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Technical Report 53

VEGETATION MAP AND RESOURCE MANAGEMENT RECOMMENDATIONS FOR KIPAHULU VALLEY (BELOW 700 METRES), HALEAKALA NATIONAL PARK

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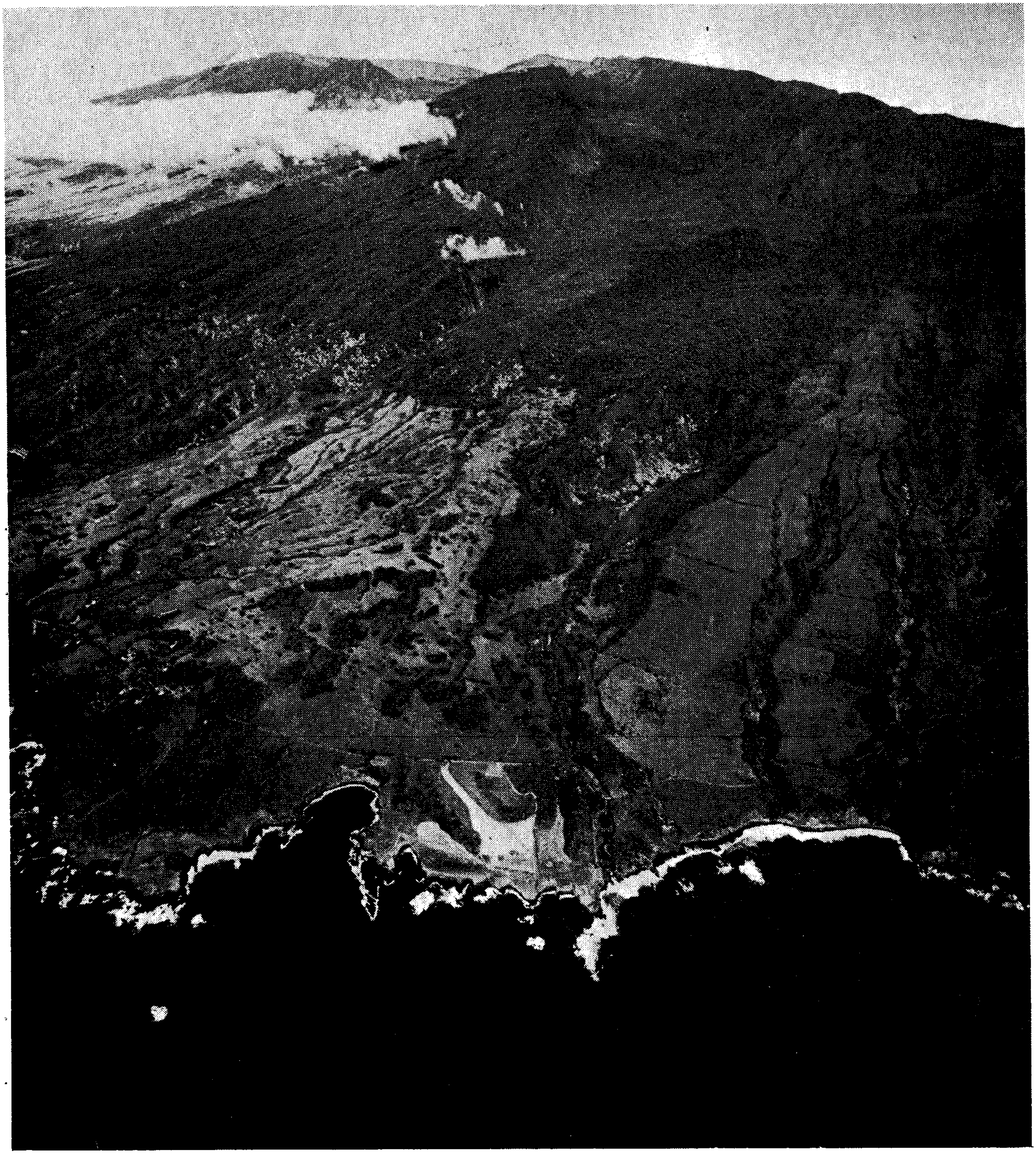

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ABSTRACT

A vegetation map (Scale 1:6,000) of Kipahulu Valley below 700m is presented. The vegetation has two principal components, pastureland and alien secondary forest. The vegetation in the study area has been disturbed for several centuries but the last two centuries have been the most devastating on the native ecosystems. Consequently, the vegetation is extremely fragmented and has been classified into 105 structural-floristic communites, an extremely high number for such a small area. Sizeable areas are essentially monotypic stands of bamboo or guava yet a significant number of native species persist in many of these areas. The significance of this pool of alien species on the native ecosystems higher up the valley is discussed. Several resource management recommendations are made with the objective of halting the further spread of aliens into the valley. Zones where resource managers can make significant headway in restoring or protecting various native species or ecosystems are presented. However, all resource management activity is dependent on their being an adequate staff to carry out the necessary activities for extended periods of time; a situation which does not currently exist. This report recommends that two permanent and five seasonal resource managers are employed in Kipahulu Valley. The most critical resource management action is the eradication of feral pigs from the valley ecosystem. Except for a few cosmetic actions, all other management activities are dependent on the removal of this highly disruptive influence. Some future research is recommended particularly on the autecology of Hilo grass and strawberry guava.

INTRODUCTION

Much of Kipahulu Valley below 700m has been authorized by the U.S. Congress for inclusion in Haleakala National Park (HALE). However, the area is owned by a number of different landowners and many parcels have clouded titles. There were, and still are, many conflicting land and resource use patterns within the area including cattle ranching, subsistence hunting, recreation (principally sightseeing), natural resource preservation and native Hawaiian agriculture. The occasionally conflicting interests led to misunderstandings between the various parties involved. In 1980, The Nature Conservancy (TNC), one of the largest landholders in the area, commissioned the Cooperative National Park Resources Studies Unit at the University of Hawaii (CPSU/UH) to produce an inventory of the resources in the area and to make recommendations for the future management of those resources. The report (Smith 1980) emphasized the need for preservation of the riparian ecosystems and the establishment of buffer zones between the lower elevation alien ecosystems and the higher elevation native ecosystems.

As part of a program to develop a strategy for the management of Kipahulu Valley, the National Park Service (NPS) contracted the CPSU/UH to develop vegetation maps of the valley. The study would be conducted in two parts concentrating on the valley below 700m initially. This emphasis was dictated by the controversy surrounding the future management of the lower elevations of the valley as well as serious threats to the integrity of the upper valley from alien influences below 700 m, e.g., weeds (Yoshinaga 1980) and feral pigs (Diong 1982, Lamoureux and Stemmermann 1976, Smith 1978). This report presents the vegetation map for the valley below 700m and recommendations for the establishment of buffer zones.

STUDY AREA

Kipahulu valley is situated on the outer ESE slopes of Haleakala (Fig. 1). The valley is isolated from surrounding areas by 335m high cliffs on both sides from approximately 400m almost to the summit. The head of the valley is between the peaks of Pohaku Palaha and Kuiki at approximately 2700m. There are two major topographical features in the valley; 1) the extinct cinder cone, Palikea, at 700m; and, 2) the valley is divided along its length with an upper shelf on the southern side 200m above the northern side. A major gorge, Koukouai Gulch, formed by the intermittent Koukouai stream, borders the southern side of the valley. At the base of the northern pali (cliff) there is a permanent stream, Palikea, but no gulch has been formed except below 400m.

The valley is an erosional feature formed during a quiescent period following the Kula volcanic series (Macdonald & Abbott 1970). Later volcanic activity during the Hana series partially filled in the valley with lava flows, principally 'a'a. A subsequent period of erosion created the lower valley and this was then partially filled by later eruptions. Both plateaus were then covered with ash from Palikea and other cinder cones.

Soils

There are five soil types found within the study area (USDA Soil Conservation Service 1972) of which two predominate--a Hydrandepts-Tropaquods Association and a silty clay of the Maka'alae Series. The other three are an extremely stony silty clay of the Maka'alae Series, rock land and rough mountainous land. These descriptions are only generalizations because most of the study area has been surveyed by reconnaisance only.

The Hydrandepts-Tropaquods Association is confined to the forest areas above Pu'u 'Ahu'ula from Koukouai Gulch to Palikea stream and the ridgetop above Waimoku Falls. The association is found in areas where the mean annual rainfall is above 100 inches and the mean annual soil temperature is below 65½F (18½C). The Hydrandepts are the well-drained soils between Puu Ahuula and Palikea Peak and the ridgetop above Waimoku Falls. The substrate is high in organic matter which overlies a dark brown to dark yellowish-brown, smeary silty clay. This soil dehydrates irreversibly into a pebblelike rubble. The Tropaquods are found in the area between Palikea stream and Pu'u 'Ahu'ula. The area is poorly drained and difficult to traverse because it is so slippery. A peaty muck surface lies on top of a dark gray clay under which there is normally a thin ironstone sheet.

The Maka'alae soils are found in all areas, except the gullies, below Pu'u 'Ahu'ula and the Pua'alu'u pastures up to the top of Waimoku Falls. The soils are relatively fertile and differ only in the degree of stoniness which is related to the slope of the land. The soil is well-drained having developed from deep volcanic ash. The mean annual rainfall is between 1750-1500mm and the mean annual soil temperature is 73½F (23½C). The upper 250mm of soil is a very dark brown silty clay beneath which there is a very dark grayish-brown silty clay more than one half meter deep overtopping 'a'a lava. Most of the area has very few stones or rocks on the surface except where the slopes approach 25 percent when the cover of exposed rock may reach 15 percent. A notable exception to this generalization is the piles of old Hawaiian terracing rocks which were aggregated together throughout the pastureland during the preparation of the area for sugarcane cultivation.

The rock land and rough mountainous terrain is confined to the gulches associated with Koukouai, Palikea-Pipiwai-'Ohe'o, and Pua'alu'u streams. The 'soils' are found in the same general area as Maka'alae Series soils. However, erosion has cut through the surface soil and frequently deep into underlying bedrock. Rock land has numerous exposed rocks and little soil other than that trapped by vegetation or between rocks. Rough mountainous land usually has a veneer of soil with few exposed rocks overlying a generally porous bedrock. In both cases the terrain is often very steep from 25 to 100 percent slope.

Climate

The average maximum temperature in coastal area varies from 27½C (80½F) in December and January to 29½C (85½F) between July and September (Anonymous 1973). The highest temperature of record in the area is 34½C (94½F). The average minimum temperature varies from 16½C (61½F) in December to 21½C (69½F) in October. The lowest temperature of record for the area is 14½C (58½F).

The rainfall in the study area is evenly spaced throughout the year. The average annual monthly rainfall ranges from a low of 150mm in April and May to a high of 280mm in December. The highest monthly rainfall of record is 1075mm in March. The rainfall gradient from the coast to 700m is thought to be quite steep. The average annual rainfall at the coast is about 1750mm, whereas at Palikea peak and the gaging station on Palikea stream, a distance of less than one statute mile, it is over 2500mm.

The relative humidity is essentially constant throughout the year. The average daily maximum fluctuates between 85 and 90 percent during any month and the average daily minimum varies between 57 and 65 percent.

The wind pattern is dominated by the northeasterly trade winds. Local topographical features have such a profound effect on wind patterns that reference to observations from a local weather station are necessary for detailed information. No suitable reference station exists in the Kipahulu area*. Normally the trade winds blow about 90 percent of the time

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* It would be very helpful for future research and resource management programs to install a weather station in the valley. It should include a raingauge, thermobarometer (temperature and relative humidity sensors) and an anemometer.

during summer but only 40 percent in winter. From October to April southerly Kona storms or southwesterly winds are common. Winds of 25 mph are not uncommon during all times of the year. Typhoons (hurricanes east of 180½) are quite rare in the islands though tropical storms pass through principally in August and September (Anonymous 1973).

METHODS AND MATERIALS

Reconnaissance and site selection

A NASA 1978 false infra-red aerial photograph was used to locate communities for mapping purposes. Forested and pasture sites were noted below 700m within the designated east-west boundaries of the study area. The eastern boundary was Maluhianiwi stream and the western boundary Koukouai stream.

Mapping

The vegetation map (500 hectares) was drawn using the NASA 1978 false infra-red photographs blown up to 1:6000. Vegetation units were outlined and assigned provisional descriptions. The descriptions and vegetation boundaries were then checked by field observations and reference to the photographs. All vegetation units were visited.

A final draft of the map was traced onto a mylar sheet. Labels and shading of the forested areas were imprinted on other sheets. The composite map was then produced by multiple exposure of the various sheets. The different intensities of black were controlled by varying the exposure times.

RESULTS

General observations

The vegetation of the area can be divided into three components: a spray-zone grassland bordering the ocean, pasture interspersed with woodland, and forest.

The spray-zone vegetation (22 hectares) is a degenerated remnant of the plant community typical of many windward areas in the islands. There are very few undisturbed examples of this vegetation type remaining. In Kipahulu, it is dominated by native herbs, principally *Fimbristylis pycnocephala*. The low shrubs, typically present elsewhere, are absent.

From the spray-zone to approximately 500m elevation the vegetation is principally a grassland (170 hectares) in areas where the soil is deep and cattle graze. Alien woodlands (30 hectares), confined principally to piles of rocks and gullies, are interspersed throughout the pasture. Forests (285 hectares) of mostly alien species are found along the upper boundary of the study area as well as in the gullies, where cattle are excluded by fencing or terrain. Above the Forest Reserve boundary, alien species gradually give way to natives increasingly so with elevation.

In the grasslands, only one native species, a sedge (Cyperus polystachyus Rottb.), is a consistent and common element of the ecosystem. All other dominant species are alien, principally grasses and sedges. Below 700 m, several distinct alien forest communities occur, including bamboo thickets, stands of Java plum, Christmasberry, and common guava, collectively or as individual stands, as well as small pockets of kukui, a Polynesian introduction. Above the forest reserve boundary, though native species are much more common and are consistently major components of plant communities, alien species are dominant in about half of the area studied. Strawberry guava, which starts to come in at 400m, replaces the common guava which disappears above 700m. The alien species, except bamboo, are consistently associated with damage by cattle or pigs in the forested areas.

Vegetation map

The final form of the vegetation map consists of labelled vegetation units outlined on a clear mylar map which also has major features in half tone for the lower portions of Kipahulu Valley. Copies of this map are on file at Western Regional Headquarters NPS, San Fransisco; Haleakala National Park Headquarters, Maui; Cooperative National Park Resources Studies Unit in the Department of Botany, University of Hawaii at Manoa, Honolulu; and The Nature Conservancy, Honolulu. The map is presented here in a blueprint version (Figure 2 in pocket on the back cover).

The communities are labelled on the map using a combination of symbols derived from generic names, plant cover designation, vegetation structure, or other predominant surface feature (Table 1). A total of 40 symbols were used to construct the map units. Symbol combinations begin with a letter indicating the structure of the community (e.g., open or closed, pasture) and are followed by the dominant tree or shrub species in order of cover. Less common, though important species follow in parantheses. In some instances individual species are not listed when several constitute a typical group for an area (e.g. upland gulch species). A comma separates the tree and shrub element from ground cover. Individual species are rarely listed in this combination unless they are obviously dominant in that vegetation layer. General descriptors are also used (e.g., native grasses) and are in their order of cover in the community.

The mapped vegetation has been classified into 92 structural-floristic communities that are grouped into two structural vegetation-types (Table 2). Forest communities were defined as those areas in which the tallest vegetation layer was composed of woody vegetation greater than or equal to 5m in height with at least 30 percent crown cover. Grassland communities were defined as areas in which grass or sedge species had more than 30 percent cover while the cover of woody species was less than 30 percent. Cover was defined as the vertical projection of the crown or shoot area of a species to the ground and expressed as a percent of the reference area (Mueller-Dombois & Ellenberg 1974). Closed canopy was defined as 60 percent or more cover. Open canopy was defined as 30-60 percent cover. These cover designations were applied to each layer of the vegetation. Thus, a community may be termed an open forest community with a closed ground cover.

This vegetation map is at a larger scale than most. The detailed information produced has resulted in an unusually large number of mapped units (136) for such a small area which is more a reflection of the considerable disturbance that this area has suffered, a problem that continues today. Only 24 (26%) of the mapped units are represented more than once on the map.

Evidence of past Hawaiian activity

Evidence of aboriginal Hawaiian agriculture (e.g. banana, sweet potato) were noted throughout the area. Bananas are found just above 700m on Palikea peak and at 1065m on the lower floor, the highest remaining evidence of past agriculture in the area. Ti (Cordyline terminalis (L.) Kunth.) grows up to 865m on the lower floor. Sweet potato (Ipomoea batatas (L.) Poir.) was found up to 600m principally at the base of the cliff bisecting the valley. Floral remnants of gardens were also observed, some of them in quite inaccessible areas which indicate that the area was under intensive agriculture prior to 1778.

Terracing, some of it still in good condition, was seen in Pua'alu'u and the 'Ohe'o stream complex gulches. Extensive terracing was also observed in the bamboo thicket between Pipiwai and Pua'alu'u particularly along the upper edge of the cliff. This terracing appears to have been constructed for dry-land agriculture.

DISCUSSION

The status of the vegetation in the study area

The study area has a long history of disturbance. Historical and biological evidence (see next section) indicate intensive aboriginal agricultural manipulation of the area. Much of the area was later converted to a sugar plantation, then briefly used as a pineapple plantation before becoming ranchland. During land clearing for plantation-style agriculture, the terracing stones of the Hawaiian lo'i were piled together in an apparently random arrangement throughout the area. All this disturbance and the introduction of many alien species has produced a vegetation which is in continuous flux.

Vestiges of native vegetation occur in many areas and some management activities can be taken to restore or stabilize native plant dominated communities. However, until the disturbance factors - cattle, pigs, strawberry guava, christmasberry, Java plum, bamboo, etc. - are eliminated there is little likelihood of any restoration of native ecological processes in the area.

Past Hawaiian activity

The distribution of wild banana, ti and sweet potato, particularly above the pastureland, is considered reliable evidence of past Hawaiian agriculture in the area. Banana and sweet potato only reproduce asexually in this environment. Ti, on the other hand, does produce viable seed but the offspring are extremely variable in size, color and shape of leaves (Watson & Yee 1976). Yet the ti plants in Kipahulu, particulary above 500m, are very uniform in these characters indicating either considerable inbreeding or clonal propagation. Because of the ease of outbreeding in ti, as well as the tendency for little sexual reproduction in very wet environments, it is concluded that the ti plants above 500m are remnants of past plantations which are maintaining themselves by layering.

Other evidence of agriculture includes the association of several plants of economic importance to the Hawaiians in pockets particularly along the cliffs up to approximately 500m. Terracing or the probable remnants of terracing are found up to at least 335m throughout the study area.

Sweet potato and ti are absent above Palikea on the upper plateau but there are a few banana plants just beyond the peak. It appears that the Hawaiians did not use the upper plateau. On the lower floor bananas are found up to 1065m, ti to 865m, and sweet potato to 600m. Sweet potato is abundant on both sides of the lower plateau whereas banana and ti are confined principally to Palikea Stream and adjacent areas. Thus, Hawaiian agriculture was probably quite intensive on the lower floor as high as 1000m elevation.

No explanation is available for the absence of agriculture on the upper plateau. It is doubtful that the steep access made much difference. In fact, the upper plateau appears to be more suitable because of its deeper soil. It may be that the upper area was abandoned earlier and thus has had a longer time in which to re-establish the native vegetation. Also, the deeper soil may have produced a more vigorous native forest allowing it to recover more rapidly. On the other hand, some sociological or religious limitation on the use of the upper plateau may have been imposed by the Hawaiians. Comparison with Kaumakani Ridge does not resolve this problem because the latter has been significantly disturbed by cattle.

The plant communities present today

Common sense and all analyses demonstrate two basic vegetation types in the study area--grassland and woodland. The grassland is not the climax community for this area and is maintained by cattle grazing. If the cattle were excluded from the area much of it would revert to woodland within a few years.

The grassland can be subdivided into three zones; the spray-zone Fimbristylis meadows, the alien grasslands dominated at lower elevations by West Indian dropseed and at higher elevations by the native Cyperus polystachyus.

The spray-zone meadows, maintained by the saltwater spray, are a species-poor representative of this community type found elsewhere in the islands. Though grazing pressure has undoubtedly had a significant impact in the past, it is suspected that most of the damage today is done by the constant human trampling to which these areas are subjected. Serious consideration should be given to restricting access to all spray-zone areas other than those around the mouth of 'Ohe'o Stream.

The distinction between the two grassland types is thought to reflect differences in the higher rainfall at higher elevations though other environmental variables may be important. The forage quality of these grasslands is low. Many of the species are palatable only when young.

None of the plant communities present in the study area are completely native. Even the forest communities at the upper elevations of the study area and above contain both herbaceous and small, arborescent weeds. This ongoing invasion of alien species plus the continuous disturbance by cattle and pigs has disrupted the ecosystem so severely that no portion is in equilibrium. The prognosis for the study area and adjacent upper areas is for further disruption leading to the probable replacement of the native flora by aliens unless the feral pigs are eliminated. It is anticipated that the invasion may creep steadily up the valley even if pigs are eliminated. However, it should be possible to check the disruption if specific weed species, in particular strawberry guava, Java plum, roseapple, and African tulip tree, are controlled. Some species may be potential targets for biological control programs.

Most woodland areas are dominated by alien species. It is quite evident that as Hilo grass, strawberry guava and roseapple become established at higher elevations, reproduction of the native species decreases. Gardner (1980) has already shown that strawberry guava will inhibit koa seedling establishment. It appears that the koa forest will decline as existing trees die, to be replaced by a rose apple forest or strawberry guava thicket.

Native species and Polynesian introductions are maintaining a tenuous existence in the area. As disturbance by feral pigs continues, the spread and cover of Hilo grass, strawberry guava and roseapple will continue replacing most native species and communities.

The coastal hala forests have also been decimated. They were probably destroyed by cattle and their regeneration is now prevented by California grass and false kamani. It should be possible to reverse this trend by planting young hala trees in the area and suppressing the aliens. Once established, hala should control most of the aliens by shading them out.

RESOURCE MANAGEMENT RECOMMENDATIONS

The nature of the problem

The Haleakala National Park general management plan (NPS 1978) states that the park was established partly "to preserve the outstanding... biological resources of Haleakala Volcano and its southeastern flank... " The management objectives, particularly numbers 1, 2, 3 and 5, emphasize a mission to preserve and protect native species and ecosystems as well as restore them except in the Kipahulu coastal area (and Hosmer Grove, an area not pertinent to this report). It is almost ironic that the only region in the study area that has a predominantly self-sustaining native ecosystem unchallenged by alien species is the coastal spray-zone vegetation, an area excluded from protection in the general management plan.

<u>The primary resource management problem in Kipahulu Valley is the feral pig</u>. Management recommendations for this organism are presented elsewhere (Diong in press). The pertinent resource management question in this report is whether or not

the control and ultimate elimination of feral pigs from the valley would allow the native ecosystems to reestablish themselves. The answer is an unequivocal no. Alien plant invasions are so pervasive below 1300m and some of the species are so aggressive that it is quite probable that they will overwhelm the native ecosystems. Similar areas on outer islands, e.g. windward side of O'ahu, which have been exposed to the same alien species are now alien plant communities with a few refugia of natives particularly where 'uluhe is abundant. There are no areas in the study region which are free of aliens. In those forested sites where native species predominate there are populations, sometimes large, of undesirable alien seedlings. Studies elsewhere in Hawaii have not shown any situation where native species have totally replaced similar alien life forms once disturbance has abated or been stopped. Jacobi (1981), Spatz and Mueller-Dombois (1975) and Wirawan (1972) have all shown a stabilization and occasionally small increases of native species in areas protected from pigs, cattle and goats. The recovery is slow. It remains to be seen whether of not native species can replace aliens completely. However, none of the above study areas are in typical guava habitats and it is these species together with Hilo grass that are of primary concern in Kipahulu.

The disturbance by feral pigs has been so severe and the establishment of aggressive alien weeds so extensive in many areas of Kipahulu Valley that they will themselves act as a source of infestation for other relatively undisturbed areas. The park's policy (NPS 1978) to date has been to treat the valley below 700m as a pastoral area and higher elevations as a science reserve of pristine ecosystems. Unfortunately, it has recently been shown (Diong in press, Yoshinaga 1980) that the lower elevations of the valley is the principal source of entry of both alien plants and animals into the upper valley. Thus the two areas cannot be managed separately and management strategies have to be developed that are more cognizant of the role of lower elevations as a disruptive influence on the almost pristine areas above.

There is also an important political perspective to the park's management of the area. The land above Palikea Peak and the Palikea gaging station was donated to the National Park Service (NPS) by The Nature Conservancy (TNC) and the State of Hawaii (SOH). The park's resolve to preserve the pristine nature of the area was very sincere (Smith 1978, see appendix). Very few people were allowed into the area until the 1976 Expedition (Lamoureux & Stemmermann 1976). This management attitude was in direct response to the recommendations of the 1967 Kipahulu Valley Expedition report (Warner 1967). Though the third recommendation in the report encouraged the reduction or elimination of feral pigs, no program was instituted due to local political considerations as well as statements to the contrary elsewhere in the report, e.g. "magnificent...forests...bear witness to the compatibility of wild pigs and a wide variety of indigenous plant species." The failure to institute a feral pig management program was also due to NPS efforts to implement a goat fencing program in the Crater Region which diverted attention away from this problem. The Kipahulu community's insistence on maintaining a rural lifestyle threatened by the visibility of the area as a national park also diverted attention away from the pig problem. At about this time Becking (in Lamoureux & Stemmermann 1976) blamed the spread of weeds into the valley on the 1967 Kipahulu Expedition members. Diong (in press) and Yoshinaga (1980) have since refuted that position by demonstrating that the feral pig is the principal agent for weed dispersion in the valley. Also, the political climate has now changed. Conservationists and the local community have found that their concerns are mutually reinforcing one another at a time when the scientific analyses of the problems have just been completed.

Possible management strategies

The following remarks on resource management strategies refer principally to the valley between 500 and 1335m. Areas below 500m are not discussed in detail because of problems regarding ownership of the property, current use of the land and the immensity of necessary management activities there. Even above 500m problems of land ownership and management exist but they appear to be resolvable if all parties concerned demonstrate good faith.

To do nothing about alien plants above 500m would lead to the degradation of all native habitats in the valley up to 1335m. It could be argued that once feral pigs are eliminated the native ecosystems will be able to recover. Unfortunately, no studies support such an assumption for forested areas. The only areas where significant recovery of native ecosystems in an area invaded by alien weeds has occurred is in a seasonal dry forest habitat on Oahu (Wirawan 1972). Alien species were still a major component of the ecosystems. To do nothing in Kipahulu Valley will likely result in the conversion of the koa and koa-'ohi'a forests below 1335m into alien woodland, principally strawberry guava thickets with Hilo grass understory.

Another management strategy could be to contain the most problematic species and keep them out of certain areas. For example, strawberry guava could be eradicated above 1165m and roseapple eliminated at Palikea and the Gaging Station. Areas outside these containment areas would be surrendered to the alien plants.

The problem with this approach is that it maintains a large number of food plants in the valley. Pigs will be attracted to the areas. Thus the 1200m contour might have to be fenced to prevent pigs moving to higher elevations. On the other hand, the concentration of so much fruit would also attract birds which could easily disperse the seed to higher elevations. Ideally it would be desirable to control species before they become ~~a threat.~~ This approach requires that alien species be evaluated as they become established in the lower valley. If found to be potentially disruptive they should be eradicated immediately.

Unfortunately, several species are significant problems in the valley already. The only hope to control these species is by using predators and parasites (biological control agents). Ideally, all alien species should be removed. Apart from being prohibitively expensive, that level of management activity would have a severe negative impact in the area.

With the above considerations in mind it is suggested that the lower valley be divided into management zones.

Resource management zones

The goals of the lower Kipahulu Valley resource management program should be:

1) To eradicate or sufficiently control any alien threat to the upper valley ecosystem.

2) To promote resource utilization practices in the lower valley that are consistent with or complimentary to goal number one.

3) To protect, encourage and restore selected ecosystems in the lower valley area.

In order to effect such a program it is recommended that five management zones (areas with intensive management of particular species) be established. However, as noted elsewhere, this approach is totally dependent on significant control or eradication of the feral pig from the valley.

Zone A lies above 1165m where alien shrubs, trees and spreading grasses would be eliminated. This area should be managed aggressively but with very careful attention to minimizing adverse impacts on the ecosystem.

Zone B is the area between Palikea peak/Gaging station up to 1165m. This area should be managed minimally initially. However, as weeds are removed from zone A management activities would move down into this area.

Unless resource management efforts are increased significantly this proposal means leaving this area to be overrun by alien plants.

Zone C lies between Pu'u 'Ahu'ula across to Waimoku Falls up to B. Since significant segments of this area are not owned by NPS or TNC, some form of cooperation agreement must be made to control pigs and alien weeds in the area. One approach would be to encourage the 'uluhe to expand by controlling the aliens at the margin of the colonies. Shading by this fern will prevent most of the guava seedlings reaching maturity. Those that did break through the canopy could be controlled manually. The fern mat also acts as a nursery area for the establishment of koa and other native species.

Zone D is an area from the Kipahulu-Hana road up to zone C. This area is the principal cattle-grazing area in the park. Because the open agricultural scene is the desired objective, a more regular weed control program should be established. Certain swampy areas below Palikea may be more appropriate for taro cultivation. Some other areas are quite appropriate for banana plantations. However, the difficult management areas for any user of zone C are the piles of rock from old lo'i and other sources. These are colonized by guava, christmasberry, Java plum, etc. and are the principal sources of weed propagules in the adjacent pastureland. To remove the rock piles would be prohibitively expensive, yet to continue to leave them uncontrolled only perpetuates the problem. A suitable alternative would be to control the alien plants and replace them by planting native species, e.g. lama, hala, kukui, which would shade out most regenerating weed seedlings. It would benefit the rancher because the aliens would be controlled. The native species would not present the same problem because they cannot grow up through thick grass mats and even if they became established they would be set back significantly by cattle activity.

There are pockets of native vegetation in this area particularly in 'Ohe'o Gulch where small groups of 'ohi'a trees are found. These areas should be mapped and alien trees in the immediate area should be poisoned or removed where feasible.

Zone E is the land below the Hana-Kipahulu Road and above the coasted spray zone. On the Hana side of 'Ohe'o Gulch there is a decadent lama woodland that could regenerate naturally if the grass cover was eliminated. Once reestablished it will probably be self-sustaining like the hala forest adjacent to the Hana airstrip.

Occasionally, tall grass and scrub areas are cleared for various purposes. It would be very appropriate to plant native trees in these areas before they are abandoned to aliens again. Below 135m, hala should be planted. Above 135m, kukui should be planted in wet areas, lama or 'ohi'a in drier areas. On the other hand, a more deliberate restoration program could be initiated in some areas, such as the area below the road on the Hana side of 'Ohe'o Gulch. Grasses could be controlled with 0.5% Roundup and hala seedlings planted or perhaps the area could be left to regenerate naturally.

Zone F is the coast spray zone, a unique ecosystem. It is particularly sensitive to trampling and many of the areas are in the camping zone. Since a fence in the area would rust away very rapidly, apart from also being unsightly, a visitor education program is probably the most effective management option. In order to accomodate people's yearning to stand above the waves breaking on the rocks, a few strategically placed boardwalks would be useful. They could also provide an opportunity to interpret the coastal fauna and flora.

In zones E and F there is a need to control the alien ants. Though none of the species are dangerous to human health they do husband the mealy bugs that damage the shoot tips of hala and other native species. They have also had a devastating impact on the native insect fauna. It is important that visitors are encouraged to dispose of their food and other trash in baskets that are emptied frequently. Removal of waste material will go a long way toward reducing the ant populations.

The most important management areas are zones A and B. It might be said that all management activity should be focused in this area. Such an approach would be ideal. However, the weather in Kipahulu Valley is such that it would be impossible to work up in zones A and B for significant periods of time. The recommendations for zones C through F are included for mangement action when access to zones A and B are impossible.

ALIEN PLANT MANAGEMENT

Limit the spread of Hilo grass and strawberry guava further up the valley

Hilo grass and strawberry guava plants should be destroyed above 935m. All plants should be carefully logged so that their status can be evaluated on an annual basis. Control should begin at the upper limit of its distribution (1250m) and work downhill. (It would be highly appropriate for the resource managers to control pigs as and when they came across them. Such activity will discourage the pigs from moving up the valley into the uninfested area.)

As each species is controlled at higher elevations the lower limit of control should be decreased. Heavy infestations should be managed first because 1) they will be a source of seed for future infestations, 2) less time will be wasted looking for plants, and 3) the negative impact of working in the area will be minimized. However, obvious outling populations should be controlled whenever located before they become established.

Eradicate Java plum, roseapple and African tuliptree

The Java plum and roseapple stands up to 700m and the African tulip trees up to 1065m should be cut down and poisoned. These plants have the potential to invade higher elevations. The African tulip tree infestation on Kaumakani Ridge should be eliminated first because the windborne seeds can be readily disseminated into the valley by the prevailing trade winds. There are major infestations of all of these species along the north shore of East Maui.

Develop cooperative alien weed control programs with adjacent landowners.

The main route of alien weed invasion into the valley is from the lower elevations (Yoshinaga 1980). Much of this land is owned by the State of Hawaii or private landowners. Cooperative weed control programs, conservation management programs by NPS, or conservation easements need to be developed to reduce the threat of these areas to the upper valley.

1. The Yoshinaga and State parcels between Pu'u 'Ahu'ula and Palikea are heavily infested with strawberry guava. Some of the densest populations occur on State property. These property owners should be encouraged or assisted in eradicating this weed.

2. The boggy area at the base of Palikea/Pu'u 'Ahu'ula across to the gaging station, currently grazed by cattle, should be managed as something other than marginal cattle pasture. Some areas are suitable for bananas, others for taro cultivation. It is very important that appropriate agricultural programs are adopted for the area. Cattle ranching is appropriate only if it is linked to a vigorous weed control program. Alternative agricultural practices include converting some of the higher elevation pasturelands to taro farming, banana plantations, etc.

CONTROL METHODOLOGIES

Strawberry guava and common guava

It is virtually impossible to eliminate these species in the short term. The trees can be poisoned most effectively using Tordon 22K (100%) on cut stumps. However, this approach is very expensive and the use of Tordon is virtually forbidden in national parks. Garlon appears to be an effective substitute. Even though these trees will be set back severely, the area will be reinfested by seedlings within a short period. However, the seedlings and regenerating shoots will not reproduce for at least three years. Thus a two or three year retreatment cycle will make a significant impact over a ten year period. Dr. Gardner is currently working on a spray technique for killing guava seedlings. It may not be feasible because the leaves are so waxy that the herbicide rolls off.

A shorter cycle of control is not recommended because natural thinning processes will decrease the number of new trees significantly. Therefore the job will decrease in complexity the longer the interval between each management. It is important, however, that the management occur before the trees reach maturity. Any addition to the seed bank is to be avoided because strawberry guava seeds have a low dormancy. Thus the seed bank is exhausted rapidly and this fact must be exploited for effective control.

Strawberry guava seedlings have an ability to survive as seedlings for several years. They will not grow until the canopy is opened. It is imperative therefore that the integrity of the fern layer is maintained. Disturbance by pigs or man will only release strawberry guava seedlings from their 'dormancy'.

Roseapple, African tulip tree

These trees should be cut down and the stumps poisoned with Roundup. They can be more easily controlled by poisoning using a hypohatchet. However, a dead standing tree is a potentially serious hazard to anyone working in the area.

Bamboo and Hilo grass

There is no known simple, cost-effective means of managing bamboo or Hilo grass at present. Research in this area is needed.

Christmasberry

This shrub is easily killed by injecting Roundup into the trunk using a hypohatchet.

MANAGEMENT IMPLEMENTATION

It is recommended that all resource management programs for the valley be directed by a resource management specialist at park headquarters. In Kipahulu, there should be a resource manager responsible for a work crew of two permanent employees and five seasonal employees. Appropriate equipment, supplies, travel, etc., would be extra. With this level of manpower it is probable that a significant reduction in the impact of alien animals and plants can be attained such that the pristine nature of the upper elevations of the valley could be maintained. The task confronting the program is almost monumental.

The local community

The local community is very concerned about the retention of what may be loosely termed the Hawaiian life style. They should be encouraged to support and participate in the management of the Kipahulu region of the park. There is no program which is recommended for implementation that contradicts their objectives. In fact, both could complement one another because both emphasize the restoration of native Hawaiian ecosystems.

Hana Ranch Company

Though this report by innuendo may be critical of the management of the ranchlands, the Hana Ranch Company cannot be held totally responsible because of the confused state of land ownership and ownership objectives in the area. The deteriorating quality of much of the pasturage must be of as much concern to them as to the National Park Service. The weed control strategies outlined above will help to alleviate some concerns but someone must direct the rancher as to what needs to be done and how if there is a property right. For example, the past practice of spraying 2,4-D on guava has not been effective because it has been very inconsistent. Spraying after the fruiting season is almost counterproductive because a fresh batch of seeds is introduced into the area. However, the economics of weed management programs may prevent their implementation. Perhaps by allowing other farming practices, especially Hawaiian agriculture, in some areas the ranch will be able to direct its attention to containing the weeds in the remaining areas.

Volunteer organizations

Volunteer organizations should be encouraged to participate in the management of the valley as practical. They will probably be more interested in working higher up the valley than they should because of the disturbance they could cause. They should be persuaded to work in those areas in which they will be most effective.

Fishing rights

The management of the coastal spray-zone ecosystem should not interfere with traditional fishing rights in the area. However, educating the fishermen of the management objectives for the area should prevent abuse or inadvertent disturbances.

RESEARCH NEEDS

Hilo grass and strawberry guava

The autecology of these species needs to be studied to answer certain questions that will help refine their management. Specific areas that should be studied are:

1) The upper elevation for germination and growth, fruiting, etc,;
2) Shade tolerance;
3) The longevity of seeds and seedlings;
4) Plant height in relation to substrate;
5) Effectiveness of herbicides and best method of application;
6) Are there any native species that can compete against them?; and,
7) Do koa and 'ohi'a reproduce in infested areas?

Weed control

Research on strategies to control strawberry guava, guava, bamboo, Hilo grass, roseapple, and California grass is urgently needed. Various strategies need to be determined for controlling weeds including immediately planting native species as replacements. Weed eradication techniques in management zone D that need to be evaluated include clear cutting, prescribed burning, etc.

Composition of native lowland forests

A comparative ecological survey of coastal spray zones on the north and east coasts of Maui and Moloka'i is needed to determine the typical species composition of this community. The reestablishment of native species should be evaluated.

Development of species replacement strategies.

Determine feasibility of eradicating christmasberry, guava and java plum from the rock piles and replacing them with lama, hala,'ohi'a, kukui, etc.

Spray zone restoration.

Conduct a comparative ecological survey of coastal spray zones on the north and east shores of Maui and Molokai to determine the typical native species composition of these ecosystems with a view to reintroducing species to the Kipahulu area.

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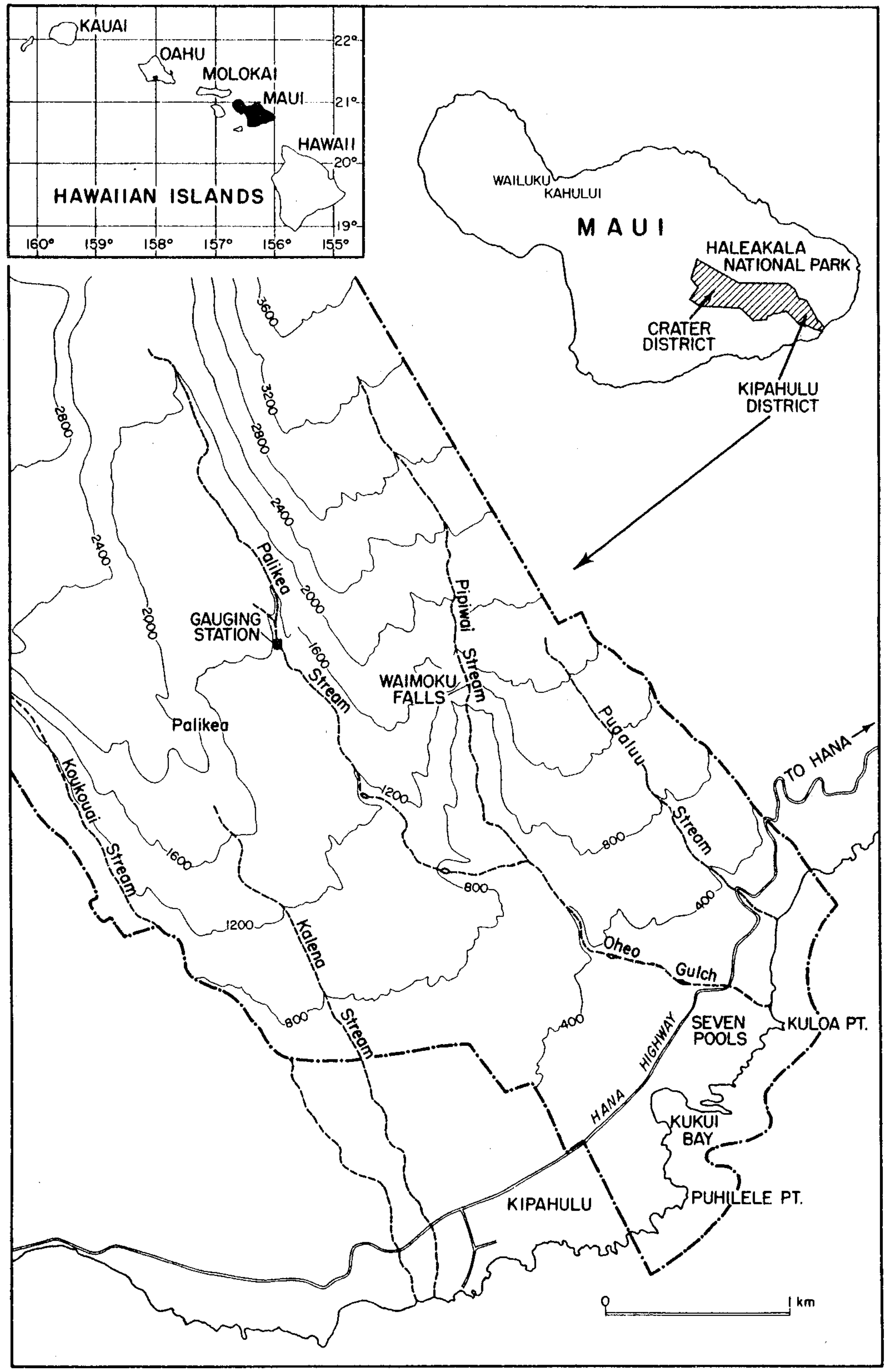

FIGURE 1. Lower Kīpahulu Valley and Haleakala National Park, Maui.

Table 1. Explanation of map symbols used for vegetation unit descriptions in Kipahulu Valley below 700m, Haleakala National Park

Symbol	Explanation
Ac	*Acacia koa* dominated or co-dominated forest
Al	*Aleurites moluccana* dominated or dominant forest
B	Boggy area species
Ba	Bamboo dominated or co-dominated forest
Br	*Brachiaria mutica* dominated or co-dominated area
cl	closed (>60% cover), used only in combination
Cp	*Cyperus polystachyus* dominated or co-dominated area
Ct	*Cordyline terminalis* dominated or co-dominated patches
Dd	*Digitaria decumbens* dominated or co-dominated area
Dl	*Dicranopteris linearis* dominated area
e	Exotic
Ec	*Eugenia cumini* dominated or co-dominated forest
Ej	*Eugenia jambos* dominated or co-dominated forest
f	forbs
G	Grassland, no grazing
g	Plants less than 1 m tall (herbaceous chamaephytes)
gr	Exotic grasses
H	*Hibiscus tiliaceus* dominated or co-dominated forest
I	*Ipomoea* sp. draped over woody vegetation
Lg	Lowland gulch species
M	*Melaleuca leucadendra* dominated forest
m	mixed (i.e., native and exotic)
Mc	*Metrosideros collina* dominated or co-dominated forest
Mg	Coastal gulch species
Mi	*Mangifera indica* dominated or co-dominated patches
n	Native
o	open (30-60% cover), used only in combinations
P	Pasture, currently grazed
p	Polynesian introduced species
Pa	*Pandanus odoratissimus* dominated or co-dominated area
Ps	*Psidium* dominated or co-dominated area
Rh	*Rhyncospora lavarum* dominated or co-dominated area
s	Sedges
Sg	*Setaria geniculata* dominated or co-dominated area
Ss	*Sporobolus indicus* dominated or co-dominated area
spr	Sea spray zone species
St	*Schinus terebinthifolius* dominated or co-dominated forest
Tc	*Terminalia catappa* dominated forest
u	Understory species
Ug	Upland gulch species

Table 2. Symbols, number of ocurrences, areal extent, and names of mapped vegetation units in Kipahulu Valley below 700m, Haleakala National Park

Map symbol	Units	Area (ha)	Community Name
B(Ps)	1	4.9	Bog with scattered Psidium trees
cl-Ac,mu(mg)	2	2.0	closed Acacia koa forest with mixed understory species and some herbaceous chamaephytes
cl-Ac,mn(mneg)	1	8.8	closed Acacia koa forest with mixed native understory and some native and exotic herbaceous chamaephytes
cl-Ac,mne(mneg)	1	8.8	closed Acacia koa forest with a mixed native and exotic understory and some native and exotic herbaceous chamaephytes
cl-Ac,mnp(mgDl)	1	21.7	closed Acacia koa forest with a mixed native and Polynesian introduction understory as well as some grasses and Dicranopteris linearis
cl-AcPs,mu(B)	1	15.3	closed Acacia koa/Psidium forest, with a mixed understory with some boggy patches
cl-AcPs,mn(mg)	1	2.1	closed Acacia koa/Psidium forest with a mixed native understory and some herbaceous chamaephytes
cl-Al	3	0.7	closed Aleurites moluccana forest
cl-AlBa	1	3.8	closed Aleurites moluccana and bamboo forest
cl-Al,mu	1	0.2	closed Aleurites moluccana forest with mixed understory
cl-Al,mu(mg)	1	8.1	closed Aleurites moluccana forest with mixed understory and some mixed herbaceous chamaephytes
cl-Al,mep(mg)	1	1.5	closed Aleurites moluccana forest with mixed exotic and Polynesian introductions and some herbaceous chamaephytes
cl-AlPs,mu(mg)	1	1.3	closed Aleurites moluccana/Psidium forest with mixed understory and some herbaceous chamaephytes
cl-Ba	5	17.7	closed bamboo thicket
cl-BaMi,mpne	1	1.0	closed bamboo thicket with Mangifera indica and mixed understory of Polynesian introductions, native and exotic species
cl-BaPs(Al)	1	2.5	closed bamboo thicket with Psidium and some Aleurites moluccana
cl-Ba(Ug)	1	0.2	closed bamboo thicket with upper gulch species
cl-CtAl	1	0.6	closed Cordyline terminalis/Aleurites moluccana forest
cl-Dl	6	1.5	closed Dicranopteris linearis canopy
cl-Dl(M)	1	1.8	closed Dicranopteris linearis canopy with some Melaleuca leucandra
cl-Dl(mu)	2	0.4	closed Dicranopteris linearis canopy with some mixed understory species

Table 2 cont.

cl-EcSt,me(mneg)	1	1.7	closed Eugenia cuminii/Schinus terebinthifolius forest with mixed exotic understory and some mixed native and exotic herbaceous chamaephytes
cl-Ej(Ac),mu(mg)	1	12.0	closed Eugenia jambos and some Acacia koa forest, with a mixed understory and some mixed herbaceous chamaephytes
cl-Ej(Ac),mneg	1	2.8	closed Eugenia jambos and some Acacia koa forest with an understory of mixed native and exotic herbaceous chamaephytes
cl-H	1	1.6	closed Hibiscus tiliaceus forest
cl-HLg	1	1.5	closed Hibiscus tiliaceus and lowland gulch species forest
cl-Lg	4	1.4	closed lowland gulch species forest
cl-LgAl,mu	1	2.3	closed lowland gulch species and Aleurites moluccana forest with a mixed understory
cl-Lg,mg	3	11.4	closed lowland gulch species forest with an understory of mixed herbaceous chamaephytes
cl-Lg,mpeg	2	13.2	closed lowland gulch species forest with an understory of mixed Polynesian introductions and exotic herbaceous chamaephytes
cl-M	1	0.7	closed Melaleuca leucandra forest
cl-McPs	1	5.4	closed Metrosideros collina/Psidium forest
cl-McPs,mu(mg)	1	2.5	closed Metrosideros collina/Psidium forest with a mixed understory and some mixed herbaceous chamaephytes
cl-Mg	2	2.5	closed Mangifera indica forest
cl-,mne	1	2.4	closed scrub of native and exotic species
cl-,mu	3	1.9	closed scrub of mixed understory species
cl-,mu(mgDl)	1	6.2	closed scrub of mixed understory species with some mixed herbaceous chamaephytes and Dicranopteris linearis
cl-PsAc(Al),mgIp	1	1.4	closed Psidium/Acacia koa with Aleurites moluccana with an understory of mixed herbaceous chamaephytes and some Ipomomea vines
cl-PsAc,mu	1	2.7	closed Psidium/Acacia koa forest with mixed understory
cl-Ps(Ac),meg	1	2.7	closed Psidium with some Acacia koa forest with an understory of exotic herbaceous chamaephytes
cl-Ps(Ac),mg	1	3.9	closed Psidium with some Acacia koa forest with an understory of mixed herbaceous chamaephytes
cl-Ps(Ac), mne(mgDl)	1	3.7	closed Psidium with some Acacia koa forest with an understory of mixed natives and exotics and some mixed herbaceous chamaephytes and Dicranopteris linearis
cl-PsAc,mu(mg)	2	22.1	closed Psidium/Acacia koa forest with mixed understory and some mixed herbaceous chamaephytes

Table 2 cont

cl-Ps(Al),mg	1	7.7	closed Psidium with some Aleurites moluccana forest with an understory of mixed herbaceous chamaephytes
cl-PsBa,mu(mg)	1	3.5	closed Psidium and bamboo forest with mixed understory species as well as some herbaceous chamaephytes
cl-PsEj,mu(mg)	1	2.0	closed Psidium/Eugenia jambos forest with mixed understory as well as some herbaceous chamaephytes
cl-PsEj,mne (mneg)	1	4.4	closed Psidium/Eugenia jambos forest with an understory of natives and exotics as well as native and exotic herbaceous chamaephytes
cl-Ps,mu	4	6.8	closed Psidium forest with a mixed understory
cl-PsMc,mu	1	1.6	closed Psidium/Metrosideros collina forest with a mixed understory
cl-Ps,mu(Ip)	1	11.2	closed Psidium forest with a mixed understory and some Ipomoea vines
cl-Ps,mu(mg)	2	2.0	closed Psidium forest with a mixed understory and some herbaceous chamaephytes
cl-Ps,mu(mgDl)	1	12.4	closed Psidium forest with a mixed understory and some herbaceous chamaephytes and some Dicranopteris linearis
cl-PsSt,mp	1	2.4	closed Psidium/Schinus terebinthifolius forest with an understory of mixed Polynesian introductions
cl-Lg,mg	1	13.6	closed lower gulch species and mixed herbaceous chamaephytes
cl-St,me(Ip)	1	4.0	closed Schinus terebinthifolius forest with a mixed exotic understory and some exotic Ipomoea vines
cl-Tc,mep(mneg)	2	4.0	closed Terminalia catappa forest with an understory of mixed exotics and Polynesian introductions as well as some herbaceous chamaephytes
cl-TcM,mep(mepg)	1	2.5	closed Terminalia catappa/Melaleuca leucandra forest with an understory of mixed exotics and Polynesian introductions
cl-Ug	2	1.7	closed upper gulch species forest
G-nsgr(PsMc)	1	2.6	grassland with native sedges and grasses and some Psidium and Metrosideros collina
o-Ac,mu(B)	2	7.0	open Acacia koa forest with a mixed understory and some boggy areas
o-Al	1	0.4	open Aleurites moluccana forest
o-Lg	1	0.5	open lower gulch forest
o-Lg,mgrf	1	2.7	open lowland gulch forest with mixed grasses and forbs
o-Mg	4	1.0	open coastal gulch forest
o-Mg,nef	1	0.5	open coastal gulch forest with native and exotic forbs
o-Ml	1	0.5	open Melaleuca leucadendra forest
o-Pa	2	2.4	open Pandanus odoratissimus forest

Table 2 cont.

o-Ps(Ac),mu(mg)	1	1.2	open Psidium with some Acacia koa and a mixed understory with mixed herbaceous chamaephytes
o-PsMc(Ac),B	1	3.7	open Psidium and Metrosideros collina with some Acacia koa; bamboo in the understory
o-PsMc,mu(mg)	1	2.8	open Psidium and Metrosideros collina forest with a mixed understory and some mixed herbaceous chamaephytes
o-PsMc(P-nsf)	1	4.6	open Psidium and Metrosideros collina forest with Psidium and native sedges and forbs in the intervening pasture
o-Ps(P-nsf)	1	2.8	open Psidium forest with an intervening pasture of native sedges and forbs
o-,mu(B)	1	0.7	open scrub of mixed species and some Bambusa
P-Br	1	0.4	pasture of Brachiaria mutica
P-Br(f)	2	2.0	pasture of Brachiaria mutica and some forbs
P-Cp(fgrPs)	1	20.0	pasture of Cyperus polystachyus and some forbs, grasses and Psidium shrubs
P-Dd(nsf)	1	4.1	pasture of Digitaria decumbens and native sedges and forbs
P-Dd(nsfPs)	1	7.0	pasture of Digitaria decumbens and native sedges, forbs and Psidium shrubs
P-Dd(RhPs)	1	4.3	pasture of Digitaria decumbens with Rhynchospora lavarum and Psidium shrubs
P-me	1	0.2	pasture of mixed exotic species
P-megf	1	7.1	pasture of mixed exotic herbaceous chamaephytes
P-m(Ps)	2		pasture of mixed exotic species and Psidium shrubs
P-nsf	2	15.1	pasture of sedges and some forbs
P-nsf(Ps)	2	12.1	pasture of sedges and some forbs with Psidium shrubs
P-SsBr	1	6.5	pasture of Sporobolus indicus and Brachiaria mutica with some forbs
P-SsDd(mePs)	1	9.6	pasture of Sporobolus indicus and Digitaria decumbens with some mixed and exotics and Psidium shrubs
P-SsDd(mgrf)	1	10.6	pasture of Sporobolus indicus and Digitaria decumbens with some mixed grasses and forbs
P-Ss(mgrf)	1	18.8	pasture of Sporobolus indicus with some mixed grasses and forbs
P-Ss(mgrf)	2	3.3	pasture of Sporobolus indicus with some mixed grasses and forbs
P-SsSg(fPs)	1	12	pasture of Sporobolus indicus and Setaria geniculata with some forbs and Psidium shrubs
P-RhDd(grfPs)	1	10	pasture of Rhynchospora lavarum and Digitaria decumbens with some grasses, forbs and Psidium shrubs
spr	6	22	spray zone grasses, sedges and forbs