

Three Mountain Alliance Weed Management Plan

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Prepared by Tanya Rubenstein and Paul Berkowitz (Maps/GIS) with assistance from Alison Ainsworth, David Benitez, Steve Bergfeld, Laura Nelson, Eldridge Naboia and Rhonda Loh

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Table of Acronyms

BIISC	Big Island Invasive Species Committee
CWCS	Comprehensive Wildlife Conservation Strategy; State of Hawai'i
DLNR	Department of Land and Natural Resources; State of Hawai'i
DOFAW	Division of Forestry and Wildlife; DLNR; State of Hawai'i
DOC	Department of Corrections; State of Hawai'i
FR	Forest Reserve; State of Hawai'i
GMAs	Game Management Areas; State of Hawai'i
HAVO	Hawai'i Volcanoes National Park; NPS
KKMA	Ka'ū Kapāpala Management Area
KCF	Kūlani Correctional Facility
KS	Kamehameha Schools
NARS	Natural Area Reserve System; State of Hawai'i
NKMA	North Kona Management Area
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge; USFWS
OHA	Office of Hawaiian Affairs; State of Hawai'i
OKMA	'Ōla'a Kīlauea Management Area
PIERC	Pacific Island Ecosystems Research Center; USGS
PWWFBS	Pu'u Wa'awa'a Forest Bird Sanctuary
SKMA	South Kona Management Area
TMA	Three Mountain Alliance
TNC	The Nature Conservancy
USDA FS	United States Department of Agriculture, Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

THE THREE MOUNTAIN ALLIANCE

1.1 Background

The Three Mountain Alliance (TMA) is a watershed management partnership comprised of nine members: Kamehameha Schools (KS), The Nature Conservancy (TNC), the State Department of Corrections Kūlani Correctional Facility (DOC), the State Department of Land and Natural Resources Division of Forestry and Wildlife (DOFAW), U.S. Department of Agriculture Forest Service (USDA FS) and Natural Resources Conservation Service (NRCS), and the U.S. Department of Interior National Park Service (NPS), Fish and Wildlife Service (USFWS), and Geological Survey (USGS).

The TMA encompasses over 404,686 hectares (one million acres) or 45% of Hawai'i island's total area and consists of four main management areas: 'Ōla'a Kīlauea (OKMA), Ka'ū Kapāpala (KKMA), South Kona (SKMA), and North Kona (NKMA). These management areas contain the best and most extensive remaining native forest on the island as determined by the Hawaiian High Islands Ecoregional Plan (The Nature Conservancy 1992) and other planning documents (Hawai'i Comprehensive Wildlife Conservation Strategy (CWCS) and U.S. Fish and Wildlife Service (FWS) recovery plans).

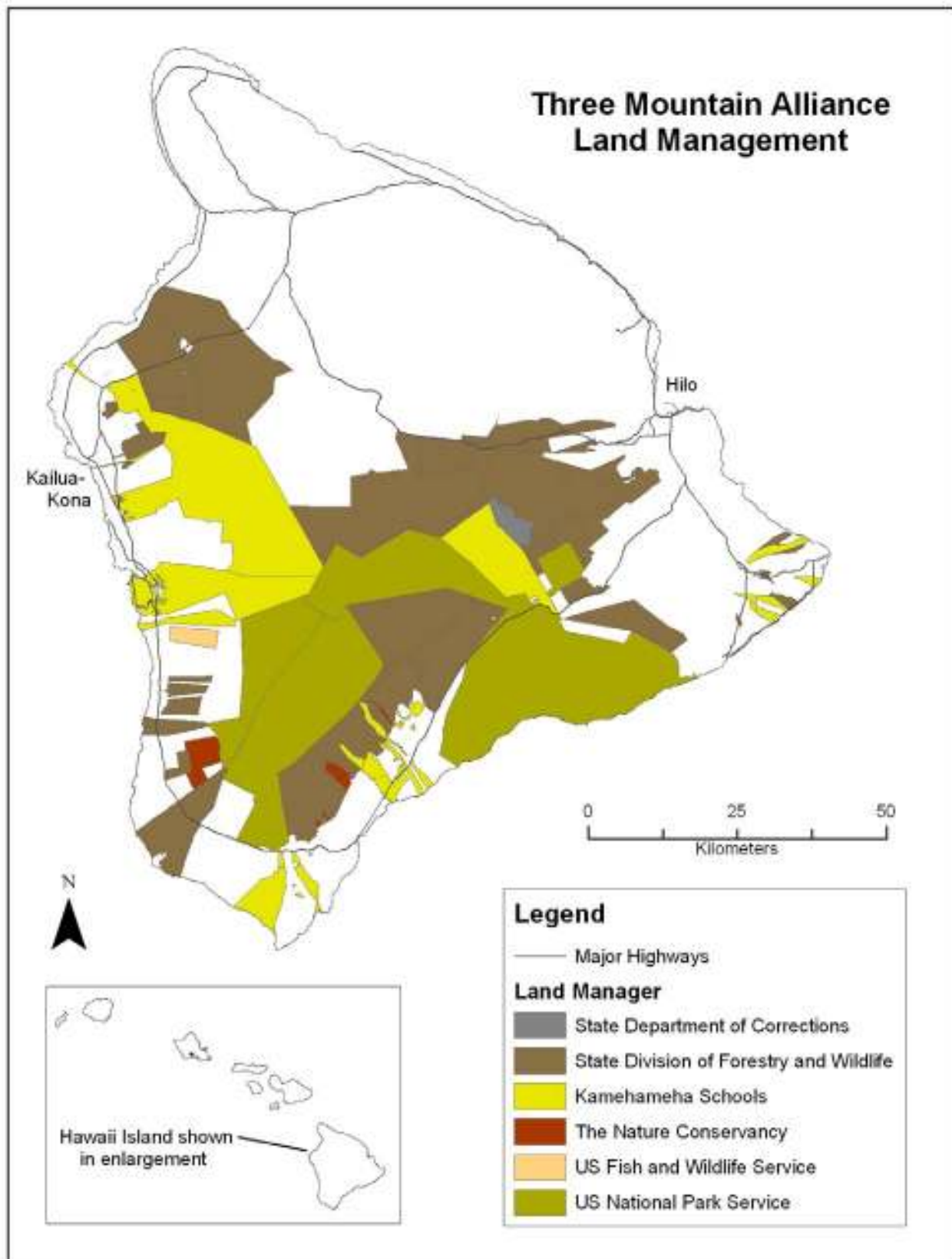
The TMA area includes three of the island's youngest volcanoes, Hualālai, Mauna Loa, and Kīlauea – all of which are active and characterize this area's landscape with extensive lava flows of varying ages influencing vegetation succession patterns. The TMA contains some of the largest expanses of intact native forest remaining in the Hawaiian Islands (approximately 50% of the State's remaining native habitat). Major native ecosystems found in the TMA include alpine, subalpine, montane (dry, mesic and wet), and lowland (dry, mesic and wet).

One of the major threats to native ecosystems and species in the TMA area is the uncontrolled spread of invasive non-native plants (weeds). The impacts of weed invasions in native Hawaiian habitats have received global attention, with over eighty-six species characterized as serious pests of native ecosystems. These and other weeds reduce habitat for native plants and animals by out-competing native plants, converting native ecosystems to non-native dominated vegetation, and altering soil moisture, nutrient and fire regimes.

Invasive non-native plants present an extremely difficult challenge. Because the seeds of some weeds persist for years in the soil bank and continued seed dispersal may occur from unmanaged areas, eradication can be exceedingly difficult after the plant is established, and control requires an ongoing effort to prevent further spread. However, control operations are expensive. TMA members have been working on weed control individually, but the most threatening weeds easily cross land ownership and management boundaries.

Weed management has been identified as a priority management action by the TMA (TMA 2007). The TMA seeks to jointly and strategically address the threat of weeds across land ownership and management boundaries at a landscape scale for greater effectiveness. A regional effort in mapping, planning and control will greatly increase the success of weed control across the TMA area and provide greater protection for the most intact native ecosystems and watersheds.

Figure 1: Three Mountain Alliance Project Area and Landowners



1.2 Weed Species Evaluation and Prioritization

Weed species were identified as priorities for each of the four TMA management areas based on observed invasiveness in natural areas in Hawaii and other criteria including growth form, dispersal mechanisms, ability to displace native vegetation and ability to alter ecosystem cycles (water, nutrients and succession). Additionally, consultation with TMA members, local invasive species managers, biologists and published literature contributed to the prioritization. New species are likely to be added to these priority lists in the future.

In order to better target joint TMA monitoring and control efforts with the limited resources available, this plan focuses on a relatively narrow list of the highest priority weed species that are currently present in the TMA. These weeds are a priority for joint management to protect and restore the highest quality native ecosystems in the TMA area. Individual landowning members of the TMA may have additional weed species they control in areas that are not necessarily a priority for the TMA. Certain weed species may be present throughout the TMA, but are identified as a TMA priority in a certain management area(s) due to the particular ecological conditions and conservation priorities for that area. Other weed species may be added to the TMA priority weed list if monitoring shows their range and abundance increasing in native ecosystems targeted for management.

The TMA will work closely with the Big Island Invasive Species Committee (BIISC) to coordinate prevention, early detection of and rapid response to weeds which are incipient to the island on partnership lands. Additionally, TMA will focus on control of established priority weeds in pristine areas or areas with recovery potential.

Priority Weed Species Description (general information compiled from various sources on www.hear.org and TMA members).

Anemone hupehensis (Japanese anemone) - Erect perennial herbs with compound basal leaves arranged in threes. White flowers, often tinged pink or purple, lower surface velvety pubescent. Wind-dispersed seeds numerous in a spherical head. In Hawai'i, this species is naturalized and locally common in open, disturbed areas and in mesic and wet forest, 1,080-1,530 meters. http://www.hear.org/species/anemone_hupehensis/ Present throughout the TMA and considered a high priority weed in some portions of the SKMA. This species appears to be more disruptive in drier disturbed habitats of the SKMA than in wet forest areas.

Ageratina adenophora (Maui pamakani) - A semi-woody shrub up to 1.5 meters tall with stems that are hairy and usually purple. The leaves are simple, opposite and diamond shaped and the flowers are white. This species is a prolific seeder naturalized from relatively dry areas to wet forest 600-2,000 m. It displaces the forest understory, preventing the re-establishment of native species and is also a pasture weed. http://www.hear.org/species/ageratina_adenophora/ Present and considered a high priority weed in the NKMA based on its impacts on Maui. It would also be a high priority if detected in other TMA management areas.

Bocconia frutescens (bocconia, plume poppy) - A shrub/small tree to 6 meters tall with large, cleft leaves which are white on the underside and turn yellow with age. Produces large numbers of bird-dispersed seeds, and appears capable of forming thick stands and out competing native species in dry to mesic environments from approximately 300 -1,768 meter elevation http://www.hear.org/species/bocconia_frutescens/. Present and considered a high priority weed in the KKMA and SKMA, and would also be a high priority if detected in other TMA management areas.

Caesalpinia decapetala (cat's claw) - A shrub or sprawling, climbing bramble with sharp thorns on its stems and leaves. Its leaves have numerous leaflets, and it bears yellow flowers in clusters. Fruits are brown pods containing 4-9 seeds. Extremely thorny and aggressive and can form impenetrable thickets in pastures and disturbed areas as well as native forests http://www.hear.org/species/caesalpinia_decapetala/. This species is a priority weed in the KKMA.

Cestrum nocturnum (night blooming jasmine) - A shrub to 3.6 meters tall with alternate, shiny, oblong to ovate leaves and greenish yellow tubular flowers that are sweet smelling at night. Berries white, hard or succulent and dispersed by birds. Shade tolerant and forms dense thickets in mesic to wet forests http://www.hear.org/species/cestrum_nocturnum/. This species is a priority weed in the KKMA.

Clidemia hirta (Koster's curse) - A branched shrub to 3 meters tall with ovate leaves with 5–7 prominent veins with distinct lateral veins between giving a checked appearance, margins with fine hairs, somewhat scalloped or toothed. The flowers are small and white, and plants flower and fruit prolifically throughout the year, producing dark-blue berries filled with many very small seeds commonly spread by birds. An aggressive invader that is shade tolerant and can dominate the understory in wet and and mesic forests http://www.hear.org/species/clidemia_hirta/. This species is a priority weed in the OKMA, KKMA, SKMA and NKMA.

Cotoneaster pannosus (silver-leaf cotoneaster) - Shrub 2-5 meters tall with leaves whitish and hairy on underside on long arching branches, white, rose-like flowers and numerous red fruits. This popular ornamental plant escapes from cultivation. Plants are dispersed by birds and can form thickets along roads and pastures, in woodlands and shrublands, and in both disturbed and natural plant communities. This plant prefers cooler climates and poses the greatest risk to native mid-elevation shrubland and mesic forests where plants can readily germinate and form large stands. http://www.hear.org/species/cotoneaster_pannosus/ This species is a priority weed in the OKMA.

Delairia odorata (Cape ivy) - Is a rapidly growing smothering vine with yellow flowers. This species threatens native shrubland, mesic and dry forests. It can spread both vegetatively, through the spread of stolons, and sexually by seeds. Fragments (as short as an inch) can break off and re-root in new areas. http://www.hear.org/species/delairea_odorata/. This species is a priority weed in the SKMA and NKMA.

Grevillea robusta (silk oak) - Is a large evergreen tree 18-30 meters tall with a straight trunk and a moderately spreading crown. The deeply incised, fern-like leaves are dark green above, grayish-white or rusty-silky beneath. The stalked flowers are golden-orange in terminal, bottlebrush-like sprays. The fruits are brownish-black, leathery follicles containing one or two flat, winged seeds. The leaves produce an allelopathic substance that inhibits the establishment of other species. Widely planted and a prolific, wind-dispersed seeder, it is a weed of drier and mesic pastures and forests between 350 - 1,600 meters. http://www.hear.org/species/grevillea_robusta/ This species is present throughout the TMA but doesn't appear to spread as quickly and modify more intact wet forest habitat. It currently poses the greatest threat to the dry and mesic forests of the NKMA and is a potential threat to the drier portions of the KKMA.

Hedychium gardnerianum (kahili ginger) - Grows just over 2 meters tall in mesic to wet habitats from sea level to 1,700 meters elevation. It has lance-shaped leaves arranged in 2 rows along

the stem, stalked inflorescences produced midsummer through fall with strongly fragrant yellow flowers with elongated red stamens. The seeds are bright red outside and orange within. This species reproduces by stolons where already established (even small root fragments will regrow thick rhizomes) and/or bird dispersed seeds. It forms vast, dense colonies, displacing other plant species http://www.hear.org/species/hedychium_gardnerianum/. This species is a priority in the OKMA, KKMA, SKMA and NKMA.

Miconia calvescens (miconia) - A tree 4-15 meters tall which occurs in tropical montane forest. It has large (up to 80 cm in length) trinerved leaves that are dark-green above and purple below. A single tree can flower/fruit 2-3 times in a year. Flowering and fruiting occurs above 3-4 meters in height and at least 4-5 years old. Ripe fruits are dark purple, with each fruit containing 50-200 tiny seeds. In Hawaii, dispersal is presumably by birds. The invasive nature of *Miconia* is evident from its invasion of Tahiti, where over 60% of the island is heavily invaded with *Miconia*. <http://www.hear.org/hnis/reports/HNIS-MicCal.pdf>. This species is a priority in the OKMA, SKMA and NKMA and would be a priority if detected in other TMA areas.

Morella faya (faya) – Is a fast growing tree that invades a variety of habitats from disturbed pasture and rangeland to native mesic and wet open forests. Commonly known to spread rapidly and form thick monotypic stands that can crowd out desirable vegetation and alter ecosystem dynamics. This evergreen shrub or small tree can grow up to 8 meters tall. The fruits are dark red or blackish when mature. The seeds are spread by fruit eating birds. http://www.hear.org/starr/hiplants/reports/pdf/morella_faya.pdf. This species is a priority in all TMA management areas.

Passiflora tarminiana (banana poka) - A climbing, semi-woody vine with three lobed leaves, pink flowers, and fleshy yellow fruit that spreads via humans, birds and mammals. Banana poka can form a dense canopy and smother vegetation. This species has invaded many of the upland wet and mesic forests on the islands of Hawai'i. http://www.hear.org/species/passiflora_tarminiana/. It is a priority weed throughout the TMA, particularly in the OKMA and the NKMA.

Pennisetum setaceum (fountain grass) – A large, wind-dispersed, fire-tolerant bunch grass that grows primarily in dry and mesic habitats from sea level to above 2,500 m elevation. http://www.hear.org/species/pennisetum_setaceum/ Fountain grass is a significant weed in the NKMA where it covers vast areas. It is present but less of a dominant ecosystem component in the other TMA management areas.

Psidium cattleianum (strawberry guava, waiwi) - A tall evergreen shrub or slender tree to 6 meters tall with smooth, reddish, peeling bark. Leaves are dark green, shiny, opposite, ovate, and aromatic leaf and flowers are white with many stamens. The fruits are purplish-red or yellow with white pulp with many small hard seeds and are dispersed by birds and pigs. This shade-tolerant species is widely distributed in mesic to wet forests in Hawaii, and produces dense thickets. The density of stands and allelopathic characteristics inhibit other species. http://www.hear.org/species/Psidium_cattleianum/. This species is a priority in the OKMA, KKMA, SKMA and NKMA.

Rubus argutus (blackberry) - A prickly bramble with long erect or arching stems to 3 m long with slightly hairy, lateral branches that bear the flowers. Leaves broad, pinnate, 3–5 leaflets, upper surface smooth, lower hairy, midrib prickly as are leaf stems, margins serrate. Flowers in clusters, white. Fruits red maturing to black are spread by birds and other animals. This species can form impenetrable thickets and is a serious weed in a variety of disturbed habitats, including

mesic to wet forest and subalpine grassland, 200-2,300 m.

http://www.hear.org/species/rubus_argutus/ This species is present throughout the TMA. It is not necessarily a habitat modifying weed; however, it can take over disturbed areas and is a priority in the OKMA, KKMA and SKMA due its presence in areas targeted for ecosystem restoration.

Rubus ellipticus (yellow Himalayan raspberry) - A raspberry with large thorns and yellow fruits. This species has spread from cultivation and has become a pest in wet forests. It forms impenetrable thickets and crowds out native species in moist to wet disturbed areas of Hawai'i from 700-1,700 meters in elevation. It spreads by vigorous vegetative growth as well as by birds. http://www.hear.org/species/rubus_ellipticus/ This species is a priority in the OKMA and KKMA.

Schinus terebinthifolius (christmas berry) is a small tree to 6 meters high. The leaves are alternate and pinnately compound with about 7 leaflets each. The greenish white flowers are in clusters and male and female trees are separate. The fruit is a cluster of bright red "berries," with a single seed per berry, dispersed by birds. It fruits in fall and winter, hence the name "christmas berry." The seed is also used as a condiment, which accounts for the name "Brazilian peppertree." The resinous sap is aromatic. This species is widespread in Hawai'i in mesic to dry areas. There are dense infestations in lower elevations of the KKMA in drier pastures and disturbed areas but it does not appear to aggressively spread into the more intact wetter forested portions of this management area. This species appears to be a greater problem in drier, disturbed habitats. http://www.hear.org/species/schinus_terebinthifolius/ Christmas berry is a priority in the SKMA in disturbed forest areas targeted for restoration.

Setaria palmifolia (palm grass) - is a large-leafed, perennial grass up to 2 m tall. Leaf blades have prominent parallel veins giving the appearance of a palm leaf. The stiff hairs at nodes make it irritating to handle. The inflorescence is a green, open, branched panicle to .6 m long with seeds distributed by wind or granivorous birds. This species displaces native species and is well adapted to fire. In Hawai'i, it is naturalized and often common in mesic valleys, wet forest, and along streams, to 2,000 m; "displaces forages in pastures and natives in disturbed areas in mesic to wet forests. http://www.hear.org/species/setaria_palmifolia/ It is found throughout the TMA and it is currently a priority in the OKMA, KKMA, and SKMA.

Sphaeropteris cooperi (Australian tree fern) - is a large fast-growing tree fern (up to 12 m tall) with large triangular leaves with lacy blades. Its scaly brown stems fall off when dead, leaving an oval scar pattern. Unlike native Hawaiian tree ferns (*Cibotium* spp.), the stems of which have red hairs and thick, soft fiber wrapping, this species has white hairs on its stalks, and lacks the thick fiber wrapping. It is suited to shade and displaces understory vegetation. Found in residential areas escaping into wild areas. http://www.hear.org/species/Sphaeropteris_cooperi/ This species is a priority in the OKMA and KKMA.

Tibouchina herbacea (cane tibouchina) - is a semi-woody shrub up to 1 m tall with pink flowers with yellow anthers. The young branches are four-sided and densely covered with hairs. Leaves have parallel main veins (typical of the melastome family). This species is a prolific seeder, spread by birds that forms dense stands in pastures and disturbed forest sites and displaces native species. http://www.hear.org/species/Tibouchina_herbacea/ This species is present throughout the TMA and considered a priority in the OKMA and KKMA.

Tibouchina urvilleana (glorybush) – is a shrub or small tree up to 4 m tall with densely fuzzy opposite leaves with 5-7 prominent veins and purple flowers. This species is a pest in wet areas

from 200 - 1700 m elevation where it forms dense thickets in disturbed areas and spreads vegetatively. It does not appear to spread via seeds.
http://www.hear.org/species/tibouchina_urvilleana/ Although widespread in portions of the OKMA, this species does not currently threaten TMA conservation targets. This species is a priority in the KKMA.

Ulex europaeus (gorse) – is a thorny shrub with long sharp spines that grows up to 4.5 m tall. Gorse produces numerous bright yellow, pea-like flowers and hairy pods that split explosively upon maturity flinging out small hard seeds. Seeds can be spread by water, birds and/or vehicles. It is naturalized in open areas and along roads in mesic habitats from 200-2,100 m, forming dense, monotypic thickets. This species is a major problem on the island, particularly in pastures and rangelands on Mauna Kea. http://www.hear.org/species/ulex_europaeus/ This species is a priority in the OKMA and would also be a priority if detected in other TMA areas.

TMA Priority Weed Species

Scientific Name	Common Name	OKMA	KKMA	SKMA	NKMA
<i>Anemone hupehensis</i>	Japanese anemone			X	
<i>Ageratina Adenophora</i>	Maui pamakani				X
<i>Bocconia frutescens</i>	plume poppy		X	X	
<i>Caesalpinia decapetala</i>	cat's claw		X		X
<i>Cestrum nocturnum</i>	night blooming jasmine		X		
<i>Clidemia hirta</i>	Koster's curse	X	X	X	X
<i>Cotoneaster pannosus</i>	silver-leaf cotoneaster	X			
<i>Delairia odorata</i>	Cape ivy			X	X
<i>Grevillea robusta</i>	silk oak				X
<i>Hedychium gardnerianum</i>	kahili ginger	X	X	X	X
<i>Miconia calvenscens</i>	miconia	X		X	X
<i>Morella faya</i>	faya	X	X	X	X
<i>Passiflora tarminiana</i>	banana poka	X	X	X	X
<i>Pennisetum setaceum</i>	fountain grass	X	X	X	X
<i>Psidium cattleianum</i>	strawberry guava, waiwi	X	X	X	X
<i>Rubus argutus</i>	blackberry	X	X	X	
<i>Rubus ellipticus</i>	yellow Himalayan raspberry	X	X		
<i>Schinus terebinthifolius</i>	christmas berry			X	
<i>Setaria palmifolia</i>	palm grass	X	X	X	
<i>Sphaeropteris cooperi</i>	Australian tree fern	X	X		
<i>Tibouchina herbacea</i>	cane tibouchina	X	X		
<i>Tibouchina urvilleana</i>	glorybush	X			
<i>Ulex europaeus</i>	gorse	X			

1.3 Description of Weed Situation

Approximately 85% of the total TMA land area is comprised of native ecosystems. In general, the most intact portions of the TMA are in the upper elevations above 3,000 feet (1,000 m) elevation. Montane wet forests in the OKMA and KKMA are in better overall condition than drier ecosystems in the SKMA and NKMA (due to vulnerability from disturbance from human and other threats, greater fragmentation, and slower natural recovery in drier areas). TNC's Ecoregional Plan rates a majority of the TMA areas as either good or in very good condition with regard to their overall ecosystem viability ranking (TNC 2006b). DOFAW also identifies many

State owned areas in the TMA as highest quality native vegetation or predominantly native vegetation according to their draft management guidelines (DOFAW 2003a).

The maps depicting the general weed situation for each of the four management areas (Figures 2.3, 3.3, 4.3 and 5.3) were developed using data from Price et al. (2007) and are beneficial in depicting land cover, particularly in low and medium quality areas. The primary data source for these maps is the HIGAP land cover classification. The “high” category includes native dominated or mixed native and alien in order to represent those areas with substantial native species composition. The “medium” category includes areas that are dominated by non-native species but are not otherwise intensively developed. The “low” category includes all land cover classes pertaining to urban land, other developed lands, and active and former cropland. Many “high quality” areas shown on these maps, particularly at low elevations, are quite weedy and are not necessarily a management priority for the TMA.

1.4 General Weed Management Strategy

The TMA management goal for weeds is to protect high quality native Hawaiian ecosystems and endangered species from habitat altering, non-native invasive plants, through coordinated, regional planning and control efforts. The TMA as a partnership will focus financial and other resources on the highest priority joint weed management projects identified in this plan.

The TMA seeks to protect and recover native ecosystems to the point that they are self-sustaining, native-dominated communities with secure populations of native plant, invertebrate and forest bird species. Long-term goals include perpetuation of natural evolutionary and ecological processes (e.g. speciation, colonization, succession), and maintenance of biological and genetic diversity. Healthy native ecosystems will be more resilient to threats such as climate change, invasion and fragmentation and will be more capable of recovery after disturbance.

The TMA will focus resources and joint management efforts on significant areas of native-dominated forest, particularly above 3,000 feet (1,000 m) elevation. The biological integrity of the forest in these areas with respect to intactness and fragmentation is good to excellent. Ecological processes, driven largely by interactions between native invertebrates and plants, appear largely intact, but are affected by the loss of lower elevation species and ecosystems.

The TMA weed control program includes distribution mapping, development of a control strategy, chemical or manual control and follow-up monitoring to evaluate the effectiveness of control efforts. Weed mapping is essential to developing a comprehensive control strategy. Distribution mapping includes compiling transect monitoring data, incidental observations and reconnaissance surveys to map the distribution and abundance of weeds. Results from these surveys can then be used to direct subsequent studies along transects or in other priority areas, to better delineate the weed populations core extent and outlying individuals, and facilitate the development of control strategies.

New mapping technologies using high resolution aerial imagery and remote sensing offer great potential for large-scale, cost effective mapping of certain priority weeds even under dense canopy vegetation. The TMA will help develop shared mapping projects in priority weed control areas as well as assist partners in sharing relevant priority weed distribution information. The TMA can also assist partners in the development and use of new weed control technologies (e.g. aerial herbicide application). New methods for precise aerial application of herbicide to control species such as faya may be more cost effective for remote, isolated populations.

Management will generally focus on a larger, ecosystem level scale rather than intensive management of individual species in highly disturbed areas. This ecosystem management approach is more cost effective and has potential for positive results on a large number of native species, both common and rare. Portions of the project area are prioritized for management based on the quality of the native ecosystem because the probability of success is higher and costs are lower when the most intact and diverse resources are managed first. This approach is based on Hawaii Volcanoes National Park (HAVO) Special Ecological Areas (SEA) (Tunison and Stone 1992, HAVO 1996).

The SEA approach will be used to control high priority weed species within high priority management areas and/or keep these species from invading these areas. In SEA's, while the goal is to eliminate all the weeds each visit, there will always be new establishment of weeds that will need to be controlled in subsequent control visits. As weed densities decrease, workloads decrease and the time between control intervals can be increased (Tunison and Stone 1992, HAVO 1996).

Although the TMA will focus most joint weed control efforts on upper elevation, forested areas, additional communities contain important native species and/or assemblages (e.g. coastal, degraded forests that require restoration, rare lowland forest). These areas provide habitat for certain rare native species and are important buffers and links between mauka lands and ocean resources. In some cases, these areas may harbor very threatening localized weed species that are important to control in a timely manner to prevent their spread into high priority TMA areas. A concerted joint effort surveying, mapping and controlling these weeds before they have a chance to become more firmly established in native habitat is critical and will reduce the cost of control programs in the future.

The TMA Management Plan (TMA 2007) also identifies the following general proposed actions:

- Hire a TMA Weed Management Specialist to manage weed distributional data from different sources and assist members with weed data management, conduct surveys, create weed distribution maps, and prioritize weeds and areas for control.
- Initiate strategic control work on the highest priority projects on TMA lands with new field staff and existing weed control personnel. Direct control of invasive plants will be by proven mechanical and chemical methods or use of approved biocontrol agents where available. Monitor and map control efforts in order to evaluate the success of control.
- Support increased biocontrol research for high priority weed species for species that are unlikely to be controlled successfully using conventional and manual methods.

2. 'ŌLA'A KĪLAUEA MANAGEMENT AREA

2.1 Background

The 'Ōla'a Kīlauea Management Area (OKMA) includes lands on Mauna Loa and Kīlauea jointly managed by Hawai'i Volcanoes National Park (HAVO), DOC Kūlani Correctional Facility (KCF), DOFAW (Natural Area Reserves (NAR) Program and Forest Reserves (FR) Program) and Kamehameha Schools (KS) (Figure 2.1). This management area is the highest priority weed management area for the TMA due to the high level of ongoing intensive management (e.g. fencing, feral ungulate control and ongoing intensive weed management by TMA members) as well as the high quality of the remaining native ecosystems.

The OKMA includes a wide variety of ecosystems from dry to wet and from lowland to alpine ecosystems (summit of Mauna Loa) (Figure 2.2). This area also has two active volcanoes and numerous recent lava flows. The OKMA contains essential habitat for four species of endangered forest bird, and also supports the endangered 'io, nēnē, Hawaiian bat, two species of seabird, numerous rare invertebrates and rare and/or endangered plant species. The TMA goal for this area is to implement projects to protect and restore ecosystems with high biological value.

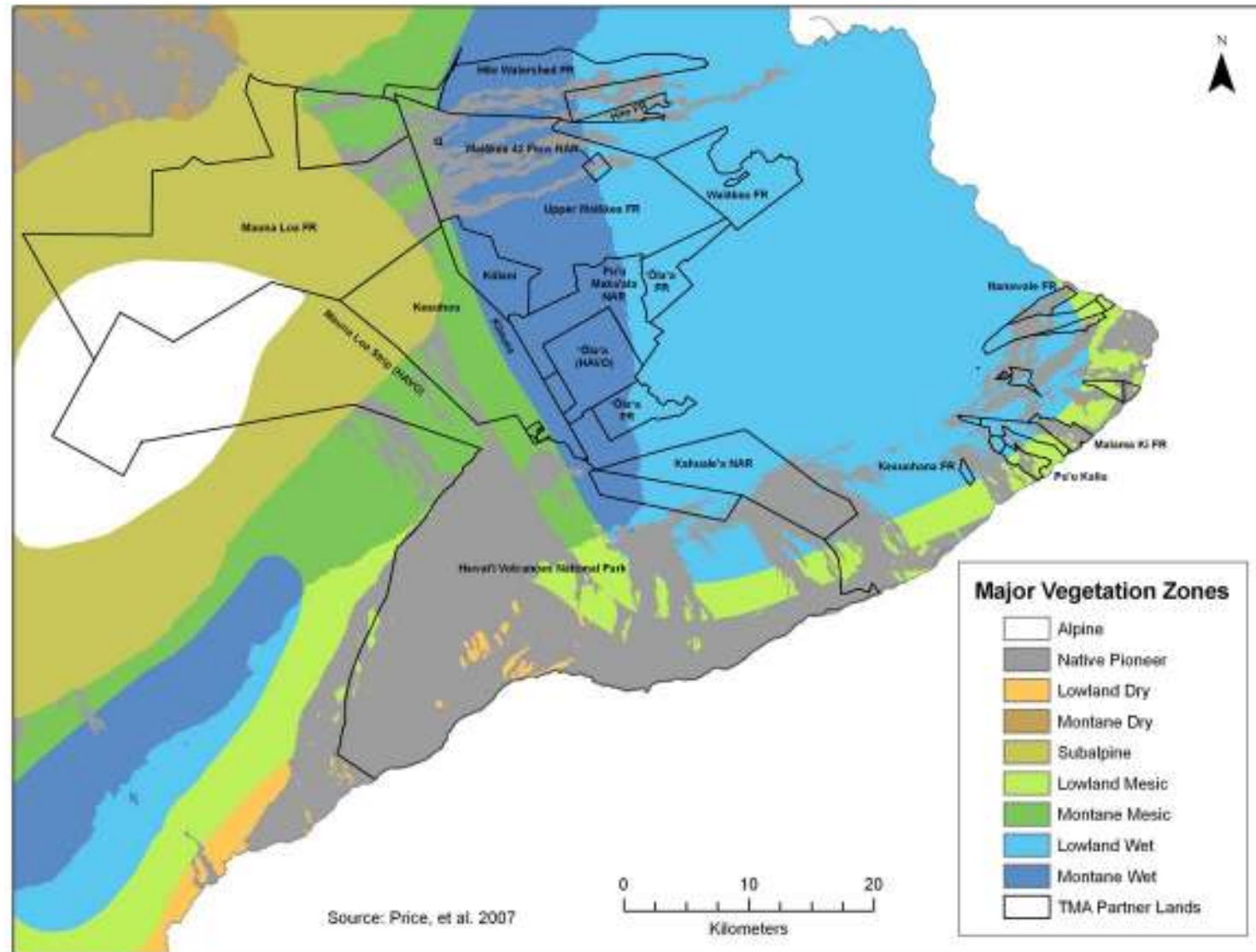
OKMA priority weed control targets are fenced, management units on private, state and federal lands in dry, mesic and wet montane and subalpine ecosystems from 1,200 -2,700 m elevation. Fencing and subsequent feral ungulate control (pigs, sheep, mouflon sheep and goats) have been the focus of TMA management efforts over the last twelve years, and the TMA has made significant progress in achieving our goal of creating a large network of contiguous, fenced management units across land ownership boundaries and reducing feral ungulate numbers. Fencing and removal of ungulates from fenced units is a critical first step in weed control because it allows for the recovery of native vegetation by minimizing ground disturbance.

The TMA has fenced and removed ungulates from 3,771 ha of the OKMA, and ungulate control work is underway in an additional 10,000 ha that has already been fenced. These units on DOFAW NAR (Pu'u Maka'ala), KCF, and KS lands (Keauhou and Kilauea) are adjacent to over 10,000 ha of existing fenced management units in HAVO ('Ōla'a and Mauna Loa Strip) (Figure 2.10). The focus of management efforts has been intact, montane, native forest. The fenced units include some of the best quality native forest in Hawai'i, and they are now being used as recovery areas for native ecosystems and rare and endangered species. The OKMA also contains degraded forest lands (former ranch lands that have been extensively logged) that are a high priority for restoration (e.g. Keauhou). Keauhou has had all cattle removed and has been fenced for feral ungulate management. Keauhou links high priority managed areas and provides important habitat for native species. Invasive weed control is now the most critical management action needed to maintain the high quality of the forest or restore important native ecosystems within fenced management units managed by TMA members.

Other portions of the OKMA are primarily managed by HAVO, DOFAW (FR and NAR), and KS. HAVO has a long-term and extensive weed management program for the portions of the park contained in the OKMA. DOFAW NAR lands (with the exception of fenced units in Pu'u Maka'ala NAR) have not been managed intensively for weeds. FR lands in the OKMA are vast and weed management (with the exception of a few high priority localized species) has not been a primary focus of management to date. KS lands at lower elevations (KS Puna lands) are highly modified remnant lowland wet forest and have had only limited management for weeds.

[illegible]

Figure 2.2. ‘Ōla’a Kīlauea Management Area Ecosystems.



2.2 Weed Inventory

Weed distribution was compiled using existing data from HAVO, USGS (data from KS lands of Keauhou and Kilauea), DOFAW – NAR (Pu'u Maka'ala NAR, Waiākea 42 Flow and Kahauale'a weed survey transects), BIISC, DOFAW FR incidental weed point/control data, and KS contractor data (Forest Solutions). Some survey data is quite old, and many portions of the OKMA have never been systematically surveyed for weeds.

Kīlauea Forest and Kūlani Correctional Facility (KS, DOC and DOFAW-NAR lands)

USGS monitored weeds along transects in Pu'u Kipu and Kūlani Cone and Mauna Loa Boy's School units for three years (1999-2001). These data provide a valuable baseline for weed distribution and abundance. USGS monitored each transect for presence or absence of 80 different weed species divided into three different priority groups and did cover estimates of weeds encountered. USGS staff also took incidental data on the presence of priority weeds during other survey and research work. In Wright Rd. unit, DOFAW NAR program has spearheaded weed monitoring along ten transects in 2003, 2006 and 2008 with assistance from TMA staff (detailed below under DOFAW – NAR).

Keauhou (KS lands)

TMA and HAVO staff did aerial surveys of portions of Keauhou and mapped priority weeds in 2006 and 2008. Aerial detection was particularly effective for locating isolated priority weeds (e.g. faya) in short stature forest at higher elevations and on open lava flows. Other portions of Keauhou have not been monitored comprehensively for weeds, but TMA staff have monitored priority weeds along several bird survey transects, and TMA and USGS staff collected incidental data on priority weeds while doing other management and research work. KS contractor (Forest Solutions) has categorized the abundance of yellow Himalayan raspberry (a focus species for intensive control efforts) in lower elevation portions of Keauhou.

HAVO (NPS)

HAVO has an extensive weed survey and monitoring program. The last comprehensive weed survey of park lands within the OKMA was done between 2001 and 2003 (Benitez in progress). The distributions of 118 target weed species were mapped along roads (137 km), trails (175 km), fences (120 km) and transects (79 km); and historic populations resurveyed. Aerial surveys were conducted across open environments extending from sea level to ~2,300 m elevation and have continued annually up to the present.

DOFAW – FR

DOFAW - FR (Mauna Loa FR, Upper Waiākea FR, Waiākea FR, 'Ōla'a FR, Hilo FR and Hilo Watershed FR) have not been systematically surveyed for weeds. DOFAW has location data for certain priority weed species location and control areas including gorse (Upper Waiākea FR), palm grass, gorse and yellow Himalayan raspberry (Hilo Watershed FR), yellow Himalayan raspberry and clidemia (Waiākea FR) and faya ('Ōla'a FR). DOFAW staff has incidental observations of expanding populations of yellow Himalayan raspberry in Upper Waiākea FR.

DOFAW - NAR

In Pu'u Maka'ala NAR staff and partners have monitored all species of non-native plants along four different sets of transects since 1988. Initially, 12.4 km of transect were read by the Hawaii Heritage Program to gather information to support the development of a comprehensive management plan. In 1995, over 27 km of new transects were installed across the higher elevation portions of the reserve above 1,000 m. As fenced units were built, additional finer scale transects were installed and monitored within specific units to document vegetation changes following ungulate removal including 4.1 km in Aku Unit (2000, 2008) and 10.6 km in the NAR portion of the Wright Rd Unit (2003, 2006 and 2008).

In Kahauale'a NAR, weeds were monitored along 15.7 km of transects by the Hawaii Heritage Program in 1988. In 1993, four additional transects were installed totaling 17.3 km within the reserve and the adjacent unencumbered State land Track 22.

In Waiākea 42 Flow NAR weed abundance and distribution were monitored in 1996 along two transects totaling 3.2 km.

Lower Puna (DOFAW FR and KS lands)

DOFAW FR in lower Puna (Nanawale FR, Malama Ki FR, Keauohana FR) have not had any systematic weed surveys. DOFAW has location data on certain priority species that have been a target of their control efforts (*Albizia* (*Albizia chinensis*), ironwood (*Casuarina equisetifolia*, palm grass and strawberry guava). BIISC has data on certain priority weeds (e.g. miconia in Nanawale FR).

Forest Solutions did weed transects and prepared a weed assessment for KS lands at Pu'u Kaliu (Koch 2007) that focused on areas that contained the best remaining native forest. Other KS parcels have not been surveyed for weeds.

2.3 High Priority Weed Species

<i>Clidemia hirta</i>	clidemia, Koster's curse
<i>Cotoneaster pannosus</i>	silver-leaf cotoneaster
<i>Hedychium gardnerianum</i>	kahili ginger
<i>Miconia calvescens</i>	miconia
<i>Morella faya</i>	faya
<i>Passiflora tarminiana</i>	banana poka
<i>Pennisetum setaceum</i>	fountain grass
<i>Psidium cattleianum</i>	strawberry guava, waiwi
<i>Rubus argutus</i>	blackberry
<i>Rubus ellipticus</i>	yellow Himalayan raspberry
<i>Setaria palmifolia</i>	palm grass
<i>Sphaeropteris cooperi</i>	Australian tree fern
<i>Tibouchina herbacea</i>	cane tibouchina
<i>Ulex europaeus</i>	gorse

2.4 Description of Weed Situation

The upper elevation portions of the OKMA (above 1,000 m) generally have a lower abundance of the most disruptive weed species. By comparison, lower elevations have extensive areas entirely covered with some of the highest priority weed species (Figure 2.3). Figures 2.4 - 2.5

shows the distribution of ten priority species within the OKMA and Figures 2.6 - 2.9 show distribution of four additional priority species within the priority TMA control areas.

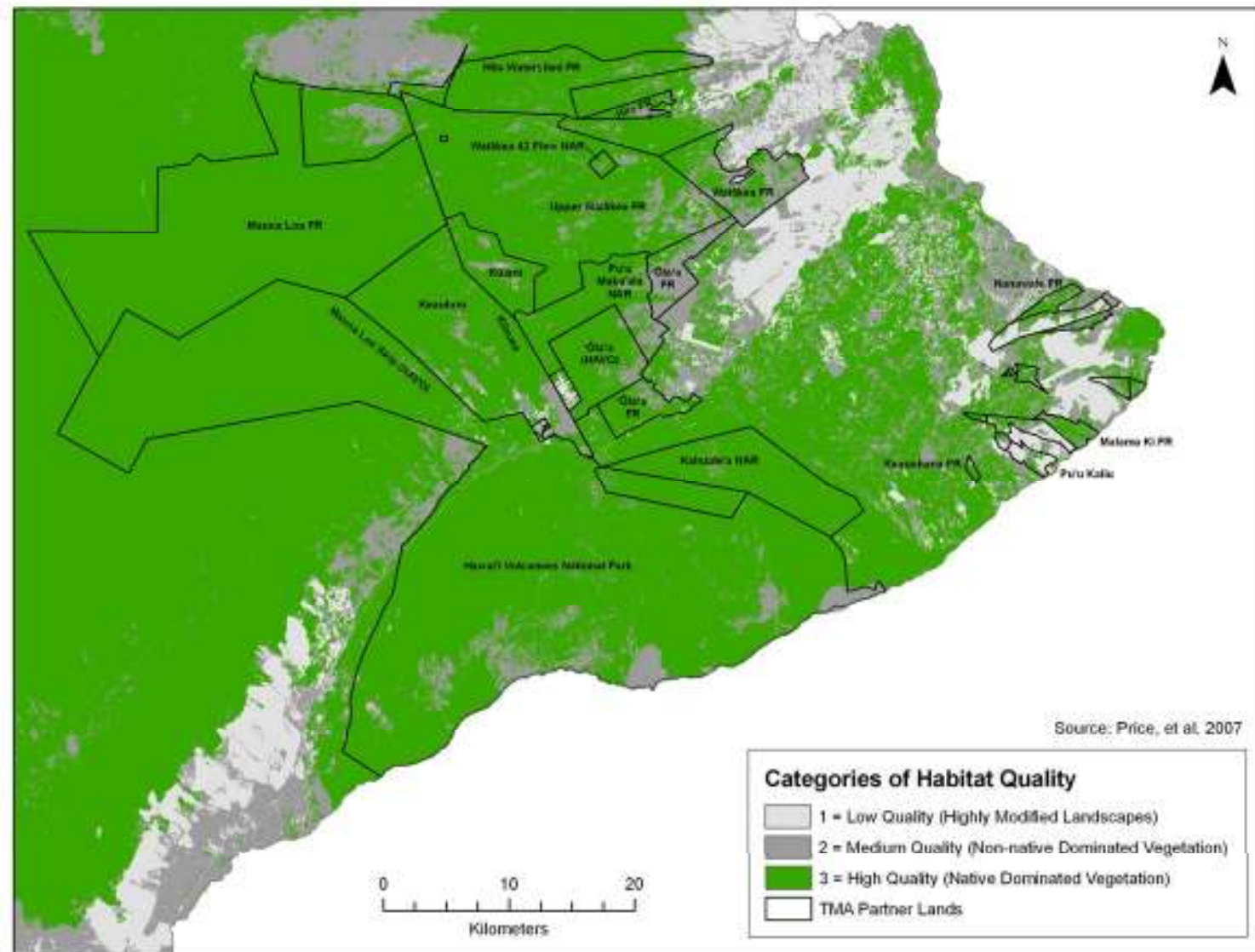
Kīlauea Forest (DOC, KS, NAR) and Kūlani Correctional Facility (DOC)

There are six fenced management units in Kīlauea Forest and at Kūlani Correctional Facility (KCF): Pu'u Kipu (DOC/KS), Kūlani Cone (KS/NAR), Wright Rd (KS/NAR), Mauna Loa Boy's School (DOC), North Boundary (DOC) and South Boundary (DOC) that protect mesic and wet montane forest ecosystems. These units, together totaling 4,557 ha, are ungulate free (with the exception of remnant pigs in the South Boundary Unit) and contain relatively low populations of priority weeds. Weed abundance and distribution in these units roughly corresponds with elevation, with the highest elevation units having the least weeds and lower elevation units the most. Roads adjacent to these units have greater weed problems than the densely forested interiors of the units. The lowest elevation unit, Wright Rd., has had impacts from past human activities (e.g. hapu'u (tree fern) harvesting) and is vulnerable to weed ingress from adjoining ranches and Volcano Village. High quality native forest within KCF is surrounded and intersected by highly disturbed areas with prison infrastructure (e.g. buildings, pastures, reservoir, cinder pit, sewage treatment facility and roads) that contain larger populations of high priority weeds. Priority weeds in these units include yellow Himalayan raspberry, banana poka, silver-leaf cotoneaster, blackberry, Australian tree fern, kahili ginger, strawberry guava and palm grass.

Keauhou (KS)

This 12,140 ha privately owned former ranch is a critical piece of land in regional conservation efforts because it connects forested lands in Kīlauea to those at HAVO, and contains important habitat for endangered bird species and plants. There are two fenced management units within Keauhou managed for feral ungulates, and the 1,214 ha Pu'u Lalaau Unit is currently ungulate-free. Ungulate control is underway in the Keauhou Unit (8,093 ha), and is scheduled to be completed in 2010. Upper elevations of Keauhou are very pristine with relatively few, localized occurrences of certain high priority weeds (e.g. faya) that are abundant in lower elevations. The Pu'u Lalaau Unit contains single individuals and/or small isolated populations of priority weeds including: kahili ginger, faya, fire thorn, yellow Himalayan raspberry, banana poka and palm grass. Blackberry, however, is widespread. Lower elevations of Keauhou have been extensively logged and ranched but still contain some very high quality native habitat. Priority weed problems are greatest in the lower elevation, wetter eastern portions of Keauhou due to past land management practices, proximity to core weed infestations and more favorable climate. This area contains the most problematic weed infestations and has been the focus of intensive control work by Forest Solutions on yellow Himalayan raspberry. This area also contains populations of other priority weeds that are rapidly expanding and spreading into the upper elevations (faya, strawberry guava, banana poka and kahili ginger).

Figure 2.3. General Weed Situation.



HAVO (NPS)

Over 400 non-native plant species grow in the OKMA portion of HAVO. Among these roughly 100 are considered highly disruptive invasive species (Smith 1985; Tunison and Stone 1992; Benitez in prep.). In general, lowland areas (<1,200 m elevation) are more degraded than upland areas. OKMA areas prioritized for weed control (>1,200 m elevation) in the park include wet forest, mesic forest, dry montane, and subalpine environments. With the exception of the eastern portion of 'Ōla'a rain forest (~2,000 ha) these areas are fenced and all ungulates excluded or reduced to remnant levels (>10,000 ha).

On the Mauna Loa Strip, montane and subalpine environments (>1,650 m) are native dominated with few invasive species. An exception is mullein (*Verbascum thapsus*) which is spreading on 'a'a flows and invading native shrublands and faya which is only just beginning to invade open areas. At lower elevations, faya becomes increasingly abundant on young lava flows, and 'ōhi'a (*Metrosideros polymorpha*) woodlands. In transitional dry to mesic koa (*Acacia koa*) forest between 1,250 and 1,650 m elevation, meadow ricegrass (*Ehrharta stipoides*), kikuyu grass (*Pennisetum clandestinum*), and blackberry are the primary weed species of concern. Strawberry guava, kahili ginger, nasturtium (*Tropaeolum majus*) and Jerusalem cherry (*Solanum pseudocapsicum*) are become increasingly widespread in the eastern portion of mesic koa forest that abuts Keauhou. Yellow Himalayan raspberry and fire thorn (*Pyracantha angustifolia*) are more locally distributed. In 2005, banana poka was discovered growing across several acres of koa forest (~1,400 m).

'Ōla'a wet forest (1,100-1,400 m) is divided into five fenced units and a sixth unit unmanaged for ungulates. Primary invasive weeds are kahili ginger, strawberry guava, yellow Himalayan raspberry and banana poka. Additional species of concern include faya, blackberry, Andean raspberry (*Rubus glaucus*), knotweed (*Persicaria capitata*) and palm grass. Weed infestations are kept low (<1% cover) in Pu'u unit and Small tract unit and in parts of Ag and Koa units through intensive weed control efforts under the SEA approach. In unmanaged areas, increasingly large populations of strawberry guava and palm grass occur eastward.

Primary invaders of wet forest on the summit of Kīlauea (~1,200 m elevation) include kahili ginger, strawberry guava, yellow Himalayan raspberry and faya. Other species of concern are blackberry, palm grass and knotweed. Several individuals of Australian tree fern were discovered in 2000, and <50 individuals have been discovered and removed since then. Weed infestations are kept low (<1% cover) in portions of rain forest currently managed for weeds under the SEA approach. Outside SEAs, populations of faya, strawberry guava and kahili ginger are increasing such that large areas are dominated by invasive weeds (>90% cover).

Dry 'ōhi'a woodlands (~1,200 m) straddle the area between the Mauna Loa Strip and Kīlauea summit. These woodlands have undergone extensive alteration by wildfire and invasive grasses (broomsedge (*Andropogon virginicus*), bush beardgrass (*Schizachyrium condensatum*) and molasses grass (*Melinis minutiflora*) and are the focus of intensive restoration efforts by the park. The area is managed as an SEA and acts as a buffer zone to reduce seed dispersal of weeds into adjacent OKMA areas identified for priority weed management. Woody invaders including faya, strawberry guava and yellow Himalayan raspberry are common and are routinely eradicated bi-annually by park staff.

Below 1,200 m, weeds are pervasive among the different plant communities. Exceptions are desert and lava flow communities, and portions of rain forest, seasonally dry woodland, and

coastal grasslands that are managed as SEAs and are relatively weed free. Included among the more widespread troublesome species are alien grasses, faya, fountain grass, Russian olive (*Olea europaea*), christmas berry and silk oak. Roughly 60 species are at an early stage of invasion with small localized populations. Boundary fences exclude feral goats, mouflon sheep and cattle throughout these lowland environments, while internal fenced units exclude feral pigs from selected rain forest and woodland sites.

DOFAW – NAR

There are three Natural Area Reserves (Pu'u Maka'ala, Kahauale'a, and Waiākea 42 Flow) within the OKMA totaling 11,927 ha. These reserves were established to preserve and protect representative samples of Hawaiian biological ecosystems and geological formations. Nonnative flora and fauna are present in all three reserves, but the extent to which they influence native vegetation and avian communities differs. Generally speaking higher elevation communities have been less impacted by past disturbance events and currently have fewer invasive plant infestations.

Pu'u Maka'ala (4,899 ha) was protected in 1981 because it contains some of the island's best wet native forest and unique geologic features and represents an important conservation link between the lower elevation HAVO and the upper elevation native forests of Kīlauea, Kūlani and Upper Waiākea. There are currently five fenced units that are ungulate free within the reserve (Lava Flow, Na Lua Mahoe, Kūlani Cone, Wright Road and Aku Unit) totaling 1,135 ha. Wright Road and Kūlani Cone Units were previously described as part of the Kīlauea forest and because they are shared units with KS. Four additional units (1,931 ha) are proposed for construction and animal exclusion during the next five years. Upon completion, 3,066 ha or 63% of Pu'u Maka'ala will be ungulate free. Target weed densities are generally low (<5%) in the higher elevation (>1,280 m) fenced units except localized populations of Himalayan yellow raspberry and banana poka near roads, open wetland sites, and previously disturbed areas. Isolated individuals of kahili ginger, strawberry guava, palm grass and Australian tree fern have been identified and controlled within these fenced units. Weed densities increase at lower elevations, particularly banana poka, Himalayan yellow raspberry and strawberry guava. Within the ungulate-free fenced Aku unit cover values are typically low, but many target weeds including strawberry guava are widely distributed. The lowest elevation portion of the reserve where fencing has not been proposed is highly weedy and along the eastern boundary 120 ha of tropical ash (*Fraxinus uhdei*) plantations constitute the reserve's only non-native dominated community. While increases in the distribution of target weeds including banana poka, strawberry guava and yellow Himalayan raspberry have been detected over time following ungulate removal, overall cover is still relatively low enabling control of these species within the units.

Kahauale'a (6,769 ha) was designated in 1987 because it protects lowland and montane wet forests and pioneer vegetation communities. The reserve is the site of much recent volcanic activity and borders the East Rift portion of HAVO on the slopes of Kīlauea volcano. Feral pigs are a serious concern in the reserve. Ungulate sign has been documented throughout the reserve and currently no ungulate free exclosures exist within the reserve. Several invasive nonnative plants are also present and threaten natural plant communities. At higher elevations faya is common and in some areas co-dominant with 'ōhi'a, while strawberry guava is more common in the lower elevations. Additional weeds widely distributed throughout the reserve include kahili ginger, broomsedge, meadow ricegrass, and in the lower elevations Hilo grass (*Paspalum conjugatum*) and *Cyperus halpan*. Localized populations of blackberry, cane tibouchina and palm grass are also present. Individual miconia plants have been identified and treated during the past two years.

Target weed species were found throughout the reserve with faya abundant in the higher elevations and strawberry guava in the lower elevations.

Waiākea 42 Flow (260 ha) was designated in 1974 to provide an opportunity to study native plant recolonization on recent lava flows. Feral sheep and goats are present in the area and likely influence vegetation establishment and development in the reserve. Many non-native grasses, sedges and herbs are widespread throughout the reserve including broomsedge, Hilo grass, *Cyperus haspan* and cane tibouchina. Localized populations of strawberry guava are also present in the reserve. Gorse is considered a potential invader in this reserve, but no individuals were found during 2005 surveys.

DOFAW-FR

There are six FRs included in the upper elevation portions of the OKMA. As in other parts of the OKMA, portions of these FRs below 1,000 m are generally weedier than the upper elevations. Mauna Loa FR (31,899 ha) contains upper elevation montane mesic and dry forests as well as subalpine shrublands, pioneer vegetation on young lava flows and alpine habitat. This FR is generally known to contain few priority weed species due to its high elevation location. Upper Waiākea FR (21,495 ha) and Hilo Restricted Watershed FR (6,563 ha) contain lowland wet, montane wet and montane mesic forests. Upper elevation montane wet and mesic forests above 1,000 m elevation contain relatively few weeds whereas the lower elevations are very weedy. Road corridors (e.g. Saddle Rd, Powerline Rd and Stainback Hwy, and roads within Waiākea Timber Management Area) serve as major corridors for weed establishment and distribution in these three FRs. Priority weeds present in these FRs include palm grass, strawberry guava, yellow Himalayan raspberry, banana poka and cane tibouchina. Upper Waiākea FR also contains incipient populations of gorse that have been a high priority for DOFAW and BIISC control efforts. Waiākea FR (3,981 ha), 'Ōla'a FR (3,809 ha) and the portion of Hilo FR included within the TMA (706 ha) are all in lower elevation areas and are adjacent to more populated and disturbed areas. These FR all contain higher numbers of weeds and/or are highly modified due to widespread, habitat-modifying weeds like strawberry guava and feral ungulates.

Lower Puna (DOFAW FR and KS lands)

KS lands in lower Puna primarily consist of four main areas that contain heavily weed invaded remnant native lowland wet forest as well as highly modified areas (e.g. papaya fields and non-native forest). Pu'u Kaliu (also known as Bryson's Cinder Pit) has the best remaining native forest. Strawberry guava is the most common and damaging weed, but the area also contains other weed species including cane tibouchina, bamboo (*Phyllostachys nigra*), clidemia, cecropia (*Cecropia obtusifolia*), albizia and miconia. Other KS owned areas have not been systematically surveyed for weeds, but are known to be highly modified and/or completely weed infested. There are feral ungulates in the area.

DOFAW lands in lower Puna include three FRs (Malama Ki, Nanawale and Keauohana). These are similar to the KS lands described above.

Figure 2.4. OKMA Known Weed Distribution (Ten Species)

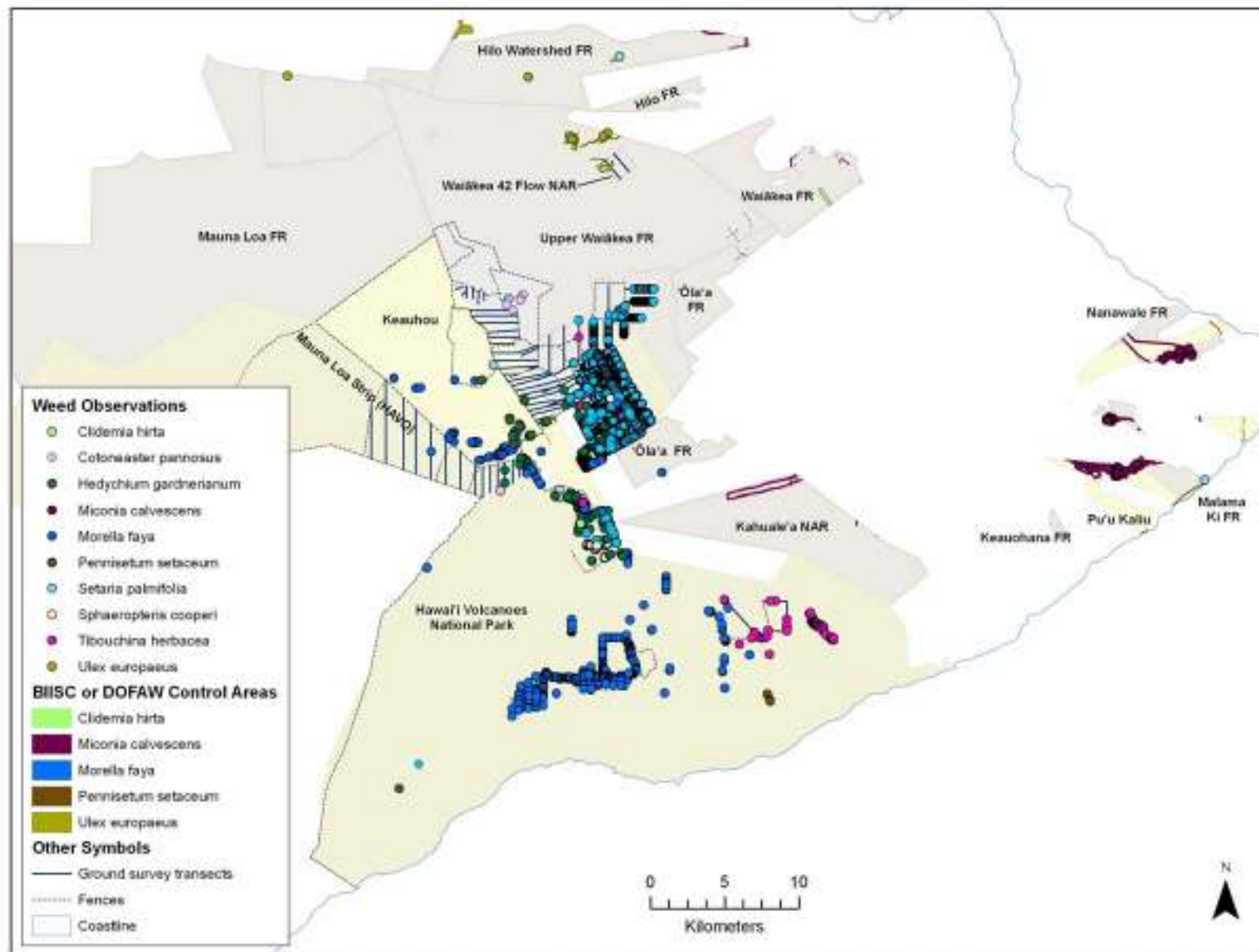


Figure 2.5. Ten Species Known Distribution in Priority Weed Management Areas (OKMA).

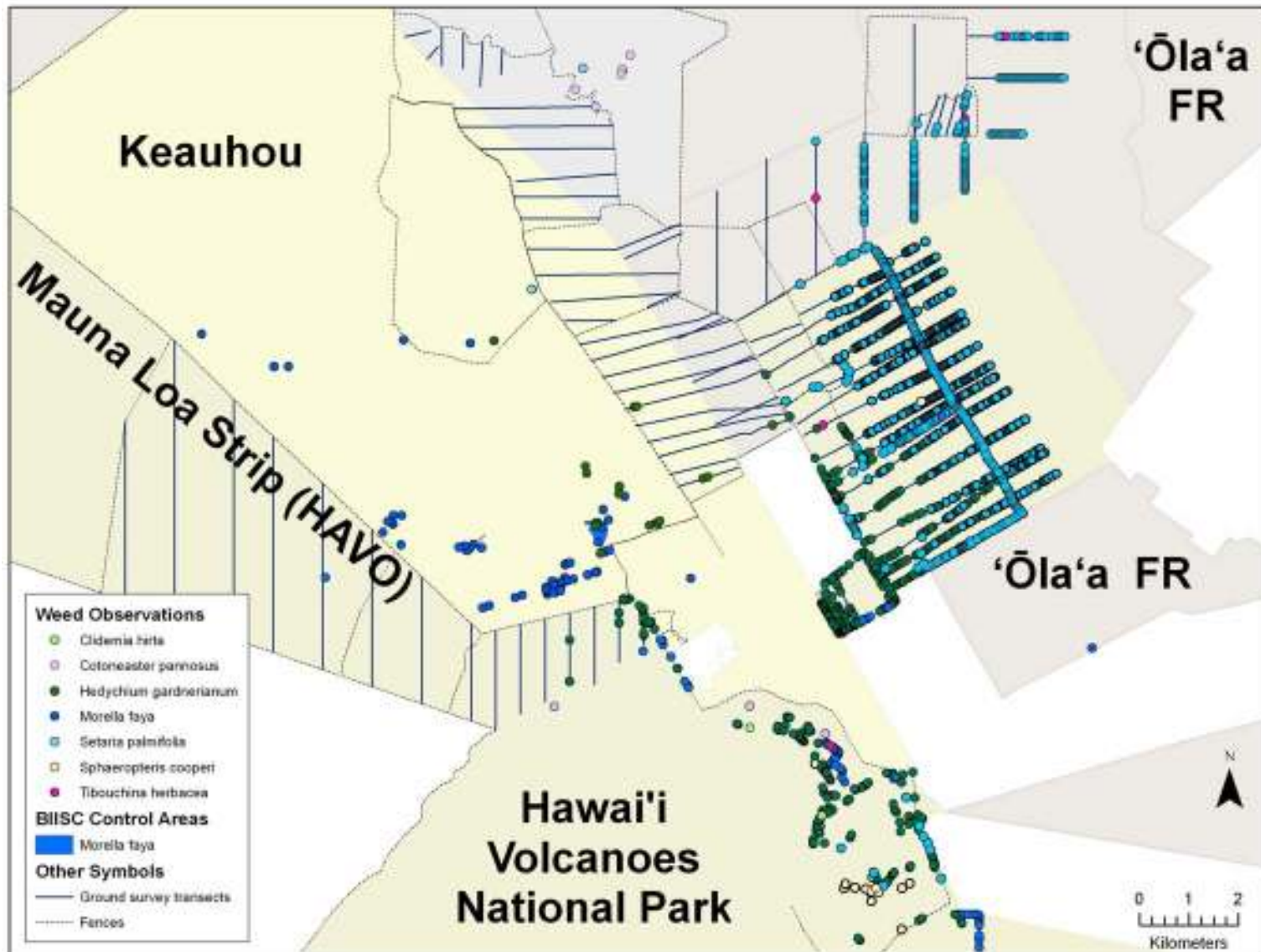


Figure 2.6. Banana Poka Known Distribution in Priority Weed Management Areas (OKMA).

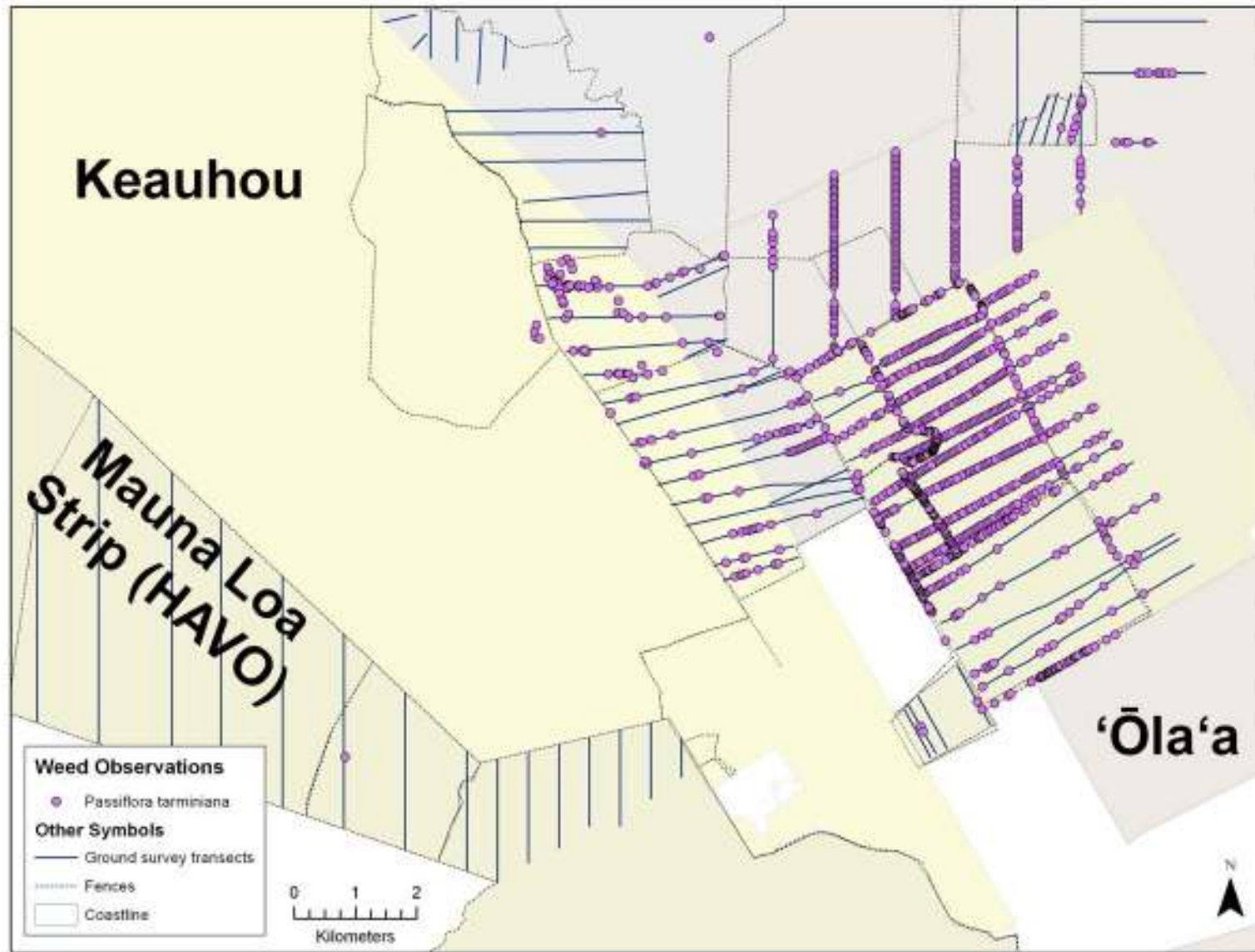


Figure 2.7. Strawberry Guava Known Distribution in Priority Weed Management Areas (OKMA).

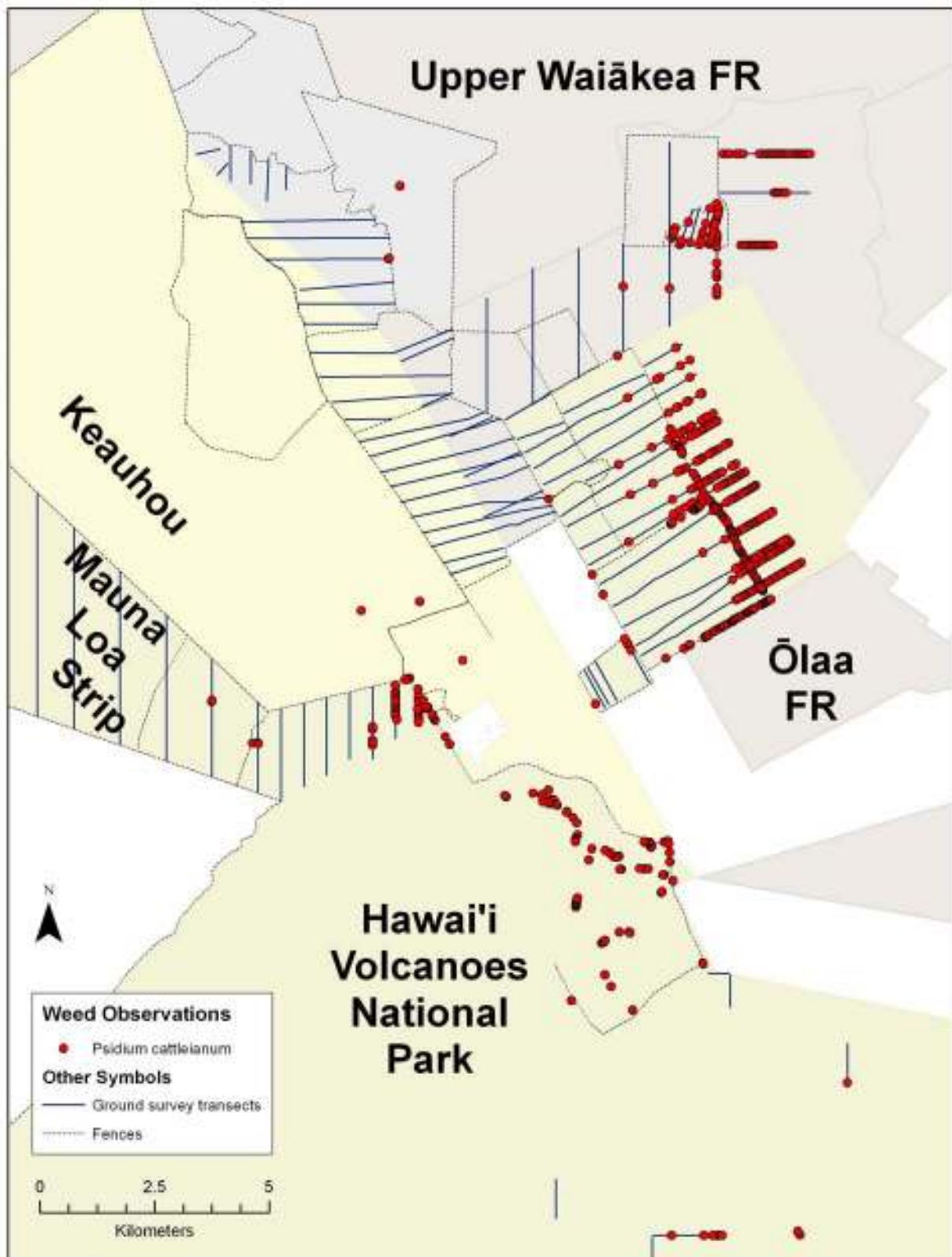


Figure 2.8. Blackberry Known Distribution in Priority Weed Management Areas (OKMA).

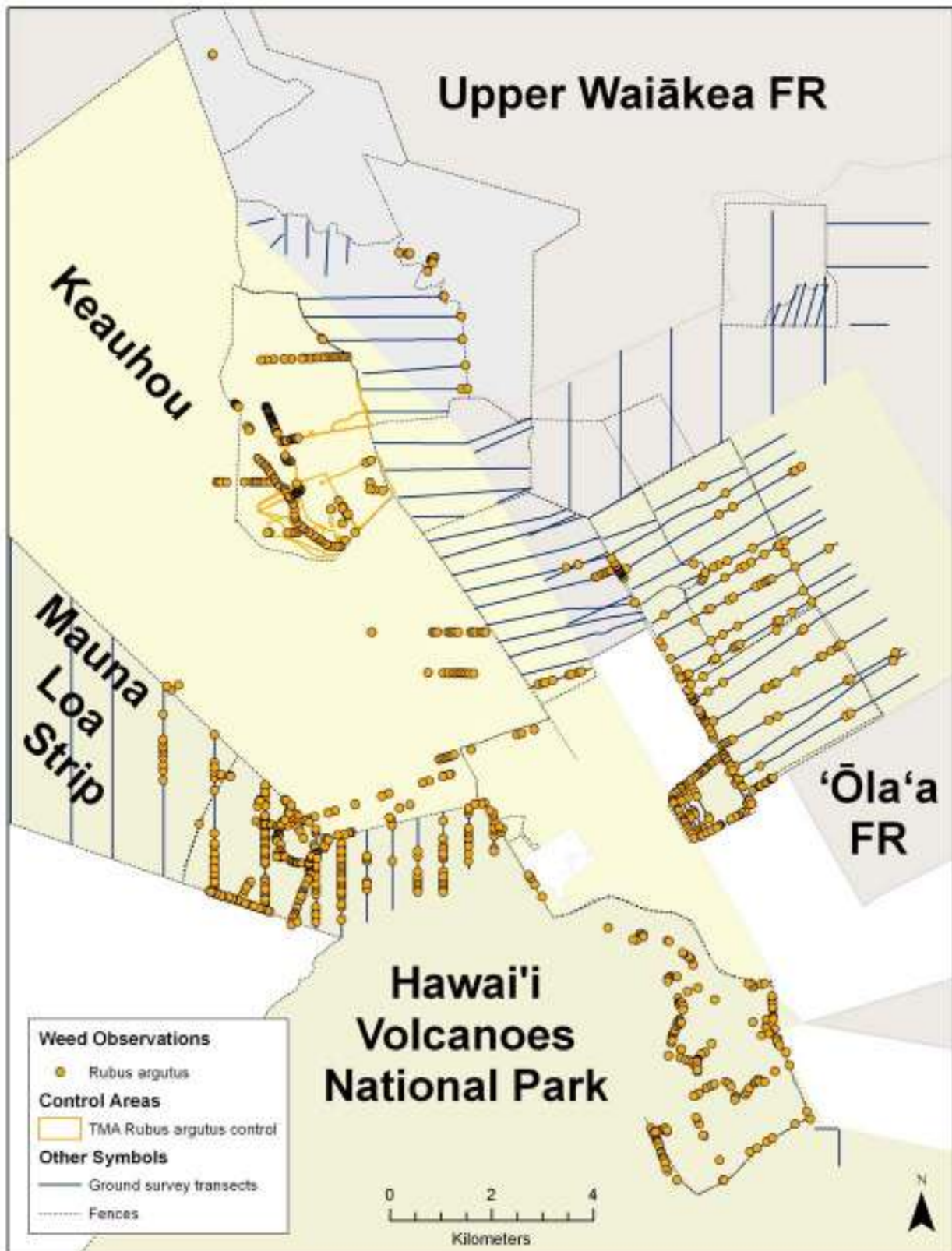
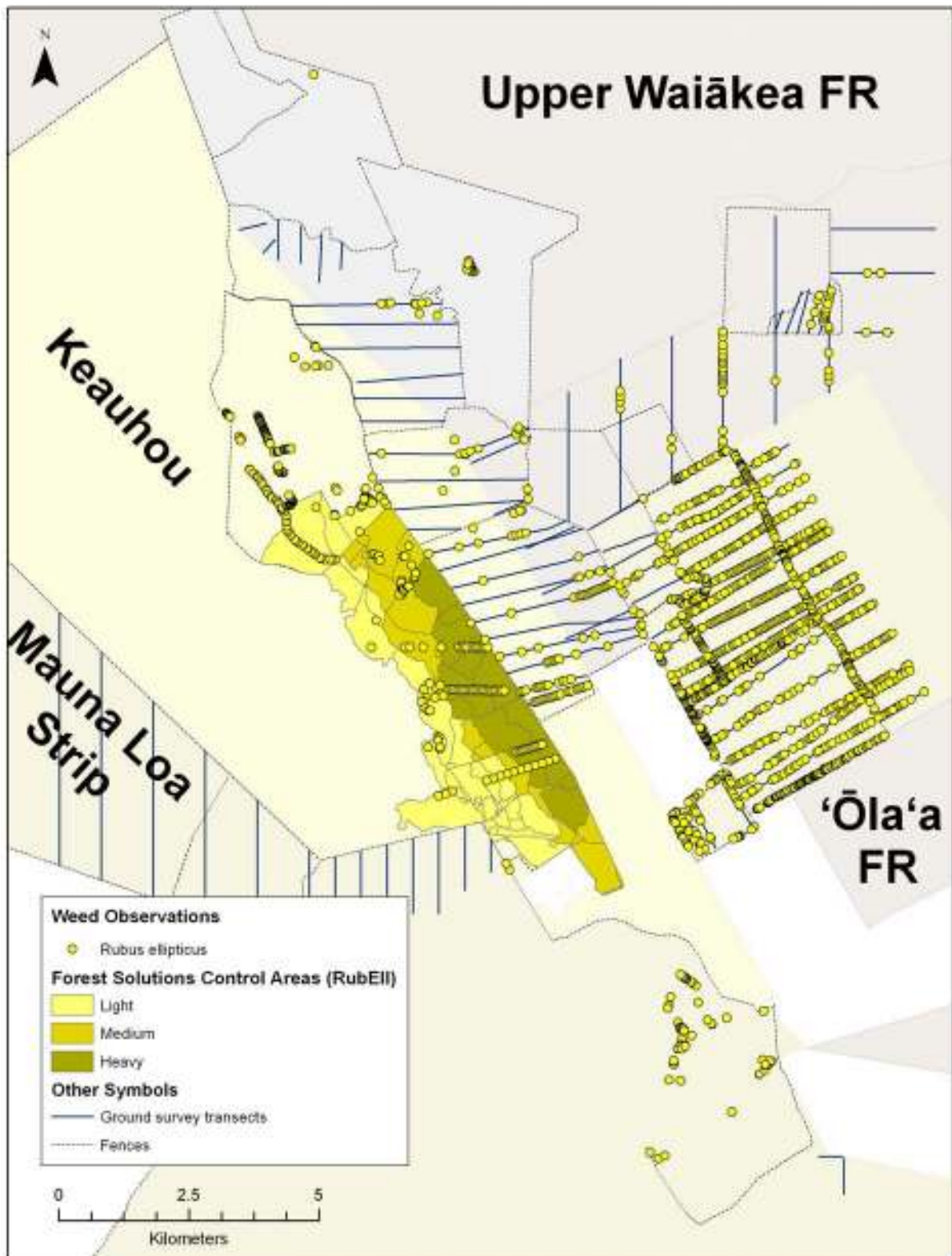


Figure 2.9. Yellow Himalayan Raspberry Known Distribution in Priority Weed Management Areas (OKMA).



2.5 Control Plans for High Priority Weed Species and Management Units

General TMA Strategy

In the OKMA, weed management priorities are the highest quality native forest within fenced management units managed for feral ungulates (Kīlauea Forest, KCF, Pu‘u Maka‘ala NAR, Keauhou and adjacent portions of HAVO).

The TMA will work with partners on cooperative watershed management planning and implementing an increased level of weed management (weed distribution surveys, monitoring and control work) in high priority areas that are not currently managed for feral ungulates and weeds, particularly in important buffers to existing fenced management units and/or high quality native forest (e.g. gorse in upper Waiākea FR, miconia).

TMA Member Control Plans

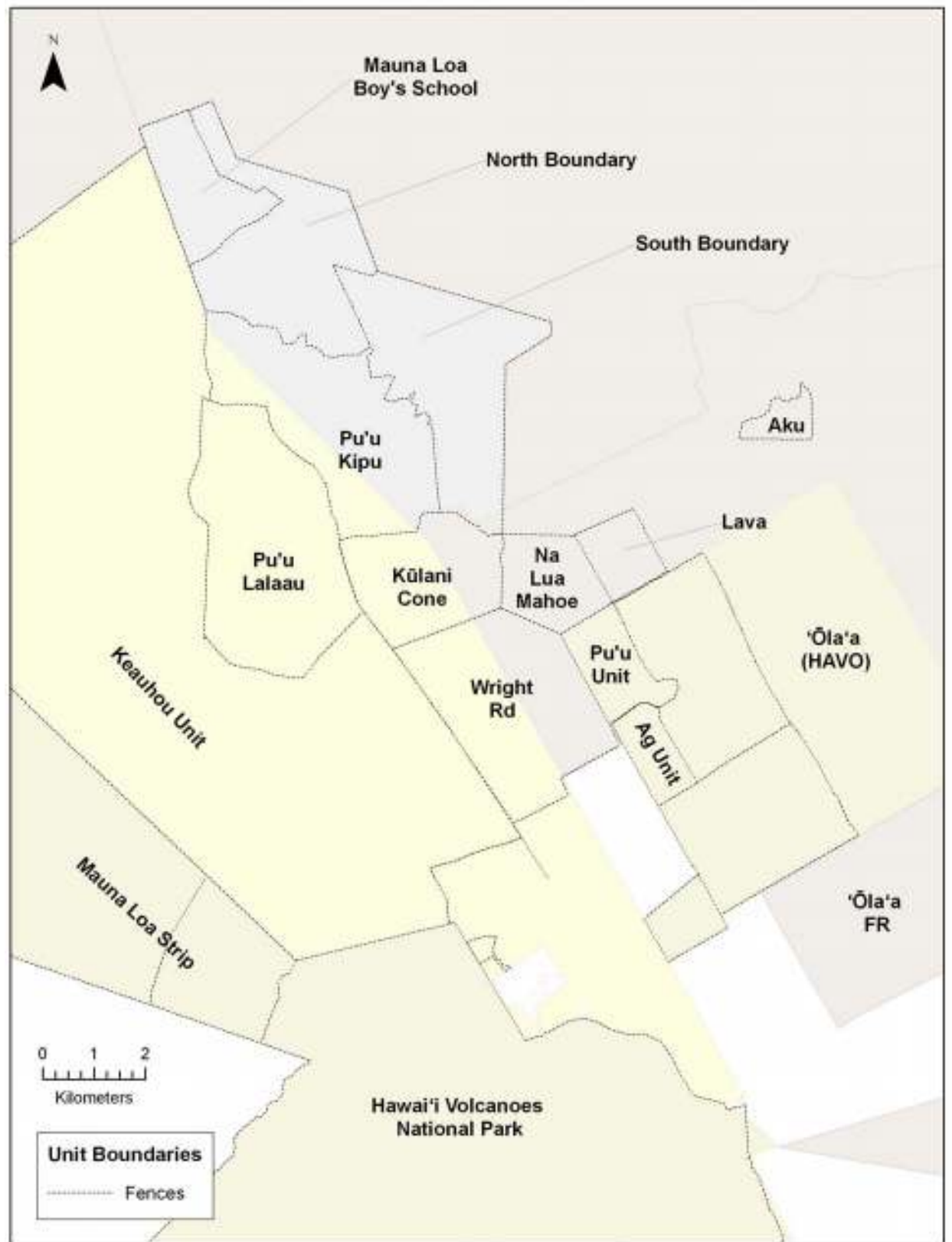
Kīlauea Forest (DOC, KS, NAR) and Kūlani Correctional Facility (DOC)

These areas are jointly managed by TMA members. We will take the SEA approach to weed control within these six management units. This approach is compatible with the NAR goals for weeds within two joint management units and adjacent HAVO ‘Ōla‘a Tract and Mauna Loa Strip Rd. units and Pu‘u Maka‘ala units. Weed control within the interior of Kīlauea Forest is very expensive (relative to more open sites) because the density of the vegetation slows field crews during ground sweeps in these areas. TMA and NAR staff initiated control sweeps to eliminate target weeds within the Wright Rd. Unit in 2008 and are planning to continue this control effort to sweep the entire unit over a three-year period. Due to limited resources for control efforts in the other five dense rain forests units, the TMA will focus monitoring and control efforts on disturbed areas such as roads, trails, pasture openings and fence lines as these areas often serve as corridors for weed establishment.

Keauhou (KS)

In upper elevations of Keauhou, TMA is planning to take the SEA approach and eliminate all observed occurrences of localized priority species. These localized species are notable for their ability to rapidly spread and increase their population size, and should be controlled to preclude costly control programs in the future. Infestation sites will be monitored with annual follow-up control visits. Aerial surveys will be required to detect some of these weeds (e.g. faya, fountain grass) due to the remoteness and size of this area. We also will control weeds along roads and fences to minimize the spread and establishment of priority species along these corridors and eventually into more remote areas. We plan to reduce systematically the cover of blackberry and grass in open areas to enhance natural regeneration and prepare sites for reforestation. Widespread weeds such as blackberry will always be present at some level, but reforestation eventually will reduce their overall abundance. In lower Keauhou, we will try to contain priority weeds, especially during the critical reforestation period, and in areas where weeds are not currently abundant (higher elevation portions of lower Keauhou). The lowest portion of the ranch needs to be monitored regularly for new incipient weeds since they are most likely to become established in this area. This area also provides a critical buffer to high priority weed management areas of Kilauea Forest to the East (Wright Rd Unit) and Mauna Loa Strip Rd. (HAVO) to the west.

Figure 2.10. Fenced Management Units in the 'Ōla'a Kīlauea Management Area.



HAVO (NPS)

Eighty-five disruptive weed species are under management at HAVO. Roughly 60 species have localized distributions and are eradicated wherever they are found. For widespread weed species, management actions are limited to containment at the invasion front and/or exclusion from high priority management units known as SEAs. The park has expanded the number of SEAs from six units (~5,000 ha) in 1985 to 27 units (~26,000 ha) in 2008. Over 50% of park areas identified by OKMA as priorities for weed management (>1,200 m elevation) are under SEA management. Species targeted for control in SEAs are primarily woody life forms (e.g. faya, yellow Himalayan raspberry, strawberry guava) and highly invasive non-woody weeds such as kahili ginger and banana poka. Management of widespread grasses (e.g. kikuyu, meadow ricegrass) is experimental and limited to small restoration sites (<100 ha) within SEAs. Management of mullein is limited to containment at the lower and upper elevation invasion fronts.

DOFAW – NAR

Consistent with TMA strategy, weed management within Pu'u Maka'ala NAR is focused on the ungulate-free fenced units. All target non-native species are mechanically and/or chemically controlled within fenced units by ground crews. Units are divided into management blocks, which are systematically swept on 3 – 5 year intervals with the exception of high infestation sites which are revisited the following year. Blocks are prioritized for control based on weed density, proximity to managed sites, and logistical feasibility. Early detection and rapid response weed monitoring/control is conducted quarterly along invasion corridors (e.g., roads, trails, and fence lines). Weed monitoring surveys will be conducted on 5 year intervals in the interior unfenced forest sections of the NAR in order to detect incipient invaders. Due to heavy infestations of banana poka and strawberry guava in particular and limited resources, NARS staff and partners intend to initiate and continue to test the efficacy of biocontrol agents within the reserve.

Weed management in Kahauale'a NAR is focused on detection and removal of target incipient weeds such as miconia. Surveys are primarily conducted by air cooperatively with BIISC. Weed status and change over time will be assessed by installing and rereading monitoring transects at five year intervals within the reserve. No on the ground eradication sweeps are planned because the reserve is heavily impacted by feral pigs and contains no ungulate-free units. Despite the presence of many target weeds within the reserve, detection of new incipient invaders is crucial because the reserve provides a critical buffer to the high priority weed management areas of Thurston and East Rift (HAVO).

Similar to Kahauale'a, weed management in Wai'ākea 42 Flow NAR is limited to early detection and removal of target incipient weeds such as gorse. The reserve is impacted by feral sheep and no exclosures are present. Weed surveys are primarily conducted by BIISC either by air or ground in attempt to detect the spread of gorse from adjacent areas. Monitoring of weed distribution and abundance along transects will occur at five year intervals and will provide valuable information of both weed status and change over time.

DOFAW-FR

Upper Wai'ākea FR contains incipient populations of gorse that have been a target for DOFAW and BIISC control efforts.

Lower Puna (DOFAW FR and KS lands)

Pu'u Kaliu (also known as Bryson's Cinder Pit) is the highest KS priority for weed management in lower Puna due to the quality of the remaining lowland native forest and the presence of rare native species. 22 ha of remnant high quality native forest will be a focal weed control area for KS with a focus on strawberry guava and miconia. While this forest will need constant management to become and remain weed free, the small area involved and accessibility make this a definite possibility (Koch 2007). KS will be working with Forest Solutions and various community groups on weed control projects in this parcel.

DOFAW FR staff has targeted albizia, palm grass and ironwood for control efforts in the lower Puna FR areas.

TMA Weed Control Goals (Figure 2.11)

1. TMA Fenced Management Units in Kīlauea, Kulani and Pu'u Maka'ala NAR (6 units) including Mauna Loa Boy's School Unit, North Boundary Unit, Pu'u Kipu Unit, Kūlani Cone Unit, South Boundary Unit and Wright Road Unit (Figure 2.10).
 - Prevent the establishment of habitat modifying weeds that are not currently present (e.g. miconia, gorse, clidemia, etc.).
 - Eliminate all known occurrences of other priority weeds along roads, trails and fences. Complete control sweeps in the Wright Rd Unit on a 3-5 year cycle (first sweep in the cycle is planned to be completed by 2012). Sweep additional units as funding becomes available.
 - Systematically monitor weed transects on a regular basis to detect ingress of new priority weeds or expansion of existing weed populations.
2. Keauhou fenced management units (Keauhou Unit and Pu'u Lalaau Unit)
 - Prevent the establishment of habitat modifying weeds that are not currently present (e.g. miconia, gorse etc.).
 - Eliminate faya in the upper elevation portions of Keauhou using annual helicopter survey with follow-up ground control (every 1-2 years).
 - Suppress faya and other priority weed species (blackberry, yellow Himalayan raspberry, kahili ginger, strawberry guava) in the lower elevations of Keauhou by gradually removing satellite populations and reducing seed spread from the core population in lower Keauhou. Follow-up with annual control sweeps on the ground and helicopter survey.
 - Eliminate all known occurrences of priority weeds in the Pu'u Lalaau Unit. Suppress blackberry in this unit.
3. HAVO - 'Ōla'a fenced management units (priority units are Pu'u Unit and Koa Unit adjacent to Pu'u Maka'ala NAR) and Mauna Loa Strip Rd.
 - Prevent the establishment of habitat modifying weeds that are not currently present (e.g. miconia, gorse, clidemia etc.).
 - Eliminate all known occurrences of other priority weeds along roads, trails and fences. Assist HAVO with monitoring and weed control sweeps of these areas.
4. DOFAW – Existing Pu'u Maka'ala management units (Na lua Mahoe, Lava and Aku) and proposed new fenced units.
 - Prevent the establishment of habitat modifying weeds that are not currently present (e.g. miconia, gorse, clidemia etc.).

- Eliminate all known occurrences of priority weeds along roads, trails and fences. Sweep existing units as funding becomes available and new fencing projects/feral ungulate control are completed.
5. Upper Waiākea FR – Eliminate gorse through joint survey and control efforts with TMA, BIISC and DOFAW staff. Prevent the spread of this species into other TMA areas. Prevent the establishment of other priority species not currently present in the area.

Figure 2.11. Priority TMA Control Projects in the 'Ōla'a Kīlauea Management Area.

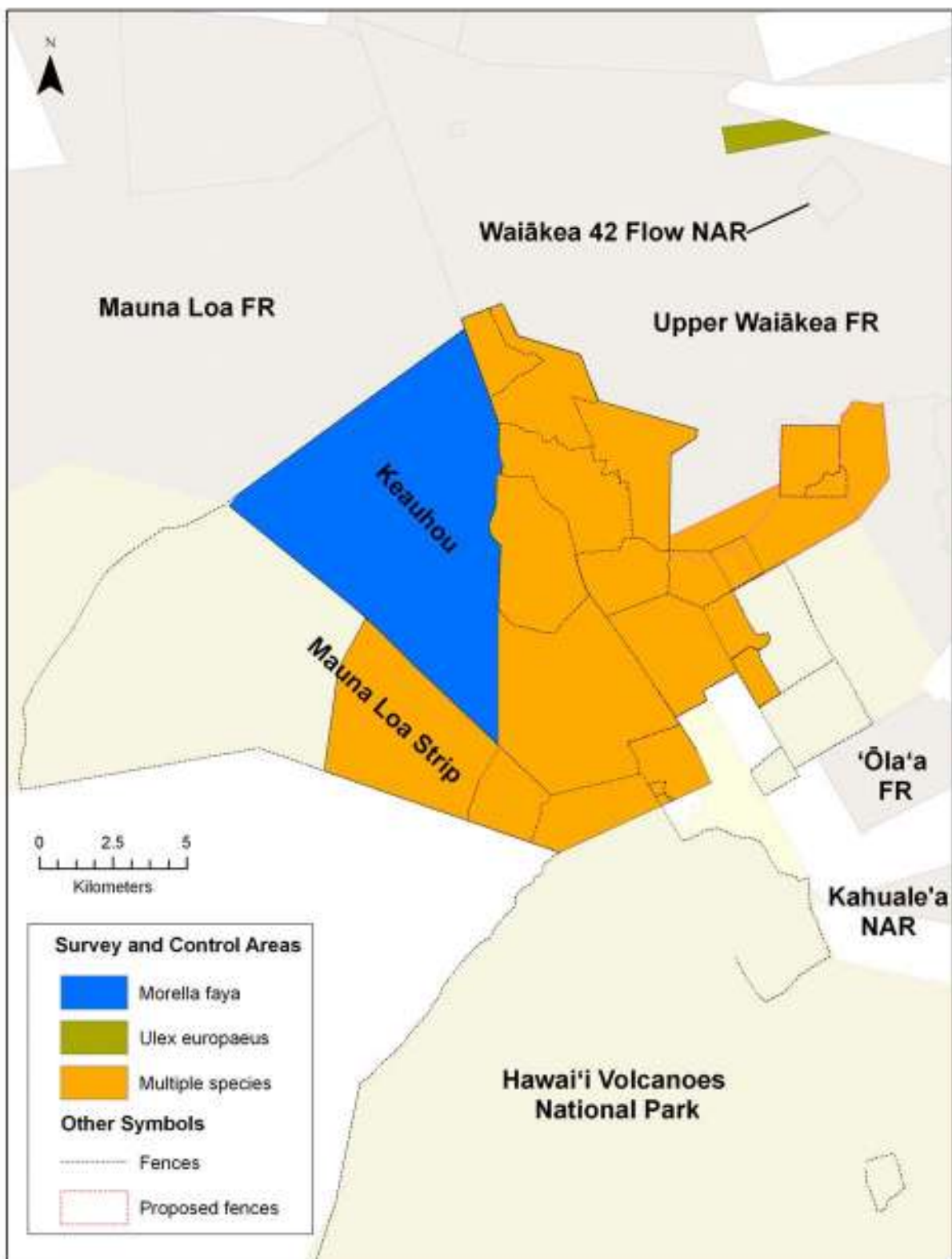


Table 2: TMA Goals and Objectives by Area/Species*

OKMA		Management Area					
		Kīlauea Forest and Kūlani	Keauhou	HAVO ('Ōlā'a)	HAVO (Strip Rd.)	Pu'u Maka'ala Units	Upper Waiākea FR
Focal Species	CLI HIR	Prevent	Prevent	Prevent	Prevent	Prevent	
	COT PAN	TBD	Prevent	Prevent	Prevent	Prevent	
	HED GAR	TBD	TBD	2010	TBD	TBD	
	MIC CAL	Prevent	Prevent	Prevent	Prevent	Prevent	Prevent
	MOR FAY		2012	2010	TBD		
	PAS TAR	TBD	TBD	2010	TBD	TBD	
	PEN SET		Prevent		Prevent		
	PSI CAT	TBD	TBD	2010	TBD	TBD	
	RUB ARG	TBD	TBD	2010	TBD	TBD	
	RUB ELL	TBD	2012	2010	TBD	TBD	
	SET PAL	TBD	TBD	2010	TBD	TBD	
	SPH COO	TBD	Prevent	Prevent	Prevent	Prevent	Prevent
	TIB HER	Prevent	Prevent				
	ULE EUR	Prevent	Prevent	Prevent	Prevent	Prevent	2010

Prevent	= Prevent any populations from establishing in this area (ongoing).
Eliminate	= Remove all occurrences of species in this area.
Suppress	= Reduce extent of core population in this area.
Contain	= Prevent expansion of core population within this area.

*Table 2 includes the date by which the TMA expects to achieve the weed control goal. Dates are included only for currently funded and/or ongoing projects. TBD is noted for unfunded projects. Ongoing follow-up control work will still be needed to maintain progress on the projects following the achievement of the goals outlined in this table.

3. KA'Ū KAPĀPALA MANAGEMENT AREA

3.1 Background

The Ka'ū Kapāpala Management Area (KKMA) consists of four principal landowners, all sharing a mandate for conservation and management of Hawai'i's natural resources: NPS, DOFAW, TNC and KS (Figure 3.1). In 2003, the NPS purchase of the 46,943 ha Kahuku Ranch as an addition to HAVO solidified the need for collaborative management of this area at the landscape level.

The KKMA contains some of the most diverse and least invaded forest on the island, and has been identified as a high priority for an increased level of watershed management and protection by the TMA. Its high stature closed canopy forests support one of the highest known vegetation biomass profiles and some of the highest densities of forest birds in the State. Lower portions of the Ka'ū Forest Reserve are known to harbor a diverse native insect fauna. The KKMA provides an elevational and moisture gradient that would allow wildlife populations to move in response to changing climate or weather conditions.

From a statewide perspective, the southeast portion of Mauna Loa (eastern side of the southwest rift zone), is surpassed only by East Maui in the number of different types of ecosystems present (Figure 3.2). This region is home to more extant, endemic species of flowering plants (178 species) than any other region of Hawai'i island. In fact, its mesic and wet forest ecosystems alone support 153 endemic plant species. The forests of the Ka'ū region are home to at least 12 known species of rare plants. The very high quality of the wet and mesic forest communities in the KKMA provides a rare opportunity to implement management before it is too late or costly (Figure 3.3).

During the last century, the forests of Ka'ū were bordered almost completely by sugar cane fields to the southeast, which were burned every 18 months. This practice kept most weeds out of the forest, but the demise of sugar, and the resulting mosaic of adjacent landowners, opened up the old cane fields to new weed invasions, which threaten the native forests.

3.2 Weed Inventory

Weed surveys have been conducted in the Kahuku portion of HAVO, TNC's Ka'ū Preserve, along the lower Ka'ū FR boundary, on Hawai'i forest bird survey transects throughout the Ka'ū FR, in KS eucalyptus plantations and Ka'ū FR for bocconia (BIISC aerial and road surveys) and along roads in plots near the eucalyptus plantations on KS lands. DOFAW-FR staff have mapped fountain grass at Kamilo in July 2008. Weed surveys have not been conducted in the Kapāpala FR or in the Kapāpala Game Management Area although some incidental observations have been noted. In addition, although not within the TMA, BIISC surveyed 282 km of roads for incipient weeds and NPS surveyed another 251 km of Hawaiian Ocean View Estates (HOVE) roads for fountain grass.

Figure 3.1. Ka'ū Kapāpala Management Area Land Ownership.

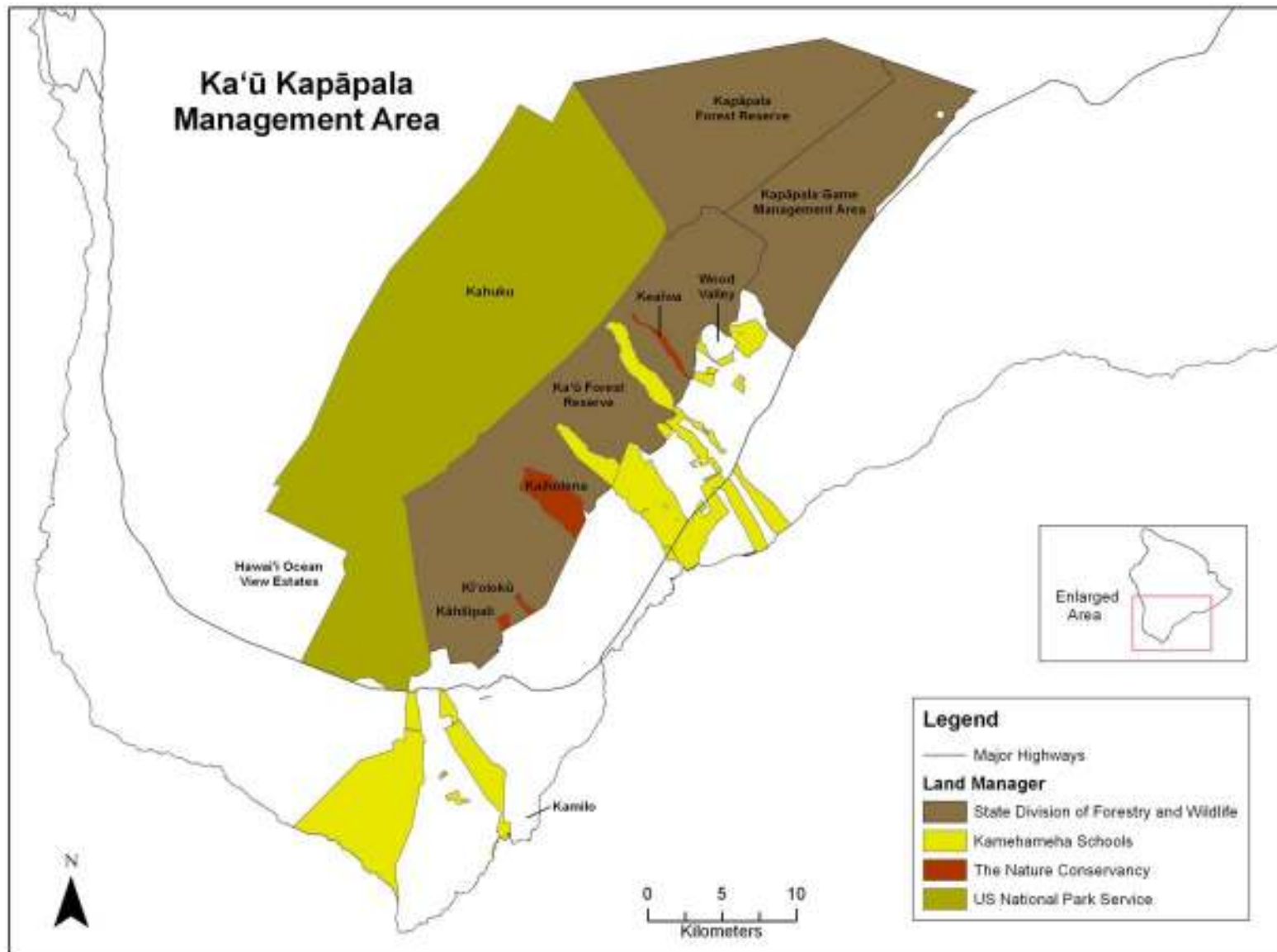
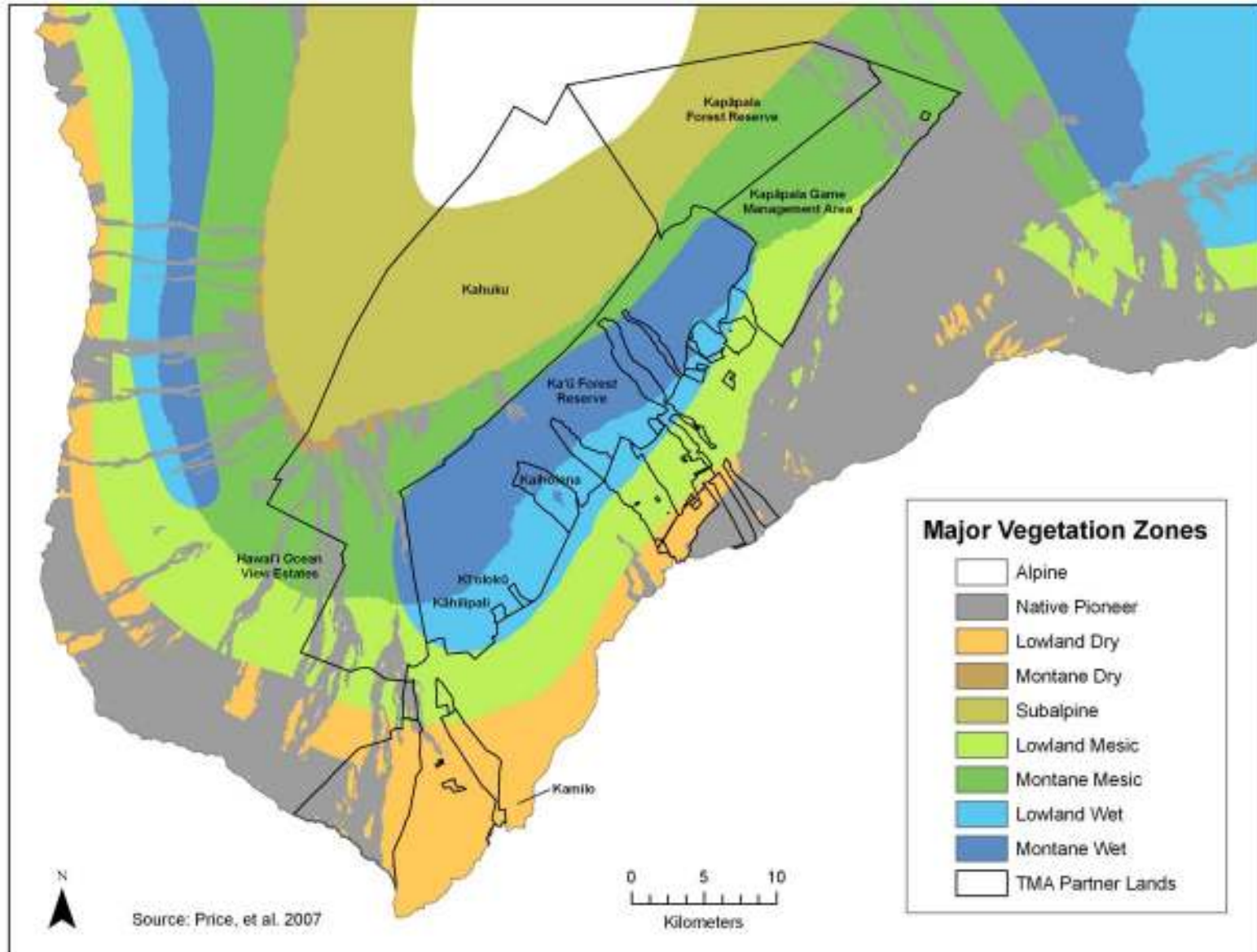


Figure 3.2. Ka'ū Kapāpala Management Area Ecosystems.



3.3 High-Priority Weed Species

<i>Bocconia frutescens</i>	bocconia, plume poppy
<i>Caesalpinia decapetala</i>	cat's claw
<i>Cestrum nocturnum</i>	night blooming jasmine
<i>Clidemia hirta</i>	clidemia, Koster's curse
<i>Hedychium gardnerianum</i>	kahili ginger
<i>Morella faya</i>	faya
<i>Pennisetum setaceum</i>	fountain grass
<i>Psidium cattleianum</i>	strawberry guava, waiawi
<i>Rubus ellipticus</i>	yellow Himalayan raspberry
<i>Setaria palmifolia</i>	palm grass
<i>Sphaeropteris cooperi</i>	Australian tree fern
<i>Tibouchina herbacea</i>	cane tibouchina
<i>Tibouchina urvilleana</i>	glory bush

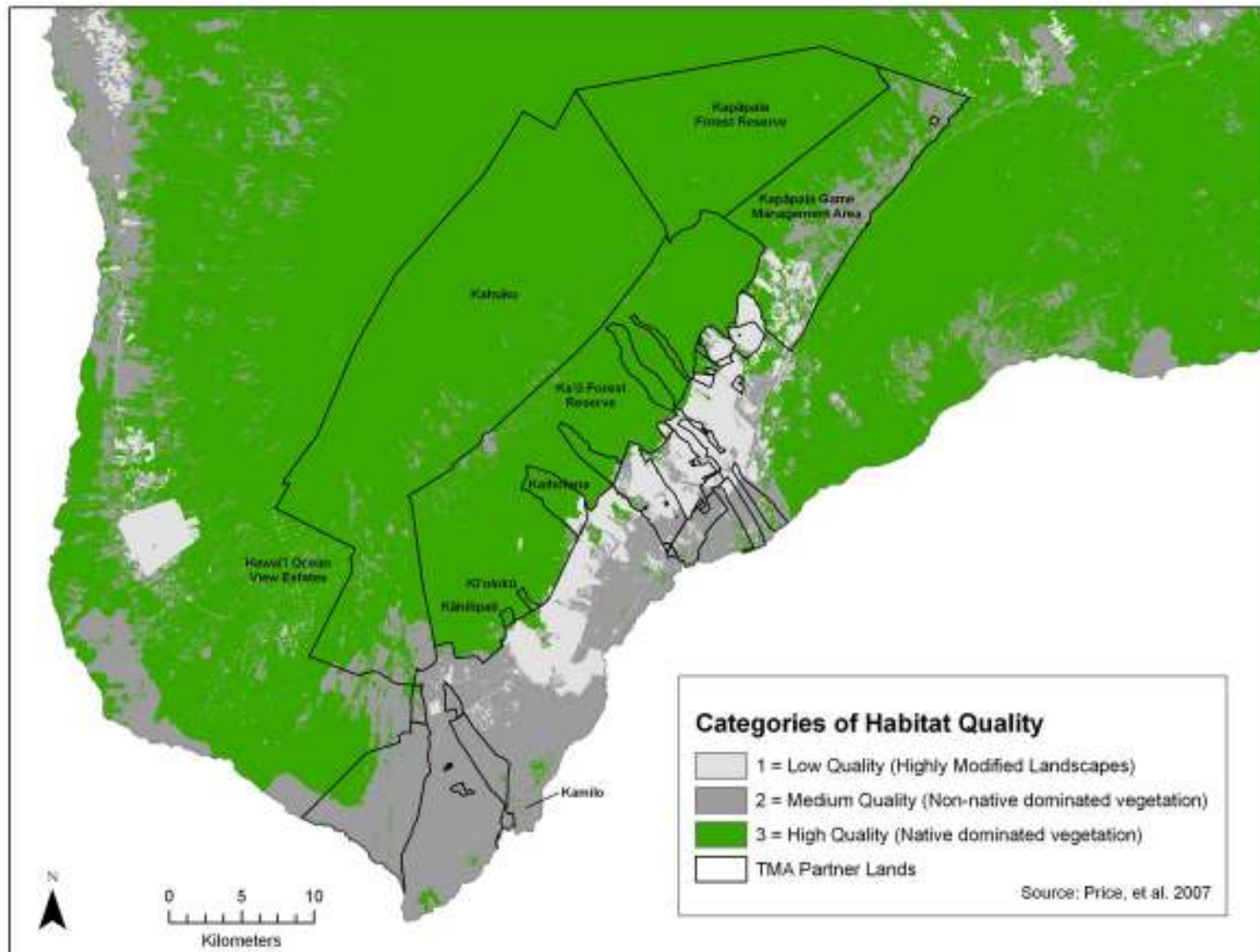
3.4 Description of Weed Situation

Ka'ū Forest Reserve (DOFAW)

In general, the upper elevations and interior portions of Ka'ū FR do not appear to be heavily infested with weeds. Only a very small portion of the interior of the FR has had systematic surveys along bird survey transects (Figure 3.4). The abundance of weed observations in areas that have been more thoroughly surveyed (e.g. Kaiholena) indicates that priority weeds probably exist in similar numbers across the FR in that elevational band. The majority of the 24,281 ha area appears to contain only scattered individuals of low priority weeds. However, there are some localized areas, particularly in the lower elevations of the FR that are known to be heavily infested with high priority weeds. Hotspots currently known within the FR include glory bush (Mountain House Road), strawberry guava on the SW end of the FR and isolated patches of cat's claw, palm grass (Mauna Kea Springs Pipeline Rd.), cane tibouchina (waterfall road) and kahili ginger (forest edge). The lower elevation forest edge, which is adjacent to lands originally cleared for sugarcane plantations and now mainly used for pasture and cattle grazing, has a 32 km long infestation of habitat modifying priority weeds, particularly strawberry guava. Night-blooming jasmine is present along the forest edge on the east side of Pu'u Enuhe, and a fairly solid infestation of this species dominates the understory of the eastern portion of the forest, northeast of Wood Valley. DOFAW staff have collected incidental location points on night-blooming jasmine at the far eastern extent of this population. Bocconia has been spreading into the FR from eucalyptus plantations in the Wood Valley area. The groundcover in the upper elevation, koa dominated eastern portion of the forest is dominated by non-native grasses, primarily meadow ricegrass which is not considered a habitat modifying weed in this area.

Kamilo is an approximately 600 ha coastal area with high quality native coastal habitat proposed for addition to the FR. This area has not been surveyed for weeds, but there are isolated populations of fountain grass that have been reported from Kamilo and adjacent sections of the coast.

Figure 3.3. General Weed Situation.



Ka'ū Preserve (TNC)

The preserve consists of four separate parcels spanning a distance of 19 km. TNC has surveyed TNC owned lands for priority weeds as well as the large portions of the lower Ka'ū FR boundary. Each TNC parcel shares three boundaries with the Ka'ū FR and one along the forest edge. The largest parcel Kaiholena (1,052 ha), is being managed as an SEA. The entire parcel has not yet been completely surveyed, but most of this parcel appears to contain very few weeds. One area however, contains a major infestation of strawberry guava and clidemia. Cane tibouchina is present along the lower edge of the parcel, and TNC staff have also collected incidental location points for two individuals of Australian tree fern at Kaiholena. The other three units are each less than 80 ha in size. The Kāhilipali unit contains the only known infestation of kahili ginger in this part of the Ka'ū forest. The Kī'olokū unit is infested with glory bush where it is spreading from Mountain House Road. Strawberry guava is spreading into the lower portions of both of parcels from the forest edge, and scattered clidemia occurs within these parcels.

Kahuku, Ka'ū portion (HAVO)

In Kahuku, NPS has identified approximately 50 species as highly aggressive invaders based on their distribution and impacts to native communities in Kahuku or elsewhere in the islands. (e.g., non-native grasses, christmas berry, faya, kahili ginger, blackberry, and strawberry guava). Highly invasive weeds with apparently limited distribution at Kahuku include silk oak, sisal (*Agave sisalana*), and fountain grass in dry habitats; kahili ginger, strawberry guava, rose apple (*Syzygium jambos*), and night blooming jasmine in mesic and wet forest fragments; and faya and mullein at higher elevations. Weeds are more abundant at lower elevations (<1,500 m elevation) in pasture and forest fragments, and less frequent at higher elevations. Included among the widespread species are non-native grasses (kikuyu, meadow ricegrass) and christmas berry (<1,300 m). Fireweed (*Senecio madagascariensis*), a species problematic on Mauna Kea, has established in parts of the pasture. Seed dispersal from populations of fountain grass and other weeds established on adjacent private lands of HOVE contribute to the spread of these weeds in Kahuku.

Kamehameha Schools Units (KS)

KS conservation-zoned lands within the Ka'ū FR have not been surveyed for weeds, but are believed to be relatively weed-free in the upper elevations (similarly to the rest of Ka'ū FR). Kahili ginger, night blooming jasmine and strawberry guava are found in the lower elevations and in more disturbed lower forest edge habitat. The KS eucalyptus plantation near Wood Valley is heavily infested with bocconia where BIISC surveys have found it is spreading mauka from the plantation into the Ka'ū FR. In general, the lowland portions of Ka'ū, where several KS parcels included in the TMA occur, are generally known to contain widespread populations of weeds such as christmas berry, strawberry guava and koa haole (*Leucaena leucocephala*); however these areas have not been surveyed.

Kapāpala Cooperative Game Management Area (GMA) (DOFAW, leased by Kapāpala Ranch)

This area has not been surveyed for weeds. Lower elevations of Kapāpala GMA are generally known to be heavily infested with widespread weeds common in the area such as christmas berry, non-native grasses, common guava (*Psidium guajava*), faya, silk oak, strawberry guava and other weeds. These weeds are generally known to be spreading from the GMA into Ka'ū FR and Kapāpala FR.

Kapāpala Forest Reserve (DOFAW)

The 15,085 ha Kapāpala FR has not been surveyed for weeds, but large portions of the upper elevation subalpine and alpine habitats are generally known to be relatively intact native habitat. The lower portions of the FR bordering the GMA have the most priority weed problems. A large population of faya (>1,000 trees) was incidentally observed above Kapāpala ranch on State land while HAVO staff were in helicopter transit to Kahuku's eastern survey region (not shown on weed distribution map).

A 508 ha portion of the Kapāpala GMA in the northwest corner known as Kapāpala Koa Canoe Management Area is in the process of being added to the FR. This area contains relatively intact native forest with a non-native grass groundcover and isolated reports of priority weeds such as strawberry guava, faya, silk oak, banana poka and yellow Himalayan raspberry.

BIISC Early Detection Roadside Surveys

A total of 175 miles of roads in Ka'ū, representing close to 100% of all major, secondary, tertiary, and some residential roads (excluding dirt and cane roads), were surveyed for incipient weeds.

Figure 3.4. Ka'u Kapāpala Known Weed Distribution.

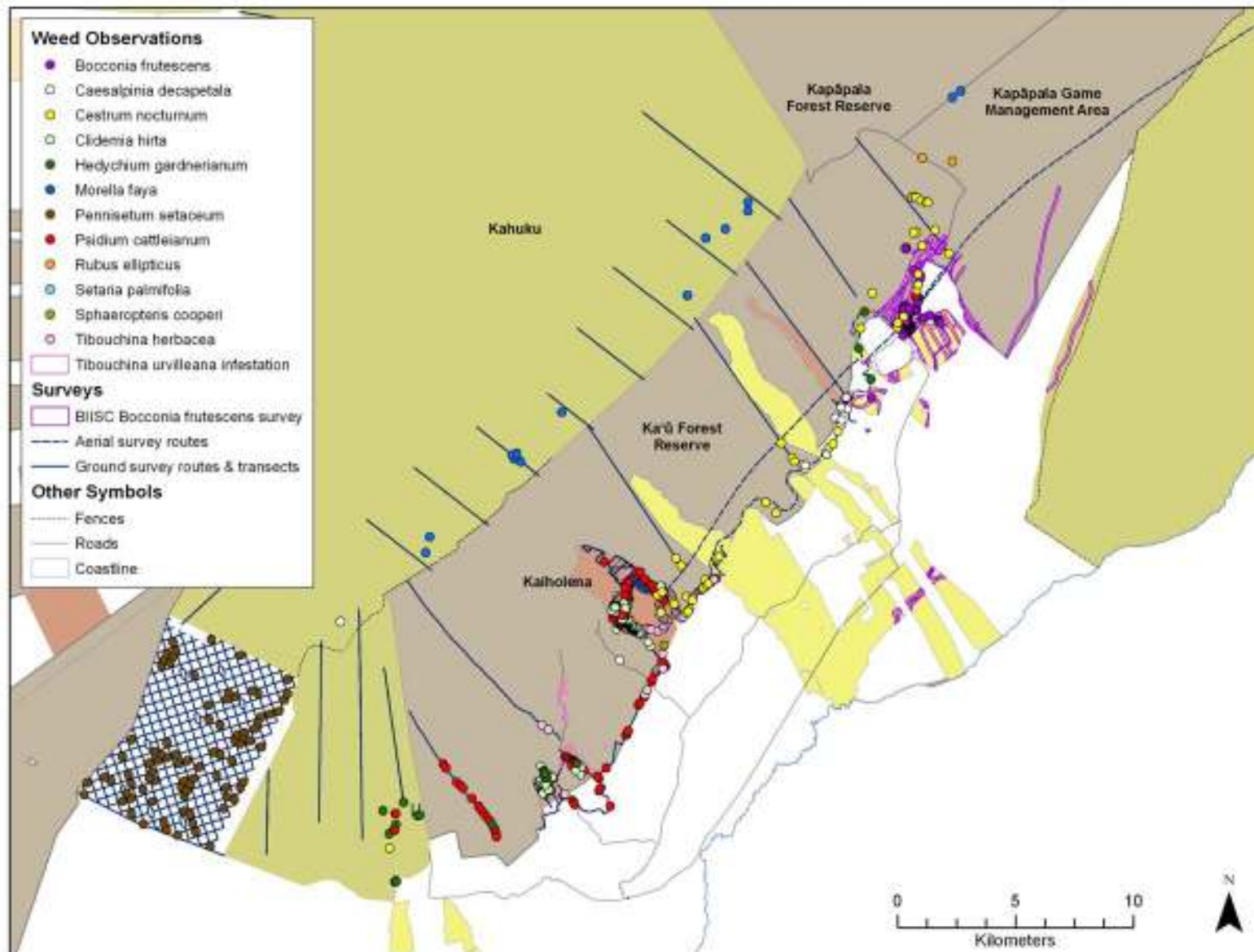
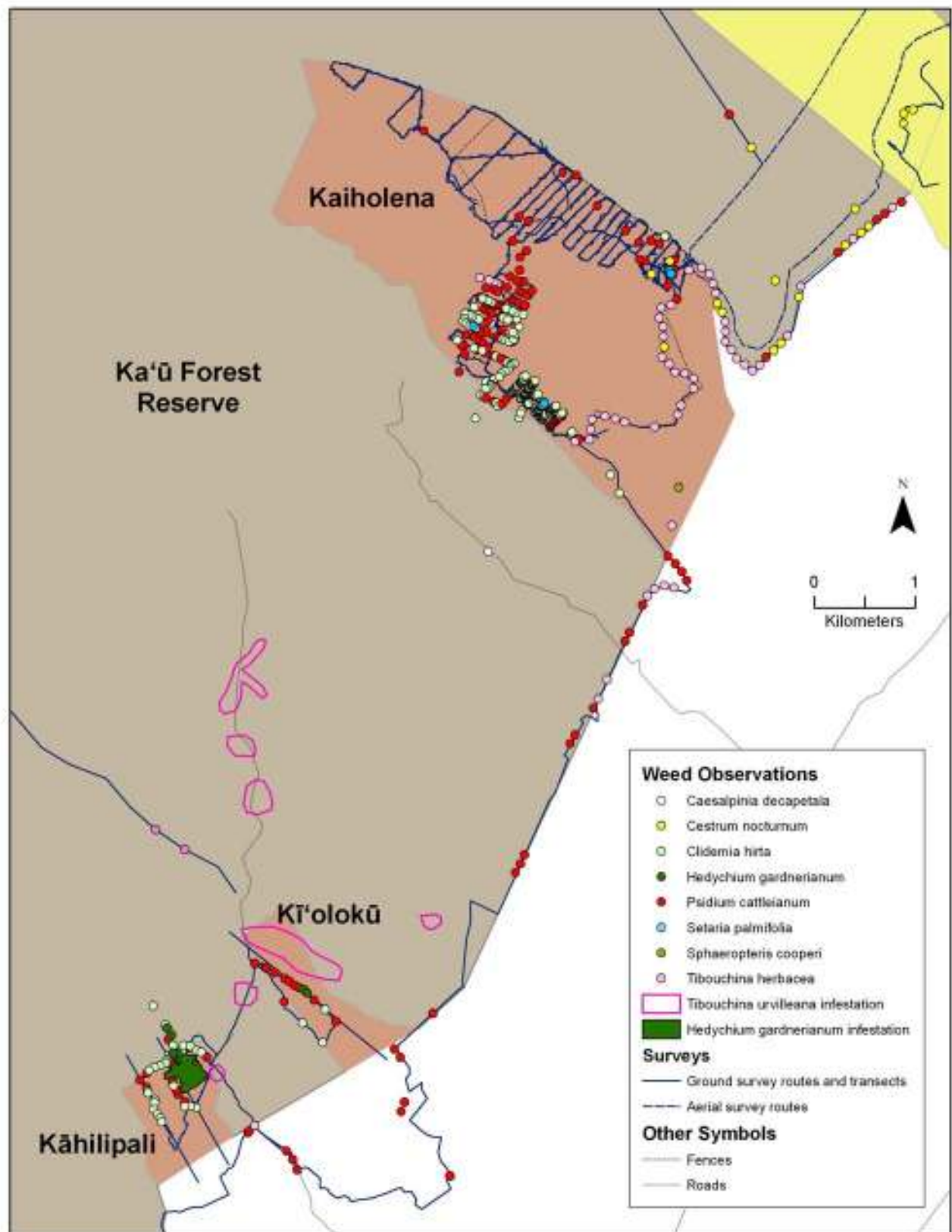


Figure 3.5. Ka'u Kapāpala Known Weed Distribution (Kaiholena Preserve).



3.5 Control Plans for High Priority Weed Species and Management Units

General TMA Strategy

The TMA will work with partners and BIISC to control high priority weeds in targeted high priority native habitat areas of the KKMA, particularly in areas identified as SEA's (e.g. Kaiholena). The TMA will assist partners in coordinating and conducting weed surveys in areas that have not been surveyed yet to better determine control strategies and priorities (e.g. Kapāpala FR, Kamilo, Kapāpala Koa Canoe Area, KS lands within Ka'ū FR). Regular surveys along the lower boundary of Ka'ū FR and along forest bird survey transects should be continued to detect new incipient weeds and increased spread of priority weeds into the upper FR. TMA weed control priorities in the two FR's include suppression and containment of priority weeds along the lower FR boundaries to prevent and reduce the spread of these weeds into more intact native forest areas in the higher elevations. Faya currently appears to be the greatest threat to the Kapāpala FR and surveys to map the population extent and outlying populations are needed.

Kaiholena Preserve, Kapāpala Koa Canoe Area and Kahuku are all targeted for vegetation and weed mapping using new mapping technologies. The TMA will help develop shared mapping projects in adjacent areas as well as assist partners in sharing relevant priority weed distribution information.

The TMA can help coordinate and raise funds to support additional private landowner and community projects. The TMA can also assist private landowners and lessees in lands adjacent to Ka'ū FR and Kapāpala FR with obtaining funding for cooperative weed control projects. New FR additions that are easily accessible to the community and that are targeted for community use (e.g. Kamilo and Kapāpala Koa Canoe Area) are ideal sites for the TMA to develop community volunteer weed control projects. The TMA can also assist NPS and BIISC in continuing the joint HOVE fountain grass removal project.

TMA Member Control Plans

Ka'ū FR and Kapāpala FR (DOFAW)

DOFAW is developing a management plan for Ka'ū FR and Kapāpala FR. The current DOFAW management priority for these areas is elimination of feral cattle from the FR's and cattle control is ongoing. Elimination of cattle is critically needed to reduce ground and forest disturbance and the subsequent spread of invasive weeds in these areas. DOFAW is also responsible for fire management. Fire, particularly in the drier forests of Kapāpala can destroy native forest which is then replaced by weeds such as faya and silk oak. Ongoing DOFAW weed control projects in these areas include control of cats claw in Ka'ū FR and yellow Himalayan raspberry and faya in Kapāpala FR. DOFAW staff have also worked jointly with TNC and TMA staff to remove night blooming jasmine adjacent to Kaiholena. Control priorities for the Ka'ū FR include suppressing the spread of night blooming jasmine, kahili ginger, bocconia and strawberry guava along the lower FR boundary to reduce spread into the more intact upper elevations of the FR. Surveys are needed for Kapāpala FR and new FR additions (Kamilo and Kapapala Koa Canoe Area) to better determine an effective strategy for control of priority species.

DOFAW has done initial control of these Kamilo fountain grass populations (6.5 ha) and follow-up treatment is scheduled for July 2009.

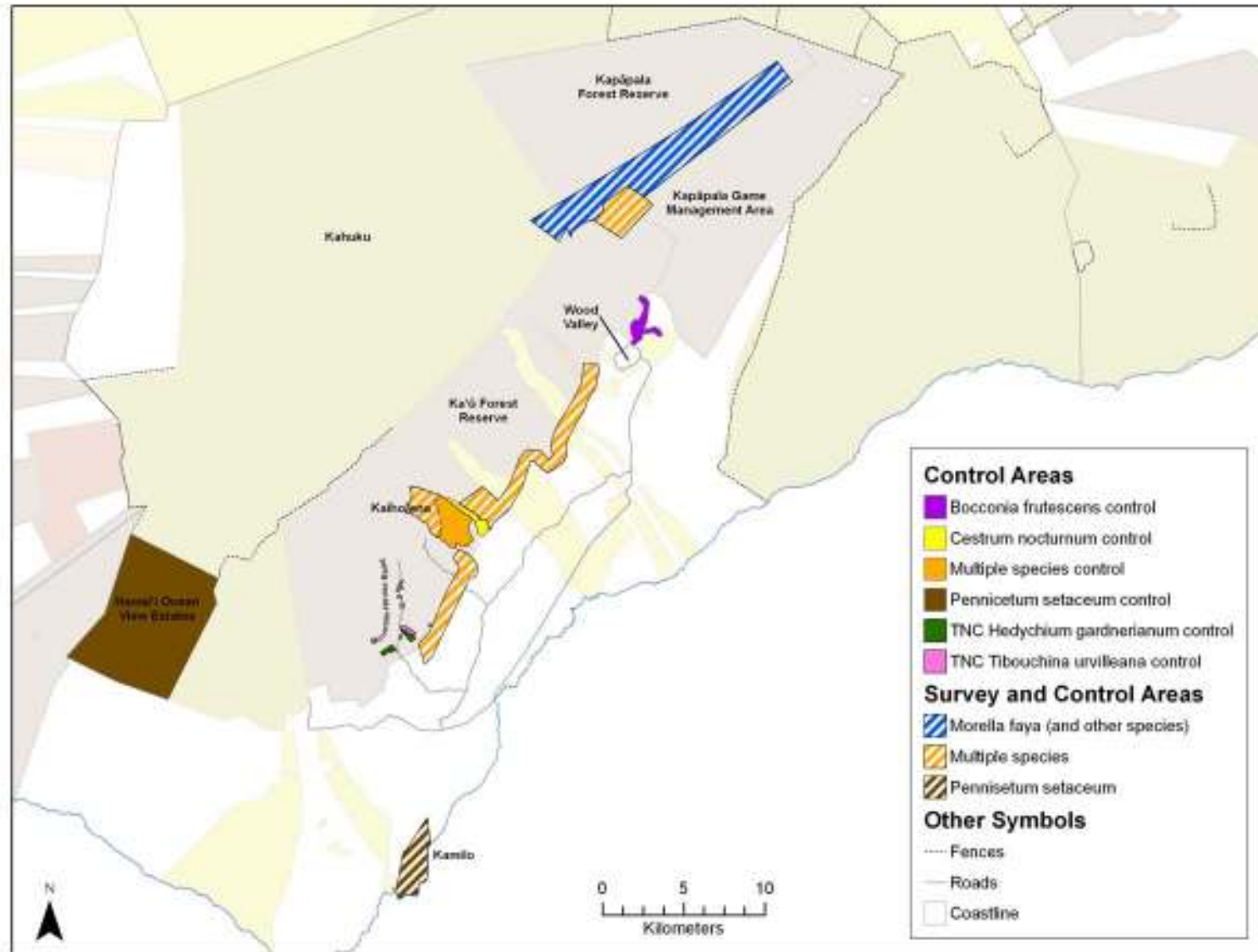
Ka'ū Preserve (TNC)

Currently the Kaiholena parcel of TNC's Ka'ū Preserve has the only fenced management unit in the Ka'ū forest. This 445 ha enclosure is one of the few lowland wet forest units in the state being managed for zero ungulates. It, along with the rest of the Kaiholena parcel, is treated as an SEA due to the high level of plant diversity and intactness of native forest. As such, the TNC strategy is to prevent high priority weeds from establishing in the weed free areas of the parcel and to suppress existing populations of strawberry guava, clidemia and cane tibouchina through staff and partner control efforts and potentially with the help of biocontrol. Of particular concern is the need to contain the night-blooming jasmine in the adjacent state FR, before it reaches the fenced management unit.

Kahuku (NPS)

The current NPS strategy at Kahuku is to eradicate the incipient weeds where ever they are found (e.g. fountain grass and faya). Additional surveys are needed to determine the extent of species such as strawberry guava, kahili ginger, and christmas berry, and then NPS will decide whether to try and contain these species or manage them using the SEA approach. HAVO is currently partnering with the adjacent HOVE community to do roadside control of fountain grass in the subdivision and is partnering with NARS and BIISC folks to do fountain grass control in other areas adjacent to the park. The spread of fireweed (sporadic but widespread) appears beyond the stage for effective management. The Kahuku area continues to be impacted by mouflon sheep, pigs and feral cattle. There are also still domestic cattle in the lower ranch area until April 2009) managed under a special use permit. NPS is currently developing a comprehensive ungulate management strategy that will assist recovery of native species in the area.

Figure 3.6. Priority TMA Control Projects in the Ka'ū Kapāpala Management Area.



TMA Weed Control Goals (Figure 3.6)

1. Kaiholena (SEA)/All priority weeds

- Conduct regular weed sweeps through weed-free areas to remove all priority species
- Suppress strawberry guava and clidemia, introduce biocontrol
- Survey portions of the preserve that have not been surveyed (e.g. slopes of Kaiholena and Pu'u Makaalia) using remote sensing as a demonstration project for other portions of the KKMA.
- Monitor adjacent pasture and roads for incipient weeds

2. Ka'ū FR

- Work with BIISC to contain Wood Valley bocconia in the eucalyptus plantation and suppress it in the FR.
- Contain night blooming jasmine in Ka'ū FR adjacent to Kaiholena. Develop a containment strategy for this species in other portions of the FR (e.g. keep Waihaka gulch population farthest to the east from spreading further east).
- Eliminate Kahili Ginger from Mauna Kea Springs Hunter Trail vicinity west of Waihaka gulch
- Initiate control of glory bush on Mountain House Road in cooperation with control efforts in the Kī'olokū parcel.
- Continue and expand cooperative weed surveys in and along the lower boundaries of Ka'ū to improve the effectiveness of control efforts.
- Kamilo (new addition to FR) - Conduct fountain grass surveys and control work at Kamilo and adjacent lands. Develop a cooperative fountain grass control project for this area with community groups.
- Develop cooperative weed control projects with private landowners and lessees adjacent to the lower FR boundary to benefit ranching, forestry and agriculture as well as suppress priority weeds in critical native forest buffer areas.

3. Kahilipali and Kī'olokū

- Eliminate the kahili ginger infestation in the Kāhilipali and Kī'olokū parcels.
- Suppress the *Tibouchina urvilleana* infestation within the Kī'olokū and Kāhilipali parcels.

4. Kapāpala FR

- Conduct systematic surveys in upper Kapāpala Ranch/Kapāpala FR for faya and other priority species to help develop a better control strategy.
- Develop cooperative weed control projects with lessees (e.g. Kapāpala Ranch) adjacent to the lower boundaries to benefit ranching as well as suppress priority weeds in critical native forest buffer areas.
- Kapāpala Koa Canoe Area - Conduct comprehensive weed surveys and develop community weed control projects.

5. Kahuku - Eliminate fountain grass in the park. Suppress fountain grass in adjacent areas by partnering with NPS, BIISC, and adjoining HOVE community to do roadside control of fountain grass in HOVE and control in other areas adjacent to the park.

Table 3. TMA Goals and Objectives by Area/Species*

KKMA		Management Area						
		Kapāpala FR	Kahuku	Ka'ū FR	Kaiholena	Kahilipali and Kī'olokū	HOVE	Wood Valley
Focal Species	BOC FRU	Prevent		2012				2012
	CAE DEC			TBD	Prevent			
	CES NOC	Prevent		TBD	2010	Prevent		
	CLI HIR			TBD	2010			
	HED GAR			TBD	2010	2012		
	MOR FAY	TBD	2010					
	PEN SET		Prevent	TBD	2012		2010	
	PSI CAT			TBD	2015			
	RUB ELL	TBD		Prevent	Prevent			
	SET PAL			TBD	2012			
	SPH COO			Prevent	Prevent	Prevent		
	TIB HER			TBD	2012			
	TIB URV			TBD		2015		

Prevent	= Prevent any populations from establishing in this area (ongoing).
Eliminate	= Remove all occurrences of species in this area.
Suppress	= Reduce extent of core population in this area.
Contain	= Prevent expansion of core population within this area.

*Table 3 includes the date by which the TMA expects to achieve the weed control goal. Dates are included only for currently funded and/or ongoing projects. TBD is noted for unfunded projects. Ongoing follow-up control work will still be needed to maintain progress on the projects following the achievement of the goals outlined in this table.

4. SOUTH KONA MANAGEMENT AREA

4.1 Background

The South Kona Management Area (SKMA) includes land managed by DOFAW (Kīpāhoehoe NAR, Manukā NAR and South Kona FR), TNC (Kona Hema Preserve), USFWS (Hakalau

National Wildlife Refuge (NWR) Kona Unit), NPS (Kahuku section) and KS (Honaunau) (Figure 4.1).

The SKMA includes habitat ranging from alpine and subalpine habitats on Mauna Loa to lowland and coastal areas (Figure 4.2). TMA management targets primarily include native-dominated landscapes. The montane mesic forest dominated by koa and 'ōhi'a found at the middle elevations along the Kona flank has been historically targeted for koa harvesting and is considered rare and imperiled. Koa/'ōhi'a montane mesic forest occupies a significant portion of the native-dominated landscape between 1,066 - 1,676 meter elevation and lies between subalpine dry shrublands above and 'ōhi'a-dominated wet and mesic forest below. The montane koa-bearing zone includes important habitat for endangered forest birds, which also occupy the 'ōhi'a -dominated forests below. Koa drops out of the forest below about 1,066 m, and 'ōhi'a montane wet forest, one of the most widespread wet forest communities in the Hawaiian Islands, prevails to about 914 m. This community type is moderately imperiled. It is often important habitat for endangered forest birds, and also includes rare plants and invertebrates. Nonnative ungulates (e.g., goats, pigs, mouflon sheep, and feral cattle) heavily impact all native plant communities within the SKMA.

Koa as a species is an important part of both the forest ecosystem and forestry industry of Kona. Thus koa is not only a conservation target that we would like to see thrive in the landscape but also provides an economic incentive for sustainability. For more than a century, cattle grazing and logging, together with invasive species, have degraded the condition of the native forest at a landscape scale. Yet, substantial tracts of relatively intact forest remain, on both public lands and on private ranches. Additionally, the forested slopes of Kona continue to provide important ecosystem services such as water catchment, sedimentation control, recreation, wood products and carbon sequestration. Most of the forested, and formerly forested, lands on the Kona flank of Mauna Loa are privately owned and zoned for agricultural use. Therefore perhaps the best hope for the protection of South Kona's native forest lies in its management as a working landscape where a transition to forest restoration and sustainable harvest of forest products is an economically attractive alternative to detrimental historic land use practices or land development. The objective would be to maintain the economic viability of working lands, while enhancing their conservation value. The measures of success in this transition would include a significant expansion of forest cover, an increase in native plant and animal diversity, recovery of rare species, increased variety of habitat types, and sustainable economic benefits.

Wildfires are a serious threat, especially to the mesic forests that occur above the 1,524-meter elevation. South Kona is one of the most drought-prone regions in Hawai'i (State of Hawai'i 1991). The summer maximum rainfall condition that occurs along the Kona area is unique within the Hawaiian archipelago, as are the ecosystems supported by that climate. Introduced grasses are a potential fuel hazard unless they are controlled and replaced with native understory species (including ferns, grasses, and shrubs). In areas from which cattle have been removed, grasses may increase the fire fuel load, especially in the mesic portions of this management area during the dry season.

Figure 4.1. South Kona Management Area Land Ownership.

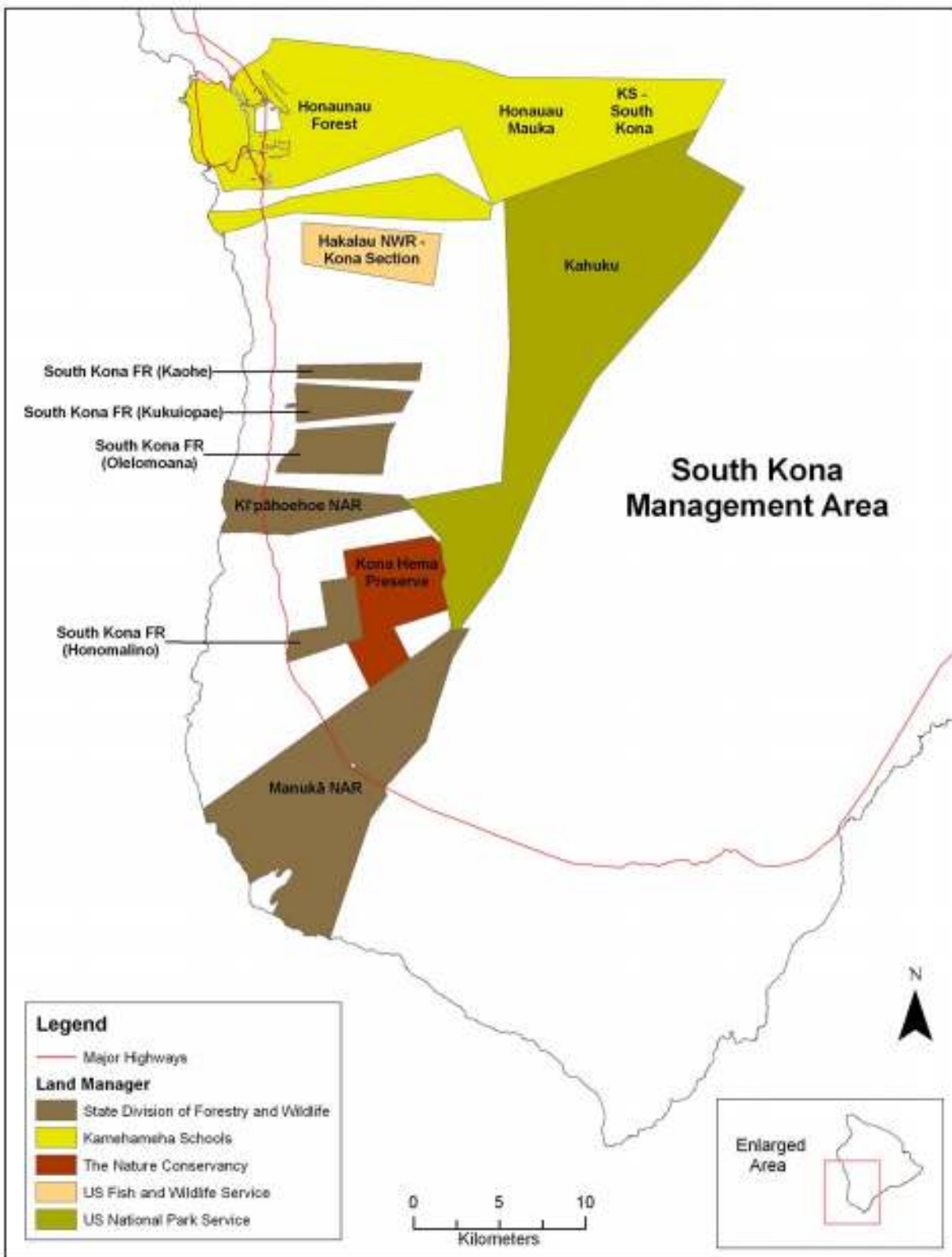
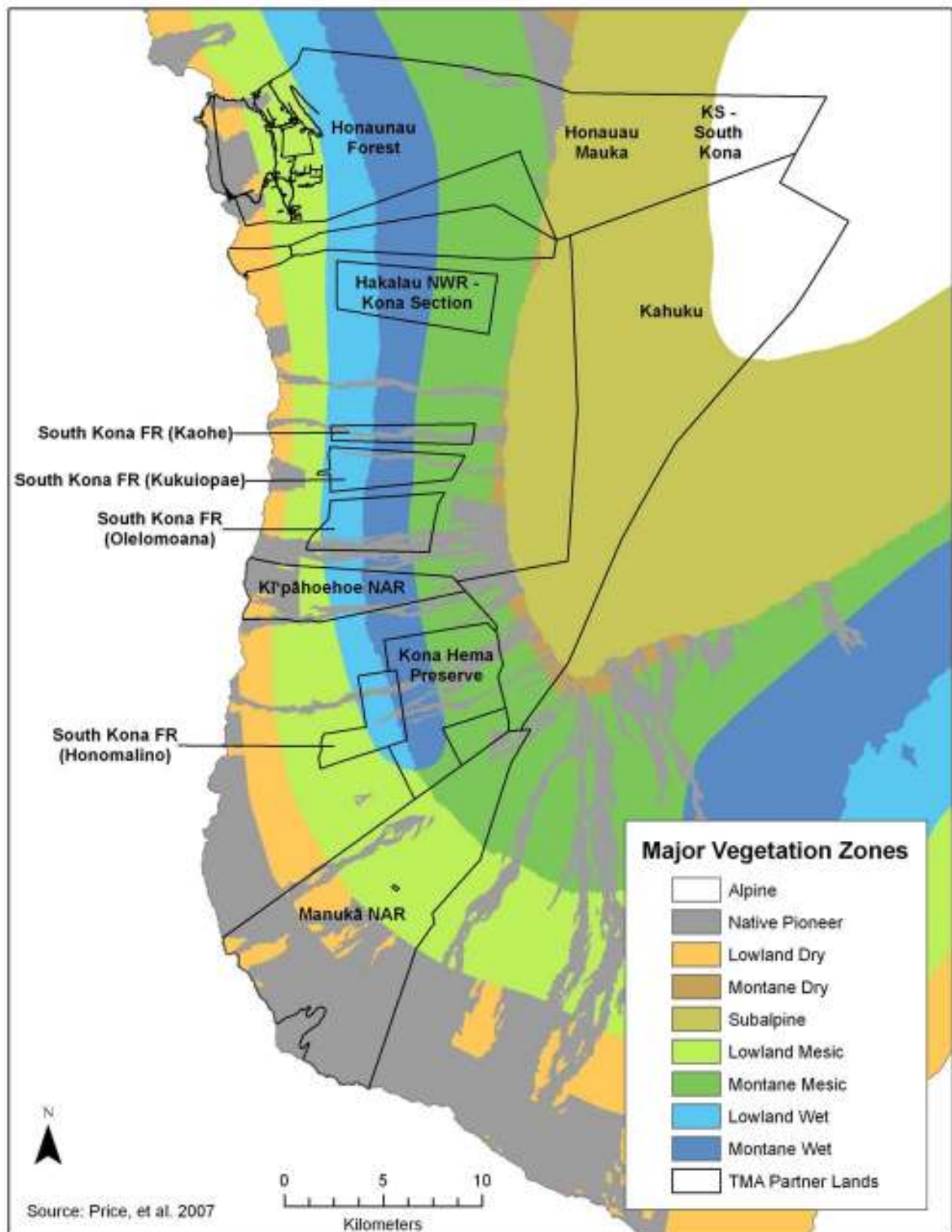


Figure 4.2. South Kona Management Areas Ecosystems.



4.2 Weed Inventory

Forest Solutions completed a weed assessment for Honaunau Forest and mauka Honaunau in 2003 (Koch 2003a-b). Weed surveys were conducted above the highway in 1996 in Manukā (16.6 km) and Kīpāhoehoe (8.4 km) by NARS staff. The Kahuku section of HAVO was inventoried between 2004 and 2006. The Hakalau NWR Kona unit was surveyed for weeds along roads (2000 and 2006) and transects (2001-2003) by USGS-BRD. TNC has conducted ongoing weed surveys in the Kona Hema Preserve units, starting in 2004. BIISC conducted both aerial and ground surveys for bocconia in Manukā NAR (2002), South Kona FR, Honomalino Section (2007). In addition, although not within the TMA, BIISC surveyed the primary roads in the South Kona district in 2008 for incipient weeds.

4.3 High Priority Weed Species

<i>Anemone hupehensis</i>	Japanese anemone
<i>Bocconia frutescens</i>	bocconia, plume poppy
<i>Clidemia hirta</i>	clidemia, Koster's curse
<i>Delairea odorata</i>	Cape ivy
<i>Hedychium gardnerianum</i>	kahili ginger
<i>Miconia calvescens</i>	miconia
<i>Morella faya</i>	faya
<i>Passiflora tarminiana</i>	banana poka
<i>Pennisetum setaceum</i>	fountain grass
<i>Psidium cattleianum</i>	strawberry guava, waiawi
<i>Rubus argutus</i>	blackberry
<i>Schinus terebinthifolius</i>	christmas berry

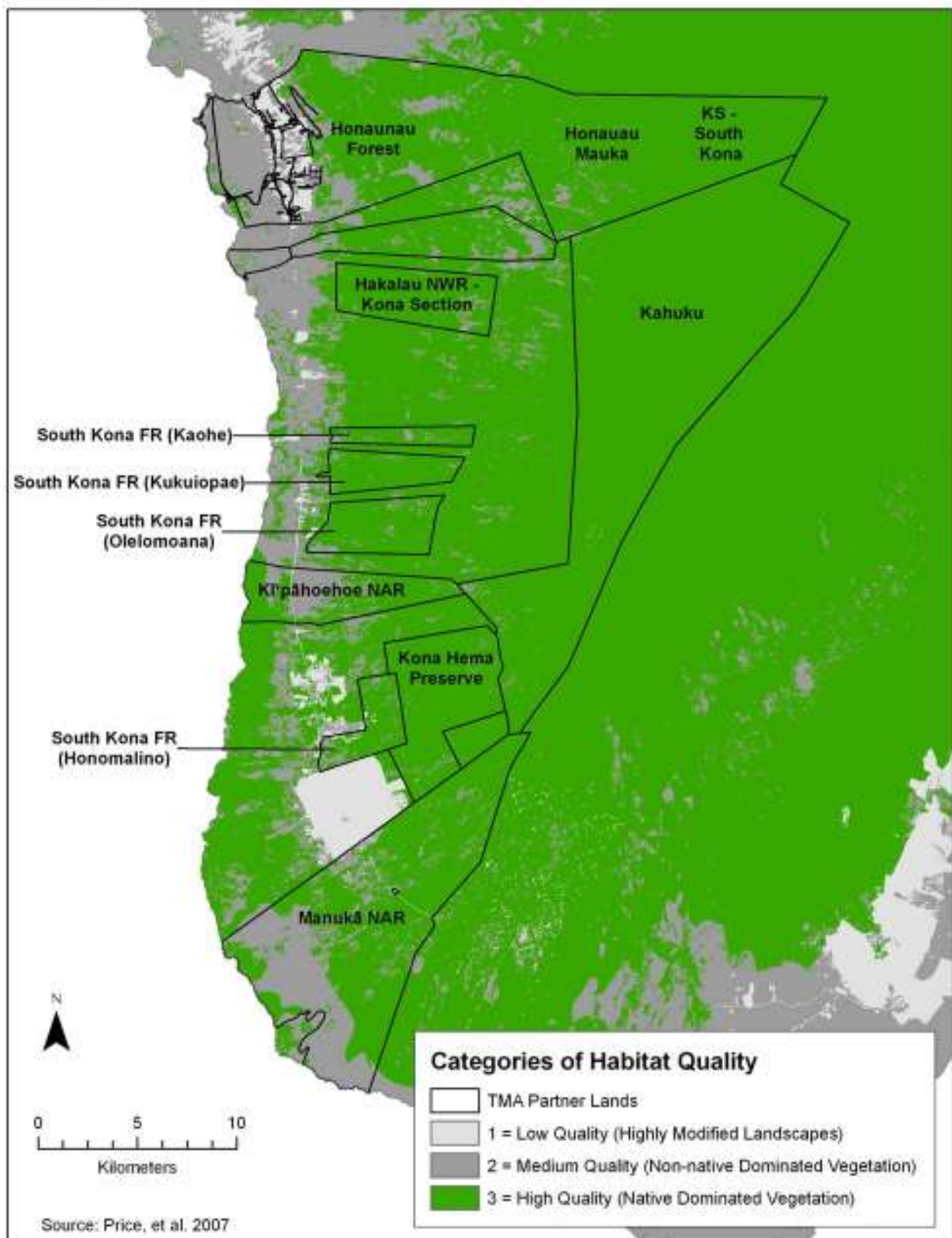
4.4 Description of Weed Situation

Honaunau (KS)

Honaunau Forest - The upper elevation forest is in better overall condition than the lower elevations. In the upper areas there are infestations of weeds (e.g. palm grass and banana poka) but these tend to be localized and small. Many of the most aggressive species known to the islands are present and are currently spreading (e.g. cat's claw, banana poka, and strawberry guava). The lower half of the forest is severely infested with weeds, particularly kahili ginger and strawberry guava. Much of this forest is a continuous thicket of strawberry guava that has slowly replaced practically every native plant. Certain planted species, particularly *Eucalyptus spp*, tropical ash, and Australian red cedar (*Toona ciliata*) seem to be self-regenerating in the timber production areas where they were planted. This is indicative of a possible weed threat from these species, particularly tropical ash. Cape ivy is found mostly in the central part of the property, along the roads and in spaces between forestry plantations (Koch 2003a).

The Honaunau Farm Lots, located makai of Honaunau Forest, consists of hundreds of small leasehold lots, occupied and managed by private lessees. Besides the common agricultural weeds that persist and are for the most part controlled by the lessees, and crop species that can become weedy themselves (e.g. coffee, cinnamon, loquat, passion fruit, raspberry), few weeds are so noxious as to be a concern to the region at large. One such species is miconia. Miconia

Figure 4.3. General Weed Situation.



trees were planted on a lot in the 1970's. From there, it was spread by birds into the other farms, ranches and Honaunau Forest, infesting an area approximately 800 ha in size. In 1999, BIISC initiated control efforts and removed 200 trees, saplings and seedlings. Miconia seeds remain viable in the soil for at least 10 years, and trees in Kona reach maturity within 4 years, so the miconia infestation is on a control schedule implemented by KS in coordination with BIISC. BIISC has focused control efforts on the farm lots with KS contractor Forest Solutions focusing control work in the Honaunau Forest.

Mauka Honaunau has relatively few weeds, and these, with the exception of Cape ivy, fireweed and tropical ash, are rather benign. Most of the weeds found there have already spread to the range that they are adapted to occupy, with little or no further spread expected. Kikuyu grass, the most common and widespread of the weed species, is likely to continue to be a part of the landscape in this area, and may indeed prevent or at least slow the spread of other, more noxious species. Tropical ash has spread from fence line plantings in Honaunau Forest into the adjacent pasture. Mullein currently inhabits alpine and sub-alpine shrubland (Koch 2003b).

Hawaii Volcanoes National Park, Kahuku Kona (NPS)

The South Kona portion of HAVO's Kahuku section occurs above 1,800 m elevation. These higher elevations are generally less weedy, and non-native taxa are of a more localized distribution. Non-native grasses are generally sparser and less numerous, and weeds are concentrated in discrete populations (e.g., faya), except in areas of koa forest that were previously logged, burned, or cleared for cattle grazing. Non-native grasses and other herbaceous weeds, including common mullein and fireweed, are prevalent throughout these highly modified areas. Kahuku's largest population of faya (170 trees) is located in the western portion of this area.

Manukā Natural Area Reserve (NARS)

Manukā Natural Area Reserve (10,340 ha) is the largest NAR in the State's system. The reserve protects a diverse range of natural communities ranging from 1,524 m to sea level including dry and mesic forests, subalpine shrublands and forest, lowland and coastal shrublands and grasslands, anchialine ponds, pioneer vegetation on lava flows, and lava tubes. Roughly, one third of the NAR is located above Highway 11 (1,700 m) and includes mesic and wet forest types. Below the highway dry forest kipukas grade into nonnative dominated coastal shrub and grass lands along the coast.

There are currently three ungulate free fenced units within the reserve including two above the highway (50 ha) and one (4 ha) below the highway. The western and northern boundaries (12 km) above the highway were fenced by neighboring landowners (MacFarms of Hawaii and HAVO) and a new fence is proposed for the remaining 8 km along the eastern boundary above the road between the NAR and Hawaiian Ocean View Estates. Upon completion of proposed fencing and ungulate control, 3,377 ha or 33% of Manukā would be ungulate free. The upper elevation portions of Manukā (above 1,200 m) are primarily exposed lava fields and scattered kipuka's with generally low weed abundance. Localized populations of Cape ivy and banana poka are expanding in all kipukas. By comparison, lower elevations have extensive areas with high coverage of invasive species targeted for control by NARS. Mauka of Highway 11 below 1,200m many target invasive tree species (strawberry guava, bocconia, Queensland maple (*Flindersia brayleyana*), Japanese holly (*Ilex crenata*), and gunpowder tree (*Trema orientalis*)), shrub species (common guava, christmas berry, soursbush (*Pluchea carolinensis*), lantana (*Lantana camara*), hill raspberry (*Rubus niveus*), senna (*Senna occidentalis* and *Senna pendula*),

and Mickey Mouse plant (*Ochna serrulata*) and herbaceous species (dog tail (*Buddleia asiatica*), Japanese anemone, basketgrass (*Oplismenus hirtellus*), meadow ricegrass, kikuyu grass, Spanish clover (*Desmodium incanum*), and fountain grass) are present. Makai of the highway the same suite of target shrub species are found throughout the former dry forest zone with localized high density fountain grass populations. Fountain grass is a considerable threat to the entire 6,963 ha makai of the highway because it greatly increases fuel loading and is currently the dominant species in over 300 ha in the coastal lowlands.

Kīpāhoehoe Natural Area Reserve (NARS)

Kīpāhoehoe Natural Area Reserve (2,259 ha) protects eight native natural communities including a rare native lowland dry grassland, four different 'ōhi'a forest communities and a tall-stature koa/'ōhi'a forest in kipukas at about 1,350 m elevation. Roughly, 70% of the NAR is located above Highway 11 (1,500 m) and includes mesic and wet forest types. Below the highway dry forest kipukas grade into coastal grasslands. There are currently two contiguous ungulate free fenced units along the top of the reserve (225 ha) and strategic fences that protect an additional 344 ha. Twenty-five percent of Kīpāhoehoe is ungulate free. These high elevation fenced portions of the NAR (above 1,100 m) consist of exposed lava fields and kipuka's with generally low target weed abundance except for some invasive grasses (meadow ricegrass and kikuyu). By comparison, lower elevations have extensive areas with high coverage of invasive weed species targeted for management by NARS. Mauka of Highway 11 below 1,100m many target invasive tree species (strawberry guava and bingabing (*Macaranga mappia*)), shrub species (common guava, christmas berry, and clidemia) and herbaceous species (Cape ivy, arthrostemma or everblooming eavender (*Arthrostemma ciliatum*), bull thistle (*Cirsium vulgare*), telegraph weed (*Heterotheca grandiflora*), sweet granadilla (*Passiflora ligularis*) and passion fruit (*Passiflora edulis*) are present. Clidemia ranges from the highway up to 792 m (with some sightings up to 975 m) with some solid stands in deep soil kipukas and adjacent pastures. Makai of the highway the same suite of target shrub species are found throughout the former dry forest zone with localized fountain grass populations.

Kona Hema Preserve (TNC)

Historic land uses have greatly impacted the weed situation on the Kona Hema preserve. For approximately 100 years, cattle grazing took place on much of the preserve until roughly 30 years ago, and koa logging continued until TNC purchased the property in 2002. The majority of this activity was concentrated in the higher elevation, koa-dominated mesic forest. As a result these areas contain diminished native plant diversity and the groundcover is currently dominated by well-established, non-native pasture grasses. Conversely, the areas that experienced little or no cattle grazing or koa logging (in the lower elevation, 'ōhi'a-dominated wet forest) contain rich native plant diversity and pasture grasses are not well-established. Therefore, for the purposes of weed management, the preserve has been divided into two units which receive different management actions, based on different overall weed management. The Biodiversity Management Area is treated as an SEA (1,023 ha). Here the goal is zero tolerance weed management so all habitat-modifying weeds are targeted, including strawberry guava and Japanese anemone. In the Conservation Management Area (2,136 ha) only the highest priority (e.g. Japanese anemone) or incipient (e.g. blackberry) weeds are targeted.

Hakalau Forest National Wildlife Refuge, Kona Forest Unit (USFWS)

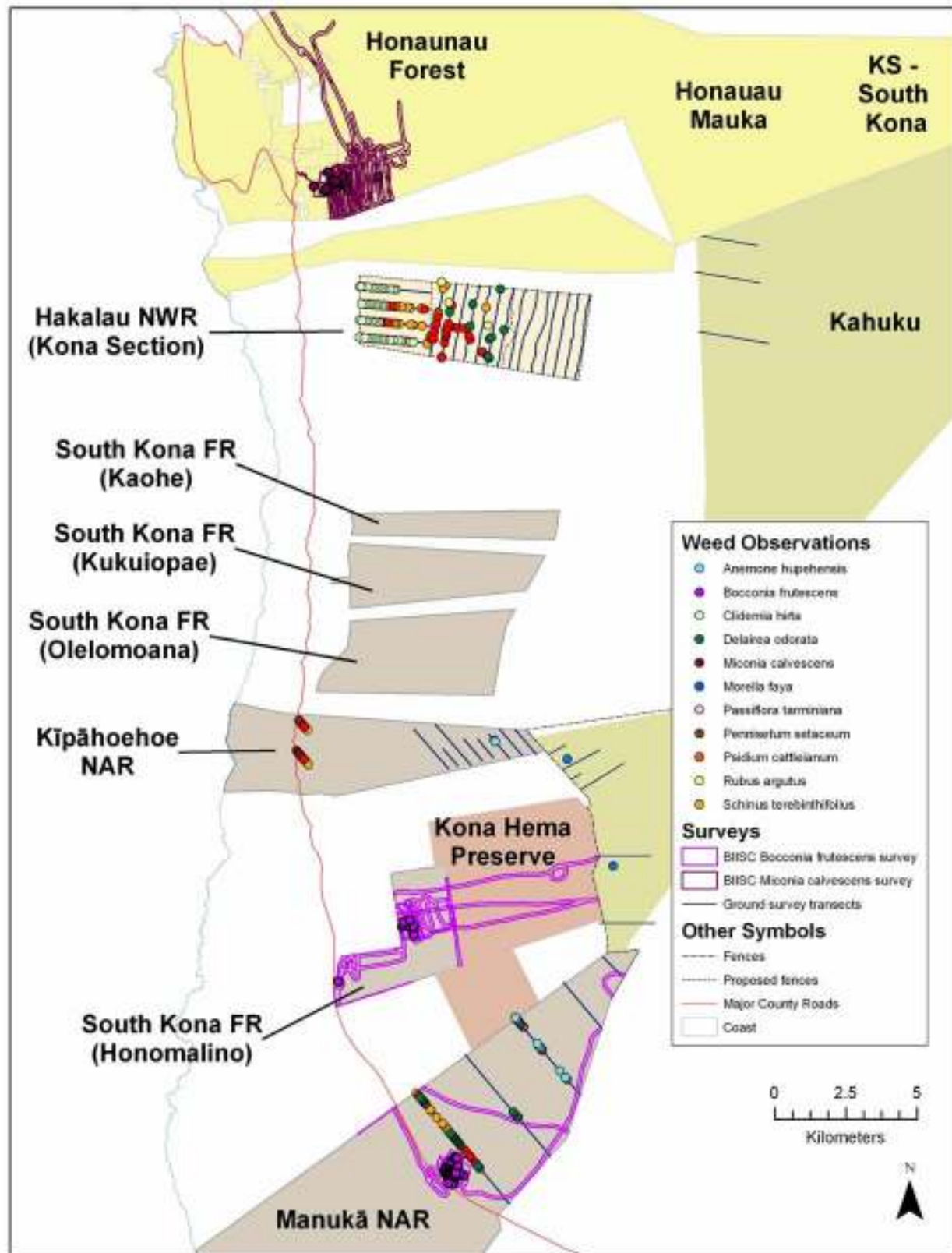
The lower portions of Kona Forest Unit, around the 610-meter elevation, are dominated by a mixture of introduced and native trees, shrubs, and grasses. Introduced invasive plants in the

lower elevations include common guava, strawberry guava, silk oak, clidemia, and christmas berry. Above the 762-meter elevation, introduced trees and shrubs become less prevalent, and the forest community becomes dominated by an overstory of 'ōhi'a trees and an understory of native trees, shrubs, and native tree ferns. Christmas berry and blackberry are priorities for control by the USFWS.

South Kona Forest Reserve (DOFAW)

The South Kona FR consists of four sections, totaling 4,449 ha in size. Priority weeds in the three northern sections (Kaohe, Kukuipae, and Olelomoana/Opihihale) include Clidemia (abundant distribution below 1,200 m elevation), scattered pockets of Cape Ivy in the upper, drier areas above 1,200 m, and sweet granadilla is common in the forest below roughly 1,060 m. The fourth unit, Honomalino section (adjacent to the TNC Kona Hema Preserve), is heavily infested with habitat-modifying weeds including common and strawberry guava, christmas berry, *Senna* spp., and *Desmodium* spp. The leading edge of a bocconia infestation that has spread mauka from farm lots below the highway occurs in this section at the 800 m elevation (above Hoomau Ranch). BIISC has initiated control efforts, but a more complete aerial survey and mapping effort is needed.

Figure 4.4. Known Weed Distribution South Kona Management Area.



4.5 Control Plans for High Priority Weed Species and Management Units

General TMA Strategy

The TMA will work with partners and BIISC to control high priority weeds in targeted high priority native habitat areas of the SKMA particularly in areas identified as SEA's (e.g. fenced units in Manukā, Kīpāhoehoe, Kona Hema and Hakalau Refuge Kona unit). The TMA will assist partners in coordinating and conducting weed surveys in areas that have not been surveyed yet to better determine control strategies and priorities (e.g. South Kona FR).

New mapping technologies using high resolution aerial imagery and remote sensing offer great potential for large-scale, cost effective mapping of certain priority weeds even under dense canopy vegetation. Kona Hema and Kahuku are targeted for mapping using these new technologies. The TMA will help develop shared mapping projects in adjacent areas as well as assist partners in sharing relevant priority weed distribution information. The TMA can also assist partners in the development and use of new weed control technologies (e.g. aerial herbicide application).

The TMA can help coordinate and raise funds to support additional private landowner and community projects. The TMA can also assist private landowners and lessees in lands adjacent to SKMA lands in the TMA with obtaining funding for cooperative weed control projects.

TMA Member Control Plans

Honaunau (KS)

KS has contracted Forest Solutions to perform control sweeps for miconia in Honaunau Forest every other year. Other projects underway in the area include control of weeds along roads to minimize the spread of weeds and the control of tropical ash to prevent movement into mauka areas. KS is considering increased control of strawberry guava in the upper portions of Honaunau Forest. KS would also like to update weed survey information for Honaunau Forest as the area as it has not been surveyed since 2003. KS weed control strategy will also be influenced by the timing of a proposed timber harvest (not yet sure when approvals will be finalized for this to occur).

Hawaii Volcanoes National Park, Kahuku Kona (NPS)

NPS goals for the South Kona section of Kahuku include working with NARS to eliminate all individuals of faya and any other incipient weeds. Other goals include figuring out a containment strategy for mullein and monitoring the area for new weed species. NPS is also working on fencing and ungulate control in this area. The southern portion is currently fenced along the boundary with TNC and DOFAW lands and mouflon sheep are reduced to remnant levels (all other ungulates not present). There are still a large number of sheep present in the northern portions of Kahuku.

Manukā and Kīpāhoehoe Natural Area Reserves (NARS)

Consistent with TMA strategy, weed management within Manukā NAR and Kīpāhoehoe NAR is focused on the ungulate-free fenced units. All target non-native species are mechanically and/or chemically controlled within the smaller fenced units annually by ground crews at Manukā. Weed

control was previously implemented in the larger fenced unit at Manukā, but has not been consistent. During the next five years managers intend to reinstate annual weed control within this unit. Early detection and rapid response weed monitoring/control is conducted biannually along invasion corridors (e.g., roads, trails, and fence lines) and by annual aerial surveys. In addition, target weeds are controlled inside fenced units when incidentally detected during maintenance and management activities (e.g., rare species outplanting). Weed monitoring surveys will be conducted on 5 year intervals in the interior unfenced forest sections of the NAR in order to detect incipient invaders.

Kona Hema Preserve (TNC)

The lower portion of the Kona Hema Preserve's Pāpā Unit is heavily infested with strawberry guava (up to 400 ha). Because this area is a Biodiversity Management Area (treated as an SEA) the goal is to suppress the strawberry guava infestation so that it no longer has a detrimental effect on native vegetation. Japanese anemone is increasing in abundance in an elevational band between 3,000-4,000 ft, particularly in the southern portion of the Preserve, where it crosses a privately owned parcel between Kona Hema and Manukā NAR. The goal is to obtain high resolution aerial photos of the heavily-infested area, determine whether Japanese anemone can be detected and mapped using these photos, and then develop a control strategy.

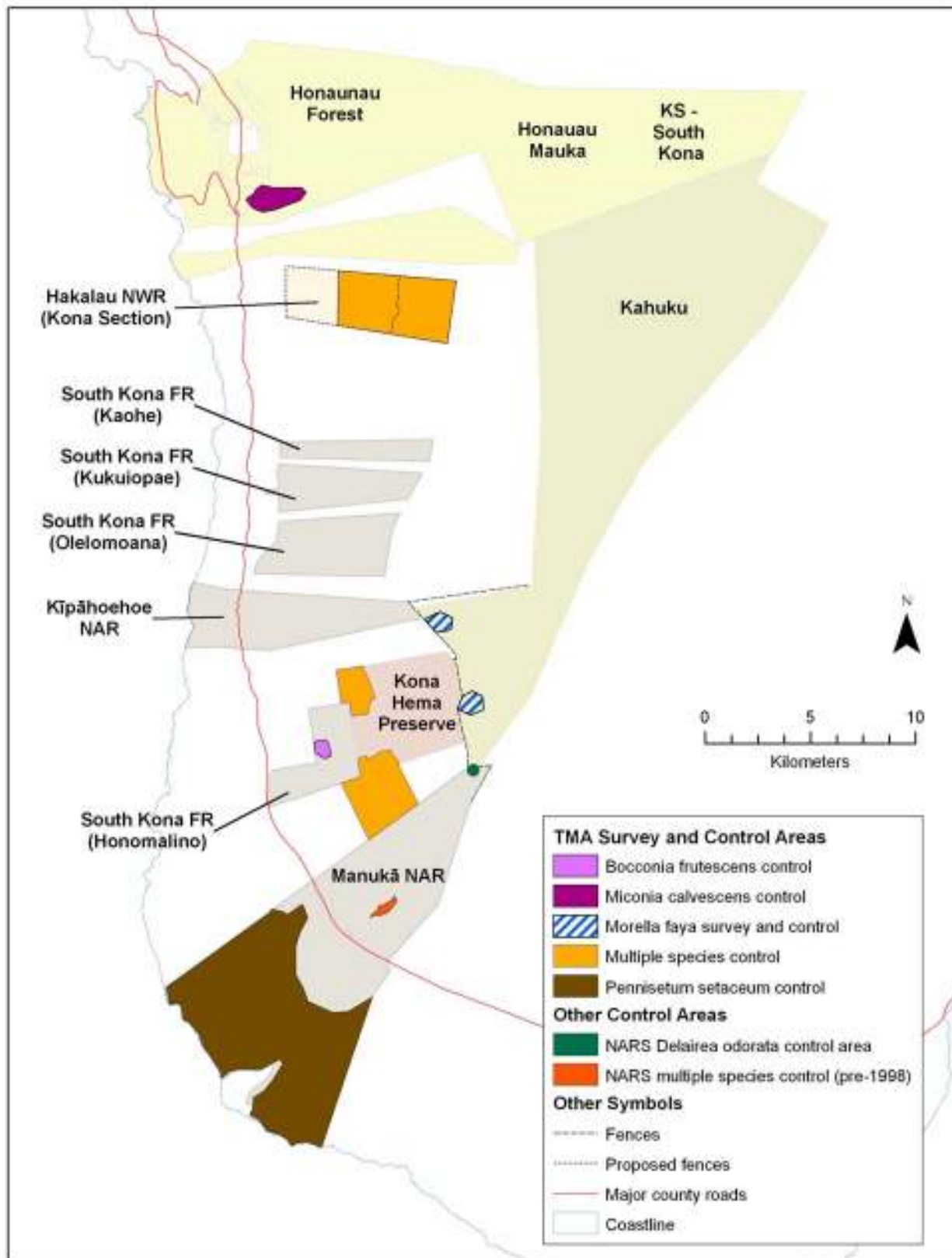
Hakalau Forest National Wildlife Refuge, Kona Forest Unit (USFWS)

Weed management goals for this area include fencing and removing ungulates from fenced units to slow or prevent the establishment of weeds. Targeted species include christmas berry and blackberry.

South Kona Forest Reserve (DOFAW)

The biggest threat to the FR is feral cattle and this is the top priority for FR management programs. Removal of the cattle will reduce forest disturbance and subsequent spread of weeds. DOFAW staff have been working on control of a small infestation of Japanese honeysuckle (*Lonicera japonica*). The bocconia population in the Honomalino section should be mapped using high resolution aerial photos so that targeted ground control efforts can then take place. BIISC is also initiating a public awareness campaign in the vicinity to garner support for bocconia eradication efforts.

Figure 4.5. Priority TMA Control Projects in the South Kona Management Area.



TMA Weed Control Goals (Figure 4.5)

1. Honaunau (KS)
 - Work with BIISC, KS and KS contractors to successfully eliminate miconia from the SKMA.
2. Hawaii Volcanoes National Park, Kahuku
 - Work with the park to eliminate faya from this area.
 - Survey adjoining lands to ensure that faya has not spread to other areas.
3. Manukā and Kīpāhoehoe Natural Area Reserves (NARS)
 - Work with NARS to suppress fountain grass in Manukā and Kīpāhoehoe as well as adjacent private lands.
 - Contain banana poka and kahili ginger which are present in Manukā but not present or in low densities in adjacent FR, HAVO and TNC lands.
 - Facilitate biocontrol for clidemia.
4. Kona Hema Preserve (TNC)
 - Conduct regular weed sweeps through Biodiversity Management areas to remove all priority species.
 - Suppress strawberry guava in the Pāpā unit.
 - Obtain high resolution aerial photos of Japanese anemone infestation to determine whether it can be detected and mapped using these photos, and then develop a control strategy in partnership with affected landowners, including NARS.
5. Hakalau Forest National Wildlife Refuge, Kona Forest
 - Complete fence installation and remove ungulates to slow weed establishment.
 - Control high priority weeds in fenced units including blackberry and christmas berry.
6. South Kona Forest Reserve (DOFAW)
 - Initiate joint weed surveys in high priority sections of the South Kona FR and establish a control strategy for high priority species.
 - Work with adjoining landowners (e.g. TNC) to implement new technologies for surveys (e.g. high resolution aerial photos for priority species such as bocconia).
 - Work with BIISC, DOFAW, TNC and other private landowners (e.g. Hoomau Ranch) to contain bocconia to the highway.
 - Facilitate biocontrol for clidemia.

Table 4: TMA Goals and Objectives by Area/Species*

SKMA		Management Unit					
		Honaunau	Kahuku	Manuka	Kona Hema	Hakalau	S Kona FR
Focal Species	ANE HUP				2015		
	BOC FRU				Prevent		TBD
	CLI HIR			TBD			TBD
	DEL ODO						
	HED GAR			TBD			
	MIC CAL	2012					
	MOR FAY		2012				
	PAS TAR			TBD			
	PEN SET			2015	Prevent		
	PSI CAT				2015		
	RUB ARG					TBD	
	SCH TER					TBD	

Prevent	= Prevent any populations from establishing in this area (ongoing).
Eliminate	= Remove all occurrences of species in this area.
Suppress	= Reduce extent of core population in this area.
Contain	= Prevent expansion of core population within this area.

*Table 4 includes the date by which the TMA expects to achieve the weed control goal. Dates are included only for currently funded and/or ongoing projects. TBD is noted for unfunded projects. Ongoing follow-up control work will still be needed to maintain progress on the projects following the achievement of the goals outlined in this table.

5. NORTH KONA MANAGEMENT AREA

5.1 Background

The North Kona Management Area (NKMA) consists of KS and State lands in the North Kona District of the island. Pu'u Wa'awa'a and Anahulu (mauka of Queen Ka'ahumanu Highway) Honua'ula Forest Reserve, and Waiaha Restricted Watershed are owned and managed by DOFAW. KS owned and managed lands in the NKMA are known as the Kona Uka lands.

The NKMA contains a wide variety of native ecosystems from coastal and lowland habitats to alpine and subalpine ecosystems. This management area has a larger proportion of dry montane ecosystems than the other management areas in the TMA due to its leeward location.

The NKMA area has been significantly modified by human activity. Wildfires and livestock grazing have removed much of the native vegetation, particularly in the lower elevations. Subsequent invasion by non-native plant species has brought about some of the most notable changes. The profusion of fountain grass and kikuyu grass has caused a major increase in the area's readily ignitable fuel load, making fires the primary threat to the remnant native dry forests. Tropical dry forests are extremely rare worldwide and are one of the most endangered habitats in Hawai'i due to threats such as land development, fire, grazing by domestic and feral ungulates and weed invasion.

Pu'u Wa'awa'a and Pu'u Anahulu (42,382 ha) are located on the northern flank of Hualālai volcano. These areas are the oldest geologic formations on Hualālai (over 100,000 years old). Due to its older age, high degree of soil development and complex topography, Pu'u Wa'awa'a cone has greater botanical diversity and supports a different plant community than the surrounding area. Dry and mesic forests in this region were once considered the most diverse forests in all the Hawaiian Islands (Rock 1913). A unique assemblage of natural communities and plant and animal species are still found within this area, many of which are rare or restricted in distribution. The Pu'u Wa'awa'a Forest Bird Sanctuary is considered essential habitat for certain endangered birds ('alalā, 'akepa, and Hawai'i creeper). Pu'u Wa'awa'a provides habitat for a diverse native arthropod community including the endangered Blackburn Sphinx moth and the beetle *Plagithmysus simplicicollis* (Cerambycidae). Pu'u Wa'awa'a is one of the best places to restore and protect many species that are found only in dry forests of Hawaii.

Honua'ula Forest Reserve (3,951 ha) is located between 457 m – 2,286 m in elevation in the Wai'aha watershed on the western slopes of Hualālai. Tracts I-III and the Hienaloli section are contiguous while the Makaula Ooma Section lies further to the north. The FR consists of lowland (wet and mesic), montane (wet, mesic and dry) and subalpine ecosystems with both intact native vegetation as well as heavily disturbed former pasture lands with scattered native trees and non-native grass groundcover. Honua'ula Tract II is predominantly characterized as open koa/'ōhiā montane mesic forest. Other portions of the FR contain native forest types including open koa/mamane (*Sophora chrysophylla*), mamane/naio (*Myoporum sandwicense*), and native shrubland. Honua'ula Tract III is largely dominated by open and closed 'ōhiā forest (wet to mesic). Hienaloli section is dominated by intermixed closed 'ōhiā forest and non-native dominated forest. Makaula Ooma is characterized as 'ōhi'a lowland mesic forest. The FR contains critical habitat for two listed endangered plants, haha (*Cyanea hamatiflora* ssp. *Carlsonii*) and popolo ku mai (*Solanum incompletum*).

KS Kona Uka lands (54,227 ha) are extensive and extend across the broad, upland plateau stretching from the western summit of Mauna Loa to the summit of Hualālai. This area includes portions of the slopes and the summit of Hualālai, Ka'ūpūlehu Forest Reserve, Kahalu'u Forest Reserve, Lupea and other adjacent lands. This area includes multiple habitat types and vegetation zones (alpine, sub-alpine, forested zones, and barren lava flows) with large portions characterized as montane dry forest. The broad saddle between Hualālai and Mauna Loa harbors the largest area of mamane forest on Mauna Loa and also supports the largest and most important stands of sandalwood (or 'iliahī) remaining on the island. This area is characterized by several vegetation types including montane dry and mesic forests and woodlands, subalpine forests, woodlands and shrublands, and grasslands. Major plant

communities include 'ōhi'a dominated forest or woodland on 'a'ā lava or at upper elevations, mixed koa forest with native shrubs, sedges, and/or grasses. Kahalu'u forest contains lowland wet and montane mesic and wet forest.

5.2 Weed Inventory

DOFAW owned lands in the NKMA have not had any systematic weed monitoring or mapping performed. Information on weeds in these areas has been obtained from incidental staff observations during other botanical surveys and general knowledge of these areas.

KS contracted Forest Solutions Inc. to do weed assessments on numerous parcels in the NKMA. Forest Solutions has completed weed surveys and reports including: an assessment of fountain grass distribution across KS Kona Uka lands, and land assessments on specific parcels (e.g. Hale Laau, Kaupulehu, Kaukohoku and Ika'aka, and Kahalu'u) (Rice 2006a-d, Koch 2003c).

USGS-BRD surveyed presence/absence of priority weeds in the Lupea area at stations along transects in 2003-2004 (Jacobi 2009).

5.3 High Priority Weed Species

<i>Ageratina adenophora</i>	Maui pamakani
<i>Clidemia hirta</i>	Koster's curse
<i>Delairia odorata</i>	Cape ivy
<i>Grevillea robusta</i>	silk oak
<i>Hedychium gardnerianum</i>	kahili ginger
<i>Miconia calvenscens</i>	miconia
<i>Morella faya</i>	faya
<i>Passiflora tarminiana</i>	banana poka
<i>Pennisetum setaceum</i>	fountain grass
<i>Psidium cattleianum</i>	strawberry guava, waiawi

Figure 5.1. North Kona Management Area Land Ownership.

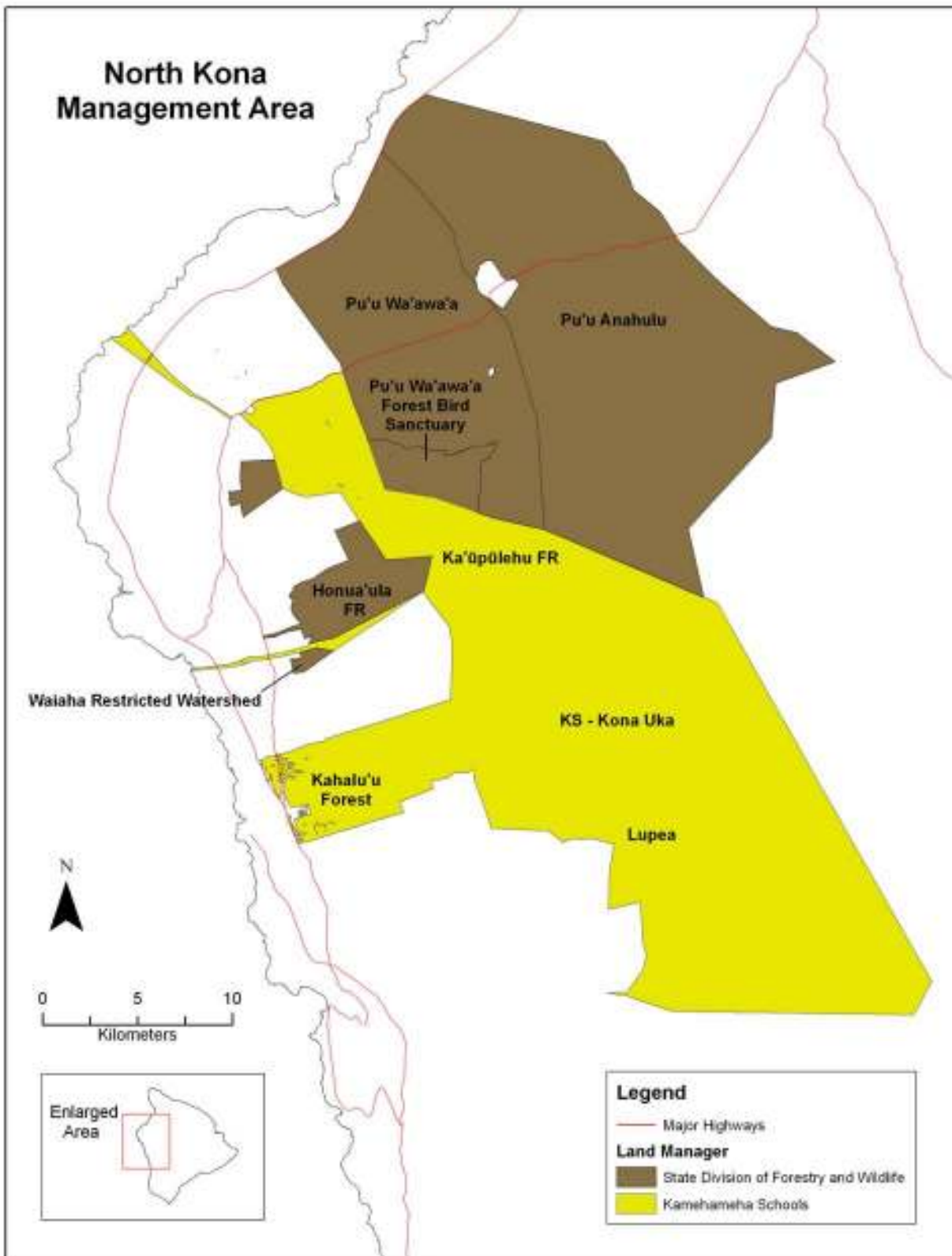
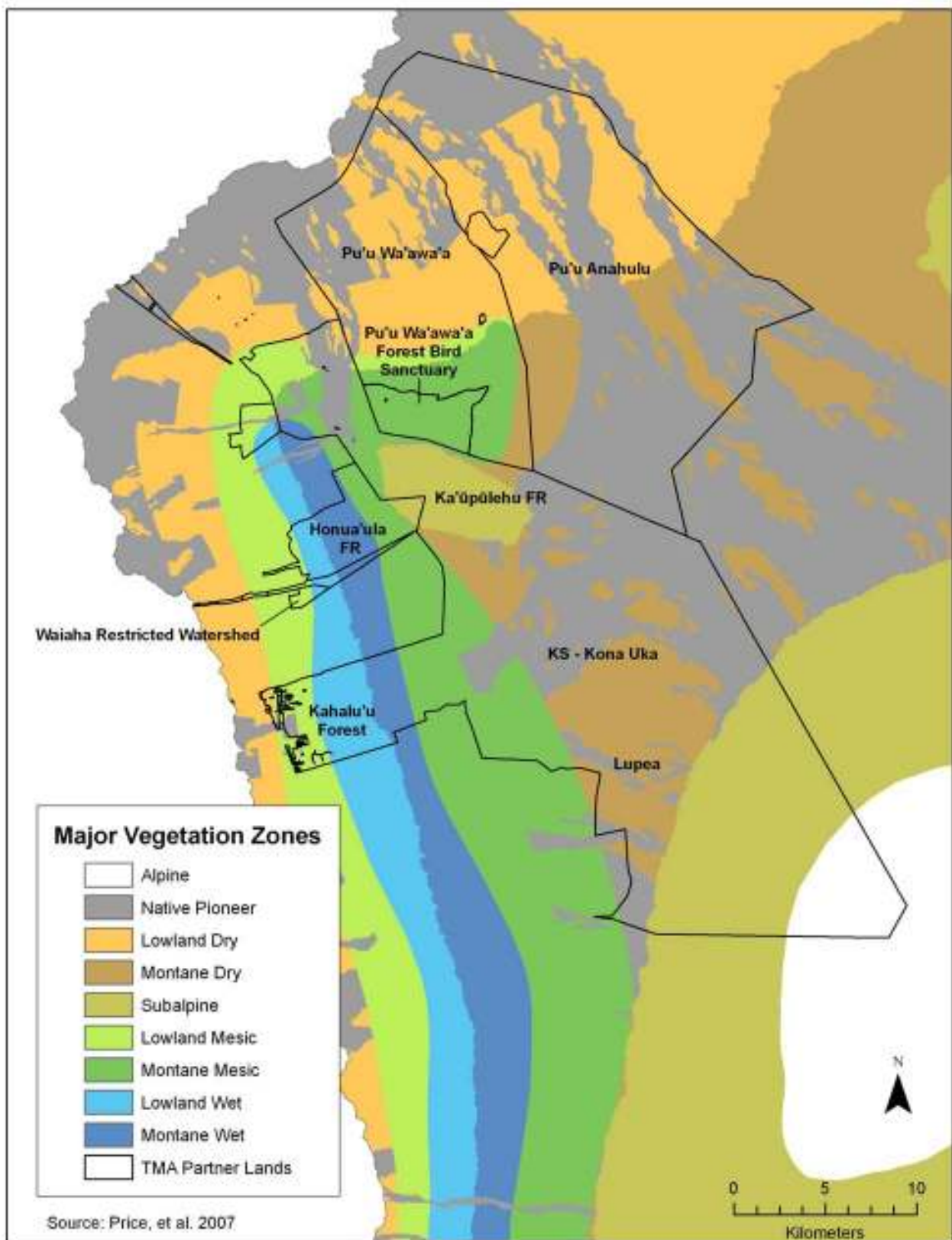


Figure 5.2. North Kona Management Areas Ecosystems.



5.4 Description of Weed Situation

Pu'u Wa'awa'a and Pu'u Anahulu

The long history of grazing by domestic and feral animals and fires has encouraged a major shift in vegetation composition, and much of the lower elevations of these areas are dominated by fountain grass and other non-native species. More than 60 non-native species have been identified in the forest bird sanctuary alone. Many of these seriously disrupt native forest ecosystems. Species presenting the greatest threat to forest recovery in this area include fountain grass, banana poka, silk oak and Cape ivy. Other prominent weeds include daisy fleabane (*Erigeron karvinskianus*), tree tobacco (*Nicotiana glauca*), fireweed, lantana, and apple of sodom (*Solanum linneanum*) (State of Hawai'i 2003c). Maui pamakani (*Ageratina adenophora*) is a concern because it has become a serious problem on Maui, and DOFAW staff believe this is the only location where it is currently known to occur on the island. Banana poka is probably the most widespread priority weed found in the forest bird sanctuary. One small population of kahili ginger has been found in the forest bird sanctuary and has been removed, and eliminating this species is a high priority for DOFAW.

Honua'ula FR

A wide variety of non-native plants, some of which are considered invasive, are spread throughout sections of the FR. Weeds identified in botanical surveys included pasture grasses, christmas berry and strawberry guava. Species of most concern include banana poka, clidemia, blackberry, Cape ivy, and fireweed. In a 1994 biological inventory of Makaula Ooma Tract it was noted that the study area had also been invaded by weeds and that vegetation in the northwest section was considered alien-dominated (e.g. christmas berry, common guava, strawberry guava and kahili ginger). The lower elevation portions of Hienaloli Tract (below 600 m) are dominated by introduced vegetation (State of Hawai'i 2008).

Kona Uka lands (KS)

Fountain grass is found throughout KS lands in the NKMA at various densities. In general, fountain grass is denser in the north and more sparse in the southern KS lands, but distribution is also dependent on habitat (e.g. it is suppressed in areas with thick kikuyu grass and in more densely forested areas) (Rice 2006d). Forest Solutions has categorized different portions of the area as having light, medium or heavy infestations. Some large portions of the area have not been fully assessed for fountain grass density.

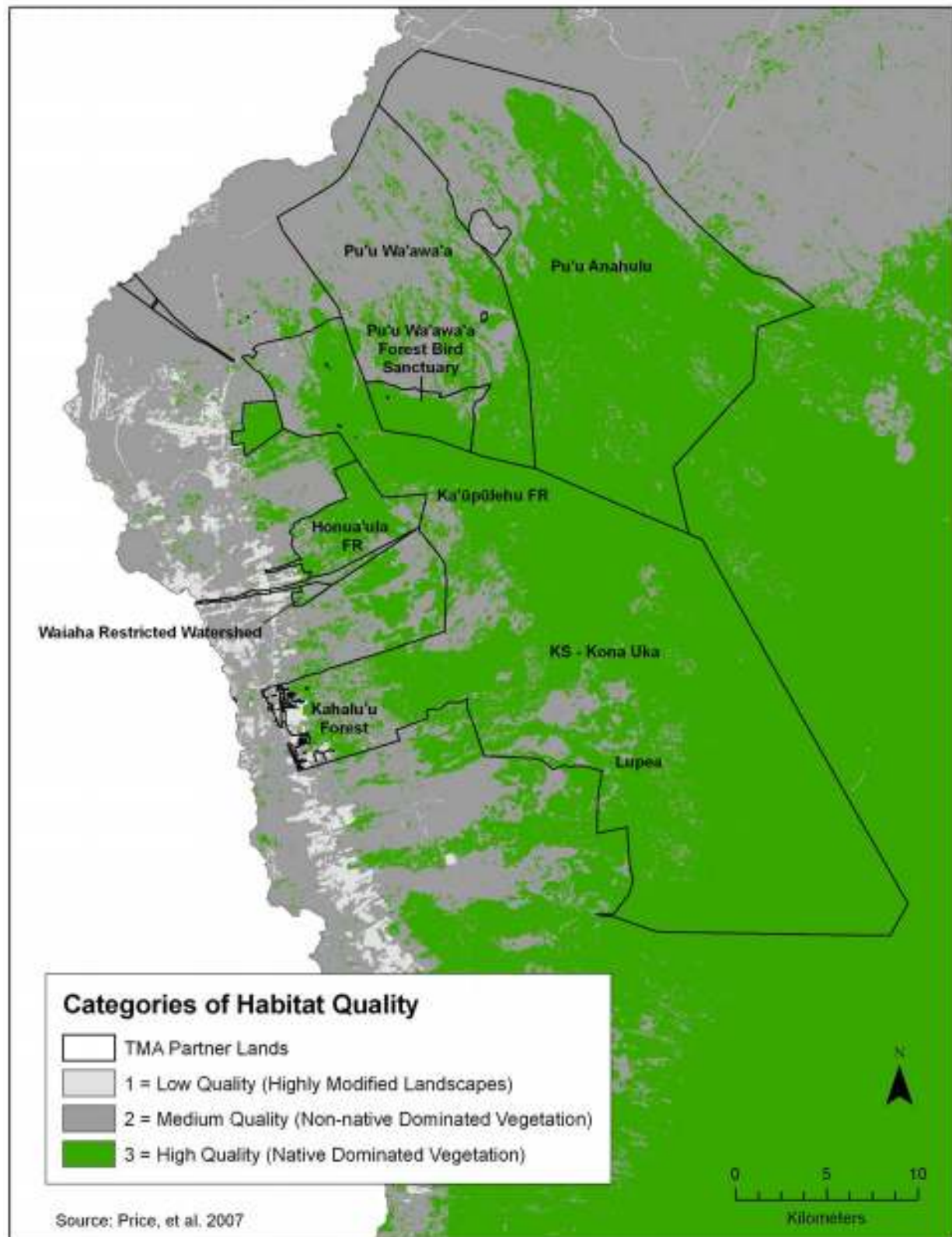
In addition to fountain grass, other priority weeds noted by Forest Solutions in the dry montane, subalpine and alpine portions of KS lands (summit and southern slopes of Hualālai) include fireweed, kikuyu grass and mullein (Hale La'au area) (Rice 2006a), 17 invasive species in the Kaukohoku and Ika'ika areas including blackberry, silverleaf cotoneaster, common guava, lantana, banana poka, Cape ivy, fireweed and other species. Of particular concern is faya, which was not observed along transects but has been reported from the area (Rice 2006c). The Ka'ūpūlehu Forest Reserve area contains 11 invasive species including high priority species such as faya, silk oak, and banana poka (Rice 2006b).

Kahalu'u forest contains both native forest and non-native forest plantations (tropical ash and eucalyptus). Disturbed areas such as forest edges nearest to and surrounded by agricultural land and pasture and areas within the forest disturbed by feral cattle are infested with a variety of weeds including strawberry guava, African tulip (*Spathodea campanulata*), christmas berry,

blackberry, clidemia and other species. Miconia was not detected in the Forest Solutions survey but had been detected and controlled by BIISC in 2003 (Koch 2003c).

In the Lupea area, USGS-BRD surveys noted weeds including kikuyu grass, fountain grass, Cape ivy, banana poka, fireweed, mullein and hill raspberry. Fountain grass and Cape ivy are the most widespread species of the greatest concern. Three invasive plants (hill raspberry, fireweed and banana poka) were extremely rare within the survey area, but do pose a threat to management of the native plant communities found there if they increase in distribution and abundance (Jacobi 2009).

Figure 5.3. General Weed Situation.



5.5 Control Plans for High Priority Weed Species and Management Units

General TMA Strategy

Proposed TMA activities in the NKMA include distribution mapping of primary threat species in high priority areas and control efforts across land ownership boundaries by jointly seeking outside funding, acquiring equipment and hiring a field crew for the region. The TMA will also focus attention on high priority management areas (e.g. fenced management units with high quality native forest or areas with restoration potential).

As in other portions of the TMA, effective weed management needs to be closely integrated with other management activities such as fencing, feral ungulate control, reforestation and fire management. Halting the spread of fountain grass into new areas to reduce fuel build up will also be a general focus of TMA weed efforts. The NKMA also provides an opportunity to consider continued use of grazing as a means to control fire fuels build up. Grazing that provides economic returns to landowners as well as ecosystem services of fire and weed management could be a valuable management tool to apply across the broader TMA landscape.

Pu'u Wa'awa'a and Pu'u Anahulu

A guiding principle of the management plan for the ahupua'a of Pu'u Wa'awa'a and the makai lands of Pu'u Anahulu (State of Hawai'i 2003b) is to protect and enhance the rich and diverse natural, cultural, and recreational resources for the enjoyment of current and future generations. Management objectives include the restoration of native ecosystems, preservation of cultural resources, reforestation, hunting, public recreation, research and other activities.

DOFAW management objectives include the phased establishment of fenced conservation units to protect and restore the best remaining native forest communities. After each unit is fenced, ungulates will be removed through a variety of methods. The Pu'u Wa'awa'a Forest Bird Sanctuary (1,540 ha) is currently the largest fenced management area and feral pig control is underway in this area. There are also 14 small fenced conservation units (7 ha) whose primary purpose is to protect rare and endangered plants. DOFAW invasive weed control will focus on these fenced conservation units. Pulse grazing of domestic livestock outside conservation units may be used to control weeds and reduce fuels in certain areas.

Honua'ula FR

DOFAW's principal objectives are to manage the lands for watershed protection including management actions related to native forest restoration, protecting rare native biological resources, and recreational and cultural uses. Planned management activities will focus on fence maintenance, feral cattle control, maintaining rare plant conservation areas, koa reforestation, native forest restoration, weed control and establishment of public access (State of Hawai'i 2007).

Kona Uka Lands (KS)

KS has designated certain portions of their lands as high priority for natural resource management due to the presence of high quality native ecosystems and/or cultural significance. Priority areas include the Kaupulehu or Hualalai summit area, Lupea, and Kahalu'u Forest. In

addition to weed control, management plans for these areas include fencing, feral ungulate control and reforestation.

KS would like to contain fountain grass by implementing roadside control to limit its spread in areas where it is just starting to become established. KS priorities include reducing the abundance of this species in the heavily infested Kaupulehu or Hualalai summit area and in areas with lighter infestations such as the Lupea Habitat Restoration Area. There are also smaller native forest remnants in heavily infested areas that have been identified as potential fountain grass control areas (e.g. Pu'u Keanui and Pu'u Pohakuloa) (Rice 2006d).

In Kahalu'u, Forest Solutions recommends control of species including miconia (if detected), blackberry, lantana, christmas berry, cats claw, tropical ash and weeping pine. They recommend evaluating feasibility and cost of future control for other species (e.g. eucalyptus, African tulip, rose apple, kahili ginger and white ginger (*Hedygium coronarium*)) (Koch 2003c).

Figure 5.4. Known Weed Distribution in the North Kona Management Area.

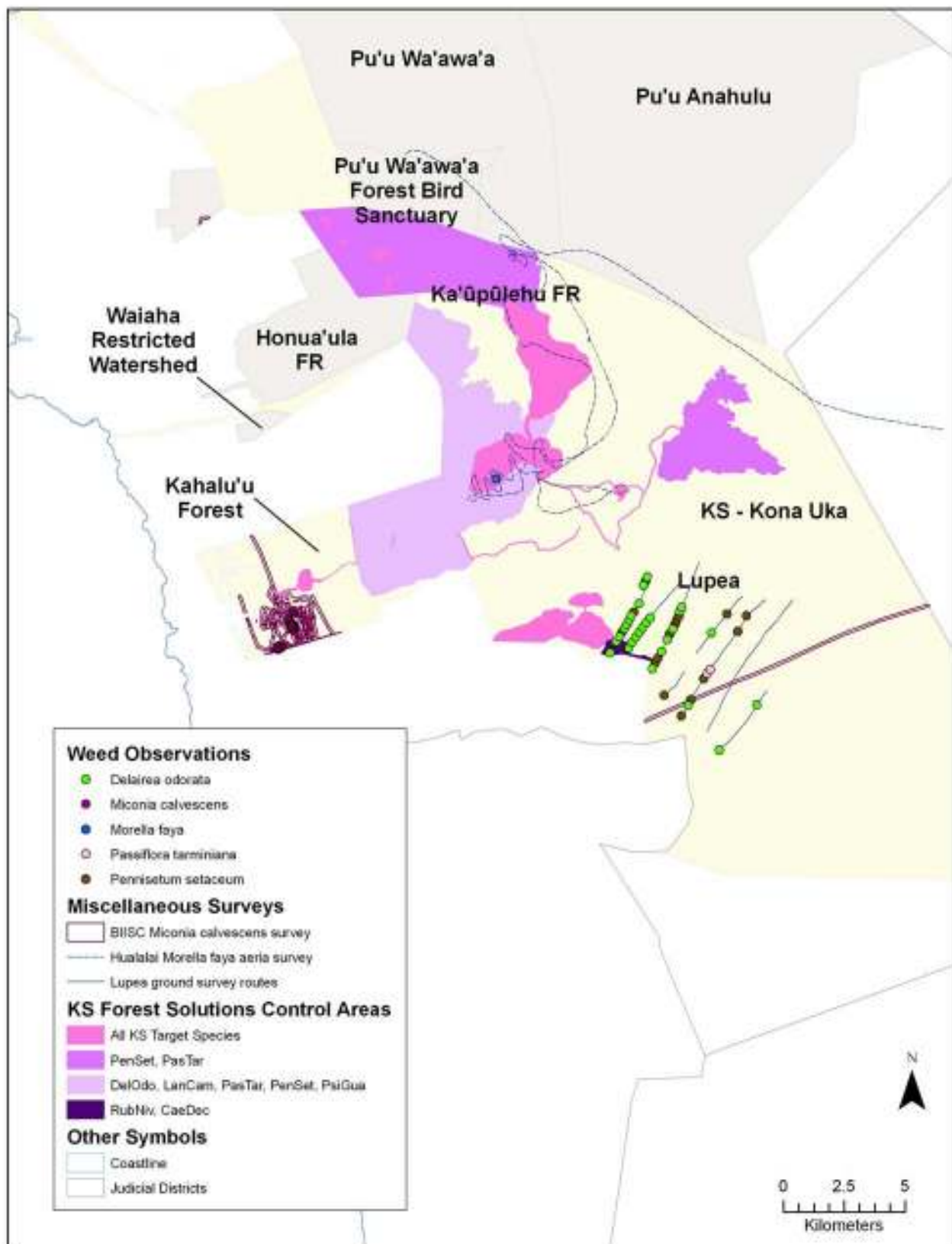
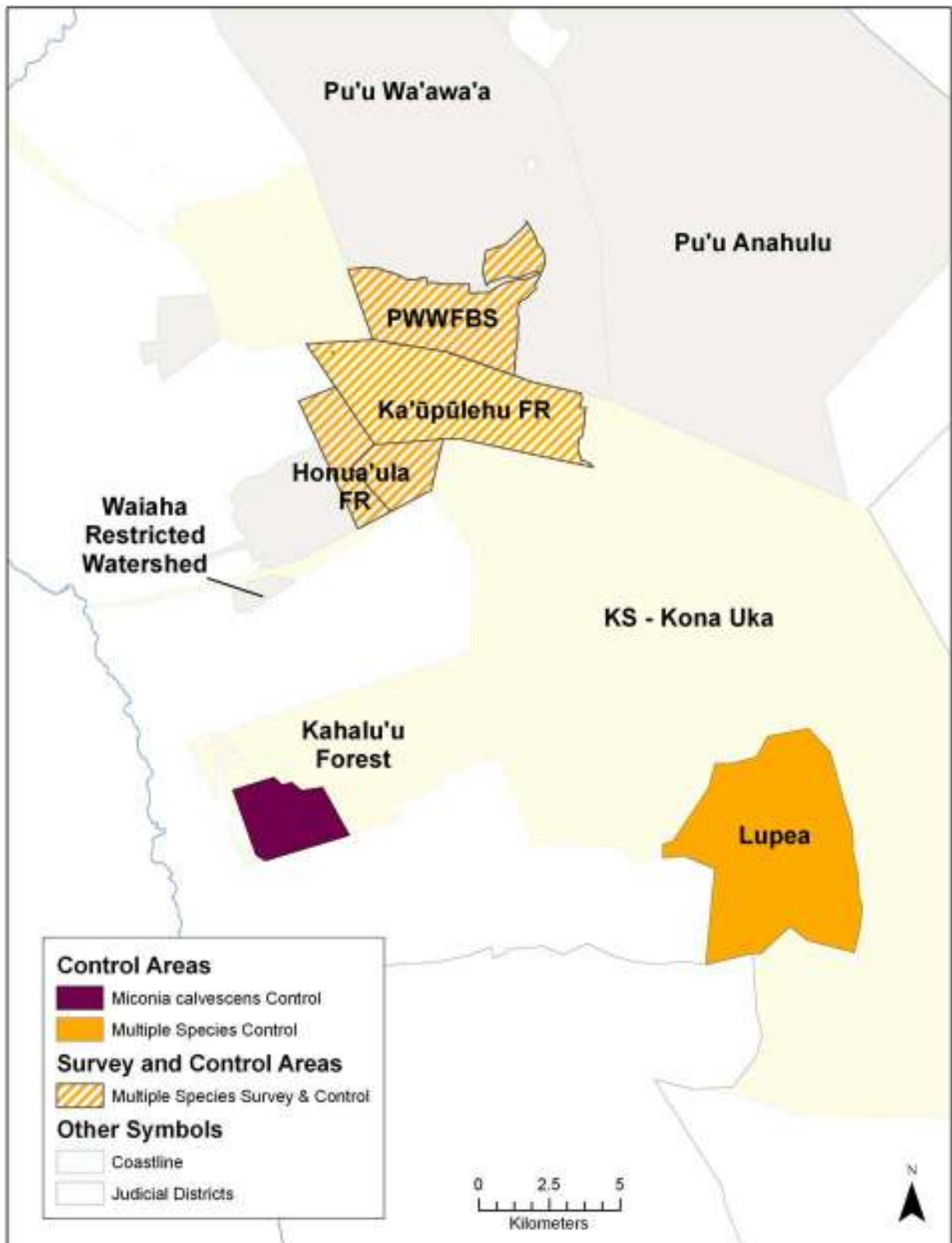


Figure 5.5. Priority TMA Control Projects in the North Kona Management Area.



TMA Weed Control Goals (Figure 5.5)

1. Pu'u Wa'awa'a Fenced Management Units

- Coordinate weed survey/monitoring in the forest bird sanctuary unit and in the proposed Henahena unit.
- Work with DOFAW staff and volunteers to implement an SEA approach to weed control for priority weed species in these two management units in conjunction with feral ungulate removal.

2. Kona Uka lands

- Faya - Work with KS contractors and lessees to assess the status of control efforts, systematically map this species across land ownership boundaries, and develop a containment strategy.
- Lupea Habitat Restoration Area - The area targeted for conservation efforts (fencing of management units, ungulate control and habitat restoration) will be a focus of TMA weed control (with initial emphasis on containing and eventually suppressing fountain grass and Cape ivy).
- Kahalu'u Forest – Support BIISC efforts to assess the status of miconia and assist BIISC with follow-up control and monitoring.
- Fountain Grass - Contain fountain grass to prevent it from spreading into new areas further to the South. Monitor fountain grass to detect satellite populations in remote areas. Develop new monitoring and control techniques (aerial mapping and control) to increase efficiency. Target TMA staff on-the-ground control work in designated high priority areas (e.g. Lupea Habitat Restoration Area)
- Manage portions of Kaupulehu Forest for priority weeds in cooperation with weed control efforts on adjacent state lands (Honu'aula FR and Pu'u Wa'awa'a). Priority species include fountain grass and faya.

3. Honu'aula FR

- Assist DOFAW with priority weed control in targeted reforestation areas with a focus on priority weeds such as banana poka (using existing biocontrol agent), Cape ivy and blackberry. Prevent establishment of clidemia, strawberry guava, silk oak and other targeted species.
- Develop weed cooperative projects with adjoining landowners.

Table 5: TMA Goals and Objectives by Area/Species*

NKMA		Management Unit				
		Puu Waa Waa	Kona Uka	Lupea	Kahalu'u	Honu'aula
Focal Species	AGE ADE	2012				
	CLI HIR				2015	TBD
	DEL ODO	2012		TBD		
	GRE ROB	2012	2012			Prevent
	HED GAR	2012			2015	TBD
	MIC CAL				2010	
	MOR FAY	Prevent	2010	Prevent		Prevent
	PAS TAR	2012			2015	
	PEN SET	2015	2015	TBD		
	PSI CAT				2015	TBD

Prevent	= Prevent any populations from establishing in this area (ongoing).
Eliminate	= Remove all occurrences of species in this area.
Suppress	= Reduce extent of core population in this area.
Contain	= Prevent expansion of core population within this area.

*Table 5 includes the date by which the TMA expects to achieve the weed control goal. Dates are included only for currently funded and/or ongoing projects. TBD is noted for unfunded projects. Ongoing follow-up control work will still be needed to maintain progress on the projects following the achievement of the goals outlined in this table.

6. APPROACH AND CONTROL METHODS (OVERALL)

The TMA will use a variety of approaches to weed management because various TMA members have their own individual weed management programs. The TMA will work to get various partners to communicate regarding their weed control programs and will provide recommendations to members for similar approaches to improve data sharing, communication about weed distribution and control strategy, and sharing of resources. The TMA will also work to strengthen and create new partnerships with the community and adjacent landowners to expand weed management areas and create protective buffer zones.

TMA approaches include the following:

Prevention - This approach is used to prevent the establishment of weeds in new areas where they do not currently exist. Prevention is best achieved through monitoring and early detection. *Miconia* is one species targeted for prevention in many high priority TMA areas.

Elimination (Eradication) - This approach is used if new species and/or populations are detected early and there are resources available to remove all individuals. Follow-up monitoring is required to confirm all individuals have been removed.

The SEA approach (developed by HAVO) is used to eliminate weeds from high priority TMA management areas that are fenced with feral ungulates removed. Field crews perform systematic ground and/or aerial sweeps to remove all target weed species detected in the area. The initial knockdown of weeds is followed by subsequent revisits at 1-4 year intervals to keep infestations at low or manageable levels (maintenance phase). Populations of weeds can be reduced and maintained at very low levels after several cycles of control work. There will be subsequent recruitment of weeds from the soil seed bank and seed rain from nearby areas so continued follow-up treatments are required in all areas and may be needed indefinitely. Workloads drop significantly after initial control efforts, but this approach requires ongoing commitment to follow-up. Long-term maintenance of SEA's is possible when initial weed infestations can be reduced to low levels, subsequent recruitment of new weeds is low, and work loads drop significantly after initial control efforts. SEA's can be added or expanded as resources permit. The main weakness of this approach is that follow-up treatment is required indefinitely, weed infestations will increase in surrounding unmanaged areas and reinvasion into units may become unmanageable if SEA's are too small.

HAVO is examining the SEA approach in different types of habitat in order to maximize cost effectiveness through optimizing intervals between follow-up treatments, applying new search and control technology, and reconfiguring size/shape of units and/or establishing managed buffer zones around smaller units.

Areas with ongoing weed control using the SEA approach include HAVO 'Ōla'a Tract Units, Wright Rd Unit (DOFAW-NARS/TMA) and Kaiholena. This approach is proposed for other fenced management units as resources become available. Priority areas include fenced management units in Kīlauea, Pu'u Maka'ala NAR, Kona Hema, and the Pu'u Waa'waa forest bird sanctuary. Other units will also be targeted for this approach as fencing and ungulate control is completed.

Containment/Suppression - This approach is used with large weed populations and/or in areas that can not yet be managed as SEA's due to limited resources. This approach is used to prevent the expansion of weeds from core infestations into new areas. Core populations can be reduced through suppression (reduction of the core population). Examples of this approach are control of faya in the OKMA (Keauhou) and fountain grass in the SKMA (Manuka NAR).

Control Methods - Control methods currently used by the TMA for various species are listed in Attachment 12.3. Other control methods are under development. The TMA will work to facilitate sharing of information regarding optimal control methods.

7. MEASURES OF SUCCESS

TMA success in surveying and controlling weeds will be measured using a variety of methods. The TMA will use monitoring methods generally used by NARS, TNC and HAVO described in Benitez (2008) as well as in Attachment 12.4. Systematic weed inventories will primarily be used in high priority weed control areas.

Weed Inventories

- Develop target weed list. Add additional invasive species to the target list if necessary (e.g. highly abundant or known to be invasive elsewhere in Hawai'i).
- Quantify distribution and cover-abundance of target weeds along belt transects in 10-m wide by 100-m long segments that subdivide each belt transect.
- Record presence/absence of weeds for each 100-m interval.
- Estimate percent cover of each species using modified Daubenmire percent cover classes.
- Collect additional point location data (Global Positioning System or GPS) for weeds observed near transects but not within the belt, from aerial surveys, and systematic surveys of localized habitats.

Data on presence/absence and cover abundance (%) of target weeds will be input in ArcGIS 9.1, and stored in projected shapefiles and associated .dbf files. The data format design is compatible for export into additional GIS and database programs to allow for future analysis by multivariate statistical packages (e.g., SYSTAT, SAS, Minitab). These data will 1) provide baseline data for comparison with future surveys to determine changes in weed abundance and distribution over time, and 2) identify high priority areas for weed management.

Goal	Metric	Period	Methods
Prevent	Acres of species found	annual	Field data
Eliminate	# of occurrences and/or area left	annual	Field data
Suppress	% change in core population	annual	GIS
Contain	# of satellites removed	quarterly	Field data

8. PREVENTION AND EARLY DETECTION

Early Detection and Rapid Response

BIISC will be taking the lead on early detection and rapid response. The TMA will work closely with BIISC to ensure priority species are addressed (e.g. share staff for joint weed control projects, joint work planning in certain areas). BIISC and TMA personnel will meet regularly to ensure joint priorities are effectively addressed.

The BIISC early detection program began in 2006 and the BIISC early detection list currently consists of 185 species. Additions to this list are expected. The early detection program targets roadsides, nurseries and botanical gardens.

BIISC is planning on continuing to survey all major, secondary and tertiary roadside (excluding agriculture and cane roads) for potential invasive weed species. BIISC surveys are currently

being done systematically by district and surveys have been completed for 468 kilometer of roads. Additional surveys will be conducted at nursery and landscaping businesses to determine what is already in the trade industry. When applicable, BIISC will conduct aerial surveys. BIISC is currently in the process of conducting a high-resolution imaging pilot-project with participating partners in the KKMA for bocconia and roadside incipient weeds.

BIISC staff will analyze field data and rate each species using the Weed Risk Assessment program to determine potential spread, particularly into sensitive areas. If the risk is determined to be high, BIISC will initiate a rapid response plan to control the population. Weed Risk Assessments have been developed for Hawaii and the Pacific Islands. The purpose of the weed risk assessment is to identify high-risk species (likely invasive pests plants), allowing us to make informed decisions that will reduce the economic and ecological harm caused by invasive plants in Hawaii and on other Pacific Islands <http://www.hear.org/wra/>

Once a species assessment is completed, and a high risk determination has been made of the species of concern, BIISC will initiate a control and/or containment plan. Immediate suppression would take place followed by an extended survey of the immediate site area within a pre-determined buffer area. Should further surveys be required, BIISC's early detection team will expand the surveys while the control team continues with other operations.

BIISC has been working on containment of miconia and bocconia as well as eradication of some incipient weeds. Species recently identified by BIISC as new concerns for the island include wax myrtle (*Morella cerifera*), smoke bush (*Buddleja madagascariensis*), Indian rubbervine (*Cryptostegia madagascariensis*) and two other Tibouchina species.

Public Education and Outreach

The TMA and BIISC will work together to educate visitors, staff and the general public about weeds so they don't spread or bring new weeds into pristine natural areas. Outreach will help increase public awareness and support for weed management in watersheds.

Sanitation

Attachment 12.1 is a sanitation protocol from TNC's: *Prevention of Alien Species Introduction* handout. It describes protocols for preventing the accidental introduction and spread of weeds.

9. RESEARCH AND DEVELOPMENT

TMA representatives individually and collectively have a wealth of expertise related to weed research, management, and control. Some members have particular strengths in weed mapping, database management, cost/benefit analysis and weed risk assessment. Landowning partners all have ongoing weed programs that can provide critical information on distribution, effective control techniques, and invasiveness of particular weed species. Sharing and centralization of weed distribution and control information will help identify data gaps, provide a more comprehensive view of the status of a particular species or habitat, and allow management decisions to be made using the most up-to-date, accurate information.

Mapping Weeds

The TMA is participating in new initiatives using high resolution aerial imagery. This weed mapping method has the potential to greatly increase the efficiency of detecting target weeds (the major cost in low density weed areas). TMA members are working on pilot projects to test and refine these new methods. This method produces high-resolution multi-spectral (15 cm/pixel) images to identify and assign a geographic coordinate to each weed individual. Accurate, cheaply produced maps of invasive weeds can then be given to field crews for targeted removal of these habitat-modifying weeds. These maps can also be used for long-term monitoring of progress of control efforts and changes in distribution of weeds on a landscape-scale.

Collection of imagery and analysis of certain weed species for selected sites in the KKMA and SKMA is scheduled to start in 2009 and includes portions of Ka'ū FR and TNC lands.

Weed Control

Biocontrol – The TMA is supportive of biocontrol research on priority weed species. Species currently under investigation include strawberry guava and miconia. Biocontrol agents for clidemia and banana poka have been released. Additional research on improving the effectiveness of these agents in TMA areas is needed.

Control Methods - The TMA is exploring new techniques for chemically treating priority weeds including new formulations of herbicide, treating of remote or inaccessible areas through helicopter spray rig and paintball.

10. RESOURCE NEEDS / BUDGET

TMA staff and budget resources are not currently adequate to accomplish even a small portion of this plan. Successful implementation will require the combined resources of all the partners to accomplish joint projects. This plan prioritizes projects for each management area and outlines some costs for current and proposed projects.

Weed Control Costs

HAVO has prepared summaries of costs/ha for weed control work in various SEA's with different habitat types. Costs of weed control decline over time, however, managers must have a commitment to follow-up regular maintenance control after initial knockdown. HAVO currently has 26,709 under weed management at an annual cost of approximately \$300,000/year.

Seasonal Dry Woodlands

- Initial knockdown (100 individuals/ha) = \$625/ha
- Maintenance (year 20) (2.5 - 25 individuals/ha) = \$100/ha every 2-4 years
- Helicopter treatment = <\$2.5/ha every 2-4 years

Rain Forest

- Initial knockdown (1,500 individuals/ha) = \$1,900/ha every 2 yrs
- Maintenance (year 12) (250 individuals/ha) = \$390/ha every 2-4 yrs

TMA Weed Budget

The TMA has various weed projects funded through KS and other TMA members. In addition, TMA members and BIISC have their own weed control budgets for various projects within the TMA area. The following table is a broad overview of current weed management budgets by the TMA and does not include all weed control funding and in-kind support by TMA members (e.g. staff support and volunteers for weed control projects). Proposed projects for 2010 are included. The TMA needs a Weed Management Specialist as well as additional field staff to do on-the-ground weed control projects, particularly in the KKMA, SKMA and NKMA.

Management Area/Project	Approximate Budget (2009)	Proposed Projects (2010)
TMA Weed Management Specialist		\$75,000/year
OKMA		
TMA (Keauhou/Kilauea)	\$ 60,000	\$ 60,000
HAVO (all weed work - 26,709 ha)	\$300,000	\$300,000
KS (Keauhou)	\$167,000	\$167,000
NARS	N/A	N/A
DOFAW FR	N/A	N/A
Subtotal	\$527,000	\$527,000
KKMA		
TNC (Kaiholena Control and Aerial Imagery)	\$208,000	\$208,000
HAVO (Kahuku)	\$ 15,000	\$ 10,000
DOFAW FR	N/A	N/A
TMA Weed Control Staff/Supplies (2 personnel)		\$110,000
Subtotal	\$208,000	\$318,000
SKMA		
TNC (Kona Hema)	\$117,000	\$117,000
DOFAW FR	N/A	N/A
NARS (Manuka fountain grass)	\$105,000	\$105,000
DOFAW FR	N/A	N/A
KS (Honaunau)	\$45,000	\$45,000
TMA Weed Control Staff/Supplies (2 personnel)		\$110,000
Subtotal	\$267,000	\$377,000
NKMA		
KS (Kahalu'u Forest)	\$ 45,500	\$ 45,500
KS (Kona Uka)	\$154,000	\$154,000
DOFAW FR	N/A	N/A
DOFAW (Pu'u Wa'awa'a)	N/A	N/A
FWS Hakalau (Kona)	N/A	N/A
TMA Weed Control Staff/Supplies (2 personnel)		\$110,000
Subtotal	\$199,500	\$309,500
TOTAL	\$1,216,500	\$1,616,500

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Agency websites:

Big Island Invasive Species Council
<http://www.hear.org/biisc/>

Hawaiian Ecosystems at Risk (HEAR) Project
<http://www.hear.org/>

Hawai'i Association of Watershed Partnerships
<http://www.hawp.org/>

Kamehameha Schools
<http://www.ksbe.edu/>

State of Hawai'i, Department of Land & Natural Resources, Division of Forestry and Wildlife
<http://www.dofaw.net/>

State of Hawai'i, Department of Land & Natural Resources, Natural Area Reserves System
<http://www.dofaw.net/nars/>

State of Hawai'i, Department of Public Safety
http://www.hawaii.gov/psd/psd_home.php

The Nature Conservancy
<http://www.nature.org/>

US Department of Agriculture, Forest Service, Institute of Pacific Islands Forestry

<http://www.fs.fed.us/psw/programs/ipif/>

US Department of Agriculture, Natural Resources Conservation Service
<http://www.nrcs.usda.gov/>

US Department of the Interior, National Park Service, Hawai'i Volcanoes National Park
<http://www.nps.gov/havo>

US Fish and Wildlife Service, Pacific Region
<http://www.pacific.fws.gov/>

US Geological Survey, Pacific Island Ecosystems Research Center
<http://biology.usgs.gov/pierc/>

12. ATTACHMENTS

12.1: Weed Sanitation Protocol

Field Gear and Field Equipment - Inspect field gear and equipment before going into the field. Clods of dirt or mud can hide weed seeds. It is necessary to inspect and clean: footwear (treads, laces, boot tongues); socks; pant legs; pockets; jackets; raingear; food-stuffs; tools; packs; tents; hammocks; tarps; helicopter sling nets; wood and building materials; fencing materials; bottoms of plastic buckets; tool bags; and other containers or equipment. Appropriate methods to clean gear include: water and hose, brush, clean rag, knife edge, or insecticide. Cleaning should be done in a designated area with a nearby receptacle for disposal. Laundering of washable items should be done after each trip. This is particularly important when working on different islands, in different areas on the same island, or on the mainland. Each area may have its own assemblage of pests that must be prevented from spreading to new locations where the pests do not currently exist. In some cases, it may be preferable to use a different set of field gear for each field site. If items can not be cleaned, they should not be used.

Field Vehicles - Keep field vehicles clean. The inside of field vehicles should be vacuumed, and pickup truck beds should be swept out after every trip to the field. Pay particular attention to seats, floors, dashboards, and door jambs. Tires (especially treads) and undercarriage of vehicles should be hosed off after each field visit to avoid transporting weed seeds. Maintaining clean field gear can be compromised by using a dirty truck.

Helicopter Landing Zones and Camp Sites - Keep helicopter landing zones and camp sites free of significant weed species. Helicopters used to transport personnel into the field fly to and from other islands and land in other natural areas. Although it may be impractical to clean helicopter skids and interiors, a well-used landing zone can be managed. Weeds in these areas should be eradicated or cut back periodically. Similarly, weeds around camp sites should be controlled or eliminated.

Travel Routes and Trails - Avoid carrying weed seeds from an infested areas to pristine areas. If travel routes go through areas infested with invasive weeds, be conscious of the potential for spread. When leaving a weedy area and entering a more pristine area, transport of weed seeds can be reduced by carrying a small brush to clean shoe soles, clothing, and packs. Stick to established and well-used trails or travel routes to avoid spreading weeds off trail.

Trash and Garbage - Pack out your trash and unused foodstuffs. Do not bury trash in the field. Avoid taking in any fruits (in your food or digestive tract) that have seeds with the potential to naturalize (e.g. cherry tomatoes, chili peppers, berries, guava). Organic trash (e.g. orange and banana skins, apple and pear cores, peach and avocado pits) should be treated as other garbage and packed out. Garbage that is discarded in the field has the potential to spread unseen insects, fungi, and other plant pathogens and may provide food for alien vertebrates.

Education - Learn to recognize invasive species, the habitats they currently occupy, and those areas where they are likely to spread. Learn which weeds are particularly invasive in Hawai'i and where they occur. Note which weeds are encountered and pay attention to any changes. If a highly invasive weed is encountered, record the location. Share this information and your knowledge with friends and colleagues when visiting other natural areas.

Early detection of weeds is critical to the successful management of natural areas. Field staff will be trained to identify and recognize potential invaders and likely pathways (roads and trails) will be surveyed on a routine basis. Early detection will be followed by rapid response so that outliers and incipient populations cannot get established.

12.2: HAVO Weed Species Targeted For Management Action

Scientific Name	Common name
<i>Abrus precatorius</i>	Black-eyed Susan
<i>Acacia confusa</i>	Formosan koa
<i>Acacia mearnsii</i>	Blackwattle
<i>Acacia melanoxylon</i>	Blackwood acacia
<i>Agave sisalana</i>	Sisal
<i>Agave americana</i>	Century plant
<i>Albizia</i> spp	Albizia
<i>Anemone hupuhensis</i>	Japanese anemone
<i>Archontophoenix alexandrae</i>	Date palm
<i>Ardisia crispa</i>	Hilo holly
<i>Banksia</i> spp.	Banksia
<i>Benicasa hispida</i>	Chinese melon
<i>Buddleia asiatica</i>	Butterfly bush
<i>Casuarina equisetifolia</i>	Ironwood
<i>Cestrum nocturnum</i>	Night cestrum
<i>Clidemia hirta</i>	Clidemia
<i>Desmodium cajanifolium</i>	Tree desmodium
<i>Desmodium intortum</i>	Desmodium (intortum)
<i>Digitaria insularis</i>	Sourgrass
<i>Ehrharta</i> spp.	Meadow ricegrass
<i>Eleagnus umbellata</i>	Gumi
<i>Eriobotrya japonica</i>	Loquat
<i>Eucalyptus</i> spp.	Eucalyptus
<i>Feijoa sellowiana</i>	Pineapple guava
<i>Ficus</i> spp	Banyan, climbing fig
<i>Fraxinus uhdei</i>	Tropical ash
<i>Fuschia paniculata</i>	Fuchsia
<i>Grevillea robusta</i>	Silk oak
<i>Grevillea banksii</i>	Bottlebrush
<i>Hedera helix</i>	English ivy
<i>Hedychium gardnerianum</i>	Kahili ginger
<i>Heterocaentron subtriplenervum</i>	Pearl flower
<i>Heterotheca grandiflora</i>	Telegraph weed
<i>Hyparrhenia rufa</i>	Thatchinggrass
<i>Jasminum</i> spp.	Jasmine
<i>Justicia betonica</i>	Shrimp tail
<i>Kalanchoe tubiflora</i>	Chandelier plant
<i>Kalanchoe pinnata</i>	Air plant
<i>Lantana camara</i>	Lantana
<i>Lathyrus odoratus</i>	Sweet pea
<i>Leucaena leucocephala</i>	Haole Koa
<i>Ligustrum</i> spp.	Privet
<i>Lonicera japonica</i>	Honeysuckle
<i>Lophospermum erubescens</i>	Roving sailor
<i>Luculia gratissima</i>	Luculia
<i>Lupinus hybridus</i>	Lupine
<i>Melaleuca quinquenervia</i>	Paperbark
<i>Melinis minutiflora</i>	Molasses grass

Melochia umbellata	Melochia
Muehlenbeckia axillaris	Wire vine
Myrica faya	Faya
Nephrolepis multiflora	Swordfern
Olea europaea	Russian olive
Opuntia ficus	Prickly pear
Paederia foetida	Maile pilau
Passiflora tarminiana	Banana poka
Pennisetum purpureum	Elephant grass
Pennisetum setaceum	Fountain grass
Persea americana	Avocado
Philodendron spp.	Philodendron
Phormium tenax	New Zealand flax
Phyllostachys nigra	Bamboo
Pinus spp.	Pine
Pittosporum undulatum	Orange pittosporum
Polygonum capitatum	Polygonum
Prosopis pallida	Kiawe
Prunus spp.	Prunus
Psidium cattleianum	Strawberry guava
Psidium guajava	Guava
Pueraria lobata	Kudzu
Pyracantha angustifolia	Firethorn
Ricinis communis	Castor bean
Rubus argutus	Blackberry
Rubus ellipticus	Yellow raspberry
Rubus glaucus	White raspberry
Schinus terebinthifolius	christmas berry
Schizachyrium condensatum	Beard grass
Sechium edule	Pipinella
Senecio madagascariensis	Fireweed
Senecio milanioides	German ivy
Setaria palmifolia	Palm grass
Solanum pseudocapsicum	Jerusalem cherry
Soliva spp	Soliva
Sphaeropteris cooperi	Australian tree fern
Spiraea cantonensis	Spirea
Syzygium jambos	Rose apple
Thunbergia alata	Black-eyed Susan
Tibouchina urvilleana	Tibouchina
Tibouchina herbacea	Cane tibouchina
Trema orientalis	Gunpowder tree
Tropaeolum majus	Nasturtium
Verbascum thapsus	Mullein
Yucca filimentosa	Yucca

12.3: TMA Weed Control Methods For Selected Species

Tier	Species	Meth.	Herb. %
1	Hedychium gardnerianum	C	1g/l Escort or Cimarron
1	Morella faya	C/Fr	50% G3A
	Passiflora mollissima (banana poka)	C	10% G3A
1	Psidium cattleianum	C	10% G3A
1	Pyracantha angustifolia	C/F	50% G3A/2% G4
1	Rubus ellipticus	C	10% G3A
1	Setaria palmifolia	F	1% RU
1	Sphaeropteris cooperi	C	
2	Anemone hupehensis	C/F	10% G3A/ 2% RU
2	Pennisetum clandestinum	F	1% RU
2	Rubus argutus (Florida blackberry)	F	2% G3A, 2% RU
2	Persicaria capitatum	F	2-5% G4
2	Sambucus mexicanus	unk	unk
2	Senecio madagascariensis	P/F	2% RU
2	Solanum pseudocapsicum	F	1% G4
2	Tibouchina herbacea	C/F	10% G3A/2% G4
2	Tropaeolum majus	P/F	1% G4
2	Verbascum thapsus	P/F	2% RU
3	Acacia confusa	B/C	15% G4,Diesel/10% G3A
3	Cestrum nocturnum	C	10% G3A
3	Clidemia hirta	F	2% G3A
3	Cotoneaster pannosus	C	50% G3A
3	Fraxinus uhdei	B	5% G4
3	Pennisetum setaceum	F	10-20% Velpar L or 5% RU
3	Schinus terebinthifolius	B/C	15% G4, Diesel/15% G3A
3	Tibouchina urvilleana	F	2% G4

Herbicides

Garlon 3A (G3A)

Garlon 4 (G4)

Roundup (RU)

Methods

C- Cut stump

F- Foliar

B- Basal Bark

P- Pull

Fr- Frill

12.4: National Park Service Inventory and Monitoring Program Invasive Species Protocol Field Methods for Collection of Weed Data (exerpts from draft)

Locating Belt Transects

Methods for selecting and locating belt transect segments and dispersal corridors are detailed in SOP's #5 and #6. A GPS unit is used to navigate to the transect endpoint, but when satellite coverage is poor compasses, altimeters, measuring tapes and maps will be used. Once crew members navigate to the sampling location, they can begin surveying according to the methods described in SOP #7 ("Conducting Invasive Plant Species Surveys").

For newly selected random transects (either fixed or temporary) the field leader first must determine if the transect location is acceptable (i.e. no unsafe working conditions such as steep cliff faces) and representative (e.g., not within the boundaries of an agricultural plot). While every effort is made to select acceptable transects prior to entering the field, it is possible that crew members will encounter a transect that proves unsafe or unrepresentative. In some instances the crew leader will recognize an unacceptable transect immediately, while in other instances the leader will not know until part way through the surveying process. In the latter case the field crew leader shall make the determination to discontinue sampling and move to the next transect. If crew members are forced to stop surveying a temporary transect, then the data collected prior to discontinuation should be used for status estimates regardless of how many segments were surveyed.

Collecting Weed Data Along Transects

A crew of two is recommended to conduct invasive plant species surveys along 5 x 10 m belt plots established contiguously along transects in selected plant communities. While placing plots contiguously presents issues of independence of data for analysis, it is logistically easy to collect data from contiguous plots and allows for more accurate mapping of weed distributions within plant communities. To address the issue of data independence, a random selection of 10% of the plots can be drawn prior to analysis.

Once field crews navigate to the transect origin, the logistics of data collection involve placing a temporary stake in the ground with a 10 m cord attached to it, and then pulling the cord tight along the transect line. One observer walks the length of the cord while the other records all target species found within 2.5 m of the transect centerline (i.e., the cord). A 2.5 m long lightweight aluminum pole works well to denote the peripheral plot boundaries. For each belt segment, one of the observers records all target invasive species present as well as modified Braun-Blanquet cover estimates for each species. Crew members can work together to reach consensus on the percent cover estimate, especially when the estimate falls along the category boundaries. The data recorder also notes location information, any targets species found beyond plot boundaries, and comments.

Recording cover estimates for target invasive species along transects provides quantitative information on the abundance and distribution of specific weed species in select plant communities. By drawing a sample of uncorrelated 5 x 10 m plots along a network of transects in a given plant community, we can make inferences to the plant community sampling frame. While in theory these transects and plots should be placed randomly, we would like to maintain our network of legacy transects and the data associated. Additionally park resource managers, who want to minimize the risk of new weed introductions, strongly prefer the use of legacy transects over new ones. Consequently we will continue to use legacy transects which have a

more systematic than random orientation. Logistically it is easy to survey all segments (or plots) along a transect even though only 10% of the plots can be analyzed without encountering issues of data independence. By sampling all plots, we (1) gain the ability to generate more accurate thematic maps of weed distributions, and (2) provide additional information to resource managers who need to know in as much detail as possible where invasive species exist.

Another way to look at this type of transect data is as frequency data, analyzing the proportion of plots that exhibit presence of a particular weed species (or group of weed species). Following this approach, we can compare proportions of presence from one time period to the next to evaluate population trends.

Collecting Weed Data in Dispersal Corridors

Human dispersal corridors including roads, trails, fencelines, and other disturbed areas will be surveyed for a list of highly disruptive invasive plant species. Crew members will monitor linear corridors in 100 m blocks that extend outward 10 m for vegetated corridors (e.g., trails) or 10 m from the paved edge for non-vegetated corridors (e.g., paved roads). In either case, crew members will record invasive species on both the left and right sides of the corridor. Unlike the transect surveys described above, observers only need to record presence or absence of weeds along these corridors, as the primary focus of surveying corridors is early detection of incipient invaders. When observed, target species greater than 10 m from the core corridor should be recorded and the approximate location identified. Two crew members are required to conduct corridor surveys, one to survey the left side and the other the right.

For nonlinear corridors such as parking lots or campgrounds, crew members shall apply a similar approach surveying the corridor area plus a 10 m buffer zone. For paved corridors (e.g., a rectangular parking lot) only the 10 m buffer zone around the corridor needs to be surveyed, while for vegetated corridors (e.g. campgrounds) both the core area and the 10 m buffer zone around it should be surveyed.

General Notes on Data Collection

Whether sampling transects or dispersal corridors, field crew members should record GPS locations, take photographs, and make comments. Field maps are created or updated for all fixed transects and corridors during each sampling event to ensure future monitoring teams are able to relocate sampling sites easily. Locations are mapped using GIS and should be marked on a topographic map of the area, an orthophoto quad or an aerial photograph. Additionally, the field leader should create a hand-drawn route map to the site including key geographic features and instructional text. It is important that the text include information on bearings and distances from reference features so that the transect origin or corridor can be found efficiently. After the first round of sampling, reasonably accurate maps and site descriptions should exist; thus future sampling efforts are likely to require only minor updates as the physical and human environment changes.