KANAIO NATURAL AREA RESERVE BIOLOGICAL INVENTORY AND MANAGEMENT RECOMMENDATIONS

Natural Area Reserve System
State of Hawai`i

March 1993

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KANAIO

Island:	Maui
Size:	876
Elevational Range:	1100 - 2780 feet
Year established:	1991
Date surveyed:	Surveyed in 1993
Description:	Dry forest with communities of native shrublands and groves of native trees. Vegetation communities: 'A'ali'i (Dodonaea) Lowland Shrublands, Lama (Diospyros) Forest, and Wiliwili (Erythrina) Forest. There is also a large stand of Halapepe (Pleomele). Principal non-native pest plants include Lantana (Lantana camara), Koa haole (Leucena leococephala), Molasses grass (Melinis minutiflora), Bocconia frutescens, and Red top (Rhnychelytrum repens).
Management plan:	Kanaio Natural Area Reserve Biological Inventory and Management Recommendations, March 1993, A.C. Medeiros, L.L. Loope, and C.G. Chimera, for the natural Area Reserves System, State of Hawai'i.

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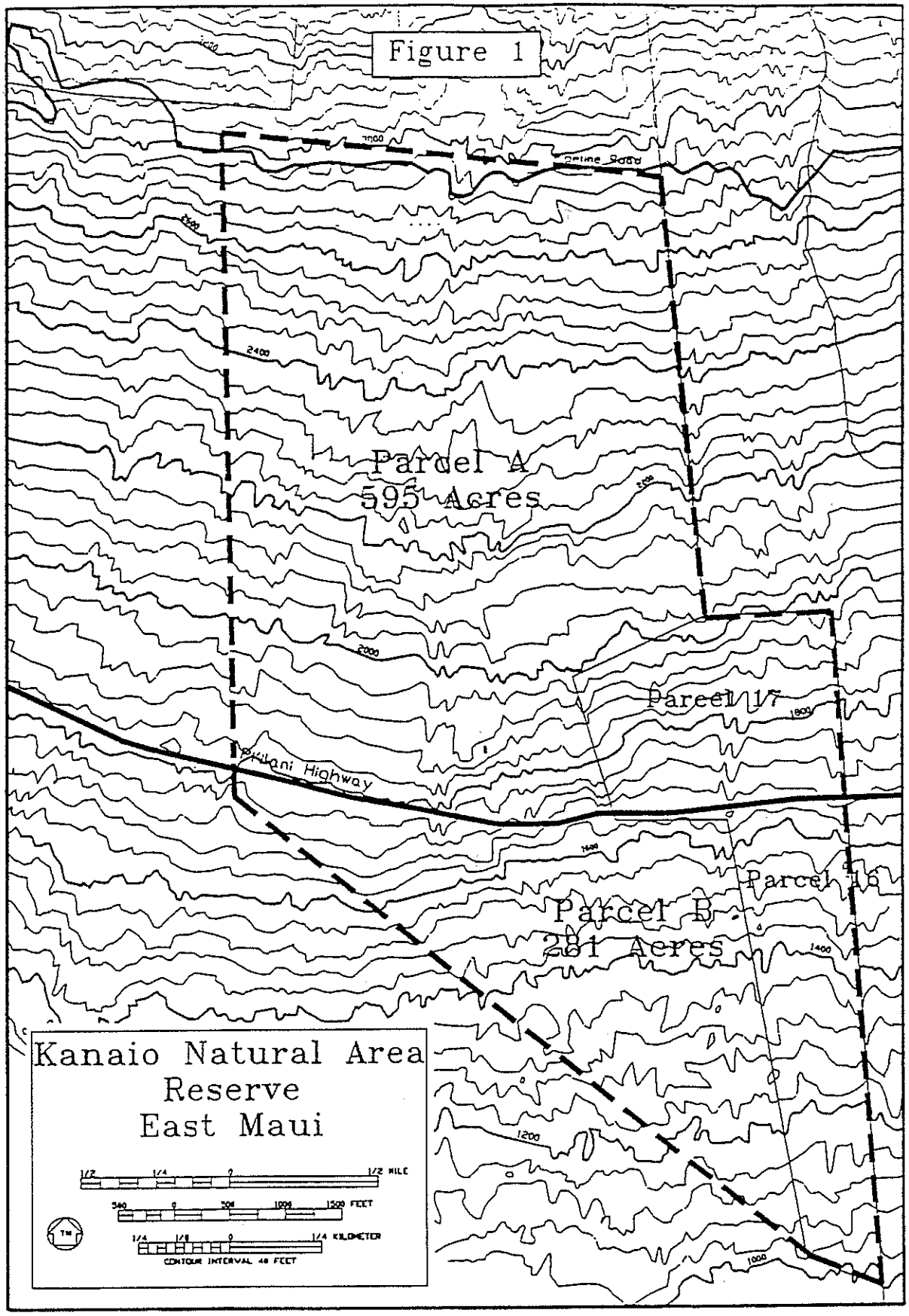


Figure 1
Pipeline Road
2400
Parcel A
595 Acres
2000
Parcel 17
1800
Pi'ilani Highway
Parcel 16
Parcel B
281 Acres
1400
1200
1000
Kanaio Natural Area
Reserve
East Maui
1/2 MILE
1500 FEET
1/4 KILOMETER
CONTOUR INTERVAL 40 FEET

1. EXECUTIVE SUMMARY

Established in 1990, the Kanaio Natural Area Reserve (NAR) comprises 876 acres (355 ha) at 1100 to 2780 feet (335 to 850 m) elevation on leeward East Maui. The reserve is divided into two parcels by highway No. 31; the portion above the road (Parcel A in the metes and bounds document) is 595 acres (241 ha), while the portion below the road (Parcel B) comprises 281 acres (114 ha). As a whole, dryland forests in Hawai'i are an endangered community that without careful management intervention may largely disappear in the next few decades. Of the dryland forests left in Hawai'i, few areas have retained diversity and biomass of native species comparable to Kanaio NAR. Based on a recent classification of Hawaiian vegetation communities (Gagné and Cuddihy in Wagner et al. 1990), Kanaio NAR contains representatives of three vegetation communities: *'A'ali'i* (*Dodonaea*) lowland shrublands, *Lama* (*Diospyros*) forest, and *Wiliwili* (*Erythrina*) forest. The neighboring district to the east, Auwahi, has been widely known as the finest dryland forest remaining on Maui and among the best remaining in the Hawaiian Islands (Rock 1913). However, despite its current richness of native dry forest tree species, the groundcover of Auwahi is dominated by the aggressive mat-forming kikuyu grass (*Pennisetum clandestinum*). This dominance is one of the primary factors contributing to the suppression of any reproduction by native tree species. In rockier Kanaio NAR, kikuyu grass is much less dominant and the native forest is much more intact. The reserve contains 161 species of vascular plants including 10 species of pteridophytes and 151 species of flowering plants (see Appendix 1). Over 60% of the species listed for the reserve, some 96 species, are introductions by humans. Of the remaining native species, indigenous species account for 14%, endemic species for 24%. Presumably due to herbivory and seasonal aridity of the reserve, there is a marked lack of diversity of ferns and native monocots. The reserve can be divided into four basic land types: 1) groves of native trees, 2) native shrubland, 3) largely barren lava, 4) alien grass, herb, and shrublands. Of these biological communities, the one with the greatest biological value are the groves of native trees. Most of the larger, more extensive groves of trees in the reserve are in Parcel A, above the main highway. It is in the upper half of Parcel A, especially in the central and eastern sections, that the reserve's greatest density and diversity of tree species occurs. Scattered groves of native dryland trees in Kanaio, Auwahi, and Luala'ilua districts are the best examples of dryland forests remaining on Maui. Twenty-two species of Hawaiian dryland forest trees are found in Kanaio NAR, over 35% of the total number of native species in the area. Of these, only eight native tree species (36%) have been observed to be reproducing. For the remaining 14 species, no reproduction has been observed. Besides direct herbivory and trampling by ungulates, the most obvious reason for the lack of tree seedlings is the modification of the original conditions by decades of overgrazing. The aridification of the understory by loss of vegetation cover and substrate disturbance by ungulates has significantly changed the temperature and moisture of both the substrate and microhabitat where tree seedlings germinate and establish. Other potential factors (discussed in Section 2.D of this report) include the loss of native pollinators and native bird seed dispersers/scarifiers.

Native shrublands are scattered throughout the reserve but occur over much larger areas and with greater diversity of native plant species in the upper parcel above the highway. Besides groves of native trees, these shrublands are biologically the next more valuable resource in the reserve. Most have suffered some degree of damage by ungulates and invasion by alien plants, but areas of relatively intact native shrublands occur locally where native species are reproducing well (*Dodonaea*, *Wikestroemia*, *Dubautia*).

Sizable areas of the reserve are dominated by alien grass, herb, and shrub species usually in areas of shallow soils overlying lava substrates. The near complete domination by alien species of these areas reflects regimes of severe disturbance likely from combinations of intense herbivory, wildfires, and seasonal drought. Two shrub species, lantana (*Lantana camara*) and *koa haole* (*Leucaena leucocephala*), form extensive thickets that exclude most other plant species. Currently, one characteristic of many areas of the reserve is a significant diversity of alien species that occur most often at minimal cover values. Though 21 alien plant species occurred in at least 20% of all the monitoring stations and 35 species in 10%, only three alien species had cover values greater than 1%. This diversity but low cover of alien species is a direct result of the intense herbivory in this seasonally arid habitat. The damage by feral goats

favors the maintenance but not dominance of small-statured, quick-growing annual species, some of which possess some adaptation to reduce herbivory.

As a result of field work conducted during this project, rare native plant species within the reserve were noted and divided into two categories for management purposes. Level 1 taxa were those whose population numbers were restricted statewide and that within the Kanaio NAR are at such low population levels that management intervention may be required to avoid extirpation from the reserve within the next few decades. These species are at such low population levels that a single catastrophic event, such as a fire or a hurricane, could cause their immediate extermination. Individual plants of all four Level 1 species are older, mature individuals with no smaller size classes present. Level 1 rare species selected are *koai'e* (*Acacia koaia*), *kauila* (*Alphitonia ponderosa*), *Bonamia menziesii*, *kāmanomano* (*Cenchrus agrimonioides* var. *agrimonioides*), and *alani* (*Melicope knudsenii*). Excluding *Cenchrus agrimonioides* of which little is known, the remaining four species flower and fruit freely but only *Bonamia* is easy to germinate and grow in cultivation. Level 2 species are endemic species that are rare or quite uncommon throughout their island range. For many Level 2 species, the populations in the reserve are some of the largest on the island, and for some, in the State. Level 2 rare species selected were *maile lau li'i* (*Alyxia olivaeformis myrtillifolia*), *'akoko* (*Chamaesyce celastroides* var. *lorifolia*), *'aiea* (*Nothocestrum latifolium*), *kulu'ī* (*Nototrichium sandwicense*), *'uki* (*Mariscus hillebrandii*), *Panicum pellitum*, *halapepe* (*Pleomele auwahiensis*), *hao* (*Rauvolfia sandwicensis*), and *maua* (*Xylosma hawaiiense*).

The majority of alien plant species may have little detrimental effect on the well-being of native plant species in the reserve. However, a few alien species are aggressively invasive into native habitats and harmful to native species. If weeds such as these are left unmanaged, they will come to dominate certain areas of the reserve and crowd out native vegetation. Within the reserve, seven species are considered invasive, posing threats to native vegetation and requiring the focus of management efforts: Spanish needle (*Bidens pilosa*), *Bocconia frutescens* (no common name), camphor tree (*Cinnamomum camphora*), *Glycine wightii* (no common name), molassesgrass (*Melinis minutiflora*), kikuyu grass (*Pennisetum clandestinum*), and Christmas berry (*Schinus terebinthifolius*)

Other alien species that currently occur in the reserve are not problem species now but may become so in the future. The comparison of repeated monitoring data could be used as a tool to indicate which alien species are invasive based on changes in distribution and abundance. Those alien species which may warrant future concern pending their spread and/or invasion into the reserve include silk oak (*Grevillea robusta*), Guinea grass (*Panicum maximum*), fountain grass (*Pennisetum setaceum*), and ivy-fruited gourd (*Coccinea grandis*). Managers of Kanaio NAR should be trained to identify the key invasive species of dryland forests in Hawai'i. Such awareness is essential for the rapid response required for cost-effective, efficient control of an alien weed invasion in or near the reserve.

Since the late 1800s, the native leeward vegetation of East Maui has become progressively degraded by domestic and feral ungulates, wildland fires, and invasion by alien plants. Feral pigs (*Sus scrofa*), axis deer (*Axis axis*), and domestic cattle (*Bos taurus*) currently pose only minor threats to the continued preservation of the reserve. Feral goats (*Capra hircus*), on the other hand, comprise the worst ungulate problem at Kanaio NAR. In fact, feeding and trampling by feral goats likely poses the greatest current threat to the long-term conservation of native vegetation in the reserve.

Besides ungulates, the Kanaio NAR contains a varied fauna including alien mammals, birds and insects and a diverse and unique native entomofauna which manages to persist despite the continued predation by alien species and the alteration of suitable habitat. Certain species in the biota of Kanaio NAR, both alien and native, carry more import than others and require a detailed and specific management response to deal with each situation accordingly.

Hawaiian ecosystems evolved without native rodents. As such, native plants have no coevolved defenses against the destruction of fruits and seeds by rodents. The introduction of the black rat (*Rattus rattus rattus*) and the house mouse (*Mus domesticus*) by early Europeans undoubtedly has diminished the

reproductive potential of many native dryland forest species. Both introduced rodents are seasonally abundant in the reserve and responsible for seed damage to certain species of endemic trees.

Other than the Hawaiian owl, the *pueo* (*Asio flammeus sandwicensis*), the only birds observed in the reserve are aliens including barn owl (*Tyto alba*), ring-necked pheasant (*Phasianus colchicus*), brown francolin (*Francolinus pondicerianus*) and black francolin (*Francolinus francolinus*). Game birds appear to have both beneficial and detrimental effects on Hawaiian nature reserves. In addition, a variety of small alien birds are also present in the reserve, the most common including Japanese white-eye (*Zosterops japonicus*) and common myna (*Acridotheres tristis*).

Evidence suggests that the leeward forests of Maui once supported a diverse and conspicuous native avian fauna. By examination of subfossil bird bones discovered in lava tube caves near the reserve, a large number of extinct endemic birds have been identified including two species of flightless ibis, three species of flightless geese, an eagle, three species of flightless rails (*moho*), a long-legged bird-hunting owl species and a variety of small passerines, including nectar-feeding, seed-feeding, and fruit-feeding species. The complete loss of the passerines native to the region, many of which were pollinators or seed dispersers, may have had significant impacts on the native vegetation.

The Hawaiian entomofauna has only one or two questionably native species of ants, a predator group which is otherwise largely absent from the native biota. Therefore, native insects lack general adaptations for coping with the fierce predation of alien ant species, the worst of which, the big-headed ant (*Pheidole megacephala*), has caused the greatest destruction of native insect life in the Hawaiian Islands up to about 4000 feet elevation. The native invertebrates of Kanaio Natural Area Reserve have apparently been heavily impacted by predation of the introduced big-headed ant which is common and widespread throughout the reserve. At present levels of technology, long-term control of ants throughout the reserve is unfeasible. Nevertheless, the utilization of a bait-toxicant mix in control of social insects such as ants and wasps can, if correctly presented, be extremely effective due to the passage of liquid foods among colony members. If it is determined that ants may be an important reason for the lack of native tree species establishment, control of the big-headed ant may be possible within small management areas of the reserve.

Despite the abundance of ants, the reserve still contains many native invertebrate taxa, some uncommon, rare, or not occurring elsewhere. Some of the native species of import include the yellow-faced bees, *Hylaeus* subgenus *Nesoprosopis (Hylaeidae)*, pollinators of many native leeward shrubland and high elevation plant species, and small endemic wasps *Odynerus* (*Vespidae*) and *Ectemnius* (*Sphecidae*). In addition, Kanaio NAR protects the only known habitat of the rare Hawaiian hawkmoth, *Manduca blackburni* (*Sphingidae*), which is found on members of the tomato family (Solanaceae) and manages to survive despite the presence of the big-headed ant.

The lack of reproduction of most native tree species is an ominous sign of the degradation of the dryland forests of Kanaio NAR. The definitive reason for this lack of reproduction by seed is unknown for any one species but an obvious impact results from the feeding and trampling by ungulates, especially feral goats. However, even if animals are removed, a variety of problems still remain for seedling establishment. Each of these problems must be looked at individually and in conjunction with the others to come up with a comprehensive management and conservation plan for the perpetuation of selected native species.

A monitoring protocol is suggested for acquiring the data necessary to make management decisions in the reserve, through recording long-term changes in the vegetation, involving a series of five roughly parallel transects established in the upper portion of the reserve. The transects run roughly north to south, starting at the pipeline road and ending at the main highway, and are oriented on ridges to facilitate their future location. Monitoring stations occur every 100 meters along the transect line and were utilized to record all vegetation within a 100 square meter area in a circular plot, as well as additional information outside that area.

The long term perpetuation of the native biota of the reserve should be the primary goal of management. The four most immediate threats jeopardizing survival of the native vegetation of Kanaio NAR include 1) browsing, grazing, and trampling by feral goats, 2) invasion of weed species, 3) wildland fires and 4) the very small population sizes of rare native species. Management strategies exist for each of these problems and are discussed in section 4.

Excluding feral goats from at least parts of the reserve seems to be the most obvious first step toward the protection and preservation of native vegetation. This could be accomplished by a variety of options from fencing of the entire reserve to small exclosures, and each option comes with its own benefits and drawbacks. The option we recommend is to fence off the upper northeast corner of the reserve (approximately 117 acres, or 13% of the total reserve) where native trees occur in the greatest densities (see Figure 6).

With the exclusion of feral goats, however, one event certain to occur is the proliferation of alien weeds now kept in check by the grazing of feral ungulates. To combat this invasion, various management techniques from mechanical to herbicidal control are suggested, depending on the weed species involved. Particular attention should be paid to the seven key alien plant species which carry the greatest potential for further spread and dominance in the reserve if not kept in check: Spanish needle (*Bidens pilosa*), *Bocconia frutescens*, camphor tree (*Cinnamomum camphora*), *Glycine wightii*, molassesgrass (*Melinis minutiflora*), kikuyu grass (*Pennisetum clandestinum*) and Christmas berry (*Schinus terebinthifolius*).

It is highly recommended that a series of small exclosures be built as a predictive tool to determine the response of vegetation to freedom from grazing and browsing. These small exclosures can be excellent indicators to guide and evaluate management actions. Even if the high priority area is protected (Figure 6), exclosures constructed within the reserve but outside the larger area of fencing will allow a solid evaluation of feasibility if further fencing efforts are to be considered in the future.

Another likely consequence of the exclusion of goats from the reserve is the threat of increased wildfires. Especially in the absence of ungulate browsing, the invasion of alien grasses and weeds will add to the biomass of fine fuels and allow fire to spread over lava flows previously unburned. Hawaiian dryland forests have apparently evolved in regimes of infrequent fire disturbance and its species respond poorly to fire. Therefore, the increased threat of wildfires provides another impetus for the control of alien, fire-adapted species as well as other weeds which might significantly increase the biomass of the fine fuels.

Finally, with the implementation of the prescribed guidelines, one possibility for certain areas of the reserve is to replant propagules of native species. The utilization of a well-conceived planting program which outlines objectives and addresses various concerns can lead to the re-establishment of stands of native dryland trees and add to the richness and uniqueness of Kanaio NAR. Our general guidelines for such a program are given in section 4.D.

During the course of this survey, a Hawaiian man, Edward 'Uweko'olani, and his family claimed ownership of a parcel of Hawaiian Homestead land (Kanaio Homesteads parcels no. 16 and 17-see Figure 1) that was included in the NAR. He established a semi-permanent residence and other substantial modifications by the end of 1992. The biological resources contained within Mr. 'Uweko'olani's claimed parcel are significant but not unique.

2. RESOURCES ASSESSMENT

A. GENERAL SETTING:

Established in 1990, the Kanaio Natural Area Reserve (NAR) comprises 876 acres (355 ha) at 1100 to 2780 feet (335 to 850 m) elevation on leeward East Maui. The reserve is divided into two discrete parcels, bisected by the main highway No 31; the portion above the road (Parcel A in the metes and bounds document) is 595 acres (241 ha), the area below the road (Parcel B) comprises 281 acres (114 ha). The upper boundary of the reserve is bordered by a private ranch road ('pipeline road') used to maintain a pipeline to bring water to range cattle. Neighboring landowners include a State of Hawai`i lease to `Ulupalakua Ranch, `Ulupalakua Ranch, and assorted private landowners to the west.

The substrate is predominantly rough *`a`a* lava with accumulation of some overlying soil, especially in low-lying *pāhoehoe* and *`a`a* lava flats. The substrate is estimated to be less than 10,000 years old (Crandell 1983). The topography is generally sloping, with trench-like channels apparently formed by deep streams of lava which align downslope, generally oriented north-south. Several deep lava tube entrances were observed on the western edge of the reserve. The area surrounding the reserve is currently largely uninhabited with the exception of a few privately-owned homes at Kanaio near the reserve's western boundary.

During the course of this survey, a Hawaiian man, Edward `Uweko`olani, and his family claimed ownership of a parcel of Hawaiian Homestead land (Kanaio Homesteads parcels no. 16 and 17 - see Figure 1) that was included in the NAR. He established a semi-permanent residence, constructed an outhouse, fences, cleared land and started constructed of a series of 4-wheel drive roads that by the end of 1992 had extended quite a distance from the main highway towards Pu`u o Nole, the upper boundary of his claimed land parcel. The senior author encountered him at least four times prior to Mr. `Uweko`olani establishing residence, showing him claimed signs of boundary pins and land ownership. The biological resources contained within Mr. `Uweko`olani's claimed parcel are significant but not unique. When checked at the end of 1992, the pvc posts with tags marking vegetation transects that pass through the disputed parcel where not tampered with.

The reserve is located on the leeward side of the island opposite prevailing tradewinds. Thus the climate of the reserve is generally arid and wind-swept with a mean annual rainfall of approximately 30 inches (750 mm). The nearest rain gage, a non-recording gage read intermittently by `Ulupalakua Ranch personnel, is located at an elevation of 2060 ft (628 m) in Auwahi. Data is transmitted to the National Weather Service and reported in their monthly publication (National Oceanic and Atmospheric Administration 1992). At the Auwahi gage, mean annual rainfall for the years 1982-1991 was 27.3 inches (693 mm),, ranging from highs of 44.8 inches (1139 mm) in 1982 and 44.3 inches (1125 mm) in 1989 to lows of 12.87 inches (329 mm) in 1983 and 14.09 inches (358 mm) in 1985. During 1982-1991, 77% of the total precipitation fell during October-March, with a mean of 20.9 inches (531 mm) during this period.

It is during the October-March wet season and shortly afterwards that the dryland forests become most biologically active. Both native and alien annual species germinate and grow rapidly, often producing substantial vegetation cover that is absent in prolonged periods without rain. The flowering and fruiting of perennial species is also keyed to the wet season. This is also the time of year when native dryland tree seedlings germinate. A high percentage of these young emergent seedlings (approaching 100% for some species) die in the following months.

During the 1991-1992 study period, events characteristic of Pacific-wide El Nino/Southern Oscillation weather conditions substantially modified the normal wet winter, dry summer cycle. During the October-March wet season of 1991-1992, only 8.0 inches (203 mm) of rain fell, 38% of normal. Phenologies of perennial plants and germination of annual plants were abnormal in response to the atypical timing of the rains. It is desirable that monitoring of vegetation in Hawaiian dryland forests should be optimally

scheduled to occur in the latter part or shortly after a typical rainy season, at least if any meaningful comparison of herbaceous or seedling vegetation over time is expected. In the case of this survey, the baseline monitoring was conducted in spite of the unusually dry winter.

B. FLORA

B.1. OVERVIEW

Hawaiian dryland forest, taken at its broadest definition, could be considered to include all native vegetation occurring on the leeward, rain-shadowed, drier slopes of the islands. Perhaps more than any other Hawaiian ecosystem, leeward forests have been incessantly displaced or degraded. As a whole, Hawaiian dryland forests should be considered an endangered community that without management may largely disappear in a few decades. Of the dryland forests left in Hawai'i, few areas have retained diversity and biomass comparable to that of Kanaio NAR. The best remaining examples of leeward forests in the State are Pu'uwa'awa'a and North and South Kona on the Big Island, Auwahi, Kanaio and Pu'u o Kali on Maui, Kanepu'u on Lāna'i, and various locales in the Wai'anae mountains of O'ahu and in the Koke'e region of Kaua'i. Of these, the Maui and Big Island sites form a relatively discrete dryland community on unweathered lava with little soil formation in contrast to the leeward examples on the other, older islands which occur predominantly on deeper soils. East Maui and Big Island communities have much in common in terms of overall community structure, common native species, and similar threats; however, each example has its unique aspects as well.

Based on a recent classification by Gagné and Cuddihy in Wagner et al. (1990), the Kanaio NAR contains representatives of three vegetation communities: *'A'ali'i* (*Dodonaea*) lowland shrublands, *Lama* (*Diospyros*) forest, and *Wiliwili* (*Erythrina*) forest. The neighboring district to the east, Auwahi, has been widely known as the finest dryland forest remaining on Maui and among the best remaining in the Hawaiian Islands (Rock 1913). However, despite remaining richness in native dry forest tree species, Auwahi is dominated by the aggressive mat-forming kikuyu grass (*Pennisetum clandestinum*). Furthermore, most native tree species of Auwahi have only older, senescent individuals present with virtually no smaller size classes to indicate a reproducing population.

The reserve contains 161 species of vascular plants including 10 species of pteridophytes and 151 species of flowering plants (Appendix 1). Over 60% of the species listed for the reserve, some 96 species, are introductions by man. Indigenous species account for 14%; endemic species for 24%. Generally, there was a lack of pteridophyte diversity presumably due to herbivory and seasonal aridity of the reserve. This lack of diversity was less marked but also present in monocots. Alien dicot species accounted for 54%; and native dicot species (endemic and indigenous combined) accounted for 30% of the totals.

Table 1. Numbers of vascular plant species of Kanaio Natural Area Reserve in major categories.

	ALIEN	INDIGENOUS	ENDEMIC	TOTAL
PTERIDOPHYTES	2	6	2	10
MONOCOTS	7	0	5	12
DICOTS	87	17	32	139*
TOTAL	96	23	39	161*

*Three dicot species were Polynesian introductions

TABLE 2

Ten most common (percentage cover) native and alien plant species by transect, Kanaio NAR

Native Plants	
Plant Species	% Cover
Dodonaea viscosa	9.3%
Wikstroemia monticola	2.3%
Osteomeles anthyllidifolia	1.6%
Pleomele auwahiensis	0.4%
Waltheria indica	0.4%
Cocculus trilobus	0.3%
Pellaea ternifolia	0.3%
Mariscus hillebrandii	0.3%
Styphelia tameiameiae	0.3%
Peperomia leptostachya	0.2%

Alien Plants	
Plant Species	% Cover
Rhynchelytrum repens	14.9%
Lantana camara	9.7%
Melinis minutiflora	2.2%
Bidens pilosa	1.0%
Pennisetum clandestinum	0.7%
Bocconia frutescens	0.7%
Sporobolus africanus	0.6%
Momordica charantia	0.6%
Ageratina adenophora	0.5%
Portulaca pilosa	0.4%

Bare Ground	45.3%

TABLE 3

Ten most frequently occurring native and alien plant species along transects, Kanaio NAR

Native Plants	
Plant Species	**% Freq.**
Waltheria indica	69.0%
Cocculus trilobus	67.8%
Dodonaea viscosa	65.0%
Pellaea ternifolia	64.9%
Wikstroemia monticola	63.6%
Mariscus hillebrandii	60.1%
Osteomeles anthyllidifolia	34.9%
Plectranthus parviflorus	33.1%
Panicum pellitum	25.1%
Peperomia leptostachya	17.0%

Alien Plants	
Plant Species	**% Freq.**
Rhynchelytrum repens	96.9%
Lantana camara	94.6%
Bidens pilosa	77.6%
Opuntia ficus-indica	69.8%
Sonchus oleraceus	67.3%
Portulaca pilosa	61.2%
Doryopteris decipiens	60.5%
Emilia spp.	52.8%
Melinis minutiflora	49.5%
Chamaecrista nictitans	49.1%

The reserve can be divided into four basic zones: 1) groves of native trees, 2) native shrubland, 3) largely barren lava, 4) alien grass, herb, and shrublands. Though these are general overview units which overlap somewhat within the reserve, practical delineation is easy to discern in the field and management implications are clear.

Scattered groves of native dryland trees in Kanaio, Auwahi, and Luala`ilua districts comprise the best examples of dryland forests remaining on Maui. The distribution of these groves likely represents a kipuka-like situation where younger substrates (colonized by vegetation only sparsely) have surrounded older substrates that support much greater diversity and biomass of biota. Twenty-two species of Hawaiian dryland forest trees are found in Kanaio NAR, over 35% of the total number of native species in the area. Of these trees, only eight species (36%) have been observed to be reproducing. For the remaining 14 species, no reproduction has been observed. Besides herbivory, the most obvious reason for the lack of tree seedlings is the modification of the original conditions by decades of overgrazing. The aridification of the understory by loss of vegetation cover and substrate disturbance by ungulates has significantly changed the temperature and moisture of both the substrate and microhabitat where tree seedlings germinate and establish. Other potential factors (discussed in Section 2.D of this report) include the loss of native pollinators and native bird seed dispersers/scarifiers.

Most of the larger, more extensive groves of trees in the reserve are in Parcel A, above the main highway. It is in the upper half of Parcel A, especially in the central and eastern sections, that the reserve's greatest density and diversity of tree species occurs.

Immediately below the highway in Parcel B are a number of good representatives of dry forest trees including *hao* (*Rauvolfia*), *wiliwili* (*Erythrina*), *`aiea* (*Nothocestrum*), and *lama* (*Diospyros*). However, with decreasing elevation towards the lower (southern) boundary of the reserve, the native tree diversity declines until virtually the only trees present are *hao* (*Rauvolfia*). Similar loss in species diversity will be expected to occur in other sections of the reserve unless some intervention efforts and management actions are implemented. Therefore, protection of dryland forest groves should be among the highest priorities of Kanaio NAR.

Table 4. Status of 22 native dryland forest trees found in Kanaio Natural Area Reserve

Hawaiian name in reserve	Scientific name	Status	Reproduction noted?
1) *`a`ali`i*	*Dodonaea viscosa*	COMMON	YES
2) *`aiea*	*Nothocestrum latifolium*	COMMON	YES
3) *`akoko*	*Chamaesyce celastroides lorifolia*	SCATTERED	YES
4) *`ālaʻa*	*Pouteria spathulata*	SCATTERED	NO
5) *alahe`e*	*Canthium odoratum*	SCATTERED	NO
6) *alani*	*Melicope knudsenii*	RARE	NO
7) *keahi*	*Nesoluma polynesicum*	SCATTERED	NO
8) *koai`e*	*Acacia koa* (*A. koaia* populations)	RARE	NO
9) *kōlea*	*Myrsine lanaiensis*	COMMON	NO
10) *kōpiko*	*Psychotria mauiensis*	RARE	NO
11) *halapepe*	*Pleomele auwahiensis*	COMMON	NO
12) *hao*	*Rauvolfia sandwicensis*	COMMON	YES
13) *`iliahi*	*Santalum ellipticum*	COMMON	NO
14) *kauila*	*Alphitonia ponderosa*	RARE	NO
15) *lama*	*Diospyros sandwicensis*	COMMON	YES

16) *māmane*	*Sophora chvrsophylla*	SCATTERED	NO
17) *maua*	*Xylosma hawaiiense*	UNCOMMON	NO
18) *naio*	*Myoporum sandwicense*	SCATTERED	YES
19) *`ohe-makai*	*Reynoldsia sandwicensis*	COMMON	YES
20) *`ohi`a*	*Metrosideros polymorpha*	SCATTERED	NO
21) *olopua*	*Nestegis sandwicensis*	SCATTERED	NO
22) *wiliwili*	*Erythrina sandwicensis*	COMMON	YES

Areas of largely barren lava in the reserve are found primarily below the main highway in Parcel B. Though largely devoid of vegetation, scattered trees occur throughout the reserve, especially *hao* (*Rauvolfia*). The twisted jumbles of black *`a`a* lava create an unusual moonscape. Though unexplored, it is possible, if not probable, that a unique invertebrate community exists on these barren areas analogous to high elevation aeolian zones and the so-called 'neogeoaeolian' zones of new flows on the Big Island (Howarth 1979).

Alien grass, herb, and shrublands occur over areas of the reserve with somewhat developed shallow soils on lava substrates. The near complete domination by alien species of these areas reflect regimes of severe disturbance likely resulting from combinations of intense herbivory, wildfires, and seasonal drought. Two shrub species in particular, lantana (*Lantana camara*) and *koa haole* (*Leucaena leucocephala*), form extensive thickets that exclude most other plant species. Thickets of the thorny pest shrub, lantana, , though weakened by a series of biological control agents, are still a dominant force in the vegetation of many areas of the reserve. *Koa haole* is primarily confined to one elongate population mostly below the main highway. This grove was completely defoliated and many plants killed outright in the early 1980s by the spread of the newly introduced homopteran insect, *Heteropsylla cf. incisa*, the *koa* psyllid.

Currently, one characteristic of many areas of the reserve is a significant diversity of alien species that occur most often at minimal cover values. Though 21 alien plant species occur in at least 20% of all the monitoring stations and 35 species in 10%, only three alien species had cover values greater than 1%. This diversity of alien species is a direct result of the intense herbivory in this seasonally arid habitat. The damage by feral goats favor the maintenance, but not dominance, of small-statured, quick-growing annual species, often with some adaptation to reduce herbivory. Of all the species in the reserve, the group which contained the greatest percentage (54%) was that of alien dicots with 87 species.

At Kanaio NAR, the most important problem with the long term conservation of the area's dryland forests is the striking lack of reproduction for many native tree species. An example of this can be found in *naio* (*Myoporum sandwicense*), which along with *wiliwili* is among the most common of Hawaiian dryland trees. In fact, the Hawaiian land district, or *'ahupua'a*, of Kanaio, for which the reserve is named, means 'the *naio*'. *Naio* is found generally on leeward exposures from low to middle elevations throughout the islands. Yet, at the reserve, *naio* is scattered and is not especially common. Dead trunks of *Myoporum* have an unmistakable appearance and the heartwood a unique fragrance. Based on the number of dead trunks of *naio* trees, this species was once much more common than it is today. In over ten years of field work, we have encountered only three *naio* saplings in the study area, presumably because of goat browsing.

B.2. RARE NATIVE PLANT SPECIES:

As a result of field work conducted during this project, rare native plant species within the reserve were noted and divided into two categories for management purposes (Table 5). Level 1 taxa were those whose population numbers were restricted statewide and that within the Kanaio NAR are at low population levels and may require management intervention to avoid extirpation from the reserve. These species are at such low population levels that a single catastrophic event, such as a fire or a hurricane could cause their immediate elimination. Individual plants of all four Level 1 species are older, mature individuals

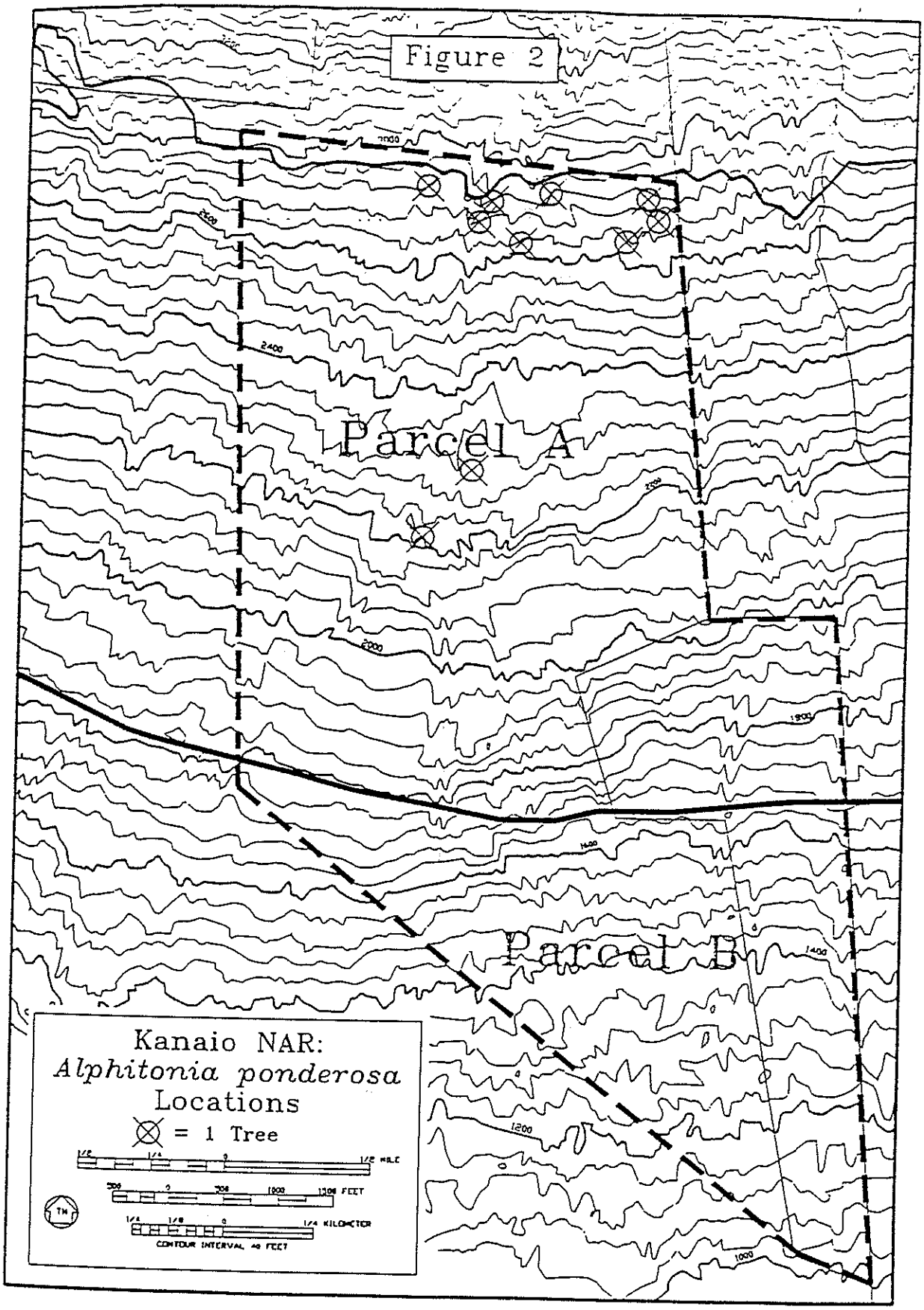


Figure 2
Parcel A
Parcel B
Kanaio NAR:
Alphitonia ponderosa
Locations
= 1 Tree
1/2 MILE
FEET
1/4 KILOMETER
CONTOUR INTERVAL 40 FEET
2400
2000
1900
1400
1200
1000

with no smaller size classes present. Although all four species flower and fruit freely, only *Bonamia* is easy to germinate and grow in cultivation. Level 2 species are endemic species that are rare or quite uncommon throughout their island range. For many Level 2 species, the populations in the reserve are some of the largest on the island, and for some, in the State.

Table 5: List of endemic species selected as rare or threatened and warranting monitoring and possibly management action, Kanaio NAR.

	STATUS IN HAWAI'I?	STATUS IN RESERVE?
LEVEL 1 RARE SPECIES:		
koai`e (*Acacia koaia*)	RARE	RARE
kauila (*Alphitonia ponderosa*)	RARE	RARE
Bonamia menziesii (no common name)	RARE	RARE
kāmanomano (*Cenchrus agrimonioides*)	RARE	RARE
alani (*Melicope knudsenii*)	RARE	RARE
LEVEL 2 RARE SPECIES:		
maile lau li`i (*Alyxia olivaeformis myrtillifolia*)	RARE	SCATTERED
`akoko (*Chamaesyce celastroides* var. *lorifolia*)	RARE	SCATTERED
`aiea (*Nothocestrum latifolium*)	UNCOMMON	COMMON
kulu`ī (*Nototrichium sandwicense*)	UNCOMMON	SCATTERED
`uki (*Mariscus hillebrandii*)	UNCOMMON	SCATTERED
Panicum pellitum	UNCOMMON	UNCOMMON
halapepe (*Pleomele auwahiensis*)	RARE	COMMON
hao (*Rauvolfia sandwicensis*)	RARE	COMMON
maua (*Xylosma hawaiiense*)	UNCOMMON	UNCOMMON

Discussion of Level 1 rare species:

Koai`e (*Acacia koaia*)

The new revision of the Hawaiian flora (Wagner *et al.* 1990) recognizes a single endemic species of *Acacia*, *A. koa* (Fabaceae), with three subspecies. Subspecies *koaie* is a small, gnarled dryland tree previously recognized as a distinct species, *Acacia koaia*. Many Hawaiian botanists still regard the dryland *Acacia koaia* as a valid species. A small scattered group of approximately four trees of this species occurs in the reserve at 2590 to 2600 ft (790-795 m) elevation. Though these trees have been observed to flower numerous times, many flowerings failed to produce pods. No reproduction of this species in the reserve has been observed.

Kauila (*Alphitonia ponderosa*)

Within Kanaio NAR, ten individuals of the endemic *kauila* tree (*Alphitonia ponderosa*) (Rhamnaceae) have been discovered in the reserve at 2200 to 2780 feet (670 to 850 m) elevation. The *kauila* trees in the reserve include a high percentage of the individuals of this species surviving on Maui, with most of the remainder found immediately upslope of the reserve. When in heavy flower, the tree produces a musky, thick fragrance attracting an abundance of insects, primarily flies and wasps. No reproduction by *kauila* from seedlings was noted; however, the trees were producing full, undamaged seeds despite the seed

predation of an unidentified beetle. In the lower parts of the reserve at 2000-2200 feet (610-670 m) elevation, several large dead trunks of *kauila* were seen below the current lower elevation limit of the species. One sapling of this species is known outside, but adjacent to, the reserve; otherwise, no other germinants are known.

Bonamia menziesii (no common name)

Four individuals of *Bonamia menziesii* (Convolvulaceae), a rare vine of dry to mesic forests, are located within the reserve, more individuals than are known anywhere else on Maui. The direct effects of browsing by feral goats comprise the primary threat to this species. The four *Bonamia* vines are found at 1800 to 2300 feet (550 to 700 m) elevation, growing on *lama* (*Diospyros*), *halapepe* (*Pleomele*), *'ohe-makai* (*Reynoldsia*), and, in one case, scrambling low over introduced *Lantana* bushes. This last individual has been growing here for at least 12 years (A.C. Medeiros, pers. observ.) and had over that time grown quite large, covering over approximately 30 m^2. In 1990, within just a few weeks, the vine was defoliated and nearly killed when a large herd of feral goats began to frequent the area. The plants in the reserve flower abundantly and produce good seeds that germinate and survive in greenhouse conditions. Despite this, no seedlings of *Bonamia* have been observed in the reserve.

Kāmanomano, kūmanomano (*Cenchrus agrimonioides* var. *agrimonioides*)

This variety of coarse, endemic grass is listed by Wagner et al. 1991 as "occurring on dry, rocky slopes and ridges, 580-760 m (1900-2500 ft), on O'ahu, Lāna'i, and Maui." The variety *laysanensis* grew in sand at elevations below 33 ft (10 m) on Kure Atoll, Midway Atoll, and Laysan; it was last collected in 1961 and may be extinct. A single plant of this species, covering approximately 1.5 square meters, was discovered by Robert Hobdy, Maui forester, in the Kanaio NAR in February 1993. The plant was growing in the bottom of a small gully of rough 'a'a lava scree at 2600 ft (795 m) elevation in the upper part of the reserve (Figure 4). Associated native species included: *Metrosideros*, *Pleomele*, *Nothocestrum*, *Dodonaea*, *Sicyos*, *Melinis*, *Rhychelytrum*, and *Passiflora subpeltata*.

Alani (*Melicope knudsenii* or *Melicope mucronulata*)

One federally listed Endangered Species found within the reserve is the *alani*, *Melicope knudsenii* (Rutaceae), a small dry forest tree endemic to southern Haleakalā and Kaua'i. (U.S. Fish and Wildlife Service 1991). A single 5 meter tall tree is known from the reserve, located in a grove of native trees at the edge of a lava canal near the center of the reserve at 2370 feet (725 meter) elevation. Specimens of these trees were identified by B.C. Stone, monographer of the genus, as unusual specimens of *Melicope multiflora*, and currently lumped with *Melicope knudsenii*. These species are morphologically very close to *Melicope mucronulata* (another species on the verge of extinction) and deserve closer examination. Tentatively they are considered *M. knudsenii*, the federally listed Endangered species. It is possible that there are a few additional trees in the reserve that have escaped detection. Filled seed are produced prolifically by the single tree but no seedlings have been observed.

Discussion of Level 2 rare species:

Maile lau li'i (*Alyxia olivaeformis* - "*myrtillifolia*" populations)

The *maile* found in dryland forests of Hawai'i is distinctive in both habitat and morphology. To the Hawaiians, it was the *maile-lau-li'i*, or small-leafed *maile*. This dryland *maile* was described nomenclaturally at various times as a species, a variety, and a form, all using the name *myrtillifolia*. In the most current treatment (Wagner *et al.* 1990), these populations are included without formal recognition under the single polymorphic endemic species, *Alyxia olivaeformis* (Apocynaceae). No reproduction has been noted in the reserve.

'Akoko (*Chamaesyce celastroides* var. *lorifolia*)

The tree form of the *'akoko*, *Chamaesyce celastroides* var. *lorifolia* (Euphorbiaceae), was formerly common throughout the lowlands of Lāna'i and Maui. Because of fire and ungulates, this species is now absent throughout most of its former range save for a few rocky refuges. During wet winters, large

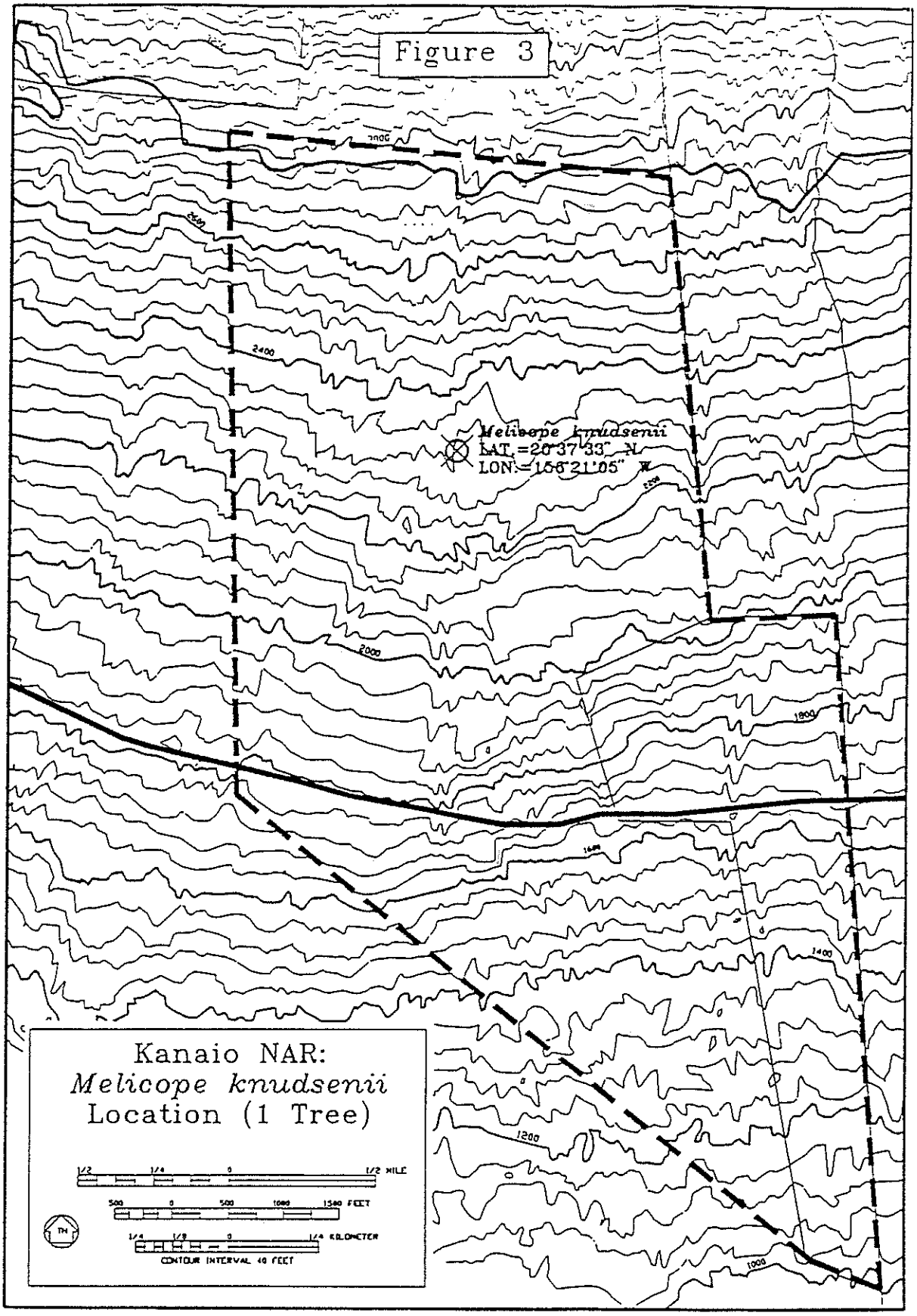


Figure 3
Melicope knudsenii
LAT.=20°37'33" N
LON.=156°21'05" W
2400
2000
1800
1400
1200
1000
Kanaio NAR:
Melicope knudsenii
Location (1 Tree)
1/2 1/4 0 1/2 MILE
500 0 500 1000 1500 FEET
1/4 1/2 0 1/4 KILOMETER
CONTOUR INTERVAL 40 FEET

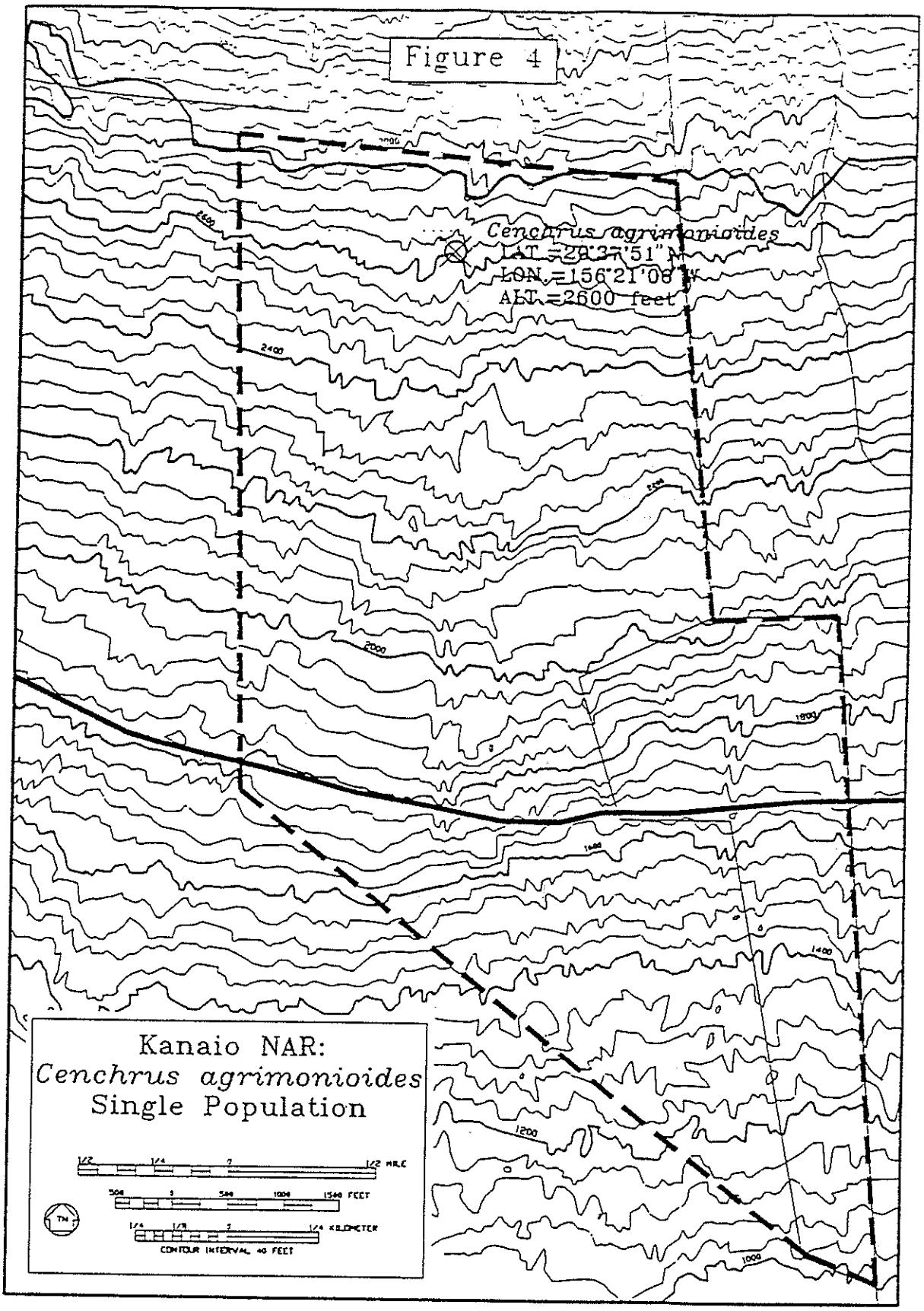


Figure 4
Cenchrus agrimonioides
LAT.=20°37'51" N
LON.=156°21'08" W
ALT.=2600 feet
2600
2400
2000
1800
1600
1400
1200
1000
Kanaio NAR:
Cenchrus agrimonioides
Single Population
1/2 1/4 0 1/2 MILE
500 0 500 1000 1500 FEET
1/4 1/8 0 1/4 KILOMETER
CONTOUR INTERVAL 40 FEET

batches of seedlings have been observed to germinate but not establish. With protection, this species has shown good recovery in formerly denuded rocklands of Kaupō Gap in Haleakalā National Park. In western Kaupō Gap, seedlings of *C. celastroides lorifolia* have been discovered in areas where no adult trees have existed for many years. A similar response can be expected with protection from ungulates at Kanaio NAR.

`Aiea (*Nothocestrum latifolium*)

The *`aiea*, *Nothocestrum latifolium* (Solanaceae), was formerly common in the dry leeward lowland forests of Moloka`i, Lāna`i, and Maui (Rock 1913). Within the last fifty years, many populations of *`aiea* have declined sharply or disappeared entirely. Today, *Nothocestrum latifolium* in the reserve may comprise the largest population in the State. Despite this abundance, there is an apparent complete lack of seedling establishment of this species. Seedlings appear after wet winters, but so far no establishment has been observed.

Kulu`ī (*Nototrichium sandwicense*)

Individuals of this silver-leafed shrub are scattered above and below the main highway that bisects the reserve. On Maui, *Nototrichium sandwicense* (Amaranthaceae) is rare except on the twin lava flows of Pu`u o Kali on southwest Haleakalā at 400 to 1500 feet (120 to 460 m) elevation. No reproduction of *kulu`ī* has been noted within the reserve, though it occurs freely on Pu`u o Kali lava flows on Haleakalā, some 8-9 miles north-northwest.

`Uki (*Mariscus hillebrandii*)

This small sedge is relatively common in the Kanaio NAR and adjacent native forests and in Kaupō Gap of Haleakalā National Park. *Mariscus hillebrandii* (Cyperaceae) is a preferred browse species and can generally be used to gauge the degree of grazing in an area. This species was quite rare in Kaupō Gap while feral goats were present, except in an exclosure. After removal of goats, *Mariscus* appeared in numerous stations along monitoring transects, apparently from seeds stored in the soil.

Panicum pellitum

Panicum pellitum (Poaceae) grows on the leeward, dryland slopes of the islands of Ni`ihau, Lāna`i, Maui and Hawai`i. This endemic annual grass has hairy stems and leaves growing to a foot or so tall (30 cm) in the best of conditions. In harsher habitats, such as in western Kaupō Gap, however, it is much smaller with mature flowering plants just over an inch (2.5 cm) tall. Sparsely scattered through the reserve at 2340-2590 ft (715-790 m), *Panicum pellitum* is found only after wet season rains (approximately November through April). Regeneration of this species occurs from seeds stored in the soil. Goat grazing, fire, and competition with alien grasses are the primary threats to *Panicum pellitum*. In Kaupō Gap where feral goats have been eliminated, this species has not thrived and perhaps has declined somewhat as the barren open areas it prefers were taken over by alien grasses.

Halapepe (*Pleomele auwahiensis*)

Small populations or single individuals of the *halapepe*, *Pleomele auwahiensis* (Agavaceae), occur in the Waikamoi, Kula, Luala`ilua, and Kaupō districts of Haleakalā and in remnant leeward forests of central Moloka`i. The only extensive groves of this species on Haleakalā occur in the adjacent districts of Auwahi and Kanaio at 2080-2760 ft (635-840 m) elevation. Perhaps the largest stand of *halapepe* forest in the State occurs in the upper central and eastern portions of the reserve. However, despite the fact that it is one of the most common trees in the reserve, all individuals are mature and have not successfully reproduced for some time. A seed collection of *halapepe* from the reserve has been sent to the National Botanical Gardens, Lawai, Kaua`i for propagation.

Hao (*Rauvolfia sandwicensis*)

Hao, *Rauvolfia sandwicensis* (Apocynaceae), is a very rare tree on Maui except for the populations along Maui's leeward slopes, especially in the Kanaio NAR. We roughly estimate the population of the reserve to be between 300 to 600 individuals. In the area of the reserve on both sides of the main highway, *hao* is one of the most common tree species, forming rounded, broad canopies of dark green foliage among the rubble of rough *'a'a* lava. Every wet season, hundreds of seedlings of *hao* spring up, especially in leaf litter in the shaded canopies of large *hao* trees. In most of the upper part of the reserve, where *hao* is a component of a fairly diverse assemblage of tree species, very few if any of these emergent seedlings survive the following dry season. Below 1500 feet (460 m) elevation in the western part of the reserve, the terrain is increasingly made up of jumbles of extremely rough *'a'a* lava generally oriented in small ridges with swales between. Because there is almost no development of soil, the site seasonally becomes a virtual desert. Here, as other trees gradually disappear with decreasing elevation, scattered *hao* trees become the sole native tree down to the reserve lower boundary at ca. 1100 ft (335 m) elevation. During this project, it was noted that many of these *Rauvolfia* trees had smaller *Rauvolfia* seedlings and saplings growing in the shade of their canopies, despite severe seasonal aridity and intense goat browsing throughout the area. This observation is especially surprising in light of the lack of reproduction of this species near the road where vegetation is denser and browsing is minimal. *Hao* trees below the road may either be producing better quality seed, or some other factor may be operative. Seedlings of *hao* near the road are often heavily attacked by scale insects tended aggressively by big-headed ants. If this herbivory by scale insects to emergent seedlings is debilitating, and the ants do not occur in these isolated trees surrounded by rough *'a'a* lava, then their absence could be the likely reason for some of the success in seedling establishment. This situation provides a unique case study in which the overwhelming herbivory by feral goats is apparently not the primary cause of the lack of seedlings.

Maua (*Xylosma hawaiiense*)

Maua, *Xylosma hawaiiense* (Flacourtiaceae), is rare on Maui and uncommon throughout the Hawaiian Islands. On Haleakalā, scattered *maua* trees occur in the Kanaio, Auwahi, and Luala'ilua districts. Likely less than 100 trees of this species occur within the reserve. Reproduction of this species has not been observed due to factors possibly related to those scenarios previously illustrated.

B.3. INVASIVE ALIEN PLANT SPECIES:

Over 60% of the plant species in the reserve are alien, introduced by Europeans after the late 1700s. Of these, most are relatively inconsequential by-products of the levels of disturbance occurring due to ungulates. The majority of alien plant species may have little detrimental effect on the well-being of native plant species in the reserve. However, a few alien species are markedly different in being both aggressively invasive into native habitats and harmful to native species. If weeds such as these are left unmanaged, they will come to dominate certain areas of the reserve and crowd out native vegetation. Within the reserve, the seven alien plant species listed in Table 6 are considered invasive, threats to native vegetation, and consequently, require a focus of management efforts. Early detection is often a necessary component for successful eradication of a noxious species, see Appendix 6.

Spanish needle, *Bidens pilosa*

Present in Hawai'i prior to 1845 (Hillebrand 1888), Spanish needle, *Bidens pilosa* (Asteraceae), native to tropical America, is an annual herb to just over 3 feet (1 meter) tall that seasonally dominates the understories of many native trees in the reserve and appears to interfere with tree seedling recruitment. The species is ubiquitous and produces copious achenes with barbed awns that disperse easily on humans, mammals, and birds. Though probably uncontrollable on a large scale due to its ubiquity and abundance, small-scale control may be practical and advisable within localized, intensely managed units, such as under the canopy of particularly rare native trees or small groves.

Bocconia frutescens

Bocconia frutescens (Papaveraceae) is a large-leaved, soft-wooded shrub/tree to 20 feet (6 m) tall, native to Central and South America and the West Indies. It was first noted by C.N. Forbes in the Kanaio area in 1920 (no. 2175.M, BISH). In his field notes made on an extensive collecting trip throughout leeward East Maui, C.N. Forbes noted seeing only a single 8 ft. tall *Bocconia* plant growing on the roadside of the old government trail in Kanaio. *Bocconia* has spread widely since, and is currently found at 1600 to 2780 feet (490-850 m) elevation. Very common in many areas, this woody shrub can reach the height and canopy dimensions of a dry forest tree. The seeds are encased in a capsule and attached to a scarlet aril which presumably facilitates the dispersal of *Bocconia* seeds by fruit-eating birds, as the distribution of seedlings would suggest (away from parent plants and under other trees). During the field work, goat damage to *Bocconia* was often observed in the reserve. The Hawai'i Department of Agriculture has also designated *Bocconia* as a noxious weed for eradication and/or control. Despite its large size, *Bocconia* is soft-wooded, and it is relatively easy to fell even large trees. Cut stumps should be treated with a suitable herbicide. It is recommended that this species be controlled in the reserve, at least in those areas of most intact native vegetation.

Table 6: List of seven alien plant species selected as aggressive and primary threats to native ecosystems, Kanaio NAR.

Spanish needle (*Bidens pilosa*)
Bocconia frutescens (no common name)
Camphor tree (*Cinnamomum camphora*)
Glycine wightii (no common name)
Molassesgrass (*Melinis minutiflora*)
Kikuyu grass (*Pennisetum clandestinum*)
Christmas berry (*Schinus terebinthifolius*)

	Status in reserve?	**Degree of threat to native veg.?**	**Difficulty of management**	**Year of Intro.**
Bidens	widespread	medium	high	< 1900s
Bocconia	common	medium	medium	1920
Cinnamomum	uncommon	medium	medium	>1930
Glycine	uncommon	high	medium	>1970s
Melinis	common	high	high	>1900s?
Pennisetum	uncommon	medium	medium	1940s
Schinus	uncommon	high	medium	>1910

Camphor tree, *Cinnamomum camphora*

Camphor tree (Lauraceae), native to Asia, grows to 40 feet (12 m) height locally. Camphor tree was first cultivated on O'ahu in 1927 (Wagner *et al.* 1990); it has only recently begun to naturalize in the reserve and is known from several very large trees and scattered seedlings and saplings. Some individuals in the reserve are up to 30 feet (9 m) tall with basal diameters exceeding 12-14 inches (30-35 cm). No camphor was noted along vegetation transects. Camphor trees in the reserve are probably derived from planted and naturalized trees mostly near 'Ulupalakua but also near Kaunauhane and Kanaio homesteads. Camphor seeds are encased in a berry likely distributed by fruit-eating birds. This species should be controlled opportunistically while it is still in its incipient invasion stages.

Glycine wightii

Glycine wightii (Fabaceae) is the most recent invasive threat in the reserve, becoming established within the last five years. A relative of the soybean, *G. wightii* is an aggressive perennial vine native to Central America, South America, and the West Indies (Wagner *et al.* 1990). In the coming years, it may prove to

be a serious management problem for the reserve, especially in areas protected from browsing. Where it was first known on Maui in 'Ulupalakua (at least since the 1970s), some 6.5 km (4 mi) west of the reserve, *Glycine* has grown in thick mats, climbing over fences and smothering trees and shrubs on the roadside. However, just a few feet away, across the fence and in the pasture, *Glycine* is absent because of grazing cattle. Recently, this weed has spread widely and now occurs on East Maui as far to the northwest as Kula and Makawao, and as far east as eastern Kaupō. Five widely scattered plants of this species were located in the reserve during the course of this study. No individuals were noted in stations along vegetation transects. The seeds of *Glycine* are enclosed in pods with a sticky, velcro-like surface, not dissimilar to those found in Spanish clover, *Desmodium*. They are dispersed by goats, cattle, humans, pigs, and birds.

Molassesgrass, *Melinis minutiflora*

Molassesgrass, native to Africa, is a vigorous, mat-forming grass to over 3 feet (1 meter) tall. The foliage is sticky with aromatic and highly flammable resins. When goats were removed elsewhere in Hawai'i, the buildup of this flammable foliage encouraged wildfires. Molassesgrass recovers well after fire, eventually coming to dominate burned areas. Seeds are small and sticky when wet, perhaps hitchhiking on animals or humans.

After control of feral goats in the mid 1980s, molassesgrass has proved a serious invader in mid-elevation leeward sites of Haleakalā National Park (Kaupō Gap), locally dominating ground cover and creating a fire hazard. A similar situation has also occurred in Hawai'i Volcanoes National Park to the point where molassesgrass now dominates large areas. In the fall of 1990, Haleakalā National Park attempted to control molassesgrass with glyphosate (ROUNDUP) delivered in a spray rig by helicopter. The object was to delay molassesgrass spread until the initial disturbance levels were reduced and recovery of native vegetation was well advanced. Initial results of this experimental treatment are encouraging. Based on observations in Kanaio and elsewhere on Maui over the last ten year, it appears that molassesgrass has increased greatly even in the presence of grazing by goats. In the reserve, molassesgrass is now common almost everywhere above 1800 feet (550 m) elevation. Now that a permanent monitoring system is established in the reserve, there will be documentation regarding future changes in abundance and distribution of molassesgrass.

Kikuyu grass, *Pennisetum clandestinum*

Kikuyu grass (Poaceae), native to Africa, is the most disruptive dry forest weed in Auwahi district adjacent to the NAR. It is because of the large scale invasion of this weed species that Auwahi, botanically richer than Kanaio, was not recommended for protection. Kikuyu grass is, for the most part, sparse in the Kanaio district, probably due to the relatively unweathered substrate and the lower elevation, drier habitat of the reserve compared with Auwahi. Kikuyu grass was planted along the pipeline road that marks the upper boundary of the reserve in the 1940s after the collapse of populations of Maui pāmakani (*Ageratina adenophora*) following the introduction of biocontrol organisms. Currently, it is found sparingly throughout the reserve from the main highway up to the pipeline road. Some populations are definitely associated with disturbance adjacent to the road surface but other patches occur scattered on ridge tops. It is presumed that these more remote patches of kikuyu grass are a product of dispersal of viable stolon or rhizome pieces in the droppings of cattle. Though somewhat achlorotic, these patches appear to be spreading in the more shaded environment of the understory of dryland trees. Kikuyu grass is sensitive to applications of ROUNDUP (glyphosate) even at a 1% concentration and many plants will succumb to a single foliar treatment. Though not the highest of priorities, it is recommended that the patches of kikuyu grass in the reserve be eliminated by herbicide application. This species flowers only when mechanically disturbed but apparently does not produce seeds.

Christmas berry, *Schinus terebinthifolius*

Christmas berry (Anacardiaceae), native to Brazil, is a small tree that forms dense thickets. Though Christmas berry has been in Hawai'i since the early 1900s, it has apparently invaded Kanaio NAR only within the last decade or so. The seeds are encased in bright red fruits which are dispersed locally by alien fruit-eating birds, such as mynah (*Acridotheres tristis*) and house finch (*Carpodacus mexicanus*).

Dense stands of this species dominate the vegetation just outside the northwest corner of the reserve. Currently within the reserve, it occurs at 1920 to 2780 feet (585-850 m) elevation. At vegetation monitoring stations within the reserve, *Schinus* occurred sparsely at only 3.2% of the stations with a low average cover of 0.02%. Christmas berry should be controlled while control is still feasible.

Other alien species that currently occur in the reserve are not problem species now but may become so in the future. The comparison of repeated monitoring data should be used as a tool to indicate which alien species are invasive based on changes in distribution and abundance.

Silk oak (*Grevillea robusta*)
Several small *Grevillea robusta* (Proteaceae) trees are growing in or very near the western boundary of the reserve, two individuals very near the main highway at 1800 feet (550 m) elevation. As with Christmas berry and camphor, silk oaks are spreading into the reserve from planted and naturalized trees in 'Ulupalakua, Kaunauhane, and Kanaio homesteads. The few trees of this species should be destroyed before they spread further.

Guinea grass (*Panicum maximum*)
Native to Africa, Guinea grass (Poaceae) is an aggressive alien species that can develop dense thickets, especially in the drier leeward and lowland windward slopes. Two small patches of *Panicum maximum* have been observed in the reserve, both on the roadside at 1640 and 1800 feet (510 and 550 m) elevation along the main highway No. 31 through the reserve. One occurs at and around the cattle guard marking the Auwahi and Kanaio districts, and the second in the western half of the reserve. This is an extremely aggressive weed on leeward deeper soil sites such as on Lāna'i where the species has become a dominant species over the past forty years (R.W. Hobdy, pers. comm.). It is not known whether this species will prove to be as invasive on more barren lava sites. However, the few patches of *P. maximum* should be destroyed while only minimum effort is still required.

Fountain grass (*Pennisetum setaceum*)
Fountain grass (Poaceae) is probably the best example of an invasive species that is extremely damaging to dryland forests elsewhere in the Hawaiian Islands but does not occur in the reserve. Currently, fountain grass is restricted on Maui to two small but persistent populations in Wailuku. On the leeward slopes of the Big Island, fountain grass forms dense carpets which both smother and crowd out native vegetation and, even worse, contribute to the buildup of fine fuels that encourage frequent and intense wildland fires. Fires, in turn, burn both young Hawaiian seedlings and older fruit-producing native trees while simultaneously clearing the terrain of competition for invasive, fire-adapted alien species such as fountain grass. The cycle of wildland fire to alien weed establishment is perpetuated until aggressive invaders come to completely dominate an area, making it biologically and aesthetically worthless. With the eventual exclusion of feral goats from Kanaio NAR, the threat of wildland fires is going to be magnified due to the buildup of fine fuels from the alien grasses and vegetation already established there. Therefore, it is imperative that fountain grass not be allowed to gain a foothold on leeward East Maui and in the reserve. Managers should be trained to recognize such an insidious invader and take immediate action to eradicate any plants which may someday appear. Otherwise, future management efforts will likely be expended on an incessant battle against the outbreak and spread of wildland fires.

Ivy-fruited gourd (*Coccinea grandis*)
In October 1992, a first plant of the smothering vine *Coccinia grandis* (Cucurbitaceae) was discovered on Maui in Kahului's industrial district; the single plant discovered and destroyed by R.H. Hobdy (pers. comm.). Later, Hobdy destroyed some 200 seedlings of *Coccinia* at the site where the first plant had previously grown. Wagner *et al.* 1991 list this species as dioecious, but this subject deserves further attention based on the first record of this species on Maui. Native to Africa, Asia, and Australia, *Coccinia* has spread very rapidly on O'ahu, coming to dominate cover by developing thick mats of interlaced stems and leaves over trees, in a fashion not unlike *Glycine wightii*. Either *Coccinea* or fountain grass, if established in the Kanaio NAR, could not only trigger the decline of much of the remaining biota but also transform the visual landscape to even the most casual of observers.

Managers of Kanaio NAR should be trained to identify the key invasive species of dryland forests in Hawai'i. Such awareness is essential for the rapid response required for cost-effective, efficient control of an alien weed invasion in or near the reserve (see Appendix 6).

C. Fauna

C.1. UNGULATES:

Since the late 1800s, the native leeward vegetation of East Maui has become progressively degraded by the actions of domestic and feral ungulates combined with wildland fires and invasion by alien plants. On the older substrates of the neighboring Auwahi district, there is greater soil development, less rocky terrain, and greater invasion by alien plant species, especially kikuyu grass (*Pennisetum clandestinum*). Though the lava flows that form the Kanaio district run adjacent and parallel to the Auwahi flows, those of Kanaio have apparently occurred more recently as the lava is much less weathered with meager soil development.

Feral pigs (*Sus scrofa*) usually associated with wet forest areas are present at low numbers throughout most of the reserve, especially in the upper sections. The damage they cause to native vegetation is relatively unimportant due to low population levels.

Despite the current lack of boundary fences, domestic cattle (*Bos taurus*) occur only infrequently in the area of Kanaio NAR. Cattle in the reserve are limited by the rough *'a'a* lava terrain combined with the seasonal lack of herbaceous forage. Cattle are still a minor problem in the reserve, with impacts especially during the spring and summer seasons when they destroy understory vegetation beneath native trees, both by seeking shade and by feeding. In Auwahi, domestic cattle comprise the greatest ungulate threat to native vegetation; in rockier Kanaio, the smaller and more agile feral goat is the primary threat.

Axis deer (*Axis axis*) were first introduced to Maui in lower elevation southwest Haleakalā in 1960 (Tomich 1986). Populations are reported to be slowly growing in size but as yet pose no substantial threat to native vegetation. To our knowledge, axis deer have never been recorded within or near the reserve.

Feral goats (*Capra hircus*) comprise the worst ungulate problem at Kanaio NAR. In fact, feeding and trampling by feral goats likely pose the greatest current threat to the long-term conservation of native vegetation in the reserve. Hunting of goats in the reserve by poachers and local ranch hands has occurred up to this point and continues to some degree presently. This hunting pressure is strongest near roads and major access points, such as the main highway 31 and the upper ranch-owned 'pipeline road' marking the upper boundary of the reserve. As a result of this, beyond the area of high weed diversity immediately at the disturbed road surface, the native vegetation of the reserve is in relatively good condition near roads.

Based on observations made during the course of field work, there appear to be two independent, loosely organized herds of feral goats in the reserve, one above the main highway in Parcel A and the other below the road in Parcel B. The Parcel A herd consists of at least 200 individuals; the Parcel B herd appears to be smaller and more dispersed, likely due to the scarcity of available vegetation for food. All goats seen in the reserve were either entirely black or predominantly black with smaller white markings. Based on the lack of goat pellets near the road surface, feral goats rarely cross the main highway.

C.2. RODENTS:

Hawaiian ecosystems evolved without native rodents; native plants therefore have no coevolved defenses against the destruction of fruits and seeds by rodents. The introduced black rat (*Rattus rattus rattus*) and the house mouse (*Mus domesticus*) are present and seasonally abundant in the reserve. Destruction of seeds by rats has been observed in the *'ohe-makai* (*Reynoldsia*), *'ili-ahi* (*Santalum*), *'aiea* (*Nothocestrum*)

and other endemic tree species. The persistent destruction of its large fruit and seeds by rodents is one of the primary causes of the endangerment of nearby populations of the rare *mahoe* tree (*Alectryon macrococcum* var. *auwahiensis*). It is unknown whether the Polynesian rat (*Rattus exulans hawaiiensis*) occurs in the reserve, but, so far, limited snap trapping caught only black rats and house mice.

C.3. HAWAIIAN BAT:

It is unknown whether the Hawaiian bat, *'ope'ape'a* (*Lasiurus cinereus* ssp. *semotus*) occurs within Kanaio NAR. This species occurs within a few miles of the reserve at 'Ulupalakua and Kaupō.

C.4. NATIVE AND ALIEN BIRDS:

The Hawaiian owl *pueo* (*Asio flammeus sandwicensis*) is rare but present in Kanaio NAR. To our knowledge, no other native birds are found in the reserve. The barn owl (*Tyto alba*) is also rare but present in the reserve, flying at night and roosting in open lava tubes by day.

Ring-necked pheasants (*Phasianus colchicus*) are present but uncommon presumably due to poor habitat. Brown francolins (*Francolinus pondicerianus*) are common long-time residents, but the more boldly marked black francolins (*Francolinus francolinus*) have been reportedly introduced into the area within the last five years for hunting (local rancher, pers. comm.). Game birds appear to have both detrimental and beneficial effects on Hawaiian nature reserves. On the one hand, they disperse and scarify native plant seeds, to some degree acting as surrogates for extinct endemic fruit-eating birds. On the other hand they likely disperse alien plant seeds, act as vectors for bird diseases, and by their presence increase predator densities that prevent re-establishment of native bird species. However, since no native bird species except the pueo currently is resident in the reserve, the effects of disease transfer to native birds may be a moot point.

A variety of other small alien birds are present in the reserve, the most common being Japanese white-eye (*Zosterops japonicus*) and common myna (*Acridotheres tristis*), but also rock dove (*Columba livia*), northern cardinal (*Cardinalis cardinalis*), nutmeg mannikin (*Lonchura punctulata*), Eurasian skylark (*Alauda arvensis*), house finch (*Carpodacus mexicanus*), mockingbird (*Mimus polyglottus*), and house sparrow (*Passer domesticus*).

C.5. FOSSIL BIRDS:

Based on the pioneering work of Storrs Olson and Helen James of the Smithsonian Institution from the 1970s to the early 1990s, it is now known that, prior to impacts of the early Hawaiians, the islands supported a diverse and conspicuous avifauna. By examination of subfossil bird bones discovered in lava tube caves in nearby leeward districts of East Maui (Olson and James 1991, James and Olson 1991), it was discovered that leeward Haleakalā (at comparable elevations and in similar habitats as the present Kanaio NAR) had a diverse and conspicuous native bird fauna (see Appendix 2). Included in the list of extinct endemic birds recorded near the reserve are two species of flightless ibis, three species of flightless geese, an eagle, three species of extinct flightless rails, a long-legged, bird-hunting owl species, and a variety of small passerines, including nectar-feeding, seed-feeding, and fruit-feeding species. The complete loss of the passerines native to the region, many which were pollinators or seed dispersers, may have had significant impacts on the native vegetation. Also found beside bones of flightless geese were bones of the modern *nēnē* (*Branta sandvicensis*), extirpated and reintroduced on Maui in the 1960s.

C.6. INVERTEBRATES:

The Hawaiian entomofauna has only one or two questionably native species of ants (Wilson and Taylor 1967). This important predator group is largely absent from the native biota. As a result, there is a general lack of adaptations in the native insects to cope with the fierce predation of many introduced ant species (Cole et al. 1992). The big-headed ant, *Pheidole megacephala* (Formicidae), has caused the

greatest destruction of native insects in the Hawaiian Islands, up to about 4000 ft (1220 m), but especially below 2000 ft (610 m) elevation (Zimmerman 1948). The native invertebrates of Kanaio Natural Area Reserve have apparently been severely impacted by predation of the introduced big-headed ant, which is common and widespread throughout the reserve.

At present levels of technology, long-term control of ants in the reserve is unfeasible. Despite this, the use of a bait-toxicant mix in control of social insects such as ants and wasps can, if correctly presented, be extremely effective due to the passage of food liquids (and as a result, the pesticide) among colony members. In Hawai`i, much effort has been expended by Neil J. Reimer and the retired Dr. John Beardsley of the Entomology Department at the University at Hawai`i at Mānoa to control the big-headed ant in Hawaiian sugar cane and pineapple fields, with industry support, but their efforts have been only partially successful. We have conducted experimental trials using chemical control of the Argentine ant at a high-elevation site within Haleakalā National Park, one of the first studies of which we are aware involving the control of ants for conservation purposes. The primary obstacle to ant control in Hawai`i is the current lack of approved and effective bait-toxicant formulations.

If it is determined that ants may be an important reason for the non-establishment of native tree species, control of the big-headed ant may eventually (when an approved and effective bait-toxicant is available) be possible within smaller management areas of the reserve. Test plots to determine if ants and their associated scale insects are damaging to native seedlings, such as *hao* (see write-up on *Rauvolfia sandwicensis* in Level 2 rare native species) should be encouraged as future management-based research.

Despite the abundance of ants, however, the reserve still contains many representatives of native invertebrate taxa, some uncommon, rare, or not occurring elsewhere. The renowned Hawaiian biologist R.C.L. Perkins suggested that in some lowland areas of rough lava or sand that are very dry, native invertebrates may survive because the arid conditions are suboptimal for introduced ants such as *Pheidole*.

The native yellow-faced bees, *Hylaeus* subgenus *Nesoprosopis* (Hylaeidae), seasonally found in the reserve, sometimes occur abundantly on the bright yellow composite flowers of the endemic shrub *nehe*, *Lipochaeta lavarum*. These native bees are important pollinators of many Hawaiian leeward shrubland and high-elevation species. The small endemic wasps *Odynerus* (Vespidae) and *Ectemnius* (Sphecidae) are fairly common on sunny days, especially when vegetation is flushing. All these hymenoptera are solitary species constructing nests in cavities, usually under rocks or in hollowed twigs. Their continued survival despite the abundance of the introduced *Pheidole* ant is a subject of considerable interest.

Kanaio NAR provides a *de facto* invertebrate reserve in protecting the only known habitat of the rare Hawaiian hawkmoth, *Manduca blackburni* (Sphingidae). This rare hawkmoth has been known from scattered collections throughout the years on Kaua`i, O`ahu, Moloka`i, and Maui. Until recently, the larvae had been collected only on cultivated and naturalized species of the tomato family (Solanaceae), primarily on the weedy tree tobacco *Nicotiana glauca*, but also on cultivated tobacco, eggplants, tomato, and *Solanum* spp. It was not until the mid-1980s that the true host plant (also predictably in the tomato family) was discovered by Betsy Harrison Gagné to be the *`aiea*, *Nothocestrum latifolium*. This tree is common in the reserve but uncommon to rare elsewhere in the Hawaiian Islands. The rare hawkmoth manages to survive the egg, larval, and year-long pupal stages despite the presence of the big-headed ant. The ecology of the moth, its possible role in pollination, and its survival in spite of introduced ants would make an excellent subject for a graduate-level investigation.

Several deep lava tube entrances were observed at the western edge of the reserve. Entrance in some cases would require ropes. It is possible that the tube sections of these entrances are intact enough in parts between the openings to enable the development of a 'dark zone', an area with no light and little air movement to the surface, allowing the unique invertebrate fauna associated with Hawaiian lava tubes to exist (Howarth 1987).

In Hawai'i, all termites are alien species, introduced inadvertently by man. One species (*Neotermes connexus* Snyder) appear to be harming trees of the endemic *'ohe-makai*, *Reynoldsia sandwicensis* in the reserve. Termites only consume dead wood, yet their consumption of dead parts near the bases of *Reynoldsia* trees appear to make them susceptible to wind breakage. Three trees were seen broken and killed in this manner, all adult apparently healthy trees with fresh green leaves just beginning to wilt and abundant signs of termite activity at the break point.

D. NON-DIRECT IMPACTS ON THE NATIVE BIOTA:

The greatest current threat to the dryland forests encompassed by the Kanaio NAR is the lack of reproduction of many tree species. The definitive reason for this lack of reproduction by seed is unknown for any species. One obvious impact is the browsing and trampling by ungulates, especially feral goats. However, if animals are removed, are all problems for seedling establishment solved? For at least some species, the answer is not likely. For certain native species, there are apt to be problems relating to production of good seed and establishment of seedlings and saplings even after feral goats are removed. One or more of the following problems may apply:

1) lack of outcrossing pollination in native plants caused by the loss and/or reduction of coevolved native insects and birds and reduction of plant populations.
2) loss of seed dispersal and scarification by native birds now extinct.
3) seed predation by introduced rodents.
4) changes in understory vegetation, producing hotter, drier sites with less leaf litter are a result of near continual disturbance and removal of herbaceous vegetation by ungulates.
5) competition with aggressive weeds for vegetative cover in the absence of browsing.
6) modification of nutrient cycling by the two previous problems compounded by loss or reduction of mycorrhizae or rhizobial symbionts.
7) impact by introduced insects or pathogens such as the black coffee twig borer and its associated harmful fungus.

3. MONITORING

To initiate long-term monitoring of vegetation changes in Kanaio NAR, a series of five roughly parallel transects were established though the upper parcel of the reserve. The transects run approximately north to south, starting at the pipeline road at 2780 ft (848 m) elevation and run down to the main highway. No transects were established in the reserve below the road. The transects were measured with standard metric hip chains, thread being removed afterwards to prevent possible entanglement by birds.

Transects were oriented to stay along ridges. We felt, based on corresponding transects in similar habitats within the Kaupō Gap area of Haleakalā National Park, that, over a period of years, transects oriented along straight line compass courses and not oriented along ridges became very difficult and in some cases perhaps impossible to relocate. By staying on prominent ridges, we have greatly facilitated the relocation of these transects. The stations are relatively permanently marked with pvc poles (save for wildfires) which should last up to twenty years. However by orienting the transects along ridges we have also somewhat biased the sample to drier, more disturbed sites that often occur in deeper swales. Either strategy of transect placement, on straight-course compass lines or along prominent ridges has its

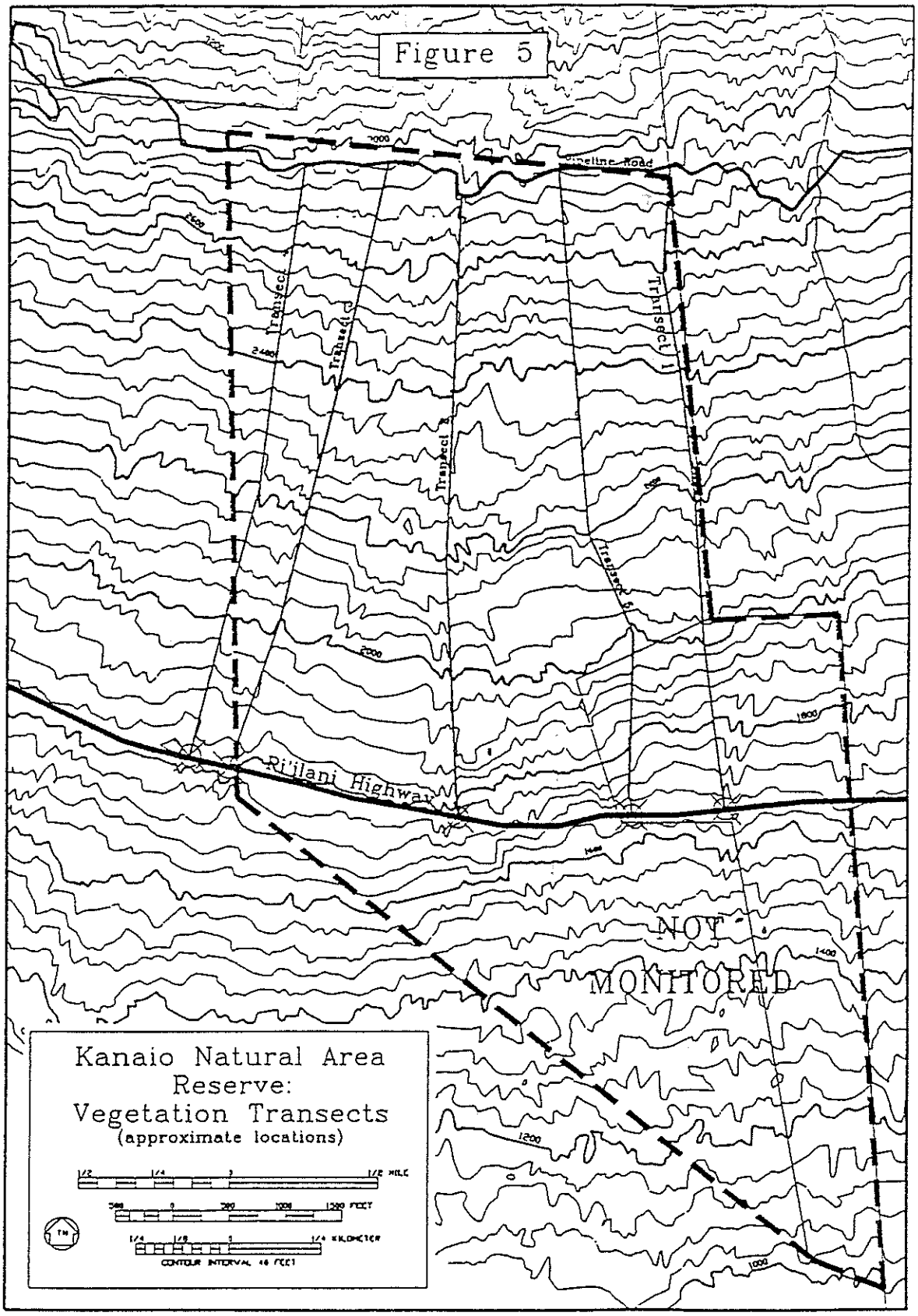


Figure 5
Pipeline Road
Transect 1
Transect 2
Transect 3
Transect 4
Transect 5
Transect 6
Ri'ilani Highway
NOT MONITORED
Kanaio Natural Area Reserve:
Vegetation Transects
(approximate locations)
1/2 1/4 0 1/2 MILE
500 0 500 1000 1500 FEET
1/4 1/2 0 1/4 KILOMETER
CONTOUR INTERVAL 40 FEET
TN

advantages and disadvantages. We have favored the strategy that facilitates relocation of transects and stations.

At 100 meter (328 feet) intervals along each transect, stations were established, marked with lengths of schedule 40 pvc plastic (polyvinyl chloride) posts (approx. 0.25 m length), each identified by an aluminum tag fastened with wire and fiberglass tape. The aluminum tag identifies the transect number, date the transect was established, and the station number.

At each station, within a radius of 5.64 meters (18.5 feet) of the marker (total of 100 m^2 area in circular plot), a list of all plant species was made and a cover index value was assigned to each as well as to bare ground. Species with less than 1% cover, i.e. $1m^2$, were coded by "R"; species with between 1 to 2.5% cover, i.e. 1 to 2.5m2, were assigned the code X; 2.5 to 25 % cover were coded "1"; 25 to 50% cover coded "2"; 50 to 75% cover coded "3"; and 75 to 100 % cover coded "4".

At each station, within a radius of 9.77 meters (32 feet) of each station (total of 300 m^2 area in circular plot), presence or absence of seven selected plant species was recorded. The criteria for selection of these plants were those species which, based on similar areas, are expected to increase markedly if provided protection from feral goats. Six of these were invasive alien species (*Bocconia frutescens, Cinnamomum camphora, Glycine wightii, Melinis minutiflora, Passiflora subpeltata*, and *Schinus terebinthifolius*); the seventh species was the native *`a`ali`i* (*Dodonaea*). Presence/absence of these seven species was also noted when they occurred within 2.5 meters on either side of the transect between stations.

At each station, the elevation and compass bearing to the next station was made. Notes were also made at each station regarding unusual alien or native species and landmarks useful in relocating the station. A latitude/longitude fix using a Magellan GPS NAV 1000 PRO unit was also attempted at many stations using the 2D mode (using three satellites with the altitude manually entered from a hand-held altimeter). In many cases, the GPS units could not produce readings because of the non-availability of usable satellites or the obstruction of their signals due to features of the terrain.

Within a 5.64 meter radius, numbers of both new and old goat droppings were estimated in the following number classes:

INDEX VALUE		NUMBER OF GOAT PELLETS
0	=	0
1	=	1-25
2	=	25-50
3	=	50-100
4	=	100-500
5	=	greater than 500

3. MANAGEMENT RECOMMENDATIONS

The long term perpetuation of the native biota of the reserve should be the goal of management. The greatest immediate threats currently operating to degrade the native vegetation of Kanaio NAR are 1) the browsing, grazing and trampling by feral goats, 2) invasion of weed species, 3) wildland fires, and 4) the very small population sizes of rare species. The following is a discussion of the management aspects of each of these four major threats.

3 A. EXCLUSION OF UNGULATES

Exclusion of feral goats from Kanaio NAR appears to be the essential first step towards protection and restoration of native vegetation. In some parts of the reserve, exclusion of goats will result in a tremendous increase in vegetation, especially grasses. This increase in fuel biomass will augment wildfire potential. Wildfires threaten humans and livestock and pose a significant threat to native vegetation. However, if feral goats are excluded from Kanaio NAR, many native species will increase significantly. The more common native species, such as *`a`ali`i* (*Dodonaea*), *`ulei* (*Osteomeles*), *wiliwili* (*Erythrina*), *na`ena`e* (*Dubautia*), and the endemic sedge *Mariscus hillebrandii* will increase quickly. Other native taxa such as *`akoko* (*Chamaesyce*), *lama* (*Diospyros*), *`ohe-makai* (*Reynoldsia*), and perhaps *naio* (*Myoporum*), *hao* (*Rauvolfia*), *kōlea* (*Myrsine*), and *`aiea* (*Nothocestrum*) will also respond, but at a somewhat slower pace.

Unless the entire reserve is scheduled to be fenced, as an early priority, it is recommended that an exclosure or series of small exclosures (e.g. 30 ft x 30 ft) be constructed at elevational intervals. Vegetation analysis prior to and following fence construction should be used to determine the effects of the removal of grazing and browsing on the cover of alien species, especially invasive species such as molassesgrass (*Melinis*). These small exclosures can be excellent indicators to guide and evaluate management actions. If a high-priority area of the reserve is protected (Figure 6), exclosures constructed elsewhere within Kanaio NAR but outside the exclosure fencing will allow a solid evaluation of feasibility of recovery of native species and of increased fuel loading if further fencing efforts are considered in the future.

The following section discusses four levels of management options for control of ungulates at Kanaio NAR. The following options are arranged in suggested order, with the most preferred options discussed first:

<u>OPTION 1 — Fence the northeast portion of Parcel A only</u>

Advantages: *moderate costs
*allows grazed areas to serve as "natural" fire breaks
*protects densest assemblages of native forest in reserve

Disadvantages: *leaves lower part of the reserve unprotected from feral goats

Our preferred management plan is not to fence the reserve in its entirety along the boundaries but rather, at least initially, to fence the northeast portion of the reserve (Figure 6). This smaller unit (approximately 117 acres, or 13% of the total reserve) contains the greatest concentrations of native tree species in the reserve. It protects the most biologically crucial area of the reserve and, by concentrating efforts, will expedite management measures.

<u>OPTION 2 — Fence entire reserve</u>

Advantages: *The native vegetation of the entire reserve would be protected from feral goats.
*The NAR boundary would be clearly delineated for the public.

Disadvantages: *higher costs
*The absence of browsing will create fuel buildups and increase the threat of wildfire, at least in some areas of the reserve.

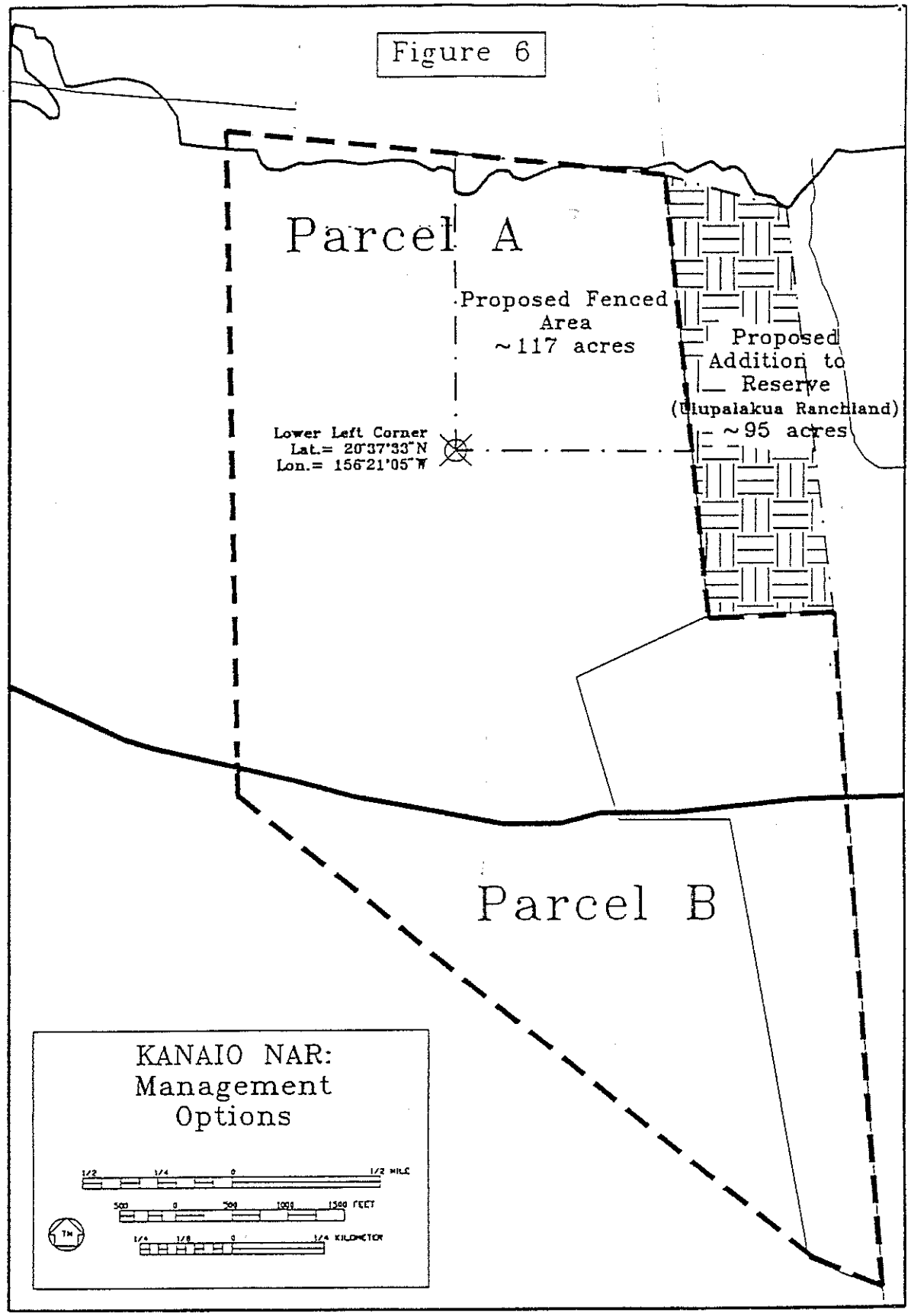


Figure 6
Parcel A
Proposed Fenced Area ~117 acres
Proposed Addition to Reserve (Ulupalakua Ranchland) ~95 acres
Lower Left Corner
Lat.= 20°37'33"N
Lon.= 156°21'05"W
Parcel B
KANAIO NAR: Management Options
1/2
1/4
0
1/2 MILE
500
0
500
1000
1500 FEET
1/4
1/8
0
1/4 KILOMETER
TN

OPTION 3 – Build a series of small exclosures to protect small groves of trees

Advantages: *Allows perpetuation of rare species and representatives of more common species at lower costs.

*Browsed areas surrounding exclosures help to establish natural firebreaks.

*Initial management costs are reduced, thus expediting an earlier completion.

*Maintenance costs of the management program should be reduced overall and concentrated where efforts will produce the greatest effects.

Disadvantages: *This option appears to be better suited to neighboring Auwahi district where there is more species diversity but fewer individuals of each species. Smaller exclosures may act to only temporary mitigate the loss of biodiversity but do not protect ecosystems.

*Numerous small exclosures may create an unsightly visual landscape.

OPTION 4 – No fencing

Advantages: *no fencing costs

Disadvantages: *The meaningful protection of native vegetation is dependent on consistent reduction of feral goat populations in the reserve. Without protection from goats, native vegetation will likely continue to decline in diversity and abundance.

Table 7: Comparison of potential management strategies regarding ungulate control for Kanaio,NAR

	FENCED AREA	COST	PROTECTS RARE NATIVE SPP.	PROTECTS COMMON NATIVE SPP.	WILDFIRE THREAT
1	NE Parcel A	moderate	moderate/good	good	moderate
2	entire reserve	high	good	good	high
3	small exclosures	moderate	good	poor	low
4	no fencing	low	no	no	low

It is our opinion that some type of fencing program should be implemented. Though weeds and increased fire hazard are drawbacks to fencing, the alternative is to do nothing and allow the degradation of the native ecosystem to continue unabated. The general increase in herbaceous vegetation that follows fencing will create more protected, moister sites that may aid the germination and establishment of native trees. The increased availability of protected moist sites for seedlings and the absence of browsing may allow many native tree species to reproduce for the first time in decades.

As stated previously, the fencing option we recommend (at least initially) is to fence off the upper northeast corner of the reserve where native trees occur in the greatest densities (Figure 6). The benefits derived from this option compared to the money spent produce a high yield for a moderate investment.

3 B. ALIEN PLANT CONTROL

The strategy for control of alien plants in the reserve is dependent on the plans for fencing. Weeds to be controlled can be classified according to whether they should be controlled throughout the entire reserve whether fenced or not, or controlled only in fenced areas without goats. Many plants that are now being

kept in check by feral goats will flush with growth after the goats are gone. Some low-growing species, usually alien grasses and herbs, will be crowded out by a thick growth of a few species of alien grasses. In Kaupō Gap, in a similar ecological situation and at a slightly higher elevation, the species that came to dominate within a single year of protection from grazing were Natal redtop (*Rhychelytrum repens*) and African rattail (*Sporobolus africanus*). In the following years, molassesgrass (*Melinis minutiflora*) and kikuyu grass (*Pennisetum clandestinum*) began to spread and become more conspicuous.

We have noted the seven species which, in our opinion, are the alien species that are the most invasive in this situation and the most damaging to native biota. Of the seven problem alien species, two species (Spanish needle and molassesgrass) are currently so abundant that any comprehensive short-term solution is unlikely. However, small-scale control of Spanish needle and aerial spraying of molassesgrass may comprise viable management options in the future depending on results of experimental work, ongoing in the latter case. Two species (kikuyu grass and *Glycine* vine) warrant careful monitoring and opportunistic control. Both occur at low levels, but *Glycine* appears to be spreading rapidly and poses a serious threat. Of the seven selected species, three (Christmas berry, camphor, and *Bocconia*) are particularly important to managers in that control is practical and warranted.

We recommend that the elimination of Christmas berry in the reserve be one of the highest priorities for alien species control. The spread of this species has been slow thus far due to the scarcity of trees large enough to fruit abundantly. There are few large individuals and scattered younger trees mostly in the northern and northwestern sections of the reserve. A good volunteer project would entail the elimination of all known Christmas berry trees in the reserve. Eradication of a dense grove of this species at the periphery of the northwest corner of the reserve should be investigated as to feasibility and, if warranted, pursued as a cooperative operation with adjacent landowners and perhaps 'Ulupalakua Ranch.

The invasion of camphor into the reserve has been slow thus far due to the scarcity of individuals large enough to reproduce. Therefore, it remains feasible and highly recommended that all known plants in the reserve be eliminated. Like Christmas berry, eradication of nearby populations at the periphery of the reserve should be explored with adjacent landowners. Control efforts for camphor tree would make a good volunteer project.

An attempt should be made to destroy all *Bocconia* in the reserve before it becomes so ubiquitous as to be unmanageable. As it is soft-wooded, it is easy to cut down even large sized individuals with hand tools. Painting of the cut-stump with an herbicide should eliminate recovery. The manual aspect of the control of *Bocconia* is a good volunteer project.

Though each of the preceding three species in which mechanical control is advocated is discussed independently, field trips with crews to eradicate weed species should ideally control all three and others opportunistically as encountered. As general control techniques for all three species are similar (i.e. remove smaller plants entirely and cut and treat stump with pesticide on larger plants), the number of tools needed for field trips can be reduced (e.g. pulaskis, machetes, pesticides, and safety gear.)

Glycine vine presents, at least potentially, a very serious threat to the reserve. However, although isolated individual plants are worth eliminating, the spread and increase in abundance of this species, if allowed to continue unchecked, will quickly make manual control an impractical and infeasible investment of time. If such a situation develops, recommendations include documenting its spread with monitoring transects, evaluating the practicality of aerial spray control, and promoting biocontrol.

Bidens is so common in the reserve that control should not even be considered except in special circumstances, such as under a rare tree to stimulate seedling germination and in small-scale intensively managed subunits. In this special case or on an experimental basis, repeated foliar spray with a low concentration of ROUNDUP (glyphosate) is recommended for *Bidens* control trials. Hand-weeding of *Bidens* should probably be avoided due to the degree of soil disturbance this causes.

Molassesgrass is a difficult species to control because of its tenacity in spreading through the islands. Specific recommendations to deal with molassesgrass are integrally related to issues of fencing and removal of goats. At minimum, molassesgrass should be prevented from dominating the understories of the groves of native trees. Secondarily, molassesgrass is also a threat to native shrublands of the reserve. If the decision is made to fence a relatively small part of the reserve, molassesgrass should be eliminated from inside exclosures. If larger areas are fenced, it may not be practical to control molassesgrass. Haleakalā National Park is conducting a large-scale experiment to control molassesgrass with helicopter-delivered selective herbicide treatment over several square miles of habitat very similar to the reserve following exclusion of feral animals. If this experiment is successful, managers at Kanaio NAR could use a similar protocol following fencing.

With kikuyu grass, it is not known at this time whether this species will be able to invade Kanaio and gain dominance as it has in Auwahi. Currently, kikuyu grass is scattered mostly in the upper Parcel A of the reserve with patches generally not exceeding 50 m^2 area. These small patches may be the result of a long-time creeping invasion in suboptimal conditions. They may also be a somewhat slow but progressive invasion by this species into the area. Periodic reevaluation of monitoring transects will detect any appreciable invasive spread or increase in cover of kikuyu grass over time. If control is warranted, kikuyu grass is sensitive even to low-dosage applications of ROUNDUP (glyphosate).

3 C. WILDLAND FIRES

The pre-human contact vegetation in the area now managed as Kanaio NAR is imprecisely known. By the time western observers arrived in the Hawaiian Islands in the late 1700s, the lands had been occupied and locally highly modified by Hawaiians for perhaps 1000 years. The areas on Maui that were apparently most impacted by the subsistence activities of Hawaiians were the low to middle elevation dryland and mesic forests and shrublands, especially those with substantial soil development. The use of fire for land clearing and soil enrichment for cultivation by the Hawaiians reduced the diversity of native plant species at sites that were capable of burning, even seasonally. Sites that were incapable of carrying a fire were located either on wet windward exposures, at higher elevations, or on lower leeward exposures possessing a relatively unweathered lava substrate with little soil development. Besides being largely resistant to fire due to scarcity and discontinuity of fuels, these areas were of little value for Hawaiian food crop cultivation. The same lands that were degraded by Polynesian fire were also those ecosystems that proved most vulnerable to the prolific ungulates introduced by western man, namely cattle, goats, and (elsewhere than on Haleakalā) sheep. Because of relatively young and unweathered substrate, the area of Kanaio NAR survived fire and browsing relatively intact; for this reason, it is one of the prime sites in the Hawaiian Islands for preservation of native dryland forest.

Still,, alien grasses probably have the potential to substantially reduce the fuel discontinuity that currently exists in many areas of the reserve. Especially in the absence of ungulate browsing, the invasion of alien grasses will allow fire to spread over lava flows previously unburned due to the lack of fine fuels. One of the greatest threats to Hawaiian dryland forest ecosystems, especially at lower elevations, is that of wildfires. In many parts of the continental United States, forests are reasonably well-adapted and even dependent on the effects of wildfires. This is likely a result of evolution of most continental ecosystems in regimes of frequent, intense wildfires. Hawaiian dryland forests have apparently evolved in regimes of infrequent fire disturbance and its species respond moderately or poorly to fire. Currently, acting in the presence of numerous fire-adapted alien plant species, wildfires rapidly erode native species diversity and clearly are a destructive force to native vegetation.

3 D. PROPAGATION OF NATIVE SPECIES, ESPECIALLY RARE SPECIES

If an organized planting program following prescribed guidelines is implemented, one potential for certain areas of Kanaio NAR is to replant propagules of native species in the hope of reestablishing stands

of native dryland trees. Suitable rare taxa for such a replanting program should include common dryland tree species (such as *halapepe, wiliwili, 'ohe-makai, naio*) as well as all level 1 rare native plant species. Because of the rarity in the reserve of adults and the availability of seed, taxa such as *kauila* (*Alphitonia*) and *Bonamia menziesii* are excellent taxa for replanting.

In a well-conceived planting program, these conditions should be followed:

a. A plan should be written outlining the objectives and methods of such a replanting program. This plan should be reviewed by the local scientific community.

b. Only plants produced by seeds gathered in the reserve should be planted in the reserve.

c. Accurate records should be kept regarding seed source, date of planting, and voucher (if possible). As much of this information as possible should be published, or at least made part of the public record.

d. Extreme caution should be used in not importing introduced invertebrate (such as alien slugs and snails) and plant species (such as lowland weeds) into the reserve with potting media, or herbivore pests such as whiteflies, scale insects, or aphids on foliage.

4 E. POTENTIAL ADDITION TO KANAIO NAR

A parcel of land of approximately 95 acres (38.5 ha) owned by 'Ulupalakua Ranch that flanks the northeast corner of the reserve contains forest comparable in quality to the most diverse areas of the reserve (Figure 6). Native trees occur in fairly dense groves and represent fairly high species diversity with minimum weed problem. If the proposed addition to the reserve is accomplished (see section 4.E), this new area and some adjacent reserve lands would become the next highest fencing priority.

LITERATURE CITED

Chapman, P.S. and P.V. Kirch. 1979. Archaeological excavations at seven sites, southeast Maui, Hawaiian Islands. Department of Anthropology, Bernice P. Bishop Museum, Honolulu. 40 pp.

Cole, F.R., A.C. Medeiros, L.L. Loope and W.W.Zuelke. 1992. Effects of the Argentine ant on the arthropod fauna of Hawaiian high-elevation shrubland. Ecology 73(4): 1313-1322.

Crandell, D.R. 1983. Potential hazards from future volcanic eruptions on the island of Maui, Hawaii. U.S. Geol. Survey, Misc. Investigations Map I-1442.

Hillebrand, W. 1888. Flora of the Hawaiian Islands: a Description of the Phanerogams and Vascular Cryptogams. Carl Winter, Heidelberg, Germany; Williams and Norgate, London; B. Westermann & Co., New York. 673 p.

Hitchcock, A.S. 1922. The Grasses of Hawaii. B. P. Bishop Museum Memoirs 8(3). 132 p.

Howarth, F.G. 1979. Neogeoaeolian habitats on new lava flows on Hawaii island: an ecosystem supported by windborne debris. Pacific Insects 20(2-3): 133-144.

Howarth, F.G. 1987. Evolutionary ecology of aeolian and subterranean habitats in Hawaii. Trends in Ecology and Evolution 2(7):220-223.

James, H.F. and S.L. Olson. 1991. Descriptions of thirty-two new species of birds from the Hawaiian Islands: part II. passeriformes. Ornithological Monographs No. 46, The American Ornithologists' Union, Washington, D.C.

Loope, L.L., R.J. Nagata, and A.C. Medeiros. 1992. Alien plants in Haleakalā National Park, p.551-576, In: Alien Plant Invasions in Native Ecosystems in Hawaii: management and research, ed. C.P. Stone, C.W. Smith, and J.T. Tunison. Cooperative National Park Resources Studies Unit, Department of Botany and University of Hawai'i Press, Honolulu.

Medeiros, A.C., L.L. Loope, and R.A. Holt. 1986. Status of native flowering plant species on the south slope of Haleakalā, East Maui, Hawaii. Cooperative National Park Resources Studies Unit, Hawai'i. Tech. Rept. 59:1-230.

National Oceanic and Atmospheric Administration. 1992. Climatological data. Hawaii and Pacific. National Climatic Data Center. Asheville, North Carolina. Published monthly.

Olson, S.L. and H.F. James. 1991. Descriptions of thirty-two new species of birds from the Hawaiian Islands: Part I. non-passeriformes. Ornithological Monographs No. 45, The American Ornithologists' Union, Washington, D.C.

Pratt, H.D., P.L. Bruner, and D.G. Berrett. 1987. A Field Guide to the Birds of Hawaii and the Tropical Pacific. Princeton University Press. Princeton, New Jersey

Pukui, M.K., and S.H. Elbert 1986. Hawaiian Dictionary. Revised and enlarged edition. University of Hawai'i Press, Honolulu.

Rock, J.F. 1913. The Indigenous Trees of the Hawaiian Islands. Publ. privately, Honolulu, 512 pp. Reprinted with introduction by Sherwin Carlquist and addendum by Derrel R. Herbst, 1974, Charles E. Tuttle Co., Rutland, Vt., 548 p.

Tomich, P.Q. 1986. Mammals in Hawai'i: A Synopsis and Notational Bibliography. 2nd ed. B.P. Bishop Museum Special Publ. 76. 375 p.

Wagner, W.L., D.R. Herbst and S.H. Sohmer 1990. Manual of the Flowering Plants of Hawai'i. B.P. Bishop Museum and University of Hawai'i Press, Honolulu.

Wilson, E.O. and R.W. Taylor. 1967. The ants of Polynesia (Hymenoptera: Formicidae). Pacific Insects Monograph 14. Entomology Dept., B.P. Bishop Museum, Honolulu.

Zimmerman, E.C. 1948. Insects of Hawaii Vol. 1 Introduction. Univ. of Hawai'i Press, Honolulu.

Zimmerman, E.C. 1958. Insects of Hawaii Vol. 7 Macrolepidoptera. Univ. of Hawai'i Press, Honolulu.

APPENDIX 1. Annotated checklist of vascular plants, Kanaio NAR

We believe an accurate annotated checklist is important in documentation of the status of the reserve's vegetation. Though quantitative monitoring with relocatable plots is essential to detect and document vegetation changes, plots are relatively small in area and comprise only a very small sample of the total reserve. For reasons of economics, monitoring of selected native and alien species must be limited to relatively few species. Supplementary notes contained within this checklist may be crucial in the future for detecting changes in distribution and abundance of both alien and native species and therefore in helping to guide management strategies.

The systematics and distributions for flowering plants largely follows Wagner *et al.* (1990). Two exceptions to the treatments of Wagner *et al.* 1990 used in this checklist are 1) in retaining species status for *Acacia koaia* (reduced to synonymy under *A. koa* by the flora) and 2) in recognizing the distinctive small-leaved *maile* that occurs in the reserve as variety *myrtillifolia* (reduced to synonymy under *Alyxia olivaeformis*). Common synonyms used in Medeiros, Loope, and Holt (1986) are included in brackets [ ]. The systematics and distributions for pteridophytes follows the Hawaiian pteridophyte work of Warren H. Wagner Jr. (University of Michigan). Usage of Hawaiian plant names follows Pukui and Elbert (1986).

Families, genera and species are listed alphabetically within the classes of pteridophytes, monocotyledons and dicotyledons. Common and Hawaiian names, references, elevational range within the reserve, and a short descriptive statement regarding abundance, ecology, history, and other remarks is given when appropriate. Specimens collected during this survey will be housed at the Herbarium Pacificum, B.P. Bishop Museum, Honolulu (BISH).

PTERIDOPHYTES (FERNS AND FERN ALLIES)

FAMILY ASPIDIACEAE

Dryopteris unidentata (Hook. & Arn.) C. Chr. — *`AKOLE*

Rare, terrestrial fern in deep lava crack on western side of reserve, 2350 ft (715 m) elevation.
[Endemic to the Hawaiian Islands]

FAMILY ASPLENIACEAE

Asplenium adiantum-nigrum L — *`IWA`IWA, MANAWAHUA*

Terrestrial fern often in rock crevices at 2000-2780 ft (610-850 m) elevation.
[Indigenous: Europe, temperate Africa and Asia, tropics including Hawaiian Islands of Kaua`i, Maui, and Hawai`i]

Asplenium praemorsum Sw. — *`IWA`IWA-A-KANE*

Terrestrial fern in dry to mesic sites, usually growing in cracks on rough lava, 2600-2780 ft (795-850 m) elevation.
[Indigenous]

FAMILY HEMIONITIDACEAE

Pityrogramma austroamericana Domin — **GOLDFERN**

1300-2780 ft (400-850 m) elevation.
[Alien: native to tropical America]

FAMILY HYPOLEPIDACEAE
Pteridium decompositum Gaud. BRACKEN FERN, *KILAU, PAI'A*
1640-2780 ft (500-850 m) elevation.
[Endemic]

FAMILY NEPHROLEPIDACEAE FISHTAIL FERN FAMILY
Nephrolepis multiflora (Roxb.) Jarrett ex Morton *'OKUPUKUPU*
Relatively common fern, especially in cracks in lava, 1640-2780 ft (500-850 m) elevation. In reserve, grazed preferentially by feral goats.
[Alien: native of Old World tropics, now widely naturalized in tropical America]

FAMILY POLYPODIACEAE POLYPODY FAMILY
Pleopeltis thunbergiana Kaulf. *PAKAHAKAHA, 'EKAHA-'AKOLEA*
Fairly common fern growing terrestrially among *'a'a* lava and less commonly as an epiphyte at 1800-2780 ft (550-850 m) elevation.
[Indigenous:]

Polypodium pellucidum Kaulf. *'A'E, 'A'AE, AE-LAU-NUI*
In reserve, uncommon, terrestrial fern above 2600 ft elevation.
[Endemic: O'ahu, Moloka'i, Maui, Hawai'i]
C73,K31,KV16,LK18,M96

FAMILY PSILOTACEAE PSILOTUM FAMILY
Psilotum nudum (L.) Beauv. *MOA*
Locally common, terrestrial plants found in a variety of dry to wet sites at 1700-2780 ft (610-850 m) elevation.
[Indigenous: pantropical and subtropical, including main Hawaiian Islands]

FAMILY SINOPTERIDACEAE
Doryopteris decipiens (Hook.) J. Sm. *'IWA'IWA, KUMUNUI*
Seasonal, perennial fern fairly common on *'a'a* lava at 1200-2780 ft (365-850 m) elevation.
[Endemic: Hawaiian Islands]

Pellaea ternifolia (Cav.) Link *KALAMOHO, KALAMOHO-LAU-LI'I*
Seasonal, perennial fern fairly common on *'a'a* lava at 1600-2780 ft (490-850 m) elevation.
[Indigenous: Texas to Chile, Hawaiian Islands (Kaua'i, O'ahu, Moloka'i, Maui, Hawai'i)]

ANGIOSPERMS
MONOCOTYLEDONS

AGAVACEAE AGAVE FAMILY
Pleomele auwahiensis St. John *HALAPEPE*

Fairly large characteristic dryland tree in leeward mesic and dryland forest at 2080-2780 ft (635-850 m) elevation. Selected as level 2 rare species.
[Endemic to Moloka`i and Maui]

CYPERACEAE SEDGE FAMILY

Carex wahuensis C. A. Mey. *`UKI*
Scattered but not uncommon in lava fields of the reserve, 2020-2780 ft (615-850 m) elevation.
[Endemic to the Hawaiian Islands]

Cyperus gracilis R. Br. McCOY'S GRASS, *MAU`U HUNEHUNE*
1640-2780 ft (500-850 m) elevation.
[Alien: native to Australia and New Caledonia]

Mariscus hillebrandii Gaud. *`UKI*
Most common sedge of lava fields, 2020-2780 ft (615-850 m) elevation. Selected as level 2 rare species.
[Endemic to Kaua`i, O`ahu, Lāna`i, Maui and Hawai`i]

POACEAE GRASS FAMILY

Bothriochloa pertusa (L.) A. Camus PITTED BEARDGRASS
Mostly confined to road edging on main highway and pipeline road at 1640-1800 ft (500-550 m) and at 2780 ft (850 m) elevation.
[Alien: native to paleotropics]

Cenchrus agrimonioides Trin. var. ***agrimoinoides*** *KĀMANOMANO, KŪMANOMANO*
Single plant (covering 1.5 square meters) in rocky scree at 2600 ft (795 m) discovered in reserve by R. Hobdy. Hitchcock (1922) reported that J.F. Rock collected this species in Auwahi in the 1920s.
[Variety *agrimonioides* endemic: O``ahu, Lāna`i, and Maui
variety *laysanensis* endemic: Kure and Midway Atolls and Laysan]

Cenchrus ciliaris L. BUFFELGRASS
1500-1680 ft (460-510 m) elevation.
[Alien: native to Africa and tropical Asia]

Cenchrus echinatus L. COMMON SANDBUR, *MAU`U KUKU*
Found along road edging on main highway, 1640-1700 ft (500-520 m) elevation.
[Alien: native to the neotropics]

Digitaria ciliaris *(Retz.) Koeler* *KUKAEPUA`A*, HENRY'S CRABGRASS
1900 ft (580 m) elevation.
[Alien: native to China, Indo-China, Samoa, and the Philippines]

Eragrostis variabilis (Gaud.) Hillebr. *`EMO-LOA*
Large, perennial bunchgrass, 1650-2780 ft (505-850 m) elevation.
[Endemic to the Hawaiian Islands]

Melinis minutiflora Beauv. MOLASSESGRASS
This mat-forming, fire-adapted, perennial grass is an aggressive species that may present a severe threat to native species. 1400-2780 ft (425-850 m) elevation. Selected as a priority 1 invasive weed species.
[Alien: native to Africa]

Panicum maximum Jacq. GUINEA GRASS
Robust, coarse, perennial grass, uncommon two small patches along main road, 1640 ft (500 m) elevation. Selected as potential invasive weed species.
[Alien: native to Africa]

Panicum pellitum Trin.
Wispy, pubescent, annual grass, rare in rocky sites, sparsely scattered throughout the reserve, 1650-2590 ft (505-790 m) elevation. Selected as level 2 rare species.
[Endemic to Ni'ihau, Lāna'i, Maui and Hawai'i]

Pennisetum clandestinum Hochst. ex Chiov. KIKUYU GRASS
Aggressive mat-forming perennial grass, extremely invasive in moist, open, dryland forest, such as at Auwahi. 1640-2780 ft (500-850 m) elevation. Selected as a priority 1 invasive weed species.
[Alien: native to tropical Africa]

Pennisetum purpureum Schumach. NAPIER GRASS, ELEPHANT GRASS
Tall grass of disturbed areas, sparingly found in reserve along main road.
[Alien: native to tropical Africa]

Rhynchelytrum repens (Willd.) C. E. Hubb. NATAL REDTOP
Dominant grass in disturbed, rocky lava, 1600-2780 ft (490-850 m) elevation.
[Alien: native to Africa]

Sporobolus africanus (Poir.) Robyns & Tournay RATTAIL GRASS, AFRICAN DROPSEED
Dominant grass in disturbed, rocky ground, 1640-2780 ft (500-850 m) elevation.
[Alien: native to Africa]

ANGIOSPERMS
DICOTYLEDONS

AMARANTHACEAE AMARANTH FAMILY

Amaranthus spinosus L. SPINY PIGWEED, *PAKAI-KUKU*
1120 ft (340 m) elevation.
[Alien: widespread]

Nototrichium sandwicense (Gray in Mann) Hbd. *KULU'I*
Uncommon silvery shrub of open lava fields, 1640-2420 ft (500-740 m) elevation. Selected as level 2 rare species.
[Endemic to the Hawaiian Islands]

ANACARDIACEAE MANGO FAMILY

Schinus terebinthifolius Raddi CHRISTMAS BERRY, *WILELAIKI*
Selected as a priority 1 invasive weed species. 1920-2780 ft (585-850 m) elevation.
[Alien: native to Brazil]

APIACEAE CARROT FAMILY

Foeniculum vulgare Mill. FENNEL
Along road edging of main highway at 1640-1700 ft (500-520 m), and on 'pipeline road' at 2780 ft (850 m) elevation.

[Alien: native to Eurasia]

Petroselinum crispum (Mill.) Hill PARSLEY
Seasonally common throughout much of the reserve, 1640-2780 ft (500-850 m) elevation.
[Alien: native to southern Europe]

APOCYNACEAE PERIWINKLE FAMILY
Alyxia olivaeformis Gaud. *MAILE LAU LI'I*
[as *Alyxia olivaeformis* var. *myrtillifolia*. *sensu* Medeiros *et al*. 1986:54-55]
The distinctive small leaf form *lau-li'i* (var. *myrtillifolia*) is uncommon on *'a'a* lava in dryland forests. 1900-2780 ft (580-850 m) elevation. Selected as level 2 rare species.
[Endemic to the Hawaiian Islands]

Rauvolfia sandwicensis A.DC. *HAO*
1100-2000 ft (335-610 m) elevation. Selected as level 2 rare species.
[Endemic to the Hawaiian Islands]

ARALIACEAE GINSENG FAMILY
Polyscias sp. PANAX
Single, sterile, stunted plant growing beneath grate of cattle guard on main highway at 1650 ft (505 m) elevation.
[Alien]

Reynoldsia sandwicensis Gray *'OHE, 'OHE MAKAI*
Common, characteristic dry forest tree of *'a'a* lava fields, 1240-2780 ft (380-850 m) elevation.
[Endemic to the Hawaiian Islands]

ASCLEPIADACEAE MILKWEED FAMILY
Asclepias curassavica L. BUTTERFLY WEED, *LAU-LELE*
1700 ft (520 m) elevation.
[Alien: native from Florida to S. America, and West Indies]

Asclepias physocarpa (E. Mey.) Schlechter BALLOON PLANT
1100-2780 ft (335 -850 m) elevation.
[Alien: native to southern Africa]

ASTERACEAE SUNFLOWER FAMILY
Ageratina adenophora (Spreng.) King and Robinson *MAUI PĀMAKANI*
Scattered throughout much of the reserve at 1800-2780 ft (550-850 m) elevation. Seasonally, this species can be surprisingly common locally.
[Alien: native to Mexico]

Ageratina riparia (Regel) King and Robinson *HAMAKUA PĀMAKANI*
Uncommon weed, 1800-2780 ft (550-850 m) elevation.
[Alien: native to Mexico and West Indies]

Ageratum conyzoides L. *MAILE HOHONO*
Uncommon, 1200 ft (365 m) elevation.
[Alien: native to Central and South America]

Bidens pilosa L. SPANISH NEEDLE, *KI-NEHE*
Annual herb occurring especially in disturbed areas. Selected as a priority 1 invasive weed species. 1500-2780 ft (460-850 m) elevation.
[Alien: native to tropical America]

Cirsium vulgare (Savi) Tenore BULL-THISTLE, *PUA KALA*
[Alien: native to Eurasia]

Conyza bonariensis (L.) Cronquist HAIRY HORSEWEED
1640-2780 ft (500-850 m) elevation.
[Alien: perhaps native to S. America, widely naturalized]

Dubautia linearis (Gaud.) Keck *NA`ENA`E*
subsp. *linearis*
1700-2780ft (520-850 m) elevation.
[Endemic to Moloka`i, Lāna`i, Maui, and Hawai`i]

Emilia fosbergii Nicolson
1680-2780 ft (510-850 m) elevation.
[Alien: native range unknown]

Galinsoga parviflora Cav. GALINSOGA
[Alien: native to tropical America]

Gnaphalium japonicum Thunb.
[Alien: native to Australia]

Gnaphalium purpureum L. PURPLE CUDWEED
[Alien: native to N. America]

Gnaphalium sandwicensium Gaud. *`ENA`ENA*
var. *sandwicensium*
Silvery, low herb of windward coastal dunes, leeward lava shrublands, and high elevation sites, 1700-2240 ft (520-685 m) elevation.
[Endemic to the Hawaiian Islands]

Heterotheca grandiflora Nutt. TELEGRAPH PLANT
Uncommon, on disturbed road edgings of both main highway and 'pipeline road', 1640-2780 ft (500-850 m) elevation.
[Alien: native to California, Arizona and Baja California, Mexico]

Hypochoeris glabra L. SMOOTH CAT'S EAR
1640-2780 ft (500-850 m) elevation.
[Alien: native to Europe]

Hypochoeris radicata L. HAIRY CAT'S EAR, GOSMORE
1350-2780 ft (410-850 m) elevation.
[Alien: native to Eurasia]

Lactuca serriola L. PRICKLY LETTUCE
1680-2780 ft (510-850 m) elevation.
[Alien: native to Europe]

Lipochaeta lavarum (Gaud.) A.DC. *NEHE*
[Endemic to Moloka'i, Lāna'i, Maui, Kaho'olawe and northwestern Hawai'i]

Pluchea symphytifolia (Miller) Gillis **SOUR BUSH**
Rare on road edging of main highway, 1640 ft (500 m) elevation.
[Alien: native to Mexico]

Siegesbeckia orientalis L. **SIEGESBECKIA**
1930-2780 ft (590-850 m) elevation.
[Alien: native to the Old World tropics and warm temperate regions]

Sonchus asper
[Alien: native to Europe]

Sonchus oleraceus L. **SOW THISTLE, *PUA-LELE***
Common annual herb at 1600-2780 ft (490-850 m) elevation.
[Alien: native to Europe]

Synedrella nodiflora (L.) Gaertn. **SYNEDRELLA**
1120-1400 ft (340-425 m) elevation.
[Alien: native to tropical America]

Tridax procumbens L. **COAT BUTTONS**
1200-2040 ft (365-620 m) elevation.
[Alien: native to Mexico, Central and S. America]

Verbesina encelioides (Cav.) B. & H. **GOLDEN CROWN-BEARD**
[Alien: native to Mexico and southwest United States]

Vernonia cinerea (L.) Less. **IRONWEED**
[Alien: native to tropical Asia]

Xanthium strumarium L. **COCKLEBUR, *KIKANIA***
Uncommon roadside weed, 1640-1800 ft (500-550 m) elevation.
[Alien: probably native to the Americas]

Zinnia peruviana (L.)L. **ZINNIA**
Common bright-flowered annual of overgrazed rocky areas, 1100-1800 ft (335-550 m) elevation.
[Alien: native from southeastern Arizona and Mexico south to Peru and Argentina, the West Indies]

BRASSICACEAE **MUSTARD FAMILY**
Capsella rubella Reuter **SHEPHERD'S PURSE**
[Alien: native to Eurasia]

Lepidium virginicum L. **WILD PEPPERGRASS**
Annual herb growing mostly in disturbed sites.
[Alien: native to eastern United States]

Sisymbrium officinale (L.) Scop. **HEDGE MUSTARD**
1400-1800 ft (425-550 m) elevation.
[Alien: native to Europe]

CACTACEAE CACTUS FAMILY

Opuntia ficus-indica (L.) Mill. PRICKLY PEAR, *PĀNINI*
Scattered but common at 1350-2780 ft (410-850 m) elevation.
[Alien: presumably native to Mexico]

CAPPARIDACEAE CAPPARIS FAMILY

Capparis sandwichiana DC. *MAI'APILO, PUAPILO*
Rare in reserve, 1800-2100 ft (550-640 m) elevation.
[Endemic to the Hawaiian Islands]

CARYOPHYLLACEAE PINK FAMILY

Arenaria serpyllifolia L. THYME-LEAVED SANDWORT
Wispy, annual herb of disturbed upper elevation rocklands.
[Alien: native to Eurasia]

Polycarpon tetraphyllum (L.) L. ALLSEED
Common herb in a variety of dry rocky sites, 1680-2780 ft (510-850 m) elevation.
[Alien: native to Europe]

Silene gallica L. SMALL-FLOWERED CATCHFLY
Common annual herb of open rocky areas in the reserve, 1680-2780 ft (510-850 m) elevation.
[Alien: native to Europe]

CHENOPODIACEAE GOOSEFOOT FAMILY

Chenopodium ambrosioides L. MEXICAN TEA
Erect herb, often with reddish foliage, usually in man-caused disturbed areas, 1200-2780 ft (365-850 m) elevation.
[Alien: native to Mexico, Central and S. America, and West Indies]

Chenopodium oahuense (Meyen) Aellen *'AHEAHEA, 'AWEOWEO*
1640-2500 ft (500-760 m) elevation.
[Endemic to the Hawaiian Islands]

CONVOLVULACEAE MORNING-GLORY FAMILY

Bonamia menziesii Gray
Four plants of this species are known in the reserve, 1800-2300 ft (550-700 m) elevation. Selected as level 1 rare species.
[Endemic to the Hawaiian Islands]

Ipomoea indica (J. Burm.) Merr. MORNING GLORY, *KOALI-AWA*
Common native lowland morning glory vine with heart-shaped leaves and purple flowers, 1100-2780 ft (335-850 m) elevation.
[Indigenous: pantropical]

Ipomoea tuboides Deg. & van Ooststr.
Fairly common, endemic, white-flowered morning glory vine, 1100-2740 ft (335-835 m) elevation.
[Endemic to the Hawaiian Islands]

Jacquemontia ovalifolia (Choisy) Hallier *PA'U-O-HI'IAKA*
[Indigenous in Mexico, West Indies, Africa and Hawaiian Islands]

CRASSULACEAE ORPINE FAMILY
Kalanchoe pinnata (Lam.) Pers. **AIR PLANT**
Scattered patches naturalizing throughout reserve, 1700-2780 ft (520-850 m) elevation.

CUCURBITACEAE GOURD OR SQUASH FAMILY
Momordica charantia L. **BALSAM PEAR**
1100-1680 ft (335-510 m) elevation.
[Alien: native from tropical Africa to Australia]

Sicyos pachycarpus Mann *KUPALA*
[= *Sicyos microcarpus* Mann *sensu* Medeiros *et al.* 1986:78]
Annual vine of dryland forest.
[Endemic to the Hawaiian Islands]

EBENACEAE EBONY FAMILY
Diospyros sandwicensis (A.DC.) Fosb. *LAMA*
1400-2780 ft (425 -850 m) elevation.
[Endemic to the Hawaiian Islands]

EPACRIDACEAE EPACRIS FAMILY
Styphelia tameiameiae (Cham. & Schlect.) F. v. Muell. *PUKIAWE*
Uncommon, 2100-2780 ft (640-850 m) elevation.
[Indigenous: Marquesas and main Hawaiian Islands]

EUPHORBIACEAE SPURGE FAMILY
Aleurites moluccana (L.) Willd. **CANDLENUT, *KUKUI***
In reserve, restricted to few scattered trees apparently planted near old homesites.
[Polynesian introduction: native to Malesia, widely introduced throughout tropics by early man]

Chamaesyce celastroides (Boiss.) Croizat and Deg. *'AKOKO, KŌKŌ*
var. ***lorifolia*** (Gray) Deg. and Deg.
[= *Euphorbia celastroides* Boiss. var. *mauiensis* Sherff *sensu* Medeiros *et al.* 1986:]
Characteristic shrub to small tree of leeward East Maui dryland forest vegetation, scattered on open lava and in lava channels at 1700-2780 ft (520-850 m) elevation. Selected as level 2 rare species.
[Endemic to the Hawaiian Islands, the variety is endemic to Lāna'i and Maui]

Chamaesyce hirta (L.) Millsp. **GARDEN SPURGE, *KOKO-KAHIKI***
Low herb of disturbed sites, 1100-2040 ft (335-620 m) elevation.
[Alien: native from southern U.S. to S. America, West Indies and Old World tropics]

Euphorbia peplus L. **PETTY SPURGE**
1350-2780 ft (410-850 m) elevation.
[Alien: native to temperate Eurasia]

Ricinus communis L. CASTOR BEAN, *KOLI*
Uncommon, sporadic, 2040 ft (620 m) elevation.
[Alien, possible Polynesian introduction or indigenous]

FABACEAE PEA FAMILY

Acacia farnesiana (L.)Willd. *KLU*
Apparently restricted to road edgings of main highway, 1640 ft (500 m) elevation.
[Alien: native to neotropics]

Acacia koaia Hbd. *KOAI'E, KOAIA*
Rare, small tree of *`a`a* lava, 2500 ft (760 m) elevation. Selected as level 1 rare species.
[Endemic to the Hawaiian Islands]

Chamaecrista nictitans (L.) Moench **PARTRIDGE PEA, *LAUKI***
1640-2780 ft (500-850 m) elevation.
[Alien: native to tropical America]

Crotolaria incana L. **FUZZY RATTLE-POD**
Scattered along road edging of main highway, 1640-1800 ft (500-550 m) elevation.
[Alien: widespread through tropics and subtropics]

Desmodium incanum DC **SPANISH CLOVER, *KA`IMI***
[Alien: native to tropical and subtropical America]

Desmodium sandwicense E. Mey. **SPANISH CLOVER**
[Alien: native to South America]

Desmodium triflorum (L.) DC. **THREE-FLOWERED BEGGARWEED**
Restricted to road edgings on main highway, 1640-1800 ft (500-550 m) elevation.
[Alien: native to Old World tropics and subtropics]

Erythrina sandwicensis Degener *WILIWILI*
1300-1800 ft (400-550 m) elevation.
[Endemic to the Hawaiian Islands]

Glycine wightii (Wight & Arnott) Verdc.
Climbing vine with leaves with three leaflets, superficially resembling native *Canavalia* species. Selected as first priority invasive weed species.
[Alien: native to Central and South America and the West Indies]

Indigofera suffruticosa Mill. **INDIGO**
1100-2780 ft (335-850 m) elevation.
[Alien: pantropical]

Leucaena leucocephala (Lam.) de Wit *KOA-HAOLE*
1100-1960 ft (335-600 m) elevation.
[Alien: native to tropical America]

Macroptilium lathyroides (L.) Urb. **WILD BEAN, COW PEA**
Scattered along and apparently confined to road edging of main highway, 1640-1800 ft (500-550 m) elevation.
[Alien: native to the neotropics]

Mimosa pudica L. *PUA-HILAHILA*, SENSITIVE PLANT
Apparently confined to road edgings of main highway, 1640-1800- ft (500-550 m) elevation.
[Alien: pantropical]

Sophora chrysophylla (Salisb.) Seem. ***MĀMANE***
Uncommon small tree of dryland forests in the lava fields, 1750 ft (535 m) elevation.
[Endemic to the Hawaiian Islands]

Tephrosia purpurea (L.) Pers. ***'AUHUHU***
[Polynesian introduction: native from Africa to southern Asia and Malesia, tropical Australia, and the Tuamotus]

Trifolium cf. repens L. **WHITE CLOVER**
Rare, on pipeline road, 2780 ft (850 m) elevation, sterile.
[Alien: native to Europe, central and northern Asia, and northern Africa]

FLACOURTIACEAE FLACOURTIA FAMILY
Xylosma hawaiiense Seem. ***MAUA***
Uncommon small tree of open lava fields, 2500-2780 ft (760-850 m) elevation. Selected as level 2 rare species.
[Endemic to the Hawaiian Islands]

GENTIANACEAE GENTIAN FAMILY
Centaurium erythraea Rafn. **BITTER HERB, EUROPEAN CENTAURY**
Common herb of disturbed and rocky sites, 1500-2780 ft (460-850 m) elevation.
[Alien: native to Eurasia, widely naturalized]

LAMIACEAE **MINT FAMILY**
Plectranthus parviflorus Willd. **SPURFLOWER, *'ALA'ALA WAI NUI***
Herb of rocky sites, 2300-2780 ft (700-850 m) elevation.
[Indigenous: Malesia and Polynesia, including the Hawaiian Islands]

Salvia coccinea Etl.
2400-2780 ft (730-850 m) elevation.
[Alien: native from southeastern United States and Texas south to South America]

Salvia occidentalis Sw.
1100-2000 ft (335-610 m) elevation. Currently scattered and uncommon in the reserve, but reported to be spreading (R. Hobdy, pers. comm.).
[Alien: widespread in new world tropics]

LAURACEAE LAUREL FAMILY
Cinnamomum camphora (L.) J. Presl **CAMPHOR**
Sparingly naturalized throughout the reserve. Selected as a priority 1 invasive weed species.
[Alien: native to Asia]

MALVACEAE MALLOW FAMILY

Abutilon grandifolium (Willd.) Sweet — HAIRY ABUTILON
1540-2740 ft (470-835 m) elevation.
[Alien: native to tropical America]

Malva parviflora L. — **CHEESE WEED**
Restricted to road edgings of main highway at ca 1680 ft (510 m) elevation, and along 'pipeline road' at 1780 ft (545 m) elevation.
[Alien: native to Mediterranean region, Asia and India]

Malvastrum coromandelianum (L.) Garcke — **FALSE-MALLOW**
Along road edging of main highway, 1660-1800 ft (505-550 m) elevation.
[Alien: pantropical]

Sida fallax Walp. — *`ILIMA*
Though common in many leeward ecosystems, *Sida* is rare in the reserve, restricted to a few isolated patches, 1640-1930 ft (500-590 m) elevation.
[Indigenous: China to Pacific Islands, including Hawaiian Islands]

Sida rhombifolia L.
1640-2780 ft (500-850 m) elevation.
[Pantropical, questionably alien but considered by Hillebrand (1888) as possibly indigenous.

MENISPERMACEAE MOONSEED FAMILY

Cocculus trilobus (Thunb.) DC. — *HUEHUE*
[as *Cocculus lonchophyllus* Hillebr. *sensu* Medeiros *et al.* 1986:108]
1100-2780 ft (335-850 m) elevation.
[Indigenous: SE Asia to Malesia and Pacific region]

MYOPORACEAE MYOPORUM FAMILY

Myoporum sandwicense Gray — *NAIO*
Characteristic leeward tree, 1240-2780 ft (380-850 m) elevation.
[Indigenous: Cook and Hawaiian Islands]

MYRSINACEAE MYRSINE FAMILY

Myrsine lanaiensis Hillebr. — *KŌLEA*
Characteristic dryland forest tree, 1980-2780 ft (605-850 m) elevation.
[Endemic to the Hawaiian Islands]

MYRTACEAE MYRTLE FAMILY

Metrosideros polymorpha Gaud. — *`OHI`A, `OHI`A-LEHUA*
This common rain forest tree occurs within the reserve only in a few isolated small groves of trees, -2780 ft (-850 m) elevation.
[Endemic to the Hawaiian Islands]

Psidium guajava L. — **GUAVA**
Rare, 2780 ft (850 m) elevation, near pipeline road.
[Alien: native to the neotropics]

NYCTAGINACEAE FOUR O' CLOCK FAMILY

Boerhavia sp.. *ALENA*

1100-1800 ft (335-550 m) elevation. Several species formerly included in *B. diffusa* are now delineated in Wagner *et al.* (1991). Vouchers were not made therefore a conclusive identification is lacking.
[Indigenous]

Mirabilis jalapa L. **COMMON FOUR O'CLOCK**

Occasional weed, 1100-2500 ft (335-760 m) elevation.
[Alien: native to tropical America]

OLEACEAE OLIVE FAMILY

Nestegis sandwicensis (Gray) Deg., Deg. & Johnson *OLOPUA*

[as *Osmanthus sandwicensis* (Gray) Knobl. *sensu* Medeiros *et al.* 1986:114-115]
Scattered trees on open lava at 2140-2740 ft (650-835 m) elevation.
[Endemic to the Hawaiian Islands]

OXALIDACEAE WOOD SORREL FAMILY

Oxalis corniculata L. **YELLOW WOOD SORREL, *`IHI-`AI***

1500-2780 ft (460-850 m) elevation.
[Long considered alien, now regarded as a Polynesian introduction or indigenous: cosmopolitan]

PAPAVERACEAE POPPY FAMILY

Argemone glauca (Nutt. ex Prain) Pope **PRICKLY POPPY, *PUA-KALA***

The white-flowered native poppy is seasonally not uncommon at 1400-2500 ft (425-760 m) elevation.
[Endemic to the Hawaiian Islands]

Bocconia frutescens L.

Fairly common small tree, especially in upper part of the reserve, 1600-2780 ft (490-850 m) elevation.
Selected as a priority 1 invasive weed species.
[Alien: native to Central and South America and the West Indies]

Hunnemannia fumariifolia Sweet

1640-1800 ft (500-550 m) elevation., roadside and immediate area
[Alien: native to Mexico]

PASSIFLORACEAE PASSION FLOWER FAMILY

Passiflora subpeltata Ortega **WHITE PASSIONFLOWER**

Seasonal vine of arid lava flows, scattered and common at 1100-2780 ft (335-850 m) elevation.
[Alien: native to Mexico, Central America and northern S. America]

PIPERACEAE PIPER FAMILY

Peperomia leptostachya Hook. & Arn. *`ALA`ALA-WAI-NUI*

Seasonally, one of the most common native species in the reserve, 1600-2780 ft (490-850 m) elevation.
[Indigenous: Australia, Micronesia, Melanesia and Polynesia; Moloka`i, Maui and Hawai`i]

Peperomia tetraphylla (Forst. f.) Hook. & Arn. *`ALA`ALA-WAI-NUI*

Uncommon, 2650 ft (810 m) elevation.

[Indigenous: pantropical and main Hawaiian Islands]

PLANTAGINACEAE PLANTAIN FAMILY

Plantago lanceolata L. NARROW-LEAVED PLANTAIN
In disturbed areas, 1640-2780 ft (500-850 m) elevation.
[Alien: native from Europe and north-central Asia]

Plantago major L. BROAD-LEAVED PLANTAIN, *LAUKAHI-NUNUI*
[Alien: native to Europe and northern and central Asia]

PLUMBAGINACEAE PLUMBAGO FAMILY

Plumbago zeylanica L. *`ILIE`E*
1500-2780 ft (460-850 m) elevation.
[Indigenous to Old World tropics and the Hawaiian Islands]

POLYGONACEAE BUCKWHEAT FAMILY

Rumex acetosella L. SHEEP SORREL
[Alien: native to Eurasia]

PORTULACACEAE PORTULACA FAMILY

Portulaca oleracea L. COMMON PURSLANE, *`AKULIKULI-KULA*
Scattered throughout the reserve, especially on barren, rocky ridgetops, 1350-2780 ft (410-850 m) elevation.
[Alien: presumably native to Old World, now nearly cosmopolitan]

Portulaca pilosa L.
1200-2780 ft (365-850 m) elevation.
[Alien: pantropical]

PRIMULACEAE PRIMROSE FAMILY

Anagallis arvensis L. SCARLET PIMPERNEL
Annual herb of disturbed sites, 1600-2780 ft (490-850 m) elevation.
[Alien: native to Europe]

PROTEACEAE PROTEA FAMILY

Grevillea robusta A. Cunn *ex* R. Br. SILK OAK
Uncommon and localized; seedlings and larger trees naturalizing at western edge of reserve along main highway, 1700-1800 ft (520-550 m) elevation.
[Alien: native to Queensland and New South Wales, Australia]

RHAMNACEAE BUCKTHORN FAMILY

Alphitonia ponderosa Hbd. *KAUILA, O`A* (Maui name)
Small trees on *`a`a* lava, 2200-2780 ft (670-850 m) elevation. Selected as level 1 rare species.
[Endemic to the Hawaiian Islands]

ROSACEAE ROSE FAMILY

Osteomeles anthyllidifolia (Sm.) Lindl. *`ULEI, ELUEHE*

Common, 1800-2780 ft (550-850 m) elevation. This species can be expected to increase if goats are excluded from the reserve.

[Indigenous: Cook Islands, Tonga and Hawaiian Islands]

RUBIACEAE COFFEE FAMILY

Canthium odoratum (G. Forster) Seem. *ALAHE`E, WALAHE`E*

Low shrub of open lava, 1970-2590 ft (600-790 m) elevation.

[Indigenous: Hawai`i, Micronesia and the southern Pacific (New Hebrides and New Caledonia east to the Tuamotus)]

Psychotria mauiensis Fosb. *KŌPIKO*

Single tree noted in reserve, ft (m) elevation.

[Endemic to Kaua`i, Moloka`i, Lāna`i, Maui and Hawai`i]

RUTACEAE RUE FAMILY

Melicope knudsenii (Hbd.) Hartley and Stone *ALANI*

Selected as level 1 rare species.

[Endemic to the East Maui and Kaua`i]

Melicope mucronulata (St. John) Hartley and Stone *ALANI*

Selected as level 1 rare species.

[Endemic to East Maui and Moloka`i]

SANTALACEAE SANDALWOOD FAMILY

Santalum ellipticum Gaud. COASTAL SANDALWOOD, *`ILI-AHI*

This dryland and coastal sandalwood is fairly common in rocky sites in the reserve, 1800-2780 ft (550-850 m) elevation. Reproduction by vegetative suckering from horizontal roots occurs but is suppressed by goat browsing. Selected as level 2 rare species.

[Endemic to the Hawaiian Islands]

SAPINDACEAE SOAPBERRY FAMILY

Dodonaea viscosa Jacq. *`A`ALI`I*

[= *Dodonaea eriocarpa* Sm. *sensu* Medeiros *et al.* 1986:142]

Small tree occurring in a wide variety of leeward habitats. With protection from goat browsing, *Dodonaea* is expected to become a dominant species in the recovering vegetation. 1100-2780 ft (335-850 m) elevation.

[Indigenous: pantropical as well as main Hawaiian Islands and Nihoa]

SAPOTACEAE SAPOTE FAMILY

Nesoluma polynesicum (Hbd.) Baill. *KEAHI*

Fairly common, round-canopied tree of open *`a`a* lava fields, 1150-2310 ft (350-705 m) elevation.

[Indigenous: native to the Austral Islands (Raivavae), Rapa, and Hawaiian Islands]

Pouteria sandwicensis (Gray) Baehni and Deg. *AULU, `ĀLA`A*

[*Planchonella spathulata sensu* Medeiros *et al.* 1986]

Common, characteristic tree of open lava in Kanaio NAR, 1800-2780 ft (550-850 m) elevation.

[Endemic to the Hawaiian Islands]]

SCROPHULARIACEAE
Veronica arvensis L. **CORN SPEEDWELL**
Small annual herb of open rocky areas.
[Alien: native to Eurasia]

SOLANACEAE NIGHTSHADE FAMILY
Datura stramonium L. **JIMSON-WEED, *KIKANIA***
Herb of disturbed sites.
[Alien: native to North America]

Nicotiana glauca Grah. **TREE TOBACCO, *MAKAHALA***
Common weed of rocky areas in leeward dryland forests on lava at 1100-2500 ft (335-760 m) elevation. This introduced weed is an alternate host for the rare Hawaiian hawkmoth *Manduca blackburni* (Sphingidae) in the reserve.
[Alien: native to Argentina]

Nothocestrum latifolium Gray *`AIEA*
Common small tree of *`a`a* lava, 1180-2780 ft (360-850 m) elevation. The *`aiea* is the native host plant for rare endemic hawkmoth *Manduca blackburni*.
[Endemic to Kaua`i, O`ahu, Moloka`i, Lā
na`i and Maui]

Physalis peruviana L. ***POHA*, CAPE GOOSEBERRY**
Uncommon herb of disturbed areas.
[Alien: native to Peru]

Solanum americanum Mill. ***POPOLO*, BLACK NIGHTSHADE**
[Alien: native to tropical and warm temperate regions]

Solanum linnaeanum Hepper and Jaeger **APPLE OF SODOM, *POPOLO-KIKANIA***
1300-1980 ft (400-605 m) elevation.
[Alien: native to Africa]

STERCULIACEAE CACAO FAMILY
Waltheria indica L. *`UHALOA, `ALA`ALAPULOA*
1120-2780 ft (340-850 m) elevation.
[Questionably indigenous. Pantropical]

THYMELAEACEAE MEZEREUM FAMILY
Wikstroemia monticola Skottsb. *`AKIA*
Common, small-leaved shrub of xeric to mesic leeward sites, 1700-2780 ft (520-850 m) elevation.
[Endemic to East Maui]

TILIACEAE LINDEN FAMILY
Triumfetta semitriloba Jacq. **BURBUSH**
1700-2780 ft (520-850 m) elevation.

[Alien: native to Baja California, Mexico to S. America, and the West Indies]

VERBENACEAE VERBENA FAMILY

Lantana camara L. **LANTANA**
1100-2780 ft (335-850 m) elevation.
[Alien: probably native to West Indies, widely naturalized in world tropics and subtropics]

Stachytarpheta urticifolia (Salisb.) Sims **NETTLE-LEAVED VERVAIN, *OI, OWI***
Along road edging, 1640-1920 ft (500-585 m) elevation.
[Alien: probably native to tropical Asia]

Verbena litoralis HBK. ***HA'UOWI, OI, OWI***
1700-2780 ft (520-850 m) elevation.
[Alien: native to Mexico, Central and S. America]

VISCACEAE MISTLETOE FAMILY

Korthalsella cylindrica (v. Tiegh.) Engler ***HULUMOA, KAUMAHANA***
[*Korthalsella remyana sensu* Medeiros *et al.*, 1986]
Parasitic mistletoe epiphyte, in the reserve found on *lama* (*Diospyros*), 1680-2010 ft (510-615 m) elevation.
[Endemic to O'ahu, Moloka'i, Lāna'i, Maui and Hawai'i]

APPENDIX 2 Checklist of birds (both fossil and extant) and mammals, Kanaio NAR.

Taxonomy and distributional information follows Pratt *et al.* (1987) and Olson and James (1991)

CLASS AVES - birds

Family Plataleidae (Ibises)

Apteribis brevis — **Hawaiian flightless ibis**
Extinct species known only from East Maui
Olson and James (1991:23-26)

Apteribis **sp. (Maui)** — **Hawaiian flightless ibis**
Olson and James (1991:26-28)
Extinct species

Family Anatidae (Swans, Geese, and Ducks)

Branta hylobadistes
Olson and James (1991:45–47)
Extinct species

Branta sandvicensis — **nēnē**
Olson and James (1991:42–45)

Ptaiochen pau
Olson and James (1991:39–42)
Extinct species

Thambetochen chauliodous
Olson and James (1991:37-38)
Extinct species

Family Accipitridae (Kites, Eagles, and Hawks)

Haliaeetus **sp.** — **Hawaiian eagle**
Olson and James (1991:62-64)
Extinct species

FAMILY PHASIANIDAE (Gallinaceous birds)

Alectoris chukar — **chukar**
[Alien: uncommon in the reserve.]

Francolinus francolinus — **black francolin**
[Alien]

Francolinus pondicerianus — **gray francolin**
[Alien]

Phasianus colchicus — **ring-necked pheasant**
[Alien]

Family Rallidae (Rails, Gallinules, and Coots)
Porzana keplerorum — *moho*
Olson and James (1991:55-56)
Extinct species

Porzana severnsi — *moho*
Olson and James (1991:60-62)
Extinct species

Porzana sp. "medium Maui rail" — *moho*
Olson and James (1991:57-59)
Extinct species

Family Columbidae (Pigeons and Doves)
Columba livia — rock dove
[Alien]

Family Tytonidae (Barn Owls)
Tyto alba — common barn owl
[Alien]

Family Strigidae (Typical Owls)
Asio flammeus — *pueo*, short-eared owl

Grallistrix erdmani
Olson and James (1991:80-81)
Extinct species

Family Alaudidae (Larks)
Alauda arvensis — Eurasian skylark
[Alien]

Family Emberizidae (Emberizine finches and their relatives)
Cardinalis cardinalis — northern cardinal
[Alien]

Family Estrildidae (Waxbills, Mannikins, and Parrotfinches)
Lonchura punctulata — nutmeg mannikin, spotted munia
[Alien]

Family Fringillidae (Grosbeaks, Finches, Sparrows, and Buntings)
Carpodacus mexicanus — house finch
[Alien]

Family Suidae (Old World SWINE)

Sus scrofa scrofa	pig, *pua`a*

Family Cervidae (Antlered ruminants)

Axis axis	**axis deer**
[Alien]	

Family Bovidae (Hollow-horned Ruminants)

Bos taurus	**domestic cattle**
[Alien]	
Capra hircus hircus	**feral goat**
[Alien]	

Family Mimidae (Mockingbirds and Thrashers)
Mimus polyglottus — mockingbird
[Alien]

Family Passeridae [Old World sparrows]
Passer domesticus — **house sparrow**
[Alien]

Family Sturnidae (Starlings and Mynas)
Acridotheres tristis — **common myna**
[Alien]

Family Zosteropidae (WHITE-EYES)
Zosterops japonicus — **Japanese white-eye**
[Alien]

CLASS MAMMALIA - mammals

Family Vespertilionidae (Common BATS)
? *Lasiurus cinereus* ssp. *semotus* — **hoary bat, *`ope`ape`a***

Family Muridae (Old World RATS and MICE)
Rattus rattus rattus — **black rat, roof rat**
[Alien]

Rattus exulans hawaiiensis — **Polynesian rat, *`iole***
[Polynesian introduction]

Mus domesticus — **European house mouse**
[Alien]

Family Canidae (WOLVES, JACKALS and allies)
Canis familiaris familiaris — **domestic dog, *`ilio***
[Alien]

Family Viverridae (CIVETS and allies)
Herpestes auropunctatus auropunctatus — **mongoose**
[Alien]

Family Felidae (CATS)
Felis catus — **house cat**
[Alien]

Appendix 3: Part L Data Summary

Species	Frequency	Cover
Indigofera suffruticosa	28.0%	0.3%
Ipomoea congesta	1.0%	0.0%
Ipomoea tuboides	12.6%	0.1%
Lactuca serriola	1.1%	0.0%
Lantana camara	94.6%	9.7%
Lepidium virginicum	7.5%	0.0%
Leucaena leucocephala	11.2%	0.3%
Lipochaeta lavarum	2.1%	0.1%
Macropilium lathyroides	1.0%	0.0%
Malva parviflora	4.2%	0.0%
Mariscus hillebrandii	60.1%	0.3%
Melinis minutiflora	49.5%	2.2%
Momordica charantia	9.4%	0.6%
Myrsine lanaiensis	1.1%	0.0%
Nephrolepis multiflora	8.2%	0.0%
Nestegis sandwicensis	1.0%	0.2%
Nicotiana glauca	14.3%	0.1%
Opuntia ficus-indica	69.8%	0.4%
Osteomeles anthyllidifolia	34.9%	1.6%
Oxalis corniculata	23.9%	0.1%
Panicum pellitum	25.1%	0.2%
Passiflora subpeltata	37.4%	0.4%
Pellaea ternifolia	64.9%	0.3%
Pennisetum clandestinum	6.4%	0.7%
Peperomia leptostachya	17.0%	0.2%
Petroselinum crispum	8.1%	0.0%
Pityrogramma calomelanos	2.1%	0.0%
Plantago lanceolata	13.8%	0.1%
Plectranthus parviflorus	33.1%	0.2%
Pleomele auwahiensis	4.1%	0.4%
Pleopeltis thunbergiana	6.2%	0.0%
Plumbago zeylanica	2.1%	0.0%
Polycarpon tetraphylum	3.3%	0.0%
Polypodium pellucidum	2.1%	0.0%
Portulaca oleracea	21.6%	0.1%
Portulaca pilosa	61.2%	0.4%
Psilotum nudum	6.3%	0.0%
Pteridium aquilinum	1.1%	0.0%
Rhynchelytrum repens	96.9%	14.9%
Salvia coccinea	14.6%	0.1%
Santalum ellipticum	1.1%	0.0%
Schinus terebinthifolius	3.2%	0.0%
Sicyos spp.	3.2%	0.0%
Sigesbeckia orientalis	24.5%	0.1%
Silene gallica	25.5%	0.1%
Sonchus oleraceus	67.3%	0.3%
Sporobolus africanus	39.9%	0.6%
Stachytarpheta spp.	11.8%	0.1%
Styphelia tamelameiae	8.3%	0.3%
Tephrosia purpurea	1.1%	0.0%
Tridax procumbens	12.8%	0.1%
Trifolium sp.	3.2%	0.0%
Triumfetta semitriloba	17.6%	0.1%
Verbena litoralis	1.1%	0.0%
Waltheria indica	69.0%	0.4%
Wikstroemia monticola	63.6%	2.3%
Xylosma hawaiiense	1.1%	0.0%
Zinnia peruviana	3.1%	0.0%

APPENDIX 3. Monitoring results

Part I. Data summaries

Part II. Raw Data

Appendix 3: Part 1, Data Summary: Average cover and frequency of native (**bold print**) and alien plant species for all transects.

Species	Frequency	Cover
Bare ground	-	45.3%
Abutilon grandifolium	4.2%	0.0%
Ageratina adenophora	**20.1%**	**0.5%**
Ageratina riparia	4.2%	0.0%
Ageratum conyzoides	1.1%	0.0%
Alphitonia ponderosa	**1.0%**	**0.2%**
Alyxia olivaeformis	**2.1%**	**0.0%**
Anagallis arvensis	22.5%	0.2%
Arenaria serpyllifolia	5.5%	0.0%
Argemone glauca	**4.2%**	**0.0%**
Asclepias spp.	16.5%	0.1%
Asplenium adiantum-nigrum	5.4%	0.0%
Asplenium rhipidoneuron	1.1%	0.0%
Axonopus fissifolius	20.5%	0.1%
Bidens pilosa	77.6%	1.0%
Bocconia frutescens	26.1%	0.7%
Bothriochloa pertusa	1.0%	0.0%
Canthium odoratum	**1.1%**	**0.0%**
Capparis sandwichiana	1.0%	0.0%
Carex wahuensis	**14.6%**	**0.1%**
Centaurium erythraea	1.1%	0.0%
Cerastium vulgatum	1.0%	0.0%
Chamaesyce celastroides	**1.1%**	**0.0%**
Chamaecrista nictitans	49.1%	0.3%
Chenopodium ambrosioides	3.1%	0.0%
Chenopodium oahuense	**2.1%**	**0.0%**
Cinnamomum camphora	0.0%	0.0%
Cocculus trilobus	**67.8%**	**0.3%**
Conyza bonariensis	29.4%	0.1%
Conyza canadensis	1.1%	0.0%
Cucumis dipsaceus	1.0%	0.0%
Cyperus gracilis	15.9%	0.1%
Datura stramonium	2.0%	0.0%
Desmodium uncinatum	7.3%	0.0%
Digitaria sp.	9.4%	0.2%
Dodonaea viscosa	**65.0%**	**9.3%**
Doryopteris decipiens	60.5%	0.3%
Dubautia linearis	**1.1%**	**0.0%**
Emilia sp.	52.8%	0.3%
Eragrostis variabilis	**2.1%**	**0.0%**
Euphorbia hirta	6.4%	0.0%
Euphorbia peplus	5.2%	0.0%
Festuca megalura	9.6%	0.0%
Foeniculum vulgare	5.2%	0.0%
Glycine wightii	0.0%	0.0%
Gnaphalium japonicum	1.1%	0.0%
Gnaphalium sandwicensium	**6.4%**	**0.0%**
Hypochoeris glabra	20.0%	0.1%
Hypochoeris radicata	18.0%	0.1%

Appendix 3: Part II, Raw monitoring data
Key to data sheets

Date in 1992	Number refers to the month and day of transect completion.
Transect #	Refers to one of five vegetation transects set in the NAR.
Station #	Refers to the individual stations along the transect line at 100m intervals.
	Species cover in a 5.64m2 radius was estimated at these stations.
Elevation	Figures refer to the elevation in feet of the corresponding numbered station.
Blue marker	A "+" or "-" symbol designates whether or not the station site was marked with blue spray paint.
Bearing to next station	Number refers to the estimated standard compass bearing in degrees from one station
	along a transect to the next consecutively numbered station.
Old goat pellets	Both headings for goat pellets refer to the rough estimate of number of fresh and older
New goat pellets	goat droppings within the 5.64m2 radius of the station. The numbers correspond to
	quantitative categories as follows.

Key To Number of Goat Pellets:

0=0	1=1-25
2=25-50	3=50-100
4=100-500	5=500+

Bare ground	Refers to the estimate of the percentage of bare ground in the 5.64m2 radius of the
	transect station. The numbers use the same key as the Species cover estimate below.
Species cover in 5.64m2 radius	
Scientific name of plant	The letters and numbers listed under the Species cover heading are categories which estimate the
Names in BOLD FACE are	pecentage cover of the corresponding plant species within the 5.64m2 radius of the station, i.e. the
indigenous or endemic	100 square meter circular area of the station. Values fo the categories are as follows:
Hawaiian plant species.	

Key To Plant Species and Bare Ground Cover Within a 5.64m2 radius:

R= <1%	X=1-5%
1=5-25%	2=25-50%
3=50-75%	4=75-100%

	Therefore, a plant with a species cover designation "X" would be estimated to occupy between
	1 and 5 percent of the ground area of the 100 square meter circular station. In other words, the
	plant would be estimated to cover or occupy 1 to 5 square meters of the station.
Presence in 9.77m2 radius	
	This category refers to the presence or absence of the specific plant within a 9.77m2 radius of the
	station, or a 300 square meter circular area. A "+" indicates presence, a "0" indicates absence.
Presence between stations	
	This category refers to the presence or absence of the specific plant within 2.5 meters of the
	100m transect line connecting consecutive stations. A "+" indicates presence, a "0" indicates absence.

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11
Transect #	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Station #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Elevation	2760	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-
Blue marker #	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bearing to next station	180	180	144	130	-	165	170	160	172	165	165	160	165	125	150	185	190	180
Old goat pellets #	1	2	5	4	4	3	4	4	4	4	4	4	3	3	4	3	3	3
New goat pellets #	0	0	0	0	0	0	0	0	0	0	3	2	1	0	2	0	0	0
Bare ground #	3	2	1	2	4	2	4	3	3	4	4	3	3	4	4	1	2	3
Species cover in 5.64m2 radius																		
Abutilon grandifolium	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Ageratina adenophora	0	0	0	0	0	0	0	R	0	0	0	0	0	R	0	0	0	0
Ageratina riparia	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0
Ageratum conyzoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alphitonia ponderosa	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alyxia olivaeformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis arvensis	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arenaria serpyllifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Argemone glauca	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Asclepias spp.	0	R	R	0	0	0	0	0	R	0	0	R	R	R	0	0	0	0
Asplenium rhoidoneuron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium adiantum-nigrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Axonopus fissifolius	0	0	0	0	0	0	0	R	R	0	R	X	R	R	R	R	R	R
Bidens pilosa	R	R	R	0	R	R	R	X	X	R	X	X	X	X	X	X	R	R
Bocconia frutescens	0	R	0	X	0	R	0	0	0	0	X	X	0	X	0	0	R	R
Bothriochloa pertusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canthium odoratum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capparis sandwichiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex wahuensis	0	R	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X
Centaurium erythraea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Cerastium vulgatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chamaesaia nictitans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Chamaesyce celastroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium ambrosioides	0	0	R	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0
Chenopodium oahuense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocculus trilobus	R	R	0	R	R	0	0	0	R	0	0	0	R	R	0	0	0	0
Conyza bonariensis	0	R	0	0	R	R	0	0	0	0	R	0	0	0	0	R	0	0
Conyza canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cucumis dipsaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus gracilis	R	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Datura stramonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Desmodium uncinatum	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Digitaria sp.	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa	0	0	R	1	0	0	0	0	0	0	0	0	R	0	0	0	0	0
Doryopteris decipiens	0	R	R	0	0	0	0	0	0	R	0	0	R	R	R	R	0	0
Dubautia linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emilia sp.	R	0	0	0	0	0	0	R	0	0	0	0	0	R	R	R	R	0
Eragrostis variabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbia hirta	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Euphorbia peplus	R	R	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Festuca megalura	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foeniculum vulgare	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium japonicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium sandwicensium	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypochoeris glabra	0	0	R	0	0	0	0	R	0	0	0	0	R	R	R	0	0	0
Hypochoeris radicata	0	0	R	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Indigofera suffruticosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Ipomoea congesta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0
Ipomoea tuboides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	R
Lactuca serriola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lantana camara	R	1	R	X	1	2	1	1	1	R	1	1	1	X	R	1	1	1
Leucaena leucocephala	0	0	0	0	0	0	0	0	0	0	0	0	R	R	0	X	R	R
Lepidium virginicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lipochaeta lavarum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroptilium lathyroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marrubium hillebrandii	X	R	R	0	0	0	0	R	0	0	0	0	0	R	R	0	R	R

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11	3/11
Transect #	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Station #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Melinis minutiflora	R	0	0	1	0	0	0	R	X	0	0	R	0	R	R	0	1	0
Momordica charantia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Myrsine lanaensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nestegis sandwicensis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Nephrolepis multiflora	0	R	0	0	0	0	0	R	0	0	0	0	R	R	R	0	0	0
Nicotiana glauca	0	0	0	0	0	0	0	0	0	R	0	X	R	R	X	0	X	R
Opuntia ficus-indica	0	R	R	0	X	R	R	0	R	0	0	0	R	0	0	0	R	R
Osteomeles anthyllidifolia	0	X	R	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxalis corniculata	R	0	0	0	0	0	0	R	0	0	0	0	R	R	R	R	R	0
Panicum pellitum	R	0	0	0	0	0	0	R	0	R	R	0	0	R	R	0	0	0
Passiflora subpeltata	0	R	R	R	0	X	0	R	X	0	0	0	R	R	0	R	R	0
Pellaea ternifolia	0	R	R	R	0	0	0	0	0	0	0	0	0	R	0	0	R	0
Pennisetum clandestinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peperomia leptostachya	1	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0
Petroselinum crispum	0	R	0	R	R	0	R	R	0	0	0	0	R	R	0	0	0	0
Pityrogramma calomelanos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Plantago lanceolata	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plectranthus parviflorus	R	R	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Pleomele auwahiensis	0	1	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0
Pleopeltis thunbergiana	0	R	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plumbago zeylanica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycarpon tetraphylum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polypodium pellucidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portulaca oleracea	0	0	0	0	R	0	0	R	R	R	0	R	R	R	0	0	R	R
Portulaca pilosa	0	0	0	0	0	R	0	R	R	R	0	R	R	R	R	R	R	R
Psilotum nudum	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0
Pteridium aquilinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchelytrum repens	0	X	3	X	X	X	X	X	X	R	X	X	X	X	R	3	1	1
Salvia coccinea	R	0	0	0	0	R	0	0	0	0	0	0	0	R	0	0	0	0
Santalum ellipticum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sicyos spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigesbeckia orientalis	0	0	R	0	0	0	0	R	0	0	0	0	0	R	0	0	0	0
Silene gallica	0	0	R	0	0	R	0	R	0	0	0	0	0	R	R	0	0	0
Sonchus oleraceus	0	R	R	0	R	R	0	R	R	R	R	0	R	R	R	R	R	R
Sporobolus africanus	R	R	1	R	R	X	X	X	0	0	0	0	0	0	0	0	0	0
Stachytarpheta spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Styphelia tameiameiae	0	R	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tephrosia purpurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tridax procumbens	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Trifolium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triumfetta semitriloba	0	R	R	0	0	0	0	0	0	0	0	0	0	0	R	R	R	R
Verbena litoralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waltheria indica	0	0	0	0	0	0	R	0	0	0	0	0	R	R	0	R	R	R
Malva parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wikstroemia monocola	X	R	X	X	0	X	R	0	0	0	R	0	0	R	0	0	0	0
Xylosma hawaiense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinnia peruviana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Presence in 9.77m2 radius																		
Melinis minutiflora	+	+	0	+	0	0	0	+	+	0	0	0	0	+	0	0	+	0
Bocconia frutescens	0	+	0	+	+	+	0	0	+	+	+	+	+	0	0	+	+	+
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	0	+	+	+	+	+	0	+	0	0	+	+	0	+	+	0	+	0
Dodonaea viscosa	+	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Presence between stations																		
Melinis minutiflora	+	+	+	+	+	+	0	+	+	+	0	0	0	0	0	+	+	+
Bocconia frutescens	+	+	0	+	+	+	0	+	+	+	+	+	+	0	0	+	+	+
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	0	0	+	+	0	+	0	0	0	0	+	+	0	0	0	0	+	0
Dodonaea viscosa	0	0	+	+	0	0	0	0	0	0	0	0	+	0	0	+	+	0

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/11	3/11	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19
Transect #	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Station #	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Elevation	-	-	2720	2690	2630	2540	2470	2420	2420	2390	2330	2320	2300	2270	2220	2130	2100
Blue marker	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bearing to next station	180	180	182	185	176	203	176	178	188	192	186	182	192	170	178	178	176
Old goat pellets	3	0	0	1	4	3	4	4	4	4	4	3	4	4	4	2	3
New goat pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare ground	3	4	2	2	2	2	1	3	3	3	3	3	1	4	3	3	2
Species cover in 5.64m2 radius																	
Abutilon grandifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ageratina adenophora	0	0	0	R	0	0	0	0	1	1	X	0	R	0	0	X	0
Ageratina mpana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ageratum conyzoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alphitonia ponderosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alyxia olivaeformis	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis arvensis	0	0	R	0	R	0	0	0	R	R	0	0	R	0	0	0	0
Arenaria serpyllifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Argemone glauca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0
Asclepias spp.	0	0	R	R	0	0	0	0	0	R	0	R	0	R	R	0	0
Asplenium rhipidoneuron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium adiantum-nigrum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Axonopus fissifolius	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bidens pilosa	X	X	R	R	R	X	R	R	R	R	R	R	R	R	R	R	0
Bocconia frutescens	0	0	1	0	0	0	0	0	0	0	0	X	R	R	0	R	0
Bothriochloa pertusa	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canthium odoratum	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0
Capparis sandwichiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex wahuensis	0	0	0	R	R	X	0	0	0	0	0	0	X	0	0	0	R
Centaurium erythraea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium vulgatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chamaecrista nictitans	R	R	R	0	0	0	R	0	0	0	0	0	R	0	0	0	0
Chamaesyce celastroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium ambrosioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium oahuense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocculus trilobus	0	0	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Conyza bonariensis	0	0	R	R	R	0	0	0	R	R	0	R	0	0	0	0	0
Conyza canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Cucumis dipsaceus	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Datura stramonium	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium uncinatum	0	R	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Digitaria sp.	0	R	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0
Dodonaea viscosa	0	0	0	1	X	1	1	0	0	0	R	0	1	R	X	1	2
Doryopteris decipiens	0	0	0	R	R	R	0	0	0	0	R	0	R	0	R	R	R
Dubautia linearis	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0
Emilia sp.	R	0	0	0	R	R	0	0	0	0	0	R	R	R	R	R	R
Eragrostis variabilis	0	0	0	R	0	X	0	0	0	0	0	0	0	0	0	0	0
Euphorbia hirta	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbia peplus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Festuca megalura	0	0	0	R	0	0	0	0	0	0	0	0	0	0	R	0	0
Foeniculum vulgare	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium japonicum	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0
Gnaphalium sandwicensium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Hypochoeris glabra	R	0	0	0	0	0	0	0	R	0	R	0	0	0	R	R	0
Hypochoeris radicata	0	0	0	R	0	R	0	0	0	R	R	R	R	0	R	0	0
Indigofera suffruticosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R
Ipomoea congesta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ipomoea tuboides	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	R	R
Lactuca serriola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lantana camara	X	X	X	X	X	1	R	1	X	X	R	R	1	R	X	1	X
Leucaena leucocephala	R	X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidium virginicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lipochaeta lavarum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroptilium lathyroides	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marrubium hillebrandii	R	0	R	R	R	R	R	R	R	R	R	R	R	0	0	R	0

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/11	3/11	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19	3/19
Transect #	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Station #	19	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Melinis minutiflora	X	0	X	X	R	0	0	0	0	R	X	0	R	0	X	1	R
Momordica charantia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrsine lanaensis	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0
Nestegis sandwicensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephrolepis multiflora	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nicotiana glauca	R	R	0	0	0	0	0	0	0	R	0	R	0	R	0	0	0
Opuntia ficus-indica	R	0	R	R	R	R	R	0	R	R	R	R	R	R	R	R	R
Osteomeles anthyllidifolia	0	0	1	1	1	R	X	1	R	R	R	0	0	0	0	0	0
Oxalis corniculata	0	0	0	R	0	R	0	0	R	R	0	R	R	R	0	0	0
Panicum pellitum	0	R	0	R	R	R	0	0	0	R	R	X	0	R	0	0	0
Passiflora subpeltata	R	X	0	R	0	R	0	R	0	R	0	0	0	R	0	0	0
Pellaea ternifolia	0	0	0	R	R	R	0	0	R	0	R	0	R	0	R	R	R
Pennisetum clandestinum	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Peperomia leptostachya	0	0	R	0	R	R	0	0	0	0	R	0	0	0	0	0	R
Petroselinum crispum	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pityrogramma calomelanos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago lanceolata	0	X	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plectranthus parviflorus	0	0	0	0	0	R	R	R	0	R	R	R	R	R	R	R	R
Pleomele auwahiensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pteopsis thunbergiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plumbago zeylanica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycarpon tetraphylum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polypodium pellucidum	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0
Portulaca oleracea	0	R	0	0	0	0	0	0	0	R	0	R	R	0	0	0	0
Portulaca pilosa	R	R	0	0	0	0	0	R	R	R	R	R	0	R	R	0	R
Psilotum nudum	0	0	0	R	0	0	0	0	0	0	R	0	0	0	0	0	0
Pteridium aquilinum	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchelytrum repens	1	0	X	1	1	X	2	1	1	1	X	1	2	X	X	1	1
Salvia coccinea	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0
Santalum ellipticum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sicyos spp.	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0
Sigesbeckia orientalis	0	0	0	0	0	0	0	0	0	R	0	R	0	R	R	R	0
Silene gallica	0	0	0	0	0	0	0	0	0	0	0	0	0	R	R	R	0
Sonchus oleraceus	R	R	0	0	R	R	0	0	R	R	R	R	R	R	R	R	R
Sporobolus africanus	0	X	X	0	R	0	0	0	0	0	0	0	0	0	0	0	0
Stachytarpheta spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Styphelia tameiameiae	0	0	R	1	R	0	X	0	R	0	0	0	0	0	0	0	0
Tephrosia purpurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tridax procumbens	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trifolium sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Triumfetta semitriloba	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0
Verbena litoralis	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waltheria indica	R	R	0	R	R	R	R	R	0	R	R	0	R	R	R	R	R
Malva parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wikstroemia monocoia	0	0	0	X	R	R	0	0	X	0	R	X	R	R	0	0	R
Xylosma hawaiensis	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0
Zinnia peruviana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Presence in 9.77m2 radius																	
Melinis minutiflora	+	0	+	+	+	0	0	0	0	0	+	+	+	+	+	+	+
Bocconia frutescens	0	0	+	0	+	0	0	+	+	0	+	+	+	+	0	+	+
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	0	+	0	0	+	0	+	+	+	0	0	0	+	0	0	0	0
Dodonaea viscosa	+	0	+	+	+	+	+	+	+	0	+	0	+	0	+	+	+
Presence between stations																	
Melinis minutiflora	0	0	+	+	0	0	+	+	+	+	+	+	+	+	+	+	+
Bocconia frutescens	0	0	+	+	+	+	+	+	+	+	+	+	+	0	+	+	+
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	0	0	0	0	0	+	+	+	+	+	+	+	0	+	+	0	0
Dodonaea viscosa	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/19	3/19	3/19	3/19	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13
Transect #	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3
Station #	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13
Elevation	2040	2010	1990	1930	2800	2740	2700	2780	2610	2550	2510	2480	2410	2380	2320	2260	2280
Blue marker	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Bearing to next station	188	188	188	0	172	180	182	160	195	200	200	190	190	205	180	185	175
Old goat pellets	3	2	1	0	0	0	1	0	4	4	4	3	1	3	2	2	0
New goat pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Base ground	3	3	3	3	3	X	X	1	2	3	1	2	2	2	1	3	1
Species cover in 5.64m2 radius																	
Abutilon grandifolium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ageratina adenophora	0	X	R	0	0	0	0	0	0	0	0	0	0	0	0	0	R
Ageratina riparia	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0
Ageratum conyzoides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alphitonia ponderosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alyxia oliveiformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis arvensis	0	0	0	0	R	R	0	0	0	0	0	0	0	0	0	0	0
Arenaria serpyllifolia	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0
Argemone glauca	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0
Asclepias spp.	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium rhipidoneuron	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0
Asplenium adiantum-nigrum	0	0	0	0	R	R	0	0	0	0	0	0	0	0	0	0	0
Axonopus fissifolius	0	0	0	0	R	R	0	R	0	0	0	0	0	0	0	0	0
Bidens pilosa	R	R	0	0	0	R	0	R	R	R	R	0	0	0	0	1	R
Bocconia frutescens	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bothriochloa pertusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canthium odoratum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capparis sandwichiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex wahuensis	0	0	0	0	0	R	0	R	0	0	0	0	0	R	R	0	0
Centaurium erythraea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium vulgatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chamaecrista nictitans	0	0	0	0	R	0	R	R	R	R	R	R	R	R	R	R	R
Chamaesyce celastroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium ambrosioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium oahuense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocculus trilobus	R	R	R	R	R	R	R	R	R	R	R	R	R	R	0	R	R
Conyza bonariensis	0	0	0	0	R	R	0	0	0	0	0	0	0	R	0	0	0
Conyza canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cucumis dipsaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus gracilis	0	0	0	0	R	R	R	0	0	0	R	0	R	0	0	R	R
Datura stramonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium uncinatum	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0
Digitaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa	1	1	1	1	X	3	1	2	R	X	1	2	X	1	2	X	2
Doryopteris decipiens	R	R	R	R	R	R	0	0	R	0	R	R	R	R	R	R	R
Dubautia linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emilia sp.	R	R	R	R	R	0	0	0	0	R	0	R	R	R	0	R	R
Eragrostis variabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbia hirta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbia peplus	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0
Festuca megalura	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Foeniculum vulgare	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium japonicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium sandwicensium	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0
Hypochoeris glabra	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R
Hypochoeris radicata	0	0	0	0	0	0	0	0	R	R	0	0	0	0	0	0	0
Indigofera suffruticosa	0	0	0	0	0	0	0	0	0	0	R	X	R	R	0	0	R
Ipomoea congesta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ipomoea tuboides	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactuca serriola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lantana camara	R	R	R	R	R	X	R	X	X	X	0	R	X	R	R	0	0
Leucaena leucocephala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	1
Leonurus virginicum	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Lipochaeta tenuifolia	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroptilium lathyroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marsilea hirsutella	0	R	R	R	R	R	R	R	R	R	R	0	0	0	R	0	R

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/19	3/19	3/19	3/19	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/13	3/1
Transect #	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3
Station #	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13
Melinis minutiflora	0	0	R	R	R	1	X	1	1	X	0	0	1	X	2	R	R
Momordica charantia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrsine lanaensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nestegis sandwicensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephrolepis multiflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nicotiana glauca	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0
Opuntia ficus-indica	0	0	R	R	0	R	R	R	R	0	0	R	0	R	R	R	R
Osteomeles anthyllidifolia	0	0	R	0	R	X	1	1	0	X	1	0	X	R	R	0	0
Oxalis corniculata	0	0	0	0	R	R	0	0	R	0	0	0	R	0	0	0	0
Panicum pellitum	R	R	0	0	0	0	0	0	0	R	0	R	0	0	0	0	0
Passiflora subpeltata	0	R	0	0	R	0	R	0	0	X	0	0	0	0	0	R	0
Pellaea ternifolia	R	R	R	0	R	R	R	R	R	R	R	R	R	R	R	0	R
Pennisetum clandestinum	0	0	0	0	R	R	0	0	0	0	0	0	0	0	0	0	0
Peperomia leptostachya	R	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Petroselinum crispum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pityrogramma calomelanos	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago lanceolata	0	0	0	0	R	R	0	0	0	0	0	0	0	R	0	R	0
Plectranthus parviflorus	R	R	0	R	0	0	0	0	0	R	0	0	0	0	0	0	0
Pleomele auwahiensis	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pleopeltis thunbergiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plumbago zeylanica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycarpon tetraphyllum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polypodium pellucidum	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portulaca oleracea	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portulaca pilosa	R	0	0	0	0	0	0	0	0	0	R	R	R	R	R	R	R
Psilotum nudum	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0
Pteridium aquilinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchelytrum repens	X	X	1	1	1	1	1	1	X	X	2	1	2	1	1	1	1
Salvia coccinea	0	0	0	0	0	0	0	0	0	R	R	0	R	0	0	0	0
Santalum ellipticum	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	R	R	0	0	0	0	0
Sicyos spp.	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0
Sigesbeckia orientalis	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0
Silene gallica	R	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Sonchus oleraceus	R	0	R	0	R	R	R	0	R	R	0	R	R	0	0	R	R
Sporobolus africanus	0	0	0	0	R	R	X	R	0	0	R	X	X	X	X	X	R
Stachytarpheta spp.	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Styphelia tameiameiae	0	0	0	0	0	0	X	0	0	0	0	0	0	0	0	0	0
Tephrosia purpurea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tridax procumbens	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Trifolium sp.	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0
Triumfetta semitriloba	0	0	0	0	0	R	0	0	R	0	0	0	0	0	0	0	0
Verbena litoralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waltheria indica	0	R	0	R	R	R	R	R	0	R	R	R	R	R	R	R	R
Malva parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0
Wikstroemia monticola	0	0	0	0	R	0	X	R	R	R	1	R	X	X	X	X	X
Xylosma hawaiense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinnia peruviana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Presence in 9.77m2 radius																	
Melinis minutiflora	0	0	+	+	+	+	+	+	+	+	0	+	+	+	+	+	+
Bocconia frutescens	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	0	0	0	0	0	+	+	0	+	0	0	0	0	0	0	0	0
Dodonaea viscosa	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Presence between stations																	
Melinis minutiflora	+	+	+	0	+	+	+	+	+	+	+	+	+	0	+	+	+
Bocconia frutescens	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	+	+
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	0	0	0	0	+	+	+	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa	+	+	+	0	+	+	+	+	+	+	+	+	+	0	+	+	+

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/13	3/13	3/13	3/13	3/13	3/13	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12
Transect #	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4
Station #	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10.	11
Elevation	2160	2100	2060	2020	1980	1940	2830	2720	-	2640	2560	2500	2440	2350	2320	2310	2240
Blue marker	-	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	0
Bearing to next station	190	200	170	185	180		162	162	180	180	180	190	180	195	170	190	180
Old goat pellets	1	0	3	0	0	0	0	2	3	2	0	0	3	1	2	1	4
New goat pellets	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bare ground	2	2	2	1	3	2	3	3	2	3	2	1	3	1	2	1	2
Species cover in 5.64m2 radius																	
Abutilon grandifolium	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0
Ageratina adenophora	R	0	R	0	0	0	0	0	0	0	0	R	R	R	R	0	0
Ageratina riparia	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0
Ageratum conyzoides	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0
Alphitonia ponderosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Alyxia olivaeformis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anagallis arvensis	0	0	0	0	0	0	R	0	R	R	0	R	0	0	R	R	0
Arenaria serpyllifolia	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	R	R
Argemone glauca	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Asclepias spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium rhipidoneuron	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Asplenium adiantum-nigrum	0	0	0	0	0	0	R	0	R	0	0	0	0	0	0	0	0
Axonopus fissifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bidens pilosa	0	X	0	0	0	X	R	R	R	R	R	0	0	0	X	R	R
Bocconia frutescens	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0
Bothriochloa pertusa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Canthium odoratum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capparis sandwichiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Carex wahuensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Centaurium erythraea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cerastium vulgatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chamaesaca nictitans	R	R	R	R	R	R	0	R	R	R	R	R	R	R	R	R	R
Chamaesyce celastroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium ambrosioides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chenopodium oahuense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cocculus trilobus	R	0	0	R	R	R	R	0	R	R	0	R	R	R	0	R	R
Conyza bonariensis	0	0	R	0	0	0	0	R	0	0	0	0	R	0	0	R	0
Conyza canadensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cucumis dipsaceus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyperus gracilis	0	R	0	R	0	0	R	0	R	0	0	0	0	R	0	0	0
Datura stramonium	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Desmodium uncinatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Digitaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dodonaea viscosa	2	2	2	1	1	1	R	R	1	X	X	1	0	1	X	X	X
Doryopteris decipiens	0	0	R	0	R	0	0	R	R	R	R	R	R	0	R	R	R
Dubautia linearis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Emilia sp.	R	R	0	0	R	0	0	0	R	0	R	R	0	0	R	R	R
Eragrostis variabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Euphorbia hirta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	R
Euphorbia peplus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0
Festuca megalura	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0
Foeniculum vulgare	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium japonicum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gnaphalium sandwicensium	0	0	0	0	R	0	0	0	0	0	R	0	0	0	0	R	0
Hypochoeris glabra	0	0	0	0	0	0	0	0	R	0	R	R	R	0	0	0	0
Hypochoeris radicata	0	0	0	0	0	0	0	0	0	0	R	R	R	0	0	0	0
Indigofera suffruticosa	R	R	0	0	R	0	0	0	X	R	X	R	0	R	0	R	R
Ipomoea congesta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ipomoea tuboides	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0
Lactuca serriola	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lantana camara	X	1	X	X	X	R	X	X	X	X	X	R	0	R	R	X	X
Leucaena leucocephala	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepidium virginicum	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	R	0
Lipochaeta lavarum	0	0	0	X	0	0	0	0	0	0	0	0	0	0	0	0	0
Macroptilium lathyroides	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marrubium hillebrandii	0	R	R	R	R	0	R	0	0	R	R	R	0	0	0	R	0

Appendix 3: Part II. Raw monitoring data

Date in 1992	3/13	3/13	3/13	3/13	3/13	3/13	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12	3/12
Transect #	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4
Station #	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11
Melinis minutiflora	X	0	0	0	R	1	X	0	0	0	0	0	X	X	X	0	R
Momordica charantia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Myrsine lanaensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nastegis sandwicensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nephrolepis multiflora	0	0	0	0	0	0	0	R	0	0	R	0	0	0	0	0	0
Nicotiana glauca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Opuntia ficus-indica	0	0	R	R	R	0	R	R	R	R	R	0	R	0	R	R	R
Osteomeles anthyllidifolia	0	0	0	0	0	0	X	X	X	R	0	X	0	0	0	0	0
Oxalis corniculata	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0
Panicum pellitum	0	0	0	0	R	0	0	0	0	0	0	0	R	0	0	0	0
Passiflora subpeltata	0	0	0	0	0	0	0	R	0	0	0	0	R	0	0	0	0
Pellaea ternifolia	0	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Pennisetum clandestinum	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Peperomia leptostachya	0	0	0	0	0	0	0	R	0	R	0	0	0	R	0	0	0
Petroselinum crispum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pityrogramma calomelanos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plantago lanceolata	0	R	0	0	0	0	0	0	0	0	0	R	0	R	0	R	0
Plectranthus parviflorus	0	0	0	0	R	0	0	R	0	R	0	R	R	R	R	0	R
Pleomele auwahiensis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pleopeltis thunbergiana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plumbago zeylanica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Polycarpon tetraphyllum	0	0	0	0	0	0	R	0	R	0	0	0	0	0	0	0	0
Polypodium pellucidum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Portulaca oleracea	0	0	0	0	0	0	0	0	X	0	0	0	0	0	0	0	0
Portulaca pilosa	0	R	R	0	0	0	R	R	X	0	R	R	R	R	X	0	R
Psilotum nudum	0	0	0	0	0	0	0	0	0	0	0	0	R	0	0	0	0
Pteridium aquilinum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rhynchelytrum repens	1	1	1	1	1	1	1	1	1	1	1	1	X	2	1	2	2
Salvia coccinea	0	0	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0
Sanicula ellipticum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sicyos spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sigesbeckia orientalis	0	0	0	0	R	0	0	0	R	0	0	R	R	R	R	R	0
Silene gallica	0	R	0	0	R	0	0	0	R	0	R	R	0	R	R	R	R
Sonchus oleraceus	0	R	0	0	R	0	R	R	R	R	R	R	R	R	R	R	R
Sporobolus africanus	0	R	0	0	0	0	R	0	X	0	0	0	0	R	0	X	R
Stachytarpheta spp.	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0	R	0
Styphelia tameiameiae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tephrosia purpurea	0	0	0	R	0	0	0	0	0	0	0	0	0	0	0	0	0
Tridax procumbens	0	R	0	0	0	0	0	0	0	0	0	0	0	0	R	0	R
Trifolium sp.	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0
Triumfetta semitriloba	0	0	0	0	0	0	R	0	0	0	0	0	0	0	0	0	0
Verbena litoralis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Waltheria indica	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Malva parviflora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wikstroemia monticola	X	1	1	1	X	0	X	X	1	1	X	X	0	X	X	X	R
Xylosma hawaiense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zinnia peruviana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Presence in 9.77m2 radius																	
Melinis minutiflora	+	0	0	0	+	+	+	0	0	0	0	0	+	+	+	0	+
Bocconia frutescens	+	0	0	+	+	0	0	0	+	0	0	0	0	0	+	+	+
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	+	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0
Passiflora subpeltata	0	0	0	0	0	0	+	+	+	0	0	+	+	0	0	0	+
Dodonaea viscosa	+	+	+	+	+	+	+	+	+	+	+	+	+	+	0	+	+
Presence between stations																	
Melinis minutiflora	+	+	0	0	+	0	+	+	+	+	0	+	+	+	0	+	+
Bocconia frutescens	+	0	0	0	+	0	+	+	+	0	0	+	0	+	0	+	+
Schinus terebinthifolius	+	0	0	0	0	0	+	0	+	0	+	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	0	0	0	0	0	0	+	+	+	+	0	+	+	0	0	0	+
Dodonaea viscosa	+	+	0	+	+	0	+	+	+	+	+	+	0	+	0	+	+

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/12	3/12	3/12	3/12	3/12	3/12	3/12	5/12	5/12	5/12	5/12	5/12	5/12	5/12	5/12	5/12
Transect #	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5
Station #	12	13	14	15	16	17	18	1	2	3	4	5	6	7	8	9
Elevation	2180	2130	2090	2040	1980	1970	NA	2830	2760	?	?	2620	2620	2540	2470	2400
Blue marker	–	–	+	–	–	–	NA	–	–	–	–	–	–	–	–	–
Bearing to next station	180	180	175	170	170	0	NA	180	170	170	180	170	164	170	160	170
Old goat pellets	4	0	1	0	0	0	NA	0	3	4	4	4	3	3	3	3
New goat pellets	0	0	0	0	0	0	NA	0	0	2	1	0	2	0	2	0
Bare ground	3	X	1	1	1	1	NA	2	3	4	1	1	1	2	2	2
Species cover in 5.64m2 radius																
Abutilon grandifolium	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Ageratina adenophora	0	0	0	0	0	0	NA	0	0	R	0	0	0	0	0	0
Ageratina riparia	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Ageratum conyzoides	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Alphitonia ponderosa	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Alyxia olivaeformis	0	0	0	0	0	0	NA	X	0	0	0	0	0	0	0	0
Anagallis arvensis	0	0	R	0	0	0	NA	0	0	0	R	0	0	R	0	0
Anemone serpyllifolia	0	0	0	0	0	R	NA	0	0	0	0	0	0	0	0	0
Argemone glauca	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Asclepias spp.	0	0	0	0	0	0	NA	0	0	0	0	R	0	0	0	0
Asplenium rhizodonaeuron	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Asplenium adiantum-nigrum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Axonopus fissifolius	0	0	0	0	0	0	NA	0	0	0	0	R	R	R	0	R
Bidens pilosa	0	0	R	R	R	R	NA	0	R	R	R	R	R	X	R	X
Bocconia frutescens	R	X	0	0	0	1	NA	X	R	0	0	R	0	X	X	0
Bothriochloa pertusa	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Canthium odoratum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Capparis sandwichiana	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Carex wahuensis	0	0	0	0	0	0	NA	0	0	R	0	R	0	0	0	0
Centaurium erythraea	0	0	0	0	0	0	NA	0	0	0	R	0	0	0	0	0
Cenchrus vulgatus	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Chamaesaia nictitans	0	R	R	R	R	R	NA	0	0	0	0	0	0	0	R	0
Chamaesyce celastroides	0	0	0	0	0	0	NA	0	0	0	0	0	X	0	0	0
Chenopodium ambrosioides	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Chenopodium oahuense	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Cocculus trilobus	0	R	R	R	R	R	NA	0	0	R	R	R	R	0	R	R
Conyza bonariensis	0	0	0	0	0	0	NA	0	R	R	R	R	R	0	0	0
Conyza canadensis	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Cucumis dipsaceus	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Cyperus gracilis	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Datura stramonium	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Desmodium uncinatum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Digitaria sp.	0	0	0	0	0	R	NA	0	0	R	0	0	0	0	0	0
Dodonaea viscosa	R	1	1	2	2	2	NA	R	0	0	1	X	0	0	R	X
Doryopteris decipiens	R	R	R	R	R	R	NA	X	R	R	R	R	R	0	R	R
Dubautia linearis	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Emilia sp.	R	R	0	R	0	R	NA	0	R	0	R	R	0	R	R	0
Eragrostis variabilis	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Euphorbia hirta	R	0	0	0	0	0	NA	0	0	0	0	0	0	0	R	0
Euphorbia peplus	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Festuca megalura	0	0	R	0	0	R	NA	0	0	0	R	0	0	0	0	0
Foeniculum vulgare	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Gnaphalium japonicum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Gnaphalium sandwicensium	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Hypochoeris glabra	0	0	0	R	0	R	NA	0	0	0	0	0	0	0	0	0
Hypochoeris radicata	0	0	0	R	0	0	NA	0	R	0	0	R	0	0	0	0
Indigofera suffruticosa	0	X	R	R	R	R	NA	0	0	0	0	0	0	0	0	0
Ipomoea congesta	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Ipomoea tuboides	R	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Lactuca serriola	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Lantana camara	R	X	R	X	X	X	NA	1	1	X	1	1	1	2	1	2
Leucaena leucocephala	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Lepidium virginicum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	R	0
Lipochaeta lavarum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Macroptilium lathyroides	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Marsicus hillebrandii	0	R	R	R	0	R	NA	0	0	R	R	R	R	R	R	R

Appendix 3: Part II, Raw monitoring data

Date in 1992	3/12	3/12	3/12	3/12	3/12	3/12	3/12	5/12	5/12	5/12	5/12	5/12	5/12	5/12	5/12	5/12
Transect #	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5
Station #	12	13	14	15	16	17	18	1	2	3	4	5	6	7	8	9
Melinis minutiflora	X	0	X	0	X	X	NA	0	0	0	0	0	0	R	0	0
Momordica charantia	0	0	0	0	0	0	NA	0	R	R	2	1	R	0	R	R
Myrsine lessenensis	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Nestegis sandwicensis	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Nephrolepis multiflora	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Nicobana glauca	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Opuntia ficus-indica	R	R	R	R	R	R	NA	0	0	R	R	R	R	0	R	R
Osteomeles anthyllidifolia	0	0	R	0	0	0	NA	1	X	R	R	0	X	0	0	0
Oxalis corniculata	0	0	0	0	0	0	NA	0	0	0	0	R	0	0	R	0
Panicum pellitum	0	0	0	0	R	X	NA	0	0	0	0	0	R	0	0	0
Passiflora suberosa	0	0	0	0	0	0	NA	X	0	0	0	R	R	R	R	X
Pellaea ternifolia	R	R	R	R	R	R	NA	R	R	R	R	R	R	R	R	0
Pennisetum clandestinum	0	0	0	0	0	0	NA	1	R	0	0	0	0	0	0	0
Peperomia leptostachya	R	0	0	R	0	0	NA	R	0	R	0	0	0	0	0	0
Petroselinum crispum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Pityrogramma calomelanos	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Plantago lanceolata	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Plectranthus parviflorus	R	R	R	0	0	0	NA	R	0	0	R	0	0	0	0	0
Pleomele auwahiensis	0	0	0	0	0	0	NA	X	0	0	0	0	0	0	0	0
Pleopeltis thunbergiana	0	0	0	0	0	0	NA	R	R	R	R	0	0	0	0	0
Plumbago zeylanica	0	0	0	0	0	0	NA	0	0	0	0	0	0	R	0	0
Polycarpon tetraphyllum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Polypodium pellucidum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Portulaca oleracea	0	0	0	0	0	0	NA	0	R	0	R	0	0	0	0	0
Portulaca pilosa	R	R	R	X	R	R	NA	R	0	R	0	0	R	0	R	R
Psilotum nudum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Pteridium aquilinum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Rhynchelytrum repens	1	1	1	1	1	1	NA	X	X	X	2	1	1	1	2	1
Salvia coccinea	0	0	0	0	0	0	NA	0	0	0	X	R	X	X	R	0
Santalum ellipticum	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	NA	R	0	0	0	0	0	0	0	0
Sicyos spp.	0	0	0	0	0	0	NA	0	0	0	0	R	0	0	0	0
Sigesbeckia orientalis	0	0	R	R	0	0	NA	0	0	0	0	0	0	0	R	0
Silene gallica	0	0	0	0	R	R	NA	0	0	0	R	0	0	0	0	0
Sonchus oleraceus	R	0	0	R	0	R	NA	0	0	0	R	R	0	R	R	R
Sporobolus africanus	0	R	R	0	0	0	NA	R	0	0	R	R	R	R	R	R
Stachytarpheta spp.	R	R	R	0	R	0	NA	0	0	0	0	0	0	0	0	0
Styphelia tameiameiae	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Tephrosia purpurea	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Tridax procumbens	0	R	R	0	0	R	NA	0	0	0	0	0	0	0	R	R
Trifolium sp.	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Triumfetta semitriloba	0	0	0	0	0	0	NA	0	R	0	0	R	R	0	0	0
Verbena litoralis	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Waltheria indica	R	R	R	R	R	R	NA	R	0	0	R	R	0	0	R	0
Malva parviflora	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Wikstroemia monticola	0	X	X	X	X	X	NA	X	R	R	R	1	1	0	X	0
Xylosma hawaiiense	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Zinnia peruviana	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Presence in 9.77m2 radius																
Melinis minutiflora	-	0	-	0	+	+	NA	0	0	+	0	+	+	0	+	+
Bocconia frutescens	+	+	0	+	0	+	NA	+	0	+	+	+	+	+	0	+
Schinus terebinthifolius	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Passiflora suberosa	0	0	0	0	0	0	NA	+	0	+	+	+	+	+	+	+
Dodonaea viscosa	+	+	+	+	+	+	NA	+	0	+	+	+	0	0	+	+
Presence between stations																
Melinis minutiflora	+	+	+	0	+	+	NA	+	0	+	+	+	0	0	+	0
Bocconia frutescens	0	+	0	+	+	+	NA	+	0	+	+	+	+	+	+	+
Schinus terebinthifolius	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Glycine wightii	-	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	NA	0	0	0	0	0	0	0	0	0
Passiflora suberosa	0	+	0	0	0	+	NA	+	0	+	+	+	+	+	+	+
Dodonaea viscosa	+	0	+	+	+	+	NA	+	0	+	+	+	0	0	+	+

Appendix 3: Part II, Raw monitoring data

Date in 1992	5/12	5/12	5/12	5/12	5/12	5/12	10/27	10/27	10/27	10/27
Transect #	5	5	5	5	5	5	5	5	5	5
Station #	10	11	12	13	14	15	16	17	18	19
Elevation	2360	2230	2300	2160	2080	2050	2000	1900	1850	1730
Blue marker	-	-	-	-	-	-	-	-	-	-
Bearing to next station	160	160	170	170	170	170	174	174	188	-
Old goat pellets	4	4	3	3	2	2	0	1	0	0
New goat pellets	2	3	0	0	1	0	0	0	0	0
Bare ground	1	1	1	1	1	X	2	4	1	2
Species cover in 3.64m2 radius										
Abutilon grandifolium	0	0	0	0	0	0	X	0	0	0
Ageratina adenophora	0	0	0	0	0	0	0	X	0	0
Ageratina riparia	0	0	0	0	0	0	0	0	0	0
Ageratum conyzoides	0	0	0	0	0	0	0	0	0	0
Alphitonia ponderosa	0	0	0	0	0	0	0	0	0	0
Alyxia olivaeformis	0	0	0	0	0	0	0	0	0	0
Anagallis arvensis	0	R	R	X	0	X	0	0	0	0
Animana serpyllifolia	0	0	0	0	0	0	0	0	0	0
Argemone glauca	0	0	0	0	0	0	0	0	0	0
Asclepias spp.	0	0	R	0	R	0	0	0	0	0
Asplenium rhipidoneuron	0	0	0	0	0	0	0	0	0	0
Asplenium adiantum-nigrum	0	0	0	0	0	0	0	0	0	0
Axonopus fissifolius	R	0	0	0	R	0	0	0	0	0
Bidens pilosa	X	X	X	X	R	R	X	X	R	R
Bocconia frutescens	R	0	R	0	0	0	0	0	0	0
Bothriochloa pertusa	0	0	0	0	0	0	0	0	0	0
Canthium odoratum	0	0	0	0	0	0	0	0	0	0
Capparis sandwichiana	0	0	0	0	0	0	0	0	0	0
Carex wahuensis	0	0	0	0	0	0	0	0	0	0
Centaurium erythraea	0	0	0	0	0	0	0	0	0	0
Cenchrus vulgatum	0	0	0	0	0	0	0	0	0	0
Chamaecrista nictitans	0	R	R	R	0	X	X	0	0	R
Chamaesyce celastroides	0	0	0	0	0	0	0	0	0	0
Chenopodium ambrosioides	0	0	0	0	0	0	0	0	0	R
Chenopodium oahuense	0	0	0	0	R	0	0	X	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0
Cocculus trilobus	R	0	R	0	0	0	0	0	0	R
Conyza bonariensis	R	R	R	R	0	R	0	0	0	0
Conyza canadensis	0	0	0	0	0	0	0	0	0	0
Cucumis dipsaceus	0	0	0	0	0	0	0	0	0	0
Cyperus gracilis	0	0	0	0	0	0	R	0	0	0
Datura stramonium	0	0	0	0	0	0	0	0	0	0
Desmodium uncinatum	0	0	0	0	R	R	0	0	0	0
Digitaria sp.	R	R	R	1	0	0	0	0	0	0
Dodonaea viscosa	0	0	R	0	0	0	X	0	1	R
Doryopteris decipiens	0	0	0	0	X	R	0	R	0	0
Dubautia linearis	0	0	0	0	0	0	0	0	0	0
Emilia sp.	R	0	R	R	R	R	0	R	0	0
Eragrostis variabilis	0	0	0	0	0	0	0	0	0	0
Euphorbia hirta	0	0	0	0	0	0	0	0	0	0
Euphorbia peplus	0	0	0	0	0	0	0	0	0	0
Festuca megalura	0	0	R	R	0	0	0	0	0	0
Foeniculum vulgare	0	0	0	0	0	0	0	0	0	R
Glycine wightii	0	0	0	0	0	0	0	0	0	0
Gnaphalium japonicum	0	0	0	0	0	0	0	0	0	0
Gnaphalium sandwicensium	0	0	0	0	0	0	0	0	0	0
Hypochoeris glabra	0	0	0	0	0	0	0	R	0	0
Hypochoeris radicata	0	0	0	0	0	0	0	0	0	0
Indigofera suffruticosa	0	0	R	R	0	X	R	0	0	0
Ipomoea congesta	0	0	0	0	0	0	0	0	0	0
Ipomoea tuboides	0	R	0	0	R	0	0	X	0	R
Lactuca serriola	0	0	0	0	0	0	0	R	0	0
Lantana camara	3	3	3	1	3	1	3	X	2	1
Leucaena leucocephala	0	0	0	0	0	0	0	0	X	R
Lepidium virginicum	R	0	R	R	0	0	0	0	0	0
Lipochaeta lavarum	0	0	0	0	0	0	0	0	0	0
Macroptilium lathyroides	0	0	0	0	0	0	0	0	0	0
Marsacus hillebrandii	R	R	R	0	0	0	0	0	0	R

Appendix 3: Part II, Raw monitoring data

Date in 1992	5/12	5/12	5/12	5/12	5/12	5/12	10/27	10/27	10/27	10/27
Transect #	5	5	5	5	5	5	5	5	5	5
Station #	10	11	12	13	14	15	16	17	18	19
Melinis minutiflora	0	R	R	R	0	0	0	0	0	0
Momordica charantia	0	0	0	0	0	0	0	0	X	0
Myrsine lessertiana	0	0	0	0	0	0	0	0	0	0
Nastegis sandwicensis	0	0	0	0	0	0	0	0	0	0
Nephrolepis multiflora	0	0	0	0	0	0	0	0	0	0
Nicotiana glauca	0	R	0	0	0	0	0	0	0	0
Opuntia ficus-indica	R	R	R	0	R	R	0	0	X	R
Osteomeles anthyllidifolia	0	0	0	0	0	0	0	0	0	0
Oxalis corniculata	R	0	R	0	0	0	0	0	0	0
Panicum pellitum	0	0	0	0	0	0	0	R	0	0
Passiflora subpeltata	X	R	R	0	X	0	X	R	0	0
Pellaea ternifolia	0	0	R	0	0	R	0	0	0	0
Pennisetum clandestinum	0	0	0	0	0	0	0	0	0	0
Peperomia leptostachya	0	0	0	0	0	0	0	0	0	0
Petroselinum crispum	0	0	0	0	0	0	0	0	0	0
Pityrogramma calomelanos	0	0	0	0	0	0	0	0	0	0
Plantago lanceolata	0	0	X	X	0	0	0	0	0	0
Plectranthus parviflorus	0	0	0	0	0	0	0	0	0	0
Pleomele auwahiensis	0	0	0	0	0	0	0	0	0	0
Pteropetis thunbergiana	0	0	0	0	0	0	0	0	0	0
Plumbago zeylanica	0	R	0	0	0	0	0	0	0	0
Polycarpon tetraphyllum	R	0	0	0	0	0	0	0	0	0
Polypodium pellucidum	0	0	0	0	0	0	0	0	0	0
Portulaca oleracea	R	R	0	0	R	0	R	0	0	0
Portulaca pilosa	R	R	X	R	0	X	R	0	0	X
Psilotum nudum	R	0	0	0	0	0	0	0	0	0
Pteridium aquilinum	0	0	0	0	0	0	0	0	0	0
Rhynchelytrum repens	1	X	1	1	1	3	2	X	1	1
Salvia coccinea	0	0	R	0	0	0	0	0	0	0
Sanicula ellipticum	0	0	0	0	0	0	0	0	0	0
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0
Sicyos spp.	0	0	0	0	0	0	0	0	0	0
Sigesbeckia orientalis	R	0	0	R	R	0	0	R	0	0
Silene gallica	0	0	R	R	0	0	0	0	0	0
Sonchus oleraceus	R	R	0	R	R	R	0	0	0	0
Sporobolus africanus	0	0	0	R	0	0	0	0	0	0
Stachytarpheta spp.	0	0	R	R	0	R	0	0	0	0
Stylphelia tameiameae	0	0	0	0	0	0	0	0	0	0
Tephrosia purpurea	0	0	0	0	0	0	0	0	0	0
Tridax procumbens	0	0	0	0	0	0	0	0	0	R
Trifolium sp.	0	0	0	R	0	0	0	0	0	0
Triumfetta semitriloba	R	0	R	0	0	0	R	R	0	0
Verbena litoralis	0	0	0	0	0	0	0	0	0	0
Waltheria indica	R	0	0	0	0	R	R	0	0	R
Malva parviflora	0	0	R	R	0	0	R	0	0	0
Wikstroemia monocola	R	0	X	R	0	X	0	0	0	0
Xylosma hawaiiense	0	0	0	0	0	0	0	0	0	0
Zinnia peruviana	0	0	R	R	0	0	0	0	0	0
Presence in 9.77m2 radius										
Melinis minutiflora	0	0	0	0	0	0	0	0	+	0
Bocconia frutescens	+	+	+	+	0	0	0	0	0	+
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	+	+	+	0	0	0	+	0	0	0
Dodonaea viscosa	0	+	+	0	+	0	+	0	+	0
Presence between stations										
Melinis minutiflora	+	+	0	0	0	0	0	0	0	0
Bocconia frutescens	+	+	0	0	0	0	+	0	+	0
Schinus terebinthifolius	0	0	0	0	0	0	0	0	0	0
Glycine wightii	0	0	0	0	0	0	0	0	0	0
Cinnamomum camphora	0	0	0	0	0	0	0	0	0	0
Passiflora subpeltata	+	+	+	+	+	0	+	0	+	0
Dodonaea viscosa	+	+	+	+	0	0	+	+	+	0

Appendix 3: Part II, Raw monitoring data

Kaneohe NAR Summary Data	Average cover in individual transects					Frequency in individual transects				
Transect Number	1	2	3	4	5	1	2	3	4	5
Bare ground	61.6%	52.2%	33.2%	47.9%	31.8%	-	-	-	-	-
Abutilon grandifolium	0.1%	0.0%	0.0%	0.0%	0.1%	10.0%	0.0%	0.0%	5.6%	5.3%
Ageratina adenophora	0.1%	2.1%	0.1%	0.1%	0.2%	10.0%	42.1%	15.8%	22.2%	10.5%
Ageratina riparia	0.1%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%	5.3%	5.6%	0.0%
Ageratum conyzoides	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%
Alphitonia ponderosa	0.8%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Alyxia oliveaformis	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	5.3%	0.0%	0.0%	5.3%
Amaranthus arvensis	0.0%	0.1%	0.1%	0.2%	0.4%	5.0%	26.3%	10.5%	38.9%	31.6%
Arenaria serpyllifolia	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	5.3%	22.2%	0.0%
Argemone glauca	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	5.3%	5.3%	5.6%	0.0%
Asclepias spp.	0.2%	0.2%	0.0%	0.0%	0.1%	30.0%	31.6%	5.3%	0.0%	15.8%
Asplenium rhipidoneuron	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%
Asplenium adiantum-nigrum	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	5.3%	10.5%	11.1%	0.0%
Axonopus fissifolius	0.4%	0.0%	0.1%	0.0%	0.2%	35.0%	0.0%	15.8%	0.0%	31.6%
Bidens pilosa	1.5%	0.5%	1.2%	0.5%	1.3%	95.0%	84.2%	47.4%	66.7%	94.7%
Bocconia frutescens	0.6%	1.0%	0.1%	1.1%	0.5%	40.0%	31.6%	5.3%	16.7%	36.8%
Bothriochloa pertusa	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Canthium odoratum	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Caspana sandwichiana	0.1%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Carex wahuensis	0.1%	0.3%	0.1%	0.0%	0.1%	15.0%	26.3%	21.1%	0.0%	10.5%
Centaurium erythraea	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%
Cenostigma vulgatum	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Chamaecrista nictitans	0.1%	0.1%	0.5%	0.4%	0.4%	15.0%	15.8%	94.7%	83.3%	36.8%
Chamaesyce celastroides	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	5.3%
Chenopodium amoroseoides	0.1%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	5.3%
Chenopodium oahuense	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	10.5%
Cinnamomum camphora	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Cocculus trilobus	0.2%	0.5%	0.4%	0.4%	0.2%	35.0%	100.0%	84.2%	72.2%	47.4%
Conyza bonariensis	0.1%	0.2%	0.1%	0.1%	0.3%	25.0%	31.6%	21.1%	16.7%	52.6%
Conyza canadensis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Cucumis dipsaceus	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Cyperus gracilis	0.1%	0.0%	0.2%	0.1%	0.0%	10.0%	0.0%	47.4%	16.7%	5.3%
Datura stramonium	0.1%	0.0%	0.0%	0.0%	0.0%	10.0%	0.0%	0.0%	0.0%	0.0%
Desmodium uncinatum	0.1%	0.0%	0.0%	0.0%	0.1%	10.0%	5.3%	5.3%	5.6%	10.5%
Digitaria sp.	0.1%	0.0%	0.0%	0.0%	0.9%	10.0%	5.3%	0.0%	5.6%	26.3%
Dodonaea viscosa	0.8%	9.4%	22.4%	11.9%	2.1%	15.0%	73.7%	100.0%	88.9%	47.4%
Doryopteris decipiens	0.2%	0.3%	0.3%	0.4%	0.5%	35.0%	63.2%	63.2%	83.3%	57.9%
Dubautia linearis	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Emilia sp.	0.2%	0.3%	0.3%	0.3%	0.3%	35.0%	63.2%	52.6%	55.6%	57.9%
Eragrostis variabilis	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	10.5%	0.0%	0.0%	0.0%
Euphorbia hirta	0.1%	0.0%	0.0%	0.1%	0.0%	10.0%	0.0%	0.0%	16.7%	5.3%
Euphorbia peplus	0.1%	0.0%	0.0%	0.0%	0.0%	15.0%	0.0%	5.3%	5.6%	0.0%
Festuca megalura	0.0%	0.1%	0.0%	0.1%	0.1%	5.0%	10.5%	0.0%	16.7%	15.8%
Foeniculum vulgare	0.1%	0.0%	0.0%	0.0%	0.0%	10.0%	5.3%	0.0%	5.6%	5.3%
Glycine wightii	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gnaphalium japonicum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Gnaphalium sandwicensium	0.0%	0.0%	0.1%	0.1%	0.0%	5.0%	5.3%	10.5%	11.1%	0.0%
Hypochoeris glabra	0.2%	0.1%	0.0%	0.2%	0.0%	30.0%	26.3%	5.3%	33.3%	5.3%
Hypochoeris radicata	0.1%	0.2%	0.1%	0.1%	0.1%	10.0%	36.8%	10.5%	22.2%	10.5%
Indigofera suffruticosa	0.0%	0.0%	0.3%	0.7%	0.2%	5.0%	5.3%	42.1%	66.7%	21.1%
Ipomoea congesta	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Ipomoea tuboides	0.1%	0.1%	0.0%	0.1%	0.2%	15.0%	15.8%	0.0%	11.1%	21.1%
Lactuca serriola	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%
Lantana camara	10.7%	4.3%	2.1%	1.8%	29.7%	100.0%	100.0%	84.2%	88.9%	100.0%
Leucaena leucocephala	0.4%	0.0%	0.8%	0.0%	0.2%	35.0%	0.0%	10.5%	0.0%	10.5%
Lepidium virginicum	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	5.3%	11.1%	21.1%
Lipochaeta lavarum	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	5.3%	5.3%	0.0%	0.0%
Macroptilium lathyroides	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Marrubium hillebrandii	0.3%	0.4%	0.3%	0.3%	0.3%	45.0%	78.9%	68.4%	50.0%	57.9%

Appendix 3: Part II, Raw monitoring data

	Average percentage cover in transects					Percentage frequency in transects				
Transect #	1	2	3	4	5	1	2	3	4	5
Melinis minutiflora	1.9%	1.5%	6.6%	1.2%	0.1%	45.0%	57.9%	73.7%	50.0%	21.1%
Momordica charantia	0.0%	0.0%	0.0%	0.0%	3.0%	5.0%	0.0%	0.0%	0.0%	42.1%
Myrsine lessenensis	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Nastegis sandwicensis	0.8%	0.0%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	0.0%	0.0%
Nephrolepis multiflora	0.2%	0.0%	0.0%	0.1%	0.0%	30.0%	0.0%	0.0%	11.1%	0.0%
Nicotiana glauca	0.5%	0.1%	0.0%	0.0%	0.0%	45.0%	15.8%	5.3%	0.0%	5.3%
Opuntia ficus-indica	0.4%	0.4%	0.3%	0.4%	0.4%	50.0%	84.2%	63.2%	83.3%	68.4%
Osteomeles anthyllidifolia	0.2%	3.4%	2.8%	0.6%	1.1%	15.0%	52.6%	47.4%	33.3%	26.3%
Oxalis corniculata	0.2%	0.2%	0.1%	0.0%	0.1%	35.0%	36.8%	21.1%	5.6%	21.1%
Panicum pellitum	0.2%	0.3%	0.1%	0.2%	0.1%	35.0%	47.4%	15.8%	16.7%	10.5%
Passiflora suberosa	0.6%	0.2%	0.2%	0.1%	0.8%	60.0%	31.6%	21.1%	11.1%	63.2%
Pellaea ternifolia	0.1%	0.3%	0.4%	0.5%	0.3%	25.0%	63.2%	89.5%	94.4%	52.6%
Pennisetum clandestinum	0.0%	2.0%	0.1%	0.9%	0.8%	0.0%	5.3%	10.5%	5.6%	10.5%
Peperomia leptostachya	0.8%	0.2%	0.0%	0.1%	0.1%	10.0%	36.8%	0.0%	27.8%	10.5%
Petroselinum crispum	0.2%	0.0%	0.0%	0.0%	0.0%	35.0%	5.3%	0.0%	0.0%	0.0%
Pityrogramma calomelanos	0.0%	0.0%	0.0%	0.0%	0.0%	5.0%	5.3%	0.0%	0.0%	0.0%
Plantago lanceolata	0.2%	0.0%	0.1%	0.1%	0.3%	10.0%	5.3%	26.3%	16.7%	10.5%
Plectranthus parviflorus	0.1%	0.4%	0.1%	0.3%	0.1%	15.0%	73.7%	10.5%	55.6%	10.5%
Pleomele aureifolia	0.9%	0.0%	0.8%	0.0%	0.1%	10.0%	0.0%	5.3%	0.0%	5.3%
Pleopeltis thunbergiana	0.1%	0.0%	0.0%	0.0%	0.1%	10.0%	0.0%	0.0%	0.0%	21.1%
Plumbago zeylanica	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	10.5%
Polycarpon tetraphyllum	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	11.1%	5.3%
Polypodium pellucidum	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	10.5%	0.0%	0.0%	0.0%
Portulaca oleracea	0.3%	0.1%	0.0%	0.1%	0.2%	50.0%	21.1%	0.0%	5.6%	31.6%
Portulaca pilosa	0.3%	0.2%	0.2%	0.8%	0.6%	65.0%	47.4%	47.4%	83.3%	63.2%
Psilotum nudum	0.0%	0.1%	0.0%	0.0%	0.0%	5.0%	10.5%	5.3%	5.6%	5.3%
Pteridium aquilinum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Rhynchelytrum repens	9.9%	12.8%	16.1%	18.2%	17.8%	90.0%	100.0%	100.0%	94.4%	100.0%
Salvia coccinea	0.1%	0.0%	0.1%	0.0%	0.5%	15.0%	5.3%	15.8%	5.6%	31.6%
Santalum ellipticum	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%
Schinus terebinthifolius	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	10.5%	0.0%	5.3%
Sicyos spp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	5.3%	0.0%	5.3%
Sigesbeckia orientalis	0.1%	0.1%	0.1%	0.2%	0.1%	15.0%	26.3%	10.5%	44.4%	26.3%
Silene gallica	0.1%	0.1%	0.1%	0.3%	0.1%	25.0%	21.1%	15.8%	50.0%	15.8%
Sonchus oleraceus	0.4%	0.3%	0.3%	0.4%	0.3%	80.0%	68.4%	57.9%	77.8%	52.6%
Sporobolus africanus	1.4%	0.2%	0.9%	0.4%	0.2%	45.0%	10.5%	63.2%	38.9%	42.1%
Stachytarpheta spp.	0.0%	0.0%	0.1%	0.1%	0.1%	5.0%	0.0%	10.5%	27.8%	15.8%
Styphelia tameiameiae	0.2%	1.0%	0.1%	0.0%	0.0%	10.0%	26.3%	5.3%	0.0%	0.0%
Tephrosia purpurea	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%
Tridax procumbens	0.1%	0.0%	0.1%	0.1%	0.1%	10.0%	0.0%	10.5%	27.8%	15.8%
Trifolium sp.	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	5.6%	5.3%
Triumfetta semitriloba	0.2%	0.0%	0.1%	0.0%	0.2%	30.0%	5.3%	10.5%	5.6%	36.8%
Verbena litoralis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Waltheria indica	0.2%	0.4%	0.5%	0.5%	0.2%	40.0%	73.7%	94.7%	94.4%	42.1%
Malva parviflora	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	5.3%	0.0%	15.8%
Wikstroemia monocoia	0.6%	0.6%	4.3%	3.6%	2.2%	40.0%	47.4%	89.5%	83.3%	57.9%
Xylosma hawaiense	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	5.3%	0.0%	0.0%	0.0%
Zinnia peruviana	0.0%	0.0%	0.0%	0.0%	0.1%	5.0%	0.0%	0.0%	0.0%	10.5%
Totals	100.0%	98.4%	97.8%	96.8%	100.7%					
% Frequency in 9.77m2 radius	1	2	3	4	5					
Melinis minutiflora	40.0%	63.2%	78.9%	50.0%	31.6%					
Bocconia frutescens	60.0%	57.9%	15.8%	44.4%	63.2%					
Schinus terebinthifolius	0.0%	0.0%	0.0%	0.0%	0.0%					
Glycine wightii	0.0%	0.0%	0.0%	5.6%	0.0%					
Cinnamomum camphora	0.0%	0.0%	0.0%	5.6%	0.0%					
Passiflora suberosa	60.0%	26.3%	15.8%	33.3%	63.2%					
Dodonaea viscosa	25.0%	84.2%	100.0%	88.9%	57.9%					
% Frequency between stations	1	2	3	4	5					
Melinis minutiflora	60.0%	84.2%	78.9%	77.8%	36.8%					
Bocconia frutescens	70.0%	84.2%	26.3%	61.1%	63.2%					
Schinus terebinthifolius	0.0%	0.0%	5.3%	16.7%	0.0%					
Glycine wightii	0.0%	0.0%	0.0%	11.1%	0.0%					
Cinnamomum camphora	0.0%	0.0%	0.0%	0.0%	0.0%					
Passiflora suberosa	30.0%	47.4%	15.8%	50.0%	78.9%					
Dodonaea viscosa	25.0%	94.7%	84.2%	77.8%	68.4%					

Appendix 4: Monitoring transect station notes

Transect 1:

Station 1: Transect starts at wooden post, makai gate on pipeline road. Not correcting for declination.

Station 2: Station 2 located just above *Alphitonia ponderosa* #1. To be counted, plants must be rooted in plot.

Station 3: Goat pellets are only counted inside a 5.64m radius.

Station 6: Station marker leaning to tree.

Station 7: *Acacia koaia* #1 located approximately 10m downslope from Station 7 on ridge.

Station 13: *Ricinus communis* located between stations 13 and 14.

Station 14: Transect line follows rock wall.

Station 16: *Glycine wightii* located just outside 10m, pollinated by honey bees.

Station 17: *Bonamia menziesii* located on ridge 93m past station 17.

Station 18: *Reynoldsia sp.* seedling located 45m past station 18.

Station 19: *Hunnemannia fumariifolia* located 19m below station 19.

Station 20: Possible native *Bidens* sp. ? Small-leafed beach legume located at station. Station located at makai SE wooden post of Auahi Kanaio cattle guard. Plot located at site of roadside disturbance.

Transect 2:

Station 1: Abundance of kikuyu grass at station due to roadside disturbance. *Alphitonia ponderosa* #3 located at pipeline roadside (not at station marker.)

Station 4: *Dubautia linearis* seedlings present.

Station 6: Kikuyu grass located outside 10m radius. *Sophora chrysophylla* located outside 10m radius.

Station 7: Kikuyu grass 45m after station, 4m east of transect.

Station 8: Unidentified grass at station. *Panicum sp.* just past flowering.

Station 9: About 26m past station, *Psychotria* cf. *mauiensis* (very sweet smell to flowers-Lep.?) collection made.

Station 11: *Gnaphalium sandwicensium* between stations 11 and 12.

Station 13: Transect switched over to ridge to west (lava tube between ridges.) *Protoleria aby.*? 80m between stations 13 and 14.

Station 15: To get to station 16, leave ridge and head west.

Station 19: Road is 56.5 m from station 19, marked with painted number and arrow.

Transect 3:

Station 1: Start of transect just west of deep lave tube.

Station 4: *Gnaphalium sandwicensium* located between transects.

Station 7: *Schinus* seedling: 8cm height, 1 mm basal diameter; farthest east to be observed in transect; destroyed. *Gnaphalium sandwicensium* observed between stations 7 and 8.

Station 8: *Schinus*: 0.75m height; 2cm basal diameter; destroyed. *Schinus*: 0.2m height; 4mm basal diameter; destroyed.

Station 9: *Gnaphalium sandwicensium* between stations 9 and 10.

Station 10: *Psidium guajava* at 56m mark between stations 10 and 11, 3m to west. *Gnaphalium sandwicensium* between stations 10 and 11.

Station 11: 6m tall *Grevillea robusta* located at 90m mark between stations 11 and 12, 5m east of transect line.

Station 12: Cat droppings within 10m of station. *Lycosa cf. hawaiiensis* seen on pipeline road; *Cyclosa* webs common throughout reserve.

Station 14: *Schinus* located 30m down transect line. Black francolin seen between stations along pipeline road.

Station 15: Cat feces present in plot.

Station 17: Transect cuts off ridge onto lava flats toward the east.

Appendix 4: Monitoring transect station notes

Transect 3:

Station 18: *Dubautia linearis* between stations.

Station 19: Painted blue arrow and transect number on road 18m from station 19.

Transect 4:

Station 1: Start on ridge above lava tube. *Kalanchoe sp.* between stations 1 and 2. *Gnaphalium sandwicensium* between stations 1 and 2. Fence at 46m mark. Lava tube between 90 and 100m mark. Howarth should explore cave.

Station 2: Station located above lave tube. Honey bee nest near lava tube.

Station 3: First *Glycine wightii* observed in transects.

Station 4: *Gnaphalium sandwicensium* located between stations 4 and 5.

Station 5: Station located at small lave tube filled with *Nephrolepis*.

Station 10: Whole transect is on east side of lava tube ridge. *Heteropogon contortus* between transects. *Oplismenus* located in lava tube at 2320' elevation.

Station 11: *Sophora chrysophylla* between stations 11 and 12 in lava tube. Barn owl roosting in lava tube between stations 11 and 12.

Station 12: *Glycine wightii* located in lava tube between stations 12 and 13.

Station 14: *Leucaena leucocephala* located between stations.

Station 18: Transect ends 7m before this station on road (93m mark.) Carnation located on roadside.

Transect 5:

Note: Transect 5 was completed on two days, May 12, 1992 and October 27, 1992.

Station 4: Numerous *Dodonaea* seedlings occur within the 5.64 m^2 radius of Station 4. Transect line follows ridge to the west.

Station 6: *Chamaesyce celastroides* seedling present at station. *Chamaesyce* reproduction likely to occur after fencing. Transect heads off ridge.

Station 10: Transect stays on small ridge heading downhill.

Station 11: Pig and cat feces present within plot.

Station 12: Station located within flat, barren, rocky area. Cat feces present within plot. *Dodonaea* seedlings present within plot.

Station 16: Weedy Malvaceae present within plot (cf. *Angustifolia*.)

Station 17: Station located on pu'u approximately 10m past dirt road.

Station 18: Station head toward Keep Out sign on ridge.

Note: Estimates for bare ground cover in transect 1 were calculated by summing plant ground cover and subtracting from 100%.

Note: The **"Blue Marker"** category in the data summary sheets designates whether a transect station was marked by a blue paint dot to facilitate the station's location.

Appendix 5: Sample and blank field form for monitoring

Monitoring Protocol: Sample Field Form
(example values; not true data)

Transect# 1	Station # 3	Date: 3 / 12 / 92	Between Stations + / -	Goat Pellets	
				Old	New
SPECIES LIST	% Cover 5.64m	9.77m + / -		3	1
Melinis minutiflora	R	+	+		
Bocconia frutescens	0	-	+		
Schinus terebinthifolius	0	-	-		
Glycine wightii	0	-	-		
Cinnamomum camphora	0	-	-		
Passiflora subpeltata	X	+	+		
Dodonaea eriocarpa	1	+	+		
Anagallis arvensis	0				
Ageratina adenophora	0				
Asclepias	1				
Axonopus	0				
Bidens pilosa	X				
Carex wahuensis	0				
Chamaecrista	1				
Cocculus	0				
Conyza	0				
Desmodium uncinatum	0				
Doryopteris	0				
Emilia spp.	0				
Hypochoeris glabra	1				
Hypochoeris radicata	0				
Indigofera	0				
Lantana camara	2				
Mariscus hillebrandii	0				
Nephrolepis	0				
Opuntia	1				
Osteomeles	0				
Panicum	0				
Pellaea ternifolia	R				
Pennisetum (Kikuyu)	0				
Petroselinum crispum	0				
Pleomele	0				
Portulaca pilosa	R				
Rhyncheletrum	3				
Silene	0				
Sonchus	0				
Sporobolus africanus	0				
Tridax	0				
Waltheria	0				
Wikstroemia	0				

Goat Pellets

# Goat Pellets
0=0 1=1-25
2=25-50 3=50-100
4=100-500
5=500+

NOTES

"A" "+" or "-" indicates presence or absence

Key To Species Cover:
R= <1%
X= 1-5%
1=5-25%
2=25-50%
3=50-75%
4=75-100%

Values from key recorded under heading "% Cover 5.64m"

Elevation:2700'

% Bare Ground:1

Uses "Species Cover Key" Values

Blue Dot Marker: +

Compass Bearing To Next Station:170

GPS Reading:
20d37'44" N
156d18'36"W

Extra space for additional plant species

Appendix 5: Blank field form for monitoring

Transect#	Station #	Date:	Between Stations	Goat Pellets	
SPECIES LIST	% Cover 5.64m	9.77m + / -	+ / -	Old	New
Melinis minutiflora					
Bocconia frutescens				# Goat Pellets	
Schinus terebinthifolius				0=0 1=1-25	
Glycine wightii				2=25-50 3=50-100	
Cinnamomum camphora				4=100-500	
Passiflora subpeltata				5=500+	
Dodonaea eriocarpa					
Anagallis arvensis					
Ageratina adenophora					
Asclepias					
Axonopus					
Bidens pilosa					
Carex wahuensis					
Chamaecrista					
Cocculus					
Conyza					
Desmodium uncinatum					
Doryopteris					
Emilia spp.					
Hypochoeris glabra					
Hypochoeris radicata					
Indigofera					
Lantana camara					
Mariscus hillebrandii					
Nephrolepis					
Opuntia					
Osteomeles					
Panicum					
Pellaea ternifolia					
Pennisetum (Kikuyu)					
Petroselinum crispum					
Pleomele					
Portulaca pilosa					
Rhyncheletrum					
Silene					
Sonchus					
Sporobolus africanus					
Tridax					
Waltheria					
Wikstroemia					

NOTES

Key To Species Cover:
R= <1%
X= 1-5%
1=5-25%
2=25-50%
3=50-75%
4=75-100%

Elevation:

Blue Dot Marker:

Compass Bearing To Next Station:

GPS Reading:

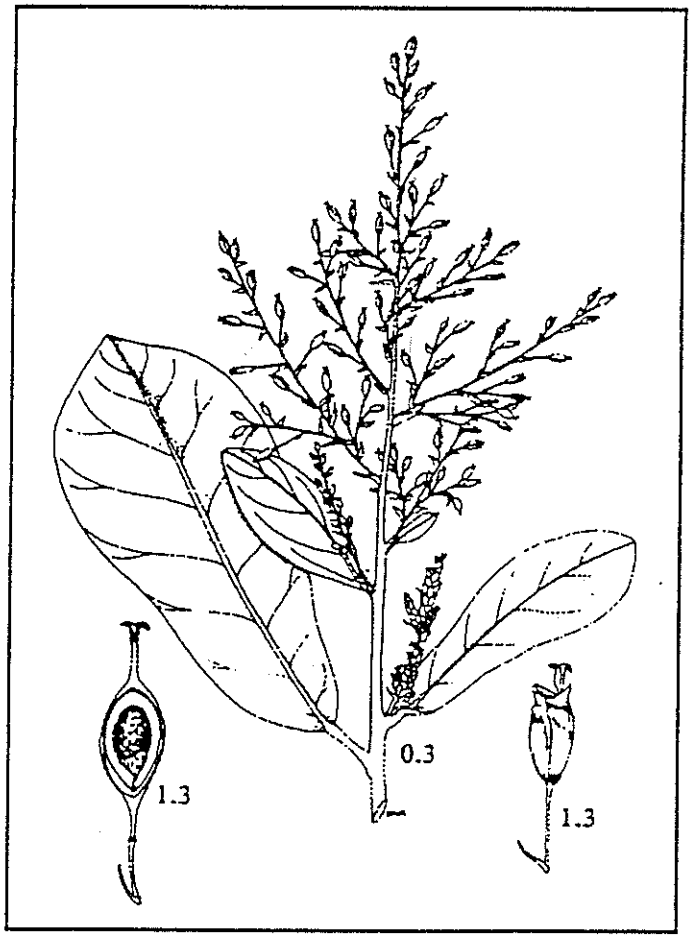
APPENDIX 6: Invasive weed identification, Kanaio NAR

Besides alien browsing animals, invasive species of alien plants are the greatest threat to the long-term conservation of Kanaio NAR. This appendix is intended to provide a brief introduction to managers regarding alien plants currently perceived as a threat, as well as those species not already well-established on Maui. Two species, fountain grass (*Pennesetum setaceum*) and ivy-fruited gourd (*Coccinia grandis*) have been reported from Maui but have never been recorded from Kanaio NAR. If they were to become established, they would likely permanently alter the biology of the reserve to the detriment of native species. Early detection is the key to early mechanical control. Such early erradication of the first populations of an invasive plant is likely to be a critical element of successful control.

Appendix 6: Invasive weed identification, Kanaio NAR

Bocconia frutescens

HISTORY & HABITAT: *Bocconia frutescens* (Papaveraceae) is a large-leaved, soft-wooded shrub/tree to 20 feet (6m) tall, native to Central and South America and the West Indies. It was first noted in the Kanaio area in 1920 when only a single 8 ft. tall *Bocconia* plant growing on the roadside of the old government trail in Kanaio was observed. *Bocconia* has spread widely since, and is currently found at 1600 to 2780 feet (490-850 m) elevation. Very common in many areas, this woody shrub can reach the height and dimensions of a dry forest tree. **THREAT IN RESERVE:** *Bocconia* may compete with and shade native vegetation, contributing to the lack of native seedling establishment. **DISPERSAL MECHANISM:** The seeds are encased in a capsule and attached to a scarlet aril which facilitates the dispersal of *Bocconia* seeds by fruit-eating birds, as the distribution of seedlings would suggest (away from parent plants and under other trees). **CONTROL:** Despite its large size, *Bocconia* is soft-wooded, and it is relatively easy to fell even large trees. Cut stumps should be treated with a suitable herbicide, such as GARLON 3A. It is recommended that this species be controlled in the reserve in those areas of most intact native vegetation.

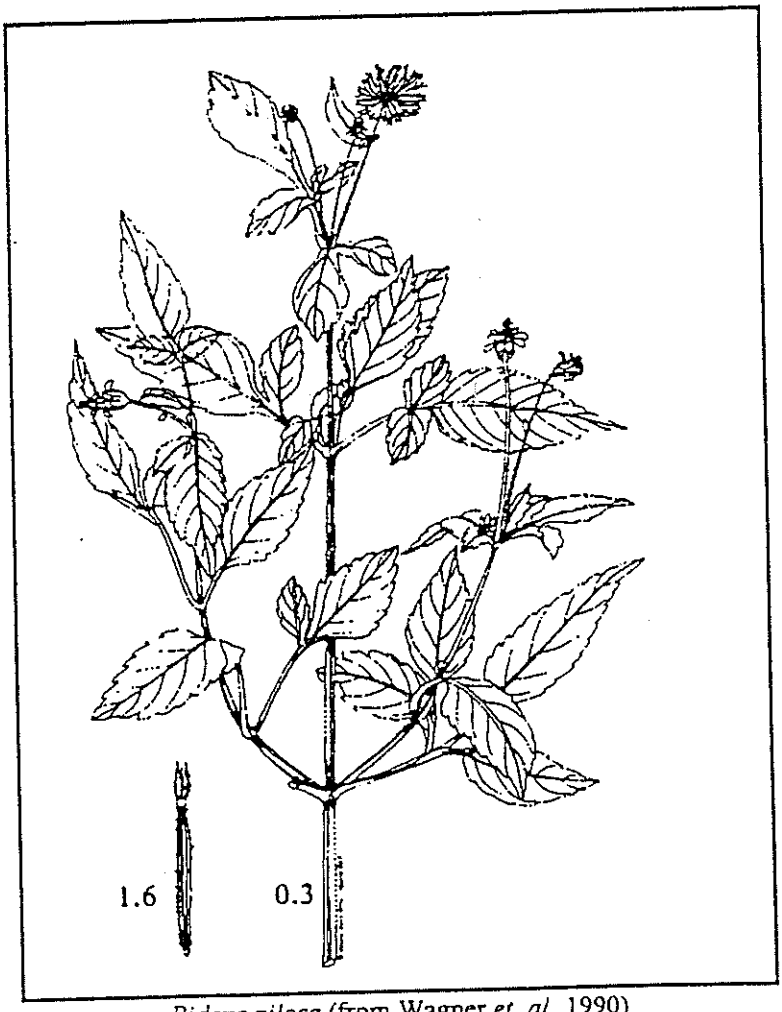


Bocconia frutescens (from Wagner *et.al.* 1990)

Appendix 6: Invasive weed identification, Kanaio NAR

Bidens pilosa — Spanish needle, Beggartick

HISTORY & HABITAT: Present in Hawai'i prior to 1945 (Hillebrand 1888), Spanish needle, *Bidens pilosa* (Asteraceae), native to tropical America, is an annual herb to just over 3 feet (1 meter) tall that is widespread in disturbed areas on all of the main islands. **THREAT IN RESERVE:** *Bidens pilosa* seasonally dominates the understories of many native trees in the reserve and may interfere with tree seedling recruitment. **DISPERSAL MECHANISM:** The species is ubiquitous throughout the reserve and produces achenes with barbed awns that disperse easily on mammals and birds. **CONTROL:** Though probably uncontrollable on a large scale due to its ubiquity and local abundance, small-scale control may be practical and advisable within localized, intensely managed units, such as under the canopy of particularly rare native trees or small groves.

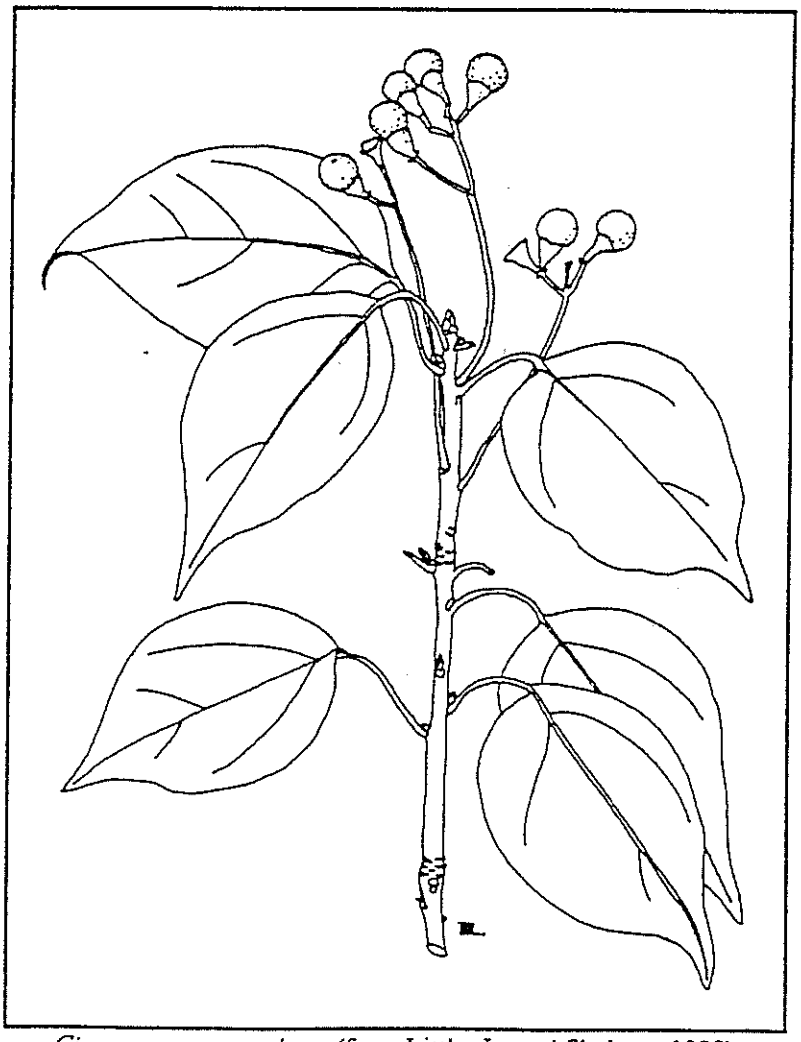


Bidens pilosa (from Wagner *et. al.* 1990)

Appendix 6: Invasive weed identification, Kanaio NAR

Cinnamomum camphora — Camphor tree

HISTORY & HABITAT: Camphor tree (Lauraceae), native to Asia, grows to 40 feet (12 m) height locally. Camphor tree was first cultivated on O'ahu in 1927 (Wagner *et al.* 1990); it has only recently begun to naturalize in the reserve and is known from several very large trees and scattered seedlings and saplings. **THREAT IN RESERVE:** Some individuals in the reserve are up to 30 feet (9 m) tall with basal diameters exceeding 12-14 inches (30-35 cm). Camphor has the potential to spread into the reserve and compete with native tree species and shade out native tree seedlings. **DISPERSAL MECHANISM:** Camphor trees in the reserve are probably derived from planted and naturalized trees from 'Ulupalakua to Kanaio homesteads. Camphor seeds are encased in a berry and are likely distributed by fruit-eating birds. **CONTROL:** This species should be controlled opportunistically while it is still in its incipient invasion stages, probably by using the cut stump treatment on larger trees. A herbicide such as GARLON 3A should then be immediately applied to the exposed cambium, preferably by painting the flat stump to avoid run off or spray drift (from Sine 1992).

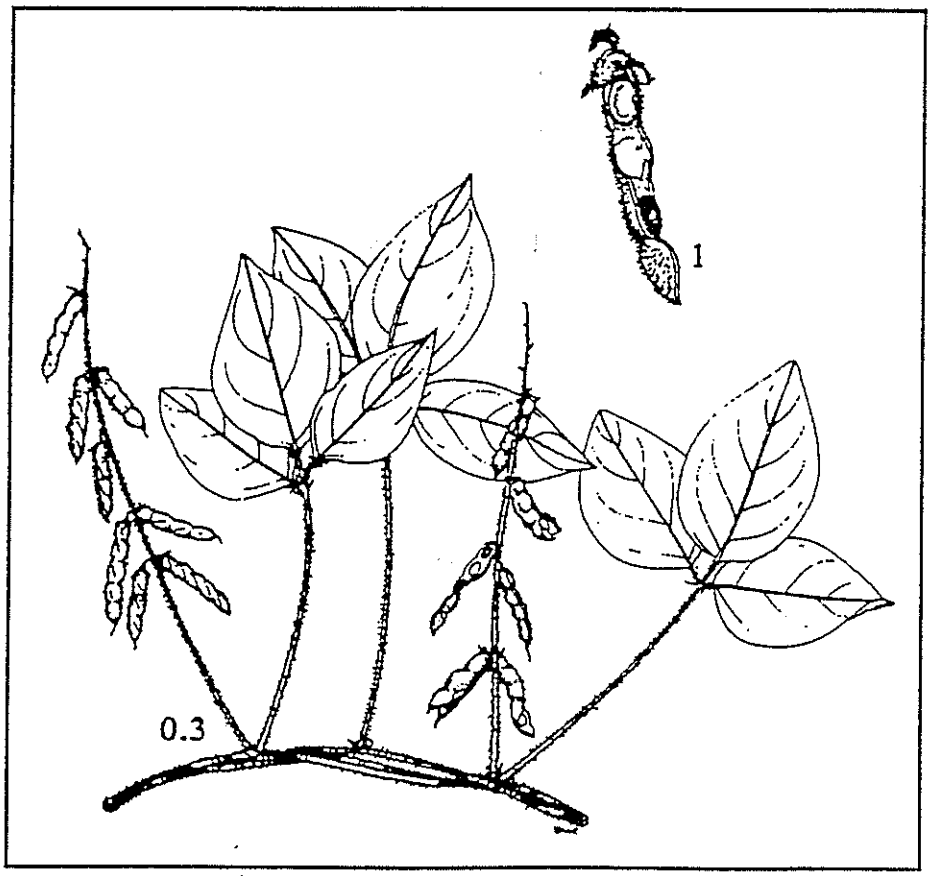


Cinnamomum camphora (from Little, Jr. and Skolmen 1989)

Appendix 6: Invasive weed identification, Kanaio NAR

Glycine wightii

HISTORY & HABITAT: *Glycine wightii* (Fabaceae) is the most recent invasive threat in the reserve, becoming established within the last five years. A relative of the soybean, *G. wightii* is an aggressive perennial vine native to Central America, South America, and the West Indies (Wagner *et al.* 1990). It was first known on Maui in 'Ulupalakua at least since the 1970s, some 6.5 km (4 mi) west of the reserve. *Glycine* grows in thick mats over fences and smothers trees and shrubs on the roadside. However, just a few feet away, across the fence and in pastures, *Glycine* is absent because of grazing pressure by domestic cattle. **THREAT IN RESERVE:** Five widely scattered individuals of this species were located in the reserve during the course of this study. No individuals were noted in stations along vegetation transects. However, in the coming years, it may prove to be a serious management problem for the reserve, especially in areas protected from browsing. **DISPERSAL MECHANISM:** The seeds of *Glycine* are enclosed in pods with a sticky, "velcro-like" surface, not dissimilar to those found in Spanish clover, *Desmodium*. They are dispersed by goats, cattle, humans, pigs and birds. **CONTROL:** Individual plants should be opportunistically controlled as encountered, and locations noted for future monitoring. In areas of wider infestation with relatively little native vegetation and more weed dominance, an herbicide such as glyphosate might be utilized to check its possible spread.

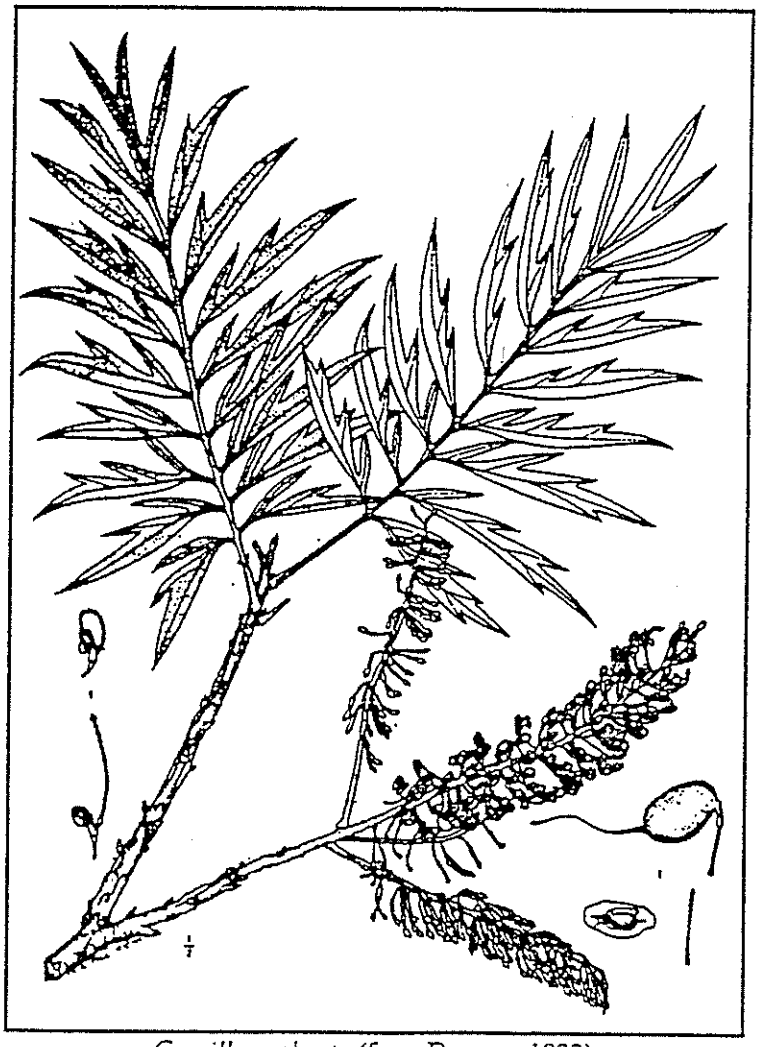


Glycine wightii (from Wagner *et al.* 1990)

Appendix 6: Invasive weed identification, Kanaio NAR

Grevillea robusta Silk oak

HISTORY & HABITAT: Silk oak, *Grevillea robusta* (Proteaceae), native to Australia, is a tree up to 70 feet (21 m) tall. Introduced to Hawaii around 1880, it is now naturalized on all islands where planted, including Maui. Several trees have been planted and have naturalized in 'Ulupalakua, Kaunauhane, and Kanaio homesteads. **THREAT IN RESERVE:** Several small trees are growing in or very near the western boundary of the reserve, two individuals very near the main highway at 1800 feet (550 m) elevation. Given its potential size and having demonstrated its ability to naturalize, *Grevillea robusta* has the potential to become a future problem if allowed to spread unchecked. **DISPERSAL MECHANISM:** The flat, elliptic seeds, with lighter winged margins, are probably wind and gravity dispersed. **CONTROL:** As with Christmas berry and camphor, silk oaks are spreading into the reserve from planted and naturalized trees in 'Ulupalakua, Kaunauhane, and Kanaio homesteads. The few trees of this species should be destroyed before they spread further, utilizing the cut stump method and treatment with a suitable herbicide such as GARLON 3A.

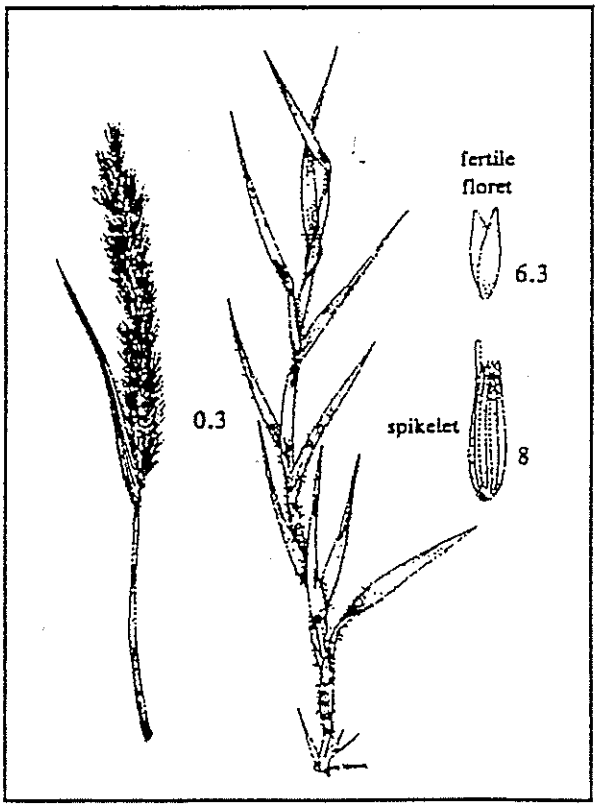


Grevillea robusta (from Degener 1933)

Appendix 6: Invasive weed identification, Kanaio NAR

Melinis minutiflora Molassesgrass

HISTORY & HABITAT: Molassesgrass, *Melinis minutiflora* (Poaceae), native to Africa, is a vigorous mat-forming grass to over 3 feet (1 meter) tall. The foliage is sticky with aromatic and highly flammable resins. **THREAT IN RESERVE:** When goats were removed elsewhere in Hawaiian lowlands, the buildup of this flammable foliage has encouraged wildfires. Based on observations in Kanaio and elsewhere on Maui over the last ten years, it appears that molassesgrass has increased even in the presence of grazing by goats. In the reserve, molassesgrass is now common almost everywhere above 1800 feet (550 m) elevation. Furthermore, molassesgrass recovers well after fire, eventually coming to dominate burned areas. Therefore, the fencing of the reserve creates the potential for molassesgrass to spread and increase the fire hazard which would in turn destroy native vegetation and perpetuate its further dominance in the reserve. **DISPERSAL MECHANISM:** Seeds are small and sticky when wet, perhaps hitchhiking on animals or humans. **CONTROL:** After control of feral goats in the mid 1980s, molassesgrass has proved a serious invader in mid-elevation leeward sites of Haleakala National Park (Kaupo Gap), locally dominating ground cover and creating a fire hazard. In the fall of 1990, Haleakala National Park attempted to control molassesgrass with glyphosate (ROUNDUP) delivered in a spray rig by helicopter. The object was to delay molassesgrass spread until the initial disturbance levels were reduced and recovery of native vegetation was well advanced. Initial results of this experimental treatment are encouraging.

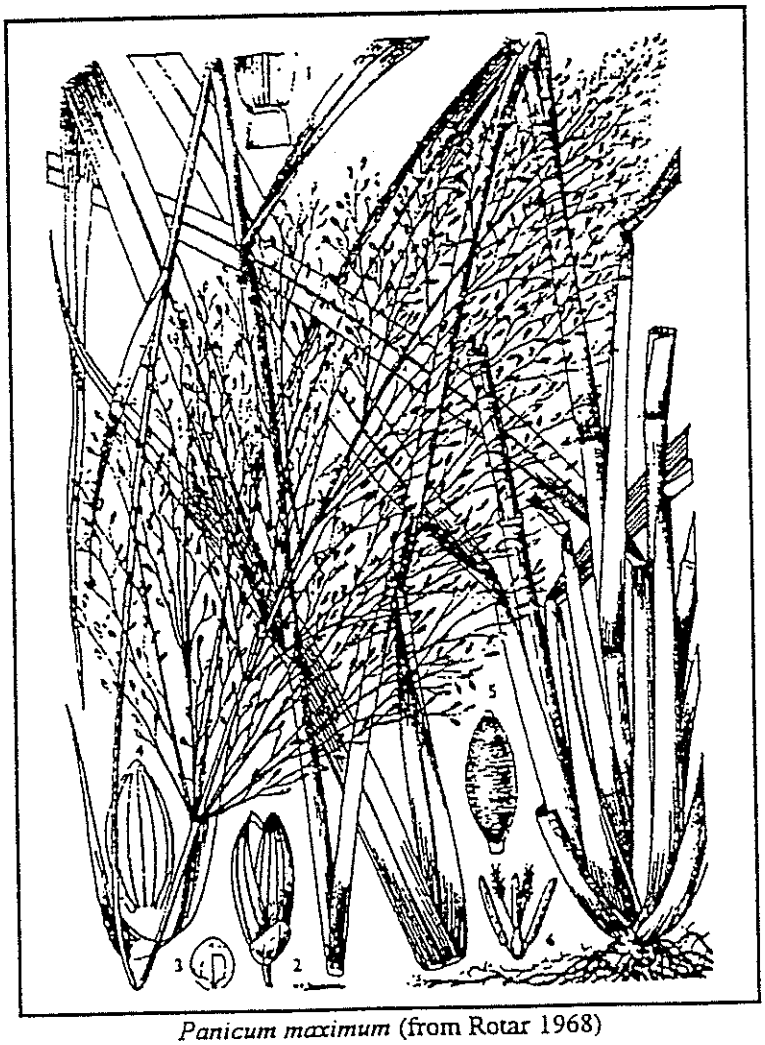


Melinis minutiflora (from Wagner *et al.* 1990)

Appendix 6: Invasive weed identification, Kanaio NAR

Panicum maximum Guinea grass

HISTORY & HABITAT: Native to Africa, Guinea grass (Poaceae) is an aggressive alien species that can develop dense thickets, especially in the drier leeward and lowland windward slopes. **THREAT IN RESERVE:** Two small patches of *Panicum maximum* have been observed in the reserve, both on the roadside at 1640 and 1800 feet (510 and 550 m) elevation along the main highway No. 31 through the reserve. One occurs at and around the cattle guard marking the Auwahi and Kanaio districts, and the second in the western half of the reserve. This is an extremely aggressive weed on leeward deeper soil sites such as on Lana'i where the species has become a dominant species over the past forty years (R. W. Hobdy, pers. comm.). It is not know whether this species will prove to be as invasive on more barren lava sites. **DISPERSAL MECHANISM:** Seeds of Guinea grass are most probably wind dispersed. **CONTROL:** The few localized patches of *P. maximum* should be destroyed while only a minimum of effort is required.

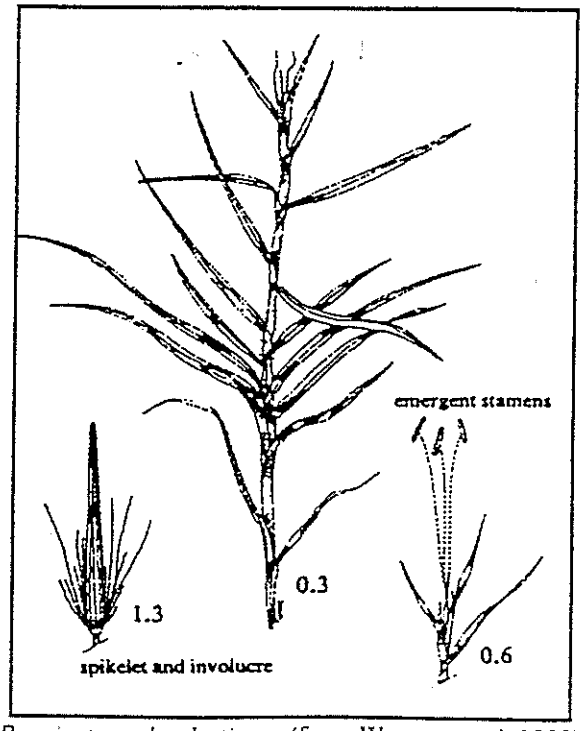


Panicum maximum (from Rotar 1968)

Appendix 6: Invasive weed identification, Kanaio NAR

Pennisetum clandestinum Kikuyu grass

HISTORY & HABITAT: Kikuyu grass, *Pennisetum clandestinum* (Poaceae), native to Africa, is the most disruptive dry forest weed in Auwahi district adjacent to Kanaio NAR. It is because of the large scale invasion of this weed species that Auwahi, botanically richer than Kanaio, was not recommended for protection. Kikuyu grass is, for the most part, sparse in the Kanaio district, probably due to the relatively unweathered substrate and the lower elevation and drier habitat of the reserve compared with Auwahi. Kikuyu grass was planted along the pipeline road that marks the upper boundary of the reserve in the 1940s after the collapse of populations of Maui pamakani (*Ageratina adenophora*) following the introduction of biocontrol organisms. **THREAT IN RESERVE:** Currently, it is found sparingly throughout the reserve from the main highway up to the pipeline road. Some populations are definitely associated with disturbance adjacent to the road surface but other patches occur scattered on the ridge tops. Though currently only a marginal threat, kikuyu grass' pervasiveness in the adjacent Auwahi district demonstrates its potential for future spread and dominance if left unchecked. **DISPERSAL MECHANISM:** It is presumed that more remote patches of kikuyu grass on scattered ridge tops are a product of dispersal of viable stolon or rhizome pieces in the droppings of cattle. Though somewhat achlorotic, these patches appear to be spreading in the more shaded environment of the understory of dryland trees. This species flowers only when mechanically disturbed but apparently does not produce seeds. **CONTROL:** Kikuyu grass is sensitive to applications of ROUNDUP (glyphosate) even at a 1% concentration and many plants will succumb to a single foliar treatment. Though not the highest of priorities, it is recommended that the patches of kikuyu grass in the reserve be eliminated by herbicide application.

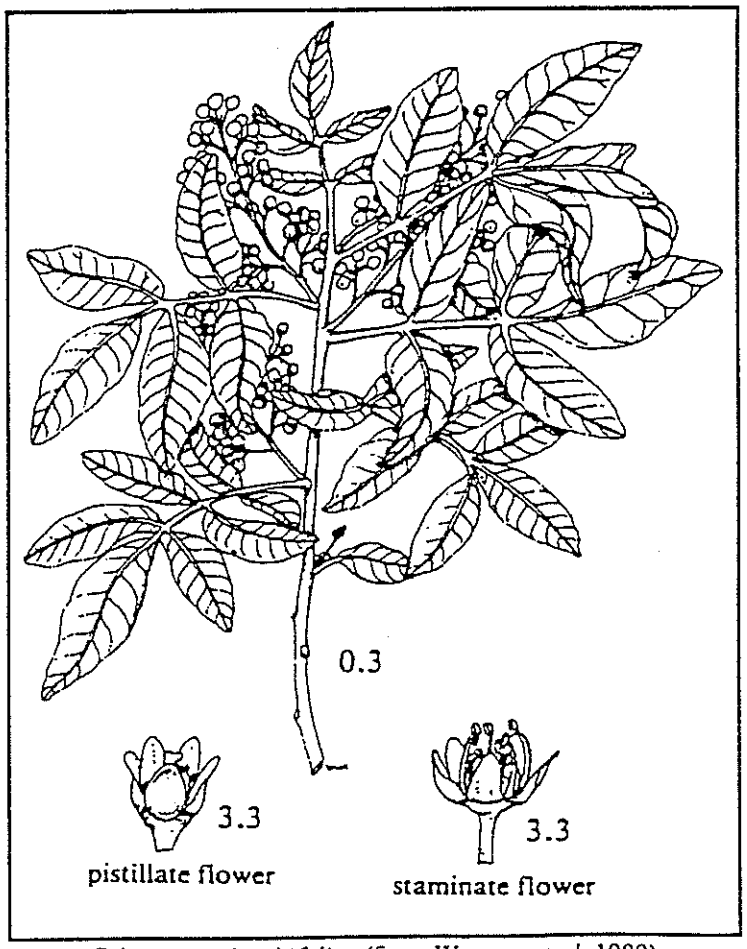


Pennisetum clandestinum (from Wagner *et al.* 1990)

Appendix 6: Invasive weed identification, Kanaio NAR

Schinus terebinthifolius Christmas berry

HISTORY & HABITAT: Christmas berry, *Schinus terebinthifolius* (Anacardiaceae), native to Brazil, is a small tree that forms dense thickets. Though Christmas berry has been in Hawai'i since the early 1900s, it has apparently invaded Kanaio NAR only within the last decade or so. **THREAT IN RESERVE:** Dense stands of this species dominate the vegetation just outside the northwest corner of the reserve. Currently within the reserve, it occurs at 1920 to 2780 feet (585-850 m) elevation. At vegetation monitoring stations within the reserve, *Schinus* occurs sparsely at only 3.2% of the stations with a low average cover of 0.02%. **DISPERSAL MECHANISM:** The seeds of Christmas berry are encased in bright red fruits which are dispersed locally by alien fruit-eating birds, such as mynah (*Acridotheres tristis*) and house finch (*Carpodacus mexicanus*). **CONTROL:** Christmas berry should be controlled while mechanical control is still feasible. A herbicide such as GARLON 3A (triclopyr) can be applied to the cut stump as soon as possible after cutting by painting the flat stump. The herbicide, applied either undiluted or in a 1:1 ratio with water, must reach the cambium and run down the sides to the root collar (from Sine 1992).

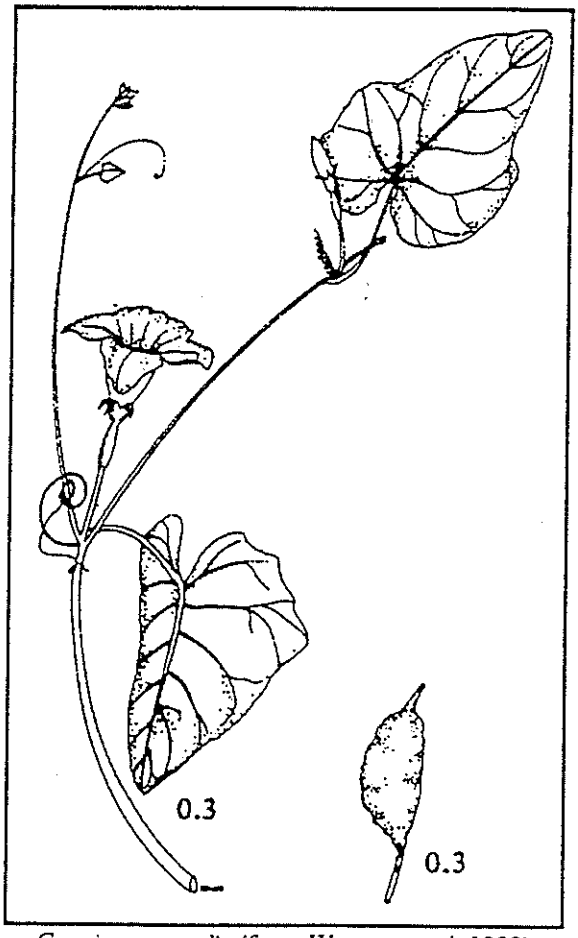


Schinus terebinthifolius (from Wagner *et al.* 1990)

Appendix 6: Invasive weed identification, Kanaio NAR

Coccinea grandis — Ivy-fruited gourd

HISTORY & HABITAT: In October 1992, a first plant of the smothering vine *Coccinea grandis* (Cucurbitaceae) was discovered on Maui in Kahului's industrial district; the single plant discovered and destroyed by R.H. Hobdy (pers. comm.). *Coccinea grandis* is dioecious (with separate male and female plants) and native to Africa, Asia and Australia. It has spread very rapidly on O'ahu, coming to dominate cover by developing thick mats of interlaced stems and leaves over trees, in a fashion not unlike *Glycine wightii*. **THREAT IN RESERVE:** Its preference for dry, hot environments and its smothering habit make *Coccinea grandis* well suited to potentially establish and choke out native trees and seedlings in Kanaio NAR. If *Coccinea* does become established, it would not only trigger the decline of much of the remaining biota but also transform the visual landscape to even the most casual of observers. **DISPERSAL MECHANISM:** The seeds inside the glabrous red fruits of *Coccinea grandis* are most likely bird dispersed. **CONTROL:** Managers of Kanaio NAR should be trained to identify *Coccinea grandis* and other key invasive species of dryland forests in Hawai'i. Such awareness is essential for the rapid response required for cost-effective, efficient control of an alien weed invasion in or near the reserve.

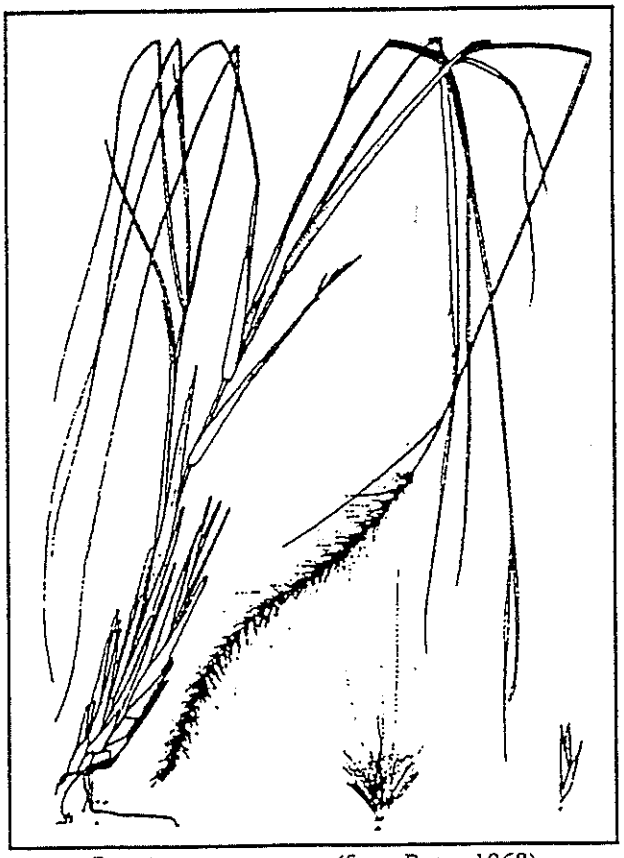


Coccinea grandis (from Wagner *et al.* 1990)

Appendix 6: Invasive weed identification, Kanaio NAR

Pennisetum setaceum — Fountain grass

HISTORY & HABITAT: Fountain grass (Poaceae) is probably the best example of an invasive species that is extremely damaging to dryland forests elsewhere in the Hawaiian Islands but does not occur in the reserve. Currently, fountain grass is restricted on Maui to two small but persistent populations in Wailuku. Native to northern Africa, it has been cultivated and naturalized in dry, open places such as barren lava flows and cinder fields (Wagner *et al.* 1990). **THREAT IN RESERVE:** With the eventual exclusion of feral goats from Kanaio NAR, the threat of wildland fires is going to be magnified due to the buildup of fine fuels from the alien grasses and vegetation already established there. The cycle of wildland fire to alien weed establishment is perpetuated until aggressive invaders come to completely dominate an area, making it biologically and aesthetically worthless. Fountain grass, as a fire-adapted species, burns swiftly and hot, causing extensive damage to associated dry forest tree species, then quickly reestablishes after fire (Wagner *et al.* 1990). **DISPERSAL MECHANISM:** The seeds of fountain grass are wind and gravity dispersed. **CONTROL:** It is imperative that fountain grass not be allowed to gain a foothold on leeward East Maui and in the reserve. Managers should be trained to recognize such an insidious invader and take immediate action to eradicate plants which may someday appear.



Pennisetum setaceum (from Rotar 1968)