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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.

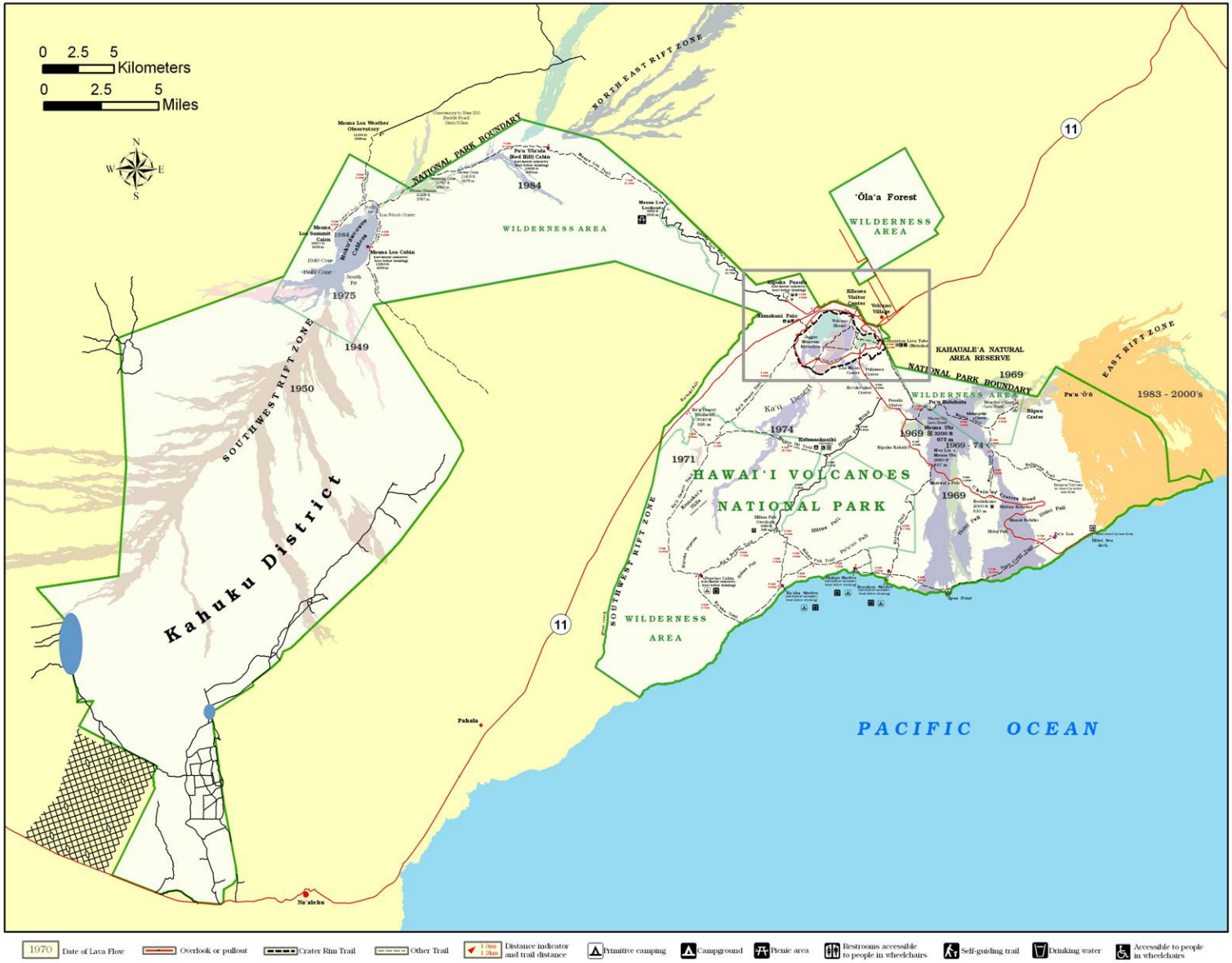

Figure 1a. Map of Hawaii Volcanoes National Park. Approximate moss survey locations for the Kahuku unit of the park are indicated by blue shading

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.

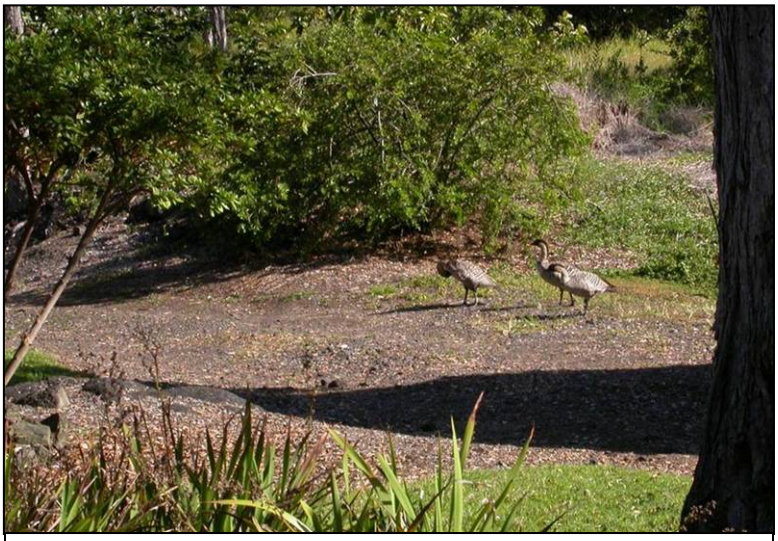

Figure 15. Nene pasture at Ainahou Ranch House

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