BUFFER ZONE LICHEN, ARTHROPOD AND BOTANICAL INVENTORY AND ASSESSMENT

THIRTY METER TELESCOPE PROJECT
MAUNA KEA SCIENCE RESERVE
NORTHERN PLATEAU
HĀMĀKUA DISTRICT, ISLAND OF HAWAIʻI

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EXECUTIVE SUMMARY

The Thirty Meter Telescope (TMT) Observatory Corporation conductied a natural resource assessment of a 500 meter buffer zone around the proposed TMT Observatory site within the Astronomy Precinct of the Mauna Kea Science Reserve on Hawai‘i Island in the State of Hawai‘i. The survey was in accordance with the Office of Mauna Kea Management (OMKM) *Mauna Kea Comprehensive Management Plan* (Mauna Kea CMP) that provides “management recommendations to ensure the protection, preservation, and enhancement of the natural resources of the UH Management Areas”. The proposed TMT Observatory would be located within the western portion of the area known as the Northern Plateau. During construction, support activities would occur within the existing Batch Plant Staging Area.

Sampling of three strata representing lichen, botanical, and arthropod fauna habitat in the buffer zone surrounding the proposed TMT observatory site was conducted May 30 through June 17, 2011. Lichen habitat was surveyed by Dr. Cliff Smith, the leading expert in lichen identification and conservation in Hawaii, Dr. Shanti Berryman, a consulting biologist with broad experience in lichen survey field work, and Dr. Gregory Brenner, whose extensive experience of the Mauna Kea summit region supported the work. The Botanical habitat survey was conducted by Dr. Gregory Brenner and Dr. Shanti Berryman, and cinder cone arthropod habitat was surveyed by Dr. Jesse Eiben, who studied wēkiu bug (*Nysius wekiuicola*) autecology for his dissertation, and Dr. Gregory Brenner, who has studied high elevation arthropod habitat in Hawaii for more than 18 years.

The survey of the Lichen habitat stratum found twenty-three species of lichens within the buffer zone. While the taxonomy is still being worked out, the work, combined with other surveys by Dr. Smith at lower elevations, has contributed greatly to the understanding of the lichens that occur on Mauna Kea. Areas of “relatively high diversity” were discovered and identified, and ‘common conditions’ were characterized and compared to conditions within the TMT observatory footprint. No high diversity areas were observed within the TMT Obserevatory footprint site.

The survey of botanical resources within the Botanical stratum found sparse vegetation cover, and only a few species of grasses, mosses, and ferns. Sampling in the arthropod habitat stratum found wēkiu bugs throughout the stratum, but with varying abundance depending on substrate conditions. No wēkiu bugs were found within the TMT observatory footprint.

The results of the surveys indicate there are no special concerns or legal constraints related to arthropod and botanical resources in the Project areas. No species listed as endangered or threatened species were detected at the Project construction areas (DLNR 1997, Federal Register 1999, 2005, 2006).

1.0 INTRODUCTION

1.1 TMT Project

The TMT Observatory is proposed to be located on Mauna Kea on Hawai‘i Island in the State of Hawai‘i. The TMT Observatory would be located on a roughly 5-acre site within the 525-acre Astronomy Precinct of the 11,288-acre Mauna Kea Science Reserve (tax map key [TMK] 4-4-15: 9), below the summit of Mauna Kea. The entire Science Reserve is designated as part of the State of Hawai‘i Conservation District, resource subzone.

The TMT Observatory would be located in the western portion of the area known as the Northern Plateau within the Astronomy Precinct, within the area identified as Area E in the Mauna Kea Science Reserve Master Plan (UH, 2000). The 2000 Master Plan identified Area E as a preferred location for the future development of a Next Generation Large Telescope (NGLT). Area E, a 36-acre area, was identified as a preferred location because it was anticipated to provide suitable observation conditions with minimum impact on existing facilities, wēkiu bug habitat, archaeological sites, and viewplanes. Area E ranges in elevation from 13,100 to 13,300 feet; the summit of Mauna Kea is at elevation 13,796 feet. Area E is located approximately 1/2-mile northwest of the eight existing optical/infrared observatories located near the summit, at elevations of 13,600 to 13,775 feet.

The Project site would be near the end of the existing 4-wheel drive road, at an elevation of approximately 13,150 feet at a location known as “13N” in reference to its elevation and its location on the Northern Plateau.

Existing 4-wheel drive road leading to “13N”.

1.2 Management Plan Survey Requirements

The *Mauna Kea Comprehensive Management Plan* (Mauna Kea CMP) provides "management recommendations to ensure the protection, preservation, and enhancement of the natural resources of the UH Management Areas". The Mauna Kea CMP provides a number of Management Actions related to natural resources (NR-1 through NR-18). A number of these Management Actions relate to conducting baseline surveys and delineating areas of high native diversity. One of the four Mauna Kea CMP subplans, the *Mauna Kea Natural Resources Management Plan* (NRMP), expands upon the natural resource Management Actions and information necessary for the Mauna Kea CMP to fulfill its goals.

Section 2 of the NRMP discusses the existing natural resources of Mauna Kea, and identifies information gaps regarding the condition of the various resources. The information gaps were identified through literature reviews and consultations with experts familiar with the summit of Mauna Kea. Section 4 of the NRMP provides "Component Plans", one of which is a Natural Resources Inventory, Monitoring, and Research Program (IM&R Program). Goal IMR-1 of the IM&R Program is to determine baseline status of the natural resources. Within this goal the NRMP states "It is also recommended that additional detailed baseline inventories be conducted at the time the [new] development is proposed, within the footprint of the area to be developed. It is recommended that these inventories also include a buffer of at least 1,640 ft (500 m) around the project footprint". The Project is funding this study in order to fulfill this recommendation in the MK CMP's NRMP subplan, as well as assist in data gathering activities in the summit area. The data gathered will be submitted to the Office of Mauna Kea Management (OMKM) to assist in the overall goal of completing baseline inventory surveys in the Astronomy Precinct.

As the NRMP states, "The purpose of conducting baseline inventories in areas of proposed development is to determine if the area contains sensitive resources such as protected species or unique geological resources, which need to be protected or mitigated for. However, without conducting baseline inventories in other portions of similar habitat on the mountain, it is difficult to know whether the proposed project area is more or less important or unique than surrounding areas. Thus, it is important to understand the distribution of natural resources over a larger area, rather than simply studying the area of proposed impact."

Ultimately, the function of the NRMP goal IMR-1 is "to understand the resources they are to manage and determine if management actions are having the desired effects". The results of the TMT survey described in the following sections will assist in OMKM achieving this goal.

The Project previously performed an extensive survey of roughly 63 acres during the Environmental Impact Statement (EIS) process (Pacific Analytics, 2009). The 63 acre area included all of Area E (a 36 acre area identified in the 2000 Master Plan) plus a small buffer around it, the Access Way and buffer along it, plus the Batch Plant Staging Area and a buffer around it (Figure 1). The NRMP had not been released prior to publication of the Draft EIS or the performance of the studies to support the Draft EIS. Therefore, a 1,640 foot buffer around the Project areas was not surveyed at that time.

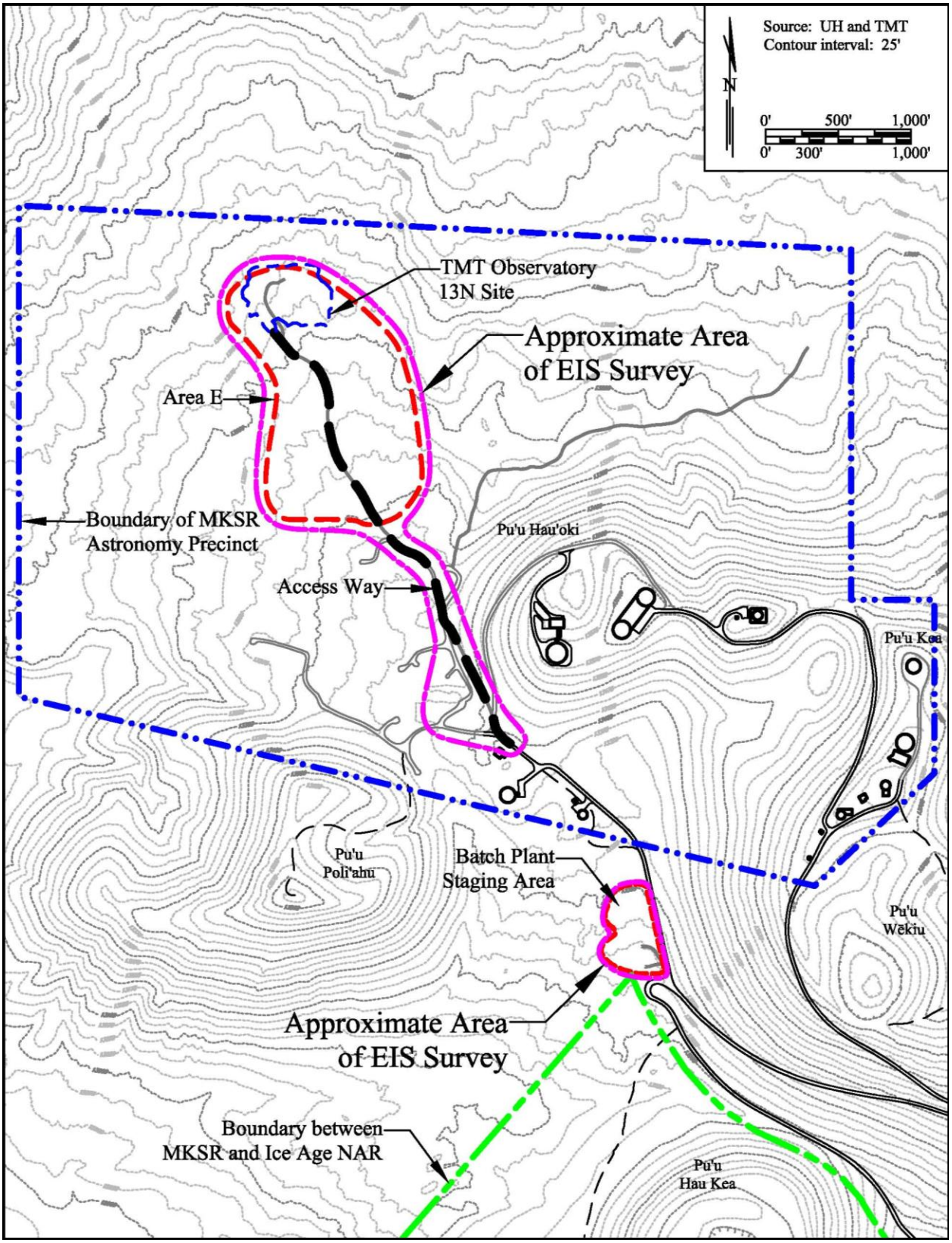


Figure 1: EIS Survey Area

1.3 Physical Setting

Mauna Kea is a dormant shield volcano and the tallest mountain on earth, rising more than 32,000 feet from the ocean floor to its summit, 13,796 feet above sea level. At the summit the night sky is dark and transparent, providing what is considered to be among the best astronomical observation conditions in the world (Parker 1994).

The Mauna Kea Science Reserve (MKSR), an 11,288-acre area at the top of Mauna Kea, is home to the largest observatory complex in the world. The MKSR is leased by the State of Hawai‘i to the University of Hawai‘i (UH), which in turn subleases certain areas to various observatories. Astronomy institutes worldwide make use of the unparalleled astronomical capabilities on Mauna Kea.

The MKSR is also home to unique plants and animals living in an alpine ecosystem. The summit region is an island within an island, separated from other ecosystems by high elevations as well as vast oceans. The species found there are not only unique; they are sometimes rare[1] and limited in population and area of distribution. For example, the wēkiu bug lives only in loose cinder habitats on the cinder cones above 11,715 feet on Mauna Kea (Porter and Englund 2006). There is a similar species, *Nysius aa* that occurs in the upper elevations on Maunaloa (Polhemus 1998).

The upper elevations of the MKSR receive almost no rainfall and snow accumulates only during the winter season. Temperatures often drop below freezing at night and reach up to 50º F during the day. Solar radiation is extreme, and evaporation rates are high. The harsh environmental conditions limit the composition of the resident floral and faunal communities found there. Under these harsh conditions, only hardy lichens, mosses, and scattered grasses, shrubs, ferns and arthropods have managed to adapt and survive (Cuddihy 1989).

Below 11,700 feet is an alpine shrublands and grasslands ecosystem growing on ‘a‘a lava flows, cinder cones, and air-fall deposits of lapilli and ash (Wolfe and others 1997). Growing well above the tree line (~9,500 feet), and becoming sparser with increasing elevation, are native shrubs, grasses, sedges, and ferns (Cuddihy 1989). The fauna of the alpine shrub zone has not been well studied. Many species of birds have been observed flying in this zone, but because the principal food resources do not occur here, they are presumably just passing through. There may be resident arthropod species in this zone, but no systematic survey has been conducted.

Below the alpine shrublands and grasslands are the *māmane* subalpine woodlands that extend down to the Saddle Road. The open-canopied *māmane* forest is home to the endangered bird,

[1] There are several terms that are used to describe the status of species. These include:
Endangered species – Any species which is in danger of extinction throughout all or a significant portion of its range.
Threatened species – Any species which is likely to become endangered within the foreseeable future.
Candidate species – Any species being considered by the Secretary of the Interior for listing as an endangered or a threatened species, but not yet the subject of a proposed rule.
Species of Concern – Those species about which regulatory agencies have some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act (ESA).
Rare species – Those species that occur very seldom, but are not classified threatened or endangered.
Sensitive species – Those species which rely on specific habitat conditions that are limited in abundance, restricted in distribution, or are particularly sensitive to development.

palila (*Loxioides bailleui*). The subalpine woodlands are dry most of the year, and *māmane* trees (*Sophora chrysophylla*) intercept fog that provides them and other plant species with the small amounts of moisture they need to survive (Gerrish 1979). The understory of the subalpine forest is comprised largely of native shrubs. In undisturbed areas clumps of the native grasses are the most abundant ground cover. Non-indigenous plants and grasses are the most abundant ground cover in areas that have been disturbed around Hale Pōhaku. The *māmane* forest on Mauna Kea has a diverse arthropod fauna. More than 200 arthropod species have been collected there.

Cattle grazing has degraded much of the forest along the lower sections of the Mauna Kea Access Road. The vegetation of the open pastures is largely introduced grasses including rattail grass, velvetgrass, sweet vernal grass, hairy oatgrass, and fescues (Mueller-Dombois and Fosberg 1998).

Mauna Kea viewed from the Saddle Road.

2.0 Survey Scope

As the NRMP recommends, TMT is surveying its Project area plus a 1,640 foot (500 meter) buffer around the Project areas. The area encompasses the TMT Observatory "13N"site,

Way, and the Batch Plant Staging Area, and surrounding 1,640 foot buffer (

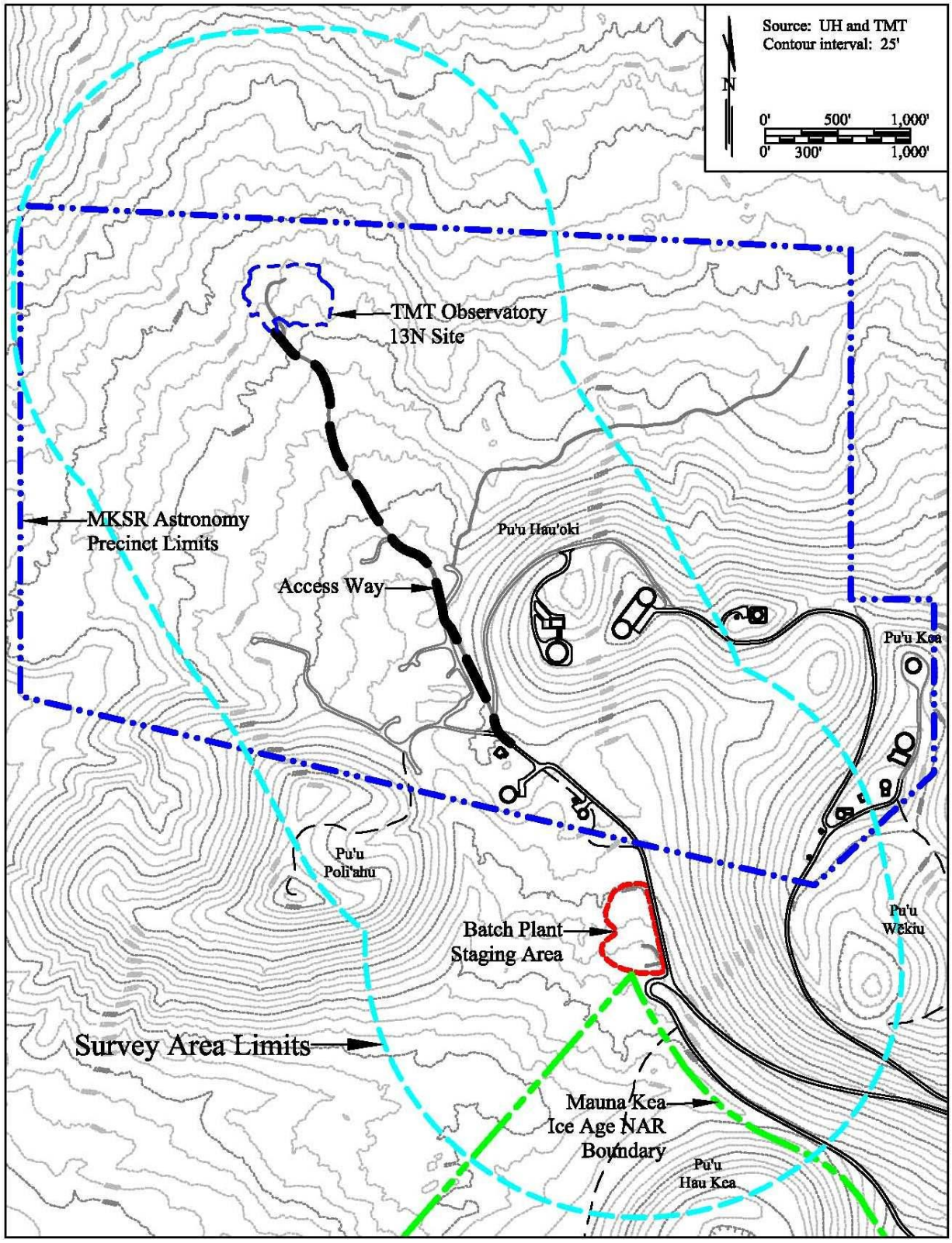


Figure 2). The survey area is approximately 659 acres.

The Mauna Kea CMP, Management Action NR-7 indicates areas of "high native diversity, unique communities, and unique geological features" should be delineated. Therefore, the scope of this survey is to identify areas of high native biological diversity and unique communities, including community composition and species abundances.

The entire survey area is above 12,800 feet elevation; generally the entire summit region above 12,800 feet is considered part of the alpine stone desert habitat. The region also consists of the following areas (or strata):

- Disturbance:

Altered areas (roads and buildings): 50.5 acres

Natural and relatively natural areas (includes some areas that were disturbed but have been renaturalized to a degree): 608.5 acres

- Land use:

Mauna Kea Science Reserve (MKSR) Astronomy Precinct: 370.5 acres or 56 percent of total survey area

MKSR Cultural and Natural Preserve: 244.5 acres or 37 percent of total survey area

Mauna Kea Ice Age Natural Area Reserve (Ice Age NAR): 44 acres or 7 percent of total survey area

- Geology (natural and relatively natural areas only):

Cinder/scoria cone (based on USGS mapping): 398 acres or 65 percent of natural and relatively natural area

Lava flow (based on USGS mapping): 210.5 acres or 35 percent of natural and relatively natural area

- Habitat types (relatively natural areas only):

Wēkiu bug Type 2 and 3 habitat (Cinder cones verified as wēkiu bug habitat): 213.5 acres or 35 percent of natural and relatively natural area

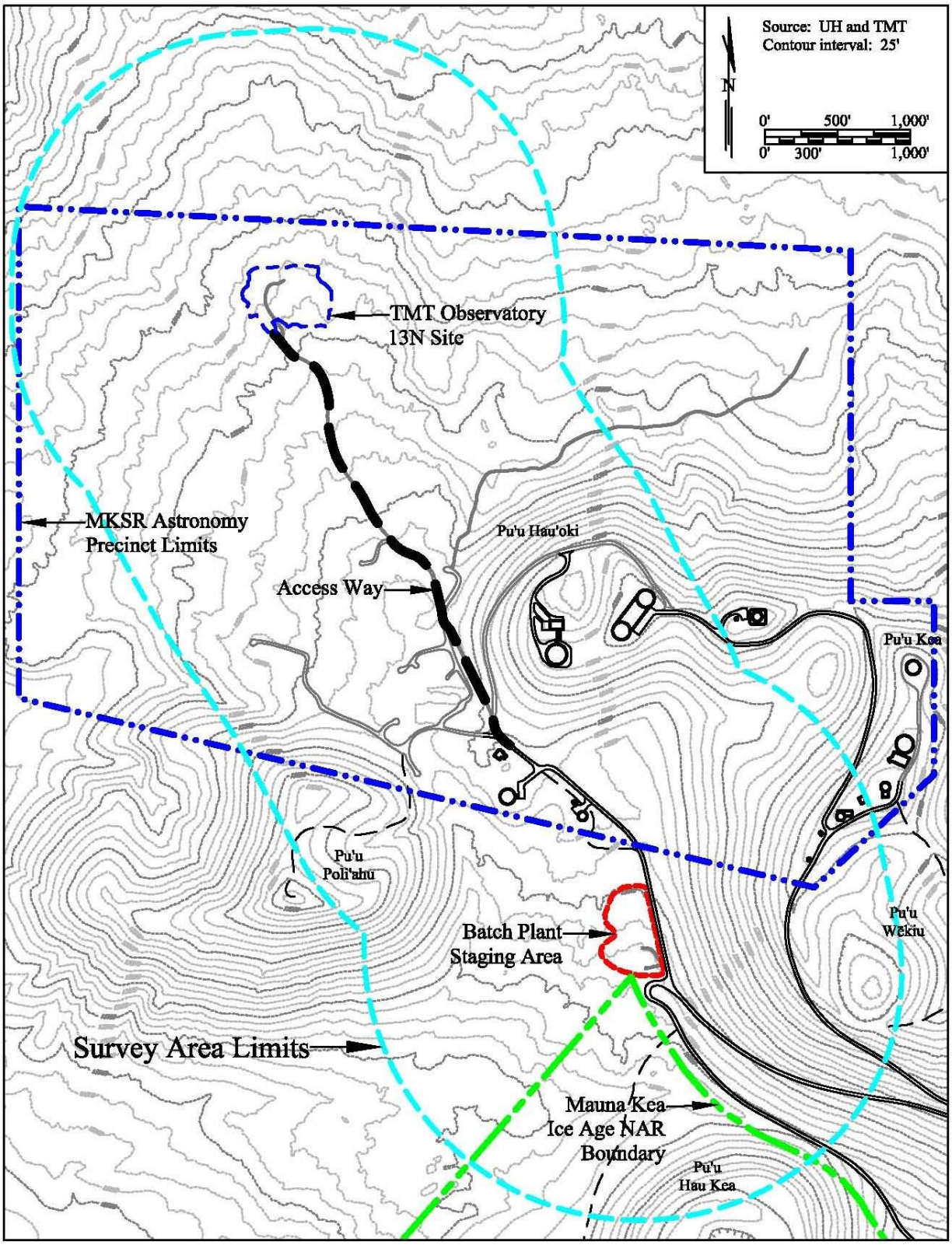
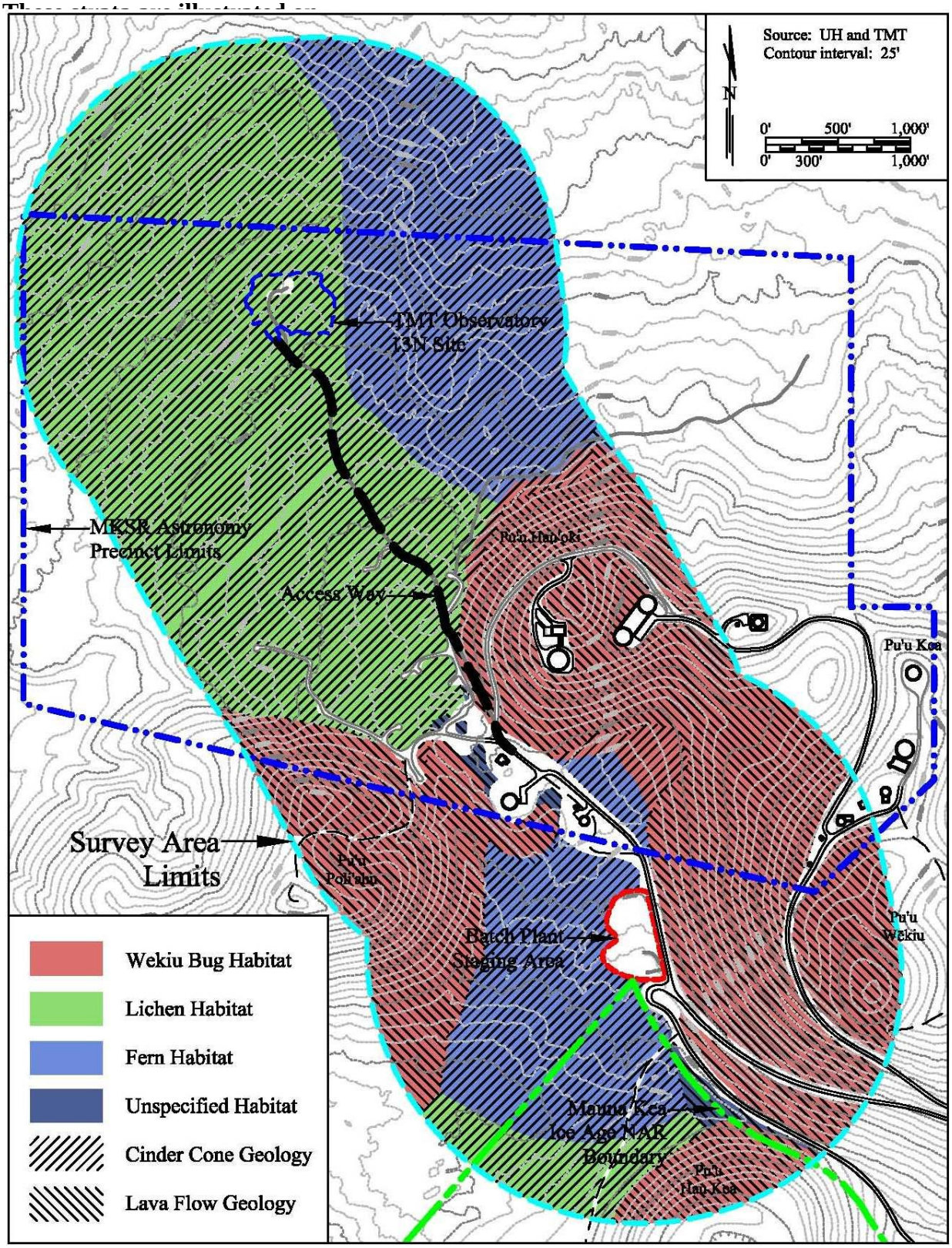


Figure 2: Survey Area

Fern habitat (from 2000 Master Plan): 152.5 acres or 25 percent of natural and relatively natural area

Lichen habitat (from 2000 Master Plan): 238 acres or 39 percent of natural and relatively natural area

Unspecified habitat: 4.5 acres or 1 percent of natural and relatively natural area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0' 500' 1,000'
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TMT Observatory
13N Site
MKSR Astronomy
Precinct Limits
Access Way
Pu'u Hau'oki
Pu'u Kea
Survey Area
Limits
Pu'u
Poli'ahu
Batch Plant
Staging Area
Pu'u
Wekiu
Mauna Kea
Ice Age NAR
Boundary
Pu'u
Hau Kea
Wekiu Bug Habitat
Lichen Habitat
Fern Habitat
Unspecified Habitat
Cinder Cone Geology
Lava Flow Geology

Figure 3. Because the USGS mapping was performed a number of years ago and at a level of detail appears to be lower than subsequent habitat mapping in the study area, the geologic areas do not overlay perfectly with the habitat areas.

Lichen habitat within the survey area.

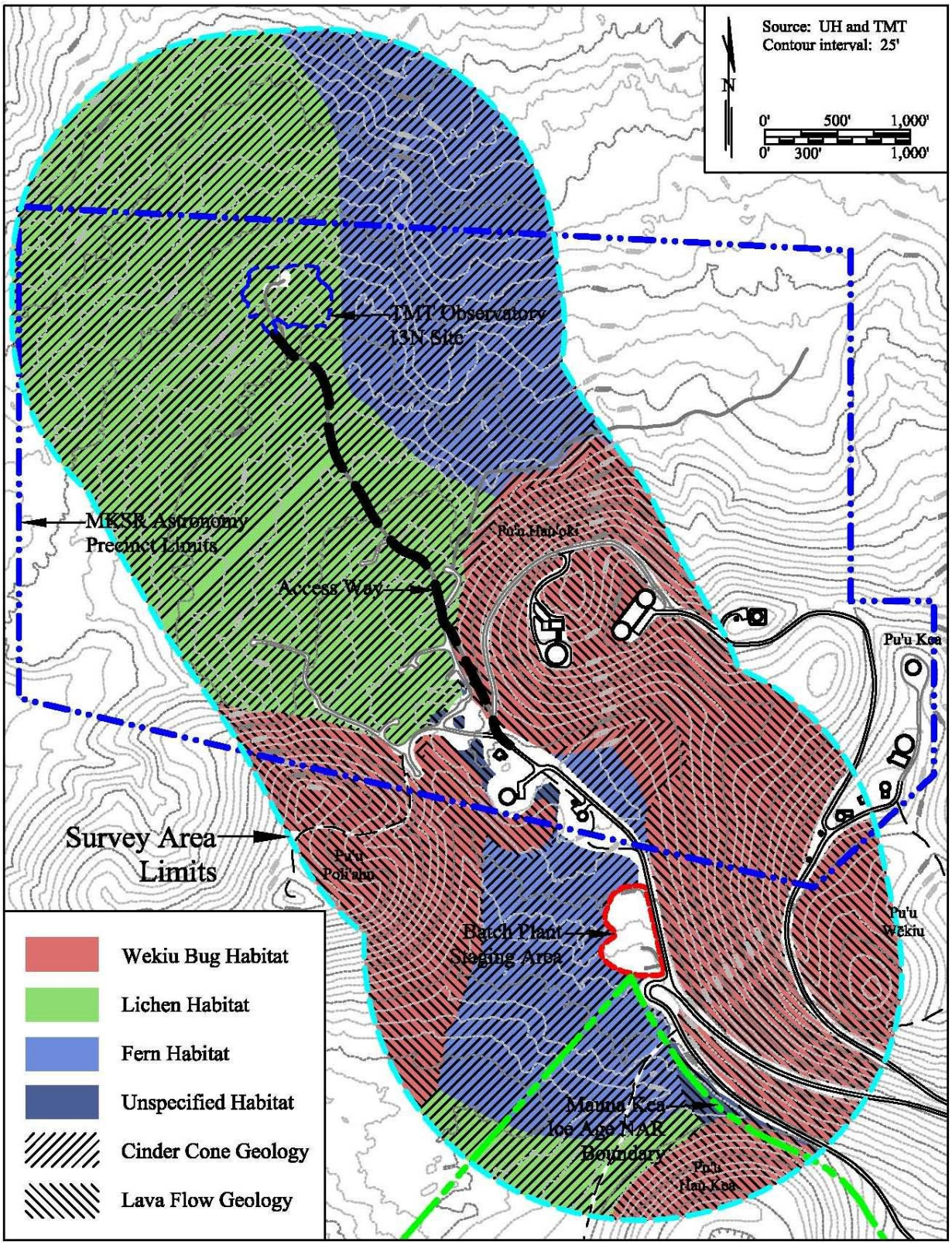


Figure 3: Strata in Survey Area

3.0 SURVEY METHODS

The survey was performed using two general methods: (1) stratified-systematic random plot survey, and (2) pedestrian/judgmental survey.

The survey had two areas of interest: (1) the entire 608.5 acre natural and relatively natural area within the entire survey area illustrated in

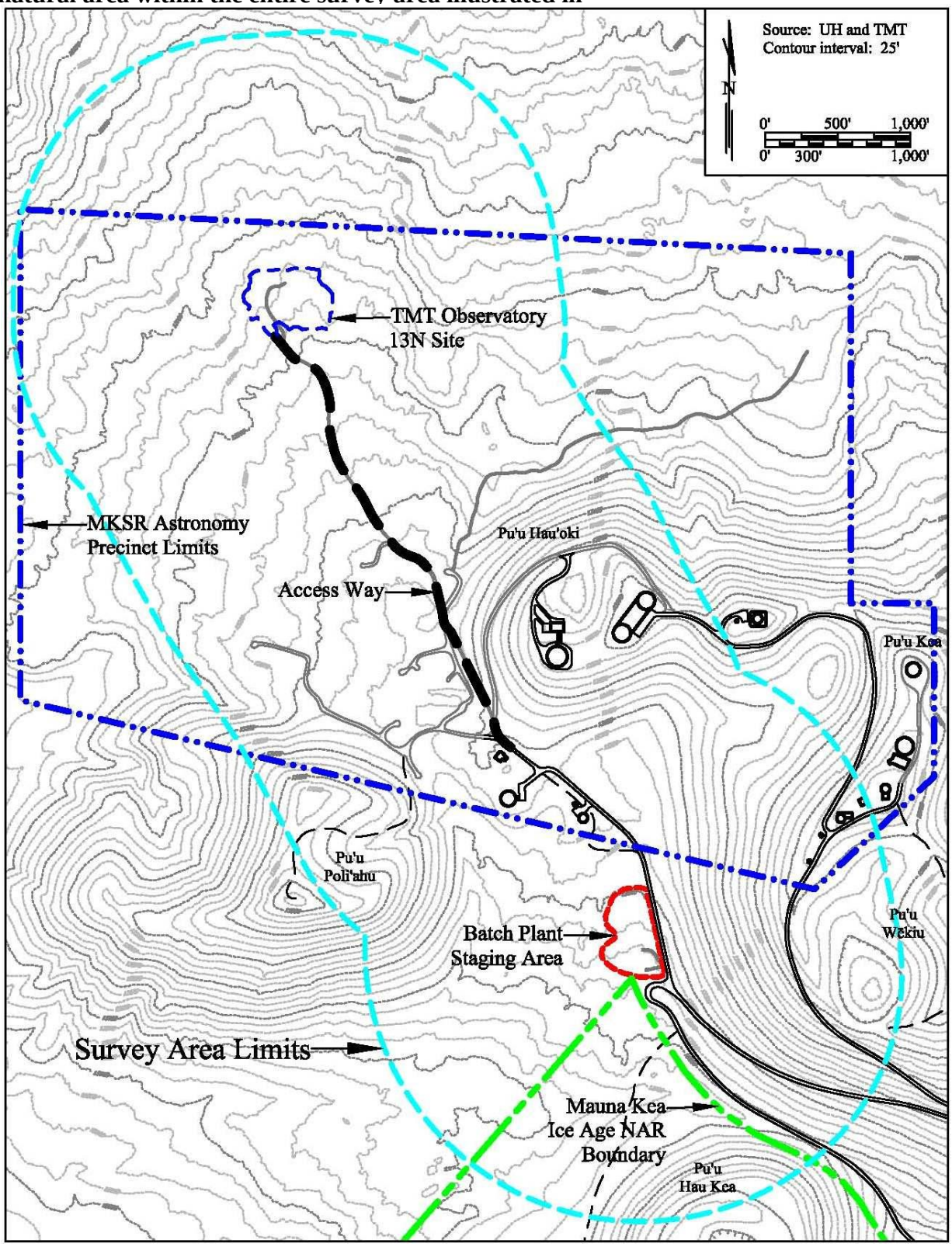


Figure 2, and (2) the TMT Observatory 13N site. Both the random survey method and pedestrian/judgmental survey methods were used within both areas. These two areas are discussed in detail in the following sections.

3.1 Area Wide Survey

3.1.1 Stratified-Systematic Random Survey Method

The stratified-systematic random survey method consisted of sampling throughout the natural and relatively natural areas within the total survey area (608.5 acres of the 659 total acres). "Stratified" indicates the random sampling was performed within the strata in representative concentrations as outlined in Table 1.

Table 1: Summary of Stratified Sampling Areas

Strata	Area (acres)	Percent of Area (%)	Number of Samples
Wēkiu bug habitat type 2 and 3	213.5	35	16
Fern and unspecified habitat	157	26	12
Lichen habitat	238	39	18
Total	608.5	100	46

Within each of these strata, the locations of samples were selected using a systematic-random method. "Systematic" indicates the sample locations are distributed relatively evenly over the area but still selected randomly. This was achieved by dividing the area of each strata into relatively equally sized subareas so that one sample is selected within each of these subareas (e.g., if there are to be 12 samples the strata area was systematically divided into 12 relatively equally sized subareas).

The plot locations were randomly selected by placing a 10 by 10 grid over each of the "Systematic" subareas, and using a random number generator to determine where on the grid the plot would be located.

Each sample location was the center of a 10-foot square study plot. Those 10 by 10 foot plots were surveyed in detail to provide a snap shot of conditions within each plot. The minimum of 12 samples within each strata were judged to be statistically sufficient to evaluate each strata in the survey area. This stratified-systematic random sampling of the survey area is a commonly accepted survey method that can be used to make predictions of conditions throughout the survey area based on statistical inference.

The forty-six randomly selected locations were established for detailed survey. The locations were selected by:

- Subdividing each strata into the necessary number of subareas – one subarea for each sample.
- Using a random number generator (Microsoft Excel spreadsheet) to select two random numbers per location (total of 92 random numbers).

- The length of the north-south extent of the subarea was multiplied by one random number and that location above the southern extent determined on a map.
- The east-west width of the subarea at that north-south location was determined through measurement on the AutoCAD survey drawing provided by UH.
- The east-west width was multiplied by a second random number and that distance measured from the western edge of the subarea at the north-south location.
- This was repeated in order to identify 46 random locations within the survey area.

Each randomly selected location served as the center of a 10-foot square plot that was surveyed in detail. **A randomly selected 10 foot by 10 foot Lichen plot (Plot L11).**

Figure 4 illustrates the location of the 46 randomly selected plots that were examined in detail. These plots will be located in the field using a GPS device and topography.

A randomly selected 10 foot by 10 foot Lichen plot (Plot L11).

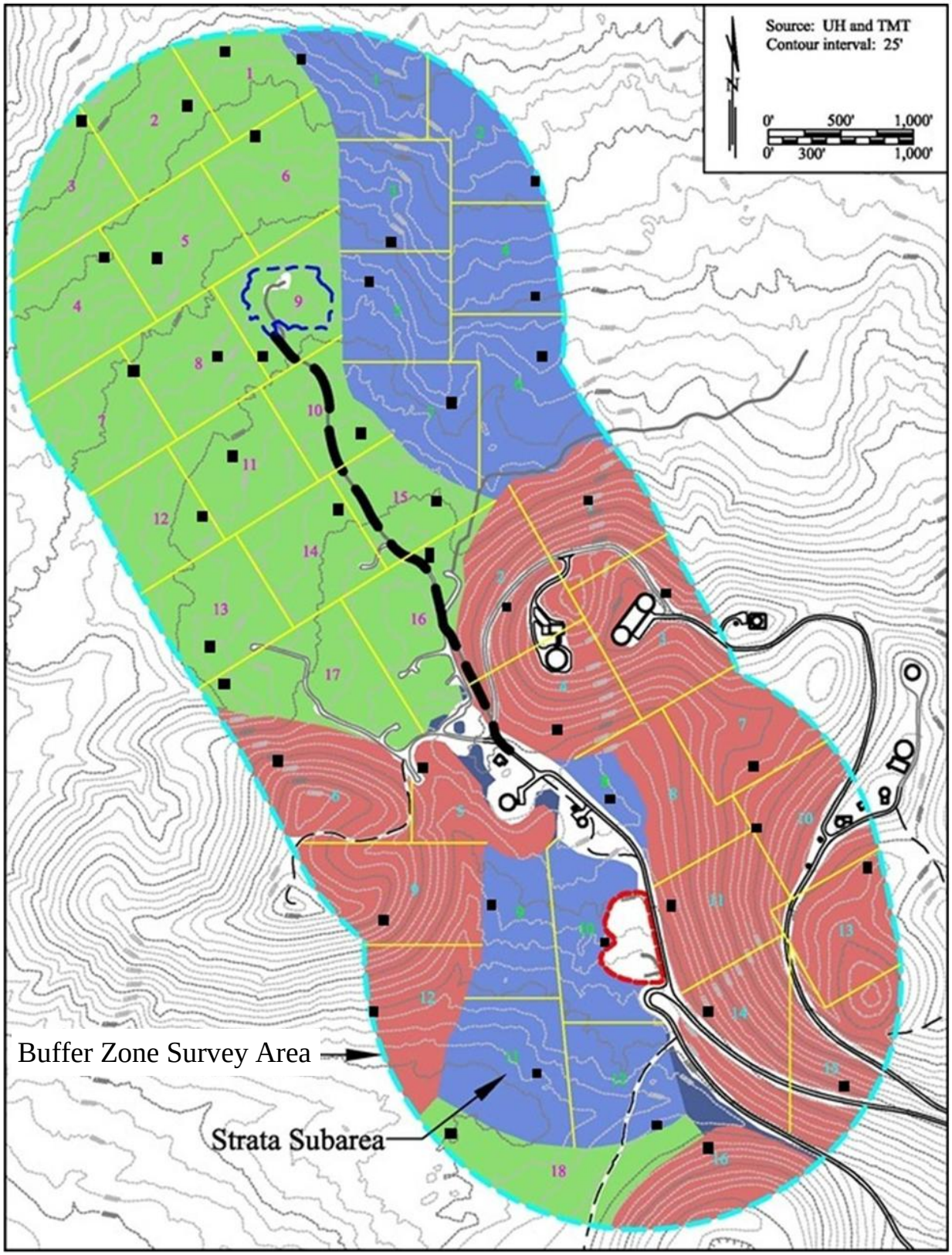


Figure 4: Locations of Randomly Selected Detailed Survey Plots (small black squares).

At each of these plots a photograph was taken and the following recorded:

- Northing, easting, and elevation according to a hand held GPS instrument (Garmin 62S).
- Strata: for example, Wēkiu bug habitat (cinder cone), lichen habitat (lava flow), or fern habitat (lava flow).
- Topography: for example, flat, gradual slope (estimate of percent slope), rugged with lava overhangs, etc.
- Geology/Soils: percentage of hard rock vs. soil cover, depth of soil cover, soil type (well-sorted sand and gravel with approximate grain size).
- Species present: lichens, mosses, ferns, vascular plants, other – list of all species observed.
- Species coverage/abundance: a visual estimate percent coverage of each species type (lichen, moss, ferns, vascular plants) within the plot.
- Arthropods present: this was performed using multiple techniques. The findings of these techniques will be recorded for abundance. The methods are:
    1. Ground-based targeted search – Twenty minutes was spent visually searching the plot area and lifting rocks in the survey plot to search for arthropods.
    2. Pit-fall traps –They were installed and maintained at an appropriate location within each randomly-selected plot for a period of three days. Pitfall traps set in Lichen and Botany plots were filled with soapy water and baited with shrimp paste. Traps in Arthropod plots were live traps typically used to sample for wēkiu bug presence and contained small pieces of cinder and a small amount of shrimp paste for bait.
    3. Protein- and sugar-based traps – these traps are typically used to sample for the presence of ants. They contained peanut butter, honey, and tuna and were installed in each of the randomly-selected plots for a period of about 30 minutes.

3.1.2 Pedestrian/Judgmental Survey

As the field crews accessed the 46 randomly selected locations they identified areas of relatively high native plant, lichen, and moss diversity, and unique communities using their past experiences and knowledge of preferable habitats as a guide. Where areas of relatively high native diversity and unique communities were observed, 10-foot square plots within such areas were surveyed using the same methods employed at the randomly-selected plots, as described in Section 3.1.1.

3.2 TMT Observatory Project Location Survey

In order to evaluate the TMT Observatory Project area relative to the larger survey area, the following survey techniques were used.

3.2.1 Random Sampling Method

Five randomly selected plots within the TMT Observatory footprint area were selected for detailed survey. This detailed survey was performed using the same methods described in Section 3.1.1. The only difference is that the randomly selected plots were restricted to the natural area of the TMT Observatory 13N site footprint.

The plots established using the random location selection process within the TMT Observatory 13N site are illustrated on **Error! Reference source not found.**.

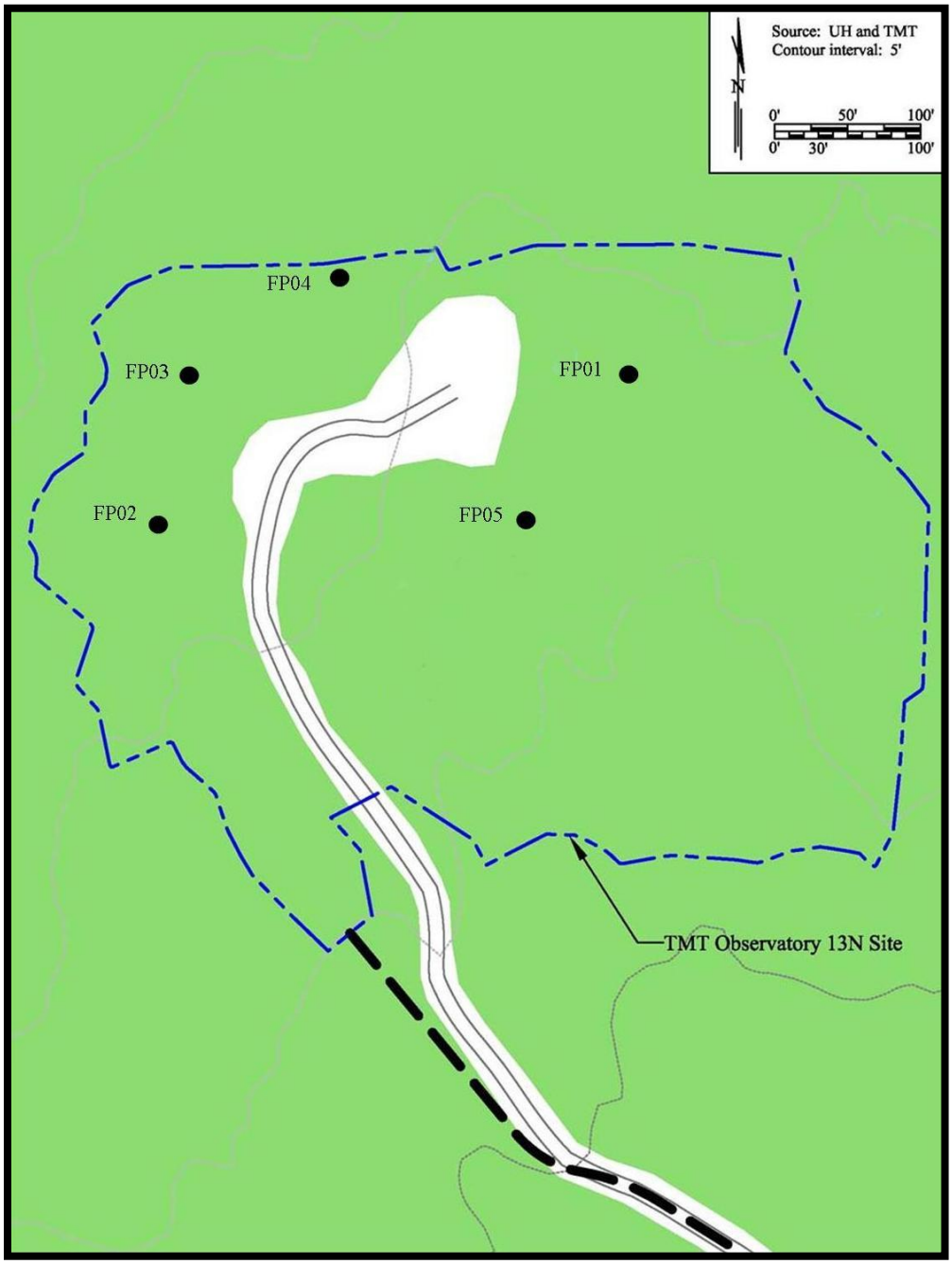


Figure 5: Random plots within the TMT Observatory 13N site.

3.2.2 Pedestrian/Judgmental Survey

A thorough pedestrian/judgmental survey has already been performed within the TMT Project areas, including the TMT Observatory 13N site, along the Access Way, and in the Batch Plant Staging Area. This was done in 2008 and 2009 to support the Project's EIS. Because the previous study area was (a) much smaller (roughly 63 acres) than the current 659 acre survey area, (b) more of the area had been previously disturbed, and (c) the area was more easily accessible, the EIS survey was more intensive that what can be done within the entire current 659 acre survey area. As described in the Final EIS for the Project, the survey did not encounter any areas of relatively high native diversity, unique communities, and unique geological features within the Project footprint.

During this survey, the surveyors walked the TMT Observatory 13N site looking for areas of relatively high native diversity or unique communities. If any such area were observed, they were characterized using the methods described in Section 3.1.2.

3.3 Permit

An application for a Research, Collection and Access Permit was submitted May 11, 2011 to the Hawai‘i Department of Land and Natural Resources (DLNR), Division of Forestry and Wildlife (DOFAW) and after review, a permit (FHM11-258) was granted on May 20, 2011, valid through October 30, 2012. The wēkiu bugs were sampled under a separate Research, Collection and Access Permit (FHM11-253) granted to Jesse Eiben, valid from May 5, 2011 through May 5, 2012.

3.4 Schedule and Personnel

In this survey, the Lichen Habitat strata plots were surveyed over five days, May 30 – June 3, 2011; the Botanical strata plots were surveyed over three days, June 4 – June 6, 2011; the Arthropod strata plots were surveyed over five days, June 10 – June 14, 2011. Additional days were required to retrieve pitfall traps and record their contents.

Gregory Brenner, Pacific Analytics, LLC and Jesse Eiben, UH Mānoa, were the investigators conducting the arthropod sampling. Dr. Brenner has a PhD in entomology from Oregon State University, Corvallis, and eighteen years of experience studying the arthropod fauna of Hawai‘i, during which he has conducted numerous scientific studies of the arthropods on Mauna Kea. Dr. Eiben has a PhD in entomology from the University of Hawai‘i's Department of Plant and Environmental Protection Sciences and conducted research on Wēkiu bug autecology and systematics for his dissertation.

Gregory Brenner, Clifford Smith, and Shanti Berryman were the investigators conducting the lichen, bryophyte and botanical sampling. Dr. Brenner is familiar with the flora of Hawai‘i having conducted many scientific studies of the plants on Mauna Kea and elsewhere in Hawai‘i. Dr. Smith has a PhD in botany and is Professor Emeritus of the Department of Botany, UH Mānoa. He is the leading expert in lichens of Hawai‘i, and has conducted research on Hawaiian lichens since 1958. Dr. Berryman received her PhD in plant community ecology and lichenology at Oregon State University in the Department of Botany and Plant Pathology. She has conducted lichen and botanical field surveys in the United States and Canada.

3.5 Nomenclature

The nomenclature used in this report follows the Hawaiian Terrestrial Arthropod Checklist, Third Edition (Nishida 1997) and the Manual of the Flowering Plants of Hawai‘i (Wagner and others 1990). Hawaiian and scientific names are italicized.

Species are discussed as being endemic, indigenous, non-indigenous, adventive, and purposely introduced. These terms are defined as:

- Endemic – A species native to, or restricted to Hawai‘i.
- Indigenous – A species native to Hawai‘i but that naturally occurs outside of Hawai‘i as well.
- Non-indigenous – A species not native to Hawai‘i.
- Adventive – Not native, a species transported into a new habitat by natural means or accidentally by human activity.
- Purposely introduced – A species released in Hawai‘i for a particular purpose, usually to control a weedy plant or another insect.

3.6 Arthropod Sampling

3.6.1 Trapping

Wēkiu Bug Traps

Pitfall live-traps were used to sample wēkiu bugs in the sixteen Arthropod strata plots using a design very similar to those by Dr. Eiben during his dissertation field work.

The traps were dug into the available ground substrate with a goal of achieving a depth where moisture was present in the ash layer. The lip of the cup was not necessarily placed flush with the ash layer, and there was no wire mesh surround to provide structure surrounding the cups. This cup design has been successful for attracting and capturing Wēkiu bugs during 2007 and 2008 (Eiben, unpublished). A cap rock was placed over the traps and elevated above the ground approximately 0.6 in with smaller rocks.

The traps were checked daily three days after installation. All live Wēkiu bugs were released near the trap in which they were captured.

Pitfall Traps

Pitfall traps were used to sample the arthropod ground fauna in Lichen and Botanical strata plots. These traps were 10oz cups placed into the ground so that the lip of the cup is level with the substrate. A small amount of soapy water was placed into the trap to kill and preserve specimens that fall into the traps. A cap rock was placed over the traps and elevated above the ground approximately 0.6 inches with smaller rocks.

Arthropod Pitfall trap on a Lichen stratum plot.

Bait Trapping

Protein- and sugar-based traps are typically used to sample for the presence of ants. The traps in this study contained peanut butter, honey, and tuna and were installed in each of the randomly-selected plots for a period of about 30 minutes.

3.6.2 Specimen Curation

The specimens in the traps were cleaned in 70 percent ethyl alcohol and sorted into the morpho-species for identification. Hard-bodied species, such as beetles, true bugs, large flies and bees were mounted on pins, either by pinning the specimen or by gluing the specimens to paper points. Soft-bodied specimens, such as immature stages, spiders, Collembola, Psyllids, Aphids, small flies and wasps, and centipedes, were stored in vials filled with 90 percent ethyl alcohol.

3.6.3 Identification

Identification to the species level for all specimens was not feasible in the time frame for this study. Important groups of endemic species, species of concern, and potentially threatening non-indigenous species were given first priority for identification. Specimens will be deposited in the UH manoa Entomology Collection when identifications are complete.

References for general identification of the specimens included *Fauna Hawaiiensis* (Sharp (ed) 1899-1913) and the 17 volumes of *Insects of Hawai'i* (Zimmerman 1948a, 1948b, 1948c, 1948d, 1948e, 1957, 1958a, 1958b, 1978, Hardy 1960, 1964, 1965, 1981, Tentorio 1969, Hardy and Delfinado 1980, Christiansen and Bellinger 1992, Liebherr and Zimmerman 2000, and Daly and Magnacca 2003). Other publications which were useful for general identification included *The Insects and Other Invertebrates of Hawaiian Sugar Cane Fields* (Williams 1931), *Common Insects of Hawai'i* (Fullaway and Krauss 1945), *Hawaiian Insects and Their Kin* (Howarth and Mull 1992), and *An Introduction to the Study of Insects Sixth Edition* (Borror, Triplehorn, and Johnson 1989).

For specific groups specialized keys were necessary. Keys used to identify Heteroptera included those by Usinger (1936, 1942), Ashlock (1966), and Gagné (1997). Keys used to identify Hymenoptera included Cushman (1944), Watanabe (1958), Townes (1958), Beardsley (1961, 1969, 1976), Yoshimoto and Ishii (1965), and Yoshimoto (1965a, 1965b).

3.7 Lichen, Bryophyte, and Botanical Sampling

Prior to field work, a search was made of the literature to review previous botanical, lichen and bryophyte studies conducted in or near the project area. Identification guides were also consulted to prepare the investigators for field identification.

3.7.1 Lichen and Bryophyte Sampling

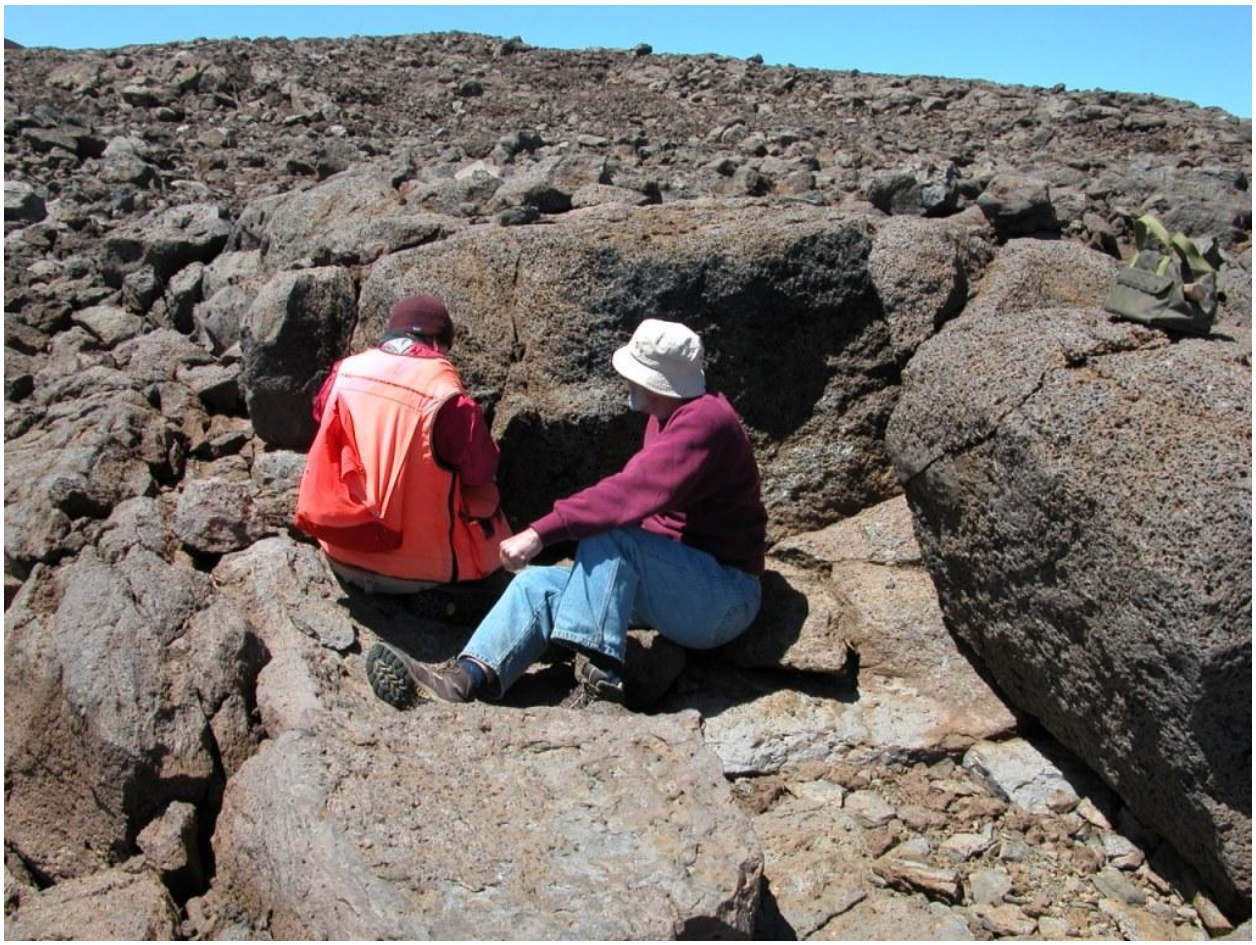
At each plot within the Lichen and Botanical strata and within the TMT Observatory footprint sites, all lichen and bryophyte species were recorded as encountered. All principal habitat types were investigated. Small caves were given extra sampling attention to confirm all species of lichens and bryophytes were detected.

The undersurfaces of twenty-five rocks were examined each of the plots and counts were made of rocks with lichens present to quantify abundance. All rocks that were examined were replaced in their original position as precisely as possible.

Small samples of all species detected were taken as vouchers. Larger specimens were taken of several species whose identity could not be confirmed in the field. These samples were studied in the laboratory or were sent to other lichen experts for identification confirmation.

3.7.2 Botanical Sampling

Plant identifications were made in the field. Plants that could not be positively identified were collected for later determination using plant keys and other identification aides. Notes were taken of the distribution of species within and surrounding each of the sites. Plant species were examined repeatedly as they were encountered to confirm identification.



Dr. Smith and Dr. Berryman examine lichens on a "High Native Diversity" plot.

3.7.3 Identification

References for general identification of the specimens included *Field Guide to Rare and Unusual Plants on the Island of Hawai'i* (Delay et al 2004), *Handbook of Hawaiian Weeds* (Haselwood and Motter 1966), *Hawaiian Heritage Plants* (Kepler 1984), *Trailside Plants of Hawai'i's National Parks* (Lamoureux 1976), *Hawaiian Forest Plants* (Merlin 1995), *Hawai'i's Vanishing Flora* (Kimura and Nagata 1980), *In Gardens of Hawai'i* (Neal 1965), *Plants and Flowers of Hawai'i* (Sohmer and Gustafson 1987), *A Tropical Garden Flora* (Staples and Herbst 2005), *Ferns of Hawai'i* (Valier 1995), *Manual of the Flowering Plants of Hawai'i* (Wagner and others 1990), and *Hawai'i's Ferns and Fern Allies* (Palmer 2003).

4.0 RESULTS

4.1 LICHEN PLOTS

4.1.1 Lichen Plot L01

GPS Coordinates and Elevation
N19 50.123 W155 28.973

13,094 ft (3,991 m)

Topography
Slope gradual, less than 5%

Geology/Soils
Glaciated pahoehoe blocks and rubble (70%) with smaller 5-10 cm rocks (30%).

Lichens

List of Species

Acaropsora sp 1
Acarospora sp 3
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Pseudephebe miniscula
Rhizocarpon geographicum
Umbilicaria deusta
Umbilicaria decussata
Umbilicaria hirsuta (two small specimens)
Unknown 1

Undersurface of rocks
5/20 *Lecanora polytropa*
1/20 *Umbilicaria decussata*

Only under fist sized rocks and above, smaller had not lichens underneath them. Probably more light gets through.

Mosses

Pohlia nutans

Vascular Plants

No Vascular Plants

Arthropods

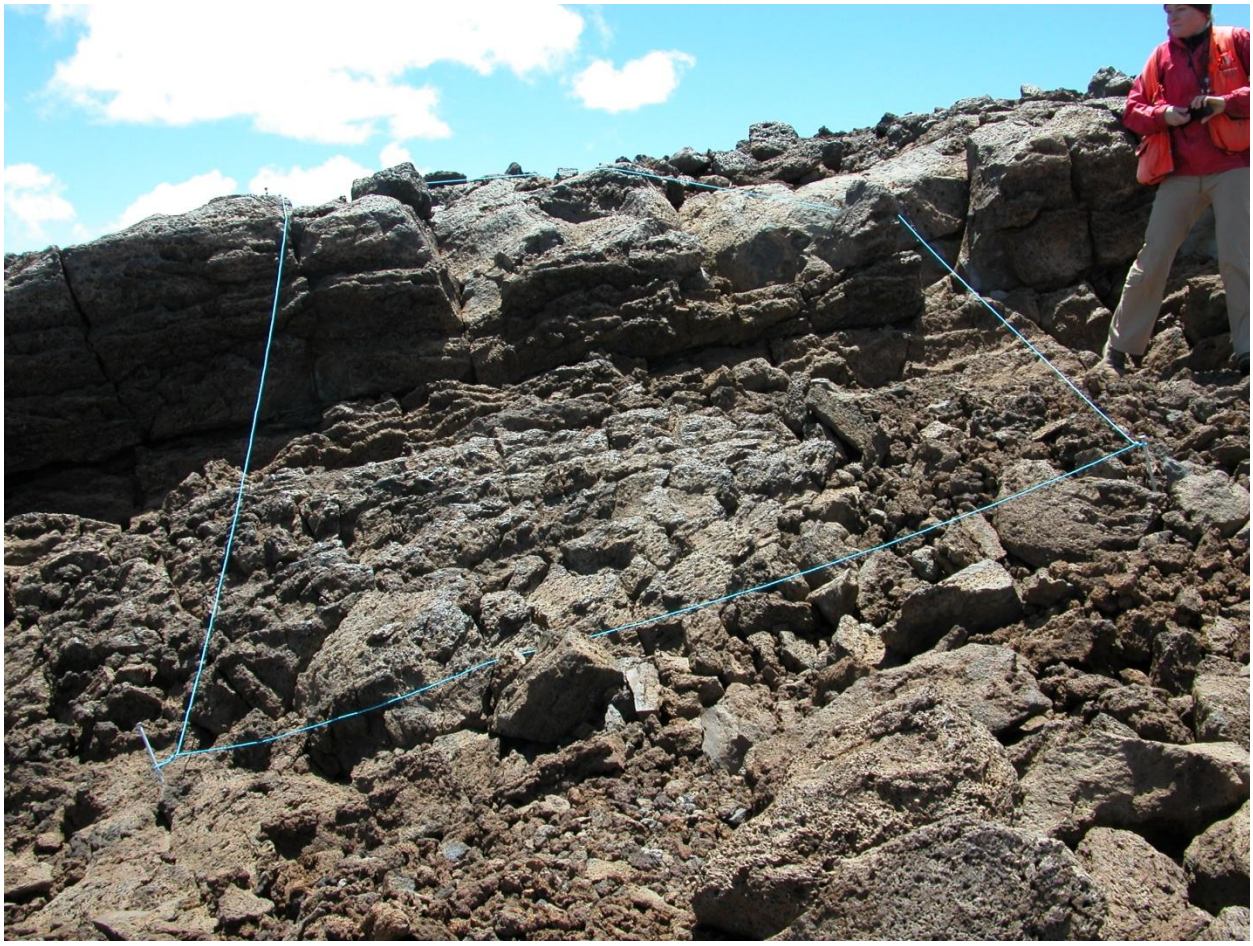
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Unknown	Unknown	Unknown		Unknown
Hymenoptera	Apidae	*Apis*	*mellifera*	Linnaeus	non-indigenous

Abundance Notes

At least two of the Blow flies (*Calliphora vomitoria*) and one *Apis mellifera* (honey bee) were present during the plot survey. Two small flies were in the pitfall trap when it was retrieved.

4.1.2 Lichen Plot L02



GPS Coordinates and Elevation
N19 50.161 W155 28.999

13,051 ft (3,978 m)

Topography
Slope ~10% with west facing cliff

Geology/Soils
Glaciated pahoehoe lava flow (70%) with patches 5-10 cm rubble (30%).

Lichens

Acarospora cf. depressa
Acarospora sp 3
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Lepraria 'vouaxii'
Umbilicaria decussata

Undersurface of rocks:
5/20 cover (*Lecanora polytropa + Lecanora aff. 'subaurea'*)
1/20 Buellia sp 1.

Mosses

Pohlia nutans

Vascular Plants

Deschampsia nubigena

Arthropods

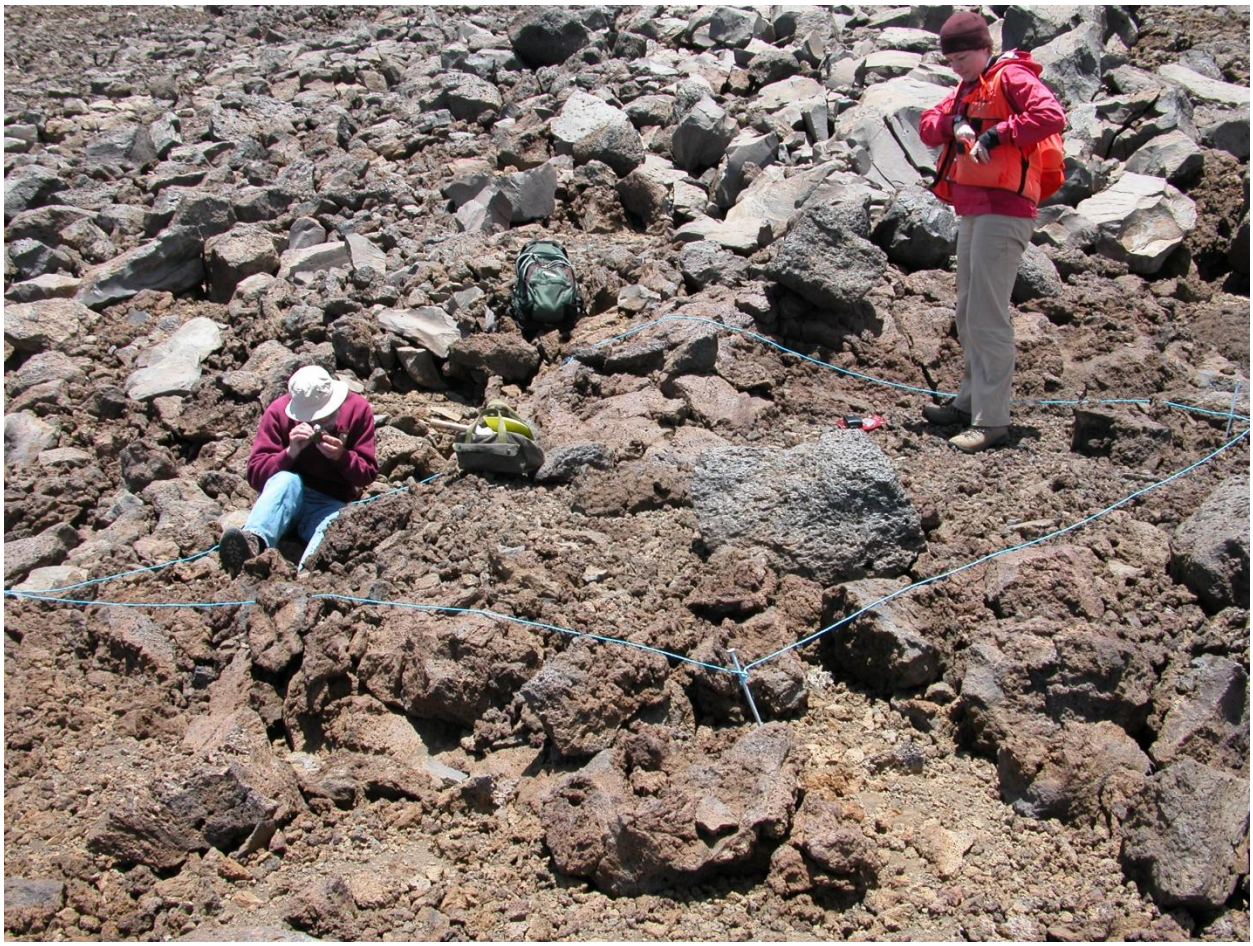
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Phoridae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

At least one Sciaridae was observed flying during the plot survey. One Phoridae and six Sciaridae were captured in the pitfall trap.

4.1.3 Lichen Plot L03



GPS Coordinates and Elevation
N19 50.173 W155 29.101

12,945 ft (3,946 m)

Topography
Slight slope (< 5%) over 60% of the plot. Fifteen percent slope over the remaining 40% of the plot.

Geology/Soils
Glaciated pahoehoe 10-40 cm rocks (80%) with solifluction lobe of 1-8 cm rocks (15%) and patches of ash 10 cm deep (5%)

Lichens

Acarospora sp 1
Acarospora sp 3
Buellia cf. fuscoachracea
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Rhizocarpon geographicum

Undersurface of rocks:
5/20 *Acarospora* sp 1
2/20 *Lecanora aff. 'subaurea'*
2/20 *Lecidea bayleyi*.

Mosses

Pohlia nutans

Vascular Plants

Deschampsia nubigena adjacent to plot

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Diptera	Syrphidae	*Allograpta*	*obliqua*	(Say)	non-indigenous

Abundance Notes

At least one Scatopsidae and one Sciaridae were observed flying during the plot survey. One Syrphidae and five Sciaridae were captured in the pitfall trap.

4.1.4 Lichen Plot L04

GPS Coordinates and Elevation
N19 49.897 W155 29.126

13,106 ft (3,995 m)

Topography
Slope ~20% with west facing cliff

Geology/Soils
Mostly andesite blocks (20%) with patches of 7-10 cm rubble (75%) over ash 10 cm deep (5%)

Lichens
Lecanora polytropa

Undersurface of rocks
3/20 *Lecanora polytropa*

Mosses
Pohlia nutans

Vascular Plants
Agrostis sandwicensis
Deschampsia nubigena

Arthropods
No arthropods observed.

4.1.5 Lichen Plot L05

GPS Coordinates and Elevation
N19 49.983 W155 29.090

13,088 ft (3,989 m)

Topography
Mostly level with some areas of gentle slope.

Geology/Soils
Glaciated pahoehoe lava blocks (15%), smaller 35-50 cm boulders (20%), and 5-10 cm rubble (65%) slightly brown but otherwise similar to andesite (grey) but more blistered and uneven and does not ring as much when struck by hammer (80%) with patches of ash 10 cm deep (5%).

Lichens
Lecanora polytropa – deep in crevices, very little exposed.

Undersurface of rock
3/20 *Lecanora polytropa* under fist-sized rocks
0 under smaller rocks.

Mosses
No Mosses

Vascular Plants
No Vascular Plants

Arthropods

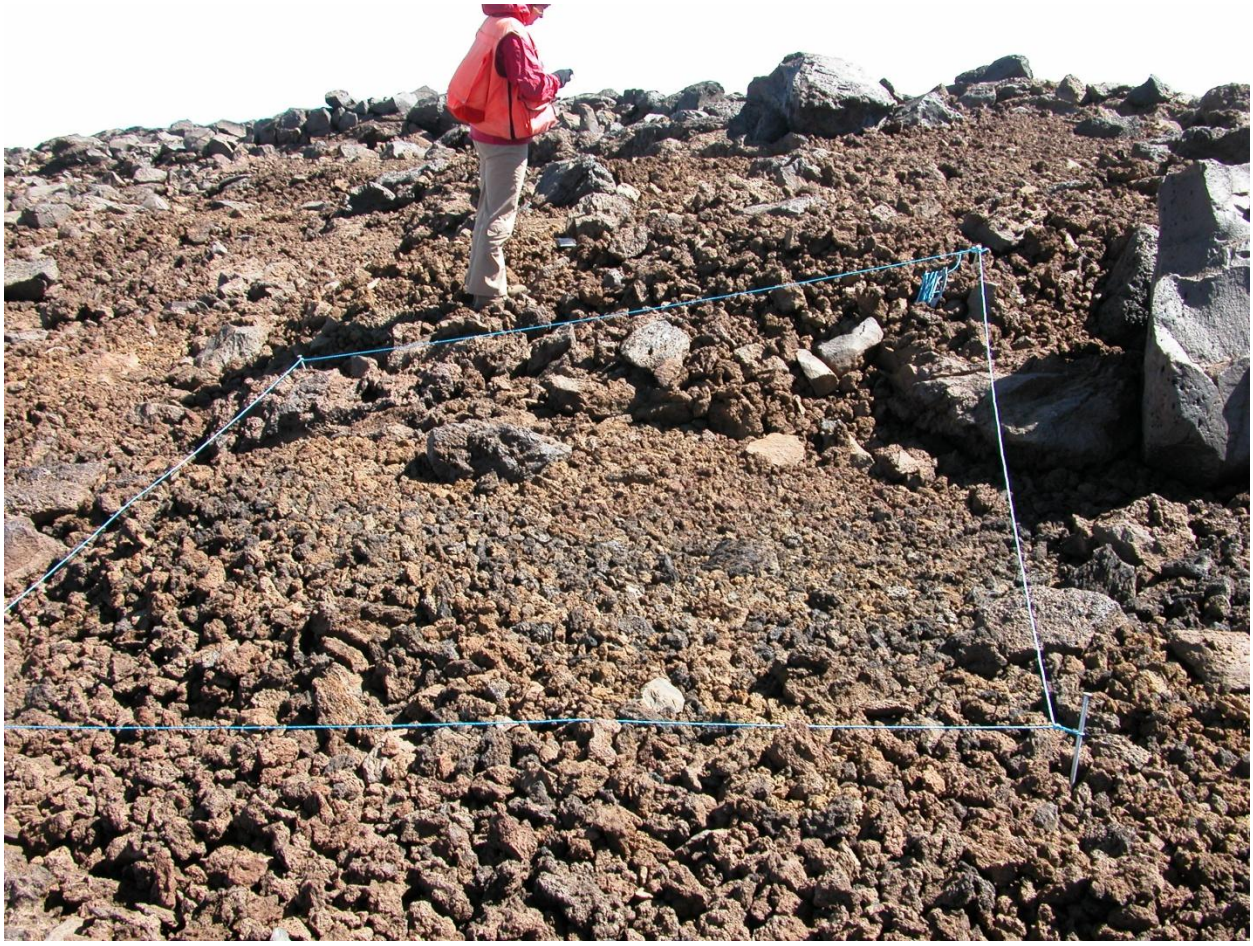
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Diptera	Syrphidae	*Allograpta*	*obliqua*	(Say)	non-indigenous
Lepidoptera	Oecophoridae	*Agonopterix*	*ulicitella*	(Stainton)	non-indigenous

Abundance Notes

At least one Blow fly, one Gorse moth and one Lycosa cast skin were observed during the plot survey. Four Scatopsidae, 1 Syrphidae, and 14 Sciaridae were captured in the pitfall trap.

4.1.6 Lichen Plot L06



GPS Coordinates and Elevation
N19 50.069 W155 29.993

13,136 ft (4,004 m)

Topography
Slope ~5%

Geology/Soils
Glacial till, 3-15 cm rocks 15 cm deep over moist ash.

Lichens

Lecanora polytropa – one little spot on the surface of a rock.

Undersurface of rocks
5/20 *Lecanora polytropa*.

On adjacent rocks of surrounding this plot:
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Pseudephebe miniscula
Umbilicaria decussata

Mosses

Pohlia nutans

Vascular Plants

No Vascular Plants

Arthropods

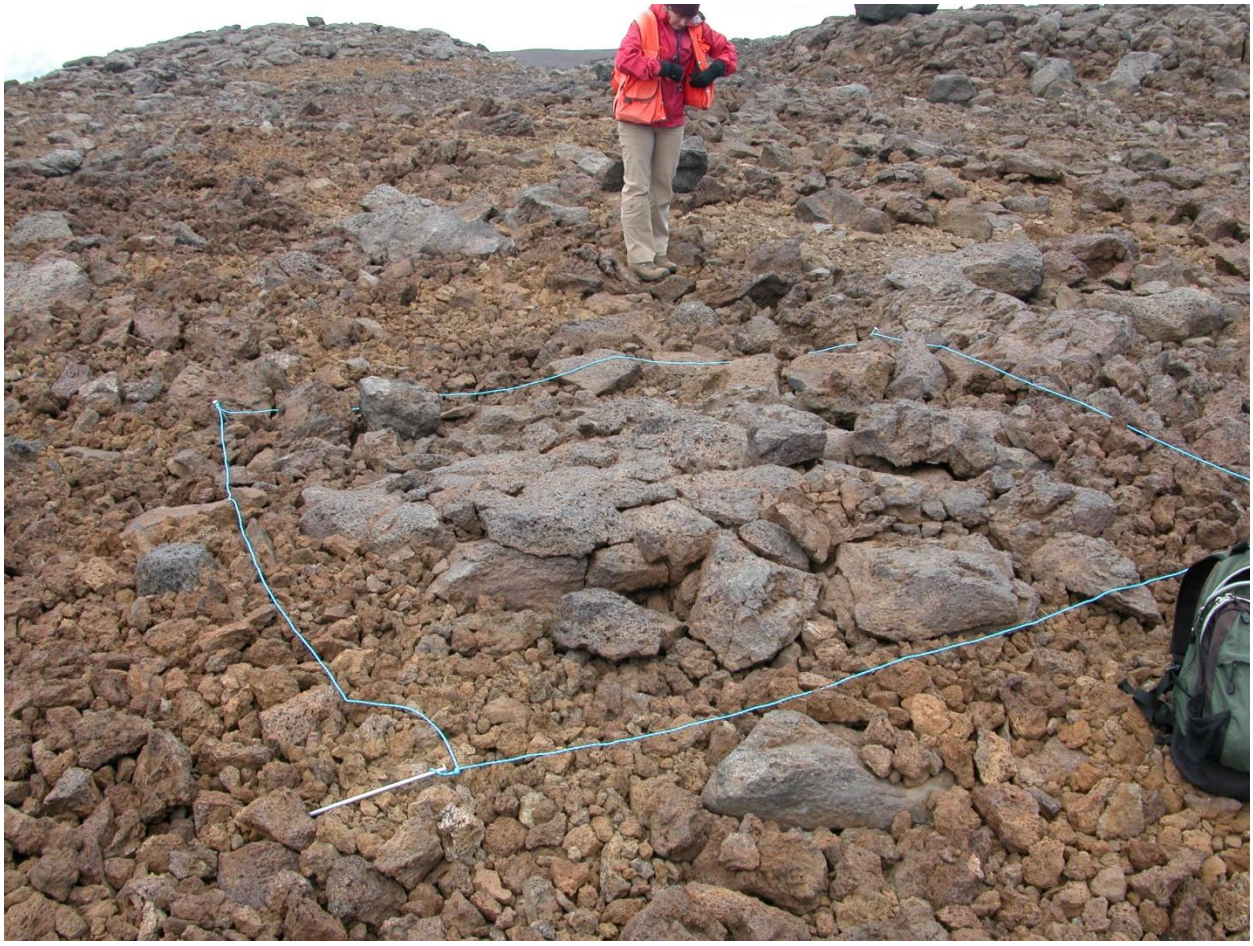
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Drosophilidae	Drosophila	Unknown		Unknown
Diptera	Phoridae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

One small Drosophila, one Lycosa, and at least one Calliphoridae were observed during the plot survey. Two Phoridae and 6 Sciaridae were captured in the pitfall trap.

4.1.7 Lichen Plot L07



GPS Coordinates and Elevation
N19 49.900 W155 29.099

13,154 ft (4,009 m)

Topography
Slope ~10%

Geology/Soils
Glaciated pahoehoe lava blocks (60%) and 5-15 cm brown rubble (40%) over ash 5 cm deep

Lichens

Acarospora sp 1
Acarospora sp 3
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lepraria 'vouaxii' – thick and white below surface.
Pseudephebe miniuscula

Undersides of rock:
3/20 *Lecanora polytropa*
1/20 *Lecidea bayleyi*
2/20 *Acarospora* sp 1
5/20 *Lecanora aff. 'subaurea'*
1/20 *Acarospora* sp 3.

Mosses

Pohlia nutans

Vascular Plants

Deschampsia nubigena

Arthropods

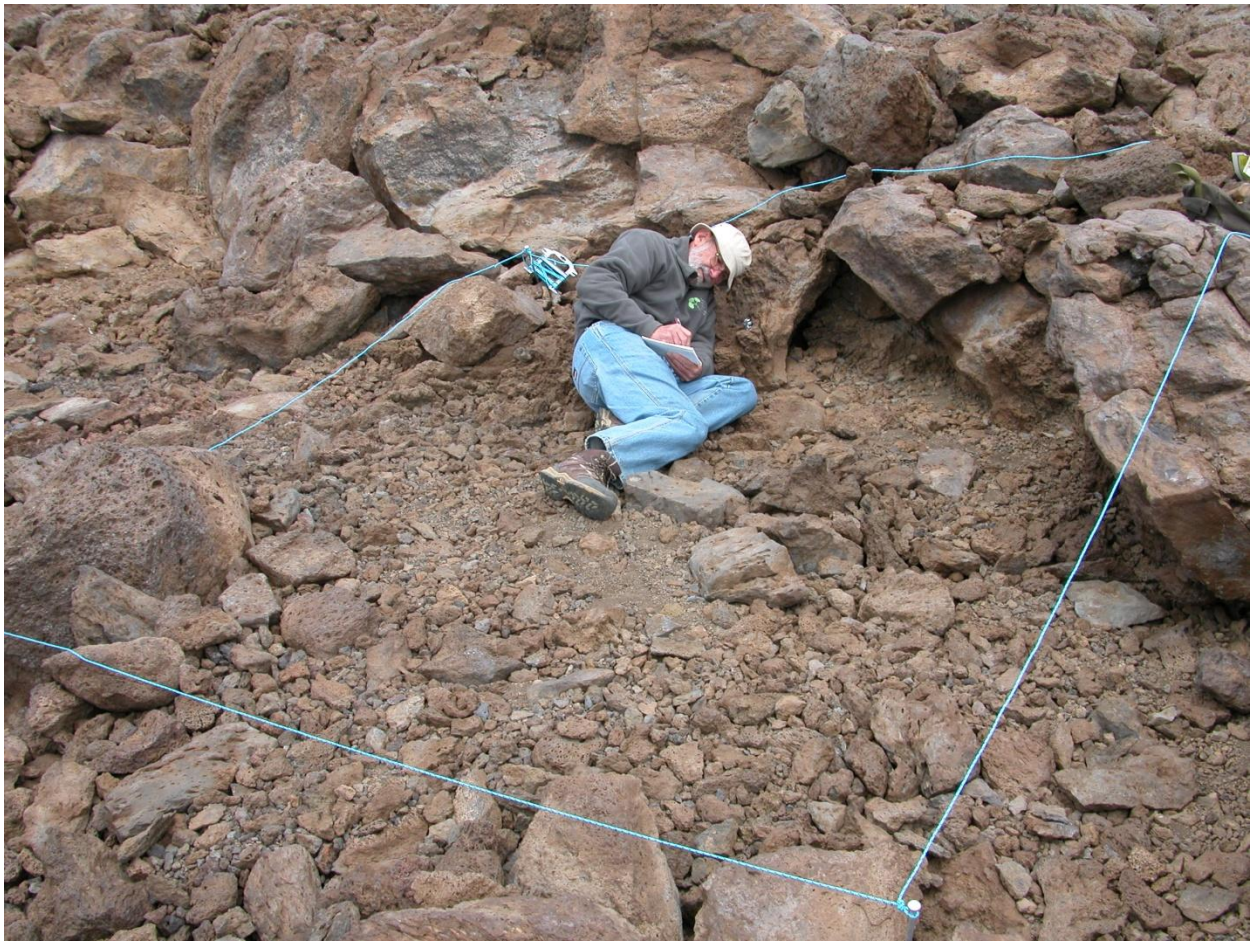
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

One Lycosa cast skin was observed during the plot survey. Two Sciaridae and 2 Scatopsidae were captured in the pitfall trap.

4.1.8 Lichen Plot L08



GPS Coordinates and Elevation
N19 49.903 W155 29.003

13,188 ft (4,020 m)

Topography
Mostly level

Geology/Soils
Glacial 20-30 cm boulders (10%) and 3-8 cm rubble (80%) with patches of ash (10%).

Lichens

Acarospora sp 1
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lepraria 'incana'
Pseudephebe miniuscula
Rhizocarpon geographicum
Umbilicaria decussata

Undersides of rocks:
1/20 *Acarospora* sp. 1
1/20 *Lecanora polytropa*
1/20 *Lecanora aff. 'subaurea'*.

Mosses

Pohlia nutans

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*coenosulus*	Stal	endemic

Abundance Notes

One Lycosa and one very small Linyphiidae were observed during the plot survey. Eight *Nysius coenosulus*, 4 Scatopsidae, and 10 Sciaridae were captured in the pitfall trap.

4.1.9 Lichen Plot L09

GPS Coordinates and Elevation
N19 49.892 W155 28.939

13,233 ft (4,033 m)

Topography
Mostly level

Geology/Soils
Glacial 2-10 cm rubble (80%) 10-15 cm deep over ash with andesite face (20%).

Lichens

Acarospora cf depressa
Acarospora sp 1
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi

Undersurface of rocks
2/20 *Lecanora polytropa*

Mosses

Pohlia nutans

Vascular Plants

Agrostis sandwicensis

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

Two *Lycosa* cast skins, one Linyphiidae, and at least one Calliphoridae and Sciaridae were observed during the plot survey. One *Lycosa*, one Calliphoridae, and 15 Sciaridae were captured in the pitfall trap.

4.1.10 Lichen Plot L10

GPS Coordinates and Elevation
N19 49.793 W155 28.822

13,335 ft (4,065 m)

Topography
Gradual slope (<5%)

Geology/Soils
Flat, smooth glaciated pahoehoe lava flow (50%) with rubble over ash (50%). Most of the surface in direct sunlight but a few areas with some shade.

Lichens

Acarospora sp 1
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae

Undersurface of rock
No lichens, rocks embedded in ash.

Mosses

Pohlia nutans

Vascular Plants

No Vascular Plants

Arthropods

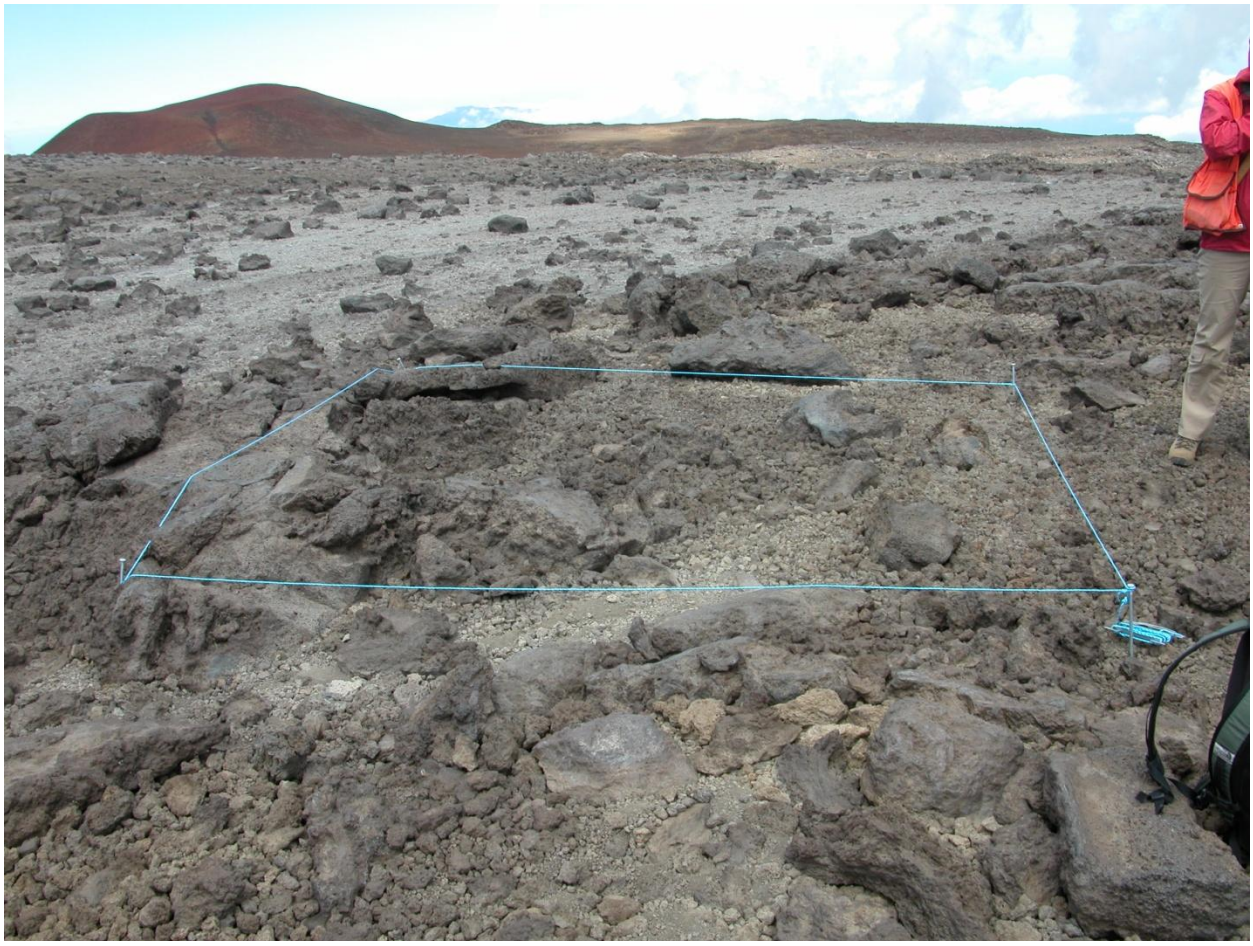
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

No arthropods were observed during the plot survey. Two Scatopsidae and 3 Sciaridae were captured in the pitfall trap.

4.1.11 Lichen Plot L11



GPS Coordinates and Elevation
N19 49.768 W155 28.961

13,303 ft (4,055 m)

Topography
Slight slope (<2%)

Geology/Soils
Smooth glaciated pahoephoe lava flow (30%) and small glacial rubble over ash (50%), with patches of rough lava (10%) and ash (10%).

Lichens

Acarospora cf. depressa
Acarospora sp 1
Acarospora sp 3
Caloplaca lithophila
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi

Underside of rocks
1/20 *Lecidea bayleyi*
2/20 *Lecanora polytropa*

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

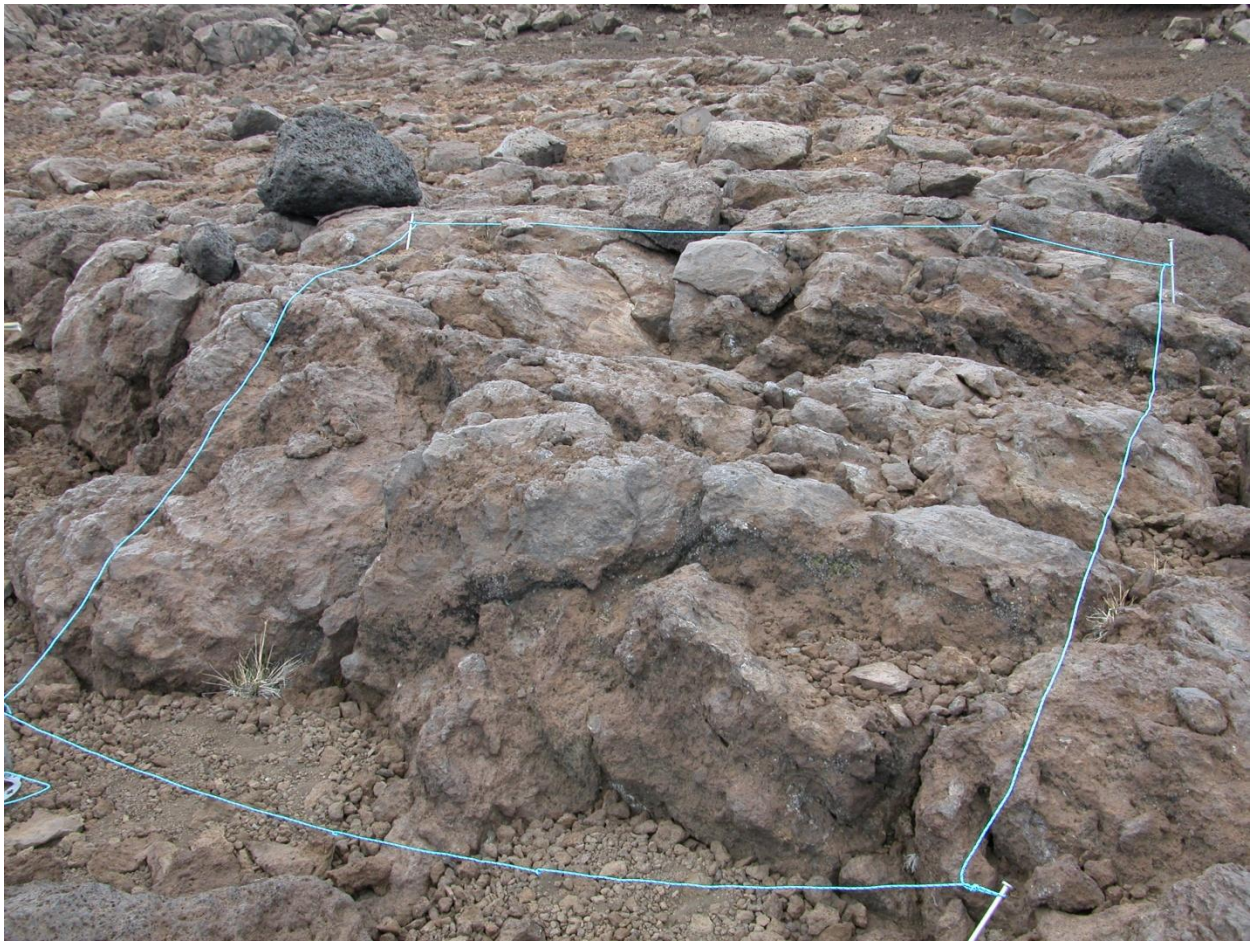
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Diptera	Syrphidae	*Allograpta*	*obliqua*	(Say)	non-indigenous
Lepidoptera	Oecophoridae	*Agonopterix*	*ulicitella*	(Stainton)	non-indigenous

Abundance Notes

One Syrphidae and one Gorse moth were observed during the plot survey. Four Scatopsidae and 3 Sciaridae were captured in the pitfall trap.

4.1.12 Lichen Plot L12A



GPS Coordinates and Elevation
N19 49.699 W155 29.001

13,276 ft (4,047 m)

Topography
The random coordinates placed Lichen Plot 12 on a wash of light grey ash with darker streaks and a few small boulders too unstable for lichens. An area adjacent to the wash was selected for the sample plot 12A. Plot 12A had a very gradual slope (<1%).

Geology/Soils
Glaciated pahoehoe lave flow (90%) with a north facing aspect. Patch of 2-5 cm cinders (10%) over ash about 20 cm deep.

Lichens

Acarospora sp 1
Buellia cf. fuscoachracea
Candelariella vitellina
Carbonea vitellinaria
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Lepraria 'incana'
Pseudephebe miniuscula
Rhizocarpon geographicum
Umbilicaria decussata

Undersurface of rocks:
8/20 *Lecanora polytropa*, *Acarospora* sp. 1, *Lecidea bayleyi*
3/20 *Candelariella vitellina*
1/20 *Lecidea bayleyi*.

Mosses

Pohlia nutans
Grimmia – very small

Vascular Plants

Agrostis sandwicensis
Cystopteris douglasii

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Muscidae	Unknown	Unknown		Unknown
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

At least one Muscidae, Coccinellidae, and Linyphiidae were observed during the plot survey. Three Scatopsidae, 6 Sciaridae, 1 Muscidae, and 1 Linyphiidae were captured in the pitfall trap.

4.1.13 Lichen Plot L13

GPS Coordinates and Elevation and Elevation
N19 49.575 W155 29.026

13,271 ft (4,045 m)

Topography
Slight slope (<1%)

Geology/Soils
Glacial rubble 3-10 cm (65%) and 10-20 cm rubble (10%) over deep ash, with glaciated lava flow (25%)

Lichens

Acarospora cf. depressa
Acarospora sp 1
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Pseudephebe miniuscula
Umbilicaria decussata

Undersurface of rocks
1/20 *Lecanora polytropa*

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Muscidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*coenosulus*	Stal	endemic

Abundance Notes

One Coccinellidae was observed during the plot survey. One Muscidae, 1 Sciaridae, and 2 *Nysius coenosulus* were captured in the pitfall trap.

4.1.14 Lichen Plot L14

GPS Coordinates and Elevation
N19 49.769 W155 28.961

13,339 ft (4,066 m)

Topography
Slight slope (<2%)

Geology/Soils
Glacial rubble 5-10 cm (80%) with larger rubble to 30 cm (20%) 25 cm deep over ash.

Lichens

Acarospora sp 1
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
All in very small quantity.

Undersurface of rocks
6/20 *Lecanora polytropa*

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Pscoptera	Unknown	Unknown	Unknown		Unknown

Abundance Notes

One Pscoptera was observed during the plot survey. Also numerous webs of sheetweb spiders were observed. The pitfall trap at this plot was not recovered due to snow cover.

4.1.15 Lichen Plot L15

GPS Coordinates and Elevation
N19 49.730 W155 28.721

13,359 ft (4,072 m)

Topography
Two areas of largely level ground (<2% slope), with a rock face.

Geology/Soils
The plot is on the margin of an andesite lava flow (60%) that drops about 2 m to rubble (30%) over ash, with open patches of ash (10%).

Lichens
Acarospora sp 1
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Pseudephebe miniuscula

Underside of rocks
1/20 *Lecanora polytropa*

Mosses
Pohlia nutans

Vascular Plants
No Vascular Plants.

Arthropods
No arthropods observed

4.1.16 Lichen Plot L16

GPS Coordinates and Elevation
N19 49.663 W155 28.732

13,396 ft (4,083 m)

Topography
The plot is on the margin of a lava flow that drops about 2 m to a level area.

Geology/Soils
Andesite flow (65%) and red ash (35%).

Lichens
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Lepraria 'incana' – heavily bleached.

Undersurface of rocks
No Lichens on undersides of rocks

Mosses
No Mosses

Vascular Plants
No Vascular Plants

Arthropods
No arthropods observed

4.1.17 Lichen Plot L17

GPS Coordinates and Elevation
N19 49.538 W155 29.010

13,290 ft (4,051 m)

Topography
Slope ~10%

Geology/Soils
Glaciated andesitic boulders (70%) and smaller rubble (30%) over ash.

Lichens

Acarospora sp 3
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Pseudephebe miniuscula
Umbilicaria decussata

Underside of rocks
No lichens on underside of rocks

Mosses

Pohlia nutans

Vascular Plants

Agrostis sandwicensis
Asplenium adiantum-nigrum

Arthropods

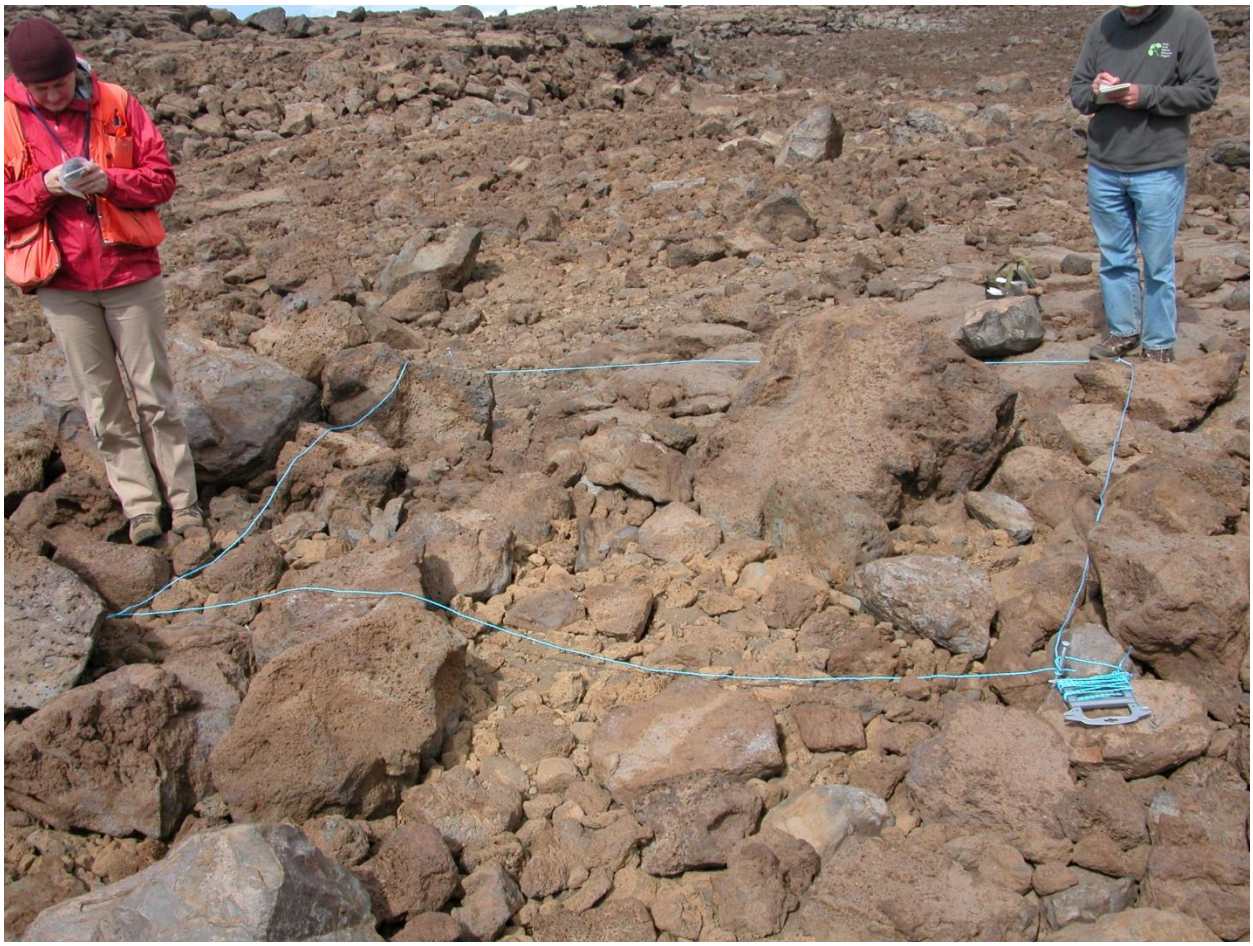
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Muscidae	Unknown	Unknown		Unknown
Diptera	Phoridae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

One Muscidae, one *Lycosa* cast skin, one Wekiu bug, and at least one Sciaridae were observed during the plot survey. Two Phoridae were captured in the pitfall trap.

4.1.18 Lichen Plot L18



GPS Coordinates and Elevation
N19 48.983 W155 28.762

13,175 ft (4,016 m)

Topography
Slope <5%

Geology/Soils
Glacial boulders (25%) and rubble (50%) over ash, some deep, some at the surface with glaciated pahoehoe lava flow (25%).

Lichens

Acarospora cf. depressa
Acarospora sp 1
Buellia cf. fuscoachracea
Candelariella vitellina
Caloplaca lithophila
Lecanora polytropa
Lecidea bayleyi
Unknown 2
Unknown 4

Undersurface of rocks:
1/20 *Buellia cf. fuscoachracea*
1/20 *Lecidea bayleyi*
1/20 *Caloplaca lithophila*
1/20 *Lecanora polytropa*
Lichens only on rocks with no ash immediately below

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Unknown	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Muscidae	Unknown	Unknown		Unknown

Abundance Notes

One Coccinellidae, 1 small spider, and 1 Muscidae were observed during the plot survey. No arthropods were captured in the pitfall trap.

4.2 AREAS OF RELATIVELY HIGH LICHEN AND MOSS DIVERSITY, AND UNIQUE COMMUNITIES

4.2.1 Lichen Plot LR01

GPS Coordinates and Elevation
N19 50.131 W155 28.960

13,104 ft (3,994 m)

Topography
Slope ~5%

Geology/Soils
Glacial rubble boulders

Lichens

Acarospora cf. depressa
Acarospora sp 3
Candelariella vitellina - sparse
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lepraria 'vouaxii'
Physcia dubia
Pseudophebe minuscula
Rhizocarpon geographicum
Umbilicaria decussata

Undersurface of rocks
1/20 *Acarospora* sp. 3, *Lecanora polytropa*.

Mosses

Pohlia nutans

Vascular Plants

Agrostis sandwicensis
Asplenium adiantum-nigrum
Deschampsia nubigena

Arthropods

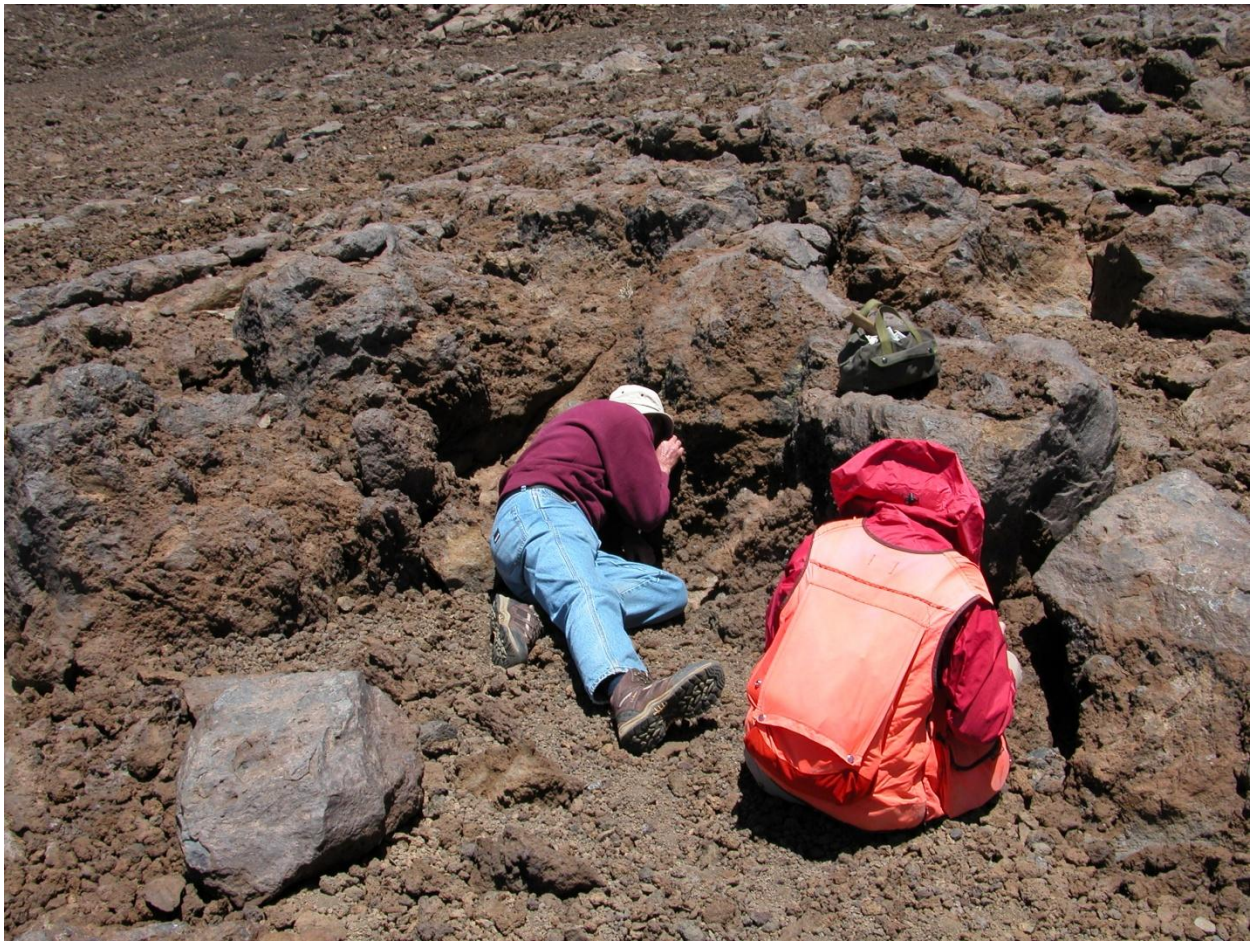
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Collembola	Entomobryidae	Unknown	Unknown		Unknown
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous

Abundance Notes

Three specimens of Collembola observed, only one specimen of each other species observed.

4.2.2 Lichen Plot LR02



GPS Coordinates and Elevation
N19 50.081 W155 29.086

13,013 ft (3,994 m)

Topography
Slight slope (<1%)

Geology/Soils
Glaciated lava flow. Reddish brown boulders (30%) and rubble in strip between two andesite borders. The rocks are quite porous with any small blisters. Solifluction lobes with smaller rocks to 5 cm, 10 cm or more deep over ash.

Lichens

Acarospora cf. depressa
Acarospora sp 1
Acarospora sp 3
Caloplaca lithophila
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Pseudophebe minuscula
Rhizocarpon geographicum
Umbilicaria decussata

Undersurface of rocks
7/20 *Lecanora polytropa*

Mosses

Andraea acutifolia
Grimmia
Pohlia nutans
Zygodon tetragonostomus

Vascular Plants

Agrostis sandwicensis
Asplenium adiantum-nigrum
Deschampsia nubigena

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

At least 1 Sciaridae was observed during the plot survey.

4.2.3 Lichen Plot LR03

GPS Coordinates and Elevation
N19 49.974 W155 29.069

13,104 ft (3,994 m)

Topography
Slope variable (<5%) with andesitic face.

Geology/Soils
Exposed andesitic rock face with large boulders (40%), and 3-6 cm rocks (60%).

Lichens

Acarospora cf. depressa
Acarospora sp 1
Buellia cf. fuscoachracea
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Pseudephebe miniuscula
Umbilicaria decussata
Umbilicaria 'deusta'

Underside of rocks
No lichens on underside of rocks

Mosses

Grimmia
Pohlia nutans

Vascular Plants

Asplenium adiantum-nigrum
Deschampsia nubigena

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Unknown	Unknown	Unknown		Unknown

Abundance Notes

Only one specimen was observed during the plot survey.

4.2.4 Lichen Plot LR04

GPS Coordinates and Elevation
N19 49.721 W155 28.762

13,362 ft (4,073 m)

Topography
Slope <2%

Geology/Soils
Andesite blocks on lava ridge (70%), with large blocky rubble (30%).

Lichens

Acarospora cf. depressa
Acarospora sp 1
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Pseudephebe miniuscula
Rhizocarpon geographicum
Umbilicaria decussata

Lepraria 'incana' on *Pohlia nutans* in crevice of adjacent andesite scarp

On smooth, glaciated pahoehoe lava fronts, slightly brown but otherwise similar to andesite (grey) but more blistered and uneven and does not ring as much when struck by hammer.

Candelariella vitellina – basal cracks
Lecanora polytropa in cracks often in moss
Lecidea bayleyi
Pseudephebe miniuscula
Rhizocarpon geographicum
Umbilicaria decussata

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Centipede	Unknown	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Geocoris*	*pallens*	Stål	non-indigenous
Heteroptera	Lygaeidae	*Nysius*	*sp.*		endemic

Abundance Notes

Only one specimen of each species was observed.

4.2.5 Lichen Plot LR05

GPS Coordinates and Elevation
N19 49.541 W155 29.011

13,279 ft (4,047 m)

Topography
Slope ~25%

Geology/Soils
Protected north facing wall of andesitic blocks with a number of brown blisters, and 20-50 cm rubble.

Lichens
Acarospora sp 1
Candelariella vitellina
Lecanora polytropa
Lecidea cf. maunakeae
Physcia dubia
Pseudephebe miniuscula
Umbilicaria decussata
Umbilicaria hirsuta

Undersurface of rocks
No lichens on underside of rocks

Mosses
Pohlia nutans

Vascular Plants
Asplenium adiantum-nigrum

Arthropods
No arthropods observed

4.2.6 Lichen Plot LR06

GPS Coordinates and Elevation
N19 48.001 W155 28.732

13,162 ft (4,012 m)

Topography
Slope

Geology/Soils
North facing glaciated pahoehoe lava flow bluff, with andesitic boulders and rubble.

Lichens

Acarospora sp 1
Acarospora sp 3
Buellia cf. fuscoachracea
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Physcia dubia
Pseudephebe miniscula
Rhizocarpon geographicum
Umbilicaria decussata

Underside of rocks
No lichens on underside of rocks

Mosses

Grimmia
Pohlia nutans

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Acari	Unknown	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

Only one specimen of each species was observed during the plot survey.

4.3 BOTANY PLOTS

4.3.1 Botany Plot B01

GPS Coordinates and Elevation
N19 50.210 W155 28.890

13,057 ft (3,980 m)

Topography
20% Slope

Geology/Soils
Glacial rubble with 15 to 40 cm rocks.

Lichens
Acarospora sp 1
Lecanora polytropa
Lecanora aff. 'subaurea'

Underside of Rocks::
1/20 *Lecanora polytropa*
4/20 *Lecanora aff. 'subaurea'*
1/20 *Acarospora sp 1*

Mosses
No Mosses

Vascular Plants
Deschampsia nubigena
Trisetum glomeratum

Arthropods

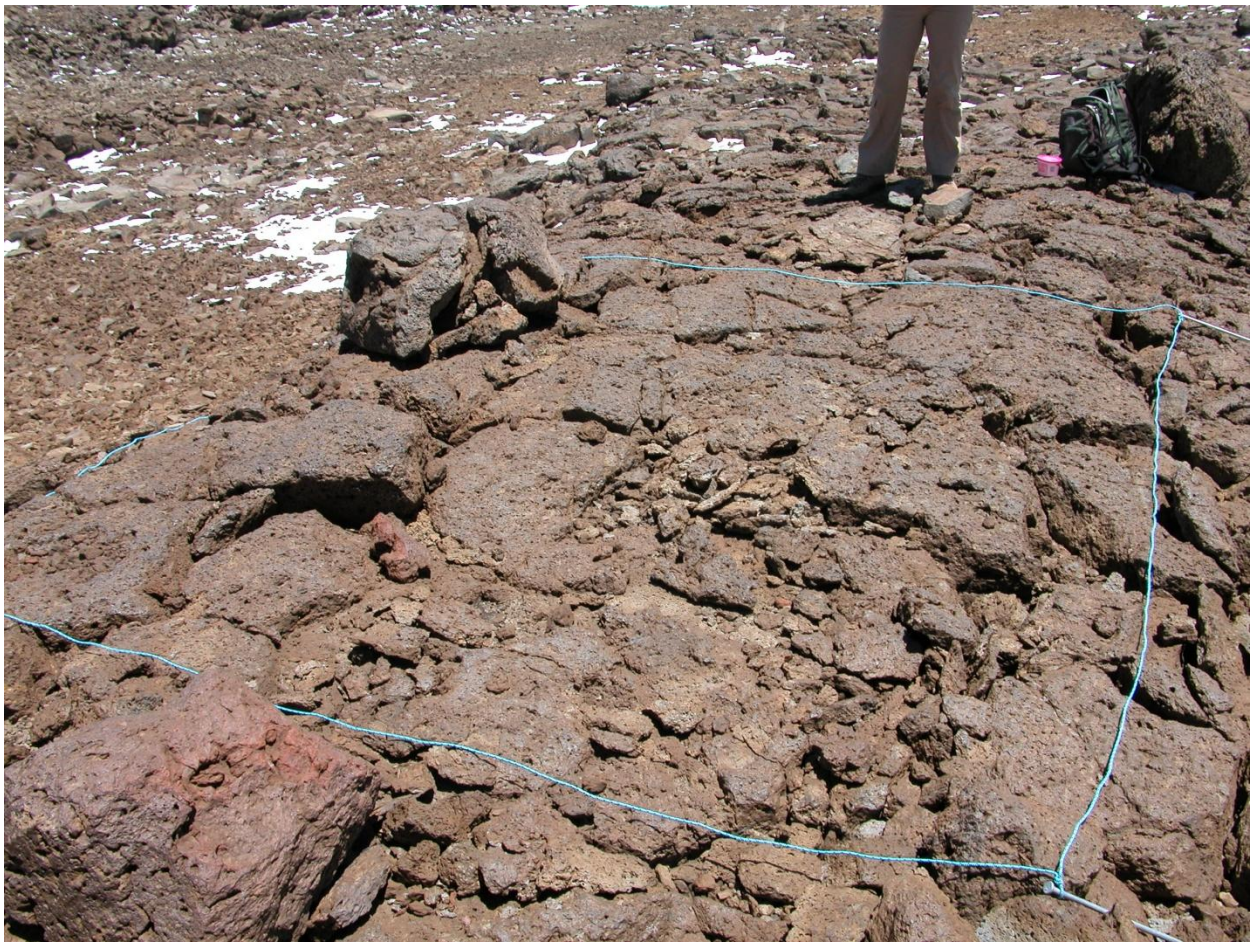
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Sciaridae	Unknown	Unknown	Unknown	

Abundance Notes

No arthropods were observed during the plot survey. Three Sciaridae were captured in the pitfall trap.

4.3.2 Botany Plot B02



GPS Coordinates and Elevation
N19 50.120 W155 28.683

13,021 ft (3,969 m)

Topography
2% Slope

Geology/Soils
Glaciated pahoehoe lava flow

Lichens

Acarospora cf. depressa
Buellia cf. fuscoachracea
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Pseudephebe miniscula
Umbillicaria decussata

Underside of Rocks:
6/20 *Acarospora cf. depressa*
2/20 *Buellia cf. fuscoachracea*
4/20 *Candelariella vitellina*
4/20 *Umbillicara desussata*
1/20 *Lecanora polytropa*
1/20 *Lecidea bayleyi*
1/20 *Pohlia nutans*

Mosses

Pohlia nutans
Free-living green algae

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*coenosulus*	Stal	endemic

Abundance Notes

One *Calliphora vomitoria*, two *Hippodemia convergens*, three *Nysius coenosulus*, one *Lycosa* and one *Lycosa* cast skin were observed during the plot survey. Three Sciaridae, two *Lycosa* and one *Hippodemia convergens* were captured in the pitfall trap.

4.3.3 Botany Plot B03

GPS Coordinates and Elevation
N19 50.027 W155 28.758

13,140 ft (4,005 m)

Topography
30% Slope

Geology/Soils
Glacial rubble with 30 to 40 cm rocks (25%, 10-30 cm andesitic rocks (45%) and cinder over ash (30%).

Lichens
Lecanora aff. 'subaurea'
Lepraria 'incana'
Lecanora polytropa

Underside of Rocks:
3/20 *Lecanora aff. 'subaurea'*
1/20 *Lepraria 'incana'*

Mosses
No Mosses

Vascular Plants
No Vascular Plants

Arthropods

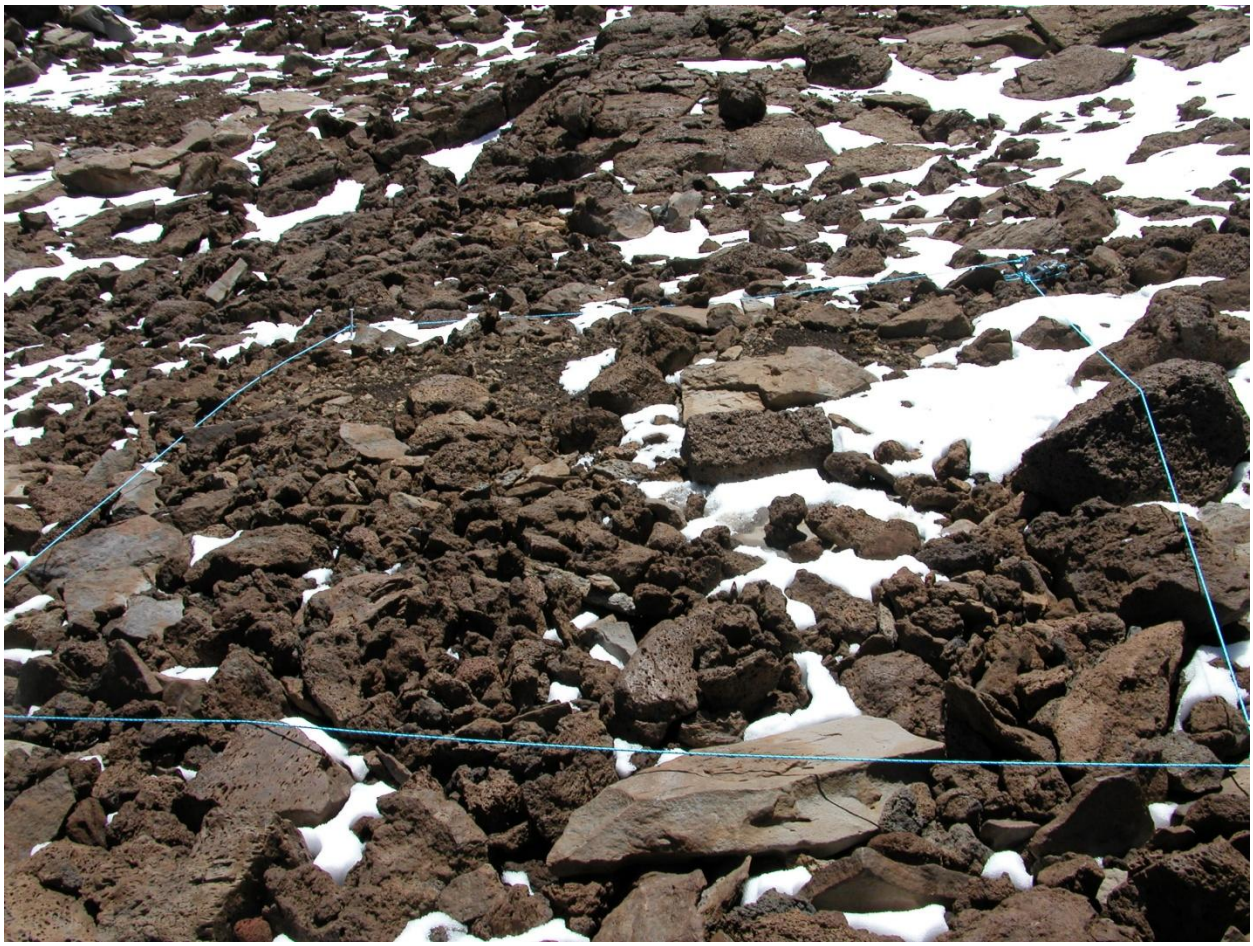
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*coenosulus*	Stal	endemic

Abundance Notes

One *Calliphora vomitoria*, one Linyphiidae, one *Nysius coenosulus*, *Hippodemia convergens*, and two Sciaridae were observed during the plot survey. One *Calliphora vomitoria* and five Sciaridae were captured in the pitfall trap.

4.3.4 Botany Plot B04



GPS Coordinates and Elevation
N19 49.941 W155 28.686

13,153ft (4,009 m)

Topography
Gradual slope

Geology/Soils
Glacial rubble with 15 to 30 cm boulders (20%), rocks to 15 cm (25%) 5 to 15 cm clinker (45%) and cinder over ash (10%).

Lichens

Acarospora cf. depressa
Acarospora sp. 1
Caloplaca lithophilla
Lecanora aff. 'subaurea'
Lecanora polytopa
Lecidea bayleyi

Underside of Rocks:
No lichens on underside of rocks

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Araneae	Unknown	Unknown	Unknown		Unknown
Diptera	Phoridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic
Homoptera	Aphidae	Unknown	Unknown		Unknown

Abundance Notes

One *Nysius wekiuicola* was observed during the plot survey. One Phoridae, one Aphidae, and one small red juvenile spider were captured in the pitfall trap.

4.3.5 Botany Plot B05

GPS Coordinates and Elevation
N19 49.971 W155 28.831

13,233 ft (4,033 m)

Topography
10 % Slope

Geology/Soils
Glacial rubble with large boulders (60%) and 10 to 30 cm clinker (40%)

Lichens

Acarospora sp. 1
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi

Underside of Rocks:
1/20 *Lecanora aff. 'subaurea'*

Mosses

Grimmia
Pohlia nutans

Vascular Plants

Asplenium trichomanes subsp. densum
Deschampsia nubigena

Arthropods

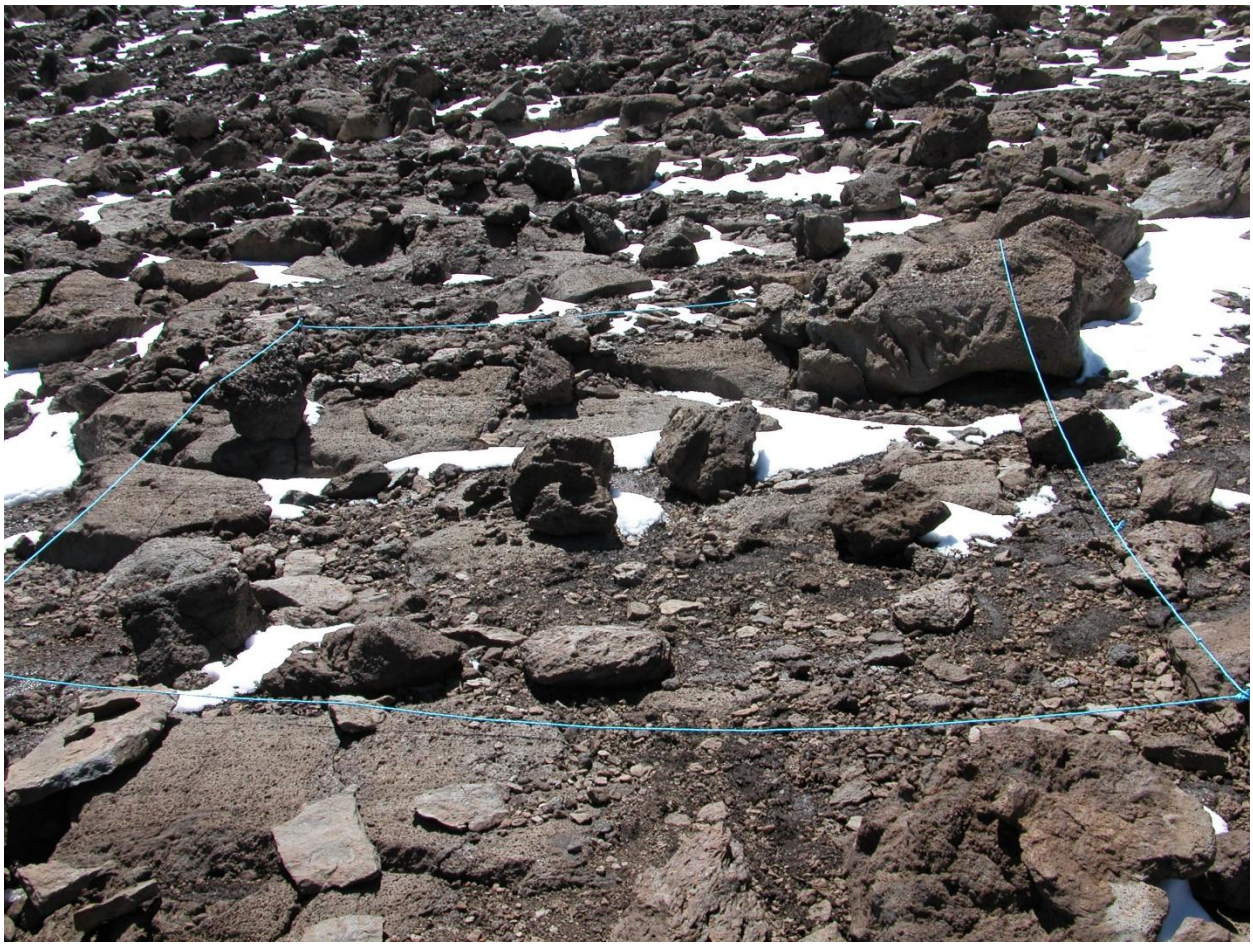
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Phoridae	Unknown	Unknown		Unknown
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

No arthropods were observed during the plot survey. Several specimens of Phoridae, Scatopsidae, and Sciaridae were captured in the pitfall trap.

4.3.6 Botany Plot B06



GPS Coordinates and Elevation
N19 49.877 W155 28.701

13,226 ft (4,031 m)

Topography
2% Slope

Geology/Soils
Glaciated pahoehoe lava flow (30%), 30 to 50 cm boulders (20%), 10 to 30 cm rocks (20%), and cinder over ash (30%).

Lichens

Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Physica dubia

Underside of rocks
No lichens on underside of rocks

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*kinbergi*	Usinger	endemic

Abundance Notes

One *Nysius wekiuicola* 2nd instar, one *Hippodemia convergens,* and three Linyphiidae were observed during the plot survey. One *Nysius kinbergii*, two *Hippodemia convergens*, and several Sciaridae were captured in the pitfall trap.

4.3.7 Botany Plot B07

GPS Coordinates and Elevation
N19 49.816 W155 28.754

13,303 ft (4,055 m)

Topography
10 % Slope

Geology/Soils
Glacial rubble with 15 to 30 cm boulders (20%), 5 to 15 cm rocks (60%), and cinder (20%).

Lichens
Acarospora sp. 1
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi

Underside of Rocks:
2/20 *Lecanora polytropa*
2/20 *Lecidea bayleyi*

Mosses
Pohlia nutans

Vascular Plants
No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Pscoptera	Unknown	Unknown	Unknown	Unknown	

Abundance Notes

One Pscoptera was observed during the plot survey. No arthropods were captured in the pitfall trap.

4.3.8 Botany Plot B08

GPS Coordinates and Elevation
N19 49.384 W155 28.519

13,447 ft (4,099 m)

Topography
Gradual Slope

Geology/Soils
20 to 60 cm boulders (20%), 10 to 20 cm rocks (30%), 5 to 10 cm rocks (15%) cinder (25%), and exposed ash (20%).

Lichens

Acarospora sp. 1
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi

Underside of Rocks:
2/20 *Lecanora aff. 'subaurea'*

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Muscidae	Unknown	Unknown		Unknown
Hymenoptera	Vespidae	*Vespula*	*pensylvanica*	Saissure	non-indigenous

Abundance Notes

One *Vespula* was observed during the plot survey. One Muscidae was captured in the pitfall trap.

4.3.9 Botany Plot B09

GPS Coordinates and Elevation
N19 49.329 W155 28.637

13,391 ft (4,082 m)

Topography
15% Slope

Geology/Soils
10 to 40 cm rocks (10%), cinder over ash (90%).

Lichens
Lecanora polytropa

Underside of rocks
No lichens on underside of rocks

Mosses
No Mosses

Vascular Plants
No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Hymenoptera	Vespidae	*Vespula*	*pensylvanica*	Saissure	non-indigenous

Abundance Notes

One Linyphiidae, one *Hippodemia convergens*, and one *Vespula* were observed during the plot survey. No arthropods were captured in the pitfall trap but a few *Calliphora vomitoria* were observed flying when retrieving the trap.

4.3.10 Botany Plot B10

GPS Coordinates and Elevation
N19 49.214 W155 28.518

13,352 ft (4,070 m)

Topography
30% Slope

Geology/Soils
Glaciated pahoehoe lava flow (60%), rocks to 10 cm (30%), exposed ash (10%).

Lichens
Acarospora cf. depressa
Caloplaca lithophilla
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Lepraria 'incana'

Underside of Rocks:
1/20 *Caloplaca lithophilla*
2/20 *Lecanora polytropa*

Mosses
Pohlia nutans

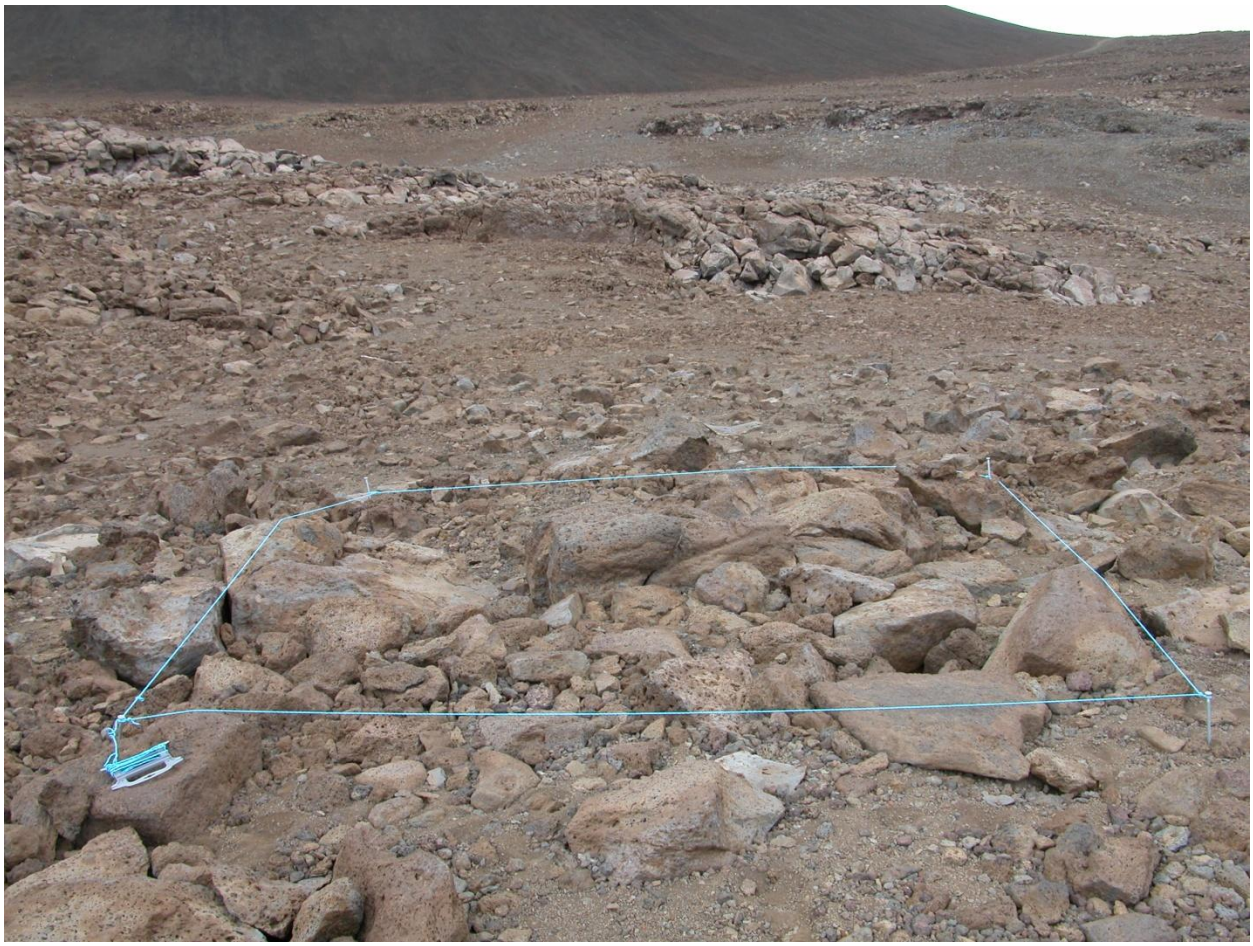
Vascular Plants
No Vascular Plants

Arthropods

List of Species
No arthropods observed

Abundance Notes
No arthropods were observed during the plot survey, nor captured in the pitfall trap.

4.3.11 Botany Plot B11



GPS Coordinates and Elevation
N19 49.071 W155 28.588

13,226 ft (4,031 m)

Topography
Gradual Slope

Geology/Soils
Glacial rubble with boulders (25%), rocks to 30 cm (15%), 10 to 30 cm rocks over ash (30%) and exposed ash (30%).

Lichens

Acarospora sp. 1
Caloplaca lithophila
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Lepraria 'incana'
Unknown 4

Underside of Rocks:
2/20 *Lecidea bayleyi*
2/20 *Lecanora polytropa*
1/20 *Acarospora sp. 1*

Mosses

No Mosses

Vascular Plants

Dead grasses not identifiable. No other evidence of Vascular Plants.
Asplenium adiantum-nigrum 5 m from edge of plot.

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Muscidae	Unknown	Unknown		Unknown

Abundance Notes

Lycosa cast skins under rocks were observed during the plot survey. One Muscidae was captured in the pitfall trap.

4.3.12 Botany Plot B12

GPS Coordinates and Elevation
N19 49.041 W155 28.467

13,226 ft (4,031 m)

Topography
10 % Slope

Geology/Soils
Andesitic boulders (30%), 15 to 40 cm glacial rubble (10%), 5 to 15 cm cinder (10%), smaller cinder to 5 cm (20%), and exposed ash (30%).

Lichens

Acarospora sp. 1
Lecanora polytropa
Lecidea bayleyi

Underside of rocks
No lichens on underside of rocks

Mosses

No Mosses

Vascular Plants

Trisetum glomeratum

Arthropods

List of Species

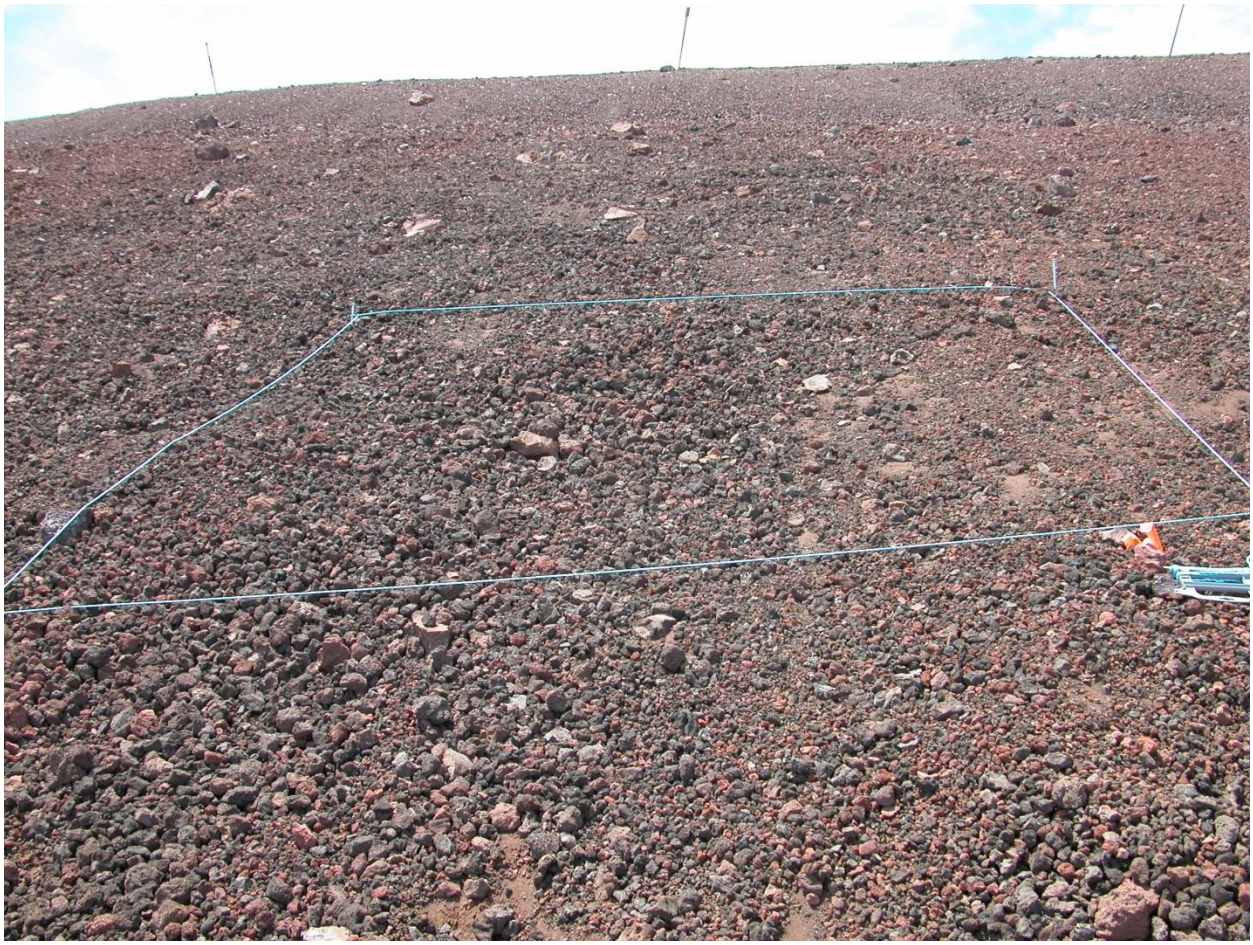
ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic

Abundance Notes

Lycosa cast skins under rocks were observed during the plot survey. No arthropods were captured in the pitfall trap.

4.4 ARTHROPOD PLOTS

4.4.1 Arthropod Plot A01



GPS Coordinates and Elevation
N19 49.671 W155 28.516

13,601 ft (4,146 m)

Topography
15% Slope

Geology/Soils
Cinder to 5 cm over ash (45%), exposed ash (30%), and deep pockets of small cinders (25%).

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic
Lepidoptera	Oecophoridae	*Agonopterix*	*ulicitella*	(Stainton)	non-indigenous

Abundance Notes

Calliphora vomitoria and *Agonopterix ulicitella* were observed during the plot survey. One 3rd instar, fifteen male and eight female (including two mating pairs) of *Nysius wekiuicola* were captured in the pitfall trap.

4.4.2 Arthropod Plot A02

GPS Coordinates and Elevation
N19 49.589 W155 28.630

13,586 ft (4,141 m)

Topography
10% Slope

Geology/Soils
40 cm boulder, with 5 cm deep cinder over exposed ash (100%).

Arthropods

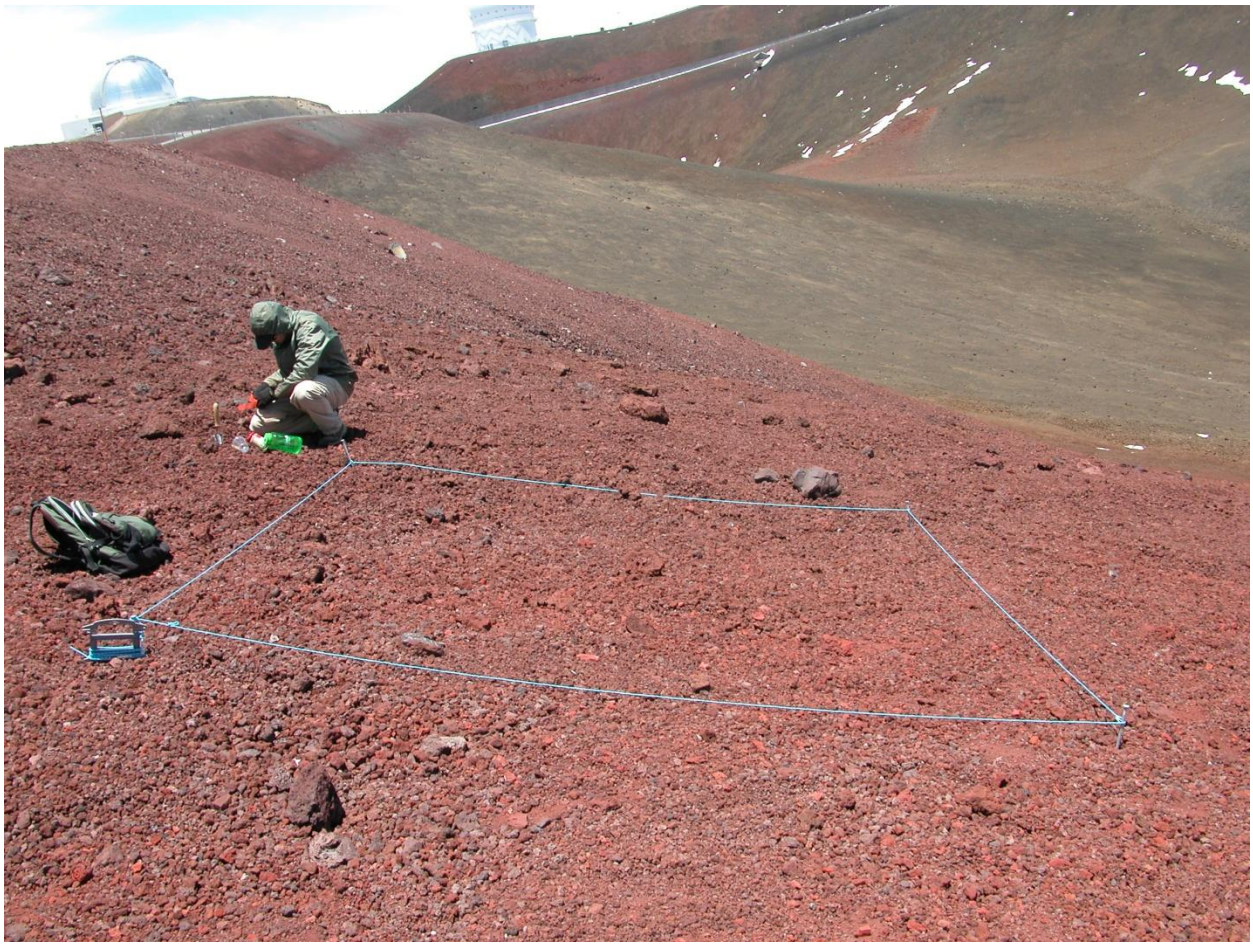
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

No arthropods were observed during the plot survey. One male *Nysius wekiuicola* and one Linyphiidae were captured in the pitfall trap.

4.4.3 Arthropod Plot A03



GPS Coordinates and Elevation
N19 49.552 W155 28.488

13,781 ft (4,200 m)

Topography
10% Slope

Geology/Soils
10 cm deep cinders over ash (60%), and sparse cinder over exposed ash (40%).

Arthropods

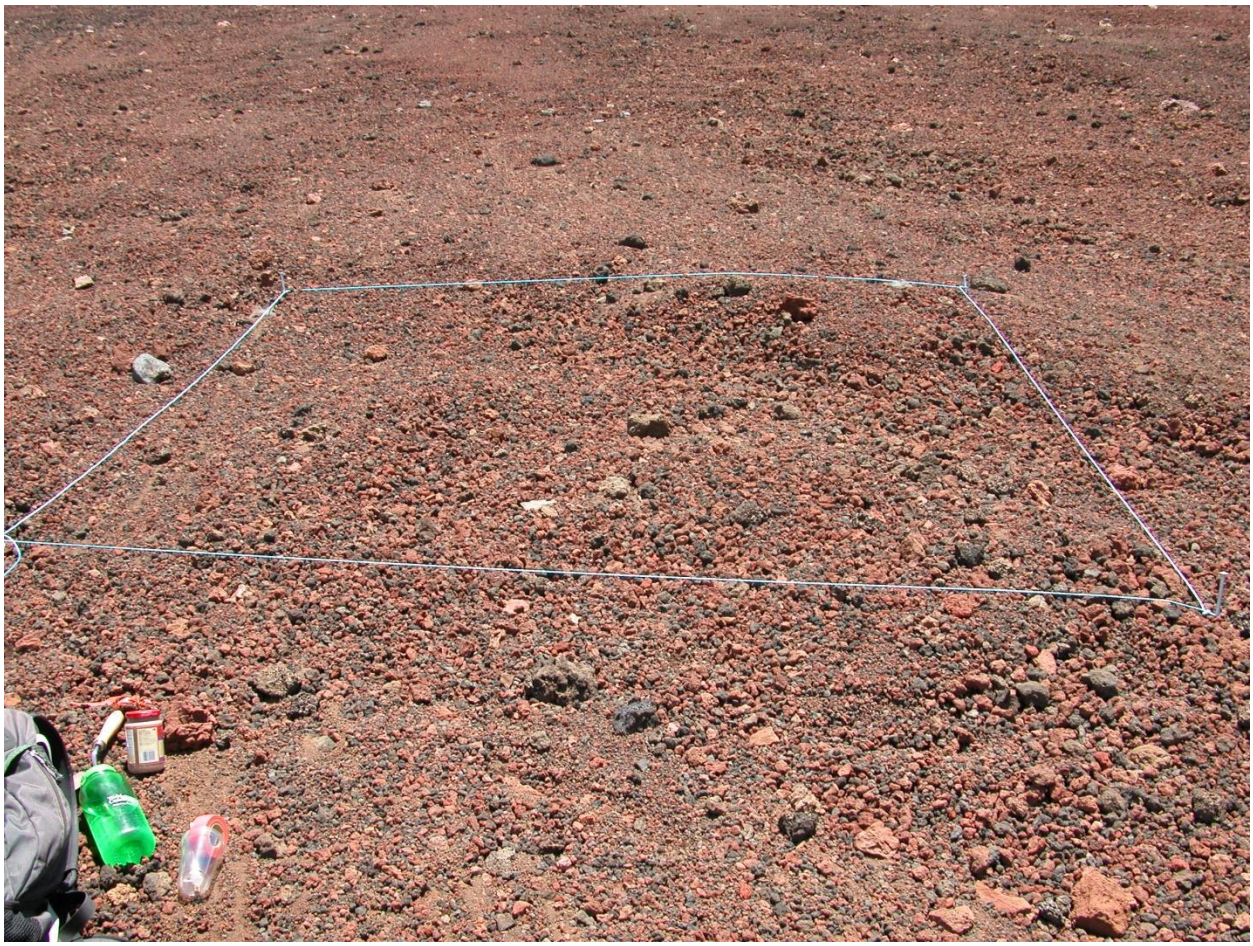
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

One Linyphiidae was observed during the plot survey. One Linyphiidae, one juvenile Linyphiidae, one *Calliphora vomitoria*, and three male and four female (including three mating pairs) of *Nysius wekiuicola* were captured in the pitfall trap.

4.4.4 Arthropod Plot A04



GPS Coordinates and Elevation
N19 49.438 W155 28.530

13,505 ft (4,116 m)

Topography
10 % Slope

Geology/Soils
10 cm deep cinders over ash (35%), exposed ash (65%)

Arthropods

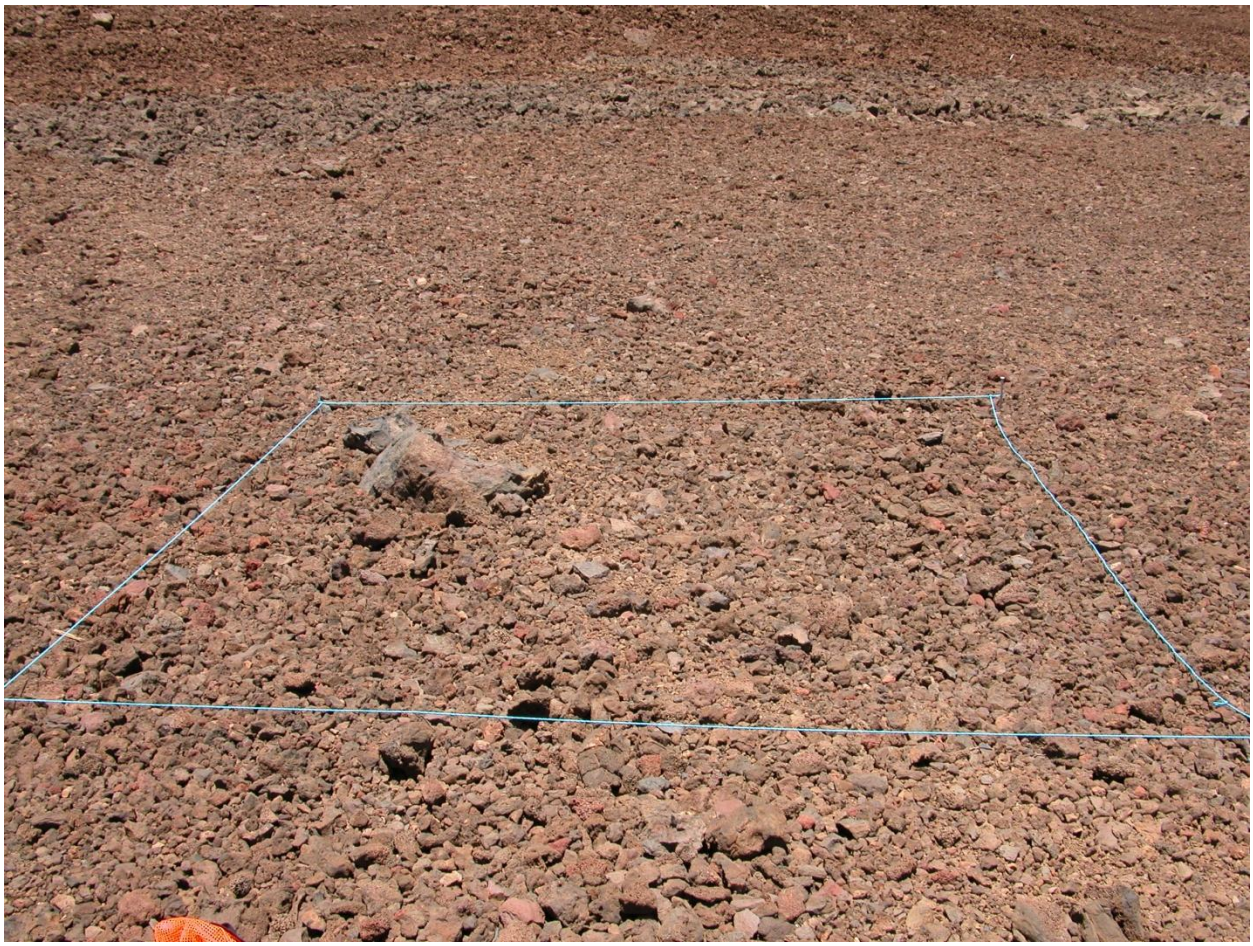
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

One Linyphiidae and two 3rd instar *Nysius wekiuicola* were observed during the plot survey. Nine 2nd instar, twenty-three 3rd instar, five 4th instar, thirty-eight male, and twenty-seven female (including twenty-one mating pairs) of *Nysius wekiuicola* were captured in the pitfall trap.

4.4.5 Arthropod Plot A05



GPS Coordinates and Elevation
N18 49.400 W155 28.721

13,483 ft (4,110 m)

Topography
Slope < 5%

Geology/Soils
One 1 m boulder, 10 to 30 cm rocks (20%), 5 to 10 cm rocks (10%), smaller cinder over ash (70%).

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Collembola	Entomobryidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

Four Linyphiidae were observed during the plot survey. Two 1st instar, three male and three female (including two mating pairs) of *Nysius wekiuicola* were captured in the pitfall trap.

4.4.6 Arthropod Plot A06

GPS Coordinates and Elevation
N19 49.437 W155 28.858

13,475 ft (4,107 m)

Topography
10% Slope

Geology/Soils
Glacial rubble with large 1 m boulders (10%), 10 to 30 cm rocks (15%), 5 to 10 cm cinder (35%), and cinders over ash (40%).

Arthropods

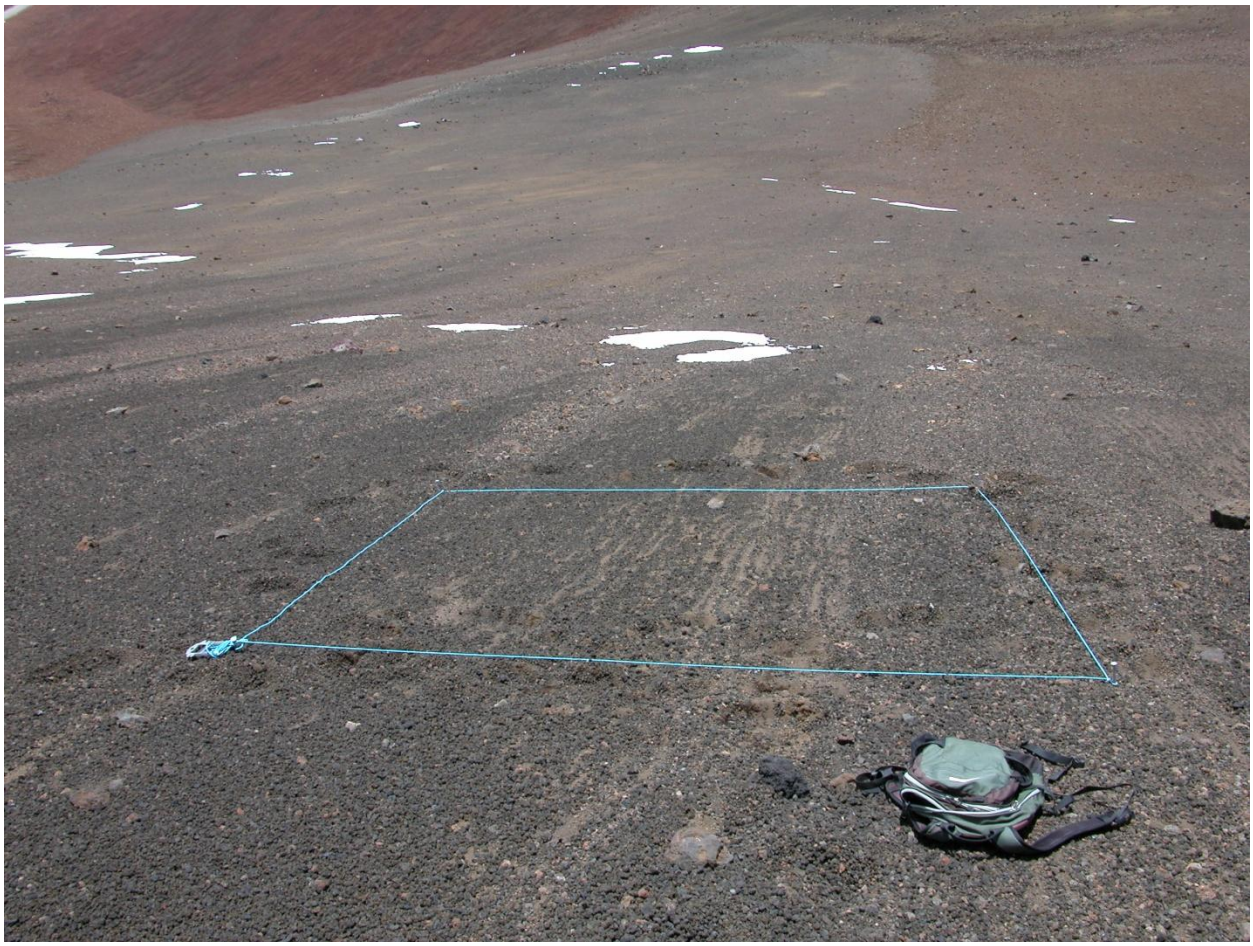
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

One 1st instar, two 3rd instar, and one male *Nysius wekiuicola* were captured in the ant trap, along with one one *Calliphora vomitoria* and one *Hippodemia convergens* were observed during the plot survey. Eleven 1st instar, nine 2nd instar, eight 3rd instar, seven male, six female *Nysius wekiuicola* (including 3 mating pairs), and two Sciaridae were captured in the pitfall trap.

4.4.7 Arthropod Plot A07



GPS Coordinates and Elevation
N19 49.384 W155 28.257

13,767 ft (4,196 m)

Topography
15% Slope

Geology/Soils
Small cinders over exposed ash (100%).

Arthropods

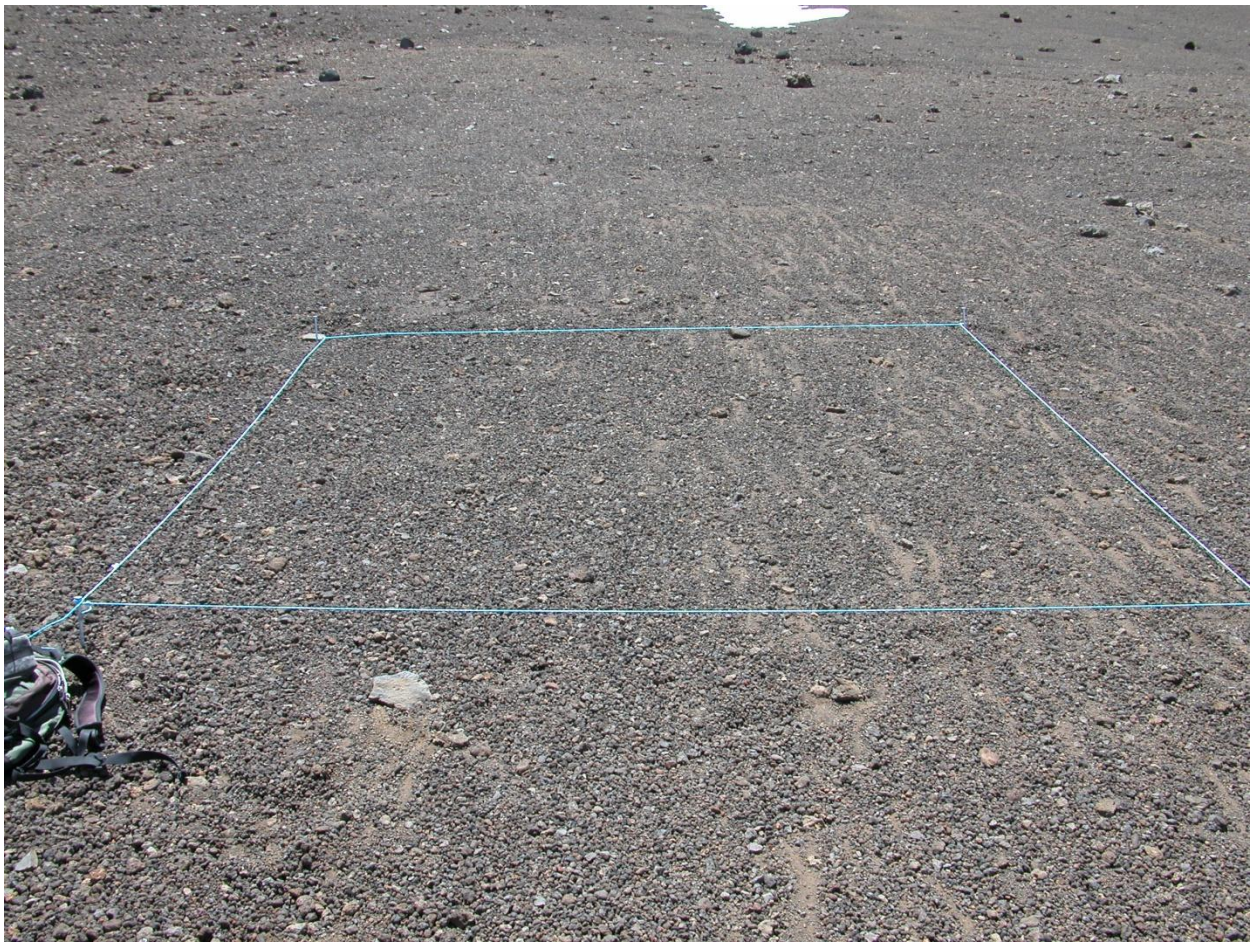
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Collembola	Entomobryidae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Geocoris*	*pallens*	Stål	non-indigenous
Heteroptera	Lygaeidae	Unknown	Unknown		Unknown

Abundance Notes

One *Hippodemia convergens* was observed during the plot survey. One Collembola was captured in the pitfall trap.

4.4.8 Arthropod Plot A08



GPS Coordinates and Elevation
N19 49.345 W155 28.443

13,482 ft (4,109 m)

Topography
10% Slope

Geology/Soils
Small cinders over exposed ash (100%).

Vascular Plants

Agrostis sandwicensis
Trisetum glomeratum

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous

Abundance Notes

One *Calliphora vomitoria* was observed during the plot survey. No arthropods were captured in the pitfall trap. One *Calliphora vomitoria* and one Linyphiidae were observed near the trap.

4.4.9 Arthropod Plot A09

GPS Coordinates and Elevation
N19 49.292 W155 28.733

13,547 ft (4,129 m)

Topography
10% Slope

Geology/Soils
10 to 20 cm rocks (10%), larger cinders to 10 cm (10%), smaller cinders over exposed ash (80%). Ash is dense, clay-like.

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Collembola	Entomobryidae	Unknown	Unknown		Unknown
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

One Calliphora vomitoria and one Linyphiidae were observed during the plot survey. Two 4th instar and one female *Nysius wekiuicola*, and one Collembola were captured in the pitfall trap. A 4th instar *Nysius wekiuicola* was observed on the Poliahu road nearby.

4.4.10 Arthropod Plot A10

GPS Coordinates and Elevation
N19 49.347 W155 28.277

13,788 ft (4,203 m)

Topography
10% Slope

Geology/Soils
Smaller cinders 2-5 cm deep over exposed ash (100%)

Arthropods

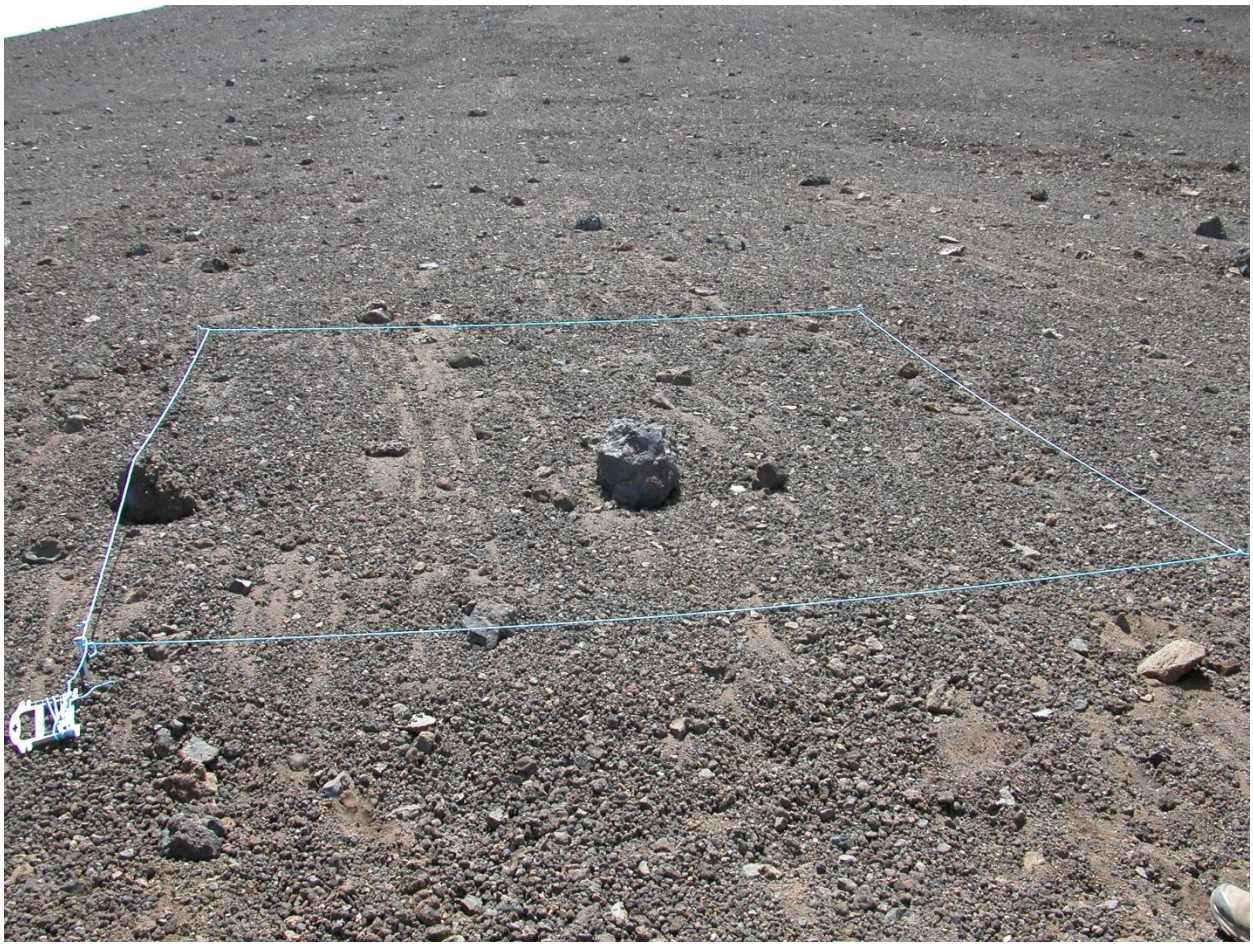
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

One *Calliphora vomitoria*, one *Hippodemia convergens*, and one Sciaridae were observed during the plot survey. Two juvenile Linyphiidae and one *Hippodemia convergens* were captured in the pitfall trap.

4.4.11 Arthropod Plot A11



GPS Coordinates and Elevation
N19 49.265 W155 438

13,440 ft (4,097 m)

Topography
10% Slope

Geology/Soils
Two 40 cm boulders and smaller cinders over exposed ash (100%).

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown

Abundance Notes

No arthropods were observed during the plot survey. One juvenile Linyphiidae was captured in the pitfall trap. The trap was dry when retrieved.

4.4.12 Arthropod Plot A12

GPS Coordinates and Elevation
N19 49.203 W155 28.689

13,343 ft (4,067 m)

Topography
Slope < 10%

Geology/Soils
10 to 20 cm rocks (5%), 5 to 10 cm cinders (10%), smaller cinders (55%), exposed ash (30%).

Arthropods

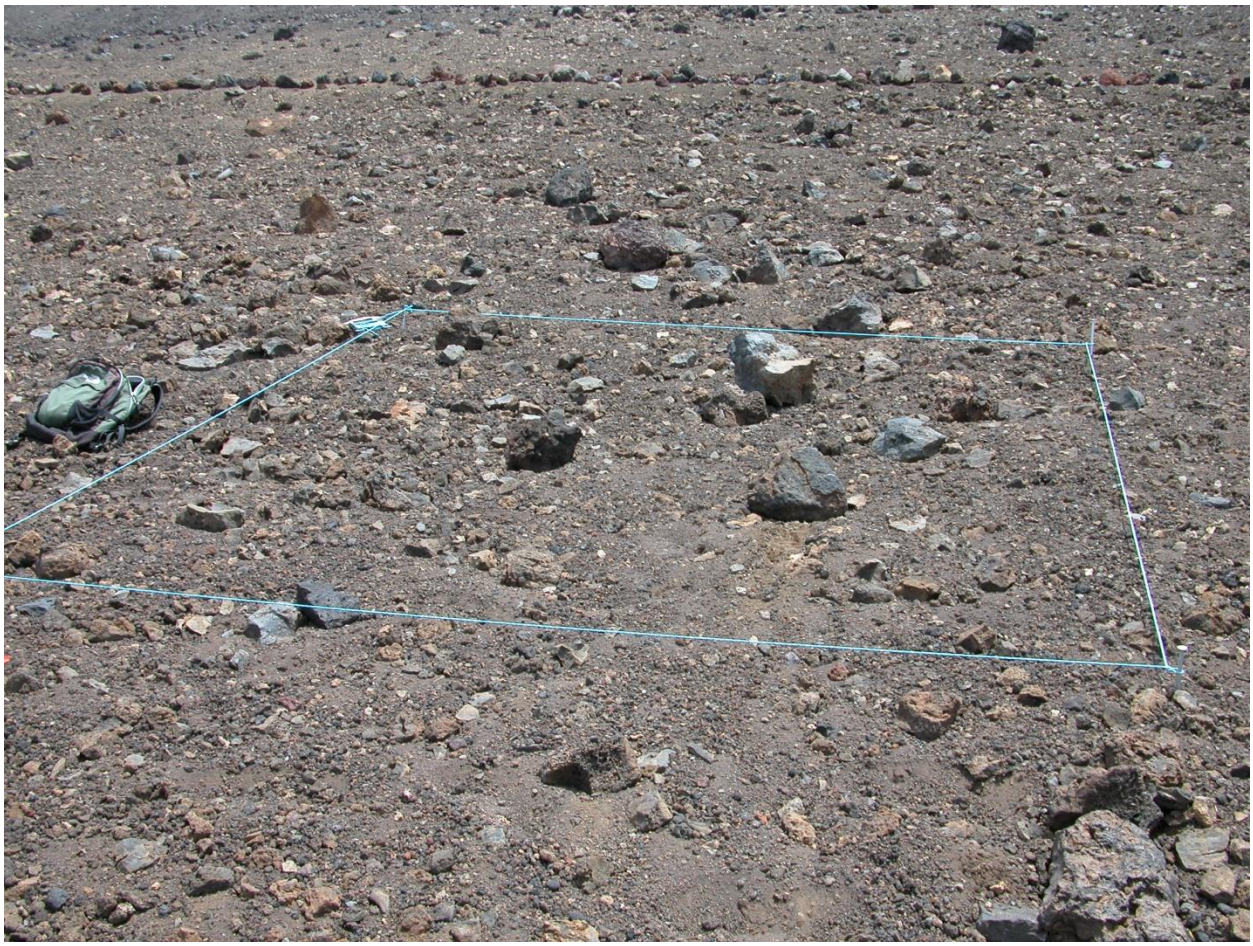
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Centipede	Unknown	Unknown	Unknown		Unknown
Collembola	Entomobryidae	Unknown	Unknown		Unknown
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

Two Collembola, three Linyphiidae, and one *Calliphora vomitoria* were observed during the plot survey. One female *Nysius wekiuicola*, one centipede, and twelve Collembola were captured in the pitfall trap.

4.4.13 Arthropod Plot A13



GPS Coordinates and Elevation
N19 49.325 W155 28.198

13,810 ft (4,209 m)

Topography
15% Slope

Geology/Soils
20 to 30 cm boulders (10%), 20 cm andesitic rocks (10%), smaller cinders over exposed ash (70%), and pockets of cinders (10%).

Arthropods

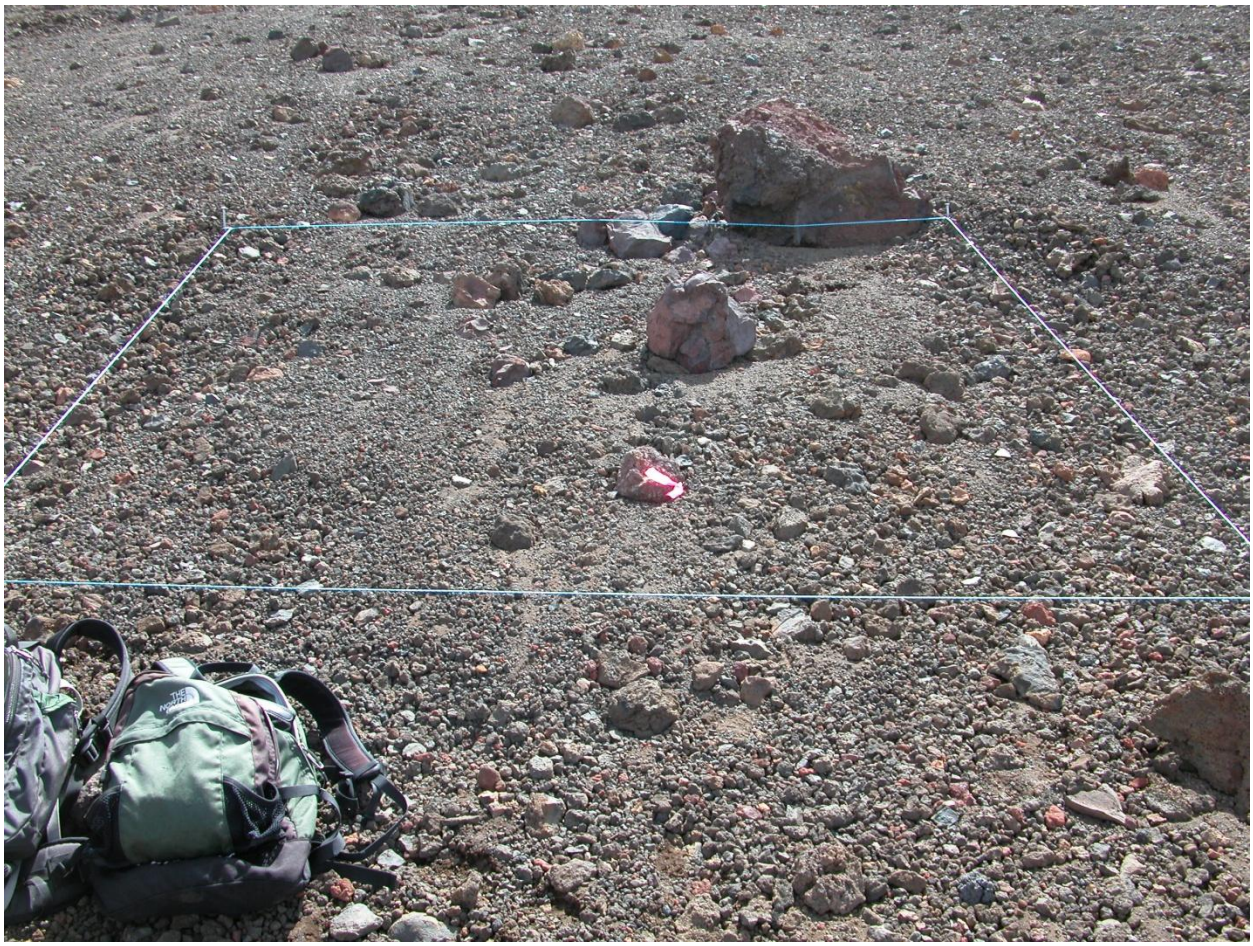
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

Two Linyphiidae were observed during the plot survey. Several Sciaridae were captured in the pitfall trap.

4.4.14 Arthropod Plot A14



GPS Coordinates and Elevation
N19 49.147 W155 28.404

13,412 ft (4,088 m)

Topography
Slope < 5%

Geology/Soils
10 to 30 cm rocks (15%), smaller cinders over exposed ash (50%), exposed ash and cinders (35%).

Arthropods

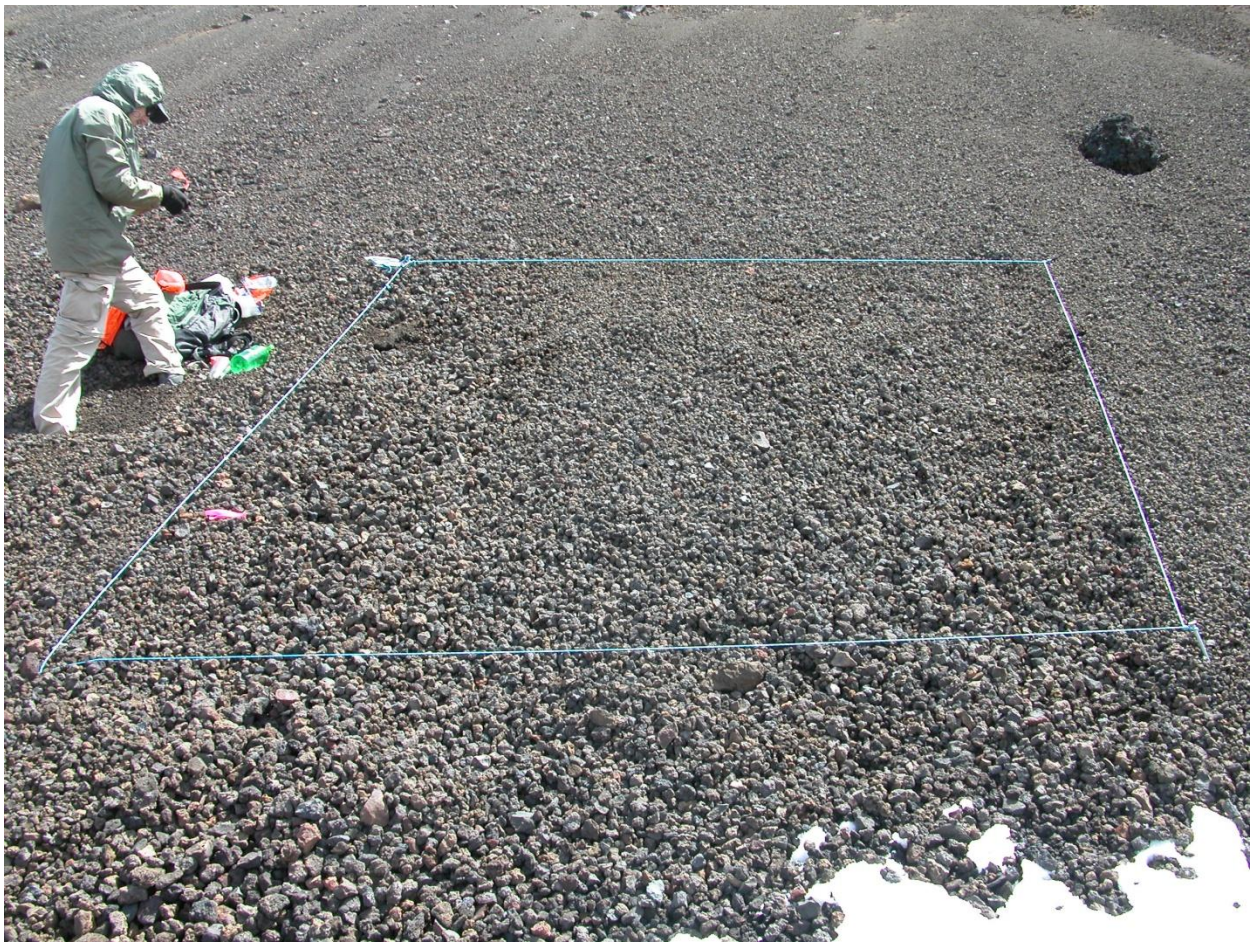
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Unknown	Unknown	Unknown		Unknown
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous

Abundance Notes

One *Calliphora vomitoria* was observed during the plot survey. One spider was collected at the plot when retrieving the pitfall trap. No arthropods were captured in the trap.

4.4.15 Arthropod Plot A15



GPS Coordinates and Elevation
N19 49.031 W155 28.164

13,514 ft (4,119 m)

Topography
15% Slope

Geology/Soils
Loose small cinders 15 to 25 cm deep over ash (100%).

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

Two *Calliphora vomitoria* were observed during the plot survey. One 2nd instar, one 3rd instar, three male and two female (including one mating pair) *Nysius wekiuicola*, and two Sciaridae were captured in the pitfall trap.

4.4.16 Arthropod Plot A16

GPS Coordinates and Elevation
N19 48.997 W155 28.387

13,310 ft (4,057 m)

Topography
5% Slope

Geology/Soils
10 to 20 cm rocks (10%), smaller cinders 25 cm deep (60%), and cinders over exposed ash (40%).

Arthropods

List of Species

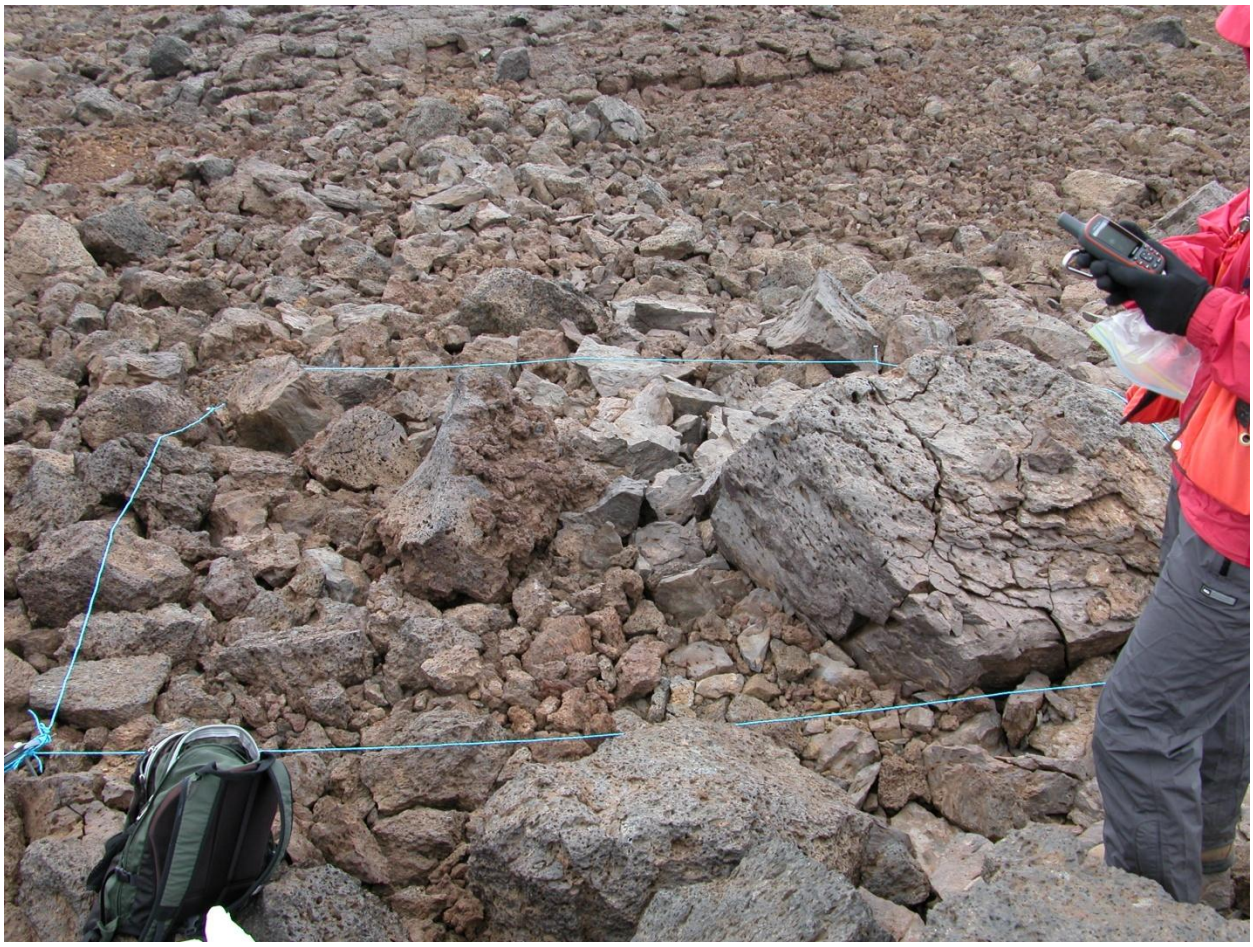
ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Calliphoridae	*Calliphora*	*vomitoria*	(Linnaeus)	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*wekiuicola*	Ashlock and Gagne	endemic

Abundance Notes

One Calliphora vomitoria, one 2nd instar, and one 3rd instar *Nysius wekiuicola* were observed during the plot survey. One 1st instar, thirty-two 2nd instar, eighty-one 3rd instar, twenty 4th instar, thirty male, and fourteen female (including six mating pairs) *Nysius wekiuicola*, one *Hippodemia convergens*, and several Sciaridae were captured in the pitfall trap.

4.5 FOOTPRINT PLOTS

4.5.1 Footprint Plot F01



GPS Coordinates and Elevation
N19 49.958 W155 28.875

13,237 ft (4,035 m)

Topography
10% Slope

Geology/Soils
Blocky glaciated pahoehoe lava flow and 10 cm rubble (70%) and smaller rubble over ash (30%). Glacial boulders, with some ice shatter, on glaciated lava flow.

Lichens

Acarospora sp 1
Acarospora sp 3
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi

Undersides of rocks
5/20 *Lecanora polytropa*
2/20 *Lecanora aff. 'subaurea', Lecidea bayleyi*

In surrounding area
Pseudephebe miniscula
Umbilicaria decussata

Mosses

Pohlia nutans

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Heteroptera	Lygaeidae	*Nysius*	*coenosulus*	Stal	endemic

Abundance Notes

One *Hippodemia convergens* and one *Nysius coenosul*us were observed during the plot survey. One Sciaridae was captured in the pitfall trap.

4.5.2 Footprint Plot F02

GPS Coordinates and Elevation
N19 49.950 W155 28.891

13,220 ft (4,030 m)

Topography
Slope variable

Geology/Soils
Collapsed pahoehoe lava tube with large overhand, glaciated lava tube (35%), large 50 to 70 cm blocks (30%), and smaller rubble to 10 cm (35%).

Lichens

Caloplaca lithophila
Candelariella vitellina
Lecanora aff. subaurea
Lecanora polytropa
Lecidea bayleyi
Lecidea cf. maunakeae
Lepraria vouaxii

Underside of rocks
2/10 *Lecanora aff. 'subaurea'*
1/20 *Lecanora polytropa*
1/20 *Lecidea bayleyi*

Mosses

Andraea acutifolia
Grimmia
Pohlia nutans

Vascular Plants

Asplenium adiantum-nigrum

Arthropods

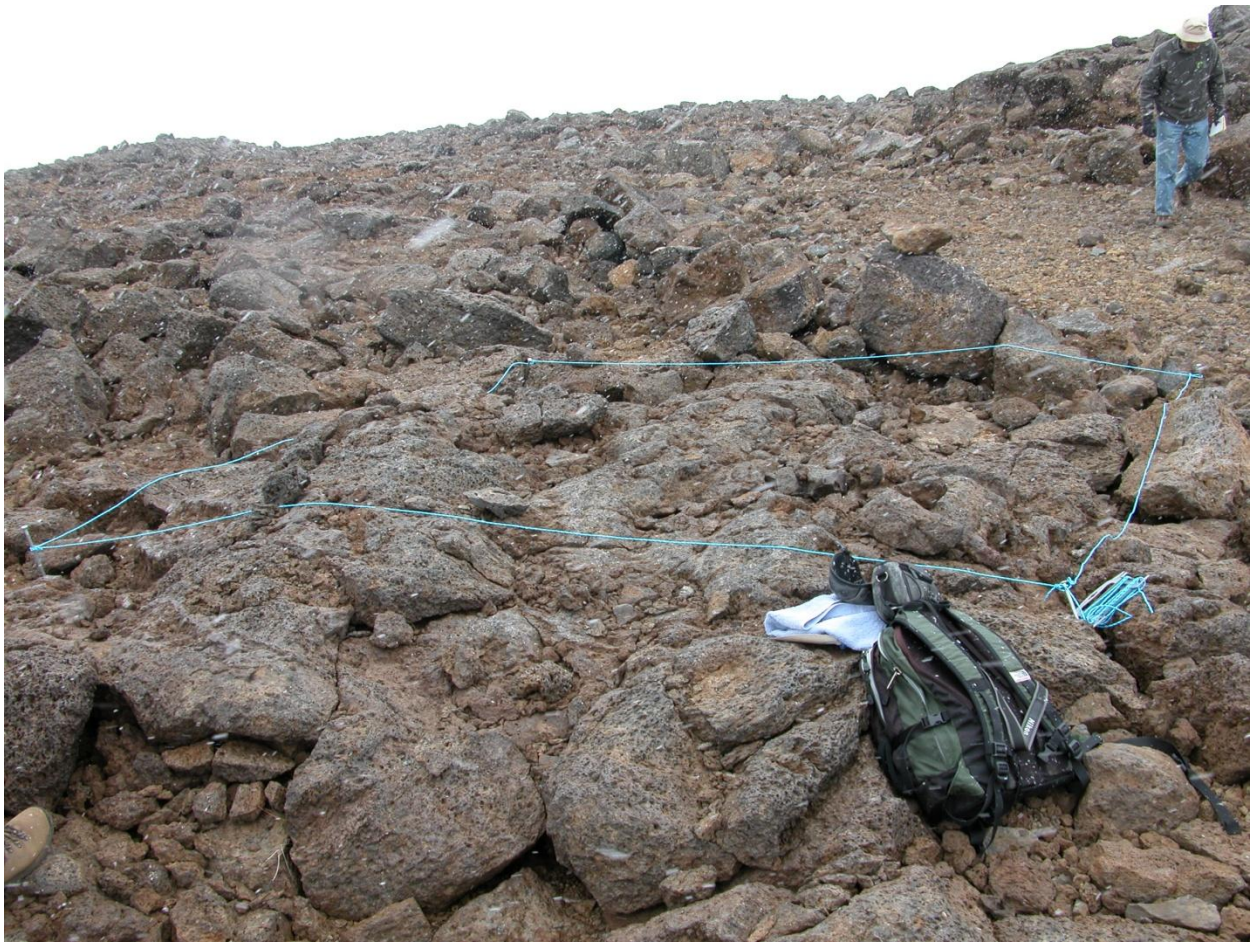
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Linyphiidae	Unknown	Unknown		Unknown
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Coleoptera	Coccinellidae	*Hippodemia*	*convergens*	Gurein-Meneville	non-indigenous
Diptera	Sciaridae	Unknown	Unknown		Unknown
Lepidoptera	Oecophoridae	*Agonopterix*	*ulicitella*	(Stainton)	non-indigenous

Abundance Notes

One *Lycosa* cast skin and one Linyphiidae, one *Hippodemia convergens*, and A*gonopterix ulicitella* were observed during the plot survey. Six Sciaridae were captured in the pitfall trap.

4.5.3 Footprint Plot F03



GPS Coordinates and Elevation
N19 49.960 W155 28.897

13,221 ft (4,030 m)

Topography
Slope < 10%

Geology/Soils
Glaciated pahoehoe lava flow (70%) with pockets of smaller rubble and ash (30%).

Lichens

Acarospora sp 1
Candelariella vitellina
Lecanora polytropa
Lecidea bayleyi
Lepraria 'vouaxii'

Underside of rocks: 10%
2/20 *Acarospora sp 1*, *Lecidea bayleyi*, *Lecanora polytropa.*

Mosses

No Mosses

Vascular Plants

No Vascular Plants

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Diptera	Scatopsidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown
Diptera	Unknown	Unknown	Unknown		Unknown
Lepidoptera	Oecophoridae	*Agonopterix*	*ulicitella*	(Stainton)	non-indigenous

Abundance Notes

Seven Diptera pupal cases (empty) and one *Agonopterix ulicitella* were observed during the plot survey. Four Sciaridae and 3 Scatopsidae were captured in the pitfall trap.

4.5.4 Footprint Plot F04

GPS Coordinates and Elevation
N19 49.966 W155 28.890

13,234 ft (4,034 m)

Topography
10% Slope

Geology/Soils
Glaciated pahoehoe lava flow 60%, rubble (35%), ash with rubble (5%)

Lichens

Acarospora sp 3
Candelariella vitellina
Lecanora polytropa
Lecidea baileyi

Undersurface of rocks:
3/20 *Acarospora sp 1*
1/20 *Lecanora polytropa, Umbilicaria decussata*

Immediate area
Pseudephebe miniscula
Umbilicaria decussata

Mosses

Pohlia nutans

Vascular Plants

No Vascular Plants

Arthropods

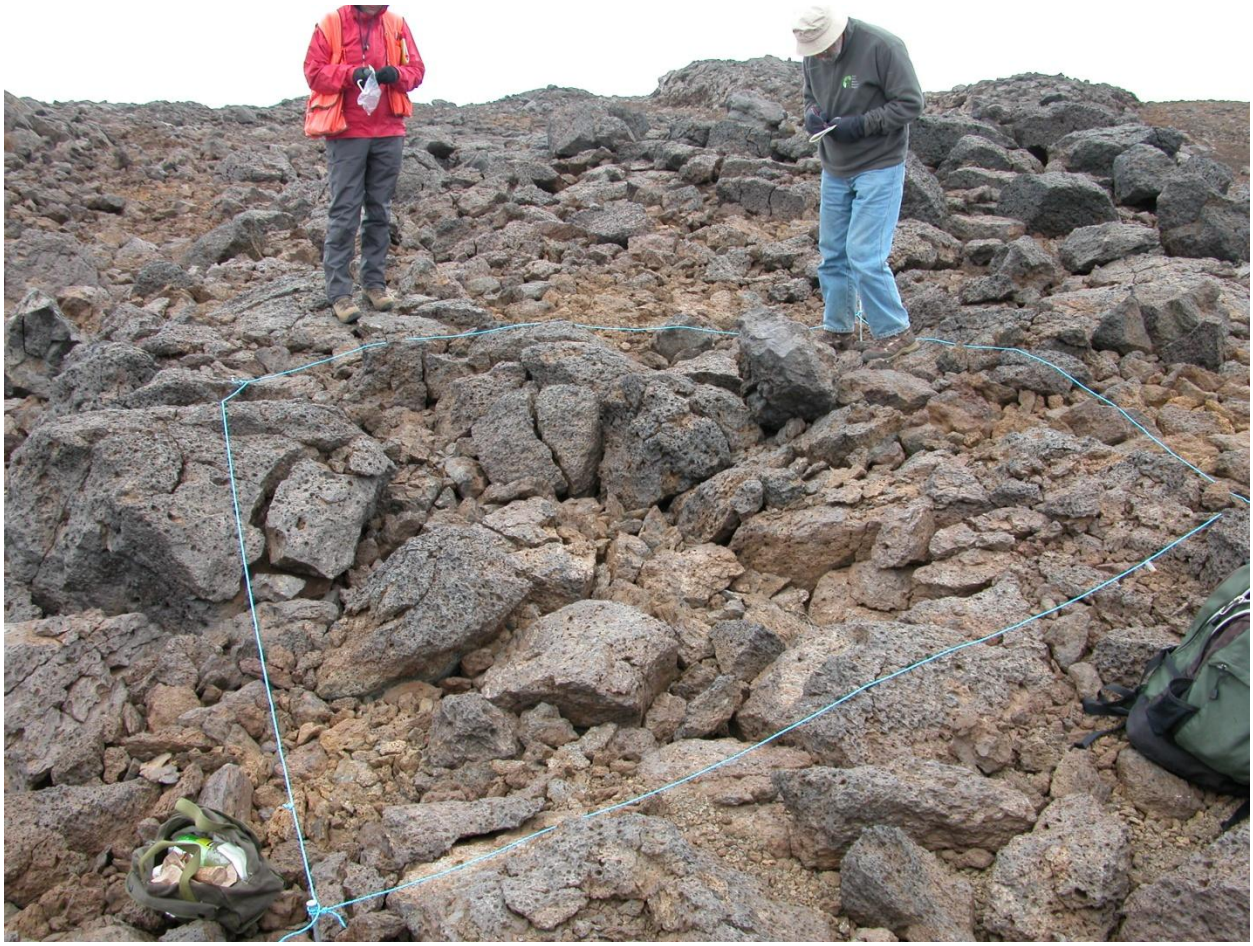
List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Collembola	Entomobryidae	Unknown	Unknown		Unknown
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

One Collembola was observed during the plot survey. One *Lycosa* and 3 Sciaridae were captured in the pitfall trap.

4.5.5 Footprint Plot F05



GPS Coordinates and Elevation
N19 49.949 W155 28.876

13,235 ft (4,034 m)

Topography
Gradual Slope variable

Geology/Soils
Large glacial rubble (30%) and 10 to 30 cm rubble (50%) over glaciated pahoehoe lava flow with smaller rubble to 10 cm over ash (20%). This was the best cave that we saw the whole trip.

Lichens

Acarospora sp 1
Buellia cf. fuscoachracea
Candelariella vitellina
Lecanora aff. 'subaurea'
Lecanora polytropa
Lecidea bayleyi
Lepraria 'vouaxii'
Pseudepheba minuscula
Umbilicaria decussata

Undersurface of rocks:
1/20 *Lecanora polytropa*

Mosses

Pohlia nutans
Zygodon tetragonostomus

Vascular Plants

Hypochaeris radicata

Arthropods

List of Species

ORDER	FAMILY	GENUS	SPECIES	AUTHOR	STATUS
Araneae	Lycosidae	*Lycosa*	*hawaiiensis*	Simon	endemic
Diptera	Sciaridae	Unknown	Unknown		Unknown

Abundance Notes

One *Lycosa* and one Sciaridae were captured in the pitfall trap. Trap was frozen at recovery.

5.0 ANALYSIS AND DISCUSSION

5.1 LICHEN STRATUM

5.1.1 Eighteen Random Plots

Lichens

The lichen vegetation of the summit of Mauna Kea within the Lichen stratum area comprises 22 species, plus one commensal, all of which have a cover value of much less than one percent over the study area. There is only one community, the foliose macrolichen *Umbilicaria decussata/Pseudephebe miniscula/Rhizocarpon geographicum* assemblage, which has a significant cover but occurs in a very specific situation highly limited in its distribution. Where it occurs, the community covers over 50% of the essentially vertical surface of andesite rock faces with a north to north-east aspect. However, suitable rock faces are few and far between. The remainder of the lichen flora consists of crustose species scattered throughout the study area on various substrates other than the shifting ash and cinder.

A number of species are present which cannot be determined beyond the genus level and three species cannot even be placed in a genus with certainty. The uncertainty is because the reproductive structures are either absent or not in adequate condition for determination. Vegetative characters are unreliable due to modifications to protect against the severe environmental conditions of the Mauna Kea summit area. The nature of the flora will only be understood after studying the flora at lower elevations on the mountain where lichens can be found in conditions of less environmental stress.

The most common lichen species in the Mauna Kea crustose flora (defined by presence on the highest number of plots) is *Lecanora polytropa* which is widely dispersed throughout the study area and was found on 100% of the plots. Other common species include *Lecidea baileyi* which appeared on 83% of the plots, *Candelariella vitellina* (72% of the plots), and *Acarospora* sp. 1 and *Lecanora 'subaurea'* (67% of the plots) (Table 2). The remaining eighteen species were found on 33% or fewer of the plots. Seven lichen species occurred on only one of the eighteen plots (*Buellia* sp. 1, *Carbonea vitellinaria*, *Umbilicaria deusta*, *Umbilicaria hirsuta*, Unknown 1, Unknown 2, and Unknown 4).

There was an average of 6.7 lichen species on the eighteen Lichen stratum plots (95% CI (2.8, 14.4)). The highest number of species found on any of the plots was twelve (2 plots), and three plots had only one species (Table 2).

Although most of the lichens are on the surface of rocks or in protected situations, four species (*Acarospora* sp 3, *Buellia* sp. 1, *Lecanora aff. 'subaurea'*, and *L. polytropa*) are found on the undersurface of loose rocks (generally under rocks 10-20 cm diam.) or on the surface of rocks underlying other rocks up to depths of approximately 10 cm. These subsurface occurrences were recorded in fifteen (83%) of the study sites. Though some lichens are known to prefer crevices and receded habitats, it is unusual that the species recorded here would occur in such a situation. However, in this very severe environment, the increased humidity under the rocks protected from

Table 2. Lichen species presence on eighteen plots within the Lichen Habitat stratum.

Name	L01	L02	L03	L04	L05	L06	L07	L08	L09	L10	L11	L12	L13	L14	L15	L16	L17	L18	# Plots Present	% Plots Present
Acarospora cf. depressa		x							x		x		x					x	5	28%
Acarospora sp 3	x	x	x				x				x						x		6	33%
Acarospora sp. 1	x		x				x	x	x	x	x	x	x	x	x			x	12	67%
Buellia cf. fuscochracea			x									x						x	3	17%
Buellia sp 1		x																	1	6%
Caloplaca lithophila											x							x	2	11%
Candelariella vitellina	x		x				x	x	x	x	x	x	x		x	x	x	x	13	72%
Carbonea vitellinaria												x							1	6%
Lecanora 'subaurea'	x	x	x				x	x	x	x	x	x	x	x			x		12	67%
Lecanora polytropa	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	18	100%
Lecidea baileyi	x	x	x				x	x	x	x	x	x	x	x	x	x	x	x	15	83%
Lecidea cf. maunakeae		x	x							x		x				x	x		6	33%
Lepraria 'incana'								x				x				x			3	17%
Lepraria 'vouaxii'		x					x												2	11%
Physcia dubia																			0	0%
Pseudephebe miniscula	x						x	x				x	x		x		x		7	39%
Rhizocarpon geographicum	x		x					x				x							4	22%
Umbilicaria decussata	x	x						x				x	x				x		6	33%
Umbilicaria deusta	x																		1	6%
Umbilicaria hirsuta	x																		1	6%
Unknown 1	x																		1	6%
Unknown 2																		x	1	6%
Unknown 4																		x	1	6%
Underside of Rocks	x	x	x	x	x	x	x	x	x		x	x	x	x	x			x	15	83%

sun and wind provides a suitable habitat for survival. In the case of *Umbilicaria decussata*, the rocks on which the lichens were found had probably been disturbed since this species requires full exposure for growth.

***Umbilicaria* lichen encrusting a rock within the Lichen stratum.**

Botanical Resources

Mosses are the only bryophytes present in the study area occurring at 67% of the study sites. *Pohlia nutans* is the most common species and is present throughout the area. The only other moss species observed on the eighteen Lichen stratum plots was *Grimmia* sp. which occurred on one plot. The mosses are most well developed in the small caves and over ash deposits in crevices where drainage is impeded. None of the mosses found bore sporophytes.

Other botanical resources include two grasses and ferns (Table 3). Two grass species were found on the eighteen Lichen stratum plots, *Agrostis sandwicensis*, which was found on four (22%) of the plots and *Deschampsia nubigena* which occurred on three (17%) of the plots. Two ferns were observed, *Asplenium adiantum-nigrum* and *Cystopteris douglasii*, both of which occurred on only one plot (6%).

Table 3. Mosses, Grasses, Ferns, Vascular Plants, and Algae presence on eighteen plots within the Lichen Habitat stratum

Name	L01	L02	L03	L04	L05	L06	L07	L08	L09	L10	L11	L12	L13	L14	L15	L16	L17	L18	# Plots Present	% Plots Present
Grimmia sp.												x							1	6%
Pohlia nutans	x	x	x	x		x	x	x	x	x		x			x		x		12	67%
Agrostis sandwicensis				x					x			x					x		4	22%
Deschampsia nubigena		x		x			x												3	17%
Asplenium adiantum-nigrum																	x		1	6%
Cystopteris douglasii												x							1	6%

Arthropods

The first reports of insects at high elevations on the Island of Hawai‘i were from Maunaloa (Guppy 1897, Meinecke 1916, Bryan 1916). The first published collection of insects from Mauna Kea was by Bryan (1923), followed by Bryan (1926) and Swezey and Williams (1932). These first investigators believed that the summit areas were “absolutely sterile” and that all the insects found there were aeolian, i.e., blown up from surrounding lowlands by wind. These early reports mention a few species of parasitic wasps, flies, true bugs, and butterflies that were more commonly found at lower elevations. It is interesting to note that the first hint of a high elevation resident was by Guppy (1897), when he mentioned a “parasitical bug” that was feeding on the bodies of dead butterflies. This insect may have been the *a‘a* bug not formally described until 1998 (Polhemus 1998).

Insects from high elevations on Mauna Kea were not mentioned in the literature again until 1971 (Gagné 1971) when acacia psyllids (a lowland species that infests *koa*) were found in great numbers on observatory walls and washed up in shore debris at Lake Waiau. Howarth (1971) was the first to hypothesize aeolian ecosystems in Hawai‘i in which the major nutrient source is windblown material from outside the ecosystem. While that study was conducted on Kilauea, his new paradigm was soon to be applied to Mauna Kea.

In 1980, Howarth and Montgomery described the ecology of a high altitude aeolian ecosystem on Mauna Kea based on new observations of arthropods near the summit (Mull and Mull 1980, Mull 1980). In this landmark paper, the authors report the “discovery” of a new flightless lygaeid bug of the genus *Nysius*, called the Wēkiu bug (Mull and Mull 1980). Ashlock and Gagné (1981) described this new species as *Nysius wekiuicola*.

Twenty-seven species of arthropods were found during this survey, seventeen of which were observed on the eighteen Lichen stratum plots (Table 4). The most abundant species are small flies of the families Sciaridae and Scatopsidae which occurred on 72% and 44% of the eighteen Lichen plots respectively. Neither of these species are residents of the summit area but are blown there by daily winds. The next most abundant species is the endemic summit resident Lycosid wolf spider, *Lycosa hawaiiensis*, which was found on 33% of the plots. Another summit resident collected on the eighteen Lichen stratum plots is an unknown Linyphiidae sheetweb spider. These small spiders spin their webs on the underside of rocks where they capture small prey such as Collembola and juvenile wēkiu bugs. The rest of the arthropod fauna comprises ladybird beetles and flies. One wēkiu bug (*Nysius wekiuicola*) was found in a trap on plot L17. Wēkiu bugs have historically been found in this stratum, especially during population irruptions.

Table 4. Arthropod species presence on eighteen plots within the Lichen Habitat stratum.

SPECIES	L01	L02	L03	L04	L05	L06	L07	L08	L09	L10	L11	L12	L13	L14	L15	L16	L17	L18	# Plots Present	% Plots Present
Unknown Linyphiidae								x	x			x							3	17%
Lycosa hawaiiensis					x	x	x	x	x								x		6	33%
Unknown Araneae																		x	1	6%
Hippodemia convergens												x	x		x			x	4	22%
Calliphora vomitoria	x				x	x			x						x				5	28%
Unknown Drosophila						x													1	6%
Unknown Muscidae												x	x				x	x	4	22%
Unknown Phoridae		x				x											x		3	17%
Unknown Scatopsidae			x		x		x	x		x	x	x			x				8	44%
Unknown Sciaridae		x	x		x	x	x	x	x	x	x	x	x		x		x		13	72%
Allograpta obliqua			x		x						x								3	17%
Unknown Diptera	x																		1	6%
Nysius conosulus								x					x						2	11%
Nysius wekiuicola																	x		1	6%
Apis melifera	x																		1	6%
Agonopterix ulicitella					x						x								2	11%
Unknown Pscoptera														x					1	6%

Common Conditions

"Common" conditions within the Lichen stratum can be characterized as a ten by ten foot plot having between six and seven lichen species, consisting of *Lecanora polytropa, Lecidea baileyi, Candelariella vitellina, Acarospora* sp. 1 and *Lecanora 'subaurea'* with two or three of the other less common lichen species. These occasional lichens occur predominantly on rough lava rocks with a North aspect. In "Common" conditions one would also likely find lichens on the underside of rocks, and moss (most likely *Pohlia nutans*) in crevices, cracks, or small caves. Other botanical species would be uncommon, found only occasionally within the Lichen stratum. "Common" conditions also comprise flies of the families Sciaridae, Scatopsidae, and Calliphoridae, lycosid wolf spiders, and the occasional sheetweb spider.

5.1.2 Pedestrian/Judgmental Survey

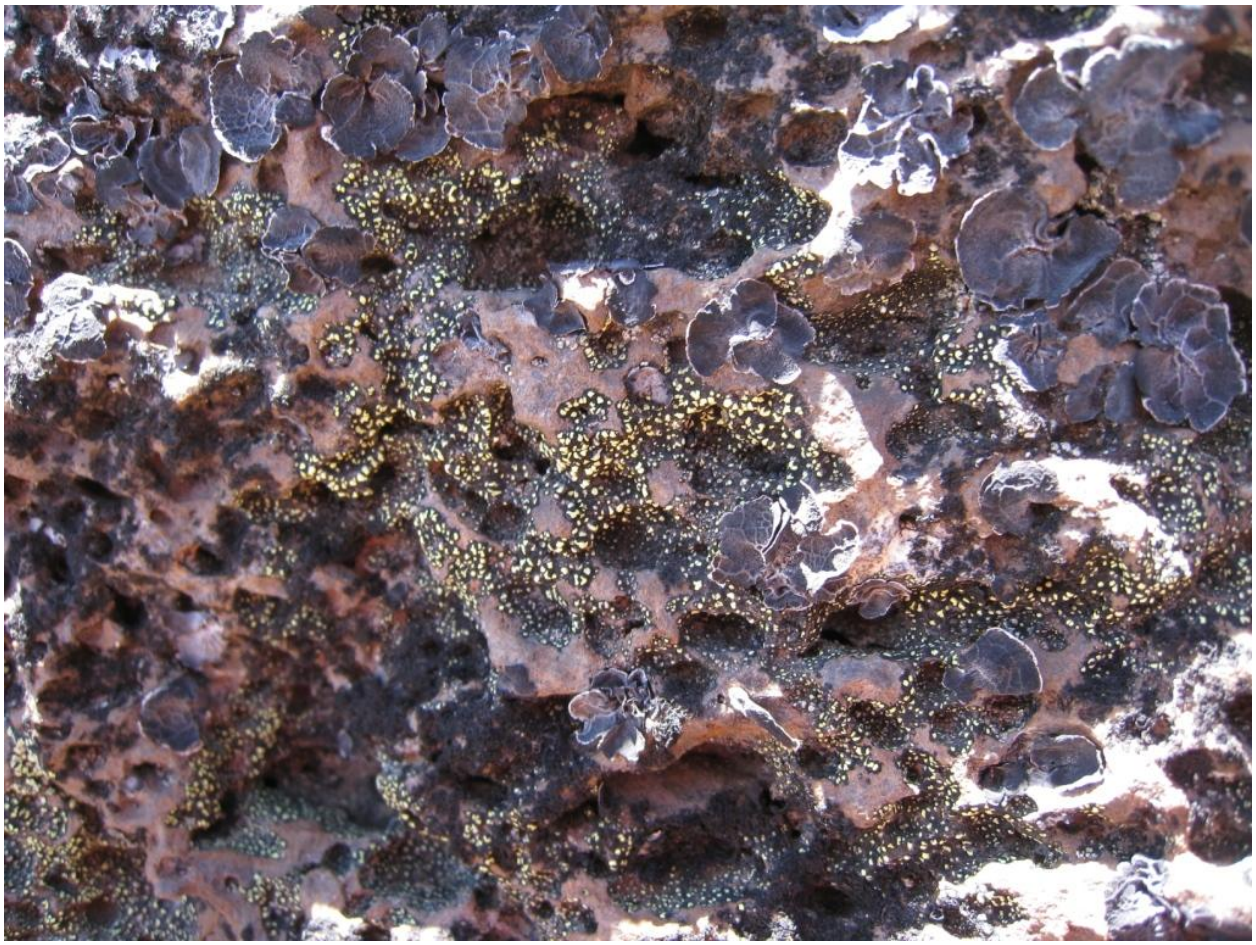
Six locations were judged as areas of "relatively high diversity" within the Lichen stratum during the Pedestrian/Judgmental survey. These sites have an average of 10.2 lichen species in the 10ft by 10 ft plots (95% CI (4.8, 18.4)) and are host to the only substantive lichen community in the study area near the summit of Mauna Kea (Table 5). This community is dominated by *Umbilicaria decussata* which is nearly always accompanied by *Pseudephebe minuscula* and generally *Rhizocarpon geographicum* and *Lecidea baileyi*. Where the community occurs it has substantial cover on the vertical surfaces of rock faces the lichens grow. The community is confined to the exposed north to north-east facing vertical faces of andesite blocks which suggests that special conditions allow growth there but not elsewhere. Conditions on flat rock surfaces and other aspects are probably too severe to allow establishment or growth since the community does not spread onto other more exposed surfaces and there are no isolated thalli elsewhere. The most notable distinction about the aspect of the habitat is that it is shielded from direct insolation for much of the year.

The "relatively high diversity" sites had a high abundance of the moss *Pohlia nutans* and the fern Asplenium adiantum-nigrum which occurred on 83% and 67% respectively (Table 6). These plots were also locations of the moss *Grammia* and the grass *Deschampsia nubigena* which were found on 50% of the plots.

Only a few arthropods were collected from these plots, the most abundant being the lady bird beetle *Hippodemia convergens* occurring on 50% of the plots (Table 7). One wēkiu bug (*Nysius wekiuicola*) was captured on plot LR06.

Areas of "relatively high diversity" are difficult to characterize accurately because they are not abundant. An acceptable threshold for such an area may be 10 lichen species (the approximate average number of lichen species on the high diversity plots found). Two of the random sites met this threshold, therefore the inference is that about 11% (2/18) of the Lichen stratum contains areas of "relatively high diversity".

Figure 6 is a map showing the approximate locations of the six "relative high diversity" plots and the two random Lichen plots that exceeded the "relative high diversity" threshold of ten lichen species on a plot.



The only substantive lichen community in the study area is dominated by *Umbilicaria decussata* which is nearly always accompanied by *Pseudephebe minuscula* and generally *Rhizocarpon geographicum* and *Lecidea baileyi*.

Iron rich rocks (the redder rock) support the highest number of lichens. The cinder cones do not support any lichens other than on the occasional larger rocks but even they host few thalli of Lecanora polytropa and Candelariella vitellina. The substrate is too unstable to allow any colonizing lichen to become established.

The small cave communities are dominated by mosses, principally *Pohlia nutans* with a relatively higher cover than outside the cave of Lecanora polytropa and Candelariella vitellina frequently on the moss clumps and Lepraria in the deeper recesses. The moss clumps are often damp and ash deeper within is visibly damp. During the day the temperature is noticeably lower inside these small caves. The water may come from percolation from above or snow, hail or rain blown in during storms but protection from the elements also contributes by limiting evaporation. The porosity and water holding capacity of the lava above the caves is not known. These small cave areas also support ferns, especially *Asplenium adiantum-nigrum*.

Table 5. Lichen species presence on six "Relatively High Diversity" plots within the Lichen Habitat stratum.

Name	LR01	LR02	LR03	LR04	LR05	LR06	# Plots Present	% Plots Present
Acarospora cf. depressa	x	x	x	x			4	67%
Acarospora sp 3	x	x				x	3	50%
Acarospora sp. 1		x	x	x	x	x	5	83%
Buellia cf. fuscochracea			x			x	2	33%
Buellia sp 1							0	0%
Caloplaca lithophila		x					1	17%
Candelariella vitellina	x	x	x	x	x	x	6	100%
Carbonea vitellinaria							0	0%
Lecanora 'subaurea'	x	x	x			x	4	67%
Lecanora polytropa	x	x	x	x	x	x	6	100%
Lecidea baileyi	x	x	x	x		x	5	83%
Lecidea cf. maunakeae		x			x	x	3	50%
Lepraria 'incana'							0	0%
Lepraria 'vouaxii'	x						1	17%
Physcia dubia	x				x	x	3	50%
Pseudephebe miniscula	x	x	x	x	x	x	6	100%
Rhizocarpon geographicum	x	x		x		x	4	67%
Umbilicaria decussata	x	x	x	x	x	x	6	100%
Umbilicaria deusta							0	0%
Umbilicaria hirsuta			x		x		2	33%
Unknown 1							0	0%
Unknown 2							0	0%
Unknown 4							0	0%
Underside of Rocks	x	x					2	33%

Table 6. Botanical species presence on six "Relatively High Diversity" plots within the Lichen Habitat stratum.

Name	LR01	LR02	LR03	LR04	LR05	LR06	# Plots Present	% Plots Present
Andraea acutifolia		x					1	17%
Grimmia sp.		x	x			x	3	50%
Pohlia nutans	x	x	x		x	x	5	83%
Zygodon tetragonostomus		x					1	17%
Agrostis sandwicensis	x	x					2	33%
Deschampsia nubigena	x	x	x				3	50%
Asplenium adiantum-nigrum	x	x	x		x		4	67%

Table 7. Arthropod species presence on six "Relatively High Diversity" plots within the Lichen Habitat stratum.

SPECIES	LR01	LR02	LR03	LR04	LR05	LR06	# Plots Present	% Plots Present
Unknown Acari						x	1	17%
Unknown Linyphiidae	x						1	17%
Unknown Centipede				x			1	17%
Hippodemia convergens	x			x		x	3	50%
Unknown Entomobryidae	x						1	17%
Calliphora vomitoria	x						1	17%
Unknown Sciaridae		x		x			2	33%
Unknown Diptera			x				1	17%
Geocoris pallens				x			1	17%
Nysius wekiuicola						x	1	17%

Dr. Smith and Dr. Berryman study lichens on a "relatively high diversity" site with vertical, North-facing, sheltered rock face.

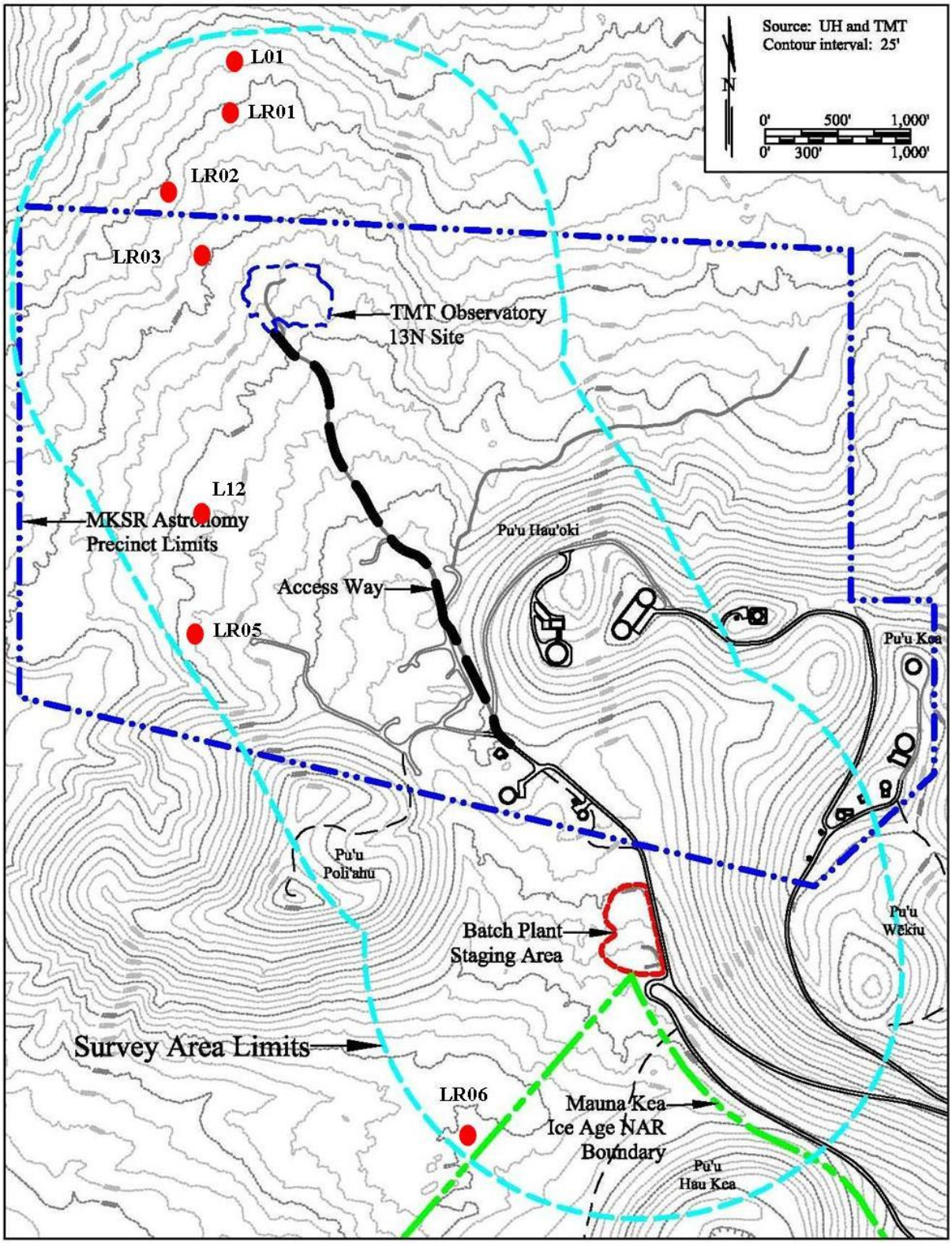


Figure 6. A map of "relative high diversity" plots and Lichen stratum plots that exceeded the "relative high diversity" threshold of ten lichen species on a plot.

5.1.3 TMT Footprint

Lichens

Twelve lichen species were found on the five TMT Observatory Footprint plots (Table 8). The most abundant species were *Candelariella vitellina* and *Lecidea baileyi*, occurring on all five plots, followed by *Acarospora* sp 3, *Lecanora polytropa*, and *Lepraria 'incana'* which occurred on 60% of the plots. There was an average of 6.5 species plot (95% CI (2.8, 14.4)).

Table 8. Lichen species presence on five TMT Observatory Footprint plots within the Lichen Habitat stratum.

Name	FP01	FP02	FP03	FP04	FP05	# Plots Present	% Plots Present
Acarospora cf. depressa						0	0%
Acarospora sp 3	x		x		x	3	60%
Acarospora sp. 1	x			x		2	40%
Buellia cf. fuscochracea						0	0%
Buellia sp 1					x	1	20%
Caloplaca lithophila		x				1	20%
Candelariella vitellina	x	x	x	x	x	5	100%
Carbonea vitellinaria						0	0%
Lecanora 'subaurea'	x	x	x	x	x	5	100%
Lecanora polytropa	x	x			x	3	60%
Lecidea baileyi	x	x	x	x	x	5	100%
Lecidea cf. maunakeae						0	0%
Lepraria 'incana'		x	x		x	3	60%
Lepraria 'vouaxii'						0	0%
Physcia dubia					x	1	20%
Pseudephebe miniscula						0	0%
Rhizocarpon geographicum				x	x	2	40%
Umbilicaria decussata						0	0%
Umbilicaria deusta						0	0%
Umbilicaria hirsuta						0	0%
Unknown 1						0	0%
Unknown 2		x				1	20%
Unknown 4						0	0%
Underside of Rocks	x		x	x	x	4	80%

Botanical Resources

Only one moss was abundant on the footprint plots, *Pohlia nutans* (Table 9). No ferns or grasses were seen on these plots. A pedestrian survey of the site revealed no other botanical resources, however the pedestrian survey was limited to the areas traveled between plots.

Table 9. Botanical species presence on five TMT Observatory Footprint plots within the Lichen Habitat stratum.

Name	FP01	FP02	FP03	FP04	FP05	# Plots Present	% Plots Present
Andraea acutifolia		x				1	20%
Grimmia sp.		x				1	20%
Pohlia nutans	x	x		x	x	4	80%
Zygodon tetragonostomus					x	1	20%
Hypochaeris radicata					x	1	20%

Arthropods

Nine species of arthropods were found on the footprint plots, with small flies of the family Sciaridae occurring on all plots (Table 10). All other arthropod species occurred on fewer than 50% of the plots. No wēkiu bugs were observed on these plots. The lower number of arthropod species on these plots is likely due to fewer plots surveyed compared to the random plots in the Lichen stratum.

Table 10. Arthropod species presence on five TMT Observatory Footprint plots within the Lichen Habitat stratum.

SPECIES	FP01	FP02	FP03	FP04	FP05	# Plots Present	% Plots Present
Unknown Linyphiidae		x				1	20%
Lycosa hawaiiensis				x	x	2	40%
Hippodemia convergens	x	x				2	40%
Unknown Entomobryidae				x		1	20%
Unknown Scatopsidae			x			1	20%
Unknown Sciaridae	x	x	x	x	x	5	100%
Unknown Diptera			x			1	20%
Nysius conosulus	x					1	20%
Agonopterix ulicitella		x	x			2	40%

Comparison of Footprint to "common conditions"

The average number of lichen species per plot in the TMT Observatory Footprint area (6.5 lichen species per plot) is about the same as the average number of lichens found on the 18 random Lichen stratum plots (6.7 lichen species per plot). The highest number of species on any one plot was 9, below the threshold established for "relatively high diversity" (10 lichen species per plot). There were also about the same number of lichens found on the underside of rocks (80% of the plots) as the random plots (83%).

Botanical resources and arthropods were less abundant than the characteristic "common conditions". This may be due to the limited size of the survey area compared to the larger Lichen stratum surveyed. Overall, the TMT Observatory Footprint is about the same as "common conditions" found throughout the Lichen stratum.

5.1.4 Discussion

The checklist of the lichens in this survey notes 23 species, twelve more than observed during the 2008 study (Smith 2008) and two more than the study in 1982 (Smith et al., 1982). The difference between the two recent studies is due to expanding the studying area down to 13,000 ft as well as including three sites on the western boundary of the area around Puu Poliahu. The

three western sites were somewhat richer in species (at least three species were unique to this region of the study area) or had better developed thalli which better linked the depauperate specimens in the TMT area with species found at Hale Pohaku, e.g., *Physcia dubia*. Some of the uncertainties in previous studies were therefore resolved. The reason for the richness of the flora in these areas around Puu Poliahu is not known.

The summit of Mauna Kea is well known for its dry air, the high number of cloud-free nights, and the stability of the atmosphere all of which suggest that climatic factors do not account for the very notable distinction in the distribution of the Umbilicaria community. However, there are topographical differences in the exposure of the andesite rock faces. Since lava flows down the mountain, the flow fronts face in the direction of the aspect of the mountain. It is the fronts and sides of the flows that appear to be the most fragmented such that on the northern side of the mountain most of the fragmented sections face north and on the southern side of the mountain they face southward. The upper area of the flow is protected by the mass of the flow around it and does not collapse. Since there are very few south-facing faces on the northern side of the mountain there is no opportunity for the Umbilicaria community to form there. But even on the southern side of the mountain the south-facing faces are generally free of lichens possibly due to the effects of insolation because crevices and vertical faces with a more northerly aspect are covered with lichen particularly where shaded to some degree. This type of distribution can be seen around the Batch Area and on flows along the road to the VLBA telescope. This hypothesis needs further study.

A wet surface may be important for the initial establishment of a community because it is unlikely that the process could be affected by a propagule absorbing water from the air. However, it is unlikely that such luxurious colonies (up to 100% cover in 1 m^2 patches within the study area) could be maintained by the very infrequent precipitation events as the thalli would rapidly dry out in such a dry environment without further wetting even though shaded from direct sunlight. The absence of all cyanolichens (lichens with a cyanobacterium as the photosynthetic symbiont) which require full saturation of their thalli for growth also suggests that continuous wet conditions are rare. The humidity of the air probably exceeds the dew point every evening as the temperature rapidly drops. Fruticose and foliose lichen thalli would be good sites to intercept such moisture. There is probably enough air movement caused by temperature changes during the evening hours sufficient to facilitate such absorption. This could be verified by visiting the colonies at dawn and checking whether or not the thalli are brittle.

Once a thallus, particularly a foliose or fruticose form, becomes established it will create its own microclimate around the thallus or within the branches. The establishment of its own propagules could be possible as well as enabling other species to establish. However, casual observations suggest that there is no close physical association of one species with another. Rather there are pockets of other species such as Pseudephebe in the same community but isolated from the dense Umbilicaria. The Umbilicaria probably overgrows all other species thus limiting the other species to peripheral situations. The initial colonization events would be few and far between. Most of the communities are large occupying much of the available habitat suggesting considerable antiquity, the result of their very slow colonization and growth. There are smaller, possibly younger, communities but they are quite rare.

STATUS

Whereas in 1982 it was noted that there was a high level of endemism (33%) in the summit flora of Mauna Kea, monographs and taxonomic revisions since then have drastically reduced the level of endemism. In this current summary, of the 23 species known to occur above 13,000 ft., none are endemic and 54% are indigenous (but 26% are of uncertain or unknown status because the species cannot be determined to the species level). In the much smaller area of the footprint of the TMT telescope, there are 12 species (0% endemic, 63% indigenous and 33% of unknown status).

SUBSTRATE TYPES

There are four principal substrate types in the summit area recognized from this and previous studies. The four principal substrates are:

- andesite slabs and blocks of grey rock which rings when hit with a hammer. The rock is quite smooth with few, if any, blisters. It forms the large lava flows the edges of which are fragmented into large, frequently cubical rocks which may have been split off by ice fracturing. Water drains off the rock rapidly. This substrate supports lichen growth.
- more typical glaciated pahoehoe which does not ring noticeably when hit with a hammer. There are numerous blisters creating a surface with an uneven microtopography creating numerous depressions where water can accumulate. The rocks are generally brown in color but some have distinctly reddish areas. When side-by-side in similar exposures, the the reddish areas generally appear to have more lichens on them than the brown areas.
- glacial rubble, often an assorted mix of various types of rock. The rocks on the surface of this rubble rarely supports lichen growth probably due to its instability. However, rocks underlying the surface rocks often have lichens growing on them. Ash accumulated under the rocks precludes lichen growth on the bottom of the rocks.
- cinder and ash, generally grey or red, is present only in pockets in small areas. This substrate is too unstable to support lichen growth.

5.2 Botanical Stratum

5.2.1 Twelve Random Plots

Lichens

There were fourteen species of lichens identified from the 12 Botanical stratum plots (Table 11). The most abundant lichen species is *Lecanora 'subaurea'* which occurred on all twelve plots. The next most abundant species are *Lecidea baileyi*, *Acarospora* sp 3, and *Candelariella vitellina* which occurred on 75%, 58%, and 50% of the plots respectively.

There was an average of 4.5 lichen species on the twelve Botanical stratum plots (95% CI (1.4, 10.6). No plot exceeded the threshold for "relatively high diversity" of 10 lichen species. The maximum number of lichen species on any plot within the Botanical stratum was seven (on 2 plots).

Table 11. Lichen species presence on twelve plots within the Botanical stratum.

Name	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	# Plots Present	% Plots Present
Acarospora cf. depressa		x		x						x			3	25%
Acarospora sp 3	x			x	x		x	x			x	x	7	58%
Buellia sp 1		x											1	8%
Caloplaca lithophila				x						x	x		3	25%
Candelariella vitellina		x				x	x	x		x	x		6	50%
Lecanora 'subaurea'	x	x	x	x	x	x	x	x	x	x	x	x	12	100%
Lecanora polytropa	x		x	x	x			x					5	42%
Lecidea baileyi		x		x	x	x	x	x		x	x	x	9	75%
Lecidea cf. maunakeae			x							x	x		3	25%
Lepraria 'vouaxii'						x							1	8%
Physcia dubia		x											1	8%
Rhizocarpon geographicum		x											1	8%
Unknown 2						x				x			2	17%
Unknown 4											x		1	8%
Underside of Rocks	x	x	x		x		x	x		x	x		8	67%

Botanical Resources

Two species of mosses were observed on the plots, but both were present on a much lower number of plots than in the Lichen stratum (Table 12). Grasses were the most abundant plant species, but the two species occurred on only 2 plots (17%) each. The only other botanical resources were a fern (*Asplenium trichomanes subsp. densum*) and a free-living algae, both of which occurred on only one plot.

Table 12. Botanical Resources presence on twelve plots within the Botanical stratum.

Name	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	# Plots Present	% Plots Present
Grimmia sp.					x								1	8%
Pohlia nutans		x			x		x			x			4	33%
Deschampsia nubigena	x				x								2	17%
Trisetum glomeratum	x										x		2	17%
A. trichomanes subsp. densum					x								1	8%
Free-living Algae		x											1	8%

Arthropods

Fifteen species of arthropods were captured on the Botanical stratum plots (Table 13). The most abundant species was a small fly in the family Sciaridae which occurred on five (42%) of the plots. One wēkiu bug was seen on plot B04.

Table 13. Arthropod species presence on twelve plots within the Botanical stratum.

SPECIES	B01	B02	B03	B04	B05	B06	B07	B08	B09	B10	B11	B12	# Plots Present	% Plots Present
Unknown Linyphiidae			x			x			x				3	25%
Lycosa hawaiiensis		x		x							x	x	4	33%
Unknown Araneae				x									1	8%
Hippodemia convergens		x	x			x			x				4	33%
Calliphora vomitoria		x	x						x				3	25%
Unknown Muscidae								x			x		2	17%
Unknown Phoridae				x	x								2	17%
Unknown Scatopsidae					x								1	8%
Unknown Sciaridae	x	x	x		x	x							5	42%
Nysius conosulus		x	x										2	17%
Nysius kinbergii						x							1	8%
Nysius wekiuicola				x									1	8%
Unknown Aphidae				x									1	8%
Vespula pensylvanica								x	x				2	17%
Unknown Pscoptera							x						1	8%

5.2.2 Pedestrain/Judgmental Survey

No areas of "relatively high diversity" or abundance was observed during the travel between random plots. Botanical resources are scarce and do not appear in clumps or communities. Even where wet ash or organic material may accumulate in crevices, plants were not abundant. Most plants occurred as solitary individuals, except for a few places where there may have been three or more clumps of grasses growing in close proximity.

5.2.3 Discussion

Few Botanical resources were observed on the twelve Botanical stratum plots. Overall diversity of lichens and arthropods were lower than found on the Lichen stratum plots. This might be due to the type of substrate, mostly glaciated lava flows, although there were several locations with a significant amount of ash component where roots could grow. In these instances, moisture was likely the limiting factor.

5.3 Arthropod Stratum

No lichen, mosses, or other botanical resources were found on the sixteen Arthropod stratum plots. Also, because of the difficulty in locating areas of "relatively high diversity" of arthropods while traveling between plots, none were recorded. Most of the Arthropod stratum plots occurred on steeply-sloped, loose cinder. Lichens cannot gain a stable substrate in this habitat and therefore do not grow, except on large boulders or outcrops. Plants have a similar challenge in establishing on this loose, unstable substrate.

Eleven species of arthropods were captured on the sixteen Arthropod stratum plots (Table 14). The most abundant species were Linyphiidae sheetweb spiders, a blow fly (Calliphora vomitoria), and wēkiu bugs (Nysius wekiuicola), all of which occurred on ten (63%) of the plots. Many more species than this have been collected during the various surveys and monitoring that has occurred on the cinder cones of the summit area over the past ten years. The low number of species present may be due to the timing of this survey, or yearly fluctuations in populations. Only four of the twelve species of arthropods found would be considered residents of the summit area.

Wēkiu bugs were very abundant on two of the plots, reaching a maximum of 180 bugs on plot A16. Only four of the plots had wēkiu bugs numbers reach double digits, and six of the plots had no wēkiu bugs at all. Obviously wēkiu bug abundance and distribution is not uniform across the Arthropod stratum. This is consistent with the results of repeated sampling on the cinder cones of the summit area over the past ten years.

Wēkiu bugs were captured in places characterized as having large areas with an assemblage of different sized rock cinder scoria in a depth of approximately 2-10 inches before the ash layer was reached. This mixed rock tephra is found on the slopes of cinder cones. The areas where wēkiu bugs are found show a constant state of flux, with the scoria slowly moving down slope by the force of gravity and undergoing frost-heaves that continually 'sift' dust and ash down in depth thereby creating a natural and very slow sorting of rock scoria with larger rocks nearer the surface and smaller cinders being closer to the ash layer. This habitat type is apparently highly suitable for supporting populations of Wēkiu bugs. There are many interconnected reasons why wēkiu bugs are associated with specific type of habitat. Wēkiu bugs can use this depth of different sized cinder to thermoregulate by moving through the innumerable crevices that the assortment of rocks create. These crevices also provide paths for escape from predators (most likely the endemic lycosid spider). Temperature and humidity data show the incredible variation found in these few inches of rock, with humidity and temperature being oppositely correlated. Near the ash layer, the temperature is cool with high humidity, and at the surface where wēkiu bugs can bask in the sun, the temperature can be very high (up to 114^{o} F) with extremely low humidity (10 percent) (Eiben unpublished). These microhabitats are necessary for the wēkiu bug physiologically, but can also create areas that hold and preserve prey items on which wēkiu bugs feed. As insects drop from the wind column and sift through the scoria, they can become protected from the intense desiccating conditions found at the surface. Of the traps that attracted wēkiu bugs, some traps were placed in areas with very little depth of this type of cinder tephra, however, since the effective range of these traps is unknown, the bugs could be attracted from adjacent deep cinder zones.

Dr. Eiben samples counts wēkiu bugs in a trap within the Arthropod stratum.

Table 14. Arthropod species presence on sixteen Arthropod stratum plots.

SPECIES	A01	A02	A03	A04	A05	A06	A07	A08	A09	A10	A11	A12	A13	A14	A15	A16	# Plots Present	% Plots Present
Unknown Linyphiidae		x	x	x	x			x	x	x	x	x	x				10	63%
Unknown Araneae														x			1	6%
Unknown Centipede												x					1	6%
Hippodemia convergens						x	x	x		x						x	5	31%
Unknown Entomobryidae					x		x		x			x					4	25%
Calliphora vomitoria	x		x			x		x	x	x		x		x	x	x	10	63%
Unknown Sciaridae					x	x				x			x		x	x	6	38%
Geocoris pallens							x										1	6%
Nysius wekiuicola	24	1	7	97	8	44	0	0	4	0	0	1	0	0	7	180	10	63%
Unknown Lygaeidae							x										1	6%
Agonopterix ulicitella	x																1	6%

5.4 Conclusions

The habitat stratification appeared to work well for lichens. Lichens were more abundant on Lichen stratum plots than they were on Botany or Arthropod strata plots and the only areas of relatively high diversity were found within the Lichen stratum. The average number of lichens on Lichen stratum plots was 6.7 per plot, with a maximum of 13 lichens on a plot. The average number of lichens on Botany stratum plots was 4.5 per plot, with a maximum of 7 lichens on a plot. There were no lichens found on any of the Arthropod stratum plots.

The Botany stratum plots did not appeared to support more plants than the Lichen stratum plots. Both strata had 2 species of grasses, two species of ferns, and two species of mosses on them. The abundance of these plant species on the plots were about the same. There were no plants that occurred on the Arthropod stratum plots.

The Arthropod stratum plots had a greater number of wēkiu bugs than either of the other two strata, but the other arthropods were about equally distributed on all the strata. The substrate in the Arthropod stratum plots is unstable and moves with frost heaving, gravity, and ground vibrations. This constant movement discourages lichen growth. While some plants may be found in the Arthropod stratum, by chance none occurred on the randomly selected plots. Plants do establish on this substrate but only sparsely.

There are no good indicators of "unique communities" of lichens. Lichens do occur in larger communities (as indicated in the "Relatively High Diversity" plots), but these communities generally contain the same species found in small colonies throughout the stratum. The 10-species rule to identify an area of "Relatively High Diversity" is a good indicator of a diverse community.

As noted in section 5.1.4 above, the checklist of the lichens in this survey notes 23 species, twelve more than observed during the 2008 study (Smith 2008) and two more than the study in 1982 (Smith et al., 1982). Generally the results are similar, with differences due to expanded area of study and range of elevations. The plant species were also similar to studies conducted in these areas. All species that were present in previous studies were found in this study. Sampling efforts differ between studies and makes direct comparisons difficult.

No lichen, plant, or arthropod species was found during this study that could be considered "invasive' and need of immediate control. Of particular interest is the fact that no ants were found on any of the plots. The extensive sampling effort to detect these species gives us confidence to say that ants do not currently occur within the TMT Observatory 500 meter buffer zone. Monitoring for these invasive species will be ongoing through the already established monitoring program.

The results of this study indicate there are no special concerns or legal constraints related to lichen, botanical, and arthropod resources in the project area and surrounding 500 meter buffer zone. No species listed as endangered or threatened were detected on the sample plots or during the pedestrian survey (DLNR 1997, Federal Register 1999, 2005, 2006). One species of concern, Douglas' bladder fern (*Cystopteris douglasii*), occurred on only one plot. This species also occurs on Maui and on the eastern slopes of Mauna Loa, and the TMT Observatory footprint and

the surrounding 500 meter buffer zone does not provide unique habitat essential for its survival (Char 1990).

Ferns and grasses occurred in crevices between rocks where soil has accumulated.

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