

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

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HALEAKALA NATIONAL PARK  
RESOURCES BASIC INVENTORY: MOSSES

William J. Hoe

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## ABSTRACT.

As the result of three summers' field work in the Crater District of Haleakala National Park, island of Maui, sponsored by the National Park Service through the Cooperative National Park Resources Studies Unit at the University of Hawaii, 128 moss species and varieties were collected and identified. The Park is now known to be the only Hawaiian locality for at least 25 taxa, and the only Maui locality for an additional 38. A large number of rare species were also collected. The general ecology of the Crater District and the mosses associated with the seven proposed vegetation types are discussed. Also discussed are the phytogeography as well as the degree of endemism of Haleakala's mosses.

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## I. INTRODUCTION.

Mosses from the upper portions of Haleakala, island of Maui (more-or-less synonymous with the old boundaries of Haleakala National Park), have been known to science since the beginnings of the 19th Century. The first known collection from Haleakala appears to be of Pilotrichella mauiensis made in 1825 by J. Macrae during the voyage of the Blonde (collection cited by Mitten, 1873: 395). As may be expected, collections from these early times were made in conjunction with natural history surveys; although they contributed greatly to the beginnings of our knowledge of the Hawaiian moss flora, they were gathered more-or-less incidentally to more generalized goals.

Bartram (1933), in his citations of species distributions, contains much valuable information on many of these old collections. An examination of these lists in relation to Haleakala illustrates the cursory nature of almost all previous work. The most notable exception to this is that of the late D. D. Baldwin, a long-time Maui resident with a strong amateur interest in bryophytes. The greater part of his collections were made in the West Maui Mountains but a few came from Haleakala, with many Hawaiian taxa still known only from his materials. More recently, collections by the Hawaiian Bog Survey of 1938 (Bartram 1942) and Otto Degener (Schultze-Motel 1963) have been the most important contributions toward our knowledge of the moss flora of this area.

The Resources Basic Inventory (RBI) surveys of 1975-1977 attempted to provide systematically collected information toward a catalogue of the biota of the Crater District of Haleakala National Park, as well as to determine species distributions and abundance. In order to accomplish this, 55 sites, placed in the major ecological types, were surveyed (Fig. 1). The species present, their abundance and substrate were noted. The impact of herbivores was recorded. More specific information on the aims of the survey and methods utilized are explained in Stemmermann et al. (1978).

For the mosses, these surveys appear largely to have accomplished their goals. Numerous new records, both for the Hawaiian Islands and for Maui, were collected and many species previously known only from single or few old collections were rediscovered. Many of these noteworthy finds have already been published (Hoe 1977, 1978a; Pursell and Hoe 1977), while others still awaiting publication are included in this report.

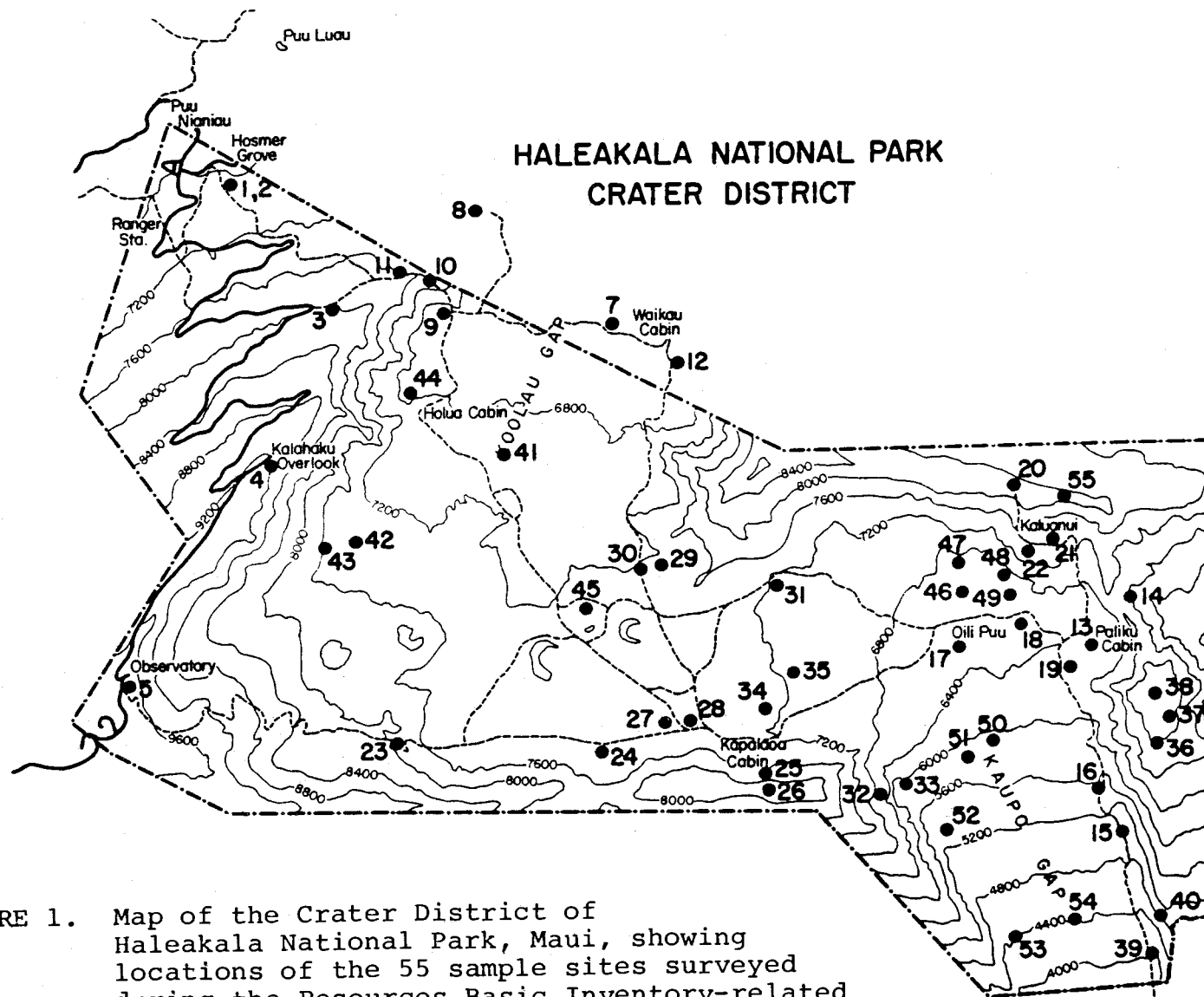


FIGURE 1. Map of the Crater District of Haleakala National Park, Maui, showing locations of the 55 sample sites surveyed during the Resources Basic Inventory-related field work. The location of the permanent quadrats, established in 1977, is also indicated.

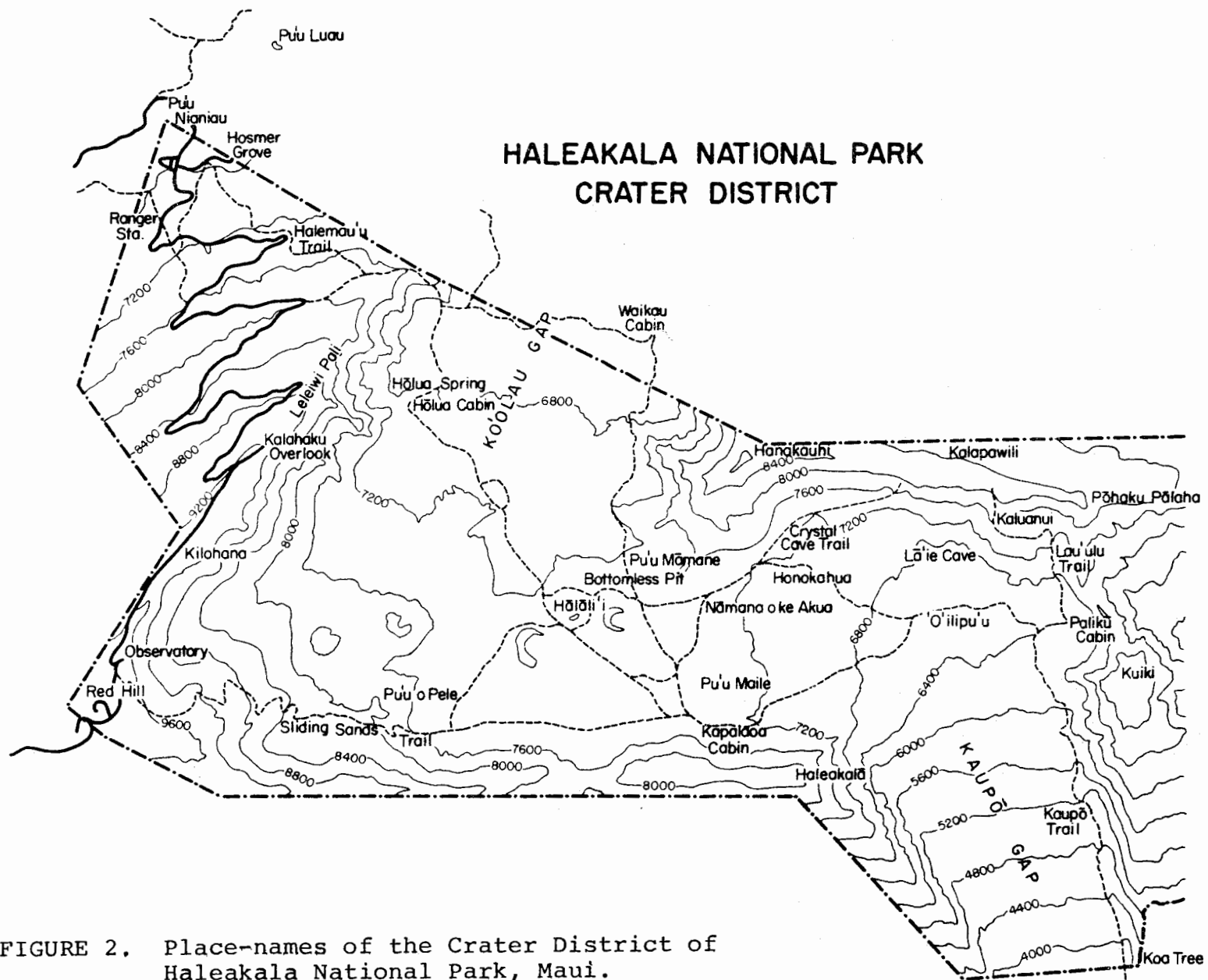


FIGURE 2. Place-names of the Crater District of Haleakala National Park, Maui.

## II. CATALOGUE OF THE TAXA.

With few exceptions, the following annotated catalogue of taxa (Appendix A) of the Crater District of Haleakala National Park and adjacent regions lists only those mosses collected and identified through the Resources Basic Inventory surveys of 1975-1977. For each, the following information is provided:

1. Name (in regular type). As accepted in Hoe (1974a) or in subsequent publications.
2. Synonyms (in parentheses). Names accepted in Hoe (1974a) but which are now considered taxonomically or nomenclaturally incorrect.
3. Status. If endemic, the taxon is restricted to one or more of the Hawaiian Islands. An indigenous species (or variety, etc.), while also found outside of the Hawaiian Islands, is considered to be a naturally occurring element of the Hawaiian bryoflora. This contrasts with the exotic taxon Hypnum plumaeforme, whose presence in the Islands appears to have been the result of man since 1788.
4. Comments. These may be of a general distributional, ecological, morphological, or historical nature and are self-explanatory. Generalized distribution in the Hawaiian Islands of all species is also given.

For each species and variety, a map showing distribution within the Crater District is provided in Appendix B.

All taxa listed are represented by collections in Herb HOE (presently at HAW), with available duplicates also at HAW and the herbarium of Haleakala National Park. To date, 42 taxa have been distributed through the Bryophyta Hawaiica Exsiccata, Series I, Decades 4-10 and are available in a large number of institutions (Hoe 1974b, 1978b).

In order to facilitate use of this list, the genera have been listed in alphabetical order, followed by (in alphabetical order) the species. The family designations are those utilized by Hoe (1974a).

## III. ANALYSIS OF THE FLORA AND DISCUSSION.\*

During three summers' field work over 900 collections, primarily of mosses, were made. These resulted in 128 taxa representing 58.4% of all recorded from Maui being identified from the Park and immediately-adjacent regions. There are

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\* References to the Haleakala moss flora and vegetation are based solely upon RBI field work and observations.



still a few species whose identities remain unknown. Such a high proportion of the Maui flora being in the Crater District is particularly impressive when one considers that except along its lower edges, the area is essentially a dry alpine ecosystem. Haleakala National Park is, nevertheless, the only known locality in the Hawaiian Islands for at least 25 taxa and the only known Maui locality for more than an additional 38. Figures such as these can only emphasize the distinctiveness of Haleakala and its mosses.

### 1. Ecological character of the Haleakala moss flora.

The greater part of the Crater District may be described as a rocky, shifting sand desert. Except in the Kaupo Gap area, it lies largely above the inversion layer. The open, dry alpine-like terrain is thus due to climatic as well as edaphic conditions. The mosses can be placed within seven vegetation types (Fig. 2).

#### A. The open, rocky, shifting sand-Grimmia desert (Type IA).

Along the upper north-sloping outer face, the landscape consists primarily of pahoehoe mounds and black cinder overlying a fine ash layer. Runoff must be very rapid. The area is nearly devoid of vegetation from the summit down to about 8000 feet (2450 m) with only scattered Railliardia and Tetramolopium. Mosses throughout this region are essentially restricted to sheltered ledges and crevices; epiphytes are absent. Except in a few locally favorable habitats, mosses are neither abundant nor conspicuous.

The only mosses which may be considered frequent belong to the genus Grimmia: Grimmia haleakalae, G. trichophylla, and, new to the Hawaiian Islands, G. cf. pilifera. Amphidium tortuosum is only sparingly present. Noteworthy in this vegetation type are Encalypta sandwicensis and Pohlia cruda, each seen as a single colony and previously unrecorded from Maui. Equally remarkable is the nearly total absence of Racomitrium lanuginosum var. pruinatum (see Part B below).

#### B. The open, rocky, shifting sand-Racomitrium desert (Type IB).

This vegetation type is, by far, the most extensive in the District encompassing the entire central and western crater floor. The overwhelming impression one gains while traversing the area is one of bleakness; it consists largely of an assemblage of apparently barren rock mounds and shifting black cinder overlying fine ash.

Although runoff in most of this area is probably as rapid as in vegetation Type IA, the availability of moisture is likely to be greater. Wind-driven clouds were often seen trapped in the Crater. The abundance of Racomitrium lanuginosum var. pruinatum,

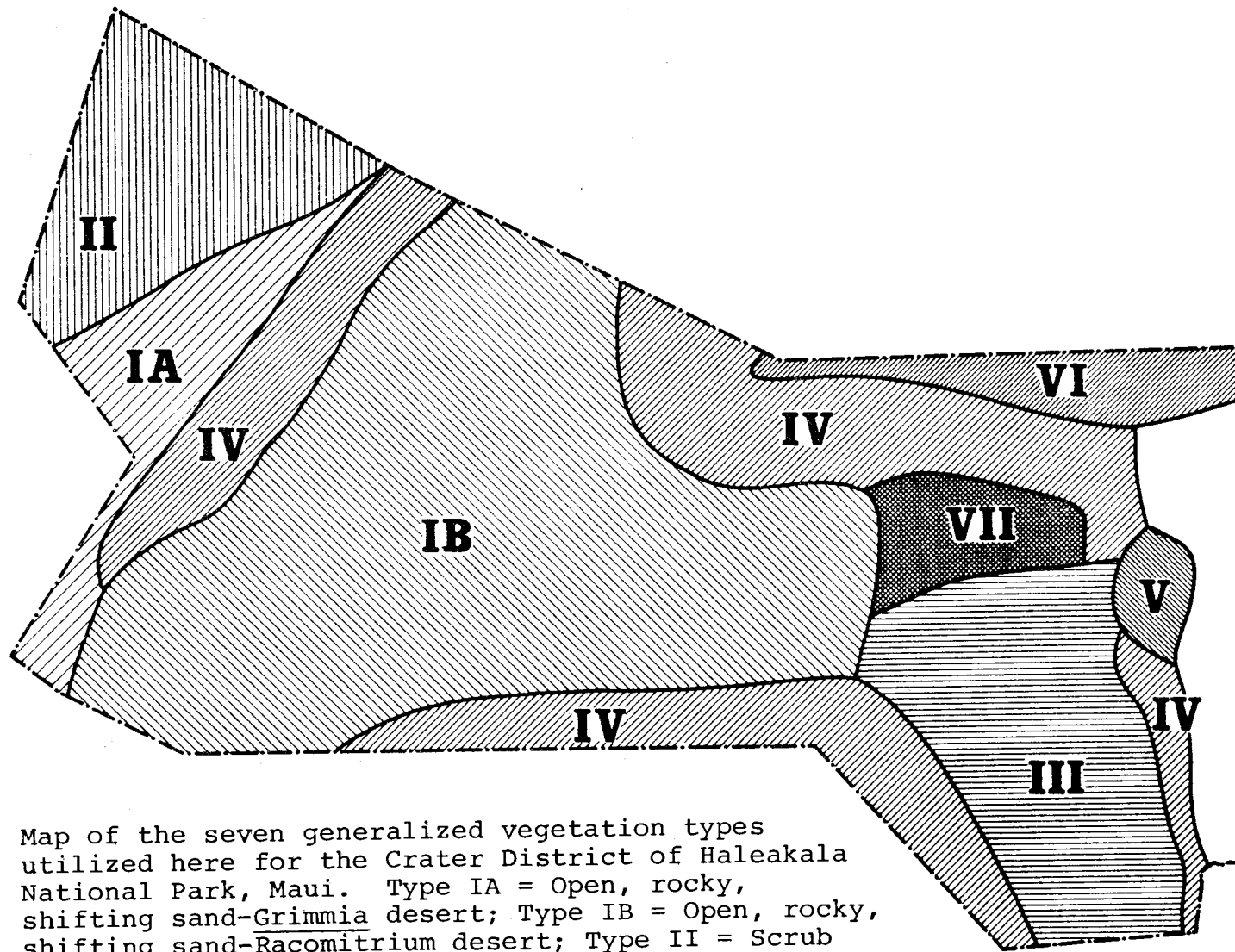


FIGURE 3. Map of the seven generalized vegetation types utilized here for the Crater District of Haleakala National Park, Maui. Type IA = Open, rocky, shifting sand-Grimmia desert; Type IB = Open, rocky, shifting sand-Racomitrium desert; Type II = Scrub vegetation; Type III = Mixed tall scrub-tree vegetation; Type IV = Cliff face vegetation; Type V = "Rain forest" vegetation; Type VI = Deschampsia grassland; Type VII = Transitional desert-scrub vegetation.

a sensitive moisture indicator (Tallis 1959), on windward-facing ledges and mounds is yet another indicator. Finally, the lichen Stereocaulon vulcani (Bory) Ach., similar to Racomitrium ecologically and morphologically, is also often present in large quantities (Smith, pers. comm.).

Trees and shrubs are present but restricted to the few older ash-covered, usually emergent surfaces or substantial depressions and major crevices. For example, both Pu'u Mamane (an old cinder cone) and Namana o ke Akua support tree-sized Sophora chrysophylla in addition to scrub vegetation. Grasses, too, may be locally common in these sites. Epiphytes are present but are confined to older trees and scrub.

In addition to the often abundant Racomitrium, the species of Grimmia of vegetation Type IA are also widespread here. Other important mosses which may be locally common but are largely restricted to scrub habitats include Brachythecium lamprocarpum, Ceratodon purpureus, Fabronia ciliaris (new to the Hawaiian Islands), and Palamocladium wilkesianum. The epiphytic species Macrocoma intricata, Orthotrichum diaphanum (new Maui record), Orthotrichum hawaicicum, and O. hillebrandii are confined to older trees and scrub. Noteworthy records for Desmatodon convolutus, Encalypta scabrata, Grimmia laevigata, and G. torquata, all known on Maui only from this vegetation type, were collected.

Although in many ways similar to the uppermost north-facing outer slopes (Type IA), the abundance of Racomitrium lanuginosum in this Type is considered of sufficient significance to justify the recognition of the greater part of the Crater (Type IB) as distinct.

### C. The scrub vegetation type (Type II).

Along the north-sloping outer face of Haleakala below 8000 feet (2450 m) there is a scrub vegetation of increasing density and stature extending downslope to the Park boundary. As compared with the substrate at higher elevations, there is considerable cinder-free exposed ash capable of colonization by plants. There is clearly a higher moisture availability as indicated by the frequency of cloud cover observed, the deep runoff gullies and ravines as well as the abundance of vegetation. Rain water for Park headquarters and residence use is also collected here.

Perhaps as the result of the greater moisture availability, there is an increase in both biomass and diversity of the mosses. Except in locally favorable habitats, however, they are primarily associated with the scrub vegetation or are scattered on sheltered ledges and in other protected sites. Only the drought-tolerant Grimmia species of vegetation Type I are likely to be on exposed rocks. Epiphytic species are sparingly present.

Mosses common in this scrub vegetation type include, in addition to the Grimmia species of vegetation Type I, Amphidium tortuosum, Anoetangium haleakalae, Ceratodon purpureus, and Ptychomitrium mauense. Two epiphytic species, Macrocoma intricata and Orthotrichum hawaiiicum, may occasionally be seen. Grimmia apocarpa var. pulvinata, G. apocarpa var. stricta, and G. pulvinata, all new to the Hawaiian Islands, are present.

Several deep ravines between Hosmer Grove and the Ko'olau Gap act as channels for cloud-bearing winds. Smooth water-worn rocks and the presence of debris tangled in branches indicate that they also serve as runoff channels during heavy rains. Standing water is occasionally present. The occurrence of large Metrosideros trees and an abundance of Sadleria clearly indicate the more favorable mesic conditions. These ravines are considered sufficiently differentiated to warrant their recognition as a distinctive vegetation subtype. However, they are not mapped here due to their small size.

The mosses of the deep ravines are dissimilar to the scrub vegetation type and have much greater cover as well. They are no longer restricted to sheltered ledges or to sites under scrub. Palamocladium wilkesianum and Plagiopus oederi are often abundant on ledges, and Grimmia cf. pilifera and Ptychomitrium mauense locally form thick carpets on rocks. Other species also common include Amphidium tortuosum, Bartramia baldwinii, and Brachythecium lamprocarpum. The epiphytic Ulota cervina is scattered. Fissidens taxifolius and Rhabdoweisia crispata, both new to Maui, are present. The type locality for Porella hoeana Hattori (a leafy liverwort species described from the RBI's first year's collection) is in this vegetation subtype.

#### D. The mixed tall scrub-tree vegetation type (Type III).

As characterized in the following paragraphs the mixed tall scrub-tree vegetation type is restricted to Kaupo Gap between O'ilipu'u and the Park boundary. It encompasses a continuum of three subtypes determined primarily by water availability: an open, very low, scattered scrub toward the southwest (the most xeric); a dense tall scrub with Metrosideros and tall Dodonaea in the central corridor (intermediate); and, along the northeast wall, a remnant Acacia-Myrsine forest (the most mesic). Due to difficulties of access, most observations were restricted to the remnant Acacia-Myrsine subtype along Kaupo Trail; this has resulted in the three subtypes being treated here as components of a single variable Type.

The entire Kaupo Gap area consists primarily of rough 'a'a flows sloping more-or-less steeply toward the southeast. It lies along the border of the leeward, rainshadow side of Haleakala. Thus, except along its eastern half, it is hot and dry. Fine ash is abundant, both in variously-sized pockets and in terrace-like level areas. Deep runoff channels along both cliff faces, sometimes with standing water, suggest at least occasionally torrential rainfall.

The western-most portion of Kaupo Gap is very hot, dry, and open. Except for scattered large Metrosideros along the runoff channel, the vegetation is low and scattered. Goats are abundant and have had a pronounced effect on the vegetation. Mosses are present but of low cover and primarily in sheltered habitats. Some species which are sparingly represented here are Bryum ceramiocarpum, Ceratodon purpureus, Didymodon vinealis var. flaccida, Grimmia haleakalae, G. cf. pilifera, and Trichostomum oblongifolium. The most noteworthy bryophyte discovered is Riccia sorocarpa Bisch., a thalloid liverwort previously unknown in the Hawaiian Islands (Hoe 1978a).

The upper (northern) end of the central corridor of Kaupo Gap consists of an undulating, south-sloping 'a'a flow. Most of the ash pockets are covered by water- and wind-transported black cinder from the central crater. Runoff and percolation through this very loose substrate must be rapid. The vegetation is primarily of 1.0 to 1.5 m tall, more-or-less open Styphelia and Dodonaea. Only three mosses may be considered frequent: Grimmia haleakalae on exposed rocks with Bryum argenteum and Ceratodon purpureus on alluvial ash deposits. These are all desiccation-tolerant species. Their cover, however, is small.

Along the edges of a few alluvial ash deposits, gnarled old Metrosideros are sometimes present. These trees, as sources of both shade and fog drip, can provide locally less severe conditions. Not surprisingly, then, the bryoflora is somewhat more diverse and the cover greater. Brachythecium lamprocarpum and Palamocladium wilkesianum are common; a few strands of Macrocoma intricata and Zygodon tetragonostomus as epiphytes are present. From a floristic point of view, however, there are no species of particular interest.

The lower central Kaupo Gap presented some of the most formidable terrain experienced during the survey's field work. Ridges and gullies of loose 'a'a, apparently the remains of collapsed lava tubes, were traversed with extreme annoyance. There is a nearly continuous cover of tangled, 2 to 3 m tall Dodonaea and Styphelia ensnaring and jabbing at the unwary. In places, mats of Eupatorium seemed present only to trip the frustrated. Conditions such as these are not conducive to careful observation and collection. However, Grimmia haleakalae, common on rocks, was noted.

Kaupo Trail provides easy access to the most mesic portions of Kaupo Gap along its eastern edge. The trail crosses southeast-sloping 'a'a lava flows as well as a number of level ash-filled terraces. A rocky drainage channel, sometimes of considerable depth, lies between the trail and the base of the cliffs. Except in the level terraces, most of the ash has settled beneath the rocky surface. Rainfall, therefore, percolates downward rapidly. The ash-filled terraces may, however, remain moist for long periods of time; standing water is sometimes present in the rocky runoff channel.

The vegetation of this area is complex. It could easily be subdivided into at least three types dependent largely, it appears, on substrate variation. The 'a'a ridges, for example, are covered primarily by a Dodonaea-Styphelia scrub of moderate height, often mixed with Vaccinium. A tree height Dodonaea scrub surrounds the ash-filled terraces along the rock-ash interface. The terraces themselves are covered by grasses. Along the lower half of the trail, groves of Myrsine and Acacia form a gallery forest along the streambed. Particularly in the remnant Myrsine forest, a number of lowland rain forest mosses may be found; this apparently marks the upper elevational limit for many, at least in the Park.

The moss vegetation of this portion of Kaupo Gap shows a complexity similar to that demonstrated by the higher plants. The terraces, for example, are almost completely devoid of mosses due to the shading and crowding effects of the grasses. Bryum argenteum, along the trail and in a few open areas, is the only frequent species. In the kikuyu grasslands (Pennisetum clandestinum Hochst. ex Chiov.) near the southern Park boundary, Campylopus umbellatus is frequent on exposed rocks; Fissidens lancifolius and F. intermedius are very sparingly present under the loose grass mats. This is the only known Park locality for F. intermedius which is usually a low elevation rain forest taxon.

The rocky scrub-dominated portions of the 'a'a ridges support a varied moss flora dependent upon the amount of exposure to which they are subjected. On more-or-less open rocks, Grimmia haleakalae and Racomitrium lanuginosum var. pruinatum are common; associated with low scrub and under trees, Anoetangium haleakalae, Macrocoma intricata, Orthotrichum hawaiiicum, Palamocladium wilkesianum, and Sematophyllum hawaiiense are frequent.

As suggested earlier, the remnant Myrsine forest supports a remarkably diverse flora because it seems to mark the upper elevational limits of many mesic rain forest species. There is deliberate emphasis on the terms "mesic" and "upper elevational" in this context; the only other comparable elevations within the Park are in the western Kaupo Gap. There, conditions are dry and mosses have an insignificant cover. On the other hand, comparable moisture transitions (such as at Paliku and the upper Ko'olau Gap) are at considerably higher elevations. Although several rain forest taxa reach Paliku and extend no further upslope, interpretation of the role of altitude there is difficult because the area seems also to be transitional for several other parameters, including rainfall, substrate, and vegetation types. Common mosses in the Myrsine forests include Brachythecium plumosum, Campylopus umbellatus, Grimmia haleakalae, Macrocoma intricata, Palamocladium wilkesianum, Ptychomitrium mauiense, and Thuidium plicatum. Most of the following rain forest species are also common in the lower eastern Kaupo Gap but are not known to extend any higher than these Myrsine stands: Barbella trichophora, Entodon solanderi, Fissidens lancifolius (rare), Racopilum cuspidigerum,

Sematophyllum hawaiiense, Thuidium crenulatum, and Trachypus humilis var. flagellifer.

E. The cliff face vegetation type (Type IV).

The central crater is surrounded on all four sides by steep cliffs, some of which are over 1000 feet (300 m) high. The two major erosion-formed gaps, Ko'olau and Kaupo, are also bordered by sheer walls. Difficulty of access prevented reconnaissance of this Type except along the established Halemau'u and Lau'ulu trails and behind the Kapalaoa and Holua cabins.

The cliff faces seen along parts of the Halemau'u Trail and in the upper western Kaupo Gap are vertical rock walls. The scattered scrub present is established in fissures. Metrosideros is the most common angiosperm in such habitats; Grimmia haleakalae seems to be the only common moss.

On less steeply-sloping cliffs, there is a considerable amount of ash present. There is often, except in the driest areas, a moderately dense to closed Styphelia scrub cover of up to about 1 to 1.5 m height. In the wetter sites, however, Vaccinium is often dominant. The very limited available data suggest, but at present are insufficient to warrant, separation of this vegetation into several subtypes. For example, the somewhat randomly and certainly incompletely collected mosses from the Halemau'u, Lau'ulu, Kapalaoa, and Holua areas show marked differences in the species composition (Table 1). Further surveys of these difficult cliff faces would probably provide the necessary basis for such refinement.

The north-facing cliffs along the upper portions of the Halemau'u Trail are, due to their interception of cloud-bearing trade winds, considerably more mesic than the other cliff faces. As a result, several rain forest taxa, including Funaria subintegra, Isopterygium albescens, Thuidium hawaiiense, and Thuidium plicatum are present. It is noteworthy that no species are known from all four areas. Several significant mosses are present in the cliff face vegetation type: Bryum ceramiocarpum and Grimmia pulvinata (new to the Hawaiian Islands), as well as the locally very rare Andreaea rupestris, Plagiopus oederi, Pohlia baldwinii, and Pohlia mauiensis.

F. The "rain forest" vegetation type (Type V).

The closest approximation to a rain forest vegetation is present in the Crater District only at Paliku and along the base of Kuiki. The true 'ohi'a rain forests on the outer southeast slopes below Kuiki, although investigated, are not included in this discussion. The area under consideration consists primarily of steep, rocky cliffs with occasional deeply eroded gullies. The cliffs are covered by very dense tree-height Metrosideros and scattered Cheirodendron. Scrub vegetation, particularly of Vaccinium, is frequent. Exposed barren rock is sparingly

TABLE 1. Mosses of the four major Crater District cliff faces. This listing is probably incomplete, due to difficulty of access to most areas. Species presence is indicated by X.

TAXON	Halemau'u	Lau'ulu	Kapalaoa	Holua
<u>Ceratodon purpureus</u>	X	X		
<u>Racomitrium lanuginosum</u>	X	X		
<u>Bartramia baldwinii</u>	X			X
<u>Grimmia haleakalae</u>	X			X
<u>Bryum argenteum</u>	X	X		X
<u>Bryum ceramiocarpum</u>	X	X		X
<u>Saelania glaucescens</u>	X	X		X
<u>Pohlia mauiensis</u>	X	X		X
<u>Palamocladium wilkesianum</u>	X		X	X
<u>Grimmia trichophylla</u>		X	X	
<u>Brachythecium lamprocarpum</u>		X	X	X
<u>Amphidium tortuosum</u>			X	X
<u>Anoetangium haleakalae</u>			X	X
<u>Philonotis turneriana</u>			X	X
<u>Campylopus umbellatus</u>	X			
<u>Ctenidium decurrens</u>	X			
<u>Funaria subintegra</u>	X			
<u>Isopterygium albescens</u>	X			
<u>Macromitrium owahiense</u>	X			
<u>Thuidium hawaiense</u>	X			
<u>Thuidium plicatum</u>	X			
<u>Bryoerythrophyllum recurvirostre</u>		X		
<u>Macrocoma intricata</u>		X		
<u>Macromitrium piliferum</u>		X		
<u>Pohlia baldwinii</u>		X		
<u>Trichostomum bartramii</u>		X		
<u>Ulota cervina</u>		X		
<u>Zygodon reinwardtii</u>		X		
<u>Andreaea rupestris</u>			X	
<u>Bryum hawaicum</u>			X	
<u>Dicranella sp.</u>			X	
<u>Encalypta scabrata</u>			X	
<u>Orthotrichum hawaicum</u>			X	
<u>Tortula princeps</u>			X	
<u>Barbula vinealis var. flaccida</u>				X
<u>Brachythecium hawaicum</u>				X
<u>Campylopus pilifer</u>				X
<u>Desmatodon convolutus</u>				X
<u>Grimmia laevigata</u>				X
<u>Grimmia pulvinata</u>				X
<u>Plagiopus oederi</u>				X
<u>Tortula alpina var. inermis</u>				X



present as vertical rock faces. The humidity in this area is high and wind-driven fog and rain from upper Kipahulu Valley frequent. The soil is probably always moist. The bryophyte vegetation is lush, and epiphytes are abundant.

The area immediately around the Paliku Cabins looks quite different. An anthropogenically-maintained grassland, utilized both for pasturage and camping, predominates. Interspersed in part of this grassland is a remnant, primarily Myrsine-Cheirodendron-Metrosideros forest. A deep, rocky runoff channel crosses this area; the lush moss vegetation in all but the grasslands is similar to the rain forest type below Kuiki. The mosses of the base of Kuiki and of Paliku will therefore be discussed together.

As previously suggested, the numerous humid and shaded runoff gullies are characterized by water-worn boulders carpeted by mosses. The most abundant species, Brachythecium plumosum, is confined to the tops of these large rocks, whereas species such as Sciaromium tricostatum and the rare Thamnobryum speciosum are restricted to the more vertical sides. Other rock tops may have large, soft yellow and black carpets of the uncommon Trachypus bicolor, or "forests" of the tree-shaped Homaliiodendron flabellatum. Other apparently rare species often encountered on rocks here include Glossadelphus chrysobasilaris, G. irroratus, and Grimmia scabrifolia. On more exposed rocks, Campylopus skottsbergii (including the first known collection of material with sporophytes) and Ptychomitrium mauianse form extended clumps. Two species new to the Hawaiian Islands, Fissidens taxifolius and Trichostomum tenuirostre, are present.

The second most common substrate in this region for mosses--tree trunks and limbs--are often clothed in epiphytes. Except for Floribundaria floribunda, however, pendant forms are absent. This growth form, as well as the epiphyllous habit not present in Haleakala, are restricted to habitats more humid and wet than are present in the Crater District. Almost all epiphytic species in the Paliku-Kuiki forests are capable of some drought tolerance: Daltonia contorta, Dicranum speirophyllum and its variety breviflagellare, Macrocoma intricata, Macromitrium owahiense, Orthotrichum hawaiicum, and Zygodon tetragonostomus.

Soil-inhabiting species are few, due to the scarcity of open ground available for colonization. Those plants which are present are often on ledges. Many of the rock-inhabiting species previously listed, such as Brachythecium plumosum, may also be found on open soil. Other species of this habitat, none very abundant, include Fissidens bryoides, Funaria subintegra, Leucobryum gracile, and Plagiothecium draytonii. Fissidens aphelotaxifolius, new to the Islands and restricted to this vegetation type, was sparingly present. On litter, epiphytic taxa such as Floribundaria floribunda, Dicranum speirophyllum, Macromitrium owahiense, and Thuidium plicatum are sometimes encountered, as are the usually epilithic Glossadelphus chrysobasilaris (often abundant), Homaliiodendron flabellatum and Thuidium plicatum.

#### G. The Deschampsia grassland (Type VI).

On the outer, north-sloping face of the Crater above Kalapawili Ridge, a dense Deschampsia grassland (probably on deep ash) with scattered Hypochaeris predominates. There are no trees, and the Vaccinium clumps (to 2 m tall) present appear restricted to areas of thin soil associated with rocky outcrops. The Deschampsia clumps produce a 100% cover with bryophytes nearly restricted to shaded litter between the closely-packed tussocks. Interception of cloud-bearing trade winds results in high rainfall and fog drip.

Two species of Thuidium, T. hawaiiense and T. plicatum, appear to be the most common moss species. Isopterygium elegans (new to the Hawaiian Islands) is also common. On overturned grass clumps with greater exposure to sunlight, the following photophilic species were encountered: Campylopus hawaiicus var. hawaiico-flexuosus, Leptodontium flexifolium, Palamocladium wilkesianum, Racomitrium crispulum, and R. lanuginosum var. pruinatum. None of these is common, however, due to the relative scarcity of this specialized habitat type.

#### H. Transitional desert-scrub vegetation (Type VII).

In the east-central Crater District massive pahoehoe and 'a'a flows, together with the near absence of both black cinder and exposed ash, create a vegetation type which is clearly transitional and which does not fit well into any of the previously-discussed types. The widespread occurrence of Racomitrium lanuginosum var. pruinatum suggests a fairly high precipitation but most of the moisture must be lost to plants because of percolation through the lava. The undulating pahoehoe supports a scattered scrub vegetation of moderate stature. The only common rock-inhabiting moss is Grimmia haleakalae. On ash, Bryum ceramicarpum and Ceratodon purpureus are frequent. The 'a'a flows, except for very scattered Railliardia, Racomitrium lanuginosum, and lichens, appear nearly devoid of vegetation.

An interesting demonstration of the effects of substrate on vegetation with a similar climate type may be made by comparing the vegetation of a small kipuka located about 0.2 mile (320 m) north of O'ilipu'u with its immediately-surrounding 'a'a flows. The kipuka contains small areas of deep ash in addition to rocky 'a'a outcrops. It is likely that this area represents a "true" kipuka in that it is an older surface surrounded by more recent flows. In this kipuka, the spaces between the predominant Sophora and Dodonaea trees are filled by Eupatorium and Pteridium. The ground is covered by litter. The following mosses are present and, in this vegetaton type, confined to the kipuka:

on ground (rock, ash, litter): Brachythecium hawaiicum (frequent), Bryum capillare, Fissidens bryoides, Palamocladium wilkesianum (common), Tortula alpina var. enermis (common), and Trichostomum bartramii.

on trees: Macrocoma intricata, Orthotrichum hawaicicum (common), and Zygodon tetragonostomus.

In the nearby lava fields, the following mosses are present: Bryum argenteum, B. ceramiocarpum, Campylopus pilifer, Ceratodon purpureus, Grimmia haleakalae, and Racomitrium lanuginosum var. pruinatum. These photophilic taxa form only scattered ground-level colonies and, with the exception of Grimmia haleakalae, are absent from the kipuka. Comparison of these two sites clearly shows that this kipuka supports a much more diverse moss flora. It also contains a much greater biomass.

## 2. Phytogeographic relationships of the Haleakala moss flora.

The preceding discussion has emphasized the relatively dry nature of the greater portion of the Crater District. As a result, mesic habitats are limited to areas near the Park boundaries and are, in fact, of a transitional nature. This results in the elimination of a large proportion of Hawai'i's rain forest taxa whose primary affinities are with the Indo-Pacific region.

For this discussion, the following categories of phytogeographical relationships are utilized: Austral (temperate Southern Hemisphere distribution); Boreal (temperate Northern Hemisphere distribution); Indo-Pacific; American (predominantly tropical and sub-tropical); widespread temperate (represented in both hemispheres); and widespread tropical or cosmopolitan. Global distributions of non-endemic taxa and of the putative ancestors of endemic taxa are from my ongoing unpublished work. Taxa preceded by an asterisk (\*) are considered endemic.

A. Austral affinities (5): Amphidium tortuosum, Andreaea acutifolia, Racomitrium crispulum, Racomitrium lanuginosum var. pruinatum, Tortella fragilis var. tortelloides.

B. Boreal affinities (28): Amphidium lapponicum, \* Bartramia baldwinii, \* Brachythecium hawaicicum, Bryhnia cf. hultenii, Bryum atrovirens, Ceratodon purpureus fo. xanthopus, \* Dicranum speirophyllum, \* Dicranum speirophyllum var. breviflagellare, Didymodon vinealis var. flaccida, Fabronia ciliaris, Fissidens apheetaxifolius, Fissidens taxifolius, Grimmia apocarpa var. pulvinata, Grimmia apocarpa var. stricta, \* Grimmia haleakalae, Grimmia cf. pilifera, \* Grimmia scabrifolia, Grimmia torquata, Haplohymenium triste, Isopterygium elegans, \* Macrocoma intricata, Orthotrichum diaphanum, \* Orthotrichum hillebrandii, Plagiopus oederi, Rhabdoweisia crispata, Tortula alpina var. inermis, Trichostomum tenuirostre, \* Ulota cervina.

- C. Indo-Pacific affinities (38): \* Barbella trichophora,  
Brachytheceium lamprocarpum, Breutelia arundinifolia,  
\* Brotherella opaeodon, Campylopus umbellatus,  
Clastobryopsis planula, \* Ctenidium decurrens,  
\* Ctenidium elegantulum, Daltonia contorta, Entodon  
solanderi, Eurhynchium vagans, Floribundaria  
floribunda, \* Funaria subintegra, \* Holomitrium  
seticalycinum, Homaliodendron flabellatum, Isopterygium  
albescens, \* Leucobryum gracile, \* Macromitrium  
owahiense, \* Palamocladium wilkesianum, Philonotis  
turneriana, \* Plagiotheceium draytonii, Pogonatum  
tahitense, Pseudosymblepharis mauiensis, Racopilum  
cuspidigerum, Rhynchostegium celebicum, Rhynchostegium  
selaginellifolium, Sematophyllum hawaiiense,  
Taxithelium mundulum, \* Thuidium crenulatum, \* Thuidium  
hawaiense, \* Thuidium plicatum, Trachypodopsis  
auriculata, Trachypus bicolor, Trachypus humilis,  
Trachypus humilis var. flagellifer, Trematodon  
latinervis, Trichostomum oblongifolium, Zygodon  
tetragonostomus.
- D. American affinities (6): Bryum ceramiocarpum, \* Daltonia  
pseudostenophylla, Fissidens intermedius, \* Fissidens  
pacificus, \* Ptychomitrium mauicense, \* Syrrophodon  
hawaiicus.
- E. Widespread temperate affinities (18): Andreaea rupestris,  
Bartramia halleriana, Bryoerythrophyllum recurvirostre,  
Campylopus pilifer, Ceratodon purpureus, Desmatodon  
convolutus, \* Encalypta sandwicensis, \* Encalypta  
scabrata, Fissidens bryoides, Grimmia laevigata,  
Grimmia pulvinata, Grimmia trichophylla, Leptodontium  
flexifolium, Pohlia cruda, Polytrichum piliferum,  
Saelania glaucescens, Tortella humilis, Tortula  
princeps.
- F. Widespread tropical or cosmopolitan affinities (8):  
Anoetangium aestivum, Brachytheceium plumosum,  
Brachytheceium rutabulum, Bryum argenteum, Bryum  
capillare, Hookeria acutifolia, Rhizogonium spiniforme,  
Zygodon reinwardtii.

Twenty-one endemic species are of unknown affinities and shall not be considered further.

Summation of the preceding lists shows the following phytogeographic relationships:

Area	No. of taxa	Percentages
Austral	5	4.9
Boreal	28	27.2
Indo-Pacific	38	36.9
American	6	5.8
Widespread temperate	18	17.5
Widespread tropical/cosmopolitan	8	7.8
	103	100

For three reasons, it seems reasonable to combine taxa of widespread temperate affinities with those of Boreal affinities. (1) The proportion of species of clearly Austral affinities is exceedingly small as compared with those of clearly Boreal affinities. The overwhelming majority of temperate species in the Haleakala Crater District are Boreal; it is considered very unlikely, therefore, that many mosses of widespread temperate affinities would have been derived from Austral sources. (2) Hawai'i, although very isolated from any large land mass, is considerably closer to the possible Boreal sources of propagules than to the possible Austral sources of propagules. (3) The direction of the tradewinds is from the northeast. Reasons 2 and 3 may be responsible for the low Austral representation.

If the taxa with widespread temperate affinities are combined with those of Boreal affinities, we obtain the following:

Area	No. of taxa	Percentages
Austral	5	4.9
Boreal	46	44.7
Indo-Pacific	38	36.9
American	6	5.8
Widespread tropical/cosmopolitan	8	7.8

These figures for Haleakala can be compared with similarly obtained percentages for the Hawaiian Islands as a whole:

Area	Approximate Percentages
Austral	2.5
Boreal	35.8
Indo-Pacific	45.7
American	7.4
Widespread tropical/cosmopolitan	8.6

The moss flora of Haleakala differs most markedly from the Hawaiian moss flora as a whole in having a higher proportion of Boreal elements and a lower proportion of Indo-Pacific species. As indicated in the introduction to this section, the majority of the Crater District's rain forest species (i.e., those of Indo-Pacific affinities) are confined to the lower elevational, transitional forest types. If one were to exclude the mosses confined to the Paliku and eastern Kaupo regions, the relative importance of the Boreal element would be even more striking.

### 3. Endemism in the Haleakala moss flora.

The information in Part II. CATALOGUE OF THE TAXA regarding distributional status of the mosses of Haleakala, and in Hoe (1974a) for Maui and the remaining Hawaiian Islands may best be summarized in the following table:

Area	Endemic Percentages	Non-Endemic Percentages
Haleakala RBI	39.4	60.0
Maui	53.0	47.0
Hawaiian Islands	51.0	49.0

Moss endemism in the upper elevations of Haleakala is lower than for either Maui or the Hawaiian Islands. Conversely, the non-endemic taxa are better represented. Several hypotheses may be advanced to explain these differences:

1. The Haleakala moss flora is, on the average, more recent than the flora of Maui or the Hawaiian Islands. There has been less time in isolation and, therefore, less speciation has occurred.
2. The dominant Boreal flora speciates more slowly than does the rain forest flora on the remainder of Maui and the Hawaiian Islands. Thus, although the upper Haleakala flora is of approximately the same age as the flora of the other areas, less speciation has occurred due to this relative "slowness."
3. The dry alpine conditions dominating the upper Haleakala region favor asexual reproduction (which does not require free water) over sexual reproduction (in which free water is needed for gamete fusion). The mosses of Haleakala, therefore, have a relatively high proportion of asexually-reproducing, clonal populations as compared with either Maui as a whole or the Hawaiian Islands. The reduced rates of genetic recombination reduce the opportunities for genetic, morphological, and physiological variation. Speciation, most often defined in morphological terms, is therefore also reduced.

4. As compared with the total moss flora for Maui and the Hawaiian Islands, the percentage of unisexual plants may be greater on the upper portions of Haleakala. Unisexuality precludes sexual reproduction; the reasoning in the proceeding hypothesis is invoked.

Attempts to answer the questions posed are beyond the scope of this report. Whatever the reason(s) may be, endemism on Haleakala has clearly been shown to be lower than for Maui as well as the remainder of the Hawaiian moss flora.

#### IV. RECOMMENDATIONS.

The distinctiveness of the moss flora of the Crater District has been emphasized in the preceding pages. As components of an easily-accessible alpine Hawaiian ecosystem, the mosses can yield much information on such topics as moss phytogeography and ecology. The "telescoping" of a wide range of habitats within a very short distance also makes this area a valuable natural laboratory for the study of evolutionary processes taking place in insular settings.

Each of the seven vegetation types (Fig. 2) was considered sufficiently distinct to warrant separation. Each contains noteworthy species. However, from a Park management point of view, not all areas are likely to require equal protection.

The greatest threats to Haleakala's ecosystems are likely to come from animals and man. Goats, which are common in the dry areas, create openings by browsing on young shoots and seedlings. Pigs, on the other hand, can cause considerable damage in wet areas by uprooting plants. Seeds dispersed with fecal material or externally may also affect the floristic composition of an area. Areas subject to frequent animal visitation, including human, often suffer from the effects of trampling. Man can also cause fires and otherwise affect the area by careless collecting or deliberate damage.

The primary effects of man and animals upon the mosses of Haleakala are likely to be due to changes in microhabitats resulting from damage to the vascular plant flora, although trampling effects in specific areas may also be severe. Goats and pigs are not likely to eat the mosses but by removing or disturbing the trees, shrubs, and herbs they will create locally drier, more exposed niches. Man, although through different activities, will also have a similar effect. Each vegetation type is briefly discussed in terms of necessary protection.

TYPE I: Open, rocky, shifting sand desert.

This habitat has, and probably always has had, a very low vegetation cover. The near absence of goats is likely due to the

loose substrate and lack of adequate food resources. The greatest danger to this vegetation type (and one considered of minimal consequence) is likely to be the wandering hiker but beyond existing protection policies, little more can be recommended.

#### TYPE II: Scrub vegetation.

This vegetation type represents, in many respects, a transition between the former upper rain forests (now in pasturage downslope from Pu'u Nianiau) and the open, rocky, shifting sand desert (Type I) above it. The bryophytes of this area are similar to those of vegetation Type IA except in the large gullies around Pu'u Nianiau and Hosmer Grove. These gullies are sheltered and also act as wind and fog channels. They are therefore more mesic than the surrounding slopes. A large number of locally rare species, both endemic and indigenous, are confined to this habitat. Loss of the now existing ecological balance by man or animals would clearly cause loss of this diverse moss flora due to xerification and trampling. Removal of feral animals is strongly urged, and visitor impact, other than on defined trails, should be curtailed. No new trails should be opened and any unofficial trails entering the gullies should be closed.

#### TYPE III: Mixed tall scrub-tree vegetation.

The heterogeneous character of the vegetation of Kaupo Gap has been discussed earlier. The very dry, extensively goat-damaged western corridor may have, at one time, supported a dry forest similar to that of the eastern corridor along Kaupo Trail. Speculation on possible potential similarities is difficult; however, in the remnant Myrsine-Acacia groves in the eastern corridor, there are some physiognomic and species similarities to the dry forests of the Waianae Mountains of O'ahu. Both are characterized by a tall dense tree crown canopy and a near absence of the herb layer. The abundance of shade loving, desiccation-tolerant moss species such as Entodon solanderi in both areas is noteworthy (E. solanderi is virtually absent from rain forests). Due to the height of the trees, the near absence of low stature vegetation, the rough 'a'a surface, and the frequency of hikers along the Kaupo Trail, herbivore damage seems to be kept at a low level. However, there is a strong possibility that goats from the large population on the adjacent cliffs are affecting regeneration of the Myrsine-Acacia forest and its associated species. This, of course, will ultimately result in a more open, probably reduced forest area as well as an increase of the more xeric vegetation characteristic of the remainder of the Gap. Loss of the dry forest would result in the loss of the many rain forest and dry forest mosses now presently known in the Park only from the eastern Kaupo region. It is important, therefore, that the large goat populations of Kaupo be brought under control, or ideally, eliminated. Pigs should also be kept out of the area.



## TYPE IV: Cliff face vegetation.

This is another heterogeneous vegetation type and one about which little is known due to the difficulties of access. Except along the vertical rock faces, however, these cliffs are clearly goat impacted and must be more xeric than before extensive herbivore damage took place. Elimination of the goats would undoubtedly result in greater vegetation density (probably of a scrub type) but as the bryophytes now present are not considered particularly noteworthy, goat control would be of value primarily in the reduction of environmental degradation.

## TYPE V: "Rain forest" vegetation.

It would appear that pigs are the primary agent of damage in this area, and they may ultimately be responsible for an opening of the forest. The immediately-adjacent grassland may be natural but certainly pigs and goats are responsible for the extreme degradation and severe erosion at the summit of Kuiki. As the grasslands and the forests are all in very close proximity to one another and to the rocky eroded Kuiki summit, further damage even to the grasslands would undoubtedly lead to severe erosion and, ultimately, loss of this vegetation type. These Metrosideros forests are the only high-elevation rain forests we studied which are within the Park; their loss would remove a very rich and diverse assemblage of moss species characteristic to the upper elevation rain forests. Control of herbivores in this area is considered to be of great importance if this vegetation type is to be saved.

TYPE VI: Deschampsia grassland.

The grassland of the north-facing Kalapawili Ridge appears to be a natural vegetation type, and pigs, through their feeding habits and dispersal of weed seeds, represent the major disruptive influence. Most of the bryophytes unique to these grasslands are confined to the spaces between tussocks, as the overturned tussocks support only photophilic (and more widespread) species. The continued uprooting of grass tussocks opens up the possibilities of wind and water erosion (as are likely to have occurred on Kuiki), and the continued introduction of herbaceous weeds will change the character of the vegetation. Control of the pigs in this area is considered vital for the protection of this vegetation type.

## TYPE VII: Transitional desert-scrub vegetation.

It appears likely that this area presently dominated by a scattered, low stature scrub may have been dominated by taller trees before goats were introduced. The Dodonaea-Sophora trees and the dense herb layer of the small kipuka north of O'ilipu'u and the remnant Metrosideros on O'ilipu'u suggest that trees were more widely distributed in the past. The rough 'a'a field

surrounding the kipuka has apparently prevented access by herbivores. The forest remnant in the kipuka is more mesic than the surrounding lava fields, and also contains a much richer and more interesting bryoflora. No action is considered necessary at this time but the kipuka should be monitored to insure its goat-free status. Forays by wandering hikers are also to be discouraged because excessive trampling resulting in soil compaction can only lead to a loss of the trees and a gradual opening of the forest cover.

#### V. ACKNOWLEDGMENTS.

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APPENDIX A

CATALOGUE  
OF  
THE MOSSES  
OF  
HALEAKALA NATIONAL PARK  
CRATER DISTRICT  
COLLECTED DURING THE  
RESOURCES BASIC INVENTORY SURVEYS  
OF  
1975 THROUGH 1977

Comments on distribution refer only to the Hawaiian Islands.  
All "Haleakala" collections discussed are based upon RBI  
collections and observations unless otherwise indicated.

## Amphidium

(Family: Dicranaceae)

lapponicum (Hedw.) Schimp.

Indigenous

New to the Hawaiian Islands and known only from a few  
fertile stems collected from the planted Eucalyptus  
grove at 8600 feet.

tortuosum (Hornsch.) Robins.

(Amphidium cyathicarpum [Mont.] Broth.)

Indigenous

Common on shaded dry ash-covered ledges above 6000  
feet. Also common on the island of Hawai'i in similar  
situations.

## Andreaea

(Family: Andreaeaceae)

acutifolia Hook. f. &amp; Wils.

Indigenous

Otherwise known only from the Subantarctic, and a new  
record for the Hawaiian Islands. Taxonomic revision in  
progress.

rupestris Hedw.

Indigenous

This alpine species was found only on rocks in Haleakala  
Crater at Kapalaoa which represents the second Maui  
collection.

## Anoectangium

(Family: Pottiaceae)

*aestivum* (Hedw.) Mitt.(*Anoectangium euchloron* [Schwaegr.] Mitt.)

Indigenous

This species was collected only sparingly along the Waikau Cabin Trail about halfway across the Ko'olau Gap as well as upper Kaupo Gap. This species is found on all of the major islands, usually at low elevations.

*haleakalae* (C. Muell.) Par.

Endemic

Common up to 8000 feet on the outer northwest slope and the upper eastern Kaupo Gap as well as at Kapalaoa. It is also known from Kaua'i, Moloka'i, and the island of Hawai'i. Zander (pers. comm.) suggests that this species is not distinct from *A. aestivum*.

## Barbella

(Family: Meteoriaceae)

*trichophora* (Mont.) Fleisch.

Endemic

This rain forest species is frequent in the eastern Kaupo Gap up to Paliku, and was also collected in the upper Ko'olau Gap at 'Ainahou. It is known from all major islands except Lana'i.

## Bartramia

(Family: Bartramiaceae)

*baldwinii* C. Muell.

Endemic

Type locality: Haleakala, at 7500 feet. Common throughout the Crater on fine ash, particularly in run-off areas. It is endemic to the Park and the immediately adjacent areas.

*halleriana* Hedw.

Indigenous

On ground in ravines. Rare. Apparently confined to Haleakala National Park and adjacent areas north to Ukulele Camp.

## Brachythecium

(Family: Brachytheciaceae)

*hawaiicum* Bartr.

Endemic

On Maui known only from two collections, both from the Crater District. Also reported from the island of Hawai'i.

*lamprocarpum* (C. Muell.) Jaeg.

Indigenous

Common throughout the Crater. Also known from Kaua'i and the island of Hawai'i.

*plumosum* (Hedw.) B.S.G.

Indigenous

Common in the Hosmer Grove and Paliku areas. It is known from all of the major islands except Lana'i.

*rutabulum* (Hedw.) B.S.G.

Indigenous

Found only at Paliku and apparently restricted to Maui.

*Breutelia*

(Family: Bartramiaceae)

cf. *arundinifolia* (Duby) Fleisch.

This upper rain forest species was found only on the ridge above Paliku. The material may represent an undescribed species.

*Brotherella*

(Family: Sematophyllaceae)

*opaeodon* (Sull.) Broth.

Endemic

This upper elevation rain forest species was found only below (SE of) Kuiki. It is also known from Kaua'i, O'ahu, Moloka'i, and the island of Hawai'i.

*Bryhnia*

(Family: Brachytheciaceae)

cf. *hultenii* Bartr. in Grout

(= *B. novae-angliae* [Sull. & Lesq.] Grout fide Robinson)

An uncertain specific determination by N. Takaki. The genus is new to the Hawaiian Islands, and is based upon part of a collection from Pu'u Nianiau.

*Bryoerythrophyllum*

(Family: Pottiaceae)

*recurvirostre* (Hedw.) Chen

Indigenous

Confined to Haleakala Crater where it is widely scattered.

*Bryum*

(Family: Bryaceae)

*argenteum* Hedw.

Indigenous

Common throughout the Park mostly as small, apparently juvenile, annuals. Also reported from Kaua'i, O'ahu, and the island of Hawai'i from sea level to the alpine zone.

cf. *atrovirens* Brid.

Found only at the Leleiwi Pali. It is also known from O'ahu and the island of Hawai'i.

*capillare* Hedw.

Indigenous

Very widely scattered. Although known on Maui only from the Park, it almost certainly is more widely distributed. It is found on the concrete foundations of the Visitor's Cabin at Paliku, at Leleiwi Pali, and a kipuka near Oili Pu'u. Reported also from Kaua'i, O'ahu, and the island of Hawai'i.

*ceramiocarpum* C. Muell.

Indigenous

Common throughout the Park on dry, semishaded to exposed, stabilized, ash banks. Locally known only from the Crater District. A new record for the Hawaiian Islands.

*hawaicum* Hoe

Endemic

Sporadic, from Pu'u Niania, the Observatory, and Kapalaoa. Probably more widespread but its small size and lack of distinctive field characters do not lend themselves to easy recognition. Otherwise known from the island of Hawai'i.

*Campylopus*

(Family: Dicranaceae)

*boswellii* (C. Muell.) Par.

Endemic

Collected once in a deep gully SE of the Park headquarters. Also known from single Kaua'i, O'ahu, and Moloka'i collections.

*fumarioli* C. Muell.

Endemic

In the Crater found only at Paliku. Although reported from all islands, it is always very scattered.

*hawaicus*

var. *hawaico-flexuosus* (C. Muell.) Frahm

(*C. densifolius* var. *hawaico-flexuosus* [C. Muell.] Mill.)

Endemic

Found in the Crater only at Paliku. It has been reported from all of the major islands.

*pilifer* Brid.

(*C. introflexus* [Hedw.] Brid.)

(*C. polytrichoides* De Not.)

Indigenous

Distribution sporadic throughout the Crater. The species is also known from Kaua'i, O'ahu, and the island of Hawai'i.

*skottsbergii* Broth.

Endemic

In the Crater found only at Paliku. It has also been reported from Kaua'i, O'ahu, and the island of Hawai'i. Fertile material collected at Paliku may be the first record for sporophytes.

*umbellatus* (Arn.) Par.

Indigenous

Found at the upper margin of the rain forest at Paliku and Hosmer Grove. Reported from all major islands except Moloka'i; it is almost certainly there as well.

*Ceratodon*

(Family: Ditrichaceae)

*purpureus* (Hedw.) Brid.

Indigenous

Common on ash throughout and probably the most widespread moss in the Crater District. It is also known from Kaua'i, O'ahu, and the island of Hawai'i.

*purpureus*

f. *xanthopus* (Sull.) Britt.

Indigenous

Although not within the Crater District, this moss was found close to Waikau Cabin and there is every reason to believe that it may be in the Crater as well. This is the only known locality on Maui for this form; it is also known from the island of Hawai'i.

*Clastobryopsis*

(Family: Sematophyllaceae)

*planula* (Mitt.) Fleisch.

(*Aptychella robusta* [Broth.] Fleisch. fide Tixier)

Indigenous

This high elevation rain forest epiphyte occurs in the Crater District only along the ridge between Kuiki and Paliku. It is also known from Kaua'i.



## Ctenidium

(Family: Hypnaceae)

## decurrens (Sull.) Broth.

Endemic

Found at the upper margin of the rain forest at Paliku and Hosmer Grove. Apparently known from all islands except Lana'i. The distinctions between this and the following species are not at all clear.

## elegantulum Broth.

Endemic

Although not found within the Crater District, this moss was collected in the 'Ainahou area and if within the Park would probably be at Paliku. Also reported from O'ahu and the island of Hawai'i.

## Daltonia

(Family: Hookeriaceae)

## contorta C. Muell.

Indigenous

Found at the upper margin of the rain forest at Paliku and the Ko'olau Gap. It is known from all islands except Lana'i, and on Maui previously recorded from a single collection.

## pseudostenophylla Bartr.

Indigenous

This moss was collected in the 'Ainahou area; if it is in the Park, it might be in the Paliku-Kipahulu area. This rare species has been reported from O'ahu and the island of Hawai'i.

## Desmatodon

(Family: Pottiaceae)

## convolutus (Brid.) Grout

Indigenous

At the foot of Kalahaku Pali; otherwise known only from Mauna Kea, island of Hawai'i.

## Dicranella

(Family: Dicranaceae)

## sp.

The species are impossible to identify unless they have mature capsules.

## Dicranoloma

(Family: Dicranaceae)

gracile Broth. ex Bartr.

Endemic

The type locality for this species is listed as Haleakala at 8000 feet, which is undoubtedly within the Park. This species is known only from Haleakala National Park and the adjacent areas, e.g., 'Ainahou.

wheeleri (C. Muell.) Par.

Endemic

In the Crater this moss is known only from Paliku. It has also been reported from Kaua'i and the island of Hawai'i.

## Dicranum

(Family: Dicranaceae)

speirophyllum Mont.

var. speirophyllum

Endemic

Common on the ridge above Paliku. It has been reported from all major islands except Lana'i.

speirophyllum

var. breviflagellare (C. Muell.) Bartr.

Endemic

Frequent on the ridge above Paliku. This variety seems to be little more than a morph of exposed habitats in the rain forest.

## Didymodon

(Family: Pottiaceae)

vinealis

var. flaccidus (B.S.G.) Zander  
(*Barbula vinealis* var. *flaccida* B.S.G.)

Indigenous

Sporadic on fine ash along the western slopes of Haleakala and gully below Paliku Pasture. The taxon is otherwise known only from O'ahu.

## Distichophyllum

(Family: Hookeriaceae)

freycinetii (Schwaegr.) Mitt.

Endemic

Frequent on the ridge above Paliku. A rain forest species common on all islands.

## Encalypta

(Family: Encalyptaceae)

*sandwicensis* Sull.

Endemic

Known on Maui only at the 9200 feet contour on the road to the summit of Haleakala. It is also known from the island on Hawai'i.

*scabrata* Bartr.

Endemic

Type locality: "Rest House at 8800 feet."  
Frequent in the western half of the Crater District; also known from the island of Hawai'i.

## Entodon

(Family: Entodontaceae)

*solanderi* (Aongstr.) Jaeg.

Indigenous

In the Crater found only on the eastern side of the Kaupo Gap where it is frequent. It has been reported from Kaua'i, O'ahu, and the island of Hawai'i.

*subcuspidatus* (C. Muell.) Bartr.

Indigenous

In the Park this rather rare moss is found only near Hosmer Grove. It has also been reported from Kaua'i and Moloka'i.

## Eurhynchium

(Family: Brachytheciaceae)

*vagans* (Jaeg.) Bartr.

Indigenous

In the Park this rain forest moss is found only near Hosmer Grove. It is known from all of the major islands.

## Fabronia

(Family: Fabroniaceae)

*ciliaris* (Brid.) Brid.

Indigenous

Haleakala National Park is the only known Hawaiian locality for this moss. These RBI collections represent a new Hawaiian record.

## Fissidens

(Family: Fissidentaceae)

*aphelotaxifolius* Pursell

Indigenous

Recently described from the Pacific Northwest, this species is known locally only from two collections from the upper Kaupo Gap at Paliku. New record for the Hawaiian Islands.

bryoides Hedw.

(Fissidens hawaiiicus Bartr.)

(Fissidens oahuensis Bartr.)

Indigenous

This desiccation-tolerant rain forest species is widely distributed in the Park wherever suitable microhabitats, e.g., springs, lava tubes, etc., are found. It has been reported from all major islands.

intermedius C. Muell.

Indigenous

Collected only once in the Park just above the Koa Tree in Kaupo Gap. This is usually a low elevation species and has been reported from all islands except Lana'i.

lancifolius Bartr.

Endemic

Collected only twice in the National Park in the eastern Kaupo Gap but also known from the 'Ainahou area of the Ko'olau Gap. It is known from all islands, usually at low elevations.

pacificus Aongstr.

(Fissidens mauiensis C. Muell.)

Endemic

A rain forest species found at its upper limit at Paliku and the 'Ainahou region of the Ko'olau Gap. It has been reported from all islands except Lana'i and Moloka'i.

taxifolius Hedw.

Indigenous

An upper elevation rain forest species found in the Paliku area and in gulches at and near Hosmer Grove. On Maui, it is restricted to the Park; it is also known from a single, morphologically somewhat dissimilar collection from O'ahu.

Floribundaria

(Family: Meteoriaceae)

floribunda (Dozy & Molk.) Fleisch.

Indigenous

Found in the National Park only at Paliku, but also known from O'ahu and the island of Hawai'i.

Funaria

(Family: Funariaceae)

subintegra Broth.

Endemic

A rain forest species found on damp soil banks in the Paliku area and in gulches at Hosmer Grove. It is widespread on all of the major islands.

## Glossadelphus

(Family: Sematophyllaceae)

*chrysobasilaris* Broth.

Endemic

A rain forest species found in the Paliku area (where it is abundant) and in the 'Ainahou area of the Ko'olau Gap. It is restricted to Maui.

*irroratus* Bartr.

Endemic

Endemic to East Maui.

In the National Park this species is known only from the Paliku area.

## Grimmia

(Family: Grimmiaceae)

*apocarpa*var. *pulvinata* (Hedw.) Jones

Indigenous

In the Islands reported from a single collection near the highway (at 9200 ft.). There is also an unpublished record from the island of Hawai'i. These collections represent a new Hawaiian record. May be placed in the segregate genus *Schistidium* as *S. apocarpum* var. *pulvinatum* (Hedw.) C. Jens.

*apocarpa*var. *stricta* (Turn.) Hook. & Tayl.

Indigenous

In the National Park this variety is known only from Hosmer Grove and Pu'u Niania. It is restricted to Haleakala. May be placed in the segregate genus *Schistidium* as *S. apocarpum* ssp. *gracile* (Roehl.) Meyl.

*haleakalae* Reichardt

Endemic

One of the most common mosses in the alpine areas of the Park; also known from the island of Hawai'i.

*laevigata* (Brid.) Brid.

Indigenous

The only known Maui locality is along the pali faces south of Holua. Otherwise, it is known from two collections from the island of Hawai'i.

cf. *pilifera* P.-Beauv.

In the islands this taxon is known only from the Crater District and the collections represent new Hawaiian records. It is common on the outer northwest slopes but scattered elsewhere. Sporophytes are needed for identification.

*pulvinata* (Hedw.) Smith

Indigenous

This species is known only from two localities in the Hawaiian Islands: at 8400 feet by the road and along the cliffs at Holua Cabin. New Hawaiian records.

*scabrifolia* Broth.

Endemic

Endemic to Haleakala National Park and the immediately adjacent areas. This species is known from Paliku and Hosmer Grove. The type locality is listed as 8000 feet on Haleakala and is probably located within the National Park. May be placed in the segregate genus *Schistidium* as *S. scabrifolium* (Broth.) Mill., Whittier & Whittier.

*torquata* Hornsch. ex Grev.

Indigenous

This species is restricted to Haleakala National Park. The only RBI collection is from the Kapalaoa region (Pu'u Maile).

*trichophylla* Grev.

Indigenous

This is a common alpine species widely scattered throughout the Crater District up to 9200 feet. It is otherwise only known from the island of Hawai'i.

*Haplohymenium*

(Family: Thuidiaceae)

*triste* (Ces.) Kindb.

Indigenous

A rain forest species collected at Paliku and Hosmer Grove. It is also known from O'ahu and the island of Hawai'i as well as Kaua'i (unpublished).

*Holomitrium*

(Family: Dicranaceae)

*seticalycinum* C. Muell.

Endemic

A rain forest species found on Kuiki and the 'Ainahou area of the Ko'olau Gap. It is known from all islands except Lana'i.

*Homaliodendron*

(Family: Neckeraceae)

*flabellatum* (Sm.) Fleisch.

Indigenous

Common on the eastern side of the Kaupo Gap up to Paliku; also collected at Pu'u Niania. It is a common rain forest species on all islands.

## Hookeria

(Family: Hookeriaceae)

*acutifolia* Hook. & Grev.

Indigenous

A rain forest taxon known from most major islands. This record is based on part of Vitt 14859, at the University of Alberta.

## Hypnum

(Family: Hypnaceae)

*plumaeforme* Wils.

Exotic

This species, collected in the 'Ainahou area of the Ko'olau Gap, has not been found in the Park.

## Isopterygium

(Family: Hypnaceae)

*albescens* (Hook.) Jaeg.

Indigenous

A rain forest species found at Paliku and along the Halemau'u Trail up the Lelewi Pali. It is known from all major islands.

*elegans* (Brid.) Lindb.

Indigenous

Frequent on the northern and northeast slopes of Haleakala on humus in cloud-swept areas. New record for the Hawaiian Islands.

## Leptodontium

(Family: Pottiaceae)

*flexifolium* (With.) Hampe

Indigenous

The collections from Kaluanui and Kuiki are the only known localities on Maui. The taxon is frequent along the upper boundaries of the rain forests on the island of Hawai'i.

## Leucobryum

(Family: Leucobryaceae)

*gracile* Sull.

Endemic

This rain forest species is known from the Paliku area and the foot of the Halemau'u Trail. It is abundant on all major islands.

## Macrocoma

(Family: Orthotrichaceae)

intricata (C. Muell.) Mill., Whittier & Whittier  
(Macromitrium intricatum C. Muell.)

Endemic

Common throughout the Crater District below 8000 feet as an epiphyte on trees and large shrubs. It is also common on the island of Hawai'i in the upper rain forest zone and the central Waianae Mts. of O'ahu. Investigation on the status of this Hawaiian taxon is now in progress.

## Macromitrium

(Family: Orthotrichaceae)

owahiense C. Muell.  
(Macromitrium reinwardtii Schwaegr.)

Endemic

A rain forest species found as an epiphyte in the Paliku-Kaupo area and upper Ko'olau Gap. It is common on all major islands.

piliferum Schwaegr.

Endemic

Occasional epiphyte in the eastern part of the Crater District; common in the rain forest on all major islands.

## Orthotrichum

(Family: Orthotrichaceae)

diaphanum Brid.

Indigenous

Rare. The only known locality on Maui is the center of Haleakala Crater as an epiphyte near the dikes west of Namana o ke Akua. It is also known from single collections from Mauna Kea and Mauna Loa, island of Hawai'i.

hawaiiicum C. Muell.

Endemic

Common epiphyte below 8000 feet throughout the Crater District; also on the island of Hawai'i.

hillebrandii C. Muell.

Endemic

Uncommon in the National Park Crater District, being known from the central crater area (Namana o ke Akua) and Hosmer Grove. It has also been reported from O'ahu and the island of Hawai'i.



Palamocladium (Family: Brachytheciaceae)

wilkesianum (Sull.) C. Muell.

Endemic

A very polymorphic taxon which I consider to include forms previously designated as var. *sciuroides* (C. Muell.) Wijk & Margadant. Extremely common on banks and ledges throughout the area below 7000 feet. It has been reported from all islands.

Philonotis (Family: Bartramiaceae)

turneriana (Schwaegr.) Mitt.

Indigenous

Occasional below 8000 feet around springs and in washes. It is known from all major islands.

Plagiomnium (Family: Mniaceae)

prorepens (C. Muell.) Kop.

Endemic

Rare. Found only at Paliku. This rain forest species is known from all major islands except Lana'i. Previously considered within *P. rostratum* (Schrad.) Kop., recent work by Koponen has shown it to be a distinct species.

Plagiopus (Family: Bartramiaceae)

oederi (Brid.) Limpr.

Indigenous

Rare. Found only at Hosmer Grove and in a small run-off area on the ridge behind Holua Cabin. In the islands this species is confined to Haleakala National Park and the immediately adjacent areas.

Plagiothecium (Family: Plagiotheciaceae)

draytonii (Sull.) Bartr.

Endemic

In the Park this rain forest species is known only from the Paliku area. It is on all islands except Lana'i.

Pogonatum (Family: Polytrichaceae)

tahitense Schimp. ex Besch.

Indigenous

A rain forest species known from the Lelewi Pali and as scattered colonies along the Kaupo Trail. It is widespread throughout all of the islands.

## Ponlia

(Family: Bryaceae)

*baldwinii* (Broth. ex Bartr.) Schultze-Mot.

Endemic

Type locality at 8000 feet is almost certainly in the Park. Restricted to Haleakala National Park and the immediately adjacent regions. During the RBI surveys, it was collected only from the upper Lau'ulu Trail.

*cruda* (Hedw.) Lindb.

Indigenous

On Maui restricted to the White Hill area. It has also been reported from the island of Hawai'i.

*mauiensis* (Broth. ex Bartr.) Schultze-Mot.

Endemic

On Maui restricted to shaded dry ash banks in Haleakala National Park and the immediately adjacent regions. Otherwise known from a single collection from the island of Hawai'i.

## Polytrichum

(Family: Polytrichaceae)

*piliferum* Hedw.

Indigenous

Known from the eastern border of the Crater District as well as from the island of Hawai'i.

## Pseudosymblepharis

(Family: Pottiaceae)

*mauiensis* (C. Muell.) Broth.

Indigenous

Rare in the Crater District (Kaupo Gap below 6000 ft.). Known also from Kaua'i, O'ahu, and the island of Hawai'i.

## Ptychomitrium

(Family: Ptychomitriaceae)

*mauiense* Broth.

Endemic

This alpine species is found on the eastern side of the Kaupo Gap up to Paliku and also at Hosmer Grove. It is additionally known from the island of Hawai'i.

## Racomitrium

(Family: Grimmiaceae)

*crispulum* (Hook. f. & Wils.) Hook. f. & Wils.

Indigenous

Frequent on the eastern side of the Kaupo Gap up to Paliku and also at Hosmer Grove. It is otherwise restricted to high elevations on Kaua'i and the island of Hawai'i.

lanuginosum  
var. pruinosum Wils.

Indigenous

Very common throughout the Crater District and reported from all islands except Lana'i.

Racopilum (Family: Racopilaceae)

cuspidigerum (Schwaegr.) Aongstr.

Indigenous

This rain forest moss is found in the Crater District only above the Koa Tree in Kaupo Gap. It is very common on all islands.

Rhabdoweisia (Family: Dicranaceae)

crispata (With.) Lindb.

Indigenous

Found in the Crater District only at Hosmer Grove. It is also known from the island of Hawai'i.

Rhizogonium (Family: Rhizogoniaceae)

spiniforme (Hedw.) Bruch

Indigenous

This is a very common rain forest moss in Hawai'i but in the Crater District is found only at Paliku.

Rhynchostegium (Family: Brachytheciaceae)

celebicum (Lac.) Jaeg.

Indigenous

This species, collected in the 'Ainahou area of the Ko'olau Gap, has not been found in the Crater District. It is known from Kaua'i, O'ahu, and Moloka'i.

selaginellifolium C. Muell.

Endemic

Same as the above species but found on all major islands except Lana'i.

Saelania (Family: Ditrichaceae)

glaucescens (Hedw.) Broth.

Indigenous

Restricted to the Crater District of Haleakala National Park and the immediately adjacent regions. Frequent and widely scattered throughout the dry areas.

- Schistidium (Family: Grimmiaceae)  
See Grimmia.
- Sciaromium (Family: Amblystegiaceae)  
tricostatum (Sull.) Mitt. Endemic  
In the Crater District this amphibious moss is confined to the Paliku area. It is known from all major islands except Lana'i.
- Sematophyllum (Family: Sematophyllaceae)  
hawaiiense (Broth.) Broth. Indigenous  
In the Crater District this moss is confined to the eastern side of Kaupo Gap below 6000 feet where it appears to be common. It has not been reported from Moloka'i.
- Syrrhopodon (Family: Calymperaceae)  
hawaiiicus C. Muell. Endemic  
This species has not been found in the Crater District. It is known from the 'Ainahou area of the Ko'olau Gap and probably occurs in the areas adjacent to the National Park. It is known from all islands except Lana'i.
- Taxithelium (Family: Sematophyllaceae)  
mundulum (Sull.) Bartr. Indigenous  
In the Crater District this rain forest moss is confined to the eastern side of the Kaupo Gap below 6500 feet. It is common on all islands.
- Thamnobryum (Family: Neckeraceae)  
speciosum (Broth.) Hoe Endemic  
In the Crater District this moss is confined to the Paliku area. It is also known from Pu'u Nianiau and the 'Ainahou area of Ko'olau Gap. This upper elevation rain forest species is otherwise known from the island of Hawai'i.

## Thuidium

(Family: Thuidiaceae)

## crenulatum Mitt.

Endemic

In the Crater District this moss is known from an area just above the Koa Tree in Kaupo Gap as well as from Pu'u Nianiau. It has additionally been reported from O'ahu and the island of Hawai'i.

## hawaiense Reichardt

Endemic

This rain forest species is found at Paliku and the Lelewi Pali close to the National Park boundary. It is widespread on all islands.

## plicatum Mitt.

Endemic

Common at Hosmer Grove and the eastern side of the Kaupo Gap. It has been reported from all islands except Lana'i.

## Tortella

(Family: Pottiaceae)

## fragilis

var. tortelloides (Greene) Zander &amp; Hoe

Indigenous

This variety was described recently as a species from Antarctic material and until now has been known only from that continent. It was collected twice in the Park: near the Visitor Center at White Hill and near the planted Eucalyptus grove at 8600 feet. A new Hawaiian record.

## humilis (Hedw.) Jenn.

Indigenous

Rare in the Park, the greater part of which may be above the species elevational range. Known only from a single Kaupo collection.

## Tortula

(Family: Pottiaceae)

## alpina

var. inermis (Milde) De Not.  
(Tortula ?fragilis Tayl.)

Indigenous

In the central crater area (Namana o ke Akua and Kapalaoa) and at 8500 feet by the road. Locally abundant. It is also locally common in the alpine regions of the island of Hawai'i.

princeps De Not.

Indigenous

Rare. On Maui this species is found only in the central crater area. It is also known from the island of Hawai'i.

Trachypodopsis

(Family: Trachypodaceae)

auriculata (Mitt.) Fleisch.

Indigenous

Found only in the Paliku-upper Kaupo area. This upper-elevational rain forest species is known from all islands except Lana'i.

Trachypus

(Family: Trachypodaceae)

bicolor Reinw. & Hornsch.

Indigenous

It is common at Paliku and in the upper Kaupo area. It is also known from the island of Hawai'i and there is an unpublished Kaua'i collection.

humilis Lindb.

var. humilis

Indigenous

Rare in the Crater District, found only in the Paliku area. Also known from Kaua'i.

humilis

var. flagellifer (Broth. ex Herz.) Mill.

Indigenous

Uncommon in the Crater District, found only on the eastern side of the Kaupo Gap. It is also known from Kaua'i and O'ahu.

Trematodon

(Family: Dicranaceae)

latinervis C. Muell.

Endemic

Found outside the Crater District along an intermittent stream southeast of Pu'u Alaea but may eventually be found in the Paliku-Kuiki area. It is known from all islands except Lana'i.

Trichostomum

(Family: Pottiaceae)

bartramii Mill.

Endemic

Found along the northern and eastern margin of the Crater District; known from all islands.

cf. *oblongifolium* Bartr.

Rare. Found only in the old spring area at the head of the western portion of the Kaupo Gap. This species, although never common, has been reported from all major islands except Lana'i.

*tenuirostre* (Hook. & Tayl.) Lindb.

Indigenous

Uncommon in the Crater District, found at Paliku and Hosmer Grove. Also known from Manoa Valley, O'ahu. These are new records for the Hawaiian islands.

*Ulota*

(Family: Orthotrichaceae)

*cervina* Hoe & Crum

Endemic

Endemic to Haleakala National Park.

Uncommon along the northern and eastern boundaries of the Crater District. This is an upper elevation rain forest species whose type locality is upper Kipahulu Valley.

*Weisia*

(Family: Pottiaceae)

*ovalis* (Williams) Bartr.

Endemic

Restricted to the upper Kaupo Gap area and seen only as a single fertile colony. It is common on all islands, usually at low elevations.

sp.

Rare. Found only in the central crater area. May be the same as the above but sterile and undeterminable.

*Zygodon*

(Family: Orthotrichaceae)

*reinwardtii* (Hornsch.) A. Br.

Indigenous

Uncommon. Found on the Leleiwi Pali close to the National Park boundary and in the Paliku area. It is restricted to Maui.

*rubrigemmius* (Hoe & Crum) Zander & Vitt

Endemic

Endemic to SE Haleakala.

Type locality : upper Kipahulu Valley.

Although this moss is common in Kipahulu Valley, it occurs in the Crater District only along the ridge between Kuiki and Paliku.

tetragonostomus A. Br.

Indigenous

Common throughout the northern and eastern Crater District. It has been reported from all islands except Lana'i and Moloka'i.



## APPENDIX B

## DISTRIBUTION MAPS OF THE SPECIES

In order to cut the cost of publishing this report the distribution maps of the 128 individual species have been produced as an addendum. Copies have been deposited in the following localities for reference.

Cooperative National Park Resources Studies Unit, University of Hawaii, Honolulu.

Hamilton Library, University of Hawaii, Honolulu.

National Park Service Hawaii State Director's Office, Honolulu.

National Park Service Western Region Office, San Francisco.

Haleakala National Park, Maui.