Programmatic Arthropod Monitoring at the Haleakalā High Altitude Observatories and Haleakalā National Park Maui, Hawai‘i

April 2014

Prepared for

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II. EXECUTIVE SUMMARY

The National Science Foundation (NSF) has authorized the development of the Daniel K. Inouye Solar Telescope (DKIST), previously known as the Advanced Technology Solar Telescope (ATST)) within the 18-acre University of Hawai`i Institute for Astronomy High Altitude Observatories (HO) site. The DKIST represents a collaboration of 22 institutions, reflecting a broad segment of the solar physics community. The DKISt project will be the largest and most capable solar telescope in the world. It will be an indispensable tool for exploring and understanding physical processes on the Sun that ultimately affect Earth. The DKIST Project will be contained within a 0.74 acre site footprint in the HO site. An Environmental Impact Statement was completed for the DKIST project (NSF 2009), and the NSF issued a Record of Decision in December of 2009.

The Haleakalā National Park (HALE) Road Corridor is being used for transportation during construction and use of the DKIST. The HO and HALE road corridor contain biological ecosystems that are both unique and fragile. The landscape at HO is considered to be an alpine dry shrubland vegetation type and resources along the Park road corridor are grouped into alpine and subalpine shrubland habitat zones, depending upon the elevation. These habitats contain several native and non-native species of plants, animals, and arthropods. While the overall impacts on Hawaiian native arthropod resources within the Park road corridor during the construction phase would be considered minor, NSF has committed to several mitigation measures to reduce the impacts to these biological resources, including programmatic monitoring for active preservation of invertebrates before, during and after construction of the proposed DKIST Project.

After some preliminary sampling near the HALE Entrance Station in 2009 Programmatic Arthropod Monitoring and Assessment at the Haleakalā High Altitude Observatories and Haleakalā National Park was initiated with two sampling sessions in 2010. Monitoring is being conducted twice a year during the construction phase of the DKIST, and occurred in 2011, 2012, and 2013.

This report presents the results of the Winter 2014 sampling. The goal is to monitor the arthropod fauna at the proposed DKIST site and along the HALE Road Corridor, identify Hawaiian native arthropod species or habitats, if any, that may be impacted by construction or operation of the DKIST, and detect and

identify alien invasive arthropod species that could have adverse impacts on the flora and fauna on Haleakalā. Programmatic Arthropod Monitoring studies are being coordinated and conducted with the approval of HALE.

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

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.

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

The DKIST Project will be contained within a 0.74 acre site footprint in the HO site. An Environmental Impact Statement was completed for the DKIST project (NSF 2009), and the NSF issued a Record of Decision in December of 2009. The Haleakalā National Park (HALE) Road Corridor is being used for transportation during construction and use of the DKIST. Construction began in December 2012 and was ongoing during the winter 2014 sampling.

The HO and HALE road corridor contain biological ecosystems that are both unique and fragile. The landscape at HO is considered to be an alpine dry shrubland vegetation type. A diverse fauna of resident insects and spiders reside there (Medeiros and Loope 1994). Some of these arthropods inhabit unique natural habitats on the bare lava flows and cinder cones with limited vegetation. Vegetation covers less than 5% of the open ground, and food is apparently scarce.

The ecosystem at the HO 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.

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 DKIST sites, and identify Hawaiian native arthropod species or habitats, if any, that could be impacted by construction or operation of the DKIST. 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. Sampling in June 2009 was conducted to establish baseline conditions for future Programmatic Monitoring.

The landscape along the HALE road corridor is classified as alpine and subalpine shrubland habitat zones, depending upon the elevation. These habitats contain several native and non-native species of plants, animals, and arthropods. 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 there covers most of the open ground, mostly with native trees and 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).

While the overall impacts on arthropod resources within the Park road corridor during the construction phase would be considered minor, NSF has committed to several mitigation measures to reduce the impacts to these biological resources, including programmatic monitoring for active preservation of invertebrates during and after construction of the proposed DKIST Project.

Environmental monitoring is the scientific investigation of the changes in environmental phenomena, attributes and characteristics that happen over time. Ecosystems are dynamic. Habitat conditions change daily, seasonally, and over longer periods of time. Animal and plant populations rise or fall in response to a host of environmental fluctuations. The general purpose of monitoring is to detect, understand, and predict the environmental changes.

The scientific scope of Arthropod Programmatic Monitoring is to repeatedly sample arthropod habitats that may be impacted by construction and operation of the proposed DKIST, document changes to native arthropod

populations, and detect new or potentially threatening invasive species of arthropods that may impact the native resident arthropod fauna. Programmatic Arthropod Monitoring includes identification and taxonomy for both ground and shrub dwellers and is being conducted in both developed and undeveloped areas of HO (excluding the Air Force site)."

Arthropod Programmatic Monitoring consists of one week sampling sessions conducted in the Summer and Winter months, standard arthropod sampling methods similar to those used during the 2007 inventory of arthropods within HALE (Kruschelnycky et al. 2007), collecting invertebrates both day and night, with identification and taxonomy for both ground and shrub dwellers in developed and undeveloped portions of the sampling areas.

The primary areas being sampled are the Haleakalā High Altitude Observatories (HO) site on Kolekole Hill, but not including the Air Force site, the DKIST Construction Site, and selected portions of the HALE Road Corridor. The 18 acre HO facility hosts several existing observatories and their support buildings, and also includes several undeveloped sites where native vegetation and the associated arthropod fauna is relatively undisturbed. The DKIST Construction Site is approximately 0.24-ha (0.60-ac) of previously undeveloped land located east of the existing Mees Solar Observatory facility. The portions of the HALE Road Corridor being sampled are determined in collaboration with the HALE staff biologists at the beginning of each sampling session.

Programmatic Monitoring will provide much of the data needed to protect and enhance natural resources, to modify management actions, to aid in compliance with environmental statutes, and to enhance public education and appreciation of the natural resources at the summit of Haleakalā.

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

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

Endemic – A species native to, or restricted to Hawai'i.

Indigenous – A species native to Hawai'i but that naturally occurs outside of Hawai'i as well.

Non-indigenous – A species not native to Hawai'i.

Adventive – Not native, a species transported into a new habitat by natural means or accidentally by human activity.

Purposely introduced – A species released in Hawai'i for a particular purpose, usually to control a weedy plant or another insect.

This report describes the results of sampling conducted in March/April 2014 is the first of two sampling sessions for Programmatic Arthropod Monitoring and Assessment this year, and continues monitoring that began in September 2009. The goal is to monitor the arthropod fauna at the HO site, the DKIST construction site, and along the selected portions of the HALE Road Corridor, identify Hawaiian native arthropod species or habitats, if any, that may be impacted by construction or operation of the DKIST, and detect and identify alien invasive arthropod species that could have adverse impacts on the flora and fauna on Haleakalā. Programmatic Arthropod Monitoring studies are being coordinated and conducted with the approval of HALE staff biologists.

Sampling of arthropod habitats was approved in a permit obtained from the Department of Land and Natural Resources (Permit # FHM14-335) issued in March, 2014 and the National Park Service (Permit # HALE-2010-SCI-0001) issued on March 22, 2010. Sampling began on March 31, 2014 and was completed on April 7, 2014.

IV. QUESTIONS OF INTEREST

Important Questions of Interest are those with answers that can be efficiently estimated and that yield the information necessary for management decision-making. The following Questions of Interest were developed for Programmatic Monitoring and are the focus of this report.

Question 1

What are the characteristic arthropod populations at the DKIST site, the larger HO site (excluding the Air Force site), and along selected areas of the HALE Road Corridor?

Justification:

Programmatic Monitoring will yield a comprehensive list of the characteristic arthropod fauna at the DKIST site, developed and undeveloped areas of the HO site, and along selected areas of the HALE Road Corridor.

Monitoring goals:

1) To describe the characteristic arthropod populations at the DKIST site, the larger HO site, and along the HALE Road Corridor,

2) To provide historical records of change in native arthropod species population attributes, and characteristics.

The results of this sampling are combined with information gathered during previous studies to develop a comprehensive list of arthropods at the Astronomy High Altitude Observatories (HO) site, the DKIST site, and along selected areas of the HALE Road Corridor, and a qualitative description of seasonal variations in their abundance.

Question 2

What adverse impacts can be detected, if any, on characteristic populations of arthropods at the DKIST site, the larger HO site (excluding the Air Force site), and along selected areas of the HALE Road Corridor that may be due to DKIST construction?

Justification:

Programmatic Monitoring of native arthropod species will yield reliable scientific information about the current status (presence and abundance) of these species at the sampling sites. The information will be useful to detect changes and trends that may be due to the construction of the DKIST.

Monitoring goals:

1) To detect changes, trends, periodicities, cycles, and/or other patterns of change in arthropods at the DKIST site, the larger HO site, and along the HALE Road Corridor during the construction of the DKIST.

Programmatic Monitoring reports provide a discussion of the results of sampling, a description of changes in presence or abundance, and an assessment of those changes that may be due to the DKIST construction, and provide opportunities for adaptive management of construction processes, through the use of control measures, where these changes and/or trends negatively affect the arthropod population.

Question 3

What non-indigenous invasive arthropod species, if any, are detected at the DKIST site, the larger HO site (excluding the Air Force site), and along selected areas of the HALE Road Corridor during DKIST construction?

Justification:

Programmatic Monitoring for non-indigenous invasive arthropod species will detect potential threats to the nearby native ecosystems before they have an opportunity to establish resident populations. Early detection will allow implementation of control measures to eradicate invasive arthropod species (e.g. ants and spiders) before they can damage the nearby native ecosystems.

Monitoring goals:

1) To detect non-indigenous invasive arthropod species at the DKIST site, the larger HO site, and along selected areas of the HALE Road Corridor during construction of the DKIST.

If any invasive arthropod species (e.g. ants and spiders) are detected, eradication measures will be implemented to prevent these species from establishing resident populations.

V. METHODS

Site Description

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 substantial telescope facilities, in addition to several smaller facilities.

The DKIST site is on undeveloped land located east of the existing Mees Solar Observatory facility. Annual precipitation 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.

Haleakalā sampling locations were determined with guidance and cooperation from HALE personnel. During this session, sampling was conducted in the area near the HALE Entrance Station, at about 2,072 m (6,800 ft) on the western slope of Haleakalā.

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 has only a small impact on the populations of interest. While this 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 and modified according to their comments.

Pitfall Trapping

After consultation with HALE natural resources staff, ten pitfall traps were installed near HALE Entrance Station site (five below the road and five above the road). Ten pitfall traps were installed at the Astronomy High Altitude Observatories (HO) site in both developed and undeveloped areas, and ten pitfall traps were deployed at the DKIST 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 four days at the DKIST site and for four days at the HALE site. 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 an 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.

Battery-powered ultraviolet light traps were operated near the HALE Entrance Station, at the HO site, and at the DKIST site. 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 were run for six nights at the DKIST site, HO site, and the HALE site. A seventh night of sampling was suspended due to heavy rain and strong winds.

Other Light Sampling at Night

Night collecting can be aided by a UV light source. Small handheld ultraviolet blacklights were 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 beaten 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.

Baited Traps

Baited traps were deployed to detect the presence of ants. These traps consisted of fresh canned tuna placed on sticky trap board and weighted down with a small rock. Traps were set near areas where ants could be introduced or where they may be foraging for food. Three baited traps were deployed on the HO and DKIST sites on two different days. The traps were checked hourly for four hours at which time the traps were be removed. Baited traps were not left opened overnight in order to avoid attracting unwanted pests.

Inspection of construction lay-down and storage areas

Construction material and equipment in developed lay-down areas were visually inspected for invasive arthropod species and evidence of their presence. Specifically, these areas were inspected for the presence of ants, spiders, spider webs, and indications of the presence of

other potentially invasive arthropod species.

Population Estimates

Although NSF committed to "population estimates for developed and undeveloped areas within HO, the DKIST Construction Site, and selected areas of the HALE road corridor" (NSF 2009), they are not possible with the approved sampling techniques. A consultation with the NPS determined that any data collected would be only a snapshot in time, reflective only of the sites sampled, and that the results are seasonal and could not be extrapolated beyond those limits. They also expressed an opinion that any "population estimates" would not be comparable over time and that accurate population estimates for arthropods are not possible with the sampling methods approved for use. In consultation with NPS staff biologists, it was decided that sampling results would be presented as presence/absence, and that qualitative abundance estimates would be a suitable substitute for "population estimates" described in the FEIS (NSF 2009).

Sampling results in this report are presented as presence/absence, and, for selected species, qualitative abundance estimates are substituted for "population estimates" described in the FEIS (NSF 2009). Relative abundance categories are

- *infrequent* (individuals captured or observed < 10),
- *uncommon* (10 < individuals captured or observed < 25),
- *common* (25 < individuals captured or observed < 100), and
- *abundant* (100 < individuals captured or observed).

It should be noted that abundance designations are based exclusively on the capture or observation of specimens encountered at the sampling sites visited during each sampling session, and may be biased against certain species. For example, some ground dwelling species may be under-sampled because traps will not be baited and therefore not attractive to these species. Other species may be more or less abundant at other times of year than those sampled, or not efficiently captured with the sampling methods used. These species may generally be more or less common than indicated from the results. The results presented in reports are only snapshots in time, reflective only of the sites sampled, and the results are seasonal and should not be extrapolated beyond those limits.

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 accurate identification and voucher specimens.

Curation

The contents of the traps were cleaned in 70% ethyl alcohol and placed in vials. The specimens were sorted into the morphospecies 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 morphospecies 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 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 (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) unless a recent major taxonomic revision was available.

Schedule/Start and End Dates

Sampling was conducted over eight days and seven nights beginning on March 31, 2014 and ending on April 07, 2014. Sampling typically began at 8:00 am and ran until about 3:00 pm. A break was taken to prepare for night sampling which resumed at 6:00 pm and continued until after midnight or until weather conditions prevented further sampling. Pitfall traps were open for 70 trap nights at each of the three sampling sites. Light traps were deployed for 6 trap nights at each sampling site, and. were allowed to run overnight or until batteries failed.

VI. RESULTS and DISCUSSION

HO SITE

The HO site covers about 18 acres and contains observatory facilities. Several areas of the site are being used to store materials and equipment Twenty-eight species of arthropods were detected at the HO site (excluding the Air Force Facility and the DKIST site). The species included ten endemic species, thirteen non-indigenous species, and six of unknown status.

A juvenile lycosid spider in a nest made of small pebbles and silken threads.

Spiders -Araneae

Juvenile and adult Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps, but only juveniles were seen actively foraging among rocks.

These spiders apparently make nests of small pebbles held together with silken threads, like the one pictured below found under a rock.

Beetles – Order Coleoptera

Three beetle species was observed at the HO site, including non-indigenous lady bird beetles (*Hippodamia convergens* Guerin-Meneville and *Olla v-nigrum* (Mulsant)). Both species were uncommon at the site, occurring on vegetation. The third species was a non – indigenous rove beetle, found infrequently.

Collembola - Springtails

At least one species of Collembola was observed at the HO site. These small insects were common in leaf litter under plants.

Flies - Order Diptera

Seven species of flies were detected at the HO site. Only one species (of the family Sciaridae) was indigenous. The non-indigenous species included a blowfly, a

small muscid, a small fruit fly, and three syrphids. No native fruit flies (family Tephritidae) were found.

A Hawaiian endemic species of plant bug found on grasses at the HO site.

True Bugs – Orders Heteroptera and Homoptera

At least three species of bugs (Heteroptera) were observed including adults and nymphs of Hawaiian endemic species in the genus *Nysius*. The others were endemic plant bugs.

Three other species of bugs were detected, including hoppers of the genus *Nesosydne*. Adults and nymphs of this genus of endemic plant hoppers were abundant on Dubautia plants. The other two species of bugs were of unknown status.

Butterflies and Moths – Order Lepidoptera

At least eight species Lepidoptera were found at the HO site. Cabbage loopers were abundant, flying all around the site, some resting on vegetation.

Three macro-moth species were collected in the light traps, including two endemic species in the genus *Agrotis*, and the non-indigenous *Pseudalecia unipuncta* (Meyrick).

Caterpillars were abundant, foraging at night on the cinder. The larger caterpillars, efficiently captured in pitfall traps, were of the genus Agrotis. Smaller caterpillars uncommon in pitfall traps were likely larva of the Haleakalā flightless moth.

Other Lepidoptera included the Painted Lady, a small tortricid, and a micro-Lepidoptera. All were uncommon at the site.

Other Observations

A single, small red-colored centipede was found near a washing station at HO.

No yellow-faced bees were observed at the HO site, although they were common at the DKIST site. These bees occur on pukiawe, a plant that occurs only infrequently at the HO site.

A complete list of arthropods observed during this sampling session at the HO site can be found in Appendix A at the end of this report. No new invasive species were observed that could impact native arthropod species. The species of indigenous arthropods detected have been observed at the site during other surveys.

DKIST SITE

Construction was started on the DKIST in December 2012 and was ongoing during the winter 2014 sampling session. The excavation for the DKIST foundation was largely completed and resulted in the removal of much of the vegetation at the site. Vegetation is now limited to the area surrounding the excavation and was mostly undisturbed there.

Twenty species of arthropods were collected at the DKIST site during the winter 2014 sampling session. The species included nine endemic Hawaiian arthropods, nine non-indigenous arthropods, and two species of unknown status.

Spiders -Araneae

Juvenile and adult Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps at the DKIST site, but only juveniles were seen actively foraging among rocks.

An adult lycosid spider collected in a pitfall trap.

Flies - Order Diptera

Seven species of flies were detected at the DKIST site. They include blowflies, a small fruit fly, a muscid, two syrphids, and a small gnat. All but the gnat are non-indigenous. No endemic fruit flies (family Tephritidae) were found.

True Bugs – Orders Heteroptera and Homoptera

Adults and nymphs of a species of Hawaiian endemic seed bug (Heteroptera: Lygaeidae) were abundant on *Dubautia* and *pukiawe*. Nymph plant bugs were also abundant on *Dubautia*.

Two leafhoppers were detected, including an abundant endemic species, and a less common species of unknown status.

Bees and Wasps – Order Hymenoptera

The endemic species of yellow-faced bees, *Hylaeus nivicola* Meade Waldo, was common on pukiawi.

Caterpillars were abundant, foraging at night.

Moths – Order Lepidoptera

Four species of Lepidoptera were collected, the endemic blue butterfly and three large moths, including two endemic species in the genus *Agrotis*, and the non-indigenous *Pseudalecia unipuncta* (Meyrick). Caterpillars of the genus *Agrotis* were abundant in pitfall traps. Caterpillars of the Haleakalā flightless moth were infrequently captured in pitfall traps.

Three butterfly species were observed, including the endemic blue butterfly and two non-indigenous species.

Cabbage loopers resting on *pukiawe* at the DKIST site.

A complete list of arthropods observed during this sampling session at the DKIST site can be found in Appendix B at the end of this report. No new invasive species were observed that could impact native arthropod species. The species of indigenous arthropods detected have been observed at the site during other surveys.

HALE SAMPLING SITE

Sampling in HALE occurred near the Entrance Station (HALE ES) at 6,250 feet elevation. Forty-five species of arthropods were collected and observed there. The species included seventeen endemic Hawaiian arthropods, seventeen non-indigenous arthropods, and eleven species of unknown status.

Beetles – Order Coleoptera

Three species of beetle were observed, including an endemic long-horned beetle, a non-indigenous weevil, and a weevil of unknown status (likely non-indigenous). All were detected as single specimens and were infrequent.

Earwigs – Order Dermaptera

One species of earwig was seen at the HALE ES, a non-indigenous species that was common as juveniles under rocks.

Flies – Order Diptera

Seven species of flies were seen at the HALE ES, including a species of crane fly (family Tipulidae), a likely indigenous species that comes to the light traps. Also observed were non-indigenous species of the family Sarcophagidae, as well as species from the families, Sciaridae, Tachinidae, Syrphidae, and Drosophilidae.

A syrphid fly on mamane.

True Bugs – Orders Heteroptera and Homoptera

Three species of true bugs (Heteroptera) were found, two from the family Miridae and two from the family Lygaeidae. All have been previously reported from the higher elevations of Haleakalā. An *Orthotylus* species was abundant on mamane trees, and an *Sarona* species were common on Pilo (*Coprosma montana)*.

Three species of Homoptera were also observed, including the indigenous genera *Nesosydne* (family Delphacidae), and two non-indigenous species.

Bees and Wasps – Order Hymenoptera

The seven species of Hymenoptera found near the HALE Entrance Station included honey bees uncommon on manane and pukiawe, a parasitoid (family Braconidae), a species of Ichneumonidae, one invasive ant, *Linepithema humile* (Mayr), a yellow jacket, and two species of indigenous yellow-faced bee (*Hylaeus nivicola* Meade Waldo). The yellow-faced bees were abundant on sunny days, foraging on pukiawe, or flying along the ground. All Hymenoptera observed have been previously reported from Haleakalā.

Sowbugs – Class Isopoda

One species of sowbug was found under rocks and plant debris at the HALE ES. The species was abundant as juveniles.

Moths – Order Lepidoptera

Seventeen species of Lepidoptera were observed or captured during this study at the HALE ES. The list includes nine endemic species, five non-indigenous species, and three species of unknown status. Four species of endemic Noctuid moths was captured in the light traps, along with a nonindigenous Noctuid, captured in high abundance. Indigenous species of microlepidoptera, two Cosmopterigidae, two species of Crambidae, a Trotricidae, and a Geometridae were observed. The introduced Lantana moth was also present with three species of micro-Leopidoptera.

Other Observations

Three other arthropods were observed at the HALE ES, including a large dragon fly, a Pscoptera, and a thrips.

A complete list of arthropods observed during this sampling session at the HALE ES site can be found in Appendix C at the end of this report. No new invasive species were observed that could impact native arthropod species. The species of indigenous arthropods detected have been observed at the site during other surveys.

DISCUSSION

The arthropods that were found during this sampling are characteristic of the fauna at both sites. No new invasive arthropods were detected at either site.

No trends in populations were detected beyond normal seasonal variation and weather related abundance. The species reported are reflective only of the sites sampled, and only qualitative data of abundance were taken.

Abundance of arthropods at the DKIST site was lower than that seen in sampling sessions before construction was started. This is due to the removal of native plants during excavation and site preparation for the new telescope. Populations of arthropods on the remaining foliage were similar to that observed during previous preconstruction monitoring sessions.

At least some recovery in arthropod abundance may be expected at the DKIST site once ground disturbing activities are completed and vegetation begins to reestablish. This phenomenon has been observed at other locations at HO where plant life recovered after construction, due in part to natural recruitment and conservation efforts.

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APPENDIX A
HO ARTHROPOD SPECIES LIST

A list of Arthropod species detected during the Winter 2014 sampling at the HO site.

Order	Family	Genus	Species	Authority	Status
Araneae	Lycosidae	Lycosa	hawaiiensis	simon	endemic
Coleoptera	Coccinellidae	Hippodemia	convergens	Gurein-Meneville	non-indigenous
Coleoptera	Coccinellidae	Olla	v-nigrum	(Mulsant)	non-indigenous
Coleoptera	Staphylinidae	Tachyporus	sp.		non-indigenous
Collembola					unknown
Diptera	Calliphoridae	Calliphora	vomitoria	(Linnaeus)	non-indigenous
Diptera	Drosophilidae	Drosophila	melanogaster	Meigen	non-indigenous
Diptera	Muscidae	Haematobia	irritans	(Linnaeus)	non-indigenous
Diptera	Sciaridae				unknown
Diptera	Syrphidae	Allograpta	exotica	(Weidemann)	non-indigenous
Diptera	Syrphidae	Copestylum	sp.		non-indigenous
Diptera	Syrphidae	Toxomerus	marginatus	(Say)	non-indigenous
Heteroptera	Lygaeidae	Nysius	coenosulus	Stål	endemic
Heteroptera	Miridae	Orthotylus	sp.1		endemic
Heteroptera	Miridae	Trigonotylus	hawaiiensis	(Kirkaldy)	endemic
Homoptera	Cicadellidae	SP1			unknown
Homoptera	Delphacidae	Nesosydne	sp.		endemic
Homoptera	Pseudococcidae	SP 1			unknown
Hymenoptera	Colletidae	Hylaeus	nivicola	Meade-Waldo	endemic
Julida	Allajulus	latistriatus		(Curtis)	non-indigenous
Lepidoptera	Microlepidoptera	SP1			unknown
Lepidoptera	Noctuidae	Agrotis	biliopa	Meyrick	endemic
Lepidoptera	Noctuidae	Agrotis	mesotoxa	Meyrick	endemic
Lepidoptera	Noctuidae	Pseudaletia	unipunctata	(Haworth)	non-indigenous
Lepidoptera	Nymphalidae	Vanessa	cardui	(Linnaeus)	non-indigenous
Lepidoptera	Oecophoridae	Thryocopa	apatela	(Walsingham)	endemic
Lepidoptera	Pieridae	Pieris	rapae	(Linnaeus)	non-indigenous
Lepidoptera	Tortricidae	SP4			unknown

APPENDIX B
DKIST ARTHROPOD SPECIES LIST

A list of Arthropod species detected during the Winter 2014 sampling at the ATST site.

Class	Order	Family	Genus	Species	Authority	Status
Arachnida	Araneae	Lycosidae	Lycosa	hawaiiensis	simon	endemic
Insecta	Diptera	Calliphoridae	Calliphora	vomitoria	(Linnaeus)	non-indigenous
Insecta	Diptera	Drosophilidae	Drosophila	melanogaster	Meigen	non-indigenous
Insecta	Diptera	Muscidae	Haematobia	irritans	(Linnaeus)	non-indigenous
Insecta	Diptera	Sarcophagidae				non-indigenous
Insecta	Diptera	Sciaridae				unknown
Insecta	Diptera	Syrphidae	Allograpta	exotica	(Weidemann)	non-indigenous
Insecta	Diptera	Syrphidae	Copestylum	sp.		non-indigenous
Insecta	Heteroptera	Lygaeidae	Nysius	coenosulus	Stål	endemic
Insecta	Heteroptera	Miridae	Orthotylus	sp.1		endemic
Insecta	Homoptera	Cicadellidae	SP1			unknown
Insecta	Homoptera	Delphacidae	Nesosydne	sp.		endemic
Insecta	Hymenoptera	Colletidae	Hylaeus	nivicola	Meade-Waldo	endemic
Insecta	Lepidoptera	Lycaenidae	Udara	blackburni	(Tuely)	endemic
Insecta	Lepidoptera	Noctuidae	Agrotis	biliopa	Meyrick	endemic
Insecta	Lepidoptera	Noctuidae	Agrotis	mesotoxa	Meyrick	endemic
Insecta	Lepidoptera	Noctuidae	Pseudaletia	unipunctata	(Haworth)	non-indigenous
Insecta	Lepidoptera	Nymphalidae	Vanessa	cardui	(Linnaeus)	non-indigenous
Insecta	Lepidoptera	Oecophoridae	Thryocopa	apatela	(Walsingham)	endemic
Insecta	Lepidoptera	Pieridae	Pieris	rapae	(Linnaeus)	non-indigenous

APPENDIX B
HALE ES ARTHROPOD SPECIES LIST

A list of Arthropod species detected during the Winter 2014 sampling at the HALE Entrance Station.

Class	Order	Family	Genus	Species	Authority	Status
Insecta	Coleoptera	Cerambycidae	Plagithmysus	funebris	Sharp	endemic
Insecta	Coleoptera	Curculionidae	Pantomorus	cervinus	(Boheman)	non-indigenous
Insecta	Coleoptera	Curculionidae				unknown
Insecta	Dermaptera	Forficulidae	Forficula	auricularia	Linnaeus	non-indigenous
Insecta	Diptera	Drosophilidae	Drosophila	melanogaster	Meigen	non-indigenous
Insecta	Diptera	Muscidae	Haematobia	irritans	(Linnaeus)	non-indigenous
Insecta	Diptera	Sarcophagidae				non-indigenous
Insecta	Diptera	Sciaridae				unknown
Insecta	Diptera	Syrphidae	Allograpta	exotica	(Weidemann)	non-indigenous
Insecta	Diptera	Tachinidae	SP1			non-indigenous
Insecta	Diptera	Tipulidae	SP1			unknown
Insecta	Heteroptera	Lygaeidae	Nesius	ochriasis	Usinger	endemic
Insecta	Heteroptera	Miridae	Orthotylus	mamane		endemic
Insecta	Heteroptera	Miridae	Sarona	sp.		endemic
Insecta	Homoptera	Cicadellidae	SP1			unknown
Insecta	Homoptera	Delphacidae	Nesosydne	sp.		endemic
Insecta	Homoptera	Psyllidae	SP1			unknown
Insecta	Hymenoptera	Apidae	Apis	mellifera	Linneaus	non-indigenous
Insecta	Hymenoptera	Braconidae				unknown
Insecta	Hymenoptera	Colletidae	Hylaeus	nivicola	Meade-Waldo	endemic
Insecta	Hymenoptera	Colletidae	Hylaeus	volatilis	(F. Smith)	endemic
Insecta	Hymenoptera	Formicidae	Linepithema	humile	(Mayr)	non-indigenous
Insecta	Hymenoptera	Ichneumonidae	Eniocospilus			endemic
Insecta	Hymenoptera	Vespidae	Vespula	vulgaris	Linnaeus	non-indigenous
Crustacea	Isopoda	Porcellionidae	Porcellio	scaber	Latreille	non-indigenous
Insecta	Lepidoptera	Cosmopterigidae	Hyposmocoma	sp.1		endemic
Insecta	Lepidoptera	Cosmopterigidae	Hyposmocoma	sp.2		endemic
Insecta	Lepidoptera	Crambidae	Eudonia	sp.		endemic
Insecta	Lepidoptera	Crambidae	Udea	pyranthes	(Meyrick)	endemic
Insecta	Lepidoptera	Geometridae	Eupithecia	craterias	(Meyrick)	endemic
Insecta	Lepidoptera	Microlepidoptera	SP2			unknown
Insecta	Lepidoptera	Microlepidoptera	SP3			unknown
Insecta	Lepidoptera	Microlepidoptera	SP4			unknown

Class	Order	Family	Genus	Species	Authority	Status
Insecta	Lepidoptera	Noctuidae	Agrotis	biliopa	Meyrick	endemic
Insecta	Lepidoptera	Noctuidae	Agrotis	perigramma	Meyrick	endemic
Insecta	Lepidoptera	Noctuidae	Agrotis	epicremna	Meyrick	endemic
Insecta	Lepidoptera	Noctuidae	Megalographa	biloba	(Stephens)	non-indigenous
Insecta	Lepidoptera	Noctuidae	Pseudaletia	unipunctata	(Haworth)	non-indigenous
Insecta	Lepidoptera	Nymphalidae	Vanessa	cardui	(Linnaeus)	non-indigenous
Insecta	Lepidoptera	Pieridae	Pieris	rapae	(Linnaeus)	non-indigenous
Insecta	Lepidoptera	Pterophoridae	Stenoptilodes	taprobanes	(Meyrick)	non-indigenous
Insecta	Lepidoptera	Tortricidae	Cydia			endemic
Insecta	Odonata	Aeshnidae	Anax	junius	(Drury)	non-indigenous
Insecta	Pscoptera					unknown
Insecta	Thysanoptera					unknown