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Technical Report 153

MOSSES OF HAWAII VOLCANOES NATIONAL PARK

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ABSTRACT

A checklist of the mosses of Hawaii Volcanoes National Park was compiled from species reported from the park in various reports and publications, and from specimens of park origin housed at the Hawaii Volcanoes National Park Herbarium and the Bernice P. Bishop Museum in Honolulu. Field surveys were conducted in the specialized habitats of geothermal features and lava tube entrances to search for new moss species. Two preliminary surveys were also conducted in the new Kahuku unit. One hundred thirteen taxa (110 species, one subspecies, and two varieties) are on the current checklist based on 111 taxa collected from within the park boundaries and three collected near the park. Six of these species are invasive or potentially invasive species warranting management concern. In total, 43 percent of all moss species in the Hawaiian Islands are represented at the park.

INTRODUCTION

Despite the wealth of botanical research in Hawaii Volcanoes National Park (HAVO) few botanists have collected the mosses such that no comprehensive list of the mosses of the park is available. Nonetheless, a number of reports refer to specific mosses, several documenting many species from HAVO. Bartram's *Manual of Hawaiian Mosses* (1933) cites many specimens from the "vicinity of Kilauea" and "Bird Park" (Kipuka Puaulu). For the creation of this checklist moss records were compiled from existing references (Bartram 1933, Doty & Mueller-Dombois 1966, Cuddihy *et al*. 1986) and from specimens housed at the Bernice P. Bishop Museum in Honolulu (hereafter referred to as Bishop Museum) and the HAVO herbarium.

This short survey, carried out in the summer of 2004, compiled lists of previously recorded mosses from various habitats and then identified areas that had not been sampled for detailed study. Puhimau Hotspot, Kilauea Caldera steam caves, Mauna Loa caves, Olaa Trench, and Ainahou Ranch were surveyed intensively. Though the Mauna Loa caldera was identified as an area of interest, it was not visited due to logistical problems. The Kahuku addition to the park was not included in the original study plan, however, two areas were visited to provide an overview for a later assessment of the flora of the area. A checklist of the mosses found in Hawaii Volcanoes National Park is appended to the report.

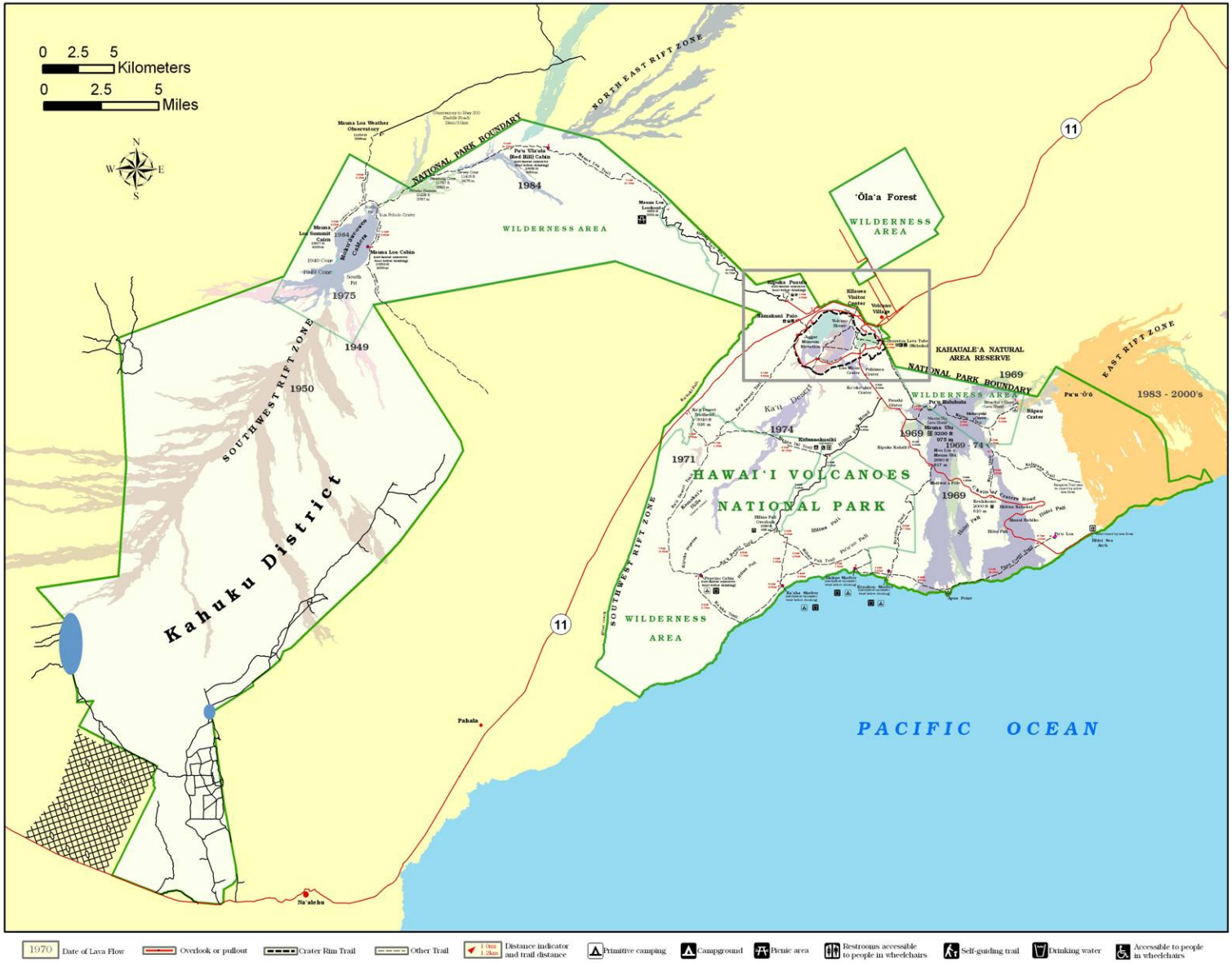

Figure 1a. Map of Hawaii Volcanoes National Park. Approximate moss survey locations for the Kahuku unit of the park are indicated by blue shading

Figure 1b. Expanded map of the Kilauea summit area in Hawaii Volcanoes National Park, showing many of the locations where mosses were found

METHODS AND MATERIALS

Field Studies

Location information from herbarium specimens, Bartram (1933), Burton (1980), and Cuddihy *et al.* (1986) suggested the regions around Kilauea Caldera, the East Rift, Bird Park (Kipuka Puaulu), and Olaa Forest Tract (with the exception of the Olaa Trench) were already relatively well collected for moss species. The following areas and habitats appeared to deserve more focused collecting:

Kahuku
Puhimau Hotspot
Kilauea Caldera hotpond and steam caves
Ainahou Ranch
Mauna Loa Caves
Olaa Trench

General surveys for the presence/absence of moss species were conducted at these areas by searching likely microhabitats (such as rock crevices, tree trunks, shaded banks, etc.) and collecting specimens of mosses encountered for later identification. The Mauna Loa summit area above 3650 m (12,000 ft.) was not surveyed though other observers report that mosses are present in steam vents and water seepages. Particularly striking species and habitats were photographed using a Nikon 4500 digital camera.

Collected specimens were placed in Ziploc plastic bags labeled in the field with collection number, date, location, substrate, surrounding vegetation, and GPS position recorded with a handheld Garmin unit. Selected specimens were prepared to serve as voucher specimens for permanent records of species presence in each area. Vouchers were put in packets folded using acid-free, 100% rag, cotton paper. Label information was printed directly onto the paper before folding it into specimen packets. All voucher specimens were deposited at the HAVO Herbarium.

Information about species occurring in HAVO was entered into NPSpecies, the National Park Service biodiversity database. The data came from existing specimens at HAVO and the Bishop Museum, from the *Manual of Hawaiian Mosses* by Bartram (1933), and from new specimens collected for this 2004 inventory. Species names were updated to current taxonomy, both current names and old synonyms were entered.

RESULTS AND DISCUSSION

Checklist

The 266 moss specimens in the HAVO Herbarium were examined to verify identification. Of these, 39 had not been identified beforehand and 17 had been misidentified resulting in a list of 68 species in the park. Nine species previously unrecorded for the park were found. The HAVO Herbarium specimens were entered into the National Park Service biodiversity database NPSpecies. Labels and acid-free specimen packets were made for 71 of the specimens.

The Bishop Museum provided a listing of moss specimens in their database from Hawaii Island. Of 1926 records, 506 came from HAVO or the Kilauea vicinity. These were edited for compatibility with NPSpecies and the species names were updated to currently accepted names as provided by the online WMOST nomenclatural database of moss taxonomy maintained by the Missouri Botanical Garden (www.mobot.org). In this process 159 moss synonyms were identified and the list of mosses updated to 110 species for HAVO. In addition, 230 species names derived from several reports (Higashino *et al*. 1988, Hoe 1967, Hoe and Smith 1980, Smith 1975) for Haleakala National Park (HALE) were similarly reduced to 154 currently accepted moss taxa and entered into NPSpecies. The 110 HAVO species names are in agreement with the names in the newly published checklist of Hawaiian mosses (Staples *et al*. 2004) except in the following six cases which are accepted as valid taxa for this report:

1) *Anoectangium haleakalae* was submerged into *A. aestivum* by Zander & Vitt (1979). It is still listed as an accepted name in the online WMOST database and the two can normally be separated in the field.

2) *Didymodon vinealis*, in its current circumscription, is a new record for the Hawaiian Islands and not in the current Hawaiian mosses checklist. Old concepts of *D. vinealis* included a taxon already recorded from the Hawaiian Islands as a variety but now classified as the separate species *D. insulanus*.

3) The type specimen of *Grimmia haleakalae* was determined to be *Amphidium tortuosum* (Staples, pers. comm.) but the species portrayed in Bartram's Manual is not *Amphidium tortuosum* and is instead *Grimmia longirostris* (Kortselius pers. comm. to Staples).

4) *Taxiphyllum laevifolium* is listed by Staples *et al*. (2004) as the accepted name for *Glossadelphus baldwinii.* However, Kis (2002) synonymized *G. balwinii* with *Phyllodon lingulatus* found in Africa and Asia. Buck (1998) states that *T. laevifolium* is often confused (including by Bartram) with *Phyllodon* species but can be distinguished by the shape of the teeth on the leaf margins wherein *T. laevifolium* has simple teeth and *Phyllodon* species have bifid teeth. The Hawaii specimens have bifid teeth and are therefore included here as *P. lingulatus.*

5) Kopponen (1982) split part of *Plagiomnium rostratum* (including all those in Hawaii) into *P. rhynchophorum*.

6) *Pyrrhobryum pungens* is listed as the accepted name for *Rhizogonium pungens* in the online WMOST database, putting it into the same genus as the closely related *P. spiniforme*.

One potential new record (*Neckera lepineana*) for HAVO at Bishop Museum was examined and found to be a misidentification of a species (*Baldwiniella kealeensis)* already known from the park.

One hundred and thirteen taxa (110 species, one subspecies, and two varieties) of mosses are recorded from Hawaii Volcanoes National Park (Appendix). Three species are included based on specimens collected outside the park boundary. *Calymperes tenerum* and *Macromitrium emersulum* are both native species that were collected outside the park in Kalapana in the 1960s and 1980s, before the current eruption of Kilauea volcano which started in 1983, covered so much of Kalapana. These two species may still survive within the park in low elevation kipukas (a Hawaiian term that describes islands of vegetation surrounded by lava). *Sematophyllum subpinnatum* is an invasive species very widespread in the lower elevation wet forests that is likely to occur in lower elevation East Rift forests. So far, *S. subpinnatum* does not appear to be very invasive at elevations above 700 m (2300 ft), based on personal observation on Oahu and Hawaii Island. About one-third of the species (37) are currently considered endemic to the Hawaiian Islands. Most of the other two-thirds are indigenous to the Hawaiian Islands. Taxonomic revisions will mostly likely reduce the number considered endemic as many modern revisions of genera have lumped Hawaiian taxa with more widespread taxa (Hoe 1974, Hoe 1979, Touw 2001). A recent revision of the genus *Thuidium,* Touw (2001) sank what had been previously considered to be two endemic species (*T. hawaiiense* and *T. plicatum*) into a single species (*T. cymbifolium*) widespread in South East Asia. Nevertheless, Touw (2001) commented that the Hawaiian specimens had more morphological variation than found in South East Asia. Vitt & Marsh (1988) similarly noted that Hawaiian specimens of the cosmopolitan *Racomitrium lanuginosum* var. *lanuginosum* were unusually variable compared to specimens from elsewhere. *Leucobryum gracile* is an example of an endemic taxon that will likely be sunk into a more widespread taxon (Hoe 1979). Four species in HAVO are non-indigenous, all of which are invasive to some extent.

Twenty eight species are known only from a single specimen from HAVO or cited in one publication only (Table 1). Future work should verify the presence of each of these species, their abundance and distribution. One species, *Breutelia affinis*, was collected once from Kilauea, Hawaii Island, more than 100 years ago and has never been collected since in the Hawaiian Islands (Virtanen 1997). Eight species (Table 2.) are new records for the Island of Hawaii. The species *Didymodon vinealis* is new to the Hawaiian Islands.

Table 1. *Moss species with only one source of documentation for Hawaii Volcanoes National Park*

Species	Bartram (1933)	Bishop Museum	HAVO Herbarium	New: this survey
Andreaea acutifolia				X
Brachythecium hawaiicum		X		
Breutelia affinis	X			
Calymperes tenerum		X		
Campylopus praemorsus		X		
Campylopus wheeleri		X		
Ctenidium elegantulum		X		
Didymodon vinealis				X
Ectropothecium sandwichense		X		
Fissidens elegans		X		
Fissidens kilaueae		X		
Fissidens lancifolius		X		
Hyophila involuta				X
Isopterygium vineale				X
Macromitrium brevisetum		X		
Macromitrium emersulum			X	
Orthotrichum diaphanum		X		
Orthotrichum hawaiicum		X		
Orthotrichum rupestre		X		
Philonotis falcata			X	
Philonotis hawaiica		X		
Phyllodon lingulatus			X	
Polytrichum commune				X
Racomitrium crispulum	X			
Rhynchostegium celebicum			X	
Rhynchostegium selaginellifolium			X	
Rosulabryum billardieri		X		
Syrrhopodon prolifer	X			

Table 2. *Moss species newly recorded in this study (2004) from Hawaii Island*

Species
Aerobryopsis subdivergens ssp. scariosa
Campylopus fragilis ssp. zollingerianus
Dicranella hawaiica
Didymodon insulanus
Didymodon vinealis
Grimmia longirostris
Philonotis falcata
Rhynchostegium celebicum

Non-indigenous Mosses at Hawaii Volcanoes National Park

In contrast to numerous species of non-indigenous species in the higher plants there are only four alien species of moss in the park. Two alien species, *Hypnum plumaeforme* and *Pseudoscleropodium purum,* are common along roadsides, trailsides, and lawns in mesic-to-wet environments from Namakani Paio campground and Kipuka Puaulu to Puhimau Crater suggesting that they are spread by roadside maintenance machinery or general traffic. An additional species, *Polytrichum commune*, was collected in the park during this survey. The fourth alien species, *Sematophyllum subpinnatum*, has not yet been collected from the park, but it is expected to occur in lower elevation forests. A fifth species, previously identified as the native *Breutelia arundinifolia*, behaves invasively in lawns and roadsides while not being found in undisturbed habitats and may in fact be an unrecognized alien species.

Hypnum plumaeforme

H. plumaeforme, from eastern Asia, was first collected on Hawaii in 1955 from "Kilauea, at 29 miles" (Hoe 1974). By 1979 it was reported to be widespread in disturbed grassy areas between 700-1300 m (2300-4300 ft) on Hawaii Island as well as at Olinda, Maui (Hoe 1979). It is now widespread and abundant in lawns and roadsides from Volcano Village to low-elevation downtown Hilo and Puna. It would spread even faster if it produced spores, but so far, no

Figure 2. ***Hypnum plumaeforme,*** **HAVO 2004**

sporophytes have been reported in Hawaii.

During the course of this moss survey I recorded the distribution of *H. plumaeforme* in HAVO. It is present along most of the roadways and trails in moderate to high rainfall areas of the park. It is especially abundant along roads, trails, and lawns by the Kilauea Visitor Center, but barely present at Puhimau Crater, Namakani Paio campground, and Kipuka Puaulu. It is absent from the drier parts, such as Ainahou Ranch and the top of Mauna Loa Strip Road. The invasion may be of most concern, with the alien *Pseodoscleropdium purum*, along the trail into Thurston Lava Tube and the trail into Kilauea Iki Crater, where it is overgrowing native bryophytes on the steep sides of the caldera wall.

H. plumaeforme is present all along Crater Rim Drive except in the drier section between the Hawaiian Volcano Observatory and Devastation Trail. *H. plumaeforme* is one the few species to grow close to the steam vents between Sulphur Banks and Kilauea Military Camp (KMC). It is present along the Chain of Craters Road downslope at least as far as the Puhimau Crater parking lot, but disappears before the drier Hilina Pali Road junction. It is not present in the Ainahou Ranch garden area or the Ainahou Nene pasture. It is very sparingly present under the *Eucalyptus* trees at Namakani Paio campground and up to the edge of the cracks behind the restroom building, but is absent in the unshaded lawn. It occurs in the horse corral near the Tree Molds area and spottily along Mauna Loa Road between Highway 11 and Kipuka Puaulu. However, within the kipuka itself it is rare and I only was able to find a single patch along the entire loop trail. It is not present along the Mauna Loa Strip Road past Kipuka Puaulu probably because of the tall, dense grass that shades out what otherwise would be typical habitat for *H. plumaeforme*. It grows all along the Crater Rim Trail except in the drier sections and unshaded bare lava.

Pseudoscleropodium purum

P. purum, from Europe, is very similar in appearance to *H. plumaeforme* and is usually found mixed with it. Hoe (1971) made the first report of this species in Hawaii from specimens he collected in HAVO from grass in the residential area of the park (Quarters 5). Hoe suggested that it may have been introduced as packing material from park employees' household goods on

Figure 3. Pseudoscleropodium purum, HAVO 2004

transfer into the park. It does not appear to survive in warmer sites, as it was not found in or around any of the steam vents surveyed, nor is it found in lower-elevation Hilo. Although *P. purum* rarely grows more than about a meter into forest vegetation from roads and trailsides, it is found much farther into the forest at Kipuka Puaulu. Perhaps this can be explained by the lack of a dense understory that would otherwise prevent sufficient light from reaching the forest floor. *P. purum* was first collected from Kipuka Puaulu in 1975 by D. Vitt (#15087 at Bishop Museum). In Kipuka Puaulu dense patches of *P. purum* were found along the upper section of the loop trail. Distantly scattered patches were found in the forest center, but were limited enough in extent to suggest that its spread is slow. There is nothing to suggest it would not cover most of the forest floor. A sudden large number of tree falls opening up the canopy could speed up that process. Like *H. plumaeforme,* it has not been collected with sporophytes in Hawaii.

Polytrichum commune

P. commune, from Eurasia and North America, was first collected on Hawaii Island from the garden area at Kulani Prison (Hoe 1971). It is now distributed in the communities of Volcano, Glenwood, as well as in the upper Stainback area near Puu Makaala Natural Area Reserve, and perhaps other upper elevation sites on the island. It is now present along Crater Rim Drive near KMC, on the KMC ball field and adjacent shrubland, and along Highway 11 within HAVO boundaries. Its limited, current distribution to roadsides suggests this species may not become a management concern in undisturbed habitats. However, it does form dense colonies along parts of the Highway 11 in Glenwood so perhaps it simply has not had time to become an obvious management concern in the park.

Figure 3. ***Polytrichum commune, HAVO 2004***

Sematophyllum subpinnatum

S. subpinnatum, from South America, is very common in Hilo but was not found at HAVO, perhaps because it is restricted to lower elevation climates. It is similar to the native *S. hawaiiense* that is common in HAVO, but is smaller, more slender, and with upright capsules rather than horizontal capsules. It will probably be found in any remaining lower elevation wet forest at HAVO. This species produces sporophytes freely allowing it to colonize sites without human dispersal. Hence, in wet low elevation areas such as lower Stainback Highway it is widely present within the forest rather than limited to roadside areas. The densities on trees in these areas suggest that it probably has some effect on other epiphytic species but no data are available to confirm this.

Sphagnum sp.

A *Sphagnum sp*., probably *S. palustre* that is indigenous to Kohala Mountain, is found in two locations near Kilauea Visitor Center in HAVO. The nearest known location is on the side of the Old Volcano Road across and upslope from the Volcano post office along the fence of a residence. It was also found (HAVO Herbarium, coll. Will Haines) at a house lot in the Hawaii Orchid Island Estates subdivision below Volcano Village under the shade of uluhe (*Dicranopteris linearis)* fern. It has recently been found in the new Kahuku unit (Belfield, pers. comm.) of HAVO. Although it is indigenous to Hawaii it was limited to the Kohala Mountains until its use with forestry seedlings spread it more widely on the island of Hawaii (Karlin & Andrus 1995).

Figure 5. *Sphagnum* sp., HAVO 2004

Since this is a naturally occurring species on the island of Hawaii it can be argued that its spread is the spread of a natural species and hence of no management concern. However, *Sphagnum* species strongly modify their habitats in ways that limit the growth of other plants. *S. palustre* was also spread to Kaala Bog on Oahu where it is displaces ground bryophytes. In the longer term it may also prevent regeneration of ohia (*Metrosideros polymorpha*) and other trees by increasing waterlogging and acidification of the ground (Vanbreemen 1995). The Army Environmental Team is conducting small-scale experiments at the Kaala Bog to control *Sphagnum* using calcium hydroxide, which very effectively kills the *Sphagnum.* An interesting side effect is a high number of ohia seedlings germinating in the dead *Sphagnum;* although it is too early to know if the seedling growth is supported much beyond germination. Very few ohia seedlings are found in live *Sphagnum* except in a few spots where the *Sphagnum* is stressed as indicated by stunted growth and dark coloration probably from sun exposure and good drainage. In the park this species should be watched where high rainfall is combined with reduced vegetation growth such as at the *Carex alligata* bogs of the Olaa Trench where poor drainage reduces vegetation growth, in the East Rift where high sulfur deposition from vog (volcanic smog) reduces vegetation growth, and in any wet areas during ohia dieback events.

Breutelia

A *Breutelia* species common in lawns in Volcano Village appears to be at the beginning stages of invading roadsides and lawns in the park. This may be an indigenous species. Bartram (1933) reports *B. arundinifolia* was collected from Kilauea. A Bishop Museum specimen from Volcano Village (where it is common in lawns) was identified by W.J. Hoe as the indigenous *Breutelia arundinifolia*. However, its distribution pattern is very much like that of recently established alien species. I found it in lawns, in roadsides, and trailsides just like *H. plumaeforme* and *P. purum* but less widely distributed and more restricted to wetter sites. I did not find any populations located away from roads, trails, lawns, or other disturbed habitats. A revision of Hawaiian *Breutelia* by Virtanen (1997) lists *B. arundinifolia* from only Kauai and, unfortunately, does not cite any specimens from Volcano or HAVO other than the very different *B. affinis*. In particular, this species is found at the lawn at the cross walk between Kilauea Visitor Center and the Volcano House, along the Escape Road and along Highway 11 where it intersects with the Escape Road, as well as at the Resources Management field station along the pavement by the greenhouses and nearby on Crater Rim Trail. In 2001, I searched for this species and found it established on the Escape Road but not at the Resources Management field station. I did not search the lawn at the Kilauea Visitor Center in that year.

Figure 6. *Breutelia* sp., HAVO 2004

Kahuku

The moss flora encountered during surveys of two areas of the new Kahuku unit of the park was the essentially the same as in the area above the Mauna Loa Strip Road. The area of Kahuku surveyed first, from 6/7/2004-6/9/2004, was on the west side of Kahuku at the koa (*Acacia koa*) regeneration study site being monitored by HAVO Resources Management staff and ranged in elevation from about 1737 - 2080 m (5700 – 6825 ft). The vegetation ranged from open forest of ohia and koa with *Erharta* grass understory on a lava substrate to open shrublands of aalii (*Dodonaea viscosa*) and pukiawe (*Leptecophylla tameiameiae*) and scattered *Deschampsia* clumps to bare aa lava (lava with a rough, jagged, and clinkery surface). Because of the dry climate, there were virtually no epiphytic mosses. Occasionally some older koa trees were found to have small pockets of humus collected at a branch junction supporting a few epiphytic mosses.

The indigenous species *Didymodon insulanus* was collected only once before in HAVO (the first collection was previously misidentified as a *Macromitrium* species).

Trichostomum crispulum was unusually abundant in this area. No alien mosses were encountered in the west Kahuku survey.

Figure 7. One of the koa regeneration plots in West Kahuku with pink flags marking koa seedlings

Figure 8. Exclosure at the koa regeneration study site, West Kahuku, June 7 2004

Figure 9. *Polytrichum piliferum* with characteristic silver-tipped leaves, East Kahuku, 2004

The second survey of Kahuku occurred in conjunction with a one-day visit to potential sheep trap sites along the unpaved contour road in the eastern part of Kahuku on 2 July 2004. The vegetation ranged from open ohia forest with scattered koa trees to open shrublands with bare pockets of ash and alien grasses. This short visit yielded one new species for the park (*Didymodon vinealis*) as well as a species which had been reported from HAVO (*Polytrichum piliferum*) by Doty & Mueller-Dombois (1966) but with no voucher specimens in the Bishop Museum and HAVO herbaria. One alien moss, *Hypnum plumaeforme*, was common along the contour road and pastures in this area.

Figure 10. Vegetation of scattered trees, shrubs and grazed grass along the contour road in East Kahuku, July 2 2004

The survey of the forest edge into the shrub lands of the upper west side of Kahuku was fairly thorough and I do not expect that many species were missed aside from those at any large cave entrances. However, there will be a few more species to record from the somewhat wetter forest vegetation along its lower boundary. The opportunity to survey the east side of Kahuku was very short and, given the wetter climate in this area, I expect there are many more species to be added to the Kahuku checklist.

Table 3*. Moss species encountered at Kahuku (2004).*

Species	West Kahuku	East Kahuku
Amphidium tortuosum		X
Anoectangium aestivum	X	X
Brachymenium exile	X	
Brachythecium lamprocarpum	X	
Brachythecium plumosum		X
Bryum argenteum var. lanatum	X	
Campylopus exasperatus Brid.	X	
Campylopus hawaiicus var. densifolius	X	X
Campylopus hawaiicus var. hawaiicus	X	
Campylopus schmidii ssp. schmidii	X	X
Campylopus umbellatus	X	X
Ceratodon purpureus	X	X
Dicranella integrifolia		X
Dicranum speirophyllum	X	X
Didymodon insulanus	X	
Didymodom vinealis		X
Ectropothecium decurrens	X	X
Fissidens bryoides	X	X
Funaria hygrometrica		X
Grimmia longirostris	X	
Hypnum plumaeforme		X
Leptodontium flexifolium		X
Leucobryum gracile	X	
Macromitrium piliferum	X	
Palamocladium wilkesianum	X	
Philonotis turneriana		X
Pogonatum tahitense		X
Polytrichum piliferum		X
Pyrrhobryum spiniforme	X	
Racomitrium lanuginosum	X	X
Racopilum cuspidigerum	X	
Rosulabryum capillare	X	
Sematophyllum hawaiiense	X	X
Thuidium cymbifolium	X	X
Trichostomum crispulum	X	X
Zygodon tetragonostomus	X	

Puhimau Hotspot

Underground magma movement close to the surface killed the forest vegetation and created the steaming, barren geologic feature now known as the Puhimau Hotspot in the winter of 1937-1938 (Smith 1981). Smith and Kappen (Kappen & Smith 1980, Smith 1981) studied the common bryophytes and lichens of this area to investigate the apparent heat tolerance of species growing in the moisture provided by the steam vents. They found that the most common moss, *Campylopus praemorsus* (now split into *C. exasperatus* and *C. praemorsus*), tolerated higher temperatures than most mosses but within the range of other heat tolerant mosses while the lichens *Cladonia skottsbergii* and *C. oceanica* were not unusually heat tolerant and instead survived by growing far enough away from the vents for the steam temperature to cool down (Kappen & Smith 1980). During the current survey (20 June 2004) the most ubiquitous moss at the Puhimau Hotspot was *Dicranella integrifolia*, rather than *C. exasperatus or C. praemorsus,* growing as thin mats on any exposed ash substrate both near and away from steam vents. Bartram (1933) noted that both *D. integrifolia* and *C. exasperatus* were common in the vicinity of Kilauea and more common on the island of Hawaii than in the other islands. A patch of *Isopterygium vineale* found growing in the wet steam of one vent is the first record of this species at HAVO.

Table 4. *Moss species encountered at Puhimau Hotspot (2004).*

Species
Campylopus exasperatus
Campylopus fragilis ssp. zollingerianus
Campylopus umbellatus
Dicranella integrifolia
Isopterygium albescens
Isopterygium vineale
Leucobryum gracile

Sulphur Banks

This area was surveyed on 6/24/2004. Sulphur Banks is the type locality of *Scopelophila infericola* described as an endemic species by William J. Hoe (Hoe 1973). Hoe (1973) expressed concern that the population was perhaps only 40 cm^2 in size, limited to only one known location and vulnerable to chance disturbances such a shift in fumarolic activity which killed half the *S. infericola* colony in 1972.

Figure 11. Sulphur Banks with *Scopelophila infericola* growing under whitened rocks

Sulphur Banks remains the only known locality for *S. infericola*, however, this survey found its population appears to have significantly increased. It is now found over an area many times larger than 40 cm^2; from the bank by the visitor platform to the exposed ash flats under the visitor platform towards KMC, and a separate subpopulation in the steam crack at the edge of the forest behind Sulphur Banks. *S. infericola* is unusual among Hawaiian plants and mosses in its ability to tolerate high mercury concentrations and temperatures (Hoe 1973, Siegel 1973). The genus *Scopelophila* typically prefers sites rich in sulfides or metallic ores, including volcanic deposits and hotsprings (Zander 1967, Eddy 1990). The status of *S. infericola* has not been evaluated. It was described as a new species because it differed in leaf-tip cell structure from *S. ligulata* in N. America (Hoe 1973). However, taxonomic drawings available more recently of *S. ligulata* from S.E. Asia (Eddy 1990) also differ in leaf-tip cell structure from N. American *S. ligulata* and appear identical to *S. infericola*. *S. cataractae* is known to have been spread to Europe from Asia or the Americas (Soderstrom 1992) demonstrating the mobility of at least one species in the genus.

Table 5. *Moss species encountered at Sulphur Banks (2004).*

Species
Campylopus exasperatus Brid.
Campylopus hawaiicus
Campylopus schmidii ssp. schmidii
Dicranella integrifolia
Isopterygium albescens
Leucobryum gracile
Racomitrium lanuginosum
Scopelophila infericola

Kilauea Caldera Hotpond and Steam Caves

The hotpond located in Kilauea Caldera below the Hawaiian Volcano Observatory was surveyed on 7/18/2004. It is a small pond with steaming vents surrounded by nearly flat, almost barren lava. It has a small clump of ohia trees on a jumble of rocks almost surrounded by the pond water. *Campylopus exasperatus, Isopterygium albescens*, and *Leucobryum gracile* were found at the base of the ohia trees. *Leucobryum gracile* and *Isopterygium albescens* are both more typical of forested habitats, but apparently the condensation from the steam allows them to survive despite the heat and lack of shade. *Dicranella integrifolia* was by far the most abundant moss and was found on any ash substrate right down to the pond surface and edges of steam vents.

Figure 12. The shallow water and vegetation of the Kilauea Caldera hotpond

Figure 13. Steam venting from Kilauea Caldera hotpond

Figure 14. A steam cave in Kilauea Caldera

On 7/25/2004 Bill Halliday and Harry Shick, two avid spelunkers with many years experience in exploring caves in Hawaii and with permits to work in HAVO, took me to nine steaming caves in Kilauea Caldera to look for mosses. We found ten species in this area. The outsides of caves consistently had *Dicranella integrifolia* and occasionally *Campylopus exasperatus* and *Racomitrium lanuginosum* as well.

Table 6. *Moss species encountered at Kilauea steaming caves (2004).*

Species
Campylopus exasperatus
Dicranella hawaiica
Dicranella integrifolia
Distichophyllum paradoxum
Leucobryum
Philonotis turneriana
Pyrrhobryum spiniforme
Racomitrium lanuginosum
Thuidium cymbifolium
Vesicularia perviridis

Dicranella integrifolia also grew inside the caves near the entrance where there was more light. Only seven species were found sporadically in the caves. The hot caves had more young *Nephrolepis* ferns and, probably, its gametophytes than any other plant, and this species grew further into the dark zone of the cave than any other species. Ohelo (*Vaccinium sp.*) seedlings were found growing in a cave not heated by steam. Some of the ohelo seedlings were growing out of recognizable rat droppings. Temperature

readings were taken in one cave where the moss-covered floor was 32.5° C, the steaming ceiling with no moss was 43-45° C, and a cooler corner with the moss *Leucobryum* was 26.1° C. *Leucobryum* was also found in two other caves that were cooler.

We also stopped at a sulfur-depositing steam vent along the Uwekahuna Trail by Halemaumau Crater. *Dicranella integrifolia, Racomitrium lanuginosum* and a liverwort were encountered but *Scopelophila infericola*, described from Sulphur Banks, was not found here perhaps because it is too dry.

Ainahou Ranch

The Ainahou ranch house and Nene pasture, located at around 915 m (3000 ft.) elevation along Chain of Crater's Road, were surveyed on 7/22/2004. The area is dry and not surprisingly yielded relatively few mosses. The ranch house garden harbored ten moss species including a species new to HAVO, *Hyophila involuta*. The Nene pasture below the ranch house was visited to see if it contained the alien moss *Hypnum plumaeforme*. No mosses, native or alien, were encountered at the Nene pasture.

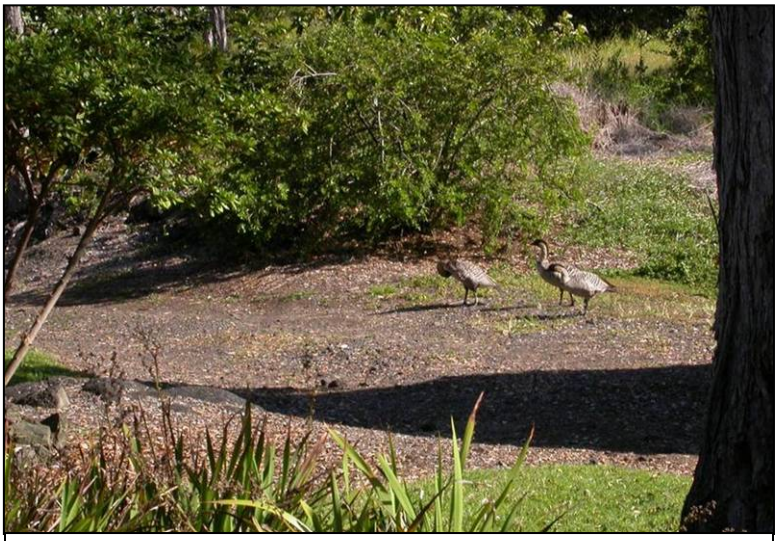

Figure 15. Nene pasture at Ainahou Ranch House

Table 7. *Moss species found around Ainahou Ranch House (2004).*

Species
Bryum argenteum var. lanatum
Bryum atrovirens
Bryum caespiticium
Campylopus umbellatus
Ceratodon purpureus
Hyophila involuta
Isopterygium albescens
Racopilum cuspidigerum
Sematophyllum hawaiiense
Weissia sp.

Mauna Loa Caves

Cave (lava tube) entrances on Mauna Loa were surveyed on June 17 and 19, July 3-4, and 12-15, 2004. Two species new to the park were discovered. *Andreaea acutifolia* was found at the entrance of one cave and *Didymodon vinealis* was found at the entrance of another cave.

Figure 16. Lava tube entrance, Mauna Loa

These high elevation lava tubes tend to have a common mix of species. The most common species on wet cave walls is *Anoectangium aestivum* which forms smooth, bright-green cushions and carpets. Patches of *Amphidium tortuosum* and *Ceratodon purpureus* are often mixed between or on the periphery of the *A. aestivum*. These same species are found on rock and on the cave floor under water drips. An as-yet-undetermined species of *Brachythecium* (probably *B. hawaiicum*) is also very common on the cave floor. Also usually present, but in lesser quantity, are *Fissidens bryoides, Rosulabryum capillare* and *Schizymenium pulvinatum.* Outside the caves but within the pits caused by the lava tube collapses are *Campylopus schmidii* ssp. *schmidii, Grimmia longirostris, Leptodontium flexifolium,* and *Racomitrium lanuginosum.* The *R. lanuginosum* at the entrances are notable because they often have sporophytes unlike the great masses of this species on exposed lava flow habitats, which never seem to bear sporophytes.

Table 8. *Moss species encountered at upper elevation Mauna Loa caves (2004).*

Species
Amphidium tortuosum
Andreaea acutifolia
Anoectangium aestivum
Anoectangium haleakalae
Brachymenium exile
Brachythecium lamprocarpum
Bryum argenteum var. lanatum
Bryum atrovirens
Bryum hawaiicum
Campylopus schmidii ssp. schmidii
Brachythecium cf. hawaiicum
Ceratodon purpureus
Dicranella integrifolia
Didymodon vinealis
Fissidens bryoides
Grimmia longirostris
Grimmia trichophylla
Isopterygium albescens
Leptodontium flexifolium
Plagiomnium rhynchophorum
Pohlia flexuosa Hook.
Racomitrium lanuginosum
Racopilum cuspidigerum
Rosulabryum capillare
Schizymenium pulvinatum
Sematophyllum hawaiiense
Thuidium cymbifolium
Tortella humilis
Trichostomum crispulum
Zygodon tetragonostomus

Olaa Trench

The Olaa Trench consists of a complex of craters in the remote northeastern quarter of Olaa Forest Tract in Hawaii Volcanoes National Park. The Olaa Trench and its environs were surveyed with Karl Magnacca on July 10, 2004. Because of the distance involved very little time was available to collect specimens. Nevertheless, we collected 22 species, including *Barbellopsis trichophora*, previously represented by only a single specimen for the park at Bishop Museum from Kipuka Puaulu.

Figure 17. View from inside Olaa Trench

Most of the specimens were collected from the steep side of the trench. *Syrrhopodon armatus,* new to the park, was collected from the trunk of a loulu palm (*Pritchardia beccariana*) just inside the park boundary on the way from Puu Makaala Natural Area Reserve.

Table 9. *Moss species encountered at Olaa Trench and trail (2004).*

Species
Acroporium fuscoflavum
Aerobryopsissubdivergens ssp. scariosa
Anoectangium haleakalae
Baldwiniella kealeensis
Barbellopsis trichophora
Campylopus hawaiicus
Campylopus hawaiicus var. densifolius
Campylopus hawaiicus var. hawaiico-flexuosus
Campylopus hawaiicus var. hawaiicus
Campylopus umbellatus
Dicranodontium porodictyon
Distichophyllum freycinetii
Distichophyllum paradoxum
Ectropothecium decurrens
Fissidens
Hookeria acutifolia
Philonotis falcata
Pseudosymblepharis angustata
Syrrhopodon armatus
Taxithelium mundulum
Thuidium cymbifolium
Trichostomum crispulum

Hawaiian Moss Names

Bartram (1933) did not include Hawaiian names in his manual of Hawaiian mosses. The Hawaiian dictionary by Pukui & Elbert (1986) lists two general terms for mosses, limu and huluhulu, and names for specific types of mosses and liverworts. Unfortunately, only one of these specific names has a scientific name attached to it, *Thuidium hawaiiense* (now *T. cymbifolium*). The rest are orphan names that cannot be attached to known species unless other records can be found. A dictionary of modern Hawaiian by Komike Hua`olelo (2003) lists another general term, mākōpi`i, and one specific term hulu pō`ē`ē for *Sphagnum* moss.

Table 10. *Known Hawaiian words for mosses, liverworts, and a lichen.*

Hawaiian	English definition
`ekaha	a moss growing on rotted trees, also limu `ekaha
hini hini `ula	an upland moss
huluhulu a Ka`au hele moa	a moss said to grow only in Palolo Valley, Honolulu, named for Ka`au-hele-moa a legendary cock defeated in battle by a hen. She pulled his feathers which became this moss. It is used in leis.
hulu pō`ē`ē	Sphagnum
huluhulu	kinds of seaweeds and mosses
huluhulu a `īlio	a green, velvety carpet-like mountain moss. The spore cases rise above the plants. Lit. fur like a dog.
iliohe	a name reported for a green freshwater moss
kala maka pi`i	same as mākole mākō pi`i and kale maka pi`i
kalau ipo	a moss found in water
kale maka pi`i	variant of kala maka pi`i, a moss
lī pepei ao	1. a seaweed 2. a freshwater moss, usually qualified by wai
lī poa kua hiwi	a non-edible mountain moss as opposed to the edible lī poa
limu	general name for plants including mosses, liverworts, lichens, etc..
limu `ahu`ula	an upland moss
limu ahi	a tree moss or liverwort
limu haea	a lichen (Stereocaulon sp.) with erect, branching stalks
limu holo `a wai	a freshwater moss
limu kaha	a kind of liverwort
limu kala maka pi`i	same as kala maka pi`i
limu kale maka pi`i	same as kale maka pi`i
limu kau lā`au	all tiny ferns (filmy ferns), lichens, liverworts, mosses growing on trees
limu kele	moss growing on trees in rainforest
limu mā kole maka `ō pi`i	same as mākole mākō pi`i
limu pepei ao	same as lī pepei ao
maka `ō pi`i	same as mākole mākō pi`i
mākō pi`i	moss general term
mākō pi`i `elenahu	peatmoss
mākole mākō pi`i	a native moss (*Thuidium hawaiiense*), the branches on one plane looking like small ferns. See mākō pi`i, maka `ō pi`i
`oau	a moss
`onohī awa	a black moss found in freshwater. Lit. eyeball of the fish awa.
`opulepule	a spotted land moss
`owau	same as `oau

Management Concerns

Alien species

The very dense growth exhibited by two alien species in the park, *Pseudoscleropodium purum* and *Hypnum plumaeforme*, strongly suggests they displace native bryophytes along roads and trails. Both species are already widespread along park roads and trails so park-wide removal is unlikely. Neither species produces spores or other wind dispersed propagules and instead are spread by human or animal activity. Efforts should be made to reduce their accidental spread by staff and visitors. For example, mowing equipment should be thoroughly cleaned before transport to job sites not yet invaded by alien moss otherwise small fragments of both moss species clinging to the equipment can easily fall off during equipment operation and grow vegetatively on any damp substrate.

High traffic centers such as the Resources Management field station should be cleared of alien mosses to reduce accidental transport by park vehicles. Special effort should be made to prevent the introduction of *P. purum* into the Kahuku unit and to prevent the introduction of *H. plumaeforme* into the western side of the Kahuku unit. *P. purum* is also growing successfully in the Kipuka Puaulu forest well beyond the trailsides. *P. purum* should be controlled at Kipuka Puaulu where it is growing under the forest beyond the trailsides to prevent potential problems with seedling recruitment and prevent total replacement of the original native terrestrial bryophyte layer which may have unknown consequences for tree fern and seedling recruitment. Both *P. purum* and *H. plumaeforme* should be controlled at Thurston Lava Tube and Kilauea Iki Trail to maintain an easily accessible example of a diverse Hawaiian bryophyte community for public enjoyment and education. Mosses grow slowly compared to vascular plants such that even one or two days of work by a group of volunteers a year might be enough to stop the increase in alien moss cover at Kipuka Puaulu, Thurston Lava Tube, and Kilauea Iki. Because *Breutelia arundinifolia* is not found in natural habitats in the park it should be treated as an alien species and controlled in high traffic sites such as the Kilauea Visitor Center and the Resource Management field station areas to prevent accidental spread further along the park's roads and trails. *Sphagnum palustre* should be monitored to see if it starts increasing in abundance anywhere in or near the park. *S. subpinnatum* spreads by spores and is consequently now too widespread to possibly control. Roadsides and lawns in Volcano Village should be monitored every few years to watch for the appearance of new alien species that may come in with horticultural plantings. The State of Hawaii should be encouraged to ban the importation of live bryophyte material to prevent the introduction of potentially invasive mosses.

Rare species

In general, too little is known about the population sizes of uncommon moss to accurately assess their risk of extinction. This is true both locally and internationally. The online database of worldwide IUCN Red List of Threatened Species includes 39 moss species currently threatened with extinction (http://www.redlist.org accessed November 3, 2005). None of the listed species are found in HAVO. However, as discussed by the IUCN Bryophyte Specialist Group, the list is admittedly incomplete because so little is known about the actual distribution and population numbers of the world's moss species

(http://www.dbs.nus.edu.sg/lab/crypto-lab/WorldBryo.htm accessed November 3, 2005). It could be argued that at least one species in the park, *Scopelophila infericola,* should be considered a critically endangered species because of its extremely narrow distribution limited to only sulfurous steam vents at Sulphur Banks. On the other hand, a taxonomic review of this species could very well find that it should be considered an isolated population of the more widespread *S. ligulata*.

Species that have not been collected for many years such as *Breutelia affinis* are probably very rare. However, in some cases they may be simply difficult to find because they are so small or difficult to distinguish from other, more common species.

Education

High rainfall and diverse microhabitats, such as Thurston Lava Tube Trail, support a high diversity of mosses in a relatively small area. The accessibility and high use of this area makes it an ideal place to introduce park visitors to a wide range of relatively large and easily identifiable mosses and their role in the ecological community.

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LITERATURE CITED

Bartram, E. B. 1933. Manual of Hawaiian Mosses. Bernice P. Bishop Museum Bulletin 101. Honolulu, Hawaii.

Buck, W.R. 1998. Pleurocarpus Mosses of the West Indies. *Memoirs of the New York Botanical Garden* 82: 1-400.

Burton, P.J. 1980. Light regimes and *Metrosideros* regeneration in a Hawaiian montane forest. Thesis (M.S.). University of Hawaii at Manoa, Honolulu.

Cuddihy, L. W., S. J.Anderson, , C. P.Stone, and C. W. Smith. 1986. A botanical baseline study of forests along the East Rift of Hawaii Volcanoes National Park adjacent to Kahaualea. Technical Report 61. Cooperative National Park Resources Studies Unit, University of Hawaii at Manoa, Honolulu.

Doty, M. S., D. Mueller-Dombois. 1966. Atlas for bioecology studies in Hawaii Volcanoes National Park. Hawaii Botanical Science Paper No. 2: University of Hawaii, Honolulu.

Eddy, A. 1990. Leucobryaceae to Buxbaumiaceae. A handbook of Malesian mosses, Volume 2. Natural History Museum Publications, London.

Higashino, P. K., L. W. Cuddihy, S. J. Anderson, and C. P. Stone. August 1988. Bryophytes and vascular plants of Kipahulu Valley, Haleakala National Park. Technical Report 65. Cooperative National Park Resources Studies Unit, Department of Botany, University of Hawaii, Honolulu.

Hoe, W.J. 1967. The mosses of Kipahulu Valley, Maui. Pp. 106-122. In Warner, R.E.(ed.), Scientific report of the Kipahulu Valley Expedition. Sponsored by The Nature Conservancy, Arlington, Virginia. 184pp.

Hoe, W. J. 1971. Additional new and noteworthy records for Hawaiian mosses. *Bryologist* 74: 501-502.

Hoe, W. J. 1973. Notes on some Hawaiian species of the Pottiaceae. *Bryologist* 76: 192–195.

Hoe, W. J. 1974. Annotated checklist of Hawaiian mosses. *Lyonia* 1(1): 1–45.

Hoe, W. J. 1979. The Phytogeographic Relationships of Hawaiian Mosses. Ph.D. Dissertation, University of Hawaii in Botanical Sciences.

Hoe, W.J. and C.W. Smith. 1980. Bryophytes (mosses, liverworts, and hornworts) of Kipahulu Valley below 2000 feet. Pp. 45-53 In Smith, C.W. (ed.), Resources base inventory of Kipahulu Valley below 2000 feet. Sponsored by The Nature Conservancy. University of Hawaii Cooperative National Park Resources Studies Unit. Department of Botany, University of Hawaii, Honolulu.

Hua`ōlelo, K., H. Kuamo`o, and A. Punana Leo. 2003. Māmaka kaiao: a modern Hawaiian vocabulary : a compilation of Hawaiian words that have been created, collected, and approved by the Hawaiian Lexicon Committee from 1987 through 2000. University of Hawai`i Press, Honolulu.

Kappen, L. & C.W. Smith. 1980. Heat tolerance of two *Cladonia* species and *Campylopus praemorsus* in a hot steam vent area of Hawaii. *Oecologia* 47: 184-189.

Karlin, E.F. & R.E. Andrus. 1995. The *Sphagna* of Hawaii. Bryologist 98: 235-238.

Kis, G. 2002. Comments on some African species of the moss genus *Glossadelphus* M. Fleisch. *Cryptogamie Bryologie* 23 (2): 157-169.

Koponen, T. 1982. The family Mniaceae in Australia and the Pacific. *Journal of the Hattori Botanical Laboratory* 52: 75-86.
Pukui M.K. and S.H. Elbert. 1986. Hawaiian Dictionary. University of Hawaii Press, Honolulu.
Redfearn, P. L., Jr., B. C. Tan & S. He. 1996. A newly updated and annotated checklist of Chinese mosses. *Journal of the Hattori Botanical Laboratory* 79: 163-357.
Siegel, S.M. 1973. Mercury: Biochemical Studies, Semi-Annual Report. Hawaii Botanical Science Paper No. 30: University of Hawaii, Honolulu.
Smith, C.W. 1981. Bryophytes and lichens of the Puhimau geothermal area, Hawaii Volcanoes National Park. *Bryologist* 84: 457-466.
Smith, C.W. ed., with A.J. Berger, J. Beardsley, R. Burkhart, P.K. Higashino, W.J. Hoe, and H.E. Smith. 1975. Haleakala National Park 1975 RBI Narrative. Technical Report 9. Cooperative National Park Resources Studies Unit, Department of Botany, University of Hawaii, Honolulu.
Soderstrom, L. 1992. Invasions and range expansions and contractions of bryophytes. In Bryophytes and lichens in a changing environment, (eds. JW Bates & AM Farmer), pp. 131-158. Oxford University Press, Oxford.
Staples, G.W., C.T. Imada, W.J. Hoe, and C.W. Smith. 2004. A revised checklist of Hawaiian Mosses. *Tropical Bryology* 25:35-69.
Touw, A. 2001. A taxonomic revision of the *Thuidiaceae* (Musci) of tropical Asia, the western Pacific, and Hawaii. *Journal of the Hattori Botanical Laboratory* 91: 1-136.
Vanbreemen, N. 1995. How *Sphagnum* bogs down other plants. *Trends in Ecology & Evolution* 10 (7): 270-275.
Virtanen, V. 1997. The genus *Breutelia* (Bartramiaceae, Musci) in Southest Asia and Oceania. *Bryologist* 100: 324–348.
Vitt, D. H. & C. Marsh. 1988. Population variation and phytogeography of *Racomitrium lanuginosum* and *R. pruinosum*. Beih. *Nova Hedwigia* 90: 235–260.
Zander, R. 1967. The New World Distribution of *Scopelophila* (=*Merceya*). *Bryologist* 70(4): 405-413.
Zander, R. H. & D. H. Vitt. 1979. Gametophytic distinctions of *Zygodon* (Orthotrichaceae) and *Anoectangium* and *Leptodontium* (Pottiaceae) and the status of *Anoectangium rubrigemmium* of Hawaii. *Canadian Journal of Botany* 57: 292–296.

APPENDIX I: CHECKLIST OF THE MOSSES OF HAWAII VOLCANOES NATIONAL PARK

Currently accepted names are listed in ***bold italic*** type followed by recently used synonyms, primarily since Bartram (1933), in *smaller italic* type. Determination of status (endemic, indigenous, or alien) and distribution in Hawaii follows Staples, et al. (2004) except where noted. Endemic refers to a species whose natural range is limited to the Hawaiian Islands, indigenous refers to a species whose natural range includes both the Hawaiian Islands and elsewhere, and alien refers to a species whose natural range does not include the Hawaiian Islands and which arrived in Hawaii via human transport. Status data may be different in NPSpecies than in the checklist below, because NPSpecies uses slightly different definitions. Known distribution within the Hawaiian Islands is listed with the abbreviations K=Kauai, O=Oahu, Mo=Molokai, L=Lanai, Ma=Maui, and H=Hawaii Island. Abundance of each species within HAVO, using the abundance terms defined in NPSpecies (see table below), was estimated based on the author's experience in the field. Specimens from the HAVO Herbarium (HAVO) or the Bishop Museum Herbarium (BISH) examined to verify identification are listed last. Only representative specimens are listed for species having an unwieldy abundance of herbarium specimens.

NPSpecies abundance terms

Abundant	Large number of individuals; wide ecological amplitude or occurring in habitats covering a large portion of the park.
Common	Large numbers of individuals predictably occurring in commonly encountered habitats but not those covering a large portion of the park.
Uncommon	Few to moderate numbers of individuals; occurring either sporadically in commonly encountered habitats or in uncommon habitats.
Rare	Few individuals, usually restricted to small areas of rare habitat.

Acroporium fuscoflavum (C. Müller) Brotherus, 1925

Endemic. K, O, Mo, L, Ma, H.

Abundant. In wet forests on trees and logs.

Representative specimens examined: Cuddihy 1742 ; Higashino & Katahira 9990, 9973 (HAVO).

Aerobryopsis subdivergens ssp. ***scariosa*** (E.B. Bartram) Nog.

Aerobryopsis scariosa Bartr. 1939

Indigenous. K, O, Mo, Ma.

Uncommon. In wet forests on humus and logs.

Specimens examined: Hoe 662.0, 1501.0 (BISH); Skottsberg 2010, 2028 (BISH); Waite 040622-03, 040710-z-01 (HAVO).

Amphidium tortuosum (Hornschuch) Cufodontis, 1951
Amphidium cyathicarpum (Montagne) Brotherus, 1902
Grimmia haleakalae Reichardt, 1877

Indigenous. Ma, H.

Uncommon. Frequent on wet rock in high elevation lava tube entrances of Mauna Loa.

Representative specimens examined: L.W. Cuddihy s.n. (HAVO); Waite 040617-06e, 040619-04-04, 040703-07-03, 040714-05a-7, 040715-03-03 (HAVO)

Andreaea acutifolia J. D. Hooker & Wilson, 1844

Indigenous. Ma, H.

Unknown abundance. On rock at high altitude.

Notes: Vitt & Hoe (1980) first report this species in Hawaii based on specimens from Haleakala and Mauna Kea.

Specimens examined: Waite 040714-06-08 (HAVO).

Anoectangium aestivum (Hedwig) Mitten, 1869
Anoectangium euchloron

Indigenous. K, O, Mo, L, Ma, H.

Common. Locally abundant on shaded, wet rock in lava tube tubes and lava cracks.

Representative specimens examined: Weber & Bujakiewicz B-81931; Waite 040608-17a-1, 040702-04b, 040703-07-04, 040703-09-04, 040715-03-01, 040715-06-11 (HAVO)

Anoectangium haleakalae (C. Müller) Paris, 1900

Endemic. K, O, Mo, Ma, H.

Uncommon. Usually intermixed with *A. aestivum* in wetter cave entrances and rocky cliffs.

Notes: Zander, et al. (1979) sunk *A. haleakalae* into *A. aestivum*. However, *A. haleakalae* is in the current list of world-wide accepted moss species (Magil et al. 2000 online at www.mobot.org).

Specimens examined: Waite 040605-09, 040605-12a, 040617-3f, 040710-z-02, 040714-05a5 (HAVO).

Baldwiniella kealeensis (Reichardt) E. B. Bartram, 1933
Baldwinella kealeensis (Reichardt) E. B. Bartram, 1933

Endemic. K, O, Mo, L, Ma, H.

Common. In very wet, shaded microhabitats such as on the forest floor in Olaa Tract and lava tube entrances in wet forest.

Specimens examined: Weber & Bujakiewicz B-81933, B-81965 (BISH & HAVO); Cuddihy s.n.; Waite s.n. (HAVO).

Barbellopsis trichophora (Montagne) W. R. Buck, 1998
Barbella trichophora (Montange) Fleischer 1906

Endemic. K, O, Mo, Ma, H.

Uncommon. On trees in mesic to wet forest

Specimens examined: Selling, O. 4694 (BISH); Waite s.n. (HAVO).

Brachymenium exile (Dozy & Molkenboer) Bosch & Sande Lacoste, 1860

Indigenous. K, O, Mo, Ma, H.

Common. Locally abundant on exposed ash soil.

Specimens examined: Waite 040607-24, 040607-36a, 040608-02h-1, 040703-01 (HAVO).

Brachythecium hawaiicum E. B. Bartram, 1939

Endemic. Ma, H.

Unknown abundance.

Specimens examined: None.

Brachythecium lamprocarpum (C. Müller) Jaeger, 1878

Indigenous. K, Ma, H.

Uncommon. On shaded rock or humus. Sometimes abundant in cave entrances.

Specimens examined: Winona Char s.n.; Waite 040608-17b-3.1, 040617-07-05, 040619-04-01, 040715-06-01 (HAVO);

Brachythecium plumosum (Hedwig) W. P. Schimper in B.S.G., 1853

Brachythecium oxyrrhynchium (Dozy & Molkenboer) Jaeger, 1876-1877

Indigenous. K, O, Mo, Ma, H.

Unknown abundance. On shaded damp soil.

Specimens examined: Waite 040702-02-09(HAVO).

Breutelia affinis (W. J. Hooker) Mitten, 1856

Breutelia kilaueae (C. Müller) Brotherus, 1904

Indigenous. H.

Rare or extinct. Not collected in the Hawaiian Islands since the first specimen was collected From Kilauea, Island of Hawaii (Virtanen, 1997).

Specimens examined: None.

Breutelia arundinifolia (Duby in Moritzi) Fleischer, 1904

Indigenous or possibly misidentified alien. K, O, Ma, H.

Uncommon. Locally abundant along roadsides near Kilauea Visitor Center and the Resources Management field station and likely to spread further along roadsides in the wetter parts of the park.

Specimens examined: Hoe 1623.0 from Volcano Village (BISH): Waite 040622-01 (HAVO).

Bryum argenteum Hedwig var. ***lanatum*** (Palisot de Beauvois) 1839

Indigenous. K, O, Ma, H.

Common. Locally abundant on ash soil or rock. Only rarely with sporophytes.

Specimens examined: Cuddihy s.n.; Waite 040607-35, 040619-05-03, 040712-03-01, 040715-06-07 (HAVO).

Bryum atrovirens Bridel, 1803

Bryum erythrocarpum Schwaegrichen, 1816

Indigenous. O, Ma, H.

Uncommon. Possibly more common but easily overlooked because of its small size. On shaded rock in dry habitats.

Specimens examined: Cuddihy 1606, Cuddihy 1585; Waite 040703-09-07, 040722-B-03 (HAVO).

Bryum caespiticium Hedwig, 1801

Indigenous. Ma, H.

Unknown abundance. Easily overlooked because of its small size. On exposed soil or rock.

Specimens examined: Waite 040722-A-02 (HAVO).

Bryum hawaiicum Hoe, 1974

Bryum crassicostatum Brotherus, 1927

Indigenous (Redfearn et al. (1996) extend the range of this species to China). Ma, H.

Common. Easily overlooked because of its small size. On exposed humus or soil.

Specimens examined Hoe s.n.; Cuddihy 1618; Waite 040608-02h-4, 040608-03a, 040617-05-02 (HAVO).

Buckiella draytonii (Sullivant) Ireland

Catagonium draytonii
Hypnum draytonii Sullivant, 1854
Hypnum eudorae Sullivant, 1854
Plagiothecium draytonii (Sullivant) E. B. Bartram, 1933

Endemic. K, O, Mo, Ma, H.

Uncommon. In shaded wet forest habitats.

Specimens examined: L.W. Pratt s.n.; Higashino 9900; Weber & Bujakiewicz B-81952 (HAVO).

Calymperes tenerum C. Müller, 1872

Indigenous. K, O, Mo, Ma, H.

Unknown abundance. Collected by Hoe from area along the Kalapana Highway just outside the park now covered by lava. Probably still extant in forested low elevation kipukas. On shaded rocks and branches.

Specimens examined: None.

Campylopodium medium (Duby in Moritzi) Giese & Frahm, 1985

Campylopodium euphorocladium (C. Müller) Bescherelle, 1873

Indigenous. K, O, Mo, Ma, H.

Unknown abundance. Easily confused with *Campylopus* species on humus and tree trunks in wet forests.

Specimens examined: Weber & Bujakiewicz B-81910; Winona Char s.n. (HAVO).

Campylopus exasperatus (Nees & Blume) Bridel, 1826

Endemic. K, O, L, Ma, H

Abundant. On exposed rock or soil especially in dry areas but frequent along roadsides in wet areas.

Representative specimens examined: Hoe 1252; Higashino & Muller 9870; Cuddihy 1617; Waite 040608-18a, 040617-08, 040624-01-04, 040720-09-02, 040721-01-02 (HAVO).

Campylopus fragilis ssp. zollingerianus

Campylopus boswellii

Indigenous. K, O, Mo, Ma

Unknown abundance.

Specimens examined: Weber & Bujakiewicz B-81921; Waite 040620-07-02, 040624-01-01(HAVO).

Campylopus hawaiicus var. densifolius (Ångström) Frahm, 1978
Campylopus densifolius var. densifolius Ångström, 1872

Endemic. K, O, Mo, Ma, H.

Abundant. On tree trunks, humus, and shaded rocks in mesic to wet forests.

Representative specimens examined: Weber & Bujakiewicz B-81907; Waite 040607-04a, 040607-25, 040607-30a (HAVO).

Campylopus hawaiicus var. hawaiico-flexuosus (C. Müller) Frahm, 1978
Campylopus densifolius var. hawaiico-flexuosus
Campylopus hawaiico-flexuosus (C. Müller) Paris, 1900

Endemic. K, O, Mo, L, Ma, H.

Abundant. On tree trunks and humus in mesic to wet forests.

Specimens examined: Weber & Bujakiewicz B-81938, B-81967; Higashino & Muller 9852; Waite 040607-11a, 040616-02, 040710-x-01 (HAVO).

Campylopus hawaiicus* (**C. Müller) Jaeger, 1872 var. ***hawaiicus
Campylopus densifolius var. purpureo-flavescens
Campylopus purpureo-flavescens Hampe, in herbaria

Indigenous. K, O, Mo, L, Ma, H.

Abundant. On tree trunks and humus in mesic to wet forests.

Specimens examined: Waite 040609-02b, 040710-y-05, 040719-03, 040720-08 (HAVO).

Campylopus latitextus Sande Lacoste, 1872
Campylopus fumarioli C. Mull., 1900

Indigenous. K, O, Mo, L, Ma, H.

Unknown abundance.

Specimens examined: None.

Campylopus praemorsus (C. Müller) Jaeger, 1872

Endemic. K, O, L, Ma, H.

Unknown abundance. Very similar in appearance to *C. exasperatus*.

Specimens examined: None.

Campylopus schmidii ssp. schimidii (C. Müller) Jaeger, 1872
Campylopus aureus Bosch & Sande Lac, 1858
Campylopus introflexus misapplied
Campylopus polytrichoides misapplied

Indigenous. K, O, Ma, H.

Abundant. Abundant on exposed soil between 1500-2100 m (5000-7000 ft.) elevation.

Representative specimens examined: Weber & Bujakiewicz B-81895; W.J. Hoe 1261; Winona Char s.n.; T. Belfield s.n.; Waite 040624-08-02, 040702-02-05, 040702-07a (HAVO).

Campylopus umbellatus (Schwägrichen & Gaudichaud ex Arnott) Paris, 1894

Indigenous. K, O, L, Ma, H.

Abundant. On exposed rock or soil in dry to wet locations.

Representative specimens examined: Waite 040608-06b, 040620-06-05, 040710-03 (HAVO).

Campylopus wheeleri (C. Müller) Hampe ex Paris, 1900
Dicranoloma wheeleri (C. Mull.) Par. 1904

Endemic. K, Ma, H.

Unknown abundance. This is recorded from the park based on a single specimen at BISH.

Specimens examined: None.

Ceratodon purpureus (Hedwig) Bridel, 1826

Indigenous. Distribution: K, O, Ma, H.

Abundant. Usually on exposed ash soil and rock but also in cave entrances at higher elevations.

Representative specimens examined: Hoe s.n.; MacDonald s.n.; Smathers s.n.; Waite 040605-03, 040702-07c, 040714-06-09, 040715-06-04, 040718-03-04, 040722-B-01 (HAVO).

Ctenidium elegantulum Brotherus, 1927

Endemic. O, Ma, H.

Unknown abundance.

Specimens examined: None.

Dicranella hawaiica (C. Müller) Brotherus, 1901

Endemic. K, O, Mo, Ma.

Unknown abundance.

Specimens examined: Cuddihy s.n.; Waite 040718-07c-02, 040725-11-02 (HAVO).

Dicranella integrifolia E. B. Bartram, 1933

Endemic. O, Mo, Ma, H.

Abundant. On exposed ash soil.

Representative specimens examined: Hoe s.n., Weber & Bujakiewicz B-81919; Waite 040624-08-06, 040702-02-06, 040718-03-03, 040718-07a, 040718-08 (HAVO).

Dicranodontium porodictyon Cardot & Thériot, 1911
Dicranodontium falcatum Brotherus, 1927

Indigenous. K, O, Mo, Ma, H.

Uncommon. On humus and tree trunks in wet forest.

Specimens examined: Higashino & Allen 10179; Waite 040710-z-04 (HAVO).

Dicranum speirophyllum Montagne, 1843

Endemic. K, O, Mo, Ma, H.

Common. On humus and logs in mesic to wet vegetation.

Representative specimens examined: Higashino & Allen 10187; Hoe 1256; Weber & Bujakiewicz B-81923; Waite 040607-40, 040608-02a, 040702-04f (HAVO).

Didymodon insulanus (De Not.) M.O. Hill
Barbula vinealis var. flaccida B.S.G., 1842
Barbula vinealis Bridel *ssp. cylindrica* (Taylor) Boulay, 1884
Didymodon vinealis var. *flaccidus* (Brach. & Schimp.) RH Zander

Indigenous. O, Ma.

Unknown abundance. On soil and rock.

Specimens examined: Weber & Bujakiewicz B-81899, B-81900; Waite 040608-16a, 040715-03-02 (HAVO).

Didymodon vinealis (Bridel) Zander, 1978
Barbula vinealis

Indigenous. H (this report)

Unknown abundance. On soil.

Notes: *D. vinealis*, in its current circumscription, is a new record for the Hawaiian Islands. Old concepts of *D. vinealis* included a taxon already recorded from the Hawaiian Islands as a variety but now classified as the separate species *D. insulanus*.

Specimens examined: Waite 040702-02-07, 040703-09-03 (HAVO).

Distichophyllum freycinetii (Schwägrichen) Mitten in Seemann, 1873

Endemic. K, O, Mo, L, Ma, H.

Common. On wet soil or humus in understory of wet forests.

Representative specimens examined: Weber & Bujakiewicz B-81989; Higashino 9894, 9899; Waite s.n. (HAVO).

Distichophyllum paradoxum (Montagne in Gaudichaud) Mitten in Seemann, 1873

Endemic. K, O, Mo, L, Ma, H.

Common. On wet soil or humus in understory of wet forests.

Specimens examined: Cuddihy 1741; Higashino & Katahira 9987; Weber & Bujakiewicz B-81947; Waite s.n., 040725-08a-03 (HAVO).

Ectropothecium arcuatum Mitten in Seemann, 1873

Endemic. K, O, Ma, H.

Unknown abundance.

Specimens examined: None.

Ectropothecium decurrens (Sullivant) Nishimura, 1985
Ctenidium decurrens (Sullivant) Brotherus, 1927

Endemic. K, O, Mo, Ma, H.

Common. On humus in partially shaded mesic to wet habitats

Specimens examined: Anonymous 1913; Waite s.n., 040607-01, 040607-12, 040609-02f, 040702-02-01(HAVO).

Ectropothecium sandwichense (W. J. Hooker & Arnott) Mitten in Seemann, 1873

Indigenous. K, O, Mo, L, Ma, H.

Unknown abundance.

Specimens examined: None.

Entosthodon subintegrus (Brotherus) H. A. Miller, H. O. Whittier & B. Whittier, 1978
Funaria subintegra Brotherus, 1927

Endemic. K, O, Mo, L, Ma, H.

Common. On partially shaded, damp soil.

Specimens examined: Cuddihy 1695; Waite 040702-02-12, 040720-02 (HAVO).

Fabronia degeneri E. B. Bartram, 1933

Endemic. O, Mo, H.

Unknown abundance. Common on *Sapindus* trees in Kipuka Puaulu.

Specimens examined: Waite 040718-02-04 (HAVO).

Fissidens bryoides Hedwig, 1801
Fissidens hawaiicus E.B. Bartram, 1933
Fissidens insularis E.B. Bartram 1933
Fissidens oahuensis E.B. Bartram 1939

Indigenous. K, O, Mo, L, Ma, H.

Abundant. On damp soil in deep shade such as under logs and in cave entrances.

Representative specimens examined: Weber & Bujakiewicz B-81949; Waite 040608-17b-2, 040617-01a, 040619-04-05, 040715-04-05 (HAVO).

Fissidens elegans Bridel, 1806
Fissidens bishopii Hoe
Fissidens baldwinii Brotherus, 1927

Indigenous. K, O, Mo, L, Ma, H.

Common. On damp soil or rock in deep shade such as in lava tube entrances.

Specimens examined: Waite 040721-01-01, 040722-01 (HAVO).

Fissidens kilaueae Hoe & H. Crum, 1971 [1972]

Endemic. K, O, L, Ma, H.

Unknown abundance. Its minute size makes it difficult to locate. Hoe & Crum (1971) described this as new species from hapu`u (*Cibotium*) stipes at Thurston Lava Tube, Hawaii Volcanoes National Park.

Specimens examined: Hoe 1072.0 (HAVO).

Fissidens lancifolius E. B. Bartram, 1939

Endemic. K, O, Mo, L, Ma, H.

Unknown abundance. This genus typically inhabits deeply shaded wet environments.

Specimens examined: None.

Funaria hygrometrica Hedwig, 1801

Indigenous. O, H.

Unknown abundance. Usually present as a weed on potting media in the green houses at near the Resource Management Field Station. An ephemeral species that usually appears in great numbers on exposed soil in the second year after fires in the park such as at Hilina Pali (CW Smith pers. comm.).

Specimens examined: Waite 040610-01 (HAVO).

Grimmia longirostris W. J. Hooker, 1818
Grimmia haleakalae Reichardt, 1877 misapplied

Indigenous. Ma.

Abundant. On exposed rock and soil at higher elevations such as at the top of the Mauna Loa Strip Road.

Representative specimens examined: Anonymous s.n.; Waite 040608-13, 040619-02-02, 040714-06-05 (HAVO).

Grimmia trichophylla Greville, 1824

Indigenous. Ma, H.

Unknown abundance.

Specimens examined: Waite 040619-05-02, 040715-06-03(HAVO).

Holomitrium seticalycinum C. Müller, 1896

Common. On tree branches in wet forests.

Endemic. K, O, Mo, L, Ma, H.

Common. On tree branches in wet forests.

Specimens examined: Cuddihy 1509; Hoe 1584; Waite 040612-04-04 (HAVO).

Homaliodendron flabellatum (Smith) Fleischer, 1906

Indigenous. K, O, Mo, L, Ma, H.

Common. On tree trunks in wet forests.

Representative Specimens examined: Cuddihy 1562; Higashino & Muller 9866; Weber & Bujakiewicz B-81948; T. Belfield s.n. (HAVO).

Hookeria acutifolia W. J. Hooker & Greville, 1825

Indigenous. O, L, Ma, H.

Common. On deeply shaded soil in wet forests.

Specimens examined: Weber & Bujakiewicz B-81996; Cuddihy s.n.; Waite s.n. (HAVO).

Hyophila involuta (W. J. Hooker) Jaeger, 1873
Hyophila dozy-molkenboeri Fleischer, 1900-1902

Indigenous. K, O, Mo, Ma, H.

Uncommon. Rock walls and trails.

Specimens examined: Waite 040720-04-03, 040722-B-04 (HAVO).

Hypnum plumaeforme Wilson, 1848

Alien. O (recent coll. Waite), Mo(recent coll. Stone), Ma, H.

Abundant. Invasive along roads, trails, and lawns in wet to mesic areas. Potentially invasive in other open canopy vegetation.

Representative specimens examined: Cuddihy s.n.; Weber & Bujakiewicz B-81912; Waite 040702-01a, 040702-02-02, 040717-03, 040718-03-02 (HAVO).

Isopterygium albescens (W. J. Hooker in Schwägrichen) Jaeger, 1878

Indigenous. K, O, Mo, L, Ma, H.

Abundant. In wet microhabitats.

Representative specimens examined: Cuddihy 1612; Higashino 9897; Smathers s.n.; Waite 040715-03-05, 040717-02, 040718-07c-05 (HAVO).

Isopterygium vineale E. B. Bartram, 1933

Endemic. K, O, Mo, Ma, H.

Unknown abundance. Only one record from the park.

Specimens examined: Waite 040620-06-01 (HAVO).

Leptobryum pyriforme (Hedwig) Wilson, 1855

Indigenous. Ma, H.

Unknown abundance. This species is probably present in the park based on its presence just outside the park. Skottsberg also collected it once from the vicinity of Kilauea (Bartram 1933).

Specimens examined: Waite 040606-01 from residence in Volcano near park (HAVO).

Leptodontium flexifolium (Dickson) Hampe in Lindberg, 1864

Leptodontium brevicaule E. B. Bartram, 1933

Indigenous. M, H.

Abundant. On exposed ash soil at higher elevations.

Representative specimens examined: Winona Char s.n.; Cuddihy s.n.; Waite 040617-05-01, 040619-01-03, 040619-05-06, 040702-07d (HAVO).

Leucobryum gracile Sullivant, 1874

Endemic. K, O, Mo, L, Ma, H.

Abundant. On humus and tree trunks in mesic to wet forests

Representative specimens examined: Cuddihy 1633; Weber & Bujakiewicz B-81904; Higashino 9908; Waite 040608-02b-1, 040620-06-02, 040718-07c-04 (HAVO).

Leucobryum seemannii Mitten in Seemann, 1873

Leucobryum hawaiiense (Reichardt) E.B. Bartram, 1933

Endemic. K, O, Mo, L, Ma, H.

Common. On humus and tree trunks in mesic to wet forests.

Representative specimens examined: Cooper s.n.; Cuddihy 1461; Hoe 1265; Higashino, Cuddihy, Weber, & Bujakiewicz 9875 (HAVO).

Macrocoma tenue ssp. ***sullivantii*** (Mull. Hal.) Vitt

Macromitrium intricatum C. Müller, 1896

Indigenous. K, O, Mo, Ma, H.

Unknown abundance. Epiphytic on small trees at the end of Mauna Loa Strip Road.

Specimens examined: Cuddihy s.n.; Waite 040619-a-01 (HAVO).

Macromitrium brevisetum Mitten in Seemann, 1873

Endemic. K, O, Mo, L, Ma, H.

Unknown abundance. Collected from Kipuka Puaulu and Kipuka Ki in 1966 by Hoe.

Specimens examined: None.

Macromitrium emersulum C. Müller, 1896

Endemic. K, O, Mo, L, Ma, H.

Probably present. This species was collected in 1983 from Kalapana outside the park (HAVO) growing epiphytically on a mango tree trunk.

Specimens examined: Weber & A. Bujakiewicz B-82000 (HAVO).

Macromitrium microstomum (W. J. Hooker & Greville) Schwägrichen, 1827
Macromitrium reinwardtii
Macromitrium owahiense C. Müller, 1864

Indigenous. K, O, Mo, L, Ma, H.

Abundant. On trees in wet forests.

Specimens examined: L.W. Cuddihy 1601; Hoe 1245; Smathers s.n.; Waite 040612-04-02 (HAVO).

Macromitrium piliferum Schwägrichen, 1826

Endemic. K, O, Mo, L, Ma, H.

Abundant. On trees in wet forests.

Representative specimens examined: Cuddihy 1570, 1431; Hoe 1258; Waite 040608-02d (HAVO).

Orthotrichum diaphanum Schrader ex Bridel, 1801

Indigenous. M, H.

Unknown abundance. Epiphytic on trees and shrubs.

Specimens examined: Hoe 981.0 (BISH).

Orthotrichum hawaiicum C. Müller, 1896

Endemic. Ma, H.

Unknown abundance. Epiphytic on trees and shrubs.

Specimens examined: Hoe 828.1, 836.0 (BISH); Vitt 14955, 14956 (BISH).

Orthotrichum rupestre Schleicher x Schwägrichen, 1816
Orthotrichum hillebrandi C. Müller, 1896

Indigenous. O, Ma, H.

Unknown abundance. Epiphytic on trees and shrubs.

Specimens examined: Hoe 828.0 (BISH).

Palamocladium wilkesianum (Sullivant) C. Müller, 1896
Pleuropus wilkesianum (Sullivant) Brotherus, 1908

Endemic. K, O, Mo, L, Ma, H.

Common. In damp, shaded places on humus, tree trunks, and rock. Variable in size and in degree of pitting in the leaf cells. Smaller sized plants with little or no pitting of the leaf cells were once recognized as the distinct variety *P. w. sciuroides*. This form is especially common at Kipuka Puaulu on *Sapindus* trunks.

Representative specimens examined: Char s.n.; Cuddihy 1728; Weber & Bujakiewicz B-81960; Waite 040607-16, 040607-33, 040619-04-02, 040718-02-02 (HAVO).

Pelekium versicolor (Hornsch. Ex Mull.Hal.) Touw, 2001
Thuidium crenulatum Mitten, 1873
Thuidium nanophyllum

Indigenous. O, Ma, H.

Unknown abundance. Very similar in appearance to the abundant *Thuidium cymbifolium*.

Specimens examined: Char s.n.; Weber & Bujakiewicz B-81961(HAVO).

Philonotis falcata (W. J. Hooker) Mitten, 1859

Indigenous. K, O, Mo, Ma.

Unknown abundance.

Specimens examined: Cuddihy 1701; Waite s.n. (HAVO).

Philonotis hawaica (C. Müller) Brotherus, 1904

Endemic. K, O, Mo, L, Ma, H.

Unknown abundance.

Specimens examined: Waite (HAVO).

Philonotis turneriana var. sullivantii (C. Müller) Bartram, 1933

Bartramia sullivantii C. Muller, 1896

Endemic. O, Ma, H.

Unknown abundance.

Specimens examined: Cuddihy 1608 (HAVO).

Philonotis turneriana var. turneriana (Schwägrichen) Mitten, 1859

Indigenous. K, O, Mo, L, Ma, H.

Common. On damp soil and humus.

Specimens examined: Waite 040718-03-01(HAVO).

Phyllodon lingulatus (Cardot) W.R. Buck, 1987

Glossadelphus baldwinii Brotherus, 1927

Glossadelphus laevifolius (Mitt.) Bartr.

Taxiphyllum laevifolium (Mitten) W. R. Buck, 1987 misapplied

Indigenous. K, O, Mo, Ma, H.

Unknown abundance. On wet soil or rock in shaded places.

Specimens examined: Higashino & Katahira 9952 (HAVO).

Plagiomnium rhynchophorum (W. J. Hooker) T. Koponen, 1971

Plagiomnium rostratum (Schrader) T. Koponen, 1968 misapplied

Mnium rostratum Schwägrichen, 1816 misapplied

Indigenous. K, O, Mo, Ma, H.

Common. On deeply shaded wet soil, humus, or rock.

Specimens examined: Cuddihy 1552; Weber & Bujakiewicz B-81995; Higashino, Cuddihy, Weber, & Bujakiewicz 9877 (HAVO).

Pogonatum tahitense W. P. Schimper in Bescherelle, 1894

Pogonatum baldwinii (C. Müller) Paris, 1898

Indigenous. K, O, Mo, L, Ma, H.

Common. On wet soil banks.

Specimens examined: Higashino & Katahira 9979; Higashino & Muller 9869;
Higashino, Cuddihy, Weber, & Bujakiewicz 9874; Cuddihy s.n.; Waite 040702-02-08 (HAVO).

Pohlia flexuosa W.J. Hooker 1836
Pohlia leucostoma (Bosch & Sande Lacoste) Fleischer, 1904
Webera leucostomoides Brotherus, 1927
Webera gracilescens E.B. Bartram, 1933

Indigenous. K, O, Mo, Ma, H.

Unknown abundance.

Specimens examined: Weber &. Bujakiewicz B-81905; Waite 040617-03g (HAVO).

Polytrichum commune Hedwig, 1801

Alien. H.

Common. On exposed soil along roadsides and in the shrub lands between Kilauea Military Camp and the Hawaiian Volcano Observatory. Extremely abundant outside the park along Highway 11 in Glenwood.

Specimens examined: Waite 040605-12b, 040624-08-04 (HAVO).

Polytrichum piliferum Hedwig, 1801

Indigenous. Ma, H.

Unknown abundance. On exposed soil.

Specimens examined: Waite 040702-07e (HAVO).

Pseudoscleropodium purum (Hedwig) Fleischer in Brotherus, 1925
S*cleropodium purum* (Hedwig)

Alien. H.

Common. Locally abundant along roadsides and lawns and in the Kipuka Puaulu forest.

Representative specimens examined: Weber & Bujakiewicz B-81962, B-81924 (HAVO); Vitt 15087 (BISH); Waite 040605-05, 040605-11, 040620-01-01 (HAVO).

Pseudosymblepharis angustata (Mitten) Hilpert, 1933
Pseudosymblepharis mauiensis (C. Müller) Brotherus, 1927

Indigenous. K, O, Mo, Ma, H.

Uncommon. Locally common to abundant on the wet cliff walls of Olaa Trench.

Specimens examined: Jacobi s.n.; Waite 040710-y-02 (HAVO).

Pyrrhobryum pungens (Sullivant) Mitten, 1868
Rhizogonium pungens Sullivant, 1854

Endemic. K, O, Mo, L, Ma, H.

Unknown abundance. This is an uncertain species for the park because specimens identified as this species in the past are not typical *P. pungens* and instead intermediate in form between *P. spiniforme* and *P. pungens*. The leaf blades of typical *P. pungens* end more or less abruptly near the base of the leaf while the blades of typical *P. spiniforme* are relatively broad from the base all the way to the tip of the leaf. *P. pungens* is also usually larger than *P. spiniforme*. The *P. pungens* identified from the park are large but have leaf blades that, although very narrow, extend all the way to the tip of the leaf.

Specimens examined: Fagerlund, G.O. & A.L. Mitchell 189, 255 (BISH); Higashino, Cuddihy, Weber, & Bujakiewicz 9876; P.K. Higashino 9890, 9909 (HAVO).

Pyrrhobryum spiniforme (Hedwig) Mitten, 1868
Rhizogonium spiniforme (Hedwig) Bruch, 1846

Indigenous. K, O, Mo, L, Ma, H.

Abundant. Widespread on humus and tree trunks in wet forests.

Representative specimens examined: Weber & Bujakiewicz B-81935; Higashino & Muller 9847; Waite 040607-06 (HAVO).

Racomitrium crispulum (J. D. Hooker & Wilson) J. D. Hooker & Wilson, 1854

Indigenous. K, Ma, H.

Unknown abundance. Reported from the vicinity of Kilauea, Hawaii Island, based on one specimen collected by Lieutenant Hinds (Bartram, 1933).

Specimens examined: None.

Racomitrium lanuginosum var. ***lanuginosum*** (Hedwig) Bridel, 1819 [1818]
Racomitrium lanuginosum var. pruinosum misapplied

Indigenous. K, O, Mo, Ma, H.

Abundant. Abundant on lava rock especially at higher elevations above 1500 m (5000 ft.)

Note: Vitt & Marsh (1988) revised *Ramomitrium lanuginosum* and *R. pruinosum* and determined that all *R. lanuginosum* and *R. pruinosum* in Hawaii were *R. lanuginosum var. lanuginosum*, that specimens previously identified as *R. pruinosum* were in fact misidentified variable *R. lanuginosum*.

Representative specimens examined: Cuddihy 1602, Higashino & Katahira 9976; Fagerlund & Mitchell 70; Waite 040607-14, 040624-08-01, 040702-04a, 040713-05-01(HAVO).

Racopilum cuspidigerum (Schwägrichen in Gaudichaud in Freycinet) Ångström, 1872
Rhacopilum cuspidigerum (Schwägrichen in Gaudichaud in Freycinet) Ångström, 1872

Indigenous. K, O, Mo, L, Ma, H.

Abundant. On soil, rock, or bark in mesic to wet forest.

Representative specimens examined: Cuddihy 1609: Higashino & Katahira 9973; Belfield/LG 32; Waite 040607-32b, 040718-02-03 (HAVO).

Radulina hamata (Dozy & Molkenboer) W. R. Buck & B. C. Tan, 1989 [1990]
Trichosteleum hamatum (Dozy & Molkenboer) Jaeger, 1876-1877

Indigenous. K, O, Mo, L, Ma, H.

Common. On humus and tree trunks in wet forests.

Specimens examined: Cuddihy 1565; Higashino & Katahira 9948; Waite 040616-01 (HAVO).

Rhynchostegium celebicum (Sande Lacoste) Jaeger, 1878
Eurhynchium celebicum (Lacoste) E.B. Bartram, 1933

Indigenous. K, O, Mo, Ma, H (this study).

Unknown abundance. In wet forest.

Specimens examined: Weber & Bujakiewicz B-81908 (HAVO).

Rhynchostegium selaginellifolium C. Müller, 1896
Eurhynchium sellaginellifolium (C. Müller) E.B. Bartram, 1933

Endemic. K, O, Mo, Ma, H.

Unknown abundance. In wet forest.

Specimens examined: Cuddihy s.n. (HAVO).

Rosulabryum billarderi (Schwägrichen) Spence, 1996
Bryum billardieri Schwägrichen, 1816
Bryum decaisnei Dozy &Molkenboery, 1845

Indigenous. O, Ma, H.

Unknown abundance. Collected twice in 1966 by Bill Hoe from the Mauna Loa Trail.

Specimens examined: None.

Rosulabryum capillare (Hedwig) Spence, 1996
Bryum capillare Hedwig, 1801
Bryum vino-viride E. B. Bartram, 1933

Indigenous. K, O, Ma, H.

Uncommon. On soil and rock at higher elevations especially in lava tube entrances.

Representative specimens examined: Waite 040607-38, 040619-04-03, 040703-05-02, 040715-02-01 (HAVO).

Schizymenium pulvinatum (C. Müller) A. J. Shaw, 1985
Mielichhoferia pulvinata C. Mull. 1896

Endemic. Ma, H.

Uncommon. On soil at higher elevations including in lava tube entrances.

Representative specimens examined: MacDonald s.n.; Waite 040702-04h, 040703-05-05, 040703-07-02, 040714-05b-09(HAVO).

Scopelophila infericola Hoe, 1973

Endemic. H.

Rare. Sulphur Banks on rock and ash substrate is the only locality known to date.

Specimens examined: Siegel s.n. (BISH); Hoe 4852.0 (BISH); Waite 040620-09-01, 040624-10-01, 040624-12-03, 040624-13-07 (HAVO).

Sematophyllum hawaiiense (Brotherus) Brotherus, 1925

Indigenous. K, O, L, Ma, H.

Common. Widespread from low to high elevations on shaded soil, rock or bark in mesic to wet vegetation.

Representative specimens examined: Waite 040612-04-01, 040619-03-03, 040717-01, 040722-A-01(HAVO).

Sematophyllum subpinnatum (Brid.) E. Britton
Acroporium caespitosum (Hedwig) W. R. Buck, 1983 misapplied
Sematophyllum caespitosum (Hedwig.) Mitt. 1869 misapplied

Alien. O, H.

Probably present. On trees and rocks in wet forests

Not collected in the park but abundant in lower elevation wet forests and probably present in the lower elevation forest kipukas in the Kalapana section of the park.

Specimens examined: Waite 040612-07 from Waiakea Forest Reserve, Road B off Stainback Hwy (HAVO).

Sphagnum palustre Linnaeus, 1753
Sphagnum henryense misapplied

Indigenous. O, H.

Unknown abundance. Recently found in the park's Kahuku Unit by Thomas Belfield. Also known from two locations near the park in Volcano Village. On humus in wet forest.

Specimens examined: Will Haines s.n.from Hawaiian Orchid Island Estates; Waite 040722-E-01 from near the Volcano Village Post Office (HAVO).

Syrrhopodon armatus Mitten, 1864
Syrrhopodon oahuense Brotherus, 1927

Indigenous. O, Ma, H.

Unknown abundance. On *Pritchardia beccariana* trunks in Olaa Tract.

Specimens examined: Waite s.n. (HAVO).

Syrrhopodon hawaiicus C. Müller, 1896

Endemic. K, O, Mo, Ma, H.

Unknown abundance. On tree trunks in wet forest.

Specimens examined: Weber & Bujakiewicz B-81940, B-81941; Waite s.n. (HAVO).

Syrrhopodon prolifer Schwägrichen, 1827
Syrrhopodon kilaueae C. Müller, 1900

Indigenous. O, Mo, Ma, H.

Unknown abundance. Specimens from Kilauea, Island of Hawaii were originally described as an endemic species in 1900.

Specimens examined: None.

Taxithelium mundulum (Sullivant) E. B. Bartram, 1933

Indigenous. K, O, Mo, L, Ma, H.

Common. On rock and bark in wet to mesic forests.

Specimens examined: Cuddihy 1727, Cuddihy 1702; Waite 040612-04-03, 040718-01-03 (HAVO).

Thuidium cymbifolium (Dozy & Molkenboer) Dozy & Molkenboer, 1865
Thuidium hawaiense Reichardt, 1877
Thuidium plicatum Mitten in Seemann, 1873

Indigenous. K, O, Mo, L, Ma, H.

Abundant. On humus, rock, and tree trunks in shaded, wet microhabitats from forest to lava tube entrances.

Representative specimens examined: Cuddihy 1481; Higashino & Katahira 9972; Hoe 1255; Waite 040607-18b, 040702-02-03, 040702-04d (HAVO).

Tortella humilis (Hedwig) Jennings, 1913
Tortella caespitosa (Schwaegrichen) Limpricht, 1888

Indigenous. K, O, L, Ma, H.

Unknown abundance. On exposed soil or rock.

Specimens examined: Cuddihy s.n.; Waite 040617-05-05(HAVO).

Trematodon latinervis C. Müller, 1896

Indigenous. K, O, Mo, Ma, H.

Common on damp, partially shaded soil.

Specimens examined: Higashio & Muller 9870 (HAVO).

Trichostomum crispulum Bruch

Trichostomum bartramii Mill. 1967

Trichostomum mauiense Brotherus, 1927

Indigenous. K, O, Mo, L, Ma, H.

Abundant. On soil, humus, and rock in dry to mesic areas especially on the west side of Kahuku unit.

Representative specimens examined: Weber & Bujakiewicz B-81915; Hoe s.n., Hoe 1578; Waite 040607-12a, 040607-15, 040607-29b, 040608-05, 040609-01a (HAVO).

Vesicularia perviridis (Ångström) C. Müller, 1896

Vesicularia graminicolor (Ångström) Brotherus, 1927

Hookeria sandvicensis Reichardt, 1877

Endemic. K, O, Mo, L, Ma, H.

Common. On soil and humus in shaded wet microhabitats

Specimens examined: Higashino & Cuddihy 9873; Waite 040722-D-02, 040725-08a-01, 040725-09-01, 040725-11-01 (HAVO).

Weissia controversa Hedwig, 1801

Weissia viridula Hedwig, 1801

Indigenous. Ni, K, O, H.

Unknown abundance. On soil. Difficult to distinguish from the following *Weissia* species.

Specimens examined: None identified to species.

Weissia ovalis (Williams) E.B. Bartram, 1933

Endemic. K, O, Mo, L, Ma, H.

Unknown abundance. On soil. Difficult to distinguish from ***W. controversa.***

Specimens examined: Waite 040608-06a (HAVO).

Zygodon tetragonostomus A. Braun ex B.S.G., 1838

Indigenous. K, O, Ma, H.

Common. On trees and shrubs an occasionally on shaded rock or soil in mesic to dry vegetation above 1200 m (4000ft).

Representative specimens examined: Char s.n.; Weber & Bujakiewicz B-81898; Waite 040608-19, 040619-03-01, 040619-05-01, 040718-02-01 (HAVO).

APPENDIX II: PHOTOGRAPHS OF MOSSES AT HAWAII VOLCANOES NATIONAL PARK

Figure A1. *Acroporium fuscoflavum* from Olaa Trench. Leaf microphotograph from Oahu specimen.

Figure A2. *Aerobryopsis subdivergens ssp. scariosa* from Olaa Trench. Leaf microphotograph from Oahu specimen.

Figure A3. *Baldwiniella kealeensis* from Olaa Trench

Figure A4. *Brachymenium exile* with immature sporophytes from West Kahuku and with mature sporophytes from Crater Rim Trail.

Figure A5. *Bryum argenteum* var. *lanatum* from West Kahuku.

Figure A6. *Campylopus umbellatus* from Olaa Trench.

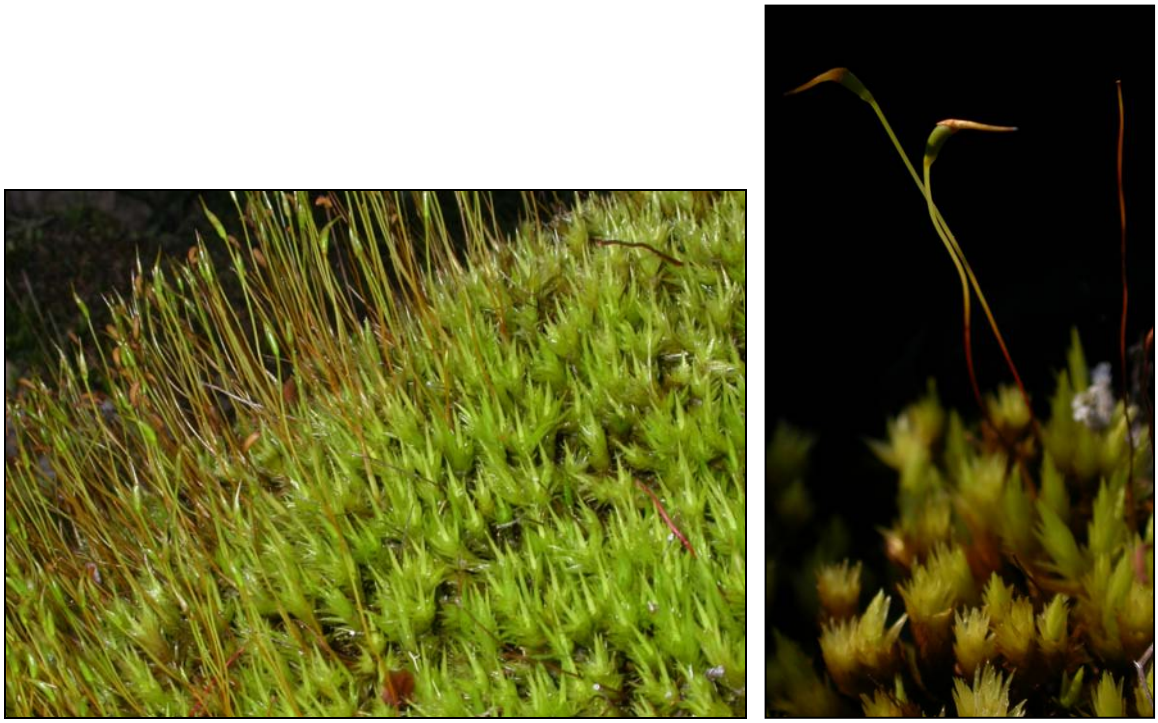

Figure A7. *Dicranum speirophyllum* from West Kahuku.

Figure A8. *Distichophyllum freycinetii* from Thurston Lava Tube area.

Figure A9. *Distichophyllum paradoxum* from Thurston Lava Tube area.

Figure A10. *Leucobryum seemannii* from Thurston Lava Tube area.

Figure A11. *Palamocladium wilkesianum* from West Kahuku.

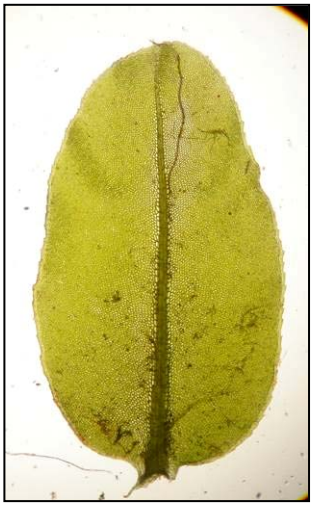

Figure A12. *Plagiomnium rhynchophorum* from a Mauna Loa lava tube. Leaf microphotograph from Oahu specimen.

Figure A13. *Pogonatum tahitense* from Crater Rim Trail.

Figure A14. *Pseudosymblepharis angustata* from Olaa Trench.

Figure A15. *Pyrrhobryum spiniforme* from Olaa Trench. Leaf microphotograph from Oahu specimen.

Figure A16. *Racomitrium lanuginosum* with sporophytes, West Kahuku.

Figure A17. *Thuidium cymbifolium*. This photograph from plant collected on Oahu