COOPERATIVE NATIONAL PARK RESOURCES STUDIES UNIT
UNIVERSITY OF HAWAII AT MANOA
Department of Botany
Honolulu, Hawaii 96822
(808) 948-8218

Clifford W. Smith, Unit Director
Associate Professor of Botany

Technical Report 28

PROPOSED NATIVE ECOSYSTEM RESTORATION PROGRAM FOR HALAPĒ, KEAUHOU, AND APUA POINT HAWAII VOLCANOES NATIONAL PARK

Clifford W. Smith

February 1980

UNIVERSITY OF HAWAII AT MANOA
NATIONAL PARK SERVICE Contract No. CX 8000 8 0001

ABSTRACT

This resource management report is a prescription for the ecosystem restoration program of the coastal lowland of Hawaii Volcanoes National Park between Apua Point and Halapē. The prescription emphasizes a vegetation community approach rather than the current introduction of individual species in widely scattered localities. Seventy-two species are discussed in the report. Eight species are recommended for introduction by planting and ten by broadcast seeding. Three species, whose classification is confused, are recommended for planting only after their taxonomy is resolved and the species appropriate for the area concerned is identified. Fifteen species should be eradicated. The remaining 36 species require no management action. It is recommended that the planting areas be monitored before and after planting.

TABLE OF CONTENTS

LIST OF TABLES

Table

LIST OF FIGURES

Figure

INTRODUCTION

The Master Plan for Hawaii Volcanoes National Park approved in November 1975 states that "the purpose of Hawaii Volcanoes National Park is to conserve...endemic Hawaiian ecosystems...and inherent scenic values...for their scientific and historic values with minimal impairment to the resources." Among the resource management objectives is the reestablishment of "the park's endemic species into their former ranges, concentrating efforts on those species which are in danger of extinction, and those that are key components of major native ecosystems...." The Master Plan was approved after public review. In order to implement the resources management objectives of the Master Plan, an environmental statement was drawn up by the Hawaii Volcanoes National Park superintendent. Three programs within the ecosystem restoration operation were identified. The first program was for "plants that are key components of major native ecosystems"; five species were identified. The second program was for "rare plants known to occur (or to have occurred) within the park"; 34 species were identified of which one was already thought to be extinct and 22 others were on a provisional list of endangered plants (U. S. Fish & Wildlife Service 1976). The scope of this program was limited and envisaged the propagation and establishment of the rare and endangered species to viable population levels. The third program was for "rare and endangered plants suspected of once appearing in the park."

The current planting program has met with considerable criticism from the scientific community which favors an ecosystem rather than a species-oriented approach. Much of the opposition stems from knowledge of many programs for species restoration which, though full of good intentions, have expended large sums of money without appreciable success. To quote Botkin (1975) "Many introductions, reintroductions, and transplants of species have been tried; most have failed." In most instances, failure can be directly attributed to a lack of understanding of the goal of the program and the factors involved in any attempt to manipulate the environment. In Hawai'i, the task has been compounded enormously by the introduction of countless alien species whose effect on the environment have been far-reaching, e.g., Andropogon, goats, etc. Therefore, in nearly all areas of Hawai'i, it will be impossible to restore native ecosystems completely.

In order to increase the chances of successful restoration of endemic species, information is needed about four factors: (1) the characteristics of the habitat as it exists and what it was like before any disturbance took place; (2) the biology of the species currently in the area and those that are to be reintroduced; (3) the interactions of the species between one another and within their habitat; and (4) the effects of exotic organisms on the natural regeneration of the communities. Though

many of these parameters may be well understood in a particular situation, success is not assured. Most programs are small in scale and normal, random, environmental fluctuations may result in the extinction of the transplant, let alone some catastrophic event, e.g., flood, fire, etc. However, small populations also suffer from reduced adaptability due to the lack of variability in their gene pool. Without that genetic resilience the odds may be stacked against success.

Nevertheless, some ecosystems show a strong potential for recovery after disastrous or catastrophic disturbances sometimes over protracted periods, e.g., the Thames Estuary in England, shorelines subjected to massive oilspills, etc. Even the ravages of surface-mined lands can be tempered and restoration and recovery markedly accelerated.

Though restoration projects are feasible they are fraught with problems. This report provides a plan for a comprehensive plant ecosystem restoration program in three areas of the coastal lowland of Hawaii Volcanoes National Park.

HISTORY OF THE AREA

The coastal zone of Hawaii Volcanoes National Park and, in particular the Kalapana Extension, is an area which has undergone abrupt and dramatic changes at least twice in recorded history. A major subsidence occurred in 1868 at which time the slippage of the coastline was sufficiently severe that ships were no longer able to load and unload at Keauhou. This event was partially responsible for the demise of the pulu industry at Napau. The second subsidence occurred in November 1975 at which time the coastline sank up to 11 feet in the Halapē area. Apart from the general subsidence, tsunamis uprooted many shrubs and trees further inland as well as flooding inundated areas with salt water, killing most of the plants.

Pre-contact Hawaiian use of the area is not completely known. However, the numerous archaeological sites and references by the early missionaries and traders attest to thriving communities though Handy and Handy (1972) indicate that Halapē was visited infrequently. Most of these communities were destroyed by the tsunami in 1868. The impact of Hawaiian use on the lowland ecosystems is unknown but the mere occupation of the area would suggest that whatever biotic communities were present were of a highly disturbed nature. The area was probably burned over quite frequently from comments made by Cook and in early expeditionary reports. However, the recent origin of the substratum and the dry conditions of the area probably account for the open scrub community structure.

In historical times, feral cattle and goats have had a significant impact in the area. At one time, much of the coastal plain behind Halapē and Apua Point was almost denuded of vegetation. After the initiation of the goat management program the vegetation has recovered somewhat. Unfortunately, exotic plants now dominate the area.

THE PLANTING PROGRAM

Areas to be Planted

Three areas are recommended for planting and intensive control of exotic species: Halapē, Keauhou, and Apua Point.

At Halapē, it is recommended that the planted area be limited by the coastline, the base of the cliff below Pu'u Kapukapu, and a north-south boundary from Keaoi Islet inland to the base of the cliff (Fig. 1).

At Keauhou, the area should be limited by the Puna coast trail, a boundary from the shelter to Keauhou Point, and a parallel boundary 300 yards to the west (Fig. 1).

At Apua Point, a much smaller area is recommended. Here, only the area between the Puna coast trail and the coastline should be planted (Fig. 1).

Only these small defined areas are recommended for planting. The program is designed to concentrate the species which will approximate their expected frequency in each area. Dispersing the individual species over larger areas circumvents the proposed community approach in which the intent is to mimic the density and association of species. It also facilitates the monitoring and evaluation of the program.

Community Types Present in the Areas

In the three areas recommended for planting there are two basic habitats--the beach strand and the recent lava flows.

The beach strand in this region is currently dominated by Scaevola taccada (naupaka) with occasional plants of Sesbania sp ('ōhai), Ipomoea brasiliensis (morning glory), and Vigna marina (nanea) (Table 1). However, the habitat is new in this area, having been formed after the significant subsidence associated with the November 1975 earthquake and tsunami. The current community is probably only a stage in secondary succession and the relative cover of species as well as species composition will undoubtedly change.

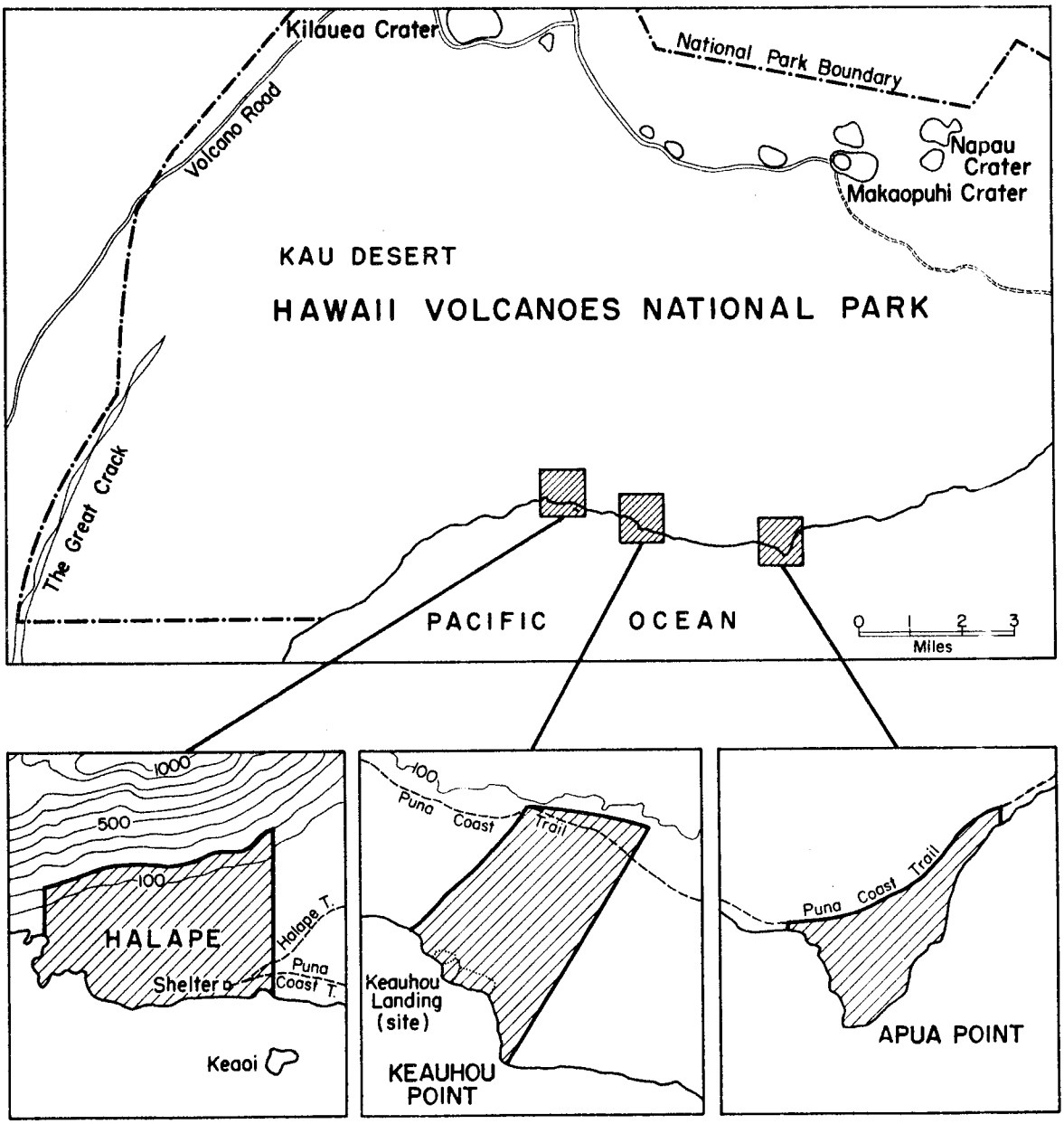

FIGURE 1. Map showing the suggested location and size of the proposed ecosystem restoration program site at Halapē, Keauhou, and Apua Point.

The recent lava flows support an open scrub community, one example of which is shown in Table 2. Many of these coastal areas were inundated by the tsunami associated with the 1975 earthquake which physically destroyed much of the scrubland as well as washing away much of the soil and poisoning that left behind. This open scrub community is probably undergoing succession and the relative proportions of species as well as the species present are likely to change with time.

At Halapē and Keauhou the scrub community will differ depending principally on the availability of subsurface fresh water. At Halapē, the subsurface water is available along the fissure at the base of Pu'u Kapukapu cliff. At Keauhou, subsurface water is present under the depressed area leading to the shallow inlet. Its extent can be predicted from the past distribution of kiawe trees in the area. Both of these areas can be expected to support a denser vegetation and a higher diversity of species including some trees. Where these subsurface freshwater springs and streams come to the surface or mix with sea water, specialized communities develop which have a limited area and are particularly susceptible to disturbances. They are very important biological resources and special attention should be drawn to these areas, not only at Halapē and Keauhou, when management plans for the coastal areas are being developed.

At Halapē, a further community type would be present on the rocky scree slopes at the base of Pu'u Kapukapu.

The plants currently present at Halapē, Keauhou, and Apua Point are listed in Tables 3, 4, and 5, respectively. An inspection of the lists shows that in all three communities there is a high percentage of exotic species present (Table 6). There is a higher percentage of exotic species at Halapē and Keauhou than at Apua Point, which may be the result of a more diverse flora in the two areas or species inadvertently introduced to these popular areas by visitors.

Procedures

1. Seed source. Seeds should be obtained from natural populations within the Park wherever possible. At least one source has been identified for all species recommended for planting (Appendix). Since most of the localities are those identified in publications or from personal communications they may not be the most suitable. Better, closer localities may be available to NPS and other personnel who are actively working in the area.

The seeds should be collected from as many different plants as possible, ideally only one or two seeds from each of many plants. In this way, the diversity of the gene pool will be maintained.

A small herbarium specimen should be collected whenever a population of plants is used as a seed source. (Mistakes in identification are made even by experts). The specimen should have both fruit and flowers attached whenever possible. Without any reproductive structures many specimens can only be identified as far as the genus. The availability of specimens for verification will aid in later evaluation of the program as well as increasing its authenticity. These specimens should be kept separate in the herbarium as their number and completeness may not be suitable for the general collection.

2. Propagation. The principal substrata for plant growth in the subject areas are beach sand and ash. Only these two materials should be used as potting material for all plants to be propagated in these areas. Top soil must not be used in the potting mixture. Apart from minimizing any adverse reaction the plants may experience when planted out, the introduction of top soil to this area is to be avoided because of its different microflora, composition, etc. The current practice of using potting material from commercial sources and washing the material off before transporting them to the field is satisfactory for shrubs and trees. Herbs are much less likely to survive the damage and shock to their root systems.

The sand, ash, and pots used in propagating the plants should be thoroughly sterilized before the seeds are sown. If the plants are propagated at the Science Center greenhouse it would be advisable to acclimate them at the Waha'ula facility for at least two weeks prior to transplanting them to the field. Just prior to their transport to the field, all plants should be fumigated with nicotine or some other general insecticide to rid the plants of parasites. The application of a nematocide would be a useful additional precaution.

3. Planting out. The density at which species are planted is a difficult parameter to establish. Overcrowding leads not only to increased mortality but also reduced reproductive output by those individuals that survive. On the other hand competition occurs naturally within and between species to varying degrees. A reasonable estimate of the minimum distance between plantings for the same species is the maximum height that the plant will attain under normal conditions. Thus trees should be planted 10 to 20 feet apart, herbs a matter of a foot or so. In order to minimize competition between different species particular attention should be paid to exotics which should be uprooted in planted areas. Unfortunately, we have very little quantitative information on competition between exotic and native species. However, even the most casual observer cannot help notice that lowland native species are crowded out by exotics. By uprooting the exotics, the native species will be given a momentary advantage particularly with regard to the most limiting factors in that area--the availability of water and the utilizable substratum on the lava flows.

Planting Prescription

All species which are recommended for management action are listed in Table 7. Comments on the species can be found in the Appendix. Species recommended for planting are indicated by the letter P followed by a number, e.g., P40, which represents the number of plants that should be planted in that area. The letter B indicates that seeds or spores should be broadcast in the area and C indicates that the species should be destroyed. It will be noted that only a few species are recommended for planting and most of these are referenced by the letter K in column 1 of Table 7. Conversely, the majority of species which are recommended for broadcast sowing are referenced by r. The distinction between the two types reflects characteristics of their growth and reproduction: K-type species are generally longer-lived trees or shrubs that produce a few, frequently large seeds over a relatively long period of time; r-type species are short-lived herbs or shrubs that produce many, small seeds over a short timespan. The different strategy for the reintroduction of these is predicated on the basis that r-type species tend toward explosive population growth because of their prolific production of seeds and rapid growth. Broadcasting the seeds in appropriate habitats will allow natural selection to act on all phases of reestablishment. However, K-type species need to be given a headstart because of their slower rates of estalishment, lower seed productivity, and slower growth rate.

Of the 72 species discussed in this report, eight are recommended for propagation by planting, 10 for broadcast sowing, three for special treatment, 15 for eradication, and 36 species for no management action.

Monitoring

Permanent line transects within and outside the managed areas should be established. Twenty meter square plots along the transects should be monitored prior to and after the implementation of the program. The monitoring could be included with that of the goat program.

A monitoring program is important for the following reasons:

1. Results from this program will be useful for future ecosystem restoration management proposals for coastal lowland areas west of Pu'u Kapukapu.

2. Species which have not become reestablished are identified. Other techniques for their reintroduction can then be tried.

3. The interaction between native and exotic species can be followed which may prove to be useful in controlling exotic species elsewhere or provide further insight into the impact of exotic species on natives.

4. The historical information on the rates and fluctuations in reestablishment will be useful to resource managers as well as interpreters.

Public Involvement

Finally, Halapē and Keauhou are very popular camping areas. It is recommended that information on the native plants and ecosystem restoration program be provided in the shelters of both areas. Visitors should be encouraged not to introduce plants, e.g., passion fruit, date palms, etc., to the area and they should remove all seeds from clothing before entering the areas. The Park may also be able to encourage at least some of the campers to assist in exotic plant control. The general public would then act to reinforce the resource management program. Similar programs have been used to good effect elsewhere and public identification with the Park's program is heightened.

Campers should be requested not to use either live or dead material from the planted areas. Since the kiawe wood source will be eliminated at Keauhou some other type of campfire fuel should be provided.

ACKNOWLEDGMENTS

I appreciate the permission of L. Cuddihy, E. Funk, and T. Parman to use their unpublished species lists and transect data in this paper. I am also grateful to the following for reading, commenting, and contributing to the preparation of this manuscript: S. Conant, L. Cuddihy, E. Funk, D. Gardner, P. Higashino, J. Jacobi, C. Lamoureux, D. Mueller-Dombois, T. Parman, D. Reeser, L. Stemmermann, R. Warshauer, and C. Zimmer. Finally, I appreciate the excellent draughtmanship of T. Nakata in preparing the figures and manuscript typing by M. Urukawa and J. Saito.

This work was partially supported by the National Park Service, Western Region Contract #CX8000 8 0001 to the CPSU/UH.

LITERATURE CITED

Beccari, O., and J. F. Rock. 1921. A monographic study of the genus Pritchardia. Mem. B. P. Bishop Mus. 8(1): 1-77.

Botkin, D. B. 1975. The reintroduction of species. In J. Cairns Jr., K. L. Dickson, and E. E. Herricks, eds. Recovery and restoration of damaged ecosystems. Univ. Press Virginia, Charlottesville. 531 pp.

Degener, O. 1933 et seq. Flora Hawaiiensis. Published privately.

Doty, M. S., and D. Mueller-Dombois. 1966. Atlas for Hawaii Volcanoes National Park. Hawaii Agric. Exp. Sta. Misc. Publ. No. 89. 507 pp.

Handy, E. S. C., and E. G. Handy. 1972. Native planters in old Hawaii: Their life, lore, and environment. B. P. Bishop Museum Bull. 233. 641 pp.

Haselwood, E. L., and G. G. Motter. 1976. Handbook of Hawaiian weeds. Lyon Arboretum Assoc., Honolulu. 479 pp.

Herat, T. R., and R. M. Herat. 1976. A checklist and status report of the ferns and fern allies in Hawaii Volcanoes National Park. CPSU/UH Tech. Rep. 8 (Dept. of Botany, University of Hawaii). 58 pp.

Hodel, D. (Undated). Hawaiian distribution of the genus Pritchardia. Dept. of Horticulture file, University of Hawaii at Manoa, Honolulu. 30 pp.

Rock, J. F. 1913. The indigenous trees of the Hawaiian Islands. Published privately.

Simpson, B. B. 1977. Mesquite. Its biology in two desert scrub ecosystems. US/IBP Synthesis Series #4. Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pa. 250 pp.

St. John, H. 1973. List and summary of the flowering plants in the Hawaiian Islands. Pac. Trop. Bot. Gdn. Mem. 1, Lawai, Kauai, Hawaii. 519 pp.

U. S. Fish and Wildlife Service. 1976. Endangered and threatened species. Plants. Federal Register 41(117): 24524-24572.

APPENDIX

Annotated catalogue of the plants in Halapē, Keauhou, and Apua Point Native Ecosystem Restoration Project.

Bidens pilosa L. Beggar's tick
(Sunflower family)

This exotic, herbaceous weed was probably introduced by visitors hiking in from Kalapana. Its absence from Apua Point is probably fortuitous. Control of the species at this stage is almost impossible because it will be reintroduced time and time again. Since the species will have little impact in the ecosystem no management is recommended.

Boerhavia diffusa L. Alena
(Four-o-clock family)

The taxonomy of this native, prostrate herb is very confused. Doty and Mueller-Dombois (1966) list two species as present in the Park. However, St. John (1973) recognizes one species only with five varieties of which two might be found on Hawai'i. The species was present at Keaoi prior to the 1976 earthquake and subsidence. It is present at Halapē, a single plant on the western side of the bay. Reestablishment of the species at Keauhou and Apua Point is recommended using material from Halapē but great care must be taken not to inadvertently destroy the single plant at Halapē.
Source: Halapē.

Bulbostylis capillaris (L.) C. B. Clarke
(Sedge family)

This weedy, exotic sedge occurs in all three areas. It poses no threat to the ecosystem and is probably impossible to eradicate.

Caesalpinia bonduc (L.) Roxb. Kakalaioa
(Pea family)

This pantropical, cultivated shrub is presently found only at Halapē. Once established in an area it can form impenetrable thickets. It should be eradicated.

Canthium odoratum (Forst. f.) Seem.
Alahe'e
(Coffee family)

This native tree is abundant in the dry forest areas of Hawai'i Volcanoes National Park (Doty & Mueller-Dombois 1966). It occurs in similar arid, coastal areas in the Hawaiian Islands. Its current absence from the subject area is probably the result of the combined activities of the pre-contact Hawaiians and feral goats. On the other hand, it may be naturally absent due to climatic limitations. Since alahe'e would constitute a significant element of the inland flora it is recommended for intensive planting in the managed areas. If the plants do not survive no follow-up is recommended.
Source: Lae Apuki.

Capparis sandwichiana var. zoharyi Deg. & Deg.
Maiapilo
(Caper family)

This endemic caper was reported from Keaoi by Doty and Mueller-Dombois (1966). It has since been reported from the lowland forest above Kamoamoa by Warshauer (pers. comm.). The species should be planted in inland ash pockets at Halapē and Keauhou. It usually grows on white sand beaches in strand habitats adjacent to HAVO.
Source: Kamoamoa and strand areas near HAVO.

Cassia leschenaultiana DC. Partridge pea
(Pea family)

This weedy, annual to perennial herb is a well-established, conspicuous plant in all three areas. Though an exotic, it poses no threat to the ecosystem. From a realistic point of view, it is impossible to eradicate.

Cassytha filiformis L. Kaunoa'oa
(Laurel family)

This native parasitic vine is abundant in the Kalapana area (Doty & Mueller-Dombois 1966). As shrubs and trees become reestablished along the coastal lowland, the species will probably invade the area. No management action is required for this species. Its reintroduction during the establishment phase of this program could have a counterproductive effect.

Cenchrus echinatus L. Common sandbur
(Grass family)

This exotic, annual grass is particularly common close to the beach at Halapē. It is dispersed by sticking to clothes and animal hair. It has been declared a noxious weed by the State of Hawaii. Its presence in strand communities detracts from the pleasures of the beach. It might be possible and very desirable to control this species in the long run by uprooting it wherever seen.

Chloris sp.
(Grass family)

This exotic grass, probably swollen fingergrass, is a common weed in disturbed areas. It is currently present only at Halapē. It poses no long-term threat to the ecosystem, fortunately, since it is nearly impossible to eradicate.

Chrysopogon aciculatus (Retz.) Trin.
Golden beardgrass
(Grass family)

This perennial, mat-forming, exotic grass is well-established at both Halapē and Keauhou but apparently absent at Apua Point. Little can be done to control the species whose seeds stick to clothing and animal hair whereby it spreads rapidly. Its absence at Apua Point is probably fortuitous.

Cocos nucifera L. Coconut
(Palm family)

The natural presence of coconut palms, a Polynesian introduction, at Halapē and Keauhou is almost impossible to determine. However, the pre-contact Hawaiians would have planted it there. This tradition has been continued by the Park Service. The apparent failure of the species to reestablish itself after the 1966 tsunami may indicate that the species is not natural to the area. An occasional census should be made to locate naturally occuring seedlings once the recently planted specimens are mature.

Cordia subcordata Lam. Kou
(Heliotrope family)

Kou was probably introduced by the early Hawaiians who used the wood quite extensively. A favorite shade tree it was probably cultivated in settlements along the coast if it had not already escaped. It is recommended for introduction in the most landward portions of the strand of all three areas.

Crotalaria mucronata Desv. Smooth Rattlepod
(Pea family)

This perennial, almost shrubby, exotic legume is present in all three areas. It can form dense thickets and therefore should be watched carefully. Its distribution along the coastline at HAVO is very sporadic. It could be eradicated from the three proposed management areas at the same time other species are controlled.

Cuscuta sandwichiana var. sandwichiana Choisy
Kauna'oa
(Morning glory family)

Recorded from Kalu'e by Doty and Mueller-Dombois (1966) and Halapē by Stemmermann (in herbarium), this parasitic vine prefers more arid conditions than Cassytha filiformis. The species will probably reinfect the area as trees and shrubs become established. No management is suggested. Its reintroduction during the establishment phase of this program could have a counterproductive effect.

Cynodon dactylon (L.) Pers. Bermudagrass
(Grass family)

This exotic, perennial grass is well-established in all three areas. There is no effective method to control the species but fortunately it is not a significant problem.

Cyperus javanicus Houtt. 'Ahu'awa
(Sedge family)

This herbaceous species has been recorded only from the Kapa'ahu Heiau area adjacent to the National Park. Though Rock (1913) suggests that this plant was a common element of coastal vegetation, there is some question as to the real status of the species. St. John (1973) considers it to be questionably indigenous. Also, since the species, like other sedges, is unlikely to have been severely depleted by goats, planting is not recommended.

Cyperus laevigatus L. Makaloa
(Sedge family)

This sedge is distributed widely throughout the tropics. It is present at Halapē. It is questionably indigenous in the Hawaiian Islands (St. John 1973). No management of the species is recommended.

Dactyloctenium aegyptium (L.) Willd.
Beach wiregrass
(Grass family)

This exotic, annual grass is present in all three areas but is particularly common at Halapē. Since it poses no threat to the ecosystem and would be virtually impossible to eradicate no management is recommended.

Desmodium triflorum (L.) DC. Three-flowered beggarweed
(Pea family)

This exotic perennial species is present in all three areas. It is a potentially troublesome weed that should be uprooted wherever possible.

Digitaria sanguinalis (L.) Heist. in Scop.
Large crabgrass, Kukaipua'a

(Grass family)

This exotic grass is present in all three areas. It should be controlled wherever possible.

Doryopteris decora Brack. Iwaiwa
(Fern)

Known from a collapsed lava tube at Halapē, this endemic fern prefers 'a'ā lava flows or cracks in well-weathered pahoehoe lava. It probably would not occur at Apua Point because the area is subject to salt spray. Since the species is present and the habitat is marginal for its survival, no management action is recommended.

Dryopteris setigera (Bl.) Kuntze
(Fern)

This indigenous fern has been collected from the Keahou area (Herat & Herat 1976). The species would be found in well-protected habitats in the subject area, e.g., the crack at Halapē or in the openings of lava tubes. Since the species is already present, no management action is recommended.

Emilia javanica (Burm. f.) C. B. Robins
Red Pualele

(Sunflower family)

This annual weed is present at Keauhou and Apua Point but is more common at higher elevations (Doty & Mueller-Dombois 1966). This exotic will have little impact in the area and no management is recommended.

Eragrostis tenella (L.) Beauv. ex R. & S.
Japanese lovegrass

(Grass family)

This exotic, annual grass is absent from Apua Point. Since it poses no long-term threat to the ecosystem no management program is advocated for those plants at Halapē and Keauhou.

Erythrina sandwicensis var. sandwicensis f. sandwicensis Deg.
Wiliwili

(Pea family)

Undoubtedly a significant component of the coastal vegetation in arid regions, this endemic tree may have been the dominant plant in such areas. The species prefers older, weathered lava flows. It is unlikely that any of the plants currently present in this area of Hawaii Volcanoes National Park are natural; most of them are in areas previously planted with wiliwili. However, plants in the Kalapana Extension are undoubtedly natural. If it is assumed that the planted specimens were produced from seeds obtained in the area in which they were

later planted, then these plants should be used as a seed source. Seeds from as many different plants as possible should be used in this program.

Source: Kamoamoa, Waha'ulu.

Euphorbia hirta L. Golden Spurge
(Spurge family)

This exotic species is an annual weed of disturbed areas. It is present at Halapē. It poses no serious threat to the communities present. No management action is recommended.

Fimbristylis hawaiiensis Hbd.
(Sedge family)

This endemic sedge occurs occasionally in isolated pockets of ash in the coastal area. Though probably not in need of assistance, seeds could be broadcast in inland areas at Halapē and Keauhou.

Source: Inland of Apua Point.

Fimbristylis pycnocephala Hbd.
(Sedge family)

This native species is listed as F. cymosa in the Atlas. It is present in all three areas and does not need any assistance.

Heteropogon contortus (L.) Beauv.
Pili
(Grass family)

Pili is already present in all three areas. However, its habitat (small cracks in pahoehoe) in these areas is often invaded by exotic grasses. The eradication of the exotics around the pili clumps may encourage its growth. Great care should be taken to return all soil to the area and avoid uprooting pili seedlings. It may be beneficial to seed the disturbed areas with pili seeds.

Hyparrhenia rufa (Nees) Stapf in Prain
Thatchingrass
(Grass family)

This exotic grass has recently become widely established in the coastal lowland section of Hawaii Volcanoes National Park. It is probably impossible to control at this time but should be removed from the immediate vicinity of planted organisms.

Indigofera suffruticosa Mill. Indigo
(Pea family)

This Polynesian introduced shrub is a major component of the coastal ecosystem in this area. Since it is unlikely to become a threat to the ecosystem and would be virtually impossible to eradicate no management is recommended.

Ipomoea brasiliensis (L.) Sweet Pohuehue
(Morning glory family)

Already present in all three areas. No further management is necessary.

Ischaemum byrone Hitchc. Hilo Ischaemum
(Grass family)

This endemic species is on the proposed list of endangered species. It has been collected at Kamoamoa. It is quite possible that it grew along the coastal plain east of Halapē. It is recommended for planting on a trial basis in all three areas.
Source: Kamoamoa.

Jacquemontia sandwichensis var. sandwicensis Gray
Pa'uohi'iaka
(Morning glory family)

Present at Apua Point and Keauhou, this endemic species is apparently absent at Halapē. Seeds should be broadcast in rocky areas within 25 feet of the high tide mark.
Source: Keauhou.

Lantana camara L. Lantana
(Verbena family)

This exotic shrub is a noxious weed as declared by the State of Hawaii. It is very common at Halapē and occasional at Keauhou but absent from the proposed management area at Apua Point. The species has a serious potential to disrupt efforts to reestablish native ecosystems due to its aggressive, weedy nature and longevity. Though currently in balance with its environment but not adequately controlled by introduced biological control agents, the role of this species in a native dryland coastal community is insufficiently known to predict its impact on the program. It is recommended that the species be controlled preferably by uprooting it.

Leucaena leucocephala (Lam.) de Wit
Koa haole
(Pea Family)

This weedy exotic shrub has the potential to invade most of the coastal lowland. It should be eradicated at Halape and Keauhou where it is present in low numbers. The area should be monitored for several years during the rainy season so that all seedlings can be destroyed before they have a chance to become established.

Malvastrum coromandelianum False mallow
(Mallow family)

This exotic shrub is present at Halapē and Keauhou. It can reach a height of about three feet. However, since it can be confused with Sida fallax (ilima), no management is recommended except by persons familiar with both species.

Melilotus sp. Sweet clover
(Pea family)

This exotic clover species poses no threat to the ecosystem.

Melinis minutiflora Beauv. Molasses grass
(Grass family)

This perennial, spreading, exotic grass is a serious weed in much of the coastal lowland. It is currently present in the proposed management area at Keauhou. This grass is a serious weed with a potential to smother herbs and seedlings. Consequently, it could inhibit the natural or assisted regeneration of the area. It should be removed during the planting and early stages of the reestablishment program.

Messerschmidia argentea (L. f.) Johnston
Tree heliotrope
(Heliotrope family)

Present at Keauhou where it has been planted. This species is questionably indigenous. It may be a Polynesian introduction which would justify its inclusion in the Park's planting program. It is recommended that seeds be broadcast in the strand communities at Halapē and Apua Point.
Source: Waha'ula.

Metrosideros collina subsp. polymorpha (Gaud.) Rock
'Ōhi'a-lehua
(Myrtle family)

It is known that 'ōhi'a did grow in most of the coastal lowland areas of the Hawaiian Islands particularly in more mesic situations. There are plants within 100 m of the coast at Kamoamoa and Keapuki in HAVO. Since a seed source is available to the north and northeast of the subject areas, seeds are probably constantly reaching the area. The inland areas at Halapē and Keauhou probably supported very scattered communities of scrub 'ōhi'a. However, it is unlikely that the seedlings would survive in the area today until a substantial revegetation has occurred. A few seedlings might survive in the crack at Halapē and the scree slope below Pu'u Kapukapu.
Source: Kamoamoa.

Morinda citrifolia L. Noni
(Coffee family)

Though present at Apua Point and Keauhou, this Polynesian introduction is apparently absent at Halapē. It is not known how natural these populations are because there are records of plantings in both areas. It is doubtful that planting of the species at Apua Point and Keauhou needs to be continued. Reintroduction at Halapē is recommended.
Source: Keauhou.

Nasturtium sarmentosum (DC.) Schinz & Guillaumin
Pa'ihi
(Mustard family)

Doty and Mueller-Dombois (1966) report this species as Cardamine sarmentosa from a lava tube at Kealakomo. St. John (1973) notes that the species is a Polynesian introduction. Its presence at Kealakomo is probably a relic of the Hawaiian occupation of the area. It is doubtful that the species can maintain itself naturally in the proposed management areas. Therefore, no propagation is recommended.

Nephrolepis sp. Boston fern
(Fern)

This exotic fern presents no significant environmental problems. No management action is recommended.

Panicum maximum Jacq. Guinea grass
(Grass family)

This exotic, bunch grass is present at Keauhou. The robust nature of the grass is a source of some concern because it can smother other species. All plants in the area should be dug up because it is difficult to uproot all underground portion just by pulling up the plant.

Panicum torridum Gaud. Kakonakona
(Grass family)

The genus Panicum is well represented in the Hawaiian Islands by 30 endemic species. Many of these species are difficult to distinguish even by accomplished botanists. There is, therefore, some confusion as to which species occurs where. Doty and Mueller-Dombois (1966) list Panicum xerophilum as questionably present near Keauhou but P. torridum is not on their list. St. John (1973) does not list P. xerophilum as present on Hawai'i. Degener (1933 et seq.) notes that P. torridum is confined to Maui and Moloka'i yet Rock (1913) implies that P. torridum occurs on all islands and St. John lists it as present on all major islands except Kaua'i. Suffice it to say that there is a native species of Panicum present in the area which needs further study. Great caution should be exercised before attempting to reestablish Panicum in the area. The recommendation is

to omit this species from the management program. However, if the plant is to be actively managed seeds from plants in immediately adjacent areas only should be used.
Source: Immediately adjacent areas.

Panicum xerophilum (Hbd.) Hitchc. Kakonakona
(Grass family)

See Panicum torridum.

Passiflora edulis Sims Liliko'i
(Passion flower family)

Probably a recent introduction at Halapē, this exotic vine is a potential problem. It could survive in the area and maybe has been deliberately propagated by visitors. However, it should be eliminated because it can shade out plants beneath it and during the fruiting season it could break the boughs of its host. Cutting the vine off at the ground is insufficient because they can resprout.

Passiflora foetida L. Scarlet-fruited passion fruit
(Passion flower family)

A common, exotic vine of roadsides and disturbed areas at low elevations though infrequent in the Park. It is present in all three areas. It should be eliminated whenever seen because it can smother small bushes, etc.

Peperomia leptostachya H. & A.
(Pepper family)

Listed in the Park as 'frequent and widespread' in Doty and Mueller-Dombois (1966), this herbaceous would be expected to occur on the talus slope behind Halapē.
Source: Waha'ulu.

Phoenix sp. Date palm
(Palm family)

Introduced exotic at Halapē. The single small tree should be destroyed.

Pluchea odorata (L.) Cass. Shrubby fleabane
(Sunflower family)

This exotic species is common in all three areas as well as in other open to semi-open areas from sea level to 4000 feet. The hardiness and weedy nature of this species merit further study because it may compete with native species for the available resources. In planted areas, the shrubs should be uprooted during the initial stages of the program.

Plumbago zeyanica L. 'Ilie'e
(Leadwort family)

This species, a native of all islands, grows among rocks in arid regions and often near the ocean. According to Doty and Mueller-Dombois (1966) it is rare in Hawaii Volcanoes National Park. It should be introduced throughout the areas under discussion except in strand communities.
Source: Kamoamoa

Portulaca cyanosperma Egler 'Ihi
(Purslane family)

This endemic species is present in all three areas. No further action is required.

Portulaca oleracea L. Purslane
(Purslane family)

This prostrate, succulent, exotic annual herb is present in all three areas. It is almost impossible to control but fortunately of little significance or impact in the coastal ecosystem. No management is recommended.

Pritchardia affinis var. halophila Becc.
Lo'ulu
(Palm family)

Lo'ulu has not been recorded as present in the areas under consideration. The type locality for the above variety is Kalapana a few miles to the east. However, there is evidence from tree moulds that this species also occurred at Punalu'u. Since the proposed management sites are between these two areas and of similar habitat type, it is reasonable to assume that lo'ulu occured all along this coastline in favorable areas, e.g., the crack at Halapē. The Hawaiians used this palm quite extensively and grew it close to their dwellings (Beccari & Rock 1921) so the species was almost certainly present in the area. Its current absence is more likely the result of the historical subsidences and associated tsunamis. It is suggested that a few specimens be planted at Halapē and Keauhou. Seeds should be obtained from the Kalapana area and from as many different trees as possible.
Source: Kalapana.

Prosopis pallida (Humb. & Bonpl. ex Willd.) HBK.
Kiawe
(Pea family)

This exotic tree is present at Keauhou and will form a closed canopy forest in the area over the subterranean freshwater stream. It can be successfully controlled by applications of 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) (Simpson 1977). The few remaining trees should be eliminated.

Rhynchelytrum repens (Willd.) C. E. Hubb. Natal Redtop
(Grass family)

Present throughout the coastal lowland, this exotic grass is a significant element of the vegetation of all three areas, particularly at Halapē. There is probably no acceptable, cost-effective method to control this species. It may be shaded out as shrubs and trees become established in the area. The species should be removed in planted areas so that the native species will have a head start.

Scaevola taccada (Gaertn.) Roxb. Naupaka-kahakai
(Naupaka family)

Already present in all three areas, no further management action is required.

Sesbania sp. 'Ōhai
(Pea family)

Sesbania tomentosa was reported from Apua Point by Doty and Mueller-Dombois (1966). According to a proposed revision of the genus by Char (pers. comm.), there are two different endemic species of the genus at Apua Point. Unfortunately, a close relative of the strand-inhabiting species from South Point has been planted in the coastal lowland area. These introduced specimens should be destroyed. No further planting activity using 'ōhai should be conducted until the South Point plants are removed. This recommendation is made in the interest of preserving the integrity of the gene pool of the plants native to the Park. It is also recommended that seedlings from the Apua Point area that have been planted out be destroyed because the seed sources were confused.

Sesuvium portulacastrum (L.) L. 'Akulikuli
(Carpetweed family)

This native species is present at Keauhou. With time, the species will probably reinvade both Apua Point and Halapē. The process could be accelerated by broadcasting seeds on spray-zone rocks in both areas.
Source: Keauhou.

Sida fallax Walp. 'Ilima
(Mallow family)

Already present in all three areas in sufficient numbers, no further management is necessary.

Sonchus oleraceus L. Sow thistle, Pualele
(Daisy family)

This annual, exotic weed is present at Halapē. It poses no threat to the ecosystem and is not recommended for management action.

Sporobolus diander (Retz.) Beauv.
Indian dropseed
(Grass family)

This perennial bunchgrass is present at Keauhou. It poses no threat to the ecosystem and is not recommended for management action.

Stachytarpheta jamaicensis (L.) Vahl
Jamaica vervain
(Vervain family)

This exotic, almost perennial herb is present at Keauhou. It can become a troublesome weed and should be uprooted wherever encountered in the planted areas.

Tephrosia purpurea (L.) Pers. 'Ahuhu
(Pea family)

Though apparently only previously recorded from Ka'ena, this native legume almost certainly occurred in the subject areas in the past. It is native to 'dry, rocky ... ground near shore or further inland on all islands' according to Degener (1933 et seq.). Its current absence from the area must be attributed to continuous grazing by goats resulting in the exhaustion of the seed stock.
Source: Waha'ula and Kalapana.

Thespesia populnea Milo
(Mallow family)

This tree is a Polynesian introduction which has been planted at Keauhou. It is recommended that seeds be broadcast in the strand communities at Halapē and Apua Point.
Source: Waha'ula.

Vernonia cinerea (L.) Less. Little ironweed
(Sunflower family)

Though present in all three areas, this annual, exotic weed will have little impact in the ecosystem. No management is recommended.

Vigna marina (Burm.) Merr. Nanea
(Pea family)

The presence of nanea or beach pea at Apua Point may be a new record for Hawaii Volcanoes National Park. This indigenous species will eventually become reestablished in much of the strand community along the coast. It should be reintroduced to Halapē and Keauhou by broadcasting lightly scarified seeds in the strand communities.

Source: Apua Point.

Waltheria americana L. Hi'aloa
(Cocoa family)

Already present in all three areas in substantial numbers, no further management is necessary.

TABLE 1. The percentage cover in the Scaevola taccada strand community at Apua Point.

Species	Percentage Cover
Ipomoea brasiliensis	6.3
Passiflora foetida	0.3
Sesbania sp.	7.7
Scaevola taccada	33.3
Vigna marina	5.7
Waltheria americana	1.3
Sand	27.0
Litter	15.0
Rock	3.3

This 60 m transect was recently established by Mrs. L. Cuddihy as part of the monitoring program studying the vegetation recovery after goat control.

TABLE 2. The percentage cover of the open scrub community on pahoehoe lava with interspersed ash deposites about 200 m east of the Keauhou shelter.

Species	Percentage Cover
Bulbostylis capillaris	1.3
Cassia leschenaultiana	1.6
Chrysopogon aciculatus	0.3
Emilia javanica	0.3
Indigofera suffruticosa	6.0
Passiflora foetida	11.3
Rhynchelytrum repens	49.0
Waltheria americana	7.3
Unknown grass	0.3
Rock	11.6
Litter	9.7
Ash	1.0

This 60 m transect and 20 x 20 m releve were established at Keauhou by Mr. T. P. Parman as part of the fire ecology project.

TABLE 3. The present flora at Halapē compiled by Mrs. E. Funk (30 Jul 1978) and Mrs. L. Cuddihy (2 Dec 1978). Asterisks indicate that the species is exotic. Species introduced by the Hawaiians are considered indigenous for the purposes of the resource management program.

*Bidens pilosa
Boerhavia diffusa
*Bulbostylis capillaris

*Caesalpinia bonduc
*Cassia leschenaultiana
*Cenchrus echinatus
*Chloris sp.
*Chrysopogon aciculatus
Cocos nucifera
*Crotalaria mucronata
*Cynodon dactylon
Cyperus laevigatus

*Dactyloctenium aegyptium
*Desmodium triflorum
*Digitaria sanguinalis
Doryopteris decora

*Eragrostis tenella
*Euphorbia hirta

Fimbristylis pycnocephala

Heteropogon contortus
*Hyparrhenia rufa

*Indigofera suffruticosa
Ipomoea brasiliensis

*Lantana camara
*Leucaena leucocephala
Lycium sandwicense

*Malvastrum coromandelianum
*Melilotus sp.

*Nephrolepis sp.

*Passiflora edulis
*Passiflora foetida
*Phoenix sp.
*Pluchea odorata
Portulaca cyanosperma
*Portulaca oleracea

*Rhynchelytrum repens
*Ricinus communis

Scaevola taccada
Sesbania sp.
Sesuvium portulacastrum
Sida fallax
*Sonchus oleraceus

*Vernonia cinerea

Waltheria americana

TABLE 4. The present flora at Keauhou compiled by Mrs. E. Funk. Asterisks indicate that the species is exotic. Species introduced by the Hawaiians are considered indigenous for the purposes of the resource management program.

*Bidens pilosa
*Bulbostylis capillaris

*Cassia leschenaultiana
*Chrysopogon aciculatus
Cocos nucifera
Cordia subcordata
*Crotalaria mucronata
*Cynodon dactylon

*Dactyloctenium aegyptium
*Desmodium triflorum
*Digitaria sanguinalis

*Emilia javanica
*Eragrostis tenella

Fimbristylis pycnocephala

Heteropogon contortus
*Hyparrhenia rufa

*Indigofera suffruticosa
Ipomoea brasiliensis

Jacquemontia sandwichensis

*Lantana camara
*Leucaena leucocephala
Lycium sandwicense

*Malvastrum coromandelianum
*Melilotus sp.
*Melinis minutiflora
*Messerschmidia argentea
Morinda citrifolia

*Nephrolepis sp.

*Panicum maximum
Panicum xerophilum
*Passiflora foetida
*Pluchea odorata
Portulaca cyanosperma
*Portulaca oleracea
*Prosopis pallida

*Rhynchelytrum repens

Scaevola taccada
Sesbania sp.
Sesuvium portulacastrum
Sida fallax
*Sporobolus diander
*Stachytarpheta jamaicensis

Thespesia populnea

*Vernonia cinerea

Waltheria americana

TABLE 5. The present flora at Apua Point compiled by Mrs. E. Funk. Asterisks indicate that the species is exotic. Species introduced by the Hawaiians are considered indigenous for the purposes of the resource management program.

*Bulbostylis capillaris

Canavalia sp.
*Cassia leschenaultiana
*Cenchrus echinatus
Cocos nucifera
*Crotalaria mucronata
*Cynodon dactylon

*Dactyloctenium aegyptium
*Desmodium triflorum
*Digitaria sanguinalis

*Emilia javanica

Fimbristylis pycnocephala

Heteropogon contortus
*Hyparrhenia rufa

*Indigofera suffruticosa
Ipomoea brasiliensis

Jacquemontia sandwichensis

*Melilotus sp.
Morinda citrifolia

*Nephrolepis sp.

*Passiflora foetida
*Pluchea odorata
Portulaca cyanosperma
*Portulaca oleracea

*Rhynchelytrum repens

Scaevola taccada
Sesbania sp.
Sida fallax

*Vernonia cinerea
Vigna marina

Waltheria americana

TABLE 6. The percentage of exotic and native species presently growing in the three areas suggested for planting.

Locality	Percent of total species		Species number
	Exotic	Native	
Halapē	68	32	44
Keauhou	64	36	45
Apua Point	55	45	31

TABLE 7. Planting prescription for the restoration of the strand and coastal vegetation at Halapē, Keauhou, and Apua Point in Hawaii Volcanoes National Park.

		Halapē				Keauhou			Apua	
		S	L	F	Z	S	L	D	S	L
r X	Bidens pilosa	no action								
r N	Boerhavia diffusa					B			B	
r X	Bulbostylis capillaris	no action								
K N	Caesalpinia major		C	C	C					
K N	Canthium odoratum		P10	P50		P50				
K E	Capparis sandwichiana var. zoharyi	P20	P20	P10	P20	P20	P20	P20		
r X	Cassia leschenaultiana	no action								
r N	Cassytha filiformis	no action								
r X	Cenchrus echinatus	no action								
r X	Chloris sp.	no action								
r X	Chrysopogon aciculatus	no action								
K N	Cocos nucifera	no action								
K N	Cordia subcordata	P10				P10			P10	

K	X	Crotalaria mucronata				no action				
r	E	Cuscuta sandwichiana var. sandwichiana				no action				
r	X	Cynodon dactylon				no action				
r	N	Cyperus javanicus				no action				
r	N	Cyperus laevigatus				no action				
r	X	Dactyloctenium aegyptium				no action				
r	X	Desmodium triflorum	C	C	C		C	C		C
r	X	Digitaria sanguinalis				no action				
r	N	Doryopteris decora				no action				
r	N	Dryopteris setigera		B	B			B		
r	X	Emilia javanica				no action				
r	X	Eragrostis tenella				no action				

KEY

B = broadcast seeds in the area
C = destroy plants in the area
D = depression at Keauhou
E = endemic
F = fissure at Halapē
K = long-lived species that produce a few, large seeds
L = lava flows
N = indigenous
S = strand areas
r = short-lived species that produce many, small seeds
X = exotic
Z = cliff base at Halapē

TABLE 7--Continued.

			Halapē			Keauhou			Apua	
			S	L	F	Z	S	L	D	S	L
K	E	Erythrina sandwicensis var. sandwicensis		P20	P10	P30		P20	P10		P10
r	X	Euphorbia hirta				no action					
r	E	Fimbristylis hawaiiensis		B	B	B		B	B		
r	N	Fimbristylis pycnocephala				no action					
r	N	Heteropogon contortus				no action					
r	X	Hyparrhenia rufa		C	C	C		C	C		C
K	X	Indigofera suffruticosa				no action					
r	N	Ipomoea brasiliensis				no action					
r	E	Ischaemum byrone		B	B	B		B	B		B
r	E	Jacquemontia sandwichensis var. sandwicensis	B								
r	X	Lantana camara		C	C	C		C	C		C
r	X	Leucaena leucocephala						C	C		
r	X	Malvastrum coromandelianum				no action					
r	X	Melilotus sp.				no action					

r	X	Melinis minutiflora					C	C		
K	N	Messerschmidia argentea	B						B	
K	E	Metrosideros collina var. polymorpha		P20	P10	P30	P30	P10		P10
K	N	Morinda citrifolia		P10	P10					
r	N	Nasturtium sarmentosum				no action				
r	X	Nephrolepis sp.				no action				
r	X	Panicum maximum					C	C		
r	E	Panicum torridum				see comments				
r	E	Panicum xerophilum				see comments				
r	X	Passiflora edulis		C	C					
r	X	Passiflora foetida		C	C	C	C	C		
r	N	Peperomia leptostachya			P30	P30				
K	X	Phoenix sp.	C							
r	X	Pluchea odorata		C	C	C	C	C		C

KEY

B = broadcast seed in the area
C = destroy plants in the area
D = depression at Keauhou
E = endemic
F = fissure at Halapē
K = long-lived species that produce a few, large seeds
L = lava flows
N = indigenous
S = strand areas
r = short-lived species that produce many, small seeds
X = exotic
Z = cliff base at Halapē

TABLE 7--Continued.

			Halapē			Keauhou			Apua	
			S	L	F	Z	S	L	D	S	L
r	N	Plumbago zeylanica		B	B	B		B	B		B
r	E	Portulaca cyanosperma				no action					
r	X	Portulaca oleracea				no action					
K	E	Pritchardia affinis var. halophila			P20				P20		
E	X	Prosopis pallida						C	C		
r	X	Rhynchelytrum repens		C	C	C		C	C		C
r	X	Ricinus communis		C	C	C					
K	N	Scaevola taccada				no action					
K	E	Sesbania sp.				see comments					
r	N	Sesuvium portulacastrum	B							B	
K	N	Sida fallax				no action					
r	X	Sonchus oleraceus				no action					
r	X	Sporobolus diander				no action					
r	X	Stachytarpheta jamaicensis						C	C		

r	N	Tephrosia purpurea		B	B	B		B	B		B	
K	N	Thespesia populnea	B							B		
r	X	Vernonia cinerea					no action					
r	N	Vigna marina	B				B					
K	N	Waltheria americana					no action					

KEY

B = broadcast seed in the area
C = destroy plants in the area
D = depression at Keauhou
E = endemic
F = fissure at Halape
K = long-lived species that produce a few, large seeds
L = lava flows
N = indigenous
S = strand areas
r = short-lived species that produce many, small seeds
X = exotic
Z = cliff base at Halapē