



Established Invasive Plant Species Monitoring

Hawai‘i Volcanoes National Park

Natural Resource Report NPS/PACN/NRR—2016/1202



ON THE COVER

Former wet forest in Kahuku, Hawai'i Volcanoes National Park.

Photograph by Inventory & Monitoring Vegetation Crew, Hawai'i Volcanoes National Park.

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Natural Resource Report NPS/PACN/NRR—2016/1202

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Abstract

In 2010 and 2011, the Pacific Island Network Inventory and Monitoring program monitored established invasive plant species at Hawai‘i Volcanoes National Park. Belt transects were utilized to monitor non-native species frequency and abundance in two different plant communities, the wet forest and the subalpine shrubland. Repeated monitoring of these plant communities is planned to occur at five year intervals with objectives to detect change in non-native plant composition, frequency, and cover. Because this report represents the first year of monitoring, change analysis is not possible. Instead, the objectives of the initial report are to 1) compare non-native richness between plant communities and sampling sites, 2) determine the most common (i.e., most frequent) non-native species within particular areas of the park, and 3) compare frequency and cover of non-native species and life forms at various scales across the park. Locations sampled within the wet forest plant community included Nāhuku/East Rift, ‘Ōla‘a, and Kahuku, while sampling within the subalpine shrubland occurred across all vegetated areas above 2000 m encompassing areas across Kahuku and above Mauna Loa strip road. The study area encompassed approximately 18,000 ha and a total of 108 non-native species were documented within these communities. Abundant non-native species in the Nāhuku/East Rift sampling frame included a fern, *Nephrolepis brownii*, a grass, *Paspalum conjugatum*, and the tree *Morella faya*. Non-native species that dominated ‘Ōla‘a were the shrub, *Rubus ellipticus* var. *orbocordatus*, grass *Setaria palmifolia*, and *Psidium cattleianum* trees. These wet forests have a history of feral ungulate disturbance, portions have recently burned and been affected by lava flows, and some non-native plant species management has occurred all influencing non-native plant species cover. In the Kahuku wet forest, much of the lower elevation site was recently a cattle pasture and unsurprisingly non-native plants in this community were dominated by introduced pasture grasses including *Cenchrus clandestinus* and *Axonopus fissifolius*. The wet forest in the upper elevation of Kahuku contained relatively few non-native plants with two grasses, *Anthoxanthum odoratum* and *Ehrharta stipoides*, occurring most frequently in the area. In the subalpine shrubland plant community, non-native plant cover was typically lower than the wet forest; however, the northwest portion of Kahuku did support a relatively large number of non-native species with high frequencies of occurrence. The herb, *Hypochoeris radicata*, was the most frequently encountered non-native species in the subalpine shrubland plant community. Though the harsh habitat of the subalpine shrubland has experienced little human manipulation, the plant community is still exposed to feral ungulates that can have a negative impact on native plants.

The results from the established invasive plant species monitoring provide a snap-shot assessment of the non-native plants in these relatively intact plant communities and compliment other plant monitoring protocols conducted by I&M, such as Focal Terrestrial Plant Community Monitoring and Early Detection of Invasive Plant Species. In addition to supplementing less-frequent surveys conducted by the park’s Resource Management division, these data collected by I&M are intended to contribute to the science-based adaptive management of Hawai‘i Volcanoes National Park and provide consistent vegetation monitoring across the parks within the Pacific Island Network. Importantly, future I&M monitoring efforts will allow for change detection along these permanent transects and increase spatial sampling area with newly established temporary transects. Greater

sampling area is critical for assessing efficacy of sampling design and detecting patchy non-natives within these relatively heterogeneous landscapes.

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Acronyms

EIPS	Established Invasive Plant Species
FTPC	Focal Terrestrial Plant Community
I&M	Inventory and Monitoring
HAVO	Hawai‘i Volcanoes National Park
NPS	National Park Service
PACN	Pacific Island Network
WF	Wet Forest
SS	Subalpine Shrubland

Introduction

Next to habitat destruction, invasive non-native species are the second greatest source of biodiversity loss in the United States today (Wilcove et al. 1998; Stein 2002). Non-native invasive plants are species introduced intentionally or accidentally through human activity that are able to successfully reproduce away from site of introduction (Richardson et al. 2000). Non-native species pose a significant threat to biodiversity and, by definition, have a high potential to severely impact the integrity of terrestrial plant communities and biological diversity through competition and displacement, resulting in both ecological and economic consequences (Williamson 1996; Vitousek et al. 1997; Pimental et al. 2005).

Oceanic islands such as the Hawaiian Islands are especially susceptible to invasion by non-native species (Darwin [1859] 1972, Denslow 2003). Compared to the continental United States, higher proportions of Hawaiian plants and birds are threatened by non-native species (Wilcove et al. 1998). Additionally, the state also ranks number one for species rarity and risk, and for the number of species already lost to extinction in the country (Stein 2002). National parks within the state also rank the highest in the percent of introduced vascular plants compared to other national parks in the country (Loope 1992). With the rate of new species introductions attributed to human activities up 50,000-fold over its estimated natural rate (Loope 1998, Price and Clague 2002), continual long-term monitoring for non-native invasive species in these islands is imperative.

One of the primary goals for the Inventory and Monitoring (I&M) Program of the National Park Service (NPS) is to monitor parks to better understand their ecological conditions and to integrate these data into planning and management. Terrestrial plant communities are central to ecosystem function and in recognition of this importance, I&M of the Pacific Island Network (PACN), identified three terrestrial plant monitoring protocols: 1) Focal Terrestrial Plant Communities (FTPC), 2) Early Detection of Invasive Plants (ED), and 3) Established Invasive Plant Species (EIPS) as described in HaySmith et al. 2005. The EIPS protocol was developed to compliment non-native species data gathered during the concurrent FTPC monitoring. In contrast to FTPC monitoring, data recorded during EIPS relates only to non-native species, is collected along transects as opposed to plots, and is generally less detailed in order to provide greater spatial coverage of non-native plant abundance estimates. EIPS includes sampling non-native species along belt transects in four relatively intact plant communities over five network parks, where non-native species are still relatively rare. Monitoring throughout the PACN is set up on a rotating basis, where one park or park unit is surveyed per field season and is resurveyed five years later.

From 2010 to 2011, the I&M Program monitored non-native plant species in wet forest and subalpine regions of Hawai'i Volcanoes National Park (HAVO), on the Island of Hawai'i. First established in 1916, the park currently encompasses 134,750 ha, ranging from sea level to the summit of Mauna Loa (4,169 m). This report presents the results and efforts from EIPS monitoring, and describes basic status parameters, such as species richness, distribution, and abundance of non-native species in focal wet forest and subalpine shrubland plant communities.

Methods

Field crews monitored established invasive plant species following protocol guidelines (Ainsworth et al. 2012). Locations within the park containing focal plant communities were divided into one or more sampling frames (Figure 1). The number of sampling frames utilized was based upon the expected range of environmental variation and the contiguity of the plant communities within the park. If additional environmental variation was expected within a sampling frame it was further stratified into different zones to ensure interspersed and adequate spatial coverage of transects across the sampling frame. Within each sampling frame, transects were set up in a split panel design and categorized as fixed (permanent) or rotational (temporary). This design allows for the detection of long-term trends over time with fixed transects while still increasing sampling area with new rotational transects added over time. In 2010 and 2011, the wet forest and subalpine shrubland plant communities at HAVO were monitored.

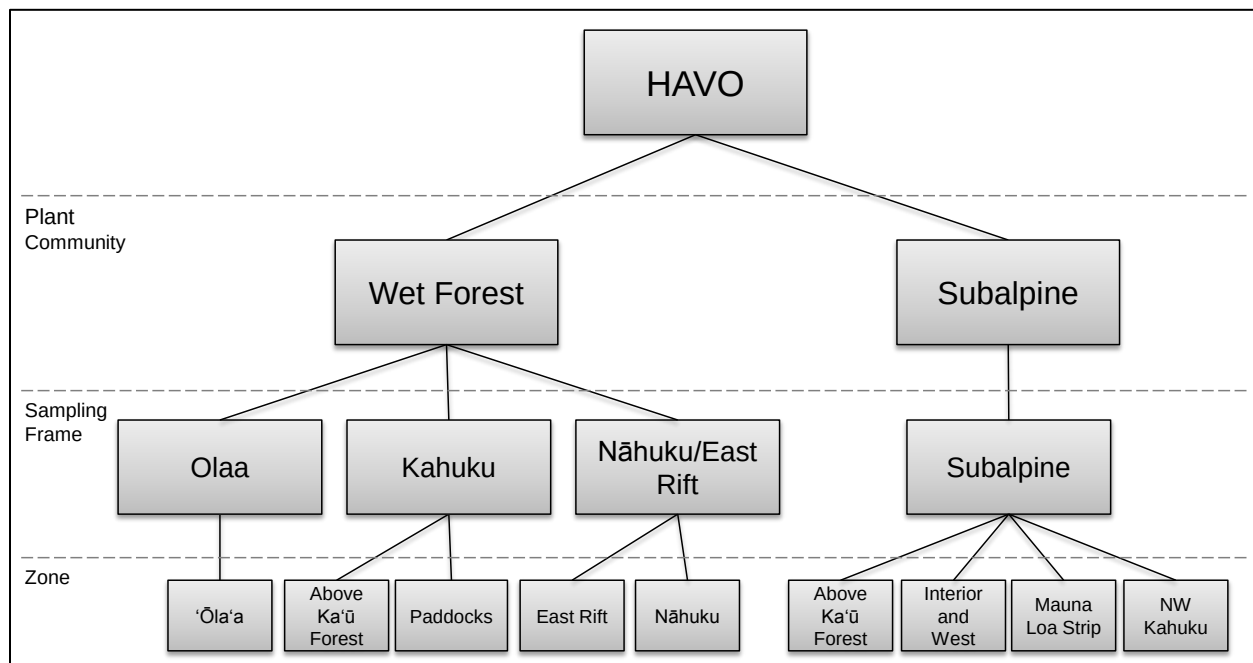


Figure 1. Hierarchy of the EIPS sampling locations for HAVO. The three stratified group levels (Plant Community, Sampling Frame, and Zone) are separated by dotted lines. Rectangles represent the strata identified within each group level.

Study Sites

HAVO’s wet forest (9281 ha) ranges from 600 to 1900 m in elevation on Kīlauea and Mauna Loa volcanoes with 1500-6000 mm of annual precipitation. The three distinct wet forest sampling frames (East Rift/Nāhuku, ‘Ōla‘a, and Kahuku WF) differ in geographic location, substrate age range, and disturbance history. Sampling covered 18.25 ha, or 0.19% of the wet forest. The subalpine shrubland (8360 ha) consists of vegetated sites above 2000 m on the Mauna Loa volcano with 600-2000 mm of annual precipitation. Sampling covered 5 ha or 0.06% of the subalpine shrubland.

Wet Forest

Nāhuku/East Rift

The Nāhuku/East Rift wet forest sampling frame (4068 ha) is located on the southeastern side of Kīlauea Volcano (Figure 2). Comprised of two separate zones, the Nāhuku zone (1868 ha) ranges from 900 to 1200 m, and the East Rift zone (2200 ha) from 600 to 900 m. Habitat in this sampling frame varies from sparsely vegetated lava flows to dense patches of native fern *Dicranopteris linearis* with *Metrosideros polymorpha* tree canopies. Substrate ranges from 200 to 3000 years old (Trusdell et al. 2005) and soils are composed of basaltic volcanic ash and organic material over pahoehoe lava flows (USDA 2008). A 31 ha section on the southeastern border of the East Rift zone consists of relatively young substrates from 1997 to 2003 (Trusdell et al. 2005). Mean annual rainfall in this lowland to montane mesic wet forest and shrubland (TNC 2005) ranges from 2500-3750 mm (Giambelluca et al. 2011). The Nāhuku zone includes areas that are more heavily used by the public, while the East Rift zone is less frequently visited, with limited public access to the rugged terrain often exposed to elevated SO₂ concentrations from the Pu‘u O‘o volcanic vent plume. Monitoring areas in the East Rift zone overlapped with several fires, including the Hana hou (1996), Kupukupu (2002), Ali lele (2003), Panau Iki (2003) and the Luhi (2003) wildfires. Nāhuku/East Rift includes 1081 ha of Special Ecological Area (SEA), park management units established to control selected disruptive invasive species (though active plant control does not occur throughout the entire SEA; Loh et al. 2014). Pigs have been removed from the northwest portion of the Nāhuku (Thurston SEA) zone north of the Thurston-Puhimau fence since 2001 (Loh et al. 2014), but only one sampled transect (14) partially overlapped this pig free area. The East Rift SEA located in the northwest portion of the East Rift zone was fenced in the 1990's, and was briefly considered pig free until the 2003 wildfires compromised the fencing. The fence was subsequently relocated to control pigs from only the northwest portion of the original SEA. An unknown number of pigs remain in the unit. Five transects overlapped this SEA at the time of sampling. Two of the five transects were not completely within the SEA, extending outside of the fenced area. Additionally, four of the five transects (5, 7, 10, and 18) partially overlap with areas that were actively managed for non-natives plants post-fire between 2003 and 2008 (Loh et al. 2014). Areas outside of the East Rift SEA, and south of the Thurston-Puhimau fence were not controlled for pigs at the time of the study. Pigs are known to be present in these areas and may contribute to non-native plant species distributions, but population sizes were unavailable (Loh pers. comm.).

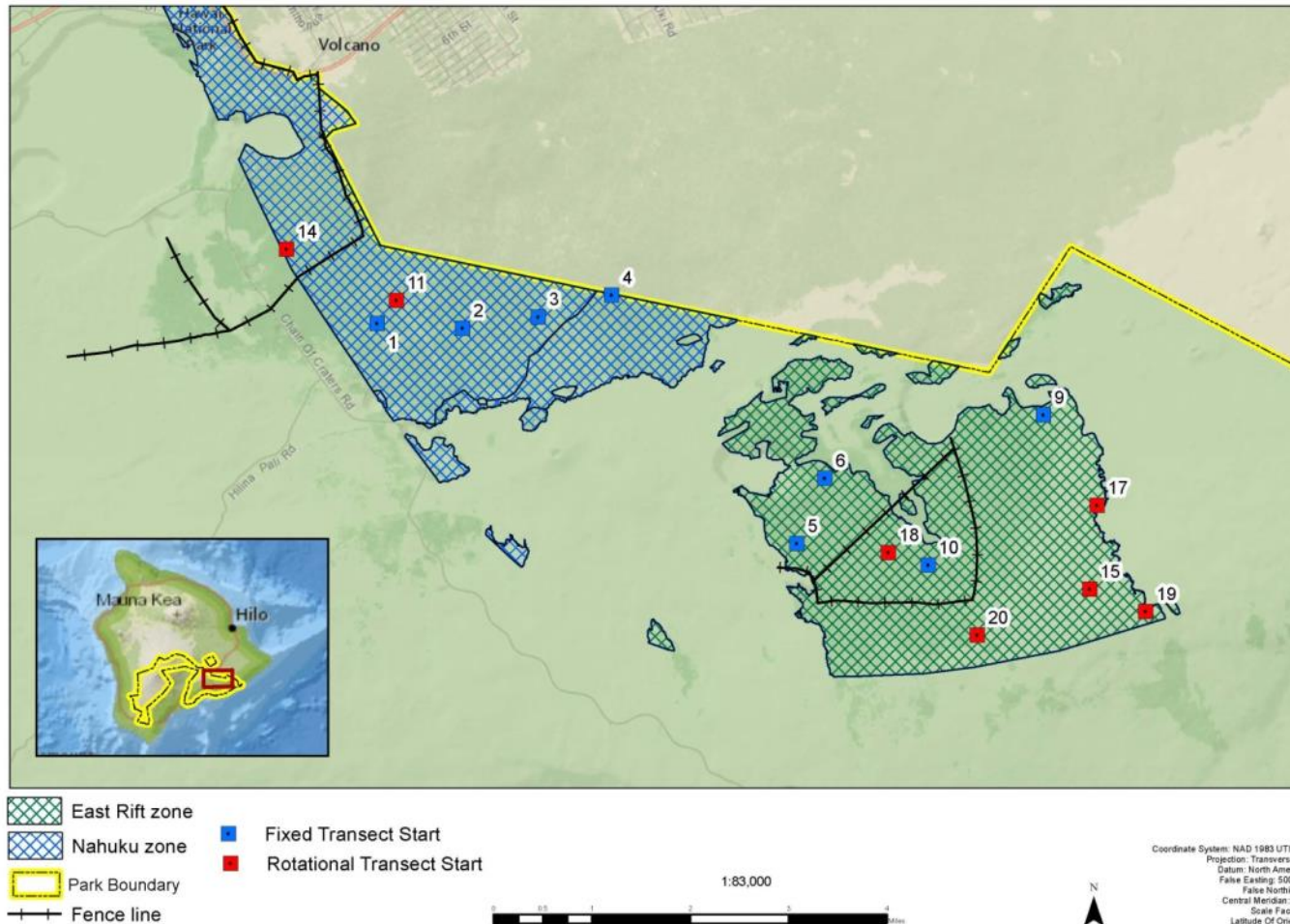


Figure 2. Nāhuku/East Rift sampling frame of HAVO wet forest plant community. Diagonal fence in East Rift was constructed in 2011 after monitoring took place. Points represent start locations of sampled transects (1000 m).

‘Ōla‘a

The ‘Ōla‘a wet forest sampling frame (3920 ha) is located on the east flank of Mauna Loa and ranges from 1000-1350 m in elevation (Figure 3). The montane wet forest (TNC 2005) receives between 2750 -5750 mm of annual rainfall (Giambelluca et al. 2011) and is dominated by a native *Metrosideros polymorpha* open canopy and *Cibotium glaucum* tree fern midstory. Substrate ranges from 750 to 30 k years old (Trusdell et al. 2005) and soils primarily consist of basaltic ash and organic material over lava flows (USDA 2008). Approximately half of the study area (2085 ha) is an SEA that was fenced between 1989 and 1999 to exclude feral pigs. The fenced units within the western portion of ‘Ōla‘a have been considered free of feral pigs since 1994 (Koa Unit), 1986 (Pu‘u and Ag Units) and 1984 (Small Tract). The New Unit is fenced but contained reduced numbers of pigs at the time of our study. The Open Unit, east of the SEAs, is not fenced nor is it controlled for pigs. Five transects (1,6,13,14,17) including one (13) that partially extends into the Ag Unit were located within the Koa Unit, while two transects (10,16) were located in the Puu Unit and three in the New Unit (6,8,9). No transects were sampled within Small Tract during this monitoring season. In addition to pig removal within SEAs, each unit has had various levels of non-native plant control. Portions of the Koa and Pu‘u Units were and continue to be controlled for weeds in multi-year intervals. Levels of control will likely affect results from EIPS monitoring in the future.

Kahuku WF

The Kahuku wet forest (1293 ha) includes three narrow sections of forest (Figure 4), a lower elevation (800-1500 m) zone of formerly-grazed Paddocks (766 ha) and a higher (1600-1900 m) zone referred to as the “WF Above Ka‘ū Forest” zone (526 ha) consisting of a narrow wet forest band bordering the upper elevational boundary of the State’s Ka‘ū Forest Reserve. The area is classified as lowland and montane mesic forest and shrublands (TNC 2005) with an annual rainfall ranging from 1500-2250 mm (Giambelluca et al. 2011). Substrate age ranges from 200 to 30 k years old (Trusdell et al. 2005) and soils consist primarily of volcanic ash over ‘a‘ā or pahoehoe lava flows (USDA 2008). The WF Above Ka‘ū Forest zone is dominated by native *M. polymorpha*/*Acacia koa* forest, while the Paddocks zone primarily consist of open pastures with remnant patches of native forest. The Paddocks zone has an extended history of land use change that includes logging and agricultural practices. Much of the unit consists of pastures and areas planted with non-native vegetation (Avery 2009). Areas throughout Kahuku also support well-established and growing populations of introduced mouflon sheep, as well as feral pig populations (Hess et al. 2006). At the time of the study in 2011, cattle had only been absent from the Paddocks unit for one year and only the Paddocks and Mauka units of the wet forest plant community had been controlled for mouflon sheep and pigs via fencing and hunting operations, but these were not void of ungulates (McDaniel pers. comm.).

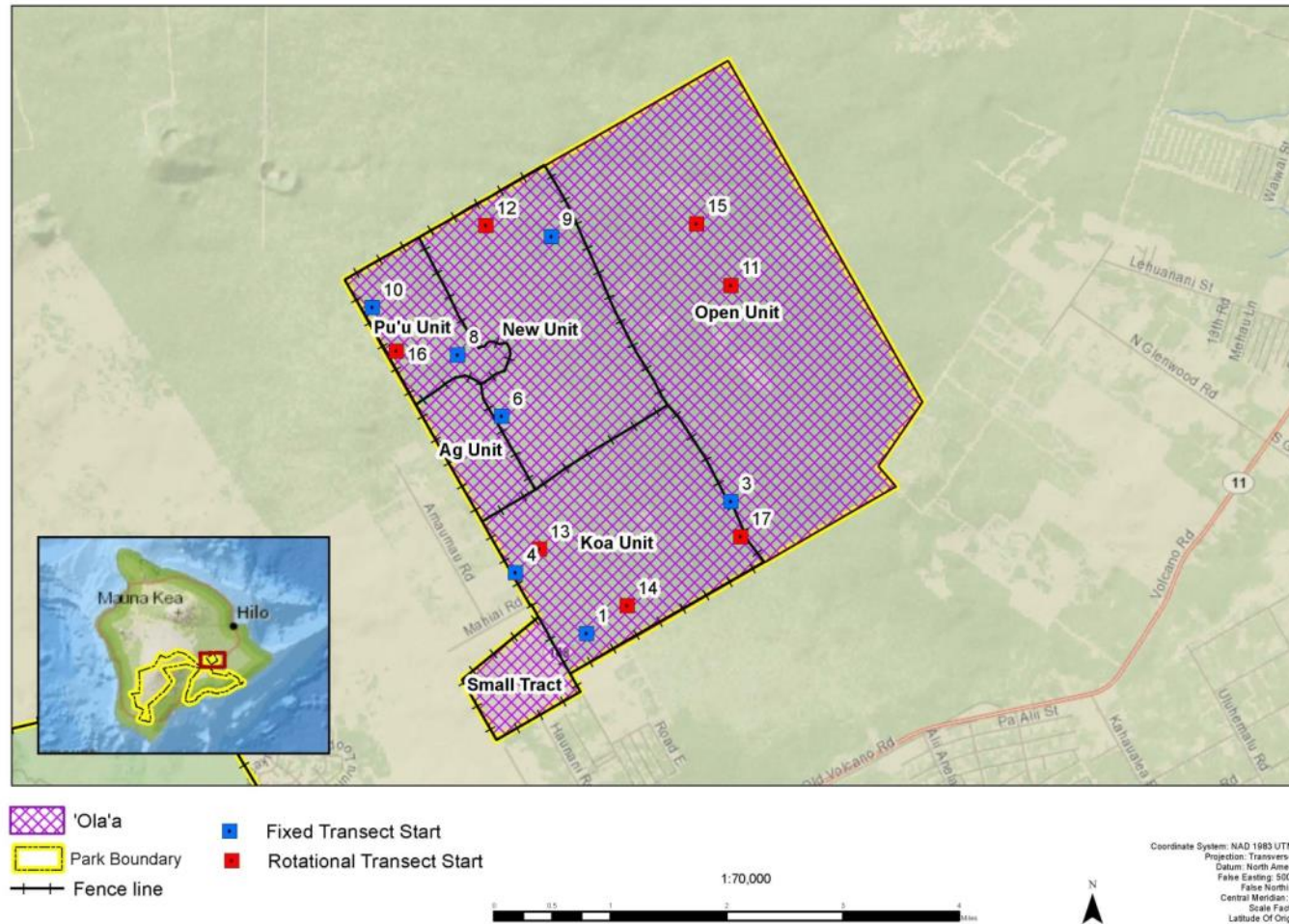


Figure 3. 'Ōla'a sampling frame of HAVO wet forest plant community. Points represent start locations of sampled transects (1000 m).

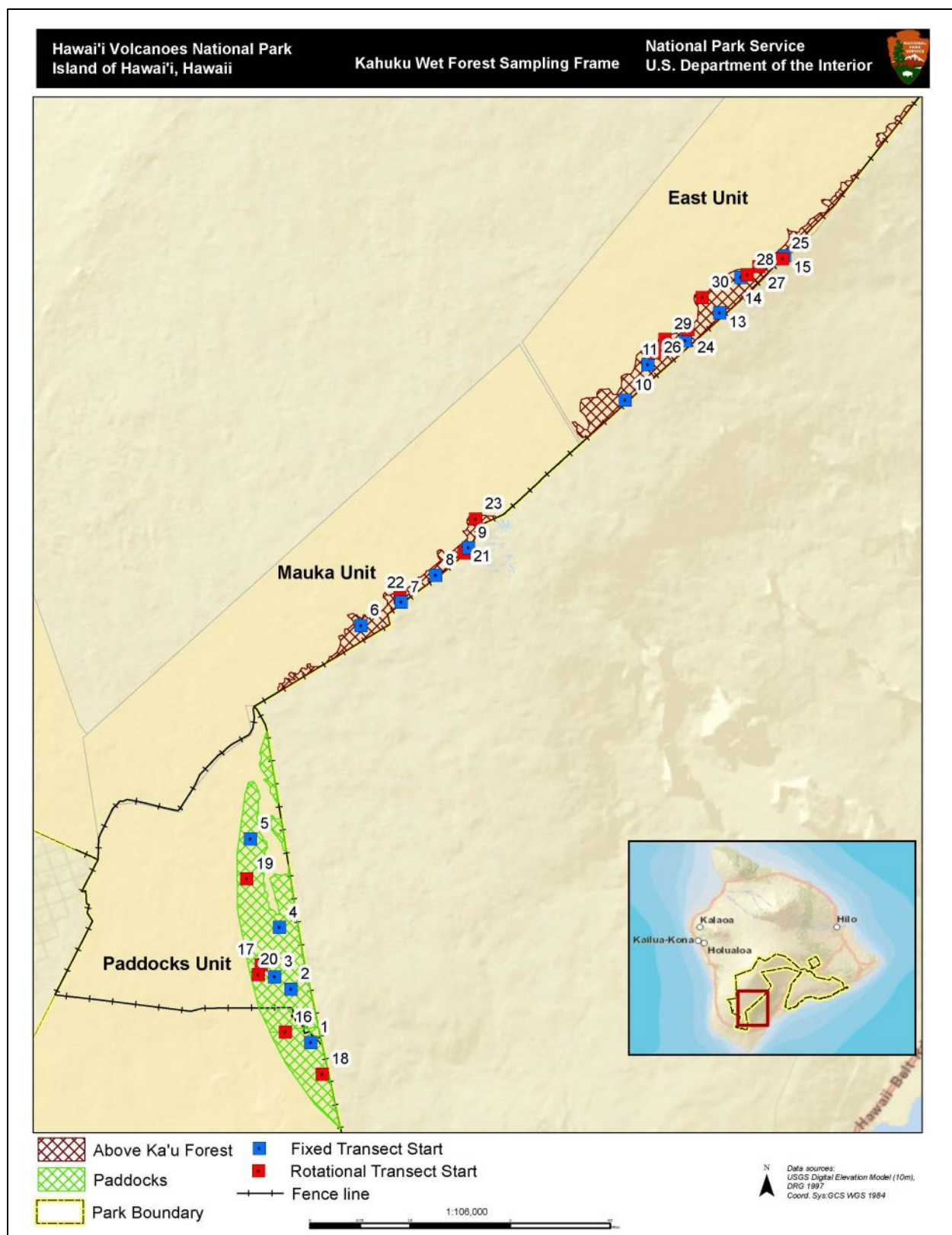


Figure 4. Kahuku WF sampling frame of HAVO wet forest community. Points represent start locations of sampled transects (250 m).

Subalpine Shrubland

The subalpine shrubland plant community at HAVO consisted of one mosaic sampling frame (8360 ha) above 2000 m elevation. Because the vegetated subalpine shrubland sampling frame is geographically complex, encompassing various small disjointed regions, we describe them in four zones (Figure 5). The SS Above Ka‘ū Forest zone (4877 ha), is located upslope from the wet forest sampling zone above the Ka‘ū Forest Reserve. It encompasses most of the East unit of Kahuku and extends upslope beyond the unit’s interior boundary. The Interior and West zone (1677 ha) incorporates areas within the West unit of Kahuku, as well as interior areas not within designated hunt units. The NW Kahuku zone (389 ha) is a small section in the northwest corner of the Kahuku unit. Outside of the Kahuku unit, the Mauna Loa Strip zone (1417 ha), is located on the eastern flank of Mauna Loa. The Mauna Loa Strip area was historically used for ranching until the 1920’s, but did contain feral ungulates until fencing was completed in the late 1990’s. The other subalpine shrubland areas still contained non-native mouflon at the time of monitoring. Substrates range from 750 to 11 k years old (Trusdell et al. 2005) and soils are dominantly basic or basaltic ash over ‘a‘ā and pahoehoe lava flows (USDA 2008). This subalpine dry forest and shrubland (TNC 2005) receives 500-2250 mm of rainfall annually (Giambelluca et al. 2011). Vegetation varies across the subalpine including montane woodlands of *M. polymorpha*, native *Dodonaea viscosa* and *Leptechophylla tameiameia* shrublands, montane and subalpine sparse vegetation (Green et al. 2015).

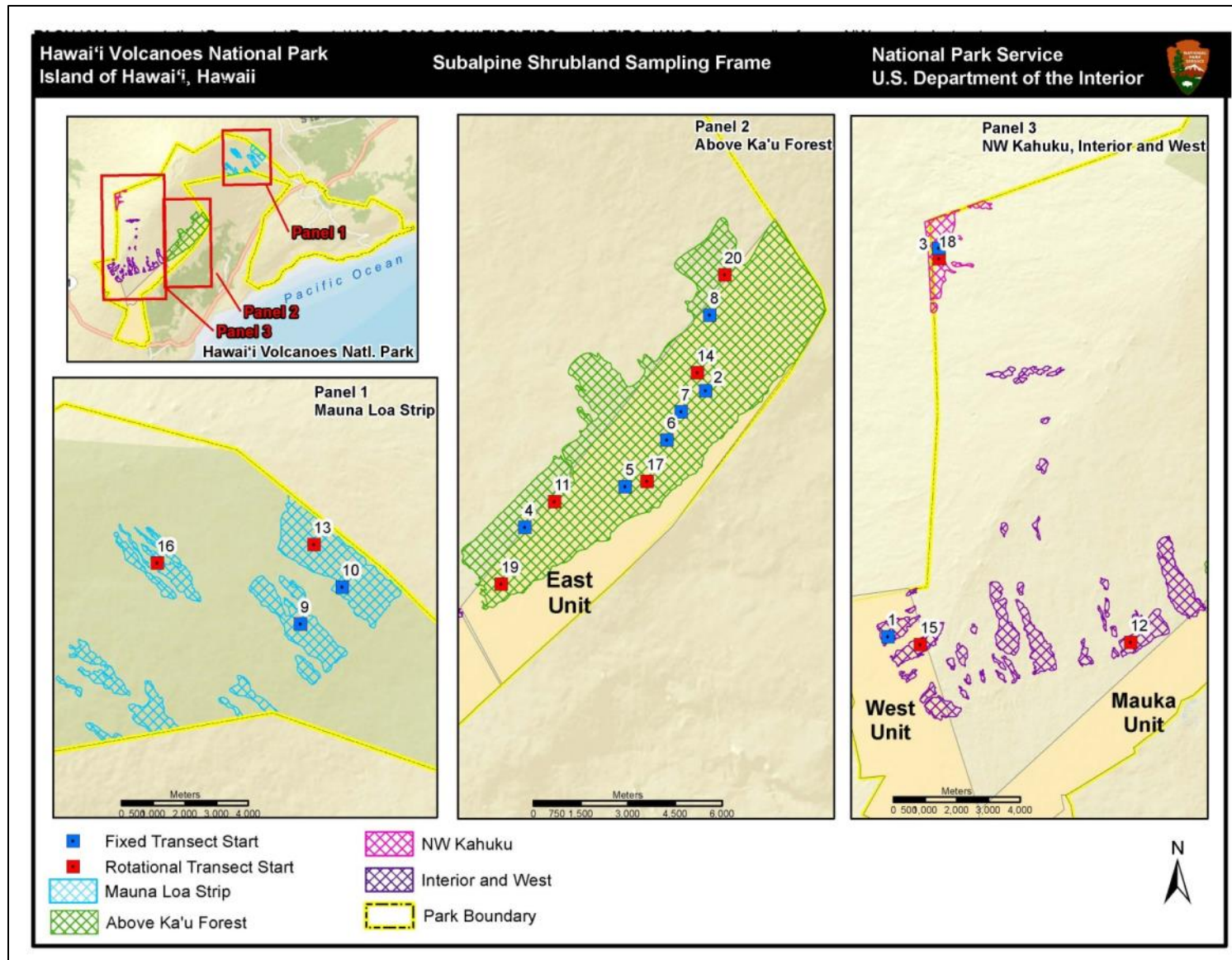


Figure 5. Subalpine shrubland sampling frame of HAVO. Points represent start locations of sampled transect (500 m).

Non-native Plant Sampling

Field crews monitored for non-native species along belt transects consisting of contiguous elongated rectangular plots varying in size depending on the plant community and sampling frame. Transects incorporated portions of “legacy transects” used in previous bird/vegetation surveys as well as newly generated transects (Ainsworth et al. 2012). All transects, legacy and newly generated, followed a random, pre-determined azimuth listed in Ainsworth et al. (2012). At each plot along a transect, the presence of all non-native plants was recorded. Cover of vegetation was estimated for non-native species or target invasive groups of species (i.e. pasture grasses, sedges, rushes) and documented using modified Braun-Blanquet cover classes (Table 2; Mueller-Dombois and Ellenberg 1974). Any foliage or stem material (live or dead) was counted in the survey if it was within the transect plot boundaries. Photos and GPS points were recorded at transect endpoints and at specific intervals (every 200 m for Nāhuku/East Rift and ‘Ōla‘a, every 50 m for Kahuku WF, and every 100 m for subalpine shrubland). Collected photo and GPS points were used for reference and map production. Transect locations and/or azimuths were adjusted in the field if the project lead or field crew leader deemed the original unsafe or inappropriate (Appendix C).

Table 1. HAVO proposed and sampled transects, area sampled and percent of sampling frame.

Sampling Frame	Dates Sampled	Plot (m)	Plot (m ²)	No. plots/ transect	Transect Length (m)	Proposed Transects	Surveyed Transects	Area sampled (ha)
Nāhuku/East Rift WF	Oct 2010 - Jan 2011	5 x 20	100	50	1000	20	15	7.5 (0.18%)
‘Ōla‘a WF	Oct 2010 - Feb 2011	5 x 20	100	50	1000	20	14	7.0 (0.18%)
Kahuku WF	June 2011- Nov 2011	5 x 10	50	25	250	30	30	3.75 (0.30%)
Subalpine Shrubland	April 2011- Oct 2011	5 x 20	100	25	500	20	20	5.0 (0.06%)

Table 2. Modified Braun-Blanquet cover classes and ranges of cover (Muller-Dombois and Ellenberg 1974) recorded for invasive species.

Cover Class	Range of Cover
1	< 1%
2	1% - <5%
3	5% - <10%
4	10% - <25%
5	25% - <50%
6	50% - <75%
7	75% - 100%

Monitoring methods were slightly modified in Kahuku WF, specifically in the Paddocks Unit. Due to the abundance of non-native grasses in pastures, it was often time consuming for crews to differentiate cover classes for each grass species. In these cases, all non-native species were identified in each plot, but only one cover class was assigned for each non-native target group (pasture grasses, sedges, rushes).

Data Analysis

Plant species nomenclature follows that of Wagner et al. 1999 with taxonomy updates from Wagner et al. 2012 and secondarily from the Integrated Taxonomic Information System (ITIS 2015). Non-native plants that could not be identified to species were excluded from richness analysis unless the individual represented a unique genus (e.g., *Aster* spp., *Galium* spp.). Two genus level species, *Eragrostis* spp. and *Oxalis* spp., were retained because more species are known from the region than those recorded.

EIPS protocol was initially designed to focus only on the most intact, native dominated, plant communities. However, the heavily invaded Paddocks zone was also selected for monitoring to track anticipated changes in the vegetation community due to livestock removal. Because the Paddocks was much more heavily dominated by non-native species than the other study sites, a decision was made to exclude the Paddocks from all of the pooled results presented. Pooled results include those summarized at the Sampling Frame, Plant Community, and Park group levels (Figure 1).

Non-native Species Richness

Total non-native species richness was compared between plant communities (wet forest and subalpine shrubland) and between the three wet forest sampling frames (Kahuku, Nāhuku/East Rift, and 'Ōla'a). Rarefaction and extrapolation of total species richness were performed to standardize comparisons amongst strata with unequal sampling effort. Rarefaction and extrapolation techniques were conducted according to Chao et al. (2014) using R package, iNEXT (Hsieh, Ma, & Chao 2014).

In addition to total species richness, average species richness per transect was also calculated for each zone. Because transect lengths varied between sampling frames, transects were divided into standardized lengths of 240 m (0.12 ha) and species occurrences were pooled accordingly.

Non-native Frequency

Frequency was calculated as the proportion of plots per transect in which non-native vegetation occurred (i.e. presence/total plots per transect). Mean frequency was calculated across all transects within a zone. If the means of two or more zones were combined, then the size (area) of each zone was used to calculate a weighted mean. Frequency was calculated for individual non-native species, categories of non-native life forms (e.g., grasses, trees, shrubs), and all non-native vegetation combined.

Non-native Cover

Modified Braun-Blanquet cover classes (Table 2) were used to estimate percent cover for each non-native species at the plot level. These data were used to construct thematic maps which display plot level species cover spatial patterns across the landscape (Appendix A). Frequency for each cover class was also calculated for all non-native species individually, combined by life form per zone,

sampling frame and community, and displayed graphically as thresholds of non-native plant cover. To compare species cover across zones, sampling frames, and communities and to combine cover for life forms, means were calculated using midpoints, despite known limitations (e.g., undefined confidence intervals or boxplots) (T. Philippi pers. comm.). Due to the patchy nature of plant communities, a large number of observations resulted in 0% cover. Therefore, standard means were not calculated. Instead, mean cover class only when the species was present (zeros removed) was reported.

Results

Non-native Species Richness

A total of 108 non-native species were recorded during EIPS monitoring (Table 3). Of these, nine species are currently classified as noxious weeds (USDA 2003, Table 3) and 26 species are considered invasive and highly disruptive within HAVO (Benitez et al. 2012, Fung Associates Inc. 2016). No species on the HAVO early detection of invasive plant species cards were documented (Speith and Harrison 2012). Two species, *Achyranthes aspera* var. *aspera* and *Veronica arvensis* were not previously documented in the park. Four species, *Coronopus didymus*, *Daucus pusillus*, *Erodium cicutarium*, and *Silene gallica* were known to occur in the park, but had not been previously documented in the Kahuku unit. Focal Terrestrial Plant Community (FTPC) monitoring conducted concurrently with EIPS monitoring and within the same sampling frames, documented 13 additional non-native species in the wet forest, and one additional species in the subalpine shrubland plant community (Table 4).

Table 3. Non-native species present in HAVO wet forest (WF) or subalpine shrubland (SS) plant communities. Asterisks indicate State of Hawaii noxious weed and bold species are of management concern at HAVO. An (x) or {x} indicates that the plant was only recorded in the Paddocks zone within the wet forest plant community or the NW Kahuku zone within the subalpine shrubland plant community, respectively.

Scientific Name	Family	Common Name	Life Form	WF	SS
<i>Achyranthes aspera</i> var. <i>aspera</i>	Amaranthaceae	devil's horsewhip	Herb		{x}
<i>Ageratina riparia</i> *	Asteraceae	Hamakua pamakani	Herb	x	x
<i>Ageratum conyzoides</i>	Asteraceae	maile honohono	Herb		x
<i>Andropogon glomeratus</i> var. <i>pumilus</i>	Poaceae		Grass	x	
<i>Andropogon virginicus</i>*	Poaceae	yellow bluestem	Grass	x	x
<i>Anemone hupehensis</i> var. <i>japonica</i>	Ranunculaceae	Japanese anemone	Herb	x	
<i>Anthoxanthum odoratum</i>	Poaceae	sweet vernalgrass	Grass	x	x
<i>Arundina graminifolia</i>	Orchidaceae	bamboo orchid	Herb	x	
<i>Aster</i> spp.	Asteraceae		Herb		{x}
<i>Axonopus fissifolius</i>	Poaceae	carpetgrass	Grass	x	
<i>Blechnum appendiculatum</i>	Blechnaceae		Fern	(x)	
<i>Buddleja asiatica</i>	Scrophulariaceae	dog tail	Shrub	x	
<i>Cardamine flexuosa</i>	Brassicaceae	bittercress	Herb	x	{x}
<i>Cenchrus clandestinus</i>	Poaceae		Grass	(x)	{x}
<i>Cenchrus polystachios</i>	Poaceae		Grass		{x}
<i>Centaurium erythraea</i> ssp. <i>erythraea</i>	Gentianaceae	bitter herb	Herb		x
<i>Cerastium fontanum</i> ssp. <i>triviale</i>	Caryophyllaceae	common mouse-ear chickweed	Herb		x

Table 3 (continued). Non-native species present in HAVO wet forest (WF) or subalpine shrubland (SS) plant communities. Asterisks indicate State of Hawaii noxious weed and bold species are of management concern at HAVO. An (x) or {x} indicates that the plant was only recorded in the Paddocks zone within the wet forest plant community or the NW Kahuku zone within the subalpine shrubland plant community, respectively.

Scientific Name	Family	Common Name	Life Form	WF	SS
<i>Chenopodium ambrosioides</i>	Amaranthaceae	Mexican tea	Herb		{x}
<i>Cirsium vulgare</i>	Asteraceae	bull thistle	Herb	x	{x}
<i>Commelina diffusa</i>	Commelinaceae	honohono	Herb	(x)	
<i>Conyza bonariensis</i>	Asteraceae	hairy horseweed	Herb	x	x
<i>Coronopus didymus</i>	Brassicaceae	lesser swinecress	Herb		{x}
<i>Crassocephalum crepidioides</i>	Asteraceae		Herb	x	{x}
<i>Cuphea carthagenensis</i>	Lythraceae	tarweed	Herb	(x)	
<i>Cyclosorus parasiticus</i>	Thelypteridaceae		Fern	(x)	
<i>Cyperus haspan</i>	Cyperaceae	haspan flatsedge	Sedge	x	
<i>Cyperus sanguinolentus</i>	Cyperaceae		Sedge	(x)	
<i>Cyperus trinervis</i>	Cyperaceae	Australian flatsedge	Sedge	x	
<i>Dactylis glomerata</i>	Poaceae	cocksfoot	Grass	(x)	
<i>Daucus carota</i> ssp. <i>sativus</i>	Apiaceae	wild carrot	Herb		{x}
<i>Daucus pusillus</i>	Apiaceae	American carrot	Herb		{x}
<i>Deparia petersenii</i>	Woodsiaceae	false spleenwort	Fern	x	
<i>Digitaria eriantha</i>	Poaceae	pangolagrass	Grass	(x)	
<i>Drymaria cordata</i> var. <i>pacifica</i>	Caryophyllaceae	pilipili	Herb	x	
<i>Ehrharta stipoides</i>	Poaceae	meadow ricegrass	Grass	x	x
<i>Emilia fosbergii</i>	Asteraceae	pua lele	Herb		{x}
<i>Epilobium billardierianum</i> ssp. <i>cinereum</i>	Onagraceae	aboriginal willowherb	Herb		x
<i>Eragrostis brownei</i>	Poaceae	sheepgrass	Grass	x	x
<i>Eragrostis</i> spp.	Poaceae	lovegrass	Grass		{x}
<i>Erechtites valerianifolia</i>	Asteraceae	fireweed	Herb	x	{x}
<i>Erodium cicutarium</i>	Geraniaceae	alfilaria, pin clover	Herb		{x}
<i>Euchiton japonicus</i>	Asteraceae	father-and-child plant	Herb		x
<i>Euchiton sphaericus</i>	Asteraceae	cudweed	Herb	x	x
<i>Euphorbia peplus</i>	Euphorbiaceae	petty spurge	Herb		{x}
<i>Festuca bromoides</i>	Poaceae		Grass		x
<i>Fragaria vesca</i>	Rosaceae	woodland strawberry	Herb		x
<i>Galium</i> spp.	Rubiaceae	bedstraw	Herb	(x)	
<i>Gamochaeta purpurea</i>	Asteraceae	purple cudweed	Herb		{x}
<i>Geranium homeanum</i>	Geraniaceae	Australasian geranium	Herb	(x)	x
<i>Hedychium gardnerianum</i>	Zingiberaceae	kahili ginger	Herb	x	

Table 3 (continued). Non-native species present in HAVO wet forest (WF) or subalpine shrubland (SS) plant communities. Asterisks indicate State of Hawaii noxious weed and bold species are of management concern at HAVO. An (x) or {x} indicates that the plant was only recorded in the Paddocks zone within the wet forest plant community or the NW Kahuku zone within the subalpine shrubland plant community, respectively.

Scientific Name	Family	Common Name	Life Form	WF	SS
<i>Helichrysum foetidum</i>	Asteraceae	stinking everlasting	Herb		{x}
<i>Holcus lanatus</i>	Poaceae	Yorkshire fog	Grass	x	x
<i>Hydrocotyle bowlesioides</i>	Araliaceae	largeleaf marshpennywort	Herb	x	
<i>Hypericum mutilum</i> ssp. <i>mutilum</i>	Hypericaceae	dwarf St. John's wort	Herb	x	
<i>Hypericum parvulum</i>	Hypericaceae	Sierra Madre St. Johnswort	Herb	x	
<i>Hypochoeris radicata</i>	Asteraceae	hairy cat's ear	Herb	x	x
<i>Juncus effusus</i>	Juncaceae	Japanese mat rush	Rush	x	
<i>Kyllinga brevifolia</i>	Cyperaceae		Sedge	(x)	
<i>Lotus uliginosus</i>	Fabaceae		Herb	x	
<i>Ludwigia palustris</i>	Onagraceae	marsh purslane	Herb	x	
<i>Marrubium vulgare</i>	Lamiaceae	Common horehound	Herb		{x}
<i>Melinis minutiflora</i>	Poaceae	molasses grass	Grass		{x}
<i>Morella faya</i>*	Myricaceae	firetree	Tree	x	
<i>Nephrolepis brownii</i>	Lomariopsidaceae		Fern	x	
<i>Oxalis corniculata</i>	Oxalidaceae	yellow wood sorrel	Herb		{x}
<i>Oxalis</i> spp.	Oxalidaceae		Herb		x
<i>Paspalum conjugatum</i>	Poaceae	Hilo grass	Grass	x	
<i>Paspalum urvillei</i>	Poaceae	Vasey grass	Grass	(x)	
<i>Passiflora edulis</i>	Passifloraceae	passionfruit	Vine	x	
<i>Passiflora ligularis</i>	Passifloraceae	sweet granadilla	Vine	(x)	
<i>Passiflora tarminiana</i>*	Passifloraceae	banana Poka	Vine	x	
<i>Persicaria capitata</i>	Polygonaceae		Herb	x	
<i>Persicaria punctata</i>	Polygonaceae		Herb	x	
<i>Phaius tankervilleae</i>	Orchidaceae	chinese ground orchid	Herb	x	
<i>Phymatosorus grossus</i>	Polypodiaceae	naturalized laua'e	Fern	x	
<i>Physalis peruviana</i>	Solanaceae	poha	Shrub	(x)	
<i>Pityrogramma austroamericana</i>	Pteridaceae	leatherleaf goldback fern	Fern	x	
<i>Plantago major</i>	Plantaginaceae	broad-leaved plantain	Herb	x	
<i>Pluchea carolinensis</i>	Asteraceae	sourbush	Shrub	x	
<i>Poa annua</i>	Poaceae	annual blue grass	Grass	x	
<i>Polycarpon tetraphyllum</i>	Caryophyllaceae	fourleaf manyseed	Herb		x
<i>Prunella vulgaris</i>	Lamiaceae	heal-all	Herb	x	{x}
<i>Psidium cattleianum</i>	Myrtaceae	strawberry guava	Tree	x	

Table 3 (continued). Non-native species present in HAVO wet forest (WF) or subalpine shrubland (SS) plant communities. Asterisks indicate State of Hawaii noxious weed and bold species are of management concern at HAVO. An (x) or {x} indicates that the plant was only recorded in the Paddocks zone within the wet forest plant community or the NW Kahuku zone within the subalpine shrubland plant community, respectively.

Scientific Name	Family	Common Name	Life Form	WF	SS
<i>Rubus argutus</i>*	Rosaceae	prickly Florida blackberry	Shrub	x	
<i>Rubus ellipticus</i> var. <i>obcordatus</i>*	Rosaceae	yellow Himalayan raspberry	Shrub	x	
<i>Rubus rosifolius</i>	Rosaceae	thimbleberry	Shrub	x	
<i>Rumex acetosella</i>	Polygonaceae	sheep sorrel	Herb		x
<i>Sacciolepis indica</i>	Poaceae	glenwood grass	Grass	x	
<i>Schedonorus arundinaceus</i>	Poaceae	reed fescue	Grass	(x)	
<i>Schizachyrium condensatum</i>	Poaceae	beardgrass	Grass	x	x
<i>Selaginella kraussiana</i>	Selaginellaceae	spreadling selaginella	Herb	x	
<i>Senecio madagascariensis</i>*	Asteraceae	Madagascar Fireweed	Herb	x	x
<i>Senecio sylvaticus</i>	Asteraceae	wood groundsel	Herb		x
<i>Setaria palmifolia</i>	Poaceae	palmgrass	Grass	x	
<i>Setaria parviflora</i>	Poaceae	foxtail	Grass	x	
<i>Silene gallica</i>	Caryophyllaceae	small-flowered catchfly	Herb		{x}
<i>Solanum</i> spp.	Solanaceae		Herb		{x}
<i>Sonchus oleraceus</i>	Asteraceae	pualele	Herb		x
<i>Sporobolus africanus</i>	Poaceae	rattail grass	Grass		x
<i>Stachytarpheta jamaicensis</i>	Verbenaceae	Jamaica vervain	Herb	x	
<i>Tibouchina herbacea</i>*	Melastomataceae	cane tibouchina	Herb	x	{x}
<i>Trifolium repens</i> var. <i>repens</i>	Fabaceae	white clover	Herb	(x)	{x}
<i>Verbascum thapsus</i>*	Scrophulariaceae	common mullein	Herb		{x}
<i>Veronica arvensis</i>	Plantaginaceae	corn speedwell	Herb		{x}
<i>Veronica peregrina</i> ssp. <i>xalapensis</i>	Plantaginaceae	necklace weed	Herb		{x}
<i>Veronica plebeia</i>	Plantaginaceae	common speedwell	Herb	x	{x}
<i>Veronica serpyllifolia</i>	Plantaginaceae	thyme-leaved speedwell	Herb	x	x
<i>Youngia japonica</i>	Asteraceae	oriental hawksbeard	Herb		{x}

Table 4. Additional non-native species documented in Focal Terrestrial Plant Community monitoring. Bold species are of management concern at HAVO.¹Present in EIPS WF; ²Present in EIPS SS

Scientific Name	Family	Common name	Life Form	WF	SS
<i>Briza minor</i>	Poaceae	little quaking grass	Grass	x	
<i>Cordyline fruticosa</i>	Asparagaceae	ti	Shrub	x	
<i>Cyclosorus dentatus</i>	Thelypteridaceae		Fern	x	
<i>Euchiton japonicus</i>	Asteraceae	father-and-child plant	Herb	x	
<i>Fragaria vesca</i>	Rosaceae	woodland strawberry	Herb	x	
<i>Juncus ensifolius</i>	Juncaceae		Rush	x	
<i>Juncus planifolius</i>	Juncaceae	rush	Rush	x	
<i>Phlebodium aureum</i>	Polypodiaceae	rabbit's-foot fern	Fern	x	
<i>Pityrogramma calomelanos</i>	Pteridaceae	silver fern	Fern	x	
<i>Pluchea carolinensis</i> ¹	Asteraceae	sourbush	Shrub		x ¹
<i>Poa annua</i> ¹	Poaceae	annual bluegrass	Grass		x ¹
<i>Poa pratensis</i>	Poaceae	Kentucky bluegrass	Grass	x	
<i>Prunus</i> spp.	Rosaceae		Tree	x	
<i>Selaginella</i> spp.	Selaginellaceae		Fern ally	x	
<i>Sphaeropteris cooperi</i>	Cyatheaceae	Australian tree fern	Tree Fern	x	
<i>Sporobolus africanus</i> ²	Poaceae	rattail grass	Grass	x ²	
<i>Wahlenbergia gracilis</i>	Campanulaceae		Herb		x

Fifty-seven non-native species were observed in the wet forest (an additional 16 species were observed in the Paddocks zone), and 57 were observed in the subalpine shrubland. A majority of the subalpine shrubland non-native species (31) were observed exclusively in the NW Kahuku zone. Out of the 108 total species, 22 (~20% of the total observed) were present in both the wet forest and subalpine plant communities (Table 3). Total species counts are heavily influenced by sampling effort and can bias results if not accounted for (Gotelli and Colwell 2011). Despite the similar total area between the wet forest and subalpine shrubland, the wet forest received more than three times the sampling effort. In order to compare total non-native species between the two plant communities, sample-based rarefaction and extrapolation were utilized (Hsieh et al. 2014). Figure 6 shows that when sampling effort in the subalpine shrubland is extrapolated to that of the wet forest (paddocks excluded), the two communities appear to have the same number of non-native species. However, the NW Kahuku zone is heavily impacting the subalpine shrubland results. While the NW Kahuku zone only contributes 5% of the total subalpine shrubland area, over half (54%) of the subalpine shrubland non-native species were found exclusively in this zone. In Figure 7 the same sample-based extrapolation was performed without the NW Kahuku zone, resulting in a dramatic reduction of total non-native species in the subalpine shrubland.

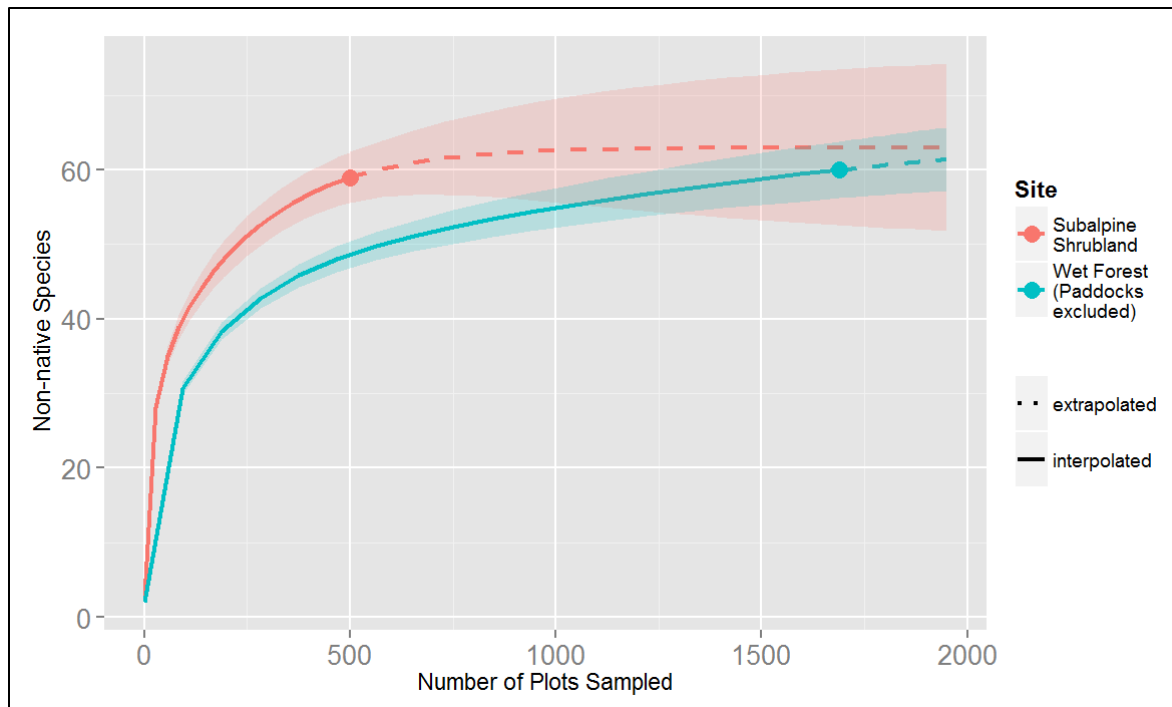


Figure 6. Species accumulation curves (sample-based rarefaction and extrapolation) and associated 95% confidence intervals for the two plant communities monitored at HAVO. The Paddocks zone was excluded from the analysis. Points indicate observed values.

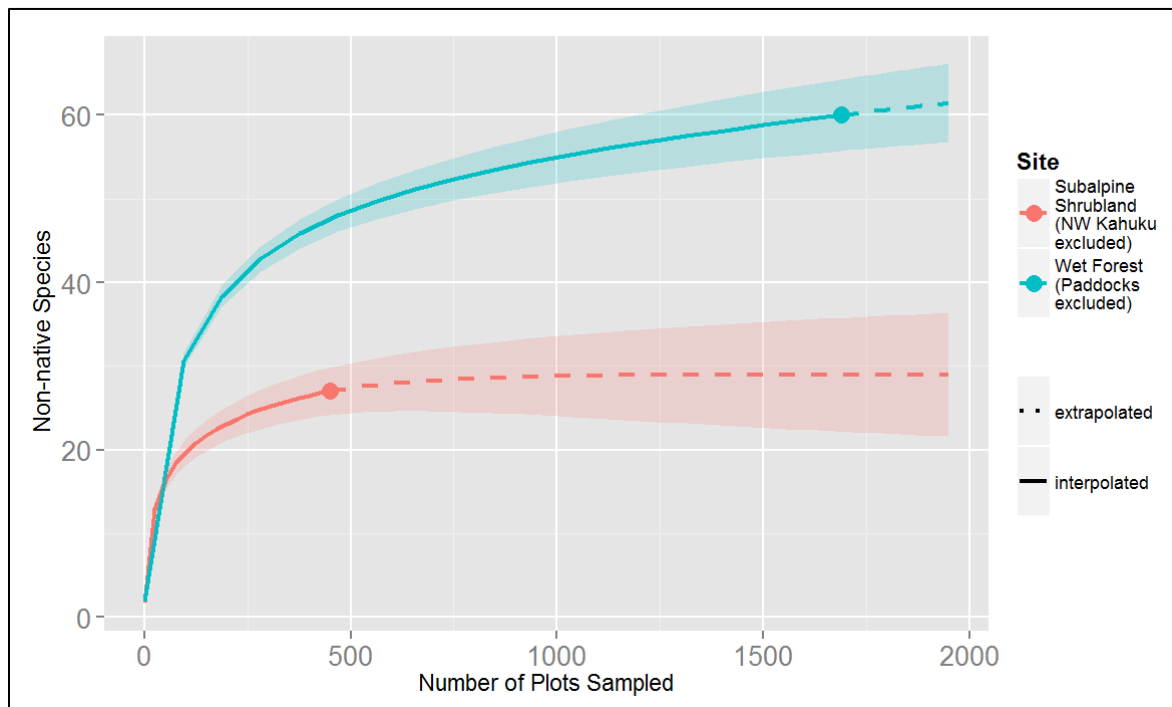


Figure 7. Species accumulation curves (sample-based rarefaction and extrapolation) and associated 95% confidence intervals for the two plant communities monitored at HAVO. The Paddocks WF zone and the NW Kahuku subalpine shrubland zone were excluded from the analysis. Points indicate observed values.

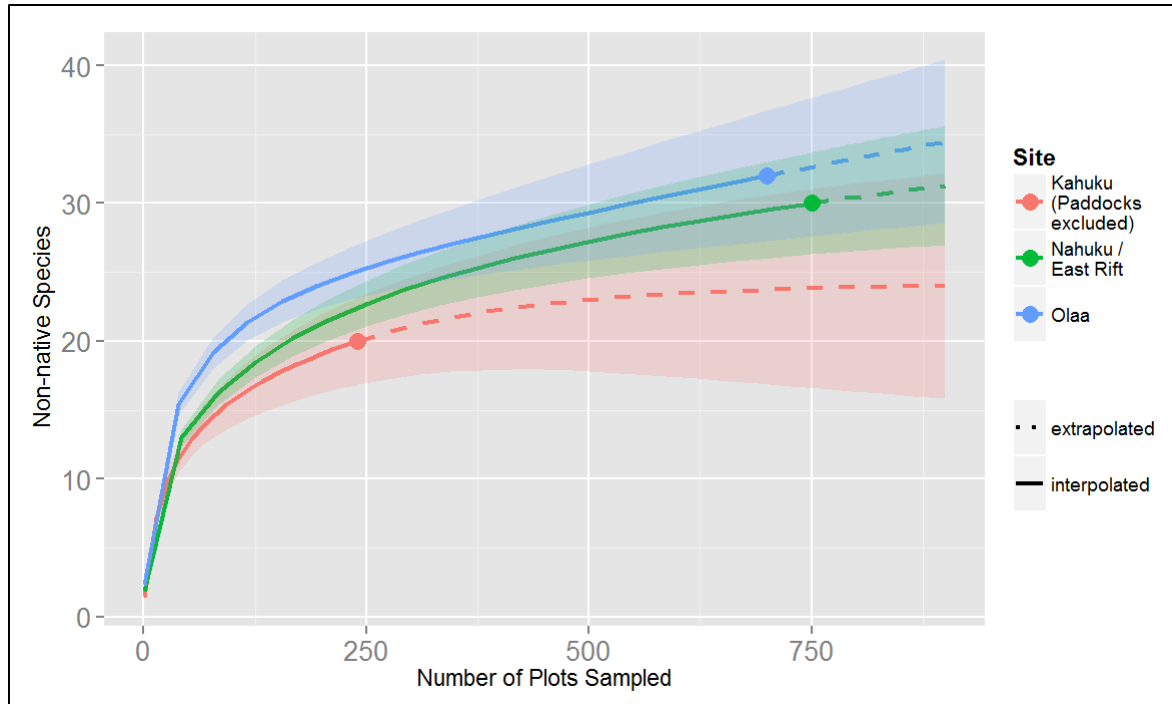


Figure 8. Species accumulation curves (sample-based rarefaction and extrapolation) and associated 95% confidence intervals for the three sampling frames within the wet forest plant community. The Paddocks zone was excluded from the analysis. Points indicate observed values.

In both Figure 6 and Figure 7 the subalpine shrubland appears to have reached an asymptote in which very few new non-native species are expected to be found with increased sampling effort.

Conversely, extrapolation of wet forest species accumulation suggests additional non-native species will be observed if sampling effort is increased. When examined individually, each of the wet forest sampling frames (Figure 8) also show some degree of increasing non-native richness with increased sampling. The addition of 13 wet forest species from the separate, but concurrent FTFC monitoring (Table 4), confirmed that the sample-based species accumulation curve for the wet forest had not yet reached an asymptote. Increasing effort in the wet forest in order to reach the asymptote may be cost prohibitive given the high diversity of species found there.

In order to compare non-native richness at a finer scale across zones, transects were subdivided into standardized lengths of 240 m and non-native species were counted accordingly. Again, the NW Kahuku zone [$n = 4$] showed a relatively high value, with a median of 30 non-native plant species per standardized transect (Figure 9). Additionally, the wet forest Paddocks zone [$n = 10$] also contained relatively high non-native richness with a median of 17 non-native species per transect. By contrast no other zones in the study contained more than a median value of 6 non-native species per 240 m.

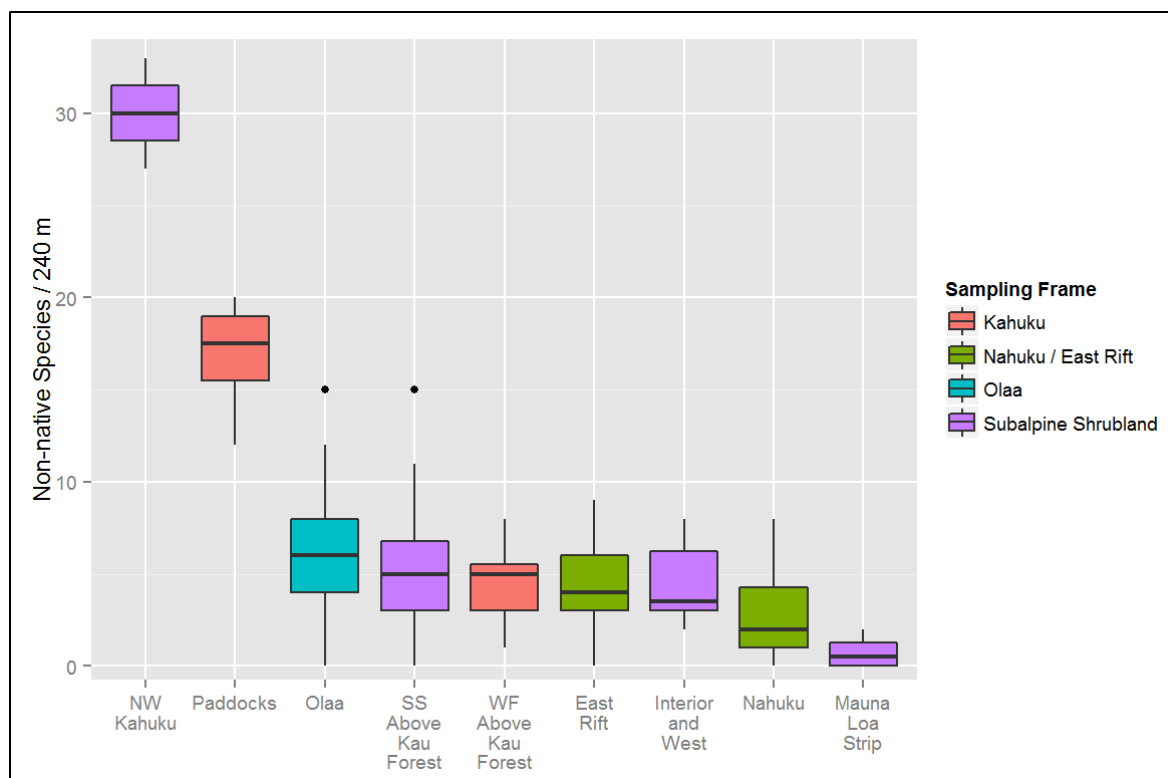


Figure 9. Boxplot of non-native species richness per standardized transect length of 240 m. Boxes represent each zone within the study and color corresponds to the sampling frame in which the zone occurs. The bottom and top of the box are the first and third quartiles and the band inside the box is the median. The whiskers represent the lowest or highest datum still within 1.5 the interquartile range of the lower or upper quantile (Tukey boxplot). Outliers are plotted as dots. Sample size of each zone is as follows: NW Kahuku [4], Paddocks [10], Ōla'a [56], SS Above Ka'ū Forest [22], WF Above Ka'ū Forest [20], East Rift [36], Interior and West [6], Nāhuku [24], Mauna Loa Strip [8].

Non-Native Frequency and Cover

Mean frequency of any non-native plant was 0.72 ± 0.02 (mean $\pm$ 95% CI) across all sampling locations (Figure 10). In general, transects within 'Ōla'a and Nāhuku/East Rift had higher combined non-native plant cover than the subalpine shrubland and Kahuku wet forest (Paddocks excluded), especially when comparing percent cover at levels $>5\%$ to $>25\%$. Plots with combined non-native cover greater than 5% were the most frequent in Nāhuku/East Rift [0.56 ± 0.12] followed by 'Ōla'a [0.46 ± 0.20], subalpine shrubland [0.10 ± 0.12], and Kahuku wet forest [0.09 ± 0.07] (Figure 10).

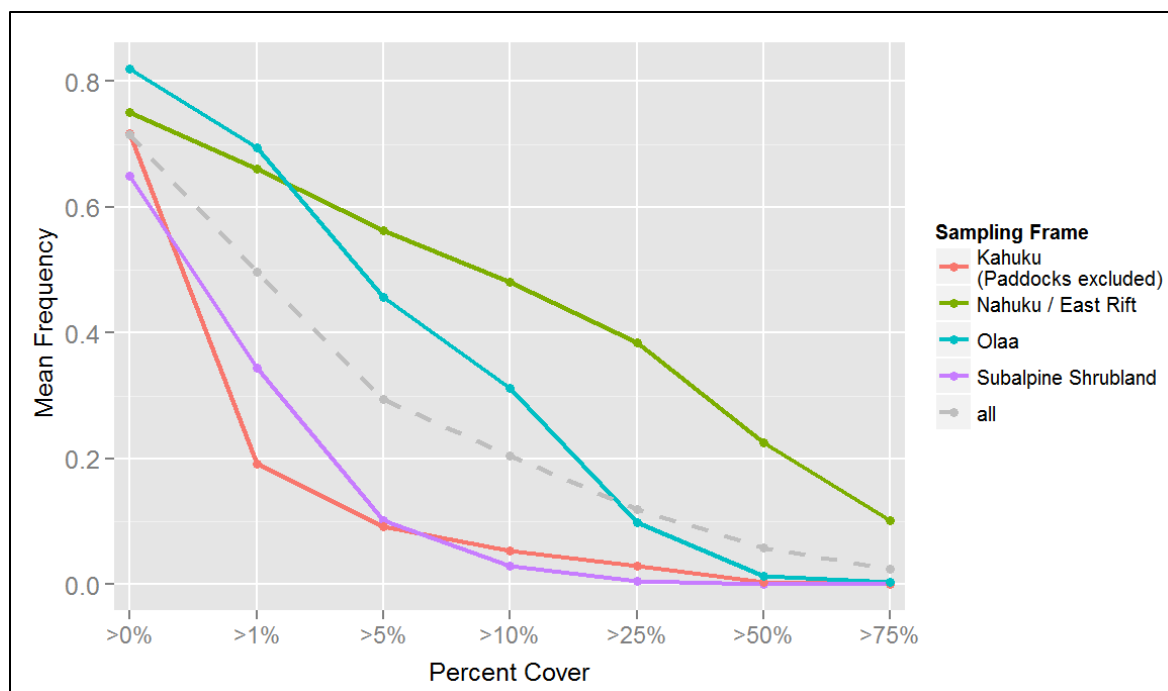


Figure 10. Mean frequency of combined non-native species cover for each sampling frame and all sampling frames combined. Frequency is the proportion of plots per transect in which the specified cover class (sum of all non-native species cover) was met. The X-axis represents cover class categories with increasing minimum cover cutoffs (moving from left to right). Frequency of 1.0 = non-native cover present (at least one non-native plant species was found) in all (100%) of plots.

Wet Forest

Results for the wet forest are presented as a whole, and then examined by individual sampling frames. The Paddocks zone is excluded from the wet forest summary, and instead, presented within its own dedicated section.

The ten most frequently encountered species in the wet forest (weighted by zone and sampling frame size) are presented in Table 5. *R. ellipticus* var. *obcordatus* and *N. brownii* were the most frequently encountered non-native plants in the wet forest, however, it should be noted that *N. brownii* was only recorded in the Nāhuku/East Rift sampling frame. The complete table of species frequencies by sampling frame and plant community is provided in Appendix B.

Cover class frequencies of all plant life forms found in the wet forest are displayed in Figure 11. Non-native grasses [0.43 ± 0.03] had the greatest frequency of any non-native life form. However, ferns occurred at cover greater than 10% more frequently.

Table 5. Most frequent non-native species among all wet forest and the sampling frames where they are present. Frequency is the proportion of plots per transect in which the species was present. Mean frequencies were weighted by zone and sampling frame size. Frequency of 1.0 = present in all or 100% of plots. 95% confidence interval is represented in parentheses. The Paddocks is excluded from Kahuku WF.

Species	Life Form	Weighted Mean Freq. (95% CI)	Nāhuku/ East Rift	‘Ōla‘a	Kahuku WF
<i>Rubus ellipticus</i> var. <i>obcordatus</i>	Shrub	0.21 (0.12-0.29)	x	x	
<i>Nephrolepis brownii</i>	Fern	0.21 (0.12-0.29)	x		
<i>Setaria palmifolia</i>	Grass	0.18 (0.11-0.26)	x	x	
<i>Psidium cattleianum</i>	Tree	0.17 (0.15-0.20)	x	x	
<i>Paspalum conjugatum</i>	Grass	0.15 (0.09-0.21)	x	x	
<i>Morella faya</i>	Tree	0.14 (0.08-0.19)	x		
<i>Hedychium gardnerianum</i>	Herb	0.14 (0.08-0.19)	x	x	
<i>Tibouchina herbacea</i>	Herb	0.12 (0.08-0.17)	x	x	
<i>Ehrharta stipoides</i>	Grass	0.11 (0.08-0.15)	x	x	x
<i>Passiflora tarminiana</i>	Vine	0.11 (0.06-0.16)		x	

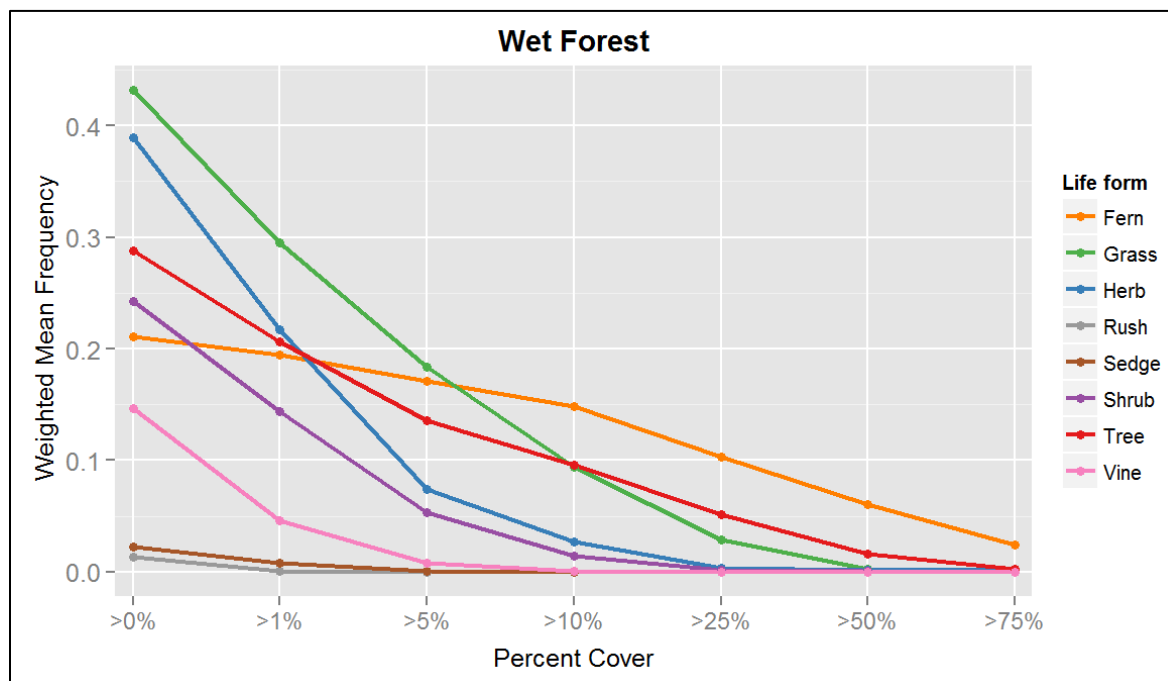


Figure 11. Mean frequency of non-native cover for each vegetation life form present within the wet forest. Frequency is the proportion of plots per transect in which the specified cover percentage was met. The X-axis represents cover class categories with increasing minimum cover cutoffs (moving from left to right). Mean frequencies were weighted by the area of the zones in which the life form occurred. Frequency of 1.0 = non-native cover present in all (100%) of plots.

Nāhuku/East Rift

The Nāhuku/East Rift sampling frame had the highest frequency of plots with greater than 5% combined non-native cover (Figure 10). High cover is primarily due to the invasive fern *N. brownii* which had the greatest frequency of any non-native species in the area [0.43 ± 0.30] and on average covered 25-50% of a plot (cover class “5”) when it occurred (Figure 12). The large confidence interval for frequency of *N. brownii* reflects the fact that it was almost exclusively found in the East Rift zone and only present along one transect in the Nāhuku zone as depicted in the frame’s thematic map (Figure A.1). All plant life forms except sedges were recorded in this sampling frame with ferns the most frequent and abundant group (Figure 13). The eight species with the highest frequency represent six different life forms (Figure 12).

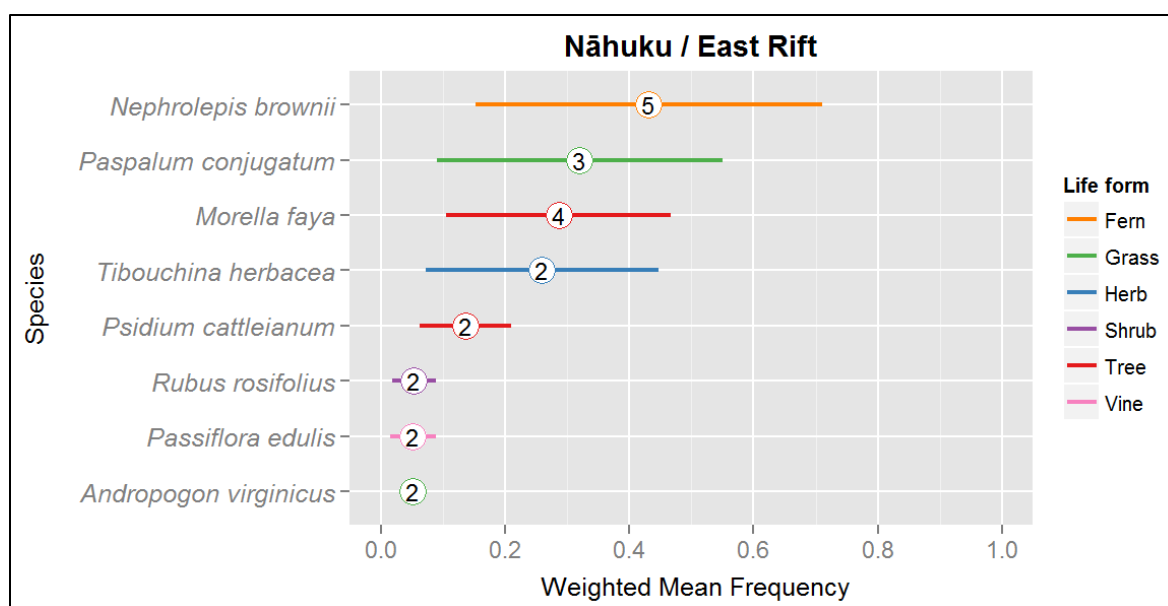


Figure 12. Eight most frequent species in Nāhuku/East Rift. Frequency is the proportion of plots per transect in which the species was present. Mean frequencies were weighted by the area of the zones in which the species occurred. Frequency of 1.0 = present in all or 100% of plots. Error bars represent the 95% confidence intervals. Numbers inside the points represent the average cover class recorded when the species occurred.

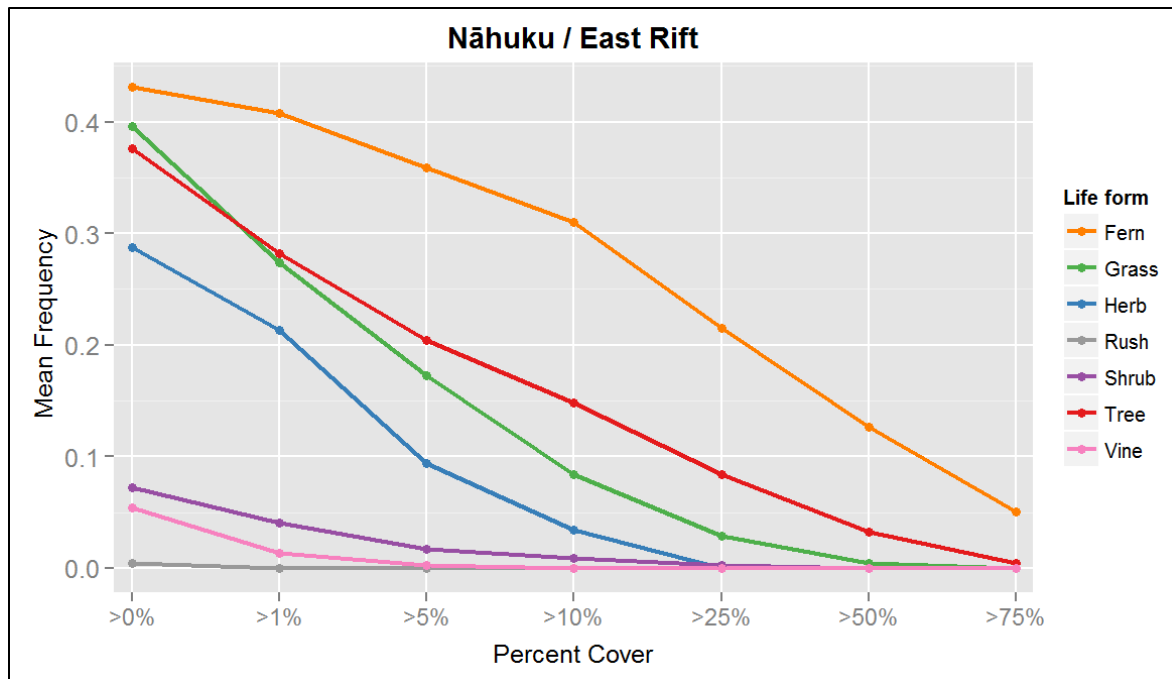


Figure 13. Mean frequency of non-native cover for each vegetation life form present within the Nāhuku/East Rift sampling frame. Frequency is the proportion of plots per transect in which the specified cover percentage was met. The X-axis represents cover class categories with increasing minimum cover cutoffs (moving from left to right). Mean frequencies were weighted by the area of the zones in which the life form occurred. Frequency of 1.0 = non-native cover present in all (100%) of plots.

‘Ōla‘a

The ‘Ōla‘a sampling frame had the highest frequency of non-native plants with over 80% of the plots per transect containing at least one non-native plant (Figure 10). The shrub, *Rubus ellipticus* var. *obcordatus* [0.45 ± 0.16] had the highest mean frequency of the ‘Ōla‘a non-native species, however the invasive grass, *Setaria palmifolia* [0.40 ± 0.22], showed similar frequency and a higher average cover class of “3” (5 - 10% cover) when it occurred (Figure 14). Thematic maps A.4 and A.5 display the widespread, but low cover pattern of *R. ellipticus* var. *obocordatus*, and the patchy high cover of *S. palmifolia*, especially in the New and Open units of ‘Ōla‘a. All non-native plant life forms were recorded in ‘Ōla‘a, with non-native herbs found in over half the plots [0.52 ± 0.18] (Figure 15). Grasses had the highest frequency of cover above 5% [0.21 ± 0.17] (Figure 15).

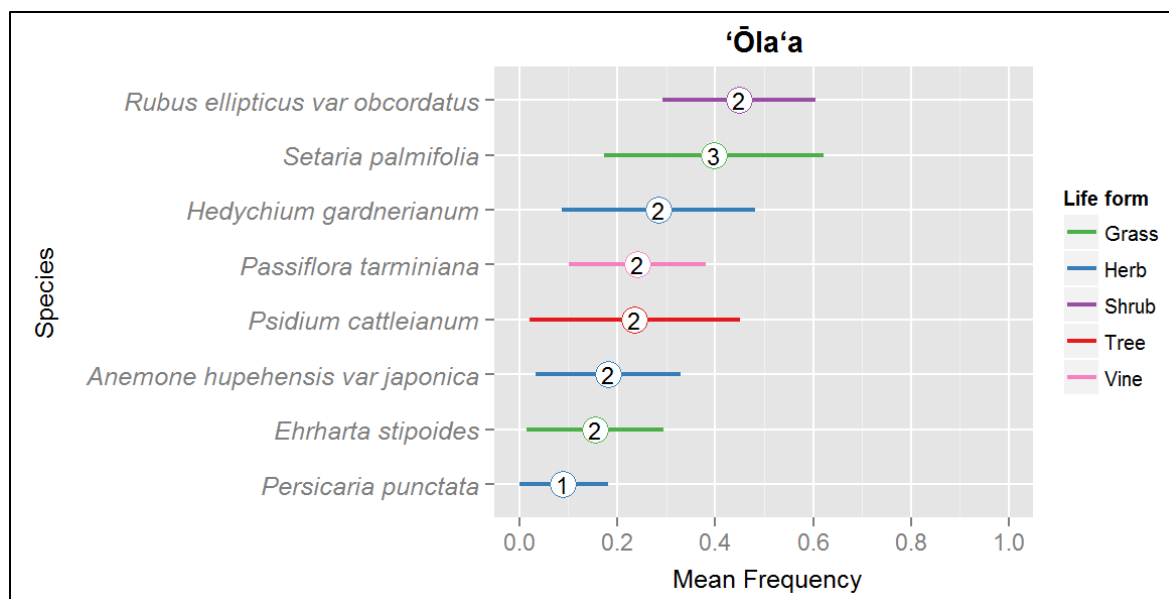


Figure 14. Eight most frequent species in 'Ōla'a. Frequency is the proportion of plots per transect in which the species was present. Frequency of 1.0 = present in all or 100% of plots. Error bars represent the 95% confidence intervals. Numbers inside the points represent the average cover class recorded when the species occurred.

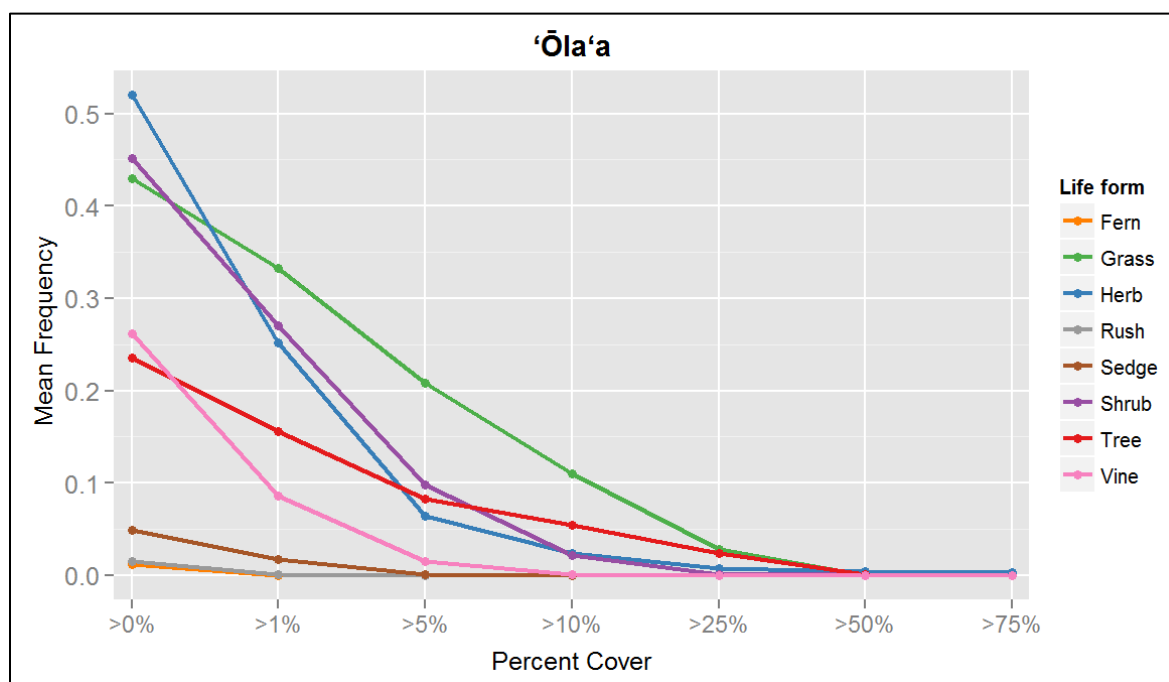


Figure 15. Mean frequency of non-native cover for each vegetation life form present within the 'Ōla'a sampling frame. Frequency is the proportion of plots per transect in which the specified cover percentage was met. The X-axis represents cover class categories with increasing minimum cover cutoffs (moving from left to right). Frequency of 1.0 = non-native cover present in all (100%) of plots.

Kahuku WF

The two zones of the Kahuku wet forest sampling frame (“WF Above Ka‘ū Forest” and “Paddocks”) were analyzed separately due to their distinct differences in management history.

WF Above Ka‘ū Forest

The Kahuku sampling frame in Figure 10 represents the WF Above Ka‘ū Forest zone because the Paddocks zone is excluded. This zone had the lowest frequency of non-native plants (cover >0%) and lowest cover of non-natives in the wet forest plant community (Figure 10). Frequency of plots containing >5% cover was only 0.09 ± 0.07 , significantly less than both the Nāhuku/East Rift [0.56 ± 0.12] and ‘Ōla‘a [0.46 ± 0.20] sampling frames (Figure 10). Similarly, non-native species richness was lower in the WF Above Ka‘ū Forest than the other wet forest sampling frames (Figure 8). *Anthoxanthum odoratum* [0.53 ± 0.16] and *Ehrharta stipoides* [0.38 ± 0.15] were the two most frequent non-native species in this zone (Figure 16). Correspondingly, grasses [0.72 ± 0.14] had the greatest mean frequency of any non-native life form and made up the majority of the non-native cover (Figure 17). Average cover class values for individual species of grasses were not calculated (Figure 16) because all cover of grass species documented in the Kahuku WF sampling frame were lumped into a composite “alien grass” category to increase efficiency in the field. Lumping of grass species cover was originally implemented in the Paddocks unit because high cover of heterogeneous grass species made individual cover class assignments very difficult and unnecessary for management recommendations. This procedure was continued in the WF Above Ka‘ū Forest zone to maintain consistency in the Kahuku sampling frame. Figures A.9 and A.10 show alien grass cover was generally low when present in the Mauka and East Units the WF Above Ka‘ū Forest. Despite lumping “alien grass” for cover, unique grass species per transect plot were identified, allowing for species richness and frequency calculations.

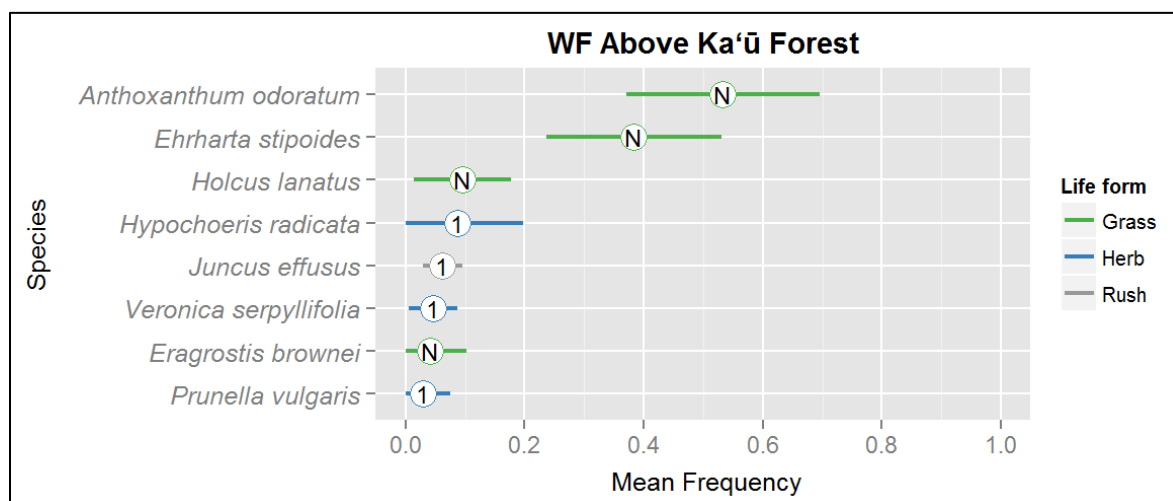


Figure 16. Eight most frequent species in WF Above Ka‘ū Forest. Frequency is the proportion of plots per transect in which the species was present. Frequency of 1.0 = present in all or 100% of plots. Error bars represent the 95% confidence intervals. Numbers inside the points represent the average cover class recorded when the species occurred. Average cover class is not available (“N”) for grasses in the Kahuku sampling frame.

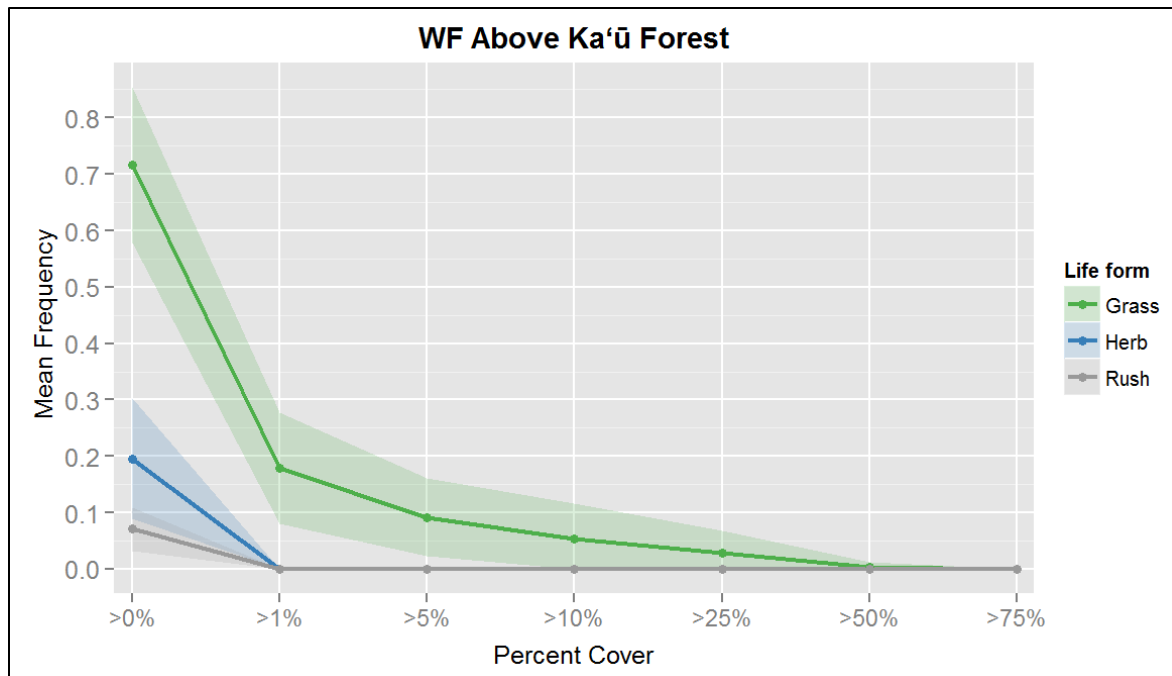


Figure 17. Mean frequency of non-native cover for each vegetation life form present within the WF Above Ka'ū Forest sampling frame. Frequency is the proportion of plots per transect in which the specified cover percentage was met. The X-axis represents cover class categories with increasing minimum cover cutoffs (moving from left to right). Frequency of 1.0 = non-native cover present in all (100%) of plots.

Paddocks

As shown in Figure 9, the Paddocks had the greatest number of non-native species per standardized transect in the wet forest. Grasses are by far the most dominant non-native life form in the Paddocks zone in terms of cover (Figure 19). In fact, non-native grass with cover >75% occurred with an average frequency of 0.92 ± 0.05 across all transects in the Paddocks [$n = 10$]. *Cenchrus clandestinus* [1.0 ± 0.00] was recorded in every plot in the Paddocks, often intermixed with *Axonopus fissifolius* [0.97 ± 0.06] (Figure 18). As described above in the WF Above Ka'ū Forest summary, average cover class values for individual species of grasses were not calculated. The wide confidence intervals for most species in Figure 18 indicate that frequency was typically patchy across the zone. For example, Figure A.13 shows frequency of *Anthoxanthum odoratum* was largely restricted to the northern portion of the Paddocks.

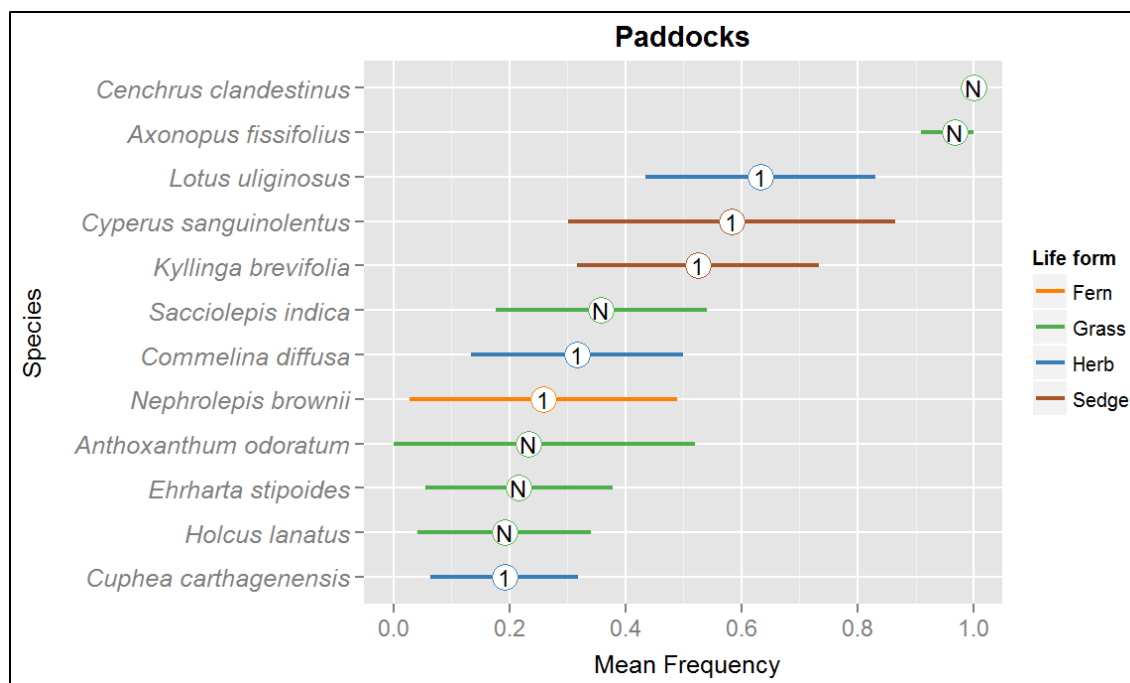


Figure 18. Twelve most frequent non-native species in the Paddocks zone. Frequency is the proportion of plots per transect in which the species was present. Frequency of 1.0 = present in all or 100% of plots. Error bars represent the 95% confidence intervals. Numbers inside the points represent the average cover class recorded when the species occurred. Average cover class is not available ("N") for grasses in the Kahuku sampling frame.

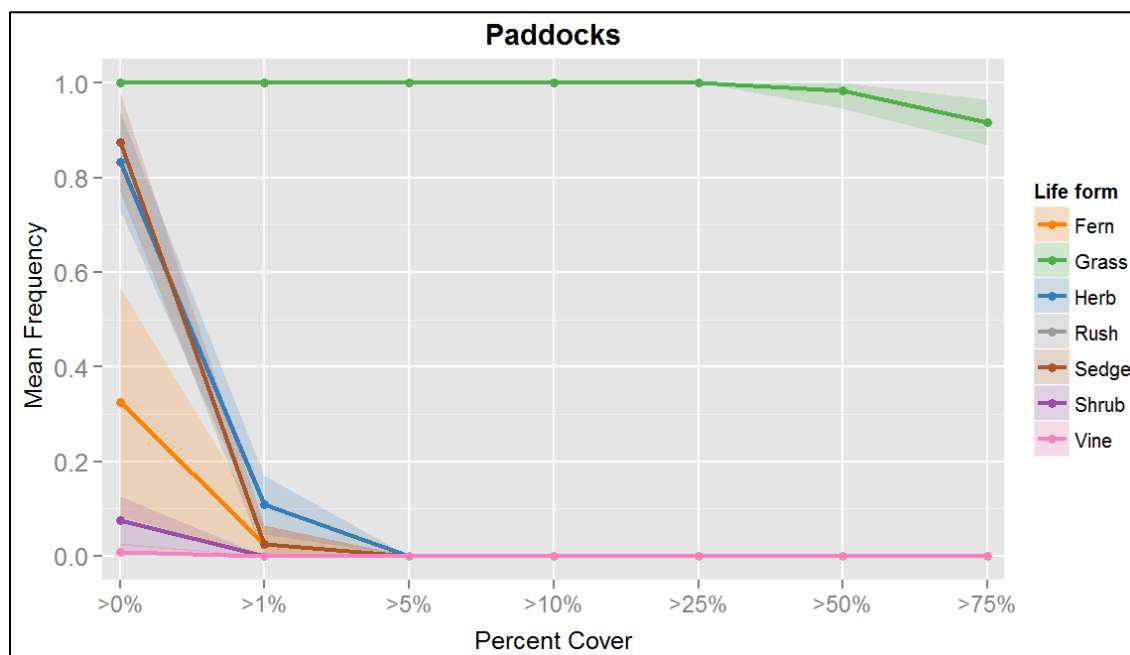


Figure 19. Mean frequency of non-native cover for each vegetation life form present within the Paddocks zone. Frequency is the proportion of plots per transect in which the specified cover percentage was met. The X-axis represents cover class categories with increasing minimum cover cutoffs (moving from left to right). Mean frequencies were weighted by the area of the zones in which the life form occurred. Frequency of 1.0 = non-native cover present in all (100%) of plots.

Subalpine Shrubland

The most frequently occurring species in the subalpine shrubland was the herb *H. radicata* [0.39 ± 0.17] (Figure 20) which was present in all zones except the Interior & West (Figure A.18-A.20). All species recorded in the subalpine shrubland occurred at relatively low average cover (class 1 or 2). Herbs and grasses were the only non-native plant life forms documented in the subalpine shrubland (Figure 21). When species were grouped by life form, herbs [0.61 ± 0.15] showed greater frequency than grasses [0.45 ± 0.18], however, grasses tended to occur with slightly greater cover (Figure 21). While only two transects were sampled within the NW Kahuku zone, non-native species frequencies along these transects were quite high. Table 6 lists the non-native species with frequencies above 0.50.

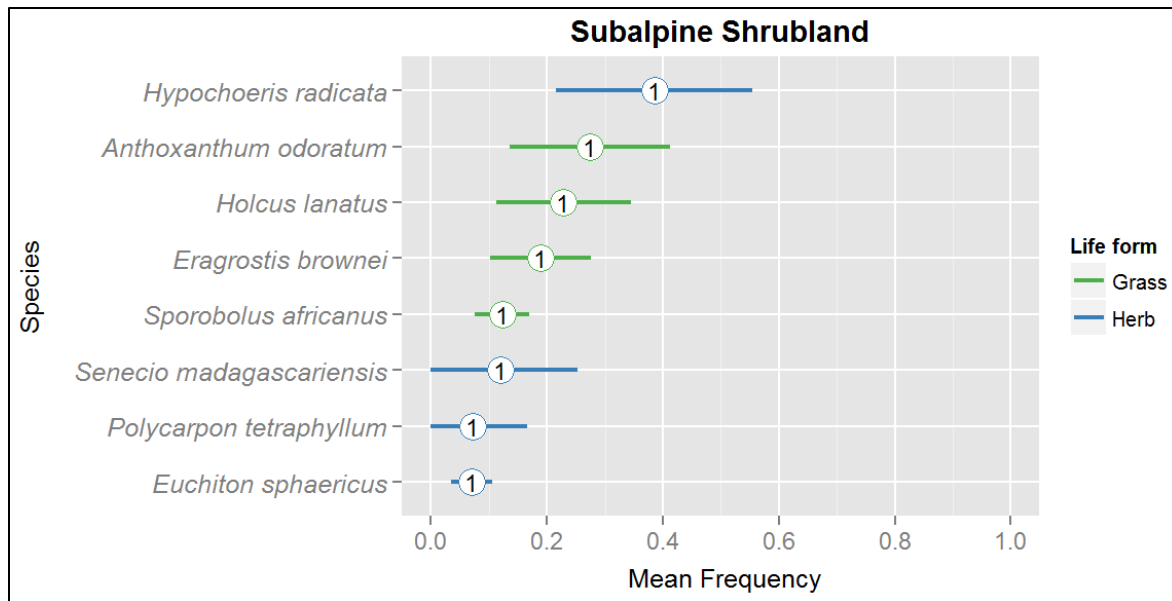


Figure 20. Eight most frequent species in the subalpine shrubland. Frequency is the proportion of plots per transect in which the species was present. Mean frequencies were weighted by the area of the zones in which the species occurred. Frequency of 1.0 = present in all or 100% of plots. Error bars represent the 95% confidence intervals. Numbers inside the points represent the average cover class recorded when the species occurred.

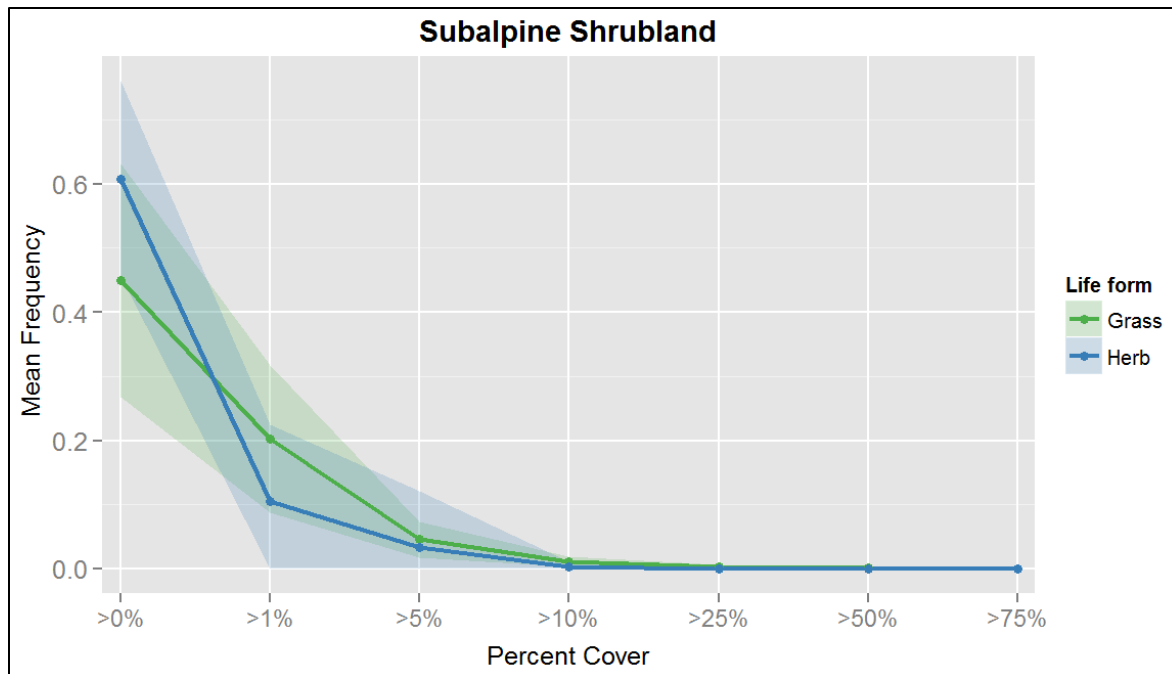


Figure 21. Mean frequency of non-native cover for each vegetation life form present within the subalpine shrubland. Frequency is the proportion of plots per transect in which the specified cover percentage was met. The X-axis represents cover class categories with increasing minimum cover cutoffs (moving from left to right). Mean frequencies were weighted by the area of the zones in which the life form occurred. Frequency of 1.0 = non-native cover present in all (100%) of plots. 95% confidence intervals shown in shaded colors.

Table 6. NW Kahuku non-native species with mean frequencies above 0.50.

Species	Mean Freq.
<i>Ehrharta stipoides</i>	1.00
<i>Oxalis corniculata</i>	0.94
<i>Rumex acetosella</i>	0.88
<i>Verbascum thapsus</i>	0.84
<i>Geranium homeanum</i>	0.80
<i>Senecio sylvaticus</i>	0.78
<i>Senecio madagascariensis</i>	0.74
<i>Polycarpon tetraphyllum</i>	0.72
<i>Veronica peregrina ssp xalapensis</i>	0.66
<i>Cenchrus clandestinus</i>	0.58
<i>Coronopus didymus</i>	0.56
<i>Cirsium vulgare</i>	0.54
<i>Veronica plebeia</i>	0.52

Discussion

Across the wet forest and subalpine shrubland of HAVO, the frequency of plots that contained non-native species was somewhat high (72%). However, total non-native cover was generally low and still manageable in many areas. None of the non-native species encountered were dominant or widespread across the entire park or plant community type. Only 20% of the species were present in both the wet forest and subalpine shrubland community types. Given the range of climates and elevation covered in the sampling, this was not a surprising result. At first glance, both the subalpine and wet forest plant communities appeared to show similar non-native richness; however, the majority of the non-native species recorded in the subalpine shrubland were found only in the NW Kahuku zone, a relatively small, west facing, drier, isolated portion of the plant community.

Results from the sample-based species accumulation curves suggested that increased sampling would likely uncover more species in the wet forest, while the subalpine shrubland may be approaching an asymptote in which very few new species are expected to be found with increased sampling. This is likely because the wet forest plant community is more heavily vegetated in general and includes a greater diversity of habitat/disturbance types. While this appears to warrant further sampling in the wet forest, it may in fact be cost-prohibitive. Gotelli and Colwell (2011) state that, in practice, achieving a species accumulation asymptote is often impossible, especially in the tropics where species diversity is high and most species rare. Although, not all non-native species known to occur within these communities were captured during this sampling event (see IRMA NPSpecies 2016, Green et al. 2015, Benitez et al. 2008, and HAVO and PACN unpublished data sets), every five years additional temporary transects will be established resulting in greater spatial coverage and species documentation over time.

Efforts to summarize results across the entire wet forest of HAVO were somewhat trivial because most non-native species exhibited patchy, localized distributions. For example, one of the most frequent non-native species, *N. brownii*, was found almost exclusively in one zone of one sampling frame (East Rift). Furthermore, out of the ten most frequent non-native species in the wet forest, only one (*E. stipoides*) occurred in all three sampling frames (Table 5). Therefore, results are more suited for examination by sampling frame and zone and are discussed accordingly.

Wet Forest

Nāhuku/East Rift

Non-native species cover was greatest in the Nāhuku/East Rift sampling frame due to *N. brownii*, *Morella faya*, and *Paspalum conjugatum*. However, the distribution of these species was not uniform across the two zones. Natural and human-induced disturbance are likely key factors that contribute to the frequency and cover of these non-native species.

N. brownii and *P. conjugatum* were the two most frequently encountered non-native species within the sampling frame. However, both species were largely restricted to the East Rift zone (Figures A.1 & A.2). The East Rift zone encompasses a geologically active area exposed to frequent lava flows and lava-ignited wildfires. *N. brownii* and *P. conjugatum* are quick to colonize after a disturbance (Palmer 2003; Ainsworth and Kauffman 2010), therefore, the high frequency and cover values may

be attributed to the repeated lava-ignited fires in the area from 1996-2003 (see Site Descriptions). *Nephrolepis brownii* also appears to be a rapid invader because it was rare in the area in the late 1980's (Jacobi 1989) and widely distributed in the East Rift by the late 1990's (Pratt et al. 1999).

M. faya, an invasive tree capable of reproducing abundantly, forming dense stands and altering soil nutrients (Vitousek and Walker 1989), also showed high frequency and cover. This species was predominantly encountered in the Nāhuku zone (Figure A.3) where the first HAVO record was reported in 1961. Vitousek and Walker (1989) stated that *M. faya* was most successful when invading open canopied forests available within the Nāhuku area due to disturbance from volcanic cinder-fall. It should therefore be noted that the southwest edge of the East Rift zone also supports low cover of *M. faya* which may indicate an advancing invasion front from the original population. Recent availability of open-canopied forests from lava-ignited fires in the East Rift zone could allow *M. faya* to spread deeper into this region and will need to be monitored closely.

Both *M. faya* and *P. cattleianum* are known to be animal-dispersed (Smith 1985, Stone 1985, PIER 2002, Nogueira-Filho et al. 2009) and have been correlated with pig activity (Aplet et al. 1991). The thematic maps for these species (A.3 & A.4) did not show an obvious decline in frequency or cover in areas where pigs have been removed as expected (see Site Descriptions for locations of pig control). However, there are other animal dispersers in this area (e.g., native and non-native birds). It is also possible that the scale used in this protocol was simply too coarse to adequately capture these potential differences. For example, only one of the eight transects in the Nāhuku zone was located within the pig-free and *M. faya* controlled area.

‘Ōla‘a

Non-native plants were found in 82% of the plots sampled in ‘Ōla‘a. The top 6 most frequent species are all considered invasive and high priority management targets (Benitez pers. comm.).

Of the most frequent species in ‘Ōla‘a, *S. palmifolia* had the highest average cover (5-10%) when present. *Setaria palmifolia* is a broadleaved invasive grass that can shade out other understory plants (Smith 1985). At HAVO, it is considered widespread and has increased in coverage since 1966 (Benitez et al. 2012). Mean frequency of *S. palmifolia* in this report is similar to the results of a 1998 survey which reported *S. palmifolia* in 40% of transect stations in ‘Ōla‘a (Benitez et al. 2012). This species is shade tolerant and can successfully establish despite pig control, and the park has determined it to be too widespread for control in the ‘Ōla‘a units (Loh and Tunison 1999; Benitez et al. 2012). A marked reduction in *S. palmifolia* frequency and cover is observable along the southwest portion of ‘Ōla‘a (Figure A.5). Because *S. palmifolia* is generally not managed in this area, this likely indicates the present status of its invasion front.

R. ellipticus var. *obcordatus* was the most frequently occurring non-native species (45%) in ‘Ōla‘a, and resulted with an average cover of 1-5%. Similarly, the 1998 survey found *R. ellipticus* occurring in 57% of the sampled plots in ‘Ōla‘a with the densest cover occurring in the Koa unit (Benitez et al. 2012). It is declared a noxious weed by the State of Hawaii and forms dense stands displacing native species (Benitez et al. 2012). Seeds are dispersed by birds and underground shoots facilitate spread

into neighboring areas (Smith 1985). The species is relatively widespread despite control efforts within portions of the fenced SEA units (see Figure A.6).

P. cattleianum was patchy across ‘Ōla‘a, and found, on average, in a quarter of the plots. The medium sized tree is considered the worst pest in Hawaii’s rain forests and can form dense monotypic stands that inhibit the growth of other plants (Smith 1985). Similar to park resource management surveys conducted in 1998 and 2005 (Benitez et al. 2012), our monitoring results showed prominent cover in the southeastern half of ‘Ōla‘a and little if any cover in the Ag and Pu‘u units (Figure A.7). However, Benitez et al. (2012) reported notable dense infestations in the ‘Ōla‘a Koa unit which were not observed during this sampling effort. While Cole et al. (2012) found *P. cattleianum* densities to remain constant in pig-present sites over time, Bentiez et al. (2012) suggested that the invasion front of this species may be advancing to the northwest.

Previous research has shown that the exclusion of feral pigs via fencing ‘Ōla‘a SEAs can lead to an increase in native plant species richness and abundance, and a decrease in some non-native species (Cole and Litton 2014; Cole et al. 2012; Loh and Tunison 1999). Feral pigs are known to facilitate the spread of invasive species such as *Passiflora tarminiana* and *P. cattleianum* (Smith 1985). Appropriately, *P. cattleianum* shows limited frequency in the SEAs with the longest history of pig exclusion. However, the other mapped species do not show this relationship which may be due to the presence of other animal vectors such as birds.

Kahuku WF

As expected, non-native species richness, frequency, and cover were much higher in the Paddocks zone (17.5 species/240 m) in comparison to the Above Ka‘ū Forest zone (5 species/240m). The Paddocks zone has had more exposure to previous agricultural practices and landscape changes compared to the Above Ka‘ū Forest zone and currently the Above Ka‘ū Forest zone supports more mature native forests (Benitez et al. 2008). Green et al. (2015) classified the Paddocks zone as *M. polymorpha/Cenchrus clandestinus* semi-natural woodland and the Above Ka‘ū Forest zone as native and montane woodlands or forests dominated by *M. polymorpha* canopies with a *Cibotium* spp. subcanopy, *Leptecophylla tameiameiae-Dodonea viscosa* shrub layer, or an herbaceous layer dominated by *Dryopteris wallichiana*.

The Above Ka‘ū Forest zone had the least amount of non-native cover within the wet forest. This zone is higher in elevation and drier than the other wet forest sites which may help limit the establishment of non-native plants from lower elevations. Two grasses, *Anthoxanthum odoratum* and *Ehrharta stipoides*, displayed the highest non-native frequency within the area. *Anthoxanthum odoratum* is able to thrive in mesic, moderate elevations to dry, subalpine elevations (Smith 1985) and was found widely distributed in the Above Ka‘ū Forest zone (Figures A.14-A.15). In the Paddocks zone, *A. odoratum* was largely restricted to the upper elevation sites (Figure A.13). Limited presence of non-native plants in the Above Ka‘ū Forest zone warrants continued management to prevent new invasive species from establishing in the area.

Grasses were also the most frequent non-native plants in the Paddocks zone with *C. clandestinus* and *Axonopus fissifolius* occurring in almost every plot. Both are naturalized and are able to invade

disturbed areas, preventing native species from establishing (Smith 1985). *C. clandestinus* was likely planted in Kahuku because it “provides good forage for livestock” and is commonly used as a pasture grass (DiTomaso and Healy 2007). In addition to its ability to shade out other plants, the species also releases allelopathic substances, further affecting the ability for native species to persist (Marais 2001). *Cenchrus clandestinus* was only documented in the Paddocks zone (Figure A.16).

Collectively, *alien grass* (any non-native grass in the Kahuku WF), had the highest average cover in both the Paddocks and Above Ka‘ū Forest zones. As mentioned in the methods section, cover classes for all non-native grasses were lumped under *alien grass* in the Kahuku wet forest as it was often difficult to assign cover values to individual grass species in the Paddocks zone. The alien grass category increased sampling efficiency with only a minor loss of management information because these grasses exhibited similar growth habit and would likely require similar treatment methods. When zones were analyzed separately, average cover class of *alien grass* was between 1-5% in the Above Ka‘ū Forest, and between 75 – 100% in the Paddocks (see Tables B.1 & B.2). As clearly depicted in thematic maps (Figures A.9 – A.11), there were fewer patches of dense non-native grasses in the Above Ka‘ū Forest compared to the Paddocks. Changes in the composition and abundance of non-native species are expected in the Paddocks zone due to the relatively recent removal of cattle from the area and ongoing fencing and ungulate removal. If closed canopy conditions can be promoted in the Paddocks, a reduction in grass cover would be expected (McDaniel and Ostertag 2010). Continued EIPS monitoring in the Paddocks zone will help managers keep a watchful eye on non-native species dynamics as this area becomes reforested.

No SEAs have been established within the Kahuku WF sampling frame (or within the Kahuku unit). SEAs are proposed, however, since the unit provides habitat for several native and endangered plants and animals (Loh et al. 2014; Benitez et al. 2008). *M. faya* invasions appear to be of concern; several individuals have been located and eradicated in Kahuku by park management, but additional searches are still needed (Loh et al. 2014). As previously mentioned, control efforts of feral animals within Kahuku is still in progress. As McDaniel et al. (2011) showed in a study within the Kahuku unit, removal of feral ungulates was critical for the establishment of native seedlings.

Subalpine Shrubland

Overall non-native species cover was low in the subalpine shrubland. The most frequent species, *H. radicata*, had an average cover class of <1% cover when present. Similarly, the frequency of encountering any non-native species with >5% cover was relatively low. However, species richness was moderate due to the increased diversity of non-native species encountered in the NW Kahuku zone. In fact, it was in the NW Kahuku zone that two new non-native species were documented for the park (*A. aspera* var. *aspera* and *V. arvensis*) and four species were newly documented for the Kahuku Unit (*C. didymus*, *D. pusillus*, *E. cicutarium*, and *S. gallica*). Compared to other zones across the wet forest and subalpine plant communities, NW Kahuku had the highest non-native species richness. Additionally, many of the species encountered there occurred at relatively high frequencies. A growing population of feral mouflon sheep resident to Kahuku plus others that travel in and out of Kahuku from adjacent ranches may have influenced non-native species distribution (Hess, pers.

comm.). Mouflon are notorious for trampling, consuming and stripping bark from native plants, as well as aiding in dispersing non-native seeds.

While non-native species cover was low, it should also be noted that vegetation cover in general is low in the subalpine shrubland. Green et al. (2015) described four vegetation types within the area: montane woodlands, shrublands, montane and subalpine sparse vegetation, and unvegetated areas. Vegetative cover can be as low as 15% in the woodlands and shrublands, and 5% in sparse vegetation. Low overall vegetative cover is one factor that can explain decreased cover and frequency of non-native species in the subalpine shrubland compared to the wet forest plant community.

Herbs and grasses were the only non-native species life forms recorded in the subalpine, a finding similar to Daehler (2005) for plants above 2000 m in the Hawaiian Islands. High frequency of herbaceous species in these upper elevations may be attributed to frequent disturbance of ungulates and humans that promote rapid-growing herbaceous species, and to a non-random pool of introductions, specifically of those associated with ranching. These species may have been introduced via contaminated grass seed or hay (feed), by seeds attached to fur of imported animals, or intentionally planted as fodder. Although, none were sampled along transects, scattered individuals of woody non-native species (e.g., *Pinus sp.*, *M. faya*, *Ulex europaeus*, *Cornus sp.*) have been documented in these subalpine sites.

H. radicata was the most frequent non-native species and was documented in the subalpine and wet forest plant communities. *H. radicata* produces large numbers of wind-dispersed seeds (Wagner 1999), is an early successional pioneer species and is able to rapidly regenerate following feral animal disturbance (Loope et al. 1992). The species is able to persist in elevations ranging from 110-3040 m (Daehler 2005) and results in a higher frequency compared to other non-native plants because it occurs in three of the four subalpine zones (Figures A.19-21).

Also present in the subalpine and wet forest plant communities, *A. odoratum* and *Holcus lanatus* had relatively high cover in the subalpine. Both species are categorized as being “disruptive in native communities”, and are able to persist even after ungulate removal (Daehler 2005). “Disruptive invaders” can also alter fire frequency and intensity, affecting native plant communities and nutrient cycling (D’Antonio and Vitousek 1992). The second most frequently encounter herb was *Senecio madagascariensis*, a noxious weed in the state of Hawaii, which can also be detrimental in the subalpine shrubland, as it can spread rapidly. Control by feral sheep grazing is limited because the plants contain alkaloids that can cause illness or death if the animals consume too much of the plant (Motooka et al. 2003).

Substrate and climate are factors that affect the plants that grow in the subalpine shrubland. High elevation areas of the sampling frame tended to be rocky, with many areas containing various ages of ‘a‘ā and pahoehoe lava, perhaps limiting microsites where plant species can establish. The cool, dry climate may be beneficial for native plants that thrive at these elevations (e.g. *Deschampsia nubigena*, *Morelotia gahniiformis*), but not ideal for the tropical non-native species that are persistent in the lower elevation forests. This explains why most of the non-native species in the subalpine are

of European, temperate origins (Daehler 2005). Climate change and the related potential increase in elevation of the trade wind inversion layer may pose a significant threat to plants that are restricted to higher elevations. Warming conditions may also allow more tropical non-native species from lower elevation forests to “climb” into the subalpine shrubland community (Angelo and Daehler 2012). The risk is compounded by feral ungulates like sheep and goats that cause disturbance and aid seed dispersal. Continued monitoring is especially important in the subalpine region where the level of non-native species cover is relatively low.

Conclusions

- The NW Kahuku zone of the subalpine shrubland contained a substantial number of non-native species (an average of 30 different species per 240 m). Individual species frequency was also relatively high in the NW Kahuku zone (i.e. 13 species with mean frequency above 0.50).
- *Nephrolepis brownii* exhibited both high mean frequency and high average cover class in the East Rift zone.
- *Morella faya* exhibited high mean frequency and high average cover in the Nahuku zone. The southwest boarder of the East Rift shows low cover of *M. faya* with potential to spread deeper into the area.
- The Above Ka'ū Forest zone in the wet forest showed less frequency and cover of non-native species than the other wet forest sampling frames. Grasses *Anthoxanthum odoratum* and *Ehrharta stipoides* are the most frequent non-native species in this zone.
- The subalpine shrubland plant community had less non-native cover than the wet forest, but also displayed less vegetation cover in general.

Recommendations

This report is the first of a long-term monitoring regime for established invasive plant species at HAVO. The results provide a snap-shot assessment of non-native plant abundance in these relatively intact plant communities and compliment other plant monitoring protocols conducted by I&M, such as Focal Terrestrial Plant Community Monitoring and Early Detection of Invasive Plant Species. Clearly, sites with histories of greater land use and/ or anthropogenic disturbance contain greater diversity of non-native species and cover (e.g., wet forest Kahuku Paddocks Unit, wet forest East Rift zone). To determine if these sites are transitional and benefiting from management efforts (i.e. eradication of cattle in the Paddocks Unit) or persisting in a non-native dominated stable state, additional monitoring is necessary. Future monitoring efforts will both allow for change detection along permanent transects and importantly provide for greater spatial coverage with new rotational transects across these relatively heterogeneous landscapes. In addition to supplementing less-frequent surveys conducted by the park's Resource Management division, these data collected by I&M are intended to contribute to the science-based adaptive management of the park. They could also be used to potentially analyze how non-native species diversity, frequency and cover change over time among PACN wet forest and subalpine communities of HAVO, Haleakalā National Park, and Kalaupapa National Historical Park.

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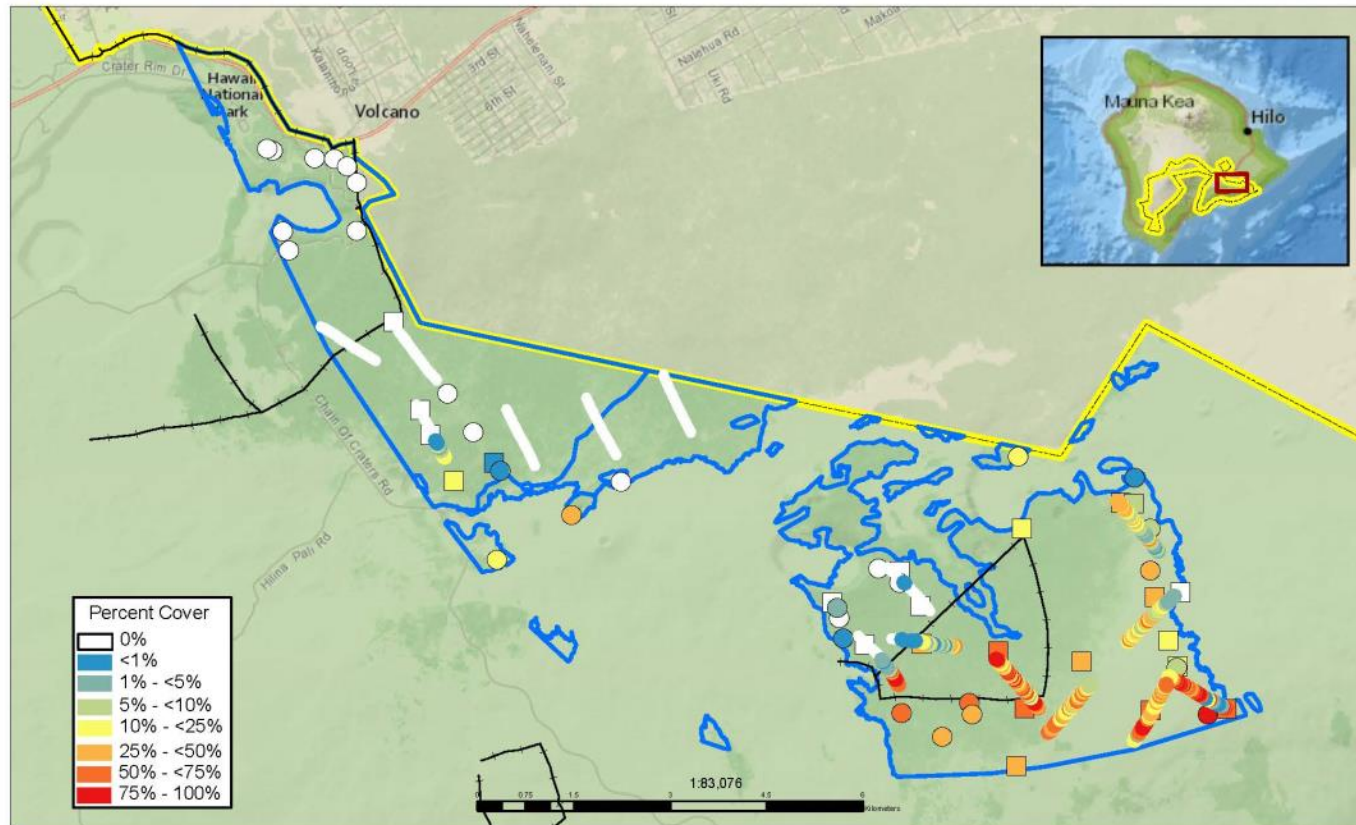
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Appendix A: Thematic maps for Established Invasive Plant Species

Thematic maps of HAVO were created in order to utilize data collected on non-native plant species from various projects conducted by PACN (I&M). Below are examples of how these data can allow us to better understand the magnitude of non-native species of interest. Along with data from the EIPS survey, included are also data from the Vegetation Mapping inventory and Focal Terrestrial Plant Community (FTPC) monitoring protocol (Green et al. 2015; Ainsworth et al. *unpublished report*). Vegetation Mapping plot data in the East Rift/Nāhuku and ‘Ōla‘a sampling frames were collected from 2009 – 2011 and consisted of circular plots, each 400 m². Vegetation Mapping data within the Kahuku Unit except the Paddocks (Kahuku WF and most of the subalpine shrubland plant communities) were based off legacy data collected by HAVO resource management in 2005 (Benitez et al. 2008). Kahuku legacy data consisted of vegetation surveys conducted within primarily circular 700 m² plots and some up to 1000 m² rectangular plots. While several plots were inventoried at HAVO, only those that fell within sampling frames are presented. Maps below include monitoring data from 101 rectangular FTPC plots (20 x 50 m) and 124 vegetation inventory plots in the HAVO wet forest and subalpine shrubland communities. Displayed cover classes correspond to percent cover based off of the modified Braun-Blanquet cover classes (Table 2). The presence or absence of a focal species is presented in the Kahuku unit when cover data were not available. All vegetation data presented were collected prior to the installation of the East Rift SEA diagonal fence in the East Rift/Nāhuku maps.

Non-native plant species sampling sites:

- [Nāhuku / East Rift](#)
- [‘Ōla‘a](#)
- [Kahuku wet forest](#)
- [Subalpine Shrubland](#) Index

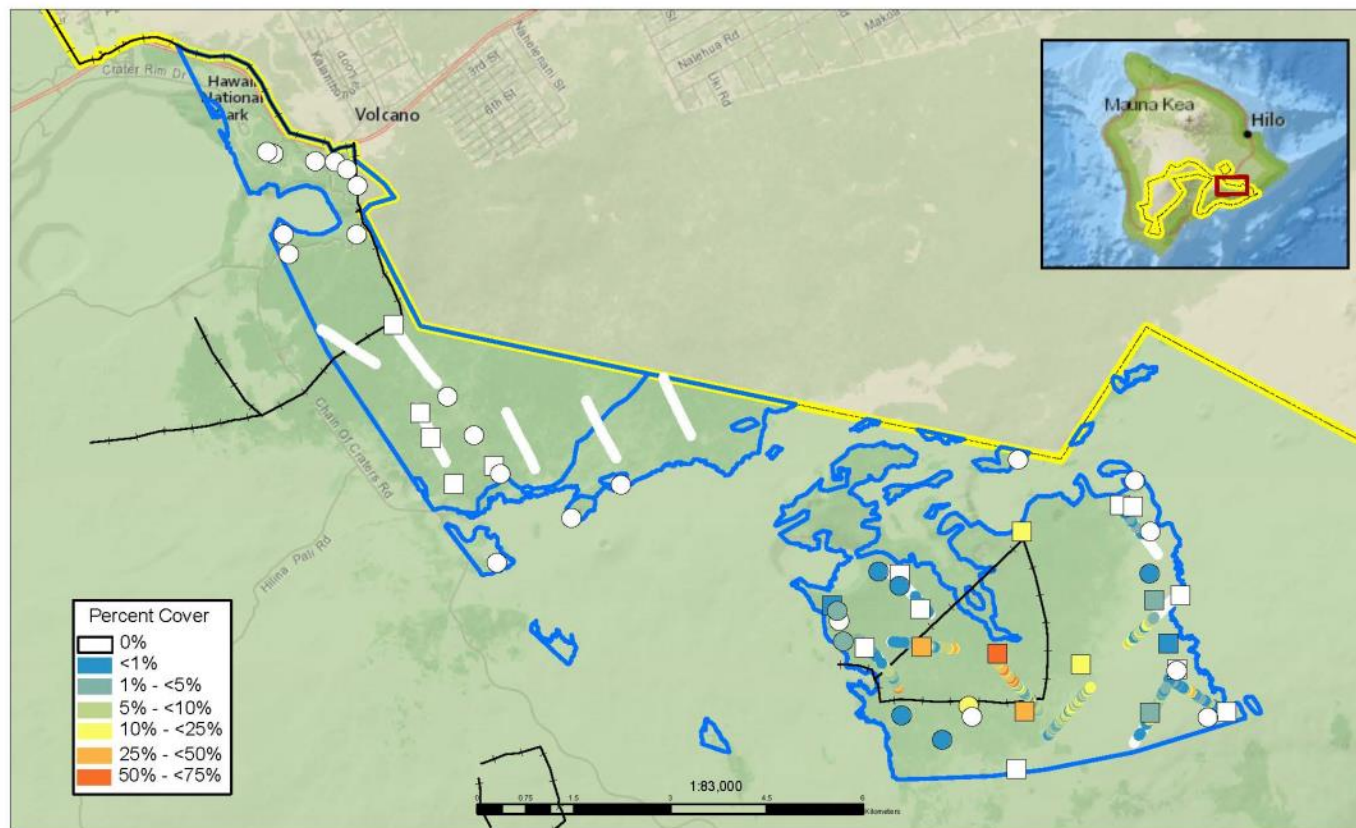


- Focal Terrestrial Plots (20 x 50 meters)
- Vegetation Mapping Plots (400 sq meters)
- ∞ Established Invasive Plant Transects (1000 meters)
- East Rift/Nahuku Sampling Frame
- Fenceline
- Park Boundary

Coordinate System: NAD 1983 UTM Zone 0N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -155.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter



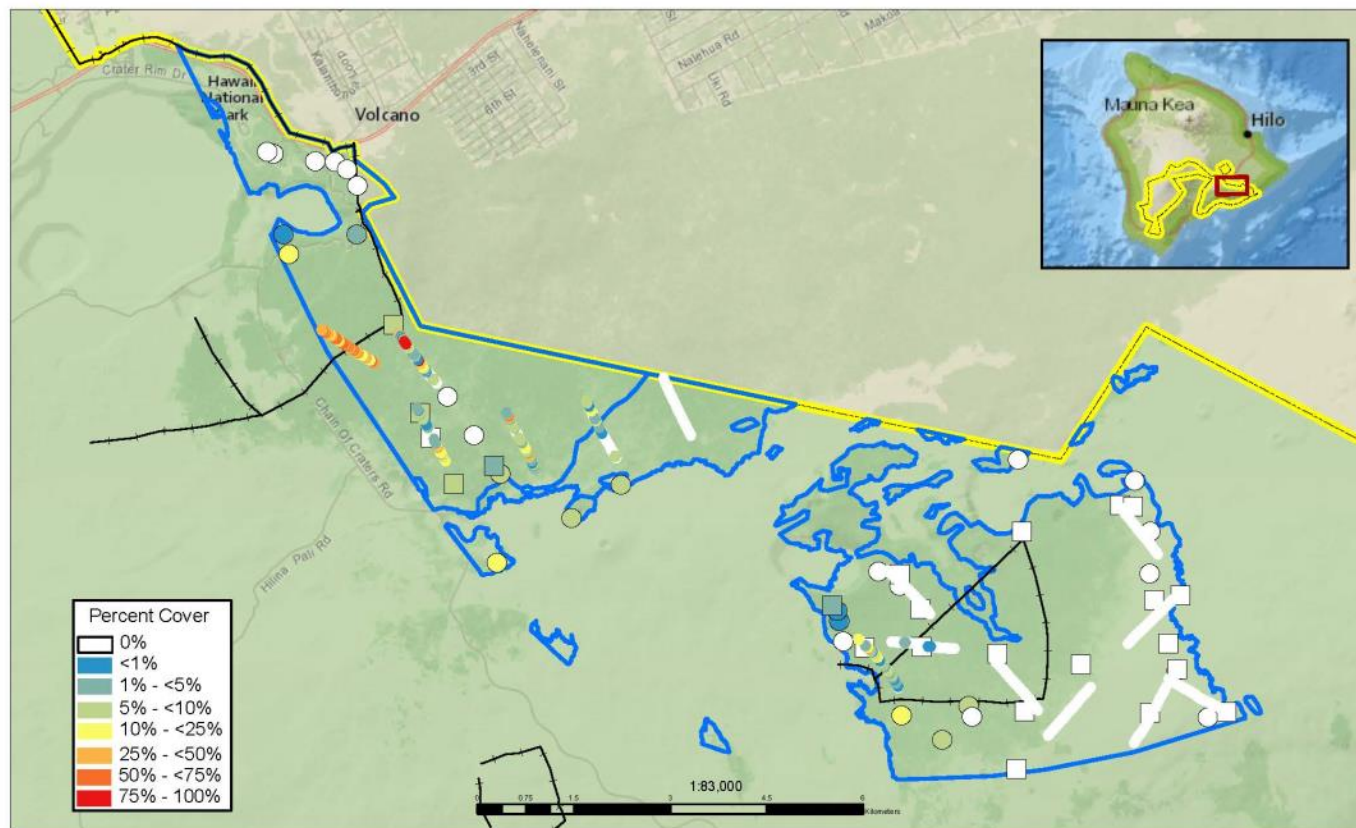
Figure A.1. *Nephrolepis brownii* is widespread and abundant in the East Rift zone and sparse in the Nāhuku zone.



- Focal Terrestrial Plots (20 x 50 meters)
- Vegetation Mapping Plots (400 sq meters)
- ∞ Established Invasive Plant Transects (1000 meters)
- East Rift/Nahuku Sampling Frame
- Fenceline
- Park Boundary

Coordinate System: NAD 1983 UTM Zone 5N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -155.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter

Figure A.2. *Paspalum conjugatum* is widespread in the East Rift zone.



□ Focal Terrestrial Plots (20 x 50 meters)

○ Vegetation Mapping Plots (400 sq meters)

∞ Established Invasive Plant Transects (1000 meters)

□ East Rift/Nahuku Sampling Frame

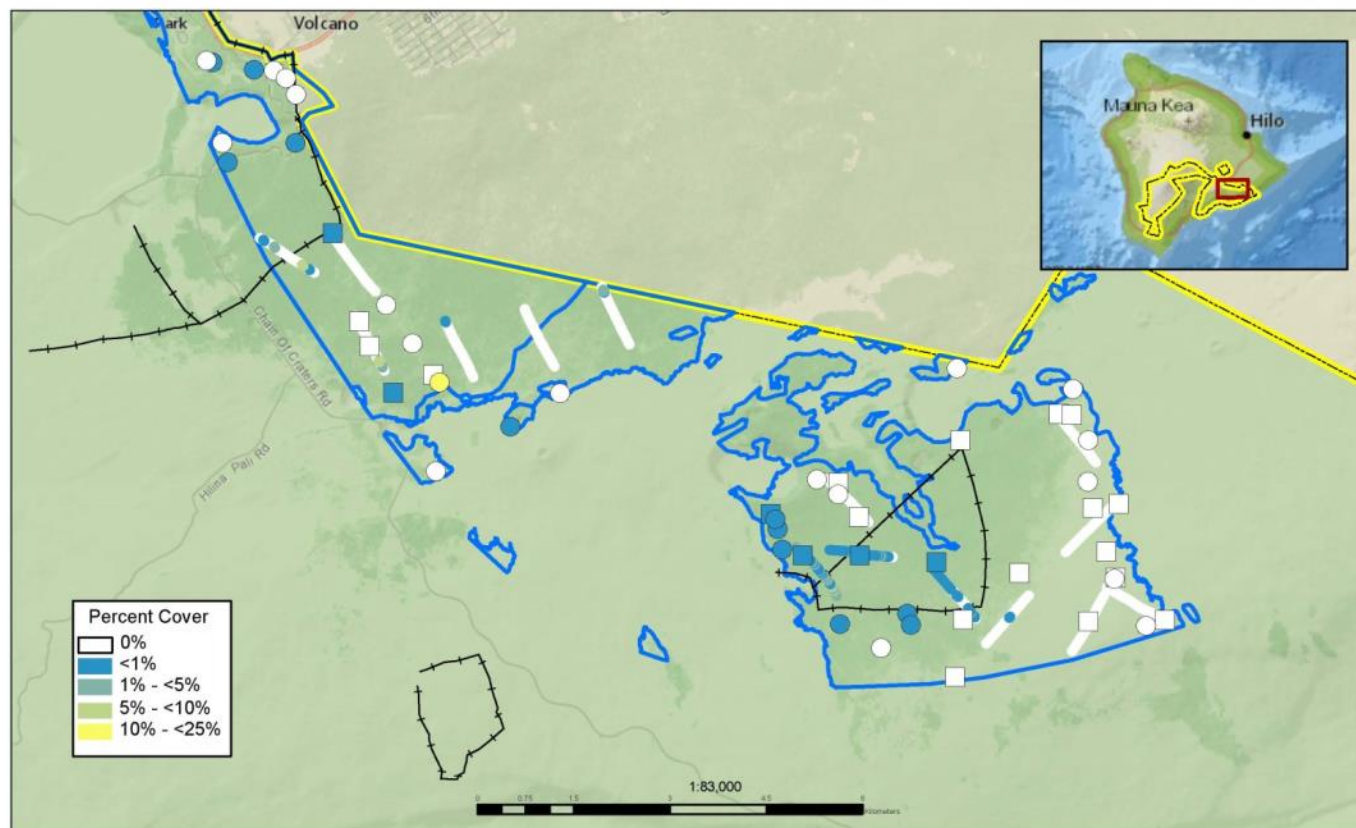
— Fenceline

□ Park Boundary

Coordinate System: NAD 1983 UTM Zone 0N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -155.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter



Figure A.3. *Morella faya* is abundant in Nāhuku, but only found along the west edge of East Rift.



- Focal Terrestrial Plots (20 x 50 meters)
- Vegetation Mapping Plots (400 sq meters)
- ∞ Established Invasive Plant Transects (1000 meters)
- Nahuku/East Rift Sampling Frame
- +— Fenceline
- ▭ Park Boundary

Coordinate System: NAD 1983 UTM Zone 5N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -153.0000
Scale Factor: 0.9996
Latitude Of Origin: 0.0000
Units: Meter



Figure A.4. *Psidium cattleianum* is widely dispersed with low cover in the East Rift/Nāhuku sampling frame.

Hawai'i Volcanoes National Park
Island of Hawai'i, Hawai'i

Percent cover of *Setaria palmifolia*
in 'Ōla'a Sampling Frame

National Park Service
U.S. Department of the Interior

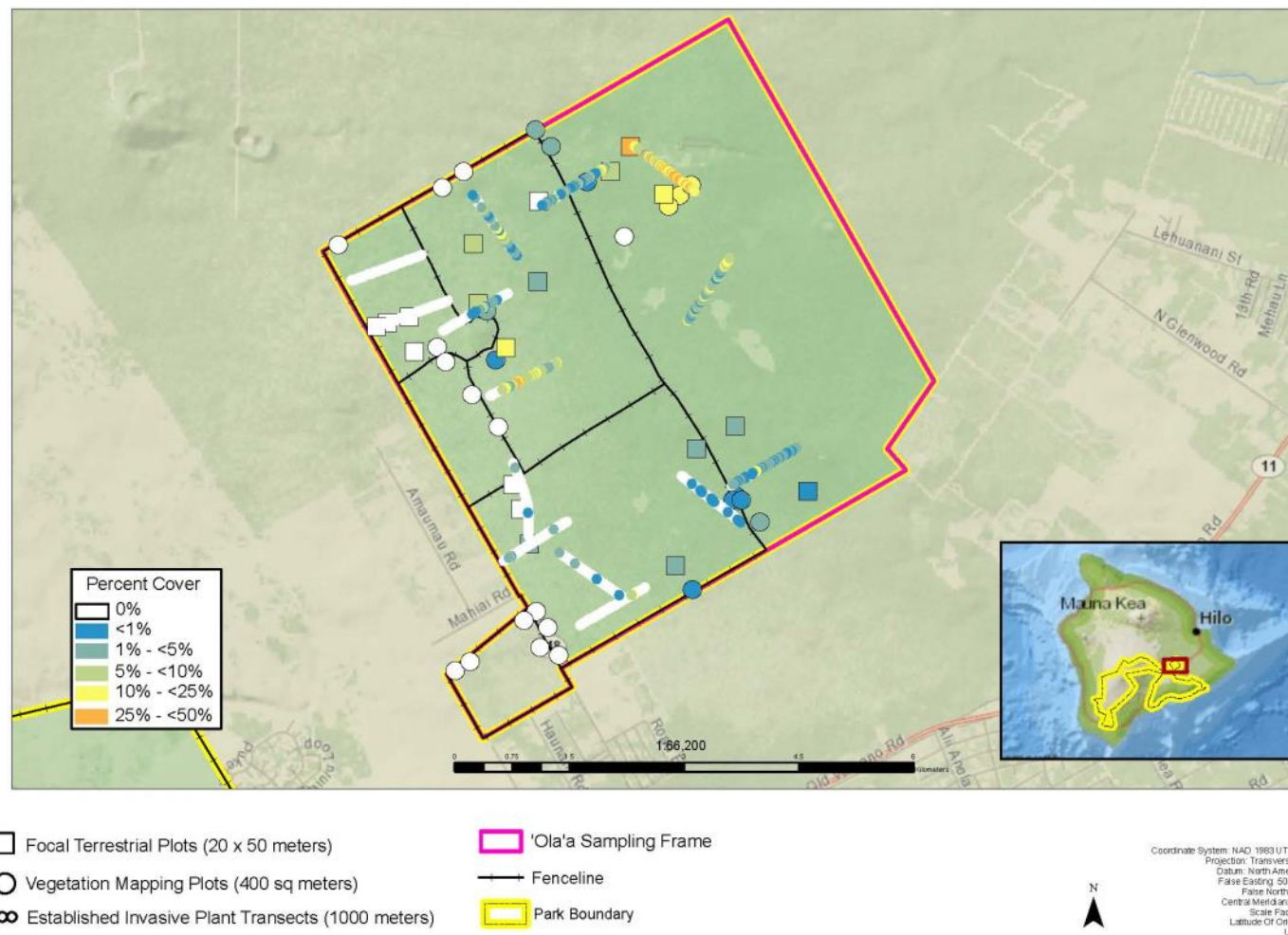


Figure A.5. *Setaria palmifolia* is scattered throughout 'Ōla'a with highest cover values in the north Open Unit.

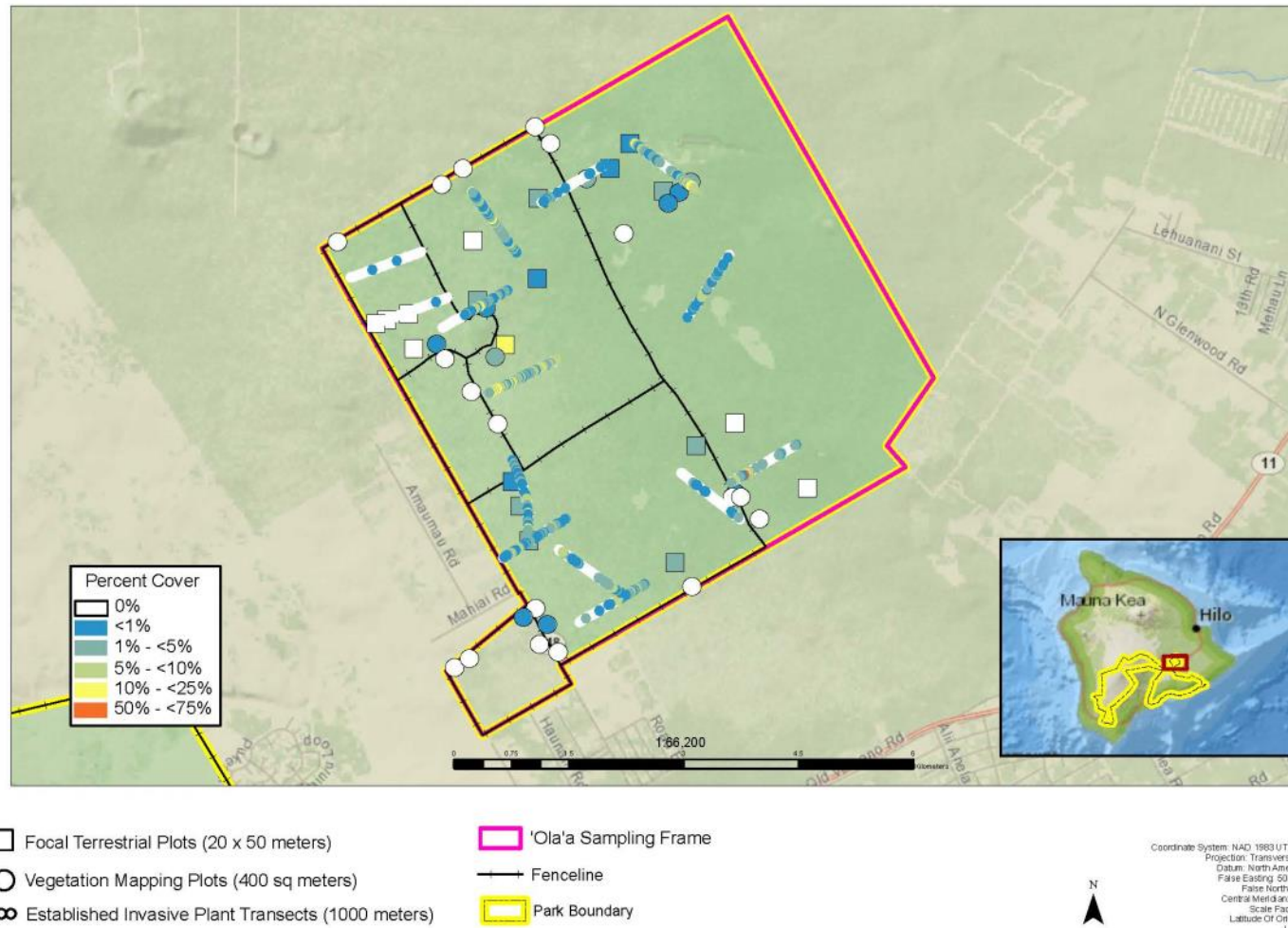


Figure A.6. *Rubus ellipticus* var. *obcordatus* is uniformly distributed across 'Ola'a.

Hawai'i Volcanoes National Park
Island of Hawai'i, Hawai'i

Percent cover of *Psidium cattleianum*
in 'Ola'a Sampling Frame

National Park Service
U.S. Department of the Interior

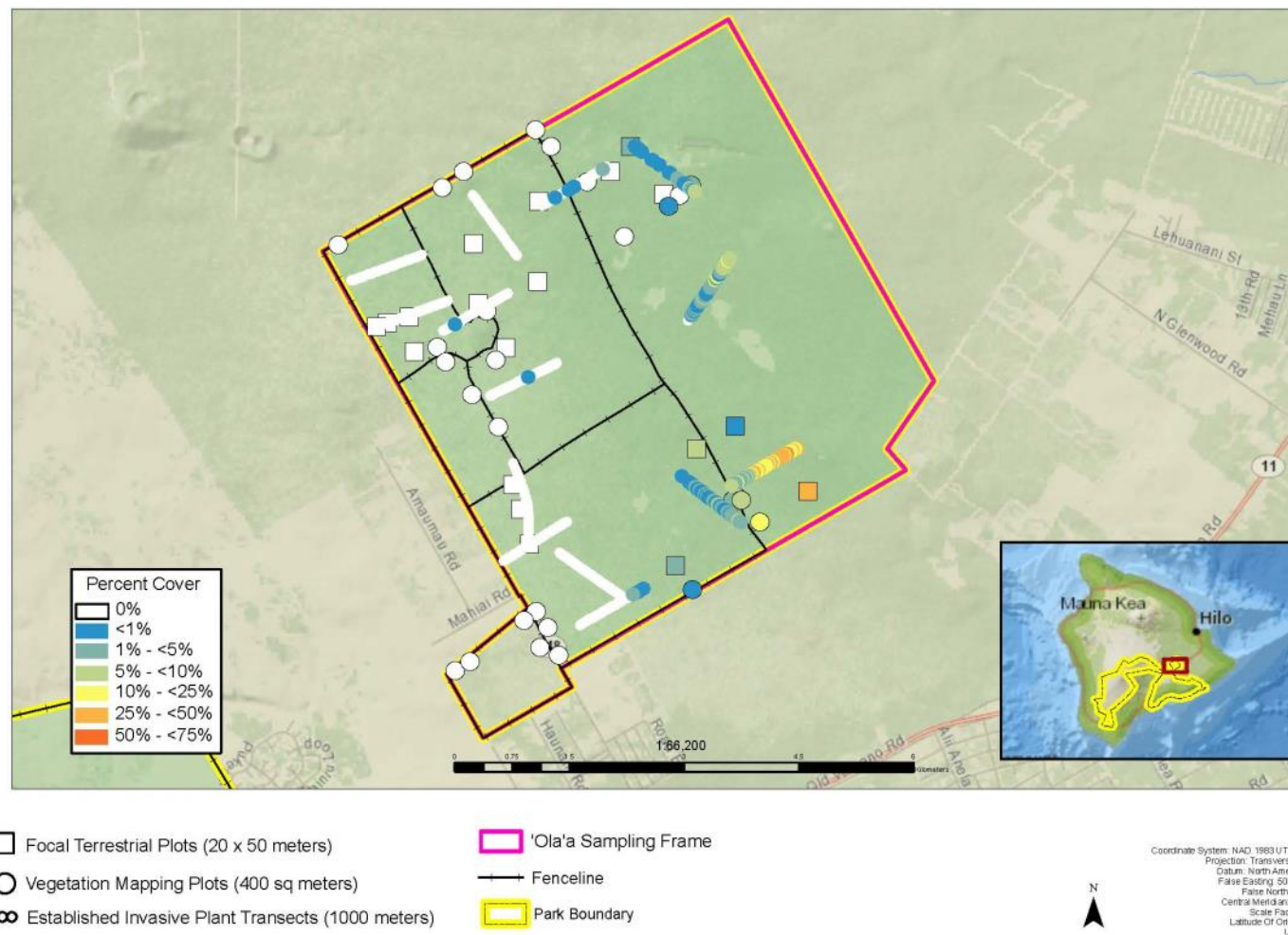


Figure A.7. *Psidium cattleianum* is found primarily in the unmanaged unit of 'Ola'a with dense cover in the southeast section.

Hawai'i Volcanoes National Park
Island of Hawai'i, Hawai'i

Percent cover of *Hedychium gardnerianum*
in 'Ola'a Sampling Frame

National Park Service
U.S. Department of the Interior

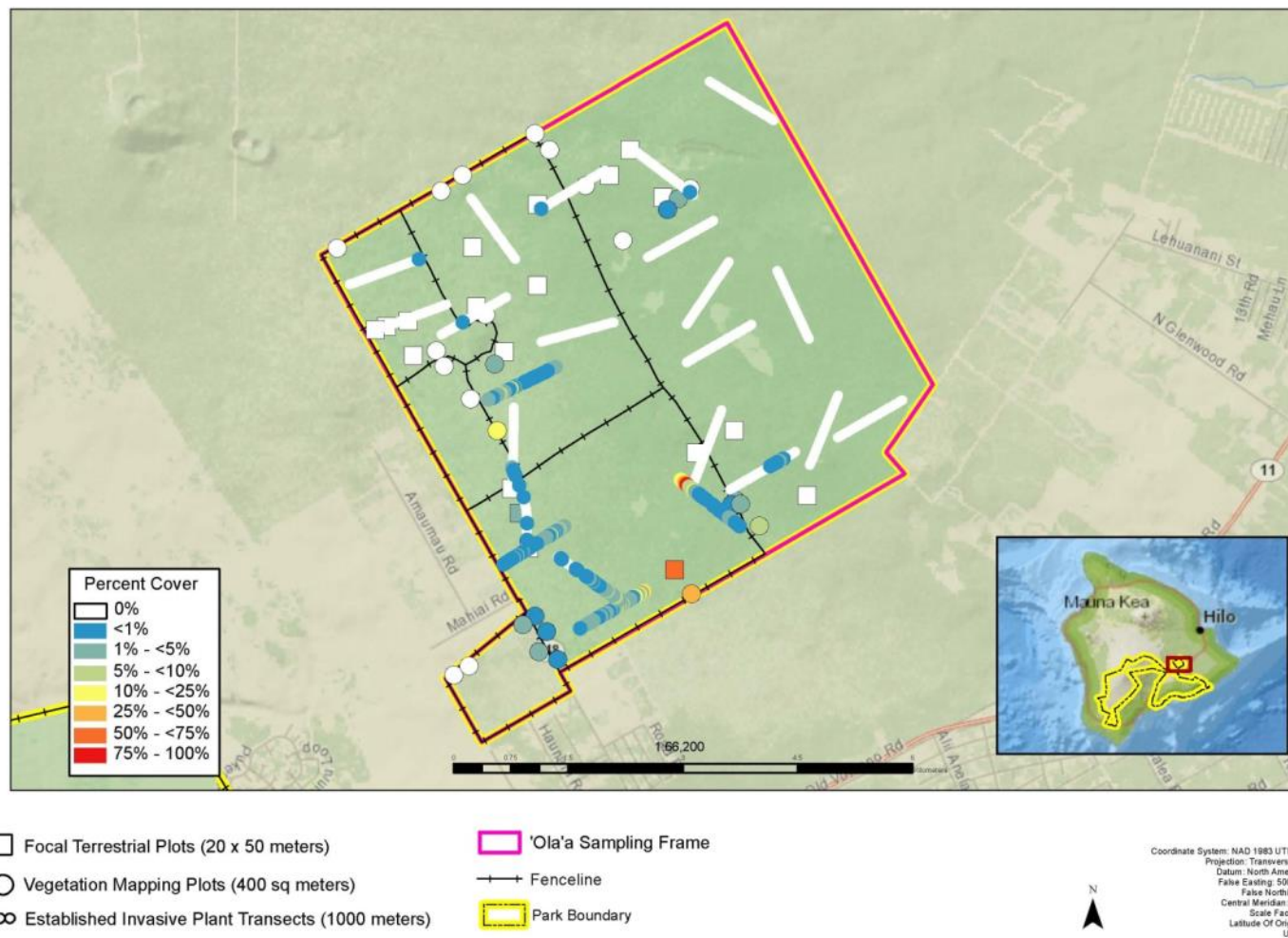


Figure A.8. *Hedychium gardnerianum* is widely dispersed in the Koa Unit, but with low cover.

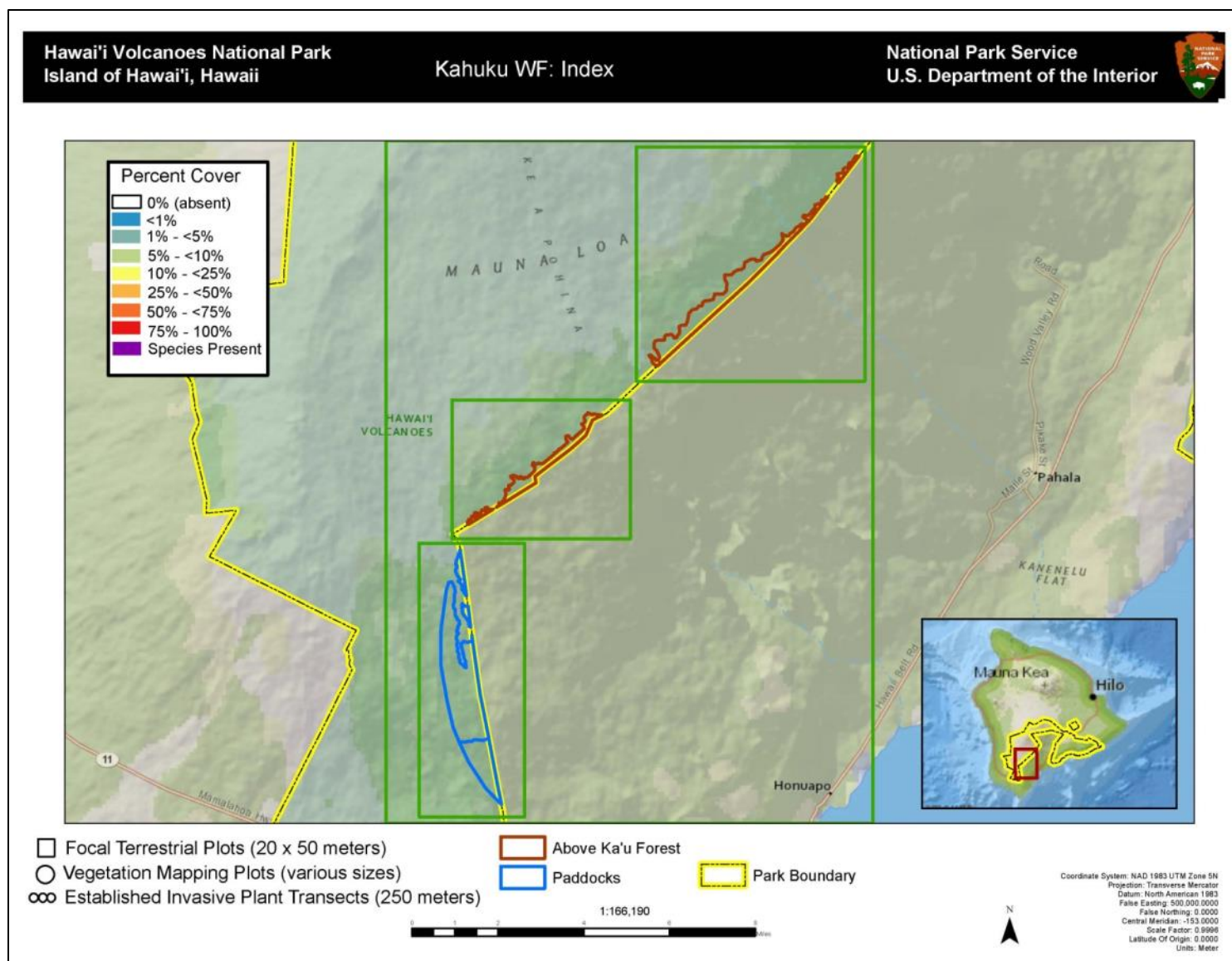


Figure A.9. Locations of zones in the Kahuku WF sampling frame.

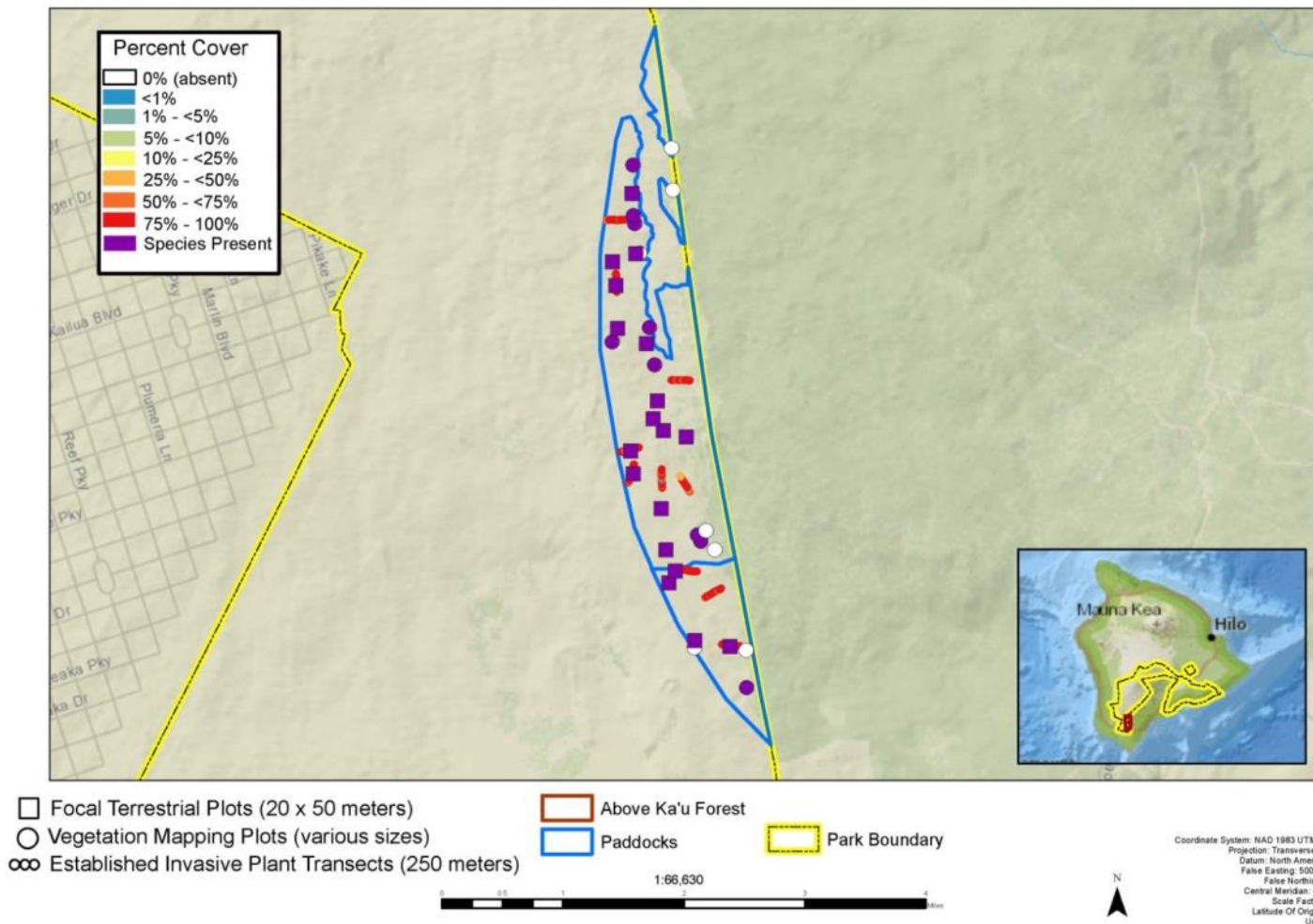


Figure A.10. The composite group "alien grass" is dominant in the Paddocks unit of Kahuku WF.

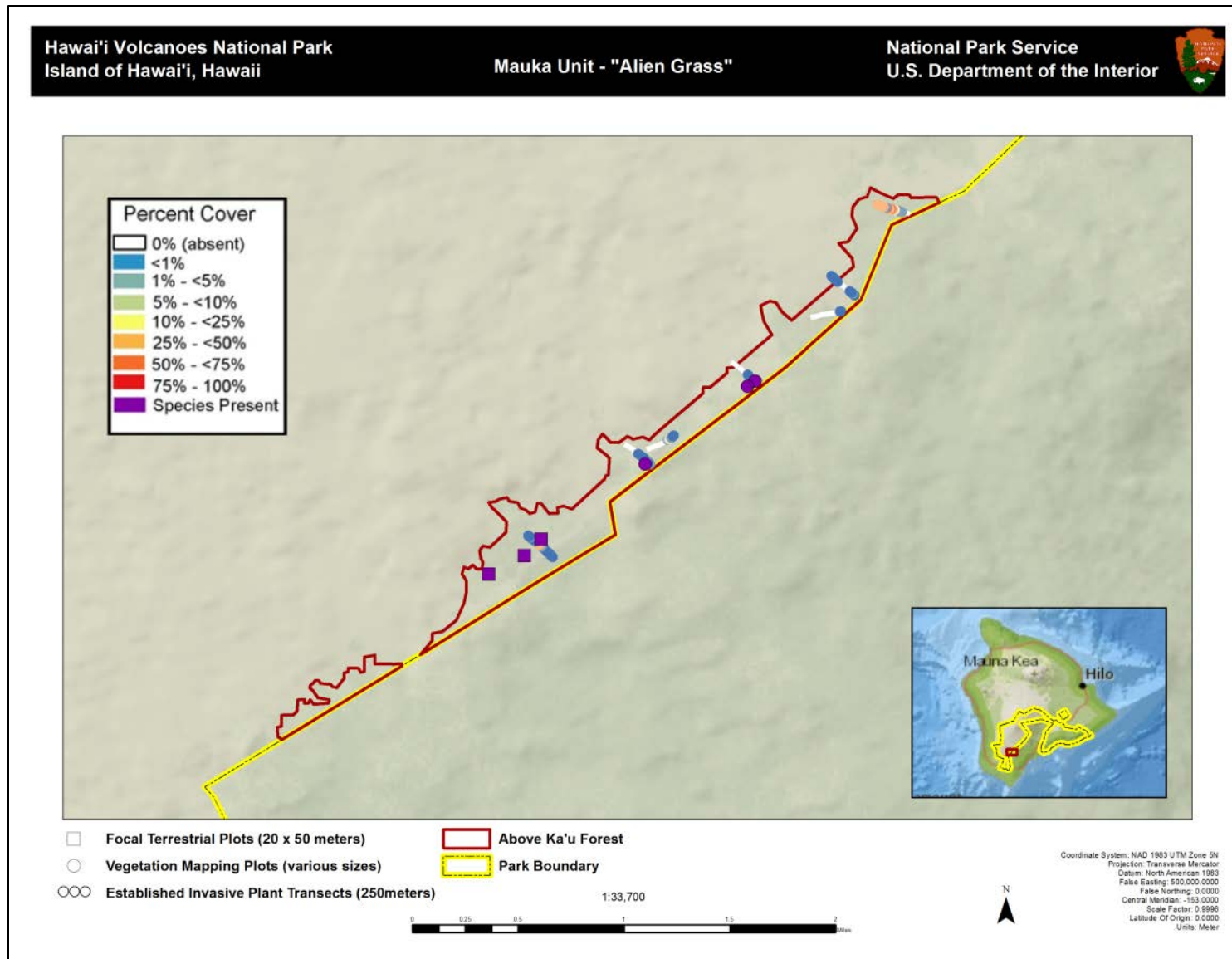


Figure A.11. "Alien grass" is less common in the Mauka unit (Above Ka'u Forest zone) than the Paddocks.

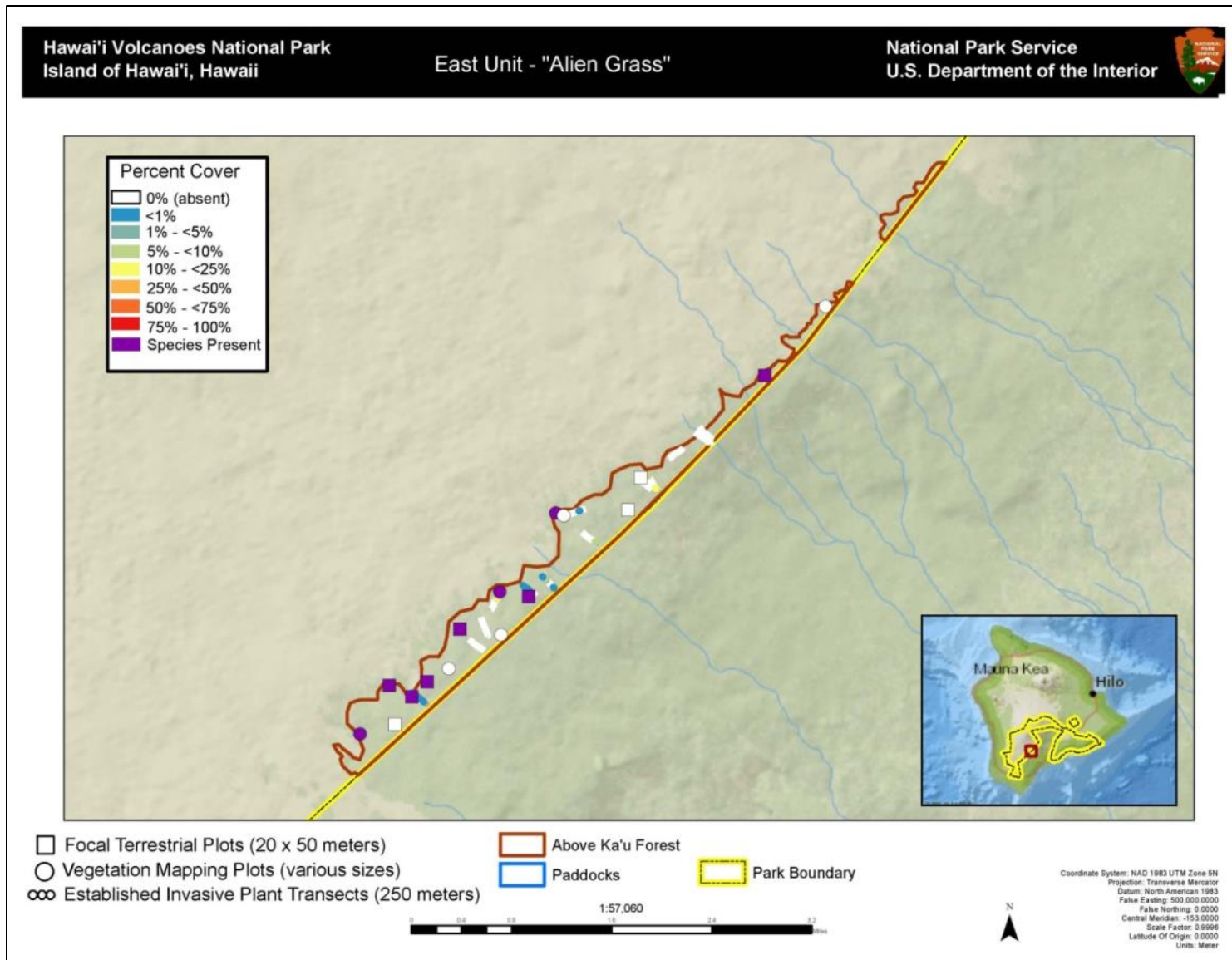


Figure A.12. "Alien grass" is less common in the East unit (Above Ka'u Forest zone), than the Paddocks.

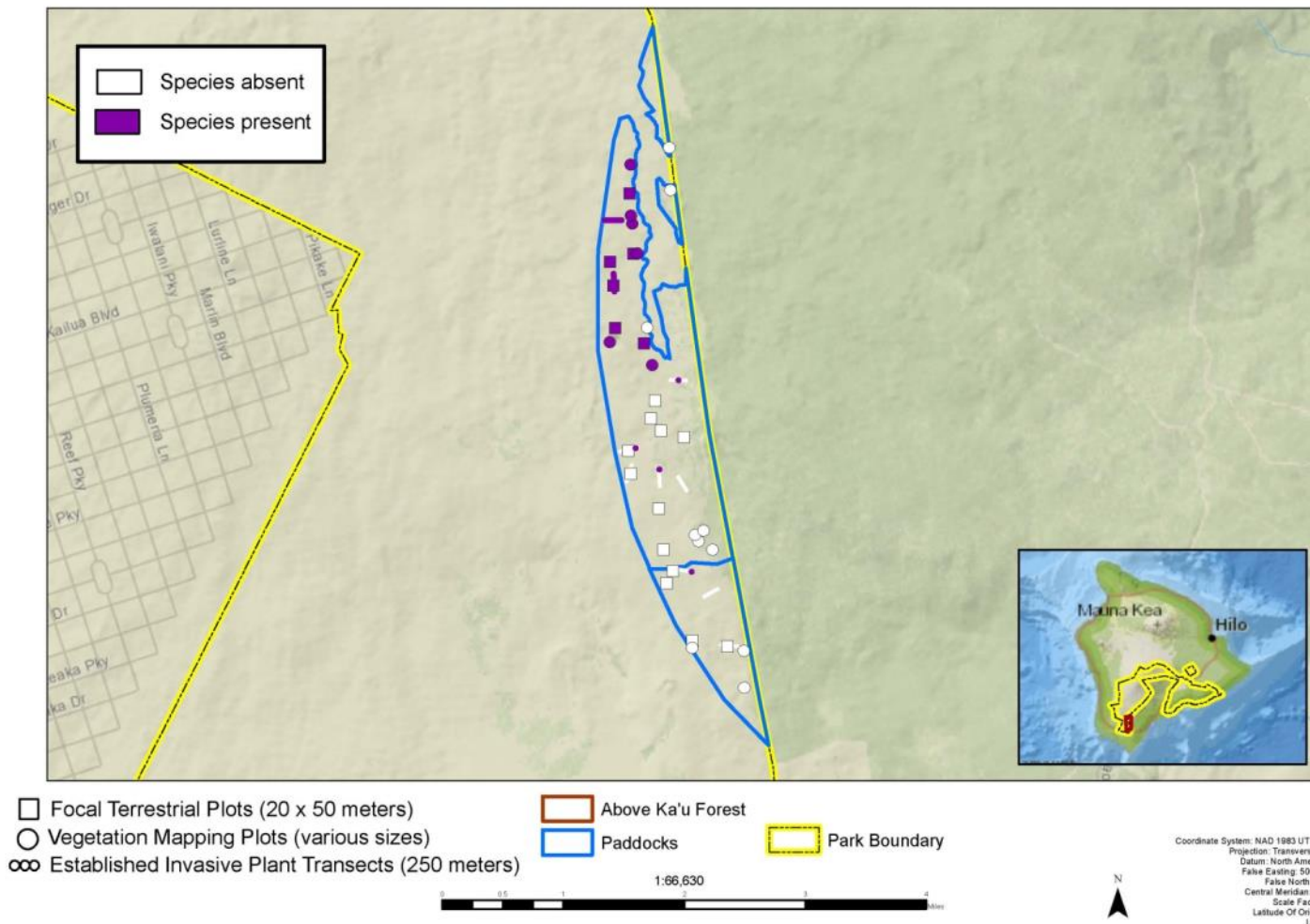


Figure A.13. *Anthoxanthum odoratum* is found at higher elevation in the Paddocks unit, Kahuku WF.

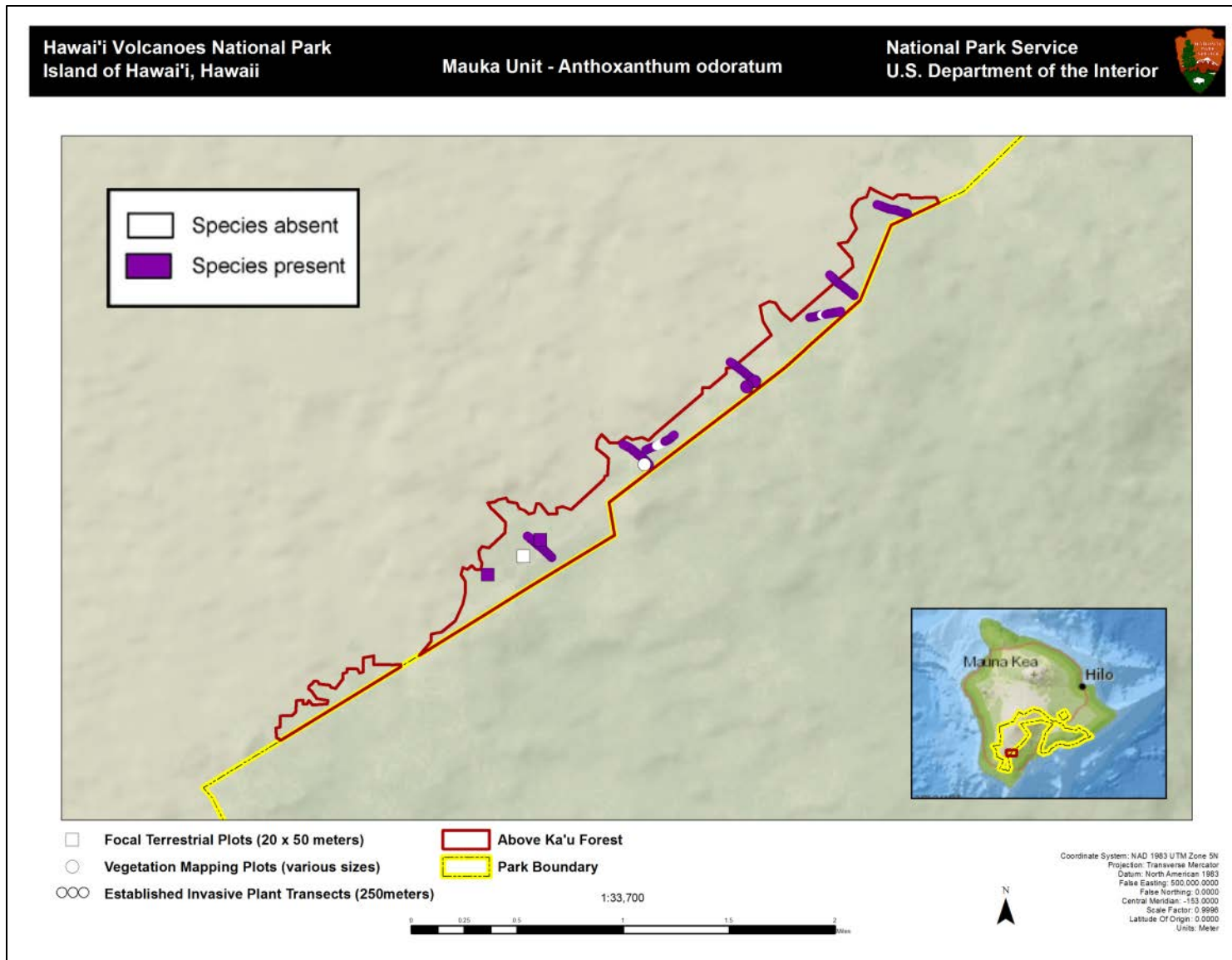


Figure A.14. *Anthoxanthum odoratum* is widely distributed in the Mauka unit (Above Ka'ū Forest zone), Kahuku WF.

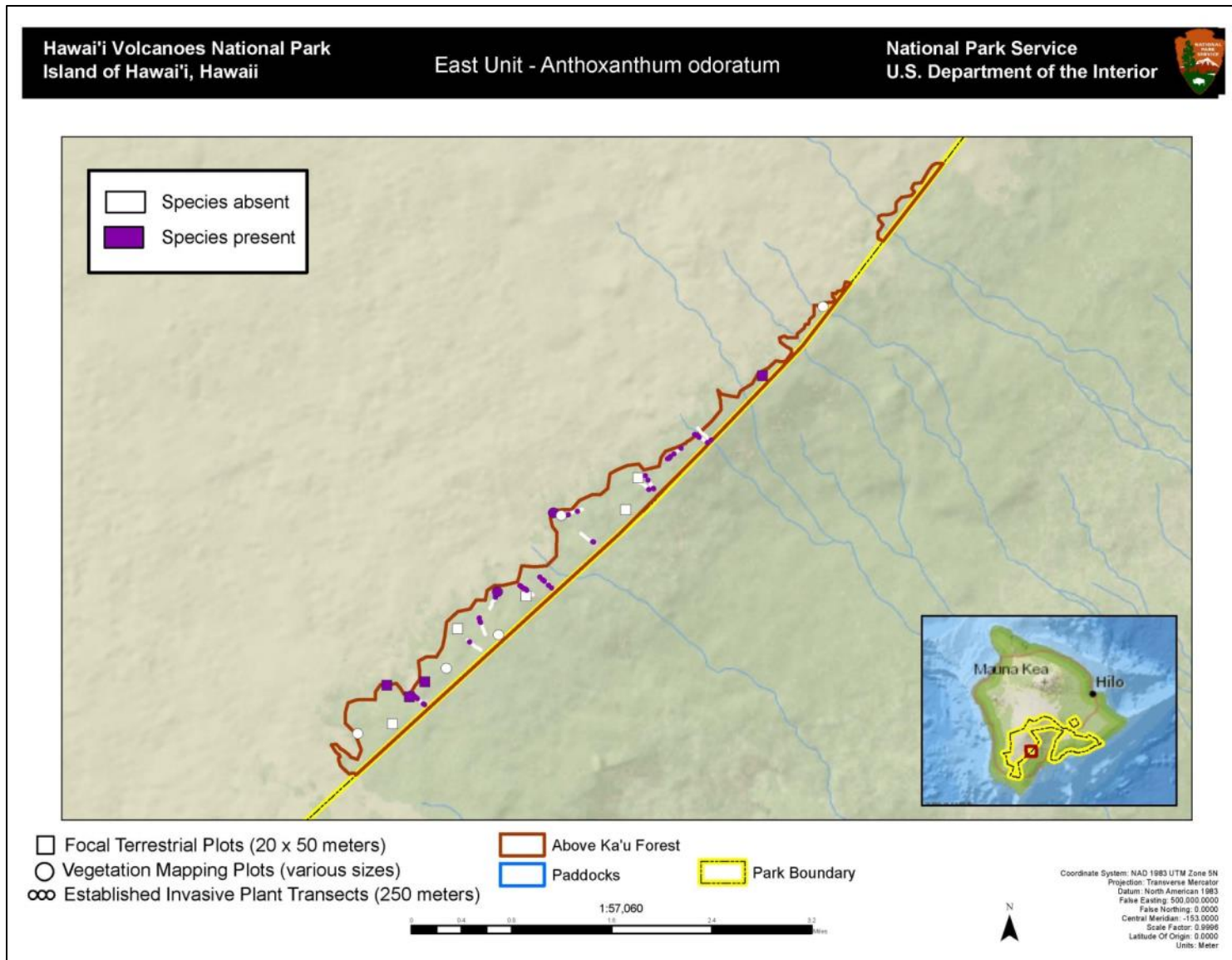


Figure A.15. *Anthoxanthum odoratum* is widely distributed in the East unit (Above Ka'u Forest zone), Kahuku WF.

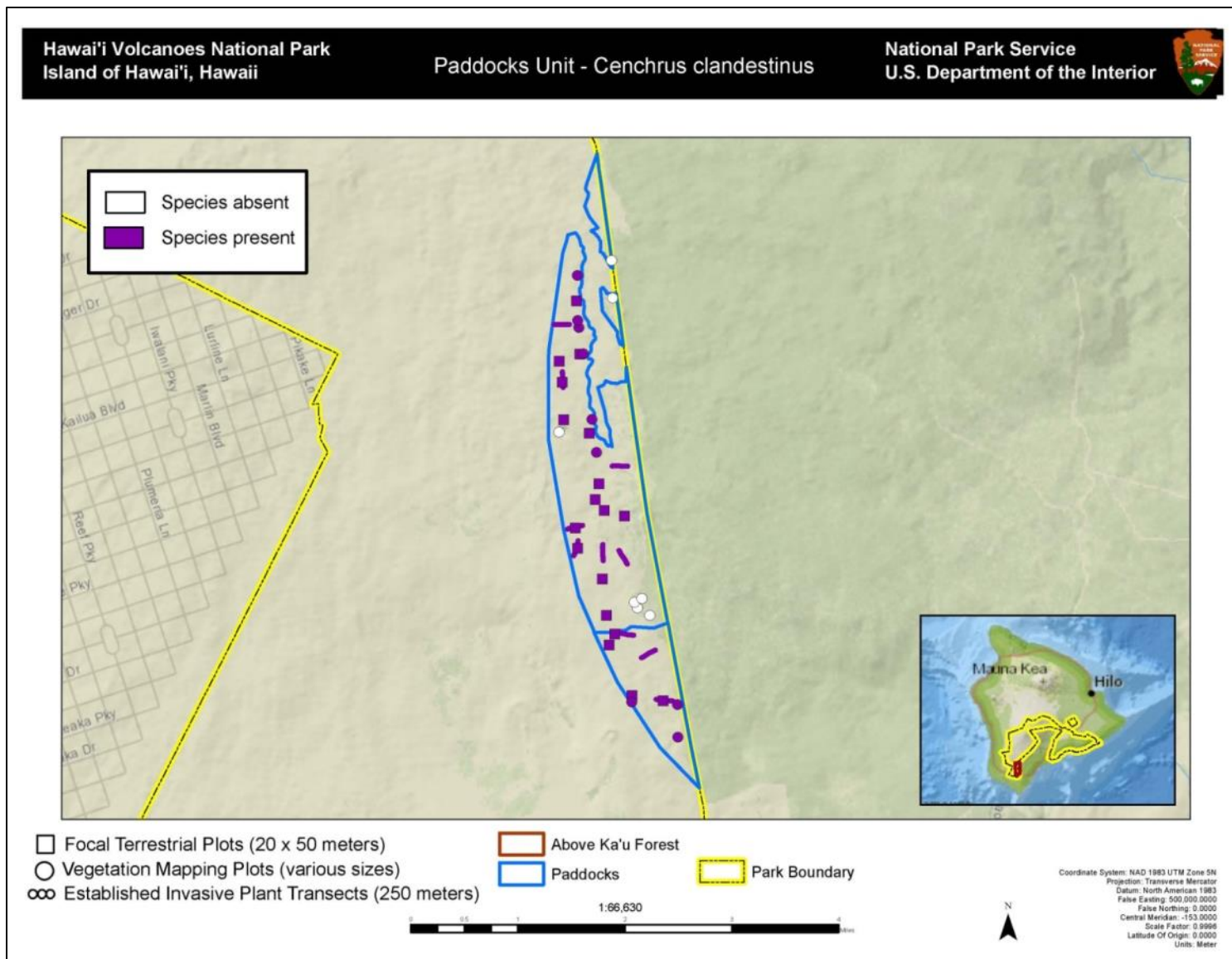


Figure A.16. *Cenchrus clandestinus* is abundant in the Paddocks unit and was not found in the Above Ka'u Forest zones of Kahuku WF.

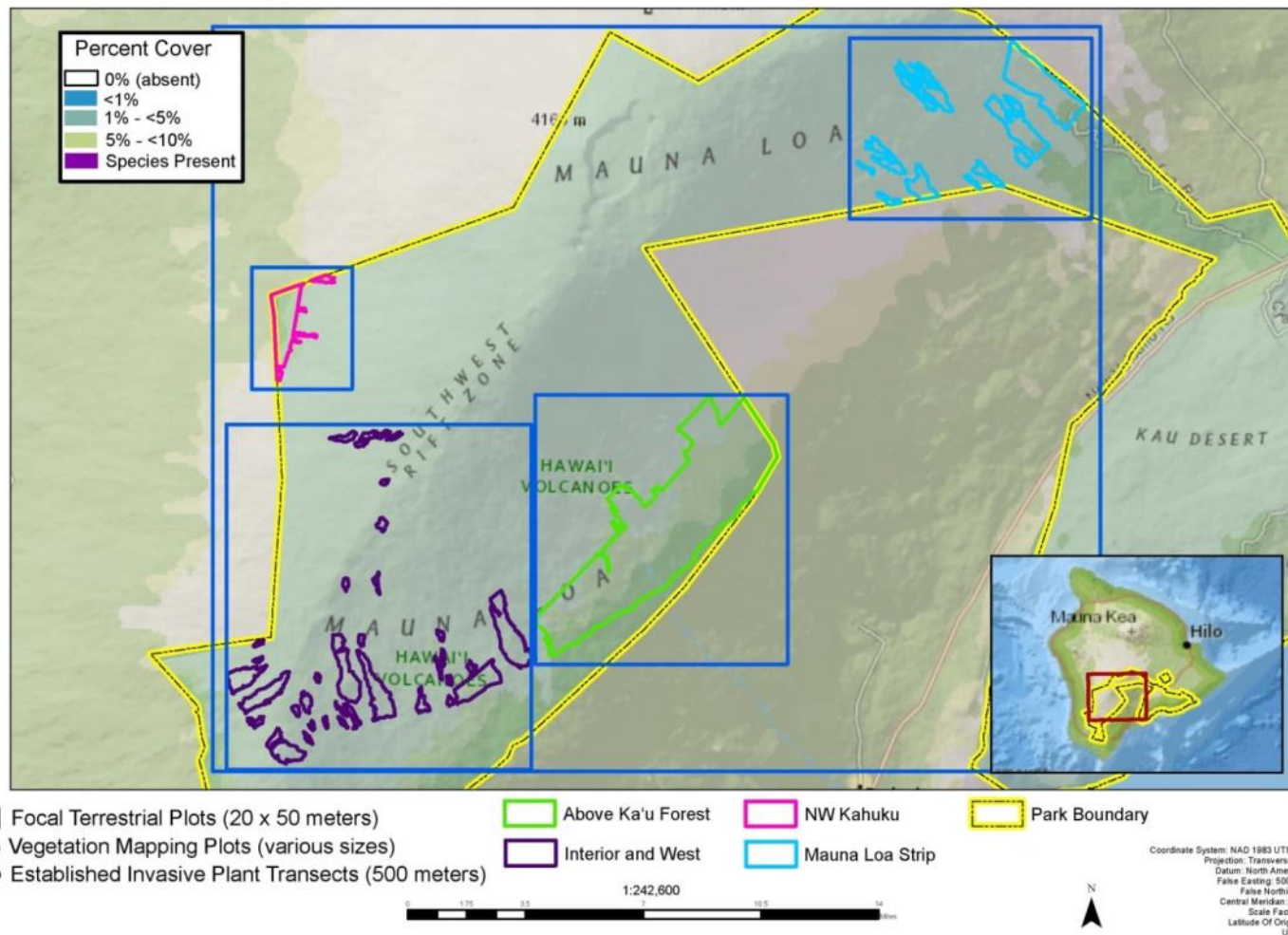


Figure A.17. Locations of zones in subalpine shrubland sampling frame.

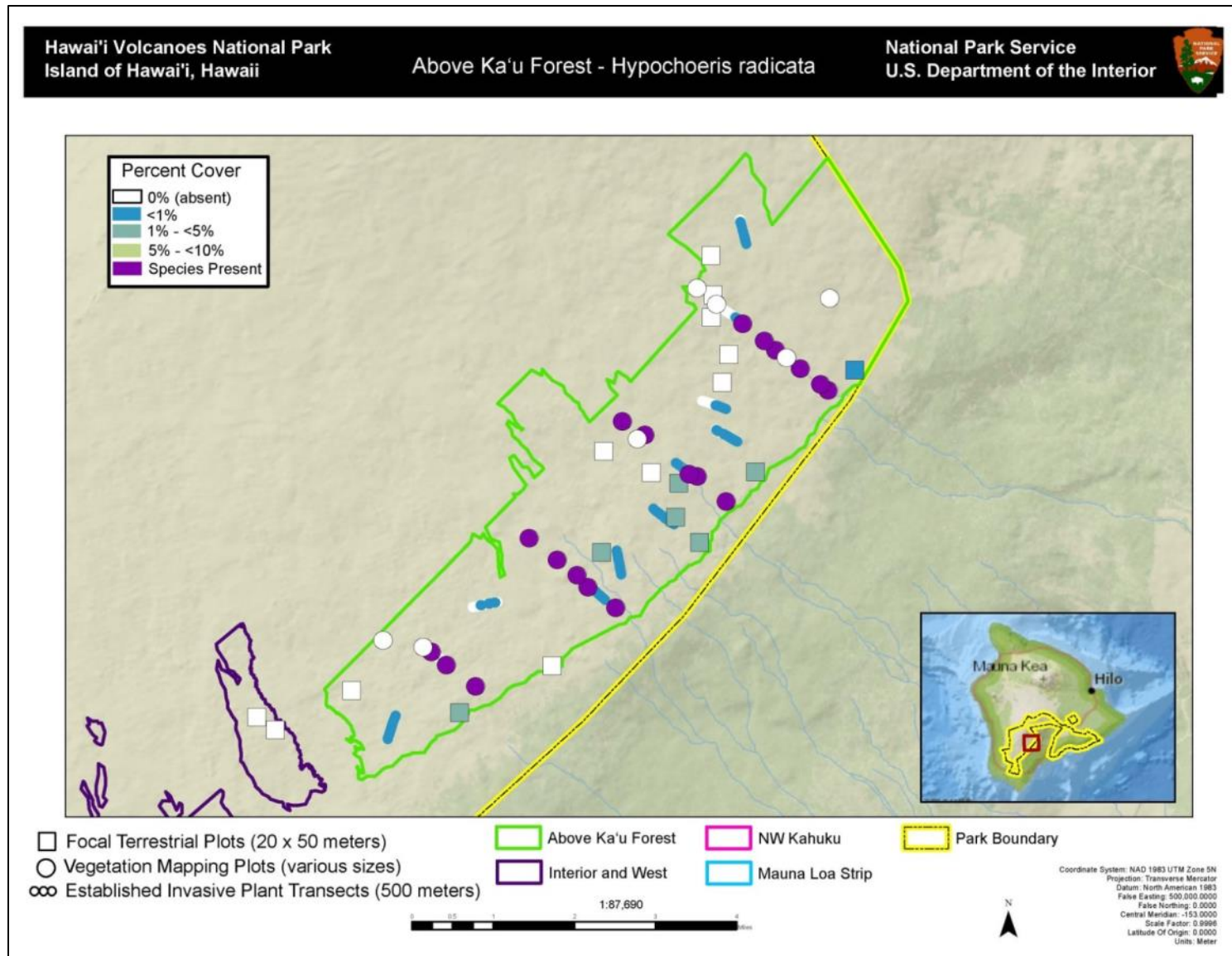


Figure A.18. *Hypochoeris radicata* is widespread Above Ka'u Forest, but absent in the Interior & West zone of the subalpine shrubland.

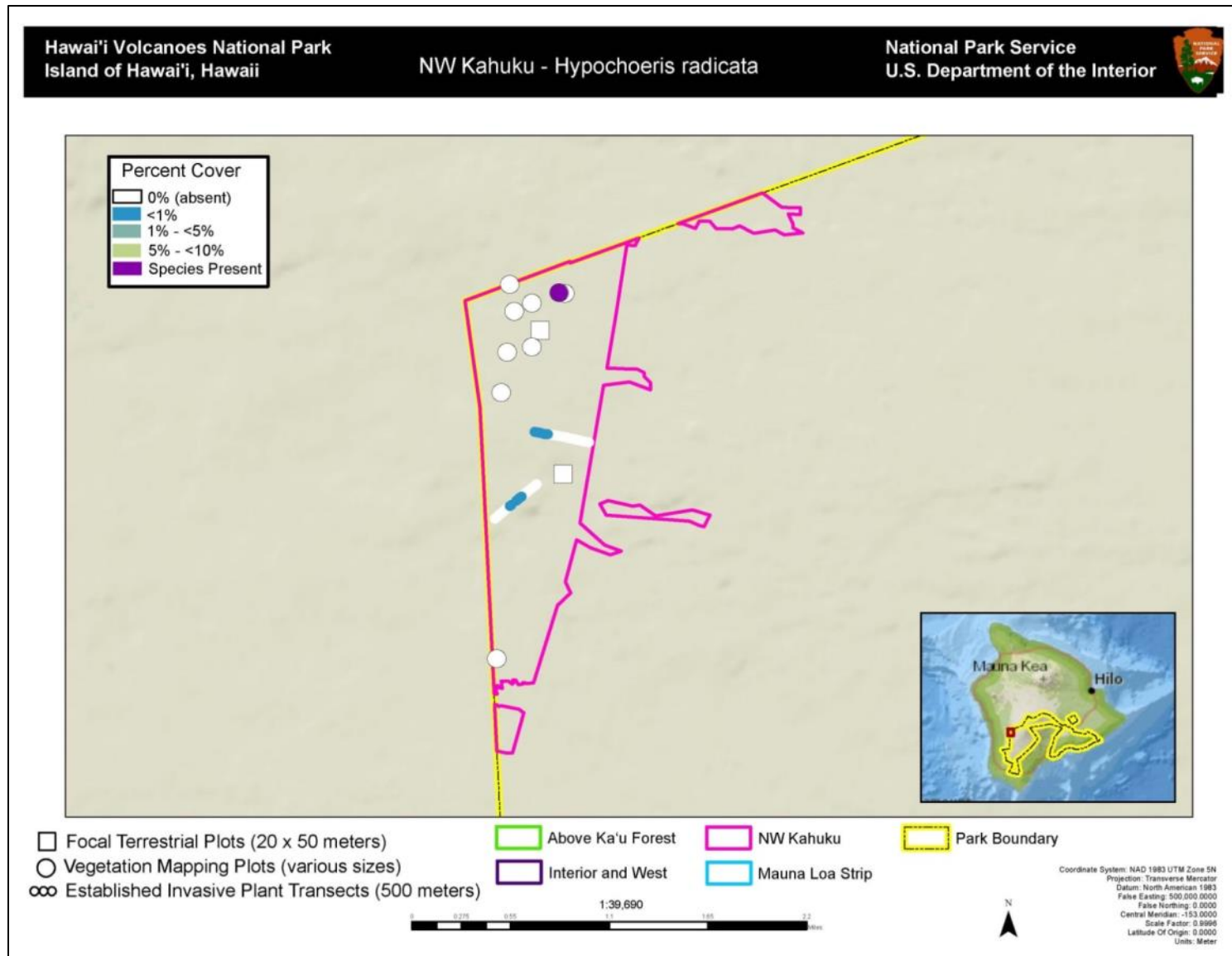


Figure A.19 *Hypochoeris radicata* is sparse in NW Kahuku, subalpine shrubland.

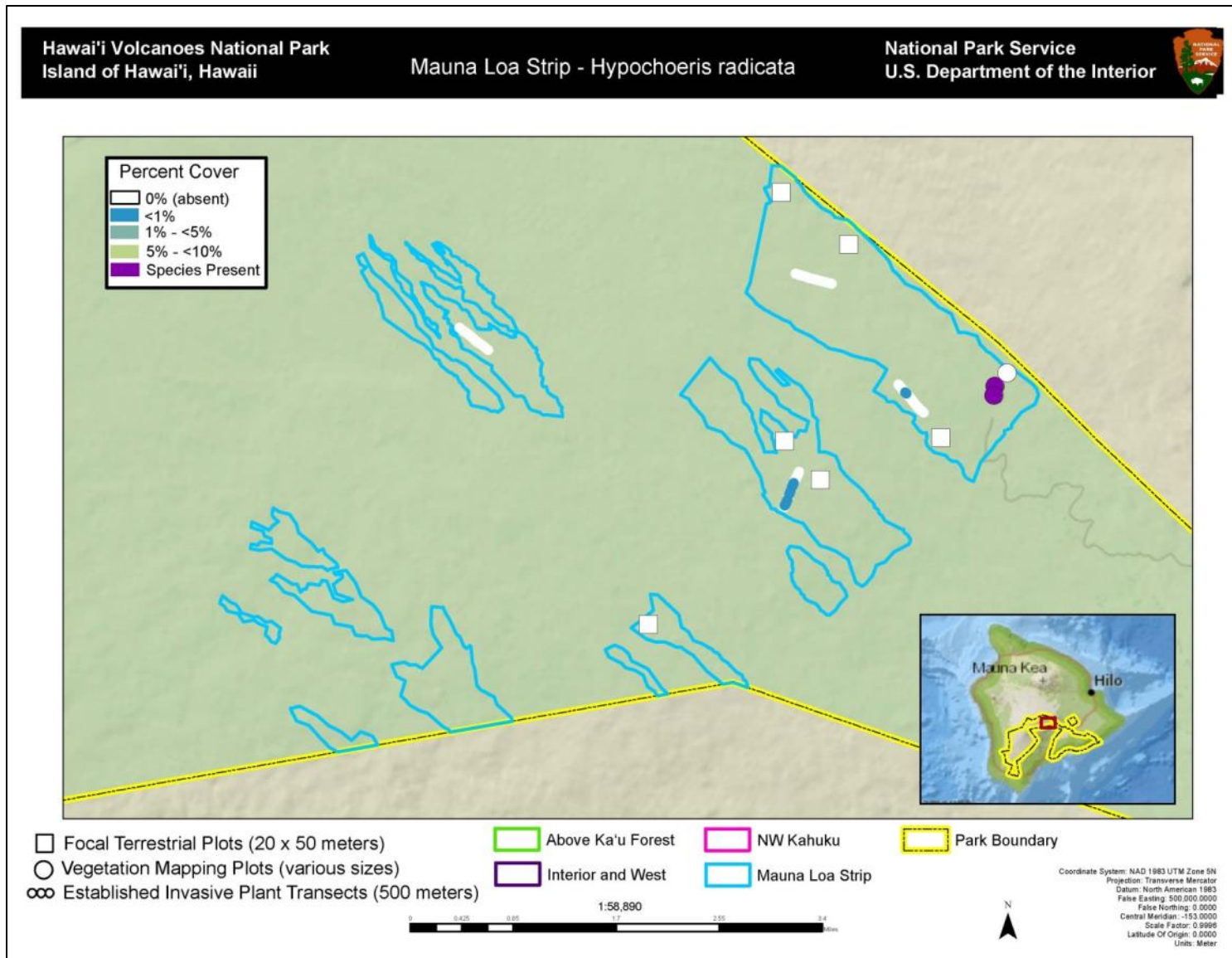


Figure A.20. *Hypochoeris radicata* is scattered in the Mauna Loa Strip zone, subalpine shrubland.

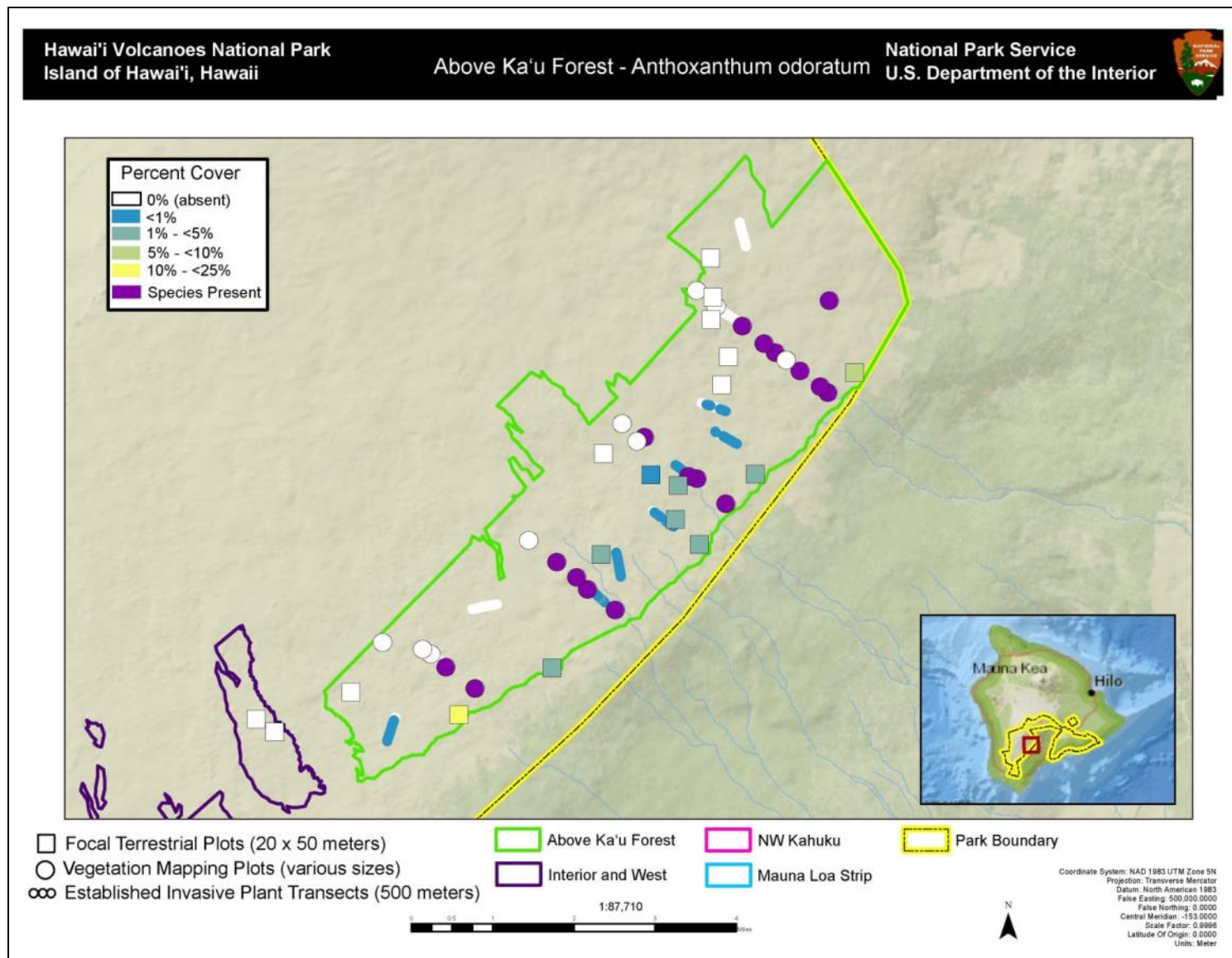


Figure A.21. *Anthoxanthum odoratum* is widespread Above Ka'u Forest, but absent in all other subalpine shrubland zones.

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Appendix B: Complete tables for non-native species frequency and cover at HAVO

Mean frequency and mean cover when present for all non-native species and life forms recorded along the established invasive plant species transects at Hawai'i Volcanoes National Park (HAVO) are provided. Table B.1 includes all HAVO sampling strata excluding the Paddocks zone which can be found in Table B.2.

Table B.1. Frequency estimates with confidence intervals and average cover class when present for non-native species at HAVO (excluding Paddocks) by sampling frame and plant community.

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
Any Non-native Species	Nāhuku / East Rift	15	0.75	0.64	0.87	5
Fern	Nāhuku / East Rift	15	0.43	0.15	0.71	4
Grass	Nāhuku / East Rift	15	0.40	0.21	0.58	2
Tree	Nāhuku / East Rift	15	0.38	0.26	0.50	3
Herb	Nāhuku / East Rift	15	0.29	0.12	0.46	2
Shrub	Nāhuku / East Rift	15	0.07	0.04	0.10	1
Vine	Nāhuku / East Rift	15	0.05	0.02	0.09	1
Rush	Nāhuku / East Rift	15	<0.01	<0.01	0.01	1
<i>Nephrolepis brownii</i>	Nāhuku / East Rift	15	0.43	0.15	0.71	5
<i>Paspalum conjugatum</i>	Nāhuku / East Rift	15	0.32	0.09	0.55	3
<i>Morella faya</i>	Nāhuku / East Rift	15	0.29	0.11	0.47	4
<i>Tibouchina herbacea</i>	Nāhuku / East Rift	15	0.26	0.07	0.45	2
<i>Psidium cattleianum</i>	Nāhuku / East Rift	15	0.14	0.06	0.21	2
<i>Rubus rosifolius</i>	Nāhuku / East Rift	15	0.05	0.02	0.09	2
<i>Passiflora edulis</i>	Nāhuku / East Rift	15	0.05	0.01	0.09	2
<i>Andropogon virginicus</i>	Nāhuku / East Rift	15	0.05	0.05	0.05	2
<i>Andropogon glomeratus var pumilus</i>	Nāhuku / East Rift	15	0.04	0.01	0.07	1
<i>Ehrharta stipoides</i>	Nāhuku / East Rift	15	0.04	0.01	0.07	2
<i>Pluchea carolinensis</i>	Nāhuku / East Rift	15	0.01	<0.01	0.02	2
<i>Setaria parviflora</i>	Nāhuku / East Rift	15	0.01	0.01	0.02	2
<i>Pityrogramma austroamericana</i>	Nāhuku / East Rift	15	0.01	<0.01	0.02	1
<i>Anemone hupehensis var japonica</i>	Nāhuku / East Rift	15	0.01	<0.01	0.02	2
<i>Hedychium gardnerianum</i>	Nāhuku / East Rift	15	0.01	<0.01	0.02	2
<i>Phymatosorus grossus</i>	Nāhuku / East Rift	15	0.01	<0.01	0.01	1
<i>Sacciolepis indica</i>	Nāhuku / East Rift	15	0.01	<0.01	0.01	1
<i>Stachytarpheta jamaicensis</i>	Nāhuku / East Rift	15	<0.01	<0.01	0.01	1
<i>Juncus effusus</i>	Nāhuku / East Rift	15	<0.01	<0.01	0.01	1
<i>Rubus argutus</i>	Nāhuku / East Rift	15	<0.01	<0.01	0.01	1
<i>Setaria palmifolia</i>	Nāhuku / East Rift	15	<0.01	<0.01	0.01	4

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Phaius tankarvilleae</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	1
<i>Passiflora spp</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	2
<i>Hypericum mutilum ssp mutilum</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	1
<i>Hypericum parvulum</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	2
<i>Persicaria capitata</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	2
<i>Rubus ellipticus var obcordatus</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	2
<i>Arundina graminifolia</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	1
<i>Buddleja asiatica</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	1
<i>Schizachyrium condensatum</i>	Nāhuku / East Rift	15	<0.01	<0.01	<0.01	2
Any Species	‘Ōla’a	14	0.82	0.65	0.99	3
Herb	‘Ōla’a	14	0.52	0.34	0.70	2
Shrub	‘Ōla’a	14	0.45	0.30	0.61	2
Grass	‘Ōla’a	14	0.43	0.21	0.65	2
Vine	‘Ōla’a	14	0.26	0.13	0.39	1
Tree	‘Ōla’a	14	0.24	0.02	0.45	2
Sedge	‘Ōla’a	14	0.05	0.02	0.08	1
Rush	‘Ōla’a	14	0.02	<0.01	0.03	1
Fern	‘Ōla’a	14	0.01	<0.01	0.04	1
<i>Rubus ellipticus var obcordatus</i>	‘Ōla’a	14	0.45	0.29	0.60	2
<i>Setaria palmifolia</i>	‘Ōla’a	14	0.40	0.17	0.62	3
<i>Hedychium gardnerianum</i>	‘Ōla’a	14	0.28	0.09	0.48	2
<i>Passiflora tarminiana</i>	‘Ōla’a	14	0.24	0.10	0.38	2
<i>Psidium cattleianum</i>	‘Ōla’a	14	0.24	0.02	0.45	2
<i>Anemone hupehensis var japonica</i>	‘Ōla’a	14	0.18	0.03	0.33	2
<i>Ehrharta stipoides</i>	‘Ōla’a	14	0.15	0.01	0.29	2
<i>Persicaria punctata</i>	‘Ōla’a	14	0.09	<0.01	0.18	1
<i>Hypericum mutilum ssp mutilum</i>	‘Ōla’a	14	0.04	0.01	0.07	1
<i>Phaius tankarvilleae</i>	‘Ōla’a	14	0.04	0.01	0.06	1
<i>Cardamine flexuosa</i>	‘Ōla’a	14	0.03	<0.01	0.05	1
<i>Cyperus trinervis</i>	‘Ōla’a	14	0.03	<0.01	0.06	2
<i>Cyperus haspan</i>	‘Ōla’a	14	0.02	<0.01	0.04	2
<i>Passiflora spp</i>	‘Ōla’a	14	0.02	<0.01	0.05	2
<i>Juncus effusus</i>	‘Ōla’a	14	0.02	<0.01	0.03	1
<i>Plantago major</i>	‘Ōla’a	14	0.01	<0.01	0.04	1
<i>Deparia petersenii</i>	‘Ōla’a	14	0.01	<0.01	0.04	1
<i>Ludwigia palustris</i>	‘Ōla’a	14	0.01	<0.01	0.02	1
Unknown species	‘Ōla’a	14	0.01	<0.01	0.03	1
<i>Erechtites valerianifolia</i>	‘Ōla’a	14	0.01	<0.01	0.02	1
<i>Rubus argutus</i>	‘Ōla’a	14	0.01	<0.01	0.02	1
<i>Ageratina riparia</i>	‘Ōla’a	14	0.01	<0.01	0.02	1

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Drymaria cordata</i> var <i>pacifica</i>	'Ōla'a	14	<0.01	<0.01	0.01	1
<i>Andropogon virginicus</i>	'Ōla'a	14	<0.01	<0.01	<0.01	3
<i>Arundina graminifolia</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
<i>Axonopus fissifolius</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
<i>Crassocephalum crepidioides</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
<i>Hypochoeris radicata</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
<i>Paspalum conjugatum</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
<i>Rubus rosifolius</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
<i>Selaginella kraussiana</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
<i>Tibouchina herbacea</i>	'Ōla'a	14	<0.01	<0.01	<0.01	1
Any Species	WF Above Ka'ū Forest	20	0.72	0.58	0.85	2
Grass	WF Above Ka'ū Forest	20	0.72	0.58	0.85	2
Herb	WF Above Ka'ū Forest	20	0.20	0.09	0.30	1
Rush	WF Above Ka'ū Forest	20	0.07	0.03	0.11	1
<i>Anthoxanthum odoratum</i>	WF Above Ka'ū Forest	20	0.53	0.37	0.70	NA
<i>Ehrharta stipoides</i>	WF Above Ka'ū Forest	20	0.38	0.24	0.53	NA
<i>Holcus lanatus</i>	WF Above Ka'ū Forest	20	0.10	0.01	0.18	NA
<i>Hypochoeris radicata</i>	WF Above Ka'ū Forest	20	0.09	<0.01	0.20	1
<i>Juncus effusus</i>	WF Above Ka'ū Forest	20	0.06	0.03	0.10	1
<i>Veronica serpyllifolia</i>	WF Above Ka'ū Forest	20	0.05	0.01	0.09	1
<i>Eragrostis brownei</i>	WF Above Ka'ū Forest	20	0.04	<0.01	0.10	NA
<i>Prunella vulgaris</i>	WF Above Ka'ū Forest	20	0.03	<0.01	0.08	1
<i>Euchiton sphaericus</i>	WF Above Ka'ū Forest	20	0.02	<0.01	0.06	1
<i>Ageratina riparia</i>	WF Above Ka'ū Forest	20	0.02	<0.01	0.04	1
<i>Poa</i> spp	WF Above Ka'ū Forest	20	0.01	<0.01	0.04	NA
<i>Andropogon virginicus</i>	WF Above Ka'ū Forest	20	0.01	<0.01	0.02	NA
<i>Juncus</i> spp	WF Above Ka'ū Forest	20	0.01	<0.01	0.03	1

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Veronica plebeia</i>	WF Above Ka'ū Forest	20	0.01	<0.01	0.03	1
<i>Axonopus fissifolius</i>	WF Above Ka'ū Forest	20	<0.01	<0.01	0.01	NA
<i>Cirsium vulgare</i>	WF Above Ka'ū Forest	20	<0.01	<0.01	0.01	1
<i>Conyza bonariensis</i>	WF Above Ka'ū Forest	20	<0.01	<0.01	0.01	1
<i>Hydrocotyle bowlesioides</i>	WF Above Ka'ū Forest	20	<0.01	<0.01	0.01	1
<i>Lotus uliginosus</i>	WF Above Ka'ū Forest	20	<0.01	<0.01	0.01	1
Any Species	Subalpine Shrubland	20	0.65	0.49	0.81	2
Herb	Subalpine Shrubland	20	0.61	0.46	0.76	1
Grass	Subalpine Shrubland	20	0.45	0.27	0.63	2
<i>Hypochoeris radicata</i>	Subalpine Shrubland	20	0.39	0.22	0.55	1
<i>Anthoxanthum odoratum</i>	Subalpine Shrubland	20	0.27	0.14	0.41	1
<i>Holcus lanatus</i>	Subalpine Shrubland	20	0.23	0.11	0.34	1
<i>Eragrostis brownei</i>	Subalpine Shrubland	20	0.19	0.10	0.28	1
<i>Sporobolus africanus</i>	Subalpine Shrubland	20	0.12	0.08	0.17	1
<i>Senecio madagascariensis</i>	Subalpine Shrubland	20	0.12	<0.01	0.25	1
<i>Polycarpon tetraphyllum</i>	Subalpine Shrubland	20	0.07	<0.01	0.17	1
<i>Euchiton sphaericus</i>	Subalpine Shrubland	20	0.07	0.03	0.11	1
<i>Euchiton japonicus</i>	Subalpine Shrubland	20	0.07	0.02	0.12	1
<i>Festuca bromoides</i>	Subalpine Shrubland	20	0.06	0.01	0.12	1
<i>Ehrharta stipoides</i>	Subalpine Shrubland	20	0.06	<0.01	0.19	2
<i>Rumex acetosella</i>	Subalpine Shrubland	20	0.05	<0.01	0.16	1
<i>Oxalis corniculata</i>	Subalpine Shrubland	20	0.04	<0.01	0.16	1
<i>Centaurium erythraea ssp erythraea</i>	Subalpine Shrubland	20	0.04	0.02	0.06	1
<i>Geranium homeanum</i>	Subalpine Shrubland	20	0.04	<0.01	0.14	1
<i>Verbascum thapsus</i>	Subalpine Shrubland	20	0.04	<0.01	0.15	1
<i>Senecio sylvaticus</i>	Subalpine Shrubland	20	0.04	<0.01	0.14	1
<i>Fragaria vesca</i>	Subalpine Shrubland	20	0.04	0.02	0.05	1
<i>Veronica serpyllifolia</i>	Subalpine Shrubland	20	0.04	<0.01	0.07	1
<i>Veronica peregrina ssp xalapensis</i>	Subalpine Shrubland	20	0.03	<0.01	0.12	1
<i>Schizachyrium condensatum</i>	Subalpine Shrubland	20	0.03	0.01	0.04	1
<i>Cenchrus clandestinus</i>	Subalpine Shrubland	20	0.03	<0.01	0.10	2
<i>Coronopus didymus</i>	Subalpine Shrubland	20	0.03	<0.01	0.10	1
<i>Cirsium vulgare</i>	Subalpine Shrubland	20	0.03	<0.01	0.09	1
<i>Veronica plebeia</i>	Subalpine Shrubland	20	0.02	<0.01	0.09	1
<i>Cardamine flexuosa</i>	Subalpine Shrubland	20	0.02	<0.01	0.07	1

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Eragrostis spp</i>	Subalpine Shrubland	20	0.02	<0.01	0.06	1
<i>Poa spp</i>	Subalpine Shrubland	20	0.02	0.01	0.02	1
<i>Cenchrus polystachios</i>	Subalpine Shrubland	20	0.01	<0.01	0.06	1
<i>Euphorbia peplus</i>	Subalpine Shrubland	20	0.01	<0.01	0.03	1
<i>Epilobium billardierianum ssp cinereum</i>	Subalpine Shrubland	20	0.01	0.01	0.01	1
<i>Ageratum conyzoides</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	1
<i>Conyza bonariensis</i>	Subalpine Shrubland	20	0.01	<0.01	0.01	1
<i>Prunella vulgaris</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	1
<i>Emilia fosbergii</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	1
<i>Ageratina riparia</i>	Subalpine Shrubland	20	0.01	<0.01	0.01	1
<i>Cerastium fontanum ssp triviale</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Andropogon virginicus</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Daucus pusillus</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Gamochaeta purpurea</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Helichrysum foetidum</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Marrubium vulgare</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Youngia japonica</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Oxalis spp</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Sonchus oleraceus</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Achyranthes aspera</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Chenopodium ambrosioides</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Daucus carota ssp sativus</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Melinis minutiflora</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Trifolium repens var repens</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Unknown species</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Veronica arvensis</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Aster spp</i>	Subalpine Shrubland	20	<0.01	<0.01	<0.01	1
<i>Crassocephalum crepidioides</i>	Subalpine Shrubland	20	<0.01	<0.01	<0.01	1
<i>Erechtites valerianifolia</i>	Subalpine Shrubland	20	<0.01	<0.01	<0.01	1
<i>Erodium cicutarium</i>	Subalpine Shrubland	20	<0.01	<0.01	<0.01	1
<i>Silene gallica</i>	Subalpine Shrubland	20	<0.01	<0.01	<0.01	1
<i>Solanum spp</i>	Subalpine Shrubland	20	<0.01	<0.01	<0.01	1
<i>Tibouchina herbacea</i>	Subalpine Shrubland	20	<0.01	<0.01	<0.01	1
Any Species	Wet Forest	49	0.78	0.77	0.80	4
Grass	Wet Forest	49	0.43	0.40	0.46	2
Herb	Wet Forest	49	0.39	0.34	0.44	2
Tree	Wet Forest	49	0.29	0.25	0.33	2
Shrub	Wet Forest	49	0.24	0.17	0.32	1
Fern	Wet Forest	49	0.21	0.13	0.29	2

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
Vine	Wet Forest	49	0.15	0.10	0.19	1
Sedge	Wet Forest	49	0.02	0.01	0.03	1
Rush	Wet Forest	49	0.01	0.01	0.02	1
<i>Rubus ellipticus</i> var <i>obcordatus</i>	Wet Forest	49	0.21	0.12	0.29	2
<i>Nephrolepis brownii</i>	Wet Forest	49	0.21	0.12	0.29	5
<i>Setaria palmifolia</i>	Wet Forest	49	0.18	0.11	0.26	3
<i>Psidium cattleianum</i>	Wet Forest	49	0.17	0.15	0.20	2
<i>Paspalum conjugatum</i>	Wet Forest	49	0.15	0.09	0.21	3
<i>Morella faya</i>	Wet Forest	49	0.14	0.08	0.19	4
<i>Hedychium gardnerianum</i>	Wet Forest	49	0.14	0.08	0.19	2
<i>Tibouchina herbacea</i>	Wet Forest	49	0.12	0.08	0.17	2
<i>Ehrharta stipoides</i>	Wet Forest	49	0.11	0.08	0.15	2
<i>Passiflora tarminiana</i>	Wet Forest	49	0.11	0.06	0.16	2
<i>Anemone hupehensis</i> var <i>japonica</i>	Wet Forest	49	0.09	0.05	0.12	2
<i>Persicaria punctata</i>	Wet Forest	49	0.04	0.02	0.06	1
<i>Anthoxanthum odoratum</i>	Wet Forest	49	0.03	<0.01	0.08	NA
<i>Rubus rosifolius</i>	Wet Forest	49	0.03	0.02	0.04	2
<i>Andropogon virginicus</i>	Wet Forest	49	0.03	0.02	0.04	2
<i>Passiflora edulis</i>	Wet Forest	49	0.02	0.01	0.03	2
<i>Andropogon glomeratus</i> var <i>pumilus</i>	Wet Forest	49	0.02	0.01	0.03	1
<i>Hypericum mutilum</i> ssp <i>mutilum</i>	Wet Forest	49	0.02	0.01	0.03	1
<i>Phaius tankervilleae</i>	Wet Forest	49	0.02	0.01	0.02	1
<i>Juncus effusus</i>	Wet Forest	49	0.01	0.01	0.02	1
<i>Cardamine flexuosa</i>	Wet Forest	49	0.01	0.01	0.02	1
<i>Cyperus trinervis</i>	Wet Forest	49	0.01	0.01	0.02	2
<i>Passiflora</i> spp	Wet Forest	49	0.01	0.01	0.02	2
<i>Cyperus haspan</i>	Wet Forest	49	0.01	0.01	0.01	2
<i>Plantago major</i>	Wet Forest	49	0.01	<0.01	0.01	1
<i>Pluchea carolinensis</i>	Wet Forest	49	0.01	<0.01	0.01	2
<i>Hypochoeris radicata</i>	Wet Forest	49	0.01	<0.01	0.01	1
<i>Setaria parviflora</i>	Wet Forest	49	0.01	<0.01	0.01	2
<i>Holcus lanatus</i>	Wet Forest	49	0.01	<0.01	0.01	NA
<i>Rubus argutus</i>	Wet Forest	49	0.01	<0.01	0.01	1
<i>Deparia petersenii</i>	Wet Forest	49	0.01	<0.01	0.01	1
<i>Ludwigia palustris</i>	Wet Forest	49	0.01	<0.01	0.01	1
Unknown species	Wet Forest	49	0.01	<0.01	0.01	1
<i>Pityrogramma austroamericana</i>	Wet Forest	49	<0.01	<0.01	0.01	1
<i>Phymatosorus grossus</i>	Wet Forest	49	<0.01	<0.01	0.01	1
<i>Ageratina riparia</i>	Wet Forest	49	<0.01	<0.01	0.01	1
<i>Erechtites valerianifolia</i>	Wet Forest	49	<0.01	<0.01	<0.01	1

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Sacciolepis indica</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Veronica serpyllifolia</i>	Wet Forest	49	<0.01	<0.01	0.01	1
<i>Eragrostis brownei</i>	Wet Forest	49	<0.01	<0.01	0.01	NA
<i>Stachytarpheta jamaicensis</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Prunella vulgaris</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Euchiton sphaericus</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Drymaria cordata</i> var <i>pacifica</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Arundina graminifolia</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Axonopus fissifolius</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Poa</i> spp	Wet Forest	49	<0.01	<0.01	<0.01	NA
<i>Hypericum parvulum</i>	Wet Forest	49	<0.01	<0.01	<0.01	2
<i>Persicaria capitata</i>	Wet Forest	49	<0.01	<0.01	<0.01	2
<i>Crassocephalum crepidioides</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Selaginella kraussiana</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Buddleja asiatica</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Schizachyrium condensatum</i>	Wet Forest	49	<0.01	<0.01	<0.01	2
<i>Juncus</i> spp	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Veronica plebeia</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Cirsium vulgare</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Conyza bonariensis</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Hydrocotyle bowlesii</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
<i>Lotus uliginosus</i>	Wet Forest	49	<0.01	<0.01	<0.01	1
Any Species	WF & SS	69	0.72	0.69	0.74	3
Herb	WF & SS	69	0.50	0.46	0.53	1
Grass	WF & SS	69	0.44	0.44	0.44	2
Tree	WF & SS	69	0.15	0.10	0.19	2
Shrub	WF & SS	69	0.12	0.08	0.16	1
Fern	WF & SS	69	0.11	0.07	0.14	2
Vine	WF & SS	69	0.07	0.05	0.10	1
Sedge	WF & SS	69	0.01	0.01	0.02	1
Rush	WF & SS	69	0.01	<0.01	0.01	1
<i>Hypochoeris radicata</i>	WF & SS	69	0.19	0.13	0.26	1
<i>Anthoxanthum odoratum</i>	WF & SS	69	0.15	0.11	0.19	1
<i>Holcus lanatus</i>	WF & SS	69	0.12	0.08	0.15	1
<i>Rubus ellipticus</i> var <i>obcordatus</i>	WF & SS	69	0.10	0.07	0.14	2
<i>Nephrolepis brownii</i>	WF & SS	69	0.10	0.07	0.14	5
<i>Eragrostis brownei</i>	WF & SS	69	0.10	0.06	0.13	1
<i>Setaria palmifolia</i>	WF & SS	69	0.09	0.06	0.12	3
<i>Psidium cattleianum</i>	WF & SS	69	0.09	0.06	0.12	2
<i>Ehrharta stipoides</i>	WF & SS	69	0.09	0.08	0.10	2

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Paspalum conjugatum</i>	WF & SS	69	0.08	0.05	0.10	3
<i>Morella faya</i>	WF & SS	69	0.07	0.05	0.09	4
<i>Hedychium gardnerianum</i>	WF & SS	69	0.07	0.05	0.09	2
<i>Tibouchina herbacea</i>	WF & SS	69	0.06	0.04	0.08	2
<i>Sporobolus africanus</i>	WF & SS	69	0.06	0.04	0.08	1
<i>Senecio madagascariensis</i>	WF & SS	69	0.06	0.04	0.08	1
<i>Passiflora tarminiana</i>	WF & SS	69	0.06	0.04	0.07	2
<i>Anemone hupehensis</i> var <i>japonica</i>	WF & SS	69	0.04	0.03	0.06	2
<i>Polycarpon tetraphyllum</i>	WF & SS	69	0.04	0.02	0.05	1
<i>Euchiton sphaericus</i>	WF & SS	69	0.04	0.02	0.05	1
<i>Euchiton japonicus</i>	WF & SS	69	0.03	0.02	0.05	1
<i>Festuca bromoides</i>	WF & SS	69	0.03	0.02	0.04	1
<i>Rumex acetosella</i>	WF & SS	69	0.02	0.02	0.03	1
<i>Oxalis corniculata</i>	WF & SS	69	0.02	0.01	0.03	1
<i>Centaureum erythraea</i> ssp <i>erythraea</i>	WF & SS	69	0.02	0.01	0.03	1
<i>Persicaria punctata</i>	WF & SS	69	0.02	0.01	0.03	1
<i>Geranium homeanum</i>	WF & SS	69	0.02	0.01	0.03	1
<i>Verbascum thapsus</i>	WF & SS	69	0.02	0.01	0.03	1
<i>Veronica serpyllifolia</i>	WF & SS	69	0.02	0.01	0.02	1
<i>Senecio sylvaticus</i>	WF & SS	69	0.02	0.01	0.03	1
<i>Fragaria vesca</i>	WF & SS	69	0.02	0.01	0.02	1
<i>Cardamine flexuosa</i>	WF & SS	69	0.02	0.01	0.02	1
<i>Veronica peregrina</i> ssp <i>xalapensis</i>	WF & SS	69	0.02	0.01	0.02	1
<i>Andropogon virginicus</i>	WF & SS	69	0.02	0.01	0.02	2
<i>Schizachyrium condensatum</i>	WF & SS	69	0.02	0.01	0.02	2
<i>Cenchrus clandestinus</i>	WF & SS	69	0.01	0.01	0.02	2
<i>Rubus rosifolius</i>	WF & SS	69	0.01	0.01	0.02	2
<i>Coronopus didymus</i>	WF & SS	69	0.01	0.01	0.02	1
<i>Cirsium vulgare</i>	WF & SS	69	0.01	0.01	0.02	1
<i>Passiflora edulis</i>	WF & SS	69	0.01	0.01	0.02	2
<i>Veronica plebeia</i>	WF & SS	69	0.01	0.01	0.02	1
<i>Andropogon glomeratus</i> var <i>pumilus</i>	WF & SS	69	0.01	0.01	0.01	1
<i>Hypericum mutilum</i> ssp <i>mutilus</i>	WF & SS	69	0.01	0.01	0.01	1
<i>Phaius tankervilleae</i>	WF & SS	69	0.01	0.01	0.01	1
<i>Eragrostis</i> spp	WF & SS	69	0.01	0.01	0.01	1
<i>Poa</i> spp	WF & SS	69	0.01	0.01	0.01	1
<i>Cenchrus polystachios</i>	WF & SS	69	0.01	<0.01	0.01	1
<i>Juncus effusus</i>	WF & SS	69	0.01	<0.01	0.01	1
<i>Cyperus trinervis</i>	WF & SS	69	0.01	<0.01	0.01	2
<i>Passiflora</i> spp	WF & SS	69	0.01	<0.01	0.01	2

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Cyperus haspan</i>	WF & SS	69	0.01	<0.01	0.01	2
<i>Ageratina riparia</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Euphorbia peplus</i>	WF & SS	69	<0.01	<0.01	0.01	1
<i>Epilobium billardierianum</i> ssp <i>cinereum</i>	WF & SS	69	<0.01	<0.01	0.01	1
<i>Prunella vulgaris</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Ageratum conyzoides</i>	WF & SS	69	<0.01	<0.01	0.01	1
<i>Unknown species</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Conyza bonariensis</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Plantago major</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Pluchea carolinensis</i>	WF & SS	69	<0.01	<0.01	<0.01	2
<i>Setaria parviflora</i>	WF & SS	69	<0.01	<0.01	<0.01	2
<i>Emilia fosbergii</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Rubus argutus</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Deparia petersenii</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Ludwigia palustris</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Cerastium fontanum</i> ssp <i>triviale</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Pityrogramma austroamericana</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Erechtites valerianifolia</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Phymatosorus grossus</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Daucus pusillus</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Sacciolepis indica</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Gamochaeta purpurea</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Helichrysum foetidum</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Marrubium vulgare</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Youngia japonica</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Oxalis</i> spp	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Sonchus oleraceus</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Stachytarpheta jamaicensis</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Achyranthes aspera</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Chenopodium ambrosioides</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Daucus carota</i> ssp <i>sativus</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Melinis minutiflora</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Trifolium repens</i> var <i>repens</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Veronica arvensis</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Crassocephalum crepidioides</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Drymaria cordata</i> var <i>pacifica</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Arundina graminifolia</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Axonopus fissifolius</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Aster</i> spp	WF & SS	69	<0.01	<0.01	<0.01	1

Species	Sampling Frame	N	Freq. Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Erodium cicutarium</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Silene gallica</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Solanum spp</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Hypericum parvulum</i>	WF & SS	69	<0.01	<0.01	<0.01	2
<i>Persicaria capitata</i>	WF & SS	69	<0.01	<0.01	<0.01	2
<i>Selaginella kraussiana</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Buddleja asiatica</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Juncus spp</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Hydrocotyle bowlesioides</i>	WF & SS	69	<0.01	<0.01	<0.01	1
<i>Lotus uliginosus</i>	WF & SS	69	<0.01	<0.01	<0.01	1

Table B.2. Frequency estimates of non-native species at Paddocks zone of Kahuku sampling frame.

Species	Sampling Frame	N	Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Any Species</i>	Paddocks	10	1.00	1.00	1.00	7
<i>Grass</i>	Paddocks	10	1.00	1.00	1.00	7
<i>Sedge</i>	Paddocks	10	0.88	0.77	0.98	1
<i>Herb</i>	Paddocks	10	0.83	0.73	0.94	1
<i>Fern</i>	Paddocks	10	0.32	0.08	0.57	1
<i>Shrub</i>	Paddocks	10	0.08	0.02	0.13	1
<i>Rush</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Vine</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Cenchrus clandestinus</i>	Paddocks	10	1.00	1.00	1.00	NA
<i>Axonopus fissifolius</i>	Paddocks	10	0.97	0.91	1.00	NA
<i>Lotus uliginosus</i>	Paddocks	10	0.63	0.44	0.83	1
<i>Cyperus sanguinolentus</i>	Paddocks	10	0.58	0.30	0.87	1
<i>Kyllinga brevifolia</i>	Paddocks	10	0.52	0.32	0.73	1
<i>Sacciolepis indica</i>	Paddocks	10	0.36	0.18	0.54	NA
<i>Commelina diffusa</i>	Paddocks	10	0.32	0.13	0.50	1
<i>Nephrolepis brownii</i>	Paddocks	10	0.26	0.03	0.49	1
<i>Anthoxanthum odoratum</i>	Paddocks	10	0.23	<0.01	0.52	NA
<i>Ehrharta stipoides</i>	Paddocks	10	0.22	0.05	0.38	NA
<i>Cuphea carthagenensis</i>	Paddocks	10	0.19	0.06	0.32	1
<i>Holcus lanatus</i>	Paddocks	10	0.19	0.04	0.34	NA
<i>Setaria parviflora</i>	Paddocks	10	0.10	<0.01	0.24	NA
<i>Deparia petersenii</i>	Paddocks	10	0.10	<0.01	0.21	1
<i>Andropogon virginicus</i>	Paddocks	10	0.08	<0.01	0.16	NA

Species	Sampling Frame	N	Estimate	95% CI Lower Bound	95% CI Upper Bound	Avg. Cover Class
<i>Hydrocotyle bowlesioides</i>	Paddocks	10	0.08	0.02	0.13	1
<i>Trifolium repens</i> var <i>repens</i>	Paddocks	10	0.06	<0.01	0.15	1
<i>Poa</i> spp	Paddocks	10	0.04	<0.01	0.13	NA
<i>Ageratina riparia</i>	Paddocks	10	0.04	<0.01	0.09	1
<i>Rubus argutus</i>	Paddocks	10	0.04	<0.01	0.09	1
<i>Paspalum conjugatum</i>	Paddocks	10	0.03	<0.01	0.08	NA
<i>Physalis peruviana</i>	Paddocks	10	0.02	<0.01	0.05	1
Unknown species	Paddocks	10	0.02	<0.01	0.06	1
<i>Blechnum appendiculatum</i>	Paddocks	10	0.02	<0.01	0.05	1
<i>Geranium homeanum</i>	Paddocks	10	0.02	<0.01	0.04	1
<i>Rubus rosifolius</i>	Paddocks	10	0.02	<0.01	0.04	1
<i>Andropogon glomeratus</i> var <i>pumilus</i>	Paddocks	10	0.01	<0.01	0.03	NA
<i>Arundina graminifolia</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Cyclosorus parasiticus</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Cyperaceae</i> spp	Paddocks	10	0.01	<0.01	0.03	1
<i>Galium</i> spp	Paddocks	10	0.01	<0.01	0.03	1
<i>Hedychium gardnerianum</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Juncus effusus</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Passiflora ligularis</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Phaius tankervilleae</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Pluchea carolinensis</i>	Paddocks	10	0.01	<0.01	0.03	1
<i>Veronica plebeia</i>	Paddocks	10	0.01	<0.01	0.03	1

Appendix C: 2010-2011 Focal Terrestrial Plant Communities and Established Invasive Plant Species Monitoring Effort

From 2010 to 2011 the Inventory and Monitoring (I&M) vegetation program implemented the Focal Terrestrial Plant Communities (FTPC) and Established Invasive Plant Species (EIPS) monitoring protocols on Hawai‘i Island. Survey efforts focused on wet forest and subalpine shrubland communities at Hawai‘i Volcanoes National Park (HAVO), and the coastal strand community in Kaloko-Honokōhau National Historical Park (KAHO). This appendix summarizes field season effort, logistical details, and future recommendations for monitoring these three communities. 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 and transect completion times within and between sampling frames, 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.

The total season effort spans the first day of seasonal technician work to the last day in the field for 2010 and from the first field day to last day of work for the seasonal technicians in 2011. Information for both protocols is presented below according to three main components: training effort, field effort and office effort. Training effort includes both office and field time used to complete certifications and to learn monitoring methods, while field effort is a sum of both access and actual survey time. Office effort, including field preparation and data processing, equals the remaining time that was not spent on training or monitoring in the field. Calculated effort for each season was compiled from original data forms, notebooks, photographs, calendars, and personnel interviews. Each effort component is presented below according to field season year, and within year, organized by sampling frame and protocol. While training and office efforts remain similar between years, field efforts vary with respect to survey time and access required for different sampling frames. Dates and effort do not include season preparation by the project lead and field leaders. The FTPC and EIPS protocols were designed to have field work carried out concurrently each year. However, the EIPS protocol was not finalized by the start of the 2010 season and therefore field work did not begin until FTPC work was almost complete. In 2011, field work for both protocols was carried out simultaneously as planned. Prior to site monitoring for FTPC and EIPS in 2011, crews took part in conducting cultural clearance surveys in selected areas of the subalpine shrubland and coastal strand. At the end of both field seasons, a subset of the FTPC plots was re-read for quality assurance.

2010

In 2010, vegetation crews surveyed FTPC plots and EIPS transects in ‘Ōla‘a and East Rift /Nāhuku (formerly Thurston) sampling frames at HAVO from May 3, 2010 to February 2, 2011. This field season was scheduled for six-months by seasonal hire technicians; however, this first season was exceptionally long (nine months) due to unforeseen hiring and access obstacles, and fine-tuning of the methodology. Crews of two to six observers (Table C.1) performed field preparation, training, data collection, and data management duties for both protocols. Alison Ainsworth, the project lead, supervised all protocol work. Corie Yanger served as primary field leader for FTPC and Adam Mehlhorn served as primary field leader for EIPS. Julie Christian focused efforts on protocol development. Three seasonal field technician positions were filled by Laura Arnold, Reid Loo, and

Daemerson Awong, the latter who began in August 2010. Two volunteers, Lauren Greig and Bret Callaway, joined the project in October 2010. While most crew members spent all of their time monitoring for either protocol, sometime was allocated to other projects such as vegetation mapping. This was especially true for the project lead and field leaders.

Table C.1. Personnel for 2010 FTPC and EIPS field season.

Observer	Position	Days worked during field season	FTPC field days	EIPS field days	% FTPC field work	% EIPS field work
Alison Ainsworth	GS-11	147	23	2	15.6	1.4
Corie Yanger	GS-7	147	50	5	34.0	3.4
Adam Mehlhorn	GS-7	102	29	22	28.4	21.6
Julie Christian	GS-7	80	5	0	6.3	0.0
Laura Arnold	GS-5	98	68	5	69.4	5.1
Reid Loo	GS-5	98	56	5	57.1	5.1
Daemerson Awong	GS-5	94	27	19	28.7	20.2
Lauren Greig	VIP	68	13	11	19.1	16.2
Bret Callaway	VIP	46	8	8	17.4	17.4

Dates for FTPC and EIPS field work only overlapped a few months. For FTPC monitoring, 40 of 60 proposed plots were established and monitored from May 3, 2010 to November 3, 2010. For EIPS, 29 of the proposed 40 transects were monitored between October 4, 2010 and February 2, 2011.

Training Effort

Crew members spent approximately three weeks participating in office and field trainings applicable to both the FTPC and EIPS. These trainings took place for one week prior to beginning field work, and then were interspersed with actual monitoring for the first few weeks of the field season. Office-based training included group (Operational Leadership, first aid/CPR, herbarium, and radio training) and individual training (defensive driving and computer security training). Field leaders were certified First Responders. All crew members that participated in helicopter operations received training in Basic Helicopter Safety (B3) and the field lead was a certified Helicopter Crew Member. Outdoor training involved learning how to navigate to monitoring sites, and how to monitor and identify plants. While all technicians had previous experience with Hawaiian flora, some additional training was needed.

Office Effort

Office effort is the remaining time during the field season 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. Note that other projects were being conducted within the field season time frame and thus not all office time was spent on FTPC or EIPS. The allotted time was not adequate to enter and check all of the

data largely due to an unfortunate server crash near the end of the field season during which all entered data were lost.

Field Effort

Field effort was calculated as the sum of days spent monitoring and accessing the plots, and was affected by HAVO natural resource management (NRM) hunter permissions, the existence and condition of access trails, vegetation composition and observer availability. Data are organized according to sampling frame and by monitoring protocol. In the ‘Ōla‘a and East Rift/Nāhuku sampling frames, 40 of 60 proposed FTPC wet forest plots were completed in 2010. One additional ‘Ōla‘a plot was monitored in 2011 (R25) to train off-island staff. Completion time for R25 was incorporated into the ‘Ōla‘a table below (Table C.2), however field personnel time for this plot was added to Table C.6 as monitoring took place with members of the 2011 field crew. For EIPS, 29 of the 40 proposed transects were completed by the 2010 field season crew. For both sampling frames and monitoring projects, field days spanned from May 2010 to February 2011 (plus two field days in November 2011). In total, crews spent 94 calendar days in the field for a grand total of 3326.75 worker hours (333 10-hour worker days). On average crew sizes consisted of four people for each day in the field. While work in ‘Ōla‘a sampling frame and Nāhuku zone was accomplished by day trips, work in the East Rift zone necessitated helicopter assistance and overnight stays. Employee backcountry permits were filed with HAVO rangers at the Kīlauea Visitors Center to camp in the East Rift zone and the NPS Pacific Area Communications Center (PACC). A NRM park ecologist also assisted with helicopter operations and field communication.

Access details for all FTPC and EIPS monitoring sites are provided below in addition to summarized completion times and crew effort (i.e., worker hours). Tables are organized by date, repeated dates are present when multiple crews sampled on the same day. Plot and transect times in the tables refer to the length of crew visits to complete monitoring. Total worker hours was calculated by adding transit plus plot/transect completion times, then multiplying by the number of crew members present. Transit times include driving time from the office, which amounted to 20-25 minutes roundtrip for ‘Ōla‘a and 0.75 - 1 hour for East Rift/Nāhuku. It also includes 10-15 minutes used for stretching and conducting safety briefings at the start of each day. Worker days (summarized in text) are based off of 10-hour worker days.

Nāhuku/East Rift

The Nāhuku/East Rift sampling frame was divided into two zones, each requiring different access methods. To access plots and transects in Nāhuku crews drove to Mauna Ulu Escape Road. To access East Rift crews drove either to Kealakomo overlook and hiked up Nāulu trail, or drove to Mauna Ulu escape road to stage helicopter operations, which were required for transporting gear and sometimes crew members. When accessing Nāhuku or staging helicopter operations from the Mauna Ulu landing zone, crews unlocked the Escape Road gate using NPS issued building keys. Below, Tables C.4 and C.5 summarize plot/transect completion times and access. Crew efforts include driving time from the office to Nāhuku/ East Rift (0.75-1.25 hour roundtrip). Monitoring sites that required helicopter assistance for both staff and/or gear are indicated in the tables. Helicopter times for gear

only transport are included to aid in future planning and budgeting, however these times were not factored into total worker hours.

East Rift

Eighteen of 19 planned FTFC plots in East Rift were completed and some alternate plot locations were used (Figure C.1). For EIPS transects, nine of the proposed ten transects were monitored (Figure C.2). Plots were completed in two phases or areas with the first area including plot F8 and all plots west of it; the second area consisted of all remaining plots to the east. Crews surveyed East Rift transects in a similar fashion, starting with the farthest transect to the west (F5), making their way east with R19 as the last transect.

From July to October 2010, the crew made day and camp trips to the western area and based operations at the pavement camp site at the intersection of Nāulu and old Kalapana trails. For those trips the project employed a helicopter to supply the crew with gear, water, and food. In order to complete plots and transects on the far eastern side of East Rift, crews also utilized helicopter-assisted trips in September and December 2010 to the Cinder Field camp (northeast forest corner near Pu‘u ‘Ō‘ō). Before staying overnight in East Rift, the crew filed employee backcountry permits at the HAVO Kīlauea Visitor Center. Crews used regular tents for camping at both sites, where tarps functioned as footprints to protect tent floors from puncturing on lava rock and cinder. Water was estimated at two gallons per person per day. A portable toilet and toilet bags (Wag Bags) were used at the Pavement camp. At Cinder Field camp, crews were able to dig holes with a trowel for personal waste disposal.

A NRM ecologist managed helicopter flights to transport personnel and/or gear. Helicopter flight plans were submitted for each trip, and the helicopter manager worked directly with PACC while conducting helicopter operations. Personal protective equipment and gear required for helicopter operations for I&M crew members was not available early in the season, so the crew borrowed flight suits, helmets, and gloves, cargo nets, swivels, and lead lines from the HAVO Fire Cache. Toward the season’s end, the project lead purchased more of these items for the I&M program so that borrowing was no longer necessary.

Pavement camp

To reach the Pavement camp (E: 272655 N: 2140559) on the west side of East Rift, crews parked a vehicle or were dropped off at the Kealakomo overlook and hiked up Nāulu trail. Roundtrip driving time between the office and Kealakomo overlook parking area ranged from 1-1.25 hours. While staying at the Pavement camp, crews set up out of sight of visitors walking on designated park trails and did not leave gear in the open. Helicopter operations were coordinated so that gear and supplies were dropped at the camp site the first week of camping and were picked up on the last day of the second week of camping to minimize helicopter time. Equipment and gear loads were flown from either HAVO rainshed or the landing zone off of Mauna Ulu escape road. The helicopter manager hooked up the load for the initial flight, and the field leader hooked up the load for the flight out. Loads were typically transferred on the morning of the first day of a camp week so that the load was being transferred while the crew set off from Nāulu trailhead toward the camp site. When it was time

to send the equipment and supplies back, the crew hiked out of the field to Kealakomo overlook after helicopter operations were complete.

Cinder Field Camp

The Cinder Field camp (E: 276610 N: 2143919) was placed strategically for quick access to plots and transects on the east side of East Rift while avoiding the plume of volcanic gases from Pu‘u ‘Ō‘ō vent. Helicopter assistance was utilized to take crew and gear to the camp where no facilities existed. The field crew utilized the Cinder Field camp for two trips in September and one trip in December 2010. From the Cinder Field camp, plots and transects were accessed by hiking along extensive lava flows bordering the forest. Camping at the Cinder Field was minimalistic; crew members brought food items that did not require much cooking (if any) and used only one small camp stove. For Cinder Field camp trips both passengers and cargo flew internal from the landing zone on Mauna Ulu escape road. Time was lost on the initial Cinder Field camp trip as the protocol maps did not include current lava flow boundaries, consequently directing the field crew to locations of wet forest that had since been covered with lava. New volcanic events along the East Rift and at Pu‘u ‘Ō‘ō vent in 2011 resulted in updated shapefiles post field season. East Rift maps provided below include the updated sampling frame, which was modified to account for the 2011 flows.

Nāhuku

At Nāhuku no camping was needed as this area was relatively close to the office and easily reached by driving. Crews parked at maintained pull-outs or enough off the roadside for other vehicles to get by. In the future, crews should not attempt to exit Mauna Ulu escape road going north because the road is blocked off for the Nāhuku Lava Tube visitor area.

Five FTPC plots and six EIPS transects were completed in Nāhuku (Figures C.1 and C.2). Monitored months before EIPS transects, all FTPC plots were located within 300 m of Mauna Ulu Escape Road as access to the east side of Nāhuku zone was questionable due to cracks. Beginning in November 2010, the I&M crew monitored three EIPS transects located northeast of the Mauna Ulu Escape Road. These proved somewhat difficult to access due to dense uluhe (*Dicranopteris linearis*) and large earth cracks. In many cases, the crew used the same route to access and leave transects since vegetation was thick and the locations of dangerous earth cracks were already noted.

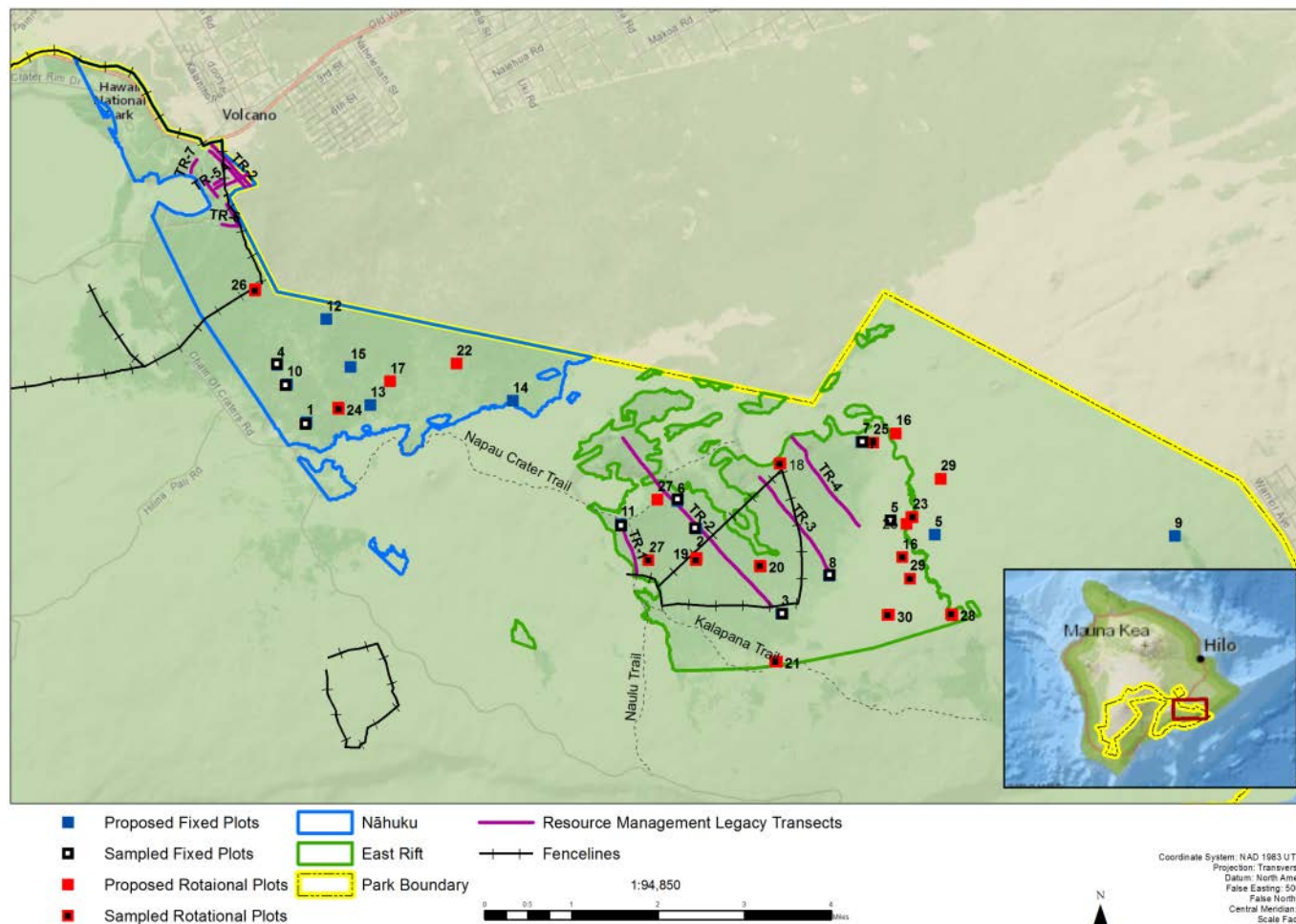


Figure C.1. Map of proposed plot centroids and completed plot start locations in East Rift/Nāhuku, HAVO.

Table C.2. Summary of FTPC plot completion and crew effort for East Rift/Nāhuku. Plot numbers are preceded by F for fixed or R for rotational. All times are listed in hours. Transit time combines vehicle travel between the office and site and hiking time. All directions originate from office or indicated campsite. Helicopter transit times are for both staff and gear transit and indicate when only gear was transported. When helicopters only transported gear, time was not added to worker hours. Total worker hours equals transit time plus hours to complete plot (monitoring time), multiplied by crew size. PM = Pavement, CF = Cinder Field, KT = Kalapana Trail, NLT = Nāulu Trail, NPT = Nāpau Trail, MUR = Mauna Ulu Road, MUER = Mauna Ulu Escape Road, MC = forest below Makaopuhi Crater.

Date	Plot	Zone	Crew No.	Camp Site	Hours to complete plot	Access	Transit time	Helicopter time	Total worker hours
7/19/10	F3	East Rift	4	PM	2.75	KT, ER SEA south fence	3.75	0.5 (gear)	26
7/20/10	F3, F8	East Rift	4	PM	5	KT, ER SEA south fence to plot 3, east fence to plot F8	4.5	0	38
7/21/10	F8	East Rift	4	PM	5	KT, ER SEA south fence, east fence	5.5	0	42
7/22/10	F11	East Rift	4	PM	5.75	NLT, MC	2.25	0	32
7/26/10	F6	East Rift	4	PM	2.5	NLT, NPT, LB-2	4.75	0	29
7/27/10	F6, F2	East Rift	4	PM	6.75	NLT, NPT, LB-2	3.25	0	40
7/28/10	F2	East Rift	4	PM	6.25	NLT, NPT, LB-2	5.25	0	46
7/29/10	R20	East Rift	4	PM	7	KT, East Rift SEA south fence	5.75	0	51
7/30/10	---	---	4	PM	---	---	1.5	0.5 (gear)	6
8/9/10	F4	Nāhuku	5	---	5	MUR, MUER	2.5	0	37.5
8/10/10	F10	Nāhuku	4	---	5.5	MUR, MUER	2.75	0	33
8/16/10	R27	East Rift	4	PM	3.5	NLR, NPT	2.25	0.5 (gear)	23
8/17/10	R27, R21	East Rift	4	PM	3.75	NLT, MC to plot R27; KT to plot R21	5.5	0	37
8/18/10	R21	East Rift	4	PM	6.5	KT	4	0	42
8/19/10	R19	East Rift	4	PM	1.5	NLT, NPT, LB-2	4	0	22
8/24/10	R19	East Rift	5	PM	4.5	NLT, NPT, LB-2	5	0	47.5
8/25/10	R18	East Rift	5	PM	4.75	KT; ER SEA south fence; east fence	6.25	0	55
8/26/10	---		5	PM	0	---	1.75	0.5 (gear)	8.75
8/30/10	R26	Nāhuku	5	---	0.75	MUR, MUER	2.5	0	16.25
8/31/10	R26	Nāhuku	3	---	6.25	MUR, MUER	2.5	0	26.25
9/1/10	R24	Nāhuku	4	---	4	MUR, MUER	2.5	0	26
9/2/10	F1	Nāhuku	5	---	4	MUR, MUER	3	0	35
9/8/10	F1	Nāhuku	5	---	3.75	MUR, MUER	3	0	33.75

Date	Plot	Zone	Crew No.	Camp Site	Hours to complete plot	Access	Transit time	Helicopter time	Total worker hours
9/13/10	F7	East Rift	4	CF	6.75	S along lava flow; across W	1.5	0.5	35
9/14/10	R28 R23	East Rift	4	CF	4.25	S along lava flow; across W	6.5	0	43
9/15/10	R30, R16	---	4	CF	5.5	S along lava flow; across W	7	0	50
9/16/10	F5	---	4	CF	3	S along lava flow; across W	3	0.5	26
9/21/10	R25	---	4	CF	4.5	S along lava flow; across W	2	0.5	28
9/22/10	R29	---	4	CF	3	S along lava flow; across W	4	0	28
9/23/10	---	---	4	CF	---	---	1	0.5	6
12/13/10	F7r	East Rift	2	CF	3	S along lava flow; across W	1.5	0.5	10
12/28/10	F4r	Nāhuku	3	---	3	MUR, MUER	2.5	0	16.5
1/4/11	F11r	East Rift	5	---	2.75	NLT, MC	5.5	0	41.25

FTPC

Including transportation and plot re-reads, a total of 1036.75 worker hours (103.6 worker days) were spent monitoring FTPC plots in the Nāhuku/East Rift sampling frame (Figure C.1). Without transit or plot re-read times, total worker hours for plot setup and monitoring took 503.5 worker hours (50.4 worker days). Average plot monitoring time cannot be provided, as times were not specified when crews monitored more than one plot in a day. Total transit time (not including plot re-reads) totaled 465.5 worker hours, or 47 worker days.

Re-read plots

At the conclusion of the FTPC monitoring, three fixed plots in East Rift/Nāhuku were re-read for quality assurance and measurement error assessment. These plots are indicated in Table C.2 with an “r” following the plot number. The field crew returned to each plot, selected based on proximity to roads or trails, using UTM coordinates collected earlier in the season. Crew members re-read photographs, species presence, understory cover data, small trees, large trees (quadrant 3 only), small tree ferns, shrubs, and seedling data. To prevent bias, data collected during the first reading was not reviewed prior to conducting a re-read. Re-reading plots took significantly less time than the original plot monitoring times. The crew spent a total of 67.75 worker hours re-reading plots with transit and 28.75 hours without. On average the crew spent 9.6 hours on plot re-read setup and monitoring.

EIPS

With travel time taken into consideration, the I&M crew spent 390.5 worker hours (39 worker days) in the field to monitor fifteen- 5m x 1000m transects for established invasive plants in East Rift/Nāhuku (Figure C.2). Not including travel times, the crew spent a total of 198 worker hours (20 worker days) surveying transects. Average time to complete one transect cannot be provided as specific times for monitoring were not documented when multiple transects were surveyed in one day. Transit alone took 192.5 worker hours, or 19.3 worker days.

Plot and Transect Access

All Nāhuku plots and transects were accessed via the Mauna Ulu Escape Road, then by hiking from the closest access point. To access plots from the Pavement camp, crews used a combination of park trails, legacy transects, and the East Rift Special Ecological Area (SEA) fence line. Plots F11 and R27 were quickest to reach as they were located very near to park trails. To access EIPS transect F5, the Nāulu Trail was used. FTPC plots F2, F6, and R19, and EIPS transects F6 and R18 were accessed by following Nāulu Trail to Nāpau Trail, then by turning right onto Forest Bird (FB) legacy transect 6. Crews were able to follow flagging along FB-6 fairly well, although the transect’s southern portion burned in the 2003 Luhi Fire (from near plot R19 to the south). I&M Landbirds protocol surveyors read and reflagged a portion of the original FB-6 in spring 2010 (LB-2) stopping several hundred meters from the south fence of the East Rift SEA. Toward the end of the season, the Landbirds shortcut leading from the south East Rift SEA fence to the last Landbirds station on LB-2 was found. The shortcut was flagged but not cut. Landbirds flagging occasionally deviated from the original transect, resulting in several forks that always led back to the original flagged transect. In the southwest, crews tried to reach plot R21 using the old Kalapana Trail, but found transit difficult as the trail had not been maintained. In the future, it may be easier to reach the plot going across the

south East Rift SEA fence, and then down toward the plot. Crews completed FTPC plots F3, F8, R18, and R20, and EIPS transects F10 and R20 by following the SEA fence until reaching the closest point to each plot. Hiking time from Nāulu trailhead to the Pavement camp site was about one hour, and between the Pavement camp site and the east corner of the SEA fence, another hour was used. To reach the East Rift SEA southwest corner, we followed a short portion of the old Kalapana Trail (about 200 m) then turned north toward the fence (total 10 minutes). Future maintenance of the old Kalapana Trail is uncertain, therefore field leaders should have the trailhead pointed out by someone familiar with the area.

On the east side of East Rift, plots F5, R16, R25, and R29, and transects R17 and R19 were moved because the proposed plots were located on a recent lava flow. Little time was needed to reach plots F7, R16, and R29, and transects F9 and R17 because they were close to the Cinder Field camp site. Crew members accessed plots F5, R23, R25, R28, and R30, and transects R15 and R19 by following the lava flow edge to the south, then moving across (west) to each plot. Plots F3, F7, F8, R19, R20, and R25, and parts or all of transects F5, F9, F10, R15, R17, R18, R19, and R20 burned in the 2003 Luhi Fire. Plots 28 and 30 burned in the 2002 Kupukupu Fire, while plots F5, R16, R21, R23, and R29 burned in both fires. Portions of EIPS transects R15, R17, R19 and R20 burned in both fires. Plots F2, F6, F11, R18, and R27, and transect F6 never burned.

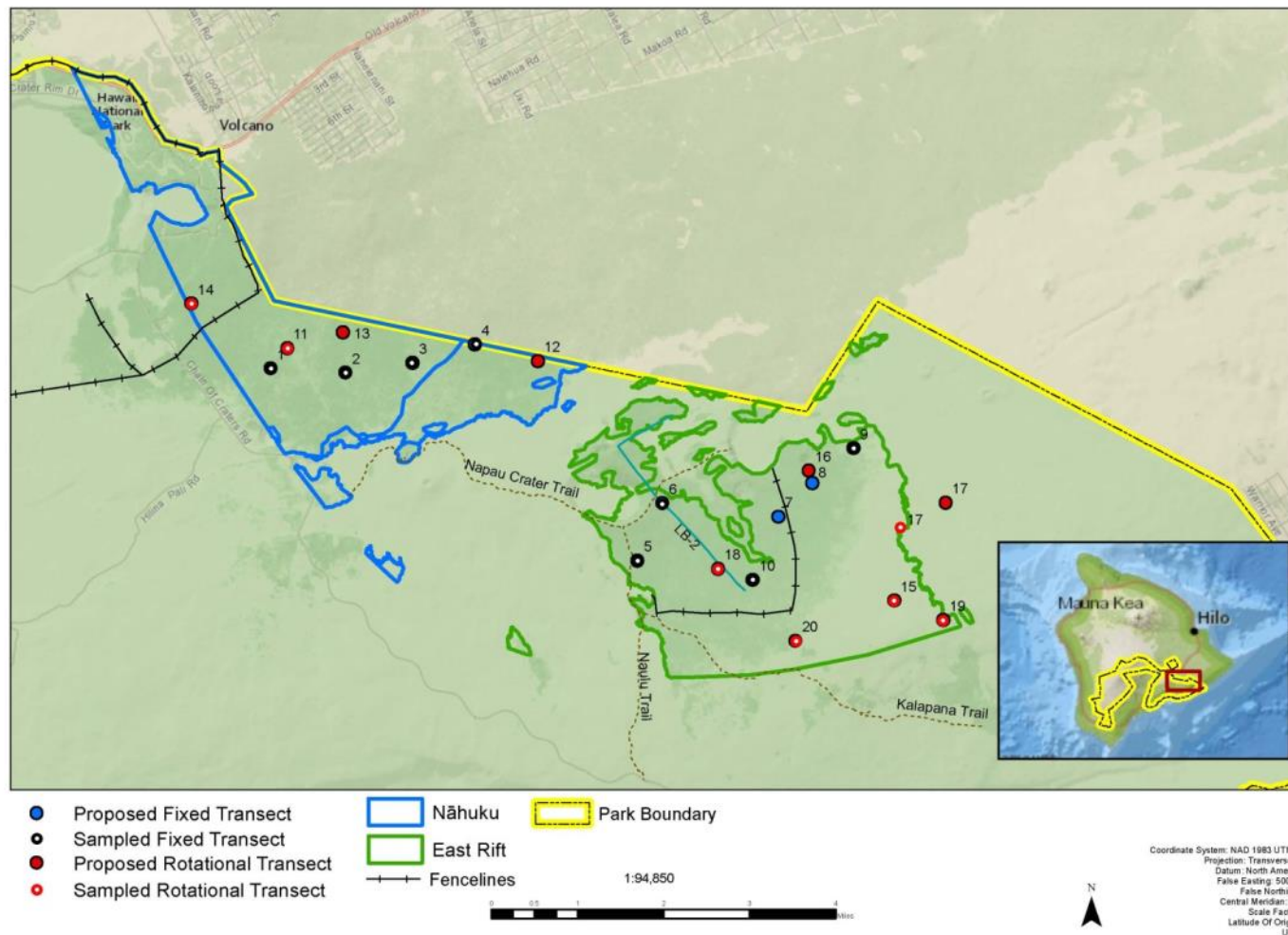


Figure C.2. Proposed and sampled EIPS transects in the East Rift/Nāhuku sampling frame. Points represent transect start points.

Table C.3. Summary of EIPS transect completion and crew effort for Nāhuku/East Rift. Transect numbers are preceded by F for fixed or R for rotational. Asterisks indicate estimated times. All times are listed in hours. Transit time combines vehicle travel between the office and site and hiking time. All directions originate from office or indicated campsite. Helicopter transit times are for both staff and gear transit and indicate when only gear was transported. When helicopters only transported gear, time was not added to worker hours. Total worker hours equals transit time plus hours at transect (monitoring time), multiplied by crew size TR= Transect, PM = Pavement, CF = Cinder Field, KT = Kalapana Trail, NLT = Nāulu Trail, NPT = Nāpau Trail, MUR = Mauna Ulu Road, MUER = Mauna Ulu Escape Road, MC = forest below Makaopuhi Crater, PH = Pu'u Huluhulu, LF = lava flow

Date	Transect	Zone	Crew No.	Camp Site	Hours to complete Transect	Access	Transit time	Helicopter time	Total worker hours
10/18/10	---	East Rift	6	PM	---	---	2	0.5 (gear)	12
10/18/10	F5	East Rift	3	PM	7.5*	NLT, MC	6*	0	40.5
10/18/10	F6	East Rift	3	PM	5	NLT, NPT, LB-2	4	0	27
10/19/10	R18	East Rift	3	PM	4	NPT, LB-2	6*	0	30
10/20/10	F10	East Rift	3	PM	4*	NLT, KT, ER SEA fence	5*	0	27
10/20/10	R20	East Rift	3	PM	5.5	KT, ER SEA fence	5.5*	0	33
10/20/10	---	East Rift	6	PM	---	---	2	0	12
11/15/10	F1	Nāhuku	3	---	4*	MUR, MUER	3*	0	21
11/16/10	R11	Nāhuku	2	---	6*	MUR, MUER	3*	0	18
11/16/10	R14	Nāhuku	2	---	5*	MUR, MUER to fence	3*	0	16
11/18/10	F2	Nāhuku	3	---	6*	MUR, MUER to fence	3*	0	27
12/7/10	F3	Nāhuku	3	---	3.5*	MUR, NPT past PH	3.5*	0	21
12/8/10	F3	Nāhuku	3	---	3.5*	MUR, NPT past PH	3.5*	0	21
12/14/10	F9, R17	East Rift	2	CF	6*	W to TR 9; S along LF to TR 17	2.5	0	17
12/15/10	R15, R19	East Rift	2	CF	7*	S along LF; across W	4*	0.5	22
1/11/11	F4	Nāhuku	3	---	3.5*	MUR, NPT past PH along LF edge	4*	0	22.5
1/20/11	F4	Nāhuku	3	---	3.5*	MUR, NPT past PH along LF edge	4*	0	22.5

In total, crews spent 48% of field efforts on travel for FTPC in East Rift/Nāhuku (not including re-read monitoring or re-read travel), and 49% for EIPS. As stated above, this amounted to 465.5 and 192.5 worker hours, respectively. Though time was saved by utilizing multi-day camp trips, future access times may be reduced with up-to-date knowledge of lava flows and trail status.

Safety in Nāhuku/East Rift

Hazards were abundant at Nāhuku/East Rift due mainly to environmental conditions. Radio communication in the sampling frame was reliable most of the time. Cell phones were typically only used to discuss protocol methods with the project lead. Efficient and safe transit within East Rift was hampered by large fallen dead trees especially along the East Rift SEA fence line. Above the tree fern dominated canopy stand numerous dead trees would fall across the fence line trail when high winds occurred. Crew members were required to maintain daily awareness of this extreme hazard while in transit along the fence line and off trail. Although the field leader tried to determine when NRM trail maintenance crews checked and cleared the fence line, no schedule was clarified.

Due to proximity to the active Pu‘u ‘Ō‘ō vent, vog events were typical for the East Rift. Each crew member was fit for a respirator to carry and use in the event of high sulfur dioxide levels. Crew members with asthma were encouraged to carry an inhaler at all times during field work, and especially in East Rift. Additionally, one sulfur dioxide monitoring badge was issued to each group. In most cases, crew members noticed sulfur dioxide fumes before the badge alarmed. Crew members should rely on their own sensitivity to sulfur dioxide in addition to the monitoring badge to determine when to use respirators. Crews should also be aware that gas badges can sometimes malfunction, and can give false alarms when exposed to citrus. Weather forecasts were consulted when planning camp trips in the East Rift, and crews were prepared for changing conditions.

At Nāhuku, uluhe cover was dense and extensive, concealing a matrix of cracks and holes. Crew members typically walked single file with the lead testing for cracks as necessary. Presence of mounds and depressions indicated likelihood of cracks in the area, and therefore extra caution was taken. Three person crews with at least two radios were preferred in this hazardous zone in case someone fell into a crack. Several large cracks that posed significant hazards were marked with GPS coordinates (see comments section in database). It was also helpful for crew members to wear gloves for pushing through fern patches in Nāhuku and East Rift, especially where the non-native swordfern (*Nephrolepis brownii*) covered cracks and holes. Uluhe was especially dense along the northern portion of the East Rift SEA fence, where crew members took three hours to reach Plot R18 from the Pavement camp site. At the East Rift zone's far eastern border, substrate consisted of cinder over weathered 'a'ā flows. While the cinder layer appeared solid, it did give way on occasion resulting in crew members occasionally falling into holes.

Ground nesting wasps and bees were occasionally encountered in both East Rift and Nāhuku and several crew members were stung. Crew members were able to avoid some nests by listening and looking carefully while working in these areas. A key behavior that helped identify ground nesting wasp nests was to watch the angle at which a wasp was flying: a 45 degree angle from the ground typically indicated a nest, while parallel flight to the ground indicated a much lower hazard. Crews should be aware if field members are allergic and always carry appropriate medications.

‘Ōla‘a

To complete field work in ‘Ōla‘a wet forest plots and transects were accessed from Wright Road via one of three ways: 1) Wright Road directly to NRM legacy transects via Koa Unit 2) Wright Road to the southeast fence to the east fence corner, or 3) Wright Road to Ama‘uma‘u Road through Pu‘u Maka‘ala Natural Area Reserve (NAR). Crews monitored ‘Ōla‘a sites on day trips because of the short driving time to the unit entrance and logistical issues with camping. This however resulted in extended travel times spent hiking in and out of monitoring sites (see Transit Time, Tables C.4 and C.5). The lack of clearings for water/supply helicopter drops and suitable camping space, plus vog prevented crews from camping in ‘Ōla‘a in 2010. Future monitoring crews should consider spike camping with hammocks to minimize travel time spent on hiking. Despite the short driving time, hiking time in ‘Ōla‘a was generally greater than that required for Nāhuku and East Rift. Vegetation in ‘Ōla‘a was very thick with many tree fern trunks hindering quick movement. Plots and transects located at the sampling frame’s unfenced far northeast side proved difficult to access and, due to time constraints, were not sampled. All plots and transects in ‘Ōla‘a are within the ‘Ōla‘a zone.

FTPC in ‘Ōla‘a

In ‘Ōla‘a sampling frame 13 plots within park fencing and five plots outside of park fencing were completed. Of those 18 plots, 12 were established as fixed and six as rotational. Overall, a total of 1528.25 worker hours (153 worker days) was spent traveling to and sampling ‘Ōla‘a focal terrestrial plant community plots. Without transit or plot re-reads, a total of 760 worker hours (76 worker days) was spent setting up and monitoring plots. Because records for specific start and stop times were not available for days crews monitored more than one plot, the average, minimum and maximum monitoring times per plot could not be provided. On average, plots in ‘Ōla‘a were visited over 2.5 calendar days. Driving and hiking transit time for ‘Ōla‘a (not including plot re-read transit) totaled 688.5 worker hours, or 68.9 worker days.

Re-read plots

Three plots in ‘Ōla‘a were “re-read” for quality assurance at the end of the field season. Plots F1, F2 and F6 were re-read and are indicated in Table C.4 by an “r” following the plot number. With transit included, a total of 79.75 worker hours (about 8 worker days) were spent re-reading plots. On average, re-read plots took 16.9 worker hours not including transit time.

EIPS in ‘Ōla‘a

Field sampling for established invasive plants in ‘Ōla‘a began on October 4, 2010 and ended on February 2, 2011. Within this time frame, 14 (seven fixed and seven rotational) of the proposed 20 transects were surveyed. Each transect measured 5m x 1000m. Only one transect was monitored per field day. The average crew size was three. With transit included, a total of 370 worker hours (37 worker days) were spent on established invasive plant species transects. Without transit, transect completion times took between nine worker hours (transects R13 and R15) and 20 worker hours (transect F9). On average and without transit, transects took 13.75 worker hours to complete. All transects in ‘Ōla‘a were completed within one day by the field crew. Transit alone for EIPS monitoring totaled 177.5 worker hours or about 18 worker days.

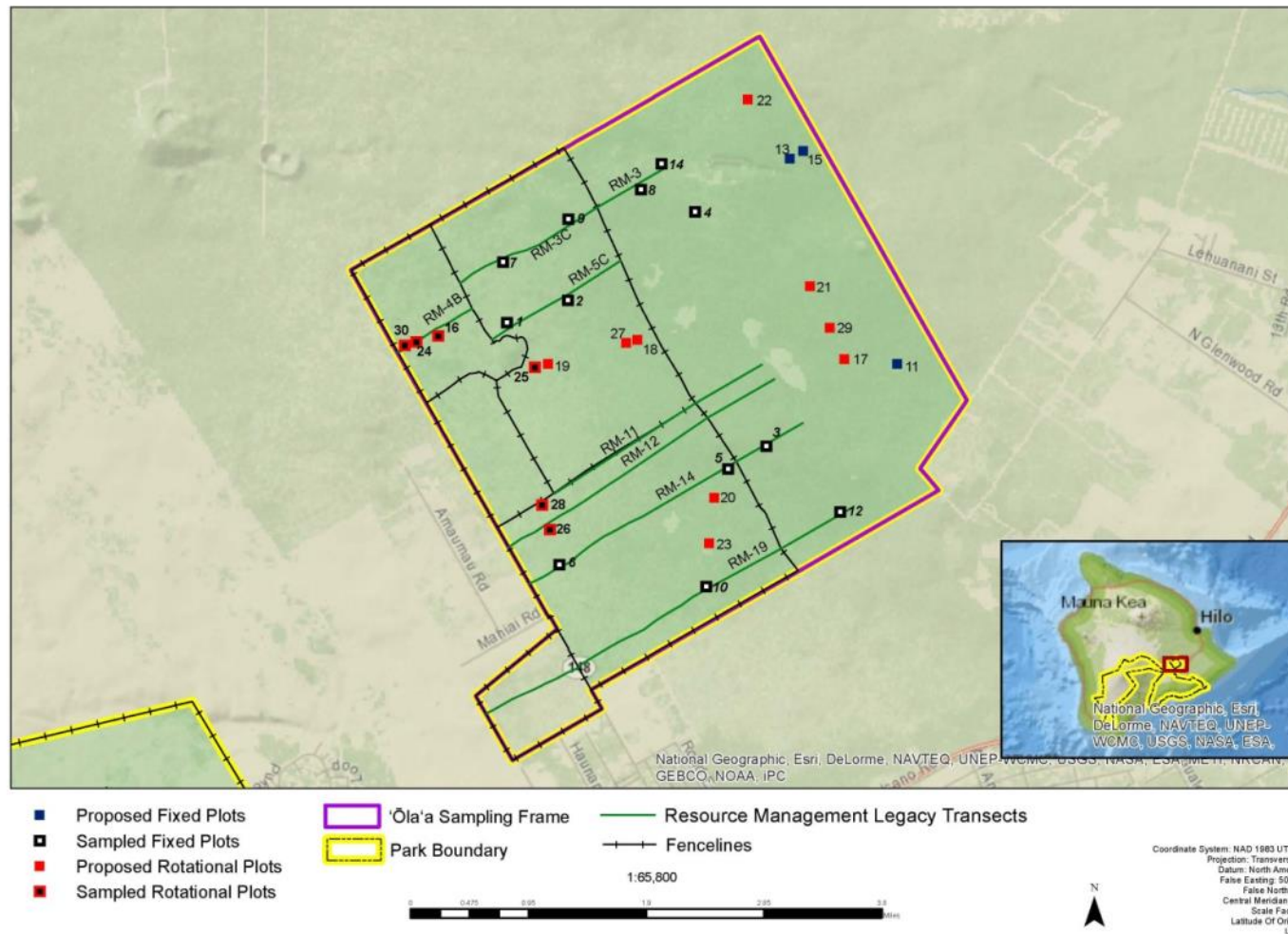


Figure C.3. Proposed and sampled FTPC plots in ʻŌlaʻa sampling frame.

Table C.4. Summary of FTPC plot completion and crew effort for 'Ōla'a sampling frame. Plot numbers are preceded by F for fixed (permanent) or R for rotational (temporary). Plot re-reads are indicated by an "r" following plot numbers. Asterisks indicate estimated times. All times are listed in hours. Total worker hours equal sampling time plus transit, multiplied by crew number. Transit time combines vehicle travel between the office and site and hiking time. All plot access directions begin from the I&M office. SW = Wright Road to SW fence, SE = Wright Road to SE fence to E fence corner, NAR = Wright Road to Ama'uma'u Road through Pu'u Maka'ala Natural Area Reserve to Pu'u Unit, NU = Shortcut to New Unit.

Date	Plot	Unit	Crew No.	Hours to complete plot	Access	Transit time	Total worker hours
5/11/10	F6	Koa	4	8.5*	RM, Koa Unit RM-14	1.5	40
5/13/10	F6	Koa	4	8.5*	RM, Koa Unit RM-14	1.5	40
5/18/10	R30	Pu'u	4	7.5	NAR, RM-4B	2.5*	40
5/19/10	R30	Pu'u	3	7.5	NAR, RM-4B	2.5*	30
5/20/10	R24	Pu'u	4	7.5	NAR, RM-4B	2.5*	40
5/24/10	R24	Pu'u	2	7.5	NAR, RM-4B	2.5*	20
5/25/10	R24, R16	Pu'u	3	7.5	NAR, RM-4B	3*	31.5
5/27/10	R16	Pu'u	4	7	NAR, RM-4B	3*	40
6/1/10	R16	Pu'u	3	7	NAR, RM-4B	3*	30
6/2/10	R16, F1	Pu'u	3	6	NAR, RM-4B to RM-5C	5*	33
6/3/10	F1	New	3	7	NAR, NU, RM-5C	3.5*	31.5
6/7/10	F1	New	4	7	NAR, NU, RM-5C	3.5*	42
6/9/10	F2	New	4	6.5	NAR, NU, RM-5C	4*	42
6/10/10	F2, F7	New	3	5	NAR, NU, RM-5C to RM-3C	5.5*	31.5
6/14/10	F7	New	3	6.5	NAR, NU, RM-3C	4.5*	33
6/15/10	F7	New	3	5.5	NAR, NU, RM-3C	4.5*	30
6/17/10	F9	New	3	6	NAR, NU, RM-3C	5.5*	34.5
6/21/10	F9	New	3	5	NAR, NU, RM-3C	6	33
6/22/10	F8	---	3	5	NAR, NU, RM-5C, RM-3 unfenced	7	36
6/23/10	F8	---	3	4.5	NAR, NU, RM-5C, RM-3 unfenced	7	34.5
6/28/10	F8, F14	---	3	4.5	NAR, NU, RM-5C, RM-3 unfenced	7	34.5
6/29/10	F14	---	3	4.5	NAR, NU, RM-5C, RM-3 unfenced	7	34.5
7/1/10	F14	---	2	3	NAR, NU, RM-5C, RM-3 unfenced	7	20
7/6/10	F14, F4	---	4	1.75	NAR, NU, RM-5C, RM-3 unfenced, RM-5 unfenced	7	35

Date	Plot	Unit	Crew No.	Hours to complete plot	Access	Transit time	Total worker hours
7/8/10	F4	---	4	5.5	NAR, NU, RM-5C, RM-5 unfenced	6	46
7/12/10	F4	---	2	3.5	NAR, NU, RM-5C, RM-5 unfenced	6	19
9/28/10	F10	Koa	5	5.5	RM, Koa Unit RM-20	6	57.5
9/30/10	F10, F5	Koa	5	4	RM, Koa Unit RM-19 to RM-14	5.5	47.5
10/4/10	F5	Koa	4	4	SE, N-NW to Koa Unit RM-14	5	36
10/5/10	F5	Koa	5	5	SE, N-NW to Koa Unit RM-15	5	50
10/6/10	F3	---	5	3.25	SE, N-NW to RM-14 unfenced	5	41.25
10/7/10	F3	---	5	4	SE, N-NW to RM-14 unfenced	5*	45
10/25/10	F12	---	5	0.5	SE, N-NW to RM-19 unfenced	9	47.5
10/26/10	F12	---	4	4	SE, N-NW to RM-19 unfenced	6	40
10/27/10	F12	---	5	4.25	SE, N-NW to RM-19 unfenced	6	51.25
10/28/10	R26	Koa	5	3	RM, Koa Unit RM-12	3.5	32.5
11/1/10	R26	Koa	4	3	RM, Koa Unit RM-12	3.5	26
11/2/10	R28	Koa	5	6	RM, Ag Unit RM-11	3.5*	47.5
12/20/10	F1r	New	3	5.25	NAR, NU, RM-5C	3.5	26.25
12/21/10	F2r	New	4	5	NAR, NU, RM-5C	3.5	34
12/22/10	F6r	Koa	3	5*	RM, Koa Unit RM-14	1.5*	19.5
11/2/11	R25	New	3	6.5	NAR, RM-6B	3	28.5
11/7/11	R25	New	3	2.5	NAR, RM-6B	3	16.5

Plot and Transect Access in 'Ōla'a

FTPC plots F6, F10, R26, and R28, plus EIPS transects F1, F3, F4, R13, and R14 intersected with RM-11 through RM-19 and were accessed from the front of Resource Management Koa Unit. To reach plots F3, F5, F12, and R20, and transect R17, the crew hiked along the inside of the southeast fence border until the fence ended (1 hour), then followed the fence to the northwest. To access plots and transects located off of transects RM-2 through RM-8, the crew drove from Wright Road to the end of Ama'uma'u Road. From there, we hiked going northwest into Pu'u Maka'ala NAR and took a right at the forest bird sign (5 minutes). An unflagged, maintained trail led to the 'Ōla'a fence border where RM transect 6B begins (15 minutes). Plots located along transects RM-3C to RM-6C required following the fence line from RM-6B to the northeast until the intersection with the east fence border of Ag Unit (20 minutes); a flagged shortcut trail takes off to the left, opposite a small gate. The shortcut trail ends close to the start of RM-5C (15 minutes). RM-5C was one of the clearest transects for accessing Pu'u Unit plots and was used to reach FTPC plots F4, F8, and F14, and EIPS transects F5 and R15. Plots in Pu'u and New Unit were completed before plots requiring hiking along the southeast border of Koa Unit.

All plots were established at their proposed location using the original azimuth, with the exception of plot R24. The proposed centroid for rotational plot R24 was located on the trail, so the crew followed SOP #7 to determine a new location; the original azimuth was used.

About 48% of both FTPC and EIPS field efforts were spent on transit alone (688.5 and 177.5 worker hours, respectively). Given the short drive to the 'Ōla'a unit entrance, much of this time can be allocated toward hiking. As previously mentioned, spike camping may be a more efficient option for future crews, given that the logistical issues are resolved.

Safety in 'Ōla'a

Wet conditions in 'Ōla'a made hiking and working in rainboots preferable for most crew members. Sections of trails and log hurdles were often very slippery. Because the terrain is mostly flat and vegetation is so thick in 'Ōla'a, crew members must mind each other and their surroundings as it is easy to become disoriented. Hypothermia was also a concern because crew members hiking with full raingear produced enough sweat to become too cool once movement stopped; some members carried extra dry clothing for this reason. Radio communication in 'Ōla'a was patchy and therefore cell phones were relied on most of the time. Future crews should refer to radio and cell phone receptivity maps produced by I&M, and plan accordingly. Field leaders worked closely with park hunters to ensure crew avoidance of hunter activities within certain units. Outside of fenced areas, crews maintained caution while working as wild pigs were occasionally encountered. Ground nesting wasps are a hazard in dry years, though none were encountered during the season. Additionally, Himalayan raspberry patches were common throughout the area, posing threats to eyes and exposed skin.

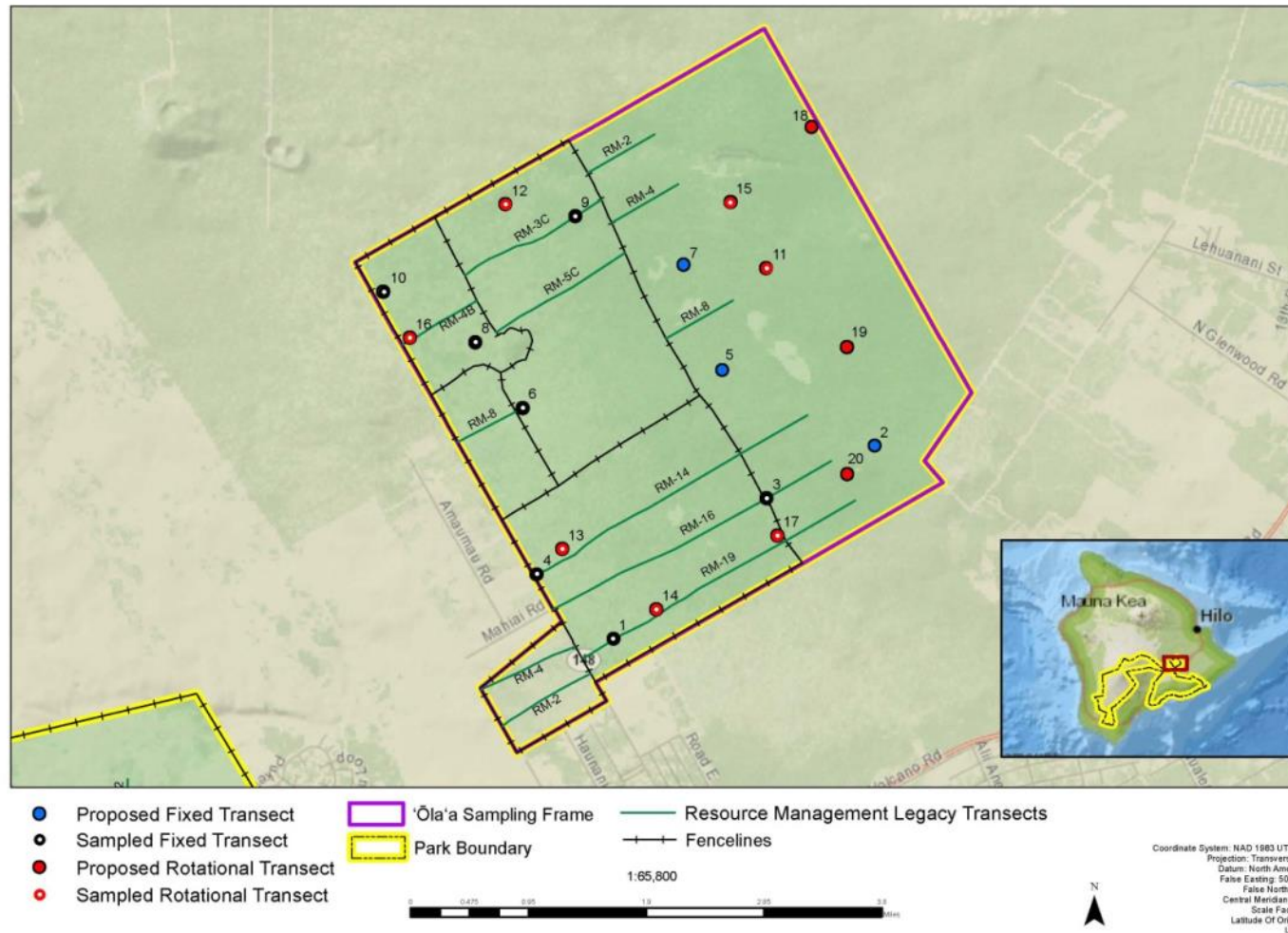


Figure C.4. Proposed and sampled EIPS transects in Ōla'a sampling frame. Points represent transect start locations.

Table C.5. Summary of transect completion and crew effort for 'Ōla'a sampling frame. Transect numbers are preceded by F for fixed (permanent) or R for rotational (temporary). Asterisks indicate estimated times. All times are listed in hours. Multiple rows with the same date indicate monitoring by more than one field crew team. Total worker hours equals sampling time plus transit, multiplied by crew number. Transit time combines vehicle travel between the office and site and hiking time. All transect access directions begin from the I&M office. SW = Wright Road to SW fence, SE = Wright Road to SE fence to E fence corner, NAR = Wright Road to Ama'uma'u Road through Pu'u Maka'ala Natural Area Reserve to Pu'u Unit, NU = Shortcut to New Unit

Date	Transect	Unit	Crew No.	Hours to complete transect	Access	Transit time	Total worker hours
10/4/10	F1	Koa	3	4.5*	SW, RM-19	1.5*	18
10/12/10	F4	Koa	3	5	SW, RM-14	2*	21
10/12/10	R14	Koa	3	6	SW, RM-19, I&M TR1	4	30
10/13/10	F3	---	3	4.5	SW, RM-16	5.5	30
10/13/10	R17	Koa	3	5.5*	SW, E fence corner, N	5*	31.5
10/20/10	F10	Puu	2	5*	NAR, RM-2	4.75*	19.5
10/27/10	R13	Koa	2	4.5	SW, RM-14, I&M TR4	3.5	16
11/8/10	R16	---	2	5*	NAR, RM-4B, LB-29	4.75*	19.5
11/9/10	F8	New	3	4.5*	NAR, NU, RM-5C	3.75*	24.75
11/23/10	F9	---	4	5*	NAR, NU, RM-3C	6.75	47
12/1/10	R12	New	3	5.5*	NAR, SW fence, NW fence	6.25*	35.25
12/22/10	F6	New	4	4.5*	NAR, Ag Unit, RM-8	3.75*	33
1/18/11	R11	---	2	5*	SE, N-NW to RM-8 unfenced	6*	22
2/2/11	R15	---	2	4.5*	NAR, NU, RM-5C, RM-5 unfenced	6.75*	22.5

Projected versus Actual Efforts for 2010

The protocols for FTPC and EIPS projected work for both monitoring projects to be completed over the course of six and a half months. Specifically, the FTPC protocol called for four months to complete 60 plots and 2.5 months for EIPS to 40 transects in the 'Ōla'a and East Rift/Nāhuku sampling frames. With a projected field crew consisting of one crew leader and three technicians working three of their four ten-hour days in the field each week, the estimated months for completion can be translated into 192 and 120 worker days, respectively (where worker days are calculated as: estimated months*4 weeks per month* 4 person crew* 3 field days per week). Actual field monitoring for FTPC took I&M crews 257 worker days with an average crew size of five people (including plot R25 in 'Ōla'a sampled in 2011). Actual field time for EIPS took 76 worker days with an average crew size of three people. As noted in the field efforts sections above, all proposed monitoring sites were not completed in 2010. Forty one of the 60 FTPC plots (68%) and 29 of the 40 transects (73%) were sampled over the course of the field season. Additionally, the field season extended longer than expected, running until February 2011 instead of November 2010. The longer field season can be attributed to the late development of the EIPS protocol, extended hiking/access times, and the fact that 2010 was a pilot year for both monitoring projects. Future crews should be sure to take diligent notes on site access to aid in future trip planning, record access and monitoring times, and camp whenever possible to decrease times spent on travel.

2011

In 2011, the I&M vegetation field crew monitored FTPC plots and EIPS transects in wet forest and subalpine shrubland communities at HAVO and FTPC in the coastal strand community at KAHO. All proposed plots and transects were completed, with a total of 60 plots and 50 transects established and monitored within wet forest and subalpine shrubland communities at HAVO. Additionally crews monitored 15 plots in the coastal strand at KAHO, and one wet forest plot in ‘Ōla‘a at HAVO.

The field season for FTPC and EIPS monitoring ran from May 24 to November 17, 2011, though four days between March to mid-May were spent in the field conducting cultural clearance surveys required for compliance with Section 106 (see subalpine shrubland and coastal strand sections for more details). The weather remained clear for the majority of the sampling period and did not hamper data collection. We accrued minimal overtime usually for transportation reasons, specifically due to long hikes or extended driving times in upper Kahuku. Because most plots were relatively close to roads, much less hiking was required for reaching plots this season, which helped to increase the number of plots and transects possible in one day. Additionally, the less vegetated subalpine shrubland, “wet forest” pastures and shorter EIPS transects allowed crews to work more efficiently and monitor plots and transects simultaneously. The project lead and field leader contacted HAVO NRM hunters for updates on road conditions and to schedule around hunting dates at Kahuku. When accessed, not all roads were in good enough condition for driving. Crews should therefore refer to field notebooks or seek advice from someone who is familiar with the roads. Future crews should also work with Kahuku rangers for cabin availability.

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 FTPC monitoring. Daemerson Awong stayed on with the program from the previous year and assisted in leading crews in EIPS transects. Three seasonal field technician positions were filled by Laura Arnold (second season), Jacob Gross, and Forrest Phifer, the latter beginning in June 2011. Volunteers Keith Burnett and Malie Larish began in May and biotechnician Melissa Simon began in October 2011. The amount of field time each person spent on FTPC and EIPS during the season is represented below as a percentage based on the number of days worked during the field season. Because crews worked on both monitoring projects, sometimes during the same day, field days were not separated by project. Though the project lead was involved in other projects during the course of the field season, crew leaders and technicians focused office time on either FTPC or EIPS protocols exclusively unlike 2010. In 2011 the project lead spent fewer days in the field than the pilot year (2010) because methods had been resolved.

Table C.6. Personnel for 2011 combined FTPC and EIPS field season at HAVO and KAHO.

Observer	Position	Field Season months employed	Days worked during field season	Field days	% Field work
Alison Ainsworth	GS-11	6.5	103	13	12.6
Corie Yanger	GS-7	6.5	103	43	41.7
Daemerson Awong	GS-5	6.5	103	48	46.6
Laura Arnold	GS-5	6	99	55	55.6
Jacob Gross	GS-5	6	97	46	47.4
Forrest Phifer	GS-5	5.5	92	39	42.4
Keith Burnett	VIP	5	77	41	53.2
Malie Larish	VIP	3.5	58	13	22.4
Melissa Simon	GS-7	1	22	6	27.3
Adam Mehlhorn	GS-7	0.5	4	3	75.0

Training Effort

Crew members spent approximately two weeks participating in office and field trainings applicable to both protocols. 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 both volunteers 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 is the remaining time that crew members did not spend 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. Throughout the season, data entry was much faster than the previous year because plots generally contained fewer large trees and tree ferns, and less coarse woody debris, than wet forest plots in 2010.

Field Effort

Similar to 2010, field effort was calculated by summing site monitoring and access times. Plot and transect times in Table C.9 refer to the length of crew visit. Total worker hours were calculated by multiplying transit and monitoring site completion times by crew size. In 2011, field work began in the Kahuku wet forest sampling frame and was almost complete when KAHO coastal strand community monitoring commenced. After KAHO was complete (two weeks), crews shifted back to Kahuku to start subalpine shrubland community monitoring. Conducting field work this way worked well to split up the season and get the crew exposed to monitoring in different communities and sites.

It was beneficial to begin with wet forest where monitoring was more complex. The transition to coastal strand and subalpine shrubland therefore ran smoother because the crew was familiar with methods and could concentrate more on plant identification. During the field season, the crew recorded travel and plot completion times, access notes and overtime in Rite-In-The-Rain notebooks. These notes were essential for calculating field effort for both protocols.

From May to November 2011, 60 FTPC plots and 50 EIPS transects were monitored in the wet forest and subalpine shrubland of HAVO, plus 15 plots on the KAHO coastal strand and one ‘Ōla‘a plot at HAVO. In total, crews spent 73 calendar days in the field, including cultural clearance surveys and partial days for travel. Crews worked on both monitoring projects throughout the field season, often sampling both FTPC plots and EIPS transects on one camping trip. On average, crew sizes consisted of four people per day, though teams sometimes split to survey multiple plots or transects at the same time. Including the three trips to the subalpine shrubland for cultural clearance surveys and transect monitoring, the I&M crew spent a total of 2221.5 worker hours (222 worker days) in the field driving, hiking and surveying FTPC plots and EIPS transects in the wet forest and subalpine communities at HAVO. During the two weeks spent at KAHO, crews spent a total of 359.5 worker hours (36 worker days) accessing and monitoring coastal strand communities.

Below we present the 2011 field efforts, first by plant community type then region for both monitoring projects. Since FTPC and EIPS ran concurrently, often with multiple plots or transects visited in one day, transit times were not separated by project. Similarly, crews occasionally monitored sites within different zones during one trip, preventing accurate transit calculations by zone or sampling frame. Daily transit times (driving and hiking summed) however, are listed within Table C.9 to aid with future monitoring plans. Field effort times summarized in the text are therefore strictly for plot and transect setup and monitoring with transit times omitted. In the Kahuku wet forest and subalpine shrubland, crews spent a total of 1062 worker hours (106 worker days) on transit alone, accounting for 48% of the total field worker hours in the two sampling frames.

Most field work in 2011 necessitated camping and some remote locations in Kahuku required helicopter assistance for transporting gear and crew members. Employee backcountry permits were filed with HAVO rangers at the Kīlauea Visitors Center for overnight stays in the Kahuku Unit. Park dispatch and a NRM park ecologist assisted with helicopter operations and field communication. Crews unlocked park gates using NPS issued keys.

Wet Forest

Within Kahuku Unit proposed plots and transects were distributed between the paddocks and a narrow strip above Ka‘ū Forest Reserve. Decades ago, the paddocks were converted from wet forest to pastures of non-native grasses and herbs with few remnant trees and kipukas (small islands) of native vegetation. The zone of wet forest above Ka‘ū Forest Reserve contains intact canopy and ungulate damaged understory.

All Kahuku wet forest sampling frame plots and transects were completed between May 24 and November 2, 2011. In total, the amount of time crew spent sampling the Kahuku wet forest was 531.5 worker hours (53 worker days) for the 30-20 m x 50 m plots and 141 worker hours (14 worker days) for 30-5 m x 250 m transects. Additionally, crews spent 30 worker hours (3 worker days) conducting plot re-reads in the wet forest. Plot completion times and access details are summarized in Table C.9.

The wet forest in Kahuku was divided into two zones. Paddocks is located in the southern portion of Kahuku, while the zone Above Ka'ū Forest runs along the border of the park. Paddocks are further divided into sections P-1, P-2 and P-3.

Table C.7. Classification of plots and transects in the Kahuku wet forest sampling frame.

Zone	Unit	Plots	Transects
Paddocks	P-1	F7, F10, R25, R26	F5, R19
	P-2	F8, F9, F11, F13-F15, R24, R27, R29, R30	F2-F4, R17, R20
	P-3	F12, R22, R23, R28	F1, R16, R18
Above Ka'ū Forest	East	F1-F6, R16, R17, R19, R20	F10-F15, R24-R30
	Mauka	R18, R21	F6-F9, R21-R23

Kahuku Paddocks Wet Forest

When conducting wet forest surveys in the paddocks, the crew stayed at the Administration building near the main Kahuku Unit entrance. Because the building was under renovation we spent most of our time outdoors, where mosquito abundance necessitated use of mosquito coils and insect repellent. Pigs were often present, though no problems arose. Some crew members slept in the house while others pitched tents on the lawn around the house.

For FTPC, nine fixed and nine rotational plots were monitored in the paddocks, totaling 329.25 worker hours (32.9 worker days, transportation excluded) with an average of 18.3 worker hours per plot. Plots F12 and F15 were re-read for quality assurance and were monitored on a camping trip from late October to early November, requiring 16 worker hours (1.6 worker days) to complete. Established invasive plant transects in the paddocks consisted of five fixed and five rotational transects. Monitored throughout the field season from June to November, crews completed transects in 61.5 worker hours (6.2 worker days), averaging 6.2 worker hours per transect.

Work-provided sport utility vehicles (SUVs) were sufficient for driving on gravel and pasture roads within the paddock system, though we may have had trouble in sustained rainy weather. Roads off of the main paddock road are almost entirely grassy and become very slippery with rain. We used caution on steep hills and often had crew members scout the road to help pick a safe path. For example, the crew drove from plot F8 to plots R24 and R29 and, after scouting, decided to park uphill from plots R24 and R29 due to a steep and rocky spot in the road.

Road conditions within the paddocks were fair with occasional hazardous spots. There was a significant dip in the roadside from the main paddock road to plot F9, and the road between plots F9

and R30 was sometimes slippery from rain. With muddy road conditions, it was also possible to get stuck on the way to plots R23, R28 and transect R18.

All plots in the Paddocks were sampled at their proposed location with the exception of FTFC plot F10. The plot was moved because the original location was in the middle of enclosure #4. The plot was randomly relocated 100m from the south end of the fence, then 100m south of the enclosure centroid.

Fixed EIPS transect F3 was adjusted from its proposed location to match the nearest station on a Forest Bird legacy transect.

Kahuku Above Ka'ū Forest Reserve Wet Forest

The area of Kahuku wet forest above Ka'ū Forest Reserve consisted of the East and Mauka Hunt Units. Although road conditions were rougher than in the paddocks, we were able to reach the Mauka Unit plots using the work SUVs. However, to access East Unit the project lead requested a vehicle trade with Resources Management, and procured a lifted crew cab truck (ability to seat 5 people comfortably) with 4-wheel drive capability for navigating the rough upper Kahuku Paddock roads. The crew utilized both the Administration building and the Nene Cabin (described in East Kahuku section) to finish wet forest plots and transects.

Completion of the twelve wet forest plots above the Ka'ū Forest took a total of 202.25 worker hours (20 worker days), with an average of 16.85 worker hours per plot. Plot F6 in the Mauka Unit, and plot F3 in the East Unit were re-read for quality assurance and required a total of 14 worker hours (1.4 worker days) for the two plots. Wet forest transects above Ka'ū Forest Reserve consisted of ten fixed and ten rotational transects and took crews 79.5 worker hours (about 8 worker days) to complete. One rotational transect (R25) was adjusted from its original location to avoid starting on state land. On average it took crews 4 worker hours to monitor one transect above Ka'ū Forest Reserve.

Wet forest plots and transects above Ka'ū Forest Reserve were located within two park hunt units. Three plots (one fixed, two rotational) and seven transects (four fixed, three rotational) were completed in the Mauka Hunt Unit. Nine plots (five fixed, four rotational) and 13 transects (six fixed, seven rotational) were completed in the East Hunt Unit. Mauka Unit plots F6, R18, and R21, and transects F6, F7, F8, and F9 were close to the road and easy to access. To reach plots F2, F3, R17, R19, and R20, and transects F10, F11, F12, R24, R26, and R29 in the East Unit we parked at the CCC cabin and hiked directly to each plot. For plots F1, F4, F5, and R16 we again parked at the CCC cabin, but first hiked to the HAVO boundary fence then across to the east. Plot R20 was slightly shifted, and plot R19 was shifted and rotated for safety reasons. After monitoring transects F13 and R30, we found that wet forest sites near the boundary fence could be more easily accessed by traversing through the forest, where crews could avoid steep hills (e.g., large ravine between plot F5 and transect F15) along the fence.

Safety in Kahuku Wet Forest

The I&M team worked closely with park hunters to ensure avoidance of hunter activities within certain units. The hunters usually released a hunting schedule one month in advance and the project lead and field leader were able to schedule camp trips and field work accordingly. Sometimes the crew worked in Mauka and East Units and had to wait until hunters were finished for the day, which at times was after dark. Other times, the crew waited for the hunters in the morning at the Administration building and both crews drove up through the paddocks together. In one incident during the season, a crew member was feeling ill and had to be brought home. The designated field leader (both the project lead and field leader were not on that trip) contacted the hunters and had to wait for confirmation of a ceasefire before proceeding to leave Kahuku through the paddock area. Such careful communication was crucial to vegetation staff safety. As an extra precaution, crew members wore bright orange field vests while working in the field at Kahuku to avoid being misidentified by hunters.

Other safety concerns included concealed holes, wild dogs and wet roads. Within the paddock area tall grasses covered holes and crews had to hike with caution. We had also been warned of wild dogs present in Kahuku Unit. The project lead purchased pepper spray as a safety precaution, but no wild dogs were encountered during the season. Crews remained cautious while driving in the paddocks when roads were wet since slippery conditions increased the risk of getting stuck.

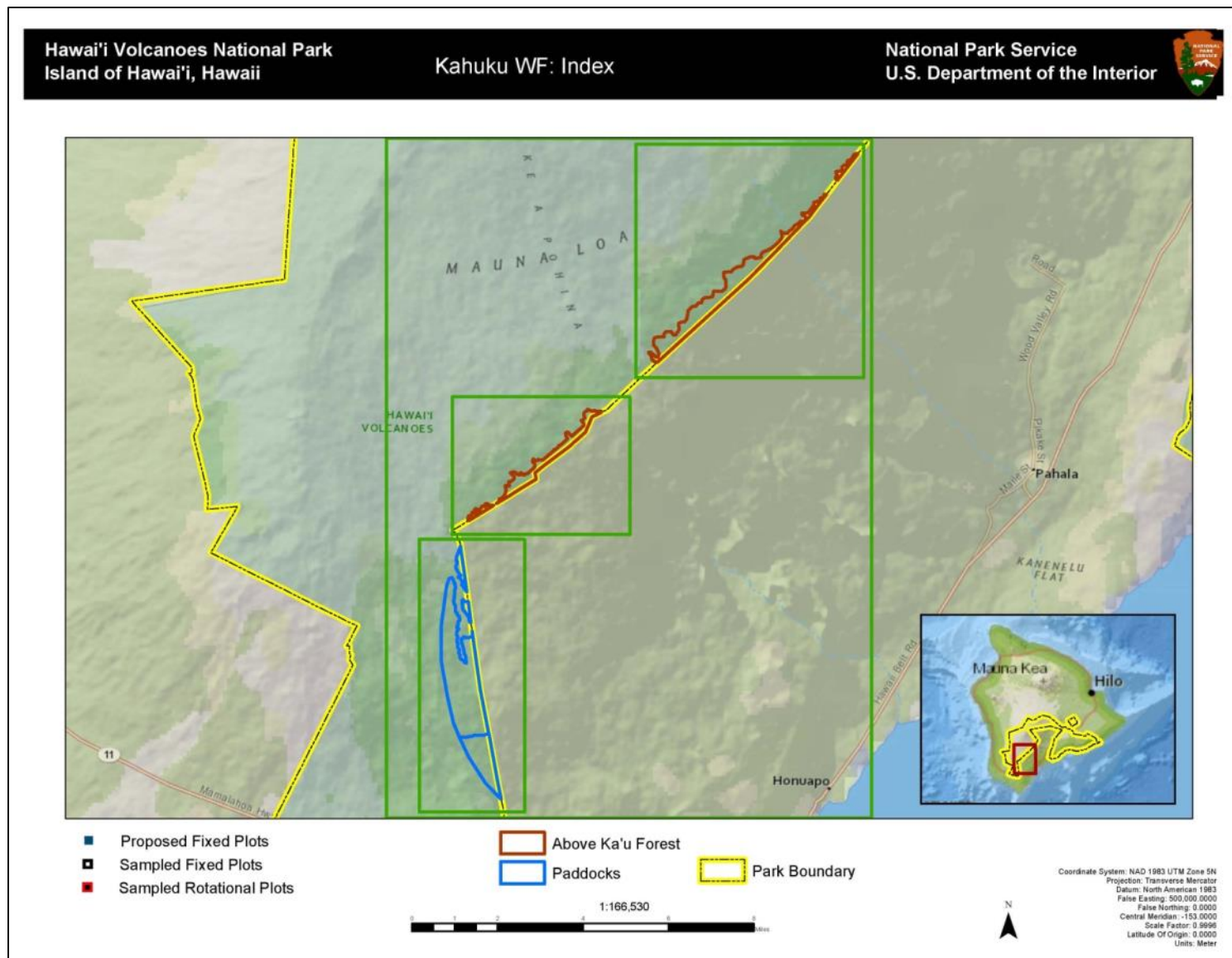
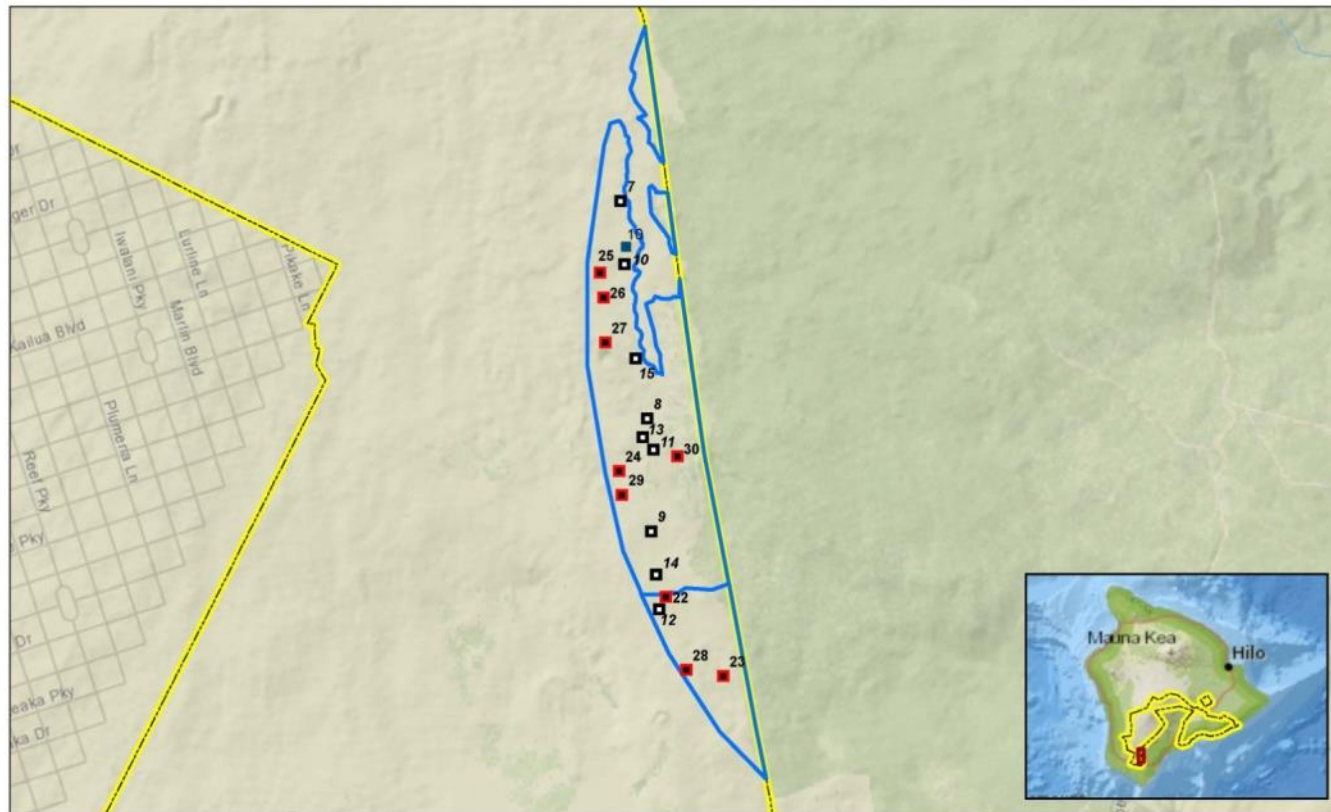
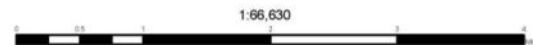


Figure C.5. Index of the Kahuku WF sampling frame. The two zones (Paddocks and Above Ka'u Forest) are outlined in blue and brown.



- Proposed Fixed Plots
- Sampled Fixed Plots
- Sampled Rotational Plots
- Above Ka'u Forest
- Paddocks
- Park Boundary



Coordinate System: NAD 1983 UTM Zone 5N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -153.0000
Scale Factor: 0.9998
Latitude Of Origin: 0.0000
Units: Meter

Figure C.6. Proposed and sampled FTPC plots in the Paddocks Unit (Paddocks zone) of the Kahuku WF. Only one plot (F10) was moved from its proposed location.

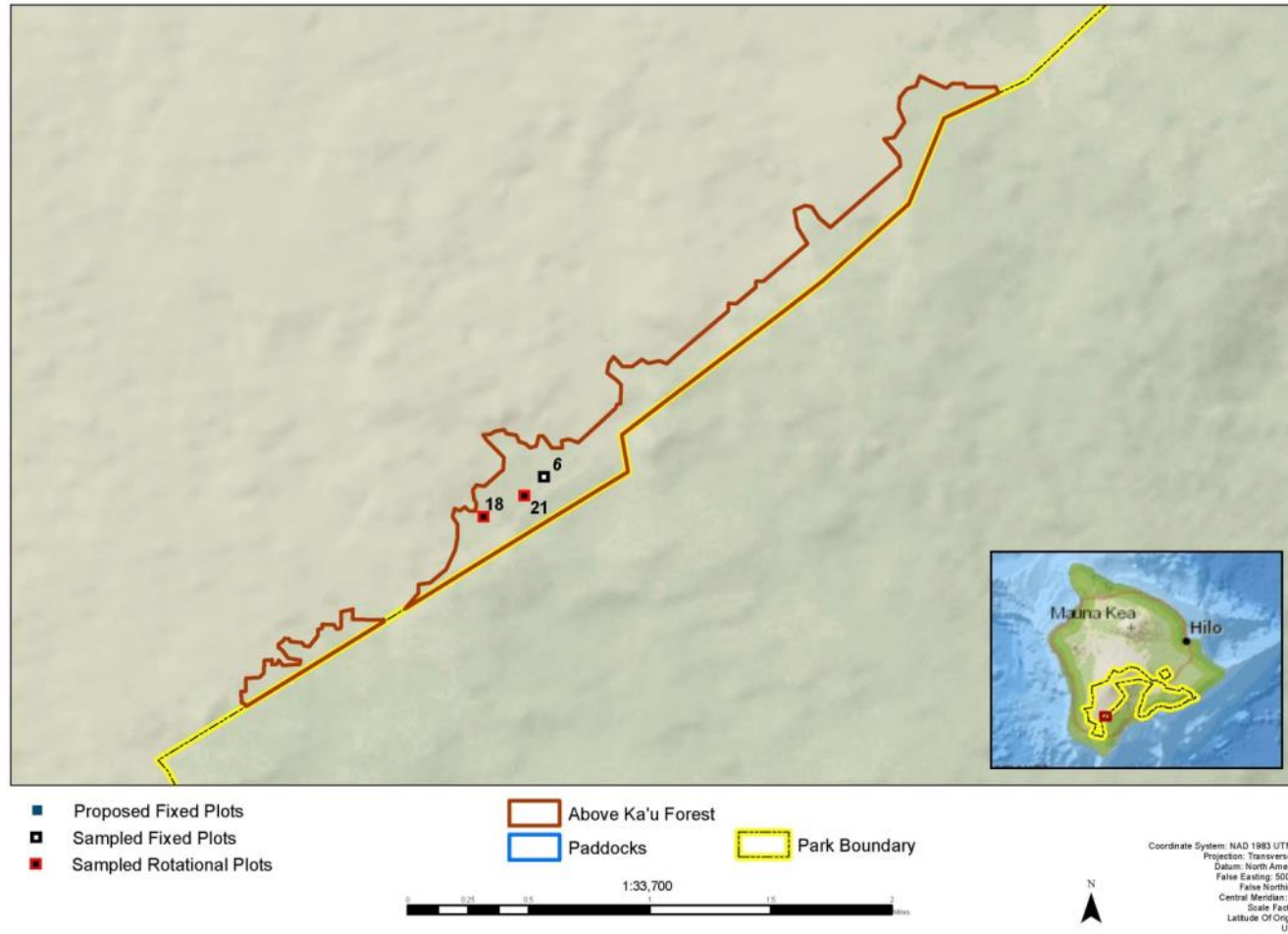


Figure C.7. Sampled FTFC plots of the Maunaka Unit (Above Ka'u Forest zone) of the Kahuku WF. All proposed locations were sampled.

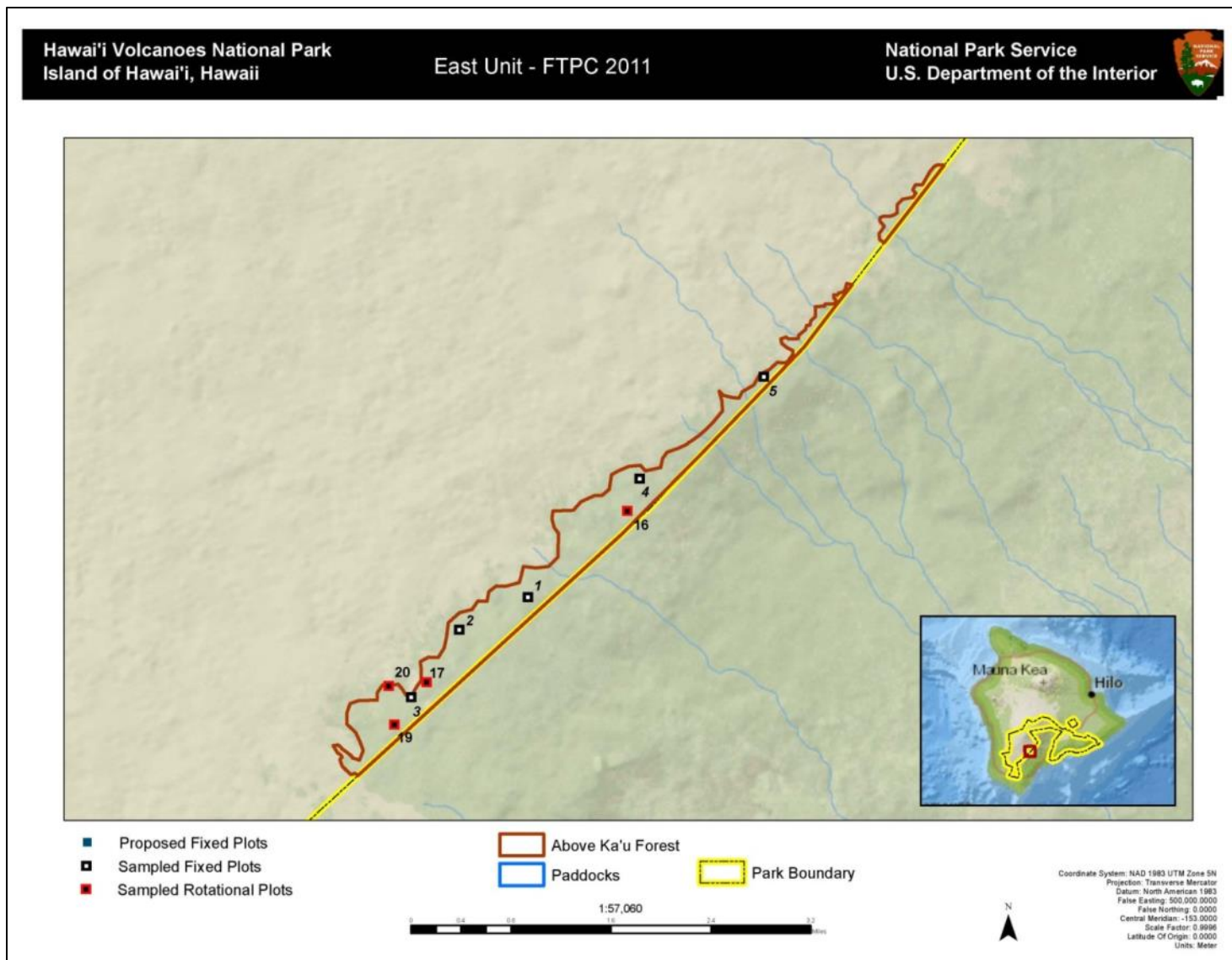


Figure C.8. Sampled FTPC plots of the East Unit (Above Ka'u Forest zone) of the Kahuku WF. Plots 19 and 20 locations were adjusted slightly for safety purposes.

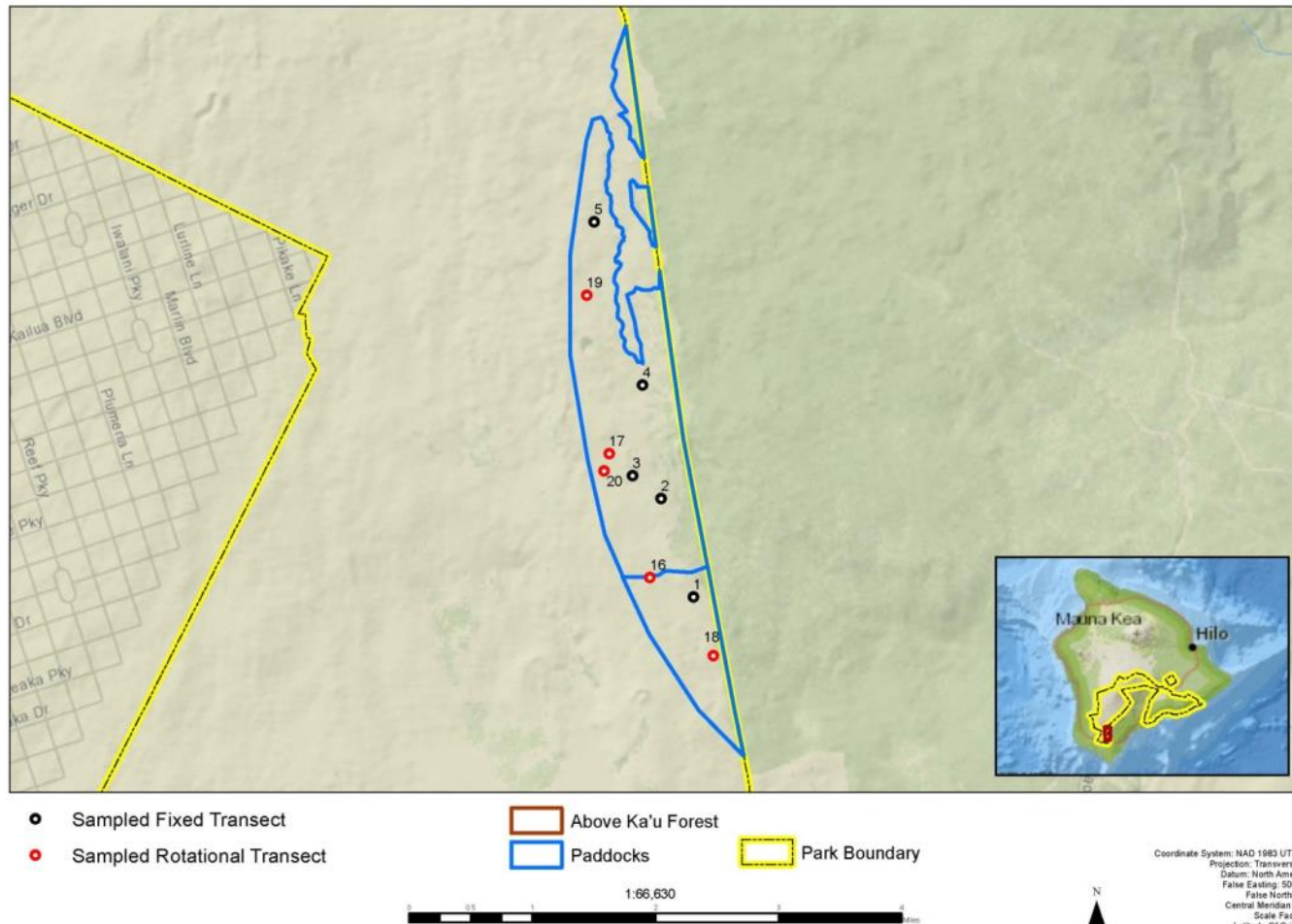


Figure C.9. Sampled EIPS transects of the Paddocks Unit (Paddocks zone) of the Kahuku WF. Points represent transect start locations. All proposed transects were sampled.

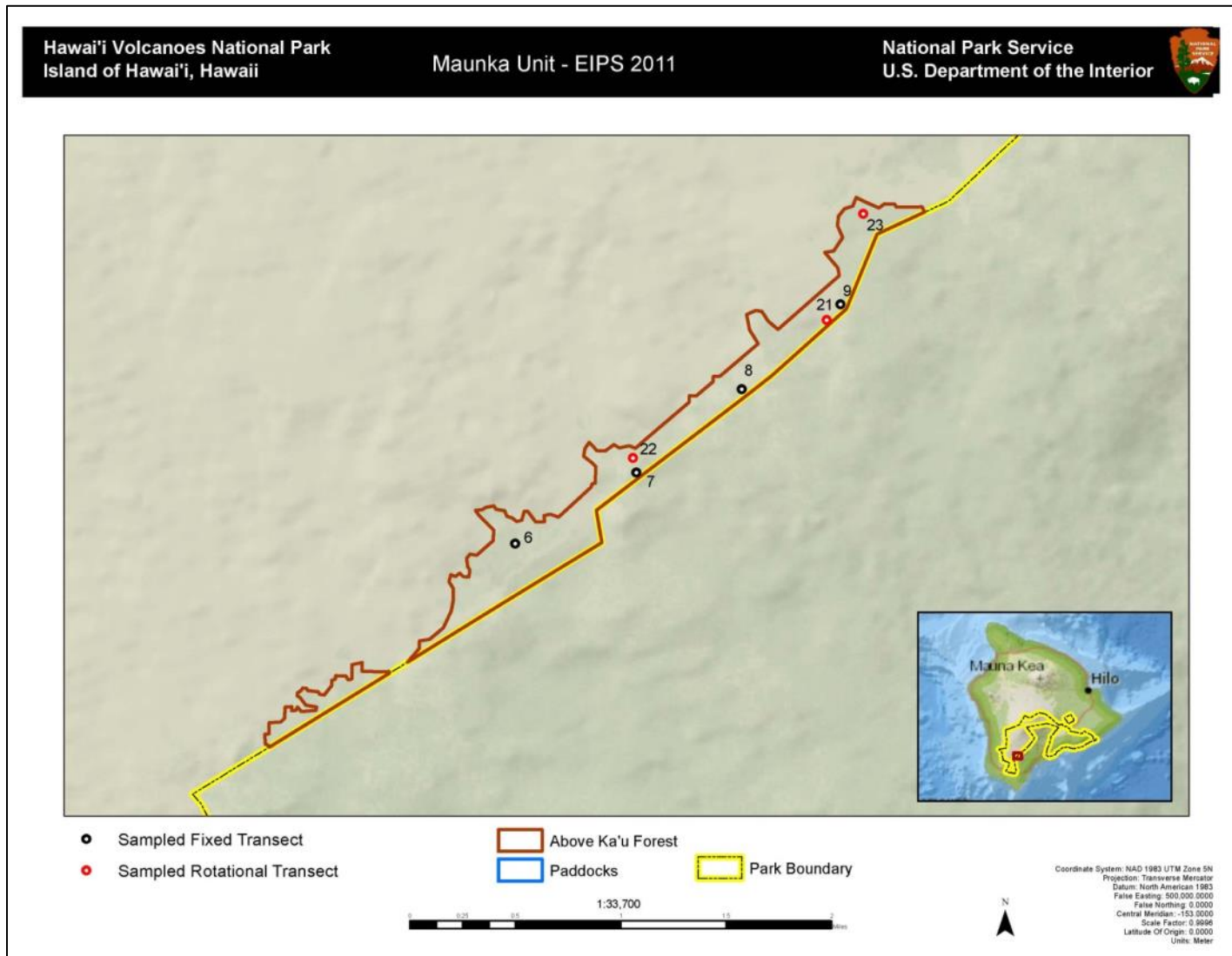
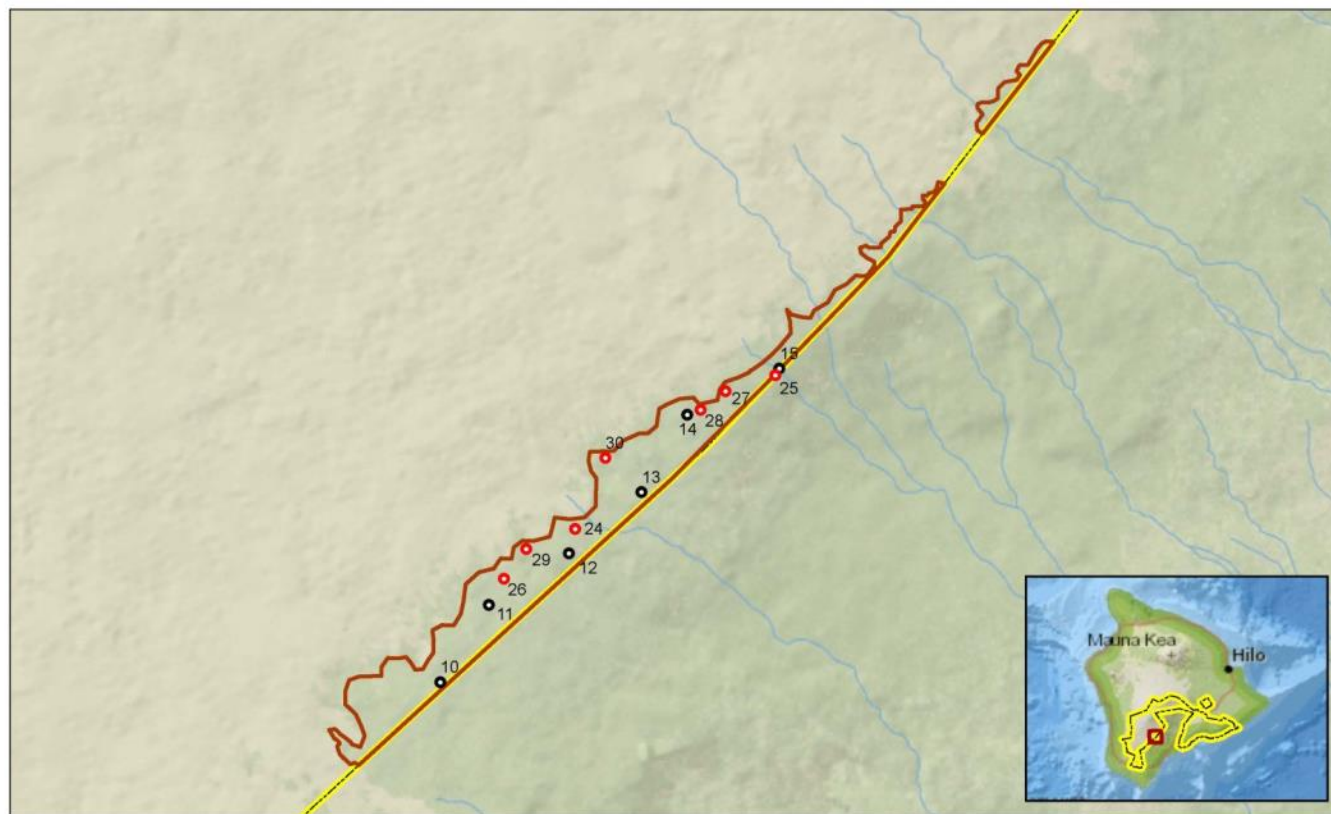


Figure C.10. Sampled EIPS transects of the Maunaka Unit (Above Ka'u Forest zone) of the Kahuku WF. Points represent transect start locations. All proposed transects were sampled.



- Sampled Fixed Transect
- Sampled Rotational Transect

- Above Ka'u Forest
- Paddocks
- Park Boundary



Coordinate System: NAD 1983 UTM Zone 5N
Projection: Transverse Mercator
Datum: North American 1983
False Easting: 500,000.0000
False Northing: 0.0000
Central Meridian: -153.0000
Scale Factor: 0.9998
Latitude Of Origin: 0.0000
Units: Meter

Figure C.11. Sampled EIPS transects of the East Unit (Above Ka'u Forest zone) of the Kahuku WF. Points represent transect start locations. All proposed transects were sampled except for R25, which was slightly shifted.

Subalpine Shrubland

In the subalpine shrubland all plots and transects were completed between July 25 and October 25, 2011 (Table 7). Because the sampling frame overlaps with sensitive cultural areas, the project lead and field leaders worked with park archeologists to comply with Section 106 and pre-check all permanent post locations for fixed plots and fixed transects not collocated with existing legacy transects. This surveying took place on four days from March to May 2011 and was done for both protocols. Since transect lines had to be walked in order to check post locations and non-native species were relatively sparse, we monitored transects F1, F6, F9 and F10 while the archeologist surveyed the area (Table C.9). This saved extra helicopter and driving trips later in the season. Though these transect surveys occurred prior to the official field season, access and completion times are still accounted for in the personnel and Kahuku work efforts tables. With travel time, transect reads and posts placed for FTPC plots, cultural clearance surveys took 53.5 worker hours in the subalpine shrubland.

Overall, 15 fixed and 15 rotational plots (20 x 50 m), plus 10 fixed and 10 rotational transects (5 x 500 m) were monitored in the subalpine shrubland community. Completion time took 308.25 worker hours (31 worker days) for plots and 116.5 worker hours (12 worker days) for transects.

Crews were divided in order to maximize plot completion in this geographically widespread community, which we categorized into four zones or areas: Above Ka‘ū Forest, Interior & West, Northwest Kahuku, and Mauna Loa Strip. Like the Kahuku wet forest zones, these were further divided into units. We used RM hunt units to classify our units and called areas between the West and East units Interior. For our descriptive purposes, we counted all plots and transects outside but upslope of the East Unit as part of the East Unit. In the 2011 field season, this applied to subalpine plots F11, R23, and R26, and transect R20.

Zone	Unit	FTPC Plots	EIPS Transects
Above Ka‘ū Forest	East	F4-F11, R19-R26	F2, F4-F8, R11, R14, R17, R19, R20
Interior & West	Interior	F12-F14, R27-R29	R12
	West	N/A	F1, R15
NW Kahuku	Open	F15, R30	F3, R18
ML Strip	ML Mauka	F1-F3, R16-R18	F9-F10, R13, R16

Subalpine Shrubland Above Ka‘ū Forest

Subalpine shrubland monitoring sites located above Ka‘ū Forest were completed by multiple camping trips between August and September, with re-reads in the months to follow. Aside from one helicopter-assisted trip in August (described below), crews completed vegetation surveys by camping at the Nene Cabin, CCC Cabin, one of two spike camps established close to the end of the upper Kahuku road (Junction camps 1 and 2), or East camp, a spike camp in the northern-most portion of the Above Ka‘ū Forest zone, accessed by helicopter. The project lead or field leader scheduled use of the cabins with park dispatch and Kahuku rangers. The Nene Cabin was equipped with a four-burner propane stovetop, though availability should be checked before going in future years. The cabin

sleeps three people, with room outside for pitching tents. Beyond the back gate is a latrine. During the field season the catchment tank was out of service. Crews should bring extra clothing for working and camping in the area because the cabin is located at 6000 ft elevation and temperatures get very cold. The CCC cabin is located at a similar elevation and has cots and an outhouse but no stove. Future crews sampling in East Kahuku may prefer to utilize the Nene Cabin as opposed to the CCC Cabin, as most subalpine monitoring sites are located above Nene Cabin and are accessible from there.

Subalpine plots above Ka'ū Forest were read between August and October and consisted of eight fixed and eight rotational plots. In total, the crew spent 181 worker hours (18 worker days) to complete monitoring in this area, with an average of 10.6 worker hours per plot. Plots F5, F6, and F7 were re-read for quality assurance from the end of October to the beginning of November, requiring 15 worker hours (1.5 worker days) to complete. Six fixed and five rotational transects were successfully monitored above Ka'ū Forest, totaling 66.75 worker hours (7 worker days). Transect F2 was adjusted from its original location because it started on lava. One transect in this zone took crews an average of 6.1 worker hours to complete.

Transect F2 (originally in the Interior zone) was relocated because vegetation was too sparse at the proposed location. Because the fixed transect required posts, it was relocated to an area Above Ka'ū Forest, specifically on an RM legacy transect that had already been approved by a cultural clearance survey.

Monitoring sites were accessed via SUV using the Kahuku Paddock Roads or via helicopter. In mid-August, a three-person crew completed FTPC plots F4, F9, F11, R19 and R26, and EIPS transects F8, R14 and R20 during a four day helicopter-assisted camp trip. The crew was flown from HAVO rainshed, and equipment in a sling load from Kapāpala, with a park ecologist serving as helicopter manager. For that trip, the primary field leader was able to show the helicopter pilot the general area to land and the pilot assisted in surveying for a suitable camp site. The field leader was required to belly hook the sling load for return operation

Interior and West

The Interior and West zone consists of subalpine shrublands that stretches from the east border of the Mauka Hunt Unit to western boundary of the West Hunt Unit (Figure C.12). Plots and transects in the Interior and West zone were completed between August and October during multiple camp trips based from the West spike camp (near plot F14) and the Nene Cabin. West camp was accessed by helicopter and established by a two-person crew in August 2011.

Three fixed and three rotational plots were monitored in the Interior and West zone. Plots were read between August and October, and totaled 35 worker hours (3.5 worker days). One fixed transect and two rotational transects were surveyed for established invasive weeds. Transect F1 was read in May 2011 and was read while a cultural clearance survey was being conducted. The two rotational transects were monitored in August and September. In total, without transit, transects in this zone required 8 worker hours (~1 worker day). No plots were re-read in the Interior and West.

Plots F12 and R29 were moved because proposed plots were unvegetated. Similarly, the azimuth of transect R15 was modified to avoid an 'a'ā flow and to follow a vegetated kipuka. Plot F13 was slightly relocated and the azimuth was adjusted to avoid a steep slope that posed a safety hazard.

Similar to the zone above Ka'ū Forest, plots in Interior and West monitoring were accessed utilizing both helicopter assistance and four-wheel drive vehicles. Transect F1 was accessed via helicopter and was monitored on May 19 alongside a cultural clearance survey. A two-person crew completed plots F14 and R29 and transect R15 in a two-day camp trip in the west in August 2011 where equipment and camp gear were minimal and both equipment and staff were internal. Helicopter operations were staged from the HAVO rainshed.

Northwest Kahuku

Northwest Kahuku was the most remote location for plot monitoring during the 2011 field season. Plots and transects in Northwest Kahuku were unique not only because of their remoteness, but also due to their diversity in non-native herbaceous species. Future crews will find it helpful to review species lists from this season to aid in the next round of monitoring, as the high plant diversity increased sampling time.

On the single trip to northwest Kahuku, one fixed plus one rotational plot and transect were surveyed for each monitoring project. Conducted from July 25-27, the crew spent a total of 32.25 worker hours on plant community plots and 27.75 worker hours on established invasive transects. On average crews spent 16.1 worker hours per plot and 13.9 per transect.

A collaborative helicopter-assisted camp trip between Resource Management (RM) and I&M took place in July 2011 to monitor plots F15 and R30 and survey transects F3 and R18. FTPC plot R30 was moved from an unvegetated a'ā flow. The Kahuku airstrip was used as a landing zone after appropriate permissions were obtained from Park personnel and a HAVO Horticulturalist served as helicopter manager. Because few camping operations had taken place in Northwest Kahuku since the Unit was acquired, the field leader had little information to help in planning the camp trip. This meant the camp site was not predetermined. From the airstrip, three personnel (two I&M, one RM) were flown to a location where plots would be easily accessible. The helicopter then went back to the airstrip to transport all field gear. The crew took all water and shelter necessities for the trip duration and established a spike camp on a flat portion of road. We recommend that future crews take narrow tents as there was limited space for tent setup. While the helicopter pilot used a long line to transport gear on the first operation, the field leader was required to belly hook the sling load for return helicopter operations. Future crews should note that it is unlikely that future trips can be staged from the Kahuku airstrip and will need to be staged from a further location.

Mauna Loa Strip

Monitoring sites in Mauna Loa Strip were sampled between late August and October, with the exception of EIPS transects F9 and F10 which were sampled alongside cultural clearance surveys in March. Camping was not necessary and crews completed surveys during day trips.

Completing focal plant community plots in Mauna Loa Strip took 60 worker hours for six plots and 3 worker hours for the plot F3 re-read. For established invasive transect monitoring, 14 worker hours were required to complete two transect surveys. On average plots in Mauna Loa Strip took 10 worker hours and transects 3.5 worker hours.

Almost all six subalpine shrubland plots located in Mauna Loa Strip were accessed by driving to the end of Mauna Loa Strip Road and then hiking. During cultural clearance surveys (March 2011), plots F1, F2, and F3 had permanent posts installed, and transects F9 and F10 were read. Only plot F2 required repeat helicopter transportation for actual plot monitoring, while plots F1 and F3 were accessed for the second time by foot. During the helicopter trip in August 2011, the crew first read transect R16 before hiking to and monitoring plot F2, where they were flown out. Crews reached plot F3 by hiking on the HAVO Mauna Loa Summit trail. Plots R16, R17, and R18, and transect R13, were also reached by hiking from the Strip Road and were completed as day trips. Plot R18 was moved north of the proposed site because it was unvegetated.

Safety in Subalpine Shrublands

Because working around and flying in helicopters are very dangerous it is highly recommended that crews operate under the guidance of a certified helicopter manager. All individuals traveling in helicopters this season were first trained in basic helicopter safety and only the field leader, with current crew member qualifications, was allowed to conduct belly hooks and long-line hook-ups. The primary field leader participated in all helicopter operations. Communication is also crucial for safety around helicopters.

Exposure to cold was a concern in subalpine shrubland. Weather was clear most of the time, so the crew applied sunscreen often and wore appropriate clothing for reducing sun exposure.

Crew members should also maintain awareness of footing. The pāhoehoe and ‘a‘ā flows in subalpine shrubland are highly uneven, and crews sometimes encountered skylights. Crew members must use extreme caution when near skylights as they are often undercut for some distance beyond the actual opening.

Beside the general concerns of exposure and uneven terrain, wild sheep and poaching were added concerns in Northwest Kahuku. Many wild sheep were encountered in the area, and although there were no dangerous encounters, crews exercised caution when sheep were nearby. Resource Managers also warned crew members of possible encounters with poachers or their ammunition although no encounters occurred during the field season. Finally, future crews should especially review identification characteristics of *Hesperocnide sandwicensis*, a stinging Hawaiian nettle encountered in Northwest Kahuku. Care should be taken around this herb as it is covered in stinging spines.

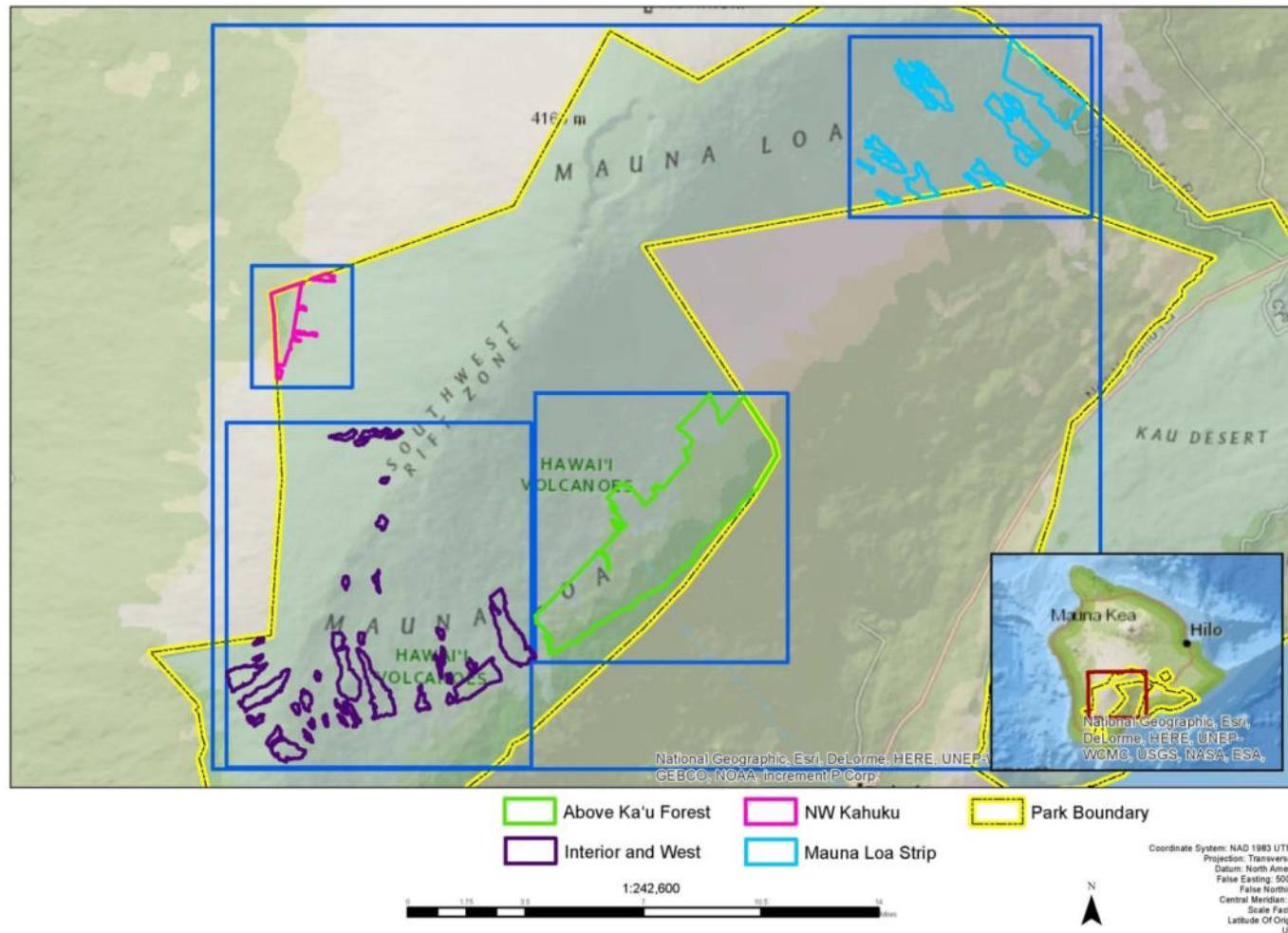


Figure C.12. Index of the subalpine shrubland sampling frame.

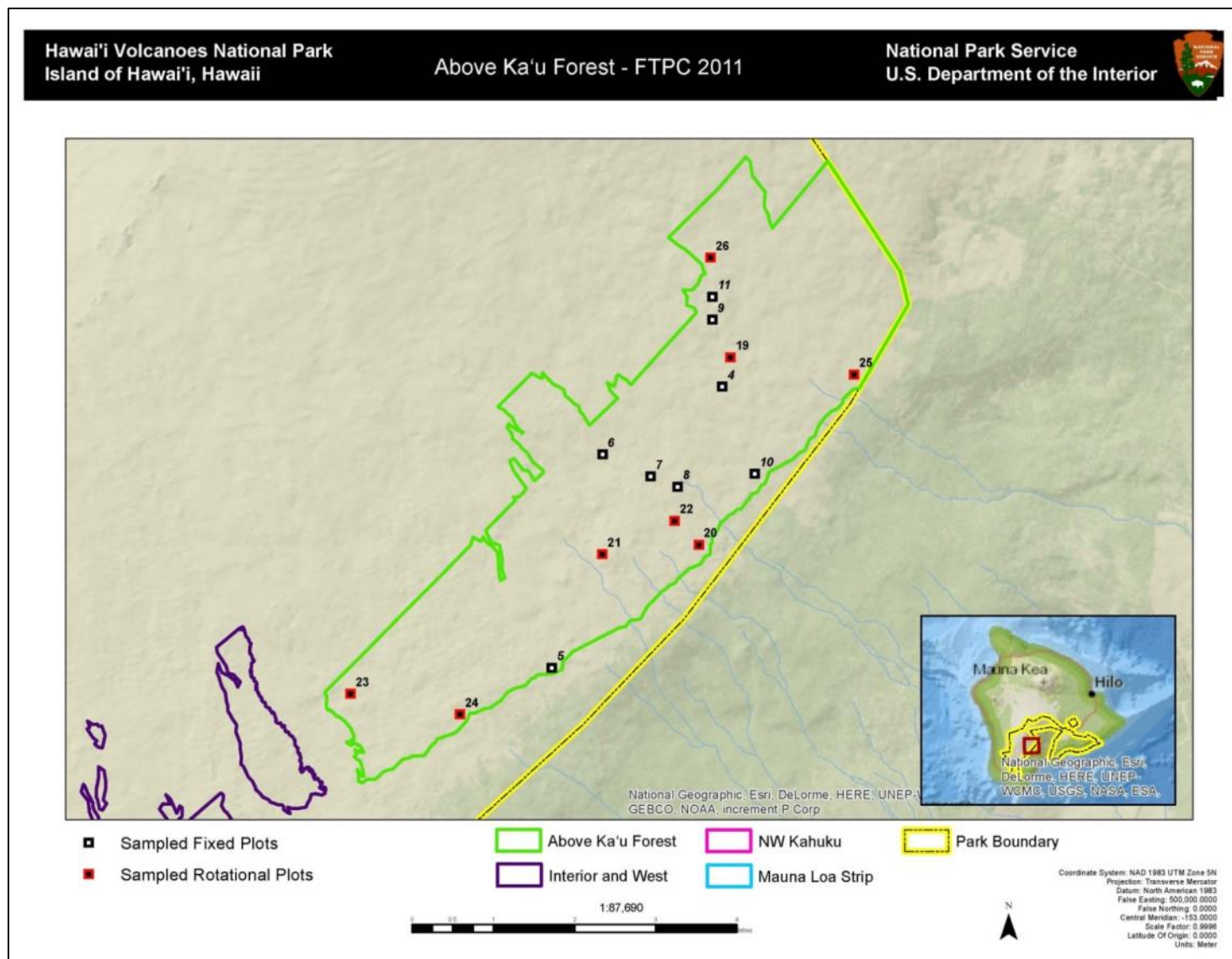


Figure C.13. Sampled FTPC plots of the Above Ka'u Forest zone of the subalpine shrubland. All proposed plots were sampled; no plots were shifted.

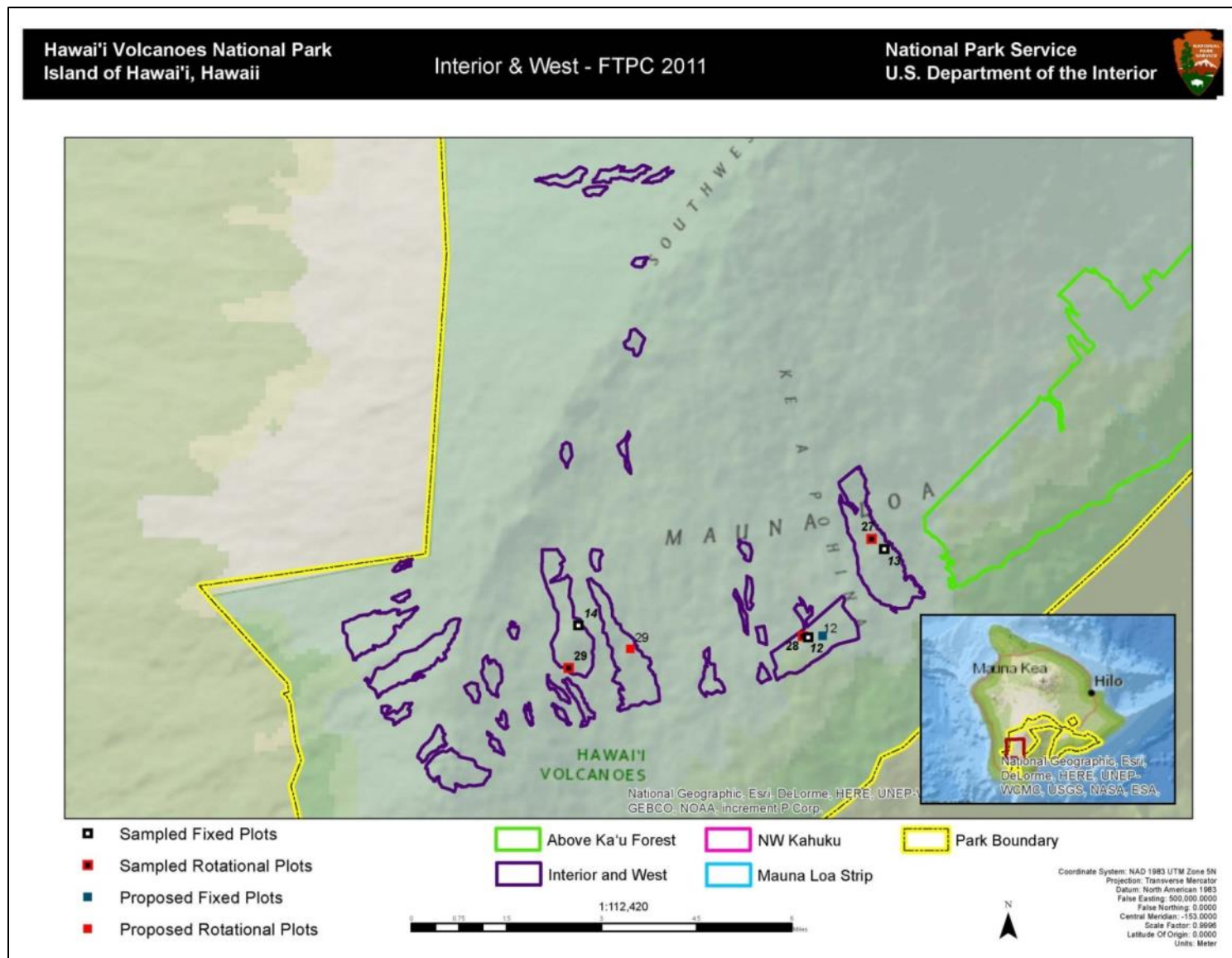


Figure C.14. Proposed and sampled FTPC plots in the Interior & West zone of the subalpine shrubland.

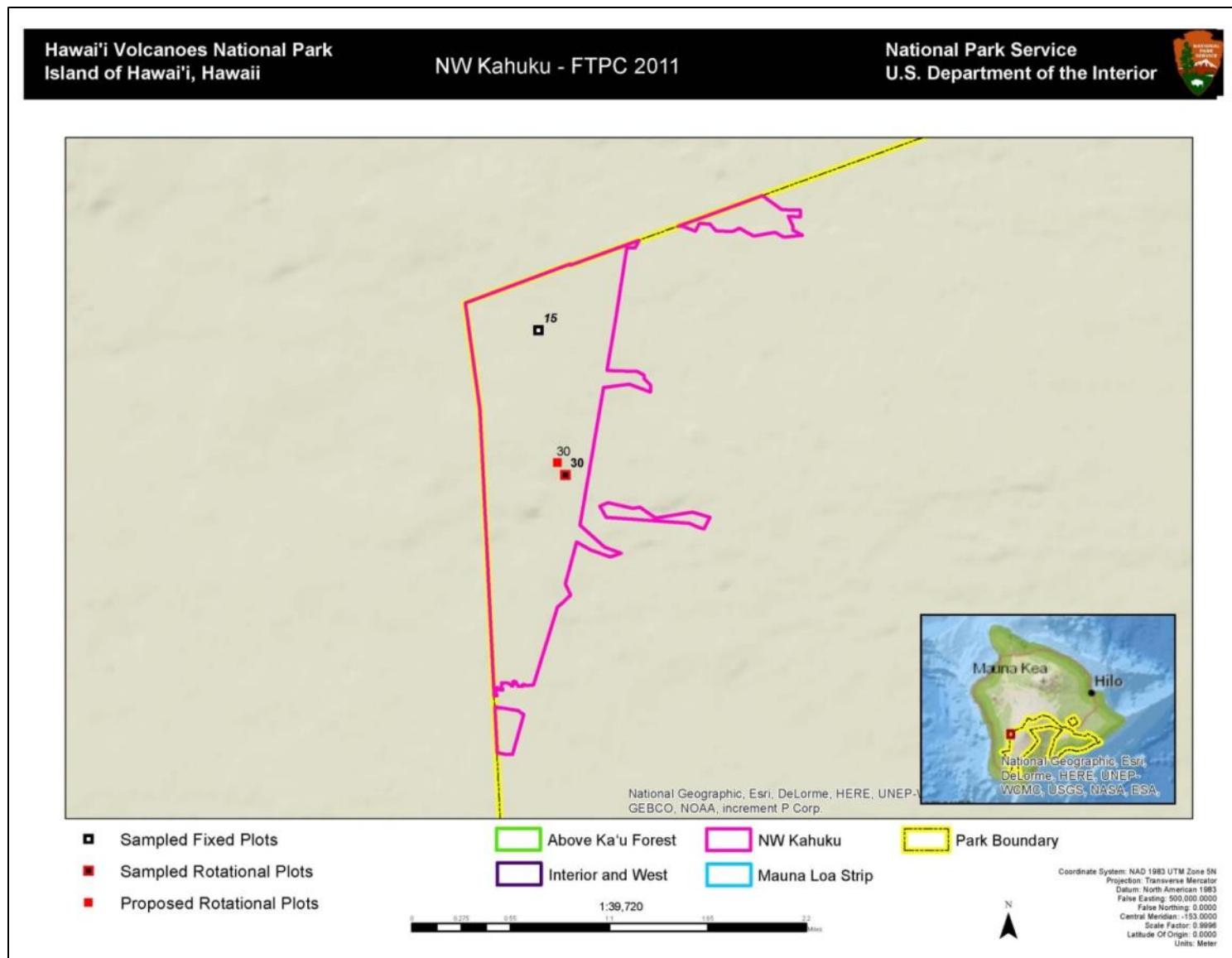


Figure C.15. Proposed and sampled FTPC plots of the NW Kahuku zone of the subalpine shrubland.

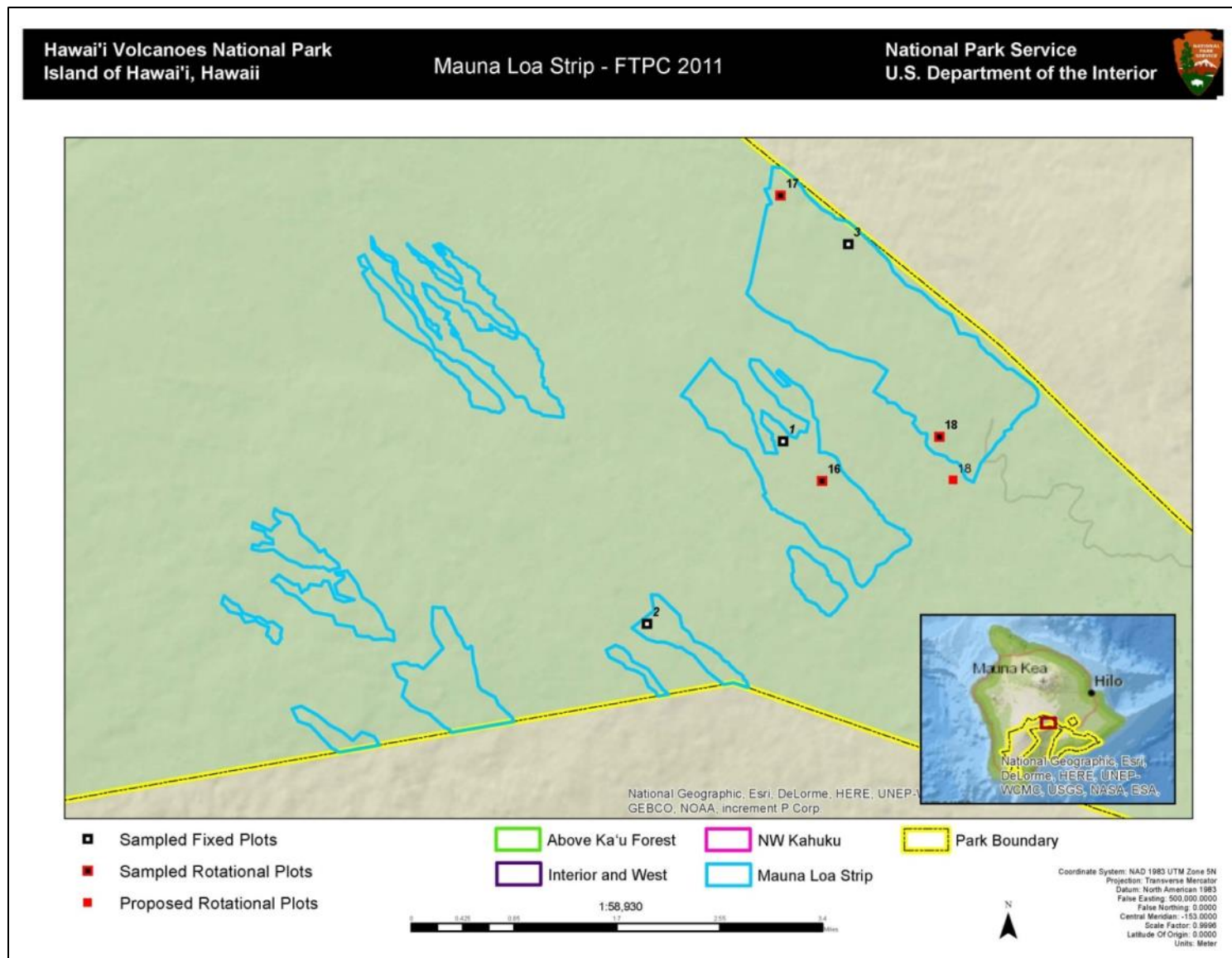


Figure C.16. Proposed and sampled FTPC plots of the Mauna Loa Strip of the subalpine shrubland.

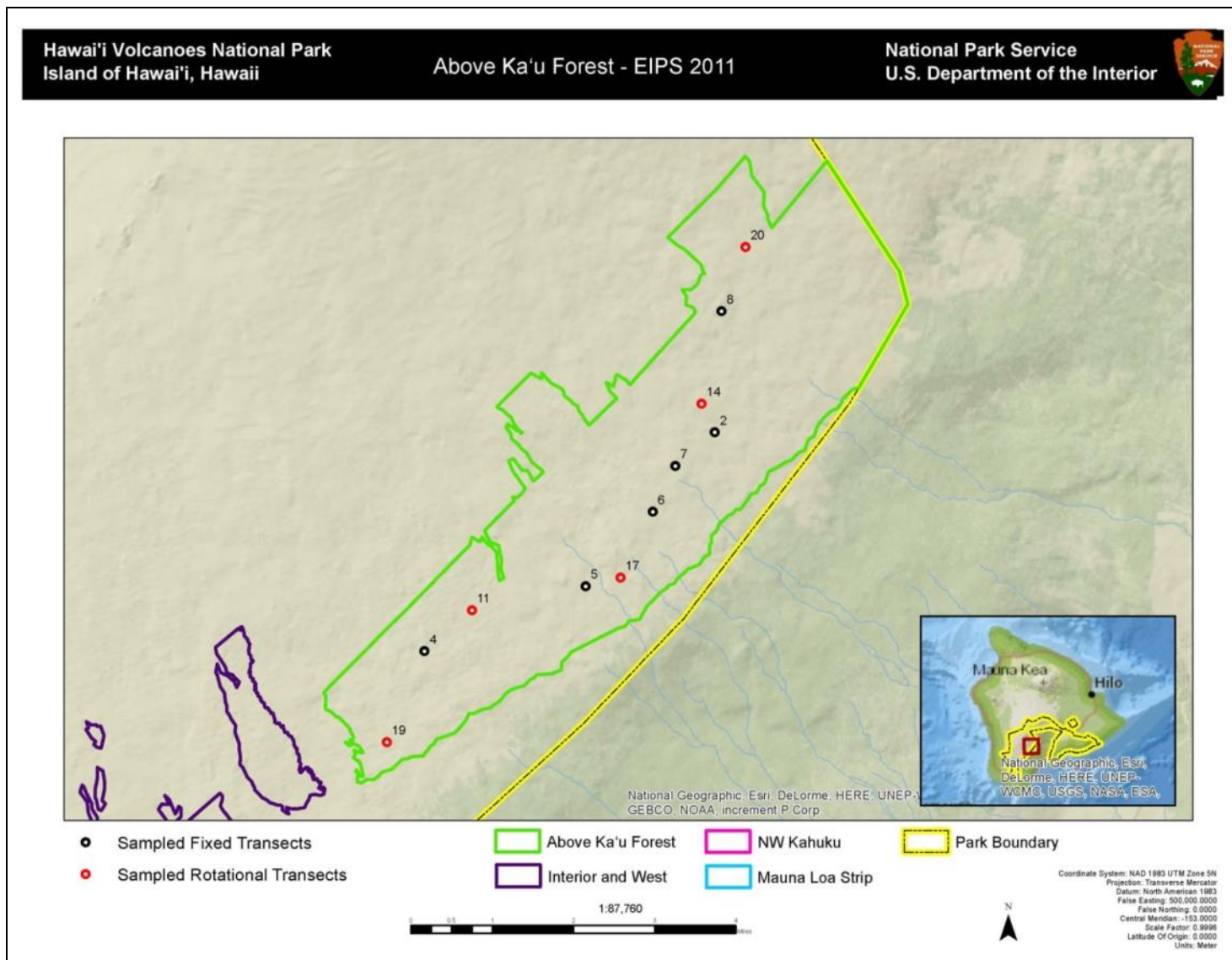


Figure C.17. Proposed and sampled EIPS transects of the Above Ka'u Forest of the subalpine shrubland. Points represent transect start locations.

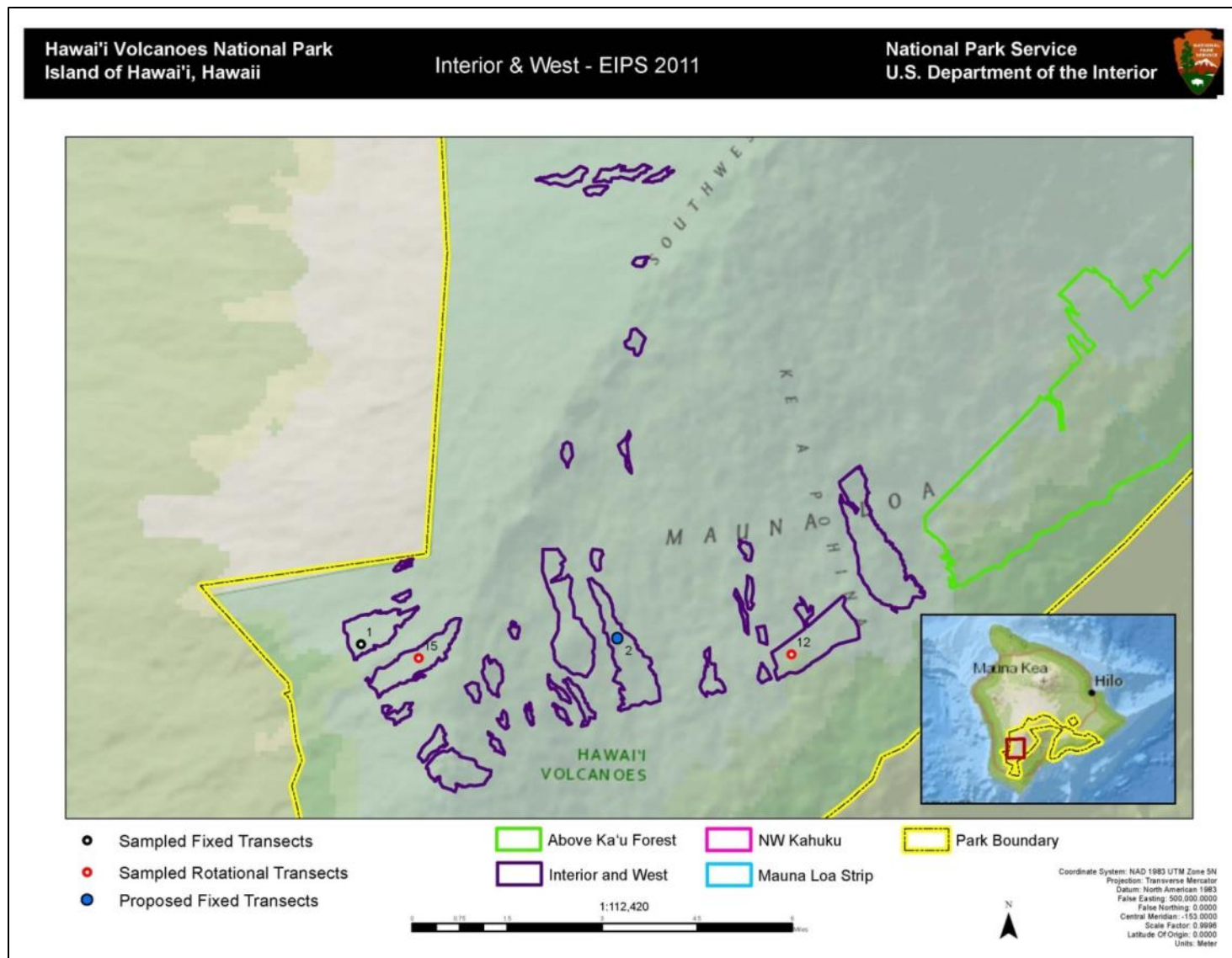


Figure C.18. Proposed and sampled EIPS transects of the Interior & West zone of the subalpine shrubland. Points represent transect start locations.

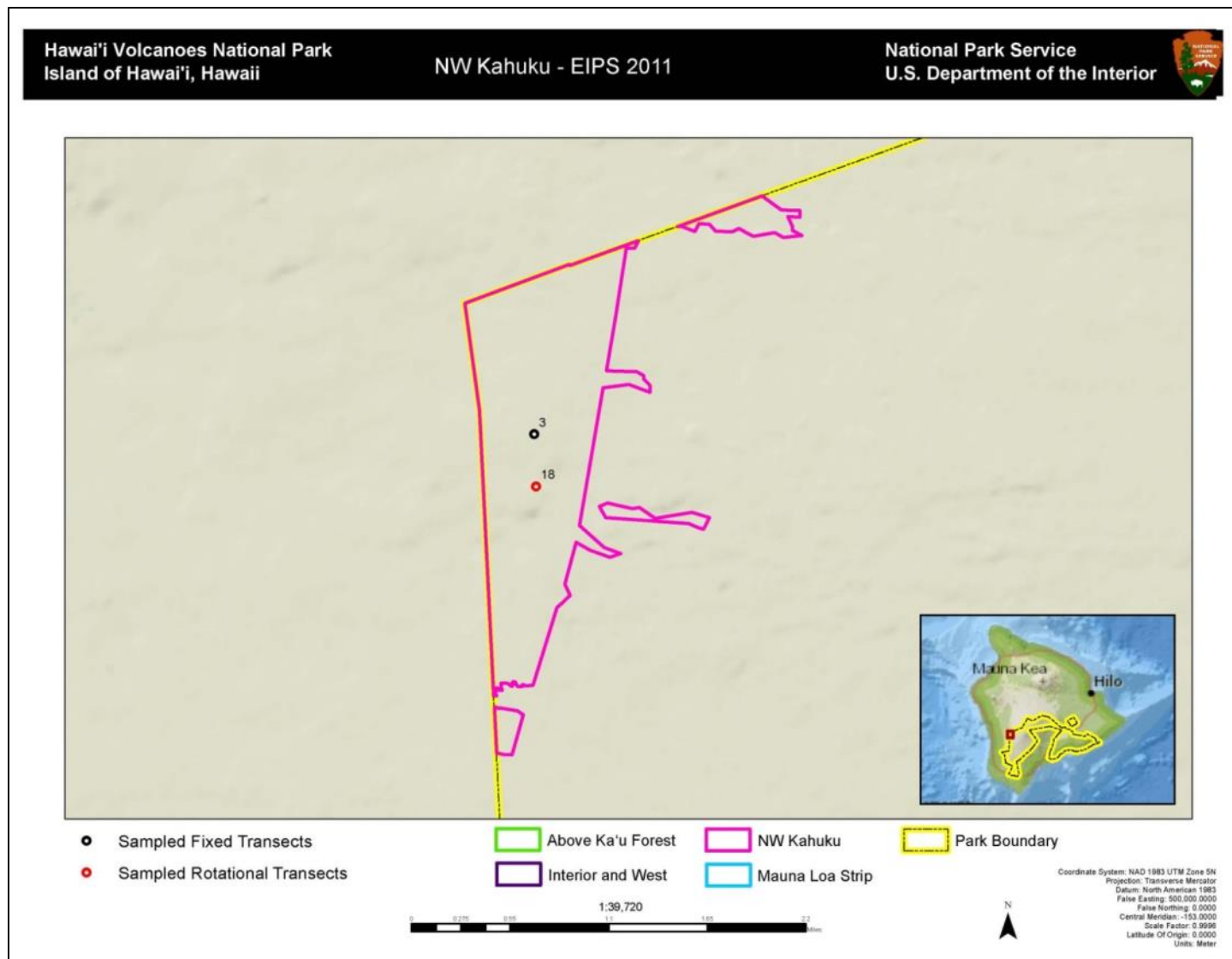


Figure C.19. Proposed and sampled EIPS transects of the Interior & West zone of the subalpine shrubland. Points represent transect start locations.

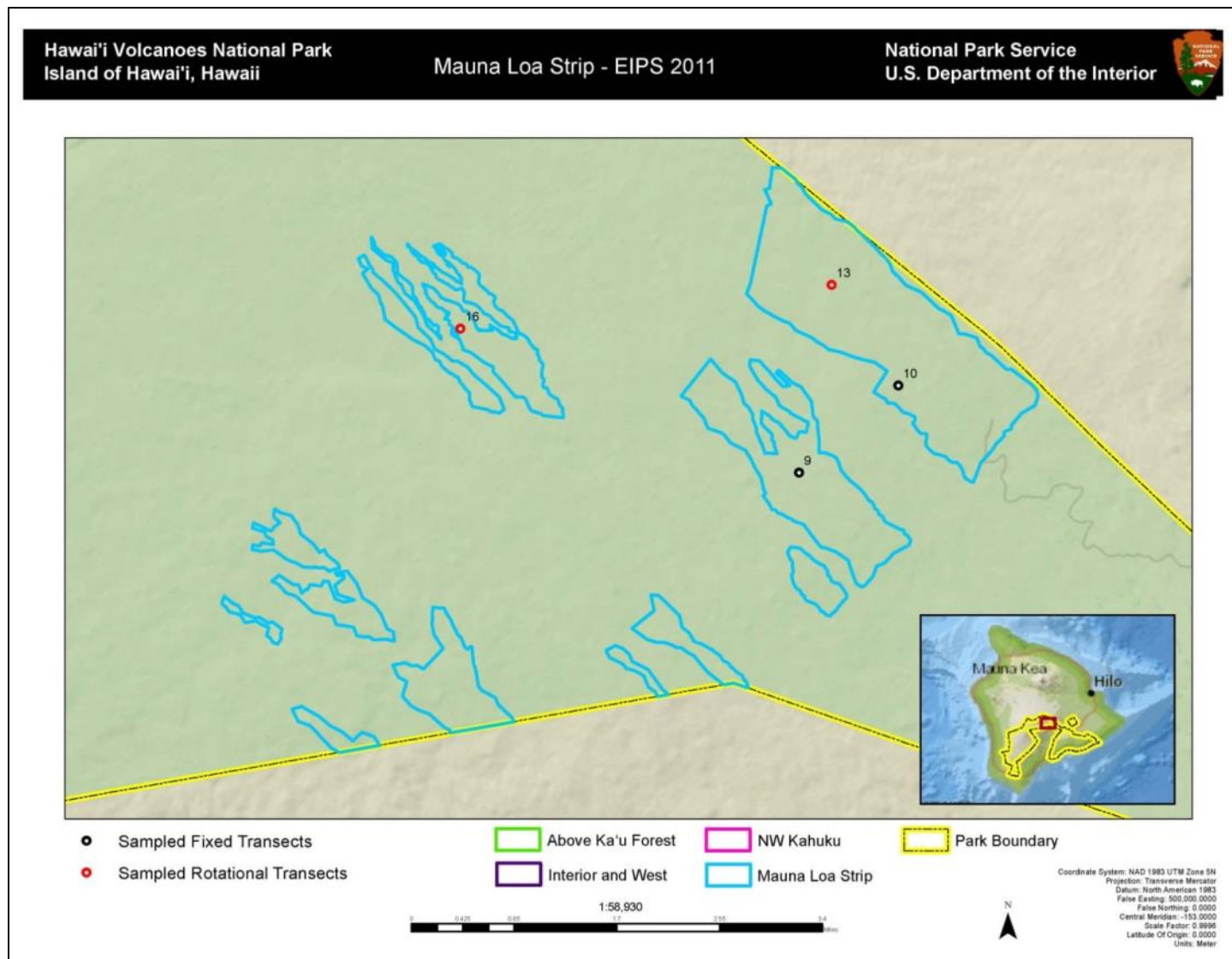


Figure C.20. Proposed and sampled EIPS transects of the Interior & West zone of the subalpine shrubland. Points represent transect start locations.

Table C.9 . Summary of plot and transect completion, access, and crew effort for Kahuku wet forest (WF) and subalpine (SA) communities. Plot numbers are preceded by F for fixed or R for rotational. Asterisks indicate estimated times. All times are listed in hours. Transit time combines vehicle travel between the office and site and hiking time. All directions originate from office or indicated campsite. Helicopter transit times are for both staff and gear transit. Plot and transect hours indicate the length of field crew visits. Total worker hours = (Plot hours + Transect hours + Transit time)*Field Crew Number. KPR = Kahuku Paddock roads, NC = Nene Cabin, CCC = CCC Cabin, ST = Summit Trail, MLS = Mauna Loa Strip, J-1 = Junction Camp 1, J- 2 = Junction Camp 2, AD = Admin Camp, KF = Kau Forest.

Date	WF Plots	WF TRs	SA Plots	SA TRs	Zone	Unit	Access	Camp Site	Crew No.	Plot hrs	TR hrs	Transit Time	Heli-copter Transit	Total wkr hrs
30-Mar	-	-	-	F9, F10			Helicopter	-	2	0	3	0	0.5	7
6-Apr	-	-	-	F6			KPR	-	2	0	1.5	7.5	0	18
19-May	-	-	-	F1			Helicopter	-	2	0	1.5	0	0.75	4.5
24-May	R25	-	-	-	Paddocks	P-1	KPR, past RM Enclosure #4	AD	7	6	0	5	0	77
25-May	F10, F7, R26	-	-	-	Paddocks	P-1	KPR to RM Enclosure #5	AD	7	8	0	3.5	0	80.5
26-May	R27	-	-	-	Paddocks	P-2	KPR	AD	7	3	0	4.5	0	52.5
2-Jun	R23, R28	-	-	-	Paddocks	P-3	KPR, near RM Enclosure #2	---	6	6	0	5	0	66
6-Jun	F9	-	-	-	Paddocks	P-2	KPR	AD	3	5	0	4.25	0	27.75
6-Jun	-	F3	-	-	Paddocks	P-2	KPR	AD	2	0	4.75	4.25	0	18
7-Jun	F15, F8	-	-	-	Paddocks	P-2	KPR	AD	2	8	0	3.25	0	22.5
7-Jun	-	F5, R19	-	-	Paddocks	P-1	KPR	AD	2	0	5	4	0	18
8-Jun	-	F3	-	-	Paddocks	P-2	KPR	AD	2	0	1	0.75	0	3.5
8-Jun	F8, R24	-	-	-	Paddocks	P-2	KPR	AD	4	6.5	0	1.5	0	32
8-Jun	-	R17, R20	-	-	Paddocks	P-2	KPR	AD	2	0	2.75	0.75	0	7
9-Jun	R29	-	-	-	Paddocks	P-2	KPR	AD	3	3	0	1.5	0	13.5
9-Jun	F14	-	-	-	Paddocks	P-2	KPR	AD	3	4.75	0	1.5	0	18.75
9-Jun	---	-	-	-			KPR	AD	6	0	0	1.5	0	9

Date	WF Plots	WF TRs	SA Plots	SA TRs	Zone	Unit	Access	Camp Site	Crew No.	Plot hrs	TR hrs	Transit Time	Heli-copter Transit	Total wkr hrs
14-Jun	F12, R22	-	-	-	Paddocks	P-3	KPR	AD	4	6.75	0	3.25	0	40
15-Jun	R22, R24, R30	F1, F16	-	-	Paddocks	P-2, P-3	KPR	AD	4	4	6	3	0	52
16-Jun	R30	-	-	-	Paddocks	P-2	KPR	AD	4	4.5	0	3	0	30
20-Jun	F11	-	-	-	Paddocks	P-2	KPR	AD	4	4.25	0	4	0	33
21-Jun	R18, F6	-	-	-	Above KF	Mauka	KPR	AD	4	6.5	0	3	0	38
22-Jun	F6	-	-	-	Above KF	Mauka	KPR, past RM Exclosure #4	AD	4	6	0	2.5	0	34
23-Jun	F13	-	-	-	Paddocks	P-2	KPR	AD	4	4	0	3	0	28
27-Jun	R21	-	-	-	Above KF	Mauka	KPR	AD	5	3	0	3	0	30
28-Jun	-	F7	-	-	Above KF	Mauka	KPR	AD	3	0	2	1.75	0	11.25
28-Jun	-	R22	-	-	Above KF	Mauka	KPR to CCC	AD	2	0	2	1.75	0	7.5
28-Jun	R17	-	-	-	Above KF	East	KPR to CCC	AD	5	3.5	0	0.75	0	21.25
28-Jun	-	F9, R21	-	-	Above KF	Mauka	KPR to CCC	AD	4	0	2	2	0	16
29-Jun	F3	-	-	-	Above KF	East	KPR to CCC	AD	5	1	0	2	0	15
29-Jun	F3	-	-	-	Above KF	East	KPR to CCC	AD	3	3.5	0	0.5	0	12
29-Jun	-	F10	-	-	Above KF	East	KPR to CCC	AD	2	0	3.5	0.5	0	8
29-Jun	R19	-	-	-	Above KF	East	KPR to CCC	AD	5	3	0	2	0	25
30-Jun	-	F2	-	-	Paddocks	P-2	KPR	AD	5	0	1.25	1.5	0	13.75
30-Jun	-	-	-	-				AD	5	0	0	1.5	0	7.5
6-Jul	-	F8	-	-	Above KF	Mauka	KPR	-	2	0	2.5	4.25	0	13.5
6-Jul	-	R23	-	-	Above KF	Mauka	KPR	-	2	0	1.5	4.25	0	11.5
11-Jul	F2	F11	-	-	Above KF	East	KPR to CCC	CCC	3	4.5	2	4.5	0	33
12-Jul	F1	F12, R29	-	-	Above KF	East	KPR to CCC	CCC	3	5	2	4.5	0	34.5
13-Jul	R20	-	-	-	Above KF	East	KPR to CCC	CCC	3	4.5	0	3.5	0	24

Date	WF Plots	WF TRs	SA Plots	SA TRs	Zone	Unit	Access	Camp Site	Crew No.	Plot hrs	TR hrs	Transit Time	Heli-copter Transit	Total wkr hrs
25-Jul	-	R24, R26	-	-	Above KF	East	KPR to CCC	CCC	2	0	2	4.5	0	13
26-Jul	-	F13, R28, R30	-	-	Above KF	East	KPR to CCC	CCC	2	0	4.25	5.5	0	19.5
25-Jul	-	-	R30	-	NW K.		Helicopter, hike S along rd then E	NW	3	3.75	0	3.5	1	24.75
26-Jul	-	-	R30	R18	NW K.	Open	Hike S along rd then E; from plot hike SW to transect	NW	3	3.25	5.25	2	0	31.5
27-Jul	-	-	F15	F3	NW K.	Open	Hike N along rd to plot; from plot hike S along road then E to transect	NW	3	4.5	4	3	0	34.5
28-Jul	-	-	-	-			Helicopter	NW	3	0	0	1.5	1	7.5
3-Aug	-	F4	-	-	Paddocks	P-2	KPR	-	2	0	2.5	5	0	15
3-Aug	-	F6	-	-	Above KF	Mauka	KPR	-	2	0	3.5	5	0	17
8-Aug	-	-	R21	-	Above KF	East	KPR past NC	Nene	3	3.75	0	3.75	0	22.5
9-Aug	F5	F15	-	-	Above KF	East	KPR past NC	Nene	3	5	1	5.5	0	34.5
10-Aug	F4	F14, R27	-	-	Above KF	East	KPR past NC	Nene	3	3.5	2	4.25	0	29.25
11-Aug	-	-	-	R11	Above KF	East	KPR	Nene	3	0	1.25	5	0	18.75
9-Aug	-	-	R29, F14	-	I&W	Interior	Helicopter, Hike S	West	2	4	0	3	0.5	15
10-Aug	-	-	-	R15	I&W	West	Helicopter	West	2	0	1	1	0.5	5
15-Aug	-	-	F13	-	I&W	Interior	Before NC on upper rd, hike along 1950s flow	Nene	3	2.5	0	5	0	22.5
16-Aug	-	-	-	F5, R17	Above KF	East	KPR past NC	Nene	3	0	5	3.75	0	26.25
17-Aug	-	-	R24	-	Above KF	East	KPR past NC	Nene	3	3.5	0	5	0	25.5

Date	WF Plots	WF TRs	SA Plots	SA TRs	Zone	Unit	Access	Camp Site	Crew No.	Plot hrs	TR hrs	Transit Time	Helicopter Transit	Total wkr hrs
15-Aug	-	-	R26	R20	Above KF	East	Helicopter to East camp; hike N to plot; from plot hike ENE to transect	East	3	1	2	2	0.75	17.25
16-Aug	-	-	F11, F9	F8	Above KF	East	Hike N to Plot 11, then S to Plot 9, then E to transect	East	3	8.5	1	3	0	37.5
17-Aug	-	-	F4, R19	R14	Above KF	East	Hike S to transect, then N to Plot 4, then NE to Plot 19	East	3	6.25	2	2.5	0	32.25
18-Aug	-	-	-	-			Helicopter	East	3	0	0	0	0.75	2.25
22-Aug	-	-	R18	-	ML Strip	ML Mauka	MLS Rd, ST, park fence line	-	4	3	0	4	0	28
23-Aug	-	-	R17	-	ML Strip	ML Mauka	MLS Rd, direct from closest access near rd end	-	4	3	0	6	0	36
24-Aug	-	-	R16	-	ML Strip	ML Mauka	MLS Rd, direct from ST	-	3	4	0	5	0	27
29-Aug	-	-	F7	-	Above KF	East	KPR past NC	Nene	3	4	0	4.5	0	25.5
30-Aug	R16	-	-	-	Above KF	East	KPR past NC	Nene	3	7.25	0	4	0	33.75
31-Aug	-	-	F5	-	Above KF	East	KPR past NC, right turn at first intersection	Nene	3	5	0	3	0	24
31-Aug	---	-	-	-				Nene	3	0	0	3.5	0	10.5
31-Aug	-	-	F2	R16	ML Strip	ML Mauka	MLS Rd	-	3	1.5	1	2.25	0.5	15.75
7-Sep	-	-	F3	-	ML Strip	ML Mauka	MLS Rd, ST, park fence line	-	3	4	0	5.5	0	28.5
12-Sep	-	-	F10	-	Above KF	East	Hike SE	J-1	4	4	0	4.25	0	33

Date	WF Plots	WF TRs	SA Plots	SA TRs	Zone	Unit	Access	Camp Site	Crew No.	Plot hrs	TR hrs	Transit Time	Heli-copter Transit	Total wkr hrs
13-Sep	-	-	R25	-	Above KF	East	N to main rd, then E	J-1	4	5	0	3	0	32
13-Sep	-	-	-	F2	Above KF	East	N to main rd, then E	J-1	2	0	2.5	1	0	7
14-Sep	-	-	F8	-	Above KF	East	N to main rd, then W	J-1	2	5	0	4	0	18
19-Sep	-	-	R20, R22	-	Above KF	East	W on main rd, then SE on 1st rd	J-2	3	4.5	0	5.75	0	30.75
20-Sep	-	-	R22, F6	F7	Above KF	East	W on main rd, then SE on 1st rd to plot, then back to main road and E	J-2	3	6.25	2.25	3.75	0	36.75
21-Sep	-	-	R23	R19	Above KF	East	W on main rd, hike N before Nene cabin	J-2	3	2.25	2.75	3.75	0	26.25
22-Sep	-	-	-	R12	I&W	Interior	W on main rd, hike N along 1950s flow	J-2	3	0	1	7	0	24
26-Sep	-	-	-	F4	Above KF	East	KPR to NC	Nene	4	0	2.5	5	0	30
27-Sep	-	-	F12, F28	-	I&W	Interior	KPR, before NC on upper rd	Nene	4	2.25	0	4	0	25
28-Sep	-	R25	-	-	Above KF	East	KPR to NC	Nene	2	0	3	0.5	0	7
28-Sep	-	-	-	-				Nene	2	0	0	0	0	0
28-Sep	-	-	-	-				Nene	4	0	0	5	0	20
5-Oct	-	-	-	R13	ML Strip	ML Mauka	MLS Rd	-	2	0	2.5	3	0	11
6-Oct	-	-	F1	-	ML Strip	ML Mauka	MLS Rd	-	3	2.5	0	5	0	22.5
24-Oct	-	-	F6r	-	Above KF	East	KPR past NC, N of rd	Nene	3	1.5	0	6.25	0	23.25
25-Oct	-	-	R27, F13	-	I&W	Interior	Before NC on upper rd, hike along 1950s flow	Nene	3	3.5	0	6.5	0	30

Date	WF Plots	WF TRs	SA Plots	SA TRs	Zone	Unit	Access	Camp Site	Crew No.	Plot hrs	TR hrs	Transit Time	Heli-copter Transit	Total wkr hrs
26-Oct	-	R5 tags	F7r	-	Paddocks, Above KF	P-1, East	KPR past NC	Nene	3	1.5	0.75	6.25	0	25.5
27-Oct	-	-	F3r	-	ML Strip	ML Mauka	MLS Rd, ST		2	1.5	0	5.5	0	14
31-Oct	F12r	R18	-	-	Paddocks	P-3	KPR	AD	4	2	2	5	0	36
1-Nov	F3r, F6r	-	F5r	-	Above KF	East	KPR	AD	4	5	0	5	0	40
2-Nov	F15r	F4 one seg	-	-	Paddocks	P-2	KPR	AD	4	2	0.25	6.5	0	35

Projected versus Actual Efforts in 2011

The FTPC and EIPS protocols projected work for both monitoring projects to be completed over six months. Specifically, the FTPC protocol called for three and a half months to complete 60 plots in the wet forest and subalpine shrubland, and three weeks to complete 15 plots in the coastal strand. For EIPS, the protocol estimated seven weeks to complete 50 transects in the wet forest and subalpine shrubland. With a projected field crew consisting of one crew leader and three technicians working three of their four ten-hour days in the field each week, the estimated months for completion can be translated into 252 worker days for FTPC and EIPS in the wet forest and subalpine shrubland, and 36 worker days for FTPC in the coastal strand (where worker days are calculated as: estimated months*4 weeks per month* 4 person crew* 3 field days per week). Actual field monitoring in the Kahuku wet forest and subalpine shrubland took I&M crews 222 worker days to complete with an average crew size of four people. The FTPC coastal strand took 38 worker days with an average crew size of five people. During the 2011 field season 100% of proposed monitoring sites for FTPC and EIPS were successfully completed during the projected field season of six months. As previously noted, the field season ran more efficiently as crew leaders and technicians were more familiar with sampling procedures. Additionally, crews were able to utilize more camping trips and work on both monitoring projects simultaneously, plus extra personnel was hired to assist in the field. Though more plots and transects were sampled during this field season, future crews should consider extended camping trips to minimize time spent on travel.

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

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National Park Service
U.S. Department of the Interior



Natural Resource Stewardship and Science

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