UNIVERSITY of HAWAI'I®
MĀNOA

Institute for Astronomy
Office of the Director



December 23, 2015

Ms. Suzanne Case, Chairperson
Board of Land and Natural Resources
1151 Punchbowl Street
Honolulu, HI 96813

Dear Ms. Case

**SUBJECT:** **Haleakala High Observatory Site Management Plan Haleakala High Altitude Observatories Site, Pu 'u Kolekole, Makawao, Maui TMK (2) 2-2-007:008**

In accordance with Condition #2 of the Board of Land and Natural Resources approved **Haleakala High Altitude Observatory Site Management Plan** and Condition #7 of **CDUP MA-3542**, the University of Hawaii is submitting the Annual Report for the 2015 reporting period. This report summarizes all construction activities occurring at HO; Habitat Conservation Plans; Monitoring Plans for Invertebrates, Flora, and Fauna; Programmatic Agreements on Cultural Resources; Invasive Species Control Plans and other related plans. Referenced reports are available on the enclosed Compact Disk (CD).

Sincerely,

Michael Maberry
Assistant Director

c: Mr. Sam Lemmo, Administrator, DLNR OCCL

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# Haleakalā High Altitude Observatory Site Management Plan

## 2015 Annual Report

### Introduction to Management of the Haleakalā High Altitude Observatory Site

The Haleakalā High Altitude Observatory Site (HO) Management Plan (MP) was approved by the Board of Land and Natural Resources (BLNR) on December 1, 2010.
Condition #2 states:
"Beginning in November 2012 the University will submit to DLNR an annual report summarizing any construction activities occurring at HO; Habitat Conservation Plans; Monitoring Plans for Invertebrates, Flora, and Fauna; Programmatic Agreements on Cultural Resources; Invasive Species Control Plans and other related plans, The Report should be brief but thorough. This report should also be presented to the Board of Land and Natural Resources for the first year, and every five years thereafter."

Therefore, this report summarizes activities that occurred under the MP from December 1, 2014 to November 30, 2015.

The land use described in this report, on activities under the HO MP, qualifies as an identified use in the General Subzone and is consistent with the objectives of the General Subzone of the land. The objectives of the General Subzone (HAR 13-5-14) are to designate open space where specific conservation uses may not be defined, but where urban uses would be premature. The land use is consistent with astronomical research facilities for advanced studies of astronomy and atmospheric sciences. HO is located within a General Subzone of the State of Hawai'i Conservation District that has been set aside for observatory site purposes only. Identified applicable land uses in the General Subzone, include R-3 Astronomy Facilities and (D-1) Astronomy facilities under an approved management plan (HAR 13-5-25).

The HO MP offers a physical plan and management structure that seeks to preserve a balance within HO, in which astronomy can continue to evolve at a premier ground-based viewing location, bringing with it the associated economic benefits, while protecting cultural and environmental resources and values.

## Construction Activities Occurring at HO Since December 2014

Section 3.5.3.1 of the MP implements a number of measures regarding construction practices, including IfA-approved environmental training for contractors, prevention of introduction of new species during construction, protection of the endangered Hawaiian petrel ('ua'u) residing in burrows on the upper slopes of Haleakalā, pollution prevention, dust prevention, and management of solid waste. In addition, the IfA requires that facilities designed for construction at HO follow certain guidelines regarding obscuration of other facilities, timing of construction to avoid impacts to nesting petrels, avoiding impacts to known archeological resources, painting to blend with surroundings where possible, consideration of site plans to population centers on Maui, use of natural materials, etc. The following construction activities have occurred at HO since December 2, 2014:

## Construction Activities

1. November 13, 2012-CDUP MA-3542 Advanced Technology Solar Telescope/underway

## Compliance

- Construction activities listed above are undertaken in compliance with applicable statutes, ordinances, rules, regulations, and conditions of the federal, state, and county governments, and applicable parts of the Hawai'i Administrative Rules, Chapter 13-5;
- Where applicable, plans were submitted and approved;
- Where applicable, notice of commencement and completion was provided;
- Where applicable, mitigations in specific or related CDUPs were/are being adhered to;
- All commercial related vehicles, equipment and materials brought to the HO site were inspected by a qualified biologist before entering Haleakalā National Park;
- Requirements set out in the Haleakalā Observatories Management Plan for Monitoring Strategies,
- Cultural and Historic Preservation Management, Environmental Protection of Site Resources,
- Construction Practices, and Facility Design Criteria were complied with and a Cultural Specialist was retained when the activity required a permit from DLNR.

## Habitat Conservation Plans (HCPs)

The National Science Foundation's Advanced Technology Solar Telescope (ATST) Project, renamed the Daniel K. Inouye Solar Telescope (DKIST) on December 15, 2013, obtained approval of an HCP from BLNR in May 27, 2011 and an Incidental Take License from U.S. Fish and Wildlife Service (USFWS) on November 30, 2011 to address anticipated impacts to state and federal threatened, endangered, and listed species from construction, pursuant to Chapter 195D, Hawai'i Revised Statutes (HRS 195D). The Hawaiian petrel ('ua'u) is the principal species of interest in the HCP. In order to initiate and pursue the mitigation measures described in the DKIST HCP, the DKIST Project has had a Resource Biologist on staff since 2011, along with seasonal and permanent field technicians under his direction implemented HCP related mitigation measures that included but are not limited to:

a) Botanical and archeological surveys of the 328 acre HCP Conservation Area assigned to DKIST;
b) Survey and census of burrows within that mitigation area;
c) Video monitoring of burrows in the area closest to DKIST site;
d) Identification of an approved control area that will not be subject to mitigation measures;
e) Initial predator control-ungulate removal and cat trapping;
f) Reproductive success monitoring; and,
g) Formal reporting on these efforts to Endangered Species Recovery Committee (ESRC), USFWS, and DLNR on October 22, 2015[1]

HCP requirements for the DKIST Project correspond with the requirements in Section 3.5.3.2 (2) of the MP regarding protection of the Hawaiian petrel ('ua'u) from noise, vibration, burrow collapse, flight collisions, lighting, and reporting on mortality.

### Monitoring Plans for Invertebrates, Flora, and Fauna

For about a year before the December 1, 2010 approval of the MP by the BLNR, programmatic monitoring of invertebrates, flora, and fauna was initiated at HO. The surveys conducted pursuant to the MP at HO are part of the long-term effort to characterize floral and faunal populations at the site that may be impacted or benefit from practices and procedures at HO, and thus be more effectively conserved, protected, and preserved by adaptive management of the site.

Annual programmatic invertebrate surveys have been conducted within HO starting in December 2010. The first survey in 2011 reported that insects were in higher abundance and diversity, likely due to the timing of the sampling, and the second survey reported that the arthropods found were characteristic of the fauna at the site. During the third and forth surveys in March and October 2012, several species that were observed in other years were not present, likely absent because of the timing of the sampling, weather conditions, or their rarity. During surveys in 2015[2&3], no non-indigenous, invasive arthropods were found at the site or on any of the construction material and equipment. The project was found to be largely compliant with all the mitigation measures in the guiding environmental documents for construction of the DKIST. The construction site and surrounding lay-down/storage areas were clean and free of non-indigenous invasive arthropods.

Botanical surveys of HO were conducted in spring[7] and fall[9] of 2015. No non-indigenous, invasive arthropods were found at the site or on any of the construction material and equipment. The project was found to be largely compliant with all the mitigation measures in the guiding environmental documents for construction of the DKIST. The construction site and surrounding lay-down/storage areas were clean and free of non-indigenous invasive arthropods.
There were two more native plant species observed at HO this survey than in Fall 2014, both had previously been known from HO and reappeared in the same general areas.
The native ena ena (Pseudognaphalium sandwicensium subsp. sandwicensium) continues to come and go here and there in disturbed sites, especially along hardened surfaces near the southeast side of the Retention Basin. There was also the reappearance of a native catchfly (Silene struthioloides) that had not been seen at HO since 2009. Two small seedlings, only a few cm in height, were found in the same area where an adult plant once lived near Mees Observatory

Programmatic faunal monitoring is being implemented during and after construction of the DKIST, which began in 2012, to insure impacts on biological resources are minimized. Monitoring includes field observations at HO for faunal presence, e.g., scat, tracks, eaten plants, etc. Faunal surveys of HO were conducted in spring[6] and fall[8] of 2015.

## Programmatic Agreements on Cultural Resources

The National Science Foundation (NSF), the National Park Service, the University of Hawai'i, the State Historic Preservation Officer, and the Advisory Council on Historic Preservation signed the Programmatic Agreement (PA). The PA established mitigation measures that include but are not limited to the establishment of a Native Hawaiian Working Group (NHWG), the retention of a Cultural Specialist; reserving up to 2% of the total DKIST usage time for Native Hawaiian scientists, when there are Native Hawaiians among the pool of qualified scientists; and providing support to an educational initiative addressing the intersection between Native Hawaiian culture and science. The IfA commits to continued mitigation of impacts on cultural resources on the Region of Impact (ROI). The IfA will provide a written annual report to the Board on the status of the implementation of the Programmatic Agreement, including: listing the proposed mitigations to impacts on cultural resources developed by the Native Hawaiian Working Group (NHWG); the response to those proposed mitigations by the signatory parties to the Programmatic Agreement; and, the implementation of any such mitigation measures by the IfA."

### *Status of the Implementation of the Programmatic Agreement*

The following summarizes the status of pertinent items under Section II- NSF's Area of Responsibility of the PA. These items are discussed as applicable during the NHWG meetings.

### *Establishment of the DKIST Native Hawaiian Working Group*

The PA was fully executed on November 13, 2009. The NHWG first met on December 5, 2009, which was within 60 days of the fully executed date. For calendar year 2015, NHWG meetings were held on March 25 and December 21.

### *Implementation of Best Management Practices*

Best Management Practices as outlined in the BLNR approved HO MP have been and will continue to be implemented.

### *Naming of HO Roads*

At the September 22, 2014 NHWG meeting a subcommittee was established to discuss naming the HO road.

### *Retention of a Cultural Specialist*

CKM Cultural Resources, LLC (Kahu Dane Uluwehiokalani Maxwell) is the DKIST Cultural Specialist.

### *Possible Repainting*

At the March 25, 2015 NHWG meeting, it was discussed that currently, no new technology has been developed.

### *Removal of Reber Circle Site #50-50-11-5443*

The Reber Circle concrete ring was removed on December 3, 2012.

### *Required "Sense of Place" Training*

All contractors and employees continue to participate in this training.

### *Exterior Design*

The NHWG has put on hold the discussion of the Exterior Design of the DKIST.

### *Possible Shelter for Cultural Practitioners*

As of September 22, 2014, the NHWG expressed interest and plans to discuss at a future meeting.

### *State Road 378*

Under Contract to IARII, Mason Architects completed the State Highway 378 Historic Evaluation Report identifying and photographing Contributing Features of historic significance along the roadway consisting of 10.1 miles from the Crater Road junction to the Haleakalā National Park entrance. The final State Road Historic Archival Engineering Report was completed and transmitted to NPS and SHPD on 11/21/13.

### *Acknowledgment of Significance of Haleakala and NSF's Gratitude*

NHWG determined that acknowledgment language would be inappropriate (closed).

### *Status of Implementation of this PA Reported on Project Website*

The "Status of Implementation of Programmatic Agreement" web page is available on the Internet at: http://dkist.nso.edu/node/747

### *DKIST Telescope time for Native Hawaiian Scientists*

Reserving up to 2% of the total DKIST usage time for Native Hawaiian scientists, when there are Native Hawaiians among the pool of qualified scientists. Not applicable at this time.

### *Providing support to an educational initiative addressing the intersection between Native Hawaiian culture and science*

The Division of Astronomical Sciences of the National Science Foundation funded the fifth year of a ten-year, $20M award has been made to the University of Hawaii Maui College (UHMC). This brings the total amount funded to UHMC under this award to $10M. The award is being funded, contingent upon the availability of appropriations, at a rate of $2M annually and is being used to operate the Ka Hikina O Ka Lā program http://maui.hawaii.edu/hikina/, which addresses the intersection of Native Hawaiian culture and science, technology, engineering and mathematics.

The terms of the award are such that subsequent years' funding will be contingent upon the construction of the DKIST. Should the DKIST not be constructed on Haleakalā, future funding would be cancelled.

Details of the award can be found at:

http://nsf.gov/awardsearch/showAward?AWD_ID=1135694

### *Proposed mitigations to impacts on cultural resources developed by the NHWG and the response to those proposed mitigations by the signatory parties to the Programmatic Agreement the implementation of any such mitigation measures by the University*

The role of the DKIST NHWG is to provide consultation concerning historic property matters related to the construction and operation of the DKIST Project. The NHWG meeting minutes are summarized and posted to the "Status of Implementation of Programmatic Agreement" web page is available on the Internet at: http://dkist.nso.edu/node/747

### Invasive Species Control

The MP provides for active prevention of introduction of invasive species that may threaten HO site resources. The implemented practices include but are not limited to weeding of HO property, vector control for rodents, soil and erosion control in accordance with the HO Storm Water Management Plan, and frequent removal of trash.

Invasive plant control for the HO has been successfully completed for 2015[4&5], the sixth successive year of invasive plant control at the site. In summary, in terms of invasives, generally, the site is looking very good, especially compared to similar sites at high elevation where invasive plant control is not being implemented. It is also much improved compared to the number of invasive plant species and their biomass found in this same area when this project started six years ago. *Lepidium*, which at project onset, numbered in the thousands, was restricted to about 50 individuals this year.

### Hawaiian Petrel Monitoring

Video and field monitoring of endangered Hawaiian petrels at HO continued throughout the 2015 nesting season (March-November). Programmatic monitoring of petrel burrows in and adjacent to HO was initiated prior to DLNR approval of the MP, and is designed to characterize changes in population from year to year and to observe changes in nesting behavior that may be due to activities at HO.

This season the reproductive success in Conservation Area was hampered by the extraordinary high number of tropical storms that traveled to the north of Maui. Although we recorded a historically high number of active burrows (168) at the beginning of the season in Conservation Area, only 29 were successful at the end of the season (17.3%, the 2nd lowest in the last 5 seasons). Just like last year, no predations were recorded in the Conservation Area, while 14 eggs were found abandoned (the highest number in the last 5 seasons) in this area. Among the 29 success burrows, 12 were located adjacent to DKIST construction site (the highest in the last 5 years).

## Summary of Activities Under the HO Site Management Plan

The IfA, its lessees, and contractors conducted numerous studies, surveys, and inventories at HO during the reporting period from December 2014 to November 2015, and undertook preventive actions to protect and preserve environmental and cultural resources. The above descriptions of programmatic activities do not include or assign credit for the many day-to-day actions by the employees and contractors at HO to preserve and protect environmental and cultural resources and values at HO. A few examples of such daily actions (and non-actions) by site occupants include:

a) Construction within HO requiring a permit from DLNR requires the consultation and monitoring of a Cultural Specialist;
b) Respectful, helpful and courteous support to Native Hawaiian practitioners who enter the HO site for traditional cultural practices;
c) Vigilance to keep seeds, spores, or invasive plants from "hitchhiking" on persons or personal items;
d) Parking only in designated areas;
e) Avoiding known archeological sites and features;
f) Care to avoid harassment or injury to endangered petrels during nesting season;
g) Not damaging or removing endangered Silversword plants; and,
h) Avoiding noise not absolutely necessary for construction or operations.

It is the commitment of the IfA to use past, present, and future knowledge of the dynamic environment at HO to continually inform its site MP, so that site personnel who work there can preserve a balance within HO. It is the objective of IfA to proactively provide effective stewardship of an environment where astronomy can continue to evolve to move mankind toward a deeper understanding of the Universe in which we live while ensuring the cultural and environmental resources and values of HO are protected.

## References

1. Chen, Huisheng / DKIST Resource Biologist. 2015 DKIST HCP State Fiscal Year Report, July 2015.

2. Pacific Analytics, LLC. Programmatic Arthropod Monitoring at the Haleakalā High Altitude Observatories and Haleakalā National Park, Maui Hawai'i, August 2015.

3. Pacific Analytics, LLC. Programmatic Arthropod Monitoring at the Haleakalā High Altitude Observatories and Haleakalā National Park, Maui Hawai'i, February 2015.

4. Arthur C. Medeiros Ph.D. Haleakala High Altitude Observatory Invasive Plant Control Project at the Haleakalā High Altitude Observatories, Maui Hawai'i, March 2015.

5. Maui Space Surveillance Complex located within the Haleakalā High Altitude Observatory (HO) Invasive Species Report (Reporting Period 1 Nov 2014 to 31 Oct 2015).

6. Starr, Forest & Kim. Starr Environmental. 2015. Faunal Survey for Haleakalā High Altitude Observatories, May 2015.

7. Starr, Forest & Kim. Starr Environmental. 2015. Botanical Survey, Fall 2015 Haleakalā High Altitude Observatories, Maui, Hawai'i, November 2014.

8. Starr, Forest & Kim. Starr Environmental. 2015. Botanical Survey, Spring 2015 Haleakalā High Altitude Observatories, Maui, Hawai'i, May 2015.

9. Starr, Forest & Kim. Starr Environmental. 2015. Faunal Survey for Haleakalā High Altitude Observatories, November 2015.

**Daniel K. Inouye Solar Telescope (DKIST)**
**Habitat Conservation Plan State Fiscal Year Report 2015**

H. Chen, C. Ganter, J. Panglao, R. Tada

July 2015

## I. INTRODUCTION

This annual report is being submitted by the Daniel K. Inouye Solar Telescope (DKIST) Resource Management Team, in accordance with the DKIST Habitat Conservation Plan (HCP) and the Final Biological Opinion (BO) of the U.S. Fish and Wildlife Service (USFWS, 1-2-2011-F-0085). The purpose of this report is to provide the collaborative primary agencies with an update on the progress and compliance of the project, as well as to summarize results of mitigation and monitoring activities being implemented for the DKIST project.

### *I A. The DKIST Project*

The Association of Universities for Research in Astronomy (AURA) is a consortium of universities, and educational and other non-profit institutions that operates world-class astronomical observatories, termed “centers”. AURA operates the National Solar Observatory (NSO) under a cooperative agreement with the National Science Foundation (NSF). Once construction is completed, the DKIST will be the world’s premier solar telescope, with unprecedented abilities to view details of the Sun. Using adaptive optics technology, DKIST will be able to provide the sharpest views ever taken of the solar surface, which will allow scientists to learn even more about the Sun and solar- terrestrial interactions.

Construction for the telescope project began on December 1, 2012. The original name for the project was the Advanced Technology Solar Telescope (ATST), and was renamed the Daniel K. Inouye Solar Telescope on December 15, 2013, in honor of the late Senator Daniel K. Inouye. The DKIST is located within the 18.166-acre University of Hawaiʻi Institute for Astronomy (IfA) Haleakalā High Altitude Observatory (HO) site at the summit of Haleakalā, County of Maui, Hawaiʻi. The DKIST facilities will include an approximately 136 ft (41.5 m) tall building housing the telescope, an attached support and operations building, and a utility building.

### *I B. DKIST Habitat Conservation Plan (HCP) and Biological Opinion (BO)*

The DKIST Habitat Conservation Plan (HCP), which was approved by the State of Hawaiʻi Board of Land and Natural Resources (BLNR) in January 2011, addresses potential impacts to state and federal threatened, endangered, and listed species during the construction of the DKIST at HO, pursuant to Chapter 195D, Hawaiʻi Revised Statutes (HRS 195D). The Biological Opinion (BO) was published on June 15, 2011 by the U.S. Fish and Wildlife Service. The species of focus in both the HCP and BO is the Hawaiian Petrel (*Pterodroma sandwichensis)*

### *I C. Incidental Take License and Incidental Take Statement*

The State BLNR issued an Incidental Take License (ITL), No. ITL-13, to the NSF on November 30, 2011, and the USFWS issued an Incidental Take Statement in the BO to address potential take during DKIST construction. The ITL was issued with the anticipation that a level of take of as many as 35 Hawaiian Petrel individuals (30 fledglings and 5 adults) would occur, and that the conservation mitigation efforts in place will offset such take during the construction phase where such take is incidental to and not the purpose of the carrying out of an otherwise lawful activity. Once construction of the DKIST is complete, the operations of the DKIST facility are not expected to result in incidental take of listed species under HRS 195D. The USFWS anticipated that project related harassment and indirect effects of birdstrike mortality will reduce the number of fledglings produced by Hawaiian Petrels by no more than 32.

***I D. FAA/Coastguard Communication Tower Monitoring***
Because of a concern that the DKIST facility may interfere with Federal Aviation Administration's (FAA) ground-to-air signal conveyance, NSF, through AURA/NSO, funded necessary tower upgrades on two of the existing FAA Radio Communication Air to Ground (RCAG) towers located on FAA property adjacent to HO. These tower upgrades were completed October 8, 2012. By agreement between NSF and FAA, the DKIST Resource Management Team continues to monitor the FAA tower site to collect potential petrel-tower collision information.

## II. HAWAIIAN PETRELS: BACKGROUND INFORMATION

***II A. Status of the Species***
The Hawaiian Petrel (*Pterodroma sandwichensis*) was listed as endangered on March 11, 1967 (32 FR 4001). The species is a medium-sized seabird in the family Procellariidae (shearwaters, petrels, and fulmars). The Hawaiian Petrel was formerly treated as a subspecies of *P. phaeopygia*, with the nominate subspecies occurring in Galapagos (*P. p. phaeopygia*). However, based on differences in morphology and vocalization, the two subspecies were reclassified as full species in 1993 (Monroe and Sibley, 1993) and genetic analysis confirmed the split several years later (Browne, et al., 1997, Welch 2011).

***II B. Historical and Current Distribution and Threats***
Hawaiian Petrels were abundant and widely distributed in prehistory; their bones have been found in archaeological sites throughout the archipelago (Olson and James, 1982). Prior to Polynesian colonization, this species had no natural terrestrial predators other than the Hawaiian owl (Pueo, *Asio flammeus sandwichensis*). When Polynesians arrived in the archipelago, they collected petrels for food (Harrison 1990) and introduced rodents, dogs (*Canis lupus familiaris*) and pigs (*Sus scrofa domesticus*). After Captain Cook landed on the islands, the introduction of avian diseases (Warner, 1968), cats (*Felis silvestris catus*), Indian small mongoose (*Herpestes javanicus*), more rodent species and ungulates has resulted in substantial declines in the distribution and numbers of this species.

Other significant anthropogenic sources of Hawaiian Petrel mortality are light attraction and collision with communications towers, power transmission lines and poles, fences, and other structures (Simons, 1983). The Hawaiian Petrels fly over 30 miles/hour (48 km/hour) (Day and Cooper, 1995), which likely reduces their ability to detect obstacles in the dark and avoid them. This problem is likely to be exacerbated by the continuing development and urbanization throughout Hawaiʻi.

Besides terrestrial threats, the species may be adversely affected by other factors as well. Hawaiian Petrels forage for food at the water's surface, and due to over-fishing, there are declining populations of large predatory fish that drive petrel prey species to the surface. That may affect the Hawaiian Petrels' ability to feed. In addition, it is known that the distribution of fish changes during El Niño years, when the surface water temperature rises and fish species migrate north to cooler temperatures (Bird Life International 2014, NOAA). Since the Hawaiian Petrels return to the same foraging locations each year, during El Niño years they may be feeding (themselves and their young) on less suitable fish. Additional factors such as Fukushima marine debris, radiation pollutants, and global weather pattern changes can also affect the Hawaiian Petrels' food supply, and therefore may adversely affect their ability to maintain proper sustenance.

Hawaiian Petrels are currently known to nest on at least four islands (Bird Life International 2014), but their distribution is limited to high alpine or rainforest sites where predation pressure is lower. An accurate estimate of total numbers of Hawaiian Petrels is not available; however, estimates range from the thousands to about 34,000 (e.g., Spear, et al., 1995; Ainley, et al., 1995). Spear, et al. (1995) estimated the at-sea population size of adult and sub-adult Hawaiian Petrels of 19,000 birds (with a 95 percent confidence interval of 11,000 to 34,000). Ainley, et al. (1997) estimates a breeding population of about 1,600 pairs on Kauaʻi and Ainley (USFWS, unpublished field notes) estimates that there are a few thousand pair occurring on Lanaʻi and 1,500 on Haleakalā. Darcy Hu (2009, personal communication) located 115 active burrows within the Hawaiʻi Volcanoes National Park (HAVO) in 2006. As of 2009 it was estimated that between 1,000 and 6,000 Hawaiian Petrels come to shore each year on all islands (Jay Penniman, personal communication 2009).

Although the Hawaiian Petrel still can be found on four of the eight major islands, each population is morphologically (Judge 2011), behaviorally (Judge 2011, Wiley et al. 2013) and genetically (Welch et. al. 2012) unique to other populations. Most of the unique Maui population nests along the rim of Haleakalā Crater, within Haleakalā National Park and in the vicinity of the DKIST action area. The most recent estimate of breeding petrel numbers in these areas is roughly 400 to 600 breeding pairs (Simons and Hodges, 1998; Bailey 2006, personal communication). A primary reason for the relatively large numbers of petrels and their successful breeding around Haleakalā summit today is likely due to the fencing and intensive predator control maintained by Haleakalā National Park since about 1982. Without such fencing, the petrel's habitat is destroyed or severely compromised by feral ungulates such as goats, and by pigs in wetter and more vegetated environments than the summit of Haleakalā. In addition to collapsing burrows and compacting the substrate, these animals act as vectors for invasive plants that alter the vegetation structure and may hinder the birds' access to traditional nesting areas (Simons, 1985).

The birds spend much of their time at sea where they are known to feed on squid, small fish, and crustaceans displaced to the surface by schools of tuna (Larson, 1967; Simons, 1985). Adult Hawaiian Petrels have been tracked taking single trips exceeding 6,200 mi (10,000 km) circumnavigating the north Pacific during the nestling stage (Adams, et al., 2006), and have been recorded in the Philippines (Rabor, et al., 1970), Japan (Nakamura, 1979), the Gulf of Alaska (Bourne, 1965), and off the coast of Oregon and California (Pyle, et al., 1993).

### *II C. Nesting Habitat in Haleakalā*

The largest known nesting colony of Hawaiian Petrels is located in and around the Haleakalā National Park (Simons and Hodges, 1998). Prior to the DKIST project, approximately 30 known burrows were located along the southeastern perimeter of HO, several burrows were northwest of HO, and additional burrows have been found northeast of the DKIST Project site (NPS, 2003).

Although historically the species may have nested at lower elevations (USFWS, 1983), the current nesting habitat of Hawaiian Petrels on Maui is at elevations above 7,200 ft. (2,195 m).

The Hawaiian Petrel nests on Haleakalā in high elevation burrows located beneath rock outcrops, under boulders and cliff faces, along talus slopes or along edges of lava flows where there is suitable soil underlying rock substrate for excavation of tunnels. Most of the nests on Haleakalā are in rock crevices in sparsely vegetated, xeric habitat (Simons and Hodges, 1998). Burrows are excavated by the petrel to a depth of 3 to 6 ft (1.0 to 1.8 m), but sometimes reach a length of 15 ft (4.6 m) or more.

The majority of known Hawaiian Petrel burrows are located along the western rim of the Haleakalā Crater, where this habitat is most abundant and also where predator control is provided. Using survey efforts from 1990-1996, previous estimates of burrow density, a portion of which included the mitigation area within HO, range from 5 to 15 burrows per ha, compared to 15 to 30 burrows per ha along the western crater rim. The difference in density may be attributed to the fact that the mitigation area had no predator control prior to 2013, and that two-thirds of the mitigation area is cinder field, which is not a suitable environment for petrel nesting. Similarly, in 2004 and 2005, Hawaiian Petrel passage rates, collected using ornithological radar, were 4 to 7 times greater during summer and fall at the Visitor's Center (Western rim), when compared to the Haleakalā Observatory complex, suggesting bird numbers are lower in areas encompassing the DKIST mitigation site. Importantly, the population trend at Haleakalā is increasing, which suggests that additional recruitment into this site is possible (Holmes, 2010).

There are four Hawaiian Petrel burrow clusters, and a number of isolated burrows, within approximately 1,250 ft (381 m) of the DKIST Project site, totaling approximately 31 individual burrows. Burrow clusters and individual burrows to the west and the northwest of the construction site historically have not been greatly used by nesting Hawaiian Petrels (Bailey, 2009, personal communication); approximately 5 to 10 burrows (mostly inactive) are 500 to 800 ft (244 m) from the construction site that is to the west.

### *II D. Nesting Phenology*

Hawaiian Petrels are present at Haleakalā from February through October and are absent from November through January.

Similar to other members of its family, the Hawaiian Petrel has a well-defined, highly synchronous nesting season (Simons, 1985). There is also clear evidence of intra-island variation in breeding phenology within Hawaiʻi, with Haleakalā breeders initiating, and completing, breeding approximately one month earlier than Kauaʻi, Lanaʻi, and Hawaiʻi Island. At the Haleakalā site, birds arrive in their colonies in late February. After a period of burrow maintenance and social activity they return to sea until late April when egg-laying commences. Non-breeding birds visit the colony from February until late July (Simons and Hodges, 1998). Many of these may be young birds seeking mates and prospecting for nest sites, but some percentage is thought to be mature adults that do not elect to breed.

Hawaiian Petrels are thought to begin breeding at about 5 or 6 years of age, and roughly 90 percent of breeders attempt to breed each year (Simons and Hodges, 1998). Beginning in mid-February to early March, after a winter absence from Hawaiʻi, breeding and non-breeding birds visit their nests regularly at night, for a period of social activity and burrow maintenance work. Pairs are site tenacious, returning to the same burrow year after year. From mid-March to mid-April, birds visit their burrows briefly at night on several occasions. Then breeding birds return to sea until late April or early May, when they return to lay and incubate their eggs.

Both adults participate in incubating the egg and feeding the chick; after a brief brooding period, both adults are foraging at sea and will have absences from the nest (Simons, 1985). Male and female birds alternate incubation attendance, and total incubation period ranges from 45 to 58 days (Simons, 1985). Egg temperature and evaporative water loss are controlled by the incubating adult. Because the metabolism of awake, resting birds is almost twice that of sleeping birds (Simons, 1985), disturbance of incubating birds' sleep could potentially result in more rapid weight loss and an inability of the adult to stay on the egg until its mate relieves it.

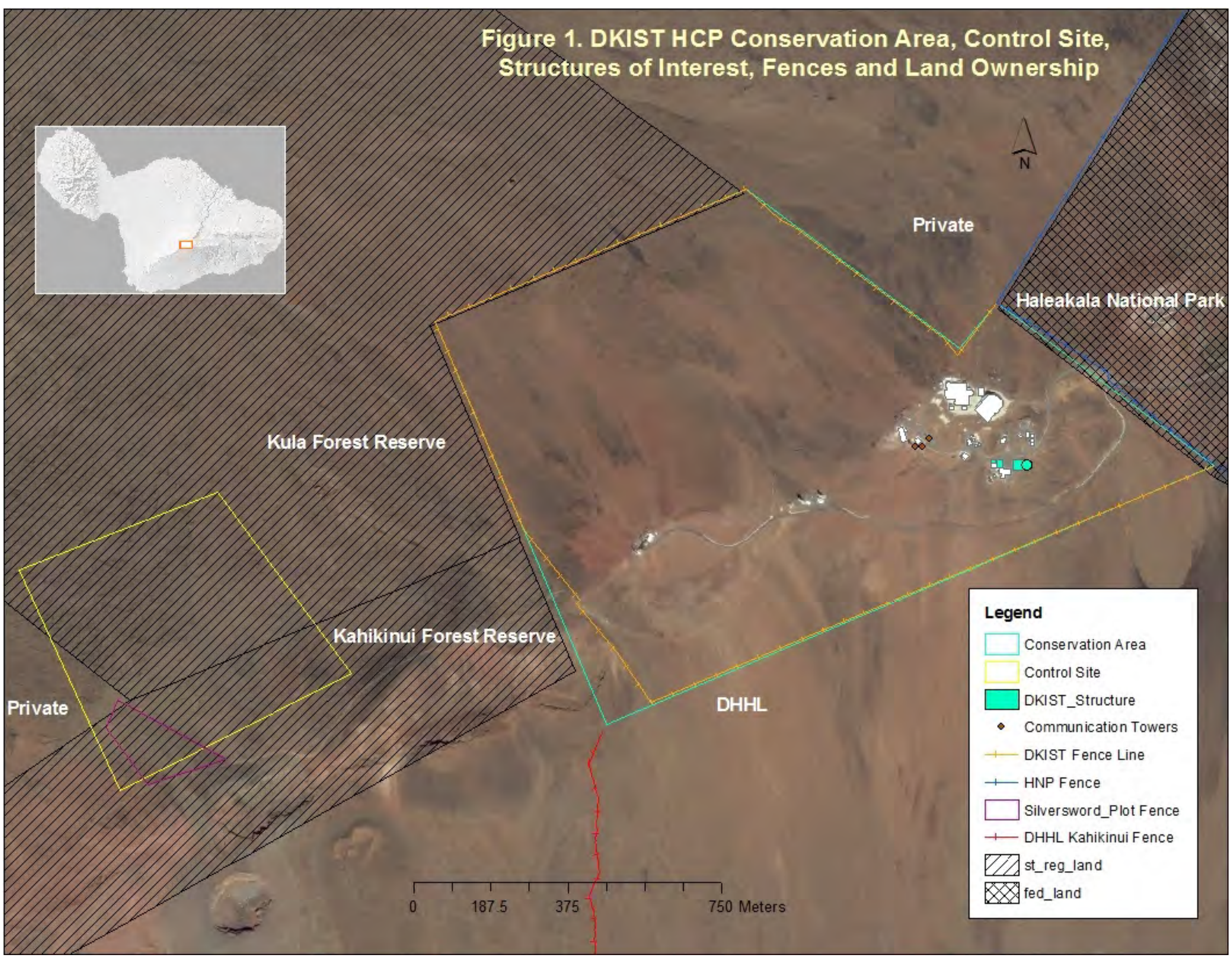
During the incubation period, many non-breeding birds also inhabit the colony. Many of these are young birds gaining experience seeking mates and prospecting for nest sites; the remaining portions are experienced breeders that did not elect to breed. Non-breeders and failed breeders typically begin leaving the colony once the eggs have hatched. The non-breeders continue to visit their burrows at night through early August (Simons, 1985). By September, the only birds visiting the colony are adults returning to feed their chicks (Simons, 1985). Chicks do not appear to require much brooding from their parents. Adults depart from the nest to forage at sea within 1 to 6 days after the chick hatches (Simons, 1985). Chicks spend 66 percent of their time alert, resting quietly, 26 percent of their time sleeping, 6 percent of their time preening or stretching, and 2 percent of their time walking around (Simons, 1985). Nocturnal feeding by one parent occurs approximately every other day until the chick is 90 days old. After 90 days, adults appear to continue to feed chicks until the chick refuses food. Chicks fledge between late September and late October, after an average of 111 days after hatching (Simons, 1985, though our data shows fledging goes into the first week of November). Although adults are occasionally observed to remain after fledglings depart, colonies generally are empty by the end of November.

A hiatus of only about three months occurs between the end of one breeding season and the beginning of the next.

## III. OVERVIEW OF THE DKIST HCP CONSERVATION AREA AND CONTROL SITE

The DKIST HCP requires the establishment of a Conservation Area to mitigate the potential negative effects related to construction of the DKIST facility. In addition, the HCP also specifies the need to establish a Control Site to compare and evaluate the DKIST Resource Management Team's conservation efforts within the HCP Conservation Area. Both of these areas have been established and maintained since 2011.

The Conservation Area (Figure 1) is located between approximately 8,800 and 10,000 ft. (2,686 to 3,048 m) in elevation, and includes observatory facilities, broadcast facilities, communication towers, and the portion of Skyline Trail dividing the area from the northeast to the southwest. Adjacent lands include the Kula Forest Reserve, Kahikinui Forest Reserve, NPS, Department of Hawaiian Home Lands (DHHL), and private land. The conservation/mitigation site contains a number of cinder cones, of which Pu'u Kolekole is the highest in elevation. This cone is about 0.3 mi (0.5 km) from the highest point on the mountain, Pu'u 'Ula'ula (Red Hill) Overlook, which is in the Park and outside of state land (Figure 1). Based on the State of Hawai'i website published TMK GIS layer, the area was estimated to be 328 ac (133 ha), however after the ground survey using existing metes and bounds was completed, it was determined the area covers an area of 321.79 ac (130.22 ha).



Note: The ground-truth DKIST HCP Conservation Area boundary on the map is different from the State of Hawaiʻi website published TMK GIS layer. The actual metes and bounds on the ground vary from the GIS layer up to 33 meters.

The annual average total precipitation on the Haleakalā summit, in the vicinity of the Conservation area, between 1949 and 2005, was 52.92 inches (in) (134 centimeters (cm). At or near the summit, sustained wind speeds of 50 miles per hour are not unusual. The peak wind speed recorded at the summit was over 125 miles (mi) per hour (201 km per hour). The topography within the Conservation Area is rugged and barren, and the elevation drops with an average slope greater than 30 percent (DKIST 2010). Temperatures at the summit of Haleakalā can range between below freezing to highs of 65°F (18°C, HALE 2011).

The Control Site (Figure 1) encompasses 80 acres and is one kilometer west of the west boundary of the Conservation Area, just north of the Skyline Trail, at an elevation of 8,700 to 9,300 ft. (2652 to 2835 m). The topography within the Control Site is similar to that of the Conservation Area.

## IV. DKIST HCP COMPLIANCE

The DKIST team continues to meet or exceed compliance with HCP required mitigation measures. Following is a summary in reverse chronological order (most recent first) highlighting the major compliances.

### *IV A. Monitoring Burrow Structures in the Impact Area: <u>February 2015</u>*

KCE has developed a new burrow scope with a remote directional control capacity for this purpose. After an initial test period in 2015, routine monitoring for potential impact to burrow structures adjacent to the DKIST construction site will be implemented. This burrow scope will only be used for this purpose during the non-breeding season to avoid risk of burrow damage during the breeding season.

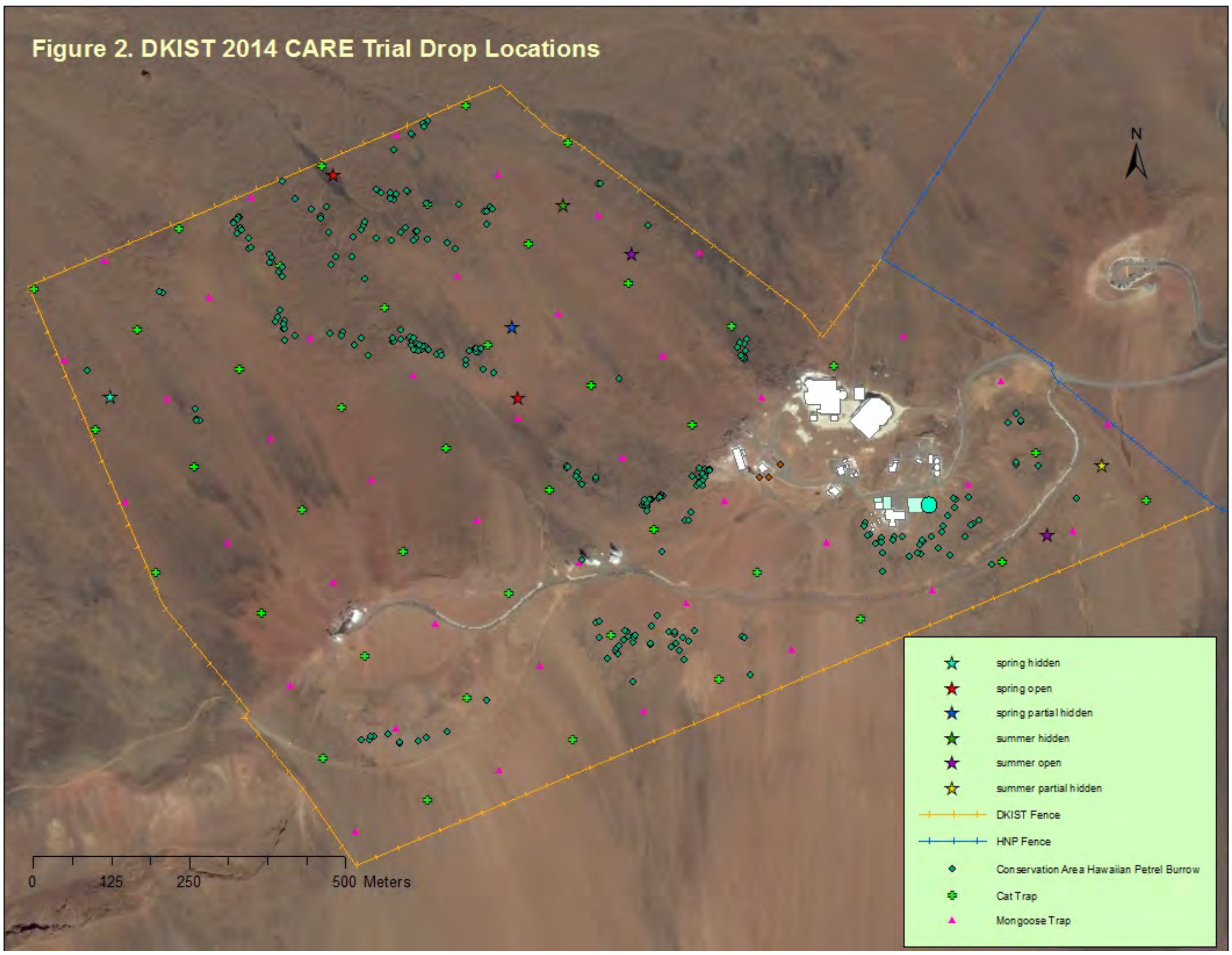
### *IV B. Silversword Outplanting and Seed Propagation: <u>November 2014</u>*

Eight hundred seeds from four flowering Silversword plants within the DKIST Conservation Area were collected on November 18, 2014 by subcontractors Starr Environmental, under a permit issued by DLNR on November 10, 2014. The seeds were turned over to Haleakalā National Park (HALE) for propagation. In compliance with the HCP, the DKIST resource management team carefully checked the source area during its June 2015 monitoring to see if there was natural regeneration from the Silversword seed bank in the area from which the seeds were collected. The resource management team could not locate any seedlings during its June, 2015 monitoring. If natural regeneration does not occur, the seedlings will be outplanted near the collection area. If such action is warranted, the seedlings will be ready for planting in the fall of 2016 (Sierra Gabrels/NPS).

### *IV C. Carcass Removal Trial (CARE): <u>Ongoing Since September 2013</u>*

Carcass Removal Trials are undertaken to determine the scavenging rate by cats, rats, mongoose or other scavengers of any birds killed via birdstrike. Pursuant to adaptive management changes approved by DOFAW and USFWS for the HCP and BO, two CARE trials will be conducted each year, during the 6 year construction period. These trials are to be conducted by a third party contractor and the information will be used to guide search intervals for birdstrike monitoring for the DKIST project.

CARE trials have been conducted by KC Environmental, Inc. (KCE) since the fall of 2013. Trials are conducted in locations approved by USFWS and DOFAW within the DKIST Conservation Area that are at least 50 meters from a Hawaiian Petrel burrow and 30 meters from baited traps. Figure 2 is an example of surrogate bird placement (from the 2014 trials). Surrogate bird (Wedge Tailed Shearwater, *Puffinus pacificus*) carcasses were placed in a variety of positions, including two that were exposed (thrown), one hidden to simulate a crippled bird and one partially hidden.




The results of the CARE trials conducted through the spring of 2015 are presented in table 1. Of the trials so far, only one bird (from the 2013 spring trial) has been scavenged. This scavenge was from a partially concealed location within two weeks of placement, with only feathers left behind.

| Table 1. the Outcome of DKIST HCP Carcass Removal Trial 2013-2015 | | | | |
|---|---|---|---|---|
| **Year** | **Season** | **Period (days)** | **% Scavenged** | **Remarks** |
| 2013 | Spring | 30 | 25 | Remains still detectable at the end of the trial |
| 2014 | Spring | 30 | 0 | |
| 2014 | Summer/fall | 60 | 0 | Extended trial |
| 2015 | Spring | 30 | 0 | |

The results of the CARE trials are consistent with the experience of the DKIST Resource Management team, in that carcass remains have been found in the Conservation Area that are often more than a year old. The CARE trials show further evidence that scavenging rates at these higher altitudes is extremely low. After four such trials, including the extended trial, only one surrogate bird showed any sign of scavenging.

These outcomes and corroborating field experience all continue to suggest that the 10% carcass removal rate used in the calculation of unobserved take for DKIST may be too high. Almost all carcasses are recorded in the search areas for DKIST, because the predation rate is very low, and even the rare predation that takes place does not seem to remove all evidence of bird mortality for as long as a year or more. The longevity of carcasses in the field also indicates that searches for downed birds at the elevations of the Conservation Area may not have to be as frequent as thought before evidence from these CARE trials and field experience became available. (Fein and Allan 2013b, 2014b, 2014c, 2015 b).

***IV D. Conservation Fence and Ungulate Eradication: <u>July 2013</u>***

A Conservation District Use Permit (CDUP) for the conservation fence was issued on May 17, 2013. On July 25, 2013, Rock N H Fencing, LLC was awarded the contract to construct the conservation fence. The construction started on September 1, 2013 and was completed on November 18, 2013. A total of 4.23 km (2.63 mi) of fence was built and 126.53 ha (312.66 ac) of Conservation Area was enclosed, which included 0.66 ha (1.64 ac) of Haleakalā National Park land outside of the park fence (Figure 1 & 3). To prevent bird collision with the conservation fence, three strands of Poly-tape installation was completed on March 13, 2014 in compliance with HCP and BO requirements.

As a result of the fence construction process and the intensive monitoring / conservation activities that were being implemented during the fence construction, all ungulates vacated the Conservation Area before the fence was completed. Based on footage from 10 long-term predator/ungulate monitoring camera traps and six additional ungulate monitor camera traps (Figure 3), no ungulates have been detected within the Conservation Area since September 12, 2013.

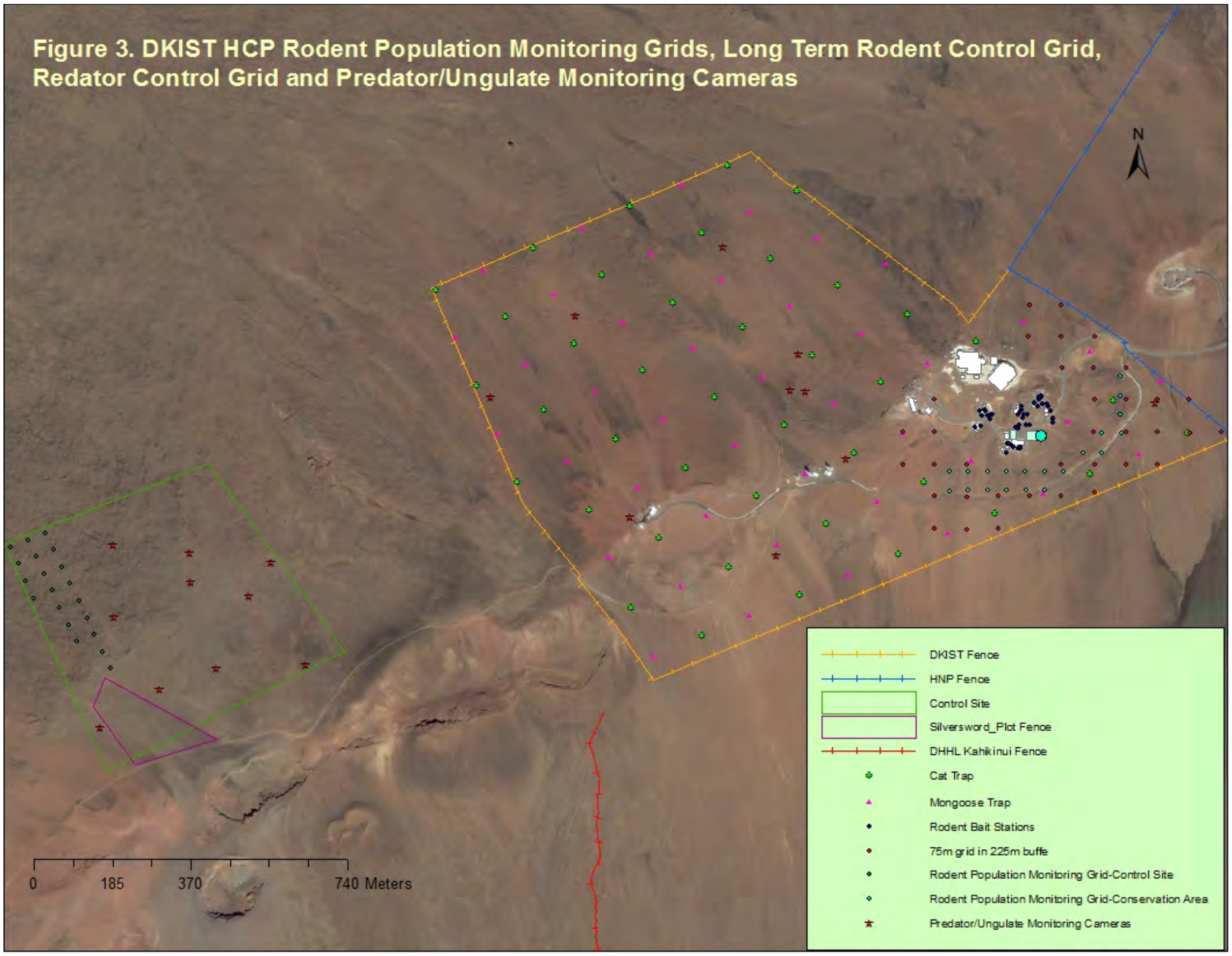


Figure 3. DKIST HCP Rodent Population Monitoring Grids, Long Term Rodent Control Grid, Redator Control Grid and Predator/Ungulate Monitoring Cameras

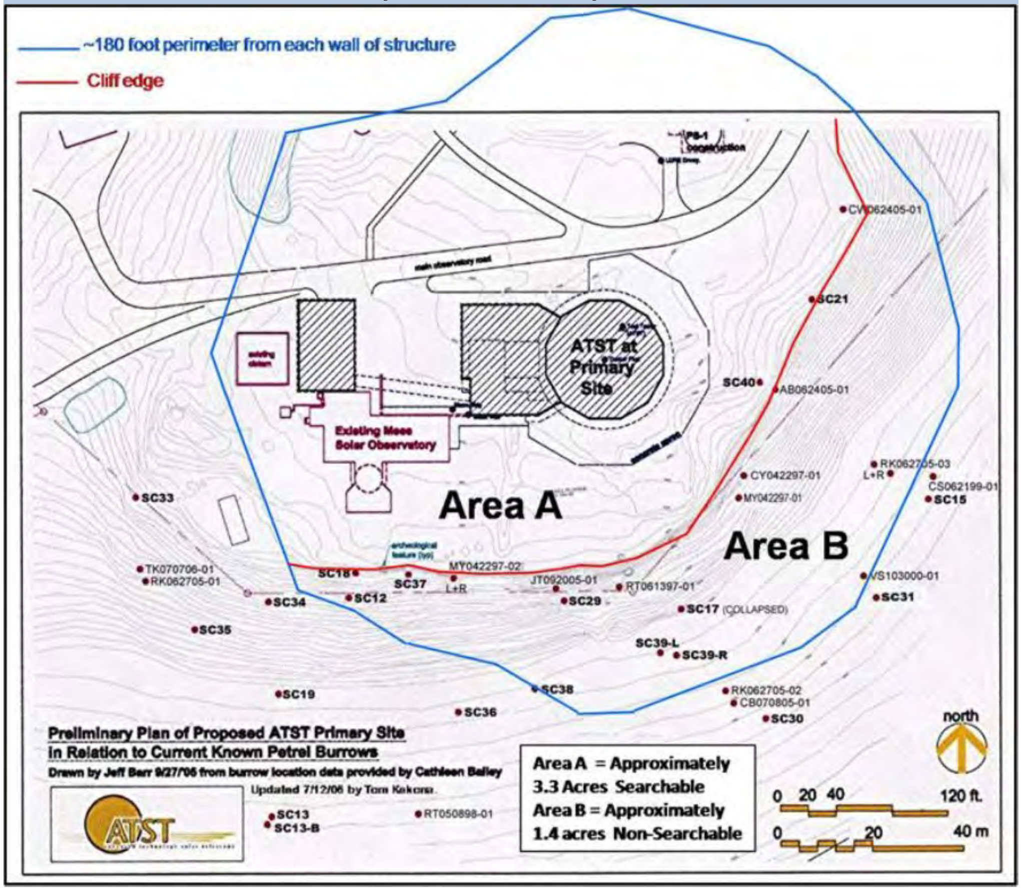
***IV E. Site Boundary, Conservation Fence Line Surveying/Marking: <u>July 2013</u>***

The DKIST Conservation Area (described in Section III above) boundary survey and marking was completed by Akamai Land Surveying Inc. on July 3, 2013 using the approved DKIST HCP area maps, the Hawai'i Government published GIS TMK map, and existing metes and bounds as guidance. Based on the survey, the Conservation Area covers an area of 130.22 ha (321.79 ac, Figures 1 & 3). To ensure the proposed fence was within the DKIST Conservation Area boundary and to avoid disturbance of any known Hawaiian Petrel burrows and cultural resource sites, a second survey to mark the fence route was conducted on August 15, 2013 by a team including personnel from the Rock N H Fencing company, an archeologist from the International Archaeological Research Institute Inc., and the DKIST resource management team.

***IV F. Searcher Efficiency Trials (SEEF): <u>Annually Since May 2013</u>***

In order to accurately evaluate the overall efficiency of carcass detection in the DKIST project area, SEEF trials are to be conducted annually. Trials were conducted within the birdstrike monitoring Search Area A of DKIST's approved Conservation Area, as discussed in detail in Section IV X, and shown in Figure 4 and 6.

**FIGURE 4. Demarcation of Area A and B of the DKIST Construction Site Birdstrike / Search Area. Searcher Efficiency Trials Were Only Conducted in Area A.**




In accordance with the requirements of the HCP, these trials are to be conducted by a third party contractor, and are to take place unbeknownst to the searcher(s). KCE was the Maui-based third party contractor selected to conduct the SEEF Trials on behalf of DKIST. In order to recover birds during the trials, the DKIST resource management team operated as a sub-permittee of KCE's Migratory Bird Permit (USFWS 02/27/2013) and Protected Wildlife Permit (DLNR 03/04/2013).

During the SEEF trials, Wedge Tailed Shearwater carcasses are used as surrogates for the petrels. Over the trial period, 20 carcasses are placed within the search area on random days and in random quantities, up to 3 carcasses per day. After discovery, events are reported only to KCE, with photos, bird tag numbers and coordinates included in the report and the carcasses are returned to a cooler at the site.

Of the 20 placed in 2013, 17 carcasses were found, resulting in a searcher efficiency rate of 85%. In the 2014 and 2015 trials, 18 of the 20 dropped carcasses were found, resulting in a searcher efficiency rate of 90% for the DKIST Resource Management team. (Fein and Allan 2013a, 2014a, 2015a).

***IV G. Rodent and Predator Population Monitoring: <u>Ongoing Since April 2013</u>***

While efforts to actually monitor rodent and predator presence are not required by the HCP or BO, the DKIST resource management team has implemented invasive mammal monitoring programs, in addition to the control program (discussed in section IV G), to help achieve Net Recovery Benefit through an adaptive management approach. Rodent population monitoring grids and predator/ungulate population monitoring camera traps in the DKIST Conservation Area and Control Site are part of these efforts.

Using the existing Long-Term Rodent Control Grid (discussed in Section IV G), rodent monitoring involves a 48 m grid system consisting of 20 stations in the DKIST Conservation Area, and 20 stations in the Control Site (Figure 3). These two rodent population monitoring grids are 2,030 meters apart to ensure the independence of the Control Site grid from the Long-Term Rodent Control Grid treatment. For this monitoring, each station was equipped with a T-Rex rat and a T-Rex mouse trap housed in Protecta tamper-resistant bait boxes. Peanut butter was used as bait and the traps were pre-baited one week before the traps were set. Each monitoring period consisted of 2 trap nights. The rodent population was monitored seasonally in March, June, September and December of each year. Table 2 summarizes the rodent monitoring results. The capture rate is low; at most only four rodents were caught during each season in each grid.

**Table 2. Rodents Caught in DKIST Rodent Monitoring Grids**

| 2013 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Season** | **Spring** | | **Summer** | | **Fall** | | **Winter** | |
| **Spp./location** | **Control** | **Conservation** | **Control** | **Conservation** | **Control** | **Conservation** | **Control** | **Conservation** |
| **Roof Rat** | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 |
| **Norway Rat** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Polynesian Rat** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Field Mouse** | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 |
| **Unidentifiable** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **2014** | | | | | | | | |
| **Roof Rat** | 2 | 0 | 2 | 0 | 4 | 0 | 1 | 0 |
| **Norway Rat** | 0 | 0 | 0 | 3 | 2 | 0 | 0 | 0 |
| **Polynesian Rat** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Field Mouse** | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 |
| **Unidentifiable** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| **2015** | | | | | | | | |
| **Roof Rat** | 0 | 0 | 1 | 0 | | | | |
| **Norway Rat** | 0 | 0 | 0 | 0 | | | | |
| **Polynesian Rat** | 0 | 0 | 0 | 0 | | | | |
| **Field Mouse** | 0 | 0 | 1 | 0 | | | | |
| **Unidentifiable** | 0 | 0 | 0 | 0 | | | | |
| **Remark: Control Site and Conservation Area were monitored during different times due to adverse weather in spring of 2015.** | | | | | | | | |

Ungulate/predator population monitoring data was collected with camera traps. Twenty Bushnell Trophy Cam HD camera traps, 10 at each site (Conservation Area and Control Site), were installed at random locations generated by ArcGIS 10.0 on 04/23/2013 in the Conservation Area and on 04/24/2013 in the Control Site (Figure 3). Six additional camera traps were mounted at six selected fence posts along the fence line between 12/03/2013 and 02/11/2014 where previous goat tracks were detected. These camera traps were initially used to monitor and determine whether ungulate eradication was needed after the completion of the ungulate fence, and continue to be utilized to obtain predator population data. Table 3 summarizes the number of photos for different animal categories recorded in the camera traps.

**Table 3. Number of Pictures of Different Identifiable Animal Categories Captured by DKIST HCP Monitoring Camera Traps.**

| Site | *Year* | Goat | Bird[2] | *Rodent*[3] | *Human*[4] |
|---|---|---|---|---|---|
| **Control** | 2013[1] | 476 | 3 | *0* | *1* |
| | 2014 | 938 | 39 | *6* | *0* |
| | 2015 | n/a | n/a | n/a | n/a |
| **Conservation** | 2013[1] | 61 | 11 | *0* | *6* |
| | 2014 | 0 | 29 | *1* | *29* |
| | 2015[5] | n/a | n/a | n/a | n/a |

**1: initiated in April**
**2: mostly Chukars (*Alectoris chukar*), few Kolea: Pacific Golden Plovers (*Pluvialis fulva*)**
**3: including DKIST personnel**
**4: unidentified rodent spp.**
**5: data will be updated at the end of the year.**

### *IV H. Long-term Rodent Control Grid: <u>Ongoing Since March 2013</u>*

In order to meet the minimum pesticide product Special Local Need Supplemental Label (SLN) label requirements, a 50 meter grid layout plan was initially submitted by the DKIST team. However, after consultations with USFWS, it was agreed that the project would implement a denser 48-meter bait box grid of 51 stations. The newer 48 meter grid layout plan was approved by USFWS in March 2013, and the implementation of the grid was completed April 2, 2013.

Each station is equipped with a Protecta ™ tamper-resistant rat bait box and a mouse box. Due to the ongoing DKIST construction activities, 44 of the planned 51 stations are in place at this time. Each rat bait box was deployed with eight 1-oz Ramik™ diphacinone blocks, for a total of 22 lbs. of diphacinone. The stations were checked after 1 week and then again in 2 weeks to evaluate the diphacinone take. However, the diphacinone SLN label expired on 05/30/2013. Thus, the use of diphacinone had to be discontinued, and the blocks were removed May 28, 2013. T-Rex rat and mouse snap traps baited with peanut butter have been deployed subsequently.

Resulting data from the diphacinone grid implemented from April 2, 2013 to May 28, 2013 showed only 6.6 oz. of diphacinone bait was taken. The snap traps used for the remainder of 2013 removed 18 field mice (*Mus musculus*), 10 roof rats (*Rattus rattus*) and 2 unidentifiable rats (*Rattus spp*.). In 2014, 20 field mice, 8 Norwegian Rats (Rattus norvegicus), 2 roof rats and 12 unidentifiable rats were caught prior to November 4.

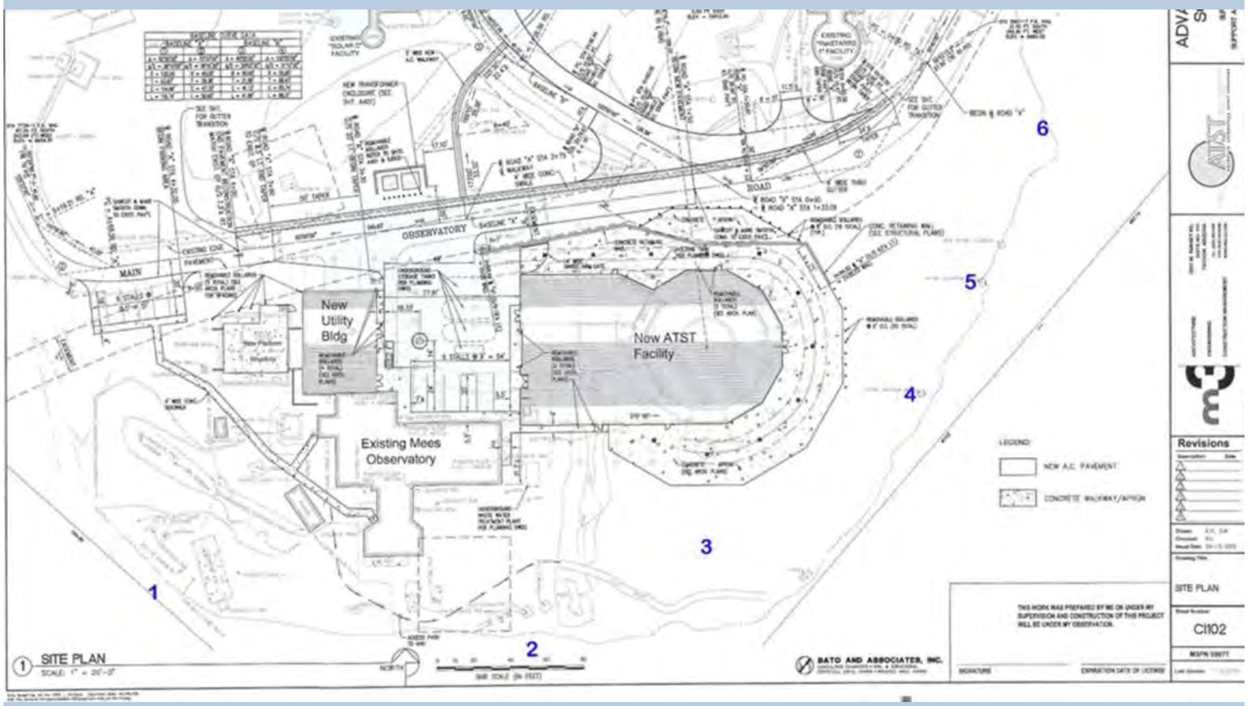
The requirements in the new SLN label published in December 2013 prohibited future diphacinone use in the Conservation Area due to boundary issues, because the label calls for the grid to be extended 225 meters past the resource to be protected, which would cross the neighboring boundaries of Haleakalā National Park, the U. S. Air Force, and Department of Hawaiian Homelands. The DKIST resource management team worked closely with USFWS and DOFAW to develop a new long-term rodent control grid methodology that is not regulated by an SLN label.

A total of 47 Protecta ™ tamper-resistant rat bait boxes were placed every 30 ft. along the perimeter of all permanent structures and trailers (office, storage) within HO, except the US Air Force compound and areas affected by construction activities. For 40 ft trailers/containers, two boxes were placed, each at diagonal corners, and for 20 ft or less trailers/containers, one box was placed. Because diphacinone is not regulated by an SLN label for use next to buildings, each rat bait box was deployed with six 1-oz Ramik™ diphacinone blocks, for a total of 17.6 lbs. We began installing the boxes on 04/30 and completed the installation on 05/07. More boxes will be installed once the DKIST external construction activities are completed to further reduce the risk of rodents due to construction activities. Outside of the construction area, we began installing a 75 meter A-24 rodent killing trap grid on 05/12 and completed the grid on 05/18. A total of 35 A-24 traps were installed. A 25 meter A-24 trap system will be installed around HO buildings once the DKIST external construction activities are completed (Figure 3).

***IV I. Noise and Vibration Monitoring: <u>Ongoing Since December 2012</u>***

Hawaiian Petrel burrows nearest to construction are monitored for vibration and noise to ensure the agreed upon thresholds documented in the HCP and BO are not exceeded during construction activities. Noise and vibration monitoring of the construction site is conducted by a third party, KCE, and has been underway since December 3, 2012, the first day of construction.

**Figure 5. DKIST HCP Locations of Seismographs**




To measure vibration, measuring stations are equipped with seismometers; depending on the location of the vibration source, one or more of six measuring stations are used to monitor ground disturbance. Two seismometers have been consistently deployed at the two burrows nearest to construction (station 4 and 6 on Figure 5). As required by the HCP, noise producing activity is also monitored at the closest burrow to the construction footprint (SC-40 at map station 4, Figure 5); both at the burrow entrance, and at a distance of 5 meters from the burrow. The data from ongoing vibration monitoring shows that as of the writing of this report no construction activity has resulted in vibration meeting or exceeding the threshold of 0.12 in/sec.

Most often, noise has not been above ambient wind levels at the burrow entrances, which can range up to 70+ dBA. KCE reported that noise levels at the burrow entrance have averaged about 56 dBA during construction, and actually decreased by about 10 dBA 5 meters closer to the source of construction. KCE explained that this decrease in noise closer to the construction can be attributed to the location of the burrow entrance being at the edge of a cliff, and often the strong trade winds at those locations induce more noise than the construction activities.

***IV J. Predator Control: Ongoing Since September 2012***

In 2012, after examining footage from surveillance cameras, the presence of a feral cat below the Mees Observatory was discovered. Camera footage revealed that the feral cat had visited five different burrows and entered at least one. A Havahart trap was set near burrow SC37 on September 13, 2012 just below the Mees Observatory. Friskies brand cat food was used as bait. The trap was labeled (CT001) along with the GPS coordinates of the trap location. The cat was captured and removed from the site.

After consulting with USFWS, a 125-meter Predator control grid system was installed consisting of 18 Havahart traps (for cats) and 19 A-24 automatic traps (New Zealand Goodnature Company, for mongoose) that cover the northern part (the lower portion with higher risk of predation) of the Conservation Area. This grid is not as uniform as it appears in plan -- in the actual on-ground layout of the grid; traps were not placed within 50 meters of any known petrel burrow to avoid attracting predators into petrel colonies. Each Havahart trap was equipped with a Telonics TBT-600NH or 503-1 trapsite transmitter to allow the traps to be monitored at least every other day to avoid petrel by-catch and to ensure the welfare of the trapped animals. The installation of the northern trap grid was completed on 09/16/2013, and was operational until 11/18/2013, when all known petrels left the Conservation Area.

In order to improve the predator control efficiency, USFWS predator control experts recommended that the project employ a more unified predator control grid system. Based on this recommendation, the DKIST resource management team installed 22 additional cat traps and 23 new mongoose traps, and relocated the traps in the northern half in 2014. The new grid of 40 cat traps and 42 A-24 mongoose traps was completed on June 19, 2014 (Figure 3).

Peanut butter was used as bait in the A24 mongoose traps at first. Using this bait, the A-24 traps killed three roof rats but no mongoose. In an attempt to better lure mongoose, a change to utilize predator-specific bait was initiated on July 24, 2014, starting with cod liver oil and then changing monthly to include salmon oil, synthetic cat nip oil, and then moving to meat-based “Violator 7” and “Feline fix” products. However, after moving from the peanut butter bait, no additional predators were caught in these traps.

The predator control traps are baited for use during the first week of February of each year and decommissioned when the last known petrel departs from the colony in late October to mid-November each year until the next petrel season begins.

In 2014, the Havahart traps caught two roof rats and no cats. As of the writing of this report nothing has been caught in the grid since February 2015.

***IV K. Control Site Selection and Setup: <u>September 2011</u>***

As discussed in Section III, in order to fulfill the monitoring obligations of the HCP, a Control Site was selected in 2011 based on GIS research and the DKIST resource management teams' ground search data in the Haleakalā summit area (Figure 1). A DLNR Permit for Access was issued on 05/31/2012 in order to conduct monitoring activities in this area.

***IV L. Hawaiian Petrel Burrow/Reproductive Success Monitoring: <u>Since June 2011</u>***

Hawaiian Petrel burrow/reproductive success monitoring has been conducted annually since the 2011 breeding season by DKIST's resource management team, in both the Conservation Area and Control Site (Figure 1).

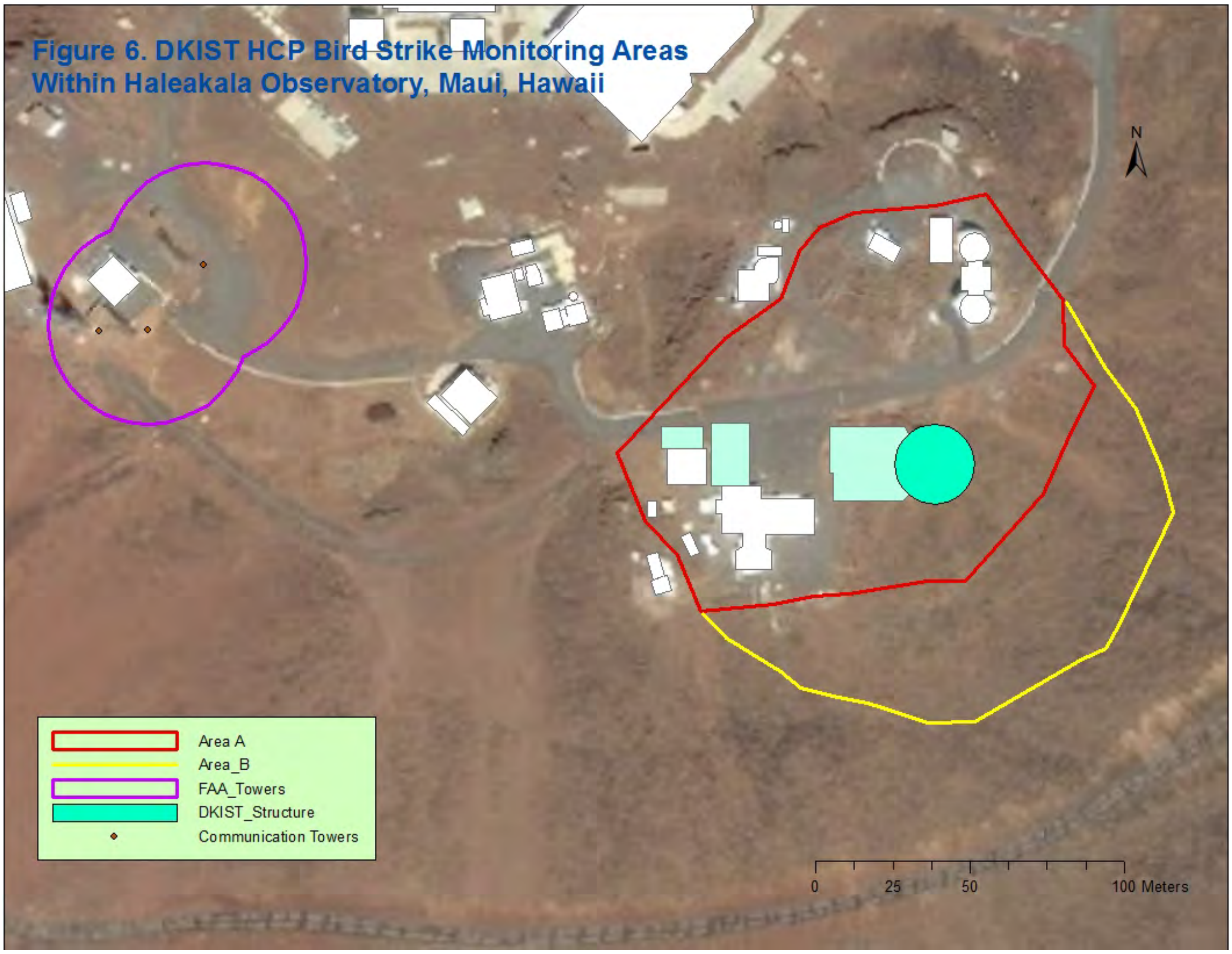
Due to the acute angle shapes of petrel burrows and the volcanic rock, utilizing a burrow scope of current design in the Haleakalā summit area has not been feasible to- date. Therefore, data on the number of petrel pairs that laid eggs is not available, and for the purpose of this report, "fledgling success" is being used as a measurement of reproductive success in this area. This issue was discussed with USFWS and DOFAW on 02/25/2014 and 09/25/2014. As a result, DOFAW (10/20/2014) and USFWS (10/30/2014) issued a letter confirming acceptance of this adaptive management approach.

***IV M. Birdstrike Monitoring: <u>Ongoing Since June 2011</u>***

Birdstrike monitoring was conducted between February 1 and November 30 in 2012 and 2013. In 2011, monitoring took place from June 7 to November 30. In 2014, the monitoring period ended on October 31, as required by the HCP and BO. We started the monitoring period on February 1 this year and anticipate ending the monitoring on October 31 as in the 2014 season.

In 2011 and 2012, prior to the start of construction of the DKIST, only the two FAA communication towers were monitored. An area equal to a 75-ft. radius of the FAA towers (Figure 6) was delineated, and this radius is 1.25 the height of the two FAA towers (60 ft.). The site was monitored every morning, seven days a week from June 7, 2011 to the second week of March 2014. During the remainder of 2014, the team reduced the monitoring schedule to reflect the HCP required frequency of twice a week (primarily Mondays and Thursdays).

In 2013, search areas A and B were added (Figure 6). The perimeter boundary of Area A and B is approximately 1.25 x the height of the DKIST observatory (136 ft.) extending from the perimeter of the DKIST observatory site. DKIST resource management team members conducted birdstrike monitoring within these two sites. Due to the cultural sensitivity in the summit area, no additional transect marking is appropriate; therefore, the resource management team uses only existing landmarks to mark search routes and systematically search these two sites. During the search, the team systematically searched Area A twice and scanned Area B once. When conducting the second search, the crew swaps their positions in the formation to increase the probability of detecting downed birds.




- Area A (3.3 ac (1.3 ha)): Lies on the more level area of Kolekole cinder cone and includes other observatories. This area includes roads, pathways, and roofs of buildings, plus open rocky habitat with little obstruction for detecting bird carcasses. No restriction within this search area exists, and all monitoring of Area A is done by systematic foot search.
- Area B (1.4 ac (0.6 ha)): Lies on the steep slopes south and east below the relatively flat area of Area A in an existing Hawaiian Petrel habitat. As instructed in the HCP, monitoring of Area B is conducted via use of binoculars to scan through the areas, since frequent monitoring by foot search is discouraged. Foot traffic could degrade breeding habitat in that area. Searchers are able to access the edge of the cliff at the demarcation between Area A and Area B for visual scanning (binocular-assisted) of Area B. However, because Area B includes rocks and boulders of various sizes that would obstruct simple observation of bird carcasses, it cannot be covered adequately enough to accurately count downed birds. Visual scanning, however, is useful in detecting and recovering any downed birds in the open, so that they do not become a predator attraction.

In 2014, monitoring of the conservation fence (Figure 1) was completed twice a week until July 5. On July 6, 2014, USFWS notified the DKIST resource management team that such monitoring could be reduced to once every other week. An adaptive management amendment to the BO to confirm the change was issued on July 29, 2014. On September 23, 2014 the monitoring schedule was again amended to once each month from February to October, because the extended two-month CARE trial identified no predation. The USFWS was satisfied that fence monitoring once each month is adequate to recover any downed birds.

Results show no collision events were detected in 2011 (154 person-days), 2012 (304 person-days), 2013 (304 person-days), 2014 (304 person-days) or 2015 (150 person-days, 02/01-06/30) at the DKIST construction site (Area A), the FAA/Coast Guard towers, or along the conservation fence.

If any collisions occur, the protocol requires recording the following information: date, time, location coordinates, species, photo of the bird in question, and person attending. This information would be included in a report that would be forwarded to the USFWS, Pacific Islands Fish and Wildlife Office, USFWS Office of Law Enforcement, and DOFAW. In accordance with the protocol, the downed birds or carcasses would be handled according to the official State of Hawai'i Downed Wildlife and the USGS Wildlife Health Center, Honolulu office protocols, and if still alive, injured individuals would be delivered to appropriate local Maui veterinarians. DKIST would fund any acute care and the transport of the bird, if necessary, to a permitted wildlife rehabilitation center (currently located on O'ahu and the island of Hawai'i).

***IV N. Resource Biologist/Team: <u>June 2011-Present</u>***

DKIST Resource Biologist, Huisheng Chen, was hired on June 1, 2011. The resource management team was formed on August 8, 2011, which included the hiring of three seasonal technicians.

## V. HAWAIIAN PETREL REPRODUCTIVE SUCCESS MONITORING: <u>METHODS</u>

***V A. Personnel Training***

All current members of the DKIST Resource Management Team received extensive training in 2011. This training included both field and administrative training. Members were trained on petrel carcass search and handling, petrel burrow identification, classification of burrow status based on signs of petrel activity, and avoidance of cultural resources during field work. In addition, the Predator Control Technician is certified for Commercial Applicators of Restricted Pesticides and each member was trained in handling rodenticide and rodent carcasses. Two of the team members were either State of Hawai'i Hunter Education certified or National Rifle Association (NRA) firearm certified. All members were previously trained in the use of GPS and ArcGIS software and all completed First Aid/First Responder and CPR certifications.

***V B. Petrel Burrow Search***

The DKIST Resource Management Team began monitoring known burrows and searching for new burrows in the HCP Conservation Area and Control site on August 10, 2011, February 22, 2012, May 7, 2013, and May 7, 2014. Monitoring ends each season after the petrel chick from the last known burrow fledges, which was November 16, 2011, November 10, 2012, October 24, 2013, and November 11, 2014.

The team begins annual monitoring by visiting all the burrows that were recorded from previous breeding seasons. Any newly identified burrows are documented as they are discovered and a systematic search of the DKIST Conservation Area and Control Site is also conducted. Newly identified burrows can either be a previously undiscovered burrow, or a newly excavated burrow. The DKIST Resource Management Team utilizes recorded information provided by the Park regarding established burrows that were confirmed prior to 2011. In order to avoid mislabeling some of the thousands of rock crevices within the Conservation Area as new burrows, a structural feature isn't officially documented as a 'burrow' until its use is established by some evidence of Petrel activity. When DKIST began monitoring in 2011, the same burrow identification system was continued from earlier, Park convention. That is, coordinates of the newly identified burrows are recorded with handheld Garmin Oregon 450 and 550 GPS units. Signs of petrel activity (feathers, droppings, egg shells, footprints, regurgitation, odor and other body parts) and GPS coordinates at each burrow are recorded. Toothpicks are placed vertically along the entrance of each burrow to monitor petrel movement in and out of burrows; fallen or height-altered toothpicks suggest current activity, while undisturbed toothpicks denote no activity (Hodges 1994, Hodges & Nagata 2001).

### *V C. Principles of Reproductive Success Monitoring*

Breeding success was classified based initially on signs at the entrance, status of placed toothpicks, and the latest date of activity. Burrows that were classified as "Active" were then re-checked weekly until signs of success or non-productivity were observed. Using the same methodology as employed by the Haleakalā National Park (Hodges 1994, Hodges & Nagata 2001), a burrow was defined to be "successful" by the presence of petrel chick down feathers at the burrow entrance, and disturbed toothpicks after mid -September of each year. Burrows classified as "non-productive" showed signs of activity during initial search, but no further signs were found while conducting the subsequent re-checks, suggesting that these burrows were either occupied by non-breeders, the nest was abandoned, or the chicks did not reach fledgling age.

### *V D. Camera Monitoring of Reproductive Success*

To supplement means of monitoring reproductive success, cable surveillance video cameras were installed and monitored every year since 2006 by KCE at burrows adjacent to the Mees Observatory, from February until all petrels left the monitored burrows.

In addition, the DKIST resource management team installed 16 Bushnell "Trophy Cam HD™" camera traps between 10/15/13 and 11/07/13 at 16 active burrows outside of the cable accessible area (all in the Conservation Area), and 39 camera traps were installed between 09/10/14 and 11/11/14, at active burrows outside of the cable accessible area; 38 in the Conservation Area and one in the Control Site.

## VI. HAWAIIAN PETREL REPRODUCTIVE SUCCESS MONITORING: RESULTS AND DISCUSSION

The 2015 Hawaiian Petrel breeding season is still ongoing, therefore the data is inconclusive as of the writing of this report. The data presented in this report is from the 2011-2014 field seasons.

***VI A. Number of Petrel Burrows*:**

Note that the number of burrows reported in this report is different from reports from previous years due to the following adjustments:

Because DKIST's Conservation Area boundary was redefined based on the certified surveyors' marking in 2013, the data from the following is no longer being included in this or future data analysis: Five non-productive burrows, one possible successful burrow, and four not active burrows that were found in 2011; one non-productive burrow and thirteen not active burrows found in 2012. In addition, two burrows monitored since 2011 in the Conservation Area were discovered to actually be secondary entrances of two other burrows in 2014, and these burrows were removed from the past and future dataset.

Table 4 summarizes the adjusted number of Hawaiian Petrel burrows recorded within DKIST monitoring areas in the past four seasons. As new burrows were located each year, the number of burrows monitored increased from 229 in 2011 to 324 in 2014.

**Table 4. Hawaiian Petrel Burrows Found* in the DKIST HCP Conservation Area and Control Site on Haleakalā, Maui, Hawaii.**

| Year | 2011 | | 2012 | | 2013 | | 2014 | | 2015 | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Area/Status** | **New** | **Old** | **New** | **Old** | **New** | **Old** | **New** | **Old** | **New** | **Old** |
| **Conservation Area** | 117 | 91 | 22 | 259 | 6 | 281 | 8 | 287 | n/a | n/a |
| **Control Site** | 21 | 0** | 4 | 21 | 1 | 25 | 3 | 26 | n/a | n/a |
| **Total** | 229 | | 306 | | 313 | | 324 | | n/a | |

***Due to the newly marked boundary, the numbers of burrows included in our monitoring results varied annually before the conservation fence was built in 2013. In addition, two Conservation Area burrows were found to be the entrances of two other burrows in 2014. The data shown are adjusted status.**
****New site that year.**

***VI B. Burrow Status***

Based on monitoring data, Hawaiian Petrel burrows were classified as "Active", "Not Active" and "Not A Burrow" (collapsed burrow). In the analysis, only burrows that were either "Active" or "Not Active" and were inside the boundary were included.

**Table 5. Hawaiian Petrel Burrows and Reproductive Success in DKIST HCP Conservation Area and Control Site on Haleakalā, Maui, Hawaii.**

| Year | $2011^{s}$ | | $2012^{s}$ | | 2013 | | $2014^{s}$ | |
|---|---|---|---|---|---|---|---|---|
| **Status/Site** | **Conservation** | **Control** | **Conservation** | **Control** | **Conservation** | **Control** | **Conservation** | **Control** |
| **Active** | 162 | 13 | 153 | 9 | 126 | 8 | 165 | 10 |
| **Successful** | 33 | 0 | 16 | 0 | 27 | 0 | 44 | 1 |
| **Non Productive** | 129 | 13 | 137 | 9 | 99 | 8 | 121 | 9 |
| **Not Active** | 36 | 8 | 114 | 16 | 155 | 18 | 128 | 19 |
| **TOTAL** | 198 | 21 | 267 | 25 | 281 | 26 | 293* | 29 |
| **Nesting Activity %** | 82 | 62 | 57 | 36 | 45 | 31 | 56 | 34 |
| **Nesting Success %** | 20.24 | 0 | 10.39 | 0 | 21.43 | 0 | 26.67 | 10 |

*2 old burrows marked as "not a burrow" were not included in this table, $^{S}$: Nesting Activity % $\chi^2$ test P<0.05

Based on the experiences from the last four seasons, the DKIST resource management team is confident that the burrows reported in 2011 and 2013 as possibly successful were actually successful. Table 5 summarizes the adjusted status of burrows found between 2011 and 2014, along with success/non-productive statistics. The significant increase in Nesting Success in the Conservation Area in 2014 is discussed beginning on page 25.

Based on recent genetic and isotope studies (Judge 2011, Welch et. al. 2012, Wiley et al. 2013), the DKIST resource management team assumes that all Hawaiian Petrel colonies on the summit of Haleakalā, Maui form a meta-population. We speculate that petrels from these colonies forage in the same foraging area, and experience the same survival conditions and challenges during the same year. Intra-year comparisons between the Conservation Area and Control Site are examined and presented in order to reduce the uncontrollable effects of inter-year environmental variances; e.g. prey population fluctuation due to yearly climate, pollution, fishery pressure, prey accessibility due to debris, and declined predatory fish population to Hawaiian Petrel reproductive performance, adult/chick survival rate, and young recruitment.

In order to evaluate whether the DKIST conservation fence and predator/rodent control grids have promoted recovery for the Hawaiian Petrel in the Conservation Area, trends of active burrow numbers and successful burrow numbers between the Conservation Area and Control Site were compared. Although the number of successful burrows and fledgling success rate fluctuated in the Conservation Area and remained at zero in the Control Site until the completion of the conservation fence and predator/rodent control grids during the first three seasons, the number of active burrows steadily declined in both the Conservation Area (by 22%) and Control Site (by 38%). The overall decline of 23% is somewhat troubling, in that almost one quarter of the potential breeders did not return to the colonies during this period of time. However, it is important to note that these declines were in both the Conservation Area and Control Sites.

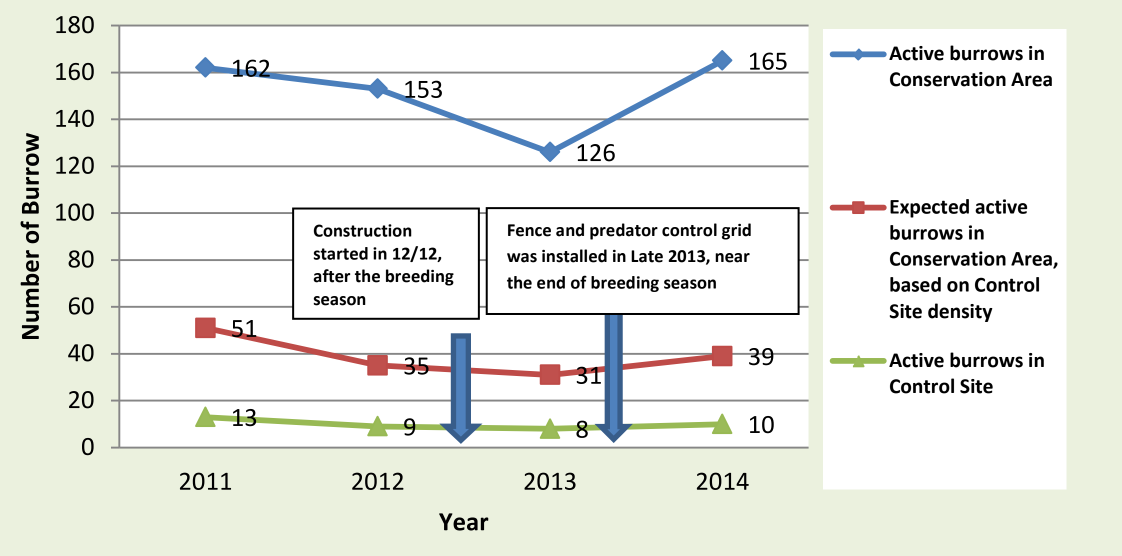
The 2014 data showed the first signs of a rebound in the Conservation Area, with a 31% increase from 126 active burrows in 2013 to 165 active burrows in 2014, and in the Control Site, with a 25% increase from 8 in 2013 to 10 in 2014 (Table 5 and Figure 7). Chi-square tests of independence were employed to identify whether the inter-year trends of change in the Control Site and Conservation Area were significantly different. As the results in Table 6 show, the fluctuation trends of active burrow numbers in the Control Site and Conservation Area did not show significant differences ($0.009<\chi^2<0.484$, df=1, $0.92>p>0.49$, Table 6); however, the active burrow number of 165 in 2014 was the highest active burrow number recorded since the start of monitoring in 2011.

**Table 6. $\chi^2$ test Results of Inter-Year Trends of Active Hawaiian Petrel Burrow Change between DKIST HCP Control Site and Conservation Area on the Summit of Haleakalā, Maui.**

| | 2011-2012 | 2012-2013 | 2013-2014 |
|---|---|---|---|
| $\chi^2$ | 0.484 | 0.023 | 0.009 |
| Degree of Freedom | 1 | 1 | 1 |
| p value | 0.49 | 0.79 | 0.92 |

The density of active petrel burrows recorded from 2011 to 2014 in the Control Site (80 ac) were used to predict the number of active petrel burrows in the Conservation Area (312.66 ac). It was found that more active petrel burrows (3- 4 X more) were recorded in the Conservation Area than were expected from 2011 to 2014, even in the years prior to the installation of the conservation fence and predator/rodent grids (Figure 7).

**Figure 7. Active Hawaiian Petrel Burrow Number Recored in DKIST HCP Monitored Area on the Summit of Haleakala, Maui from 2011 to 2014.**




Since the Control Site and part of the DKIST Conservation Area are in the same elevation contour zone in an area between 8,800 and 9,300 ft (Figure 8), data subsets for burrows between these two elevations were extracted and compared for both the Control Site and Conservation Area, to obtain a more objective comparison of the effects of altitude on the activity status of burrows with and without mitigation measures in place. The area between these two contour lines in the Control Site is 73.6 ac, while the Conservation Area was 67.4 ac. The numbers of active burrows recorded in these two areas are shown in Table 7. Chi-square tests of independence were conducted to compare intra-year trends of active burrow number change in the Control Site and Conservation Area. The result showed that the trends of inter-year change were not significantly different ($0.597>\chi2>0.008$, df=1, $0.93<p<0.44$, Table 8) in the same contour zone in the Control Site and Conservation Area from 2011 to 2014.

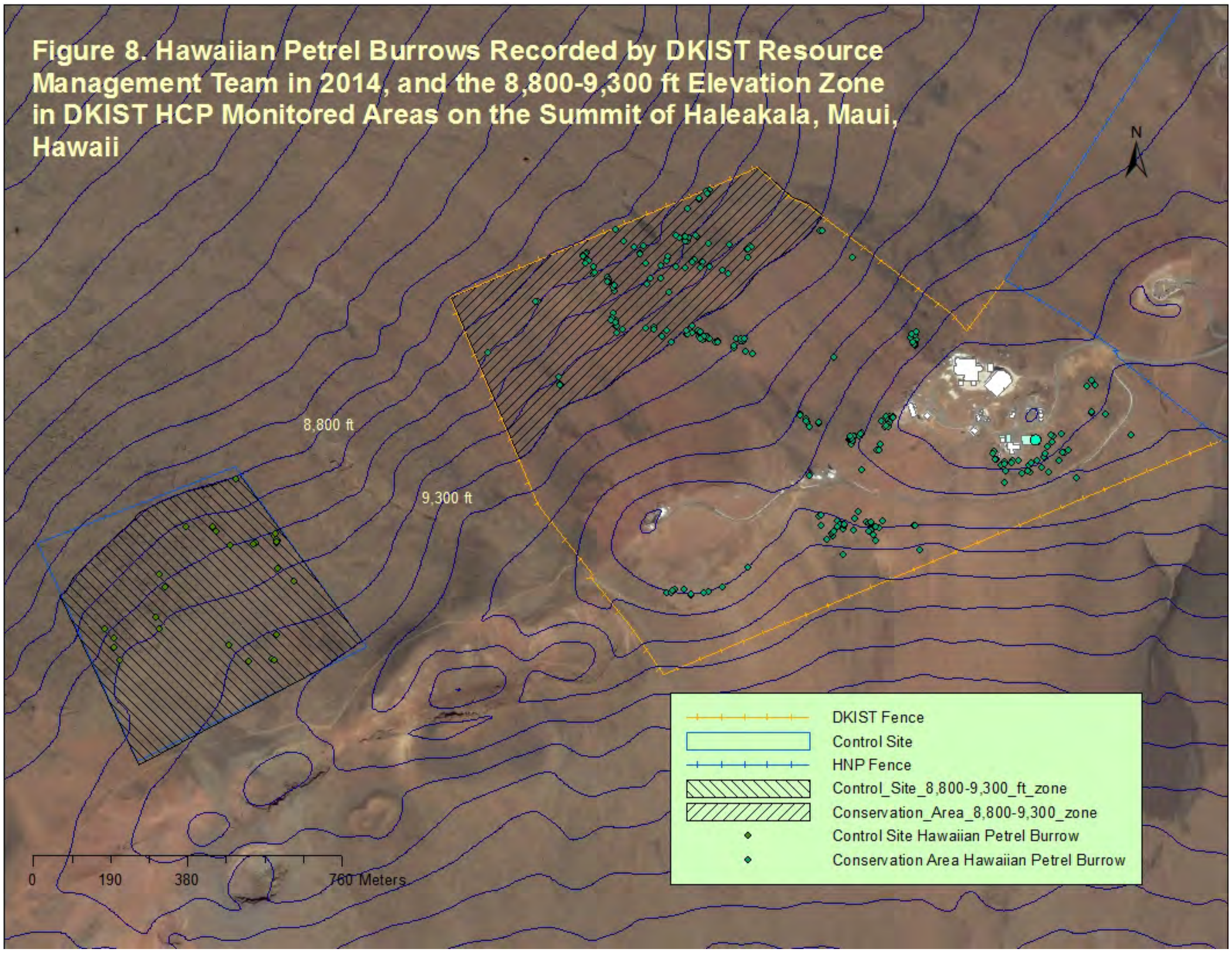


Figure 8. Hawaiian Petrel Burrows Recorded by DKIST Resource Management Team in 2014, and the 8,800-9,300 ft Elevation Zone in DKIST HCP Monitored Areas on the Summit of Haleakala, Maui, Hawaii

**Table 7. Active and Successful Hawaiian Petrel Burrows Recorded Between 8,800 And 9,300 FT. Elevation in DKIST HCP Monitored Areas on the Summit of Haleakalā, Maui From 2011 to 2014.**

| Year | 2011 | | 2012 | | 2013* | | 2014 | |
|---|---|---|---|---|---|---|---|---|
| Sites | Control | Conservation | Control | Conservation | Control | Conservation | Control | Conservation |
| # Active Burrows | 13 | 50 | 9 | 50 | 8 | 39 | 10 | 51 |
| # Successful Burrows | 0 | 3 | 0 | 0 | 0 | 8 | 1 | 20 |

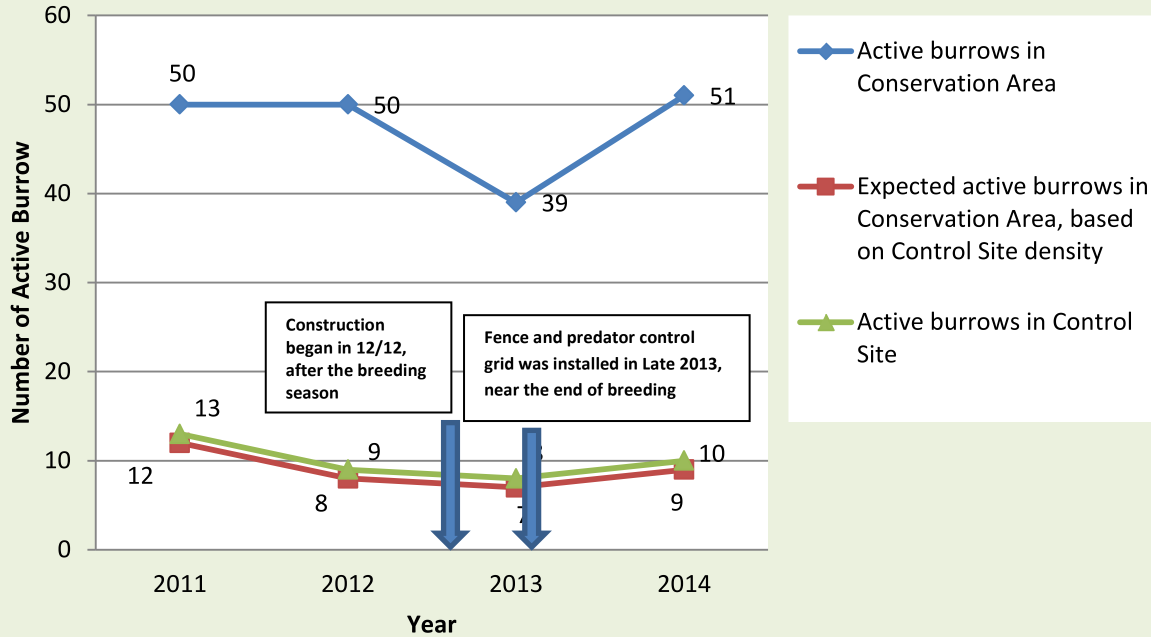
*conservation fence and predator control grid installation started during the latter part of this year.
Remark: Control Site = 73.6 ac, Conservation Area = 67.4 ac.

**Table 8. $\chi^2$ test Results of Inter-Year Trends of Active Hawaiian Petrel Burrow Change between DKIST HCP Control Site and Conservation Area Between 8,800 and 9,300 ft Elevation on the Summit of Haleakalā, Maui.**

| | 2011-2012 | 2012-2013 | 2013-2014 |
|---|---|---|---|
| $\chi^2$ | 0.597 | 0.061 | 0.008 |
| Degree of Freedom | 1 | 1 | 1 |
| p value | 0.44 | 0.80 | 0.93 |

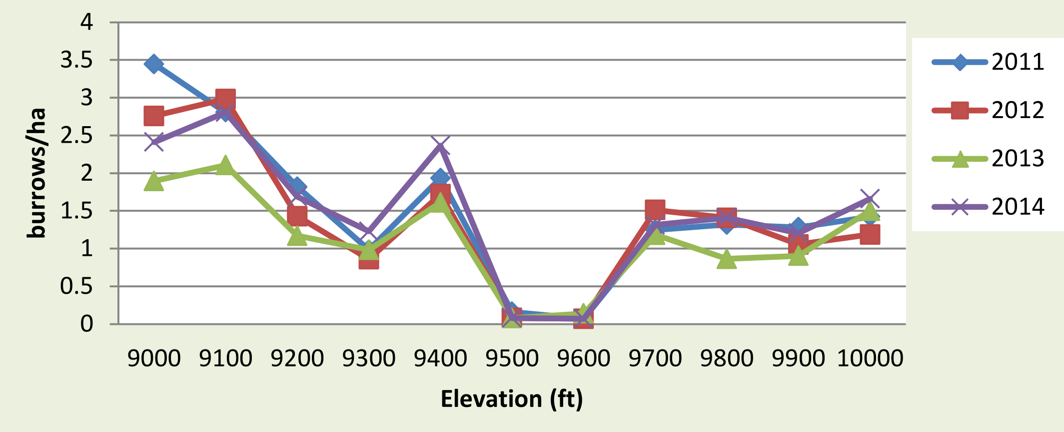
In addition to the results discussed after Table 6, the density of active petrel burrows recorded from 2011 to 2014 in the Control Site in this contour zone were used to predict the number of active petrel burrows in this contour zone of the Conservation Area, and the data shows that four to five times more active petrel burrows were also recorded in the Conservation Area than expected from 2011 to 2014, even in the years prior to the installation of the conservation fence and predator/rodent grids (Figure 9).

**Figure 9. Active Hawaiian Petrel Burrow Number Recorded in DKIST HCP Monitored Areas Between 8,800 and 9,300 ft Elevation on the Summit of Haleakala, Maui**




Upon examination of the density distribution of active petrel burrow within the Conservation Area in different years and at different elevations, almost identical density distribution patterns in different years can be observed. The biggest deviation is observed between 8,900 and 9,100 ft. of elevation near the bottom of the Conservation Area, where predators from lower elevations have been observed. An empty zone between the 9,400 and 9,600 ft. elevation levels (Figure 10) was also observed. Figure 8 also shows that petrel burrows in the HCP monitored areas are inconsistently distributed, and not evenly or randomly distributed. Further investigation of the distribution indicates that burrows are located in lava rock areas and that cinder areas are vacant of petrel burrows.

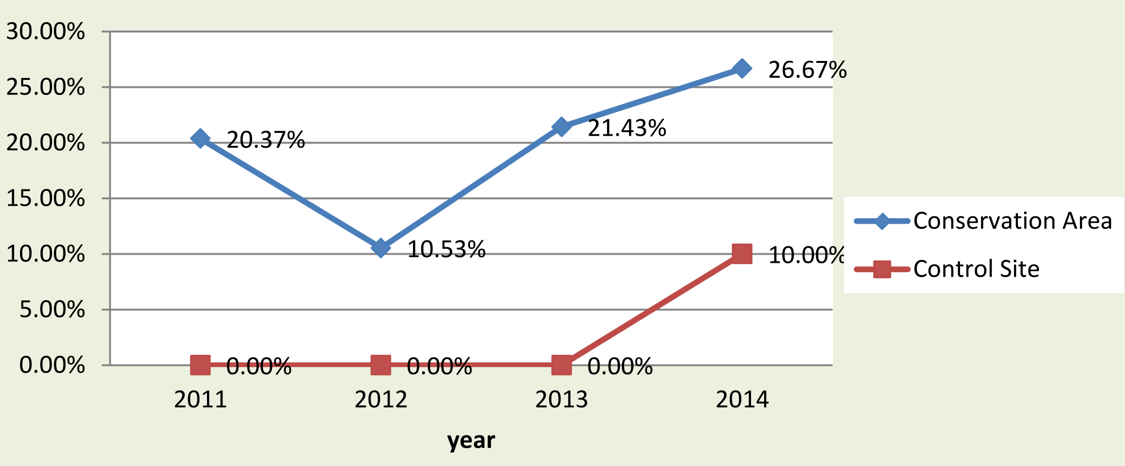
**Figure 10. Active Hawaiian Petrel Burrow Density in DKIST HCP Conservation Area in Different Elevations Recorded from 2011 to 2014 at the Summit of Haleakala, Maui.**




"Nesting Activity" (the proportion of burrows surveyed that show signs of burrow activity) and "Nesting or Fledgling Success" (the proportion of active burrows that show signs of fledging chicks, Hodges & Nagata 2001), were also compared between the Conservation Area and Control Site, as shown in Table 5. A significantly ($p<0.05$) higher percent of Nesting Activity in the Conservation Area was apparent in 2011, 2012, and 2014, compared to the Control Site (Chi Square Test).

Due to zero Nesting (Fledging) Success recorded in 2011-2013 and only one Fledging Success recorded in 2014 in the Control Site, Chi Square statistical analysis is not appropriate. The Nesting Success rate in the Conservation Area decreased from 2011 to 2012, then rebounded and surpassed the 2011 level in 2013, and even higher in 2014 (Table 5 and Figure 11).

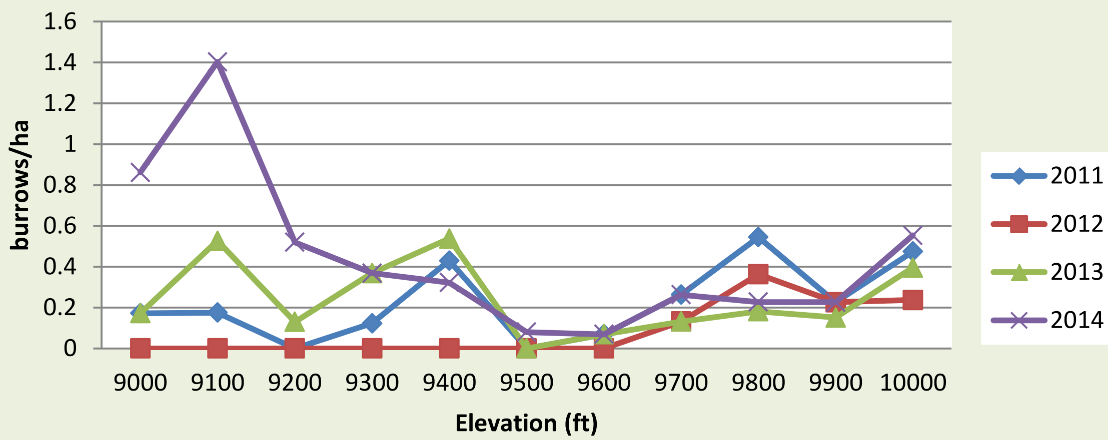
**Figure 11. Annual Hawaiian Petrel Nesting Success Rate Recorded in DKIST HCP Monitored Areas on the Summit of Haleakala, Maui.**

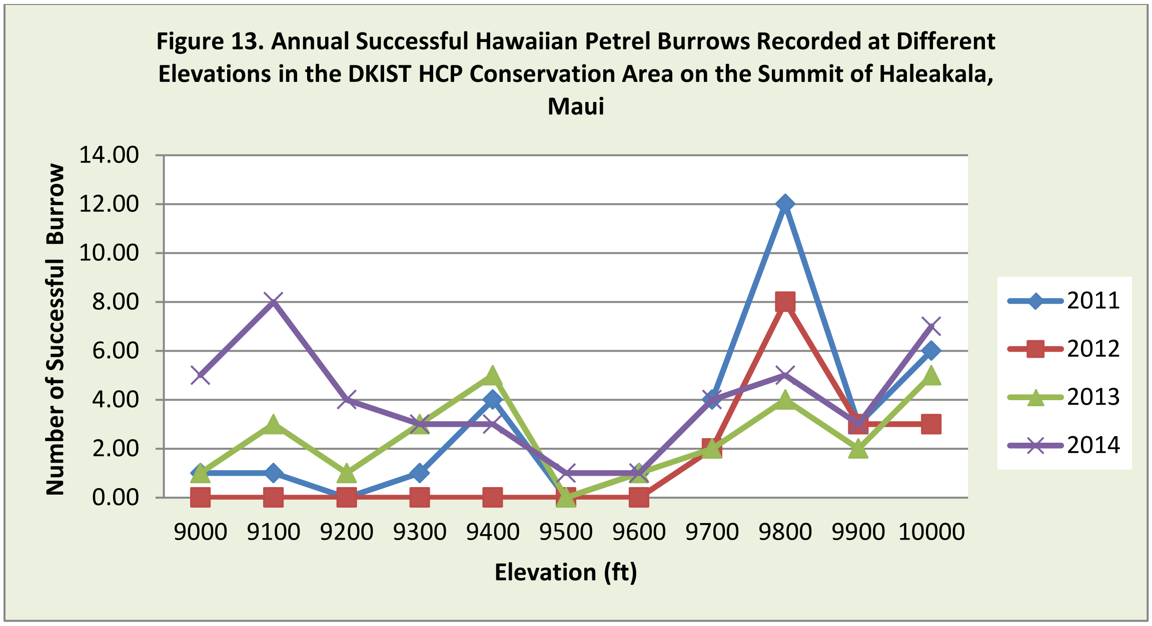


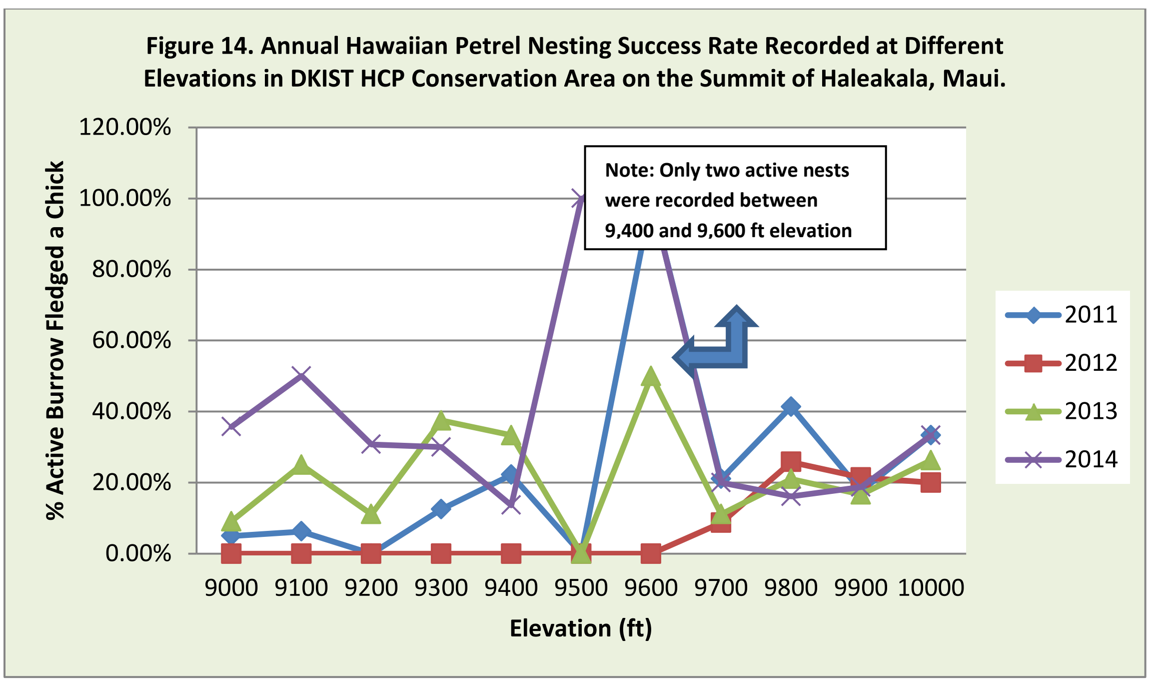
The analyses of Nesting Success density, rate and number at different elevations in the Conservation Area (Figures 12, 13, and 14) suggests that the DKIST conservation fence and predator/rodent control grids implemented in the later part of 2013, and completed in early 2014 breeding season in the Conservation Area, may have already promoted an increase of successful burrow density and numbers in 2014, from 4 to 8 times, below the 9,200 ft elevation. This is compared to 2011 and 2012 data, where high predation events were recorded in 2011 and 2012. Since the sample size is small to-date, further data yields during successive seasons will verify whether increased burrow density is a function of conservation/predator/rodent control measures implemented in 2014.

A concern is the diminution trend of successful petrel burrow numbers and density between 9,700 and 9,800 ft. of elevation, about 0.3 miles from DKIST construction. This contour zone had been key to the highest number, rate and density of successful petrel burrows in 2011, then it decreased by 2/3 in 2013, and then slightly rebounded this year (Nesting Success rate is still the lowest). It is notable that the largest number of both active burrows and successful burrows above the 9,900 ft. elevation were recorded in 2014, immediately adjacent to DKIST construction.

**Figure 12. Annual Successful Hawaiian Petrel Burrow Density Recorded at Different Elevations in the DKIST HCP Conservation Area on the summit of Haleakala, Maui.**






Of additional note is that 2014 was the first year that a burrow successfully fledged a chick in the upper-most portion of the Control Site. It was possibly due to the DOFAW re-installation of polytape on the ungulate fence enclosing the state Silversword outplanting area earlier in the year, the more frequent use of mountain bikers on Skyline trail rather than off-trail, and the intensive monitoring activities of the DKIST resource management team that reduced the predator activities adjacent to this burrow (Table 5 and Figure 11). Once again, successive years of data will shed more light on reproductive success within the Control Site.

A comparison for future development is between the DKIST Conservation Area and the HALE petrel colony. The conservation measures of predator/rodent control grids and conservation fence implemented at the end of the 2013 breeding season in the DKIST Conservation Area are similar to those at HALE (since 1979, Simons 1985). Since Hawaiian Petrel colonies on Haleakalā are thought to be influenced by the same environmental factors, the only major differences between them would likely be potential negative impacts from DKIST construction activities that began after the 2012 breeding season.

HALE biologists were still preparing their Hawaiian Petrel monitoring data when this report was written, so a comparison will await the next report.

***VI C. Hawaiian Petrel Mortality***

Table 9 summarizes all known mortality events recorded between the 2011 and 2014 breeding seasons. Invasive mammalian predators were the cause of 68.2% of all detected petrel mortality in the DKIST Conservation Area. It should be noted that Control Site predation diminished more quickly than in the Conservation Area during the period from 2011 to 2014. However, the Conservation Area is four times larger than the Control Site, and if we factor in burrow density, the predation in the Conservation Area actually diminished more than in the Control Site.

**Table 9. Known Hawaiian Petrel Mortality Events Recorded between 2011 and 2014 in DKIST HCP Conservation Area and Control Site**

| Year | 2011 | | 2012 | | 2013* | | 2014** | |
|---|---|---|---|---|---|---|---|---|
| Age/Site | Conservation | Control | Conservation | Control | Conservation | Control | Conservation | Control |
| **Other** | | | | | | | | |
| Egg | 4 | 0 | 1 | 0 | 1 | 0 | 2 | 0 |
| Chick | 2 | 0 | 0 | 0 | 2 | 0 | 1 | 0 |
| Adult | 1 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| **Predation/burrow trampling** | | | | | | | | |
| Egg | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 1 |
| Chick | 6 | 3 | 1 | 0 | 3 | 0 | 0 | 0 |
| Adult | 1 | 9 | 3 | 1 | 0 | 0 | 1 | 0 |
| TOTAL | 15 | 12 | 7 | 1 | 9 | 0 | 4 | 1 |

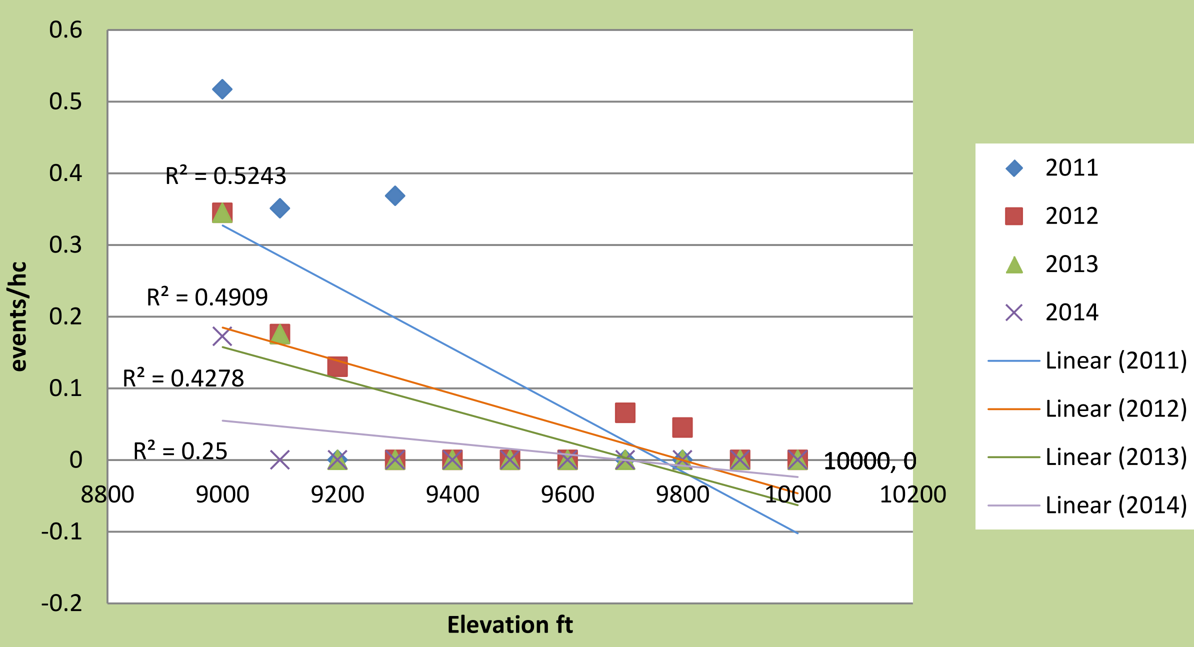
* Not including a burrow trampled by ungulates in the early stage of breeding season, and an adult and a chick mortality event that occurred prior to 2013.
** Not including one burrow collapse in each site due to an unknown cause and consequence in early stage of breeding season. The collapsed burrow in Conservation Area was 210 m from the nearest DKIST staging area and more than 400 m from construction site.

In the Conservation Area during 2014, one adult of unknown sex was killed (by an unknown predator) next to the entrance of a burrow adjacent to the north fence at the beginning of the egg-laying season. Two eggs had rolled out of the burrow in the early stage, probably a result of inexperienced adults (Cathleen Bailey/HALE). One egg rolled out and hatched outside of the burrow, and based on what was observed on the surveillance video of this burrow, the chick subsequently died without the presence of its parent. In the Control Site, one egg was predated by an unknown predator.

The smallest fraction (1/4) and number (1) of predation induced mortalities were recorded in 2014. The predation recorded does not appear to be correlated with burrow density. We can see from the active burrow locations on Figure 2 & 8 that active petrel burrows are concentrated in two areas: below 9,400 ft. and above 9,600 ft, but predation rarely occurred above 9,600 ft. (Figure 15). According to the data from 2011 to 2014, predation was more likely to occur in the lower portion of the DKIST HCP monitored area. In order to standardize the impact of predation at different elevations, predation/trampling density (events/hectare) was used as the metric in this analysis. Also found was a strong negative correlation ($R^2$>0.49) between predation/density of trampling event, and elevation in 2011 and 2012, where predation events were recorded up to 9,800 ft.

After implementing the HCP conservation measures in the later part of 2013 (the ungulate fence and northern section of the predator control grid were installed in 2013. The grid configuration was modified based on the Service's recommendations before the southern section was installed), the correlation between predation and altitude began to decline and no predation was recorded above 9,100 ft. of elevation. When installation of these measures was completed in the first part of 2014, the correlation further declined to an $R^2$ of 0.25 and no predation was recorded above 9,000 ft. (Figure 15). Due to the small sample size recorded in 2014, correlation coefficient analysis to compare trends was not useful; the number is presented to demonstrate the declining trend of predation/trampling events over the last four seasons.

**Figure 15. Density of Hawaiian Petrel Predation/Trampling Recorded at Different Elevations in the DKIST HCP Conservation Area from 2011 to 2014 on the Summit of Haleakala, Maui.**




The overall petrel mortality events recorded in the monitoring area went through a steady decline; from 27 in 2011 down to five in 2014, and predation/trampling events went from 20 in 2011 down to 2 in

2014, in both the Conservation Area and Control Site (Table 9). This may coincide with the departure of feral goats from the Conservation Area that occurred during the building of the fence in the Conservation Area--possibly just the construction, intensive monitoring, and predator control activities were sufficient enough to reduce predator presence and predation of Hawaiian Petrels in both the Conservation Area and Control Site. The smell of coyote (*Canis latrans*, a natural predator of feral cats) glands in the commercial predator bait “Violator 7” used in the predator control traps may also have intimidated the cats and mongoose in the Conservation Area.

This result suggests:

**1.** a reduced predation event density nearest to the DKIST construction site before and after construction started. Concentrated human activity during the day at the summit area may have reduced predator activities or predation frequency.

**2.** although not statistically significant due to a small sample size, a trend of reduced predation/trampling was detected in both the Conservation Area and Control Site.

**3.** the implementation of the DKIST HCP conservation fence and predator control grid has greatly reduced the number of predation and trampling events in the predator impacted lower portion of the Conservation Area, even though no feral cats or mongooses were trapped.

Further, in order to understand whether DKIST construction activities resulted in the decline of active Hawaiian Petrel burrow numbers, the trend of active burrow numbers adjacent to the DKIST construction site was examined (Figure 16). The number of active petrel burrows actually increased in this area, even in years when the overall number of active petrel burrows was declining (2011-2013). The DKIST construction appears to attract petrels to breed in this area, and while it is too soon to definitively correlate construction activity with the number of active burrows, it may turn out that exterior construction activities have some as yet not understood benefit on petrel reproductive performance. (Figure 17).

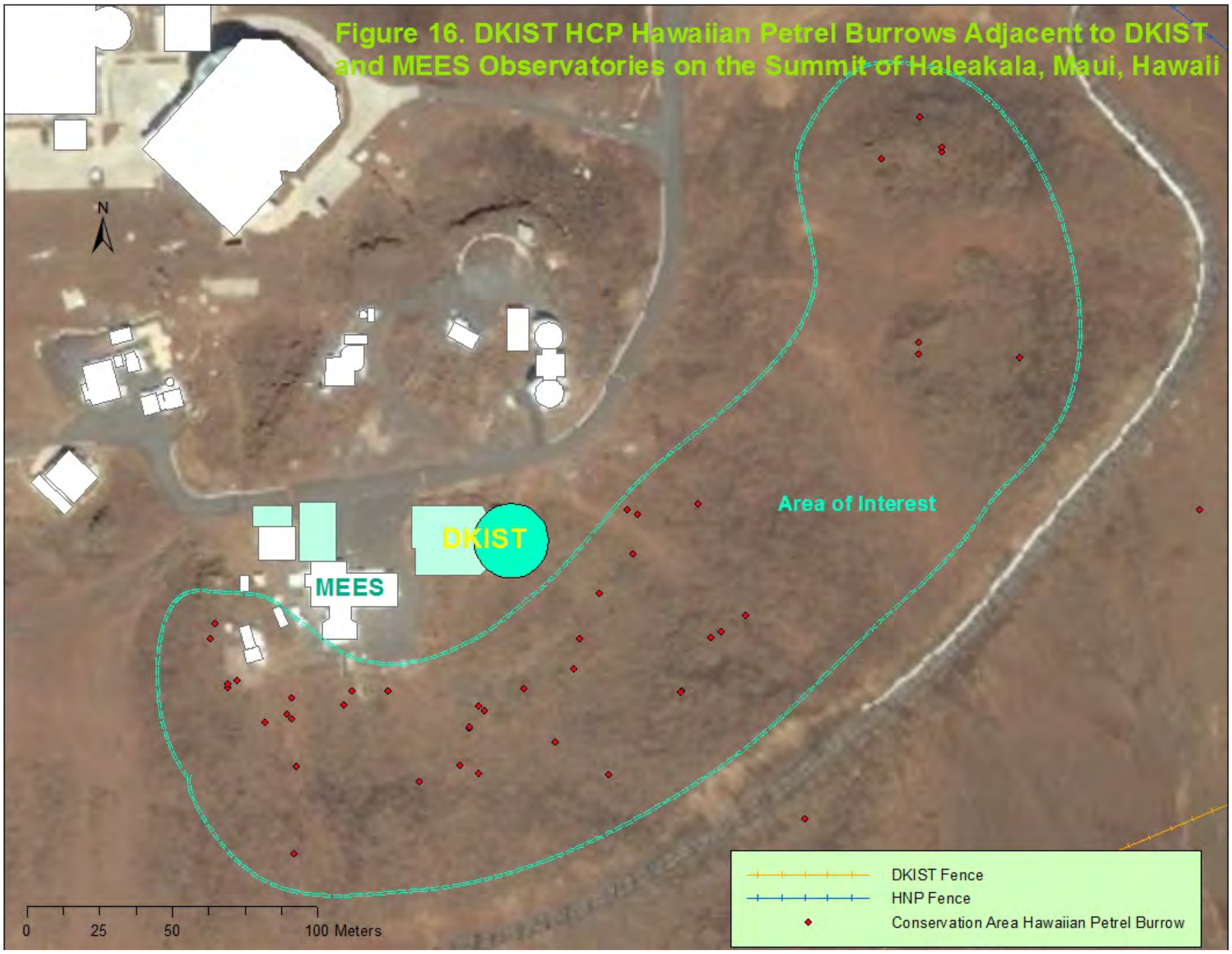
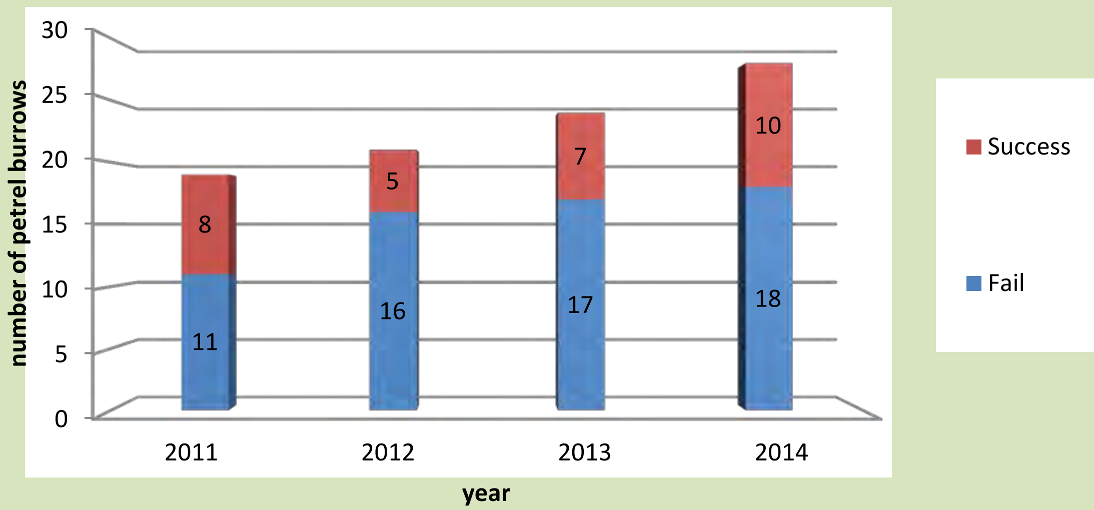


Figure 16. DKIST HCP Hawaiian Petrel Burrows Adjacent to DKIST and MEES Observatories on the Summit of Haleakala, Maui, Hawaii
N
Area of Interest
DKIST
MEES
0 25 50 100 Meters
DKIST Fence
HNP Fence
Conservation Area Hawaiian Petrel Burrow

**Figure 17. Number of Active Hawaiian Petrel Burrows Adjacent to DKIST Construction Site, Near the Summit of Haleakala, Maui in 2011-2014**

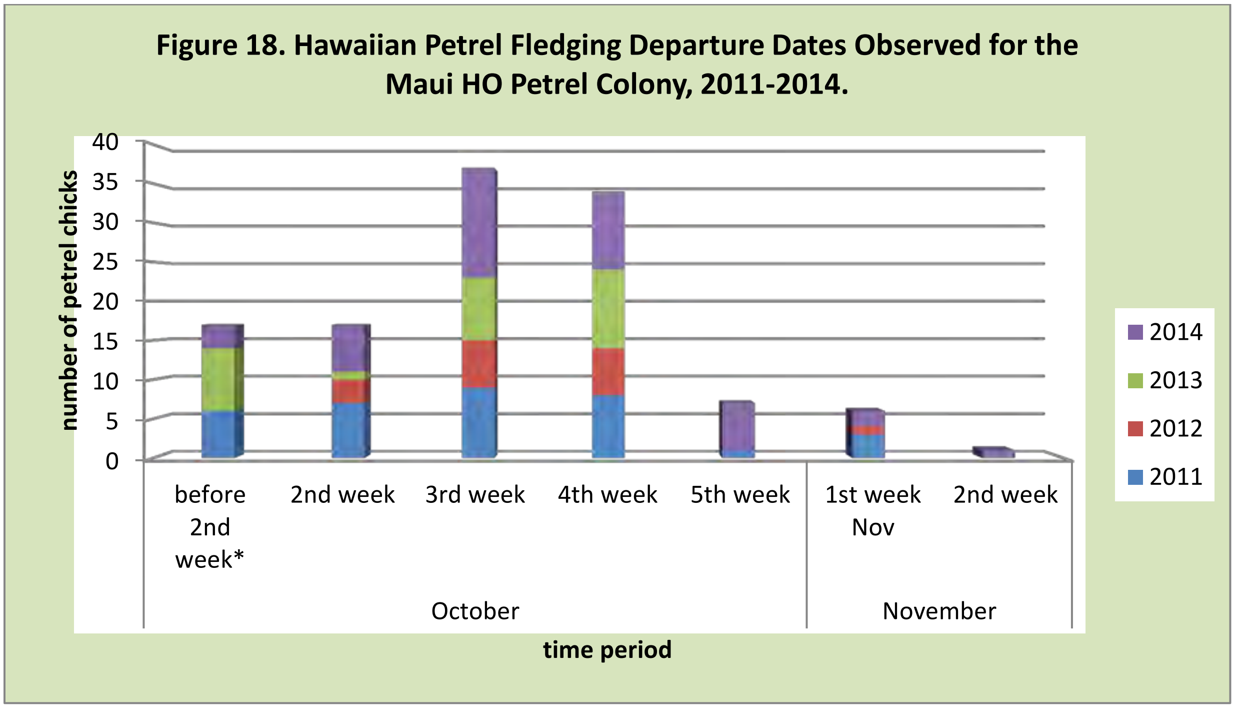



Based on the trend of reduced predation events (which was assumed to help increase the active burrow number; Table 8 and Figure 15), increase in the active burrows adjacent to the DKIST site from 2011 to 2014 (Figure 17), and the fact that DKIST construction did not begin until December of 2012, it seems highly unlikely that construction activities were the cause of the decrease in overall active burrow numbers from 2011 to 2013 (Figure 9). It is speculated that the decline of active petrel burrows recorded in the larger DKIST HCP monitoring area probably occurred external to the breeding colonies and/or during the nonbreeding season, when they were travelling on the open ocean, and not while the petrels were in the breeding colonies.

***VI D. Fledgling Dates***

Historical Data: During the three years of his study Simon (1985) reported the Hawaiian Petrel fledging period to extend from 8 October to 30 October. The median fledging date was 23 October 1979 (±6.5 days), 19 October 1980 (±6.7 days), and 19 October 1981 (±6.1 days). To investigate the potential impacts of DKIST construction on fledgling dates, the resource management team has monitored chicks' first appearance outside burrows and fledgling departures since 2011.

Project Data: Figure 18 presents the overall fledging departure dates from 2011-2014 in weekly intervals.




***2011 -2013***

- In 2011, 8 of the 17 burrows being monitored by cameras were successful. Based on the video recordings of the eight successful burrows around the Mees Observatory, the earliest fledging date was on 10/19 and the latest date was 10/25 (median date: 10/22).

- In 2012, 6 of the 18 burrows being monitored by cameras were successful. Based on the video recordings of the six successful burrows around the Mees Observatory, the earliest fledging date was on October 12, 2012 and the latest date was on October 19, 2012 (median date 10/17).

  Based on the 18 surveillance camera video data recorded in 2012, the adults of seven non-productive burrows were last seen between 07/25 and 08/10. These petrels may be ones that attempted to breed, but did not successfully lay eggs or hatch chicks. Adults of the other five non-productive burrows stopped returning between 09/06 and 09/26. These adults may have produced eggs and hatched chicks; however, if they did, the chicks did not reach fledgling age for unknown reasons.

- In 2013, 7 of the 19 burrows being monitored by cameras were successful in fledging petrels. We also placed 16 camera traps at active burrow sites outside of the Mees Observatory area. Among these 16 additional camera traps, we recorded fledging dates at 10 burrows. Based on 17 image recordings, the fledging dates were between 10/10 and 10/24 (median date: 10/19).

Based on the seven surveillance cameras near the Mees Observatory, the earliest that petrel chicks first emerged from their burrows to exercise their wings was 10/01 and the last was on 10/10 (median date: 10/06). The adults of successful burrows stopped returning to their burrows between 09/27 and 10/19 (median date: 10/10).

As in 2012, the adults of non-productive burrows stopped returning to their burrows during two peak periods of time. Data from the 19 petrel burrows monitored by surveillance cameras in 2013 shows that both adults died at SC 21 on 06/14. In addition, the male at SC 15 kept visiting the burrow until 07/27 even though its mate was killed on 05/05. The adults of the other eight non-productive burrows were last seen between 07/28 and 08/28. These petrels may be the ones that attempted to breed, but did not successfully lay eggs or hatch chicks. Adults of the other two non-productive burrows stopped returning between 09/09 and 09/16. These adults may have produced eggs or hatched chicks; however, if they did, the chicks did not reach fledgling age for unknown reasons.

The average days between petrel chicks' first emergence and fledging was 11.43 days (7-14 days, SD=2.5). The average days between adults' last visit and chicks' first emergence was -1.57 days (-12 to 9 days, SD=7.21). In other words, one adult's last return to the burrows was nine days prior to its chicks' first emergence from the burrow and one adult's last return to the burrows was 12 days after its chicks' first emergence from the burrow, while the others fell in between. The average days between adults' last return and chicks' fledge date was 9.86 days (1-21 days, SD=7.22).

***2014 Fledging Dates***

- In 2014, 10 of the 19 burrows being monitored by cameras were successful in fledging petrels. We also placed 39 camera traps at active burrow sites outside of the Mees Observatory area. Among these camera traps, the exact fledging dates at 25 burrows were recorded. The exact fledging dates at 3 burrows manually monitored were also observed. Based on 38 fledging date recordings, the fledging dates were between 09/24 and 11/09 (median date: 10/17).

  Based on the 10 surveillance cameras near the Mees Observatory, the earliest that petrel chicks first emerged from their burrows to exercise their wings was 09/30 and the last was on 10/27 (middle date: 10/09-10). The adults stopped returning to their burrows between 09/22 and 10/27 (middle date: 10/08-09).

  As in previous years, the adults of non-productive burrows stopped returning to their burrows during two peak periods of time. Based on the 19 petrel burrows monitored by surveillance cameras in 2014, the adults of the eight non-productive burrows were last seen between 07/01 and 08/27. These petrels may be the ones that attempted to breed, but did not successfully lay eggs or hatch chicks. Adults of another non-productive burrow stopped returning 10/07. These adults may have produced eggs or hatched chicks; however, if they did, the chicks did not reach fledgling age for unknown reasons.

The average days between petrel chicks' first emergence and fledging was 10.30 days (5-18 days, SD=3.8). The average days between adults' last visit and chicks' first emergence was 3.5 days (-6 to 13 days, SD=5.46). In other words, one adult's last return to the burrows was 6 days prior to its chicks' first emergence from the burrow and one adult's last return to the burrows was 13 days after its chicks' first emergence from the burrow, while the others fell in between. The average days between adults' last return and chicks' fledge date was 13.8 days (4-29 days, SD=7.49. That is a new record for this species, in which a chick without care by its parents for 29 days could still fledge successfully.

The fledging dates collected from 2011 to 2013 were within the range of what Simons (1985) reported, such that no impact on petrel fledging dates from DKIST construction activities could be detected.

The recorded events of 2014 confirmed that Hawaiian Petrels begin fledging from their burrows during the latter part of October as was the case in previous breeding seasons. The 3$^{rd}$ and 4$^{th}$ weeks of October accounted for the largest number of fledged chicks. By the end of the 2$^{nd}$ week of November, all chicks had already fledged and left the breeding colony. The 2014 fledging dates started 2 weeks earlier and ended one week later than the previous years and historic data collected by HALE (Figure 18). Three chicks were killed prior to their fledgling time in 2013 when predator control measures were not fully in place, therefore the success rate of late fledglings in 2014 may be attributed to predator control measures that appear to have improved the survival rate of chicks that have fledged outside of the peak fledging period.

***VI E. Summary of Results***

<u>Petrel Collision: The</u> DKIST team did not detect any Hawaiian Petrel collisions with any DKIST-related structures between June 7, 2011 and June 30, 2015.

<u>Impact on Nesting Activity and Fledgling Success</u>:

- No adverse impacts were statistically detected on Hawaiian Petrel Nesting Activity and Nesting Success percentages resulting from DKIST construction activities and conservation measures implemented in the Conservation Area (utilizing the acknowledged weak statistical comparison between the Conservation Area and small sample size of the Control Site data). The Control Site and Conservation Area seem to have a different quality of Hawaiian Petrel breeding habitat such that even before construction began and mitigation measures were in place, burrow density and nesting success rates in the Conservation Area were four to five times higher.
- The largest number of both active and successful burrows, and highest density, were recorded in 2014 (the first year all HCP required conservation measures were completed).
- The number of active and successful burrows continues to increase adjacent to the DKIST construction site (around Mees Observatory).
- The active and successful burrow density increased at the lower boundary area after the predator grid was installed in 2014.

- All of the above have demonstrated that thus far, DKIST construction activities seem to have no adverse impact on petrel reproductive performance in this area, and in 2014 DKIST conservation measures were likely aiding petrels in high predator impact areas in the lower parts of the Conservation Area.

Predation Mortality: It appears that DKIST mitigation measures have helped reduce predation mortality by 87.5% (from 8 in 2011 to 1 in 2014) within the Conservation Area. Overall mortality events have declined from 15 in 2011 to 4 in 2014.

Fledging Dates: No obvious fledging date changes could be detected in the first three years. An extended fledging period in 2014 was recorded; this might be due to higher nesting success observed in the Conservation Area.

## VII. SUSPENSION OR REMOVAL OF THE FOLLOWING MITIGATION MEASURES

Certain mitigation measures that were originally in the HCP or BO have been reconsidered. After extensive fieldwork, the DKIST resource management team and the supporting agencies have agreed to the following: while Hawaiian Petrel social attraction/artificial burrows can be reinstated, this measure is not currently necessary. Also, due to its infeasibility, landscape scale rodent control has been permanently removed as a required measure.

- *Hawaiian Petrel Social Attraction/Artificial Burrows*
  The purpose of these two measures was to recruit non-breeders into managed vacant areas to compensate for the effects of lack of suitable burrows. However, since 150+ non active burrows have been recorded in the Conservation Area each year, it would seem artificial burrows may not be necessary, since there is already an abundance of unoccupied burrows. Also, 120-160 active breeding pairs exhibiting courtship behavior in the last four seasons were recorded, suggesting that there are more "real petrels" attracting other petrels into a "hospitable habitat" than recordings/decoy birds could accomplish. Another aspect to consider is that predation of live Hawaiian Petrels is still a threat in the Conservation Area, and broadcasting courtship sounds might attract predators into the area. Another concern is that broadcasting petrel sounds might disturb the behavior of the local population. These may be future adaptive management measures to be implemented if Net Recovery Benefit does not meet annual objectives. However, at present it appears that Net Recovery Benefit can be achieved without implementing social attraction/artificial burrows.

- *Landscape Scale Rodent Control*
  This landscape scale short term rodent control 50 m grid was required only in the BO. The largest landscape scale rodent control grid in Hawaii is at the 20-ha Ka'ena Point Natural Area Reserve. The world's largest 307-ha Orokonui Ecosanctuary of New Zealand employed aerial broadcasts (which is still illegal in Hawaii). Both sites were equipped with "predator-proof" fences to prevent rodent re-ingress. Without a predator proof fence, rodent re-ingress will be repetitive and negate any landscape rodent control grid.

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# Programmatic Arthropod Monitoring at the Haleakalā High Altitude Observatories and Haleakalā National Park and Annual Inspection of the DKIST Facilities and Grounds, Maui, Hawaiʻi

**August 2015**

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

## I. TABLE OF CONTENTS

# 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 DKIST Project.

After preliminary sampling near the HALE Entrance Station and at the DKIST site 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 which began in December 2012. Semi-annual monitoring has occurred in 2011, 2012, 2013, and 2014.

This report presents the results of the Summer 2015 sampling. The goal is to monitor the arthropod fauna at the DKIST site and along the HALE Road Corridor, identify Hawaiian native arthropod species or habitats, if any, that may be impacted by construction 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.

In addition to semi-annual monitoring required by the FEIS, pursuant to the approved HCP and published BO, an inspection for non-indigenous arthropod species is required to be conducted on an ongoing annual basis during the approximate 5-year construction phase and 50 year lifespan of the DKIST for programmatic monitoring. Facilities and grounds within 100 feet of the DKIST observatory buildings are to be thoroughly inspected for introduced species that may have eluded the cargo inspection processes or transported to the site by construction personnel.

This report also describes the results of the Annual Inspection conducted in July 2015. The goal is to verify that the DKIST is in compliance with the conditions and mitigation measures described in the guiding environmental documents.

The 2015 Annual Inspection was conducted on July 22, 2015. No non-indigenous, invasive arthropods were found at the site or on any of the construction material and equipment. The project was found to be largely compliant with all the mitigation measures in the guiding environmental documents for construction of the DKIST. The construction site and surrounding lay-down/storage areas were clean and free of non-indigenous invasive arthropods.

# III. INTRODUCTION

**Programmatic Monitoring**

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 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 Summer 2015 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 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 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 biological changes.

The scientific scope of the current phase of Arthropod Monitoring is to repeatedly sample arthropod habitats that may be impacted by construction of the 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 using 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. Although the overall footprint of DKIST is about 0.74 ac, the site where DKIST construction is currently taking place is approximately 0.24-ha (0.6 ac) of previously undisturbed 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 July 2015, the second 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 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 # FHM15-364), effective date January 1, 2015 – December 31, 2015, and the National Park Service (Permit # HALE-2010-SCI-0001) issued on March 22, 2010. Sampling began on July 20, 2015 and was completed on July 27, 2015.

**Annual Inspection**

An inspection is required to be conducted on an ongoing annual basis during the approximate 5-year construction phase and 50 year lifespan of the DKIST. The inspection was conducted on July 22, 2015. DKIST interior facilities and grounds within 100 feet of the buildings are to be thoroughly inspected for introduced species that may have eluded the cargo inspection processes or transported to the site by construction personnel. Any newly-discovered non-native, invasive arthropod are to be photo documented, mapped, and described. Arrangements will be made for eradication of any invasive introduced species found inside or within 100 feet of the DKIST buildings. Appropriate control methods include the use of available herbicides and pesticides, in accordance with established practice at HO (University of Hawaii 2010) and pursuant to label requirements.

Annual Inspections provide information about compliance with the guiding environmental documents prepared for the DKIST project. These documents include the DKIST Habitat Conservation Plan, USFWS biological Opinion, and the DKIST FEIS. In addition, the inspection meets the requirements of the University of Hawaii Institute for Astronomy Management Plan, which describes mitigation measures to prevent introduction of introduced species.

# 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 the Annual Inspection, and are the focus of this report.

**Programmatic Monitoring**

## *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.

**Annual Inspection**

## *Question 4*

***What non-indigenous arthropod species, if any, are detected within the interior of DKIST facilities and the grounds within 100 ft. (30 m) of the buildings?***

**Justification:**

Detailed site inspections for non-indigenous arthropod species can detect potential threats to the nearby native ecosystems that may have escaped detection during the regular inspection process or programmatic monitoring. Early detection will allow implementation of control measures to eradicate invasive arthropod species (e.g. ants and spiders) before they have an opportunity to establish resident populations that could damage nearby native ecosystems.

**Inspection goals:**

1) To detect invasive non-indigenous arthropod species inside of the DKIST facilities and the grounds within 100 feet of the buildings.

If any invasive arthropod species (e.g. ants and spiders) are detected, they will be photo documented, mapped, and described, and then exterminated. Eradication measures may include brushing away spider webs to disrupt mating and foraging, sticky traps to capture ants, and the application of pesticides in accordance with established practice at HO (University of Hawaii 2010) and pursuant to label requirements.

## *Question 5*

***What non-indigenous invasive arthropod species, if any, are detected at the DKIST construction, lay-down and staging areas?***

**Justification:**

While these areas are sampled during Programmatic Monitoring, they will receive increased scrutiny during the Annual Inspection. Annual inspection for non-indigenous arthropod species will detect potential threats to the nearby native ecosystems that may have escaped earlier detection and 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.

**Inspection goals:**

1) To detect invasive non-indigenous arthropod species at the DKIST lay-down and staging areas.

If any invasive arthropod species (e.g. ants and spiders) are detected, they will be photo documented, mapped, and described, and then eradicated to prevent these species from establishing resident populations. Eradication measures may include brushing away spider webs to disrupt mating and foraging, sticky traps to capture ants, and the application of pesticides in accordance with established practice at HO (University of Hawaii 2010) and pursuant to label requirements.

## *Question 6*

***Are mitigation measures implemented that prevent the establishment of invasive species due to DKIST construction activities?***

**Justification:**

NSF has committed to several mitigation measures described in the DKIST FEIS, Habitat Conservation Plan (HCP), and USFWS Biological Opinion (BO) to prevent the introduction of invasive species to those areas surrounding the DKIST construction activities. The Annual Inspection will include examination of the DKIST Construction Site to ensure mitigation measures are being implemented correctly.

**Monitoring goals:**

1) To confirm that mitigation measures to prevent the establishment of invasive non-indigenous arthropod species committed to in the DKIST FEIS, HCP, and BO are being implemented correctly.

If any violations of the mitigation measures are detected, they will be photo documented, mapped, and described, and then reported to the Construction Site Manager, who will arrange for proper implementation of the measures to prevent invasive species from establishing resident populations.

**Specific Alien Arthropod Control Measures to be taken**
**(Habitat Conservation Plan Page 54 – 57 and Biological Opinion Page 20-24)**

Alien arthropods can arrive at the site by two general pathways. First, alien species already on Maui can spread to new locations. Second, alien species can arrive on the island with construction materials in or on shipping crates and containers. In order to block the first pathway, heavy equipment, trucks, and trailers will be pressure-washed before being moved to the DKIST construction site. The following specific alien arthropod control measures, adapted from those already required pursuant to the HO Management Plan will be implemented to further minimize the spread and establishment of alien insects. These six specific alien arthropod control measures are as follows:

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

a. Pressure-wash to remove alien arthropods: 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 may colonize mud and dirt stuck on earthmoving equipment and could then be transported to uninfested areas. Pressure-washing of equipment before it is transported to the site will be thorough enough to remove dirt and mud and to 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 HO Management Plan, large trucks, tractors, and other heavy equipment will be inspected before entering the Park. Inspection will be recorded in a log book kept at the site.

2) All construction materials, crates, shipping containers, packaging material, and observatory equipment will be free of alien arthropods when it is delivered to the site.

a. Inspect shipping crates, containers, and packing materials before shipment to Hawaiʻi: Alien arthropods can be transported to Hawaiʻi via crates and packaging. Therefore, only high quality, virgin packaging materials will be used when shipping supplies and equipment to the DKIST Project site. Pallet wood will be free of bark and other habitat that can facilitate the transport of alien species. Federal and Hawaiʻi State agricultural inspectors do not currently check all imported non-food items for alien arthropods. DKIST construction management will communicate to shippers and suppliers the environmental concerns regarding alien arthropods, and inform them about appropriate inspection measures to ensure that supplies and equipment shipped to Hawaiʻi are free of alien arthropods at the points of departure and arrival.

b. Shipping containers will be inspected and any visible arthropods will be 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 be done to minimize the transport of alien arthropods.

c. After arrival in Hawaiʻi, crates or boxes to be transported to the site will 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 will be completed to reduce the potential for undetected arthropods to reach the construction site. Arrangements will be made stipulating mandatory use of the Maui Alien Species Action Plan (ASAP) building for complete inspection of all possible items. This will prevent /or best allow for alien species interdiction on arriving materials.

i. Inspect construction materials before entering the 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 will be taken to ensure that alien arthropods are not introduced to the HO site.

ii. Construction materials will be inspected before transport to the construction site.

If any alien arthropods are discovered, the infestation will 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.

3) Sanitary control of food and garbage will prevent access to food resources that could be used by invading ants and yellow jackets. Outdoor trash receptacles will be secured to the ground, have attached lids and plastic liners, and their contents will be collected frequently to reduce food availability for alien predators. Heavy, hinged lids will be used to prevent wind dispersal of garbage. Refuse will be collected on a regular basis to ensure containers do not become full or overflow. This could entail collection several times a week, particularly in eating areas and during periods of heavy use of the area. Containers will be regularly washed using steam or soap to reduce odors that attract ants. Plastic bag liners will be used in all garbage containers receiving food to contain leaking fluids.

4) Ensure construction waste and debris is secured to ensure it is not dispersed.

a. 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.

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

c. Construction trash containers will be tightly covered to prevent construction wastes from being dispersed by wind. This will be accomplished during construction of DKIST pursuant to the best management practices described in the HO Management Plan.

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 will 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.

5) Invasive species detection and interdiction will be the responsibility of the resource biologist for DKIST and supporting avian biologist. Detection and interdiction will be conducted routinely by these personnel to ensure that new introductions are controlled.

a. A biological monitor will be employed during construction and programmatic arthropod sampling will be done in accordance with the schedule described within Section 2.3-DKIST Project Description of the HCP, and Section 3.0 of the BO. Monitoring for new alien arthropod introductions will be conducted during construction activities and any populations detected will 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.

b. Ant eradication: Sticky traps designed to capture ants will be deployed immediately after any ants are detected. Persistence of ant detections are indicative of larger infestations, and will prompt a search for and eradication of colonies. Bait and chemical control will be employed only when absolutely necessary and only by a certified pest control professional.

c. Alien spider eradication: Any alien spider webs detected will be removed. Native lycosid wolf spiders do not make webs. Native sheet-web spiders make tiny webs under the cinder surface. Only alien spiders would make large spider webs at HO. Sweeping such webs away with a broom disrupts alien spider food capture success and destroys egg masses. Follow-up measures will be developed and implemented to control alien spiders when they are detected.

6) Construction materials stored at the site will be covered with tarps, or anchored in place, and will not be susceptible to movement by wind. Securing materials will reduce the chances of debris being dispersed from the site into native arthropod habitat. Construction materials and supplies will 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 will be tied down or otherwise secured during high winds and at close of work each day. If construction materials and trash are blown into native arthropod habitat, they will be collected with a minimum of disturbance to the habitat.

# V. METHODS

## Site Description

The Haleakalā High Altitude Observatories (HO) site is located on Kolekole Hill. The highest point on the HO site is at 3,052-m (10,012-ft) above sea level. 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 at 3,042-m (9,980-ft) above sea level. 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.

## Monitoring 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 seven days at the DKIST site and for seven 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. Efforts were made to avoid known burrows. Pitfall traps are placed below ground and covered with a heavy cap rock. This makes it very unlikely that petrels could access the traps.

All pitfall traps were installed on July 21, 2015 and their contents collected on July 27, 2015.

## 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 five nights at the DKIST site, HO site, and the HALE site.

An additional night of sampling was suspended due to weather conditions.

Light traps were deployed for five trap nights at each sampling site, and were allowed to run overnight or until batteries failed.

### 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 beat again to dislodge persistent individuals. Care was taken to avoid sensitive plants and to leave 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 an index card 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. Baited traps were deployed on the HO and DKIST sites on three different days. The traps were checked after forty-five minutes at which time the traps were be removed. Baited traps were not left opened overnight in order to avoid attracting unwanted pests.

Baited ant traps were deployed on two different days at the HO/DKIST sites, twenty-five the first day and thirty-five on a second day. Twenty baited traps were deployed at the HALE ES site on one day.

## 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), Gagné (1997), Polhemus (2002, 2005, 2011, 2014), and Asquith (1994, 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 July 20, 2015 and ending on July 27, 2015.

## Annual Inspection Procedures

**Inspection of DKIST building interiors and within 100 feet of the DKIST buildings.**

During the inspection, the interiors of all DKIST buildings were be examined for evidence of non-indigenous invasive species. If any invasive arthropod species (e.g. ants and spiders) were detected, they would have been photo documented, mapped, and described, and then arrangements would be made for eradication to prevent these species from establishing resident populations. Eradication measures may include brushing away spider webs to disrupt mating and foraging, sticky traps to capture ants, and the application of pesticides in accordance with established practice at HO (University of Hawaii 2010) and pursuant to label requirements.

**Inspection of DKIST construction, lay-down and staging areas.**

During the Annual Inspection, construction lay-down and staging areas were examined for evidence of non-indigenous invasive species. If any invasive arthropod species (e.g. ants and spiders) were detected, they would have been photo documented, mapped, and described, and then arrangements would have been made for eradication to prevent these species from establishing resident populations. Eradication measures may include brushing away spider webs to disrupt mating and foraging, sticky traps to capture ants, and the application of pesticides in accordance with established practice at

HO (University of Hawaii 2010) and pursuant to label requirements.

**Earthmoving Equipment**
Earthmoving equipment and vehicles were inspected to verify they are being properly washed.

**Construction materials, crates, shipping containers, packaging material, and observatory equipment**
Construction materials, crates, shipping containers, packaging material, and observatory equipment were examined for evidence of non-indigenous arthropod species.

**Sanitary control of food and garbage**
Outdoor trash receptacles were examined to ensure they were secured to the ground, had attached lids and plastic liners. Containers were examined to verify that they were washed and that odors were not present that may attract ants or yellow jackets.

**Construction Waste and Debris**
"Roll-off" containers, construction trash, and building materials were inspected to verify that the containers were tightly covered to prevent construction wastes from being dispersed by wind.

**Stored Construction materials**
Building materials and equipment at the DKIST site, or in lay-down or storage areas that are susceptible to wind dispersal were examined to verify that they were secured to prevent their movement by wind into native arthropod habitats.

## Inspection Date

Sampling and inspection was conducted on July 22, 2015.

# VI. RESULTS and DISCUSSION

## Programmatic Monitoring

### HIGH ALTITUDE OBSERVATORIES

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

**Spiders and Mites - Arachnida**

Juvenile and adult Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps, and were actively foraging among rocks. Small spiders of the family Linyphiidae were observed under rocks, and may represent several species.

**Springtails - Collembola**

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

**Beetles – Order Coleoptera**

Ten beetle species were observed at the HO site. A species of endemic long-horned beetles (genus *Plagithmysus*) was found on *Dubautia*.

The Hawaiian native long-horned beetle found on *Dubautia.*

*Trechus obtusus* Erichson, an introduced ground beetle native to Europe and North Africa was found under rocks. First reported from Maui in 1998, this species appears regularly in Programmatic Monitoring samples. Six species of non-indigenous ladybird beetles (family Coccinellidae) were observed, including the seven-spotted ladybird beetle (*Coccinella septempunctata* L.) and the convergent ladybird beetle (*Hippodamia convergens* Guerin-Meneville). The larvae of these species feed on small insects, such as aphids, and are considered beneficial insects. A small rove beetle (family Staphylinidae) and feather winged beetle (family Ptiliidae) were collected in pitfall traps, both as single specimens.

**Flies - Order Diptera**

Thirteen species of flies were detected at the HO site. Two are endemic species of fruit flies (family Tephritidae). Eight species are non-indigenous and have been common in previous monitoring samples. The status of three species of flies collected was unknown.

**A species of Hawaiian native fruit fly.**

**True Bugs – Orders Heteroptera and Homoptera**

Eleven species of true bugs (order Heteroptera) were observed including adults and nymphs of three Hawaiian endemic species in the genus *Nysius* (family Lygaeidae). Two of these species (*Nysius coenosulus* and *N. communis*) are common residents at the site and occur in abundance on both *Dubautia* and *pukiawe*. Other Lygaeidae were the non-indigenous white-crossed seed bug (*Neacoryphus bicrucis* (Say)). Specimens from the family Miridae included the endemic species *Engytates hawaiiensis* (Kirkaldy), found on *Dubautia*, *Trigonotylus hawaiiensis* (Kirkaldy), found on grasses, and *Hyalopeplus pelucidus* Stål. Adults and nymphs of *Geocoris pallens* Stål were abundant on vegetation at the HO site.

Six species of Homoptera were found, including an endemic species of plant hopper of the genus *Nesosydne*, common on *Dubautia*. The Acacia psyllid, *Acizzia uncatoides* (Ferris & Klyver) were abundant.

The Haleakalā flightless moth found near a light trap.

**Butterflies and Moths – Order Lepidoptera**

Eleven species of Lepidoptera were found at the HO site. These include three endemic species in the genus *Agrotis*, and two other unknown species in the same genus. The non-indigenous *Pseudalecia unipuncta* (Meyrick) was also found. Adults of the Haleakalā flightless moth (*Thyrocopa apatela* (Walsingham)) were collected in the morning near light traps that had run all night.

Other Lepidoptera included the endemic Hawaiian Blue (*Udara blackburni* (Tuely)), and a species of *Hyposmocoma*.

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.

Largely undisturbed habitat near the Las Cumbres Telescope at the HO site has native vegetation that supports native Hawaiian arthropods.

**DKIST CONSTRUCTION SITE**

Construction was started on the DKIST in December 2012 and was ongoing during the Summer 2015 sampling session. Excavation was completed in 2014 and most earth-moving equipment has been removed from the site.

Sixty-two species of arthropods were collected at the DKIST site during the Summer 2015 sampling session. The species included twenty-one endemic Hawaiian arthropods, twenty-eight non-indigenous arthropods, and thirteen species of unknown status.

**Spiders and Mites - Arachnida**

Juvenile and adult Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps at the DKIST site, and were seen actively foraging among rocks. A small Linyphiidae spider was also seen under rocks.

**Springtails - Collembola**

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

**Beetles – Order Coleoptera**

Nine species of beetles were observed at the DKIST site, all non-indigenous. The species included six ladybird beetles, an unknown leaf beetle (family Chrysomelidae), and the pepper weevil (*Anthonomus eugenii* Cano).

Non-indigenous ladybird beetles are abundant on vegetation.

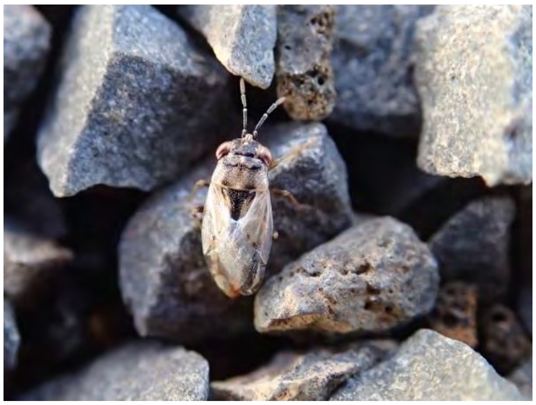
**Flies - Order Diptera**

Fourteen species of flies were detected at the DKIST site. Only one endemic species, a fruit fly (family Tephritidae) was observed. The rest were non-indigenous and have been observed at the site during previous sampling.

**True Bugs – Orders Heteroptera and Homoptera**

Eleven species of true bugs (Order Heteroptera) were observed at the DKIST site, including seven endemic species. Adults and nymphs of two species of the Hawaiian endemic seed bug genus *Nysius* (*N. coenosulus* Stål and *N. communis* Usinger) were abundant on *Dubautia* and *pukiawe*. A third species of this genus (*N. lichenicola* Kirkaldy) was found in leaf litter under plants. The abundance of this species was infrequent.

Non-indigenous species included *Geocoris pallens* Stål and a seed bug from the genus *Pachybrachius*.



The non-indigenous big-eyed bug, *Geocoris pallens* Stål found at the DKIST site.

Adults and nymphs of three plant bugs (family Miridae) were also observed. *Engytates hawaiiensis* (Kirkaldy) is uncommon, found on *Dubautia*, *Trigonotylus hawaiiensis* (Kirkaldy), is found only on grasses, and *Hyalopeplus pelucidus* Stål found on vegetation. All are endemic species.

Other Heteroptera that were collected include the green stink bug (*Nezara viridula* L.) and the white-crossed seed bug (*Neacoryphus bicrucis* (Say)).

Five species of Homoptera were collected, including a species of the endemic genus *Nesosydne* that was abundant on *Dubautia*. Non-indigenous species include a species of aphid and planthopper and the abundant Acacia psyllid.

The Acacia Psyllid was very abundant at the DKIST.

An unknown scale insect (family Pseudococcidae) was present on *Tetramolopium humile* and may be an indigenous species.

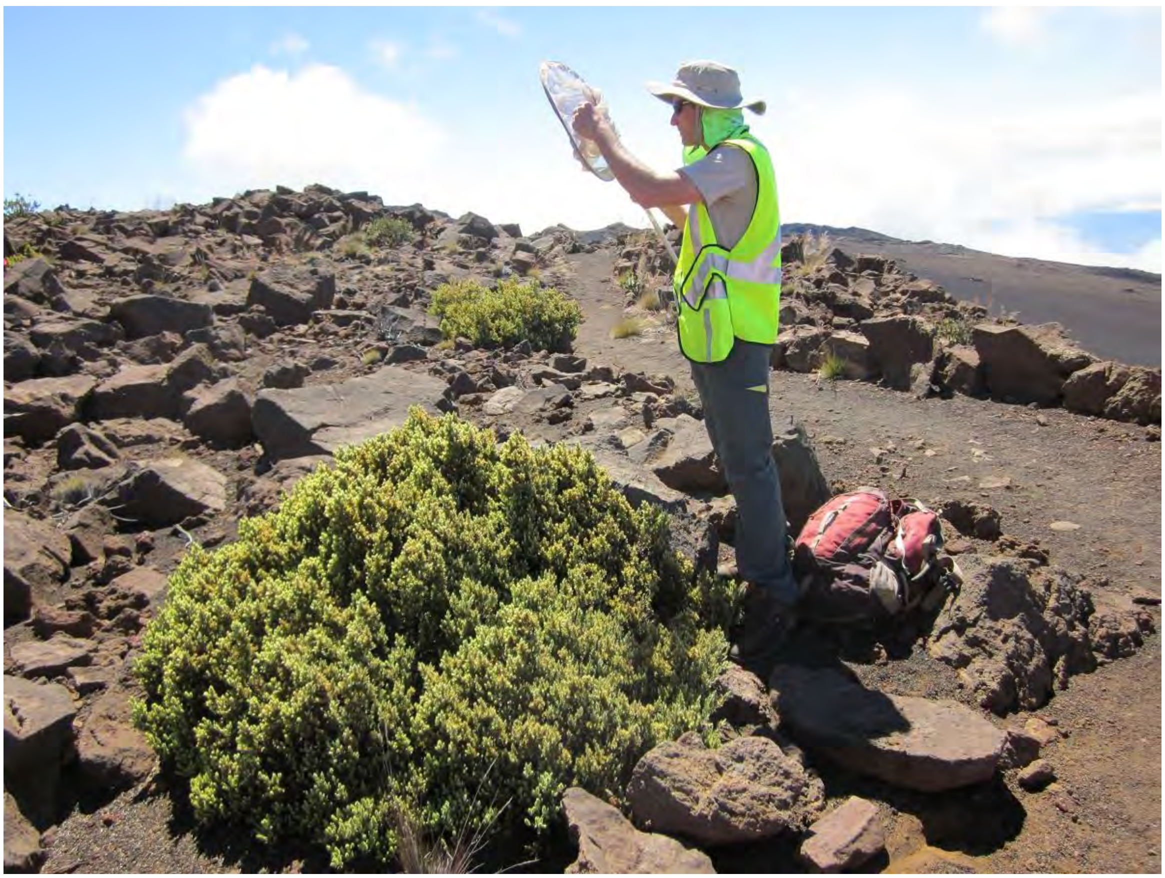
**Bees and Wasps – Order Hymenoptera**

The endemic species of yellow-faced bees, *Hylaeus nivicola* Meade Waldo, was common on *pukiawe*. Other Hymenoptera observed include small parasitic wasps and yellow jackets, *Vespula pensylvanica* (Saussure).

**Moths – Order Lepidoptera**

Eight species of Lepidoptera were collected, all endemic species. Four large moths in the genus *Agrotis* were captured in light traps. Caterpillars of the genus *Agrotis* were found in pitfall traps. Haleakalā flightless moths (*Thyrocopa apatela* (Walsingham)) were observed hopping in the cinder habitat.

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.



Dr. Will Haines sampling pukiawe adjacent to the DKIST site.

## HALEAKALĀ ENTRANCE STATION

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

**Spiders and Mites - Arachnida**

Six species of spiders were recorded at the HALE ES site. The only species identified as endemic was a crab spider (*Mecaphesa sp. nr. kanakanus* (Karsch)), uncommon on vegetation.

A non-indigenous hunting spider (*Cheiracanthium mordax* L. Koch) was uncommon in sweep net sampling over grasses. Another non-indigenous species recorded was a comb-footed spider (*Steatoda grossa* (C. L. Koch)). Similar in appearance to the black widow, this uncommon species was found under logs and rocks. Both of these species have reported from HALE in the past.

**Collembola - Springtails**

At least two species of Collembola were observed at the HALE site. These small insects were common in leaf litter under plants and in pitfall traps.

**Beetles – Order Coleoptera**

Nine species of beetles were observed, including an endemic ground beetle (genus *Mecyclothorax*) and a similar-looking, but somewhat smaller, non-indigenous ground beetle, *Trechus obtusus* Erichson.

Non-indigenous beetles include two common species of ladybird beetles and three well known weevils, as well as an unknown rove beetle (family Staphylinidae).

The Eucalyptus leaf beetle (*Paropsisterna (Chrysophtharta) m-fuscum*) was discovered on Eucalyptus trees near the HALE ES. Native to Australia and New Guinea, this species is also widespread in Southern California and was recently found in South Carolina. Adults are 6-7 mm (about ¼ inch) long, brown with darker mottled spots, and look like a brown ladybird beetle. Blue gum Eucalyptus is the principal host plant for this species. Adult beetles and larvae chew notches along the edges of eucalyptus leaves, leaving them unsightly and torn. The beetles alone are not known to kill eucalyptus trees; however, heavy infestations of beetles can consume almost all of the leaf tissue, stressing the plant enough that it will eventually die. This is a new state record for this species and the Hawaii State

Department of Agriculture has been notified of the discovery.

HALE ES is probably not the site of first introduction, and it's not likely to be something that came in on construction equipment or materials. It is more likely that this beetle arrived in Hawaii on cut foliage used in flower arrangements. It probably worked its way up from Kula or the ranch below the National Park. Eucalyptus trees at the lower end of the crater road (Hwy 378) have signs of defoliation by this beetle.

**Flies – Order Diptera**

Fourteen species of flies were seen at the HALE ES. Ten species were from families of common non-indigenous flies (e.g.: blow flies, and bee flies) previously reported from HALE ES. One specimen of an endemic fruit fly (*Trupanea crassipes* (Thomson)) was found at a light trap.

Fruit fly, fungus gnats, and craneflies of unknown status, complete the species found at the HALE ES.

**True Bugs – Orders Heteroptera and Homoptera**

Six species of true bugs (Heteroptera) were found, three endemic species from the family Miridae. *Orthotylus coprosmophila* Polhemus, common on *Coprosma*, *Orthotylus sophoriodes* Polhemus, abundant on *manane*, and *Hyalopeplus pelucidus* Stål, which was very common at all three sampling sites. Three non-indigenous species from other families, a seed bug (family Lygaeidae), a damsel bug (family Nabidae), and another seed bug (family Rhyparochromidae).

Four species of Homoptera were observed, one a Hawaiian endemic. This species, from the indigenous genus *Nesophrosyne* (family Cicadellidae), was uncommon on vegetation.

A close up of *Ectemnius nesiotes* (Pate), an indigenous predatory wasp.

**Bees and Wasps – Order Hymenoptera**

The nine species of Hymenoptera found near the HALE Entrance Station included three indigenous species, a solitary predatory wasp (family (Crabronidae), a hunting wasp (family

Bethylidae), and a vespid wasp (*Odynerus* sp.).

The six non-indigenous species include three ants, *Cardiocondyla kagutsuchi/ venestula*, *Hypoponera opaciceps*, and *Linepithema humile,* and three parasitoids. No yellow-faced bees (genus *Hylaeus*) were detected. Normally present at the HALE ES, the activity of these bees may have been limited by wet weather conditions.

**Butterflies and Moths – Order Lepidoptera**

Lepidoptera were the most diverse group with twenty-seven species, 20 endemic to Hawaii. The endemics are mostly moths, such as the mamane moth (*Uresiphita polygonalis virescens* (Butler)) but are also represented by seven species of larger noctuid moths and the Hawaiian blue (Udara blackburni (Tuely)). The non-indigenous are mostly larger noctuid moth species, but also include two lantana biocontrols and two smaller tortricid moths.

**Other Observations**

Other arthropods were observed at the HALE ES, including centipedes, millipedes, and sowbugs common in pitfall traps, under rocks, and in decaying vegetation.

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.

## Programmatic Monitoring Discussion

The arthropods that were found during this sampling are characteristic of the fauna found during previous monitoring. Only one new invasive arthropod was detected at any of the sites (HALE ES), the Eucalyptus leaf beetle (*Paropsisterna m-fuscum*).

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.

Sampling at the HALE ES was limited by wet conditions. Dense fog and rain caused the vegetation to be wet which reduces insect activity and detection.

There are three main Questions of Interest that are to be answered by this monitoring:

### *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?***

The Characteristic arthropods found at the monitored sites can be found in the species lists in the appendices at the end of this report.

### *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?***

There have been minor adverse impacts on indigenous arthropod species at the monitored sites. Native vegetation was removed from the construction site during site excavation. This reduced the size of the arthropod population at the site, however, vegetation is already recovering and it can be expected that native arthropods will return to the site to exploit the renewed plant resources.

### *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?***

There were no non-indigenous arthropod species detected at the HO and DKIST sites. One new invasive arthropod species was discovered at the HALE ES site, the Eucalyptus Leaf Beetle (Paropsisterna m-fuscum). It is unlikely that this beetle was carried into the Park on construction materials of vehicles. The species is found on blue gum Eucalyptus leaves where it spends most of its life cycle. The beetle was probably introduced into Hawaii via florist foliage. Leaf damage was detected on the lower section of the Crater Highway (HWY 378), and the beetle has likely migrated up the road to the Park following the Eucalyptus food resources.

## Annual Inspection

One day was allocated to the Annual Inspection during the Summer Programmatic Monitoring session. The inspection took place on July 22, 2015. During the inspection, the interiors of DKIST structures were examined for evidence of non-indigenous invasive species. No new invasive arthropod species were detected. The following pages describe the results of the inspection.

The following were inspected:
DKIST Observatory Building
DKIST Utility Building
DKIST Site Manager's Trailer
DKIST First Aid Trailer
Cultural Monitor Trailer
Reef Development Trailer 1
DU-WATTS Trailer
Reber Circle Storage Container 1
Reber Circle Storage Container 2
Reber Circle Storage Container 3
Reber Circle Storage Container 4
Steel Tech Storage Container
Storage Container 1
Storage Container 2
Storage Container 3
Storage Container 4
Container Support Office 1
Container Support Office 2
Material Storage and Lay-Down Areas
Earth-moving Equipment
Motorized Construction Vehicles
Pickups and other Trucks

**Office Trailers**

Seven office trailer s were inspected. The offices contain desks, chairs, and file cabinets. The seven trailer offices were all found to be free of non-indigenous invasive arthropod species. Trash cans in these offices had liners and containers used for food waste had proper fitting lids.


**The Construction Site Manager Office trailer was found to be free of non-indigenous invasive arthropods.**

The trash can outside the Reef Development office trailer had an improper lid and contained food waste. The Site Manager was informed and he immediately took steps to correct the violation. The trash can had a plastic liner and the Site Manager said that the waste was taken away from the site daily for proper disposal.

Reef Development office trailer. Red arrow points to trash can with improper lid and food waste.

**A trash can outside the Reef Development trailer office with an improper lid and food waste. By the end of the day this can had a proper lid and was emptied.**

**Storage Containers**

There were ten storage containers on the DKIST construction site. Five storage containers were locked and not available for interior inspection. The interiors of the open containers were inspected and found to be free of non-indigenous invasive arthropods. Trash containers inside these storage containers were lined and are dumped daily.

**Typical storage container at the DKIST construction site.**

Interior of a storage container with lined trash can for disposal of soda bottles. This trash can is emptied daily and trash is taken away from the site for proper disposal.

**Observatory Buildings and Support Structures**

The DKIST observatory building and the support structures were inspected and found to be free of non-indigenous invasive arthropod species. The interior of these structures are frequently swept clean of debris, and most trash cans are lined and have proper fitting lids. Two trashcans inside the observatory structure had no lids and were overfilled with trash. No food waste was observed in these trash containers.

**DKIST observatory building.**

**Interior of the DKIST observatory building. The building is kept clean and trash is disposed of daily.**


**Trash cans inside the DKIST observatory building was covered.**

**Laydown and Construction Material Storage Areas**

Laydown and construction material storage areas were inspected and found to be free of non-indigenous invasive arthropod species. The areas are kept free of trash and wind-blown debris and material that can become wind-blown are tied down and secured to prevent movement.

**Construction material storage area was free of non-indigenous invasive arthropods. The areas are also free of trash and wind-blown debris.**

**Earth-moving Equipment**

Only one piece of earth-moving equipment is left at the site, a small Caterpillar skid steer. This vehicle was inspected and found to be free of invasive arthropods.


**Most earth-moving equipment has been removed from the construction site. This remaining skid steer was free of invasive arthropod species.**

**Outdoor Construction Waste Containers**

There are two large drop-off trash containers at the construction site. Both had secure lids and are dumped when full. The containers were inspected and found to be free of non-indigenous invasive arthropod species.


**Drop-off trash container outside of the DKIST observatory building. The container has a secure lid and is dumped frequently as needed.**

**Sanitary Control**

Food waste is disposed of in special lined trash cans with tight fitting lids. Except for the uncovered trash can outside the Reef Development office trailer, the food waste containers were found to be properly covered and lined and free of non-indigenous invasive arthropod species.


**Trash containers not used for food waste are labeled to prevent improper disposal of food waste.**

## ANNUAL INSPECTION DISCUSSION

The DKIST construction site and surrounding lay-down/storage areas were found to be well organized and kept neat and clean. There were no signs of invasive non-indigenous arthropods. Except for one uncovered trash can, the site was compliant with all the incumbent environmental documents.

There are three main Questions of Interest that are to be answered by this annual inspection.

### *Question 1*

***What non-indigenous arthropod species, if any, are detected within the interior of DKIST facilities and the grounds within 100 ft. (30 m) of the buildings?***

There were no non-indigenous arthropods found in or around the DKIST buildings that were potentially threatening to native flora and fauna.

### *Question 2*

***What non-indigenous invasive arthropod species, if any, are detected at the DKIST construction, lay-down and staging areas?***

There were no non-indigenous arthropods found in or around the DKIST buildings that were potentially threatening to native flora and fauna.

### *Question 3*

***Are mitigation measures implemented that prevent the establishment of invasive species due to DKIST construction activities?***

Except for the one uncovered trash container, all mitigation measures were found to be implemented to prevent establishment of invasive species due to construction activities.

Earthmoving equipment were free of large deposits of soil, dirt and vegetation debris that could harbor alien arthropods. All construction materials, crates, shipping containers, packaging material, and observatory equipment were free of alien arthropods. Sanitary control of food and garbage is preventing use by invading ants and yellow jackets. Outdoor trash receptacles are secured to the ground, have attached lids and most have plastic liners. Their contents are collected frequently to reduce food availability for alien predators. The roll-off containers have heavy, hinged lids to prevent wind dispersal of garbage. Refuse is collected on a regular basis to ensure containers do not become full or overflow.

Some trash containers inside the observatory building were uncovered and contained debris susceptible to becoming wind-blown. Trash containers used for food waste were clean and lined with plastic bags. They are apparently washed regularly to reduce odors that attract ants. Plastic bag liners are used in all garbage containers receiving food to contain leaking fluids.

Construction materials stored at the site that are susceptible to becoming wind-blown were covered with tarps, or anchored in place. Excavated material was covered to prevent excess dust and the site is watered several times a day to prevent dust from vehicle traffic. There was no pieces of wind-blown trash in the habitat surrounding the site.

The Construction Site Manager and his crew do an excellent job ensuring that the construction site is a safe place to work, and has a minimal impact on the surrounding habitat.

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# APPENDIX A
# HO ARTHROPOD SPECIES LIST

**A list of Arthropod species detected during the Summer 2015 sampling at the HO site.**

| Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|
| Araneae | Linyphiidae | | | | unknown |
| Araneae | Lycosidae | Lycosa | hawaiiensis | simon | endemic |
| Lithobiomorpha | | | | | unknown |
| Entomobryidae | | | | | endemic |
| Isopoda | Porcellionidae | Porcellio | scaber | Latreille | non-indigenous |
| Coleoptera | Carabidae | Trechus | obtusus | Erichson | non-indigenous |
| Coleoptera | Cerambycidae | Plagithmysus | dubautianus | Gressit and Davis | endemic |
| Coleoptera | Cerambycidae | Plagithmysus | swezeyanus | Gressitt and Davis | endemic |
| Coleoptera | Coccinellidae | Coccinella | septempunctata | Linnaeus | non-indigenous |
| Coleoptera | Coccinellidae | Harmonia | conformis | (Boisduval) | non-indigenous |
| Coleoptera | Coccinellidae | Hippodemia | convergens | Gurein-Meneville | non-indigenous |
| Coleoptera | Coccinellidae | Olla | v-nigrum | (Mulsant) | non-indigenous |
| Coleoptera | Coccinellidae | Rodolia | cardinalis | (Mulsant) | non-indigenous |
| Coleoptera | Coccinellidae | Scymnus | sp. | | non-indigenous |
| Coleoptera | Ptiliidae | | | | unknown |
| Coleoptera | Staphylinidae | | | | unknown |
| Diptera | Anthomyiidae | Delia | platura | (Meigen) | non-indigenous |
| Diptera | Calliphoridae | Calliphora | latifrons | Hough | non-indigenous |
| Diptera | Calliphoridae | Calliphora | vomitoria | (Linnaeus) | non-indigenous |
| Diptera | Drosophilidae | | | | unknown |
| Diptera | Phoridae | Megaselia | | | non-indigenous |
| Diptera | Sciaridae | | | | unknown |
| Diptera | Sepsidae | Sepsis | thoracica | (Robineau-Desvoidy) | non-indigenous |
| Diptera | Syrphidae | Allograpta | exotica | (Weidemann) | non-indigenous |
| Diptera | Syrphidae | Eristalis | tenax | (Linneaus) | non-indigenous |
| Diptera | Syrphidae | | | | non-indigenous |
| Diptera | Tephritidae | Trupanea | crassipes | (Thomson) | endemic |
| Diptera | Tephritidae | Trupanea | cratericola | (Grimshaw) | endemic |
| Diptera | Tipulidae | SP1 | | | unknown |
| Heteroptera | Geocoridae | Geocoris | pallens | Stål | non-indigenous |
| Heteroptera | Lygaeidae | Neacoryphus | bicrucis | (Say) | non-indigenous |
| Heteroptera | Lygaeidae | Nysius | coenosulus | Stål | endemic |
| Heteroptera | Lygaeidae | Nysius | communis | Usinger | endemic |
| Heteroptera | Lygaeidae | Nysius | palor | Ashlock | endemic |
| Heteroptera | Miridae | Engytates | hawaiiensis | (Kirkaldy) | endemic |
| Heteroptera | Miridae | Hyalopeplus | pelucidus | Stål | endemic |
| Heteroptera | Miridae | Koanoa? | | | endemic? |

| Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|
| Heteroptera | Miridae | Taylorilygus | apicalis | (Fieber) | non-indigenous |
| Heteroptera | Miridae | Trigonotylus | hawaiiensis | (Kirkaldy) | endemic |
| Heteroptera | Rhyparochromidae | Brentiscerus | putoni (= australis) | (White) | non-indigenous |
| Homoptera | Aphididae | SP1 | | | non-indigenous |
| Homoptera | Cercopidae | Clastoptera | xanthocephala | Germar | non-indigenous |
| Homoptera | Cicadellidae | SP1 | | | unknown |
| Homoptera | Delphacidae | Nesosydne | sp. | | endemic |
| Homoptera | Psyllidae | Acizzia | uncatoides | (Ferris & Klyver) | non-indigenous |
| Homoptera | Psyllidae | SP1 | | | |
| Lepidoptera | Cosmopterigidae | Hyposmocoma | sp.1 | | endemic |
| Lepidoptera | Crambidae | Nomophila | noctuella | (Denis & Schiffermüller) | non-indigenous |
| Lepidoptera | Lycaenidae | Udara | blackburni | (Tuely) | endemic |
| Lepidoptera | Noctuidae | Agrotis | baliopa | Meyrick | endemic |
| Lepidoptera | Noctuidae | Agrotis | epicremna | Meyrick | endemic |
| Lepidoptera | Noctuidae | Agrotis | sp. A | | endemic? |
| Lepidoptera | Noctuidae | Agrotis | sp. B | | endemic? |
| Lepidoptera | Noctuidae | Agrotis | xiphias | Meyrick | endemic |
| Lepidoptera | Noctuidae | Peseudaletia | unipunctata | (Haworth) | non-indigenous |
| Lepidoptera | Oecophoridae | Thyrocopa | apatela | (Walsingham) | endemic |
| Lepidoptera | Tortricidae | | | | unknown |
| Odonata | Aeshnidae | Anax | junius | (Drury) | non-indigenous |
| Psocoptera | | | | | unknown |

# APPENDIX B
# DKIST ARTHROPOD SPECIES LIST

**A list of Arthropod species detected during the Summer 2015 sampling at the DKIST site.**

| Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|
| Araneae | Linyphiidae | | | | unknown |
| Araneae | Lycosidae | Lycosa | hawaiiensis | simon | endemic |
| Lithobiomorpha | | | | | unknown |
| Entomobryidae | | | | | endemic |
| Hypogastruridae | | | | | endemic |
| "Slugs" | | | | | non-indigenous |
| Coleoptera | Carabidae | Trechus | obtusus | Erichson | non-indigenous |
| Coleoptera | Chrysomelidae | | | | non-indigenous |
| Coleoptera | Coccinellidae | Coccinella | septempunctata | Linnaeus | non-indigenous |
| Coleoptera | Coccinellidae | Diomus | notescens | (Blackburn) | non-indigenous |
| Coleoptera | Coccinellidae | Hippodemia | convergens | Gurein-Meneville | non-indigenous |
| Coleoptera | Coccinellidae | Hyperaspis | pantherina or sylvestrii | | non-indigenous |
| Coleoptera | Coccinellidae | Olla | v-nigrum | (Mulsant) | non-indigenous |
| Coleoptera | Coccinellidae | Rodolia | cardinalis | (Mulsant) | non-indigenous |
| Coleoptera | Curculionidae | Anthonomus | eugenii | Cano | non-indigenous |
| Diptera | Anthomyiidae | Delia | platura | (Meigen) | non-indigenous |
| Diptera | Calliphoridae | Calliphora | latifrons | Hough | non-indigenous |
| Diptera | Calliphoridae | Calliphora | vomitoria | (Linnaeus) | non-indigenous |
| Diptera | Chironomidae | | | | unknown |
| Diptera | Drosophilidae | | | | unknown |
| Diptera | Phoridae | Megaselia | | | non-indigenous |
| Diptera | Sciaridae | | | | unknown |
| Diptera | Sepsidae | Sepsis | thoracica | (Robineau-Desvoidy) | non-indigenous |
| Diptera | Syrphidae | Allograpta | exotica | (Weidemann) | non-indigenous |
| Diptera | Syrphidae | Simosyrphus | grandicornis | (Macquart) | non-indigenous |
| Diptera | Syrphidae | Toxomerus | marginatus | (Say) | non-indigenous |
| Diptera | Syrphidae | | | | non-indigenous |
| Diptera | Tephritidae | Trupanea | cratericola | (Grimshaw) | endemic |
| Diptera | Tipulidae | SP1 | | | unknown |
| Heteroptera | Anthocoridae | | | | |
| Heteroptera | Lygaeidae | Nysius | coenosulus | Stål | endemic |
| Heteroptera | Lygaeidae | Nysius | communis | Usinger | endemic |
| Heteroptera | Lygaeidae | Nysius | lichenicola | Kirkaldy | endemic |
| Heteroptera | Lygaeidae | Pachybrachius | nr. fracticollis | | non-indigenous |
| Heteroptera | Miridae | Engytates | hawaiiensis | (Kirkaldy) | endemic |
| Heteroptera | Miridae | Hyalopeplus | pelucidus | Stål | endemic |
| Heteroptera | Miridae | Opuna | n. sp. 1 (of Krushelnycky) | | endemic |

| Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|
| Heteroptera | Miridae | Trigonotylus | hawaiiensis | (Kirkaldy) | endemic |
| Heteroptera | Pentatomidae | Nezara | viridula | Linnaeus | ohelo |
| Heteroptera | Rhyparochromidae | Brentiscerus | putoni (= australis) | (White) | non-indigenous |
| Homoptera | Aphididae | SP1 | | | non-indigenous |
| Homoptera | Cicadellidae | SP1 | | | unknown |
| Homoptera | Delphacidae | Nesosydne | sp. | | endemic |
| Homoptera | Pseudococcidae | SP 1 | | | unknown |
| Homoptera | Psyllidae | Acizzia | uncatoides | (Ferris & Klyver) | non-indigenous |
| Hymenoptera | Braconidae | Apateles | | | unknown |
| Hymenoptera | Colletidae | Hylaeus | nivicola | Meade-Waldo | endemic |
| Hymenoptera | Ichneumonidae | Gelis | | | non-indigenous |
| Hymenoptera | Ichneumonidae | Priostomerus | hawaiiensis | Perkins | non-indigenous |
| Hymenoptera | Torymidae | | | | |
| Hymenoptera | Vespidae | Vespula | pensylvanica | (Saussure) | non-indigenous |
| Lepidoptera | Cosmopterigidae | Hyposmocoma | sp.1 | | endemic |
| Lepidoptera | Crambidae | Eudonia | sp. | | endemic |
| Lepidoptera | Geometridae | Eupithecia | monticolans | Butler | endemic |
| Lepidoptera | Noctuidae | Agrotis | baliopa | Meyrick | endemic |
| Lepidoptera | Noctuidae | Agrotis | epicremna | Meyrick | endemic |
| Lepidoptera | Noctuidae | Agrotis | giffardi (or mesotoxa) | | endemic |
| Lepidoptera | Noctuidae | Agrotis | sp. A | | endemic? |
| Lepidoptera | Oecophoridae | Thyrocopa | apatela | (Walsingham) | endemic |
| Psocoptera | | | | | unknown |
| Thysanoptera | | | | | unknown |

# APPENDIX C
# HALE ES ARTHROPOD SPECIES LIST

**A list of Arthropod species detected during the Summer 2015 sampling at the HALE Entrance Station.**

| Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|
| Araneae | Clubionidae | Cheiracanthium | mordax | L. Koch | non-indigenous |
| Araneae | Linyphiidae | | | | unknown |
| Araneae | Tetragnathidae | | | | unknown |
| Araneae | Theridiidae | Steatoda | grossa | (C. L. Koch) | non-indigenous |
| Araneae | Theridiidae | | | | unknown |
| Araneae | Thomisidae | Mecaphesa | sp. nr. kanakanus | (Karsch) | endemic |
| Lithobiomorpha | | | | | unknown |
| Entomobryidae | | | | | endemic |
| Hypogastruridae | | | | | endemic |
| Isopoda | Porcellionidae | Porcellio | scaber | Latreille | non-indigenous |
| Julida | Allajulus | latistriatus | | (Curtis) | non-indigenous |
| "Slugs" | | | | | non-indigenous |
| Stylommatophora | Zonitidae | Oxychilus | alliarius | (J.S. Miller) | non-indigenous |
| Coleoptera | Carabidae | Mecyclothorax | spp. | | endemic |
| Coleoptera | Carabidae | Trechus | obtusus | Erichson | non-indigenous |
| Coleoptera | Chrysomelidae | Paropsisterna | m-fuscum | | non-indigenous |
| Coleoptera | Coccinellidae | Olla | v-nigrum | (Mulsant) | non-indigenous |
| Coleoptera | Coccinellidae | Rhyzobius | lophanthae | (Blaisdell) | non-indigenous |
| Coleoptera | Curculionidae | Gonipterus | scutellatus | | non-indigenous |
| Coleoptera | Curculionidae | Otiorhynchus | cribricollis | Gyllenhal | non-indigenous |
| Coleoptera | Curculionidae | Tychius | picirostris | (Fabricius) | non-indigenous |
| Coleoptera | Staphylinidae | | | | unknown |
| Dermaptera | Forficulidae | Forficula | auricularia | Linnaeus | non-indigenous |
| Diptera | Anisopodidae | Sylvicola | cinctus | (Fabricius) | non-indigenous |
| Diptera | Anthomyiidae | Delia | platura | (Meigen) | non-indigenous |
| Diptera | Calliphoridae | Calliphora | latifrons | Hough | non-indigenous |
| Diptera | Calliphoridae | Calliphora | vomitoria | (Linnaeus) | non-indigenous |
| Diptera | Calliphoridae | Lucilia | sericata | (Meigen) | non-indigenous |
| Diptera | Calliphoridae | Phormia | regina | (Meigen) | non-indigenous |
| Diptera | Drosophilidae | | | | unknown |
| Diptera | Sarcophagidae | Blaesoxipha | plinthopyga | (Wiedemann) | non-indigenous |
| Diptera | Sciaridae | | | | unknown |
| Diptera | Sepsidae | Sepsis | thoracica | (Robineau-Desvoidy) | non-indigenous |
| Diptera | Syrphidae | Toxomerus | marginatus | (Say) | non-indigenous |
| Diptera | Syrphidae | | | | non-indigenous |

| Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|
| Diptera | Tephritidae | Trupanea | crassipes | (Thomson) | endemic |
| Diptera | Tipulidae | SP1 | | | unknown |
| Heteroptera | Lygaeidae | Pachybrachius | nr. fracticollis | | non-indigenous |
| Heteroptera | Miridae | Hyalopeplus | pelucidus | Stål | endemic |
| Heteroptera | Miridae | Orthotylus | coprosmaphila | Polhemus | endemic |
| Heteroptera | Miridae | Orthotylus | sophoriodes | Polhemus | endemic |
| Heteroptera | Nabidae | Nabis | capsiformis | Germar | non-indigenous |
| Heteroptera | Rhyparochromidae | Brentiscerus | putoni (= australis) | (White) | non-indigenous |
| Homoptera | Aphididae | SP1 | | | non-indigenous |
| Homoptera | Cicadellidae | Nesophrosyne | sp. 1 | | endemic |
| Homoptera | Psyllidae | Acizzia | uncatoides | (Ferris & Klyver) | non-indigenous |
| Homoptera | Psyllidae | Ctenarytaina | eucalypti | (Maskell) | non-indigenous |
| Hymenoptera | Bethylidae | Sierola | spp. | | endemic |
| Hymenoptera | Braconidae | Meteorus | laphygmae | Viereck | non-indigenous |
| Hymenoptera | Crabronidae | Ectemnius | nesiotes | (Pate) | endemic |
| Hymenoptera | Encyrtidae | Psyllaephagus | pilosus | (Maskell) | non-indigenous |
| Hymenoptera | Formicidae | Cardiocondyla | kagutsuchi/venestula | | non-indigenous |
| Hymenoptera | Formicidae | Hypoponera | opaciceps | (Mayr) | non-indigenous |
| Hymenoptera | Formicidae | Linepithema | humile | (Mayr) | non-indigenous |
| Hymenoptera | Ichneumonidae | Gelis | | | non-indigenous |
| Hymenoptera | Vespidae | Odynerus | | | endemic |
| Lepidoptera | Carposinidae | Carposina | sp. A | | endemic |
| Lepidoptera | Carposinidae | Carposina | sp. B | | endemic |
| Lepidoptera | Carposinidae? | Carposina? | sp. C? | | endemic? |
| Lepidoptera | Cosmopterigidae | Hyposmocoma | sp.1 | | endemic |
| Lepidoptera | Crambidae | Eudonia | sp. | | endemic |
| Lepidoptera | Crambidae | Mestolobes | | | endemic |
| Lepidoptera | Crambidae | Udea | heterodoxa | (Meyrick) | endemic |
| Lepidoptera | Crambidae | Udea | pyranthes | (Meyrick) | endemic |
| Lepidoptera | Crambidae | Uresiphita | polygonalis | (Butler) | endemic |
| Lepidoptera | Geometridae | Eupithecia | monticolans | Butler | endemic |
| Lepidoptera | Geometridae | Scotorythra | corticea | (Butler) | endemic |
| Lepidoptera | Geometridae | Scotorythra | paludicola | (Butler) | endemic |
| Lepidoptera | Lycaenidae | Udara | blackburni | (Tuely) | endemic |
| Lepidoptera | Noctuidae | Agrotis | baliopa | Meyrick | endemic |
| Lepidoptera | Noctuidae | Agrotis | giffardi (or mesotoxa) | | endemic |
| Lepidoptera | Noctuidae | Agrotis | ipsilon | (Hufnagel) | non-indigenous |
| Lepidoptera | Noctuidae | Agrotis | xiphias | Meyrick | endemic |
| Lepidoptera | Noctuidae | Athetis | thoracica | (Moore) | non-indigenous |
| Lepidoptera | Noctuidae | Chrysodeixis | eriosoma | (Doubleday) | non-indigenous |
| Lepidoptera | Noctuidae | Haliophyle | sp. A | | endemic |
| Lepidoptera | Noctuidae | Megalographa | biloba | (Stephens) | non-indigenous |
| Lepidoptera | Noctuidae | Peridroma | cinctipennis | (Warren) | endemic |

| Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|
| Lepidoptera | Noctuidae | Peridroma | cinctipennis | (Butler) | endemic |
| Lepidoptera | Noctuidae | Peseudaletia | unipunctata | (Haworth) | non-indigenous |
| Lepidoptera | Noctuidae | Pseudaletia | sp. A (large reddish) | | endemic |
| Lepidoptera | Pterophoridae | Stenoptilodes | littoralis | (Meyrick) | non-indigenous |
| Lepidoptera | Pterophoridae | Stenoptilodes | littoralis | (Meyrick) | non-indigenous |
| Lepidoptera | Tortricidae | Bactra | straminea | (Butler) | non-indigenous? |
| Lepidoptera | Tortricidae | | | | unknown |
| Neuroptera | Hemerobiidae | SP1 | | | |
| Neuroptera | Hemerobiidae | | | | unknown |
| Psocoptera | | | | | unknown |

# Programmatic Arthropod Monitoring at the Haleakalā High Altitude Observatories and Haleakalā National Park Maui, Hawaiʻi

**February 2015**

**Prepared for**

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

## I. TABLE OF CONTENTS

# II. EXECUTIVE SUMMARY

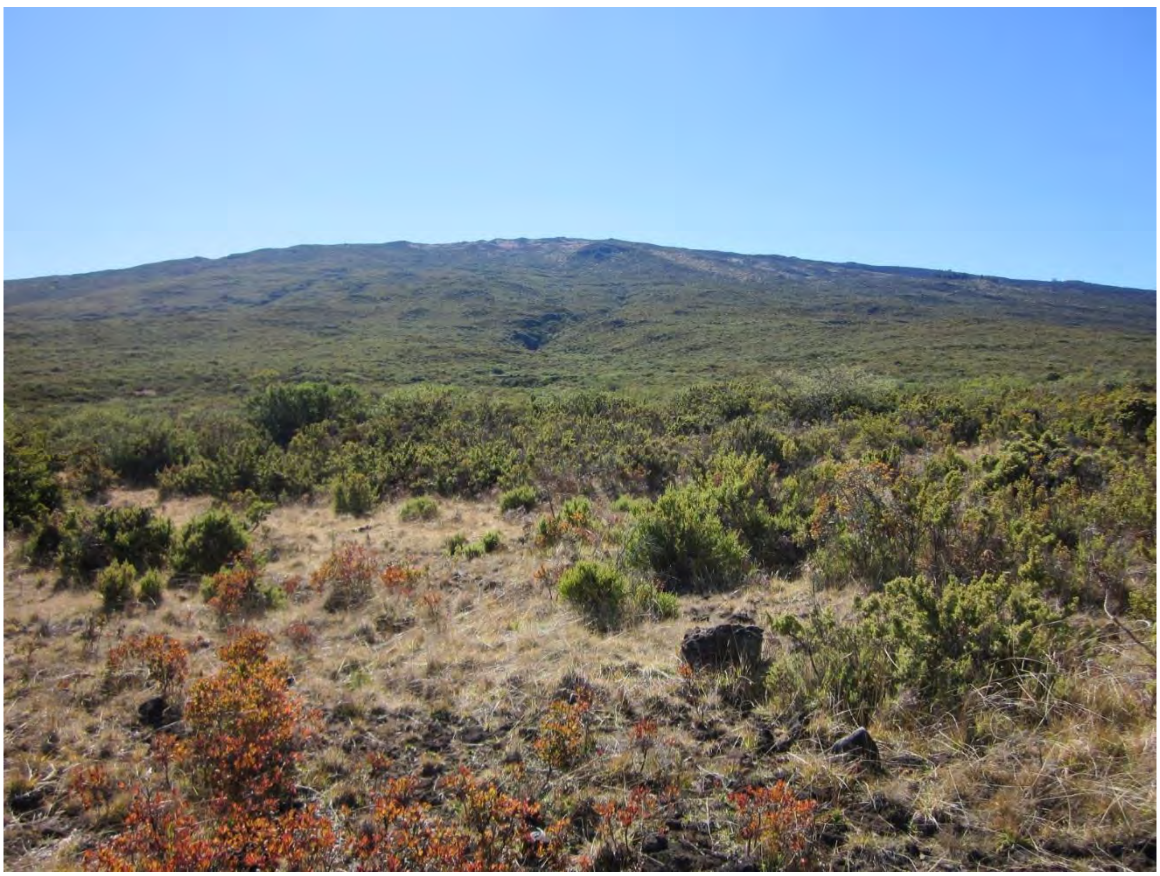
The National Science Foundation (NSF) has authorized the development of the Daniel K. Inouye Solar Telescope (DKIST), previously known as the Advanced Technology Solar Telescope (ATST)) within the 18-acre University of Hawai`i Institute for Astronomy High Altitude Observatories (HO) site. The DKIST represents 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 DKIST Project.

After preliminary sampling near the HALE Entrance Station and at the DKIST site 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 which began in December 2012. Semi-annual monitoring has occurred in 2011, 2012, 2013, and 2014.

This report presents the results of the Winter 2015 sampling. The goal is to monitor the arthropod fauna at the DKIST site and along the HALE Road Corridor, identify Hawaiian native arthropod species or habitats, if any, that may be impacted by construction 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.



Subalpine shrubland above the HALE Entrance Station

# 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 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 2015 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 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 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 biological changes.

The scientific scope of the current phase of Arthropod Monitoring is to repeatedly sample arthropod habitats that may be impacted by construction of the 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 using 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. Although the overall footprint of DKIST is about 0.74 ac, the site where DKIST construction is currently taking place is approximately 0.24-ha (0.6 ac) of previously undisturbed 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 January 2015, 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 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 # FHM15-364), effective date January 1, 2015 – December 31, 2015, and the National Park Service (Permit # HALE-2010-SCI-0001) issued on March 22, 2010. Sampling began on January 13, 2015 and was completed on January 20, 2015.

# 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 highest point on the HO site is at 3,052-m (10,012-ft) above sea level. 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 at 3,042-m (9,980-ft) above sea level. 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 seven days at the DKIST site and for seven 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. Even though the petrels were not nesting at the time of the sampling, efforts were made to avoid known burrows. Pitfall traps are placed below ground and covered with a heavy cap rock. This makes it very unlikely that petrels could access the traps.

All pitfall traps were installed on January 13, 2015 and their contents collected on January 19, 2015.

## 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 circumstances beyond our control.

### 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 beat again to dislodge persistent individuals. Care was taken to avoid sensitive plants and to leave 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. Five baited traps were deployed on the HO and DKIST sites on three 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), Gagné (1997), Polhemus (2002, 2005, 2011, 2014), and Asquith (1994, 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 January 13, 2015 and ending on January 20, 2015. 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 60 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-two species of arthropods were detected at the HO site (excluding the Air Force Facility and the DKIST site). The species included eleven endemic species, six non-indigenous species, and five of unknown status.

**Spiders and Mites - Arachnida**

Abundant juvenile and adult Lycosid spiders, *Lycosa hawaiiensis* Simon, occurred in pitfall traps, and were actively foraging among rocks. In one of the pitfall traps, in which all water had evaporated, an adult Lycosid was captured with numerous juvenile crawling on its back. Wolf spiders often carry their eggs in an egg sac attached to the spinnerets at the end of the abdomen. The abdomen is held in a raised position to keep the egg case from dragging on the ground. The adult Lycosid is not handicapped by this burden, and is still capable of hunting. When the juveniles emerge from their protective silken case, they climb up their mother's legs onto her abdomen.

Small red mites were observed, commonly occurring in leaf litter under vegetation.

**Beetles – Order Coleoptera**

Three beetle species were observed at the HO site. The non-indigenous seven-spotted lady bird beetle (*Hippodamia convergens* Guerin-Meneville) was infrequent at the site, found on vegetation. A single specimen of the non-indigenous vegetable weevil, *Listroderes costirostris* Schonherr, was found on *Dubautia*. A small rove beetle (family Staphylinidae) was collected in a pitfall trap.

**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**

Four species of flies were detected at the HO site. Two species were indigenous, a fungus gnat and a humpedback fly. The two non-indigenous species included a blowfly and a flesh fly, both common flying around vegetation and rocks.

**True Bugs – Orders Heteroptera and Homoptera**

Six species of true bugs (order Heteroptera) were observed including adults and nymphs of four Hawaiian endemic species in the genus *Nysius*. Two of these species (*Nysius coenosulus* and *N. communis*) are common residents at the site and occur in abundance on both *Dubautia* and *pukiawe*. The other two species (*Nysius lichenicola* and *N. terrestris*) occur infrequently in leaf litter. Other true bugs were from the family Miridae, *Engytates hawaiiensis* (Kirkaldy) is uncommon, found on *Dubautia*, and *Trigonotylus hawaiiensis* (Kirkaldy), found on grasses. Both are endemic species.

One endemic species of plant hoppers of the genus *Nesosydne* was common on *Dubautia*.

**Butterflies and Moths – Order Lepidoptera**

At least four species Lepidoptera were found at the HO site. These include three endemic species in the genus *Agrotis*, and the non-indigenous *Pseudalecia unipuncta* (Meyrick). All were collected in light traps.

Large caterpillars, probably also of the genus *Agrotis*, were common in pitfall traps. These caterpillars were observed foraging at night. During the day they burrow into loose cinder to avoid predation and desiccation. Smaller caterpillars uncommon in pitfall traps were likely larva of the Haleakalā flightless moth.

**Other Observations**

A single, small red-colored centipede was found near a washing station at HO. This is likely the species *Lamyctes emarginatus* Newport, a non-indigenous resident at the summit.

No yellow-faced bees were observed at the HO site, although they were common at the DKIST site. These bees occur on blooming *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 2015 sampling session. The excavation for the DKIST foundation resulted in the removal of much of the vegetation at the site. Vegetation is now limited to the area surrounding the excavation and is mostly undisturbed.

Twenty-seven species of arthropods were collected at the DKIST site during the winter 2015 sampling session. The species included fifteen endemic Hawaiian arthropods, eight non-indigenous arthropods, and four species of unknown status.

**Spiders and Mites - Arachnida**

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.

Small red mites were observed, commonly occurring in leaf litter under vegetation.

**Collembola - Springtails**

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

**Flies - Order Diptera**

Six species of flies were detected at the DKIST site. They include blowflies, a midge, two syrphids, a humpbacked fly, and a small gnat. The humpbacked fly, and the small gnat indigenous. No endemic fruit flies (family Tephritidae) were observed.

**True Bugs – Orders Heteroptera and Homoptera**

Six species of true bugs (Order Heteroptera) were observed at the DKIST site, including five endemic species. Adults and nymphs of two species of the Hawaiian endemic seed bug genus *Nysius* (*N. coenosulus* Stål and *N. communis* Usinger) were abundant on *Dubautia* and *pukiawe*. A third species of this genus (*N. lichenicola* Kirkaldy) was found in leaf litter under plants. The abundance of this species was infrequent. A single specimen of the non-indigenous *Geocoris pallens* Stål was also collected in a pitfall trap.

Adults and nymphs of two plant bugs (family Miridae) were also observed. *Engytates hawaiiensis* (Kirkaldy) is uncommon, found on *Dubautia*, and *Trigonotylus hawaiiensis* (Kirkaldy), is found only on grasses. Both are endemic species.

Three species of Homoptera were collected, including a species of the endemic genus *Nesosydne* that was abundant on *Dubautia*. Non-indigenous species include a species of aphid and planthopper. Both of these species were infrequent.

**Bees and Wasps – Order Hymenoptera**

The endemic species of yellow-faced bees, *Hylaeus nivicola* Meade Waldo, was common on pukiawi. Other Hymenoptera observed include honey bees and a small parasitic wasp.

**Moths – Order Lepidoptera**

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

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. Twenty-nine species of arthropods were collected and observed there. The species included eleven endemic Hawaiian arthropods, thirteen non-indigenous arthropods, and five species of unknown status.

**Spiders and Mites - Arachnida**

One species of crab spider (family Thomiscidae) was uncommon on vegetation. A single specimen of another spider, of unknown status, was also observed.

Small red mites were observed, commonly occurring in leaf litter under vegetation.

**Collembola - Springtails**

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

**Beetles – Order Coleoptera**

Two species of beetles were observed, including the non-indigenous ground beetle *Trechus obtusus* Erichson, and an unknkown rove beetle (family Staphylinidae). Both were infrequent.

**Flies – Order Diptera**

Four species of flies were seen at the HALE ES, all non-indigenous species from the families Calliphoridae, Muscidae, Tachinidae.

**True Bugs – Orders Heteroptera and Homoptera**

Two species of true bugs (Heteroptera) were found, both from the family Miridae. *Orthotylus coprosmophila* Polhemus was common on *Coprosma*, and *Orthotylus sophoriodes* Polhemus was abundant on *manane*.

One species of Homoptera was observed. This species, from the indigenous genus *Nesophrosyne* (family Cicadellidae), was uncommon on vegetation.

**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 Eurytomidae), one species of Ichneumonidae, one invasive ant, *Linepithema humile* (Mayr), and three species of indigenous yellow-faced bee (*Hylaeus nivicola* Meade Waldo, *H. difficillis* (Perkins), and *H. volitilis* (F. Smith)). 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.

**Butterflies and Moths – Order Lepidoptera**

Five species of Lepidoptera were observed or captured during this study at the HALE ES. The list includes three endemic species and two non-indigenous species. Endemic species of microlepidoptera, a Cosmopterigidae, a Crambidae, and a Tortricidae were observed. The introduced Lantana moth was also present, along with a large orange sulphur (*Phoebis agarithe* (Boisduval)).

**Other Observations**

Four other arthropods were observed at the HALE ES, including a centipede, a millipede, a Pscoptera, and a sowbug.

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 any of the sites.

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.

Native vegetation is recovering at the DKIST site and at least some recovery in arthropod abundance may be expected once these plants mature and flower. 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 2015 sampling at the HO site.**

| Class | Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|---|
| Arachnida | Acari | mite | | | | unknown |
| Arachnida | Araneae | Lycosidae | Lycosa | hawaiiensis | simon | endemic |
| Chilopoda | Lithobiomorpha | Henicopidae | Lamyctes | emarginatus | Newport | non-indigenous |
| Collembola | Entomobriidae | | | | | endemic |
| Insecta | Coleoptera | Coccinellidae | Coccinella | septempunctata | Linnaeus | non-indigenous |
| Insecta | Coleoptera | Curculionidae | Listroderes | costirostris | Schonherr | non-indigenous |
| Insecta | Coleoptera | Staphylinidae | | | | unknown |
| Insecta | Diptera | Calliphoridae | Calliphora | vomitoria | (Linnaeus) | non-indigenous |
| Insecta | Diptera | Phoridae | | | | endemic |
| Insecta | Diptera | Sarcophagidae | | | | non-indigenous |
| Insecta | Diptera | Sciaridae | | | | endemic |
| Insecta | Heteroptera | Lygaeidae | Nysius | coenosulus | Stål | endemic |
| Insecta | Heteroptera | Lygaeidae | Nysius | communis | Usinger | endemic |
| Insecta | Heteroptera | Lygaeidae | Nysius | lichenicola | Kirkaldy | endemic |
| Insecta | Heteroptera | Lygaeidae | Nysius | terrestris | Usinger | endemic |
| Insecta | Heteroptera | Miridae | Engytates | hawaiiensis | (Kirkaldy) | endemic |
| Insecta | Heteroptera | Miridae | Trigonotylus | hawaiiensis | (Kirkaldy) | endemic |
| Insecta | Homoptera | Delphacidae | Nesosydne | sp. 1 | | endemic |
| Insecta | Lepidoptera | Noctuidae | Agrotis | baliopa | Meyrick | endemic |
| Insecta | Lepidoptera | Noctuidae | Agrotis | epicremna | Meyrick | endemic |
| Insecta | Lepidoptera | Noctuidae | Agrotis | mesotoxa | Meyrick | endemic |
| Insecta | Lepidoptera | Noctuidae | larvae | | | unknown |
| Insecta | Lepidoptera | Noctuidae | Pseudaletia | unipunctata | (Haworth) | non-indigenous |
| Insecta | Lepidoptera | Oecophoridae | Thryocopa | apatela | (Walsingham) | endemic |

# APPENDIX B
# DKIST ARTHROPOD SPECIES LIST

**A list of Arthropod species detected during the Winter 2015 sampling at the DKIST site.**

| Class | Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|---|
| Arachnida | Acari | mite | | | | unknown |
| Arachnida | Araneae | Lycosidae | Lycosa | hawaiiensis | simon | endemic |
| Collembola | Entomobriidae | | | | | endemic |
| Insecta | Diptera | Calliphoridae | Calliphora | vomitoria | (Linnaeus) | non-indigenous |
| Insecta | Diptera | Chironomidae | | | | unknown |
| Insecta | Diptera | Phoridae | | | | endemic |
| Insecta | Diptera | Sciaridae | | | | endemic |
| Insecta | Diptera | Syrphidae | Allograpta | exotica | (Weidemann) | non-indigenous |
| Insecta | Diptera | Syrphidae | Eristalis | tenax | (Linneaus) | non-indigenous |
| Insecta | Heteroptera | Lygaeidae | Geocoris | pallens | Stål | non-indigenous |
| Insecta | Heteroptera | Lygaeidae | Nysius | coenosulus | Stål | endemic |
| Insecta | Heteroptera | Lygaeidae | Nysius | communis | Usinger | endemic |
| Insecta | Heteroptera | Lygaeidae | Nysius | lichenicola | Kirkaldy | endemic |
| Insecta | Heteroptera | Miridae | Engytates | hawaiiensis | (Kirkaldy) | endemic |
| Insecta | Heteroptera | Miridae | Trigonotylus | hawaiiensis | (Kirkaldy) | endemic |
| Insecta | Homoptera | Aphididae | | | | non-indigenous |
| Insecta | Homoptera | Cicadellidae | SP1 | | | unknown |
| Insecta | Homoptera | Delphacidae | Nesosydne | sp. 1 | | endemic |
| Insecta | Hymenoptera | Apidae | Apis | mellifera | Linneaus | non-indigenous |
| Insecta | Hymenoptera | Colletidae | Hylaeus | nivicola | Meade-Waldo | endemic |
| Insecta | Hymenoptera | Eurytomidae | | | | non-indigenous |
| Insecta | Lepidoptera | Noctuidae | Agrotis | baliopa | Meyrick | endemic |
| Insecta | Lepidoptera | Noctuidae | Agrotis | epicremna | Meyrick | endemic |
| Insecta | Lepidoptera | Noctuidae | Agrotis | mesotoxa | Meyrick | endemic |
| Insecta | Lepidoptera | Noctuidae | larvae | | | unknown |
| Insecta | Lepidoptera | Noctuidae | Pseudaletia | unipunctata | (Haworth) | non-indigenous |
| Insecta | Lepidoptera | Oecophoridae | Thryocopa | apatela | (Walsingham) | endemic |

# APPENDIX B
# HALE ES ARTHROPOD SPECIES LIST

**A list of Arthropod species detected during the Winter 2015 sampling at the HALE Entrance Station.**

| Class | Order | Family | Genus | Species | Authority | Status |
|---|---|---|---|---|---|---|
| Arachnida | Acari | | | | | unknown |
| Arachnida | Araneae | Thomisidae | | | | endemic |
| Arachnida | Araneae | Unknown 2 | | | | unknown |
| Chilopoda | Lithobiomorpha | Henicopidae | Lamyctes | emarginatus | Newport | non-indigenous |
| Collembola | Entomobriidae | | | | | endemic |
| Crustacea | Isopoda | Porcellionidae | Porcellio | scaber | Latreille | non-indigenous |
| Diplopoda | Julida | Julidae | Allajulus | latistriatus | (Curtis) | non-indigenous |
| Insecta | Coleoptera | Carabidae | Trechus | obtusus | Erichson | non-indigenous |
| Insecta | Coleoptera | Staphylinidae | | | | unknown |
| Insecta | Diptera | Calliphoridae | Calliphora | vomitoria | (Linnaeus) | non-indigenous |
| Insecta | Diptera | Muscidae | Haematobia | irritans | (Linnaeus) | non-indigenous |
| Insecta | Diptera | Tachinidae | SP1 | | | non-indigenous |
| Insecta | Diptera | Tachinidae | SP2 | | | non-indigenous |
| Insecta | Heteroptera | Miridae | Orthotylus | coprosmophila | Polhemus | endemic |
| Insecta | Heteroptera | Miridae | Orthotylus | sophoriodes | Polhemus | endemic |
| Insecta | Homoptera | Cicadellidae | Nesophrosyne | sp. | | endemic |
| Insecta | Hymenoptera | Apidae | Apis | mellifera | Linneaus | non-indigenous |
| Insecta | Hymenoptera | Colletidae | Hylaeus | nivicola | Meade-Waldo | endemic |
| Insecta | Hymenoptera | Collitidae | Hylaeus | difficillis | (Perkins) | endemic |
| Insecta | Hymenoptera | Collitidae | Hylaeus | volatilis | F. Smith | endemic |
| Insecta | Hymenoptera | Eurytomidae | | | | non-indigenous |
| Insecta | Hymenoptera | Formicidae | Hypoponera | opaciceps | (Mayr) | non-indigenous |
| Insecta | Hymenoptera | Ichneumonidae | Echthromorpha | agrestoria | (Fabricius) | endemic |
| Insecta | Lepidoptera | Cosmopterigidae | Hyposmocoma | sp.1 | | endemic |
| Insecta | Lepidoptera | Crambidae | Omiodes | sp. | | endemic |
| Insecta | Lepidoptera | Pieridae | Phoebis | agarithe | (Boisduval) | non-indigenous |
| Insecta | Lepidoptera | Pterophoridae | Stenoptilodes | littoralis | (Meyrick) | non-indigenous |
| Insecta | Lepidoptera | Torticidae | Cydia | plicata | (Walsingham) | endemic |
| Insecta | Pscoptera | | | | | unknown |

# Invasive non-native Plant Control for the Haleakala High Altitude Observatory Site (HO) 2015

Arthur C. Medeiros Ph.D. (artcmedeiros@gmail.com) March 31, 2015

Invasive plant control for the Haleakala High Altitude Observatory Site (HO) has been successfully completed for 2015, the sixth successive year of invasive plant control at the site. The weather was ideal, warm, sunny and near windless and the effort went extremely well.

In summary, in terms of invasives, generally, the site is looking very good, especially compared to similar sites at high elevation where invasive plant control is not being implemented. It is also much improved compared to the number of invasive plant species and their biomass found in this same area when this project started six years ago. *Lepidium*, which at project onset, numbered in the thousands, was restricted to about 50 individuals this year.

The HO site functionally now has two types of areas with distinct invasive plant species characteristics. The first type has never had substantial ground disturbance and are more intact with original rocks and vegetation. Here, invasive plant species and apparently their seed banks have largely been eliminated over the six years of invasive plant control. In these areas, native shrubs and grasses dominate the vegetation. Although these areas have been reduced in terms of area by construction over the last two years, the remaining areas are more weed free than similar sites in adjacent Haleakala National Park and would be suitable for more guided native plant restoration in the future if desired.

The second type of area are those highly modified areas such as those used for storage of equipment and large stores of building materials that have been compacted as well as between and around buildings. Invasive plants thrive in disturbed sites like these and these trampled areas may well become very weedy in the future without invasive species control.

Invasive plant control work was performed this year in spring instead of summer as it usually has been. For some species, the spring timing was ideal. An example was Kentucky bluegrass (*Poa pratensis*), a persistent invasive that is difficult to control in late summer due to pale fading foliage had dark green foliage at this time of year; spring application was ideal for this species. For other species, spring was less ideal. For example, early in season, grasses at the site are sterile and hence more difficult to identify. The similarity when sterile of native grasses *Deschampsia nubgena* and *Trisetum glomeratum* with other non-native grasses present at the site requires caution.

Utilizing a low pressure backpack sprayer, approximately 3.8 gallons of 1.5% glyphosate (Roundup)-water mix were successfully applied this year at times when the summit had very low wind speeds and sunny clear skies.

All persons engaged in mechanical and herbicidal control this year were experienced, completely briefed and repeatedly tested to make sure they could differentiate between native and non-native species in the local flora, had completed Safety and Environmental Compliance Training at the Daniel K. Inouye Solar Telescope facility in Pukalani, and were aware of parcel boundaries. As in previous years, > 95% of invasive plants found within the work site were treated with herbicide this season. All detectable invasive plants located in multiple sweeps were removed or treated. In sensitive areas, a weighted cardboard box was again used to protect native species while spraying.

**DEPARTMENT OF THE AIR FORCE**
**AIR FORCE RESEARCH LABORATORY**
**(AFMC)**

2 Dec 2015

Memorandum for the Record

SUBJECT: Maui Space Surveillance Complex located within the Haleakalā High Altitude Observatory (HO) Invasive Plant Control Report (Reporting Period 1 Nov 2014 to 31 Oct 2015)

1. The Air Force Research Laboratory (AFRL) Directed Energy Directorate, Detachment 15, Maui HI occupies 4.4 acres within the HO. The AFRL manages this property IAW Lease Agreement, AF instructions and guidance AFI 32-7064 and incompliance with DoD, State and Federal laws. Detachment 15 follows an Integrated Natural Resources Management Plan and Integrated Pest Management Plan to assist the installation commander with the conservation and rehabilitation of natural resources where practical. The goals of the INRMP are:

   a. Ensure populations of threatened and endangered species on or near the site are protected and managed in compliance with the Endangered Species Act of 1973, as amended (ESA);

   b. Foster an atmosphere of coordination and cooperation with the U.S. Fish and Wildlife Service (USFWS), National Park Service (NPS), and Hawaii Department of Land and Natural Resources (DLNR) to inventory, map, and preserve endangered species on or near the site;

   c. Prevent the introduction or spread of invasive species to the summit area. The sparse vegetation of the site limits grounds maintenance to periodic cleanup and removal of noxious weeds growing around buildings and paved areas. AFRL does not use herbicides for invasive species control, relying only one mechanical treatment methods and there is a semi-annual pickup of loose trash around the site.

   d. Any contractor working at the MSSC is required to take the following measures to prevent construction or repair activities from introducing new species:

      1) Any equipment, supplies, and containers with construction materials that originate from elsewhere (e.g., the other islands or the mainland) must be checked for infestation by unwanted species by a qualified biologist or agricultural inspector prior to being transported to the summit. All construction vehicles that will be used off paved surfaces must be steam cleaned/pressure washed before they travel or are transported through Haleakalā National Park. All construction and maintenance contracts include provisions for the contractors to comply with IfA HOMP and site environmental requirements.

2) Importation of fill material to the site is prohibited, unless such fill (e.g., sand) is sterilized to remove seeds, larvae, insects, and other biota that could survive at HO and propagate. All material obtained from excavation is to remain on Haleakalā. Surplus excavated cinders, soil, etc., is to be offered to other agencies located at the summit or Haleakalā National Park.

3) Contractors are required to participate in HO-approved pre-construction briefings to inform workers of the damage that can be done by unwanted introductions. Satisfactory fulfillment of this requirement can be evidenced by a signed certification from the contractor.

4) Parking of heavy equipment and storage of construction materials outside the immediate confines of HO property is prohibited.

5) Contractors are required to remove construction trash frequently, particularly materials that could serve as a food source that would increase the population of mice and rats that prey on native species.

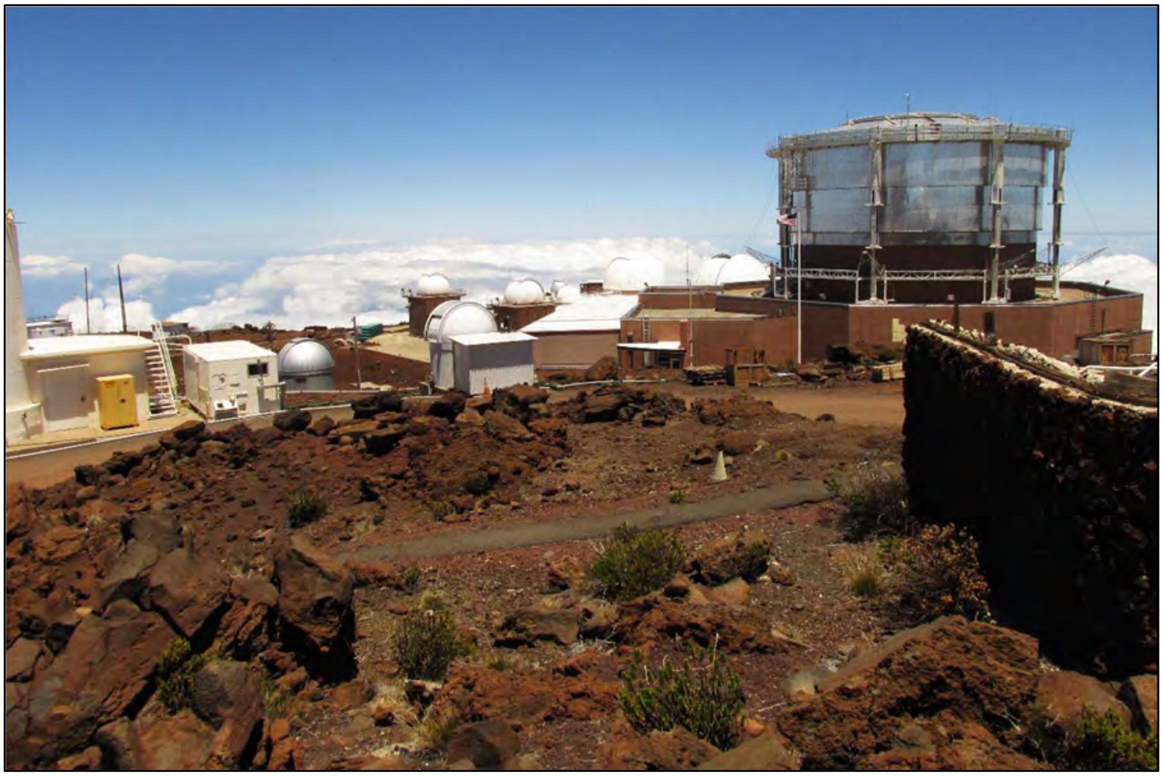
2. During this reporting period AFRL increased the mechanical removal of invasive species by maintenance personnel to monthly to ensure invasive species do not build up excessively. This frequency will minimize the propagation of unwanted non-native species at the MSSC site.

3. If you have any questions regarding AFRL/Det 15 invasive species control please contact Mr. Jim Gardner at 808-891-7748 or me at 505-846-4574.

Michelle Hedrick

Michelle Hedrick
Lead Test & Environmental Engineer

# FAUNAL SURVEY
# HALEAKALA OBSERVATORIES
# SPRING 2015



Prepared for:
**KC Environmental**
**Maui, Hawaii**

Prepared by:
**Forest Starr & Kim Starr**
**Starr Environmental**
**Maui, Hawaii**

**May 2015**

## OVERVIEW

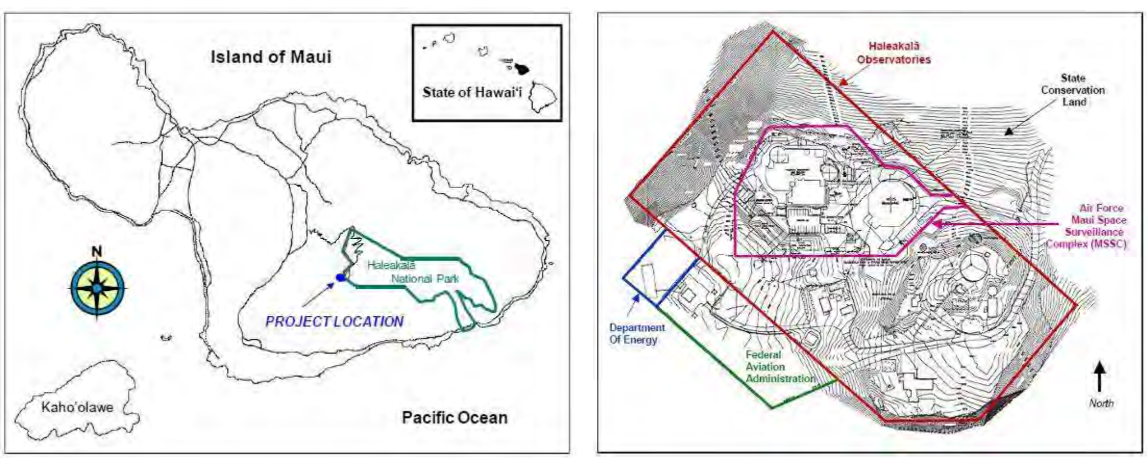
The Daniel K. Inouye Solar Telescope (DKIST), will be a 4-meter (13.1 ft) optical telescope, contained in a structure 41.5 meters (136 ft) tall, to serve the solar physics community. It will host an array of instruments designed to provide insights about the sun.

In accordance with the Final Environmental Impact Statement (FEIS) (NSF 2009), programmatic monitoring has been implemented during construction and will be continued after construction of DKIST, which began in December 2012, to ensure that impacts on biological resources are minimized. Monitoring includes field observations at Haleakala High Altitude Observatories Site (HO) and selected areas of the Haleakala National Park (HALE) Park road corridor for faunal presence, e.g., scat, tracks, eaten plants, etc. This document reports on the survey of HO.

## PROJECT LOCATION

The DKIST construction site is approximately 0.75 acre and is located on TMK 222007008 (HO is a 18.166-acre parcel largely within the Kolekole cinder cone, and is roughly rectangular in shape. It is mostly surrounded by State Conservation District lands, with a small adjoining Federal property on the southwest boundary, and Haleakala National Park nearby to the East.

Additionally, about 17 km (11 miles) of road that travels through Haleakala National Park is being utilized during construction and operation of the DKIST.




**General and detailed site location maps of Haleakala Observatories.**

## BIOLOGICAL SETTING

HO is located near the summit of Haleakala, at 2,999-3,052 m (9,840-10,012 ft) elevation. Average annual rainfall is a moderate 1,037 mm (41 in), occurring primarily during the winter months from November through March (Giambelluca et al. 2013). Temperatures can be cold at the site, and occasionally dip below freezing, with average annual temperature at the summit of Haleakala ranging from 43-50 degrees F (6-10 degrees C), and once every few years it will snow (County of Maui, 1998). The soils are volcanic, a mixture of ash, cinders, pumice, and lava (RTS, 2002). Vegetation at HO is relatively sparse, a mix of native and non-native plants.

There are very few birds at HO, except for Hawaiian Petrels (*Pterodroma sandwichensis*), which occupy pre-existing or bird excavated burrows under lava shelves to nest in. Occasionally other birds are seen, especially Chukars (*Alectoris chukar*).

Hawaiian Hoary Bats (*Lasiurus cinereus semotus*) have not been documented from HO, but have been seen at 2750 m (9,000 ft) on the south slope of Haleakala and may likely utilize episodically abundant insects anywhere on Maui.

There are no feral ungulates within the area, which was fenced in 2013. However, goats (*Capra hircus*), pigs (*Sus scrofa*), and deer (*Axis axis*), reside in adjacent areas. Subsequent to fencing, DKIST now employs extensive predator grids for rats (*Rattus* spp.), cats (*Felis catis*), and mongoose (*Herpestes auropunctatus*), which results in fewer numbers of these predators in the area.

**HO is mostly open and barren, with only sparse low growing plants.**

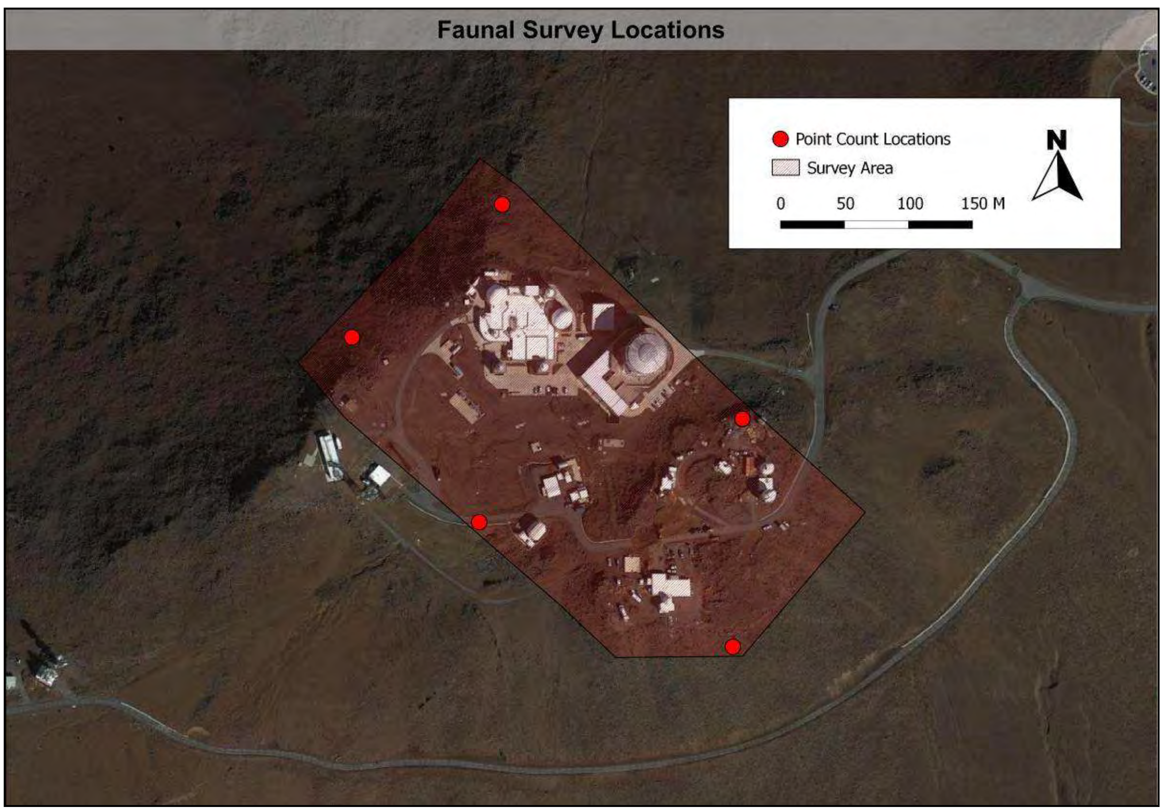
## METHODOLOGY

Five point count stations were established within the survey area and are surveyed once every six months. Additionally, the entire project area is surveyed for incidental sightings. Surveys were conducted May 7, 2015.

Point counts are conducted at prominent high points and locations with good visibility. Most are easily accessible, with paths leading up to them. Counts last ten minutes. All birds observed or heard for an unlimited distance are recorded.

At all point count stations, and over the entire project area, signs of native and non-native mammals are searched for, such as scat, tracks, carcasses, or browsing. Additionally, along with listening for birds, mammals are also listened for.

Initial efforts of searched for bats at HO used active bat detectors that required a person to be present. More recent methodology employs passive detectors that record ultrasonic bat calls and can be left out all night for multiple nights and analyzed later. A bat detector was placed near the cinder parking lot by HO the week of May 7-14, 2015.




**Survey area and point count locations, HO.**

## RESULTS / DISCUSSION

### BIRDS

No birds were heard or observed at HO during the survey, though active petrel burrows were observed.

We again received reports of Red-billed Leiothrix (*Leiothrix lutea*) at the summit from folks who work at HO. Occasionally, especially in the Fall, flocks of this species end up at the summit of Haleakala and Mauna Kea, where they often perish.

**Dead Red-billed Leiothrix, Found elsewhere (Kula) Maui.**

### PREDATORS

No predators or signs of their presence were observed at HO during this survey.

### UNGULATES

No new scat or other signs of ungulates were observed. The skeleton of the small pig (*Sus scrofa*) that wandered up to HO a few years ago is still visible, but is less and less discernable each year.

Old ungulate scat, likely goat (*Capra hircus*), is still present at HO, mostly on the steep northern slope of the property. It continues to decay and become less prevalent, now that an ungulate fence has been erected around HO as part of the HCP and BO.

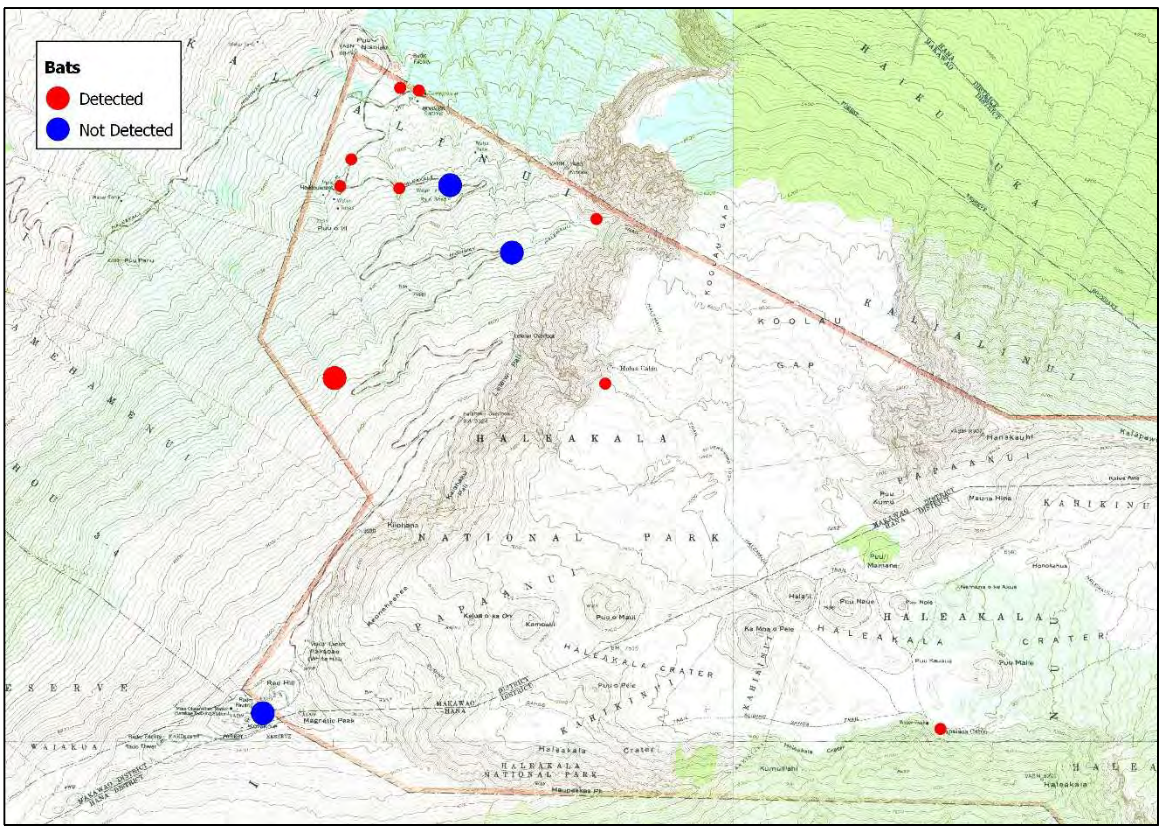
**BATS**

No bats were detected at HO this survey. A bat detector was placed near the cinder parking lot by HO from May 7-14, with no detections during that period.

Below is a map showing bat detections in the summit region of Haleakala since surveys began. Bats were not detected at HO this survey. This does not mean there are never bats at HO, but it does suggest the likelihood of bats occurring at HO on a given night is lower than other areas further down the mountain.

To date, the area with the most consistent bat detections in areas surveyed has been the 8,500 ft. Eucalyptus Grove, where bats have been detected every night detectors have been put out.

Future surveys will help further bring to light the currently mostly unknown distribution, abundance, and habits of this elusive native mammal in the summit region of Haleakala.




**Locations at which Hawaiian Hoary Bats were detected and not detected. Large dots are from the current survey, smaller dots are from previous surveys.**

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**Sunset at Haleakala Observatories.**

# BOTANICAL SURVEY
# HALEAKALA OBSERVATORIES
# SPRING 2015

Prepared for:
**KC Environmental**
**Maui, Hawaii**

Prepared by:
**Forest Starr & Kim Starr**
**Starr Environmental**
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**May 2015**

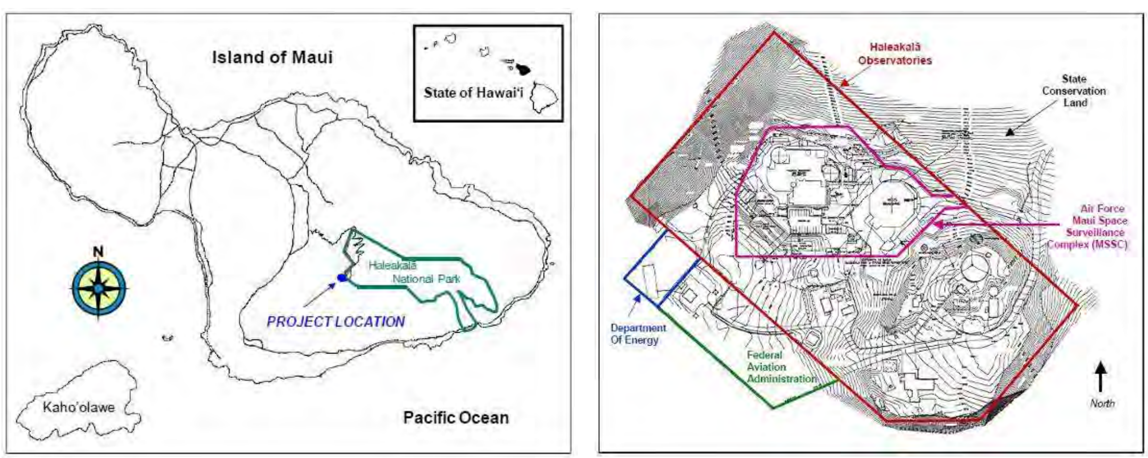
# INTRODUCTION

The Daniel K. Inouye Solar Telescope (DKIST) will be a 4-meter (13.1 ft) optical telescope, contained in a structure 41.5 meters (136 ft) tall, to serve the solar physics community. It will host an array of instruments designed to provide insights about the Sun.

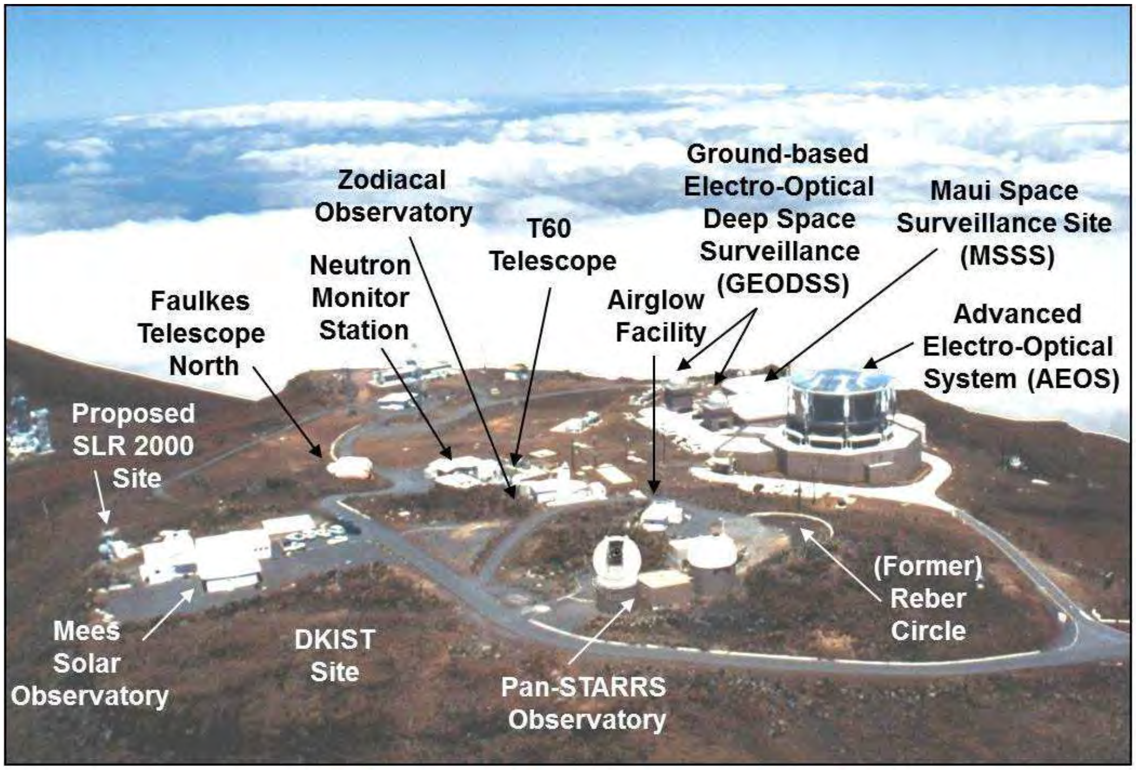
In accordance with the Final Environmental Impact Statement (FEIS) (NSF 2009), programmatic monitoring has been implemented for construction of the DKIST, which began in December 2012, and will continue afterward, to ensure that impacts on biological resources are minimized. Monitoring includes semi-annual botanical surveys at Haleakala High Altitude Observatories Site (HO) and along the Haleakala National Park (HALE) road corridor, including characterization of types, diversity, stage of development, coverage, and health of endangered Haleakala Silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*), and non-endangered endemic or alien invasive species at HO and selected areas of the Park road corridor. This report is the botanical survey of HO.

# SITE DESCRIPTION

The project site is TMK 222007008 (HO). The 18.166-acre parcel is located largely within the Kolekole cinder cone, and the property is roughly rectangular in shape. It is mostly surrounded by State Conservation District lands, with a small adjoining Federal property on the southwest boundary, and Haleakalā National Park nearby to the East.




**General and detailed site location maps of Haleakalā Observatories.**




**Aerial image of facilities at HO.**

HO is located near the summit of Haleakalā, at 2,999-3,052 m (9,840-10,012 ft) elevation. Average annual rainfall is a moderate 112 cm (44 in), occurring primarily during the winter months. Temperatures can be cold at the site, and occasionally dip below freezing, with average annual temperatures at the summit of Haleakalā ranging from 43 - 50 degrees F (6 - 10 degrees C), and once every few years it will snow (County of Maui, 1998). The soils are volcanic, a mixture of ash, cinders, pumice, and lava (RTS, 2002).

HO houses astronomical research facilities for advanced studies of astronomy and atmospheric sciences at HO. The construction, operation, and maintenance of these facilities constitute the bulk of activity at HO. The facilities sit on one of the highest peaks on East Maui, in a relatively undisturbed and pristine portion of the mountain.

## BIOLOGICAL HISTORY

About 128,000 years ago the site where HO now sits would have been the active cinder cone Kolekole, (Sherrod *et al*., 2003; Terry, 2005) with lava flows pouring from the highest point of HO, the former Reber Circle telescope site, and fountains of lava creating the cinder and lava bombs found scattered across HO today. At this point in time, there would have been no vegetation on Kolekole.

After the volcanic activity passed at Kolekole, vegetation would have slowly started reappearing from nearby areas that weren't covered with lava. Many of the native plants in this aeolian zone are wind dispersed. Visiting birds would also leave seeds in their droppings when passing through the area. Eventually, though sparse, vegetation would come to occupy much of Kolekole and nearby areas.

During pre-contact times, Hawaiians used the Kolekole area, as evidenced by wind-shelters, and other sites found in the general area (Maxwell, 2006; Fredericksen, 2006). Despite this, the area probably remained relatively unchanged floristically, until development for astronomy began, with the building of a radio telescope at Reber Circle in 1951 (KC Environmental, Inc., 2009).

Since 1950, much of the surface of Kolekole has been reworked by heavy machinery to develop what is collectively known as "Science City", destroying the much of the original vegetation that occupied the site. In areas that hadn't become impermeable through development, plants returned. Often these plants were native, though occasionally they were non-native.

Today, Kolekole appears to support more vegetation than nearby areas, presumably from ground disturbance and runoff from structures. Much of the vegetation is native, especially in the least disturbed areas. However, some of the vegetation is non-native, a subset of which is thought not to occur in adjacent areas. In 2009 efforts began at addressing the establishment and spread of weedy non-native plants at HO.

## DESCRIPTION OF THE VEGETATION

The vegetation community type at HO is an *Argyroxiphium* / *Dubautia* alpine dry shrubland. Dry alpine shrublands are open communities, occurring at 3,000-3,400 m (9,842-11,155 ft) elevation on the islands of Maui and Hawaiʻi, predominantly on barren cinders, with very sparse vegetation cover, giving a nearly plant-free impression from afar (Wagner *et al.*, 1999). The vegetation at HO ranges from a near barren <1% cover, to >10% cover in the most vegetated portions. The plants are no more than one meter (3 ft) tall anywhere on the site. There are many native plants at HO, including the threatened Haleakalā silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*). HO also has many non-native plants, some of which do not appear to be found in nearby undeveloped areas.

**Typical sparse, low-statured vegetation at HO, which remains mostly the same today as it was in this picture from 2002.**

## OBJECTIVES

- Provide general descriptions of the vegetation.
- Note any changes in vegetation over time.
- Inventory terrestrial vascular flora.
- Identify any vegetation that has federal status, and indicate locations on a map.
- Provide recommendations to minimize negative impacts on botanical resources.

## METHODS

Previous botanical surveys conducted at HO were reviewed prior to conducting the fieldwork. Some of the previous surveys covered the entire HO property, others were for discrete projects within HO or had limited access to parts of the property. Bishop Museum's online herbarium was also reviewed, for collections previously made at HO (Bishop Museum, 2009).

Additionally, the survey and assessment reports in the Final Environmental Impact Statement (FEIS) for DKIST were reviewed to update our knowledge of the current resources at HO, such as archeological sites, insects, and petrel burrow locations, to help minimize our disturbance during surveys, and be aware of any plant related issues discussed in those reports. Further HO information, including historical video footage of the site, was provided by Mike Maberry at the Institute for Astronomy and KCE VP, Dr. Charlie Fein.

A walk through survey method was used. Two biologists, Forest Starr and Kim Starr, surveyed HO on May 7, 2015. All plants were noted and their locations recorded using a Garmin eTrex LegendH GPS (Global Positioning System). Where plants were continuous a point was recorded every 3 m. Species identification was made in the field. Care was taken during surveys to avoid disturbing the facilities, native vegetation, native insects, petrel burrows, and archeological sites.

**Surveying the vegetation at HO. May 2013.**

## RESULTS AND DISCUSSION

### CHANGES IN VEGETATION OVER TIME

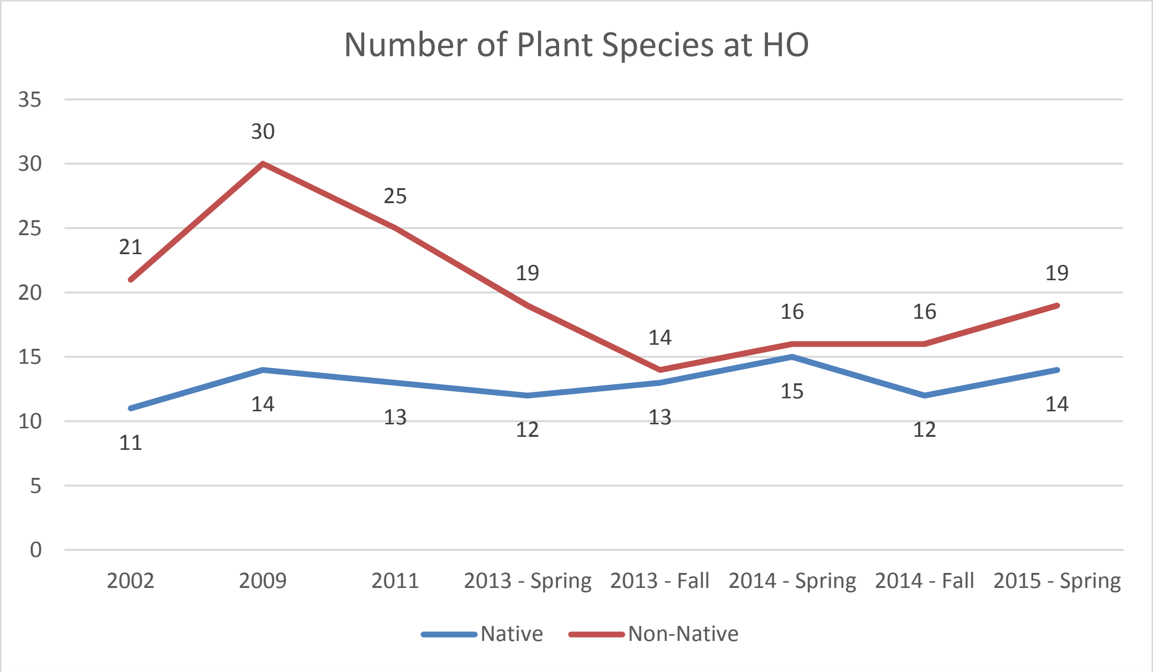
The total number of species at HO increased over time until 2009. The number of non-native species has generally declined since then through weed control efforts, construction activities, and perhaps less rainfall.

The largest changes noted in recent surveys continue to be construction activities, which displaced a number of native and non-native plants over much of the property.

Additional information for each species can be found in the Annotated Checklist.

**Number of Plant Species at HO**

| Year | Total | Native | Non-Native |
|---|---|---|---|
| 2002 | 32 | 11 | 21 |
| 2009 | 44 | 14 | 30 |
| 2011 | 38 | 13 | 25 |
| 2013 - Spring | 31 | 12 | 19 |
| 2013 - Fall | 27 | 13 | 14 |
| 2014 - Spring | 31 | 15 | 16 |
| 2014 - Fall | 28 | 12 | 16 |
| 2015 - Spring | 33 | 14 | 19 |



**NON-NATIVE PLANTS**

The number of non-native plants was up a bit this past survey. The increase was partly due to ephemeral grasses that had previously been recorded at HO, but were not seen in the last survey, and recently germinated from a seed bank during the winter rains.

Additionally, a new non-native plant was found at HO this survey, corn speedwell (*Veronica arvensis*). This ephemeral herb is occasionally found elsewhere in developed areas of subalpine East Maui, such as the nearby Haleakala Visitor Center.

Though the number of non-native species remains relatively stable at HO, both the abundance and distribution of those non-native species has declined since earlier surveys. Additionally, the plants are now mostly in the seedling to young plant stage, rather than large mature plants. Most of this decline appears due to recent weed control efforts, DKIST construction activities, and years of drought conditions.

That said, HO remains disproportionately weedy compared to undeveloped areas surrounding HO, which continue to be virtually weed free.

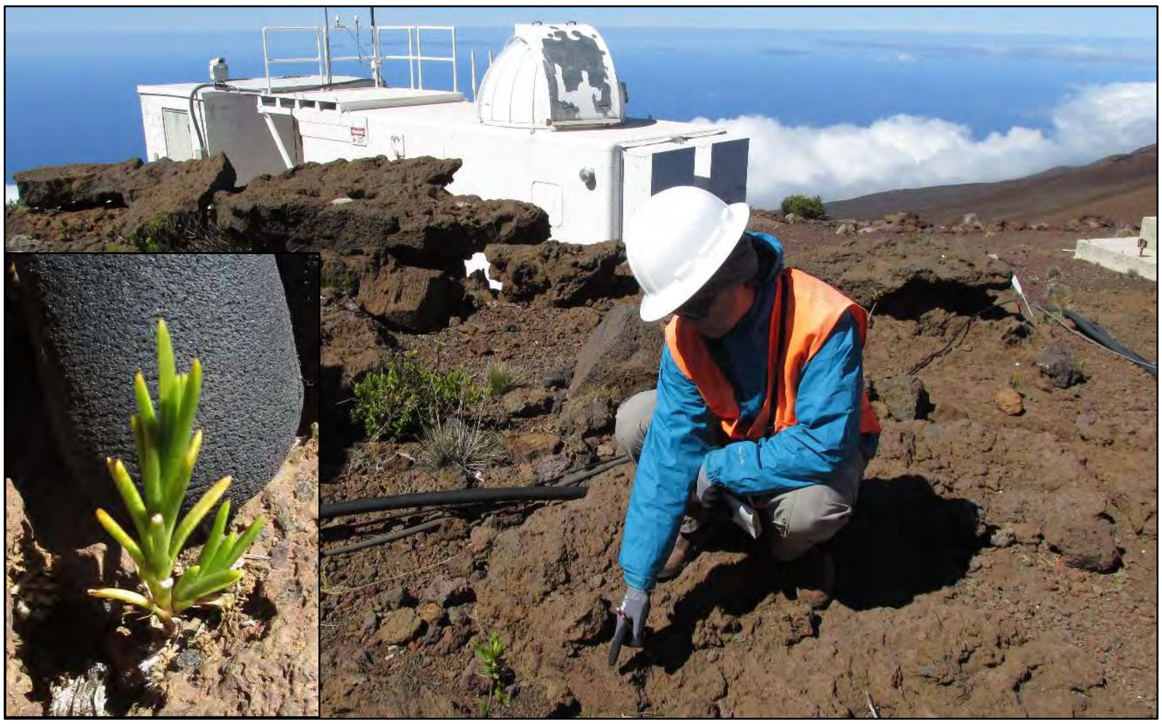
**Corn speedwell (*Veronica arvensis*), observed at HO for the first time this survey.**

**NATIVE PLANTS**

There were two more native plant species observed at HO this survey than in Fall 2014, both had previously been known from HO and reappeared in the same general areas.

The native ena ena (*Pseudognaphalium sandwicensium* subsp. *sandwicensium*) continues to come and go here and there in disturbed sites, especially along hardened surfaces near the southeast side of the Retention Basin.

There was also the reappearance of a native catchfly (*Silene struthioloides*) that had not been seen at HO since 2009. Two small seedlings, only a few cm in height, were found in the same area where an adult plant once lived near Mees Observatory.



**Two very small plants of *Silene struthioloides* reappeared at HO this survey.**

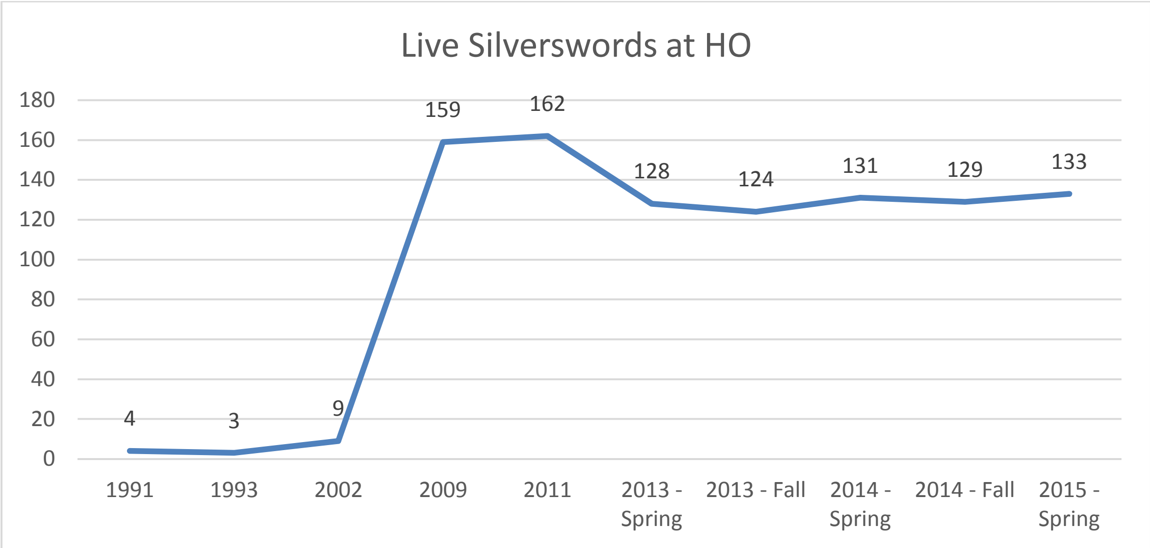
**SILVERSWORDS**

Haleakala silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*) are the only plant with federal status on the HO property, they are federally listed as "threatened", meaning they may become endangered throughout all or a significant portion of their range if no protection measures are taken.

**Haleakala Silversword (*Argyroxiphium sandwicense*)**

We counted 133 silverswords at HO. This is a decline from a peak of 162 silverswords in 2011, yet remains a huge increase from 2002, when only 9 live silverswords were known from HO. All live plants are located on or near the Maui Space Surveillance Complex (MSSC), on land that has undergone heavy construction activities in the past. The silverswords do not appear affected by recent construction activities at HO.

In 2014 a few small silversword / kupaoa hybrids (*Argyroxiphium x Dubautia*) were observed. In Spring 2015, four of these hybrids were still alive and growing.




**Number of Live Silverswords at HO.**

**CONSTRUCTION**

The biggest changes at HO since the last survey continue to be associated with construction. The main area affected is where the DKIST telescope is being built. Other areas of HO that have been affected by construction include a corridor running from the Advanced Electro-Optical System (AEOS) over Puu Kolekole to Mees. These areas received much ground disturbance and many native and non-native plants were removed in the process. There are also large piles of rocks and soil that have been staged on the margin of the retention basin.

No new weeds have been found at HO that could be attributed to recent construction activities. No Threatened or Endangered plants appear to have been impacted by construction. As construction wanes, it is likely that native and non-native vegetation will re-colonize the site, as has happened at HO in the past.


**Surveying plants at HO, May 2015.**

**WEED PREVENTION**

HO and surrounding areas are special places, holding a unique assemblage of native plants and animals found no where else on Earth. Accidentally introducing non-native species to the summit area during facility construction and operation can disrupt the native ecosystem and have adverse effects on the native biota. Taking the following steps will reduce the potential for unwanted introduction and spread of weeds at HO.

- Workers should be aware the summit area contains valuable botanical resources and do their best to promote their well being while at HO.
- Workers should clean shoes before entering HO, especially if noticeably soiled, to help prevent seeds and other organisms from hitching a ride.
- The same general cleanliness should apply to vehicles, equipment, and materials; visibly soiled items should be cleaned before entering HO.
- Plantings of non-native species should be avoided.
- Regular weed control should be done on the entire HO property.

**These Spanish needle (*Bidens pilosa*) seeds were found in a shoelace in Kihei, Maui. March 19, 2002. Boots and other gear should be cleaned to prevent spread of weed seeds to HO.**

## PLANT CHECKLIST

The following is a checklist of all vascular plant species observed during the past nine botanical surveys at HO. Plants are listed alphabetically by species. Taxonomy and nomenclature follow Wagner *et al.* (1999), Palmer (2003) and Bishop Museum (2011). Native species are noted by an asterisk (*). The relative abundance of each species observed is also noted, the following abbreviations / definitions are used:

- **D = Dominant** - Forming a major part of the vegetation within the project area.
- **C = Common** - Widely scattered throughout area or locally abundant within a portion of it.
- **O = Occasional** - Scattered sparsely throughout area or in a few small patches.
- **R = Rare** - Only a few isolated individuals within the project area.
- **X = Observed** - Present during survey. No abundance estimate.

Botanical surveys of HO, and portion of HO covered in each survey:

- **2002, 2009, 2011, 2013-2015** Starr Environmental - Surveyed all of HO.
- **2012** Starr Environmental - Surveyed all of HO, except Air Force.
- **2005** Starr Environmental - Surveyed proposed ATST sites.
- **2002** Rocketdyne Technical Services - Surveyed Maui Space Surveillance Site (MSSS).
- **2000** Winona Char and Associates - Surveyed Faulkes site.
- **1994** Belt Collins & Associates - Surveyed MSSS
- **1991** Air Force - Surveyed MSSS

**Native hairgrass (*Deschampsia nubigena*), a common species at HO.**

# PLANTS OBSERVED AT HO

| Native | Scientific name | 2015 - Spring | 2014 - Fall | 2014 - Spring | 2013 - Fall | 2013 - Spring | 2012 | 2011 | 2009 | 2005 | 2002 | 2002 | 2000 | 1994 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ageratina adenophora* | | | | | | | | R | | | | | | |
| * | *Agrostis sandwicensis* | C | C | C | C | C | C | C | C | X | O | | | X | X |
| | *Anthoxanthum odoratum* | | | | | R | | | | | R | | | | |
| | *Arenaria serpyllifolia* | C | O/C | C | C | C | C | C | O | X | R | | | | |
| * | *Argyroxiphium sandwicense* subsp. *macrocephalum* | C | C | C | C | C | | C | C | X | R | X | | X | X |
| * | *Argyroxiphium x Dubautia* | R | R | R | | | | | | | | | | | |
| * | *Asplenium adiantum-nigrum* | O/C | O | O/C | O | O/C | O/C | C | C | X | R | | | | |
| * | *Asplenium trichomanes* subsp. *densum* | R/O | R/O | O | O | R/O | O | O | O | X | R | | | | |
| | *Axonopus* sp. | | | | | | | | R | | | | | | |
| | *Bidens pilosa* | | | | | | | R | | | | | | | |
| | *Bromus catharticus* | R | R | R | | R | R | O | O | X | R | | | | |
| | *Bromus diandrus* | R | | R | | | | R | R | | | | | | |
| | *Conyza bonariensis* | R | R | R | | | | R | R | | | | | | |
| | *Cryptomeria japonica* | | | | | | | | | X | | | | | |
| | *Cynodon dactylon* | | | | | | | | R | | R | | | | |
| | *Dactylis glomerata* | | | | | | | | R | | | | | | |
| * | *Deschampsia nubigena* | D | D | D | D | D | D | D | C | X | C | X | X | X | X |
| * | *Dryopteris wallichiana* | | | R | R | | R | R | R | | | | | | |
| * | *Dubautia menziesii* | D | D | D | D | D | D | D | C | X | C | X | X | X | X |
| | *Erodium cicutarium* | C | C | C | C | C | C | C | C | X | O | | | | |
| | *Festuca rubra* | R | | | | R | R | R | O | | | | | | |
| | *Foeniculum vulgare* | | | | | | | R | | | | | | | |
| * | *Geranium cuneatum* subsp. *tridens* | | | | | | | | | | | | | X | |

| Native | Scientific name | 2015 - Spring | 2014 - Fall | 2014 - Spring | 2013 - Fall | 2013 - Spring | 2012 | 2011 | 2009 | 2005 | 2002 | 2002 | 2000 | 1994 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Gutierrezia sarothrae* | | | | | | | R | R | | | | | | |
| | *Holcus lanatus* | R | | R | R | R | R | R | O | X | O | | | | |
| | *Hypochoeris radicata* | R/O | R | O/C | O | C | O | C | C | X | O | X | X | X | X |
| | *Lepidium virginicum* | O | O | C | O/C | C | O | C | C | X | O | | | | |
| * | *Leptecophylla tameiameiae* | R/O | R/O | O | O | C | C | C | O | X | O | | X | X | |
| * | *Lythrum maritimum* | | | | | | | | | X | | | | | |
| | *Malva neglecta* | R | R | | | R | | | R | | R | | | | |
| | *Medicago lupulina* | O | O | O | O | O | O | C | C | X | O | | | | |
| | *Oenothera stricta* subsp. *stricta* | R | R | | R | R | C | C | C | X | R | | | | |
| * | *Pellaea ternifolia* | O | O | O | O | O | O | O | O | X | R | | | | |
| | *Pennisetum clandestinum* | | | | | | | | R | | | | | | |
| | *Pinus* sp. | | | | | | | | R | X | R | | | | |
| | *Plantago lanceolata* | O | O | O | O | O/C | O | C | C | X | O | | | | |
| | *Poa annua* | R | R | R | | R | R | | R | | R | | | | |
| | *Poa pratensis* | O/C | O | C | O | C | O/C | C | C | X | O | | | | |
| | *Polycarpon tetraphyllum* | | R | R | R | | | O | R | | R | | | | |
| * | *Pseudognaphalium sandwicensium* var. *sandwicensium* | R | | R | | | | | | | | | | | |
| * | *Pteridium aquilinum* var. *decompositum* | | | R | R | R | R | R | R | | | | | | |
| | *Rumex acetosella* | | R | R | R | R | | | R | | O | | | | |
| | *Senecio madagascariensis* | R | | | | R | | R | | | | | | | |
| | *Senecio sylvaticus* | | | | | | | R | | | R | | | | |
| | *Senecio vulgaris* | | | | | | | | | | | X | | X | X |
| * | *Silene struthioloides* | R | | | | | | | R | | | | | | |
| | *Sonchus oleraceus* | | | | | R | | R | R | | R | | | | |

| Native | Scientific name | 2015 - Spring | 2014 - Fall | 2014 - Spring | 2013 - Fall | 2013 - Spring | 2012 | 2011 | 2009 | 2005 | 2002 | 2002 | 2000 | 1994 | 1991 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Taraxacum officinale* | O/C | O | C | O | C | R | C | C | | O | X | | X | X |
| * | *Tetramolopium humile* subsp. *haleakalae* | O/C | O | O/C | C | C | C/D | C | C | X | C | X | X | X | X |
| | *Trifolium repens* | | | | R | | R | R | R | | | | | | |
| * | *Trisetum glomeratum* | C | C | C | C | C/D | C/D | D | C | X | C | X | X | X | X |
| * | *Vaccinium reticulatum* | R/O | R/O | O | O | O | O | O | O | X | R | | | X | |
| | *Veronica arvensis* | R | | | | | | | | | | | | | |
| | *Vicia sativa* | | | | | | | R | R | X | | | | | |
| | *Vulpia bromoides* | | | | | | | O | O | | O | | | | |
| | *Vulpia myuros* | | | | | | | O | O | | | | | | |
| | *Vulpia* spp. | O/C | O | O/C | O | O/C | O | | | | | | | | |

## ANNOTATED PLANT CHECKLIST

The following annotated checklist is designed to record the history of all plant species ever reported from HO, and to provide an identification guide and maps to assist with management of the botanical resources.

Each plant has the scientific name, common name, family name, nativity status, an image (images not always from HO), a history of the plant from previous botanical surveys, the current status of the species at HO, and locations for species observed during botanical survey that include GPS mapping.

Maps are only included for years in which the species was observed. The native plants *Deschampsia nubigena* and *Dubautia menziesii* are not GPS'd each year as they are abundant over HO.

The annotated checklist includes all plant species ever recorded from HO, resulting in species included that were not observed in the most recent survey.

**Native ohelo berry (*Vaccinium reticulatum*).**

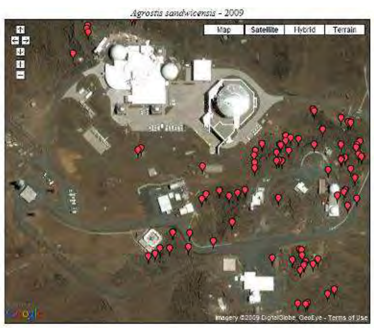
## *Ageratina adenophora* (Asteraceae)
## Maui pamakani (Non-native)

Not observed during this survey nor since 2009 when one small infertile plant was found and pulled. Perhaps pulling the lone sterile plant in 2009 prevented it from establishing. It could possibly show up from time to time in the moister areas of HO, germinating from seed blown up from lower elevations.

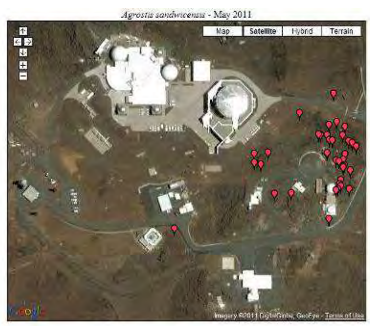

2009

# *Agrostis sandwicensis* (Poaceae)
# Bentgrass (Native: Endemic)

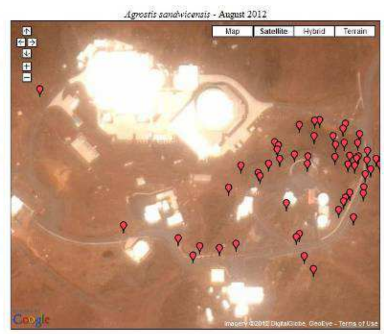
This native clumping grass remains common in the same general areas of HO it has been known from, especially in less disturbed areas. The exception being active construction areas around DKIST, Pan-STARRS, and the former Reber Circle telescope site where the native grass is now absent. It may recolonize some of these areas when construction is completed.




2009




2011




2012


2013

2014

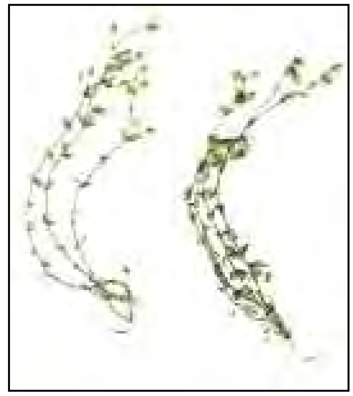
2015

## *Anthoxanthum odoratum* (Poaceae)
## Sweet vernal grass (Non-native)

Not observed during this survey. Seen on and off throughout the previous years of survey and likely to pop up again by seedbank or reinvasion. It is common lower down the mountain.

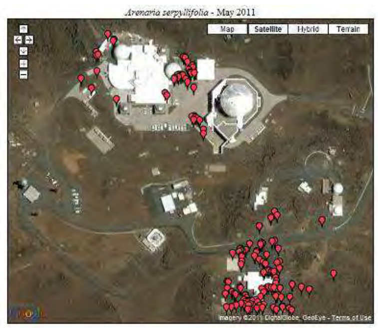

2013

## *Arenaria serpyllifolia* (Caryophyllaceae)
## Thyme-leaved sandwort (Non-native)

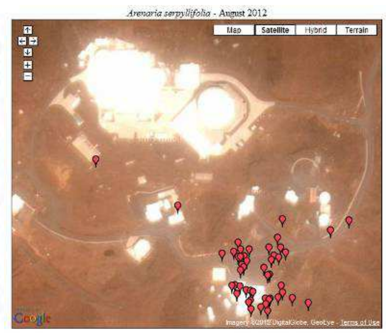


This small herbaceous plant had a similar distribution as previous years, it remains common around buildings, near the MSSS and the Mees Solar Observatory.


2009




2011




2012


2013

2014

2015

## *Argyroxiphium sandwicense* subsp. *macrocephalum* (Asteraceae) ʻĀhinahina, silversword (Native: Endemic)

The iconic Haleakalā silversword is the only plant species at HO that has any Federal status, it is currently listed as Threatened by the United States Fish and Wildlife Service.

There were 133 silverswords found during surveys this year, about the same as last year, and located in the same general areas. The bulk occur around the MSSC buildings and parking areas in cinder planter boxes. There are also a few on the north edge of the property, in a jumble of rocks.

2009

2011

2013


2014


2015

# *Argyroxiphium* x *Dubautia* (Asteraceae)
# Silversword Dubautia hybrid
# (Native: Endemic)

A total of 4 plants were observed this survey in one of the planted boxes by the original, oldest Air Force facility, known as the Maui Space Surveillance Site (MSSS), now part of the larger Maui Space Surveillance Complex (MSSC). One was smaller than the other 3, though none were very large yet.

We were perhaps mistaking some of these for silverswords in the past, but when they grew bigger, it became more noticeable that they were hybrids.

Previously not known from the project area. First observed in 2014 where only 1 was observed. During this survey one small plant was observed at the MSSC in a planter box on the west side of the building. Hybrids between silverswords and Dubautia can vary in appearance but generally have traits of both plants. This particular hybrid seems to have the form of a silversword with the color of Dubautia. It is likely one of the seedlings from around 2004 that we were calling a silversword in previous years, but this year, the plant became large / old enough to recognize it as a hybrid.

2014

2015

# *Asplenium adiantum-nigrum* (Aspleniaceae) ‘Iwa‘iwa (Native: Indigenous)

This small native fern continues to be occasional to common in mostly undisturbed rocky areas of the entire site and found in the same general areas as before, except for the areas in construction zones and disturbance, where it has been displaced.


2009


2011


2012

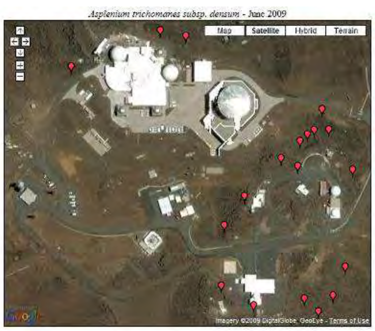

2013

2014

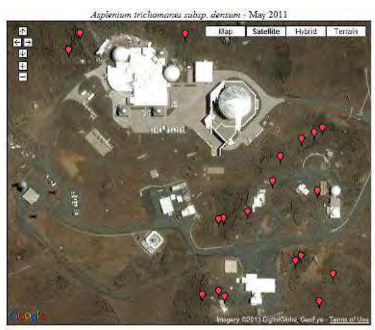
2015

# *Asplenium trichomanes* subsp. *densum* (Aspleniaceae)
# Maidenhair spleenwort (Native: Endemic)

This small native fern remains occasionally observed in rocky crevices in undisturbed areas.




2009




2011


2012

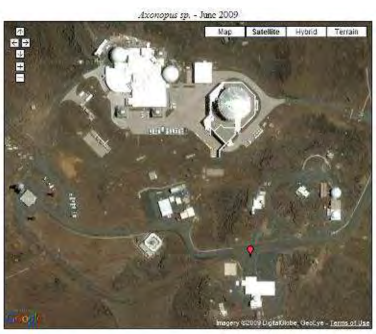

2013

2014

2015

## *Axonopus* sp. (Poaceae)
## Carpet grass (Non-native)

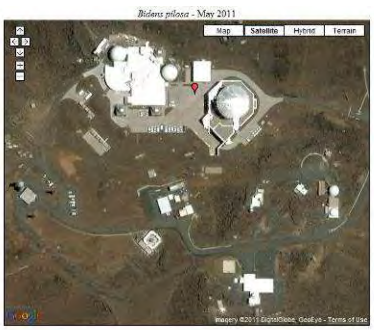
Not observed during this survey. This small infertile plant was first observed in 2009 in a road crack near the Mees parking lot area and was pulled. It has not been found again since then.




2009

## *Bidens pilosa* (Asteraceae)
## Spanish needles (Non-native)

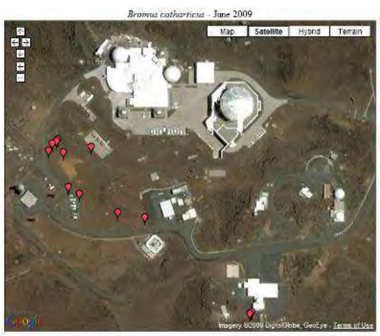
Not observed during this survey. This weedy herbaceous plant with seeds that stick to passers by was first found in 2011 at the edge of the concrete near the buildings at MSSC. At the time a single plant that had not yet gone to seed was found and pulled. It has not been seen again since then. It is a common weed elsewhere on Maui and occurs just below the HO property along Park roads. It could turn up again and would be good to keep an eye out for any new plants which should be pulled before they seed to prevent establishment of this pesky weed at this site.



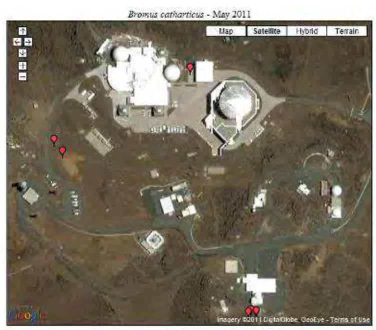

2011

# *Bromus catharticus* (Poaceae)
# Rescue grass (Non-native)

A lone plant observed near the retention basin. First collected at the site in 1982, surveys since then have resulted in a few plants found in these same areas, with the most found in 2009. It likely persists from a seed bank.




2009




2011


2012

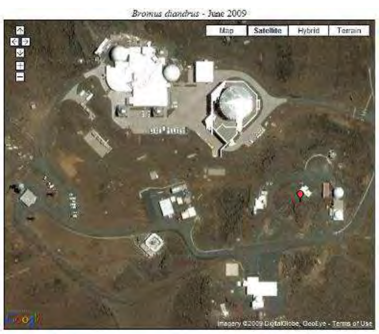

2013

2014

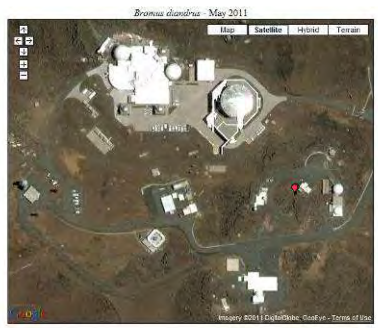
2015

## *Bromus diandrus* (Poaceae)
## Ripgut grass (Non-native)

A few plants were again found near the Airglow Facility near Pan-STARRS. This grass was first found in 2009 in the same location and likely persists from a seed bank.




2009



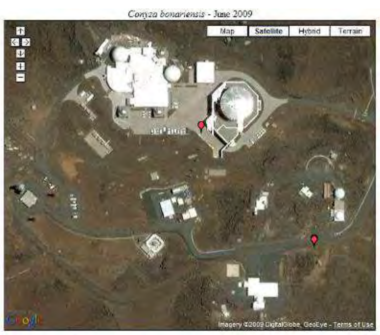

2011

2014

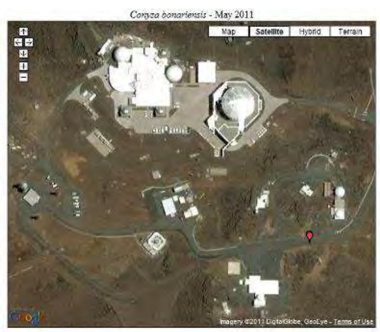
2015

## *Conyza bonariensis* (Asteraceae)
## Hairy horseweed (Non-native)

One small sterile plant was found in a crack in the road west of MSSC. It was pulled. A few plants were also found during 2009 and 2011 surveys and were pulled as well. A widespread wind dispersed weed elsewhere on Maui, it seems to occasionally pop up in road cracks and other disturbed sites, but so far has been pulled when seen at the site.




2009




2011

2014

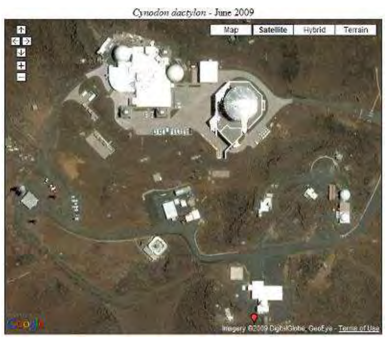
2015

## *Cryptomeria japonica* (Taxodiaceae)
## Japanese tsugi pine (Non-native)

Not observed since 2005, when a lone possibly cultivated tree was found near the former LURE facility and was later removed.

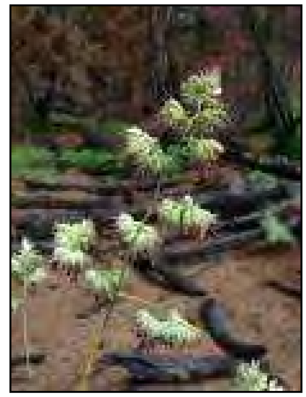
# *Cynodon dactylon* (Poaceae)
# Bermuda grass (Non-native)

Not observed during this survey. Previously found during the 2002 and 2009 surveys from a small patch near Mees, though not seen during more recent surveys.

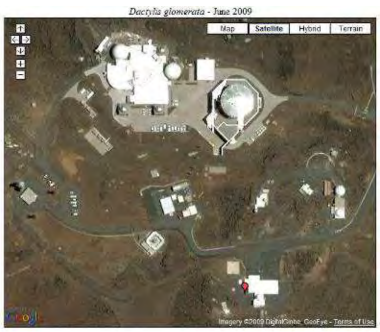



2009

# *Dactylis glomerata* (Poaceae)
# Cocksfoot (Non-native)



Not observed during this survey. One plant was found in 2009 on the west side of the Mees building and it has not been seen since. This tall grass could be gone, have been overlooked, or persist as seeds in the soil.

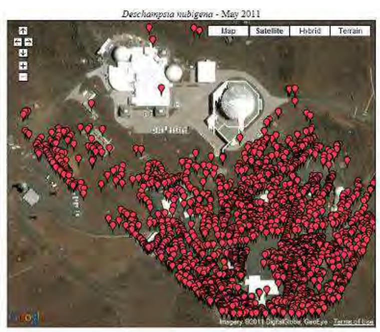



2009

## *Deschampsia nubigena* (Poaceae)
## Hairgrass (Native: Endemic)

Not mapped this survey. Still a dominant component of the vegetation at HO. It was displaced in the current construction areas, but may recolonize the area once the project is completed.

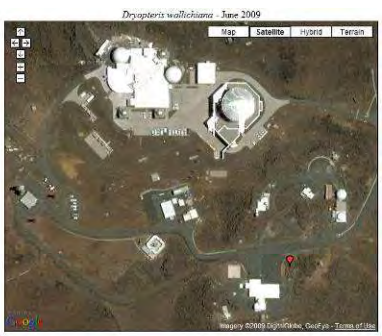

2009



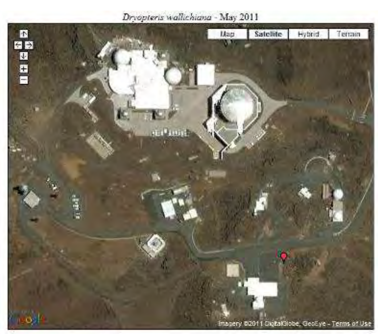

2011

# *Dryopteris wallichiana* (Dryopteridaceae) Laukahi (Native: Indigenous)

Not observed this survey. In 2013, one small plant was found along a crack in the concrete wall by the Faulkes Telescope. Before that, it was known from an area among the rocks that are in the DKIST construction zone and has not been seen there in recent surveys. Elsewhere on Maui, this fern is typically found in more moist mesic forested areas. It is likely that the spores of this fern are spread in the wind and able to germinate at the site where suitable conditions occur.




2009




2011


2012

2014

## *Dubautia menziesii* (Asteraceae)
## Kūpaoa (Native: Endemic)

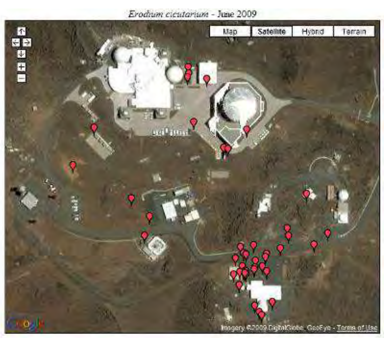
Not mapped this survey. This native shrub is still a dominant over much of the site, but now displaced from the construction disturbed sites. It may return once construction is completed.


2009

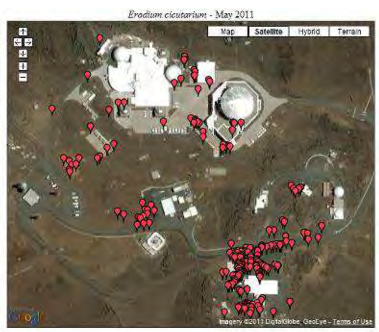

2011

## *Erodium cicutarium* (Geraniaceae)
## Pin clover, storksbill (Non-native)

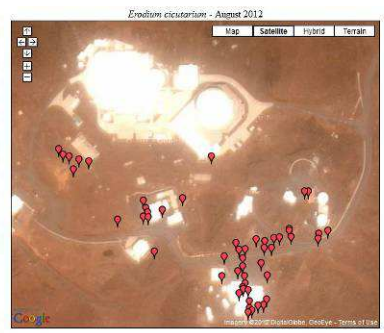
A small herbaceous plant that remains common in disturbed areas and near the buildings over most of the site, except for construction areas where it no longer occurs.




2009




2011



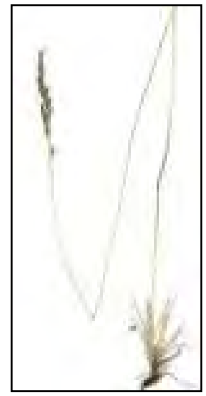

2012


2013

2014

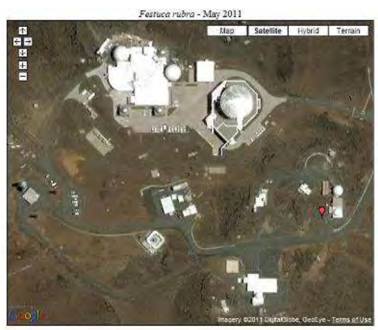
2015

# *Festuca rubra* (Poaceae)
# Red fescue (Non-native)



A few small clumps observed on margin of asphalt by Pan-STARRS. Occasionally found in low numbers in previous surveys. Seeds could likely persist in the soil at the site or recolonize on occasion.


2009




2011


2012


2013

2015

## *Foeniculum vulgare* (Apiaceae)
## Fennel (Non-native)

Not observed since a single small sterile plant was found near Mees in 2011 and was pulled. It probably no longer occurs at HO.

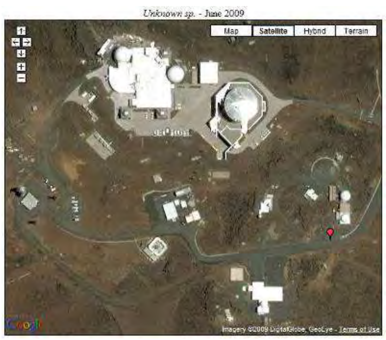

2011

## *Geranium cuneatum* subsp. *tridens* (Geraniaceae)
## Hinahina (Native: Endemic)

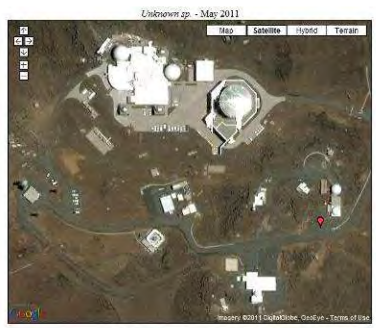
Not observed during this survey. Reported from the site in 1994. Not seen since then.

## *Gutierrezia sarothrae* (Asteraceae)
## Broom snakeweed (Non-native)

Not observed during this survey. The area where it was previously located has been disturbed due to construction activities. There was no sign of broom snakeweed found. This small herb was found for the first time in the State of Hawaii during the 2009 survey near Pan-STARRS. The site will be continually monitored for future plants that may pop up.




2009




2011

# *Holcus lanatus* (Poaceae)
# Yorkshire fog (Non-native)

A lone tussock found and pulled during this survey, near the Airglow Facility. Despite repeated control efforts, this grass regularly returns to this location, perhaps from a seed bank. In the past it has also been observed on the south west side of Mees.


2009


2011


2012


2013

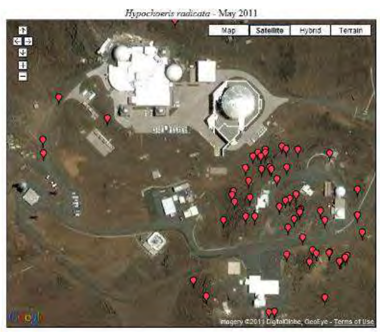
2014

2015

## *Hypochoeris radicata* (Asteraceae)
## Hairy cat's ear (Non-native)

Still present in the same areas it has been present in before, mostly along the eastern edge of the DKIST construction area, by Mees, and between Pan-STARRS and MSSC. There seems to be less than in previous years, perhaps from a combination of weed control, construction, and dry conditions in recent years.


2009




2011


2012


2013

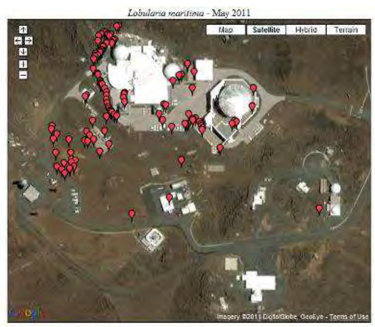
2014

2015

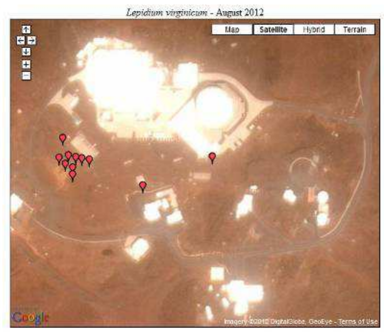
# *Lepidium virginicum* (Brassicaceae)
# Virginia pepperweed (Non-native)

Present, especially around the Air Force property. Not nearly as abundant as it used to be.


2009




2011




2012

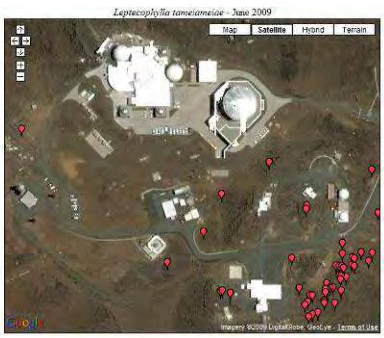

2013

2014

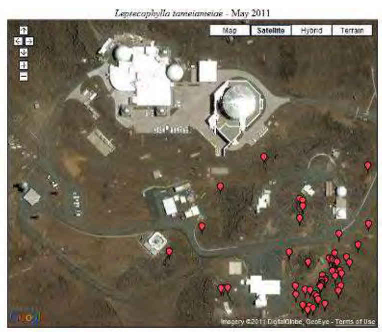
2015

## *Leptecophylla* [*Styphelia*] *tameiameiae* (Ericaceae)
## Pūkiawe (Native: Indigenous)

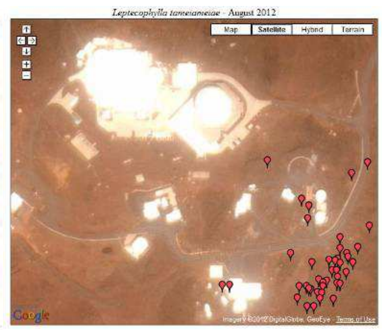
This native shrub remains locally common in the undisturbed rocks on the eastern flank of DKIST and occasionally around Pan-STARRS and other parts of HO.




2009




2011




2012


2013

2014

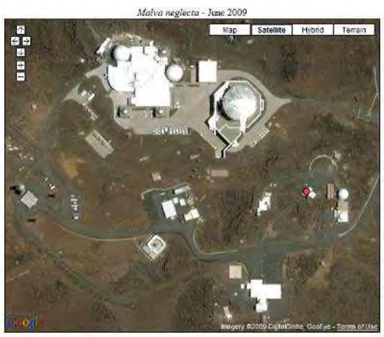
2015

## *Lythrum maritimum* (Lythraceae)
## Lythrum (Native: Questionably Indigenous)

Not observed during this survey. This herbaceous sprawling plant is usually found in moister areas. It was first recorded from the site in 2005 where a small patch was found near the Airglow Facility, but has not been seen since and probably no longer occurs at the site.

# *Malva neglecta* (Malvaceae)
# Common mallow (Non-native)

Observed once again near the Airglow Facility, where it was previously known. First observed in 2002 in this same area. This plant has been observed in the same area on and off for the past couple years and probably persists from a seed bank.



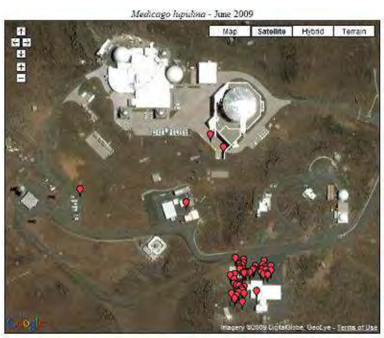

2009


2013

2015

# *Medicago lupulina* (Fabaceae)
# Black medic (Non-native)

This mat forming herb with yellow flowers continues to be locally common around Mees, and a few plants were again found in the retention basin.




2009


2011


2012

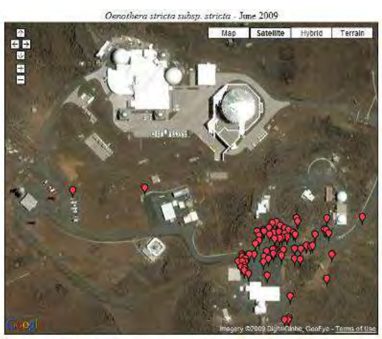

2013

2014

2015

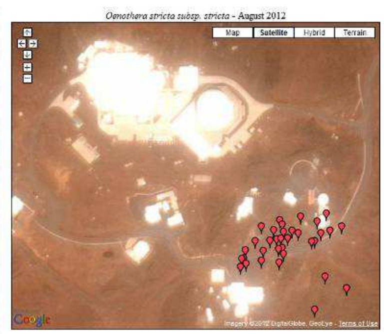
## *Oenothera stricta* subsp. *stricta* (Onagraceae) Evening primrose (Non-native)

A few plants found in the same areas where it was once much more common. This species has greatly decreased in abundance, possibly due to a combination of control efforts, construction and disturbance, and dry conditions.




2009


2011



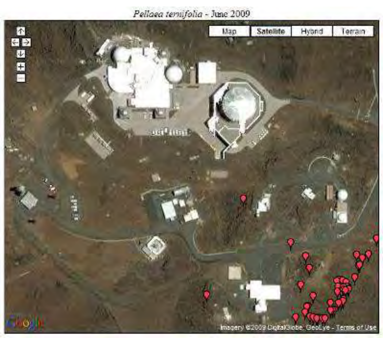

2012


2013

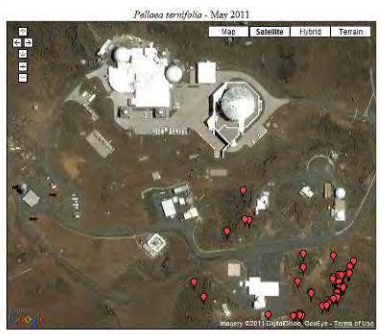
2015

## *Pellaea ternifolia* (Pteridaceae)
## Kalamoho (Native: Indigenous)

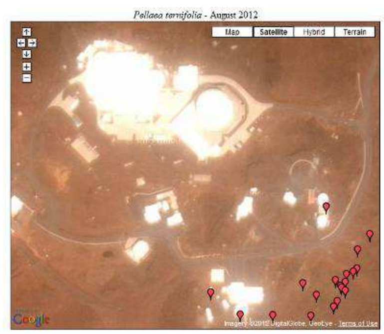
Found mostly around the eastern flank of the DKIST site tucked into rock crevices in undisturbed areas. Sparingly found elsewhere on HO.




2009




2011




2012

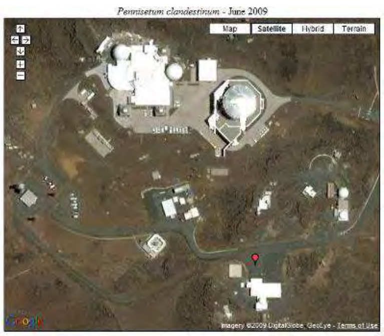

2013

2014

2015

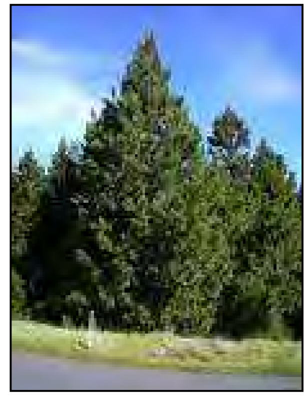
## *Pennisetum clandestinum* (Poaceae)
## Kikuyu grass (Non-native)

Not observed during this survey. First found in 2009, when a single small sterile plant was found and pulled. It has not been seen since and is likely no longer present at HO.




2009

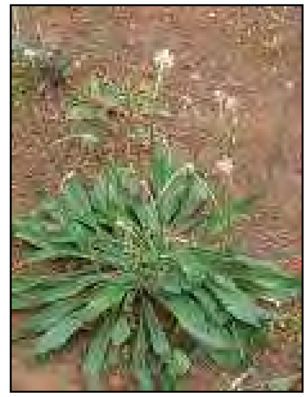
## *Pinus* sp. (Pinaceae)
## Pine (Non-native)



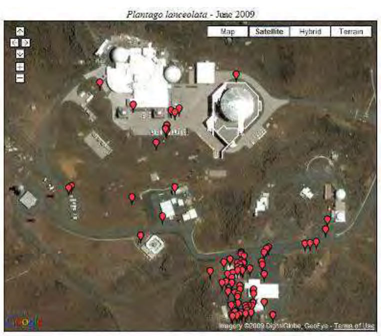
Not observed during this survey. Previously two cultivated plants were found and removed in 2002. Then in 2009 a small wild pine seedling was found in a road crack near the retention basin and pulled. No new seedlings have been observed since, though pines surround the area and can disperse seeds long distances.


2009

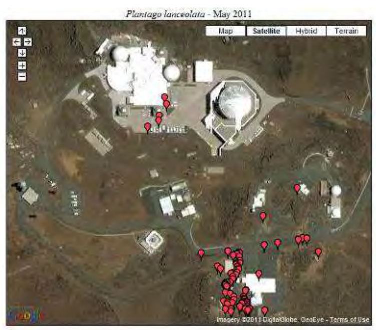
## *Plantago lanceolata* (Plantaginaceae)
## Narrow-leaved plantain (Non-native)



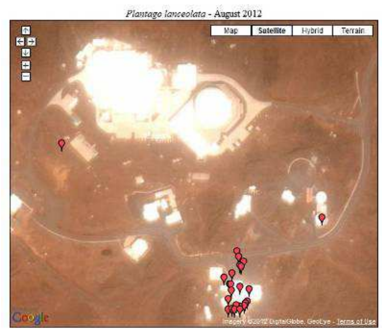
Locally common around Mees. A few plants observed near MSSC. A cosmopolitan weed that is still present at the site, but less abundant than in previous surveys.




2009




2011




2012


2013

2014

2015

# *Poa annua* (Poaceae)
# Annual bluegrass (Non-native)

A few small plants were once again found near a building on the north facing side of MSSS. This is the same area where they are regularly found, and may persist from seeds in the soil.


2009

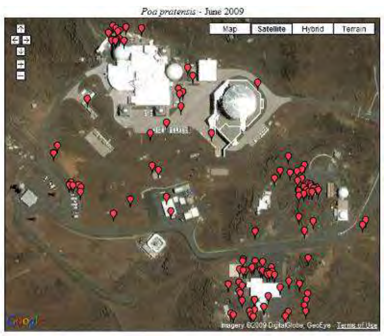

2012

2014

2015

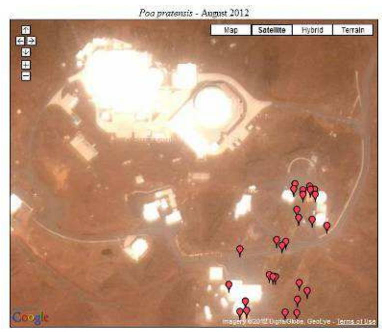
## *Poa pratensis* (Poaceae)
## Kentucky bluegrass (Non-native)

This patch forming grass was found to be common throughout most of the site. It prefers somewhat moist sites and is most abundant by buildings and other areas that catch moisture.




2009


2011




2012


2013

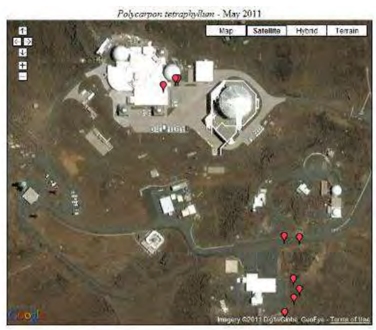
2014

2015

# *Polycarpon tetraphyllum* (Caryophyllaceae) Polycarpon (Non-native)

Not observed this survey. Previously found in a planter box near the MSSS building. Plants at the DKIST site have been displaced by construction activities.


2009




2011

2014

# *Pseudognaphalium sandwicensium* var. *sandwicensium* (Asteraceae)
# Ena ena (Native: Endemic)

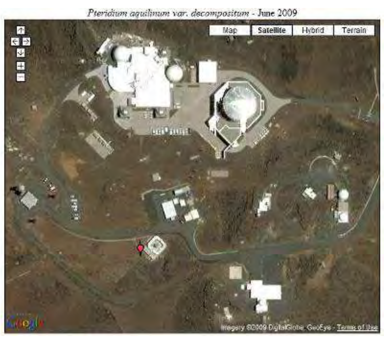
Observed in two locations this survey. This native herb was first observed at HO in 2014. Elsewhere, this species is occasionally found in similar subalpine habitat, such as the Crater of Haleakala National Park, growing in rock crevices and cindery areas.

2014

2015

# *Pteridium aquilinum* var. *decompositum* (Hypolepidaceae)
# Bracken fern (Native: Endemic)

Not observed this survey. It had previously been growing near the Faulkes telescope. First recorded in 2009, where it was growing under a concrete ledge in a moist protected spot.




2009

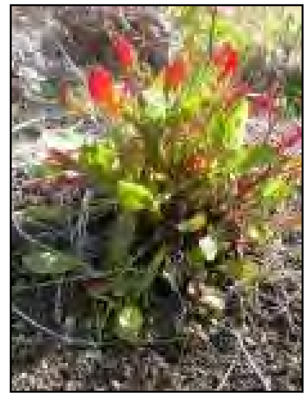

2011


2012

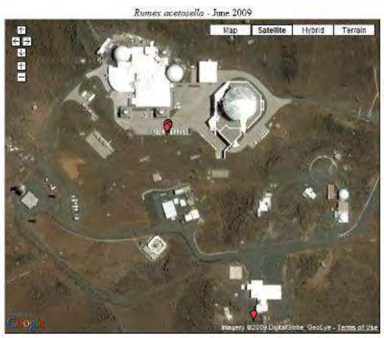

2013

2014

# *Rumex acetosella* (Polygonaceae)
# Sheep sorrel (Non-native)



Not observed this survey. In the past, a small patch of this plant was persisting near Mees, where there is likely a seed bank.



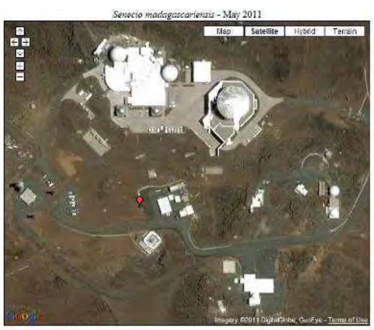

2009


2013

2014

## *Senecio madagascariensis* (Asteraceae) Fireweed (Non-native)

A lone plant found near the edge of the retention basin by the Neutron Monitoring Station. This yellow flowered plant is widespread in Upcountry areas of Maui and has seeds that can spread long distances on the wind. It is being found increasingly along the Park road, with densities highest near Headquarters and less dense toward higher elevations. The plant will likely continue to show up now and then and early control will help prevent its establishment at HO.



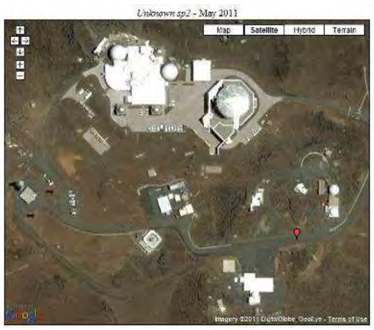

2011


2013

2015

## *Senecio sylvaticus* (Asteraceae)
## Common groundsel (Non-native)

Not observed during this survey. Found during a few surveys in the past, but only in small numbers. It has never been common at the site and is pulled when found. When sterile is difficult to tell from the related *Senecio vulgaris*, which has also been found at the site in previous surveys.

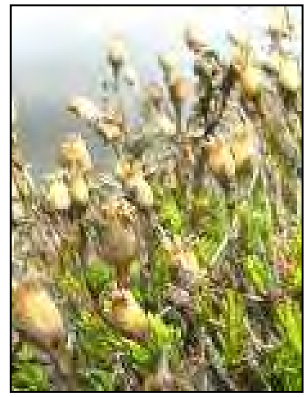



2011

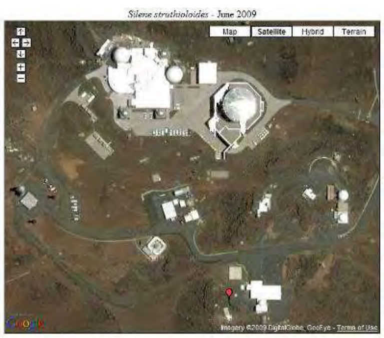
## *Senecio vulgaris* (Asteraceae)
## Common groundsel (Non-native)

Not observed during this survey. Similar to the related *Senecio sylvaticus* and hard to tell apart when young, only an occasional plant found in previous surveys that may show up from time to time either through seed bank or reinvasion. Prefers disturbed sites.

# *Silene struthioloides* (Caryophyllaceae) Catchfly (Native: Endemic)



Two  very small plants found this survey, in the same spot where a lone plant was observed near Mees in 2009.

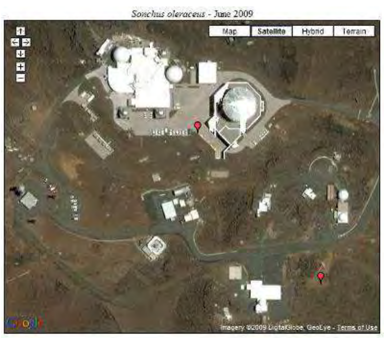



2009

2015

## *Sonchus oleraceus* (Asteraceae)
## Sow thistle (Non-native)

Not observed during this survey. Previously found in low numbers in disturbed areas. With wind born seeds, this plant will likely continue to show up and can be removed when found.




2009


2011


2013

# *Taraxacum officinale* (Asteraceae)
# Common dandelion (Non-native)

This weedy herb remains common around MSSS and to a lesser extent around Pan-STARRS, mostly near buildings and other disturbed areas where the plant is likely getting extra moisture.


2009


2011


2012


2013

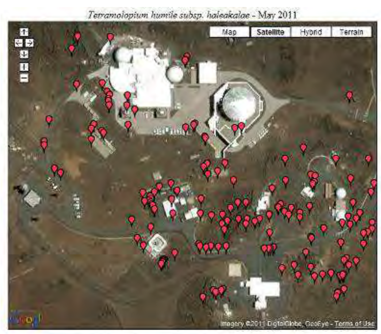
2014

2015

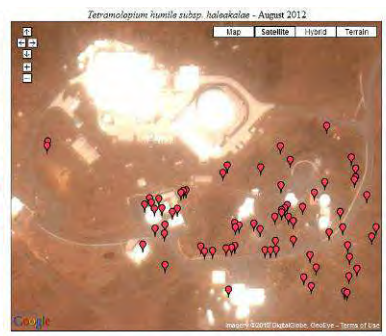
## ***Tetramolopium humile*** **subsp.** ***haleakalae*** **(Asteraceae)** **Tetramolopium (Native: Endemic)**

Still present over most of the site, though less abundant now in areas affected by construction. This hearty small native herb may return to some of these sites when construction is completed. The last few dry years may also have led to a decrease in other areas. Perhaps some of the recent rains will stimulate some germination.


2009




2011



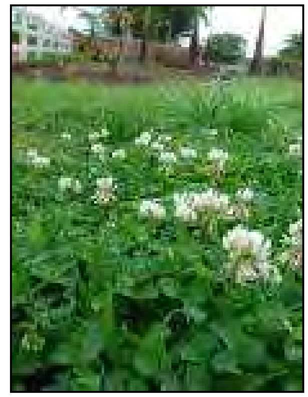

2012


2013

2014

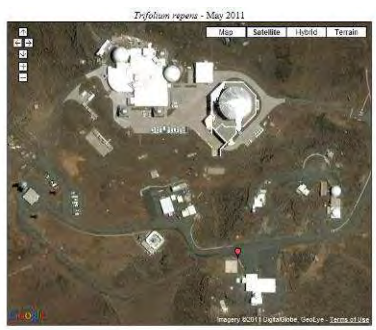
2015

# *Trifolium repens* (Fabaceae)
# White clover (Non-native)



Not observed during this survey. First observed in 2009. Since then a plant or two have been recorded from time to time near the old parking area and behind the building by Mees. It has not been seen in recent years and the area by the parking lot is now within the construction zone and likely no longer exists. The plant behind the building may no longer be there, though it is a tiny plant that has a similar appearance to *Medicago* which is common in the same area, so it could be overlooked.


2009

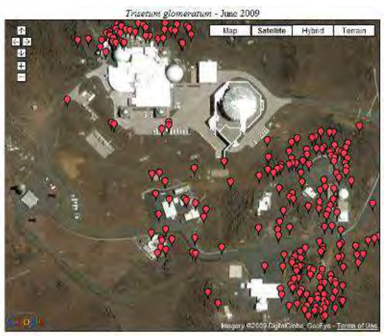



2011

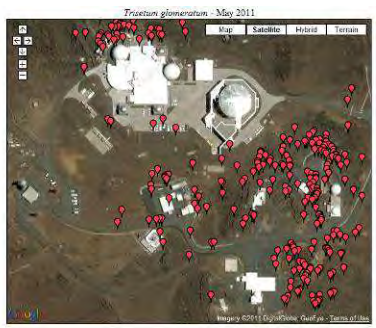

2012

## *Trisetum glomeratum* (Poaceae)
## Pili uka (Native: Endemic)

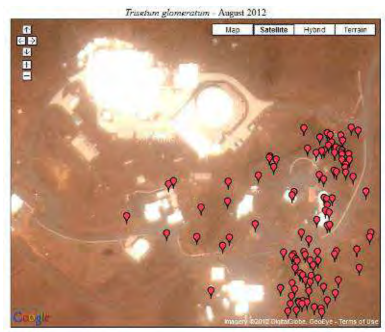
This native grass remains common over much of the site, in mostly non disturbed areas. There has been some decrease in abundance construction, though this hardy grass many recolonize some of the areas once construction is completed.



2009



2011



2012

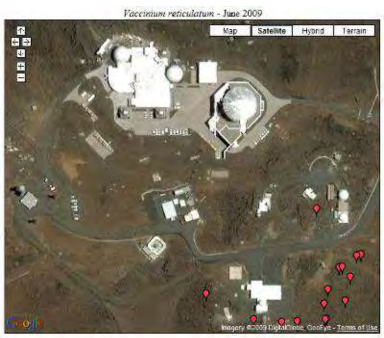
2013

2014

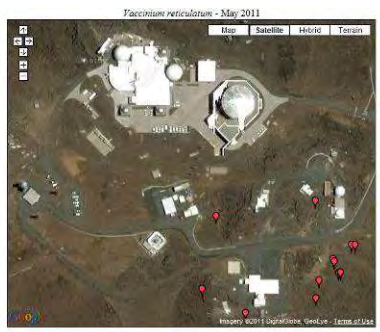
2015

## *Vaccinium reticulatum* (Ericaceae)
## ʻŌhelo (Native: Endemic)

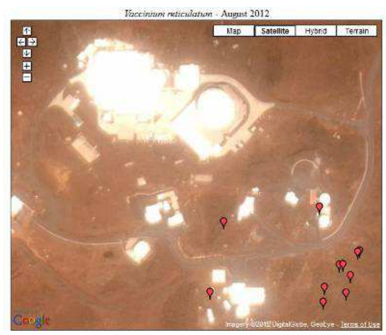
Occasionally found in the less disturbed rocky outcrops near Mees and Pan-STARRS. The distribution has remained rather stable over the past few years.




2009




2011




2012


2013

2014

2015

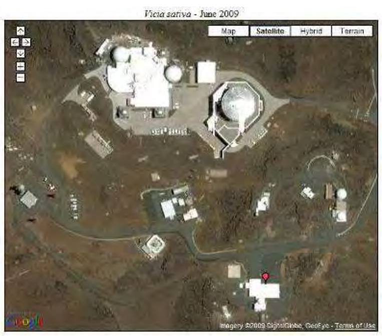
## *Veronica arvensis* (Plantaginaceae)
## Corn speedwell (Non-Native)

Observed for the first time at HO in the MSSC area. A patch of dozens of small plants observed on north part of the Air Force property, located in a cinder planter near the buildings.

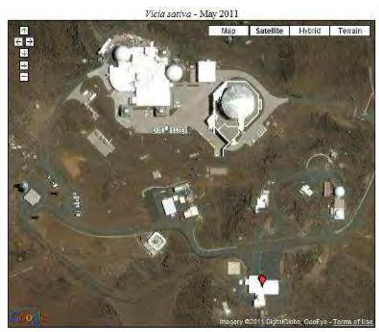
2015

# *Vicia sativa* (Fabaceae)
# Vetch (Non-native)

Not observed during this survey. One small plant was first observed in 2005 near the front of the Mees building. It was found again and pulled in 2009. In 2011 a few small plants, likely seedlings, were seen and pulled. It was not seen after that and the area has been affected by construction activities. This plant likely no longer exists at the site.



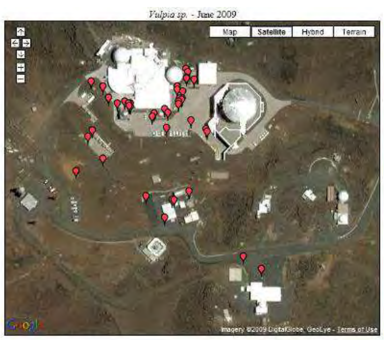

2009



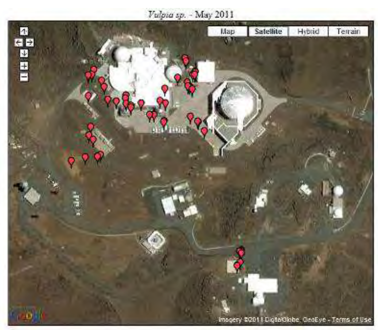

2011

# *Vulpia* spp. (Poaceae) Non-Native
# *Vulpia bromoides* (Brome fescue)
# *Vulpia myuros* (Rat tail fescue)

Remains common around disturbed areas at MSSC and rare at Mees. *V. bromoides* is very similar looking to *V. myuros*, which also occurs at HO, and is virtually indistinguishable without a microscope, especially when young. Because of this, the two species are lumped for mapping and management purposes.




2009




2011


2012


2013

2014

2015

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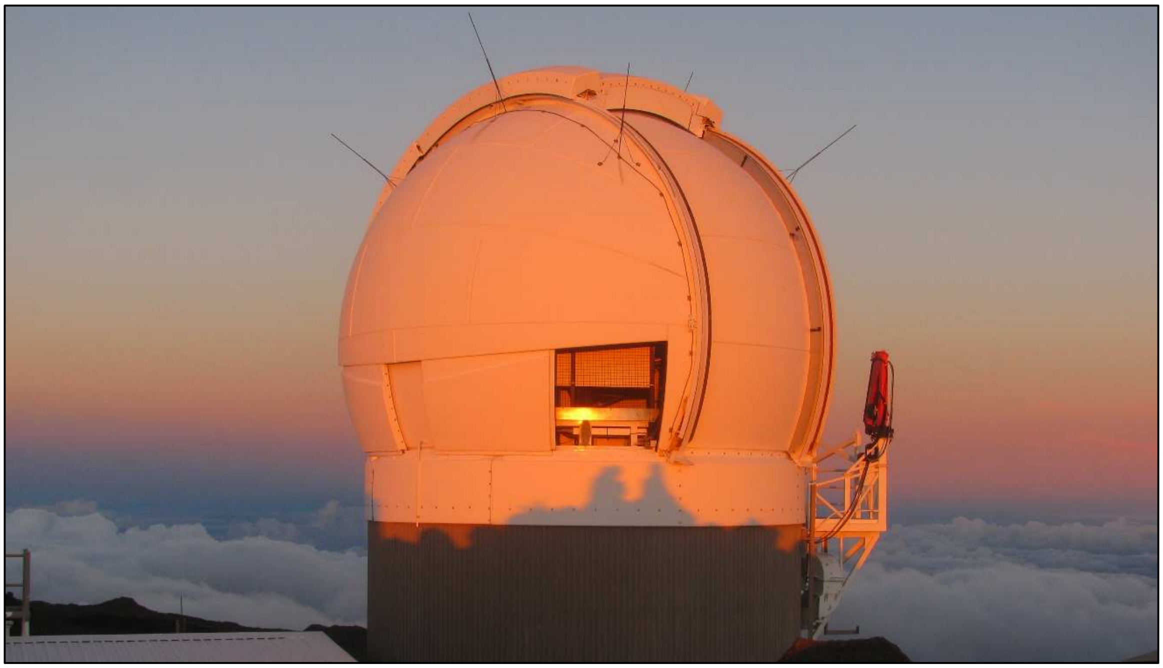


**HO at sunset, May 2013.**

# FAUNAL SURVEY
# & ANNUAL INSPECTION
# HALEAKALA OBSERVATORIES
# FALL 2015

Prepared for:
**KC Environmental**
**Maui, Hawaii**

Prepared by:
**Forest Starr & Kim Starr**
**Starr Environmental**
**Maui, Hawaii**

**November 2015**

## OVERVIEW

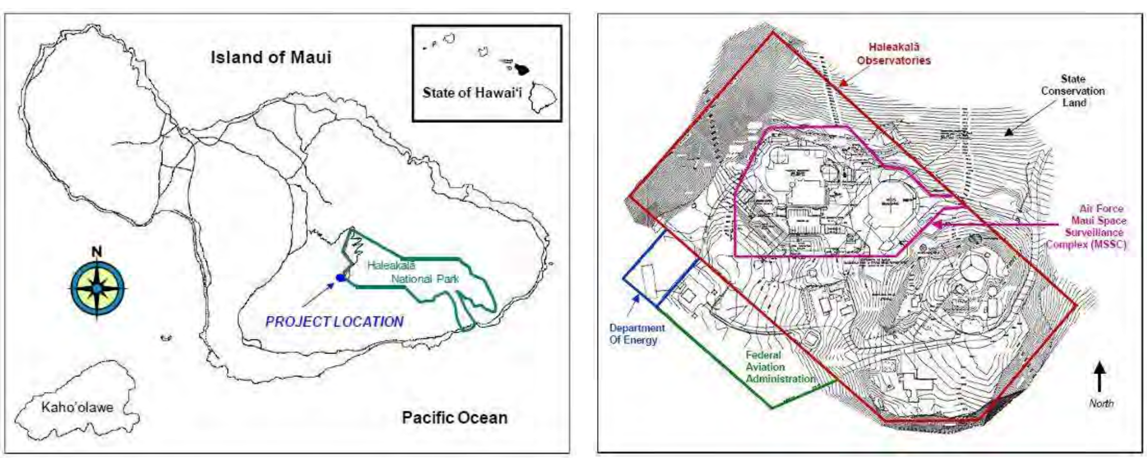
The Daniel K. Inouye Solar Telescope (DKIST), will be a 4-meter (13.1 ft) optical telescope, contained in a structure 41.5 meters (136 ft) tall, to serve the solar physics community. It will host an array of instruments designed to provide insights about the sun.

In accordance with the Final Environmental Impact Statement (FEIS) (NSF 2009), programmatic monitoring has been implemented during construction and will be continued after construction of DKIST, which began in December 2012, to ensure that impacts on biological resources are minimized. Monitoring includes field observations at Haleakala High Altitude Observatories Site (HO) and selected areas of the Haleakala National Park (HALE) Park road corridor for faunal presence, e.g., scat, tracks, eaten plants, etc. This document reports on the survey of HO.

In addition to the semi-annual surveys required by the FEIS, pursuant to the DKIST approved Habitat Conservation Plan (HCP) (NSF 2010) and published Biological Opinion (BO) (USFWS 2011), an annual inspection for invasive species will be conducted. DKIST facilities and grounds within 100 feet of the buildings are to be thoroughly inspected for introduced species that may have eluded the cargo inspection processes, or transported to the site by construction personnel. This document also reports on the faunal inspection of HO.

## PROJECT LOCATION

The DKIST construction site is approximately 0.75 acre and is located on TMK 222007008 (HO is a 18.166-acre parcel largely within the Kolekole cinder cone, and is roughly rectangular in shape. It is mostly surrounded by State Conservation District lands, with a small adjoining Federal property on the southwest boundary, and Haleakala National Park nearby to the East. Additionally, about 17 km (11 miles) of road that travels through Haleakala National Park is being utilized during construction and operation of the DKIST.




**General and detailed site location maps of Haleakala Observatories.**

## BIOLOGICAL SETTING

HO is located near the summit of Haleakala, at 2,999-3,052 m (9,840-10,012 ft) elevation. Average annual rainfall is a moderate 1,037 mm (41 in), occurring primarily during the winter months from November through March (Giambelluca et al. 2013). Temperatures can be cold at the site, and occasionally dip below freezing, with average annual temperature at the summit of Haleakala ranging from 43-50 degrees F (6-10 degrees C), and once every few years it will snow (County of Maui, 1998). The soils are volcanic, a mixture of ash, cinders, pumice, and lava (RTS, 2002). Vegetation at HO is relatively sparse, a mix of native and non-native plants.

There are very few birds at HO, except for Hawaiian Petrels (*Pterodroma sandwichensis*), which occupy pre-existing or bird-excavated burrows under lava shelves to nest in. Occasionally other birds are seen, especially Chukars (*Alectoris chukar*).

Hawaiian Hoary Bats (*Lasiurus cinereus semotus*) have not been documented from HO, but have been seen at 2750 m (9,000 ft) on the south slope of Haleakala and may likely utilize episodically abundant insects anywhere on Maui.

There are no feral ungulates within the area, which was fenced in 2013. However, goats (*Capra hircus*), pigs (*Sus scrofa*), and deer (*Axis axis*), reside in adjacent areas. Subsequent to fencing, DKIST now employs extensive predator grids for rats (*Rattus* spp.), cats (*Felis catis*), and mongoose (*Herpestes auropunctatus*), which results in fewer numbers of these predators in the area.

**HO is mostly open terrain, with sparse, low growing plants and very few birds.**

## METHODOLOGY

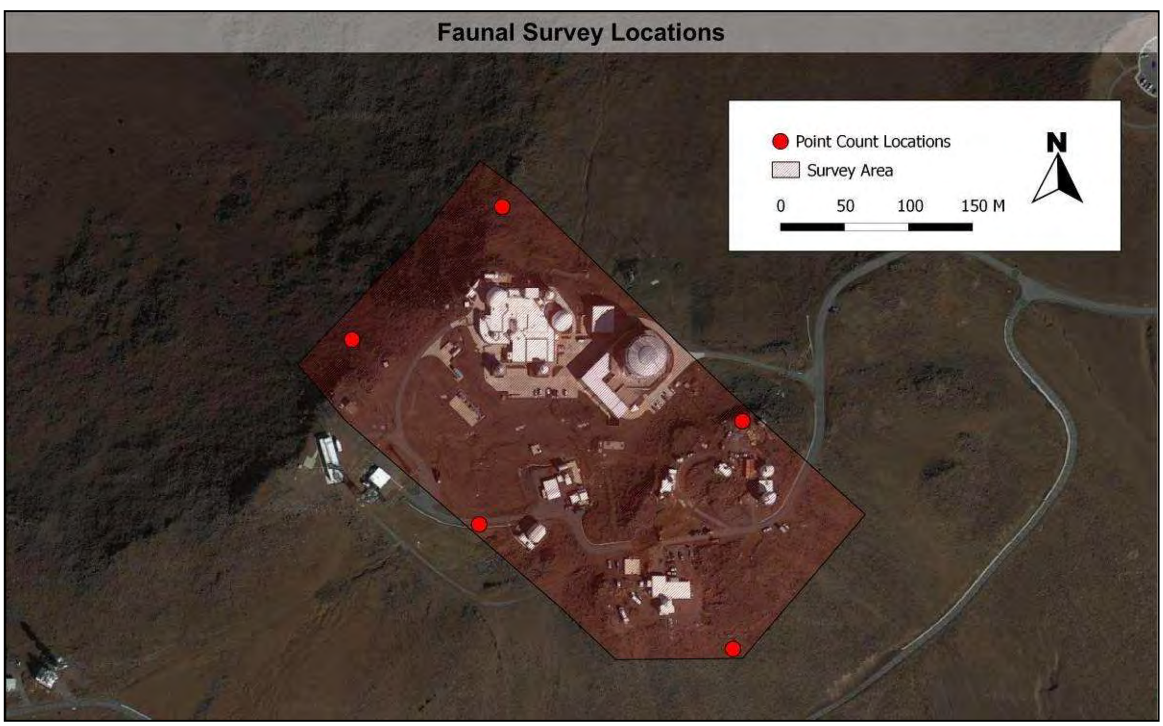
Five point count stations were established within the survey area and are surveyed once every six months. Additionally, the entire project area is surveyed for incidental sightings. Surveys were conducted November 6, 2015.

Point counts are conducted at prominent high points and locations with good visibility. Most are easily accessible, with paths leading up to them. Counts last ten minutes. All birds observed or heard for an unlimited distance are recorded.

At all point count stations, and over the entire project area, signs of native and non-native mammals are searched for, such as scat, tracks, carcasses, or browsing. Additionally, along with listening for birds, mammals are also listened for.

Initial efforts of searched for bats at HO used active bat detectors that required a person to be present. More recent methodology employs passive detectors that record ultrasonic bat calls and can be left out all night for multiple nights and analyzed later. Along with a survey at HO at dusk on November 6, 2015, a bat detector was placed near the cinder parking lot at the entrance to HO from November 6-11, 2015.

To minimize the likelihood of an invasive species introduction, DKIST interior facilities and grounds within 100 ft (30 m) of the buildings are thoroughly inspected on an ongoing annual basis for non-native species that may have eluded the cargo and luggage (load) inspections. Any newly-discovered non-native, invasive plant or animal will be photo documented, mapped, and described.




**Survey area and point count locations, HO.**

## RESULTS / DISCUSSION

### ANNUAL INSPECTION

No signs of non-native invasive animal species were found inside or within 100 ft (30 m) of the DKIST buildings.

### BIRDS

The only bird heard during the survey was a lone Chukar (*Alectoris chukar*), which was calling from the rocks near the former Reber Circle site. Hawaiian Petrel (*Pterodroma sandwichensis*) burrows were observed at the site, but DKIST resource management personnel informed us that the chicks from this year had fledged the previous week and burrows were now empty.

**Chukar at HO, June 2009.**

We again received reports of birds matching the description of Red-billed Leiothrix (*Leiothrix lutea*) at the summit from folks who work at HO. In the fall, after the breeding season, flocks of this non-native bird migrate out of the wet forest. Some of these birds end up at the summit of Haleakala, where they often perish.

### PREDATORS

No predators or signs of their presence were observed at HO. A number of predator control stations maintained by DKIST resource management personnel were observed at and near HO.

### UNGULATES

No new scat or other signs of ungulates were observed. Old ungulate scat, likely goat (*Capra hircus*), is still present at HO, mostly on the steep northern slope of the property. It continues to decay and become less prevalent, now that an ungulate fence has been erected around HO as part of the HCP and BO.

**BATS**

No bats were detected during 5 nights of surveys near HO, which now marks 20 nights of surveys without a bat detection there.

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# BOTANICAL SURVEY
# & ANNUAL INSPECTION
# HALEAKALA OBSERVATORIES
# FALL 2015

Prepared for:
**KC Environmental**
**Maui, Hawaii**

Prepared by:
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**Starr Environmental**
**Maui, Hawaii**

**November 2015**

## OVERVIEW

The Daniel K. Inouye Solar Telescope (DKIST) will be a 4-meter (13.1 ft) optical telescope, contained in a structure 41.5 meters (136 ft) tall, to serve the solar physics community. It will host an array of instruments designed to provide insights about the sun.

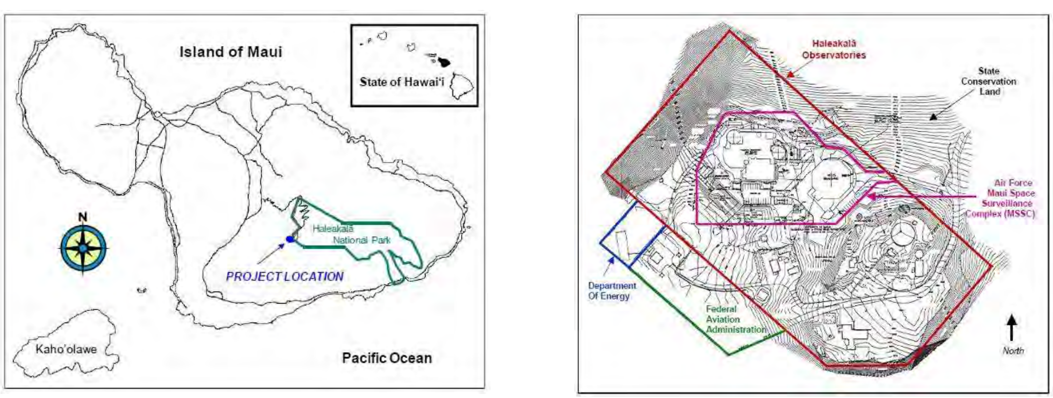
In accordance with the Final Environmental Impact Statement (FEIS) (NSF 2009), programmatic monitoring is being implemented during and after construction of the DKIST, which began in December 2012, to insure that impacts on biological resources are minimized. Monitoring includes semi-annual botanical surveys at Haleakala High Altitude Observatories Site (HO) and along the Haleakala National Park (HALE) road corridor, including characterization of types, diversity, stage of development, coverage, and health of endangered Haleakala Silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*), and non-endangered endemic or alien invasive species at HO and selected areas of the Park road corridor. This report is on the botanical survey of HO.

In addition to the semi-annual surveys required by the FEIS, pursuant to the DKIST approved Habitat Conservation Plan (HCP) (NSF 2010) and published Biological Opinion (BO) (USFWS 2011), an annual inspection for invasive species will be conducted. DKIST facilities and grounds within 100 feet of the buildings are to be thoroughly inspected for introduced species that may have eluded the cargo inspection processes, or transported to the site by construction personnel. This document also reports on the floral inspection of HO.

Detailed GPS mapping of all plant species, other than the very common *Deschampsia* and *Dubautia*, is conducted in the spring when all plant species are better represented.

## PROJECT LOCATION

The site is TMK 222007008 (HO), a 18.166-acre parcel located largely within the Kolekole cinder cone, and roughly rectangular in shape. It is mostly surrounded by State Conservation District lands, with a small adjoining Federal property on the southwest boundary, and Haleakala National Park nearby to the East.




**General and detailed site location maps of Haleakala Observatories.**

## BIOLOGICAL SETTING

HO is located near the summit of Haleakala, at 2,999-3,052 m (9,840-10,012 ft) elevation. Average annual rainfall is a moderate 1,037 mm (41 in), occurring primarily during the winter months from November through March (Giambelluca et al. 2013). Temperatures can be cold at the site, and occasionally dip below freezing, with average annual temperature at the summit of Haleakala ranging from 43-50 degrees F (6-10 degrees C), and once every few years it will snow (County of Maui, 1998). The soils are volcanic, a mixture of ash, cinders, pumice, and lava (RTS, 2002). Vegetation at HO is relatively sparse, a mix of native and non-native plants.

## METHODS

Two biologists, Forest Starr and Kim Starr, surveyed HO on Nov. 6, 2015. A walk-through survey method was used. Focus was placed on areas that could harbor rare or invasive plants. All plants and their abundance were noted. Species identification was made in the field. Care was taken during surveys to avoid disturbing the facilities, native vegetation, native insects, petrel burrows, archeological sites, and construction activities.

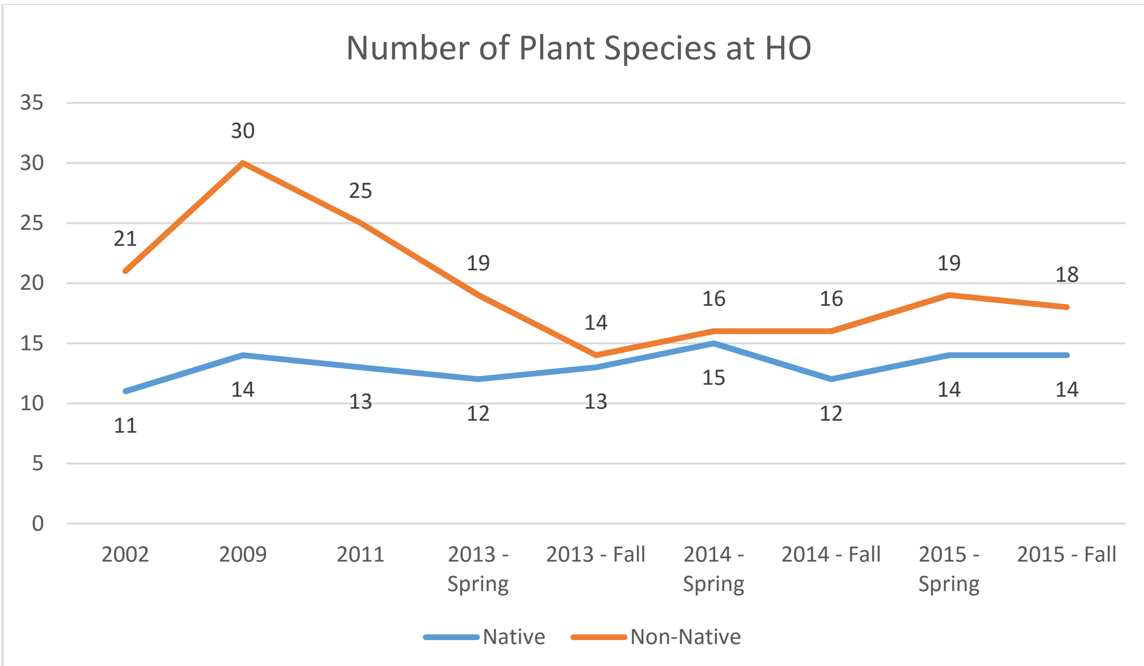
To minimize the likelihood of an invasive species introduction, DKIST interior facilities and grounds within 100 ft (30 m) of the buildings are thoroughly inspected on an ongoing annual basis for non-native species that may have eluded the cargo and luggage (load) inspections. Any newly-discovered non-native, invasive plant or animal will be photo documented, mapped, and described.

**Surveying plants at HO. The vegetation at HO is sparse and low growing.**

## RESULTS & DISCUSSION

### CHANGES IN VEGETATION OVER TIME

During the survey, we observed 14 native and 18 non-native plant species. This is about the same as it has been for the past two years.




**Number of species observed at HO in recent surveys**

### NATIVES

There were the same native species present this survey as last spring. Most plants appeared lush and healthy, with the abundant El Nino rainfall that fell this summer.

Of note were 99 silversword (*Argyroxiphium sandwicense* subsp. *macrocephalum*) seedlings found this year, generally near plants that had flowered last year. A similar flush of seedlings is occurring across the entire range of this species.

A few small, less than 10 cm tall, plants of native catchfly (*Silene struthioloides*) continue to persist and get larger in lava cracks near Mees.

Ena ena (*Pseudognaphalium sandwicensium* var. *sandwicensium*), continues to be found in a few disturbed sites, such as near drainages.

**NON-NATIVES**

There was one fewer non-native plant species found during this survey, compared to last spring. Evening primrose (*Oenothera stricta* var. *stricta*) was never common and used to be located where the current construction is occurring.

There seemed to be considerably less pepperweed (*Lepidium virginicum*) at HO, and some appeared to have been recently pulled out around the MSSS.

Some non-native plants continue to persist in very limited distribution in the same locations, such as Yorkshire fog (*Holcus lanatus*), annual ryegrass (*Poa annua*), common mallow (*Malva neglecta*), and hairy horseweed (*Conyza bonariensis*). We pull these each survey, and they are removed during programmatic weeding of HO as well, but they germinate and set seed before the next survey six months later.

**Dandelion (*Taraxacum officinale*) is one of the persistent non-native plants at HO, occurring in the same general locations despite occasional control efforts.**

## SILVERSWORDS

Haleakala silverswords (*Argyroxiphium sandwicense* subsp. *macrocephalum*) are federally listed as "threatened", meaning they may become endangered throughout all or a significant portion of their range if no protection measures are taken.

**Haleakala Silversword**

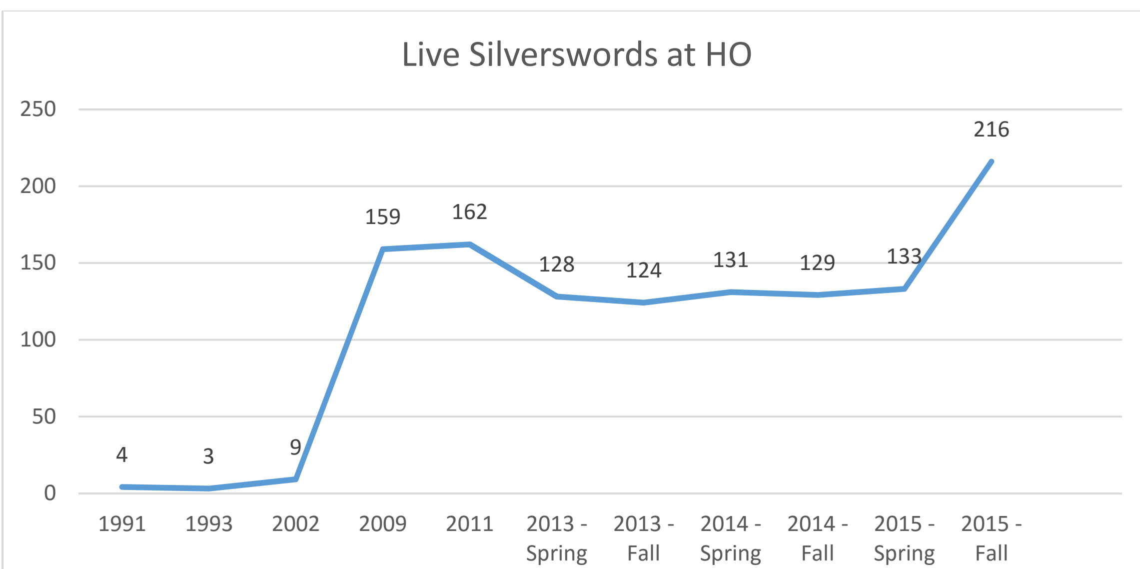
There were 216 silverswords observed at HO this survey, 6 of which were in flower. This is the largest number of silverswords recorded within HO.

Of these, 99 were seedlings, most of which were less than 2 cm wide. Additional seedlings could have been overlooked. Also, many seedlings were in cotyledon stage, suggesting germination is continuing.

Most of the seedlings were near plants that flowered last year. A similar cohort of seedling germination is occurring over the entire range of the silversword right now, the largest since 2004, presumably the result of above average summer rainfall from El Nino weather conditions.

A few of the silverswords that flowered this year had some or all of the seed heads removed by United States Fish and Wildlife Service (USFWS) and HALE personnel, to prevent seedlings from growing in areas they aren't wanted. Plants from these seeds will be planted by HALE personnel at visitor centers and other developed areas within HALE.

All live silversword plants at HO are located on or near MSSS, on land that has undergone heavy construction activities in the past. The silverswords do not appear affected by recent construction activities at HO.




**Number of live silverswords at HO.**

**CONSTRUCTION**

The biggest changes at HO continue to be associated with construction. The main area affected is where the DKIST telescope is being built. Other areas of HO that have been affected by construction include a corridor running from the Advanced Electro-Optical System (AEOS) over Puu Kolekole to Mees. These areas received much ground disturbance and many native and non-native plants were removed in the process. There are also large piles of rocks and soil that have been staged by the retention basin.

No new weeds have been found at HO that could be attributed to recent construction activities. No Threatened or Endangered plants appear to have been impacted by construction.

As construction wanes, it is likely that native and non-native vegetation will re-colonize the site, as has happened at HO in the past.

**ANNUAL INSPECTION**

No new non-native, invasive plants were found during the annual inspection. Most of the area within 100 ft. (30m) of the DKIST is unvegetated due to ongoing construction.

**Surveying around DKIST for new non-native plants. No new plants were found.**

## PLANT CHECKLIST

The following is a checklist of vascular plant species observed during recent botanical surveys of HO. Plants are listed alphabetically by species. Taxonomy and nomenclature follow Wagner *et al.* (1999), Palmer (2003) and Bishop Museum (2013). Native species are noted by an asterisk (*). The relative abundance of each species observed is also noted, the following abbreviations / definitions are used:

- **D = Dominant** - Forming a major part of the vegetation within the project area.
- **C = Common** - Widely scattered throughout area or locally abundant within a portion of it.
- **O = Occasional** - Scattered sparsely throughout area or in a few small patches.
- **R = Rare** - Only a few isolated individuals within the project area.
- **X = Observed** - Present during survey. No abundance estimate.

| Native | Scientific name | 2015 - Fall | 2015 - Spring | 2014 - Fall | 2014 - Spring | 2013 - Fall | 2013 - Spring | 2009 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| | *Ageratina adenophora* | | | | | | | R | |
| * | *Agrostis sandwicensis* | C | C | C | C | C | C | C | O |
| | *Anthoxanthum odoratum* | | | | | | R | | R |
| | *Arenaria serpyllifolia* | C | C | O/C | C | C | C | O | R |
| * | *Argyroxiphium sandwicense* subsp. *macrocephalum* | C | C | C | C | C | C | C | R |
| * | *Argyroxiphium x Dubautia* | R | R | R | R | | | | |
| * | *Asplenium adiantum-nigrum* | O/C | O/C | O | O/C | O | O/C | C | R |
| * | *Asplenium trichomanes* subsp. *densum* | R/O | R/O | R/O | O | O | R/O | O | R |
| | *Axonopus* sp. | | | | | | | R | |
| | *Bidens pilosa* | | | | | | | | |
| | *Bromus catharticus* | R | O/C | R | R | | R | O | R |
| | *Bromus diandrus* | | R | | R | | | R | |
| | *Conyza bonariensis* | R | R | R | R | | | R | |
| | *Cryptomeria japonica* | | | | | | | | |
| | *Cynodon dactylon* | | | | | | | R | R |
| | *Dactylis glomerata* | | | | | | | R | |
| * | *Deschampsia nubigena* | D | D | D | D | D | D | C | C |
| * | *Dryopteris wallichiana* | | | | R | R | | R | |
| * | *Dubautia menziesii* | D | D | D | D | D | D | C | C |

| Native | Scientific name | 2015 - Fall | 2015 - Spring | 2014 - Fall | 2014 - Spring | 2013 - Fall | 2013 - Spring | 2009 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| | *Erodium cicutarium* | C | C | C | C | C | C | C | O |
| | *Festuca rubra* | | R | | | | R | O | |
| | *Foeniculum vulgare* | | | | | | | | |
| * | *Geranium cuneatum* subsp. *tridens* | | | | | | | | |
| | *Gutierrezia sarothrae* | | | | | | | R | |
| | *Holcus lanatus* | R | R | | R | R | R | O | O |
| | *Hypochoeris radicata* | R/O | R/O | R | O/C | O | C | C | O |
| | *Lepidium virginicum* | R/O | O | O | C | O/C | C | C | O |
| * | *Leptecophylla tameiameiae* | R/O | R/O | R/O | O | O | C | O | O |
| * | *Lythrum maritimum* | | | | | | | | |
| | *Malva neglecta* | R | R | R | | | R | R | R |
| | *Medicago lupulina* | O | O | O | O | O | O | C | O |
| | *Oenothera stricta* subsp. *stricta* | | R | R | | R | R | C | R |
| * | *Pellaea ternifolia* | O | O | O | O | O | O | O | R |
| | *Pennisetum clandestinum* | | | | | | | R | |
| | *Pinus* sp. | | | | | | | R | R |
| | *Plantago lanceolata* | O | O | O | O | O | O/C | C | O |
| | *Poa annua* | R | R | R | R | | R | R | R |
| | *Poa pratensis* | O/C | O/C | O | C | O | C | C | O |
| | *Polycarpon tetraphyllum* | R | | R | R | R | | R | R |
| * | *Pseudognaphalium sandwicensium* var. *sandwicensium* | R | R | | R | | | | |
| * | *Pteridium aquilinum* var. *decompositum* | | | | R | R | R | R | |
| | *Rumex acetosella* | R | | R | R | R | R | R | O |
| | *Senecio madagascariensis* | R | R | | | | R | | |
| | *Senecio sylvaticus* | | | | | | | | R |
| | *Senecio vulgaris* | | | | | | | | |
| * | *Silene struthioloides* | R | R | | | | | R | |
| | *Sonchus oleraceus* | | | | | | R | R | R |
| | *Taraxacum officinale* | O | O/C | O | C | O | C | C | O |
| * | *Tetramolopium humile* subsp. *haleakalae* | O/C | O/C | O | O/C | C | C | C | C |
| | *Trifolium repens* | | | | | R | | R | |

| Native | Scientific name | 2015 - Fall | 2015 - Spring | 2014 - Fall | 2014 - Spring | 2013 - Fall | 2013 - Spring | 2009 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| * | *Trisetum glomeratum* | C | C | C | C | C | C/D | C | C |
| * | *Vaccinium reticulatum* | R/O | R/O | R/O | O | O | O | O | R |
| | *Veronica arvensis* | R | R | | | | | | |
| | *Vicia sativa* | | | | | | | R | |
| | *Vulpia bromoides* | | | | | | | O | O |
| | *Vulpia myuros* | | | | | | | O | |
| | *Vulpia* spp. | O | O/C | O | O/C | O | O/C | | |

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