ALIEN PLANTS IN HALEAKALA NATIONAL PARK

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ABSTRACT

The alien plant problems of Haleakala National Park are substantial but may be fewer than those of other Hawaiian natural areas, partly because most of the Park is at high elevation (75% above 5,000 ft or 1,525 m). However, potential problems with alien plants are still not clear because of the suppression of all vegetation by intense herbivory by feral goats (*Capra hircus*), which has occurred until very recently. Alpine cinder desert and dense rain forest above 4,000 ft (1,220 m) have so far proved relatively resistant to invasion. High-elevation grasslands, bogs, and shrublands have undergone degradation and alien plant invasion as long as feral animals have been present, but these areas will undergo at least partial recovery as long as these ungulates are under control. In the absence of feral goats, native and alien plant species are rapidly increasing in leeward Kaupō Gap. The threat of wildland fire due to fuel buildup by spreading alien grasses has the potential to negate recovery. Control of feral pigs (*Sus scrofa*) may slow the spread of alien plants below 4,000 ft (1,220 m) in Kīpahulu Valley, but dispersal of strawberry guava (*Psidium cattleianum*) and other weeds will continue, and active vegetation management is needed to prevent the decline and disappearance of rare native species. The following alien plant species must be controlled to avoid future irreversible vegetation changes: strawberry guava (above 3,000 ft or 910 m), molasses grass (*Melinis minutiflora*), blackberry (*Rubus argutus*), Australian tree fern (*Cyathea cooperi*), kāhili ginger (*Hedychium gardnerianum*), gorse (*Ulex europaeus*), pines (*Pinus*, three species), and *Eucalyptus globulus*. Clidemia (*Clidemia hirta*), banana poka (*Passiflora mollissima*), and fountain grass (*Pennisetum setaceum*), among the most invasive alien species in Hawai'i overall, are present on Maui and threaten Haleakala National Park. These threats will be reduced but not eliminated as feral animals are controlled in the Park.

INTRODUCTION

Although alien plants create serious problems for preserving native ecosystems in Haleakala National Park, these problems are reduced somewhat because much of the Park is at high elevation (Fig. 1). About 75% is located above 5,000 ft (1,525 m); 80% is above 4,000 ft (1,220 m). Haleakalā has a rich native vascular flora in spite of its relatively small area (12% as large as Hawaii Volcanoes National Park) but has substantially fewer alien plant species (Table 1). Haleakala National Park largely lacks extensive areas of highly flammable alien grasses (*Andropogon virginicus, Schizachyrium condensatum*, and others), although approximately 1,235 a (500 ha) in Kaupō Gap and the western edge of the Manawainui planeze are vulnerable. The Park also lacks large areas susceptible to dominance by low-elevation alien tree and shrub species such as koa haole *(Leucaena leucocephala)*. Having stated that the alien plant problem at Haleakalā is relatively manageable, we believe real problems do exist and urgently require active management to avoid loss of species and ecosystems. In this paper, we attempt to assess the Park's alien plant problems and describe a program to deal with the worst of them.

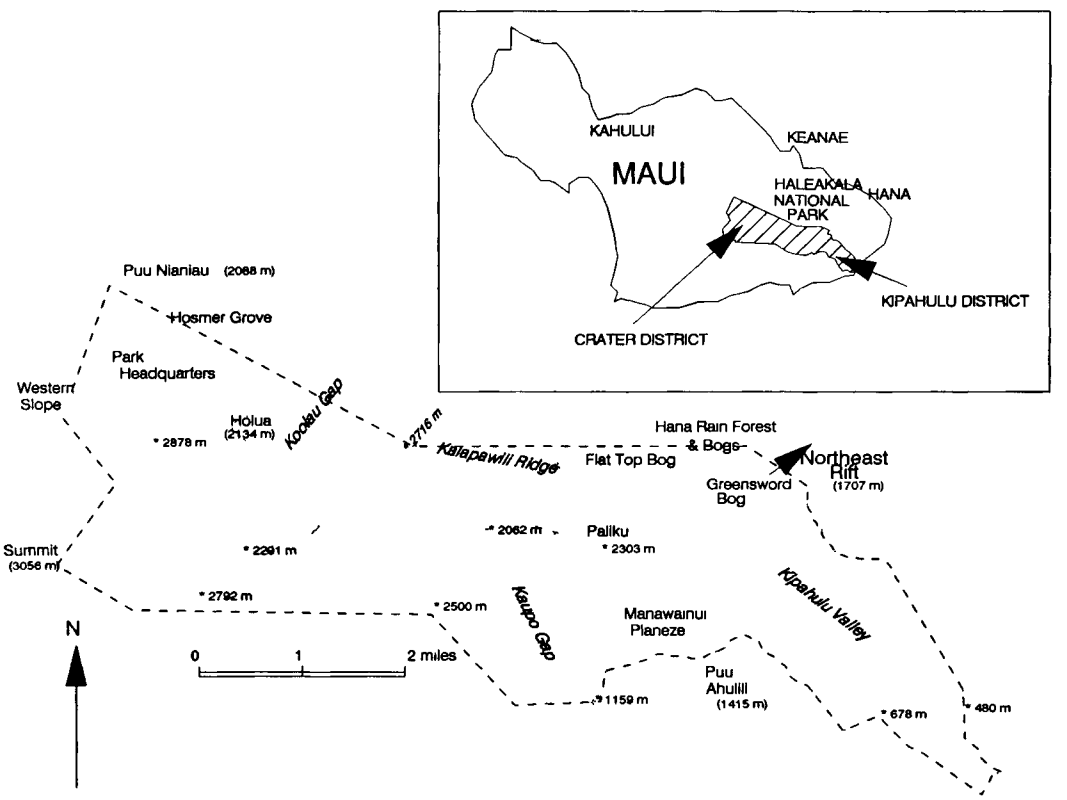

Figure 1. Haleakala National Park (elevations in meters).

Table 1. Comparison of vascular floras of Haleakala and Hawaii Volcanoes National Parks.*

	Haleakala	Hawaii Volcanoes
Park area (ha)	11,400	93,000
% of park area above 6,000 ft (1,500 m)	ca. 75	ca. 20
Number of ferns and fern allies		
Indigenous	41	35
Endemic	63	60
Historic Introductions	12	14
Number of gymnosperm species (all introduced)	19	14
Number of flowering plant species		
Indigenous	57	44
Endemic	189	174
Polynesian Introductions	21	20
Historic Introductions	282	574
Total native vascular plant species	334	313
Total introduced vascular plant species	334	602

*Based on compilation of data from Medeiros and Loope for Haleakala and from Higashino *et al.* 1988 a for Hawaii Volcanoes. Taxonomic status used is that of Wagner *et al.* 1990.

DISTURBANCE HISTORY AND MODES OF INTRODUCTION

The Crater district of Haleakala National Park has a history of human disturbance, probably dating back to Polynesian practices of burning and harvesting birds for food and feathers. Disturbance was greatly accelerated with the introduction of goats (*Capra hircus*) and cattle (*Bos taurus*) to Maui in the 1790s. Wilkes (1845) reported seeing "a few goats" as well as "bullock" tracks and those of wild dogs (*Canis domesticus*) near the summit of Haleakalā Volcano in 1841. Domestic cattle were brought into the Crater beginning in the late 1800s and were at least occasionally taken up to the Kalapawili grasslands to graze (von Tempski 1940). Degener (1930) lamented the damage to native vegetation by cattle on his 1927 trip into Ko'olau Gap. The dominance of alien grasses in the pasture-like areas below Hōlua and at Palikū probably had its origin

in this grazing during the early 1900s. Many alien plant species were undoubtedly introduced to the Crater with cattle and horses (*Equus caballus*). Cattle grazing ceased in the 1930s, soon after the Park was designated.

The first feral pigs (*Sus scrofa*) were seen in the Crater in the 1930s, apparently having come up through Ko'olau Gap from piggeries near the coast (Diong 1983); pigs later became widespread in the Crater and surrounding forests. The mid-elevation (2,700 to 5,400 ft or 825-1,650 m) portion of Kīpahulu Valley was reportedly near-pristine, showing little or no pig activity when a 1967 Kīpahulu Expedition explored the area; however, pigs were sighted in the upper and lower parts of the Valley (Warner 1968; Diong 1983). East Maui's montane bogs were nearly pristine when first explored in the early 1970s. When Vogl and Henrickson (1971) visited Flat Top Bog in 1969, gosmore (*Hypochoeris radicata*) was the only alien plant recorded, with 0.1% cover. When the larger bogs were first visited in the early 1970s, there was very low cover of alien plants, although 10 alien species were present (Loope *et al.*, in press).

Much of the Kīpahulu district below 2,000 ft (610 m) was used intensively for agriculture by the pre-European contact Hawaiians. These lower slopes were used for sugar (*Saccharum officinarum*) and pineapple (*Ananas comosus*) production and eventually converted to pasture (Krauss 1980).

The experimental plantings by the forester Ralph Hosmer in 1910 at 6,800 ft (2,075 m) and 8,500 ft (2,590 m) provided a seed source for alien species, especially blue gum (*Eucalyptus globulus*). Eucalyptus has spread extensively in a watercourse downslope from the 8,500 ft elevation grove. Extensive plantings of pines and other conifers for "watershed improvement" (R. Hobdy, pers. comm.) on ranchland below Hosmer Grove in the early 1940s were the apparent source of invasive pines. Three planted pine species (*Pinus radiata*, *P. patula*, and *P. pinaster*) perpetually establish fast-growing seedlings on Park lands, and if unchecked these species would eventually convert large expanses of native shrubland to alien coniferous forest.

Military use of the area below Park headquarters during World War II, accompanied by transport of materials from O'ahu and other parts of the world, was a significant source of alien plant introductions. Also contributing to weed introductions has been the presence of horse stable facilities in the same area. Another major contribution to the introduction of alien species into the Park was the extensive road construction and resurfacing in the late 1970s and early 1980s. Many alien plants have been recorded only in the area below Park headquarters or along the highway embankment and areas of construction (*e.g.*, the water catchment and purification unit). About 20 new alien plant species appeared in 1978-81 during road and water catchment construction (Table 2). Few persisted as of 1991, and none are believed to constitute a significant threat to native ecosystems. Nevertheless, the potential threat of such alien plant introductions is difficult to accurately assess in advance.

Table 2. Plant species introduced to the western slope of Haleakalā in 1976-81 during widening and resurfacing of Haleakalā Highway.* As of April 1991, only *Vicia sativa* persists.

Species	Location	Date First Observed
Amaranthus spinosus	roadsides	06/81
Amaranthus viridis	roadsides near 7,000 ft	summer 1981
Atriplex suberecta	roadsides near 7,000 ft, stables	summer 1981
Capsicum annuum	headquarters	1981
Chenopodium carinatum	roadsides	06/81
Crotalaria incana	roadsides	1981
Datura stramonium	headquarters, stables	08/81
Descurainia sophia	stables area	11/78
Lamium amplexicaule	headquarters, stables	1981
Leucaena leucocephala	headquarters	1981
Lycopersicon pimpinellifolium	roadside	08/81
Malvastrum coromandelianum	headquarters	10/81
Melilotus alba	near summit	11/78
Nicotiana glauca	occasional roadside weed	summer 1981
Polygonum aviculare	stables, roadsides, headquarters	08/81
Polygonum convolvulus	stables, landfill	1981
Portulaca oleracea	roadside	08/81

Table 2, continued.

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Species	Location	Date First Observed
Sisymbrium altissimum	stables and headquarters	1980
Verbesina encelioides	roadside	08/81
Vicia sativa	stables, headquarters	09/81
Xanthium strumarium	roadsides, stables	06/81

*The source of most is believed to have been heavy equipment or fill brought from low elevation near Kahului, Maui. Some equipment came from Washington State. Only one species persisted for more than 10 years, and none are believed to present a serious threat to native ecosystems. The potential for introductions in this manner is obvious, however. Two species (*Descurainia sophia* and *Lamium amplexicaule*) were new state records.

DYNAMICS OF MAJOR PLANT COMMUNITIES WITH AND WITHOUT FERAL ANIMALS

The current strategy for preservation of native ecosystems of Haleakala National Park involves fencing, control of feral animals, and strategic removal of alien plants. As of 1991, all fencing was complete. Feral animal control is well advanced in both districts of the Park. With the results of exclosure studies, we are able to better understand and predict trends of vegetation dynamics. In the absence of definitive research, such "best guess" predictions are necessary for the early guidance of crucial management decisions. Continued monitoring is essential to allow evaluation and adjustment of management strategies and priorities.

Alpine Cinder Deserts

Because of its relatively harsh environment (particularly so for seedling establishment), this is one of the least modified of Haleakalā's vegetation types. Extreme conditions of this ecosystem include potential freezing temperatures any night of the year, large diurnal temperature fluctuations with periodically high soil surface temperatures, and a desiccated layer of surface soil. Although no alien plant species thrives throughout this habitat, sorrel (*Rumex acetosella*), gosmore, and a few other species are established sporadically. The monocarpic Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) exists virtually without competition from alien plant species on cinder cones in Haleakalā Crater and in relatively barren sites near the summit. However,

mullein (*Verbascum thapsus*), abundant on upper Mauna Kea (Juvik and Juvik, this volume), is a potential invader of this zone. Two mullein plants (the first records of this species on Maui) were found and destroyed on Haleakala National Park roadsides at 6,800 ft (2,070 m) and 9,000 ft (2,750 m) in 1986-87.

Subalpine Shrubland

The subalpine shrubland has been modified by years of impact of goats, cattle, and pigs. The often dense mat of alien grasses such as velvet grass (*Holcus lanatus*), sweet vernalgrass (*Anthoxanthum odoratum*), and orchard grass (*Dactylis glomerata*) inhibits reproduction by seed of native shrubs. Pines, eucalypts, gorse (*Ulex europaeus*), and blackberry (*Rubus argutus*) are also potentially serious invaders of this zone.

Subalpine Grassland

Pigs, digging for bracken fern (*Pteridium aquilinum* var. *decompositum*), gosmore rhizomes, and invertebrates, uproot large areas of native vegetation, which are invaded by gosmore and by velvet grass (Jacobi 1981). By mid-1989, pigs and goats were eliminated from a 270-a (110 ha) exclosure in the grasslands, and areas dug up by pigs were revegetated. Initially, the removal of pigs resulted in large increases of gosmore. However, in the absence of continual disturbance, the endemic grass *Deschampsia nubigena* overtops alien grasses and forbs and may eventually eliminate them except in drainages, where velvet grass appears capable of persisting. The most serious problem in the Kalapawili grasslands is the spread of blackberry, dispersed by pigs and birds. Alien blackberry continues to increase, and control appears necessary.

Montane Bogs

Most bogs in the Park were damaged (some severely) by pig digging, beginning in the late 1970s. Introduced plants began to invade these bogs in pig-rooted areas, and some alien species achieved substantial cover. Flat Top Bog at 7,400 ft (2,260 m) was fenced in 1979 but showed continued degradation through spread of already-abundant alien species. In 1969, the cover of alien plant species in Flat Top Bog was 0.1% (Vogl and Henrickson 1971); by 1983, cover of velvet grass and gosmore had increased to 12% in the center (wettest area) and 42% on the grassland margin of the bog (Medeiros and Loope, unpub. data).

On the other hand, Greensword Bog, at 6,100 ft (1,860 m), recovered quickly with native sedges and grasses after near destruction of the bog by pigs in 1981. The bog was fenced in June 1981 in an emergency attempt to protect it. Three months after fencing, the most disturbed central portion of the bog had 96% bare ground. By October 1984, bare ground had been reduced to only 10% by the recovery of native sedges *Oreobolus furcatus* and *Carex echinata* and grasses *Deschampsia nubigena* and *Dichanthelium cynodon*. Alien species had not become established by the time the bog was fenced and have not invaded since (Loope *et al.* 1991b).

Prior to protection by fencing in 1987-88, the two largest bogs (Mid Camp and Big Bog) at 5,400-5,440 ft (1,650-1,660 m) were undergoing chronic pig damage and substantial invasion of alien plant species. Permanent vegetation plots, monitored in 1982, 1984, 1986, and 1988, showed progressive increase in alien species, especially velvet grass, Glenwood grass *(Sacciolepis indica), Juncus planifolius, Cyperus halpan,* Asiatic pennywort (*Centella asiatica*), and sheepgrass (*Eragrostis brownei*). These species have the potential of displacing natives by preventing establishment of native seedlings. The fencing of bog areas is expected to slow the invasion and allow native vegetation to at least partially recover (Medeiros *et al.* 1991).

ʻŌhiʻa-dominated Rain Forests (above 4,000 ft)

The cool, damp, shaded understories of high-elevation East Maui rain forests have up to now been relatively resistant to invasion by alien plants. ʻŌhiʻa (*Metrosideros polymorpha*)-dominated rain forests of upper Kīpahulu Valley, the northeast rift, and the Manawainui planeze have been highly disturbed locally by feral pigs in recent years, with the reduction of ground bryophytes and certain preferred vascular plant species. Alien plants invading these forests include blackberry, velvet grass, gosmore, thimbleberry *(Rubus rosifolius), Erechtites valerianifolia*, selfheal (*Prunella vulgaris*), and Maui pāmakani (*Ageratina adenophora*). Up to now, their overall impacts on the system appear to be minimal, but their presence appears to inhibit the establishment of native species in stream courses. Stream courses are much more susceptible to invasion by alien species than is the surrounding forest, probably due to a regime of more frequent disturbance and higher levels of incident sunlight.

Like montane bogs, high-elevation rain forests, under regimes of limited disturbance by feral pigs, have proved relatively resistant to invasion by alien plants. After removal of feral pigs, these ecosystems undergo rapid recovery of dominant species, *e.g., Diplazium sandwichianum, Athyrium microphyllum,* and other ferns in rain forests, and *Oreobolus* and native *Carex* spp. in bogs. It remains to be seen whether drastically depleted rare species can recover after removal of feral pigs.

Koa-dominated Rain Forests (below 4,000 ft)

Compared to the situation in high-elevation ʻōhiʻa forests, alien plant species pose a much more formidable problem for long-term preservation of native ecosystems below 4,000 ft (1,220 m) in Kīpahulu Valley. Two reasons for this are: 1) there is greater disturbance in lower-elevation forests, and 2) more alien species are adjacent to and thrive in lower-elevation rain forests. Alien strawberry guava (*Psidium cattleianum*) locally grows in such dense stands that native shrubs and herbs are shaded and crowded out and koa *(Acacia koa)* seedlings are unable to establish. Hilo grass (*Paspalum conjugatum*) establishes dense mats and also appears to inhibit establishment of native species. These two aliens are still spreading in koa-dominated forest up to 3,500-4,000 ft (1,070-1,220 m). Rose apple (*Syzygium jambos*), fortunately found only below 2,200 ft (670 m) elevation so far, is even more aggressive than strawberry guava in its tendency to dominate forest stands. Feral pigs are believed the

primary agent for the dispersal and disturbance that have allowed alien species to become so well established. Even with control of pigs, alien plant species may persist and spread, but at a slower rate. A recent discovery is an invasion of an Australian tree fern (*Cyathea cooperi*) into this habitat (Higashino *et al.* 1988b).

Dry Forest and Shrubland

The rich flora of leeward East Maui has undergone much damage from feral and domestic animals and alien plants. Of the 239 native angiosperm species in the flora, 46 have already been extirpated (Medeiros *et al.* 1986). Of all the native ecosystems of Haleakala National Park, the dryland forest flora is the most threatened. Due to the low number of surviving individuals of many rare dryland forest species and the degree to which this ecosystem has been altered, some extirpations will almost certainly occur here during the coming decades. Other species, however, may recover to varying degrees. The lower Kaupō Gap portion of the Park, descending to 3,800 ft (1,160 m), provides a relatively secure refuge for most of the 119 leeward species found within Park boundaries. However, their survival is by no means assured through the control of feral goats and pigs.

A small, particularly rich, grove of rare leeward forest trees is concentrated on a single ridge on the eastern wall of Kaupō Gap. Alien kikuyu grass (*Pennisetum clandestinum*), Maui pāmakani, and (potentially) molasses grass (*Melinis minutiflora*) create a formidable barrier to reproduction of many dryland forest tree species in eastern Kaupō Gap. In western Kaupō Gap, alien grasses can carry fire, increasing the potential threat to the reestablishment of native vegetation. Without the effects of wildland fire, however, ʻaʻaliʻi (*Dodonaea viscosa*), pūkiawe (*Styphelia tameiameiae*), and ʻūlei (*Osteomeles anthyllidifolia*) have recovered rapidly in a 10-year-old exclosure at 4,000 ft (1,220 m) in western Kaupō Gap that was previously almost barren of vegetation (A.C. Medeiros and L.L. Loope, unpub. data).

Highly Disturbed Vegetation below 2,000 ft in Kīpahulu District

In this area, only the coastal strand vegetation is primarily native, although stands of relatively intact mesic lowland forest, unique within the Park, are scattered locally above 1,000 ft (305 m). The pasture is dominated by the alien rattail grass (*Sporobolus africanus*) and kikuyu grass, with dense stands of common guava (*Psidium guajava*), Christmas berry (*Schinus terebinthifolius*), Java plum (*Syzygium cumini*), and mango (*Mangifera indica*) occupying areas where rocks have been piled from the days of field clearing for planting of sugar cane. In recent years, with minimal pasture maintenance, the alien trees have gradually invaded the open pasture. Black bamboo (*Phyllostachys nigra*) dominates the northeastern section of the Valley above the pasture area, interspersed with stands of native forest species being gradually replaced by strawberry guava, common guava, rose apple, Java plum, and African tulip tree (*Spathodea campanulata*). This constantly changing vegetation was well mapped by Smith *et al.* (1985).

THE WORST ALIEN PLANT INVADERS OF HALEAKALĀ

As with the previous section, much of the following discussion of individual species is based on preliminary data and anecdotal information and needs to be reevaluated periodically through monitoring.

Strawberry guava, *Psidium cattleianum*

Varying from shrub to large tree, depending on density of stocking and habitat conditions, strawberry guava establishes dense stands from primarily pig-dispersed seed (Diong 1983) and tends to displace native species. Its elevational range in Kīpahulu Valley is 300-4,000 ft (90-1,220 m), but it is abundant only up to about 3,200 ft (975 m). It is shade tolerant and grows in nearly impenetrable thickets in Kīpahulu Valley at 1,500-2,500 ft (460-760 m). Strawberry guava potentially threatens numerous low- to mid-elevation rain forest plant species with extirpation from Haleakala National Park through displacement of reproduction. Species particularly threatened in this way include *Antidesma platyphyllum, Claoxylon sandwicense, Cyanea grimesiana, Joinvillea gaudichaudiana, Nothocestrum longifolium,* and *Strongylodon ruber.* These species are rare, with some very near extirpation. The rare tree *Antidesma* is one of the primary host trees for the very rare arboreal snail *Partulina porcellana*, an East Maui endemic (M. Hadfield, pers. comm.).

Strawberry guava reaches its current maximum development on East Maui on the southeast flanks of the Volcano below Pu'u 'Ahulili, where it occurs as high as 4,600 ft (1,400 m). In this area, at 3,300-3,900 ft (1,000-1,190 m), it occupies over 25% of the forest understory. Below 3,300 ft (1,000 m), it occupies over 75% of the understory, rising into the canopy and attaining 60 ft (18 m) heights and 12 in. (30 cm) diameters (J. Jacobi, pers. comm.). On Haleakalā's north slope, strawberry guava commonly occurs above 3,000 ft (915 m) and reaches 3,900 ft (1,190 m) below Pu'u o Kaka'e near Waikamoi Stream (J. Jacobi, pers. comm.).

Molasses grass, *Melinis minutiflora*

After exclusion of feral goats from the lower elevations of Hawaii Volcanoes National Park, this mat-forming grass spread explosively throughout formerly open goat-browsed areas, developing local populations with nearly 100% cover. A similar situation occurred on East Maui in the Healani exclosure in goat-damaged koa forest at 4,000 ft (1,220 m) about 1.5 km south of the Haleakala National Park boundary. Within the exclosure, molasses grass developed dense mats that inhibited reproduction of koa and other native species (Scowcroft and Hobdy 1986). By 1988, after removal of feral goats from the Crater District of the Park, molasses grass had increased its biomass and distribution substantially in Kaupō Gap and on the western edge of the Manawainui planeze at 4,000-5,500 ft (1,220-1,680 m).

The most critical aspect of the biology of this species is its ability to fuel, carry, and subsequently quickly recover from wildfires. Wildfires are one of the most serious threats to the long-term perpetuation of dryland forest on leeward Haleakalā. Survival within the Park of such rare species as *Nothocestrum latifolium, Pelea hawaiensis, Pouteria*

sandwicensis, Pleomele auwahiensis, Sanicula sandwicensis, Viola chamissoniana, and *Zanthoxylum kauaense* is increasingly threatened as fuel increases. Experimental control of molasses grass with glyphosate was initiated at Haleakalā in late 1990, with the hope of preventing the (unfortunate) scenario that occurred with molasses grass in the lowlands of Hawaii Volcanoes from recurring in the middle elevations of the leeward Crater District of the Park. The outcome of this experimental control is still being evaluated as of April 1991.

Hilo grass, *Paspalum conjugatum*

Hilo grass was first recorded in the Park as a component of the koa forest understory in the 1919 field notes of C.N. Forbes (A.C. Medeiros and L.L. Loope, unpub. data). It now occurs up to 4,450 ft (1360 m) in Haleakalā's Kīpahulu Valley, where it forms a mat, (sometimes) thick and dense, under koa forest at 2,200-3,400 ft (670-1,040 m). Although this sprawling grass may inhibit seedling establishment of koa and other native species, these seedlings are still able to establish on decaying logs and other raised microsites. Hilo grass threatens the survival of many of the same rare native species of koa forests of Kīpahulu Valley previously mentioned as threatened by strawberry guava. Despite its negative effects on native biota, no action is planned for the immediate future due to its pervasiveness.

Blackberry, *Rubus argutus*

Spread of this thorny species native to the southeastern U.S. presents potentially severe problems in high-elevation grasslands and rain forests of Haleakalā, where large fruits are formed at irregular intervals. Pig control may slow its spread in the grasslands, since pigs disperse it and it becomes established primarily in areas of pig digging. However, birds also eat the fruit and disperse the seeds, with new plants sometimes appearing as far away as 0.6 mi (1 km) from the nearest established population (A.C. Medeiros, unpub. data). Once established, its primary method of spread in an area is vegetative, by underground rhizomes. Backcountry personnel in the Park have been combating blackberry for years in the Palikū pasture and have succeeded in keeping it localized. Extensive stands occur along the lower edge of the Kalapawili grasslands between Pu'u 'Alaea and Flat Top Bog. Large infestations occur near the Park in the Ko'olau Forest Reserve, Hanawī Natural Area Reserve, and Waikamoi Preserve below Pu'u 'Alaea. A smaller population occurs in Waikamoi Preserve in eastern Ko'olau Gap.

Australian tree fern, *Cyathea cooperi*

Native to eastern Australia and Tasmania, the Australian tree fern is widely planted in Hawai'i, as it is faster growing than native Hawaiian tree ferns (*Cibotium* spp.) (G. Wescott, pers. comm.). First reported in Kīpahulu Valley in 1988 (Higashino *et al.* 1988b), A.C. Medeiros (unpub. data) counted 279 tree ferns of this species in 1989 with trunk diameters greater than 3 in. (7.5 cm) in three populations covering several thousand square meters at 2,400-3,400 ft (730-1,040 m) elevation. The average height of these ferns was 3-6 ft (1-2 m), with some individuals over 12 ft (4 m) tall. In 'ōhi'a and koa forests of Kīpahulu Valley, Australian tree fern has achieved impressive local dominance and shown

considerable invasive potential. *Cyathea* is considered an aggressive alien species that should be controlled if feasible.

Unlike native *Cibotium* tree ferns, Australian tree fern does not support epiphytic native species. The Australian tree fern also acts as a host for an alien herbivorous beetle, the Australian fern weevil (*Syagrius fulvitarsus*), which occurred in epidemic numbers in Hawaii Volcanoes National Park in the 1950s, defoliating endemic 'ama'u ferns (*Sadleria cyatheoides*). It is quite possible that as Australian tree fern increases, this alien insect may begin to seriously impact nearby native ferns. An exploratory attempt to control this species in Kīpahulu Valley was initiated in April 1991.

Kikuyu grass, *Pennisetum clandestinum*

Introduced to Maui as a pasture grass in the 1920s-1940s, kikuyu grass (from East Africa) has filled that role successfully on East Maui ranchlands, spreading in disturbed mesic habitats from near sea level to 10,000 ft (3,050 m), although uncommon above 7,000 ft (2,130 m). At high elevations, periodic freezing temperatures damage it and generally prevent it from competing well. It dominates in certain leeward areas at elevations of 3,000-5,000 ft (915-1,525 m) and typically forms dense mats (up to 3 ft or 1 m thick) that can overwhelm all low-growing vegetation and prevent any native seedling establishment. It presents a serious problem in Kaupō Gap, where it first spread from ranchlands about 1945 (Mitchell 1945) and is still expanding its range. Kikuyu grass can be killed by application of glyphosate (a non-persistent organophosphorus herbicide) at a sufficiently low concentration that native species are not harmed (Gardner and Kageler 1983). Thus, the potential exists for eliminating this species from areas even where it is well established and possibly allowing for the reestablishment of native species.

Kāhili ginger, *Hedychium gardnerianum*

This large (to 6 ft or 2 m tall) ginger with bright golden-yellow flowers is an aggressive invader of low- to mid-elevation rain forest in Kīpahulu Valley up to about 4,000 ft (1,220 m) elevation. Kāhili ginger is dispersed, sometimes long distances apparently, by birds that eat its large, fleshy, orange fruits. Once kāhili ginger establishes at a site, it spreads vegetatively, forming large, continuous clumps that displace nearly all other understory vegetation. It is especially aggressive in wet, disturbed, well-lit areas, such as open-canopied forest understory and along streambeds. An especially large population of kāhili ginger occurs along the Ko'ūko'ūai stream in southwestern Kīpahulu Valley at 3,500-3,600 ft (1,070-1,100 m) (Anderson *et al.*, this volume).

Velvet grass, *Holcus lanatus*

This perennial grass from Europe is abundant in most open shrubland habitats of East Maui at 6,000-9,000 ft (1,830-2,745 m). It is particularly dense in the lower elevation subalpine shrubland of northwestern Haleakalā between Hosmer Grove and Park Headquarters. Wherever it grows it displaces seedling establishment by native species, such as the important shrub/tree māmane (*Sophora chrysophylla*). Velvet grass is also the major alien species invading pig-damaged montane bogs of

northeastern Haleakalā. Though it is currently a serious threat, control of the widespread velvet grass is impractical.

Maui pāmakani, *Ageratina adenophora*

This subshrub, native to Mexico, was brought to Hawai'i before 1900 and spread quickly on Maui, coming to dominate large areas by 1913 (see Plates 89, 108, 147, and 173 in Rock 1974). In some areas, it formed pure stands, reaching up to 5 ft (1.5 m) in height. A stem gall fly (*Procecidochares utilis*), introduced to Maui in 1945-1947 for biocontrol purposes from the native habitat of this species, aided in bringing it under control (Bess and Haramoto 1972). In many pastureland areas of Maui, it was replaced by another alien, kikuyu grass, planted to revegetate the barren areas. Maui pāmakani still occurs throughout much of the Park; most populations are infected by the biocontrol gall fly, but not at sufficient levels to eliminate the weed. In eastern Kaupō Gap at elevations of 4,000-6,000 ft (1,220-1,830 m), it grows in locally dense monospecific stands. It also grows in open areas in rain forest and along stream courses in Kīpahulu Valley. In other parts of Haleakalā Crater (*e.g.*, Pu'u Māmane) at elevations up to ca 8,000 ft (2,440 m), it is sparsely present and until recently was typically cropped by goats. This is one alien species that may increase markedly in certain areas of the Crater District now that goats are under control.

Black bamboo, *Phyllostachys nigra*

This large bamboo occurs in dense, monospecific stands below 2,000 ft (610 m) in the Kīpahulu District. We are unaware of the reproductive biology of this species, although it may, like many bamboos that flower at intervals of a century or longer, eventually flower, set seed, and die synchronously (Janzen 1976). Up to now spread has presumably been vegetative. Since no clones on East Maui are known to extend above 2,000 ft (610 m), this species may not threaten forests above that level. Alternatively, the species may have the potential for spreading but is slowed by its purely vegetative reproduction. Its status should be carefully monitored since bamboo thickets result in elimination of virtually all native plant and animal species. Bamboo is one of the most difficult alien plant species to control, even locally.

Broomsedge, *Andropogon virginicus*

Although well established in many low-elevation areas of East Maui, including wet slopes and clearings in Kīpahulu Valley, broomsedge is still very rare in Kaupō Gap. Because of its well-known negative effects in Hawaii Volcanoes National Park, linked to fire, at elevations comparable to Kaupō Gap, it warrants early control in Haleakalā. Interestingly, this bunchgrass, generally associated with leeward, drier sites, has recently been recorded in the wet montane bogs of Haleakalā's Northeast Rift. Opportunistic control has prevented its further spread there and should be continued.

Gorse, *Ulex europaeus*

On East Maui, this spiny shrub from Europe is abundant in the Olinda area and is locally common just within and outside the northwestern boundaries of Haleakala National Park. Seed weevils and a flower-feeding

caterpillar introduced in the past for biocontrol reduced the reproductive potential of gorse by 73% on Maui (Markin 1984). A major gorse biocontrol program is under way, and additional insects are being released on Maui, beginning in 1989 with the moth *Agonopterix ulicitella*, which feeds on new shoots. Long-time persistence of dormant seeds makes early control important before populations become well established. Its potential invasiveness in subalpine shrublands of the Park warrants prompt control, which thus far has been attempted within the Park, largely by volunteer groups.

Pines, *Pinus* spp.

Pinus radiata from California, *Pinus patula* from Mexico, and *Pinus pinaster* from southern Europe are the only conifers (of many planted species in the Hosmer Grove area) to aggressively establish seedlings in native shrubland of the Park along the boundary adjacent to an experimental watershed improvement project on ranchland. On favorable sites these species can grow in height at a rate of about 12 in./yr (30 cm/year) and start to produce cones after six to eight years.

Rose apple, *Syzygium jambos*

Rose apple is a very aggressive invader of low-elevation forests in Hawai'i. It is found up to 2,200 ft (670 m) in Kīpahulu Valley, often forming impenetrable thickets. Its spread should be carefully monitored, since within its lower elevation range it forms even more dense monospecific stands than strawberry guava.

Chinese banyan, *Ficus microcarpa*

Chinese banyan is a strangling, aggressive invader on rocky walls of low-elevation stream courses and sea cliffs in lower Kīpahulu. The several dozen known established plants present in the Park should be removed as soon as possible in order to prevent this species from taking over these habitats.

Christmas berry, *Schinus terebinthifolius*

Stemmermann *et al.* (1981) noted the presence of a single large individual of Christmas berry in western Kaupō Gap. By the mid-1980s, individuals of *Schinus* were scattered within the pūkiawe/'a'ali'i shrubland of lower central Kaupō Gap. The species is common on lower-elevation Haleakalā outside the Park but is seldom found above 4,000 ft (1,220 m) and consequently poses little threat to the Park's Crater District except in extreme lower Kaupō Gap. Christmas berry is abundant in the highly disturbed pastures of lower Kīpahulu, but because of its poor shade tolerance, as well as a preference for mesic rather than wet sites, it presents little threat to the native forests in Kīpahulu Valley.

Juncus planifolius

This species was found by Medeiros *et al.* (1991) to be among the more aggressive weeds invading montane bogs in Haleakala National Park. First recorded in 1982, by 1988 *Juncus planifolius* had a mean cover of 8.4% in seven 10 m x 10 m plots within *Carex echinata*-dominated bogs at 5,400-5440 ft (1,650-1,660 m). It is also an aggressive invader of Alaka'i and Wai'ale'ale bogs on Kaua'i.

Glenwood grass, *Sacciolepis indica*

This grass is an aggressive invader of East Maui bogs, first recorded there in 1973 (Loope *et al.* 1991a). Over a period of six years from 1982 through 1988, it tripled its frequency (from 9 to 30%) in *Carex*-dominated bog plots at 5,400-5,440 ft (1,650-1,660 m) elevation (Medeiros *et al.* 1991). Once established, it spreads rapidly both by seed and vegetatively, often colonizing areas dug up by pigs and water courses. Like velvet grass and *Juncus planifolius*, it has the potential for displacing endemic bog species such as *Dichanthelium cynodon, Selaginella deflexa,* and *Viola maviensis.* In bogs protected from pigs, native grasses and sedges recover well, and this pioneer species may be reduced. We recommend no control measures, but continued monitoring, at this time.

Rattail grass, *Sporobolus africanus*, and Natal redtop, *Rhyncheletrum repens*

These grasses are abundant on leeward Haleakalā at 3,000-6,000 ft (915-1830 m) as well as in pastures of lower Kīpahulu. Currently, these two grass species make up much of the alien grass cover of western Kaupō Gap. They produce sufficient combustible material to carry wildfires once feral goats are controlled. Fire would enormously retard recovery of native shrubs and herbs. However, the threat of these grasses is considerably less than that presented by molasses grass.

THE REMAINDER OF THE ALIEN FLORA

The Haleakala National Park flora includes more than 300 additional introduced species beyond those already discussed as the worst alien plant species. Many of these are confined to the highly modified area below 2,000 ft (610 m) in the Park's Kīpahulu district and present little threat to upland native ecosystems. Many more of those occurring in the Crater and Kīpahulu districts above 2,000 ft (610 m) may represent little more than aesthetic intrusions. Some remaining species warrant special mention and concern, however.

Common guava (*Psidium guajava*) occurs together with, but at lower densities than, strawberry guava in the rain forest of lower Kīpahulu Valley to above 4,100 ft (1,250 m) elevation. Its effects are similar to those of its more threatening congener, and any efforts at control of strawberry guava should be applied to common guava in the same area.

Gosmore (*Hypochoeris radicata*), a yellow-flowered composite, is almost ubiquitous in non-forest vegetation from dry sites of Haleakalā Crater to bogs of the northeast rift. Although its total ground cover at a given site rarely exceeds 10% in sites not recently disturbed and averages 5% or less, it occupies a significant area that might otherwise be available to seedlings of native plants. In recent pig diggings, cover of this species may sometimes approach 50%. This species is very conspicuous after removal of feral pigs and goats in the Kalapawili grasslands. It appears to be an early successional pioneer forb that decreases with time. However, it may persist especially in areas of frequent disturbance, *e.g.*, trailsides, streambeds, and landslides.

A spiny Eurasian thistle, *Cirsium vulgare*, has been controlled locally by backcountry personnel and volunteers for several years with some success. At present it is unclear what the long-term effect of goat removal on this species will be. Goats eat it but may also encourage its establishment through grazing and trampling of native vegetation. We expect that it may increase initially following goat removal but may decline and perhaps even disappear eventually (except along trails, in other disturbed areas, and on scree slopes) as goat impacts are eliminated at Haleakalā. We interpret the thistle problem at Haleakala National Park primarily as an aesthetic one and for that reason place it lower in priority for control. Volunteer effort may help reduce thistle populations but is unlikely to completely eliminate it from areas with continuing disturbance.

Coffee senna (*Senna occidentalis*) is an alien shrub found in lower eastern and central Kaupō Gap below 4,800 ft (1,400 m). It should be controlled before it spreads farther.

Castor bean (*Ricinus communis*) occurs in a small area of eastern Kaupō Gap at about 4,100 ft (1,250 m). Though perhaps a Polynesian introduction, castor bean is potentially invasive and should eventually be eliminated through repeated mechanical and/or herbicidal treatment.

African tulip tree (*Spathodea campanulata*) is a large tree that is established sporadically in lower and middle Kīpahulu Valley and on adjacent Kaumakani Planeze. It has become aggressively invasive in some rain forest areas of Hawai'i (Smith 1985). It should be monitored and opportunistically controlled in conjunction with systematic control of strawberry guava and other rain forest weeds.

Sweet fennel (*Foeniculum vulgare*) occurs sporadically in the Park at present on the lower western slope (about 7,000 ft or 2,130 m) and in the Hōlua area of Haleakalā Crater. Because of its tall growth form, it is a conspicuous aesthetic intrusion in the shrubland ecosystem. It should be opportunistically or systematically controlled before it becomes more widespread.

The Park has over 50 species of alien grasses and sedges, some of which surely displace native species. Beyond those already mentioned, the most abundant include sweet vernalgrass, orchard grass, hairy oatgrass (*Danthonia pilosa*), brome fescue (*Vulpia bromoides*), annual bluegrass (*Poa annua*), Kentucky bluegrass (*Poa pratensis*), and *Rhynchospora* spp. Although their combined effects may be significant, they are generally overshadowed by the dominant alien grasses already mentioned.

THE THREAT OF FURTHER INVASION

A number of species not yet in Haleakala National Park but found on Maui pose severe problems in other parts of the State. Other species already on Maui are well known for their aggressive behavior elsewhere in the world.

These species have the potential to eventually cause problems in Haleakala National Park.

Clidemia or Koster's curse, *Clidemia hirta*

This densely branching shrub (to 13 ft or 4 m tall) is native to the Neotropics (southern Mexico and West Indes to Argentina). It has become an aggressive alien in many parts of Africa, Asia, and the Pacific islands. A particularly severe invasion in Fiji was controlled by the intentional introduction of a thrips (*Liothrips urichi*) native to Trinidad (Wester and Wood 1977). This same organism has been introduced to Hawai'i but has proved effective in controlling clidemia only in open (non-shaded) habitats. Other biological control agents, more recently brought to Hawai'i, show promise of increased control (Smith, this volume; Nakahara *et al.*, this volume).

Clidemia was first introduced in the Hawaiian Islands on O'ahu in 1941. Since then it has become very widespread on that Island, dominating large areas of rain forest understories. It was first recognized as a pest in the Islands in the 1950s, at which time *Liothrips* was introduced. However, the severity of the problem was not generally recognized by government agencies until the 1970s. Clidemia seeds are believed to be dispersed by the abundant alien Japanese white-eye (*Zosterops japonicus*) (Wester and Wood 1977) and probably by other alien birds, but mongooses (*Herpestes auropunctatus*) disperse it as well (A.C. Medeiros, unpub. data). Clidemia was first noted on northern East Maui in 1977 (Nāhiku District) and 1980 (Makaīwa District) on lands owned by the State of Hawai'i and East Maui Irrigation Company. By 1988, clidemia had spread along watercourses and established along the main Hāna highway in numerous drainages (Medeiros *et al.* 1989). A single plant was found (and destroyed) by L. Cuddihy and G. Santos at 2,800 ft (850 m) in Kīpahulu Valley in October 1988. Clidemia may provide a major threat to rain forests below about 5,000 ft (1,525 m) on Park lands in the future. As of 1991, clidemia was not known to be established in Kīpahulu Valley but had reached as far east on Nāhiku in lower-elevation East Maui.

Banana poka, *Passiflora mollissima*

This passionflower vine, locally known as banana poka, was introduced to the Hawaiian Islands as an ornamental in the early 1900s. It is uncommon in its native habitat in the Andes, where it is controlled by numerous species of co-evolved insects and where humans are destroying its habitat. Lacking natural herbivores in Hawai'i, it has become established in more than 190 mi^2 (500 km^2) of native forest on the islands of Hawai'i and Kaua'i. In some areas, it has become so dense that the vines drape from tree to tree, smothering large tracts of native forest. It occupies elevations of 2,000-5,000 ft (610-1,525 m) and thrives where mean annual precipitation is between 20 and 200 in. (500-5000 mm). Feral pigs are its primary dispersal agent, but alien birds spread it as well (Warshauer *et al.* 1983; LaRosa 1984; LaRosa, this volume).

In 1971 a group of three mature banana poka plants was reported from a farm lot in Kula, Maui. Hawaii Department of Agriculture personnel on Maui periodically attempted eradication in that area but had difficulty

destroying all plants. The problem was still considered manageable until November 1984, when State Forestry crews combatting a persistent fire in the Kula Forest Reserve noted the unsuspected spread of this weedy vine throughout several hundred hectares of dense black wattle (*Acacia mearnsii*, alien) forest in upper Kula (Waiakoa, 'Alae, at about 3,500-4,000 ft or 1,070-1,220 m). Prospects for control of this infestation are complicated by its occurrence on private lands. A well-organized education and eradication campaign was mounted, however, by L. Harrison of Makawao, Maui, in 1987-88. This effort led directly to funding by the State Legislature for mechanical control of banana poka through the Department of Land and Natural Resources in 1989-90. A cooperative effort is under way by Federal and State agencies to screen organisms from *P. mollissima* native habitat in South America for introduction of biocontrol agents to Hawai'i (Gardner, this volume; Markin, this volume). In April 1991, two herbivorous moths (*Cyanotricha necyria* and *Pyrausta perelegans*) were released for control of banana poka in the Kula area. Unless control measures succeed, the plant poses a threat to Kīpahulu Valley koa forests as well as to many other natural areas on Maui.

Fountain grass, *Pennisetum setaceum*

This large bunchgrass from northern Africa has spread aggressively throughout leeward Hawai'i Island during the past two decades, becoming potentially uncontrollable in Hawaii Volcanoes National Park (Tunison, this volume). Fountain grass creates an exceptionally large standing fuel source and promotes the spread of fires more than any other grass yet introduced to the Hawaiian Islands. Fountain grass is present on Maui only in a small area of the sand hills of southeastern Wailuku. However, it poses a serious threat to rangelands of southern East Maui with lightly vegetated, young volcanic substrates as well as to the largely barren, relatively undisturbed ecosystems of upper Haleakalā. Based on its occurrence as high as 9,000 ft (2,740 m) on Mauna Kea (J. Jacobi, pers. comm.), it must be regarded as a potential invader of Haleakalā Crater. Persistent control efforts by the Maui weed control office of the Hawaii Department of Agriculture for over 20 years have kept fountain grass confined to two small populations, one a residential area where the invasive populations apparently originated from an ornamental planting. A larger secondary population in a nearby dump area occupies more favorable habitat on relatively open, sandy sites. These populations are controlled by hand pulling of seedlings and mature plants at one- to two-month intervals, with bagging of seeding inflorescences for disposal at a nearby landfill. An average of about 2,000 plants/year were removed from 1983 to 1985 (E. Tamura, Hawaii Department of Agriculture, pers. comm.). In May 1986, population numbers were low and apparently decreasing due to a declining seed bank after several years of concerted effort at control of young plants before seed was set. As of early 1991, however, a small population persisted.

Firetree, *Myrica faya*

One of the worst invaders in Hawaii Volcanoes National Park and on Kaua'i (Whiteaker and Gardner 1985), this tree from the Azores, Madeira, and the Canary Islands fixes nitrogen in root nodules and has great

potential for massive alteration of ecosystems (Vitousek, this volume). A large infestation occurs on Haleakalā's western slope, particularly in the Kula Forest reserve at 3,200-6,400 ft (975-1,950 m) (Whiteaker and Gardner 1985). The upper firetree populations approach the Park boundary.

Miconia, *Miconia calvescens*

Miconia calvescens, native to middle-elevation (980 to 5,900 ft or 300-1,800 m) forests of Central and South America, has large, dark green leaves with maroon undersides. Because of its perceived attractiveness as an ornamental, it has been introduced recently through the horticultural industry to at least three Hawaiian Islands -- Hawai'i, O'ahu, and Maui. Miconia has gained special notoriety for its spread in Tahiti and Moorea, where in the past two decades it has extensively invaded forests (Gaubert and Florence 1991). The species is believed to have first reached windward eastern Maui in the early 1980s, but founding individuals have already grown to over 30 ft (10 m) tall and produced abundant seedlings locally. Tiny, bird-dispersed seeds are produced after a few years of vegetative growth; seedlings become established in open sunlight or dense shade. Growth is rapid, so that trees over 30 ft tall are produced after as few as five years. As of May 1991, there are seven known foci of this species on East Maui, but we are still in the information-gathering stage. A cooperative effort to eradicate it is being developed (Gagné *et al.* 1991).

It can be confidently predicted that propagules of additional aggressive plant species from various parts of the world will arrive on Maui in the future. We know of no way to accurately predict which species will become future invaders, but likely candidates include aggressive plants already occurring in the Hawaiian Islands (*e.g., Coccinia grandis, Oxyspora paniculata*). Indeed, alien plant problems now may represent merely the "tip of the iceberg" in relation to what potential invaders exist. Efforts to prevent as many additional introductions of aggressive plant species as possible would appear highly cost effective. Admittedly, documenting the prevention of an introduction may usually be so difficult that cost/benefit analyses may be impossible. Eradication of a species already introduced is easier to document. Strangely, however, there appear to be few, if any, documented cases where an aggressive weed has been eradicated. Maui, as well as other Hawaiian Islands, needs to develop and refine interagency cooperation to avoid the absurd, but probably common, situation in which aggressive species become established because no agency believes that it has the mandate or responsibility to stop them.

CONTROL EFFORTS TO DATE

Sustained efforts at control of gorse, pines, eucalyptus, thistle, and blackberry have been carried out at Haleakalā over the past decade, but only on a very limited basis and primarily through use of volunteers supervised by Park employees. In addition, isolated individuals or small populations of many species have been removed, including Christmas berry, castor bean, black wattle, and many other species not yet established in the Park. Pine and eucalyptus control on the northwestern slope of

Haleakalā has consisted of removing seedlings and saplings three to four times a year. Gorse has been monitored and patches reduced opportunistically with volunteers. Herbicide has been applied to these populations every three to four years. Thistles and blackberry have been controlled in limited areas of the backcountry whenever volunteers are available. These efforts have been highly successful in slowing invasions and will help to achieve eventual complete control. Although the use of volunteers can serve as a meaningful supplement to the Park's alien plant control effort, it cannot substitute for a full-fledged program, especially in remote rain forest sites. Many major problem species have continued to increase during past years. In addition, some problems can be anticipated with effective removal of goats in the Park and with species already present on Maui known to be detrimental elsewhere. Efforts must be accelerated in the near future for the highest priority species before they reach the irreversible stage in which future effort and expenditures cannot compensate for past neglect.

CONTROL NEEDS, PRIORITIES, AND STRATEGIES FOR THE FUTURE

Control of feral goats and pigs is currently the highest resource management priority at Haleakalā. Strategy has involved fencing the perimeter of the Crater District, to prevent ingress of animals from adjacent areas, and constructing three barrier fences across Kīpahulu Valley to establish management units for pig control. Control of feral pigs is a very important step toward controlling the establishment and spread of alien plants. Pigs are believed to be important for the spread of strawberry guava, molasses grass, Hilo grass, blackberry, kāhili ginger, velvet grass, rose apple, common guava, *Juncus planifolius*, and Glenwood grass. As ungulate control programs require less effort, funding should shift to alien plant control programs. Priorities for alien plant control at Haleakala National Park follow.

1. Strawberry guava provides the greatest long-term threat to the Park. It has the potential to affect the rain forests of Kīpahulu Valley below 4,000-4,600 ft (1,220-1,400 m) and could drastically transform this species-rich system, eliminating some native species and sharply reducing the rest. Banana poka and clidemia, not yet established in the Park, have similar potential. The spread of all three of these alien species (and most others as well) is greatly aided by feral pigs. If control of pigs can continue to succeed in Kīpahulu Valley, we expect much less rapid spread of banana poka and clidemia. Strawberry guava should be controlled above the "Dogleg" area (2,800 ft or 850 m elevation) through an aggressive, well-funded program involving cutting and application of herbicide to the stumps. (Santos *et al.* 1989 recommended use of Garlon for control of this species.)

2. Molasses grass control in Kaupō Gap should be continued, with the objective of at least delaying the spread of this fire-promoting grass until succession of native shrubs produces a more stable native-dominated vegetation that is relatively resistant to fire.

3. Australian tree fern and kāhili ginger problems should be addressed as soon as possible. Management strategies should be developed and action taken.

4. Pine, gorse, and eucalyptus control on the western slope near Park Headquarters has a very high ratio of benefit to cost. Without persistent control of these species, they would gradually become established and perhaps eventually gain dominance within the otherwise largely native vegetation of the subalpine shrubland.

5. Blackberry control in the Kalapawili grasslands and adjacent forest openings is another needed and very cost effective (at least in the long run) project. After a major initial effort at control, maintenance may be relatively easy with only limited local seed sources and absence of pigs. Without a major blackberry control effort in the next decade, this species may become uncontrollable. Biocontrol is another possibility (see below).

6. Strategic control of alien grasses and forbs will prove useful in certain small-scale (probably no more than several acres each) "special ecological areas" (similar to those described for Hawaii Volcanoes National Park by Tunison and Stone, this volume) after control of feral animals. Areas considered for such selective control include bogs, prime leeward forest areas, and sites threatened by Hilo grass in Kīpahulu Valley.

7. Kikuyu grass control in eastern Kaupō Gap could greatly stimulate reestablishment of koa forest. Control of Christmas berry and *Senna occidentalis* in eastern Kaupō Gap would assist recovery from goat browsing of native vegetation in that area.

8. Helicopter landing sites, especially in rain forest areas, are major sites for introduction and spread of alien plant species. "Helipads" where alien species are gaining a foothold should be periodically sprayed with glyphosate, with continual followup monitoring.

9. State and private control efforts for banana poka, fountain grass, firetree, and other species outside the Park should continue to be supported.

10. The Park needs to develop a balanced and sustained program to stop introduction and spread of new alien species before they become established on Maui, using direct attack, research and monitoring, and education of the public. We also need to work harder to gain support of local and state governments. The truly threatening alien invasions on the Island should be mapped using a Geographic Information System to develop management tactics and to educate constituencies. This work should be closely coordinated with the County of Maui and with State (Department of Land and Natural Resources, Department of Agriculture), Federal (Animal and Plant Health Inspection Service, U.S. Fish and Wildlife Service), and private (The Nature Conservancy, Maui Land and Pineapple Company) agencies and organizations.

Priorities for research and monitoring to aid alien plant control efforts at Haleakalā follow.

1. Monitoring of vegetation change, including changes in populations of rare plant species, throughout the Park following removal of feral animals is an essential adjunct to all efforts at ecosystem management through control of alien species. Lower Kaupō Gap, middle Kīpahulu Valley, and the montane bogs are particularly critical sites for monitoring, but a comprehensive network of sites throughout the Park is needed. Ehrlich (1983) and Soulé (1983) have pointed out the crucial value of long-term monitoring in any effort to formulate strategies for preventing extinction. Along similar lines, Macnab (1983) pointed out the shortsighted failure of most manipulative wildlife management efforts to adequately evaluate the effects of the management. Such monitoring may at times simply verify the appropriateness of management actions, but monitoring often detects unforeseen trends that may lead to rethinking management strategies and priorities.

2. Explore methodology for a campaign to prevent introduction of new aggressive nonnative species. Develop protocols for cooperative monitoring of alien plants outside the Park.

3. Experimental use of herbicidal treatments to determine optimal methods for control of strawberry guava, molasses grass, blackberry, kāhili ginger, and other invasive alien species is needed. Although efforts from Hawaii Volcanoes are applicable, additional research in Haleakalā will probably be necessary because of elevation, vegetation, soil, and climatic differences.

4. Continued research on and monitoring of biocontrol agents for banana poka and clidemia are also necessary. Biocontrol is the only hope for defense against these aggressive rain forest invaders. These aliens will probably spread throughout forests of East Maui in the coming decades, including those of the Park, unless efforts at biocontrol are successful.

5. Biological control of blackberry may become an important tool. Efforts already under way could prove valuable for control of this alien invader. We should continue to support these efforts.

6. Biological control should be investigated for strawberry guava, Haleakalā's primary alien plant problem.

7. A study of vegetation and faunal dynamics in Kīpahulu Valley below 4,000 ft (1,220 m) should be conducted. The resources and alien species that threaten them are still largely unexplored. Such research is essential to develop realistic and effective resource management strategies.

8. The biology of black bamboo should be studied, and monitoring of bamboo in lower Kīpahulu Valley should be started.

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