ARTHROPOD INVENTORY AND ASSESSMENT HALEAKALĀ HIGH ALTITUDE OBSERVATORY SITE MAUI, HAWAI`I

July 2003

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I. TABLE OF CONTENTS

II. EXECUTIVE SUMMARY

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 10,023 feet (3,055 m) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. In 1961, an Executive Order of Hawai`i Governor Quinn established the Haleakalā High Altitude Observatories Site, sometimes referred to as "Science City". The site is managed by the University of Hawai`i.

The long range development planning effort for Haleakalā Observatories has been in progress by the University of Hawai`i Institute for Astronomy (IfA) since 1999. KC Environmental Inc. is managing the environmental and cultural surveys and preparing survey-based recommendations for the IfA committee responsible for long range development planning.

Pacific Analytics, LLC was contracted to conduct an inventory and assessment of the arthropod fauna at the Haleakalā High Altitude Observatories Site.

This report is the result of sampling at the Haleakalā High Altitude Observatories Site. It contains sampling methodology, site description, discussion of findings, and eight recommendations for the conservation of native arthropods found at the site. Also included is an extensive Bibliography.

III. INTRODUCTION

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 10,023 feet (3,055 m) at its summit on Pu`u `Ula`ula. Near the summit is a volcanic cone known as Kolekole with some of the best astronomy viewing in the world. In 1961, an Executive Order of Hawai`i Governor Quinn established the Haleakalā High Altitude Observatories Site, sometimes referred to as "Science City". The site is managed by the University of Hawai`i.

The highest elevations of Haleakalā were once considered largely lifeless with only sparse vegetation, but biologists have discovered a diverse fauna of resident insects and spiders there that are found nowhere else in the world (Medeiros and Loope 1994). These arthropods inhabit unique natural habitats on the bare lava flows and cinder cones. Feeding primarily on windblown organic material, they form an aeolian ecosystem.

The term aeolian has generally been used to describe ecosystems on snow, ice, meltwater, and barren rock, but in Hawai`i it has been used to characterize non-weathered lava substrates, mostly but not exclusively found at high elevations (Howarth 1987, Medeiros and Loope 1994).

On Haleakalā, aeolian and sub-aeolian ecosystems begin at about 7,546 feet (2,300 m) elevation in the cinder-dominated habitat inside the crater, and at around 8,530 feet (2,600 m) on the older western slope of the volcano, and extend up to the summit at 10,023 feet (3,055 m). Climate conditions are extreme, with widely varying diurnal temperatures and little precipitation. Solar radiation can be intense, and the conditions often affect visitors not accustomed to high elevations.

The Haleakalā aeolian ecosystem is extremely xeric, caused by relatively low precipitation, porous lava substrates that retain negligible amounts of moisture, little plant cover, and high solar radiation. The dark, heat-absorbing cinder provides only slight protection from the extreme temperatures. Thermal regulation and moisture conservation are critical adaptations of arthropods that occur in this unusual habitat.

Vegetation covers less than 5% of the open ground, and food is apparently scarce. Wind-assisted diurnal movement and seasonal migrations of insects from the surrounding lowlands are the primary source of food for the resident scavenger and predator arthropods in this remarkable ecosystem. Aeolian ecosystems are not unique to Haleakalā in Hawai`i. Similar ecosystems also occur on Mauna Kea and Mauna Loa on the Island of Hawai`i (Howarth and Montgomery 1980). Each volcano has its own unique aeolian fauna that exploit the windblown organic material.

The long range development planning effort for Haleakalā Observatories has been in progress by the University of Hawai`i Institute for Astronomy (IfA) since 1999. In 2001 the Hawai`i state legislature appropriated an increment of the planning funds requested to initiate the necessary studies for preparing a Long Range Development Plan for the Haleakalā High Altitude Observatories Site. Funding was released in the second quarter of 2002. KC Environmental Inc. is managing the environmental and cultural surveys and preparing survey-based recommendations for the IfA committee responsible for long range development planning. The surveys and studies are anticipated to be completed in the third quarter of 2003.

Pacific Analytics, LLC was contracted to conduct an inventory and assessment of the arthropod fauna at the Haleakalā High Altitude Observatories Site. Pacific Analytics personnel have extensive experience with ecological research, wildlife inventory, monitoring, and consulting. Pacific Analytics personnel have many years of professional experience in tropical and temperate ecosystems, including natural resource inventory and monitoring, forest and riparian entomology, endangered species research, mitigation, and habitat management, forensic entomology, integrated pest management, and land management.

The University of Hawai`i Institute for Astronomy plans to protect the cultural resources and native Hawaiian ecosystems during any future development at the Haleakalā High Altitude Observatories Site. To that end they have funded this study and others like it.

Sampling of arthropod habitats was approved in a permit obtained from the Department of Land and Natural Resources (DLNR) issued in May, 2003. Sampling began on June 5, 2003 and was completed on July 3, 2003.

The intended purpose of this study is to conduct a baseline survey of resident invertebrates and to gather reliable scientific information about the current status of arthropods and other invertebrates as part of the preparation of a Long Range Development Plan for the Haleakalā High Altitude Observatories Site.

This study provides a means of gathering information that can be used to protect the native Arthropod species during development and operation of observatory facilities. This study supports astronomy programs at the Haleakalā High Altitude Observatory Site by promoting the good stewardship of the natural resources located there.

IV. PROJECT DESCRIPTION

The Project consists of six tasks. The tasks were:

Task I) Visual reconnaissance of the site to determine habitats of interest and the special collecting methods that may be deployed.

Task II) Establishing standard traps (i.e., pitfall traps) at the site;
Up to five pitfall traps to be on each acre of undeveloped ground.

Task III) Collecting under rocks, on vegetation and leaf litter, and in special habitats (e.g., for ground dwelling arthropods).

Task IV) Collecting material from pitfall traps after operating for one month.

Task V) Laboratory identification and curation of specimens collected.

Task VI) Preparation of a Final Report of Findings.

a. Review of former inventories and assessments,
b. Discussion of the status of resident Arthropods,
c. List of species of concern or special interest,
d. Recommendations for Arthropod conservation and habitat protection.

V. METHODS

Site Description

The Haleakalā High Altitude Observatory Site is located on Kolekole Hill. The site is at 10,012 feet (3,052 m) above sea level, adjacent to Pu`u `Ula`ula, also known as Red Hill, the highest elevation on Maui (10,023 feet (3,055 m)).

The 18.1 acre (7.3 hectare) site was established in 1961, and the first telescope, the Mees Solar observatory was dedicated in 1964. The site now consists of five telescope facilities.

The Haleakalā High Altitude Observatory Site
Photograph by Frank Rizzo

Annual precipitation averages 53.14 inches (1,349.2 mm), falling primarily as rain and mist during the winter months from November through April. Snow rarely falls at the site.

Monthly mean temperatures range from 50˚F (10˚C) in February to 57˚F (14˚C) in July and August. The average high is 62.5˚F (18.5˚C), and the average low is 44.8˚F (7.3˚C). Daily temperatures can range from below freezing at night to near 80˚F (27˚C) during the day. In June, the average high temperature is 65˚F (18˚C), and the average low temperature is 47˚F (8˚C) (Weather.com website).

The prevailing Northeast trade winds occur a majority of the time between May and November and over 60% of the time the rest of the year (ATST website).

Sampling

Prior to sampling, reports and publications of previous arthropod surveys and studies were examined to determine the best approach to sample the site. Two reports (Beardsley 1980 and Medeiros and Loope 1994) were extremely useful because they are specific to the site and nearby crater.

After reviewing historical reports it was decided that ethylene glycol pitfall traps, foliage beating, and visual searching would be the most efficient methods to inventory arthropods at this site.

Pitfall Traps

The selection of a trapping technique used in a study needs to be carefully considered. If the target species of the trapping system are rare or important for another reason (i.e., endangered, keystone species, etc.) live-trapping should be considered. Entomologists have long believed that they can sample without an impact on the population being sampled. It has been assumed that collecting makes only a small impact on the populations of interest. While that assumption remains to be tested, responsible entomologists consider appropriate trapping techniques to ensure survival of local populations of interest.

Because sampling was to occur for only one month, ethylene glycol traps were used to sample the arthropod ground fauna. Ethylene glycol pitfall traps are cups placed into the ground so that the lip of the cup is level with the substrate. A small amount of ethylene glycol is placed into the trap to kill and preserve specimens that fall into the traps. Ethylene glycol is used because it has a low evaporation rate and because it prevents specimen decomposition during the sampling period. Additionally, it is easily cleaned from the specimens.

Catches in pitfall traps record the activity of ground-active arthropods. The more active the organism, the more likely it is to fall into a trap (Greenslade 1964, Luff 1975, Adis 1979, Baars 1979, Spence and Niemelä 1994). Pitfall trapping gives a reliable estimate of the relative densities of active adult species (Baars 1979, Rieske and Raffa 1993), although the method may not be useful for estimating absolute densities of species (Briggs 1960, Greenslade 1964, Adis 1978, Baars 1979, Desender and Maelfait 1983, Waage 1985). Luff et al. (1989) concluded that analysis of pitfall trap data collected under standardized conditions could lead to meaningful results.

The results of sampling depend largely on the species being sampled and the density of traps at the site. The target of pitfall trapping in this study was ground-active arthropod species. The sampling goal was to place five traps per acre of suitable habitat. Thirty-seven pitfall traps were set at the site, covering representative habitat at a density of approximately five traps per acre. The locations of the pitfall traps are reported in Figure 1.

Protocol for Setting Traps

Habitat was accessed with a minimum of disturbance to the habitat and cinder slopes. Care was taken to prevent creation of new trails or evidence of foot traffic. A map of significant historic and cultural sites was provided by KC Environmental, Inc., and sampling near these sites was avoided. Petrel nesting sites were also identified during a site review, and no traps were set within the nesting area.

Sampling stations were selected in suitable habitat (Step 1). Traps were installed at each sampling station by carefully digging into the cinder, disturbing only the amount of cinder necessary to set up the trap (Step 2). A 12 ounce plastic cup was inserted into the hole so that the top of the cup was slightly below the existing surface (Step 3). The hole around the cup was refilled with the cinder that was removed from the hole and a 4-inch apron of local ash and small-sized cinder was created around each trap (Step 4). The apron allows arthropods to easily walk into the traps.

Traps were set by pouring about 15 ml of ethylene glycol (antifreeze) into the cups (Step 5). Flagging tape to mark the locations was wrapped around cap rocks, ten to fifteen inches in diameter. The cap rocks were then placed over each trap such that the entire trap was shaded from sunlight (Step 6).

Traps were installed on June 5 – 6, 2003, and were checked over the next two days to determine if they were capturing a large amount of arthropods. This was done to ensure that traps would not have a serious impact on resident arthropods. Traps were collected on July 2 - 3, 2003. The contents of the traps were screened to remove the ethylene glycol, and dead arthropod specimens were collected in vials filled with alcohol. The ethylene glycol was deposited at a local auto parts store (Kahului Carquest) for recycling. The ground around the traps was restored to near original condition.

Substrate surface at much of the site is graded cinder and ash.

Trap Locations

An effort was made to sample representative examples of all habitat types on the site. The site is located primarily in the crater of Kolekole cinder cone. This cone is transitional between the Kula and Hana formation series and was formed during the Pleistocene (MacDonald 1978, Chatterjee *et al.* in press).

The surface of the substrate on much of the site consists of broken fragmental ankaramite lavas and spatter, such as scoria, cinder, and lapilli, with blankets of cinder and ash (Bhattacharji 2003).

Substrate surface near the Faulkes facility showing scoria, cinder, lapilli, and ash.

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Setting an Ethylene Glycol Pitfall Trap

Step 1
Select Sampling Site

Step 2
Dig a hole for the trap cup

Step 3
Install 12 oz. plastic cup

Step 4
Refill hole and create apron

Step 5
Pour in 15 ml of Ethylene glycol

Step 6
Emplace Cap Rock

In some areas, aa lava flows of picrite basalt form large rock outcrops.

Aa flow near the Zodiacal Light facility forms a rocky cliff face.

Exposed polygonal to sub-columnar non-vesicular lava horizons broken into large blocks along vertical and horizontal joints form blocky rock cliffs.

Basalt flow near the MSSC facility forms a blocky cliff.

Vesicular lava flows also form cliffs at the site. Ash, cinder, and sand-sized particles fill the spaces between larger rocks, and offer habitat for vegetation.

Vesicular lava cliffs near the Faulkes facility offer habitat for vegetation.

Much of the surface shows signs of moderate to large amounts of erosion and weathering (MacDonald 1978).

Special habitats were sampled to determine if the arthropods present there are different from those found elsewhere on the site. One such habitat was the "mud flats" area near the MSSC facility. This area floods during heavy rainfall and water may stand for several days.

"Mud Flats" area near the MSSC facility parking lot.

Another area of special interest was east of the Mees Observatory. The habitat here was different than that found on most of the rest of the site, being relatively level ash and cinder with an abundance of blocky scoria and cinder.

Habitat east of the Mees Observatory facility.

There have been some concerns expressed about insects living in the ground and the small amount of information known about their distribution at the site. Most of the open ground is scoria, cinder, lapilli, and ash. A large percentage of this substrate is composed of ash and sand-sized particles. When a hole is dug in this kind of substrate, the sides quickly collapse and fill in the hole. Pitfall traps were used to sample this habitat type. It is unlikely that abundant and active ground-dwelling arthropods would not be collected in these traps. Even when arthropods live in the ground, they generally must come to the surface to feed. When they do, they should be captured by the pitfall traps.

Trapping Precautions

Cultural and Historic Sites

Care was taken to avoid archeological sites. These sites have cultural and historical significance and precautions were made to prevent their disturbance. Traps were not placed in these sites.

Temporary habitation shelter near the MSSC facility.

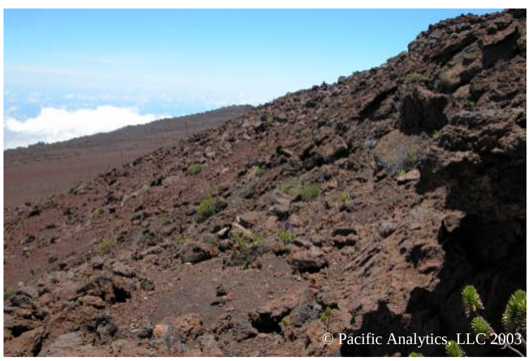
Habitat was accessed with a minimum of disturbance to the habitat and cinder slopes. Care was taken to prevent creation of new trails or evidence of foot traffic. A map of significant historic and cultural sites was provided by KC Environmental, Inc.

Red arrow points to metal fencing delineating an archeological site.

Some sites were marked with white flagging and others were delineated with metal fencing to prevent disturbance.

Sensitive Nesting Sites

Care was also taken to avoid disturbing nesting petrels. These endangered birds dig into the cinder to make burrows for nesting. Nesting is seasonal and was occurring during the arthropod sampling.



Petrel nesting habitat on the Northwest slope of Pu`u Kolekole.

Petrel nesting sites were marked by National park personnel using white flagging to identify active burrows. Because most of the petrel burrows were in habitat on the Northwest slope of Pu`u Kolokole, this area was generally avoided. Two traps were placed above and two below the petrel nesting habitat in areas that were well away from any marked petrel burrows.

Other Sampling

Visual Observations and Habitat Collecting Under Rocks

Approximately six hours were spent visually observing the site and turning over rocks and sorting through leaf litter to locate and collect arthropods. Several specimens of the Haleakalā Flightless moth (Oecophoridae: Thyrocopa apatela (Walsingham)) were collected in this manner. When disturbed, they appear to jump into the air and are carried by the wind to a new location. This makes them very difficult to capture.

Haleakalā Flightless Moths were seen being carried by the wind during a visual sampling of the site.

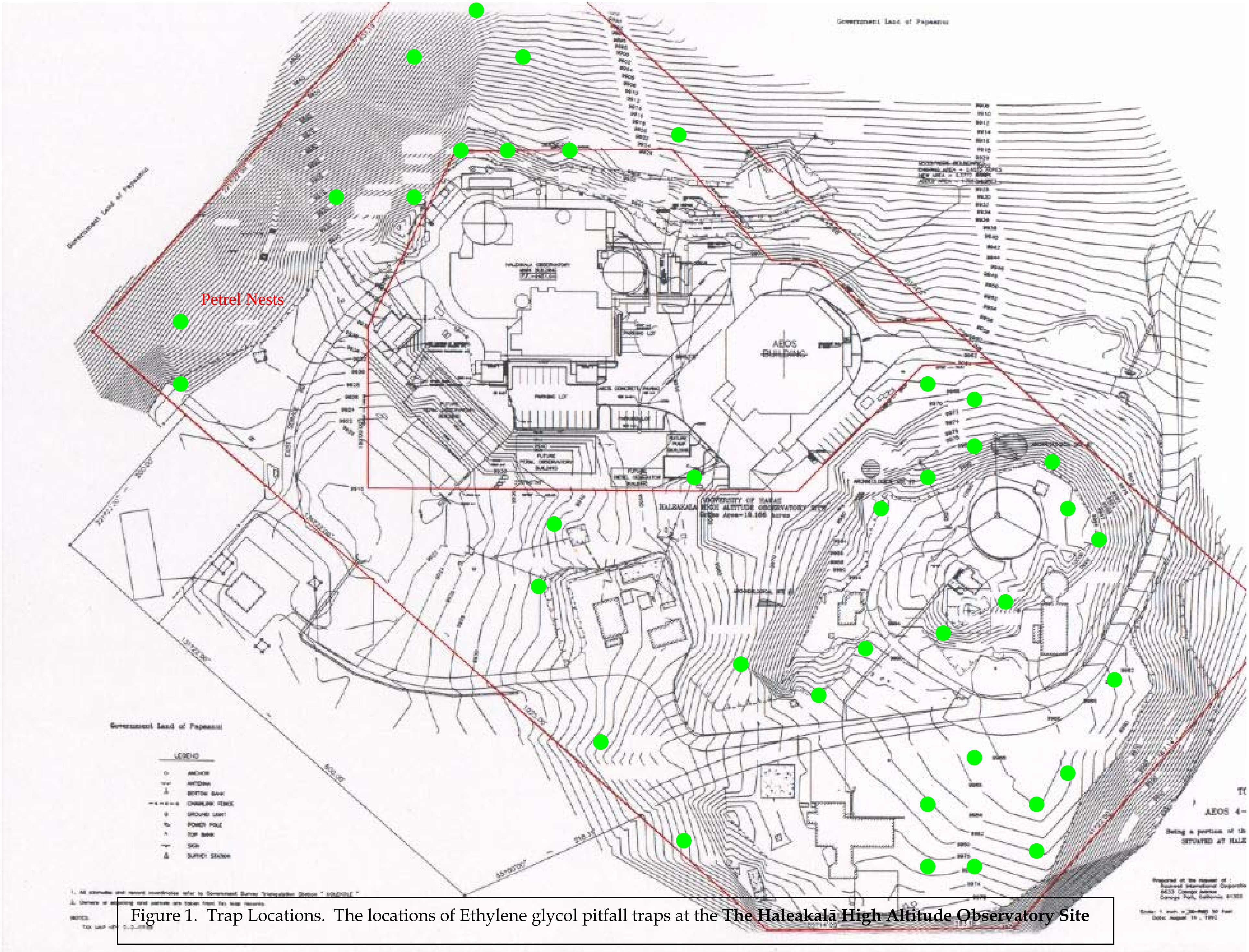


Figure 1. Trap Locations. The locations of Ethylene glycol pitfall traps at the **The Haleakalā High Altitude Observatory Site**

Collecting on Foliage

The vegetation type at this site is an Argyroxiphium/Dubatia alpine dry shrubland (Starr and Starr, 2002). Foliage of various common plant species was sampled by beating sheet. A one-meter square beating sheet was placed under the foliage being sampled and the branch was hit sharply three times using the handle of a collecting net.

Na`ena`e, *Dubautia menziesii*, was sampled using a beating sheet.

Plants sampled using a beating sheet included na`ena`e (*Dubautia menziesii*), pukiawe (*Styphelia tameiamieae*), ohelo (*Vaccinium reticulatum*), and others.

Pukiawe, *Styphelia tameiameiae*, was sampled using a beating sheet.

Grasses, such as pili uka (*Trisetum glomeratum*) and Hairgrass (*Deschampsia nubigena*), were also sampled using a beating sheet. The beating sheet was placed next to and under the grass clump and the stems were brushed by hand to remove arthropods. Common plants and grasses were also sampled using a sweep net.

Hairgrass, *Deschampsia nubigena*, and other grasses were sampled with a beating sheet.

Plant species that were relatively less abundant were sampled with special techniques so as not to disturb their growth. Sampling was conducted by carefully inspecting the plants for arthropods.

The delicate Asteraceae, *Tetramolopium humile*, was sampled by visual inspection.

Plants sampled by visual inspection include *Tetramolopium humile*, `iwa`iwa (*Asplenium adiantum-nigrum*).

`Iwa`iwa (*Asplenium adiantum-nigrum*) and other delicate plants were sampled by visual inspection.

Mosses and lichens were also visually inspected for arthropods that may be restricted to these species. These species occurred in rock crevices, small caves, or under overhangs, where they were protected for strong sunlight. Care was taken to avoid disturbing their habitats.

Moss under a small overhang was sampled by visual inspection.

Vegetation was sampled on June 5 – 7, 2003 and again on July 2-3, 2003. Arthropod specimens (except Lepidoptera species were collected and stored in vials of 70% ethyl alcohol. Lepidoptera species were collected in ethyl acetate kill jars and stored in snap-cap vials or acetate sleeves until mounted.

Lichen growing on rocks shaded from intense direct sunlight.

Quantification and Curation

The contents of the traps were cleaned in 70% ethyl alcohol and placed in separate vials for each trap. Specimens were then counted, sorting them into morphospecies for later identification.

After quantifying the trap captures, the specimens were sorted into the morphospecies for identification. Hard-bodied species, such as beetles, true bugs, large flies and wasps were mounted on pins, either by pinning the specimen or by gluing the specimens to paper points. Pinned specimens were placed into Schmidt boxes. Soft-bodied specimens, such as immature stages, spiders, Collembola, Psyllids, Aphids, small flies and wasps, and millipedes and centipedes, were stored in vials filled with 70% ethyl alcohol.

Identification

Identification to the species level for all specimens was not feasible in the time frame for this project. Important groups of endemic species, species of concern, and potentially threatening non-indigenous species were given first priority for identification. Other specimens will continue to be identified and the results of those identifications will be reported as an addendum to this report at a later date.

Species identification of those specimens identified to genus or species level are unconfirmed and subject to change after comparison to specimens in museums. However, the discussion of the results will not be impacted greatly by changes in species identification because many of the species captured occurred in very low numbers and were not greatly influential to the overall arthropod community.

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 that 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. Most of these had to be obtained through library searches. Keys used to identify Heteroptera included those by Usinger (1936, 1942), Ashlock (1966), Beardsley (1966, 1977), 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 (1965,a, 1965b).

In many cases changes in family and generic status and species synonymies caused species names to change from those in the keys. Species names used in this report are those listed in Hawaiian Terrestrial Arthropod Checklist Third Edition (Nishida 1997).

VI. RESULTS AND DISCUSSION

General Observations

A majority of the arthropod specimens were collected in pitfall traps and on foliage. Only a small number of specimens were collected from under rocks or through general collecting. A total of fifty-eight arthropod species were collected representing thirty-six families in twelve orders.

About 60 percent of the 18.1 acre (7.3 hectare)site has been disturbed by construction. Vegetation occurred in the areas largely undisturbed by construction. It was in these areas where arthropods were most abundant, although flies, true bugs, and spiders were commonly observed near observatory buildings around the site.

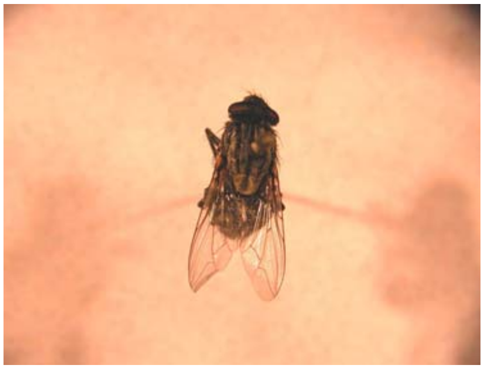
Several groups of arthropods were captured in the pitfall traps. Three groups of arthropods with nearly microscopic species (< 3mm) were abundant in most traps. These groups include the Psyllids (Homoptera: Psyllidae), the Aphids (Homoptera: Aphididae), and the Collembola. These groups are ubiquitous and generally occur in large numbers in most common habitats around the world.

Another group that occurred in nearly all pitfall traps was the Lycosid spider, *Lycosa hawaiiensis* Simon. They appeared abundantly as adults and juveniles.

Lycosid spider, *Lycosa hawaiiensis*, abundant at the site.

This spider is the predominant predator of the arthropod fauna at the site (Medeiros and Loope 1994). This spider was also commonly observed in visual habitat searches under rocks and on open ground.

Several species of large alien flies in the families Muscidae, Tachinidae, Calliphoridae, and Sacrophagidae also occurred in most pitfall traps. These species are cosmopolitan in distribution. They were also visually observed to be abundant near the septic drain field northeast of the MSSC.



Large alien flies were abundant at the site.

Another insect observed was the Haleakalā Flightless Moth, *Thyrocopa apatela* (Walsingham). They averaged about 1 adult per pitfall trap and were seen walking and jumping across the cinder substrate.

Haleakalā Flightless Moth.

True bugs of the genus Lygaeidae were abundant on the vegetation at the site. These endemic species have been collected from the site in previous surveys.

Lygaeidae, *Nysius nemorivagus* White, abundant on foliage at the site.

Previous Studies

The summit of Haleakalā has been sampled by several entomologists. Some of the first specimens known from there were collected by the Reverend Thomas Blackburn over 100 years ago. Near the beginning of the twentieth century, R.C.L. Perkins sampled the upper reaches of Haleakalā. During the first half of the century other entomologists who sampled Haleakalā included O.H. Swezey who recorded host plant information for many insect species, E.C. Zimmerman who collected information for the Insects of Hawaiʻi series and studied the flightless lacewings of Haleakalā, and D.E. Hardy who worked extensively with the Diptera (flies) found there.

Entomological studies continued in the 1960's when John Beardsley (1966) investigated species of *Nysius* that were disrupting operation of the Haleakalā Observatory. In that study Beardsley collected fifty-one insect species from 36 families in nine orders from malaise traps on Pu`u Kolokole.

In 1980, John Beardsley completed his basic inventory of the Insects of the Haleakalā National Park crater district for the Cooperative National Park Resources Studies Unit of the University of Hawaiʻi at Manoa. This was the first published report of a thorough inventory of the upper portion of Haleakalā listing the species collected. Three hundred and eighty-nine species of insects representing ninety families from thirteen orders were collected from the Crater District in this study. About 60% of the species were believed to be endemic to Hawaiʻi, and 83 species (21%) were determined to be endemic to Haleakalā.

The last review of the arthropod fauna at the Haleakalā High Altitude Observatories Site before the current study occurred in 1994 (Medeiros and Loope 1994). The study was limited to the proposed Air Force Construction Site. The number of species collected is not listed in that report. The report concluded "The study site is basically a typical but somewhat depauperate example of the Haleakalā aeolian zone."

Current Study

Of the fifty-eight arthropod species collected during this study, twenty-nine (53%) are apparently endemic to Hawaiʻi. Thirty-six of the species collected have been previously reported from upper elevations on Haleakalā . Twenty-one species (37%) are new records for the Haleakalā High Altitude Observatories Site.

The arthropod fauna collected during this study will be discussed according to their taxonomic groups.

Class Arachnida

Order Acari
Mites

There are 572 species of Acari (mites) reported in Hawaiʻi (Nishida 1997), ninety-one that occur on Maui. They may be sorted into two major groups, free-living and parasitic. Free-living mites can be further classified into predaceous, phytophagous (plant-feeding), mycophagous (fungi-feeding), saprophagous (feeding on dead tissue), and coprophagous (dung-feeding) forms.

Mites perform important functions in ecosystems. They help breakdown plant litter and implement nutrient recycling. Predaceous mites feed on other arthropods and help to balance their populations.

Their diversity in form, habitat, and behavior make mites difficult to identify taxonomically. Three morphospecies of mites were identified from pitfall traps during this study. They were relatively rare, and occurred only in three traps on the outer northwest slopes of Pu`u Kolekole. As a comparison, only one species mite was reported from pitfall trapping in the summit area of Mauna Kea (Howarth et al. 1999).

Because mites were not mentioned in previous reports about the arthropod fauna of Haleakalā, it is difficult to determine any change in their status at this site. It is likely that mites naturally occur on the site, and that none are endemic to only the site, although some may be found only in habitats on Haleakalā. Mite habitats at the Haleakalā High Altitude Observatories Site also occur over a large area of Haleakalā and site development has probably not significantly reduced available specific mite habitat overall.

Order Araneae
Spiders

Spiders are one of the most abundant arthropods at the Haleakalā High Altitude Observatories Site. The large endemic wolf spider, *Lycosa hawaiiensis* Simon, was frequently encountered when searching under rocks and collecting at the site. Adults and juveniles also occurred in pitfall traps, averaging over nine specimens per trap (~ 2 adults and 7 juveniles).

Adults of this large predator can reach up to 2 inches (5 cm) in length. Juveniles that appeared in traps were as small as 1 cm in length. To protect themselves from the climatic extremes, Lycosids construct burrows under rocks by cementing leaves and wind-blown detritus together with silk (Medeiros and Loope 1994). During favorable conditions, these spiders emerge from their burrows to hunt for prey.

The wolf spider are most commonly found under rocks in open cinder habitat. They occur down to 7,875 ft (2,400 m) on Haleakalā, and are also found on Oahu and Hawai'i.

Spiders of the family Linyphiidae were also observed on the site. Linyphiid spiders are small, usually less then 2 mm in length, and are difficult to see during visual reconnaissance. Only five species of these spiders are reported from Maui, 3 endemic and two nonindigenous (Nishida 1997).

Only a few individuals were collected in pitfall traps, and none were observed during habitat searches. They were also relatively rare during the 1994 survey (Medeiros and Loope), and their status is unchanged. This group of spiders is not well studied and little is known about their distribution and abundance.

No other taxa of spiders were found during this study. While some of the Linyphiidae spiders may be introductions, more taxonomic work needs to be completed before definitive conclusions about observatory operational impacts can be assessed, however because of their relatively low abundance it is unlikely that spiders introduced (if any) by observatory construction and operations are significantly impacting habitats on Haleakalā.

Class Chilopoda
Centipedes

Centipedes are elongate, flattened arthropods with 15 or more pairs of legs, one pair per body segment. They occur in a variety of habitats, where they feed on spiders and insects.
There are 24 species of centipedes reported in Hawaiʻi, only one from Maui, the nonindigenous, *Mecistocephalus spissus* Wood (Nishida 1997). Only five specimens of centipedes were collected in this study. Because of a lack of taxonomic keys, they were not identified.

Class Diplopoda
Millipedes

Millipedes are elongate, wormlike arthropods with 30 or more pairs of legs, two pair per body segment. Millipedes are scavengers and feed on decaying plant material. There are 25 species known in Hawaiʻi, 8 on Maui.

Thirty specimens of millipedes were collected in pitfall traps during this study. All were apparently the same species. Because of a lack of taxonomic keys, they were not identified.

Class Insecta

Order Coleoptera
Beetles

Beetles are the most diverse group of arthropods in Hawaiʻi. There are 1,983 species of beetles reported in Hawaiʻi (Nishida 1997), 544 on Maui (B.P. Bishop Museum 2002).

Eleven species of beetles were found during this study. Only two are endemic to Hawaiʻi. In his 1980 study, Beardsley reported 45 species from the

Crater District of Haleakalā, including 29 endemic species. In the last arthropod survey at the Haleakalā High Altitude Observatories Site, fewer than 10 species were reported, only one of which is endemic (Medeiros and Loope 1994).

The most interesting endemic species captured are the two Carabidae species. Both were reported in the 1980 Crater District survey, and one, *Blackburnia rupicola* (Blackburn), was previously reported from the Haleakalā High Altitude Observatories Site. This species is the largest and most common of the 10 native carabid beetles known from the aeolian zone on Haleakalā.

Carabid beetle, *Blackburnia rupicola*.

The smaller species, *Bembidion molokaiense* (Sharp), was last recorded from Haleakalā in 1980 near the Kuiki Trail at 6,400 ft (1,950 m). While only a few specimens of the species were collected, evidently habitat for both continues to persist at the study site.

The most abundant nonindigenous beetle family collected during this study was Coccinellidae, Ladybird beetles. Three species of this family were found, all purposely introduced for biological control of pests.

Five specimens of Fuller's rose weevil, *Pantomorus cervinus* (Boheman), was collected. This flightless weevil is found throughout the southern United States and is believed to be native to tropical America. It is a pest on roses and is also known to feed on coffee leaves. It was last reported on Haleakalā at Waikau. It has likely established a population on local vegetation at the site. It is a potential pest, but is not considered extremely damaging.

A few individual specimens of other beetle families also occurred in pitfall traps. Single specimens of nonindigenous Cerambycidae, Cleridae, and Chrysomelidae appeared in pitfall traps. In addition, a few specimens of Desmestidae and Staphylinidae were found. None of these were abundant and are cosmopolitan in distribution.

Alien Chrysomelidae beetle.

Order Collembola
Springtails

Collembola are small, insect-like arthropods. They are abundant and ubiquitous, exceeding all other insects in numbers of individuals (Christiansen and Bellinger 1992). Most species are detritivors and few are pests. One hundred and sixty-nine species of Collembola are found in Hawai'i, sixty on Maui (Nishida 1997).

Because of their small size (0.25 – 6 mm), Collembola are seldom observed or reported. In 1980, five species of Collembola were reported from the Crater District of Haleakalā. At least two species were collected during this study. They were abundant in pitfall traps, occurring in the hundreds in some locations, especially on the outer northwest slopes of Pu`u Kolekole.

Order Diptera
Flies

Diptera is the second most diverse order of insects in Hawai'i, with 1,449 species representing fifty-seven families. Some of the families, such as Dolichopodidae and Drosophilidae, showed remarkable species radiations and unusual evolutionary developments (Howarth and Mull 1992).

In previous studies on Haleakalā , more than 115 species of flies were recorded (Beardsley 1980, Medeiros and Loope 1994). Only a few of those species were recorded near the 10,000 ft summit of the volcano.

During this study, nine species of flies were captured. The most abundant were nonindigenous species of Muscidae (house flies) and Calliphoridae (blow flies). These species are attracted to traps with dead arthropods and therefore their relative abundances are exaggerated.

Several observatory personnel asked about the pesky flies that appeared in large numbers during certain times of the year. Muscids can become locally abundant and are a nuisance during peak seasons.

Except near the septic leach field northeast of the site, no flies were visually abundant. Flies of the families Calliphoridae and Sarcophagidae were observed to be abundant near the leach field, probably attracted to the distinctive odor from the vents.

The flesh fly, *Blaesoxipha plinthopyga* was collected on northeast portion of the site.

Several specimens of Phoridae (hump-backed flies), Drosophilidae (pomace flies, and Sciaridae (dark-winged fungus gnats) were collected. Some of these may be endemic species, but individuals from these families were not abundant in traps or during the visual reconnaissance.

Order Heteroptera
True Bugs

The order Heteroptera contains 408 species in Hawaiʻi, 304 of which are endemic. Most species feed on plants, inserting their straw-like mouth parts into the plant to extract the juices. Some species are predaceous. One species, the Wēkiu bug, *Nysius wekiuicola*, has made a remarkable evolutionary modification, adapting to high elevations on Mauna Kea and feeding on wind-blown insects instead of seeds like its closest relatives.

Forty species of true bugs were recorded during the 1980 Crater District inventory on Haleakalā, but most occurred well below the summit area. Eight species of true bugs were recorded during the investigation conducted on the Haleakalā High Altitude Observatories Site in 1966. Of these six species, only three actually are residents of the site (Beardsley 1966).

In the current study, eight species of true bugs, all endemic to Hawaiʻi , were found in pitfall traps and on plants. With one exception, a Nabidae or damsel bug, these species feed on plants The damsel bug is predaceous and feeds on other insects.

Two of the true bug species were abundant at the study site, *Nysius coenosulus* White, and *Nysius nemorivagus* White. Both were abundant on *Dubautia menziesii* , with several hundred appearing on beating sheets during foliage sampling. The species were also abundant in pitfall traps, averaging about 5.5 bugs per trap.

These species are known to accumulate in large aggregations at the site and can disrupt observatory operations (Beardsley 1966).

The Mirid, *Hyalopeplus palucides* was found on foliage and the sides of buildings.

Order Homoptera
Psyllids, Aphids, and Hoppers

The order Homoptera is another large and diverse group of insects. There are 695 species of Homoptera found in Hawai'i, 386 considered endemic (Nishida 1997). All species feed on plant juices and like the Heteroptera, they use their straw-like mouthparts to feed.

In the 1980 insect inventory of the Crater District of Haleakalā, 44 species of Homoptera were found on various plants, but only nine species occurred above 8,000 ft. In his investigation in 1966, Beardsley (1966) found only two species of Homoptera at the Haleakalā High Altitude Observatories Site.

In the current study we collected nine species of Homoptera. All but one of these species are endemic to Hawai'i. The species not endemic was an aphid of cosmopolitan distribution and probably occurs naturally Hawai'i.

Two species were abundant in pitfall traps and on foliage, the endemic Psyllid (jumping plant lice) of the genus *Kuwayama*, and the aphid. In relatively smaller abundance was another Psyllid, *Swezeyana elongate* Caldwell. The other species of Homoptera were collected as individual specimens and probably are not residents at the site.

Order Hymenoptera
Bees and Wasps

Bees and wasps are common in Hawai'i. There are 1,270 species that occur in Hawai'i. Of these species, 652 are endemic to Hawai'i that consist largely of small parasitic wasps, mud-daubers, and yellow-faced bees. The yellow-faced bees (family Colletidae) are important pollinators of native plants (Howarth and Mull 1992). Many of the nonindigenous species were purposely released for biological control of agricultural pests.

The wasp, *Enicospilus mauicola.*

Another important group of Hymenoptera are the ants (family Formicidae). There are no endemic ants in Hawaiʻi, but at least forty-four species that now occur here. All were accidentally transported to Hawaiʻi where they have become a major threat to native arthropods. No ants were found during this study, and none were reported in previous studies.

At least eleven species of Hymenoptera were collected during this study. Many were very small parasitic wasps that are difficult to identify with current keys. Hymenoptera were relatively uncommon at the site, a similar finding as that recorded in 1994 (Medeiros and Loope). In an earlier investigation (Beardsley 1966), 12 species of Hymenoptera were collected at the site, mostly small parasitic wasps. Most of the species are not likely residents of the site and probably are carried by winds from lower elevations. The status of this group is largely unchanged since 1966.

Order Lepidoptera
Moths and Butterflies

There are 1,148 species of moths and butterflies found in Hawaiʻi, a majority (957) of which are endemic. Many of the endemic species are small moths with a wingspan of less than 1 cm (Howarth and Mull 1992).

Endemic Lepidoptera in Hawaiʻi have made a remarkable feeding adaptation. In most of the World, butterfly and moth larvae are plant feeders. In Hawaiʻi several species of butterflies and moths have been found to be insectivorous. Larvae of some forest inch worms (family Geometridae) species are ambush predators that blend imperceptibly into their surroundings. Small hairs and nerves on their backs indicate the presence of prey. In a fraction of a second the caterpillar can snap backward and grab its meal with pincer-tipped forelegs.

In higher elevations, larvae of some moths in the family Noctuidae eat wind-blown lowland arthropods that become moribund as nighttime temperatures drop. They may also feed on leaves of the few plants that occur in their habitat. Noctuid caterpillars were captured in pitfall traps averaging less than one per trap during the study.

Caterpillar of the Haleakalā Flightless Moth

Not more than 6 species of Lepidoptera have been reported from Pu`u Kolekole during previous studies (Beardsley 1966, 1980, Medeiros and Loope 1994). Only two Lepidoptera species are considered residents of the site and both were found in low abundance in this current work. A few individual specimens of Pyralidae and microlepidoptera were also collected during this study.

Summary of the Arthropod Fauna

The arthropods species that were collected during this study were typical of what has been found during previous studies. No species were found that are locally unique to the site. Nor were any species found whose habitat is threatened by normal observatory operations. Several species were new site records, and as the site is studied more extensively new site species records could be expected.

The diversity of the arthropod fauna at the Haleakalā High Altitude Observatories Site is somewhat less than what has been reported in adjacent, undisturbed habitat. This could be expected given the fact that about 40% of the site is occupied by buildings, roads, parking areas, and walkways. Also, much of the ground surrounding the buildings is disturbed and compacted from observatory operations. However, the undisturbed habitat on the site that was sampled has an arthropod fauna generally similar to what could be expected from other sites on the volcano with similar undisturbed habitat.

While development of the site has impacted the availability of some habitat locally, it is unlikely that observatory construction has eliminated a significant amount of habitat on the volcano overall. The 18.1 acre (7.3 hectare) facility occupies less than one percent of similar habitat available on the volcano (MacDonald 1978). The undisturbed portions of the Haleakalā High Altitude Observatories Site is representative of the surrounding habitat on Haleakalā.

Most of the arthropods collected during this study are largely associated with the vegetation at the site. Apparently observatory construction and operations has increased the suitability of some habitats for some plants (Starr and Starr 2002). Increased vegetation has probably caused an increase in the populations of some of the native arthropod species, specifically Heteroptera in the genus *Nysius*. Unfortunately these are the same species that can disrupt astronomical research at the site (Beardsley 1966). If long range development diminishes the presence of the native vegetation, the arthropod diversity will probably decline as well. This should not threaten the persistence of any species found at the site because the site is only a small part of the overall habitat available for occupancy.

Only a few exclusively ground-dwelling species were found during this study. These include the wolf spider, ground beetle and flightless moth. These species make their home under rocks and in crevices and do not burrow into the cinder substrate. There are no large accumulations of loose cinder at the site and no arthropod species were collected that would use such habitats.

No obvious threats to species survival were evident at the Haleakalā High Altitude Observatories Site. Some species may become extinct on the site because of loss of habitat locally, but their persistence in the larger ecosystem should not be threatened by current activities.

One of the biggest concerns of past evaluations was the presence of ants. None were found during this study, but ants are reported from nearby National Park facilities. With some practical precautions, the site should remain ant free.

Alien arthropod species also have the potential to impact the native ecosystem. No obviously threatening alien species were found during this study and with similar precautions as those used for ants, none should be introduced by observatory construction or operations. The harsh environment of this aeolian ecosystem should make it difficult for most alien species to establish populations.

The most interesting arthropods found during this study were the native wolf spiders, *Lycosa hawaiiensis* Simon, the ground beetle, *Blackburnia rupicola* (Blackburn), and the Haleakalā Flightless Moth, *Thyrocopa apatela* (Walsingham). These species are unique to the higher elevations of Haleakalā and have made interesting adaptations to the harsh environment. Observatory development at the site has not significantly reduced the available habitat for these species and they should persist in the large amount of surrounding undisturbed habitat in the adjacent National Park.

VII. RECOMMENDATIONS

ALIEN ARTHROPOD CONTROL

Analysis of Potential Impacts

Arthropods, segmented animals with hard exoskeletons and jointed appendages, are the most diverse group of animals on earth today. Arthropods are insects, spiders, centipedes, and crustaceans, and are found in all habitats from the bottom of the oceans to the tops of the highest mountains. Arthropod species introduced outside their natural range represent a threat to natural systems because they can deplete native arthropod food resources and prey on native species, sometimes driving natives to extinction. Alien species that successfully establish populations within the Haleakalā High Altitude Observatories Site could out-compete or exclude native species, such as the Haleakalā Flightless Moth, lycosid wolf spider, and other native resident arthropods.

Alien species are those that occur outside of their natural range. Accidentally introduced alien arthropods arrive in the United States at the rate of about 11 new species per year (Sailer 1983). It has been estimated that more than 3,200 alien arthropods have been accidentally or intentionally introduced in Hawai'i (Howarth and Mull 1992). About 2,500 of these species have established resident populations. Alien arthropods appear in virtually every Hawaiian habitat from sea level to the summits of the highest mountains.

Many insect introductions are regarded as beneficial (i.e., honeybees and biological control agents), but some are feared as potentially dangerous (i.e., ants, spiders, and wasps). The populations of some introduced species have reached destructive numbers and caused serious environmental damage to natural areas. The decline of Hawaiian endemic arthropod populations, resulting from accidental introduction of alien arthropods, is well documented (Howarth 1985).

One destructive alien species that has been reported in low numbers near Pu`u Kolekole is the yellowjacket (*Vespula pensylvanica*). It appeared in low numbers during the 1994 arthropod study of the Air Force Facility. While none were found during the current study, the species can become abundant seasonally in September through November (Medeiros and Lope 1994).

This predator arrived in Hawaiʻi in 1977 on imported Christmas trees (Gambino et al. 1990). It quickly became established and spread to all of the main islands. In some places the increasing yellowjacket population corresponded to an alarming decline in many native arthropods vulnerable to the new predator (Gambino et al. 1990). Current yellowjacket populations are too low at the Haleakalā High Altitude Observatories Site to contribute to the decline of native arthropod. If yellowjacket numbers increase at the site, however, native populations could be impacted.

Yellowjacket, *Vespula pensylvanica*, introduced to Hawaiʻi on Christmas trees. Photo courtesy Ohio State University.

Ants are another group of alien species that have impacted native Hawaiian arthropod populations. Forty-four ant species, none of which are native, have been recorded in the Hawaiian Islands. All were accidentally introduced. Ants can have a devastating impact on the native fauna and flora. Hawaiʻi's endemic arthropods never evolved adaptations such as mimicry, or secretions to avoid predation by ants, as is commonly observed with arthropods from areas where ants occur naturally. The establishment of ants within the Haleakalā High Altitude Observatories Site could result in the reduction and possible elimination of many native arthropods.

Perhaps the greatest alien threat to native arthropods is the Argentine ant, (*Linepithema humile*). Although they are relatively small (even for ants), the Argentines nevertheless are quite prolific. Colonies create anywhere from 20 to 100 queens, each producing vast numbers of eggs that keep the colony growing and expanding. In order to feed all the ants that build up in a single colony, Argentine ants utilize and monopolize every available food resource. Vulnerable food resources include not only the wind-borne food of the naturally occurring species, but also the resident native arthropods themselves. Especially vulnerable to ants are the small, immature, nymph stages or instars of native arthropods.

The Argentine ant, (*Linepithema humile*), is common in lowlands on all main islands in Hawaiʻi.

The Argentine ant occurs in several areas in Hawaiʻi, including high elevation sites such as Haleakalā National Park on Maui, Hawaiʻi Volcanoes National Park, and up to 8,500 feet on Mauna Kea. No Argentine ants were found during this study and the Haleakalā High Altitude Observatories Site is believed to be currently free of ants (Medeiros and Loope 1994).

Other ant species of concern are the big-headed ant, (*Pheidole megacephala*), the long-legged ant, (*Anoplolepis longipes*), the fire ants, (*Solenopsis geminata* and *S. papuana*), and the black house ant, (*Ochetellus glaber*). All these species are present on the Island but have never been reported to occur on the Haleakalā High Altitude Observatories Site.

Alien spiders are another potential threat to the resident native arthropods. The South American hunting spider, (*Meriola arcifera*) has been collected near observatories on Mauna Kea. While its method of introduction is unconfirmed, its occurrence has been linked to observatory operations by some environmental groups. It does not build webs but instead hunts on the surface and interstitial spaces of the cinder cones. The hunting spider is large enough to capture many of the native arthropods at the Haleakalā High Altitude Observatories Site and can potentially reduce their population.

The probability for the introduction of a serious predator is small. It is important, however, to prevent the establishment of alien species in the sensitive high elevation habitats. Alien arthropod control is therefore an essential consideration during future observatory construction and operation.

Alien Arthropod Control Recommendations

The following actions are recommended to prevent the establishment of alien arthropods on the Haleakalā High Altitude Observatories Site. If these recommendations are followed, no significant impact to native arthropod populations should occur as a result of alien arthropod introductions during the construction and/or operation of the observatories at the site.

Recommendation 1

Earthmoving equipment should be free of large deposits of soil, dirt and vegetation debris that could harbor alien arthropods.

(a) Pressure-wash to remove alien arthropods.

Alien arthropods can arrive at the site by two general pathways. First, alien species already on the Island can spread to new localities. Second, alien species can arrive with shipping crates and containers. In order to block the first pathway, heavy equipment, trucks, and trailers should be pressure-washed before being moved to the site.

Earthmoving equipment and large vehicles and trailers often sit at storage sites for several days or weeks between jobs. Most of these storage sites are located in industrial areas and usually support colonies of ants and other alien arthropods. These species often use stored equipment as refuges from rain, heat, and cold. Ants will colonize mud and dirt stuck to earthmoving equipment and could then be transported to uninfested areas. Spiders occupy stored equipment, looking for food or escaping predation by hiding in protected niches. Once transported to the site, these species could migrate to surrounding habitat.

Pressure-washing of equipment before transportation to the site will remove dirt and mud and wash away ants, spiders and other alien arthropods, thereby reducing the chances of transporting these species to the site area.

(b) Inspect large trucks, tractors, and other heavy equipment before entering Haleakalā National Park.

Tractor-trailer rigs, earthmoving machinery, and other heavy equipment should be inspected before Haleakalā National Park. Inspection should be recorded a log book kept at the site.

Recommendation 2

All construction materials, crates, shipping containers, packaging material, and observatory equipment should be free of alien arthropods when delivered to the site.

(a) Inspect shipping crates, containers, and packing materials before shipment to Hawai'i

Alien arthropods can be transported to Hawai'i via crates and packaging. Only high quality, virgin packaging materials should be used when shipping supplies and equipment. Pallet wood should be free of bark and other habitat that can facilitate the transport of alien species. Federal and Hawaiʻi State agricultural inspectors do not currently check all imported non-food items for alien arthropods. Haleakalā National Park resource managers should communicate to shippers, and suppliers the environmental concerns regarding alien arthropods, and inform them about appropriate inspection measures to ensure that supplies and equipment shipped to Hawaiʻi are free of alien arthropods at the points of departure and arrival.

Shipping containers should be inspected and any visible arthropods removed. Construction of crates immediately prior to use will prevent alien arthropods from establishing nests or webs. Cleaning containers just prior to being loaded for shipping will also eliminate alien arthropod infestations.

After arrival in Hawaiʻi, crates or boxes to be transported to the site should be inspected for spider webs, egg masses, and other signs of alien arthropods. Arthropods are small and easily overlooked during hectic assembly and packaging activity off-island. Many arthropods could escape detection during shipping inspections. Re-inspection prior to transport to the site should reduce the potential for undetected arthropods reaching the construction site.

(b) Inspect construction materials before entering Haleakalā National Park.

Alien arthropods already resident in Hawaiʻi are capable of hitchhiking on construction material such as bricks and blocks, plywood, dimension lumber, pipes, and other supplies. Precautions should be taken to ensure that alien arthropods are not introduced to the Haleakalā High Altitude Observatories Site.

Construction materials should be inspected before transport to the construction site. If any alien arthropods are discovered, the infestation should be removed prior to transport. Infestations of ants can be removed using pressure-washing. Infestations of spiders can be removed using brooms, vacuum cleaners, or other similar methods. Pesticide use on materials to be transported to the site should be avoided.

Recommendation 3

As is currently being done at the site, outdoor trash receptacles should continue to be secured to the ground, have attached lids and plastic liners, and collected frequently to reduce food availability for alien predators.

Readily available food supplies can facilitate the establishment of alien arthropods at the Haleakalā High Altitude Observatories Site. Sanitary control of food and garbage will prevent access to food resources that could be used by invading ants and yellowjackets.

Refuse containers should be heavy and secured to the ground. Heavy, hinged lids will prevent wind dispersal of garbage. Refuse should be collected on a regular basis before containers are completely full or overflowing. This could entail collection several times a week, particularly in eating areas and during periods of heavy use of the area.

Containers should be regularly washed using steam and/or soap to reduce odors that attract ants and yellowjackets. Plastic bag liners should be used in all garbage containers receiving food to control leaking fluids.

Recommendation 4

Monitoring for new alien arthropod introductions should be conducted during any construction activities. Any populations detected during monitoring should be eradicated.

Monitoring for alien populations is relatively easy and inexpensive to conduct. Baited traps have been shown to detect alien populations before they reach damaging proportions.

(a) Ant eradication

Sticky traps designed to capture ants should be deployed immediately after any ants are detected. Persistence of ant detections is indicative of larger infestations, and should prompt a search for and eradication of colonies. Bait and chemical control should be employed only when absolutely necessary and only by a certified pest control professional. In no case should pesticides be applied on or near native arthropod habitat.

(b) Yellowjacket eradication

Traps should be deployed when yellowjackets are detected. Trapping yellowjackets is a useful method of control that does not require pesticides. Lures or baits will improve the effectiveness of traps. Localized yellowjacket populations can be reduced to non-threatening levels if trapping is employed immediately after detection. Traps should be maintained until yellowjackets are no longer detected.

(c) Alien spider eradication

Alien spider webs should be removed when detected. Native lycosid wolf spiders do not make webs. Native sheet-web spiders make tiny webs under the cinder surface. Only alien spiders make large spider webs on the Haleakalā High Altitude Observatories Site. Sweeping such webs away with a broom disrupts alien spider food capture success and destroys egg masses.

TRASH CONTROL RECOMMENDATIONS

Analysis of Potential Impacts

Construction activity may generate a considerable amount of waste debris. Typically construction debris is disposed of in "roll-off" containers that are periodically picked up and emptied at a landfill. Large "roll-off" containers can accommodate debris generated over several days of construction. Debris disposed of in these containers consists of wood, scrap insulation, packaging material, waste concrete, and various other construction wastes.

High winds at the site can extract construction debris from the containers and disperse the material into adjacent arthropod habitat. Unsecured building materials and equipment on-site is also susceptible to wind dispersal. The construction trash and building material is not believed to significantly impact native arthropod species, but the collection of the wind-blown material could potentially disturb their habitat (e.g., Howarth et al. 1999).

Recommendation 5

Construction trash containers should be tightly covered to prevent construction wastes from being dispersed by wind.

Covering containers will decrease the amount of construction debris that could be blown onto adjacent native arthropod habitat. "Roll off" containers can be equipped with tarps held securely with cables. Containers should be collected on a regular basis before they are completely full or overflowing. This could entail collection several times a week, particularly during periods of heavy use.

"Roll off" trash container frequently used at construction sites. Photo courtesy Bucks Fabricating.

Recommendation 6

Construction materials stored at the site should be covered with tarps, or anchored in place, and not be susceptible to movement by wind.

Construction materials and supplies should be prevented from being blown into native arthropod habitat by covering them with heavy canvas tarps, using steel cables, attached to anchors that are driven into the ground.

Construction materials at the site should be tied down or otherwise secured during high winds and at close of work each day. Securing materials will reduce the chances of debris being blown off the site into native arthropod habitat. Preventing debris from blowing around and off the site will reduce costs and the potential habitat disturbance necessary to retrieve the items.

Recommendation 7

Outdoor trash receptacles should be secured to the ground and have attached lids.

Workers and visitors to the Haleakalā High Altitude Observatories Site unfortunately often bring trash with them. Lunch bags, film canisters, wrappers, etc. can be easily blown into arthropod habitat. Receptacles should be provided to eliminate the dispersal of this kind of trash. The receptacles should be heavy and have attached lids so that they do not become flying objects in the high winds at the site.

Recommendation 8

If construction materials and trash are blown into native arthropod habitat, they should be collected with a minimum of disturbance to the habitat.

Despite efforts to prevent wind-blown construction materials and trash, some debris could end up in native arthropod habitat. Retrieving this debris from sensitive areas should be done carefully and with minimum disturbance. Small pieces of debris should be allowed to blow out of habitat to spots where they can be collected safely. Larger debris should be removed with minimum disturbance to slope stability and structure. Methods for removal may vary depending on the material and its location. Contractors should be educated about appropriate debris retrieval methods.

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