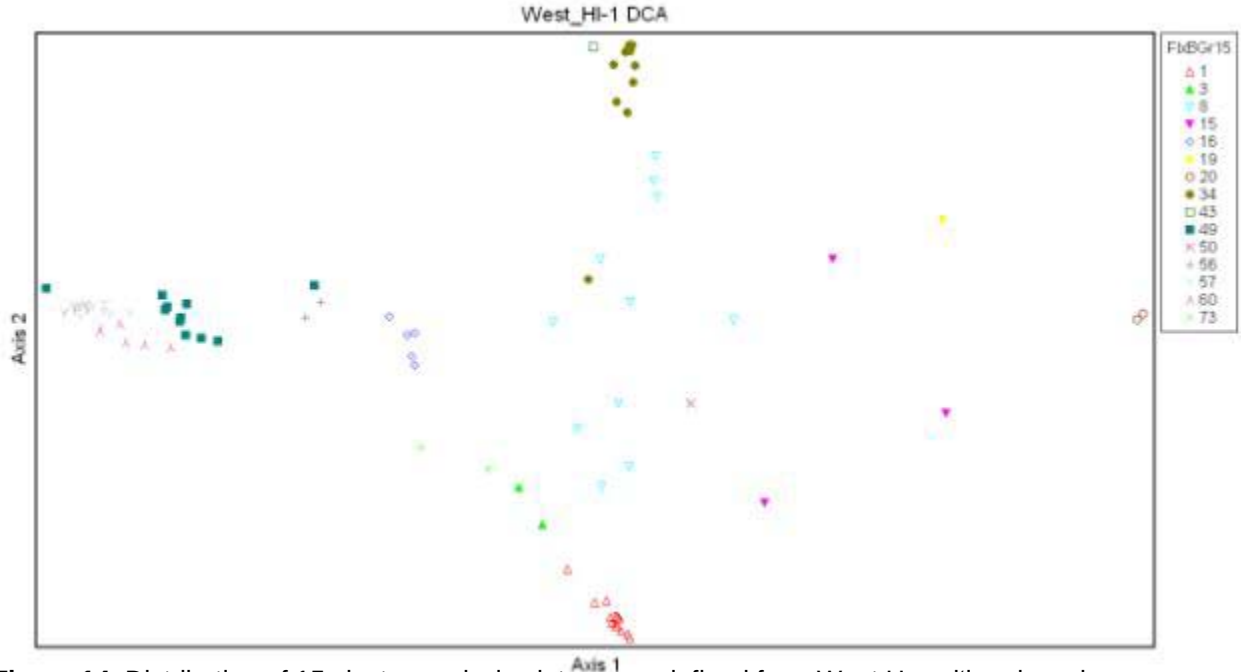


Figure 14. Distribution of 15 cluster analysis plot groups defined from West Hawai'i parks using Detrended Correspondence Analysis (DCA) ordination.

Digital Imagery and Mapping

Since PUHO represented a fairly small and accessible site, no new imagery or aerial photography were deemed necessary for this project. Instead, existing sources of imagery were evaluated and two products were selected to be used as the initial base maps. These included the 2006 Quickbird and 2002 Ikonos products (Figure 15). The 2006 product was deemed superior by CTI technicians since it had better resolution and contained the color infrared (CIR) band. The 2002 product had 1-meter resolution and was provided in true-color format (3-bands).

After obtaining both sets, the 2006 imagery was color balanced in Imagine Software to remove some of the edge-matching issues and sharpen the image. The 2002 imagery was also color balanced, but edge-matching was not preformed. The resulting image from the 2006 imagery was pieced together as a mosaic and clipped to just beyond the extent of the project boundary.

Interpretation of the vegetation at PUHO involved a three step process: (1) image segmentation, (2) cleaning and smoothing, and (3) ground-truthing of the data. First, the 2006 imagery was re-sampled to a 3-meter pixel resolution to reduce noise and to generalize the vegetation signatures. Next, this imagery was segmented to delineate obvious landforms (e.g. open water and fields) and physiognomic features (e.g. grasslands versus woodlands). The initial segments were created using a series of trial and error multi-resolution segmentation routines in the software. The settings for scale and shape were manipulated until a desired network of images resulted. The objective of the segmentation was to create a system of lines with as coarse a scale as possible without omitting most of the small, important and obvious land cover patches. By incrementally increasing segmentation size within the program, small image objects (i.e., preliminary polygons) were continuously merged into larger ones. Completion of the segmentation was based on visual judgment of the CTI analyst when obvious, distinct features were lost. At this point in the process, the previous segmentation was adopted as the final treatment.

Following segmentation, the lines were exported as ArcInfo shapefiles and converted to ArcInfo coverages. The resulting coverages were run through a series of smoothing routines provided in the ArcGIS software. Smoothing was conducted to reduce the stair-stepping pattern of the lines resulting from the large pixels. Smoothing ended when no obvious artificial or relict breaks in the lines were visible. Following smoothing, the line-work was manually cleaned to remove extraneous lines, small polygons, and polygons that obviously split a homogenous stand of vegetation. The cleaning stage was considered complete when all resulting polygons matched homogenous stands of vegetation apparent on the 2006 imagery.

The lines resulting from the 2006 imagery segmentation were visually inspected in ArcInfo. Any obvious problems in the mapping (such as shifting and sliver polygons) were edited and resolved. Review of the merged polygon layer revealed that the roads and the facilities were not adequately separated from the surrounding vegetation. To resolve this, all developed areas,

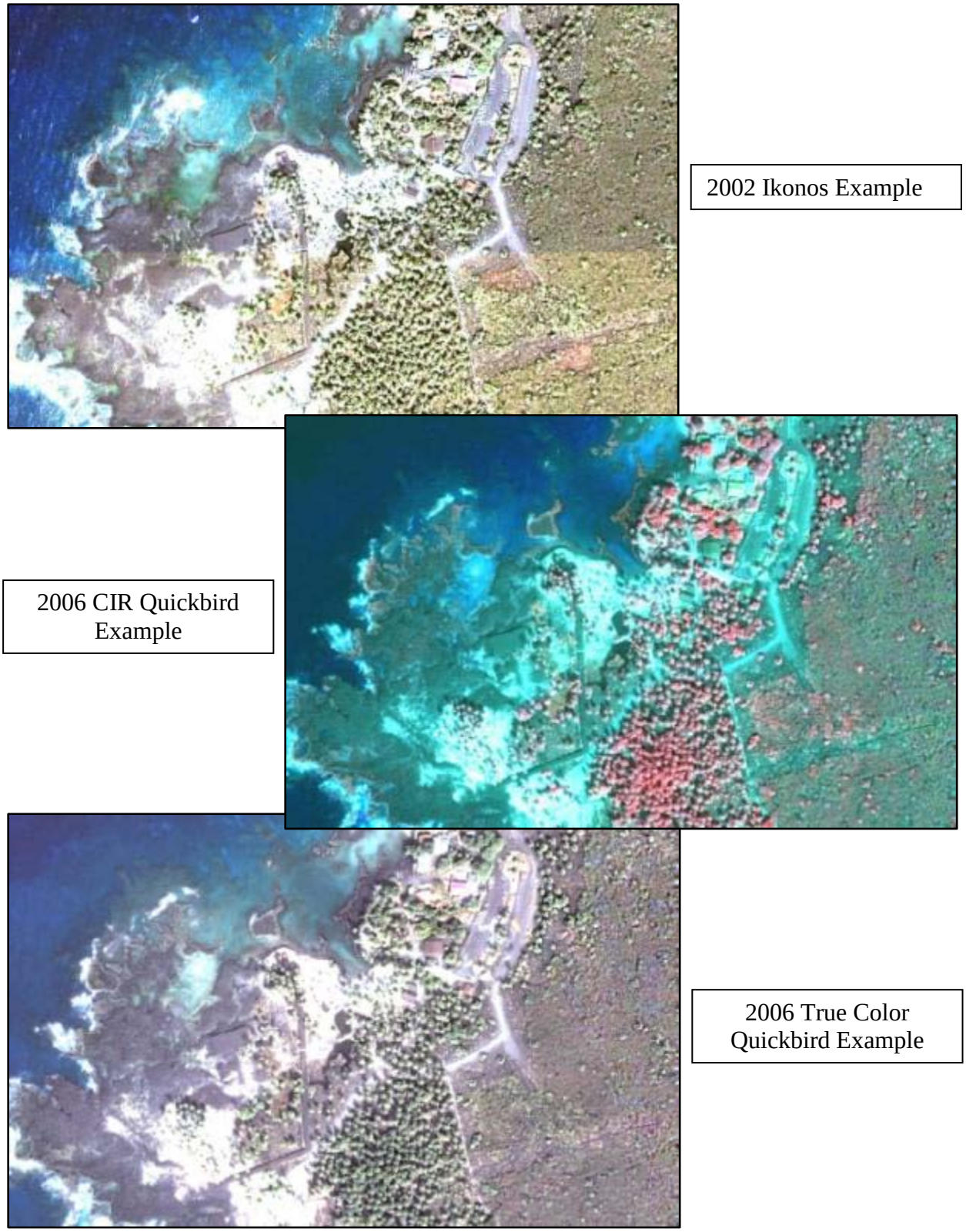


Figure 15. Examples of the Ikonos 2002 and Quickbird 2006 imagery for PUHO.

roads, streams and other linear or rectangular features were manually digitized directly off the 2008 imagery and incorporated into the final segmentation. After merging the digitized lines with the segmented linework the resulting preliminary GIS layer was considered complete and ready to be ground-truthed in the field.

Ground-truthing the preliminary vegetation layer for PUHO involved printing 1:6,000-scale hardcopy maps. These contained the 2006 basemaps and the linework as an overlay. During three days in 2009, researchers from CTI visited representative polygons at PUHO, KAHO and PUHE. Ground-truthing consisted of verifying the maps against the actual vegetation on the ground to ensure that the polygons were labeled properly and to locate any extra or missing vegetation polygons. More general observations were also taken during this trip to help write map unit descriptions and ultimately create the mapping scheme. All the information from this trip was subsequently added to the final GIS layer to correct any errors.

Upon return from the field, CTI researchers used the final classification supplied by NatureServe to create the mapping scheme. In most cases, the map units were derived on a 1 association or alliance to 1 map unit basis. Due to the limitations of the imagery, some of the associations could not be recognized consistently. This issue was addressed by either scaling up the rUSNVCS to the alliance level or combining similar associations/alliances into complexes. All of the resulting map units were then correlated or "crosswalked" by noting when plant associations were used as a map unit or when they were grouped. To round-out the mapping scheme, map units were created for land use types based on a mapping system developed by Anderson et al. (1976). This included unvegetated lands not in the rUSNVC, such as roads, facilities, and bare lava. A separate class of map modifiers or "Park Specials" was defined especially for PUHO to cover types that occurred either outside of the park boundary or where too small to sample. These included the coastal strand and a few other map units. All of the resulting map unit names, map unit codes, rUSNVC information, and other relevant attributes were added to each polygon in the GIS layer (Table 7).

Accuracy Assessment

Once the vegetation layer was completed and finalized the accuracy assessment (AA) was conducted. Typically, in mapping exercises both thematic or attribute map accuracy as well as the positional or polygon line accuracy are considered. In the case of the NVIP however, the positional accuracy is usually omitted since rarely does vegetation split on discrete edges that can be positively located in the field. The subjectivity involved in this effort plus the high resolution and accuracy of Quickbird imagery allows for the assumption that all products derived from them are well within National Map Accuracy Standards for 1:12,000-scale maps (±30 feet).

The thematic accuracy of the vegetation map was assessed using the methodology following the standards provided by the NVIP (TNC and ESRI 1994c). This protocol has since been revised by the NVIP (Lea and Curtis 2010) but this project was started before the new standards were in place. The previous protocols included a four step AA process consisting of a sample design, sample site selection, data collection, and data analysis. The design of the AA process followed the five possible scenarios provided in the field manual with stratified random targets placed in each map class based on their respective frequency and abundance (Table 8).

Table 7. Polygon attribute items and descriptions used in the PUHO GIS coverage.

ATTRIBUTE	DESCRIPTION
OBJECTID*	Unique code for each polygon
AREA*	Surface area of the polygon in meters squared
PERIMETER*	Perimeter of the polygon in meters
VEG_CODE	Final Map Unit Codes – Project specific
MAP_DESC	Map Unit Common Description Name – Project specific
DENS_MOD	Modifier - Percent cover of the upper stratum layer in the polygon Percent cover classes: Sparse **10 - 25%,** Open **25 - 60%,** Discontinuous - Closed **> 60%**
PTRN_MOD	Modifier - Vegetation pattern within the polygon Vegetation pattern classes: Evenly Dispersed **= Homogeneous** Grouped Stands of Vegetation = **Bunched / Clumped,** String of Vegetation **= Linear**
HT_MOD	Modifier - Height range of the dominant vegetation layer Height classes: **< 1, 1-5, 5-15, 15-30 & >30 meters**
NVC_ELCODE	Corresponding Association Code – NVCS derived (NatureServe) Association **=** Community Element Global Code – Elcode link to the NVCS
ASSN_NAME	Project Community Name - NVCS Association(s)
ASSN_CNAME	Project Common Community Name - synonym name of Association(s)
ALL_CODE	Alliance Name Code – NVCS derived (NatureServe) Alliance = Alliance Global Code – Alliance Link to the NVCS
ALL_NAME	Project Alliance Name = NVCS Alliance(s)
ALL_CNAME	Project Common Alliance Name = NVCS Alliance(s)
GROUP	NVCS Group= Group name
MACROGROUP	NVCS Macrogroup = Macrogroup name
DIVISION	NVCS Division = Division name
FORMATION	NVCS Formation = Formation name
SUBCLASS	NVCS Subclass = Subclass name
CLASS	NVCS Class = Class name
LUC_II_GEN	General Land Use and Land Cover Classification System Name Project specific based on Level I or II of Anderson et al. (1976)
LUC_II	Specific Land Use and Land Cover Classification System Name Project specific Level II or Level III of Anderson et al. (1976)
COMMENTS	Additional Comments about the Vegetation in Individual Polygons
ACRES	Surface area of the polygon in acres

(*****ArcInfo© default items)

These parameters were loaded into a custom GIS program along with the vegetation layer. This program picked the random target locations and also buffered them 10 meters (33 ft) away from any polygon boundary and 50 meters (165 ft) away from any other point. Being able to choose minimum distance to polygon boundaries helped to minimize confusion and accounted for the horizontal error typically encountered in common GPS receivers (±5 m). To complete the sampling targets, additional points were added to long linear polygons and rare types. The resulting target locations were restricted to those within the boundaries of PUHO.

Once the target locations were selected, PACN botanists were provided with draft field maps, overview maps, map unit definitions, the key to the associations (Appendix D), and digital GPS files containing the location of the target AA sites. Between November 2009 and February 2010, the botanists traveled to the AA target sites and determined the vegetation association using the field key. At each target they recorded the primary and secondary associations that occurred within the mapped polygon up to roughly 50 m (165 ft) radius. They also recorded height and cover of vegetative strata, environmental data, and percent canopy cover of the major species (see AA point form in Appendix A). Other nearby vegetation types and any recent disturbance were also recorded. To better assist the analysis a minimum of four photographs were taken at each AA point in the sequence of cardinal directions, N-E-S-W. If the point was too close to dense, especially shrubby vegetation, one or more optional photographs were taken at a distance to show the character of the vegetation.

Table 8. NVIP Sampling protocol for AA points.

Scenario	Description	# Polygons	Area (ac)	Recommended # of Samples
A	The class is abundant. It covers more than 50 hectares of the total area and consists of at least 30 polygons. In this case, the recommended sample size is 30.	> 30	> 125	30
B	The class is relatively abundant. It covers more than 50 hectares of the total area but consists of fewer than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size for this type of class is that sample sites are more difficult to find because of the lower frequency of the class.	< 30	> 125	20
C	The class is relatively rare. It covers less than 50 hectares of the total area but consists of more than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size is that the class occupies a small area. At the same time, however, the class consists of a considerable number of distinct polygons that are possibly widely distributed. The number of samples therefore remains relatively high because of the high frequency of the class.	> 30	< 125	20
D	The class is rare. It has more than 5 but fewer than 30 polygons and covers less than 50 hectares of the area. In this case, the recommended number of samples is 5. The rationale for reducing the sample size is that the class consists of small polygons and the frequency of the polygons is low. Specifying more than 5 sample sites will therefore probably result in multiple sample sites within the same (small) polygon. Collecting 5 sample sites will allow an accuracy estimate to be computed, although it will not be very precise.	5-30	< 125	5
E	The class is very rare. It has fewer than 5 polygons and occupies less than 50 hectares of the total area. In this case, it is recommended that the existence of the class be confirmed by a visit to each sample site. The rationale for the recommendation is that with fewer than 5 sample sites (assuming 1 site per polygon) no estimate of level of confidence can be established for the sample (the existence of the class can only be confirmed through field checking).	< 5	< 125	Visit all and confirm

During 2009/10, a total of 82 points were sampled (Figure 16). The data recorded on the field forms were subsequently entered into a Microsoft Access database and reviewed for data entry errors by NPS staff. Incomplete data on the field sheets were corrected if possible. The results were imported from the database into a GIS layer where they were visually compared in two stages to the vegetation map coverage. The first step was to compare the AA points to the original target locations to check for errors and correct if possible. General errors in the data included incorrect UTM coordinates (standing outside of the target polygon), incorrect field call (based on actual species cover values) or incomplete polygons (i.e. unclosed polygons). Changes were made and recorded in the comments field of the AA point layer. The most common GPS receiver error included transposing two UTM coordinate numbers.

The second review step involved deciding between the primary, secondary or tertiary field call for the plant association as recorded by the field crew. To accomplish this, CTI had to assign a final map unit for every point by choosing between the different calls. This was done by first adding a new attribute to the AA point layer and then comparing the assigned field names of the point with its corresponding location on the digital imagery. In most cases, the primary vegetation map unit name assigned by the field crew was used. However, some points were assigned their secondary field call based on one of the following reasons: (1) it appeared that the second call was the better choice due to the overhead perspective (e.g. a stand judged to be sparse woodland on the imagery vs. called herbaceous vegetation in the field), (2) the data were actually recorded in a stand that was too small (i.e. inclusion below MMU size), or (3) the second call more appropriately matched the ecological context (e.g. coastal strand vegetation along the coast vs. upland vegetation).

Once the data were reviewed, the accuracy analysis was conducted. This was accomplished by using CTI custom GIS programs and AA templates supplied by the NVIP. Through this automated process, the final map units in the AA layer were compared to the map unit designations for their corresponding polygons. All of the statistics and calculations used to analyze these data are described at length in the program manuals (TNC and ESRI 1994c and Lea and Curtis 2010). Final assessments for each point were recorded using error matrices.

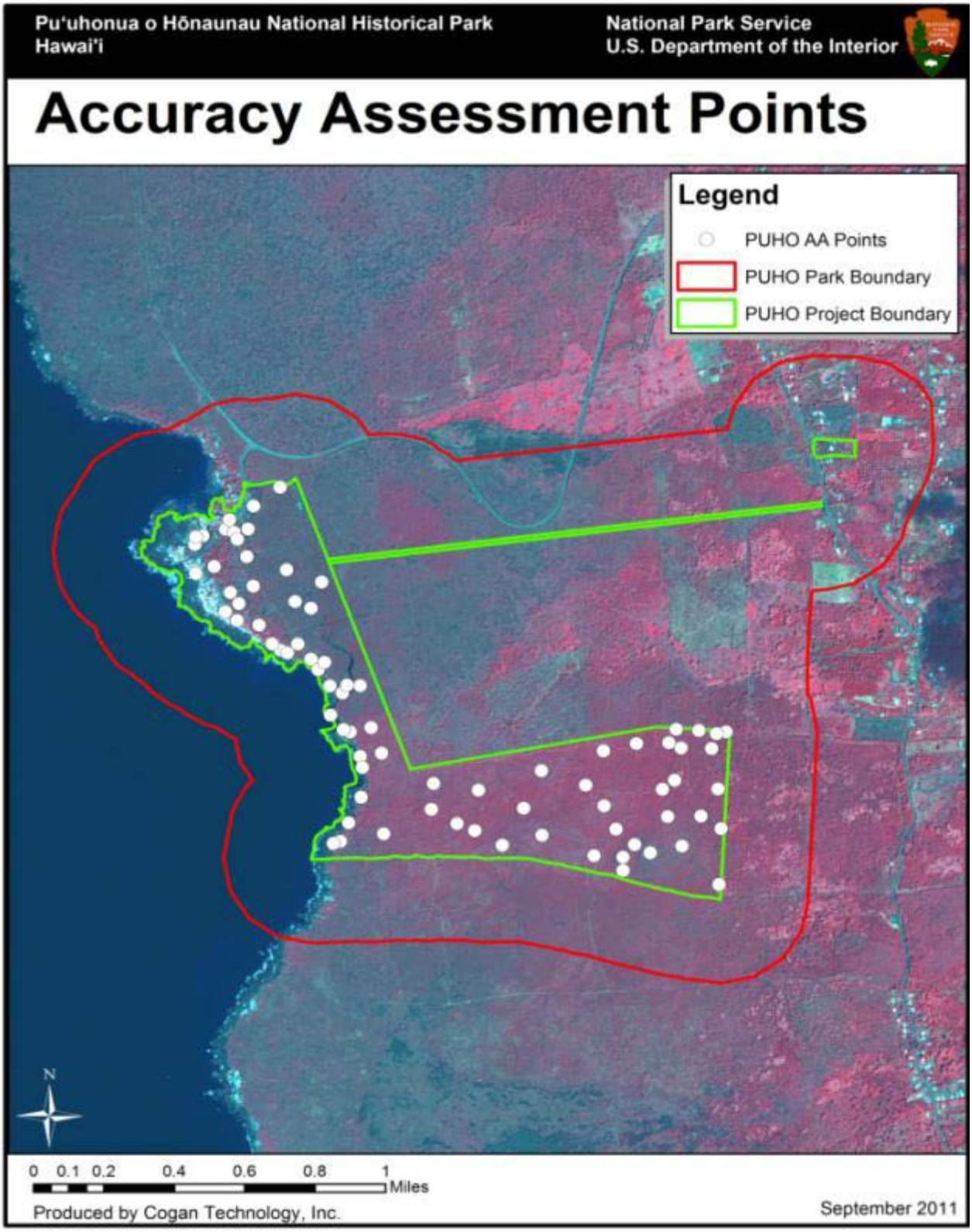


Figure 16. Location of accuracy assessment points collected at PUHO.

Results

Vegetation Classification

This combined classification for the West Hawai‘i parks (PUHO, KAHO and PUHE) totaled 25 vegetation types including nine woodlands, eight shrublands, six herbaceous vegetation types, and two sparsely vegetated types (Table 9). This vegetation classification work produced a total of 18 rUSNVC Associations representing 11 Alliances and six Groups. Seven Park Special vegetation types were created that represent local vegetation stands that differ significantly from existing rUSNVC association concepts, but lack enough data to develop into a new association. Park Special types are not officially included in the rUSNVC Hierarchy, but many times can be linked to the Group level for classification and mapping purposes. Some of these Park Special communities may become new associations with additional data or they may be subsumed into existing rUSNVC associations.

There was some overlap between the three parks with five types sampled in more than one park and three types sampled in all three parks. Some types such as the two sparse vegetation types were mapped in all parks although only sampled at KAHO. The majority of these vegetation types are dominated by non-native species (19 of 25) and considered semi-natural or ruderal.

The vegetation classification work at PUHO resulted in 14 vegetation types. When summarized by class there are five woodlands, five shrublands, and four herbaceous vegetation types documented with plots at PUHO. The PUHO classification includes a total of 11 rUSNVC Associations and 3 Park Specials, representing 10 Alliances and 5 Groups. Table 10a lists the PUHO vegetation classification to the group level.

The PUHO vegetation classification is based on plot data sampled by field crews. However, there were nine additional vegetation types in the map legend that are not in the PUHO vegetation classification (Table 10b). These include: Christmas berry / Fountain grass Semi-natural Woodland, Bougainvillea (*Bougainvillea glabra*) Semi-natural / Planted Shrubland, Fountain Grass Semi-natural Herbaceous Vegetation, A‘a Lava with Sparse Vegetation, Coastal Strand Sparse Vegetation, Pahoehoe Lava Sparse Vegetation, Mixed Semi-natural / Ornamental Tree Woodland, Kukui (*Aleurites moluccana*) Woodland Stand and Pili Planted Herbaceous Vegetation. Three of these additional types were Park Specials with field plots from KAHO, four are unclassified map units and only two were rUSNVC associations.

These additional vegetation types in the map legend were identified during accuracy assessment. Two of these types, Pili Planted Herbaceous Vegetation, and Kukui Woodland Stand, were primarily identified either in restored areas or in the environs (buffer) surrounding PUHO. Most of the other additional types have been sampled from either KAHO or PUHE and are generally dominated by non-native species. These additional types are unclassified map units and included in the dichotomous field key (Appendix D), but local descriptions were not written because information to create descriptions was not collected from PUHO. Lists of plots and local descriptions of associations and park specials are available in Appendix C and Appendix E, respectively.

Table 9. Summary Plant Associations and Park Specials for West Hawai'i parks with number of plots sampled.

Plant Communities of West Hawai'i Parks	PUHO	KAHO	PUHE	Total
A'a Lava with Sparse Vegetation [Park Special]		2		2
Batis maritima Semi-natural Dwarf-shrubland		6		6
Bougainvillea glabra Semi-natural / Planted Shrubland [Park Special]		1		1
Cenchrus ciliaris Semi-natural Herbaceous Vegetation[2]			12	12
Coastal Strand Sparse Vegetation [Park Special][1]		1		1
Cocos nucifera Strand Woodland[1]	6	1	1	8
Fimbristylis spp. Coastal Dry Herbaceous Vegetation[1]	1			1
Leucaena leucocephala - Pithecellobium dulce Semi-natural Shrubland [Park Special]	2			2
Leucaena leucocephala / Pennisetum setaceum Semi-natural Shrubland		8		8
Leucaena leucocephala / Panicum maximum Semi-natural Shrubland[2]	12			12
Leucaena leucocephala Lowland Dry Semi-natural Shrubland	11			11
Macroptilium lathyroides Herbaceous Vegetation [Park Special]			2	2
Melinis repens Semi-Natural Herbaceous Vegetation	2			2
Paspalum vaginatum Semi-natural Herbaceous Vegetation		3		3
Panicum maximum Lowland Dry Semi-natural Herbaceous Vegetation[2]	5			5
Pennisetum setaceum Semi-natural Herbaceous Vegetation		8		8
Pithecellobium dulce Semi-natural Woodland	8			8
Prosopis pallida Coastal Dry Semi-natural Woodland	1	9	10	20
Samanea saman - Schinus terebinthifolius Semi-natural Woodland [Park Special]	2			2
Scaevola taccada Coastal Dry Shrubland[1,2]	1	1		2
Schinus terebinthifolius / Pennisetum setaceum Semi-natural Woodland		3		3
Sida cordifolia Semi-natural Herbaceous Vegetation [Park Special]	1			1
Thespesia populnea / Sparse Understory Woodland[1]	1	3	1	5
Tournefortia argentea Semi-natural Woodland		2		2
Waltheria indica - Sida fallax Shrubland[1]	1	6		7
Total number of plots	54	54	26	134

[1] Native or early Polynesian introduced naturalized types.
[2] rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

Table 10a. PUHO vegetation classification with rUSNVC hierarchy to Group level.

Association Name	Common Name	Elcode [1]	Alliance Name	A.Key [2]	Group Name
Woodlands (Native)					
Cocos nucifera Strand Woodland	Coconut Palm Strand Woodland	CEGL 005402	*Cocos nucifera* Coastal Woodland Alliance	A.2691	Hawaiian Dry Scrub & Herb Coastal Strand Group
Thespesia populnea / Sparse Understory Woodland	Milo / Sparse Understory Woodland	CEGL 005412	*Thespesia populnea* Coastal Woodland Alliance	A.2690	Hawaiian Lowland Dry Forest & Woodland Group
Woodlands (Ruderal)					
Prosopis pallida Coastal Dry Semi-natural Woodland	Kiawe Coastal Dry Semi-natural Woodland	CEGL 008118	*Prosopis pallida* Ruderal Woodland Alliance	A.2699	Hawaiian Ruderal Dry Forest Group
Pithecellobium dulce Semi-natural Woodland	‘Opiuma Semi-natural Woodland	CEGL 005409	*(Samanea saman - Schinus terebinthifolius - Pithecellobium dulce - Tournefortia argentea)* Ruderal Woodland Alliance	A.2695	Hawaiian Ruderal Dry Forest Group
Samanea saman - Schinus terebinthifolius Semi-natural Woodland	Monkeypod - Christmas Berry Semi-natural Woodland	CEPS 009515	N/A	N/A	Hawaiian Ruderal Dry Forest Group
Shrublands (Native)					
Scaevola taccada Coastal Dry Shrubland[3]	Naupaka Kahakai Coastal Dry Shrubland	CEGL 008054	*Scaevola taccada* Shrubland Alliance[3]	A.716	Hawaiian Dry Scrub & Herb Coastal Strand Group
Waltheria indica - Sida fallax Shrubland	‘Uhaloa - ‘Ilima Shrubland	CEGL 005414	*Waltheria indica* Shrubland Alliance	A.2698	Hawaiian Lowland Dry Shrubland & Grassland Group

Table 10a. PUHO vegetation classification with rUSNVC hierarchy to Group level (continued).

Association Name	Common Name	Elcode [1]	Alliance Name	A.Key [2]	Group Name
Shrublands (Ruderal)					
Leucaena leucocephala / Panicum maximum Semi-natural Shrubland[3]	Koa Haole / Guinea Grass Semi-natural Shrubland	CEGL 005404	*Leucaena leucocephala* Lowland Ruderal Shrubland Alliance[3]	A.2700	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group
Leucaena leucocephala Lowland Dry Semi-natural Shrubland	Koa Haole Lowland Dry Semi-natural Shrubland	CEGL 008114	*Leucaena leucocephala* Lowland Ruderal Shrubland Alliance	A.2700	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group
Leucaena leucocephala - Pithecellobium dulce Semi-natural Shrubland	Koa Haole / ʻOpiuma Semi-natural Shrubland	CEPS 009518	N/A	N/A	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group
Herbaceous Vegetation (Native)					
Fimbristylis spp. Coastal Dry Herbaceous Vegetation	Mauʻu Coastal Dry Herbaceous Vegetation	CEGL 008089	*Fimbristylis* spp. Coastal Herbaceous Alliance	A.1143	Hawaiian Dry Scrub & Herb Coastal Strand Group
Herbaceous Vegetation (Ruderal)					
Melinis repens Semi-Natural Herbaceous Vegetation	Natal Redtop Semi-Natural Herbaceous Vegetation	CEGL 005405	*(Cenchrus ciliaris – Pennisetum setaceum)* - Mixed Medium-Tall Ruderal Grassland Alliance[3]	A.2693	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group
Sida cordifolia Semi-natural Herbaceous Vegetation	Mallow Plant Semi-natural Herbaceous Vegetation	CEPS 009516	N/A	N/A	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group
Panicum maximum Lowland Dry Semi-natural Herbaceous Vegetation[3]	Guinea Grass Lowland Dry Semi-natural Herbaceous Vegetation	CEGL 008109	*Panicum maximum* Ruderal Herbaceous Alliance[3]	A.2701	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group

[1]Unique rUSNVC Association Element Code with "CEPS" indicating Park Specials.
[2]Unique rUSNVC Alliance Key Code.
[3]rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

Table 10b. Additional vegetation types identified and mapped at PUHO, but not sampled with field plots.

Association Name	Common Name	Elcode[1]	Alliance Name	A.Key[2]	Group Name
Woodland (Ruderal)					
Schinus terebinthifolius / Pennisetum setaceum Semi-natural Woodland	Christmas Berry / Fountain Grass Semi-natural Woodland	CEGL 005411	*(Samanea saman - Schinus terebinthifolius - Pithecellobium dulce - Tournefortia argentea)* Ruderal Woodland Alliance	A.2695	Hawaiian Ruderal Dry Forest Group
Shrubland (Ruderal)					
Bougainvillea glabra Semi-natural / Planted Shrubland	Bougainvillea Semi-natural / Planted Shrubland	Park Special	N/A	N/A	N/A
Sparse Vegetation (Ruderal)					
A‘a Lava with Sparse Vegetation	A‘a Lava with Sparse Vegetation	CEPS 009514	N/A	N/A	Hawaiian Ruderal Dry-Site Lava Flow Group
Coastal Strand Sparse Vegetation	Coastal Strand Sparse Vegetation	CEPS 009513	N/A	N/A	Hawaiian Dry Scrub & Herb Coastal Strand Group
Herbaceous Vegetation (Ruderal)					
Pennisetum setaceum Semi-natural Herbaceous Vegetation	Fountain Grass Semi-natural Herbaceous Vegetation	CEGL 008117	*(Cenchrus ciliaris – Pennisetum setaceum)* - Mixed Medium-Tall Ruderal Grassland Alliance[3]	A.2693	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group
Unclassified Map Units					
Aleurites moluccana Woodland Stand	Kukui Woodland Stand	Map Class	N/A	N/A	N/A
Heteropogon contortus Planted Herbaceous Vegetation	Pili Planted Herbaceous Vegetation	Map Class	N/A	N/A	N/A
Mixed Semi-natural / Ornamental Tree Woodland	Mixed Semi-natural / Ornamental Tree Woodland	Map Class	N/A	N/A	N/A
Pahoehoe Lava Sparse Vegetation	Pahoehoe Lava Sparse Vegetation	Map Class	N/A	N/A	N/A

[1] Unique rUSNVC Association Element Code with “CEPS” indicating Park Specials.
[2] Unique rUSNVC Alliance Key Code.
[3] rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

Digital Imagery and Mapping

For PUHO, 40 map units (23 vegetated, five barren, and 12 land-use/land-cover) were developed. The final list of map classes/units was directly crosswalked to corresponding plant associations and land use classes (Table 11). PUHO map classes represent a compromise between the detail of the rUSNVC, resource management needs, and the limitations of the imagery. As a result, the mapping legend does not exactly match the rUSNVC. In most cases the rUSNVC or Park Special associations were used as map units. However, in four cases additional vegetation map units (Unclassified Map Unit) were used when unique stands of vegetation were apparent on the imagery, but did not have corresponding plant associations. Appendix F contains descriptions and representative photographs of all of the vegetation map units.

The following types represent the possible map scenarios encountered in the PUHO project:

1. **One-to-one relationship** = When a plant association or vegetation alliance had a unique photo signature and could be readily delineated on the imagery, the map unit adopted the plant association/alliance name or similar synonym.
2. **Unclassified Map Unit** = When unique stands of vegetation apparent on the imagery did not have a corresponding rUSNVC plant association, Park Special, or vegetation alliance either due to their small size or location outside of PUHO.
3. **Land Use – Land Cover** = Non-vegetated areas and vegetation types not recognized by the NVCS received Anderson et al. (1976, updated 2002) map unit designations.

Vegetation Map

The PUHO vegetation map consisted of 611 polygons totaling 810 ha (2,001 ac) (Appendix G); average polygon size was about 1.2 ha (3 ac) (Table 12). The small polygon size was due to the small size of the park and the importance of the rare vegetation and small stands of non-native vegetation. The mapping was also finely detailed since the imagery was of high resolution allowing for very small stands of vegetation to be accurately delineated.

Lands managed by NPS consisted of 177 ha (437 ac) representing about 22% of the total project area. Of the NPS land, 66% (116 ha) consisted of one of the three Koa Haole Semi-natural Shrubland map classes. The remaining mapping in the environs consisted of a mixture of private, state and county lands totaling 633 ha (1,564 ac). Of the total 238 polygons, a majority (66% or 534 ha) were comprised of the dominant non-native vegetation (W_PIDU, W_PRPA, W_SCTE, S_LELE, S_LEPI, S_LEPA, and H_PAMA map units). The most prevalent map class (59 polygons) was the ‘Opiuma Semi-natural Woodland that represented many isolated stands.

The PUHO vegetation map should be considered a spatial database that contains many polygon attributes not presented in the preceding table (i.e. density, height, and pattern in particular). These extensive data are difficult to convey in a table or on a two-dimensional map, but it should be understood that the different attributes can be combined in many ways and at different scales and resolutions to produce additional products better representing the full spectrum of the vegetative diversity. For example, older, more mature stands of non-native vegetation can quickly be located by querying the GIS vegetation layer for non-native vegetation types along with high density (>60%) and the tallest height class (5-15 m). Figure 17 is an example of a fine scale (1:6,000-scale) PUHO vegetation map centered on the visitor’s center created from the GIS spatial database with the 2006 Quickbird imagery as the background.

Table 11. Map classes and relationships to plant associations and other maps units.

Map Code	Map Class Name	rUSNVC Association Assigned to Map Class (or Map Unit Description)	Relationship
W_ALMO	*Aleurites moluccana* Woodland Stand	(No Association –Planted/Escaped)	Unclassified Map Unit
W_CONU	*Cocos nucifera* Strand Woodland	*Cocos nucifera* Strand Woodland	1 : 1
W_ORNA	Mixed Semi-natural / Ornamental Tree Woodland	(No Association –Planted/Escaped)	Unclassified Map Unit
W_PIDU	*Pithecellobium dulce* Semi-natural Woodland	*Pithecellobium dulce* Semi-natural Woodland	1 : 1
W_PRPA	*Prosopis pallida* Coastal Dry Semi-natural Woodland	*Prosopis pallida* Coastal Dry Semi-natural Woodland	1 : 1
W_SASA	*Samanea saman - Schinus terebinthifolius* Semi-natural Woodland	*Samanea saman - Schinus terebinthifolius* Semi-natural Woodland [Park Special]	1 : 1
W_SCTE	*Schinus terebinthifolius* / *Pennisetum setaceum* Semi-natural Woodland	*Schinus terebinthifolius* / *Pennisetum setaceum* Semi-natural Woodland	1 : 1
W_THPO	*Thespesia populnea* / Sparse Understory Woodland	*Thespesia populnea* / Sparse Understory Woodland	1 : 1
S_BOGL	*Bougainvillea glabra* Semi-natural / Planted Shrubland	*Bougainvillea glabra* Semi-natural / Planted Shrubland	1 : 1
S_LELE	*Leucaena leucocephala* Lowland Dry Semi-natural Shrubland	*Leucaena leucocephala* Lowland Dry Semi-natural Shrubland	1 : 1
S_LEPI	*Leucaena leucocephala - Pithecellobium dulce* Semi-natural Shrubland	*Leucaena leucocephala - Pithecellobium dulce* Semi-natural Shrubland [Park Special]	1 : 1
S_LEPA	*Leucaena leucocephala / Panicum maximum* Semi-natural Shrubland	*Leucaena leucocephala / Panicum maximum* Semi-natural Shrubland[1]	1 : 1
S_SCTA	*Scaevola taccada* Coastal Dry Shrubland	*Scaevola taccada* Coastal Dry Shrubland[1]	1 : 1
S_WAIN	*Waltheria indica - Sida fallax* Shrubland	*Waltheria indica - Sida fallax* Shrubland	1 : 1
H_FIMB	*Fimbristylis* spp. Coastal Dry Herbaceous Vegetation	*Fimbristylis* spp. Coastal Dry Herbaceous Vegetation	1 : 1
H_HECO	*Heteropogon contortus* Planted Herbaceous Vegetation	(No Association -Planted)	Unclassified Map Unit
H_MERE	*Melinis repens* Semi-natural Herbaceous Vegetation	*Melinis repens* Semi-Natural Herbaceous Vegetation	1 : 1

[1]rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

Table 11. Map classes and relationships to plant associations and other maps units (continued).

Map Code	Map Class Name	rUSNVC Association Assigned to Map Class (or Map Unit Description)	Relationship
H_SICO	*Sida cordifolia* Semi-natural Herbaceous Vegetation	*Sida cordifolia* Semi-natural Herbaceous Vegetation [Park Special]	1 : 1
H_PAMA	*Panicum maximum* Lowland Dry Semi-natural Herbaceous Vegetation	*Panicum maximum* Lowland Dry Semi-natural Herbaceous Vegetation[1]	1 : 1
H_PESE	*Pennisetum setaceum* Semi-natural Herbaceous Vegetation	*Pennisetum setaceum* Semi-natural Herbaceous Vegetation	1 : 1
SV_A'A	A'a Lava with Sparse Vegetation	A'a Lava with Sparse Vegetation [Park Special]	1 : 1
SV_CS	Coastal Strand Sparse Vegetation	Coastal Strand Sparse Vegetation [Park Special]	1 : 1
SV_PA	Pahoehoe Lava Sparse Vegetation	(No Association)	Unclassified Map Unit
B_BE	Beaches	(Barren sand beaches)	Land Use - Cover
B_CB	Coastal Basalt	(Barren pahoehoe lava cliffs)	Land Use - Cover
B_DL	Developed Lava	(Barren crushed or rock lava used for cultural sites, roadsides piers)	Land Use - Cover
B_ER	Exposed Reef and Tidal Pools	(Submerged features)	Land Use - Cover
B_PA	Pahoehoe Lava	(Barren pahoehoe lava)	Land Use - Cover
L_AGRI	Agricultural Business	(Coffee plantation buildings and other agricultural developments)	Land Use - Cover
L_BAY	Bay / Estuary	(Semi-protected bays and estuaries)	Land Use - Cover
L_FACL	Facilities	(NPS buildings and facilities)	Land Use - Cover
L_FILD	Planted / Cultivated	(Small row crops)	Land Use - Cover
L_LIIN	Commercial / Light Industry	(Businesses and surrounding lands in the environs)	Land Use - Cover
L_ORCH	Irrigated Orchard / Vineyards / Groves	(Coffee and other cultivated tree fields)	Land Use - Cover
L_POND	Lake / Pond	(Anchialine pools and fish ponds)	Land Use - Cover
L_RESD	Residential	(Off-park houses and trailers)	Land Use - Cover
L_ROAD	Transportation	(Roads and major trails)	Land Use - Cover
L_SEA	Sea / Ocean	(Pacific Ocean)	Land Use - Cover
L_TRAN	Transitional	(Fallow and disturbed fields)	Land Use - Cover
L_URBN	Mixed Urban	(Mix of homes and agricultural buildings)	Land Use - Cover

[1]rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

Table 12. Summary statistics for the PUHO map class polygons.

Map Code	Map Unit Description	NPS Lands			Total Project Area		
		# of Polygons	Acres	Hectares	# of Polygons	Acres	Hectares
W_ALMO	*Aleurites moluccana* Woodland Stand	8	2.4	1.0	40	71.1	28.8
W_CONU	*Cocos nucifera* Strand Woodland	26	15.4	6.2	27	16.0	6.5
W_ORNA	Mixed Semi-natural / Ornamental Tree Woodland	2	2.8	1.1	13	9.7	3.9
W_PIDU	*Pithecellobium dulce* Semi-natural Woodland	30	24.2	9.8	56	272.1	110.2
W_PRPA	*Prosopis pallida* Coastal Dry Semi-natural Woodland	25	12.7	5.1	43	37.9	15.3
W_SASA	*Samanea saman* - *Schinus terebinthifolius* Semi-natural Woodland	8	0.4	0.2	18	6.1	2.5
W_SCTE	*Schinus terebinthifolius* / *Pennisetum setaceum* Semi-natural Woodland	5	2.1	0.9	35	92.2	37.3
W_THPO	*Thespesia populnea* / Sparse Understory Woodland	6	0.7	0.3	6	0.7	0.3
S_BOGL	*Bougainvillea glabra* Semi-natural / Planted Shrubland	0	0	0	5	4.9	2.0
S_LELE	*Leucaena leucocephala* Lowland Dry Semi-natural Shrubland	32	68.5	27.7	51	319.3	129.3
S_LEPI	*Leucaena leucocephala* - *Pithecellobium dulce* Semi-natural Shrubland	11	38.1	15.4	14	183.9	74.5
S_LEPA	*Leucaena leucocephala* / *Panicum maximum* Semi-natural Shrubland	22	180.1	72.9	31	333.0	133.9
S_SCTA	*Scaevola taccada* Coastal Dry Shrubland	6	0.7	0.3	6	0.7	0.3
S_WAIN	*Waltheria indica* - *Sida fallax* Shrubland	11	5.5	2.2	11	5.6	2.3
H_FIMB	*Fimbristylis* spp. Coastal Dry Herbaceous Vegetation	1	0.1	0.1	1	0.1	0.1
H_HECO	*Heteropogon contortus* Lowland Dry Herbaceous Vegetation	6	0.2	0.1	6	0.2	0.1
H_MERE	*Melinis repens* Semi-natural Herbaceous Vegetation	11	2.9	1.2	11	2.9	1.2
H_PAMA	*Panicum maximum* Lowland Dry Semi-natural Herbaceous Vegetation	5	24.3	9.8	10	81.8	34.1
H_PESE	*Pennisetum setaceum* Semi-natural Herbaceous Vegetation	0	0	0	5	31.0	12.6
H_SICO	*Sida cordifolia* Semi-natural Herbaceous Vegetation	5	1.9	0.8	5	1.9	0.8
SV_A'A	A'a Lava with Sparse Vegetation	2	0.1	0.1	4	1.0	0.4
SV_CS	Coastal Strand Sparse Vegetation	12	2.8	1.1	18	4.8	1.9
SV_PA	Pahoehoe Lava Sparse Vegetation	8	1.9	0.8	16	9.6	3.9

Table 12. Summary statistics for the PUHO map class polygons (continued).

Map Code	Map Unit Description	NPS Lands			Total Project Area		
		# of Polygons	Acres	Hectares	# of Polygons	Acres	Hectares
B_BE	Beaches	19	5.1	2.1	20	5.7	2.3
B_CB	Coastal Basalt	2	1.4	0.6	2	1.4	0.6
B_DL	Developed Lava	12	2.3	0.9	31	10.8	4.4
B_ER	Exposed Reef and Tidal Pools	30	4.8	1.9	17	17.0	6.9
B_PA	Pahoehoe Lava	10	20.9	8.5	12	26.8	10.9
L_AGRI	Agricultural Business	1	0.3	0.1	17	5.4	2.2
L_BAY	Bay / Estuary	2	0.5	0.2	3	2.6	1.1
L_FACL	Facilities	5	1.8	0.7	5	1.8	0.7
L_FILD	Planted / Cultivated	0	0	0	6	12.0	4.9
L_LIIN	Commercial / Light Industry	0	0	0	2	1.4	0.6
L_ORCH	Irrigated Orchard / Vineyards / Groves	1	0.1	0.1	21	68.1	27.6
L_POND	Lake / Pond	3	0.3	0.1	3	0.3	0.1
L_RESD	Residential	1	0.0	0.0	9	3.8	1.5
L_ROAD	Transportation	15	8.4	3.4	11	33.7	13.6
L_SEA	Sea / Ocean	23	2.8	1.1	1	291.1	117.9
L_TRAN	Transitional	0	0	0	6	26.8	10.9
L_URBN	Mixed Urban	1	0.1	0.1	13	5.3	2.1
	Total Vegetation	242	388	157	432	1,487	602
	Total Barren Geology	73	35	14	82	62	25
	Total Land Use / Land Cover	52	14	6	97	452	183
	Totals	367	436	177	611	2,001	810

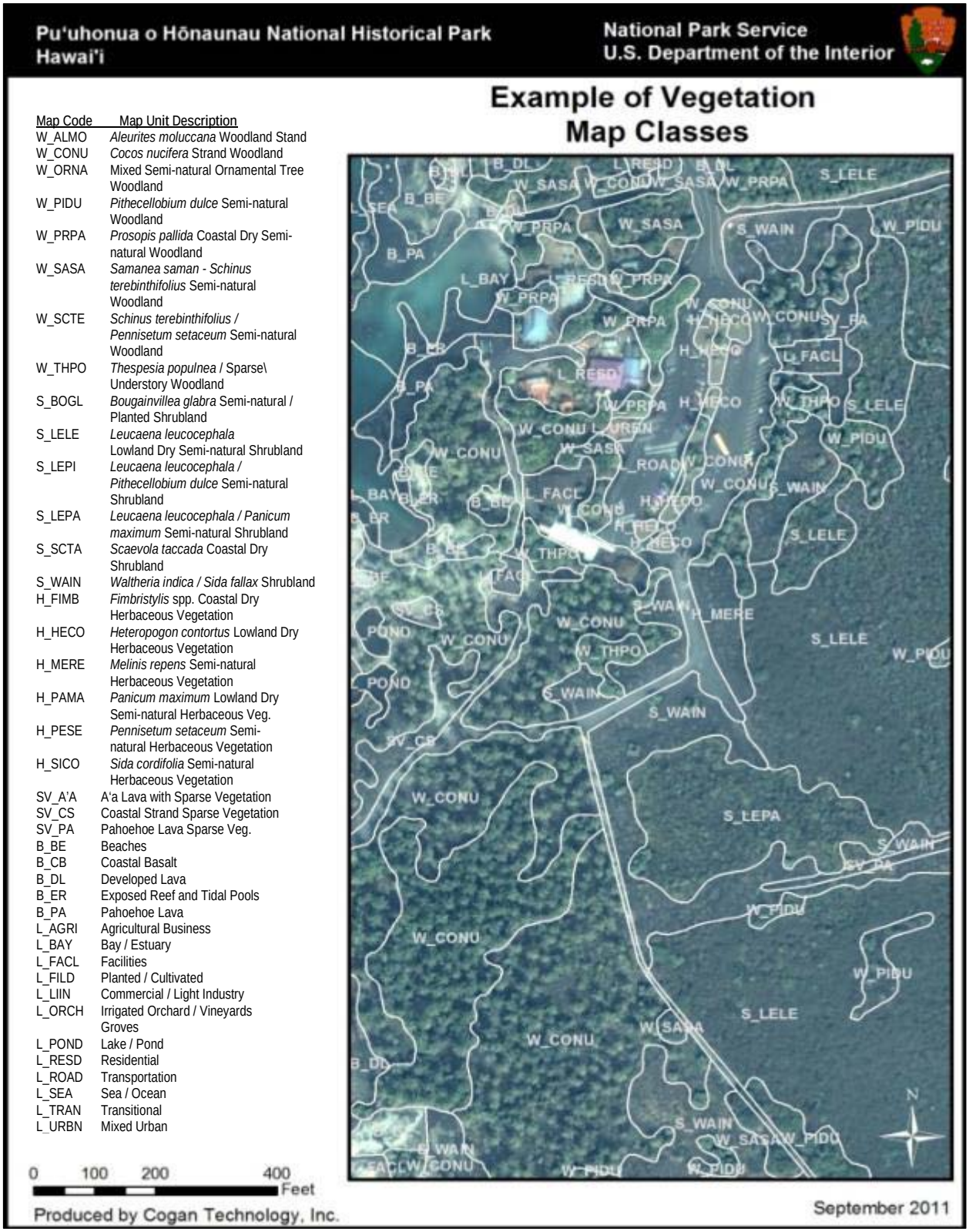


Figure 17. Example of the PUHO vegetation map layer.

Accuracy Assessment

The 2009/10 AA effort yielded 82 points distributed throughout PUHO. In addition to using the AA points in the following map analysis, many of the points were also used to update the classification and to revise the local descriptions. Upon review of the data five points were removed from analysis since they occurred in areas treated (i.e. tree removal) since the timing of the imagery. This yielded a final AA sample size of 77 points.

Analysis of the AA points involved a point-by-point review in two stages. In stage one, an AA GIS point file was created from the point coordinates recorded in the field. These sites were digitally overlaid on the vegetation map and a comparison of the final AA field call versus the vegetation polygon label was conducted by CTI staff. Stage one resulted in a preliminary error matrix that was reviewed by PACN and CTI. Adjustments were made to the field calls at this time based on the actual cover values recorded and taking into account possible correct second and third field calls. In most cases, the correct second and third calls were very closely related to the incorrect primary call. Following incorporation of changes, the raw, overall accuracy of the PUHO vegetation layer was found to be 83%. Results were presented to PACN staff and recommendations were made to improve the accuracy of the map. These included:

- Agreement with all location and type code adjustments made by CTI;
- Split Kukui Woodland Stand from Mixed Semi-natural Ornamental Tree Woodland;
- The Mallow Plant Semi-natural Herbaceous Vegetation was retained with low accuracy since it provides the park with more information on weedy and coastal strand communities. Further ground-truthing may warrant combining this class with the Coastal Strand Sparse Vegetation map class;
- The Seashore Paspalum Semi-natural Herbaceous Vegetation map class was combined with the Strand Sparse Vegetation map class since it only occurred in one polygon that was currently dominated by other coastal herbaceous species;
- Created a Koa Haole - ‘Opiuma Semi-natural Shrubland as a park special to address large areas that have both species as co-dominates and retained the lower accuracy. This map class likely needs more ground-truthing to better distinguish it from the other koa haole types;
- The Monkeypod - Christmas Berry Semi-natural Woodland type was not sampled during the AA since most polygons represented single trees and were located outside of the park. This type was retained as a valid map unit to provide more detail, but future AA work maybe conducted by PACN to better document this type;
- The Kiawe Coastal Dry Semi-natural Woodland was retained with lower accuracy;
- The Milo / Sparse Understory Woodland Semi-natural Woodland was retained with lower accuracy to provide more detail;
- The Pili Planted Herbaceous Vegetation map unit was retained as a park special for restoration areas;
- Fountain Grass Semi-natural Herbaceous Vegetation was not assessed since all polygons were located outside of the park boundary;
- The Mixed Semi-natural / Ornamental Tree Woodland map class was not assessed since all polygons were located outside of the park boundary;

- All other vegetated and barren map units that were not assessed were retained since they likely occur outside of the park boundary.

Stage two of the analysis involved incorporating the NPS recommendations and re-running the accuracy assessment using the new NVIP protocols (Lea and Curtis 2010). Following the vegetation map update, errors were reported in both a sample contingency table (Table 13) and a population contingency table (Table 14). The sample contingency table includes the observation counts, with the predicted, sample data values (vegetation map classes) as rows and the observed reference data values (vegetation types as identified on the ground) as columns. The value in the cells is the number of accuracy assessment observations mapped in each class (row) that were found to be of a specific class (column) in the field. The values in the shaded cells along the diagonal represent counts for correctly classified observations, where the reference data (column) vegetation type matches the mapped vegetation type (row) value.

The population contingency table is similar to the sample table; however the values in each cell are the proportion of the target area in the corresponding true and mapped vegetation classes, rather than the raw count of observations. The row sums $pi+$ are the proportions of the total area mapped as type i. The column sums $p+J$ are the proportions of the total area that are truly class J, which is not known, but can be estimated from the reference data values.

Table 13. Sample Contingency Table for PUHO. Columns represent predicted mapping unit names (polygon labels) and rows represent AA observation names (field calls).

Map Code	W_ALMO	W_COUN	W_PIDU	W_PRPA	W_SCTE	W_THPO	S_LELE	S_LEPI	S_LEPA	S_SCTA	S_WAIN	H_FIMB	H_MERE	H_SICO	H_PAMA	SV_CS	SV_PA	Row Total
W_ALMO	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
W_CONU	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
W_PIDU	0	0	4	0	0	0	1	1	1	0	1	0	0	0	0	0	0	8
W_PRPA	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	6
W_SCTE	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
W_THPO	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
S_LELE	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	6
S_LEPI	0	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	4
S_LEPA	0	0	0	0	0	0	0	1	18	0	0	0	0	0	0	0	0	19
S_SCTA	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S_WAIN	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	4
H_FIMB	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
H_MERE	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
H_SICO	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	3
H_PAMA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4
SV_CS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	6
SV_PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Column Total	5	4	4	6	2	1	7	5	19	2	5	1	1	2	5	7	1	

Table 14. Population Contingency Table for PUHO.

Map Code	W_ALMO	W_COUN	W_PIDU	W_PRPA	W_SCTE	W_THPO	S_LELE	S_LEPI	S_LEPA	S_SCTA	S_WAIN	H_FIMB	H_MERE	H_SICO	H_PAMA	SV_CS	SV_PA	1	2	3	4
W_ALMO	0.050	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	90%	100%	5%
W_CONU	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	88%	100%	1%
W_PIDU	0.000	0.000	0.095	0.000	0.000	0.000	0.024	0.024	0.024	0.000	0.024	0.000	0.000	0.000	0.000	0.000	0.000	50%	15%	85%	19%
W_PRPA	0.000	0.000	0.000	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	92%	100%	3%
W_SCTE	0.000	0.000	0.000	0.000	0.064	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	75%	100%	6%
W_THPO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	50%	0%	100%	0%
S_LELE	0.000	0.000	0.000	0.000	0.000	0.000	0.223	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	92%	100%	22%
S_LEPI	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.096	0.000	0.000	0.000	0.000	0.000	0.000	0.032	0.000	0.000	75%	27%	100%	13%
S_LEPA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.218	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	95%	84%	100%	23%
S_SCTA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	50%	100%	0%
S_WAIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	100%	88%	100%	0%
H_FIMB	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	50%	100%	0%
H_MERE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	100%	50%	100%	0%
H_SICO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	67%	5%	100%	0%
H_PAMA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.059	0.000	0.000	100%	88%	100%	6%
SV_CS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	100%	92%	100%	0%
SV_PA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.007	100%	50%	100%	1%
A	100%	100%	100%	100%	100%	100%	90%	73%	90%	67%	14%	100%	100%	100%	65%	88%	100%				
B	100%	100%	95%	100%	100%	100%	89%	67%	88%	67%	13%	100%	100%	100%	64%	88%	100%				
C	100%	100%	100%	100%	100%	100%	91%	78%	92%	67%	15%	100%	100%	100%	65%	88%	100%				
D	28.8	6.5	55.1	15.3	37.3	0.1	143.1	76.7	140.6	0.4	16.0	0.0	1.2	0.5	52.7	2.2	3.9				

ROW A = PRODUCERS' ACCURACY ($P_{i=Y|J=Y}$)
ROW B = LOWER LIMIT, 90% CONFIDENCE INTERVAL, PRODUCERS' ACCURACY
ROW C = UPPER LIMIT, 90% CONFIDENCE INTERVAL, PRODUCERS' ACCURACY
ROW D = ESTIMATED TRUE AREA (A_{+J}) (HECTARES)

COLUMN 1 = USERS' ACCURACY ($P_{J=X|i=X}$)
COLUMN 2 = LOWER LIMIT, 90% CONFIDENCE INTERVAL, USERS' ACCURACY
COLUMN 3 = UPPER LIMIT, 90% CONFIDENCE INTERVAL, USERS' ACCURACY
COLUMN 4 = p*i*+, PROPORTIONS OF THE TOTAL AREA MAPPED AS TYPE *i*

The final overall accuracy, kappa statistics and 90% confidence intervals for PUHO are as follows:

OVERALL ACCURACY (P_c)	=	86.0%
LOWER LIMIT, 90% CONFIDENCE INTERVAL	=	78.6%
UPPER LIMIT, 90% CONFIDENCE INTERVAL	=	93.4%
KAPPA (**K**):	=	88.4%
LOWER LIMIT, 90% CONFIDENCE INTERVAL, **K**	=	72.0%
UPPER LIMIT, 90% CONFIDENCE INTERVAL, **K**	=	94.7%

Examination of the contingency tables finds that 17 out of 23 vegetated map classes for PUHO were accessed. Four of the un-accessed map classes (W_ORNA, S_BOGL, SV_A'A, and H_PESE) were found outside of PUHO and were mapped based on similar documented signatures found at KAHO and PUHE. The monkeypod (W_SASA) map unit was not accessed since it is very rare in PUHO and only occurs as single trees. Finally the pili map class (H_HECO) was not accessed since it was a planted type only occurring in the parking lot area.

All of the classes that were accessed had high user's accuracy except for the W_PIDU, W_THPO, and the S_SICO map classes. The 'opiuma (W_THPO) woodland type was often confused with the koa haole map classes likely due to their similar signatures on the color infrared imagery and the intermingling of the same species in all four map units. In fact, the 'opiuma woodland type often had high amounts of koa haole in the understory and vice versa. The milo map unit (W_THPO) was somewhat rare in PUHO limiting the sample size. Where it was checked it was mistaken one time with Christmas berry and this is also likely due to similar signatures and species. Finally the S_SICO type along with the other coastal strand shrubland and herbaceous types (S_WAIN, H_FIMB, S_MERE, and SV_CS) were difficult to distinguish from one another on the imagery due to their similar size and color. This was compounded by the active restoration and clearing activities by the park along the coastal trail.

The sources of producer's error can likely be explained by the difficulty in resolving the difference in scale and perspective between viewing the vegetation on the imagery and assessing it on the ground. For example, sampling could have occurred in inclusions or canopy openings that were called H_PAMA but were actually a part of larger S_LEPI. Also the intricate intermingling of the coastal strand map units caused some confusion in the mapping signatures leading to incorrect polygon boundaries (i.e. the sparse vegetation was likely part of the woodland understory).

Discussion

Pu‘uhonua o Hōnaunau National Historical Park is truly a special place combining a rich mix of ancient archeological sites, current cultural restorations, and remnants of native coastal plant communities. Across this landscape a variety of non-native plants thrive in habitats typical of the leeward coast of Hawai‘i. The ruggedness of the lava fields and the intermixing of plant species made it very challenging to both classify and map the vegetation. However, due to the small size of the park and the accessibility afforded the sampling and verification efforts, a highly accurate classification and detailed map layer was completed. Even though the accuracy is high there are still some areas were improvements can be made, which are summarized below.

Approaches that worked well: Field data and feedback provided by PACN ecologists were extremely helpful in the classification and delineation of the different plant associations. High-quality plot, observation point, and legacy data, in addition to focused local plant association descriptions greatly aided this project on all levels. Additional data collected by CTI during site visits further informed the PUHO classification and mapping.

Areas for Improvement: Inherent to all vegetation inventory projects is the need to pigeon-hole a continuum of vegetation into discrete units. This is made even more difficult at places like PUHO with a long history of anthropogenic disturbance. When the native vegetation has been replaced and altered it is extremely hard to correctly determine where one plant association starts and where the other ends. This can be witnessed in the classification stage by the high overlap in dominant species between the different plant associations. Further in the mapping stage, subtle vegetation characteristics such as cover value breaks (e.g. < > 20%) that can be seen on the ground are not necessarily apparent on the imagery. Canopy closure, shadows, soil reflections and the timing of the imagery acquisition can all impact where lines are drawn. Newer, high-resolution imagery and more ground-based observations may go a long way to improve both the classification of the non-native vegetation and its delineation.

Field Survey

The vegetation classification data presented in this project should be used as the baseline from which to begin future vegetation studies. New survey work in a judicious timeframe would improve both the classification (six plant association descriptions are based only on one or two plots) and mapping (refined linework) efforts. Using the accuracy assessment as a guide, map classes with lower accuracy could be further surveyed and boundaries delineated in the field to create a more accurate GIS layer. While it may appear that there are a large number of plant associations and vegetation alliances described for this very small study area, some were only minimally sampled likely due to access limitations. Also future restoration efforts to reduce invasive tree and shrub cover on archeological sites may greatly alter the existing plant assemblages. It is recommended that these changes be recorded and used to update the GIS layer and classification as needed.

Classification

Non-native species and vegetation types dominate the vegetation at PUHO with only four native and one Polynesian introduced species dominated vegetation types of the 14 classified. Most of these vegetation types occurred on all three park units and were sampled on or near the coastal strand. The native plant communities sampled include Mauʻu Coastal Dry Herbaceous Vegetation, Naupaka Kahakai Coastal Dry Shrubland, Milo / Sparse Understory Woodland, ʻUhaloa - ʻIlima Shrubland, and an early Polynesian naturalized type Coconut Palm Strand Woodland.

NatureServe and its network of state natural heritage programs indicate the rarity and degree of imperilment of plant communities by assigning state and global conservation status ranks to each. The rank scale ranges from 1 to 5; a rank of 1 indicates critical imperilment due to rarity, endemism, and/or threats, while a rank of 5 indicates little or no risk of extirpation of the plant community. One community at PUHO, Mauʻu Coastal Dry Herbaceous Vegetation is globally ranked as a G3 and considered Vulnerable defined as "at moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors." The other plant communities at PUHO have not been ranked to date. More information on NatureServe Conservation Status Ranking can be found at http://www.natureserve.org/explorer/ranking.htm.

Ecologically there are a number of closely related vegetation types at PUHO that may be confusing to distinguish in the field, especially grasslands with scattered trees and/or shrubs versus open shrublands or open woodlands with grass understory. There is a continuum of tree and shrub densities from grasslands with no woody species, to scattered trees and shrub, to dense woodlands and shrublands. Rather than have three analogs of very similar floristic composition: 1) grasslands without woody plants or with sparse trees or sparse shrubs; 2) grasslands with moderate shrubs or moderate trees (tree savanna or shrub steppe); and 3) denser woodlands or shrublands with grass understory, NatureServe defined only two types: 1) grasslands (grass dominated stands that may include significant cover of trees or shrubs <20% cover trees or < 20% cover or shrubs) and 2) open to dense woodlands or shrublands with >20% cover of trees or > 20% cover of shrubs trees. Stands with > 20% cover of trees are woodlands regardless of understory. For woodlands, shrub cover may be high (exceeding the tree cover) if tree cover is 20% or more. If tree cover is 10-19% then it must exceed shrub and perennial herbaceous cover (i.e. trees dominate the vegetation). [Note: koa haole was considered a shrub and not a small tree in the classification.] The plot data showed tree and shrub cover breaks between 15-20% for kiawe and koa haole types and 20% worked best with plot data, but this needs to be verified in the field.

The final classification is a result of both quantitative and qualitative analysis. Multivariate analysis works better with multiple plots per group. NatureServe analyzed data from all three of the West Hawaiʻi parks together because they have similar plant species, vegetation, and environments. Having more samples clarifies the range of variation and increases confidence of the type, especially if the type is rare or under-sampled in a given park unit. For example, the Aʻa Lava with Sparse Vegetation and Coastal Strand Sparse Vegetation types were only sampled in PUHO, but also occurred at PUHE and KAHO and were mapped there as well. In addition, in these parks much of the data characterized ruderal vegetation from disturbed areas. Non-native species will often invade multiple plant communities, which results in a homogenizing effect on

the multivariate analysis. Expert review (i.e. qualitative analysis) is needed to address the homogenizing effect of the high number and high abundance of non-native species.

Additionally with vegetation classification, not all species are given equal weight. Native species such as milo, ʻuhaloa, and naupaka kahakai are given higher diagnostic value over non-native species. A native vegetation type may be invaded by non-native species (via disturbance) and as long as the non-native species do not strongly dominate the vegetation type (i.e. not a complete conversion to a non-native or introduced type), the stand may be characterized by native species. Annual species are rarely considered important diagnostically unless they strongly dominate the herbaceous layer or indicate a particular habitat such as coastal strand or a disturbance type.

At PUHO there were three types that also occur on PUHE and KAHO: Coconut Palm Strand Woodland, Kiawe Coastal Dry Semi-natural Woodland, and Milo / Sparse Understory Woodland. Two other PUHO types, Naupaka Kahakai Coastal Dry Shrubland and ʻUhaloa - ʻIlima (*Sida fallax*) Shrubland also occurred at KAHO. The majority of the plots representing Kiawe Coastal Dry Semi-natural Woodland, Milo / Sparse Understory Woodland and ʻUhaloa - ʻIlima Shrubland were sampled at KAHO or PUHE. Surprisingly, the 10 remaining vegetation types were not sampled in the other park units.

The distribution of dominant grasses was also interesting. Guinea grass was particularly abundant at PUHO, but not KAHO or PUHE, although it was sampled a few times at KAHO. Buffelgrass (*Cenchrus ciliaris*) was dominant at PUHE and fountain grass (*Pennisetum setaceum*) was dominant on KAHO, although documented a few times at PUHE.

Koa haole was particularly abundant and diverse with three koa haole shrubland types. At PUHO individuals were often taller with a single stem, exhibiting a small tree growth form rather than a short or tall shrub. Similarly, Kiawe Coastal Dry Semi-natural Woodland was abundant at all three park units and also exhibited significant variation in the understory (some stands dominated by the dominant grasses listed above, *Talinum fruticosum* or sparse understory). Further classification work in Hawaiʻi may justify splitting this broad type into finer associations.

Digital Imagery and Mapping

The vegetation map for PUHO was based on the 2006 Quickbird ortho-imagery. Therefore, all of the resulting mapping products correspond to 2006 timing of the image acquisition (i.e. snapshot in time). As the data are used, it is important to remember that fires, resource management actions, or landscape altering events since 2006 are not included. In the future it would be beneficial to update the map based on newer imagery or from GPS coordinates (e.g., fire permeters).

Accuracy Assessment

An important and necessary aspect of this project is the accuracy assessment. Collecting independent ground data determines the usefulness of the vegetation map. Users of this product should remember that the GIS mapping and the classification portions of this project were conducted separately from both the plot and AA field data collection. Employing divisions in completing tasks created some challenges related to communication among the teams, including: 1) adequately conveying changes to the vegetation classification based on finding potentially

new vegetation types during the field portion of the AA, 2) thoroughly testing and adjusting the field key to remove confusing splits among similar types, 3) insuring that adequate sample sizes are collected for rare and infrequent types, and 4) avoiding having to collect more than the estimated 30 data points for common types.

Actual errors in the mapping likely stemmed from the limitations of the ortho-photography as previously described, natural changes in the vegetation between sampling and the acquisition date of the imagery, errors in the field key, or the difficulty in establishing an overhead perspective to exactly match the ground view. Although the accuracy for PUHO appears moderate to high, improvements can be made and users should fully explore and understand the sources of error as presented in the error matrix.

It is also important for users to remember that since the mapping portion of this project is primarily a remotely sensed exercise and the field work was conducted on site, all resulting products are scale dependent. In general the mapping portions should be viewed as a broader overview and the field data as more site specific. Although one can zoom in further than 1:12,000-scale using GIS software, the actual mapping was conducted at this scale. As such, any work performed with this product at a finer scale could lead to some uncertainty. In contrast, the field work was conducted at individual locations at one specific time and any extrapolation from these locations to out-lying areas or using them to determine what is there at different times is less reliable. Future users should fully appreciate these scale limitations and balance their efforts accordingly.

Future Recommendations

This project represents the best efforts put forth by a multi-disciplinary team over a short time period. In order to create the best possible "long-term" vegetation classification for PUHO and the most accurate and detailed GIS layer, this project should be viewed as a place to start rather than an end product. In other words, present and future NPS staff should be encouraged to scrutinize this project, building from its strengths and bolstering its weaknesses. One way would be to periodically perform field checking by examining the map in the field by qualified NPS or contract staff, documenting any changes, and incorporating these into newer versions. By keeping in mind that this project represents just a snapshot in time, future efforts can help complete the understanding of the vegetation in and around PUHO and how it changes. It is the hope of the producers that the products presented here will help direct future efforts, as follows:

1. The high amount of non-native plant species and the on-going restoration efforts (e.g. coastal strand species re-introduction, protection of archeological sites, etc.) at PUHO seems to warrant future periodic **field surveys** of the vegetation by experienced ecologists. Further, the close proximity of this site to highly disturbed lands in the environs should be addressed by seeking permission to sample and verify the vegetation. In this way new plant associations could be discovered, existing types could be updated, and integrated invasive species management strategies could be expanded. All new information could be used to update both the GIS map layer (i.e. better delineation) and the classification (i.e. new associations).

2. Remote sensing does not replace on-the-ground knowledge provided by GPS-linked plots, observations, photographs, and ground verification. Time, topographic features, and funding limitations curtailed the amount of map **ground-truthing** performed. As research

3. opportunities arise, maps should be examined in the field by experienced crews. Also GPS receiver data and other GIS layers (such as soils and geology) should be used to improve and update the spatial data. Data could be collected on a standard field form, stored, and then used to update the GIS layer on an annual basis. The vegetation map layer should not be viewed as static but should be updated with more current and accurate information.

4. To better understand the limitations of the map, the **accuracy assessment** data presented in the error matrices should be thoroughly reviewed by NPS staff. Map classes with low accuracy should be examined to see if they could be improved with future studies using ground-truthing or other remote-sensing formats (i.e. fine-scale imagery, hyperspectral, etc). Also, landscape modeling may help to tease out the location of specific types based on specific habitat information. Finally for some applications it may make sense to combine map classes into higher units, such as alliances or ecological systems to improve their accuracy**.**

5. In the future, resource management personnel could link the habitat for **species of concern** to specific associations and map units. These map units could then be used to help locate potential sites of rare, endangered, or threatened species and communities in the field or identify areas for non-native plant removal or treatment. Known populations and individual species of concern can be overlain using point or small polygon layers.

Research Opportunities

Having an accurate and current vegetation classification and map presents many new and exciting research opportunities. Research could include expanding or linking the GIS layer to derive other information including fire models, habitat monitoring locations, guides for rare plant surveys, wildlife habitat structural analyses, and inventorying areas that are likely vectors for invasive species. The map could also be enhanced by overlaying other existing GIS layers including geology, hydrology, elevation, and soils. In this manner complex interactions between these layers could be examined and yield important information about growth rates, regeneration after disturbance, biomass distribution, and stream morphology. Finally, through innovative analyses the vegetation layer could possibly be used as a springboard for other ecological studies including examining how the vegetation interacts with soil chemistry, pollution, paleontological/archeological sites, weather patterns, etc.

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Appendix A: PUHO Field Data Forms

PACN PLOT SURVEY FORM
2008 VEGETATION MAPPING PROGRAM

SURVEY AND SITE INFORMATION

Plot Code: _____ Descriptive Location _____ Survey Date: _____
Park Site Name_____ Park Name : _____
Surveyors_____

Datum: WGS 84 NAD 83 Other_____Field Northing _____ (UTM) Field Easting_____(UTM)
GPS UNIT: Garmin 76 Garmin 5 Other: _____ Error: +/- _____m
GPS Comments:

Directions to Plot:

Sq plot (20 x 20) (10m x 10m)	Rect Plot: len(m)_____ x wid(m)_____	Circ. Plot (100 m^2, 400 m^2, 1000m^2)	Azi _____deg

Camera ID ____ Camera Ht: _____ m **Photopoint coords (if not plot center)** Northing____ ___ (UTM) Easting__ __ _ _____(UTM)

Description of Photopoint:_____

View#	Time	V or H	Bearing	Photographer	View from Photopoint
1					
2					
3					
4					
a					

Views 1-4 - cardinal directions N,E,S,W; view a - person standing on the photopoint itself to help relocate it in future, additional representative views

Plot representativeness (discuss plot placement and explain non-representativeness):

ENVIRONMENTAL DESCRIPTION

Elevation _____ m From: GPS / Map (circle one)	Slope _____(deg) Aspect_____
Topographic Position: High level High Slope Mid Slope Low Slope Backslope Step in Slope Toe Slope Low Level Interfluve	
Landform: Alluvial Fan, Colluvium, Rockpile, Drainage Channel, Valley Bottom Fill, Side Slope, Interfluve, Intermittent Stream, Ridge, Terrace, Butte, Cliff, Talus, Sand Dune, Plateau, Beach, Recent Lava Flow, Other: _____	**Geology**: A'a lava, Pahoehoe Lava, Limestone, Coral, Pumice, Ash, Other: _____

Environmental Comments (factors controlling community/plant distribution, seral stage, fire history etc):

PACN PLOT SURVEY FORM

2008 VEGETATION MAPPING PROGRAM

PLOT CODE: _____ DATE: _____

ENVIRONMENTAL DESCRIPTION (Continued)

Ground Cover: *(please estimate to the nearest percentage. Sum = 100%)*

___ Bare soil (<0.1 mm)
___ Sand (0.1-2 mm)
___ Gravel (2 mm – 6.4 cm)
___ Rock (> 6.4 cm)
___ Bedrock (solid surface)

___ Litter/Duff (dead plant material <3 cm diameter)
___ Coarse woody debris (dead wood 3-10 cm)
___ Woody debris structure (dead >10 cm deep & wide)
___ Live veg (litter / wood)

___ Lichen (ground)
___ Moss (ground)
___ Microbiotic soil crust
___ Water
___ Other: _____

Soil Texture (optional - see soil key): modify to fewer classes
___ sand ___loam ___silt ___clay ___peat ___muck

Surface Water w/in 25m? YES/NO Seep, Spring, Stream, Pothole, River, Anchialine Pond, Ocean, Estuary

Soil Moisture: dry moist saturated standing water

Animal Use Evidence:
___ Burrows
___ Scat (Whose? _____)
___ Browsing Evidence
___ Grazing Evidence
___ Animal / Game Trails
___ Vegetation Damage (animal)
___ Bedding Sites
___ Nests (Whose? _____)
___ Animal Sighting
___ Other: _____

Anthropogenic Disturbances:
___ Campsite Evidence
___ Trails
___ Rock Cairns
___ Vegetation Damage (human)
___ ORV Evidence
___ Historic Feature
___ Archaeological Feature
___ Other: _____

Natural disturbances:
___ Drought (tree & shrub die-back)
___ Fire
___ Flood
___ Mass Wasting
___ Water gullies
___ Vegetation Damage (natural)
___ Other: _____

Other Comments. **Describe surrounding communities and how they relate to the plot**.

VEGETATION DESCRIPTION (Only check one within each box)

Phenological notes: For each strata, note phenological state of dominant species. (Especially note in herbeous vegetation if annuals or perennials are dominant)	Leaf Type (of dominant stratum) ___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte ___Non-vascular ___Mixed (describe)	Physiognomic Class (see cheat sheet) ___Forest ___Woodland ___Shrubland ___Wooded Shrubland ___Dwarf Shrubland ___Shrub Herbaceous ___Wooded Herbaceous ___Herbaceous ___Nonvascular ___Sparsely Vegetated	

PACN PLOT SURVEY FORM

Plot Name: _ _ _ _ _ _ Date: _____

VEGETATION DESCRIPTION

Provisional Community Name: _____

Species/Strata: Starting with the uppermost stratum list all species with full scientific names, cover class and % cover for each species in the stratum. For each tree species estimate seedling, sapling and total cover in appropriate stratum. Once species level information is completed, then complete height class and cover class for each strata (shaded blocks). Indicate with an asterisk (*) diagnostic species for each stratum and check whether a specimen has been collected. Additional space is available on the back side of this form. List species outside the plot at the end of the table and designate with a 0 in Cover Class Column.

SPECIES/STRATA TABLE / TREES & SHRUBS					SPECIES/STRATA TABLE / HERBACEOUS				
Strata / Species Scientific Name	*	Cover Class	% Cover	Spec ✓	Strata / Species Scientific Name	*	Cover Class	% Cover	Spec ✓
Whole Plot: **Total Vegetation Cover ____ (%)**					**Maximum Vegetation Height ___ (m)**				
T1 EMERGENT Strata Height ___ Strata Cover ____					H: HERBACEOUS Sum of H1, H2, H3, H4 Strata Height ____ Strata Cover ____				
					H1 GRAMINOID Strata Height ____ Strata Cover ____				
T2 CANOPY Strata Height ___ Strata Cover ____									
T3 SUBCANOPY Strata Height ___ Strata Cover ____									
					H2 FORBS Strata Height ____ Strata Cover ____				
S1 TALL SHRUB (> 2m) Strata Height ____ Strata Cover ____									
S2 SHORT SHRUB (<2m) Strata Height ____ Strata Cover ____									
					H3 FERNS & ALLIES Strata Height ____ Strata Cover ____				
					H4 TREE SEEDLINGS Strata Height ____ Strata Cover ____				
S3 DWARF SHRUB (< 0.5m) Strata Height ____ Strata Cover ____									
					NON-VASCULAR Strata Height ____ Strata Cover ____				

Cover Scale for Species

t = few T = <1% 1a = 5.01 –>10 % 2 = 15.01 –>25% 4 = 35.01 –> 45% 6 = 55.01 –> 65% 8 = 75.01 –> 85% 10 = >95%
P = 1-5% 1b = 10.01 –>15% 3 = 25.01 –>35% 5 = 45.01 –> 55% 7 = 65.01 –> 75% 9 = 85.01 –> 95%

Height Scale for Strata

01 = < 0.5 m 03 = 1.01 –>2 m 05 = 5.01 –> 10 m 07 = 15.01 –>20 m 09 = 35.01 –> 50 m
02 = 0.5-1 m 04 = 2.01 –>5 m 06 = 10.01 –> 15 m 08 = 20.01 –>35 m 10 = > 50 m

PACN VEGETATION OBSERVATION FORM

2008 VEGETATION MAPPING PROGRAM

SURVEY AND SITE INFORMATION

Location: _____ _____ Survey Date: _____

Park Site Name_____ Park Name :_____

Surveyors_____

Datum: WGS 84 NAD 83 Other_____ Field Northing _____ (UTM) Field Easting_____(UTM)
GPS UNIT: Garmin 76 Garmin 5 Other: _____ Error: +/- _____m

GPS Comments:

Camera ID ____ Camera Ht: _____ m **Photopoint coords (if not plot center)** Northing____ ___ (UTM) Easting__ __._ _____(UTM)

Description of Photopoint:_____

View#	Time	V or H	Bearing	Photographer	View from Photopoint
1					
2					
3					
4					
a					

Views 1-4 - cardinal directions N,E,S,W; view a - person standing on the photopoint itself to help relocate it in future; additional representative views

Representativeness (estimate extent of uniform vegetation) :

ENVIRONMENTAL DESCRIPTION

Elevation _____ m From: GPS / Map (circle one)	Slope _____(deg) Aspect_____
Topographic Position: High level High Slope Mid Slope Low Slope Backslope Step in Slope Toe Slope Low Level Interfluve	
Landform: Alluvial Fan, Colluvium, Rockpile, Drainage Channel, Valley Bottom Fill, Side Slope, Interfluve, Intermittent Stream, Ridge, Terrace, Beach, Butte, Cliff, Talus, Sand Dune, Plateau, Recent lava, Other: _____	**Geology**: A'a lava, Pahoehoe Lava, Limestone, Coral, Pumice, Ash, Other_____

Ground Cover: *(please estimate to the nearest percentage. Sum = 100%)*

___ Bare soil (<0.1 mm)
___ Sand (0.1-2 mm)
___ Gravel (2 mm – 6.4 cm)
___ Rock (> 6.4 cm)
___ Bedrock (solid surface)
___ Litter/Duff (dead plant material <3 cm diameter)
___ Coarse woody debris (dead wood 3-10 cm)
___ Woody debris structure (dead >10 cm deep & wide)
___ Live veg (litter / wood)
___ Lichen (ground)
___ Moss (ground)
___ Microbiotic soil crust
___ Water
___ Other:_____

Soil Texture (optional - see soil key): ___ sand ___loam ___silt ___clay ___peat ___muck	
Surface Water w/in 25m? YES/NO Seep, Spring, Stream, Pothole, River, Anchialine Pond, Ocean, Estuary.	Soil Moisture: Dry, Moist, Saturated, Standing Water

PACN VEGETATION OBSERVATION FORM
2008 VEGETATION MAPPING PROGRAM

VEGETATION DESCRIPTION (Only check one within each box)

Phenological notes: For each strata, note phenological state of dominant species. (Especially note in herbaceous vegetation if annuals or perennials are dominant).	Leaf Type (of dominant stratum) ___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte ___Non-vascular ___Mixed (describe)	Physiognomic Class (see cheat sheet) ___Forest ___Woodland ___Shrubland ___Wooded Shrubland ___Dwarf Shrubland ___Shrub Herbaceous ___Wooded Herbaceous ___Herbaceous ___Nonvascular ___Sparsely Vegetated	

Stratum Code	Stratum Ht Class	Stratum Cvr Class	Dominant Species (mark diagnostic species with *)	% Cover
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____
			_____	_____
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____

Strata:

T1	Emergent (above canopy)	**S1**	Tall Shrub (> 2m)	**H1**	Graminoids	**H4**	Tree Seedlings
T2	Canopy	**S2**	Short Shrub (< 2m)	**H2**	Forbs	**N**	Non-vascular
T3	Sub-canopy	**S3**	Dwarf Shrub (< 0.5m)	**H3**	Ferns & Allies		

Height Scale for Strata:		**Cover Scale for Strata & Ground Cover:**	
01 = < 0.5 m	06 = 10-15 m	01 = 0 – 10%	
02 = 0.5-1 m	07 = 15-20 m	02 = 10 – 25%	
03 = 1-2 m	08 = 20-35 m	03 = 25 – 60%	
04 = 2-5 m	09 = 35-50 m	04 = 60 – 100%	
05 = 5-10 m	10 = >50 m		

Additional observation comments:

PACN VEGETATION MAPPING ACCURACY ASSESSMENT FORM

IDENTIFIERS/LOCATORS

AA Target No. _____ Park Name: _____ State/Island:_____

Park Site Name _____ Initial Mapping Code _____

Survey Date_____ Surveyors_____

Datum: WGS 84 NAD 83 Field UTM X___ ___ ___ ___ ___ ___ m (E) Field UTM Y___ ___ ___ ___ ___ ___ ___ m (N)

GPS Unit: Garmin 76 / 5 / 60CSX Trimble Other _____ Error +/-_____ m

GPS Notes: _____

Camera: Ricoh-GPS Other:_____

View#	Bearing	Photographer	Comments
1			
2			
3			
4			

ASSOCIATION INFORMATION

Primary Name Veg Assoc/Alliance/Group: _____Corresponding Map Code:_____

Secondary Name Veg Assoc/Alliance/Group:_____ Corresponding Map Code:_____

Tertiary Name Veg Assoc/Alliance/Group:_____ Corresponding Map Code:_____

Other Veg Assoc within 50 m: 1)_____

2)_____ 3)_____

Representativeness of point within polygon: Good Fair Poor ...of association to description: Good Fair Poor N/A

Classification Comments: (complications, uncertainties, explanation of poor representativeness)

Does the key work? Yes ____ No____ Comments:

Is the corresponding description accurate? Yes ____ No____ Comments:

Target Number_____ **Date:**_____

ENVIRONMENTAL DESCRIPTION

Elevation _____ From: GPS / Map (circle one) Slope _____ Aspect_____

Topographic Position: High level High Slope Mid Slope Low Slope Backslope Step in Slope Toe Slope Low Level Interfluve

Landform: Alluvial Fan, Colluvium, Rockpile, Drainage Channel, Valley Bottom Fill, Side Slope, Interfluve, Intermittent Stream, Ridge, Terrace, Butte, Cliff, Talus, Sand Dune, Plateau, Beach, Recent Lava Flow, Other: _____

Geology: A 'a lava, Pahoehoe Lava, Ash, Cinder, Coral, Limestone, Pumice, Obscured by soil, Other:_____

Environmental Comments:

VEGETATION DESCRIPTION

Phenology (all species)	Leaf Type (of dominant stratum)	Physiognomic class	Height Scale	Cover Scale
	___Broad-leaved ___Needle-leaved ___Mixed Broad/Needle-lvd ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf-shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 < 0.5 m 02 0.5-1 m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35-50 m 10 > 50 m	T <1% P 1-5% 1a 5.01-10% 1b 10.01-15% 02 15.01-25% 03 25.01-35% 04 35.01-45% 05 45.01-55% 06 55.01-65% 07 65.01-75% 08 75.01-85% 09 85.01-95% 10 >95%

Total Vegetation Cover _____ Cover estimates based on: **plot / polygon**

Stratum Code	Height Class	Cover Class	Dominant species (mark diagnostic species with a *)	% Cover
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____
_____	_____	_____	_____	_____
			_____	_____
			_____	_____
			_____	_____

Strata:

T1 Emergent (above canopy) **S1** Tall shrub (>2 m) **H1** Graminoids **H4** Tree Seedlings
T2 Canopy **S2** Short Shrub (>0.5 m- 2 m) **H2** Forbs **N** Nonvascular
T3 Sub-canopy **S3** Dwarf-shrub (< 0.5 m) **H3** Ferns & Allies

Appendix B: Plant Species Found within Sample Plots at Pu‘uhonua o Hōnaunau National Historical Park

Ninety-eight plant species were encountered while sampling field plots, observation points, and accuracy assessment plots. Family, genus species, common names and nativity are reported. Plant species are indicated that were not present in sample plots at PUHO, but are important for community classification. Nomenclature follows that of Wagner and Herbst (2003) and Wagner et al. (1999) for flowering plants and Palmer (2003) for ferns. Common names listed were selected primarily from Wagner et al. (1999) by PACN and used throughout the document. Species names that differ from those in the rUSNVC are identified with footnotes.

Family	Genus species	Common Name	Nativity
Agavaceae	*Cordyline fruticosa* (L.) A. Chev.	ti	Non-Native
Aizoaceae	*Sesuvium portulacastrum* (L.) L.	‘ākulikuli	Native
Aloeaceae	*Aloe vera* (L.) Burm. f.	aloe	Non-Native
Anacardiaceae	*Mangifera indica* L.	mango	Non-Native
Anacardiaceae	*Schinus terebinthifolius* Raddi	Christmas berry	Non-Native
Apocynaceae	*Catharanthus roseus* (L.) G. Don	Madagascar periwinkle	Non-Native
Arecaceae	*Cocos nucifera* L.	coconut palm	Non-Native
Arecaceae	*Pritchardia* spp.	loulu	Native
Asteraceae	*Bidens pilosa* L.	nehe	Non-Native
Asteraceae	*Crassocephalum crepidioides* (Benth.) S. Moore		Non-Native
Asteraceae	*Mikania scandens* (L.) Willd.	climbing hempvine	Non-Native
Asteraceae	*Pluchea carolinensis* (Jacq.) G. Don	sourbush	Non-Native
Asteraceae	*Tridax procumbens* L.	coat buttons	Non-Native
Bataceae	Batis maritima L.[1]	pickleweed	Non-Native
Boraginaceae	*Cordia subcordata* Lam.	kou	Native
Boraginaceae	*Heliotropium amplexicaule* Vahl		Non-Native
Boraginaceae	*Heliotropium curassavicum* L.	kīpūkai	Native
Boraginaceae	*Tournefortia argentea* L. fil.	tree heliotrope	Non-Native
Capparaceae	*Cleome gynandra* L.	wild spider flower	Non-Native
Caricaceae	*Carica papaya* L.	papaya	Non-Native
Clusiaceae	*Calophyllum inophyllum* L.	kamani	Non-Native
Commelinaceae	*Commelina benghalensis* L.	hairy honohono	Non-Native
Convolvulaceae	*Ipomoea pes-caprae* (L.) R. Br.	pohuehue	Native
Convolvulaceae	*Jacquemontia ovalifolia ssp. sandwicensis* (Gray) Robertson	pā‘ūohi‘iaka	Native
Crassulaceae	*Kalanchoe pinnata* (Lam.) Pers.	air plant	Non-Native
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	ivy gourd	Non-Native
Cucurbitaceae	*Cucumis dipsaceus* Ehrenb. ex Spach	teasel gourd	Non-Native
Cucurbitaceae	*Momordica charantia* L.	balsam pear	Non-Native
Cyperaceae	*Cyperus javanicus* Houtt.	‘ahu‘awa	Native
Cyperaceae	*Cyperus laevigatus* L.	makaloa	Native

Family	Genus species	Common Name	Nativity
Cyperaceae	*Fimbristylis cymosa* R. Br.	mau'u	Native
Cyperaceae	*Kyllinga brevifolia* Rottb.		Non-Native
Dryopteridaceae	*Nephrolepis exaltata* ssp. *hawaiiensis* W. H. Wagner	kupukupu	Native
Dryopteridaceae	*Nephrolepis multiflora* (Roxb.) F.M. Jarrett ex C.V. Morton	sword fern	Non-Native
Euphorbiaceae	*Aleurites moluccana* (L.) Willd.	kukui	Non-Native
Euphorbiaceae	*Chamaesyce prostrata* (Aiton) Small	prostrate spurge	Non-Native
Euphorbiaceae	*Chamaesyce* sp. 1		Non-Native
Euphorbiaceae	*Phyllanthus debilis* Klein ex Willd.	niruri	Non-Native
Euphorbiaceae	*Ricinus communis* L.	castor bean	Non-Native
Fabaceae	*Acacia farnesiana* (L.) Willd.	klu	Non-Native
Fabaceae	*Caesalpinia bonduc* (L.) Roxb.	kākalaioa	Native
Fabaceae	*Chamaecrista nictitans ssp. patellaria var. glabrata* (Vogel) H. Irwin & Barneby	partridge pea	Non-Native
Fabaceae	*Crotalaria pallida* Aiton	smooth rattlepod	Non-Native
Fabaceae	*Desmodium tortuosum* (Sw.) DC.	Florida beggarweed	Non-Native
Fabaceae	*Indigofera suffruticosa* Mill.		Non-Native
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	koa haole	Non-Native
Fabaceae	*Macroptilium lathyroides* (L.) Urb.	wild bean	Non-Native
Fabaceae	*Neonotonia wightii* (Wight & Arn.) Lacey		Non-Native
Fabaceae	*Pithecellobium dulce* (Roxb.) Benth.	'opiuma	Non-Native
Fabaceae	*Prosopis pallida* (Humb. & Bonpl. ex Willd.) Kunth	kiawe	Non-Native
Fabaceae	*Samanea saman* (Jacq.) Merr.	monkeypod	Non-Native
Fabaceae	*Senna occidentalis* (L.) Link	coffee senna	Non-Native
Fabaceae	*Senna pendula var. advena* (Vogel) Irwin & Barneby		Non-Native
Fabaceae	*Senna* spp.		Non-Native
Fabaceae	*Sesbania tomentosa* Hook. & Arnott	'ohai	Native
Fabaceae	*Tamarindus indica* L.	tamarind	Non-Native
Goodeniaceae	*Scaevola taccada* (Gaertn.) Roxb.[2]	naupaka kahakai	Native
Lamiaceae	*Hyptis pectinata* (L.) Poit.	comb hyptis	Non-Native
Lamiaceae	*Ocimum gratissimum* L.		Non-Native
Lamiaceae	*Plectranthus parviflorus* Willd.	'ala'ala wai nui wahine	Native
Lythraceae	*Cuphea carthagenensis* (Jacq.) Macbr.	tarweed	Non-Native
Malvaceae	*Abutilon grandifolium* (Willd.) Sweet	ma'o	Non-Native
Malvaceae	*Malvastrum coromandelianum* (L.) Garcke	false mallow	Non-Native
Malvaceae	*Malvastrum coromandelianum ssp. coromandelianum* (L.) Garcke	false mallow	Non-Native
Malvaceae	*Sida cordifolia* L.	mallow plant	Non-Native
Malvaceae	*Sida fallax* Walp.	'ilima	Native
Malvaceae	*Sida rhombifolia* L.		Non-Native

Family	Genus species	Common Name	Nativity
Malvaceae	*Sida* spp.		Non-Native
Malvaceae	*Thespesia populnea* (L.) Sol. ex Correa	milo	Native
Nyctaginaceae	*Boerhavia coccinea* Mill.	scarlet spiderling	Non-Native
Nyctaginaceae	*Boerhavia repens* L.	alena	Native
Nyctaginaceae	*Bougainvillea glabra* Choisy[1]	bougainvillea	Non-Native
Pandanaceae	*Pandanus tectorius* S. Parkinson ex Z	hala	Native
Passifloraceae	*Passiflora edulis* Sims	passionfruit	Non-Native
Passifloraceae	*Passiflora foetida* L.	love-in-a-mist	Non-Native
Passifloraceae	*Passiflora suberosa* L.		Non-Native
Phytolaccaceae	*Rivina humilis* L.	coral berry	Non-Native
Piperaceae	*Peperomia blanda var. floribunda* (Miq.) H. Huber	‘ala‘ala wai nui	Native
Piperaceae	*Peperomia* sp. 1		Native
Plumbaginaceae	*Plumbago zeylanica* L.	‘ilie‘e	Native
Poaceae	*Cynodon dactylon* (L.) Pers.		Non-Native
Poaceae	*Eragrostis amabilis* (L.) Wight & Arn.		Non-Native
Poaceae	*Eragrostis tenella* (L.) P. Beauv. Ex Roem. & Schult	lovegrass	Non-Native
Poaceae	*Heteropogon contortus* (L.) Beauv. ex Roemer & J.A. Schultes[1]	pili	Native
Poaceae	*Melinis repens* (Willd.) Zizka	natal redtop	Non-Native
Poaceae	*Panicum maximum* Jacq.[3]	guinea grass	Non-Native
Poaceae	*Paspalum vaginatum* Sw.[1]	seashore paspalum	Non-Native
Poaceae	*Pennisetum setaceum* (Forsk.) Chiov.[1]	fountain grass	Non-Native
Poaceae	*Sporobolus africanus* (Poir.) Robyns & Tournay	rattail grass	Non-Native
Polypodiaceae	*Phymatosorus grossus* (Langsd. & Fisch.) Brownlie	naturalized laua‘e	Non-Native
Portulacaceae	*Portulaca oleracea* L.	pigweed	Non-Native
Portulacaceae	*Portulaca pilosa* L.		Non-Native
Portulacaceae	*Portulaca villosa* Cham	‘ihi	Native
Portulacaceae	*Talinum fruticosum* (L.) Juss.		Non-Native
Portulacaceae	*Talinum paniculatum* (Jacq.) Gaertn.	jewels of Opar	Non-Native
Rubiaceae	*Morinda citrifolia* L.	noni	Non-Native
Solanaceae	*Nicotiana glauca R. C.* Graham	tree tobacco	Non-Native
Sterculiaceae	*Waltheria indica* L.	‘uhaloa	Native
Tiliaceae	*Triumfetta procumbens* G. Forst.		Non-Native
Verbenaceae	*Lantana camara* L.	lantana	Non-Native
Verbenaceae	*Stachytarpheta jamaicensis* (L.) Vahl	ōwī	Non-Native
Verbenaceae	*Vitex rotundifolia* L. fil.	pōhinahina	Native
Zygophyllaceae	*Tribulus terrestris* L.	puncture vine	Non-Native

[1] Species important for community types, but not sampled in vegetation plots at PUHO.
[2] Listed in rUSNVC as *Scaevola sericea var. taccada.*
[3] Listed in rUSNVC as *Urochloa maxima.*

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Appendix C: Field Plot Crosswalk to Revised US National Vegetation Classification Associations

At Pu‘uhonua o Hōnaunau National Historical Park 54 plots and observation points were assigned to revised US National Vegetation Classification (rUSNVC) associations and park specials. A total of 11 rUSNVC associations and three “Park Special” were classified. Element codes are used by NatureServe and state Natural Heritage Programs to track nomenclature and status of rare plants, rare animals, and communities (“elements”). Nomenclature used by the rUSNVC follows Kartesz (1999) with Pacific Island modifications based on Wagner and Herbst (2003) and Wagner et al. (1999).

Plant Association Scientific Name	Element Code	No. of Samples	Supporting Plots and Observation Points
Woodlands (Native and Polynesian introduced)			
Cocos nucifera Strand Woodland	CEGL005402	6	PUHO.0008, PUHO.0015, PUHO.0021, PUHO.0022, PUHO.0026, PUHO.2200
Thespesia populnea / Sparse Understory Woodland	CEGL005412	1	PUHO.0100
Woodlands (Ruderal)			
Pithecellobium dulce Semi-natural Woodland	CEGL005409	8	PUHO.0012, PUHO.0013, PUHO.0023, PUHO.0030, PUHO.0035, PUHO.0041, PUHO.0046, PUHO.0050
Prosopis pallida Coastal Dry Semi-natural Woodland	CEGL008118	1	PUHO.0051
Samanea saman - Schinus terebinthifolius Semi-natural Woodland [Park Special]	CEPS009515	2	PUHO.0036, PUHO.0037
Shrublands (Native)			
Scaevola taccada Coastal Dry Shrubland[1]	CEGL008054	1	PUHO.0002
Waltheria indica - Sida fallax Shrubland	CEGL005414	1	PUHO.0005
Shrublands (Ruderal)			
Leucaena leucocephala - Pithecellobium dulce Semi-natural Shrubland [Park Special]	CEPS009518	2	PUHO.0018, PUHO.0048
Leucaena leucocephala / Panicum maximum Semi-natural Shrubland[1]	CEGL005404	12	PUHO.0009, PUHO.0011, PUHO.0017, PUHO.0031, PUHO.0033, PUHO.0038, PUHO.0039, PUHO.0042, PUHO.0044, PUHO.0045, PUHO.0049, PUHO.0190

Plant Association Scientific Name	Element Code	No. of Samples	Supporting Plots and Observation Points
Leucaena leucocephala Lowland Dry Semi-natural Shrubland	CEGL008114	11	PUHO.0001, PUHO.0003, PUHO.0004, PUHO.0006, PUHO.0007, PUHO.0014, PUHO.0016, PUHO.0032, PUHO.0040, PUHO.0170, PUHO.0180
Herbaceous Vegetation (Native)			
Fimbristylis spp. Coastal Dry Herbaceous Vegetation	CEGL008089	1	PUHO.1200
Herbaceous Vegetation (Ruderal)			
Melinis repens Semi-Natural Herbaceous Vegetation	CEGL005405	2	PUHO.0024, PUHO.0025
Sida cordifolia Semi-natural Herbaceous Vegetation [Park Special]	CEPS009516	1	PUHO.0124
Panicum maximum Lowland Dry Semi-natural Herbaceous Vegetation[1]	CEGL008109	5	PUHO.0010,PUHO.0034, PUHO.0043, PUHO.0047, PUHO.0200

[1]rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

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Appendix D: Field Key to the Vegetation of Pu‘uhonua o Hōnaunau National Historical Park, Hawai‘i

The vegetation of Pu‘uhonua o Hōnaunau National Historic Park (PUHO) was characterized using field data collected in 2008 under the National Park Service’s National Vegetation Mapping Program. To assist in the accurate field identification of the plant associations or vegetation cover types described for PUHO, this dichotomous key has been developed from plot data.

This key is structured to facilitate identification of vegetation types with one or a combination of dominant or diagnostic species, and in some cases, the key also relates types to their primary habitats and range within the Historic Park. Because of natural variation within vegetation types, it is possible that a community can be keyed using more than one of the physiognomic keys. For sites within ecotones (boundary or transition zones between vegetation types where diagnostic species intermix), it may be difficult to determine a definitive type. A mapped type may have small inclusions of other vegetation types.

How To Use The Key

The key can be used to identify at three hierarchical levels within the revised US National Vegetation Classification (rUSNVC). The broadest level is the Group, then Alliance and at the finest scale is the rUSNVC Association. The key focuses on the Association level with an occasional reference to Group level, as needed to allow for unclassified types. However, when the association is identified, then the alliance and group are known because of the hierarchical nature of the rUSNVC (Table 10). This allows the user to determine which hierarchy level is appropriate.

Park Specials represent local vegetation types that differ significantly from existing rUSNVC association concepts, but lack enough data to develop into a new association. Park Special types are not officially included in the rUSNVC Hierarachy, but many times can be linked to the Group level for classification and mapping purposes (Table 10).

The key is divided into Sparse, Coastal Strand, and Inland (Woodland, Shrubland and Herbaceous Vegetation) Zones. Some vegetation types may occur in multiple zones, especially inland types extending to the coast, so if the key is not working well try using other zones in the key before assuming vegetation is not described. The name of each Association and Park Special are provided using both common names and scientific names for species as well as the map code in parentheses. If the type was mapped, but not sampled at the site then a description was not written and “(no description)” was added to the couplet.

Special Instructions

There are a number of closely related vegetation types at PUHO that may be confusing in the field e.g., grasslands with scattered trees or shrubs vs. an open shrubland or woodland. We are using a 20% minimum tree and shrub canopy cover threshold for woodlands and shrublands with a strong herbaceous layer. Stands with less than 20% tree or shrub cover are classified as an herbaceous type unless the tree or shrub layer dominates the vegetation and herbaceous cover is low in which case the stand is classified as an open woodland or shrubland. Percent canopy cover values are all absolute, not relative. Species dominance is important is keying vegetation. Dominant species are the predominant species in a community because of size, abundance or coverage. A dominant or co-dominant species might have high relative cover in the tree, shrub or herbaceous layer or be the largest and most prominent species present in the stand, such as coconut trees in an open coconut palm strand woodland, but not necessarily the most abundant or have the highest cover.

When keying vegetation with seasonally deciduous trees and shrubs, estimate what the live crown canopy would be at full foliage. Canopy cover is used as a measure of species dominance in plant community classification and should not vary seasonally.

Not all species are given equal weight in classification. Native species such as milo *(Thespesia populnea),* ʻuhaloa *(Waltheria indica),* and naupaka kahakai *(Scaevola taccada)* are given more diagnostic value over non-native species in determining the vegetation type. A native vegetation type may be invaded (disturbance) by non-native species and as long as the non-native species do not strongly dominate the vegetation type (conversion to introduced or non-native type) the stand may be characterized by diagnostic native species and considered a poor condition example of a native plant community. Annual species are rarely considered important diagnostically unless they strongly dominate the herbaceous layer or indicate a particular habitat such as coastal strand or a disturbance type.

A Key to the Vegetation Associations and Park-specific Map Classes at Pu‘uhonua o Hōnaunau National Historical Park (PUHO)

1a) Land is developed or vegetation is absent or very sparse <2% cover (e.g., barren lava, rocky or sandy shoreline) (See Geologic and Land Use Map Classes).
1b) Vegetation is present with sparse to dense cover (≥2% total vegetation cover). **(2)**

2a) Site is sparsely vegetated (2-9% total vegetation cover). Site is too sparse to be considered an open grassland, shrubland or woodland. **(3)**
2b) Vegetation is present with 10% or more total vegetation cover. **(7)**

Sparse Vegetation

3a) Vegetation is dominated by mau‘u (*Fimbristylis cymosa*) and occurs on coastal strand. – **Mau‘u Coastal Dry Herbaceous Vegetation; *Fimbristylis* spp. Coastal Dry Herbaceous Vegetation (H_FIMB)**
3b) Vegetation is not dominated by mau‘u (*Fimbristylis cymosa*), other species are present. **(4)**

4a) Site is restricted to coastal shoreline. – **Coastal Strand Sparse Vegetation [Park Special] (SV_CS) (No description)**
4b) Site is not restricted to coastal shoreline. **(5)**

5a) Site is restricted to lava flows. **(6)**
5b) Site is not restricted to lava flows. – **Undescribed PUHO Sparse Vegetation**

6a) Site is restricted to a‘a lava. – **A‘a Lava with Sparse Vegetation [Park Special] (SV_A‘A) (No description)**
6b) Site is restricted to pahoehoe lava. – **Pahoehoe Lava Sparse Vegetation (SV_PA) (No description)**

Non-Sparse Vegetation

7a) Vegetation is restricted to the coastal shoreline and does not significantly extend into coastal uplands. **(8)**
7b) Vegetation is not restricted to coastal shoreline. Some inland vegetation types occasionally extend down to coastal strand (such as kiawe [*Prosopis pallida*] woodland). **(16)**

Coastal Strand Vegetation

8a) Trees typically dominate strand vegetation. **(9)**
8b) Herbaceous or shrub vegetation typically dominates strand vegetation. **(13)**

9a) Vegetation is dominated or co-dominated by native or Polynesian introduced tree species. **(10)**
9b) Vegetation is dominated by non-native tree species. **(12)**

10a) Vegetation is typically an open tree canopy dominated or co-dominated by coconut palm *(Cocos nucifera)*. Includes stands down to 5% cover of coconut palm as long as it dominates the tree layer. – **Coconut Palm Strand Woodland; *Cocos nucifera* Strand Woodland (W_CONU)**

10b) Vegetation is not dominated or co-dominated by coconut palm (*Cocos nucifera*). **(12)**

11a) Vegetation is an open tree canopy dominated or co-dominated by milo *(Thespesia populnea)*. The non-native kiawe *(Prosopis pallida)* may be present to co-dominant in tree layer. – **Milo / Sparse Understory Woodland; *Thespesia populnea* / Sparse Understory Woodland (W_THPO)**

11b) Vegetation is not dominated or co-dominated by milo *(Thespesia populnea)*. – **Undescribed PUHO vegetation in the Hawaiian Lowland Dry Forest & Woodland Group (G405)**

12a) Woody vegetation is dominated by the non-native species tree heliotrope *(Tournefortia argentea)*. – **Tree Heliotrope Semi-natural Woodland; *Tournefortia argentea* Semi-natural Woodland (W_TOAR)**

12b) Woody vegetation is not dominated by tree heliotrope *(Tournefortia argentea)*. – **Undescribed PUHO vegetation in the Hawaiian Ruderal Dry Forest Group (G407)**

13a) Vegetation is dominated or co-dominated by native species. – **Hawaiian Dry Scrub & Herb Coastal Strand Group (G421) (14)**

13b) Vegetation is dominated by non-native species. – **Hawaiian Ruderal Scrub & Herb Coastal Strand Group (G423)**

14a) Vegetation is an open shrub canopy dominated or co-dominated by naupaka kahakai *(Scaevola taccada)*. – **Naupaka Kahakai Coastal Dry Shrubland; *Scaevola taccada* Coastal Dry Shrubland[1] (S_SCTA)**

14b) Vegetation is not dominated or co-dominated by naupaka kahakai *(Scaevola taccada)*. **(15)**

15a) Vegetation is dominated by mauʻu (*Fimbristylis cymosa*) and occurs on coastal strand. – **Mauʻu Coastal Dry Herbaceous Vegetation; *Fimbristylis* spp. Coastal Dry Herbaceous Vegetation (H_FIMB)**

15b) Vegetation is not dominated by mauʻu (*Fimbristylis cymosa*), other species are present. – **Undescribed PUHO vegetation in the Hawaiian Dry Scrub & Herb Coastal Strand Group (G421)**

Inland Vegetation

16a) Vegetation is composed of trees or shrubs with at least 20% cover. Woody cover may be lower (10-19%) as long as it exceeds any perennial herbaceous vegetation present. **(17)**

16b) Vegetation is dominated by grasses and/or broad-leaf herbs (forbs). Shrubs or trees may be present, but tree or shrub cover is lower than perennial herbaceous layer and does not exceed 20%. **(32)**

17a) Vegetation is typically dominated by trees (usually >20% cover). Shrub cover may be high (exceeding the tree cover) if tree cover is 20% or more. If tree cover is 10-19% then it must exceed shrub and perennial herbaceous cover (i.e. trees dominate the vegetation). Koa haole *(Leucaena leucocephala)* is considered to be a shrub and not a tree in this key. **(18)**

17b) Vegetation is dominated by shrubs (usually >20% cover). Trees may be present with less than 20% total cover. The shrub canopy may be less (10-20%) as long as it is greater than the perennial herbaceous cover. **(26)**

Woodlands

18a) Tree canopy is dominated or co-dominated by native trees. Sparse to dense shrubs may be present, but trees dominate or have greater than 20% canopy cover. – **Hawaiian Lowland Dry Forest & Woodland Group (G405) (19)**

18b) Tree canopy is dominated by non-native trees. Sparse to dense shrubs may be present, but trees dominate or have greater than 20% canopy cover. – **Hawaiian Ruderal Dry Forest Group (G407) (20)**

19a) Vegetation is an open tree canopy dominated or co-dominated by milo *(Thespesia populnea).* Kiawe *(Prosopis pallida)* may be present to co-dominant in the tree layer. – **Milo / Sparse Understory Woodland; *Thespesia populnea* / Sparse Understory Woodland (W_THPO)**

19b) Vegetation is dominated by other native tree species. – **Undescribed PUHO vegetation in the Hawaiian Lowland Dry Forest & Woodland Group (G405)**

20a) Tree canopy is dominated by koa haole *(Leucaena leucocephala).* In the rUSNVC, koa haole is treated as a short to tall shrub, not a small tree even though some stands in Hawai‘i have tree form individuals. **(26)**

20b) Tree canopy is <u>not</u> dominated by koa haole *(Leucaena leucocephala)* although it may be present in the shrub layer. **(21)**

21a) Tree canopy is dominated by Christmas berry *(Schinus terebinthifolius).* Fountain grass *(Pennisetum setaceum)* dominates the herbaceous layer. – **Christmas berry / Fountain grass Semi-natural Woodland; *Schinus terebinthifolius / Pennisetum setaceum* Semi-natural Woodland (W_SCTE) (No description)**

21b) Tree canopy is <u>not</u> dominated by Christmas berry *(Schinus terebinthifolius);* however it may be present to co-dominant with monkeypod *(Samanea saman).* **(22)**

22a) Tree canopy is dominated or co-dominated by monkeypod *(Samanea saman)* and Christmas berry *(Schinus terebinthifolius).* Kiawe *(Prosopis pallida)* may be present with low cover. – **Monkeypod - Christmas Berry Semi-natural Woodland; *Samanea saman - Schinus terebinthifolius* Semi-natural Woodland (W_SASA)**

22b) Tree canopy is <u>not</u> co-dominated by monkeypod *(Samanea saman)* and Christmas berry *(Schinus terebinthifolius).* **(23)**

23a) Tree canopy is dominated by ʻopiuma *(Pithecellobium dulce)* with 20-80% cover or ʻopiuma co-dominates with noni *(Morinda citrifolia)* or other non-native trees totaling at least 20% tree canopy. Koa haole *(Leucaena leucocephala)* may be present to dominate in shrub layer (see #29 in key to compare). – **ʻOpiuma Semi-natural Woodland; *Pithecellobium dulce* Semi-natural Woodland (W_PIDU)**

23b) Tree canopy is <u>not</u> dominated by ʻopiuma *(Pithecellobium dulce)* or co-dominated by noni *(Morinda citrifolia)* and ʻopiuma. **(24)**

24a) Tree canopy is dominated by kiawe *(Prosopis pallida).* – **Kiawe Coastal Dry Semi-natural Woodland; *Prosopis pallida* Coastal Dry Woodland (W_PRPA)**

24b) Tree canopy is <u>not</u> dominated by kiawe *(Prosopis pallida).* **(25)**

25a) Tree canopy is dominated by kukui *(Aleurites moluccana)* a Polynesian introduced species. – ***Aleurites moluccana* Woodland Stand (W_ ALMO) (No description)**

25b) Tree canopy is dominated by papaya *(Carica papaya)* or other planted trees including milo *(Thespesia populnea),* monkeypod *(Samanea saman),* and ʻopiuma (*Pithecellobium dulce)* trees. Kukui *(Aleurites moluccana)* may be present, but not dominant. – **Mixed Semi-natural Ornamental Tree Woodland (W_ORNA) (No description)**

Shrublands

26a) Shrub canopy is dominated by native shrubs. – **Hawaiian Lowland Dry Shrubland & Grassland Group (G410) (27)**

26b) Shrub canopy is dominated by non-native shrubs. – **Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413) (28)**

27a) Shrub canopy is dominated or co-dominated by ʻuhaloa *(Waltheria indica).* ʻIlima *(Sida fallax)* typically dominates the herbaceous layer. – **ʻUhaloa - ʻIlima Shrubland; *Waltheria indica* - *Sida fallax* Shrubland (S_WAIN)**

27b) Other native shrub species dominate. – **Undescribed PUHO vegetation in the Hawaiian Lowland Dry Shrubland & Grassland Group (G410)**

28a) Shrub canopy is dominated by bougainvillea *(Bougainvillea glabra).* – **Bougainvillea Semi-natural / Planted Shrubland [Park Special]; *Bougainvillea glabra* Semi-natural / Planted Shrubland [Park Special] (S_BOGL) (No description)**

28b) Vegetation is <u>not</u> dominated by bougainvillea *(Bougainvillea glabra).* **(29)**

29a) Shrub canopy is dominated by koa haole *(Leucaena leucocephala)* with scattered (10-19% cover) ʻopiuma *(Pithecellobium dulce*) trees and shrubs present. ʻOpiuma is generally scattered emergent trees, but may be sapling size (shrub layer). – **Koa Haole - ʻOpiuma Semi-natural Shrubland [Park Special]; *Leucaena leucocephala* - *Pithecellobium dulce* Semi-natural Shrubland [Park Special] (S_LEPI)**

29b) If shrub canopy is dominated by koa haole *(Leucaena leucocephala),* then ʻopiuma *(Pithecellobium dulce)* is absent or has less than 10% cover (<u>not</u> co-dominant). Christmas berry *(Schinus terebinthifolius)* may also be present. (If Christmas berry is dominant then see # 21 & #22 as it is treated as a small tree in the rUSNVC, although it may have a tall shrub life form in some stands). **(30)**

30a) Shrub canopy is dominated or co-dominated by koa haole *(Leucaena leucocephala)* with a sparse or dense herbaceous layer that is dominated by guinea grass *(Panicum maximum).* – **Koa Haole / Guinea Grass Semi-natural Shrubland; *Leucaena leucocephala* / *Panicum maximum* Semi-natural Shrubland[1] (S_LEPA)**

30b) If shrub canopy is dominated by koa haole *(Leucaena leucocephala),* then guinea grass *(Panicum maximum)* does not dominate the understory. **(31)**

31a) Shrub canopy is dominated or co-dominated by koa haole *(Leucaena leucocephala).* Understory is a sparse or dense herbaceous layer that is not dominated by guinea grass *(Panicum maximum)* or fountain grass *(Pennisetum setaceum).* Monkeypod *(Pithecellobium dulce)* is absent or has low cover (not co-dominant). – **Koa Haole Lowland Dry Semi-natural Shrubland; *Leucaena leucocephala* Lowland Dry Semi-natural Shrubland (S_LELE)**

31b) Shrub canopy is dominated or co-dominated by other non-native shrub species. **Undescribed PUHO vegetation in the Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)**

Herbaceous Vegetation

32a) Vegetation is planted or part of a landscaped area (cultural type). Herbaceous layer is dominated by pili grass *(Heteropogon contortus).* – **Pili Planted Herbaceous Vegetation; *Heteropogon contortus* Planted Herbaceous Vegetation (G_HECO) (No description)**

32b) Herbaceous layer is not planted. Species may include native and non-native species. **(33)**

33a) Vegetation is dominated or co-dominated by native herbaceous species. Stands may include scattered trees or shrubs with up to 19% cover if the herbaceous cover is greater than the woody cover. – **Undescribed PUHO vegetation in the Hawaiian Lowland Dry Shrubland & Grassland Group (G410)**

33b) Vegetation is dominated by non-native herbaceous species, but may include scattered trees or shrubs with up to 19% cover if the herbaceous cover is greater than the woody cover. – **Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413) (34)**

34a) Herbaceous layer is dominated by the non-native forb, mallow plant *(Sida cordifolia).* – **Mallow Plant Semi-natural Herbaceous Vegetation [Park Special]; *Sida cordifolia* Semi-natural Herbaceous Vegetation [Park Special] (H_SICO)**

34b) Herbaceous layer is not dominated by mallow plant *(Sida cordifolia).* **(35)**

35a) Herbaceous layer is dominated by non-native perennial grass, natal redtop *(Melinis repens).* – **Natal Redtop Semi-Natural Herbaceous Vegetation; *Melinis repens* Semi-Natural Herbaceous Vegetation (H_MERE)**

35b) Vegetation is not dominated by natal redtop *(Melinis repens).* **(36)**

36a) Herbaceous layer is dominated by guinea grass *(Panicum maximum).* – **Guinea Grass Lowland Dry Herbaceous Vegetation; *Panicum maximum* Lowland Dry Herbaceous Vegetation**[1] **(H_PAMA)**

36b) Herbaceous layer is not dominated by guinea grass *(Panicum maximum).* **(37)**

37a) Herbaceous layer is dominated by fountain grass *(Pennisetum setaceum).* – **Fountain grass Semi-natural Herbaceous Vegetation; *Pennisetum setaceum* Semi-natural Herbaceous Vegetation (H_PESE) (No description)**

37b) Herbaceous layer is dominated by other non-native species. – **Undescribed PUHO vegetation in the Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)**

[1]rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

Literature Cited

Wagner, W. L. and D. R. Herbst. 2003. Supplement to the Manual of flowering plants of Hawai‘i *in* Manual of the flowering plants of Hawaii, revised edition. Volumes 1 and 2. University of Hawaii Press and Bishop Museum Special Publication 97, Honolulu. 1855-1918 pp.

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1999. Manual of the flowering plants of Hawaii. Revised edition. Volumes 1 and 2. University of Hawaii Press and Bishop Museum Press, Honolulu. 1919 pp.

Appendix E: Plant Association Descriptions for Pu‘uhonua o Hōnaunau National Historical Park, Hawai‘i

REVISED US NATIONAL VEGETATION CLASSIFICATION

Vegetation Associations of
Pu‘uhonua o Hōnaunau National Historical Park
15 June 2010

by

NatureServe

1101 Wilson Blvd., 15th floor
Arlington, VA 22209

4001 Discovery, Suite 270
Boulder, CO 80303

This subset of the International Ecological Classification Standard covers vegetation associations of Pu'uhonua o Hōnaunau National Historical Park. This classification has been developed in consultation with many individuals and agencies and incorporates information from a variety of publications and other classifications. Comments and suggestions regarding the contents of this subset should be directed to Mary J. Russo, Central Ecology Data Manager, Durham, NC mary_russo@natureserve.org, and/or Keith Schulz, Vegetation Ecologist, Boulder, CO <keith_schulz@natureserve.org>.

Citations:

The following citation should be used in any published materials which reference ecological system and/or International Vegetation Classification (IVC hierarchy) and association data:

NatureServe. 2010. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA. U.S.A. Data current as of 15 June 2010.

NatureServe
1101 Wilson Blvd, 15th floor
Arlington, VA 22209

These data are extracted from:

NatureServe. 2010. International Ecological Classification Standard: Terrestrial Ecological Classifications. NatureServe Central Databases. Arlington, VA. U.S.A. Data current as of 15 June 2010.

This document may be generally cited as follows:

NatureServe[1]. 2010. International Ecological Classification Standard: Terrestrial Ecological Classifications. Vegetation Associations of Pu‘uhonua o Hōnaunau National Historical Park. NatureServe Central Databases. Arlington, VA. Data current as of 15 June 2010.

[1] NatureServe is an international organization including NatureServe regional offices, a NatureServe central office, U.S. State Natural Heritage Programs, and Conservation Data Centres (CDC) in Canada and Latin America and the Caribbean. Ecologists from the following organizations have contributed the development of the ecological systems classification:

United States
Central NatureServe Office, Arlington, VA; Eastern Regional Office, Boston, MA; Midwestern Regional Office, Minneapolis, MN; Southeastern Regional Office, Durham, NC; Western Regional Office, Boulder, CO; Alabama Natural Heritage Program, Montgomery AL; Alaska Natural Heritage Program, Anchorage, AK; Arizona Heritage Data Management Center, Phoenix AZ; Arkansas Natural Heritage Commission Little Rock, AR; Blue Ridge Parkway, Asheville, NC; California Natural Heritage Program, Sacramento, CA; Colorado Natural Heritage Program, Fort Collins, CO; Connecticut Natural Diversity Database, Hartford, CT; Delaware Natural Heritage Program, Smyrna, DE; District of Columbia Natural Heritage Program/National Capital Region Conservation Data Center, Washington DC; Florida Natural Areas Inventory, Tallahassee, FL; Georgia Natural Heritage Program, Social Circle, GA; Great Smoky Mountains National Park, Gatlinburg, TN; Gulf Islands National Seashore, Gulf Breeze, FL; Hawaii Natural Heritage Program, Honolulu, Hawaii; Idaho Conservation Data Center, Boise, ID; Illinois Natural Heritage Division/Illinois Natural Heritage Database Program, Springfield, IL; Indiana Natural Heritage Data Center, Indianapolis, IN; Iowa Natural Areas Inventory, Des Moines, IA; Kansas Natural Heritage Inventory, Lawrence, KS; Kentucky Natural Heritage Program, Frankfort, KY; Louisiana Natural Heritage Program, Baton Rouge, LA; Maine Natural Areas Program, Augusta, ME; Mammoth Cave National Park, Mammoth Cave, KY; Maryland Wildlife & Heritage Division, Annapolis, MD; Massachusetts Natural Heritage & Endangered Species Program, Westborough, MA; Michigan Natural Features Inventory, Lansing, MI; Minnesota Natural Heritage & Nongame Research and Minnesota County Biological Survey, St. Paul, MN; Mississippi Natural Heritage Program, Jackson, MI; Missouri Natural Heritage Database, Jefferson City, MO; Montana Natural Heritage Program, Helena, MT; National Forest in North Carolina, Asheville, NC; National Forests in Florida, Tallahassee, FL; National Park Service, Southeastern Regional Office, Atlanta, GA; Navajo Natural Heritage Program, Window Rock, AZ; Nebraska Natural Heritage Program, Lincoln, NE; Nevada Natural Heritage Program, Carson City, NV; New Hampshire Natural Heritage Inventory, Concord, NH; New Jersey Natural Heritage Program, Trenton, NJ; New Mexico Natural Heritage Program, Albuquerque , NM; New York Natural Heritage Program, Latham, NY; North Carolina Natural Heritage Program, Raleigh, NC; North Dakota Natural Heritage Inventory, Bismarck, ND; Ohio Natural Heritage Database, Columbus, OH; Oklahoma Natural Heritage Inventory, Norman, OK; Oregon Natural Heritage Program, Portland, OR; Pennsylvania Natural Diversity Inventory, PA; Rhode Island Natural Heritage Program, Providence, RI; South Carolina Heritage Trust, Columbia, SC; South Dakota Natural Heritage Data Base, Pierre, SD; Tennessee Division of Natural Heritage, Nashville, TN; Tennessee Valley Authority Heritage Program, Norris, TN; Texas Conservation Data Center, San Antonio, TX; Utah Natural Heritage Program, Salt Lake City, UT; Vermont Nongame & Natural Heritage Program, Waterbury, VT; Virginia Division of Natural Heritage, Richmond, VA; Washington Natural Heritage Program, Olympia, WA; West Virginia Natural Heritage Program, Elkins, WV; Wisconsin Natural Heritage Program, Madison, WI; Wyoming Natural Diversity Database, Laramie, WY

Canada
Alberta Natural Heritage Information Centre, Edmonton, AB, Canada; Atlantic Canada Conservation Data Centre, Sackville, New Brunswick, Canada; British Columbia Conservation Data Centre, Victoria, BC, Canada; Manitoba Conservation Data Centre. Winnipeg, MB, Canada; Ontario Natural Heritage Information Centre, Peterborough, ON, Canada; Quebec Conservation Data Centre, Quebec, QC, Canada; Saskatchewan Conservation Data Centre, Regina, SK, Canada; Yukon Conservation Data Centre, Yukon, Canada

Latin American and Caribbean
Centro de Datos para la Conservacion de Bolivia, La Paz , Bolivia; Centro de Datos para la Conservacion de Colombia, Cali,Valle, Columbia; Centro de Datos para la Conservacion de Ecuador, Quito, Ecuador; Centro de Datos para la Conservacion de Guatemala, Ciudad de Guatemala , Guatemala; Centro de Datos para la Conservacion de Panama, Querry Heights , Panama; Centro de Datos para la Conservacion de Paraguay, San Lorenzo , Paraguay; Centro de Datos para la Conservacion de Peru, Lima, Peru; Centro de Datos para la Conservacion de Sonora, Hermosillo, Sonora , Mexico; Netherlands Antilles Natural Heritage Program, Curacao , Netherlands Antilles; Puerto Rico-Departmento De Recursos Naturales Y Ambientales, Puerto Rico; Virgin Islands Conservation Data Center, St. Thomas, Virgin Islands.

NatureServe also has partnered with many International and United States Federal and State organizations, which have also contributed significantly to the development of the International Classification. Partners include the following The Nature Conservancy; Provincial Forest Ecosystem Classification Groups in Canada; Canadian Forest Service; Parks Canada; United States Forest Service; National GAP Analysis Program; United States National Park Service; United States Fish and Wildlife Service; United States Geological Survey; United States Department of Defense; Ecological Society of America; Environmental Protection Agency; Natural Resource Conservation Services; United States Department of Energy; and the Tennessee Valley Authority. Many individual state organizations and people from academic institutions have also contributed to the development of this classification.

TABLE OF CONTENTS

1. Forest & Woodland

1.B.1. Tropical (Semi-) Deciduous Forest
1.B.1.Oc. Polynesian Dry Forest
M210. Hawaiian Dry Forest
G405. Hawaiian Lowland Dry Forest & Woodland Group

Milo / Sparse Understory Woodland
***Thespesia populnea* / Sparse Understory Woodland**
Identifier: CEGL005412

rUSNVC CLASSIFICATION

Division Polynesian Dry Forest (1.B.1.Oc)
Macrogroup Hawaiian Dry Forest (M210)
Group Hawaiian Lowland Dry Forest & Woodland Group (G405)
Alliance *Thespesia populnea* Coastal Woodland Alliance (A.2690)
Association (Local name) Milo / Sparse Understory Woodland

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was sampled once in the park. It is found on a low-elevation site with a gentle slope over recent lava. The ground surface is mostly bedrock and litter.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: The sampled site for this association is a very open woodland with 15% tree cover, primarily milo (*Thespesia populnea*). There is a very sparse shrub stratum dominated by ‘uhaloa (*Waltheria indica*). The herbaceous stratum has 2% cover and is composed of *Crassocephalum crepidioides*.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Broad-leaved evergreen tree	milo

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: milo

CLASSIFICATION

Related Concepts:

- 11. Milo forest on sandy back of strand (Canfield 1990) F
- 21. Milo shrubs in marshy meadow (Canfield 1990) F

ELEMENT DISTRIBUTION

Range: This woodland is currently sampled from one site.
Federal Lands: NPS (Kaloko-Honokōhau, Pu‘uhonua o Hōnaunau, Pu‘ukohola Heiau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0100.
Local Description Authors: J. Drake
References: Canfield 1990, Western Ecology Working Group n.d.

M213. Polynesian Ruderal Dry Forest
G407. Hawaiian Ruderal Dry Forest Group

Kiawe Coastal Dry Semi-natural Woodland

rUSNVC CLASSIFICATION

Division Polynesian Dry Forest (1.B.1.Oc)
Macrogroup Polynesian Ruderal Dry Forest (M213)
Group Hawaiian Ruderal Dry Forest Group (G407)
Alliance *Prosopis pallida* Ruderal Woodland Alliance (A.2699)
Association (Local name) Kiawe Coastal Dry Semi-natural Woodland

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was only sampled once in the park on a coastal strand. The ground surface is mostly bedrock with small amounts of dead plant litter and rocks.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This woodland has a moderately open tree canopy and tree subcanopy, though together they provide 60-70% canopy. Kiawe (*Prosopis pallida*) dominates the tree canopy with koa haole (*Leucaena leucocephala*) of secondary importance. Koa haole comprises nearly all the tree subcanopy. The shrub stratum has 10% cover and is a mix of love-in-a-mist (*Passiflora foetida*) with some ‘uhaloa (*Waltheria indica*). The herbaceous stratum has 15% cover and is dominated by *Talinum fruticosum*.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Broad-leaved deciduous tree	kiawe
Tall shrub/sapling	Broad-leaved deciduous shrub	koa haole
Short shrub/sapling	Broad-leaved deciduous shrub	‘uhaloa
Herb (field)	Forb	*Talinum fruticosum*

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: kiawe

CLASSIFICATION

Pu‘uhonua o Hōnaunau National Historical Park Comments: In the NVC, koa haole is treated as a short to tall shrub, not a small tree, even though some stands in Hawaii have tree form individuals.

Related Concepts:

- 12. Kiawe forest on sandy back of strand (Canfield 1990) F
- 27. Kiawe inland forest on pahoehoe (Canfield 1990) F
- Kiawe Forest (Gagne and Cuddihy 1990)

ELEMENT DISTRIBUTION

Range: The community is not common and was only sampled once at this park.
Federal Lands: NPS (Kaloko-Honokōhau, Pu‘uhonua o Hōnaunau, Pu‘ukohola Heiau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0051.
Local Description Authors: J. Drake
References: Canfield 1990, Gagne and Cuddihy 1990, Wagner et al. 1999, Western Ecology Working Group n.d.

ʻOpiuma Semi-natural Woodland

***Pithecellobium dulce* Semi-natural Woodland**

Identifier: CEGL005409

rUSNVC CLASSIFICATION

Division	Polynesian Dry Forest (1.B.1.Oc)
Macrogroup	Polynesian Ruderal Dry Forest (M213)
Group	Hawaiian Ruderal Dry Forest Group (G407)
Alliance	(*Samanea saman* - *Schinus terebinthifolius* - *Pithecellobium dulce* – *Tournefortia argentea*) Ruderal Woodland Alliance (A.2695)
Association (Local name)	ʻOpiuma Semi-natural Woodland

ENVIRONMENTAL DESCRIPTION

Puʻuhonua o Hōnaunau National Historical Park Environment: This association was sampled 10 times in the park. It is found on midslopes, lowslopes, and low level areas with gentle to no slope. All sites are over recent lavaflows. Bedrock, rocks, and litter comprise the surface cover.

VEGETATION DESCRIPTION

Puʻuhonua o Hōnaunau National Historical Park Vegetation: This community is typically an open woodland dominated by the non-native species ʻopiuma (*Pithecellobium dulce*). The canopy is short (2-10 m tall) and open (20-60% cover) with few other species occurring frequently at lower elevations. At upper elevations, Christmas berry (*Schinus terebinthifolius*) is common in the subcanopy. Noni (*Morinda citrifolia*) is co-dominant in one plot. The shrub canopy is absent to sparse with an average cover of 5% (0-20%). *Passiflora suberosa* and lantana (*Lantana camara*) are the most common taxa found in the shrub strata. Some stands have significant cover of koa haole (*Leucaena leucocephala*) in the shrub layer. The herbaceous stratum is fairly diverse and averages 35% cover. Guinea grass (*Panicum maximum*) and *Talinum fruticosum* are in every plot and averages 24% and 5% cover, respectively. *Bidens pilosa*, hairy honohono (*Commelina benghalensis*), and air plant (*Kalanchoe pinnata*) are commonly encountered.

MOST ABUNDANT SPECIES

Puʻuhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Broad-leaved deciduous tree	ʻopiuma
Tall shrub/sapling	Broad-leaved deciduous shrub	koa haole
Herb (field)	Graminoid	guinea grass

CHARACTERISTIC SPECIES

Puʻuhonua o Hōnaunau National Historical Park: ʻopiuma

CLASSIFICATION

Puʻuhonua o Hōnaunau National Historical Park Comments: In the rUSNVC, koa haole is treated as a short to tall shrub, not a small tree, even though some stands in Hawaii have tree form individuals.

ELEMENT DISTRIBUTION

Range: This community was common in upland sites at this park.

Federal Lands: NPS (Puʻuhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0012, PUHO.0013, PUHO.0023, PUHO.0030, PUHO.0035, PUHO.0041, PUHO.0046, PUHO.0050.
Local Description Authors: J. Drake
References: Western Ecology Working Group n.d.

Monkeypod - Christmas Berry Semi-natural Woodland [Park Special]

***Samanea saman* - *Schinus terebinthifolius* Semi-natural Woodland [Park Special]**
Identifier: CEPS009515

rUSNVC CLASSIFICATION

Division Polynesian Dry Forest (1.B.1.Oc)
Macrogroup Polynesian Ruderal Dry Forest (M213)
Group Hawaiian Ruderal Dry Forest Group (G407)
Alliance na
Association (Local name) Monkeypod - Christmas Berry Semi-natural Woodland [Park Special]

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This community was sampled twice in the park. It is found on gentle, west-facing slopes near 200 m elevation. The sites are over recent pahoehoe lava. Both sites are disturbed and the ground cover is mostly litter and rocks.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This woodland has an open to moderately open canopy (30-50%) dominated by non-native species. Christmas berry (*Schinus terebinthifolius*) and monkeypod (*Samanea saman*) comprise nearly the entire tree canopy. The shrub stratum has 10% cover with lantana (*Lantana camara*) as the dominant. The herbaceous stratum is also sparse (4% average cover) and is mostly guinea grass (*Panicum maximum*).

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Broad-leaved deciduous tree	monkeypod
Tree canopy	Broad-leaved evergreen tree	Christmas berry
Herb (field)	Graminoid	guinea grass

CLASSIFICATION

Status: Nonstandard

ELEMENT DISTRIBUTION

Range: This woodland is uncommon in the park and sampled only twice on upland sites.
Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0036, PUHO.0037.
Local Description Authors: J. Drake
References: Western Ecology Working Group n.d.

2. Shrubland & Grassland

2.A.1. Tropical Lowland Shrubland, Grassland & Savanna
2.A.1.Ol. Polynesian Lowland Shrubland, Grassland & Savanna
M217. Hawaiian Lowland Shrubland, Grassland & Savanna
G410. Hawaiian Lowland Dry Shrubland & Grassland Group

ʻUhaloa - ʻIlima Shrubland
***Waltheria indica* - *Sida fallax* Shrubland**
Identifier: CEGL005414

rUSNVC CLASSIFICATION

Division Polynesian Lowland Shrubland, Grassland & Savanna (2.A.1.Ol)
Macrogroup Hawaiian Lowland Shrubland, Grassland & Savanna (M217)
Group Hawaiian Lowland Dry Shrubland & Grassland Group (G410)
Alliance *Waltheria indica* Shrubland Alliance (A.2698)
Association (Local name) ʻUhaloa - ʻIlima Shrubland

ENVIRONMENTAL DESCRIPTION

Puʻuhonua o Hōnaunau National Historical Park Environment: This association was sampled once in the park. It is found on a site with moderate slope near sea level that is influenced by salt spray. The substrate is mostly recent lava.

VEGETATION DESCRIPTION

Puʻuhonua o Hōnaunau National Historical Park Vegetation: This is a relatively sparsely vegetated community. There is a sparse short-shrub stratum composed of ʻuhaloa (*Waltheria indica*) and koa haole (*Leucaena leucocephala*) over a sparse dwarf-shrub stratum. The dwarf-shrub stratum is dominated by alena (*Boerhavia repens*) and ʻilima (*Sida fallax*). Total herbaceous cover is 4% and is composed of sword fern (*Nephrolepis multiflora*), prostrate spurge (*Chamaesyce prostrate*), wild spider flower (*Cleome gynandra*), balsam pear (*Momordica charantia*), ʻilieʻe (*Plumbago zeylanica*), *Talinum fruticosum*, mauʻu (*Fimbristylis cymosa*), and natal redtop (*Melinis repens*).

MOST ABUNDANT SPECIES

Puʻuhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Short shrub/sapling	Broad-leaved deciduous shrub	koa haole, ʻuhaloa
Herb (field)	Dwarf-shrub	alena, ʻilima

CHARACTERISTIC SPECIES

Puʻuhonua o Hōnaunau National Historical Park: ʻuhaloa

CLASSIFICATION

Puʻuhonua o Hōnaunau National Historical Park Comments: Koa haole is considered a shrub for vegetation classification purposes in the rUSNVC; however, some individuals develop a small tree growth form.

ELEMENT DISTRIBUTION

Range: This community is currently sampled from one coastal site in this park
Federal Lands: NPS (Kaloko-Honokōhau, Pu**ʻ**uhonua o Hōnaunau)

ELEMENT SOURCES

Puʻuhonua o Hōnaunau National Historical Park Plots: PAHO.0005.

Local Description Authors: J. Drake
References: Western Ecology Working Group n.d.

M220. Polynesian Ruderal Lowland Shrubland, Grassland & Savanna

G413. Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group

Koa Haole / Guinea Grass Semi-natural Shrubland

***Leucaena leucocephala / Panicum maximum* Semi-natural Shrubland**[1]
Identifier: CEGL005404

rUSNVC CLASSIFICATION

Division	Polynesian Lowland Shrubland, Grassland & Savanna (2.A.1.Ol)
Macrogroup	Polynesian Ruderal Lowland Shrubland, Grassland & Savanna (M220)
Group	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)
Alliance	*Leucaena leucocephala* Lowland Ruderal Shrubland Alliance (A.2700)
Association (Local name)	Koa Haole / Guinea grass Semi-natural Shrubland

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was sampled 12 times at the park. It is found across the park from 6 to 58 m (20-190 feet) in elevation on gentle slopes. The ground is mostly covered by live vegetation. The remaining surface is mostly dead litter and rocks.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: The shrub canopy cover is moderately open (35% average) and short (2-5 m). Koa haole (*Leucaena leucocephala*) is the dominant species. No other species is abundant, though ‘opiuma (*Pithecellobium dulce*) may be present in low amounts. There is essentially no shorter shrub stratum. The herbaceous stratum averages 75% cover and is strongly dominated by guinea grass (*Panicum maximum*). *Talinum fruticosum* is found in most plots but not dominant. Air plant (*Kalanchoe pinnata*) and seedlings of koa haole are often present in low amounts. Nearly all sites show evidence of disturbance and species diversity is fairly low.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tall shrub/sapling	Broad-leaved deciduous shrub	koa haole
Herb (field)	Graminoid	guinea grass

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: koa haole

CLASSIFICATION

Pu‘uhonua o Hōnaunau National Historical Park Comments: Koa haole is considered a shrub for vegetation classification purposes in the rUSNVC; however, some individuals develop a small tree growth form.

Related Concepts:

- Koa Haole Shrubland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This community is widespread in upland sites at this park.
Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0009, PUHO.0011, PUHO.0017, PUHO.0031, PUHO.0033, PUHO.0038, PUHO.0039, PUHO.0042, PUHO.0044, PUHO.0045, PUHO.0049, PUHO.0190.
Local Description Authors: J. Drake
References: Gagne and Cuddihy 1990, Western Ecology Working Group n.d.

Koa Haole Lowland Dry Semi-natural Shrubland

***Leucaena leucocephala* Lowland Dry Semi-natural Shrubland**
Identifier: CEGL008114

rUSNVC CLASSIFICATION

Division	Polynesian Lowland Shrubland, Grassland & Savanna (2.A.1.Ol)
Macrogroup	Polynesian Ruderal Lowland Shrubland, Grassland & Savanna (M220)
Group	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)
Alliance	*Leucaena leucocephala* Lowland Ruderal Shrubland Alliance (A.2700)
Association (Local name)	Koa Haole Lowland Dry Semi-natural Shrubland

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was sampled 11 times in the park. It is found on gentle low and midslopes, usually near sea level (<12 m [40 feet]) but occasionally up to 50 m (160 feet). Most of the unvegetated ground surface is covered by bedrock or litter.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This is a moderately closed-canopy (50%) tall shrubland (2-5 m tall). The tallest shrub stratum is nearly monotypic koa haole (*Leucaena leucocephala*). *Passiflora suberosa* is frequently found and is abundant in one plot, though more often in the shorter shrub strata than the canopy. ‘Opiuma (*Pithecellobium dulce*) is in most plots but always at low levels. One plot has a dense low-shrub stratum composed of mallow plant (*Sida cordifolia*). Otherwise, there is often a sparse low-shrub stratum though no single taxon is dominant. Other shrubs include ‘ilima (*Sida fallax*), ‘uhaloa (*Waltheria indica*), and *Indigofera suffruticosa*. The herbaceous stratum averages 20% cover. It is dominated by *Talinum fruticosum* with some guinea grass (*Panicum maximum*) and scattered seedlings of canopy trees, air plant (*Kalanchoe pinnata*), love-in-a-mist (*Passiflora foetida*), Madagascar periwinkle (*Catharanthus roseus*), and hairy honohono (*Commelina benghalensis*).

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tall shrub/sapling	Broad-leaved deciduous shrub	koa haole
Herb (field)	Forb	*Talinum fruticosum*

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: koa haole

CLASSIFICATION

Pu‘uhonua o Hōnaunau National Historical Park Comments: Koa haole is considered a shrub for vegetation classification purposes in the rUSNVC; however, some individuals develop a small tree growth form.
Related Concepts:

- Koa Haole Shrubland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This association is widespread in this park in the uplands.
Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0001, PUHO.0003, PUHO.0004, PUHO.0006, PUHO.0007, PUHO.0014, PUHO.0016, PUHO.0032, PUHO.0040, PUHO.0170, PUHO.0180.
Local Description Authors: J. Drake
References: Gagne and Cuddihy 1990, Wagner et al. 1999, Western Ecology Working Group n.d.

Koa Haole - ʻOpiuma Semi-natural Shrubland [Park Special]

***Leucaena leucocephala* - *Pithecellobium dulce* Semi-natural Shrubland [Park Special]**
Identifier: CEPS009518

USNVC CLASSIFICATION

Division	Polynesian Lowland Shrubland, Grassland & Savanna (2.A.1.Ol)
Macrogroup	Polynesian Ruderal Lowland Shrubland, Grassland & Savanna (M220)
Group	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)
Alliance	*Leucaena leucocephala* Lowland Ruderal Shrubland Alliance (A.2700)
Association (Local name)	Koa Haole - ‘Opiuma Semi-natural Shrubland [Park Special]

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was sampled two times at the park. It is found across the park from 12 m (40 feet) in elevation on gentle slopes growing on pahoehoe. The ground is mostly covered by live vegetation. The remaining surface is mostly dead litter and rocks.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: The shrub canopy cover is moderately open (20-40%) and short (2-5 m). Koa haole (*Leucaena leucocephala*) is the dominant species with ‘opiuma (*Pithecellobium dulce*) co-dominant to present as scattered emergent trees or a co-dominant tall shrub with <10-20% total cover. The herbaceous stratum ranges from 30-80% and is dominated either by *Talinum fruticosum* or guinea grass (*Panicum maximum*) with the other present. The only other forbs present are ivy gourd (*Coccinia grandis*) and *Passiflora suberosa*.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Broad-leaved deciduous tree	‘opiuma
Tall shrub/sapling	Broad-leaved deciduous shrub	koa haole, ‘opiuma
Herb (field)	Forb	*Talinum fruticosum*
Herb (field)	Graminoid	guinea grass

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: koa haole, ‘opiuma

CLASSIFICATION

Pu‘uhonua o Hōnaunau National Historical Park Comments: In the rUSNVC, koa haole is treated as a short to tall shrub, not a small tree even though some stands in Hawaii have tree form individuals.

Related Concepts:

- Koa Haole Shrubland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This community is uncommon at the park and was sampled only a couple of times in upland sites.

Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0018, PUHO.0048.

Local Description Authors: K.A. Schulz

References: Gagne and Cuddihy 1990, Western Ecology Working Group n.d.

Natal Redtop Semi-natural Herbaceous Vegetation

***Melinis repens* Semi-natural Herbaceous Vegetation**

Identifier: CEGL005405

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rUSNVC CLASSIFICATION

Division	Polynesian Lowland Shrubland, Grassland & Savanna (2.A.1.Ol)
Macrogroup	Polynesian Ruderal Lowland Shrubland, Grassland & Savanna (M220)
Group	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)
Alliance	*(Cenchrus ciliaris - Pennisetum setaceum)* - Mixed Medium-Tall Ruderal Grassland Alliance[1] (A.2693)
Association (Local name)	Natal Redtop Semi-natural Herbaceous Vegetation

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was sampled twice in the park. It is found near sea level on gentle slopes. The substrate is mostly bedrock or rocks. One site is noted as a "rockpile."

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This ruderal herbaceous community has often has widely scattered shrubs or trees present over grasses. The herbaceous stratum averages 30% cover and is strongly dominated by natal redtop (*Melinis repens*). Koa haole (*Leucaena leucocephala*), love-in-a-mist (*Passiflora foetida*), and *Talinum fruticosum* are also found in this community. The sparse tree canopy contains noni (*Morinda citrifolia*) and coconut palm (*Cocos nucifera*). There is also a sparse shrub canopy composed of ‘uhaloa (*Waltheria indica*).

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Herb (field)	Graminoid	natal redtop

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: natal redtop

CLASSIFICATION

Pu‘uhonua o Hōnaunau National Historical Park Comments: Koa haole is considered a shrub for vegetation classification purposes in the rUSNVC; however, some individuals develop a small tree growth form.

Related Concepts:

- Natal Redtop Grassland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This invasive community was sampled from two sites at this park.
Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0024, PUHO.0025.
Local Description Authors: J. Drake
References: Gagne and Cuddihy 1990, Western Ecology Working Group n.d.

Mallow Plant Semi-natural Herbaceous Vegetation [Park Special]

***Sida cordifolia* Semi-natural Herbaceous Vegetation [Park Special]**
Identifier: CEPS009516

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rUSNVC CLASSIFICATION

Division	Polynesian Lowland Shrubland, Grassland & Savanna (2.A.1.Ol)
Macrogroup	Polynesian Ruderal Lowland Shrubland, Grassland & Savanna (M220)
Group	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)
Alliance	na
Association (Local name)	Mallow Plant Semi-natural Herbaceous Vegetation [Park Special]

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This community was sampled once in the park. It is found near sea level, adjacent to a beach on a gentle, southwest-facing slope. The substrate is a mix of bedrock (recent lava), rocks, and litter.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This community is dominated by invasive herbaceous species. Total cover of the herbaceous stratum is 70% and the dominant species is mallow plant (*Sida cordifolia*). Love-in-a-mist (*Passiflora foetida*) and *Talinum fruticosum* are of secondary importance. There is sparse cover of the vine *Passiflora suberosa*.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Herb (field)	Semi-shrub	mallow plant
Herb (field)	Forb	love-in-a-mist

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: mallow plant

ELEMENT DISTRIBUTION

Range: This non-native community is uncommon at this park and sampled only once near the shoreline.
Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0124.
Local Description Authors: J. Drake
References: Western Ecology Working Group n.d.

Guinea Grass Lowland Dry Semi-natural Herbaceous Vegetation

***Panicum maximum* Lowland Dry Semi-natural Herbaceous Vegetation**[1]
Identifier: CEGL008109

rUSNVC CLASSIFICATION

Division	Polynesian Lowland Shrubland, Grassland & Savanna (2.A.1.Ol)
Macrogroup	Polynesian Ruderal Lowland Shrubland, Grassland & Savanna (M220)
Group	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)
Alliance	*Panicum maximum* Ruderal Herbaceous Alliance[1] (A.2701)
Association (Local name)	Guinea Grass Lowland Dry Semi-natural Herbaceous Vegetation

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was sampled five times in the park. It is found on gentle, southwest-facing low and midslopes ranging from near the ocean to 60 m (200 feet) elevation. The unvegetated surface is mostly bedrock and rocks.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This association is dominated by herbaceous species with scattered trees. The herbaceous stratum averages 55% cover, nearly all of which is guinea grass (*Panicum maximum*). There are small amounts of koa haole (*Leucaena leucocephala*) seedlings, *Kyllinga brevifolia*, and *Talinum fruticosum*. The tree stratum averages approximately 10% cover and is dominated by ‘opiuma (*Pithecellobium dulce*) and koa haole.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Herb (field)	Graminoid	guinea grass

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: guinea grass

CLASSIFICATION

Pu‘uhonua o Hōnaunau National Historical Park Comments: Koa haole is considered a shrub for vegetation classification purposes in the rUSNVC; however, some individuals develop a small tree growth form.

ELEMENT DISTRIBUTION

Range: This community is widespread throughout the uplands of this park.
Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0010, PUHO.0034, PUHO.0043, PUHO.0047, PUHO.0200.
Local Description Authors: J. Drake
References: Wagner et al. 1999, Western Ecology Working Group n.d.

2.A.3. Tropical Scrub & Herb Coastal Vegetation
2.A.3.Ob. Polynesian Scrub & Herb Coastal Vegetation
M231. Hawaiian Scrub & Herb Coastal Vegetation
G421. Hawaiian Dry Scrub & Herb Coastal Strand Group

Coconut Palm Strand Woodland

***Cocos nucifera* Strand Woodland**
Identifier: CEGL005402

USNVC CLASSIFICATION

Division	Polynesian Scrub & Herb Coastal Vegetation (2.A.3.Ob)
Macrogroup	Hawaiian Scrub & Herb Coastal Vegetation (M231)
Group	Hawaiian Dry Scrub & Herb Coastal Strand Group (G421)
Alliance	*Cocos nucifera* Coastal Woodland Alliance (A.2691)
Association (Local name)	Coconut Palm Strand Woodland

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This community was sampled six times within the park. It is found on gently sloping to flat sites on recent lava or beach. The ground is mostly sand (on beach sites) or bedrock/rock (on sites with recent lavaflows).

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This woodland community has an open canopy (20-40%) 10-20 m tall. Coconut palm (*Cocos nucifera*) is the dominant species in the tree canopy and subcanopy and usually makes up >75% of those strata. Milo (*Thespesia populnea*), hala (*Pandanus tectorius*), and noni (*Morinda citrifolia*) are present in small amounts. The shrub strata are absent to moderate (0-30%) with an average cover of 15%. noni is the only common shrub, though naupaka kahakai (*Scaevola taccada*) and *Passiflora suberosa* are found in several stands. The herbaceous stratum is sparse with an average cover of 5%. No species are consistently present and only one, natal redtop (*Melinis repens*), has more than 3% cover in any plot. Love-in-a-mist (*Passiflora foetida*), ‘ākulikuli (*Sesuvium portulacastrum*), and mau‘u (*Fimbristylis cymosa*) are the other most commonly found herbaceous species.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Palm tree	coconut palm

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: coconut palm

CLASSIFICATION

Related Concepts:

- 14. Coconut grove on recently inhabited sandy ground (Canfield 1990) =

ELEMENT DISTRIBUTION

Range: This usually open coastal scrub woodland is occurs in scattered locations along the coast.

Federal Lands: NPS (Kaloko-Honokōhau, Pu‘uhonua o Hōnaunau, Pu‘ukohola Heiau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0008, PUHO.0015, PUHO.0021, PUHO.0022, PUHO.0026, PUHO.2200.
Local Description Authors: J. Drake
References: Canfield 1990, NatureServe n.d.

Naupaka Kahakai Coastal Dry Shrubland

***Scaevola taccada* Coastal Dry Shrubland**[1]
Identifier: CEGL008054

rUSNVC CLASSIFICATION

Division Polynesian Scrub & Herb Coastal Vegetation (2.A.3.Ob)
Macrogroup Hawaiian Scrub & Herb Coastal Vegetation (M231)
Group Hawaiian Dry Scrub & Herb Coastal Strand Group (G421)
Alliance *Scaevola taccada* Shrubland Alliance[1] (A.716)
Association (Local name) Naupaka Kahakai Coastal Dry Shrubland
Ecological System(s): Hawai‘i Dry Coastal Strand (CES412.418)

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was only sampled once in the park. The site is very near the ocean and affected by sea spray. The substrate is lava with some coral/beach sand.

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This shrubland has relatively little vegetation cover. It is dominated by scattered naupaka kahakai (*Scaevola taccada*) (20% cover) 1-2 m tall. There are widely scattered short trees with approximately 2% cover and widely scattered herbaceous species with approximately 4% cover. The herbaceous stratum includes prostrate spurge (*Chamaesyce prostrate*), love-in-a-mist (*Passiflora foetida*), *Portulaca pilosa*, *Cynodon dactylon*, and mau‘u (*Fimbristylis cymosa*). No single species has more than trace cover besides naupaka kahakai.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Short shrub/sapling	Broad-leaved evergreen shrub	naupaka kahakai

CHARACTERISTIC SPECIES

Pu‘uhonua o Hōnaunau National Historical Park: naupaka kahakai

CLASSIFICATION

Related Concepts:

- 6. Naupaka scrub on sandy strand (Canfield 1990) F
- 7. Shrubby naupaka on sandy back of strand (Canfield 1990) F
- Naupaka kahakai Shrubland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This community occurs on coastal sites.
Federal Lands: NPS (Kaloko-Honokōhau, Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.0002.
Local Description Authors: J. Drake
References: Canfield 1990, Gagne and Cuddihy 1990, Western Ecology Working Group n.d.

Mau‘u Coastal Dry Herbaceous Vegetation

***Fimbristylis* spp. Coastal Dry Herbaceous Vegetation**
Identifier: CEGL008089

rUSNVC CLASSIFICATION

Division Polynesian Scrub & Herb Coastal Vegetation (2.A.3.Ob)
Macrogroup Hawaiian Scrub & Herb Coastal Vegetation (M231)
Group Hawaiian Dry Scrub & Herb Coastal Strand Group (G421)
Alliance *Fimbristylis* spp. Coastal Herbaceous Alliance (A.1143)
Association (Local name) Mau‘u Coastal Dry Herbaceous Vegetation
Ecological System(s): Hawai‘i Lowland Dry Grassland (CES412.410)

ENVIRONMENTAL DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Environment: This association was sampled once in the park. The site is found on a low slope about 20 m from the ocean. Nearly all the ground surface is bedrock (recent lava).

VEGETATION DESCRIPTION

Pu‘uhonua o Hōnaunau National Historical Park Vegetation: This association has sparse cover with only one species noted in the sampled stand; mau‘u (*Fimbristylis cymosa*) has 4% cover. It occurs with higher cover on more stable substrates.

MOST ABUNDANT SPECIES

Pu‘uhonua o Hōnaunau National Historical Park

Stratum	Lifeform	Species
Herb (field)	Graminoid	mau‘u

ELEMENT DISTRIBUTION

Range: This community is currently sampled from only one site along shore in this park.
Federal Lands: NPS (Pu‘uhonua o Hōnaunau)

ELEMENT SOURCES

Pu‘uhonua o Hōnaunau National Historical Park Plots: PUHO.1200.
Local Description Authors: J. Drake
References: Western Ecology Working Group n.d.

[1]rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999).

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Appendix F: Mapping Conventions and Visual Key

Pu‘uhonua o Hōnaunau National Historical Park- Map Units

This appendix describes the map units for the Pu‘uhonua o Hōnaunau National Historical Park (PUHO) Vegetation Inventory Project. Its purpose is to:

- Describe the vegetation of each map unit;
- Provide a representative ground photograph/image for each map unit;
- Describe the link between each map unit and the revised U.S. National Vegetation Classification (rUSNVC);
- Provide visual examples of each map unit with digital overhead images and delineated overlays.

The map units for PUHO were based on a combination of rUSNVC plant associations, local requests (i.e. Park Specials), the limitations of the digital imagery, and land use / land cover classes. The vegetation described in this section reflects the classification designed specifically for this project. Non-vegetated and land-use map units are not described in this key. For more information on the development of the mapping scheme for PUHO please reference the mapping sections of this report and the digital information (i.e. lookup tables, metadata) included on the project DVD.

This key follows the physiognomic grouping of each map unit starting with woodland types. Each map unit is fully described by a variety of characteristics and features. First the rUSNVC crosswalk (if applicable) to associations and the common plant species for each association are presented. Next is a description of the mapping concept and a representative ground photograph. A map of the distribution for each mapping unit across the study area follows along with an example of the 2006 Quickbird digital basemap ortho-imagery (color infrared bands). The imagery snapshot examples also include representative polygon outlines that highlight the map unit signatures. Many of the map unit descriptions rely heavily on the vegetation plot data collected in 2008. The sample ground photographs were taken during the 2008 plot data collection or during the 2009/10 accuracy assessment by National Park Service staff.

Woodlands

Map Code **Kukui Woodland Stand**
W_ALMO ***Aleurites moluccana* Woodland Stand**

Common Species
kukui (*Aleurites moluccana)*
koa haole (*Leucaena leucocephala*)
‘opiuma (*Pithecellobium dulce*)
milo (*Thespesia populnea)*
kiawe (*Prosopis pallida*)
guinea grass (*Panicum maximum*)

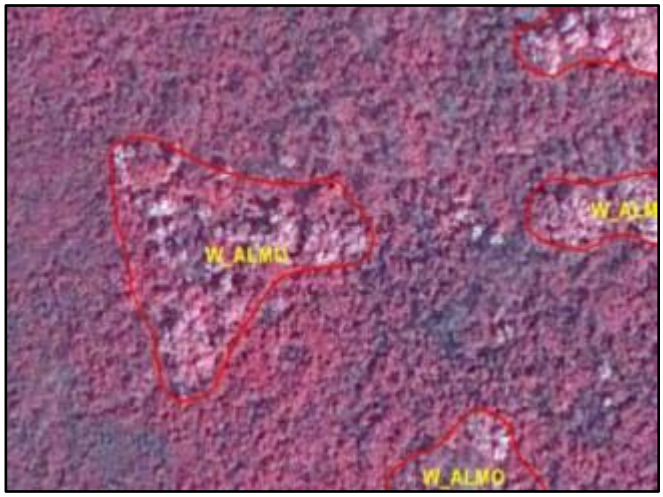
rUSNVC Association
- No Association – Unclassified Map Unit

Description
Stands of kukui trees were somewhat common in the newly acquired lands at PUHO. Stands were found along the eastern boundary and extended into the environs buffer. In these areas the kukui trees were usually surrounded by extensive stands of koa haole, ‘opiuma, and guinea grass. On the Quickbird imagery kukui trees had a characteristic dense pink, mottled canopy that was readily observable. This type likely occurred with other Polynesian and non-native trees.

Representative Ground Photo

Range and Distribution

Photo Signature Example



Map Code **Coconut Palm Strand Woodland**
W_CONU ***Cocos nucifera* Strand Woodland**

Common Species

coconut palm (*Cocos nucifera*)
milo (*Thespesia populnea*)
naupaka kahakai (*Scaevola taccada*)
kiawe (*Prosopis pallida*)
milo (*Thespesia populnea)*
noni *(Morinda citrifolia)*

rUSNVC Association

- *Cocos nucifera* Strand Woodland

Representative Ground Photo

Description

Stands of coconut palms were common at PUHO in parking area, royal grounds, and surrounding the park's facility buildings. In these areas the coconuts were likely planted at one time or are decedents of one's planted by early Hawaiians. On the Quickbird imagery the coconut trees had a characteristic, pink fan appearance due to their sparse canopy and the spreading of their fronds. This type likely occurred with trees from the other woodland map units and some single coconut trees were probably mapped with these other map classes.

Range and Distribution

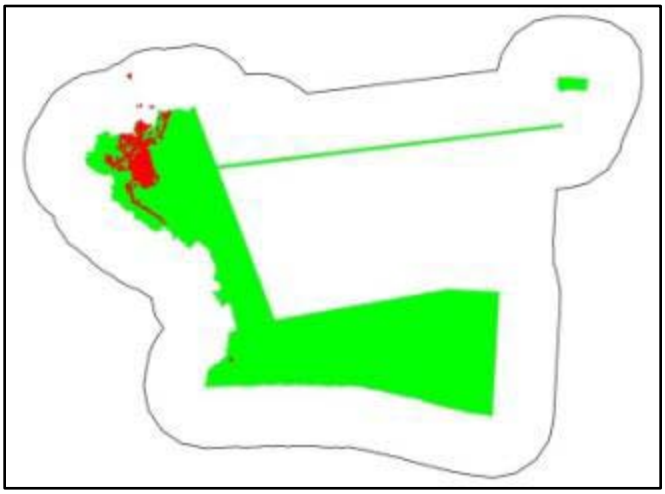
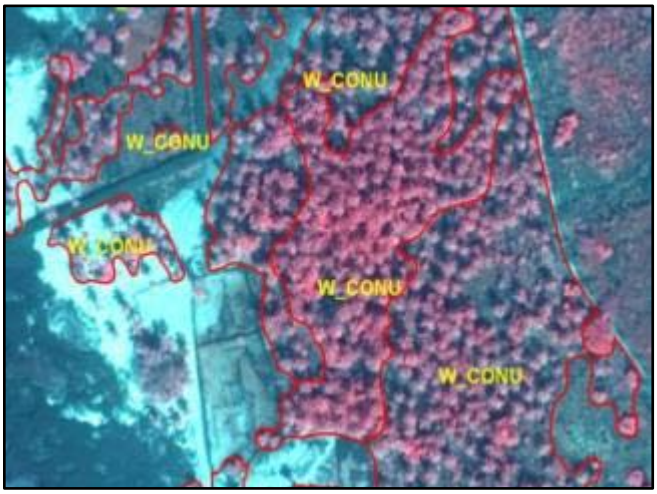


Photo Signature Example



Map Code W_ORNA Mixed Semi-natural / Ornamental Tree Woodland

Representative Ground Photo

Common Species

papaya *(Carica papaya)*
monkeypod (*Samanea saman*)
‘opiuma (*Pithecellobium dulce*)
milo (*Thespesia populnea)*
kukui (*Aleurites moluccana)*
coconut palm (*Cocos nucifera*)

rUSNVC Association

- No Association – Unclassified Map Unit

Description

The mixed semi-natural and ornamental tree woodland map class was used to map managed areas that were likely planted with a mixture of native and ornamental trees. This catch-all category was only used in the eastern portion of PUHO next to, and intermixed with heavily developed agricultural areas where no plot data was collected. The trees in this map class exhibited a range of signatures related to closed canopy or single large, spreading trees. Most of the canopies were bright red with a mottled appearance when viewed with the color infrared bands of the Quickbird imagery. More plot and verification data in these areas may warrant creating new woodland associations or merging this type with other existing woodland classes.

Range and Distribution

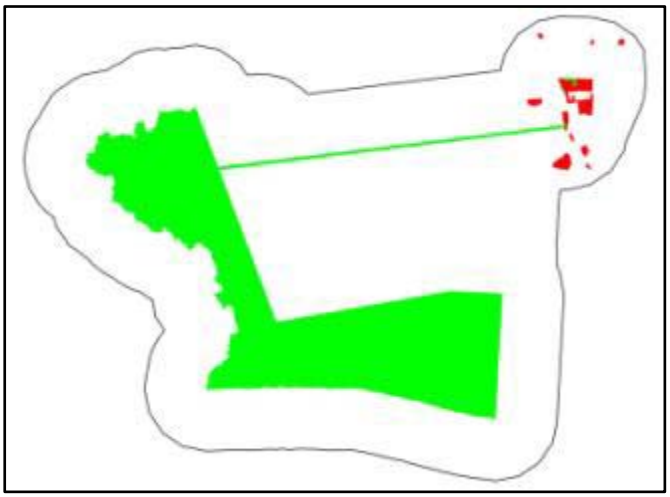
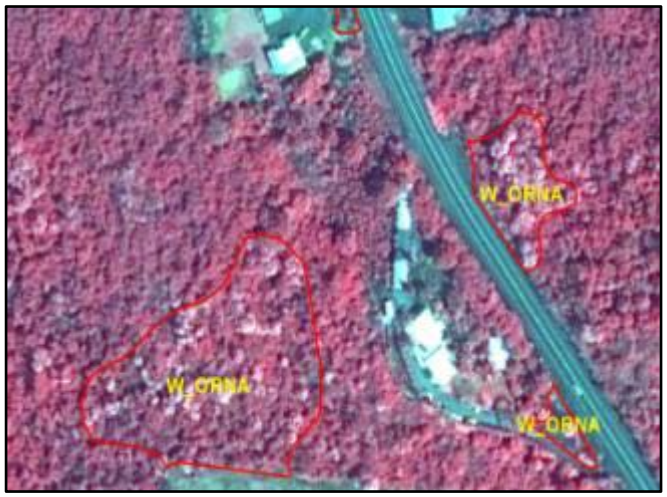


Photo Signature Example



Map Code **‘Opiuma Semi-natural Woodland**
W_PIDU ***Pithecellobium dulce* Semi-natural Woodland**

Representative Ground Photo

Common Species
‘opiuma (*Pithecellobium dulce*)
koa haole (*Leucaena leucocephala*)
kiawe (*Prosopis pallida*)
guinea grass (*Panicum maximum*)

rUSNVC Association
- *Pithecellobium dulce* Semi-natural Woodland

Description
This widespread class was very common in PUHO and surrounding areas. ‘Opiuma trees where the diagnostic species exhibiting a dark red, smooth signature on the color infrared imagery. Stands of this type ranged in both density and height with some of the stands along the coast forming closed canopy forests. Elsewhere, the ‘opiuma was less dense and grew more as sparse shrubs with guinea grass and koa haole in the understory. ‘Opiuma trees are also likely present in the other woodland map classes as associated species.

Range and Distribution

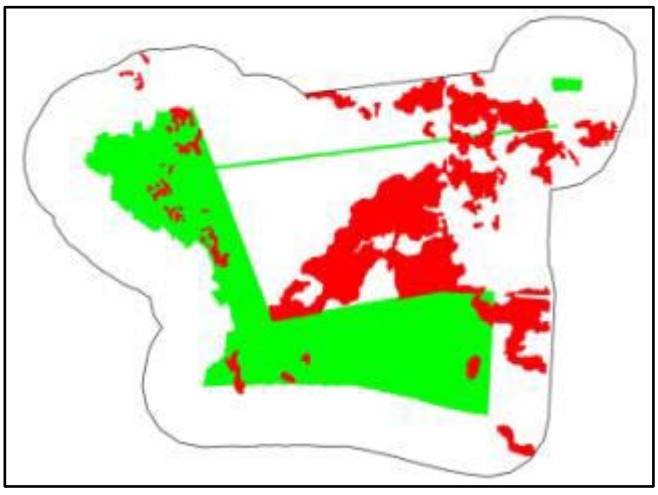
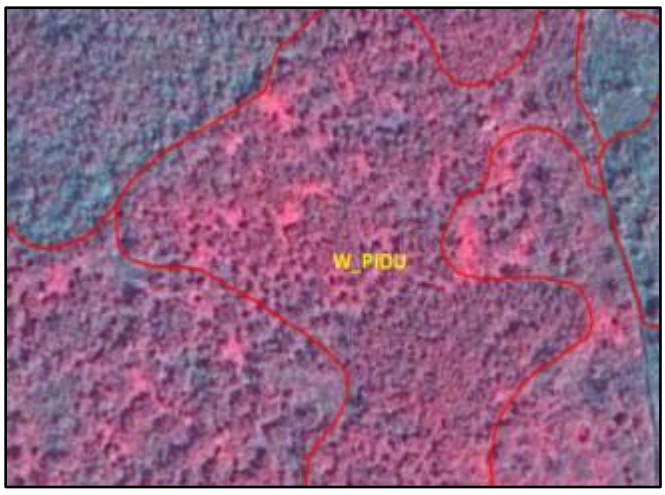


Photo Signature Example



Map Code **Kiawe Coastal Dry Semi-natural Woodland**
W_PRPA ***Prosopis pallida* Coastal Dry Semi-natural Woodland**

Representative Ground Photo

Common Species

kiawe (*Prosopis pallida*)
koa haole (*Leucaena leucocephala*)
guinea grass (*Panicum maximum*)
Christmas berry *(Schinus terebinthifolius)*
ʻopiuma (*Pithecellobium dulce*)

rUSNVC Association

- *Prosopis pallida* Coastal Dry Semi-natural Woodland

Description

The kiawe map class was common in PUHO along the coast and in the upper beach margins. Kiawe trees where the diagnostic species exhibiting a light red, mottled signature on the color infrared imagery. Stands of this type were typically over 5 meters tall and occurred in closed canopy, tall woodlands. Elsewhere, the kiawe was less dense and grew more as sparse shrubs with guinea grass and koa haole in the understory. Kiawe trees are also likely present in the other woodland map classes as associated species.

Range and Distribution

Photo Signature Example

Map Code **Monkeypod – Christmas Berry Semi-natural Woodland**
W_SASA ***Samanea saman - Schinus terebinthifolius* Semi-natural Woodland**

Representative Ground Photo

Common Species

monkeypod (*Samanea saman*)
Christmas berry *(Schinus terebinthifolius)*
kiawe (*Prosopis pallida*)
coconut palm (*Cocos nucifera*)
naupaka kahakai (*Scaevola taccada*)
guinea grass (*Panicum maximum*)

rUSNVC Association

- *Samanea saman - Schinus terebinthifolius*
Semi-natural Woodland [Park Special]

Description

The monkeypod – Christmas berry semi-natural woodland type was used to map managed areas that contained either escaped or planted non-native trees. This category was only used at PUHO around the royal village and off the park in residential and agricultural sites. This map class differed from the mixed semi-natural / ornamental tree woodland class in that most of the trees were verified as monkeypods. Most of the canopies were red to pink with a mottled appearance when viewed with the color infrared bands of the Quickbird imagery. More monkeypod trees may exist in the project area but were probably mapped as one of the other woodland map classes.

Range and Distribution

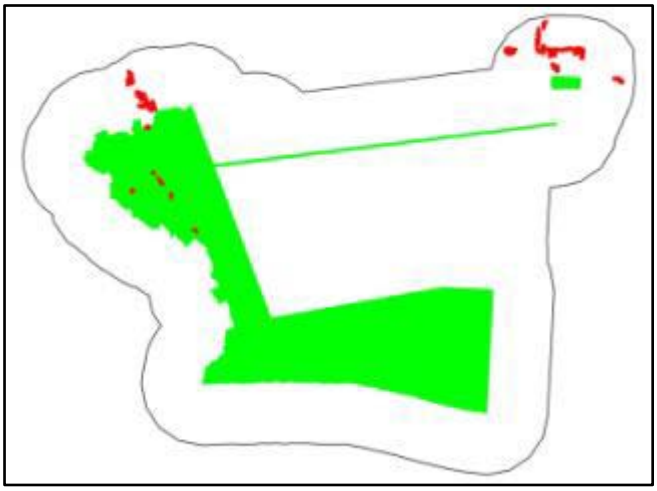


Photo Signature Example

Map Code	Christmas Berry / Fountain Grass Semi-natural Woodland
W_SCTE	*Schinus terebinthifolius / Pennisetum setaceum* Semi-natural Woodland

Common Species

Christmas berry *(Schinus terebinthifolius)*
monkeypod (*Samanea saman*)
'opiuma (*Pithecellobium dulce*)
kiawe (*Prosopis pallida*)
koa haole (*Leucaena leucocephala*)
guinea grass (*Panicum maximum*)
natal redtop (*Melinis repens*)

rUSNVC Association

- *Schinus terebinthifolius / Pennisetum setaceum* Semi-natural Woodland

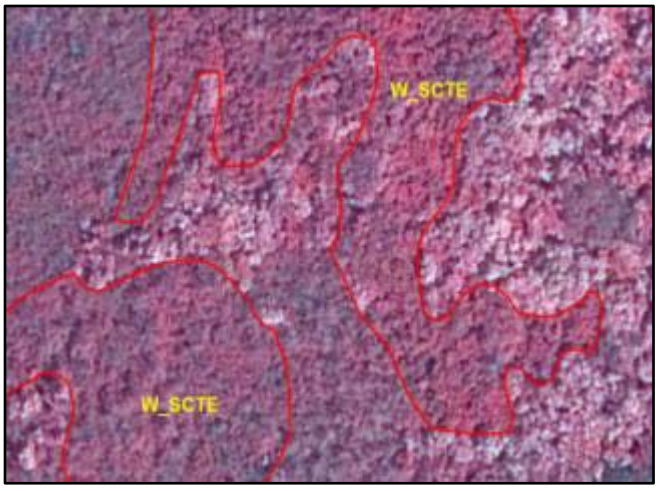
Representative Ground Photo

Description

Christmas berry / fountain grass semi-natural woodland type was used to map both tall shrub and woodland Christmas berry stands. The shrub version of this type was located primarily in the environs buffer were it formed dense stands with koa haole shrubs and 'opiuma trees. Christmas berry canopies were dark red with a mottled appearance when viewed with the color infrared bands of the Quickbird imagery. More Christmas berry trees and shrubs likely exist in the project area but were probably mapped as one of the other woodland map classes.

Range and Distribution

Photo Signature Example



Map Code **Milo / Sparse Understory Woodland**
W_THPO ***Thespesia populnea* / Sparse Understory Woodland**

Common Species
milo (*Thespesia populnea*)
kiawe (*Prosopis pallida*)
noni *(Morinda citrifolia)*
guinea grass (*Panicum maximum*)
‘opiuma (*Pithecellobium dulce*)
koa haole (*Leucaena leucocephala*)
naupaka kahakai (*Scaevola taccada*)

rUSNVC Association
- *Thespesia populnea* / Sparse Understory Woodland

Representative Ground Photo

Description
Milo trees and shrubs (short-statured trees) were found throughout the study area along the coast making-up a small portion of the coastal strand vegetation. Milo was fairly common and it tended to intermingle with ‘opiuma and koa haole map classes. Some polygons of this type likely include noni, naupaka kahakai and other common coastal strand species. Due to the mixing of species this type may have been confused with the kiawe, Christmas berry or ‘opiuma types. On the color infrared imagery trees of this type had a characteristic bright pink to light red signature and the texture of the canopy was somewhat smoother than the other woodland types.

Range and Distribution

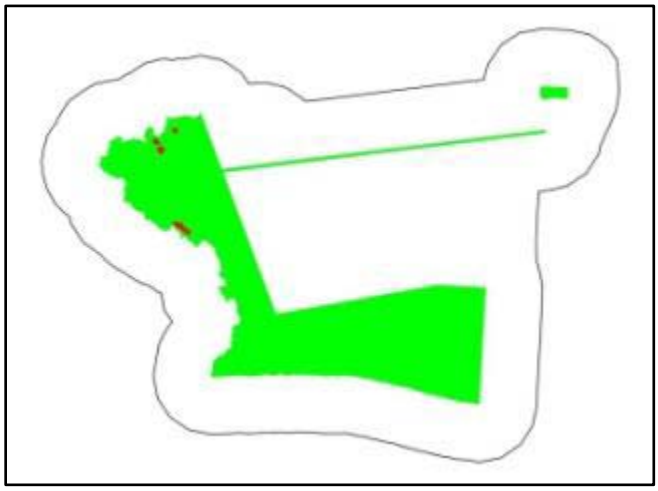


Photo Signature Example

Shrublands

Map Code ***Bougainvillea glabra*** **Semi-natural / Planted Shrubland**
S_BOGL **Bougainvillea Semi-natural / Planted Shrubland**

Common Species
bougainvillea (*Bougainvillea glabra*)
fountain grass (*Pennisetum setaceum*)
guinea grass (*Panicum maximum*)
natal redtop (*Melinis repens*)

rUSNVC Association
- *Bougainvillea glabra* Semi-natural / Planted Shrubland [Park Special]

Representative Ground Photo

(Photo from KAHO)

Description
This rare type only occurred as long bands of shrubs adjacent to the City of Refuge road and the Highway. Although this type was not sampled it was verified in the field. Bougainvillea shrubs are common roadside plantings in Hawai‘i and it is likely that polygons of this type represent managed and planted stands as well. On the color infrared imagery this type appeared as short-statured shrubs exhibiting a light pink, almost white signature. Individual bougainvillea shrubs may also occur in other areas around PUHO (especially along roadsides and in horticultural planting).

Range and Distribution

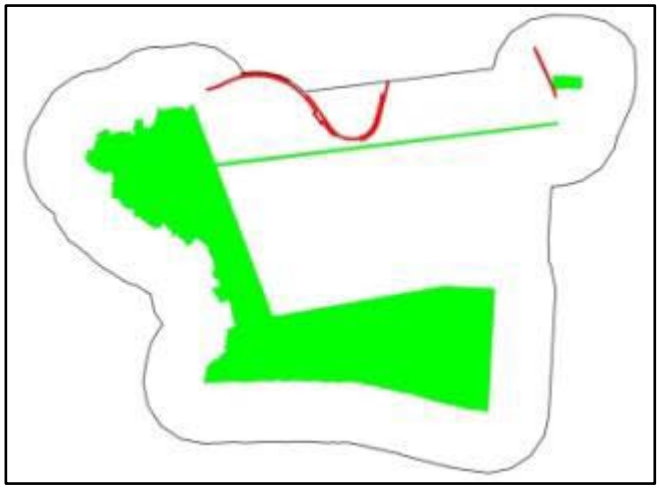


Photo Signature Example

Map Code **Koa Haole Lowland Dry Semi-natural Shrubland**
S_LELE ***Leucaena leucocephala* Lowland Dry Semi-natural Shrubland**

Common Species

koa haole (*Leucaena leucocephala*)
kiawe (*Prosopis pallida*)
guinea grass (*Panicum maximum*)
Christmas berry *(Schinus terebinthifolius)*
natal redtop (*Melinis repens*)

rUSNVC Association

- *Leucaena leucocephala* Lowland Dry Semi-natural Shrubland

Representative Ground Photo

Description

Almost pure koa haole shrublands were fairly common on arid, older lava flows at PUHO. Polygons of this type were usually surrounding by large stands of koa haole belonging to one of the other two koa haole map classes. The splitting of the three koa haole types was made to better delineate the disturbance and moisture gradients at PUHO; with this map class representing the driest and less dense of the three. Polygons of this type often contained only koa haole shrubs with only minimal guinea grass in the understory. Where it did occur as pure stands, the koa haole shrubs had a light pink signature against a bluish (lava) background. Since koa haole is so widespread at PUHO this type may need more ground-truthing to better delineate the actual breaks between this type and other two koa hoale map classes.

Range and Distribution

Photo Signature Example

Map Code **Koa Haole - ‘Opiuma Semi-natural Shrubland**
S_LEPI ***Leucaena leucocephala - Pithecellobium dulce* Semi-natural Shrubland**

Common Species

koa haole (*Leucaena leucocephala*)
kiawe (*Prosopis pallida*)
guinea grass (*Panicum maximum*)
fountain grass (*Pennisetum setaceum*)
‘opiuma (*Pithecellobium dulce*)
Christmas berry *(Schinus terebinthifolius)*
natal redtop (*Melinis repens*)

rUSNVC Association

- *Leucaena leucocephala - Pithecellobium dulce* Semi-natural Shrubland [Park Special]

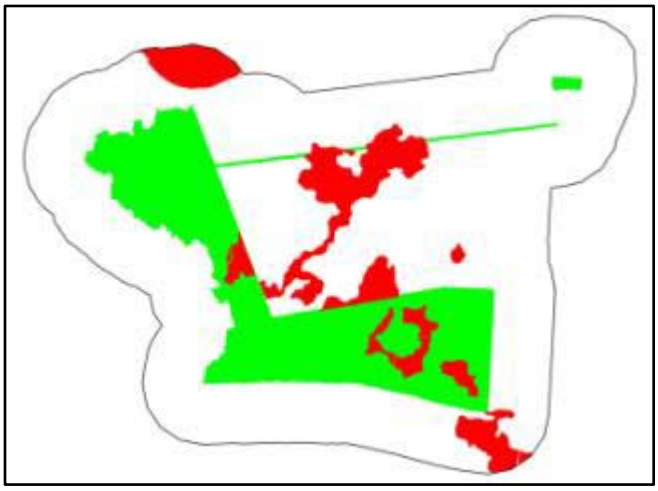
Representative Ground Photo

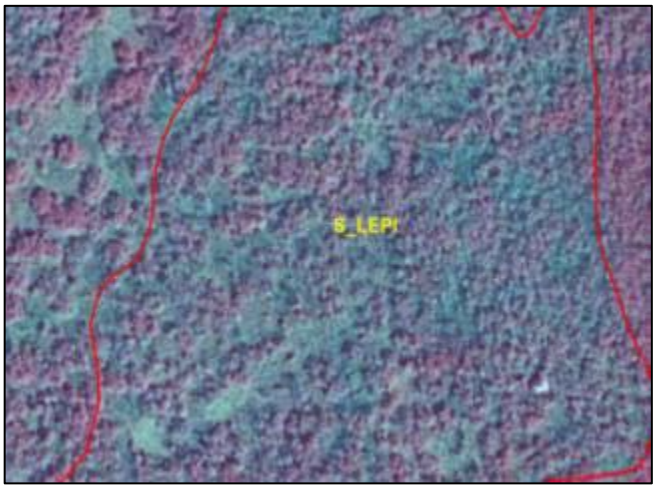
Description

Koa haole shrublands intermixed with ‘opiuma were fairly common at PUHO. Polygons of this type were usually surrounding by other stands of koa haole that lacked the ‘opiuma associate. This map class tended to have large koa haole shrubs (trees) with canopy openings dominated by ‘opiuma and guinea grass. Polygons of this type may also have had more disturbance or represent areas with higher moisture levels. On the color infrared imagery koa haole with ‘opiuma had a light pink, mottled signature against a bluish (lava) background.

Photo Signature Example

Range and Distribution





Map Code **Koa Haole / Guinea Grass Semi-natural Shrubland**
S_LEPA ***Leucaena leucocephala / Panicum maximum* Semi-natural Shrubland**

Common Species

koa haole (*Leucaena leucocephala*)
kiawe (*Prosopis pallida*)
guinea grass (*Panicum maximum*)
fountain grass (*Pennisetum setaceum*)
natal redtop (*Melinis repens*)

rUSNVC Association

- *Leucaena leucocephala / Panicum maximum* Semi-natural Shrubland (rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999))

Representative Ground Photo

Description

Koa haole shrublands with guinea grass in the understory were common at PUHO. Polygons of this type contained short, sparse koa haole shrubs and lush guinea grass. Of the three koa haole map classes, this type may represent more transitional areas where the young koa haole have not yet shaded out the understory species. Due to the short stature of the koa haole shrubs this map class appeared very similar to the pure guinea grass map class and some confusion likely occurred between them. On the color infrared imagery the koa haole shrubs with guinea grass had a bright pink, smooth signature against a bluish (lava) background.

Range and Distribution

Photo Signature Example

Map Code **Naupaka Kahakai Coastal Dry Shrubland**
S_SCTA ***Scaevola taccada* Coastal Dry Shrubland**

Common Species

naupaka kahakai (*Scaevola taccada*)
milo (*Thespesia populnea*)
kiawe (*Prosopis pallida*)
pickleweed *(Batis maritima)*
sourbush *(Pluchea carolinensis)*
ʻuhaloa *(Waltheria indica)*
noni *(Morinda citrifolia)*
ʻopiuma (*Pithecellobium dulce*)

rUSNVC Association

- *Scaevola taccada* Coastal Dry Shrubland
(rUSNVC name modified based on Wagner and Herbst (2003) and Wagner et al. (1999))

Representative Ground Photo

Description

Naupaka kahakai was a locally common coastal strand shrub that often intermingled and occurred in the understory of the milo, kiawe, and ʻopiuma woodlands. In PUHO, naupaka kahakai polygons were primarily restricted to the upper beach margins. This map unit exhibited a dark red circular signature and pattern on the color infrared imagery. Polygons of this type likely also included noni trees and other common coastal strand species. Due to the mixing of species this type may have been confused with kiawe, milo and ʻopiuma.

Range and Distribution

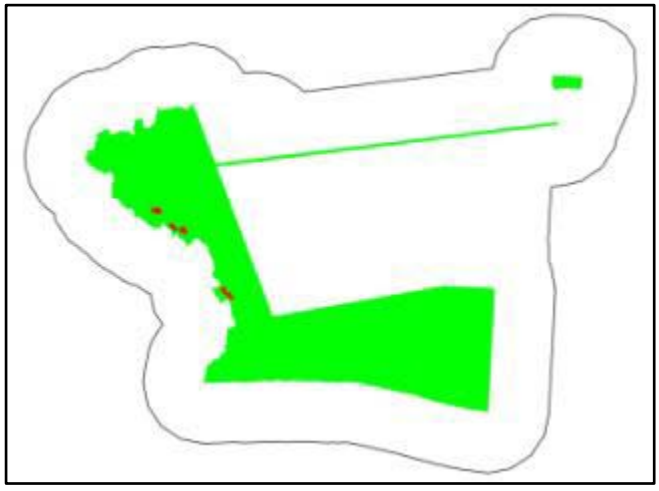
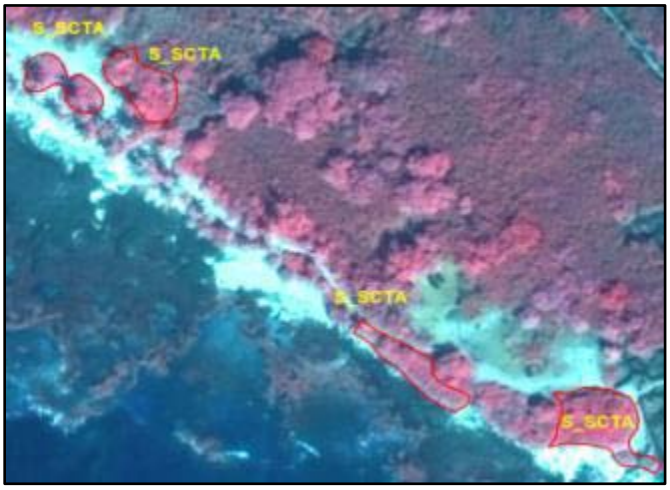


Photo Signature Example



Map Code **‘Uhaloa - ‘Ilima Shrubland**
S_WAIN ***Waltheria indica - Sida fallax* Shrubland**

Common Species

‘uhaloa *(Waltheria indica)*
‘ilima *(Sida fallax)*
koa haole (*Leucaena leucocephala*)
kiawe (*Prosopis pallida*)
guinea grass (*Panicum maximum*)
natal redtop (*Melinis repens*)

rUSNVC Association

- *Waltheria indica - Sida fallax* Shrubland

Representative Ground Photo

Description

‘Uhaloa (also known as hi’ola) and ‘ilima are short shrubs common to the upland lava flows at PUHO. Individual ‘uhaloa and ‘ilima shrubs were common all across PUHO occurring as minor associates in many of the kiawe, koa haole, and guinea grass polygons. This type was only found to be the clear dominant in a few restored sites next to the coastal trail. It is likely that more of this native type exists at PUHO but is currently being dominated by non-native vegetation. On the color infrared imagery this type presented a very smooth whitish to grey signature interspersed with blue and black lava components.

Range and Distribution

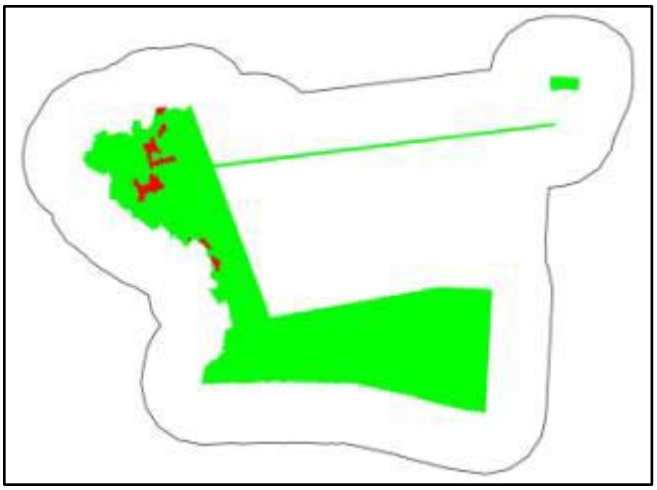
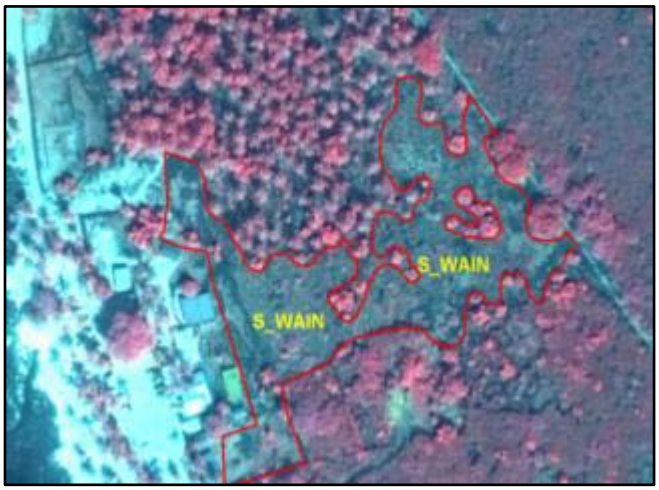


Photo Signature Example



Herbaceous Vegetation

Map Code **Mauʻu Coastal Dry Herbaceous Vegetation**
H_FIMB ***Fimbristylis* spp. Coastal Dry Herbaceous Vegetation**

Representative Ground Photo

Common Species

mauʻu (*Fimbristylis* spp.)
ʻuhaloa (*Waltheria indica*)
ʻilima (*Sida fallax*)
guinea grass (*Panicum maximum*)

rUSNVC Association

- *Fimbristylis* spp. Coastal Dry Herbaceous Vegetation

Description

Mauʻu was a rare coastal strand species at PUHO only occurring in one stand large enough to be mapped. It is likely that this type also occurs on the coastal basalt and pahoehoe lava outcrops above the tidal line as sparse pioneering tuffs. Since the only polygon of this type was mapped based on the field plot data no characteristic signature was discernable. More ground-truthing and updating of this type should occur in the future to determine if it is a true type at PUHO or if it should be combined with the coastal strand sparse vegetation map class.

Range and Distribution

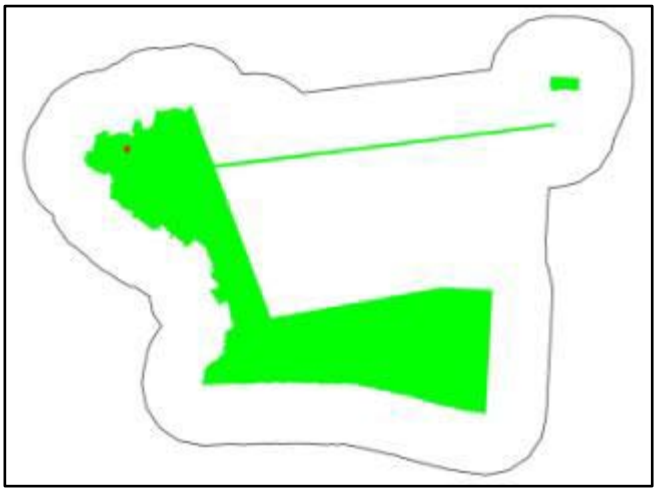
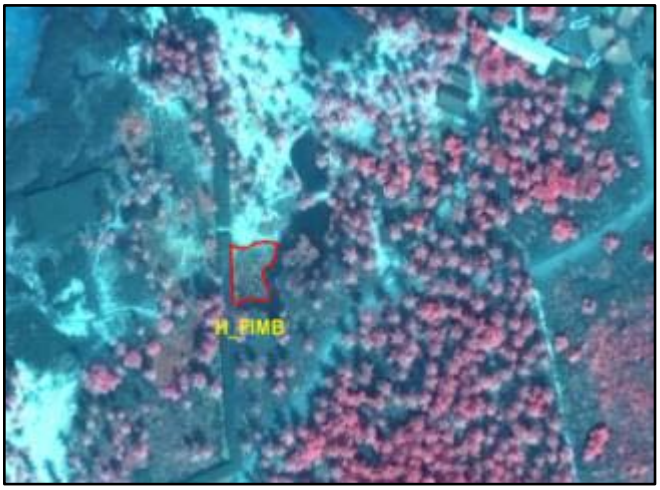


Photo Signature Example



Map Code **Pili Planted Herbaceous Vegetation**
H_HECO ***Heteropogon contortus* Planted Herbaceous Vegetation**

Common Species
pili (*Heteropogon contortus*)

rUSNVC Association
- No Association – Unclassified Map Unit

Representative Ground Photo

Description
Pili grass was likely the dominant grass species at PUHO in historic times before the arrival of Europeans and the introduction of guinea grass. Today, pili is actively being restored to some areas of PUHO and this map class represents known reintroduction sites associated with the visitor center parking lot. In addition to these polygons, pili remnants may also occur in the lava fields (sparse a‘a and pahoehoe vegetation types) but did not occur in sufficient quantities to classify or map. This type was mapped primarily from ground observations and as such, had no characteristic signature to reliably map from. More ground-truthing and updating of this type should occur in the future to better inventory and monitor its success.

Range and Distribution

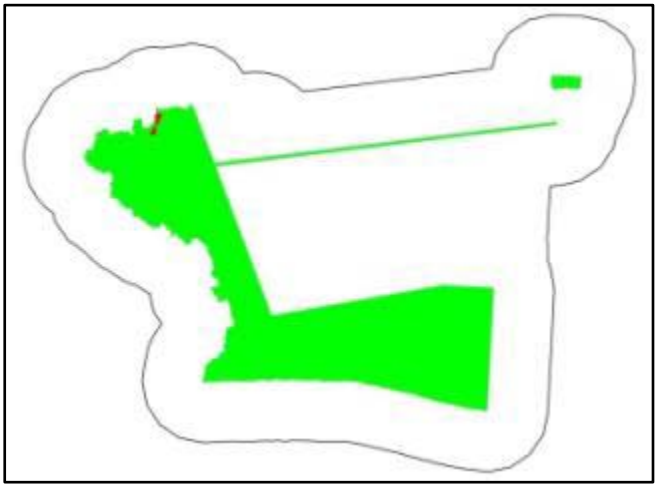


Photo Signature Example

Map Code **Natal Redtop Semi-Natural Herbaceous Vegetation**
H_MERE ***Melinis repens* Semi-natural Herbaceous Vegetation**

Common Species
natal redtop (*Melinis repens*)
guinea grass (*Panicum maximum*)
pigweed (*Portulaca oleracea*)
ʻuhaloa (*Waltheria indica*)

Representative Ground Photo

rUSNVC Association
- *Melinis repens* Semi-Natural Herbaceous Vegetation

Description
Natal redtop and guinea grass are two common non-native grasses occurring at PUHO. Pure natal redtop stands at PUHO tended to be sparser and occurred in many small areas along the coastal trail. Polygons of this type may represent recently disturbed sites that were treated with herbicide or cleared. On the color infrared imagery redtop appeared as a thin white to pink haze on a blue (lava) background.

Range and Distribution

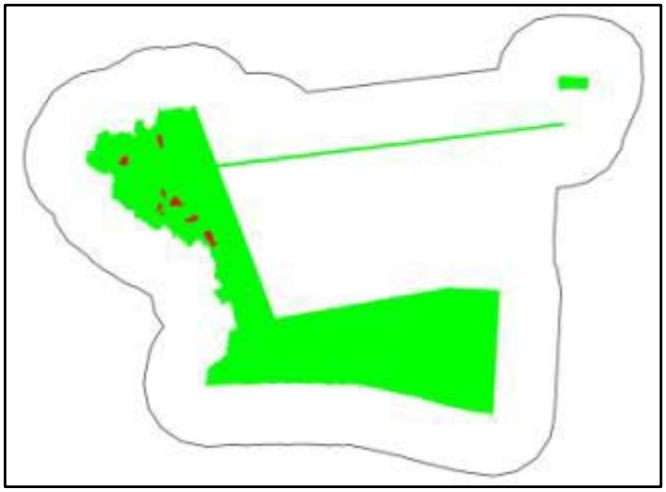


Photo Signature Example

Map Code	Guinea Grass Lowland Dry Semi-natural Herbaceous Vegetation
H_PAMA	*Panicum maximum* Lowland Dry Semi-natural Herbaceous Vegetation

Common Species

guinea grass (*Panicum maximum*)
natal redtop (*Melinis repens*)
koa haole (*Leucaena leucocephala*)

rUSNVC Association

- *Panicum maximum* Lowland Dry Semi-natural Herbaceous Vegetation

Representative Ground Photo

Description

Guinea grass is currently the dominate grassland type at PUHO where it was found to occur in varying densities across the upland lava flows. Polygons of this map unit varied in cover likely based on moisture levels, soil type and topographic positions. On more developed soils and in drainage bottoms, guinea grass was dense and grew up to 70 cm tall. On broken lava, this type tended to be sparse, patchy and stunted. Due to its lush growth in many places this type appeared as smooth, bright pink polygons. Where it was sparse, the lava substrate signature on the color infrared imagery (dark blue-black) was more pronounced.

Range and Distribution

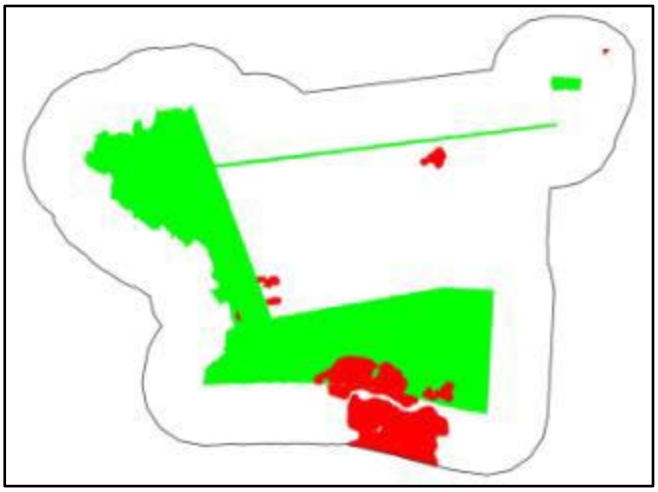
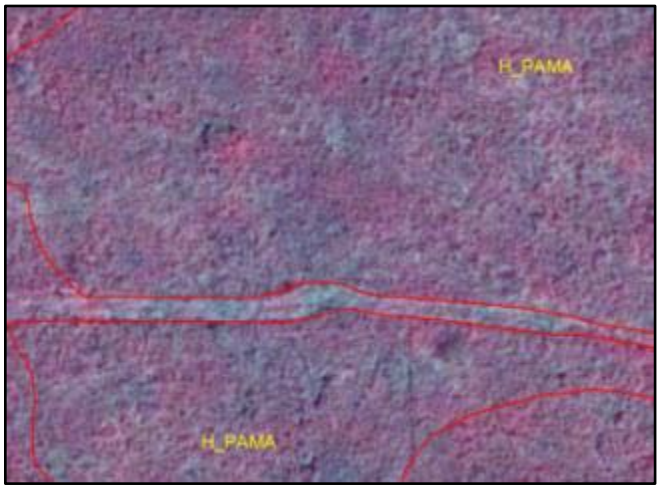


Photo Signature Example



Map Code **Fountain Grass Semi-natural Herbaceous Vegetation**
H_PESE ***Pennisetum setaceum* Semi-natural Herbaceous Vegetation**

Common Species

fountain grass (*Pennisetum setaceum*)
koa haole (*Leucaena leucocephala*)
guinea grass (*Panicum maximum*)

rUSNVC Association

- *Pennisetum setaceum* Semi-natural Herbaceous Vegetation

Representative Ground Photo

(Photo from KAHO)

Description

Fountain grass at PUHO was only mapped in the environs located east and north of the park boundary. Since no plot data were collected in these sites fountain grass was mapped based on a similar signature (i.e. smooth, bright pink) found on the same imagery at KAHO. It is likely that these polygons may not be dominated by fountain grass, but could contain very lush stands of guinea grass or other non-native graminoids. More ground-truthing and updating of this type should occur in the future to better inventory and describe the vegetation present here.

Range and Distribution

Photo Signature Example

Map Code **Mallow Plant Semi-natural Herbaceous Vegetation**
H_SICO ***Sida cordifolia* Semi-natural Herbaceous Vegetation**

Representative Ground Photo

Common Species

mallow plant (*Sida cordifolia*)
ʻuhaloa (*Waltheria indica*)
guinea grass (*Panicum maximum*)

rUSNVC Association

- *Sida cordifolia* Semi-natural Herbaceous Vegetation [Park Special]

Description

Mallow plant was another locally abundant coastal strand species that occurred at PUHO along the coastal trail. Polygons of this type were sparse and could represent restoration or disturbed sites. On the color infrared imagery this type appeared vary similar to the ʻuhaloa and mauʻu map units (light white haze on a blue lava) and is likely a constituent of the coastal strand sparse vegetation type. Since it is non-native, an effort was made to map mallow for inventory and monitoring purposes. More ground-truthing and updating of the mallow polygons is warranted to better determine if it is true type or if it should be combined with the ʻuhaloa or coastal strand map units.

Range and Distribution

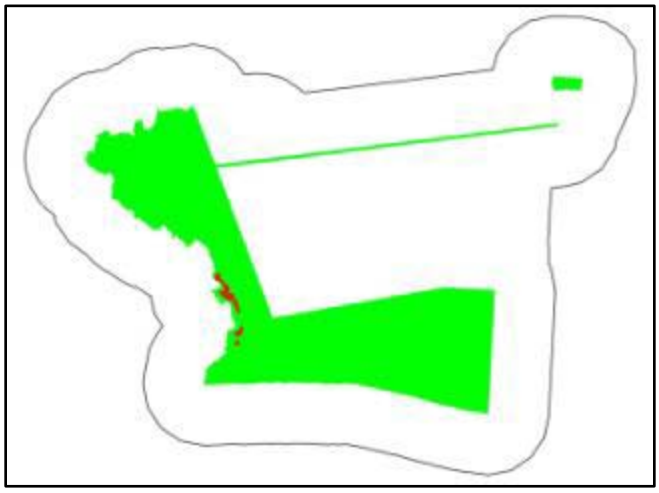
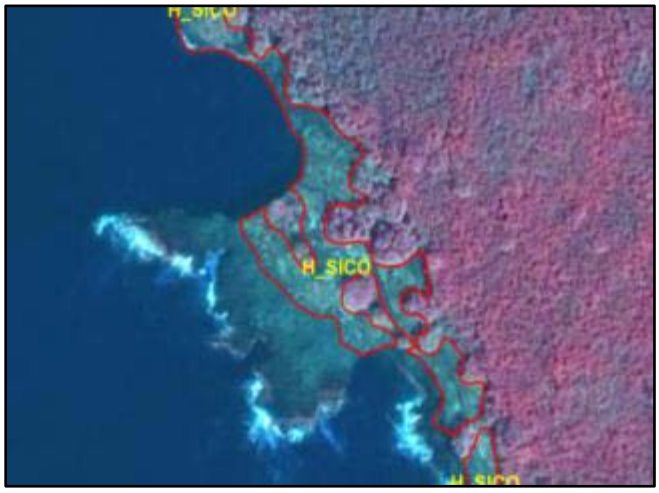


Photo Signature Example



Sparse Vegetation

Map Code SV_A‘A **A‘a Lava with Sparse Vegetation**

Common Species
guinea grass (*Panicum maximum*)
koa haole (*Leucaena leucocephala*)

rUSNVC Association
- A‘a Lava with Sparse Vegetation [Park Special]

Representative Ground Photo

(Photo from KAHO)

Description
Rugged and sparsely vegetated a‘a lava was only found in three small polygons in areas surrounding the PUHO boundary. It is likely that polygons of this type contain some fountain grass, ferns and other herbaceous vegetation. This map class along with the pahoehoe lava sparse vegetation class was used to help differentiate lava fields supporting minimal vegetation from those that are completely devoid of any plants. On the color infrared imagery this type appeared black to dark blue in color with some texture characteristic of rough a‘a lava deposits.

Range and Distribution

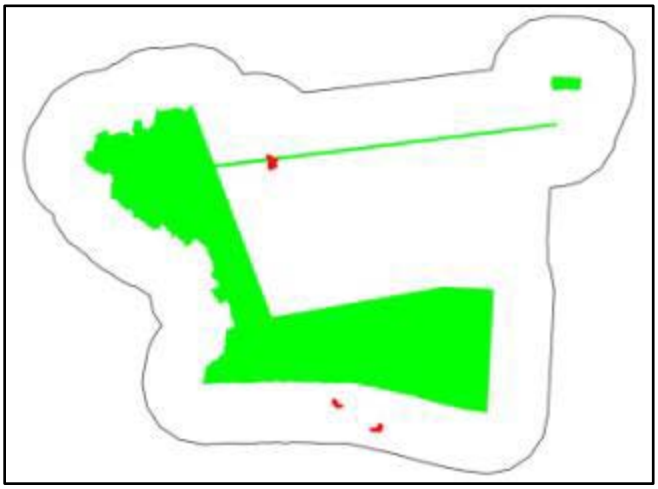
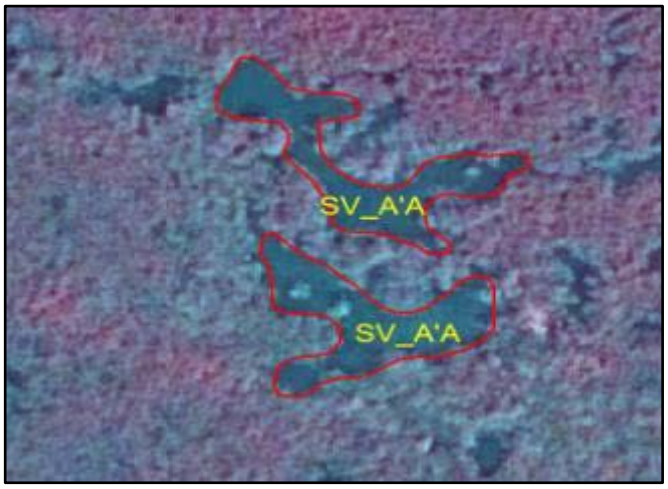


Photo Signature Example



Map Code SV_CS Coastal Strand Sparse Vegetation

Common Species

ʻākulikuli (*Sesuvium portulacastrum)*
pickleweed (*Batis maritima*)
mauʻu (*Fimbristylis* spp.)
ʻuhaloa (*Waltheria indica*)
ʻilima (*Sida fallax*)

rUSNVC Association

- Coastal Strand Sparse Vegetation [Park Special]

Representative Ground Photos

Description

The coastal strand sparse vegetation map class was used to map small polygons in around the beaches and coastal areas of PUHO. This broad catch-all class was used since no clear dominant species was established and since these sites likely vary in vegetation composition yearly and seasonally. Plant species of this type also likely occur as understory constituents within the coconut palm, ʻopiuma and milo map units. On the color infrared imagery this type appeared as a light pink to brown haze on a white (sand) or blue (lava) background. More plot and verification data in these areas may warrant creating a new herbaceous association or merging this type with other existing coastal strand associations.

Range and Distribution

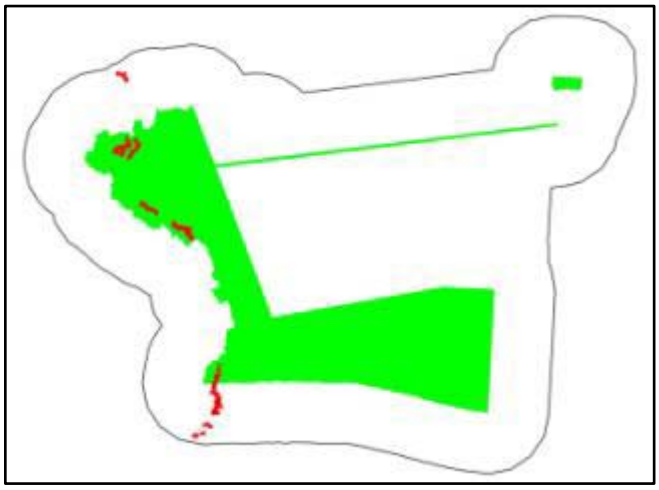


Photo Signature Example

Map Code SV_PA Pahoehoe Lava Sparse Vegetation

Representative Ground Photo

Common Species

mau‘u (*Fimbristylis* spp.)
‘uhaloa (*Waltheria indica*)
‘ilima (*Sida fallax*)
guinea grass (*Panicum maximum*)
koa haole (*Leucaena leucocephala*)

rUSNVC Association

- No Association – Unclassified Map Unit

Description

Sparse pahoehoe lava was similar in appearance to the a‘a sparse vegetated class due to the sparse and widely-spaced nature of the vegetation. Within PUHO, this map class was used to map areas above the tidal line that were either recently cleared or contained very little vegetation. It is likely that these areas contain some ‘uhaloa, guinea grass or small koa haole shrubs. On the color infrared imagery this type exhibited a characteristic smooth, deep blue signature with pink or white spots (vegetation) and some whitish streaks (sand or other deposits).

Range and Distribution

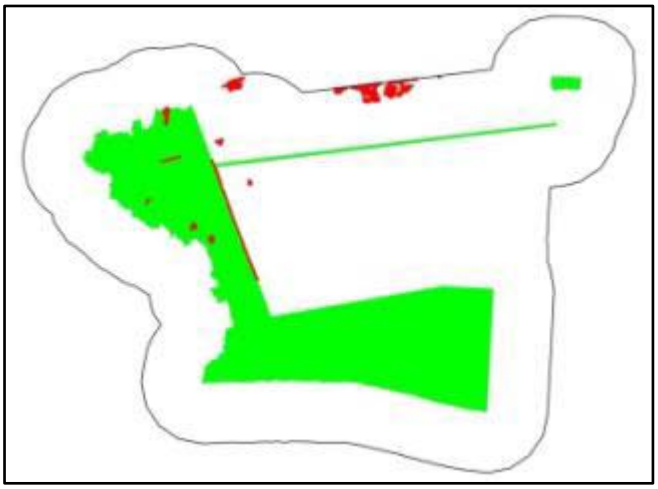
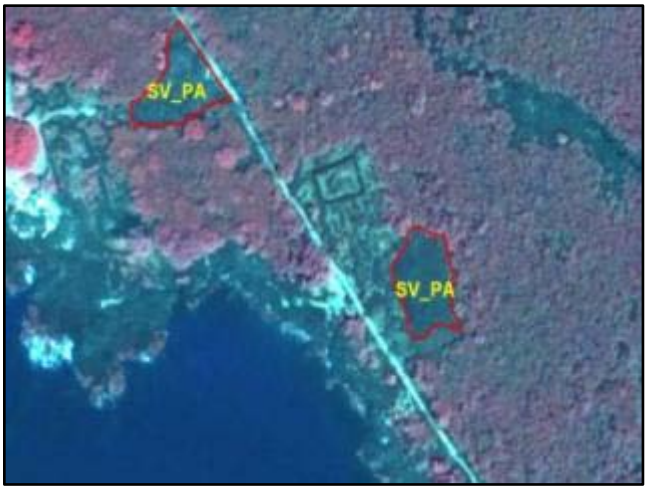
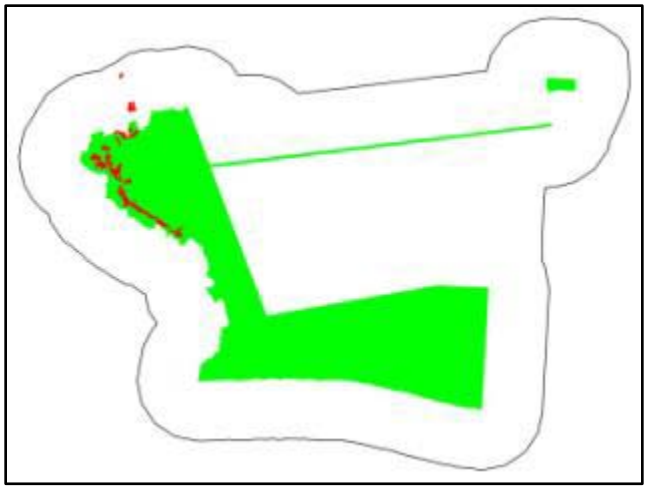


Photo Signature Example

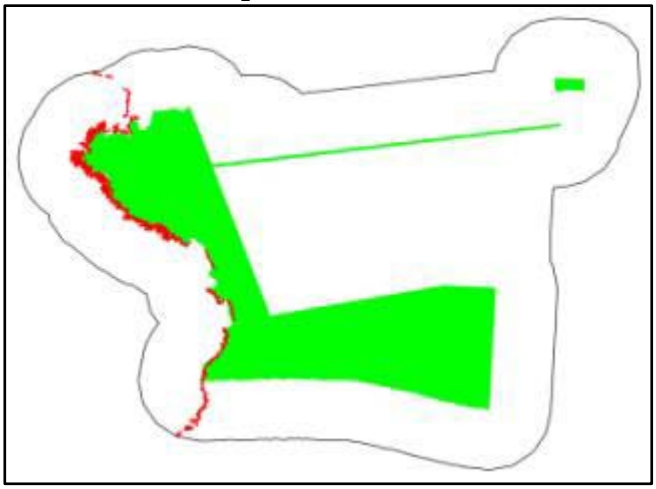


BARREN

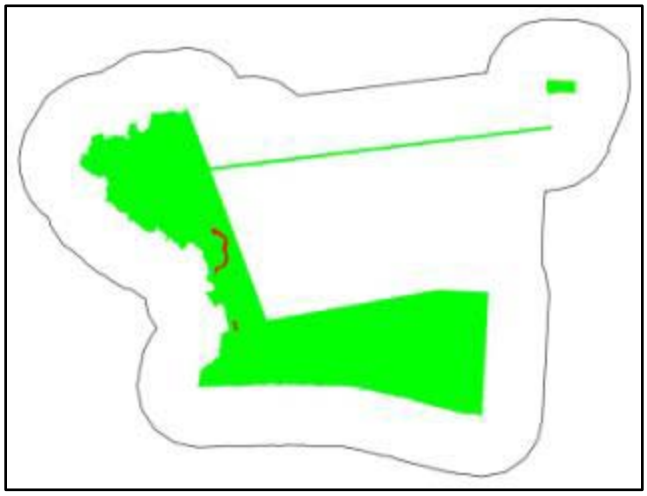
B_BE Beaches



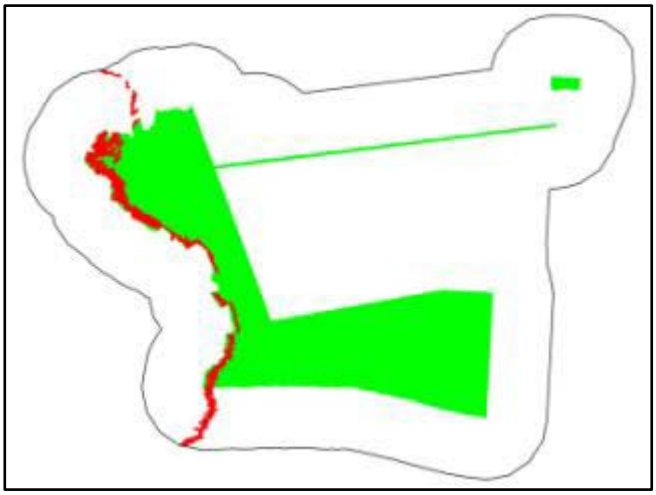
B_ER Exposed Reef and Tidal Pools



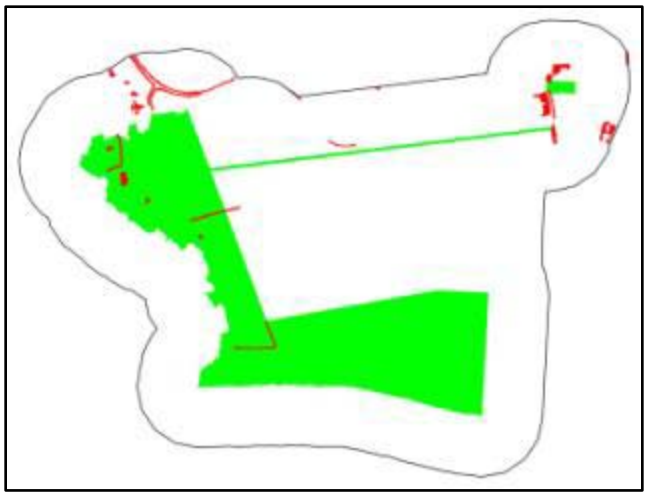
B_CB Coastal Basalt



B_PA Pahoehoe Lava

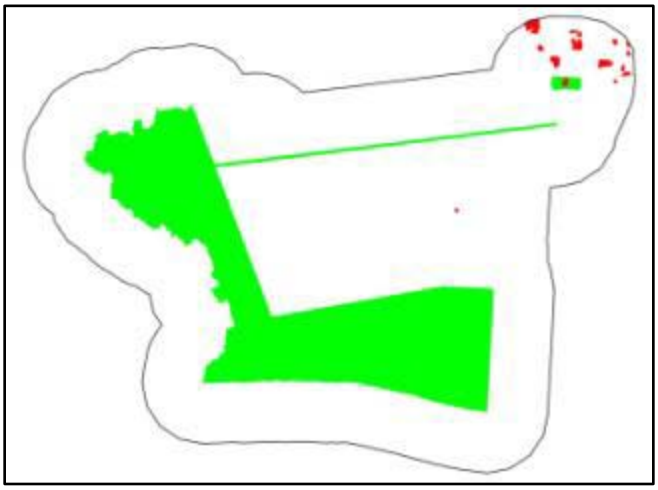


B_DL Developed Lava

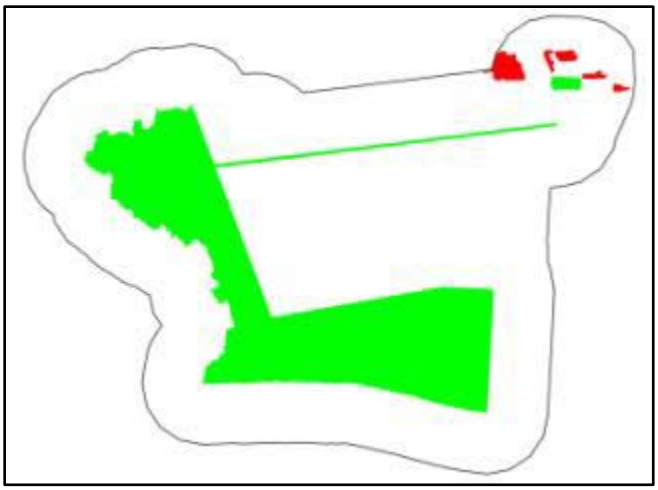


LAND COVER – LAND USE

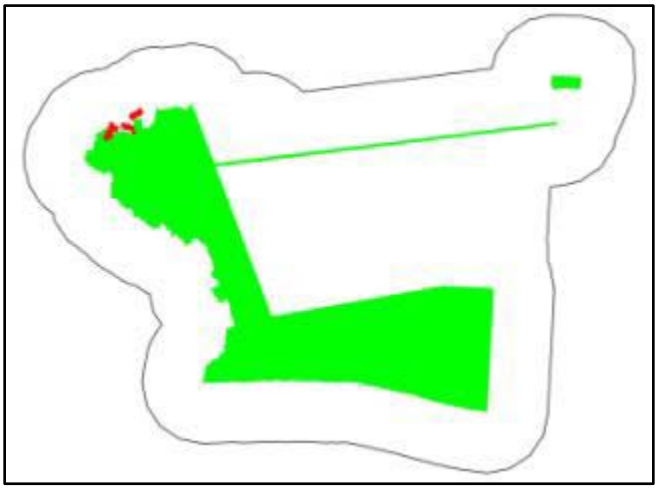
L_AGRI Agricultural Business



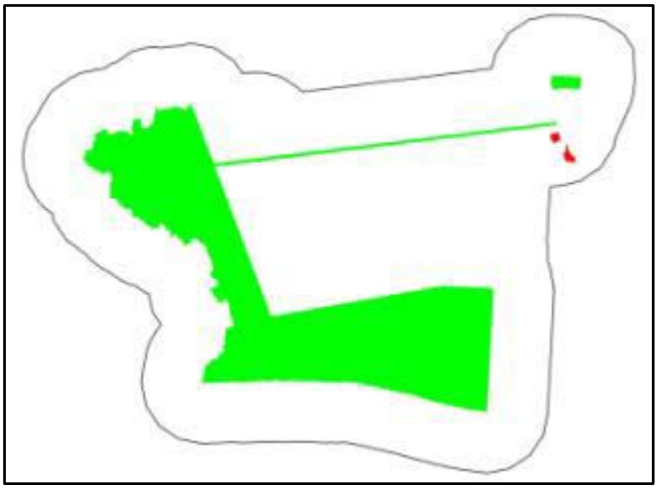
L_FILD Planted / Cultivated



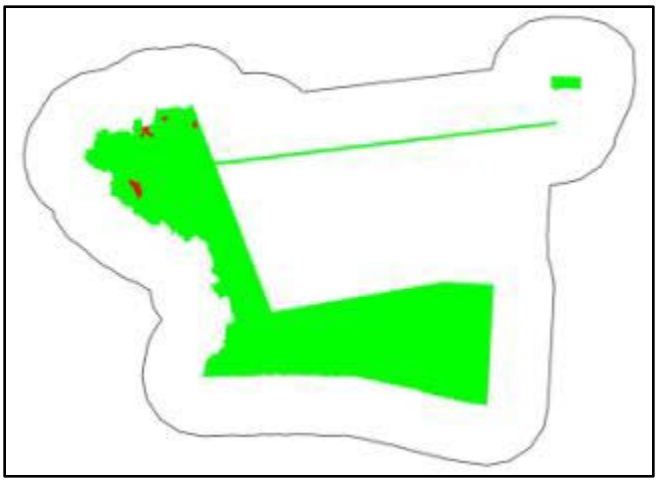
L_BAY Bay / Estuary



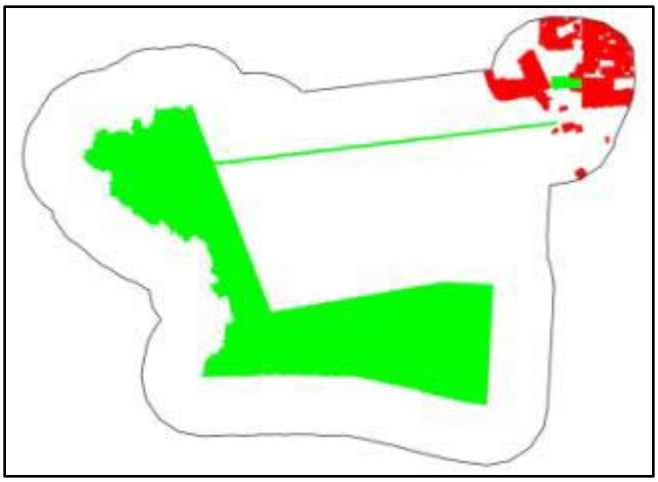
L_LIIN Commercial / Light Industry



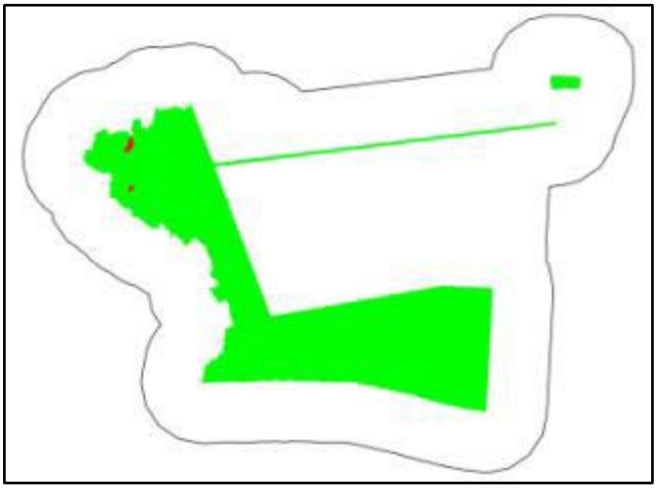
L_FACL Facilities



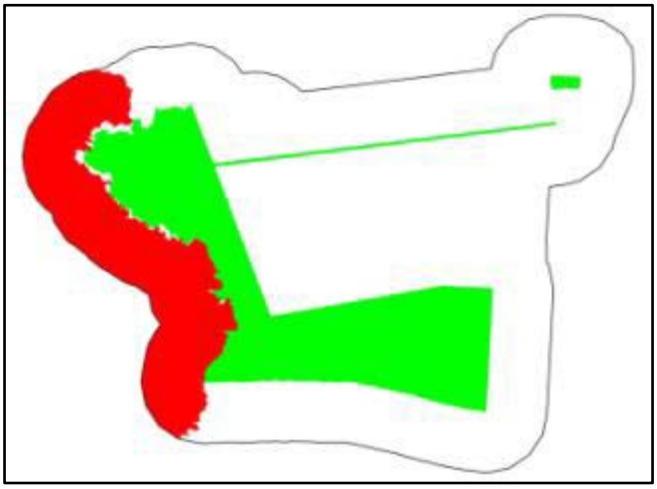
L_ORCH Irrigated Orchard / Vineyards / Groves



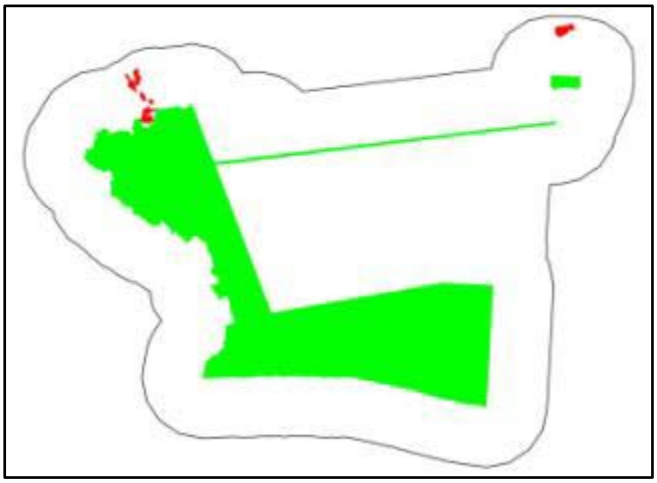
L_POND Lake / Pond



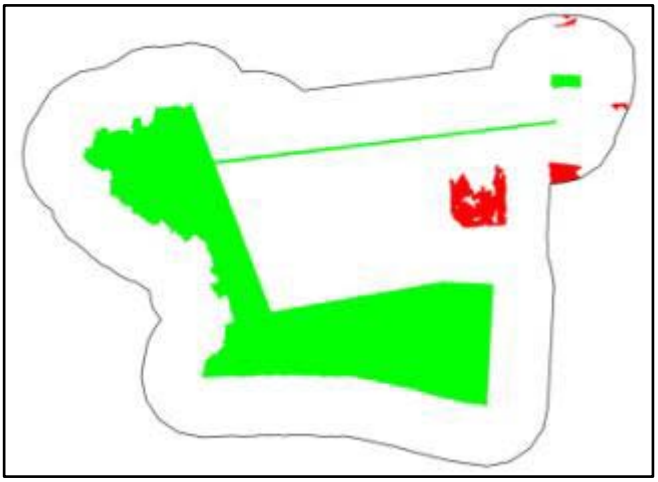
L_SEA Sea / Ocean



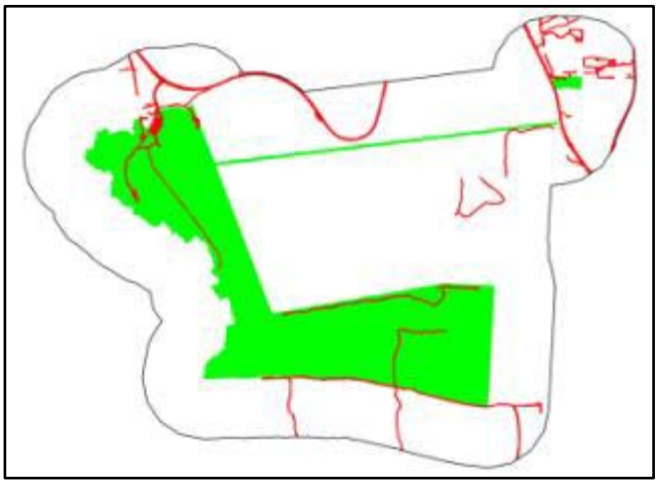
L_RESD Residential



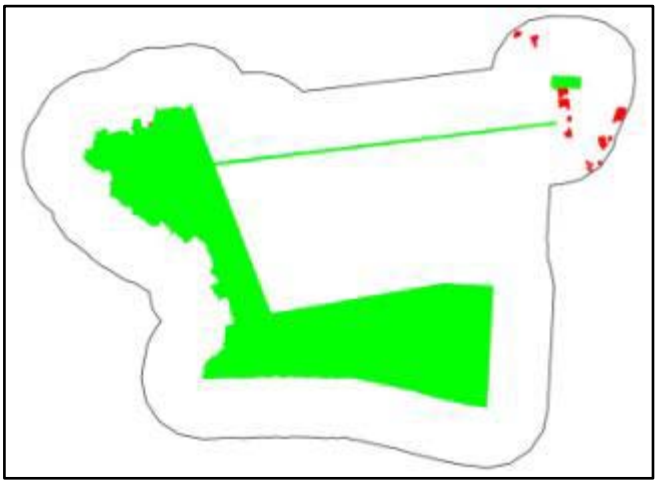
L_TRAN Transitional



L_ROAD Transportation



L_URBN Mixed Urban



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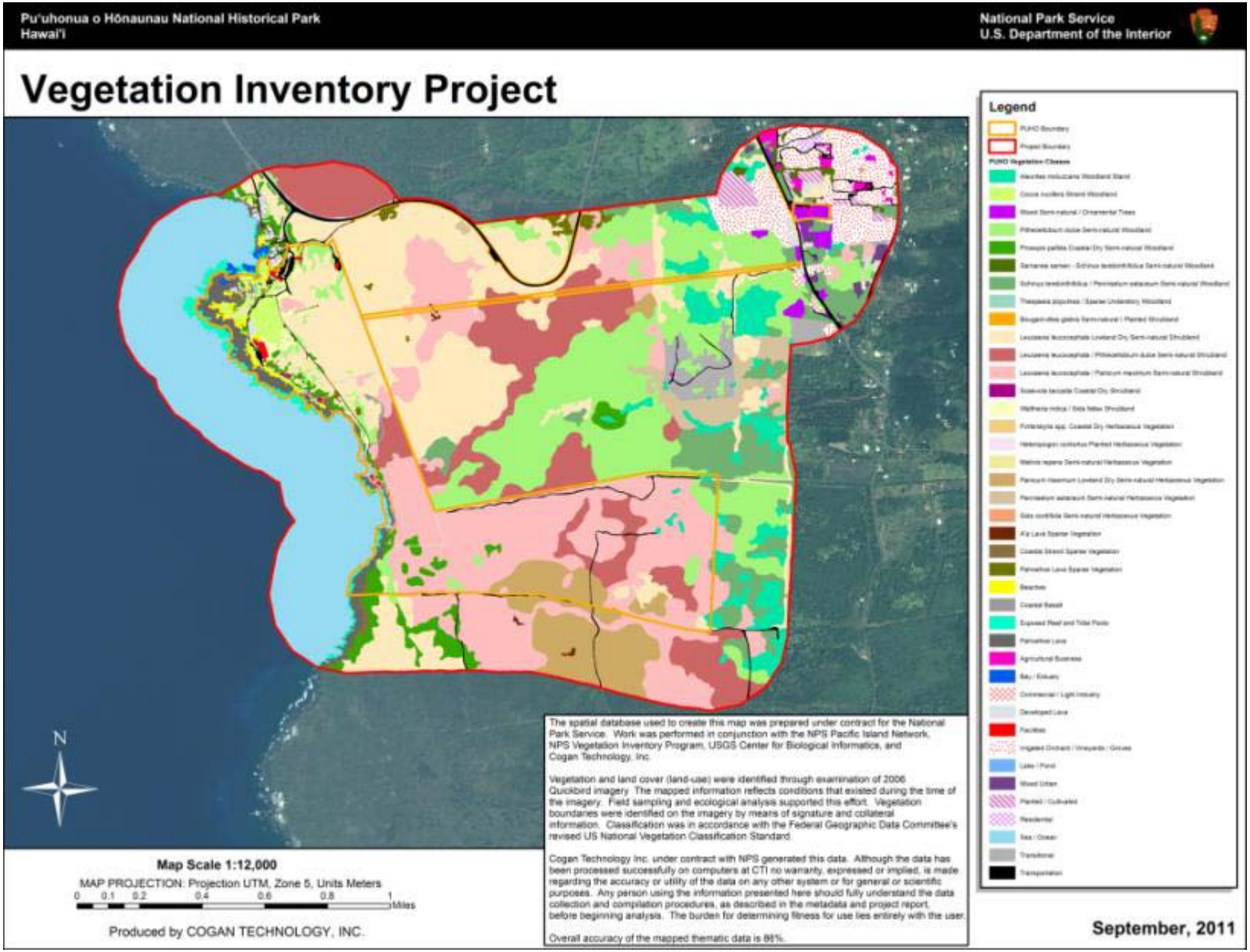
Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1999. Manual of the flowering plants of Hawaii. Revised edition. Volumes 1 and 2. University of Hawaii Press and Bishop Museum Press, Honolulu. 1919 pp.


Pu'uhonua o Hōnaunau National Historical Park
Hawai'i
National Park Service
U.S. Department of the Interior
Vegetation Inventory Project
Legend
N
Map Scale 1:12,000
MAP PROJECTION: Projection UTM, Zone 5, Units Meters
0 0.1 0.2 0.4 0.6 0.8 1 Miles
Produced by COGAN TECHNOLOGY, INC.
The spatial database used to create this map was prepared under contract for the National Park Service. Work was performed in conjunction with the NPS Pacific Island Network, NPS Vegetation Inventory Program, USGS Center for Biological Informatics, and Cogan Technology, Inc.
Vegetation and land cover (land-use) were identified through examination of 2006 Quickbird imagery. The mapped information reflects conditions that existed during the time of the imagery. Field sampling and ecological analysis supported this effort. Vegetation boundaries were identified on the imagery by means of signature and collateral information. Classification was in accordance with the Federal Geographic Data Committee's revised US National Vegetation Classification Standard.
Cogan Technology Inc. under contract with NPS generated this data. Although the data has been processed successfully on computers at CTI no warranty, expressed or implied, is made regarding the accuracy or utility of the data on any other system or for general or scientific purposes. Any person using the information presented here should fully understand the data collection and compilation procedures, as described in the metadata and project report, before beginning analysis. The burden for determining fitness for use lies entirely with the user.
Overall accuracy of the mapped thematic data is 86%.
September, 2011

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 415/110808, October 2011

National Park Service
U.S. Department of the Interior

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