National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Vegetation Inventory Project

Kaloko-Honokōhau National Historical Park

Natural Resource Report NPS/KAHO/NRR—2011/462

ON THE COVER
Kaloko-Honokōhau visitor center - Hale Hoʻokipa (House of Welcome) and landscape plantings of native plant species under drip irrigation.

Vegetation Inventory Project

Kaloko-Honokōhau National Historical Park

Natural Resource Report NPS/KAHO/NRR—2011/462

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October 2011

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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This report is available from NPS Inventory and Monitoring, Pacific Island Network (http://science.nature.nps.gov/im/uites/pacn/index.cfm) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/nrpm/). Please cite this publication as:

Cogan, D., K. Schulz, D. Benitez, G. Kudray, and A. Ainsworth. 2011. Vegetation inventory project: Kaloko-Honokōhau National Historical Park. Natural Resource Report NPS/KAHO/NRR—2011/462. National Park Service, Fort Collins, Colorado.

NPS 466/110853, October 2011

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Executive Summary

Kaloko-Honokōhau National Historical Park (KAHO) covers approximately 486 ha (1,200 ac) on the western coast of the island of Hawai‘i. The park was established to preserve, protect, and interpret ancient Hawaiian settlements and structures including fishponds, fish-traps, anchialine ponds, petroglyphs, rock structures, and historic roads and trails. KAHO is situated on a vast lava field sloping westward towards the Pacific Ocean. KAHO supports 116 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 fountain grass (*Pennisetum setaceum*), koa haole (*Leucaena leucocephala*) shrubs, and kiawe (*Prosopis pallida*) trees. 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 KAHO in 2007.

A three-year, four phase program was initiated to complete the task of mapping and classifying the vegetation at KAHO. Phase one conducted by PACN staff in 2008, collected 33 field plots and 22 observation points. In phase two, NatureServe's Western Regional Office used this field data in conjunction with data collected at two other parks to classify 16 new plant associations for KAHO 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 90 accuracy assessment points in 2010 used to check and finalize the map.

To produce the spatial database and map layer, 2006, 0.6-meter, 4-band Quickbird satellite imagery (supplemented with 2008 Quickbird imagery) was provided by PACN. By comparing the signatures on the imagery to field and ground data 30 map units (18 vegetated, five barren, and seven 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 90 independent accuracy assessment points. The final overall accuracy of the map layer was determined to be 97% with a Kappa value of 82%.

Products developed for KAHO 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‘ukoholā Heiau National Historic Site project and Jim analyzed data for the classification and wrote the vegetation community descriptions.

We are grateful to the staff at Kaloko-Honokōhau National Historical Park especially Sallie Beavers, Kathy Billings, Mandy Johnson, and Joseph Bybee, 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 Kaloko-Honokōhau National Historical Park (KAHO) 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. KAHO 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 Network, Inventory and Monitoring Program

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.

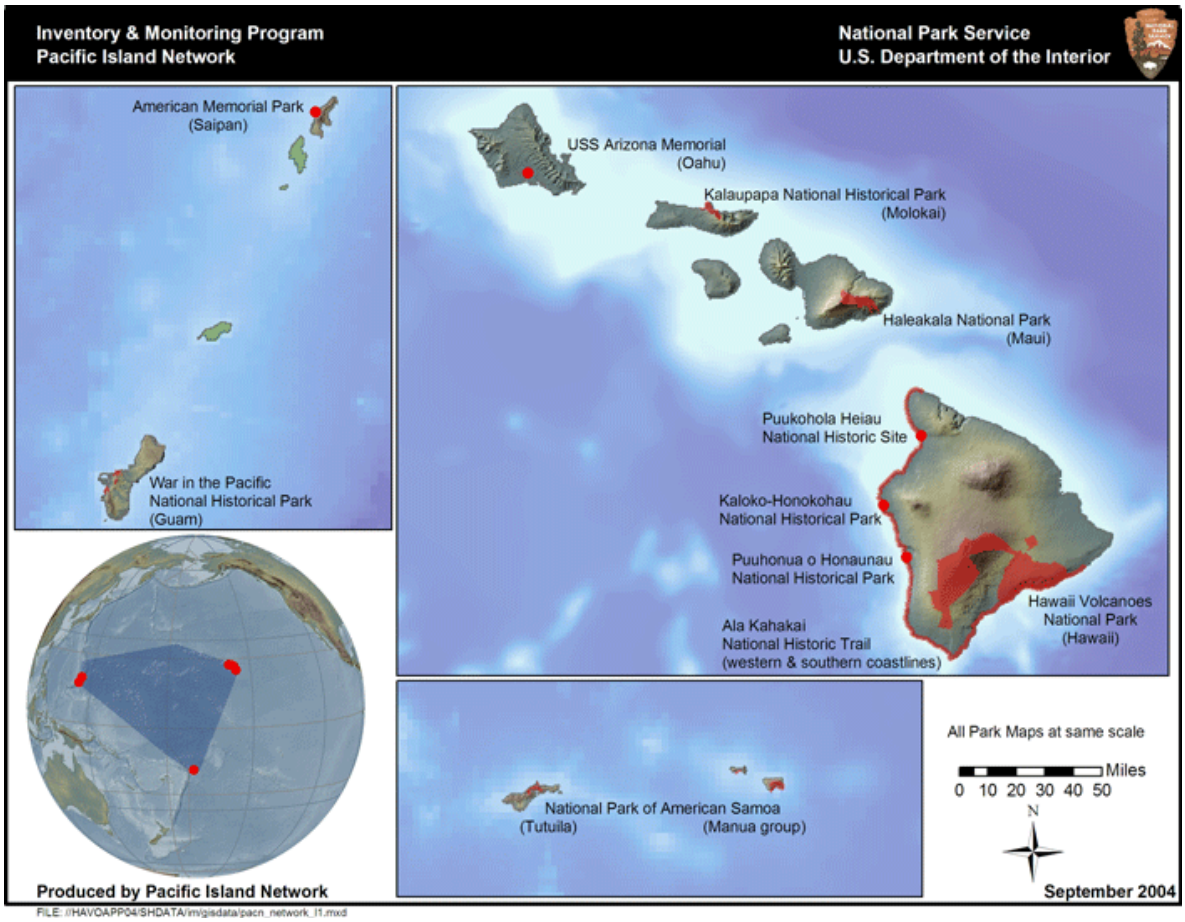


Figure 1. The 11 national parks included within the Pacific Island Network.

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

Kaloko-Honokōhau National Historical Park

KAHO encompasses approximately 486 ha (1,200 ac) consisting of lava-flow uplands, beaches, anchialine ponds, and the Pacific Ocean. KAHO is located in Hawai‘i County on the west-central coast of the island of Hawai‘i (leeward coast) and adjacent to State Highway 19 north of the city of Kailua-Kona (GPO 2007) (Figure 2).

Figure 2. NPS Kaloko-Honokōhau National Historical Park map.

Also managed within KAHO are segments of ALKA (Coastal Trail) and the Mamalahoa Trail (Hawaiʻi Belt Road). Access from Highway19 into KAHO includes the Ale Nui Kaloko gravel road to Kaloko Fishpond; the paved road to the Visitor Center and the paved road to the Honokohau Small Boat Harbor (Kealakehe Parkway). The northern boundary encompasses Wawahiwaʻa Point, the eastern boundary is adjacent to Highway 19, and the southern boundary parallels Kealakehe Parkway and the Honokohau Small Boat Harbor. Sites preserved and interpreted within KAHO include Kaloko Fishpond, ʻAimakapa Fishpond, ʻAiʻopio Fishtrap, anchialine ponds (140 brackish water pools), petroglyphs, a Heiau (religious temple), a holua (stone slide), ahu (rock cairns), rock structures, the Ala Hele Huʻe Huʻe historic ranch road, Belt Road, and the Coastal Trail (NPS 2008; undated, GPO 2007).

Natural Setting

A warm sub-tropical climate is common for KAHO, with periodic rains and long periods of drought (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 are common, 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 and difficulty in vegetation establishment on exposed lava. Temperatures range from 67 to 82° F (February) to 74 to 88°F (August); record low/high temperatures are 57°F/95°F. Annual precipitation at Kailua-Kona averages 360 mm (14 in) (mainly in the summer months) (USGS-NPS 2008).

Hawaiʻi 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). KAHO is located at the base of the Hualalai Volcano (an inactive shield volcano) and is characterized by historic basaltic lava flows (USGS-NPS 2008). Lava flows of three different ages occur within KAHO: (1) 10,000 to 5,000 years before present (BP); (2) 5,000-3,000 BP; and (3) 3,000-1,000 BP. The most recent eruption of Hualalai Volcano was documented in 1800-1801 that deposited lava approximately 3.2 km (2 mi) north of KAHO (USGS-NPS 2008). The Hualalai Volcanics are transitional between alkaline olivine basalt and trachyte with pahoehoe and aʻa lava beds visible (Figure 3).

Topographically, KAHO slopes gently seaward with the highest elevation measured at approximately 28 m (90 ft) along the eastern border (NPS 2008; USGS-NPS 2008). Because the basaltic lava flows occurred recently and with the dry climate at KAHO, only thin and poorly developed soils have formed (USGS-NPS 2008). Aʻa and pahoehoe lava bedrock are characterized by no soil to very thin soil and very little vegetation cover (vegetation roots within bedrock cracks and crevices). Aʻa soils occur in the central portion of KAHO and pahoehoe soils have developed in both the north and south portions. East of Kaloko Fishpond is a small area of Punaluu extremely rocky peat, which consists of a thin layer of permeable organic peat overlying pahoehoe lava bedrock (USGS-NPS 2008).

Figure 3. Representative unvegetated a‘a (top) and pahoehoe lava (bottom) surfaces at KAHO.

Beaches are classified as a soil type and are distributed as an uneven narrow band along the KAHO coastline (Figure 4). Beaches comprised of sand are unvegetated and occur as either intertidal accumulations of sediment subjected regularly to wave interaction or as perched supratidal sediment deposits that are typically active only during large-wave events. The beach fronting the ‘Aimakapa Fishpond is the largest sandy beach in KAHO, with a width of about 32 m (105 ft) and a maximum height of 3 m (10 ft) above mean low water (USGS-NPS 2008). A few smaller beach accumulations of gravel-sized material also occur (USGS-NPS 2008).

Figure 4. Representative KAHO sandy beach deposits adjacent to basalt rocks (top) with a halau (open air house) (bottom).

Vegetation

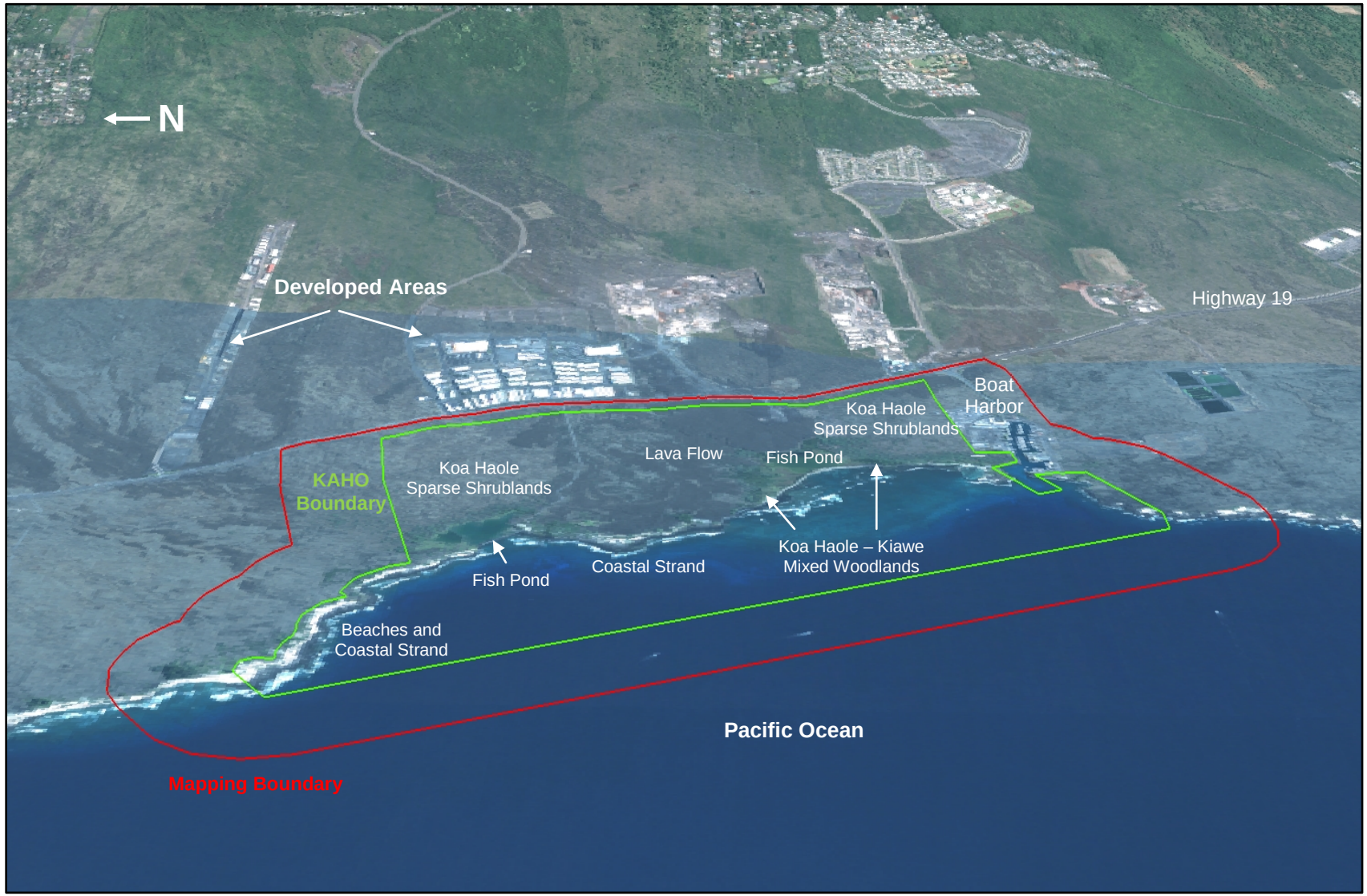
Prior to this project, the vegetation of KAHO was surveyed in 1992-93. Of the 116 plant species previously identified in this study nearly 69% were non-native species (Pratt and Abbott 1996). In addition to the recent non-native species, KAHO also contains four naturalized plant species likely introduced and planted by the first Polynesian settlers for food, thatching, and other cultural needs (Pratt and Abbott 1996). These include: noni (*Morinda citrifolia*), kou (*Cordia subcordata*), ‘auhuhu (*Tephrosia purpurea* var. *purpurea*), and niu or coconut palm (*Cocus nucifera*) (prominent in the Kaloko Fishpond parking area). These four species often form small stands around the ponds or are a common component of the coastal strand areas at KAHO.

Native plants are uncommon at KAHO but 32 native plant species were found in KAHO during the 1992-93 survey (Pratt and Abbott 1996). Most of these (27) are indigenous or native to Hawai‘i and five found within the Park are endemic or unique to the Hawaiian Islands (Pratt and Abbott 1996). There is one candidate endangered plant species ko‘oko‘olau (*Bidens micrantha* ssp. *ctenophylla*) within KAHO (NPS 2008) and five endangered plant species that have been out-planted. These include: loulu (*Pritchardia affinis*), hala pepe (*Pleomele hawaiiensis*), uhiuhi (*Caesalpinia kavaiense*), koki‘o (*Kokia drynarioides*), and ko‘oloa‘ula (*Abutilon menziesii*). Among the most common of the native species are koali‘awa (*Ipomoea indica*) (a vine found in the lowland areas), waltheria or ‘uhaloa (*Waltheria indica*) and ‘ilima (*Sida fallax*) (both shrubs common on the lava flows).

All of the native, non-native, and Polynesian introduced species at KAHO 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 5). The gentle east to west sloping nature of the park combined with the lava substrate and close proximity to the Pacific Ocean creates unique vegetation life zones (Figure 6). The upland lava flows range from bare lava (no vegetation) to shrub-like stands of sparse non-native koa haole (*Leucaena leucocephala*) and kiawe (*Prosopis pallida*) on older flows. Scattered throughout this harsh environment are sparse stands of the non-native fountain grass (*Pennisetum setaceum*). This bunchgrass is common throughout the lava fields of KAHO and is intermixed with many of the non-native tree and shrub species. More extensive woodlands of koa haole and kiawe along with non-native Christmas berry (*Schinus terebinthifolius*) trees are common along the upper beach margins and the lower edge of the lava flows adjacent to the coast. Kiawe and Christmas berry stands provide moderate cover and support little understory. Saturated margins of the Kaloko Fishpond and nearby beach margins on lava support non-native coastal strand vegetation commonly consisting of (*Batis maritima*) and tree heliotrope (*Tournefortia argentea*).

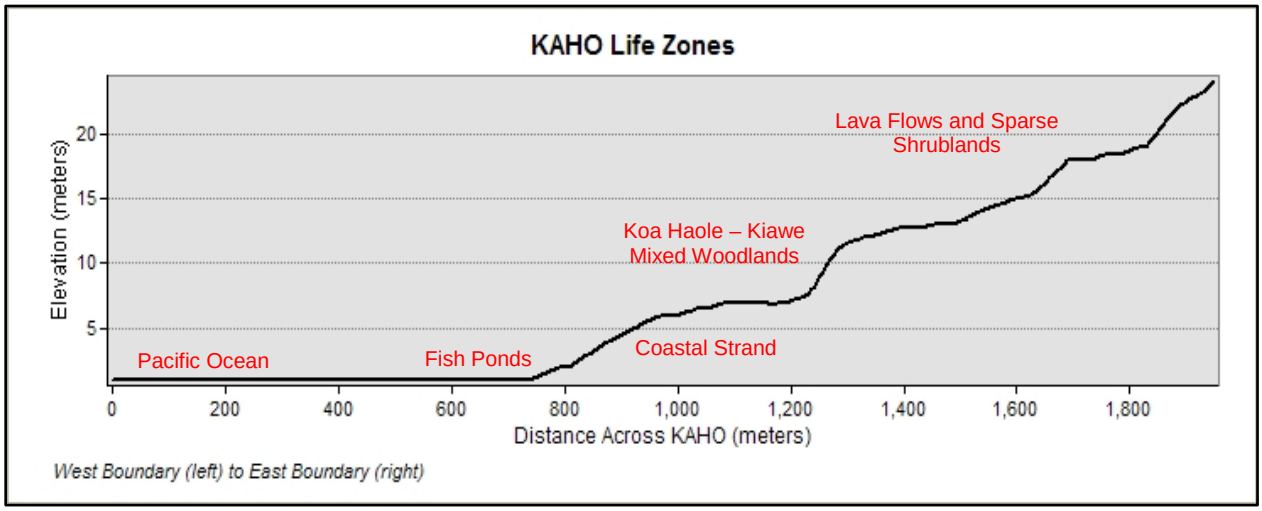
Coatal strand with native or indigenous species are fairly common at KAHO located in close proximity to the ocean, along ponds, or occur in small intermittent drainages. Common coastal strand and wetland native plants include a coastal sedge mau‘u (*Fimbristylis cymosa*), coastal shrub naupaka kahakai (*Scaevola sericea*), and two coastal trees: milo (*Thespesia populnea*) and hau (*Hibiscus tiliaceus*). Additionally, unknown species of marine algae are frequent on the coastal pahoehoe lava and anchialine ponds that are inundated by the Pacific Ocean at high tide.

Ground photo examples of KAHO’s more prominent vegetation communities contained in these life zones are shown in Figure 7.



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

Figure 5. 3D overview image of KAHO and surrounding areas showing common vegetation patterns.



Source: CTI and USGS 10-meter DEM

Figure 6. Representative cross-section of KAHO's topography showing general vegetation life zones.

Non-native Vegetation Control and Revegetation

Restoration of native shrubs and grasses is on-going at KAHO and consists of plantings in the vicinity of the Visitor Center and adjacent parking lot. 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 KAHO. One restoration species is the native bunchgrass pili (*Heteropogon contortus*), thought to be the dominant lowland grass before it was overgrazed and replaced by fountain grass and other exotic species.

In addition to the restoration of native species, KAHO staff has also been actively engaged in controlling and/or eradicating non-native species. One non-native brackish water shrub, the red mangrove (*Rhizophora mangle*) was hand-removed from KAHO in the early 1990s primarily because it was damaging cultural rock structures. KAHO has also used hand-held torches to singe pickleweed stands. Herbicides are continuously employed at KAHO to control hazardous fuels including non-native grasses and shrubs. Recent control efforts of koa haole have resulted in the natural revegetation of 'ilima and 'uhaloa. Fuel breaks are also regularly cleared using non-fire applications.

Fountain grass along the Mamalahoa Trail

Koa haole shrubland with fountain grass understory

‘Uhaloa shrubland

Kiawe woodland (upper beach margin)

Pili grass and native loulu palm reintroductions

Milo woodland

Figure 7. Common vegetation types at KAHO.

Hau woodland

Seashore paspalum (*Paspalum vaginatum*) (center)

Marine algae on pahoehoe lava

Pickleweed dwarf-shrubland

Naupaka kahakai shrubland

Coconut palm woodland

Figure 7. Common vegetation types at KAHO (continued).

Tree heliotrope woodlands (trail) Tree heliotrope woodlands (picnic grounds)

Figure 7. Common vegetation types at KAHO (continued).

Vegetation Inventory Project

The specific decision to classify and map the vegetation at KAHO 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 KAHO 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 KAHO 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. 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 KAHO-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 KAHO occurred within an approximate 878 ha (2,170 ac) project boundary, encompassing the boundary of KAHO (as provided by PACN) and a general 0.5 km (0.31 mi) environ radius on the north, south and west sides and 75 m (0.05 mi) on the east side of KAHO (adjacent to Highway 19) (Figure 8). The final project area determination was based on management needs, financial constraints, and time limitations. The nominal 0.5 km environs were used in this project to insure completeness and to capture some minimal data for various management considerations outside of KAHO (such as non-native plant vectors). Since the area east of KAHO and Highway 19 is heavily developed, mapping stopped along the highway on this side of the park. 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.

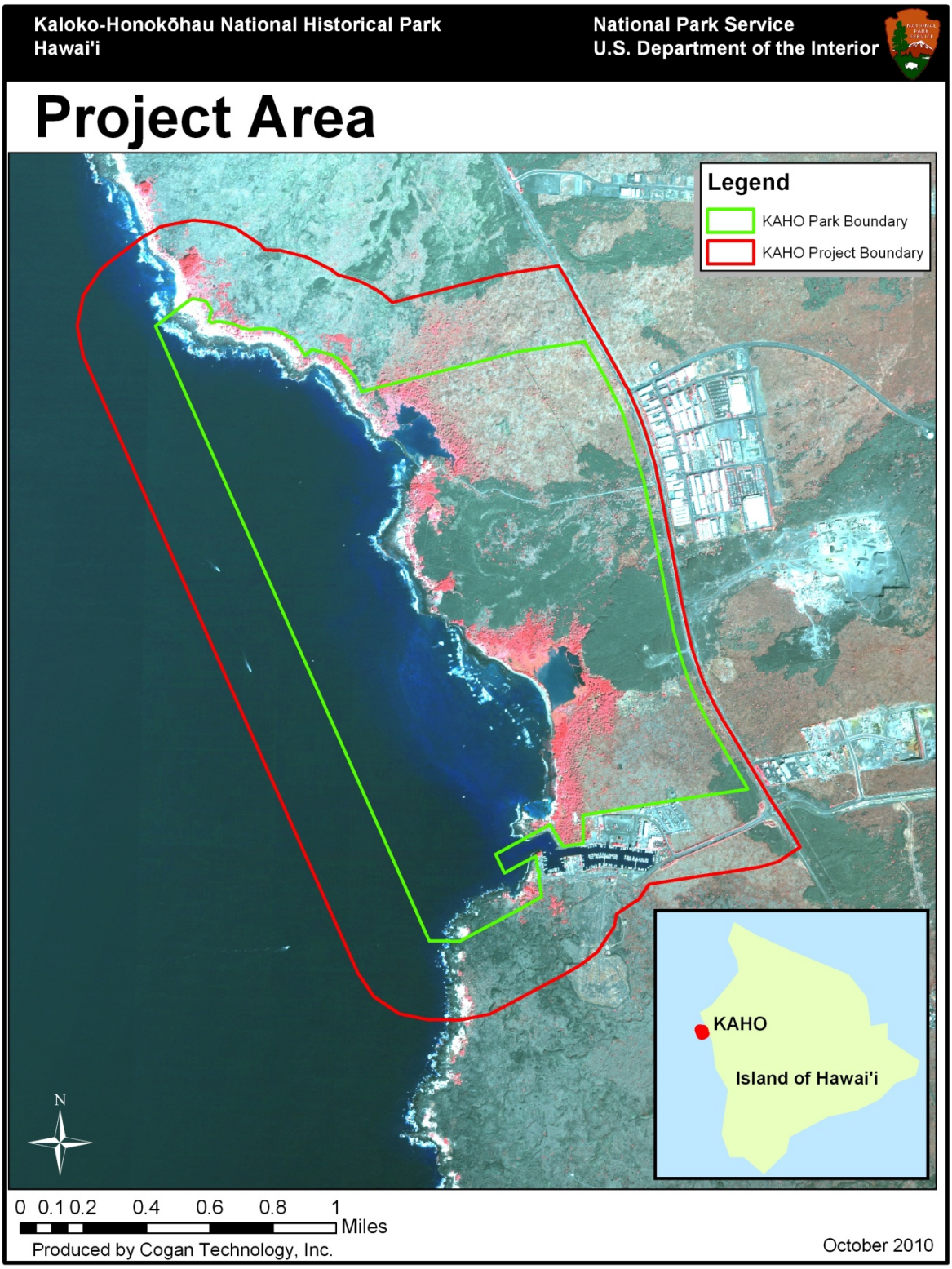


Figure 8. The vegetation mapping project boundary and KAHO park boundary.

Methods

The vegetation mapping project at KAHO 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 KAHO 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 KAHO 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 Hawaiʻi. The specific imagery tiles covering the KAHO 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 KAHO, but due to cloud cover and ensuing changes at KAHO 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 KAHO 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 KAHO;
- 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 KAHO;
- Write a field key to the vegetation types found at KAHO;
- Write vegetation sections (classification methods, results and discussion) for 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 KAHO followed the methodology outlined by the NVIP (TNC and ESRI 1994b) for small sized parks. 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 KAHO 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 KAHO (Table 2).

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

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 to 10 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 creation of local descriptions (Appendix E). 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, and a total of three 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 KAHO 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 KAHO staff including invasive plant stands;
- To document a vegetation type that consistently occurred in stands smaller than the 0.5 ha (1.2 ac) 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 33 classification plots and 22 observation points (Figure 9).

Vegetation Classification

The first step in classifying the vegetation at KAHO 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 Hawaiʻi. This list covered a much broader area than the KAHO project area and included many types that occur in the park, as well as associations that may occur in other parks 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 typos. 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 KAHO plot and observation data contained within the database with the similar data obtained at PUHE and PUHO (137 total). The first review indicated 49 field observations did not have enough detail to fit the analysis 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.

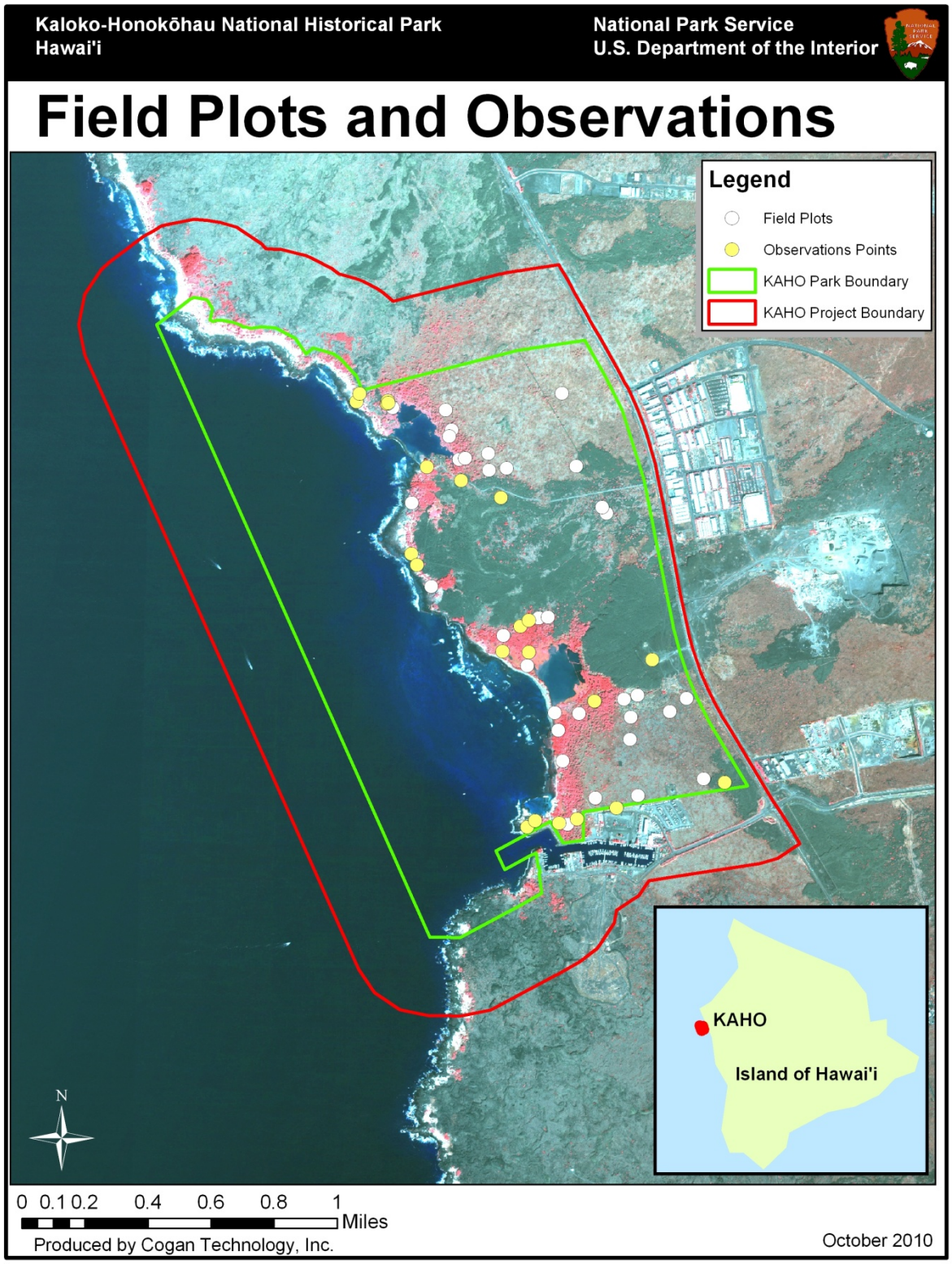


Figure 9. Location of vegetation plots and observation points collected at KAHO.

After standardizing the database, NatureServe found some additional inconsistencies when the field crews assigned taxa to strata. To correct these issues, NatureServe ecologists first, equalized the strata so that all shrub and herbaceous vegetation (included tree seedlings) were in the proper strata. NatureServe 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 NVC is that of the Integrated Taxonomic Information System (ITIS) as reflected by the PLANTS Database (USDA -NRCS 2007). For this study, wom NVCS names were modified based on Wagner and Herbst (2003) and Wagner et al. (1999). 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 KAHO, PUHO 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 10 and 11). 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 KAHO or PUHO 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 parks 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).

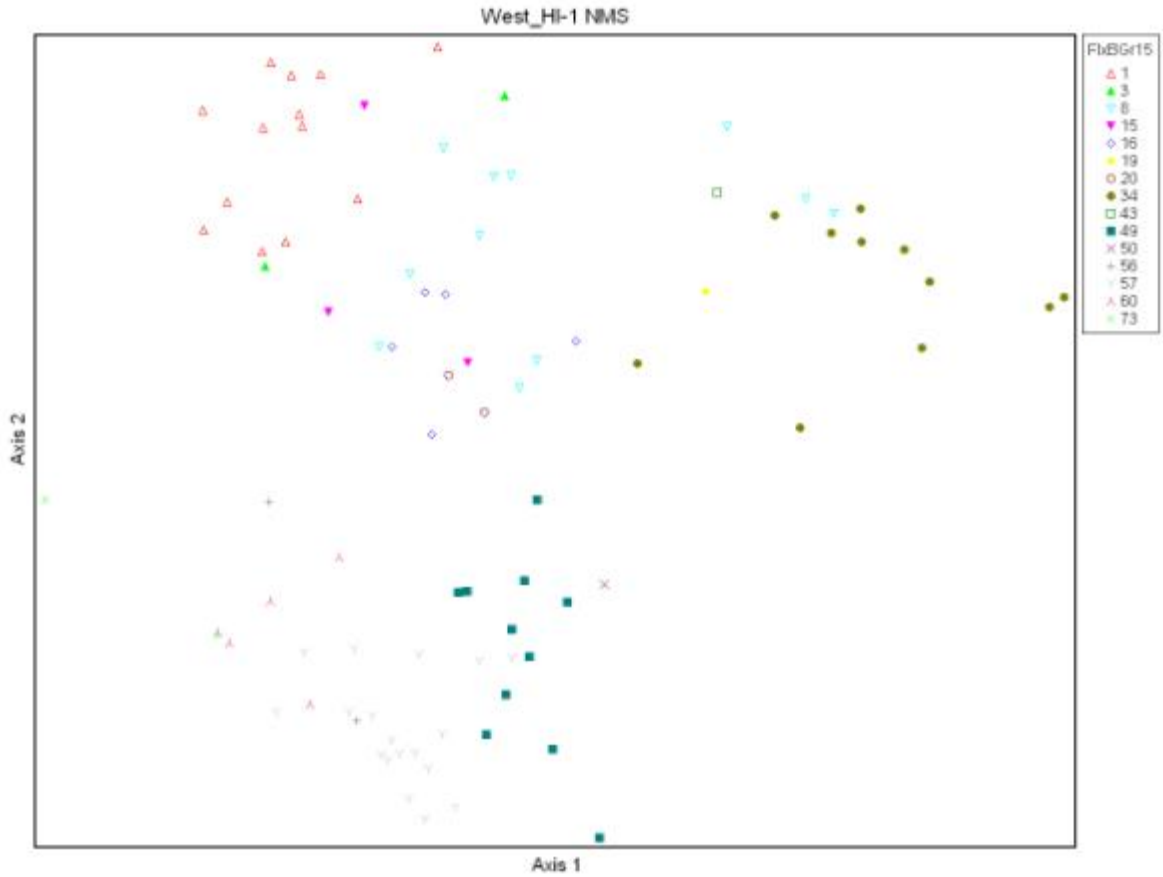


Figure 10. Distribution of 15 cluster analysis plot groups defined from West Hawaiʻi parks using Nonmetric Multidimensional Scaling (NMS) ordination.

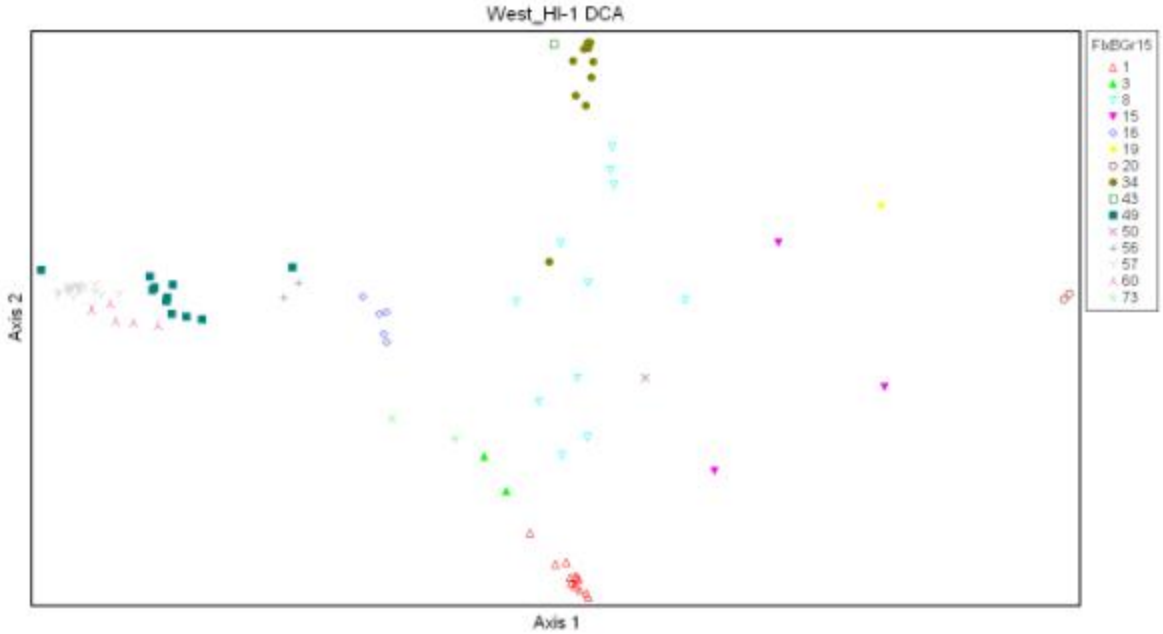


Figure 11. Distribution of 15 cluster analysis plot groups defined from West Hawaiʻi parks using Detrended Correspondence Analysis (DCA) ordination.

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
Cenchrus ciliaris	92.2	*Pennisetum setaceum*	73.9
Batis maritima	88	*Tournefortia argentea*	66.7
Schinus terebinthifolius	85	*Sesuvium portulacastrum*	66.7
Pithecellobium dulce	80.8	*Leucaena leucocephala*	59.1
Prosopis pallida	80.6	*Bidens pilosa*	57.7

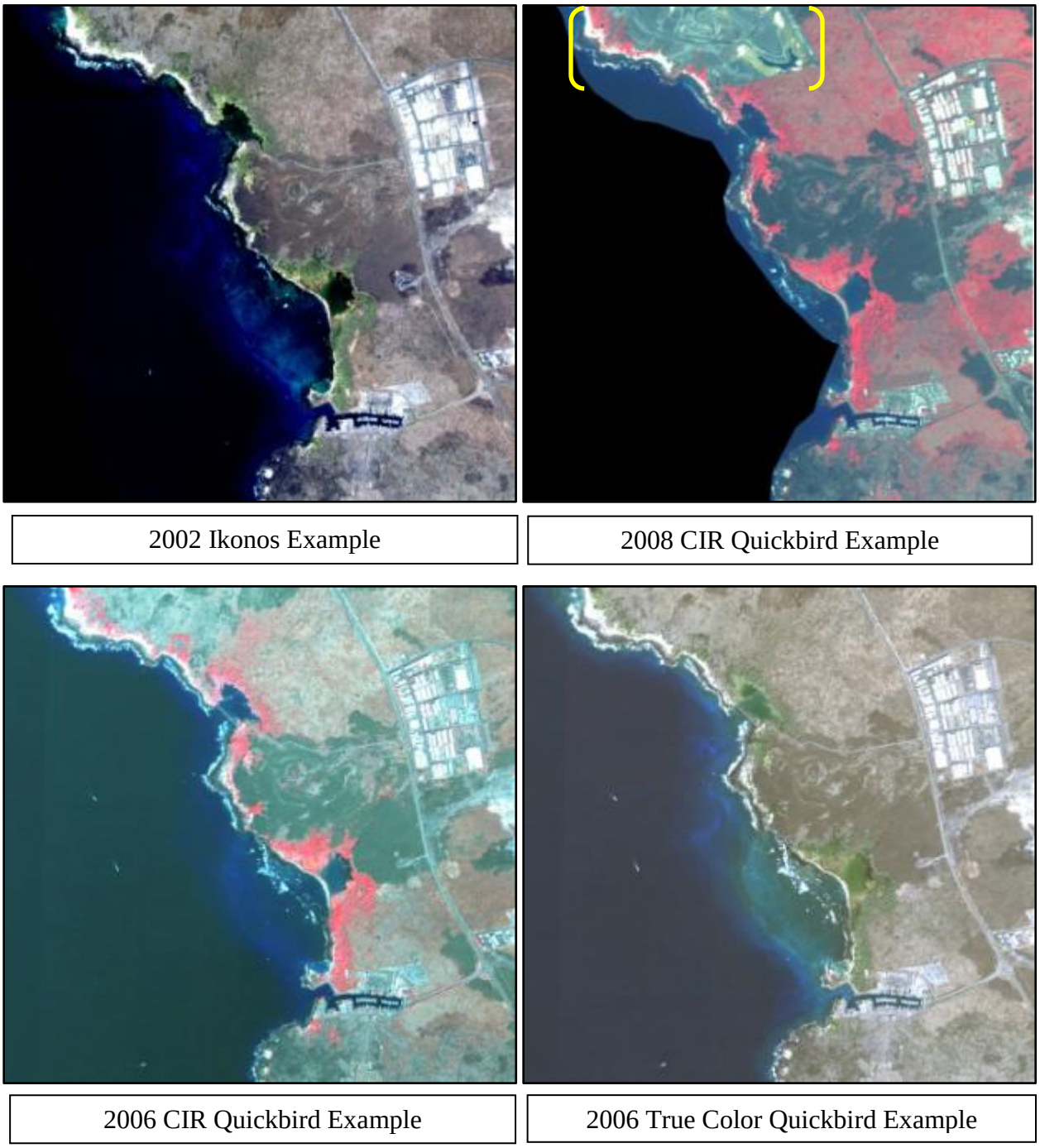
To supplement the initial classification results and to finalize the vegetation classification, NatureServe ecologists also used ordination to examine a portion of the draft classification and displayed the types over the ordination results (quantitative analysis) using DCA and NMS methods. The results 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.

Digital Imagery and Mapping

Since KAHO represented a fairly small and accessible site, no new imagery or aerial photography was 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 12). 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 reviewing the imagery it was determined that both sets did not reflect the most recent landscape changes at KAHO. Specifically, since 2006 KAHO has completed its new visitor center and access road and the areas north of KAHO have been cleared for development. Based on these recent changes a newer Quickbird image was obtained from PACN. This additional image was also a 4-band, 2-meter resolution Quickbird scene acquired in 2008 (Figure 10). The 2008 lacked the resolution of the 2006 image but did reflect the most recent changes at KAHO.



***Note recent development north of KAHO (upper right corner)**

Figure 12. Examples of the Ikonos 2002, Quickbird 2006, and Quickbird 2008 imagery for KAHO.

After obtaining all three sets, the 2006 and 2008 imagery were color balanced in Imagine Software to remove some of the edge-matching issues and sharpen the images. The 2002 imagery was also color balanced, but edge-matching was not preformed. The resulting images from 2006 and 2008 were pieced together as a mosaic and clipped to just beyond the extent of the project boundary. Since the 2006 imagery had better resolution it was used as the primary basemap and the 2008 scene was used to supplement the mapping by incorporating all of the landscape and vegetation changes at KAHO since 2006.

Interpretation of the vegetation at KAHO 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, 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 KAHO 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 KAHO, PUHO 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 one association or alliance to one 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 KAHO to cover types that occurred either outside of the park boundary or were 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).

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 m (33 ft) away from any polygon boundary and 50 m (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 KAHO.

Table 7. Polygon attribute items and descriptions used in the KAHO 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)

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 roughly up to 50 m (165 ft) radius (Figure 13). 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 90 points were sampled (Figure 14). 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 13. Accuracy assessment field data collection at KAHO.

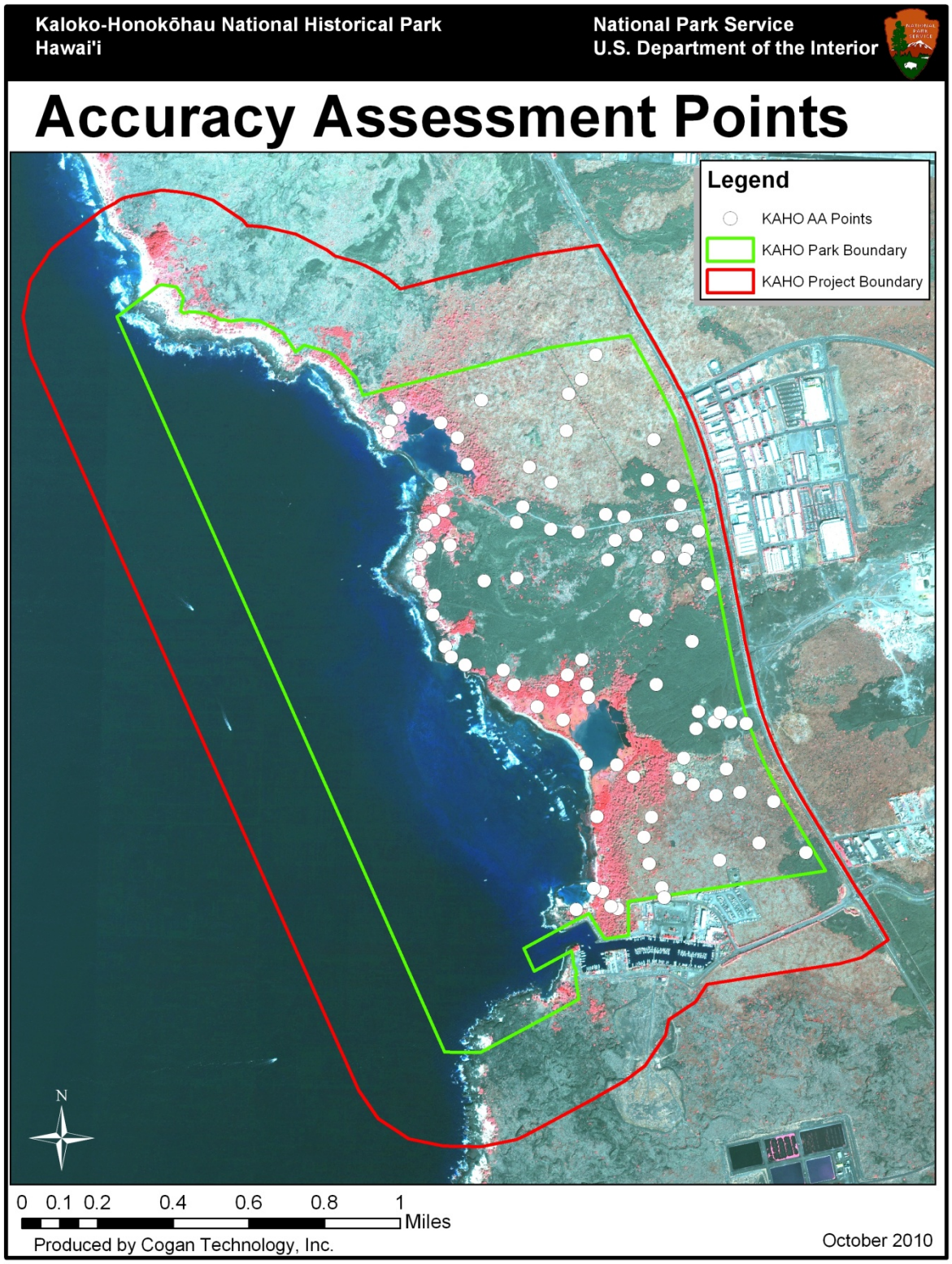


Figure 14. Location of accuracy assessment points collected at KAHO.

Results

Vegetation Classification

This combined classification for the West Hawai‘i Parks (KAHO, PUHO 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 KAHO resulted in 14 vegetation types. When summarized by class, KAHO contained five woodlands, five shrublands, two herbaceous vegetation types, and two sparsely vegetated types. The KAHO classification includes a total of eleven rUSNVC Associations and three Park Specials, representing nine Alliances and six Groups. Table 10 lists the final KAHO classification up to group level of the rUSNVC.

The KAHO classification is based on plot data sampled by field crews. However, there are four additional vegetation types in the map legend that are not in the KAHO vegetation classification. These include: (1) Mixed Semi-natural / Ornamental Tree Woodland (2) Pili Planted Herbaceous Vegetation, (3) Pahoehoe Lava Sparse Vegetation, and (4) Sourbush (*Pluchea carolinensis*) / Pickleweed Semi-natural Shrubland. These types were identified during accuracy assessment and mapped at KAHO or in the buffer area. These additional types are unclassified map units and included in the field key (Appendix D), but local descriptions were not written because KAHO plot data to create descriptions were not collected at KAHO. Appendix E contains all of the association descriptions from the final classification.

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	**KAHO**	**PUHE**	**PUHO**	**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]	1	1	6	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	9	10	1	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]	3	1	1	5
Tournefortia argentea Semi-natural Woodland	2			2
Waltheria indica - Sida fallax Shrubland[1]	6		1	7
Total number of plots	54	26	54	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 10. KAHO vegetation classification with rUSNVC hierarchy to Group level.

Association Name	Common Name	Elcode[1]	Alliance Name	A.Key[2]	Group Name
Woodlands (Native and Polynesian introduced)					
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
Woodland (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
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
Tournefortia argentea Semi-natural Woodland	Tree Heliotrope Semi-natural Woodland	CEGL 005413	*(Samanea saman - Schinus terebinthifolius - Pithecellobium dulce - Tournefortia argentea)* Ruderal Woodland Alliance	A.2695	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
Shrublands (Ruderal)					
Batis maritima Semi-natural Dwarf-shrubland	Pickleweed Semi-natural Dwarf-shrubland	CEGL 005401	*Batis maritima* Coastal Ruderal Dwarf-shrubland Alliance	A.2692	Hawaiian Ruderal Scrub & Herb Coastal Strand Group
Bougainvillea glabra Semi-natural / Planted Shrubland	Bougainvillea Semi-natural / Planted Shrubland	Park Special	N/A	N/A	N/A
Leucaena leucocephala / Pennisetum setaceum Semi-natural Shrubland	Koa Haole / Fountain Grass Semi-natural Shrubland	CEGL 005403	*Leucaena leucocephala* Lowland Ruderal Shrubland Alliance	A.2700	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 10. KAHO vegetation classification with rUSNVC hierarchy to Group level (continued).

Association Name	Common Name	Elcode[1]	Alliance Name	A.Key[2]	Group Name
Herbaceous Vegetation (Ruderal)					
Paspalum vaginatum Semi-natural Herbaceous Vegetation	Seashore Paspalum Semi-natural Herbaceous Vegetation	CEGL 005406	*(Cenchrus ciliaris / Pennisetum setaceum)* - Mixed Medium-Tall Ruderal Grassland Alliance[3]	A.2693	Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group
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
Sparse Vegetation					
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
Unclassified Map Units[4]					
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	Hawaiian Ruderal Dry-Site Lava Flow Group
Pluchea carolinensis / Batis maritima Semi-natural Shrubland	Sourbush / Pickleweed Semi-natural Shrubland	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).
[4] Additional vegetation types identified and mapped at KAHO, but not sampled with field plots.

Digital Imagery and Mapping

For KAHO, 30 map units (18 vegetated, five barren, and seven 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). KAHO 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 for all of the vegetation map units.

The following types represent the possible map scenarios for the KAHO 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 KAHO.
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 KAHO vegetation map consisted of 634 polygons totaling 878 ha (2,170 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 exotic 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 the NPS consisted of almost 515 ha (1,273 ac) representing about 59% of the total project area. Of the NPS land, 45% (233 ha) consisted of ocean and bays. The remaining mapping in the environs consisted of a mixture of private, state and county lands totaling 363 ha (898 ac). Of the total 634 polygons, a majority (23% or 200 ha) were comprised of the dominant non-native vegetation (S_LEPE, W_PRPA and H_PESE map units). The most prevalent map class in terms of polygons (115 polygons) was the Kiawe Coastal Dry Semi-natural Woodland that represented many isolated stands scattered across the lava beds.

The KAHO vegetation map should more appropriately be considered a spatial database that also contains many additional polygon attributes not presented in the preceding table. The 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 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 exotic vegetation types along with high density (>60%) and the tallest height class (5to15 m). Figure 15 is an example of a fine scale (1:6,000-scale) KAHO vegetation map 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 map units.

Map Code	Map Class Name	rUSNVC Association Assigned to Map Class (or Map Unit Description)	Relationship
W_CONU	*Cocos nucifera* Strand Woodland	*Cocos nucifera* Strand Woodland	1 : 1
W_ORNA	Mixed Semi-natural / Ornamental Tree Woodland	(No Association -Planted)	Unclassified Map Unit
W_PRPA	*Prosopis pallida* Coastal Dry Semi-natural Woodland	*Prosopis pallida* Coastal Dry Semi-natural Woodland	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
W_TOAR	*Tournefortia argentea* Semi-natural Woodland	*Tournefortia argentea* Semi-natural Woodland	1 : 1
S_BOGL	*Bougainvillea glabra* Semi-natural / Planted Shrubland	*Bougainvillea glabra* Semi-natural / Planted Shrubland	1 : 1
S_LEPE	*Leucaena leucocephala / Pennisetum setaceum* Semi-natural Shrubland	*Leucaena leucocephala / Pennisetum setaceum* Semi-natural Shrubland	1 : 1
S_PLCA	*Pluchea carolinensis / Batis maritima* Semi-natural Shrubland	(No Association)	Unclassified Map Unit
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
DS_BAM	*Batis maritima* Semi-natural Dwarf-shrubland	*Batis maritima* Semi-natural Dwarf-shrubland	1 : 1
H_HECO	*Heteropogon contortus* Planted Herbaceous Vegetation	(No Association -Planted)	Unclassified Map Unit
H_PAVA	*Paspalum vaginatum* Semi-natural Herbaceous Vegetation	*Paspalum vaginatum* Semi-natural Herbaceous Vegetation	1 : 1
H_PESE	*Pennisetum setaceum* Semi-natural Herbaceous Vegetation	*Pennisetum setaceum* Semi-natural Herbaceous Vegetation	1 : 1
SV_AA	A‘a Lava with Sparse Vegetation	A‘a Lava with Sparse Vegetation	1 : 1
SV_CS	Coastal Strand Sparse Vegetation	Coastal Strand Sparse Vegetation	1 : 1
SV_PA	Pahoehoe Lava Sparse Vegetation	(No Association)	Unclassified Map Unit

Table 11. Assignment of 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
B_AA	A‘a Lava	(Barren a‘a lava)	Land Use - Cover
B_BE	Beaches	(Barren Sand Beaches)	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_BAY	Bay / Estuary	(Semi-protected bays and estuaries)	Land Use - Cover
L_FACL	Facilities	(NPS buildings and facilities)	Land Use - Cover
L_LIIN	Commercial / Light Industry	(Businesses and surrounding lands in environs)	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

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

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

Map Code	Map Unit Description	NPS Lands			Total Project Area		
		# of Polygons	Acres	Hectares	# of Polygons	Acres	Hectares
W_CONU	*Cocos nucifera* Strand Woodland	3	0.4	0.2	6	3.2	1.3
W_ORNA	Mixed Semi-natural / Ornamental Tree Woodland	0	0.0	0.0	2	2.5	1.0
W_PRPA	*Prosopis pallida* Coastal Dry Semi-natural Woodland	94	96.1	38.9	115	115.8	46.9
W_SCTE	*Schinus terebinthifolius* / *Pennisetum setaceum* Semi-natural Woodland	21	15.5	6.3	22	19.5	7.9
W_THPO	*Thespesia populnea* / Sparse Understory Woodland	35	24.1	9.8	42	26.6	10.8
W_TOAR	*Tournefortia argentea* Semi-natural Woodland	24	10.4	4.2	28	11.9	4.8
S_BOGL	*Bougainvillea glabra* Semi-natural / Planted Shrubland	0	0.0	0.0	9	2.5	1.0
S_LEPE	*Leucaena leucocephala / Pennisetum setaceum* Semi-natural Shrubland	26	172.2	69.7	26	234.9	95.1
S_PLCA	*Pluchea carolinensis / Batis maritima* Semi-natural Shrubland	1	0.2	0.1	1	0.2	0.1
S_SCTA	*Scaevola taccada* Coastal Dry Shrubland	11	2.0	0.8	11	2.4	1.0
S_WAIN	*Waltheria indica - Sida fallax* Shrubland	17	17.3	7.0	17	18.0	7.3
DS_BAM	*Batis maritima* Semi-natural Dwarf-shrubland	20	9.3	3.8	23	10.5	4.3
H_HECO	*Heteropogon contortus* Planted Herbaceous Vegetation	4	0.3	0.1	4	0.3	0.1
H_PAVA	*Paspalum vaginatum* Semi-natural Herbaceous Vegetation	10	7.0	2.8	11	7.3	3.0
H_PESE	*Pennisetum setaceum* Semi-natural Herbaceous Vegetation	45	48.9	19.8	59	144.8	58.6
SV_AA	A‘a Lava Sparse Vegetation	32	29.9	12.1	47	43.2	17.5
SV_CS	Coastal Strand Sparse Vegetation	35	6.8	2.8	39	8.4	3.4
SV_PA	Pahoehoe Lava Sparse Vegetation	2	3.2	1.3	2	20.6	8.3
B_AA	A‘a Lava	22	143.4	58.1	25	161.9	65.6
B_BE	Beaches	16	12.9	5.2	19	17.0	6.9
B_DL	Developed Lava	18	9.7	3.9	54	149.9	60.7
B_ER	Exposed Reef and Tidal Pools	15	18.1	7.3	16	19.1	7.7
B_PA	Pahoehoe Lava	13	33.5	13.6	15	42.5	17.2
L_BAY	Bay / Estuary	1	2.5	1.0	2	19.3	7.8

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

Map Code	Map Unit Description	NPS Lands			Total Project Area		
		# of Polygons	Acres	Hectares	# of Polygons	Acres	Hectares
L_FACL	Facilities	5	1.3	0.5	5	1.3	0.5
L_LIIN	Commercial / Light Industry	0	0.0	0.0	12	5.1	2.1
L_POND	Lake / Pond	9	23.6	9.6	15	27.2	11.0
L_RESD	Residential	0	0.0	0.0	2	4.0	1.6
L_ROAD	Transportation	9	10.2	4.1	4	57.7	23.4
L_SEA	Sea / Ocean	1	573.6	232.3	1	992.7	402.0
	Total Vegetation	380	443.6	179.7	464	672.6	272.4
	Total Barren Geology	84	217.6	88.1	129	390.4	158.1
	Total Land Use / Land Cover	25	611.2	247.5	41	1107.3	448.5
	Totals	489	1272.4	515.3	634	2170.3	879.0

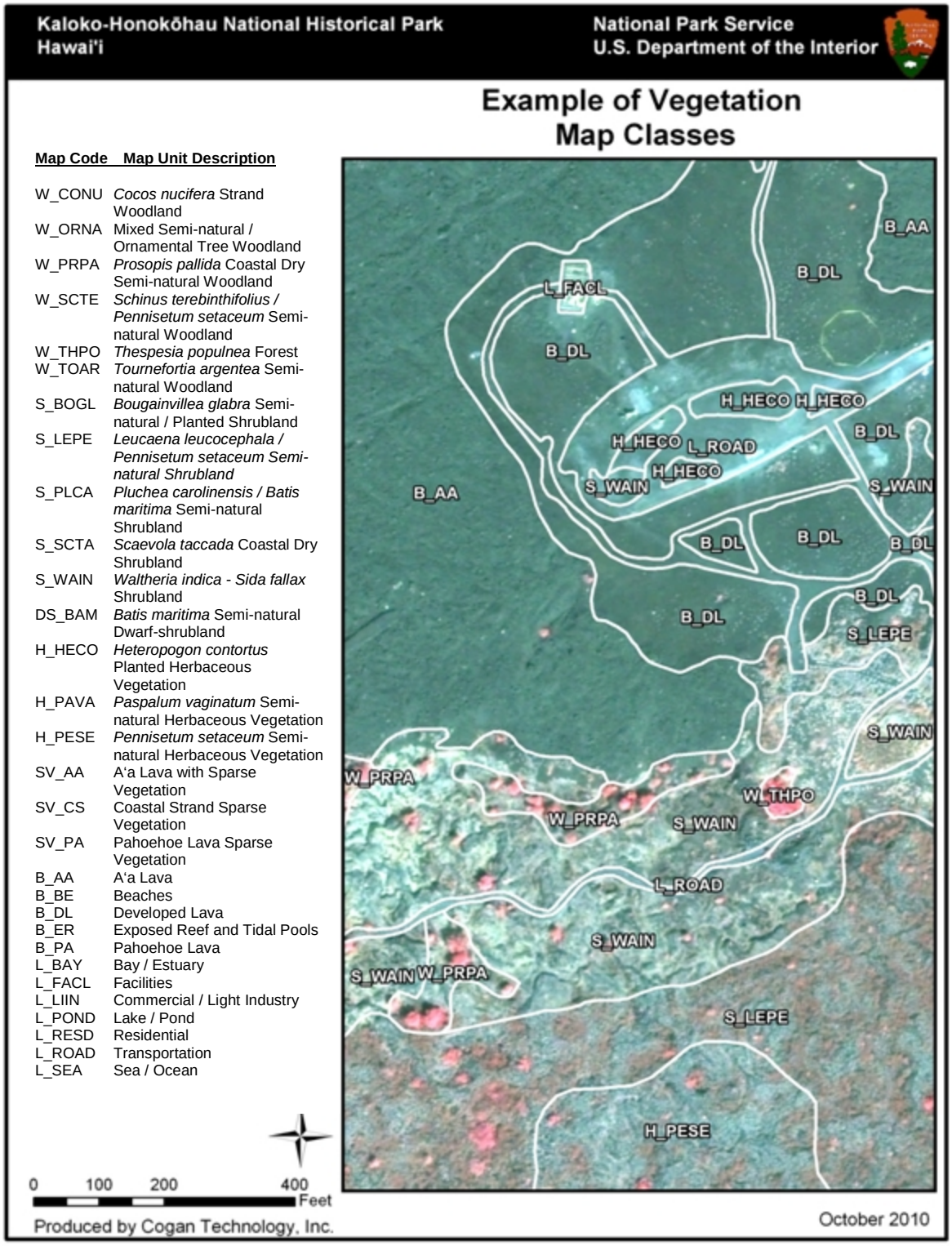


Figure 15. Example of the KAHO vegetation map layer.

Accuracy Assessment

The 2010 AA effort yielded 90 points distributed throughout KAHO. In addition to using the AA points in the map analysis, many of the points were also used to update the classification and to revise the field key and local descriptions. Upon review of the data, one point was removed from analysis since it couldn't be accurately keyed to any map unit. This yielded a final AA sample size of 89 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 KAHO vegetation layer was found to be 86%. 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;
- AA Point: KAHO.AA.0061 was removed from analysis since the vegetation at could not be keyed (i.e. Undescribed Vegetation);
- The Sourbush / Pickleweed Semi-natural Shrubland type was retained with low accuracy since it likely occurs at KAHO but is very rare. The one polygon of this type was adjusted since the original plot data collected at this site was incorrectly entered into the database (i.e. less cover of PLCA than documented);
- The Naupaka Kahakai Coastal Dry Shrubland type was not sampled during the AA but was retained as a valid map unit (future AA work maybe conducted by PACN to better document this type);
- Coastal Strand Sparse Vegetation was retained with lower accuracy although more field work maybe needed to better document this type;
- The Kiawe Coastal Dry Semi-natural Woodland was retained with lower accuracy;
- The Christmas Berry /Fountain Grass Semi-natural Woodland was retained with lower accuracy;
- The Pili Planted Herbaceous Vegetation map unit was retained as an unclassified map unit;
- 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 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 KAHO. Columns represent predicted mapping unit names (polygon labels) and rows represent AA observation names (field calls).

Map Code	W_CONU	W_PRPA	W_SCTE	W_THPO	W_TOAR	S_BOGL	S_LEPE	S_PLCA	S_SCTA	S_WAIN	DS_BAM	H_HECO	H_PAVA	H_PESE	SV_AA	SV_CS	SV_PA	B_AA	B_DL	Row Total
W_CONU	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
W_PRPA	0	**11**	**2**	0	0	0	**2**	0	0	0	0	0	0	0	**1**	0	0	0	0	**16**
W_SCTE	0	0	**3**	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	**4**
W_THPO	0	0	0	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
W_TOAR	0	0	0	0	**7**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**7**
S_BOGL	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
S_LEPE	0	0	0	0	0	0	**14**	0	0	0	0	0	0	**3**	0	0	0	0	0	**17**
S_PLCA	0	**1**	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	**1**
S_SCTA	0	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	**0**
S_WAIN	0	0	0	0	0	0	0	0	0	**4**	0	0	0	0	**1**	0	0	0	0	**5**
DS_BAM	0	0	0	0	0	0	0	0	0	0	**5**	0	0	0	0	0	0	0	0	**5**
H_HECO	0	0	0	0	0	0	0	0	0	0	0	**2**	0	0	0	0	0	0	0	**2**
H_PAVA	0	0	0	0	0	0	0	0	0	0	0	0	**4**	0	0	0	0	0	0	**4**
H_PESE	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**	0	0	0	0	0	**3**
SV_AA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**	0	0	0	0	**3**
SV_CS	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	**2**
SV_PA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	**1**
B_AA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**10**	0	**10**
B_DL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**	**2**
Column Total	**3**	**12**	**5**	**3**	**8**	**1**	**16**	**0**	**0**	**4**	**5**	**2**	**4**	**7**	**5**	**1**	**1**	**10**	**2**	

Table 14. Population Contingency Table for KAHO.

Map Code	W_CONU	W_PRPA	W_SCTE	W_THPO	W_TOAR	S_BOGL	S_LEPE	S_PLCA	S_WAIN	DS_BAM	H_HECO	H_PAVA	H_PESE	SV_AA	SV_CS	SV_PA	B_AA	B_DL	1	2	3	4
W_CONU	0.003	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%	83%	100%	0.3%
W_PRPA	0.000	0.081	0.015	0.000	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.000	0.000	0.000	0.000	69%	47%	91%	11.8%
W_SCTE	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	75%	27%	100%	2.0%
W_THPO	0.000	0.000	0.000	0.027	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%	83%	100%	2.7%
W_TOAR	0.000	0.000	0.000	0.000	0.012	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%	93%	100%	1.2%
S_BOGL	0.000	0.000	0.000	0.000	0.000	0.003	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%	0.3%
S_LEPE	0.000	0.000	0.000	0.000	0.000	0.000	0.197	0.000	0.000	0.000	0.000	0.000	0.042	0.000	0.000	0.000	0.000	0.000	82%	64%	100%	23.9%
S_PLCA	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	0.000	0	0	50%	0
S_WAIN	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.015	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	80%	41%	100%	1.8%
DS_BAM	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	100%	90%	100%	1.1%
H_HECO	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	0.000	100%	75%	100%	0.0%
H_PAVA	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.000	100%	88%	100%	0.8%
H_PESE	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.147	0.000	0.000	0.000	0.000	0.000	100%	83%	100%	14.7%
SV_AA	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	0.044	0.000	0.000	0.000	0.000	100%	83%	100%	4.4%
SV_CS	0.000	0.000	0.000	0.000	0.004	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	50%	0	100%	0.9%
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	0.021	0.000	0.000	100%	50%	100%	2.1%
B_AA	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	0.165	0.000	100%	95%	100%	16.5%
B_DL	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	0.153	100%	75%	100%	15.3%
A	100%	100%	50%	100%	74%	100%	93%	0%	100%	100%	100%	100%	76%	80%	100%	100%	100%	100%				
B	100%	98%	49%	100%	74%	100%	90%	0%	100%	100%	100%	100%	75%	80%	100%	100%	100%	100%				
C	100%	102%	52%	100%	74%	100%	96%	0%	100%	100%	100%	100%	77%	80%	100%	100%	100%	100%				
D	1.3	32.3	11.8	10.8	6.5	1.0	84.0	0.0	5.8	4.3	0.1	3.0	77.2	21.8	1.7	8.3	65.4	60.6				

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 = pi+, PROPORTIONS OF TOTAL AREA MAPPED AS TYPE

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

OVERALL ACCURACY (P_c)	=	97.4%
LOWER LIMIT, 90% CONFIDENCE INTERVAL	=	95.5%
UPPER LIMIT, 90% CONFIDENCE INTERVAL	=	99.4%
KAPPA (**K**):	=	82.1%
LOWER LIMIT, 90% CONFIDENCE INTERVAL, **K**	=	78.5%
UPPER LIMIT, 90% CONFIDENCE INTERVAL, **K**	=	91.7%

Examination of the contingency tables finds that 16 out of 18 vegetated map classes for KAHO were accessed. The Naupaka Kahakai Coastal Dry Shrubland was not accessed since this type was added after the AA field work had begun and no targets for this type were selected. The Mixed Semi-natural / Ornamental Tree Woodland map unit type was only used for two polygons off the park in the northern environs. In addition to the vegetation, PACN requested that additional AA points be placed in the barren classes that occur in the park. To accommodate this request, 10 targets were placed in the barren a‘a lava and two were placed in the barren developed lava types.

All of the classes that were accessed had high user’s accuracy except for the W_PRPA, W_SCTE, S_PLCA, and SV_CS map classes. It is likely that the two woodland types were often confused with each other since they intermixed at KAHO and had a similar signature on the imagery. The shrubland type was very rare (only one documented location) and the coastal strand sparse vegetation class was likely confused with overstory trees that were in close proximity. The accuracy for four of these types were accepted by PACN and left in the map layer due to their importance for resource management.

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_PESE but were actually a part of larger S_LEPE or W_SCTE polygons. Also the intricate intermingling of the coastal strand map units (SV_CS, W_TOAR in particular) 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

Kaloko-Honokōhau National Historical Park is truly a special place combining a rich mix of ancient archeological sites, fish ponds, and remnants of native coastal plant communities. Across this landscape a variety of non-native plants thrive in arid habitats typical of the leeward coast of Hawai‘i. The ruggedness of the a‘a 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 KAHO 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 KAHO 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 will improve 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 or surrounding 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 KAHO with only one early Polynesian introduced type (Coconut Palm Strand Woodland) and four native dominated vegetation types of the 14 classified. Most of these native and Polynesian introduced vegetation types occurred on all three parks and were sampled on or near coastal strand or were being re-introduced through plantings. The native plant communities include the Coastal Strand Sparse Vegetation [Park Special], Naupaka Kahakai Coastal Dry Shrubland, Milo / Sparse Understory Woodland, and ‘Uhaloa -‘Ilima Shrubland Shrubland. Native species such as milo are given higher diagnostic value over non-native species in determining the vegetation type, thereby skewing the classification. It is important to remember that a native vegetation type may still have a high level of non-native species (via disturbance) but as long as the non-native species does not strongly dominate the vegetation type (i.e. not complete conversion to non-native type); the stand may be characterized as a poor condition example of a native plant community.

Ecologically there are a number of closely related vegetation types at KAHO that may be confusing to distinguish in the field, especially grasslands with scattered trees and/or shrubs versus open shrublands or woodlands. There is a continuum of tree and shrub densities from grasslands with no woody species, to scattered shrub and trees, to dense woodlands and shrublands. Rather than have three analogs of very similar floristic composition (grasslands with sparse shrubs or trees, grasslands with moderate shrubs or trees, and shrubland and woodlands with dense 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. For woodlands, shrub cover may be high (exceeding the tree cover) if tree cover is 20% or more. It is important to note that koa haole was considered a shrub and not a small tree in the classification.

NatureServe analyzed data from all three of the West Hawai‘i parks (KAHO, PUHE, and PUHO) together since they have similar plant species, vegetation structure, 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 A‘a Lava with Sparse Vegetation and Coastal Strand Sparse Vegetation types were only sampled in KAHO, but also occurred and were mapped at PUHE and PUHO. In these parks most of the vegetation was non-native and characterized as ruderal in disturbed areas. Introduced 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 introduced species.

At KAHO there were three types that also occur in PUHE and PUHO including: Coconut Palm Strand Woodland, Kiawe Coastal Dry Semi-natural Woodland, and Milo / Sparse Understory Woodland. Two other types, Naupaka Kahakai Coastal Dry Shrubland and ‘Uhaloa -‘Ilima Shrubland also occur at PUHO. The majority of the plots representing Kiawe Coastal Dry Semi-natural Woodland, Milo / Sparse Understory Woodland, Christmas Berry / Fountain Grass Semi-natural Woodland, Koa Haole / Fountain Grass Semi-natural Shrubland, ‘Uhaloa -‘Ilima Shrubland, Pickleweed Semi-natural Dwarf-shrubland and Fountain Grass Semi-natural

Herbaceous Vegetation were sampled from KAHO. Surprisingly nine of the 14 KAHO vegetation types were not sampled in the other parks.

The distribution of dominant grasses was also interesting. Fountain grass was particularly abundant at KAHO, but not in PUHE or PUHO, although it was sampled a few times at PUHE. Buffelgrass (*Cenchrus ciliaris =Pennisetum ciliare*) was dominant at PUHE and guinea grass (*Panicum maximum = Urochloa maxima*) was dominant at PUHO, although sampled a few times at KAHO as well.

Kiawe Coastal Dry Semi-natural Woodland was abundant at all three parks and exhibited significant variation in the understory. The understories were dominated by the grasses listed above (fountain grass, buffelgrass, and guinea grass), *Talinum fruticosum* or sparse understory. Further classification work in Hawai‘i may justify splitting this type into finer associations based on understory assemblages.

Digital Imagery and Mapping

The vegetation map for KAHO was based on the 2006 and 2008 Quickbird ortho-imagery. Therefore, all of the resulting mapping products correspond to 2008 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 2008 are not included. In the future it would be beneficial to update the map based on newer imagery or from GPS coordinates.

Since KAHO lies on the far western edge of Hawai‘i Island, the park projection is actually in Zone 4 of the Universal Transverse Mercator coordinate grid projection system (UTM). Since this is the only NPS unit on the island of Hawai‘i that isn’t in zone 5 all of the KAHO GIS data layers (plots, AA points, and vegetation map) were re-projected from zone 4 into zone 5 to match the base imagery and to make it compatible with similar data collected at PUHE and PUHO. In the future these data should be re-projected back into zone 4 if taken into the field and any additional data collected to supplement this effort (i.e. ground-truthing points, fire perimeters, etc.) should first be projected into zone 5.

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 difficulty in establishing an overhead perspective

to exactly match the ground view. Although the accuracy for KAHO 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 KAHO 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 KAHO 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 KAHO 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 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.

3. 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**.**

4. 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: KAHO 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 m², 400 m², 1000m²)	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):

2008: Feb 21 ; v3.01 (Plot Form) 1

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 herbaceous vegetation if annuals or perennials are dominant)	Leaf Type (of dominant stratum)	Physiognomic Class (see cheat sheet)	
	___Broad-leaved ___Needle-leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte ___Non-vascular ___Mixed (describe)	___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 ____

T2 CANOPY — Strata Height ____ Strata Cover ____

T3 SUBCANOPY — Strata Height ____ Strata Cover ____

S1 TALL SHRUB (> 2m) — Strata Height ____ Strata Cover ____

S2 SHORT SHRUB (<2m) — Strata Height ____ Strata Cover ____

S3 DWARF SHRUB (< 0.5m) — Strata Height ____ Strata Cover ____

Hr HERBACEOUS Sum of H1, H2, H3, H4 — Strata Height ____ Strata Cover ____

H1 GRAMINOIDS — Strata Height ____ Strata Cover ____

H2 FORBS — Strata Height ____ Strata Cover ____

H3 FERNS & ALLIES — Strata Height ____ Strata Cover ____

H4 TREE SEEDLINGS — Strata Height ____ Strata Cover ____

NONVASCULAR — 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

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 P 1a 1b 02 03 04 05 06 07 08 09 10	< 1% 1-5% 5.01-10% 10.01-15% 15.01-25% 25.01-35% 35.01-45% 45.01-55% 55.01-65% 65.01-75% 75.01-85% 85.01-95% > 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 Kaloko-Honokōhau National Historical Park

71 plant species were encountered while sampling field plots, observation points, and accuracy assessment plots at KAHO. Family, genus species, common names and nativity are reported. One plant species (monkeypod) is included even though it was not present in the sample plots at KAHO because it is 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
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 affinis* Becc.	loulu	Native
Asteraceae	*Bidens hawaiensis* A. Gray	ko‘oko‘olau	Native
Asteraceae	*Bidens micrantha ssp. ctenophylla* (Sherff) Nagata & Ganders	ko‘oko‘olau	Native
Asteraceae	*Crassocephalum crepidioides (Benth.) S. Moore*		Non-Native
Asteraceae	*Pluchea carolinensis* (Jacq.) G. Don	sourbush	Non-Native
Asteraceae	*Pluchea indica* (L.) Less.	Indian fleabane	Non-Native
Bataceae	*Batis maritima* L.	pickleweed	Non-Native
Boraginaceae	*Cordia subcordata* Lam.	kou	Native
Boraginaceae	*Tournefortia argentea* L. fil.	tree heliotrope	Non-Native
Cactaceae	*Opuntia ficus-indica* (L.) Mill.	panini	Non-Native
Capparaceae	*Capparis sandwichiana* DC.	maiapilo	Native
Capparaceae	*Cleome gynandra* L.	wild spider flower	Non-Native
Caricaceae	*Carica papaya* L.	papaya	Non-Native
Chenopodiaceae	*Chenopodium oahuense* (Meyen) Aellen	aheahea	Native
Convolvulaceae	*Ipomoea indica* (Burm. f.) Merr.	koali ‘awa	Native
Convolvulaceae	*Ipomoea pes-caprae* (L.) R. Br.	pōhuehue	Native
Convolvulaceae	*Ipomoea* sp. 1	morning glory	
Convolvulaceae	*Jacquemontia ovalifolia ssp. sandwicensis* (Gray) Robertson	pa‘uohi‘iaka	Native
Crassulaceae	*Kalanchoe pinnata* (Lam.) Pers.	air plant	Non-Native
Cucurbitaceae	*Coccinia grandis* (L.) Voigt	ivy gourd	Non-Native
Cyperaceae	*Bolboschoenus maritimus ssp. paludosus* (A. Nels.) A.& D. Löve	kaluha	Native
Cyperaceae	*Cyperus javanicus* Houtt.	‘ahu‘awa	Native
Cyperaceae	*Fimbristylis cymosa* R. Br.	mau‘u	Native

Family	Genus species	Common Name	Nativity
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
Fabaceae	*Acacia farnesiana* (L.) Willd.	klu	Non-Native
Fabaceae	*Chamaecrista nictitans ssp. patellaria var. glabrata* (Vogel) H. Irwin & Barneby	partridge pea	Non-Native
Fabaceae	*Desmodium tortuosum* (Sw.) DC.	Florida beggarweed	Non-Native
Fabaceae	*Indigofera suffruticosa* Mill.	indigo	Non-Native
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	koa haole	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.[1]	monkeypod	Non-Native
Fabaceae	*Sesbania tomentosa* Hook. & Arnott	‘ohai	Native
Fabaceae	*Tephrosia purpurea var. purpurea* (L.) Pers.	‘auhuhu	Native
Goodeniaceae	*Scaevola taccada* (Gaertn.) Roxb.[2]	naupaka kahakai	Native
Malvaceae	*Abutilon grandifolium* (Willd.) Sweet	ma‘o	Non-Native
Malvaceae	*Abutilon menziesii* Seem.	ko‘oloa‘ula	Native
Malvaceae	*Malvastrum coromandelianum* (L.) Garcke	false mallow	Non-Native
Malvaceae	*Sida fallax* Walp.	‘ilima	Native
Malvaceae	*Thespesia populnea* (L.) Sol. ex Correa	milo	Native
Moraceae	*Ficus benjamina* L.	weeping fig	Non-Native
Myoporaceae	*Myoporum sandwicense* A. Gray	naio	Native
Nyctaginaceae	*Boerhavia coccinea* Mill.		Non-Native
Nyctaginaceae	*Bougainvillea glabra* Choisy	bougainvillea	Non-Native
Papaveraceae	*Argemone glauca* (Nutt. ex Prain) Pope	pua kala	Native
Passifloraceae	*Passiflora foetida* L.	love-in-a-mist	Non-Native
Passifloraceae	*Passiflora suberosa* L.	huehue haole	Non-Native
Poaceae	*Heteropogon contortus* (L.) P. Beauv. Ex roem. & Schult.	pili	Native
Poaceae	*Melinis repens* (Willd.) Zizka	natal redtop	Non-Native
Poaceae	*Panicum maximum* Jacq.[3]	guinea grass	Non-Native
Poaceae	*Paspalum vaginatum* Sw.	seashore paspalum	Non-Native
Poaceae	*Pennisetum setaceum* (Forsk.) Chiov.	fountain grass	Non-Native
Poaceae	*Sporobolus virginicus* (L.) Kunth	‘aki‘aki	Native
Portulacaceae	*Portulaca pilosa* L.		Non-Native
Portulacaceae	*Talinum fruticosum* (L.) Juss.		Non-Native
Rubiaceae	*Morinda citrifolia* L.	noni	Non-Native
Sapindaceae	*Dodonaea viscosa* Jacq.	a‘ali‘i	Native
Scrophulariaceae	*Bacopa monnieri* (L.) Pennell	‘ae‘ae	Native
Solanaceae	*Lycium sandwicense* A. Gray	‘ohelo kai	Native
Sterculiaceae	*Waltheria indica* L.	‘uhaloa	Native
Verbenaceae	*Lantana camara* L.	lantana	Non-Native

Family	Genus species	Common Name	Nativity
Verbenaceae	*Stachytarpheta jamaicensis* (L.) Vahl	Jamaica vervain	Non-Native
Zygophyllaceae	*Tribulus terrestris* L.	puncture vine	Non-Native

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

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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.

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

At Kaloko-Honokōhau National Historical Park 55 plots and observation points assigned to revised US National Vegetation Classification (rUSNVC) associations and park specials. A total of 11 rUSNVC associations, three "Park Specials" and one cultural type 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 NVC 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
Woodland			
Cocos nucifera Strand Woodland	CEGL005402	1	KAHO.0600
Prosopis pallida Coastal Dry Semi-natural Woodland	CEGL008118	9	KAHO.0008, KAHO.0009, KAHO.0010, KAHO.0013, KAHO.0014, KAHO.0018, KAHO.0025. KAHO.0029, KAHO.0130
Schinus terebinthifolius / Pennisetum setaceum Semi-natural Woodland	CEGL005411	3	KAHO.0026, KAHO.0027, KAHO.0140
Thespesia populnea / Sparse understory Woodland	CEGL005412	3	KAHO.0019, KAHO.0110, KAHO.0150
Tournefortia argentea Semi-natural Woodland	CEGL005413	2	KAHO.0015, KAHO.0160
Shrubland			
Batis maritima Semi-natural Dwarf-shrubland	CEGL005401	6	KAHO.0028, KAHO.0044, KAHO.0120, KAHO.1400, KAHO.1500, KAHO.2000
Bougainvillea glabra Semi-natural / Planted Shrubland [Park Special]	Park Special	1	KAHO.0170
Leucaena leucocephala / Pennisetum setaceum Semi-natural Shrubland	CEGL005403	8	KAHO.0002, KAHO.0004, KAHO.0006, KAHO.0011, KAHO.0012, KAHO.0021, KAHO.0041, KAHO.0043
Scaevola taccada Coastal Dry Shrubland	CEGL008054	1	KAHO.0200
Waltheria indica - Sida fallax Shrubland	CEGL005414	6	KAHO.0016, KAHO.0017, KAHO.0022, KAHO.0023, KAHO.0100, KAHO.0400

Plant Association Scientific Name	Element Code	No. of Samples	Supporting Plots and Observation Points
Herbaceous			
Paspalum vaginatum Semi-natural Herbaceous Vegetation	CEGL005406	3	KAHO.0020, KAHO.0024, KAHO.0800
Pennisetum setaceum Semi-natural Herbaceous Vegetation	CEGL008117	8	KAHO.0001, KAHO.0003, KAHO.0005, KAHO.0007, KAHO.0042, KAHO.0190, KAHO.0300, KAHO.1000
A‘a Lava with Sparse Vegetation [Park Special]	CEPS009514	2	KAHO.0500, KAHO.0900
Coastal Strand Sparse Vegetation [Park Special]	CEPS009513	1	KAHO.0700

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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.

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Appendix D: Field Key to the Vegetation of Kaloko-Honokōhau National Historical Park, Hawai‘i

The vegetation of Kaloko-Honokōhau National Historical Park (KAHO) 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 KAHO, 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. 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 differs significantly from existing rUSNVC association concepts, but lacks 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 (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 coast, so if the key is not working well try using other zones in 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 also added to couplet.

Special Instructions

There are a number of closely related vegetation types at KAHO that may be confusing in the field e.g., grasslands with scattered trees or shrubs vs. an open shrublands or woodlands. 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)*, ‘uhaloa *(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 Kaloko-Honokōhau National Historical Park (KAHO)

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. **(6)**

Sparse Vegetation
3a) Site is restricted to coastal shoreline. – **Coastal Strand Sparse Vegetation [Park Special] (SV_CS)**
3b) Site is not restricted to coastal shoreline. **(4)**

4a) Site is restricted to lava flows. **(5)**
4b) Site is not restricted to lava flows. – **Undescribed KAHO Sparse Vegetation**

5a) Site is restricted to a‘a lava. – **A‘a Lava with Sparse Vegetation [Park Special] (SV_AA)**
5b) Site is restricted to pahoehoe lava. – **Pahoehoe Lava Sparse Vegetation (SV_PA) (No description)**

Non-Sparse Vegetation
6a) Vegetation is restricted to the coastal shoreline and does not significantly extend into coastal uplands. **(7)**
6b) 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
7a) Trees typically dominate strand vegetation. **(8)**
7b) Herbaceous or shrub vegetation typically dominates strand vegetation. **(12)**

8a) Vegetation is dominated or co-dominated by native or Polynesian introduced tree species. **(9)**
8b) Vegetation is dominated by non-native tree species. **(11)**

9a) 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)**

9b) Vegetation is <u>not</u> dominated or co-dominated by coconut palm (*Cocos nucifera*). **(10)**

10a) 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)**

10b) Vegetation is not dominated by milo (*Thespesia populnea*). – **Undescribed KAHO vegetation in the Hawaiian Lowland Dry Forest & Woodland Group (G405)**

11a) 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)**

11b) Woody vegetation is not dominated by tree heliotrope (*Tournefortia argentea*). – **Undescribed KAHO vegetation in the Hawaiian Ruderal Dry Forest Group (G407)**

12a) Vegetation is co-dominated or dominated by native species. – **Hawaiian Dry Scrub & Herb Coastal Strand Group (G421) (13)**

12b) Vegetation is dominated by non-native species. – **Hawaiian Ruderal Scrub & Herb Coastal Strand Group (G423) (14)**

13a) Vegetation is typically 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)**

13b) Vegetation is not dominated or co-dominated by naupaka kahakai (*Scaevola taccada*). – **Undescribed KAHO vegetation in the Hawaiian Dry Scrub & Herb Coastal Strand Group (G421)**

14a) Vegetation is dominated by pickleweed (*Batis maritima*). – **Pickleweed Semi-natural Dwarf-shrubland; *Batis maritima* Semi-natural Dwarf-shrubland (S_BAMA)**

14b) Vegetation is not dominated by pickleweed (*Batis maritima*). **(15)**

15a) Vegetation is dominated by seashore paspalum (*Paspalum vaginatum*). – **Seashore Paspalum Semi-natural Herbaceous Vegetation; *Paspalum vaginatum* Semi-natural Herbaceous Vegetation (H_PAVA)**

15b) Vegetation is not dominated by seashore paspalum (*Paspalum vaginatum*). – **Undescribed KAHO herbaceous vegetation in the Hawaiian Ruderal Scrub & Herb Coastal Strand Group (G423)**

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%. **(28)**

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 typically 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. **(23)**

Woodlands

18a) Tree canopy is co-dominated or 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. – **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 KAHO 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. **(23)**

20b) Tree canopy is not 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*) typically dominates the herbaceous layer. – **Christmas Berry / Fountain Grass Semi-natural Woodland; *Schinus terebinthifolius* / *Pennisetum setaceum* Semi-natural Woodland (W_SCTE)**

21b) Tree canopy is not dominated by Christmas berry (*Schinus terebinthifolius*). **(22)**

22a) Tree canopy is dominated by kiawe (*Prosopis pallida*). – **Kiawe Coastal Dry Semi-natural Woodland; *Prosopis pallida* Coastal Dry Woodland (W_PRPA)**

22b) Tree canopy is not dominated by kiawe (*Prosopis pallida*). Tree canopy is often dominated by kukui (*Aleurites moluccana*) a Polynesian introduced species, papaya (Carica papaya) or other planted trees including milo (*Thespesia populnea*), monkeypod (*Samanea saman*), and ‘opiuma (*Pithecellobium dulce*) trees. – **Mixed Semi-natural / Ornamental Tree Woodland (W_ORNA) (No description)**

Shrublands

23a) Shrub canopy is dominated or co-dominated by native shrubs. – **Hawaiian Lowland Dry Shrubland & Grassland Group (G410) (24)**

23b) Shrub canopy is dominated by introduced shrub species. – **Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413) (25)**

24a) Shrub canopy is dominated or co-dominated by ‘uhaloa (*Waltheria indica*). ‘Ilima (*Sida fallax*) typically dominates the herbaceous layer. – **‘Uhaloa -‘Ilima Shrubland; *Waltheria indica* - *Sida fallax* Shrubland (S_WAIN)**

24b) Other native shrub species dominate. – **Undescribed KAHO vegetation in the Hawaiian Lowland Dry Shrubland & Grassland Group (G410)**

25a) 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)**

25b) Vegetation is not dominated by bougainvillea (*Bougainvillea glabra*). **(26)**

26a) Vegetation is an open shrub canopy dominated or co-dominated by sourbush (*Pluchea carolinensis*). Pickleweed (*Batis maritima*) is typically present to dominant in the dwarf-shrub layer.– **Sourbush / Pickleweed Semi-natural Shrubland; *Pluchea carolinensis* / *Batis maritima* Semi-natural Shrubland (S_PLCA) (No description)**

26b) Vegetation is not dominated or co-dominated by sourbush (*Pluchea carolinensis*). **(27)**

27a) Shrub canopy is dominated or co-dominated by koa haole (*Leucaena leucocephala*) with a sparse or dense herbaceous layer that is dominated by fountain grass (*Pennisetum setaceum*). – **Koa Haole / Fountain Grass Semi-natural Shrubland; *Leucaena leucocephala* / *Pennisetum setaceum* Semi-natural Shrubland (S_LEPE)**

27b) Shrub canopy is not dominated or co-dominated by koa haole (*Leucaena leucocephala*). – **Undescribed KAHO vegetation in the Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)**

Herbaceous Vegetation

28a) 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)**

28b) Herbaceous layer is not planted. Species may include native and non-native species. **(29)**

29a) Vegetation is co-dominated or 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 KAHO vegetation in the Hawaiian Lowland Dry Shrubland & Grassland Group (G410)**

29b) 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) (30)**

30a) Herbaceous layer is dominated by fountain grass (*Pennisetum setaceum*). – **Fountain Grass Semi-natural Herbaceous Vegetation; *Pennisetum setaceum* Semi-natural Herbaceous Vegetation (H_PESE)**

30b) Herbaceous layer is not dominated by fountain grass (*Pennisetum setaceum*). – **Undescribed KAHO vegetation in the Hawaiian Ruderal Lowland Shrubland, Grassland & Savanna Group (G413)**

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[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.

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Appendix E: Plant Association Descriptions for Kaloko-Honokōhau National Historic Park, Hawai‘i

REVISED US NATIONAL VEGETATION CLASSIFICATION

Vegetation Associations of
Kaloko-Honokōhau National Historical Park
23 June 2010

by

NatureServe

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This subset of the International Ecological Classification Standard covers vegetation associations of Kaloko-Honokōhau 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>.

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NatureServe[1]. 2010. International Ecological Classification Standard: Terrestrial Ecological Classifications. Vegetation Associations of Kaloko-Honokōhau National Historical Park. NatureServe Central Databases. Arlington, VA. Data current as of 23 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 Centers (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.

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6.A.1. Tropical Cliff, Scree & Rock Vegetation E.20

6.A.1.Oa. Polynesian Cliff, Scree, & Rock Vegetation E.20

M268. Polynesian Ruderal Cliff, Scree, & Rock Vegetation E.20

G441. Hawaiian Ruderal Dry-Site Lava Flow Group E.20
A‘a Lava with Sparse Vegetation [Park Special] E.20

Bibliography E.21

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

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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

Kaloko-Honokōhau National Historical Park Environment: This association was sampled three times in the park. It is found on flat to gently sloping sites. It occurs on beaches, recent lava flows, and on an island in a marsh. Ocean influence was noted in most of the sites. Dead and live plant material covers most of the ground.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This association is a relatively closed woodland with an average canopy cover of 65%. The canopy is typically short (2-5 m) though it could range to 5-10 m. Milo (*Thespesia populnea*) is nearly the only taxon in the tree canopy. Very small amounts of kiawe (*Prosopis pallida*) and tree heliotrope (*Tournefortia argentea*) are also present. The shrub and herbaceous strata are sparse to absent, and no single taxon was noted in more than one plot. Naupaka kahakai (*Scaevola taccada*) is common in one plot, and pickleweed (*Batis maritima*), ‘uhaloa (*Waltheria indica*), sourbush (*Pluchea carolinensis*), and fountain grass (*Pennisetum setaceum*) were found in small amounts in one plot each.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Broad-leaved evergreen tree	milo

CHARACTERISTIC SPECIES

Kaloko-Honokōhau 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 occurs near the coast on a variety of sites at Kaloko-Honokōhau National Historical Park including beaches and lava flows.

Federal Lands: NPS (Kaloko-Honokōhau, Puʻuhonua o Hōnaunau, Puʻukoholā Heiau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0019, KAHO.0110, KAHO.0150.
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
***Prosopis pallida* Coastal Dry Semi-natural Woodland**
Identifier: CEGL008118

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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

Kaloko-Honokōhau National Historical Park Environment: This association was sampled nine times in the park. It is found very near sea level on flat to gentle slopes . The geology is recent pahoehoe lava. The cover of the surface of the ground is varied. Sites have a mixture of bedrock, rocks, dead vegetation, and/or coarse woody debris.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: The tree canopy of this association averages 40% (range 25-60%) and is 5-10 m tall. Kiawe (*Prosopis pallida*) makes up nearly the entire canopy. Milo (*Thespesia populnea*) may be present at low levels in some plots. There is also a tree subcanopy dominated by kiawe in most stands. Sparse tall and short-shrub strata are present in most stands. Shrub strata are dominated by koa haole (*Leucaena leucocephala*) with lesser amounts of Christmas berry (*Schinus terebinthifolius*), ʻilima (*Sida fallax*), and noni (*Morinda citrifolia*). The herbaceous stratum averages 25% cover (range 5-40%). Fountain grass (*Pennisetum setaceum*) and *Talinum fruticosum* are both in all but one stand, and fountain grass is dominant in most. Pickleweed (*Batis maritima*) is present (and dominant) in only a few stands near water or in inundated areas.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau 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	koa haole
Herb (field)	Forb	*Talinum triangulare*
Herb (field)	Graminoid	fountain grass

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: kiawe

CLASSIFICATION

Kaloko-Honokōhau 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:

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

ELEMENT DISTRIBUTION

Range: This woodland is widespread in the park on a variety of sites at Kaloko-Honokōhau National Historical Park.

Federal Lands: NPS (Kaloko-Honokōhau, Puʻuhonua o Hōnaunau, Puʻukoholā Heiau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0008, KAHO.0009, KAHO.0010, KAHO.0013, KAHO.0014, KAHO.0018, KAHO.0025, KAHO.0029, KAHO.0130.

Local Description Authors: J. Drake

References: Canfield 1990, Gagne and Cuddihy 1990, Wagner et al. 1999, Western Ecology Working Group n.d.

Christmas Berry / Fountain Grass Semi-natural Woodland

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

Identifier: CEGL005411

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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)	Christmas Berry / Fountain Grass Semi-natural Woodland

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled three times in the park. It is found on flat, very low-elevation (almost sea level) sites. The substrate is both aʻa and pahoehoe lava. Most of the surface of the ground is covered by live vegetation. The remainder is mostly bedrock and rocks.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This association has a highly variable tree canopy. It averages 35% cover but ranges from 15-80% and is 2-10 m tall. Christmas berry (*Schinus terebinthifolius*) is the only taxon noted in the tree canopy. There is a very sparse shrub canopy with koa haole (*Leucaena leucocephala*) being the most common species. The herbaceous stratum is typically well-established and averages 40% cover. Fountain grass (*Pennisetum setaceum*) is nearly the only species present in this stratum.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

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

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: fountain grass, Christmas berry

CONSERVATION STATUS RANK

Global Rank & Reasons: GNA (invasive) (2-Apr-2010).

CLASSIFICATION

Status: Standard

Kaloko-Honokōhau 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.

Global Related Concepts:

- 13. Christmas berry scrub forest on sandy back of strand (Canfield 1990) F
- 18. Christmas berry on pahoehoe at anchialine ponds (Canfield 1990) F
- 25. Christmas berry inland scrub on basalt (Canfield 1990) F

ELEMENT DISTRIBUTION

Range: This community was sampled from low areas near the coast of Kaloko-Honokōhau National Historical Park.

Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0026, KAHO.0027, KAHO.0140.

Local Description Authors: J. Drake

References: Canfield 1990, Western Ecology Working Group n.d.

Tree Heliotrope Semi-natural Woodland

***Tournefortia argentea* Semi-natural Woodland**

Identifier: CEGL005413

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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)	Tree Heliotrope Semi-natural Woodland

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled twice in the park. It is found on flat sites influenced by sea spray. Approximately half of the surface of the ground is covered by live vegetation and most of the rest by rocks or sand.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: The samples for this association vary widely in their structure. One has a moderately open (45%) tree canopy 5-10 m tall. The other has a very open (15%) tree canopy 2-5 m tall. Both are dominated by tree heliotrope (*Tournefortia argentea*) with small amounts of kiawe (*Prosopis pallida*) and Christmas berry (*Schinus terebinthifolius*). The more vegetated plot has a moderately well-developed shrub stratum, while the other has a sparse shrub stratum. Both shrub strata are dominated by naupaka kahakai (*Scaevola taccada*). Both plots have sparse herbaceous strata, averaging about 10% cover. Seedlings of the overstory trees and pickleweed (*Batis maritima*) are the most common components.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Broad-leaved deciduous tree	tree heliotrope

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: tree heliotrope

CLASSIFICATION

Related Concepts:

- 10. Low tree heliotrope (*Tournefortia argentea*) forest or scattered trees on coastal lava (Canfield 1990) F
- 8. Shrubby tree heliotrope on sandy strand (Canfield 1990) F

ELEMENT DISTRIBUTION

Range: This community was sampled from the coast of Kaloko-Honokōhau National Historical Park.

Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0015, KAHO.0160.

Local Description Authors: J. Drake

References: Canfield 1990, 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

‘Uhaloa -‘Ilima Shrubland
***Waltheria indica - Sida fallax* Shrubland**
Identifier: CEGL005414

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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)	‘Uhaloa -‘Ilima Shrubland

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled six times in the park. It is found on low, level sites, and the surface of the ground is mostly covered by a mix of bedrock and litter. All sites are on recent pahoehoe lava flows.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This dry shrubland is dominated by short shrubs 0.5-2 m tall. The short-shrub canopy ranges from 10-30% cover and averages 15%. ‘Uhaloa (*Waltheria indica*) is the dominant short shrub with maiapilo (*Capparis sandwichiana*) and koa haole (*Leucaena leucocephala*) commonly present. This is a short-shrub stratum dominated by ‘ilima (*Sida fallax*) averages 10% cover. The herbaceous stratum is poorly developed, averaging 3% cover and never exceeding 10%. *Boerhavia coccinea*, partridge pea (*Chamaecrista nictitans ssp. patellaria var. glabrata*), *Talinum fruticosum*, and *Portulaca pilosa* are the most common species in the herbaceous stratum.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Short shrub/sapling	Broad-leaved deciduous shrub	‘ilima, ‘uhaloa

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: ‘ilima, ‘uhaloa

CLASSIFICATION

Kaloko-Honokōhau 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 sampled from pahoehoe lava flow sites at Kaloko-Honokōhau National Historical Park.
Federal Lands: NPS (Kaloko-Honokōhau, Puʻuhonua o Hōnaunau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0016, KAHO.0017, KAHO.0022, KAHO.0023, KAHO.0100, KAHO.0400.
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

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Bougainvillea Semi-natural / Planted Shrubland [Park Special]
***Bougainvillea glabra* Semi-natural / Planted Shrubland [Park Special]**
Identifier: Park Special

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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 Group (G413)
Alliance	na
Association (Local name)	Bougainvillea Semi-natural / Planted Shrubland [Park Special]

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This community was sampled once in the park. It was found on a rock berm near the harbor. The site was flat and very near sea level. The surface of the ground was covered by rocks and live vegetation (basal area) in almost equal amounts.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This community was formed by landscaping an area with the dominant plant, bougainvillea (*Bougainvillea glabra*). This species formed a canopy of 50% in the 2-5 m tall shrub stratum. Trace amounts of koa haole (*Leucaena leucocephala*), Florida beggarweed (*Desmodium tortuosum*), ‘ilima (*Sida fallax*), ‘uhaloa (*Waltheria indica*), and sourbush (*Pluchea carolinensis*) were also in the shrub stratum. There were very small amounts of the herbaceous species *Boerhavia coccinea, Portulaca pilosa* and *Talinum fruticosum*.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Short shrub/sapling	Broad-leaved deciduous shrub	bougainvillea

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: Bougainvillea

CLASSIFICATION

Kaloko-Honokōhau National Historical Park Comments: This one plot sampled was planted. It is not clear if this species is invasive and naturalized to any extent.

ELEMENT DISTRIBUTION

Range: This community was sampled from a landscaped area at Kaloko-Honokōhau National Historical Park.
Federal Lands: NPS (Kaloko-Honokōhau, Puʻuhonua o Hōnaunau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0170
Local Description Authors: J. Drake
References: Western Ecology Working Group n.d.

Koa Haole / Fountain Grass Semi-natural Shrubland

***Leucaena leucocephala / Pennisetum setaceum* Semi-natural Shrubland**
Identifier: CEGL005403

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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	*Leucaena leucocephala* Lowland Ruderal Shrubland Alliance (A.2700)
Association (Local name)	Koa Haole / Fountain Grass Semi-natural Shrubland

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled eight times in the park. It is found on flat to gently sloping sites near sea level. The substrate is aʻa or pahoehoe lava. Nearly three-quarters of the surface of the ground is covered by live vegetation (basal area). The remainder is mostly bedrock.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This dry shrubland has an open shrub canopy that averages 30% cover (range 15-60%). The shrubs were typically 1-2 m tall, though one site has a well-established shrub canopy 2-5 m tall. Koa haole (*Leucaena leucocephala*) forms nearly 90% of the shrub stratum. Klu (*Acacia farnesiana*), ʻilima (*Sida fallax*) and ʻuhaloa (*Waltheria indica*) are found in most stands but never abundantly. The herbaceous stratum has an average cover of 50% and is nearly all fountain grass (*Pennisetum setaceum*).

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

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

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: koa haole, fountain grass

CLASSIFICATION

Kaloko-Honokōhau 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:

- 24. Koa haole inland scrub on pahoehoe (Canfield 1990) F
- Koa haole (*Leucaena*) Shrubland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This community occurs widely at Kaloko-Honokōhau National Historical Park on lava flows.
Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0002, KAHO.0004, KAHO.0006, KAHO.0011, KAHO.0012, KAHO.0021, KAHO.0041, KAHO.0043.
Local Description Authors: J. Drake
References: Canfield 1990, Gagne and Cuddihy 1990, Western Ecology Working Group n.d.

Seashore Paspalum Semi-natural Herbaceous Vegetation

***Paspalum vaginatum* Semi-natural Herbaceous Vegetation**
Identifier: CEGL005406

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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 (A.2693)
Association (Local name) Seashore Paspalum Semi-natural Herbaceous Vegetation

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled three times in the park. It is found on low, level sites at sea level. All sites are wet with brackish or salt water. Nearly the entire surface of the ground is covered by live vegetation (basal area).

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This herbaceous wetland has dense vegetation cover but few species. The herbaceous stratum has 60-95% cover (average 85%) and is strongly dominated by seashore paspalum (*Paspalum vaginatum*). Pickleweed (*Batis maritima*) and ‘ahu‘awa (*Cyperus javanicus*) are the only other herbaceous species noted in the plots, and both occur at low levels. A few seedlings and short milo (*Thespesia populnea*) trees were noted.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Herb (field)	Graminoid	seashore paspalum

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: seashore paspalum

ELEMENT DISTRIBUTION

Range: This community was sampled from saline wetland sites at Kaloko-Honokōhau National Historical Park.
Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0020, KAHO.0024, KAHO.0800.

Local Description Authors: J. Drake

References: Canfield 1990, Western Ecology Working Group n.d.

Fountain Grass Semi-natural Herbaceous Vegetation

***Pennisetum setaceum* Semi-natural Herbaceous Vegetation**

Identifier: CEGL008117

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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 (A.2693)
Association (Local name)	Fountain Grass Semi-natural Herbaceous Vegetation

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled six times in the park. It is found on low, level sites from near sea level to several meters above it. Substrate is mostly pahoehoe though some is on aʻa lava. The ground surface is typically a mix of bedrock/rock and live vegetation (basal area).

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This association is dominated by grasses with scattered shrubs and trees. The herbaceous stratum averages 40% cover (range 20-70%) of which nearly all is fountain grass (*Pennisetum setaceum*). *Talinum fruticosum* is present in some stands. Widely scattered trees with an average of 3% cover (range 0-10%) are often present, typically kiawe (*Prosopis pallida*) and less often Christmas berry (*Schinus terebinthifolius*). The scattered shrub stratum averages 10% cover (range 1-20%). Koa haole (*Leucaena leucocephala*) is the most common shrub with klu (*Acacia farnesiana*), ʻilima (*Sida fallax*), and ʻuhaloa (*Waltheria indica*) frequently present.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Herb (field)	Graminoid	fountain grass

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: fountain grass

CLASSIFICATION

Kaloko-Honokōhau 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:

- 17. Fountain grass on pahoehoe at anchialine ponds (Canfield 1990) F

- 23. Fountain grass grassland on pahoehoe (Canfield 1990) F
- 26. Fountain grass savanna on pahoehoe (Canfield 1990) F
- 4. Fountain grass low vegetation on sandy strand (Canfield 1990) F
- Fountain Grass (*Pennisetum*) Grassland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This community is common at Kaloko-Honokōhau National Historical Park, especially in pahoehoe lava flow areas.
Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0001, KAHO.0003, KAHO.0005, KAHO.0007, KAHO.0042, KAHO.0190, KAHO.0300, KAHO.1000.
Local Description Authors: J. Drake
References: Canfield 1990, Gagne and Cuddihy 1990, 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

Coastal Strand Sparse Vegetation [Park Special]
Coastal Strand Sparse Vegetation [Park Special]
Identifier: CEPS009513

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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	na
Association (Local name)	Coastal Strand Sparse Vegetation [Park Special]

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This community was sampled once in the park. It is found on a gently sloping to level site of recent pahoehoe lavaflow near the ocean. The covering of the surface of the ground is mostly a mix of bedrock and live vegetation.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This is a sparsely vegetated community with a total vegetation cover of about 5%. There is a very sparse short tree canopy with coconut palm (*Cocos nucifera*) and, kiawe (*Prosopis pallida*). The shrub stratum contains, ‘uhaloa (*Waltheria indica*), and the herbaceous stratum contains *Boerhavia coccinea*, wild spider flower (*Cleome gynandra*), *Portulaca pilosa*, and puncture vine (*Tribulus terrestris*). None of the individual taxa has more than 1% cover.

CLASSIFICATION

Kaloko-Honokōhau National Historical Park Comments: Coastal Strand Sparse Vegetation [Park Special] is currently placed in the Hawaiian Dry Scrub & Herb Coastal Strand Group (G421). However, the Lithomorphic Vegetation Class in the revised USNVC is currently under

review, and this placement of this type may be moved to a group in the Lithomorphic Class in the future.

Related Concepts:

- 4. Fountain grass low vegetation on sandy strand (Canfield 1990) F

ELEMENT DISTRIBUTION

Range: This community is restricted to coastal areas in Kaloko-Honokōhau National Historical Park.

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Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0700.
Local Description Authors: J. Drake
References: Canfield 1990, Western Ecology Working Group n.d.

Coconut Palm Strand Woodland

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

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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	*Cocos nucifera* Coastal Woodland Alliance (A.2691)
Association (Local name)	Coconut Palm Strand Woodland

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled once in the park. It is found on a gently sloping beach. The surface of the ground is mostly sand with small amounts of gravel and live vegetation.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This woodland community has an open tree canopy (30%) dominated by coconut palm (*Cocos nucifera*) with a small amount of kiawe (*Prosopis pallida*). The canopy is 15-20 m tall. There is a sparse (10%) tree subcanopy 5-10 m tall composed of equal amounts of milo (*Thespesia populnea*) and tree heliotrope (*Tournefortia argentea*). No shrub or herbaceous strata were noted.

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Tree canopy	Palm tree	coconut palm

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: coconut palm

CLASSIFICATION

Related Concepts:

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

ELEMENT DISTRIBUTION

Range: This community was sampled from coastal strand sites at Kaloko-Honokōhau National Historical Park.
Federal Lands: NPS (Kaloko-Honokōhau, Puʻuhonua o Hōnaunau, Puʻukoholā Heiau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0600.
Local Description Authors: J. Drake
References: Canfield 1990, NatureServe n.d.

Naupaka Kahakai Coastal Dry Shrubland

***Scaevola taccada* Coastal Dry Shrubland**
Identifier: CEGL008054

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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 (A.716)
Association (Local name)	Naupaka Kahakai Coastal Dry Shrubland

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled once in the park. It is found in a swath 10-25 m away from the high tide line. The site is level and over pahoehoe lava. The surface of the ground is mostly sand with some live vegetation (basal area) and rocks.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This is a low, open-canopied shrubland. The shrub canopy has 25% cover and averages 0.5-1 m tall. It is co-dominated by naupaka kahakai (*Scaevola taccada*) and sourbush (*Pluchea carolinensis*). There is a very sparse (5%) tree canopy comprised of tree heliotrope (*Tournefortia argentea*) and a similarly sparse (5%) herbaceous canopy comprised of fountain grass (*Pennisetum setaceum*).

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

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

CHARACTERISTIC SPECIES

Kaloko-Honokōhau 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 (*Scaevola*) Shrubland (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This community was sampled from a coastal site at Kaloko-Honokōhau National Historical Park.
Federal Lands: NPS (Kaloko-Honokōhau, Puʻuhonua o Hōnaunau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0200.
Local Description Authors: J. Drake
References: Canfield 1990, Gagne and Cuddihy 1990, Western Ecology Working Group n.d.

M234. Polynesian Ruderal Scrub & Herb Coastal Strand
G423. Hawaiian Ruderal Scrub & Herb Coastal Strand Group

Pickleweed Semi-natural Dwarf-shrubland
***Batis maritima* Semi-natural Dwarf-shrubland**
Identifier: CEGL005401

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rUSNVC CLASSIFICATION

Division	Polynesian Scrub & Herb Coastal Vegetation (2.A.3.Ob)
Macrogroup	Polynesian Ruderal Scrub & Herb Coastal Strand (M234)
Group	Hawaiian Ruderal Scrub & Herb Coastal Strand Group (G423)
Alliance	*Batis maritima* Coastal Ruderal Dwarf-shrubland Alliance (A.2692)
Association (Local name)	Pickleweed Semi-natural Dwarf-shrubland

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This association was sampled five times in the park. It is found on low, level sites on the ocean beach or in marshy areas. Vegetation covers nearly all the ground on most sites. Two sites have substantial amounts of rock/bedrock on the surface. Water, either anchialine pools or ocean water, was noted on all sites.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This wet dwarf-shrubland has a well-developed herbaceous stratum averaging 75% cover (range 50-95%). Pickleweed (*Batis maritima*) makes up nearly all the dwarf-shrub stratum in most stands. ʻĀkulikuli (*Sesuvium portulacastrum*) and seashore paspalum (*Paspalum vaginatum*) are common in the herbaceous stratum, though not dominant in one stand each. Scattered trees may be present with low cover 0-6%,(average 2%) and do not form a stratum..

MOST ABUNDANT SPECIES

Kaloko-Honokōhau National Historical Park

Stratum	Lifeform	Species
Herb (field)	Dwarf-shrub	pickleweed

CHARACTERISTIC SPECIES

Kaloko-Honokōhau National Historical Park: pickleweed

CONSERVATION STATUS RANK

Global Rank & Reasons: GNA (2-Apr-2010).

CLASSIFICATION

Related Concepts:

- 15. ʻĀkulikuli-kai on pahoehoe at anchialine ponds (Canfield 1990) F
- Pickleweed (*Batis*) Marsh (Gagne and Cuddihy 1990) B

ELEMENT DISTRIBUTION

Range: This community is found on low, level saline sites on the ocean beach or in marshy areas at Kaloko-Honokōhau National Historical Park.
Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0028, KAHO.0120, KAHO.1400, KAHO.1500, KAHO.2000.
Local Description Authors: J. Drake
References: Canfield 1990, Gagne and Cuddihy 1990, Western Ecology Working Group n.d.

6.A.1. Tropical Nonvascular & Sparse Vegetation
6.A.1.Oa. Polynesian Cliff, Scree, & Rock Vegetation
M268. Polynesian Cliff, Scree, & Rock Vegetation
G441. Hawaiian Ruderal Dry Site Lava Flow Group

Aʻa Lava with Sparse Vegetation [Park Special]
Aʻa Lava with Sparse Vegetation [Park Special]
Identifier: CEPS009514

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rUSNVC CLASSIFICATION

Division	Polynesian Cliff, Scree & Rock Vegetation (6.A.1.Oa)
Macrogroup	Polynesian Cliff, Scree & Rock Vegetation (M268)
Group	Hawaiian Ruderal Dry-Site Lava Flow Group (G441)
Alliance	na
Association (Local name)	Aʻa Lava with Sparse Vegetation [Park Special]

ENVIRONMENTAL DESCRIPTION

Kaloko-Honokōhau National Historical Park Environment: This community was sampled twice in the park. It is found on gently sloping to flat recent lava flows near sea level. Vegetation has not colonized the lava flows so nearly the entire ground surface is either solid or broken lava.

VEGETATION DESCRIPTION

Kaloko-Honokōhau National Historical Park Vegetation: This community is sparsely vegetated. Total vegetation cover averages about 5%. There are widely scattered short trees and shrubs: koa haole (*Leucaena leucocephala*), Christmas berry (*Schinus terebinthifolius*), noni (*Morinda citrifolia*), and herbaceous fountain grass with no individual taxon having more than 5% cover.

CONSERVATION STATUS RANK

Global Rank & Reasons: GNR (26-May-2010).

CLASSIFICATION

Kaloko-Honokōhau 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. Species are mostly introduced, but more information is needed.

Related Concepts:

- 1. Barren inland aʻa (Canfield 1990) F
- 2. Fountain grass on barren aʻa (Canfield 1990) F

ELEMENT DISTRIBUTION

Range: This sparsely vegetated community is common on the lava flows at Kaloko-Honokōhau National Historical Park.
Federal Lands: NPS (Kaloko-Honokōhau)

ELEMENT SOURCES

Kaloko-Honokōhau National Historical Park Plots: KAHO.0500, KAHO.0900.
Local Description Authors: J. Drake
References: Canfield 1990, Western Ecology Working Group n.d.

Bibliography

Canfield, J. E. 1990. Description and map of the plant communities of the Kaloko-Honokōhau National Cultural Park. University of Hawaii Cooperative National Park Resources Studies Unit Technical Report 73, Department of Botany, University of Hawaii, Honolulu. 29 pp.

Gagne, W. C., and L. W. Cuddihy. 1990. Vegetation. Pages 45-114 in: W. L. Wagner, D. R. Herbst, and S. H. Sohmer, editors. Manual of the Flowering Plants of Hawaii. 2 volumes. University of Hawaii Press, Honolulu.

NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Central Databases. NatureServe, Arlington, VA.

Wagner, W. L. and D. R. Herbst. 2003. Supplement to the Manual of flowering plants of Hawaiʻi *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.

Western Ecology Working Group of NatureServe. No date. International Ecological Classification Standard: International Vegetation Classification. Terrestrial Vegetation. NatureServe, Boulder, CO.

Appendix F: Mapping Conventions and Visual Key

Kaloko-Honokōhau National Historical Park- Map Units

This appendix describes the map units for the Kaloko-Honokōhau National Historical Park (KAHO) 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 KAHO 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 KAHO 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 is 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 accuracy assessment by National Park Service staff.

Woodlands

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

Representative Ground Photo

Common Species
coconut palm (*Cocos nucifera*)
milo (*Thespesia populnea*)
naupaka kahakai (*Scaevola taccada*)
kiawe (*Prosopis pallida*)
fountain grass (*Pennisetum setaceum*)

rUSNVC Association
- *Cocos nucifera* Strand Woodland

Description
Stands of coconut palms were rare at KAHO and primarily occurred in the Kaloko fish pond parking area and in and around the Honokohau small boat harbor. In these areas the coconut palm trees were likely planted at one time or are decedents of ones planted by early Hawaiians. On the Quickbird imagery the coconut palm 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 palm trees were probably mapped with these other map classes.

Range and Distribution

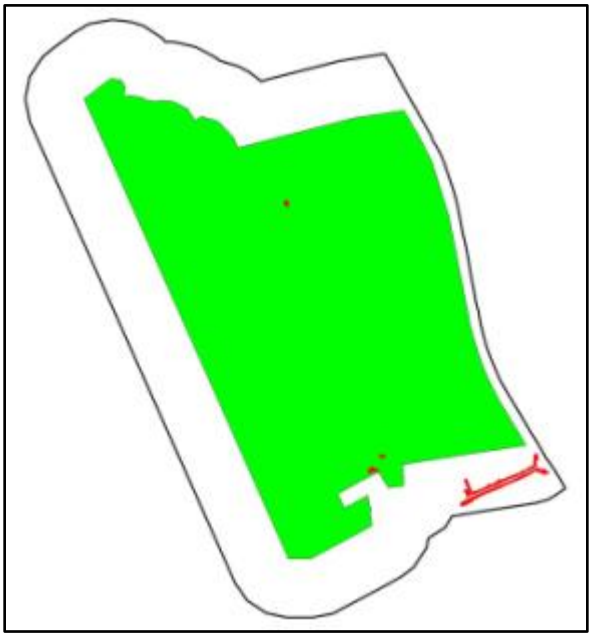


Photo Signature Example

Map Code W_ORNA **Mixed Semi-natural / Ornamental Tree Woodland**

Representative Ground Photo

Common Species

monkeypod (*Samanea saman*)
'opiuma (*Pithecellobium dulce*)
milo (*Thespesia populnea)*

rUSNVC Association

- No Association – Unclassified Map Unit

Description

The mixed semi-natural and ornamental tree map class was used to map managed areas that were likely planted with a mixture of indigenous and ornamental trees. This catch-all category was only used outside of KAHO in the northern coastal strand areas where no plot data were 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

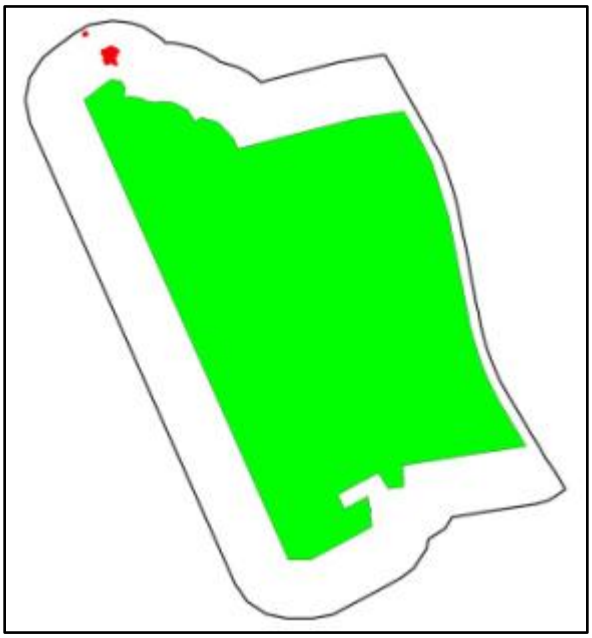


Photo Signature Example

Map Code	**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*)
fountain grass (*Pennisetum setaceum*)
Christmas berry *(Schinus terebinthifolius)*
noni *(Morinda citrifolia)*
milo (*Thespesia populnea*)
'ilima *(Sida fallax)*
klu (*Acacia farnesiana)*

rUSNVC Association

- *Prosopis pallida* Coastal Dry Semi-natural Woodland

Description

This widespread class was very common in KAHO and surrounding areas. Kiawe trees were the diagnostic species exhibiting a light red, mottled 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, tall forests. Elsewhere, the kiawe was less dense and grew more as sparse shrubs with fountain grass and koa haole in the understory. Kiawe trees are also likely present in the other woodland map classes as associated species. Also very short-statured kiawe seedlings were likely mapped as part of the koa haole or fountain grass map units.

Range and Distribution

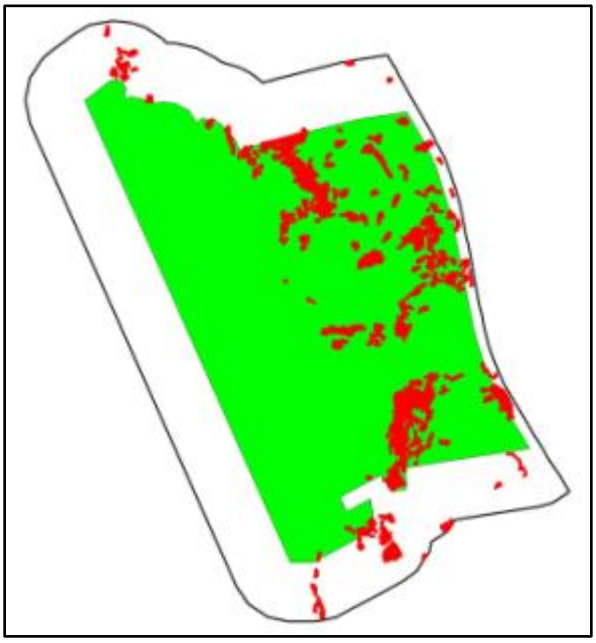
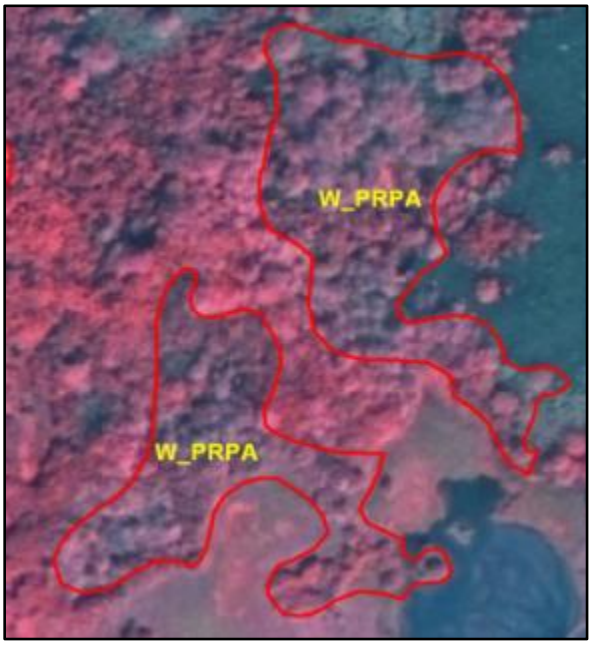


Photo Signature Example



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

Common Species

Christmas berry *(Schinus terebinthifolius)*
fountain grass (*Pennisetum setaceum*)
kiawe (*Prosopis pallida*)
koa haole (*Leucaena leucocephala*)

Representative Ground Photo

rUSNVC Association

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

Description

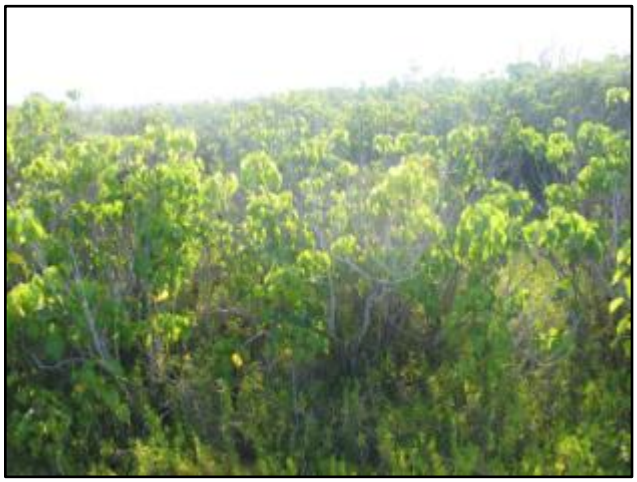
Christmas berry / fountain grass semi-natural woodland type was used to map both tall shrub and woodland Christmas berry stands. The shrub version of this type was located in the lava fields along the coast where Christmas berry plants were either stunted from the harsh conditions or are recent invaders. The tree form was more common in the upper beach margins where it often mixed with kiawe 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**

Representative Ground Photo



Common Species

milo (*Thespesia populnea*)
kiawe (*Prosopis pallida*)
noni *(Morinda citrifolia)*

rUSNVC Association

- *Thespesia populnea* / Sparse Understory Woodland

Description

Milo trees and shrubs (short-statured trees) were found throughout the study area along the coast making-up a large portion of the coastal strand vegetation. Milo was fairly common and it tended to intermingle with Christmas berry and kiawe map classes. Some polygons of this type likely include large amounts of noni and other common coastal strand species. Due to the mixing of species this type may have been confused with kiawe, Christmas berry and tree heliotrope. 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 smoother than the other woodland types.

Range and Distribution

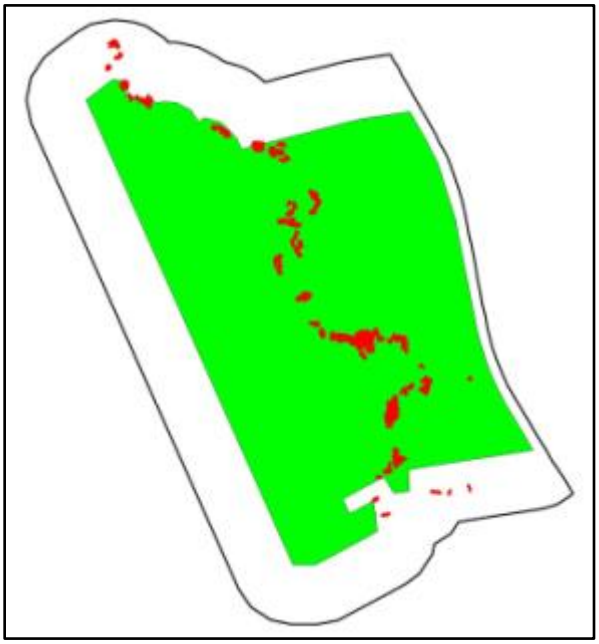
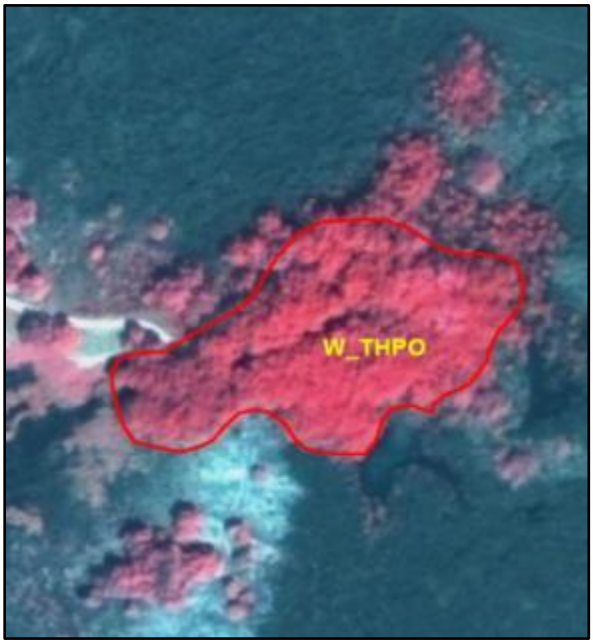


Photo Signature Example



Map Code **Tree Heliotrope Semi-natural Woodland**
W_TOAR ***Tournefortia argentea* Semi-natural Woodland**

Common Species

tree heliotrope *(Tournefortia argentea)*
milo (*Thespesia populnea*)
naupaka kahakai (*Scaevola taccada*)
kiawe (*Prosopis pallida*)
pickleweed *(Batis maritima)*
seashore paspalum *(Paspalum vaginatum)*
ʻākulikuli (*Sesuvium portulacastrum)*

rUSNVC Association

- *Tournefortia argentea* Semi-natural Woodland

Representative Ground Photo

Description

Tree heliotrope was a common species in the coastal portions of the KAHO mapping area. Stands of this type tended to have moderate to sparse cover and were often associated with the coastal strand sparse vegetation map class. Trees and tall shrubs of this type tended to intertwine with the kiawe and milo map classes and some confusion between these types may have occurred. On the color infrared imagery trees of this type had a characteristic pink to light red signature with a white (sand) or black (lava) understory color.

Range and Distribution

Photo Signature Example

Shrublands

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

Representative Ground Photo

Common Species
bougainvillea (*Bougainvillea glabra*)
fountain grass (*Pennisetum setaceum*)
coconut palm (*Cocos nucifera*)

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

Description
This rare type only occurred as a long band of shrubs adjacent to Highway 19 and along the access road to the Honokohau boat harbor. Bougainvillea shrubs are common roadside plantings in Hawaiʻi 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 orange signature. Individual bougainvillea shrubs may also occur in other areas around KAHO (especially along roadsides and in horticultural plantings).

Range and Distribution

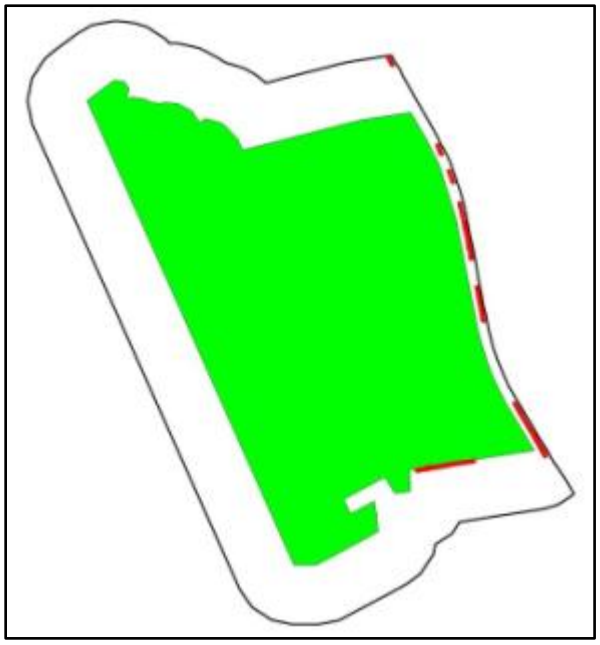


Photo Signature Example

Map Code	**Koa Haole / Fountain Grass Semi-natural Shrubland**
S_LEPE	***Leucaena leucocephala / Pennisetum setaceum* Semi-natural Shrubland**

Common Species

koa haole (*Leucaena leucocephala*)
kiawe (*Prosopis pallida*)
fountain grass (*Pennisetum setaceum*)
'uhaloa *(Waltheria indica)*
maiapilo *(Capparis sandwichiana)*
'ilima *(Sida fallax)*
Christmas berry *(Schinus terebinthifolius)*

rUSNVC Association

- *Leucaena leucocephala / Pennisetum setaceum* Semi-natural Shrubland

Representative Ground Photo

Description

Koa haole shrublands were fairly common on the older lava flows at KAHO. Polygons of this type were usually surrounded by stands of kiawe and fountain grass likely representing disturbance gradients or ecotones. Further, polygons of this type often contained single kiawe trees and contained fountain grass in the understory. Where it did occur as pure stands, the koa haole shrubs had a light brown to pink signature against a bluish (lava) or whitish (fountain grass) background. Koa haole was also mapped as part of the kiawe map class where it was one of the dominant understory species.

Range and Distribution

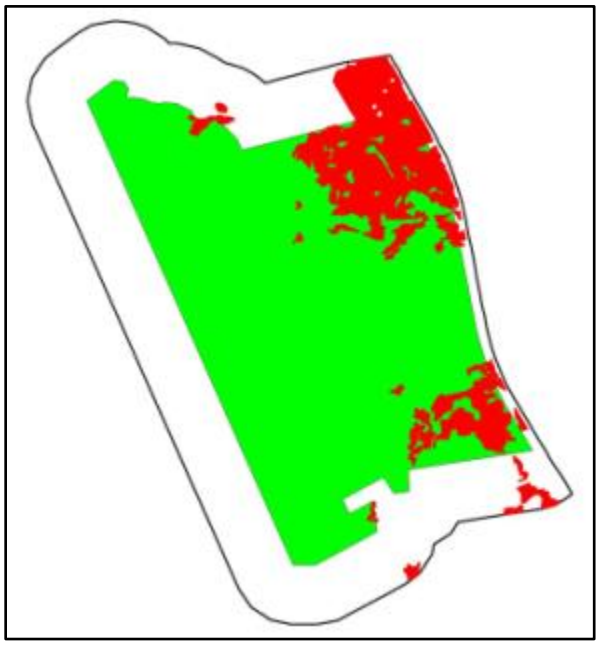


Photo Signature Example

Map Code **Sourbush / Pickleweed Semi-natural Shrubland**
S_PLCA ***Pluchea carolinensis / Batis maritima* Semi-natural Shrubland**

Representative Ground Photo

Common Species

sourbush *(Pluchea carolinensis)*
koa haole (*Leucaena leucocephala*)
kiawe (*Prosopis pallida*)
fountain grass (*Pennisetum setaceum*)
pickleweed *(Batis maritima)*
seashore paspalum *(Paspalum vaginatum)*

rUSNVC Association

- *Pluchea carolinensis / Batis maritima* Semi-natural Shrubland

Description

Sourbush stands were very rare at KAHO, only occurring in one mappable location. At this site sourbush was associated with kiawe trees and pickleweed dwarf shrubs. This map unit had a very similar signature to the pickleweed map unit (smooth, bright pink color) and may have been confused with this related map unit in other areas. Since sourbush is an aggressive non-native, this type was likely controlled in the past (especially around the anchialine pools and other coastal areas) reducing the amount of sourbush cover that could be seen on the 2006 imagery. Due to its small stature and spreading nature this type was only mapped on a where known basis.

Range and Distribution

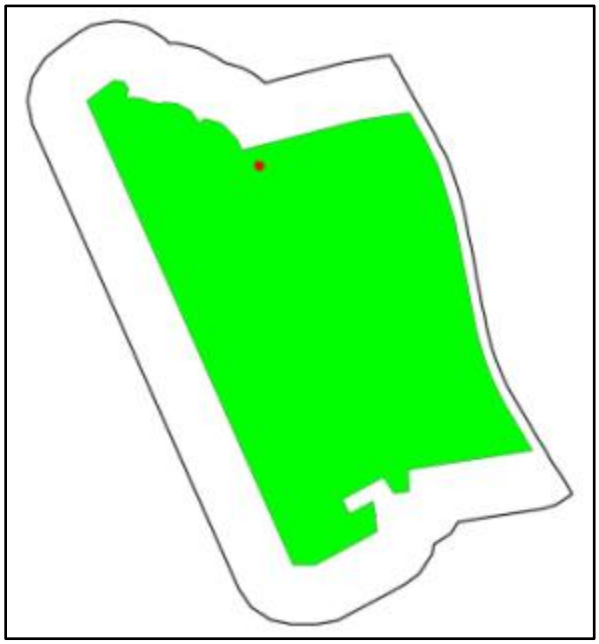


Photo Signature Example

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

Common Species

naupaka kahakai (*Scaevola taccada)*
tree heliotrope *(Tournefortia argentea)*
milo *(Thespesia populnea)*
fountain grass (*Pennisetum setaceum*)
sourbush *(Pluchea carolinensis)*
'uhaloa *(Waltheria indica)*
noni *(Morinda citrifolia)*

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 tree heliotrope woodlands. In KAHO, naupaka kahakai polygons were primarily restricted to the upper beach margins and the edges of the Aimakapa fish pond. This map unit exhibited a very characteristic signature on the color infrared imagery consisting of dark red circles. Polygons of this type likely include noni trees and other common coastal strand species. Due to the mixing of species this type may have been confused with kiawe, milo and tree heliotrope.

Range and Distribution

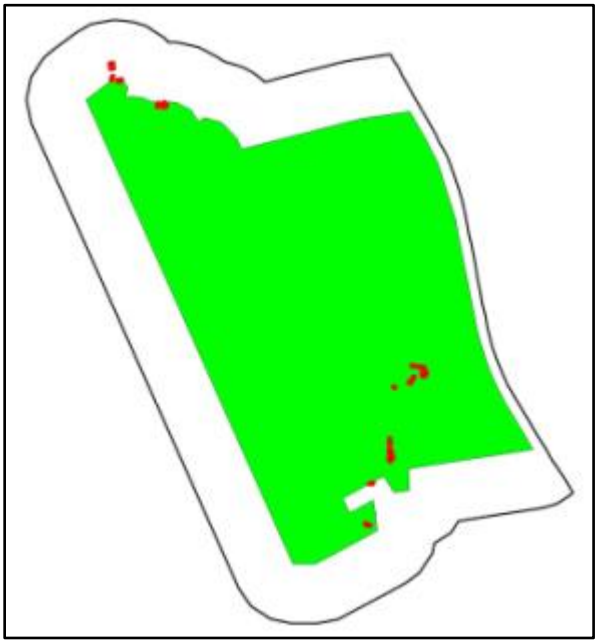


Photo Signature Example

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*)
fountain grass (*Pennisetum setaceum*)
a‘ali‘i (*Dodonaea viscosa)*
ko‘oko‘olau *(Bidens hawaiensis)*
lantana *(Lantana camara)*

rUSNVC Association

- *Waltheria indica - Sida fallax* Shrubland

Representative Ground Photo

Description

‘Uhaloa and ‘ilima are short shrubs common to the upland lava flows at KAHO. Individual ‘uhaloa and ‘ilima shrubs were common all across KAHO occurring as minor associates in many of the kiawe, koa haole, and fountain grass polygons. This type was only found to be the clear dominant in a few restored sites next to the new visitor center and north of the boat harbor. It is likely that more of this native type exists at KAHO 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

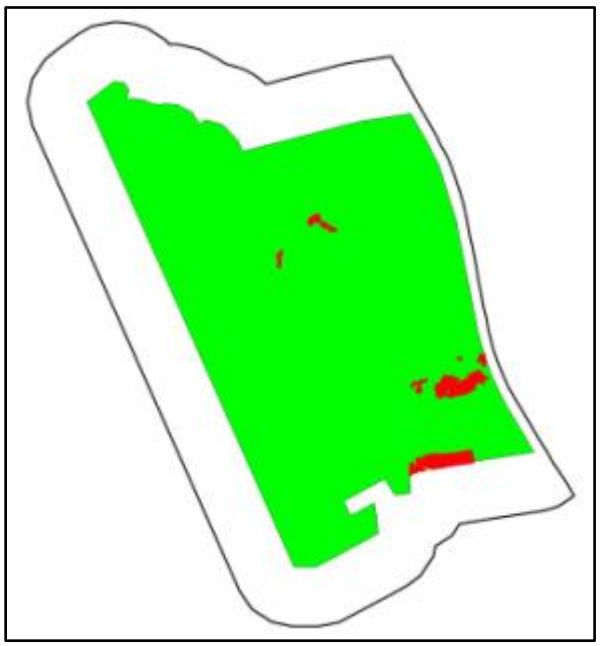


Photo Signature Example

Map Code	Pickleweed Semi-natural Dwarf-shrubland
DS_BAM	***Batis maritima*** **Semi-natural Dwarf-shrubland**

Representative Ground Photo

Common Species

pickleweed *(Batis maritima)*
seashore paspalum *(Paspalum vaginatum)*
fountain grass (*Pennisetum setaceum*)
sourbush *(Pluchea carolinensis)*

rUSNVC Association

- *Batis maritima* Semi-natural Dwarf-shrubland

Description

Pickleweed forms large sprawling mats along the coast and around the margins of the fish ponds at KAHO. Pickleweed is a low-growing, dense, succulent plant that forms monotypic stands in mesic areas as evidenced by its presence in and around the Kaloko and Aimakapa ponds. This map unit was characterized by a smooth, bright pink signature on the color infrared imagery representing the lush growth of this type. Due to its growth form and presence near water pickleweed may have been confused with both the sourbush and seashore paspalum map units.

Range and Distribution

Photo Signature Example

Herbaceous Vegetation

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

Representative Ground Photo

Common Species
pili *(Heteropogon contortus)*

rUSNVC Association
- No Association – Unclassified Map Unit

Description
Pili was likely the dominant grass species at KAHO in historic times before the arrival of Europeans and the introduction of fountain grass. Today, pili is actively being restored to some areas of KAHO 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

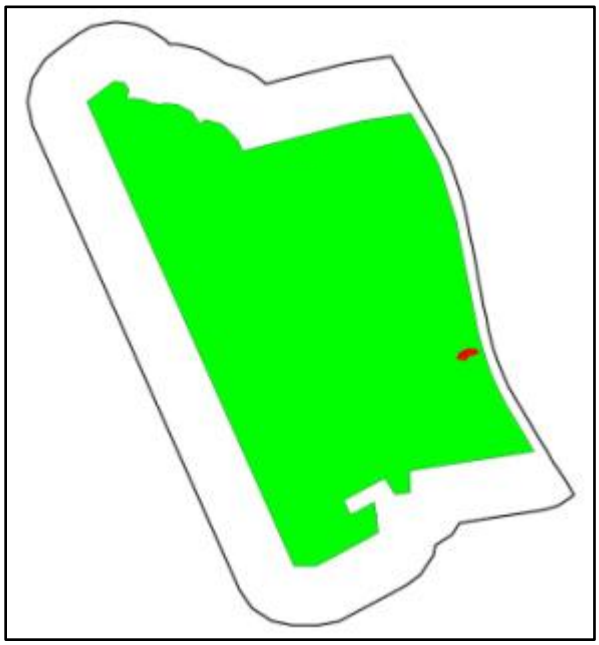


Photo Signature Example

Map Code	Seashore Paspalum Semi-natural Herbaceous Vegetation
H_PAVA	***Paspalum vaginatum*** **Semi-natural Herbaceous Vegetation**

Representative Ground Photo

Common Species

seashore paspalum *(Paspalum vaginatum)*
milo *(Thespesia populnea)*
‘ahu‘awa (*Cyperus javanicus)*
pickleweed *(Batis maritima)*

rUSNVC Association

- *Paspalum vaginatum* Semi-natural Herbaceous Vegetation

Description

Seashore paspalum along with pickleweed and sourbush comprised the primary plant species present in the marsh communities along the coast and surrounding the fish ponds at KAHO. Seashore paspalum is a non-native graminoid that can develop into large monotypic stands. At KAHO this map unit was lush and low-growing, traits that translated into a smooth, light pink to brown signature on the color infrared imagery. Due to their similar growth forms and close proximity to open water, it is likely that this type was confused somewhat with the pickleweed map unit.

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*)
kiawe (*Prosopis pallida*)
koa haole (*Leucaena leucocephala*)
klu (*Acacia farnesiana)*
'uhaloa *(Waltheria indica)*
'ilima *(Sida fallax)*

rUSNVC Association

- *Pennisetum setaceum* Semi-natural Herbaceous Vegetation

Representative Ground Photo

Description

Fountain grass is one of the dominant vegetation communities at KAHO 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 position. On more developed soils and in drainage bottoms, fountain grass was dense and grew up to 0.6 m (2 ft) tall. On broken lava, this type tended to be sparse, patchy and stunted. Due to the lack of moisture, fountain grass was senescent at the time of the imagery and appeared as smooth, yellow to white polygons. Where it was sparse, the lava substrate signature on the color infrared imagery (dark blue-black) was more pronounced.

Range and Distribution

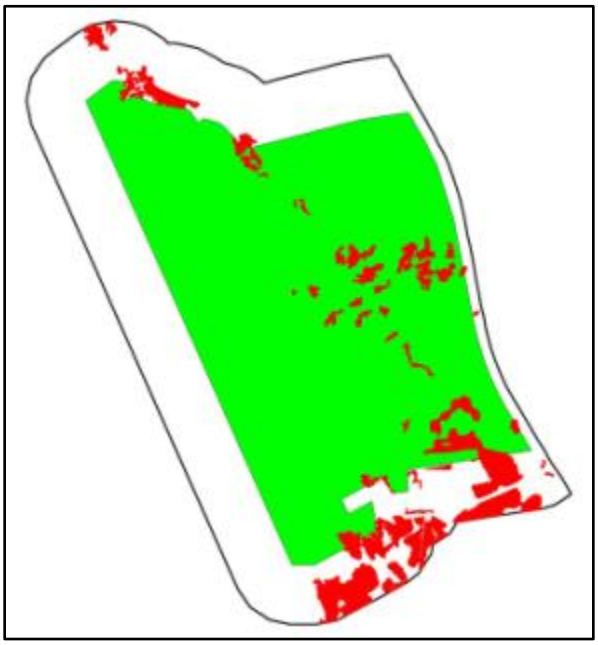


Photo Signature Example

Sparse Vegetation

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

Representative Ground Photo

Common Species

fountain grass (*Pennisetum setaceum*)
koa haole (*Leucaena leucocephala*)

rUSNVC Association

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

Description

Rugged and sparsely vegetated a‘a lava was found across a large portion of the KAHO project area. 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)*
fountain grass (*Pennisetum setaceum*)
tree heliotrope *(Tournefortia argentea)*
ʻuhaloa *(Waltheria indica)*
ʻaeʻae (*Bacopa monnieri)*

rUSNVC Association

- Coastal Strand Sparse Vegetation [Park Special]

Representative Ground Photo

Description

The coastal strand sparse vegetation map class was used to map small polygons in around the beaches and coastal areas of KAHO. 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, heliotrope 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 associations.

Range and Distribution

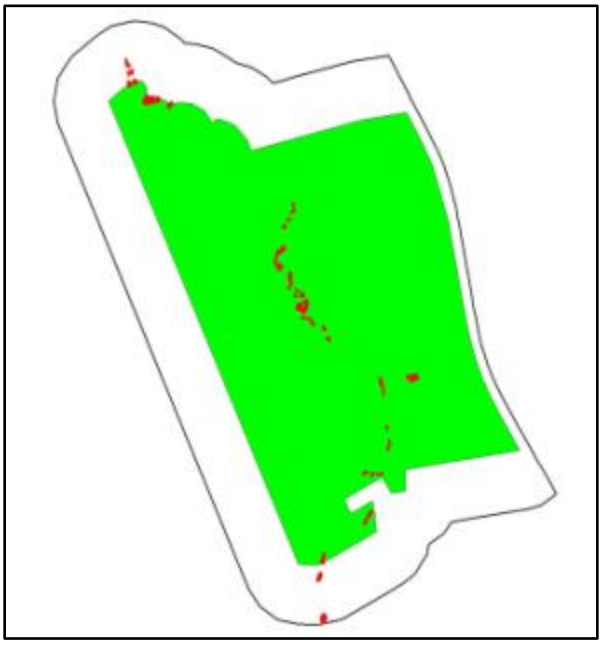


Photo Signature Example

Map Code SV_PA **Pahoehoe Lava Sparse Vegetation**

Common Species

fountain grass (*Pennisetum setaceum*)
koa haole (*Leucaena leucocephala*)
‘uhaloa (*Waltheria indica*)
‘ilima (*Sida fallax*)

Representative Ground Photo

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 KAHO, this map class was used to map two areas south of the park that appeared to support some minimal vegetation. It is likely that these areas contain some ‘uhaloa, fountain grass or small koa hoale shrubs. On the color infrared imagery this type exhibited a characteristic smooth, deep blue signature with pinks spots (vegetation) and some whitish streaks (sand or other deposits).

Range and Distribution

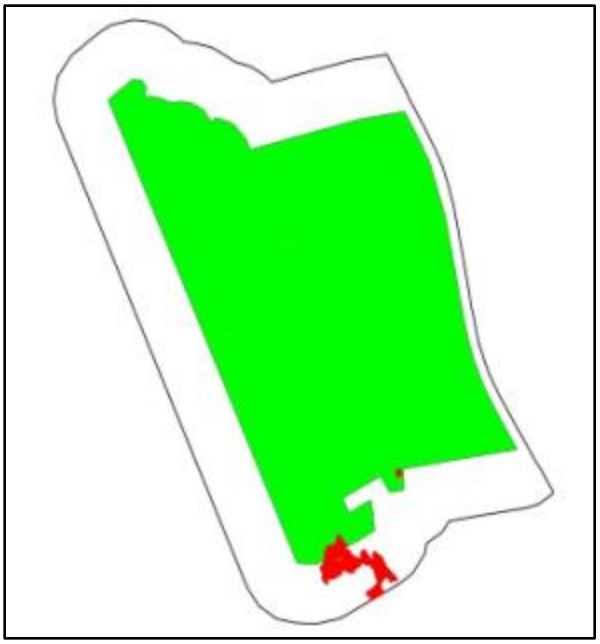
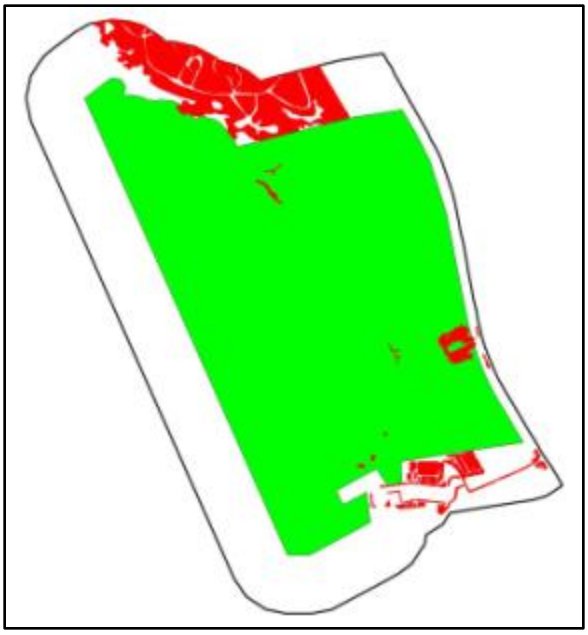


Photo Signature Example

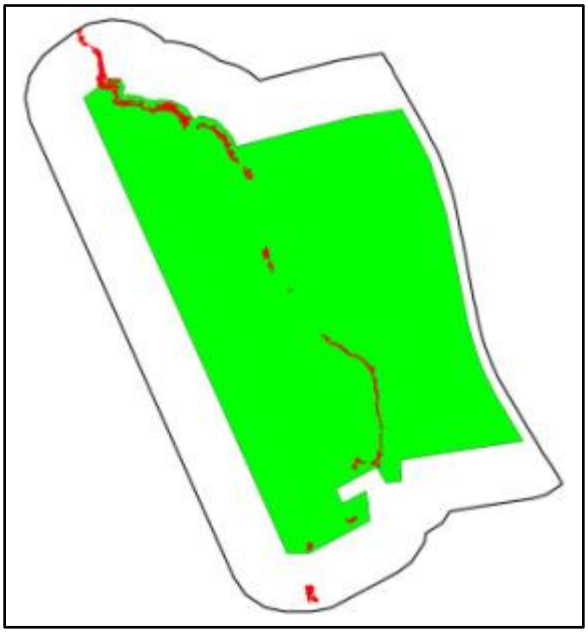
BARREN

B_ AA

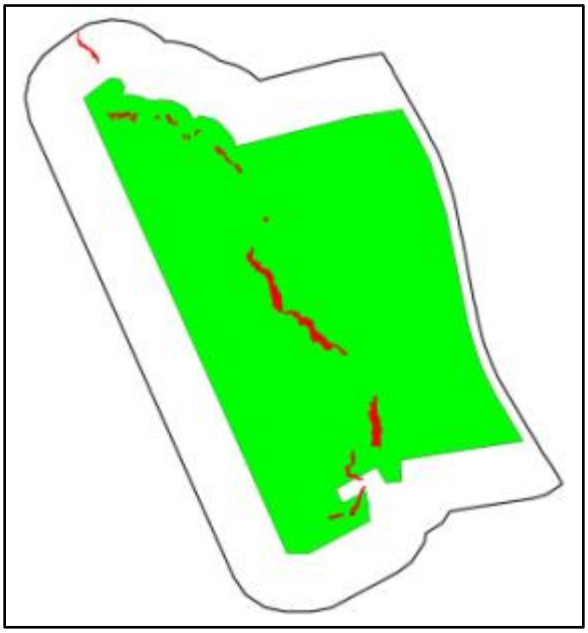
B_DL Developed Lava



B_BE Beaches

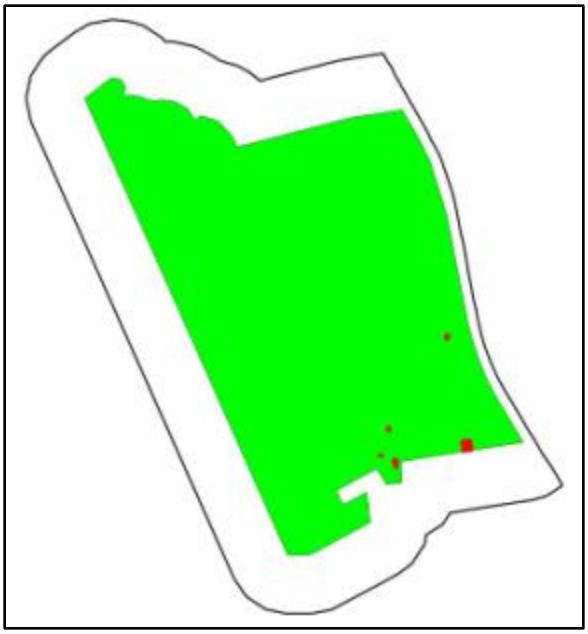


B_ER Exposed Reef and Tidal Pools



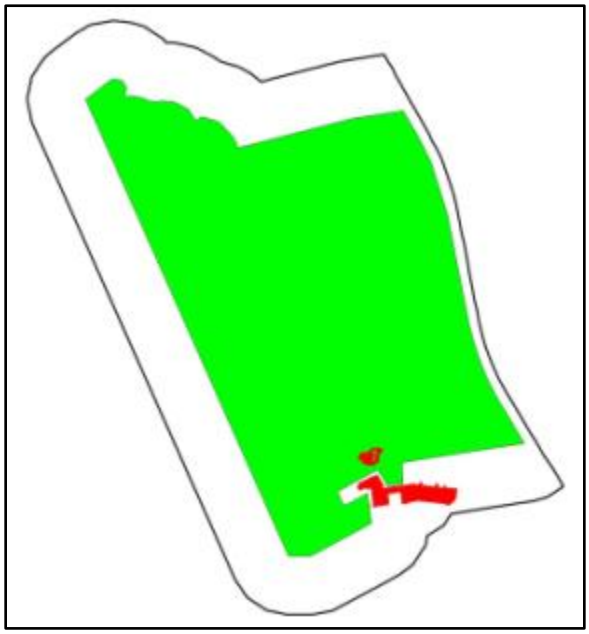
B_PA Pahoehoe Lava

L_FACL Facilities

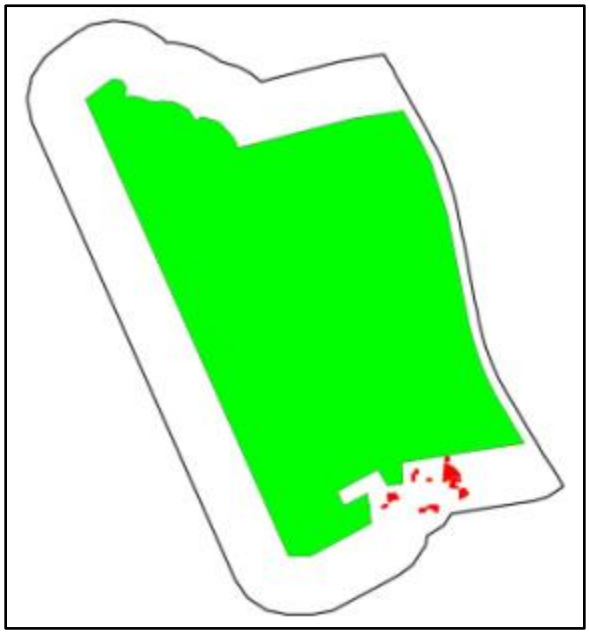


<u>LAND COVER – LAND USE</u>

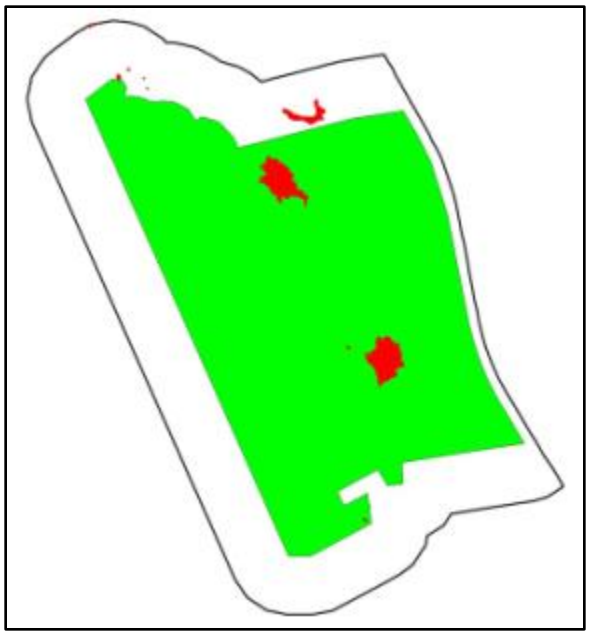
L_BAY Bay / Estuary



L_LIIN Commercial / Light Industry

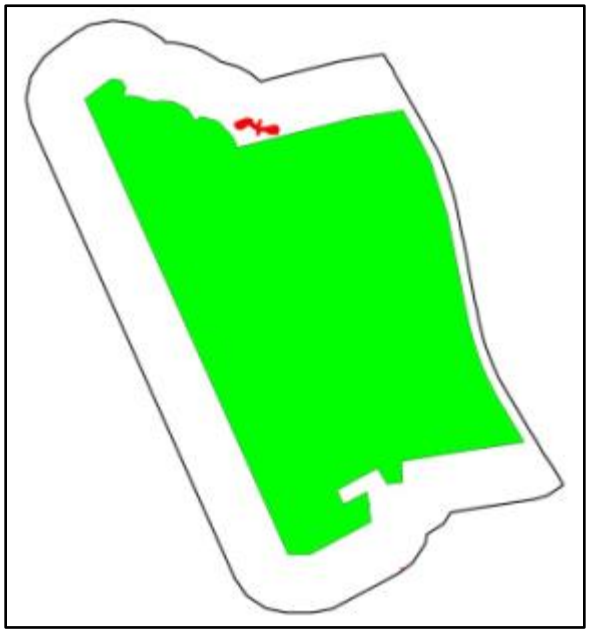


L_POND Lake / Pond

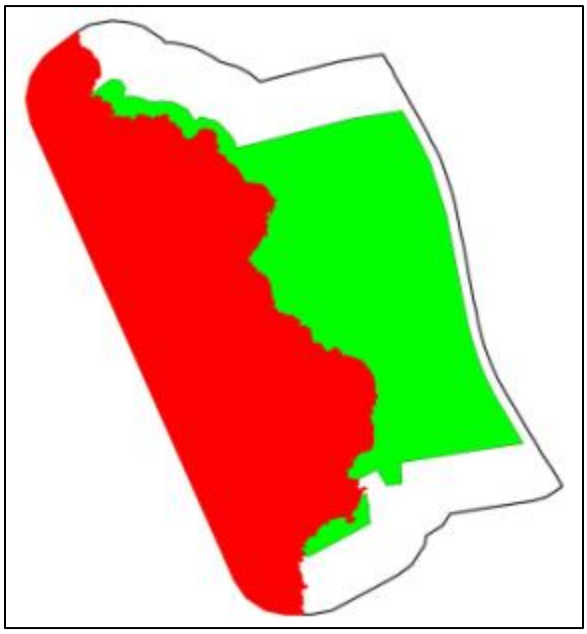


L_ROAD Transportation

L_RESD Residential



L_SEA Sea / Ocean

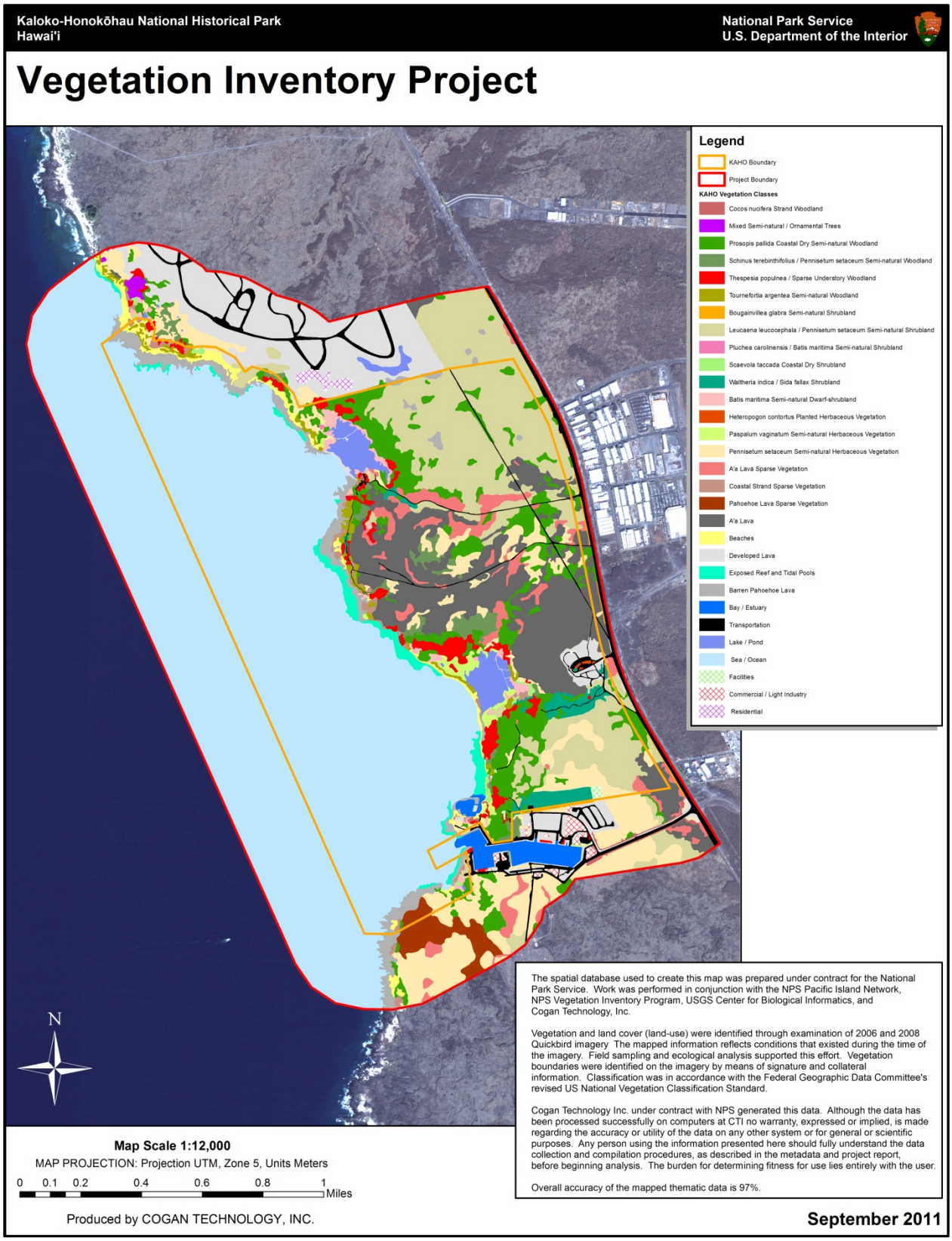


Literature Cited

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 G: Final KAHO Vegetation Map



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NPS 466/110853, October 2011

National Park Service
U.S. Department of the Interior

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