ARTHROPOD INVENTORY AND ASSESSMENT AT THE HALEAKALĀ NATIONAL PARK ENTRANCE STATION AND AT THE HALEAKALĀ HIGH ALTITUDE OBSERVATORIES MAUI, HAWAI`I

In support of the Advanced Technology Solar Telescope Environmental Impact Analysis Process

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II. EXECUTIVE SUMMARY

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) 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. The summit of Haleakalā is also the home to unique cultural and natural resources. Important cultural places and sites are found here that are spoken of in numerous Hawaiian mele (songs), oli (chants) and legends (NPS 2005). Arthropods occur near the summit of Haleakalā in an aeolian ecosystem that was once considered virtually lifeless. The subalpine shrubland within the Haleakalā National Park is also host to a wide variety of indigenous species. Because these areas remain fairly intact, they represent important habitat for unique and highly adapted native arthropod species (Loope and Medeiros 1994).

The National Science Foundation (NSF) has proposed the development of the Advanced Technology Solar Telescope (ATST) within the 18-acre University of Hawai`i Institute for Astronomy High Altitude Observatories (HO) site. The ATST represents a collaboration of 22 institutions, reflecting a broad segment of the solar physics community. The proposed ATST project would be the largest and most capable solar telescope in the world. It would be an indispensable tool for exploring and understanding physical processes on the Sun that ultimately affect Earth. The proposed ATST Project would be contained within a 0.74 acre site footprint (FEIS, 2009) in the HO site.

The current configuration of the existing entrance station for Haleakalā National Park (HALE) has been identified as a restriction to wide truck loads necessary during construction of the ATST. Loads up to about 33 feet wide would be required to move telescope components to the ATST site. The HALE entrance station currently provides one paved driving lane approximately 12 feet wide on both the entrance and exiting sides. HALE staff has identified a mutually preferred option to temporarily widen and improve the shoulder of the entry on the uphill side of the entrance station to accommodate the large loads. The provision of wide-load truck access at the HALE entrance station would require mitigations related to that project, as described in Section 4.18.5 of the Final Environmental Impact Statement (2009). The proposed mitigation includes protection of habitat for biological resources and HALE infrastructure. Additional information about arthropods that may occur near the entrance station is necessary to understand potential impacts, if any, due to the proposed road modifications made there.

An inventory and assessment of the arthropod fauna at the proposed ATST sites was conducted in 2005 with supplemental sampling in 2007. The goal of this study was to inventory the arthropod fauna near the entrance station and at the proposed ATST sites, identify Hawaiian native arthropod species or habitats, if any, that could be adversely affected by construction or operation of the ATST, and provide a seasonal component of baseline information that may be used for proposed programmatic monitoring.

III. INTRODUCTION

The Haleakalā volcano on the island of Maui is one of the highest mountains in Hawai`i, reaching an elevation of 3,055-m (10,023-ft) 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 (HO) 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 unique resident insects and spiders (Medeiros and Loope 1994). These arthropods inhabit unusual 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 2,300-m (7,546-ft) elevation in the cinder-dominated habitat inside the crater, and at around 2,600-m (8,530-ft) on the older western slope of the volcano, and extend up to the summit at 3,055-m (10,023-ft). 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.

An inventory and assessment of the arthropod fauna at the HO site was conducted in 2003 as part of the Long Range Development Plan (LRDP) for the Haleakalā High Altitude Observatories. This inventory and assessment was updated in December 2005 to provide a more detailed description of the arthropod fauna at the two proposed ATST sites, and identify Hawaiian native arthropod species or habitats, if any, that could be impacted by construction or operation of the ATST. In an effort to be complete, supplemental sampling was conducted in 2007 to provide a seasonal component and additional nighttime sampling not included in the previous two inventories.

The subalpine shrubland within the Haleakalā National Park is also host to a wide variety of indigenous arthropod species (Krushelnycky et al. 2007). The vegetation here covers most of the open ground, mostly with *pūkiawe* (*Styphelia tameiameiae*), *ōhelo* (*Vaccinium reticulatum*), and occasional *mamane* (*Sophora chrysophylla*) trees and *Coprosma* shrubs, with native and alien grasses growing between. Precipitation in the form of rainfall and fog is frequent, with about 70 inches falling throughout the year (Giambelluca et al. 1986).

Because the areas proposed for development remain fairly intact, they represent important habitat for unique and highly adapted native arthropod species (Loope and Medeiros 1994). Sampling of arthropod habitats was approved in a permit obtained from the Department of Land and Natural Resources (Permit # FHM09-188) and the National Park Service (Permit # HALE-2009-SCI-0007), both issued in June, 2009. Sampling began on June 19, 2009 and was completed on June 26, 2009.

The intended purpose of this study is to gather reliable scientific information about the current status of arthropods and other invertebrate species near the HALE entrance station and at the proposed ATST primary and alternative sites within the HO site that would be used to assess the potential impacts, if any, due to construction of the proposed ATST.

This study provides a means of gathering information that can be used to establish a baseline for proposed programmatic monitoring of native arthropod and invertebrate species over the next ten years as part of the proposed ATST Project mitigation measures described in Section 4.18.3 of the FEIS. This study supports natural resource management programs at Haleakalā National Park and is consistent with the Long Range Development Plan for the Haleakalā High Altitude Observatories Site (HO) by promoting the good stewardship of the natural resources located there.

IV. METHODS

Description of study area

The Haleakalā High Altitude Observatories (HO) site is located on Kolekole Hill. The site is at 3,052-m (10,012-ft) above sea level, adjacent to Pu`u `Ula`ula, also known as Red Hill, the highest elevation on Maui, 3,055-m (10,023-ft). The 7.3-ha (18.1-ac) 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 proposed ATST primary site is on undeveloped land located east of the existing Mees Solar Observatory facility. The proposed alternative site is at Reber Circle, a previously developed site located north of the existing LURE/PS-1 facility.

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

The Haleakalā National Park Entrance Station is at about 2,072 m (6,800 ft) on the western slope of Haleakalā. Sampling locations were determined with guidance and cooperation from HALE personnel. Annual precipitation here averages 1,750 mm (70 in), falling primarily as rain and mist during the winter months from November through April.

Procedures

The selection of a trapping technique used in a study was carefully considered. When the target species of the trapping system are rare or important for other reasons (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. The sampling methods that were used during this study are similar to those used during the 2007 arthropod inventory conducted on the western slope of Haleakalā and were reviewed by HALE natural resource staff modified according to their comments.

Pitfall Traps

After consultation with HALE natural resources staff, twelve pitfall traps were installed (eight below the road and four above the road) near the HALE entrance station. Nine pitfall traps were installed at the proposed ATST sites (five at the Mees site and four at the Reber Circle site). The traps (300 ml [10 oz], 80 mm diameter cups) were filled with soapy water solution as preservative. Concerns about endangered native birds precluded the use of ethylene glycol. The traps were spaced at least 2 m apart, and left open for one week. It was decided that pitfall traps would not be baited around the rim with blended fish because they might attract birds. This is a trapping method similar to that used during the 2007 arthropod survey conducted in 2007 (Krushelnycky et al. 2007).

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 or near these sites. A map of significant historic and cultural sites within 50 feet of the road corridor was used to avoid such sites. Habitat was accessed with a minimum of disturbance to the habitat. Care was also taken to prevent creation of new trails or evidence of foot traffic.

Care was also taken to avoid disturbing nesting petrels and other wildlife species. The endangered petrels dig into cinder to make burrows for nesting. Incubation of fledglings was underway and all efforts were made to avoid active nests. Pitfall traps are placed below ground and covered with a heavy cap rock. This makes it very unlikely that petrels could access the traps.

Light-Trapping

Sampling for nocturnal insects is vital to understanding the complete faunal presence. Some insects are only active and moving around at night. Many insects have a nocturnal activity cycle to evade birds, and to locate certain food sources. Night collecting is important in environments like dry locations where insects may choose this strategy to avoid desiccation. Thyrocopa moths, for example, have been seen at lights in restrooms at the HALE Visitor Center, at 9,740 ft.

Battery-powered ultraviolet light traps were operated near the entrance station and at the ATST sites. The traps consisted of a 3.5 gallon polypropylene bucket, a smooth surface funnel, a 22 watt Circline blacklight tube mounted on top of vanes under an aluminum lid that directs light downwards. The effective range of the 22 watt lamp is less than 100 feet, and traps were always located more than 100 feet from the nearest petrel burrow. Light traps will be run every night for seven nights (a total of 14 trap nights).

Other light sampling at night

Night collecting can be aided by a UV light source. An ultraviolet blacklight was placed on top of a white sheet and arthropods that were attracted to the light were collected as they are observed.

Small handheld ultraviolet blacklights were also used for additional sampling for foliage and ground-dwelling arthropods.

Visual Observations and Habitat Collecting Under Rocks and in Leaf Litter

Time was spent sampling under rocks, in leaf litter, and on foliage to locate and collect arthropods at each sampling station. Hand picking, while sorting through leaf litter and bunch grasses, and searching beneath stones was the most effective sampling for litter and soil associated forms.

Collecting on Foliage

Foliage of various common plant species was sampled by beating sheet. A one-meter square beating sheet or insect net was placed under the foliage being sampled and the branch hit sharply three times using a small plastic pipe. After the initial collection the foliage was beat again to dislodge persistent individuals. Care was taken to avoid sensitive plants and to leave all vegetation intact.

Nets

Aerial nets and sweep nets were used as necessary to capture flying insects and arthropods that occur on grasses.

Collections

Arthropods that appear in traps were stored and later mounted for identification. Arthropods that are observed during hand collecting and netting were collected only as necessary to provide voucher specimens.

Curation

The contents of the traps were cleaned in 70% ethyl alcohol and placed in vials. The specimens were sorted into the morpho-species for identification. Hard-bodied species, such as beetles, moths, true bugs, 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 spiders and caterpillars were stored in vials filled with 70% ethyl alcohol.

Identification

Specimens were mounted and identified to the lowest taxonomic level possible within the time frame of the study. Many small flies and micro-Hymenoptera were sorted to morpho-species and will be sent to reliable experts for identification. Identification of arthropods is difficult, even for experts. More time needs to be allotted for this necessary task in all arthropod inventory projects. All specimen identifications are provisional until they can be confirmed by comparison to museum specimens or by group/taxon experts.

References for general identification of the specimens included Fauna Hawaiiensis (Sharp (ed) 1899-1913) and the 17 volumes of Insects of Hawaiʻi (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 Hawaiʻi (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 (1965a, 1965b).

Species identification of those specimens identified to genus or species levels are unconfirmed and subject to change after comparison to specimens in museums.

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).

Schedule/Start and End dates

Sampling was conducted over eight days and nights in June 2009, starting on June 19, 2009 and ending on June 26, 2009. Sampling typically began at 9:00 am and run until about 2:00 pm. A break was taken to prepare for night sampling which resumed at 8:00 pm and continued until midnight. It is estimated that approximately seventy person hours were spent sampling during the day and fifty person hours after dark. Pitfall traps were open for 147 trap nights, and light traps were deployed for 21 trap nights. Three days was allocated for mounting and identification.

V. LITERATURE SUMMARY

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. Beardsley collected fifty-one insect species from 36 families in nine orders from malaise traps on Pu`u Kolekole in that study.

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.

An inventory of arthropods of the west slope shrubland and alpine ecosystems of HALE was conducted in 2007 (Krushelnycky et al.). The investigators collected a total of 60,146 individual arthropods in the course of the inventory. Of these, 11,086 (18.4%) were mites (Acari), mealybugs (Hemiptera: Pseudococcidae), or parasitic wasps (Hymenoptera), and were not further identified. The remaining arthropods represented a total of 257 taxa in 17 orders.

The HO property adjacent to HALE has been studied several times. The first review of the arthropod fauna at the HO site occurred in 1994 (Medeiros and Loope 1994). The study was limited to the proposed Air Force Advanced Electro-Optical System (AEOS) 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."

An inventory of arthropods at the HO site was conducted in 2003 (Pacific Analytics 2003). In that study, fifty-eight arthropod species were identified from the facility, twenty-nine that are indigenous to Hawai`i. Finally, an ATST site-specific update to that study was conducted in 2005 (Pacific Analytics 2005) and a supplemental sampling specifically for the purpose of night sampling was conducted in March 2007 (Pacific Analytics 2007). During June 2009, additional sampling was conducted at HO to further supplement the first three collections, including nighttime samples.

VI. RESULTS AND DISCUSSION

Observations

High Altitude Observatories ATST Sites
The Mees site has had minimal disturbance from previous construction. Vegetation in this area is largely undisturbed and is a mix of native and non-native species. About eighty percent of the Reber Circle site has been disturbed by previous construction. Native vegetation occurs only at the north and east portions of this site.

Sixty-two species of arthropods were collected at the two sites and around the HO facility. Night sampling was fairly effective. Two species of endemic moths were collected in the light traps and a few specimens of the Haleakalā flightless moth (*Thyrocopa apatela*) were found on rocks. They did not appear to be attracted to the lights. An *Agrotis* moth larva was observed foraging at night. *Nysius* (true bugs) species were resting between *Dubautia* leaves and under shrubs, but appeared to be active when disturbed, even at low nighttime temperatures.

Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps at both ATST sites. Several juvenile spiders were observed during daytime sampling. *Lycosa hawaiiensis* is the predominant predator of the arthropod fauna in from the crater district of Haleakalā (Medeiros and Loope 1994). This spider is also known from the islands of Oahu and Hawai`i. They were observed to be especially active during the day.

The pitfall traps also captured several noctuid larvae (caterpillars). Two *Agrotis* moth species were captured in the light traps and these caterpillars may be their larvae. One specimen of the endemic carabid beetle, *Mecyclothorax* sp., was found in the pitfall traps. They are not abundant at the sites although several were found searching under rocks and leaf litter.

The most effective sampling method was foliage beating and searching. Small centipedes and millipedes were found, presumably indigenous species. Twelve species of beetles were found, four that are endemic to Hawai`i. The most interesting of these are the previously mentioned *Mecyclothorax*, and two species of long horn beetles of the genus *Plagithmysus*. *Mecyclothorax* populations appear to be impacted when alien predators are introduced to their habitats (Liebherr and Krushelnycky 2007) and their conservation is considered important. The two species of long horn beetles are considered rare and are infrequently collected.

Thirteen species of flies were collected, only two endemic to Hawai`i. Of interest were the specimens of native fruit flies (Tephritidae). These flies are often important pollinators of native plants and may be important in preserving native ecosystems. These flies were uncommon on *pūkiawe* likely feeding on nectar. The non-indigenous flies are common in the lowlands surrounding Haleakalā and may be blown up to the HO site by wind.

The most abundant insects were the seed bugs of the genus *Nysius*. These bugs were especially common on *pūkiawe* and *ōhelo*. These insects are known to have huge population explosions and sometimes interfere with observatory operations (Beardsley 1966). Three species of the endemic plant hoppers of the genus *Nesosydne* were collected. These species are more abundant in lower elevations but appear to be breeding at the HO sites as juveniles were also collected.

Eleven species of Hymenoptera were found. Except for the European honeybee and native *Hylaeus* bee, they were all small parasitic wasps. These kinds of wasps have been released throughout Hawai`i as biological control agents and whether they are breeding at the high elevations of Haleakalā remains to be investigated.

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.

Other 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 the ATST observatory construction or operation. The harsh environment of this aeolian ecosystem should make it difficult for most alien species to establish populations.

The development of the ATST facility would diminish a small amount of arthropod habitat, including the presence of native plants, and thereby reduce native arthropod species diversity and abundance at the proposed ATST sites, but would not likely to have a direct impact on the persistence of arthropod species on Haleakalā.

Haleakalā National Park Entrance Station Site

The area surrounding the HALE entrance station is largely native shrubs and grasses and occasional trees. The widening project will require some fill to be brought in, but will displace only a small amount of habitat.

Sixty species of arthropods were observed near the entrance station. The light traps were highly effective at collecting night-flying moths. Fourteen species of moths were collected, ten endemic to Hawai`i. None of these species have a restricted distribution and are all considered common.

The same two species of centipede and millipede were found that were collected at the HO sites. Eight species of beetles were seen, including an endemic species of carabid, *Mecyclothorax*. This was the only endemic species, the rest being introduced non-indigenous species.

A non-indigenous earwig was common in the area, and this species is also common throughout Hawai`i. Seven species of flies were collected, the only native one being a fruit fly of the genus *Trupanea*. As mentioned above, these species can be important pollinators of native plants.

Thirteen species of true bugs (Heteroptera and Homoptera) were found. Most of these are endemic species that are common and widely distributed in Hawai`i. The most interesting was the native stinkbug, *Oechalia pacifica*. This genus of stinkbug is being threatened by the introduction of biological control species, especially those released for the introduced green stink bug. The species that occurs near the entrance station also occurs on Kauai, Oahu, Molokai, and Lanai.

Fourteen species of Hymenoptera were collected at the entrance station, including two species of endemic bees of the genus *Hylaeus*. Both species appear to be limited to habitats on Haleakalā. These species may also be important pollinators of native plant species. Two ant species were collected near the entrance station. Ants represent one of the biggest threats to native arthropods. Much research has been conducted trying to discover a method of controlling these serious pests. Care must be taken during construction to prevent further introductions or spreading of these ants.

Besides the ants, there were no seriously threatening non-indigenous species of arthropods and none should be introduced by ATST development if precautions are followed to prevent their release. The development at the entrance station will displace only a small amount of habitat, most already disturbed by previous park development activities.

Arthropods are seasonal and their abundance and even presence varies throughout the year. The sampling conducted during this inventory is reflective of the time of year it was performed, and is reflective of only the sites surveyed, and thus should not be extrapolated to areas beyond those boundaries. More seasonal sampling would be necessary to establish a complete baseline of current conditions. This study does contribute an important seasonal component to the inventory of the ATST and HO sites, but is only a snapshot of the arthropod fauna at the HALE entrance station. A comprehensive monitoring program will consider seasonal variation when it is implemented.

The results of this arthropod survey indicate there are no special concerns or legal constraints related to invertebrate resources in the project areas. No invertebrate species listed as endangered, threatened, or that are currently proposed for listing under either federal or State of Hawai’i endangered species statutes were found at the project site (DLNR 1997, Federal Register 1999, 2005).

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 Hawaiʻi (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.

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. Hawai‘i’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 occurs in several areas in Hawai‘i, including high elevation sites such as Haleakalā National Park on Maui, Hawai‘i 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, should it occur there, 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.

The 2005 Institute for Astronomy Long Range Development Plan (LRDP) the Haleakalā Observatories (HO) (http://www.ifa.hawaii.edu/haleakala/LRDP/) was created to provide a structure for sustainable, focused management of the resources and operations of the HO, in order to protect historic/cultural resources: e.g. archaeology sites, traditional cultural practices, to protect natural resources, protect and enhance education and research. Many of these protection measures are already incorporated into the LRDP and in the ATST FEIS are repeated here to emphasize their importance.

Recommendation 1

As required by the LRDP, 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) As required by the LRDP, 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
As required by the LRDP, 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 Hawai‘i 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 Hawai‘i 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 Hawai‘i, 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 Hawai‘i 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. Plastic bag liners should be used in all garbage containers receiving food to control leaking fluids.

Recommendation 4
As described in Section 4.18.5 of the FEIS, a biological monitor will be employed during construction and programmatic arthropod sampling will be done in accordance with the schedule shown in Section 4.18.3. Monitoring for new alien arthropod introductions should be conducted during any construction activities. Any populations detected during monitoring would 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) 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

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).

Trash Control Recommendations

Recommendation 5
Construction trash containers should be tightly covered to prevent construction wastes from being dispersed by wind. This would be accomplished during construction of ATST by Best Management Practices.

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.

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
As required by the LRDP, 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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APPENDIX A

SPECIES LIST

The following list is the provisional identifications of specimens collected during the sampling described in this report. All identifications are provisional and may change when compared to museum specimens or from comments by taxonomic experts.

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Coleoptera	Anobiidae	Xyletobius				endemic		X
Insecta	Coleoptera	Apionidae	Exapion	ulicis		(Forster)	non-indigenous	X	
Insecta	Coleoptera	Carabidae	Mecyclothorax	spp.			endemic	X	X
Insecta	Coleoptera	Carabidae	Trechus				non-indigenous	X	
Insecta	Coleoptera	Cerambycidae	Plagithmysus	dubautianus		Gressit and Davis	endemic		X
Insecta	Coleoptera	Cerambycidae	Plagithmysus	railliardiae		(Perkins)	endemic		X
Insecta	Coleoptera	Chrysomelidae	Altica	carinata		(Germar)	non-indigenous	X	X
Insecta	Coleoptera	Coccinellidae	Diamus	notescens		(Blackburn)	non-indigenous		X
Insecta	Coleoptera	Coccinellidae	Hippodemia	convergens		Gurein-Meneville	non-indigenous	X	X
Insecta	Coleoptera	Coccinellidae	Olla	v-nigrum		(Mulsant)	non-indigenous		X
Insecta	Coleoptera	Coccinellidae	Scymnus	loewii		Mulsant	non-indigenous	X	
Insecta	Coleoptera	Coccinellidae	Scymnus	sp.			non-indigenous		X
Insecta	Coleoptera	Coccinellidae	SP1				non-indigenous		X
Insecta	Coleoptera	Curculionidae	Pantomorus	cervinus		(Boheman)	non-indigenous	X	
Insecta	Coleoptera	Nitidulidae	Carpophilus	hemipterus		(Linnaeus)	non-indigenous		X
Insecta	Coleoptera	Staphylinidae	Philonthus	sp.				X	
Insecta	Coleoptera	Staphylinidae	Tachyporus	sp.					X
Insecta	Dermaptera	Forficulidae	Forficula	auricularia		Linnaeus	non-indigenous	X	
Insecta	Diptera	Calliphoridae	Calliphora	vomitoria		(Linnaeus)	non-indigenous		X
Insecta	Diptera	Calliphoridae	Lucilia	sericata		(Meigen)	non-indigenous	X	
Insecta	Diptera	Calliphoridae	SP1					X	
Insecta	Diptera	Muscidae	SP1						X
Insecta	Diptera	Muscidae	SP2						X
Insecta	Diptera	Muscidae	SP3						X
Insecta	Diptera	Muscidae	SP4					X	
Insecta	Diptera	Pipunculidae	Pipunculus	sp.			endemic		X
Insecta	Diptera	Sepsidae	Sepsis	thoracica		(Robineau-Desvoidy)	non-indigenous	X	X
Insecta	Diptera	SP1						X	X
Insecta	Diptera	Syrphidae	Allograpta	exotica		(Weidemann)	non-indigenous		X
Insecta	Diptera	Syrphidae	Allograpta	obliqua		(Say)	non-indigenous		X

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Diptera	Syrphidae	Copestylum	sp.			non-indigenous		X
Insecta	Diptera	Syrphidae	Toxomerus	marginatus		(Say)	non-indigenous		X
Insecta	Diptera	Tachinidae	SP1				non-indigenous	X	X
Insecta	Diptera	Tephrytidae	Trupanea	sp.			endemic	X	X
Insecta	Heteroptera	Lygaeidae	Geocoris	pallens		Stål	non-indigenous	X	
Insecta	Heteroptera	Lygaeidae	Nysius	coenosulus		Stål	endemic	X	X
Insecta	Heteroptera	Lygaeidae	Nysius	communis		Usinger	endemic	X	X
Insecta	Heteroptera	Lygaeidae	Nysius	lichenicola		Kirkaldy	endemic	X	X
Insecta	Heteroptera	Lygaeidae	Nysius	palor		Ashlock	endemic		X
Insecta	Heteroptera	Lygaeidae	Nysius	terrestris		Usinger	endemic	X	X
Insecta	Heteroptera	Miridae	Engytatus	hawaiiensis		(Kirkaldy)	endemic		X
Insecta	Heteroptera	Miridae	Hyalopeplus	pelucidus		Stål	endemic		X
Insecta	Heteroptera	Miridae	Orthotylus	sp.1			endemic		X
Insecta	Heteroptera	Miridae	Orthotylus	sp.2				X	
Insecta	Heteroptera	Miridae	Psallus	sp.			endemic	X	X
Insecta	Heteroptera	Miridae	Sarona	sp.			endemic		X
Insecta	Heteroptera	Miridae	SP1					X	
Insecta	Heteroptera	Miridae	Trigonotylus	hawaiiensis		(Kirkaldy)	endemic		X
Insecta	Heteroptera	Pentatomidae	Nezara	viridula		Linnaeus	ohelo		X
Insecta	Heteroptera	Pentatomidae	Oechalia	pacifica		(Stal)	endemic	X	X
Insecta	Homoptera	Aphididae	SP1					X	
Insecta	Homoptera	Cercopidae	Clastoptera	xanthocephala		Germar	non-indigenous	X	
Insecta	Homoptera	Cicadellidae	SP1					X	
Insecta	Homoptera	Delphacidae	Nesosydne	geranii		(Muir)	endemic		X
Insecta	Homoptera	Delphacidae	Nesosydne	sp. 1			endemic		X
Insecta	Homoptera	Delphacidae	Nesosydne	sp. 2			endemic		X
Insecta	Homoptera	Delphacidae	SP1					X	
Insecta	Homoptera	Psyllidae	Trioza	ohiacola		Crawford	endemic		X
Insecta	Hymenoptera	Apidae	Apis	mellifera		Linneaus	non-indigenous	X	X
Insecta	Hymenoptera	Braconidae	Meteorus	laphygmae		Viereck	non-indigenous	X	

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Hymenoptera	Colletidae	Hylaeus	melanothrix		(Perkins)	endemic	X	
Insecta	Hymenoptera	Colletidae	Hylaeus	nivicola		Meade-Waldo	endemic	X	X
Insecta	Hymenoptera	Colletidae	Hylaeus	sp.			endemic	X	
Insecta	Hymenoptera	Formicidae	Hypoponera	opaciceps		(Mayr)	non-indigenous	X	
Insecta	Hymenoptera	Formicidae	Linepithema	humile		(Mayr)	non-indigenous	X	
Insecta	Hymenoptera	Ichneumonidae	Diplazon	laetatorius		(Fabricius)	non-indigenous		X
Insecta	Hymenoptera	Unknown 1							X
Insecta	Hymenoptera	Unknown 2							X
Insecta	Hymenoptera	Unknown 3							X
Insecta	Hymenoptera	Unknown 4						X	X
Insecta	Hymenoptera	Unknown 5							X
Insecta	Hymenoptera	Unknown 6							X
Insecta	Hymenoptera	Unknown 7							X
Insecta	Hymenoptera	Unknown 8						X	
Insecta	Hymenoptera	Unknown 9						X	
Insecta	Hymenoptera	Unknown 10						X	
Insecta	Hymenoptera	Unknown 11						X	
Insecta	Hymenoptera	Unknown 12						X	
Insecta	Hymenoptera	Unknown 13						X	
Insecta	Hymenoptera	Vespidae	Odynerus				endemic		X
Insecta	Isopoda	Porcellionidae	Porcellio	scaber		Latreille	non-indigenous	X	X
Insecta	Lepidoptera	Cosmopterigidae	Hyposmocoma	sp.1			endemic		X
Insecta	Lepidoptera	Cosmopterigidae	Hyposmocoma	sp.2			endemic	X	
Insecta	Lepidoptera	Crambidae	Eudonia	sp.			endemic		
Insecta	Lepidoptera	Crambidae	Udea	pyranthes		(Meyrick)	endemic		
Insecta	Lepidoptera	Geometridae	Scotorythra	sp.			endemic		
Insecta	Lepidoptera	Lycaenidae	Udara	blackburni		(Tuely)	endemic		X
Insecta	Lepidoptera	Noctuidae	Agrotis	biliopa		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	epicremna		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	giffardi (or mesotoxa)			endemic		

SPECIES LIST

								Location	
Class	Order	Family	Genus	Species	Subspecies	Authority	Status	HES	HO
Insecta	Lepidoptera	Noctuidae	Agrotis	mesotoxa		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	perigramma		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Agrotis	xiphias		Meyrick	endemic		
Insecta	Lepidoptera	Noctuidae	Ascalapha	odorata		(Linnaeus)	non-indigenous	X	
Insecta	Lepidoptera	Noctuidae	Megalographa	biloba		(Stephens)	non-indigenous		
Insecta	Lepidoptera	Noctuidae	Peridroma	albiorbis		Zimmerman	endemic		
Insecta	Lepidoptera	Noctuidae	Peridroma	cinctipennis	albostigma	(Warren)	endemic		
Insecta	Lepidoptera	Noctuidae	Peseudaletia	unipunctata		(Haworth)	non-indigenous		
Insecta	Lepidoptera	Oecophoridae	Thryocopa	apatela		(Walsingham)	endemic		X
Insecta	Lepidoptera	Pterophoridae	Stenoptilodes	littoralis	rhynchophora	(Meyrick)	non-indigenous		X
Insecta	Lepidoptera	Sphingidae	Agrius	cingulata		(Fabricius)	non-indigenous	X	
Chilopoda	Lithobiomorpha	Lamyctes	sp.1					X	X
Diplopoda	Julida	SP1						X	X