SPECIAL ECOLOGICAL AREAS: AN APPROACH TO ALIEN PLANT CONTROL IN HAWAII VOLCANOES NATIONAL PARK

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ABSTRACT

A Special Ecological Areas approach to alien plant management was adopted at Hawaii Volcanoes National Park in 1985. The approach involves control of widespread, disruptive alien plant species in Special Ecological Areas, which are intensive management and research units in the Park. Special Ecological Areas management developed from these perceptions: 1) unmanaged alien species were affecting many of the most valuable biological sites in the Park; 2) some widespread alien plants had increased their ranges dramatically in recent years; 3) alien plant control efforts were focused on species in degraded parts of the Park; and 4) biological control was not a panacea for widespread weed problems. Areas were selected according to the following criteria: Representativeness/rarity of vegetation type, vegetation intactness, plant species diversity/richness, manageability, presence of rare flora, preserve design considerations, immediacy of threat from alien plants, and research and interpretive values. Eleven species were targeted for control in Special Ecological Areas, were usually monitored by counting individuals encountered, and were controlled on an annual basis. All target species have declined sharply since initiation of treatment. For example, density or biomass of the three most important alien species, firetree (*Myrica faya*), strawberry guava (*Psidium cattleianum*), and kāhili ginger (*Hedychium gardnerianum*), declined by 86%, 85%, and 96% respectively in Special Ecological Areas treated from 1985 to 1988. The number of worker days required for control efforts declined 73% over the same interval. Tentative conclusions about alien plant control in Special Ecological Areas are: 1) populations of alien plant species can be significantly reduced and maintained at very low levels after three to four years of control work; 2) recruitment of alien plant species is usually very low; 3) continued follow-up treatments are required in all areas and may be needed indefinitely; 4) workloads drop significantly after initial control efforts; and 5) Special Ecological Areas serve as effective models for management of other areas. Special Ecological Areas also provide a focus for research on and monitoring of native and alien species as related to management. Permanent monitoring systems will soon be established for birds, Hawaiian bats (*Lasiurus cinereus semotus*), invertebrates, and rare

plants, including candidate endangered species. Habitat correlates for key species and groups will be determined so that Park managers can better protect essential areas in the Park. Baseline information on the ecology and responses of Special Ecological Areas to management may lead to translocation and reestablishment of birds and plants previously found in the Park.

INTRODUCTION

A Special Ecological Areas approach to alien plant management was adopted in Hawaii Volcanoes National Park in 1985. The approach involves control of widespread, disruptive alien plant species in the Areas, intensive management and research units in the Park selected for their biological and management values. Eight Special Ecological Areas totalling 12,954 a (5,266 ha) have been established to date (1988) (Fig. 1). The purpose of this paper is to:

1. Describe the current alien plant control program in Special Ecological Areas and how the Special Ecological Areas strategy developed.

2. Document changes in alien plant populations under management.

3. Summarize long-term monitoring and research supporting alien plant control programs in Special Ecological Areas.

4. Discuss strengths and weaknesses of a Special Ecological Areas approach to alien plant management.

5. Outline long-term plans for alien plant management in Special Ecological Areas.

REASONS FOR SPECIAL ECOLOGICAL AREAS

The Special Ecological Areas approach markedly changed existing alien plant control strategies at Hawaii Volcanoes National Park. Prior to this strategy, alien plant management emphasized control of localized alien plant species and control of firetree (*Myrica faya*), fountain grass (*Pennisetum setaceum*), koa haole (*Leucaena leucocephala*), and other widespread weeds found mostly in the coastal lowland or submontane seasonal zones, the two ecological zones in the Park with the highest proportion of alien plant species. Control was not begun on a number of target widespread weeds found in the more intact plant communities (*e.g.*, banana poka (*Passiflora mollissima*), kāhili ginger (*Hedychium gardnerianum*), and strawberry guava (*Psidium cattleianum*)) because these species could not be controlled parkwide. Biological control was perceived as the only solution to the control of most widespread alien plant species.

New alien plant distribution information and uncertainties about the effectiveness and timeliness of biological control provoked a reevaluation of our approach to alien plant management. Distribution mapping completed

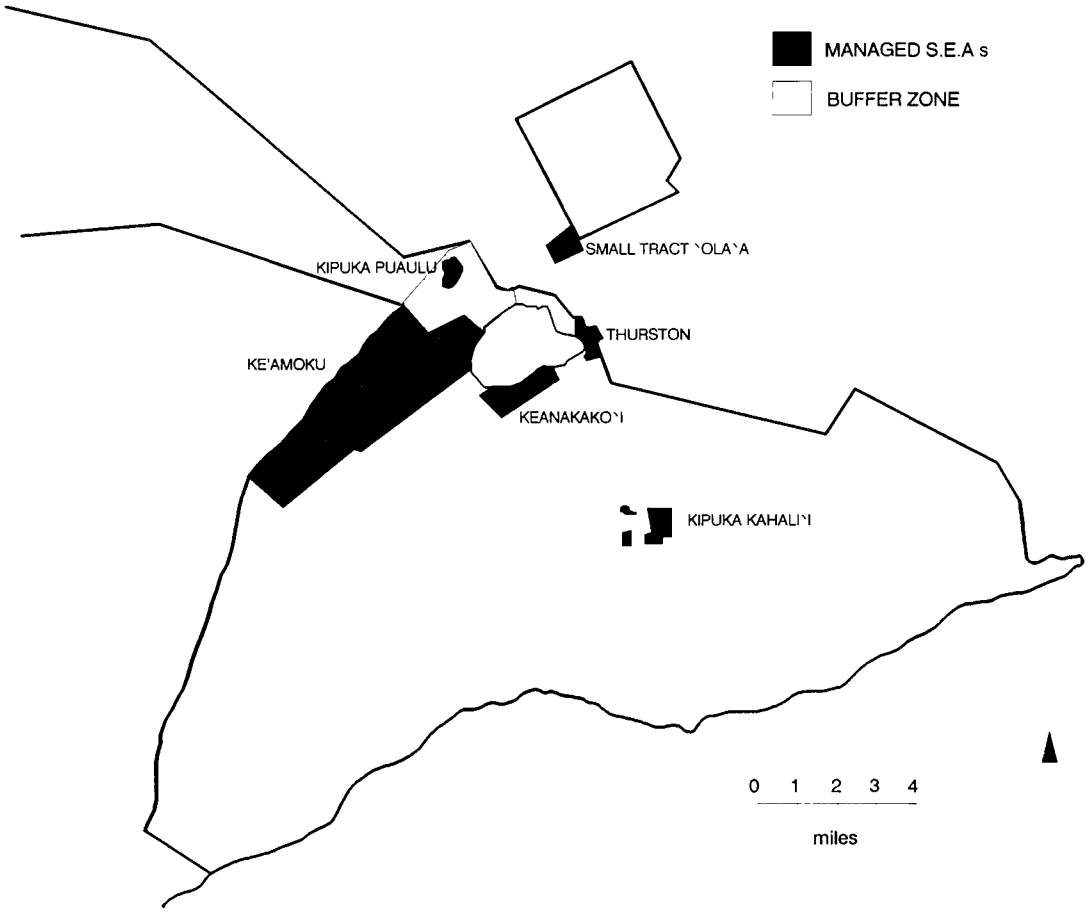

Figure 1. Special Ecological Areas in Hawaii Volcanoes National Park as of 1988.

in 1985 indicated that many target species, such as fountain grass, koa haole, and silk oak (*Grevillea robusta*), were too widely distributed for parkwide control without marked funding increases (Tunison *et al.*, in press; Tunison, this volume). Distribution mapping also indicated that firetree and banana poka had spread rapidly into extensive, mostly intact areas of the Park (Warshauer *et al.* 1982; Whiteaker and Gardner 1985). As the biocontrol program developed, it became clear that effective biocontrol agents might not be found or that irreversible ecological damage might occur before biological controls for such widespread species became effective (Gardner and Davis 1982; Markin *et al.*, this volume).

Additional considerations important in adopting and using a Special Ecological Areas approach are:

1. The most intact, diverse, unique, and valuable research and interpretive sites in the Park can be protected from the impacts of alien plant species with alien plant control in Special Ecological Areas. Uprooting of plants or chemical control can protect such sites until biological controls become effective or if biological controls are not found.

2. Alien plant control is more feasible in Special Ecological Areas than in more degraded parts of Hawaii Volcanoes National Park. Native vegetation in these areas is mostly intact, and alien plant control is more feasible because target alien populations are localized or at low densities.

3. Special Ecological Areas allows an incremental approach to management, a strategy that has proven effective in control of alien species in Hawai'i. When adequate control of an alien plant species in a Special Ecological Area is assured, the area can be expanded or additional areas established.

4. Special Ecological Areas can be models for management of other areas. Treatment methods and management strategies can be developed in Special Ecological Areas and applied to other areas. Prior to this approach, alien plant management was not conducted in many plant communities, and many of the most important alien plant species were not controlled.

5. Special Ecological Areas are sites for integrating feral animal and alien plant management. Feral goats (*Capra hircus*) have been controlled in all but the subalpine and alpine zones of the Park (Katahira and Stone 1982). Feral pigs (*Sus scrofa*) have been controlled in approximately 30% of their habitat in the Park (Katahira *et al.*, in press). Special Ecological Areas represent a way to organize the necessary follow-up management of alien plant species in those portions of the Park where ungulate management has been successful. For example, it is probably not feasible or worthwhile to control feral pigs and alien plants in all rain forest areas. Special Ecological Areas provide a means of selecting the best areas to manage for both pigs and alien plants.

6. Special Ecological Areas serve as a focus for research and interpretation. Biological understanding can be gained through long-term monitoring and research in the most diverse, intact, representative, and unique areas. Special Ecological Areas can be used to illustrate intact native ecosystems to the public and interpret the need for intensive management of alien species in Hawai'i.

SELECTION OF SPECIAL ECOLOGICAL AREAS

Special Ecological Areas were selected on the basis of the following criteria (Tunison and Stone 1986):

1. **Representativeness and/or rarity of vegetation.** These features were considered on parkwide, regional, and statewide bases. Special Ecological Areas were proposed in all six major ecological zones of the Park to assure representativeness. No systematic attempt was made to locate Special Ecological Areas in all vegetation types in these zones.

2. **Vegetation intactness.** Special Ecological Areas have low densities of alien plant species, usually resist most alien plant invasions, are

often less vulnerable to fire, and are typically more manageable than more degraded areas.

3. **Plant species diversity/richness.** Plants rather than animals were considered initially because we lack information about invertebrates, native avifauna are scarce, and because bird species have broad habitat correlates or ranges.

4. **Manageability.** Manageability is a function of size, accessibility, intactness, and kinds of alien plant problems.

5. **Presence of rare flora and, to the extent known, rare fauna.**

6. **Preserve design considerations.** Proximity to other Special Ecological Areas, presence of similar but less intact habitat as a buffer against threats or as a source of genetic stock, and the size of the Special Ecological Area were factors. Preference was given to proposed areas that are contiguous with or near other intact areas to enhance chances of dispersal or gene flow among areas. Larger areas were preferred because they have greater interior to edge ratios, which reduces the probability of dispersal of alien species into Special Ecological Areas and decreases adverse edge effects. Larger areas also were more capable of supporting larger populations of native species (species/area relationships), which minimizes population extinctions from stochastic demographic events and genetic losses.

7. **Degree of immediacy of threats from alien biota.** Some areas contain small populations of disruptive species, and successful management is feasible if control efforts are begun immediately. These areas were designated Special Ecological Areas before other areas with fewer alien species problems.

8. **Research and interpretive values.** Intact and diverse sites are ideal for understanding native Hawaiian ecosystems and obtaining baseline information on them. Managed and unmanaged communities can be studied in Special Ecological Areas and adjacent areas. Areas accessible to the public along roads and trails are preferred for educational purposes because they represent natural communities. Guided walks can be conducted or nature trails established in these areas to interpret not only natural history but also management of Hawaiian systems.

The selection criteria for Special Ecological Areas were generally ranked in the above order. However, lower-priority criteria, particularly manageability, immediacy of threat, and potential for interpretation, were overriding criteria in designating some dry ʻōhiʻa (*Metrosideros polymorpha*) scrub and woodland areas along Chain of Craters and Hilina Pali roads. Some rain forest and mesic forest and scrub had considerable past research data available and were considered especially important.

The designation of Special Ecological Areas to date has been based on existing biological information about potential areas, rather than waiting

for a systematic program of data collection. Specific boundaries were refined through ground surveys by Park resource managers, who prepared management plans. Alien plant management commenced after a consensus of interested managers and researchers developed. Alien plant control efforts were started by a large volunteer group in residence in the Park in 1985. Work was begun in six Special Ecological Areas requiring immediate management: Thurston, Ke'āmoku, North 'Āinahou, South 'Āinahou, Small Tract 'Ōla'a, and Kīpuka Puaulu (and buffer zone). Alien plant control work began in Kīpuka Kahali'i, Keanakāko'i, and Hilina Pali Road Special Ecological Areas in 1986-1988. Kīpuka Puaulu and Thurston Special Ecological Areas were expanded as control efforts became successful. Selection criteria, ecological zones, major management problems, and research for managed and proposed Special Ecological Areas are presented in Table 1.

MONITORING ALIEN PLANT POPULATIONS

Populations of target alien plants were monitored in each managed Special Ecological Area to determine the effectiveness of control efforts. Usually, numbers of individual alien plants treated (*i.e.*, found or occurring in the Special Ecological Area), as reported by field workers, were used to monitor populations. In one case, the area infested by a target species was mapped at yearly intervals; in another case, the weight of rhizomes removed was estimated by the volume removed, and treated individuals were categorized according to those uprooted and those treated with herbicide. Belt transects were also established in Kīpuka Puaulu, Thurston, and Small Tract 'Ōla'a Special Ecological Areas to facilitate annual determination of the densities of target species by size classes. Large permanent plots were established in Keamoku and Keanakāko'i Special Ecological Areas to assess recruitment of firetree in these areas. Monitoring and inventory of biota other than alien plants is being explored by researchers in a project discussed later in this paper.

POPULATION CHANGES OF TARGET ALIEN PLANT SPECIES

Eleven alien plant species were targeted for control in Special Ecological Areas: firetree, kāhili ginger, strawberry guava, banana poka, Jerusalem cherry (*Solanum pseudocapsicum*), palm grass (*Setaria palmifolia*), silk oak, olive (*Olea europaea* subsp. *africana*), fountain grass (*Pennisetum setaceum*), yellow Himalayan raspberry (*Rubus ellipticus*), and nasturtium (*Tropaeolum majus*). The three target species requir- ing the greatest expenditure of worker resources and found in most Special Ecological Areas were firetree, strawberry guava, and kāhili ginger; all declined greatly after four years of control work. Firetree density de- clined by 86%, strawberry guava density by 95%, and kāhili ginger rhizome biomass declined by 96% (Fig. 2). Population levels after control were very low: firetree occurred at approximately 0.8 plant/a (2 plants/ha), strawberry guava at less than 0.5 plant/a (1 plant/ha), and kāhili ginger rhizome biomass at less than 4.5 lb/a (5 kg/ha) in infested areas.

Table 1. Ecological and management features of Special Ecological Areas in Hawaii Volcanoes National Park.

Special Ecological Area	Proposed/ Managed	Area (ha)	Ecological Zone	Plant Community/ Vegetation Type	Selection Criteria	Management/ Threats
Hōlei	Proposed	286	Coastal lowlands	Pili grassland/ savanna	Representativeness Intactness Interpretation Manageability Rarity in State	Thatching grass, fountain grass; goats controlled
Kamoamoa Makai	**Proposed**	**77**	**Coastal lowlands**	Native scrub, dry forest	Uniqueness Intactness Rare plant species	Strawberry guava, Christmas berry, fountain grass; goats controlled
Kamoamoa Mauka	Proposed	758	Submontane seasonal/ montane rain forest	Mesic forest, wet forest	As above	Strawberry guava; goats controlled
Poliokeawe	Proposed	257	Coastal lowlands	Dry ‘ōhi’a woodland	Intactness Manageability Rarity in State	Located in fountain grass control unit; goats controlled
Ka‘aha	Proposed	391	Coastal lowlands	Pili grassland	Intactness Representativeness Rarity in State	Thatching grass in site; located in fountain grass control unit; goats controlled
‘Āpua Point	**Proposed**	**23**	**Coastal lowlands**	**Coastal strand**	Intactness Rare plants Uniqueness in Park	Threats not known; goats controlled

Table 1, continued.

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Special Ecological Area	Proposed/ Managed	Area (ha)	Ecological Zone	Plant Community/ Vegetation Type	Selection Criteria	Management/ Threats
ʻĀinahou North	Managed	17	Submontane seasonal	Dry ʻōhiʻa woodland and scrub	Plant species richness Representativeness Rare plants	Firetree, olive, strawberry guava? Goats controlled; pigs not controlled
ʻĀinahou South	**Managed**	**25**	**Submontane seasonal**	Dry ʻōhiʻa woodland	Rare plants **Representativeness**	Same as ʻĀinahou North
Keʻāmoku	**Managed**	3,380	**Submontane seasonal**	Dry ʻōhiʻa scrub	Intactness Representativeness Potential for Interp.	Firetree, silk oak. Fountain grass controlled, goats controlled; pigs not a problem
Kīpuka Kahaliʻi	**Managed**	**272**	**Submontane seasonal**	Dry ʻōhiʻa scrub/ woodland; lava flows	Manageability Intactness Representativeness Potential for Interp. Rare plants	Firetree, olive controlled; goats controlled; pigs not a problem
Keanakākoʻi	**Managed**	**366**	**Submontane seasonal**	ʻŌhiʻa forest/ woodland/scrub/ lava flows	Intactness Rare plants Potential for Interp. Manageability	Firetree controlled; goats and pigs controlled

Special Ecological Area	Proposed/ Managed	Area (ha)	Ecological Zone	Plant Community/ Vegetation Type	Selection Criteria	Management/ Threats
Hilina Pali Road	Proposed	401	Submontane seasonal	Dry ʻōhiʻa scrub/ woodland	Potential for Interp. Manageability Representativeness Rare plants	Firetree controlled; goats controlled; pigs not a problem
Kamakaiʻa Hills	Proposed	2,535	Submontane seasonal	Dry ʻōhiʻa scrub	Manageability Representativeness	Fountain grass controlled; goats controlled; pigs not a problem
Nāulu	Proposed	76	Submontane seasonal	Lama forest lava flows	Species richness Rare plants	Fountain grass
Puhimau Hot Spot	Proposed	10	Submontane seasonal	Hydrothermal	Uniqueness Rare plants	No alien species threats
ʻŌlaʻa Large Tract	Proposed	2,279	Montane rain forest	Hapuʻu/ʻōhiʻa	Intactness Representativeness Rare plants	Several Areas may be selected in this area; Areas will be less than total proposed, which is fenced for pig control. Threats are kāhili ginger, yellow Himalayan raspberry, palm grass, and strawberry guava

Table 1, continued.

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Special Ecological Area	Proposed/ Managed	Area (ha)	Ecological Zone	Plant Community/ Vegetation Type	Selection Criteria	Management/ Threats
ʻŌlaʻa Small Tract	Managed	133	Montane rain forest	Hapuʻu/ʻōhiʻa	Intactness Representativeness Rare plants	Alien plants/rare plants monitored; experimental alien plant control plot established; pigs controlled
Thurston	**Managed**	**48**	**Montane rain forest**	ʻŌhiʻa/hapuʻu, ʻōhiʻa/uluhe	Intactness Representativeness Potential for Interp.	Firetree, strawberry guava, kāhili ginger, palm grass, yellow Himalayan raspberry controlled; pigs controlled
East Rift	Proposed	2,704	**Montane rain forest**	ʻŌhiʻa/hapuʻu ʻōhiʻa/uluhe lava flows	Intactness Representativeness Rare plants	Strawberry guava; pigs need to be controlled
Kīpuka Puaulu	Managed	73	Montane seasonal	Mesic forest	Uniqueness Plant species richness Potential for Interp. Rare plants	Kāhili ginger, strawberry guava, Jerusalem cherry, nasturtium controlled; goats and pigs controlled; alien grasses and fire are problems

Special Ecological Area	Proposed/ Managed	Area (ha)	Ecological Zone	Plant Community/ Vegetation Type	Selection Criteria	Management/ Threats
Kīpuka Puaulu Buffer Zone	Managed	952	Montane seasonal	ʻŌhiʻa or koa woodlands/forest	N/A	Firetree controlled; pigs and goats controlled
Kīpuka Kī	Proposed	87	Montane seasonal	Mesic forest	Plant species richness Potential for Interp. Uniqueness	Jerusalem cherry, blackberry, alien grasses are major problems; goats and pigs controlled
Mauna Loa	Proposed	4,142	Montane seasonal Subalpine	Mountain parkland; Subalpine scrub	Intactness Representativeness	No major alien plant problems; firetree and fountain grass are potential threats; goats and pigs controlled

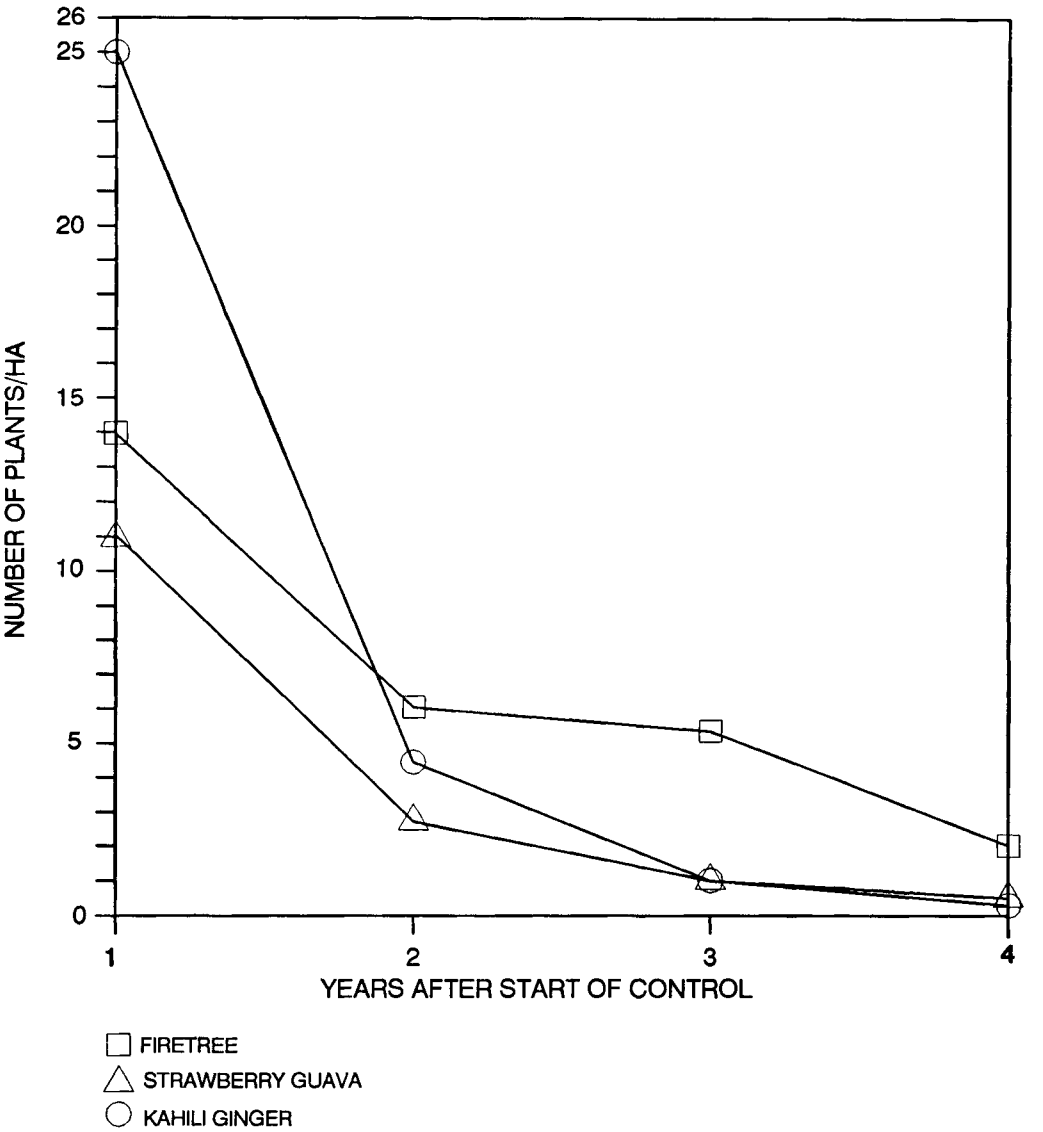

Figure 2. Densities of firetree (*Myrica faya*), strawberry guava (*Psidium cattleianum*), and kāhili ginger (*Hedychium gardnerianum*) in all Special Ecological Areas in Hawaii Volcanoes National Park. Density (number of plants/ha) was used to indicate population levels because size of Special Ecological Areas was increased over time.

Populations of less-widespread target alien plant species also declined sharply (Table 2). The area infested by Jerusalem cherry decreased by 96%, from 65,070 ft^2 to 2,690 ft^2 (6,045 m^2 to 250 m^2) in Kīpuka Puaulu Special Ecological Area. The frequency of nasturtium along five belt transects in Kīpuka Puaulu Special Ecological Area declined from 65% to 2%. Palm grass decreased 54%, from 1,984 ft^2 of infested area to 872 ft^2 (175 m^2 to 81 m^2) in Thurston Special Ecological Area. Silk oak declined 97%, from 110 to 3 plants in Ke'āmoku

Table 2. Population levels of minor target alien plant species in Special Ecological Areas in Hawaii Volcanoes National Park.

Target Species	Location (Special Ecological Area)	Monitoring Units	Population Levels after Treatment			
			0-12 mo	13-24 mo	25-36 mo	37-48 mo
Jerusalem cherry (*Solanum pseudocapsicum*)	Kīpuka Puaulu	m^2 infested	N/A	6,045	325	250
Fountain grass (*Pennisetum setaceum*)	Ke'āmoku	No. of plants	27	71	8	34
Nasturtium (*Tropaeolum majus*)	Kīpuka Puaulu	% cover in 29 monitoring plots	65%	44%	14%	2%
Palm grass (*Setaria palmifolia*)	Thurston	m^2 infested	175	90	81	N/A
Olive (*Olea europaea* subsp. *africana*)	Kīpuka Kahali'i	No. of plants	10	N/A	N/A	N/A
Silk oak (*Grevillea robusta*)	Ke'āmoku	No. of plants	110	1	10	3
Yellow Himalayan raspberry (*Rubus ellipticus*)	Thurston	No. of plants	287	33	40	0

Special Ecological Area. Yellow Himalayan raspberry declined 100%, from 287 to 0 plants in Thurston Special Ecological Area. Olive decreased 80%, from 665 plants to 134 plants in ʻĀinahou North, ʻĀinahou South, and Kīpuka Kahaliʻi Special Ecological Areas. Population changes of alien plant species are described in greater detail by Tunison *et al.* (1992). Fountain grass populations increased slightly, from 27 to 34 plants in Keʻāmoku Special Ecological Area.

The number of worker days required for alien plant control efforts in all Special Ecological Areas declined 73% (Fig. 3). In nearly all cases, as many worker days were required in the first 12 months of control as in the subsequent 36 months. The work load requirement dropped sharply in the second 12 months, with the rate of decrease declining over the next three years. Approximately 280 worker field days were expended on all alien plant control work in all Special Ecological Areas in 1988.

DISCUSSION

Need for Long-term Management

Follow-up alien plant treatments are required in all Special Ecological Areas. No target species have been eliminated in any Special Ecological Area, even though some species have been reduced to very low levels.

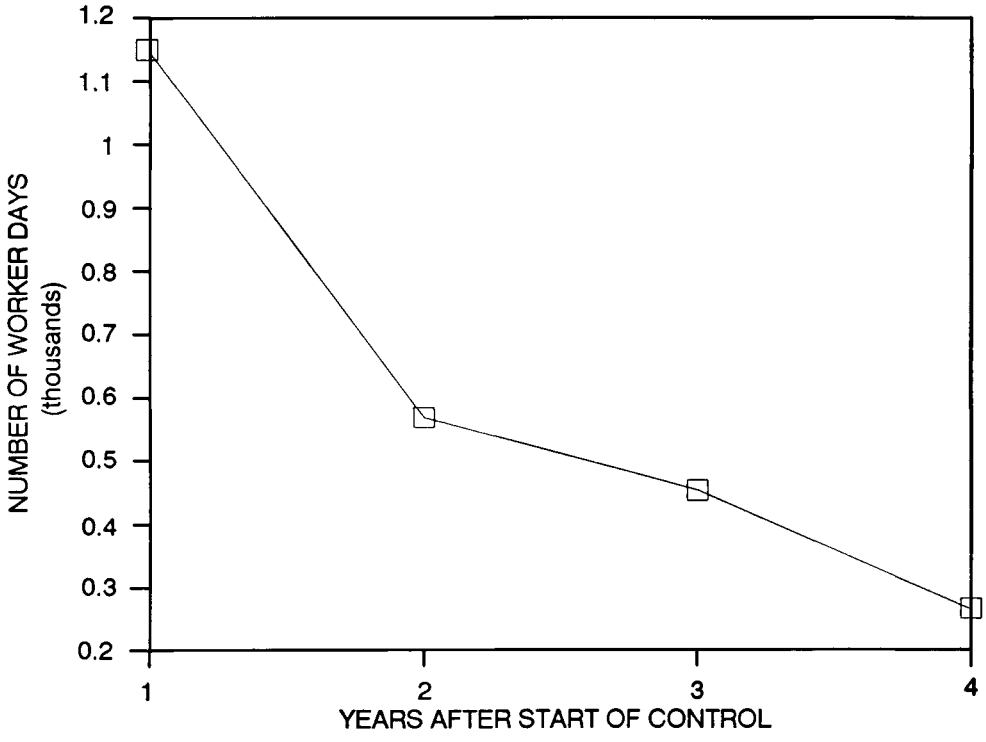

Figure 3. Number of worker days expended in controlling alien plants in Special Ecological Areas in Hawaii Volcanoes National Park.

Population levels of firetree are still noticeably dropping, but populations of kāhili ginger and strawberry guava have plateaued at low levels (Fig. 2). Results from localized alien plant control records indicate that even small populations of localized species can be very persistent (Tunison and Zimmer, this volume), mainly because of recruitment from long-lived seed banks. In addition, managed species are also established in surrounding areas and will continue to be dispersed into Special Ecological Areas. Since most alien plants probably cannot be eliminated in Special Ecological Areas, follow-up maintenance treatments may be required indefinitely.

Decreases in Work Load

Work loads decrease over time because alien plant population densities decline and because uprooting replaces cut-stump treatments. Treatments also become more efficient as workers become more familiar with the location of alien plant populations. The work load in Keamoku and Thurston Special Ecological Areas is expected to drop dramatically because low population levels now permit follow-up every other year rather than annually. Biennial treatments may eventually be applied to other areas. However, a minimum number of worker days will be required because of the need to systematically resurvey each Special Ecological Area, even if no plants are treated. As the work load in Special Ecological Areas decreases, new areas can be established or current areas expanded.

Weaknesses of the Special Ecological Areas Approach

A potential shortcoming of the Special Ecological Areas approach is that areas will become surrounded by increasing densities of alien plant species, dispersal of aliens into the area will increase greatly, and recruitment will reach unmanageable levels. Three strategies are designed to reduce alien plant species populations in areas between Special Ecological Areas. First, many of the plant species controlled in Special Ecological Areas are targeted for biological control, which may provide effective long-term control. Second, new alien plants are prevented from entering the Park by controlling localized alien plant species (Tunison and Zimmer, this volume). Third, buffer zones serve to keep population levels of selected alien plants low in surrounding areas. Kīpuka Puaulu is surrounded by a 2,350-a (952-ha) buffer zone. Finally, feral ungulate control occurs in larger management units containing Special Ecological Areas and serves to reduce disturbance and alien plant dispersal.

Another shortcoming of Special Ecological Areas may be the small size of some areas. Special Ecological Areas range from 42 to 8,350 a (17-3,380 ha) and average 1,576 a (638 ha). Native plant and animal populations in smaller areas may be too low to maintain fitness or evolutionary potential. Small populations are also vulnerable to stochastic demographic erosion.

Special Ecological Areas as Models for Managing Other Areas

Managed Special Ecological Areas provide information leading to expansion or establishment of new Special Ecological Areas. The effectiveness of alien plant control treatment methods in Special Ecological Areas as well as the effects of treatment methods on nontarget

species can be tested. Work load requirements and recruitment rates of target alien plants can be determined, allowing efficient planning for additional efforts.

Additional Special Ecological Areas are continually being added to the system in Hawaii Volcanoes National Park. Management of alien plants was started in Special Ecological Areas where problems required immediate attention, especially in submontane seasonal environments. About 79% of the area of managed Special Ecological Areas is in this ecological zone, although nearly half of the alien plant control field days are now allocated to rain forest and mesic forest areas, and more than half if monitoring activities are considered. Thirteen additional areas totalling 31,825 a (12,884 ha) have been proposed as Special Ecological Areas (Table 1). Additions to the Special Ecological Areas system will emphasize rain forest, mesic forest, mountain parkland, subalpine, alpine, and native grasslands and forest in the coastal lowlands. Most proposed Special Ecological Areas appear to have low densities of disruptive but manageable alien plant species. However, monitoring will be required to determine management needs. A few Special Ecological Areas (Large Tract ʻŌlaʻa, East Rift, and Kīpuka Kī) have high densities of alien plants requiring management.

Research and Other Monitoring Emphases

Special Ecological Areas are attractive foci for research efforts because of their intactness, richness, representativeness, and the presence of rare species. They are also important areas in which to study responses to management actions, including alien plant control, and to establish long-term monitoring programs for native and alien species. In Hawaii Volcanoes National Park, where most effort has been spent in controlling alien species of plants and animals, the efficacy of management in restoring native biota is especially important. Probably no better place exists to study dynamics of invasions, native and alien interactions, and the response to management of aliens. Major long-term research projects funded through Stanford University and the University of Hawaii, as well as National Park Service efforts, are leading to better understandings of plant and animal invasions and their management.

The necessary emphasis of management and research on alien species to date has resulted in lack of knowledge about the native flora and fauna. No Resources Base Inventory has ever been conducted in the Park, although some information is available from research conducted during the International Biological Program in parts of Hawaii Volcanoes. Abundance and distribution of important groups, including birds, various invertebrates, and higher and lower plants, have not received systematic study, even in the most valuable ecological areas of the Park. Population sizes, dynamics, limiting factors, and long-term natural variability are unknown for most native species, especially in relation to variation caused by humans and their management programs. Undisturbed behaviors of many important native animals have not received thorough study, and nests of some avian species have not even been described.

Statistically adequate, long-term monitoring systems have not been established in the Park, even for such visible groups as birds. Lack of avian population data hampers our understandings of long-term trends, responses to disease and predators, and response to management practices, including removal of ungulates such as pigs and goats and removal of alien plants from native bird habitat. Indicator species have not been determined for any groups. Voucher specimens of animals have not been systematically and adequately collected for most species to allow detection of changes with time. Native plants, including candidate endangered species, are not monitored adequately, and a database for the future is not available. Similarly, native invertebrates have not been systematically surveyed for distribution, abundance, variability, and their value as indicators of environmental change or management effectiveness. Since Hawaii Volcanoes National Park is an International Biosphere Reserve and a World Heritage Site, collection of good baseline data is an extremely important function. The Park should serve as a well-documented, near-native resource for comparison with more-rapidly changing unmanaged areas elsewhere in Hawai'i. The purpose of management programs for alien plants and animals is ultimately to return communities to near-native states that can be maintained for future generations. Adequate methods of monitoring progress toward that goal are essential.

Beginning in 1991, a three-year research project will attempt to remedy some deficiencies in our understanding of native species abundance, distribution, and interactions with other native and alien species. It is beyond the scope of this paper to do more than summarize the approach, but a major objective is to establish permanent monitoring transects, plots, and protocols for Special Ecological Areas throughout the Park. Native and alien plants, birds, invertebrates, and mammals will be sampled in Special Ecological Areas to determine abundance, distribution, and variability, at least on a preliminary basis. Special research projects will emphasize impacts of important alien species and their management on native flora and fauna; recovery of vegetation after ungulate and alien plant removal; population structures and dynamics of alien and native plants and animals; and other key topics. Systematic studies of insect, bird, and Hawaiian bat distribution and habitat correlates should help us to further identify the most important and responsive areas in the Park to target for protection and management of native species. Adequate information about native species will help refine the ranking of areas in which to expend efforts on control of aliens, the primary driving force for Special Ecological Areas management to date.

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