



Technical Report HCSU-032

SURVEY OF ROADSIDE ALIEN PLANTS IN HAWAI`I
VOLCANOES NATIONAL PARK AND ADJACENT RESIDENTIAL
AREAS 2001–2005

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ABSTRACT

The sides of all paved roads of Hawai`i Volcanoes National Park (HAVO) were surveyed on foot in 2001 to 2005, and the roadside presence of 240 target invasive and potentially invasive alien plant species was recorded in mile-long increments. Buffer zones 5–10 miles (8–16 km) long along Highway 11 on either side of the Kīlauea and Kahuku Units of the park, as well as Wright Road that passed by the disjunct `Ōla`a Tract Unit, were included in the survey. Highway 11 is the primary road through the park and a major island thoroughfare. Three residential subdivisions adjacent to the park were similarly surveyed in 0.5–1 mile (0.8–1.6 km) intervals in 2003, and data were analyzed separately. Two roads to the east and northeast were also surveyed, but data from these disjunct areas were analyzed separately from park roads. In total, 174 of the target alien species were observed along HAVO roads and buffers, exclusive of residential areas, and the mean number of target aliens per mile surveyed was 20.6. Highway 11 and its buffer zones had the highest mean number of target alien plants per mile (26.7) of all park roads, and the Mauna Loa Strip Road had the lowest mean (11.7). Segments of Highway 11 adjacent to HAVO and Wright Road next to `Ōla`a Tract had mean numbers of target alien per mile (24–47) higher than those of any internal road. Alien plant frequencies were summarized for each road in HAVO. Fifteen new records of vascular plants for HAVO were observed and collected along park roads. An additional 28 alien plant species not known from HAVO were observed along the buffer segments of Highway 11 adjacent to the park. Within the adjacent residential subdivisions, 65 target alien plant species were sighted along roadsides. At least 15 potentially invasive species not currently found within HAVO were observed along residential roads, and several other species found there have been previously eliminated from the park or controlled to remnant populations. Data collected from this survey can be used by the park and other landowners to help detect and manage invasive plant species that threaten the natural resources of their lands, and survey findings will inform managers of threats from alien species established along corridors beyond park boundaries. Recommendations were made for refining the list of incipient invasive plant species to search for near the park and for the repetition of periodic roadside weed surveys in the park.

INTRODUCTION

Naturalized alien plant species are a major component of the current flora of the Hawaiian Islands; the main Hawaiian Islands have a flora of approximately 1,100 native flowering plant taxa, as well as more than 860 naturalized alien plants (Wagner *et al.* 1999, Imada 2011). In addition, there are more than 8,000 cultivated non-native plants in Hawai`i, exclusive of forestry plantings (Staples and Herbst 2005), and many of these have invasive characteristics (Staples *et al.* 2000). Within Hawai`i Volcanoes National Park (HAVO) alien species, including cultivated plants, now make up more than half of the park's vascular flora (Higashino *et al.* 1988). Alien plant species were also strongly represented at the Kahuku Unit of the park, when that large former ranch was recently added to HAVO (Benitez *et al.* 2008). The percentage of alien to native species at HAVO has increased with every checklist documenting the occurrence of vascular plants within the park from the earliest comprehensive list of Fagerlund and Mitchell (1944) to Fosberg (1966, 1976) and Higashino *et al.* (1988). In 1944, there were 238 alien plant species known to be present in HAVO, and by 1988 this number had increased to 602, including species planted within the park but not naturalized. Since the last published park checklist, at least 25 additional alien plant species have been observed within HAVO, exclusive of the additions from the current survey (Benitez *et al.* 2012; L. Pratt, pers. obs.).

Alien plant species are considered damaging to the native ecosystems of many U.S. national parks (Loope 1992), where they may impact native species and communities and alter ecosystem properties (Vitousek 1992). Alien plant species are, along with introduced mammals, currently the most serious threat to the conservation of native biodiversity in the Hawaiian Islands (Smith 1985, Pratt and Jacobi 2009). Islands, including the Hawaiian Islands, appear to be particularly vulnerable to invasion and negative impacts from introduced species (Loope and Mueller-Dombois 1989, Simberloff 1995, Denslow 2003). The Hawaiian Islands are home to more than 300 listed endangered and threatened plant species (U.S. Fish and Wildlife Service, no date), and the habitats of many of these vulnerable plants are essentially unmanaged and infested by invasive alien plants and feral ungulates. Hawai`i's national parks, wildlife refuges, and natural area reserves are among the few large areas in the state that are fenced and managed to reduce threats to native forests and their rare inhabitants. Hawai`i Volcanoes National Park managers have a well-established program for controlling widely distributed alien plants in designated areas with important resource values, called Special Ecological Areas or SEAs (Tunison and Stone 1992, Loh and Tunison 2009), and they have also targeted for eradication those alien plant species with more restricted localized distributions in the park (Tunison and Zimmer 1992). The early detection and control of alien plant species, both inside and adjacent to the park, are recognized as urgently needed to prevent plant invasions from becoming intractable problems (Loope *et al.* 2001); such actions are also among the most economically effective management strategies for HAVO.

Road corridors are well-known conduits for non-native plant species in mainland North American natural areas (Tyser and Worley 1992, Tromulak and Frissell 2000, Watkins *et al.* 2003, Fowler *et al.* 2008) and on islands (Wester and Juvik 1983, Arévalo *et al.* 2005). There is some evidence that the verges of improved paved roads support more alien species and greater alien plant cover than do those of unpaved, more primitive roads (Gelbard and Belnap 2003). Although some writers have suggested that roads are not important sources of plant invaders into surrounding natural vegetation (Forman and Alexander 1998), both roads and trails have been implicated as sources of alien plant invasions in many U.S. national parks (Allen *et al.* 2009). In both Australia and Europe, motor vehicles have been shown to be vectors of weed seeds (Lonsdale and Lane 1994, Zwaenepoel *et al.* 2006). Disturbance of vegetation adjacent to roads may facilitate the establishment of alien plants (Gelbard and Belnap 2003), and some disturbance regimes have been recognized as favorable to invasive plants (Daehler 2003).

Roadside surveys for target alien plants have been recognized as an efficient way to detect recently introduced species that may be vectored along these corridors and to aid with mapping weed distributions in Hawai`i (Kueffer and Loope 2009). A main objective of this weed survey was to determine the distribution and frequency along major roads within and adjacent to HAVO of a selected group of known widespread invasive plants, localized or regional invasive species, and those thought to be incipient in the park or region. Additionally, the survey was designed to identify newly established alien plants on roadsides of HAVO and to determine the frequency of target alien species and potentially invasive ornamental plants along roads in residential subdivisions adjacent to HAVO. Data collected from this survey can be used by the park and other landowners to help identify and manage invasive species that threaten the natural resources of their lands. Knowing the location of potentially invasive new introductions will allow park managers to eradicate some from HAVO, and others may be mapped thoroughly and monitored. The survey of landscaped subdivisions adjacent to the park identified ornamental species with potential to naturalize in the park and these findings alert park managers to species that may appear in HAVO in the near future.

METHODS

Study Area

Hawai`i Volcanoes National Park has an area of 323,421 acres (130,944 ha) on the southeastern part of the island of Hawai`i (Figure 1). The park includes the summit area and south slope of Kīlauea Volcano and the summit of Mauna Loa Volcano, as well as large sections of the eastern and southern slope of that volcano. Major roads of the original unit of the national park include Highway 11 that circles the island and secondary paved roads that extend from the coastline to an elevation of 6,700 ft (2,040 m) on Mauna Loa. The Kahuku Unit, a former cattle ranch on the southern slope of Mauna Loa, contains an extensive network of gravel and grass jeep trails, but no paved roads. Highway 11, the major road of the island, passes along the Kahuku lower-elevation boundary.

Field Surveys

The primary and secondary paved roads within HAVO, exclusive of Kīlauea Military Camp and the park housing area, were surveyed on foot for invasive alien plant species between May and August 2001 (Figure 2). Park residential areas and trails were not included in this study because they were surveyed in a separate project (Benitez *et al.* 2012). Data collection on internal HAVO roads was completed in 2001, but additional surveys of areas adjacent to the park took place in 2002, 2003, and 2005. Highway 11 adjacent to the Kahuku addition was walked in 2002, and Wright Road that passes by the disjunct `Ōla`a Tract was surveyed in 2003. Highway 11 was divided into two segments: the original section of the park and the new Kahuku Unit. Both segments included five-mile buffers beyond the park boundaries (a 10-mile buffer on the west side of the original Kīlauea section of the park). Two roads farther removed from HAVO, Highway 130 east of the park in Puna District and Stainback Highway northeast of `Ōla`a Tract, were surveyed in 2005 (Figure 3). Roadsides in subdivisions adjacent to HAVO were walked in August 2003; these residential areas included Volcano Village, Mauna Loa Estates, and the Volcano Golf Course subdivision (Figure 4).

The roadside survey was accomplished on foot with at least one observer walking on each side of the road except for the Mauna Loa Strip Road where only one observer surveyed both sides of the narrow single-lane road. Three primary observers (Keali`i Bio, Linda Pratt, Laura Nelson) and four secondary observers (see Acknowledgments) were involved in the survey. One primary observer was present at all surveys (KB) except the Mauna Loa Road (LP). The same two observers (KB and LP) surveyed all internal park roads and the three adjacent residential subdivisions.

Target Plant Species

Prior to data collection, a preliminary target list of 180 alien plant species was generated for use on the roadside survey; botanists from both HAVO natural resources management division and U.S. Geological Survey contributed to the selection of target alien plant species. This list included selected invasive species widely distributed on the island (widespread), invasive species believed to be restricted to the region including the park (regional), alien plants recently established or present in low numbers in and near the park (incipient), and ornamental plants that appeared to have escaped from cultivation (ornamental, incipient). Other cultivated plant species not obviously naturalized (ornamental) were noted if they were on a list of potentially invasive cultivated plants in Hawai`i or in the same genus as species on the list (Staples *et al.* 2000). This list of alien plant species on which to collect data was developed following a review of the State Noxious Weed Rules (Hawai`i State Department of Agriculture 1992), a list of

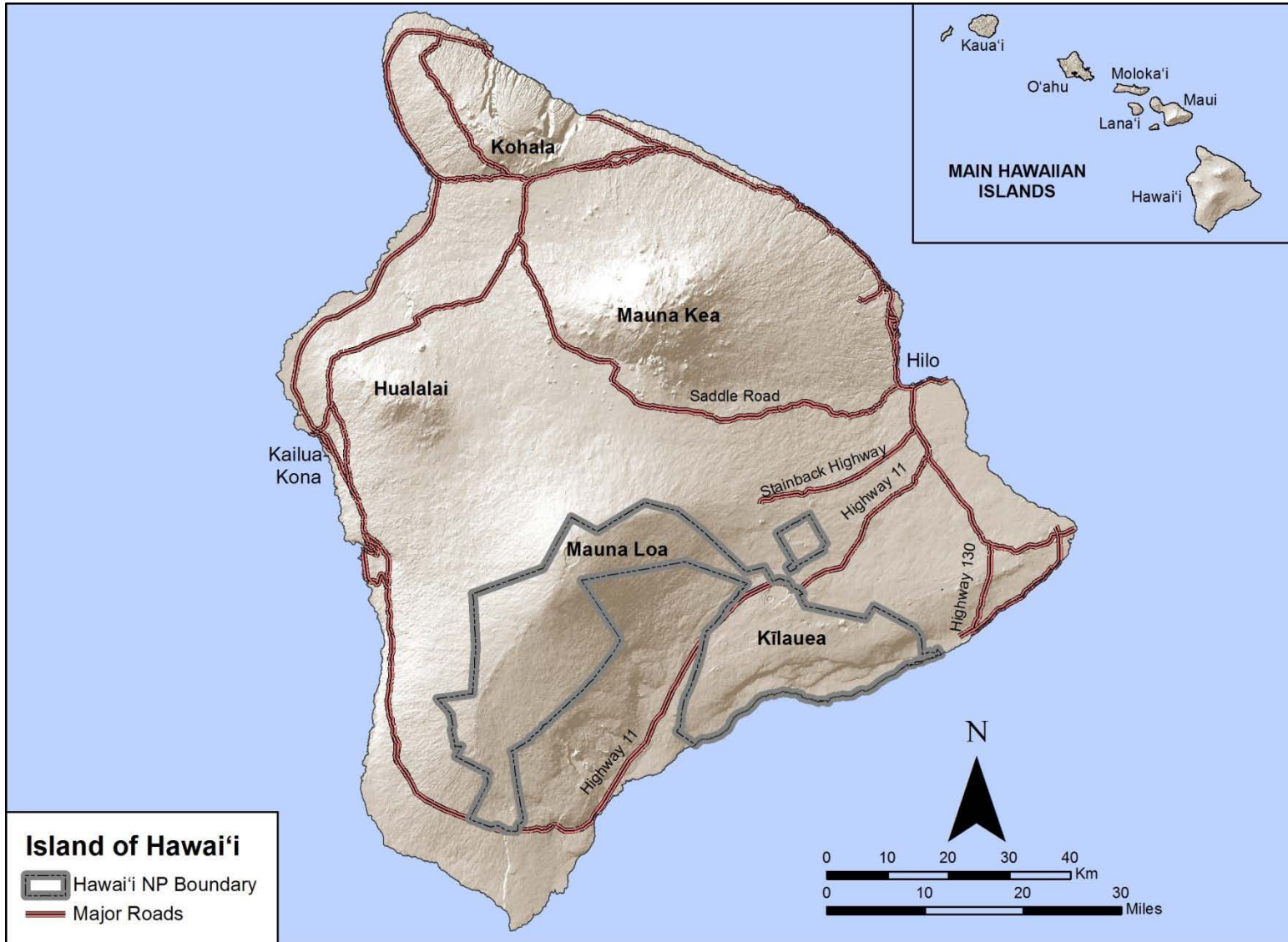


Figure 1. Major roads on the island of Hawai`i and location of Hawai`i Volcanoes National Park (Hawai`i NP).

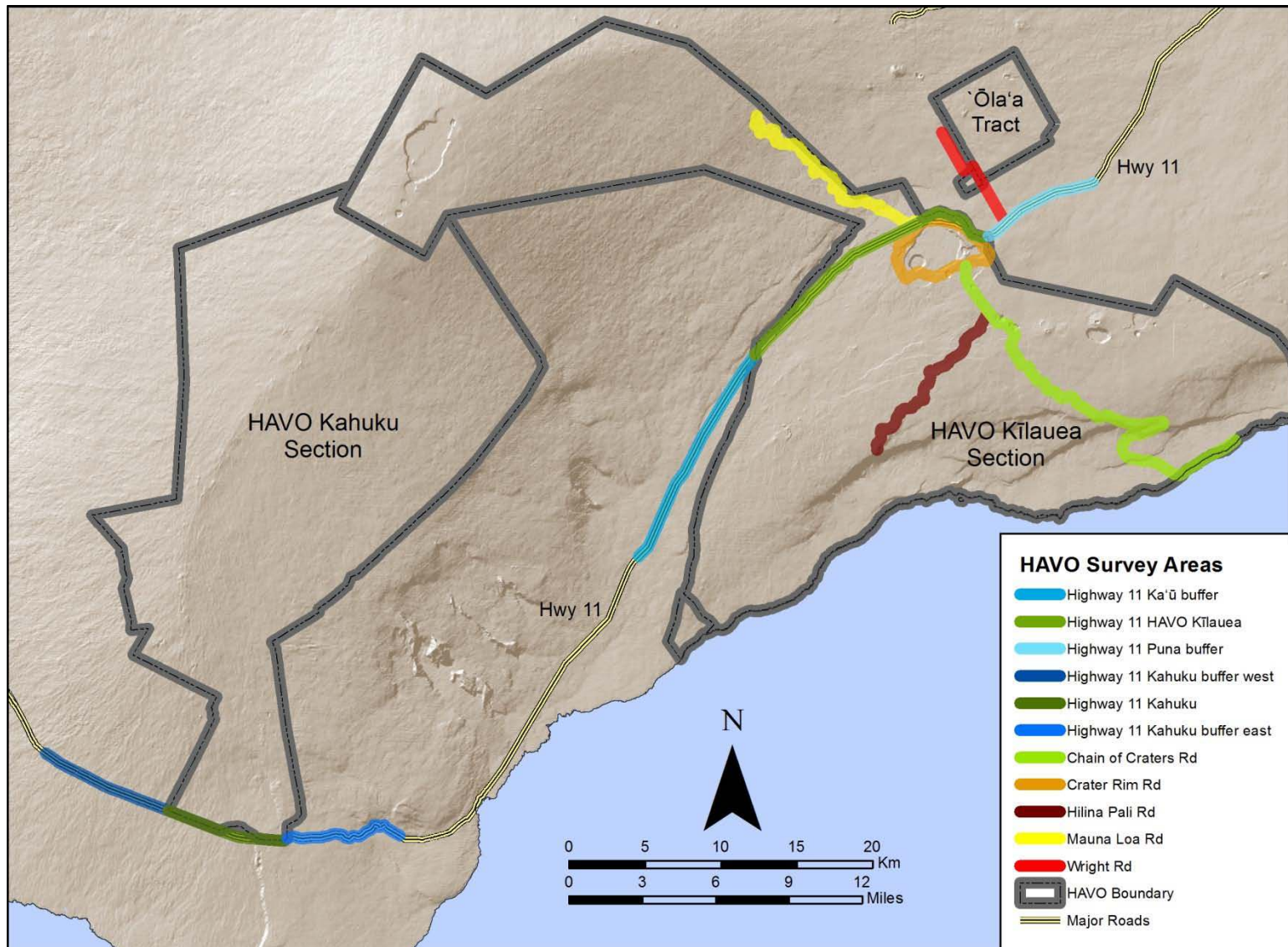


Figure 2. Location of Hawai'i Volcanoes National Park (HAVO) and roads surveyed for alien plants, 2001–2005.

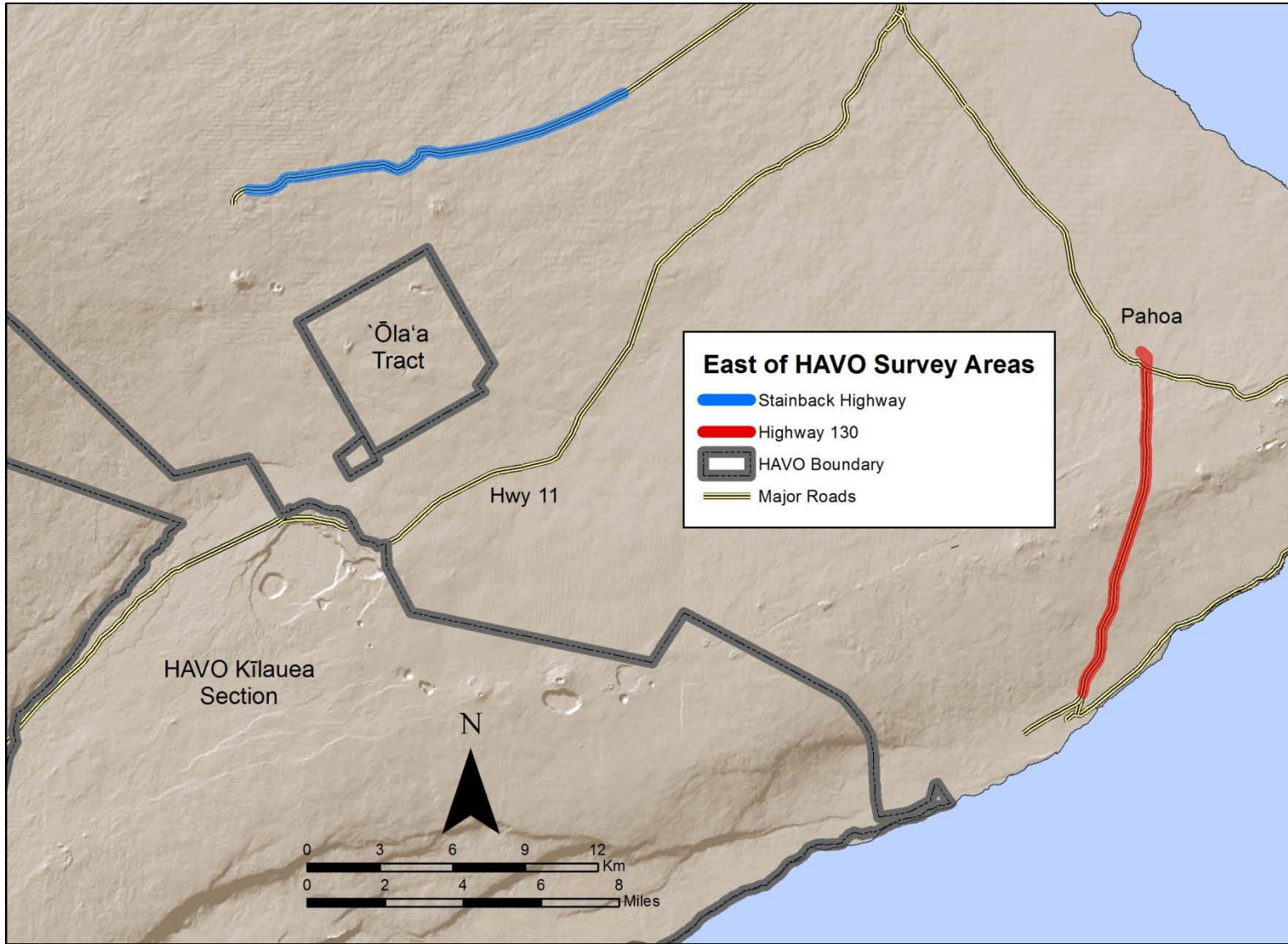


Figure 3. Location of roads east of Hawai'i Volcanoes National Park (HAVO) surveyed for alien plants in 2005.

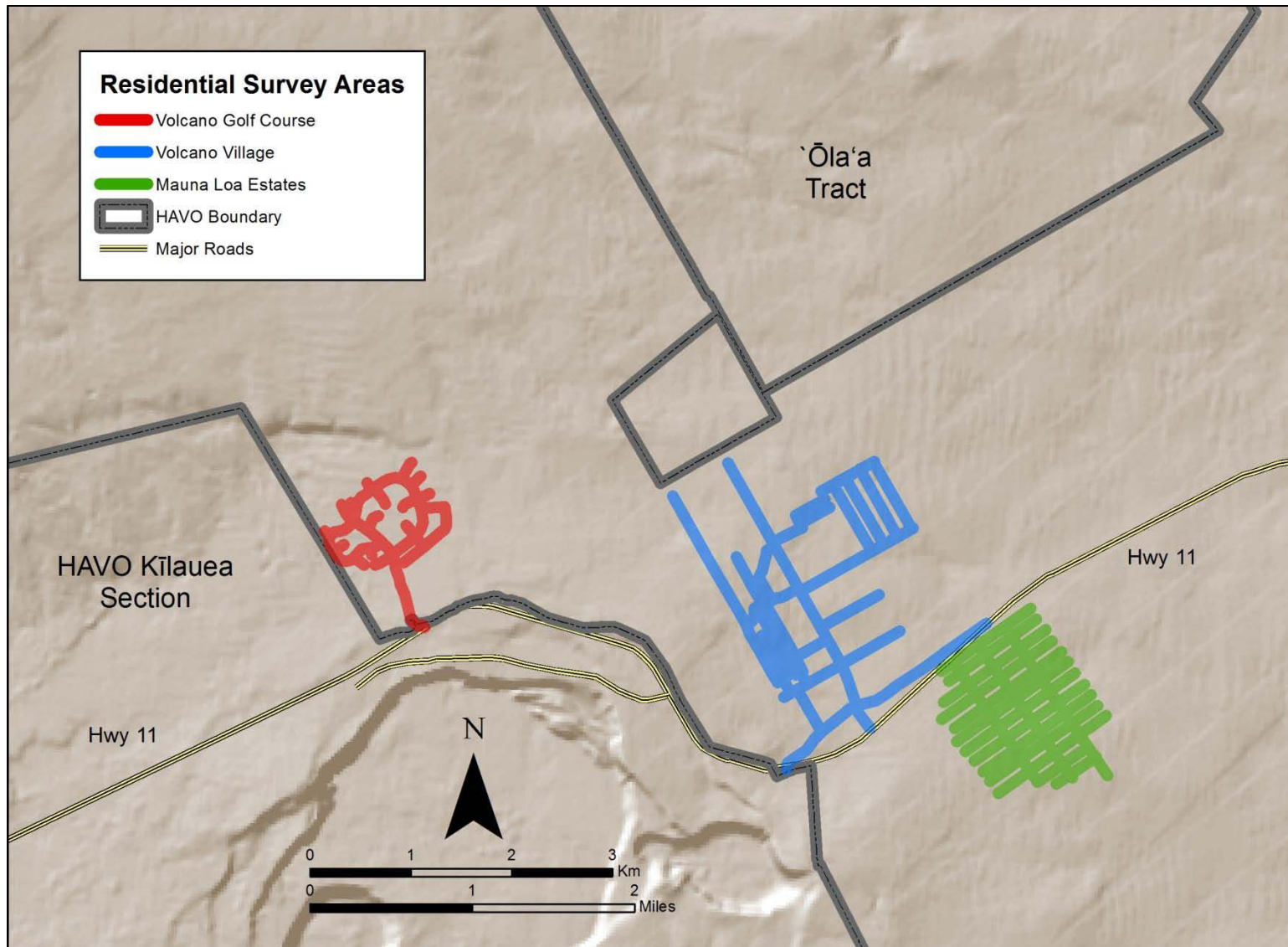


Figure 4. Residential areas adjacent to Hawai'i Volcanoes National Park (HAVO) surveyed for roadside alien plants in 2003.

Hawai`i's most invasive horticultural plants (Hawai`i State Alien Species Coordinator, no date), lists of alien plant species of management concern in HAVO (Tunison 1992), a list of localized alien plant species known from one or few sites in HAVO (Tunison and Zimmer 1992), previous HAVO plant checklists (Fosberg 1966, 1976; Higashino *et al.* 1988), and unpublished lists generated by the Big Island and Maui Invasive Species Committees (BIISC and MIISC). The Hawai`i Weed Risk Assessment (Daehler and Denslow 2011) ratings were reviewed for species on the preliminary list. Some species listed as noxious weeds by the state were not included on the initial target list because they were not known to occur on the island.

Newly-established alien plants within and near the park (those not on previous park checklists) and potentially invasive ornamentals (Staples *et al.* 2000) were added to the list as they were encountered and were tracked on subsequent surveyed roads. It was often not possible to distinguish whether ornamental and ornamental, incipient species were intentionally planted or established as naturalized plants. Additions to the target plant list amounted to 60 species, and the final list contained 240 species (Appendix 1). Nomenclature of naturalized weed species follows Wagner *et al.* (1999), the supplement to the *Manual of the Flora of Hawai`i* (Wagner *et al.* 2012), a recent Pacific grass key (Clayton and Snow 2010), and various articles published in the Bishop Museum Occasional Papers (Imada 2011). Fern nomenclature follows Palmer (2003), Snow *et al.* (2011), and Hovencamp and Miyamoto (2005). Names of ornamental plant species not listed as naturalized by Wagner *et al.* (1999) or Palmer (2003) are from Staples and Herbst (2005).

Data Collection

All alien plant species on the target list encountered along HAVO and adjacent roadsides were recorded in 1-mile (1.6-km) plot increments. Highway mile markers were used to delineate plots when available; otherwise one-mile intervals were measured with a vehicle odometer prior to the survey and were marked temporarily with GPS coordinates taken on the road to be surveyed. Detectability of alien plant species varied from approximately 10 to 50 m beyond the edge of the road. The three residential subdivisions adjacent to the park were surveyed in plot increments less than one mile long because many residential roads were short cul-de-sacs or connections between longer roads. Volcano Village roadside data were collected along 0.5-mile (0.8-km) increments, and Mauna Loa Estates data were recorded in 0.75-mile (1.2-km) increments on cross roads and in 1-mile (1.6-km) intervals along the three main roads perpendicular to Highway 11. Data were collected on a road-by-road basis on the short residential roads of the Volcano Golf Course subdivision and in 0.5-mile (0.8-km) intervals on the longer Pukeawe Circle and Pi`imauna access road.

Alien plant species that were new records to the park were recorded on park and buffer roads even if they were not on the list of target invasive alien plant species. Voucher specimens were made of additions to the park's flora, plants of target weed genera not identified to species, species that seemed to be range extensions or new district records, and any plant of questionable identification. All voucher specimens were placed in the HAVO natural history collection (herbarium), except those that were island records or could not be identified, which were deposited in the *Herbarium Pacificum* at the Bishop Museum in Honolulu (Pratt and Bio 2012).

Data Analysis

The frequency of each species encountered was calculated as the number of surveyed segments containing the species divided by the total number of segments surveyed (100 miles

inside the park including buffer areas). Weed frequencies were also calculated for each individual road inside the park. The sum total of target weeds observed and the mean number of alien plants per mile were determined for each road surveyed and for all park roads and buffer areas combined. Data collected along Highway 130 and Stainback Highway east of the park were considered separately from data recorded on park roads and buffers. Residential road data were also analyzed independently from the park roads data set.

RESULTS

Of the possible 240 target alien plant species 174 were encountered along HAVO roads and buffers, exclusive of the nearby subdivisions and non-adjacent roads (Highway 130 and Stainback; Appendix 1). An additional 28 species were seen exclusively on the nearby Highway 130 and Stainback, and 10 species (mostly ornamentals) were noted only in subdivisions adjacent to the park. Twenty-eight other species on the target list were not seen on any surveyed road. Target species were, for the most part, invasive plants either widespread on the island or regional in the districts near HAVO (139 species combined), and most of these were encountered on park roads. Only 9 of the widespread target invasive species and 23 of the species considered to be regionally established were not found along HAVO roads or adjacent buffer zones. Almost all the regional alien species that were not encountered in the survey were plants known to be established at low elevations.

Most of the target species considered to be incipient invaders in the region were observed along park roads and within buffer zones (47 of 56), and 5 other incipient species not seen within the park were found roadside in adjacent residential areas or along Highway 130 east of HAVO. Fifteen of the incipient species found along park roads were new records for HAVO and will be described in a following section. Potentially invasive ornamentals and cultivated plants that have naturalized ("ornamental" and "ornamental, incipient" in Appendix 1) amounted to 40 species on the target list, but less than half of these (17) were encountered along park roads and buffer segments. An additional 8 ornamental species were observed only in residential areas near HAVO.

The mean number of target alien plants observed on 100 miles (160 km) of roads in or adjacent to HAVO was 20.6 species/mile; this represented the distance of all surveyed park roads including Highway 11 buffers and Wright Road. The mean weeds per mile was variable on the surveyed park roads, with Highway 11 having a higher average number of target alien plants compared with other interior park roads (Table 1). Segments of Highway 11 in the buffer zones near the park and Wright Road adjacent to `Ōla`a Tract had averages for species per mile even higher than that of Highway 11 overall. The non-adjacent Highway 130 in the lowlands east of HAVO had the highest mean number of target alien species encountered in the survey. Summaries of the alien plants found on the individual road segments are presented in the next section.

Alien Plant Species on Individual Park Roads

Hilina Pali Road

The narrow road stretching from the Chain of Craters Road to the lookout at the edge of Hilina Pali is nine miles (14.4 km) long and passes through *Metrosideros polymorpha* woodland and grassland dominated by alien bunchgrasses. Twenty-two of the survey's target weeds were encountered along Hilina Pali Road, and the mean number of species per mile was the second lowest of all park roads (13.1; Table 1). More than half of the weed species observed were

Table 1. Number of miles surveyed and mean number of target alien plant species encountered per mile on individual roads within and adjacent to HAVO.

Highway/road	# Miles surveyed	Total # of target species on road	Sum of # species encountered/mile	Mean # spp/mile
Hilina Pali Rd	9	22	118	13.1
Chain of Craters Rd	20	43	278	13.9
Crater Rim Rd	11	44	185	16.8
Mauna Loa Strip Rd	11	25	129	11.7
Highway 11 HAVO & buffers	44	140	1174	26.7
(Hwy 11 Puna buffer)*	[5]		150	30.0
(Hwy 11 HAVO, Kīlauea Unit)*	[12]		216	18.0
(Hwy 11 Ka`ū buffer)*	[10]		244	24.0
(Hwy 11 Kahuku Unit buffer east)*	[5]		236	47.2
(Hwy 11 Kahuku Unit)*	[7]		169	24.1
(Hwy 11 Kahuku Unit buffer west)*	[5]		158	31.6
Wright Rd (adjacent to `Ōla`a)	5	70	178	35.6
All HAVO (including buffers)	100	174	2062	20.6
Highway 130 (east of HAVO)	10	105	480	48.0
Upper Stainback Highway (northeast of HAVO)	10	41	228	22.8

* Subsets of Highway 11

grasses, and the widespread grasses *Andropogon virginicus* (broomsedge), *Melinis minutiflora* (molasses grass), *Axonopus fissifolius* (narrow-leaf carpetgrass), and *Schizachyrium condensatum* (bush beardgrass) were ubiquitous along the road, occurring at 100% frequency (Table 2). Several other alien grasses occurred at frequencies >50%. The ecosystem-altering tree *Morella faya* (firetree or faya) was seen on eight of the mile segments (88.9%), while *Psidium cattleianum* (strawberry guava), one of the most invasive alien trees of Hawai`i, was recorded along a single mile segment (11.1%). Another widespread shrubby species, *Lantana camara* (lantana), was noted with a frequency of 44.1%. The herbaceous *Persicaria capitata* (knotweed), widely distributed elsewhere in the park and controlled along HAVO roadsides (Benitez *et al.* 2012), occurred along a single mile segment of the road. One new park record, the grass *Sporobolus indicus* (Indian dropseed), was collected at a single site on Hilina Pali Road at 1,965 ft (600 m) elevation.

Chain of Craters Road

The Chain of Craters Road is 20 miles (32 km) long, beginning at Crater Rim Road near 3,700 ft (1,130 m) elevation and ending at the coast where the road has been covered by lava from the ongoing Pu`u `Ō`ō eruption. Vegetation along the road varies from closed wet *Metrosideros* forest at the top to dry grassland with native shrubs and coastal cliff vegetation in the coastal lowlands. Along the way, the road passes through expanses of recent nearly barren lava flows and *Metrosideros/Dodonaea* (`a`ali`i) woodland. A total of 43 target alien species was observed along the Chain of Craters Road, and the mean species/mile was 13.9 (Table 1). As

Table 2. Frequency of target alien plant species along Hilina Pali Road (9 intervals).

Scientific name	Common name	Category	# Intervals occupied	Frequency (%)
<i>Andropogon virginicus</i>	broomsedge	widespread	9	100.0
<i>Arundina graminifolia</i>	bamboo orchid	widespread	6	66.7
<i>Asclepias physocarpa</i>	balloon plant	widespread	2	22.2
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	9	100.0
<i>Cenchrus echinatus</i>	common sandbur	widespread	5	55.6
<i>Holcus lanatus</i>	velvetgrass	widespread	1	11.1
<i>Hyparrhenia rufa</i>	thatching grass, jaragua	regional	6	66.7
<i>Lantana camara</i>	lantana	widespread	4	44.4
<i>Melinis minutiflora</i>	molasses grass	widespread	9	100.0
<i>Melinis repens</i>	Natal redtop	widespread	8	88.9
<i>Morella faya</i>	firetree, faya	widespread	8	88.9
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	7	77.8
<i>Paspalum conjugatum</i>	Hilo grass	widespread	2	22.2
<i>Paspalum urvillei</i>	Vasey grass	widespread	8	88.9
<i>Pennisetum clandestinum</i>	kikuyu grass	widespread	5	55.6
<i>Persicaria capitata</i>	knotweed, smartweed	widespread	1	11.1
<i>Pityrogramma calomelanos/ P. austroamericana</i>	silver fern, gold fern	widespread	6	66.7
<i>Pluchea carolinensis</i>	sour bush	widespread	6	66.7
<i>Psidium cattleianum</i>	strawberry guava, waiawi	widespread	1	11.1
<i>Psidium guajava</i>	common guava	widespread	5	55.6
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	9	100.0
<i>Sporobolus indicus</i>	Indian dropseed	incipient	1	11.1

was seen on the Hilina Pali Road, a suite of alien grasses was widely distributed along the Chain of Craters; *Andropogon virginicus*, *Axonopus fissifolius*, *Melinis minutiflora*, *M. repens* (Natal redtop), *Paspalum urvillei* (Vasey grass), and *Schizachyrium condensatum* occurred with 75–100% frequency (Table 3). *Morella faya* was seen with a frequency of 45%, and the highly invasive *Psidium cattleianum* was less widespread with a frequency of 15%; the latter species was found in the two upper miles of the road and also in the coastal section where *P. cattleianum* was rare and largely replaced by *P. guajava*. *Schinus terebinthifolius* (Christmas berry), an invasive shrub of the lowlands, was noted with 25% frequency, primarily along the coastal and low-elevation portion of the road. *Persicaria capitata*, an escaped ornamental ground cover, was distributed along 65% of the mile segments, and the invasive *Rubus argutus* (blackberry) was found with a frequency of 20%. Several species that are common outside HAVO, which have long been the target of control efforts as localized alien plant species in the park (Tunison *et al.* 1992), were sighted at single sites along the Chain of Craters Road; these included the trees *Melochia umbellata* and *Trema orientalis* (gunpowder tree), the vine *Paederia foetida* (maile pilau), and the shrub *Leucaena leucocephala* (koa haole).

Table 3. Frequency of target alien plant species along Chain of Craters Road (20 intervals).

Scientific name	Common name	Category	# Intervals occupied	Frequency (%)
<i>Ageratina riparia</i>	spreading mist flower	widespread	4	20.0
<i>Andropogon virginicus</i>	broomsedge	widespread	20	100.0
<i>Anemone hupehensis</i> var. <i>japonica</i>	Japanese anemone	widespread	4	20.0
<i>Arundina graminifolia</i>	bamboo orchid	widespread	9	45.0
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	19	95.0
<i>Bryophyllum pinnatum</i>	air plant	widespread	1	5.0
<i>Buddleja asiatica</i>	Asiatic butterfly bush	widespread	7	35.0
<i>Cenchrus echinatus</i>	common sandbur	widespread	1	5.0
<i>Crotalaria lanceolata</i>	lance-leaf rattlepod	incipient	1	5.0
<i>Desmodium incanum</i> /D. <i>intortum</i>	Spanish clover	regional	1	5.0
<i>Digitaria insularis</i>	sourgrass	incipient	1	5.0
<i>Ehrharta stipoides</i>	meadow ricegrass	widespread	2	10.0
<i>Hedychium gardnerianum</i>	kāhili ginger	widespread	2	10.0
<i>Holcus lanatus</i>	velvetgrass	widespread	4	20.0
<i>Hyparrhenia rufa</i>	thatching grass, jaragua	regional	4	20.0
<i>Impatiens walleriana</i>	balsam, touch-me-not	regional	1	5.0
<i>Justicia betonica</i>	white shrimp plant	incipient	1	5.0
<i>Lantana camara</i>	lantana	widespread	11	55.0
<i>Leucaena leucocephala</i>	koa haole	widespread	1	5.0
<i>Melinis minutiflora</i>	molasses grass	widespread	20	100.0
<i>Melinis repens</i>	Natal redtop	widespread	18	90.0
<i>Melochia umbellata</i>	no common name	regional	1	5.0
<i>Morella faya</i>	firetree, faya	widespread	9	45.0
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	20	100.0
<i>Paederia foetida</i>	maile pilau	regional	1	5.0
<i>Paspalum conjugatum</i>	Hilo grass	widespread	1	5.0
<i>Paspalum urvillei</i>	Vasey grass	widespread	15	75.0
<i>Passiflora edulis</i>	liliko`i, passion fruit	regional	1	5.0
<i>Passiflora foetida</i>	love-in-a-mist	widespread	5	25.0
<i>Pennisetum clandestinum</i>	kikuyu grass	widespread	6	30.0
<i>Pennisetum setaceum</i>	fountain grass	widespread	1	5.0
<i>Persicaria capitata</i>	knotweed, smartweed	widespread	13	65.0
<i>Pityrogramma calomelanos</i> /P. <i>austroamericana</i>	silver fern, gold fern	widespread	10	50.0
<i>Pluchea carolinensis</i>	sour bush	widespread	19	95.0
<i>Psidium cattleianum</i>	strawberry guava, waiawi	widespread	3	15.0
<i>Psidium guajava</i>	common guava	widespread	12	60.0

Table 3 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Rubus argutus</i>	blackberry	widespread	4	20.0
<i>Rubus rosifolius</i>	thimbleberry	widespread	2	10.0
<i>Schinus terebinthifolius</i>	Christmas berry	widespread	5	25.0
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	15	75.0
<i>Sporobolus indicus</i>	Indian dropseed	incipient	1	5.0
<i>Trema orientalis</i>	gunpowder tree	widespread	1	5.0
<i>Urochloa maxima</i>	Guinea grass	widespread	1	5.0

More concerning was the sighting of *Pennisetum setaceum* (fountain grass) in a single mile increment; this bunchgrass has been the target of a multi-decade control effort in HAVO (Tunison *et al.* 1994). Because fountain grass is abundant on the island and easily vectored by vehicles, it reappears frequently within the park. The grass was seen in HAVO as a single plant at only one site during this survey. The fountain grass clump had probably recently appeared on the roadside; the park's program of containment and periodic roadside treatment appears to be successful at preventing the establishment of additional populations of this highly invasive weed (D. Benitez, pers. comm.). One unusual single occurrence on the roadside (opposite a paved pull-out) was that of *Justicia betonica* (white shrimp plant), a naturalized ornamental species previously known in the park only from a cultivated plant in the residence area (Fosberg 1966). This patch of shrimp plant was recently treated and apparently controlled at the Chain of Craters roadside site (Benitez *et al.* 2012). The grass *Sporobolus indicus*, a new record for HAVO found on three park roads, was also observed at only one site along the Chain of Craters Road at 1,670 ft (510 m) elevation.

Crater Rim Road

The road circling Kīlauea Caldera roughly follows the 3,800–3,900 ft (1,160–1,190 m) contours and traverses varied habitats ranging from closed montane wet forest of *Metrosideros polymorpha* and *Cibotium glaucum* (hāpu`u tree fern) to nearly barren recent lava and scattered low shrubs on dry ash and cinder substrate in the upper Ka`ū Desert south of Halema`uma`u Crater. The Crater Rim Road is 11 miles (17.6 km) long, but at present (since 2008) the southern and western portions of the road are closed due to volcanic activity in Halema`uma`u, and traffic is severely limited. Crater Rim Road supported 44 of the target alien plant species; the mean number of target species per mile was 16.8 (Table 1). As was seen on the Chain of Craters and Hilina Pali Roads, several widespread grass species were seen on most (>60%) or all of the Crater Rim intervals; these included *Andropogon virginicus*, *Axonopus fissifolius*, *Holcus lanatus* (velvet grass), *Melinis minutiflora*, *Paspalum urvillei*, *Pennisetum clandestinum* (kikuyu grass), and *Schizachyrium condensatum* (Table 4). Other highly invasive alien plants observed at high frequency along the Crater Rim Road were the tree *Morella faya* (82%), the strawberry guava tree *Psidium cattleianum* (55%), and the large herbaceous ginger *Hedychium gardnerianum* (kāhili ginger; 55%). *Rubus ellipticus* (yellow Himalayan raspberry), a serious invader of park rain forests, had a relatively low frequency of 18%, but *Rubus argutus*, a blackberry that is more invasive at higher elevation, was present on 55% of the mile intervals. The melastomes *Tibouchina urvilleana* (glorybush) and *Heterocentron subtriplinervium* (pearl flower), which are currently being controlled along park roadsides, were observed on 27 to 36% of the Crater Rim Road segments, respectively. These two species are members of the Melastomataceae, a plant family particularly invasive in Hawai`i.

Table 4. Frequency of target alien plant species along Crater Rim Road (11 intervals).

Scientific name	Common name	Category	# Intervals occupied	Frequency (%)
<i>Ageratina riparia</i>	spreading mist flower	widespread	2	18.2
<i>Andropogon virginicus</i>	broomsedge	widespread	11	100.0
<i>Anemone hupehensis</i> var. <i>japonica</i>	Japanese anemone	widespread	3	27.3
<i>Arundina graminifolia</i>	bamboo orchid	widespread	8	72.7
<i>Axonopus compressus</i>	broad-leaf carpetgrass	regional	1	9.1
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	11	100.0
<i>Buddleja asiatica</i>	Asiatic butterfly bush	widespread	3	27.3
<i>Dactylis glomerata</i>	orchardgrass, cocksfoot	widespread	1	9.1
<i>Desmodium incanum</i> / <i>D. intortum</i>	Spanish clover	regional	2	18.2
<i>Digitaria cf. abyssinica?</i>	no common name	incipient	1	9.1
<i>Ehrharta stipoides</i>	meadow ricegrass	widespread	4	36.4
<i>Erigeron karvinskianus</i>	daisy fleabane	incipient	2	18.2
<i>Hebe speciosa</i>	hebe, showy veronica	ornamental, incipient	1	9.1
<i>Hedychium flavescens</i>	yellow ginger	widespread	2	18.2
<i>Hedychium gardnerianum</i>	kāhili ginger	widespread	6	54.5
<i>Heterocentron subtripplinervium</i>	pearl flower	regional	4	36.4
<i>Holcus lanatus</i>	velvetgrass	widespread	8	72.7
<i>Lonicera japonica</i>	Japanese honeysuckle	incipient	1	9.1
<i>Melinis minutiflora</i>	molasses grass	widespread	11	100.0
<i>Melinis repens</i>	Natal redtop	widespread	5	45.5
<i>Morella faya</i>	firetree, faya	widespread	9	81.8
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	9	81.8
<i>Panicum repens</i>	torpedo grass	widespread	1	9.1
<i>Paspalum conjugatum</i>	Hilo grass	widespread	5	45.5
<i>Paspalum dilatatum</i>	Dallis grass	widespread	4	36.4
<i>Paspalum notatum</i>	Bahia grass	incipient	1	9.1
<i>Paspalum paniculatum</i>	no common name	incipient	1	9.1
<i>Paspalum urvillei</i>	Vasey grass	widespread	9	81.8
<i>Pennisetum clandestinum</i>	kikuyu grass	widespread	7	63.6
<i>Persicaria capitata</i>	knotweed, smartweed	widespread	7	63.6
<i>Pityrogramma calomelanos</i> / <i>P. austroamericana</i>	silver fern, gold fern	widespread	5	45.5
<i>Pluchea carolinensis</i>	sour bush	widespread	4	36.4
<i>Psidium cattleianum</i>	strawberry guava, waiawi	widespread	6	54.5
<i>Psidium guajava</i>	common guava	widespread	2	18.2
<i>Pyracantha</i> spp.	firethorn, 3 species	widespread	1	9.1
<i>Rubus argutus</i>	blackberry	widespread	6	54.5

Table 4 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Rubus ellipticus</i> var. <i>obcordatus</i>	yellow Himalayan raspberry	regional	2	18.2
<i>Schedonorus arundinaceus</i>	reed fescue	incipient	1	9.1
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	9	81.8
<i>Setaria palmifolia</i>	palmgrass	widespread	3	27.3
<i>Sphagneticola trilobata</i>	wedelia	incipient	1	9.1
<i>Sporobolus indicus</i>	Indian dropseed	incipient	1	9.1
<i>Tibouchina urvilleana</i>	glorybush	regional	3	27.3
<i>Urochloa mutica</i>	California grass	widespread	1	9.1

Escaped ornamentals noted with low frequency of occurrence included *Hebe speciosa* (hebe), *Lonicera japonica* (Japanese honeysuckle), and *Sphagneticola trilobata* (wedelia) on single mile segments (9%) and *Erigeron karvinskianus* (daisy fleabane) on two segments (18%) near the Kīlauea summit. Wedelia is a new record for HAVO, as are the grasses *Axonopus compressus* (wide-leaf carpetgrass), *Digitaria cf. abyssinica*, *Paspalum notatum* (Bahia grass), *P. paniculatum*, *Schedonorus arundinaceus* (reed fescue), and *Sporobolus indicus* (Indian dropseed), each found at single sites on the Crater Rim Road. This was the third occurrence of Indian dropseed noted on park roads during the survey.

Mauna Loa Strip Road

This road runs from Highway 11 near the Kīlauea summit at 4,020 ft (1,225 m) to the start of the Mauna Loa summit trail at 6,700 ft (2,040 m) elevation. This 11-mile (17.6-km) stretch of road is two lanes wide for the first mile between Highway 11 and Kīpuka Puaulu and then reduces to a narrow single-lane pavement through *Acacia koa* (koa) forest and native shrubland. The Mauna Loa Road had 25 of the target alien plant species and the lowest mean number of species/mile (11.7) of all interior park roads (Table 1).

A suite of seven grasses was found on all or almost all (90–100%) mile increments; these were the widespread *Andropogon virginicus*, *Axonopus fissifolius*, *Holcus lanatus*, *Paspalum urvillei*, and *Schizachyrium condensatum*, with the addition of the high-elevation inhabiting species *Ehrharta stipoides* (meadow ricegrass) and *Paspalum dilatatum* (Dallis grass; Table 5). Six other target alien grasses occurred with lower frequencies. The widely-distributed and highly invasive tree species *Morella faya* and *Psidium cattleianum*, which are being controlled in the buffer area around the Special Ecological Areas of Kīpuka Puaulu and Kīpuka Kī, were noted at single sites along the Mauna Loa Road, as was the biennial herb *Verbascum thapsus* (common mullein). *Rubus argutus* (blackberry) and *Solanum pseudocapsicum* (Jerusalem cherry), two regionally common species treated within the kīpuka forests of the Mauna Loa Road, were found to be widely distributed along 63.6 and 27.3% of the segments, respectively. No incipient alien plant invaders on the list of targets or new plant records for the park were observed along the relatively high-elevation stretch of this narrow road.

Highway 11 and Buffer Areas

Highway 11 is the largest and longest highway within HAVO, amounting to 44 miles (70.4 km), including the stretch of road on the boundary of the Kahuku Unit and 5–10 mile (8–16 km) buffer zones on either side of the original park (Kīlauea Unit) and Kahuku. This highway has a

Table 5. Frequency of target alien plant species along Mauna Loa Strip Road (11 intervals).

Scientific name	Common name	Category	# Intervals occupied	Frequency (%)
<i>Andropogon virginicus</i>	broomsedge	widespread	11	100.0
<i>Arundina graminifolia</i>	bamboo orchid	widespread	1	9.1
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	10	90.9
<i>Bromus catharticus</i>	rescue grass	widespread	3	27.3
<i>Bromus diandrus</i>	ripgut grass	widespread	2	18.2
<i>Dactylis glomerata</i>	orchardgrass, cocksfoot	widespread	7	63.6
<i>Desmodium incanum/D. intortum</i>	Spanish clover	regional	1	9.1
<i>Ehrharta stipoides</i>	meadow ricegrass	widespread	10	90.9
<i>Hedychium gardnerianum</i>	kāhili ginger	widespread	1	9.1
<i>Holcus lanatus</i>	velvetgrass	widespread	11	100.0
<i>Melinis minutiflora</i>	molasses grass	widespread	8	72.7
<i>Melinis repens</i>	Natal redtop	widespread	6	54.5
<i>Morella faya</i>	firetree, faya	widespread	1	9.1
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	3	27.3
<i>Paspalum dilatatum</i>	Dallis grass	widespread	10	90.9
<i>Paspalum urvillei</i>	Vasey grass	widespread	10	90.9
<i>Pennisetum clandestinum</i>	kikuyu grass	widespread	7	63.6
<i>Persicaria capitata</i>	knotweed, smartweed	widespread	2	18.2
<i>Pityrogramma calomelanos/P. austroamericana</i>	silver fern, gold fern	widespread	1	9.1
<i>Psidium cattleianum</i>	strawberry guava	widespread	1	9.1
<i>Rubus argutus</i>	blackberry	widespread	7	63.6
<i>Rubus rosifolius</i>	thimbleberry	widespread	1	9.1
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	11	100.0
<i>Solanum pseudocapsicum</i>	Jerusalem cherry	widespread	3	27.3
<i>Verbascum thapsus</i>	common mullein	widespread	1	9.1

wide variety of habitats along its length in HAVO ranging from montane wet forests of *Metrosideros polymorpha* and *Cibotium glaucum* on the eastern side of Kīlauea summit to dry lava flows supporting open *Metrosideros* woodland with native shrubs on the western side of Kīlauea. The road within the 10-mile (16-km) buffer west of the Kīlauea Unit park boundary passes through ranchland, and the vegetation varies from developed pastures to *Metrosideros* woodland with an understory of native and alien shrubs and ground cover of grazed grasses. The vegetation along the Kahuku Unit boundary is also a mix of pastureland and *Metrosideros* woodland, but the 5-mile (8-km) buffer areas on either side of the unit include the village of Wai`ōhinu on the east and the residential subdivision of Hawai`i Ocean View Estates (HOVE) on the west. The highway segments in both of these buffer areas passed by a large number of residences with landscaped yards and gardens.

The long stretch of Highway 11 and its buffers contained 140 of the targeted alien plant species, and the mean number of species encountered per mile for the entire surveyed portion was 26.7, the highest average of any of the interior park roads (Table 1). The alien plants were not evenly distributed along the highway, and the buffer zones had higher averages than did the part of Highway 11 that actually traversed the park. While the part of the highway within the original section of HAVO on Kilauea had a mean of 18.1 species/mile, the 5-mile (8-km) buffer on the eastern wet side of the park in Puna District averaged 30.0 species/mile, and the 10-mile (16-km) buffer on the western boundary of HAVO, a dry area with low rainfall, had an average of 24.4 species/mile. The stretch of Highway 11 along the boundary of the Kahuku Unit averaged 24.1 target species/mile, but the buffer zone to the east toward Wai`ōhinu had nearly double the number of occurrences with a mean of 47.2/mile. The buffer zone on the west along the edge of HOVE also had an elevated mean of 31.6 species/mile.

Target alien plant species with the highest frequencies of occurrence along Highway 11 (80–100%) were grasses *Andropogon virginicus*, *Melinis minutiflora*, *M. repens*, *Urochloa maxima* (Guinea grass), and *Schizachyrium condensatum*, Asian swordfern *Nephrolepis brownii*, and the shrub *Pluchea carolinensis* (sourbush; Table 6). *Urochloa maxima* was rare on the east side of the park, but was found in almost every mile increment west of mile marker 30, including all of the western buffer zone and every mile along Kahuku and its buffers. Alien plants that occurred with a frequency >50% included widespread species such as *Arundina graminifolia* (bamboo orchid), *Asclepias physocarpa* (balloon plant), *Buddleja asiatica* (Asiatic butterfly bush or dog tail), *Grevillea robusta* (silk oak), *Hyptis pectinata* (comb hyptis), *Leucaena leucocephala* (koa haole), *Paspalum urvillei* (Vasey grass), *Pennisetum clandestinum* (kikuyu grass), *Persicaria capitata*, *Psidium guajava* (common guava), and *Schinus terebinthifolius* (Christmas berry). While *A. graminifolia*, *A. physocarpa*, *B. asiatica*, and *H. pectinata* are relatively innocuous inhabitants of disturbed areas, the remaining grasses, vine, and woody plants have all been the targets of control efforts in SEAs or at localized sites within HAVO.

Several other species found within the buffer zone of Highway 11 have been the focus of localized control efforts within the park. Trees such as *Acacia confusa* (Formosa koa), *A. mearnsii* (black wattle), *Casuarina equisetifolia* (ironwood), *Falcataria moluccana* (albizia), and *Melaleuca quinquenervia* (paperbark), the shrub *Ardisia crenata* (Hilo holly), and the ornamental herb *Phormium tenax* (New Zealand flax) were previously treated and either eradicated from the park or reduced to remnant populations of seedlings where they occurred in the coastal lowlands, `Āinahou Ranch, or developed areas (Tunison *et al.* 1992, Tunison and Zimmer 1992). These species and almost 100 other localized alien plants are periodically controlled when they appear along park roadsides and at sites of former infestations in HAVO (Benitez *et al.* 2012). Their presence along the highway in the 5 to 10-mile stretch adjacent to HAVO indicates that seed sources for likely reinvasion of the park remain in the near vicinity.

Falcataria moluccana, in particular, has a very great potential to invade and establish in the eastern lowlands of the park; this nitrogen-fixing tree has spread explosively in windward Hawai`i and has altered many wet lowland forests of Puna District (Hughes and Denslow 2005). Apart from roadside occurrences, *Falcataria* has so far been found primarily in the western park lowlands, where trees are destroyed during fountain grass survey and control operations (Benitez *et al.* 2012; R. Loh, pers. comm.). *Acacia confusa* was found scattered along the highway in the western half of the park and along the western buffer along Kapāpala Ranch, as well as along the Kahuku boundary. By contrast, *A. mearnsii*, a former forestry planting (Skolmen 1979), was seen only along the western highway buffer near Kapāpala. *Melaleuca*

Table 6. Frequency of target alien plant species along Highway 11 and buffer zones (44 intervals). Species not in HAVO, but found only within buffer zones are marked with *.

Scientific name	Common name	Category	# Intervals occupied	Frequency (%)
<i>Abutilon grandifolium</i>	hairy abutilon	widespread	9	20.5
<i>Acacia confusa</i>	Formosa koa	widespread	8	18.2
<i>Acacia mearnsii</i>	black wattle	widespread	5	11.4
<i>Agave americana</i>	century plant	ornamental	4	9.1
<i>Agave sisalana</i>	sisal, malina	widespread	6	13.6
<i>Ageratina riparia</i>	spreading mist flower	widespread	17	38.6
<i>Allamanda cathartica</i> *	allamanda	ornamental	6	13.6
<i>Andropogon virginicus</i>	broomsedge	widespread	35	79.5
<i>Ardisia crenata</i>	Hilo holly	ornamental incipient	1	2.3
<i>Arundina graminifolia</i>	bamboo orchid	widespread	28	63.6
<i>Asclepias physocarpa</i>	balloon plant	widespread	22	50.0
<i>Axonopus compressus</i>	broad-leaf carpetgrass	regional	3	6.8
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	17	38.6
<i>Bambusa</i> spp.	unidentified bamboo	ornamental	7	15.9
<i>Bauhinia monandra</i> *	orchid tree	regional	2	4.5
<i>Bryophyllum pinnatum</i>	air plant	widespread	15	34.1
<i>Bryophyllum tubiflorum</i>	chandelier plant	widespread	4	9.1
<i>Buddleja asiatica</i>	Asiatic butterfly bush	widespread	28	63.6
<i>Buddleja davidii</i>	butterfly bush	ornamental	1	2.3
<i>Buddleja madagascariensis</i> *	smoke bush	incipient	2	4.5
<i>Caesalpinia decapetala</i> *	wait-a-bit	regional	4	9.1
<i>Casuarina equisetifolia</i>	ironwood	widespread	3	6.8
<i>Casuarina</i> spp.*	ironwood	incipient	6	13.6
<i>Cecropia obtusifolia</i> *	guarumo, trumpet tree	regional	3	6.8
<i>Cenchrus echinatus</i>	common sandbur	widespread	5	11.4
<i>Citharexylum spinosum</i> *	fiddlewood	incipient	2	4.5
<i>Clusia rosea</i> *	autograph tree	widespread	2	4.5
<i>Crotalaria lanceolata</i>	lance-leaf rattlepod	incipient	1	2.3
<i>Desmodium cajanifolium</i>	tick trefoil	widespread	7	15.9
<i>Desmodium incanum/D. intortum</i>	Spanish clover	regional	10	22.7
<i>Digitaria insularis</i>	sourgrass	incipient	3	6.8
<i>Ehrharta stipoides</i>	meadow ricegrass	widespread	4	9.1
<i>Eragrostis elongata</i>	lovegrass	incipient	1	2.3
<i>Erigeron karvinskianus</i>	daisy fleabane	incipient	3	6.8
<i>Eriobotrya japonica</i>	loquat	incipient	7	15.9

Table 6 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Eucalyptus</i> spp.	eucalyptus	widespread	16	36.4
<i>Euphorbia hyssopifolia</i>	spurge	incipient	1	2.3
<i>Falcataria moluccana</i>	albizia	widespread	4	9.1
<i>Ficus microcarpa</i> *	Chinese banyan	widespread	2	4.5
<i>Flindersia brayleyana</i> *	Queensland maple	regional	1	2.3
<i>Grevillea banksii</i>	kāhili flower	regional	5	11.4
<i>Grevillea robusta</i>	silk oak, silver oak	widespread	23	52.3
<i>Hedychium coronarium</i>	white ginger	widespread	9	20.5
<i>Hedychium flavescens</i>	yellow ginger	widespread	11	25.0
<i>Hedychium gardnerianum</i>	kāhili ginger	widespread	12	27.3
<i>Heliotropium amplexicaule</i>	heliotrope	incipient	2	4.5
<i>Heterotheca grandiflora</i>	telegraph plant	incipient	5	11.4
<i>Holcus lanatus</i>	velvetgrass	widespread	10	22.7
<i>Homolanthus populifolius</i> *	bleeding heart	incipient	1	2.3
<i>Hyparrhenia rufa</i>	thatching grass	regional	17	38.6
<i>Hyptis pectinata</i>	comb hyptis	widespread	26	59.1
<i>Impatiens walleriana</i>	balsam, touch-me-not	regional	6	13.6
<i>Jacaranda mimosifolia</i>	jacaranda	regional	6	13.6
<i>Juncus effusus</i>	Japanese mat rush	widespread	1	2.3
<i>Justicia betonica</i>	white shrimp plant	incipient	3	6.8
<i>Lantana camara</i>	lantana	widespread	19	43.2
<i>Leonotis nepetifolia</i>	lion's ear	incipient	1	2.3
<i>Lepidium africanum</i>	pepperwort	incipient	1	2.3
<i>Leucaena leucocephala</i>	koa haole	widespread	24	54.5
<i>Lonicera japonica</i>	Japanese honeysuckle	incipient	3	6.8
<i>Lophospermum erubescens</i>	large roving sailor	incipient	3	6.8
<i>Macaranga mappa</i> *	bingabing	regional	3	6.8
<i>Macaranga tanarius</i>	no common name	incipient	1	2.3
<i>Macleaya cordata</i> *	plume poppy	regional	3	6.8
<i>Manihot glaziovii</i> *	Ceara rubber tree	regional	1	2.3
<i>Melaleuca quinquenervia</i>	paperbark	regional	8	18.2
<i>Melastoma sanquineum</i> *	fox-tongued melastoma	regional	1	2.3
<i>Melastoma septemnerium</i>	melastoma	regional	3	6.8
<i>Melia azedarach</i>	Chinaberry	widespread	2	4.5
<i>Melinis minutiflora</i>	molasses grass	widespread	44	100.0
<i>Melinis repens</i>	Natal redbtop	widespread	39	88.6
<i>Melochia umbellata</i>	no common name	regional	4	9.1

Table 6 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Merremia tuberosa</i> *	wood rose	regional	2	4.5
<i>Montanoa hibiscifolia</i> *	tree daisy	incipient	5	11.4
<i>Morella faya</i>	firetree, faya	widespread	9	20.5
<i>Murdannia</i> sp.*	no common name	incipient	1	2.3
<i>Neonotonia wightii</i>	glycine	regional	17	38.6
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	41	93.2
<i>Ochna serrulata</i> *	mickey mouse plant	incipient	2	4.5
<i>Olea europaea</i> ssp. <i>cuspidata</i>	African olive	widespread	4	9.1
<i>Olea europaea</i> ssp. <i>europaea</i>	olive	ornamental	1	2.3
<i>Oplismenus hirtellus</i>	basketgrass	regional	1	2.3
<i>Panicum repens</i>	torpedo grass	widespread	7	15.9
<i>Paspalum conjugatum</i>	Hilo grass	widespread	6	13.6
<i>Paspalum dilatatum</i>	Dallis grass	widespread	12	27.3
<i>Paspalum notatum</i>	Bahia grass	incipient	8	18.2
<i>Paspalum paniculatum</i>	no common name	incipient	8	18.2
<i>Paspalum urvillei</i>	Vasey grass	widespread	23	52.3
<i>Passiflora edulis</i>	lilikoi`i, passion fruit	regional	4	9.1
<i>Pennisetum clandestinum</i>	kikuyu grass	widespread	28	63.6
<i>Pennisetum purpureum</i>	elephant grass	widespread	12	27.3
<i>Pennisetum setaceum</i>	fountain grass	widespread	15	34.1
<i>Persicaria capitata</i>	knotweed, smartweed	widespread	30	68.2
<i>Phormium tenax</i>	New Zealand flax	incipient	1	2.3
<i>Pinus patula</i>	Mexican weeping pine	ornamental	1	2.3
<i>Pinus radiata</i>	Monterey pine	ornamental incipient	1	2.3
<i>Pityrogramma calomelanos</i> <i>/P. austroamericana</i>	silver fern, gold fern	widespread	16	36.4
<i>Pluchea carolinensis</i>	sour bush	widespread	41	93.2
<i>Psidium cattleianum</i>	strawberry guava	widespread	17	38.6
<i>Psidium cattleianum</i> var. <i>littorale</i>	strawberry guava	regional	3	6.8
<i>Psidium guajava</i>	common guava	widespread	29	65.9
<i>Pyracantha</i> spp. (incl. <i>P. angustifolia</i> , <i>P.</i> <i>crenatoserrata</i>)	firethorn, 3 species	widespread	7	15.9
<i>Rhynchospora caduca</i>	beak-rush	regional	6	13.6
<i>Ricinus communis</i>	castor bean	widespread	12	27.3
<i>Rubus argutus</i>	blackberry	widespread	9	20.5
<i>Rubus ellipticus</i> var.	yellow Himalayan	regional	7	15.9

Table 6 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>obcordatus</i>	raspberry			
<i>Rubus niveus*</i>	hill raspberry	incipient	1	2.3
<i>Rubus rosifolius</i>	thimbleberry	widespread	5	11.4
<i>Rubus</i> sp.	raspberry	unknown	1	2.3
<i>Samanea saman</i>	monkey pod	regional	1	2.3
<i>Schefflera actinophylla</i>	octopus tree	incipient	6	13.6
<i>Schefflera arboricola*</i>	dwarf octopus tree	incipient	1	2.3
<i>Schinus molle*</i>	pepper tree	regional	4	9.1
<i>Schinus terebinthifolius</i>	Christmas berry	widespread	23	52.3
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	38	86.4
<i>Senecio madagascariensis</i>	fireweed	incipient	6	13.6
<i>Senna occidentalis</i>	coffee senna	widespread	1	2.3
<i>Senna pendula</i>	kolomona, kalamona	widespread	2	4.5
<i>Setaria palmifolia</i>	palmgrass	widespread	7	15.9
<i>Setaria sphacelata</i>	foxtail grass	incipient	2	4.5
<i>Sorghum arundinaceum*</i>	sorghum	incipient	1	2.3
<i>Spathodea campanulata</i>	African tulip tree	regional	2	4.5
<i>Sphagneticola trilobata</i>	wedelia	incipient	4	9.1
<i>Syzygium cumini</i>	Java plum	widespread	3	6.8
<i>Syzygium jambos</i>	rose apple	widespread	3	6.8
<i>Thevetia peruviana*</i>	yellow oleander	ornamental incipient	4	9.1
<i>Thunbergia alata</i>	black-eyed susan	incipient	1	2.3
<i>Thunbergia fragrans*</i>	white thunbergia	widespread	3	6.8
<i>Tibouchina herbacea</i>	glorybush	widespread	2	4.5
<i>Tibouchina urvilleana</i>	glorybush	regional	5	11.4
<i>Tithonia diversifolia*</i>	tree marigold	regional	3	6.8
<i>Toona ciliata*</i>	Australian red cedar	regional	2	4.5
Tree sp. 2, unidentified	unidentified tree	unknown	1	2.3
<i>Trema orientalis</i>	gunpowder tree	widespread	6	13.6
<i>Tropaeolum majus</i>	nasturtium	regional	3	6.8
<i>Urochloa maxima</i>	Guinea grass	widespread	36	81.8
<i>Urochloa mutica</i>	California grass	widespread	9	20.5
<i>Urochloa plantaginea*</i>	no common name	incipient	1	2.3
<i>Verbascum thapsus</i>	common mullein	widespread	1	2.3
<i>Verbascum virgatum</i>	wand mullein	incipient	1	2.3

quinquenervia, a species used for reforestation and ornamental plantings, was widespread but occurred in low numbers along the Puna and Ka`ū buffers and along the highway at Kahuku. *Casuarina equisetifolia* was rare along Highway 11, occurring in only three sites at Kahuku and in the western buffer of the Kīlauea section of HAVO. The ornamental shrub *Ardisia crenata* was

seen only once at Kahuku, and *Phormium tenax* was noted once in the Puna buffer of HAVO, where it was likely a planting.

Twenty-eight species found along Highway 11 in the buffer zones had not yet established within HAVO as of 2005 and may warrant some level of monitoring to prevent their expansion into the park. Among these species are incipient invaders or regional weeds, such as *Buddleja madagascariensis* (smoke bush), the target of eradication efforts elsewhere on the island; *Rubus niveus* (hill raspberry), well known as an invader on Maui and previously reported from the Volcano dump (Nagata 1995), Ka`ū, and South Kona (Gerrish *et al.* 1992); *Macleaya cordata* (plume poppy), a serious weed of dry forests on Maui that is well established in Ka`ū District (Benitez and Saulibio 2007); *Citharexylum spinosum* (fiddlewood), a tree only recently recognized as naturalized (Herbarium Pacificum Staff 1998); and *Macaranga mappia* (bingabing). *Macaranga tanarius* was also found only in the buffer zone during the roadside survey, but it was recently documented at a quarry within HAVO (Benitez *et al.* 2012). Other widespread or regional invasive species that have not yet established within HAVO but were found along Highway 11 were the trees *Bauhinia monandra* (orchid tree), *Cecropia obtusifolia* (trumpet tree), and *Clusea rosea* (autograph tree), the spiny climber *Caesalpinia decapelata* (wait-a-bit), and the flowering shrubs *Tithonia diversifolia* (tree marigold) and *Montanoa hibiscifolia* (tree daisy).

Eight additions to the flora of HAVO were noted along Highway 11 inside the park boundaries: the invasive *Senecio madagascariensis* (fireweed), a noxious pest of ranchlands; two pasture grasses, *Paspalum notatum* (Bahia grass) and *P. paniculatum*; a foxtail grass only recently recognized as naturalized on the island, *Setaria sphacelata* (Herbst *et al.* 2004); the naturalized ornamental herb *Leonotis nepetifolia* (lion's ear); and three small herbaceous plants, *Euphorbia hyssopifolia*, *Heliotropium amplexicaule*, and *Lepidium africanum*. An additional species not previously known from HAVO, the rush *Juncus acuminatus*, was found within the park boundary near the eastern HAVO entrance (mile 28 of Highway 11), but was excluded from the data set because it was not a consistent target species on other park roads.

Wright Road

A relatively short road of 5 miles (8 km), Wright Road joins Highway 11 east of HAVO and passes through part of Volcano Village, beyond which the road separates the park's `Ōla`a Large Tract from the Small Tract. These disjunct park units provide habitat for a number of rare and endangered plant species, as well as recent re-introduction plantings. The two tracts are considered SEAs and are intensively managed to reduce and control alien plants. The vegetation along Wright Road is mostly closed wet montane forest of *Metrosideros polymorpha* and *Cibotium glaucum*, but much of the forest has been developed for house lots and farms, and some of the area has been converted to pasture with scattered trees. Almost one-third (71) of the survey's target alien plants were observed along Wright Road, and the mean number of species per mile was 35.6, much higher than that of any other road within the park or of Highway 11 (Tables 1 and 7).

The alien grass species that were nearly ubiquitous along other park roads were somewhat less frequent along Wright Road with only *Axonopus fissifolius*, *Paspalum urvillei*, and *Pennisetum clandestinum* achieving 100% frequency (Table 7). Several serious invaders of wet forest were found on most segments of Wright Road, including *Rubus ellipticus* (yellow Himalayan raspberry) and *Hedychium gardnerianum* (kāhili ginger) with 100% frequency, *Psidium cattleianum* along 80% of the road, and *Setaria palmifolia* (palmgrass) with 60% frequency.

Table 7. Frequency of target alien plant species along Wright Road (five intervals).

Scientific name	Common name	Category	# Intervals occupied	Frequency (%)
<i>Agave americana</i>	century plant	ornamental	1	20.0
<i>Ageratina riparia</i>	spreading mist flower	widespread	1	20.0
<i>Andropogon virginicus</i>	broomsedge	widespread	3	60.0
<i>Anemone hupehensis</i> var. <i>japonica</i>	Japanese anemone	widespread	2	40.0
<i>Arundina graminifolia</i>	bamboo orchid	widespread	5	100.0
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	5	100.0
<i>Bambusa</i> spp.	unidentified bamboo	ornamental	3	60.0
<i>Blechnum appendiculatum</i>	no common name	regional	1	20.0
<i>Buddleja asiatica</i>	Asiatic butterfly bush	widespread	5	100.0
<i>Buddleja davidii</i>	butterfly bush	ornamental	2	40.0
<i>Calotropis gigantea</i> /C. <i>procera</i>	crownflower	incipient	1	20.0
<i>Casuarina equisetifolia</i>	ironwood	widespread	1	20.0
<i>Cestrum nocturnum</i>	night cestrum	incipient	1	20.0
<i>Cortaderia</i> sp.	Pampas grass	ornamental	2	40.0
<i>Desmodium incanum</i> /D. <i>intortum</i>	Spanish clover	regional	1	20.0
<i>Dicksonia</i> sp.	New Zealand tree fern	ornamental	1	20.0
<i>Ehrharta stipoides</i>	meadow ricegrass	widespread	2	40.0
<i>Epidendrum x obrienianum</i>	butterfly orchid	incipient	1	20.0
<i>Erigeron karvinskianus</i>	daisy fleabane	incipient	1	20.0
<i>Eriobotrya japonica</i>	loquat	incipient	1	20.0
<i>Eucalyptus</i> spp.	eucalyptus	widespread	2	40.0
<i>Grevillea robusta</i>	silk oak, silver oak	widespread	1	20.0
<i>Hedera helix</i>	English ivy	widespread	4	80.0
<i>Hedychium coronarium</i>	white ginger	widespread	5	100.0
<i>Hedychium flavescens</i>	yellow ginger	widespread	2	40.0
<i>Hedychium gardnerianum</i>	kāhili ginger	widespread	5	100.0
<i>Hedychium greenei</i>	red-flowered ginger	ornamental	3	60.0
<i>Heterocentron subtriplinervium</i>	pearl flower	regional	2	40.0
<i>Holcus lanatus</i>	velvetgrass	widespread	4	80.0
<i>Hypericum kouytchense</i>	St. John's wort	incipient	2	40.0
<i>Ilex aquifolium</i>	English holly	ornamental incipient	1	20.0
<i>Impatiens walleriana</i>	balsam, touch-me-not	regional	5	100.0
<i>Leptospermum scoparium</i>	manukā, tea tree	ornamental incipient	1	20.0
<i>Ligustrum sinense</i>	Chinese privet	incipient	1	20.0

Table 7 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Lonicera japonica</i>	Japanese honeysuckle	incipient	3	60.0
<i>Melaleuca quinquenervia</i>	paperbark	regional	4	80.0
<i>Melinis minutiflora</i>	molasses grass	widespread	3	60.0
<i>Monstera deliciosa</i>	monstera	ornamental	3	60.0
<i>Morella faya</i>	firetree, faya	widespread	3	60.0
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	2	40.0
<i>Panicum repens</i>	torpedo grass	widespread	4	80.0
<i>Paspalum conjugatum</i>	Hilo grass	widespread	1	20.0
<i>Paspalum urvillei</i>	Vasey grass	widespread	5	100.0
<i>Paspalum</i> sp. 6	unidentified <i>Paspalum</i>	incipient	1	20.0
<i>Paspalum</i> sp. 8	unidentified <i>Paspalum</i>	incipient	1	20.0
<i>Passiflora ligularis</i>	sweet granadilla	regional	2	40.0
<i>Passiflora tarminiana</i>	banana poka	widespread	2	40.0
<i>Pennisetum clandestinum</i>	kikuyu grass	widespread	5	100.0
<i>Pennisetum purpureum</i>	elephant grass	widespread	1	20.0
<i>Persicaria capitata</i>	knotweed, smartweed	widespread	5	100.0
<i>Phormium tenax</i>	New Zealand flax	incipient	2	40.0
<i>Pinus</i> sp.	unidentified pine	unknown	3	60.0
<i>Pluchea carolinensis</i>	sour bush	widespread	4	80.0
<i>Psidium cattleianum</i>	strawberry guava, waiawi	widespread	4	80.0
<i>Pyracantha</i> spp.	firethorn, 3 species	widespread	4	80.0
<i>Rhynchospora caduca</i>	beak-rush	regional	2	40.0
<i>Rubus argutus</i>	blackberry	widespread	5	100.0
<i>Rubus ellipticus</i> var. <i>obcordatus</i>	yellow Himalayan raspberry	regional	5	100.0
<i>Rubus glaucus</i>	no common name	incipient	1	20.0
<i>Sambucus mexicana</i>	elderberry	incipient	3	60.0
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	3	60.0
<i>Setaria palmifolia</i>	palmgrass	widespread	3	60.0
<i>Sphaeropteris cooperi</i>	Cooper's tree fern	incipient	1	20.0
<i>Syzygium jambos</i>	rose apple	widespread	1	20.0
<i>Thunbergia alata</i>	black-eyed susan vine	incipient	3	60.0
<i>Tibouchina granulosa</i>	no common name	ornamental	1	20.0
<i>Tibouchina herbacea</i>	glorybush	widespread	2	40.0
<i>Tibouchina urvilleana</i>	glorybush	regional	2	40.0
<i>Toona ciliata</i>	Australian red cedar	regional	1	20.0
<i>Tropaeolum majus</i>	nasturtium	regional	4	80.0
<i>Urochloa mutica</i>	California grass	widespread	1	20.0

Other threatening invasive species along the road were *Morella faya* with 60% frequency and *Anemone huphensis* var. *japonica* (Japanese anemone), *Hedychium coronarium* (white ginger), *Passiflora tarminiana* (banana poka), *P. ligularis* (sweet granadilla), and two species of *Tibouchina* or glorybush (*T. urvilleana* and *T. herbacea*) all with 40% frequency. Eight of these ecosystem-altering alien species are currently treated within managed fenced units within the adjacent `Ōla`a Tract. Several escaped ornamental plants were seen along Wright Road that did not occur elsewhere along internal park roads; at least three of these, *Sphaeropteris cooperi* (Cooper's or Australian tree fern), *Ligustrum sinense* (Chinese privet), and *Cestrum nocturnum* (night cestrum) have already been collected within the park's `Ōla`a Forest and are clearly capable of invading wet native forests of HAVO (Benitez *et al.* 2012). The herbaceous *Persicaria capitata*, originally introduced as an ornamental (Staples and Herbst 2005), was ubiquitous along Wright Road, from which it has been observed invading `Ōla`a Large Tract. This knotweed is known to be capable of establishing in deep shade, and shady invaded sites within `Ōla`a Forest have been periodically controlled with herbicide (Benitez *et al.* 2012).

Other ornamental plants seen on Wright Road have been noted as invasive elsewhere on the island but have not yet been found naturalized within HAVO, including *Calotropis* sp. (crownflower), *Cortaderia* sp. (Pampas grass), *Hypericum kouytchense* (St. John's wort), *Ilex aquifolium* (English holly), and *Leptospermum scoparium* (manukā). *Cortaderia* is invasive on Maui (Starr *et al.* in prep.), and *Ilex aquifolium* is an incipient invader at Hakalau Refuge on Mauna Kea (Stone *et al.* 1991). Three apparently cultivated plants along Wright Road are naturalized in HAVO, but not currently known from `Ōla`a Forest: *Syzygium jambos* (rose apple), *Thunbergia alata* (black-eyed susan vine), and *Tropaeolum majus* (nasturtium). It is uncertain whether these ornamental weeds are capable of invading undisturbed rain forest, although *Tropaeolum* is a persistent problem in the mesic forests of the nearby Mauna Loa Strip, and has been previously found and treated in `Ōla`a Forest.

Several cultivated ornamentals that did not seem to be naturalized were seen along Wright Road: *Hedychium greenii* (red-flowered ginger), *Dicksonia* sp. (New Zealand tree fern), and *Tibouchina granulosa* (melastome with no common name). Because these ornamentals are congeneric with recognized invasive species, they may warrant some level of monitoring to determine whether they will escape cultivation. It is uncertain whether the *Dicksonia* tree fern found during the survey is the ornamental *D. squarrosa* or *D. fibrosa*; the latter species has been noted as naturalized on Hawai`i Island (Lorence and Flynn 2006) and has been reported from Volcano Village (D. Benitez, pers. comm.). No new records for the park were found along the short stretch of Wright Road adjacent to `Ōla`a Forest.

Highway 130

While not adjacent to HAVO, Highway 130 between Pāhoa and Kalapana runs roughly parallel to the park's East Rift section, approximately 6 miles (10 km) to the east at the nearest point (Figure 3). The 10-mile (16-km) stretch from the junction of Highway 130 with the Kapoho Road to the coast was surveyed in 2005. This road passes through highly variable vegetation ranging from 50-year-old lava flows with scattered *Metrosideros* trees to highly developed areas near the subdivisions of Leilani Estates and Kēōkea. Some lowland forest persists along the road at Keauohana Forest Reserve. A total of 105 target alien plant species was encountered along Highway 130, and the mean number of species per mile was 48, much higher than the average for any of the park's interior roads and higher even than that of Wright Road adjacent to HAVO (Table 1).

Species that were observed in every mile increment of Highway 130 included a suite of alien grasses (*Andropogon virginicus*, *Axonopus fissifolius*, *Melinis minutiflora*, *M. repens*, *Schizachyrium condensatum*), a group of widespread introduced shrub and tree species (*Hyptis pectinata*, *Buddleja asiatica*, *Melochia umbellata*, *Psidium guajava*, *P. cattleianum*, *Trema orientalis*), the bamboo orchid *Arundina graminifolia*, the Asian swordfern *Nephrolepis brownii*, and the weedy vine *Paederia foetida* (Table 8). Weedy melastomes were well represented along Highway 130, including the highly invasive *Miconia calvescens* (velvet tree) and *Clidemia hirta* (clidemia), two species that have been the subject of biocontrol research. *Miconia* has not yet been observed in HAVO, and *Clidemia* has recently been found in the park but has been managed to eradicate the incipient HAVO populations (Benitez *et al.* 2012). Other incipient invaders in the Melastome Family were also seen along Highway 130, such as *Arthrostemma ciliatum*, *Dissotis rotundifolia*, and *Tibouchina longifolia*; none has yet been detected within HAVO. This highway was the only road surveyed that supported the highly invasive king fern, *Angiopteris evecta*.

Other species that were found along most of Highway 130 but have not yet established in the park were the trees *Albizia chinensis* (Chinese albizia) and *Schefflera actinophylla* (octopus tree) and the tall Lyon's grass *Themeda villosa*. A few ornamentals were seen along the highway in apparently non-cultivated situations and may represent incipient naturalizations: *Alpinia* sp. (shell ginger), *Allamanda schottii* (dwarf allamanda), and *Cestrum aurantiacum* (orange cestrum). The large number of invasive species found along Highway 130 made this nearby road a potential source of plants new to the park. A large expanse of recent lava separates the Highway 130 area from the forests and other natural vegetation of HAVO and may act as a barrier to invasion. However, the area surveyed on Highway 130 is upwind of the park, and the prevailing northeast tradewinds may blow propagules in the park's direction. Also, the forests and lava fields along the eastern boundary of HAVO are remote, difficult to access, and are under-represented in park weed surveys (D. Benitez, pers. comm.).

Upper Stainback Highway

The upper reach of Stainback Highway was surveyed between the junction of North Kūlani Road and the boundary with Kūlani Project (Figure 3) because this road lies within 3 miles (5 km) of HAVO's `Ōla`a Forest and provides a possible route for alien plants from low-elevation disturbed areas to access the upper-elevation native forest. A total of 40 target alien plant species was found along the entire 10 miles (16 km) of surveyed road, and the mean number of target species per mile was 22.8 (Table 1). Most of the upper Stainback Highway traverses montane forest of *Metrosideros* and mixed alien species, but some forestry planting areas of *Eucalyptus* and other timber trees were found in the survey area. The lower Stainback near Hilo passes through disturbed lowland forest and developed areas near the county zoo and residences.

The same suite of grasses that was found on most park roads also had high frequency on Stainback Highway, with the addition of wet-adapted grasses such as *Panicum repens* (torpedo grass) and *Paspalum urvillei* (Vasey grass). Yellow ginger, *Hedychium flavescens*, and the knotweed *Persicaria capitata* were ubiquitous along the highway, and *Psidium cattleianum* occurred along 80% of the road segments (Table 9). Several invasive species that are problems in managed units of `Ōla`a were found with high frequency along Stainback Highway, including *Anemone hupehensis* (60%), *Setaria palmifolia* (palmgrass, 70%), and the melastome *Tibouchina herbacea* (80%). The invasive melastome *Clidemia hirta* was found along 40% of the highway segments (particularly in the lower-elevation section of the 10-mile stretch), and

Table 8. Frequency of target alien plant species along Highway 130 (10 intervals).

Scientific name	Common name	Category	# Intervals occupied	Frequency (%)
<i>Acacia confusa</i>	Formosa koa	widespread	2	20.0
<i>Agave americana</i>	century plant	ornamental	1	10.0
<i>Agave sisalana</i>	sisal	widespread	1	10.0
<i>Ageratina riparia</i>	spreading mist flower	widespread	2	20.0
<i>Albizia chinensis</i>	Chinese albizia	regional	7	70.0
<i>Allamanda cathartica</i>	allamanda	ornamental	3	30.0
<i>Allamanda schottii</i>	dwarf allamanda	ornamental	1	10.0
<i>Alpinia</i> sp.	shell ginger	ornamental	1	10.0
<i>Andropogon virginicus</i>	broomsedge	widespread	10	100.0
<i>Angiopteris evecta</i>	king fern	incipient	1	10.0
<i>Archontophoenix alexandrae</i>	Alexandra palm	regional	3	30.0
<i>Arthrostemma ciliatum</i>	no common name	incipient	3	30.0
<i>Arundina graminifolia</i>	bamboo orchid	widespread	10	100.0
<i>Asclepias curassavicum</i>	butterfly weed	widespread	2	20.0
<i>Axonopus compressus</i>	broad-leaf carpetgrass	regional	7	70.0
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	10	100.0
<i>Bambusa</i> spp.	unidentified bamboos	ornamental	2	20.0
<i>Bambusa vulgaris</i>	common bamboo	ornamental	2	20.0
<i>Bauhinia monandra</i>	orchid tree	regional	1	10.0
<i>Begonia hirtella</i>	begonia	regional	9	90.0
<i>Bryophyllum pinnatum</i>	air plant	widespread	1	10.0
<i>Buddleja asiatica</i>	Asiatic butterfly bush	widespread	10	100.0
<i>Casuarina equisetifolia</i>	ironwood	widespread	5	50.0
<i>Cecropia obtusifolia</i>	trumpet tree	regional	7	70.0
<i>Cestrum aurantiacum</i>	orange cestrum	ornamental incipient	1	10.0
<i>Citharexylum spinosum</i>	fiddlewood	incipient	1	10.0
<i>Clidemia hirta</i>	Koster's curse	widespread	6	60.0
<i>Clusia rosea</i>	autograph tree	widespread	5	50.0
<i>Coffea arabica</i>	Arabian coffee	ornamental	2	20.0
<i>Crotalaria lanceolata</i>	lance-leaf rattlepod	incipient	2	20.0
<i>Desmodium cajanifolium</i>	tick trefoil	widespread	8	80.0
<i>Desmodium incanum/D. intortum</i>	Spanish clover	regional	3	30.0
<i>Digitaria insularis</i>	sourgrass	incipient	4	40.0
<i>Dissotis rotundifolia</i>	no common name	ornamental incipient	6	60.0
<i>Epidendrum x obrienianum</i>	butterfly orchid	incipient	1	10.0
<i>Eragrostis elongata</i>	lovegrass	incipient	1	10.0
<i>Eriobotrya japonica</i>	loquat	incipient	1	10.0

Table 8 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Eucalyptus robusta</i>	swamp mahogany	widespread	2	20.0
<i>Falcataria moluccana</i>	albizia	widespread	8	80.0
<i>Ficus elastica</i>	rubber tree	ornamental	1	10.0
<i>Ficus microcarpa</i>	Chinese banyan	widespread	4	40.0
<i>Flindersia brayleyana</i>	Queensland maple	regional	3	30.0
<i>Grevillea robusta</i>	silk oak, silver oak	widespread	1	10.0
<i>Hedychium coronarium</i>	white ginger	widespread	4	40.0
<i>Hedychium flavescens</i>	yellow ginger	widespread	6	60.0
<i>Heliocarpus popayanensis</i>	white moho	regional	1	10.0
<i>Heterocentron subtriplinervium</i>	pearl flower	regional	2	20.0
<i>Hippobroma longiflora</i>	star of Bethlehem	regional	3	30.0
<i>Hyptis pectinata</i>	comb hyptis	widespread	10	100.0
<i>Impatiens walleriana</i>	balsam, touch-me-not	regional	6	60.0
<i>Jacaranda mimosifolia</i>	jacaranda	regional	1	10.0
<i>Lantana camara</i>	lantana	widespread	6	60.0
<i>Leucaena leucocephala</i>	koa haole	widespread	2	20.0
<i>Macaranga mappa</i>	bingabing	regional	1	10.0
<i>Macaranga tanarius</i>	no common name	incipient	4	40.0
<i>Manihot glaziovii</i>	Ceara rubber tree	regional	1	10.0
<i>Melastoma sanguineum</i>	fox-tongued melastoma	regional	3	30.0
<i>Melastoma septemnerivium</i>	melastoma	regional	8	80.0
<i>Melia azedarach</i>	Chinaberry	widespread	1	10.0
<i>Melinis minutiflora</i>	molasses grass	widespread	10	100.0
<i>Melinis repens</i>	Natal redtop	widespread	10	100.0
<i>Melochia umbellata</i>	no common name	regional	10	100.0
<i>Miconia calvescens</i>	velvet tree	widespread	1	10.0
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	10	100.0
<i>Oplismenus hirtellus</i>	basketgrass	regional	7	70.0
<i>Paederia foetida</i>	maile pilau	regional	10	100.0
<i>Panicum repens</i>	torpedo grass	widespread	2	20.0
<i>Paspalum conjugatum</i>	Hilo grass	widespread	8	80.0
<i>Paspalum paniculatum</i>	No common name	incipient	8	80.0
<i>Paspalum urvillei</i>	Vasey grass	widespread	9	90.0
<i>Passiflora edulis</i>	liliko`i, passion fruit	regional	5	50.0
<i>Passiflora foetida</i>	love-in-a-mist	widespread	3	30.0
<i>Pennisetum purpureum</i>	elephant grass	widespread	6	60.0
<i>Persicaria capitata</i>	knotweed, smartweed	widespread	5	50.0
<i>Phyllostachys nigra</i>	black bamboo	regional	4	40.0
<i>Pityrogramma calomelanos/P. austroamericana</i>	silver fern, gold fern	widespread	4	40.0
<i>Pluchea carolinensis</i>	sour bush	widespread	9	90.0

Table 8 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Psidium cattleianum</i>	strawberry guava, waiawi	widespread	10	100.0
<i>Psidium guajava</i>	common guava	widespread	10	100.0
<i>Pterolepis glomerata</i>	no common name	regional	2	20.0
<i>Rhynchospora caduca</i>	beak-rush	regional	2	20.0
<i>Ricinus communis</i>	castor bean	widespread	3	30.0
<i>Rubus ellipticus</i> var. <i>obcordatus</i>	yellow Himalayan raspberry	regional	1	10.0
<i>Rubus rosifolius</i>	thimbleberry	widespread	9	90.0
<i>Schefflera actinophylla</i>	octopus tree	incipient	7	70.0
<i>Schinus terebinthifolius</i>	Christmas berry	widespread	5	50.0
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	10	100.0
<i>Senna occidentalis</i>	coffee senna	widespread	7	70.0
<i>Setaria palmifolia</i>	palmgrass	widespread	4	40.0
<i>Sorghum arundinaceum</i>	sorghum	incipient	2	20.0
<i>Spathodea campanulata</i>	African tulip tree	regional	4	40.0
<i>Sphagneticola trilobata</i>	wedelia	incipient	6	60.0
<i>Syzygium cumini</i>	Java plum	widespread	6	60.0
<i>Syzygium jambos</i>	rose apple	widespread	4	40.0
<i>Terminalia catappa</i>	tropical almond	regional	1	10.0
<i>Themeda villosa</i>	Lyon's grass	incipient	5	50.0
<i>Thunbergia fragrans</i>	white thunbergia	widespread	6	60.0
<i>Tibouchina herbacea</i>	glorybush	widespread	6	60.0
<i>Tibouchina longifolia</i>	no common name	regional	1	10.0
<i>Trema orientalis</i>	gunpowder tree	widespread	10	100.0
<i>Urochloa maxima</i>	Guinea grass	Widespread	9	90.00
<i>Urochloa mutica</i>	California grass	widespread	5	50.0
<i>Urochloa</i> sp.	unidentified <i>Urochloa</i>	incipient	2	20.0
Vine, unidentified	unidentified vine	unknown	1	10.0
<i>Wisteria</i> sp.	wisteria	ornamental	1	10.0

Table 9. Frequency of target alien plant species along upper Stainback Highway (10 intervals).

Scientific name	Common name	Category	# Intervals	Frequency
			occupied	(%)
<i>Acacia confusa</i>	Formosa koa	widespread	1	10.0
<i>Ageratina riparia</i>	spreading mist flower	widespread	9	90.0
<i>Andropogon virginicus</i>	broomsedge	widespread	10	100.0
<i>Anemone hupehensis</i> var. <i>japonica</i>	Japanese anemone	widespread	6	60.0
<i>Angiopteris evecta</i>	king fern	incipient	1	10.0
<i>Arundina graminifolia</i>	bamboo orchid	widespread	10	100.0

Table 9 continued			# Intervals	Frequency
Scientific name	Common name	Category	occupied	(%)
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	widespread	10	100.0
<i>Buddleja asiatica</i>	Asiatic butterfly bush	widespread	9	90.0
<i>Clidemia hirta</i>	Koster's curse	widespread	4	40.0
<i>Eragrostis elongata</i>	lovegrass	incipient	1	10.0
<i>Eucalyptus robusta</i>	swamp mahogany	widespread	2	20.0
<i>Eucalyptus</i> spp.	eucalyptus	widespread	4	40.0
<i>Fraxinus uhdei</i>	tropical ash	widespread	8	80.0
<i>Fuchsia magellanica</i>	fuchsia	ornamental	8	80.0
<i>Hedychium coronarium</i>	white ginger	widespread	2	20.0
<i>Hedychium flavescens</i>	yellow ginger	widespread	10	100.0
<i>Heterocentron subtriplinervium</i>	pearl flower	regional	2	20.0
<i>Holcus lanatus</i>	velvetgrass	widespread	7	70.0
<i>Melastoma septemnerium</i>	melastoma	regional	2	20.0
<i>Melinis minutiflora</i>	molasses grass	widespread	10	100.0
<i>Nephrolepis brownii</i>	Asian swordfern	widespread	4	40.0
<i>Panicum repens</i>	torpedo grass	widespread	10	100.0
<i>Paspalum conjugatum</i>	Hilo grass	widespread	3	30.0
<i>Paspalum urvillei</i>	Vasey grass	widespread	10	100.0
<i>Pennisetum clandestinum</i>	kikuyu grass	widespread	6	60.0
<i>Pennisetum purpureum</i>	elephant grass	widespread	1	10.0
<i>Persicaria capitata</i>	knotweed	widespread	10	100.0
<i>Pityrogramma calomelanos</i> <i>/P. austroamericana</i>	silver fern, gold fern	widespread	1	10.0
<i>Pluchea carolinensis</i>	sour bush	widespread	7	70.0
<i>Psidium cattleianum</i>	strawberry guava, waiawi	widespread	8	80.0
<i>Psidium guajava</i>	common guava	widespread	4	40.0
<i>Pterolepis glomerata</i>	no common name	regional	4	40.0
<i>Pyracantha</i> spp.	firethorn, 3 species	widespread	1	10.0
<i>Rhynchospora caduca</i>	beak-rush	regional	9	90.0
<i>Rubus ellipticus</i> var. <i>obcordatus</i>	yellow Himalayan raspberry	regional	3	30.0
<i>Rubus rosifolius</i>	thimbleberry	widespread	5	50.0
<i>Schizachyrium condensatum</i>	bush beardgrass	widespread	10	100.0
<i>Setaria palmifolia</i>	palmgrass	widespread	7	70.0
<i>Tibouchina herbacea</i>	glorybush	widespread	8	80.0
<i>Toona ciliata</i>	Australian red cedar	regional	1	10.0

the incipient invader *Angiopteris evecta*, a giant fern, was found at one site. Apart from this fern, the only target species seen along Stainback Highway that does not already occur within

HAVO was *Toona ciliata* (Australian red cedar), a forestry planting. Other uncommon alien species, such as the trees *Tetrazygia bicolor* (a melastome) and *Morella cerifera* (bayberry) and the Japanese climbing fern *Lygodium japonicum*, were seen along lower Stainback, but were not present along the surveyed upper stretch of road nearest HAVO. These three species are of concern because *Tetrazygia bicolor* is a member of the highly invasive Melastome Family. *Morella cerifera* is an eradication target for BIISC, and the fern *Lygodium japonicum* is recognized as an invasive weed on the mainland and appears to be expanding its range on Hawai`i Island (Palmer 2003).

Alien Plants in Residential Subdivisions Adjacent to HAVO

In a survey of the roadsides of the three subdivisions nearest HAVO, 65 of the target alien plant species were encountered, including several unidentified ornamental species and species encountered only in the residential areas. Of the three subdivisions, Mauna Loa Estates, east of HAVO on the south side of Highway 11, had the highest mean number of target alien plant species (14.9/interval) along its 16 roads. The Volcano Village east of the park and north of Highway 11, had a mean of 11.3 target alien plant species on 22 roads and 0.5 mile (0.8 km) segments of roads. The Golf Course subdivision north of Kīlauea Caldera and just east of the Mauna Loa Strip had the lowest mean number of target species of the residential areas, at 9.2/interval for its 20 short cul-de-sac roads and 0.5 mile (0.8 km) segments. (All Golf Course road segments were 0.5 mile long or shorter).

Mauna Loa Estates (MLE) roads cut through an area originally covered with montane wet *Metrosideros polymorpha* forest, and much of the forest remains because not all of the relatively large (0.5 acre or 0.2 ha) lots have been developed. This subdivision had very high frequencies of some of the worst invaders of rain forest in the park. *Hedychium gardnerianum*, a highly invasive ginger species, and the woody invaders *Morella faya*, *Psidium cattleianum*, and *Rubus ellipticus* each had 90–100% frequency of occurrence along roads in Mauna Loa Estates (Table 10). The shrubby glorybush *Tibouchina herbacea* was present along 81.3% of road increments, and the ornamental, purple-flowered *Tibouchina urvilleana* had a frequency of 75%. *Rubus argutus*, a shrub more invasive at higher elevations, was seen on 93.8% of the Mauna Loa Estates roads, and *Tropaeolum majus* (nasturtium), a vine that has been a persistent weed of mesic forests, was found on 31% of the surveyed roads.

Several species that have been documented from the park but have not yet established large populations in natural areas there were found to occur with relatively high frequencies in Mauna Loa Estates. *Cestrum nocturnum*, a shrub which is known to invade wet to mesic forests in Ka`ū and forms dense thickets under native tree canopy, occurred along 56.3% of road segments, and *Schefflera arboricola* (dwarf octopus tree), recently recognized as a naturalized species (Starr *et al.* 2003), was observed on 25% of roadsides. Ornamental species that have been previously controlled or eradicated from the park (Benitez *et al.* 2012) but were found in Mauna Loa Estates include *Ardisia crenata* (Hilo holly, 6.3% frequency), a shrub with red bird-dispersed berries, and *Phormium tenax* (New Zealand flax, 25% frequency), a large herb with showy orange flowers. Ornamental species seen at single sites that may have the ability to spread included *Equisetum* sp. (scouring rush), *Cestrum diurnum* (day cestrum), *Fuchsia paniculata*, and *Homalanthus populifolius* (bleeding heart); the latter species was recently noted as naturalized in Ka`ū District (Oppenheimer 2004). Mauna Loa Estates is less than a mile (1.5 km) east of the park's Thurston Special Ecological Area, a managed rain forest in which most invasive plants are controlled.

Table 10. Target alien plant species along roads in three residential subdivisions adjacent to HAVO (0.5–1 mile intervals).

Scientific name	Common name	MLE ¹ frequency (%)	Village ² frequency (%)	VGC ³ frequency (%)
<i>Acacia confusa</i>	Formosa koa		4.5	10.0
<i>Agave americana</i>	century plant	25.0		15.0
<i>Agave sisalana</i>	sisal		4.5	5.0
<i>Anemone hupehensis</i> var. <i>japonica</i>	Japanese anemone	43.8	4.5	
<i>Ardisia crenata</i>	Hilo holly	6.3	4.5	
<i>Bauhinia monandra</i> *	orchid tree		4.5	
<i>Bignoniaceae</i> unknown*	unknown vine			5.0
<i>Buddleja davidii</i>	butterfly bush		4.5	10.0
<i>Buddleja madagascariensis</i> *	smoke bush		13.6	
<i>Casuarina equisetifolia</i>	ironwood	6.3	9.1	5.0
<i>Cestrum diurnum</i> *	day cestrum	6.3		
<i>Cestrum nocturnum</i>	night cestrum	56.3	22.7	
<i>Cortaderia</i> sp.*	Pampas grass		4.5	5.0
<i>Cotoneaster pannosa</i>	cotoneaster			15.0
<i>Desmodium incanum</i>	Spanish clover	6.3	9.1	15.0
<i>Dicksonia</i> sp.*	New Zealand tree fern	6.3	13.6	
<i>Elaeagnus</i> sp.	oleaster		22.7	
<i>Epidendrum x obrienianum</i>	butterfly orchid		27.3	25.0
<i>Equisetum</i> sp.*	scouring rush	6.3		
<i>Erigeron karvinskianus</i>	daisy fleabane		4.5	
<i>Falcataria moluccana</i>	albizia			5.0
<i>Ficus elastica</i> *	rubber tree		9.1	
<i>Ficus microcarpa</i> *	Chinese banyan	6.3		
<i>Fraxinus uhdei</i>	tropical ash		4.5	
<i>Fuchsia paniculata</i>	fuchsia	6.3	18.2	5.0
<i>Grevillea robusta</i>	silk oak	6.3	18.2	5.0
<i>Hebe speciosa</i>	hebe	12.5	9.1	
<i>Hedychium greenei</i> *	red-flowered ginger	93.8	63.6	20.0
<i>Hedychium gardnerianum</i>	kāhili ginger	100.0	100.0	95.0
<i>Hedera helix</i>	English ivy	43.8	63.6	
<i>Homalanthus populifolius</i> *	bleeding heart	6.3		
<i>Ipomoea</i> sp.*	morning glory	6.3		
<i>Jacaranda mimosifolia</i>	jacaranda	6.3		15.0
<i>Lantana camara</i>	lantana		4.5	
<i>Leptospermum scoparium</i> *	manukā, tea tree	6.3	4.5	25.0
<i>Ligustrum sinense</i>	Chinese privet	12.5	40.9	
<i>Luculia gratissimum</i>	luculia		4.5	
<i>Melaleuca quinquenervia</i>	paperbark	37.5	18.2	15.0
<i>Melastoma septemnerium</i>	melastoma	31.3		
<i>Metrosideros excelsa</i> *	pohutukawa			10.0
<i>Morella faya</i>	firetree, faya	93.8	86.4	100.0
<i>Olea europaea</i> ssp. <i>cuspidata</i>	African olive	12.5	9.1	25.0

Table 10 continued		MLE ¹	Village ²	VGC ³
Scientific name	Common name	frequency (%)	frequency (%)	frequency (%)
<i>Paederia foetida</i>	maile pilau		4.5	
<i>Persicaria capitata</i>	knotweed	100.0	77.3	95.0
<i>Photinia davidiana</i> *	photinia		4.5	
<i>Phormium tenax</i>	New Zealand flax	25.0	36.4	30.0
<i>Pinus radiata</i>	Monterey pine			5.0
<i>Psidium cattleianum</i>	strawberry guava	87.5	90.9	30.0
<i>Psidium guajava</i>	common guava	6.3		
<i>Pyracantha</i> spp.	firethorn	6.3	45.5	55.0
<i>Rhodomyrtus tomentosa</i> *	downy myrtle		4.5	
<i>Rubus argutus</i>	blackberry	93.8	40.9	100.0
<i>Rubus ellipticus</i> var. <i>obcordatus</i>	yellow Himalayan raspberry	100.0	63.6	70.0
<i>Schefflera actinophylla</i>	octopus tree	12.5		
<i>Schefflera arboricola</i> **	dwarf octopus tree	25.0		
<i>Schinus molle</i> **	pepper tree			10.0
<i>Setaria palmifolia</i>	palmgrass	37.5	18.2	10.0
<i>Sphaeropteris cooperi</i>	Cooper's tree fern			10.0
<i>Sphagnetocola trilobata</i>	wedelia	12.5		
<i>Thunbergia alata</i>	black-eyed susan	12.5	18.2	25.0
<i>Tibouchina granulosa</i> *	no common name		9.1	
<i>Tibouchina herbacea</i>	glorybush	81.3		
<i>Tibouchina urvillei</i>	glorybush	75.0	86.4	
<i>Trema orientalis</i>	gunpowder tree	6.3		
<i>Tropaeolum majus</i>	nasturtium	31.3	18.2	25.0

¹ Mauna Loa Estates, 16 roads with 0.75–1 mile (1.2–1.6 km) intervals

² Volcano Village, 22 roads or intervals of 0.5 mile (0.8 km)

³ Volcano Golf Course, 20 roads or intervals of 0.5 mile (0.8 km)

* Species not known from HAVO in 2001–2005

** Species collected in HAVO subsequent to roadside survey

Volcano Village has been a residential area for more than 100 years (Warshauer 2001) and, like Mauna Loa Estates, is located in a montane wet forest of *Metrosideros polymorpha* and *Cibotium glaucum*. As was seen in the neighboring subdivision, several highly invasive species of wet forests were noted with high frequencies (86–100%) along roads in Volcano Village, including *Hedychium gardnerianum*, *Morella faya*, *Psidium cattleianum*, and *Tibouchina urvilleana* (Table 10). The invasive raspberry and blackberry, *Rubus ellipticus* and *R. argutus* occurred on 63.6% and 40.9% of village roads, respectively. Species that have recently invaded the park's `Ōla`a Forest and have been treated and apparently controlled there (Benitez *et al.* 2012) were also relatively common, including *Cestrum nocturnum* (22.7% frequency), *Ligustrum sinense* (40.9% frequency), and the nearly ubiquitous viny knotweed, *Persicaria capitata* (77.3% frequency). Other ornamental species previously removed from HAVO or targeted for eradication (Benitez *et al.* 2012) were found planted in Volcano Village, such as *Ardisia crenata* (4.5% frequency), *Buddleja davidii* (butterfly bush, 4.5% frequency), *Elaeagnus* sp. (oleaster, 22.7% frequency), *Luculia gratissima* (luculia, 4.5%), and *Phormium tenax* (36.4% frequency). At least three species that are incipient invaders on the island but not yet known from the park were observed along village roads, including *Buddleja madagascariensis*

(smoke bush, 13.6% frequency), *Photinia davidiana* (a single occurrence, 4.5%), and *Rhodomyrtus tomentosa* (downy myrtle, 4.5%). Surprisingly, no Australian or Cooper's tree fern, *Sphaeropteris cooperi*, was sighted along Volcano Village roads, although this popular ornamental is likely present out of sight in village gardens, and the fern was found along Wright Road (previous section). Another alien tree fern, *Dicksonia* sp. from New Zealand, was sighted along 13.6% of Volcano Village roads. If some of these plantings represent *D. fibrosa*, newly recognized as naturalized on the island, this fern may eventually become established in the Volcano area.

The Volcano Golf Course subdivision (VGC) is in an area with less rainfall (Giambelluca *et al.* 1986) and a somewhat drier habitat than the Volcano Village to the east; the golf course development was established in an area previously used as a cattle ranch. Vegetation here ranged from *Metrosideros* and *Acacia koa* woodland with native shrubs to areas dominated by the invasive *Morella faya* and clearings covered with alien grass. The roads within the subdivision are mostly short cul-de-sacs connected by a large circle (Pukeawe Circle) and an access road, Pi`imauna Road (divided into 0.5 mile or 0.8 km intervals). The widespread invasive species *Morella faya* and *Rubus argutus* occurred with 100% frequency, and *Hedychium gardnerianum* was seen on 95% of the subdivision roads, while *Psidium cattleianum* had a frequency of only 30%. *Rubus ellipticus*, generally considered a wet forest pest, had a high frequency of 70% in the Volcano Golf Course. *Pyracantha* spp. (firethorn), primarily *P. crenatoserrata*, was observed on 55% of road increments, in close proximity to the lower Mauna Loa Strip, where the bird-dispersed weed is being controlled (Benitez *et al.* 2012). The invasive vines *Tropaeolum majus* and *Thunbergia alata* were each found along 25% of VGC roads, while the mat-forming *Persicaria capitata* was nearly ubiquitous with 95% frequency.

Several species generally thought to be controlled within HAVO occurred on roadsides in the Volcano Golf Course subdivision. These included the trees *Acacia confusa* and *Melaleuca quinquenervia* (paperbark) and the shrubs *Buddleja davidii* and *Cotoneaster pannosa* (cotoneaster), each of which had 10–15% frequency, and the large herb *Phormium tenax*, which was observed on 30% of VGC roads. The alien tree fern *Sphaeropteris cooperi* was present on 10% of subdivision roads, and the VGC subdivision is directly upslope of Kīlauea Caldera, around which infestations of the fern have been observed and treated. *Schinus molle* (peppertree), a tree established on the west side of the island (Wagner *et al.* 1999), was found along 10% of VGC roads, and the potentially invasive *Cortaderia* sp., Pampas grass, occurred at one site (5%); neither species is currently naturalized in HAVO.

DISCUSSION

New Additions to the Flora of HAVO and Island Range Extensions

Fifteen alien plant species not previously known from HAVO (Fosberg 1966, 1976; Higashino *et al.* 1988) were found along roadsides within the park (Table 11, Figure 5). Half of the new records for HAVO were grasses (Poaceae), and most of these likely had their origin in nearby ranches. *Schedonorus arundinaceus* (reed fescue, synonym *Festuca arundinacea*) has been known from Hawai`i pastures since the 1930s (Wagner *et al.* 1999) and was observed in pastures of Kahuku when that unit was surveyed (Benitez *et al.* 2008), but the grass had not previously been collected in the Kīlauea section of HAVO. Two species of *Paspalum* new to HAVO were found at multiple sites along Highway 11 near Kapāpala Ranch and were also observed near the Steam Vents parking area on Crater Rim Road. Both *P. notatum* and *P.*

Table 11. New records of alien plant species within HAVO from the roadside weed survey and their Hawai`i Weed Risk Assessment ratings.

Species and code name ¹	Common name	Family	Location in HAVO	HWRA ² category
<i>Axonopus compressus</i> (AxoCom)	wide leaf carpetgrass	Poaceae	Highway 11, Crater Rim Rd.	15 H
<i>Crotalaria lanceolata</i> (CroLan)	rattlepod	Fabaceae	Highway 11, Chain of Craters Rd.	n/a ³
<i>Digitaria cf. abyssinica</i> (DigAby)	no common name	Poaceae	Crater Rim Rd. near T junction	n/a ³
<i>Euphorbia hyssopifolia</i> (EupHys)	spurge	Euphorbiaceae	Highway 11 near Nāmakani Paio	n/a ³
<i>Heliotropium amplexicaule</i> (HelAmp)	heliotrope	Boraginaceae	Highway 11 near Nāmakani Paio	n/a ³
<i>Leonotis nepetifolia</i> (LeoNep)	lion's ear	Lamiaceae	Highway 11 near western boundary	19 H
<i>Lepidium africanum</i> (LepAfr)	pepperwort	Brassicaceae	Highway 11	n/a ³
<i>Neonotonia wightii</i> (NeoWig)	glycine	Fabaceae	Highway 11	7 H
<i>Paspalum notatum</i> (PasNot)	Bahia grass	Poaceae	Highway 11 and Crater Rim Rd.	16 H
<i>Paspalum paniculatum</i> (PasPan)	no common name	Poaceae	Highway 11 and Crater Rim Rd.	n/a ³
<i>Schedonorus arundinaceus</i> (SchAru)	reed fescue	Poaceae	Crater Rim Rd. near Kīlauea Military Camp	n/a ³
<i>Senecio madagascariensis</i> (SenMad)	Madagascar fireweed	Asteraceae	Highway 11 near Nāmakani Paio	23 H
<i>Setaria sphacelata</i> (SetSph)	foxtail	Poaceae	Highway 11 near western boundary	n/a ³
<i>Sphagneticola trilobata</i> (SphTri)	wedelia	Asteraceae	Crater Rim Rd. near Lava Tube	13 H
<i>Sporobolus indicus</i> (SpoInd)	Indian dropseed	Poaceae	Chain of Craters, Crater Rim, and Hilina Pali Roads	n/a ³

¹ Code name used to map locations of species on Figure 5.

² Hawai`i Weed Risk Assessment: H = high, likely to be invasive (Daehler and Denslow 2011)

³ n/a = not assessed in HWRA

paniculatum have only recently been noted as naturalized on Maui, where they do not yet appear to be aggressive invaders (Oppenheimer 2007); however *P. notatum* has a Hawai`i Weed Risk Assessment (HWRA) rating of 16 High (Daehler and Denslow 2011). It is unclear if a record of *P. notatum* (Bahia grass) has been previously published for Hawai`i Island (Imada 2011), although there is a specimen from the island in the Bishop Museum Herbarium Pacificum. The foxtail grass *Setaria sphacelata* is a previously cultivated grass only recently observed as naturalized on Maui (Starr *et al.* 2002) and Hawai`i (Herbst *et al.* 2004). A *Digitaria* or crabgrass of uncertain identification that was observed once on the Crater Rim Road was possibly *D. abyssinica*, an intentionally introduced African grass not known to be naturalized on Hawai`i Island (Herbst and Clayton 1998). The crabgrass was not controlled, but subsequently

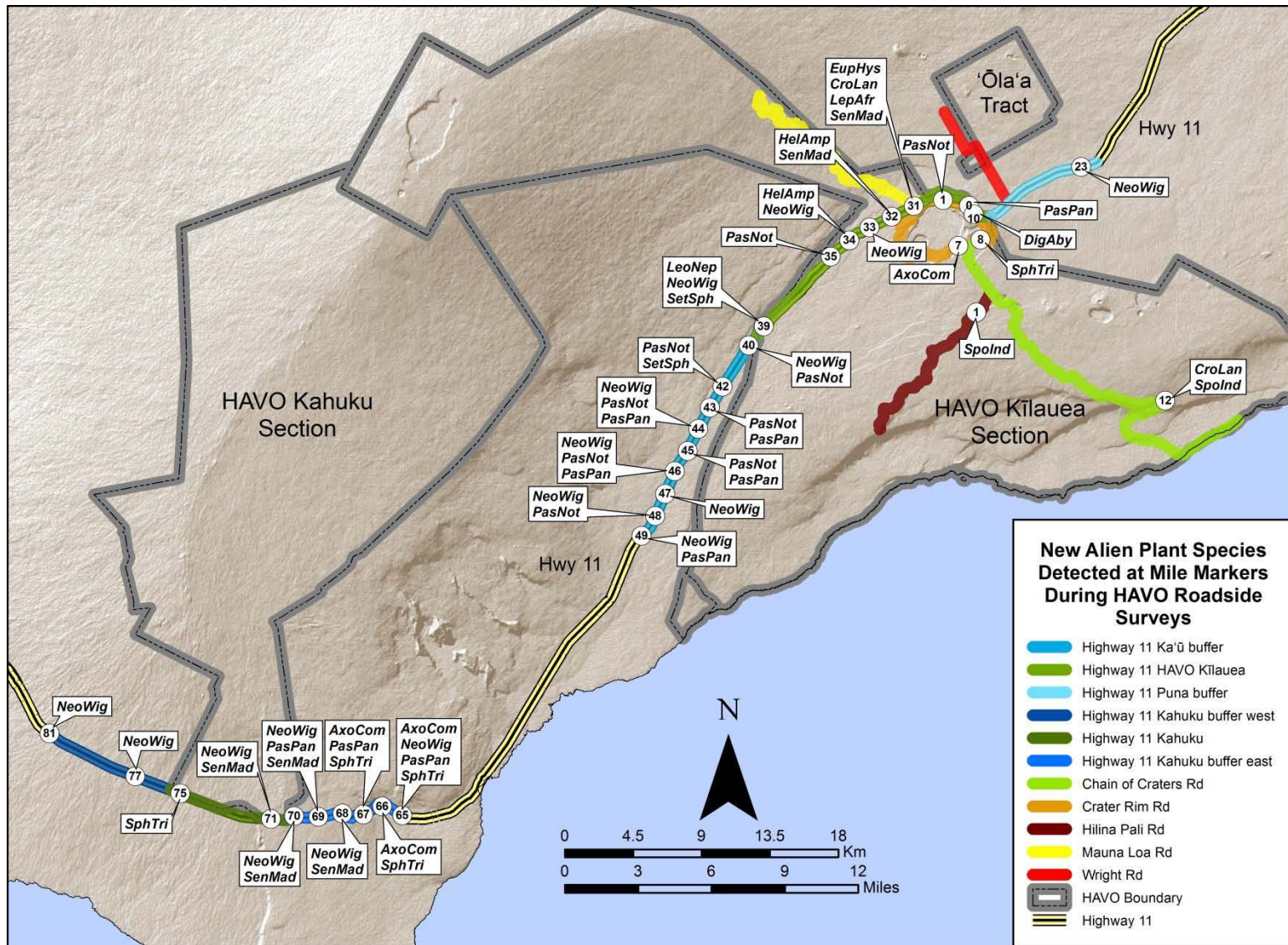


Figure 5. Location of new park records of incipient alien plant species detected during roadside weed surveys within Hawaii`i Volcanoes National Park (HAVO) and the Highway 11 buffer zones. (Code names of species listed in Table 11.)

disappeared from this roadside site; because the grass was near the verge of the road, it may have been destroyed by normal mowing activities of HAVO maintenance division. Because the grass bore seeds when detected on the survey, it may be expected to reappear at or near the Crater Rim Road site.

Two of the new grasses were probably not associated with cattle grazing; *Axonopus compressus* (wide leaf carpetgrass) is a common component of lawns in Hilo as well as on other islands (Oppenheimer 2007), and *Sporobolus indicus* (Indian dropseed) is widely naturalized in the Hawaiian Islands where it has been present since the 1920s (Wagner *et al.* 1999). *Axonopus* has a HWRA rating of 16 High (Daehler and Denslow 2011), and *S. indicus* has not been assessed.

Two of the non-grass species new to HAVO are also probably connected to cattle grazing activities. *Neonotonia wightii* (glycine) is a viny legume used as a fodder for cattle and has been naturalized on the island for more than 35 years (Wagner *et al.* 1999). This species had high frequency on Highway 11 (38.6%) and was observed both within the park and along the adjacent buffer areas both east (Puna) and west (Ka`ū District) of HAVO; it is surprising that this species had not been previously collected in the Kīlauea section of HAVO. The vine is widely naturalized in the tropics (Wagner *et al.* 1999) and has a HWRA rating of 7 High (Daehler and Denslow 2011). The composite *Senecio madagascariensis* (Madagascar fireweed) first appeared in pastures of the North Kohala District as a naturalized plant before 1992 and was already widespread when first reported (Smith 1992); it is thought to have invaded other islands as a contaminant in grass seed (Lorence *et al.* 1995). The species has a high rating in the HWRA (23) indicating invasiveness (Daehler and Denslow 2011). The first collection of this invasive composite in HAVO was on Highway 11 near Nāmakani Paio, but the weed was also found in five other road increments of Highway 11 in and near the park. All highway occurrences of fireweed during this survey were destroyed and reported to natural resources management pest controllers. Since the time of the roadside survey, this *Senecio* has been collected in the Mauna Loa Strip near Kapāpala Ranch, on the Keauhou Ranch east of HAVO (HAVO Herbarium), and most recently (2011) near Kīpuka Nēnē about 0.6 mile (1 km) from Hilina Road (C. D'Antonio, pers. comm.); it is also known from Kahuku Unit (Benitez *et al.* 2008).

Two of the six other alien plants that were new records for HAVO were escaped ornamentals and four were herbs or low shrubs naturalized on the island for more than 35 years. One of the escaped ornamental species was *Sphagneticola trilobata*, wedelia. Wedelia was observed only once near Thurston Lava Tube (Nāhuku), where it may represent a persistent planting or an accidental introduction along the roadside. The viny ornamental received a high rating (13) in the HWRA (Daehler and Denslow 2011). The roadside site was not treated, and the wedelia is likely still present. The species does not seem to be a serious threat to the nearby montane rain forest, as it typically spreads only vegetatively (Wagner *et al.* 1999) and is found naturalized only at lower elevation (120 ft) on Hawai`i Island (Imada *et al.* 2000). The second ornamental was *Leonotis nepetifolia* (lion's ear), an herb with showy orange flowers that has been naturalized in low-elevation dry areas of the island since the 1930s (Wagner *et al.* 1999); this species was observed only once on Highway 11 near the western boundary of the park.

The other four park records include *Crotalaria lanceolata*, rattlepod, a weedy species that was first observed at low elevations on Hawai`i Island more than 35 years ago (Wagner *et al.* 1999). This rattlepod was seen at single sites on both Highway 11 and Chain of Craters Road, but subsequent to this survey the weed has appeared at additional localities within HAVO

(Benitez *et al.* 2012). The lance-leaf rattlepod joins five other weedy species of the genus already present in HAVO (Higashino *et al.* 1988, Benitez *et al.* 2008); all these rattlepods appear to be relatively innocuous weeds of disturbed areas. The herbs *Euphorbia hyssopifolia* (*Chamaesyce*), a spurge, and *Lepidium africanum*, a pepperwort, have been known from the island for 35–50 years, and heliotrope or *Heliotropium amplexicaule* was first collected as a naturalized plant almost 100 years ago (Wagner *et al.* 1999); these species, each seen at one or two park sites, may be slowly increasing their range on the island or they may have been overlooked as components of the HAVO flora because of their small size and inconspicuous appearance. *Lepidium africanum*, previously misidentified as *L. hyssopifolia*, has been collected on the island in Hamākua and North Kona Districts and on Mauna Kea (Wagner and Herbst 1995); the species may be invasive as it received a high rating (10) in the HWRA (Daehler and Denslow 2011). At present these three herbaceous weeds appear to be restricted to disturbed roadsides in HAVO and are unlikely to become highly invasive in upland forests and shrublands. In summary, with one exception, none of the 15 species that are new records for HAVO appear to be highly disruptive invaders of great concern to managers. The exception is *Senecio madagascariensis*, which has spread rapidly across the island and is capable of forming dense stands in dry grasslands and shrublands. This species may require targeted control efforts to prevent its establishment in the park.

Several alien species observed along HAVO roads appear to be growing at higher elevations than their ranges as published in the comprehensive *Manual to the Flowering Plants of Hawai`i* (Wagner *et al.* 1999). Two *Paspalum* species, *P. dilatatum* and *P. urvillei* were found along the upper reaches of the Mauna Loa Road up to 6,360 ft (1,940 m) elevation, higher than the previously reported upper limits of 4,200–5,310 ft (1,280–1,620 m) elevation. The grass *Schizachyrium condensatum* occurred even higher at 6,700 ft (2,040 m) elevation on the Mauna Loa Road, although its highest published elevation in Hawai`i was 4,300 ft (1,310 m). The herbaceous *Persicaria capitata* occurred at the top of the Mauna Loa Road near 6,700 ft and in the coastal lowlands along the Chain of Craters Road at 1,080 ft (330 m) elevation and its published range in Wagner *et al.* 1999 was 2,000–5,800 ft (600–1,770 m). Woody plants also appeared in the park at higher elevations than those previously published. The invasive *Leucaena leucocephala* was found at 3,610 ft (1,100 m) elevation, far higher than the 1,150 ft (350 m) upper range listed by Wagner *et al.* (1999).

Alien Plant Species Found on Highway 11 Near HAVO

Many alien plant species not known to occur within the park (28) were found along Highway 11 within the area adjacent to the park boundary to a point 5 miles away (10 miles on the Ka`ū or western side of the Kīlauea Unit of HAVO) or along the highway at Kahuku outside the park boundary (Figure 6). Among the 28 species found along Highway 11 (Table 12) were seven plants considered to be among the 86 most serious pests of natural ecosystems in the Hawaiian Islands: *Casuarina* spp., *Cecropia obtusifolia*, *Citharexylum spinosum*, *Ficus microcarpa*, *Macleaya cordata*, *Merremia tuberosa*, and *Rubus niveus* (Smith 1985). *Macleaya cordata* (plume poppy) and *Cecropia obtusifolia* are woody species that are well established near the park. *Macleaya*, formerly known as *Bocconia frutescens*, is highly invasive in Ka`ū District, where there are major infestations in Wood Valley and Manukā Natural Area Reserve (Benitez and Saulibio 2007). In our roadside survey, the shrub was found at three sites along Highway 11; two were in the northern buffer of Kahuku Unit near Manukā and one was in the tenth mile increment beyond the western boundary of Kīlauea unit of HAVO, just southeast of Wood Valley. *Cecropia* is a fast-growing, prolifically fruiting, pioneer tree species (Estrada *et al.* 1984)

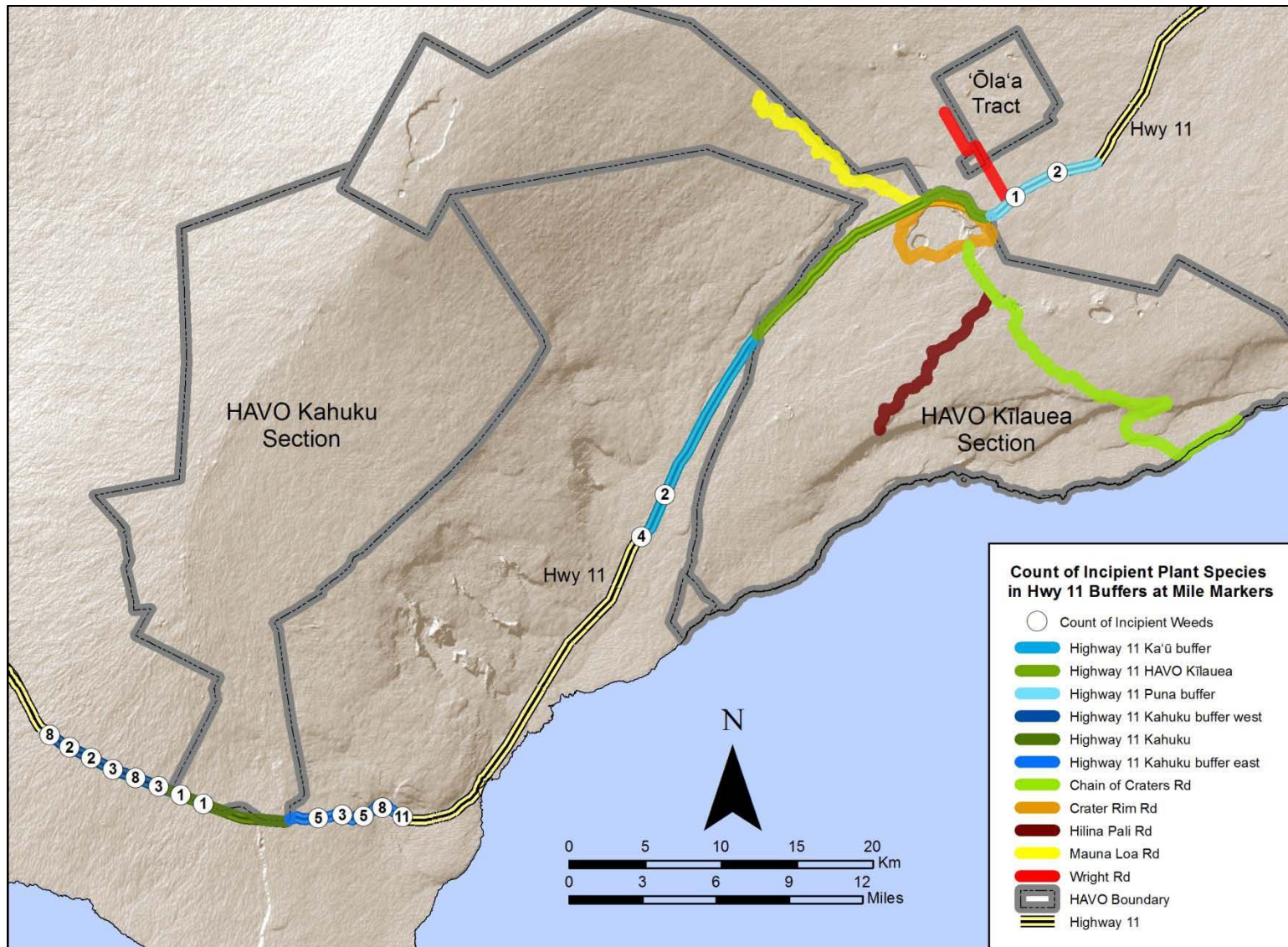


Figure 6. Location and count of incipient alien plant species found during the roadside weed survey in the Highway 11 buffer zones that were not known from Hawai'i Volcanoes National Park (HAVO) in 2001–2005.

Table 12. Alien plant species found in the Highway 11 buffer zones but not known from HAVO in 2001–2005, with their Hawai`i Weed Risk Assessment (HWRA) ratings and dispersal syndromes.

Scientific name	Common name	# Intervals occupied	Buffer zones occupied	HWRA ¹	Dispersal syndrome ²
<i>Allamanda cathartica</i>	allamanda	6	Kahuku East/West	8 H	unknown!
<i>Bauhinia monandra</i>	orchid tree	2	Kahuku East/West	7 H	unknown
<i>Buddleja madagascariensis</i>	smoke bush	2	HAVO Puna	7 H	bird
<i>Caesalpinia decapetala</i>	wait-a-bit	4	HAVO Ka`ū, Kahuku East/West	20 H	unknown!
<i>Casuarina</i> spp.	ironwood	6	Kahuku East/West	12–20 H	wind
<i>Cecropia obtusifolia</i>	guarumo, trumpet tree	3	Kahuku West	10 H	bird
<i>Citharexylum spinosum</i>	fiddlewood	2	Kahuku East	7 H	bird
<i>Clusia rosea</i>	autograph tree	2	Kahuku East/West	5 Eval.	bird
<i>Ficus microcarpa</i>	Chinese banyan	2	Kahuku East	10 H	bird
<i>Flindersia brayleyana</i>	Queensland maple	1	Kahuku West	- 3 L	wind
<i>Homolanthus populifolius</i>	bleeding heart	1	Kahuku West	n/a	bird*
<i>Macaranga tanarius</i>	no common name	1	Kahuku West	n/a	bird
<i>Macleaya cordata</i>	plume poppy	3	HAVO Ka`ū, Kahuku West	n/a	bird?
<i>Manihot glaziovii</i>	Ceara rubber tree	1	Kahuku West	n/a	unknown!
<i>Melastoma sanguineum</i>	fox-tongued melastoma	1	HAVO Puna	n/a	bird
<i>Merremia tuberosa</i>	wood rose	2	Kahuku East	12 H	aquatic?
<i>Montanoa hibiscifolia</i>	tree daisy	5	HAVO Ka`ū, Kahuku East	13 H	wind?
<i>Murdannia</i> sp.	no common name	1	Kahuku East	n/a	unknown!
<i>Ochna serrulata</i>	mickey-mouse plant	2	Kahuku East/West	11 H	bird
<i>Rubus niveus</i> *	hill raspberry	1	Kahuku West	n/a	bird
<i>Schefflera arboricola</i> *	dwarf octopus tree	1	Kahuku East	3 Eval.	bird
<i>Schinus molle</i> *	pepper tree	4	Kahuku East/West	10 H	bird
<i>Sorghum arundinaceum</i>	sorghum	1	HAVO Ka`ū	n/a	unknown!
<i>Thevetia peruviana</i>	yellow oleander	4	Kahuku East/West	9 H	unknown!
<i>Thunbergia fragrans</i>	white thunbergia	3	Kahuku East	n/a	unknown

Table 12 continued Scientific name	Common name	# Intervals occupied	Buffer zones occupied	HWRA ¹	Dispersal syndrome ²
<i>Tithonia diversifolia</i>	tree marigold	3	Kahuku East/West	n/a	wind?
<i>Toona ciliata</i>	Australian red cedar	2	Kahuku East/West	2 Eval.	wind
<i>Urochloa plantaginea</i>	no common name	1	HAVO Ka`ū	n/a	unknown!

¹ Hawai`i Weed Risk Assessment: H = likely to be invasive; L = not recognized as invasive in Hawai`i; Eval. = Evaluate; n/a = not assessed (Daehler *et al.* 2004, Daehler and Denslow 2011)

² Dispersal Syndrome from Staples *et al.* 2000, except those marked with "!"

* Collected in HAVO, including Kahuku Unit, subsequent to the roadside weed survey

introduced to at least six forest reserves on Hawai`i Island (Skolmen 1979) and now spreading at low elevation, particularly in Puna and Hilo Districts (Smith 1985). On Highway 11, *Cecropia* was found at three sites in the northern buffer zone of Kahuku Unit, and the species was almost ubiquitous on Highway 130 east of HAVO. Both *M. cordata* and *C. obtusifolia* have high ratings in the HWRA (Daehler and Denslow 2011) and are bird-dispersed (Staples *et al.* 2000).

Three trees on Smith's (1985) list of most invasive species that occurred in the buffer zone of Highway 11 were *Casuarina* spp. (ironwood), *Citharexylum spinosum* (fiddlewood), and *Ficus microcarpa* (Chinese banyan). These species have all been used as ornamentals and are either bird or wind dispersed (Staples *et al.* 2000); all have high (>7) HWRA ratings (Daehler and Denslow 2011). *Rubus niveus*, one of several invasive raspberry species in Hawai`i (Wagner *et al.* 1999), was found in only one site in the 5-mile buffer north of Kahuku Unit. While currently known from few sites in South Kona, Ka`ū, and Hāmākua Districts on Hawai`i Island (Gerrish *et al.* 1992), the prickly shrub is known to be invasive at high elevation on Maui (Smith 1985) and was recently (2007) collected in the central pastures of Kahuku (C. Yanger, pers. comm. and HAVO Herbarium), as well as in woodland north of Kahuku near Pu`u Lehua (Jacobi *et al.* 2010), and within Kūlani Correctional Facility (J. Jacobi, unpublished data). The only vine among Smith's most invasive species that was found in the Highway 11 buffer was *Merremia tuberosa*, wood rose, an ornamental considered by Wagner *et al.* (1999) to be only sparingly naturalized. This potentially invasive ornamental is possibly dispersed by water (Staples *et al.* 2000), and has a high HWRA rating (Daehler and Denslow 2011). Although generally thought to be confined to elevations below 1,640 ft (500 m) elevation (Wagner *et al.* 1999), Smith (1985) reported that the species was distributed to 4,590 ft (1,400 m) and was a pest on Kaua`i.

In addition to the species considered invasive by Smith (1985), most of the plants in the Highway 11 buffer area not yet found in the park (Table 12) appear to have invasive characteristics; of the 17 species in this group evaluated in the HWRA all but four were given high ratings (>7) indicating high potential for invasiveness (Daehler and Denslow 2011, Daehler *et al.* 2004). Several of these species were found near the park during a previous survey of potentially invasive species by Stemmermann (1987). She recognized the bird-dispersed species *Clusia rosea* as one of two species most likely to move into HAVO. Stemmermann considered *Buddleja madagascariensis* one of the two most important species to treat in the vicinity of the park; the second invasive but treatable species she noted adjacent to the park, *Delairea odorata* (cape ivy; synonym *Senecio mikanioides*), was not observed in our survey.

With the exception of one ornamental not considered established in the wild (*Allamanda cathartica*; Staples and Herbst 2005, Imada 2011), all of the buffer zone species not yet known to be in the park are cultivated or formerly cultivated plants that have naturalized and are now categorized as widespread, regional, or incipient; these include species currently considered ornamental (Staples and Herbst 2005), introductions for forestry (Skolmen 1979), or pasture grasses (Wagner *et al.* 1999). The grass *Urochloa plantaginea* (synonym: *Brachiaria plantaginea*), is known to have been introduced for agricultural purposes on O`ahu (Wagner and Herbst 1995), and a specimen collected along Highway 11 during this survey was the first record of the species on Hawai`i Island; a second grass collected in the Ka`ū buffer of Highway 11, *Sorghum arundinaceum*, was a new state record of a naturalized species (Snow and Lau 2010).

A few of the ornamentals, like *Ochna serrulata* (mickey-mouse plant), *Bauhinia monandra* (orchid tree), and *Homalanthus populifolius* (bleeding heart), have been only recently recognized as naturalized on Hawai`i Island (*Herbarium Pacificum* Staff 1998, Lorence and Flynn 1999, Oppenheimer 2004) and are now incipient invaders in Ka`ū or South Kona Districts. Most of the escaped ornamentals present in the highway buffer zone are considered potentially invasive (Staples *et al.* 2000). Because these species are currently planted as ornamentals and/or escaped near HAVO, they will potentially be a source of propagules, which may result in their becoming established in the park. *Tithonia diversifolia* (tree marigold), an ornamental known to be naturalized on four Hawaiian Islands (Wagner *et al.* 1999), was observed at three intervals in the Kahuku buffer, including one site along the park boundary; this wind-dispersed species may be expected to eventually invade the Kahuku Unit of HAVO.

Potentially Invasive Ornamental Species in Residential Subdivisions Adjacent to HAVO

While most of the target alien plants observed along roadsides in the three subdivisions adjacent to HAVO were species already established within HAVO, a total of 19 plant species found near residences were not known to occur within the park in 2003 (those marked with a * on Table 10; those marked with ** have been collected within HAVO subsequent to this roadside survey). Many of the plants that are now considered invasive in the Hawaiian Islands were intentionally introduced as ornamentals (Smith 1985, Staples *et al.* 2000), and half of the naturalized plant species in mainland United States were deliberately introduced, many as ornamentals (Mack and Erneberg 2002). Knowledge of the presence of novel cultivated species near the park may allow park managers to detect invaders early if they move into HAVO. While a few of the 19 observed species are not known to have escaped cultivation (unknown Bignoniaceae vine, *Equisetum* sp., *Ficus elastica*, *Hedychium greenei*, *Metrosideros excelsa*, *Tibouchina granulosa*), most have already become naturalized elsewhere in the Hawaiian Islands.

Several ornamental trees or shrubs, a grass, and a fern found in these areas seem particularly likely to be future invaders of HAVO. One of these shrubs is *Rhodomyrtus tomentosa*, downy or rose myrtle, which was observed only once in Volcano Village. While it is naturalized primarily at lower elevation (<1,970 ft or 600 m; Wagner *et al.* 1999), the shrub is a serious pest on Kaua`i (Smith 1985). *Rhodomyrtus* has been considered a noxious weed in Hawai`i for almost 20 years (Hawai`i State Department of Agriculture 1992) and was recently targeted for control on Maui by the Maui Invasive Species Committee (Penniman *et al.* 2011). *Photinia davidiana*, a shrub in the Rose Family with fleshy red fruits, was also observed only once in Volcano Village. This species has been reported as naturalized at relatively high elevation (ca. 5,250–5,900 ft or

1,600–1,800 m) on both Maui and Hawai`i Island (*Herbarium Pacificum* Staff 1996), and is recognized as invasive and expanding in the Hakalau Forest National Wildlife Refuge on the island of Hawai`i between 4,000 and 6,000 ft elevation (J. Jacobi, unpublished data). Both *Rhodomertus* and *Photinia* are bird-dispersed (Staples *et al.* 2000). Based on current distributions on Hawai`i Island, *Photinia* would be most likely to invade montane wet and mesic forests, and *Rhodomertus* would probably establish in the wet forests and shrublands of the eastern lowlands of the park. *Cestrum diurnum* (day cestrum), a shrub similar to *C. nocturnum*, a related shrub that is already naturalized within HAVO, was seen only once in Mauna Loa Estates, where it appeared to be cultivated rather than growing wild. Wagner *et al.* (1999) did not list this species as naturalized on Hawai`i Island, but it has escaped and spread on three other Hawaiian Islands. Its black shiny berries are bird dispersed (Staples *et al.* 2000). This species would be most likely to invade wet forest at lower elevation.

Cortaderia sp. (Pampas grass) is a large ornamental grass, and two species are present in the Hawaiian Islands: *C. selloana* and *C. jubata*, the latter commonly called jubata grass. *Cortaderia jubata* is a highly invasive species at high elevation on Maui and has been a control target of Haleakalā National Park and the Maui Invasive Species Committee (Loope and Medeiros 1992, Starr *et al.* in prep.) Neither species is currently listed as naturalized on Hawai`i Island (Imada 2011). *Cortaderia selloana* has been considered unlikely to naturalize because typically only the female plants with showy pink inflorescences are planted, and the co-occurrence of male plants is required for seed production. However, both male and female, as well as hermaphroditic plants, are now available in the nursery trade (DiTomaso and Healy 2007, Okada *et al.* 2007), and sexually reproducing *C. selloana* has become highly invasive in non-disturbed habitats of California (Lambrinos 2001). During the roadside survey, Pampas grass that was likely *C. selloana* was observed at one site in Volcano Village and at a second site in Volcano Golf Course subdivision. While we saw no sign of seedlings or spreading clumps to indicate the grass was currently naturalized in residential areas, future ornamental plantings may lead to the production of seeds. If Pampas grass planted in subdivisions near HAVO produced viable seeds, much of the park would be vulnerable to invasion, as *C. selloana* is capable of establishing in a wide range of climate zones (DiTomaso and Healy 2007).

Tree ferns are popular as ornamental plants in Hawai`i (Staples and Herbst 2005), and at least one widely planted, fast-growing tree fern native to Australia, *Sphaeropteris cooperi* (formerly known as *Cyathea cooperi*) or Cooper's tree fern (Wilson 1991) has escaped cultivation and is invasive in natural areas on Maui, O`ahu, and Kaua`i (Medeiros *et al.* 1992). Cooper's tree fern has already been observed as a naturalized plant within HAVO; wild plants were first discovered along the Crater Rim Trail in 2000 (T. Tunison and R. Loh, pers. comm.), and subsequently ferns have appeared on trails near Byron's Ledge, in Thurston SEA, and within `Ōla`a (Benitez *et al.* 2012, HAVO Herbarium). All known occurrences of this species are being controlled in HAVO as part of the localized alien plant program. Cooper's tree fern is easily dispersed by its tiny spores; on Maui, infestations in Kīpahulu Valley, Haleakalā, are thought to have spread from plantings 7.5 miles (12 km) away (Medeiros *et al.* 1992). During the roadside weed survey, Cooper's tree fern was noted at two localities in the golf course subdivision; these sites may have been the source of park infestations, although the areas where the tree fern has appeared in HAVO are not directly downwind of that subdivision during typical tradewind conditions. It is likely that additional Cooper's tree ferns were present within Volcano Village and Mauna Loa Estates, but were out of sight of the road and not detected during the roadside survey. Apparently, this Australian tree fern has been the most available tree fern in Hawaiian plant nurseries for more than 20 years (Wilson 1991). Young tree ferns are difficult to

distinguish from native terrestrial ferns in areas with heavy ground cover, and park infestations may become well established before they are recognized.

At least four species previously eradicated from the park and several others targeted for eradication (Benitez *et al.* 2012) were present as plantings in one or more of the subdivisions adjacent to the park. Among the previously eradicated species are the fleshy-fruited shrubs *Ardisia crenata*, *Cotoneaster pannosa*, and *Elaeagnus* sp., which are all bird dispersed and potentially invasive (Staples *et al.* 2000). All three shrub species have Hawai`i Weed Risk Assessment ratings of 7 or greater, indicating invasiveness. *Phormium tenax*, New Zealand flax, was also previously eradicated from the park. While this large ornamental herb has not been noted as spreading from plantings, it has a high HWRA rating (8) and is very common in adjacent subdivisions, where it was found on a quarter to a third of road segments in all three surveyed residential areas. *Buddleja davidii*, *Luculia gratissima*, *Cestrum nocturnum*, and the vine *Thunbergia alata*, all species targeted for eradication in HAVO, were found along roads of the three subdivisions closest to the park. *Cestrum* and *Thunbergia* had high frequencies in two to three of the residential areas, and prevention of the spread of these fast-growing species, one of which is bird-dispersed (*Cestrum*), will present challenges to park managers. Monitoring of areas near shared boundaries of the park with the subdivisions to detect ingress of invasive ornamentals was recently suggested by Benitez *et al.* (2012), and this tactic will be a key element in preventing the invasion of bird- or wind-dispersed propagules from planted ornamentals with invasive tendencies.

Among all of these potentially invasive ornamentals already present adjacent to the park, two species are most likely to become significant problems within HAVO. Based on their current behavior elsewhere on the island and their dispersal potential, both *Cestrum nocturnum* and the tree fern *Sphaeropteris cooperi* deserve particular management attention to prevent their becoming too widespread to control in HAVO. Because *Cestrum* is planted at so many sites in adjacent subdivisions and is bird-dispersed, it is highly likely that it will appear as an invader in rain forests of the Kīlauea summit or the disjunct `Ōla`a Tract. Periodic monitoring along fencelines and trails of `Ōla`a Forest, the Thurston SEA and other summit forests will be important to effect early detection of the shrub's invasion of the park. Cooper's tree fern will be more difficult to monitor, as its tiny spores may travel long distances from the source population (Medeiros *et al.* 1992). Outreach to homeowners in the adjacent communities and education regarding the tree fern's invasive tendencies (Stone 1992) may be efficient strategies to decrease the number of Cooper's tree fern planted and thus reduce the likelihood of future invasion into HAVO from multiple fronts.

Two Notable Widespread Alien Plants and Their History in HAVO

Hedychium gardnerianum, kāhili ginger, is a large herb with showy yellow and red flowers from high elevation areas in Nepal and India considered by many gardeners to be a desirable ornamental in Hawai`i and other tropical lands (Staples and Herbst 2005). The species was not listed as present in the first annotated checklist for HAVO in 1944 (Fagerlund and Mitchell 1944), but three years later the ginger was noted as "in gardens only" in a list of the exotic plants of the park (Fagerlund 1947). The next annotated checklist of HAVO in 1966 still did not report the species as escaped and cited as the only park specimen a collection made in the housing area in 1943 (Fosberg 1966). The ginger became well established in HAVO between the 1960s and 1980s, because by the publication of the next checklist of park plants in 1988 (Higashino *et al.* 1988) *Hedychium gardnerianum* was noted as naturalized in both wet and mesic forest zones. In the 1980s and 1990s, the ginger was the target of control efforts in three

Special Ecological Areas (Tunison and Stone 1992), and today it is one of the most intensively managed alien species in the park. By 2001, *H. gardnerianum* was distributed along roadsides in 26% of one-mile increments within HAVO, including half of the Crater Rim Road and the upper two miles of the Chain of Craters Road. The forested areas near these two roads were probably invaded from the original planting in the housing area in the 1940s, but the presence of the ginger along every increment of Wright Road outside the park and its high frequency in Volcano Village and Mauna Loa Estates suggest that multiple introduction sites may have contributed to the current distribution of the species in the park.

Hedychium gardnerianum is one of the most invasive alien plant species of HAVO, and dense infestations greatly damage native forests and even reduce the amount of nitrogen available to native `ōhi`a (*Metrosideros polymorpha*) trees (Asner and Vitousek 2005). The negative impact of kāhili ginger is severe in native montane rain forests, as the large herb is capable of forming very dense stands that shade out native herbs and ferns and exclude recruitment of native woody species. The enormous rhizome mass of dense ginger displaces other plants of the forest floor. Without ginger control, the park's native wet and mesic forests will eventually be transformed to alien-dominated vegetation with scattered native trees.

Persicaria capitata, knotweed, is a mat-forming herb from the Himalayas that has been used in Hawai`i as an ornamental ground cover plant (Staples and Herbst 2005). The species was first collected as a naturalized plant on the island in 1960 (Wagner *et al.* 1999). Fosberg (1969) noted it was common on the Hilo-Volcano Road in the early 1960s, and he collected the first park specimens on the Chain of Craters Road near Makaopuhi Crater and on the Crater Rim Road in 1968 (Bishop Museum *Herbarium Pacificum*). Fosberg suggested the knotweed would spread in cooler areas. The species was first acknowledged as part of the flora of the park by the revised checklist of Fosberg (1976). By the 1980s, *P. capitata* was reported from the submontane seasonal and rain forest zones of the park, as well as along roadsides and in cultivation (Higashino *et al.* 1988). In the last 24 years, knotweed has been observed invading forested Special Ecological Areas and has been treated at `Ōla`a and Kīpuka Puauulu, as well as along selected roadsides (Benitez *et al.* 2012). Despite control efforts, *P. capitata* was distributed along 58% of surveyed HAVO roads. The herb was most abundant along the roads where it was first observed in and near the park, with 68.2% frequency on Highway 11 and >60% frequency on both the Chain of Craters and Crater Rim Roads. While less abundant on the Mauna Loa and Hilina Pali Roads, *P. capitata* was ubiquitous along Wright Road, which passes by the disjunct `Ōla`a Forest. The abundance of this invasive species along park roads and its ability to invade disparate habitats are evidence that the continued surveys of fencelines and trails (Benitez *et al.* 2012) are important tools to help prevent the spread of *P. capitata* into intact forests and shrublands.

The impacts of *P. capitata* on native forests have not been well studied, but dense infestations of the mat-forming weed are likely to reduce native plant regeneration in the ground cover. In both the wet forest of `Ōla`a and the mesic forest of Kīpuka Puauulu, *P. capitata* was observed to form a dense mat of ground cover that precluded the growth of any native herbs or small seedlings. These infestations were arrested soon after their discovery, and herbicidal treatment prevented the knotweed from becoming well-established in either forest. The impacts of the knotweed in native communities of more remote regions of the park are not known with certainty, but the viny species may be expected to behave similarly and displace native ground cover in invaded lowland forests. It is not known whether the presence of *P. capitata* on recent lava flows of Kīlauea's East Rift interferes with normal succession of native plants. *Persicaria*

capitata was not included on a list of 41 localized alien plant species to be treated throughout the park in the 1990s (Tunison and Zimmer 1992, Tunison *et al.* 1992), presumably because the species was already too widespread to control except in Special Ecological Areas.

Widespread weeds, by definition, are not controllable throughout the park by standard mechanical and chemical methods. Nonetheless, a containment strategy similar to that successfully employed for *Pennisetum setaceum* (fountain grass) within HAVO (Tunison 1992) could be applied to additional established weeds to prevent their becoming widespread invaders of natural systems in the park. Using such a strategy, this highly invasive alien bunchgrass has been largely confined to the park's coastal lowlands for more than 25 years, and cover of the grass has also been greatly reduced at the original establishment site in HAVO (Tunison *et al.* 1994). For alien plant species already widespread in HAVO, careful sanitation methods to prevent the spread of propagules of additional park sites is currently employed and appears to be successful (Benitez *et al.* 2012). Cooperation of multiple divisions within the park is essential to the success of phytosanitation programs. Ultimately, introduction of successful biocontrol agents may be necessary to reduce the impacts of widespread, ecosystem-altering alien species such as *Hedychium gardnerianum*. One potential biocontrol agent that caused death in k̄hili ginger, a bacterial wilt (*Ralstonia solanacearum*), was studied in HAVO more than a decade ago, but inoculation methods were not practical for large-scale use (Anderson and Gardner 1999), and the agent has not been used in actual park control efforts.

Incipient Invaders, Determining Which Species to Control

The two notable species described above are examples of highly invasive plants now far too widespread to eradicate from the park. However, both could possibly have been removed from the park and prevented from spreading if their invasive tendencies had been recognized early. *Hedychium gardnerianum* or k̄hili ginger appeared to have a "lag phase" between its introduction to the park and its spread into forests more than 20 years later. This phenomenon is common and may lead to invasive species not being recognized as such until they are uncontrollable (Loope *et al.* 2001). The case of *Persicaria capitata* is not as compelling, and it is possible that this disturbance-loving herb may be prevented from invading native forests of HAVO by ongoing control efforts. If invasion of park forests is not totally preventable, at least the ingress of this species and other weed propagules may be slowed by treatment of weeds in selected corridors near SEAs. Both of these widespread species (*H. gardnerianum* and *P. capitata*) share the trait of bird-dispersed fruits; avian dispersal is thought to be a major factor in invasion of Hawaiian ecosystems by alien plants (Staples *et al.* 2000).

Prediction of which alien plant species will become invasive and merit control efforts is difficult but desirable to reduce the cost of management. Characteristics of the "ideal weed" were listed by Baker (1974) and included rapid growth, continuous seed production and high seed output, self-compatibility, wind-pollination or unspecialized pollinators, vigorous vegetative reproduction, ability to compete by special means, and others. Later work highlighted the characteristics of successful invaders as small seed size, short juvenile period, and short interval between large seed crops (Rejmáněk and Richardson 1996). Daehler (1998) pointed out that woody plant species and climbers were highly represented among natural area invaders; he also noted that few natural area invaders were also agricultural pests. Staples *et al.* (2000) noted that the characters that made cultivated plants invasive were adaptability to different habitats, tolerance of variable conditions and disturbance, fast growth, high dispersibility, and high reproductive capability. A recent comparison of invasive species and related native Hawaiian plants determined that the invasive species were more efficient at using limited

resources (light, nitrogen, water) over the short-term (Funk and Vitousek 2007). Invasibility of natural communities is a function of the characteristics of both the habitat and invading species (Sakai *et al.* 2001, Denslow 2003). Islands in general and Hawai`i in particular have been viewed as vulnerable to invasion (Loope and Mueller-Dombois 1989, Simberloff 1995). Denslow (2003) concluded that high resource availability and poor ability of native species to use all the available resources made island communities vulnerable to alien species invasion; she suggested that aggressive management of forests and reduction of alien plant propagule abundance was necessary to protect island ecosystems.

Based on the characteristics of successful weeds presented above, it is likely that at least one of the 15 new weed records in HAVO and at least two of the alien plants detected in adjacent subdivisions will become invasive in HAVO. These are the newly-recorded *Senecio madagascariensis*, which has increased exponentially in pasture lands and disturbed areas west of the park; *Sphaeropteris cooperi*, an ornamental tree fern still widely used in landscaping that has tiny, wind-borne spores capable of traveling long distances; and *Cestrum nocturnum*, also widely used in landscaping, readily available in the local plant nurseries, and easily spread by birds feeding on its fleshy white berries. Other ornamental species planted adjacent to the park that are worthy of monitoring for ingress include *Photinia davidiana* and *Ligustrum sinense*; both have bird-dispersed fleshy fruit and have already invaded other native montane forests on the island. Among species detected in the Highway 11 buffer zones, two plants stand out as most likely to invade HAVO; these are *Rubus niveus*, hill raspberry, and *Macleaya cordata*, plume poppy. Alien *Rubus* species, in general, have become significant pests of montane forests and shrublands of Hawai`i, and *R. niveus* has a wide elevational range (Gerrish *et al.* 1992). This species is likely to rapidly expand its range near the park and invade both Kahuku and the Mauna Loa Strip, if unchecked by control efforts. Similarly, plume poppy has become a serious pest of dry forests and woodlands on Maui (Smith 1985), and the alien shrub is well established in Wood Valley near Kahuku (Benitez and Saulibio 2007), from which it is likely to invade the former ranchlands of the park. Moving beyond shrub species, grasses are among the worst invaders in the world and are often capable of altering native ecosystems (D'Antonio and Vitousek 1992); it would be prudent for several newly recognized alien grass species found inside the park (e.g., *Paspalum notatum*, *P. paniculatum*, *Schedonorus arundinaceus*) to be controlled to prevent establishment and to confirm the eradication of those already treated. Hawai`i Weed Risk Assessment ratings for all survey targets that have been evaluated are presented in Appendix 1.

Control of localized alien plants within the park has been recognized as a component of alien plant management for almost 30 years (Tunison 1992). Since 1982, park resource managers have treated and attempted to eradicate a suite of >40 localized alien plant species selected on the basis of their known weediness elsewhere, their dispersibility, or their tendency to spread in the park (Tunison and Zimmer 1992). For many of the targeted species early treatment was effective (Benitez *et al.* 2012), and the control action may have prevented establishment of additional alien plant species in the park. Today the Hawai`i Weed Risk Assessment (Daehler and Denslow 2011) and other databases (Randall 2007, Global Compendium of Weeds) are available to assist managers in the determination of which weeds to control. New information about potentially invasive incipient plant species has recently been collected on Maui (Starr *et al.* in prep.), and newly naturalized plants of Maui (which is the nearest island to Hawai`i and has similar habitats) are likely to eventually appear on Hawai`i Island and thus warrant addition to future target lists of incipient invaders. The publications of F. and K. Starr, H. Oppenheimer, and others that appear almost yearly in the Bishop Museum Occasional Papers (Oppenheimer *et*

al. 1999; Starr *et al.* 1999, 2002, 2003, 2006, 2008, 2010, 2011; Oppenheimer and Bartlett 2000, 2002; Oppenheimer 2003, 2004, 2007, 2008, 2010; Herbst *et al.* 2004) are starting points to identify alien species that are likely to appear on Hawai`i Island and may eventually invade HAVO.

The best predictor of invasion likelihood in an area is the ability of a species to invade similar habitats elsewhere (Reichard and Hamilton 1997). The park's target list of potential incipient invasive plants could thus be updated yearly with information on newly recognized alien plants that have invaded either Hawai`i or Maui Islands in habitats similar to those of HAVO. Roadside and trailside surveys and monitoring of disturbed areas near buildings and high visitor use sites are tools to alert park managers to the presence of newly arrived potentially invasive species within or near HAVO. Routine surveys to detect new invasive plant species and rapid removal of all newly appearing alien plants in the park will likely be cost-effective in the long run, and these strategies are a continuation of past and current management activities in HAVO (Tunison 1992, Tunison and Zimmer 1992, Benitez *et al.* 2012). Periodic surveys of adjacent lands for potentially invasive ornamental plants to identify source populations close to the park will be needed to reduce the threat from encroaching alien species. Finally, outreach and education of park visitors and neighbors is a method to raise awareness of alien plant invasion problems and to enlist support for reduction in weed propagule ingress to the park and slowing the introduction of potentially invasive ornamental plant species. Most visitors are likely unaware that they may be carriers of weed seeds, and many homeowners do not appreciate the possible negative effects of their choices of ornamental species for landscaping. Examples of past and recent outreach activities that were successful include sole cleaning for runners in organized races in HAVO (Higashino *et al.* 1983) and replacement of alien tree ferns by native species for homeowners near the park (T. Tunison, pers. comm.).

Recommendations

- Refine and regularly update the list of target incipient invasive species near the park, using information from the Hawai`i Weed Risk Assessment, published records of new alien plant species on Hawai`i and Maui Islands, and the work of the Invasive Species Committees, such as BIISC. All new alien plant records for the park and ornamentals present in adjacent subdivisions that are known to be naturalized elsewhere are appropriate additions to the target incipient species list of HAVO.
- Periodically repeat the roadside weed survey within and near HAVO, at least every five years.
- If resources are available, it would be prudent to survey Highway 11 and Crater Rim Road more often than every five years, as these were the internal roads with the highest number of target alien species and the sites where new introductions to the park were found. Yearly surveys on foot of these two park roads, as well as examination of the area around park headquarters and offices, concessions, and the parking lots of well-visited overlooks would be useful for early detection of incipient alien plants. While vehicular weed surveys have been used on other islands (Starr *et al.* in prep.), many herbaceous weeds and alien grasses are missed by driving rather than walking (K. Bio, unpublished data).
- Conducting outreach to homeowners in residential subdivisions near the park to discourage the planting of invasive species that may invade HAVO may be an effective way to reduce the number of invasive alien plant species near the park. There are now community groups in the Volcano area conducting outreach to homeowners regarding landscaping with natives

and avoidance of invasive alien plants (Volcano Community Association [VCA] 2009). Partnership with local organizations already engaged in outreach and education about invasive plants and animals (VCA, BIISC) may be a cost-effective way to achieve some of the park's goals for reduction of potential invasive plants in adjacent lands.

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APPENDIX 1

Alien plant species targeted for the roadside survey, showing frequency along roadsides in HAVO (including buffers but excluding Highway 130 and Stainback) and Hawai`i Weed Risk Assessment (HWRA) rating.

Scientific name	Common name	Family	Category	Frequency (%)	HWRA ¹ category	Comments
<i>Abutilon grandifolium</i>	hairy abutilon	Malvaceae	widespread	9.0	n/a	
<i>Acacia confusa</i>	Formosa koa	Fabaceae	widespread	8.0	10 H	
<i>Acacia farnesiana</i>	klu	Fabaceae	regional	0.0	14 H	not encountered
<i>Acacia mearnsii</i> **	black wattle	Fabaceae	widespread	5.0	15 H	
<i>Acacia melanoxylon</i>	Australian blackwood	Fabaceae	incipient	0.0	12 H	not encountered
<i>Acacia paramattensis</i>	no common name	Fabaceae	unknown	0.0	9 H	not encountered
<i>Agave americana</i>	century plant	Agavaceae	ornamental	5.0	n/a	
<i>Agave sisalana</i>	sisal, malina	Agavaceae	widespread	6.0	n/a	
<i>Ageratina riparia</i> **	spreading mist flower	Asteraceae	widespread	24.0	n/a	
<i>Albizia chinensis</i>	Chinese albizia	Fabaceae	regional	0.0	8 H	Hwy 130 only
<i>Allamanda cathartica</i>	allamanda	Apocynaceae	ornamental	6.0	8 H	
<i>Allamanda schottii</i>	dwarf allamanda	Apocynaceae	ornamental	0.0	n/a	Hwy 130 only
<i>Alpinia</i> sp.	shell ginger	Zingiberaceae	ornamental	0.0	4 to 10	Hwy 130 only
<i>Andropogon virginicus</i> **	broomsedge	Poaceae	widespread	89.0	n/a	
<i>Anemone hupehensis</i> var. <i>japonica</i>	Japanese anemone	Ranunculaceae	widespread	9.0	n/a	
<i>Angiopteris evecta</i>	king fern	Marattiaceae	incipient	0.0	8 H	Hwy 130 and Stainback
<i>Archontophoenix alexandrae</i>	Alexandra palm	Arecaceae	regional	0.0	8 H	Hwy 130 only
<i>Ardisia crenata</i>	Hilo holly	Myrsinaceae	ornamental incipient	1.0	10 H	
<i>Arthrostemum ciliatum</i>	no common name	Melastomataceae	incipient	0.0	n/a	Hwy 130 only
<i>Arundina graminifolia</i>	bamboo orchid	Orchidaceae	widespread	57.0	n/a	
<i>Arundo donax</i>	Spanish reed	Poaceae	incipient	0.0	12 H	not encountered
<i>Asclepias curassavicum</i>	butterfly weed	Asclepiadaceae (Apocynaceae)	widespread	0.0	n/a	Hwy 130 only
<i>Asclepias physocarpa</i>	balloon plant	Asclepiadaceae	widespread	24.0	8 H	

Scientific name	Common name	Family	Category	Frequency (%)	HWRA ¹ category	Comments
<i>Axonopus compressus</i>	broad-leaf carpetgrass	Poaceae	regional	4.0	15 H	
<i>Axonopus fissifolius</i>	narrow-leaf carpetgrass	Poaceae	widespread	71.0	15 H	
<i>Bambusa</i> spp.	unidentified bamboo	Poaceae	ornamental	10.0		
<i>Bambusa vulgaris</i>	common bamboo	Poaceae	ornamental	0.0	5 L	Hwy 130 only
<i>Bauhinia monandra</i>	orchid tree	Fabaceae	regional	2.0	7 H	
<i>Begonia hirtella</i>	begonia	Begoniaceae	regional	0.0	n/a	Hwy 130 only
<i>Begonia reniformis</i>	grape-leaf begonia	Begoniaceae	regional	0.0	n/a	not encountered
<i>Begonia</i> spp.	begonia, unidentified	Begoniaceae	ornamental	0.0	n/a	not encountered
<i>Blechnum appendiculatum</i>	no common name	Blechnaceae	regional	1.0	n/a	synonym: <i>Blechnum occidentale</i>
<i>Bromus catharticus</i>	rescue grass	Poaceae	widespread	3.0	n/a	
<i>Bromus diandrus</i>	ripgut grass	Poaceae	widespread	2.0	n/a	synonym: <i>Bromus rigidus</i>
<i>Bryophyllum pinnatum</i>	air plant	Crassulaceae	widespread	16.0	n/a	synonym: <i>Kalanchoe pinnata</i>
<i>Bryophyllum tubiflorum</i>	chandelier plant	Crassulaceae	widespread	4.0	n/a	synonym: <i>Kalanchoe tubiflora</i>
<i>Buddleja asiatica</i>	Asiatic butterfly bush, dog tail	Buddlejaceae (Scrophulariaceae)	widespread	43.0	9 H	
<i>Buddleja davidii</i>	butterfly bush	Buddlejaceae (Scrophulariaceae)	ornamental	3.0	13 H	
<i>Buddleja madagascariensis</i>	smoke bush	Buddlejaceae (Scrophulariaceae)	incipient	2.0	7 H	
<i>Caesalpinia decapetala</i>	wait-a-bit, mysore thorn	Fabaceae	regional	4.0	20 H	
<i>Calotropis gigantea/C. procera</i>	crownflower	Asclepiadaceae	incipient	1.0	15 H	combined species
<i>Casuarina equisetifolia</i>	ironwood	Casuarinaceae	widespread	4.0	21 H	
<i>Casuarina</i> spp.	ironwood, unidentified	Casuarinaceae	incipient	6.0	12 to 20 H	

Scientific name	Common name	Family	Category	Frequency (%)	HWRA ¹ category	Comments
<i>Cecropia obtusifolia</i>	trumpet tree	Cecropiaceae (Urticaceae)	regional	3.0	10 H	
<i>Cenchrus ciliaris</i>	Buffel grass	Poaceae	widespread	0.0	n/a	not encountered
<i>Cenchrus echinatus</i>	common sandbur	Poaceae	widespread	13.0	n/a	
<i>Cestrum aurantiacum</i>	orange cestrum	Solanaceae	ornamental incipient	0.0	n/a	Hwy 130 only
<i>Cestrum diurnum</i>	day cestrum	Solanaceae	ornamental incipient	0.0	n/a	residential only
<i>Cestrum nocturnum</i>	night cestrum	Solanaceae	incipient	1.0	17 H	
<i>Citharexylum spinosum</i>	fiddlewood	Verbenaceae	incipient	2.0	7 H	
<i>Clidemia hirta</i> **	Koster's curse	Melastomataceae	widespread	0.0	n/a	Hwy 130 and Stainback
<i>Clusia rosea</i>	autograph tree	Clusiaceae	widespread	2.0	5 Eval.	
<i>Coccinia grandis</i> **	ivy gourd	Cucurbitaceae	regional	0.0	21 H	not encountered
<i>Coffea arabica</i>	Arabian coffee	Rubiaceae	ornamental	0.0	2 H	Hwy 130 only
<i>Cortaderia</i> spp. **	Pampas grass	Poaceae	ornamental	2.0	24 to 25 H	
<i>Cotoneaster pannosus</i>	cotoneaster	Rosaceae	ornamental incipient	0.0	7 H	residential only
<i>Crotalaria lanceolata</i>	lance-leaf rattlepod	Fabaceae	incipient	2.0	n/a	Hwy 11, Chain of Craters, and 130
<i>Cryptostegia grandiflora</i>	India rubber vine	Asclepiadaceae	incipient	0.0	13 H	not encountered
<i>Cyperus rotundus</i>	nut grass	Cyperaceae	widespread	0.0	n/a	not encountered
<i>Dactylis glomerata</i>	orchardgrass	Poaceae	widespread	8.0	n/a	
<i>Delairea odorata</i>	German ivy	Asteraceae	widespread	0.0	14 H	synonym: <i>Senecio mikanioides</i> ; not encountered
<i>Desmodium cajanifolium</i>	tick trefoil	Fabaceae	widespread	7.0	n/a	
<i>Desmodium incanum</i> /D. <i>intortum</i>	Spanish clover	Fabaceae	regional	15.0	n/a	
<i>Dicksonia</i> spp.	New Zealand tree fern	Dicksoniaceae	ornamental	1.0	n/a	
<i>Digitaria abyssinica</i> ?	no common name	Poaceae	incipient	1.0	n/a	tentative identification
<i>Digitaria insularis</i>	sourgrass	Poaceae	incipient	4.0	n/a	

Scientific name	Common name	Family	Category	Frequency (%)	HWRA ¹ category	Comments
<i>Dissotis rotundifolia</i>	no common name	Melastomataceae	ornamental incipient	0.0	10 H	Hwy 130 only
<i>Ehrharta stipoides</i>	meadow ricegrass	Poaceae	widespread	22.0	n/a	
<i>Elaeagnus</i> sp.	oleaster	Eleagnaceae	ornamental incipient	0.0	13 H	residential only
<i>Epidendrum x obrienianum</i>	butterfly orchid	Orchidaceae	incipient	1.0	n/a	
<i>Equisetum</i> sp.	scouring rush	Equisetaceae	ornamental incipient	0.0	n/a	residential only, maybe <i>E. hyemale</i>
<i>Eragrostis elongata</i>	lovegrass	Poaceae	incipient	1.0	n/a	Hwy 11, 130, Stainback
<i>Erigeron karvinskianus</i>	daisy fleabane	Asteraceae	incipient	6.0	11 H	
<i>Eriobotrya japonica</i>	loquat	Rosaceae	incipient	8.0	0.5 Eval.	
<i>Eucalyptus robusta</i>	swamp mahogany	Myrtaceae	widespread	0.0	3 L	Hwy 130 and Stainback
<i>Eucalyptus</i> spp.	eucalyptus	Myrtaceae	widespread	18.0	- 3 - 11 H	
<i>Euphorbia hyssopifolia</i>	spurge	Euphorbiaceae	incipient	1.0	n/a	addition, Hwy 11 synonym: <i>Chamaesyce hyssopifolia</i>
<i>Falcataria moluccana</i>	albizia	Fabaceae	widespread	4.0	8 H	synonym: <i>Paraserianthes falcataria</i>
<i>Ficus elastica</i>	rubber tree	Moraceae	ornamental	0.0	- 5 L	Hwy 130 only
<i>Ficus macrophylla</i>	Moreton bay fig	Moraceae	incipient	0.0	3 Eval.	not encountered
<i>Ficus microcarpa</i>	Chinese banyan	Moraceae	widespread	2.0	10 H	
<i>Ficus platypoda</i>	Australian fig	Moraceae	ornamental	0.0	n/a	not encountered
<i>Flindersia brayleyana</i>	Queensland maple	Rutaceae	regional	1.0	- 3 L	
<i>Fraxinus uhdei</i>	tropical ash	Oleaceae	widespread	0.0	11 H	Stainback Hwy only
<i>Fuchsia magellanica</i>	fuchsia	Onagraceae	ornamental	0.0	n/a	Stainback Hwy only
<i>Fuchsia paniculata</i>	fuchsia	Onagraceae	ornamental	0.0	n/a	residential only
<i>Grevillea banksii</i> **	kāhili flower	Proteaceae	regional	5.0	8 H	
<i>Grevillea robusta</i>	silk oak, silver oak	Proteaceae	widespread	24.0	5 Eval.	
<i>Hebe speciosa</i>	hebe, showy veronica	Scrophulariaceae (Plantaginaceae)	ornamental incipient	1.0	n/a	residential and Crater Rim
<i>Hedera helix</i>	English ivy	Araliaceae	widespread	4.0	10 H	
<i>Hedychium coronarium</i>	white ginger	Zingiberaceae	widespread	14.0	14 H	
<i>Hedychium flavescens</i>	yellow ginger	Zingiberaceae	widespread	15.0	n/a	
<i>Hedychium gardnerianum</i>	kāhili ginger	Zingiberaceae	widespread	26.0	16 H	

Scientific name	Common name	Family	Category	Frequency (%)	HWRA ¹ category	Comments
<i>Hedychium greenei</i>	red-flowered ginger	Zingiberaceae	ornamental	3.0	n/a	
<i>Heliocarpus popayanensis</i>	white moho	Tiliaceae(Malvaceae)	regional	0.0	7 H	Hwy 130 only
<i>Heliotropium amplexicaule</i>	heliotrope	Boraginaceae	incipient	2.0	n/a	addition, Hwy 11
<i>Heterocentron subtriplinervium</i>	pearl flower	Melastomataceae	regional	6.0	n/a	
<i>Heterotheca grandiflora</i>	telegraph plant	Asteraceae	incipient	5.0	n/a	
<i>Hippobroma longiflora</i>	star of Bethlehem	Campanulaceae	regional	0.0	n/a	Hwy 130 only
<i>Holcus lanatus</i>	velvetgrass	Poaceae	widespread	38.0	n/a	
<i>Homolanthus populifolius</i>	bleeding heart	Euphorbiaceae	incipient	1.0	n/a	synonym: <i>Omalanthus populifolius</i>
<i>Hyparrhenia rufa</i>	thatching grass, jaragua	Poaceae	regional	27.0	n/a	
<i>Hypericum kouytchense</i>	St. John's wort	Clusiaceae (Hypericaceae)	incipient	2.0	n/a	
<i>Hyptis pectinata</i> **	comb hyptis	Lamiaceae	widespread	26.0	n/a	
<i>Ilex aquifolium</i>	English holly	Aquifoliaceae	ornamental incipient	1.0	n/a	
<i>Impatiens walleriana</i>	balsam, touch-me-not	Balsaminaceae	regional	12.0	6 L	
<i>Ipomoea</i> sp.	morning glory	Convolvulaceae	ornamental incipient	0.0	1 to 14	residential only
<i>Jacaranda mimosifolia</i>	jacaranda	Bignoniaceae	regional	6.0	1 L	
<i>Jasminum fluminense</i>	jasmine	Oleaceae	regional	0.0	16 H	not encountered
<i>Juncus effusus</i>	Japanese mat rush	Juncaceae	widespread	1.0	n/a	
<i>Justicia betonica</i>	white shrimp plant	Acanthaceae	incipient	4.0	n/a	
<i>Lantana camara</i>	lantana	Verbenaceae	widespread	4.0	21 H	
<i>Lantana montevidensis</i>	trailing lantana	Verbenaceae	ornamental	0.0	16 H	not encountered
<i>Leonotis nepetifolia</i>	lion's ear	Lamiaceae	incipient	1.0	19 H	addition, Hwy 11
<i>Lepidium africanum</i>	pepperwort	Apiaceae	incipient	1.0	10 H	addition, Hwy 11
<i>Leptospermum scoparium</i>	manuka	Myrtaceae	ornamental incipient	1.0	3 H	
<i>Leucaena leucocephala</i>	koa haole	Fabaceae	widespread	25.0	15 H	
<i>Ligustrum sinense</i>	Chinese privet	Oleaceae	incipient	1.0	11 H	
<i>Lonicera japonica</i>	Japanese honeysuckle	Caprifoliaceae	incipient	7.0	12 H	

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<i>Lophospermum erubescens</i>	large roving sailor	Scrophulariaceae (Plantaginaceae)	incipient	3.0	5 L	
<i>Luculia gratissima</i>	luculia	Rubiaceae	ornamental incipient	0.0	n/a	residential only
<i>Macaranga mappa</i>	bingabing	Euphorbiaceae	regional	3.0	11 H	
<i>Macaranga tanarius</i>	no common name	Euphorbiaceae	incipient	1.0	n/a	
<i>Macleaya cordata</i> **	plume poppy	Papaveraceae	regional	3.0	n/a	synonym: <i>Bocconia frutescens</i>
<i>Manihot glaziovii</i>	Ceara rubber tree	Euphorbiaceae	regional	1.0	n/a	
<i>Melaleuca quinquenervia</i>	paperbark	Myrtaceae	regional	12.0	15 H	
<i>Melastoma sanquineum</i> **	fox-tongued melastoma	Melastomataceae	regional	1.0	n/a	
<i>Melastoma septemnerivium</i> **	melastoma	Melastomataceae	regional	3.0	13 H	synonym: <i>Melastoma candidum</i>
<i>Melia azedarach</i>	Chinaberry	Meliaceae	widespread	2.0	14 H	
<i>Melinis minutiflora</i>	molasses grass	Poaceae	widespread	95.0	n/a	
<i>Melinis repens</i>	Natal redbtop	Poaceae	widespread	76.0	n/a	
<i>Melochia umbellata</i>	no common name	Sterculiaceae (Malvaceae)	regional	5.0	n/a	
<i>Merremia aegyptia</i>	hairy merremia	Convolvulaceae	regional	0.0	n/a	not encountered
<i>Merremia tuberosa</i>	wood rose	Convolvulaceae	regional	2.0	12 H	
<i>Metrosideros excelsa</i>	pohutukawa	Myrtaceae	ornamental	0.0	5 L	residential only
<i>Miconia calvescens</i>	velvet tree	Melastomataceae	widespread	0.0	14 H	Hwy 130 only
<i>Monstera deliciosa</i>	monstera	Araceae	ornamental	3.0	1 L	
<i>Montanoa hibiscifolia</i> **	tree daisy	Asteraceae	incipient	5.0	13 H	
<i>Morella faya</i> **	firetree, faya	Myricaceae	widespread	39.0	8 H	synonym: <i>Myrica faya</i>
<i>Murdannia</i> sp.	no common name	Commelinaceae	incipient	1.0	n/a	synonym: <i>Aneilema</i> sp.
<i>Neonotonia wightii</i>	glycine	Fabaceae	regional	17.0	7 H	synonym: <i>Glycine wightii</i>
<i>Nephrolepis brownii</i>	Asian swordfern	Lomariopsidaceae	widespread	82.0	n/a	synonym: <i>Nephrolepis multiflora</i>
<i>Nicotiana glauca</i>	tree tobacco	Solanaceae	regional	0.0	15 H	not encountered
<i>Nicotiana tabacum</i>	tobacco	Solanaceae	ornamental	0.0	n/a	not encountered
<i>Ochna serrulata</i>	mickey-mouse plant	Ochnaceae	incipient	2.0	11 H	

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<i>Olea europaea</i> ssp. <i>cuspidata</i>	African olive	Oleaceae	widespread	4.0	n/a	synonym: <i>O. europaea</i> ssp. <i>africana</i>
<i>Olea europaea</i> ssp. <i>europaea</i>	olive	Oleaceae	ornamental	1.0	5 Eval.	
<i>Oplismenus hirtellus</i>	basketgrass	Poaceae	regional	1.0	n/a	
<i>Paederia foetida</i>	maile pilau	Rubiaceae	regional	1.0	21 H	synonym: <i>Paederia scandens</i>
<i>Panicum repens</i> **	torpedo grass	Poaceae	widespread	12.0	n/a	
<i>Paspalum conjugatum</i>	Hilo grass	Poaceae	widespread	15.0	28 H	
<i>Paspalum dilatatum</i>	Dallis grass	Poaceae	widespread	26.0	12 H	
<i>Paspalum notatum</i>	Bahia grass	Poaceae	incipient	9.0	16 H	
<i>Paspalum paniculatum</i>	no common name	Poaceae	incipient	9.0	n/a	
<i>Paspalum urvillei</i>	Vasey grass	Poaceae	widespread	70.0	n/a	
<i>Paspalum</i> sp. 6	unidentified	Poaceae	incipient	1.0	n/a	
	<i>Paspalum</i>					
<i>Paspalum</i> sp. 8	unidentified	Poaceae	incipient	1.0	n/a	
	<i>Paspalum</i>					
<i>Passiflora edulis</i>	liliko`i, passion fruit	Passifloraceae	regional	5.0	6 L	
<i>Passiflora foetida</i>	love-in-a-mist	Passifloraceae	widespread	5.0	n/a	
<i>Passiflora ligularis</i>	sweet granadilla	Passifloraceae	regional	2.0	n/a	
<i>Passiflora suberosa</i>	huehue haole	Passifloraceae	regional	0.0	n/a	not encountered
<i>Passiflora tarminiana</i> **	banana poka	Passifloraceae	widespread	2.0	24 H	
<i>Pennisetum clandestinum</i>	kikuyu grass	Poaceae	widespread	58.0	18 H	
<i>Pennisetum purpureum</i>	elephant grass	Poaceae	widespread	13.0	16 H	
<i>Pennisetum setaceum</i> **	fountain grass	Poaceae	widespread	16.0	26 H	
<i>Persicaria capitata</i>	knotweed, smartweed	Polygonaceae	widespread	58.0	n/a	synonym: <i>Polygonum capitatum</i>
<i>Phormium tenax</i>	New Zealand flax	Agavaceae (Xanthorrhoeaceae)	incipient	3.0	8 H	
<i>Photinia davidiana</i>	photinia	Rosaceae	incipient	0.0	- 2 L	residential only
<i>Phyllostachys nigra</i>	black bamboo	Poaceae	regional	0.0	n/a	Hwy 130 only
<i>Pinus patula</i>	Mexican weeping pine	Pinaceae	ornamental	1.0	n/a	
<i>Pinus radiata</i>	Monterey pine	Pinaceae	ornamental incipient	1.0	5 Eval.	
<i>Pinus</i> sp.	unidentified pine	Pinaceae	unknown	3.0	n/a	

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<i>Pithecellobium dulce</i>	Manila tamarind	Fabaceae	regional	0.0	14 H	not encountered
<i>Pityrogramma calomelanos/P. austroamericana</i>	silver fern, gold fern	Pteridaceae	widespread	38.0	n/a	combined two fern species
<i>Pluchea carolinensis</i>	sour bush	Asteraceae	widespread	74.0	n/a	synonym: <i>Pluchea symphytifolia</i>
<i>Pluchea indica</i>	Indian fleabane	Asteraceae	regional	0.0	n/a	not encountered
<i>Prosopis pallida</i>	kiawe, mesquite	Fabaceae	regional	0.0	n/a	not encountered
<i>Psidium cattleianum</i>	strawberry guava, waiawi	Myrtaceae	widespread	32.0	18 H	
<i>Psidium cattleianum</i> var. <i>littorale</i>	strawberry guava	Myrtaceae	regional	3.0	n/a	
<i>Psidium guajava</i>	common guava	Myrtaceae	widespread	50.0	21 H	
<i>Pterolepis glomerata</i>	no common name	Melastomataceae	regional	0.0	n/a	Hwy 130 and Stainback
<i>Pyracantha</i> spp.	firethorn, 3 species	Rosaceae	widespread	12.0	13 H	
<i>Rhodomyrtus tomentosa</i> **	downy myrtle	Myrtaceae	regional	0.0	8 H	residential only
<i>Rhynchospora caduca</i>	beak-rush	Cyperaceae	regional	8.0	n/a	
<i>Ricinus communis</i>	castor bean	Euphorbiaceae	widespread	12.0	21 H	
<i>Rubus argutus</i> **	blackberry	Rosaceae	widespread	31.0	21.5 H	
<i>Rubus ellipticus</i> var. <i>obcordatus</i> **	yellow Himalayan raspberry	Rosaceae	regional	14.0	18 H	
<i>Rubus glaucus</i>	no common name	Rosaceae	incipient	1.0	n/a	
<i>Rubus niveus</i> **	hill raspberry	Rosaceae	incipient	1.0	n/a	
<i>Rubus rosifolius</i>	thimbleberry	Rosaceae	widespread	8.0	10 H	
<i>Rubus</i> sp.	unidentified raspberry	Rosaceae	incipient	1.0	n/a	
<i>Samanea saman</i>	monkey pod	Fabaceae	regional	1.0	4 L	
<i>Sambucus mexicana</i>	elderberry	Caprifoliaceae (Adoxaceae)	incipient	3.0	9 H	
<i>Schedonorus arundinaceus</i>	reed fescue	Poaceae	incipient	1.0	n/a	synonym: <i>Festuca arundinacea</i>
<i>Schefflera actinophylla</i>	octopus tree	Araliaceae	incipient	6.0	13 H	
<i>Schefflera arboricola</i>	dwarf octopus tree	Araliaceae	incipient	1.0	3 Eval.	
<i>Schinus molle</i>	pepper tree	Anacardiaceae	regional	4.0	10 H	
<i>Schinus terebinthifolius</i>	Christmas berry	Anacardiaceae	widespread	28.0	19 H	

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<i>Schizachyrium condensatum</i>	bush beardgrass	Poaceae	widespread	85.0	8 H	
<i>Senecio madagascariensis</i> **	fireweed	Asteraceae	incipient	6.0	23 H	
<i>Senna occidentalis</i>	coffee senna	Fabaceae	widespread	1.0	n/a	synonym: <i>Cassia occidentalis</i>
<i>Senna pendula</i>	kolomona, kalamona	Fabaceae	widespread	2.0	n/a	synonyms: <i>Cassia pendula</i> , <i>C. bicapsularis</i>
<i>Senna surattensis</i>	kolomona, kalamona	Fabaceae	ornamental	0.0	0 Eval.	not encountered
<i>Setaria palmifolia</i>	palmgrass	Poaceae	widespread	13.0	n/a	
<i>Setaria sphacelata</i>	foxtail grass	Poaceae	incipient	2.0	n/a	new addition
<i>Solandra maxima</i>	cup of gold	Solanaceae	ornamental incipient	0.0	3 Eval.	not encountered
<i>Solanum pseudocapsicum</i>	Jerusalem cherry	Solanaceae	widespread	3.0	n/a	
<i>Sorghum arundinaceum</i>	sorghum	Poaceae	incipient	1.0	n/a	
<i>Spathodea campanulata</i>	African tulip tree	Bignoniaceae	regional	2.0	14 H	
<i>Sphaeropteris cooperi</i>	Cooper's tree fern, Australian tree fern	Cyatheaceae	incipient	1.0	8 H	residential and Wright Rd; synonym: <i>Cyathea cooperi</i>
<i>Sphagneticola trilobata</i>	wedelia	Asteraceae	incipient	5.0	13 H	synonym: <i>Wedelia trilobata</i>
<i>Sporobolus indicus</i>	Indian dropseed	Poaceae	incipient	3.0	n/a	addition, Chain of Craters and Hilina Pali
<i>Stenotaphrum secundatum</i>	St. Augustine grass	Poaceae	regional	0.0	n/a	not encountered
<i>Syzygium cumini</i>	Java plum	Myrtaceae	widespread	3.0	n/a	synonym: <i>Eugenia cumini</i>
<i>Syzygium jambos</i>	rose apple	Myrtaceae	widespread	4.0	n/a	synonym: <i>Eugenia jambos</i>
<i>Terminalia catappa</i>	tropical almond	Combretaceae	regional	0.0	4 L	Hwy 130 only
<i>Themeda villosa</i> **	Lyon's grass	Poaceae	incipient	0.0	n/a	Hwy 130 only
<i>Thevetia peruviana</i>	yellow oleander	Apocynaceae	ornamental incipient	4.0	9 H	
<i>Thunbergia alata</i>	black-eyed susan vine	Acanthaceae	incipient	4.0	n/a	
<i>Thunbergia fragrans</i>	white thunbergia	Acanthaceae	widespread	3.0	n/a	
<i>Thunbergia grandiflora</i>	Bengal trumpet vine	Acanthaceae	regional	0.0	11 H	not encountered

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<i>Thunbergia laurifolia</i>	purple allamanda	Acanthaceae	regional	0.0	11 H	not encountered
<i>Tibouchina granulose</i> **	no common name	Melastomataceae	ornamental	1.0	1 L	
<i>Tibouchina herbacea</i> **	glorybush	Melastomataceae	widespread	4.0	24 H	
<i>Tibouchina longifolia</i> **	no common name	Melastomataceae	regional	0.0	n/a	Hwy 130 only
<i>Tibouchina urvilleana</i> **	glorybush	Melastomataceae	regional	10.0	10 H	
<i>Tithonia diversifolia</i>	tree marigold	Asteraceae	regional	3.0	n/a	
<i>Toona ciliata</i>	Australian red cedar	Meliaceae	regional	3.0	2 Eval.	
Tree sp. 2, unidentified	unidentified tree	unknown	unknown	1.0	n/a	unidentified tree, Hwy 11
<i>Trema orientalis</i>	gunpowder tree	Ulmaceae (Cannabaceae)	widespread	7.0	n/a	
<i>Tropaeolum majus</i>	nasturtium	Tropaeolaceae	regional	7.0	n/a	
<i>Urochloa maxima</i>	Guinea grass	Poaceae	widespread	37.0	17 H	synonym: <i>Panicum maximum</i>
<i>Urochloa mutica</i>	California grass	Poaceae	widespread	11.0	n/a	synonym: <i>Brachiaria mutica</i>
<i>Urochloa plantaginea</i>	no common name	Poaceae	incipient	1.0	n/a	synonym: <i>Brachiaria plantaginea</i>
<i>Urochloa</i> sp.	unidentified	Poaceae	incipient	0.0	n/a	Hwy 130 only
	<i>Urochloa</i>					
<i>Verbascum thapsus</i> **	common mullein	Scrophulariaceae	widespread	2.0	n/a	
<i>Verbascum virgatum</i>	virgate or wand mullein	Scrophulariaceae	incipient	1.0	n/a	
Vine, unidentified	unidentified vine	unknown	unknown	0.0	n/a	Hwy 130 only
<i>Wisteria</i> sp.	wisteria	Fabaceae	ornamental	0.0	n/a	Hwy 130 only
<i>Xanthium strumarium</i> var. <i>canadense</i>	cocklebur	Asteraceae	widespread	0.0	n/a	not encountered

¹ Hawai`i Weed Risk Assessment: H = likely to be invasive; L = not recognized as invasive in Hawai`i; Eval. = Evaluate; n/a = not assessed (Daehler *et al.* 2004 and Daehler and Denslow 2011, website: http://www.botany.hawaii.edu/faculty/daehler/WRA/full_table.asp)

** Plant species designated as noxious weeds on at least one Hawaiian Island (Hawai`i State Department of Agriculture 1992).