ACCESS WAY ARTHROPOD MONITORING REPORT

THIRTY METER TELESCOPE PROJECT ASTRONOMY PRECINCT MAUNA KEA SCIENCE RESERVE HĀMĀKUA DISTRICT, ISLAND OF HAWAI'I

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EXECUTIVE SUMMARY

The TMT Observatory is proposed to be located on Mauna Kea on Hawai'i Island in the State of Hawai'i. The Observatory would be located in the western portion of the area known as the Northern Plateau within the Astronomy Precinct approximately 1/2-mile northwest of the eight existing optical/infrared observatories located near the summit of Mauna Kea.

The Final Environmental Impact Statement, Thirty Meter Telescope Project, dated May 8, 2009, (page 3-76 and page 3-195) commits the TMT Observatory Corporation to monitoring arthropods in the area of the Access Way on the alpine cinder cone habitat before, during, and for two years after construction of that portion of the Access Way. The extent of Access Way construction activities within the alpine cinder cone habitat extend from the southern end of the Access Way and extends roughly 760 feet to the north where the Access Way enters a lava flow habitat.

A proposed Arthropod Access Way Monitoring Plan was reviewed and modified by OMKM and DLNR and the revised plan was implemented in June 2011. The purpose of monitoring in the area of the Access Way is to provide data regarding the presence of arthropods, including wēkiu bugs and potential invasive species prior to, during, and after construction. Monitoring along the Access Way will allow detection of trends in wēkiu bugs that may be related to construction activities. With this knowledge OMKM then may change or implement new management strategies to reduce impacts to wēkiu bugs and their habitat.

The Monitoring Plan consists of four tasks. The first of these tasks were completed in June, 2011 by Pacific Analytics, LLC. This task, a single arthropod monitoring event prior to the start of construction activities, was conducted in six locations, at sites along the Access Way and two nearby control sites that are presumably beyond the potential area of effect of future TMT construction activities.. Paired pitfall live-traps and a protein- and sugar-based trap were placed at the eight sites and allowed to sample for three days.

A total of one hundred fifty-one (151) wēkiu bugs were captured and later released. Thirteen (13) wēkiu bugs were captured at the six sites along the Access Way, two (2) were captured at a control site above the Mauna Kea Loop Road on Pu'u Hau'oki ¹and one hundred thirty-six (136) were captured at a control site on Pu'u Poli'ahu. No invasive arthropods were found during the sampling.

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¹ In the past this pu'u, on which both Subaru and Keck site, has been referred to as Pu'u Hau'oki. Pu'u Hau'oki is actually the pu'u on which the IRTF sits. Both of these pu'u are part of Pu'u Kūkahau'ula, the traditional Hawaiian name of the summit pu'u. This pu'u will be referred to as Pu'u Hau'oki in this report.

1.1 TMT Project

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

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

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

1.2 Arthropod Monitoring Requirements

The Final Environmental Impact Statement, Thirty Meter Telescope Project, dated May 8, 2009, (page 3-76 and page 3-195) commits the TMT Observatory Corporation to monitoring arthropods in the area of the Access Way on the alpine cinder cone habitat before, during, and for two years after construction of that portion of the Access Way. The extent of Access Way construction activities within the alpine cinder cone habitat extend from the southern end of the Access Way (at the existing electrical panel across from the SMA building) and extends roughly 760 feet to the north (Figure 1) where the Access Way enters a lava flow habitat.

A proposed monitoring plan was reviewed and modified by OMKM and DLNR and the revised plan was implemented in June 2011. The Monitoring Plan is consistent with the Natural Resources Management Plan (2009), a sub-plan of the Mauna Kea Comprehensive Management Plan (designed to help Office of Mauna Kea Management (OMKM) achieve its mission by providing natural resource management goals, objectives, and activities that protect, preserve, and enhance the natural resources of Mauna Kea.



Figure 1: Extent of Access Way Work on Cinder Cone Habitat.

The purpose of monitoring in the area of the Access Way is to provide data regarding the presence of arthropods, including we kiu bugs and potential invasive species prior to, during, and after construction. Monitoring along the Access Way will allow detection of trends in wēkiu bugs that may be related to construction activities. With this knowledge OMKM then may change or implement new management strategies to reduce impacts to wekiu bugs and their habitat.

It is also important to monitor along the Access Way because movement of vehicles, personnel, and equipment to the Project areas may accidentally introduce invasive, non-indigenous species to the Mauna Kea summit region. Invasive plant species can displace indigenous species and thereby reduce their populations. Arthropods introduced outside of their natural range can represent a threat to natural systems because they can deplete indigenous arthropod food resources and/or prey on indigenous species. Nonindigenous arthropod species that successfully establish populations within the Mauna Kea Science Reserve could out-compete or exclude indigenous species, such as the wekiu bug, lycosid wolf spider, and other native resident arthropods.

1.3 Physical Setting

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

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

The MKSR is also home to unique plants and animals living in an alpine ecosystem. The summit region is an island within an island, separated from other ecosystems by high elevations as well as vast oceans. The species found there are not only unique; they are sometimes rare² and limited in population and area of distribution. For example, the Wēkiu bug lives only in loose cinder habitats on the cinder cones above 11,715 feet on Mauna Kea (Porter and Englund 2006). There is a similar species, Nysius aa that occurs in the upper elevations on Mauna Loa (Polhemus 1998).

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²There are several terms that are used to describe the status of species. These include:

Endangered species – Any species which is in danger of extinction throughout all or a significant portion of its range.

Threatened species – Any species which is likely to become endangered within the foreseeable future. Candidate species - Any species being considered by the Secretary of the Interior for listing as an endangered or a threatened species, but not yet the subject of a proposed rule.

Species of Concern - Those species about which regulatory agencies have some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the Endangered Species Act (ESA).

Rare species – Those species that occur very seldom, but are not classified threatened or endangered. Sensitive species – Those species which rely on specific habitat conditions that are limited in abundance, restricted in distribution, or are particularly sensitive to development.

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



The TMT Access Way cinder cone habitat area. Photo taken October 1, 2009.

2.0 Monitoring Tasks and Locations

Access Way monitoring consists of the following tasks:

- **TASK 1:** A single arthropod monitoring event prior to the start of construction activities. Timing of monitoring was coordinated with OMKM's ongoing survey schedule. Monitoring took place at the following general locations:
 - 1. Three locations above the 4-wheel drive road, the alignment of the proposed TMT Access Way, and electrical boxes across from the SMA building (Figure 2). The elevations of these monitoring points vary, but average roughly 13,400 feet.
 - 2. Three locations between the 4-wheel drive road, the alignment of the proposed TMT Access Way, and the lower SMA road (Figure 2). The elevations of these monitoring points vary, but average roughly 13,375 feet.
 - 3. Two nearby locations:
 - A location between the Mauna Kea Loop Road to Subaru and Keck observatories and the Subaru Observatory, at an elevation of roughly 13,500 feet (Figure 2). This location is roughly 300 feet from the Access Way construction area.
 - A location on the lower, northern slope of Pu'u Poli'ahu. This location is at an elevation of roughly 13,350 feet and roughly 1,000 feet from the Access Way construction area (Figure 2).

Future Access Way monitoring will consist of the following tasks:

TASK 2: Perform arthropod monitoring according to a schedule approved by OMKM, during the period of construction within the alpine cinder cone habitat. Monitoring will take place at the general locations outlined above with two traps deployed per location.

Brief reports summarizing the results of each monitoring event will be produced and shared with OMKM, the wēkiu bug working group, DLNR, and USFWS. The reports will include the results of all previous monitoring events.

TASK 3: Perform arthropod monitoring twice a year according to a schedule approved by OMKM, for a period of two years after completion of construction in that area. Monitoring will take place at the general locations outlined above with two traps deployed per location.

Brief reports summarizing the results of each monitoring event will be produced and shared with OMKM, the wēkiu bug working group, DLNR, and USFWS. The reports will include the results of all previous monitoring events.

TASK 4: Prepare a final report that (a) summarizes the results of the surveys, and (b) discusses the presence/introduction of new arthropod species (invasive or otherwise) during the monitoring period.

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Figure 2: Arthropod Monitoring Locations in Vicinity of Access Way

Task 1 conducted for this monitoring was performed by Dr. Jesse Eiben and Dr. Gregory Brenner June 12 - 15, 2011.

3.0 Monitoring Methods

3.1 Arthropod sampling

At each monitoring location, two pitfall live-traps were placed within roughly 10 feet of each other (pitfall trap "a" and pitfall trap "b"). Where ever possible the two traps were placed in different microhabitat types (ex. large rock jumble vs. ash layer near the surface) to attempt to sample the diversity of the habitat at each location. A live-trap design very similar to that employed by Dr. Eiben in 2007 and 2008 during his dissertation field studies, and Dr. Eiben and Dr. Brenner in 2008 and 2009 for the TMT Project was used to trap wēkiu bugs and other arthropods. The trap was successful in those studies and is described in the "Arthropod and Botanical Inventory and Assessment" included as Appendix K of the <u>Final Environmental Impact Statement, Thirty Meter Telescope Project</u> (dated May 8, 2009).

The trap includes a 10-ounce clear plastic cup with a few small pieces of rock in the cup. Attractant shrimp paste was smeared on the side of the cup and on a cap rock. These traps are designed to record the presence of wēkiu bugs, and have been demonstrated to be effective at detecting them (Eiben 2012).

The traps were dug into the available ground substrate with a goal of achieving a depth where moisture was present (if moisture is available) in the ash layer. A cap rock was placed over the traps and elevated above the ground approximately 0.5-inch with smaller rocks.

The traps were checked three days after installation. Wēkiu bugs and other arthropods captured were removed and indigenous species released near the trap in which they were captured. Non-indigenous species were collected for future reference.

In addition to the pitfall live-traps, each monitoring location was visually searched 20 minutes for native and non-native arthropods. The search was conducted in a way to minimize impact of the substrate by visually searching the substrate surface, and by occasionally lifting rocks and searching below the surface for arthropods. Cinder rocks were placed back in their original positions. The field crew had aspirators and aerial nets available for collecting arthropods observed either on the ground or in the air.

A protein- and sugar-based trap was placed at each monitoring location. These traps are typically used to sample for the presence of ants. They contained peanut butter, honey, and tuna and were installed in each of the monitoring locations for a period of about 30 minutes. The contents were recorded.

3.2 Permit

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



An installed monitoring pitfall trap.

3.3 Personnel

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

3.4 Nomenclature

The nomenclature used in this report follows the Hawaiian Terrestrial Arthropod Checklist, Third Edition (Nishida 1997). Hawaiian and scientific names are italicized.

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

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

3.5 Specimen Curation

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

3.6 Identification

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

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

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

4.0 RESULTS

4.1 Monitoring Station M01

N19 49.448 W155 28.623 13527 ft. elevation



Monitoring Station M01 was located east of the Mauna Kea Loop Road and near the beginning of the Access Way about twenty feet up the steep slope of the cinder cone. During the trap installation and 20-minute search two small Linyphild spiders were found.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap.

Pitfall Trap M01a

Four (4) adult wēkiu bugs (one male, three females, and one mating pair) were captured in this trap. One small Brachonid wasp and one fly (Loniceridae) were also captured in the trap.

Pitfall Trap M01b

Two (2) $3^{\overline{rd}}$ instar and six (6) adult male for a total of eight (8) we kiu bugs were captured in this trap. One Calliphoridae fly was observed flying near this trap.

4.2 Monitoring Station M02

N19 49.494 W155 28.615 13555 ft. elevation



Monitoring Station M02 was located west of the Mauna Kea Loop Road and the Access Way about half way up the cinder slope on Pu'u Hau'oki. During the trap installation and 20-minute search a Calliphorid fly and gorse moth were observed near the traps.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap.

Pitfall Trap M02a Two (2) adult wēkiu bugs (one male, one female, one mating pair) were captured in this trap. One Sciarid fly was also captured in the trap.

Pitfall Trap M02b No arthropods were captured in this trap.

4.3 Monitoring Station M03

N19 49.443 W155 28.817 13477 ft. elevation



Monitoring Station M03 was located on the north-east slope of Pu'u Poli'ahu west of the Smithsonian Array Access Road about forty feet up the cinder slope. During the trap installation and 20-minute search one unidentified Lygaeid bug, one Labybird beetle, and one Calliphorid fly were found.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap, but two 1^{st} instar, one 3^{rd} instar, and two adult (one male, one female, one mating pair) were found in the trap.

Pitfall Trap M03a

Forty-nine (49) 1^{st} instar, thirty-one (31) 2^{nd} instar, ten (10) 3^{rd} instar, and twenty-five (25) adult wēkiu bugs (twenty-one (21) males, four (4) females) for a total of 115 wēkiu bugs were captured in this trap. No other arthropods were captured in the trap.

Pitfall Trap M03b Two (2) 1^{st} instar, three (3) 2^{nd} instar, three (3) 3^{rd} instar and eight (8) adult (six (6) males, two (2) females) wēkiu bugs for a total of 16 wēkiu bugs were captured in this trap. No other arthropods were found in the trap.

4.4 Monitoring Station M04

N19 49.492 W155 28.666 13499 ft. elevation



Monitoring Station M04 was located west of the Access Way between the Smithsonian Array Access Road and the Access Way. During the trap installation and 20-minute search one small Linyphild spider and one Calliphorid fly were found.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap.

Pitfall Trap M04a No wēkiu bugs were captured in this trap. One small Linyphiid spider was captured in the trap.

Pitfall Trap M04b

One (1) adult male wēkiu bug was captured in this trap. Two Calliphorid flies were observed near the trap.

4.5 Monitoring Station M05

N19 49.494 W155 28.657 13502 ft. elevation



Monitoring Station M05 was located between the Mauna Kea Loop Road and the Access Way. During the trap installation and 20-minute search one Calliphorid fly and one small Linyphiid spider was found.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap.

Pitfall Trap M05a No wēkiu bugs were captured in this trap. One unidentified Collembola was captured in the trap.

Pitfall Trap M05b No wēkiu bugs were captured in this trap. Four Sciarid flies were captured in the trap.

4.6 Monitoring Station M06

N19 49.510 W155 28.670 13488 ft. elevation



Monitoring Station M06 was located west of the Access Way between the Smithsonian Array Access Road and the Access Way. During the trap installation and 20-minute search one Calliphorid fly was observed.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap.

Pitfall Trap M06a No wēkiu bugs were captured in this trap. One Calliphorid fly and one Brachonid wasp were captured in the trap.

Pitfall Trap M06b No wēkiu bugs were captured in this trap. One Ichneumonid wasp was found in the trap.

4.7 Monitoring Station M07

N19 49.548 W155 28.685 13492 ft. elevation



Monitoring Station M07 was located near the north end of the Access Way between the Smithsonian Array Access Road and the Access Way. During the trap installation and 20-minute search one Calliphorid fly, one Linyphiid (?) spider egg sac and one Collembola were observed.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap.

Pitfall Trap M07a No wēkiu bugs were captured in this trap. No other arthropods were captured in the trap.

Pitfall Trap M07b No wēkiu bugs were captured in this trap. No other arthropods were captured in the trap.

4.8 Monitoring Station M08

N19 49.568 W155 28.690 13463 ft. elevation



Monitoring Station M08 was located west of the Access Way near the bottom of the cinder slope. During the trap installation and 20-minute search one Muscid fly and one Calliphorid fly were found.

Ant Trap: - No ants were captured or observed near the protein- and sugar-based trap.

Pitfall Trap M08a No wēkiu bugs were captured in this trap. No other arthropods were captured in the trap.

Pitfall Trap M08b No wēkiu bugs were captured in this trap. No other arthropods were captured in the trap.

Table 1. Wēkiu bugs and ants captured in traps during Access Way Arthropod Monitoring	in
June 2011.	

		Protein/Sugar Traps		Wēkiu buas in	Wēkiu bugs in	
Location	Site ID	Ants	Wēkiu bugs	Pitfall Trap "a"	Pitfall Trap "b"	
Above Loop Road	M01	0	0	4	8	
Above Loop Road Control Site	M02	0	0	2	0	
Pu'u Poli'ahu Control Site	M03	0	5	115	16	
Between SMA road and Access Way	M04	0	0	0	1	
Between Loop road and Access Way	M05	0	0	0	0	
Between SMA road and Access Way	M06	0	0	0	0	
Between SMA road and Access Way	M07	0	0	0	0	
Between Loop road and Access Way	M08	0	0	0	0	

Table 2. For comparison purposes, a summary the results of a similar monitoring event in April 2009.

Location	April 2009 Site ID	Near June 2011 Site ID	Wēkiu bugs in Pitfall Traps
Above Loop Road	T1	M01	12
Between SMA road and Access Way	T2	NA	8
Between Loop road and Access Way	Т3	M05	7
Between SMA road and Access Way	T4	M04	4
Between Loop road and Access Way	T5	M08	7
Between SMA road and Access Way	Т6	M07	1
Pu'u Poli'ahu	P1	M03	35
Pu'u Poli'ahu	P2	M03	3
Pu'u Hau 'Oki	H1	NA	34
Pu'u Hau 'Oki	H2	NA	23

5.0 ANALYSIS AND DISCUSSION

Thirteen (13) wēkiu bugs were captured in the twelve (12) pitfall traps placed at the six monitoring sites along the Access Way (M01, M04-M08), approximately one per trap (Table 1). Only three of the twelve (25%) traps captured wēkiu bugs. During the April 2009 (Pacific Analytics, 2009) survey thirty-nine (39) wēkiu bugs were found in the six live-traps placed along the proposed Access Way, about seven per trap (Table 2). Wēkiu bugs appeared in all six traps (100%) over the 3-day sampling. Trap locations were virtually identical for both samplings. Both of these collection dates occurred pre-construction, but at slightly different times of the year. Weather conditions, temperature, and other factors were also different. The difference between the 2009 and 2011 trap captures could be considered natural variation because no known or intensive disturbance had occurred between sampling dates to cause the capture rate differences.

One hundred thirty-one (131) wēkiu bugs were captured in two pitfall traps at monitoring location M03 on Pu'u Poli'ahu during this monitoring session (about 65 per trap). Wēkiu bugs were found in both traps (100%). Thirty-eight (38) wēkiu bugs were captured in two traps in approximately the same location in April of 2009 (about 19 per trap) (Table 2). Wēkiu bugs were also found in both traps (100%). The differences between 2009 and 2011 sampling dates are within normal variation found in previous studies and could be considered natural variation. Similar factors to those listed above may influence trap capture rate differences between sampling dates.

Only two (2) wēkiu bugs were captured in the two traps on the upper slope of Pu'u Hau'oki (monitoring location M02) during this monitoring session (Table 1). In April 2009 fifty-seven (57) wēkiu bugs were captured in two traps in a different location on the pu'u (about 28 per trap) (Table 2). The differences may be due to trap location as well as other factors mentioned above.

The trap capture rates during this study along the Access Way were approximately one wēkiu bug per trap is much lower than the rate of thirty-three (33) wēkiu bugs per trap in the control sites away from the Access Way. Whereas true densities of wēkiu bugs outside traps is unknown, it is likely that the population of wēkiu bugs residing immediately beside the Access Way is generally lower than areas outside this area with comparable substrate types.

No work has been started on the Access Way and no vehicle traffic has been allowed on this blocked 4-wheel drive road for several years. No other known disturbance has occurred along the Access Way, therefore differences in trap captures between areas adjacent to the Access Way and largely undisturbed areas on Pu'u Poli'ahu and Pu'u Hau'oki may be attributed to previous disturbance, weather conditions, temperature change, and natural fluxuations in the wēkiu bug population in the areas sampled.

Two Spring samplings have occurred along the TMT Access Way since the TMT Observatory project began, one in April 2009 and this one completed in June 2011. More studies are recommended to establish a sufficient baseline of the wēkiu bug population along the Access Way in order to detect changes that vary beyond normal background variation in the population (i.e., due to weather, temperature, and natural fluxuations).

No invasive species were observed during this monitoring. It is especially important to monitor for ants along the Access Way and at the construction site once construction begins. Detecting ants early, if introduced by construction crews, other TMT Observatory activity, or Summit visitors is critical to preservation of the Mauna Kea summit biota. We recommend weekly monitoring during construction for ants using protein- and sugar-based traps similar to those deployed during this monitoring session. The traps are very easy to construct and deploy and the contents do not require detailed entomological expertise to analyze the results.



Dr. Jesse Eiben sampling for wēkiu bugs on a cinder slope in June 2011.

6.0 BIBLIOGRAPHY

- Ashlock, P.D. 1966. New Hawaiian Orsillinae (Hemiptera-Heteroptera: Lygaeidae). Pacific Insects 8(4): 805-825.
- Ashlock, P.D. and W.C. Gagne. 1983. A remarkable new micropterous *Nysius* species from the aeolian zone of Mauna Kea, Hawai'i Island (Hemiptera: Heteroptera: Lygaeidae). International Journal of Entomology 25(1):47-55.
- Borror, D.J., C.A. Triplehorn, and N.F. Johnson. An Introduction to the Study of Insects. Sixth Edition. Saunders College Press, San Francisco.
- Beardsley, J.W. 1961. A review of the Hawaiian Braconidae (Hymenoptera). Proceedings of the Hawaiian Entomological Society 17(3): 333-366.
- Beardsley, J.W. 1969. The Anagyrina of the Hawaiian Islands (Hymenoptera: Encyrtidae) with descriptions of two new species. Proceedings of the Hawaiian Entomological Society 20(2): 287-310.
- Beardsley, J.W. 1976. A synopsis of the Encyrtidae of the Hawaiian Islands with keys to genera and species (Hymenoptera: Chalcidoidae). Proceedings of the Hawaiian Entomological Society 22(2): 181-228.
- Brenner, G.J. 2002a. Wēkiu Bug Baseline Monitoring. Quarterly Report, 1st Quarter 2002. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2002b. Wēkiu Bug Baseline Monitoring. Quarterly Report, 2nd Quarter 2002. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2002c. Wēkiu Bug Baseline Monitoring. Quarterly Report, 3rd Quarter 2002. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2002d. Wēkiu Bug Baseline Monitoring. Quarterly Report, 4th Quarter 2002. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2003a. Wēkiu Bug Baseline Monitoring. Quarterly Report, 1st Quarter 2003. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2003b. Wēkiu Bug Baseline Monitoring. Quarterly Report, 2nd Quarter 2003. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2003c. Wēkiu Bug Baseline Monitoring. Quarterly Report, 3rd Quarter 2003. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2003d. Wēkiu Bug Baseline Monitoring. Quarterly Report, 4th Quarter 2003. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2004a. Wēkiu Bug Baseline Monitoring. Quarterly Report, 1st Quarter 2004. A Technical Report Prepared for the W.M. Keck Observatory.

- Brenner, G.J. 2004b. Wēkiu Bug Baseline Monitoring. Quarterly Report, 2nd Quarter 2004. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2004c. Wēkiu Bug Baseline Monitoring. Quarterly Report, 3rd Quarter 2004. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2004d. Wēkiu Bug Baseline Monitoring. Quarterly Report, 4th Quarter 2004. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2004e. Botanical Survey Of The Hale Pōhaku Mid-Elevation Facilities Construction Staging Area. Prepared for The Outrigger Telescopes Project National Aeronautics and Space Administration.
- Brenner, G.J. 2005a. Wēkiu Bug Baseline Monitoring. Quarterly Report, 1st Quarter 2005. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2005b. Wēkiu Bug Baseline Monitoring. Quarterly Report, 2nd Quarter 2005. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2005c. Wēkiu Bug Baseline Monitoring. Quarterly Report, 3rd Quarter 2005. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2005d. Wēkiu Bug Baseline Monitoring. Quarterly Report, 4th Quarter 2005. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2006a. Wēkiu Bug Baseline Monitoring. Quarterly Report, 1st Quarter 2006. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. 2006b. Wēkiu Bug Baseline Monitoring. Quarterly Report, 2nd Quarter 2006. A Technical Report Prepared for the W.M. Keck Observatory.
- Brenner, G.J. and J. Lockwood. 2005. Wēkiu Bug Habitat Quantitative Cinder Evaluation. Technical Report prepared for the Outrigger Telescopes Project. 44 pages.
- Christiansen, K. and P. Bellinger. 1992. Insects of Hawai'i Collembola. Volume 15. University of Hawai'i Press, Honolulu. 445 pp.
- Cuddihy, L.W. 1989. Vegetation Zones of the Hawaiian Islands. Pages 27-37 in C.P. Stone and D.B. Stone (editors). Conservation Biology in Hawai'i. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu, HI. 252 pages.
- Cushman, R.A. 1944. The Hawaiian species of Enicospilus and Abanchogastra (Hymenoptera: Ichneumonidae). Proc Haw Ent Soc 12(1): 39-56.
- Daly, H.V. and K.N. Magnacca 2003 Hawaiian *Hylaeus (Nesoprosopis)* Bees (Hymenoptera:Apoidea) Volume 17. University of Hawai'i Press, Honolulu. 234 pp.
- Delay, J., M. Merlin, J. Juvik, M. Castillo, and L. Perry. 2004. Field Guide to Rare and Unusual Plants on the Island of Hawai'i. Lyon Arboretum Special Publication. Hilo Bay Printing Co., Ltd. Hilo, HI.

- Department of Land and Natural Resources (DLNR). 1997. Indigenous Wildlife, Endangered and Threatened Wildlife and Plants, and Introduced Birds. Department of Land and Natural Resources, State of Hawai'i. Administrative Rules §13-1 through §13-134-10, dated February 01, 1997.
- Federal Register. 1999. Department of the Interior, Fish and Wildlife Service, Endangered and Threatened Wildlife and Plants. 50 CFR 17:11 and 17:12 – December 3, 1999
- Federal Register. 2005. Department of the Interior, Fish and Wildlife Service, 50 CFR 17.
 Endangered and Threatened Wildlife and Plants. Review of Species That Are Candidates or Proposed for Listing as Endangered or Threatened; Annual Notice of Findings on Resubmitted Petition; Annual Description of Progress on Listing Actions. Federal Register, 70 No. 90 (Wednesday, May 11, 2005): 24870-24934.
- Federal Register. 2006. Department of the Interior, Fish and Wildlife Service, 50 CFR 17.
 Endangered and Threatened Wildlife and Plants--Proposed Critical Habitat Designations;
 Proposed Rule. Federal Register, 70 No. 90 (September 12, 2006): 53755-53835.
- Fullaway, D.T. & N.L.H. Krauss. 1945. Common Insects of Hawai'i. Tongg Publishing Co., Honolulu. 228 pp.
- Hardy, D.E. 1960. Diptera: Nematocera-Brachycera. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 10. Diptera: Nematocera--Brachycera. University of Hawai'i Press, Honolulu. ix + 368 pp.
- Hardy, D.E. 1965. Diptera: Cyclorrhapha II, series Schizophora, section Acalypterae I, family Drosophilidae. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 12. University of Hawai'i Press, Honolulu. vii + 814 pp.
- Hardy, D.E. 1966. Descriptions and notes on Hawaiian Drosophilidae (Diptera). Pp. 195-244 In: M.R. Wheeler (ed.). Studies in genetics. III. Morgan centennial issue. The University of Texas, Austin. vi + 563 pp.
- Hardy, D.E. 1981. Diptera: Cyclorrhapha IV, series Schizophora, section Calyptratae. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 14. University of Hawai'i Press, Honolulu. vi + 491 pp.
- Hardy, D.E. & M.D. Delfinado. 1980. Diptera: Cyclorrhapha III, series Schizophora, section Acalypterae, exclusive of family Drosophilidae. Pp. 1-451 In: Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 13. University of Hawai'i Press, Honolulu. vi + 451 pp.
- Howarth, F.G. and W.P. Mull. 1992. Hawaiian Insects and their Kin. University of Hawai'i Press, Honolulu.
- Kepler, A.K. 1984. Hawaiian Heritage Plants. The Oriental Publishing Co., Honolulu.

- Liebherr, J.K. and E.C. Zimmerman 2000. Hawaiian Carabidae (coleopteran), Part 1: Introduction and Tribe Platynini. Volume 16. University of Hawai'i Press, Honolulu. 494 pp.
- Nishida, G. M. 1997. Hawaiian Terrestrial Arthropod Checklist Third Edition. Hawai'i Biological Survey. Bishop Museum Technical Report No. 12. Bishop Museum, Honolulu.
- Pacific Analytics, LLC. 2009. Arthropod And Botanical Inventory And Assessment Thirty Meter Telescope Project Mauna Kea Science Reserve Northern Plateau And Hale Pohaku Hāmākua District, Island Of Hawai'I. Prepared for Parsons Brinckerhoff, Honolulu, Hawai'i. 76 pages.
- Parker, Barry. 1994. Stairway to the Stars: the Story of the World's Largest Observatory. Plenum Press, New York, NY. 350 pp.
- Polhemus, D.A. 1998. *Nysius aa* (Heteroptera: Lygaeidae), A new species of micropterous wekiu bug from the summit of Mauna Loa Volcano, Hawai'i. Proceedings of the Entomological Society of Washington 100(1):25-31.
- Porter, S.C. and R.A. Englund. 2006. Possible Geologic Factors Influencing the Distribution on the Wēkiu Bug on Mauna Kea, Hawai'i. Final Report prepared for the Office of Mauna Kea Management, Hilo, Hawai'i. 29 pages.
- Sharp (ed). 1899-1913. Fauna Hawaiiensis. Cambridge-at-the-University-Press.
- Tentorio, J.M. 1969. Insects of Hawai'i Volume 11, Supplement. Diptera: Dolichopodidae Appendix (Phoridae). University of Hawai'i Press, Honolulu. 73 pp.
- Townes, H. 1958. Insects of Micronesia Hymenoptera: Ichneumonidae, Stephanidae, and Evaniidae. Insects of Micronesia 19(2):35-87. B.P. Bishop Museum, Honolulu.
- U.S. Fish and Wildlife Service. 1999. U.S. Fish and Wildlife Service Species List, plants. March 23, 1999. Pacific Islands Ecoregion, Honolulu, HI.
- University of Hawai'i. 1999. Mauna Kea Science Reserve Master Plan. Prepared by Group 70, International, Inc., Honolulu.
- University of Hawai'i. 2000. Mauna Kea Science Reserve Master Plan. Final Environmental Impact Statement. Volume I and II. Prepared by Group 70, International, Inc., Honolulu.
- Usinger, R.L. 1936. The genus Geocoris in the Hawaiian Islands (Lygaeidae, Hemiptera). Proc Haw Ent Soc 9(2): 212-215.
- Usinger, R.L. 1942. The genus Nysius and its allies in the Hawaiian Islands (Hemiptera, Lygaeidae, Orsillini). Bull B P Bishop Mus 173: 1-167. 13 plates.
- Watanabe, C. 1958. Insects of Micronesia Hymenoptera: Eucharidae. Insects of Micronesia 19(2):1-34. B.P. Bishop Museum, Honolulu.

- Williams, F.X. 1931. Handbook of the insects and other invertebrates of Hawaiian sugar cane fields. Hawaiian Sugar Planters' Association, Honolulu. 400 pp.
- Yoshimoto, C.M. 1965a. Synopsis of Hawaiian Eulophidae including Aphelininae (Hym.: Chalcidoidea). Pac Ins 7(4): 665-699.
- Yoshimoto, C.M. 1965b. The Hawaiian Thysaninae (Hym.: Chalcidoidea: Encyrtidae). Pac Ins 7(4): 703-704.
- Yoshimoto, C.M. and T. Ishii. 1965. Insects of Micronesia Hymenoptera: Chalcidoidea: Eulophidae, Encyrtidae (part), Pteromalidae. Insects of Micronesia 19(4):109-178. B.P. Bishop Museum, Honolulu.
- Zimmerman, E.C. 1948. Introduction. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 1. University of Hawai'i Press, Honolulu. xx + 206 pp.
- Zimmerman, E.C. 1948. Apterygota to Thysanoptera inclusive. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 2. University of Hawai'i Press, Honolulu. viii + 475 pp.
- Zimmerman, E.C. 1948. Heteroptera. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 3. University of Hawai'i Press, Honolulu. 255 pp.
- Zimmerman, E.C. 1948. Homoptera: Auchenorhyncha. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 4. University of Hawai'i Press, Honolulu. vii + 268 pp.
- Zimmerman, E.C. 1948. Homoptera: Sternorhyncha. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 5. University of Hawai'i Press, Honolulu. vii + 464 pp.
- Zimmerman, E.C. 1957. Ephemeroptera-Neuroptera-Trichoptera and supplement to volumes 1 to 5. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 6. University of Hawai'i Press, Honolulu. ix + 209 pp.
- Zimmerman, E.C. 1958. Macrolepidoptera. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 7. University of Hawai'i Press, Honolulu. ix + 542 pp.
- Zimmerman, E.C. 1958. Lepidoptera: Pyraloidea. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin,

distribution, hosts, parasites, etc. Volume 8. University of Hawai'i Press, Honolulu. ix + 456 pp.

- Zimmerman, E.C.. 1964. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 11. Diptera: Brachycera, Family Dolichopodidae. Cyclorrhapha, series Aschiza. Families Lonchopteridae, Phoridae, Pipunculidae, and Syrphidae. University of Hawai'i Press, Honolulu. vii + 458 pp.
- Zimmerman, E.C. 1978. Microlepidoptera. Part I. Monotrysia, Tineoidea, Tortricoidea, Gracillarioidea, Yponomeutoidea, and Alucitoidea. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 9. University of Hawai'i Press, Honolulu. xx + 882 pp.
- Zimmerman, E.C. 1978. Microlepidoptera. Part II. Gelechioidea. Insects of Hawai'i. A manual of the insects of the Hawaiian Islands, including an enumeration of the species and notes on their origin, distribution, hosts, parasites, etc. Volume 9. University Press of Hawai'i, Honolulu. 883-1903 pp.