



Established Invasive Plant Species Monitoring

Haleakalā National Park 2012 Summary Report

Natural Resource Report NPS/PACN/NRR—2017/1417



ON THE COVER

Subalpine shrubland invasive species monitoring at Haleakalā National Park.

Photograph by Inventory & Monitoring Vegetation Crew, Haleakalā National Park.

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Natural Resource Report NPS/PACN/NRR—2017/1417

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April 2017

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

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Please cite this publication as:

Gross J., M. Simon, A. Ainsworth, and W. Mallinson. 2017. Natural Resource Report NPS/PACN/NRR—2017/1417. National Park Service, Fort Collins, Colorado.

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Abstract

In 2012 and 2013, the Pacific Island Network Inventory and Monitoring program established transects to monitor non-native, invasive plant species at Haleakalā National Park. Belt transects were utilized to monitor non-native species frequency and abundance in two plant communities, wet forest and 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, distribution frequency, and cover. Because this report represents the first read of transects, an analysis of change over time is not possible. Instead, the objectives of the initial report are to 1) summarize and compare non-native richness at the plant community level, 2) determine the most common (i.e., most frequent) non-native species within each plant community, and 3) document the spatial distribution of non-native species cover across each plant community. The wet forest plant community, encompassing Kīpahulu Valley, ranged from 240-2280 m, while the subalpine shrubland ranged from 1980-3000 m, encompassing the park's summit, headquarters, and several hiking trails open to the public. These plant communities have a history of feral ungulate disturbance along with recent and ongoing efforts to control non-native plants and animals.

The study area included approximately 7,000 ha and a total of 60 non-native species were documented. Eight species of management concern to the park were recorded in the wet forest. Three of these species were the most frequently encountered non-native plants; including the shrub, *Clidemia hirta*, the herb, *Hedychium gardnerianum*, and the tree, *Psidium cattleianum*. Neither *C. hirta* nor *H. gardnerianum* were documented along transect surveys conducted 24 years prior. Non-native plant cover within the wet forest generally decreased with increased elevation. Ten species of management concern to the park were recorded in the subalpine shrubland. However, these species occurred at relatively low frequencies along transects. Overall, non-native plant frequency was higher in the subalpine shrubland than in the wet forest. This was largely due to the herb, *Hypochaeris radicata*, and the grass, *Holcus lanatus*, the most frequently encountered non-native species in the subalpine shrubland plant community.

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 management of Haleakalā 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.

Acknowledgments

Special thanks to Colin Meston, Avery McChristian, Liz Moore, Elizabeth Urbanski, and Laura Arnold for assistance with field work, data collection and processing. Thank you, Greg Kudray for program management, Kelly Kozar and Asia Addlesberger for data management, and Scott Kichman for GIS assistance. Thanks to James Leary and Jeremy Gooding for providing thoughtful reviews and comments and thanks to Ryan Monello for providing additional feedback to improve and clarify the manuscript. We would also like to thank the staff at Haleakalā National Park for all their support and logistical assistance especially Matt Brown and Steve Anderson.

Acronyms

EIPS	Established Invasive Plant Species
FTPC	Focal Terrestrial Plant Community
I&M	Inventory and Monitoring
HALE	Haleakalā National Park
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). Invasive 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 invasions by non-native species due to their evolution in relative isolation and in the absence of some of the forces shaping continental organisms (Darwin [1859] 1972, Loope and Mueller-Dombois 1989, 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 Hawaii also rank highest in 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, the Pacific Island I&M Network (PACN) and park staff, 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 broader spatial coverage of non-native plant abundance estimates. EIPS includes sampling non-native species along belt transects in four relatively intact plant communities across five network parks, where native plant communities are largely intact and non-native species are still relatively rare. Monitoring throughout the PACN is set up on a rotating basis.

From 2012 to 2013, the I&M Program monitored non-native plant species in wet forest and subalpine regions of Haleakalā National Park (HALE), on the island of Maui. First established in 1916, the park currently encompasses 13,463 ha, ranging from sea level to the summit of Haleakalā (3,055m). 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 communities.

Methods

In 2012 and 2013, non-native invasive plants were monitored within wet forest and subalpine shrubland plant communities at HALE (See Appendix C for specific survey dates). Field crews conducted the monitoring effort following protocol guidelines defined by Ainsworth et al. (2012). Within each plant community, transects were set up in a split panel design and categorized as fixed (permanent) or rotational (temporary) (Figure 1&2). 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. Of the 20 proposed 1000 m wet forest transects, 10 transects were completed entirely. Due to time and safety constraints, 6 transects were incomplete and shortened to lengths ranging between 560-720 m, and 4 transects were unvisited due to logistical constraints. Of the 20 proposed 500 m transects in the subalpine shrubland, all twenty were visited, with two transects shortened to 420 m and 480 m due to safety constraints.

Study Sites

Wet Forest

The wet forest sampling frame (2,627 ha) is located on the eastern side of HALE, encompassing the Kīpahulu Valley (Figure 1). The vegetation is characterized by native forests and woodlands dominated by trees, *Metrosideros polymorpha*, *Cheirodendron trigynum*, shrubs, *Rubus hawaiiensis*, and ferns, *Dicranopteris linearis*. Lower elevation regions of the sampling area, however, are characterized by semi-natural woodlands and forests, with areas of significant *Psidium cattleianum* and *Syzygium jambos* tree cover (Green et al. 2015). Soils are described as well to poorly drained, developed in volcanic ash and in material weathered from cinders and basic igneous rock. Relatively small portions of the sampling frame have substrates defined as cinder and rough mountainous land (USDA 1972). Mean annual rainfall in the wet forest ranges between 3500 – 8000 mm/year (Giambelluca et al. 2011) and elevation within the sampling frame ranges from 240-2280 m. The entire sampling frame for the wet forest is part of a restricted-entry Scientific Reserve and closed to public access.

A series of fences were established in Kīpahulu Valley to create smaller management units (Figure 1) to control feral ungulate (e.g. pig, [*Sus scrofa*] and goat [*Capra hircus*]) populations. A cross-fence at 750-950 m elevation separate lower Kīpahulu (transects 4,10) from middle Kīpahulu (transects 3,6,7,14,20) and another cross-fence at 1430 m separate middle and upper Kīpahulu (transects 2,5,16,19). The length of Kīpahulu Valley is naturally divided by a ridge which creates the Lower Plateau on the northeast and the Upper Plateau on the southwest. In addition to fencing, steep cliffs on either side of the valley provide some restrictions to ungulate movement. By 1988, feral pigs and goats were reduced to remnant levels in middle and upper Kīpahulu (Anderson and Welton 1993). Currently, upper Kīpahulu is still considered ungulate free while middle Kīpahulu has experienced occasional ingress of pigs. In addition to Kīpahulu Valley, the wet forest sampling frame includes four other management units: Manawainui, upper Hanā wet forest, Kaumakani, and Ka‘āpahu (Figure 1). Manawainui (transects 1,12,15) and upper Hanā wet forest (transect 9) have fenced boundaries and low ungulate populations. The Kaumakani management unit (not sampled during the 2012 EIPS monitoring effort), in the southeastern most portion of the sampling frame, also has a

fenced boundary, with some ungulate control. The Ka‘āpahu portion of the park (transect 18) was acquired in 1999 and has not been fenced or managed for ungulates. Heavy invasive plant cover stretches from the gardens and pasturelands below the wet forest sampling frame up through lower Kīpahulu and into middle Kīpahulu (Anderson 1992). Due to limited resources, invasive plant management is focused primarily in the less invaded middle and upper portions of Kīpahulu with everything above 1067 m (3500 ft) considered the highest priority (Figure 1).

Subalpine Shrubland

The subalpine shrubland sampling frame (4,460 ha) consists of generally vegetated sites above 1980 m and is located on the western side of HALE, encompassing the park’s summit, visitor center, headquarters, and several hiking trails open to the public (Figure 2). The area is dominated by shrublands and grasslands, but also includes sections classified as unvegetated (less than 5% vegetation cover) or with sparse cover (5 – 15% vegetation cover; Green et al. 2015). Substrate and soil vary, and range from cinder and ‘a‘ā, to substrates developed in volcanic ash and in material weathered from cinders (USDA 1972). Mean annual rainfall ranges from 1000 to 5000 mm, with higher rainfall on the east side of the sampling frame (Giambelluca et al. 2011).

The subalpine shrubland has a history of human disturbance with direct and indirect modes of non-native plant introduction. Feral ungulates have been a major catalyst of vegetation change in the area (Anderson et al 1992). Goats and cattle (*Bos taurus*) were introduced to Maui in the 1790s and brought directly into the subalpine shrubland in the late 1800s (Loope et al 1992). Cattle grazing ceased in the 1930s, after the park was designated. Feral pigs were first seen in the area as early as the 1930s. Believed to have traveled from piggeries near the coast, they quickly became widespread throughout the subalpine shrubland. Adjacent farmlands, experimental tree plantings, construction of roads and infrastructure, and military operations, have also contributed to numerous non-native plant introductions in the study area. Fencing of the subalpine shrubland was completed by 1991 and goats and pigs have been reduced throughout the area. Management of invasive plant species occurs throughout the subalpine shrubland, but limited resources constrain the breadth and frequency of these control efforts.

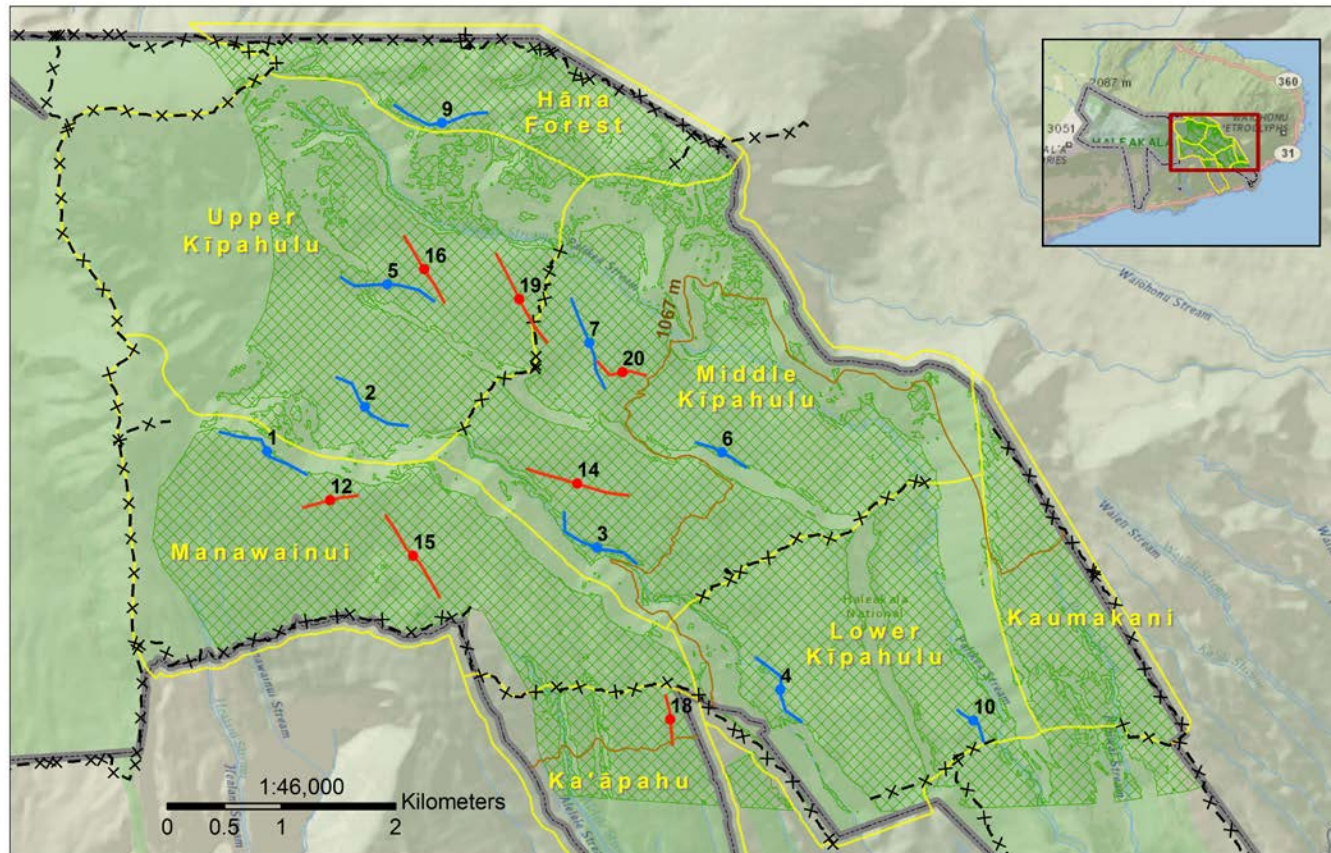


Figure 1. Wet forest sampling frame with location of fixed and rotational transects visited in 2012 (transect lengths between 560 and 1,000 m).

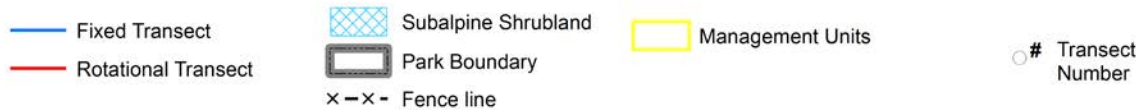
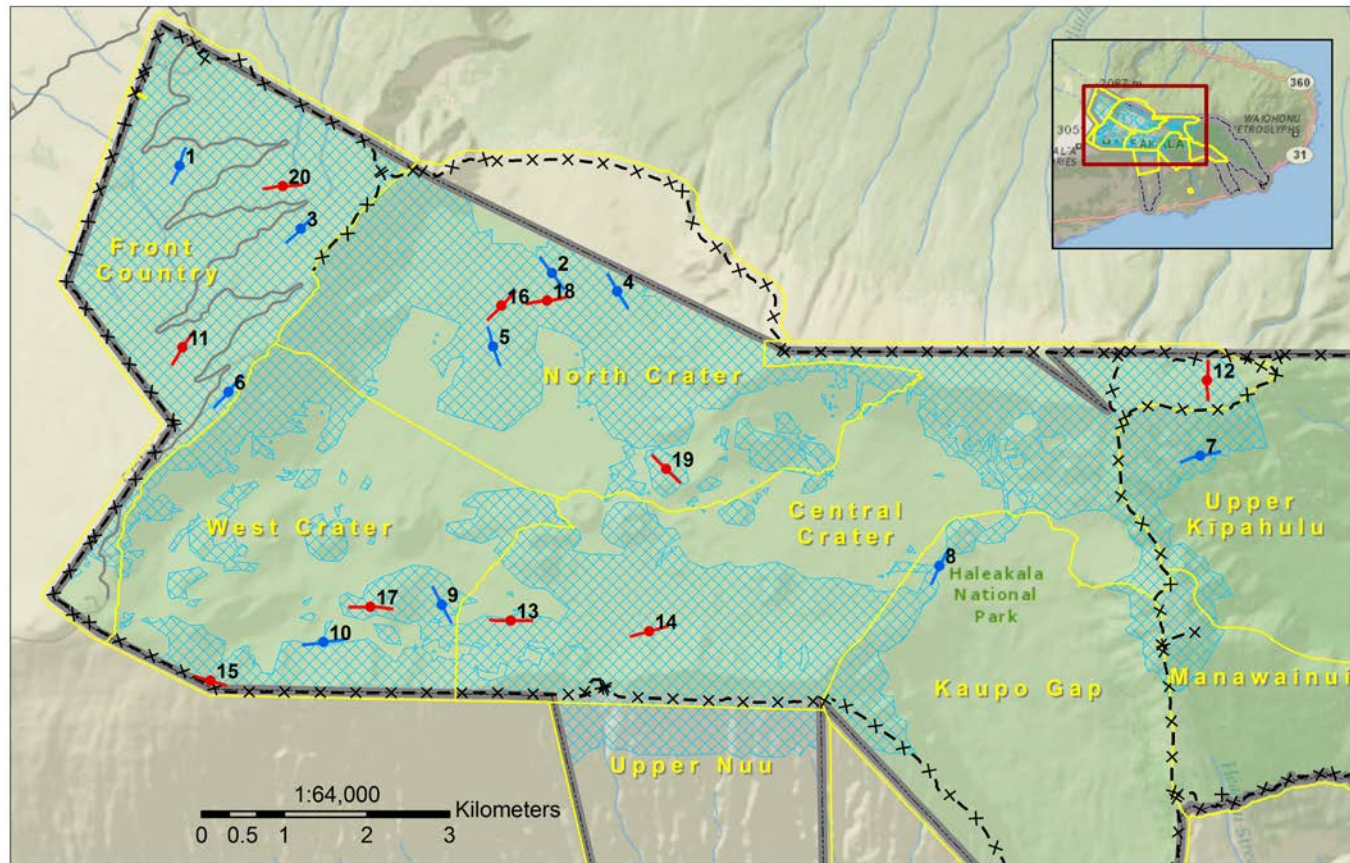


Figure 2. Subalpine shrubland sampling frame with location of fixed and rotational transects visited in 2012 (transect lengths between 420 and 500 m).

Non-native Plant Sampling

Field crews monitored for non-native species along belt transects consisting of contiguous elongated rectangular plots (5 x 20 m) with transects varying in length depending on the plant community sampled (Table 1). 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 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 wet forest 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. HALE proposed and completed transects, area sampled, and percent of sampling frame. *Six and **two transects incomplete due to safety and logistical reasons.

Sampling Frame	Dates Sampled	Plot (m)	Plot (m ²)	No. plots/ transect	Transect Length (m)	Proposed Transects	Completed Transects	Directly Observed Area (ha)
Wet Forest	July 2012-Jan 2013	5 x 20	100	50	1000	20	16*	6.76
Subalpine Shrubland	May 2012 – Feb 2013	5 x 20	100	25	500	20	20**	4.93

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%

Data Analysis

Plant species nomenclature follows that of Wagner et al. 1999 and Palmer 2003 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 analysis unless the individual represented a unique genus, or more species were known from the region than those recorded (e.g. *Oxalis spp.*). Some plants observed were not identified to species due to an

absence of diagnostic features (e.g. a grass without a seed head). These “unknown species” were organized by life form (e.g. “unknown grass”, “unknown herb”, etc.) and recorded as separate instances (e.g. “unknown grass 1”, “unknown grass 2”) if the observed characteristics of the plant warranted the distinction. Unknown species may not represent unique species to those identified; therefore, all unknown species were excluded from the species list (Table 3) and from all analyses of non-native species richness, frequency, and cover. Unknown species in the wet forest included three herbs, two sedges, and one rush, while unknown species in the subalpine shrubland included two grasses, one herb, and one unknown plant not assigned to a life form.

Non-native Species Richness

Total non-native species richness was compared between plant communities (wet forest and subalpine shrubland). Rarefaction and extrapolation of total species richness were performed to standardize comparisons between communities which were subject to 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 non-native species richness per transect was also calculated for each community. The longer wet forest transects (Table 1) were divided in half and treated as independent samples (pseudo-sampling) to standardize transect size between the plant communities. Partially completed transects that did not total 500 m (6 half-transects in the WF, 2 transects in SS) were removed from this analysis.

Non-native Frequency

Frequency of all non-native species combined 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 plant community. Frequency was also calculated for individual non-native species and categories of non-native life forms (e.g., grasses, trees, shrubs).

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 classes were used directly in the construction of thematic maps which display plot level species cover spatial patterns across the landscape (Appendix A). To calculate mean cover of a species, Braun-Blanquet cover classes were converted to mid-point values, then averaged across all plots in the sampling frame (i.e. transect association was ignored). Because plant species distributions are often patchy and localized, mean species cover calculations were based on only plots with occurrence data (i.e. plots with zero species cover were removed before means were calculated). Therefore, mean species cover should be interpreted here as the mean percent of plot covered by the species when encountered, not as the mean cover across the entire transect.

Life form cover and total non-native cover were derived from species-level cover by converting the modified Braun-Blanquet class ranges to mid-point values, then summing midpoint cover values at the plot level. It is possible for life form and total non-native cover to result in values above 100% cover in a plot because vegetation can occur at multiple levels (e.g. ground cover, mid-canopy, canopy, etc.) and because of the distortion in converting ranges to specific values. Although the

conversion of cover classes to midpoints can result in certain limitations (e.g. lack of well-defined confidence intervals and boxplots, T. Philippi pers. comm.) these metrics still provide valuable visual aids to understand non-native plant distributions. Mean cover of non-native life forms and of all non-native plants combined (total) were calculated first at the transect level then further summarized by sampling frame. Mean cover for life forms and total non-native cover included plots with zero cover in the calculation.

Results

Non-native Species Richness

A total of 60 non-native species were recorded during EIPS monitoring (Table 3). Of these, five species are classified as noxious weeds (Hawai'i 1992) and 14 species are considered priority management species within HALE. Four documented species in the subalpine shrubland, *Cirsium vulgare*, *Heterotheca grandiflora*, *Pinus radiata*, and *Senecio madagascariensis* are listed as early detection species for HALE (Speith & Harrison 2012). Focal Terrestrial Plant Community (FTPC) monitoring conducted concurrently with EIPS monitoring and within the same sampling frames, documented four additional non-native species in the wet forest, and seven additional species in the subalpine shrubland plant community (Table 4; National Park Service 2016b).

Table 3. Non-native species detected during EIPS monitoring within HALE wet forest (WF) and subalpine shrubland (SS) plant communities. An (x) in parentheses indicates that the plant was only recorded below 1067 m in the wet forest; above 1067 m (3500 ft) is the park's native plant dominated, high priority management area.

Scientific name	Family	Common name	Life form	WF	SS
<i>Ageratina adenophora</i> ¹	Asteraceae	Maui pamakani	Shrub	x	x
<i>Ageratina riparia</i> ¹	Asteraceae	hamakua pamakani	Herb	x	x
<i>Aira caryophyllea</i>	Poaceae	silver hairgrass	Grass		x
<i>Anagallis arvensis</i>	Primulaceae	scarlet pimpernel	Herb		x
<i>Anthoxanthum odoratum</i>	Poaceae	sweet vernalgrass	Grass		x
<i>Arenaria serpyllifolia</i>	Caryophyllaceae	thyme-leaved sandwort	Herb		x
<i>Axonopus fissifolius</i>	Poaceae	carpetgrass	Grass	x	
<i>Blechnum appendiculatum</i>	Blechnaceae	Blechnum appendiculatum	Fern	(x)	
<i>Bromus tectorum</i> ²	Poaceae	cheat grass	Grass		x
<i>Carex longii</i>	Cyperaceae	Carex longii	Sedge	x	
<i>Cenchrus clandestinus</i> ²	Poaceae	kikuyu grass	Grass		x
<i>Centella asiatica</i>	Apiaceae	Asiatic pennywort	Herb	x	
<i>Cirsium vulgare</i> ²	Asteraceae	bull thistle	Herb		x
<i>Clidemia hirta</i> ^{1, 2}	Melastomataceae	Koster's curse	Shrub	x	
<i>Coix lacryma-jobi</i>	Poaceae	kukaekolea	Grass	(x)	
<i>Conyza bonariensis</i>	Asteraceae	hairy horseweed	Herb		x
<i>Conyza canadensis</i> var. <i>pusilla</i>	Asteraceae	horseweed	Herb		x
<i>Cyclosorus dentatus</i>	Thelypteridaceae	Cyclosorus dentatus	Fern	(x)	
<i>Cyperus haspan</i>	Cyperaceae	Cyperus haspan	Sedge	x	
<i>Dactylis glomerata</i>	Poaceae	cocksfoot	Grass		x
<i>Deparia petersenii</i>	Woodsiaceae	false spleenwort	Fern	x	
<i>Eragrostis brownei</i>	Poaceae	sheepgrass	Grass		x
<i>Erechtites valerianifolia</i>	Asteraceae	fireweed	Herb	x	

¹ State of Hawaii noxious weed.

² Species are of management concern at HALE.

Table 3 (continued). Non-native species detected during EIPS monitoring within HALE wet forest (WF) and subalpine shrubland (SS) plant communities. An (x) in parentheses indicates that the plant was only recorded below 1067 m in the wet forest; above 1067 m (3500 ft) is the park's native plant dominated, high priority management area.

Scientific name	Family	Common name	Life form	WF	SS
<i>Festuca myuros</i>	Poaceae	rat tail fescue	Grass		x
<i>Festuca rubra</i>	Poaceae	red fescue	Grass		x
<i>Hedychium gardnerianum</i>²	Zingiberaceae	kahili ginger	Herb	x	
<i>Heterotheca grandiflora</i>²	Asteraceae	telegraph weed	Herb		x
<i>Holcus lanatus</i>	Poaceae	common velvet grass	Grass	x	x
<i>Hypochaeris radicata</i>	Asteraceae	hairy cat's ear	Herb	x	x
<i>Juncus planifolius</i>	Juncaceae	rush	Rush	x	x
<i>Kyllinga brevifolia</i>	Cyperaceae	Kyllinga brevifolia	Sedge	(x)	
<i>Lythrum maritimum</i>	Lythraceae	pukamole	Shrub	x	x
<i>Medicago lupulina</i>	Fabaceae	black medick	Herb		x
<i>Nephrolepis brownii</i>	Lomariopsidaceae	swordfern	Fern	(x)	
<i>Oenothera stricta</i> ssp. <i>stricta</i>	Onagraceae	evening primrose	Herb		x
<i>Oplismenus hirtellus</i>	Poaceae	basketgrass	Grass	(x)	
<i>Oxalis corniculata</i>	Oxalidaceae	yellow wood sorrel	Herb		x
<i>Oxalis</i> spp.	Oxalidaceae	wood sorrel	Herb	x	x
<i>Paspalum conjugatum</i>	Poaceae	Hilo grass	Grass	x	
<i>Petrorhagia dubia</i>	Caryophyllaceae	hairypink	Herb		x
<i>Pinus radiata</i>²	Pinaceae	Monterey pine	Tree		x
<i>Plantago lanceolata</i>²	Plantaginaceae	English plantain	Herb		x
<i>Prunella vulgaris</i>	Lamiaceae	heal-all	Herb	x	x
<i>Psidium cattleianum</i>²	Myrtaceae	strawberry guava	Tree	x	
<i>Psidium guajava</i>²	Myrtaceae	common guava	Shrub	(x)	
<i>Rhynchospora caduca</i>	Cyperaceae	beak-rush	Sedge	x	
<i>Rubus rosifolius</i>	Rosaceae	thimbleberry	Shrub	x	
<i>Rumex acetosella</i>	Polygonaceae	sheep sorrel	Herb		x
<i>Rytidosperma pilosum</i>	Poaceae	hairy wallaby grass	Grass		x
<i>Sacciolepis indica</i>	Poaceae	glenwood grass	Grass	(x)	
<i>Senecio madagascariensis</i>^{1, 2}	Asteraceae	fireweed	Herb		x
<i>Setaria palmifolia</i>	Poaceae	palmgrass	Grass	(x)	
<i>Silene gallica</i>	Caryophyllaceae	small-flowered catchfly	Herb		x
<i>Spathodea campanulata</i>²	Bignoniaceae	African tuliptree	Tree	(x)	
<i>Sphaeropteris cooperi</i>²	Cyatheaceae	Australian tree fern	Tree Fern	x	
<i>Sporobolus africanus</i>	Poaceae	rattail grass	Grass		x
<i>Syzygium jambos</i>	Myrtaceae	rose apple	Tree	(x)	

¹ State of Hawaii noxious weed.

² Species are of management concern at HALE.

Table 3 (continued). Non-native species detected during EIPS monitoring within HALE wet forest (WF) and subalpine shrubland (SS) plant communities. An (x) in parentheses indicates that the plant was only recorded below 1067 m in the wet forest; above 1067 m (3500 ft) is the park's native plant dominated, high priority management area.

Scientific name	Family	Common name	Life form	WF	SS
<i>Syzygium malaccense</i>	Myrtaceae	mountain apple	Tree	(x)	
<i>Tibouchina herbacea</i> ^{1, 2}	Melastomataceae	cane tibouchina	Herb	x	
<i>Youngia japonica</i>	Asteraceae	oriental hawksbeard	Herb	x	

¹ State of Hawaii noxious weed.

² Species are of management concern at HALE.

Table 4. Additional non-native species documented in Focal Terrestrial Plant Community monitoring (National Park Service 2016). Asterisks indicate State of Hawaii noxious weed and bold species are of management concern at HALE.

Scientific name	Family	Common name	Life form	WF	SS
<i>Asparagus spp.</i>	Asparagaceae		Herb	x	
<i>Cardimine spp.</i>	Brassicaceae	bittercress	Herb	x	
<i>Elaeagnus spp.</i>	Elaeagnaceae	oleaster	Shrub	x	
<i>Erodium cicutarium</i> ²	Geraniaceae	filaree	Herb		x
<i>Gastridium ventricosum</i>	Poaceae	nitgrass	Grass		x
<i>Melinis minutiflora</i> ²	Poaceae	molasses grass	Grass	x	
<i>Paspalum urvillei</i>	Poaceae	vasey grass	Grass	x	
<i>Pinus patula</i> ²	Pinaceae	Mexican weeping pine	Tree		x
<i>Poa pratensis</i>	Poaceae	Kentucky bluegrass	Grass		x
<i>Polycarpon tetraphyllum</i>	Caryophyllaceae	allseed	Herb		x
<i>Rubus argutus</i> ^{1, 2}	Rosaceae	blackberry	Shrub		x
<i>Taraxacum officinale</i>	Asteraceae	dandelion	Herb		x

¹ State of Hawaii noxious weed.

² Species are of management concern at HALE.

Thirty-five non-native species were identified in the wet forest (with 12 species recorded exclusively below 1067 m) and 33 were identified in the subalpine shrubland from EIPS monitoring. Of the sixty total species recorded, eight (~13%) were present in both the wet forest and subalpine plant communities. Total species richness counts are heavily influenced by sampling effort and can bias results if not accounted for (Gotelli and Colwell 2011). Because the wet forest received greater sampling effort than the subalpine shrubland, estimates of plant community non-native richness were compared using sample-based rarefaction and extrapolation (Hsieh et al. 2014). Figure 3 illustrates that when sampling effort in the subalpine shrubland is extrapolated to that of the wet forest, the two communities still demonstrate similar richness of non-native species. However, further extrapolation of wet forest species accumulation suggests additional non-native species will be observed if sampling effort is increased. The subalpine shrubland, conversely, appears to have reached an asymptote in which few new non-native species are expected to be found with increased sampling effort. The addition of five wet forest species from the separate, concurrent FTPC monitoring effort

(Table 4) supports the idea that the sample-based species accumulation curve for the wet forest had not yet reached an asymptote. However, FTPC monitoring also identified an additional seven species in the subalpine shrubland which is more than expected from the extrapolated accumulation curve for the area.

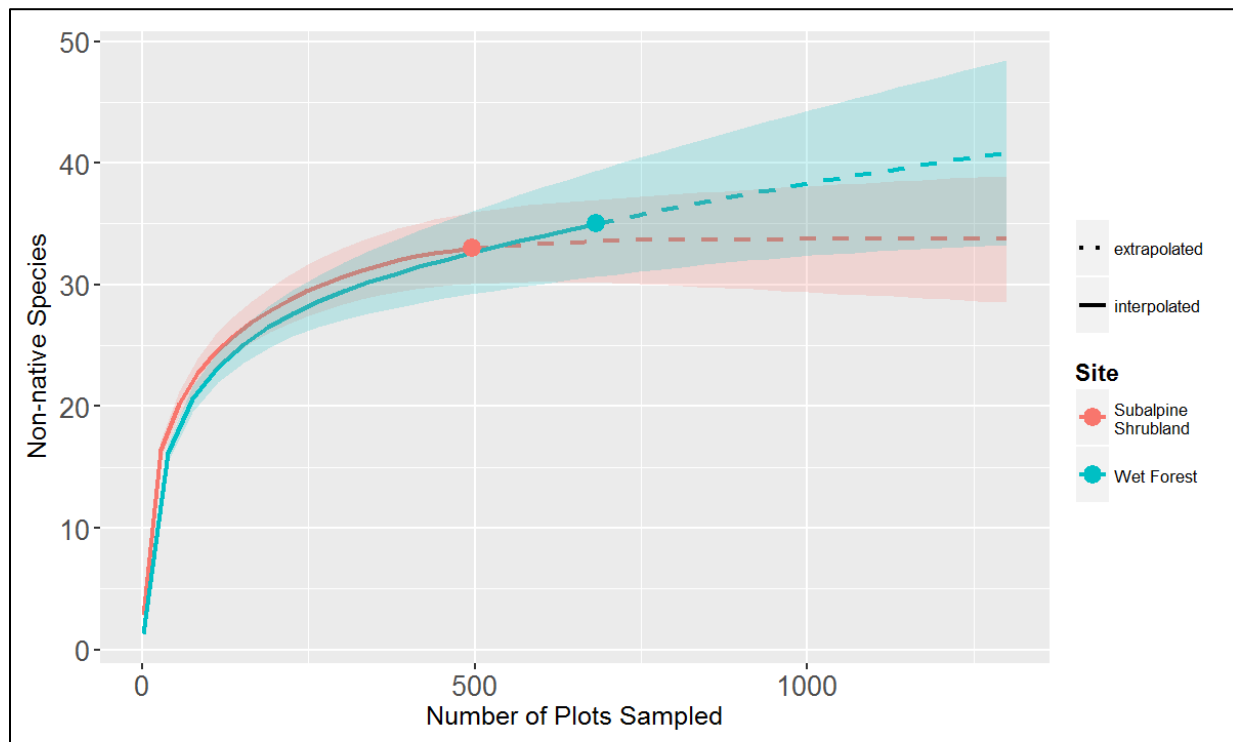


Figure 3. Species accumulation curves (sample-based rarefaction and extrapolation) and associated 95% confidence intervals for the two plant communities monitored at HALE. Points indicate observed values.

In order to compare non-native richness at a smaller scale across plant communities, wet forest transects were subdivided into lengths of 500 m to match the lengths of the subalpine shrubland transects and non-native species were pooled accordingly. The subalpine shrubland showed higher median non-native species richness [8] than the wet forest [3.5] (Figure 4). Wet forest transect 10 shows up as an outlier with 20 non-native species (Figure 4), this was the lowest elevation transect (495-528 m) sampled (Figure 5). Other low elevation transects in the wet forest also displayed relatively high non-native richness. In the subalpine shrubland, the lowest elevation transect (Transect 8; Figure 6), also resulted in the most non-native species (16 species). Other subalpine shrubland transects with relatively high non-native richness occurred in the front country management unit along the park entrance road.

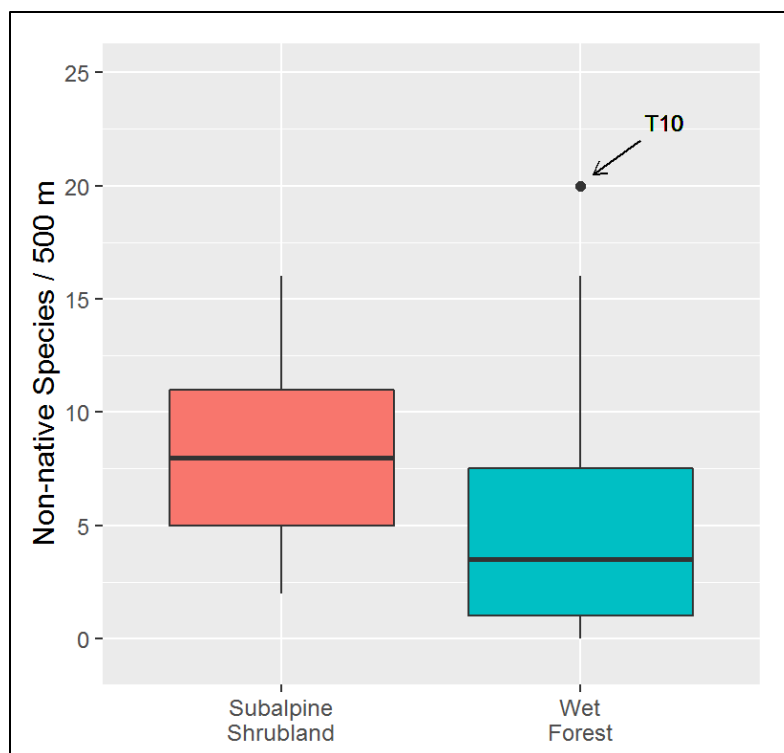


Figure 4. Boxplot of non-native species richness per standardized transect length of 500 m. Boxes represent each plant community within the study. The bottom and top of the box are the first and third quartiles and the band inside the box is the median. The whiskers represent the lowest or highest datum still within 1.5 the interquartile range of the lower or upper quantile (Tukey boxplot). Outlier is plotted as dot. Sample size of each community is as follows: Subalpine Shrubland [18], Wet Forest [26].

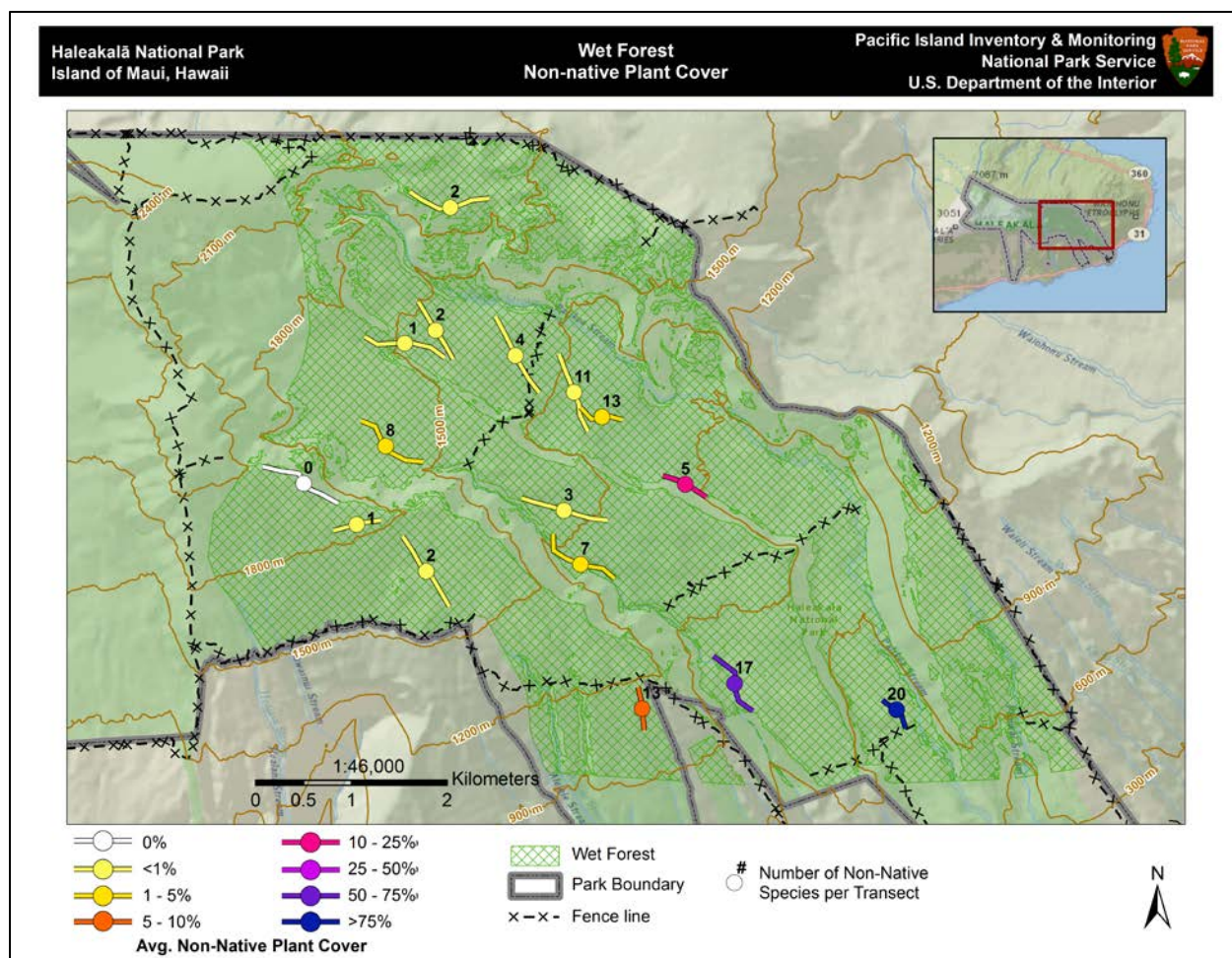


Figure 5. Non-native species richness (numerical value adjacent to transects) and mean non-native plant cover (color-coded transects) per transect within the wet forest sampling frame. Transect lengths = 1000 m. Non-native plant cover is the sum of all non-native species cover at the plot level (can be greater than 100%). Mean non-native plant cover in this figure is absolute (calculation included plots with zero non-native cover).

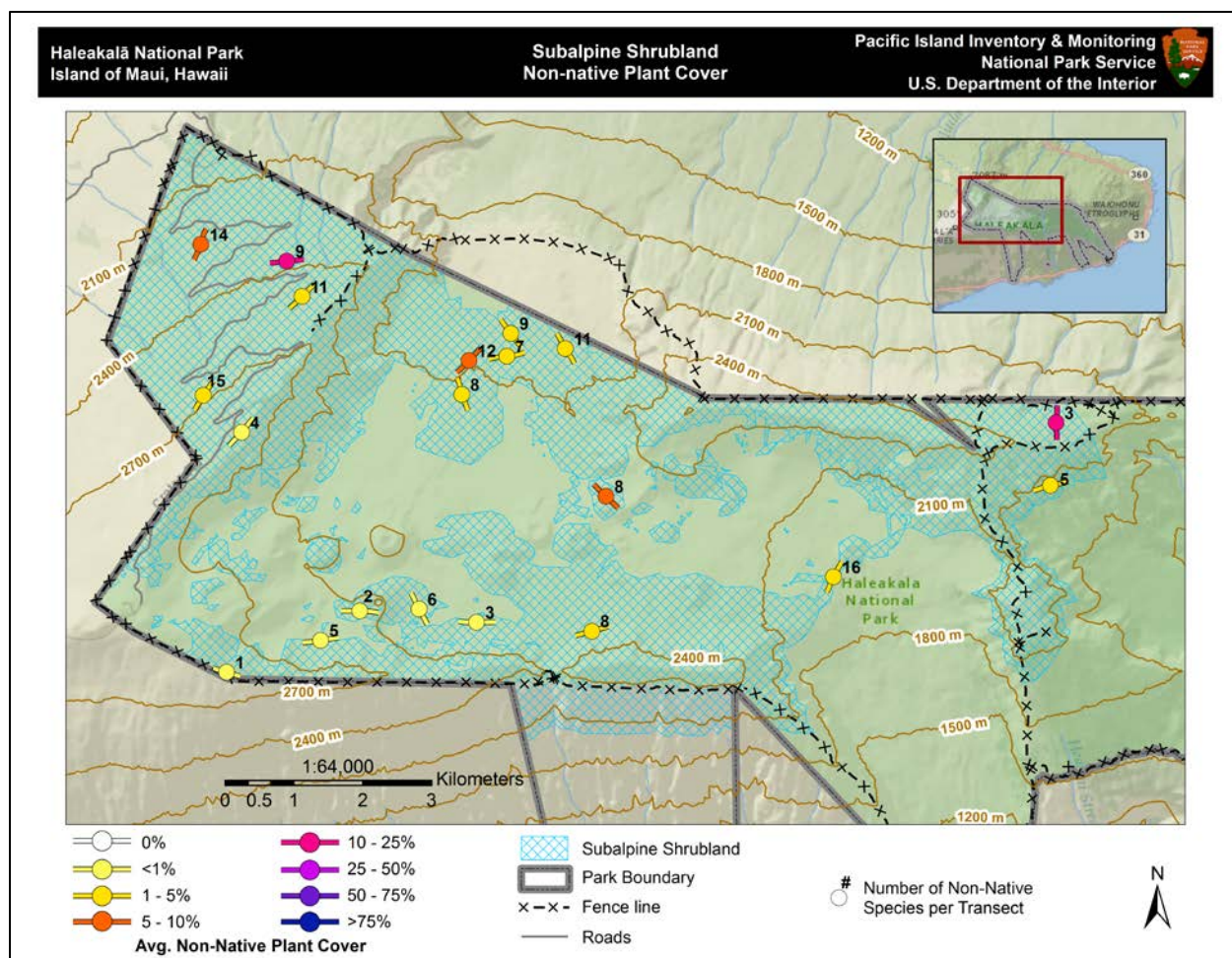


Figure 6. Non-native species richness (numerical value adjacent to transects) and mean non-native plant cover (color-coded transects) per transect within the subalpine shrubland sampling frame. Transect lengths = 500 m. Non-native plant cover is the sum of all non-native species cover at the plot level (can be greater than 100%). Mean non-native plant cover in this figure is absolute (calculation included plots with zero non-native cover).

Non-native Frequency and Cover

Mean frequency of any non-native plant was 0.48 ± 0.22 (mean $\pm$ 95% CI) in the wet forest and 0.88 ± 0.09 in the subalpine shrubland (Figure 7). Non-native plant cover >5% occurred at nearly the same average frequency [~ 0.24] in both the wet forest and subalpine shrubland. However, the wet forest showed greater average frequencies of non-native plant cover >10% and at all other cover groupings above 10% than the subalpine shrubland. The subalpine shrubland had no plots with non-native cover >50% while the wet forest had an average frequency of $0.08 [\pm 0.13]$ plots with non-native cover above 75% (Figure 7).

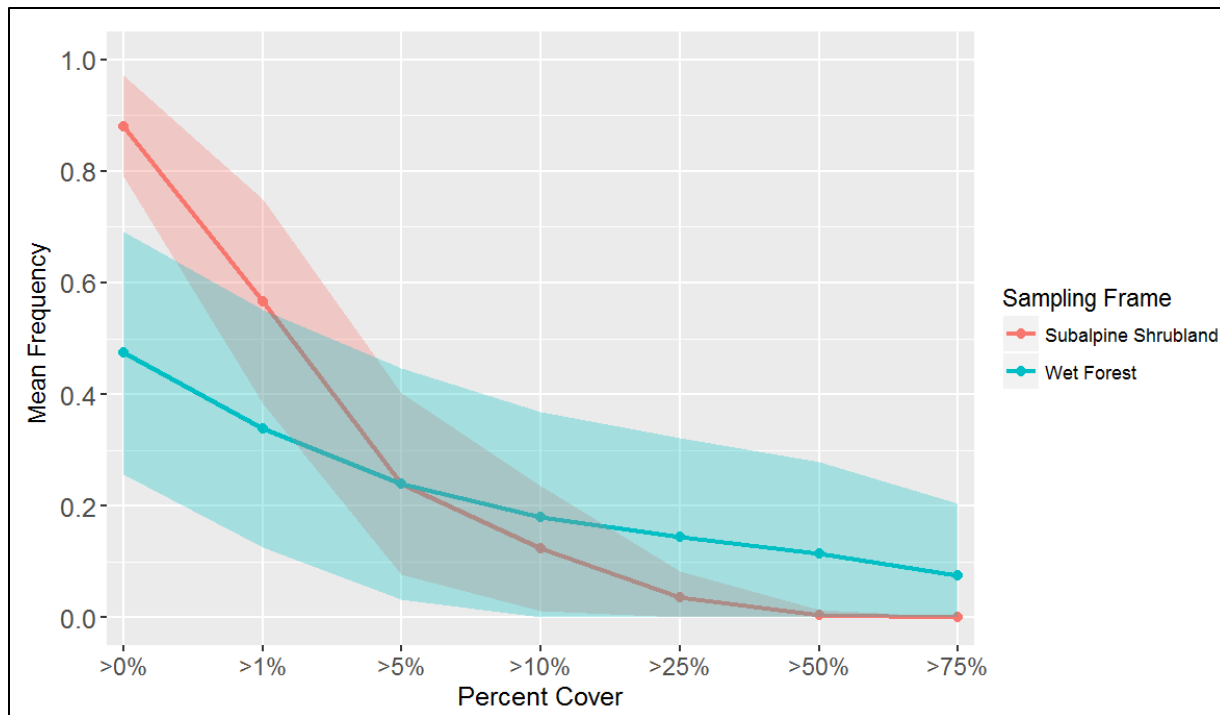


Figure 7. Mean frequency of non-native cover for each sampling frame and associated 95% C.I. (shaded areas). Frequency is the proportion of plots per transect in which the specified cover was met. The X-axis represents combined non-native cover with increasing minimum cover cutoffs (moving from left to right). A mean frequency of 1.0 would indicate that the corresponding non-native cover was recorded in all (100%) of the plots sampled. Example: on average, 18% [0.18] of the plots within each wet forest transect had greater than 10% cover of non-native plants.

Wet Forest

The most frequently occurring non-native plants in the wet forest (Figure 8) were the shrubs *Clidemia hirta* [0.22 ± 0.20] and *Rubus rosifolius* [0.18 ± 0.13], the herb *Hedychium gardnerianum* [0.19 ± 0.16], the tree *Psidium cattleianum* [0.17 ± 0.19], and the fern *Deparia petersenii* [0.13 ± 0.14]. The complete table of average species frequencies and cover class when present is provided in Appendix B. All species recorded in the wet forest occurred with relatively low average cover (class 1 or 2), except for *P. cattleianum*, which on average covered 25-50% of a plot (cover class “5”) when it occurred. When grouping species by life form, shrubs [0.32 ± 0.20] and herbs [0.31 ± 0.17] showed the greatest frequency of occurrence in the wet forest, but trees occurred with greater cover (Figure 9), largely driven by *P. cattleianum*. *Clidemia hirta* (Figure A.1) and *P. cattleianum* (Figure A.5) were both concentrated in lower Kipahulu and largely absent above 1100 m. Localized plant distributions such as these contribute to the correspondingly large confidence intervals seen in Figure 8.

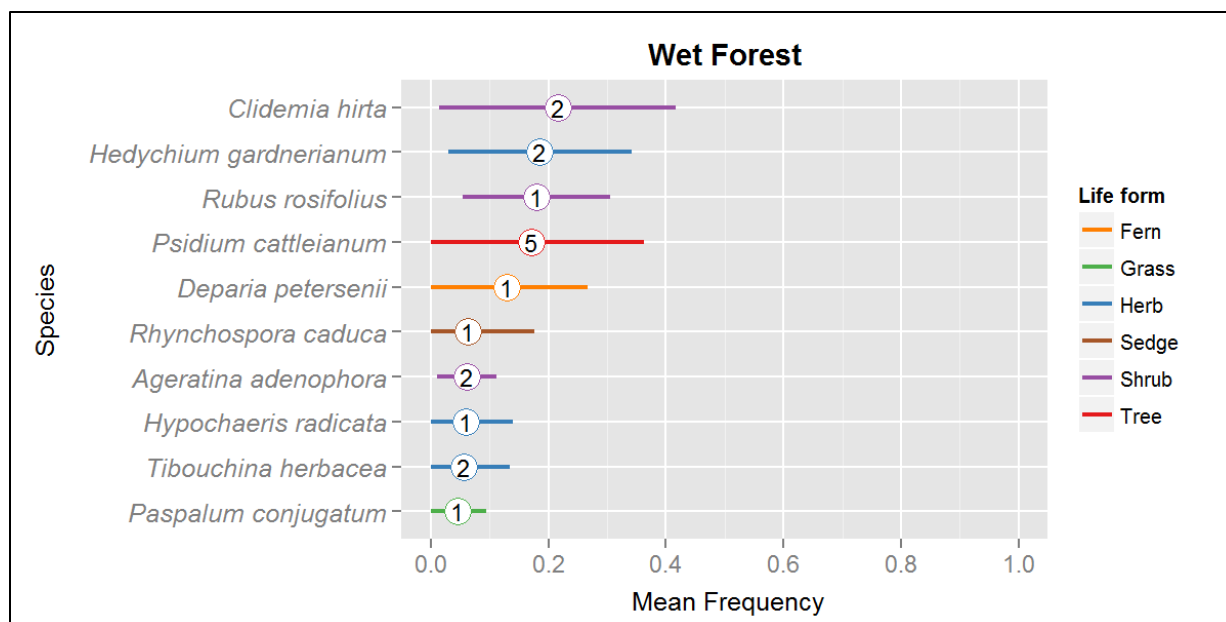


Figure 8. Ten most frequent species in the wet forest. Frequency is the proportion of plots per transect in which the species was present. Frequency of 1.0 = present in all or 100% of plots. Error bars represent the 95% confidence intervals. Numbers inside the points represent the average cover class recorded when the species occurred.

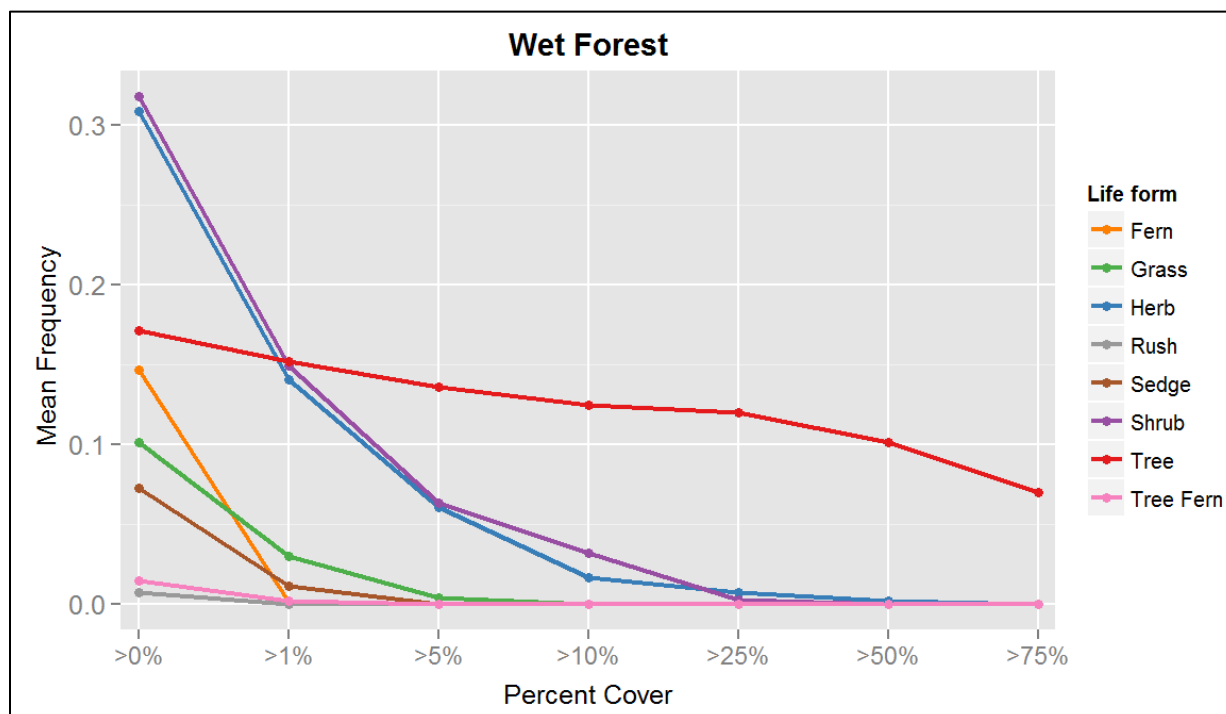


Figure 9. Mean frequency of non-native cover for each vegetation life form present within the wet forest. Frequency is the proportion of plots per transect in which the specified cover was met. The X-axis represents combined non-native cover with increasing minimum cover cutoffs (moving from left to right). Frequency of 1.0 = non-native cover denoted is present in all (100%) of plots. Species per life form [n]: Fern [4], Grass [7], Herb [9], Rush [1], Sedge [4], Shrub [5], Tree [4], Tree Fern [1].

The wet forest map of mean non-native cover (Figure 5) showed the greatest non-native cover occurred in the southeast region of the wet forest sampling frame, specifically where transects fell below 1000 m in elevation. Transect 10, the southern-most and lowest transect in elevation documented the highest mean non-native cover (89%). In general, total non-native plant cover in the wet forest was found to decrease as elevation increased (Figure 10).

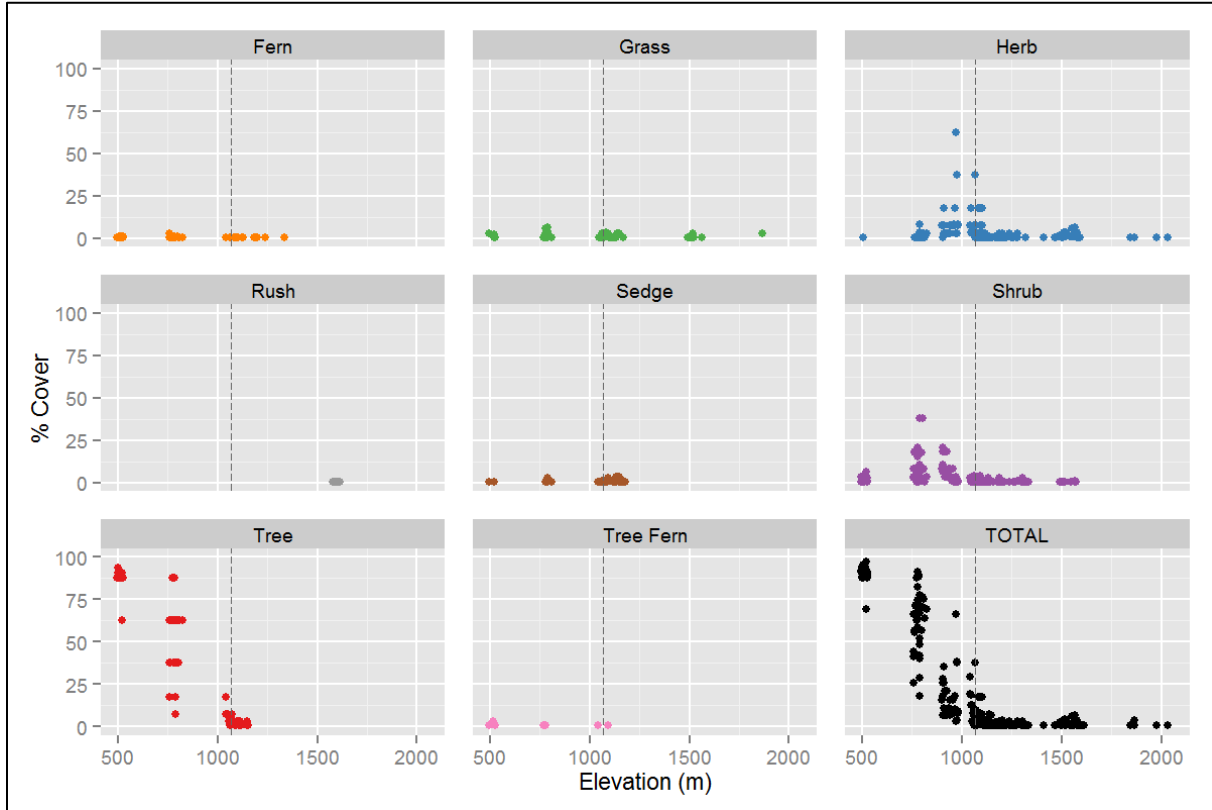


Figure 10. Scatterplots depicting the relationship between non-native cover and elevation for each non-native plant life form detected in the wet forest. Each dot represents one 5x20 m plot. Cover is the sum of all non-native species cover classes (midpoints) per life form and can total >100%. Plots that did not contain the specific life form were removed from the corresponding graph. The vertical dotted line indicates the high priority management area above 1067 m (3500').

Subalpine Shrubland

The most frequently occurring species in the subalpine shrubland was the herb *Hypochaeris radicata* [0.73 ± 0.15] and the grass *Holcus lanatus* [0.51 ± 0.20] (Figure 11). All species recorded in the subalpine shrubland occurred at relatively low average cover (class 1 or 2). Non-native plant life forms in the subalpine shrubland were dominated by herbs and grasses (Figure 12), however, two species of shrubs (*Ageratina adenophora*, *Lythrum maritimum*), one tree (*Pinus radiata*), and one rush (*Juncus planifolius*) were also documented in the subalpine shrubland sampling frame. Herbs [0.85 ± 0.11] showed greater frequency than grasses [0.56 ± 0.36], however, grasses occurred with slightly greater cover (Figure 12). Average non-native plant cover was greatest in both the northeast and northwest corners of the sampling frame (Figure 8), largely due to *H. lanatus* and *H. radicata* (Figures A.15 & A.16).

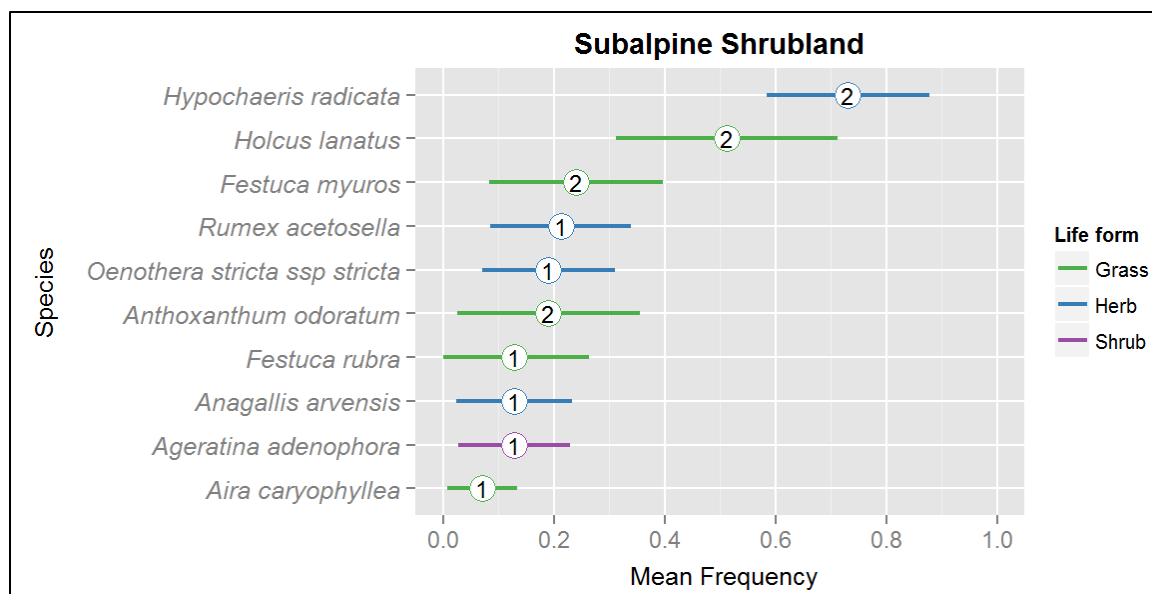


Figure 11. Ten most frequent species in the subalpine shrubland. Frequency is the proportion of plots per transect in which the species was present. Frequency of 1.0 = present in all or 100% of plots. Error bars represent the 95% confidence intervals. Numbers inside the points represent the average cover class recorded when the species occurred.

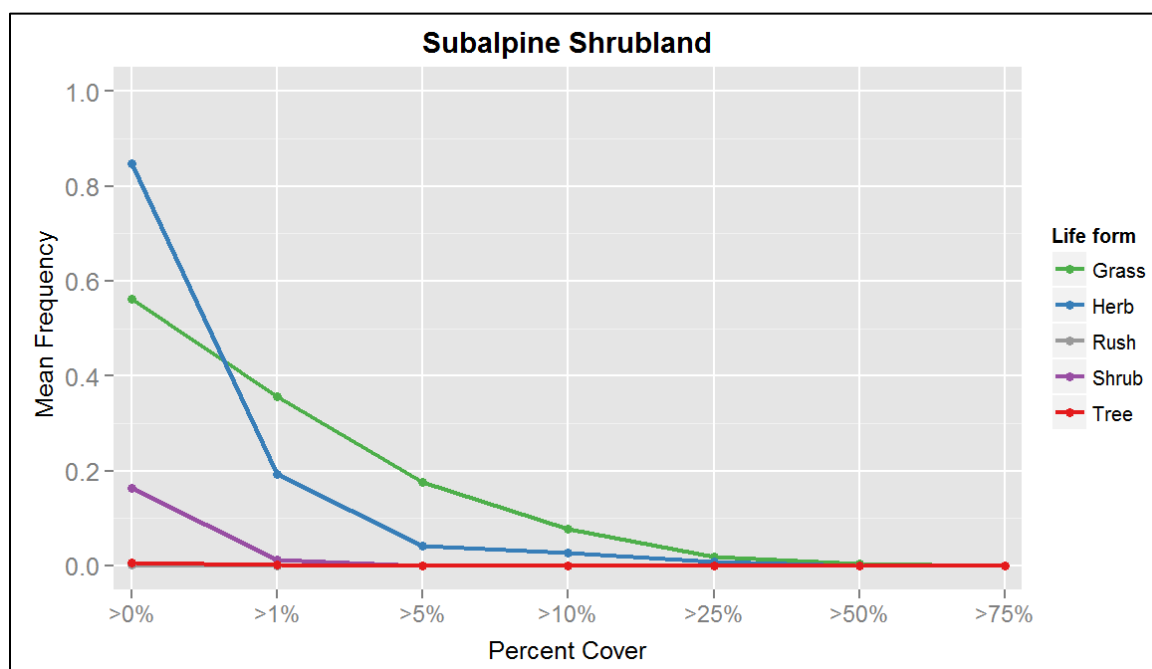


Figure 12. Mean frequency of non-native cover for each vegetation life form present within the subalpine shrubland. Frequency is the proportion of plots per transect in which the specified cover was met. The X-axis represents combined non-native cover with increasing minimum cover cutoffs (moving from left to right). Frequency of 1.0 = non-native cover denoted is present in all (100%) of plots.. Species per life form [n]: Grass [11], Herb [18], Rush [1], Shrub [2], Tree [1].

Discussion

Non-native Species Richness

Both the subalpine and wet forest plant communities appeared to show similar total non-native richness. Results from the EIPS sample-based species accumulation curves (Figure 3) suggest that increased sampling would likely uncover more species in the wet forest, and possibly a few more in the subalpine shrubland. Additional sampling effort from the separate, but concurrent, FTPC monitoring resulted in 5 additional wet forest species and 7 additional subalpine shrubland species, more than expected in the subalpine shrubland. The area covered by the FTPC sampling translates to roughly 300 additional EIPS plots per plant community (although the sampling design is considerably different between the two protocols). The extrapolation of 300 additional plots in Figure 3 shows that the wet forest extrapolation is in agreement with the additional species detected during the FTPC monitoring. However, the additional 7 species found in the subalpine shrubland is in the upper 95% confidence interval for predicted additional species. It is important to note that not all non-native species previously recorded within these communities were captured during this sampling event (see IRMA NPSpecies 2016, Green et al. 2015, Medeiros et al 1998, and HALE and PACN unpublished data sets). One of the assumptions of sample-based rarefaction and extrapolation is sufficient sampling. It may be that the larger area and shorter transects in the subalpine shrubland, compared to that of the wet forest, was insufficient in producing a reliable extrapolation. Currently, results suggest that the wet forest and subalpine shrubland show comparable non-native species richness. Every five years additional temporary transects will be established resulting in greater spatial coverage and species documentation over time. This approach will also offer an excellent opportunity to assess whether or not current methods should be adjusted.

Non-native Species Richness

Wet Forest

Kīpahulu Valley is a restricted-entry Scientific Reserve with only a few (5-6) vegetation inventories occurring since the first in 1967 (Aruch 2006). One of the most recent publications that reported on observed vascular plant data in Kīpahulu was by Anderson et al. (1992). That study tracked the seasonal status of non-native plants during a five year (1983-1988) pig removal effort. The sampling design utilized 97, 400-m² plots arranged across 20 transects spanning from 716 – 2073 m elevation. Similar to Anderson et al. (1992), we found that non-native plant species richness, frequency, and cover were greatest within the lower elevations of the wet forest sampling frame. The two lowest elevation transects (4 and 10; Figure 5) each had 100% transect plot occupancy with at least one non-native species. These transects also reported the greatest non-native richness (17 and 20 species per transect, respectively) and the greatest mean non-native cover (64% and 90%, respectively). Anderson et al. (1992) reported that this low elevation non-native plant invasion extended upslope to 1200 m. The criteria used by Anderson et al. (1992) to select 1200 m as the invasion front was not described in the study, but our results show a clear decrease in non-native cover near the 1200 m elevational gradient (Figure 10). Future EIPS and FTPC monitoring will help to determine elevational trends in non-native plant cover and track any changes in this invasion front.

Clidemia hirta, was the most frequently occurring non-native species in the wet forest (0.22), with an average cover of 1-5% when it occurred. Its distribution was largely concentrated in lower Kīpahulu (Figure A.1) with a maximum observed elevation of 1103 m. The first record of this species in Kīpahulu Valley was at 850 m in 1988. Loope et al (1992) reported no known establishments in Kīpahulu Valley in 1991.

Hedychium gardnerianum, the second most frequent non-native species, had an observed mean frequency of 0.19 and average cover of 1-5% when present. Occurrence along EIPS transects ranged between 778 – 1322 m in elevation (Figure A.2). Anderson et al. (1992) listed *H. gardnerianum* as the most immediate threat to displacement of native flora in Kīpahulu and noted several incipient populations at 880 m and 1100 m but none recorded along study transects at that time.

Rubus rosifolius had an observed mean frequency of 0.18 and an average cover of <1% when it occurred. EIPS monitoring showed the range extending from 504 – 1570 m (Figure A.7). It was noted to occur in Kīpahulu Valley as early as 1945 (Medeiros et al. 1998). Anderson et al. (1992) recorded *R. rosifolius* consistently along transects up to 1494 m. Although widespread, *R. rosifolius* is not currently perceived as an imminent conservation threat in Hawai‘i.

Psidium cattleianum (mean frequency 0.17) had the greatest average cover (25-50% when present) of any non-native plant because of the dense stands located in lower Kīpahulu. Anderson et al. (1992) stated that the uppermost elevation at which this species was sighted was 1220 m. The highest occurrence recorded along EIPS transects was 1156 m, however, *P. cattleianum* was recorded as high as 1543 m in the Manawainui management unit during vegetation mapping (Green et al. 2015) and 1212 m in middle Kīpahulu during FTPC monitoring (Figure A.5).

After the initial removal of pigs from middle and upper Kīpahulu (1988), reduction in non-native species cover was reported (Anderson and Welton 1993; Meston and Mallinson 2011). However, the most frequent non-native plants reported here (*C. hirta*, *H. gardnerianum*, *R. rosifolius*, *P. cattleianum*) are still capable of spreading in spite of pig control (Loope et al. 1992; Loh and Tunison 1999; Cole et al. 2012). Common, non-native passerines (e.g. *Zosterops japonicas* and *Leiothrix lutea*) readily disperse seeds from all four of these species (Medeiros 2004). Additionally, *H. gardnerianum* spreads vegetatively by rapidly growing rhizomes.

Paspalum conjugatum was described by Anderson et al. (1992) as a major threat to Kīpahulu Valley due to its ability to vegetatively spread into non-disturbed sites and after witnessing a 10 year pig enclosure become overrun with a “pure carpet” of *P. conjugatum*. However, Meston and Mallinson (2011) have reported a decrease in *P. conjugatum* cover after revisiting some of the same transects monitored by Anderson et al. (1992). The decrease in *P. conjugatum* cover is believed to be a result of increased native and non-native shrubs in the absence of pig disturbance. Anderson et al. (1992) described continuous distribution of *P. conjugatum* from 1140 – 1220 m and the upper range reaching to 1430 m on the Upper Plateau. We observed *P. conjugatum* with an average frequency of 0.05. It was recorded along 5 different transects ranging in elevation from 519 – 1167 m with an average cover of <1% when it occurred (Figure A.4).

Tibouchina herbacea (mean frequency 0.06) is another non-native plant with a relatively recent history in the park. It was first documented in 1988 and has since been discovered and destroyed in sections of the park from 610 – 1524 m elevation (Medeiros et al. 1998). We documented *T. herbacea* along 7 transects ranging in elevation from 771 – 1466 m (Figure A.10).

Other species observed in the wet forest that are of management concern to HALE include: *Melinis minutiflora* (Figure A.3), *Psidium guajava* (A.6), *Spathodea campanulata* (A.8), and *Sphaeropteris cooperi* (A.9). These species were detected with average frequencies of 0.01 or less but are still threats to the native wet forest plant community. While the thematic map for *S. cooperi* shows low recorded occurrence along transects, it is still widely dispersed in the lower portion of the wet forest. This species warrants continued vigilant monitoring and control as it severely alters structure and function of wet forest systems and has a demonstrated ability to spread throughout intact, native plant communities (Medeiros et al. 1992, Palmer 2003). A recently discovered large infestation at HAVO has forced managers there to reevaluate the park's control strategy (D. Benitez 2017, pers. comm., 27 March).

Subalpine Shrubland

Similar to EIPS results at HAVO (Simon et al. 2016), non-natives in the subalpine shrubland primarily consisted of herbs and grasses (Figure 11 & Figure 12). 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 (Daehler 2005). 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 (Daehler 2005). In addition to grasses and herbs, HALE's subalpine shrubland also included non-native shrubs, *Ageratina adenophora* and *Lythrum maritimum*, and the early detection-listed tree, *Pinus radiata*.

The herb, *Hypochaeris radicata* (Figure A.16), and the grass, *Holcus lanatus* (Figure A.15), greatly contributed to non-native frequency in the subalpine shrubland (frequencies of 0.73 and 0.51, respectively). These species were also two of the most frequent non-native subalpine shrubland species at HAVO (Simon et al. 2016). Both species are categorized as being “disruptive in native communities”, and are able to persist even after ungulate removal (Daehler 2005). *H. radicata* can persist in elevations ranging from 110-3040 m (Daehler 2005), 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). Goats have been associated with trampling, and pigs with trampling and rooting in areas invaded with *H. radicata*, *H. lanatus*, and *Rumex acetosella* (Anderson et al. 1992). Both goats and pigs have been documented to seek out or select *H. radicata* plants for flower heads or tap roots. The consequent trampling and digging creates more niches for the plant as well as other weedy species (Yocom 1967; Anderson 1992). Despite fencing and hunting efforts, periodic ingress of feral ungulates still occurs and requires continued management efforts in this area.

Other species observed in the subalpine shrubland that are of management concern to HALE include: *Bromus tectorum*, *Cirsium vulgare*, *Erodium cicutarium*, *Heterotheca grandiflora*, *Pinus patula*,

Pinus radiata, *Plantago lanceolata*, *Rubus argutus*, and *Senecio madagascariensis*. With the exception of *Plantago lanceolata* (0.04) and *Bromus tectorum* (0.02), these species were detected at average frequencies of 0.01 or less. Mapped occurrence and cover of these species can be found in the subalpine shrubland portion of Appendix A (Figures A.11 – A.21). Although these species showed relatively low frequencies, their ability to rapidly spread should not be overlooked. For example, *S. madagascariensis* was first documented in Hawai‘i on the Big Island in the early 1980s. It is now considered one of the worst pasture weeds in Hawai‘i and has been documented spreading through natural areas from near sea level to above 10,000 feet (Kueffer and Loope 2009). *Senecio madagascariensis* was the second most frequent non-native herb in the subalpine shrubland at HAVO where it reached an average mean frequency of 0.74 in one heavily invaded area (Simon et al. 2016).

Compared to the wet forest, the subalpine shrubland documented more plots occupied by at least one non-native species (Figure 7). Furthermore, non-native plant frequency and cover were greater within HALE subalpine shrubland when compared to HAVO subalpine shrubland (Simon et al. 2016). One explanation for this could be the greater accessibility of subalpine shrubland at HALE. The subalpine shrubland encompasses infrastructure, several roads, and trails that are frequented by park staff and visitors. While humans are known vectors for non-native species spread, further analysis is needed, especially when determining how distance from these corridors correlates with non-native species cover. Other protocols conducted by I&M, including Early Detection of Invasive Plant Species Monitoring (Ainsworth et al. in press), will help inform these analyses and ultimately resource management.

The cool, dry climate of the subalpine shrubland 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 that cause disturbance and aid seed dispersal.

Future edits to Sampling Frame in Wet Forest and Subalpine Shrubland

Vegetation monitoring in HALE in 2012 utilized the original sampling frames (Ainsworth et al. 2012), which were produced prior to the vegetation mapping inventory of the park (Green et al. 2015). Based on the results of vegetation map and the 2012 EIPS and FTPC data analysis, future vegetation monitoring at HALE will be conducted using updated sampling frames. Specifically, areas that were classified in the vegetation map as bog, wet and mesic forests, will be removed from the subalpine shrubland and appended to the wet forest sampling frame. Because original frames were used for the 2012 monitoring cycle at HALE, some non-native species associated with wet forest environments were captured within the subalpine shrubland. Transect 7 in the subalpine shrubland frame crossed through a *Metrosideros polymorpha*/*Rubus hawaiiensis* Montane Wet Forest (Green et

al. 2015), documenting *Juncus planifolius* and *Lythrum maritimum*, two species typically found in moist areas, and at the margins of wet forests (Wagner 1999).

In addition to appending the upper elevation of the wet forest sampling frame, the lower section of the wet forest sampling frame will be removed from future sampling. Specifically, the new wet forest sampling frame will not extend below 740 m and previously sampled sites below this elevation will not be resampled. The decision not to sample in this area was made primarily due to the high concentration of non-native species. This area is not considered high priority for management within the park and removing it will increase monitoring efficiency in the remaining sample sites and reduce the risk of inadvertently spreading non-native species into the more intact areas of the wet forest. This decision can be revisited if significant management efforts were ever to occur in the area, or if there was ever a desire to learn more about non-native invasion processes, which would not necessitate a five year return interval.

Conclusions

- Across the wet forest and subalpine shrubland transects, the average frequency of encountering a non-native species was somewhat high (wet forest [0.48], subalpine shrubland [0.88]). Yet, aside from the low elevation wet forest, non-native cover within a plot was generally low and still manageable in many areas.
- Anderson et al. (1992) recognized *C. hirta* and *H. gardnerianum* as immediate threats to Kīpahulu Valley, these species were not recorded along any transect at the time of the Anderson et al. (1992) study, but are now the most frequent non-native species across the HALE wet forest plant community.
- Anderson et al. (1992) reported an elevational invasion front of non-native plants extending from lower elevation up to 1200 m in Kīpahulu Valley. Our results also show a clear elevational trend in non-native cover near this elevational gradient. Future EIPS and FTFC monitoring will help to determine elevational trends in non-native plant cover and track any changes in this invasion front.
- Transects in the subalpine shrubland plant community showed higher frequencies of non-native plants than transects in the wet forest. The herb, *H. radicata*, and the grass, *H. lanatus*, greatly contributed to non-native plant frequencies in the subalpine shrubland.

Recommendations

As the result of years of diligence in active ecosystem management, the wet forest of Kīpahulu Valley are among the richest and most ecologically intact surviving within the protection of the National Park Service. Although the results of resources management across the valley have been impressive, continued work battling invasive species and restoring rare and endangered species is requisite. Mid to high elevation areas remain relatively intact with overall low non-native species cover. However, this outstanding assemblage of endemic bio-diversity protected in the Haleakalā wet forest is imminently threatened with displacement by ecosystem modifying species such as *Clidemia hirta* and *Hedychium gardnerianum*. In response to the high frequency but low cover of non-native species such as *C. hirta* and *H. gardnerianum*, great emphasis should be on controlling incipient non-native species populations throughout mid to high elevation areas of Kīpahulu Valley.

This report is the first of a long-term monitoring regime for established invasive plant species at HALE. 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. 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 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 HALE, HAVO, and Kalaupapa National Historical Park.

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Appendix A: Thematic maps for Established Invasive Plant Species

Thematic maps of HALE 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 distribution and magnitude of non-native species of interest. Along with data from the EIPS survey (National Park Service 2016a), included are data from the Vegetation Mapping inventory (Green et al. 2015) and Focal Terrestrial Plant Community (FTPC) monitoring (National Park Service 2016b). Vegetation mapping plot data in the wet forest and subalpine shrubland sampling frames were collected in 2011 and consisted of 400 m² circular plots. While several plots were inventoried at HALE, only those that fell within EIPS sampling frame borders are presented. Maps below include monitoring data from 57 rectangular FTPC plots (20x50m) and 88 vegetation inventory plots in the HALE wet forest and subalpine shrubland communities. Displayed cover classes correspond to percent cover based off of the modified Braun-Blanquet cover classes (Table 2).

Non-native plant species sampling sites:

- [Wet Forest](#)
- [Subalpine Shrubland](#)

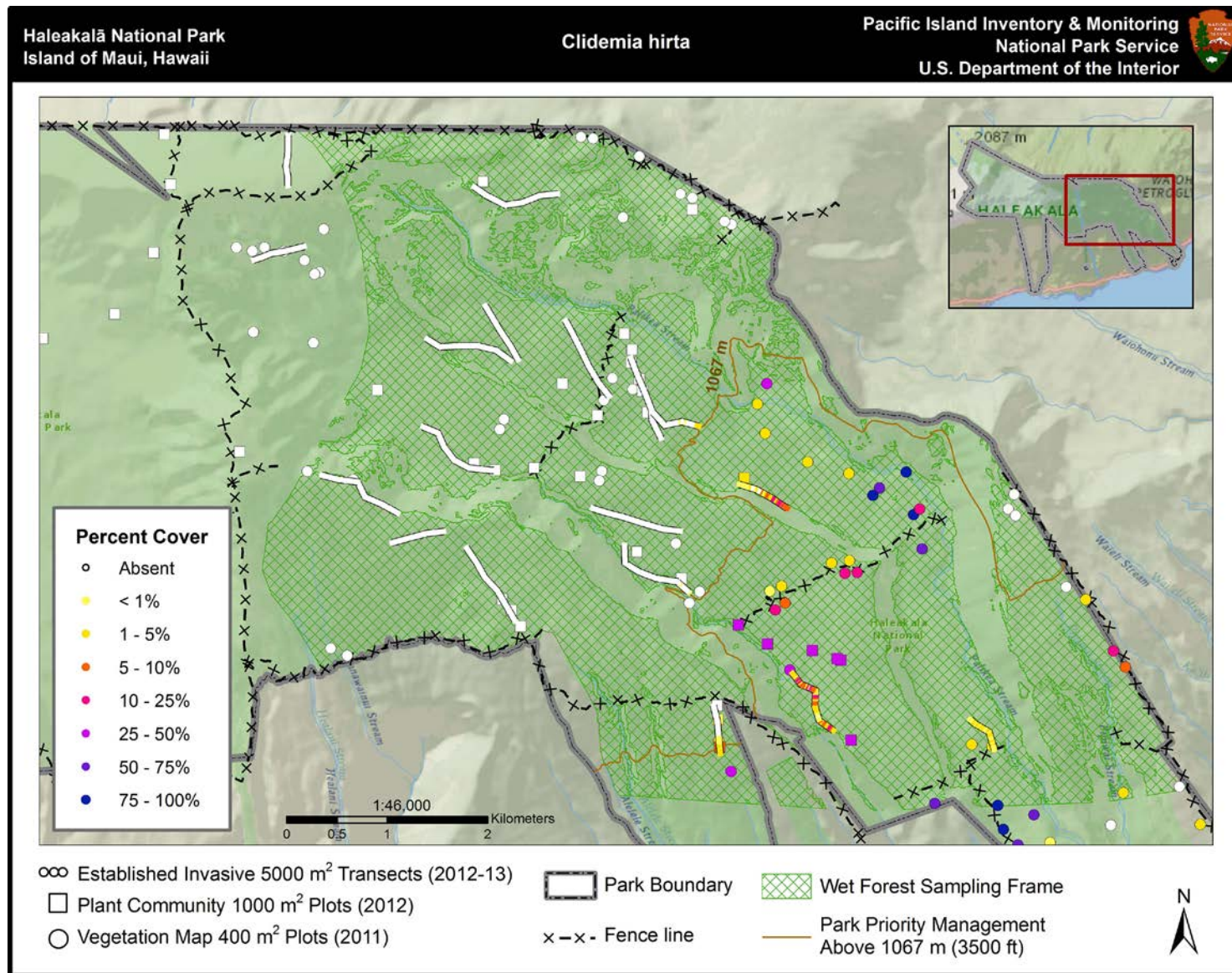


Figure A.1. *Clidemia hirta* is widespread and abundant in the wet forest below 1000 m.

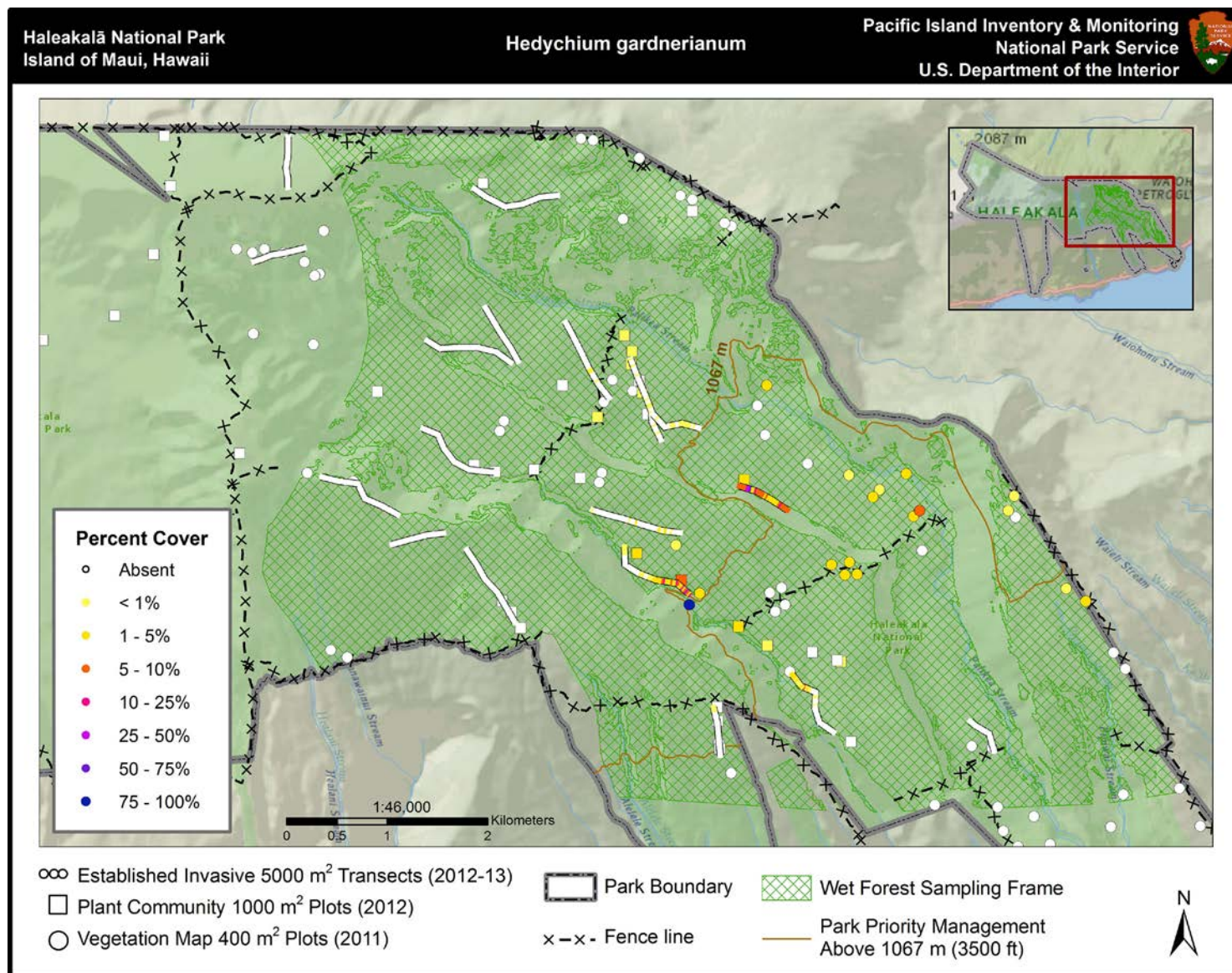


Figure A.2. *Hedychium gardnerianum* cover is largely concentrated between 800-1200 m elevations in the wet forest.

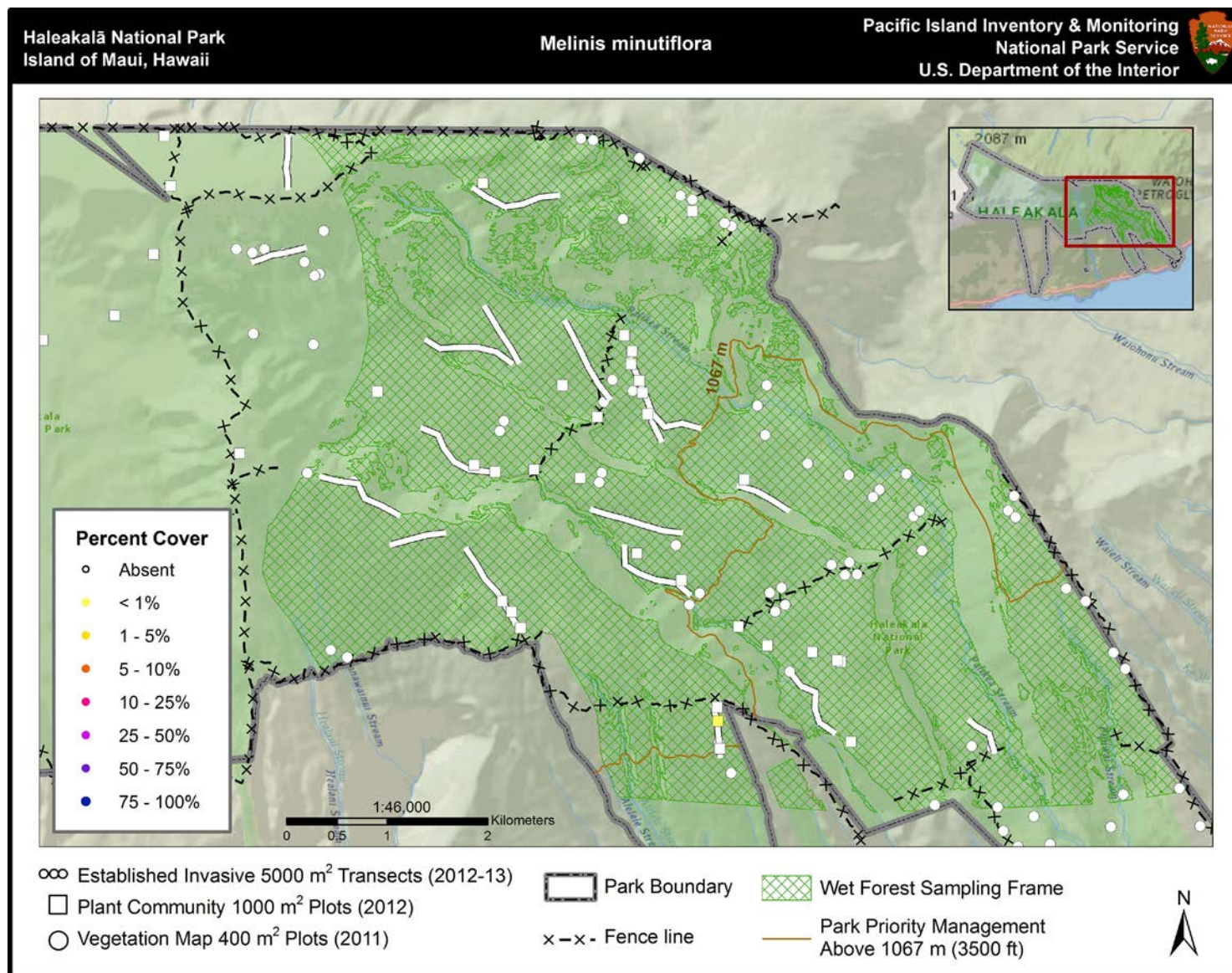


Figure A.3. *Melinis minutiflora* was found in one Plant Community plot in Ka'āpahu.

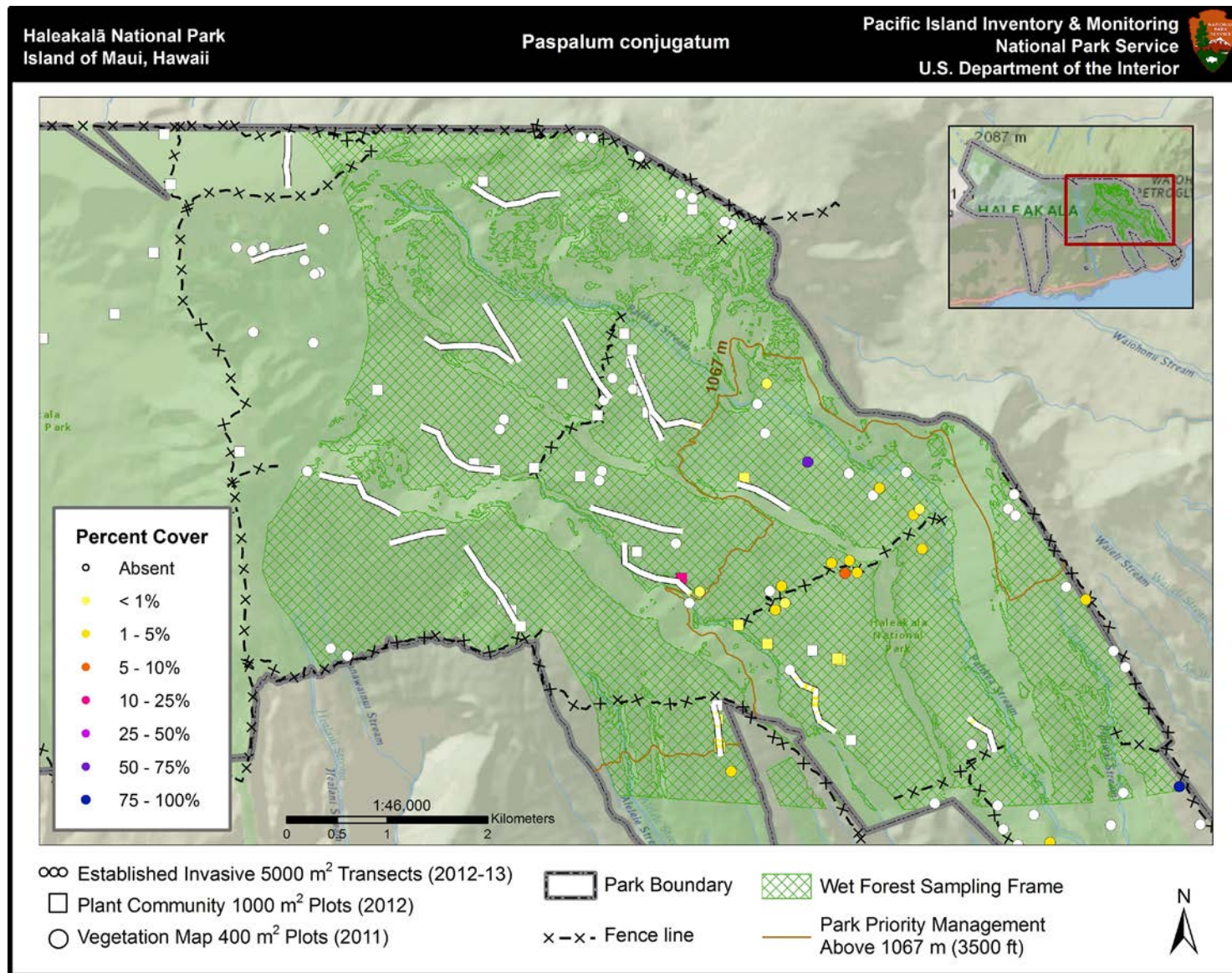


Figure A.4. *Paspalum conjugatum* is scattered throughout the lower half of the wet forest with various cover values.

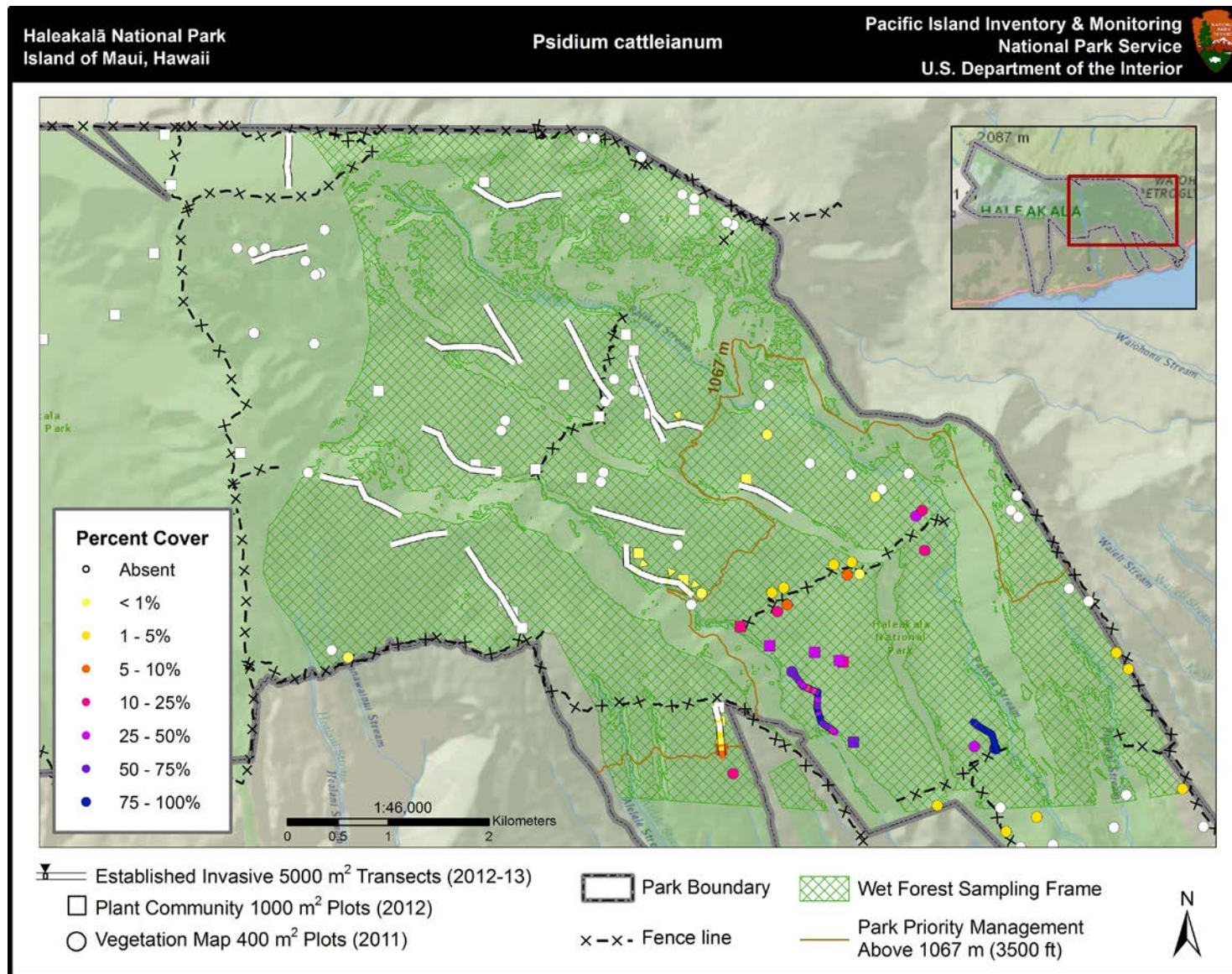


Figure A.5. *Psidium cattleianum* is widespread and abundant in lower Kīpahulu.



Figure A.6. *Psidium guajava* is abundant on the southern boundary of the wet forest sampling frame. The one record in the Plant Community plot was recorded as *Psidium* sp.

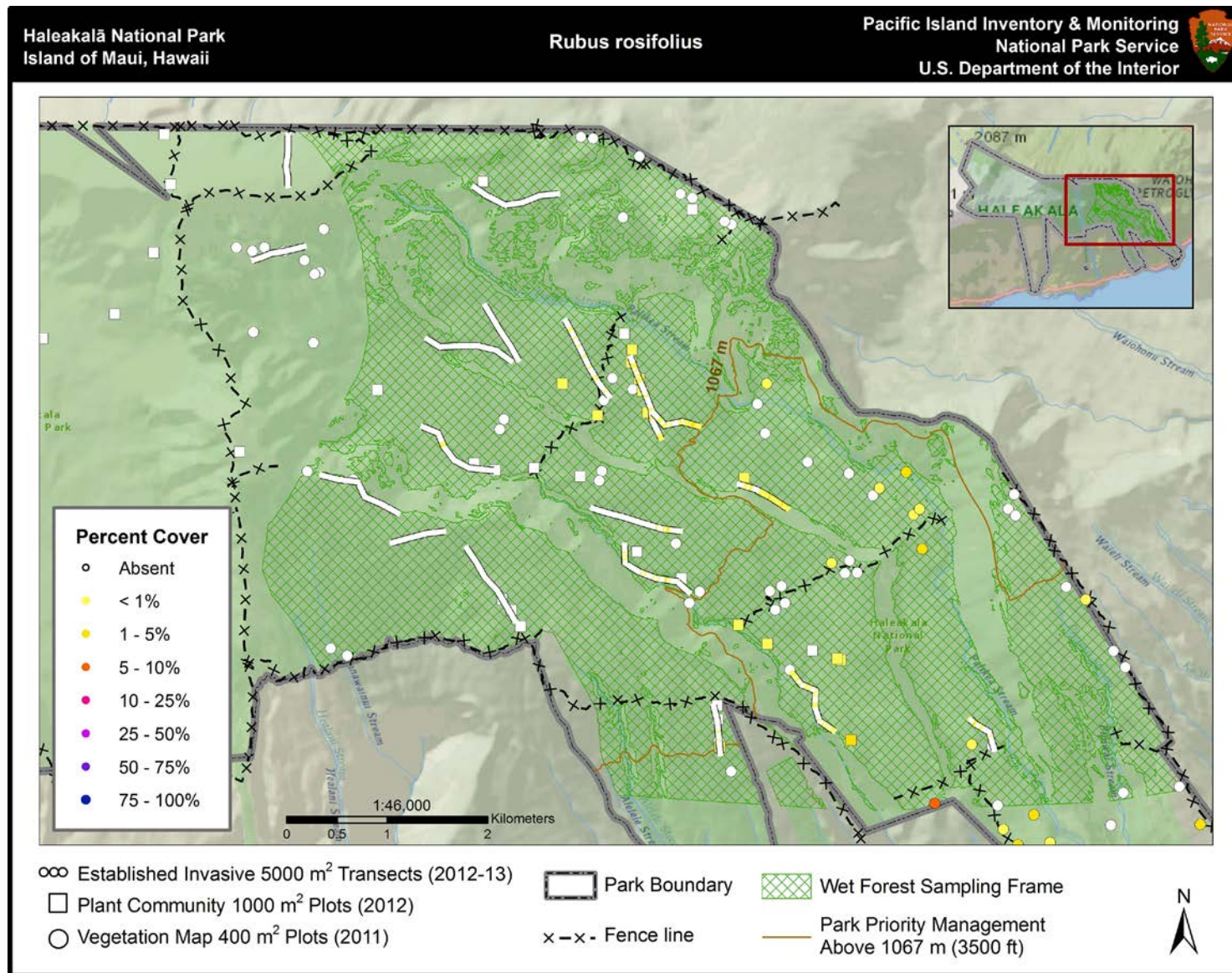


Figure A.7. *Rubus rosifolius* is dispersed throughout the wet forest, but with low cover.

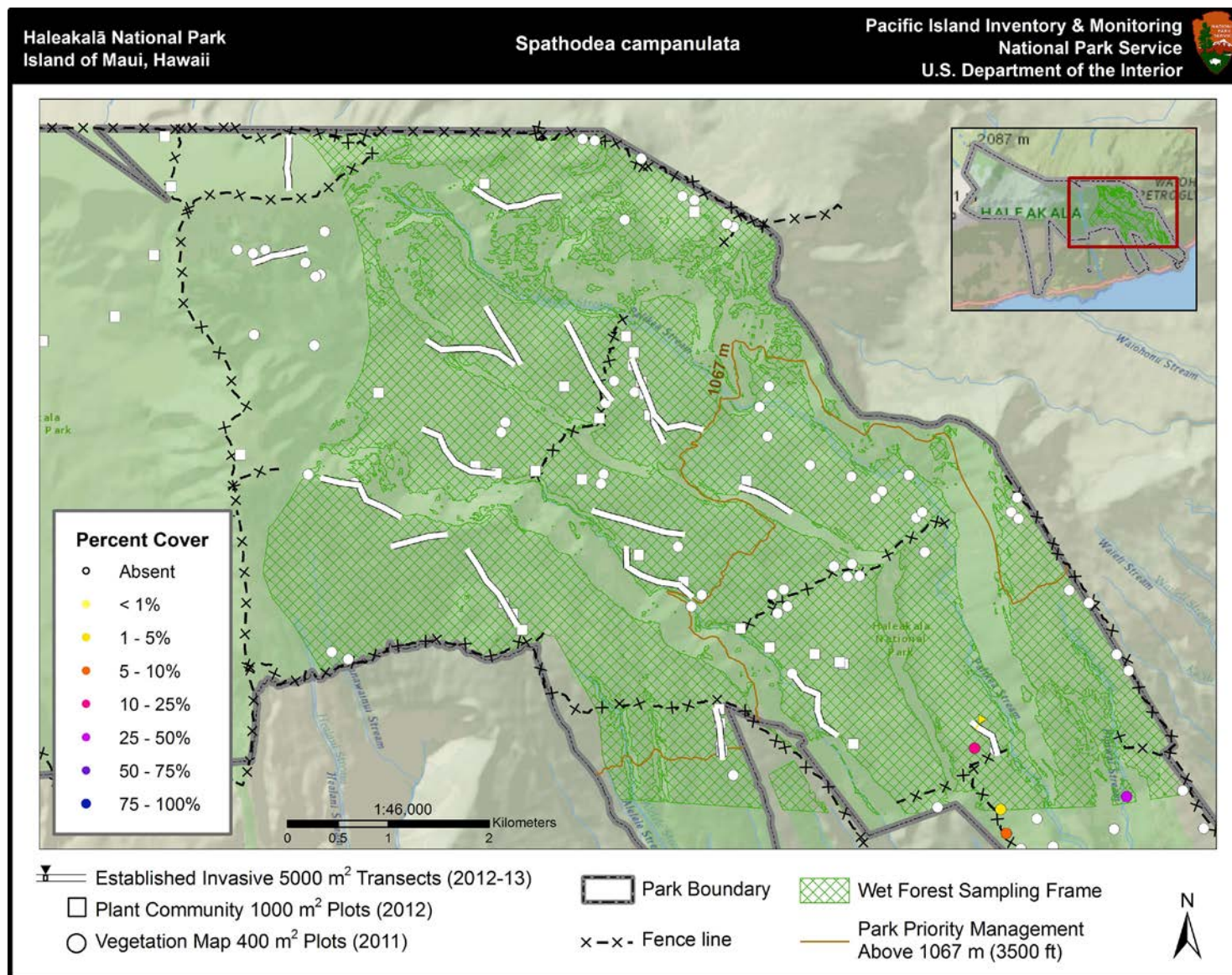


Figure A.8. *Spathodea campanulata* occurred along the southeast boundary of the wet forest sampling frame with intermediate cover.

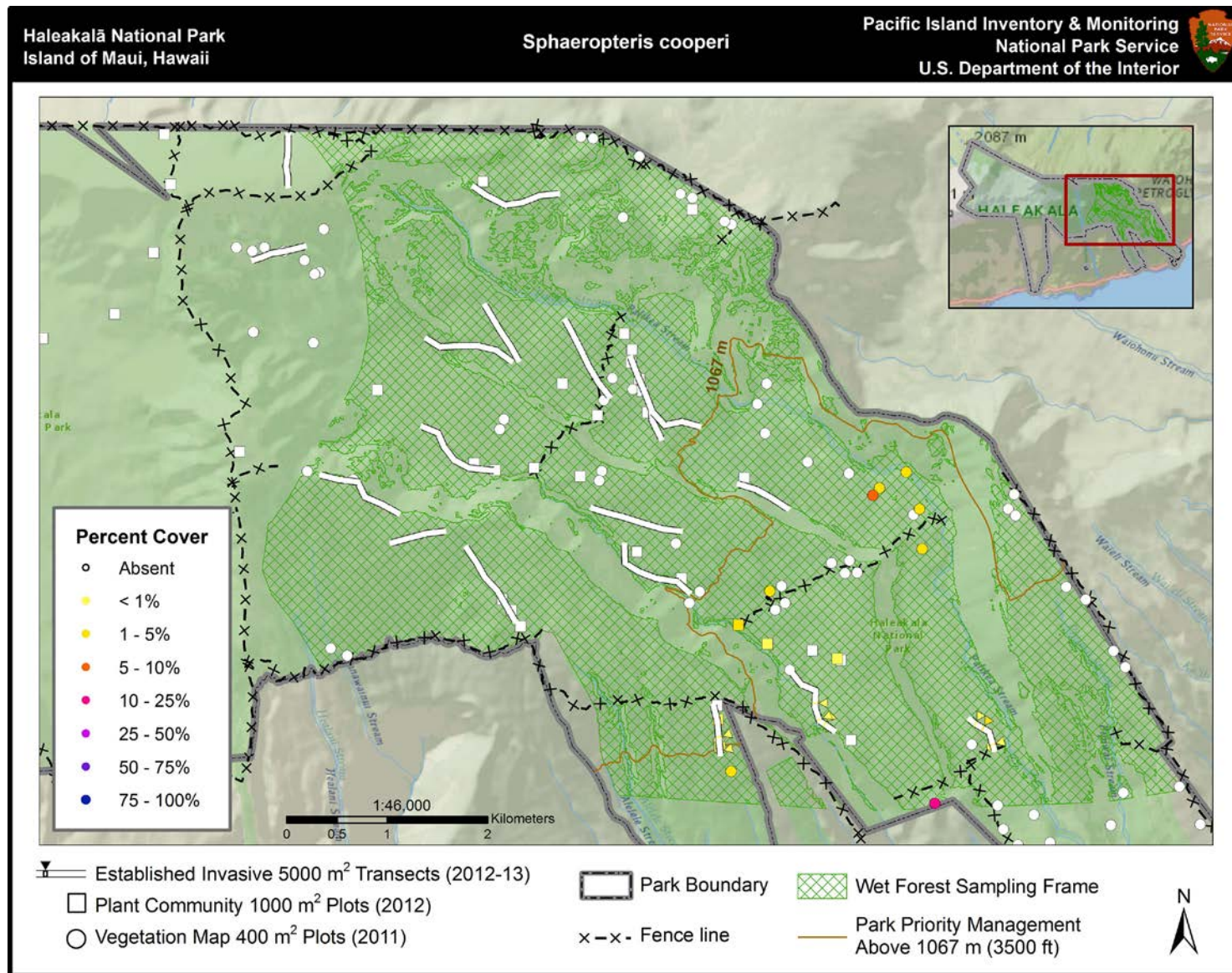


Figure A.9. *Sphaeropteris cooperi* is dispersed with low cover in Ka'āpahu and lower Kīpahulu into middle Ka'āpahu.

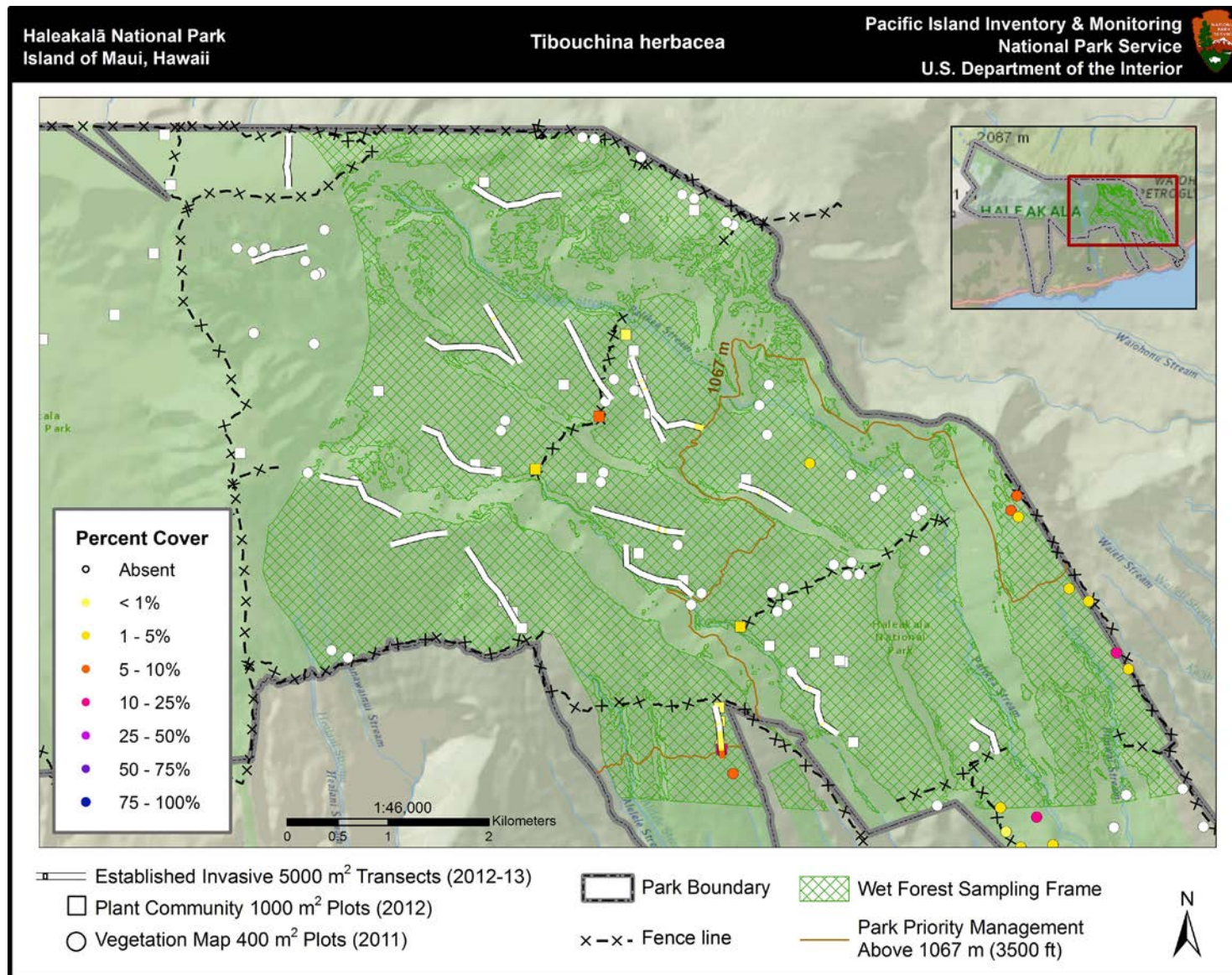


Figure A.10. *Tibouchina herbacea* is scattered throughout Kīpahulu with low cover.

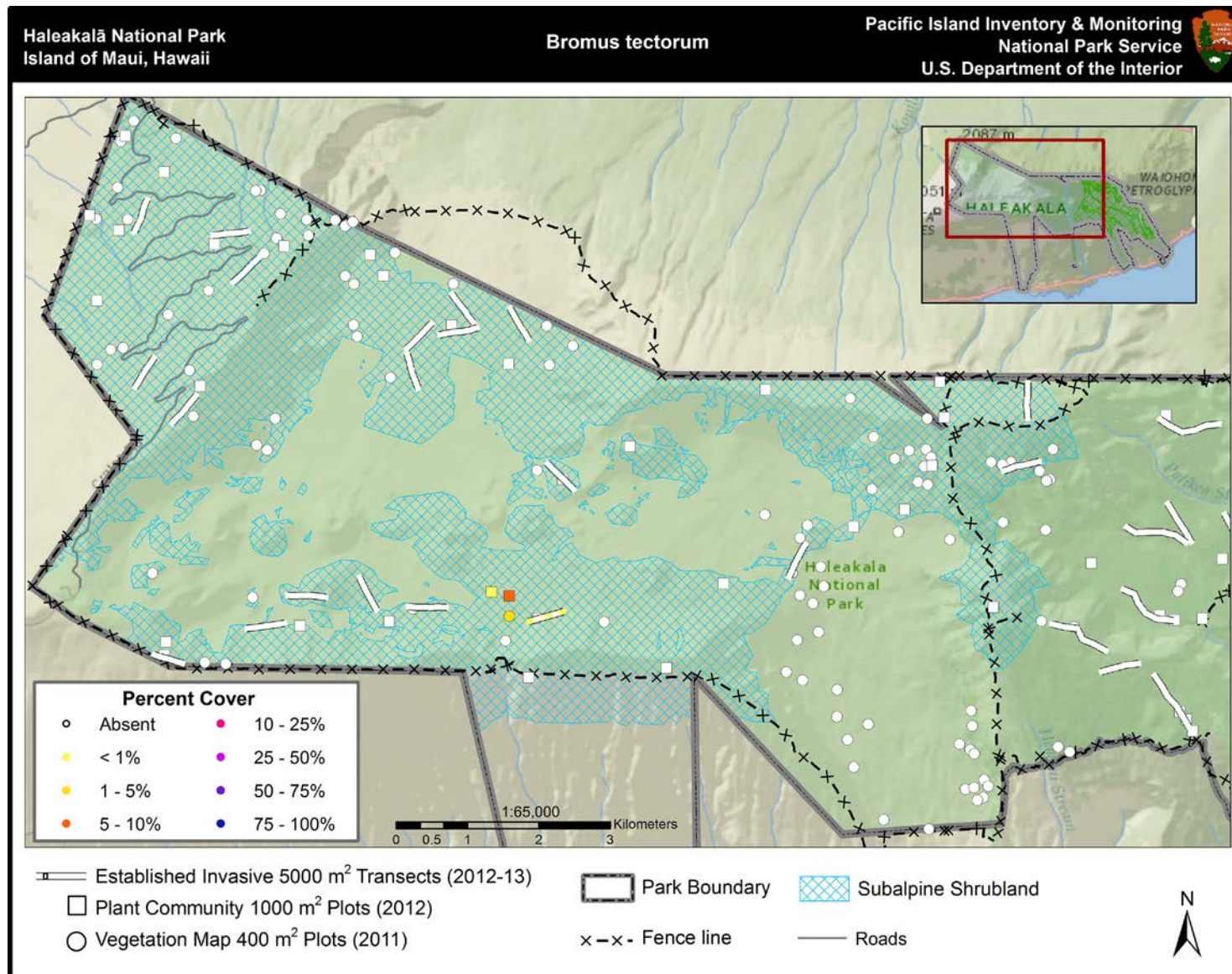


Figure A.11. *Bromus tectorum* is restricted to southern portion of the central crater management unit with low cover.

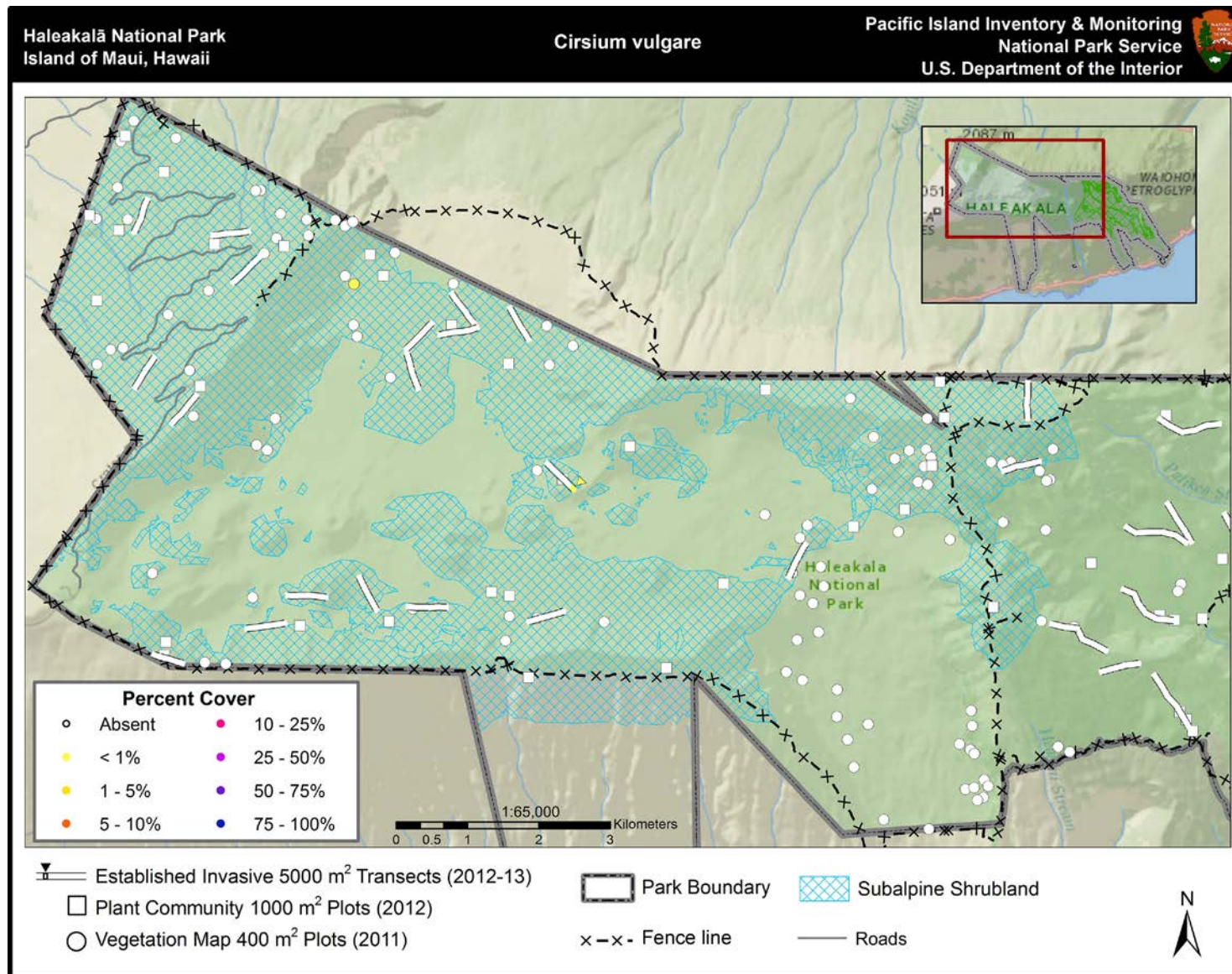


Figure A.12. *Cirsium vulgare* was found at two locations within the subalpine shrubland.

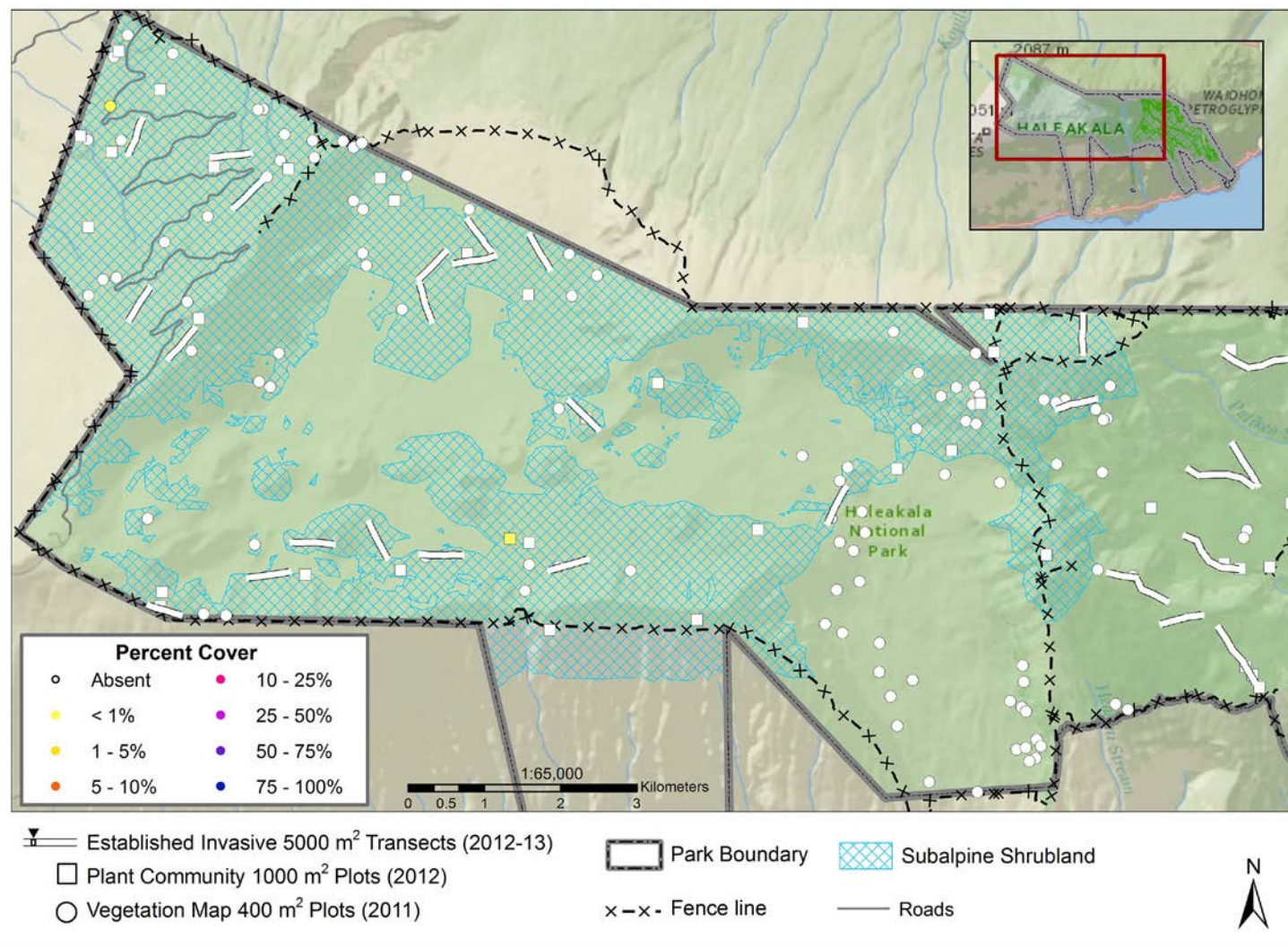


Figure A.13. *Erodium cicutarium* was found at two separate locations with low cover in the subalpine shrubland.

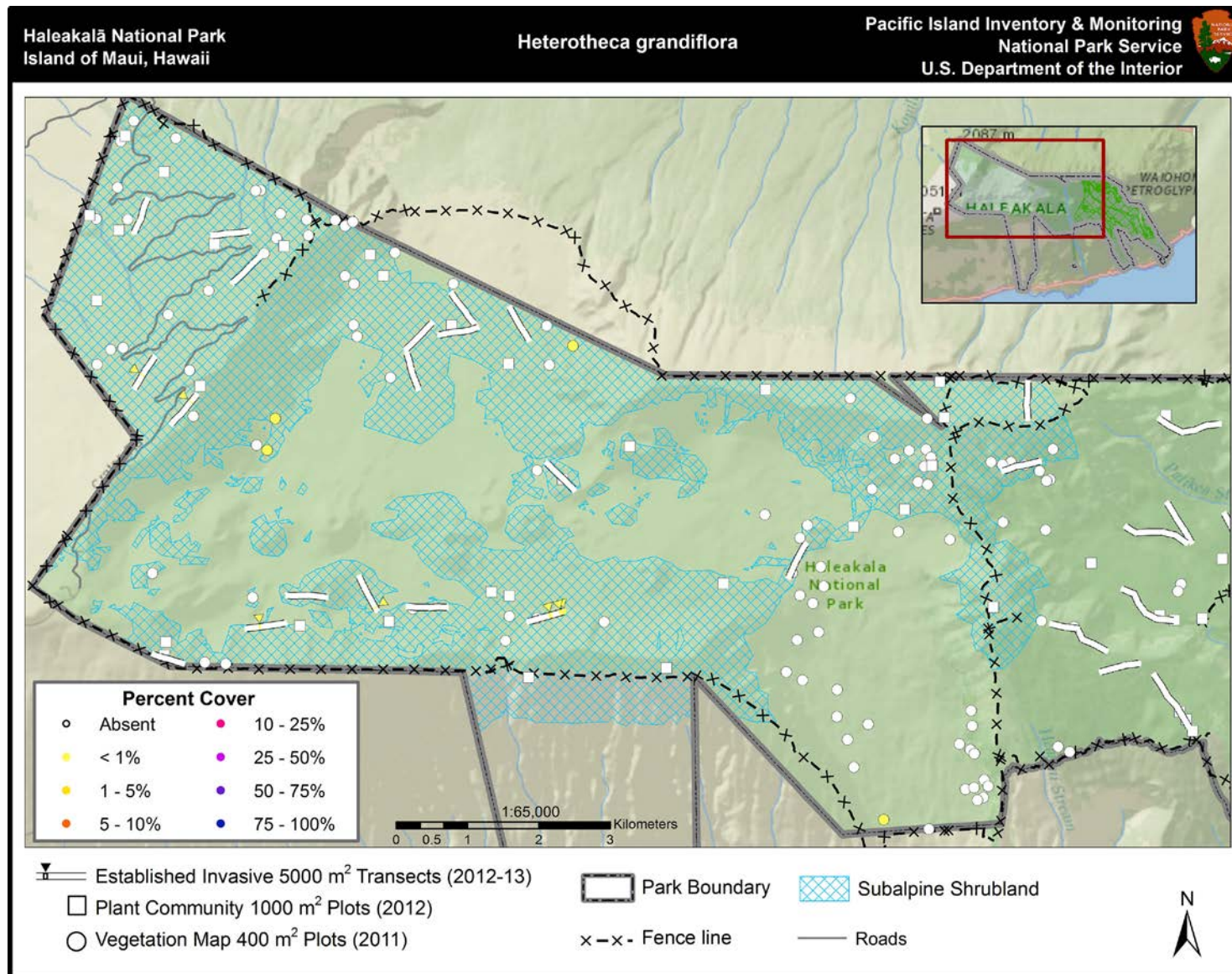


Figure A.14. *Heterotheca grandiflora* is scattered throughout the subalpine shrubland with low cover.

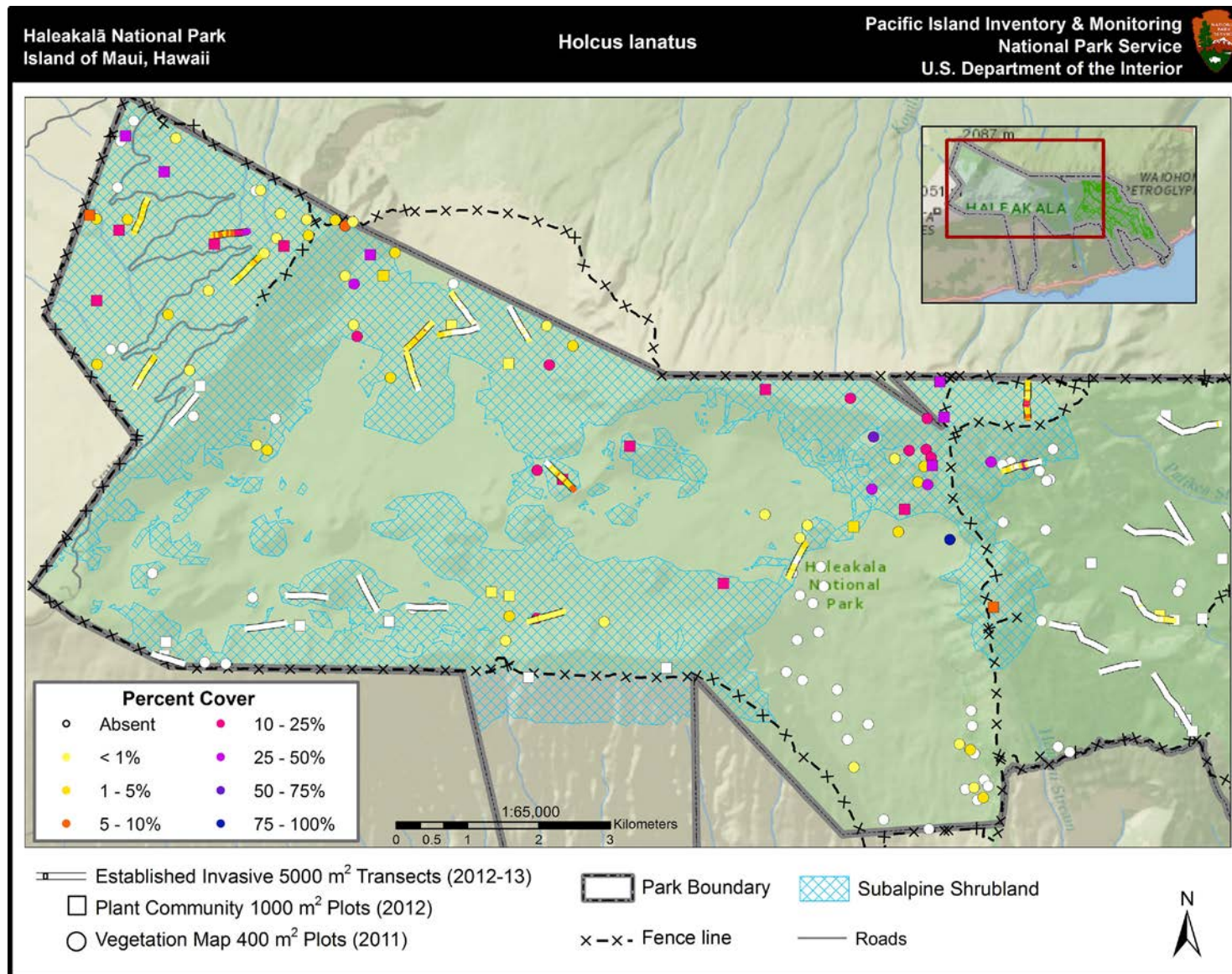


Figure A.15. *Holcus lanatus* is widespread in the subalpine shrubland and abundant along the northern boundary of HALE.

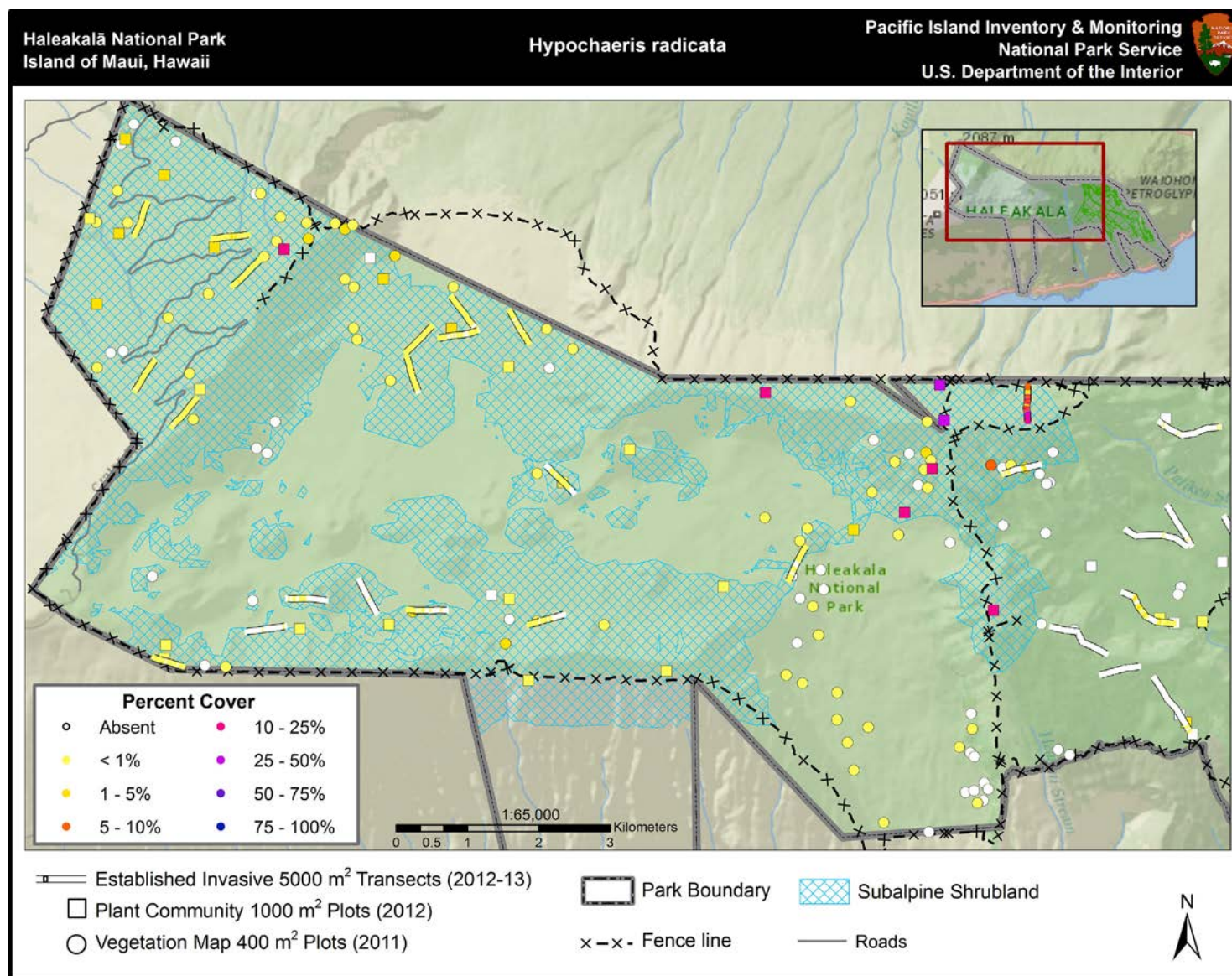


Figure A.16. *Hypochaeris radicata* is widespread in the subalpine shrubland, with the greatest cover on the Kīpahulu side of the Crater.

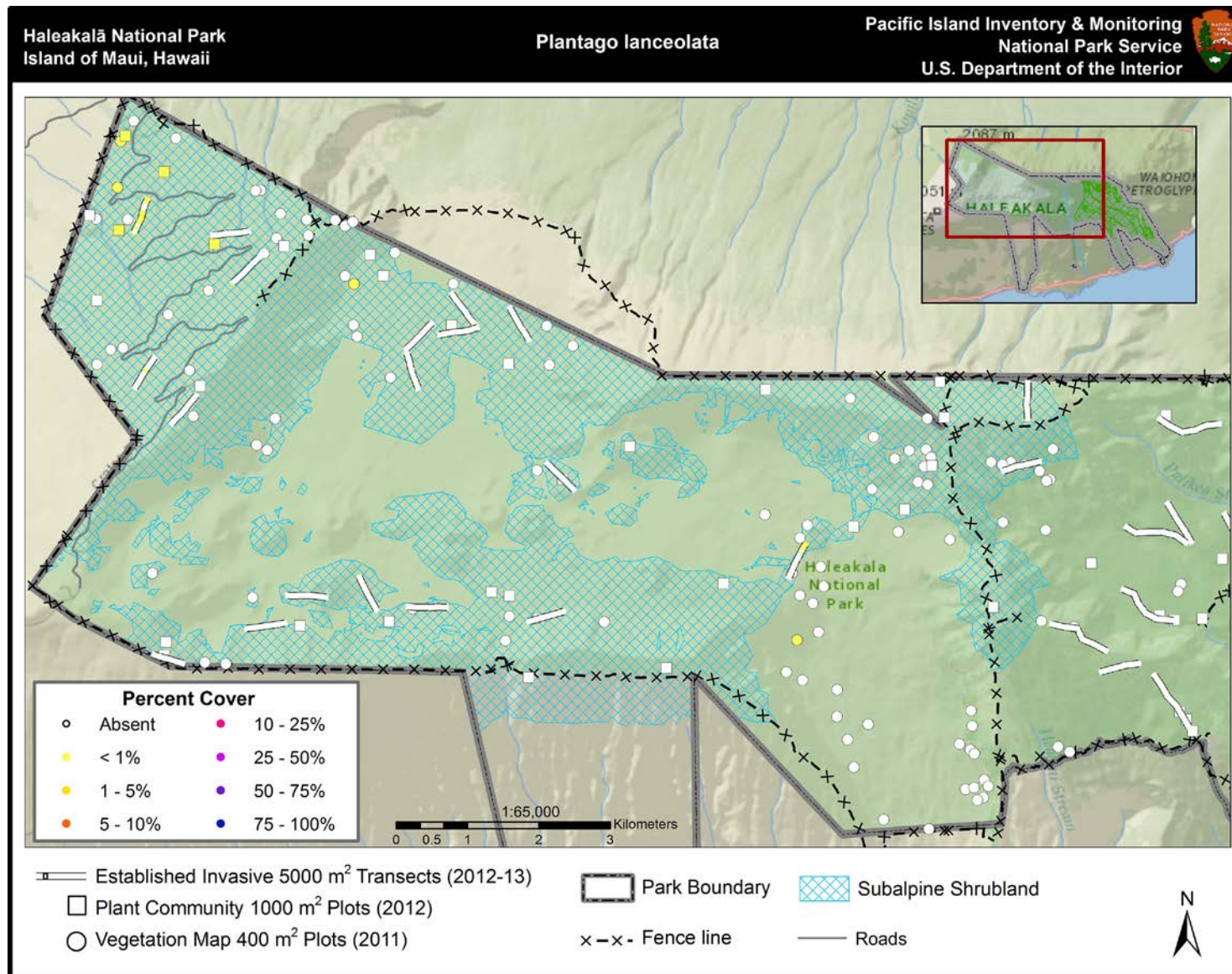


Figure A.17. *Plantago lanceolata* occurs at low cover in the northwest and southeast portions of the subalpine shrubland.

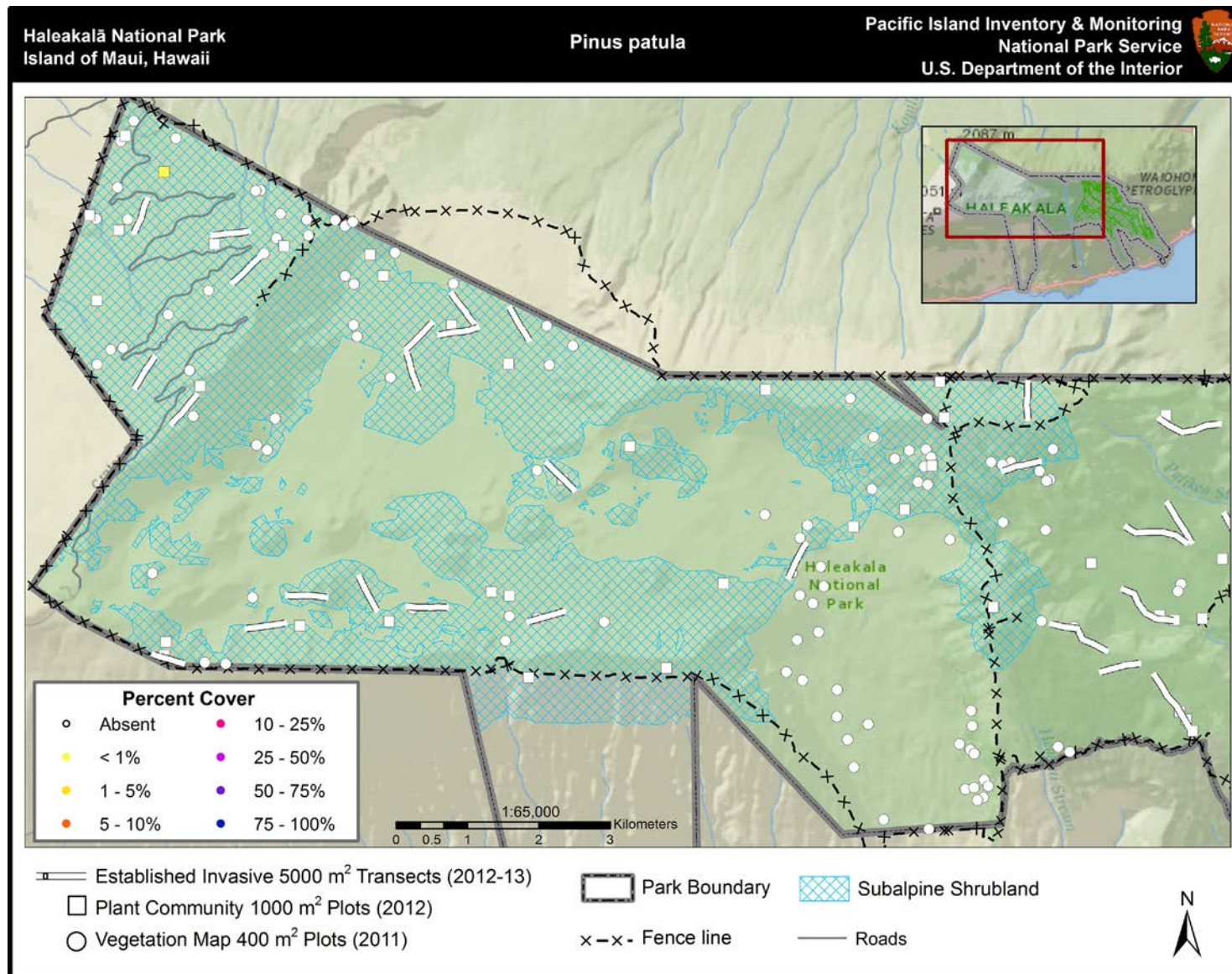


Figure A.18. *Pinus patula* occurred in one Plant Community plot in the northwest corner of the subalpine shrubland.

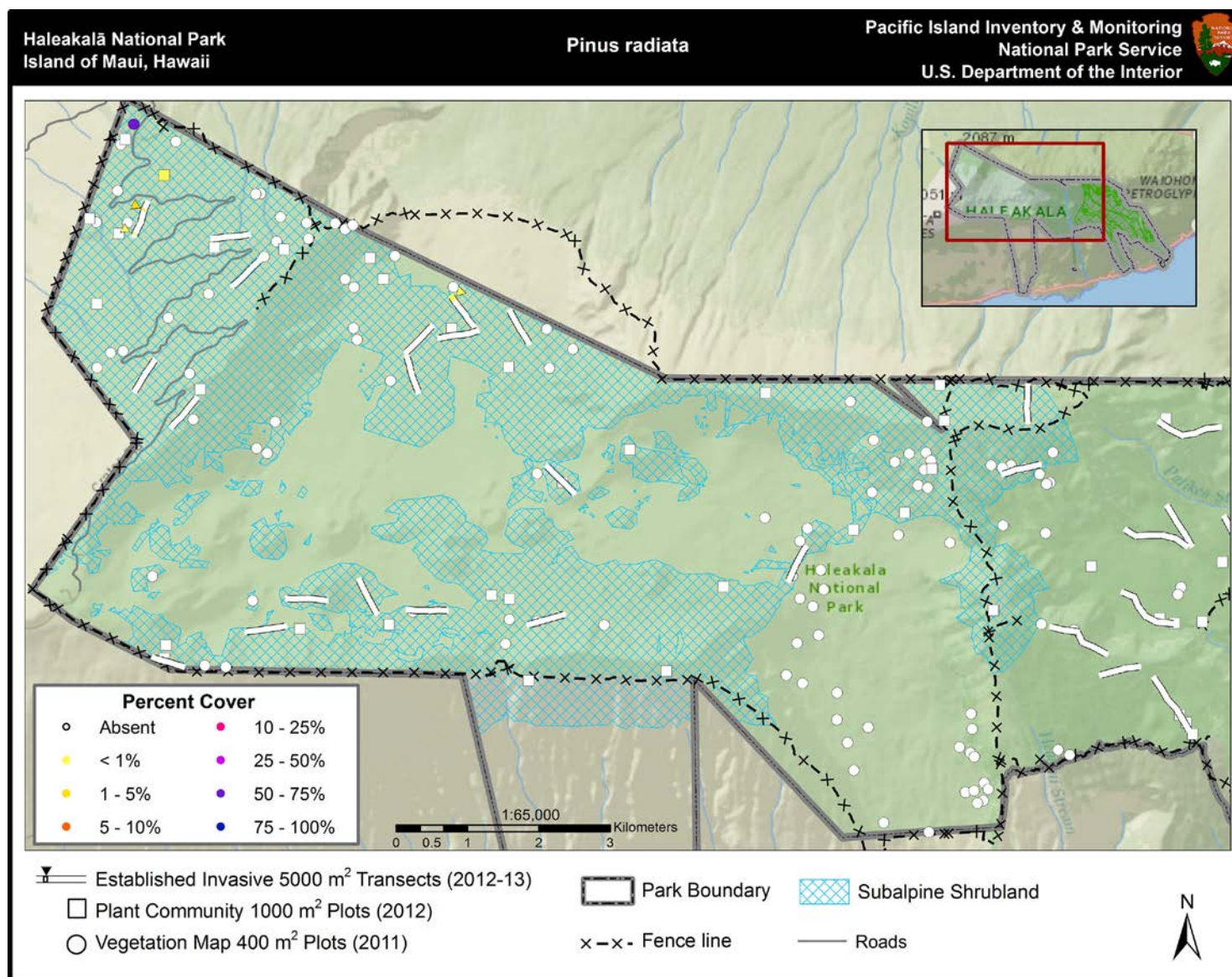


Figure A.19. *Pinus radiata* is scattered across the northwest corner of the subalpine shrubland.

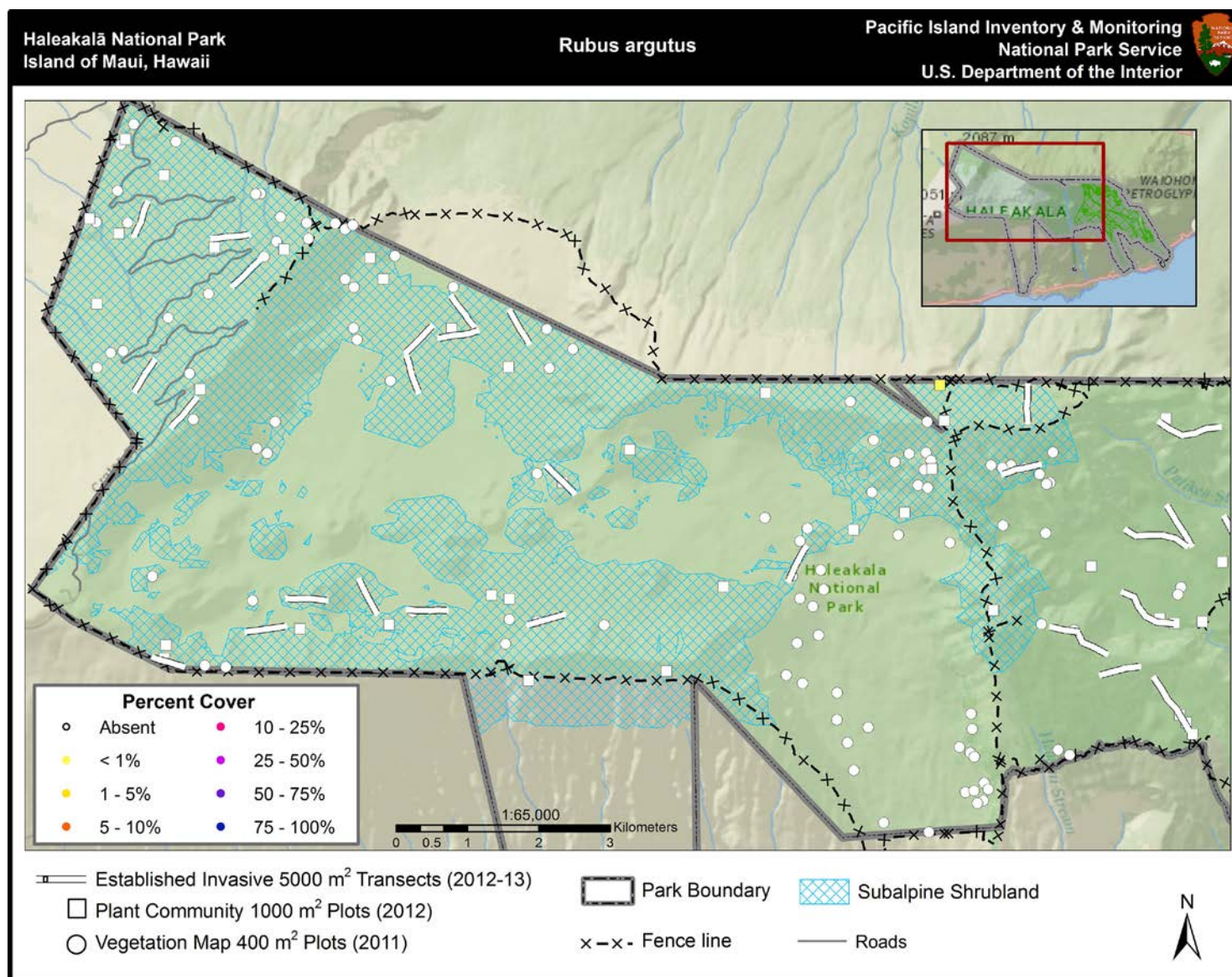


Figure A.20. *Rubus argutus* is found in one Plant Community plot along the northeast edge of the subalpine shrubland.

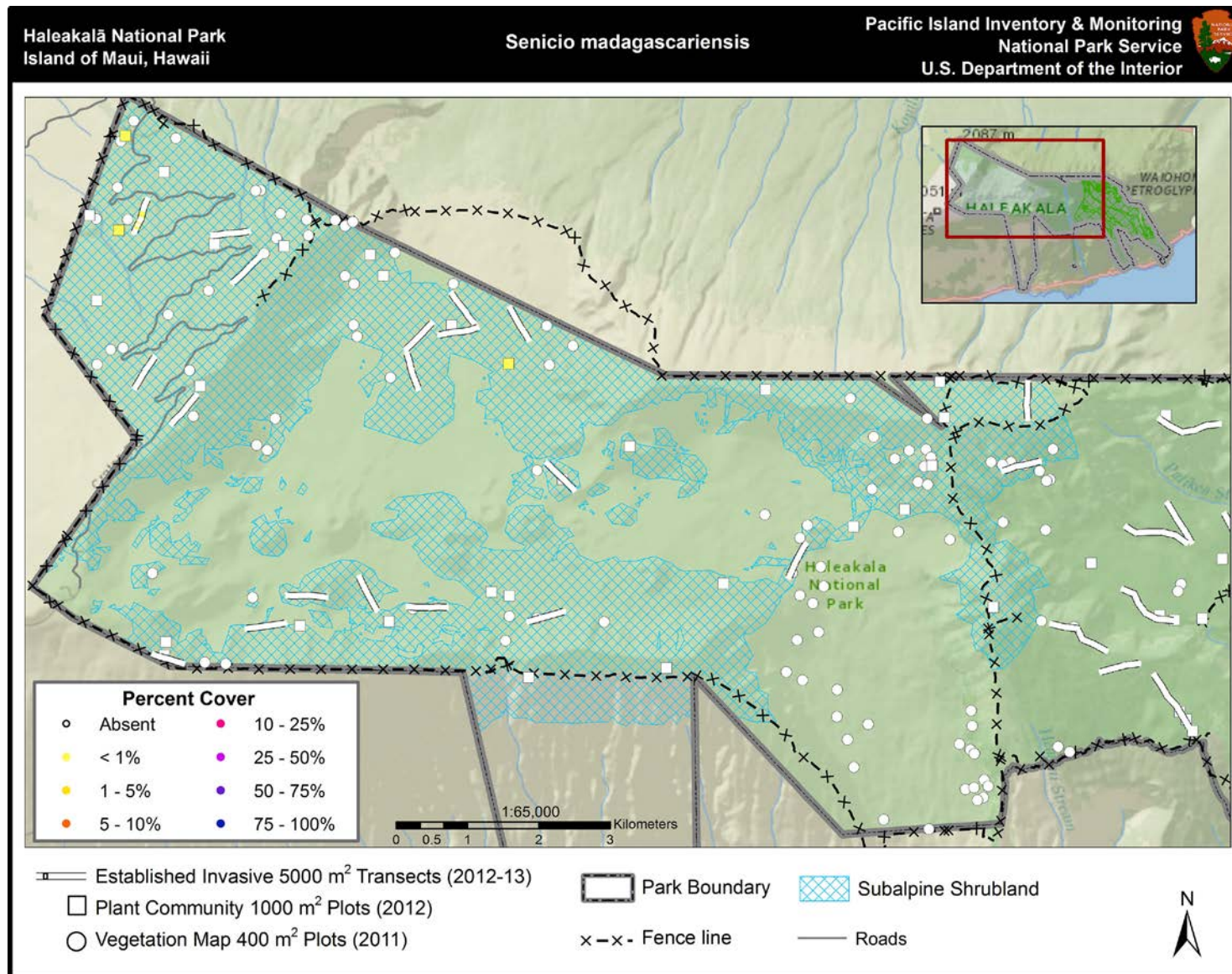


Figure A.21. *Senecio madagascariensis* occurs with low cover in the northwest portion of the subalpine shrubland.

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

Table B.1. Mean frequency and mean cover when present for all non-native species and life forms recorded along the established invasive plant species transects at Haleakalā National Park (HALE).

Species	Sampling Frame	N	Estimate	95% CI Lower Bound	95% CI Upper Bound	Mean Cover Class
Any Non-native Species	Subalpine Shrubland	20	0.88	0.79	0.97	2
Herb	Subalpine Shrubland	20	0.85	0.74	0.95	2
Grass	Subalpine Shrubland	20	0.56	0.36	0.76	2
Shrub	Subalpine Shrubland	20	0.16	0.05	0.27	1
Tree	Subalpine Shrubland	20	0.01	<0.01	0.02	1
Rush	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Hypochaeris.radicata</i>	Subalpine Shrubland	20	0.73	0.58	0.88	2
<i>Holcus.lanatus</i>	Subalpine Shrubland	20	0.51	0.31	0.71	2
<i>Festuca.myuros</i>	Subalpine Shrubland	20	0.24	0.08	0.4	2
<i>Rumex.acetosella</i>	Subalpine Shrubland	20	0.21	0.08	0.34	1
<i>Oenothera.stricta.ssp.stricta</i>	Subalpine Shrubland	20	0.19	0.07	0.31	1
<i>Anthoxanthum.odorum</i>	Subalpine Shrubland	20	0.19	0.02	0.36	2
<i>Ageratina.adenophora</i>	Subalpine Shrubland	20	0.13	0.03	0.23	1
<i>Anagallis.arvensis</i>	Subalpine Shrubland	20	0.13	0.02	0.23	1
<i>Festuca.rubra</i>	Subalpine Shrubland	20	0.13	<0.01	0.26	1
<i>Aira.caryophyllea</i>	Subalpine Shrubland	20	0.07	0.01	0.13	1
<i>Rytidosperma.pilosum</i>	Subalpine Shrubland	20	0.05	<0.01	0.1	1
<i>Lythrum.maritimum</i>	Subalpine Shrubland	20	0.04	<0.01	0.08	1
<i>Plantago.lanceolata</i>	Subalpine Shrubland	20	0.04	<0.01	0.11	1
<i>Eragrostis.brownei</i>	Subalpine Shrubland	20	0.03	<0.01	0.05	1
<i>Silene.gallica</i>	Subalpine Shrubland	20	0.02	<0.01	0.05	1
<i>Sporobolus.africanus</i>	Subalpine Shrubland	20	0.02	<0.01	0.07	1
<i>Bromus.tectorum</i>	Subalpine Shrubland	20	0.02	<0.01	0.06	1
<i>Unknown.species</i>	Subalpine Shrubland	20	0.02	<0.01	0.04	2
<i>Arenaria.serpyllifolia</i>	Subalpine Shrubland	20	0.02	<0.01	0.03	1
<i>Senecio.madagascariensis</i>	Subalpine Shrubland	20	0.01	<0.01	0.04	1
<i>Heterotheca.grandiflora</i>	Subalpine Shrubland	20	0.01	<0.01	0.03	1
<i>Conyza.bonariensis</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	1
<i>Conyza.canadensis.var.pusilla</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	1
<i>Oxalis.corniculata</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	1
<i>Pinus.radiata</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	2
<i>Unknown.Grass</i>	Subalpine Shrubland	20	0.01	<0.01	0.02	1

Table B.1 (continued). Mean frequency and mean cover when present for all non-native species and life forms recorded along the established invasive plant species transects at Haleakalā National Park (HALE).

Species	Sampling Frame	N	Estimate	95% CI Lower Bound	95% CI Upper Bound	Mean Cover Class
<i>Prunella.vulgaris</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Ageratina.riparia</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Cenchrus.clandestinus</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Dactylis.glomerata</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>Petrorhagia.dubia</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Cirsium.vulgare</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Juncus.planifolius</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Medicago.lupulina</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
<i>Unknown.Forb</i>	Subalpine Shrubland	20	<0.01	<0.01	0.01	1
Any Non-native Species	Wet Forest	16	0.48	0.26	0.69	4
Shrub	Wet Forest	16	0.32	0.12	0.52	2
Herb	Wet Forest	16	0.31	0.14	0.48	2
Tree	Wet Forest	16	0.17	<0.01	0.36	3
Fern	Wet Forest	16	0.15	<0.01	0.31	1
Grass	Wet Forest	16	0.10	<0.01	0.21	1
Sedge	Wet Forest	16	0.07	<0.01	0.19	1
Tree Fern	Wet Forest	16	0.01	<0.01	0.03	1
Rush	Wet Forest	16	0.01	<0.01	0.02	1
<i>Clidemia.hirta</i>	Wet Forest	16	0.22	0.01	0.42	2
<i>Hedychium.gardnerianum</i>	Wet Forest	16	0.19	0.03	0.34	2
<i>Rubus.rosifolius</i>	Wet Forest	16	0.18	0.05	0.3	1
<i>Psidium.cattleianum</i>	Wet Forest	16	0.17	<0.01	0.36	5
<i>Deparia.petersenii</i>	Wet Forest	16	0.13	<0.01	0.27	1
<i>Rhynchospora.caduca</i>	Wet Forest	16	0.06	<0.01	0.18	1
<i>Ageratina.adenophora</i>	Wet Forest	16	0.06	0.01	0.11	2
<i>Hypochaeris.radicata</i>	Wet Forest	16	0.06	<0.01	0.14	1
<i>Tibouchina.herbacea</i>	Wet Forest	16	0.06	<0.01	0.13	2
<i>Paspalum.conjugatum</i>	Wet Forest	16	0.05	<0.01	0.09	1
<i>Erechtites.valerianifolia</i>	Wet Forest	16	0.04	<0.01	0.1	1
<i>Axonopus.fissifolius</i>	Wet Forest	16	0.04	<0.01	0.12	1
<i>Prunella.vulgaris</i>	Wet Forest	16	0.04	<0.01	0.11	1
<i>Blechnum.appendiculatum</i>	Wet Forest	16	0.03	<0.01	0.08	1
<i>Cyperus.haspan</i>	Wet Forest	16	0.02	<0.01	0.04	1
<i>Centella.asiatica</i>	Wet Forest	16	0.01	<0.01	0.04	1

Table B.1 (continued). Mean frequency and mean cover when present for all non-native species and life forms recorded along the established invasive plant species transects at Haleakalā National Park (HALE).

Species	Sampling Frame	N	Estimate	95% CI Lower Bound	95% CI Upper Bound	Mean Cover Class
<i>Sphaeropteris.cooperi</i>	Wet Forest	16	0.01	<0.01	0.03	1
<i>Holcus.lanatus</i>	Wet Forest	16	0.01	<0.01	0.04	2
<i>Oplismenus.hirtellus</i>	Wet Forest	16	0.01	<0.01	0.03	1
<i>Unknown.Forb</i>	Wet Forest	16	0.01	<0.01	0.03	1
<i>Syzygium.jambos</i>	Wet Forest	16	0.01	<0.01	0.03	2
<i>Youngia.japonica</i>	Wet Forest	16	0.01	<0.01	0.02	1
<i>Juncus.planifolius</i>	Wet Forest	16	0.01	<0.01	0.02	1
<i>Sacciolepis.indica</i>	Wet Forest	16	0.01	<0.01	0.02	2
<i>Syzygium.malaccense</i>	Wet Forest	16	0.01	<0.01	0.02	2
<i>Unknown.species</i>	Wet Forest	16	0.01	<0.01	0.01	1
<i>Oxalis.spp.</i>	Wet Forest	16	<0.01	<0.01	0.01	1
<i>Ageratina.riparia</i>	Wet Forest	16	<0.01	<0.01	0.01	1
<i>Carex.longii</i>	Wet Forest	16	<0.01	<0.01	0.01	2
<i>Coix.lacryma.jobi</i>	Wet Forest	16	<0.01	<0.01	0.01	1
<i>Cyclosorus.dentatus</i>	Wet Forest	16	<0.01	<0.01	0.01	1
<i>Kyllinga.brevifolia</i>	Wet Forest	16	<0.01	<0.01	0.01	1
<i>Nephrolepis.spp.</i>	Wet Forest	16	<0.01	<0.01	0.01	1
<i>Psidium.guajava</i>	Wet Forest	16	<0.01	<0.01	0.01	1
<i>Spathodea.campanulata</i>	Wet Forest	16	<0.01	<0.01	0.01	2
<i>Lythrum.maritimum</i>	Wet Forest	16	<0.01	<0.01	<0.01	1
<i>Setaria.palmifolia</i>	Wet Forest	16	<0.01	<0.01	<0.01	1
Any Non-native Species	WF & SS	36	0.68	0.58	0.78	3
Herb	WF & SS	36	0.58	0.45	0.71	2
Grass	WF & SS	36	0.33	0.22	0.44	2
Shrub	WF & SS	36	0.24	0.2	0.28	1
Tree	WF & SS	36	0.09	0.05	0.13	2
Fern	WF & SS	36	0.07	0.04	0.11	1
Sedge	WF & SS	36	0.04	0.02	0.05	1
Tree Fern	WF & SS	36	0.01	<0.01	0.01	1
Rush	WF & SS	36	<0.01	<0.01	0.01	1
<i>Hypochaeris.radicata</i>	WF & SS	36	0.40	0.23	0.56	2
<i>Holcus.lanatus</i>	WF & SS	36	0.26	0.14	0.38	2
<i>Festuca.myuros</i>	WF & SS	36	0.12	0.06	0.18	2
<i>Clidemia.hirta</i>	WF & SS	36	0.11	0.06	0.16	2
<i>Rumex.acetosella</i>	WF & SS	36	0.11	0.06	0.16	1

Table B.1 (continued). Mean frequency and mean cover when present for all non-native species and life forms recorded along the established invasive plant species transects at Haleakalā National Park (HALE).

Species	Sampling Frame	N	Estimate	95% CI Lower Bound	95% CI Upper Bound	Mean Cover Class
<i>Oenothera.stricta.ssp.stricta</i>	WF & SS	36	0.10	0.05	0.14	1
<i>Anthoxanthum.odorum</i>	WF & SS	36	0.10	0.05	0.14	2
<i>Ageratina.adenophora</i>	WF & SS	36	0.09	0.08	0.11	1
<i>Hedychium.gardnerianum</i>	WF & SS	36	0.09	0.05	0.14	2
<i>Rubus.rosifolius</i>	WF & SS	36	0.09	0.05	0.13	1
<i>Psidium.cattleianum</i>	WF & SS	36	0.09	0.04	0.13	5
<i>Deparia.petersenii</i>	WF & SS	36	0.06	0.03	0.1	1
<i>Anagallis.arvensis</i>	WF & SS	36	0.06	0.03	0.09	1
<i>Festuca.rubra</i>	WF & SS	36	0.06	0.03	0.09	1
<i>Aira.caryophyllea</i>	WF & SS	36	0.03	0.02	0.05	1
<i>Rhynchospora.caduca</i>	WF & SS	36	0.03	0.02	0.05	1
<i>Tibouchina.herbacea</i>	WF & SS	36	0.03	0.01	0.04	2
<i>Rytidosperma.pilosum</i>	WF & SS	36	0.02	0.01	0.03	1
<i>Paspalum.conjugatum</i>	WF & SS	36	0.02	0.01	0.03	1
<i>Erechtites.valerianifolia</i>	WF & SS	36	0.02	0.01	0.03	1
<i>Lythrum.maritimum</i>	WF & SS	36	0.02	0.01	0.03	1
<i>Prunella.vulgaris</i>	WF & SS	36	0.02	0.01	0.03	1
<i>Plantago.lanceolata</i>	WF & SS	36	0.02	0.01	0.03	1
<i>Axonopus.fissifolius</i>	WF & SS	36	0.02	0.01	0.03	1
<i>Blechnum.appendiculatum</i>	WF & SS	36	0.02	0.01	0.02	1
<i>Eragrostis.brownei</i>	WF & SS	36	0.01	0.01	0.02	1
<i>Unknown.species</i>	WF & SS	36	0.01	0.01	0.01	2
<i>Silene.gallica</i>	WF & SS	36	0.01	0.01	0.02	1
<i>Sporobolus.africanus</i>	WF & SS	36	0.01	0.01	0.02	1
<i>Bromus.tectorum</i>	WF & SS	36	0.01	0.01	0.01	1
<i>Arenaria.serpyllifolia</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Cyperus.haspan</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Centella.asiatica</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Sphaeropteris.cooperi</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Senecio.madagascariensis</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Heterotheca.grandiflora</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Unknown.Forb</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Oplismenus.hirtellus</i>	WF & SS	36	0.01	<0.01	0.01	1
<i>Syzygium.jambos</i>	WF & SS	36	0.01	<0.01	0.01	2
<i>Youngia.japonica</i>	WF & SS	36	<0.01	<0.01	0.01	1

Table B.1 (continued). Mean frequency and mean cover when present for all non-native species and life forms recorded along the established invasive plant species transects at Haleakalā National Park (HALE).

Species	Sampling Frame	N	Estimate	95% CI Lower Bound	95% CI Upper Bound	Mean Cover Class
<i>Juncus.planifolius</i>	WF & SS	36	<0.01	<0.01	0.01	1
<i>Oxalis.spp.</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Ageratina.riparia</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Sacciolepis.indica</i>	WF & SS	36	<0.01	<0.01	0.01	2
<i>Syzygium.malaccense</i>	WF & SS	36	<0.01	<0.01	<0.01	2
<i>Conyza.bonariensis</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Conyza.canadensis.var.pusilla</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Oxalis.corniculata</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Pinus.radiata</i>	WF & SS	36	<0.01	<0.01	<0.01	2
<i>Unknown.Grass</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Cenchrus.clandestinus</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Dactylis.glomerata</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Petrorhagia.dubia</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Carex.longii</i>	WF & SS	36	<0.01	<0.01	<0.01	2
<i>Coix.lacryma.jobi</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Cyclosorus.dentatus</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Kyllinga.brevifolia</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Nephrolepis.spp.</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Psidium.guajava</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Spathodea.campanulata</i>	WF & SS	36	<0.01	<0.01	<0.01	2
<i>Cirsium.vulgare</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Medicago.lupulina</i>	WF & SS	36	<0.01	<0.01	<0.01	1
<i>Setaria.palmifolia</i>	WF & SS	36	<0.01	<0.01	<0.01	1

Appendix C: 2012-2013 Focal Terrestrial Plant Communities and Established Invasive Plant Species Monitoring Effort

From May 2012 to July 2013 the Inventory and Monitoring (I&M) vegetation program implemented the Focal Terrestrial Plant Communities (FTPC) and Established Invasive Plant Species (EIPS) monitoring protocols in wet forest and subalpine shrubland communities at Haleakalā National Park (HALE). This appendix summarizes the field season effort, logistical details, and future recommendations for monitoring these 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 monitoring completion times within and between sampling frames, and 3) monitoring site access and transit times to aid in planning for future field seasons.

The total season effort spans the first day of temporary technician work to the last day in the field for 2012 and 2013. Information for both protocols is presented below according to three main components: training effort, field effort and office effort. Training effort includes office and field time used to complete safety certifications and to learn monitoring methods, while field effort is the sum of access time and monitoring time. Office effort includes field preparation and data processing, and equals the remaining time that was not spent on training or monitoring in the field. Effort was compiled from original data forms, notebooks, photographs, calendars, and personnel interviews. Each effort component is presented below by sampling frame and protocol. 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 and this was accomplished whenever feasible.

Colin Meston served as the park project coordinator with Woody Mallinson as crew lead. Four temporary Biological Science Technicians were hired starting May 7; Laura Arnold, Avery (Brian) McChristian, Elizabeth Moore, and Elizabeth Urbanski. Laura Arnold and Avery McChristian finished their six month tour on November 16, 2012. Elizabeth Moore was extended to 15 April 2013 and Elizabeth Urbanski was extended to 1 August 2013. One volunteer, Michelle Osgood, helped the effort from 15 October 2012 to 29 March 2013. Crews of two to six observers performed field preparation, training, data collection, and data management duties. While most crew members spent all of their time monitoring, some staff spent a bit of time on other projects such as vegetation mapping, maintaining relevant qualifications, planning and organizing field logistics, and collaborating with HALE park staff. This was especially true for the project lead and field leader. Sick, annual, and credit leave taken is incorporated into office work as effort to maintain the health of the crew.

Training Effort

Crew members spent approximately three weeks in trainings. 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 trainings included Operational Leadership, helicopter crew member, first aid/CPR, radio training, and defensive driving. Field leaders were certified First Responders. Field trainings involved learning how to navigate to monitoring sites, monitoring methods and plant identification skills.

Office Effort

Office effort was calculated as the 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.

Field Effort

Field effort was calculated as the sum of field monitoring effort and access time. Effort time was affected by the existence and condition of access trails, vegetation composition and observer availability. Access details for FTPC and EIPS monitoring sites are provided below in addition to summarized completion times and crew effort for wet forest (Tables C.1 and C.2) and subalpine shrubland (Tables C.3 and C.4) communities. Tables are organized by date and list repeated dates when multiple crews sampled on the same day. Monitoring time is the length of time a crew spends in each plot or transect, if work is completed for both protocols on the same day, the times are separated by an addition symbol. Total worker hours were calculated by adding transit times plus monitoring time, then multiplying by the number of crew members present. Transit times include driving time, helicopter transportation, and hiking to and from plot locations and transect end points. These times are presented in the tables as one roundtrip value.

Table C.1. HALE wet forest field monitoring and transit time effort. The final FTPC plot and EIPS transect numbers are listed with proposed sites included in the comments if they differ from the final (TR included for proposed EIPS sites). Transit time combines vehicle travel, helicopter transport, and hiking time. Worker hours per day are calculated as the time spent monitoring plus time spent in transit multiplied by the crew number.

Date	Camp Trip	FTPC	EIPS	Crew No.	Monitor (hrs)	Access	Transit (hrs)	Worker (hrs)	Comments
4/30/2012	WF 1	–	–	4		HQ to Palikea	6.0	24.0	Helicopter
5/1/2012	WF 1	R30	–	4	6.0	Palikea	2.0	32.0	Training
5/2/2012	WF 1	R30	–	4	6.0	Palikea	2.0	32.0	Training
5/3/2012	WF 1	R27	–	4	7.5	Palikea	1.5	36.0	Training
5/4/2012	WF 1	–	–	4		Palikea to HQ	5.0	20.0	Helicopter
6/4/2012	WF 2	–	–	6		HQ to Ginger	6.0	36.0	Helicopter
6/5/2012	WF 2	F1	–	6	6.0	Ginger	3.0	54.0	FA1
6/6/2012	WF 2	F1	–	6	6.0	Ginger	3.0	54.0	FA1
6/7/2012	WF 2	F14	–	6	7.5	Ginger	3.0	63.0	FA9
6/8/2012	WF 2	–	–	6		Ginger to HQ	5.0	30.0	Helicopter
7/9/2012	WF 3	–	–	6		HQ to West&Charlie	6.0	36.0	Helicopter
7/10/2012	WF 3	F12	–	3	6.0	Charlie	3.0	27.0	2 day plot
7/10/2012	WF 3	–	–	3	5.0	West	4.0	27.0	–
7/11/2012	WF 3	F12	–	3	6.0	Charlie	3.0	27.0	2 day plot
7/11/2012	WF 3	R16	–	3	5.0	West	4.0	27.0	–
7/12/2012	WF 3	–	–	6		West&Charlie to HQ	6.0	36.0	Helicopter
8/27/2012	WF 4	–	–	6		HQ to Charlie&Ohe	6.0	36.0	Helicopter
8/28/2012	WF 4	F11	–	3	5.0	Charlie	4.0	27.0	–
8/28/2012	WF 4	F9	–	3	7.0	Ohe	2.0	27.0	–
8/29/2012	WF 4	–	–	3	8.0	Charlie	0.0	24.0	rained out
8/29/2012	WF 4	–	–	3	8.0	Ohe	0.0	24.0	rained out
8/30/2012	WF 4	F15	–	3	5.0	Charlie	4.0	27.0	FA10
8/30/2012	WF 4	F13	–	3	6.5	Ohe	2.0	25.5	–

Table C.1 (continued). HALE wet forest field monitoring and transit time effort. The final FTPC plot and EIPS transect numbers are listed with proposed sites included in the comments if they differ from the final (TR included for proposed EIPS sites). Transit time combines vehicle travel, helicopter transport, and hiking time. Worker hours per day are calculated as the time spent monitoring plus time spent in transit multiplied by the crew number.

Date	Camp Trip	FTPC	EIPS	Crew No.	Monitor (hrs)	Access	Transit (hrs)	Worker (hrs)	Comments
8/31/2012	WF 4	–	–	6		Ohe&Charlie to HQ	5.0	30.0	Helicopter
9/24/2012	WF 5	–	–	4	–	HQ to Palikea	6.0	24.0	Helicopter
9/25/2012	WF 5	R28	–	4	7.0	Palikea	2.5	38.0	–
9/26/2012	WF 5	R20	–	4	7.5	Palikea	2.0	38.0	–
9/27/2012	WF 5	R21	–	4	7.0	Palikea	2.5	38.0	–
9/28/2012	WF 5	–	–	4	–	Palikea to HQ	5.0	20.0	Helicopter
10/15/2012	WF 6	–	–	7	–	HQ to Palikea&Smith	6.0	42.0	Helicopter
10/16/2012	WF 6	F7	–	4	7.0	Palikea	2.0	36.0	FA7
10/16/2012	WF 6	F8	–	3	7.5	Smith	2.0	28.5	–
10/17/2012	WF 6	F2	–	4	6.0	Palikea	3.5	38.0	FA4
10/17/2012	WF 6	F10	F9	3	4.0+3.0	Smith	2.0	27.0	Helicopter bump
10/18/2012	WF 6	F2	F7	4	2+2	Palikea	5.5	38.0	FA4; TRR11
10/18/2012	WF 6	–	–	3	–	Smith	8.0	24.0	Rejected F14
10/19/2012	WF 6	–	–	7	–	Palikea&Smith to HQ	5.0	35.0	Helicopter
10/29/2012	WF 7	–	–	7	–	HQ to Kaapahu&Ohia	6.0	42.0	Helicopter
10/30/2012	WF 7	R26	–	4	6.0	Kaapahu	1.0	28.0	–
10/30/2012	WF 7	R24	–	3	7.0	Ohia	1.0	24.0	–
10/31/2012	WF 7	R18	–	4	6.5	Kaapahu	1.0	30.0	RA10
10/31/2012	WF 7	R17	–	3	7.0	Ohia	1.0	24.0	–
11/1/2012	WF 7	R19	R18	4	6.0+1.5	Kaapahu	2.5	40.0	–
11/1/2012	WF 7	R29	R15	3	7.0+2.5	Ohia	3.0	37.5	–
11/2/2012	WF 7	–	–	7	–	Kaapahu&Ohia to HQ	5.0	35.0	Helicopter
11/26/2012	WF 8	–	–	4	–	HQ to Palikea	6.0	24.0	Helicopter

Table C.1 (continued). HALE wet forest field monitoring and transit time effort. The final FTPC plot and EIPS transect numbers are listed with proposed sites included in the comments if they differ from the final (TR included for proposed EIPS sites). Transit time combines vehicle travel, helicopter transport, and hiking time. Worker hours per day are calculated as the time spent monitoring plus time spent in transit multiplied by the crew number.

Date	Camp Trip	FTPC	EIPS	Crew No.	Monitor (hrs)	Access	Transit (hrs)	Worker (hrs)	Comments
11/27/2012	WF 8	–	F5, R19	2+2	3.0+4.0	Palikea	4.0	22.0	TRR24 became TRR19; Crew split
11/28/2012	WF 8	F3	–	4	5.0	Palikea	3.0	34.0	FA3; hike to Delta
11/29/2012	WF 8	F5	–	4	6.0	Delta	3.0	36.0	–
11/30/2012	WF 8	–	–	4	–	Delta to HQ	5.0	20.0	Helicopter
1/28/2013	WF 9	–	–	5	–	HQ to Charlie&Palikea	6.0	30.0	Helicopter
1/29/2013	WF 9	F6	F2	3	6.0+4.0	Charlie	3.0	39.0	FA8
1/29/2013	WF 9	–	R16	2	4.0	Palikea	2.0	12.0	–
1/30/2013	WF 9	F6	R20	3	2.5	Charlie	2.0	13.5	FA8; TRR25
1/31/2013	WF 9	–	F3	3	2.5	Charlie to Ohe	3.0	16.5	–
1/31/2013	WF 9	–	F6	2	2.5	Palikea to Delta	3.0	11.0	–
2/1/2013	WF 9	–	–	5	–	Ohe&Delta to HQ	5.0	25.0	Helicopter
2/11/2013	WF 10	–	–	4	–	HQ to Oheo	3.0	12.0	Drive
2/12/2013	WF 10	–	F10	4	1.5	Oheo	4.0	22.0	–
2/13/2013	WF 10	–	–	4	–	Oheo to HQ	3.0	12.0	Drive
3/12/2013	WF 11	–	–	4	–	HQ to Oheo	3.0	12.0	Drive
3/13/2013	WF 11	F4	F4	4	4.0+3.0	Ginger to Bravo	4.0	44.0	Helicopter
3/14/2013	WF 11	–	–	4	–	Oheo to HQ	3.0	12.0	Drive
3/25/2013	WF 12	–	–	5	–	HQ to Ginger	6.0	30.0	Helicopter
3/26/2013	WF 12	R23	–	5	6.0	Ginger	3.0	45.0	–
3/27/2013	WF 12	R25	–	5	5.0	Ginger	2.5	37.5	–
3/28/2013	WF 12	R22	–	5	6.0	Ginger	2.5	42.5	RA5
3/29/2013	WF 12	–	–	5	–	Ginger to HQ	5.0	25.0	Helicopter
4/3/2013	WF 13	–	F1	3	2.0	Kuiki to Ohia	6.0	24.0	Drive to Nu'u LZ

Table C.1 (continued). HALE wet forest field monitoring and transit time effort. The final FTPC plot and EIPS transect numbers are listed with proposed sites included in the comments if they differ from the final (TR included for proposed EIPS sites). Transit time combines vehicle travel, helicopter transport, and hiking time. Worker hours per day are calculated as the time spent monitoring plus time spent in transit multiplied by the crew number.

Date	Camp Trip	FTPC	EIPS	Crew No.	Monitor (hrs)	Access	Transit (hrs)	Worker (hrs)	Comments
4/3/2013	WF 13	–	R12	3	1.5	Ohia	3.0	13.5	Rejected TRR21
4/4/2013	WF 13	–	–	3	–	Ohia to (HQ)	3.0	9.0	From Haiku
7/8/2013	WF 14	–	–	3	–	HQ to Ohe	6.0	18.0	Helicopter
7/9/2013	WF 14	–	–	3	–	Ohe	6.0	18.0	RM chief and super
7/10/2013	WF 14	–	R14	3	3.0	Ohe	3.0	18.0	TR read backwards
7/11/2013	WF 14	–	–	3	–	Ohe to Ginger	6.0	18.0	–
7/12/2013	WF 14	–	–	3	–	Ginger to HQ	5.0	15.0	Helicopter

Table C.2. Total worker hours and days to complete field sampling for HALE wet forest in 2012 - 2013. Wet forest effort took a four person field crew working 8-hours per day approximately 4.3 months to complete.

Effort	Activity	Worker Hours	Worker Days
Office	Field Preparation	95	12
	Data Management	456	57
	Total Office	551	69
Field	Transit Time	1203	150
	Monitoring Time	996	125
	Total Field	2199	275
Total Effort		2750	344

Table C.3. HALE subalpine shrubland field monitoring and transit time effort. The final FTPC plot are listed with proposed sites included in the comments if they differ from the final (no EIPS transects were renamed). Transit time combines vehicle travel and hiking time. Worker hours per day are calculated as the time spent monitoring plus time spent in transit multiplied by the crew number.

Date	Camp Trip	FTPC	EIPS	Crew No.	Monitor (hrs)	Access	Transit (hrs)	Worker (hrs)	Comments
5/8/2012	–	F2	–	3	4.00	HQ	1.0	15.0	–
5/9/2012	–		F1	3	3.00	HQ	1.5	13.5	–
5/16/2012	–	F1	–	6	7.00	HQ	1.5	51.0	–
5/17/2012	–	F9	R15	6	3.00+ 1.00	HQ	4.0	48.0	–
5/18/2012	–	R29	–	6	5.00	HQ	1.5	39.0	–
5/22/2012	SS 1		R13	4	2.00	HQ to Paliku	6.0	32.0	–
5/23/2012	SS 1	R17	–	4	2.50	Paliku	2.0	18.0	–
5/24/2012	SS 1	R26	–	4	5.00	Paliku	4.0	36.0	–
5/25/2012	SS 1	–	R16	4	2.00	Paliku to HQ	8.0	40.0	–
6/12/2012	SS 2	–	R14	4	2.00	HQ to Paliku	6.0	32.0	–
6/13/2012	SS 2	F4	–	4	4.00	Paliku	5.0	36.0	–
6/14/2012	SS 2	R21	–	4	4.5.00	Paliku	2.0	26.0	–
6/15/2012	SS 2	–	–	4	–	Paliku to HQ	8.0	32.0	Travel day
6/19/2012	SS 3	–	–	4	–	HQ to Holua	4.0	16.0	Travel day
6/20/2012	SS 3	–	F2	4	3.50	Holua	2.0	22.0	–
6/21/2012	SS 3	R16	R18	4	2.00+ 1.75	Holua	4.0	31.0	
6/22/2012	SS 3	F5	–	4	4.00	Holua to HQ	5.0	36.0	–
6/26/2012	–	–	R11	2	2.50	HQ	2.0	9.0	–
6/29/2012	–	–	F6	4	3.00	HQ	2.0	20.0	–
7/2/2012	–	–	F3	2	3.00	HQ	2.0	10.0	–
7/10/2012	SS 4	–	F7	3	4.00	West camp	4.0	32.0	Changed from WF
7/30/2012	SS 5	–	–	3		HQ to Holua	4.0	12.0	Travel day

Table C.3 (continued). HALE subalpine shrubland field monitoring and transit time effort. The final FTPC plot are listed with proposed sites included in the comments if they differ from the final (no EIPS transects were renamed). Transit time combines vehicle travel and hiking time. Worker hours per day are calculated as the time spent monitoring plus time spent in transit multiplied by the crew number.

Date	Camp Trip	FTPC	EIPS	Crew No.	Monitor (hrs)	Access	Transit (hrs)	Worker (hrs)	Comments
7/31/2012	SS 5	F15	F5	3	3.00+ 2.00	Holua	6.0	33.0	–
8/1/2012	SS 5	–	F4	3	3.00	Holua	3.0	18.0	–
8/2/2012	SS 5	F3	–	3	2.50	Holua to HQ	4.0	19.5	–
8/7/2012	–	R18	–	3	2.50	HQ	2.0	13.5	RA20
8/8/2012	–	F10	–	3	2.50	HQ	2.0	13.5	–
8/9/2012	–	F7	–	3	3.50	HQ	2.0	16.5	–
8/10/2012	–	R27	–	3	2.00	HQ	1.0	9.0	–
10/1/2012	SS 6		F10, R17	3+2	1.50+ 1.50	Summit to Kapalaoa	6.0	45.0	Split crew
10/2/2012	SS 6	F14, R25	F8	3	4.00+ 2.00	Kapalaoa	4.0	30.0	FA14 renamed as F14
10/2/2012	SS 6	R24		2	4.00	Kapalaoa	1.0	10.0	–
10/2/2012	SS 6	R20	R19	3	3.00+ 1.00	Kapalaoa	2.0	18.0	EM joins crew pm
10/3/2012	SS 6	F6	–	6	2.00	Kapalaoa	6.0	48.0	FA6
10/4/2012	SS 6		–	6		Kapalaoa to Summit	5.0	35.0	Travel day
10/9/2012	–	F7	–	3	3.50	HQ	2.0	16.5	–
10/10/2012	–	R27	–	3	3.50	HQ	1.5	15.0	–
10/22/2012	SS 7	–	–	4		HQ-Paliku	6.0	24.0	–
10/23/2012	SS 7	F8	–	4	2.50	Paliku	6.0	34.0	–
10/24/2012	SS 7	R30	–	4	3.00	Paliku	3.5	26.0	–
10/25/2012	SS 7	F11	–	4	2.50	Paliku	3.0	22.0	FA1
10/26/2012	SS 7		–	4		Paliku-HQ	8.0	32.0	Travel day
11/6/2012	–	R22	–	4	2.00	HQ	5.0	28.0	–

Table C.3 (continued). HALE subalpine shrubland field monitoring and transit time effort. The final FTPC plot are listed with proposed sites included in the comments if they differ from the final (no EIPS transects were renamed). Transit time combines vehicle travel and hiking time. Worker hours per day are calculated as the time spent monitoring plus time spent in transit multiplied by the crew number.

Date	Camp Trip	FTPC	EIPS	Crew No.	Monitor (hrs)	Access	Transit (hrs)	Worker (hrs)	Comments
12/4/2012	–	F12	–	5	1.00	HQ	3.0	20.0	FA8
2/14/2013	–	R28	R20	4	2.00+ 1.00	HQ	2.0	20.0	RA22
2/19/2013	SS 8	–	F9	3	1.50	Summit to Kapalaoa	4.0	16.5	–
2/20/2013	SS 8	R23	–	4	3.00	Kapalaoa	4.0	28.0	–
2/21/2013	SS 8	R13, R19	–	4	6.00	Kapalaoa	2.0	32.0	FA3 renamed as R13
2/22/2013	SS 8	–	–	4	–	Kapalaoa to Summit	5.0	20.0	Travel day
3/20/2013	SS 9	–	–	2	–	HQ to Paliku	5.0	10.0	Travel day
3/21/2013	SS 9	–	R12	2	2.00	Paliku	8.0	20.0	–
3/22/2013	SS 9	–	–	2	–	Paliku to HQ	6.0	12.0	Travel day

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Table C.4. Total worker hours and days to complete field sampling for HALE subalpine shrubland in 2012 - 2013. Subalpine shrubland effort took a four person field crew working 8-hours per day approximately 2 months to complete.

Effort	Activity	Worker Hours	Worker Days
Office	Field Preparation	45	6
	Data Management	400	50
	Total Office	445	56
Field	Transit Time	743	93
	Monitoring Time	536	67
	Total Field	1279	160
Total Effort		1724	216

Wet Forest (Kipahulu, Manawainui, Northeast Rift)

Completing the wet forest field work (30 FTPC plots and 16 EIPS transects) at HALE required the majority of the field time including fourteen helicopter supported camp trips (Table C.1). All plots and transects within the wet forest of HALE are located in close proximity to established legacy transects (USFW bird monitoring transects 18, 17, 16 and 10) and/or fence lines to minimize our disturbance to native vegetation. Due to challenging access and steep slopes some proposed FTPC plots were rejected and alternates were used in their place (Figure C.1). Similarly, some EIPS transects were cut short for safety, one was stopped short because of extremely dense non-native vegetation, and four (TR-F8, TR-R11, TR-R13, TR-R17) were not completed due to time constraints (Figure C.2). For both protocols, half of the monitoring sites are permanent (blue symbols) and will be re-monitored every five years. Temporary sites (red symbols) have no markers and will not be revisited, instead new temporary sites will be added every five years to increase the spatial coverage of the community over time.

Including office and field time, 344 worker days were required to complete wet forest plant monitoring at HALE (Table C.2). Considering that the crew, on average, included four staff, worked 8-hours per day, 5-days per week, with 4-weeks per month, this work took 4.3 months for the crew. As depicted in the schedule, wet forest work was not completed consecutively, rather it was interspersed with HALE subalpine shrubland FTPC and EIPS monitoring (Table C.3) and Kalaupapa National Historical Park wet forest FTPC monitoring.

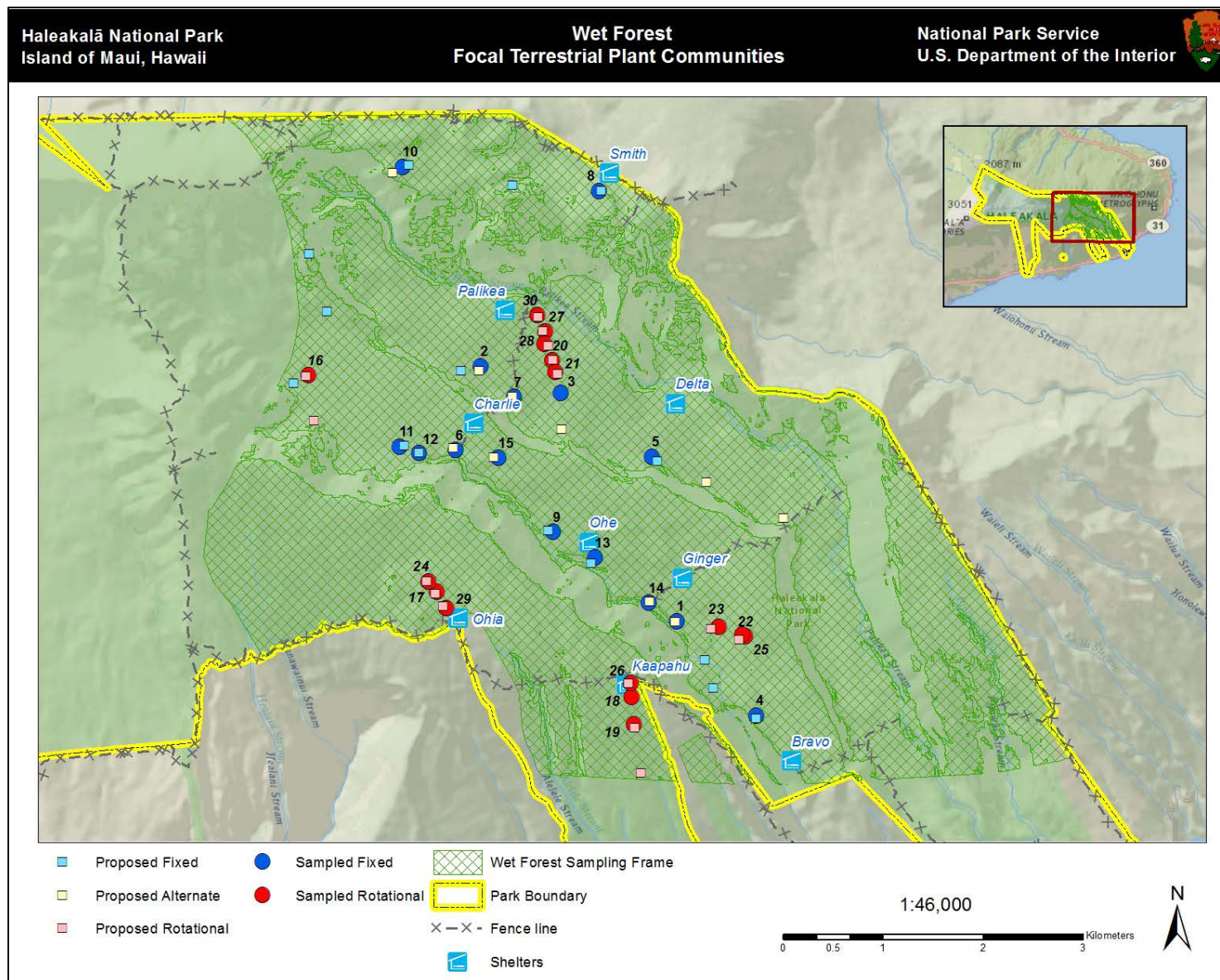


Figure C.1. Sampled wet forest FTPC plot (20x50m) centroids (circles) with proposed plot centroids (squares) overlain and access camps.

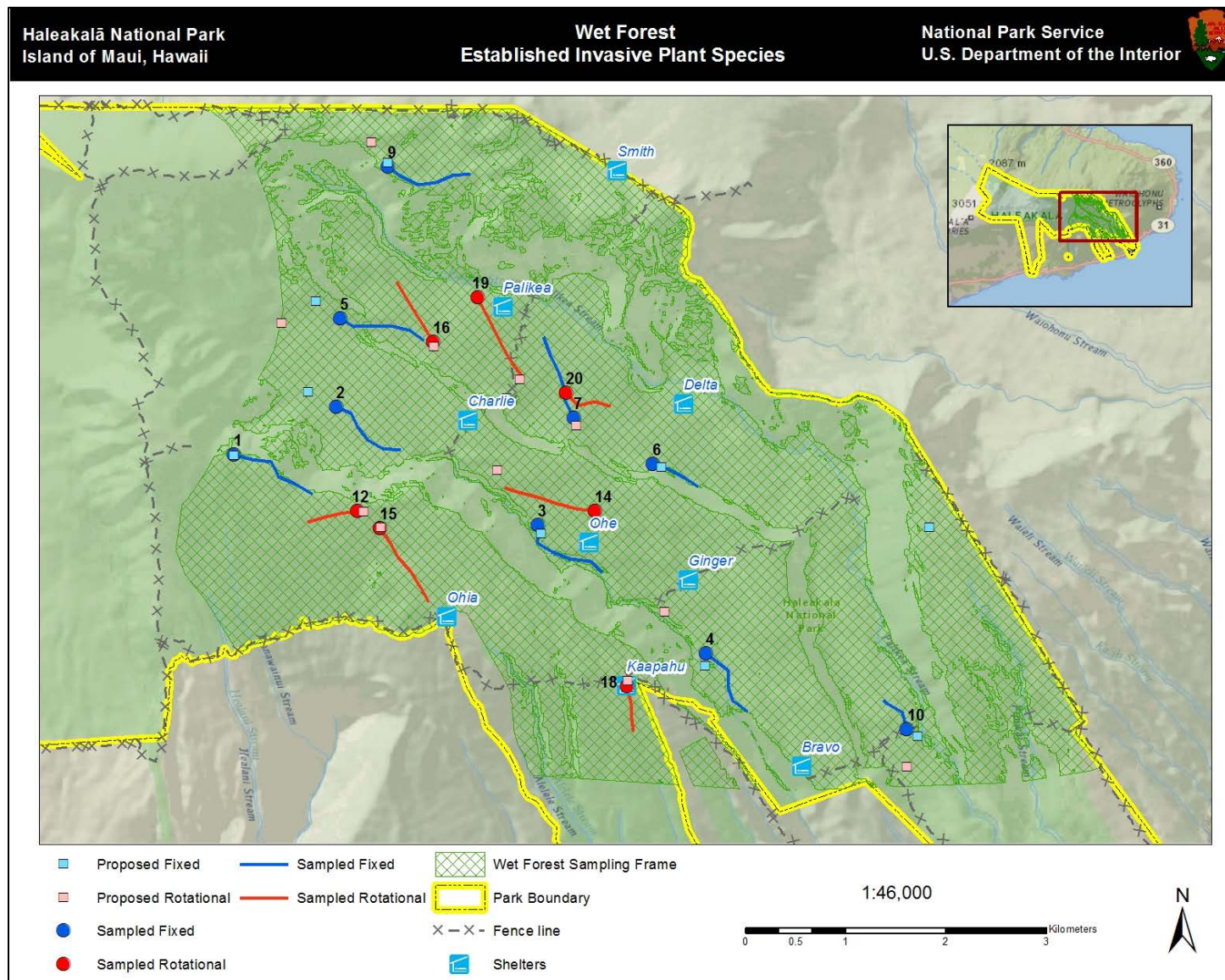


Figure C.2. Sampled wet forest EIPS starts (circles) and transect lines ($\leq 1000\text{m}$) with proposed starts (squares) overlain and access camps.

Plot Access/Comments

All plots in HALE wet forest were accessed with helicopter support into established camps. These camps range from just a landing zone to enclosed cabins. Weather often prohibits helicopter operations, especially to the higher elevation camps. During the course of the field work we were rained out multiple times, which necessitated multiple contingency plans. Camp gear was flown in depending on the amenities of the camp. The current condition of shelters and their inventory need to be investigated during trip preparation. A narrative of shelter descriptions and inventory lists should be available. In addition, crews should consult staff members that have been to the shelters most recently.

The trail systems within the wet forest of HALE are marked by blue flagging which tends to deteriorate rapidly. Trails can also be overgrown or blocked by fallen trees/branches. The USFWS transects and fence lines are the most reliable to follow. All other 'marked trails' should not be relied on, but can be used as evidence of previous safe passage and location orientation. GPS units with the most up to date map layers of trails, fence lines and shelters are absolutely essential for safely navigating this very dense environment. Traveling through this environment on marked routes is often as slow as 0.5 miles/hour and off routes can be even slower. Park staff with current knowledge of trails and conditions needs to be present.

Due to the steep terrain many of the plots and some transects in this area were moved to nearby locations as per the protocol (Figures C.1 and C.2). As much as a few hours (allocated to transit time) was spent moving these plot and transect locations. Similar to other natural areas of Hawaii, many of the rare plant species are located on steep slopes or in narrow gulches.

The presence of noxious weeds in the lower portion of Kipahulu Valley and Manawainui are a big concern for HALE park managers. Diligent effort from crew members is required not to spread these weeds into non-infested areas. Current knowledge of noxious weeds present and locations needs to be obtained. Diligent practice of using weed-free gear in non-infested areas is required as well as routine cleaning of gear that has been exposed to weed seeds. Certain camps currently lie on the border of infested and non-infested areas and when working in these areas special attention to movements needs to be taken. The typical practice is to work in non-infested areas before moving into weedy areas as well as bringing 2 sets of gear and insuring that the exposed gear is properly contained after use until they can be properly cleaned back at headquarters.

The remote and difficult terrain led to 55% of our field effort being spent in transit. An entire day was taken to get the crew from HALE headquarters to the backcountry sites, which included driving to helicopter landing zones and flight operations.

Safety

Wet and steep conditions increased the potential for injury and necessitated slow and deliberate travel. Most crew members preferred to wear rubber boots. Wearing protective gloves is also recommended while traveling through this dense vegetation and along fence lines. Some crew members also preferred to wear protective eyewear, though fogging lenses can be a problem. When moving through extremely dense vegetation the use of hand tools may be helpful, though care should

be taken not to overly damage native vegetation and not used within plot boundaries. 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. 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.

Communication via radio was reliable throughout the valley with a few dead spots mainly in the gulches or next to the major cliffs. Multiple forms of communication should be brought at all times in the field with good coordination with local park staff and the following of backcountry check-in guidelines.

Protocol Modifications

Few modifications were made to the protocol for establishing and conducting Wet Forest plots at HALE. The most notable change was made to the observation of large tree ferns. In Kipahulu wet forest plots, large tree ferns were measured and recorded in all quadrats not just in quad 4 as the protocol states. This was decided during the initially training trip into Kipahulu Valley when it was noted that there are far fewer tree ferns at HALE than there are at HAVO or KALA. It was also noted at HALE that there is a difference in the observation of certain species due to their life form. In the wet forest it can be subjective whether a larger woody species should be called a shrub or a tree. The measurement of these species needs to be consistent throughout the survey and their life form should be designated and maintained. An effort was made to do this during the 2012/2013 season, but there was potential for inconsistency from individual readers as these designations were discussed and debated throughout the season. It is especially useful to make notes on the shrub belt datasheet as to which life form a species is recorded, so that any corrections or updates can be made during data management.

Subalpine Shrubland

Completing the subalpine shrubland field work (30 FTFC plots and 20 EIPS transects) at HALE required nine camp trips and many day trips (Table C.3). No helicopter support was necessary with the exception of EIPS F7 which was accessed from West camp in upper Kipahulu Valley. All FTFC plots and EIPS transects were accessed via established trails and fence lines until it was necessary to proceed off trail (Figures C.3 and C.4). Including office and field time, 344 worker days were required (Table C.2). Considering that the crew, on average, included four staff, worked 8-hours per day, 5-days per week, with 4-weeks per month, this work took 2 months to complete. As depicted in the schedule, similar to the wet forest work, subalpine shrubland monitoring was not completed consecutively.

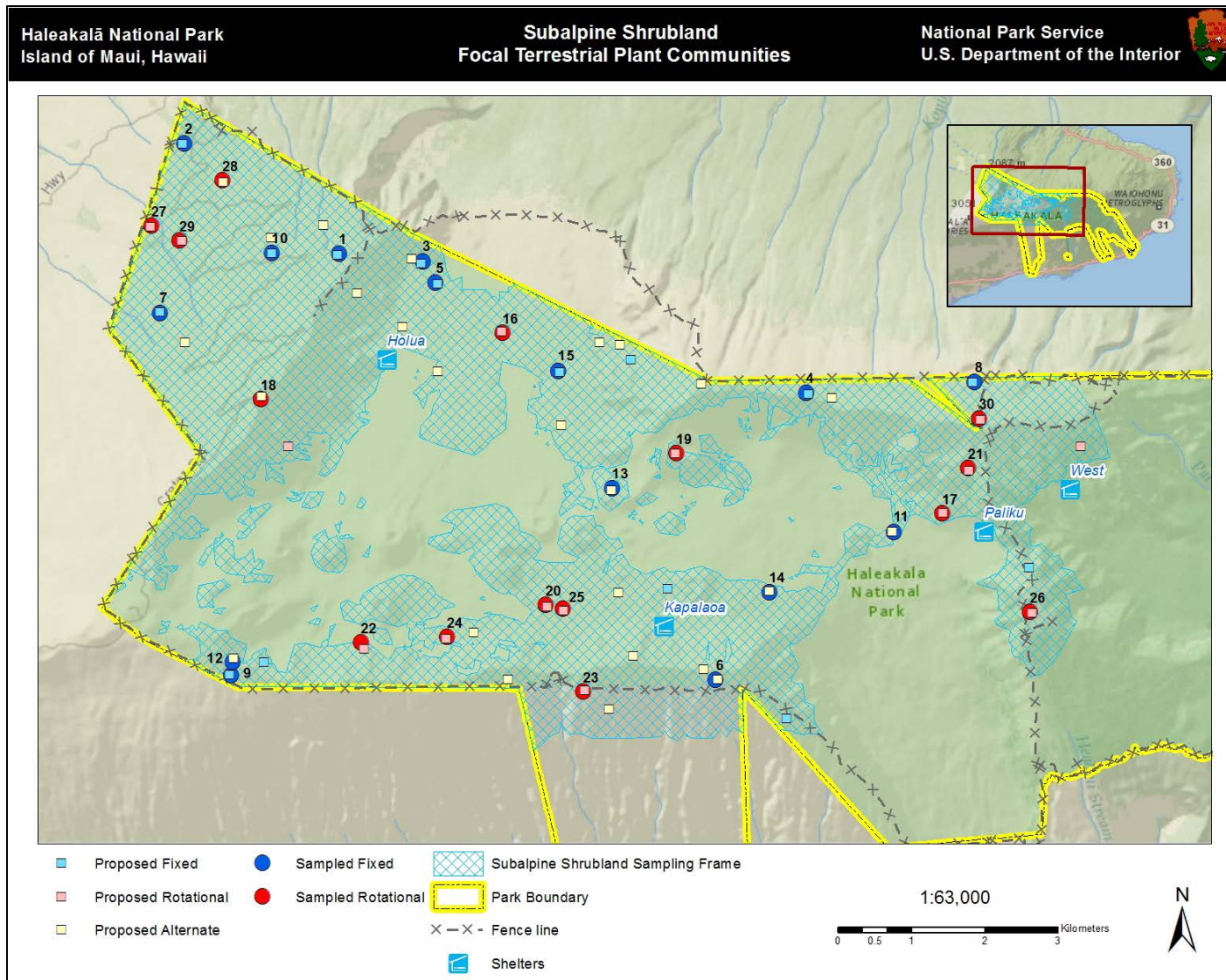


Figure C.3. Sampled subalpine FTPC plot (20x50m) centroids (circles) with proposed plot centroids (squares) overlain and access camps.

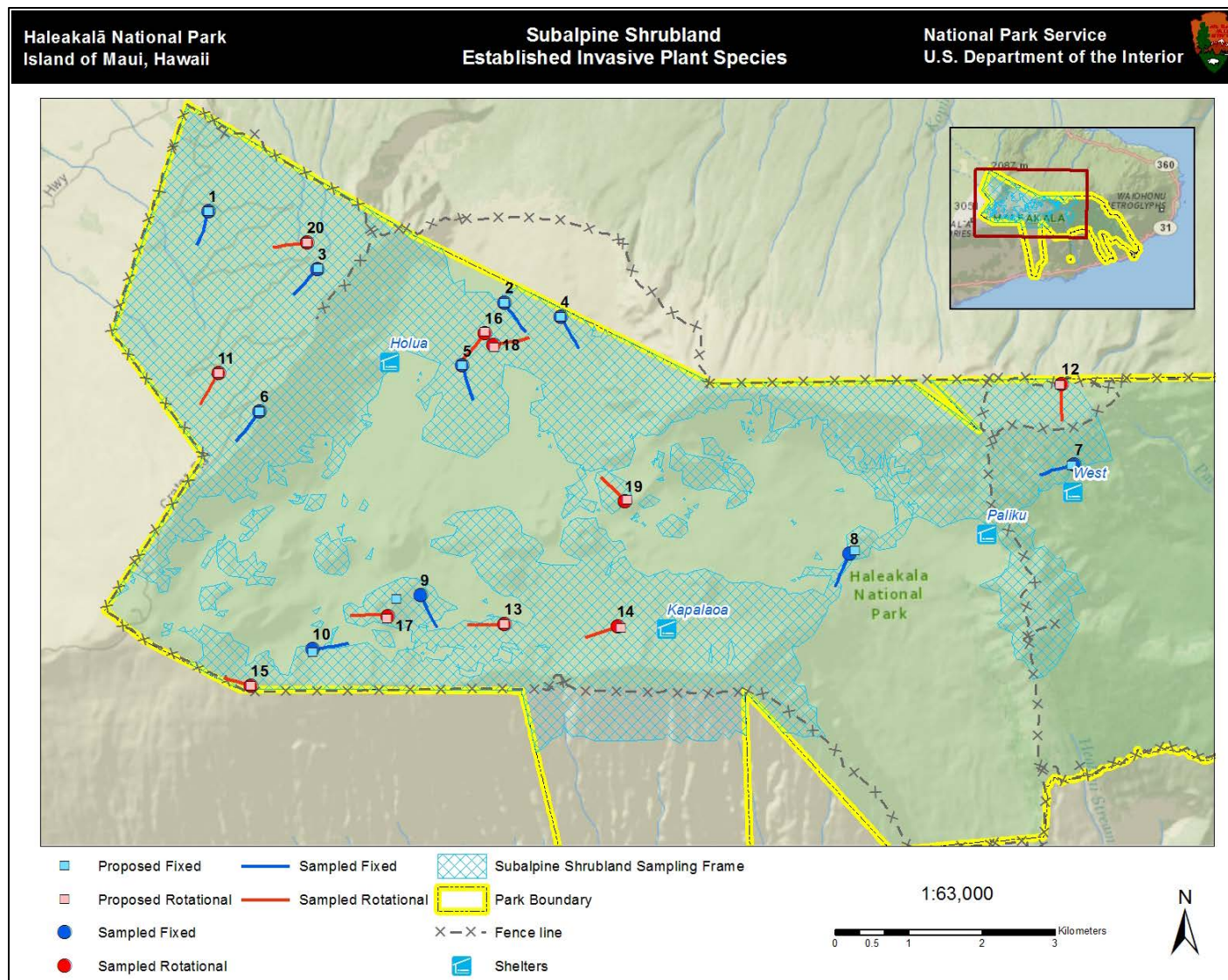


Figure C.4. Sampled subalpine EIPS starts (circles) and transect lines ($\leq 500\text{m}$) with proposed starts (squares) overlain and access camps.

Plot Access/Comments

All plots and transects in the subalpine shrubland were accessed from Park headquarters, Holua cabin, Kapalaoa cabin, or Paliku cabin. With the exception of EIPS transect F7, which was accessed from West camp in upper Kipahulu Valley and was originally classified as a wet forest transect, but was found to be located in a mostly shrubland environment during the field visit. Travel to this transect required helicopter travel to the backcountry camp. Off trail travel was limited as much as possible by utilizing the public trail system. Extra consideration for routes was required for travel across cinder substrates and near culturally significant features within the crater of Haleakala. Tracks in the cinder from foot travel can last months in this fragile environment and can encourage Park visitors to follow tracks off the established trail system.

Most plots were able to be sampled without adjustment to the plot location. The remote and difficult terrain led to 58% of our field effort being spent in transit. Large lava flows and steep terrain makes access difficult even with the established trail system.

Safety

Wet and steep conditions increased the potential for injury and necessitated slow and deliberate travel. Travel to monitoring sites can involve hiking across steep jagged lava flows. Sturdy foot wear is essential and crew members often wore protective gloves while hiking in this environment. Other areas of the shrubland can be very dense with coarse vegetation and crew members should wear extra protective clothing when necessary. Weather conditions in the shrubland can change quickly from hot to cold and wet to dry. Rain gear and warm layers should be carried at all times as well as gear to protect from the high elevation sun exposure. Radio communication was reliable in all of these areas and was not a hindrance. Multiple forms of communication should be brought at all times in the field with good coordination with local park staff.

Protocol Modifications

Few modifications were made to the protocols for establishing and conducting subalpine shrubland plots and transects at HALE. The use of PVC posts when establishing fixed plots and transects within the Summit district of the Park is restricted and was only utilized when the fixed monitoring point was obscured by thick vegetation or large rocks. A few monitoring sites within the crater were offset or rejected to avoid impact to culturally significant features. Very few plots within the subalpine shrubland environment at HALE contain trees or tree ferns. A few monitoring sites that occurred close to wetter areas of HALE did contain short stature ohia trees and bunches of ama'u tree ferns. Often their growth forms are not conducive to accurate protocol measurements and special consideration needs to be taken when measuring these species. Ohia trees in these transition zones often are short stature and have multiple boles and require careful measurement. Ama'u tree ferns often do not have a large enough diameter to make the large tree fern datasheet, but should not be overlooked while recording small tree ferns on the shrub belt.

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NPS 162/137676, April 2017

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