Results of the Thirty Meter Telescope Proposed Site Evaluation for the Wekiu Bug (*Nysius wekiuicola*): Fall 2008

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EXHIBIT A-49

Summary

A four day sampling regime with the use of 45 baited attractant live traps designed for monitoring the presence and absence of the Wekiu bug (*Nysius wekiuicola* Ashlock and Gagné) was used to create part of the biological assessment of a proposed site for the Thirty Meter Telescope on Maunakea, Hawai'i. Three Wekiu bugs were captured and counted before being released at the end of the sampling period on September 28, 2008. No Wekiu bugs were found in the area purported to be directly physically impacted by any possible observatory construction activity. The fall season is not the best time to look for the presence or absence of the Wekiu bug anywhere in its range, so there can be only limited conclusions drawn from this sampling period. However, there is broad accord among scientists that the type of rock substrate in the Northern Plateau is not known to regularly harbor large numbers of Wekiu bugs.

Introduction

As part of a project by Pacific Analytics, LLC for the Thirty Meter Telescope Project, I have been contracted to sample for the Wekiu bug in areas selected as possible sites for Project construction on the Northern Plateau of Maunakea. This project is different from, yet is informed by, scientific research I am conducting for my PhD in entomology at the University of Hawai'i at Manoa involving the life history and population genetics of the Wekiu bug.

The Wekiu bug, *Nysius wekiuicola* Ashlock and Gagné, on the Island of Hawai'i has been the focus of much attention in its native range on and near the summit of Hawai'i's tallest mountain, Maunakea. Since the bug's formal description in 1983 by Ashlock and Gagné, the bug's habitat and life history has been of great interest to scientists, conservationists, and the public as a whole. The specialized life history allowing the Wekiu bug to survive the extremes of temperature, solar radiation, and water and food availability make this insect a true marvel of adaptation. Due to its limited range, specialized habitat requirements, isolated populations, and habitat destruction, the Wekiu bug was is currently a candidate for listing priority 8 under the Endangered Species Act (Endangered, 2006). Explorations of the summit area over the past 10 years by entomologists representing the Bishop Museum, Pacific Analytics, LLC, and the University of Hawai'i at Manoa have greatly enhanced our knowledge of the types of areas Wekiu bugs inhabit, their behaviors and life history (Pacific Analytics, 2006, Englund et al. 2007, Eiben, unpublished).

The objectives for this study are to provide presence and absence data of the Wekiu bug in a subset of its range on and near the summit of Maunakea as part of the biological assessment of a potential site for a new observatory in the Astronomy Precinct being prepared by Pacific Analytics, LLC.

Materials and Methods

Study Area:

The area of Maunakea being sampled for Wekiu bugs is known as Area E on the Northern Plateau of the mountain. In practical terms, the area encompasses a part of the west and northwest zone of the Astronomy Precinct on the summit of Maunakea. Specific locations for wekiu bug live-trap placements were haphazardly selected in Area E, along the 4-wheel drive road to Area E, around the Batch Plant, and in two control locations not in the expected

construction disturbance areas where Wekiu bugs have been found multiple times in 2007 and 2008 (Eiben, unpublished).

Trapping Methods:

A live pitfall trap design very similar to those described by Englund et al. (2002) and Pacific Analytics (2002) was used to attract Wekiu bugs. The modifications in design are as follows. Two 10oz clear plastic cups were used for each trap. The upper cup was punctured with one small hole in the bottom center through which a small absorbent wick made of tissue (Kimtech Science) was pushed. A small amount of water was poured into the bottom of the lower reservoir cup. The attractant shrimp paste was placed in the upper cup contacting the wick, on a few small pieces of rock in the cup, smeared on the side of the cup, and on a cap rock. The traps were dug into the available ground substrate attempting to achieve a depth where moisture was present in the ash layer. The lip of the cup was not necessarily placed flush with ash layer, and there was no wire mesh surround to provide structure surrounding the cups. This cup design has been successful for attracting and capturing Wekiu bugs during 2007 and 2008 (Eiben, unpublished). Most sites selected for sampling used a pair of traps within 16.4 feet of each other in different microhabitat types (ex. large rock jumble vs. ash layer near the surface) to attempt to sample the true diversity of the habitat (see Tables 1 and 2). The traps were checked daily and bugs captured were removed for the duration of the sampling period to prevent recounts. Bugs were held for up to three days in captivity with food and water sources.

Results

No Wekiu bugs were observed while hiking through the trapping areas, nor were any Wekiu bugs observed while emplacing the traps. Forty-five traps were placed for three or four days from September 25-28. Three Wekiu bugs were captured in two locations over the sampling period (see Table 1, Table 2, and Figure 1). One adult female and one 5th instar nymph Wekiu bug were captured in the control area near the SE base of Puu Hau Oki on September 26, 2008. One 5th instar nymph Wekiu bug was found in the control area on the E base area of Puu Poliahu on September 28, 2008. All three Wekiu bugs found in the traps were alive and were released alive in good condition where they were captured on September 28, 2008.

Discussion

Though the sampling effort (number of traps) for Wekiu bugs during this sampling period was quite intense given the area surveyed, there can be little information drawn from the lack of bugs found in Area E. During the fall season, the number of Wekiu bugs found on Maunakea throughout its range are much less than during other times of the year. The reason for this is unknown. Wekiu bugs are found in much higher numbers during the late spring and early summer, and these areas are correlated to lasting snow pack (Englund et al. 2007). The duration and availability of moisture sources may indeed be a limiting factor for the year-round distribution of the Wekiu bug within its range. The spring sampling period of Area E should be much more informative for determining the presence or absence of the Wekiu bug in the possible construction zone for the Project.

Acknowledgements

I would like to thank Greg Brenner of Pacific Analytics, LLC for his help in the field and valuable insights about the Wekiu bug and its habitat. Betsy Gagné at DLNR has proven

instrumental in obtaining permits for all work relating to the genus Nysius in Hawai'i. The support of Stephanie Nagata at OMKM is crucial to all work involving the Wekiu bug and is always most helpful.

Table 1. Detail of baited shrimp trap locations and wekiu bug captures during September, 2008

Site Description	Trap Name	Paired traps	GPS Coordinates (NAD83)		Wekiu Bug Captures			
					25-Sep-08	26-Sep-08	27-Sep-08	28-Sep-08
Site 1 footprint	TMT1A	Yes	19°49'57.22"N	155°28'52.93"W	Install	0	0	0
Site 1 footprint	TMT1B	Yes			Install	0	0	0
Site 1 footprint	TMT2A	Yes	19°49'57.90"N	155°28'53.69"W	Install	0	0	0
Site 1 footprint	TMT2B	Yes			Install	0	0	0
Site 1 footprint	TMT3A	Yes	19°49'56.35"N	155°28'53.65"W	Install	0	0	0
Site 1 footprint	TMT3B	Yes			Install	0	0	0
Site 1 footprint	TMT4A	Yes	19°49'55.42"N	155°28'53.08"W	Install	0	0	0
Site 1 footprint	TMT4B	Yes			Install	0	0	0
Site 1 footprint	TMT5A	Yes	19°49'53.80"N	155°28'52.97"W	Install	0	0	0
Site 1 footprint	TMT5B	Yes			Install	0	0	0
Road	TMT6A	Yes	19°49'52.46"N	155°28'53.04"W	Install	0	0	0
Road	TMT6B	Yes			Install	0	0	0
Road	TMT7A	Yes	19°49'51.67"N	155°28'50.74"W	Install	0	0	0
Road	TMT7B	Yes			Install	0	0	0
Site area	TMT8A	Yes	19°49'52.10"N	155°28'49.69"W	Install	0	0	0
Site area	TMT8B	Yes			Install	0	0	0
Site area	TMT9A	Yes	19°49'52.68"N	155°28'48.22"W	Install	0	0	0
Site area	TMT9B	Yes			Install	0	0	0
Site 2 footprint	TMT10A	Yes	19°49'41.02"N	155°28'46.45"W	Install	0	0	0
Site 2 footprint	TMT10B	Yes			Install	0	0	0
Site 2 footprint	TMT11A	Yes	19°49'41.84"N	155°28'45.01"W	Install	0	0	0
Site 2 footprint	TMT11B	Yes			Install	0	0	0
Site 2 footprint	TMT12A	Yes	19°49'43.10"N	155°28'44.08"W	Install	0	0	0
Site 2 footprint	TMT12B	Yes			Install	0	0	0

Table 2. Detail of baited shrimp trap locations and wekiu bug captures during September, 2008

Site Description	Trap Name	Paired traps	GPS Coordinates (NAD83)		Wekiu Bug Captures			
					25-Sep-08	26-Sep-08	27-Sep-08	28-Sep-08
Site 2 footprint	TMT13A	Yes	19°49'43.61"N	155°28'45.84"W	Install	0	0	0
Site 2 footprint	TMT13B	Yes			Install	0	0	0
Site 2 footprint	TMT14A	Yes	19°49'46.49"N	155°28'47.39"W	Install	0	0	0
Site 2 footprint	TMT14B	Yes			Install	0	0	0
Site Area	TMT15A	Yes	19°49'43.79"N	155°28'51.78"W	Install	0	0	0
Site Area	TMT15B	Yes			Install	0	0	0
Site Area	TMT16A	Yes	19°49'45.55"N	155°28'53.47"W	Install	0	0	0
Site Area	TMT16B	Yes			Install	0	0	0
Road	TMT road1	No	19°49'28.63"N	155°28'40.01"W	N/A	Install	0	0
Road	TMT road2	No	19°49'32.48"N	155°28'41.26"W	N/A	Install	0	0
Road	TMT road3	No	19°49'38.27"N	155°28'44.31"W	N/A	Install	0	0
Road	TMT road4	No	19°49'43.75"N	155°28'48.79"W	N/A	Install	0	0
Batch plant	TMTbatch1A	Yes	19°49'12.65"N	155°28'27.44"W	N/A	Install	0	0
Batch plant	TMT batch1B	Yes			N/A	Install	0	0
Batch plant	TMT batch2A	Yes	19°49'12.72"N	155°28'29.82"W	N/A	Install	0	0
Batch plant	TMT batch2B	Yes			N/A	Install	0	0
Batch plant	TMT batch3	No	19°49'11.04"N	155°28'30.52"W	N/A	Install	0	0
Non-construction	TMT Pol contA	Yes	19°49'26.54"N	155°28'48.36"W	N/A	Install	0	1*
Non-construction	TMT Pol contB	Yes			N/A	Install	0	0
Non-construction	TMT Oki contA	Yes	19°49'25.72"N	155°28'31.66"W	Install	2**	0	0
Non-construction	TMT Oki contB	Yes			Install	0	0	0

*one fifth instar nymph captured
**one adult female and one fifth instar nymph captured

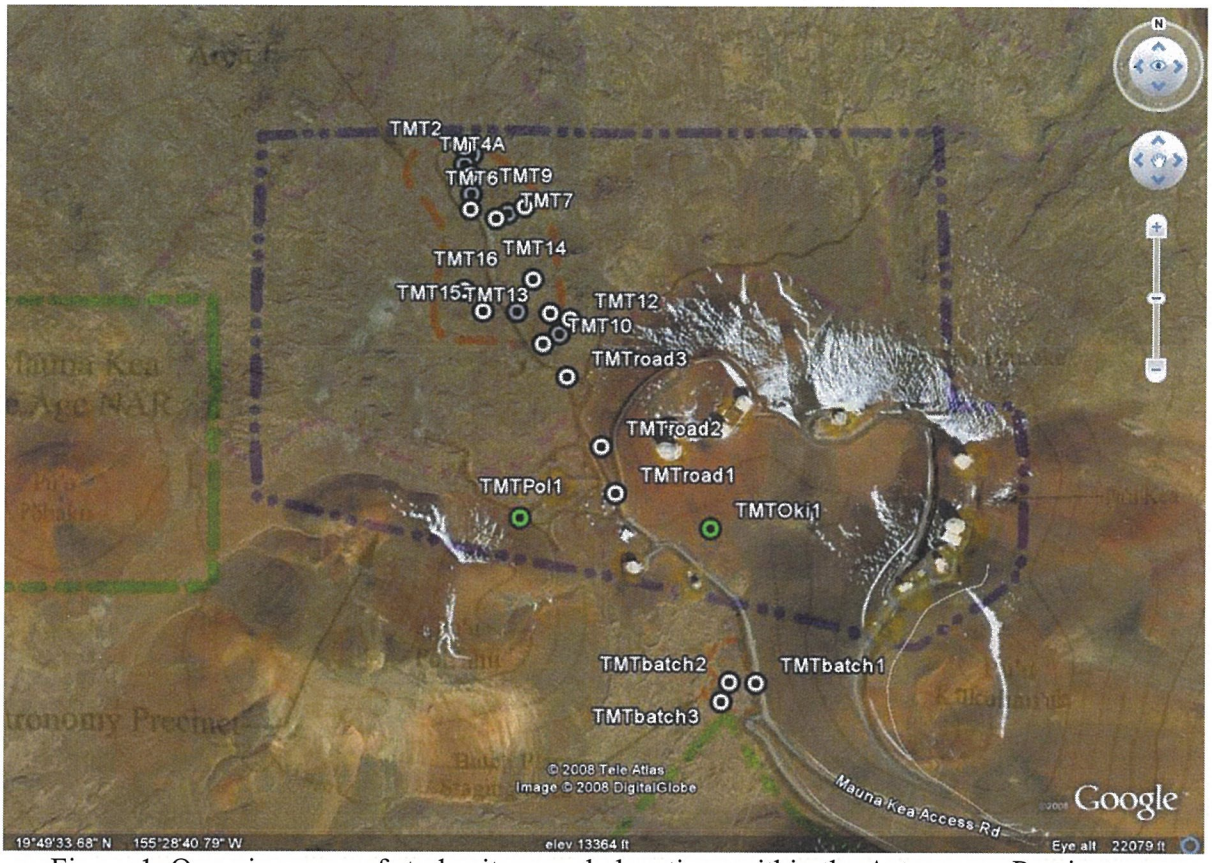

Figure 1. Overview map of study site sample locations within the Astronomy Precinct on Maunakea, Hawai'i

*Astronomy Precinct outlined in purple

**Green dots indicate Wekiu bug capture locations

References

Ashlock, P. D. and W. C. Gagné. 1983. A remarkable new micropterous Nysius species from the aeolian zone of Mauna Kea, Hawaii Island (Hemiptera: Heteroptera: Lygaeidae). International Journal of Entomology 25(1): 47-55.

Endangered and Threatened Wildlife and Plants; Review of Native Species That Are Candidates or Proposed for Listing as Endangered or Threatened; Annual Notice of Findings on Resubmitted Petitions; Annual Description of Progress on Listing Actions. 2006. Federal Register 71(176): 53756-53835.

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APPENDIX B

Results of the Thirty Meter Telescope Proposed Site Evaluation for the Wekiu Bug (*Nysius wekiuicola*): Spring 2009.

Technical Report prepared by Jesse Eiben, M.S.

Results of the Thirty Meter Telescope Proposed Site Evaluation for the Wekiu Bug (*Nysius wekiuicola*): Spring 2009

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Summary

A four day sampling regime with the use of 24 baited attractant live traps designed for monitoring the presence and absence of the Wekiu bug (*Nysius wekiuicola* Ashlock and Gagné) was used to create part of the biological assessment of a proposed site for the Thirty Meter Telescope on Maunakea, Hawai'i. A total of 146 wekiu bugs were observed and/or captured between April 20 and 23, 2009. In the past, Wekiu bugs have often been captured in greater numbers during late March, April and May than during the summer and fall (Eiben pers. obs.). This cycle of Wekiu bug activity was confirmed during the two sampling periods for the proposed TMT site. Wekiu bugs were found in areas impacted previously by construction and in areas that are considered unaltered habitat. No Wekiu bugs were found in the area of the proposed construction footprint of the Project construction, however there were many Wekiu bugs found along the currently closed unpaved 4-wheel drive road north of the SMA array. This road may be impacted by Project construction, and Wekiu bug habitat and populations will need to be taken into consideration in the event of the road reopening. There is still broad accord among scientists that the type of rock substrate in the Northern Plateau is not known to regularly harbor large numbers of Wekiu bugs, and this was confirmed during the spring 2009 sampling session.

Introduction

As part of a project by Pacific Analytics, LLC for the Thirty Meter Telescope, I have been contracted to sample for the Wekiu bug in areas selected as possible sites for observatory facility construction on the Northern Plateau of Maunakea. This project is different from, yet is informed by, scientific research I am conducting for my PhD in entomology at the University of Hawai'i at Manoa involving the life history and population genetics of the Wekiu bug.

The Wekiu bug, *Nysius wekiuicola* Ashlock and Gagné, on the Island of Hawai'i has been the focus of much attention in its native range on and near the summit of Hawai'i's tallest mountain, Maunakea. Since the bug's formal description in 1983 by Ashlock and Gagné, the bug's habitat and life history has been of great interest to scientists, conservationists, and the public as a whole. The specialized life history allowing the Wekiu bug to survive the extremes of temperature, solar radiation, and water and food availability make this insect a true marvel of adaptation. Due to its limited range, specialized habitat requirements, isolated populations, and habitat destruction, the Wekiu bug is currently a candidate for listing priority 8 under the Endangered Species Act (Endangered, 2006). Explorations of the summit area over the past 10 years by entomologists representing the Bishop Museum, Pacific Analytics, LLC, and the University of Hawai'i at Manoa have greatly enhanced our knowledge of the types of areas Wekiu bugs inhabit, their behaviors and life history (Pacific Analytics, 2006, Englund et al. 2007, Eiben, unpub.).

The objectives for this study are to provide presence and absence data of the Wekiu bug in a subset of its range on and near the summit of Maunakea as part of the biological assessment of a potential site for a new observatory in the Astronomy Precinct being prepared by Pacific Analytics, LLC.

Materials and Methods

Study Area:

The area of Maunakea being sampled for Wekiu bugs is known as Area E on the Northern Plateau of the mountain. In practical terms, the area encompasses a part of the west and northwest zone of the Astronomy Precinct on the summit of Maunakea. Specific locations for Wekiu bug live-trap placements were haphazardly selected in Area E in the proposed footprint sites of the TMT Project, along the 4-wheel drive road to Area E, around the Batch Plant, and in two control locations not in the expected construction disturbance areas where Wekiu bugs have been found multiple times in 2007 and 2008 (Eiben, unpublished).

Trapping Methods:

A live pitfall trap design very similar to those described by Englund et al. (2002) and Pacific Analytics (2002) was used to attract Wekiu bugs. The modifications in design are as follows. Two 10oz clear plastic cups were used for each trap. The upper cup was punctured with one small hole in the bottom center through which a small absorbent wick made of tissue (Kimtech Science) was pushed. A small amount of water was poured into the bottom of the lower reservoir cup. The attractant shrimp paste was placed in the upper cup contacting the wick, on a few small pieces of rock in the cup, smeared on the side of the cup, and on a cap rock. The traps were dug into the available ground substrate attempting to achieve a depth where moisture was present in the ash layer. The lip of the cup was not necessarily placed flush with ash layer, and there was no wire mesh surround to provide structure surrounding the cups. This cup design has been successful for attracting and capturing Wekiu bugs during 2007 and 2008 (Eiben, unpublished). Most sites selected for sampling used a pair of traps within 5 meters of each other in different microhabitat types (ex. large rock jumble vs. ash layer near the surface) to attempt to sample the true diversity of the habitat (see Table 1). The traps were checked daily and bugs captured were removed for the duration of the sampling period to prevent recounts. Bugs were held for up to three days in captivity with food and water sources.

Results

A total of 146 Wekiu bugs were observed in the baited traps and in the immediate vicinity of the traps. Twenty four traps were placed for three full days starting on April 20 and removed on April 23. No Wekiu bugs were captured or observed in the area known as Area E on the Northern Plateau (12 traps), nor near the Batch Plant area (2 traps), 41 Wekiu bugs were found in 6 traps along the dirt road that is currently closed adjacent to the SMA array, and 105 Wekiu bugs were captured in four traps in two control locations not in areas with any planned direct impacts by construction activities of the Project (see Table 1, and Figure 1). Five nymph, 102 adult male, and 39 adult female Wekiu bugs were captured in total. Twenty seven live Wekiu bugs captured in the two "Poi Bowl, Pu'u Hau 'Oki" control trap sites were collected and moved to the University of Hawai'i lab colony by myself, Jesse Eiben, as per my permit allowances for the life history study of the Wekiu bug. There was an 85 percent survivorship rate of Wekiu bugs trapped in this sampling period with eighteen Wekiu bugs found dead in the traps, and four Wekiu bugs dying in captivity.

Discussion

The sampling effort during the spring sampling session was less intense (24 traps vs. 45 traps) than the fall sampling period because the spring is typically the active season for adult Wekiu bugs. As expected, we observed much higher trapping rates than in the fall of 2008 when Wekiu bugs are scarce and/or not attracted to traps. The weather at the summit during the sampling period of April 20-23, 2009 was quite cold and windy with the daytime high air temperature hovering only slightly above freezing at 34-41°F and wind gusts up to 94 mph with ~45mph constant wind speeds. The lower trap catches on April 22 could be correlated to the overcast sky the previous day. Wekiu bugs were less likely to be active during the time between the traps were checked because they were simply too cold to be attracted and move in high numbers toward the baited traps on April 21st. Important to note is the complete lack of any recent wind deposited insect food sources for the Wekiu bugs. Virtually no by-catch of other insects was found in the traps, and the snow-covered areas of the mountain observed were bereft of insects.

Wekiu bugs were captured in places characterized as having large areas with an assemblage of different sized rock cinder scoria in a depth of approximately 2-10 inches before the ash layer was reached. This mixed rock tephra is found on the slopes of cinder cones. The areas where Wekiu bugs are found show a constant state of flux, with the scoria slowly moving down slope by the force of gravity and undergoing frost-heaves that continually 'sift' dust and ash down in depth thereby creating a natural and very slow sorting of rock scoria with larger rocks nearer the surface and smaller cinders being closer to the ash layer. This habitat type is apparently highly suitable for supporting populations of Wekiu bugs. There are many interconnected reasons why Wekiu bugs are associated with specific type of habitat. Wekiu bugs can use this depth of different sized cinder to thermoregulate by moving through the innumerable crevices that the assortment of rocks create. These crevices also provide paths for escape from predators (most likely the endemic lycosid spider). Temperature and humidity data show the incredible variation found in these few inches of rock, with humidity and temperature being oppositely correlated. Near the ash layer, the temperature is cool with high humidity, and at the surface where Wekiu bugs can bask in the sun, the temperature can be very high (up to 114° F) with extremely low humidity (10 percent) (Eiben unpublished). These microhabitats are necessary for the Wekiu bug physiologically, but can also create areas that hold and preserve prey items on which Wekiu bugs feed. As insects drop from the wind column and sift through the scoria, they can become protected from the intense desiccating conditions found at the surface. Of the traps that attracted Wekiu bugs, some traps were placed in areas with very little depth of this type of cinder tephra, however, since the effective range of these traps is unknown, the bugs could be attracted from adjacent deep cinder zones.

It has previously been shown that Wekiu bugs are found in much higher numbers during the late spring and early summer, and these areas are correlated to lasting snow pack (Englund et al. 2007). During this trapping session and others (Eiben, unpublished), it is apparent that Wekiu bugs are often found in areas that have no current adjacent snow pack (along the dirt road north of SMA, and at the lower trap sites on Pu'u Poliahu and Pu'u Hau 'Oki). The duration and availability of moisture sources may indeed be a limiting factor for the year-round distribution of the Wekiu bug within its range. When discussing insect populations and habitats, it essential to be cognizant that the individual organism does not seek out and use habitat on a very large scale. Population growth in an area will be at the whim of the food and climate (microclimate)

available. This is especially true on Maunakea, where weather events can drastically change the time and duration of activity possible and availability of fresh prey items for Wekiu bugs.

Acknowledgements

I would like to thank Greg Brenner of Pacific Analytics, LLC for his help in the field and valuable insights about the Wekiu bug and its habitat. Betsy Gagné at DLNR has proven instrumental in obtaining permits for all work relating to the genus Nysius in Hawai'i. The support of Stephanie Nagata at OMKM is crucial to all work involving the Wekiu bug and is always most helpful.

Table 1. Detail of baited shrimp trap locations and wekiu bug captures during April, 2009

Site Description	Trap Name	Paired traps	GPS Coordinates (NAD83)	Wekiu Bug Captures				
				20-Apr-09	21-Apr-09	22-Apr-09	23-Apr-09	TOTALS
SMA Access Road	STMTR1-A	No	N19 49.482 W155 28.648	Install	9	0	3	= 12
SMA Access Road	STMTR1-B	No	N19 49.481 W155 28.653	Install	3	0	7	= 10
SMA Access Road	STMTR2-A	No	N19 49.505 W155 28.659	Install	2	0	5	= 7
SMA Access Road	STMTR2-B	No	N19 49.503 W155 28.656	Install	1	1	2	= 4
SMA Access Road	STMTR3-A	No	N19 49.549 W155 28.679	Install	1	0	6	= 7
SMA Access Road	STMTR3-B	No	N19 49.549 W155 28.686	Install	0	0	1	= 1
Site 1 Footprint	STMTF1-A	Yes	N19 49.968 W155 28.880	Install	0	0	0	0
Site 1 Footprint	STMTF1-A			Install	0	0	0	0
Site 1 Footprint	STMTF1-B	Yes	N19 49.975 W155 28.895	Install	0	0	0	0
Site 1 Footprint	STMTF1-B			Install	0	0	0	0
Site 1 Footprint	STMTF1-C	Yes	N19 49.932 W155 28.898	Install	0	0	0	0
Site 1 Footprint	STMTF1-C			Install	0	0	0	0
Site 2 Footprint	STMTF2-A	Yes	N19 49.903 W155 28.887	Install	0	0	0	0
Site 2 Footprint	STMTF2-A			Install	0	0	0	0
Site 2 Footprint	STMTF2-B	Yes	N19 49.908 W155 28.853	Install	0	0	0	0
Site 2 Footprint	STMTF2-B			Install	0	0	0	0
Site 2 Footprint	STMTF2-C	Yes	N19 49.885 W155 28.849	Install	0	0	0	0
Site 2 Footprint	STMTF2-C			Install	0	0	0	0
Batch Plant	STMTbatch	Yes	N19 49.175 W155 28.492	Install	0	0	0	0
Batch Plant	STMTbatch			Install	0	0	0	0
Non-Construction	STMTPol-A	Yes	N19 49.448 W155 28.802	Install - 1	14	6	21	= 42
Non-Construction	STMTPol-B			Install	2	0	1	= 3
Non-Construction	STMTPoi-A	Yes	N19 49.429 W155 28.517	Install	6	13	16	= 35
Non-Construction	STMTPoi-B			Install	3	5	17	= 25

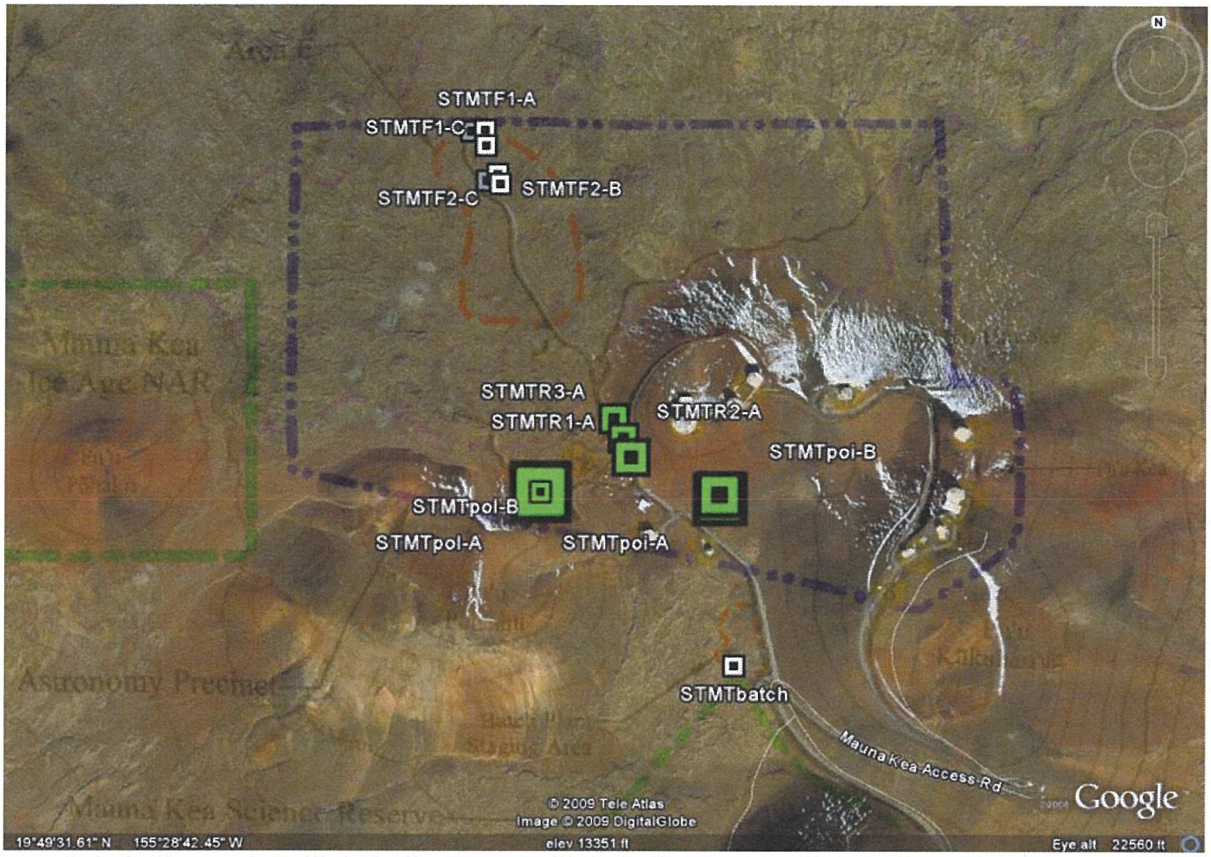

Figure 1. Overview map of study site sample locations within the Astronomy Precinct on Maunakea, Hawai'i

*Astronomy Precinct outlined in purple

**Green squares indicate Wekiu bug capture locations, size correlated to trap captures

References

Ashlock, P. D. and W. C. Gagné. 1983. A remarkable new micropterous Nysius species from the aeolian zone of Mauna Kea, Hawaii Island (Hemiptera: Heteroptera: Lygaeidae). International Journal of Entomology 25(1): 47-55.

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