



Coastal Strand Plant Community Monitoring

Kaloko-Honokōhau National Historical Park

Natural Resource Data Series NPS/PACN/NRDS—2015/760



ON THE COVER

Coastal strand habitat at Kaloko-Honokōhau National Historical Park.
Photograph by K. Ballard.

Coastal Strand Plant Community Monitoring

Kaloko-Honokōhau National Historical Park

Natural Resource Data Series NPS/PACN/NRDS—2015/760

Alison Ainsworth, Colin Phifer, Melissa Simon, and Corie Yanger

National Park Service

Pacific Island Network – Inventory & Monitoring Program

PO Box 52

Hawai‘i National Park, HI 96718

February 2015

U.S. Department of the Interior

National Park Service

Natural Resource Stewardship and Science

Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocol.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from NPS Inventory and Monitoring, Pacific Island Network website (<http://science.nature.nps.gov/IM/units/pacn/index.cfm>), and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email irma@nps.gov.

Please cite this publication as:

Ainsworth, A., C. Phifer, M. Simon, and C. Yanger. 2015. Coastal strand plant community monitoring: Kaloko-Honokōhau National Historical Park. Natural Resource Data Series NPS/PACN/NRDS—2015/760. National Park Service, Fort Collins, Colorado.

Contents

	Page
Figures.....	v
Tables.....	v
Appendices.....	v
Abstract.....	vii
Acknowledgments.....	ix
Introduction.....	1
Methods.....	3
Site Description	3
Field Methods.....	3
Analysis	6
Results.....	7
Species richness and diversity	7
Species composition	9
Forest Structure	9
Substrate	11
Discussion.....	13
Literature Cited	17

Figures

	Page
Figure 1. Sampled plots (200m ²) in 2011 at KAHO.....	4
Figure 2. Coastal communities sampling plot layout used to quantify vegetation composition and structure..	5
Figure 3. Average species richness per plot by origin and life form.	8
Figure 4. Non-native woody species were more abundant in the understory than non-native herbaceous, native woody, and native herbaceous species	9
Figure 5. Eleven non-native (blue) and native species (green) covered at least one percent of the coastal strand understory and differed in average cover per plot.....	10
Figure 6. Population structure of the five live tree species found in the coastal strand plots.....	11
Figure 7. Percent cover by substrate type in the coastal strand ($P < 0.01$).	12
Figure 8. KAHO coastal strand sampling frame including eleven different mapped vegetation associations based on Cogan et al. 2011.	14

Tables

	Page
Table 1. Plant species found in the coastal strand monitoring plots including life form, constancy (number of plots found within the 13 sampled), and average percent understory cover.....	7

Appendices

	Page
Appendix A: Monitoring Effort	APP A.1
Appendix B: Modification of the Coastal Strand Sampling Frame	APP B.1

Abstract

A critical mission of the Pacific Island Network Inventory and Monitoring program is to monitor park ecosystems to better understand their dynamic nature and provide park managers with current data to inform management actions. The coastal strand plant community at Kaloko-Honokōhau (KAHO) is a narrow band of vegetation consisting of plant species adapted to salt spray, waves, wind, and poor soils. This community at KAHO is significant despite its small size because it is protected from shoreline development, unlike much of state's coastal strand. By establishing baseline vegetation information, we can determine if and to what extent these coastal strand plant communities are changing.

In July 2011, ten permanent and three rotational or temporary monitoring plots (200 m²) were established in the coastal strand at KAHO. Thirty-one plant species were recorded including 11 native, 19 non-native, and one Polynesian-introduced species. Species richness ranged widely among plots (3-13 species/plot) with nearly twice as many non-native species as native species per plot. Species diversity and evenness were relatively high due to this variance among plots, with 13 species only found in one plot. One of these species was the native endemic shrub, maiapilo (*Capparis sandwichiana*), which is currently listed as a species of concern. The most frequently encountered species were woody, disturbance tolerant species including native naupaka kahakai (*Scaevola taccada*), and non-native tree heliotrope (*Tournefortia argentea*) and Christmas berry (*Schinus terebinthifolius*).

The understory of the coastal strand was mostly vegetated (73% cover) with non-native species accounting for 67% of the relative vegetated cover. Similar to species richness, woody species cover was more abundant than herbaceous species cover. High non-native woody cover was primarily due to the non-native coastal tree heliotrope and native woody cover was due to naupaka kahakai and milo (*Thespesia populnea*). Tree distribution is clumped across the coastal strand with tree heliotropes dominating the large (> 10 cm diameter) live and dead trees, but encouragingly native milo was common in the small tree and seedling categories. Despite the abundance of tree heliotropes, few large downed logs were encountered and all but one were sound wood. Considering the dry windswept climate of the strand, decomposition of large logs is likely to be slow and they rarely seem to serve as nurse logs in this environment.

Currently, the coastal strand at KAHO is an assortment of microhabitats and plant associations with varying levels of invasion and few consistently dominant species. Long-term, the coastal strand is likely to be impacted by sea level rise, subsidence, drought, and as a result of growing visitor use, increased human disturbance and non-native species invasion. We expect to return to KAHO and re-measure the coastal strand plant community in 2016 to gain a greater understanding of the variance within this community and to quantify any species and population changes.

Acknowledgments

We thank Sallie Beavers and Tyler Paikuli-Campbell at Kaloko-Honokōhau National Historical Park for access, logistical support, and importantly, archaeological guidance. This work would not have been possible without the dedication of several terrific National Park Service Pacific Island Inventory and Monitoring (PACN) biological technicians (Laura Arnold, Daemerson Awong, Jacob Gross, and Forrest Phifer) and our volunteer (Keith Burnett). Kelly Kozar and Scott Kichman also with PACN provided critical data support and assistance through all aspects of this project.

Introduction

A critical mission of the Pacific Island Network (PACN) Inventory and Monitoring (I&M) program is to monitor park ecosystems to better understand their dynamic nature and to provide park managers with current data to inform management actions. Fourteen vital signs were selected to represent the overall health or condition of network park resources. Terrestrial plant communities were ranked the second most important vital sign behind water quality because plant communities are a foundational part of the natural environment and provide habitat for other species. To accomplish this objective, I&M developed the Focal Terrestrial Plant Communities (FTPC) monitoring protocol to determine the current status and assess changes in plant communities over time (Ainsworth et al. 2011).

Kaloko-Honokōhau National Historical Park (KAHO) is one of seven national parks where PACN vegetation monitoring takes place. KAHO is located just outside Kailua-Kona on the west coast of Hawai'i Island. Encompassing 469 hectares, KAHO was established in 1978 to preserve, interpret, and perpetuate the ancient and living cultural heritage of the Hawaiian people and the environment. Though surrounded by modern development, KAHO features an undeveloped, relatively intact coastal strand vegetation community (Ainsworth et al. 2011). The coastal strand vegetation consists of plant species adapted to the salt spray, waves, wind, and poor soil that border the coastline (Warshauer et al. 2009). This narrow band of vegetation is largely imperiled throughout the state due to shoreline development (Warshauer et al. 2009). For this reason, the PACN I&M program includes KAHO's coastal strand as a focal community monitored under the FTPC protocol.

The PACN vegetation monitoring project is not the first effort to document the coastal strand plant community at KAHO. Three park-wide plant surveys and mapping projects have been conducted at KAHO within the last 25 years including the recent 2011 I&M vegetation mapping inventory (Cogan et al. 2011). In 1990, Canfield detected 74 plant species within the park and adjacent lands, including 41 in the coastal strand. The coastal strand was divided into four sub-categories based upon distance from the ocean, substrate, and plant associations with increasing non-native plant dominance correlated with distance from the ocean except for the non-native beach heliotrope, (*Tournefortia argentea*) dominated shrubland sites. Three years later, 116 plant species were documented within the park during belt-transect surveys perpendicular to the ocean (Pratt & Abbott 1996). While most of the additional species documented were non-native (46 plants), nine additional indigenous and one endemic species were found. Due to the design of that study, few plots were established within the coastal strand, but those present were largely consistent with Canfield's beach heliotrope shrubland type. The 2011 vegetation mapping inventory identified 16 vegetation associations park-wide, including 11 within the coastal strand belt, three of which were only found in the coastal strand (Cogan et al. 2011). Pockets of Polynesian-introduced and cultivated plants such as noni (*Morinda citrifolia*) also intermingle with native and non-native species. Importantly, because these lowland communities appear to be subject to frequent new invaders, baseline community information and long-term monitoring are essential aids for adaptive management. Prior to the establishment of these FTPC plots, the park lacked a long-term vegetation monitoring program. Understanding how the

coastal strand plant communities are changing can inform us about other coastal communities, providing natural resources managers with predictive tools.

Looking ahead towards a changing future, this historical park faces many challenges that will affect the coastal vegetation community including climate change, subsidence, sea level rise, development, lowering of the water table due to extraction, and increased visitor usage. With our eyes toward the future, the PACN monitoring program objectives are two-fold: (1) to document the current status of the coastal strand community at KAHO; and (2) to determine the trends in plant community changes over time by resampling every five years. These monitoring objectives complement the one-time plant inventory mapping project that provided a park-wide analysis of the vegetation community through a rigorous, ground-truthed remote sensing approach (Cogan et al. 2011). In future years, the combination of permanent and temporary plots will empower us to detect community-wide changes to the vegetation and inform park managers on the health of coastal strand plant ecosystem.

In July 2011, PACN field crews spent two weeks installing long-term monitoring plots within the park's coastal strand community. This report summarizes key findings from 2011, the first year of protocol implementation at KAHO. As the first in a series of five-year reports that will assess the coastal strand vegetation community at KAHO, these findings represent a “down payment” on our long-term strategy to quantify and qualify changes to the vegetative community of KAHO in years to come.

Methods

Site Description

The park has a gentle slope towards the water with the highest point reaching 28 m. The soil throughout the coastal strand is thin and poorly developed with near-bare ‘a‘ā and pahoehoe bedrock patches and beach deposits along the shoreline (USGS-NPS 2008).

The coastal strand encompasses KAHO’s western border along the Pacific Ocean, a narrow band of rock, beach, and forested woodlands approximately 5 km long and as narrow as 10 m (Figure 1). The coastal strand sampling frame measures 4.8 ha, about 1% of the park, making it one of the smallest vegetation communities within the park. The sampling frame includes the land between the vegetated shoreline and just beyond the coastal trail, except for the wetlands and fishponds. Vegetation varies dramatically across the strand including the saturated margin of Kaloko fishpond, nearby beach margins on lava commonly consisting of non-native lowlying pickleweed (*Batis maritima*) and tree heliotropes, and dense patches of native naupaka kahakai (*Scaevola taccada*) shrublands in the sand (Canfield 1990, Cogan et al. 2011).

In contrast to the east side of the island, which generally experiences a wet winter and drier summer, KAHO experiences bimodal seasonality with two wet seasons (November/December and May/June) typical of the island’s leeward side. In the last five years, the park received an average of 362 mm of rain each year and fluctuates in temperature around 24.8° C (76.6° F; Casey 2012). Offshore winds are common in the morning with onshore breezes in the afternoon and humidity ranging from 50-80%.

Field Methods

In 2011, 15 (200 m²) coastal strand plots were monitored using a modified random sampling design according to the Focal Terrestrial Plant Communities Monitoring Protocol (Figure 1; Ainsworth et al. 2011). HAVO-based staff spent one cultural reconnaissance day and two weeks monitoring the coastal strand (Appendix A). Ten plots are permanent and will be re-read in five years and five plots are rotational or one-time temporary plots, providing greater spatial coverage of the strand. Only 13 plots are included in the following analyses, because two of the sampled rotational plots fell outside of the revised sampling frame (Appendix B).

Plots (10 x 20 m) are randomly oriented and contain nested subplots to sample different plant life forms (Figure 2). In each plot, data were collected on native and non-native plant species diversity, frequency of species occurrence, density of woody species, substrate type, and coarse woody debris. All live species rooted in the plot were recorded for the species list. Trees larger than 10 cm diameter at breast height (DBH) were counted with diameter, number of boles, and vigor recorded. Because of the unusual growth habit of tree heliotropes, they were measured at the base of the stem before it split rather than at breast height. When the heliotrope stem was oblong, the longest axis and perpendicular axis were measured and averaged to estimate basal diameter.



Figure 1. Sampled plots (200m²) in 2011 at KAHO. Rotational plots 14 and 15 were excluded from the corrected sampling frame in 2013 due to frequent water inundation.

Small trees ($1 \text{ cm} \leq \text{DBH} \leq 10 \text{ cm}$), tree seedlings ($<1 \text{ DBH}$ and $\geq 50 \text{ cm}$ in length), and shrubs were subsampled in two $2 \times 20 \text{ m}$ belt transects that parallel the long sides of the plot. The growth form of some species [naupaka kahakai, pa'uohi'iaka (*Jacquemontia ovalifolia*), and pōhuehue (*Ipomoea pes-caprae* ssp. *brasiliensis*)] were not conducive to individual counts and excluded from the shrub belt measurement. Abundance measures for these species were documented in the understory percent cover estimates only.

Understory percent cover was calculated using the pole intercept method along three 20 m transects. Every 20 cm along each transect, the substrate was recorded and intersecting species were recorded at $0\text{--}1 \text{ m}$ and $1\text{--}2 \text{ m}$ height categories. Species rooted outside the plot that overhang and intercept the 2 m pole were included.

Fallen logs or coarse woody debris (CWD) volume was estimated within each plot using Brown's planar intercept technique (Brown 1974). Wood pieces $\geq 7.6 \text{ cm}$ in diameter and at an angle $<45^\circ$ with the ground that intersected transects 2, 4, and 6 (40 m total transect length) were recorded by species, diameter, and decay class. Decay classes 1-3 are "sound" and 4-5 are "rotten" with full class descriptions available in the monitoring protocol (Ainsworth et al. 2011).

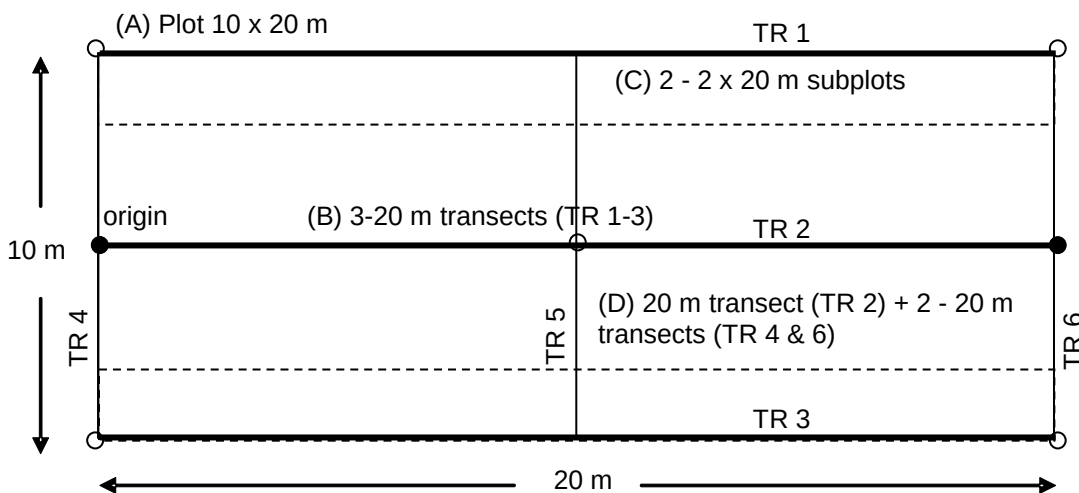


Figure 2. Coastal communities sampling plot layout used to quantify vegetation composition and structure. (A) Species presence and large tree density were recorded in the entire $10 \times 20 \text{ m}$ plot. (B) Plant species cover was recorded in two height layers ($<1 \text{ m}$ and $1\text{--}2 \text{ m}$) every 0.2 m along three 20 m transects. (C) Small tree, tree seedling, and shrub densities were read within two $2 \times 20 \text{ m}$ subplots which lie along the inside lengths of TRs 1 and 3 from 0 m to 20 m . (D) Dead downed wood ($\geq 7.6 \text{ cm}$) is quantified along the 20 m centerline (TR 2) and the two 10 m end lines (TR 4 and TR 6). Modified from Ainsworth et al. 2011.

Analysis

Statistical analyses on species richness, diversity, understory cover, and substrate were conducted using R version 3.1.1 (R Core Team 2014). The sampling unit used in analysis for all parameters was the 10 x 20 m plot. In order to compare parameters measured in subplots (e.g., small trees, seedlings, shrubs) with those measured on the plots scale (e.g., large trees), average values were calculated by multiplying the sum of the subplot counts x 2.5.

Species richness was derived from presence/absence data and includes all of the species found rooted within each plot. Measures of understory plant diversity were calculated from the cover data using the Shannon-Wiener Diversity Index (H') (Shannon & Weaver 1949) and by calculating evenness (J') (Pielou 1966, 1969). Absolute percent cover values per species and substrate type were calculated by dividing the actual cover hits by the total possible cover hits per plot (300). Absolute percent cover for composite groups (e.g., natives, non-natives, graminoids, woody species) were generated by treating each group as a species with a maximum of one hit per 20 cm or a total of 300 possible hits per plot equaling 100% cover.

Differences in species richness and arcsine squareroot transformed combined understory cover were analyzed using two sample, two-tailed t -tests (native vs. non-native) and one-way analysis of variance (ANOVA) with Tukey's multiple comparison tests (origin x life form combinations). ANOVA and t -tests were performed with an $\alpha = 0.05$. Individual species cover values and substrate were compared using nonparametric tests (Kruskal-Wallis with corrected pairwise comparisons) because the assumptions of ANOVA were not met due to lack of normality and large differences in variance among groups.

CWD volume per unit of area (V ; m^3/ha) was calculated for sound and rotten wood as $V = \pi^2 \sum d^2 / 8L$, where d (cm) is the diameter of each piece where it intersects the transect, and L (m) is the total length of transect measured per plot (Harmon 1986).

Results

Species richness and diversity

Thirty-one plant species were recorded in the coastal strand including 11 native, 19 non-native, and one Polynesian-introduced species (Table 1). Species richness (alpha) ranged widely among plots (3-13 species/plot) with an average of 6.9 ± 0.8 species per plot (200 m²) and on average nearly twice as many non-native species were present than native species ($P = 0.05$). Species diversity ($H' = 1.07$) and evenness ($J' = 0.57$) were relatively high due to the variance among plots and lack of single species dominants across the coastal strand. Thirteen species were singletons (only found in one plot each), but importantly one of these species was the native endemic shrub, maiapilo (*Capparis sandwichiana*), which is currently listed as a species of concern. The most constant or frequent species were woody, disturbance-tolerant species including native naupaka kahakai, and non-native Christmas berry (*Schinus terebinthifolius*), and tree heliotrope. On average, nearly twice as many non-native woody species (shrubs+trees) were encountered per plot than non-native herbaceous, native woody or native herbaceous species ($P < 0.01$; Figure 3).

Table 1. Plant species found in the coastal strand monitoring plots including life form, constancy (number of plots found within the 13 sampled), and average percent understory cover.

Scientific name	Common name	Family	Life form	Constancy	Understory Cover (%)
Native					
<i>Boerhavia repens</i>	alena	Nyctaginaceae	Herb	1	<1
<i>Capparis sandwichiana</i> ^{1,2}	maiapilo	Capparaceae	Shrub	1	<1
<i>Cordia subcordata</i> ¹	kou	Boraginaceae	Tree	1	<1
<i>Fimbristylis cymosa</i> ssp. <i>umbellato-capitata</i> ¹	mau'u	Cyperaceae	Sedge	2	<1
<i>Ipomoea pes-caprae</i> ssp. <i>brasiliensis</i>	pōhuehue	Convolvulaceae	Vine	3	1.5
<i>Jacquemontia sandwicensis</i>	pa'uohi'iaka	Convolvulaceae	Vine	2	<1
<i>Myoporum sandwicense</i> ³	naio	Myoporaceae	Tree	1	<1
<i>Scaevola taccada</i>	naupaka kahakai	Goodeniaceae	Shrub	9	17.2
<i>Sesuvium portulacastrum</i>	'ākulikuli	Aizoaceae	Herb	4	<1
<i>Solanum americanum</i>	pōpolo	Solanaceae	Herb	1	<1
<i>Thespesia populnea</i>	milo	Malvaceae	Tree	6	7.2
<i>Waltheria indica</i>	'uhaloa	Malvaceae	Herb	5	<1
Non-native					
<i>Abutilon grandifolium</i>	hairy abutilon	Malvaceae	Shrub	1	<1
<i>Batis maritima</i>	pickleweed	Bataceae	Shrub	3	8.1
<i>Catharanthus roseus</i>	Madagascar periwinkle	Apocynaceae	Herb	1	<1
<i>Cenchrus setaceus</i>	fountain grass	Poaceae	Grass	4	5
<i>Cynodon dactylon</i>	Bermuda grass	Poaceae	Grass	2	<1
<i>Euphorbia hirta</i>	hairy spurge	Phyllanthaceae	Herb	2	<1
<i>Lantana camara</i>	lantana	Verbenaceae	Shrub	1	<1
<i>Leucaena leucocephala</i>	koa haole	Fabaceae	Shrub	4	1.8

Table 2 (continued). Plant species found in the coastal strand monitoring plots including life form, constancy (number of plots found within the 13 sampled), and average percent understory cover.

Scientific name	Common name	Family	Life form	Constancy	Understory Cover (%)
<i>Morinda citrifolia</i> ⁴	noni	Rubiaceae	Tree	2	<1
<i>Paspalum vaginatum</i>	seashore paspalum	Poaceae	Grass	1	3.6
<i>Pluchea carolinensis</i>	sourbush	Asteraceae	Shrub	3	2.4
<i>Portulaca oleracea</i> ¹	pigweed	Portulacaceae	Herb	1	<1
<i>Portulaca pilosa</i>		Portulacaceae	Herb	1	<1
<i>Prosopis pallida</i>	kiawe	Fabaceae	Tree	2	3
<i>Schinus terebinthifolius</i>	Christmas berry	Anacardiaceae	Tree	8	3.4
<i>Stachytarpheta jamaicensis</i>	Jamaica vervain	Verbenaceae	Herb	1	<1
<i>Talinum fruticosum</i> ¹	talinum	Portulacaceae	Herb	5	<1
<i>Tournefortia argentea</i>	tree heliotrope	Boraginaceae	Tree	9	30.3
<i>Urochloa maxima</i>	Guinea grass	Poaceae	Grass	1	<1
<i>Vachellia farnesiana</i>	klu	Fabaceae	Shrub	2	<1

¹Species rooted in plots, but rare enough to not be encountered along cover transects.

²Endemic species.

³Tree leaning into plot on cover line, but not rooted within the plot and not included in density or presence counts.

⁴Polynesian-introduced species.

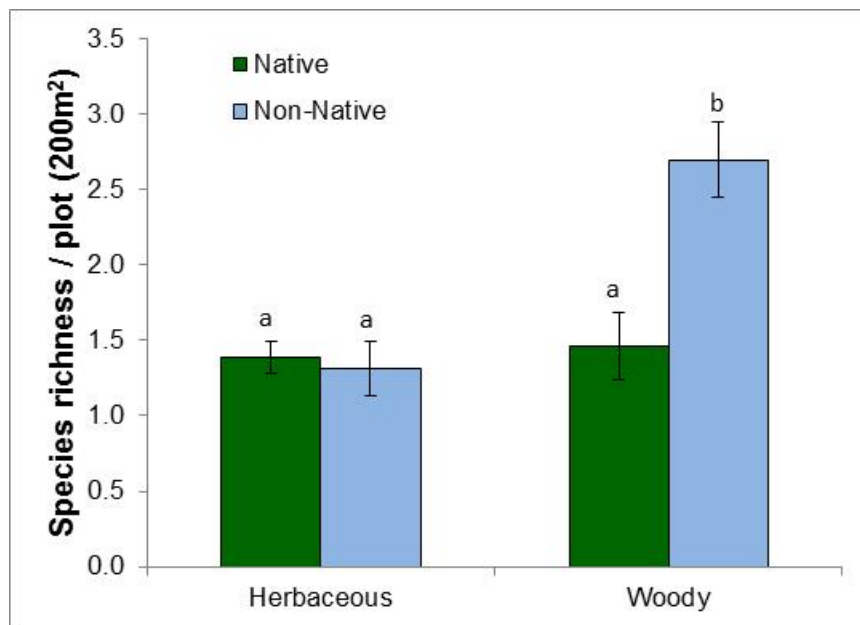


Figure 3. Average species richness per plot by origin and life form ($P < 0.01$). Non-native woody species (trees and shrubs) were the most diverse life form per plot. Data are means $\pm$ 1 SE. Letters indicate significant differences.

Species composition

The understory (<2 m) of the coastal strand was mostly vegetated (73% cover) with non-native species accounting for 67% of the relative vegetated cover ($P < 0.01$). Data are presented for the combined understory tiers because little difference was found between the lower (0-1 m) and upper tiers (1-2 m). Woody species were more abundant than herbaceous species for natives and non-natives (Figure 4). Non-native woody trees and shrubs covered nearly half of the understory tier while native woody species covered less than a quarter. Similarly, non-native herb and grass cover was three-fold more abundant (10%) than native herbaceous species cover (3%). Eleven of the 27 species found along cover lines had greater than 1% cover and most were woody species (Figure 5). High non-native woody cover was primarily due to the non-native coastal tree heliotrope. This species was found in 85% of the plots sampled and averaged over 30% cover. The low branching architecture of tree heliotropes creates abundant understory cover and deep shade. The low-lying invasive shrub pickleweed, was also very abundant in patches (up to 80% cover), but only found in 23% of the plots along the coast resulting in low average cover (<10%). Two native woody species, naupaka kahakai (17% cover) and milo (*Thespesia populnea*; 7% cover), were also frequently encountered and abundant in portions of the strand accounting for nearly all of the native woody understory cover.

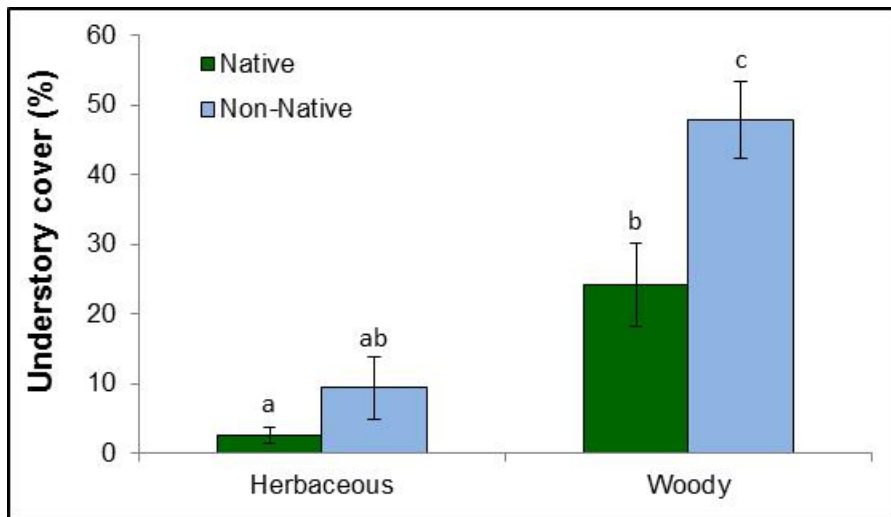


Figure 4. Non-native woody species were more abundant in the understory than non-native herbaceous, native woody, and native herbaceous species ($P < 0.01$). Data are means $\pm$ 1 SE. Letters indicate significant differences.

Forest Structure

Tree distribution is clumped across the coastal strand with only one native and five non-native tree species documented within plots (Figure 6). Tree density within plots ranged from no trees in two plots to 18 (nine large and nine small trees) in the densest plot. On average, plots contained over three trees. Live non-native tree heliotrope dominated the large tree size class accounting for 41 trees or 89% of the large trees. This result is not surprising considering that all six tree species encountered are generally considered “small trees” and only tree heliotropes were measured as basal diameters, which are typically larger than DBH. On average, large tree heliotropes were vigorous

(>75% of branches alive) and had 2.2 boles at the base with an average bole basal diameter of 15.8 cm. Despite the abundance of large tree heliotropes, regeneration (small trees and seedlings) of these species was low in plots. The native tree, milo, was the most abundant small tree (1-10 cm diameter) averaging one per plot and encouragingly regenerating with 0.5 seedlings per plot. One additional small native tree, kou (*Cordia subcordata*), was present in one plot, but was not sampled as it was not rooted within the small tree subplot. Few invasive trees, kiawe (*Prosopis pallida*) and Christmas berry, and Polynesian-introduced, noni (*Morinda citrifolia*), were present within plots. Twenty-two dead trees or snags were recorded, accounting for 32% of the canopy structure. Similar to the live large trees, dead tree heliotropes dominated, averaging over one dead tree per plot and kiawe averaged just over 0.3 dead trees per plot. On average, 1.7 dead small trees or seedlings were found within plots with tree heliotropes the most common.

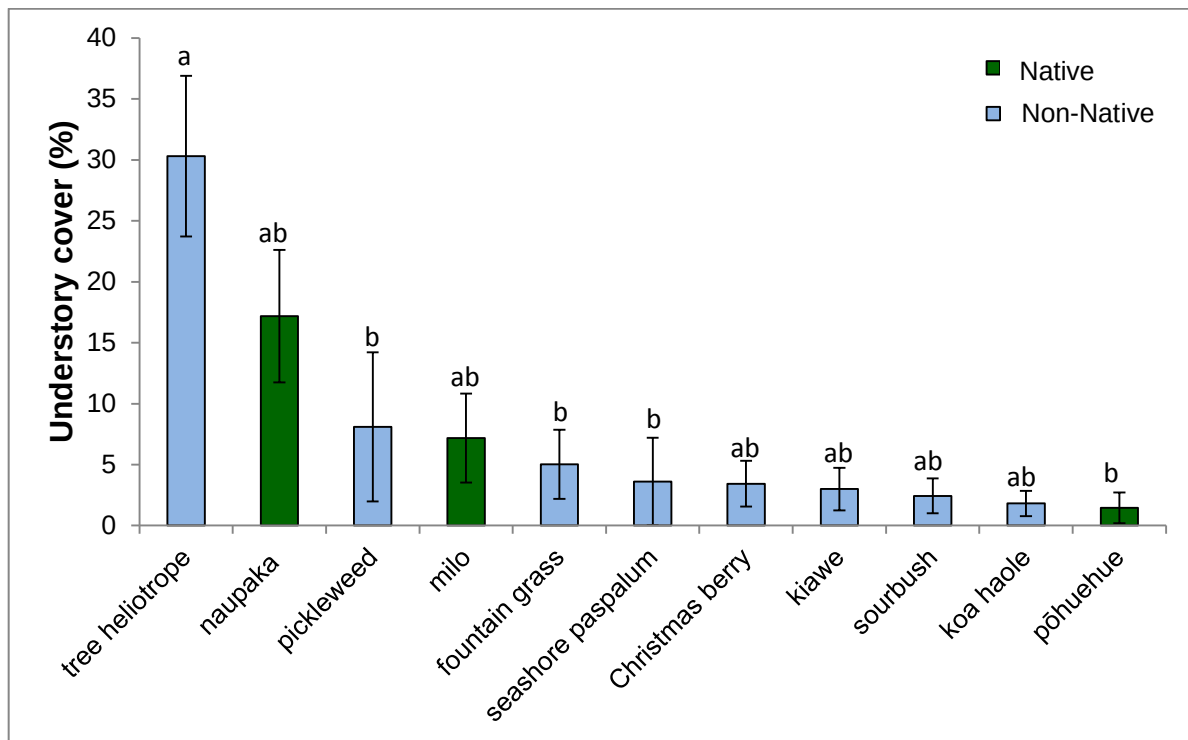


Figure 5. Eleven non-native (blue) and native species (green) covered at least one percent of the coastal strand understory and differed in average cover per plot ($P < 0.01$). Due to the high variability among plots across the strand, tree heliotrope had significantly higher cover than pickleweed, fountain grass, seashore paspalum, and pōhuehue. Data are means $\pm$ 1 SE. Letters indicate significant differences.

Shrub density was also patchy for the three non-native species, koa haole (*Leucaena leucocephala*), sourbush (*Pluchea carolinensis*), and klu (*Vachellia farnesiana*) were recorded. The most abundant shrub, koa hoale, was found in four of the thirteen plots sampled and for those plots averaged 2.5 individuals per plot. Similarly, sourbush and klu were only found in three and two plots respectively. Density was not measured for the other five shrub species encountered because they were either difficult to distinguish as individuals or rare. Two of the most abundant understory species (Figure 5), pickleweed and naupaka kahakai, do not have recorded shrub densities because it was too challenging to accurately define individuals for these crawling, branching, frequently rooting species.

Three other shrubs, hairy abutilon (*Abutilon grandifolium*), maiapilo, and lantana (*Lantana camara*) were uncommon and not rooted within any sampling subplots.

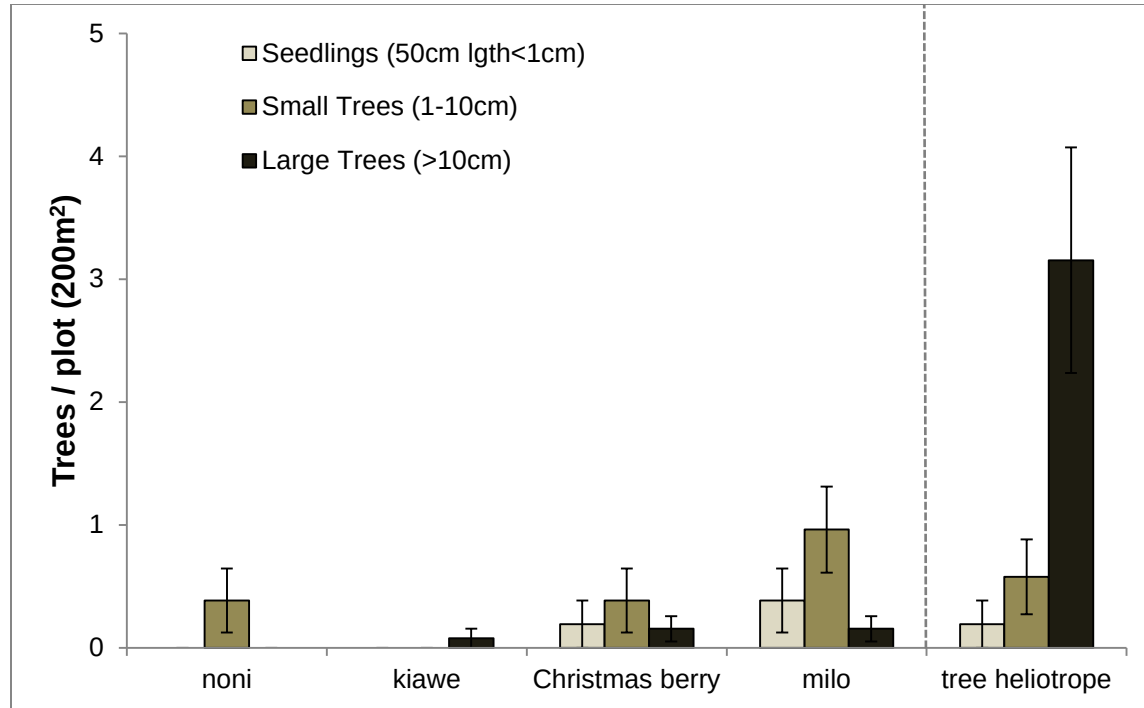


Figure 6. Population structure of the five live tree species found in the coastal strand plots. Non-native trees dominate with only one native (milo) and one Polynesian-introduced tree (noni). Size classes represent dbh except tree heliotrope, which was measured as basal diameter due to its low branching growth form. Statistical analyses were not conducted due to the low sample sizes. Data are means $\pm$ 1 SE.

Substrate

Litter, defined as loose dead plant material (i.e., leaves, twigs) covered 68% of the surface substrate in the coastal strand with exposed rock/coral, sand, and soil accounting for the rest (Figure 7). Soil was minimal and rock, coral, and sand, covered 31% of the surface indicating that nearly a third of the area contains challenging substrate for seedling establishment.

Despite the abundance of woody vegetation and snags at KAHO, large downed logs (>7.3cm diameter) or fallen CWD were not abundant within the plots. In total, only seven sound pieces and one rotten piece of woody debris were measured in seven plots. The rotten piece had a diameter of 10.5 cm and on average across the strand the calculated volume for rotten wood was 0.26 ± 0.26 m³/ha. The sound wood had an average diameter of 21.7 ± 10.0 cm and calculated volume of 14.3 ± 11.8 m³/ha.

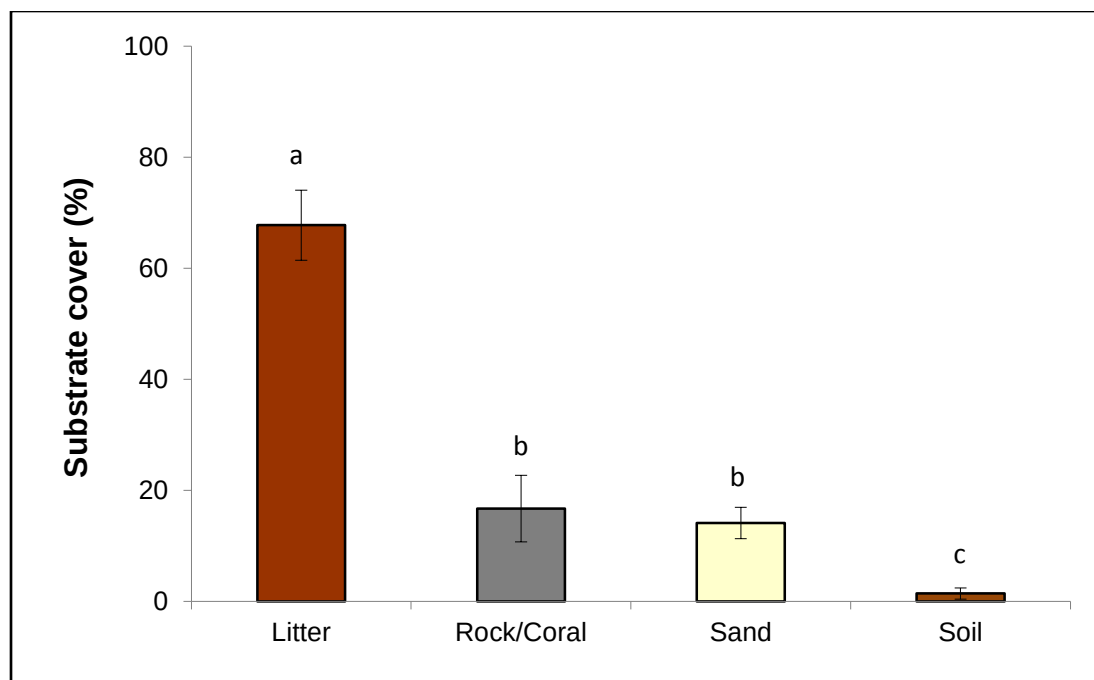


Figure 7. Percent cover by substrate type in the coastal strand ($P < 0.01$). Litter, loose dead plant material, was the most abundant type. Data are means $\pm$ 1 SE. Letters indicate significant differences.

Discussion

The coastal strand is an assortment of microhabitats and plant associations sharing the same narrow band of coastline. Our results paint a complex landscape with few dominant species. The varying species composition and structure among FTPC monitoring plots is largely consistent with the 2011 vegetation inventory map (Cogan et al. 2011) that delineated 11 different plant associations within the coastal strand sampling frame (Figure 8). Similarly, the earlier Canfield 1990 report identified four different types of coastal strand and then as now, woody shrubs and trees were the most dominant life form primarily consisting of non-native/invasive pickleweed, tree heliotrope, and Christmas berry and native naupaka kahakai and milo.

Nearly three quarters of the understory within the coastal strand was vegetated with non-native species accounting for over half the total cover. The remaining unvegetated area consisted of exposed rock, coral, and sand. Despite relatively consistent vegetated cover across FTPC plots, the structure varies dramatically. Currently, the least invaded portion of the strand community is located on sandy coastal berm and dominated by interwoven indigenous naupaka kahakai shrubs. These tropical and subtropical coastal dominant shrubs are very resilient to disturbance including salt spray and variable substrate salinity (Goldstein et al. 1986). Additionally, broken branches resulting from high surf activity have been observed re-establishing as rooted shrubs (A. Ainsworth, pers. observation). Importantly, these coastal patches of native naupaka kahakai represent potential endangered hawksbill sea turtle (*Eretmochelys imbricata*) nesting habitat.

Many slightly elevated plots on mixed sandy sites are dominated by non-native tree heliotropes with low branching overlapping architecture typically creating dense shade. Although these species seem to outcompete native vegetation and likely limit regeneration, they do provide valuable shade enjoyed by park day-use visitors (S. Beavers pers. communication). Wetter sites are typically dominated by the low crawling invasive shrub, pickleweed, with few other species and minimal structural complexity. Plots in these important wetland sites along the coastal perimeter of the Kaloko and 'Aimakapā fishponds provide key baseline information for park managers both to gauge invasive species spread and/or future management efficacy. Some scattered, inland dry and rocky sites contained non-native invasive fountain grass resulting in elevated fuel loads and increased fire risk (Blackmore and Vitousek 2006).

Despite the abundance of non-native plant species, the coastal strand, adjacent wetlands, and anchialine pools provide important habitat for many rare animals including basking sea turtles, birds, shrimps, and insects. Specifically, the wetlands and fishponds provide habitat for ae'o or Hawaiian stilt (*Himantopus mexicanus knudseni*) and 'alae ke'oke'o or Hawaiian coot (*Fulica alai*), two federally endangered shore birds. To date, the park has made great progress improving wetland habitat by eradicating highly invasive red mangroves (*Rhizophora mangle*) and controlling kiawe around 'Aimakapā and Kaloko fishponds. Additionally, efforts have begun to remove pickleweed and paspalum grass around the fishponds. The majority of recent control efforts have been focused in drier sites primarily inland from the strand including kiawe and koa haole removal where they

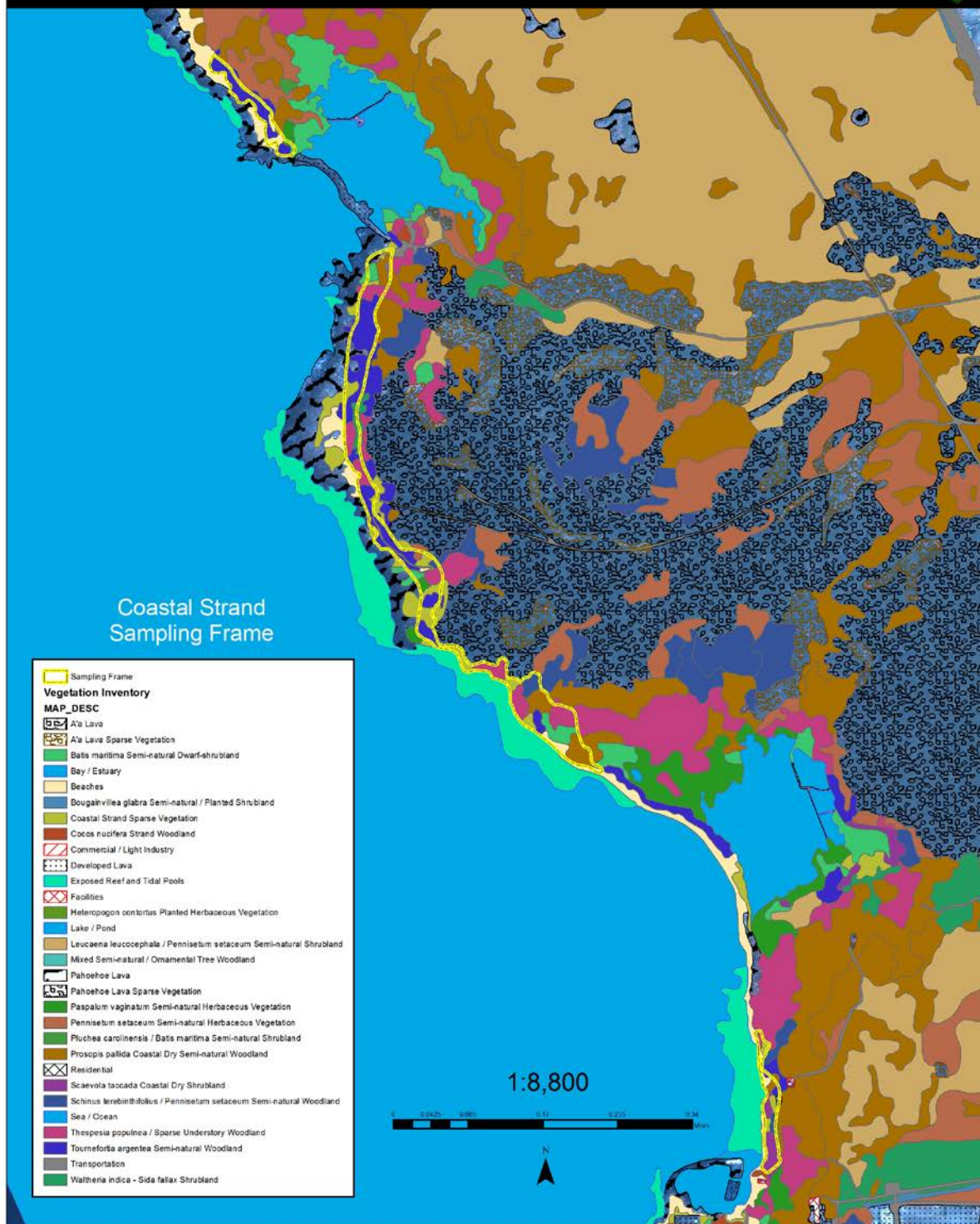


Figure 8. KAHO coastal strand sampling frame including eleven different mapped vegetation associations based on Cogan et al. 2011.

negatively impacting cultural resources and fountain grass control. These FTPC plot data may provide important quantitative structural information on invasive plant stem densities that can be used to improve control cost and labor estimates (Leary and Gross 2013).

Long-term, the KAHO coastal strand is likely to be impacted by sea level rise, subsidence, drought and increased human disturbance and non-native species invasion as a result of growing visitor usage. Sea level rise may directly impact plant species through loss of habitat, high tides and storm surges as well as indirectly through spoiling of vital subterranean freshwater sources (IPCC 2013). Recent modeled sea level rise projections for KAHO identify key areas where some anchialine pools will be inundated with water and fishpond and wetland habitat will shift inland in the landscape, clearly impacting the existing coastal strand vegetation (Marrack and O'Grady 2014). Additionally, the continuing trend of increasing temperature and potentially decreasing precipitation in Hawaii will also impact the availability of water for coastal plants (Diaz and Giambelluca 2012).

We expect to return to KAHO and re-measure the coastal strand plant community in 2016. Future reports will feature not only a summary of the statistics of the current year findings, but will include species and population trends for the park as we begin to systematically document if and how the coastal community is changing over time.

Literature Cited

- Ainsworth, A., P. Berkowitz, J.D. Jacobi, R.K. Loh, and K. Kozar. 2011. Focal terrestrial plant communities monitoring protocol: Pacific Island Network. Natural Resource Report NPS/PACN/NRR-2011/410. National Park Service, Fort Collins, Colorado.
- Blackmore, M. and P. Vitousek. 2000. Cattle grazing, forest loss, and fuel loading in a dry forest ecosystem at Pu'u Wa'a Wa'a Ranch, Hawaii. *Biotropica* 32:625-632.
- Brown, J. K. 1974. Handbook for inventorying downed woody material. USDA Forest Service Gen. Tech. Rep. INT-16. Intermountain Forest and Range Experiment Station. Ogden, Utah.
- Canfield, J. E. 1990. Distribution and map of the plant communities of Kaloko-Honokōhau National Historical Park. Technical Report 73. Pacific Cooperative Studies Unit. Honolulu, Hawaii.
- Casey, T. L. 2012. Annual weather/climate data summary 2010: Pacific Island Network. Natural Resource Data Series NPS/PACN/NRDS—2012/273. National Park Service, Fort Collins, Colorado.
- 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.
- Diaz, H. F. and T. W. Giambelluca. 2012. Changes in atmospheric circulation patterns associated with high and low rainfall regimes in the Hawaiian Islands region on multiple time scales. *Global and Planetary Change* 98-99:97-108.
- Goldstein, G., D. Drake, C. Alpha, P. Melcher, J. Heraux, and A. Azocar. 1996. Growth and photosynthetic responses of *Scaevola sericea*, a Hawaiian coastal shrub, to substrate salinity and salt spray. *Int. J. Plant Sci.* 157:171-179.
- Harmon, M. E., J. F. Franklin, F. J. Swanson, P. Sollins, S. V. Gregory, J. D. Lattin, N. H. Anderson, C. P. Cline, N. G. Aumen, J. R. Sedell, G. W. Lienkaemper, K. Cromack, and K. W. Cummins. 1986. Ecology of coarse woody debris in temperate ecosystems. *Advances in Ecological Research* 15:133-302.
- Intergovernmental Panel on Climate Change (IPCC). 2013. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, New York.
- Leary, J. and J. Gross. 2013. Characterizing weed management activities for archeological site preservation and grass-fire mitigation at Kaloko-Honokōhau National Historical Park. Technical Report No. 184. Pacific Cooperative Studies Unit, University of Hawai'i, Honolulu, Hawai'i.

- Marrack, L. and P. O'Grady. 2014. Predicting impacts of sea level rise for cultural and natural resources in five National Park units on the Island of Hawaii. Technical Report No. 188. Pacific Cooperative Studies Unit, University of Hawaii, Honolulu, Hawaii.
- Pielou, E. C. 1966. An introduction to mathematical ecology. John Wiley and Sons, New York, New York.
- Pielou, E. C. 1969. Shannon's formula as a measure of specific diversity: Its use and misuse. *American Naturalist* 100:463-465.
- Pratt, L. W. and L. L. Abbott. 1996. Distribution and abundance of alien and native plant species in Kaloko-Honokohau National Historical Park. Technical Report 103. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa University of Hawaii Press, Honolulu, Hawaii.
- R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. (<http://www.R-project.org>)
- Shannon, C. E. and W. Weaver. 1949. The mathematical theory of communications. University of Illinois Press, Urbana, Illinois.
- Warshauer, F. R., J. D. Jacobi, and J. P. Price. 2009. Native coastal flora and plant communities in Hawai'i: Their composition, distribution, and status. Hawai'i Cooperative Studies Unit Technical Report HCSU-014. University of Hawai'i at Hilo. Hilo, Hawaii.
- United States Geological Survey and National Park Service. 2008. Geologic resource evaluation for Kaloko-Honokōhau National Historical Site, Hawai'i: Geology and Coastal Landforms. B. M. Richmond, A. E. Gibbs, and S. A. Cochran. Open File Report 2008-1191. Reston, Virginia.

Appendix A: Monitoring Effort

This appendix summarizes field season effort, logistical details, and future recommendations for monitoring Kaloko-Honōkohau National Historical Park (KAHO) coastal strand. By documenting actual field season effort staff may examine 1) how crews spent time in the office versus in the field, 2) patterns for plot completion times, 3) monitoring site access and transit times to aid in planning for future trips, and 4) what improvements can be made to make time use more efficient.

Training Effort

Crews consisted of two to seven individuals. Alison Ainsworth, the project lead, supervised the field crew while Corie Yanger served as primary field leader for focal terrestrial plant communities monitoring. Daemerson Awong stayed on with the program from the previous year and also assisted in leading crews. Three seasonal field technician positions were filled by Laura Arnold (second season), Jacob Gross, and Forrest Phifer, the latter beginning in June 2011. One volunteer, Keith Burnett, assisted with KAHO monitoring.

Training effort includes both office and field time used to complete certifications and to learn monitoring methods. Crew members spent approximately two weeks participating in office and field trainings applicable to both the focal terrestrial plant communities (HAVO and KAHO) and established invasive plant species (HAVO) projects. Office-based trainings included defensive driving, computer security, herbarium and radio. All crew were current in first aid and CPR. A few of the technicians and the volunteer received training in Basic Helicopter Safety (B3). All field leaders were certified First Responders. Field training involved learning how to navigate to monitoring sites, and survey and identify plants. While all technicians had previous experience with Hawaiian flora, some additional training was needed.

Office Effort

Office effort, including field preparation and data processing, equals the remaining time that was not spent on training or monitoring in the field. Work accomplished during this time included photograph and GPS downloading and processing, preparing for camping trips, scanning datasheets, and entering and checking data. Field work processing tasks were delegated according to each person's strengths, and crew members alternated for fieldwork, usually leaving at least one person to work in the office while the others camped. This system helped to keep data entry from backing up and allowed everyone the opportunity to take a break from the field if needed.

Field Effort

Calculated field effort was compiled from original data forms, notebooks, photographs, calendars, and personnel interviews. Total worker hours were calculated by multiplying transit and monitoring site completion times by crew size. Fifteen FTPC plots (10 m x 20 m) were completed in two consecutive week-long trips in July 2011. The project lead arranged for lodging at the Pu‘uhonua o Hōnaunau National Historical Park (PUHO) dorm in Hōnaunau on Hawai‘i Island.

The project lead and field leader conducted a one-day reconnaissance trip for cultural clearance on June 15, surveying ten fixed plots over 19 worker hours (about 2 worker days). All fixed plots were

re-located during reconnaissance for one of several reasons: 1) proposed plot located in ocean or in tidal pool area, 2) plot located on park trail, 3) plot too close to cultural feature. Rotational plots were not visited during reconnaissance because they did not require the installation of permanent markers. However, once vegetation monitoring began on July 11, 2011, numerous proposed rotational plots were also relocated because they were in the ocean or on a trail. In the future, field leaders should continue to work with park cultural resource managers to maintain awareness of sensitive cultural features. Additionally, crews should monitor changes in the tide as some plots became inundated with water. Plot R14 was located in a patch of pickleweed (*Batis maritima*), which concealed cracks and water. Largely due to the commuting time from the PUHO dorm, the crew accumulated some overtime while working at KAHO.

Table A.1. Focal terrestrial plots completed in coastal strand at KAHO. KP = Kaloko pond parking area, KTH = Kaloko trail toward harbor, FP = across fishpond wall, HH = Honokōhau Harbor to Honokōhau trail and shore access.

Date	Plot No.	Crew No.	Hours/Plot	Access Location	Transit Hours	Total worker Hours
7/11/11	R11	4	3	KP, KTH	6.25	37
7/12/11	F3, R14	4	3.75	KP, FP	4.5	33
7/13/11	F4, F6, F1	4	4.75	KP, KTH	4.5	37
7/14/11	F7	4	2.5	KP, KTH	6.25	35
7/18/11	F8	6	2.5	HH	6.25	52.5
7/19/11	F2, F10, R15	6	5.25	KP, KTH	4.5	58.5
7/20/11	F9, R12, R13	6	5	KP, KTH	4.5	57
7/21/11	F5	6	2	HH	6.25	49.5

Over the two weeks sampling in KAHO, the crew spent a total of 144.5 worker hours (14.5 worker days) on plot setup and sampling averaging about two hours per plot (Table A.1). With transportation included, the crew required a total of 359.5 worker hours (36 worker days) to successfully complete the 15 plant community plots at KAHO. Transportation time included two hours to/from HAVO per week and 1-1.5 hours to/from PUHO dorm during the week.

High daily temperatures and humidity made heat exhaustion a major concern at KAHO. To stay comfortable, the crew froze water bottles overnight to have cool water throughout the day, took short breaks often, and used sun protection. Crews also adjusted to begin work at 0500 instead of the usual 0600 to limit exposure during the hottest times of the day. The park requested that the I&M crew wear bright yellow KAHO safety vests to identify crew members as well as conduct a daily check in and out with park dispatch. Crews must maintain awareness of footing at all times, especially while working or hiking on rocks made slick by the tides. These rocks are slippery even when they are not covered with water and can pose an even higher risk to unwary crew members. Thick vegetation and non-native orb-weaving and spiny-backed spiders are abundant in KAHO coastal strand. One crew member was injured by a broken branch while working in thick heliotrope trees, and some staff fell into water-filled cracks that were concealed by pickleweed.

Appendix B: Modification of the Coastal Strand Sampling Frame

The KAHŌ focal terrestrial plant community (FTPC) coastal strand sampling frame was permanently adjusted in 2013 because the original frame proposed in Ainsworth et al. 2011 was inaccurate (Figures B.1-B.4). During the 2011 baseline monitoring 10 of the 15 proposed FTPC plots were located in the ocean or other unsuitable unvegetated locations, forcing the botanist (Ainsworth) in consultation with the park archaeologist to randomly relocate the plots on-the-fly in the field. Sampled plots are indicated on maps as boxes with check marks (Figures B.1-B.4).

The adjusted sampling frame (Figure 1) is based on the original frame (Figures B.1-B.4) that was generated from the Canfield 1990 vegetation survey, with modifications based on 2006 QuickBird satellite imagery and the Cogan et al. 2011 vegetation inventory map layer. We realigned the sampling frame with the satellite imagery to exclude raw pahoehoe lava and sandy beaches that border the shore. The interior or western boundary of the sampling frame is primarily consistent with the coastal trail. The frame expands beyond the coastal trail where the trail divides consistent substrate and coastal strand vegetation. In these instances, we used the 2011 vegetation mapping inventory as a guide. Finally, we excluded the wetlands surrounding Kaloko and 'Aimakapa fishponds because they receive regular water inundation.

Sampled rotational plots 14 and 15 were excluded from the adjusted frame because they were inundated with water during high tide. Further, the 1990 vegetation survey assessed these plot locations as being in marshland and mangrove forests, two vegetative types we are not including in the FTPC coastal strand community.

The size of the new sampling frame is 4.8 ha compared to the incorrect legacy sampling frame of 10.1 ha, a 52.5% reduction in size. This redefined frame will serve as the permanent coastal strand sampling frame for future resampling efforts.



Figure B.1. Proposed and sampled plots (check marks) in the north part of the park and the original legacy frame.



Figure B.2. Proposed and sampled (check marks) plots and the original legacy frame.

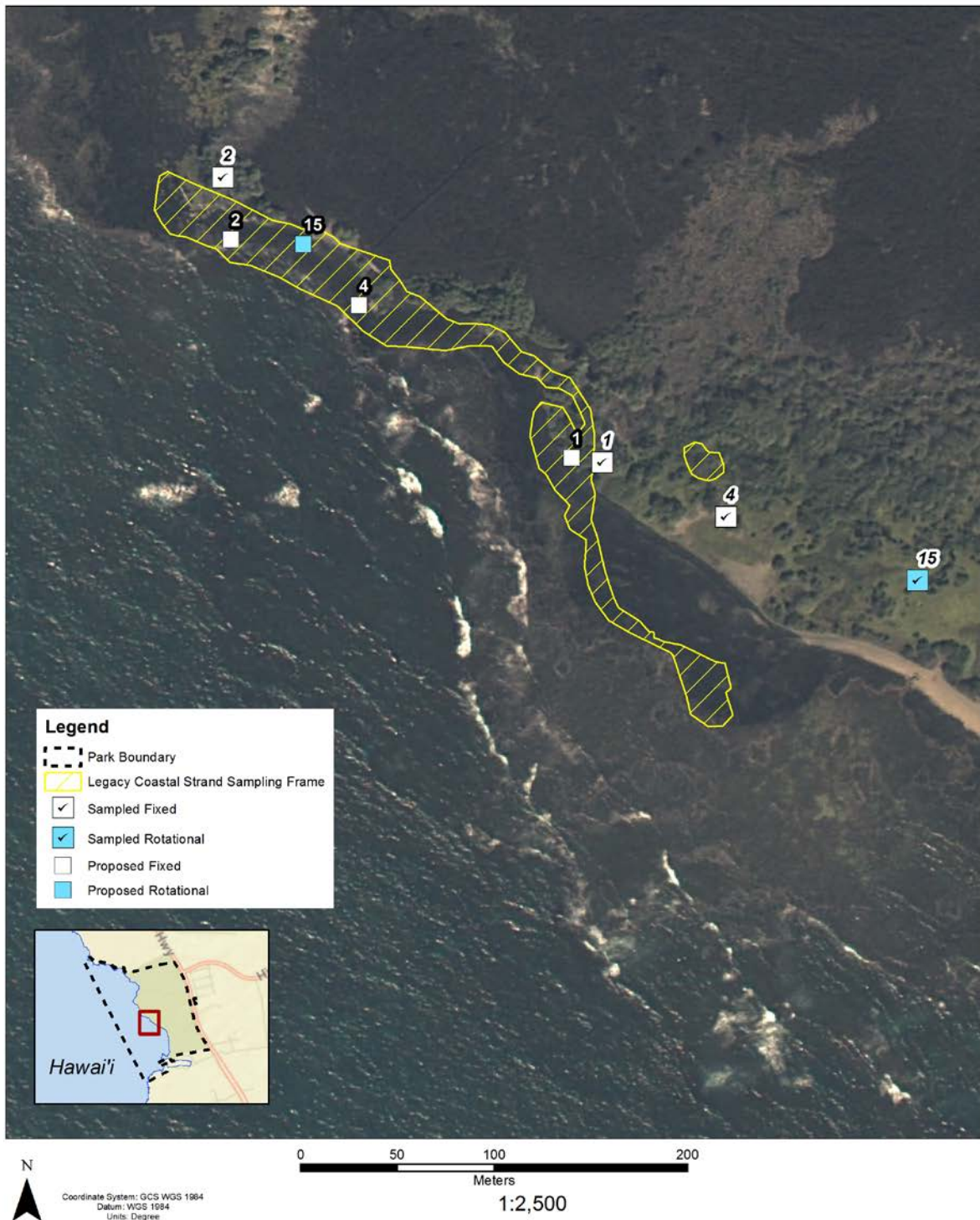


Figure B.3. Proposed and sampled (check marks) plots and the original legacy frame.

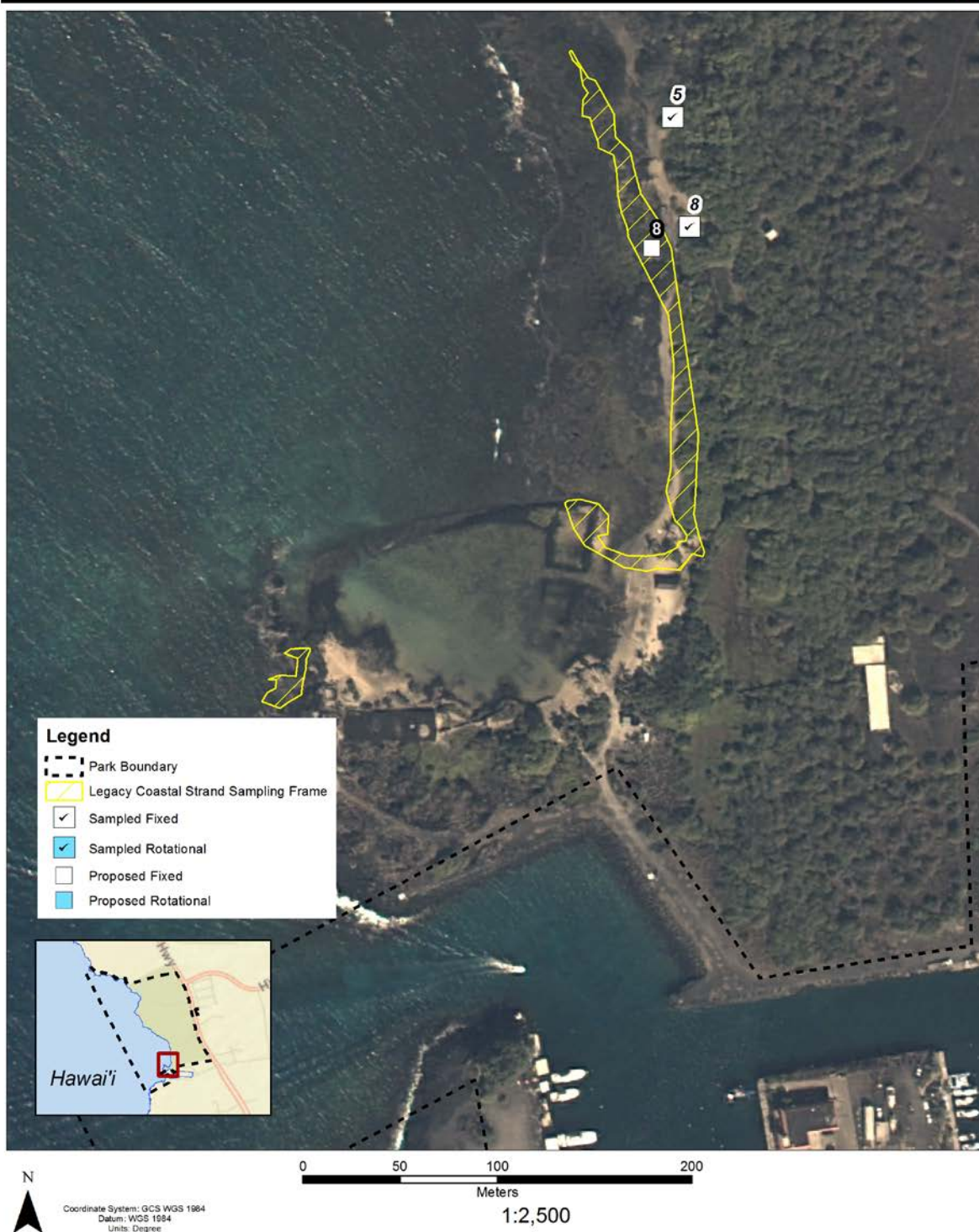


Figure B.4. Proposed and sampled (check marks) plots and the original legacy frame

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

NPS 466/127959, February 2015

National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov